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Hearing to Helmond

Articles in This Slice

HEARING (formed from the verb "to hear," O. Eng. *hyran*, *heran*, &c., a common Teutonic verb; cf. Ger. *hören*, Dutch *hooren*, &c.; the O. Teut. form is seen in Goth. *hausjan*; the initial *h* makes any connexion with "ear," Lat. *audire*, or Gr. ἀκούειν very doubtful), in physiology, the function of the ear (*q.v.*), and the general term for the sense or special sensation, the cause of which is an excitation of the auditory nerves by the vibrations of sonorous bodies. The anatomy of the ear is described in the separate article on that organ. A description of sonorous vibrations is given in the article Sound; here we shall consider the transmission of such vibrations from the external ear to the auditory nerve, and the physiological characters of auditory sensation. 122

1. *Transmission in External Ear.*—The external ear consists of the *pinna*, or auricle, and the *external auditory meatus*, or canal, at the bottom of which we find the *membrana tympani*, or drum head. In many animals the auricle is trumpet-shaped, and, being freely movable by muscles, serves to collect sonorous waves coming from various directions. The auricle of the human ear presents many irregularities of surface. If these irregularities are abolished by filling them up with a soft material such as wax or oil, leaving the entrance to the canal free, experiment shows that the intensity of sounds is weakened, and that there is more difficulty in judging of their direction. When waves of sound strike the auricle, they are partly reflected outwards, while the remainder, impinging at various angles, undergo a number of reflections so as to be directed into the auditory canal. Vibrations are transmitted along the auditory canal, partly by the air it contains and partly by its walls, to the membrana tympani. The absence of the auricle, as the result of accident or injury, does not cause diminution of hearing. In the auditory canal waves of sound are reflected from side to 123
side until they reach the membrana tympani. From the obliquity in position and peculiar curvature of this membrane, most of the waves strike it nearly perpendicularly, and in the most advantageous direction.

2. *Transmission in Middle Ear.*—The middle ear is a small cavity, the walls of which are rigid with the exception of the portions consisting of the membrana tympani, and the membrane of the round window and of the apparatus filling the oval window. This cavity communicates with the pharynx by the *Eustachian tube*, which forms an air-tube between the pharynx and the tympanum for the purpose of regulating pressure on the membrana tympani. During rest the tube is open, but it is closed during the act of deglutition. As this action is frequently taking place, not only when food or drink is introduced, but when saliva is swallowed, it is evident that the pressure of the air in the tympanum will be kept in a state of equilibrium with that of the external air on the outer surface of the membrana tympani, and that thus the membrana tympani will be rendered independent of variations of atmospheric pressure such as occur when we descend in a diving bell or ascend in a balloon.

By a forcible expiration, the oral and nasal cavities being closed, air may be driven into the tympanum, while a forcible inspiration (Valsalva's experiment) will draw air from that cavity. In the first case, the membrana tympani will bulge outwards, in the second case inwards, and in both, from excessive stretching of the membrane, there will be partial deafness, especially for sounds of high pitch. Permanent occlusion of the tube is one of the most common causes of deafness.

The membrana tympani is capable of being set into vibration by a sound of any pitch included in the range of perceptible sounds. It responds exactly as to number of vibrations (pitch), intensity of vibrations (intensity), and complexity of vibration (quality or timbre). Consequently we can hear a sound of any given pitch, of a certain intensity, and in its own specific timbre or quality. Generally speaking, very high tones are heard more easily than low tones of the same intensity. As the membrana tympani is not only fixed by its margin to a ring or tube of bone, but is also adherent to the handle of the malleus, which follows its movements, its vibrations meet with considerable resistance. This diminishes the intensity of its vibrations, and prevents also the continued vibration of the membrane after an external pressure has ceased, so that a sound is not heard much longer than its physical cause lasts. The tension of the membrane may be affected (1) by differences of pressure on the two surfaces of the membrana tympani, as may occur during forcible expiration or inspiration, and (2) by muscular action, due to contraction of the *tensor tympani* muscle. This small muscle arises from the apex of the petrous temporal and the cartilage of the Eustachian tube, enters the tympanum at its anterior wall, and is inserted into the malleus near its root. The handle of the malleus is inserted between the layers of the membrana tympani, and, as the malleus and incus move round an axis passing through the neck of the malleus from before backwards, the action of the muscle is to pull the membrana tympani inwards towards the tympanic cavity in the form of a cone, the meridians of which are not straight but curved, with convexity outwards. When the muscle contracts, the handle of the malleus is drawn still farther inwards, and thus a greater tension of the tympanic membrane is produced. On relaxation of the muscle, the membrane returns to its position of equilibrium by its elasticity and by the elasticity of the chain of bones. This power of varying the tension of the membrane is an accommodating mechanism for receiving and transmitting sounds of different pitch. With different degrees of tension it will respond more readily to sounds of different pitch. Thus, when the membrane is tense, it will readily respond to high sounds, while relaxation will be the condition most adapted for low tones. In addition, increased tension of the membrane, by increasing the resistance, will diminish the intensity of vibrations. This is especially the case for sounds of low pitch.

The vibrations of the membrana tympani are transmitted to the internal ear partly by the air which the middle ear or tympanum contains, and partly by the chain of bones, consisting of the malleus, incus and stapes. Of these, transmission by the chain of bones is by far the most important. In birds and in the amphibia, this chain is represented by a single rod-like ossicle, the *columella*, but in man the two membranes—the membrana tympani and the membrane filling the fenestra ovalis—are connected by a compound lever consisting of three bones, namely, the *malleus*, or hammer, inserted into the membrana tympani, the *incus*, or anvil, and the *stapes*, or stirrup, the base of which is attached to a membrane covering the oval window. It must also be noted that in the transmission of vibrations of the membrana tympani to the fluid in the labyrinth or internal ear, through the oval window, the chain of ossicles vibrates as a whole and acts efficiently, although its length may be only a fraction of the wave-length of the sound transmitted. The chain is a lever in which the handle of the malleus forms the long arm, the fulcrum is where the short process of the incus abuts against the wall of the tympanum, while the long process of the incus, carrying the stapes, forms the short arm. The mechanism is a lever of the second order. Measurements show that the ratio of the lengths of the two arms is as 1.5 : 1; the ratio of the resulting force at the stapes is therefore as 1 : 1.5; while the amplitudes of the movements at the tip of the handle of the malleus and the stapes is as 1.5 : 1. Hence, while there is a diminution in amplitude there is a gain in power, and thus the pressures are conveyed with great efficiency from the membrana tympani to the labyrinth, while the amplitude of the oscillation is diminished so as to be adapted to the small capacity of the labyrinth. As the drum-head is nearly twenty times greater in area than the membrane covering the oval window, with which the base of the stapes is connected, the energy of the movements of the membrana tympani is concentrated on an area twenty times smaller; hence the pressure is increased thirtyfold (1.5×20) when it acts at the base of the stapes. Experiments on the human ear have shown that the movement of greatest amplitude was at the tip of the handle of the malleus, 0.76 mm.; the movement of the tip of the long arm process of the incus was 0.21 mm.; while the greatest amplitude at the base of the stapes was only .0714 mm. Other observations have shown the movements at the stapes to have a still smaller amplitude, varying from 0.001 to 0.032 mm. With tones of feeble intensity the movements must be almost infinitesimal. There may also be very minute transverse movements at the base of the stapes.

3. *Transmission in the Internal Ear.*—The internal ear is composed of the labyrinth, formed of the vestibule or central part, the semicircular canals, and the cochlea, each of which consists of an osseous and a membranous portion. The osseous labyrinth may be regarded as an osseous mould in the petrous portion of the temporal bone, lined by tesselated endothelium, and containing a small quantity of fluid called the *perilymph*. In this mould, partially surrounded by, and to some extent floating in, this fluid, there is the membranous labyrinth, in certain parts of which we find the terminal apparatus in connexion with the auditory nerve, immersed in another fluid called the *endolymph*. The membranous labyrinth consists of a vestibular portion formed by two small sac-like dilatations, called the *saccule* and the *utricle*, the latter of which communicates with the semicircular canals by five openings. Each canal consists of a tube, bulging out at each extremity so as to form the so-called *ampulla*, in which, on a projecting ridge, called the *crista acustica*, there are cells bearing long *auditory hairs*, which are the peripheral end-organs of the vestibular branches of the auditory nerve. The cochlear division of the membranous labyrinth consists of the *ductus cochlearis*, a tube of triangular form fitting in between the two cavities in the cochlea, called the *scala vestibuli*, because it commences in the vestibule, and the *scala tympani*, because it ends in the tympanum, at the round window. These two scalae communicate at the apex of the cochlea. The roof of the ductus cochlearis is formed by a thin membrane called the *membrane of Reissner*, while its floor consists of the *basilar membrane*, on which we find the remarkable *organ of Corti*, which constitutes the terminal 124
organ of the cochlear division of the auditory nerve. It is sufficient to state here that this organ consists essentially of an arrangement of epithelial cells bearing hairs which are in communication with the terminal filaments of this portion of the auditory nerve, and that groups of these hairs pass through holes in a closely investing membrane, *membrana reticularis*, which may act as a damping apparatus, so as quickly to stop their movements. The ductus cochlearis and the two scalae are filled with fluid. Sonorous vibrations may reach the fluid in the labyrinth by three different ways—(1) by the osseous walls of the labyrinth, (2) by the air in the tympanum and the round window, and (3) by the base of the stapes inserted into the oval window.

When the head is plunged into water, or brought into direct contact with any vibrating body, vibrations must be transmitted directly. Vibrations of the air in the mouth and in the nasal passages are also communicated directly to the walls of the cranium, and thus pass to the labyrinth. In like manner, we may experience auditive sensations, such as blowing, rubbing and hissing sounds, due to muscular contraction or to the passage of blood in vessels close to the auditory organ. It is doubtful whether any vibrations are communicated to the fluid in the labyrinth by the round window. Vibrations which cause hearing are communicated by the chain of bones. When the base of the stirrup is pushed into the oval window, the pressure in the labyrinth increases, and, as the only mobile part of the wall of the labyrinth is the membrane covering the round window, this membrane is forced outwards; when the base of the stirrup moves outwards a reverse action takes place. Thus the fluid of the labyrinth receives a series of pulses isochronous with the movements of the base of the stirrup, and these pulses affect the terminal apparatus in connexion with the auditory nerve.

The sacs of the internal ear, known as the utricle and saccule, receive the impulses of the base of the stapes. They are organs connected with the perception of sounds as sounds, without reference to pitch or quality. For the *analysis* of tone a cochlea is necessary. Even in mammals all the parts of the ear may be destroyed or affected by disease, except these sacs, without causing complete deafness.

It has been suggested by Lee (*Amer. Jour. of Physiol.* vol. i. No. 1, p. 128) that in fishes the sac has nothing to do with hearing, but serves for the perception of movements, such as those of rotation and translation through space, movements much coarser than those that form the physical basis of sound. He considers, also, that as fishes, with few exceptions, are dumb, they are also deaf. In the fish there are peculiar organs along the lateral line which are known to be connected with the perception of movements of the body as a whole, and Beard (*Zool. Anz. Leipzig*, 1884, Bd. vii. S. 140) has attempted to trace a phylogenetic connexion between the sacs of the internal ear and the organs in the lateral line. According to this view, when animals became air-breathers, a part of the ear (the *papilla acustica basilaris*) was gradually evolved for the perception of delicate vibrations of sound. (See

Equilibrium.)

It is by means of the cochlea that we discriminate pitch, hear beats, and are affected by quality of tone.

Since the size of the membranous labyrinth is so small, measuring, in man, not more than ½ in. in length by ⅛ in. in diameter at its widest part, and since it is a chamber consisting partly of conduits of very irregular form, it is impossible to state accurately the course of vibrations transmitted to it by impulses communicated from the base of the stirrup. In the cochlea vibrations must pass from the saccule along the scala vestibuli to the apex, thus affecting the membrane of Reissner, which forms its roof; then, passing through the opening at the apex (the *helicotrema*), they must descend by the scala tympani to the round window, and affect in their passage the membrana basilaris, on which the organ of Corti is situated. From the round window impulses must be reflected backwards, but how they affect the advancing impulses is not known. But the problem is even more complex when we take into account the fact that impulses are transmitted simultaneously to the utricle and to the semicircular canals communicating with it by five openings. The mode of action of these vibrations or impulses upon the nervous terminations is still unknown; but to appreciate critically the hypothesis which has been advanced to explain it, it is necessary, in the first place, to refer to some of the general characters of auditory sensation.

4. *General Characters of Auditory Sensations.*—Certain conditions are necessary for excitation of the auditory nerve sufficient to produce a sensation. In the first place, the vibrations must have a certain *amplitude* and *energy*; if too feeble, no impression will be produced.

Various physicists have attempted to measure the sensitiveness of the ear by estimating the amplitude of the molecular movements necessary to call forth the feeblest audible sound. Thus A. Töpler and L. Boltzmann, on data founded on experiments with organ pipes, state that the ear is affected by vibrations of molecules of the air not more in amplitude than .0004 mm. at the ear, or 0.1 of the wave-length of green light, and that the energy of such a vibration on the drum-head is not more than $1/543$ billionth kilog., or $1/17$th of that produced upon an equal surface of the retina by a single candle at the same distance (*Ann. d. Phys. u. Chem.*, Leipzig. 1870, Bd. cxli. S. 321). Lord Rayleigh, by two other methods, arrived at the conclusion “that the streams of energy required to influence the eye and ear are of the same order of magnitude.” He estimated the amplitude of the movement of the aërial particles, with a sound just audible, as less than the ten-millionth of a centimetre, and the energy emitted when the sound was first becoming audible, at 42.1 ergs per second. He also states that in considering the amplitude or condensation in progressive aërial waves, at a distance of 27.4 metres from a tuning-fork, the maximum condensation was $= 6.0 \times 10^{-9}$ cm., a result showing “that the ear is able to recognize the addition or subtraction of densities far less than those to be found in our highest vacua” (*Proc. Roy. Soc.*, 1877, vol. xxvi. p. 248; *Lond. Edin. and Dub. Phil. Mag.*, 1894, vol. xxxviii. p. 366).

In the next place, vibrations must have a certain *duration* to be perceived; and lastly, to excite a sensation of a continuous musical sound, a certain *number* of impulses must occur in a given interval of time. The lower limit is about 30, and the upper about 30,000 vibrations per second. Below 30, the individual impulses may be observed, and above 30,000 few ears can detect any sound at all. The extreme upper limit is not more than 35,000 vibrations per second. Auditory sensations are of two kinds—noises and musical sounds. *Noises* are caused by impulses which are not regular in intensity or duration, or are not periodic, or they may be caused by a series of musical sounds occurring instantaneously so as to produce discords, as when we place our hand at random on the keyboard of a piano. *Musical tones* are produced by periodic and regular vibrations. In musical sounds three characters are prominent—intensity, pitch and quality. *Intensity* depends on the amplitude of the vibration, and a greater or lesser amplitude of the vibration will cause a corresponding movement of the transmitting apparatus, and a corresponding intensity of excitation of the terminal apparatus. *Pitch*, as a sensation, depends on the length of time in which a single vibration is executed, or, in other words, the number of vibrations in a given interval of time. The ear is capable of appreciating the relative pitch or height of a sound as compared with another, although it may not ascertain precisely the absolute pitch of a sound. What we call an acute or high tone is produced by a large number of vibrations, while a grave or low tone is caused by few. The musical tones which can be used with advantage range between 40 and 4000 vibrations per second, extending thus from 6 to 7 octaves. According to E. H. Weber, practised musicians can perceive a difference of pitch amounting to only the $1/64$th of a semitone, but this is far beyond average attainment. In a few

individuals, and especially in early life, there may be an appreciation of absolute pitch. *Quality* or *timbre* (or *Klang*) is that peculiar characteristic of a musical sound by which we may identify it as proceeding from a particular instrument or from a particular human voice. It depends on the fact that many waves of sound that reach the ear are compound wave 125
systems, built up of constituent waves, each of which is capable of exciting a sensation of a simple tone if it be singled out and reinforced by a resonator (see Sound), and which may sometimes be heard without a resonator, after special practice and tuition. Thus it appears that the ear must have some arrangement by which it resolves every wave system, however complex, into simple pendular vibrations. When we listen to a sound of any quality we recognize that it is of a certain pitch. This depends on the number of vibrations of one tone, predominant in intensity over the others, called the fundamental or ground tone, or first partial tone. The quality, or timbre, depends on the number and intensity of other tones added to it. These are termed *harmonic* or *partial tones*, and they are related to the first partial or fundamental tone in a very simple manner, being multiples of the fundamental tone: thus—

	Fundamental Tone	Upper Partials or Harmonics.								
Notes	do^1	do^2	sol^2	do^3	mi^3	sol^3	si♭^{3}	do^4	re^4	mi^4
Partial tones	1	2	3	4	5	6	7	8	9	10
Number of vibrations	33	66	99	132	165	198	231	264	297	330

When a simple tone, or one free from partials, is heard, it gives rise to a simple, soft, somewhat insipid sensation, as may be obtained by blowing across the mouth of an open bottle or by a tuning-fork. The lower partials added to the fundamental tone give softness combined with richness; while the higher, especially if they be very high, produce a brilliant and thrilling effect, as is caused by the brass instruments of an orchestra. Such being the facts, how may they be explained physiologically?

Little is yet known regarding the mode of action of the vibrations of the fluid in the labyrinth upon the terminal apparatus connected with the auditory nerve. There can be no doubt that it is a mechanical action, a communication of impulses to delicate hair-like processes, by the movements of which the nervous filaments are irritated. In the human ear it has been estimated that there are about 3000 small arches formed by the *rods of Corti.* Each arch rests on the basilar membrane, and supports rows of cells having minute hair-like processes. It would appear also that the filaments of the auditory nerve terminate in the basilar membrane, and possibly they may be connected with the hair-cells. At one time it was supposed by Helmholtz that these fibres of Corti were elastic and that they were tuned for particular sounds, so as to form a regular series corresponding to all the tones audible to the human ear. Thus 2800 fibres distributed over the tones of seven octaves would give 400 fibres for each octave, or nearly 33 for a semitone. Helmholtz put forward the hypothesis that, when a pendular vibration reaches the ear, it excites by sympathetic vibration the fibre of Corti which is tuned for its proper number of vibrations. If, then, different fibres are tuned to tones of different pitch, it is evident that we have here a mechanism which, by exciting different nerve fibres, will give rise to sensations of pitch. When the vibration is not simple but compound, in consequence of the blending of vibrations corresponding to various harmonics or partial tones, the ear has the power of resolving this compound vibration into its elements. It can only do so by different fibres responding to the constituent vibrations of the sound—one for the fundamental tone being stronger, and giving the sensation of a particular pitch to the sound, and the others, corresponding to the upper partial tones, being weaker, and causing undefined sensations, which are so blended together in consciousness as to terminate in a complex sensation of a tone of a certain quality or timbre. It would appear at first sight that 33 fibres of Corti for a semitone are not sufficient to enable us to detect all the gradations of pitch in that interval, since, as has been stated above, trained musicians may distinguish a difference of $\frac{1}{64}$th of a semitone. To meet this difficulty, Helmholtz stated that if a sound is produced, the pitch of which may be supposed to come between two adjacent fibres of Corti, both of these will be set into sympathetic vibration, but the one which comes nearest to the pitch of the sound will vibrate with greater intensity than the other, and that consequently the pitch of that sound would be thus appreciated. These theoretical views of Helmholtz have derived much support from experiments of V. Hensen, who observed that certain hairs on the antennae of *Mysis*, a Crustacean, when seen with a low microscopic power, vibrated with certain tones produced by a keyed horn. It was seen that certain tones of the horn set some hairs into strong vibration, and other tones other hairs. Each hair responded also to several tones of the horn. Thus one hair responded strongly to d♯ and d′♯, more weakly to g, and very weakly to G. It was probably tuned to some pitch between d″ and d″♯. (*Studien über das Gehörorgan der Decapoden*, Leipzig, 1863.)

Histological researches have led to a modification of this hypothesis. It has been found that the rods or arches of Corti are stiff structures, not adapted for vibrating, but apparently constituting a support for the hair-cells. It is also known that there are no rods of Corti in the cochlea of birds, which are capable nevertheless of appreciating pitch. Hensen and Helmholtz suggested the view that not only may the segments of the membrana basilaris be stretched more in the radial than in the longitudinal direction, but different segments may be stretched radially with different degrees of tension so as to resemble a series of tense strings of gradually increasing length. Each string would then respond to a vibration of a particular pitch communicated to it by the hair-cells. The exact mechanism of the hair-cells and of the membrana reticularis, which looks like a damping apparatus, is unknown.

5. *Physiological Characters of Auditory Sensation.*—Under ordinary circumstances auditory sensations are referred to the outer world. When we hear a sound, we associate it with some external cause, and it appears to originate in a particular place or to come in a particular direction. This feeling of *exteriority* of sound seems to require transmission through the membrana tympani. Sounds which are sent through the walls of the cranium, as when the head is immersed in, and the external auditory canals are filled with, water, appear to originate in the body itself.

An auditory sensation lasts a short time after the cessation of the exciting cause, so that a number of separate vibrations, each capable of exciting a distinct sensation if heard alone, may succeed each other so rapidly that they are fused into a single sensation. If we listen to the puffs of a syren, or to vibrating tongues of low pitch, the single sensation is usually produced by about 30 or 35 vibrations per second; but when we listen to beats of considerable intensity, produced by two adjacent tones of sufficiently high pitch, the ear may follow as many as 132 intermissions per second.

The sensibility of the ear for sounds of different pitch is not the same. It is more sensitive for acute than for grave sounds, and it is probable that the maximum degree of acuteness is for sounds produced by about 3000 vibrations per second, that is near fa^5♯. Sensibility as to pitch varies much with the individual. Thus some musicians may detect a difference of 1/1000th of the total number of vibrations, while other persons may have difficulty in appreciating a semitone.

6. *Analytical Power of the Ear.*—When we listen to a compound tone, we have the power of picking out these partials from the general mass of sound. It is known that the frequencies of the partials as compared with that of the fundamental tone are simple multiples of the frequency of the fundamental, and also that physically the waves of the partials so blend with each other as to produce waves of very complicated forms. Yet the ear, or the ear and the brain together, can resolve this complicated wave-form into its constituents, and this is done more easily if we listen to the sound with resonators, the pitch of which corresponds, or nearly corresponds, to the frequencies of the partials. Much discussion has taken place as to how the ear accomplishes this analysis. All are agreed that there is a complicated apparatus in the cochlea which may serve this purpose; but while some are of opinion that this structure is sufficient, others hold that the analysis takes place in the brain. When a complicated wave falls on the drum-head, it must move out and in in a way corresponding to the variations of pressure, and these variations will, in a single vibration, depend on the greater or less degree of complexity of the wave. Thus a single tone will cause a movement like that of a pendulum, a simple pendular vibration, while a complex tone, although 126 occurring in the same duration of time, will cause the drum-head to move out and in in a much more complicated manner. The complex movement will be conveyed to the base of the stapes, thence to the vestibule, and thence to the cochlea, in which we find the ductus cochlearis containing the organ of Corti. It is to be noted also that the parts in the cochlea are so small as to constitute only a fraction of the wave-length of most tones audible to the human ear. Now it is evident that the cochlea must act either as a whole, all the nerve fibres being affected by any variations of pressure, or the nerve fibres may have a selective action, each fibre being excited by a wave of a definite period, or there may exist small vibratile bodies between the nerve filaments and the pressures sent into the organ. The last hypothesis gives the most rational explanation of the phenomena, and on it is founded a theory generally accepted and associated with the names of Thomas Young and Hermann Helmholtz. It may be shortly stated as follows:—

"(1) In the cochlea there are vibrators, tuned to frequencies within the limits of hearing, say from 30 to 40,000 or 50,000 vibs. per second. (2) Each vibrator is capable of exciting its appropriate nerve filament or filaments, so that a nervous impulse, corresponding to the frequency of the vibrator, is transmitted to the brain—not corresponding necessarily, as regards the number of nervous impulses, but in such a way that when the impulses along a particular nerve filament reach the brain, a state of consciousness is aroused which does correspond with the number of the physical stimuli and with the period of the auditory vibrator. (3) The mass of each vibrator is such that it will be easily set in motion, and after the stimulus has ceased it will readily come to rest. (4) Damping arrangements exist in the ear, so as quickly to extinguish movements of the vibrators. (5) If a simple tone falls on the ear, there is a pendular movement of the base of the stapes, which will affect all the parts, causing them to move; but any part whose natural period is nearly the same as that of the sound will respond on the principle of sympathetic resonance, a particular nerve filament or nerve filaments will be affected, and a sensation of a tone of definite pitch will be experienced, thus accounting for discrimination in pitch. (6) Intensity or loudness will depend on the amplitude of movement of the vibrating body, and consequently on the intensity of nerve stimulation. (7) If a compound wave of pressure be communicated by the base of the stapes, it will be resolved into its constituents by the vibrators corresponding to tones existing in it, each picking out its appropriate portion of the wave, and thus irritating corresponding nerve filaments, so that nervous impulses are transmitted to the brain, where they are fused in such a way as to give rise to a sensation of a particular quality or character, but still so imperfectly fused that each constituent, by a strong effort of attention, may be specially recognized" (article "Ear," by M'Kendrick, Schäfer's *Text-Book*, *loc. cit.*).

The structure of the ductus cochlearis meets the demands of this theory, it is highly differentiated, and it can be shown that in it there are a sufficient number of elements to account for the delicate appreciation of pitch possessed by the human ear, and on the basis that the highly trained ear of a violinist can detect a difference of $\frac{1}{64}$th of a semitone (M'Kendrick, *Trans. Roy. Soc. Ed.*, 1896, vol. xxxviii. p. 780; also Schäfer's *Text-Book*, *loc. cit.*). Measurements of the cochlea have also shown such differentiation as to make it difficult to imagine that it can act as a whole. A much less complex organ might have served this purpose (M'Kendrick, *op. cit.*). The following table, given by Retzius (*Das Gehörorgan der Wirbelthiere*, Bd. ii. S. 356), shows differentiations in the cochlea of man, the cat and the rabbit, all of which no doubt hear tones, although in all probability they have very different powers of discrimination:—

	Man.	Cat.	Rabbit.
Ear-teeth	2,490	2,430	1,550
Holes in habenula for nerves	3,985	2,780	1,650
Inner rods of Corti's organ	5,590	4,700	2,800
Outer rods of Corti's organ	3,848	3,300	1,900
Inner hair-cells (one row)	3,487	2,600	1,600
Outer hair-cells (several rows)	11,750	9,900	6,100
Fibres in basilar membrane	23,750	15,700	10,500

7. *Dissonance.*—The theory can also be used to explain dissonance. When two tones sufficiently near in pitch are simultaneously sounded, beats are produced. If the beats are few in number they can be counted, because they give rise to separate and distinct sensations; but if they are numerous they blend so as to give roughness or dissonance to the interval. The roughness or dissonance is most disagreeable with about 33 beats falling on the ear per second. When two compound tones are sounded, say a minor third on a harmonium in the lower part of the keyboard, then we have beats not only between the primaries, but also between the upper partials of each of the primaries. The beating distance may, for tones of medium pitch, be fixed at about a minor third, but this interval will expand for intervals on low tones and contract for intervals on high ones. This explains why the same interval in the lower part of the scale may give slow beats that are not disagreeable, while in the higher part it may cause harsh and unpleasant dissonance. The partials up to the seventh are beyond beating distance, but above this they come close together. Consequently instruments (such as tongues, or reeds) that abound in upper partials cause an intolerable dissonance if one of the primaries is slightly out of tune. Some intervals are pleasant and satisfying when produced on instruments having few partials in their tones. These are concords. Others are less so, and they may give rise to an uncomfortable sensation. These are discords. In this way unison, $\frac{1}{1}$, minor third $\frac{6}{5}$, major third $\frac{5}{4}$, fourth $\frac{4}{3}$, fifth $\frac{3}{2}$, minor sixth $\frac{8}{5}$, major sixth $\frac{5}{3}$ and octave $\frac{2}{1}$, are all concords; while a second $\frac{9}{8}$, minor seventh $\frac{16}{9}$ and major seventh $\frac{15}{8}$, are discords. Helmholtz compares the sensation of dissonance to that of a flickering light on the eye. "Something similar I have found to be produced by simultaneously stimulating the skin, or margin of the lips, by bristles attached to tuning-forks giving forth beats. If the frequency of the forks is great, the sensation is that of a most disagreeable tickling. It may be that the instinctive effort at analysis of tones close in pitch causes the disagreeable sensation" (Schäfer's *Text-Book*, *op. cit.* p. 1187).

8. *Other Theories.*—In 1865 Rennie objected to the analysis theory, and urged that the cochlea acted as a whole (*Ztschr. f. rat. Med.*, Dritte Reihe, Bd. xxiv. Heft 1, S. 12-64). This view was revived by Voltolini (Virchow’s *Archiv*, Bd. c. S. 27) some years later, and in 1886 it was urged by E. Rutherford (*Rep. Brit. Assoc. Ad. Sc.*, 1886), who compared the action of the cochlea to that of a telephone plate. According to this theory, all the hairs of the auditory cells vibrate to every note, and the hair-cells transform sound vibrations into nerve vibrations or impulses, similar in frequency, amplitude and character to the sound vibrations. There is no analysis in the peripheral organ. A. D. Waller, in 1891 (*Proc. Physiol. Soc.*, Jan. 20, 1891) suggested that the basilar membrane as a whole vibrates to every note, thus repeating the vibrations of the membrana tympani; and since the hair-cells move with the basilar membrane, they produce what may be called pressure patterns against the tectorial membranes, and filaments of the auditory nerve are stimulated by these pressures. Waller admits a certain degree of peripheral analysis, but he relegates ultimate analysis to the brain. These theories, dispensing with peripheral analysis, leave out of account the highly complex structure of the cochlea, or, in other words, they assign to that structure a comparatively simple function which could be performed by a simple membrane capable of vibrating. We find that the cochlea becomes more elaborate as we ascend the scale of animals, until in man, who possesses greater powers of analysis than any other being, the number of hair-cells, fibres of the basilar membrane and arches of Corti are all much increased in number (see Retzius’s table, *supra*). The principle of sympathetic resonance appears, therefore, to offer the most likely solution of the problem. Hurst’s view is that with each movement of the stapes a wave is generated which travels up the scala vestibuli, through the helicotrema into the scala tympani and down the latter to the fenestra rotunda. The wave, however, is not merely a movement of the basilar membrane, but an actual movement of fluid or a transmission of pressure. As the one wave ascends while the other descends, a pressure of the basilar membrane occurs at the point where they meet; this causes the basilar membrane to move towards the tectorial membrane, forcing this membrane suddenly against the apices of the hair-cells, thus irritating the nerves. The point at which the waves meet will depend on the time interval between the waves (Hurst, “A New Theory of Hearing,” *Trans. Biol. Soc. Liverpool*, 1895, vol. ix. p. 321). More recently Max Mayer has advanced a theory somewhat similar. He supposes that with each movement of the stapes corresponding to a vibration, a wave travels up the scala vestibuli, pressing the basilar membrane downwards. As it meets with resistance in passing upwards, its amplitude therefore diminishes, and in this way the distance up the scala through which the wave progresses will be determined by its amplitude. The wave in its progress irritates a certain number of nerve terminations, consequently feeble tones will irritate only those nerve fibres that are near the fenestra ovalis, while stronger tones will pass farther up and irritate a larger number of nerve fibres the same number of times per unit of time. Pitch, according to this view, depends on the number of stimuli per second, while loudness depends on the number of nerve fibres irritated. Mayer also applies the theory to the explanation of the powers of the cochlea as an analyser, by supposing that with a compound tone these are at maxima and minima of stimulation. As the compound wave travels up the scala, portions of the wave corresponding to maxima and minima die away in consecutive series, until only a maximum and minimum are left; and, finally, as the wave travels farther, these also disappear. With each maximum and minimum different parts of the basilar membrane are affected, and affected a different number of times per second, according to the frequencies of the partials existing in the compound tone. Thus with a fifth, 2 : 3, there are three maxima and three minima; but the compound tone is resolved into three tones having vibration frequencies in the ratio of 3 : 2 : 1. According to Mayer, we actually hear when a fifth is sounded tones of the relationship of 3 : 2 : 1, the last (1) being the differential tone. He holds, also, that combinational tones are entirely subjective (Max Mayer, *Ztschr. f. Psych. und Phys. d. Sinnesorgane*, Leipzig, Bd. xvi. and xvii.; also *Verhandl. d. physiolog. Gesellsch. zu Berlin*, Feb. 18, 1898, S. 49). Two fatal objections can be urged to these theories, namely, first, it is impossible to conceive of minute waves following each other in rapid succession in 127 the minute tubes forming the scalae—the length of the scala being only a very small part of the wave-length of the sound; and, secondly, neither theory takes into account the differentiation of structure found in the epithelium of the organ of Corti. Each push in and out of the base of the stapes must cause a movement of the fluid, or a pressure, in the scalae as a whole.

There are difficulties in the way of applying the resonance theory to the perception of noises. Noises have pitch, and also each noise has a special character; if so, if the noise is analysed into its constituents, why is it that it seems impossible to analyse a noise, or to perceive any musical element in it? Helmholtz assumed that a sound is noisy when the wave is irregular in rhythm, and he suggested that the crista and macula acustica, structures that exist not in the cochlea but in the vestibule, have to do with the perception of noise. These structures, however, are concerned rather in the sense of the perception of equilibrium than of sound (see Equilibrium).

9. Hitherto we have considered only the audition of a single sound, but it is possible also to have simultaneous auditive sensations, as in musical harmony. It is difficult to ascertain what is the limit beyond which distinct auditory sensations may be perceived. We have in listening to an orchestra a multiplicity of sensations which produces a total effect, while, at the same time, we can with ease single out and notice attentively the tones of one or two special instruments. Thus the pleasure of music may arise partly from listening to simultaneous, and partly from the effect of contrast or suggestion in passing through successive, auditory sensations.

The principles of harmony belong to the subject of music (see Harmony), but it is necessary here briefly to refer to these from the physiological point of view. If two musical sounds reach the ear at the same moment, an agreeable or disagreeable sensation is experienced, which may be termed a *concord* or a *discord*, and it can be shown by experiment with the syren that this depends upon the vibrational numbers of the two tones. The octave (1 : 2), the twelfth (1 : 3) and double octave (1 : 4) are absolutely consonant sounds; the fifth (2 : 3) is said to be perfectly consonant; then follow, in the direction of dissonance, the fourth (3 : 4), major sixth (3 : 5), major third (4 : 5), minor sixth (5 : 8) and the minor third (5 : 6). Helmholtz has attempted to account for this by the application of his theory of *beats*.

Beats are observed when two sounds of nearly the same pitch are produced together, and the number of beats per second is equal to the difference of the number of vibrations of the two sounds. Beats give rise to a peculiarly disagreeable intermittent sensation. The maximum roughness of beats is attained by 33 per second; beyond 132 per second, the individual impulses are blended into one uniform auditory sensation. When two notes are sounded, say on a piano, not only may the first, fundamental or prime tones beat, but partial tones of each of the primaries may beat also, and as the difference of pitch of two simultaneous sounds augments, the number of beats, both of prime tones and of harmonics, augments also. The physiological effect of beats, though these may not be individually distinguishable, is to give roughness to the ear. If harmonics or partial tones of prime tones coincide, there are no beats; if they do not coincide, the beats produced will give a character of roughness to the interval. Thus in the octave and twelfth, all the partial tones of the acute sound coincide with the partial tones of the grave sound; in the fourth, major sixth and major third, only two pairs of the partial tones coincide, while in the minor sixth, minor third and minor seventh only one pair of the harmonics coincide.

It is possible by means of beats to measure the sensitiveness of the ear by determining the smallest difference in pitch that may give rise to a beat. In no part of the scale can a difference smaller than 0.2 vibration per second be distinguished. The sensitiveness varies with pitch. Thus at 120 vibs. per second 0.4 vib. per second, at 500 about 0.3 vib. per second, and at 1000, 0.5 vib. per second can be distinguished. This is a remarkable illustration of the sensitiveness of the ear. When tones of low pitch are produced that do not rapidly die away, as by sounding heavy tuning-forks, not only may the beats be perceived corresponding to the difference between the frequencies of the forks, but also other sets of beats. Thus, if the two tones have frequencies of 40 and 74, a two-order beat may be heard, one having a frequency of 34 and the other of 6, as 74 ÷ 40 = 1 + a positive remainder of 34, and 74 ÷ 40 = 2 − 6, or 80 − 74, a negative remainder of 6. The lower beat is heard most distinctly when the number is less than half the frequency of the lower primary, and the upper when the number is greater. The beats we have been considering are produced when two notes are sounded slightly differing in frequency, or at all events their frequencies are not so great as those of two notes separated by a musical interval, such as an octave or a fifth. But Lord Kelvin has shown that beats may also be produced on slightly inharmonious musical intervals (*Proc. Roy. Soc. Ed.* 1878, vol. ix. p. 602). Thus, take two tuning-forks, ut_2 = 256 and ut_3 = 512; slightly flatten ut_3 so as to make its frequency 510, and we hear, not a roughness corresponding to 254 beats, but a slow beat of 2 per second. The sensation also passes through a cycle, the beats now sounding loudly and fading away in intensity, again sounding loudly, and so on. One might suppose that the beat occurred between 510 (the frequency of ut_3 flattened) and 512, the first partial of ut_2, namely ut_3, but this is not so, as the beat is most audible when ut_2 is sounded feebly. In a similar way, beats may be produced on the approximate harmonies 2 : 3, 3 : 4, 4 : 5, 5 : 6, 6 : 7, 7 : 8, 1 : 3, 3 : 5, and beats may even be produced on the major chord 4 : 5 : 6 by sounding ut_3, mi_3, sol_3, with sol_3 or mi_3 slightly flattened, "when a peculiar beat will be heard as if a wheel were being turned against a surface, one small part of which was rougher than the rest." These beats on imperfect harmonies appear to indicate that the ear does distinguish between an increase of pressure on the drum-head and a diminution, or between a push and a pull, or, in other words, that it is affected by phase. This was denied by Helmholtz.

10. *Beat Tones.*—Considerable difference of opinion exists as to whether beats can blend so as to give a sensation of tone; but R. König, by using pure tones of high pitch, has settled the question. These tones were produced by large tuning-forks. Thus ut_6 = 2048 and re_6 =

2304. Then the beat tone is ut_3 = 256 (2304-2048). If we strike the two forks, ut_3 sounds as a grave or lower beat tone. Again, ut_6 = 2048 and si_6 = 3840. Then $(2048)_2 - 3840 = 256$, a negative remainder, ut_3, as before, and when both forks are sounded ut_3 will be heard. Again, ut_6 = 2048 and sol_6 = 3072, and 3072 − 2048 = 1024, or ut_6, which will be distinctly heard when ut_6 and sol_6 are sounded (König, *Quelques expériences d'acoustique*, Paris, 1882, p. 87).

11. *Combination Tones.*—Frequently, when two tones are sounded, not only do we hear the compound sound, from which we can pick out the constituent tones, but we may hear other tones, one of which is lower in pitch than the lowest primary, and the other is higher in pitch than the higher primary. These, known as combination tones, are of two classes: *differential* tones, in which the frequency is the difference of the frequencies of the generating tones, and *summational* tones, having a frequency which is the sum of the frequencies of the tones producing them. Differential tones, first noticed by Sorge about 1740, are easily heard. Thus an interval of a fifth, 2 : 3, gives a differential tone 1, that is, an octave below 2; a fourth, 3 : 4, gives 1, a twelfth below 3; a major third, 4 : 5, gives 1, two octaves below 4; a minor third, 5 : 6, gives 1, two octaves and a major third below 5; a major sixth, 3 : 5, gives 2, that is, a fifth below 3; and a minor sixth, 5 : 8, gives 3, that is, a major sixth below 5. Summational tones, first noticed by Helmholtz, are so difficult to hear that much controversy has taken place as to their very existence. Some have contended that they are produced by beats. It appears to be proved physically that they may exist in the air outside of the ear. Further differential tones may be generated in the middle ear. Helmholtz also demonstrated their independent existence, and he states that "whenever the vibrations of the air or of other elastic bodies, which are set in motion at the same time by two generating simple tones, are so powerful that they can no longer be considered infinitely small, mathematical theory shows that vibrations of the air must arise which have the same vibrational numbers as the combination tones" (Helmholtz, *Sensations of Tone*, p. 235). The importance of these combinational tones in the theory of hearing is obvious. If the ear can only analyse compound waves into simple pendular vibrations of a certain order (simple multiples of the prime tone), how can it detect combinational tones, which do not belong to that order? Again, if such tones are purely subjective and only exist in the mind of the listener, the fact would be fatal to the resonance theory. There can be no doubt, however, that the ear, in dealing with them, vibrates in some part of its mechanism with each generator, while it also is affected by the combinational tone itself, according to its frequency.

12. Hearing with two ears does not appear materially to influence auditive sensation, but probably the two organs are enabled, not only to correct each other's errors, but also to aid us in determining the locality in which a sound originates. It is asserted by G. T. Fechner that one ear may perceive the same tone at a slightly higher pitch than the other, but this may probably be due to some slight pathological condition in one ear. If two tones, produced by two tuning-forks, of equal pitch, are produced one near each ear, there is a uniform single sensation; if one of the tuning-forks be made to revolve round its axis in such a way that its tone increases and diminishes in intensity, neither fork is heard continuously, but both sound alternately, the fixed one being only audible when the revolving one is not. It is difficult to decide whether excitations of corresponding elements in the two ears can be distinguished from each other. It is probable that the resulting sensations may be distinguished, provided one of the generating tones differs from the other in intensity or quality, although it may be the same in pitch. Our judgment as to the direction of sounds is formed mainly from the different degrees of intensity with which they are heard by two ears. Lord Rayleigh states that diffraction of the sound-waves will occur as they pass round the head to the ear farthest from the source of sound; thus partial tones will reach the two ears with different intensities, and thus quality of tone may be affected (*Trans. Music. Soc.*, London, 1876). Silvanus P. Thompson advocates a similar view, and he shows that the direction of a complex tone can be more accurately determined than the direction of a simple tone, especially if it be of low pitch (*Phil. Mag.*, 1882).

(J. G. M.)

HEARN, LAFCADIO (1850-1904), author of books about Japan, was born on the 27th of June 1850 in Leucadia (pronounced Lefcadia, whence his name, which was one adopted by himself), one of the Greek Ionian Islands. He was the son of Surgeon-major Charles Hearn, of King's County, Ireland, who, during the English occupation of the Ionian Islands, was stationed there, and who married a Greek wife. Artistic and rather bohemian tastes were in Lafcadio Hearn's blood. His father's brother Richard was at one time a well-known member of the Barbizon set of artists, though he made no mark as a painter through his lack of energy. Young Hearn had rather a casual education, but was for a time (1865) at Ushaw Roman Catholic College, Durham. The religious faith in which he was brought up was, however, soon lost; and at nineteen, being thrown on his own resources, he went to America and at first picked up a living in the lower grades of newspaper work. The details are obscure, but he continued to occupy himself with journalism and with out-of-the-way observation and reading, and meanwhile his erratic, romantic and rather morbid idiosyncrasies developed. He was for some time in New Orleans, writing for the *Times Democrat*, and was sent by that paper for two years as correspondent to the West Indies, where he gathered material for his *Two Years in the French West Indies* (1890). At last, in 1891, he went to Japan with a commission as a newspaper correspondent, which was quickly broken off. But here he found his true sphere. The list of his books on Japanese subjects tells its own tale: *Glimpses of Unfamiliar Japan* (1894); *Out of the East* (1895); *Kokoro* (1896); *Gleanings in Buddha Fields* (1897); *Exotics and Retrospections* (1898); *In Ghostly Japan* (1899); *Shadowings* (1900); *A Japanese Miscellany* (1901); *Kotto* (1902); *Japanese Fairy Tales* and *Kwaidan* (1903), and (published just after his death) *Japan, an Attempt at Interpretation* (1904), a study full of knowledge and insight. He became a teacher of English at the University of Tokyo, and soon fell completely under the spell of Japanese ideas. He married a Japanese wife, became a naturalized Japanese under the name of Yakumo Koizumi, and adopted the Buddhist religion. For the last two years of his life (he died on the 26th of September 1904) his health was failing, and he was deprived of his lecturersbip at the University. But he had gradually become known to the world at large by the originality, power and literary charm of his writings. This wayward bohemian genius, who had seen life in so many climes, and turned from Roman Catholic to atheist and then to Buddhist, was curiously qualified, among all those who were "interpreting" the new and the old Japan to the Western world, to see it with unfettered understanding, and to express its life and thought with most intimate and most artistic sincerity. Lafcadio Hearn's books were indeed unique for their day in the literature about Japan, in their combination of real knowledge with a literary art which is often exquisite.

See Elizabeth Bisland, *The Life and Letters of Lafcadio Hearn* (2 vols., 1906); G. M. Gould, *Concerning Lafcadio Hearn* (1908).

HEARNE, SAMUEL (1745-1792), English explorer, was born in London. In 1756 he entered the navy, and was some time with Lord Hood; at the end of the Seven Years' War (1763) he took service with the Hudson's Bay Company. In 1768 he examined portions of the Hudson's Bay coasts with a view to improving the cod fishery, and in 1769-1772 he was employed in north-western discovery, searching especially for certain copper mines described by Indians. His first attempt (from the 6th of November 1769) failed through the desertion of his Indians; his second (from the 23rd of February 1770) through the breaking of his quadrant; but in his third (December 1770 to June 1772) he was successful, not only discovering the copper of the Coppermine river basin, but tracing this river to the Arctic Ocean. He reappeared at Fort Prince of Wales on the 30th of June 1772. Becoming governor of this fort in 1775, he was taken prisoner by the French under La Pérouse in 1782. He returned to England in 1787 and died there in 1792.

See his posthumous *Journey from Prince of Wales Fort in Hudson's Bay to the Northern Ocean* (London, 1795).

HEARNE, THOMAS (1678-1735), English antiquary, was born in July 1678 at Littlefield Green in the parish of White Waltham, Berkshire. Having received his early education from his father, George Hearne, the parish clerk, he showed such taste for study that a wealthy neighbour, Francis Cherry of Shottesbrooke (*c.* 1665-1713), a celebrated nonjuror, interested himself in the boy, and sent him to the school at Bray "on purpose to learn the Latin tongue." Soon Cherry took him into his own house, and his education was continued at

Bray until Easter 1696, when he matriculated at St Edmund Hall, Oxford. At the university he attracted the attention of Dr John Mill (1645-1707), the principal of St Edmund Hall, who employed him to compare manuscripts and in other ways. Having taken the degree of B.A. in 1699 he was made assistant keeper of the Bodleian Library, where he worked on the catalogue of books, and in 1712 he was appointed second keeper. In 1715 Hearne was elected architypographus and esquire bedell in civil law in the university, but objection having been made to his holding this office together with that of second librarian, he resigned it in the same year. As a nonjuror he refused to take the oaths of allegiance to King George I., and early in 1716 he was deprived of his librarianship. However he continued to reside in Oxford, and occupied himself in editing the English chroniclers. Having refused several important academical positions, including the librarianship of the Bodleian and the Camden professorship of ancient history, rather than take the oaths, he died on the 10th of June 1735.

Hearne's most important work was done as editor of many of the English chroniclers, and until the appearance of the "Rolls" series his editions were in many cases the only ones extant. Very carefully prepared, they were, and indeed are still, of the greatest value to historical students. Perhaps the most important of a long list are: Benedict of Peterborough's (Benedictus Abbas) *De vita et gestis Henrici II. et Ricardi I.* (1735); John of Fordun's *Scotichronicon* (1722); the monk of Evesham's *Historia vitae et regni Ricardi II.* (1729); Robert Mannyng's translation of Peter Langtoft's *Chronicle* (1725); the work of Thomas Otterbourne and John Whethamstede as *Duo rerum Anglicarum scriptores veteres* (1732); Robert of Gloucester's *Chronicle* (1724); J. Sprott's *Chronica* (1719); the *Vita et gesta Henrici V.*, wrongly attributed to Thomas Elmham (1727); Titus Livy's *Vita Henrici V.* (1716); Walter of Hemingburgh's *Chronicon* (1731); and William of Newburgh's *Historia rerum Anglicarum* (1719). He also edited John Leland's *Itinerary* (1710-1712) and the same author's *Collectanea* (1715); W. Camden's *Annales rerum Anglicarum et Hibernicarum regnante Elizabetha* (1717); Sir John Spelman's *Life of Alfred* (1709); and W. Roper's *Life of Sir Thomas More* (1716). He brought out an edition of Livy (1708); one of Pliny's *Epistolae et panegyricus* (1703); and one of the Acts of the Apostles (1715). Among his other compilations may be mentioned: *Ductor historicus, a Short System of Universal History* (1704, 1705, 1714, 1724); *A Collection of Curious Discourses by Eminent Antiquaries* (1720); and *Reliquiae Bodleianae* (1703).

Hearne left his manuscripts to William Bedford, who sold them to Dr Richard Rawlinson, who in his turn bequeathed them to the Bodleian. Two volumes of extracts from his voluminous diary were published by Philip Bliss (Oxford, 1857), and afterwards an enlarged edition in three volumes appeared (London, 1869). A large part of his diary entitled *Remarks and Collections, 1705-1714*, edited by C. E. Doble and D. W. Rannie, has been published by the Oxford Historical Society (1885-1898). *Bibliotheca Hearniana*, excerpts from the catalogue of Hearne's library, has been edited by B. Botfield (1848).

See *Impartial Memorials of the Life and Writings of Thomas Hearne by several hands* (1736); and W. D. Macray, *Annals of the Bodleian Library* (1890). Hearne's autobiography is published in W. Huddesford's *Lives of Leland, Hearne and Wood* (Oxford, 1772). T. Ouvry's *Letters addressed to Thomas Hearne* has been privately printed (London, 1874).

HEARSE (an adaptation of Fr. *herse*, a harrow, from Lat. *hirpex*, *hirpicem*, rake or harrow, Greek ἅρπαξ, a vehicle for the conveyance of a dead body at a funeral. The most usual shape is a four-wheeled car, with a roofed and enclosed body, sometimes with glass panels, which contains the coffin. This is the only current use of the word. In its earlier forms it is usually found as "herse," and meant, as the French word did, a harrow (*q.v.*). It was then applied to other objects resembling a harrow, following the French. It was then used of a portcullis, and thus becomes a heraldic term, the "herse" being frequently borne as a "charge," as in the arms of the City of Westminster. The chief application of the word is, however, to various objects used in funeral ceremonies. A "herse" or "hearse" seems first to have been a barrow-shaped framework of wood, to hold lighted tapers and decorations placed on a bier or coffin; this later developed into an elaborate pagoda-shaped erection of woodwork or metal for the funerals of royal or other distinguished persons. This held banners, candles, armorial bearings and other heraldic devices. Complimentary verses or epitaphs were often attached to the "hearse." An elaborate "hearse" was designed by Inigo Jones for the funeral of James I. The "hearse" is also found as a permanent erection over tombs. It is generally made of iron or other metal, and was used, not only to carry lighted candles, but also for the support of a pall during the funeral ceremony. There is a brass "hearse" in the Beauchamp Chapel at Warwick Castle, and one over the tomb of Robert Marmion and his wife at Tanfield Church near Ripon.

HEART, in anatomy.—The heart[1] is a four-chambered muscular bag, which lies in the cavity of the thorax between the two lungs. It is surrounded by another bag, the pericardium, for protective and lubricating purposes (see COELOM AND SEROUS MEMBRANES). Externally the heart is somewhat conical, its base being directed upward, backward and to the right, its apex downward, forward and to the left. In transverse section the cone is flattened, so that there is an anterior and a posterior surface and a superior and inferior border. The superior border, running obliquely downward and to the left, is very thick, and so gains the name of *margo obtusus*, while the inferior border is horizontal and sharp and is called *margo acutus* (see fig. 1). The divisions between the four chambers of the heart (namely, the two auricles and two ventricles) are indicated on the surface by grooves, and when these are followed it will be seen that the right auricle and ventricle lie on the front and right side, while the left auricle and ventricle are behind and on the left.

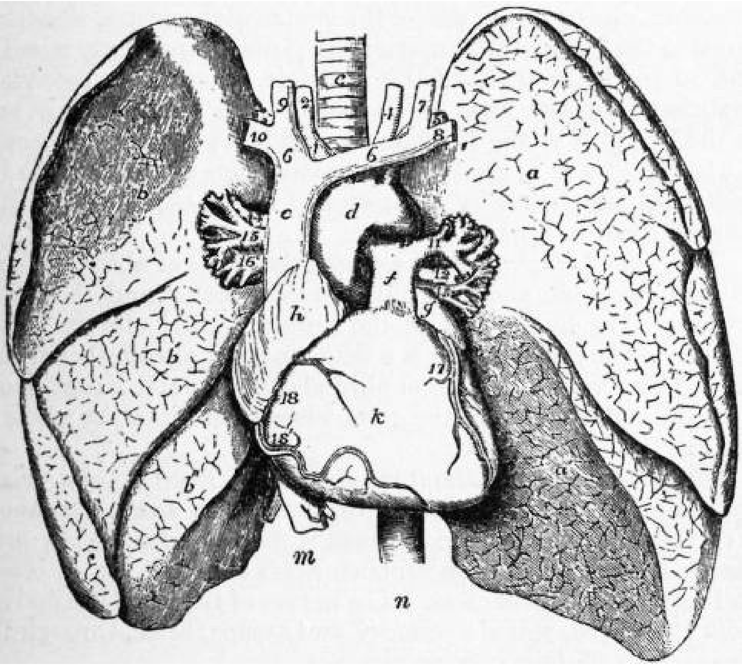

FIG. 1. The Thoracic Viscera.—In this diagram the lungs are turned to the side, and the pericardium removed to display the heart, *a*, upper, a′, lower lobe of left lung; *b*, upper, *b′*, middle, *b″*, lower lobe of right lung; *c*, trachea; *d*, arch of aorta; *e*, superior vena cava; *f*, pulmonary artery; *g*, left, and *h*, right auricle; *k*, right, and *l*, left ventricle; *m*, inferior vena cava; *n*, descending aorta; 1, innominate artery; 2, right, and 4, left common carotid artery; 3, right, and 5, left subclavian artery; 6, 6, right and left innominate vein; 7 and 9, left and right internal jugular veins; 8 and 10, left and right subclavian veins; 11, 12, 13, left pulmonary artery, bronchus and vein; 14, 15, 16, right pulmonary bronchus, artery and vein; 17 and 18, left and right coronary arteries.

The *right auricle* is situated at the base of the heart, and its outline is seen on looking at the organ from in front. Into the posterior part of it open the two venae cavae (see fig. 2), the superior (*a*) above and the inferior (*b*) below. In front and to the left of the superior vena cava is the right auricular appendage (*e*) which overlaps the front of the root of the aorta, while running obliquely from the front of one vena cava to the other is a shallow groove called the *sulcus terminalis*, which indicates the original separation between the true auricle in front and the sinus venosus behind. When the auricle is opened by turning the front wall to the right as a flap the following structures are exposed:

1. A muscular ridge, called the *crista terminalis*, corresponding to the sulcus terminalis on the exterior.

2. A series of ridges on the anterior wall and in the appendage, running downward from the last and at right angles to it, like the teeth of a comb; these are known as *Musculi pectinati*.

3. The orifice of the superior vena cava (fig. 2, *a*) at the upper and back part of the chamber.

4. The orifice of the inferior vena cava (fig. 2, *b*) at the lower and back part.

5. Attached to the right and lower margins of this opening are the remains of the *Eustachian valve* (fig. 2, *h*), which in the foetus directs the blood from the inferior vena cava, through the *foramen ovale*, into the left auricle.

6. Below and to the left of this is the opening of the *coronary sinus* (fig. 2, *k*), which collects most of the veins returning blood from the substance of the heart.

7. Guarding this opening is the *coronary valve* or *valve of Thebesius*.

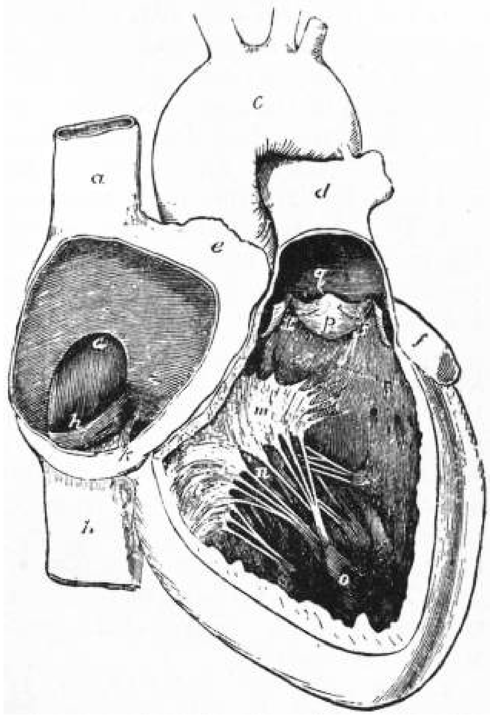

FIG. 2. Cavities of the Right Side of the Heart.—*a*, superior, and *b*, inferior vena cava; *c*, arch of aorta; *d*, pulmonary artery; *e*, right, and *f*, left auricular appendage; *g*, fossa ovalis; *h*, Eustachian valve; *k*, mouth of coronary vein; *l*, *m*, *n*, cusps of the tricuspid valve; *o*, *o*, papillary muscles; *p*, semilunar valve; *q*, corpus Arantii; *r*, lunula.

8. On the posterior or septal wall, between the two auricles, is an oval depression, called the *fossa ovalis* (fig. 2, *g*), the remains of the original communication between the two auricles. In about a quarter of all normal hearts there is a small valvular communication between the two auricles in the left margin of this depression (see “7th Report of the Committee of Collective Investigation,” *J. Anat. and Phys.* vol. xxxii. p. 164).

9. The *annulus ovalis* is the raised margin surrounding this depression.

10. On the left side, opening into the right ventricle, is the *right auriculo-ventricular opening*.

11. On the right wall, between the two caval openings, may occasionally be seen a slight eminence, the *tubercle of Lower*, which is supposed to separate the two streams of blood in the embryo.

12. Scattered all over the auricular wall are minute depressions, the *foramina Thebesii*, some of which receive small veins from the substance of the heart.

The *right ventricle* is a triangular cavity (see fig. 2) the base of which is largely formed by the auriculo-ventricular orifice. To the left of this it is continued up into the root of the pulmonary artery, and this part is known as the *infundibulum*. Its anterior wall forms part of the anterior surface of the heart, while its posterior wall is chiefly formed by the septum ventriculorum, between it and the left ventricle. Its lower border is the margo acutus 130
already mentioned. In transverse section it is crescentic, since the septal wall bulges into its cavity. In its interior the following structures are seen:

1. The *tricuspid valve* (fig. 2, *l*, *m*, *n*) guarding against reflux of blood into the right auricle. This consists of a short cylindrical curtain of fibrous tissue, which projects into the ventricle from the margin of the auriculo-ventricular aperture, while from its free edge three triangular flaps hang down, the bases of which touch one another. These cusps are spoken of as septal, marginal and infundibular, from their position.

2. The *chordae tendineae* are fine fibrous cords which fasten the cusps to the musculi papillares and ventricular wall, and prevent the valve being turned inside out when the ventricle contracts.

3. The *columnae carneae* are fleshy columns, and are of three kinds. The first are attached

to the wall of the ventricle in their whole length and are merely sculptured in relief, as it were; the second are attached by both ends and are free in the middle; while the third are known as the *musculi papillares* and are attached by one end to the ventricular wall, the other end giving attachment to the chordae tendineae. These musculi papillares are grouped into three bundles (fig. 2, *o*).

4. The *moderator band* is really one of the second kind of columnae carneae which stretches from the septal to the anterior wall of the ventricle.

5. The *pulmonary valve* (fig. 2, *p*) at the opening of the pulmonary artery has three crescentic, pocket-like cusps, which, when the ventricle is filling, completely close the aperture, but during the contraction of the ventricle fit into three small niches known as the *sinuses of Valsalva*, and so are quite out of the way of the escaping blood. In the middle of the free margin of each is a small knob called the *corpus Arantii* (fig. 2, *q*), and on each side of this a thin crescent-shaped flap, the *lunula* (fig. 2, *r*), which is only made of two layers of endocardium, whereas in the rest of the cusp there is a fibrous backing between these two layers.

The *left auricle* is situated at the back of the base of the heart, behind and to the left of the right auricle. Running down behind it are the oesophagus and the thoracic aorta. When it is opened it is seen to have a much lighter colour than the other cavities, owing to the greater thickness of its endocardium obscuring the red muscle beneath. There are no musculi pectinati except in the auricular appendage. The openings of the four pulmonary veins are placed two on each side of the posterior wall, but sometimes there may be three on the right side, and only one on the left. On the septal wall is a small depression like the mark of a finger-nail, which corresponds to the anterior part of the fossa ovalis and often forms a valvular communication with the right auricle. The auriculo-ventricular orifice is large and oval, and is directed downward and to the left. Foramina Thebesii and venae minimae cordis are found in this auricle, as in the right, although the chamber is one for arterial or oxidized blood.

At the lower part of the posterior surface of the unopened auricle, lying in the left auriculo-ventricular furrow, is the coronary sinus, which receives most of the veins returning the blood from the heart substance; these are the right and left coronary veins at each extremity and the posterior and left cardiac veins from below. One small vein, called the oblique vein of Marshall, runs down into it across the posterior surface of the auricle, from below the left lower pulmonary vein, and is of morphological interest.

The *left ventricle* is conical, the base being above, behind and to the right, while the apex corresponds to the apex of the heart and lies opposite the fifth intercostal space, 3½ in. from the mid line. The following structures are seen inside it:—

1. The *mitral valve* guarding the auriculo-ventricular opening has the same arrangement as the tricuspid, already described, save that there are only two cusps, named marginal and aortic, the latter of which is the larger.

2. The chordae tendineae and columnae carneae resemble those of the right ventricle, though there are only two bundles of musculi papillares instead of three. These are very large. A moderator band has been found as an abnormality (see *J. Anat. and Phys.* vol. xxx. p. 568).

3. The *aortic valve* has the same structure as the pulmonary, though the cusps are more massive. From the anterior and left posterior sinuses of Valsalva the coronary arteries arise. That part of the ventricle just below the aortic valve, corresponding to the infundibulum on the right, is known as the aortic vestibule.

The walls of the left ventricle are three times as thick as those of the right, except at the apex, where they are thinner. The septum ventriculorum is concave towards the left ventricle, so that a transverse section of that cavity is nearly circular. The greater part of it has nearly the same thickness as the rest of the left ventricular wall and is muscular, but a small portion of the upper part is membranous and thin, and is called the *pars membranacea septi*; it lies between the aortic and pulmonary orifices.

Structure of the Heart.—The arrangement of the muscular fibres of the heart is very complicated and only imperfectly known. For details one of the larger manuals, such as Cunningham’s *Anatomy* (London, 1910), or Gray’s *Anatomy* (London, 1909), should be consulted. The general scheme is that there are superficial fibres common to the two auricles and two ventricles and deeper fibres for each cavity. Until recently no fibres had been traced from the auricles to the ventricles, though Gaskell predicted that these would be found, and the credit for first demonstrating them is due to Stanley Kent, their details having subsequently been worked out by W. His, Junr., and S. Tawara. The fibres of this *auriculo-ventricular bundle* begin, in the right auricle, below the opening of the coronary sinus, and run forward on the right side of the auricular septum, below the fossa ovalis, and close to the auriculo-ventricular septum. Above the septal flap of the tricuspid valve they thicken and divide into two main branches, one on either side of the ventricular septum, which run down to the bases of the anterior and posterior papillary muscles, and so reach the walls of the ventricle, where their secondary branches form the *fibres of Purkinje*. The bundle is best seen in the hearts of young Ruminants, and it is presumably through it that the wave of contraction passes from the auricles to the ventricles (see article by A. Keith and M. Flack, *Lancet*, 11th of August 1906, p. 359).

The *central fibrous body* is a triangular mass of fibro-cartilage, situated between the two auriculo-ventricular and the aortic orifices. The upper part of the septum ventriculorum blends with it. The *endocardium* is a delicate layer of endothelial cells backed by a very thin layer of fibro-elastic tissue; it is continuous with the endothelium of the great vessels and lines the whole of the cavities of the heart.

The heart is roughly about the size of the closed fist and weighs from 8 to 12 oz.; it continues to increase in size up to about fifty years of age, but the increase is more marked in the male than in the female. Each ventricle holds about 4 f. oz. of blood, and each auricle rather less. The nerves of the heart are derived from the vagus, spinal accessory and sympathetic, through the superficial and deep cardiac plexuses.

Embryology.

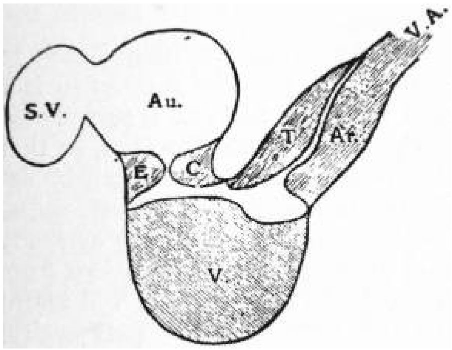

Fig. 3.—Formation of Septa. Diagram of the formation of some of the septa of the heart (viewed from the right side).

S.V. Sinus venosus.
Au. Auricle.
E.C. Endocardial cushions forming septum intermedium. 131
V. Septum ventriculorum.
T. Ar. Septum aorticum intruncus arteriosus.
V.A. Ventral aorta.

In the article on the arteries (*q.v.*) the formation and coalescence of the two *primitive ventral aortae* to form the heart are noticed, so that we may here start with a straight median tube lying ventral to the pharynx and being prolonged cephalad into the ventral aortae and caudad into the vitelline veins. This soon shows four dilatations, which, from the tail towards the head end, are called the sinus venosus, the auricle, the ventricle and the truncus[2] arteriosus. As the tubular heart grows more rapidly than the pericardium which contains it, it becomes bent into the form of an S laid on its side (∾), the ventral convexity being the ventricle and the dorsal the auricle. The passage from the auricle to the ventricle is known as the *auricular canal*, and in the dorsal and ventral parts of this appear two thickenings known as *endocardial cushions*, which approach one another and leave a transverse slit between them (fig. 3, E.C.). Eventually these two cushions fuse in the middle line, obliterating the central part of the slit, while the lateral parts remain as the two auriculo-ventricular orifices; this fusion is known as the *septum intermedium*. From the bottom (ventral convexity) of the ventricle an antero-posterior median septum grows up, which is the *septum inferius* or *septum ventriculorum* (fig. 3, V). Posteriorly (caudally) this septum fuses with the septum intermedium, but anteriorly it is free at the lower part of the truncus arteriosus. On referring to the development of the arteries (see Arteries) it will be seen that another septum starts between the last two pairs of aortic arches and grows downward (caudad) until it reaches and joins with the septum inferius just mentioned. This *septum aorticum* (formed by two ingrowths from the wall of the vessel which fuse later) becomes twisted in such a way that the right ventricle is continuous with the last pair of aortic arches (pulmonary artery), while the left ventricle communicates with the other arches (the permanent ventral aorta and its branches); it joins the septum ventriculorum in the upper part of the ventricular cavity and so forms the *pars membranacea septi* (fig. 3, T. Ar).

The fate of the sinus venosus and auricle must now be followed. Into the former, at first, only the two vitelline veins open, but later, as they develop, the *ducts of Cuvier* and the *umbilical veins* join in (see VEINS). As the ducts of Cuvier come from each side the sinus spreads out to meet them and becomes transversely elongated. The slight constriction, which at first is the only separation between the sinus and the auricle, becomes more marked, and later the opening is into the right part of the auricle, and is guarded by two valvular folds of endocardium (the *venous valves*) which project into that cavity, and are continuous above with a temporary downgrowth from the roof, known as the *septum spurium*. Later the right side of the sinus enlarges, and so does the right part of the aperture, until the back part of the right side of the auricle and the right part of the sinus venosus are thrown into one, and the only remnants of the partition are the crista terminalis and the Eustachian and Thebesian Valves. The left part of the sinus venosus, which does not enlarge at the same rate as the right part, remains as the coronary sinus. It will now be seen why, in the adult heart, all the veins which open into the right auricle open into its posterior part, behind the crista terminalis. The septum spurium has been referred to as a temporary structure; the real division between the two auricles occurs at a later date than that between the ventricles and to the left of the septum spurium. It is formed by two partitions, the first of which, called the *septum primum*, grows down from the auricular roof. At first it does not quite reach the endocardial cushions in the auricular canal, already mentioned, but leaves a gap, called the *ostium primum*, between. This has nothing to do with the *foramen ovale*, which occurs as an independent perforation higher up, and at first is known as the *ostium secundum*. When it is established the septum primum grows down and meets the endocardial cushions, and so the ostium primum is obliterated. The *septum secundum* grows down on the right of the septum primum and is never complete; it grows round and largely overlaps the foramen ovale and its edges form the annulus ovalis, so that, in the later months of foetal life, the foramen ovale is a valvular opening, the floor of which is formed by the septum primum and the margins by the septum secundum. The closure of the foramen is brought about by adhesion of the two septa.

The pulmonary veins of the two sides at first join one another, dorsal to the left auricle, and open into that cavity by a single median trunk, but, as the auricle grows, this trunk and part of the right and left veins are absorbed into its cavity.

The mitral and tricuspid valves are formed by the shortening of the auricular canal which becomes telescoped into the ventricle, and the cusps are the remnants of this telescoping process.

The columnae carneae and chordae tendineae are the remains of a spongy network which originally filled the cavity of the primary ventricle.

The aortic and pulmonary valves are laid down in the ventral aorta, before it is divided into aorta and pulmonary artery, as four endocardial cushions; anterior, posterior and two lateral. The septum aorticum cuts the latter two into two, so that each artery has the rudiments of three cusps.

Abnormalities of the heart are very numerous, and can usually be explained by a knowledge of its development. They often cause grave clinical symptoms. A clear and well-illustrated review of the most important of them will be found in the chapter on congenital disease of the heart in *Clinical Applied Anatomy*, by C. R. Box and W. McAdam Eccles, London, 1906.

For further details of the embryology of the heart see Oscar Hertwig’s *Entwicklungslehre der Wirbeltiere* (Jena, 1902); G. Born, “Entwicklung des Säugetierherzens,” *Archiv f. mik. Anat.* Bd. 33 (1889); W. His, *Anatomie menschlicher Embryonen* (Leipzig, 1881-1885); Quain’s *Anatomy*, vol. i. (1908); C. S. Minot, *Human Embryology* (New York, 1892); and A. Keith, *Human Embryology and Morphology* (London, 1905).

Comparative Anatomy.

In the Acrania (*e.g.* lancelet) there is no heart, though the vessels are specially contractile in the ventral part of the pharynx.

In the Cyclostomata (lamprey and hag), and Fishes, the heart has the same arrangement which has been noticed in the human embryo. There is a smooth, thin-walled sinus venosus, a thin reticulate-walled auricle, produced laterally into two appendages, a thick-walled ventricle, and a *conus arteriosus* containing valves. In addition to these the beginning of the ventral aorta is often thickened and expanded to form a *bulbus arteriosus*, which is non-contractile, and, strictly speaking, should rather be described with the arteries than with the heart. In relation to human embryology the smooth sinus venosus and reticulated auricle are interesting. Between the auricle and ventricle is the auriculo-ventricular valve, which primarily consists of two cusps, comparable to the two endocardial cushions of the human embryo, though in some forms they may be subdivided. In the interior of the ventricle is a network of muscular trabeculae. The conus arteriosus in the Elasmobranchs (sharks and rays) and Ganoids (sturgeon) is large and provided with several rows of semilunar valves, but in the Cyclostomes (lamprey) and Teleosts (bony fishes) the conus is reduced and only the anterior (cephalic) row of valves retained. With the reduction of the conus the bulbus arteriosus is enlarged. So far the heart is a single tubular organ expanded into various cavities and having the characteristic ∾-shaped form seen in the human embryo; it contains only venous blood which is forced through the gills to be oxidized on its way to the tissues. In the Dipnoi (mud fish), in which rudimentary lungs, as well as gills, are developed, the auricle is divided into two, and the sinus venosus opens into the right auricle. The conus arteriosus too begins to be divided into two chambers, and in Protopterus this division is complete. This division of the heart is one instance in which mammalian ontogeny does not repeat the processes of phylogeny, because, in the human embryo, it has been shown that the ventricular septum appears before the auricular. This want of harmony is sometimes spoken of as the "falsification of the embryological record."

In the Amphibia there are also two auricles and one ventricle, though in the Urodela 132
(tailed amphibians) the auricular septum is often fenestrated. The sinus venosus is still a separate chamber, and the conus arteriosus, which may contain many or few valves, is usually divided into two by a spiral fold. Structurally the amphibian heart closely resembles the dipnoan, though the increased size of the left auricle is an advance. In the Anura (frogs and toads) the whole ventricle is filled with a spongy network which prevents the arterial and venous blood from the two auricles mixing to any great extent. (For the anatomy and physiology of the frog's heart, see *The Frog*, by Milnes Marshall.)

In the Reptiles the ventricular septum begins to appear; this in the lizards is quite incomplete, but in the crocodiles, which are usually regarded as the highest order of living reptiles, the partition has nearly reached the top of the ventricle, and the condition resembles that of the human embryo before the pars membranacea septi is formed. The conus arteriosus becomes included in the ventricular cavity, but the sinus venosus still remains distinct, and its opening into the right ventricle is guarded by two valves which closely resemble the two venous valves in the auricle of the human embryo already referred to.

In the Birds the auricular and ventricular septa are complete; the right ventricle is thin-walled and crescentic in section, as in Man, and the musculi papillares are developed. The left auriculo-ventricular valve has three membranous cusps with chordae tendineae attached to them, but the right auriculo-ventricular valve has a large fleshy cusp without chordae tendineae. The sinus venosus is largely included in the right auricle, but remains of the two venous valves are seen on each side of the orifice of the inferior vena cava.

In the Mammals the structure of the heart corresponds closely with the description of that of Man already given. In the Ornithorynchus, among the Monotremes, the right auriculo-ventricular valve has two fleshy and two membranous cusps, thus showing a resemblance to that of the bird. In the Echidna, the other member of the order, however, both auriculo-ventricular valves are membranous. In the Edentates the remains of the venous valves at the opening of the inferior vena cava are better marked than in other orders. In the Ungulates the moderator band in the right ventricle is especially well developed, and the central fibrous body at the base of the heart is often ossified, forming the os cordis so well known in the heart of the ox.

The position of the heart in the lower mammals is not so oblique as it is in Man.

For further details, see C. Rose, *Beitr. z. vergl. Anal. des Herzens der Wirbelthiere Morph. Jahrb.*, Bd. xvi. (1890); R. Wiedersheim, *Vergleichende Anatomie der Wirbelthiere* (Jena, 1902) (for literature); also Parker and Haswell's *Zoology* (London, 1897).

(F. G. P.)

Heart Disease.—In the early ages of medicine, the absence of correct anatomical, physiological and pathological knowledge prevented diseases of the heart from being recognized with any certainty during life, and almost entirely precluded them from becoming the object of medical treatment. But no sooner did Harvey (1628) publish his discovery of the circulation of the blood, and its dependence on the heart as its central organ, than derangements of the circulation began to be recognized as signs of disease of that central organ. (See also under Vascular System.)

Among the earliest to profit by this discovery and to make important contributions to the literature of diseases of the heart and circulation were, R. Lower (1631-1691), R. Vieussens (1641-1716). H. Boerhave (1668-1738) and the great pathologists at the beginning of the 18th century, G. M. Lancisi (1654-1720), G. B. Morgagni (1682-1771) and J. B. Senac (1693-1770). The works of these writers form very interesting reading, and it is remarkable how careful were the observations made, and how sound the conclusions drawn, by these pioneers of scientific medicine. J. N. Corvisart (1755-1821) was one of the earliest to make practical use of R. T. Auenbrugger's (1722-1809) invention of percussion to determine the size of the heart. R. T. H. Laennec (1781-1826) was the first to make a scientific application of mediate auscultation to the diagnosis of disease of the chest, by the invention of the stethoscope. J. Bouillaud (1796-1881) extended its use to the diagnosis of disease of the heart. To James Hope (1801-1841) we owe much of the precision we have now attained in diagnosis of valvular disease from abnormalities in the sounds produced during cardiac movements. This short list by no means exhausts the earlier literature on the subject, but each of these names marks an era in the progress of the diagnosis of cardiac disease. In later years the literature on this subject has become very copious.

The heart and great vessels occupy a position immediately to the left of the centre of the thoracic cavity. The anterior surface of the heart is projected against the chest wall and is surrounded on either side by the lungs, which are resonant organs, so that any increase in the size of the heart, "dilatation," can be detected by percussion. By placing the hand on the chest, palpation, the impulse of the left ventricle, or apex beat, can normally be felt just below and internal to the nipple. Deviations from the normal in the position or force of the apex beat will afford important information as to the nature of the pathological changes in the heart. Thus, displacement downwards and outwards of the apex beat, with a forcible thrusting impulse, will indicate hypertrophy, or increase of the muscular wall and increased driving power of the left ventricle, whereas a similar displacement with a feeble diffuse impulse will indicate dilatation, or over-distension of its cavity from stretching of the walls.

By auscultation, or listening with a suitable instrument named a stethoscope over appropriate areas, we can detect any abnormality in the sounds of the heart, and the presence of murmurs indicative of disease of one or other of the valves of the heart.

The pericardium is a fibro-serous sac which loosely envelops the heart and the origin of the great vessels. Inflammation of this sac, or *pericarditis*, is apt to occur as a result of rheumatism, more especially in children. It may also occur as a complication of pneumonia. It is a serious affection associated with pain over the heart, fever, shortness of breath, rapid pulse and dilatation of the heart. As a result of the inflammation, fluid may accumulate in the pericardial sac, or the walls of the sac may become adherent to the heart and tend to embarrass its action. In favourable cases, however, recovery may take place without any untoward sequelae.

Diseases of the heart may be classified in two main groups, (1) Disease of the valves, and (2) Disease of the walls of the heart.

1. *Valvular Disease.*—Inflammation of the valves of the heart, or *endocarditis*, is one of the most common complications of rheumatism in children and young adults. More severe types, which are apt to prove fatal from a form of blood poisoning, may result when the valves of the heart are attacked by certain micro-organisms, such as the pneumococcus, which is responsible for pneumonia, the streptococcus and the staphylococcus pyogenes, the gonococcus and the influenza bacillus.

As a result of endocarditis, one or more of the valves may be seriously damaged, so that it leaks or becomes incompetent. The valves of the left side of the heart, the aortic and mitral valves, are affected far more commonly than those of the right side. It is indeed comparatively rarely that the latter are attacked. In the process of healing of a damaged valve, scar tissue is formed which has a tendency to contract, so that in some cases the orifice of the valve becomes narrowed, and the resulting stenosis or narrowing gives rise to obstruction of the blood stream. We may thus have incompetence or stenosis of a valve or both combined.

Valvular lesions are detected on auscultation over appropriate areas by the blowing sounds or murmurs to which they give rise, which modify or replace the normal heart sounds. Thus, lesions of the mitral valve give rise to murmurs which are heard at the apex beat of the heart, and lesions of the aortic valves to murmurs which are heard over the aortic area, in the second right intercostal space. Accurate timing of the murmurs in relation to the heart sounds enables us to judge whether the murmur is due to stenosis or incompetence of the valve affected.

If the valvular lesion is severe, it is essential for the proper maintenance of the circulation that certain changes should take place in the heart to compensate for or neutralize the effects of the regurgitation or obstruction, as the case may be. In affections of the aortic valve, the extra work falls on the left ventricle, which enlarges proportionately and undergoes hypertrophy. In affections of the mitral valve the effect is felt primarily by the left auricle, which is a thin walled structure incapable of undergoing the requisite increase in power to resist the backward flow through the mitral orifice in case of leakage, or to overcome the effects of obstruction in case of stenosis. The back pressure is therefore transmitted to the pulmonary circulation, and as the right ventricle is responsible for maintaining the flow of blood through the lungs, the strain and extra work fall on the right ventricle, which in turn enlarges and undergoes hypertrophy. The degree of hypertrophy of the left or right ventricle is thus, up to a certain point, a measure of the extent of the lesion of the aortic or mitral valve respectively. When the effects of the valvular lesion are so neutralized by these structural changes in the heart that the circulation is equably maintained, "compensation" is said to be efficient.

When the heart gives way under the strain, compensation is said to break down, and dropsy, shortness of breath, cough and cyanosis, are among the distressing symptoms which may set in. The mere existence of a valvular lesion does not call for any special treatment so long as compensation is efficient, and a large number of people with slight valvular lesions are living lives indistinguishable from those of their neighbours. It will, however, be readily understood that in the case of the more serious lesions certain precautions should be observed in regard to over-exertion, excitement, over-indulgence in tobacco or alcohol, &c., as the balance is more readily upset and any undue strain on the heart may cause a breakdown of compensation. When this occurs treatment is required. A period of rest in bed is often sufficient to enable the heart to recover, and this may be supplemented as required by the administration of mercurial and saline purgatives to relieve the embarrassed circulation, and of suitable cardiac tonics, such as digitalis and strychnin, to reinforce and strengthen the heart's action.

2. *Affections of the Muscular Wall of the Heart.*—Dilatation of the heart, or stretching of the walls of the heart, is an incident, as has already been stated, in pericarditis and in the earlier stages of valvular disease antecedent to hypertrophy. Temporary over-distension or dilatation of the cavities of the heart occurs in violent and protracted exertion, but rapidly subsides and is in no wise harmful to the sound and vigorous heart of the young. It is otherwise if the heart is weak and flabby from a too sedentary life or degenerative changes in its walls or during convalescence from a severe illness, when the same circumstances which will not injure a healthy heart, may give rise to serious dilatation from which recovery may be very protracted.

Influenza is a common cause of cardiac dilatation, and is liable to be a source of trouble after the acute illness has subsided, if the patient goes about and resumes his ordinary avocations too soon.

Fatty or fibroid degeneration of the heart wall may occur in later life from impaired nutrition of the muscle, due to partial obstruction of the blood-vessels supplying it, when they are the seat of the degenerative changes known as arteriosclerosis or atheroma. The affection known as *angina pectoris* (*q.v.*) may be a further consequence of this defective blood-supply.

The treatment will vary according to the nature of the case. In serious cases of dilatation, rest in bed, purgatives and cardiac tonics may be required.

In commencing degenerative change the Oertel treatment, consisting of graduated exercise up a gentle slope, limitation of fluids and a special diet, may be indicated.

In cases of slight dilatation after influenza or recent illness, the Schott treatment by baths and exercises as carried out at Nauheim may be sometimes beneficial. The change of air and scene, the enforced rest, the placid life, together with freedom from excitement and worry, are among the most important factors which contribute to success in this class of case.

Disorders of Rhythm of the Heart's Action.—Under this heading may be grouped a number of conditions to which the name "functional affections of the heart" has sometimes been applied, inasmuch as the disturbances in question cannot usually be attributed to definite organic disease of the heart. We must, of course, exclude from this category the irregularity in the force and frequency of the pulse, which is commonly associated with incompetence of the mitral valve.

The heart is a muscular organ possessing certain properties, rhythmicity, excitability, contractility, conductivity and tonicity, as pointed out by Gaskell, in virtue of which it is able to maintain a regular automatic beat independently of nerve stimulation. It is, however, intimately connected with the brain, blood-vessels and the abdominal and thoracic viscera, by innumerable nerves, through which impulses or messages are being constantly sent to and received from these various portions of the body. Such messages may give rise to disturbances of rhythm with which we are all familiar. For instance, sudden fright or emotion may cause a momentary arrest of the heart's action, and excitement or apprehension may set up a rapid action of the heart or *palpitation*. Palpitation, again, is often the result of digestive disorders, the message in this case being received from the stomach, instead of the brain as in emotional disturbances. It may also result from over-indulgence in tobacco and alcohol.

Tachycardia is the name applied to a more or less permanent increase in the rate of the heart-beat. It is usually a prominent feature in the affection known as Graves' disease or exophthalmic goitre. It may also result from chronic alcoholism. In the condition known as paroxysmal tachycardia there appears to be no adequate explanation for its onset.

Bradycardia or abnormal slowness of the heart-beat, is the converse of tachycardia. An abnormally slow pulse is met with in melancholia, cerebral tumour, jaundice and certain toxic conditions, or may follow an attack of influenza. There is, however, a peculiar affection characterized by abnormal slowness of pulse (often ranging as low as 30), and the onset, from time to time, of epileptiform or syncopal attacks. To this the name "Stokes-Adams disease" has been applied, as it was first called attention to by Adams in 1827, and subsequently fully described by Stokes in 1836. It is usually associated with senile degenerative change of the heart and vascular system, and is held to be due to impairment of conductivity in the muscular fibres (bundle of His) which transmit the wave of contraction from the auricle to the ventricle. It is of serious significance in view of the symptoms associated with it.

Intermittency of the Pulse.—By this is understood a pulse in which a beat is dropped from time to time. The dropping of a beat may occur at regular intervals every two, four or six beats, &c., or occasionally at irregular intervals after a series of normal beats. On examining the heart, it is found, as a rule, that the cause of the intermission at the wrist is not actual omission of a heart-beat, but the occurrence of a hurried imperfect cardiac contraction which does not transmit a pulse-wave to the wrist. It is not characteristic of any special form of heart affection, and is rarely of serious import. It may be due to reflex digestive disturbances, or be associated with conditions of nervous breakdown and irritability, or with an atonic and relaxed condition of the heart muscle. The treatment of these disorders of rhythm of the heart will vary greatly according to the cause and is often a matter of considerable difficulty.

(J. F. H. B.)

Surgery of Heart and Pericardium.—As the result of acute or chronic inflammation of the lining membrane of the fibrous sac which surrounds the heart and the neighbouring parts of the large blood-vessels, a dropsical or a purulent collection may form in it, or the sac may be quietly distended by a thin watery fluid. In either case, but especially in the latter, the heart may be so embarrassed in its work that death seems imminent. The condition is generally due to the cultivation in the pericardium of the germs of rheumatism, influenza or gonorrhoea, or of those of ordinary suppuration. Respiration as well as circulation is embarrassed, and there is a marked fulness and dulness of the front wall of the chest to the left of the breast-bone. In that region also pain and tenderness are complained of. By using the slender, hollow needle of an aspirator great relief may be afforded, but the tapping may have to be repeated from time to time. If the fluid drawn off is found to be purulent, it may be necessary to make a trap-door opening into the chest by cutting across the 4th and 5th ribs, incising and evacuating the pericardium and providing for drainage. In short, an abscess in the pericardium must be treated like an abscess in the pleura. 134

Wounds of the heart are apt to be quickly fatal. If the probability is that the enfeebled action of the heart is due to pressure from blood which is leaking into, and is locked up in the pericardium, the proper treatment will be to open the pericardium, as described above, and, if possible, to close the opening in the auricle, ventricle or large vessel, by sutures.

(E. O.*)

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1 In O. Eng. *heorte*; this is a common Teut. word, cf. Dut. *hart*, Ger. *Herz*, Goth. *hairto*; related by root are Lat. *cor* and Gr. καρδία; the ultimate root is *kard-*, to quiver, shake.

2 This is often called bulbus arteriosus, but it will be seen that the term is used rather differently

in comparative anatomy.

HEART-BURIAL, the burial of the heart apart from the body. This is a very ancient practice, the special reverence shown towards the heart being doubtless due to its early association with the soul of man, his affections, courage and conscience. In medieval Europe heart-burial was fairly common. Some of the more notable cases are those of Richard I., whose heart, preserved in a casket, was placed in Rouen cathedral; Henry III., buried in Normandy; Eleanor, queen of Edward I., at Lincoln; Edward I., at Jerusalem; Louis IX., Philip III., Louis XIII. and Louis XIV., in Paris. Since the 17th century the hearts of deceased members of the house of Habsburg have been buried apart from the body in the Loretto chapel in the Augustiner Kirche, Vienna. The most romantic story of heart-burial is that of Robert Bruce. He wished his heart to rest at Jerusalem in the church of the Holy Sepulchre, and on his deathbed entrusted the fulfilment of his wish to Douglas. The latter broke his journey to join the Spaniards in their war with the Moorish king of Granada, and was killed in battle, the heart of Bruce enclosed in a silver casket hanging round his neck. Subsequently the heart was buried at Melrose Abbey. The heart of James, marquess of Montrose, executed by the Scottish Covenanters in 1650, was recovered from his body, which had been buried by the roadside outside Edinburgh, and, enclosed in a steel box, was sent to the duke of Montrose, then in exile. It was lost on its journey, and years afterwards was discovered in a curiosity shop in Flanders. Taken by a member of the Montrose family to India, it was stolen as an amulet by a native chief, was once more regained, and finally lost in France during the Revolution. Of notable 17th-century cases there is that of James II., whose heart was buried in the church of the convent of the Visitation at Chaillot near Paris, and that of Sir William Temple, at Moor Park, Farnham. The last ceremonial burial of a heart in England was that of Paul Whitehead, secretary to the Monks of Medmenham club, in 1775, the interment taking place in the Le Despenser mausoleum at High Wycombe, Bucks. Of later cases the most notable are those of Daniel O’Connell, whose heart is at Rome, Shelley at Bournemouth, Louis XVII. at Venice, Kosciusko at the Polish museum at Rapperschwyll, Lake Zürich, and the marquess of Bute, taken by his widow to Jerusalem for burial in 1900. Sometimes other parts of the body, removed in the process of embalming, are given separate and solemn burial. Thus the viscera of the popes from Sixtus V. (1590) onward have been preserved in the parish church of the Quirinal. The custom of heart-burial was forbidden by Pope Boniface VIII. (1294-1303), but Benedict XI. withdrew the prohibition.

See Pettigrew, *Chronicles of the Tombs* (1857).

HEARTH (a word which appears in various forms in several Teutonic languages, cf. Dutch *haard*, German *Herd*, in the sense of “floor”), the part of a room where a fire is made, usually constructed of stone, bricks, tiles or earth, beaten hard and having a chimney above; the fire being lighted either on the hearth itself, or in a receptacle placed there for the purpose. Like the Latin *focus*, especially in the phrase for “hearth and home” answering to *pro aris et focis*, the word is used as equivalent to the home or household. The word is also applied to the fire and cooking apparatus on board ship; the floor of a smith’s forge; the floor of a reverberatory furnace on which the ore is exposed to the flame; the lower part of a blast furnace through which the metal goes down into the crucible; in soldering, a portable brazier or chafing dish, and an iron box sunk in the middle of a flat iron plate or table. An “open-hearth furnace” is a regenerative furnace of the reverberatory type used in making steel, hence “open-hearth steel” (see Iron and Steel).

Hearth-money, hearth tax or chimney-money, was a tax imposed in England on all houses except cottages at a rate of two shillings for every hearth. It was first levied in 1662, but owing to its unpopularity, chiefly caused by the domiciliary visits of the collectors, it was repealed in 1689, although it was producing £170,000 a year. The principle of the tax was not new in the history of taxation, for in Anglo-Saxon times the king derived a part of his revenue from a *fumage* or tax of smoke farthings levied on all hearths except those of the poor. It appears also in the hearth-penny or tax of a penny on every hearth, which as early as the 10th century was paid annually to the pope (see Peter’s Pence).

HEARTS, a game of cards of recent origin, though founded upon the same principle as many old games, such as *Slobberhannes*, *Four Jacks* and *Enflé*, namely, that of losing instead of winning as many tricks as possible. Hearts is played with a full pack, ace counting highest and deuce lowest. In the four-handed game, which is usually played, the entire pack is dealt out as at whist (but without turning up the last card, since there are no trumps), and the player at the dealer’s left begins by leading any card he chooses, the trick being taken by the highest card of the suit led. Each player must follow suit if he can; if he has no cards of the suit led he is privileged to throw away any card he likes, thus having an opportunity of getting rid of his hearts, which is the object of the game. When all thirteen tricks have been played each player counts the hearts he has taken in and pays into the pool a certain number of counters for them, according to an arrangement made before beginning play. In the four-handed, or sweepstake, game the method of settling called “Howell’s,” from the name of the inventor, has been generally adopted, according to which each player begins with an equal number of chips, say 100, and, after the hand has been played, pays into the pool as many chips for each heart he had taken as there are players besides himself. Then each player takes out of the pool one chip for every heart he did not win. The pool is thus exhausted with every deal. Hearts may be played by two, three, four or even more players, each playing for himself.

Spot Hearts.—In this variation the hearts count according to the number of spots on the cards, excepting that the ace counts 14, the king 13, queen 12 and knave 11, the combined score of the thirteen hearts being thus 104.

Auction Hearts.—In this the eldest hand examines his hand and bids a certain number of counters for the privilege of naming the suit to be got rid of, but without naming the suit. The other players in succession have the privilege of outbidding him, and whoever bids most declares the suit and pays the amount of his bid into the pool, the winner taking it.

Joker Hearts.—Here the deuce of hearts is discarded, and an extra card, called the joker, takes its place, ranking in value between ten and knave. It cannot be thrown away, excepting when hearts are led and an ace or court card is played, though if an opponent discards the ace or a court card of hearts, then the holder of the joker may discard it. The joker is usually considered worth five chips, which are either paid into the pool or to the player who succeeds in discarding the joker.

Heartsette.—In this variation the deuce of spades is deleted and the three cards left after dealing twelve cards to each player are called the *widow* (or *kitty*), and are left face downward on the table. The winner of the first trick must take the widow without showing it to his opponents.

Slobberhannes.—The object of this older form of Hearts is to avoid taking either the first or last trick or a trick containing the queen of clubs. A euchre pack (thirty two-cards, lacking all below the 7) is used, and each player is given 10 counters, one being forfeited to the pool if a player takes the first or last trick, or that containing the club queen. If he takes all three he forfeits four points.

Four Jacks (*Polignac or Quatre-Valets*) is usually played with a piquet pack, the cards ranking in France as at écarté, but in Great Britain and America as at piquet. There is no trump suit. Counters are used, and the object of the game is to avoid taking any trick containing a knave, especially the knave of spades, called *Polignac*. The player taking such a trick forfeits one counter to the pool.

Enflé (or *Schwellen*) is usually played by four persons with a piquet pack and for a pool. The cards rank as at Hearts, and there is no trump suit. A player must follow suit if he can, but if he cannot he may not discard, but must take up all tricks already won and add them to his hand. Play is continued until one player gets rid of all his cards and thus wins.

HEAT (O. E. *haétu*, which like "hot," Old Eng. *hát*, is from the Teutonic type *haita, hit*, to be hot; cf. Ger. *hitze, heiss*; Dutch, *hitte, heet*, &c.), a general term applied to that branch of physical science which deals with the effects produced by heat on material bodies, with the laws of transference of heat, and with the transformations of heat into other kinds of energy. The object of the present article is to give a brief sketch of the historical development of the science of heat, and to indicate the relation of the different branches of the subject, which are discussed in greater detail with reference to the latest progress in separate articles.

1. *Meanings of the Term Heat.*—The term heat is employed in ordinary language in a number of different senses. This makes it a convenient term to employ for the general title of the science, but the different meanings must be carefully distinguished in scientific reasoning. For the present purpose, omitting metaphorical significations, we may distinguish four principal uses of the term: (*a*) Sensation of heat; (*b*) Temperature, or degree of hotness; (*c*) Quantity of thermal energy; (*d*) Radiant heat, or energy of radiation.

(*a*) From the sense of heat, aided in the case of very hot bodies by the sense of sight, we obtain our first rough notions of heat as a physical entity, which alters the state of a body and its condition in respect of warmth, and is capable of passing from one body to another. By touching a body we can tell whether it is warmer or colder than the hand, and, by touching two similar bodies in succession, we can form a rough estimate, by the acuteness of the sensation experienced, of their difference in hotness or coldness over a limited range. If a hot iron is placed on a cold iron plate, we may observe that the plate is heated and the iron cooled until both attain appreciably the same degree of warmth; and we infer from similar cases that something which we call "heat" tends to pass from hot to cold bodies, and to attain finally a state of equable diffusion when all the bodies concerned are equally warm or cold. Ideas such as these derived entirely from the sense of heat, are, so to speak, embedded in the language of every nation from the earliest times.

(*b*) From the sense of heat, again, we naturally derive the idea of a continuous scale or order, expressed by such terms as summer heat, blood heat, fever heat, red heat, white heat, in which all bodies may be placed with regard to their degrees of hotness, and we speak of the *temperature* of a body as denoting its place in the scale, in contradistinction to the quantity of heat it may contain.

(*c*) The quantity of heat contained in a body obviously depends on the size of the body considered. Thus a large kettleful of boiling water will evidently contain more heat than a teacupful, though both may be at the same temperature. The temperature does not depend on the size of the body, but on the degree of concentration of the heat in it, *i.e.* on the quantity of heat per unit mass, other things being equal. We may regard it as axiomatic that a given body (say a pound of water) in a given state (say boiling under a given pressure) must always contain the same quantity of heat, and conversely that, if it contains a given quantity of heat, and if it is under conditions in other respects, it must be at a definite temperature, which will always be the same for the same given conditions.

(*d*) It is a matter of common observation that rays of the sun or of a fire falling on a body warm it, and it was in the first instance natural to suppose that heat itself somehow travelled across the intervening space from the sun or fire to the body warmed, in much the same way as heat may be carried by a current of hot air or water. But we now know that energy of radiation is not the same thing as heat, though it is converted into heat when the rays strike an absorbing substance. The term "radiant heat," however, is generally retained, because radiation is commonly measured in terms of the heat it produces, and because the transference of energy by radiation and absorption is the most important agency in the diffusion of heat.

2. *Evolution of the Thermometer.*—The first step in the development of the science of heat was necessarily the invention of a thermometer, an instrument for indicating temperature and measuring its changes. The first requisite in the case of such an instrument is that it should always give, at least approximately the same indication at the same temperature. The air-thermoscope of Galileo, illustrated in fig. 1, which consisted of a glass bulb containing air, connected to a glass tube of small bore dipping into a coloured liquid, though very sensitive to variations of temperature, was not satisfactory as a measuring instrument, because it was also affected by variations of atmospheric pressure. The invention of the type of thermometer familiar at the present day, containing a liquid hermetically sealed in a glass bulb with a fine tube attached, is also generally attributed to Galileo at a slightly later date, about 1612. Alcohol was the liquid first

employed, and the degrees, intended to represent thousandths of the volume of the bulb, were marked with small beads of enamel fused on the stem, as shown in fig. 2. In order to render the readings of such instruments comparable with each other, it was necessary to select a fixed point or standard temperature as the zero or starting-point of the graduations. Instead of making each degree a given fraction of the volume of the bulb, which would be difficult in practice, and would give different values for the degree with different liquids, it was soon found to be preferable to take *two fixed points*, and to divide the interval between them into the same number of degrees. It was natural in the first instance to take the temperature of the human body as one of the fixed points. In 1701 Sir Isaac Newton proposed a scale in which the freezing-point of water was taken as zero, and the temperature of the human body as 12°. About the same date (1714) Gabriel Daniel Fahrenheit proposed to take as zero the lowest temperature obtainable with a freezing mixture of ice and salt, and to divide the interval between this temperature and that of the human body into 12°. To obtain finer graduations the number was subsequently increased to 96°. The freezing-point of water was at that time supposed to be somewhat variable, because as a matter of fact it is possible to cool water several degrees below its freezing-point in the absence of ice. Fahrenheit showed, however, that as soon as ice began to form the temperature always rose to the same point, and that a mixture of ice or snow with pure water always gave the same temperature. At a later period he also showed that the temperature of boiling water varied with the barometric pressure, but that it was always the same at the same pressure, and might therefore be used as the second fixed point (as Edmund Halley and others had suggested) provided that a definite pressure, such as the average atmospheric pressure, were specified. The freezing and boiling-points on one of his thermometers, graduated as already explained, with the temperature of the body as 96°, came out in the neighbourhood of 32° and 212° respectively, giving an interval of 180° between these points. Shortly after Fahrenheit's death (1736) the freezing and boiling-points of water were generally recognized as the most convenient fixed points to adopt, but different systems of subdivision were employed. Fahrenheit's scale, with its small degrees and its zero below the freezing-point, possesses undoubted advantages for meteorological work, and is still retained in most English-speaking countries. But for general scientific purposes, the centigrade system, in which the freezing-point is marked 0° and the boiling-point 100°, is now almost universally employed, on account of its greater simplicity from an arithmetical point of view. For work of precision the fixed points have been more exactly defined (see Thermometry), but no change has been made in the fundamental principle of graduation.

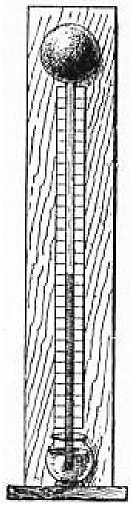


Fig. 1.

Fig. 2.

3. *Comparison of Scales based on Expansion.*—Thermometers constructed in the manner already described will give strictly comparable readings, provided that the tubes be of uniform bore, and that the same liquid and glass be employed in their construction. But they 136
possess one obvious defect from a theoretical point of view, namely, that the subdivision of the temperature scale depends on the expansion of the particular liquid selected as the standard. A liquid such as water, which, when continuously heated at a uniform rate from its freezing-point, first contracts and then expands, at a rapidly increasing rate, would obviously be unsuitable. But there is no a priori reason why other liquids should not behave to some extent in a similar way. As a matter of fact, it was soon observed that thermometers carefully constructed with different liquids, such as alcohol, oil and mercury, did not agree precisely in their indications at points of the scale intermediate between the fixed points, and diverged even more widely outside these limits. Another possible method, proposed in 1694 by Carlo Renaldeni (1615-1698), professor of mathematics and philosophy at Pisa, would be to determine the intermediate points of the scale by observing the temperatures of mixtures of ice-cold and boiling water in varying proportions. On this method, the temperature of 50° C. would be defined as that obtained by mixing equal weights of water at 0° C. and 100° C.; 20° C., that obtained by mixing 80 parts of water at 0° C. with 20 parts of water at 100° C. and so on. Each degree rise of temperature in a mass of water would then represent the addition of the same quantity of heat. The scale thus obtained would, as a matter of fact, agree very closely with that of a mercury thermometer, but the method would be very difficult to put in practice, and would still have the disadvantage of depending on the properties of a particular liquid, namely, water, which is known to behave in an anomalous manner in other respects. At a later date, the researches of Gay-Lussac (1802) and Regnault (1847) showed that the laws of the expansion of gases are much simpler than those of liquids. Whereas the expansion of alcohol between 0° C. and 100° C. is nearly seven times as

great as that of mercury, all gases (excluding easily condensible vapours) expand equally, or so nearly equally that the differences between them cannot be detected without the most refined observations. This equality of expansion affords a strong a priori argument for selecting the scale given by the expansion of a gas as the standard scale of temperature, but there are still stronger theoretical grounds for this choice, which will be indicated in discussing the absolute scale (§ 21). Among liquids mercury is found to agree most nearly with the gas scale, and is generally employed in thermometers for scientific purposes on account of its high boiling-point and for other reasons. The differences of the mercurial scale from the gas scale having been carefully determined, the mercury thermometer can be used as a secondary standard to replace the gas thermometer within certain limits, as the gas thermometer would be very troublesome to employ directly in ordinary investigations. For certain purposes, and especially at temperatures beyond the range of mercury thermometers, electrical thermometers, also standardized by reference to the gas thermometer, have been very generally employed in recent years, while for still higher temperatures beyond the range of the gas thermometer, thermometers based on the recently established laws of radiation are the only instruments available. For a further discussion of the theory and practice of the measurement of temperature, the reader is referred to the article THERMOMETRY.

4. *Change of State.*—Among the most important effects of heat is that of changing the state of a substance from solid to liquid, or from liquid to vapour. With very few exceptions, all substances, whether simple or compound, are known to be capable of existing in each of the three states under suitable conditions of temperature and pressure. The transition of any substance, from the state of liquid to that of solid or vapour under the ordinary atmospheric pressure, takes place at fixed temperatures, the freezing and boiling-points, which are very sharply defined for pure crystalline substances, and serve in fact as fixed points of the thermometric scale. A change of state cannot, however, be effected in any case without the addition or subtraction of a certain definite quantity of heat. If a piece of ice below the freezing-point is gradually heated at a uniform rate, its temperature may be observed to rise regularly till the freezing-point is reached. At this point it begins to melt, and its temperature ceases to rise. The melting takes a considerable time, during the whole of which heat is being continuously supplied without producing any rise of temperature, although if the same quantity of heat were supplied to an equal mass of water, the temperature of the water would be raised nearly 80° C. Heat thus absorbed in producing a change of state without rise of temperature is called "Latent Heat," a term introduced by Joseph Black, who was one of the first to study the subject of change of state from the point of view of heat absorbed, and who in many cases actually adopted the comparatively rough method described above of estimating quantities of heat by observing the time required to produce a given change when the substance was receiving heat at a steady rate from its surroundings. For every change of state a definite quantity of heat is required, without which the change cannot take place. Heat must be added to melt a solid, or to vaporize a solid or a liquid, and conversely, heat must be subtracted to reverse the change, *i.e.* to condense a vapour or freeze a liquid. The quantity required for any given change depends on the nature of the substance and the change considered, and varies to some extent with the conditions (as to pressure, &c.) under which the change is made, but is always the same for the same change under the same conditions. A rough measurement of the latent heat of steam was made as early as 1764 by James Watt, who found that steam at 212° F., when passed from a kettle into a jar of cold water, was capable of raising nearly six times its weight of water to the boiling point. He gives the volume of the steam as about 1800 times that of an equal weight of water.

The phenomena which accompany change of state, and the physical laws by which such changes are governed, are discussed in a series of special articles dealing with particular cases. The articles on FUSION and ALLOYS deal with the change from the solid to the liquid state, and the analogous case of solution is discussed in the article on SOLUTION. The articles on CONDENSATION OF GASES, LIQUID GASES and VAPORIZATION deal with the theory of the change of state from liquid to vapour, and with the important applications of liquid gases to other researches. The methods of measuring the latent heat of fusion or vaporization are described in the article CALORIMETRY, and need not be further discussed here except as an introduction to the history of the evolution of knowledge with regard to the nature of heat.

5. *Calorimetry by Latent Heat.*—In principle, the simplest and most direct method of measuring quantities of heat consists in observing the effects produced in melting a solid or vaporizing a liquid. It was, in fact, by the fusion of ice that quantities of heat were first measured. If a hot body is placed in a cavity in a block of ice at 0° C., and is covered by a closely fitting slab of ice, the quantity of ice melted will be directly proportional to the

quantity of heat lost by the body in cooling to 0° C. None of the heat can possibly escape through the ice, and conversely no heat can possibly get in from outside. The body must cool exactly to 0° C., and every fraction of the heat it loses must melt an equivalent quantity of ice. Apart from heat lost in transferring the heated body to the ice block, the method is theoretically perfect. The only difficulty consists in the practical measurement of the quantity of ice melted. Black estimated this quantity by mopping out the cavity with a sponge before and after the operation. But there is a variable film of water adhering to the walls of the cavity, which gives trouble in accurate work. In 1780 Laplace and Lavoisier used a double-walled metallic vessel containing broken ice, which was in many respects more convenient than the block, but aggravated the difficulty of the film of water adhering to the ice. In spite of this practical difficulty, the quantity of heat required to melt unit weight of ice was for a long time taken as the unit of heat. This unit possesses the great advantage that it is independent of the scale of temperature adopted. At a much later date R. Bunsen (*Phil. Mag.*, 1871), adopting a suggestion of Sir John Herschel's, devised an ice-calorimeter suitable for measuring small quantities of heat, in which the difficulty of the water film was overcome by measuring the change in volume due to the melting of the ice. The volume of unit mass of ice is approximately 1.0920 times that of unit mass of water, so that the diminution of volume is 0.092 a cubic centimetre for each gramme of ice melted. The 137
method requires careful attention to details of manipulation, which are more fully discussed in the article on Calorimetry.

For measuring large quantities of heat, such as those produced by the combustion of fuel in a boiler, the most convenient method is the evaporation of water, which is commonly employed by engineers for the purpose. The natural unit in this case is the quantity of heat required to evaporate unit mass of water at the boiling point under atmospheric pressure. In boilers working at a higher pressure, or supplied with water at a lower temperature, appropriate corrections are applied to deduce the quantity evaporated in terms of this unit.

For laboratory work on a small scale the converse method of condensation has been successfully applied by John Joly, in whose steam-calorimeter the quantity of heat required to raise the temperature of a body from the atmospheric temperature to that of steam condensing at atmospheric pressure is observed by weighing the mass of steam condensed on it. (See Calorimetry.)

6. *Thermometric Calorimetry.*—For the majority of purposes the most convenient and the most readily applicable method of measuring quantities of heat, is to observe the rise of temperature produced in a known mass of water contained in a suitable vessel or calorimeter. This method was employed from a very early date by Count Rumford and other investigators, and was brought to a high pitch of perfection by Regnault in his extensive calorimetric researches (*Mémoires de l'Institut de Paris*, 1847); but it is only within comparatively recent years that it has really been placed on a satisfactory basis by the accurate definition of the units involved. The theoretical objections to the method, as compared with latent heat calorimetry, are that some heat is necessarily lost by the calorimeter when its temperature is raised above that of the surroundings, and that some heat is used in heating the vessel containing the water. These are small corrections, which can be estimated with considerable accuracy in practice. A more serious difficulty, which has impaired the value of much careful work by this method, is that the quantity of heat required to raise the temperature of a given mass of water 1° C. depends on the temperature at which the water is taken, and also on the scale of the thermometer employed. It is for this reason, in many cases, impossible to say, at the present time, what was the precise value, within ½ or even 1% of the heat unit, in terms of which many of the older results, such as those of Regnault, were expressed. For many purposes this would not be a serious matter, but for work of scientific precision such a limitation of accuracy would constitute a very serious bar to progress. The unit generally adopted for scientific purposes is the quantity of heat required to raise 1 gram (or kilogram) of water 1° C., and is called the calorie (or kilo-calorie). English engineers usually state results in terms of the British Thermal Unit (B.Th.U.), which is the quantity of heat required to raise 1 ℔ of water 1° F.

7. *Watt's Indicator Diagram; Work of Expansion.*—The rapid development of the steam-engine (*q.v.*) in England during the latter part of the 18th century had a marked effect on the progress of the science of heat. In the first steam-engines the working cylinder served both as boiler and condenser, a very wasteful method, as most of the heat was transferred directly from the fire to the condensing water without useful effect. The first improvement (about 1700) was to use a separate boiler, but the greater part of the steam supplied was still wasted in reheating the cylinder, which had been cooled by the injection of cold water to condense the steam after the previous stroke. In 1769 James Watt showed how to avoid

this waste by using a separate condenser and keeping the cylinder as hot as possible. In his earlier engines the steam at full boiler pressure was allowed to raise the piston through nearly the whole of its stroke. Connexion with the boiler was then cut off, and the steam at full pressure was discharged into the condenser. Here again there was unnecessary waste, as the steam was still capable of doing useful work. He subsequently introduced "expansive working," which effected still further economy. The connexion with the boiler was cut off when a fraction only, say ¼, of the stroke had been completed, the remainder of the stroke being effected by the expansion of the steam already in the cylinder with continually diminishing pressure. By the end of the stroke, when connexion was made to the condenser, the pressure was so reduced that there was comparatively little waste from this cause. Watt also devised an instrument called an *indicator* (see STEAM ENGINE), in which a pencil, moved up and down vertically by the steam pressure, recorded the pressure in the cylinder at every point of the stroke on a sheet of paper moving horizontally in time with the stroke of the piston. The diagram thus obtained made it possible to study what was happening inside the cylinder, and to deduce the work done by the steam in each stroke. The method of the indicator diagram has since proved of great utility in physics in studying the properties of gases and vapours. The work done, or the useful effect obtained from an engine or any kind of machine, is measured by the product of the resistance overcome and the distance through which it is overcome. The result is generally expressed in terms of the equivalent weight raised through a certain height against the force of gravity.[1] If, for instance, the pressure on a piston is 50 ℔ per sq. in., and the area of the piston is 100 sq. in., the force on the piston is 138
5000 ℔ weight. If the stroke of the piston is 1 ft., the work done per stroke is capable of raising a weight of 5000 ℔ through a height of 1 ft., or 50 ℔ through a height of 100 ft. and so on.

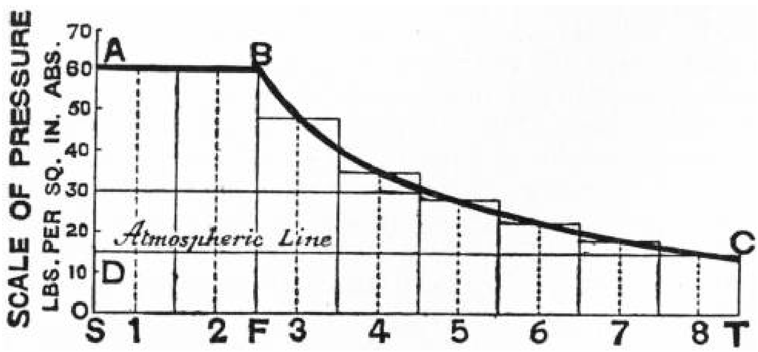


FIG. 3.—Watt's Indicator Diagram. Patent of 1782.

Fig. 3 represents an imaginary indicator diagram for a steam-engine, taken from one of Watt's patents. Steam is admitted to the cylinder when the piston is at the beginning of its stroke, at S. ST represents the length of the stroke or the limit of horizontal movement of the paper on which the diagram is drawn. The indicating pencil rises to the point A, representing the absolute pressure of 60 ℔ per sq. in. As the piston moves outwards the pencil traces the horizontal line AB, the pressure remaining constant till the point B is reached, at which connexion to the boiler is cut off. The work done so far is represented by the area of the rectangle ABSF, namely AS × SF, multiplied by the area of the piston in sq. in. The result is in foot-pounds if the fraction of the stroke SF is taken in feet. After cut-off at B the steam expands under diminishing pressure, and the pencil falls gradually from B to C, following the steam pressure until the exhaust valve opens at the end of the stroke. The pressure then falls rapidly to that of the condenser, which for an ideal case may be taken as zero, following Watt. The work done during expansion is found by dividing the remainder of the stroke FT into a number of equal parts (say 8, Watt takes 20) and measuring the pressure at the points 1, 2, 3, 4, &c., corresponding to the middle of each. We thus obtain a number of small rectangles, the sum of which is evidently very nearly equal to the whole area BCTF under the expansion curve, or to the remainder of the stroke FT multiplied by the average or mean value of the pressure. The whole work done in the forward stroke is represented by the area ABCTSA, or by the average value of the pressure P over the whole stroke multiplied by the stroke L. This area must be multiplied by the area of the piston A in sq. in. as before, to get the work done per stroke in foot-pounds, which is PLA. If the engine repeats this cycle N times per minute, the work done per minute is PLAN foot-pounds, which is reduced to horse-power by dividing by 33,000. If the steam is ejected by the piston at atmospheric pressure (15 ℔ per sq. in.) instead of being condensed at zero pressure, the area CDST under the atmospheric line CD, representing work done against back-pressure on the return stroke must be subtracted. If the engine repeats the same cycle or series of operations continuously, the indicator diagram will be a closed curve, and the nett work done per cycle will be represented by the included area, whatever the form of the curve.

8. *Thermal Efficiency.*—The thermal efficiency of an engine is the ratio of the work done by the engine to the heat supplied to it. According to Watt's observations, confirmed later by Clément and Désormes, the total heat required to produce 1 ℔ of saturated steam at any temperature from water at 0° C. was approximately 650 times the quantity of heat required to raise 1 ℔ of water 1° C. Since 1 ℔ of steam represented on this assumption a certain quantity of heat, the efficiency could be measured naturally in foot-pounds of work obtainable per ℔ of steam, or conversely in pounds of steam consumed per horse-power-hour.

In his patent of 1782 Watt gives the following example of the improvement in thermal efficiency obtained by expansive working. Taking the diagram already given, if the quantity of steam represented by AB, or 300 cub. in. at 60 ℔ pressure, were employed without expansion, the work realized, represented by the area ABSF, would be 6000/4 = 1500 foot-pounds. With expansion to 4 times its original volume, as shown in the diagram by the whole area ABCTSA, the mean pressure (as calculated by Watt, assuming Boyle's law) would be 0.58 of the original pressure, and the work done would be 6000 × 0.58 = 3480 foot-pounds for the same quantity of steam, or the thermal efficiency would be 2.32 times greater. The advantage actually obtained would not be so great as this, on account of losses by condensation, back-pressure, &c., which are neglected in Watt's calculation, but the margin would still be very considerable. Three hundred cub. in. of steam at 60 ℔ pressure would represent about .0245 of 1 ℔ of steam, or 28.7 B.Th.U., so that, neglecting all losses, the possible thermal efficiency attainable with steam at this pressure and four expansions (¼ cut-off) would be 3480/28.7, or 121 foot-pounds per B.Th.U. At a later date, about 1820, it was usual to include the efficiency of the boiler with that of the engine, and to reckon the efficiency or "duty" in foot-pounds per bushel or cwt. of coal. The best Cornish pumping-engines of that date achieved about 70 million foot-pounds per cwt., or consumed about 3.2 ℔ per horse-power-hour, which is roughly equivalent to 43 foot-pounds per B.Th.U. The efficiency gradually increased as higher pressures were used, with more complete expansion, but the conditions upon which the efficiency depended were not fully worked out till a much later date. Much additional knowledge with regard to the nature of heat, and the properties of gases and vapours, was required before the problem could be attacked theoretically.

9. *Of the Nature of Heat.*—In the early days of the science it was natural to ascribe the manifestations of heat to the action of a subtle imponderable fluid called "caloric," with the power of penetrating, expanding and dissolving bodies, or dissipating them in vapour. The fluid was imponderable, because the most careful experiments failed to show that heat produced any increase in weight. The opposite property of levitation was often ascribed to heat, but it was shown by more cautious investigators that the apparent loss of weight due to heating was to be attributed to evaporation or to upward air currents. The fundamental idea of an imaginary fluid to represent heat was useful as helping the mind to a conception of something remaining invariable in quantity through many transformations, but in some respects the analogy was misleading, and tended greatly to retard the progress of science. The caloric theory was very simple in its application to the majority of calorimetric experiments, and gave a fair account of the elementary phenomena of change of state, but it encountered serious difficulties in explaining the production of heat by friction, or the changes of temperature accompanying the compression or expansion of a gas. The explanation which the calorists offered of the production of heat by friction or compression was that some of the latent caloric was squeezed or ground out of the bodies concerned and became "sensible." In the case of heat developed by friction, they supposed that the abraded portions of the material were capable of holding a smaller quantity of heat, or had less "capacity for heat," than the original material. From a logical point of view, this was a perfectly tenable hypothesis, and one difficult to refute. It was easy to account in this way for the heat produced in boring cannon and similar operations, where the amount of abraded material was large. To refute this explanation, Rumford (*Phil. Trans.*, 1798) made his celebrated experiments with a blunt borer, in one of which he succeeded in boiling by friction 26.5 ℔ of cold water in 2½ hours, with the production of only 4145 grains of metallic powder. He then showed by experiment that the metallic powder required the same amount of heat to raise its temperature 1°, as an equal weight of the original metal, or that its "capacity for heat" (in this sense) was unaltered by reducing it to powder; and he argued that "in any case so small a quantity of powder could not possibly account for all the heat generated, that the supply of heat appeared to be inexhaustible, and that heat could not be a material substance, but must be something of the nature of motion." Unfortunately Rumford's argument was not quite conclusive. The supporters of the caloric theory appear, whether consciously or unconsciously, to have used the phrase "capacity for heat" in two

entirely distinct senses without any clear definition of the difference. The phrase "capacity for heat" might very naturally denote the total quantity of heat contained in a body, which we have no means of measuring, but it was generally used to signify the quantity of heat required to raise the temperature of a body one degree, which is quite a different thing, and has no necessary relation to the total heat. In proving that the powder and the solid metal required the same quantity of heat to raise the temperature of equal masses of either one degree, Rumford did not prove that they contained equal quantities of heat, which was the real point at issue in this instance. The metal tin actually changes into powder below a certain temperature, and in so doing evolves a measurable quantity of heat. A mixture of the gases oxygen and hydrogen, in the proportions in which they combine to form water, evolves when burnt sufficient heat to raise more than thirty times its weight of water from the freezing to the boiling point; and the mixture of gases may, in this sense, be said to contain so much more heat than the water, although its capacity for heat in the ordinary sense is only about half that of the water produced. To complete the refutation of the calorists' explanation of the heat produced by friction, it would have been necessary for Rumford to show that the powder when reconverted into the same state as the solid metal did not absorb a quantity of heat equivalent to that evolved in the grinding; in other words that the heat produced by friction was not simply that due to the change of state of the metal from solid to powder.

Shortly afterwards, in 1799, Davy[2] described an experiment in which he melted ice by rubbing two blocks together. This experiment afforded a very direct refutation of the calorists' view, because it was a well-known fact that ice required to have a quantity of heat added to it to convert it into water, so that the water produced by the friction contained more heat than the ice. In stating as the conclusion to be drawn from this experiment that "friction consequently does not diminish the capacity of bodies for heat," Davy apparently uses the phrase capacity for heat in the sense of total heat contained in a body, because in a later section of the same essay he definitely gives the phrase this meaning, and uses the term "capability of temperature" to denote what we now term capacity for heat.

The delay in the overthrow of the caloric theory, and in the acceptance of the view that heat is a mode of motion, was no doubt partly due to some fundamental confusion of ideas in the use of the term "capacity for heat" and similar phrases. A still greater obstacle lay in the comparative vagueness of the motion or vibration theory. Davy speaks of heat as being "repulsive motion," and distinguishes it from light, which is "projective motion"; though heat is certainly not a substance—according to Davy in the essay under discussion—and may not even be treated as an imponderable fluid, light as certainly is a material substance, and is capable of forming chemical compounds with ordinary matter, such as oxygen gas, which is not a simple substance, but a compound, termed phosoxygen, of light and oxygen. Accepting the conclusions of Davy and Rumford that heat is not a material substance but a mode of motion, there still remains the question, what definite conception is to be attached to a quantity of heat? What do we mean by a quantity of vibratory motion, how is the quantity of motion to be estimated, and why should it remain invariable in many transformations? The idea that heat was a "mode of motion" was applicable as a qualitative explanation of many of the effects of heat, but it lacked the quantitative precision of a scientific statement, and could not be applied to the calculation and prediction of definite results. The state of science at the time of Rumford's and Davy's experiments did not admit of a more exact generalization. The way was paved in the first instance by a more complete study of the laws of gases, to which Laplace, Dalton, Gay-Lussac, Dulong and many others contributed both on the experimental and theoretical side. Although the development proceeded simultaneously along many parallel lines, it is interesting and instructive to take the investigation of the properties of gases, and to endeavour to trace the steps by which the true theory was finally attained.

10. *Thermal Properties of Gases.*—The most characteristic property of a gaseous or elastic fluid, namely, the elasticity, or resistance to compression, was first investigated scientifically by Robert Boyle (1662), who showed that the pressure p of a given mass of gas varied inversely as the volume v, provided that the temperature remained constant. This is generally expressed by the formula $pv = C$, where C is a constant for any given temperature, and v is taken to represent the specific volume, or the volume of unit mass, of the gas at the given pressure and temperature. Boyle was well aware of the effect of heat in expanding a gas, but he was unable to investigate this properly as no thermometric scale had been defined at that date. According to Boyle's law, when a mass of gas is compressed by a small amount at constant temperature, the percentage increase of pressure is equal to the percentage diminution of volume (if the compression is $v/100$, the increase of pressure is very nearly $p/100$). Adopting this law, Newton showed, by a most ingenious piece of

reasoning (*Principia*, ii., sect. 8), that the velocity of sound in air should be equal to the velocity acquired by a body falling under gravity through a distance equal to half the height of the atmosphere, considered as being of uniform density equal to that at the surface of the earth. This gave the result 918 ft. per sec. (280 metres per sec.) for the velocity at the freezing point. Newton was aware that the actual velocity of sound was somewhat greater than this, but supposed that the difference might be due in some way to the size of the air particles, of which no account could be taken in the calculation. The first accurate measurement of the velocity of sound by the French Académie des Sciences in 1738 gave the value 332 metres per sec. as the velocity at 0° C. The true explanation of the discrepancy was not discovered till nearly 100 years later.

The law of expansion of gases with change of temperature was investigated by Dalton and Gay-Lussac (1802), who found that the volume of a gas under constant pressure increased by 1/267th part of its volume at 0° C. for each 1° C. rise in temperature. This value was generally assumed in all calculations for nearly 50 years. More exact researches, especially those of Regnault, at a later date, showed that the law was very nearly correct for all permanent gases, but that the value of the coefficient should be $\frac{1}{173}$rd. According to this law the volume of a gas at any temperature t° C. should be proportional to 273 + t, *i.e.* to the temperature reckoned from a zero 273° below that of the Centigrade scale, which was called the absolute zero of the gas thermometer. If T = 273 + t, denotes the temperature measured from this zero, the law of expansion of a gas may be combined with Boyle's law in the simple formula

$$pv = \mathrm{RT} \tag{1}$$

which is generally taken as the expression of the gaseous laws. If equal volumes of different gases are taken at the same temperature and pressure, it follows that the constant R is the same for all gases. If equal masses are taken, the value of the constant R for different gases varies inversely as the molecular weight or as the density relative to hydrogen.

Dalton also investigated the laws of vapours, and of mixtures of gases and vapours. He found that condensible vapours approximately followed Boyle's law when compressed, until the condensation pressure was reached, at which the vapour liquefied without further increase of pressure. He found that when a liquid was introduced into a closed space, and allowed to evaporate until the space was saturated with the vapour and evaporation ceased, the increase of pressure in the space was equal to the condensation pressure of the vapour, and did not depend on the volume of the space or the presence of any other gas or vapour 140
provided that there was no solution or chemical action. He showed that the condensation or saturation-pressure of a vapour depended only on the temperature, and increased by nearly the same fraction of itself per degree rise of temperature, and that the pressures of different vapours were nearly the same at equal distances from their boiling points. The increase of pressure per degree C. at the boiling point was about $\frac{1}{28}$th of 760 mm. or 27.2 mm., but increased in geometrical progression with rise of temperature. These results of Dalton's were confirmed, and in part corrected, as regards increase of vapour-pressure, by Gay-Lussac, Dulong, Regnault and other investigators, but were found to be as close an approximation to the truth as could be obtained with such simple expressions. More accurate empirical expressions for the increase of vapour-pressure of a liquid with temperature were soon obtained by Thomas Young, J. P. L. A. Roche and others, but the explanation of the relation was not arrived at until a much later date (see Vaporization).

11. *Specific Heats of Gases.*—In order to estimate the quantities of heat concerned in experiments with gases, it was necessary in the first instance to measure their specific heats, which presented formidable difficulties. The earlier attempts by Lavoisier and others, employing the ordinary methods of calorimetry, gave very uncertain and discordant results, which were not regarded with any confidence even by the experimentalists themselves. Gay-Lussac (*Mémoires d'Arcueil*, 1807) devised an ingenious experiment, which, though misinterpreted at the time, is very interesting and instructive. With the object of comparing the specific heats of different gases, he took two equal globes A and B connected by a tube with a stop-cock. The globe B was exhausted, the other A being filled with gas. On opening the tap between the vessels, the gas flowed from A to B and the pressure was rapidly equalized. He observed that the fall of temperature in A was nearly equal to the rise of temperature in B, and that for the same initial pressure the change of temperature was very nearly the same for all the gases he tried, except hydrogen, which showed greater changes of temperature than other gases. He concluded from this experiment that equal volumes of gases had the same capacity for heat, except hydrogen, which he supposed to have a larger capacity, because it showed a greater effect. The method does not in reality afford any

direct information with regard to the specific heats, and the conclusion with regard to hydrogen is evidently wrong. At a later date (*Ann. de Chim.*, 1812, 81, p. 98) Gay-Lussac adopted A. Crawford’s method of mixture, allowing two equal streams of different gases, one heated and the other cooled about 20° C., to mix in a tube containing a thermometer. The resulting temperature was in all cases nearly the mean of the two, from which he concluded that equal volumes of all the gases tried, namely, hydrogen, carbon dioxide, air, oxygen and nitrogen, had the same thermal capacity. This was correct, except as regards carbon dioxide, but did not give any information as to the actual specific heats referred to water or any known substance. About the same time, F. Delaroche and J. E. Bérard (*Ann. de chim.*, 1813, 85, p. 72) made direct determinations of the specific heats of air, oxygen, hydrogen, carbon monoxide, carbon dioxide, nitrous oxide and ethylene, by passing a stream of gas heated to nearly 100° C. through a spiral tube in a calorimeter containing water. Their work was a great advance on previous attempts, and gave the first trustworthy results. With the exception of hydrogen, which presents peculiar difficulties, they found that equal volumes of the permanent gases, air, oxygen and carbon monoxide, had nearly the same thermal capacity, but that the compound condensible gases, carbon dioxide, nitrous oxide and ethylene, had larger thermal capacities in the order given. They were unable to state whether the specific heats of the gases increased or diminished with temperature, but from experiments on air at pressures of 740 mm. and 1000 mm., they found the specific heats to be .269 and .245 respectively, and concluded that the specific heat diminished with increase of pressure. The difference they observed was really due to errors of experiment, but they regarded it as proving beyond doubt the truth of the calorists’ contention that the heat disengaged on the compression of a gas was due to the diminution of its thermal capacity.

Dalton and others had endeavoured to measure directly the rise of temperature produced by the compression of a gas. Dalton had observed a rise of 50° F. in a gas when suddenly compressed to half its volume, but no thermometers at that time were sufficiently sensitive to indicate more than a fraction of the change of temperature. Laplace was the first to see in this phenomenon the probable explanation of the discrepancy between Newton’s calculation of the velocity of sound and the observed value. The increase of pressure due to a sudden compression, in which no heat was allowed to escape, or as we now call it an “adiabatic” compression, would necessarily be greater than the increase of pressure in a slow isothermal compression, on account of the rise of temperature. As the rapid compressions and rarefactions occurring in the propagation of a sound wave were perfectly adiabatic, it was necessary to take account of the rise of temperature due to compression in calculating the velocity. To reconcile the observed and calculated values of the velocity, the increase of pressure in adiabatic compression must be 1.410 times greater than in isothermal compression. This is the ratio of the adiabatic elasticity of air to the isothermal elasticity. It was a long time, however, before Laplace saw his way to any direct experimental verification of the value of this ratio. At a later date (*Ann. de chim.*, 1816, 3, p. 238) he stated that he had succeeded in proving that the ratio in question must be the same as the ratio of the specific heat of air at constant pressure to the specific heat at constant volume.

In the method of measuring the specific heat adopted by Delaroche and Bérard, the gas under experiment, while passing through a tube at practically constant pressure, contracts in cooling, as it gives up its heat to the calorimeter. Part of the heat surrendered to the calorimeter is due to the contraction of volume. If a gramme of gas at pressure p, volume v and temperature T abs. is heated 1° C. at constant pressure p, it absorbs a quantity of heat S = .238 calorie (according to Regnault) the specific heat at constant pressure. At the same time the gas expands by a fraction 1/T of v, which is the same as 1/273 of its volume at 0° C. If now the air is suddenly compressed by an amount v/T, it will be restored to its original volume, and its temperature will be raised by the liberation of a quantity of heat R′, the latent heat of expansion for an increase of volume v/T. If no heat has been allowed to escape, the air will now be in the same state as if a quantity of heat S had been communicated to it at its original volume v without expansion. The rise of temperature above the original temperature T will be S/s degrees, where s is the specific heat at constant volume, which is obviously equal to S − R′. Since p/T is the increase of pressure for 1° C. rise of temperature at constant volume, the increase of pressure for a rise of S/s degrees will be γp/T, where γ is the ratio S/s. But this is the rise of pressure produced by a sudden compression v/T, and is seen to be γ times the rise of pressure p/T produced by the same compression at constant temperature. The ratio of the adiabatic to the isothermal elasticity, required for calculating the velocity of sound, is therefore the same as the ratio of the specific heat at constant pressure to that at constant volume.

12. *Experimental Verification of the Ratio of Specific Heats.*—This was a most interesting and important theoretical relation to discover, but unfortunately it did not help much in the determination of the ratio required, because it was not practically possible at that time to

measure the specific heat of air at constant volume in a closed vessel. Attempts had been made to do this, but they had signally failed, on account of the small heat capacity of the gas as compared with the containing vessel. Laplace endeavoured to extract some confirmation of his views from the values given by Delaroche and Bérard for the specific heat of air at 1000 and 740 mm. pressure. On the assumption that the quantities of heat contained in a given mass of air increased in direct proportion to its volume when heated at constant pressure, he deduced, by some rather obscure reasoning, that the ratio of the specific heats S and s should be about 1.5 to 1, which he regarded as a fairly satisfactory agreement with the value $\gamma = 1.41$ deduced from the velocity of sound.

The ratio of the specific heats could not be directly measured, but a few years later, Clément and Désormes (*Journ. de Phys.*, Nov. 1819) succeeded in making a direct measurement of the ratio of the elasticities in a very simple manner. They took a large globe containing air at atmospheric pressure and temperature, and removed a small quantity of air. They then observed the defect of pressure p_0 when the air had regained its original temperature. By suddenly opening the globe, and immediately closing it, the pressure was restored almost instantaneously to the atmospheric, the rise of pressure p_0 corresponding to the sudden compression produced. The air, having been heated by the compression, was 141
allowed to regain its original temperature, the tap remaining closed, and the final defect of pressure p^1 was noted. The change of pressure for the same compression performed isothermally is then $p_0 - p^1$. The ratio $p_0/(p_0 - p^1)$ is the ratio of the adiabatic and isothermal elasticities, provided that p_0 is small compared with the whole atmospheric pressure. In this way they found the ratio 1.354, which is not much smaller than the value 1.410 required to reconcile the observed and calculated values of the velocity of sound. Gay-Lussac and J. J. Welter (*Ann. de chim.*, 1822) repeated the experiment with slight improvements, using expansion instead of compression, and found the ratio 1.375. The experiment has often been repeated since that time, and there is no doubt that the value of the ratio deduced from the velocity of sound is correct, the defect of the value obtained by direct experiment being due to the fact that the compression or expansion is not perfectly adiabatic. Gay-Lussac and Welter found the ratio practically constant for a range of pressure 144 to 1460 mm., and for a range of temperature from −20° to +40° C. The velocity of sound at Quito, at a pressure of 544 mm. was found to be the same as at Paris at 760 mm. at the same temperature. Assuming on this evidence the constancy of the ratio of the specific heats of air, Laplace (*Mécanique céleste*, v. 143) showed that, if the specific heat at constant pressure was independent of the temperature, the specific heat per unit volume at a pressure p must vary as $p^{1/\gamma}$, according to the caloric theory. The specific heat per unit mass must then vary as $p^{1/\gamma-1}$ which he found agreed precisely with the experiment of Delaroche and Bérard already cited. This was undoubtedly a strong confirmation of the caloric theory. Poisson by the same assumptions (*Ann. de chim.*, 1823, 23, p. 337) obtained the same results, and also showed that the relation between the pressure and the volume of a gas in adiabatic compression or expansion must be of the form pv^γ = constant.

P. L. Dulong (*Ann. de chim.*, 1829, 41, p. 156), adopting a method due to E. F. F. Chladni, compared the velocities of sound in different gases by observing the pitch of the note given by the same tube when filled with the gases in question. He thus obtained the values of the ratios of the elasticities or of the specific heats for the gases employed. For oxygen, hydrogen and carbonic oxide, these ratios were the same as for air. But for carbonic acid, nitrous oxide and olefiant gas, the values were much smaller, showing that these gases experienced a smaller change of temperature in compression. On comparing his results with the values of the specific heats for the same gases found by Delaroche and Bérard, Dulong observed that the changes of temperature for the same compression were in the inverse ratio of the specific heats at constant volume, and deduced the important conclusion that “*Equal volumes of all gases under the same conditions evolve on compression the same quantity of heat*.” This is equivalent to the statement that the difference of the specific heats, or the latent heat of expansion R′ per 1°, is the same for all gases if equal volumes are taken. Assuming the ratio $\gamma = 1.410$, and taking Delaroche and Bérard’s value for the specific heat of air at constant pressure S = .267, we have s = S/1.41 = .189, and the difference of the specific heats per unit mass of air S − s = R′ = .078. Adopting Regnault’s value of the specific heat of air, namely, S = .238, we should have S − s = .069. This quantity represents the heat absorbed by unit mass of air in expanding at constant temperature T by a fraction 1/T of its volume v, or by $1/273$rd of its volume 0° C.

If, instead of taking unit mass, we take a volume v_0 = 22.30 litres at 0° C. and 760 mm. being the volume of the molecular weight of the gas in grammes, the quantity of heat evolved by a compression equal to v/T will be approximately 2 calories, and is the same for all gases. The work done in this compression is pv/T = R, and is also the same for all gases, namely, 8.3 joules. Dulong’s experimental result, therefore, shows that the heat evolved in the compression of a gas is proportional to the work done. This result had previously been deduced theoretically by Carnot (1824). At a later date it was assumed by Mayer, Clausius and others, on the evidence of these experiments, that the heat evolved was not merely proportional to the work done, but was equivalent to it. The further experimental evidence required to justify this assumption was first supplied by Joule.

Latent heat of expansion R′	= .069 calorie per gramme of air, per 1° C.
	= 2.0 calories per gramme-molecule of any gas.
Work done in expansion R	= .287 joule per gramme of air per 1° C.
	= 8.3 joules per gramme-molecule of any gas.

13. *Carnot: On the Motive Power of Heat.*—A practical and theoretical question of the greatest importance was first answered by Sadi Carnot about this time in his *Reflections on the Motive Power of Heat* (1824). How much motive power (defined by Carnot as weight lifted through a certain height) can be obtained from heat alone by means of an engine repeating a regular succession or "cycle" of operations continuously? Is the efficiency limited, and, if so, how is it limited? Are other agents preferable to steam for developing motive power from heat? In discussing this problem, we cannot do better than follow Carnot's reasoning which, in its main features could hardly be improved at the present day.

Carnot points out that in order to obtain an answer to this question, it is necessary to consider the essential conditions of the process, apart from the mechanism of the engine and the working substance or agent employed. Work cannot be said to be produced *from heat alone* unless nothing but heat is supplied, and the working substance and all parts of the engine are at the end of the process in precisely the same state as at the beginning.[3]

Carnot's Axiom.—Carnot here, and throughout his reasoning, makes a fundamental assumption, which he states as follows: "When a body has undergone any changes and after a certain number of transformations is brought back identically to its original state, considered relatively to density, temperature and mode of aggregation, it must contain the same quantity of heat as it contained originally."[4]

Heat, according to Carnot, in the type of engine we are considering, can evidently be a cause of motive power only by virtue of changes of volume or form produced by alternate heating and cooling. This involves the existence of cold and hot bodies to act as boiler and condenser, or source and sink of heat, respectively. Wherever there exists a difference of temperature, it is possible to have the production of motive power from heat; and conversely, production of motive power, from heat alone, is impossible without difference of temperature. In other words the production of motive power from heat is not merely a question of the consumption of heat, but always requires transference of heat from hot to cold. What then are the conditions which enable the difference of temperature to be most advantageously employed in the production of motive power, and how much motive power can be obtained with a given difference of temperature from a given quantity of heat?

Carnot's Rule for Maximum Effect.—In order to realize the maximum effect, it is necessary that, in the process employed, there should not be any direct interchange of heat between bodies at different temperatures. Direct transference of heat by conduction or radiation between bodies at different temperatures is equivalent to wasting a difference of temperature which might have been utilized to produce motive power. The working substance must throughout every stage of the process be in equilibrium with itself (*i.e.* at uniform temperature and pressure) and also with external bodies, such as the boiler and condenser, at such times as it is put in communication with them. In the actual engine there is always some interchange of heat between the steam and the cylinder, and some loss of heat to external bodies. There may also be some difference of temperature between the boiler steam and the cylinder on admission, or between the waste steam and the condenser at release. These differences represent losses of efficiency which may be reduced indefinitely, at least in imagination, by suitable means, and designers had even at that date been very successful in reducing them. All such losses are supposed to be absent in 142
deducing the ideal limit of efficiency, beyond which it would be impossible to go.

14. *Carnot's Description of his Ideal Cycle.*—Carnot first gives a rough illustration of an incomplete cycle, using steam much in the same way as it is employed in an ordinary steam-engine. After expansion down to condenser pressure the steam is completely condensed to water, and is then returned as cold water to the hot boiler. He points out that the last step does not conform exactly to the condition he laid down, because although the water is restored to its initial state, there is direct passage of heat from a hot body to a cold body in the last process. He points out that this difficulty might be overcome by supposing the

difference of temperature small, and by employing a series of engines, each working through a small range, to cover a finite interval of temperature. Having established the general notions of a perfect cycle, he proceeds to give a more exact illustration, employing a gas as the working substance. He takes as the basis of his demonstration the well-established experimental fact that a gas is heated by rapid compression and cooled by rapid expansion, and that if compressed or expanded slowly in contact with conducting bodies, the gas will give out heat in compression or absorb heat in expansion while its temperature remains constant. He then goes on to say:—

"This preliminary notion being settled, let us imagine an elastic fluid, atmospheric air for example, enclosed in a cylinder *abcd*, fig. 4, fitted with a movable diaphragm or piston *cd*. Let there also be two bodies A, B, each maintained at a constant temperature, that of A being more elevated than that of B. Let us now suppose the following series of operations to be performed:

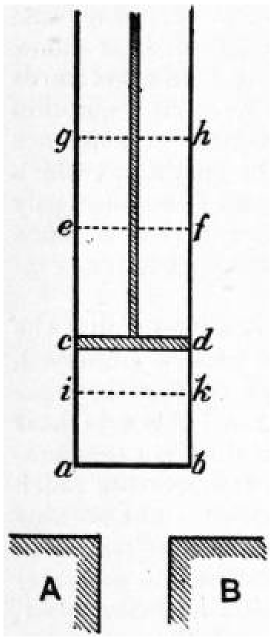


Fig 4.

Carnot's Cylinder.

"1. Contact of the body A with the air contained in the space *abcd*, or with the bottom of the cylinder, which we will suppose to transmit heat easily. The air is now at the temperature of the body A, and *cd* is the actual position of the piston.

"2. The piston is gradually raised, and takes the position *ef*. The air remains in contact with the body A, and is thereby maintained at a constant temperature during the expansion. The body A furnishes the heat necessary to maintain the constancy of temperature.

"3. The body A is removed, and the air no longer being in contact with any body capable of giving it heat, the piston continues nevertheless to rise, and passes from the position *ef* to *gh*. The air expands without receiving heat and its temperature falls. Let us imagine that it falls until it is just equal to that of the body B. At this moment the piston is stopped and occupies the position *gh*.

"4. The air is placed in contact with the body B; it is compressed by the return of the piston, which is brought from the position *gh* to the position *cd*. The air remains meanwhile at a constant temperature, because of its contact with the body B to which it gives up its heat.

"5. The body B is removed, and the compression of the air is continued. The air being now isolated, rises in temperature. The compression is continued until the air has acquired the temperature of the body A. The piston passes meanwhile from the position *cd* to the position *ik*.

"6. The air is replaced in contact with the body A, and the piston returns from the position *ik* to the position *ef*, the temperature remaining invariable.

"7. The period described under (3) is repeated, then successively the periods (4), (5), (6); (3), (4), (5), (6); (3), (4), (5), (6); and so on.

"During these operations the air enclosed in the cylinder exerts an effort more or less great on the piston. The pressure of the air varies both on account of changes of volume and on account of changes of temperature; but it should be observed that for equal volumes, that is to say, for like positions of the piston, the temperature is higher during the dilatation than during the compression. Since the pressure is greater during the expansion, the quantity of motive power produced by the dilatation is greater than that consumed by the compression. We shall thus obtain a balance of motive power, which may be employed for any purpose. The air has served as working substance in a heat-engine; it has also been employed in the most advantageous manner possible, since no useless re-establishment of the equilibrium of heat has been allowed to occur.

"All the operations above described may be executed in the reverse order and direction. Let us imagine that after the sixth period, that is to say, when the piston has reached the position *ef*, we make it return to the position *ik*, and that at the same time we keep the air in contact with the hot body A; the heat furnished by this body during the sixth period will return to its source, that is, to the body A, and everything will be as it was at the end of the fifth period. If now we remove the body A, and if we make the piston move from *ik* to *cd*, the temperature of the air will decrease by just as many degrees as it increased during the fifth period, and will become that of the body B. We can evidently continue in this way a series of operations the exact reverse of those which were previously described; it suffices to place oneself in the same circumstances and to execute for each period a movement of expansion in place of a movement of compression, and vice versa.

> "The result of the first series of operations was the production of a certain quantity of motive power, and the transport of heat from the body A to the body B; the result of the reverse operations is the consumption of the motive power produced in the first case, and the return of heat from the body B to the body A, in such sort that these two series of operations annul and neutralize each other.
>
> "The impossibility of producing by the agency of heat alone a quantity of motive power greater than that which we have obtained in our first series of operations is now easy to prove. It is demonstrated by reasoning exactly similar to that which we have already given. The reasoning will have in this case a greater degree of exactitude; the air of which we made use to develop the motive power is brought back at the end of each cycle of operations precisely to its initial state, whereas this was not quite exactly the case for the vapour of water, as we have already remarked."

15. *Proof of Carnot's Principle.*—Carnot considered the proof too obvious to be worth repeating, but, unfortunately, his previous demonstration, referring to an incomplete cycle, is not so exactly worded that exception cannot be taken to it. We will therefore repeat his proof in a slightly more definite and exact form. Suppose that a reversible engine R, working in the cycle above described, takes a quantity of heat H from the source in each cycle, and performs a quantity of useful work W_r. If it were possible for any other engine S, working with the same two bodies A and B as source and refrigerator, to perform a greater amount of useful work W_s per cycle for the same quantity of heat H taken from the source, it would suffice to take a portion W_r of this motive power (since W_s is by hypothesis greater than W_r) to drive the engine R backwards, and return a quantity of heat H to the source in each cycle. The process might be repeated indefinitely, and we should obtain at each repetition a balance of useful work $W_s - W_r$, *without taking any heat from the source*, which is contrary to experience. Whether the quantity of heat taken from the condenser by R is equal to that given to the condenser by S is immaterial. The hot body A might be a comparatively small boiler, since no heat is taken from it. The cold body B might be the ocean, or the whole earth. We might thus obtain without any consumption of fuel a practically unlimited supply of motive power. Which is absurd.

Carnot's Statement of his Principle.[5]—If the above reasoning be admitted, we must conclude with Carnot that *the motive power obtainable from heat is independent of the agents employed to realize it. The efficiency is fixed solely by the temperatures of the bodies between which, in the last resort, the transfer of heat is effected.* "We must understand here that each of the methods of developing motive power attains the perfection of which it is susceptible. This condition is fulfilled if, according to our rule, there is produced in the body no change of temperature that is not due to change of volume, or in other words, if there is no direct interchange of heat between bodies of sensibly different temperatures."

It is characteristic of a state of frictionless mechanical equilibrium that an indefinitely small difference of pressure suffices to upset the equilibrium and reverse the motion. Similarly in thermal equilibrium between bodies at the same temperature, an indefinitely small difference of temperature suffices to reverse the transfer of heat. Carnot's rule is therefore the criterion of the reversibility of a cycle of operations as regards transfer of heat. It is assumed that the ideal engine is mechanically reversible, that there is not, for 143 instance, any communication between reservoirs of gas or vapour at sensibly different pressures, and that there is no waste of power in friction. If there is equilibrium both mechanical and thermal at every stage of the cycle, the ideal engine will be perfectly reversible. That is to say, all its operations will be exactly reversed as regards transfer of heat and work, when the operations are performed in the reverse order and direction. On this understanding Carnot's principle may be put in a different way, which is often adopted, but is really only the same thing put in different words: *The efficiency of a perfectly reversible engine is the maximum possible, and is a function solely of the limits of temperature between which it works*. This result depends essentially on the existence of a state of thermal equilibrium defined by equality of temperature, and independent, in the majority of cases, of the state of a body in other respects. In order to apply the principle to the calculation and prediction of results, it is sufficient to determine the manner in which the efficiency depends on the temperature for one particular case, since the efficiency must be the same for all reversible engines.

> 16. *Experimental Verification of Carnot's Principle.*—Carnot endeavoured to test his result by the following simple calculations. Suppose that we have a cylinder fitted with a frictionless piston, containing 1 gram of water at 100° C., and that the pressure of the steam, namely 760 mm., is in equilibrium with the external pressure on the piston at this temperature. Place the cylinder in connexion with a boiler or hot body at 101° C. The water

will then acquire the temperature of 101° C., and will absorb 1 gram-calorie of heat. Some waste of motive power occurs here because heat is allowed to pass from one body to another at a different temperature, but the waste in this case is so small as to be immaterial. Keep the cylinder in contact with the hot body at 101° C. and allow the piston to rise. It may be made to perform useful work as the pressure is now 27.7 mm. (or 37.7 grams per sq. cm.) in excess of the external pressure. Continue the process till all the water is converted into steam. The heat absorbed from the hot body will be nearly 540 gram-calories, the latent heat of steam at this temperature. The increase of volume will be approximately 1620 c.c., the volume of 1 gram of steam at this pressure and temperature. The work done by the excess pressure will be 37.7 × 1620 = 61,000 gram-centimetres or 0.61 of a kilogrammetre. Remove the hot body, and allow the steam to expand further till its pressure is 760 mm. and its temperature has fallen to 100° C. The work which might be done in this expansion is less than $^{1}/_{1000}$th part of a kilogrammetre, and may be neglected for the present purpose. Place the cylinder in contact with the cold body at 100° C., and allow the steam to condense at this temperature. No work is done on the piston, because there is equilibrium of pressure, but a quantity of heat equal to the latent heat of steam at 100° C. is given to the cold body. The water is now in its initial condition, and the result of the process has been to gain 0.61 of a kilogrammetre of work by allowing 540 gram-calories of heat to pass from a body at 101° C. to a body at 100° C. by means of an ideally simple steam-engine. The work obtainable in this way from 1000 gram-calories of heat, or 1 kilo-calorie, would evidently be 1.13 kilogrammetre (= 0.61 × $^{1000}/_{540}$).

Taking the same range of temperature, namely 101° to 100° C., we may perform a similar series of operations with air in the cylinder, instead of water and steam. Suppose the cylinder to contain 1 gramme of air at 100° C. and 760 mm. pressure instead of water. Compress it without loss of heat (adiabatically), so as to raise its temperature to 101° C. Place it in contact with the hot body at 101° C., and allow it to expand at this temperature, absorbing heat from the hot body, until its volume is increased by $^{1}/_{374}$th part (the expansion per degree at constant pressure). The quantity of heat absorbed in this expansion, as explained in § 14, will be the difference of the specific heats or the latent heat of expansion R′ = .069 calorie. Remove the hot body, and allow the gas to expand further without gain of heat till its temperature falls to 100° C. Compress it at 100° C. to its original volume, abstracting the heat of compression by contact with the cold body at 100° C. The air is now in its original state, and the process has been carried out in strict accordance with Carnot’s rule. The quantity of external work done in the cycle is easily obtained by the aid of the indicator diagram ABCD (fig. 5), which is approximately a parallelogram in this instance. The area of the diagram is equal to that of the rectangle BEHG, being the product of the vertical height BE, namely, the increase of pressure per 1° at constant volume, by the increase of volume BG, which is $^{1}/_{273}$rd of the volume at 0° C. and 760 mm., or 2.83 c.c. The increase of pressure BE is $^{760}/_{373}$, or 2.03 mm., which is equivalent to 2.76 gm. per sq. cm. The work done in the cycle is 2.76 × 2.83 = 7.82 gm. cm., or .0782 gram-metre. The heat absorbed at 101° C. was .069 gram-calorie, so that the work obtained is .0782/.069 or 1.13 gram-metre per gram-calorie, or 1.13 kilogrammetre per kilogram-calorie. This result is precisely the same as that obtained by using steam with the same range of temperature, but a very different kind of cycle. Carnot in making the same calculation did not obtain quite so good an agreement, because the experimental data at that time available were not so accurate. He used the value $^{1}/_{267}$ for the coefficient of expansion, and .267 for the specific heat of air. Moreover, he did not feel justified in assuming, as above, that the difference of the specific heats was the same at 100° C. as at the ordinary temperature of 15° to 20° C., at which it had been experimentally determined. He made similar calculations for the vapour of alcohol, which differed slightly from the vapour of water. But the agreement he found was close enough to satisfy him that his theoretical deductions were correct, and that the resulting ratio of work to heat should be the same for all substances at the same temperature.

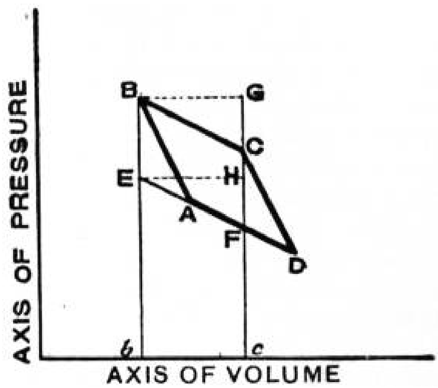


Fig. 5.—Elementary Carnot Cycle for Gas.

17. *Carnot’s Function. Variation of Efficiency with Temperature.*—By means of calculations, similar to those given above, Carnot endeavoured to find the amount of motive power obtainable from one unit of heat per degree fall at various temperatures with various substances. The value found above, namely 1.13 kilogrammetre per kilo-calorie per 1° fall, is the value of the efficiency per 1° fall at 100° C. He was able to show that the efficiency per degree fall probably diminished with rise of temperature, but the experimental data at that

time were too inconsistent to suggest the true relation. He took as the analytical expression of his principle that the efficiency W/H of a perfect engine taking in heat H at a temperature t° C., and rejecting heat at the temperature 0° C., must be some function F*t* of the temperature *t*, which would be the same for all substances. The efficiency per degree fall at a temperature t he represented by F′*t*, the derived function of F*t*. The function F′*t* would be the same for all substances at the same temperature, but would have different values at different temperatures. In terms of this function, which is generally known as Carnot’s function, the results obtained in the previous section might be expressed as follows:—

“The increase of volume of a mixture of liquid and vapour per unit-mass vaporized at any temperature, multiplied by the increase of vapour-pressure per degree, is equal to the product of the function F′*t* by the latent heat of vaporization.

“The difference of the specific heats, or the latent heat of expansion for any substance multiplied by the function F′*t*, is equal to the product of the expansion per degree at constant pressure by the increase of pressure per degree at constant volume.”

Since the last two coefficients are the same for all gases if equal volumes are taken, Carnot concluded that: “The difference of the specific heats at constant pressure and volume is the same for equal volumes of all gases at the same temperature and pressure.”

Taking the expression $W = RT \log_e r$ for the whole work done by a gas obeying the gaseous laws $pv = RT$ in expanding at a temperature T from a volume 1 (unity) to a volume *r*, or for a ratio of expansion r, and putting $W' = R \log_e r$ for the work done in a cycle of range 1°, Carnot obtained the expression for the heat absorbed by a gas in isothermal expansion

$$H = R \log_e r / F't. \qquad (2)$$

He gives several important deductions which follow from this formula, which is the analytical expression of the experimental result already quoted as having been discovered subsequently by Dulong. Employing the above expression for the latent heat of expansion, Carnot deduced a general expression for the specific heat of a gas at constant volume on the basis of the caloric theory. He showed that if the specific heat was independent of the temperature (the hypothesis already adopted by Laplace and Poisson) the function F′*t* must be of the form

$$F't = R/C\,(t + t_0) \qquad (3)$$

where C and t_0 are unknown constants. A similar result follows from his expression for the difference of the specific heats. If this is assumed to be constant and equal to C, the expression for F′*t* becomes R/CT, which is the same as the above if $t_0 = 273$. Assuming the specific heat to be also independent of the volume, he shows that the function F′t should be constant. But this assumption is inconsistent with the caloric theory of latent heat of expansion, which requires the specific heat to be a function of the volume. It appears in fact impossible to reconcile Carnot’s principle with the caloric theory on any simple assumptions. As Carnot remarks: “The main principles on which the theory of heat rests require most careful examination. Many experimental facts appear almost inexplicable in the present state of this theory.”

Carnot’s work was subsequently put in a more complete analytical form by B. P. E. Clapeyron (*Journ. de l’Éc. polytechn.*, Paris, 1832, 14, p. 153), who also made use of Watt’s 144 indicator diagram for the first time in discussing physical problems. Clapeyron gave the general expressions for the latent heat of a vapour, and for the latent heat of isothermal expansion of any substance, in terms of Carnot’s function, employing the notation of the calculus. The expressions he gave are the same in form as those in use at the present day. He also gave the general expression for Carnot’s function, and endeavoured to find its variation with temperature; but having no better data, he succeeded no better than Carnot. Unfortunately, in describing Carnot’s cycle, he assumed the caloric theory of heat, and made some unnecessary mistakes, which Carnot (who, we now know, was a believer in the mechanical theory) had been very careful to avoid. Clapeyron directs one to compress the gas at the lower temperature in contact with the body B *until the heat disengaged is equal to that which has been absorbed at the higher temperature*.[6] He assumes that the gas at this point contains the same quantity of heat as it contained in its original state at the higher temperature, and that, when the body B is removed, the gas will be restored to its original temperature, when compressed to its initial volume. This mistake is still attributed to Carnot, and regarded as a fatal objection to his reasoning by nearly all writers at the present day.

18. *Mechanical Theory of Heat.*—According to the caloric theory, the heat absorbed in the

expansion of a gas became latent, like the latent heat of vaporization of a liquid, but remained in the gas and was again evolved on compressing the gas. This theory gave no explanation of the source of the motive power produced by expansion. The mechanical theory had explained the production of heat by friction as being due to transformation of visible motion into a brisk agitation of the ultimate molecules, but it had not so far given any definite explanation of the converse production of motive power at the expense of heat. The theory could not be regarded as complete until it had been shown that in the production of work from heat, a certain quantity of heat disappeared, and ceased to exist as heat; and that this quantity was the same as that which could be generated by the expenditure of the work produced. The earliest complete statement of the mechanical theory from this point of view is contained in some notes written by Carnot, about 1830, but published by his brother (*Life of Sadi Carnot*, Paris, 1878). Taking the difference of the specific heats to be .078, he estimated the mechanical equivalent at 370 kilogrammetres. But he fully recognized that there were no experimental data at that time available for a quantitative test of the theory, although it appeared to afford a good qualitative explanation of the phenomena. He therefore planned a number of crucial experiments such as the “porous plug” experiment, to test the equivalence of heat and motive power. His early death in 1836 put a stop to these experiments, but many of them have since been independently carried out by other observers.

The most obvious case of the production of work from heat is in the expansion of a gas or vapour, which served in the first instance as a means of calculating the ratio of equivalence, on the assumption that all the heat which disappeared had been transformed into work and had not merely become latent. Marc Séguin, in his *De l’influence des chemins de fer* (Paris, 1839), made a rough estimate in this manner of the mechanical equivalent of heat, assuming that the loss of heat represented by the fall of temperature of steam on expanding was equivalent to the mechanical effect produced by the expansion. He also remarks (*loc. cit.* p. 382) that it was absurd to suppose that “a finite quantity of heat could produce an indefinite quantity of mechanical action, and that it was more natural to assume that a certain quantity of heat disappeared in the very act of producing motive power.” J. R. Mayer (*Liebig’s Annalen*, 1842, 42, p. 233) stated the equivalence of heat and work more definitely, deducing it from the old principle, *causa aequat effectum*. Assuming that the sinking of a mercury column by which a gas was compressed was equivalent to the heat set free by the compression, he deduced that the warming of a kilogramme of water 1° C. would correspond to the fall of a weight of one kilogramme from a height of about 365 metres. But Mayer did not adduce any fresh experimental evidence, and made no attempt to apply his theory to the fundamental equations of thermodynamics. It has since been urged that the experiment of Gay-Lussac (1807), on the expansion of gas from one globe to another (see above, § 11), was sufficient justification for the assumption tacitly involved in Mayer’s calculation. But Joule was the first to supply the correct interpretation of this experiment, and to repeat it on an adequate scale with suitable precautions. Joule was also the first to measure directly the amount of heat liberated by the compression of a gas, and to prove that heat was not merely rendered latent, but disappeared altogether as heat, when a gas did work in expansion.

19. *Joule’s Determinations of the Mechanical Equivalent.*—The honour of placing the mechanical theory of heat on a sound *experimental* basis belongs almost exclusively to J. P. Joule, who showed by direct experiment that in all the most important cases in which heat was generated by the expenditure of mechanical work, or mechanical work was produced at the expense of heat, there was a constant ratio of equivalence between the heat generated and the work expended and vice versa. His first experiments were on the relation of the chemical and electric energy expended to the heat produced in metallic conductors and voltaic and electrolytic cells; these experiments were described in a series of papers published in the *Phil. Mag.*, 1840-1843. He first proved the relation, known as Joule’s law, that the heat produced in a conductor of resistance R by a current C is proportional to C^2R per second. He went on to show that the total heat produced in any voltaic circuit was proportional to the electromotive force E of the battery and to the number of equivalents electrolysed in it. Faraday had shown that electromotive force depends on chemical affinity. Joule measured the corresponding heats of combustion, and showed that the electromotive force corresponding to a chemical reaction is proportional to the heat of combustion of the electrochemical equivalent. He also measured the E.M.F. required to decompose water, and showed that when part of the electric energy EC is thus expended in a voltameter, the heat generated is less than the heat of combustion corresponding to EC by a quantity representing the heat of combustion of the decomposed gases. His papers so far had been concerned with the relations between electrical energy, chemical energy and heat which he

showed to be mutually equivalent. The first paper in which he discussed the relation of heat to mechanical power was entitled “On the Calorific Effects of Magneto-Electricity, and on the Mechanical Value of Heat” (*Brit. Assoc.*, 1843; *Phil. Mag.*, 23, p. 263). In this paper he showed that the heat produced by currents generated by magneto-electric induction followed the same law as voltaic currents. By a simple and ingenious arrangement he succeeded in measuring the mechanical power expended in producing the currents, and deduced the mechanical equivalent of heat and of electrical energy. The amount of mechanical work required to raise 1 ℔ of water 1° F. (1 B.Th.U.), as found by this method, was 838 foot-pounds. In a note added to the paper he states that he found the value 770 foot-pounds by the more direct method of forcing water through fine tubes. In a paper “On the Changes of Temperature produced by the Rarefaction and Condensation of Air” (*Phil. Mag.*, May 1845), he made the first direct measurements of the quantity of heat disengaged by compressing air, and also of the heat absorbed when the air was allowed to expand against atmospheric pressure; as the result he deduced the value 798 foot-pounds for the mechanical equivalent of 1 B.Th.U. He also showed that there was no appreciable absorption of heat when air was allowed to expand in such a manner as not to develop mechanical power, and he pointed out that the mechanical equivalent of heat could not be satisfactorily deduced from the relations of the specific heats, because the knowledge of the specific heats 145
of gases at that time was of so uncertain a character. He attributed most weight to his later determinations of the mechanical equivalent made by the direct method of friction of liquids. He showed that the results obtained with different liquids, water, mercury and sperm oil, were the same, namely, 782 foot-pounds; and finally repeating the method with water, using all the precautions and improvements which his experience had suggested, he obtained the value 772 foot-pounds, which was accepted universally for many years, and has only recently required alteration on account of the more exact definition of the heat unit, and the standard scale of temperature (see Calorimetry). The great value of Joule’s work for the general establishment of the principle of the conservation of energy lay in the variety and completeness of the experimental evidence he adduced. It was not sufficient to find the relation between heat and mechanical work or other forms of energy in one particular case. It was necessary to show that the same relation held in all cases which could be examined experimentally, and that the ratio of equivalence of the different forms of energy, measured in different ways, was independent of the manner in which the conversion was effected and of the material or working substance employed.

As the result of Joule’s experiments, we are justified in concluding that heat is a form of energy, and that all its transformations are subject to the general principle of the conservation of energy. As applied to heat, the principle is called the first law of thermodynamics, and may be stated as follows: *When heat is transformed into any other kind of energy, or vice versa, the total quantity of energy remains invariable; that is to say, the quantity of heat which disappears is equivalent to the quantity of the other kind of energy produced and vice versa.*

The number of units of mechanical work equivalent to one unit of heat is generally called the mechanical equivalent of heat, or Joule’s equivalent, and is denoted by the letter J. Its numerical value depends on the units employed for heat and mechanical energy respectively. The values of the equivalent in terms of the units most commonly employed at the present time are as follows:—

777 foot-pounds (Lat. 45°)	are equivalent to	1 B.Th.U. (℔ deg. Fahr.)
1399 foot-pounds ″	″ ″	1 ℔ deg. C.
426.3 kilogrammetres	″ ″	1 kilogram-deg. C. or kilo-calorie.
426.3 grammetres	″ ″	1 gram-deg. C. or calorie.
4.180 joules	″ ″	1 gram-deg. C. or calorie.

The water for the heat units is supposed to be taken at 20° C. or 68° F., and the degree of temperature is supposed to be measured by the hydrogen thermometer. The acceleration of gravity in latitude 45° is taken as 980.7 C.G.S. For details of more recent and accurate methods of determination, the reader should refer to the article Calorimetry, where tables of the variation of the specific heat of water with temperature are also given.

The second law of thermodynamics is a title often used to denote Carnot’s principle or some equivalent mathematical expression. In some cases this title is not conferred on Carnot’s principle itself, but on some axiom from which the principle may be indirectly deduced. These axioms, however, cannot as a rule be directly applied, so that it would appear preferable to take Carnot’s principle itself as the second law. It may be observed that, as a matter of history, Carnot’s principle was established and generally admitted before the principle of the conservation of energy as applied to heat, and that from this point of view the titles, first and second laws, are not particularly appropriate.

20. *Combination of Carnot’s Principle with the Mechanical Theory.*—A very instructive paper, as showing the state of the science of heat about this time, is that of C. H. A. Holtzmann, “On the Heat and Elasticity of Gases and Vapours” (Mannheim, 1845; Taylor’s *Scientific Memoirs*, iv. 189). He points out that the theory of Laplace and Poisson does not agree with facts when applied to vapours, and that Clapeyron’s formulae, though probably correct, contain an undetermined function (Carnot’s F′*t*, Clapeyron’s 1/C) of the temperature. He determines the value of this function to be J/T by assuming, with Séguin and Mayer, that the work done in the isothermal expansion of a gas is a measure of the heat absorbed. From the then accepted value .078 of the difference of the specific heats of air, he finds the numerical value of J to be 374 kilogrammetres per kilo-calorie. *Assuming the heat equivalent of the work to remain in the gas*, he obtains expressions similar to Clapeyron’s for the total heat and the specific heats. In consequence of this assumption, the formulae he obtained for adiabatic expansion were necessarily wrong, but no data existed at that time for testing them. In applying his formulae to vapours, he obtained an expression for the saturation-pressure of steam, which agreed with the empirical formula of Roche, and satisfied other experimental data on the supposition that the coefficient of expansion of steam was .00423, and its specific heat 1.69—values which are now known to be impossible, but which appeared at the time to give a very satisfactory explanation of the phenomena.

The essay of Hermann Helmholtz, *On the Conservation of Force* (Berlin, 1847), discusses all the known cases of the transformation of energy, and is justly regarded as one of the chief landmarks in the establishment of the energy-principle. Helmholtz gives an admirable statement of the fundamental principle as applied to heat, but makes no attempt to formulate the correct equations of thermodynamics on the mechanical theory. He points out the fallacy of Holtzmann’s (and Mayer’s) calculation of the equivalent, but admits that it is supported by Joule’s experiments, though he does not seem to appreciate the true value of Joule’s work. He considers that Holtzmann’s formulae are well supported by experiment, and are much preferable to Clapeyron’s, because the value of the undetermined function F′*t* is found. But he fails to notice that Holtzmann’s equations are fundamentally inconsistent with the conservation of energy, because the heat equivalent of the external work done is supposed to remain in the gas.

That a quantity of heat equivalent to the work performed actually disappears when a gas does work in expansion, was first shown by Joule in the paper on condensation and rarefaction of air (1845) already referred to. At the conclusion of this paper he felt justified by direct experimental evidence in reasserting definitely the hypothesis of Séguin (*loc. cit.* p. 383) that “the steam while expanding in the cylinder loses heat in quantity exactly proportional to the mechanical force developed, and that on the condensation of the steam the heat thus converted into power is not given back.” He did not see his way to reconcile this conclusion with Clapeyron’s description of Carnot’s cycle. At a later date, in a letter to Professor W. Thomson (Lord Kelvin) (1848), he pointed out that, since, according to his own experiments, the work done in the expansion of a gas at constant temperature is equivalent to the heat absorbed, by equating Carnot’s expressions (given in § 17) for the work done and the heat absorbed, the value of Carnot’s function F′*t* must be equal to J/T, in order to reconcile his principle with the mechanical theory.

Professor W. Thomson gave an account of Carnot’s theory (*Trans. Roy. Soc. Edin.*, Jan. 1849), in which he recognized the discrepancy between Clapeyron’s statement and Joule’s experiments, but did not see his way out of the difficulty. He therefore adopted Carnot’s principle provisionally, and proceeded to calculate a table of values of Carnot’s function F′*t*, from the values of the total-heat and vapour-pressure of steam-then recently determined by Regnault (*Mémoires de l’Institut de Paris*, 1847). In making the calculation, he assumed that the specific volume v of saturated steam at any temperature T and pressure *p* is that given by the gaseous laws, *pv* = RT. The results are otherwise correct so far as Regnault’s data are accurate, because the values of the efficiency per degree F′t are not affected by any assumption with regard to the nature of heat. He obtained the values of the efficiency F′*t* over a finite range from *t* to 0° C., by adding up the values of F′*t* for the separate degrees. This latter proceeding is inconsistent with the mechanical theory, but is the correct method 146 on the assumption that the heat given up to the condenser is equal to that taken from the source. The values he obtained for F′*t* agreed very well with those previously given by Carnot and Clapeyron, and showed that this function diminishes with rise of temperature roughly in the inverse ratio of T, as suggested by Joule.

R. J. E. Clausius (*Pogg. Ann.*, 1850, 79, p. 369) and W. J. M. Rankine (*Trans. Roy. Soc.

Edin., 1850) were the first to develop the correct equations of thermodynamics on the mechanical theory. When heat was supplied to a body to change its temperature or state, part remained in the body as intrinsic heat energy E, but part was converted into external work of expansion W and ceased to exist as heat. The part remaining in the body was always the same for the same change of state, however performed, as required by Carnot's fundamental axiom, but the part corresponding to the external work was necessarily different for different values of the work done. Thus in any cycle in which the body was exactly restored to its initial state, the heat remaining in the body would always be the same, or as Carnot puts it, the quantities of heat absorbed and given out in its diverse transformations are exactly "compensated," so far as the body is concerned. But the quantities of heat absorbed and given out are not necessarily equal. On the contrary, they differ by the equivalent of the external work done in the cycle. Applying this principle to the case of steam, Clausius deduced a fact previously unknown, that the specific heat of steam maintained in a state of saturation is negative, which was also deduced by Rankine (*loc. cit.*) about the same time. In applying the principle to gases Clausius assumes (with Mayer and Holtzmann) that the heat absorbed by a gas in isothermal expansion is equivalent to the work done, but he does not appear to be acquainted with Joule's experiment, and the reasons he adduces in support of this assumption are not conclusive. This being admitted, he deduces from the energy principle alone the propositions already given by Carnot with reference to gases, and shows in addition that the specific heat of a perfect gas must be independent of the density. In the second part of his paper he introduces Carnot's principle, which he quotes as follows: "The performance of work is equivalent to a transference of heat from a hot to a cold body without the quantity of heat being thereby diminished." This is not Carnot's way of stating his principle (see § 15), but has the effect of exaggerating the importance of Clapeyron's unnecessary assumption. By equating the expressions given by Carnot for the work done and the heat absorbed in the expansion of a gas, he deduces (following Holtzmann) the value J/T for Carnot's function F′*t* (which Clapeyron denotes by 1/C). He shows that this assumption gives values of Carnot's function which agree fairly well with those calculated by Clapeyron and Thomson, and that it leads to values of the mechanical equivalent not differing greatly from those of Joule. Substituting the value J/T for C in the analytical expressions given by Clapeyron for the latent heat of expansion and vaporization, these relations are immediately reduced to their modern form (see Thermodynamics, § 4). Being unacquainted with Carnot's original work, but recognizing the invalidity of Clapeyron's description of Carnot's cycle, Clausius substituted a proof consistent with the mechanical theory, which he based on the axiom that "heat cannot of itself pass from cold to hot." The proof on this basis involves the application of the energy principle, which does not appear to be necessary, and the axiom to which final appeal is made does not appear more convincing than Carnot's. Strange to say, Clausius did not in this paper give the expression for the efficiency in a Carnot cycle of finite range (Carnot's F*t*) which follows immediately from the value J/T assumed for the efficiency F′t of a cycle of infinitesimal range at the temperature *t* C or T Abs.

Rankine did not make the same assumption as Clausius explicitly, but applied the mechanical theory of heat to the development of his hypothesis of molecular vortices, and deduced from it a number of results similar to those obtained by Clausius. Unfortunately the paper (*loc. cit.*) was not published till some time later, but in a summary given in the *Phil. Mag.* (July 1851) the principal results were detailed. Assuming the value of Joule's equivalent, Rankine deduced the value 0.2404 for the specific heat of air at constant pressure, in place of 0.267 as found by Delaroche and Bérard. The subsequent verification of this value by Regnault (*Comptes rendus*, 1853) afforded strong confirmation of the accuracy of Joule's work. In a note appended to the abstract in the *Phil. Mag.* Rankine states that he has succeeded in proving that the maximum efficiency of an engine working in a Carnot cycle of finite range t_1 to t_0 is of the form $(t_1 - t_0) / (t_1 - k)$, where k is a constant, the same for all substances. This is correct if t represents temperature Centigrade, and $k = -273$.

Professor W. Thomson (Lord Kelvin) in a paper "On the Dynamical Theory of Heat" (*Trans. Roy. Soc. Edin.*, 1851, first published in the *Phil. Mag.*, 1852) gave a very clear statement of the position of the theory at that time. He showed that the value F′*t* = J/T, assumed for Carnot's function by Clausius without any experimental justification, rested solely on the evidence of Joule's experiment, and might possibly not be true at all temperatures. Assuming the value J/T with this reservation, he gave as the expression for the efficiency over a finite range t_1 to t_0 C., or T_1 to T_0 Abs., the result,

$$W/H = (t_1 - t_0) / (t_1 + 273) = (T_1 - T_0) / T_1 \quad (4)$$

which, he observed, agrees in form with that found by Rankine.

21. *The Absolute Scale of Temperature.*—Since Carnot’s function is the same for all substances at the same temperature, and is a function of the temperature only, it supplies a means of measuring temperature independently of the properties of any particular substance. This proposal was first made by Lord Kelvin (*Phil. Mag.*, 1848), who suggested that the degree of temperature should be chosen so that the efficiency of a perfect engine at any point of the scale should be the same, or that Carnot’s function F′t should be constant. This would give the simplest expression for the efficiency on the caloric theory, but the scale so obtained, when the values of Carnot’s function were calculated from Regnault’s observations on steam, was found to differ considerably from the scale of the mercury or air-thermometer. At a later date, when it became clear that the value of Carnot’s function was very nearly proportional to the reciprocal of the temperature T measured from the absolute zero of the gas thermometer, he proposed a simpler method (*Phil. Trans.*, 1854), namely, to define absolute temperature θ as proportional to the reciprocal of Carnot’s function. On this definition of absolute temperature, the expression $(\theta_1 - \theta_0) / \theta_1$ for the efficiency of a Carnot cycle with limits θ_1 and θ_0 would be exact, and it became a most important problem to determine how far the temperature T by gas thermometer differed from the absolute temperature θ. With this object he devised a very delicate method, known as the “porous plug experiment” (see Thermodynamics) of testing the deviation of the gas thermometer from the absolute scale. The experiments were carried out in conjunction with Joule, and finally resulted in showing (*Phil. Trans.*, 1862, “On the Thermal Effects of Fluids in Motion”) that the deviations of the air thermometer from the absolute scale as above defined are almost negligible, and that in the case of the gas hydrogen the deviations are so small that a thermometer containing this gas may be taken for all practical purposes as agreeing exactly with the absolute scale at all ordinary temperatures. For this reason the hydrogen thermometer has since been generally adopted as the standard.

22. *Availability of Heat of Combustion.*—Taking the value 1.13 kilogrammetres per kilo-calorie for 1° C. fall of temperature at 100° C., Carnot attempted to estimate the possible performance of a steam-engine receiving heat at 160° C. and rejecting it at 40° C. Assuming the performance to be simply proportional to the temperature fall, the work done for 120° fall would be 134 kilogrammetres per kilo-calorie. To make an accurate calculation required a knowledge of the variation of the function F′t with temperature. Taking the accurate formula of § 20, the work obtainable is 118 kilogrammetres per kilo-calorie, which is 28% of 147
426, the mechanical equivalent of the kilo-calorie in kilogrammetres. Carnot pointed out that the fall of 120° C. utilized in the steam-engine was only a small fraction of the whole temperature fall obtainable by combustion, and made an estimate of the total power available if the whole fall could be utilized, allowing for the probable diminution of the function F′*t* with rise of temperature. His estimate was 3.9 million kilogrammetres per kilogramme of coal. This was certainly an over-estimate, but was surprisingly close, considering the scanty data at his disposal.

In reality the fraction of the heat of combustion available, even in an ideal engine and apart from practical limitations, is much less than might be inferred from the efficiency formula of the Carnot cycle. In applying this formula to estimate the availability of the heat it is usual to take the temperature obtainable by the combustion of the fuel as the upper limit of temperature in the formula. For carbon burnt *in air* at constant pressure without any loss of heat, the products of combustion might be raised 2300° C. in temperature, assuming that the specific heats of the products were constant and that there was no dissociation. If all the heat could be supplied to the working fluid at this temperature, that of the condenser being 40° C., the possible efficiency by the formula of § 20 would be 89%. But the combustion obviously cannot maintain so high a temperature if heat is being continuously abstracted by a boiler. Suppose that θ′ is the maximum temperature of combustion as above estimated, θ″ the temperature of the boiler, and θ^0 that of the condenser. Of the whole heat supplied by combustion represented by the rise of temperature $\theta' - \theta^0$, the fraction $(\theta' - \theta'') / (\theta' - \theta^0)$ is the maximum that could be supplied to the boiler, the fraction $(\theta'' - \theta^0) / (\theta' - \theta^0)$ being carried away with the waste gases. Of the heat supplied to the boiler, the fraction $(\theta' - \theta^0) / \theta''$ might theoretically be converted into work. The problem in the case of an engine using a separate working fluid, like a steam-engine, is to find what must be the temperature θ″ of the boiler in order to obtain the largest possible fraction of the heat of combustion in the form of work. It is easy to show that θ″ must be the geometric mean of θ′ and θ^0, or $\theta'' = \sqrt{\theta'\theta^0}$. Taking $\theta' - \theta^0 = 2300°$ C., and $\theta^0 = 313°$ Abs. as before, we find θ″ = 903° Abs. or 630° C. The heat supplied to the boiler is then 74.4% of the heat of combustion, and of this 65.3% is converted into work, giving a maximum possible efficiency of 49% in place of 89%. With the boiler at 160° C., the possible efficiency, calculated in a similar manner, would be 26.3%, which shows that the possible increase of efficiency by increasing the temperature range is not so great as is usually supposed. If the temperature of the boiler were raised to 300° C., corresponding to a pressure of 1260 ℔ per sq. in., which is occasionally surpassed in modern flash-boilers, the possible efficiency would be 40%. The waste heat from the boiler, supposed perfectly efficient, would be in this case 11%, of which less than a quarter could be utilized in the form of work. Carnot foresaw that in order to utilize a larger percentage of the heat of combustion it would be necessary to employ a series of working fluids, the waste heat from one boiler and condenser serving to supply the next in the series. This has actually been effected in a few cases, *e.g.* steam and SO_2, when special circumstances exist to compensate for the extra complication. Improvements in the steam-engine since Carnot's time have been mainly in the direction of reducing waste due to condensation and leakage by multiple expansion, superheating, &c. The gain by increased temperature range has been comparatively small owing to limitations of pressure, and the best modern steam-engines do not utilize more than 20% of the heat of combustion. This is in reality a very respectable fraction of the ideal limit of 40% above calculated on the assumption of 1260 ℔ initial pressure, with a perfectly efficient boiler and complete expansion, and with an ideal engine which does not waste available motive power by complete condensation of the steam before it is returned to the boiler.

23. *Advantages of Internal Combustion.*—As Carnot pointed out, the chief advantage of using atmospheric air as a working fluid in a heat-engine lies in the possibility of imparting heat to it directly by internal combustion. This avoids the limitation imposed by the use of a separate boiler, which as we have seen reduces the possible efficiency at least 50%. Even with internal combustion, however, the full range of temperature is not available, because the heat cannot conveniently in practice be communicated to the working fluid at constant temperature, owing to the large range of expansion at constant temperature required for the absorption of a sufficient quantity of heat. Air-engines of this type, such as Stirling's or Ericsson's, taking in heat at constant temperature, though theoretically the most perfect, are bulky and mechanically inefficient. In practical engines the heat is generated by the combustion of an explosive mixture at constant volume or at constant pressure. The heat is not all communicated at the highest temperature, but over a range of temperature from that of the mixture at the beginning of combustion to the maximum temperature. The earliest instance of this type of engine is the lycopodium engine of M. M. Niepce, discussed by Carnot, in which a combustible mixture of air and lycopodium powder at atmospheric pressure was ignited in a cylinder, and did work on a piston. The early gas-engines of E. Lenoir (1860) and N. Otto and E. Langen (1866), operated in a similar manner with illuminating gas in place of lycopodium. Combustion in this case is effected practically at constant volume, and the maximum efficiency theoretically obtainable is $1 - \log_e r / (r - 1)$, where r is the ratio of the maximum temperature θ' to the initial temperature θ^0. In order to obtain this efficiency it would be necessary to follow Carnot's rule, and expand the gas after ignition without loss or gain of heat from θ' down to θ^0, and then to compress it at θ^0 to its initial volume. If the rise of temperature in combustion were 2300° C., and the initial temperature were 0° C. or 273° Abs., the theoretical efficiency would be 73.3%, which is much greater than that obtainable with a boiler. But in order to reach this value, it would be necessary to expand the mixture to about 270 times its initial volume, which is obviously impracticable. Owing to incomplete expansion and rapid cooling of the heated gases by the large surface exposed, the actual efficiency of the Lenoir engine was less than 5%, and of the Otto and Langen, with more rapid expansion, about 10%. Carnot foresaw that in order to render an engine of this type practically efficient, it would be necessary to compress the mixture before ignition. Compression is beneficial in three ways: (1) it permits a greater range of expansion after ignition; (2) it raises the mean effective pressure, and thus improves the mechanical efficiency and the power in proportion to size and weight; (3) it reduces the loss of heat during ignition by reducing the surface exposed to the hot gases. In the modern gas or petrol motor, compression is employed as in Carnot's cycle, but the efficiency attainable is limited not so much by considerations of temperature as by limitations of volume. It is impracticable before combustion at constant volume to compress a rich mixture to much less than ⅕th of its initial volume, and, for mechanical simplicity, the range of expansion is made equal to that of compression. The cycle employed was patented in 1862 by Beau de Rochas (d. 1892), but was first successfully carried out by Otto (1876). It differs from the Carnot cycle in employing reception and rejection of heat at constant volume instead of at constant temperature. This cycle is not so efficient as the Carnot cycle for given limits of temperature, but, *for the given limits of volume imposed*, it gives a much higher efficiency than the Carnot cycle. The efficiency depends only on the range of temperature in expansion and compression, and is given by the formula $(\theta' - \theta'') / \theta'$, where

θ′ is the maximum temperature, and θ″ the temperature at the end of expansion. The formula is the same as that for the Carnot cycle with the same range of temperature in expansion. The ratio θ′ / θ″ is $r^{\gamma-1}$, where *r* is the given ratio of expansion or compression, and γ is the ratio of the specific heats of the working fluid. Assuming the working fluid to be a perfect gas with the same properties as air, we should have γ = 1.41. Taking *r* = 5, the formula gives 48% for the maximum possible efficiency. The actual products of combustion vary with the nature of the fuel employed, and have different properties from air, but the efficiency is 148
found to vary with compression in the same manner as for air. For this reason a committee of the Institution of Civil Engineers in 1905 recommended the adoption of the air-standard for estimating the effects of varying the compression ratio, and defined the relative efficiency of an internal combustion engine as the ratio of its observed efficiency to that of a perfect air-engine with the same compression.

24. *Effect of Dissociation, and Increase of Specific Heat.*—One of the most important effects of heat is the decomposition or dissociation of compound molecules. Just as the molecules of a vapour combine with evolution of heat to form the more complicated molecules of the liquid, and as the liquid molecules require the addition of heat to effect their separation into molecules of vapour; so in the case of molecules of different kinds which combine with evolution of heat, the reversal of the process can be effected either by the agency of heat, or indirectly by supplying the requisite amount of energy by electrical or other methods. Just as the latent heat of vaporization diminishes with rise of temperature, and the pressure of the dissociated vapour molecules increases, so in the case of compound molecules in general the heat of combination diminishes with rise of temperature, and the pressure of the products of dissociation increases. There is evidence that the compound carbon dioxide, CO_2, is partly dissociated into carbon monoxide and oxygen at high temperatures, and that the proportion dissociated increases with rise of temperature. There is a very close analogy between these phenomena and the vaporization of a liquid. The laws which govern dissociation are the same fundamental laws of thermodynamics, but the relations involved are necessarily more complex on account of the presence of different kinds of molecules, and present special difficulties for accurate investigation in the case where dissociation does not begin to be appreciable until a high temperature is reached. It is easy, however, to see that the general effect of dissociation must be to diminish the available temperature of combustion, and all experiments go to show that in ordinary combustible mixtures the rise of temperature actually attained is much less than that calculated as in § 22, on the assumption that the whole heat of combustion is developed and communicated to products of constant specific heat. The defect of temperature observed can be represented by supposing that the specific heat of the products of combustion increases with rise of temperature. This is the case for CO_2 even at ordinary temperatures, according to Regnault, and probably also for air and steam at higher temperatures. Increase of specific heat is a necessary accompaniment of dissociation, and from some points of view may be regarded as merely another way of stating the facts. It is the most convenient method to adopt in the case of products of combustion consisting of a mixture of CO_2 and steam with a large excess of inert gases, because the relations of equilibrium of dissociated molecules of so many different kinds would be too complex to permit of any other method of expression. It appears from the researches of Dugald Clerk, H. le Chatelier and others that the apparent specific heat of the products of combustion in a gas-engine may be taken as approximately .34 to .33 in place of .24 at working temperatures between 1000° C. and 1700° C., and that the ratio of the specific heats is about 1.29 in place of 1.41. This limits the availability of the heat of combustion by reducing the rise of temperature actually obtainable in combustion at constant volume by 30 or 40%, and also by reducing the range of temperature θ′ / θ″ for a given ratio of expansions r from r^{41} to r^{29}. The formula given in § 21 is no longer quite exact, because the ratio of the specific heats of the mixture during compression is not the same as that of the products of combustion during expansion. But since the work done depends principally on the expansion curve, the ratio of the range of temperature in expansion (θ′ − θ″) to the maximum temperature θ′ will still give a very good approximation to the possible efficiency. Taking *r* = 5, as before, for the compression ratio, the possible efficiency is reduced from 48% to 38%, if γ = 1.29 instead of 1.41. A large gas-engine of the present day with *r* = 5 may actually realize as much as 34% indicated efficiency, which is 90% of the maximum possible, showing how perfectly all avoidable heat losses have been minimized.

It is often urged that the gas-engine is relatively less efficient than the steam-engine, because, although it has a much higher absolute efficiency, it does not utilize so large a fraction of its temperature range, reckoning that of the steam-engine from the temperature of the boiler to that of the condenser, and that of the gas-engine from the maximum temperature of combustion to that of the air. This is not quite fair, and has given rise to the mistaken notion that “there is an immense margin for improvement in the gas-engine,” which is not the case if the practical limitations of volume are rightly considered. If expansion could be carried out in accordance with Carnot’s principle of maximum efficiency, down to the lower limit of temperature θ_0, with rejection of heat at θ_0 during compression to the original volume V_0, it would no doubt be possible to obtain an ideal efficiency of nearly 80%. But this would be quite impracticable, as it would require expansion to about 100 times v_0, or 500 times the compression volume. Some advantage no doubt might be obtained by carrying the expansion beyond the original volume. This has been done, but is not found to be worth the extra complication. A more practical method, which has been applied by Diesel for liquid fuel, is to introduce the fuel at the end of compression, and adjust the supply in such a manner as to give combustion at nearly constant pressure. This makes it possible to employ higher compression, with a corresponding increase in the ratio of expansion and the theoretical efficiency. With a compression ratio of 14, an indicated efficiency of 40% has been obtained In this way, but owing to additional complications the brake efficiency was only 31%, which is hardly any improvement on the brake efficiency of 30% obtained with the ordinary type of gas-engine. Although Carnot’s principle makes it possible to calculate in every case what the limiting possible efficiency would be for any kind of cycle if all heat losses were abolished, it is very necessary, in applying the principle to practical cases, to take account of the possibility of avoiding the heat losses which are supposed to be absent, and of other practical limitations in the working of the actual engine. An immense amount of time and ingenuity has been wasted in striving to realize impossible margins of ideal efficiency, which a close study of the practical conditions would have shown to be illusory. As Carnot remarks at the conclusion of his essay: “Economy of fuel is only one of the conditions a heat-engine must satisfy; in many cases it is only secondary, and must often give way to considerations of safety, strength and wearing qualities of the machine, of smallness of space occupied, or of expense in erecting. To know how to appreciate justly in each case the considerations of convenience and economy, to be able to distinguish the essential from the accessory, to balance all fairly, and finally to arrive at the best result by the simplest means, such must be the principal talent of the man called on to direct and co-ordinate the work of his fellows for the attainment of a useful object of any kind.”

Transference of Heat

25. *Modes of Transference.*—There are three principal modes of transference of heat, namely (1) convection, (2) conduction, and (3) radiation.

(1) In convection, heat is carried or conveyed by the motion of heated masses of matter. The most familiar illustrations of this method of transference are the heating of buildings by the circulation of steam or hot water, or the equalization of temperature of a mass of unequally heated liquid or gas by convection currents, produced by natural changes of density or by artificial stirring. (2) In conduction, heat is transferred by contact between contiguous particles of matter and is passed on from one particle to the next without visible relative motion of the parts of the body. A familiar illustration of conduction is the passage of heat through the metal plates of a boiler from the fire to the water inside, or the transference of heat from a soldering bolt to the solder and the metal with which it is placed in contact. (3) In radiation, the heated body gives rise to a motion of vibration in the aether, 149
which is propagated equally in all directions, and is reconverted into heat when it encounters any obstacle capable of absorbing it. Thus radiation differs from conduction and convection in taking place most perfectly in the absence of matter, whereas conduction and convection require material communication between the bodies concerned.

In the majority of cases of transference of heat all three modes of transference are simultaneously operative in a greater or less degree, and the combined effect is generally of great complexity. The different modes of transference are subject to widely different laws, and the difficulty of disentangling their effects and subjecting them to calculation is often one of the most serious obstacles in the experimental investigation of heat. In space void of matter, we should have pure radiation, but it is difficult to obtain so perfect a vacuum that the effects of the residual gas in transferring heat by conduction or convection are inappreciable. In the interior of an opaque solid we should have pure conduction, but if the solid is sensibly transparent in thin layers there must also be an internal radiation, while in a liquid or a gas it is very difficult to eliminate the effects of convection. These difficulties are well illustrated in the historical development of the subject by the experimental investigations which have been made to determine the laws of heat-transference, such as the laws of cooling, of radiation and of conduction.

26. *Newton's Law of Cooling.*—There is one essential condition common to all three modes of heat-transference, namely, that they depend on difference of temperature, that the direction of the transfer of heat is always from hot to cold, and that the rate of transference is, for small differences, directly proportional to the difference of temperature. Without difference of temperature there is no transfer of heat. When two bodies have been brought to the same temperature by conduction, they are also in equilibrium as regards radiation, and vice versa. If this were not the case, there could be no equilibrium of heat defined by equality of temperature. A hot body placed in an enclosure of lower temperature, *e.g.* a calorimeter in its containing vessel, generally loses heat by all three modes simultaneously in different degrees. The loss by each mode will depend in different ways on the form, extent and nature of its surface and on that of the enclosure, on the manner in which it is supported, on its relative position and distance from the enclosure, and on the nature of the intervening medium. But provided that the difference of temperature is small, the rate of loss of heat by all modes will be approximately proportional to the difference of temperature, the other conditions remaining constant. The rate of cooling or the rate of fall of temperature will also be nearly proportional to the rate of loss of heat, if the specific heat of the cooling body is constant, or the rate of cooling at any moment will be proportional to the difference of temperature. This simple relation is commonly known as Newton's law of cooling, but is limited in its application to comparatively simple cases such as the foregoing. Newton himself applied it to estimate the temperature of a red-hot iron ball, by observing the time which it took to cool from a red heat to a known temperature, and comparing this with the time taken to cool through a known range at ordinary temperatures. According to this law if the excess of temperature of the body above its surroundings is observed at equal intervals of time, the observed values will form a geometrical progression with a common ratio. Supposing, for instance, that the surrounding temperature were 0° C., that the red-hot ball took 25 minutes to cool from its original temperature to 20° C., and 5 minutes to cool from 20° C. to 10° C., the original temperature is easily calculated on the assumption that the excess of temperature above 0° C. falls to half its value in each interval of 5 minutes. Doubling the value 20° at 25 minutes five times, we arrive at 640° C. as the original temperature. No other method of estimation of such temperatures was available in the time of Newton, but, as we now know, the simple law of proportionality to the temperature difference is inapplicable over such large ranges of temperature. The rate of loss of heat by radiation, and also by convection and conduction to the surrounding air, increases much more rapidly than in simple proportion to the temperature difference, and the rate of increase of each follows a different law. At a later date Sir John Herschel measured the intensity of the solar radiation at the surface of the earth, and endeavoured to form an estimate of the temperature of the sun by comparison with terrestrial sources on the assumption that the intensity of radiation was simply proportional to the temperature difference. He thus arrived at an estimate of several million degrees, which we now know would be about a thousand times too great. The application of Newton's law necessarily leads to absurd results when the difference of temperature is very large, but the error will not in general exceed 2 to 3% if the temperature difference does not exceed 10° C., and the percentage error is proportionately much smaller for smaller differences.

27. *Dulong and Petit's Empirical Laws of Cooling.*—One of the most elaborate experimental investigations of the law of cooling was that of Dulong and Petit (*Ann. Chim. Phys.*, 1817, 7, pp. 225 and 337), who observed the rate of cooling of a mercury thermometer from 300° C. in a water-jacketed enclosure at various temperatures from 0° C. to 80° C. In order to obtain the rate of cooling by radiation alone, they exhausted the enclosure as perfectly as possible after the introduction of the thermometer, but with the imperfect appliances available at that time they were not able to obtain a vacuum better than about 3 or 4 mm. of mercury. They found that the velocity of cooling V in a vacuum could be represented by a formula of the type

$$V = A\,(a^{t} - a^{t_0}) \qquad (5)$$

in which t is the temperature of the thermometer, and t_0 that of the enclosure, a is a constant having the value 1.0075, and the coefficient A depends on the form of the bulb and the nature of its surface. For the ranges of temperature they employed, this formula gives much better results than Newton's, but it must be remembered that the temperatures were expressed on the arbitrary scale of the mercury thermometer, and were not corrected for the large and uncertain errors of stem-exposure (see Thermometry). Moreover, although the effects of cooling by convection currents are practically eliminated by exhausting to 3 or 4 mm. (since the density of the gas is reduced to $\frac{1}{200}$th while its viscosity is not appreciably affected), the rate of cooling by conduction is not materially diminished, since the conductivity, like the viscosity, is nearly independent of pressure. It has since been shown by Sir William Crookes (*Proc. Roy. Soc.*, 1881, 21, p. 239) that the rate of cooling of a mercury thermometer in a vacuum suffers a very great diminution when the pressure is reduced from 1 mm. to .001 mm., at which pressure the effect of conduction by the residual gas has practically disappeared.

Dulong and Petit also observed the rate of cooling under the same conditions with the enclosure filled with various gases. They found that the cooling effect of the gas could be represented by adding to the term already given as representing radiation, an expression of the form

$$V' = Bp^{c} (t - t_0)^{1.233}. \qquad (6)$$

They found that the cooling effect of convection, unlike that of radiation, was independent of the nature of the surface of the thermometer, whether silvered or blackened, that it varied as some power c of the pressure p, and that it was independent of the absolute temperature of the enclosure, but varied as the excess temperature $(t - t_0)$ raised to the power 1.233. This highly artificial result undoubtedly contains some elements of truth, but could only be applied to experiments similar to those from which it was derived. F. Hervé de la Provostaye and P. Q. Desains (*Ann. Chim. Phys.*, 1846, 16, p. 337), in repeating these experiments under various conditions, found that the coefficients A and B were to some extent dependent on the temperature, and that the manner in which the cooling effect varied with the pressure depended on the form and size of the enclosure. It is evident that this should be the case, since the cooling effect of the gas depends partly on convective currents. which are 150
necessarily greatly modified by the form of the enclosure in a manner which it would appear hopeless to attempt to represent by any general formula.

28. *Surface Emissivity.*—The same remark applies to many attempts which have since been made to determine the general value of the constant termed by Fourier and early writers the “exterior conductibility,” but now called the surface emissivity. This coefficient represents the rate of loss of heat from a body per unit area of surface per degree excess of temperature, and includes the effects of radiation, convection and conduction. As already pointed out, the combined effect will be nearly proportional to the excess of temperature in any given case provided that the excess is small, but it is not necessarily proportional to the extent of surface exposed except in the case of pure radiation. The rate of loss by convection and conduction varies greatly with the form of the surface, and, unless the enclosure is very large compared with the cooling body, the effect depends also on the size and form of the enclosure. Heat is necessarily communicated from the cooling body to the layer of gas in contact with it by conduction. If the linear dimensions of the body are small, as in the case of a fine wire, or if it is separated from the enclosure by a thin layer of gas, the rate of loss depends chiefly on conduction. For very fine metallic wires heated by an electric current, W. E. Ayrton and H. Kilgour (*Phil. Trans.*, 1892) showed that the rate of loss is nearly independent of the surface, instead of being directly proportional to it. This should be the case, as Porter has shown (*Phil. Mag.*, March 1895), since the effect depends mainly on conduction. The effects of conduction and radiation may be approximately estimated if the conductivity of the gas and the nature and forms of the surfaces of the body and enclosure are known, but the effect of convection in any case can be determined only by experiment. It has been found that the rate of cooling by a current of air is approximately proportional to the velocity of the current, other things being equal. It is obvious that this should be the case, but the result cannot generally be applied to convection currents. Values which are commonly given for the surface emissivity must therefore be accepted with great reserve. They can be regarded only as approximate, and as applicable only to cases precisely similar to those for which they were experimentally obtained. There cannot be said to be any general law of convection. The loss of heat is not necessarily proportional to the area of the surface, and no general value of the coefficient can be given to suit all cases. The laws of conduction and radiation admit of being more precisely formulated, and their effects predicted, except in so far as they are complicated by convection.

29. *Conduction of Heat.*—The laws of transference of heat in the interior of a solid body formed one of the earliest subjects of mathematical and experimental treatment in the theory of heat. The law assumed by Fourier was of the simplest possible type, but the mathematical application, except in the simplest cases, was so difficult as to require the development of a new mathematical method. Fourier succeeded in showing how, by his method of analysis, the solution of any given problem with regard to the flow of heat by conduction in any material could be obtained in terms of a physical constant, the thermal conductivity of the material, and that the results obtained by experiment agreed in a

qualitative manner with those predicted by his theory. But the experimental determination of the actual values of these constants presented formidable difficulties which were not surmounted till a later date. The experimental methods and difficulties are discussed in a special article on Conduction of Heat. It will suffice here to give a brief historical sketch, including a few of the more important results by way of illustration.

30. *Comparison of Conducting Powers.*—That the power of transmitting heat by conduction varied widely in different materials was probably known in a general way from prehistoric times. Empirical knowledge of this kind is shown in the construction of many articles for heating, cooking, &c., such as the copper soldering bolt, or the Norwegian cooking-stove. One of the earliest experiments for making an actual comparison of conducting powers was that suggested by Franklin, but carried out by Jan Ingenhousz (*Journ. de phys.*, 1789, 34, pp. 68 and 380). Exactly similar bars of different materials, glass, wood, metal, &c., thinly coated with wax, were fixed in the side of a trough of boiling water so as to project for equal distances through the side of the trough into the external air. The wax coating was observed to melt as the heat travelled along the bars, the distance from the trough to which the wax was melted along each affording an approximate indication of the distribution of temperature. When the temperature of each bar had become stationary the heat which it gained by conduction from the trough must be equal to the heat lost to the surrounding air, and must therefore be approximately proportional to the distance to which the wax had melted along the bar. But the temperature fall per unit length, or the temperature-gradient, in each bar at the point where it emerged from the trough would be inversely proportional to the same distance. For equal temperature-gradients the quantities of heat conducted (or the relative conducting powers of the bars) would therefore be proportional to the squares of the distances to which the wax finally melted on each bar. This was shown by Fourier and Despretz (*Ann. chim. phys.*, 1822, 19, p. 97).

31. *Diffusion of Temperature.*—It was shown in connexion with this experiment by Sir H. Davy, and the experiment was later popularized by John Tyndall, that the rate at which wax melted along the bar, or the rate of propagation of a given temperature, during the first moments of heating, as distinguished from the melting-distance finally attained, depended on the specific heat as well as the conductivity. Short prisms of iron and bismuth coated with wax were placed on a hot metal plate. The wax was observed to melt first on the bismuth, although its conductivity is less than that of iron. The reason is that its specific heat is less than that of iron in the proportion of 3 to 11. The densities of iron and bismuth being 7.8 and 9.8, the thermal capacities of equal prisms will be in the ratio .86 for iron to .29 for bismuth. If the prisms receive heat at equal rates, the bismuth will reach the temperature of melting wax nearly three times as quickly as the iron. It is often stated on the strength of this experiment that the rate of propagation of a temperature wave, which depends on the ratio of the conductivity to the specific heat per unit volume, is greater in bismuth than in iron (*e.g.* Preston, *Heat*, p. 628). This is quite incorrect, because the conductivity of iron is about six times that of bismuth, and the rate of propagation of a temperature wave is therefore twice as great in iron as in bismuth. The experiment in reality is misleading because the rates of reception of heat by the prisms are limited by the very imperfect contact with the hot metal plate, and are not proportional to the respective conductivities. If the iron and bismuth bars are properly faced and soldered to the top of a copper box (in order to ensure good metallic contact, and exclude a non-conducting film of air), and the box is then heated by steam, the rates of reception of heat will be nearly proportional to the conductivities, and the wax will melt nearly twice as fast along the iron as along the bismuth. A bar of lead similarly treated will show a faster rate of propagation than iron, because, although its conductivity is only half that of iron, its specific heat per unit volume is 2.5 times smaller.

32. *Bad Conductors. Liquids and Gases.*—Count Rumford (1792) compared the conducting powers of substances used in clothing, such as wool and cotton, fur and down, by observing the time which a thermometer took to cool when embedded in a globe filled successively with the different materials. The times of cooling observed for a given range varied from 1300 to 900 seconds for different materials. The low conducting power of such materials is principally due to the presence of air in the interstices, which is prevented from forming convection currents by the presence of the fibrous material. Finely powdered silica is a very bad conductor, but in the compact form of rock crystal it is as good a conductor as some of the metals. According to the kinetic theory of gases, the conductivity of a gas depends on molecular diffusion. Maxwell estimated the conductivity of air at ordinary temperatures at about 20,000 times less than that of copper. This has been verified experimentally by Kundt and Warburg, Stefan and Winkelmann, by taking special precautions to eliminate the effects of convection currents and radiation. It was for some time doubted whether a gas possessed

any true conductivity for heat. The experiment of T. Andrews, repeated by Grove, and Magnus, showing that a wire heated by an electric current was raised to a higher temperature in air than in hydrogen, was explained by Tyndall as being due to the greater mobility of hydrogen which gave rise to stronger convection currents. In reality the effect is due chiefly to the greater velocity of motion of the ultimate molecules of hydrogen, and is most marked if molar (as opposed to molecular) convection is eliminated. Molecular convection or diffusion, which cannot be distinguished experimentally from conduction, as it follows the same law, is also the main cause of conduction of heat in liquids. Both in liquids and gases the effects of convection currents are so much greater than those of diffusion or conduction that the latter are very difficult to measure, and, except in special cases, comparatively unimportant as affecting the transference of heat. Owing to the difficulty of eliminating the effects of radiation and convection, the results obtained for the conductivities of liquids are somewhat discordant, and there is in most cases great uncertainty whether the conductivity increases or diminishes with rise of temperature. It would appear, however, that liquids, such as water and glycerin, differ remarkably little in conductivity in spite of enormous differences of viscosity. The viscosity of a liquid diminishes very rapidly with rise of temperature, without any marked change in the conductivity, whereas the viscosity of a gas increases with rise of temperature, and is always nearly proportional to the conductivity.

33. *Difficulty of Quantitative Estimation of Heat Transmitted.*—The conducting powers of different metals were compared by C. M. Despretz, and later by G. H. Wiedemann and R. Franz, employing an extension of the method of Jan Ingenhousz, in which the temperatures at different points along a bar heated at one end were measured by thermometers or thermocouples let into small holes in the bars, instead of being measured at one point only by means of melting wax. These experiments undoubtedly gave fairly accurate relative values, but did not permit the calculation of the absolute amounts of heat transmitted. This was first obtained by J. D. Forbes (*Brit. Assoc. Rep.*, 1852; *Trans. Roy. Soc. Ed.*, 1862, 23, p. 133) by deducing the amount of heat lost to the surrounding air from a separate experiment in which the rate of cooling of the bar was observed (see Conduction of Heat). Clément (*Ann. chim. phys.*, 1841) had previously attempted to determine the conductivities of metals by observing the amount of heat transmitted by a plate with one side exposed to steam at 100° C., and the other side cooled by water at 28° C. Employing a copper plate 3 mm. thick, and assuming that the two surfaces of the plate were at the same temperatures as the water and the steam to which they were exposed, or that the temperature-gradient in the metal was 72° in 3 mm., he had thus obtained a value which we now know to be nearly 200 times too small. The actual temperature difference in the metal itself was really about 0.36° C. The remainder of the 72° drop was in the badly conducting films of water and steam close to the metal surface. Similarly in a boiler plate in contact with flame at 1500° C. on one side and water at, say, 150° C. on the other, the actual difference of temperature in the metal, even if it is an inch thick, is only a few degrees. The metal, unless badly furred with incrustation, is but little hotter than the water. It is immaterial so far as the transmission of heat is concerned, whether the plates are iron or copper. The greater part of the resistance to the passage of heat resides in a comparatively quiescent film of gas close to the surface, through which film the heat has to pass mainly by conduction. If a Bunsen flame, preferably coloured with sodium, is observed impinging on a cold metal plate, it will be seen to be separated from the plate by a dark space of a millimetre or less, throughout which the temperature of the gas is lowered by its own conductivity below the temperature of incandescence. There is no abrupt change of temperature in passing from the gas to the metal, but a continuous temperature-gradient from the temperature of the metal to that of the flame. It is true that this gradient may be upwards of 1000° C. per mm., but there is no discontinuity.

34. *Resistance of a Gas Film to the Passage of Heat.*—It is possible to make a rough estimate of the resistance of such a film to the passage of heat through it. Taking the average conductivity of the gas in the film as 10,000 times less than that of copper (about double the conductivity of air at ordinary temperatures) a millimetre film would be equivalent to a thickness of 10 metres of copper, or about 1.2 metres of iron. Taking the temperature-gradient as 1000° C. per mm. such a film would transmit 1 gramme-calorie per sq. cm. per sec., or 36,000 kilo-calories per sq. metre per hour. With an area of 100 sq. cms. the heat transmitted at this rate would raise a litre of water from 20° C. to 100° C. in 800 secs. By experiment with a strong Bunsen flame it takes from 8 to 10 minutes to do this, which would indicate that on the above assumptions the equivalent thickness of quiescent film should be rather less than 1 mm. in this case. The thickness of the film diminishes with the velocity of the burning gases impinging on the surface. This accounts for the rapidity of heating by a blowpipe flame, which is not due to any great increase in temperature of the

flame as compared with a Bunsen. Similarly the efficiency of a boiler is but slightly reduced if half the tubes are stopped up, because the increase of draught through the remainder compensates partly for the diminished heating surface. Some resistance to the passage of heat into a boiler is also due to the water film on the inside. But this is of less account, because the conductivity of water is much greater than that of air, and because the film is continually broken up by the formation of steam, which abstracts heat very rapidly.

35. *Heating by Condensation of Steam.*—It is often stated that the rate at which steam will condense on a metal surface at a temperature below that corresponding to the saturation pressure of the steam is practically infinite (*e.g.* Osborne Reynolds, *Proc. Roy. Soc. Ed.*, 1873, p. 275), and conversely that the rate at which water will abstract heat from a metal surface by the formation of steam (if the metal is above the temperature of saturation of the steam) is limited only by the rate at which the metal can supply heat by conduction to its surface layer. The rate at which heat can be supplied by condensation of steam appears to be much greater than that at which heat can be supplied by a flame under ordinary conditions, but there is no reason to suppose that it is infinite, or that any discontinuity exists. Experiments by H. L. Callendar and J. T. Nicolson by three independent methods (*Proc. Inst. Civ. Eng.*, 1898, 131, p. 147; *Brit. Assoc. Rep.* p. 418) appear to show that the rate of abstraction of heat by evaporation, or that of communication of heat by condensation, depends chiefly on the difference of temperature between the metal surface and the saturated steam, and is nearly proportional to the temperature difference (not to the pressure difference, as suggested by Reynolds) for such ranges of pressure as are common in practice. The rate of heat transmission they observed was equivalent to about 8 calories per sq. cm. per sec., for a difference of 20° C. between the temperature of the metal surface and the saturation temperature of the steam. This would correspond to a condensation of 530 kilogrammes of steam at 100° C. per sq. metre per hour, or 109 ℔ per sq. ft. per hour for the same difference of temperature, values which are many times greater than those actually obtained in ordinary surface condensers. The reason for this is that there is generally some air mixed with the steam in a surface condenser, which greatly retards the condensation. It is also difficult to keep the temperature of the metal as much as 20° C. below the temperature of the steam unless a very free and copious circulation of cold water is available. For the same difference of temperature, steam can supply heat by condensation about a thousand times faster than hot air. This rate is not often approached in practice, but the facility of generation and transmission of steam, combined with its high latent heat and 152
the accuracy of control and regulation of temperature afforded, render it one of the most convenient agents for the distribution of large quantities of heat in all kinds of manufacturing processes.

36. *Spheroidal State.*—An interesting contrast to the extreme rapidity with which heat is abstracted by the evaporation of a liquid in contact with a metal plate, is the so-called spheroidal state. A small drop of liquid thrown on a red-hot metal plate assumes a spheroidal form, and continues swimming about for some time, while it slowly evaporates at a temperature somewhat below its boiling-point. The explanation is simply that the liquid itself cannot come in actual contact with the metal plate (especially if the latter is above the critical temperature), but is separated from it by a badly conducting film of vapour, through which, as we have seen, the heat is comparatively slowly transmitted even if the difference of temperature is several hundred degrees. If the metal plate is allowed to cool gradually, the drop remains suspended on its cushion of vapour, until, in the case of water, a temperature of about 200° C. is reached, at which the liquid comes in contact with the plate and boils explosively, reducing the temperature of the plate, if thin, almost instantaneously to 100° C. The temperature of the metal is readily observed by a thermo-electric method, employing a platinum dish with a platinum-rhodium wire soldered with gold to its under side. The absence of contact between the liquid and the dish in the spheroidal state may also be shown by connecting one terminal of a galvanometer to the drop and the other through a battery to the dish, and observing that no current passes until the drop boils.

37. *Early Theories of Radiation.*—It was at one time supposed that there were three distinct kinds of radiation—thermal, luminous and actinic, combined in the radiation from a luminous source such as the sun or a flame. The first gave rise to heat, the second to light and the third to chemical action. The three kinds were partially separated by a prism, the actinic rays being generally more refracted, and the thermal rays less refracted than the luminous. This conception arose very naturally from the observation that the feebly luminous blue and violet rays produced the greatest photographic effects, which also showed the existence of dark rays beyond the violet, whereas the brilliant yellow and red were practically without action on the photographic plate. A thermometer placed in the blue or violet showed no appreciable rise of temperature, and even in the yellow the effect was

hardly discernible. The effect increased rapidly as the light faded towards the extreme red, and reached a maximum beyond the extreme limits of the spectrum (Herschel), showing that the greater part of the thermal radiation was altogether non-luminous. It is now a commonplace that chemical action, colour sensation and heat are merely different effects of one and the same kind of radiation, the particular effect produced in each case depending on the frequency and intensity of the vibration, and on the nature of the substance on which it falls. When radiation is completely absorbed by a black substance, it is converted into heat, the quantity of heat produced being equivalent to the total energy of the radiation absorbed, irrespective of the colour or frequency of the different rays. The actinic or chemical effects, on the other hand, depend essentially on some relation between the period of the vibration and the properties of the substance acted on. The rays producing such effects are generally those which are most strongly absorbed. The spectrum of chlorophyll, the green colouring matter of plants, shows two very strong absorption bands in the red. The red rays of corresponding period are found to be the most active in promoting the growth of the plant. The chemically active rays are not necessarily the shortest. Even photographic plates may be made to respond to the red rays by staining them with pinachrome or some other suitable dye.

The action of light rays on the retina is closely analogous to the action on a photographic plate. The retina, like the plate, is sensitive only to rays within certain restricted limits of frequency. The limits of sensitiveness of each colour sensation are not exactly defined, but vary slightly from one individual to another, especially in cases of partial colour-blindness, and are modified by conditions of fatigue. We are not here concerned with these important physiological and chemical effects of radiation, but rather with the question of the conversion of energy of radiation into heat, and with the laws of emission and absorption of radiation in relation to temperature. We may here also assume the identity of visible and invisible radiations from a heated body in all their physical properties. It has been abundantly proved that the invisible rays, like the visible, (1) are propagated in straight lines in homogeneous media; (2) are reflected and diffused from the surface of bodies according to the same law; (3) travel with the same velocity in free space, but with slightly different velocities in denser media, being subject to the same law of refraction; (4) exhibit all the phenomena of diffraction and interference which are characteristic of wave-motion in general; (5) are capable of polarization and double refraction; (6) exhibit similar effects of selective absorption. These properties are more easily demonstrated in the case of visible rays on account of the great sensitiveness of the eye. But with the aid of the thermopile or other sensitive radiometer, they may be shown to belong equally to all the radiations from a heated body, even such as are thirty to fifty times slower in frequency than the longest visible rays. The same physical properties have also been shown to belong to electromagnetic waves excited by an electric discharge, whatever the frequency, thus including all kinds of aetherial radiation in the same category as light.

38. *Theory of Exchanges.*—The apparent concentration of cold by a concave mirror, observed by G. B. Porta and rediscovered by M. A. Pictet, led to the enunciation of the theory of exchanges by Pierre Prevost in 1791. Prevost’s leading idea was that all bodies, whether cold or hot, are constantly radiating heat. Heat equilibrium, he says, consists in an equality of exchange. When equilibrium is interfered with, it is re-established by inequalities of exchange. If into a locality at uniform temperature a refracting or reflecting body is introduced, it has no effect in the way of changing the temperature at any point of that locality. A reflecting body, heated or cooled in the interior of such an enclosure, will acquire the surrounding temperature more slowly than would a non-reflector, and will less affect another body placed at a little distance, but will not affect the final equality of temperature. Apparent radiation of cold, as from a block of ice to a thermometer placed near it, is due to the fact that the thermometer being at a higher temperature sends more heat to the ice than it received back from it. Although Prevost does not make the statement in so many words, it is clear that he regards the radiation from a body as depending only on its own nature and temperature, and as independent of the nature and presence of any adjacent body. Heat equilibrium in an enclosure of constant temperature such as is here postulated by Prevost, has often been regarded as a consequence of Carnot’s principle. Since difference of temperature is required for transforming heat into work, no work could be obtained from heat in such a system, and no spontaneous changes of temperature can take place, as any such changes might be utilized for the production of work. This line of reasoning does not appear quite satisfactory, because it is tacitly assumed, in the reasoning by which Carnot’s principle was established, as a result of universal experience, that a number of bodies within the same impervious enclosure, which contains no source of heat, will ultimately acquire the same temperature, and that difference of temperature is required to produce flow of heat.

Thus although we may regard the equilibrium in such an enclosure as being due to equal exchanges of heat in all directions, the equal and opposite streams of radiation annul and neutralize each other in such a way that no actual transfer of energy in any direction takes place. The state of the medium is everywhere the same in such an enclosure, but its energy of agitation per unit volume is a function of the temperature, and is such that it would not be in equilibrium with any body at a different temperature.

39. *"Full" and Selective Radiation. Correspondence of Emission and Absorption.*—The most obvious difficulties in the way of this theory arise from the fact that nearly all radiation 153
is more or less selective in character, as regards the quality and frequency of the rays emitted and absorbed. It was shown by J. Leslie, M. Melloni and other experimentalists that many substances such as glass and water, which are very transparent to visible rays, are extremely opaque to much of the invisible radiation of lower frequency; and that polished metals, which are perfect reflectors, are very feeble radiators as compared with dull or black bodies at the same temperature. If two bodies emit rays of different periods in different proportions, it is not at first sight easy to see how their radiations can balance each other at the same temperature. The key to all such difficulties lies in the fundamental conception, so strongly insisted on by Balfour Stewart, of the absolute uniformity (qualitative as well as quantitative) of the full or complete radiation stream inside an impervious enclosure of uniform temperature. It follows from this conception that the proportion of the full radiation stream absorbed by any body in such an enclosure must be exactly compensated in quality as well as quantity by the proportion emitted, or that the emissive and absorptive powers of any body at a given temperature must be precisely equal. A good reflector, like a polished metal, must also be a feeble radiator and absorber. Of the incident radiation it absorbs a small fraction and reflects the remainder, which together with the radiation emitted (being precisely equal to that absorbed) makes up the full radiation stream. A partly transparent material, like glass, absorbs part of the full radiation and transmits part. But it emits rays precisely equal in quality and intensity to those which it absorbs, which together with the transmitted portion make up the full stream. The ideal black body or perfect radiator is a body which absorbs all the radiation incident on it. The rays emitted from such a body at any temperature must be equal to the full radiation stream in an isothermal enclosure at the same temperature. Lampblack, which may absorb between 98 to 99% of the incident radiation, is generally taken as the type of a black body. But a closer approximation to full radiation may be obtained by employing a hollow vessel the internal walls of which are blackened and maintained at a uniform temperature by a steam jacket or other suitable means. If a relatively small hole is made in the side of such a vessel, the radiation proceeding through the aperture will be the full radiation corresponding to the temperature. Such a vessel is also a perfect absorber. Of radiation entering through the aperture an infinitesimal fraction only could possibly emerge by successive reflection even if the sides were of polished metal internally. A thin platinum tube heated by an electric current appears feebly luminous as compared with a blackened tube at the same temperature. But if a small hole is made in the side of the polished tube, the light proceeding through the hole appears brighter than the blackened tube, as though the inside of the tube were much hotter than the outside, which is not the case to any appreciable extent if the tube is thin. The radiation proceeding through the hole is nearly that of a perfectly black body if the hole is small. If there were no hole the internal stream of radiation would be exactly that of a black body at the same temperature however perfect the reflecting power, or however low the emissive power of the walls, because the defect in emissive power would be exactly compensated by the internal reflection.

Balfour Stewart gave a number of striking illustrations of the qualitative identity of emission and absorption of a substance. Pieces of coloured glass placed in a fire appear to lose their colour when at the same temperature as the coals behind them, because they compensate exactly for their selective absorption by radiating chiefly those colours which they absorb. Rocksalt is remarkably transparent to thermal radiation of nearly all kinds, but it is extremely opaque to radiation from a heated plate of rocksalt, because it emits when heated precisely those rays which it absorbs. A plate of tourmaline cut parallel to the axis absorbs almost completely light polarized in a plane parallel to the axis, but transmits freely light polarized in a perpendicular plane. When heated its radiation is polarized in the same plane as the radiation which it absorbs. In the case of incandescent vapours, the exact correspondence of emission and absorption as regards wave-length of frequency of the light emitted and absorbed forms the foundation of the science of spectrum analysis. Fraunhofer had noticed the coincidence of a pair of bright yellow lines seen in the spectrum of a candle flame with the dark D lines in the solar spectrum, a coincidence which was afterwards more exactly verified by W. A. Miller. Foucault found that the flame of the electric arc showed the same lines bright in its spectrum, and proved that they appeared as dark lines in the otherwise continuous spectrum when the light from the carbon poles was transmitted through the arc. Stokes gave a dynamical explanation of the phenomenon and illustrated it by the analogous case of resonance in sound. Kirchhoff completed the explanation (*Phil. Mag.*, 1860) of the dark lines in the solar spectrum by showing that the reversal of the spectral lines depended on the fact that the body of the sun giving the continuous spectrum was at a higher temperature than the absorbing layer of gases surrounding it. Whatever be the nature of the selective radiation from a body, the radiation of light of any particular wave-length cannot be greater than a certain fraction E of the radiation R of the same wave-length from a black body at the same temperature. The fraction E measures the emissive power of the body for that particular wave-length, and cannot be greater than unity. The same fraction, by the principle of equality of emissive and absorptive powers, will measure the proportion absorbed of incident radiation R′. If the black body emitting the radiation R′ is at the same temperature as the absorbing layer, $R = R'$, the emission balances the absorption, and the line will appear neither bright nor dark. If the source and the absorbing layer are at different temperatures, the radiation absorbed will be ER′, and that transmitted will be $R' - ER'$. To this must be added the radiation emitted by the absorbing layer, namely ER, giving $R' - E(R' - R)$. The lines will appear darker than the background R′ if R′ is greater than R, but bright if the reverse is the case. The D lines are dark in the sun because the photosphere is much hotter than the reversing layer. They appear bright in the candle-flame because the outside mantle of the flame, in which the sodium burns and combustion is complete, is hotter than the inner reducing flame containing the incandescent particles of carbon which give rise to the continuous spectrum. This qualitative identity of emission and absorption as regards wave-length can be most exactly and easily verified for luminous rays, and we are justified in assuming that the relation holds with the same exactitude for non-luminous rays, although in many cases the experimental proof is less complete and exact.

40. *Diathermancy.*—A great array of data with regard to the transmissive power or diathermancy of transparent substances for the heat radiated from various sources at different temperatures were collected by Melloni, Tyndall, Magnus and other experimentalists. The measurements were chiefly of a qualitative character, and were made by interposing between the source and a thermopile a layer or plate of the substance to be examined. This method lacked quantitative precision, but led to a number of striking and interesting results, which are admirably set forth in Tyndall’s *Heat.* It also gave rise to many curious discrepancies, some of which were recognized as being due to selective absorption, while others are probably to be explained by imperfections in the methods of experiment adopted. The general result of such researches was to show that substances, like water, alum and glass, which are practically opaque to radiation from a source at low temperature, such as a vessel filled with boiling water, transmit an increasing percentage of the radiation when the temperature of the source is increased. This is what would be expected, as these substances are very transparent to visible rays. That the proportion transmitted is not merely a question of the temperature of the source, but also of the quality of the radiation, was shown by a number of experiments. For instance, K. H. Knoblauch (*Pogg. Ann.*, 1847) found that a plate of glass interposed between a spirit lamp and a thermopile intercepts a larger proportion of the radiation from the flame itself than of the radiation from a platinum spiral heated in the flame, although the spiral is undoubtedly at a lower temperature than 154
the flame. The explanation is that the spiral is a fairly good radiator of the visible rays to which the glass is transparent, but a bad radiator of the invisible rays absorbed by the glass which constitute the greater portion of the heat-radiation from the feebly luminous flame.

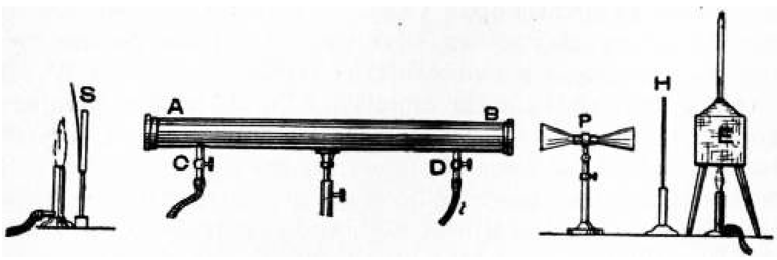


Fig. 6.—Tyndall’s Apparatus for observing absorption of heat by gas and vapours.

Assuming that the radiation from the source under investigation is qualitatively determinate, like that of a black body at a given temperature, the proportion transmitted by plates of various substances may easily be measured and tabulated for given plates and sources. But owing to the highly selective character of the radiation and absorption, it is impossible to give any general relation between the thickness of the absorbing plate or layer and the proportion of the total energy absorbed. For these reasons the relative diathermancies of different materials do not admit of any simple numerical statement as physical constants, though many of the qualitative results obtained are very striking. Among the most interesting experiments were those of Tyndall, on the absorptive powers of gases and vapours, which led to a good deal of controversy at the time, owing to the difficulty of the experiments, and the contradictory results obtained by other observers. The arrangement employed by Tyndall for these measurements is shown in Fig. 6. A brass tube AB, polished inside, and closed with plates of highly diathermanous rocksalt at either end, was fitted with stopcocks C and D for exhausting and admitting air or other gases or vapours. The source of heat S was usually a plate of copper heated by a Bunsen burner, or a Leslie cube containing boiling water as shown at E. To obtain greater sensitiveness for differential measurements, the radiation through the tube AB incident on one face of the pile P was balanced against the radiation from a Leslie cube on the other face of the pile by means of an adjustable screen H. The radiation on the two faces of the pile being thus balanced with the tube exhausted, Tyndall found that the admission of dry air into the tube produced practically no absorption of the radiation, whereas compound gases such as carbonic acid, ethylene or ammonia absorbed 20 to 90%, and a trace of aqueous vapour in the air increased its absorption 50 to 100 times. H. G. Magnus, on the other hand, employing a thermopile and a source of heat, both of which were enclosed in the same exhausted receiver, in order to avoid interposing any rocksalt or other plates between the source and the pile, found an absorption of 11% on admitting dry air, but could not detect any difference whether the air were dry or moist. Tyndall suggested that the apparent absorption observed by Magnus may have been due to the cooling of his radiating surface by convection, which is a very probable source of error in this method of experiment. Magnus considered that the remarkable effect of aqueous vapour observed by Tyndall might have been caused by condensation on the polished internal walls of his experimental tube, or on the rocksalt plates at either end.[7] The question of the relative diathermancy of air and aqueous vapour for radiation from the sun to the earth and from the earth into space is one of great interest and importance in meteorology. Assuming with Magnus that at least 10% of the heat from a source at 100° C. is absorbed in passing through a single foot of air, a very moderate thickness of atmosphere should suffice to absorb practically all the heat radiated from the earth into space. This could not be reconciled with well-known facts in regard to terrestrial radiation, and it was generally recognized that the result found by Magnus must be erroneous. Tyndall's experiment on the great diathermancy of dry air agreed much better with meteorological phenomena, but he appears to have exaggerated the effect of aqueous vapour. He concluded from his experiments that the water vapour present in the air absorbs at least 10% of the heat radiated from the earth within 10 ft. of its surface, and that the absorptive power of the vapour is about 17,000 times that of air at the same pressure. If the absorption of aqueous vapour were really of this order of magnitude, it would exert a far greater effect in modifying climate than is actually observed to be the case. Radiation is observed to take place freely through the atmosphere at times when the proportion of aqueous vapour is such as would practically stop all radiation if Tyndall's results were correct. The very careful experiments of E. Lecher and J. Pernter (*Phil. Mag.*, Jan. 1881) confirmed Tyndall's observations on the absorptive powers of gases and vapours satisfactorily in nearly all cases with the single exception of aqueous vapour. They found that there was no appreciable absorption of heat from a source at 100° C. in passing through 1 ft. of air (whether dry or moist), but that CO and CO_2 at atmospheric pressure absorbed about 8%, and ethylene (olefiant gas) about 50% in the same distance; the vapours of alcohol and ether showed absorptive powers of the same order as that of ethylene. They confirmed Tyndall's important result that the absorption does not diminish in proportion to the pressure, being much greater in proportion for smaller pressures in consequence of the selective character of the effect. They also supported his conclusion that absorptive power increases with the complexity of the molecule. But they could not detect any absorption by water vapour at a pressure of 7 mm., though alcohol at the same pressure absorbed 3% and acetic acid 10%. Later researches, especially those of S. P. Langley with the spectro-bolometer on the infra-red spectrum of sunlight, demonstrated the existence of marked absorption bands, some of which are due to water vapour. From the character of these bands and the manner in which they vary with the state of the air and the thickness traversed, it may be inferred that absorption by water vapour plays an important part in meteorology, but that it is too small to be readily detected by laboratory experiments in a 4 ft. tube, without the aid of spectrum analysis.

41. *Relation between Radiation and Temperature.*—Assuming, in accordance with the reasoning of Balfour Stewart and Kirchhoff, that the radiation stream inside an impervious

enclosure at a uniform temperature is independent of the nature of the walls of the enclosure, and is the same for all substances at the same temperature, it follows that the full stream of radiation in such an enclosure, or the radiation emitted by an ideal black body or full radiator, is a function of the temperature only. The form of this function may be determined experimentally by observing the radiation between two black bodies at different temperatures, which will be proportional to the difference of the full radiation streams corresponding to their several temperatures. The law now generally accepted was first proposed by Stefan as an empirical relation. Tyndall had found that the radiation from a white hot platinum wire at 1200° C. was 11.7 times its radiation when dull red at 525° C. Stefan (*Wien. Akad. Ber.*, 1879, 79, p. 421) noticed that the ratio 11.7 is nearly that of the fourth power of the absolute temperatures as estimated by Tyndall. On making the somewhat different assumption that the radiation between two bodies varied as the difference of the fourth powers of their absolute temperatures, he found that it satisfied approximately the experiments of Dulong and Petit and other observers. According to this law the radiation between a black body at a temperature θ and a black enclosure or a black radiometer at a temperature θ_0 should be proportional to $(\theta^4 - \theta_0{}^4)$. The law was very simple and convenient in form, but it rested so far on very insecure foundations. The temperatures given by Tyndall were merely estimated from the colour of the light emitted, and might have been some hundred degrees in error. We now know that the radiation from polished platinum is of a highly selective character, and varies more nearly as the fifth power of the absolute temperature. The agreement of the fourth power law with Tyndall's experiment appears therefore to be due to a purely accidental error in estimating the temperatures of the wire. Stefan also found a very fair agreement with Draper's observations of the intensity of radiation from a platinum wire, in which the temperature of the wire was deduced from the expansion. Here again the apparent agreement was largely due to errors in estimating the temperature, arising from the fact that the coefficient of expansion of platinum increases considerably with rise of temperature. So far as the experimental results available at that time were concerned, Stefan's law could be regarded only as an empirical expression of doubtful significance. But it received a much greater importance from theoretical investigations which were even then in progress. James Clerk Maxwell (*Electricity and Magnetism*, 1873) had shown that a directed beam of electromagnetic radiation or light incident normally on an absorbing surface should produce a mechanical pressure equal to the energy of the radiation per unit volume. A. G. Bartoli (1875) took up this idea and made it the basis of a thermodynamic treatment of radiation. P. N. Lebedew in 1900, and E. F. Nichols and G. F. Hull in 1901, proved the existence of this pressure by direct experiments. L. Boltzmann (1884) employing radiation as the working substance in a Carnot cycle, showed that the energy of full radiation at any temperature per unit volume should be proportional to the fourth power of the absolute temperature. This law was first verified in a satisfactory manner by Heinrich Schneebeli (*Wied. Ann.*, 1884, 22, p. 30). He observed the radiation from the bulb of an air thermometer heated to known temperatures through a small aperture in the walls of the furnace. With this arrangement the radiation was very nearly that of a black body. Measurements by J. T. Bottomley, August Schleiermacher, L. C. H. F. Paschen and others of the radiation from electrically heated platinum, failed to give concordant results on account of differences in the quality of the radiation, the importance of which was not fully realized at first. Later researches by Paschen with improved methods verified the law, and greatly extended our knowledge of radiation in other directions. One of the most complete series of experiments on the relation between full radiation and temperature is that of O. R. Lummer and Ernst Pringsheim (*Ann. Phys.*, 1897, 63, p. 395). They employed an aperture in the side of an enclosure at uniform temperature as the source of radiation, and compared the intensities at different temperatures by means of a bolometer. The fourth power law was well satisfied throughout the whole range of their experiments from −190° C. to 2300° C. According to this law, the rate of loss of heat by radiation R from a body of emissive power E and surface S at a temperature θ in an enclosure at θ_0 is given by the formula

$$R = \sigma ES\,(\theta^4 - \theta_0{}^4),$$

where σ is the radiation constant. The absolute value of σ was determined by F. Kurlbaum using an electric compensation method (*Wied. Ann.*, 1898, 65, p. 746), in which the radiation received by a bolometer from a black body at a known temperature was measured by finding the electric current required to produce the same rise of temperature in the bolometer. K. Ångstrom employed a similar method for solar radiation. Kurlbaum gives the value $\sigma = 5.32 \times 10^{-5}$ ergs per sq. cm. per sec. C. Christiansen (*Wied. Ann.*, 1883, 19, p. 267) had previously found a value about 5% smaller, by observing the rate of cooling of a copper plate of known thermal capacity, which is probably a less accurate method.

42. *Theoretical Proof of the Fourth Power Law.*—The proof given by Boltzmann may be somewhat simplified if we observe that full radiation in an enclosure at constant temperature behaves exactly like a saturated vapour, and must therefore obey Carnot’s or Clapeyron’s equation given in section 17. The energy of radiation per unit volume, and the radiation-pressure at any temperature, are functions of the temperature only, like the pressure of a saturated vapour. If the volume of the enclosure is increased by any finite amount, the temperature remaining the same, radiation is given off from the walls so as to fill the space to the same pressure as before. The heat absorbed when the volume is increased corresponds with the latent heat of vaporization. In the case of radiation, as in the case of a vapour, the latent heat consists partly of internal energy of formation and partly of external work of expansion at constant pressure. Since in the case of full or undirected radiation the pressure is one-third of the energy per unit volume, the external work for any expansion is one-third of the internal energy added. The latent heat absorbed is, therefore, four times the external work of expansion. Since the external work is the product of the pressure P and the increase of volume V, the latent heat per unit increase of volume is four times the pressure. But by Carnot’s equation the latent heat of a saturated vapour per unit increase of volume is equal to the rate of increase of saturation-pressure per degree divided by Carnot’s function or multiplied by the absolute temperature. Expressed in symbols we have,

$$\theta\ (dP/d\theta) = L/V = 4P,$$

where $(dP/d\theta)$ represents the rate of increase of pressure. This equation shows that the percentage rate of increase of pressure is four times the percentage rate of increase of temperature, or that if the temperature is increased by 1%, the pressure is increased by 4%. This is equivalent to the statement that the pressure varies as the fourth power of the temperature, a result which is mathematically deduced by integrating the equation.

43. *Wien’s Displacement Law.*—Assuming that the fourth power law gives the quantity of full radiation at any temperature, it remains to determine how the quality of the radiation varies with the temperature, since as we have seen both quantity and quality are determinate. This question may be regarded as consisting of two parts. (1) How is the wave-length or frequency of any given kind of radiation changed when its temperature is altered? (2) What is the form of the curve expressing the distribution of energy between the various wave-lengths in the spectrum of full radiation, or what is the distribution of heat in the spectrum? The researches of Tyndall, Draper, Langley and other investigators had shown that while the energy of radiation of each frequency increased with rise of temperature, the maximum of intensity was shifted or displaced along the spectrum in the direction of shorter wave-lengths or higher frequencies. W. Wien (*Ann. Phys.*, 1898, 58, p. 662), applying Doppler’s principle to the adiabatic compression of radiation in a perfectly reflecting enclosure, deduced that the wave-length of each constituent of the radiation should be shortened in proportion to the rise of temperature produced by the compression, in such a 156
manner that the product $\lambda\theta$ of wave-length and the absolute temperature should remain constant. According to this relation, which is known as Wien’s Displacement Law, the frequency corresponding to the maximum ordinate of the energy curve of the normal spectrum of full radiation should vary directly (or the wave-length inversely) as the absolute temperature, a result previously obtained by H. F. Weber (1888). Paschen, and Lummer and Pringsheim verified this relation by observing with a bolometer the intensity at different points in the spectrum produced by a fluorite prism. The intensities were corrected and reduced to a wave-length scale with the aid of Paschen’s results on the dispersion formula of fluorite (*Wied. Ann.*, 1894, 53, p. 301). The curves in fig. 7 illustrate results obtained by Lummer and Pringsheim (*Ber. deut. phys. Ges.*, 1899, 1, p. 34) at three different temperatures, namely 1377°, 1087° and 836° absolute, plotted on a wave-length base with a scale of microns (μ) or millionths of a metre. The wave-lengths O*a*, O*b*, O*c*, corresponding to the maximum ordinates of each curve, vary inversely as the absolute temperatures given. The constant value of the product $\lambda\theta$ at the maximum point is found to be 2920. Thus for a temperature of 1000° Abs. the maximum is at wave-length 2.92 μ; at 2000° the maximum is at 1.46 μ.

44. *Form of the Curve representing the Distribution of Energy in the Spectrum.*—Assuming Wien’s displacement law, it follows that the form of the curve representing the distribution of energy in the spectrum of full radiation should be the same for different temperatures with the maximum displaced in proportion to the absolute temperature, and with the total area increased in proportion to the fourth power of the absolute temperature. Observations taken with a bolometer along the length of a normal or wave-length spectrum, would give the form of the curve plotted on a wave-length base. The height of the ordinate at each point would represent the energy included between given limits of wave-length,

depending on the width of the bolometer strip and the slit. Supposing that the bolometer strip had a width corresponding to .01 μ, and were placed at 1.0 μ in the spectrum of radiation at 2000° Abs., it would receive the energy corresponding to wave-lengths between 1.00 and 1.01 μ. At a temperature of 1000° Abs. the corresponding part of the energy, by Wien's displacement law, would lie between the limits 2.00 and 2.02 μ, and the total energy between these limits would be 16 times smaller. But the bolometer strip placed at 2.0 μ would now receive only half of the energy, or the energy in a band .01 μ wide, and the deflection would be 32 times less. Corresponding ordinates of the curves at different temperatures will therefore vary as the fifth power of the temperature, when the curves are plotted on a wave-length base. The maximum ordinates in the curves already given are found to vary as the fifth powers of the corresponding temperatures. The equation representing the distribution of energy on a wave-length base must be of the form

$$E = C\lambda^{-5}F(\lambda\theta) = C\theta^{5}(\lambda\theta)^{-5}F(\lambda\theta)$$

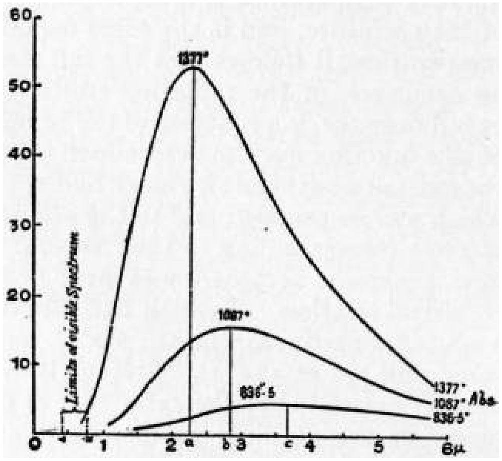


FIG. 7.—Distribution of energy in the spectrum of a black body.

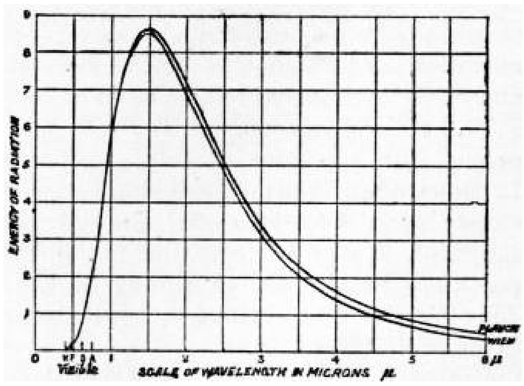


FIG. 8.—Distribution of energy in the spectrum of full radiation at 2000° Abs. according to formulae of Planck & Wien.

where F (λθ) represents some function of the product of the wave-length and temperature, which remains constant for corresponding wave-lengths when θ is changed. If the curves were plotted on a frequency base, owing to the change of scale, the maximum ordinates would vary as the cube of the temperature instead of the fifth power, but the form of the function F would remain unaltered. Reasoning on the analogy of the distribution of velocities among the particles of a gas on the kinetic theory, which is a very similar problem, Wien was led to assume that the function F should be of the form $e^{-c/\lambda\theta}$, where *e* is the base of Napierian logarithms, and *c* is a constant having the value 14,600 if the wave-length is measured in microns μ. This expression was found by Paschen to give a very good approximation to the form of the curve obtained experimentally for those portions of the visible and infra-red spectrum where observations could be most accurately made. The formula was tested in two ways: (1) by plotting the curves of distribution of energy in the spectrum for constant temperatures as illustrated in fig. 7; (2) by plotting the energy corresponding to a given wave-length as a function of the temperature. Both methods gave very good agreement with Wien's formula for values of the product λθ not much exceeding 3000. A method of isolating rays of great wave-length by successive reflection was devised by H. Rubens and E. F. Nichols (*Wied. Ann.*, 1897, 60, p. 418). They found that quartz and fluorite possessed the property of selective reflection for rays of wave-length 8.8μ and 24μ to 32μ respectively, so that after four to six reflections these rays could be isolated from a source at any temperature in a state of considerable purity. The residual impurity at any stage could be estimated by interposing a thin plate of quartz or fluorite which completely reflected or absorbed the residual rays, but allowed the impurity to pass. H. Beckmann, under the direction of Rubens, investigated the variation with temperature of the residual rays reflected from fluorite employing sources from −80° to 600° C., and found the results could not be represented by Wien's formula unless the constant c were taken as 26,000 in place of 14,600. In their first series of observations extending to 6μ O. R. Lummer and E. Pringsheim (*Deut. phys. Ges.*, 1899, 1, p. 34) found systematic deviations indicating an increase in the value of the constant *c* for long waves and high temperatures. In a theoretical discussion of the subject, Lord Rayleigh (*Phil. Mag.*, 1900, 49, p. 539) pointed out that Wien's law would lead to a limiting value $C\lambda^{-5}$, of the radiation corresponding to any particular wave-length when the temperature increased to infinity, whereas according to his view the radiation of great wave-length should ultimately increase in direct proportion to the temperature. Lummer and Pringsheim (*Deut.

phys. Ges., 1900, 2, p. 163) extended the range of their observations to 18 μ by employing a prism of sylvine in place of fluorite. They found deviations from Wien's formula increasing to nearly 50% at 18μ, where, however, the observations were very difficult on account of the smallness of the energy to be measured. Rubens and F. Kurlbaum (*Ann. Phys.*, 1901, 4, p. 649) extended the residual reflection method to a temperature range from −190° to 1500° C., and employed the rays reflected from quartz 8.8μ, and rocksalt 51μ, in addition to those from fluorite. It appeared from these researches that the rays of great wave-length from a source at a high temperature tended to vary in the limit directly as the absolute temperature of the source, as suggested by Lord Rayleigh, and could not be represented by Wien's formula with any value of the constant c. The simplest type of formula satisfying the required conditions is that proposed by Max Planck (*Ann. Phys.*, 1901, 4, p. 553) namely,

$$E = C\lambda^{-5} (e^{c/\lambda\theta} - 1)^{-1},$$

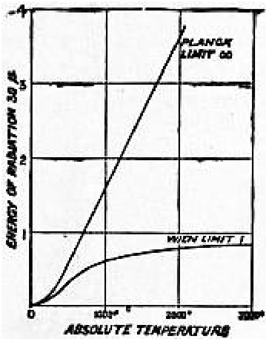


Fig. 9.—Variation of energy of radiation corresponding to wave-length 30μ, with temperature of source.

which agrees with Wien's formula when θ is small, where Wien's formula is known to be satisfactory, but approaches the limiting 157
form $E = C\lambda^{-4}\theta/c$, when θ is large, thus satisfying the condition proposed by Lord Rayleigh. The theoretical interpretation of this formula remains to some extent a matter of future investigation, but it appears to satisfy experiment within the limits of observational error. In order to compare Planck's formula graphically with Wien's, the distribution curves corresponding to both formulae are plotted in fig. 8 for a temperature of 2000° abs., taking the value of the constant c = 14,600 with a scale of wave-length in microns μ. The curves in fig. 9 illustrate the difference between the two formulae for the variation of the intensity of radiation corresponding to a fixed wave-length 30μ. Assuming Wien's displacement law, the curves may be applied to find the energy for any other wave-length or temperature, by simply altering the wave-length scale in inverse ratio to the temperature, or vice versa. Thus to find the distribution curve for 1000° abs., it is only necessary to multiply all the numbers in the wave-length scale of fig. 8 by 2; or to find the variation curve for wave-length 60μ, the numbers on the temperature scale of fig. 9 should be divided by 2. The ordinate scales must be increased in proportion to the fifth power of the temperature, or inversely as the fifth power of the wave-length respectively in figs. 8 and 9 if comparative results are required for different temperatures or wave-lengths. The results hitherto obtained for cases other than full radiation are not sufficiently simple and definite to admit of profitable discussion in the present article.

Bibliography.—It would not be possible, within the limits of an article like the present, to give tables of the specific thermal properties of different substances so far as they have been ascertained by experiment. To be of any use, such tables require to be extremely detailed, with very full references and explanations with regard to the value of the experimental evidence, and the limits within which the results may be relied on. The quantity of material available is so enormous and its value so varied, that the most elaborate tables still require reference to the original authorities. Much information will be found collected in Landolt and Bornstein's *Physical and Chemical Tables* (Berlin, 1905). Shorter tables, such as Everett's *Units and Physical Constants*, are useful as illustrations of a system, but are not sufficiently complete for use in scientific investigations. Some of the larger works of reference, such as A. A. Winkelmann's *Handbuch der Physik*, contain fairly complete tables of specific properties, but these tables occupy so much space, and are so misleading if incomplete, that they are generally omitted in theoretical textbooks.

Among older textbooks on heat, Tyndall's *Heat* may be recommended for its vivid popular interest, and Balfour Stewart's *Heat* for early theories of radiation. Maxwell's *Theory of Heat* and Tait's *Heat* give a broad and philosophical survey of the subject. Among modern textbooks, Preston's *Theory of Heat* and Poynting and Thomson's *Heat* are the best known, and have been brought well up to date. Sections on heat are included in all the general textbooks of Physics, such as those of Deschanel (translated by Everett), Ganot (translated by Atkinson), Daniell, Watson, &c. Of the original investigations on the subject, the most important have already been cited. Others will be found in the collected papers of Joule, Kelvin and Maxwell. Treatises on special branches of the subject, such as Fourier's *Conduction of Heat*, are referred to in the separate articles in this encyclopaedia dealing with recent progress, of which the following is a list: Calorimetry, Condensation of Gases, Conduction of Heat, Diffusion, Energetics, Fusion, Liquid Gases, Radiation, Radiometer, Solution, Thermodynamics, Thermoelectricity, Thermometry, Vaporization. For the practical aspects of heating see Heating.

(H. L. C.)

1 *Units of Work, Energy and Power.*—In English-speaking countries work is generally measured in *foot-pounds*. Elsewhere it is generally measured in *kilogrammetres*, or in terms of the work done in raising 1 kilogramme weight through the height of 1 metre. In the middle of the 19th century the terms "force" and "motive power" were commonly employed in the sense of "power of doing work." The term "energy" is now employed in this sense. A quantity of energy is measured by the work it is capable of performing. A body may possess energy in virtue of its state (gas or steam under pressure), or in virtue of its position (a raised weight), or in various other ways, when at rest. In these cases it is said to possess *potential energy*. It may also possess energy in virtue of its motion or rotation (as a fly-wheel or a cannon-ball). In this case it is said to possess *kinetic energy*, or energy of motion. In many cases the energy (as in the case of a vibrating body, like a pendulum) is partly kinetic and partly potential, and changes continually from one to the other throughout the motion. For instance, the energy of a pendulum is wholly potential when it is momentarily at rest at the top of its swing, but is wholly kinetic when the pendulum is moving with its maximum velocity at the lowest point of its swing. The whole energy at any moment is the sum of the potential and kinetic energy, and this sum remains constant so long as the amplitude of the vibration remains the same. The potential energy of a weight W ℔ raised to a height h ft. above the earth, is Wh foot-pounds. If allowed to fall freely, without doing work, its kinetic energy on reaching the earth would be Wh foot-pounds, and its velocity of motion would be such that if projected upwards with the same velocity it would rise to the height h from which it fell. We have here a simple and familiar case of the conversion of one kind of energy into a different kind. But the two kinds of energy are mechanically equivalent, and they can both be measured in terms of the same units. The units already considered, namely foot-pounds or kilogrammetres, are gravitational units, depending on the force of gravity. This is the most obvious and natural method of measuring the potential energy of a raised weight, but it has the disadvantage of varying with the force of gravity at different places. The natural measure of the kinetic energy of a moving body is the product of its mass by half the square of its velocity, which gives a measure in kinetic or absolute units independent of the force of gravity. Kinetic and gravitational units are merely different ways of measuring the same thing. Just as foot-pounds may be reduced to kilogrammetres by dividing by the number of foot-pounds in one kilogrammetre, so kinetic may be reduced to gravitational units by dividing by the kinetic measure of the intensity of gravity, namely, the work in kinetic units done by the weight of unit mass acting through unit distance. For scientific purposes, it is necessary to take account of the variation of gravity. The scientific unit of energy is called the *erg*. The erg is the kinetic energy of a mass of 2 gm. moving with a velocity of 1 cm. per sec. The work in ergs done by a force acting through a distance of 1 cm. is the absolute measure of the force. A force equal to the weight of 1 gm. (in England) acting through a distance of 1 cm. does 981 ergs of work. A force equal to the weight of 1000 gm. (1 kilogramme) acting through a distance of 1 metre (100 cm.) does 98.1 million ergs of work. As the erg is a very small unit, for many purposes, a unit equal to 10 million ergs, called a *joule*, is employed. In England, where the weight of 1 gm. is 981 ergs per cm., a foot-pound is equal to 1.356 joules, and a kilogrammetre is equal to 9.81 joules.

The term *power* is now generally restricted to mean "rate of working." Watt estimated that an average horse was capable of raising 550 ℔ 1 ft. in each second, or doing work at the rate of 550 foot-pounds per second, or 33,000 foot-pounds per minute. This conventional horse-power is the unit commonly employed for estimating the power of engines. The *horse-power-hour*, or the work done by one horse-power in one hour, is nearly 2 million foot-pounds. For electrical and scientific purposes the unit of power employed is called the *watt*. The watt is the work per second done by an electromotive force of 1 volt in driving a current of 1 ampere, and is equal to 10 million ergs or 1 joule per second. One horse-power is 746 watts or nearly ¾ of a kilowatt. The *kilowatt-hour*, which is the unit by which electrical energy is sold, is 3.6 million joules or 2.65 million foot-pounds, or 366,000 kilogrammetres, and is capable of raising nearly 19 ℔ of water from the freezing to the boiling point.

2 In an essay on "Heat, Light, and Combinations of Light," republished in Sir H. Davy's *Collected Works*, ii. (London, 1836).

3 For instance a mass of compressed air, if allowed to expand in a cylinder at the ordinary temperature, will do work, and will at the same time absorb a quantity of heat which, as we now know, is the thermal equivalent of the work done. But this work cannot be said to have been produced solely from the heat absorbed in the process, because the air at the end of the process is in a changed condition, and could not be restored to its original state at the same temperature without having work done upon it precisely equal to that obtained by its expansion. The process could not be repeated indefinitely without a continual supply of compressed air. The source of the work in this case is work previously done in compressing the air, and no part of the work is really generated at the expense of heat alone, unless the compression is effected at a lower temperature than the expansion.

4 Clausius (*Pogg. Ann.* 79, p. 369) and others have misinterpreted this assumption, and have taken it to mean that the quantity of heat required to produce any given change of state is independent of the manner in which the change is effected, which Carnot does not here assume.

5 Carnot's description of his cycle and statement of his principle have been given as nearly as possible in his own words, because some injustice has been done him by erroneous descriptions

and statements.

6 It was for this reason that Professor W. Thomson (Lord Kelvin) stated (*Phil. Mag.*, 1852, 4) that "Carnot's original demonstration utterly fails," and that he introduced the "corrections" attributed to James Thomson and Clerk Maxwell respectively. In reality Carnot's original demonstration requires no correction.

7 In reference to this objection, Tyndall remarks (*Phil. Mag.*, 1862, p. 422; *Heat*, p. 385); "In the first place the plate of salt nearest the source of heat is never moistened, unless the experiments are of the roughest character. Its proximity to the source enables the heat to chase away every trace of humidity from its surface." He therefore took precautions to dry only the circumferential portions of the plate nearest the pile, assuming that the flux of heat through the central portions would suffice to keep them dry. This reasoning is not at all satisfactory, because rocksalt is very hygroscopic and becomes wet, even in unsaturated air, if the vapour pressure is greater than that of a saturated solution of salt at the temperature of the plate. Assuming that the vapour pressure of the saturated salt solution is only half that of pure water, it would require an elevation of temperature of 10° C. to dry the rocksalt plates in saturated air at 15° C. It is only fair to say that the laws of the vapour pressures of solutions were unknown in Tyndall's time, and that it was usual to assume that the plates would not become wetted until the dew-point was reached. The writer has repeated Tyndall's experiments with a facsimile of one of Tyndall's tubes in the possession of the Royal College of Science, fitted with plates of rocksalt cut from the same block as Tyndall's, and therefore of the same hygroscopic quality. Employing a reflecting galvanometer in conjunction with a differential bolometer, which is quicker in its action than Tyndall's pile, there appears to be hardly any difference between dry and moist air, provided that the latter is not more than half saturated. Using saturated air with a Leslie cube as source of heat, both rocksalt plates invariably become wet in a minute or two and the absorption rises to 10 or 20% according to the thickness of the film of deposited moisture. Employing the open tube method as described by Tyndall, without the rocksalt plates, the absorption is certainly less than 1% in 3 ft. of air saturated at 20° C., unless condensation is induced on the walls of the tube. It is possible that the walls of Tyndall's tube may have become covered with a very hygroscopic film from the powder of the calcium chloride which he was in the habit of introducing near one end. Such a film would be exceedingly difficult to remove, and would account for the excessive precautions which he found necessary in drying the air in order to obtain the same transmitting power as a vacuum. It is probable that Tyndall's experiments on aqueous vapour were effected by experimental errors of this character.

HEATH, BENJAMIN (1704-1766), English classical scholar and bibliophile, was born at Exeter on the 20th of April 1704. He was the son of a wealthy merchant, and was thus able to devote himself mainly to travel and book-collecting. He became town clerk of his native city in 1752, and held the office till his death on the 13th of September 1766. In 1763 he had published a pamphlet advocating the repeal of the cider tax in Devonshire, and his endeavours led to success three years later. As a classical scholar he made his reputation by his critical and metrical notes on the Greek tragedians, which procured him an honorary D.C.L. from Oxford (31st of March 1752). He also left MS. notes on Burmann's and Martyn's editions of Virgil, on Euripides, Catullus, Tibullus, and the greater part of Hesiod. In some of these he adopts the whimsical name Dexiades Ericius. His *Revisal of Shakespear's Text* (1765) was an answer to the "insolent dogmatism" of Bishop Warburton. *The Essay towards a Demonstrative Proof of the Divine Existence, Unity and Attributes* (1740) was intended to combat the opinions of Voltaire, Rousseau and Hume. Two of his sons (among a family of thirteen) were Benjamin, headmaster of Harrow (1771-1785), and George, headmaster of Eton (1796). His collection of rare classical works formed the nucleus of his son Benjamin's famous library (Bibliotheca Heathiana).

An account of the Heath family will be found in Sir W. R. Drake's *Heathiana* (1882).

HEATH, NICHOLAS (*c.* 1501-1578), archbishop of York and lord chancellor, was born in London about 1501 and graduated B.A. at Oxford in 1519. He then migrated to Christ's College, Cambridge, where he graduated B.A. in 1520, M.A. in 1522, and was elected fellow in 1524. After holding minor preferments he was appointed archdeacon of Stafford in 1534 and graduated D.D. in 1535. He then accompanied Edward Fox (*q.v.*), bishop of Hereford, on his mission to promote a theological and political understanding with the Lutheran princes of Germany. His selection for this duty implies a readiness on Heath's part to proceed some distance along the path of reform; but his dealings with the Lutherans did not confirm this tendency, and Heath's subsequent career was closely associated with the cause of reaction. In 1539, the year of the Six Articles, he was made bishop of Rochester, and in 1543 he succeeded Latimer at Worcester. His Catholicism, however, was of a less rigid type than Gardiner's and Bonner's; he felt something of the force of the national antipathy to foreign influence, whether ecclesiastical or secular, and was always impressed by the necessity of national unity, so far as was possible, in matters of faith. Apparently he made no difficulty about carrying out the earlier reforms of Edward VI., and he accepted the first book of common prayer after it had been modified by the House of Lords in a Catholic direction.

His definite breach with the Reformation occurred on the grounds, on which four centuries later Leo XIII. denied the Catholicity of the reformed English Church, namely, on the question of the Ordinal drawn up in February 1550. Heath refused to accept it, was imprisoned, and in 1551 deprived of his bishopric. On Mary's accession he was released and restored, and made president of the council of the Marches and Wales. In 1555 he was promoted to the archbishopric of York, which he did much to enrich after the Protestant spoliation; he built York House in the Strand. After Gardiner's death he was appointed lord chancellor, probably on Pole's recommendation; for Heath, like Pole himself, disliked the Spanish party in England. Unlike Pole, however, he seems to have been averse from the excessive persecution of Mary's reign, and no Protestants were burnt in his diocese. He exercised, however, little influence on Mary's secular or ecclesiastical policy.

On Mary's death Heath as chancellor at once proclaimed Elizabeth. Like Sir Thomas More he held that it was entirely within the competence of the national state, represented by parliament, to determine questions of the succession to the throne; and although Elizabeth did not renew his commission as lord chancellor, he continued to sit in the privy council for two months until the government had determined to complete the breach with the Roman Catholic Church; and as late as April 1559 he assisted the government by helping to arrange the Westminster Conference, and reproving his more truculent co-religionists. He refused to crown Elizabeth because she would not have the coronation service accompanied with the elevation of the Host; and ecclesiastical ceremonies and doctrine could not, in Heath's view, be altered or abrogated by any mere national authority. Hence he steadily resisted Elizabeth's acts of supremacy and uniformity, although he had acquiesced in the acts of 1534 and 1549. Like others of Henry's bishops, he had been convinced by the events of Edward VI.'s reign that Sir Thomas More was right and Henry VIII. was wrong in their 158
attitude towards the claims of the papacy and the Catholic Church. He was therefore necessarily deprived of his archbishopric in 1559, but he remained loyal to Elizabeth; and after a temporary confinement he was suffered to pass the remaining nineteen years of his life in peace and quiet, never attending public worship and sometimes hearing mass in private. The queen visited him more than once at his house at Chobham, Surrey; he died and was buried there at the end of 1578.

Authorities.—Letters and Papers of Henry VIII.; Acts of the Privy Council; Cal. State Papers, Domestic, Addenda, Spanish and Venetian; Kemp's Loseley MSS.; Froude's *History*; Burnet, Collier, Dixon and Frere's *Church Histories*; Strype's *Works* (General Index); Parker Soc. Publications (Gough's Index); Birt's *Elizabethan Settlement*.

(A. F. P.)

HEATH, WILLIAM (1737-1814), American soldier, was born in Roxbury, Massachusetts, on the 2nd of March 1737 (old style). He was brought up as a farmer and had a passion for military exercises. In 1765 he entered the Ancient and Honourable Artillery Company of Boston, of which he became commander in 1770. In the same year he wrote to the *Boston Gazette* letters signed "A Military Countryman," urging the necessity of military training. He was a member of the Massachusetts General Court from 1770 to 1774, of the provincial committee of safety, and in 1774-1775 of the provincial congress. He was commissioned a provincial brig.-general in December 1774, directed the pursuit of the British from Concord (April 19, 1775), was promoted to be provincial major-general on the 20th of June 1775, and two days later was commissioned fourth brig.-general in the Continental Army. He became major-general on the 9th of August 1776, and was in active service around New York until early the next year. In January 1777 he attempted to take Fort Independence, near Spuyten Duyvil, then garrisoned by about 2000 Hessians, but at the first sally of the garrison his troops became panic-stricken and a few days later he withdrew. Washington reprimanded him and never again entrusted to him any important operation in the field. Throughout the war, however, Heath was very efficient in muster service and in the barracks. From March 1777 to October 1778 he was in command of the Eastern Department with headquarters at Boston, and had charge (Nov. 1777-Oct. 1778) of the prisoners of war from Burgoyne's army held at Cambridge, Massachusetts. In May 1779 he was appointed a commissioner of the Board of War. He was placed in command of the troops on the E. side of the Hudson in June 1779, and of other troops and posts on the Hudson in November of the same year. In July 1780 he met the French allies under Rochambeau on their arrival in Rhode Island; in October of the same year he succeeded Arnold in command of West Point and its dependencies; and in August 1781, when Washington went south to meet Cornwallis, Heath was left in command of the Army of the Hudson to watch Clinton. After the war he retired to his farm at Roxbury, was a member of the state House of Representatives in 1788, of the Massachusetts convention which ratified the Federal Constitution in the same year, and of the governor's council in 1789-1790, was a state senator (1791-1793), and in 1806 was elected lieutenant-governor of Massachusetts but declined to serve. He died at Roxbury on the 24th of January 1814, the last of the major-generals of the War of American Independence.

See *Memoirs of Major-General Heath, containing Anecdotes, Details of Skirmishes, Battles and other Military Events during the American War, written by Himself* (Boston, 1798; frequently reprinted, perhaps the best edition being that published in New York in 1901 by William Abbatt), particularly valuable for the descriptions of Lexington and Bunker Hill, of the fighting around New York, of the controversies with Burgoyne and his officers during their stay in Boston, and of relations with Rochambeau; and his correspondence, *The Heath Papers*, vols. iv.-v., seventh series, *Massachusetts Historical Society Collections* (Boston, 1904-1905).

HEATH, the English form of a name given in most Teutonic dialects to the common ling or heather (*Calluna vulgaris*), but now applied to all species of *Erica*, an extensive genus of monopetalous plants, belonging to the order Ericaceae. The heaths are evergreen shrubs, with small narrow leaves, in whorls usually set rather thickly on the shoots; the persistent flowers have 4 sepals, and a 4-cleft campanulate or tubular corolla, in many species more or less ventricose or inflated; the dry capsule is 4-celled, and opens, in the true Ericae, in 4 segments, to the middle of which the partitions adhere, though in the ling the valves separate at the dissepiments. The plants are mostly of low growth, but several African kinds reach the size of large bushes, and a common South European species, *E. arborea*, occasionally attains almost the aspect and dimensions of a tree.

One of the best known and most interesting of the family is the common heath, heather or ling, *Calluna vulgaris* (fig. 1), placed by most botanists in a separate genus on account of the peculiar dehiscence of the fruit, and from the coloured calyx, which extends beyond the corolla, having a whorl of sepal-like bracts beneath. This shrub derives some economic importance from its forming the chief vegetation on many of those extensive wastes that occupy so large a portion of the more sterile lands of northern and western Europe, the usually desolate appearance of which is enlivened in the latter part of summer by its abundant pink blossoms. When growing erect to the height of 3 ft. or more, as it often does in sheltered places, its purple stems, close-leaved green shoots and feathery spikes of bell-shaped flowers render it one of the handsomest of the heaths; but on the bleaker elevations and more arid slopes it frequently rises only a few inches above the ground. In all moorland countries the ling is applied to many rural purposes; the larger stems are made into brooms, the shorter tied up into bundles that serve as brushes, while the long trailing shoots are woven into baskets. Pared up with the peat about its roots it forms a good fuel, often the only one obtainable on the drier moors. The shielings of the Scottish Highlanders were formerly constructed of heath stems, cemented together with peat-mud, worked into a kind of mortar with dry grass or straw; hovels and sheds for temporary purposes are still sometimes built in a similar way, and roofed in with ling. Laid on the ground, with the flowers above, it forms a soft springy bed, the luxurious couch of the ancient Gael, still gladly resorted to at times by the hill shepherd or hardy deer-stalker. The young shoots were in former days employed as a substitute for hops in brewing, while their astringency rendered them valuable as a tanning material in Ireland and the Western Isles. They are said also to have been used by the Highlanders for dyeing woollen yarn yellow, and other colours are asserted to have been obtained from them, but some writers appear to confuse the dyer's-weed, *Genista tinctoria*, with the heather. The young juicy shoots and the seeds, which remain long in the capsules, furnish the red grouse of Scotland with the larger portion of its sustenance; the ripe seeds are eaten by many birds. The tops of the ling afford a considerable part of the winter fodder of the hill flocks, and are popularly supposed to communicate the fine flavour to Welsh and Highland mutton, but sheep seldom crop heather while the mountain grasses and rushes are sweet and accessible. Ling has been suggested as a material for paper, but the stems are hardly sufficiently fibrous for that purpose. The purple or fine-leaved heath, *E. cinerea* (fig. 2), one of the most beautiful of the genus, abounds on the lower moors and commons of Great Britain and western Europe, in such situations being sometimes more prevalent than the ling. The flowers of both these species yield much honey, furnishing a plentiful supply to the bees in moorland districts; from this heath honey the Picts probably brewed the mead said by Boetius to have been made from the flowers themselves.

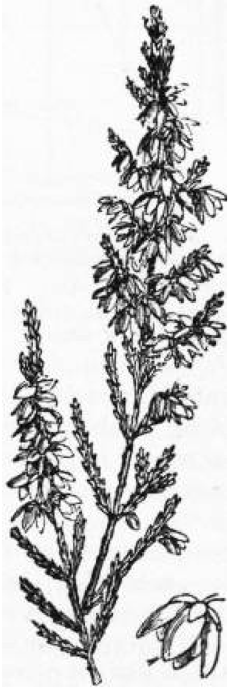


Fig. 1.

Calluna vulgaris.

The genus contains about 420 known species, by far the greater part being indigenous to the western districts of South Africa, but it is also a characteristic genus of the Mediterranean region, while several species extend into northern Europe. No species is native in America, but ling occurs as an introduced plant on the Atlantic side from Newfoundland to New Jersey. Five species occur in Britain: *E. cinerea*, *E. tetralix* (cross-leaved heath), both abundant on heaths and commons, *E. vagans*, Cornish heath, found only in West Cornwall, *E. ciliaris* in the west of England and Ireland and *E. mediterranea* in Ireland. The three last are south-west European species which reach the northern limit of their distribution in the west of England and Ireland. *E. scoparia* is a common heath in the centre of France and elsewhere in the Mediterranean region, forming a spreading bush several feet high. It is known as *bruyère*, and its stout underground rootstocks yield the briar-wood used for pipes.

Fig. 2.

Erica cinerea.

The Cape heaths have long been favourite objects of horticulture. In the warmer parts of Britain several will bear exposure to the cold of ordinary winters in a sheltered border, but most need the protection of the conservatory. They are sometimes raised from seed, but are chiefly multiplied by cuttings "struck" in sand, and afterwards transferred to pots filled with a mixture of black peat and sand; the peat should be dry and free from sourness. Much attention is requisite in watering heaths, as they seldom recover if once allowed to droop, while they will not bear much water about their roots: the heath-house should be light and well ventilated, the plants requiring sun, and soon perishing in a close or permanently damp atmosphere; in England little or no heat is needed in ordinary seasons. The European heaths succeed well in English gardens, only requiring a peaty soil and sunny situation to thrive as well as in their native localities: *E. carnea*, *mediterranea*, *ciliaris*, *vagans*, and the pretty cross-leaved heath of boggy moors, *E. Tetralix*, are among those most worthy of cultivation. The beautiful large-flowered St Dabeoc's heath, belonging to the closely allied genus *Dabeocia*, is likewise often seen in gardens. It is found in boggy heaths in Connemara and Mayo, and is also native in West France, Spain and the Azores.

A beautiful work on heaths is that by H. C. Andrews, containing coloured engravings of nearly 300 species and varieties, with descriptions in English and Latin (4 vols., 1802-1805).

HEATHCOAT, JOHN (1783-1861), English inventor, was born at Duffield near Derby on the 7th of August 1783. During his apprenticeship to a framesmith near Loughborough, he made an improvement in the construction of the warp-loom, so as to produce mitts of a lace-like appearance by means of it. He began business on his own account at Nottingham, but finding himself subjected to the intrusion of competing inventors he removed to Hathern. There in 1808 he constructed a machine capable of producing an exact imitation of real pillow-lace. This was by far the most expensive and complex textile apparatus till then existing; and in describing the process of his invention Heathcoat said in 1836, “The single difficulty of getting the diagonal threads to twist in the allotted space was so great that, if now to be done, I should probably not attempt its accomplishment.” Some time before perfecting his invention, which he patented in 1809, he removed to Loughborough, where he entered into partnership with Charles Lacy, a Nottingham manufacturer; but in 1816 their factory was attacked by the Luddites and their 55 lace frames destroyed. The damages were assessed in the King’s Bench at £10,000; but as Heathcoat declined to expend the money in the county of Leicester he never received any part of it. Undaunted by his loss, he began at once to construct new and greatly improved machines in an unoccupied factory at Tiverton, Devon, propelling them by water-power and afterwards by steam. His claim to the invention of the twisting and traversing lace machine was disputed, and a patent was taken out by a clever workman for a similar machine, which was decided at a trial in 1816 to be an infringement of Heathcoat’s patent. He followed his great invention by others of much ability, as, for instance, contrivances for ornamenting net while in course of manufacture and for making ribbons and platted and twisted net upon his machines, improved yarn spinning-frames, and methods for winding raw silk from cocoons. He also patented an improved process for extracting and purifying salt. An offer of £10,000 was made to him in 1833 for the use of his processes in dressing and finishing silk nets, but he allowed the highly profitable secret to remain undivulged. In 1832 he patented a steam plough. Heathcoat was elected member of parliament for Tiverton in 1832. Though he seldom spoke in the House he was constantly engaged on committees, where his thorough knowledge of business and sound judgment were highly valued. He retained his seat until 1859, and after two years of declining health he died on the 18th of January 1861 at Bolham House, near Tiverton.

HEATHCOTE, SIR GILBERT (*c.* 1651-1733), lord mayor of London, belonged to an old Derbyshire family and was educated at Christ’s College, Cambridge, afterwards becoming a merchant in London. His trading ventures were very successful; he was one of the promoters of the new East India company and he emerged victorious from a contest between himself and the old East India company in 1693; he was also one of the founders and first directors of the bank of England. In 1702 he became an alderman of the city of London and was knighted; he served as lord mayor in 1711, being the last lord mayor to ride on horseback in his procession. In 1700 Heathcote was sent to parliament as member for the city of London, but he was soon expelled for his share in the circulation of some exchequer bills; however, he was again elected for the city later in the same year, and he retained his seat until 1710. In 1714 he was member for Helston, in 1722 for New Lymington, and in 1727 for St Germans. He was a consistent Whig, and was made a baronet eight days before his death. Although extremely rich, Heathcote’s meanness is referred to by Pope; and it was this trait that accounts largely for his unpopularity with the lower classes. He died in London on the 25th of January 1733 and was buried at Normanton, Rutland, a residence which he had purchased from the Mackworths.

A descendant, Sir Gilbert John Heathcote, Bart. (1795-1867), was created Baron Aveland in 1856; and his son Gilbert Henry, who in 1888 inherited from his mother the barony of Willoughby de Eresby, became 1st earl of Ancaster in 1892.

HEATHEN, a term originally applied to all persons or races who did not hold the Jewish or Christian belief, thus including Mahommedans. It is now more usually given to polytheistic races, thus excluding Mahommedans. The derivation of the word has been much debated. It is common to all Germanic languages; cf. German *Heide*, Dutch *heiden*. It is usually ascribed to a Gothic *haiþi*, heath. In Ulfilas' Gothic version of the Bible, the earliest extant literary monument of the Germanic languages, the Syrophoenician woman (Mark vii. 26) is called *haiþno*, where the Vulgate has *gentilis*. "Heathen," *i.e.* the people of the heath or open country, would thus be a translation of the Latin *paganus*, pagan, *i.e.* the people of the *pagus* or village, applied to the dwellers in the country where the worship of the old gods still lingered, when the people of the towns were Christians (but see Pagan for a more tenable explanation of that term). On the other hand it has been suggested (Prof. S. Bugge, *Indo-German. Forschungen*, v. 178, quoted in the *New English Dictionary*) that Ulfilas may have adopted the word from the Armenian *hetanos*, *i.e.* Greek ἔθνη, tribes, races, the word used for the "Gentiles" in the New Testament. *Gentilis* in Latin, properly meaning "tribesman," came to be used of foreigners and non-Roman peoples, and was adopted in ecclesiastical usage for the non-Christian nations and in the Old Testament for non-Jewish races.

HEATHFIELD, GEORGE AUGUSTUS ELIOTT, Baron (1717-1790), British general, a younger son of Sir Gilbert Eliott, Bart., of Stobs, Roxburghshire, was born on the 25th of 160
December 1717, and educated abroad for the military profession. As a volunteer he fought with the Prussian army in 1735 and 1736, and then entered the Grenadier Guards. He went through the war of the Austrian Succession, and was wounded at Dettingen, rising to be lieutenant-colonel in 1754. In 1759 he became colonel of a new regiment of light horse (afterwards the 15th Hussars) and became well known for the efficiency which it displayed in the subsequent campaigns. He became lieutenant-general in 1765. In 1775 he was selected to be governor of Gibraltar (*q.v.*), and it is in connexion with his magnificent defence in the great siege of 1779 that his name is famous. His portrait by Sir Joshua Reynolds is in the National Gallery. In 1787 he was created Baron Heathfield of Gibraltar, but died on the 6th of July 1790. He had married in 1748 the heiress of the Drake family, to which Sir Francis Drake belonged. His son, the 2nd baron, died in 1813 and the peerage became extinct, but the estates went to the family of Eliott-Drake (baronetcy of 1821) through his sister.

HEATING. In temperate latitudes the climate is generally such as to necessitate in dwellings during a great portion of the year a temperature warmer than that out of doors. The object of the art of heating is to secure this required warmth with the greatest economy and efficiency. For reasons of health it may be assumed that no system of heating is advisable which does not provide for a constant renewal of the air in the locality warmed, and on this account there is a difficulty in treating as separate matters the subjects of heating and ventilation, which in practical schemes should be considered conjointly. (See Ventilation).

The object of all heating apparatus is the transference of heat from the fire to the various parts of the building it is intended to warm, and this transfer may be effected by radiation, by conduction or by convection. An open fire acts by radiation; it warms the air in a room by first warming the walls, floor, ceiling and articles in the room, and these in turn warm the air. Therefore in a room with an open fire the air is, as a rule, less heated than the walls. In many forms of fireplaces fresh air is brought in and passed around the back and sides of the stove before being admitted into the room. A closed stove acts mainly by convection; though when heated to a high temperature it gives out radiant heat. Windows have a chilling effect on a room, and in calculations extra allowance should be made for window areas.

There are a number of methods available for adoption in the heating of buildings, but it is a matter of considerable difficulty to suit the method of warming to the class of building to be warmed. Heating may be effected by one of the following systems, or installations may be so arranged as to combine the advantages of more than one method: open fires, closed stoves, hot-air apparatus, hot water circulating in pipes at low or at high pressure, or steam at high or low pressure.

Open fires.

The open grate still holds favour in England, though in America and on the continent of Europe it has been superseded by the closed stove. The old form of open fire is certainly wasteful of fuel, and the loss of heat up the chimney and by conduction into the brickwork backing of the stove is considerable. Great improvements, however, have been effected in the design of open fireplaces, and many ingenious contrivances of this nature are now in the market which combine efficiency of heating with economy of fuel. Unless suitable fresh air inlets are provided, this form of stove will cause the room to be draughty, the strong current of warm air up the flue drawing cold air in through the crevices in the doors and windows. The best form of open fireplace is the ventilating stove, in which fresh air is passed around the back and sides of the stove before being admitted through convenient openings into the room. This has immense advantages over the ordinary type of fireplace. The illustrations show two forms of ventilating fireplace, one (fig. 1) similar in appearance to the ordinary domestic grate, the other (fig. 2) with descending smoke flue suitable for hospitals and public rooms, where it might be fixed in the middle of the apartment. The fixing of stoves of this kind entails the laying of pipes or ducts from the open to convey fresh air to the back of the stove.

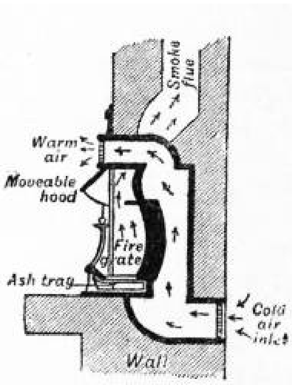


Fig. 1.

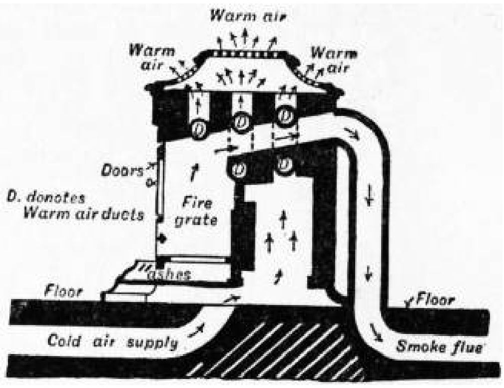


Fig. 2.

Closed stoves.

With closed stoves much less heat is wasted, and consequently less fuel is burned, than with open grates, but they often cause an unpleasant sensation of dryness in the air, and the products of combustion also escape to some extent, rendering this method of heating not only unpleasant but sometimes even dangerous. The method in Great Britain is almost entirely confined to places of public assembly, but in America and on the continent of Europe it is much used for domestic heating. If the flue pipe be carried up a considerable distance inside the apartment to be warmed before being turned into the external air, practically the whole of the heat generated will be utilized. Charcoal, coke or anthracite coal are the fuels generally used in slow combustion heating stoves.

Gas fires.

Gas fires, as a substitute for the open coal fire, have many points in their favour, for they are conducive to cleanliness, they need but little attention, and the heat is easily controlled. On the other hand, they may give off unhealthy fumes and produce unpleasant odours. They usually take the form of cast iron open stoves fitted with a number of Bunsen burners which heat perforated lumps of asbestos. The best form of stove is that with which perfect combustion is most nearly attained, and to which a pan of water is affixed to supply a desirable humidity to the air, the gas having the effect of drying the atmosphere. With another form of gas stove coke is used in place of the perforated asbestos; the fire is started with the gas, which, when the coke is well alight, may be dispensed with, and the fire kept up with coke in the usual way.

Electrical heating appliances have only recently passed the experimental stage; there is, however, undoubtedly a great future for electric heating, and the perfecting of the stove, together with the cheapening of the electric current, may be expected to

Electrical heating.

result in many of the other stoves and convectors being superseded. Hitherto the large bill for electric energy has debarred the general use of electrical heating, in spite of its numerous advantages.

Oil stoves.

Oils are powerful fuels, but the high price of refined petroleum, the oil generally preferred, precludes its widespread use for many purposes for which it is suitable. In small stoves for warming and for cooking, petroleum presents some advantages over other fuels, in that there is no chimney to sweep, and if well managed no unpleasant fumes, and the stoves are easily portable. On the other hand, these stoves need a considerable amount of attention in filling, trimming and cleaning, and there is some risk of explosion and damage by accidental leaking and smoking. Crude or unrefined petroleum needs a special air-spray pressure burner for its use, and this suffers from the disadvantage of being noisy. Gas and oil radiators would be more properly termed "convectors," since they warm mainly by converted currents. They are similar in appearance to a hot-water or steam radiator, and, indeed, some are designed to be filled with water and used as such. They should always be fitted with a pan of water to supply the necessary humidity to the warmed air, and a flue to carry off any disagreeable fumes.

Warm air.

Heating by warmed air, one of the oldest methods in use, has been much improved by 161
attention to the construction of the apparatus, and if properly installed will give as good effects as it is possible to obtain. The system is especially suitable for churches, assembly halls and large rooms. A stove of special design is placed in a chamber in the basement or cellar, and cold fresh air is passed through it, and led by means of flues to the various apartments for distribution by means of easily regulated inlet valves. To prevent the atmosphere from becoming unduly dry a pan of water is fitted to the stove; this serves to moisten the air before it passes into the distributing flues. If each distributing flue is connected by means of a mixing valve with a cold-air flue, the warmth of the incoming air can be regulated to a nicety (see VENTILATION).

Low pressure hot water.

There are many different systems of heating by hot water circulating in pipes. The oldest and best known is the "two pipe" system, others being the "one pipe" or "simple circuit," and the "drop" or "overhead." The high pressure system is of later invention, having been first put to practical use by A. M. Perkins in 1845. All these methods warm chiefly by means of convected heat, the amount of true radiation from the pipes being small. The manner in which the circulation of hot water takes place in the tubes is as follows. Fire heats the water in a boiler from the top of which a "flow" pipe communicates with the rooms to be warmed (fig. 3). As the water is heated it becomes lighter, rises to the top of the boiler, and passes along the flow pipe. It is followed by more and more hot water, and so travels along the flow pipe, which is rising all the time, to the farthest point of the circuit, by which time it has in all probability cooled considerably. From this point the "return" pipe drops, usually at the same rate as the flow pipe rises; and in due course the water reaches its starting point, the boiler, and is again heated and again circulated through the system. The connexion of the return pipe is made with the lower part of the boiler. Branches may be made from the main pipes by means of smaller pipes arranged in the same manner as the mains, the branch flow pipe being connected with the main flow pipe and returning into the main return. To obtain a larger heating surface than a pipe affords, radiators are connected with the pipes where desired, and the water passing through them warms the surrounding air.

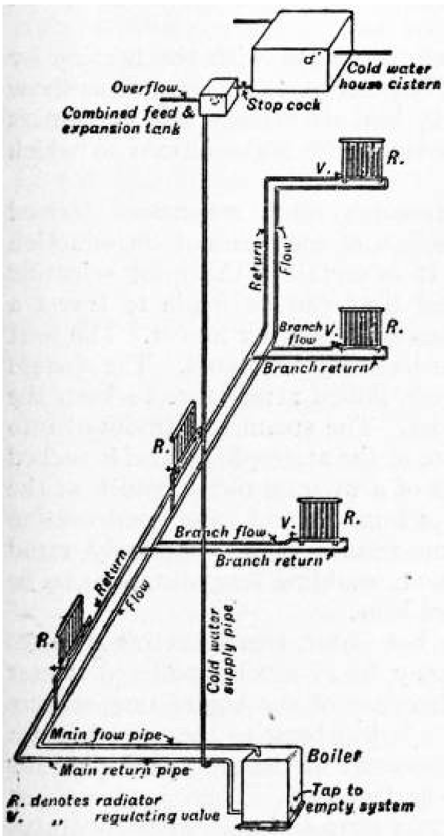


FIG. 3.

The "one pipe" system (fig. 4) acts on precisely the same principle, but in place of two pipes being placed in adjacent positions one large main makes a complete circuit of the area to be warmed, starting from and returning to the boiler, and from this main flow and return branches are taken and connected with radiators and other heating appliances.

In the “drop” or “overhead” system (fig. 5) a rising main is taken directly from the boiler to the topmost floor of the building, and from this branches are dropped to the lower floors, and connected by means of smaller branches to radiators or coils. The vertical branches descend to the basement and generally merge in a single return pipe which is connected to the lower part of the boiler.

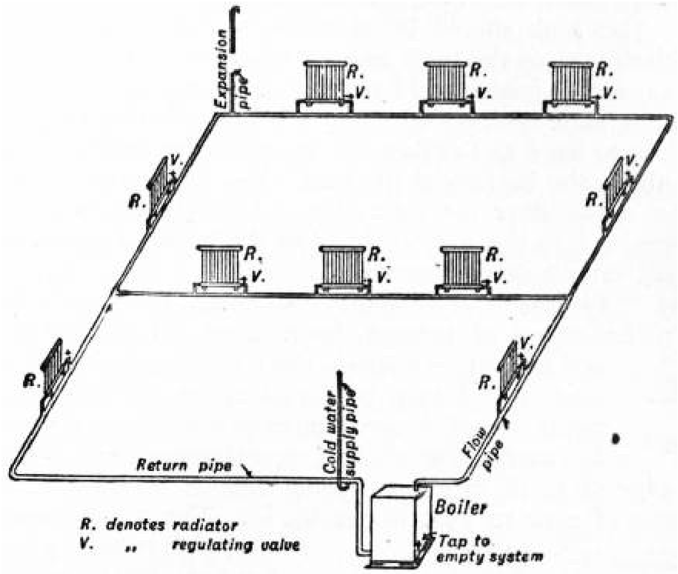


FIG. 4.

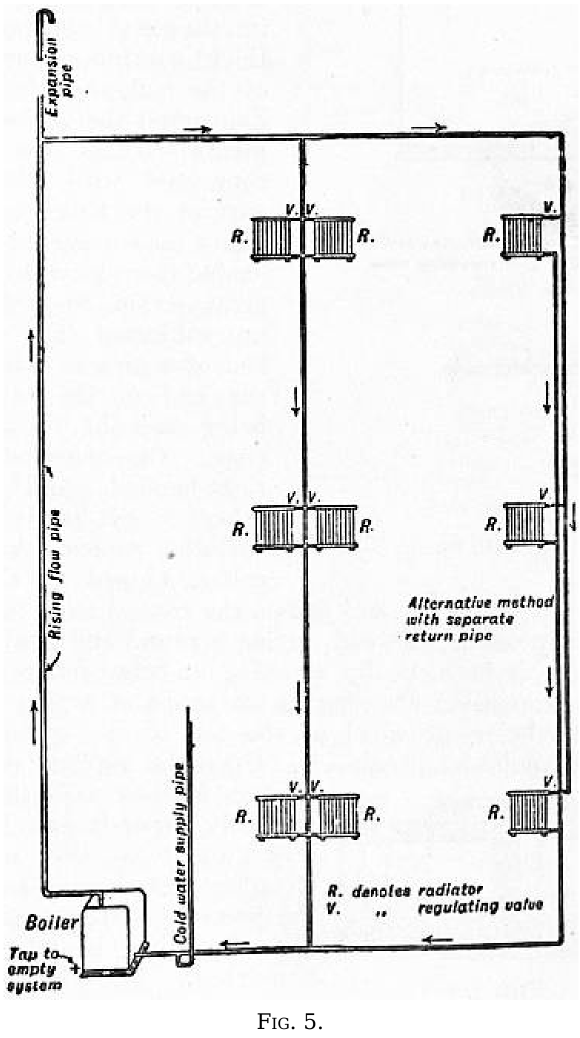


FIG. 5.

The rate of circulation in the ordinary low pressure hot-water system may be considerably accelerated by means of steam injections. The water after being heated passes into a circulating tank into which steam is introduced; this, mixing with the hot water, gives it additional motive power, resulting in a faster circulation. This steam condensing adds to the water in the pipe and naturally causes an overflow, which is led back to the boiler and re-used. In districts where the water is hard, this arrangement considerably lengthens the life of the boiler, as the same water is used over and over again, and no fresh deposit of fur occurs. Owing to the very rapid movement and the consequent increased rate of transmission of heat, the pipes and radiators may be reduced in size, in many circumstances a very desirable thing to achieve. With this system the temperature can be quickly raised 162 and easily controlled. If the weather is mild, a moderate heat may be obtained by using the apparatus as an ordinary hot water system, and shutting off the steam injectors.

The cold-water supply and expansion tank (fig. 3) are often combined in one tank placed at a point above the level of circulation. The tank should be of a size to hold not less than a twentieth part of the total amount of water held in the system. The automatic inlet of cold water to the hot water system from the main house tank or other source is controlled by a ball valve, which is so fixed as to allow the water to rise no more than an inch above the bottom of the tank, thus leaving the remainder of the space clear for expansion. An overflow is provided, discharging into the open air to allow the water to escape should the ball valve become defective.

High pressure hot water.

The "Perkins" or "small bore high pressure" system (fig. 6) has many advantages, for it is safe, the boiler is small and is easily managed, the temperature is well under control and may be regulated to suit the changing weather, and the small pipes present a neat appearance in a room. The whole system is constructed of wrought iron pipe of small diameter, strong enough to resist a testing pressure of 2000 to 2500 ℔ per sq. in. The boiler consists of similar pipe coiled up to form a fire-box, inside which the furnace is lighted. The coil is encased with firebricks and brickwork, and the smoke from the fire is carried off by a flue in the ordinary way. The flow pipe of similar section (usually having an internal diameter of about 1 in., the metal being nearly ¼ in. thick) continues from the top of the coil, and after travelling round the various apartments returns to, and is connected with, the lowest part of the boiler coil. The joints take a special form to enable them to withstand the great strain to which they are subjected (fig. 7). One end of a pipe is finished flat, the end of the other pipe being brought to a conical edge. On one end also a right-handed, and on the other a left-handed, screw-thread is turned. A coupling collar, tapped in the same manner, is screwed on, and causes the conical edge to impress itself tightly on the flat end, giving a sound and lasting joint. The system is hermetically sealed after being pumped full of water, an expansion chamber in the shape of a pipe of larger dimensions being provided at the top of the system above the highest point of circulation. Upon the application of heat to the fire-box coil the water naturally expands and forces its way up into the expansion chamber; but there it encounters the pressure of the confined air, and ebullition is consequently prevented. Thus at no time can steam form in the system. This system is trustworthy and safe in working. The smallness of the pipes renders it liable to damage by frost, but this accident may be prevented by always keeping in frosty weather a small fire in the furnace. If this course is inconvenient, some liquid of low freezing-point, such as glycerine, may be mixed with the water.

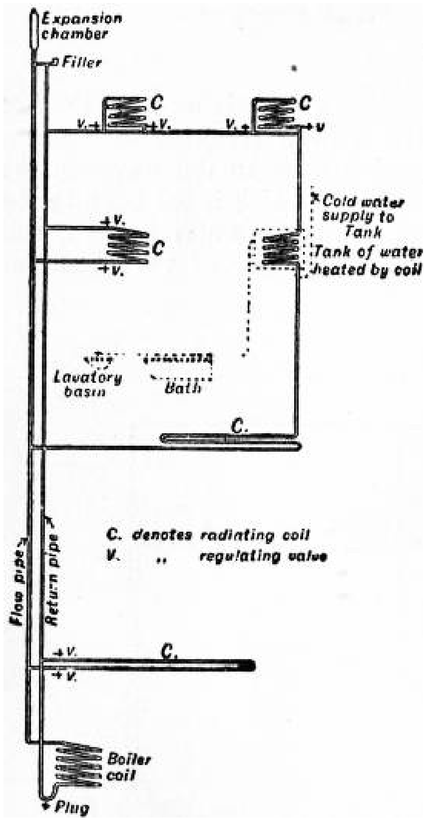


Fig. 6.

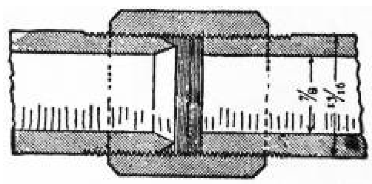


Fig. 7.

Steam heating.

For large public buildings, factories, &c., heating by steam is generally adopted on account of the rapidity with which heat is available, and the great distance from the boiler at which warming is effected. In the case of factories the exhaust steam from the engines used for driving the working machinery is made use of and forms the most economical method of heating possible. There are several different systems of heating by steam—low pressure, high pressure and minus pressure.

In the low pressure two pipe system the flow pipe is carried to a sufficient height directly above the boiler to allow of its gradual fall to a little beyond the most distant point at which connexion is to be made with the return pipe, which thence slopes towards the boiler. Branches are taken off the flow pipe, and after circulating through coils or radiators are connected with the return pipe. In a well-proportioned system the pressure need not exceed 2 or 3 ℔ per sq. in. for excellent results to be obtained. The one-pipe system is similar in principle, the pipe rising to its greatest height above the boiler and being then carried around as a single pipe falling all the while. It resembles in many points the one-pipe low pressure hot-water system. Radiators are fed directly from the main. Where, as in factories or workshops, there are already installed engines working at a high steam pressure, say 120 to 180 ℔ per sq. in., a portion of the steam generated in the boilers may be utilized for heating by the aid of a reducing valve. The steam is passed through the valve and emerges at the pressure required generally from 3 ℔ upwards. It is then used for one of the systems described above.

High-pressure steam-heating, compared with the heating by low pressure, is little used. The principles are the same as those applied to low-pressure work, but all fittings and appliances must, of course, be made to stand the higher strain to which they are subjected.

The “minus pressure” steam system, sometimes termed “atmospheric” or “vacuum,” is of more recent introduction than those just described. It is certainly the most scientific method of steam-heating, and heat can be made to travel a greater distance by its aid than by any other means. The heat of the pipes is great, but can be easily regulated. The system is economical in fuel, but needs skilled attendance to keep the appliances and fittings in order. The steam is introduced into the pipes at about the pressure of the atmosphere, and is sucked through the system by means of a vacuum pump, which at the same operation frees the pipes from air and from condensation water. This pumping action results in an extremely rapid circulation of the heating agent, enabling long distances to be traversed without much loss of heat.

Compared with heating by hot water, steam-heating requires less piping, which, further, may be of much smaller diameter to attain a similar result, because of the higher temperature of the heat yielding surface. A drawback to the use of steam is the fact that the high temperature of the pipes and radiators attracts and spreads a great deal of dust. There is also a risk that woodwork near the pipes may warp and split. The apparatus needs constant attention, since neglect in stoking would result in stopping the generation of steam, and the whole system would almost immediately cool. To regulate the heat it is necessary either to instal a number of small radiators or to divide the radiators into sections, each section controlled by distinct valves; steam may then be admitted to all the sections of the radiator or to any less number of sections as desired. In a hot-water system the heat is given off at a lower temperature and is consequently more agreeable than that yielded by a steam-heating apparatus. The joint most commonly used for hot-water pipes is termed the “rust” joint, which is cheap to make, but unfortunately is inefficient. The materials required are iron borings, sal-ammoniac and sulphur; these are mixed together, moistened with water, and rammed into the socket, which is previously half filled with yarn, well caulked. The materials mixed with the iron borings cause them to rust into a solid mass, and in doing so a slight expansion takes place. On this account it is necessary to exercise some skill in forming 163
the joint, or the socket of the pipe will be split; numbers of pipes are undoubtedly spoilt in this way. Suitable proportions of materials to form a rust joint are 90 parts by weight of iron borings well mixed with 2 parts of flowers of sulphur, and 1 part of powdered sal-ammoniac. Another joint, less rigid but sound and durable, is made with yarn and white and red lead. The white and red lead are mixed together to form a putty, and are filled into the socket alternately with layers of well-caulked yarn, starting with yarn and finishing off with the lead mixture.

Joints for pipes.

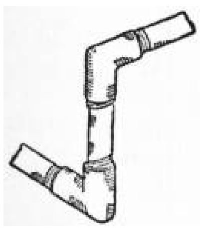


Fig. 8.

Iron expands when heated to the temperature of boiling water (212° F.) about 1 part in 900, that is to say, a pipe 100 ft. long would expand or increase in length when heated to this temperature about 1½ in., an amount which seems small but which would be quite sufficient to destroy one or more of the joints if provision were not made to prevent damage. The amount of expansion increases as the temperature is raised; at 340° F. it is 2½ in. in 100 ft. With wrought iron pipes bends may be arranged, as shown in fig. 8, to take up this expansion. With cast iron pipe this cannot be done, and no length of piping over 40 ft. should be without a proper expansion joint. The pipes are best supported on rollers which allow of movement without straining the joints.

There are several joints in general use for the best class of work which are formed with the aid of india-rubber rings or collars, any expansion being divided amongst the whole number of joints. In the rubber ring joint an india-rubber ring is used; slightly less in diameter than the pipe. The rubber is circular in section, and about ½ in. thick, and is stretched on the extreme end of a pipe which is then forced into the next socket. This joint is durable, secure and easily made; it allows for expansion and by its use the risk of pipe sockets being cracked is avoided. It is much used for greenhouse heating works. Richardson’s patent joint (fig. 9) is a good form of this class of joint. The pipes have specially shaped ends between which a rubber collar is placed, the joint being held together by clips. The result is very satisfactory and will stand heavy water pressure. Messenger’s joint (fig. 10) is designed to allow more freedom of expansion and at the same time to withstand considerable pressure; one loose cast iron collar is used, and another is formed as a socket on the end of the pipe itself. One end of each pipe is plain, so that it may be cut to any desired length; pipes with shaped ends obviously must be obtained in the exact lengths required. Jones’s expansion joint (fig. 11) is somewhat similar to Messenger’s but it is not capable of withstanding so great a pressure. In this case both collars of cast iron are loose.

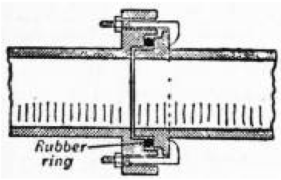


FIG. 9.

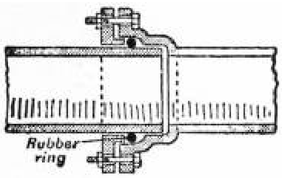


FIG. 10.

Radiators.

Radiators (really convectors) were in their primitive design coils of pipe, used to give a larger heating area than the single pipe would afford. They are now usually of special design, and may be divided into three classes—indirect radiators, direct radiators and direct ventilating radiators. Indirect radiators are placed beneath the floor of the apartment to be heated and give off heat through a grating. This method is frequently adopted in combined schemes of heating and ventilating; the fresh air is warmed by being passed over their surfaces previously to being admitted through the gratings into the room. Direct radiators are a development of the early coil of pipe; they are made in various types and designs and are usually of cast iron. Ventilating radiators are similar, but have an inlet arrangement at the base to allow external air to pass over the heating surface before passing out through the perforations. Radiators should not be fixed directly on to the main heating pipe, but always on branches of smaller diameter leading from the flow pipe to one end of the radiator and back to the main return pipe from the other end; they may then be easily controlled by a valve placed on the branch from the flow pipe. To each radiator should be fitted an air tap, which when opened will permit the escape of any air that has accumulated in the coil; otherwise free circulation is impossible, and the full benefit of the heat is not obtained.

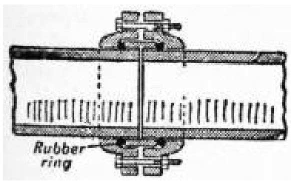


FIG. 11.

Hot-water supply.

A plentiful supply of hot water is a necessity in every house for domestic and hygienic purposes. In small houses all requirements may be satisfied with a boiler heated by the kitchen fire. For large buildings where large quantities of hot water are used an independent boiler of suitable size should be installed. Every installation is made up of a boiler or other water heater, a tank or cylinder to contain the water when heated, and a cistern of cold water, the supply from which to the system is regulated automatically by a ball valve. These containers, proportioned to the required supply of hot water, are connected with each other by means of pipes, a “flow” and a “return” connecting the boiler with the cylinder or tank (fig. 12). The flow pipe starts from the top of the boiler and is connected near the top of the cylinder, the return pipe joining the lower portions of the cylinder and boiler. The supply from the cold water cistern enters the bottom of the cylinder, and thence travels by way of the return pipe to the boiler, where it is heated, and back through the flow pipe to the cylinder, which is thus soon filled with hot water. A flow pipe which serves also for expansion is taken from the top of the cylinder to a point above the cold-water supply and turned down to prevent the ingress of dirt. From this pipe at various points are taken the supply pipes to baths, lavatories, sinks and other appliances. It will be observed that in fig. 12 the cylinder is placed in proximity to the boiler; this is the usual and most effective method, but it may be placed some distance away if desired. The tank system is of much earlier date than this cylinder system, and although the two resemble each other in many respects, the tank system is in practice the less effective. The tank is placed above the level of the topmost draw off, and often in a cupboard which it will warm sufficiently to permit of its being used as a linen airing closet. An expansion pipe is taken from the top of the tank to a point above the roof. All draw off services are taken off from the flow pipe which connects the boiler with the tank. This method differs from that adopted in the cylinder system, where all services are led from the top of the cylinder. A suitable proportion between the size of the tank or cylinder and that of the boiler is 8 or 10 to 1. Water may also be heated by placing a coil of steam or high-pressure hot-water pipes in a water tank (fig. 6), the water heated in this way circulating in the manner already described. An alternative plan is to pass the water through pipes placed in a steam chest.

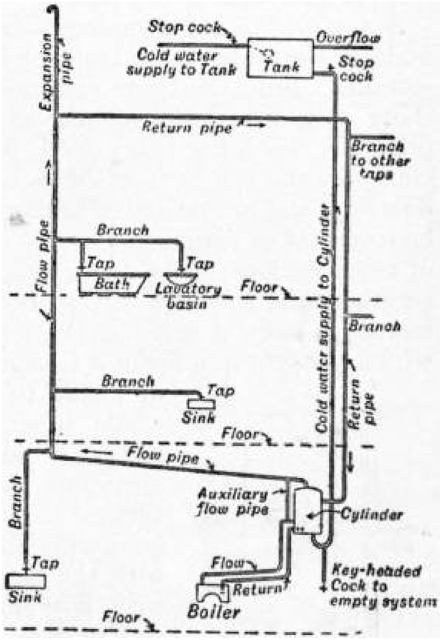


FIG. 12.

Cylinders, tanks and independent boilers should be encased in a non-conducting material such as silicate cotton, thick felt or asbestos composition. The two first mentioned are affixed by means of bands or straps or stitched on; the asbestos is laid on in the form of a 164
plaster from 2 to 6 in. thick.

Taps to baths and lavatories should be connected to the main services by a flow and return pipe so that hot water is constantly flowing past the tap, thus enabling hot water to be obtained immediately. Frequently a single pipe is led to the tap, but the water in this branch cools and must therefore be drawn off before hot water can be obtained.

Boilers.

Two classes of boilers are chiefly used in hot-water heating installations, viz. those heated by the fire of the kitchen range, and those heated separately or independently. Of the first class there are two varieties in common use—a form of “saddle” boiler (fig. 13) and the “boot” boiler (fig. 14). Independent boilers are made in every conceivable size and form of construction, and many of them are capable of doing excellent work. In the choice of a boiler of this description it should be remembered that rapid heating, economical combustion of fuel, and facilities for cleaning, are requisites, the absence of any of which considerably lowers the efficiency of the apparatus. Boilers set in brickwork are sometimes used in domestic work, although they are more favoured for horticultural heating. The shape mostly used is the “saddle” boiler, or some variation upon this very old pattern. The coiled pipe fire-box of the high-pressure hot-water system previously described may be also classed with boilers.

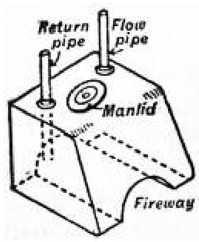


FIG. 13.

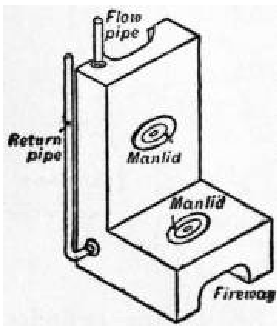


FIG. 14.

A notable feature of modern boiler construction is the mode of building the apparatus of cast iron in either horizontal or vertical sections. Both the types intended to be set in brickwork and those working independently are formed on the sectional principle, which has many good points. The parts are easy of transport and can be handled without difficulty through narrow doorways and in confined situations. The size of the boiler may be increased or diminished by the addition or subtraction of one or more sections; these, being simple in design, are easily fitted together, and should a section become defective it is a simple matter to insert a new one in its place. Should a defect occur with a wrought iron boiler it is usually necessary for the purpose of repair to disconnect and remove the whole apparatus, the heating system of which it forms a part being in the meantime useless. In a type built with vertical sections each division is complete in itself, and is not directly connected with the next section, but communicates with flow and return drums. A defective section may thus be left in position and stopped off by means of plugs from the drums until it is convenient to fit a new one in its place. A boiler with horizontal sections is shown in fig. 15; it will be seen that each of the upper sections has a number of cross waterways which form a series of gratings over the fire-box and intercept most of the heat generated, effecting great economy of fuel.

Safety valves.

In the ordinary working of a hot-water apparatus the expansion pipe already referred to will prevent any overdue pressure occurring in the boiler; should, however, the pipes become blocked in any way while the apparatus is in use, or the water in them become frozen, the lighting of the fire would cause the water to expand, and having no outlet it would in all probability burst the boiler. To prevent this a safety valve should be fitted on the top of the boiler, or be connected thereto with a large pipe so as to be visible. The valve may be of the dead weight (fig. 16), lever weight, spring (fig. 17) or diaphragm variety. The three first named are largely used. In the diaphragm valve a thin piece of metal is fixed to an outlet from the boiler, and when a moderate pressure is exceeded this gives way, allowing the water and steam to escape.

Fusible plugs are little used; they consist of pieces of softer metal inserted on the side of the boiler, which melt should the heat of the water rise above a certain temperature.

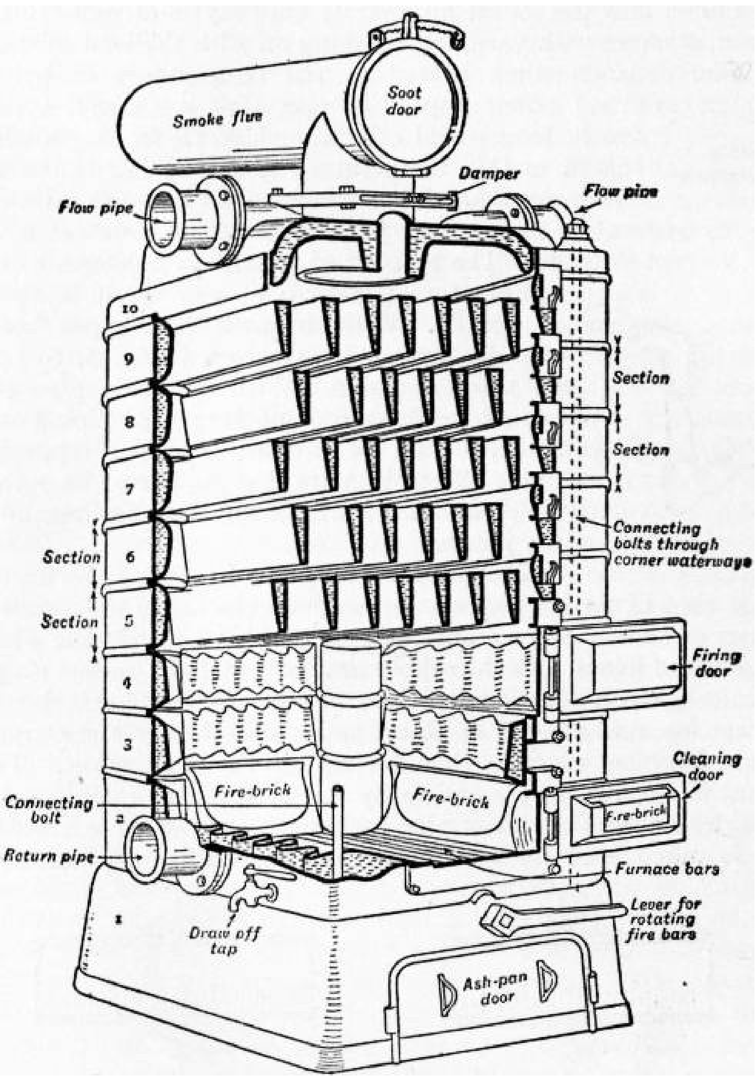
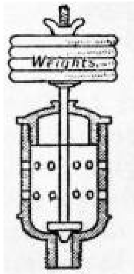


FIG. 15.

Geysers.

A “Geyser” is a very convenient form of apparatus for heating a quantity of water in a short time. A water pipe of copper or wrought iron is passed through a cylinder in which gas or oil heating burners are placed. The piping takes a winding or zigzag course, and by the time the outlet is reached, the water it contains has reached a high temperature. By this means a continuous stream of hot water is obtained, greater or smaller in proportion to the size and power of the apparatus. The improved types of gas geysers are provided with a single control to both gas and water supplies, with a small “pilot” burner to ignite the gas. A flue should in all cases be provided to carry off the fumes of the fuel.



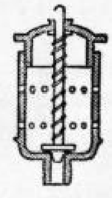


Fig. 16. Fig. 17.

Incrustation.

In districts where the water is of a “hard nature,” that is, contains bicarbonate of lime in solution, the interior of the boiler, cylinders, tanks and pipes of a hot water system will become incrusted with a deposit of lime which is gradually precipitated as the water is heated to boiling point. With “very hard” water this deposit may require removal every three months; in London it is usual to clean out the boiler every six months and the cylinders and tanks at longer intervals. For this purpose manlids must be provided (figs. 13 and 14), and pipes should be fitted with removable caps at the bends to allow for periodical cleaning. The lime deposit or “fur” is a poor conductor of heat, and it is therefore most detrimental to the efficiency of the system to allow the interior of the boiler or any other portion to become furred up. Further, if not removed, the fur will in a short time bring about a fracture in the boiler. The use of soft water entails a disadvantage of another character—that of corroding iron and lead work, soft water exercising a very vigorous chemical action upon these metals. In districts 165
supplied with soft water, copper should be employed to as large an extent as possible.

The table given below will be useful in calculating the size of the radiating surface necessary to raise the temperature to the extent required when the external air is at freezing point (32° Fahr.):—

Description of Building to be heated.	Temperature required.	Cubic Feet of Air heated by 1 sq. ft. of Radiator or Pipe Surface.	
		Low Pressure Water.	Low Pressure Steam.
Dwelling rooms	55°-60°	85-90	115-125
Schools	60°	90-100	120-130
Churches and chapels	55°-60°	100-120	135-160
Offices and shops	55°-60°	120-125	160-170
Public halls, workshops, waiting-rooms	55°	130-150	175-200
Warehouses, stores	50°-55°	140-160	190-220

Steam supply at Lockport.

In closing this account of heating and the practical methods of application of heat, an example may be mentioned to show the great capabilities of a carefully planned system. At the city of Lockport in New York state, America, an interesting example of the direct application of steam-heating on a large scale has been carried out under the direction of Mr Birdsill Holly of that city. Houses within a radius of 3 m. from the boiler house are supplied with superheated steam at a pressure of 35 ℔ to the in. The mains, the largest of which are 4 in. in diameter, and the smallest 2 in., are wrapped in asbestos, felt and other non-conducting materials, and are placed in wooden tubes laid under ground like water and gas pipes. The house branches pipes are 1½ in. in diameter, and ¾-in. pipes are used inside the houses. The steam is employed for warming apartments by means of pipe radiators, for heating water by steam injections, and for all cooking purposes. The steam mains to the houses are laid by the supply company; the internal pipes and fittings are paid for or rented by the occupier, costing for an installation from £30 for an ordinary eight-roomed house to £100 or more for larger buildings. With the success of this undertaking in view it is a matter of wonder that the example set in this instance has not been adopted to a much greater extent elsewhere.

The principal publications on heating are: Hood, *Practical Treatise on Warming Buildings by Hot Water*; Baldwin, *Hot Water Heating and Fittings*; Baldwin, *Steam Heating for Buildings*; Billings, *Ventilation and Heating*; Carpenter, *Heating and Ventilating Buildings*; Jones, *Heating by Hot Water, Ventilation and Hot Water Supply*; Dye, *Hot Water Supply*.

(J. Bt.)

HEAVEN (O. Eng. *hefen*, *heofon*, *heofone*; this word appears in O.S. *hevan*; the High. Ger. word appears in Ger. *Himmel*, Dutch *hemel*; there does not seem to be any connexion between the two words, and the ultimate derivation of the word is unknown; the suggestion that it is connected with "to heave," in the sense of something "lifted up," is erroneous), properly the expanse, taking the appearance of a domed vault above the earth, in which the sun, moon, planets and stars seem to be placed, the firmament; hence also used, generally in the plural, of the space immediately above the earth, the atmospheric region of winds, rain, clouds, and of the birds of the air. The heaven and the earth together, therefore, to the ancient cosmographers, and still in poetical language, make up the universe. In the cosmogonies of many ancient peoples there was a plurality of heavens, probably among the earlier Hebrews, the idea being elaborated in rabbinical literature, among the Babylonians and in Zoroastrianism. The number of these heavens, the higher transcending the lower in glory, varied from three to seven. Heaven, as in the Hebrew *shamayim*, the Greek οὐρανός, the Latin *caelum*, is the abode of God, and as such in Christian eschatology is the place of the blessed in the next world (see Eschatology and Paradise).

HEBBEL, CHRISTIAN FRIEDRICH (1813-1863), German poet and dramatist, was born at Wesselburen in Ditmarschen, Holstein, on the 18th of March 1813. Though only the son of a poor bricklayer, he early showed a talent for poetry, which was first displayed to the world by the publication, in the Hamburg *Modezeitung*, of verses which he had sent to Amalie Schoppe (1791-1858), a then popular journalist and author of nursery tales. Through the kindness of this lady, who interested several of her friends on his behalf, he was enabled to go to Hamburg and there prepare himself for the university. A year later he went to Heidelberg to study law, but finding this uncongenial he passed on to the university of Munich, where he devoted himself to philosophy, history and literature. In 1839 Hebbel left Munich and wandered back to Hamburg on foot, where he resumed his relations with Elsie Lensing, whose self-sacrificing assistance had helped him over the darkest days in Munich. In the same year he wrote his first tragedy *Judith* (published 1841), which in the following year was performed in Hamburg and Berlin and made his name known throughout Germany. In 1840 he wrote the tragedy *Genoveva*, and the following year finished a comedy, *Der Diamant*, which he had begun at Munich. In 1842 he visited Copenhagen, where he obtained from the king of Denmark a small travelling studentship, which enabled him to spend some time in Paris and two years (1844-1846) in Italy. In Paris he wrote his fine "tragedy of common life," *Maria Magdalene* (1844). On his return from Italy Hebbel met at Vienna two Polish noblemen, the brothers Zerboni di Sposetti, who in their enthusiasm for his genius urged him to remain, and supplied him with the means to mingle in the best intellectual society of the Austrian capital. The unwonted life of ease had its effect. The old precarious existence became a horror to him, he made a deliberate breach with it by marrying (in 1846) the beautiful and wealthy actress Christine Enghaus, ruthlessly sacrificing the girl who had given up all for him and who remained faithful till her death, on the ground that "a man's first duty is to the most powerful force within him, that which alone can give him happiness and be of service to the world": in his case the poetical faculty, which would have perished "in the miserable struggle for existence." This "deadly sin," which, "if peace of conscience be the test of action," was, he considered, the best act of his life, established his fortunes. Elise, however, still provided useful inspiration for his art. As late as 1855, shortly after her death, he wrote the little epic *Mutter und Kind*, intended to show that the relation of parent and child is the essential factor which makes the quality of happiness among all classes and under all conditions equal. Long before this Hebbel had become famous. German sovereigns bestowed decorations upon him; and in foreign capitals he was fêted as the greatest of living German dramatists. From the grand-duke of Saxe-Weimar he received a flattering invitation to take up his residence at Weimar, where several of his plays were first performed. He remained, however, at Vienna until his death on the 13th of December 1863.

Besides the works already mentioned, Hebbel's principal tragedies are *Herodes und Mariamne* (1850); *Julia* (1851); *Michel Angelo* (1851); *Agnes Bernauer* (1855); *Gyges und sein Ring* (1856), and the magnificently conceived trilogy *Die Nibelungen* (1862), his last work (consisting of a prologue, *Der gehörnte Siegfried*, and the tragedies, *Siegfrieds Tod* and *Kriemhilds Rache*), which won for the author the Schiller prize. Of his comedies *Der Diamant* (1847), *Der Rubin* (1850), and the tragi-comedy *Ein Trauerspiel in Sizilien* (1845), are the more important, but they are heavy and hardly rise above mediocrity. All his dramatic productions, however, exhibit skill in characterization, great glow of passion, and a true feeling for dramatic situation; but their poetic effect is frequently marred by extravagances which border on the grotesque, and by the introduction of incidents the unpleasant character of which is not sufficiently relieved. In many of his lyric poems, and especially in *Mutter und Kind*, published in 1859, Hebbel showed that his poetic gifts were not restricted to the drama.

His collected works were first published by E. Kuh (12 vols., Hamburg, 1866-1868); 166
revised by H. Krumm (12 vols., Hamburg, 1892). The best critical edition is that by R. M. Werner (12 vols., 1901-1903), to which have been added Hebbel’s Diaries (4 vols.) and Correspondence (6 vols.). Hebbel’s *Briefwechsel mit Freunden und berühmten Zeitgenossen* was issued by F. Bamberg (1890-1892). The chief biographies of Hebbel are those by E. Kuh (1877) and R. M. Werner (1905). See also L. A. Frankl, *Zur Biographie F. Hebbels* (1884); T. Poppe, *F. Hebbel und sein Drama* (1900); A. Scheunert, *Der Pantragismus als System der Weltanschauung und Ästhetik Hebbels* (1903); E. A. Georgy, *Die Tragödie F. Hebbels nach ihrem Ideengehalt* (1904).

HEBBURN, an urban district in the Jarrow parliamentary division of Durham, England, on the right bank of the Tyne, 4½ m. below Newcastle, and on a branch of the North-Eastern railway. Pop. (1881), 11,802; (1901), 20,901. It has extensive shipbuilding and engineering works, rope and sail factories, chemical, colour and cement works, and collieries.

HEBDEN BRIDGE, an urban district in the Sowerby parliamentary division of the West Riding of Yorkshire, England, on the Calder and Hebden rivers, 7 m. W. by N. of Halifax by the Lancashire and Yorkshire railway. Pop. (1901), 7536. The town has cotton factories, dye-works, foundries and manufactories of shuttles. The upper Calder valley, between Halifax and Todmorden, is walled with bold hills, the summits of which consist of wild moorland. The vale itself is densely populated, but its beauty is not destroyed, and the contrast with its desolate surroundings is remarkable.

HEBE, in Greek mythology, daughter of Zeus and Hera, the goddess of youth. In the Homeric poems she is the female counterpart of Ganymede, and acts as cupbearer to the gods (*Iliad*, iv. 2). She was the special attendant of her mother, whose horses she harnessed (*Iliad*, v. 722). When Heracles was received amongst the gods, Hebe was bestowed upon him in marriage (*Odyssey*, xi. 603). When the custom of the heroic age, which permitted female cupbearers, fell into disuse, Hebe was replaced by Ganymede in the popular mythology. To account for her retirement from her office, it was said that she fell down in the presence of the gods while handing the wine, and was so ashamed that she refused to appear before them again. Hebe exhibits many striking points of resemblance with the pure Greek goddess Aphrodite. She is the daughter of Zeus and Hera, Aphrodite of Zeus and Dione; but Dione and Hera are often identified. Hebe is called Dia, a regular epithet of Aphrodite; at Phlius, a festival called Κισσοτόμοι (the days of ivy-cutting) was annually celebrated in her honour (Pausanias, ii. 13); and ivy was sacred also to Aphrodite. The apotheosis of Heracles and his marriage with Hebe became a favourite subject with poets and painters, and many instances occur on vases. In later art she is often represented, like Ganymede, caressing the eagle.

See R. Kekulé, *Hebe* (1867), mainly dealing with the representations of Hebe in art; and P. Decharme in Daremberg and Saglio’s *Dictionnaire des antiquités*.

The meaning of the word Hebe tended to transform the goddess into a mere personification of the eternal youth that belongs to the gods, and this conception is frequently met with. Then she becomes identical with the Roman Juventas, who is simply an abstraction of an attribute of Jupiter Juventus, the god of increase and blessing and youth. To Juventas, as personifying the eternal youth of the Roman state, a chapel was dedicated in very early times in the *cella* of Minerva in the temple of Jupiter Capitolinus. With this temple is connected the legend of Juventas and Terminus, who alone of all the gods refused to give way when it was being built—an indication of the eternal solidity and youth of Rome. The cult of Juventas did not, however, become firmly established until the time of the second Punic war. In 218 the Sibylline books ordered a lectisternium in honour of Juventas and a supplicatio in honour of Hercules, and in 191 a temple was dedicated in her honour in the Circus Maximus. In later times Juventas became the personification, not of the Roman youth, but of the emperor, who assumed the attributes of a god (Livy v. 54, xxi. 62, xxxvi. 36; Dion. Halic. iii. 69; G. Wissowa in Roscher’s *Lexikon der Mythologie*).

HEBEL, JOHANN PETER (1760-1826), German poet and popular writer, was born at Basel on the 10th of May 1760. The father dying when the child was little over a year old, he was brought up amidst poverty-stricken conditions in the village of Hausen in the Wiesental, where he received his earliest education. Being of brilliant promise, he found friends who enabled him to complete his school education and to study theology (1778-1780) at Erlangen. At the end of his university course he was for a time a private tutor, then became teacher at the Gymnasium in Karlsruhe, and in 1808 was appointed director of the school. He was subsequently appointed member of the Consistory and “evangelical prelate.” He died at Schwetzingen, near Heidelberg, on the 22nd of September 1826. Hebel is one of the most widely read of all German popular poets and writers. His poetical narratives and lyric poems, written in the “Alemanic” dialect, are “popular” in the best sense. His *Allemannische Gedichte* (1803) “bucolicize,” in the words of Goethe, “the whole world in the most attractive manner” (*verbauert das ganze Universum auf die anmutigste Weise*). Indeed, few modern German poets surpass him in fidelity, *naïveté*, humour, and in the freshness and vigour of his descriptions. His poem, *Die Wiese*, has been described by Johannes Scherr as the “pearl of German idyllic poetry”; while his prose writings, especially the narratives and essays contained in the *Schatzkästlein des rheinischen Hausfreundes* (Tübingen, 1811; new edition, Stuttg. 1869, 1888), belong to the best class of German stories, and according to August Friedrich Christian Vilmar (1800-1868) in his *Geschichte der deutschen Literatur* are “worth more than a cartload of novels” (*wiegen ein ganzes Fuder Romane auf*). Memorials have been erected to him at Karlsruhe, Basel and Schwetzingen.

A complete edition of Hebel’s works—*Sämtliche Werke*—was first published at Stuttgart in 8 vols. (1832-1834); subsequent editions appeared in 1847 (3 vols.), 1868 (2 vols.), 1873 (edited by G. Wendt, 2 vols.), 1883-1885 (edited by O. Behaghel, 2 vols.) and 1905 (edited by E. Keller, 5 vols.), as well as innumerable reprints. Hebel’s correspondence has been edited by O. Behaghel (1883). See G. Längin, *J. P. Hebel, ein Lebensbild* (1894), and the introduction to Behaghel’s edition.

HEBER, REGINALD (1783-1826), English bishop and hymn-writer, was born at Malpas in Cheshire on the 21st of April 1783. His father, who belonged to an old Yorkshire family, held a moiety of the living of Malpas. Reginald Heber early showed remarkable promise, and was entered in November 1800 at Brasenose College, Oxford, where he proved a distinguished student, carrying off prizes for a Latin poem entitled *Carmen seculare*, an English poem on *Palestine*, and a prose essay on *The Sense of Honour*. In November 1804 he was elected a fellow of All Souls College; and, after finishing his distinguished university career, he made a long tour in Europe. He was admitted to holy orders in 1807, and was then presented to the family living of Hodnet in Shropshire. In 1809 Heber married Amelia, daughter of Dr Shipley, dean of St Asaph. He was made prebendary of St Asaph in 1812, appointed Bampton lecturer for 1815, preacher at Lincoln’s Inn in 1822, and bishop of Calcutta in January 1823. Before sailing for India he received the degree of D.D. from the university of Oxford. In India Bishop Heber laboured indefatigably, not only for the good of his own diocese, but for the spread of Christianity throughout the East. He undertook numerous tours in India, consecrating churches, founding schools and discharging other Christian duties. His devotion to his work in a trying climate told severely on his health. At Trichinopoly he was seized with an apoplectic fit when in his bath, and died on the 3rd of April 1826. A statue of him, by Chantrey, was erected at Calcutta.

Heber was a pious man of profound learning, literary taste and great practical energy. His fame rests mainly on his hymns, which rank among the best in the English language. The following may be instanced: “Lord of mercy and of might”; “Brightest and best of the sons of the morning”; “By cool Siloam’s shady rill”; “God, that madest earth and heaven”; “The Lord of might from Sinai’s brow”; “Holy, holy, holy, Lord God Almighty”; “From Greenland’s icy mountains”; “The Lord will come, the earth shall quake”; “The Son of God goes forth to 167
war.” Heber’s hymns and other poems are distinguished by finish of style, pathos and soaring aspiration; but they lack originality, and are rather rhetorical than poetical in the strict sense.

Among Heber’s works are: *Palestine: a Poem, to which is added the Passage of the Red Sea* (1809); *Europe: Lines on the Present War* (1809); a volume of poems in 1812; *The Personality and Office of the Christian Comforter asserted and explained* (being the Bampton Lectures for 1815); *The Whole Works of Bishop Jeremy Taylor, with a Life of the Author, and a Critical Examination of his Writings* (1822); *Hymns written and adapted to the Weekly Church Service of the Year, principally by Bishop Heber* (1827); *A Journey through India* (1828); *Sermons preached in England*, and *Sermons preached in India* (1829); *Sermons on the Lessons, the Gospel, or the Epistle for every Sunday in the Year* (1837). *The Poetical Works of Reginald Heber* were collected in 1841.

See the *Life of Reginald Heber, D.D. ...*, by his widow, Amelia Heber (1830), which also contains a number of Heber’s miscellaneous writings; *The Last Days of Bishop Heber*, by Thomas Robinson, A.M., archdeacon of Madras (1830); T. S. Smyth, The Character and Religious Doctrine of Bishop Heber (1831), and *Memorials of a Quiet Life*, by Augustus J. C. Hare (1874).

HEBER, RICHARD (1773-1833), English book-collector, the half-brother of Reginald Heber, was born in London on the 5th of January 1773. As an undergraduate at Brasenose College, Oxford, he began to collect a purely classical library, but his taste broadening, he became interested in early English drama and literature, and began his wonderful collection of rare books in these departments. He attended continental book-sales, purchasing sometimes single volumes, sometimes whole libraries. Sir Walter Scott, whose intimate friend he was, and who dedicated to him the sixth canto of *Marmion*, classed Heber’s library as “superior to all others in the world”; Campbell described him as “the fiercest and strongest of all the bibliomaniacs.” He did not confine himself to the purchase of a single copy of a work which took his fancy. “No gentleman,” he remarked, “can be without three copies of a book, one for show, one for use, and one for borrowers.” To such a size did his library grow that it over-ran eight houses, some in England, some on the Continent. It is estimated to have cost over £100,000, and after his death the sale of that part of his collection stored in England realized more than £56,000. He is known to have owned 150,000 volumes, and probably many more. He possessed extensive landed property in Shropshire and Yorkshire, and was sheriff of the former county in 1821, was member of Parliament for Oxford University from 1821-1826, and in 1822 was made a D.C.L. of that University. He was one of the founders of the Athenaeum Club, London. He died in London on the 4th of October 1833.

HEBERDEN, WILLIAM (1710-1801), English physician, was born in London in 1710. In the end of 1724 he was sent to St John’s College, Cambridge, where he obtained a fellowship about 1730, became master of arts in 1732, and took the degree of M.D. in 1739. He remained at Cambridge nearly ten years longer practising medicine, and gave an annual course of lectures on materia medica. In 1746 he became a fellow of the Royal College of Physicians in London; and two years later he settled in London, where he was elected a fellow of the Royal Society in 1749, and enjoyed an extensive medical practice for more than thirty years. At the age of seventy-two he partially retired, spending his summers at a house which he had taken at Windsor, but he continued to practise in London during the winter for some years longer. In 1778 he was made an honorary member of the Paris Royal Society of Medicine. He died in London on the 17th of May 1801. Heberden, who was a good classical scholar, published several papers in the Phil. Trans. of the Royal Society, and among his noteworthy contributions to the *Medical Transactions* (issued, largely at his suggestion, by the College of Physicians) were papers on chicken-pox (1767) and angina pectoris (1768). His *Commentarii de morborum historia et curatione*, the result of careful notes made in his pocket-book at the bedside of his patients, were published in 1802; in the following year an English translation appeared, believed to be from the pen of his son, William Heberden (1767-1845), also a distinguished scholar and physician, who attended King George III. in his last illness.

HÉBERT, EDMOND (1812-1890), French geologist, was born at Villefargau, Yonne, on the 12th of June 1812. He was educated at the Collège de Meaux, Auxerre, and at the École Normale in Paris. In 1836 he became professor at Meaux, in 1838 demonstrator in chemistry and physics at the École Normale, and in 1841 sub-director of studies at that school and lecturer on geology. In 1857 the degree of D. ès Sc. was conferred upon him, and he was appointed professor of geology at the Sorbonne. There he was eminently successful as a teacher, and worked with great zeal in the field, adding much to the knowledge of the Jurassic and older strata. He devoted, however, special attention to the subdivisions of the Cretaceous and Tertiary formations in France, and to their correlation with the strata in England and in southern Europe. To him we owe the first definite arrangement of the Chalk into palaeontological zones (see Table in *Geol. Mag.*, 1869, p. 200). During his later years he was regarded as the leading geologist in France. He was elected a member of the Institute in 1877, Commander of the Legion of Honour in 1885, and he was three times president of the Geological Society of France. He died in Paris on the 4th of April 1890.

HÉBERT, JACQUES RENÉ (1757-1794), French Revolutionist, called "Père Duchesne," from the newspaper he edited, was born at Alençon, on the 15th of November 1757, where his father, who kept a goldsmith's shop, had held some municipal office. His family was ruined, however, by a lawsuit while he was still young, and Hébert came to Paris, where in his struggle against poverty he endured great hardships; the accusations of theft directed against him later by Camille Desmoulins were, however, without foundation. In 1790 he attracted attention by some pamphlets, and became a prominent member of the club of the Cordeliers in 1791. On the 10th of August 1792 he was a member of the revolutionary Commune of Paris, and became second substitute of the *procureur* of the Commune on the 2nd of December 1792. His violent attacks on the Girondists led to his arrest on the 24th of May 1793, but he was released owing to the threatening attitude of the mob. Henceforth very popular, Hébert organized with P. G. Chaumette (*q.v.*) the "worship of Reason," in opposition to the theistic cult inaugurated by Robespierre, against whom he tried to excite a popular movement. The failure of this brought about the arrest of the Hébertists, or *enragés*, as his partisans were called. Hébert was guillotined on the 24th of March 1794. His wife, who had been a nun, was executed twenty days later. Hébert's influence was mainly due to his articles in his journal *Le Père Duchesne*,[1] which appeared from 1790 to 1794. These articles, while not lacking in a certain cleverness, were violent and abusive, and purposely couched in foul language in order to appeal to the mob.

See Louis Duval, "Hébert chez lui," in *La Révolution Française, revue d'histoire moderne et contemporaine*, t. xii. and t. xiii.; D. Mater, *J. R. Hébert, l'auteur du Père Duchesne avant la journée du 10 août 1792* (Bourges, Comm. Hist. du Cher, 1888); F. A. Aulard, *Le Culte de la raison et de l'être suprême* (Paris, 1892).

1 There were several journals of this name, the best known of the others being that edited by Lemaire.

HEBREW LANGUAGE. The name “Hebrew” is derived, through the Greek Ἑβραῖος, from *ʽibhray*, the Aramaic equivalent of the Old Testament word *ʽibhrī*, denoting the people who commonly spoke of themselves as Israel or Children of Israel from the name of their common ancestor (see Jews). The later derivative *Yisraʼelī*, Israelite, from Yisraʼel, is not found in the Old Testament.[1] Other names used for the language of Israel are *speech of Canaan* (Isa. xix. 18) and *Yehūdhīth*, Jewish, (2 Kings xviii. 26). In later times it was called the *holy tongue*. The real meaning of the word *ʽibhrī* must ultimately be sought in the root *ʽabhar*, to pass across, to go beyond, from which is derived the noun *ʽebher*, meaning the “farther bank” of a river. The usual explanation of the term is that of Jewish tradition that 168 *ʽibhrī* means the man “from the other side,” *i.e.* either of the Euphrates or the Jordan. Hence the Septuagint in Gen. xiv. 13 render Abram *ha-ʽibhrī* by ὁ περάτης, the “crosser,” and Aquila, following the same tradition, has ὁ περαΐτης, the man “from beyond.” This view of course implies that the term was originally applied to Abram or his descendants by a people living on the west of the Euphrates or of the Jordan. It has been suggested that the root *ʽabhar* is to be taken in the sense of “travelling,” and that Abram the wandering Aramaean (Deut. xxvi. 5) was called *ha-ʽibhrī* because he travelled about for trading purposes, his language, *ʽibhrī*, being the *lingua franca* of Eastern trade. The use of the term ἑβραϊστί for biblical Hebrew is first found in the Greek prologue to Ecclesiasticus (*c.* 130 B.C.). In the New Testament it denotes the native language of Palestine (Aramaic and Hebrew being popularly confused) as opposed to Greek. In modern usage the name Hebrew is applied to that branch of the northern part of the Semitic family of languages which was used by the Israelites during most of the time of their national existence in Palestine, and in which nearly all their sacred writings are composed. As to its characteristics and relation to other languages of the same stock, see Semitic Languages. It also includes the later forms of the same language as used by Jewish writers after the close of the Canon throughout the middle ages (Rabbinical Hebrew) and to the present day (New Hebrew).

Before the rise of comparative philology it was a popular opinion that Hebrew was the original speech of mankind, from which all others were descended. This belief, derived from the Jews (cf. Pal. Targ. Gen. xi. 1), was supported by the etymologies and other data supplied by the early chapters of Genesis. But though Hebrew possesses a very old literature, it is not, as we know it, structurally as early as, *e.g.* Arabic, or, in other words, it does not come so near to that primitive Semitic speech which may be pre-supposed as the common parent of all the Semitic languages. Owing to the imperfection of the Hebrew alphabet, which, like that of most Semitic languages, has no means of expressing vowel-sounds, it is only partly possible to trace the development of the language. In its earliest form it was no doubt most closely allied to the Canaanite or Phoenician stock, to the language of Moab, as revealed by the stele of Mesha (*c.* 850 B.C.), and to Edomite. The vocalization of Canaanite, as far as it is known to us, *e.g.* from glosses in the Tell-el-Amarna tablets (15th century B.C.)[2] and much later from the Punic passages in the *Poenulus* of Plautus, differs in many respects from that of the Hebrew of the Old Testament, as also does the Septuagint transcription of proper names. The uniformity, however, of the Old Testament text is due to the labours of successive schools of grammarians who elaborated the Massorah (see Hebrew Literature), thereby obliterating local or dialectic differences, which undoubtedly existed, and establishing the pronunciation current in the synagogues about the 7th century A.D. The only mention of such differences in the Old Testament is in Judges xii. 6, where it is stated that the Ephraimites pronounced ש (sh) as ש or ס (s). In Neh. xiii. 24, the “speech of Ashdod” is more probably a distinct (Philistine) language. Certain peculiarities in the language of the Pentateuch (הוא for היא, נער for נערה), which used to be regarded as archaisms, are to be explained as purely orthographical.[3] In a series of writings, however, extending over so long a period as those of the Old Testament, some variation or development in language is to be expected apart from the natural differences between the poetic (or prophetic) and prose styles. The consonantal text sometimes betrays these in spite of the Massorah. In general, the later books of the Old Testament show, roughly speaking, a greater simplicity and uniformity of style, as well as a tendency to Aramaisms. For some centuries after the Exile, the people of Palestine must have been bilingual, speaking Aramaic

for ordinary purposes, but still at least understanding Hebrew. Not that they forgot their own tongue in the Captivity and learnt Aramaic in Babylon, as used to be supposed. In the western provinces of the Persian empire Aramaic was the official language, spoken not only in Palestine but in all the surrounding countries, even in Egypt and among Arab tribes such as the Nabateans. It is natural, therefore, that it should influence and finally supplant Hebrew in popular use, so that translations even of the Old Testament eventually appear in it (Targums). Meanwhile Hebrew did not become a dead language—indeed it can hardly be said ever to have died, since it has continued in use till the present day for the purposes of ordinary life among educated Jews in all parts of the world. It gradually became a literary rather than a popular tongue, as appears from the style of the later books of the Old Testament (Chron., Dan., Eccles.), and from the Hebrew text of Ecclesiasticus (*c.* 170 B.C.). During the 1st century B.C. and the 1st century A.D. we have no direct evidence of its characteristics. After that period there is a great development in the language of the Mishna. It was still living Hebrew, although mainly confined to the schools, with very clear differences from the biblical language. In the Old Testament the range of subjects was limited. In the Mishna it was very much extended. Matters relating to daily life had to be discussed, and words and phrases were adopted from what was no doubt the popular language of an earlier period. A great many foreign words were also introduced. The language being no longer familiar in the same sense as formerly, greater definiteness of expression became necessary in the written style. In order to avoid the uncertainty arising from the lack of vowels to distinguish forms consisting of the same consonants (for the vowel-points were not yet invented), the aramaising use of the reflexive conjugations (Hithpaʿel, Nithpaʿel) for the internal passives (Puʿal, Hophʿal) became common; particles were used to express the genitive and other relations, and in general there was an endeavour to avoid the obscurities of a purely consonantal writing. What is practically Mishnic Hebrew continued to be used in Midrash for some centuries. The language of both Talmuds, which, roughly speaking, were growing contemporaneously with Midrash, is a mixture of Hebrew and Aramaic (Eastern Aram. in the Babylonian, Western in the Jerusalem Talmud), as was also that of the earlier commentators. As the popular use of Aramaic was gradually restricted by the spread of Arabic as the vernacular (from the 7th century onwards), while the dispersion of the Jews became wider, biblical Hebrew again came to be the natural standard both of East and West. The cultivation of it is shown and was no doubt promoted by the many philological works (grammars, lexicons and masorah) which are extant from the 10th century onward. In Spain, under Moorish dominion, most of the important works of that period were composed in Arabic, and the influence of Arabic writers both on language and method may be seen in contemporaneous Hebrew compositions. No other vernacular (except, of course, Aramaic) ever had the same influence upon Hebrew, largely because no other bears so close a relation to it. At the present day in the East, and among learned Jews elsewhere, Hebrew is still cultivated conversationally, and it is widely used for literary purposes. Numerous works on all kinds of subjects are produced in various countries, periodicals flourish, and Hebrew is the vehicle of correspondence between Jews in all parts of the world. Naturally its quality varies with the ability and education of the writer. In the modern *pronunciation* the principal differences are between the Ashkenazim (German and Polish Jews) and the Sephardim (Spanish and Portuguese Jews), and concern not only the vowels but also certain consonants, and in some cases probably go back to early times. As regards *writing*, it is most likely that the oldest Hebrew records were preserved in some form of cuneiform script. The alphabet (see Writing) subsequently adopted is seen in its earliest form on the stele of Mesha, and has been retained, with modifications, by the Samaritans. According to Jewish tradition Ezra introduced the Assyrian character (כתב אשורי), a much-debated statement which no doubt means that the Aramaic hand in use in Babylonia was adopted by the Jews about the 5th century B.C. Another form of the same hand, allowing for differences of material, is found in Egyptian Aramaic papyri of the 5th
and 4th centuries B.C. From this were developed (*a*) the *square* character used in MSS. of 169
the Bible or important texts, and in most printed books, (*b*) the *Rabbinic* (or Rashi) character, used in commentaries and treatises of all kinds, both in MS. and in printed books, (*c*) the *Cursive* character, used in letters and for informal purposes, not as a rule printed. In the present state of Hebrew palaeography it is not possible to determine accurately the date of a MS., but it is easy to recognize the country in which it was written. The most clearly marked distinctions are between Spanish, French, German, Italian, Maghrebi, Greek, Syrian (including Egyptian), Yemenite, Persian and Qaraite hands. It is in the Rabbinic and Cursive characters that the differences are most noticeable. The Hebrew alphabet is also used, generally with the addition of some diacritical marks, by Jews to write other languages, chiefly Arabic, Spanish, Persian, Greek, Tatar (by Qaraites) and in later times German.

The philological study of Hebrew among the Jews is described below, under Hebrew

Literature, of which it formed an integral part. Among Christian scholars there was no independent school of Hebraists before the revival of learning. In the Greek and Latin Church the few fathers who, like Origen and Jerome, knew something of the language, were wholly dependent on their Jewish teachers, and their chief value for us is as depositaries of Jewish tradition. Similarly in the East, the Syriac version of the Old Testament is largely under the influence of the synagogue, and the homilies of Aphraates are a mine of Rabbinic lore. In the middle ages some knowledge of Hebrew was preserved in the Church by converted Jews and even by non-Jewish scholars, of whom the most notable were the Dominican controversialist Raymundus Martini (in his *Pugio fidei*) and the Franciscan Nicolaus of Lyra, on whom Luther drew largely in his interpretation of Scripture. But there was no tradition of Hebrew study apart from the Jews, and in the 15th century when an interest in the subject was awakened, only the most ardent zeal could conquer the obstacles that lay in the way. Orthodox Jews refused to teach those who were not of their faith, and on the other hand many churchmen conscientiously believed in the duty of entirely suppressing Jewish learning. Even books were to be had only with the greatest difficulty, at least north of the Alps. In Italy things were somewhat better. Jews expelled from Spain received favour from the popes. Study was facilitated by the use of the printing-press, and some of the earliest books printed were in Hebrew. The father of Hebrew study among Christians was the humanist Johann Reuchlin (1455-1522), the author of the *Rudimenta Hebraica* (Pforzheim, 1506), whose contest with the converted Jew Pfefferkorn and the Cologne obscurantists, established the claim of the new study to recognition by the Church. Interest in the subject spread rapidly. Among Reuchlin’s own pupils were Melanchthon, Oecolampadius and Cellarius, while Sebastian Münster in Heidelberg (afterwards professor at Basel), and Büchlein (Fagius) at Isny, Strasburg and Cambridge, were pupils of the liberal Jewish scholar Elias Levita. France drew teachers from Italy. Santes Pagninus of Lucca was at Lyons; and the trilingual college of Francis I. at Paris, with Vatablus and le Mercier, attracted, among other foreigners, Giustiniani, bishop of Nebbio, the editor of the Genoa psalter of 1516. In Rome the converted Jew Felix Pratensis taught under the patronage of Leo X., and did useful work in connexion with the great Bomberg Bibles. In Spain Hebrew learning was promoted by Cardinal Ximenes, the patron of the Complutensian Polyglot. The printers, as J. Froben at Basel and Etienne at Paris, also produced Hebrew books. For a time Christian scholars still leaned mainly on the Rabbis. But a more independent spirit soon arose, of which le Mercier in the 16th, and Drusius early in the 17th century, may be taken as representatives. In the 17th century too the cognate languages were studied by J. Selden, E. Castell (Heptaglott lexicon) and E. Pococke (Arabic) in England, Ludovicus de Dieu in Holland, S. Bochart in France, J. Ludolf (Ethiopic) and J. H. Hottinger (Syriac) in Germany, with advantage to the Hebrew grammar and lexicon. Rabbinic learning moreover was cultivated at Basel by the elder Buxtorf who was the author of grammatical works and a lexicon. With the rise of criticism Hebrew philology soon became a necessary department of theology. Cappellus (d. 1658) followed Levita in maintaining, against Buxtorf, the late introduction of the vowel-points, a controversy in which the authority of the massoretic text was concerned. He was supported by J. Morin and R. Simon in France. In the 18th century in Holland A. Schultens and N. W. Schroeder used the comparative method, with great success, relying mainly on Arabic. In Germany there was the meritorious J. D. Michaelis and in France the brilliant S. de Sacy. In the 19th century the greatest name among Hebraists is that of Gesenius, at Halle, whose shorter grammar (of Biblical Hebrew) first published in 1813, is still the standard work, thanks to the ability with which his pupil E. Rödiger and recently E. Kautzsch have revised and enlarged it. Important work was also done by G. H. A. Ewald, J. Olshausen and P. A. de Lagarde, not to mention later scholars who have utilized the valuable results of Assyriological research.

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Wörterbuch (Leipzig, 1876-1889); Jastrow, Dictionary of the Targumi, &c. (New York, 1886, &c.); Dalman, *Aramaisches neuhebräisches Wörterbuch* (Frankfort a. M., 1897); Kohut, *Aruch completum* (Vienna, 1878-1890) (in Hebrew) is valuable for the language of the Talmud.

(A. Cy.)

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1 In 2 Sam. xvii. 25 *Israelite* should be *Ishmaelite*, as in the parallel passage 1 Chron. ii. 17.

2 See Zimmern, in *Ztsch. für Assyriol.* (1891), p. 154.

3 See Gesenius-Kautzsch, *Hebr. Gram.* § 17 c.

HEBREW LITERATURE. Properly speaking, "Hebrew Literature" denotes all works written in the Hebrew language. In catalogues and bibliographies, however, the expression is now generally used, conveniently if incorrectly, as synonymous with Jewish literature, including all works written by Jews in Hebrew characters, whether the language be Aramaic, Arabic or even some vernacular not related to Hebrew.

Old Testament-Scriptures.

The literature begins with, as it is almost entirely based upon, the Old Testament. There were no doubt in the earliest times popular songs orally transmitted and perhaps books of annals and laws, but except in so far as remnants of them are embedded in the biblical books, they have entirely disappeared. Thus the Book of the Wars of the Lord is mentioned in Num. xxi. 14; the Book of Jashar in Josh. x. 13, 2. Sam. i. 18; the Song of the Well is quoted in Num. xxi. 17, 18, and the song of Sihon and Moab, ib. 27-30; of Lamech, Gen. iv. 23, 24; of Moses, Exod. xv. As in other literatures, these popular elements form the foundation on which greater works are gradually built, and it is one function of literary criticism to show the way in which the component parts were welded into a uniform whole. The traditional view that Moses was the author of the Pentateuch in its present form, would make this the earliest monument of Hebrew literature. Modern inquiry, however, has arrived at other conclusions (see Bible, *Old Testament*), which may be briefly summarized as follows: the Pentateuch is compiled from various documents, the earliest of which is denoted by J (beginning at Gen. ii. 4) from the fact that its author regularly uses the divine name Jehovah (Yahweh). Its date is now usually given as about 800 B.C.[1] In the next century the document E was composed, so called from its using Elohīm (God) instead of Yahweh. Both these documents are considered 170
to have originated in the Northern kingdom, Israel, where also in the 8th century appeared the prophets Amos and Hosea. To the same period belong the book of Micah, the earlier parts of the books of Samuel, of Isaiah and of Proverbs, and perhaps some Psalms. In 722 B.C. Samaria was taken and the Northern kingdom ceased to exist. Judah suffered also, and it is not until a century later that any important literary activity is again manifested. The main part of the book of Deuteronomy was "found" shortly before 621 B.C. and about the same time appeared the prophets Jeremiah and Zephaniah, and perhaps the book of Ruth. A few years later (about 600) the two Pentateuchal documents J and E were woven together, the books of Kings were compiled, the book of Habakkuk and parts of the Proverbs were written. Early in the next century Jerusalem was taken by Nebuchadrezzar, and the prophet Ezekiel was among the exiles with Jehoiachin. Somewhat later (*c.* 550) the combined document JE was edited by a writer under the influence of Deuteronomy, the later parts of the books of Samuel were written, parts of Isaiah, the books of Obadiah, Haggai, Zechariah and perhaps the later Proverbs. In the exile, but probably after 500 B.C., an important section of the Hexateuch, usually called the Priest's Code (P), was drawn up. At various times in the same century are to be placed the book of Job, the post-exilic parts of Isaiah, the books of Joel, Jonah, Malachi and the Song of Songs. The Pentateuch (or Hexateuch) was finally completed in its present form at some time before 400 B.C. The latest parts of the Old Testament are the books of Chronicles, Ezra and Nehemiah (*c.* 330 B.C.), Ecclesiastes and Esther (3rd century) and Daniel, composed either in the 3rd century or according to some views as late as the time of Antiochus Epiphanes (*c.* 168 B.C.). With regard to the date of the Psalms, internal evidence, from the nature of the case, leads to few results which are convincing. The most reasonable view seems to be that the collection was formed gradually and that the process was going on during most of the period sketched above.

It is not to be supposed that all the contents of the Old Testament were immediately accepted as sacred, or that they were ever all regarded as being on the same level. The

Apocryphal literature.

Torah, the Law delivered to Moses, held among the Jews of the 4th century B.C. as it holds now, a pre-eminent position. The inclusion of other books in the Canon was gradual, and was effected only after centuries of debate. The Jews have always been, however, an intensely literary people, and the books ultimately accepted as canonical were only a selection from the literature in existence at the beginning of the Christian era. The rejected books receiving little attention have mostly either been altogether lost or have survived only in translations, as in the case of the Apocrypha. Hence from the composition of the latest canonical books to the redaction of the Mishna (see below) in the 2nd century A.D., the remains of Hebrew literature are very scanty. Of books of this period which are known to have existed in Hebrew or Aramaic up to the time of Jerome (and even later) we now possess most of the original Hebrew text of Ben Sira (Ecclesiasticus) in a somewhat corrupt form, and fragments of an Aramaic text of a recension of the Testaments of the Twelve Patriarchs, both discovered within recent years. Besides definite works of this kind, there was also being formed during this period a large body of exegetical and legal material, for the most part orally transmitted, which only received its literary form much later. As Hebrew became less familiar to the people, a system of translating the text of the Law into the Aramaic vernacular verse by verse, was adopted in the synagogue. The beginnings of it are supposed to be indicated in Neh. viii. 8. The translation was no doubt originally extemporary, and varied with the individual translators, but its form gradually became fixed and was ultimately written down. It was called *Targum*, from the Aramaic *targem*, to translate. The earliest to be thus edited was the Targum of Onkelos (Onqelōs), the proselyte, on the Law. It received its final form in Babylonia probably in the 3rd century A.D. The Samaritan Targum, of about the same date, clearly rests on the same tradition. Parallel to Onkelos was another Targum on the Law, generally called pseudo-Jonathan, which was edited in the 7th century in Palestine, and is based on the same system of interpretation but is fuller and closer to the original tradition. There is also a fragmentary Targum (Palestinian) the relation of which to the others is obscure. It may be only a series of disconnected glosses on Onkelos. For the other books, the recognized Targum on the Prophets is that ascribed to Jonathan ben Uzziel (4th century?), which originated in Palestine, but was edited in Babylonia, so that it has the same history and linguistic character as Onkelos. Just as there is a Palestinian Targum on the Law parallel to the Babylonian Onkelos, so there is a Palestinian Targum (called *Yerushalmi*) on the Prophets parallel to that of Ben Uzziel, but of later date and incomplete. The Law and the Prophets being alone used in the services of the synagogue, there was no authorized version of the rest of the Canon. There are, however, Targumim on the Psalms and Job, composed in the 5th century, on Proverbs, resembling the Peshiṭṭā version, on the five Meghillōth, paraphrastic and agadic (see below) in character, and on Chronicles—all Palestinian. There is also a second Targum on Esther. There is none on Daniel, Ezra and Nehemiah.

Targum.

We must now return to the 2nd century. During the period which followed the later canonical books, not only was translation, and therefore exegesis, cultivated, but even more the amplification of the Law. According to Jewish teaching (*e.g.* Abhoth i. 1) Moses received on Mount Sinai not only the written Law as set down in the Pentateuch, but also the Oral Law, which he communicated personally to the 70 elders and through them by a "chain of tradition" to succeeding ages. The application of this oral law is called *Halakhah*, the rules by which a man's daily "walk" is regulated. The halakhah was by no means inferior in prestige to the written Law. Indeed some teachers even went so far as to ascribe a higher value to it, since it comes into closer relation with the details of everyday life. It was not independent of the written Law, still less could it be in opposition to it. Rather it was implicitly contained in the Torah, and the duty of the teacher was to show this. It was therefore of the first importance that the chain of tradition should be continuous and trustworthy. The line is traced through biblical teachers to Ezra, the first of the Sōpherīm or scribes, who handed on the charge to the "men of the Great Synagogue," a much-discussed term for a body or succession of teachers inaugurated by Ezra. The last member of it, Simon the Just (either Simon I., who died about 300 B.C., or Simon II., who died about 200 B.C.), was the first of the next series, called Elders, represented in the tradition by *pairs* of teachers, ending with Hillel and Shammai about the beginning of the Christian era. Their pupils form the starting-point of the next series, the Tannāīm (from Aram. *tenā* to teach), who occupy the first two centuries A.D.

Halakhah.

By this time the collection of halakhic material had become very large and various, and after several attempts had been made to reduce it to uniformity, a code of oral tradition was finally drawn up in the 2nd century by Judah ha-Nasī, called Rabbi *par excellence*. This was the Mishnah. Its name is derived from the Hebrew

Mishnah.

shanah, corresponding to the Aramaic *tenā*, and therefore a suitable name for a tannaitic work, meaning the *repetition* or *teaching* of the oral law. It is written in the Hebrew of the schools (*leshōn hakhamīm*) which differs in many respects from that of the Old Testament (see Hebrew Language). It is divided into six "orders," according to subject, and each order is subdivided into chapters. In making his selection of halakhōth, Rabbi used the earlier compilations, which are quoted as "words of Rabbi 'Aqība" or of R. Me'īr, but rejected much which was afterwards collected under the title of Tosefta (*addition*) and Baraita (*outside* the Mishnah).

Traditional teaching was, however, not confined to halakhah. As observed above, it was the duty of the teachers to show the connexion of practical rules with the written Law, the more so since the Sadducees rejected the authority of the oral law as such. Hence arises Midrash, *exposition*, from *darash* to "investigate" a scriptural passage. Of this halakhic Midrash we possess that on Exodus, called Mekhilta, that on Leviticus, called Sifra, and that on Numbers and Deuteronomy, called Sifrē. All of these were drawn up in the period of the Amorāīm, the order of teachers who succeeded the Tannāīm, from the close of the Mishnah to about A.D. 500. The term Midrash, however, more commonly implies *agada*, *i.e.* the homiletical exposition of the text, with illustrations designed to make it more attractive to the readers or hearers. Picturesque teaching of this kind was always popular, and specimens of it are familiar in the Gospel discourses. It began, as a method, with the Sōpherīm (though there are traces in the Old Testament itself), and was most developed among the Tannāīm and Amorāīm, rivalling even the study of halakhah. As the existing halakhōth were collected and edited in the Mishnah, so the much larger agadic material was gathered together and arranged in the Midrashīm. Apart from the agadic parts of the earlier Mekhilta, Sifra and Sifrē, the most important of these collections (which are anonymous) form a sort of continuous commentary on various books of the Bible. They were called *Rabbōth* (*great* Midrashīm) to distinguish them from preceding smaller collections. *Bereshīth Rabba*, on Genesis, and *Ēkhah Rabbatī*, on Lamentations, were probably edited in the 7th century. Of the same character and of about the same date are the *Pesīqta*, on the lessons for Sabbaths and feast-days, and *Wayyiqra R.* on Leviticus. A century perhaps later is the *Tanḥūma*, on the sections of the Pentateuch, and later still the *Pesīqta Rabbatī*, *Shemōth R.* (on Exodus), *Bemidhbar R.* (on Numbers), *Debharīm R.* (on Deuteronomy). There are also Midrashīm on the Canticle, Ruth, Ecclesiastes, Esther and the Psalms, belonging to this later period, the *Pirqē R. Eliezer*, of the 8th or 9th century, a sort of history of creation and of the patriarchs, and the *Tanna debē Eliyahū* (an ethical work of the 10th century but containing much that is old), besides a large number of minor compositions.[2] In general, these performed very much the same function as the lives of saints in the early and medieval church. Very important for the study of Midrashic literature are the *Yalqūṭ* (*gleaning*) *Shim'ōnī*, on the whole Bible, the *Yalqūṭ Mekhīrī*, on the Prophets, Psalms, Proverbs and Job, and the *Midrash ha-gadhōl*,[3] all of which are of uncertain but late date and preserve earlier material. The last, which is preserved in MSS. from Yemen, is especially valuable as representing an independent tradition.

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Meanwhile, if agadic exegesis was popular in the centuries following the redaction of the Mishna, the study of halakhah was by no means neglected. As the discussion of the Law led up to the compilation of the Mishnah, so the Mishnah itself became in turn the subject of further discussion. The material thus accumulated, both halakhic and agadic, forming a commentary on and amplification of the Mishnah, was eventually written down under the name of *Gemara* (from *gemar*, to learn completely), the two together forming the *Talmud* (properly "*instruction*"). The tradition, as in the case of the Targums, was again twofold; that which had grown up in the Palestinian Schools and that of Babylonia. The foundation, however, the Mishnah, was the same in both. Both works were due to the Amoraim and were completed by about A.D. 500, though the date at which they were actually committed to writing is very uncertain. It is probable that notes or selections were from time to time written down to help in teaching and learning the immense mass of material, in spite of the fact that even in Sherira's time (11th century) such aids to memory were not officially recognized. Both Talmuds are arranged according to the six orders of the Mishnah, but the discussion of the Mishnic text often wanders off into widely different topics. Neither is altogether complete. In the Palestinian Talmud (*Yerushalmī*) the gemara of the 5th order (*Qodashīm*) and of nearly all the 6th (*Ṭohōrōth*) is missing, besides smaller parts. In the Babylonian Talmud (*Babhlī*) there is no gemara to the smaller tractates of Order 1, and to parts of ii., iv., v., vi. The language of both gemaras is in the main the Aramaic vernacular (western Aramaic in Yerushalmī, eastern in Babhlī), but early halakhic traditions (*e.g.* of Tannaitic origin) are given in their original form, and the

Talmud.

discussion of them is usually also in Hebrew. Babhlī is not only greater in bulk than Yerushalmī, but has also received far greater attention, so that the name Talmud alone is often used for it. As being a constant object of study numerous commentaries have been written on the Talmud from the earliest times till the present. The most important of them for the understanding of the gemara (Babhlī) is that of Rashi[4] (Solomon ben Isaac, d. 1104) with the Tōsafōth (*additions*, not to be confused with the Tosefta) chiefly by the French school of rabbis following Rashi. These are always printed in the editions on the same page as the Mishnah and Gemara, the whole, with various other matter, filling generally about 12 folio volumes. Since the introduction of printing, the Talmud is always cited by the number of the leaf in the first edition (Venice, 1520, &c.), to which all subsequent editions conform. In order to facilitate the practical study of the Talmud, it was natural that abridgements of it should be made. Two of these may be mentioned which are usually found in the larger editions: that by Isaac Alfasī (*i.e.* of Fez) in the 11th century, often cited in the Jewish manner as *Rif*; and that by Asher ben Yeḥīel (d. 1328) of Toledo, usually cited as *Rabbenū Asher*. The object of both was to collect all halakhōth having a practical importance, omitting all those which owing to circumstances no longer possess more than an academic interest, and excluding the discussions on them and all agada. Both add notes and explanations of their own, and both have in turn formed the text of commentaries.

Masorah.

With the Talmud, the anonymous period of Hebrew literature may be considered to end. Henceforward important works are produced not by schools but by particular teachers, who, however, no doubt often represent the opinions of a school. There are two branches of work which partake of both characters, the Masorah and the Liturgy. The name Masorah (Massorah) is usually derived from *masar*, to hand on, and explained as “tradition.” According to others[5] it is the word found in Ezek. xx. 37, meaning a “fetter.” Its object was to fix the biblical text unalterably. It is generally divided into the Great and the Small Masorah, forming together an *apparatus criticus* which grew up gradually in the course of centuries and now accompanies the text in most MSS. and printed editions to a greater or less extent. There are also separate masoretic treatises. Some system of the kind was necessary to guard against corruptions of copyists, while the care bestowed upon it no doubt reacted so as to enhance the sanctity ascribed to the text. Many apparent puerilities, such as the counting of letters and the marking of the middle point of books, had a practical use in enabling copyists of MSS. to determine the amount of work done. The registration of anomalies, such as the suspended letters, inverted *nūns* and larger letters, enabled any one to test the accuracy of a copy. But the work of the Masoretes was much greater than this. Their long lists of the occurrences of words and forms fixed with accuracy the present (Masoretic) text, which they had produced, and were invaluable to subsequent lexicographers, while their system of vowel-points and accents not only gives us the pronunciation and manner of reading traditional about the 7th century A.D., but frequently serves also the purpose of an explanatory commentary. (See further under Bible.) Most of the Masorah is anonymous, including the *Massekheth Sōferīm* (of various dates from perhaps the 6th to the 9th century) and the *Okhlah we-Okhlah*, but when the period of anonymous literature ceases, there appear (in the 10th century) Ben Asher of Tiberias, the greatest authority on the subject, and his opponent Ben Naphthali. Later on, Jacob ben 172
Ḥayyīm arranged the Masorah for the great Bomberg Bible of 1524. Elias Levita’s *Massoreth ha-Massoreth* (1538) and Buxtorf’s *Tiberias* (1620) are also important.

Liturgy.

We must now turn back to a most difficult subject—the growth of the Liturgy. We are not concerned here with indications of the ritual used in the Temple. Of the prayer-book as it is at present, the earliest parts are the Shema‘ (Deut. vi. 4, &c.) and the anonymous blessings commonly called Shemoneh ‘Esreh (the Eighteen), together with certain Psalms. (Readings from the Law and the Prophets [Haphṭarah] also formed part of the service.) To this framework were fitted, from time to time, various prayers, and, for festivals especially, numerous hymns. The earliest existing codification of the prayer-book is the *Siddūr* (*order*) drawn up by Amram Gaon of Sura about 850. Half a century later the famous Gaon Seadiah, also of Sura, issued his *Siddūr*, in which the rubrical matter is in Arabic. Besides the *Siddūr*, or order for Sabbaths and general use, there is the *Maḥzōr* (*cycle*) for festivals and fasts. In both there are ritual differences according to the Sephardic (Spanish), Ashkenazic (German-Polish), Roman (Greek and South Italian) and some minor uses, in the later additions to the Liturgy. The Maḥzor of each rite is also distinguished by hymns (*piyyūṭīm*) composed by authors (*payyeṭanīm*) of the district. The most important writers are Yoseh ben Yoseh, probably in the 6th century, chiefly known for his compositions for the day of Atonement, Eleazar Qalīr, the founder of the payyetanic style, perhaps in the 7th century, Seadiah, and the Spanish school consisting of Joseph ibn Abitur (died in 970), Ibn Gabirol, Isaac Gayyath, Moses ben Ezra, Abraham ben Ezra and

Judah ha-levi, who will be mentioned below; later, Moses ben Naḥman and Isaac Luria the Kabbalist.[6]

The order of the Amoraim, which ended with the close of the Talmud (A.D. 500), was succeeded by that of the Sabōrāīm, who merely continued and explained the work of their predecessors, and these again were followed by the Geōnīm, the heads of the schools of Sura and Pumbeditha in Babylonia. The office of Gaōn lasted for something over 400 years, beginning about A.D. 600, and varied in importance according to the ability of the holders of it. Individual Geōnīm produced valuable works (of which later), but what is perhaps most important from the point of view of the development of Judaism is the literature of their Responsa or answers to questions, chiefly on halakhic matters, addressed to them from various countries. Some of these were actual decisions of particular Geōnīm; others were an official summary of the discussion of the subject by the members of the School. They begin with Mar Rab Sheshna (7th century) and continue to Hai Gaon, who died in 1038, and are full of historical and literary interest.[7] The She’iltōth (*questions*) of Rab Aḥai (8th century) also belong probably to the school of Pumbeditha, though their author was not Gaon. Besides the Responsa, but closely related to them, we have the lesser Halakhōth of Yehūdai Gaon of Sura (8th century) and the great Halakhōth of Simeon Qayyara of Sura (not Gaon) in the 9th century. In a different department there is the first Talmud lexicon (*‘Arūkh*) now lost, by Ẓemaḥ ben Palṭoi, Gaon of Pumbeditha in the 9th century. The *Siddūr* of Amram ben Sheshna has been already mentioned. All these writers, however, are entirely eclipsed by the commanding personality of the most famous of the Geōnīm, Seadiah ben Joseph (*q.v.*) of Sura, often called al-Fayyūmī (of the Fayum in Egypt), one of the greatest representatives of Jewish learning of all times, who died in 942. The last three holders of the office were also distinguished. Sherira of Pumbeditha (d. 998) was the author of the famous “Letter” (in the form of a Responsum to a question addressed to him by residents in Kairawan), an historical document of the highest value and the foundation of our knowledge of the history of tradition. His son Hai, last Gaon of Pumbeditha (d. 1038), a man of wide learning, wrote (partly in Arabic) not only numerous Responsa, but also treatises on law, commentaries on the Mishnah and the Bible, a lexicon called in Arabic *al-Ḥāwī*, and poems such as the *Mūsar Haskel*, but most of them are now lost or known only from translations or quotations. Though his teaching was largely directed against superstition, he seems to have been inclined to mysticism, and perhaps for this reason various kabbalistic works were ascribed to him in later times. His father-in-law Samuel ben Ḥophni, last Gaon of Sura (d. 1034), was a voluminous writer on law, translated the Pentateuch into Arabic, commented on much of the Bible, and composed an Arabic introduction to the Talmud, of which the existing Hebrew introduction (by Samuel the Nagid) is perhaps a translation. Most of his works are now lost.

The Geōnīm.

In the Geonic period there came into prominence the sect of the Karaites (*Benē miqrā*), “followers of the Scripture”, the protestants of Judaism, who rejected rabbinical authority, basing their doctrine and practice exclusively on the Bible. The sect was founded by ‘Anan in the 8th century, and, after many vicissitudes, still exists. Their literature, with which alone we are here concerned, is largely polemical and to a great extent deals with grammar and exegesis. Of their first important authors, Benjamin al-Nehawendi and Daniel al-Qūmisī (both in the 9th century), little is preserved. In the 10th century Jacob al-Qirqisanī wrote his *Kitāb al-anwār*, on law, Solomon ben Yeruḥam (against Seadiah) and Yefet ben ‘Alī wrote exegetical works; in the 11th century Abū’l-faraj Furqān, exegesis, and Yūsuf al-Baṣīr against Samuel ben Ḥophni. Most of these wrote in Arabic. In the 12th century and in S. Europe, Judah Hadassi composed his *Eshkol ha-Kōpher*, a great theological compendium in the form of a commentary on the Decalogue. Other writers are Aaron (the elder) ben Joseph, 13th century, who wrote the commentary *Sepher ha-mibhḥar*; Aaron (the younger) of Nicomedia (14th century), author of *‘Eẓ Ḥayyīm*, on philosophy, *Gan ‘Eden*, on law, and the commentary *Kether Tōrah*; in the 15th century Elijah Bashyaẓī, on law (*Addereth Eliyahū*), and Caleb Efendipoulo, poet and theologian; in the 16th century Moses Bashyaẓī, theologian. From the 12th century onward the sect gradually declined, being ultimately restricted mainly to the Crimea and Lithuania, learning disappeared and their literature became merely popular and of little interest. Much of it in later times was written in a curious Tatar dialect. Mention need only be made further of Isaac of Troki, whose anti-Christian polemic *Ḥizzūq Emūnah* (1593) was translated into English by Moses Mocatta under the title of *Faith Strengthened* (1851); Solomon of Troki, whose *Appiryōn*, an account of Karaism, was written at the request of Pufendorf (about 1700); and Abraham Firkovich, who, in spite of his impostures, did much for the literature of his people about the middle of the 19th century. (See also Qaraites.)

The Karaites.

To return to the period of the Geōnīm. While the schools of Babylonia were flourishing as the religious head of Judaism, the West, and especially Spain under Moorish rule, was becoming the home of Jewish scholarship. On the breaking up of the schools many of the fugitives fled to the West and helped to promote rabbinical learning there. The communities of Fez, Kairawan and N. Africa were in close relation with those of Spain, and as early as the beginning of the 9th century Judah ben Quraish of Tahort had composed his *Risālah* (*letter*) to the Jews of Fez on grammatical subjects from a comparative point of view, and a dictionary now lost. His work was used in the 10th century by Menahem ben Sarūq, of Cordova, in his *Mahbereth* (dictionary). Menahem's system of bi-literal and uni-literal roots was violently attacked by Dūnash ibn Labrāṭ, and as violently defended by the author's pupils. Among these was Judah Ḥayyūj of Cordova, the father of modern Hebrew grammar, who first established the principle of tri-literal roots. His treatises on the verbs, written in Arabic, were translated into Hebrew by Moses Giqatilla (11th century), himself a considerable grammarian and commentator, and by Ibn Ezra. His system was adopted by Abū'l-walīd ibn Jannāḥ, of Saragossa (died early in the 11th century), in his lexicon (*Kitāb al-uṣūl*, in Arabic) and other works. In Italy appeared the invaluable Talmud-lexicon (*'Arūkh*) by Nathan b. Yehiel, of Rome (d. 1106), who was indirectly indebted to Babylonian teaching. He does not strictly follow the system of Ḥayyūj. Other works of a different kind also originated in Italy about this time: the very popular history of the Jews, called *Josippon* (probably of the 10th or even 9th century), ascribed to Joseph ben Gōriōn (Gorionides)[8]; the medical treatises of Shabbethai Donnolo (10th century) and his commentary on the *Sepher Yeẓīrah*, the anonymous and earliest Hebrew kabbalistic work ascribed to the patriarch Abraham. In North Africa, probably in the 9th century, appeared the book known under the name of *Eldad ha-Danī*, giving an account of the ten tribes, from which much medieval legend was derived;[9] and in Kairawan the medical and philosophical treatises of Isaac Israeli, who died in 932. 173

Medieval scholarship.

The aim of the grammatical studies of the Spanish school was ultimately exegesis. This had already been cultivated in the East. In the 9th century Ḥīvī of Balkh wrote a rationalistic treatise[10] on difficulties in the Bible, which was refuted by Seadiah. The commentaries of the Geonim have been mentioned above. The impulse to similar work in the West came also from Babylonia. In the 10th century Ḥushīel, one of four prisoners, perhaps from Babylonia, though that is doubtful, was ransomed and settled at Kairawan, where he acquired great reputation as a Talmudist. His son Hananeel (d. 1050) wrote a commentary on (probably all) the Talmud, and one now lost on the Pentateuch. Hananeel's contemporary Nissīm ben Jacob, of Kairawan, who corresponded with Hai Gaon of Pumbeditha as well as with Samuel the Nagīd in Spain, likewise wrote on the Talmud, and is probably the author of a collection of *Ma'asiyyōth* or edifying stories, besides works now lost. The activity in North Africa reacted on Spain. There the most prominent figure was that of Samuel ibn Nagdela (or Nagrela), generally known as Samuel the Nagīd or head of the Jewish settlement, who died in 1055. As vizier to the Moorish king at Granada, he was not only a patron of learning, but himself a man of wide knowledge and a considerable author. Some of his poems are extant, and an Introduction to the Talmud mentioned above. In grammar he followed Ḥayyūj, whose pupil he was. Among others he was the patron of Solomon ibn Gabirol (*q.v.*), the poet and philosopher. To this period belong Ḥafẓ al-Qūṭī (the Goth?) who made a version of the Psalms in Arabic rhyme, and Baḥya (more correctly Beḥai) ibn Paqūda, dayyan at Saragossa, whose Arabic ethical treatise has always had great popularity among the Jews in its Hebrew translation, *Ḥōbhōth ha-lebhabhōth*. He also composed liturgical poems. At the end of the 11th century Judah ibn Bal'am wrote grammatical works and commentaries (on the Pentateuch, Isaiah, &c.) in Arabic; the liturgist Isaac Gayyath (d. in 1089 at Cordova) wrote on ritual. Moses Giqatilla has been already mentioned.

Exegesis.

The French school of the 11th century was hardly less important. Gershom ben Judah, the "Light of the Exile" (d. in 1040 at Mainz), a famous Talmudist and commentator, his pupil Jacob ben Yaqar, and Moses of Narbonne, called ha-Darshan, the "Exegete," were the forerunners of the greatest of all Jewish commentators, Solomon ben Isaac (Rashi), who died at Troyes in 1105. Rashi was a pupil of Jacob ben Yaqar, and studied at Worms and Mainz. Unlike his contemporaries in Spain, he seems to have confined himself wholly to Jewish learning, and to have known nothing of Arabic or other languages except his native French. Yet no commentator is more valuable or indeed more voluminous, and for the study of the Talmud he is even now indispensable. He commented on all the Bible and on nearly all the Talmud, has been himself the text of several super-commentaries, and has exercised great influence on Christian exegesis. The biblical commentary was translated into Latin by Breithaupt (Gotha, 1710-1714), that on the

Rashi.

Pentateuch rather freely into German by L. Dukes (Prag, 1838, in Hebrew-German characters, with the text), and parts by others. Closely connected with Rashi, or of his school, are Joseph Qara, of Troyes (d. about 1130), the commentator, and his teacher Menahem ben Ḥelbō, Jacob ben Me’īr, called Rabbenū Tam (d. 1171), the most important of the Tosaphists (*v. sup.*), and later in the 12th century the liberal and rationalizing Joseph Bekhōr Shōr, and Samuel ben Me’īr (d. about 1174) of Ramerupt, commentator and Talmudist.

In the 12th and 13th centuries literature maintained a high level in Spain. Abraham bar Ḥiyya, known to Christian scholars as Abraham Judaeus (d. about 1136), was a mathematician, astronomer and philosopher much studied in the middle ages. Moses ben Ezra, of Granada (d. about 1140), wrote in Arabic a philosophical work based on Greek and Arabic as well as Jewish authorities, known by the name of the Hebrew translation as *‘Arūgath ha-bosem*, and the *Kitāb al-Maḥaḍarah*, of great value for literary history. He is even better known as a poet, for his *Dīwān* and the *‘Anaq*, and as a hymn-writer. His relative Abraham ben Ezra, generally called simply Ibn Ezra,[11] was still more distinguished. He was born at Toledo, spent most of his life in travel, wandering even to England and to the East, and died in 1167. Yet he contrived to write his great commentary on the Pentateuch and other books of the Bible, treatises on philosophy (as the *Yesōdh mōra*), astronomy, mathematics, grammar (translation of Ḥayyūj), besides a Dīwān. The man, however, who shares with Ibn Gabirol the first place in Jewish poetry is Judah Ha-levi, of Toledo, who died in Jerusalem about 1140. His poems, both secular and religious, contained in his Dīwān and scattered in the liturgy, are all in Hebrew, though he employed Arabic metres. In Arabic he wrote his philosophical work, called in the Hebrew translation *Sepher ha-Kūzarī*, a defence of revelation as against non-Jewish philosophy and Qaraite doctrine. It shows considerable knowledge of Greek and Arabic thought (Avicenna). Joseph ibn Mīgāsh (d. 1141 at Lucena), a friend of Judah Ha-levi and of Moses ben Ezra, wrote Responsa and Ḥiddūshīn (*annotations*) on parts of the Talmud. In another sphere mention must be made of the travellers Benjamin of Tudela (d. after 1173), whose Massa’ōth are of great value for the history and geography of his time, and (though not belonging to Spain) Pethahiah, of Regensburg (d. about 1190), who wrote short notes of his journeys. Abraham ben David, of Toledo (d. about 1180), in philosophy an Aristotelian (through Avicenna) and the precursor of Maimonides, is chiefly known for his *Sepher ha-qabbalah*, written as a polemic against Karaism, but valuable for the history of tradition.

Maimonides.

The greatest of all medieval Jewish scholars was Moses ben Maimōn (Rambam), called *Maimonides* by Christians. He was born at Cordova in 1135, fled with his parents from persecution in 1148, settled at Fez in 1160, passing there for a Moslem, fled again to Jerusalem in 1165, and finally went to Cairo where he died in 1204. He was distinguished in his profession as a physician, and wrote a number of medical works in Arabic (including a commentary on the aphorisms of Hippocrates), all of which were translated into Hebrew, and most of them into Latin, becoming the textbooks of Europe in the succeeding centuries. But his fame rests mainly on his theological works. Passing over the less important, these are the *Mōreh Nebhūkhīm* (so the Hebrew translation of the Arabic original), an endeavour to show philosophically the reasonableness of the faith, parts of which, translated into Latin, were studied by the Christian schoolmen, and the *Mishneh Tōrah*, also called *Yad haḥazaqah* (14 = יד, the number of the parts), a classified compendium of the Law, written in Hebrew and early translated into Arabic. The latter of these, though generally accepted in the East, was much opposed in the West, especially at the time by the Talmudist Abraham ben David of Posquières (d. 1198). Maimonides also wrote an Arabic commentary on the Mishnah, soon afterwards translated into Hebrew, commentaries on parts of the Talmud (now lost), and a treatise on Logic. His breadth of view and his Aristotelianism were a stumbling-block to the orthodox, and subsequent teachers may be mostly classified as Maimonists or anti-Maimonists. Even his friend Joseph ibn ‘Aqnīn (d. 1226), author of a philosophical treatise in Arabic and of a commentary on the Song of Solomon, found so much difficulty in the new views that the *Mōreh Nebhūkhīm* was written in order to convince him. Maimonides’ son Abraham (d. 1234), also a great Talmudist, wrote in Arabic *Ma‘aseh Yerūshalmī*, on oaths, and *Kitāb al-Kifāyah*, theology. His grandson David was also an author. A very different person was Moses ben Naḥman (Ramban) or Nahmanides, who was born at Gerona in 1194 and died in Palestine about 1270. His whole tendency was as conservative as that of Maimonides was liberal, and like all conservatives he may be said to represent a lost though not necessarily a less desirable cause. Much of his life was spent in controversy, not only with Christians (in 1293 before the king of Aragon), but also with his own people and on the

Maimonists and anti-Maimonists.

views of the time. His greatest work is the commentary on the Pentateuch in opposition to Maimonides and Ibn Ezra. He had a strong inclination to mysticism, but whether certain kabbalistic works are rightly attributed to him is doubtful. It is, however, not a mere coincidence that the two great kabbalistic textbooks, the *Bahir* and the *Zohar* (both meaning "brightness"), appear first in the 13th century. If not due to his teaching they are at least in sympathy with it. The *Bahir*, a sort of outline of the *Zohar*, and traditionally ascribed to Neḥunya (1st century), is believed by some to be the work of Isaac the Blind ben Abraham of Posquières (d. early in the 13th century), the founder of the modern Kabbalah and the author of the names for the 10 Sephīrōth. The *Zohar*, supposed to be by Simeon ben Yoḥai (2nd century), is now generally attributed to Moses of Leon (d. 1305), who, however, drew his material in part from earlier written or traditional sources, such as the Sepher Yeẓīrah. At any rate the work was immediately accepted by the kabbalists, and has formed the basis of all subsequent study of the subject. Though put into the form of a commentary on the Pentateuch, it is really an exposition of the kabbalistic view of the universe, and incidentally shows considerable acquaintance with the natural science of the time. A pupil, though not a follower of Nahmanides, was Solomon Adreth (not Addereth), of Barcelona (d. 1310), a prolific writer of Talmudic and polemical works (against the Kabbalists and Mahommedans) as well as of responsa. He was opposed by Abraham Abulafia (d. about 1291) and his pupil Joseph Giqatilla (d. about 1305), the author of numerous kabbalistic works. Solomon's pupil Baḥya ben Asher, of Saragossa (d. 1340) was the author of a very popular commentary on the Pentateuch and of religious discourses entitled *Kad ha-qemaḥ*, in both of which, unlike his teacher, he made large use of the Kabbalah. Other studies, however, were not neglected. In the first half of the 13th century, Abraham ibn Ḥasdai, a vigorous supporter of Maimonides, translated (or adapted) a large number of philosophical works from Arabic, among them being the *Sepher ha-tappūaḥ*, based on Aristotle's *de Anima*, and the *Mōzenē Ẓedeq* of Ghazzali on moral philosophy, of both of which the originals are lost. Another Maimonist was Shem Ṭōbh ben Joseph Falaquera (d. after 1290), philosopher (following Averroes), poet and author of a commentary on the Mōreh. A curious mixture of mysticism and Aristotelianism is seen in Isaac Aboab (about 1300), whose *Menorath ha-Ma'ōr*, a collection of agadōth, attained great popularity and has been frequently printed and translated. Somewhat earlier in the 13th century lived Judah al-Ḥarīzī, who belongs in spirit to the time of Ibn Gabirol and Judah ha-levi. He wrote numerous translations, of Galen, Aristotle, Ḥarīrī, Ḥunain ben Isaac and Maimonides, as well as several original works, a *Sepher 'Anaq* in imitation of Moses ben Ezra, and treatises on grammar and medicine (*Rephūath geviyyah*), but he is best known for his *Taḥkemōnī*, a diwan in the style of Ḥarīrī's *Maqāmāt*.

Meanwhile the literary activity of the Jews in Spain had its effect on those of France. The fact that many of the most important works were written in Arabic, the vernacular of the Spanish Jews under the Moors, which was not understood in France, gave rise to a number of translations into Hebrew, chiefly by the family of Ibn Tibbōn (or Tabbōn). The first of them, Judah ibn Tibbōn, translated works of Baḥya ibn Paqūdah, Judah ha-levi, Seadiah, Abū'lwalīd and Ibn Gabirol, besides writing works of his own. He was a native of Granada, but migrated to Lunel, where he probably died about 1190. His son Samuel, who died at Marseilles about 1230, was equally prolific. He translated the *Mōreh Nebhūkhīm* during the life of the author, and with some help from him, so that this may be regarded as the authorized version; Maimonides' commentary on the Mishnah tractate *Pirqē Abhōth*, and some minor works; treatises of Averroes and other Arabic authors. His original works are mostly biblical commentaries and some additional matter on the Mōreh. His son Moses, who died about the end of the 13th century, translated the rest of Maimonides, much of Averroes, the lesser Canon of Avicenna, Euclid's *Elements* (from the Arabic version), Ibn al-Jazzār's *Viaticum*, medical works of Ḥunain ben Isaac (Johannitius) and Razi (Rhazes), besides works of less-known Arabic authors. His original works are commentaries and perhaps a treatise on immortality. His nephew Jacob ben Makhīr, of Montpellier (d. about 1304), translated Arabic scientific works, such as parts of Averroes and Ghazzali, Arabic versions from the Greek, as Euclid's *Data*, Autolycus, Menelaus (מיליום) and Theodosius on the Sphere, and Ptolemy's *Almagest*. He also compiled astronomical tables and a treatise on the quadrant. The great importance of these translations is that many of them were afterwards rendered into Latin,[12] thus making Arabic and, through it, Greek learning accessible to medieval Europe. Another important family about this time is that of Qimḥi (or Qamḥi). It also originated in Spain, where Joseph ben Isaac Qimḥi was born, who migrated to S. France, probably for the same reason which caused the flight of Maimonides, and died there about 1170. He wrote on grammar (*Sepher ha-galui* and *Sepher Zikkaron*), commentaries on Proverbs and the Song of Solomon, an apologetic work, *Sepher ha-berīth*, and a translation of Baḥya's *Ḥōbhōth ha-lebhabhōth*. His son Moses (d. about 1190) also

wrote on grammar and some commentaries, wrongly attributed to Ibn Ezra. A younger son, David (Radaq) of Narbonne (d. 1235) is the most famous of the name. His great work, the *Mikhlōl*, consists of a grammar and lexicon; his commentaries on various parts of the Bible are admirably luminous, and, in spite of his anti-Christian remarks, have been widely used by Christian theologians and largely influenced the English authorized version of the Bible. A friend of Joseph Qimḥi, Jacob ben Me’īr, known as Rabbenū Tam of Ramerupt (d. 1171), the grandson of Rashi, wrote the *Sepher ha-yashar* (ḥiddūshīn and responsa) and was one of the chief Tosaphists. Of the same school were Menahem ben Simeon of Posquières, a commentator, who died about the end of the 12th century, and Moses ben Jacob of Coucy (13th century), author of the *Semag* (book of precepts, positive and negative) a very popular and valuable halakhic work. A younger contemporary of David Qimḥi was Abraham ben Isaac Bedersi (*i.e.* of Béziers), the poet, and some time in the 13th century lived Joseph Ezobhi of Perpignan, whose ethical poem, *Qe‘arath Yōseph*, was translated by Reuchlin and later by others. Berachiah,[13] the compiler of the “Fox Fables” (which have much in common with the “Ysopet” of Marie de France), is generally thought to have lived in Provence in the 13th century, but according to others in England in the 12th century. In Germany, Eleazar ben Judah of Worms (d. 1238), besides being a Talmudist, was an earnest promoter of 175
kabbalistic studies. Isaac ben Moses (d. about 1270), who had studied in France, wrote the famous *Or Zarūa‘* (from which he is often called), an halakhic work somewhat resembling Maimonides’ *Mishneh Tōrah*, but more diffuse. In the course of his wanderings he settled for a time at Würzburg, where he had as a pupil Me’īr of Rothenburg (d. 1293). The latter was a prolific writer of great influence, chiefly known for his Responsa, but also for his halakhic treatises, ḥiddūshīn and tōsaphōth. He also composed a number of piyyūṭīm. Me’īr’s pupil, Mordecai ben Hillel of Nürnberg (d. 1298), had an even greater influence through his halakhic work, usually known as the *Mordekhai*. This is a codification of halakhōth, based on all the authorities then known, some of them now lost. Owing to the fact that the material collected by Mordecai was left to his pupils to arrange, the work was current in two recensions, an Eastern (in Austria) and a Western (in Germany, France, &c.). In the East, Tanḥūm ben Joseph of Jerusalem was the author of commentaries (not to be confounded with the *Midrash Tanḥūmā*) on many books of the Bible, and of an extensive lexicon (*Kitāb al-Murshid*) to the Mishnah, all in Arabic.

With the 13th century Hebrew literature may be said to have reached the limit of its development. Later writers to a large extent used over again the materials of their predecessors, while secular works tend to be influenced by the surrounding civilization, or even are composed in the vernacular languages. From the 14th century onward only the most notable names can be mentioned. In Italy Immanuel ben Solomon, of Rome (d. about 1330), perhaps the friend and certainly the imitator of Dante, wrote his diwan, of which the last part, “Topheth ve-‘Eden,” is suggested by the *Divina Commedia*. In Spain Israel Israeli, of Toledo (d. 1326), was a translator and the author of an Arabic work on ritual and a commentary on *Pirqē Abhōth*. About the same time Isaac Israeli wrote his *Yesōdh ‘Olam* and other astronomical works which were much studied. Asher ben Jehiel, a pupil of Me’īr of Rothenburg, was the author of the popular Talmudic compendium, generally quoted as *Rabbenu Asher*, on the lines of Alfasi, besides other halakhic works. He migrated from Germany and settled at Toledo, where he died in 1328. His son Jacob, of Toledo (d. 1340), was the author of the *Tūr* (or the four Ṭūrīm), a most important manual of Jewish law, serving as an abridgement of the *Mishneh Tōrah* brought up to date. His pupil David Abudrahim, of Seville (d. after 1340), wrote a commentary on the liturgy. Both the 14th and 15th centuries in Spain were largely taken up with controversy, as by Isaac ibn Pulgar (about 1350), and Shem Ṭōbh ibn Shaprūṭ (about 1380), who translated St Matthew’s gospel into Hebrew. In France Jedaiah Bedersi, *i.e.* of Béziers (d. about 1340), wrote poems (*Beḥīnath ha-‘ōlam*), commentaries on agada and a defence of Maimonides against Solomon Adreth. Levi ben Gershom (d. 1344), called Ralbag, the great commentator on the Bible and Talmud, in philosophy a follower of Aristotle and Averroes, known to Christians as Leo Hebraeus, wrote also many works on halakhah, mathematics and astronomy. Joseph Kaspī, *i.e.* of Largentière (d. 1340), wrote a large number of treatises on grammar and philosophy (mystical), besides commentaries and piyyūṭim. In the first half of the 14th century lived the two translators Qalonymos ben David and Qalonymos ben Qalonymos, the latter of whom translated many works of Galen and Averroes, and various scientific treatises, besides writing original works, *e.g.* one against Kaspī, and an ethical work entitled *Eben Bōḥan*. At the end of the century Isaac ben Moses, called Profiat Duran (Efodi), is chiefly known as an anti-Christian controversialist (letter to Me’īr Alguadez), but also wrote on grammar (*Ma‘aseh Efod*) and a commentary on the Mōreh. In philosophy he was an Aristotelian. About the same time in Spain controversy was very active. Ḥasdai Crescas (d. 1410) wrote against Christianity and in his *Or Adōnai* against the Aristotelianism of the Maimonists. His pupil Joseph Albo in his *ʿIqqarīm* had the same two objects. On the side of the Maimonists was Simeon Duran (d. at Algiers 1444) in his *Magen Abhōth* and in his numerous commentaries. Shem Ṭōbh ibn Shem Ṭōbh, the kabbalist, was a strong anti-Maimonist, as was his son Joseph of Castile (d. 1480), a commentator with kabbalistic tendencies but versed in Aristotle, Averroes and Christian doctrine. Joseph’s son Shem Ṭōbh was, on the contrary, a follower of Maimonides and the Aristotelians. In other subjects, Saadyah ibn Danān, of Granada (d. at Oran after 1473), is chiefly important for his grammar and lexicon, in Arabic; Judah ibn Verga, of Seville (d. after 1480), was a mathematician and astronomer; Solomon ibn Verga, somewhat later, wrote *Shebeṭ Yehūdah*, of doubtful value historically; Abraham Zakkuth or Zakkuto, of Salamanca (d. after 1510), astronomer, wrote the *Sepher Yuḥasīn*, an historical work of importance. In Italy, Obadiah Bertinoro (d. about 1500) compiled his very useful commentary on the Mishnah, based on those of Rashi and Maimonides. His account of his travels and his letters are also of great interest. Isaac Abravanel (d. 1508) wrote commentaries (not of the first rank) on the Pentateuch and Prophets and on the Mōreh, philosophical treatises and apologetics, such as the *Yeshūʿoth Meshīḥō*, all of which had considerable influence. Elijah Delmedigo, of Crete (d. 1497), a strong opponent of Kabbalah, was the author of the philosophical treatise *Beḥīnath ha-dath*, but most of his work (on Averroes) was in Latin.

Later writers.

The introduction of printing (first dated Hebrew printed book, Rashi, Reggio, 1475) gave occasion for a number of scholarly compositors and proof-readers, some of whom were also authors, such as Jacob ben Ḥayyīm of Tunis (d. about 1530), proof-reader to Bomberg, chiefly known for his masoretic work in connexion with the Rabbinic Bible and his introduction to it; Elias Levita, of Venice (d. 1549), also proof-reader to Bomberg, author of the *Massoreth ha-Massoreth* and other works on grammar and lexicography; and Cornelius Adelkind, who however was not an author. In the East, Joseph Karo (Qārō) wrote his *Bēth Yōseph* (Venice, 1550), a commentary on the *Ṭūr*, and his *Shulḥan ʿArūkh* (Venice, 1564) an halakhic work like the *Ṭūr*, which is still a standard authority. The influence of non-Jewish methods is seen in the more modern tendency of Azariah dei Rossi, who was opposed by Joseph Karo. In his *Meʾōr ʿEnayīm* (Mantua, 1573) Del Rossi endeavoured to investigate Jewish history in a scientific spirit, with the aid of non-Jewish authorities, and even criticizes Talmudic and traditional statements. Another historian living also in Italy was Joseph ben Joshua, whose *Dibhrē ha-yamīm* (Venice, 1534) is a sort of history of the world, and his *ʿEmeq ha-bakhah* an account of Jewish troubles to the year 1575. In Germany David Gans wrote on astronomy, and also the historical work *Ẓemaḥ David* (Prag, 1592). The study of Kabbalah was promoted and the practical Kabbalah founded by Isaac Luria in Palestine (d. 1572). Numerous works, representing the extreme of mysticism, were published by his pupils as the result of his teaching. Foremost among these was Ḥayyīm Vital, author of the *ʾEz ḥayyīm*, and his son Samuel, who wrote an introduction to the Kabbalah, called *Shemoneh Sheʿarīm*. To the same school belonged Moses Zakkuto, of Mantua (d. 1697), poet and kabbalist. Contemporary with Luria and also living at Safed, was Moses Cordovero (d. 1570), the kabbalist, whose chief work was the *Pardes Rimmōnīm* (Cracow, 1591). In the 17th century Leon of Modena (d. 1648) wrote his *Bēth Yehūdah*, and probably *Qōl Sakhal*, against traditionalism, besides many controversial works and commentaries. Joseph Delmedigo, of Prag (d. 1655), wrote almost entirely on scientific subjects. Also connected with Prag was Yōm Ṭōbh Lipmann Heller, a voluminous author, best known for the *Tōsaphōth Yōm Tōbh* on the Mishna (Prag, 1614; Cracow, 1643). Another important Talmudist, Shabbethai ben Meʼīr, of Wilna (d. 1662), commented on the *Shulḥan ʿArūkh*. In the East, David Conforte (d. about 1685) wrote the historical work *Qōrē ha-dōrōth* (Venice, 1746), using Jewish and other sources; Jacob ben Ḥayyīm Ẓemaḥ, kabbalist and student of Luria, wrote *Qōl be-ramah*, a commentary on the *Zohar* and on the liturgy; Abraham Hayekīnī, kabbalist, chiefly remembered as a supporter of the would-be Messiah, Shabbethai Zebhī, wrote *Hōd Malkūth* (Constantinople, 1655) and sermons. In the 18th century the study of the kabbalah was cultivated by Moses 176 Ḥayyīm Luzzatto (d. 1747) and by Elijah ben Solomon, called Gaon, of Wilna (d. 1797), who commented on the whole Bible and on many Talmudic and kabbalistic works. In spite of his own leaning towards mysticism he was a strong opponent of the Ḥasīdīm, a mystical sect founded by Israel Baʼal Shem Ṭōbh (Beshṭ) and promoted by Baer of Meseritz. Elijah’s son Abraham (d. 1808), the commentator, is valuable for his work on Midrash. An historical work which makes an attempt to be scientific, is the *Seder ha-dōrōth* of Yeḥiel Heilprin (d. 1746). These, however, belong in spirit to the previous century.

The characteristic of the 18th and 19th centuries is the endeavour, connected with the name of Moses Mendelssohn, to bring Judaism more into relation with external learning, and in using the Hebrew language to purify and develop it in accordance with the biblical

Modernizing tendencies.

standard. The result, while linguistically more uniform and pleasing, often lacks the spontaneity of medieval literature. It was Moses Mendelssohn's German translation of the Pentateuch (1780-1793) which marked the new spirit, while the views of his opponents belong to a bygone age. In fact the controversy of which he was the centre may fitly be compared with the earlier battles between the Maimonists and anti-Maimonists. One of the most remarkable writers of the new Hebrew was Mendelssohn's friend N. H. Wessely, of Hamburg (d. 1805), author of *Shīrē Tiphe'reth*, a long poem on the Exodus, *Dibhrē Shalōm*, a plea for liberalism, *Sepher ha-middōth*, on ethics, besides philological works and commentaries. A curious combination of new and old was Ḥayyīm Azulai (d. 1807), a kabbalist, but also the author of *Shem ha-gedhōlīm*, a valuable contribution to literary history.

In the 19th century the modernizing tendency continued to grow, though always side by side with a strong conservative opposition, and the most prominent names on both sides are those of scholars rather than literary men. Among them may be mentioned, Akiba ('Aqībhā) Eger (d. 1837), Talmudist of the orthodox, conservative school; W. Heidenheim (d. 1832), a liberal, and editor of the Pentateuch and Maḥzor; N. Krochmal, of Galicia (d. 1840), author of *Mōreh Nebhūkhē ha-zeman*, on Jewish history and literature; his son Abraham (d. 1895), conservative commentator and philosopher. One consequence of the Mendelssohn movement was that many writers used their vernacular language besides or instead of Hebrew, or translated from one to the other. Thus Isaac Samuel Reggio (d. 1855), a strong liberal, wrote both in Hebrew and Italian; Joseph Almanzi, of Padua (d. 1860), a poet, translated Italian poems into Hebrew; S. D. Luzzatto, of Padua (d. 1865), a distinguished scholar and opponent of the philosophy of Maimonides, wrote much in Italian; M. H. Letteris, of Vienna (d. 1871), translated German poems into Hebrew; S. Bacher, of Hungary (d. 1891), was a poet and moderate liberal; L. Gordon (d. 1892), poet and prose-writer in Hebrew and Russian, of liberal views; A. Jellinek, of Vienna (d. 1893), preacher and scholar; Jacob Reifmann (d. 1895), scholar, wrote only in Hebrew. The endeavour to bring Judaism into relation with the modern world and to change the current impressions about Jews by making their teaching accessible to the rest of the world, is connected chiefly with the names of Z. Frankel (d. 1875), the first Jewish scholar to study the Septuagint; Abraham Geiger (d. 1874), critic of the first rank; L. Zunz (d. 1884) and L. Dukes (d. 1891), both scholarly investigators of Jewish literary history. Their most important works are in German. The question of the use of the vernacular or of Hebrew is bound up with the differences between the orthodox and the liberal or reform parties, complicated by the many problems involved. Patriotic efforts are made to encourage the use of Hebrew both for writing and speaking, but the continued existence of it as a literary language depends on the direction in which the future history of the Jews will develop.

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(A. Cy.)

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1 The dating of these documents is extremely difficult, since it is based entirely on internal evidence. Various scholars, while agreeing on the actual divisions of the text, differ on the

question of priority. The dates here given are those which seem to be most generally accepted at the present time. They are not put forward as the result of an independent review of the evidence.

2 See especially A. Jellinek's *Bet-ha-Midrasch* (Leipzig, 1853), for these lesser midrashīm.

3 That on Genesis was edited for the first time by Schechter (Cambridge, 1902).

4 In Hebrew רשי, from the initial letters of Rabbi Shelomoh Yiẓḥaqī, a convenient method used by Jewish writers in referring to well-known authors. The name Jarchi, formerly used for Rashi, rests on a misunderstanding.

5 So Bacher in *J.Q.R.* iii. 785 sqq.

6 For the history of the very extensive literature of this class, Zunz, *Literaturgeschichte der synagogalen Poesie* (Berlin, 1865), is indispensable.

7 See the edition of them in Harkavy, *Studien*, iv. (Berlin, 1885).

8 Two different texts of it exist: (1) in the ed. pr. (Mantua, 1476); (2) ed. by Seb. Münster (Basel, 1541). There is also an early Arabic recension, but its relation to the Hebrew and to the Arabic 2 Maccabees is still obscure. See *J. Q. R.*, xi. 355 sqq. The Hebrew text was edited with a Latin translation by Breithaupt (Gotha, 1707).

9 On the various recensions of the text see D. H. Müller in the *Denkschriften* of the Vienna Academy (*Phil.-hist. Cl.*, xli. 1, p. 41) and Epstein's ed. (Pressburg, 1891).

10 A fragment of such a work, probably emanating from the school of Ḥīvī was found by Schechter and published in *J.Q.R.*, xiii. 345 sqq.

11 See M. Friedländer in *Publications of the Society of Hebrew Lit.*, 1st ser. vol. i., and 2nd ser. vol. iv.

12 The fullest account of them is to be found in Steinschneider's *Hebräische Übersetzungen des Mittelalters* (Berlin, 1893).

13 See H. Gollancz, *The Ethical Treatises of Berachya* (London, 1902).

HEBREW RELIGION (1) *Introductory.*—To trace the history of the religion of the Hebrews is a complex task, because the literary sources from which our knowledge of that history is derived are themselves complex and replete with problems as to age and authorship, some of which have been solved according to the consensus of nearly all the best scholars, but some of which still await solution or are matters of dispute. Even if the analysis of the literature into component documents were complete, we should still possess a most imperfect record, since the documents themselves have passed through many redactions, and these redactions have proceeded from varying standpoints of religious tradition, successively eliminating or modifying certain elements deemed inconsistent with the canons of religious usage or propriety which prevailed in the age when the redaction took place. Lastly it should be recollected that the entire body of the fragments of tradition and literature belonging to *northern* Israel has come down to us through the channel of *Judaean* recensions.

The influence of the Deuteronomic tradition in redaction is seen in such passages as Genesis xxxiii. 20 (cf. xxxi. 45 fol.); Josh. iv. 9-20, xxiv. 26 fol.; 1 Sam. vii. 12, where the *maṣṣēbhah* or stone symbol of deity (forbidden in Deut. xii. 3, xvi. 22) is in some way got rid of (in Gen. xxxiii. 20 the word "altar" in Hebrew is substituted). Similarly in Gen. xiii. 18, xiv. 13, xviii. 1, the Septuagint shows that the singular form "terebinth" stood in the original text. But the Massoretes altered this to the plural as this form was less suggestive of tree-worship (see Smend, *A. Tliche Religionsgesch.* i. p. 134, footnote 1; Nowack, *Heb. Archäol.* p. 12, footnote 1). Many other examples might be cited, as the "suspended *nun*" which transforms the pronunciation of the original Mosheh (Moses) into Menashsheh (Manasseh) owing to the irregular practices of his descendant, Jonathan ben Gershom (Jud. xviii. 30). It is not improbable that in 2 Kings iii. 27 the words "from Kemōsh" stood after "great wrath" in the original document, as the phraseology seems bald without them, and the motives for their suppression are obvious.

So far as concerns the critical problems which stand at the threshold of our task, it must suffice to say that the main conclusions reached by the school of Kuenen and Wellhausen as to the literary problems of the Old Testament are assumed throughout this sketch of the

evolution of Hebrew religion. The documents underlying the Pentateuch and book of Joshua, represented by the ciphers J, E, D and P, are assumed to have been drawn up in the chronological order in which those ciphers are here set down, and the period of their composition extends from the 9th century B.C., in which the earlier portions of J were written, to the 5th century B.C., in which P finally took shape. The view of Professor Dillmann, who placed P before D in the regal period (though he admitted exilic and post-exilic additions in Exod., Levit. and Numb.), a view which he maintained in his commentary 177
on Genesis (edition of 1892), has now been abandoned by nearly all scholars of repute. In the following pages we shall not attempt to do more than to sketch in very succinct outline the general results of investigation into the origins and growth of Hebrew religion.

2. *Pre-Mosaic Religion.*—Can any clear indications be found to guide us as to the religion of the Hebrew clans before the time of Moses? That Moses united the scattered tribes, probably consisting at first mainly of the Josephite, under the common worship of Yahweh, and that upon the religion of Yahweh a distinctly ethical character was impressed, is generally recognized. The tradition of the earliest document J ascribes the worship of Yahweh to much earlier times, in fact to the dawn of human life. A close survey of the facts, however, would lead us to regard it as probable that some at least of the Hebrew clans had patron-deities of their own.

(*a*) Both Moab and Ammon as well as Edom had their separate tribal deities, viz. Chemosh (Moab) and Milk (Milcōm), the god of Ammon, and in the case of Edom a deity known from the inscriptions as Kōs (in Assyrian Kauš).[1] From the patriarchal narratives and genealogies in Genesis we infer that these races were closely allied to Israel. That in early pre-Mosaic times parallel cults existed among the various Hebrew tribes is by no means improbable. It would be reasonable to assume that Moab, Ammon, Edom and kindred tribes of Israel in the 15th and preceding centuries were included in the generic term Ḥabirī (or Hebrews) mentioned in the Tell el-Amarna inscriptions as forming predatory bands that disturbed the security of the Canaanite dwellers west of the Jordan. Lastly pre-Mosaic polytheism seems to be implied in the Mosaic prohibition Ex. xx. 3, xxii. 20.

(*b*) The tribal names Gad and Asher are suggestive of the worship of a deity of fortune (Gad) and of the male counterpart of the goddess, Ashērah. Under the name Shaddai (which Nöldeke suggests[2] was originally Shēdī “my demon”) it is possible to discern the name of a deity who in later times came to be identified with Yahweh. On the other hand, the connexion of the name Samson with sun-worship throws light on the period of the Hebrew settlement in Canaan and not on pre-Mosaic times. Nor is it possible to agree with Baudissin (*Studien zur semit. Religionsgesch.* i. 55) that Elōhīm as a plural form for the name of the Hebrew deity “can hardly be understood otherwise than as a comprehensive expression for the multitude of gods embraced in the One God of Old Testament religion,” in other words that it presupposes an original polytheism. For (1) Elōhīm is also applied in Judges xi. 24 to the Moabite Chemosh (Kemōsh); in 1 Sam. v. 7 to Dagon; in 1 Kings xi. 5 to Ashtoreth; in 2 Kings i. 2, iii. 6, 16 to Baʿal Zebūl of Ekron. (2) It is merely a plural of dignity (*pluralis majestatis*) parallel to *adōnīm* (applied to a king in 1 Kings xviii. 8, whereas in the previous verse the *singular* form *adōni* is applied to the prophet Elijah). (3) The Tell el-Amarna inscriptions indicate that the term *Elōhīm* might even be applied in abject homage to an Egyptian monarch as the use of the term *ilāni* in this connexion obviously implies.[3]

The religion of the Arabian tribes in the days of Mahomet, of which a picture is presented to us by Wellhausen in his *Remains of Arabic Heathendom*, furnishes some suggestive indications of the religion that prevailed in nomadic Israel before as well as during the lifetime of Moses. It is true that Arabian polytheism in the time of Mahomet was in a state of decay. Nevertheless the life of the desert changes but slowly. We may therefore infer that ancient Israel during the period when they inhabited the *negebh* (S. of Canaan) stood in awe of the demons (Jinn) of the desert, just as the Arabs at the present day described in Doughty’s *Arabia deserta*. We know that diseases were attributed by the Israelites to malignant demons which they, like the Arabs, identified with serpents. The counterspell took the form of a bronze image of the serpent-demon; see Frazer, *Golden Bough*, ii. 426; and I Sam. v. 6, vi. 4, 5 (LXX. and Heb.) as well as Buchanan Gray’s instructive note in *Numbers*, p. 276. The slaughter of a lamb at the Passover or Easter season, whose blood was smeared on the door-post, as described in Ex. xii. 21-23, probably points back to an immemorial custom. In this case the counterspell assumed a different form. Westermarck has shown from his observations in Morocco that the blood of the victim was considered to visit a curse upon the object to whom the sacrifice is offered and thereby the latter is made amenable to the sacrificer.[4] It is hardly possible to doubt that in the original form of the rite described in Exodus the blood offering was made to the plague demon (“the destroyer”) and possessed over him a magic power of arrest.

It is therefore certain that belief in demons and magic spells prevailed in pre-Mosaic times[5] among the Israelite clans. And it is also probable that certain persons combined in their own individuality the functions of magician and sacrificer as well as soothsayer. For we know that in Arabic the *Kāhin*, or soothsayer, is the same participial form that we meet with in the Hebrew *Kōhēn*, or priest, and in the early period of Hebrew history (*e.g.* in the days of Saul and David) it was the priest with the ephod or image of Yahweh who gave answers to those who consulted him. How far *totemism*, or belief in deified animal ancestors, existed in prehistoric Israel, as evidenced by the tribal names Simeon (hyena, wolf), Caleb (dog), Ḥamor (ass), Raḥel (ewe) and Leah (wild cow), &c.,[6] as well as by the laws respecting clean and unclean animals, is too intricate and speculative a problem to be discussed here. That the food-taboo against eating the flesh of a particular animal would prevail in the clan of which that animal was the deified totem-ancestor is obvious, and it would be a plausible theory to hold that the laws in question arose when the Israelite tribes were to be consolidated into a national unity (*i.e.* in the time of David and Solomon), but the application of this theory to the list of unclean foods in Deut. xiv. (Lev. xi.) seems to present insuperable difficulties. In fact, while Robertson Smith (in *Kinship and Marriage in Early Arabia*, as well as his *Religion of the Semites*, followed by Stade and Benzinger) strongly advocated the view that clear traces of totemism can be found in early Israel, later writers, such as Marti, *Gesch. der israelit. Religion*, 4th ed., p. 24, Kautzsch in his *Religion of Israel* already cited, p. 613, and recently Addis in his *Hebrew Religion*, p. 33 foll., have abandoned the theory as applied to Israel.[7] On the other hand, the evidence for the existence of ancestor-worship in primitive Israel cannot be so easily disposed of as Kautzsch (*ibid.* p. 615) appears to think. We have examples (1 Sam. xxviii. 13) in which *Elōhīm* is the term which is applied to departed spirits. Oracles were received from them (Isa. viii. 19, xxviii. 15, 18; Deut. xviii. 10 foll.). At the graves of national heroes or ancestors worship was paid. In Gen. xxxv. 20 we read that a *maṣṣēbah* or sacred pillar was erected at Raḥel’s tomb. That the Terāphīm, which we know to have resembled the human form (1 Sam. xix. 13, 16), were ancestral images is a reasonable theory. That they were employed in divination is consonant with the facts already noted. Lastly, the rite of circumcision (*q.v.*), which the Hebrews practised in common with their Semitic neighbours as well as the Egyptians, belonged to ages long anterior to the time of Moses. This is a fact which has long been recognized: cf. Gen. xvii. 10 foll., Herod. ii. 104, and Barton, *Semitic Origins*, pp. 98-100. Probably the custom was of African origin, and came from eastern Africa along with the Semitic race. Respecting Arabia, see Doughty, *Arabia deserta*, i. 340 foll. 178

It is necessary here to advert to a subject much debated during recent years, viz. the effects of Babylonian culture in western Asia on Israel and Israel’s religion in early times even preceding the advent of Moses. The great influence exercised by Babylonian culture over Palestine between 2000 and 1400 B.C. (*circa*), which has been clearly revealed to us since 1887 by the discovery of the Tell el Amarna tablets, is now universally acknowledged. The subsequent discovery of a document written in Babylonian cuneiform at Lachish (Tell el Hesy), and more recently still of another in the excavations at Ta’annek, have established the fact beyond all dispute. The last discovery had tended to confirm the views of Fried. Delitzsch, Jeremias (*Monotheistische Strömungen*) and Baentsch, that monotheistic tendencies are to be found in the midst of Babylonian polytheism. Page Renouf, in his Hibbert lectures, *Origin and Growth of Religion as illustrated by that of Ancient Egypt* (1879), p. 89 foll., pointed out this monotheistic tendency in Egyptian religion, as did de Rougé before him. Baentsch draws attention to this feature in his monograph *Altorientalischer u. israelitischer Monotheismus* (1906). This tendency, however, he, unlike the earlier conservative writers, rightly considers to have emerged out of polytheism. He ventures into a more disputable region when he penetrates into the obscure realm of the Abrahamic migration and finds in the Abrahamic traditions of Genesis the higher Canaanite monotheistic tendencies evolved out of Babylonian astral religion, and reflected in the name El ‘Elyon (Gen. xiv. 18, 22). Further discoveries like Sellin’s find at Ta’annek may elucidate the problem. See Baudissin in *Theolog. lit. Zeitung* (27th October 1906).

3. *The Era of Moses.*—We are now on safer ground though still obscure. Moses was the first historic individuality who can be said to have welded the Israelite clans into a whole. This could never have been accomplished without unity of worship. The object of this worship was Yahweh. As we have already indicated, the document J assumes that Yahweh was worshipped by the Hebrew race from the first. On the other hand, according to P (Ex. vi. 2), God spake to Moses and said to him: “I am Yahweh. But I appeared to Abraham, Isaac and Jacob as El Shaddai and by my name Yahweh I did not make myself known to them.” According to this later tradition Yahweh was unknown till the days of Moses, and under the

aegis of His power the Hebrew tribes were delivered from Egyptian thraldom. The truth probably lies somewhere between these two sharply contrasted traditions. So much is clear. Yahweh now becomes the supreme deity of the Hebrew people, and an ark analogous to the Egyptian and Babylonian arks portrayed on the monuments[8] was constructed as embodiment of the *numen* of Yahweh and was borne in front of the Hebrew army when it marched to war. It was the signal victory won by Moses at the exodus against the Egyptians and in the subsequent battle at Rephīdīm against ‘Amālēk (Ex. xvii.) that consolidated the prestige of Yahweh, Israel’s war-god. Indications in the Old Testament itself clearly point to the celestial or atmospheric character of the Yahweh of the Hebrews. The supposition that the name originally contained the notion of permanent or eternal being, and was derived from the verbal root signifying “to be,” involves too abstract a conception to be probable, though it is based on Ex. iii. 15 (E) representing a tradition which may have prevailed in the 8th century B.C. Kautzsch, however, supports it (Hastings’s *D.B.*, extra vol. “Rel. of Isr.” p. 625 foll.) against the other derivations proposed by recent scholars (see Jehovah). That the name also prevailed as that of a god among other Semitic races (or even non-Semitic) is rendered certain by the proper names Jau-bi’-di (= Ilu-bi‘di) of Hamath in Sargon’s inscriptions, Aḥi-jawi (mi) in Sellin’s discovered tablet at Ta‘annek, to say nothing of those which have been found in the documents of Khammurabi’s reign. It has generally been held that Stade’s supposition has much to recommend it, that it was derived by Moses from the Kenites, and should be connected with the Sinai-Horeb region. The name Sinai suggests moon-worship and the moon-god Sin; and it also suggests Babylonian influence (cf. also Mount Nebo, which was a place-name both in Moab and in Judah, and naturally connects itself with the name of the Babylonian deity). Several indications favour the view of the connexion in the age of Moses between the Yahweh-cult at Sinai and the moon-worship of Babylonian origin to which the name Sinai points (Sin being the Babylonian moon-god). We note (*a*) that in the worship of Yahweh the sacred seasons of new moon and Sabbath are obviously *lunar*. Recent investigations have even been held to disclose the fact that the Sabbath coincided originally, *i.e.* in early pre-exilian days, with the full moon.[9] (*b*) It also accords with the name bestowed on Yahweh as “Lord of Hosts” (*ṣebāōth*) or stars, which were regarded as personified beings (Job xxxviii. 7) and attendants on the celestial Yahweh, constituting His retinue (1 Kings xxii. 19) which fought on high while the earthly armies of Israel, His people, contended below (Judges v. 20).

The atmospheric and celestial character which belonged from the first to the Hebrew conception of Yahweh explains to us the ease with which the idea of His universal sovereignty arose, which the Yahwistic creation account (belonging to the earlier stratum of J, Gen. ii. 4*b* foll.) presupposes. How this came to be overlaid by narrow local limitations of His power and province will be shown later. It is probable that Moses held the larger rather than the narrower conception of Yahweh’s sphere of influence. While the ark carried with Israel’s host symbolized His presence in their midst, He was also known to be present in the cloud which hovered before the host and in the lightning (’*ēsh Yahweh* or “fire of Yahweh”) and the thunder (*kōl Yahweh* or “voice of Yahweh”) which played around Mount Sinai. Moreover, it is hardly probable that a great leader like Moses remained unaffected by the higher conceptions tending towards monotheism which prevailed in the great empires on the Nile and on the Euphrates. In Egypt we know that Amenophis IV. came under this monotheistic movement, and attempted to suppress all other cults except that of the sun-deity, of which he was a devoted worshipper. We also know that between 2000 and 1400 B.C. 179
the Babylonian language as well as Babylonian civilization and ideas spread over Palestine (as the Tell el Amarna tables clearly testify). The ancient Babylonian psalms clearly reveal that the highest minds were moving out of polytheism to a monotheistic identification of various deities as diverse phases of one underlying essence. A remarkable Babylonian tablet discovered by Dr Pinches represents Marduk, the god of light, as identified in his person with all the chief deities of Babylonia, who are evidently regarded as his varying manifestations.[10]

Through the influence of Mosaic teaching and law a definitely ethical character was ascribed to Yahweh. It was His “finger” that wrote the brief code which has come down to us in the decalogue. At first, as Erdmanns suggests, it may have consisted of only seven commands. So also Kautzsch, *ibid.* p. 634. The most strongly distinguishing feature of the code is the rigid exclusion of the worship of other gods than Yahweh. Moreover, the definitely ethical character of the religion of Yahweh established by Moses is exhibited in the strict exclusion of all sexual impurity in His worship. Unlike the Canaanite Baal, Yahweh has no female consort, and this remained throughout a distinguishing trait of the original and unadulterated Hebrew religion (see Bäthgen, *Beiträge*, p. 265). Indeed, Hebrew, unlike Assyrian or Phoenician, has no distinctive form for “goddess.” From first to last the true religion of Yahweh was pure of sexual taint. The kedēshīm and kedēshōth, the male and female priest attendants in the Baal and ʿAshtoreth shrines (cf. the *kadishtu* of the temples of the Babylonian Ishtar) were foreign Canaanite elements which became imported into Hebrew worship during the period of the Hebrew settlement in Canaan.

Lastly, the earliest codes of Hebrew legislation (Ex. xxi.-xxiii.) bear the distinct impress of the high ethical character of Yahweh's requirements originally set forth by Moses. Of this tradition the Naboth incident in the time of Ahab furnishes a clear example which brings to light the contrast between the Tyrian Baal-cult, which was scarcely ethical, and of which Jezebel and Ahab were devotees, and the moral requirements of the religion of Yahweh of which Elijah was the prophet and impassioned exponent. It was this definite basis of ethical Mosaic religion to which the prophets of the 8th century appealed, and apart from which their denunciations become meaningless. To this early standard of life and practice Ephraim was faithless in the days of the prophet Hosea (see his oracles *passim*—especially chaps. i.-iv. and xiv.), and Judah in the time of Isaiah turned a deaf ear (Isa. i. 2-4, 21).

4. *Influence of Canaan.*—The entrance of Israel into Canaan marks the beginning of a new epoch in the development of Israel's religious life. For it involved a transition from the simple nomadic relations to those of the agricultural and more highly civilized Canaanite life. This subject has been recently treated with admirable clearness by Marti in his useful treatise *Die Religion des A.T.* (1906), pp. 25-41.

It is in the festivals of the annual calendar that this agricultural impress is most fully manifested. To the original nomadic *Pesaḥ* (Passover)—sacrifice of a lamb—there was attached a distinct and agricultural festival of unleavened cakes (*maṣṣōth*) which marks the beginning of the corn harvest in the middle of the month *Abīb* (the name of which points to its Canaanite and agricultural origin). The close of the corn-harvest was marked by the festival *Shabhūōth* (weeks) or *Ḳāṣīr* (harvest) held seven weeks after maṣṣōth. The last and most characteristic festival of Canaanite life was that of *Asīph* or "ingathering" which after the Deuteronomic reformation (621 B.C.) had made a single sanctuary and therefore a considerable journey with a longer stay necessary, came to be called *Succōth* or booths. This was the autumn festival held at the close of September or beginning of October. It marked the close of the year's agricultural operations when the olives and grapes had been gathered [Ex. xxiii. 14-17 (E), xxxiv. 18, 22, 23 (J)]; see Feasts, Passover, Pentecost and Tabernacles. Another special characteristic of Israel's religion in Canaan was the considerable increase of sacrificial offerings. Animal sacrifices became much more frequent, and included not only the bloody sacrifice (Zebaḥ) but also burnt offerings (*kālīl*, *ʿōlah*) whereby the whole animal was consumed (see Sacrifice). But we have in addition to the animal sacrifices, vegetable offerings of meal, oil and cakes (*maṣṣōth*, *ashīshah* and *kawwān*, which last is specially connected with the ʿAshtoreth cult: Jer. vii. 18, xliv. 19), as well as the "bread of the Presence" (*leḥem happānīm*), 1 Sam. xxi. 6. Whether the primitive rite of *water-offerings* (1 Sam. vii. 6; 2 Sam. xxiii. 16) belonged to early nomadic Israel (as seems probable) it is not possible to determine with any certainty.

Again, the conception of Yahweh suffered modification. In the desert he was worshipped as an atmospheric deity, who manifested himself in thunder and lightning, whose abode was in the sky, whose sanctuary was on the mountain summit of Horeb-Sinai, and whose movable palladium was the ark of the covenant. But when the nomadic clans of Israel came to occupy the settled abodes of the agricultural Canaanites who had a stake in the soil which they cultivated, these conditions evidently reacted on their religion. Now the local Baal was the divine owner of the fertile spot where his sanctuary (*qōdesh*) was marked by the upright stone pillar, the symbol of his presence, on which the blood of the slaughtered victim was smeared. To this Baal the productiveness of the soil was due. Consequently it was needful to secure his favour, and in order to gain this, gifts were made to him by the local resident population who depended on the produce of the land (see Baal, especially *ad init.*). Now when the Hebrews succeeded to these agricultural conditions and acquired possession of the Canaanite abodes, they naturally fell into the same cycle of religious ideas and tradition. Yahweh ceased to be exclusively regarded as god of the atmosphere, worshipped in a distant mountain, Horeb-Sinai, situated in the south country (*negebh*), and moving in the clouds of heaven before the Israelites in the desert, but he came to be associated with Israel's life in Canaan. He manifested His presence either by a signal victory over Israel's foes (Josh. x. 10, 11; 1 Sam. vii. 10-12) or by a thunderstorm (1 Sam. xii. 18) or through a dream (Gen. xxviii. 16 foll.; cf. 1 Kings iii. 5 foll.) at a sacred spot like Bethel. Accordingly, whenever His presence and power were displayed in places where the Canaanite Baal had been worshipped, they came to be attached to these spots. He had "put his name," *i.e.* power and presence (*numen*) there, and the same festivals and sacrifices which had previously been devoted to the cult of the Canaanite Baal were now annexed to the service of Yahweh, the war-god of the conquering race. The process of transference was facilitated by two potent causes: (*a*) Both Canaanite and Hebrew spoke a common language; (*b*) the name Baal is not in reality an individual proper name like Kemōsh (Chemosh), Rammān or Hadad, but is, like Ēl (Ilu) "god," an appellative meaning "lord," "owner" or "husband." The name Baal might therefore be used for any deity such as Milk (Milcom) or Shemesh ("sun") who was the divine owner of the spot. It was simply a covering epithet, and like the word "god" could be transferred from one deity to another. In this way Yahweh came to be called the Baal or "lord" of any sacred place where the armies of Israel by their victories attested "his mighty hand and outstretched arm." (See Kautzsch in Hastings's *D.B.*, extra vol., p. 645 foll.)

Such was the path of syncretism, and it was fraught with peril to the older and purer faith. 180
For when Yahweh gradually became Israel's local Baal he became worshipped like the old Canaanite deity, and all the sensuous accompaniments of Kedēshōth,[11] as well as the presence of the *ashērah* or sacred pole, became attached to his cult. But the symbol carried with it the *numen* of the goddess symbolized, and there can be little doubt that Ashērah came to be regarded as Yahweh's consort. In the days of Manasseh syncretism went on unchecked even in the Jerusalem temple and its precincts, and it was not till the year of Jesiah's reformation (621 B.C.) that the Kedēshīm and Kedēshōth as well as the Ashērah were banished for ever from Yahweh's sanctuary (2 Kings xxi. 7, xxiii. 7), which their presence had profaned.

Now local worship means the differentiation of the personality worshipped in the varied local shrines, in other words Ba'ālīm or Baals. Just as we have in Assyria an Ishtar of Arbela and an Ishtar of Nineveh (treated in Assur-bani-pal's (Rassam) cylinder[12] like two distinct deities), as we have local Madonnas in Roman Catholic countries, so must it have been with the cults of Yahweh in the regal period carried on in the numerous high places, Bethel, Shechem, Shiloh (till its destruction in the days of Eli) and Jerusalem. Each in turn claimed that Yahweh had placed his name (*i.e.* personal presence and power or numen) *there*. Each had a Yahweh of its own.

On the other hand, old deities still lurked in old spots which had been for centuries their abode. It was no easy task to establish Yahweh in permanent possession of the new lands conquered by the Hebrew settlers. The old gods were not to be at once discrowned of might. Of this we have a vivid example in the episode 2 Kings xviii. 24-28. The inhabitants of Babylonia and other regions whom the Assyrian kings had settled in Ephraim after 721 B.C. (cf. Ezra iv. 10) are described as suffering from the depredations of lions, and a priest from the deported Ephraimites is sent to them to teach them the worship of Yahweh, the god of the land. Similarly in the earlier pre-exilian period of Israel's occupation of Canaanite territory the Hebrews were always subject to this tendency to worship the *old* Baal or 'Ashtoreth (the goddess who made the cattle and flocks prolific).[13] A few years of drought or of bad seasons would make a Hebrew settler betake himself to the old Canaanite gods. Even in the days of Hosea the rivalry between Yahweh and the old Canaanite Baal still continued. The prophet reproaches his Ephraimite countrymen for going after their "lovers," the old local Baals who were supposed to have bestowed on them the bread, water, wool, flax and oil, and for not knowing that "it is I (Yahweh) who have bestowed on her (*i.e.* Israel) the corn, the new wine and the oil, and have bestowed on her silver and gold in abundance which they have wrought into a Baal image" (Hos. ii. 10).

External danger from a foreign foe, such as Midian or the Philistines, at once brought into prominence the claim and power of Yahweh, Israel's national war-god since the great days of the exodus. The religion of Yahweh (as Wellhausen said) meant patriotism, and in war-time tended to weld the participating tribes into a national unity. The book of Judges with its "monotonous tempo—religious declension, oppression, repentance, peace," to which Wellhausen[14] refers as its ever-recurring cycle, makes us familiar with these alternating phases of action and reaction. Times of peace meant national disintegration and the lapse of Israel into the Canaanite local cults, which is interpreted by the redactor as the prophets of the 8th century would have interpreted it, viz. as defection from Yahweh. On the other hand, times of war against a foreign foe meant on the religious side the unification, partial or complete, of the Israelite tribes by the rallying cry "the sword of Yahweh" (Judges vii. 20). In this way 'Ophrah became the centre of the coalition under Gideon in the tribe of Manasseh. Its importance is attested by Judges viii. 22-28, and we may disregard the "snare" which the Deuteronomic writer condemns in accordance with the later canons of orthodoxy. What 'Ophrah became on a small scale in the days of Gideon, Jerusalem became on a larger scale in the days of David and his successors. It was the religious expression of the unity of Israel which the life and death struggle with the Philistines had gradually wrought out.

Despite the capture of the ark after the disastrous battle of Shiloh, Yahweh had in the end shown himself through a destructive plague superior in might to the Philistine Dagon. There are indeed abundant indications that prove that in the prevalent popular religion of the regal period monotheistic conceptions had no place. Yahweh was god only of Israel and of Israel’s land. An invasion of foreign territory would bring Israel under the power of its patron-deity. The wrath with which the Israelite armies believed themselves to be visited (probably an outbreak of pestilence) when the king of Moab was reduced to his last extremity, was obviously the wrath of Chemosh the god of Moab, which the king’s sacrifice of his only son had awakened against the invading army (2 Kings iii. 27). In other words, the ordinary Israelite worshipper of Yahweh was at this time far removed from monotheism, and still remained in the preliminary stage of henotheism, which regarded Yahweh as sole god of Israel and Israel’s land, but at the same time recognized the existence and power of the deities of other lands and peoples. Of this we have recurring examples in pre-exilian Hebrew history. See 1 Sam. xxvi. 19; Judges xi. 23, 24; Ruth i. 16.

Material objects.

5. *Characteristics and Constituent Elements.*—It is only possible here to refer in briefest enumeration to the material and external objects and forms of popular Hebrew religion. These were of the simplest character. The upright stone (or *maṣṣēbah*) was the material symbol of deity on which the blood of sacrifice was smeared, and in which the *numen* of the god resided. It is probable that in some primitive sanctuaries no real distinction was made between this stone-pillar and the altar or place where the animal was slaughtered. In ordinary pre-exilian high places the custom described in the primitive compend of laws (Ex. xx. 24) would be observed. A mound of earth was raised which would serve as a platform on which the victim would be slaughtered in the presence of the concourse of spectators. In the more important shrines, as at Jerusalem or Samaria, there would be an altar of stone or of bronze. Another accompaniment of the sanctuary would be the sacred tree—most frequently a terebinth (cf. Judges ix. 37 “terebinth of soothsayers”), or it might be a palm tree (cf. “palm tree of Deborah” in Judges iv. 5), or a tamarisk (*‘ēshel*), or pomegranate (*rimmōn*), as at the high place in Gibeah where Saul abode. Moreover, we have frequent references to sacred springs, as that of *Beēr-sheba*, *‘Ēnharōd* (*‘ēyn-ḥarod*) (Judges vii. 1; cf. also Judges 19, *‘Ēn-haḳḳōrē* [*‘ēyn-haqqōre’*]). (On this subject of holy trees, holy waters and holy stones, consult article Tree-Worship, and Robertson Smith’s *Religion of the Semites*, 2nd ed., pp. 165-197.)

The wide prevalence of magic and soothsaying may be illustrated from the historical books of the Old Testament as well as from the pre-exilian prophets. The latter indeed tolerated the *qōsēm* (soothsayer) as they did the seer (rō’ēh). The rhabdomancy denounced by Hosea (iv. 12) was associated with idolatry at the high places. But the arts of the necromancer were always and without exception treated as foreign to the religion of Yahweh. The necromancer of *ba‘al ‘ōbh’* was held to be possessed of the spirit who spoke through him with a hollow voice. Indeed both necromancer and the spirit that possessed him were sometimes identified, and the former was simply called *ōbh*. It is probable that necromancy, like the worship of Ashērah and ’Ashtoreth, as well as the cult of graven images, was a Canaanite importation into Israel’s religious practices. (See Marti, *Religion des A.T.*, p. 32.)

Priesthood.

The history of the rise of the priesthood in Israel is exceedingly obscure. In the nomadic 181
period and during the earlier years of the settlement of Israel in Canaan the head of every family could offer sacrifices. In the primitive codes, Ex. xx. 22-xxiii. 19 (E), xxxiv. 10-28 (J), we have no allusion to any separate order of men who were qualified to offer sacrifices. In Ex. xxiv. 5 (E) we read that Moses simply commissioned young men to offer sacrifices. On the other hand the *addendum* to the book of Judges, chaps. xvii., xviii. (which Budde, Moore and other critics consider to belong to the two sources of the narratives in Judges, viz. J[15] as well as E), makes reference to a Levite of Bethlehem-Judah, expressly stated in xvii. 7 as belonging to a clan of Judah. This man Micah took into his household as priest. This narrative has all the marks of primitive simplicity. There can be no reasonable doubt that the Levite here was member of a priestly tribe or order, and this view is confirmed by the discovery of what is really the same word in south Arabian inscriptions.[16] The narrative is of some value as it shows that while it was possible to appoint any one as a priest, since Micah, like David, appointed one of his own sons (xvii. 5), yet a special priest-tribe or order also existed, and Micah considered that the acquisition of one of its members was for his household a very exceptional advantage: “Now I know that Yahweh will befriend me because I have the *Levite* as priest.”[17] In other words a priest who was a Levite possessed a superior professional qualification. He is paid ten shekels per annum, together with his food and clothing, and is dignified by the appellation “father” (cf. the like epithet of “mother” applied to the prophetess Deborah, Judges v. 7; see also 2 Kings ii. 12, vi. 21, xiii. 14). This same narrative dwells upon the graven images, ephod and

terāphīm, as forming the apparatus of religious ceremonial in Micah's household. Now the ephod and teraphim are constantly mentioned together (cf. Hos. iii. 4) and were used in divination. The former was the plated image of Yahweh (cf. Judges viii. 26, 27) and the latter were ancestral images (see Marti, *op. cit.* pp. 27, 29; Harper, *Int. Comm.* "Amos and Hosea," p. 222). In other words the function of the priest was not merely sacrificial (a duty which Kautzsch unnecessarily detaches from the services which he originally rendered), nor did he merely bear the ark of the covenant and take charge of God's house; but he was also and mainly (as the Arabic name *kāhin* shows) the *soothsayer* who consulted the ephod and gave the answers required on the field of battle (see 1 Sam. and 2 Sam. *passim*) and on other occasions. This is clearly shown in the "blessing of Moses" (Deut. xxxiii. 8), where the Levite is specially associated with another apparatus of inquiry, viz. the sacred lots, *Urīm* and *Thummīm*. The true character of *Urīm* (as expressing "aye") and *Thummīm* (as expressing "nay") is shown by the reconstructed text of 1 Sam. xiv. 41 on the basis of the Septuagint. See Driver *ad loc.*

Geniality of Worship.

The chief and most salient characteristic of the worship of the high places was geniality. The sacrifice was a feast of social communion between the deity and his worshippers, and knit both deity and clan-members together in the bonds of a close fellowship. This genial aspect of Hebrew worship is nowhere depicted more graphically than in the old narrative (a J section = Budde's G) 1 Sam. ix. 19-24, where a day of sacrifice in the high place is described. Saul and his attendant are invited by the seer-priest Samuel into the banqueting chamber (*lishkah*) where thirty persons partake of the sacrificial meal. It was the *'āsīph* or festival of ingathering, when the agricultural operations were brought to a close, which exhibited these genial features of Canaanite-Hebrew life most vividly. References to them abound in pre-exilian literature: Judges xxi. 21 (cf. ix. 27); Amos viii. 1 foll.; Hos. ix. 1 foll., Jer. xxxi. 4; Isa. xvi. 10 (Jer. xlviii. 33). These festivals formed the veins and arteries of ancient Hebrew clan and tribal life.[18] Wellhausen's characterization of the Arabian *hajj*[19] applies with equal force to the Hebrew *hagg* (festival): "They formed the rendezvous of ancient life. Here came under the protection of the peace of God the tribes and clans which otherwise lived apart from one another and only knew peace and security within their own frontiers." 1 Sam. xx. 28 foll. indicates the strong claims on personal attendance exercised on each individual member by the local clan festival at Bethlehem-Judah.

It is easy to discern from varied allusions in the Old Testament that the Canaanite impress of sensuous life clung to the autumnal vintage festivals. They became orgiastic in character and scenes of drunkenness, cf. Judges ix. 27; 1 Sam. 14-16; Isa. xxviii. 7, 8. Against this tendency the *Nazirite* order and tradition was a protest. Cf. Amos ii. 11 foll.; Judges xiii. 7, 14. As certain sanctuaries, Shiloh, Shechem, Bethel, &c., grew in importance, the priesthoods that officiated at them would acquire special prestige. Eli, the head priest at Shiloh in the early youth of Samuel, held an important position in what was then the chief religious and political centre of Ephraim; and the office passed by inheritance to the sons in ordinary cases. In the regal period the royal residence gave the priesthood of that place an exceptional position. Thus Zadok, who obtained the priestly office at Jerusalem in the reign of Solomon and was succeeded by his sons, was regarded in later days as the founder of the true and legitimate succession of the priesthood descended from Levi (Ezek. xl. 46, xliii. 19, xliv. 15; cf. 1 Kings ii. 27, 35). His descent, however, from Eleazar, the elder brother of Aaron, can only be regarded as the later artificial construction of the post-exilian chronicler (1 Chron. vi. 4-15, 50-53, xxiv. 1 foll.), who was controlled by the traditions which prevailed in the 4th century B.C. and after.

6. *The Prophets.*—The rise of the order of prophets, who gradually emerged out of and became distinct from the old Hebrew "seer" or augur (1 Sam. ix. 9),[20] marks a new epoch in the religious development of the Hebrews. Over the successive stages of this growth we pass lightly (see PROPHET). The life-and-death struggle between Israel and the Philistines in the reign of Saul called forth under Samuel's leadership a new order of "men of God," who were called "prophets" or divinely inspired speakers.[21] These men were distributed in various settlements, and their exercises were usually of an ecstatic character. The closest modern analogy would be the orders of dervishes in Islām. Probably there was little externally to distinguish the prophet of Yahweh in the days of Samuel from the Canaanite-Phoenician prophets of Baal and Ashērah (1 Kings xviii. 19, 26, 28), for the practices of both were ecstatic and orgiastic (cf. 1 Sam. x. 5 foll., xviii. 10, xix. 23 foll.). The special quality which distinguished these prophetic gilds or companies was an intense patriotism combined with enthusiastic devotion to the cause of Yahweh. This necessarily involved in that primitive age an extreme jealousy of foreign importations or innovations in ritual. It is obvious from numerous passages that these prophetic gilds recognized the superior position and

leadership of Samuel, or of any other distinguished prophet such as Elijah or Elisha. Thus 1 Sam. xix. 20, 23 et seq. show that Samuel was regarded as head of the prophetic settlement at Naiōth. With reference to Elijah and Elisha, see 2 Kings ii. 3, 5, 15, iv. 1, 38 et seq., vi. 1 et seq. There cannot be any doubt that such enthusiastic devotees of Yahweh, in days when religion meant patriotism, did much to keep alive the flame of Israel's hope and courage in the dark period of national disaster. It is significant that Saul in his last unavailing struggle against the overwhelming forces of the Philistines sought through the medium of a sorceress for an interview with the deceased prophet Samuel. It was the advice of Elisha that rescued the armies of Jehoram and Jehoshaphat in their war against Moab when they were involved in the waterless wastes that surrounded them (2 Kings iii. 14 foll.). We again find Elisha intervening with effect on behalf of Israel in the wars against Syria, so that his fame spread to Syria itself (2 Kings v.-viii. 7 foll.). Lastly it was the fiery counsels of the dying prophet, accompanied by the acted magic of the arrow shot through the open window, and also of the thrice smitten floor, that gave nerve and courage to Joash, king of Israel, when the armies of Syria pressed heavily on the northern kingdom (2 Kings xiii. 14-19). 182

We see that the prophet had now definitely emerged from the old position of "seer." Prophetic personality now moved in a larger sphere than that of divination, important though that function be in the social life of the ancient state[22] as instrumental in declaring the will of the deity when any enterprise was on foot. For the prophet's function became in an increasing degree a function of *mind*, and not merely of traditional routine or mechanical technique, like that of the diviner with his arrows or his lots which he cast in the presence of the ephod or plated Yahweh image. The new name *nabhi'* became necessary to express this function of more exalted significance, in which human personality played its larger rôle. Even as early as the time of David it would seem that Nathan assumed this more developed function as interpreter of Yahweh's righteous will to David. But both in 2 Sam. xii. 1-15 as well as in 2 Sam. vii. we have sections which are evidently coloured by the conceptions of a later time. We stand on safer ground when we come to Elijah's bold intervention on behalf of righteousness when he declared in the name of Yahweh the divine judgment on Ahab and his house for the judicial murder of Naboth. We here observe a great advance in the vocation of the prophet. He becomes the interpreter and vindicator of divine justice, the vocal exponent of a nation's conscience. For Elijah was in this case obviously no originator or innovator. He represents the old ethical Mosaism, which had not disappeared from the national consciousness, but still remained as the moral pre-supposition on which the prophets of the following century based their appeals and denunciations. It is highly significant that Elijah, when driven from the northern kingdom by the threats of the Tyrian Jezebel, retreats to the old sanctuary at Horeb, whence Moses derived his inspiration and his Tōrah.

We have hitherto dealt with isolated examples of prophetism and its rare and distinguished personalities. The ordinary Hebrew *nabhi'* still remained not the reflective visionary, stirred at times by music into strange raptures (2 Kings iii. 15), but the ecstatic and orgiastic dervish who was *meshuggah* or "frenzied," a term which was constantly applied to him from the days of Elisha to those of Jeremiah (2 Kings ix. 11; in Hos. ix. 7 and Jer. xxix. 26 it is regarded as a term of reproach). It is only in rare instances that some exalted personality is raised to a higher level. Of this we have an interesting example in the vivid episode that preceded the battle of Ramoth-Gilead described in 1 Kings xxii., when Micaiah appears as the true prophet of Yahweh, who in his rare independence stands in sharp contrast with the conventional court prophets, who prophesied then, as their descendants prophesied more than two centuries later, smooth things.

It is not, however, till the 8th century that prophecy attained its highest level as the interpreter of God's ways to men. This is due to the fact that it for the first time unfolded the true character of Yahweh, implicit in the old Mosaic religion and submerged in the subsequent centuries of Israel's life in Canaan, but now at length made clear and explicit to the mind of the nation. It became now detached from the limitations of nationalism and local association with which it had been hitherto circumscribed.

Even Elisha, the greatest prophet of the 9th century, had remained within these national limitations which characterized the popular conceptions of Yahweh. Yahweh was Israel's war-god. His power was asserted in and from Canaanite soil. If Naaman was to be healed, it could only be in a Palestinian river, and two mules' load of earth would be the only permanent guarantee of Yahweh's effective blessing on the Syrian general in his Syrian home.

That larger conceptions prevailed in some of the loftier minds of Israel, and may be held to have existed even as far back as the age of Moses, is a fact which the Yahwistic cosmogony in Gen. ii. 4*b*-9 (which may have been composed in the 9th century B.C.) clearly suggests, and it is strongly sustained by the overwhelming evidence of the powerful influence of Babylonian culture in the Palestinian region during the centuries 2000-1400 B.C.[23] Probably in our modern construction of ancient Hebrew history sufficient consideration has not been given to the inevitable coexistence of different types and planes of thought, each evolved from earlier and more primordial forms. In other words we have to deal not with *one* evolution but with evolutions.

The existence of the purer and larger conception of Yahweh's character and power before the advent of Amos indicates that the transition from the past was not so sudden as Wellhausen's graphic portrayal in the 9th edition of this *Encyclopaedia* (art. ISRAEL) would have led us to suppose. There were pre-existent ideas upon which that prophet's epoch-making message was based. Yet this consideration should in no way obscure the fact that the prophet lived and worked in the all-pervading atmosphere of the popular syncretic Yahweh religion, intensely national and local in its character. In Wellhausen's words, each petty state "revolved on its own axis" of social-religious life till the armies of Tiglath-Pileser III. broke up the security within the Canaanite borders. According to the dominating popular conception, the destruction of the national power by a foreign army meant the overthrow of the prestige of the national deity by the foreign nation's god. If Assyria finally overthrew Israel and carried off Yahweh's shrine, Assur (Ašur), the tutelary deity of Assyria, was mightier than Yahweh. This was precisely what was happening among the northern states, and Amos foresaw that this might eventually be Israel's doom. Rabshakeh's appeal to the besieged inhabitants of Jerusalem was based on these same considerations. He argued from past history that Yahweh would be powerless in the presence of Ashur (2 Kings xviii. 33-35). 183

This problem of religion was solved by Amos and by the prophets who succeeded him through a more exalted conception of Yahweh and His sphere of working, which tended to detach Him from His limited realm as a national deity. Amos exhibited Him to his countrymen as lord of the universe, who made the seven stars and Orion and turns the deep midnight darkness into morning. He calls to the waters of the sea and pours them on the earth's surface (chap. v. 8). Such a universal God of the world would hardly make Israel His exclusive concern. Thus He not only brought the Israelites out of Egypt, but also the Philistines from Caphtor and the Syrians from Kir (ix. 7). But Amos went beyond this. Yahweh was not only the lord of the universe and possessed of sovereign power. The prophet also emphasized with passionate earnestness that Yahweh was a God whose character was righteous, and God's demand upon His people Israel was not for sacrifices but for *righteous conduct*. Sacrifice, as this prophet, like his successor Jeremiah, insisted (Amos v. 25; cf. Jer. vii. 22) played no part in Mosaic religion. In words which evidently impressed his younger contemporary Isaiah (cf. esp. Is. chap. i. 11-17), Amos denounced the non-ethical ceremonial formalism of his countrymen which then prevailed (chap. v. 21 foll.):—

> "I hate, I contemn your festivals and in your feasts I delight not; for when you offer me your burnt-offerings and gifts, I do not regard them with favour and your fatted peace-offerings I will not look at. Take away from me the clamour of your songs; and the music of your viols I will not hear. But let judgment roll down like waters and justice like a perennial brook."

In the younger contemporary prophet of Ephraim, Hosea, the stress is laid on the relation of love (*ḥesēd*) between Yahweh, the divine husband, and Israel, the faithless spouse. Israel's faithlessness is shown in idolatry and the prevailing corruption of the high places in which the old Canaanite Baal was worshipped instead of Yahweh. It is shown, moreover, in foreign alliances. Compacts with a powerful foreign state, under whose aegis Israel was glad to shelter, involved covenants sealed by sacrificial rites in which the deity or deities of the foreign state were involved as well as Yahweh, the god of the weaker vassal-state. And so Yahweh's honour was compromised. While these aspects of Israel's relation to Yahweh are emphasized by the Ephraimite prophet, the larger conceptions of Yahweh's character as universal Lord and the God of righteousness, whose government of the world is ethical, emphasized by the prophet of Tekoah, are scarcely presented.

In Isaiah both aspects—divine universal sovereignty and justice, taught by Amos, and divine loving-kindness to Israel and God's claims on His people's allegiance, taught by Hosea—are fully expressed. Yahweh's relation of love to Israel is exhibited under the purer symbol of fatherhood (Isa. i. 2-4), a conception which was as ancient and familiar as that of husband, though perhaps the latter recurs more frequently in prophecy (Isa. i. 21; Ezek. xvi. &c.). Even more insistently does Isaiah present the great truth of God's universal sovereignty. As with his elder contemporary, the foreign peoples—(but in Isaiah's oracles Assyria and Egypt as well as the Palestinian races)—come within his survey. The "fullness of the earth" is Yahweh's glory (vi. 3) and the nations of the earth are the instruments of His irresistible and righteous will. Assyria is the "bee" and Egypt the "fly" for which Yahweh hisses. Assyria is the "hired razor" (Isa. vii. 18, 19), or the "rod of His wrath," for the chastisement of Israel (x. 5). But the instrument unduly exalts itself, and Assyria itself shall suffer humiliation at the hands of the world's divine sovereign (x. 7-15).

And so the old limitations of Israel's popular religion,—the same limitations that encumbered also the religions of all the neighbouring races that succumbed in turn to Assyria's invincible progress,—now began to disappear. Therefore, while every other religion which was purely national was extinguished in the nation's overthrow, the religion of Israel survived even amid exile and dispersion. For Amos and Isaiah were able to single out those loftier spiritual and ethical elements which lay implicit in Mosaism and to lift them into their due place of prominence. National *sacra* and the ceremonial requirements were made to assume a secondary rôle or were even ignored.[24] The centre of gravity in Hebrew religion was shifted from ceremonial observance and local sacra to righteous conduct. Religion and righteousness were henceforth welded into an indissoluble whole. The religion of Yahweh was no longer to rest upon the narrow perishable basis of locality and national sacra, but on the broad adamantine foundations of a universal divine sovereignty over all mankind and of righteousness as the essential element in the character of Yahweh and in his claims on man. This was the "corner-stone of precious solid foundation": "I will make judgment the measuring-line and righteousness the plummet" (Isa. xxviii. 16, 17). The religion of the Hebrew race—properly the Jews—now enters on a new stage, for it should be observed that it was Amos, Isaiah and Micah—prophets of Judah—who laid the actual foundations. The latter half of the 8th century, which witnessed a rapid succession of reigns in the northern kingdom accompanied by dismemberment of its territory and final overthrow, witnessed also the humiliating vassalage and religious decline of the kingdom of Judah. Unlike Amos and Micah, Isaiah was not only the prophet of denunciation but also the prophet of hope. Though Yahweh's chastisements on Ephraim and Judah would continue to fall till scarcely a remnant was left (Isa. vi. 13, LXX.), yet all was not to be lost. A remnant of the people was to return, *i.e.* be converted to Yahweh. The name given to an infant child—Immanuel—was to become the mystic symbol of a growing hope. God's presence was to abide in Jerusalem, and, as the century drew near its close, "Immanuel" became the watchword and talisman of a strong faith that God would never permit Jerusalem to be captured by the Assyrians. In fact it is not improbable that the words of consolation uttered by the prophet (Isa. viii. 9-10) in the dark days of Ahaz (735-734 B.C.) were among the oracles which God commanded Isaiah "to seal up among his disciples" (verse 16), and that they were quoted once more with effect as the armies of Sennacherib closed around Jerusalem. The talismanic name Immanuel became the nucleus out of which the later *Messianic* prophecies of Isaiah grew. To this age alone can we probably assign Isa. ix. 1-7, xi. 1-9, xxxii. 1-3. The hopes expressed in the word Immanuel, "God with us," were to become embodied in a personality of the royal seed of David, an ideal righteous ruler who was to bring peace to the war-distraught realm. Thus Isaiah became in that troubled age the true founder of *Messianic* prophecy. The strange contrast between the succession of dynasties and kings cut off by assassination in the northern kingdom, ending in the tragic overthrow of 721 B.C., and the persistent succession through three centuries of the seed of David on the throne of Jerusalem, as well as the marvellous escape of Jerusalem in 701 B.C. from the fate of Samaria, must have invested the seed of David in the eyes of all thoughtful observers with a mysterious and divine significance. The Messianic prophecies of Isaiah, the prophet of faith and deliverance, were destined to reverberate through all subsequent centuries. We hear the echoes in Jeremiah and Ezekiel and lastly in Haggai in ever feebler tones, and they were destined to reawaken in the Psalter (Pss. ii. and lxxii.), in the psalms of Solomon and in the days of Christ. See MESSIAH (and also the article "Messiah" in Hastings's *Dict. of Christ and the Gospels*).

The next notable contribution to the permanent growth of Hebrew prophetic religion was made about a century after the lifetime of Isaiah by Jeremiah and Ezekiel. The reaction into idolatry and Babylonian star worship in the long reign of Manasseh synchronized and was connected with vassalage to Assyria, while the reformation in the reign of Josiah (621 B.C.) is
conversely associated with the decay of Assyrian power after the death of Assur-bani-pal. That reformation failed to effect its purifying mission. The hurt of the daughter of God's people was but lightly healed (Jer. vi. 14, 15; cf. viii. 11, 12). No possibility of recovery now remained to the diseased Hebrew state. The outlook appeared indeed far darker to Jeremiah than it seemed more than a century before to Isaiah in the evil days of Jotham and Ahaz, "when the whole head was sick and the whole heart faint" (Isa. i. 5). Jeremiah foresaw that there was now no possibility of recovery. The Hebrew state was doomed and even its temple was to be destroyed. This involved an entire reconstruction of theological ideas which went

beyond even the reconstructions of Amos and Isaiah. In the old religion the race or clan was the unit of religion as well as of social life. Properly speaking, the individual was related to God only through the externalities of the clan or tribal life, its common temple and its common *sacra*. But now that these external bases of the old religion were to be swept away, a reconstruction of religious ideas became necessary. For the external supports which had vanished Jeremiah substituted a basis which was *internal, personal and spiritual* (*i.e. ethical*). In place of the old covenant based on external observance, which had been violated, there was to be a *new covenant* which was to consist not in outward prescription, but in the law which God would place *in the heart* (Jer. xxxi. 30-33). This was to take place by an act of divine grace (Jer. xxiv. 5 foll.): “I will give them an heart to know me that I am the Lord” (verse 7). Ezekiel, who borrowed both Jeremiah’s language and ideas, expresses the same thought in the well-known words that Yahweh would give the people instead of a heart of stone a heart of flesh (Ezek. xi. 19, 20, xx. 40 foll., xxxvi. 25-27), and would shame them by his loving-kindness into repentance, and there “shall ye remember your ways and all your doings wherein ye have been defiled and ye shall loathe yourselves in your own sight” (xx. 43).

Personal religion now became an important element in Hebrew piety and upon this there logically followed the idea of *personal responsibility*. The solidarity of race or family was expressed in the old tradition reflected in Deut. v. 9, 10, that God would visit the sins of the fathers upon the children, and it lived on in later Judaism under exaggerated forms. The hopes of the individual Jew were based on the piety of holy ancestors. “We have Abraham as our father.” But *Ezekiel* expressed the strong reaction which had set in against this belief in its older forms. He denies that the individual ever dies for the sins of the father. “The soul that sinneth, it (the pronoun emphasized in the original) shall die” (Ezek. xviii. 4). Neither Noah, Daniel nor Job could have rescued by his righteousness any but his own soul (xiv. 14). And as a further consequence *individual freedom* is strongly asserted. It is possible for every sinner to turn to God and escape punishment, and conversely for a righteous man to backslide and fall. In the presence of these awful truths which Ezekiel preached of individual freedom and of impending judgment, the prophet is weighted with a heavy responsibility. It is his duty to warn every individual, for no sinner is to be punished without warning (Ezek. iii. 16 foll. xxxiii.).

The closing years of the Judaean kingdom and the final destruction of the temple (586 B.C.) shattered the Messianic ideals cherished in the evening of Isaiah’s lifetime and again in the opening years of the reign of Josiah. The untimely death of that monarch upon the battlefield of Megiddo (608 B.C.), followed by the inglorious reigns of the kings who succeeded him, who became puppets in turn of Egypt or of Babylonia, silenced for a while the Messianic hopes for a future king or line of kings of Davidic lineage who would rule a renovated kingdom in righteousness and peace. Even in the darkness of the exile period hopes did not die. Yet they no longer remained the same. In the Deutero-Isaiah (chaps. xl.-lv.) we have no longer a Jewish but a *foreign* messiah. The onward progress of the Persian Cyrus and his anticipated conquest of Babylonia marked him out as Yahweh’s anointed instrument for effecting the deliverance of exiled Israel and their restoration to their old home and city (Isa. xli. 2, xliv. 24, xlv.). This was, however, but a subsidiary issue and possesses no permanent spiritual significance. Of far more vital importance is the conception of Israel as God’s *suffering servant*. This is not the place to enter into the prolonged controversy as to the real significance of this term, whether it signifies the nation Israel or the righteous community only, or finally an idealized prophetic individual who, like the prophet Jeremiah, was destined to suffer for the well-being of his people. Duhm, in his epoch-making commentary, distinguishes on the grounds of metre and contents *the four servant-passages*, in the last of which (lii. 13-liii. 12) the ideal suffering servant of Yahweh is portrayed most definitely as an individual. In the “servant-passages” he is innocent, while in the rest of the Deutero-Isaiah he appears as by no means faultless, and the personal traits are not prominent. These views of Duhm, in which a severe distinction is thus drawn between the representation of Yahweh’s servant in the servant-passages, and that which meets us in the rest of the Deutero-Isaiah, have been challenged by a succession of critics.[25] It is only necessary for us to take note of the ideal in its general features. It probably arose from the fact that the calamities from which Israel had suffered both before and during the exile had drawn the reflective minds of the race to the contemplation of the problem of suffering. The “servant of Yahweh” presents one aspect of the problem and its attempted solution, the book of Job another, while in the Psalms, *e.g.* Pss. xxii., xlii.-xliii., lxxiii., lxxvii., other phases of the problem are presented. In the Deutero-Isaiah the meaning of Israel’s sufferings is exhibited as vicarious. Israel is suffering for a great end. He suffers, is despised, rejected, chastened and afflicted that others may be blessed and be at peace through his chastisement. This noble conception of Israel’s great destiny is conveyed in Isa. xlix. 6, in words which may be regarded as perhaps the noblest utterance in Hebrew prophecy: “To establish the tribes of Jacob and bring back the preserved of Israel is less important than being my servant. Yea, I will make you a light to the *Gentiles* that my salvation may be unto the end of the earth.”[26] This passage, which belongs to the second of the brief “servant-songs,” sets the mission of Israel in its true relation to the world. It is the necessary corollary to the teaching of Amos, that God is the righteous lord of all the world. If Jerusalem has been chosen as His sanctuary and Israel as His own people, it is only that Israel may diffuse God’s blessings in the world even at the cost of Israel’s own humiliation, exile and dispersion.

The Deutero-Isaiah closes a great prophetic succession, which begins with Amos, continues in Isaiah in even greater splendour with the added elements of hope and Messianic expectation, and receives further accession in Jeremiah with his special teaching on inward spiritual and personal religion which constituted the new covenant of divine grace. Finally the Deutero-Isaiah conveyed to captive Israel the message of Yahweh’s unceasing love and care, and the certainty of their return to Judaea and the restoration of the national prosperity which Ezekiel had already announced in the earlier period of the exile. To this is united the noble ideal of the suffering servant, which serves both as a contribution to the great problem of suffering as purifying and vicarious and as the interpretation to the mind of the nation itself of that nation’s true function in the future, a lesson which the actual future showed that Israel was slow to receive. Nowhere in the Old Testament does the doctrine taught by Amos of Yahweh’s universal power and sovereignty 185
receive ampler and more splendid exposition than in the great lyrical passages of chap. xl. It marks the highest point to which the Hebrew race attained in its progress from henotheism to monotheism. Here again we see the wholesome influences of the exile. The Jew had passed from the narrow confines of his homeland into a wider world, and this larger vision of human life reacted on the prophet’s theology. This closes the evolution of Hebrew prophetism. What immediately follows is on a descending slope with some striking exceptions, *e.g.* the book of Job and the book of Jonah.

7. *Deuteronomic Legalism.*—The book of Deuteronomy was the product of prophetic teaching operating on traditional custom, which was represented in its essential features by the two codes of legislation contained in Ex. xx. 24-xxiii. 19 (E) and Ex. xxxiv. 10-26 (J), but had also become tainted and corrupted by centuries of Canaanite influence and practice which especially infected the cult of the *high places*. The existence of “high places” is pre-supposed in those two ancient codes and is also presumed in the narratives of the documents E and J which contain them. But the prevalence of the worship of “other gods” and of graven images in these “high places,” and the moral debasement of life which accompanied these cults, made it clear that the “high places” were sources of grave injury to Israel’s social life. In all probability the reformation instituted in the reign of Hezekiah, to which 2 Kings xviii. 4 (cf. verse 22) refers, was only partial. It is hardly possible that all the high places were suppressed. The idolatrous reaction in the reign of Manasseh appears to have restored all the evils of the past and added to them. Another and more drastic reform than that which had been previously initiated (probably at the instigation of Isaiah and Micah) now became necessary to save the state. It is universally held by critics that our present book of Deuteronomy (certainly chaps. xii.-xxvi.) is closely connected with the reformation in the reign of Josiah. It is quite clear that many provisions in the old codes of J and E expanded lie at the basis of the book of Deuteronomy. But new features were added. We note for the first time definite regulations respecting Passover and the close union of that celebration with *Massōth* or “unleavened bread.” We note the laws respecting the clean and unclean animals (certainly based on ancient custom). Moreover, the prohibitions are strengthened and multiplied. In addition to the bare interdict of the sorceress (Ex. xxii. 18), of stone pillars to the Canaanite Baal, of the Ashērah-pole, molten images and the worship of other gods than Yahweh (Ex. xxxiv. 13-17), we now have the strict prohibition of *any employment whatever* of the stone-symbol (*Maṣṣēbhah*), and of all forms of sorcery, soothsaying and necromancy (Deut. xviii. 10, 11. Respecting the stone-pillar see xvi. 22). But of much more far-reaching importance was the *law of the central sanctuary* which constantly meets us in Deuteronomy in the reference to “the place (*i.e.* Jerusalem) which Yahweh your God shall choose out of all your tribes to put His name there” (xii. 5, xvi. 5, 11, 16, xxvi. 2). There alone all offerings of any kind were to be presented (xii. 6, 7, xvi. 7). By this positive enactment all the high places outside the one sanctuary in Jerusalem became illegitimate. A further consequence directly followed from the limitation as to sanctuary, viz. limitation as to the officiating ministers of the sanctuary. In the “book of the covenant” (Ex. xx. 22-xxii. 19), as we have already seen, and in the general practice of the regal period, there was no limitation as to the priesthood, but a definite order of priesthood, viz. Levites,

existed, to whom a higher professional prestige belonged. As it was impossible to find a place for the officiating priests of the high places, non-levitical as well as levitical, in the single sanctuary, it became necessary to restrict the functions of sacrifice to the Levites only as well as to the existing official priesthood of the Jerusalem temple (see PRIEST). Doubtless such a reform met with strong resistance from the disestablished and vested interests, but it was firmly supported by royal influence and by the Jerusalem priesthood as well as by the true prophets of Yahweh who had protested against the idolatrous usages and corruptions of the high places.

The strong impress of Hebrew prophecy is to be found in the deeply marked ethical spirit of the Deuteronomic legislation. Love to God and love to man is stamped on a large number of its provisions. Love to God is emphasized in Deut. vi. 5, while love to man meets us in the constant reference to the fatherless and the widow (cf. especially Deut. xvi.). This note of philanthropy is frequently found as a mitigating element (*e.g.* in the laws respecting slavery and war)[27] that subdues or even removes the harshness of earlier laws or usages. It should be noted, however, that the spirit of brotherly love was confined within national barriers. It did not operate as a rule beyond the limits of race.

The book of Deuteronomy, in conjunction with the reformation of Josiah's reign (which synchronizes with the rapid decline of Assyria and the reviving prestige of Yahweh), appeared to mark the triumph of the great prophetic movement. It became at once a codified standard of purer religious life and ultimately served as a beacon of light for the future. But there was shadow as well as light. We note (*a*) that though the book of Deuteronomy bears the prophetic impress, the priestly impress is perhaps more marked. The writer "evinces a warm regard for the priestly tribe; he guards its privileges (xviii. 1-8), demands obedience for its decisions (xxiv. 8; cf. xvii. 10-12) and earnestly commends its members to the Israelites' benevolence (xii. 18-19, xiv. 27-29, &c.)."[28] (*b*) In many passages Jewish particularism is painfully manifest. Yahweh's care for other peoples does not appear. The flesh of a dead (unslaughtered) beast is not to be eaten, but it may be given to the "stranger within the gates"! (Deut. xiv. 21).[29] (*c*) Prophetic religion was a religion of the spirit which came to the messenger (Isa. lxi. 1) and expressed itself as a word of instruction of Yahweh (*tōrah*); see Isa. 1. 10. Now when the Hebrew religion was reduced to written form it began to be a book-religion, and since the book consisted of fixed rules and enactments, religion began to acquire a stereotyped character. It will be seen in the sequel that this was destined to be the growing tendency of Jewish religious life—to conform itself to prescribed rules, in other words, it became *legalism*. (*d*) Lastly, the old genial life of the high places, in which the "new moon" or Sabbath or the annual festival was a sacrificial feast of communion, in which the members of the local community or clan enjoyed fellowship with one another—all this picturesque life ceased to be. And though there was positive gain in the removal of idolatrous and corrupt modes of worship, there was also positive loss in the disappearance of this old genial phase of Hebrew social life and worship. It involved a vast difference to many a Judaean village when the festival pilgrimage was no longer made to the familiar local sanctuary with its hoary associations of ancient heroic or patriarchal story, but to a distant and comparatively unfamiliar city with its stately shrine and priesthood.

8. *Ezekiel's System.*—Ezekiel was the successor of Jeremiah and inherited his conceptions. But though the younger prophet adopted the ideas respecting personal religion and individual responsibility from the elder, the characters of the two men were very different. Jeremiah, when he foretold the destruction of the external state and temple ritual, found no resource save in a reconstruction that was internal and spiritual. In this he was true to his prophetic impulse and genius. But Ezekiel was, as Wellhausen well describes him, "a priest in prophet's mantle." While Jeremiah's tendency was spiritual and ideal, Ezekiel's was constructive and practical. He was the first to foretell with clearness the return of his people from captivity foreshadowed by Jeremiah, and he set himself the task even in the midnight 186
darkness of Israel's exile to prepare for the nation's renewed life. The external bases of Israel's religion had been swept away, and in exchange for these Jeremiah had led his countrymen to the more permanent internal grounds of a spiritual renewal. But a religion could not permanently subsist in this world of space and time without some external concrete embodiment. It was the task of Ezekiel to take up once more the broken threads of Israel's religious traditions, and weave them anew into statelier forms of ritual and national polity. The priest-prophet's keen eye for detail, manifested in the elaborate vision of the wheels and living creatures (Ezek. i.) and in his lamentation on Tyre (chap. xxvii.), is also exhibited in the visions contained in chaps. xl.-xlviii., which describe the ideal reconstructed temple and theocracy of the restored Israel. The foreground is filled by the temple and its precincts. The officiating priests are now the descendants of the line of Zadok belonging to

the tribe of Levi. Thus the priesthood is still further restricted as compared with the restriction already noted in the Deuteronomic legislation. It is the sons of Zadok only that have any right to offer sacrifice at the altar of burnt offering (xliii. 19, xliv. 15 foll.). The Levites, who formerly ministered in the high places, now discharge the subordinate offices of gate-keepers and slaughterers of the sacrificial victims.

Another element in this ideal scheme which comes into prominence is the sharp distinction between *holy* and *profane*. The word *holiness* (*qodesh*) in primitive Hebrew usage partook of the nature of taboo, and came to be applied to whatever, whether thing or person, stood in close relation to deity and belonged to him, and could not, therefore, be used or treated like other objects not so related, and so was separated or stood apart. The idea underlying the word, which to *us* is invested with deep ethical meaning, had only this non-ethical, ritual significance in Ezekiel. Unlike the old temple and city, the ideal temple of Ezekiel is entirely separate from the city of Jerusalem. In the immediate surroundings of the temple there is an open space. Then come two concentric forecourts of the temple. The temple stands in the midst of what is called the *gizrah* or space severed off. The outer court lies higher than the open space, the inner court higher still, and the temple-building in the centre highest of all. No heathen may tread the outer court, no layman the inner court, while the holiest of all may not be trodden even by the priest Ezekiel but only by the angel who accompanies him. “The temple-house has a graduated series of compartments increasing in sanctity inwards” (Davidson). In the innermost the presence of Yahweh abides.

We are here moving in a realm of ideas prevailing in ancient Israel respecting *holiness*, *uncleanness* and *sin*, which are ceremonial and not ethical; see especially Robertson Smith’s *Religion of the Semites*, 2nd ed., p. 446 foll. (additional note B.) on holiness, uncleanness and taboo. It is, of course, true that the ethical conception of sin as violation of righteousness and an act of rebellion against the divine righteous will had been developed since the days of Amos and Isaiah; but, as we have already observed, cultus and prophetic teaching were separated by an immense gulf, and in spite of the reformation of 621 B.C. still remain separated. In the sacrificial system of sin-offerings (*ḥattāth* and *’āshām*) we have to do with sin as ceremonial violation and neglect (frequently involuntary), or violation of holiness in the old sense of the term or as personal uncleanness (touching a corpse, eating unclean food, sexual impurity, &c.). In the historical evolution of Hebrew sacrifice it is remarkable how long this non-ethical and primitive survival of old custom still survived, even far into post-exilian times. (See SACRIFICE; also Moore’s art. “Sacrifice” in *Ency. Bibl.*)

One conspicuous feature of Ezekiel’s system is the predominance of piacular sacrifice. It undoubtedly existed in pre-exilian Israel, especially in times of crisis or calamity, for the appeasement of an offended deity (2 Sam. xxiv. 18 foll.), and in Deut. xxi. 1-9, we have details of the purificatory rite which was necessary when human blood was shed; but now and in the future propitiatory sacrifice and ideas of propitiation began to overshadow all the other forms of sacrifice and their ideas. Ezekiel prescribes a half-yearly ritual of sin-offering whereby atonement was to be made (xlv. 18-20). We shall see subsequently to what great institution this led the way.

Ezekiel’s system constituted an *ecclesiastical* in place of a political organization, a *church-state* in place of a nation. We clearly discern how this reacted on his Messianic conceptions. In his earlier oracles (xxxiv. 23 foll.) we find one shepherd ruling over united Israel, viz. Yahweh’s servant David, whereas in the ideal scheme detailed in chap. xl. et seq. the rôle of the prince as a ruler is a very shadowy one. The prince, it is true, has a central domain, but his functions are ecclesiastical and subordinate and his powers strictly limited (xlvi. 3-8, 12, 16-18).

Thus the exile period marks the parting of the ways in the development of Hebrew religion. In the Deutero-Isaiah we reach the highest point in the evolution of prophetism. It is true that we have some noble resounding echoes in the lyrical passages lx.-lxii. In the Trito-Isaiah during the post-exilian period, and in such psalm literature as Pss. xxii., xxxvii., l., lxii., cvii., cxlv. 9-12 and others; and also in Isa. xxxv., which is obviously a lyrical reproduction of earlier literature. But it cannot be said that we possess in later literature any fresh contribution to the conception of God or any presentation of a higher ideal of human life[30] or national destiny than that which meets us in chap. xl. or in the servant-passages of the Deutero-Isaiah. It may with truth be said that *after Jeremiah we discern the parting of the ways*. The *first* is represented by the Deutero-Isaiah, who constitutes the climax and close of Hebrew prophetism, which is henceforth (with the possible exception of the Trito-Isaiah, Malachi and Jonah, who reproduce some features of the earlier prophecy) a virtually arrested development. The *second path* is that which is traced out by the priest-prophet Ezekiel, and is that of *legalism*, which was destined to secure a permanent place in the life and literature of the Jewish people. It is essentially the path which may be summed up in the word *Judaism*, though, as will be shown in the sequel, Judaism came to include many other factors. The statement, however, remains virtually true, since Judaism is mainly constituted by the body of legal precepts called the Tōrah, and, moreover, by the post-exilian Tōrah.

9. *Post-exilian Law—The Priestercodex.*[31]—The oracles of Malachi clearly reveal the continued influence of the book of Deuteronomy in his day. But the new conditions created by the return of the exiles and the germinating influence of Ezekiel's ideas developed a process of new legislative construction. The code of holiness (Lev. xvii.-xxvi.) is the most obvious product of that influence. The ideas of expiation and atonement so prevalent in Ezekiel's scheme, which there find expression in the half-yearly sacrificial celebrations, are expressed in Lev. xvi. in the single *annual great fast of atonement*. It is impossible to enter here into the numerous details of that impressive ceremonial. Two special features, however, which characterize the celebration should here be noted: (*a*) The person of the *high priest*, who is throughout the entire drama the chief and indeed the sole actor. This supreme official, who was destined ultimately to take the place of the king in the church-nation of post-exilian Judaism, is mentioned for the first time in Zech. iii. 1[32] (in the person of Joshua). In the Priestercodex he stands at the head of the priests, who are, in the post-exilian system, the *sons of Aaron* and possessed the sole right to offer the temple sacrifices. On the great day of atonement the high priest appears in a vicarious and representative capacity, and offers on behalf of the whole nation which he was considered to embody in his sacred person. (*b*) The rite of the *goat devoted to Azazel*. There can be little doubt that 187
Azazel was an evil demon (like an Arabic Jinn) of the desert. The goat set apart for Azazel was in the concluding part of the ceremonial brought before the high priest, who laid both his hands upon it and confessed over it the sins of the people. It was then carried off by an appointed person to a lonely spot and there set free.

In later post-exilian times this great day of atonement became to an increasing degree a day of humiliation for sin and penitent sorrow, accompanied by confession; and the sins confessed were not only of a purely ceremonial character, whether voluntary or inadvertent, but also sins against righteousness and the duties which we owe to God and man. This element of public confession for sin became more prominent in the days when synagogal worship developed, and prayer took the place of the sacrificial offerings which could only be offered in the Jerusalem temple. The development of the priestly code of legislation (Priestercodex) was a gradual process, and probably occupied a considerable part of the 5th century B.C. The Hebrew race now definitely entered upon the new path of organized Jewish legalism which had been originally marked out for it by Ezekiel in the preceding century. It became a holy people on holy ground. Circumcision and Sabbath, separation from marriage with a foreigner, which rendered a Jew unclean, as well as strict conformity to the precepts of the Tōrah, constituted henceforth an adamantine bond which was to preserve the Jewish communities from disintegration.

10. *The later Post-exilian Developments in Jewish Religion.*—These may be briefly referred to under the following aspects:

(*a*) *Codified law* and the written record of the patriarchal history, as well as the life and work of the lawgiver Moses (to whom the entire body of law came to be ascribed), assumed an ever greater importance. The reverence felt for the canonized *Tōrah* or law (the Pentateuch or so-called five books of Moses) grew even into worship. Of this spirit we find clear expression in some of the later psalms, *e.g.* the elaborate alphabetic Ps. cxix. and the latter portion of Ps. xix. There were various causes which combined to enhance the importance of the written *Tōrah* (the "instruction" *par excellence* communicated by God through Moses). Chief among these were (1) *The conception of God as transcendent*. We have taken due note of Amos, who unfolded the character of Yahweh as universal righteous sovereign; and also the sublime portrayal of His exalted nature in Isa. xl. (verse 15; cf. 22-26, and Job xxxvi. 22-xlii. 6). The intellectual influence of Greece, manifested in Alexandrian philosophy, tended to remove God still further from the human world of phenomena into that of an inaccessible transcendental abstraction. Little, therefore, was possible for the Jew save strict performance of the requirements of the Tōrah, once for all given to Moses on Sinai, and, in his approach to the awful and unknown mystery, to rely on ceremonial and ascetic performances (see Wendt's *Teaching of Jesus*, i. 55 foll.). The same tendency led the pious worshippers to avoid His awful name and to substitute *Adonai* in their scriptures or to use in the Mishna the term "name" (*shēm*) or "heaven." (2) The *Maccabean conflict* (165 B.C.) tended to accentuate the national sentiment of antagonism to Hellenic influence. The Ḥasīdim or pious devotees, who arose at that time, were the originators of the Pharisaic movement which was conservative as well as national, and laid stress on the strict performance of the law.

(*b*) *Eschatology* in the Judaism of the Greek period began to assume a new form. The pre-exilian prophets (especially Isaiah) spoke of the forthcoming crisis in the world's history as a "day of the Lord." These were usually regarded as visitations of chastisement for national sins and vindications of divine righteousness or judgments, *i.e.* assertions of God's power as judge (*shōphet*). By the older prophets this judgment of God or "day of Yahweh" was never held to be far removed from the horizon of the present or the world in which they lived. But now as we enter the Greek period (320 B.C. and onwards) there is a gradual change from prophecy to *apocalyptic*. "It may be asserted in general terms that whereas prophecy foretells a definite future which has its foundation in the present, apocalyptic directs its anticipations solely and simply to the future, to a new world-period which stands sharply contrasted with the present. The classical model for all apocalyptic is to be found in Dan. vii. It is only after a great war of destruction, a day of Yahweh's great judgment, that the dominion of God will begin" (Bousset). Ezek. xxxviii. and xxxix. clearly bear the apocalyptic character; so also Isa. xxxiv. and notably Isa. xxiv.-xxvii. Apocalyptic, as Baldensperger has shown, formed a counterpoise to the normal current of conformity to law. It arose from a spiritual movement in answer to the yearning of the heart: "O that Thou mightest rend the heavens and come down and the mountains quake at Thy presence!" (Isa. lxiv. 1 [Heb. lxiii. 19]); and it was intended to meet the craving of souls sick with waiting and disappointment. The present outlook was hopeless, but in the enlarged horizon of time as well as space the thoughts of some of the most spiritual minds in Judaism were directed to the transcendent and ultimate. The present world was corrupt and subject to Satan and the powers of darkness. This they called "the present *aeon*" (age). Their hopes were therefore directed to "the coming aeon." Between the two aeons there would take place the *advent of the Messiah*, who would lead the struggle with evil powers which was called "the agonies of the Messiah." This terrible intermezzo was no longer terrestrial, but was a cosmic and universal crisis in which the Messiah would emerge victorious from the final conflict with the heathen and demonic powers. This victory inaugurates the entrance of the "aeon to come," in which the faithful Jews would enter their inheritance. In this way we perceive the transformation of the old Messianic doctrine through apocalyptic. Of apocalyptic literature we have numerous examples extending from the 2nd century B.C. to the 2nd century A.D. (See especially Charles's *Book of Enoch*.)

The doctrine of the *resurrection of the righteous* to life in the heavenly world became engrafted on to the old doctrine of Sheōl, or the dark shadowy underworld (Hades), where life was joyless and feeble, and from which the soul might be for a brief space summoned forth by the arts of the necromancer. The most vivid portraiture of Sheōl is to be found in the exilian passage Isa. xiv. 9-20 (cf. Job x. 21-22). With this also compare the Babylonian *Descent of Ishtar to Hades*. The added conception of the resurrection of the righteous does not appear in the world of Jewish thought till the early Greek period in Isa. xxvi. 19. R. H. Charles thinks that in this passage the idea of resurrection is of purely Jewish and not of Mazdaan (or Zoroastrian) origin, but it is otherwise with Dan. xii. 2; see his *Eschatology, Hebrew, Jewish and Christian*. Corresponding to heaven, the abode of the righteous, we have *Gē-henna* (originally *Gē-Hinnom*, the scene of the Moloch rites of human sacrifice), the place of punishment after death for apostate Jews.

(*c*) *Doctrine of Angels and of Hypostases.*—In the writings of the pre-exilian period we have frequent references to supernatural personalities good and bad. It is only necessary to refer to them by name. *Sebāōth*, or "hosts," attached to the name of Yahweh, denoted the heavenly retinue of stars. The *seraphīm* were burning serpentine forms who hovered above the enthroned Yahweh and chanted the Trisagion in Isaiah's consecration vision (Isa. vi.). We have also constant references to "angels" (*malāchīm*) of God, divine messengers who represent Him and may be regarded as the manifestation of His power and presence. This especially applies to the "angel of Yahweh" or angel of His Presence [Ex. xxiii. 20, 23 (E). Note in Ex. xxxiii. 14 (J) he is called "my face" or "presence"[33] (cf. Isa. lxiii. 9)]. We also know that from earliest times Israel believed in the evil as well as good spirits. Like the Arabs they held that demons became incorporate in serpents, as in Gen. iii. The *nephīlīm* were a monstrous brood begotten of the intercourse of the supernatural beings called "sons of God" with the women of earth. We also read of the "evil spirit" that came upon Saul. Contact with Babylonia tended to stimulate the angelology and demonology of Israel. The 188 Hebrew word *shēd* or "demon" is no more than a Babylonian loan word, and came to designate the deities of foreign peoples degraded into the position of demons.[34] *Līlīth*, the blood-sucking night-hag of the post-exilian Isa. xxxiv. 14, is the Babylonian *Lilātu*. Whether the *se'īrīm* or shaggy satyrs (Isa. xiii. 31; Lev. xvii. 7) and *Azāzēl* were of Babylonian origin it is difficult to determine. The emergence of *Satan* as a definite supernatural personality, the head or prince of the world of evil spirits, is entirely a phenomenon of post-exilian Judaism. He is portrayed as the arch-adversary and accuser of man. It is impossible to deny Persian influence in the development of this conception, and that the Persian Ahriman (Angromainyu), the evil personality opposed to the good, Ahura Mazda, moulded the Jewish counterpart, Satan. But in Judaism monotheistic conceptions reigned supreme, and the Satan of Jewish belief as opposed to God stops short of the dualism of Persian religion. Of this we see evidence in the multiplication of Satans in the Book of Enoch. In the Book of Jubilees he is called *mastēmā*. In later Judaism *Sammael* is the equivalent of Satan. Persian influence is also responsible for the *vast multiplication of good spirits or angels*, Gabriel, Raphael, Michael, &c., who play their part in apocalyptic works, such as the Book of Daniel and the Book of Enoch.

Probably the transcendent nature of the deity in the Judaism of this later period made the interposition of mediating spirits an intellectual necessity (cf. Ps. civ. 4). It also stimulated the creation of *divine hypostases*. First among these may be mentioned *Wisdom*. The roots of this conception belong to pre-exilian times, in which the "word" of divine denunciation was regarded as a quasi-material thing. (It is hurled against offending Israel, Isa. ix. 8.). In the post-exilian cosmogony it is the divine word or fiat that creates the world (Gen. i.; cf. Ps. xxxiii. 6, 9). Out of these earlier conceptions the idea of the divine wisdom (Heb. *ḥokhmah*) gradually arose during the Persian period. The expression "wisdom," as it is employed in the *locus classicus*, Prov. viii., connotes the contents of the Divine reason—His conscious life, out of which created things emerge. This wisdom is personified. It dwelt with God (Prov. viii. 22 foll.) before the world was made. It is the companion of His throne, and by it He made the world (Prov. iii. 19, viii. 27; cf. Ps. civ. 24). It, moreover, enters into the life of the world and especially man (Prov. viii. 31). This conception of wisdom became still further hypostatized. It becomes redemptive of man. In the Wisdom of Solomon it is the sharer of God's throne (πάρεδρος), the effulgence of the eternal light and the outflow of His glory (Wisd. vii. 25, viii. 3 foll., ix. 4, 9); "Them that love her the Lord doth love" (Ecclesiasticus iv. 14). This group of ideas culminated in the Logos of Philo, expressing the world of divine ideas which God first of all creates and which becomes the mediating and formative power between the absolute and transcendent deity and passive formless matter, transmuted thereby into a rational, ordered universe.

In later Jewish literature we meet with further examples of similar hypostases in the form of *Mēmrā*, *Metatron*, *Shechinah*, *Holy Spirit* and *Bath kōl*.

(*d*) The doctrine of *pre-existence* is another product of the speculative tendency of the Jewish mind. The Messiah's pre-existent state before the creation of the world is asserted in the Book of Enoch (xlviii. 6, 7). Pre-existence is also asserted of Moses and of sacred institutions such as the New Jerusalem, the Temple, Paradise, the Tōrah, &c. (Apocal. of Baruch iv. 3-lix. 4; Assumptio Mosis i. 14, 17); Edersheim's *Life and Times of the Messiah*, i. 175 and footnote 1.

11. *Christ resumes the Broken Tradition of Prophetism.*—The Psalms of Solomon and the synoptic Gospels (70 B.C.-A.D. 100) clearly reveal the powerful revival of Messianic hopes of a national deliverer of the seed of David. This Messianic expectation had been a fermenting leaven since the great days of Judas Maccabaeus. The conceptions of Jesus of Nazareth, however, were not the Messianic conceptions of his fellow-countrymen, but of the spiritual "son of man" destined to found a kingdom of God which was righteousness and peace. The Tōrah of Jesus was essentially prophetic and in no sense priestly or legal. The arrested prophetic movement of Jeremiah and Deutero-Isaiah reappears in John the Baptist and Jesus after an interval of more than five centuries. The new covenant of redeeming grace—the righteousness which is in the heart and not in externalities of legal observance or ceremonial—are once more proclaimed, and the exalted ideals of the suffering servant of Isa. xlix. 6 and Isa. liii. (nearly suppressed in the Targum of Jonathan) are reasserted and vindicated by the words and life of Jesus. Like Jeremiah He foretold the destruction of the temple and suffered the extreme penalties of anti-patriotism. And thus Israel's old prophetic Tōrah was at length to achieve its victory, for after Jesus came St Paul. "Many shall come from the east and the west and sit down with Abraham, Isaac and Jacob in the kingdom of heaven" (Matt. viii. 11, 12). The fetters of nationalism were to be broken, and the Hebrew religion in its essential spiritual elements was to become the heritage of all humanity.

AUTHORITIES.—1. On Semitic religion generally: Wellhausen's *Reste des arabischen Heidentums* (2nd ed.) and Robertson Smith's *Religion of the Semites* (2nd ed.) are chiefly to be recommended. Barton's *Semitic Origins* is extremely able, but his doctrine of the derivation of male from original female deities is pushed to an extreme. Bäthgen's *Beiträge*

zur semitischen Religionsgeschichte (1888) is most useful, and contains valuable epigraphic material. Baudissin's *Studien zur semitischen Religionsgeschichte* (1876) is still valuable. See also Kuenen's *National Religions and Universal Religions* (Hibbert lectures) and Lagrange's *Études sur les religions sémitiques* (2nd ed.).

2. On Hebrew religion in particular: specially full and helpful is Kautzsch's article "Religion of Israel" in Hastings's D.B., extra vol.; Marti's recent *Religion des A.T.* (1906) and his *Geschichte der israelitischen Religion*, are clear, compact and most serviceable, and the former work presents the subject in fresh and suggestive aspects. Wellhausen's *Prolegomena* and *Jüdische Geschichte* should be read both for criticism and Hebrew history generally. Duhm's *Theologie der Propheten* and Robertson Smith's *Prophets of Israel* should also be consulted. Strongly to be recommended are Smend, *Lehrbuch der alttestamentlichen Religionsgeschichte*; Bennett, *Theology of the Old Testament* and *Religion of the Post-Exilic Prophets*; A. B. Davidson, *The Theology of the Old Testament*, as well as the sections devoted to "Sacralaltertümer" in the *Hebräische Archäologie* both of Benzinger and also of Nowack. Budde's *Die Religion des Volkes Israel bis zur Verbannung*, as well as Addis's recent *Hebrew Religion* (1906), is a most careful and scholarly compendium. Harper's Introd. to his *Commentary on Amos and Hosea* (I. and T. Clark) contains a useful survey of the history of Hebrew religion before the 8th century. Buchanan Gray's *Divine Discipline of Israel*, and A. S. Peake's *Problem of Suffering in the O.T.*, are suggestive. See also S. A. Cook, *Religion of Ancient Palestine*.

3. On the history of Judaism till the time of Christ, Schürer's *Geschichte des jüdischen Volkes im Zeitalter Christi* (3rd ed.), vol. ii. and in part vol. iii., are indispensable. Bousset's *Religion des Judentums* (2nd ed.), and Volz, *Die jüdische Eschatologie von Daniel bis Akiba*, are highly to be commended. Weber's *Jüdische Theologie* is a useful compendium of the theology of later Judaism.

4. On the special department of eschatology the standard works are R. H. Charles, *Eschatology, Hebrew, Jewish and Christian*, and Schwally, *Das Leben nach dem Tode*, as well as Gressmann's suggestive work *Der Ursprung der israelitisch-jüdischen Eschatologie*, which contains, however, much that is speculative. On apocalyptic generally the introductions to Charles's Book of Enoch, Apocalypse of Baruch, Ascension of Isaiah and Book of Jubilees, should be carefully noted. See also Eschatology.

5. On the religion of Babylonia, Jastrow's work is the standard one. Zimmern's Heft ii. in *K.A.T.* (3rd ed.) is specially important to the Old Testament student. See also W. Schrank, *Babylonische Sühnriten*.

(O. C. W.)

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1 See Bäthgen, *Beiträge zur semit. Religionsgesch.* p. 11 (Edom); and cf. Schrader, C.O.T. i. 137; K.A.T. (3rd ed.), p. 472 foll. See also *Beiträge*, pp. 13-15; K.A.T. (3rd ed.), pp. 469-472.

2 *Z.D.M.G.* (1886). It is impossible to discuss the other theories of the origin of this name. See Driver, *Commentary on Genesis*, excursus i. pp. 404-406.

3 The Tell el-Amarna despatches are crowded with evidences of Canaanite forms and idioms impressed on the Babylonian language of these cuneiform documents. *Ilāni* here simply corresponds to the Canaanite *Elōhīm*. See opening of the letters of Abimelech of Tyre, Bezold's *Oriental Diplomacy*, Nos. 28, 29, 30.

4 "Magic and Social Relations" in *Sociological Papers*, ii. 160.

5 See Kautzsch, "Religion of Israel," in Hastings's *Dict. of the Bible*, extra vol., p. 614.

6 See Benzinger, *Hebräische Archäologie*, pp. 152, 297 foll. (1st ed.).

7 The theory was opposed by Nöldeke, 1886 (*Z.D.M.G.* p. 157 foll.), as well as Wellhausen, and since then by Jacobs and Zapletal. (*Der Totemismus u. die Religion Israels*). See Stanley A. Cook, "Israel and Totemism," in *J.Q.R.* (April, 1902).

8 These sacred arks were carried in procession accompanied by symbolic figures. We note in this connexion the form of a sacred bark represented in Meyer's *Hist. of Egypt* (Oncken series), p. 257, viz. the procession carrying the sacred ark and the bark of the god Amōn belonging to the reign of Rameses II. (Lepsius, *Denkmäler*, iii. 189b). See also Birch, *Egypt* (S.P.C.K.), p. 151 (ark of Khonsu); cf. Jeremias, *Das A.T. im Lichte des alten Orients* (2nd ed.), pp. 436-441.

9 Cf. Zimmern in *Z.D.M.G.* (1904), pp. 199 foll., 458 foll. This view is based on Dr Pinches's discovered list in which *Sapatti* is called the 15th day (*Proc. of the Soc. of Biblical Arch.*, p. 51 foll.). See A. Jeremias, *Das A. T. im Lichte des alten Orients* (2nd ed.), pp. 182-187. Marti, in his stimulating work *Religion des A.T.*, pp. 5, 72, advocates the exclusive reference of the word Sabbath to the full moon until the time of Ezekiel on the basis of Meinhold's arguments in *Sabbat u. Woche im A.T.* The latter regards Ezekiel as the organizer of the Jewish community and the originator of the sanctity of the Sabbath as a seventh day (Ezek. xlvi. 1; cf. Ezek. xx. 12, 13, 16,

20, 24, xxii. 8, 26, xxiii. 38, in which the reproaches for the profanation or neglect of the Sabbath in no way sustain Meinhold’s view). In opposition to Meinhold, see Lotz in *P.R.E.* (3rd ed., art. “Sabbath,” vol. xvii. pp. 286-289). To this Meinhold replies in *Z.A.T.W.* (1909), p. 81 f. Cf. also Hehn, *Siebenzahl und Sabbat*. While admitting that a special significance may have been attached in pre-exilian times to the full-moon Sabbath, and that the latter may have been specially intended in the combination “new moon and Sabbath” in the 8th-century prophets (Hos. ii. 13; Amos viii. 5; Isa. i. 13), we are not prepared to deny that the institution of a seventh-day Sabbath was an ancient pre-exilian tradition. The sacredness of the number seven is based on the seven planetary deities to whom each day of the week was respectively dedicated, *i.e.* was astral in origin. Cf. *C.O.T.* i. 18 foll., and Winckler, *Religionsgeschichtlicher u. geschichtlicher Orient*, p. 39. See also *K.A.T.* (3rd ed.), pp. 620-626. In the Old Testament the sanctity of the number seven is clearly fundamental (*e.g.* in the Nif’al form *nišba’*, “to swear,” in the derivative subst. for “oath,” in Beēr-sheba’, &c.). The seventh day of rest was parallel to the seventh year of release and of the fallow field. It is, therefore, impossible to detach Ex. xxiii. 12 from Ex. xxi. 2. xxiii. 10 foll.; cf. Ex. xxxiv. 21. We therefore hold that the law of the seventh-day Sabbath goes back to the Mosaic age. The general coincidence of the Sabbath or seventh day with the easily recognized first quarter and full moon established its sacred character as *lunar* as well as planetary.

10 The tablet is neo-Babylonian and published by Dr Pinches in the *Transactions of the Victoria Institute*, and is cited by Professor Fried. Delitzsch in the notes appended to his first lecture *Babel u. Bibel* (5th German ed., p. 81 ad fin. and p. 82). On this subject of Babylonian influence over Israel see Jeremias, *Monotheistische Strömungen innerhalb der babylonischen Religion*, and E. Baentsch, *Altorientalischer u. israelitischer Monotheismus*. The text and rendering of the passage are doubtful in the cuneiform letter discovered by Sellin in Ta’annek (biblical Ta’anach, near Megiddo) addressed by Aḥi-jawi (? Aḥijah) to Ishtar-wasur, in which the following remarkable phrases are read: “May the Lord of the gods protect thy life.... Above thy head is one who is above the towns. See now whether he will show thee good. When he reveals his face, then will they be put to shame and the victory will be complete.” The letter appears to belong to about 1400 B.C. See A. Jeremias, *Das A.T. im Lichte des alten Orients* (2nd ed.), pp. 315, 316, 323. Sellin, *Ertrag der Ausgrabungen im Orient*.

11 The allusion in Amos ii. 7; Hos. iv. 13, 14 is sufficiently explicit; cf. Jer. ii. 20-23, iii. 6-11, v. 7, 8. The practice is prohibited in Deut. xxiii. 17.

12 Column i. 15, 16, 42, 43, ii. 128, iii. 30, 31, iv. 47, 48, &c. Probably we should regard them as differentiated *hypostases*.

13 Hence the ’Ashtārōth or offspring of flocks in Deut. vii. 13, xxviii. 18. A like function belonged to the Babylonian Ishtar. See “Descent of Ishtar to Hades,” Rev. lines 6-10, where universal non-intercourse of sexes follows Ishtar’s departure from earth to Hades.

14 *Proleg. Gesch. Israels* (2nd ed.), p. 240 foll., cf. p. 258.

15 *Internat. Crit. Commentary, Judges*, Introd. p. xxx., also p. 367 foll.

16 לוא “priest,” לואת “priestess”; see Hommel, *Süd-arabische Chrestomathie*, p. 127; *Ancient Hebrew Tradition*, p. 278 foll.

17 Moore regards this verse as belonging to the J or older document, *op. cit.* p. 367.

18 Similarly in ancient Greece. See the instructive passage in Aristotle, *Nic. Eth.* viii. 9 (4, 5), on the relation of Greek sacrifices and festivals to κοινωνίαι and politics: αἱ γὰρ ἀρχαῖαι θυσίαι καὶ σύνοδοι φαίνονται γίγνεσθαι μετὰ τὰς τῶν καρπῶν συγκομιδὰς οἷον ἀπαρχαί; cf. Grote on Pan-Hellenic festivals, *History of Greece*, vol. iii., ch. 28.

19 Wellhausen, *Reste arabischen Heidentums* (2nd ed.), p. 89.

20 Though this be an interpolated gloss (Thenius, Budde), it states a significant truth as Kautzsch clearly shows, *op. cit.* p. 672. In Micah iii. 7 the *ḥōzeh* is mentioned in a sense analogous to the *rō’ēh* or “seer,” and coupled with the *qōsēm* or “soothsayer,” viz. as spurious; cf. Deut. xviii. 10.

21 No better derivation is forthcoming of the word *nabhi’*, “prophet,” than that it is a Kāṭīl form of the root *nābā* = Assyr. *nabū*, “speak.”

22 In Isa. iii. 2 the soothsayer is placed on a level with the judge, prophet and elder.

23 Kautzsch, in his profoundly learned article on the “Religion of Israel,” to which frequent reference has been made, exhibits (pp. 669-671) an excess of scepticism, in our opinion, towards the views propounded by Gunkel in 1895 (*Schöpfung und Chaos*) respecting the intimate connexion between the early Hebrew cosmogonic ideas and those of Babylonia. Stade indeed (*Z.A.T.W.*, 1903, pp. 176-178) maintained that the conception of Yahweh as creator of the world could not have arisen till after the middle of the 8th century as the result of prophetic teaching, and that it was not till the time of Ezekiel that Babylonian conceptions entered the world of Hebrew thought in any fulness. Such a theory appears to ignore the remarkable results of archaeology since 1887. At that time Stade’s position might have appeared reasonable. It was the conclusion to which Wellhausen’s brilliant literary analysis, when not supplemented by the discoveries at Tell el-Amarna and Tell el-Hesi, appeared to many scholars (by no means all)

inevitably to conduct us. But the years 1887 to 1891 opened many eyes to the fact that the Hebrews lived their life on the great highways of intercourse between Egypt on the one hand, and Babylonia, Assyria and the N. Palestinian states on the other, and that they could scarcely have escaped the all-pervading Babylonian influences of 2000-1400 B.C. It is now becoming clearer every day, especially since the discovery of the laws of Khammurabi, that, if we are to think sanely about Hebrew history *before* as well as after the exile, we can only think of Israel as part of the great complex of Semitic and especially Canaanite humanity that lived its life in western Asia between 2000 and 600 B.C.; and that while the Hebrew race maintained by the aid of prophetism its own individual and exalted place, it was not less susceptible *then*, than it has been since, to the moulding influences of great adjacent civilizations and ideas. Cf. C. H. W. Johns in *Interpreter*, pp. 300-304 (in April 1906), on prophetism in Babylonia.

24 There is some danger in too strictly construing the language of the prophets and also the psalmists. It is not to be supposed that either Amos or Isaiah would have countenanced the total suppression of all sacrificial observance. It was the existing ceremonial observance *divorced from the ethical piety* that they denounced. The speech of prophecy is poetical and rhetorical, not strictly defined and logical like that of a modern essayist. See Moore in *Encyc. Bibl.*, “Sacrifice,” col. 4222.

25 Viz. Budde in *Die so-genannten Ebed-Jahweh Lieder u. die Bedeutung des Knechtes Jahwehs in Jes. xl.-lv.* (Giessen, 1900); Karl Marti in his well-known commentary on Isaiah, and F. Giesebrecht, *Der Knecht Jahwes des Deuterojesaja*. The special servant-songs which Duhm asserts can be readily detached from the texture of the Deutero-Isaiah without disturbance to its integrity are Isa. xlii. 1-4, xlix. 1-6, l. 4-9, lii. 13-liii. 12.

26 We have here followed Dillmann’s construction of a difficult passage which Duhm attempts to simplify by omission of the complicating clause without altering the general sense.

27 : Thus in comparison with the “book of the covenant,” Deuteronomy adds the stipulation in reference to the release of the slave; that his master was to provide him liberally from his flocks, his corn and his wine (Deut. xv. 13, 14). See Hastings’s *D.B.*, arts. “Servant,” “Slave,” p. 464, where other examples may be found. In war fruit-trees are to be spared (Deut. xx. 19 foll.), whereas the old universal practice is the barbarous custom Elisha commended (2 Kings iii. 19) of ruthlessly destroying them.

28 Driver, *Internat. Commentary on Deuteronomy*, Introd. p. xxx.

29 It should be noted that in P (Code of Holiness) Lev. xvii. 15 foll. the resident alien (*gēr*) is placed on an equality with the Jew.

30 We shall have to note the emergence of the doctrine of the *resurrection of the righteous* in later Judaism, which is obviously a fresh contribution of permanent value to Hebrew doctrine. On the other hand, the doctrine of *pre-existence* is speculative rather than religious, and applies to institutions rather than persons.

31 The legislative portions are mainly comprised in Ex. xxxv.-end, Leviticus entire and Num. i.-x.

32 But this term (literally the *chief* priest) was already in use during the regal period to designate the head priest of an important sanctuary such as Jerusalem (2 Kings xii. 11).

33 Cf. the Phoenician parallel of “Face of Baal,” worshipped as Tanit, “queen of Heaven” (Bäthgen, *Beiträge zur Semit. Religionsgeschichte*, p. 55 foll.); also the place Penuel (face of God).

34 Deut. xxxii. 17; Ps. cvi. 37. Baal Zebūb of the Philistine Ekron became the Beelzebub who was equivalent to Satan.

HEBREWS, EPISTLE TO THE, one of the books of the New Testament. In the oldest MSS. it bears no other title than “To Hebrews.” This brief heading embraces all that on which Christian tradition from the end of the 2nd century was unanimous; and it says no more than that the readers addressed were Christians of Jewish extraction. This would be no sufficient address for an epistolary writing (xiii. 22) directed to a definite circle of readers, to whose history repeated reference is made, and with whom the author had personal relations (xiii. 19, 23). Probably, then, the original and limited address, or rather salutation, was never copied when this treatise in letter form, like the epistle to the Romans, passed into the wider circulation which its contents merited. In any case the Roman Church, where 189
the first traces of the epistle occur, about A.D. 96 (1 Clement), had nothing to contribute to the question of authorship except the negative opinion that it was not by Paul (Euseb. *Eccl. Hist.* iii. 3): yet this central church was in constant connexion with provincial churches.

The earliest positive traditions belong to Alexandria and N. Africa. The Alexandrine tradition can be traced back as far as a teacher of Clement, presumably Pantaenus (Euseb. *Eccl. Hist.* vi. 14), who sought to explain why Paul did not name himself as usual at the head of the epistle. Clement himself, taking it for granted that an epistle to Hebrews must have been written in Hebrew, supposes that Luke translated it for the Greeks. Origen implies that "the men of old" regarded it as Paul's, and that some churches at least in his own day shared this opinion. But he feels that the language is un-Pauline, though the "admirable" thoughts are not second to those of Paul's unquestioned writings. Thus he is led to the view that the ideas were orally set forth by Paul, but that the language and composition were due to some one giving from memory a sort of free interpretation of his teacher's mind. According to some this disciple was Clement of Rome; others name Luke; but the truth, says Origen, is known to God alone (Euseb. vi. 25, cf. iii. 38). Still from the time of Origen the opinion that Paul wrote the epistle became prevalent in the East. The earliest African tradition, on the other hand, preserved by Tertullian[1] (*De pudicitia*, c. 20), but certainly not invented by him, ascribed the epistle to Barnabas. Yet it was perhaps, like those named by Origen, only an inference from the epistle itself, as if a "word of exhortation" (xiii. 22) by the Son of Exhortation (Acts iv. 36; see BARNABAS). On the whole, then, the earliest traditions in East and West alike agree in effect, viz. that our epistle was not by Paul, but by one of his associates.

This is also the twofold result reached by modern scholarship with growing clearness. The vacillation of tradition and the dissimilarity of the epistle from those of Paul were brought out with great force by Erasmus. Luther (who suggests Apollos) and Calvin (who thinks of Luke or Clement) followed with the decisive argument that Paul, who lays such stress on the fact that his gospel was not taught him by man (Gal. i.), could not have written Heb. ii. 3. Yet the wave of reaction which soon overwhelmed the freer tendencies of the first reformers, brought back the old view until the revival of biblical criticism more than a century ago. Since then the current of opinion has set irrevocably against any form of Pauline authorship. Its type of thought is quite unique. The Jewish Law is viewed not as a code of ethics or "works of righteousness," as by Paul, but as a system of religious rites (vii. 11) shadowing forth the way of access to God in worship, of which the Gospel reveals the archetypal realities (ix. 1, 11, 15, 23 f., x. 1 ff., 19 ff.). The Old and the New Covenants are related to one another as imperfect (earthly) and perfect (heavenly) forms of the same method of salvation, each with its own type of sacrifice and priesthood. Thus the conception of Christ as High Priest emerges, for the first time, as a central point in the author's conception of Christianity. The Old Testament is cited after the Alexandrian version more exclusively than by Paul, even where the Hebrew is divergent. Nor is this accidental. There is every appearance that the author was a Hellenist who lacked knowledge of the Hebrew text, and derived his metaphysic and his allegorical method from the Alexandrian rather than the Palestinian schools. Yet the epistle has manifest Pauline affinities, and can hardly have originated beyond the Pauline circle, to which it is referred not only by the author's friendship with Timothy (xiii. 23), but by many echoes of the Pauline theology and even, it seems, of passages in Paul's epistles (see Holtzmann, *Einleitung in das N. T.*, 1892, p. 298). These features early suggested Paul as the author of a book which stood in MSS. immediately after the epistles of that apostle, and contained nothing in its title to distinguish it from the preceding books with like headings, "To the Romans," "To the Corinthians," and the like. A similar history attaches to the so-called Second Epistle of Clement (see CLEMENTINE LITERATURE).

Everything turns, then, on internal criticism of the epistle, working on the distinctive features already noticed, together with such personal allusions as it affords. As to its first readers, with whom the author stood in close relations (xiii. 19, 23, cf. vi. 10, x. 32-34), it used generally to be agreed that they were "Hebrews" or Christians of Jewish birth. But, for a generation or so, it has been denied that this can be inferred simply from the fact that the epistle approaches all Christian truth through Old Testament forms. This, it is said, was the common method of proof, since the Jewish scriptures were the Word of God to all Christians alike. Still it remains true that the exclusive use of the argument from Mosaism, as itself implying the Gospel of Jesus the Christ as final cause (τέλος), does favour the view that the readers were of Jewish origin. Further there is no allusion to the incorporation of "strangers and foreigners" (Eph. ii. 19) with the people of God. Yet the readers are not to be sought in Jerusalem (see *e.g.* ii. 3), nor anywhere in Judaea proper. The whole Hellenistic culture of the epistle (let alone its language), and the personal references in it, notably that to Timothy in xiii. 23, are against any such view: while the doubly emphatic "all" in xiii. 24 suggests that those addressed were but part of a community composed of both Jews and Gentiles. Caesarea, indeed, as a city of mixed population and lying just outside Judaea proper—a place, moreover, where Timothy might have become known during Paul's two years' detention there—would satisfy many conditions of the problem. Yet these very conditions are no more than might exist among intensely Jewish members of the Dispersion, like "the Jews of Asia" (cf. Sir W. M. Ramsay, *The Letters to the Seven Churches*, 155 f.), whose zeal for the Temple and the Mosaic ritual customs led to Paul's arrest in Jerusalem (Acts xix. 27 f., cf. 20 f.), in keeping both with his former experiences at their hands and with his forebodings resulting therefrom (xx. 19, 22-24). Our "Hebrews" had obviously high regard for the ordinances of Temple worship. But this was the case with the dispersed Jews generally, who kept in touch with the Temple, and its intercessory worship for all Israel, in every possible way; in token of this they sent with great care their annual contribution to its services, the Temple tribute. This bond was doubtless preserved by Christian Hellenists, and must have tended to continue their reliance on the Temple services for the forgiveness of their recurring "sins of ignorance"—subsequent to the great initial Messianic forgiveness coming with faith in Jesus. Accordingly many of them, while placing their hope for the future upon Messiah and His eagerly expected return in power, might seek assurance of present forgiveness of daily offences and cleansing of conscience in the old mediatorial system. In particular the annual Day of Atonement would be relied on, and that in proportion as the expected Parousia tarried, and the first enthusiasm of a faith that was largely eschatological died away, while ever-present temptation pressed the harder as disappointment and perplexity increased.

Such was the general situation of the readers of this epistle, men who rested partly on the Gospel and partly on Judaism. For lack of a true theory as to the relation between the two, they were now drifting away (ii. 1) from effective faith in the Gospel, as being mainly future in its application, while Judaism was a very present, concrete, and impressive system of religious aids—to which also their sacred scriptures gave constant witness. The points at which it chiefly touched them may be inferred from the author's counter-argument, with its emphasis in the spiritual ineffectiveness of the whole Temple-system, its high-priesthood and its supreme sacrifice on the Day of Atonement. With passionate earnestness he sets over against these his constructive theory as to the efficacy, the heavenly yet unseen reality, of the definitive "purification of sins" (i. 3) and perfected access to God's inmost presence, secured for Christians as such by Jesus the Son of God (x. 9-22), and traces their moral feebleness and slackened zeal to want of progressive insight into the essential nature of the Gospel as a "new covenant," moving on a totally different plane of religious reality from the now antiquated covenant given by Moses (viii. 13). 190

The following plan of the epistle may help to make apparent the writer's theory of Christianity as distinct from Judaism, which is related to it as "shadow" to reality:

Thesis: The finality of the form of religion mediated in God's Son, i. 1-4.

i. The supreme excellence of the Son's Person (i. 5-iii. 6), as compared with (*a*) angels, (*b*) Moses.

Practical exhortation, iii. 7-iv. 13, leading up to:

ii. The corresponding efficacy of the Son's High-priesthood (iv. 14-ix.).

(1) The Son has the qualifications of all priesthood, especially sympathy.

Exhortation, raising the reader's thought to the height of the topic reached (v. 11-vi. 20).

(2) The Son as absolute high priest, in an order transcending the Aaronic (vii.) and relative to a Tabernacle of ministry and a Covenant higher than the Mosaic in point of reality and finality (viii., ix.).

(3) His Sacrifice, then, is definitive in its effects (τετελείωκε), and supersedes all others (x. 1-18).

iii. Appropriation of the benefits of the Son's high-priesthood, by steadfast faith, the paramount duty (x. 19-xii.). More personal epilogue (xiii.).

As lack of insight lay at the root of their troubles, it was not enough simply to enjoin the moral fidelity to conviction which is three parts of faith to the writer, who has but little sense of the mystical side of faith, so marked in Paul. There was need of a positive theory based on real insight, in order to inspire faith for more strenuous conflict with the influences tending to produce the apostasy from Christ, and so from "the living God," which already threatened some of them (iii. 12). Such "apostasy" was not a formal abjuring of Jesus as Messiah, but the subtler lapse involved in ceasing to rely on relation to Him for daily moral and religious needs, summed up in purity of conscience and peace before God (x. 19-23, xiii.

20 f.). This "falling aside" (vi. 5, cf. xii. 12 f.), rather than conscious "turning back," is what is implied in the repeated exhortations which show the intensely practical spirit of the whole argument. These exhortations are directed chiefly against the dullness of spirit which hinders progressive moral insight into the genius of the New Covenant (v. 11-vi. 8), and which, in its blindness to the full work of Jesus, amounts to counting His blood as devoid of divine efficacy to consecrate the life (x. 26, 29), and so to a personal "crucifying anew" of the Son of God (vi. 6). The antidote to such "profane" negligence (ii. 1, 3, xii. 12 f., 15-17) is an earnestness animated by a fully-assured hope, and sustained by a "faith" marked by patient waiting (μακροθυμία) for the inheritance guaranteed by divine promise (x. ii f.). The outward expression of such a spirit is "bold confession," a glorying in that Hope, and mutual encouragement therein (iii. 6, 12 f.); while the sign of its decay is neglect to assemble together for mutual stimulus, as if it were not worth the odium and opposition from fellow Jews called forth by a marked Christian confession (x. 23-25, xii. 3)—a very different estimate of the new bond from that shown by readiness in days gone by to suffer for it (x. 32 ff.). Their special danger, then, the sin which deceived (iii. 13) the more easily that it represented the line of least resistance (perhaps the best paraphrase of εὐπερίστατος ἁμαρτία in xii. i), was the exact opposite of "faith" as the author uses it, especially in the chapter devoted to its illustration by Old Testament examples. His readers needed most the moral heroism of fidelity to the Unseen, which made men "despise shame" due to aught that sinners in their unbelief might do to them (xii. 2-11, xiii. 5 f.)—and of which Jesus Himself was at once the example and the inspiration. To quicken this by awakening deeper insight into the real objects of "faith," as these bore on their actual life, he develops his high argument on the lines already indicated.

Their situation was so dangerous just because it combined inward debility and outward pressure, both tending to the same result, viz. practical disuse of the distinctively Christian means of grace, as compared with those recognized by Judaism, and such conformity to the latter as would make the reproach of the Cross to cease (xiii. 13, cf. xi. 26). This might, indeed, relieve the external strain of the contest (ἀγών xii. 1), which had become well-nigh intolerable to them. But the practical surrender of what was distinctive in their new faith meant a theoretic surrender of the value once placed on that element, when it was matter of a living religious experience far in advance of what Judaism had given them (vi. 4 [ff]., x. 26-29). This twofold infidelity, in thought and deed, God, the "living" God of progress from the "shadow" to the substance, would require at their hands (x. 30 f., xii. 22-29). For it meant turning away from an appeal that had been known as "heavenly," for something inferior and earthly (xii. 25); from a call sanctioned by the incomparable authority of Him in whom it had reached men, a greater than Moses and all media of the Old Covenant, even the Son of God. Thus the key of the whole exhortation is struck in the opening words, which contrast the piecemeal revelation "to the fathers" in the past, with the complete and final revelation to themselves in the last stage of the existing order of the world's history, in a Son of transcendent dignity (i. 1 ff., cf. ii. 1 ff., x. 28 f., xii. 18 ff.). This goes to the root of their difficulty, ambiguity as to the relation of the old and the new elements in Judaeo-Christian piety, so that there was constant danger of the old overshadowing the new, since national Judaism remained hostile. At a stroke the author separates the new from the old, as belonging to a new "covenant" or order of God's revealed will. It is a confusion, resulting in loss, not in gain, as regards spiritual power, to try to combine the two types of piety, as his readers were more and more apt to do. There is *no use*, religiously, in falling back upon the old forms, in order to avoid the social penalties of a sectarian position within Judaism, when the secret of religious "perfection" or maturity (vi. 1, cf. the frequent use of the kindred verb) lies elsewhere. Hence the moral of his whole argument as to the two covenants, though it is formulated only incidentally amid final detailed counsels (xiii. 13 f.) is to leave Judaism, and adopt a frankly Christian standing, on the same footing with their non-Jewish brethren in the local church. For this the time was now ripe; and in it lay the true path of safety—eternal safety as before God, whatever man might say or do (xiii. 5 f.).

The obscure section, xiii. 9 f., is to be taken as "only a symptom of the general retrogression of religious energy" (Jülicher), and not as bearing directly on the main danger of these "Hebrews." The "foods" in question probably refer neither to temple sacrifices nor to the Levitical laws of clean and unclean foods, nor yet to ascetic scruples (as in Rom. xiv., Col. ii. 20 ff.), but rather to some form of the idea, found also among the Essenes, that food might so be partaken of as to have the value of a sacrifice (see verse 15 foll.) and thus ensure divine favour. Over against this view, which might well grow up among the Jews of the Dispersion as a sort of substitute for the possibility of offering sacrifices in the Temple—but which would be a lame addition to the Christianity of their own former leaders (xiii. 7 f.)—the author first points his readers to its refutation from experience, and then to the fact that the Christian’s “altar” or sacrifice (*i.e.* the supreme sin-offering) is of the kind which the Law itself forbids to be associated with “eating.” If Christians wish to offer any special sacrifice to God, let it be that of grateful praise or deeds of beneficence (15 f.).

In trying further to define the readers addressed in the epistle, one must note the stress laid on suffering as part of the divinely appointed discipline of sonship (ii. 10, v. 8, xii. 7 f.), and the way in which the analogy in this respect between Jesus, as Messianic Son, and those united to Him by faith, is set in relief. He is not only the inspiring example for heroic faith in the face of opposition due to unbelievers (xii. 3 ff.), but also the mediator qualified by his very experience of suffering to sympathize with His tried followers, and so to afford them moral aid (ii. 17 f., v. 8 f., cf. iv. 15). This means that suffering for Christianity, at least in respect of possessions (xiii. 5 f., cf. x. 34) and social standing, was imminent for those addressed: and it seems as if they were mostly men of wealth and position (xiii. 1-6, vi. 10 f., 191
x. 34), who would feel this sort of trial acutely (cf. Jas. i. 10). Such men would also possess a superior mental culture (cf. v. 11 f.), capable of appreciating the form of an epistle “far too learned for the average Christian” (Jülicher), yet for which its author apologizes to them as inadequate (xiii. 22). It was now long since they themselves had suffered seriously for their faith (x. 32 f.); but others had recently been harassed even to the point of imprisonment (xiii. 3); and the writer’s very impatience to hurry to their side implies that the crisis was both sudden and urgent. The finished form of the epistle’s argument is sometimes urged to prove that it was not originally an epistle at all, written more or less on the spur of the moment, but a literary composition, half treatise and half homily, to which its author—as an afterthought—gave the suggestion of being a Pauline epistle by adding the personal matter in ch. xiii. (so W. Wrede, *Das literarische Rätsel des Hebräerbriefs*, 1906, pp. 70-73). The latter part of this theory fails to explain why the Pauline origin was not made more obvious, *e.g.* in an opening address. But even the first part of it overlooks the probability that our author was here only fusing into a fresh form materials often used before in his oral ministry of Christian instruction.

Many attempts have been made to identify the home of the Hellenistic Christians addressed in this epistle. For Alexandria little can be urged save a certain strain of “Alexandrine” idealism and allegorism, mingling with the more Palestinian realism which marks the references to Christ’s sufferings, as well as the eschatology, and recalling many a passage in Philo. But Alexandrinism was a mode of thought diffused throughout the Eastern Mediterranean, and the divergences from Philo’s spirit are as notable as the affinities (cf. Milligan, *ut infra*, 203 ff.). For Rome there is more to be said, in view of the references to Timothy and to “them of Italy” (xiii. 23 f.); and the theory has found many supporters. It usually contemplates a special Jewish-Christian house-church (so Zahn), like those which Paul salutes at the end of Romans, *e.g.* that meeting in the house of Prisca and Aquila (xvi. 5); and Harnack has gone so far as to suggest that they, and especially Prisca, actually wrote our epistle. There is, however, really little that points to Rome in particular, and a good deal that points away from it. The words in xii. 4, “Not yet unto blood have ye resisted,” would ill suit Rome after the Neronian “bath of blood” in A.D. 64 (as is usually held), save at a date too late to suit the reference to Timothy. Nor does early currency in Rome prove that the epistle was written to Rome, any more than do the words “they of Italy salute you.” This clause must in fact be read in the light of the reference to Timothy, which suggests that he had been in prison in Rome and was about to return, possibly in the writer’s company, to the region which was apparently the headquarters of both. Now this in Timothy’s case, as far as we can trace his steps, was Ephesus; and it is natural to ask whether it will not suit all the conditions of the problem. It suits those of the readers,[2] as analysed above; and it has the merit of suggesting to us as author the very person of all those described in the New Testament who seems most capable of the task, Apollos, the learned Alexandrian (Acts xviii. 24 ff.), connected with Ephesus and with Paul and his circle (cf. 1 Cor. xvi. 12), yet having his own distinctive manner of presenting the Gospel (1 Cor. iv. 6). That Apollos visited Italy at any rate once during Paul’s imprisonment in Rome is a reasonable inference from Titus iii. 13 (see Paul); and if so, it is quite natural that he should be there again about the time of Paul’s martyrdom. With that event it is again natural to connect Timothy’s imprisonment, his release from which our author records in closing; while the news of Jewish success in Paul’s case would enhance any tendency among Asian Jewish Christians to shirk “boldness” of confession (x. 23, 35, 38 f.), in fear of further aggression from their compatriots. On the chronology adopted in the article Paul, this would yield as probable date for the epistle A.D. 61-62. The place of writing would be some spot in Italy (“they of Italy salute you”) outside Rome, probably a port of embarkation for Asia, such as Brundisium.

Be this as it may, the epistle is of great historical importance, as reflecting a crisis inevitable in the development of the Jewish-Christian consciousness, when a definite choice between the old and the new form of Israel’s religion had to be made, both for internal and external reasons. It seems to follow directly on the situation implied by the appeal of James to Israel in dispersion, in view of Messiah’s winnowing-fan in their midst (i. 1-4, ii. 1-7, v. 1-6, and especially v. 7-11). It may well be the immediate antecedent of that revealed in 1 Peter, an epistle which perhaps shows traces of its influence (*e.g.* in i. 2, “sprinkling of the blood of Jesus Christ,” cf. Heb. ix. 13 f., x. 22, xii. 24). It is also of high interest theologically, as exhibiting, along with affinities to several types of New Testament teaching (see Stephen), a type all its own, and one which has had much influence on later Christian thought (cf. Milligan, *ut infra*, ch. ix.). Indeed, it shares with Romans the right to be styled “the first treatise of Christian theology.”

Literature.—The older literature may be seen in the great work of F. Bleek, *Der Brief an die Hebräer* (1828-1840), still a valuable storehouse of material, while Bleek’s later views are to be found in a posthumous work (Elberfeld, 1868); also in Franz Delitzsch’s *Commentary* (Edinburgh, 1868). The more recent literature is given in G. Milligan, *The Theology of the Epistle of the Hebrews* (1899), a useful summary of all bearing on the epistle, and in the large New Testament Introductions and Biblical Theologies. See also Hastings’s *Dict. of the Bible*, the *Encycl. Biblica* and T. Zahn’s article in Hauck’s *Realencyklopädie*.

(J. V. B.)

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1 Also in Codex Claromontanus, the *Tractatus de libris* (x.), Philastrius of Brescia (*c.* A.D. 380), and a prologue to the Catholic Epistles (*Revue bénédictine*, xxiii. 82 ff.). It is defended in a monograph by H. H. B. Ayles (Cambridge, 1899).

2 *i.e.* a house-church of upper-class Jewish Christians, not fully in touch with the attitude even of their own past and present “leaders” (xiii. 7, 17), as distinct from the local church generally (xiii. 24). The Gospel had reached them, as also the writer himself (cf. Acts xviii. 25), through certain hearers of the Lord (ii. 3), not necessarily apostles.

HEBRIDES, THE, or Western Isles, a group of islands off the west coast of Scotland. They are situated between 55° 35′ and 58° 30′ N. and 5° 26′ and 8° 40′ W. Formerly the term was held to embrace not only all the islands off the Scottish western coast, including the islands in the Firth of Clyde, but also the peninsula of Kintyre, the Isle of Man and the Isle of Rathlin, off the coast of Antrim. They have been broadly classified into the Outer Hebrides and the Inner Hebrides, the Minch and Little Minch dividing the one group from the other. Geologically, they have also been differentiated as the Gneiss Islands and the Trap Islands. The Outer Hebrides being almost entirely composed of gneiss the epithet suitably serves them, but, strictly speaking, only the more northerly of the Inner Hebrides may be distinguished as Trap Islands. The chief islands of the Outer Hebrides are Lewis-with-Harris (or Long Island), North Uist, Benbecula, South Uist, Barra, the Shiants, St Kilda and the Flannan Isles, or Seven Hunters, an uninhabited group, about 20 m. N.W. of Gallon Head in Lewis. Of these the Lewis portion of Long Island, the Shiants and the Flannan belong to the county of Ross and Cromarty, and the remainder to Inverness-shire. The total length of this group, from Barra Head to the Butt of Lewis, is 130 m., the breadth varying from less than 1 m. to 30 m. The Inner Hebrides are much more scattered and principally include Skye, Small Isles (Canna, Sanday, Rum, Eigg and Muck), Coll, Tyree, Lismore, Mull, Ulva, Staffa, Iona, Kerrera, the Slate Islands (Seil, Easdale, Luing, Shuna, Torsay), Colonsay, Oronsay, Scarba, Jura, Islay and Gigha. Of these Skye and Small Isles belong to Inverness-shire, and the rest to Argyllshire. The Hebridean islands exceed 500 in number, of which one-fifth are inhabited. Of the inhabited islands 11 belong to Ross and Cromarty, 47 to Inverness-shire, and 44 to Argyllshire, but of this total of 102 islands, one-third have a population of only 10 souls, or fewer, each. The population of the Hebrides in 1901 numbered 78,947 (or 28 to the sq. m.), of whom 41,031 were females, who thus exceeded the males by 10%, and 22,733 spoke Gaelic only and 47,666 Gaelic and English. The most populous island is Lewis-with-Harris (32,160), and next to it are Skye (13,883), Islay (6857) and Mull (4334).

Of the total area of 1,800,000 acres, or 2812 sq. m., only one-ninth is cultivated, most of the surface being moorland and mountain. The annual rainfall, particularly in the Inner Hebrides, is heavy (42.6 in. at Stornoway) but the temperature is high, averaging for the year 47° F. Potatoes and turnips are the only root crops that succeed, and barley and oats are grown in some of the islands. Sheep-farming and cattle-raising are carried on very 192 generally, and, with the fisheries, provide the main occupation of the inhabitants, though they profit not a little from the tourists who flock to many of the islands throughout the summer. The principal industries include distilling, slate-quarrying and the manufacture of tweeds, tartans and other woollens. There are extensive deer forests in Lewis-with-Harris, Skye, Mull and Jura. On many of the islands there are prehistoric remains and antiquities within the Christian period. The more populous islands are in regular communication with certain points of the mainland by means of steamers from Glasgow, Oban and Mallaig. The United Free Church has a strong hold on the people, but in a few of the islands the Roman Catholics have a great following. In the larger inhabited islands board schools have been established. The islands unite with the counties to which they belong in returning members to parliament (one for each shire).

History.—The Hebrides are mentioned by Ptolemy under the name of Ἔβουδαι and by Pliny under that of *Hebudes*, the modern spelling having, it is said, originated in a misprint. By the Norwegians they were called *Sudreyjar* or Southern Islands. The Latinized form was *Sodorenses*, preserved to modern times in the title of the bishop of Sodor and Man. The original inhabitants seem to have been of the same Celtic race as those settled on the mainland. In the 6th century Scandinavian hordes poured in with their northern idolatry and lust of plunder, but in time they adopted the language and faith of the islanders. Mention is made of incursions of the vikings as early as 793, but the principal immigration took place towards the end of the 9th century in the early part of the reign of Harald Fairhair, king of Norway, and consisted of persons driven to the Hebrides, as well as to Orkney and Shetland, to escape from his tyrannous rule. Soon afterwards they began to make incursions against their mother-country, and on this account Harald fitted out an expedition against them, and placed Orkney, Shetland, the Hebrides and the Isle of Man under Norwegian government. The chief seat of the Norwegian sovereignty was Colonsay. About the year 1095 Godred Crovan, king of Dublin, Man and the Hebrides, died in Islay. His third son, Olaf, succeeded to the government about 1103, and the daughter of Olaf was married to Somerled, who became the founder of the dynasty known as Lords of the Isles. Many efforts were made by the Scottish monarchs to displace the Norwegians. Alexander II. led a fleet and army to the shores of Argyllshire in 1249, but he died on the island of Kerrera. On the other hand, Haakon IV., king of Norway, at once to restrain the independence of his jarls and to keep in check the ambition of the Scottish kings, set sail in 1263 on a great expedition, which, however, ended disastrously at Largs. Magnus, son of Haakon, concluded in 1266 a peace with the Scots, renouncing all claim to the Hebrides and other islands except Orkney and Shetland, and Alexander III. agreed to give him a sum of 4000 merks in four yearly payments. It was also stipulated that Margaret, daughter of Alexander, should be betrothed to Eric, the son of Magnus, whom she married in 1281. She died two years later, leaving an only daughter afterwards known as the Maid of Norway.

The race of Somerled continued to rule the islands, and from a younger son of the same potentate sprang the lords of Lorne, who took the patronymic of Macdougall. John Macdonald of Islay, who died about 1386, was the first to adopt the title of Lord of the Isles. He was one of the most potent of the island princes, and was married to a daughter of the earl of Strathearn, afterwards Robert II. His son, Donald of the Isles, was memorable for his rebellion in support of his claim to the earldom of Ross, in which, however, he was unsuccessful. Alexander, son of Donald, resumed the hereditary warfare against the Scottish crown; and in 1462 a treaty was concluded between Alexander’s son and successor John and Edward IV. of England, by which John, his son John, and his cousin Donald Balloch, became bound to assist King Edward and James, earl of Douglas, in subduing the kingdom of Scotland. The alliance seems to have led to no active operations. In the reign of James V. another John of Islay resumed the title of Lord of the Isles, but was compelled to surrender the dignity. The glory of the lordship of the isles—the insular sovereignty—had departed. From the time of Bruce the Campbells had been gaining the ascendancy in Argyll. The Macleans, Macnaughtons, Maclachlans, Lamonts, and other ancient races had sunk before this favoured family. The lordship of Lorne was wrested from the Macdougalls by Robert Bruce, and their extensive possessions, with Dunstaffnage Castle, bestowed on the king’s relative, Stewart, and his descendants, afterwards lords of Lorne. The Macdonalds of Sleat, the direct representatives of Somerled, though driven from Islay and deprived of supreme power by James V., still kept a sort of insular state in Skye. There were also the Macdonalds of Clanranald and Glengarry (descendants of Somerled), with the powerful houses of Macleod of Dunvegan and Macleod of Harris, M‘Neill of Barra and Maclean of Mull. Sanguinary feuds continued throughout the 16th and 17th centuries among these rival clans and their dependent tribes, and the turbulent spirit was not subdued till a comparatively recent period. James VI. made an abortive endeavour to colonize Lewis. William III. and

Queen Anne attempted to subsidize the chiefs in order to preserve tranquillity, but the wars of Montrose and Dundee, and the Jacobite insurrections of 1715 and 1745, showed how futile were all such efforts. It was not till 1748, when a decisive blow was struck at the power of the chiefs by the abolition of heritable jurisdictions, and the appointment of sheriffs in the different districts, that the arts of peace and social improvement made way in these remote regions. The change was great, and at first not unmixed with evil. A new system of management and high rents was imposed, in consequence of which numbers of the tacksmen, or large tenants, emigrated to North America. The exodus continued for many years. Sheep-farming on a large scale was next introduced, and the crofters were thrust into villages or barren corners of the land. The result was that, despite the numbers who entered the army or emigrated to Canada, the standard of civilization sank lower, and the population multiplied in the islands. The people came to subsist almost entirely on potatoes and herrings; and in 1846, when the potato blight began its ravages, nearly universal destitution ensued—embracing, over the islands generally, 70% of the inhabitants. Temporary relief was administered in the shape of employment on roads and other works; and an emigration fund being raised, from 4000 to 5000 of the people in the most crowded districts were removed to Australia. Matters, however, were not really mended, and in 1884 a royal commission reported upon the condition of the crofters of the islands and mainland. As a result of their inquiry the Crofters' Holdings Act was passed in 1886, and in the course of a few years some improvement was evident and has since been sustained.

Authorities.—Martin Martin's *Description of the Western Islands of Scotland* (1703); T. Pennant's *Tour in Scotland and Voyage to the Hebrides* (1774); James Boswell's *Tour to the Hebrides with Samuel Johnson, LL.D.* (1898); John Macculloch's *Geological Account of the Hebrides* (1819); Hugh Miller's *Cruise of the "Betsy"* (1858); W. A. Smith's *Lewisiana, or Life in the Outer Hebrides* (1874); Alexander Smith, *A Summer in Skye* (1865); Robert Buchanan, *The Hebrid Isles* (1883); C. F. Gordon-Cumming, *In the Hebrides* (1883); *Report of the Crofters' Commission* (1884); A. Goodrich-Freer, *Outer Isles* (1902); and W. C. Mackenzie, *History of the Outer Hebrides* (1903). Their history under Norwegian rule is given in the *Chronica regum Manniae et insularum*, edited, with learned notes, from the MS. in the British Museum by Professor P. A. Münch of Christiania (1860).

HEBRON (mod. *Khulīl er-Rahmān*, *i.e.* "the friend of the Merciful One"—an allusion to Abraham), a city of Palestine some 20 m. S. by S.W. of Jerusalem. The city, which lies 3040 ft. above the sea, is of extreme antiquity (see Num. xiii. 22, and Josephus, *War*, iv. 9, 7) and until taken by the Calebites (Josh. xv. 13) bore the name Kirjath-Arba. Biblical traditions connect it closely with the patriarch Abraham and make it a "city of refuge." The town figures prominently under David as the headquarters of his early rule, the scene of Abner's murder and the centre of Absalom's rebellion. In later days the Edomites held it for a time, 193
but Judas Maccabaeus recovered it. It was destroyed in the great war under Vespasian. In A.D. 1167 Hebron became the see of a Latin bishop, and it was taken in 1187 by Saladin. In 1834 it joined the rebellion against Ibrahim Pasha, who took the town and pillaged it. Modern Hebron rises on the east slope of a shallow valley—a long narrow town of stone houses, the flat roofs having small stone domes. The main quarter is about 700 yds. long, and two smaller groups of houses exist north and south of this. The hill behind is terraced, and luxuriant vineyards and fruit plantations surround the place, which is well watered on the north by three principal springs, including the Well Sirah, now 'Ain Sāra (2 Sam. iii. 26). Three conspicuous minarets rise, two from the *Haram*, the other in the north quarter. The population (10,000) includes Moslems and about 500 Jews. The Bedouins bring wool and camel's hair to the market; and glass bracelets, lamps and leather water-skins are manufactured in the town. The most conspicuous building is the *Haram* built over the supposed site of the cave of Machpelah. It is an enclosure measuring 112 ft. east and west by 198 north and south, surrounded with high rampart walls of masonry similar in size and dressing to that of the Jerusalem Haram walls. These ramparts are ascribed by architectural authorities to the Herodian period. The interior area is partly occupied by a 12th-century Gothic church, and contains six modern cenotaphs of Abraham, Isaac, Jacob, Sarah, Rebecca and Leah. The cave beneath the platform has probably not been entered for at least 600 years. The numerous traditional sites now shown round Hebron are traceable generally to medieval legendary topography; they include the Oak of Mamre (Gen. xiii. 18 R.V.) which has at various times been shown in different positions from ¾ to 2 m. from the town.

There are a British medical mission, a German Protestant mission with church and schools, and, near Abraham's Oak, a Russian mission. Since 1880 several notices of the Haram, within which are the tombs of the Patriarchs, have appeared.

See C. R. Conder, Pal. Exp. Fund, *Memoirs*, iii. 333, &c.; Riant, *Archives de l'orient latin*, ii. 411, &c.; Dalton and Chaplin, *P.E.F. Quarterly Statement* (1897); Goldziher, "Das Patriarchengrab in Hebron," in *Zeitschrift d. Dn. Pal. Vereins*, xvii.

(R. A. S. M.)

HECATAEUS OF ABDERA (or of Teos), Greek historian and Sceptic philosopher, flourished in the 4th century B.C. He accompanied Ptolemy I. Soter in an expedition to Syria, and sailed up the Nile with him as far as Thebes (Diogenes Laërtius ix. 61). The result of his travels was set down by him in two works—Αἰγυπτιακά and Περὶ Ὑπερβορέων, which were used by Diodorus Siculus. According to Suidas, he also wrote a treatise on the poetry of Hesiod and Homer. Regarding his authorship of a work on the Jews (utilized by Josephus in *Contra Apionem*), it is conjectured that portions of the Αἰγυπτιακά were revised by a Hellenistic Jew from his point of view and published as a special work.

Fragments in C. W. Müller's *Fragmenta historicorum Graecorum*.

HECATAEUS OF MILETUS (6th-5th century B.C.), Greek historian, son of Hegesander, flourished during the time of the Persian invasion. After having travelled extensively, he settled in his native city, where he occupied a high position, and devoted his time to the composition of geographical and historical works. When Aristagoras held a council of the leading Ionians at Miletus, to organize a revolt against the Persian rule, Hecataeus in vain tried to dissuade his countrymen from the undertaking (Herodotus v. 36, 125). In 494, when the defeated Ionians were obliged to sue for terms, he was one of the ambassadors to the Persian satrap Artaphernes, whom he persuaded to restore the constitution of the Ionic cities (Diod. Sic. x. 25). He is by some credited with a work entitled Γῆς περίοδος ("Travels round the Earth"), in two books, one on Europe, the other on Asia, in which were described the countries and inhabitants of the known world, the account of Egypt being especially comprehensive; the descriptive matter was accompanied by a map, based upon Anaximander's map of the earth, which he corrected and enlarged. The authenticity of the work is, however, strongly attacked by J. Wells in the *Journal of Hellenic Studies*, xxix. pt. i. 1909. The only certainly genuine work of Hecataeus was the Γενεηλογίαι or Ἱστορίαι, a systematic account of the traditions and mythology of the Greeks. He was probably the first to attempt a serious prose history and to employ critical method to distinguish myth from historical fact, though he accepts Homer and the other poets as trustworthy authority. Herodotus, though he once at least controverts his statements, is indebted to Hecataeus not only for facts, but also in regard of method and general scheme, but the extent of the debt depends on the genuineness of the Γῆς περίοδος.

See fragments in C. W. Müller, *Fragmenta historicorum Graecorum*, i.; H. Berger, *Geschichte der wissenschaftlichen Erdkunde der Griechen* (1903); E. H. Bunbury, *History of Ancient Geography*, i.; W. Mure, *History of Greek Literature*, iv.; especially J. V. Prašek, *Hekataios als Herodots Quelle zur Geschichte Vorderasiens. Beiträge zur alten Geschichte* (*Klio*), iv. 193 seq. (1904), and J. Wells in *Journ. Hell. Stud.*, as above.

HECATE (Gr. Ἑκατή, "she who works from afar"[1]), a goddess in Greek mythology. According to the generally accepted view, she is of Hellenic origin, but Farnell regards her as a foreign importation from Thrace, the home of Bendis, with whom Hecate has many points in common. She is not mentioned in the *Iliad* or the *Odyssey*, but in Hesiod (*Theogony*, 409) she is the daughter of the Titan Perses and Asterie, in a passage which may be a later interpolation by the Orphists (for other genealogies see Steuding in Roscher's *Lexikon*). She is there represented as a mighty goddess, having power over heaven, earth and sea; hence she is the bestower of wealth and all the blessings of daily life. The range of her influence is most varied, extending to war, athletic games, the tending of cattle, hunting, the assembly of the people and the law-courts. Hecate is frequently identified with Artemis, an identification usually justified by the assumption that both were moon-goddesses. Farnell, who regards Artemis as originally an earth-goddess, while recognizing a "genuine lunar element" in Hecate from the 5th century, considers her a chthonian rather than a lunar divinity (see also Warr in *Classical Review*, ix. 390). He is of opinion that neither borrowed much from, nor exercised much influence on, the cult and character of the other.

Hecate is the chief goddess who presides over magic arts and spells, and in this connexion she is the mother of the sorceresses Circe and Medea. She is constantly invoked, in the well-known idyll (ii.) of Theocritus, in the incantation to bring back a woman's faithless lover. As a chthonian power, she is worshipped at the Samothracian mysteries, and is closely connected with Demeter. Alone of the gods besides Helios, she witnessed the abduction of Persephone, and, torch in hand (a natural symbol for the moon's light, but see Farnell), assisted Demeter in her search for her daughter. On moonlight nights she is seen at the cross-roads (hence her name τριοδῖτις, Lat. *Trivia*) accompanied by the dogs of the Styx and crowds of the dead. Here, on the last day of the month, eggs and fish were offered to her. Black puppies and she-lambs (black victims being offered to chthonian deities) were also sacrificed (Schol. on Theocritus ii. 12). Pillars like the Hermae, called Hecataea, stood, especially in Athens, at cross-roads and doorways, perhaps to keep away the spirits of evil. Like Artemis, Hecate is also a goddess of fertility, presiding especially over the birth and the youth of wild animals, and over human birth and marriage. She also attends when the soul leaves the body at death, and is found near graves, and on the hearth, where the master of the house was formerly buried. It is to be noted that Hecate plays little or no part in mythological legend. Her worship seems to have flourished especially in the wilder parts of Greece, such as Samothrace and Thessaly, in Caria and on the coasts of Asia Minor. In Greece proper it prevailed on the east coast and especially in Aegina, where her aid was invoked against madness.

In older times Hecate is represented as single-formed, clad in a long robe, holding burning 194
torches; later she becomes *triformis*, "triple-formed," with three bodies standing back to back—corresponding, according to those who regard her as a moon-goddess, to the new, the full and the waning moon. In her six hands are torches, sometimes a snake, a key (as wardress of the lower world), a whip or a dagger; her favourite animal was the dog, which was sacrificed to her—an indication of her non-Hellenic origin, since this animal very rarely fills this part in genuine Greek ritual.

See H. Steuding in Roscher's *Lexikon*, where the functions of Hecate are systematically derived from the conception of her as a moon-goddess; L. R. Farnell, *Cults of the Greek States*, ii., where this view is examined; P. Paris in Daremberg and Saglio's *Dictionnaire des antiquités*; O. Gruppe, *Griechische Mythologie*, ii. (1906) p. 1288.

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1 J. B. Bury, in *Classical Review*, iii. p. 416, suggests that the name means "dog," against which see J. H. Vince, ib. iv. p. 47. G. C. Warr, ib. ix. 390, takes the Hesiodic Hecate to be a moon-goddess, daughter of the sun-god Perseus.

HECATOMB (Gr. ἑκατόμβη from ἑκατόν, a hundred, and βοῦς, an ox), originally the sacrifice of a hundred oxen in the religious ceremonies of the Greeks and Romans; later a large number of any kind of animals devoted for sacrifice. Figuratively, "hecatomb" is used to describe the sacrifice or destruction by fire, tempest, disease or the sword of any large number of persons or animals; and also of the wholesale destruction of inanimate objects, and even of mental and moral attributes.

HECATO OF RHODES, Greek Stoic philosopher and disciple of Panaetius (Cicero, *De officiis*, iii. 15). Nothing else is known of his life, but it is clear that he was eminent amongst the Stoics of the period. He was a voluminous writer, but nothing remains. A list is preserved by Diogenes, who mentions works on *Duty*, *Good*, *Virtues*, *Ends*. The first, dedicated to Tubero, is eulogized by Cicero in the *De officiis*, and Seneca refers to him frequently in the *De beneficiis*. According to Diogenes Laërtius, he divided the virtues into two kinds, those founded on scientific intellectual principles (*i.e.* wisdom and justice), and those which have no such basis (*e.g.* temperance and the resultant health and vigour). Cicero shows that he was much interested in casuistical questions, as, for example, whether a good man who had received a coin which he knew to be bad was justified in passing it on to another. On the whole, his moral attitude is cynical, and he is inclined to regard self-interest as the best criterion. This he modifies by explaining that self-interest is based on the relationships of life; a man needs money for the sake of his children, his friends and the state whose general prosperity depends on the wealth of its citizens. Like the earlier Stoics, Cleanthes and Chrysippus, he held that virtue may be taught. (See Stoics and Panaetius.)

HECKER, FRIEDRICH FRANZ KARL (1811-1881), German revolutionist, was born at Eichtersheim in the Palatinate on the 28th of September 1811, his father being a revenue official. He studied law with the intention of becoming an advocate, but soon became absorbed in politics. On entering the Second Chamber of Baden in 1842, he at once began to take part in the opposition against the government, which assumed a more and more openly Radical character, and in the course of which his talents as an agitator and his personal charm won him wide popularity and influence. A speech, denouncing the projected incorporation of Schleswig and Holstein with Denmark, delivered in the Chamber of Baden on the 6th of February 1845, spread his fame beyond the limits of his own state, and his popularity was increased by his expulsion from Prussia on the occasion of a journey to Stettin. After the death of his more moderate-minded friend Adolf Sander (March 9th, 1845), Hecker's tone towards the government became more and more bitter. In spite of the shallowness and his culture and his extremely weak character, he enjoyed an ever-increasing popularity. Even before the outbreak of the revolution he included Socialistic claims in his programme. In 1847 he was temporarily occupied with ideas of emigration, and with this object made a journey to Algiers, but returned to Baden and resumed his former position as the Radical champion of popular rights, later becoming president of the *Volksverein*, where he was destined to fall still further under the influence of the agitator Gustav von Struve. In conjunction with Struve he drew up the Radical programme carried at the great Liberal meeting held at Offenburg on the 12th of September 1847 (entitled "Thirteen Claims put forward by the People of Baden"). In addition to the Offenburg programme, the *Sturmpetition* of the 1st of March 1848 attempted to extort from the government the most far-reaching concessions. But it was in vain that on becoming a deputy Hecker endeavoured to carry out its impracticable provisions. He had to yield to the more moderate majority, but on this account was driven still further towards the Left. The proof lies in the new Offenburg demands of the 19th of March, and in the resolution moved by Hecker in the preliminary parliament of Frankfort that Germany should be declared a republic. But neither in Baden nor Frankfort did he at any time gain his point.

This double failure, combined with various energetic measures of the government, which were indirectly aimed at him (*e.g.* the arrest of the editor of the *Constanzer Seeblatt*, a friend of Hecker's, in Karlsruhe station on the 8th of April), inspired Hecker with the idea of an armed rising under pretext of the foundation of the German republic. The 9th to the 11th of April was secretly spent in preliminaries. On the 12th of April Hecker and Struve sent a proclamation to the inhabitants of the *Seekreis* and of the Black Forest "to summon the people who can bear arms to Donaueschingen at mid-day on the 14th, with arms, ammunition and provisions for six days." They expected 70,000 men, but only a few thousand appeared. The grand-ducal government of the *Seekreis* was dissolved, and Hecker gradually gained reinforcements. But friendly advisers also joined him, pointing out the risks of his undertaking. Hecker, however, was not at all ready to listen to them; on the contrary, he added to violence an absurd defiance, and offered an amnesty to the German princes on condition of their retiring within fourteen days into private life. The troops of Baden and Hesse marched against him, under the command of General Friedrich von Gagern, and on the 20th of April they met near Kandern, where Gagern was killed, it is true, but Hecker was completely defeated.

Like many of the revolutionaries of that period, Hecker retired to Switzerland. He was, it is true, again elected to the Chamber of Baden by the circle of Thiengen, but the government, no longer willing to respect his immunity as a deputy, refused its ratification. On this account Hecker resolved in September 1848 to emigrate to North America, and obtained possession of a farm near Belleville in the state of Illinois.

During the second rising in Baden in the spring of 1849 he again made efforts to obtain a footing in his own state, but without success. He only came as far as Strassburg, but had to retreat before the victories of the Prussian troops over the Baden insurgents.

On his return to America he won some distinction during the Civil War as colonel of a regiment which he had himself got together on the Federal side in 1861 and 1864. It was with great joy that he heard of the union of Germany brought about by the victory over France in 1870-71. It was then that he made his famous festival speech at St Louis, in which he gave an animated expression to the enthusiasm of the German Americans for their newly-united fatherland. He received a less favourable impression during a journey he made in Germany in 1873. He died at St Louis on the 24th of March 1881.

Hecker was always very much beloved of all the German democrats. The song and the hat named after him (the latter a broad slouch hat with a feather) became famous as the symbols of the middle-classes in revolt. In America, too, he had won great esteem, not only on political grounds but also for his personal qualities.

See F. Hecker, *Die Erhebung des Volkes in Baden für die deutsche Republik* (Baden, 1848); F. Hecker, *Reden und Vorlesungen* (Neerstadt a. d. H., 1872); F. v. Weech, *Badische Biographien*, iv. (1891); L. Mathy, *Aus dem Nachlasse von K. Matty, Briefe aus den Jahren 1846-1848* (Leipzig, 1898).

(J. Hn.)

HECKER, ISAAC THOMAS (1819-1888), American Roman Catholic priest, the founder of the “Paulist Fathers,” was born in New York City, of German immigrant parents, on the 18th of December 1819. When barely twelve years of age, he had to go to work, and pushed a baker’s cart for his elder brothers, who had a bakery in Rutgers Street. But he studied at 195
every possible opportunity, becoming immersed in Kant’s *Critique of Pure Reason*, and while still a lad took part in certain politico-social movements which aimed at the elevation of the working man. It was at this juncture that he met Orestes Brownson, who exercised a marked influence over him. Isaac was deeply religious, a characteristic for which he gave much credit to his prayerful mother, and remained so amid all the reading and agitating in which he engaged. Having grown into young manhood, he joined the Brook Farm movement, and in that colony he tarried some six months. Shortly after leaving it (in 1844) he was baptized into the Roman Catholic Church by Bishop McCloskey of New York. One year later he was entered in the novitiate of the Redemptorists in Belgium, and there he cultivated to a high degree the spirit of lofty mystical piety which marked him through life.

Ordained a priest in London by Wiseman in 1849, he returned to America, and worked until 1857 as a Redemptorist missionary. With all his mysticism, Isaac Hecker had the wide-awake mind of the typical American, and he perceived that the missionary activity of the Catholic Church in the United States must remain to a large extent ineffective unless it adopted methods suited to the country and the age. In this he had the sympathy of four fellow Redemptorists, who like himself were of American birth and converts from Protestantism. Acting as their agent, and with the consent of his local superiors, Hecker went to Rome to beg of the Rector Major of his Order that a Redemptorist novitiate might be opened in the United States, in order thus to attract American youths to the missionary life. In furtherance of this request, he took with him the strong approval of some members of the American hierarchy. The Rector Major, instead of listening to Father Hecker, expelled him from the Order for having made the journey to Rome without sufficient authorization. The outcome of the trouble was that Hecker and the other four American Redemptorists were permitted by Pius IX. in 1858 to form the separate religious community of the Paulists. Hecker trained and governed this community in spiritual exercises and mission-preaching until his death in New York City, after seventeen years of suffering, on the 22nd of

December 1888. He founded and was the director of the Catholic Publication Society, was the founder, and from 1865 until his death the editor, of the *Catholic World*, and wrote *Questions of the Soul* (1855), *Aspirations of Nature* (1857), *Catholicity in the United States* (1879) and *The Church and the Age* (1888).

The name of Hecker is closely associated with that of “Americanism.” To understand this movement it is necessary to comprehend the tendency of events in Catholic Europe rather than in America itself. The steady decline in the power and influence of French Catholicism since shortly after 1870 is the most remarkable feature of the history of the Third Republic. Not only did the French State pass laws bearing more and more stringently on the Church, under each succeeding ministry, but the bulk of the people acquiesced in the policy of its legislators. The clergy, if not Catholicism, was rapidly losing its hold over the once Catholic nation. Observing this fact, and encouraged by the action of Leo XIII., who, in 1892 called on French Catholics loyally to accept the Republic, a body of vigorous young French priests set themselves to check the disaster. They studied the causes which produced it. These causes, they considered to be, first, the clergy’s predominant sympathy with the monarchists, and in its undisguised hostility to the Republic; secondly, the Church’s aloofness from modern men, methods and thought. The progressive party believed that there was too little cultivation of individual, independent character, while too much stress was laid upon what might be called the mechanical or routine side of religion. The party perceived, too, that Catholicism was making scarcely any use of modern aggressive modes of propaganda; that, for example, the Church took but an insignificant part in social movements, in the organization of clubs for social study, in the establishing of settlements and similar philanthropic endeavour. Lack of adaptability to modern needs expresses in short the deficiencies in Catholicism which these men endeavoured to correct. They began a domestic apostolate which had for one of its rallying cries, “*Allons au peuple*,”—“Let us go to the people.” They agitated for the inauguration of social works, for a more intimate mingling of priests with the people, and for general cultivation of personal initiative, both in clergy and in laity.

Not unnaturally, they looked for inspiration to America. There they saw a vigorous Church among a free people, with priests publicly respected, and with a note of aggressive zeal in every project of Catholic enterprise. From the American priesthood, Father Hecker stood out conspicuous for sturdy courage, deep interior piety, an assertive self-initiative and immense love of modern times and modern liberty. So they took Father Hecker for a kind of patron saint. His biography (New York, 1891), written in English by the Paulist Father Elliott, was translated into French (1897), and speedily became the book of the hour. Under the inspiration of Father Hecker’s life and character, the more spirited section of the French clergy undertook the task of persuading their fellow-priests loyally to accept the actual political establishment, and then, breaking out of their isolation, to put themselves in touch with the intellectual life of the country, and take an active part in the work of social amelioration.

In 1897 the movement received an impetus—and a warning—when Mgr O’Connell, former Rector of the American College in Rome, spoke on behalf of Father Hecker’s ideas at the Catholic Congress in Friburg. The conservatives took alarm at what they considered to be symptoms of pernicious modernism or “Liberalism.” Did not the watchword “*Allons au peuple*” savour of heresy? Did it not tend toward breaking down the divinely established distinction between the priest and the layman, and conceding something to the laity in the management of the Church? The insistence upon individual initiative was judged to be incompatible with the fundamental principle of Catholicism, obedience to authority. Moreover, the conservatives were, almost to a man, anti-republicans who distrusted and disliked the democratic abbés. Complaints were sent to Rome. A violent polemic against the new movement was launched in Abbé Maignan’s *Le père Hecker, est-il un saint?* (1898). Repugnance to American tendencies and influences had a strong representation in the Curia and in powerful circles in Rome. Leo XIII. was extremely reluctant to pronounce any strictures upon American Catholics, of whose loyalty to the Roman See, and to their faith, he had often spoken in terms of high approbation. But he yielded, in a measure, to the pressure brought to bear upon him, and, early in February 1899, addressed to Cardinal Gibbons the Brief *Testem Benevolentiae*. This document contained a condemnation of the following doctrines or tendencies: (*a*) undue insistence on interior initiative in the spiritual life, as leading to disobedience; (*b*) attacks on religious vows, and disparagement of the value in the present age, of religious orders; (*c*) minimizing Catholic doctrine; (*d*) minimizing the importance of spiritual direction. The brief did not assert that any unsound doctrine on the above points had been held by Hecker or existed among Americans. Its tenour was, that if such opinions did exist, the Pope called upon the hierarchy to eradicate the evil. Cardinal Gibbons and many other prelates replied to Rome. With all but unanimity, they declared that the incriminated opinions had no existence among American Catholics. It was well known that Hecker never had countenanced the slightest departure from Catholic principles in their fullest and most strict application. The disturbance caused by the condemnation was slight;

almost the entire laity, and a considerable part of the clergy, never understood what the noise was about. The affair was soon forgotten, but the result was to strengthen the hands of the conservatives in France.

(J. J. F.)

HECKMONDWIKE, an urban district in the Spen Valley parliamentary division of the West Riding of Yorkshire, England, 8 m. S.S.E. of Bradford, on the Lancashire & Yorkshire, Great Northern, and London & North-Western railways. Pop. (1901), 9459. Like the town of Dewsbury, on the south-east, it is an important centre of the blanket and carpet manufactures, and there are also machine works, dye works and iron foundries. Coal is extensively wrought in the vicinity.

HECTOR, in Greek mythology, son of Priam and Hecuba, the husband of Andromache. Like Paris and other Trojans, he had an Oriental name, Darius. In Homer he is represented as an ideal warrior, the champion of the Trojans and the mainstay of the city. His character, is drawn in most favourable colours as a good son, a loving husband and father, and a trusty friend. His leave-taking of Andromache in the sixth book of the *Iliad*, and his departure to meet Achilles for the last time, are most touchingly described. He is an especial favourite of Apollo; and later poets even describe him as son of that god. His chief exploits during the war were his defence of the wounded Sarpedon, his fight with Ajax, son of Telamon (his particular enemy), and the storming of the Greek ramparts. When Achilles, enraged with Agamemnon, deserted the Greeks, Hector drove them back to their ships, which he almost succeeded in burning. Patroclus, the friend of Achilles, who came to the help of the Greeks, was slain by Hector with the help of Apollo. Then Achilles, to revenge his friend’s death, returned to the war, slew Hector, dragged his body behind his chariot to the camp, and afterwards round the tomb of Patroclus. Aphrodite and Apollo preserved it from corruption 196
and mutilation. Priam, guarded by Hermes, went to Achilles and prevailed on him to give back the body, which was buried with great honour. Hector was afterwards worshipped in the Troad by the Boeotian tribe Gephyraei, who offered sacrifices at his grave.

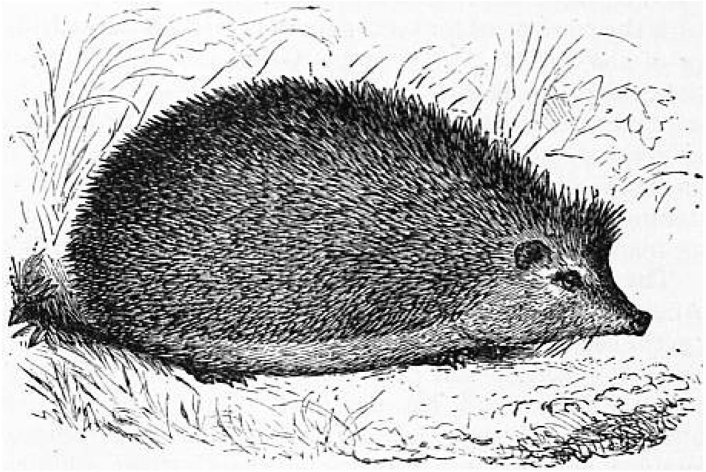
HECUBA (Gr. Ἑκάβη), wife of Priam, daughter of the Phrygian king Dymas (or of Cisseus, or of the river-god Sangarius). According to Homer she was the mother of nineteen of Priam’s fifty sons. When Troy was captured and Priam slain, she was made prisoner by the Greeks. Her fate is told in various ways, most of which connect her with the promontory Cynossema, on the Thracian shore of the Hellespont. According to Euripides (in the *Hecuba*), her youngest son Polydorus had been placed during the siege of Troy under the care of Polymestor, king of Thrace. When the Greeks reached the Thracian Chersonese on their way home Hecuba discovered that her son had been murdered, and in revenge put out the eyes of Polymestor and murdered his two sons. She was acquitted by Agamemnon; but, as Polymestor foretold, she was turned into a dog, and her grave became a mark for ships (Ovid, *Metam.* xiii. 399-575; Juvenal x. 271 and Mayor’s note). According to another story, she fell to the lot of Odysseus, as a slave, and in despair threw herself into the Hellespont; or, she used such insulting language towards her captors that they put her to death (Dictys Cretensis v. 13. 16). It is obvious from the tales of Hecuba’s transformation and death that she is a form of some goddess to whom dogs were sacred; and the analogy with Scylla is striking.

HEDA, WILLEM CLAASZ (*c.* 1504-*c.* 1670), Dutch painter, born at Haarlem, was one of the earliest Dutchmen who devoted himself exclusively to the painting of still life. He was the contemporary and comrade of Dirk Hals, with whom he had in common pictorial touch and technical execution. But Heda was more careful and finished than Hals, and showed considerable skill and not a little taste in arranging and colouring chased cups and beakers and tankards of precious and inferior metals. Nothing is so appetizing as his “luncheon,” with rare comestibles set out upon rich plate, oysters—seldom without the cut lemon—bread, champagne, olives and pastry. Even the commoner “refection” is also not without charm, as it comprises a cut ham, bread, walnuts and beer. One of Heda’s early masterpieces, dated 1623, in the Munich Pinakothek is as homely as a later one of 1651 in the Liechtenstein Gallery at Vienna. A more luxurious repast is a “Luncheon in the Augsburg Gallery,” dated 1644. Most of Heda’s pictures are on the European continent, notably in the galleries of Paris, Parma, Ghent, Darmstadt, Gotha, Munich and Vienna. He was a man of repute in his native city, and filled all the offices of dignity and trust in the gild of Haarlem. He seems to have had considerable influence in forming the younger Frans Hals.

HEDDLE, MATTHEW FORSTER (1828-1897), Scottish mineralogist, was born at Hoy in Orkney on the 28th of April 1828. After receiving his early education at the Edinburgh academy, he entered as a medical student at the university in that city, and subsequently studied chemistry and mineralogy at Klausthal and Freiburg. In 1851 he took his degree of M.D. at Edinburgh, and for about five years practised there. Medical work, however, possessed for him little attraction; he became assistant to Prof. Connell, who held the chair of chemistry at St Andrews, and in 1862 succeeded him as professor. This post he held until in 1880 he was invited to report on some gold mines in South Africa. On his return he devoted himself with great assiduity to mineralogy, and formed one of the finest collections by means of personal exploration in almost every part of Scotland. His specimens are now in the Royal Scottish Museum at Edinburgh. It had been his intention to publish a comprehensive work on the mineralogy of Scotland. This he did not live to complete, but the MSS. fell into able hands, and *The Mineralogy of Scotland*, in 2 vols., edited by J. G. Goodchild, was issued in 1901. Heddle was one of the founders of the Mineralogical Society, and he contributed many articles on Scottish minerals, and on the geology of the northern parts of Scotland, to the *Mineralogical Magazine*, as well as to the *Transactions of the Royal Society of Edinburgh*. He died on the 19th of November 1897.

See *Dr Heddle and his Geological Work* (with portrait), by J. G. Goodchild, *Trans. Edin. Geol. Soc.* (1898) vii. 317.

HEDGEHOG, or Urchin, a member of the mammalian order Insectivora, remarkable for its dentition, its armature of spines and its short tail. The upper jaw is longer than the lower, the snout is long and flexible, with the nostrils narrow, and the claws are long but weak. The animal is about 10 in. long, its eyes are small, and the lower surface covered with hairs of the ordinary character. The brain is remarkable for its low development, the cerebral hemispheres being small, and marked with but one groove, and that a shallow one, on each side. The hedgehog has the power of rolling itself up into a ball, from which the spines stand out in every direction. The spines are sharp, hard and elastic, and form so efficient a defence that there are few animals able to effect a successful attack on this creature. The moment it is touched, or even hears the report of a gun, it rolls itself up by the action of the muscles beneath the skin, while this contraction effects the erection of the spines. The most important muscle is the *orbicularis panniculi*, which extends over the anterior region of the skull, as far down the body as the ventral hairy region, and on to the tail, but three other muscles aid in the contraction.



The Hedgehog (*Erinaceus europaeus*).

Though insectivorous, the hedgehog is reported to have a liking for mice, while frogs and toads, as well as plants and fruits, all seem to be acceptable. It will also eat snakes, and its fondness for eggs has caused it to meet with the enmity of game-preservers; and there is no doubt it occasionally attacks leverets and game-chicks. In a state of nature it does not emerge from its retreat during daylight, unless urged by hunger or by the necessities of its young. During winter it passes into a state of hibernation, when its temperature falls considerably; having provided itself with a nest of dry leaves, it is well protected from the influences of the rain, and rolling itself up, remains undisturbed till warmer weather returns. In July or August the female brings forth four to eight young, or, according to others, two to four at a somewhat earlier period; at birth the spines, which in the adult are black in the middle, are white and soft, but soon harden, though they do not attain their full size until the succeeding spring.

The hedgehog, which is known scientifically as *Erinaceus europaeus*, and is the type of the family *Erinaceidae*, is found in woods and gardens, and extends over nearly the whole of Europe; and has been found at 6000 to 8000 ft. above the level of the sea. The adult is provided with thirty-six teeth; in the upper jaw are 6 incisors, 2 canines and 12 cheek-teeth, and in the lower jaw 4 incisors, 2 canines and 10 cheek-teeth. The genus is represented by about a score of species, ranging over Europe, Asia, except the Malay countries, and Africa.

(R. L.*)

HEDGES AND FENCES. The object of the hedge[1] or fence (abbreviation of “defence”) is
to mark a boundary or to enclose an area of land on which stock is kept. The hedge, *i.e.* a 197
row of bushes or small trees, forms a characteristic feature of the scenery of England, especially in the midlands and south; it is more rarely found in other countries. Its disadvantages as a fence are that it is not portable, that it requires cutting and training while young, that it harbours weeds and vermin and that it occupies together with the ditch which usually borders it a considerable space of ground, the margins of which cannot be cultivated. For these reasons it is to some extent superseded by the fence proper, especially where shelter for cattle is not required. In Great Britain the hawthorn (*q.v.*) is by far the most important of hedge plants. Holly resembles the hawthorn in its amenability to pruning and in its prickly nature and closeness of growth, which make it an effective barrier to, and shelter for, stock, but it is less hardy and more slow-growing than the hawthorn. Hornbeam, beech, myrobalan or cherry plum and blackthorn also have their advantages, hornbeam being proof against great exposure, blackthorn thriving on poor land and possessing great impenetrability and so on. Box, yew, privet and many other plants are used for ornamental hedging; in the United States the osage orange and honey locust are favourite hedge plants. As fences, wooden posts and rails and stone walls may be conveniently used in districts where the requisite materials are plentiful. But the most modern form of fence is formed of wire strands either smooth or barbed (see Barbed Wire), strained between iron standards or wooden or concrete posts. The wire may be interwoven with vertical strands or, if necessary, may be kept apart by iron droppers between the standards. Fences of a lighter description are machine-made with pickets of split chestnut or other wood closely set, woven with a few strands of wire; they are braced by posts at intervals.

From the fact that tramps and vagabonds frequently sleep under hedges the word has come to be used as a term of contempt, as in "hedge-priest," an inferior and illiterate kind of parson at one time existing in England and Ireland, and in "hedge-school," a low class school held in the open air, formerly very common in Ireland. From the sense of "hedge" as an enclosure or barrier the verb "to hedge" means to enclose, to form a barrier or defence, to bound or limit. As a sporting term the word is used in betting to mean protection from loss, by betting on both sides, by "laying off" on one side, after laying odds on another or vice versa. The word was early used figuratively in the sense of to avoid committing oneself.

See articles in the *Cyclopaedia of American Agriculture*, vol. i., ed. by L. H. Bailey (New York, 1907); in the *Standard Cyclopaedia of Modern Agriculture*, ed. by R. P. Wright (London, 1908-1909); and in the *Encyclopaedia of Agriculture*, vol. ii., ed. by C. E. Green and D. Young (Edinburgh, 1908).

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1 Hedge is a Teutonic word, cf. Dutch *heg*, Ger. *Hecke*; the root appears in other English words, *e.g.* "haw," as in "hawthorn."

HEDON, a municipal borough in the Holderness parliamentary division of the East Riding of Yorkshire, England, 8 m. E. of Hull by a branch of the North-Eastern railway. Pop. (1901), 1010. It stands in a low-lying, flat district bordering the Humber. It is 2 m. from the river, but was formerly reached by a navigable inlet, now dry, and was a considerable port. There is a small harbour, but the prosperity of the port has passed to Hull. The church of St Augustine is a splendid cruciform building with central tower. It is Early English, Decorated and Perpendicular, the tower being of the last period. The west front is particularly fine, and the church, with its noble proportions and lofty clerestories, resembles a cathedral in miniature. There are a manufacture of bricks and an agricultural trade. The corporation consists of a mayor, 3 aldermen and 9 councillors; and possesses a remarkable ancient mace, of 15th-century workmanship. Area, 321 acres.

According to tradition the men of Hedon received a charter of liberties from King Æthelstan, but there is no evidence to prove this or indeed to prove any settlement in the town until after the Conquest. The manor is not mentioned in the Domesday Survey, but formed part of the lordship of Holderness which William the Conqueror granted to Odo, count of Albemarle. A charter of Henry II., which is undated, contains the first certain evidence of settlement. By it the king granted to William, count of Albemarle, free borough rights in Hedon so that his burgesses there might hold of him as freely and quietly as the burgesses of York or Lincoln held of the king. An earlier charter granted to the inhabitants of York shows that these rights included a trade gild and freedom from many dues not only in England but also in France. King John in 1200 granted a confirmation of these liberties to Baldwin, count of Albemarle, and Hawisia his wife and for this second charter the burgesses themselves paid 70 marks. In 1272 Henry III. granted to Edmund, earl of Lancaster, and Avelina his wife, then lord and lady of the manor, the right of holding a fair at Hedon on the eve, day, and morrow of the feast of St Augustine and for five following days. After the countess's death the manor came to the hands of Edward I. In 1280 it was found by an inquisition that the men of Hedon "were few and poor" and that if the town were demised at a fee-farm rent the town might improve. The grant, however, does not appear to have been made until 1346. Besides this charter Edward III. also granted the burgesses the privilege of electing a mayor and bailiffs every year. At that time Hedon was one of the chief ports in the Humber, but its place was gradually taken by Hull after that town came into the hands of the king. Hedon was incorporated by Charles II. in 1661, and James II. in 1680 gave the burgesses another charter granting among other privileges that of holding two extra fairs, but of this they never appear to have taken advantage. The burgesses returned two members to parliament in 1295, and from 1547 to 1832 when the borough was disfranchised.

See *Victoria County History, Yorkshire*; J. R. Boyle, *The Early History of the Town and Port of Hedon* (Hull and York, 1895); G. H. Park, *History of the Ancient Borough of Hedon* (Hull, 1895).

HEDONISM (Gr. ἡδονή, pleasure, from ἡδύς, sweet, pleasant), in ethics, a general term for all theories of conduct in which the criterion is pleasure of one kind or another. Hedonistic theories of conduct have been held from the earliest times, though they have been by no means of the same character. Moreover, hedonism has, especially by its critics, been very much misrepresented owing mainly to two simple misconceptions. In the first place hedonism may confine itself to the view that, as a matter of observed fact, all men do in practice make pleasure the criterion of action, or it may go further and assert that men ought to seek pleasure as the sole human good. The former statement takes no view as to whether or not there is any absolute good: if merely denies that men aim at anything more than pleasure. The latter statement admits an ideal, *summum bonum*—namely, pleasure. The second confusion is the tacit assumption that the pleasure of the hedonist is necessarily or characteristically of a purely physical kind; this assumption is in the case of some hedonistic theories a pure perversion of the facts. Practically all hedonists have argued that what are known as the "lower" pleasures are not only ephemeral in themselves but also productive of so great an amount of consequent pain that the wise man cannot regard them as truly pleasurable; the sane hedonist will, therefore, seek those so-called "higher" pleasures which are at once more lasting and less likely to be discounted by consequent pain. It should be observed, however, that this choice of pleasures by a hedonist is conditioned not by "moral" (absolute) but by prudential (relative) considerations.

The earliest and the most extreme type of hedonism is that of the Cyrenaic School as stated by Aristippus, who argued that the only good for man is the sentient pleasure of the moment. Since (following Protagoras) knowledge is solely of momentary sensations, it is useless to try, as Socrates recommended, to make calculations as to future pleasures, and to balance present enjoyment with disagreeable consequences. The true art of life is to crowd as much enjoyment as possible into every moment. This extreme or "pure" hedonism regarded as a definite philosophic theory practically died with the Cyrenaics, though the same spirit has frequently found expression in ancient and modern, especially poetical, literature.

The confusion already alluded to between "pure" and "rational" hedonism is nowhere more clearly exemplified than in the misconceptions which have arisen as to the doctrine of 198
the Epicureans. To identify Epicureanism with Cyrenaicism is a complete misunderstanding. It is true that pleasure is the *summum bonum* of Epicurus, but his conception of that pleasure is profoundly modified by the Socratic doctrine of prudence and the eudaemonism of Aristotle. The true hedonist will aim at a life of enduring rational happiness; pleasure is the end of life, but true pleasure can be obtained only under the guidance of reason. Self-control in the choice of pleasures with a view to reducing pain to a minimum is indispensable. "Of all this, the beginning, and the greatest good, is prudence." The negative side of Epicurean hedonism was developed to such an extent by some members of the school (see Hegesias) that the ideal life is held to be rather indifference to pain than positive enjoyment. This pessimistic attitude is far removed from the positive hedonism of Aristippus.

Between the hedonism of the ancients and that of modern philosophers there lies a great gulf. Practically speaking ancient hedonism advocated the happiness of the individual: the modern hedonism of Hume, Bentham and Mill is based on a wider conception of life. The only real happiness is the happiness of the community, or at least of the majority: the criterion is society, not the individual. Thus we pass from Egoistic to Universalistic hedonism, Utilitarianism, Social Ethics, more especially in relation to the still broader theories of evolution. These theories are confronted by the problem of reconciling and adjusting the claims of the individual with those of society. One of the most important contributions to the discussion is that of Sir Leslie Stephen (*Science of Ethics*), who elaborated a theory of the "social organism" in relation to the individual. The end of the evolution process is the production of a "social tissue" which will be "vitally efficient." Instead, therefore, of the criterion of "the greatest happiness of the greatest number," Stephen has that of the "health of the organism." Life is not "a series of detached acts, in each of which a man can calculate the sum of happiness or misery attainable by different courses." Each action must be regarded as directly bearing upon the structure of society.

A criticism of the various hedonistic theories will be found in the article Ethics (*ad fin.*). See also, beside works quoted under Cyrenaics, Epicurus, &c., and the general histories of philosophy, J. S. Mackenzie, *Manual of Ethics* (3rd ed., 1897); J. H. Muirhead, *Elements of Ethics* (1892); J. Watson, *Hedonistic Theories* (1895); J. Martineau, *Types of Ethical Theory* (2nd ed., 1886); F. H. Bradley, *Ethical Studies* (1876); H. Sidgwick, *Methods of Ethics* (6th ed., 1901); Jas. Seth, *Ethical Principles* (3rd ed., 1898); other works quoted under Ethics.

HEEL. (1) (O. Eng. *héla*, cf. Dutch *hiel*; a derivative of O. Eng. hóh, hough, hock), that part of the foot in man which is situated below and behind the ankle; by analogy, the calcaneal part of the tarsus in other vertebrates. The heel proper in digitigrades and ungulates is raised off the ground and is commonly known as the "knee" or "hock," while the term "heel" is applied to the hind hoofs. (2) (A variant of the earlier *hield*; cf. Dutch *hellen*, for *helden*), to turn over to one side, especially of a ship. It is this word probably, in the sense of "tip-up," used particularly of the tilting or tipping of a cask or barrel of liquor, that explains the origin of the expression "no heel-taps," a direction to the drinkers of a toast to drain their glasses and leave no dregs remaining. "Tap" is a common word for liquor, and a cask is said to be "heeled" when it is tipped and only dregs or muddy liquor are left. This suits the actual sense of the phrase better than the explanations which connect it with tapping the "heel" or bottom of the glass (see *Notes and Queries*, 4th series, vols. xi.-xii., and 5th series, vol. i.).

HEEM, JAN DAVIDSZ VAN (or Johannes de), (*c.*1600-*c.*1683), Dutch painter. He was, if not the first, certainly the greatest painter of still life in Holland; no artist of his class combined more successfully perfect reality of form and colour with brilliancy and harmony of tints. No object of stone or silver, no flower humble or gorgeous, no fruit of Europe or the tropics, no twig or leaf, with which he was not familiar. Sometimes he merely represented a festoon or a nosegay. More frequently he worked with a purpose to point a moral or illustrate a motto. Here the snake lies coiled under the grass, there a skull rests on blooming plants. Gold and silver tankards or cups suggest the vanity of earthly possessions; salvation is allegorized in a chalice amidst blossoms, death as a crucifix inside a wreath. Sometimes de Heem painted alone, sometimes in company with men of his school, Madonnas or portraits surrounded by festoons of fruit or flowers. At one time he signed with initials, at others with Johannes, at others again with the name of his father joined to his own. At rare intervals he condescended to a date, and when he did the work was certainly of the best. De Heem entered the gild of Antwerp in 1635-1636, and became a burgher of that city in 1637. He steadily maintained his residence till 1667, when he moved to Utrecht, where traces of his presence are preserved in records of 1668, 1669 and 1670. It is not known when he finally returned to Antwerp, but his death is recorded in the gild books of that place. A very early picture, dated 1628, in the gallery of Gotha, bearing the signature of Johannes in full, shows that de Heem at that time was familiar with the technical habits of execution peculiar to the youth of Albert Cuyp. In later years he completely shook off dependence, and appears in all the vigour of his own originality.

Out of 100 pictures or more to be met with in European galleries scarcely eighteen are dated. The earliest after that of Gotha is a chased tankard, with a bottle, a silver cup, and a lemon on a marble table, dated 1640, in the museum of Amsterdam. A similar work of 1645, with the addition of fruit and flowers and a distant landscape, is in Lord Radnor's collection at Longford. A chalice in a wreath, with the radiant host amidst wheatsheaves, grapes and flowers, is a masterpiece of 1648 in the Belvedere of Vienna. A wreath round a Madonna of life size, dated 1650, in the museum of Berlin, shows that de Heem could paint brightly and harmoniously on a large scale. In the Pinakothek at Munich is the celebrated composition of 1653, in which creepers, beautifully commingled with gourds and blackberries, twigs of orange, myrtle and peach, are enlivened by butterflies, moths and beetles. A landscape with a blooming rose tree, a jug of strawberries, a selection of fruit, and a marble bust of Pan, dated 1655, is in the Hermitage at St Petersburg; an allegory of abundance in a medallion wreathed with fruit and flowers, in the gallery of Brussels, is inscribed with de Heem's monogram, the date of 1668, and the name of an obscure artist called Lambrechts. All these pieces exhibit the master in full possession of his artistic faculties.

Cornelius de Heem, the son of Johannes, was in practice as a flower painter at Utrecht in 1658, and was still active in his profession in 1671 at the Hague. His pictures are not equal to those of his father, but they are all well authenticated, and most of them in the galleries of the Hague, Dresden, Cassel, Vienna and Berlin. In the Staedel at Frankfort is a fruit piece, with pot-herbs and a porcelain jug, dated 1658; another, dated 1671, is in the museum of Brussels. David de Heem, another member of the family, entered the gild of Utrecht in 1668 and that of Antwerp in 1693. The best piece assigned to him is a table with a lobster, fruit and glasses, in the gallery of Amsterdam; others bear his signature in the museums of Florence, St Petersburg and Brunswick. It is well to guard against the fallacy that David de

Heem above mentioned is the father of Jan de Heem. We should also be careful not to make two persons of the first artist, who sometimes signs Johannes, sometimes Jan Davidsz or J. D. Heem.

HEEMSKERK, JOHAN VAN (1597-1656), Dutch poet, was born at Amsterdam in 1597. He was educated as a child at Bayonne, and entered the university of Leiden in 1617. In 1621 he went abroad on the grand tour, leaving behind him his first volume of poems, *Minnekunst* (The Art of Love), which appeared in 1622. He was absent from Holland four years. He was made master of arts at Bourges in 1623, and in 1624 visited Hugo Grotius in Paris. On his return in 1625 he published *Minnepligt* (The Duty of Love), and began to practise as an advocate in the Hague. In 1628 he was sent to England in his legal capacity by the Dutch East India Company, to settle the dispute respecting Amboyna. In the same year he published the poem entitled *Minnekunde*, or the Science of Love. He proceeded to Amsterdam in 1640, where he married Alida, sister of the statesman Van Beuningen. In 1641 he published a Dutch version of Corneille's *The Cid*, a tragi-comedy, and in 1647 his most famous work, the pastoral romance of *Batavische Arcadia*, which he had written ten years before. During the last twelve years of his life Heemskerk sat in the upper chamber of the states-general. He died at Amsterdam on the 27th of February 1656. 199

The poetry of Heemskerk, which fell into oblivion during the 18th century, is once more read and valued. His famous pastoral, the *Batavische Arcadia*, which was founded on the *Astrée* of Honoré d'Urfé, enjoyed a great popularity for more than a century, and passed through twelve editions. It provoked a host of more or less able imitations, of which the most distinguished were the *Dordrechtsche Arcadia* (1663) of Lambert van den Bos (1610-1698), the *Saanlandsche Arcadia* (1658) of Hendrik Sooteboom (1616-1678) and the *Rotterdamsche Arcadia* (1703) of Willem den Elger (d. 1703). But the original work of Heemskerk, in which a party of nymphs and shepherds go out from the Hague to Katwijk, and there indulge in polite and pastoral discourse, surpasses all these in brightness and versatility.

HEEMSKERK, MARTIN JACOBSZ (1498-1574), Dutch painter, sometimes called Van Veen, was born at Heemskerk in Holland in 1498, and apprenticed by his father, a small farmer, to Cornelisz Willemsz, a painter at Haarlem. Recalled after a time to the paternal homestead and put to the plough or the milking of cows, young Heemskerk took the first opportunity that offered to run away, and demonstrated his wish to leave home for ever by walking in a single day the 50 miles which separate his native hamlet from the town of Delft. There he studied under a local master whom he soon deserted for John Schoreel of Haarlem. At Haarlem he formed what is known as his first manner, which is but a quaint and *gauche* imitation of the florid style brought from Italy by Mabuse and others. He then started on a wandering tour, during which he visited the whole of northern and central Italy, stopping at Rome, where he had letters for a cardinal. It is evidence of the facility with which he acquired the rapid execution of a scene-painter that he was selected to co-operate with Antonio da San Gallo, Battista Franco and Francesco Salviati to decorate the triumphal arches erected at Rome in April 1536 in honour of Charles V. Vasari, who saw the battle-pieces which Heemskerk then produced, says they were well composed and boldly executed. On his return to the Netherlands he settled at Haarlem, where he soon (1540) became president of his gild, married twice, and secured a large and lucrative practice. In 1572 he left Haarlem for Amsterdam, to avoid the siege which the Spaniards laid to the place, and there he made a will which has been preserved, and shows that he had lived long enough and prosperously enough to make a fortune. At his death, which took place on the 1st of October 1574, he left money and land in trust to the orphanage of Haarlem, with interest to be paid yearly to any couple who should be willing to perform the marriage ceremony on the slab of his tomb in the cathedral of Haarlem. It was a superstition which still exists in Catholic Holland that a marriage so celebrated would secure the peace of the dead within the tomb.

The works of Heemskerk are still very numerous. “Adam and Eve,” and “St Luke painting the Likeness of the Virgin and Child” in presence of a poet crowned with ivy leaves, and a parrot in a cage—an altar-piece in the gallery of Haarlem, and the “Ecce Homo” in the museum of Ghent, are characteristic works of the period preceding Heemskerk’s visit to Italy. An altar-piece executed for St Laurence of Alkmaar in 1538-1541, and composed of at least a dozen large panels, would, if preserved, have given us a clue to his style after his return from the south. In its absence we have a “Crucifixion” executed for the Riches Claires at Ghent (now in the Ghent Museum) in 1543, and the altar-piece of the Drapers Company at Haarlem, now in the gallery of the Hague, and finished in 1546. In these we observe that Heemskerk studied and repeated the forms which he had seen at Rome in the works of Michelangelo and Raphael, and in Lombardy in the frescoes of Mantegna and Giulio Romano. But he never forgot the while his Dutch origin or the models first presented to him by Schoreel and Mabuse. As late as 1551 his memory still served him to produce a copy from Raphael’s “Madonna di Loretto” (gallery of Haarlem). A “Judgment of Momus,” dated 1561, in the Berlin Museum, proves him to have been well acquainted with anatomy, but incapable of selection and insensible of grace, bold of hand and prone to daring though tawdry contrasts of colour, and fond of florid architecture. Two altar-pieces which he finished for churches at Delft in 1551 and 1559, one complete, the other a fragment, in the museum of Haarlem, a third of 1551 in the Brussels Museum, representing “Golgotha,” the “Crucifixion,” the “Flight into Egypt,” “Christ on the Mount,” and scenes from the lives of St Bernard and St Benedict, are all fairly representative of his style. Besides these we have the “Crucifixion” in the Hermitage of St Petersburg, and two “Triumphs of Silenus” in the gallery of Vienna, in which the same relation to Giulio Romano may be noted as we mark in the canvases of Rinaldo of Mantua. Other pieces of varying importance are in the galleries of Rotterdam, Munich, Cassel, Brunswick, Karlsruhe, Mainz and Copenhagen. In England the master is best known by his drawings. A comparatively feeble picture by him is the “Last Judgment” in the palace of Hampton Court.

HEER, OSWALD (1809-1883), Swiss geologist and naturalist, was born at Nieder-Utzwyl in Canton St Gallen on the 31st of August 1809. He was educated as a clergyman and took holy orders, and he also graduated as doctor of philosophy and medicine. Early in life his interest was aroused in entomology, on which subject he acquired special knowledge, and later he took up the study of plants and became one of the pioneers in palaeo-botany, distinguished for his researches on the Miocene flora. In 1851 he became professor of botany in the university of Zürich, and he directed his attention to the Tertiary plants and insects of Switzerland. For some time he was director of the botanic garden at Zürich. In 1863 (with W. Pengelly, *Phil. Trans.*, 1862) he investigated the plant-remains from the lignite-deposits of Bovey Tracey in Devonshire, regarding them as of Miocene age; but they are now classed as Eocene. Heer also reported on the Miocene flora of Arctic regions, on the plants of the Pleistocene lignites of Dürnten on lake Zürich, and on the cereals of some of the lake-dwellings (*Die Pflanzen der Pfahlbauten*, 1866). During a great part of his career he was hampered by slender means and ill-health, but his services to science were acknowledged in 1873 when the Geological Society of London awarded to him the Wollaston medal. Dr Heer died at Lausanne on the 27th of September 1883. He published *Flora Tertiaria Helvetiae* (3 vols., 1855-1859); *Die Urwelt der Schweiz* (1865), and *Flora fossilis Arctica* (1868-1883).

HEEREN, ARNOLD HERMANN LUDWIG (1760-1842), German historian, was born on the 25th of October 1760 at Arbergen, near Bremen. He studied philosophy, theology and history at Göttingen, and thereafter travelled in France, Italy and the Netherlands. In 1787 he was appointed one of the professors of philosophy, and then of history at Göttingen, and he afterwards was chosen aulic councillor, privy councillor, &c., the usual rewards of successful German scholars. He died at Göttingen on the 6th of March 1842. Heeren’s great merit as an historian was that he regarded the states of antiquity from an altogether fresh point of view. Instead of limiting himself to a narration of their political events, he examined their economic relations, their constitutions, their financial systems, and thus was enabled to throw a new light on the development of the old world. He possessed vast and varied learning, perfect calmness and impartiality, and great power of historical insight, and is now looked back to as the pioneer in the movement for the economic interpretation of history.

Heeren's chief works are: *Ideen über Politik, den Verkehr, und den Handel der vornehmsten Völker der alten Welt* (2 vols., Göttingen, 1793-1796; 4th ed., 6 vols., 1824-1826; Eng. trans., Oxford, 1833); *Geschichte des Studiums der klassischen Litteratur seit dem Wiederaufleben der Wissenschaften* (2 vols., Göttingen, 1797-1802; new ed., 1822); *Geschichte der Staaten des Altertums* (Göttingen, 1799; Eng. trans., Oxford, 1840); *Geschichte des europäischen Staatensystems* (Göttingen, 1800; 5th ed., 1830; Eng. trans., 1834); *Versuch einer Entwicklung der Folgen der Kreuzzüge* (Göttingen, 1808; French trans., Paris, 1808), a prize essay of the Institute of France. Besides these, Heeren wrote 200
brief biographical sketches of Johann von Müller (Leipzig, 1809); Ludwig Spittler (Berlin, 1812); and Christian Heyne (Göttingen, 1813). With Friedrich August Ukert (1780-1851) he founded the famous historical collection, *Geschichte der europäischen Staaten* (Gotha, 1819 seq.), and contributed many papers to learned periodicals.

A collection of his historical works, with autobiographical notice, was published in 15 volumes (Göttingen, 1821-1830).

HEFELE, KARL JOSEF VON (1809-1893), German theologian, was born at Unterkochen in Württemberg on the 15th of March 1809, and was educated at Tübingen, where in 1839 he became professor-ordinary of Church history and patristics in the Roman Catholic faculty of theology. From 1842 to 1845 he sat in the National Assembly of Württemberg. In December 1869 he was enthroned bishop of Rottenburg. His literary activity, which had been considerable, was in no way diminished by his elevation to the episcopate. Among his numerous theological works may be mentioned his well-known edition of the *Apostolic Fathers*, issued in 1839; his *Life of Cardinal Ximenes*, published in 1844 (Eng. trans., 1860); and his still more celebrated *History of the Councils of the Church*, in seven volumes, which appeared between 1855 and 1874 (Eng. trans., 1871, 1882). Hefele's theological opinions inclined towards the more liberal school in the Roman Catholic Church, but he nevertheless received considerable signs of favour from its authorities, and was a member of the commission that made preparations for the Vatican Council of 1870. On the eve of that council he published at Naples his *Causa Honorii Papae*, which aimed at demonstrating the moral and historical impossibility of papal infallibility. About the same time he brought out a work in German on the same subject. He took rather a prominent part in the discussions at the council, associating himself with Félix Dupanloup and with Georges Darboy, archbishop of Paris, in his opposition to the doctrine of Infallibility, and supporting their arguments from his vast knowledge of ecclesiastical history. In the preliminary discussions he voted against the promulgation of the dogma. He was absent from the important sitting of the 18th of June 1870, and did not send in his submission to the decrees until 1871, when he explained in a pastoral letter that the dogma "referred only to doctrine given forth *ex cathedra*, and therein to the definitions proper only, but not to its proofs or explanations." In 1872 he took part in the congress summoned by the Ultramontanes at Fulda, and by his judicious use of minimizing tactics he kept his diocese free from any participation in the Old Catholic schism. The last four volumes of the second edition of his *History of the Councils* have been described as skilfully adapted to the new situation created by the Vatican decrees. During the later years of his life he undertook no further literary efforts on behalf of his church, but retired into comparative privacy. He died on the 6th of June 1893.

See Herzog-Hauck's *Realencyklopädie*, vii. 525.

HEGEL, GEORG WILHELM FRIEDRICH (1770-1831), German philosopher, was born at Stuttgart on the 27th of August 1770. His father, an official in the fiscal service of

Württemberg, is not otherwise known to fame; and of his mother we hear only that she had scholarship enough to teach him the elements of Latin. He had one sister, Christiana, who died unmarried, and a brother Ludwig, who served in the campaigns of Napoleon. At the grammar school of Stuttgart, where Hegel was educated between the ages of seven and eighteen, he was not remarkable. His main productions were a diary kept at intervals during eighteen months (1785-1787), and translations of the *Antigone*, the *Manual* of Epictetus, &c. But the characteristic feature of his studies was the copious extracts which from this time onward he unremittingly made and preserved. This collection, alphabetically arranged, comprised annotations on classical authors, passages from newspapers, treatises on morals and mathematics from the standard works of the period. In this way he absorbed in their integrity the raw materials for elaboration. Yet as evidence that he was not merely receptive we have essays already breathing that admiration of the classical world which he never lost. His chief amusement was cards, and he began the habit of taking snuff.

In the autumn of 1788 he entered at Tübingen as a student of theology; but he showed no interest in theology: his sermons were a failure, and he found more congenial reading in the classics, on the advantages of studying which his first essay was written. After two years he took the degree of Ph.D., and in the autumn of 1793 received his theological certificate, stating him to be of good abilities, but of middling industry and knowledge, and especially deficient in philosophy.

As a student, his elderly appearance gained him the title “Old man,” but he took part in the walks, beer-drinking and love-making of his fellows. He gained most from intellectual intercourse with his contemporaries, the two best known of whom were J. C. F. Hölderlin and Schelling. With Hölderlin Hegel learned to feel for the old Greeks a love which grew stronger as the semi-Kantianized theology of his teachers more and more failed to interest him. With Schelling like sympathies bound him. They both protested against the political and ecclesiastical inertia of their native state, and adopted the doctrines of freedom and reason. The story which tells how the two went out one morning to dance round a tree of liberty in a meadow is an anachronism, though in keeping with their opinions.

On leaving college, he became a private tutor at Bern and lived in intellectual isolation. He was, however, far from inactive. He compiled a systematic account of the fiscal system of the canton Bern, but the main factor in his mental growth came from his study of Christianity. Under the impulse given by Lessing and Kant he turned to the original records of Christianity, and attempted to construe for himself the real significance of Christ. He wrote a life of Jesus, in which Jesus was simply the son of Joseph and Mary. He did not stop to criticize as a philologist, and ignored the miraculous. He asked for the secret contained in the conduct and sayings of this man which made him the hope of the human race. Jesus appeared as revealing the unity with God in which the Greeks in their best days unwittingly rejoiced, and as lifting the eyes of the Jews from a lawgiver who metes out punishment on the transgressor, to the destiny which in the Greek conception falls on the just no less than on the unjust.

The interest of these ideas is twofold. In Jesus Hegel finds the expression for something higher than mere morality: he finds a noble spirit which rises above the contrasts of virtue and vice into the concrete life, seeing the infinite always embracing our finitude, and proclaiming the divine which is in man and cannot be overcome by error and evil, unless the man close his eyes and ears to the godlike presence within him. In religious life, in short, he finds the principle which reconciles the opposition of the temporal mind. But, secondly, the general source of the doctrine that life is higher than all its incidents is of interest. He does not free himself from the current theology either by rational moralizing like Kant, or by bold speculative synthesis like Fichte and Schelling. He finds his panacea in the concrete life of humanity. But although he goes to the Scriptures, and tastes the mystical spirit of the medieval saints, the Christ of his conception has traits that seem borrowed from Socrates and from the heroes of Attic tragedy, who suffer much and yet smile gently on a destiny to which they were reconciled. Instead of the Hebraic doctrine of a Jesus punished for our sins, we have the Hellenic idea of a man who is calmly tranquil in the consciousness of his unity with God.

During these years Hegel kept up a slack correspondence with Schelling and Hölderlin. Schelling, already on the way to fame, kept Hegel abreast with German speculation. Both of them were intent on forcing the theologians into the daylight, and grudged them any aid they might expect from Kant’s postulation of God and immortality to crown the edifice of ethics. Meanwhile, Hölderlin in Jena had been following Fichte’s career with an enthusiasm with which he infected Hegel.

It is pleasing to turn from these vehement struggles of thought to a tour which Hegel in company with three other tutors made through the Bernese Oberland in July and August 1796. Of this tour he left a minute diary. He was delighted with the varied play of the waterfalls, but no glamour blinded him to the squalor of Swiss peasant life. The glaciers and the rocks called forth no raptures. “The spectacle of these eternally dead masses gave me 201
nothing but the monotonous and at last tedious idea, ‘Es ist so.’”

Towards the close of his engagement at Bern, Hegel had received hopes from Schelling of a post at Jena. Fortunately his friend Hölderlin, now tutor in Frankfort, secured a similar situation there for Hegel in the family of Herr Gogol, a merchant (January 1797). The new post gave him more leisure and the society he needed.

About this time he turned to questions of economics and government. He had studied Gibbon, Hume and Montesquieu in Switzerland. We now find him making extracts from the English newspapers on the Poor-Law Bill of 1796; criticising the Prussian land laws, promulgated about the same time; and writing a commentary on Sir James Steuart’s *Inquiry into the Principles of Political Economy*. Here, as in contemporaneous criticisms of Kant’s ethical writings, Hegel aims at correcting the abstract discussion of a topic by treating it in its systematic interconnexions. Church and state, law and morality, commerce and art are reduced to factors in the totality of human life, from which the specialists had isolated them.

But the best evidence of Hegel’s attention to contemporary politics is two unpublished essays—one of them written in 1798, “On the Internal Condition of Württemberg in Recent Times, particularly on the Defects in the Magistracy,” the other a criticism on the constitution of Germany, written, probably, not long after the peace of Lunéville (1801). Both essays are critical rather than constructive. In the first Hegel showed how the supineness of the committee of estates in Württemberg had favoured the usurpations of the superior officials in whom the court had found compliant servants. And though he perceived the advantages of change in the constitution of the estates, he still doubted if an improved system could work in the actual conditions of his native province. The main feature in the pamphlet is the recognition that a spirit of reform is abroad. If Württemberg suffered from a bureaucracy tempered by despotism, the Fatherland in general suffered no less. “Germany,” so begins the second of these unpublished papers, “is no longer a state.” Referring the collapse of the empire to the retention of feudal forms and to the action of religious animosities, Hegel looked forward to reorganization by a central power (Austria) wielding the imperial army, and by a representative body elected by the geographical districts of the empire. But such an issue, he saw well, could only be the outcome of violence—of “blood and iron.” The philosopher did not pose as a practical statesman. He described the German empire in its nullity as a conception without existence in fact. In such a state of things it was the business of the philosopher to set forth the outlines of the coming epoch, as they were already moulding themselves into shape, amidst what the ordinary eye saw only as the disintegration of the old forms of social life.

His old interest in the religious question reappears, but in a more philosophical form. Starting with the contrast between a natural and a positive religion, he regards a positive religion as one imposed upon the mind from without, not a natural growth crowning the round of human life. A natural religion, on the other hand, was not, he thought, the one universal religion of every clime and age, but rather the spontaneous development of the national conscience varying in varying circumstances. A people’s religion completes and consecrates their whole activity: in it the people rises above its finite life in limited spheres to an infinite life where it feels itself all at one. Even philosophy with Hegel at this epoch was subordinate to religion; for philosophy must never abandon the finite in the search for the infinite. Soon, however, Hegel adopted a view according to which philosophy is a higher mode of apprehending the infinite than even religion.

At Frankfort, meanwhile, the philosophic ideas of Hegel first assumed the proper philosophic form. In a MS. of 102 quarto sheets, of which the first three and the seventh are wanting, there is preserved the original sketch of the Hegelian system, so far as the logic and metaphysics and part of the philosophy of nature are concerned. The third part of the system—the ethical theory—seems to have been composed afterwards; it is contained in its first draft in another MS. of 30 sheets. Even these had been preceded by earlier Pythagorean constructions envisaging the divine life in divine triangles.

Circumstances soon put Hegel in the way to complete these outlines. His father died in January 1799; and the slender sum which Hegel received as his inheritance, 3154 gulden (about £260), enabled him to think once more of a studious life. At the close of 1800 we find him asking Schelling for letters of introduction to Bamberg, where with cheap living and good beer he hoped to prepare himself for the intellectual excitement of Jena. The upshot was that Hegel arrived at Jena in January 1801. An end had already come to the brilliant epoch at Jena, when the romantic poets, Tieck, Novalis and the Schlegels made it the headquarters of their fantastic mysticism, and Fichte turned the results of Kant into the banner of revolutionary ideas. Schelling was the main philosophical lion of the time; and in some quarters Hegel was spoken of as a new champion summoned to help him in his struggle with the more prosaic continuators of Kant. Hegel's first performance seemed to justify the rumour. It was an essay on the difference between the philosophic systems of Fichte and Schelling, tending in the main to support the latter. Still more striking was the agreement shown in the *Critical Journal of Philosophy*, which Schelling and Hegel wrote conjointly during the years 1802-1803. So latent was the difference between them at this epoch that in one or two cases it is not possible to determine by whom the essay was written. Even at a later period foreign critics like Cousin saw much that was alike in the two doctrines, and did not hesitate to regard Hegel as a disciple of Schelling. The dissertation by which Hegel qualified for the position of *Privatdozent* (*De orbitis planetarum*) was probably chosen under the influence of Schelling's philosophy of nature. It was an unfortunate subject. For while Hegel, depending on a numerical proportion suggested by Plato, hinted in a single sentence that it might be a mistake to look for a planet between Mars and Jupiter, Giuseppe Piazzi (*q.v.*) had already discovered the first of the asteroids (Ceres) on the 1st of January 1801. Apparently in August, when Hegel qualified, the news of the discovery had not yet reached him, but critics have made this luckless suggestion the ground of attack on a priori philosophy.

Hegel's lectures, in the winter of 1801-1802, on logic and metaphysics were attended by about eleven students. Later, in 1804, we find him with a class of about thirty, lecturing on his whole system; but his average attendance was rather less. Besides philosophy, he once at least lectured on mathematics. As he taught, he was led to modify his original system, and notice after notice of his lectures promised a text-book of philosophy—which, however, failed to appear. Meanwhile, after the departure of Schelling from Jena in the middle of 1803, Hegel was left to work out his own views. Besides philosophical studies, where he now added Aristotle to Plato, he read Homer and the Greek tragedians, made extracts from books, attended lectures on physiology, and dabbled in other sciences. On his own representation at Weimar, he was in February 1805 made a professor extraordinarius, and in July 1806 drew his first and only stipend—100 thalers. At Jena, though some of his hearers became attached to him, Hegel was not a popular lecturer any more than K. C. F. Krause (*q.v.*). The ordinary student found J. F. Fries (*q.v.*) more intelligible.

Of the lectures of that period there still remain considerable notes. The language often had a theological tinge (never entirely absent), as when the "idea" was spoken of, or "the night of the divine mystery," or the dialectic of the absolute called the "course of the divine life." Still his view was growing clearer, and his difference from Schelling more palpable. Both Schelling and Hegel stand in a relation to art, but while the aesthetic model of Schelling was found in the contemporary world, where art was a special sphere and the artist a separate profession in no intimate connexion with the age and nation, the model of
Hegel was found rather in those works of national art in which art is not a part but an aspect 202
of the common life, and the artist is not a mere individual but a concentration of the passion and power of beauty in the whole community. "Such art," says Hegel, "is the common good and the work of all. Each generation hands it on beautified to the next; each has done something to give utterance to the universal thought. Those who are said to have genius have acquired some special aptitude by which they render the general shapes of the nation their own work, one in one point, another in another. What they produce is not their invention, but the invention of the whole nation; or rather, what they find is that the whole nation has found its true nature. Each, as it were, piles up his stone. So too does the artist. Somehow he has the good fortune to come last, and when he places his stone the arch stands self-supported." Hegel, as we have already seen, was fully aware of the change that was coming over the world. "A new epoch," he says, "has arisen. It seems as if the world-spirit had now succeeded in freeing itself from all foreign objective existence, and finally apprehending itself as absolute mind." These words come from lectures on the history of philosophy, which laid the foundation for his *Phänomenologie des Geistes* (Bamberg, 1807).

On the 14th of October 1806 Napoleon was at Jena. Hegel, like Goethe, felt no patriotic shudder at the national disaster, and in Prussia he saw only a corrupt and conceited bureaucracy. Writing to his friend F. J. Niethammer (1766-1848) on the day before the battle, he speaks with admiration of the "world-soul," the emperor, and with satisfaction of the probable overthrow of the Prussians. The scholar's wish was to see the clouds of war pass away, and leave thinkers to their peaceful work. His manuscripts were his main care;

and doubtful of the safety of his last despatch to Bamberg, and disturbed by the French soldiers in his lodgings, he hurried off, with the last pages of the *Phänomenologie*, to take refuge in the pro-rector’s house. Hegel’s fortunes were now at the lowest ebb. Without means, and obliged to borrow from Niethammer, he had no further hopes from the impoverished university. He had already tried to get away from Jena. In 1805, when several lecturers left in consequence of diminished classes, he had written to Johann Heinrich Voss (*q.v.*), suggesting that his philosophy might find more congenial soil in Heidelberg; but the application bore no fruit. He was, therefore, glad to become editor of the *Bamberger Zeitung* (1807-1808). Of his editorial work there is little to tell; no leading articles appeared in his columns. It was not a suitable vocation, and he gladly accepted the rectorship of the Aegidien-gymnasium in Nuremberg, a post which he held from December 1808 to August 1816. Bavaria at this time was modernizing her institutions. The school system was reorganized by new regulations, in accordance with which Hegel wrote a series of lessons in the outlines of philosophy—ethical, logical and psychological. They were published in 1840 by Rosenkranz from Hegel’s papers.

As a teacher and master Hegel inspired confidence in his pupils, and maintained discipline without pedantic interference in their associations and sports. On prize-days his addresses summing up the history of the school year discussed some topic of general interest. Five of these addresses are preserved. The first is an exposition of the advantages of a classical training, when it is not confined to mere grammar. “The perfection and grandeur of the master-works of Greek and Roman literature must be the intellectual bath, the secular baptism, which gives the first and unfading tone and tincture of taste and science.” In another address, speaking of the introduction of military exercises at school, he says: “These exercises, while not intended to withdraw the students from their more immediate duty, so far as they have any calling to it, still remind them of the possibility that every one, whatever rank in society he may belong to, may one day have to defend his country and his king, or help to that end. This duty, which is natural to all, was formerly recognized by every citizen, though whole ranks in the state have become strangers to the very idea of it.”

On the 16th of September 1811 Hegel married Marie von Tucher (twenty-two years his junior) of Nuremberg. She brought her husband no fortune, but the marriage was entirely happy. The husband kept a careful record of income and expenditure. His income amounted at Nuremberg to 1500 gulden (£130) and a house; at Heidelberg, as professor, he received about the same sum; at Berlin about 3000 thalers (£300). Two sons were born to them; the elder, Karl, became eminent as a historian. The younger, Immanuel, was born on the 24th of September 1816. Hegel’s letters to his wife, written during his solitary holiday tours to Vienna, the Netherlands and Paris, breathe of kindly and happy affection. Hegel the tourist —recalling happy days spent together; confessing that, were it not because of his sense of duty as a traveller, he would rather be at home, dividing his time between his books and his wife; commenting on the shop windows at Vienna; describing the straw hats of the Parisian ladies—is a contrast to the professor of a profound philosophical system. But it shows that the enthusiasm which in his days of courtship moved him to verse had blossomed into a later age of domestic bliss.

In 1812 appeared the first two volumes of his *Wissenschaft der Logik*, and the work was completed by a third in 1816. This work, in which his system was for the first time presented in what, with a few minor alterations, was its ultimate shape, found some audience in the world. Towards the close of his eighth session three professorships were almost simultaneously put within his reach—at Erlangen, Berlin and Heidelberg. The Prussian offer expressed a doubt that his long absence from university teaching might have made him rusty, so he accepted the post at Heidelberg, whence Fries had just gone to Jena (October 1816). Only four hearers turned up for one of his courses. Others, however, on the encyclopaedia of philosophy and the history of philosophy drew classes of twenty to thirty. While he was there Cousin first made his acquaintance, but a more intimate relation dates from Berlin. Among his pupils was Hermann F. W. Hinrichs (*q.v.*), to whose *Religion in its Inward Relation to Science* (1822) Hegel contributed an important preface. The strangest of his hearers was an Esthonian baron, Boris d’Yrkull, who after serving in the Russian army came to Heidelberg to hear the wisdom of Hegel. But his books and his lectures were alike obscure to the baron, who betook himself by Hegel’s advice to simpler studies before he returned to the Hegelian system.

At Heidelberg Hegel was active in a literary way also. In 1817 he brought out the *Enzyklopädie d. philos. Wissenschaften im Grundrisse* (4th ed., Berlin, 1817; new ed., 1870) for use at his lectures. It is the only exposition of the Hegelian system as a whole which we have direct from Hegel’s own hand. Besides this work he wrote two reviews for the

Heidelberg *Jahrbücher*—the first on F. H. Jacobi, the other a political pamphlet which called forth violent criticism. It was entitled a *Criticism on the Transactions of the Estates of Württemberg in 1815-1816*. On the 15th of March 1815 King Frederick of Württemberg, at a meeting of the estates of his kingdom, laid before them the draft of a new constitution, in accordance with the resolutions of the congress of Vienna. Though an improvement on the old constitution, it was unacceptable to the estates, jealous of their old privileges and suspicious of the king's intentions. A decided majority demanded the restitution of their old laws, though the kingdom now included a large population to which the old rights were strange. Hegel in his essay, which was republished at Stuttgart, supported the royal proposals, and animadverted on the backwardness of the bureaucracy and the landed interests. In the main he was right; but he forgot too much the provocation they had received, the usurpations and selfishness of the governing family, and the unpatriotic character of the king.

In 1818 Hegel accepted the renewed offer of the chair of philosophy at Berlin, vacant since the death of Fichte. The hopes which this offer raised of a position less precarious than that of a university teacher of philosophy were in one sense disappointed; for more than a professor Hegel never became. But his influence upon his pupils, and his solidarity with the 203
Prussian government, gave him a position such as few professors have held.

In 1821 Hegel published the *Grundlinien der Philosophie des Rechts* (2nd ed., 1840; ed. G. J. B. Bolland, 1901; Eng. trans., *Philosophy of Right*, by S. W. Dyde, 1896). It is a combined system of moral and political philosophy, or a sociology dominated by the idea of the state. It turns away contemptuously and fiercely from the sentimental aspirations of reformers possessed by the democratic doctrine of the rights of the omnipotent nation. Fries is stigmatized as one of the "ringleaders of shallowness" who were bent on substituting a fancied tie of enthusiasm and friendship for the established order of the state. The disciplined philosopher, who had devoted himself to the task of comprehending the organism of the state, had no patience with feebler or more mercurial minds who recklessly laid hands on established ordinances, and set them aside where they contravened humanitarian sentiments. With the principle that whatever is real is rational, and whatever is rational is real, Hegel fancied that he had stopped the mouths of political critics and constitution-mongers. His theory was not a mere formulation of the Prussian state. Much that he construed as necessary to a state was wanting in Prussia; and some of the reforms already introduced did not find their place in his system. Yet, on the whole, he had taken his side with the government. Altenstein even expressed his satisfaction with the book. In his disgust at the crude conceptions of the enthusiasts, who had hoped that the war of liberation might end in a realm of internal liberty, Hegel had forgotten his own youthful vows recorded in verse to Hölderlin, "never, never to live in peace with the ordinance which regulates feeling and opinion." And yet if we look deeper we see that this is no worship of existing powers. It is rather due to an overpowering sense of the value of organization—a sense that liberty can never be dissevered from order, that a vital interconnexion between all the parts of the body politic is the source of all good, so that while he can find nothing but brute weight in an organized public, he can compare the royal person in his ideal form of constitutional monarchy to the dot upon the letter *i*. A keen sense of how much is at stake in any alteration breeds suspicion of every reform.

During his thirteen years at Berlin Hegel's whole soul seems to have been in his lectures. Between 1823 and 1827 his activity reached its maximum. His notes were subjected to perpetual revisions and additions. We can form an idea of them from the shape in which they appear in his published writings. Those on *Aesthetics*, on the *Philosophy of Religion*, on the *Philosophy of History* and on the *History of Philosophy*, have been published by his editors, mainly from the notes of his students, under their separate heads; while those on logic, psychology and the philosophy of nature are appended in the form of illustrative and explanatory notes to the sections of his *Encyklopädie*. During these years hundreds of hearers from all parts of Germany, and beyond, came under his influence. His fame was carried abroad by eager or intelligent disciples. At Berlin Henning served to prepare the intending disciple for fuller initiation by the master himself. Edward Gans (*q.v.*) and Heinrich Gustav Hotho (*q.v.*) carried the method into special spheres of inquiry. At Halle Hinrichs maintained the standard of Hegelianism amid the opposition or indifference of his colleagues.

Three courses of lectures are especially the product of his Berlin period: those on aesthetics, the philosophy of religion and the philosophy of history. In the years preceding the revolution of 1830, public interest, excluded from political life, turned to theatres, concert-rooms and picture-galleries. At these Hegel became a frequent and appreciative visitor and made extracts from the art-notes in the newspapers. In his holiday excursions, the interest in the fine arts more than once took him out of his way to see some old painting. At Vienna in 1824 he spent every moment at the Italian opera, the ballet and the picture-galleries. In Paris, in 1827, he saw Charles Kemble and an English company play Shakespeare. This familiarity with the facts of art, though neither deep nor historical, gave a freshness to his lectures on aesthetics, which, as put together from the notes of 1820, 1823, 1826, are in many ways the most successful of his efforts.

The lectures on the philosophy of religion are another application of his method. Shortly before his death he had prepared for the press a course of lectures on the proofs for the existence of God. In his lectures on religion he dealt with Christianity, as in his philosophy of morals he had regarded the state. On the one hand he turned his weapons against the rationalistic school, who reduced religion to the modicum compatible with an ordinary worldly mind. On the other hand he criticized the school of Schleiermacher, who elevated feeling to a place in religion above systematic theology. His middle way attempts to show that the dogmatic creed is the rational development of what was implicit in religious feeling. To do so, of course, philosophy becomes the interpreter and the superior. To the new school of E. W. Hengstenberg, which regarded Revelation itself as supreme, such interpretation was an abomination.

A Hegelian school began to gather. The flock included intelligent pupils, empty-headed imitators, and romantic natures who turned philosophy into lyric measures. Opposition and criticism only served to define more precisely the adherents of the new doctrine. Hegel himself grew more and more into a belief in his own doctrine as the one truth for the world. He was in harmony with the government, and his followers were on the winning side. Though he had soon resigned all direct official connexion with the schools of Brandenburg, his real influence in Prussia was considerable, and as usual was largely exaggerated in popular estimate. In the narrower circle of his friends his birthdays were the signal for congratulatory verses. In 1826 a formal festival was got up by some of his admirers, one of whom, Herder, spoke of his categories as new gods; and he was presented with much poetry and a silver mug. In 1830 the students struck a medal in his honour, and in 1831 he was decorated by an order from Frederick William III. In 1830 he was rector of the university; and in his speech at the tricentenary of the Augsburg Confession in that year he charged the Catholic Church with regarding the virtues of the pagan world as brilliant vices, and giving the crown of perfection to poverty, continence and obedience.

One of the last literary undertakings in which he took part was the establishment of the Berlin *Jahrbücher für wissenschaftliche Kritik*, in which he assisted Edward Gans and Varnhagen von Ense. The aim of this review was to give a critical account, certified by the names of the contributors, of the literary and philosophical productions of the time, in relation to the general progress of knowledge. The journal was not solely in the Hegelian interest; and more than once, when Hegel attempted to domineer over the other editors, he was met by vehement and vigorous opposition.

The revolution of 1830 was a great blow to him, and the prospect of democratic advances almost made him ill. His last literary work, the first part of which appeared in the *Preussische Staatszeitung*, was an essay on the English Reform Bill of 1831. It contains primarily a consideration of its probable effects on the character of the new members of parliament, and the measures which they may introduce. In the latter connexion he enlarged on several points in which England had done less than many continental states for the abolition of monopolies and abuses. Surveying the questions connected with landed property, with the game laws, the poor, the Established Church, especially in Ireland, he expressed grave doubt on the legislative capacity of the English parliament as compared with the power of renovation manifested in other states of western Europe.

In 1831 cholera first entered Europe. Hegel and his family retired for the summer to the suburbs, and there he finished the revision of the first part of his *Science of Logic*. On the beginning of the winter session, however, he returned to his house in the Kupfergraben. On this occasion an altercation occurred between him and his friend Gans, who in his notice of lectures on jurisprudence had recommended Hegel’s *Philosophy of Right*. Hegel, indignant at what he deemed patronage, demanded that the note should be withdrawn. On the 14th of November, after one day’s illness, he died of cholera and was buried, as he had wished, 204
between Fichte and Solger.

Hegel in his class-room was neither imposing nor fascinating. You saw a plain, old-fashioned face, without life or lustre—a figure which had never looked young, and was now prematurely aged; the furrowed face bore witness to concentrated thought. Sitting with his snuff-box before him, and his head bent down, he looked ill at ease, and kept turning the folios of his notes. His utterance was interrupted by frequent coughing; every sentence came out with a struggle. The style was no less irregular. Sometimes in plain narrative the lecturer would be specially awkward, while in abstruse passages he seemed specially at home, rose into a natural eloquence, and carried away the hearer by the grandeur of his diction.

Philosophy.—Hegelianism is confessedly one of the most difficult of all philosophies. Every one has heard the legend which makes Hegel say, "One man has understood me, and even he has not." He abruptly hurls us into a world where old habits of thought fail us. In three places, indeed, he has attempted to exhibit the transition to his own system from other levels of thought; but in none with much success. In the introductory lectures on the philosophy of religion he gives a rationale of the difference between the modes of consciousness in religion and philosophy (between *Vorstellung* and *Begriff*). In the beginning of the *Encyklopädie* he discusses the defects of dogmatism, empiricism, the philosophies of Kant and Jacobi. In the first case he treats the formal or psychological aspect of the difference; in the latter he presents his doctrine less in its essential character than in special relations to the prominent systems of his time. The *Phenomenology of Spirit*, regarded as an introduction, suffers from a different fault. It is not an introduction—for the philosophy which it was to introduce was not then fully elaborated. Even to the last Hegel had not so externalized his system as to treat it as something to be led up to by gradual steps. His philosophy was not one aspect of his intellectual life, to be contemplated from others; it was the ripe fruit of concentrated reflection, and had become the one all-embracing form and principle of his thinking. More than most thinkers he had quietly laid himself open to the influences of his time and the lessons of history.

The Phenomenology.

The *Phenomenology* is the picture of the Hegelian philosophy in the making—at the stage before the scaffolding has been removed from the building. For this reason the book is at once the most brilliant and the most difficult of Hegel's works—the most brilliant because it is to some degree an autobiography of Hegel's mind—not the abstract record of a logical evolution, but the real history of an intellectual growth; the most difficult because, instead of treating the rise of intelligence (from its first appearance in contrast with the real world to its final recognition of its presence in, and rule over, all things) as a purely subjective process, it exhibits this rise as wrought out in historical epochs, national characteristics, forms of culture and faith, and philosophical systems. The theme is identical with the introduction to the *Encyklopädie*; but it is treated in a very different style. From all periods of the world—from medieval piety and stoical pride, Kant and Sophocles, science and art, religion and philosophy—with disdain of mere chronology, Hegel gathers in the vineyards of the human spirit the grapes from which he crushes the wine of thought. The mind coming through a thousand phases of mistake and disappointment to a sense and realization of its true position in the universe—such is the drama which is consciously Hegel's own history, but is represented objectively as the process of spiritual history which the philosopher reproduces in himself. The *Phenomenology* stands to the *Encyklopädie* somewhat as the dialogues of Plato stand to the Aristotelian treatises. It contains almost all his philosophy—but irregularly and without due proportion. The personal element gives an undue prominence to recent phenomena of the philosophic atmosphere. It is the account given by an inventor of his own discovery, not the explanation of an outsider. It therefore to some extent assumes from the first the position which it proposes ultimately to reach, and gives not a proof of that position, but an account of the experience (*Erfahrung*) by which consciousness is forced from one position to another till it finds rest in *Absolutes Wissen*.

The *Phenomenology* is neither mere psychology, nor logic, nor moral philosophy, nor history, but is all of these and a great deal more. It needs not distillation, but expansion and illustration from contemporary and antecedent thought and literature. It treats of the attitudes of consciousness towards reality under the six heads of consciousness, self-consciousness, reason (*Vernunft*), spirit (*Geist*), religion and absolute knowledge. The native attitude of consciousness towards existence is reliance on the evidence of the senses; but a little reflection is sufficient to show that the reality attributed to the external world is as much due to intellectual conceptions as to the senses, and that these conceptions elude us when we try to fix them. If consciousness cannot detect a permanent object outside it, so self-consciousness cannot find a permanent subject in itself. It may, like the Stoic, assert freedom by holding aloof from the entanglements of real life, or like the sceptic regard the world as a delusion, or finally, as the "unhappy consciousness" (*Unglückliches Bewusstseyn*), may be a recurrent falling short of a perfection which it has placed above it in the heavens. But in this isolation from the world, self-consciousness has closed its gates against the stream of life. The perception of this is reason. Reason convinced that the world and the soul are alike rational observes the external world, mental phenomena, and specially the nervous organism, as the meeting ground of body and mind. But reason finds much in the world recognizing no kindred with her, and so turning to practical activity seeks in the world the realization of her own aims. Either in a crude way she pursues her own pleasure, and finds that necessity counteracts her cravings; or she endeavours to find the world in harmony with the heart, and yet is unwilling to see fine aspirations crystallized by the act of realizing them. Finally, unable to impose upon the world either selfish or humanitarian ends, she folds her arms in pharisaic virtue, with the hope that some hidden power will give the victory to righteousness. But the world goes on in its life, heedless of the demands of virtue. The principle of nature is to live and let live. Reason abandons her efforts to mould the world, and is content to let the aims of individuals work out their results independently, only stepping in to lay down precepts for the cases where individual actions conflict, and to test these precepts by the rules of formal logic.

So far we have seen consciousness on one hand and the real world on the other. The stage of *Geist* reveals the consciousness no longer as critical and antagonistic but as the indwelling spirit of a community, as no longer isolated from its surroundings but the union of the single and real consciousness with the vital feeling that animates the community. This is the lowest stage of concrete consciousness—life, and not knowledge; the spirit inspires, but does not reflect. It is the age of unconscious morality, when the individual's life is lost in the society of which he is an organic member. But increasing culture presents new ideals, and the mind, absorbing the ethical spirit of its environment, gradually emancipates itself from conventions and superstitions. This *Aufklärung* prepares the way for the rule of conscience, for the moral view of the world as subject of a moral law. From the moral world the next step is religion; the moral law gives place to God; but the idea of Godhead, too, as it first appears, is imperfect, and has to pass through the forms of nature-worship and of art before it reaches a full utterance in Christianity. Religion in this shape is the nearest step to the stage of absolute knowledge; and this absolute knowledge—"the spirit knowing itself as spirit"—is not something which leaves these other forms behind but the full comprehension of them as the organic constituents of its empire; "they are the memory and the sepulchre of its history, and at the same time the actuality, truth and certainty of its throne." Here, according to Hegel, is the field of philosophy.

The preface to the *Phenomenology* signalled the separation from Schelling—the adieu to romantic. It declared that a genuine philosophy has no kindred with the mere aspirations of artistic minds, but must earn its bread by the sweat of its brow. It sets its face against the idealism which either thundered against the world for its deficiencies, or sought something finer than reality. Philosophy is to be the science of the actual world—it is the spirit comprehending itself in its own externalizations and manifestations. The philosophy of Hegel is idealism, but it is an idealism in which every idealistic unification has its other face in the multiplicity of existence. It is realism as well as idealism, and never quits its hold on facts. Compared with Fichte and Schelling, Hegel has a sober, hard, realistic character. At a later date, with the call of Schelling to Berlin in 1841, it became fashionable to speak of Hegelianism as a negative philosophy requiring to be complemented by a "positive" philosophy which would give reality and not mere ideas. The cry was the same as that of Krug (*q.v.*), asking the philosophers who expounded the absolute to construe his pen. It was the cry of the Evangelical school for a personal Christ and not a dialectical Logos. The claims of the individual, the real, material and historical fact, it was said, had been sacrificed by Hegel to the universal, the ideal, the spiritual and the logical.

There was a truth in these criticisms. It was the very aim of Hegelianism to render fluid the fixed phases of reality—to show existence not to be an immovable rock limiting the efforts of thought, but to have thought implicit in it, waiting for release from its petrifaction. Nature was no longer, as with Fichte, to be a mere spring-board to evoke the latent powers of the spirit. Nor was it, as in Schelling's earlier system, to be a collateral progeny with mind from the same womb of indifference and identity. Nature and mind in the Hegelian system—the external and the spiritual world—have the same origin, but are not co-equal branches. The natural world proceeds from the "idea," the spiritual from the idea and nature. It is impossible, beginning with the natural world, to explain the mind by any process of distillation or development, unless consciousness or its potentiality has been there from the first. Reality, independent of the individual consciousness, there must be; reality, independent of all mind, is an impossibility. At the basis of all reality, whether material or mental, there is thought. But the thought thus regarded as the basis of all existence is not consciousness with its distinction of ego and non-ego. It is rather the stuff of which both mind and nature are made, neither extended as in the natural world, nor self-centred as in mind. Thought in its primary form is, as it were, thoroughly transparent and absolutely fluid, free and mutually interpenetrable in every part—the spirit in its seraphic scientific life, before creation had produced a natural world, and thought had risen to independent existence in the social organism. Thought in this primary form, when in all its parts completed, is what Hegel calls the "idea." But the idea, though fundamental, is in another sense final, in the process of the world. It only appears in consciousness as the crowning development of the mind. Only with philosophy does thought become fully conscious of itself in its origin and development. Accordingly the history of philosophy is the pre-supposition of logic, or the three branches of philosophy form a circle.

The exposition or constitution of the "idea" is the work of the Logic. As the total system falls into three parts, so every part of the system follows the triadic law. Every truth, every reality, has three aspects or stages; it is the unification of two contradictory elements, of two partial aspects of truth which are not merely contrary, like black and white, but contradictory, like same and different. The first step is a preliminary affirmation and unification, the second a negation and differentiation, the third a final synthesis. For example, the seed of the plant is an initial unity of life, which when placed in its proper soil suffers disintegration into its constitutents, and yet in virtue of its vital unity keeps these divergent elements together, and reappears as the plant with its members in organic union. Or again, the process of scientific induction is a threefold chain; the original hypothesis (the first unification of the fact) seems to melt away when confronted with opposite facts, and yet no scientific progress is possible unless the stimulus of the original unification is strong enough to clasp the discordant facts and establish a reunification. Thesis, antithesis and synthesis, a Fichtean formula, is generalized by Hegel into the perpetual law of thought.

Logic.

In what we may call their psychological aspect these three stages are known as the abstract stage, or that of understanding (*Verstand*), the dialectical stage, or that of negative reason, and the speculative stage, or that of positive reason (*Vernunft*). The first of these attitudes taken alone is dogmatism; the second, when similarly isolated, is scepticism; the third, when unexplained by its elements, is mysticism. Thus Hegelianism reduces dogmatism, scepticism and mysticism to factors in philosophy. The abstract or dogmatic thinker believes his object to be one, simple and stationary, and intelligible apart from its surrounding. He speaks, *e.g.*, as if species and genera were fixed and unchangeable; and fixing his eye on the ideal forms in their purity and self-sameness, he scorns the phenomenal world, whence this identity and persistence are absent. The dialectic of negative reason rudely dispels these theories. Appealing to reality it shows that the identity and permanence of forms are contradicted by history; instead of unity it exhibits multiplicity, instead of identity difference, instead of a whole, only parts. Dialectic is, therefore, a dislocating power; it shakes the solid structures of material thought, and exhibits the instability latent in such conceptions of the world. It is the spirit of progress and change, the enemy of convention and conservatism; it is absolute and universal unrest. In the realm of abstract thought these transitions take place lightly. In the worlds of nature and mind they are more palpable and violent. So far as this Hegel seems on the side of revolution. But reason is not negative only; while it disintegrates the mass or unconscious unity, it builds up a new unity with higher organization. But this third stage is the place of effort, requiring neither the surrender of the original unity nor the ignoring of the diversity afterwards suggested. The stimulus of contradiction is no doubt a strong one; but the easiest way of escaping it is to shut our eyes to one side of the antithesis. What is required, therefore, is to readjust our original thesis in such a way as to include and give expression to both the elements in the process.

The universe, then, is a process or development, to the eye of philosophy. It is the process of the absolute—in religious language, the manifestation of God. In the background of all the absolute is eternally present; the rhythmic movement of thought is the self-unfolding of the absolute. God reveals Himself in the logical idea, in nature and in mind; but mind is not alike conscious of its absoluteness in every stage of development. Philosophy alone sees God revealing Himself in the ideal organism of thought as it were a possible deity prior to the world and to any relation between God and actuality; in the natural world, as a series of materialized forces and forms of life; and in the spiritual world as the human soul, the legal and moral order of society, and the creations of art, religion and philosophy.

This introduction of the absolute became a stumbling-block to Feuerbach and other members of the "Left." They rejected as an illegitimate interpolation the eternal subject of development, and, instead of one continuing God as the subject of all the predicates by which in the logic the absolute is defined, assumed only a series of ideas, products of philosophic activity. They denied the theological value of the logical forms—the development of these forms being in their opinion due to the human thinker, not to a self-revealing absolute. Thus they made man the creator of the absolute. But with this modification on the system another necessarily followed; a mere logical series could not create nature. And thus the material universe became the real starting-point. Thought became only the result of organic conditions—subjective and human; and the system of Hegel was no longer an idealization of religion, but a naturalistic theory with a prominent and peculiar logic.

The logic of Hegel is the only rival to the logic of Aristotle. What Aristotle did for the theory of demonstrative reasoning, Hegel attempted to do for the whole of human knowledge. His logic is an enumeration of the forms or categories by which our experience exists. It carried out Kant's doctrine of the categories as a priori synthetic principles, but removed the limitation by which Kant denied them any constitutive value except in alliance with experience. According to Hegel the terms in which thought exhibits itself are a system of their own, with laws and relations which reappear in a less obvious shape in the theories of nature and mind. Nor are they restricted to the small number which Kant obtained by manipulating the current subdivision of judgments. But all forms by which thought holds sensations in unity (the formative or synthetic elements of language) had their place assigned in a system where one leads up to and passes over into another.

The fact which ordinary thought ignores, and of which ordinary logic therefore provides no account, is the presence of gradation and continuity in the world. The general terms of language simplify the universe by reducing its variety of individuals to a few forms, none of which exists simply and perfectly. The method of the understanding is to divide and then to give a separate reality to what it has thus distinguished. It is part of Hegel's plan to remedy this one-sided character of thought, by laying bare the gradations of ideas. He lays special stress on the point that abstract ideas when held in their abstraction are almost interchangeable with their opposites—that extremes meet, and that in every true and concrete idea there is a coincidence of opposites.

The beginning of the logic is an illustration of this. The logical idea is treated under the three heads of being (*Seyn*), essence (*Wesen*) and notion (*Begriff*). The simplest term of thought is being; we cannot think less about anything than when we merely say that it is. Being—the abstract "is"—is *nothing* definite, and nothing at least is. Being and not being are thus declared identical—a proposition which in this unqualified shape was to most people a stumbling-block at the very door of the system. Instead of the mere "is" which is as yet nothing, we should rather say "becomes," and as "becomes" always implies "something," we have determinate being—"a being" which in the next stage of definiteness becomes "one." And in this way we pass on to the quantitative aspects of being.

The terms treated under the first head, in addition to those already mentioned, are the abstract principles of quantity and number, and their application in measure to determine the limits of being. Under the title of essence are discussed those pairs of correlative terms which are habitually employed in the explanation of the world—such as law and phenomenon, cause and effect, reason and consequence, substance and attribute. Under the head of notion are considered, firstly, the subjective forms of conception, judgment and syllogism; secondly, their realization in objects as mechanically, chemically or teleologically constituted; and thirdly, the idea first of life, and next of science, as the complete interpenetration of thought and objectivity. The third part of logic evidently is what contains the topics usually treated in logic-books, though even here the province of logic in the ordinary sense is exceeded. The first two divisions—the "objective logic"—are what is usually called metaphysics.

The characteristic of the system is the gradual way in which idea is linked to idea so as to make the division into chapters only an arrangement of convenience. The judgment is completed in the syllogism; the syllogistic form as the perfection of subjective thought passes into objectivity, where it first appears embodied in a mechanical system; and the teleological object, in which the members are as means and end, leads up to the idea of life, where the end is means and means end indissolubly till death. In some cases these transitions may be unsatisfactory and forced; it is apparent that the linear development from "being" to the "idea" is got by transforming into a logical order the sequence that has roughly prevailed in philosophy from the Eleatics; cases might be quoted where the reasoning seems a play upon words; and it may often be doubted whether certain ideas do not involve extra-logical considerations. The order of the categories is in the main outlines fixed; but in the minor details much depends upon the philosopher, who has to fill in the gaps between ideas, with little guidance from the data of experience, and to assign to the stages of development names which occasionally deal hardly with language. The merit of Hegel is to have indicated and to a large extent displayed the filiation and mutual limitation of our forms of thought; to have arranged them in the order of their comparative capacity to give a satisfactory expression to truth in the totality of its relations; and to have broken down the partition which in Kant separated the formal logic from the transcendental analytic, as well as the general disruption between logic and metaphysic. It must at the same time be admitted that much of the work of weaving the terms of thought, the categories, into a system has a hypothetical and tentative character, and that Hegel has rather pointed out the path which logic must follow, viz. a criticism of the terms of scientific and ordinary thought in their filiation and interdependence, than himself in every case kept to the right way. The day for a fuller investigation of this problem will partly depend upon the progress of the study of language in the direction marked out by W. von Humboldt. 206

The Philosophy of Nature starts with the result of the logical development, with the full scientific "idea." But the relations of pure thought, losing their inwardness, appear as relations of space and time; the abstract development of thought appears as matter and movement. Instead of thought, we have perception; instead of dialectic, gravitation; instead of causation, sequence in time. The whole falls under the three heads of mechanics, physics and "organic"—the content under each varying somewhat in the three editions of the *Encyklopädie*. The first treats of space, time, matter, movement; and in the solar system we have the representation of the idea in its general and abstract material form. Under the head of physics we have the theory of the elements, of sound, heat and cohesion, and finally of chemical affinity—presenting the phenomena of material change and interchange in a series of special forces which generate the variety of the life of nature. Lastly, under the head of "organic," come geology, botany and animal physiology—presenting the concrete results of these processes in the three kingdoms of nature.

Philosophy of nature.

The charges of superficial analogies, so freely urged against the "Natur-philosophie" by critics who forget the impulse it gave to physical research by the identification of forces then believed to be radically distinct, do not particularly affect Hegel. But in general it may be said that he looked down upon the mere natural world. The meanest of the fancies of the mind and the most casual of its whims he regarded as a better warrant for the being of God than any single object of nature. Those who supposed astronomy to inspire religious awe were horrified to hear the stars compared to eruptive spots on the face of the sky. Even in the animal world, the highest stage of nature, he saw a failure to reach an independent and rational system of organization; and its feelings under the continuous violence and menaces of the environment he described as insecure, anxious and unhappy.

His point of view was essentially opposed to the current views of science. To metamorphosis he only allowed a logical value, as explaining the natural classification; the only real, existent metamorphosis he saw in the development of the individual from its embryonic stage. Still more distinctly did he contravene the general tendency of scientific explanation. "It is held the triumph of science to recognize in the general process of the earth the same categories as are exhibited in the processes of isolated bodies. This is, however, an application of categories from a field where the conditions are finite to a sphere in which the circumstances are infinite." In astronomy he depreciates the merits of Newton and elevates Kepler, accusing Newton particularly, à propos of the distinction of centrifugal and centripetal forces, of leading to a confusion between what is mathematically to be distinguished and what is physically separate. The principles which explain the fall of an apple will not do for the planets. As to colour, he follows Goethe, and uses strong language against Newton's theory, for the barbarism of the conception that light is a compound, the incorrectness of his observations, &c. In chemistry, again, he objects to the way in which all the chemical elements are treated as on the same level.

The third part of the system is the Philosophy of Mind. Its three divisions are the "subjective mind" (psychology), the "objective mind" (philosophic jurisprudence, moral and political philosophy) and the "absolute mind" (the philosophy of art, religion and philosophy). The subjects of the second and third divisions have been treated by Hegel with great detail. The "objective mind" is the topic of the *Rechts-Philosophie*, and of the lectures on the Philosophy of History; while on the "absolute mind" we have the lectures on Aesthetic, on the Philosophy of Religion and on the History of Philosophy—in short, more than one-third of his works.

Philosophy of mind. 1. Psychology.

The purely psychological branch of the subject takes up half of the space allotted to *Geist* in the *Encyklopädie*. It falls under the three heads of anthropology, phenomenology and psychology proper. Anthropology treats of the mind in union with the body—of the natural soul—and discusses the relations of the soul with the planets, the races of mankind, the differences of age, dreams, animal magnetism, insanity and phrenology. In this obscure region it is rich in suggestions and rapprochements; but the ingenuity of these speculations attracts curiosity more than it satisfies scientific inquiry. In the Phenomenology consciousness, self-consciousness and reason are dealt with. The title of the section and the contents recall, though with some important variations, the earlier half of his first work; only that here the historical background on which the stages in the development of the ego were represented has disappeared. Psychology, in the stricter sense, deals with the various forms of theoretical and practical intellect, such as attention, memory, desire and will. In this account of the development of an independent, active and intelligent being from the stage where man like the Dryad is a portion of the natural life around him, Hegel has combined what may be termed a physiology and pathology of the mind—a subject far wider than that of ordinary psychologies, and one of vast intrinsic importance. It is, of course, easy to set aside these questions as unanswerable, and to find artificiality in the arrangement. Still it remains a great point to have even attempted some system in the dark anomalies which lie under the normal consciousness, and to have traced the genesis of the intellectual faculties from animal sensitivity.

The theory of the mind as objectified in the institutions of law, the family and the state is discussed in the "Philosophy of Right." Beginning with the antithesis of a legal system and morality, Hegel, carrying out the work of Kant, presents the synthesis of these elements in the ethical life (*Sittlichkeit*) of the family and the state. Treating the family as an instinctive realization of the moral life, and not as the result of contract, he shows how by the means of wider associations due to private interests the state issues as the full home of the moral spirit, where intimacy of interdependence is combined with freedom of independent growth. The state is the consummation of man as finite; it is the necessary starting-point whence the spirit rises to an absolute existence in the spheres of art, religion and philosophy. In the finite world or temporal state, religion, as the finite organization of a church, is, like other societies, subordinate to the state. But on another side, as absolute spirit, religion, like art and philosophy, is not subject to the state, but belongs to a higher region.

2. Law and history.

The political state is always an individual, and the relations of these states with each other and the "world-spirit" of which they are the manifestations constitute the material of history. The *Lectures on the Philosophy of History*, edited by Gans and subsequently by Karl Hegel, is the most popular of Hegel's works. The history of the world is a scene of judgment where one people and one alone holds for awhile the sceptre, as the unconscious instrument of the universal spirit, till another rises in its place, with a fuller measure of liberty—a larger superiority to the bonds of natural and artificial circumstance. Three main periods—the Oriental, the Classical and the Germanic—in which respectively the single despot, the dominant order, and the man as man possess freedom—constitute the history of the world. Inaccuracy in detail and artifice in the arrangement of isolated peoples are inevitable in such a scheme. A graver mistake, according to some critics, is that Hegel, far from giving a law of progress, seems to suggest that the history of the world is nearing an end, and has merely reduced the past to a logical formula. The answer to this charge is partly that such a law seems unattainable, and partly that the idealistic content of the present which philosophy extracts is always an advance upon actual fact, and so does throw a light into the future. And at any rate the method is greater than Hegel's employment of it.

But as with Aristotle so with Hegel—beyond the ethical and political sphere rises the world of absolute spirit in art, religion and philosophy. The psychological distinction between the three forms is that sensuous perception (*Anschauung*) is the organon of the first, presentative conception (*Vorstellung*) of the second and free thought of the third. The work of art, the first embodiment of absolute mind, shows a sensuous conformity between the idea and the reality in which it is expressed. The so-called beauty of nature is for Hegel an adventitious beauty. The beauty of art is a beauty born in the spirit of the artist and born again in the spectator; it is not like the beauty of natural things, an incident of their existence, but is "essentially a question, an address to a responding breast, a call to the heart and spirit." The perfection of art depends on the degree of intimacy in which idea and form appear worked into each other. From the different proportion between the idea and the shape in which it is realized arise three different forms of art. When the idea, itself indefinite, gets no further than a struggle and endeavour for its appropriate expression, we have the symbolic, which is the Oriental, form of art, which seeks to compensate its imperfect expression by colossal and enigmatic structures. In the second or classical form of art the idea of humanity finds an adequate sensuous representation. But this form disappears with the decease of Greek national life, and on its collapse follows the romantic, the third form of art; where the harmony of form and content again grows defective, because the object of Christian art—the infinite spirit—is a theme too high for art. Corresponding to this division is the classification of the single arts. First comes architecture—in the main, symbolic art; then sculpture, the classical art *par excellence*; they are found, however, in all three forms. Painting and music are the specially romantic arts. Lastly, as a union of painting and music comes poetry, where the sensuous element is more than ever subordinate to the spirit.

3. Art, religion and philosophy.

The lectures on the Philosophy of Art stray largely into the next sphere and dwell with zest on the close connexion of art and religion; and the discussion of the decadence and rise of religions, of the aesthetic qualities of Christian legend, of the age of chivalry, &c., make the *Ästhetik* a book of varied interest.

The lectures on the Philosophy of Religion, though unequal in their composition and belonging to different dates, serve to exhibit the vital connexion of the system with Christianity. Religion, like art, is inferior to philosophy as an exponent of the harmony between man and the absolute. In it the absolute exists as the poetry and music of the heart, in the inwardness of feeling. Hegel after expounding the nature of religion passes on to discuss its historical phases, but in the immature state of religious science falls into several mistakes. At the bottom of the scale of nature-worships he places the religion of sorcery. The gradations which follow are apportioned with some uncertainty amongst the religions of the East. With the Persian religion of light and the Egyptian of enigmas we pass to those faiths where Godhead takes the form of a spiritual individuality, *i.e.* to the Hebrew religion (of sublimity), the Greek (of beauty) and the Roman (of adaptation). Last comes absolute religion, in which the mystery of the reconciliation between God and man is an open doctrine. This is Christianity, in which God is a Trinity, because He is a spirit. The revelation of this truth is the subject of the Christian Scriptures. For the Son of God, in the immediate aspect, is the finite world of nature and man, which far from being at one with its Father is originally in an attitude of estrangement. The history of Christ is the visible reconciliation between man and the eternal. With the death of Christ this union, ceasing to be a mere fact, becomes a vital idea—the Spirit of God which dwells in the Christian community.

The lectures on the History of Philosophy deal disproportionately with the various epochs, and in some parts date from the beginning of Hegel’s career. In trying to subject history to the order of logic they sometimes misconceive the filiation of ideas. But they created the history of philosophy as a scientific study. They showed that a philosophical theory is not an accident or whim, but an exponent of its age determined by its antecedents and environments, and handing on its results to the future.

(W. W.; X.)

Hegelianism in England.—On the continent of Europe the direct influence of Hegelianism was comparatively short-lived. This was due among other causes to the direction of attention to the rising science of psychology, partly to the reaction against the speculative method. In England and Scotland it had another fate. Both in theory and practice it here seemed to supply precisely the counter-active to prevailing tendencies towards empiricism and individualism that was required. In this respect it stood to philosophy in somewhat the same relation that the influence of Goethe stood to literature. This explains the hold which it had obtained upon both English and Scottish thought soon after the middle of the 19th century. The first impulse came from J. F. Ferrier and J. H. Stirling in Edinburgh, and B. Jowett in Oxford. Already in the seventies there was a powerful school of English thinkers under the lead of Edward Caird and T. H. Green devoted to the study and exposition of the Hegelian system. With the general acceptance of its main principle that the real is the rational, there came in the eighties a more critical examination of the precise meaning to be attached to it and its bearing on the problems of religion. The earlier Hegelians had interpreted it in the sense that the world in its ultimate essence was not only spiritual but self-conscious intelligence whose nature was reflected inadequately but truly in the finite mind. They thus seemed to come forward in the character of exponents rather than critics of the Western belief in God, freedom and immortality. As time went on it became obvious that without departure from the spirit of idealism Hegel’s principle was susceptible of a different interpretation. Granted that rationality taken in the sense of inner coherence and self-consistency is the ultimate standard of truth and reality, does self-consciousness itself answer to the demands of this criterion? If not, are we not forced to deny ultimate reality to personality whether human or divine? The question was definitely raised in F. H. Bradley’s *Appearance and Reality* (1893; 2nd ed., 1897) and answered in the negative. The completeness and self-consistency which our ideal requires can be realized only in a form of being in which subject and object, will and desire, no longer stand as exclusive opposites, from which it seemed at once to follow that the finite self could not be a reality nor the infinite reality a self. On this basis Bradley developed a theory of the Absolute which, while not denying that it must be conceived of spiritually, insisted that its spirituality is of a kind that finds no analogy in our self-conscious experience. More recently J. M. E. McTaggart’s *Studies in Hegelian Dialectic* (1896), *Studies in Hegelian Cosmology* (1901) and *Some Dogmas of Religion* (1906) have opened a new chapter in the interpretation of Hegelianism. Truly perceiving that the ultimate metaphysical problem is, here as ever, the relation of the One and the Many, McTaggart starts with a definition of the ideal in which our thought upon it can come to rest. He finds it where (*a*) the unity is for each individual, (*b*) the whole nature of the individual is to be *for* the unity. It follows from such a conception of the relation that the whole cannot itself be an individual apart from the individuals in whom it is realized, in other words, the Absolute cannot be a Person. But for the same reason—viz. that in it first and in it alone this condition is realized—the individual soul must be held to be an ultimate reality reflecting in its inmost nature, like the monad of Leibniz, the complete fulness and harmony of the whole. In reply to Bradley’s argument for the unreality of the self, Hegel is interpreted as meaning that the opposition between self and not-self on which it is founded is one that is self-made and in being made is transcended. The fuller our knowledge of reality the more does the object stand out as an invulnerable system of ordered parts, but the process by which it is thus set in opposition to the subject is also the process by which we understand and transform it into the substance of our own thought. From this position further consequences followed. Seeing that the individual soul must thus be taken to stand in respect to its inmost essence in complete harmony with the whole, it must eternally be at one with itself: all change must be appearance. Seeing, moreover, that it is, and is maintained in being, by a fixed relation to the Absolute, it cannot fail of immortality. No pantheistic theory of an eternal substance continuously expressing itself in different individuals who fall back into its being like drops into the ocean will here be sufficient. The ocean is the drops. "The Absolute requires each self not to make up a sum or to maintain an average but in respect of the self's special and unique nature." Finally as it cannot cease, neither can the individual soul have had a beginning. Pre-existence is as necessary and certain as a future life. If memory is lacking as a link between the different lives, this only shows that memory is not of the substance of the soul.

In view of these differences (amounting almost to an antinomy of paradoxes) in interpretation, it is not surprising to find that recent years have witnessed a violent reaction in some quarters against Hegelian influence. This has taken the direction on the one hand of a revival of realism (see Metaphysics), on the other of a new form of subjective idealism (see Pragmatism). As yet neither of these movements has shown sufficient coherence or stability to establish itself as a rival to the main current of philosophy in England. But they have both been urged with sufficient ability to arrest its progress and to call for a reconsideration and restatement of the fundamental principle of idealist philosophy and its relation to the fundamental problems of religion. This will probably be the main work of the next generation of thinkers in England (see Idealism).

Among Italian Hegelians are A. Vera, Raffaele Mariano and B. Spaventa (1817-1883); see V. de Lucia, *L'Hegel in Italia* (1891). In Sweden, J. J. Borelius of Lund; in Norway, G. V. Lyng (d. 1884), M. J. Monrad (1816-1897) and G. Kent (d. 1892) have adopted Hegelianism; in France, P. Leroux and P. Prévost.

Bibliography.—Shortly after Hegel's death his collected works were published by a number of his friends, who combined for the purpose. They appeared in eighteen volumes in 1832, and a second edition came out about twelve years later. Volumes i.-viii. contain the works published by himself; the remainder is made up of his lectures on the Philosophy of History, Aesthetic, the Philosophy of Religion and the History of Philosophy, besides some essays and reviews, with a few of his letters, and the Philosophical Propaedeutic.

For his life see K. Rosenkranz, *Leben Hegels* (Berlin, 1844); R. R. Haym, *Hegel und seine Zeit* (Berlin, 1857); K. Köstlin, *Hegel in philosophischer, politischer und nationaler Beziehung* (Tübingen, 1870); Rosenkranz, *Hegel als deutscher National-Philosoph* (Berlin, 1870), and his *Neue Studien*, vol. iv. (Berlin, 1878); Kuno Fischer, *Hegels Leben und Werke*.

For the philosophy see A. Ruge's *Aus früherer Zeit*, vol. iv. (Berlin, 1867); Haym (as above); F. A. Trendelenburg (in *Logische Untersuchungen*); A. L. Kym (*Metaphysische Untersuchungen*) and C. Hermann (*Hegel und die logische Frage* and other works) are noticeable as modern critics. Georges Noël, *La Logique de Hegel* (Paris, 1897); Aloys Schmid, *Die Entwickelungsgeschichte der Hegelschen Logik* (Regensburg, 1858). Vera has translated the *Encyklopädie* into French, with notes; C. Bénard, the *Ästhetik*. In English J. Hutcheson Stirling's *Secret of Hegel* (2 vols., London, 1865) contains a translation of the beginning of the *Wissenschaft der Logik*; the "Logic" from the *Encyklopädie* has been translated, with Prolegomena, by W. Wallace (Oxford, 1874). W. Wallace also translated the third part of the *Encyklopädie in Hegel's Philosophy of Mind* (1894); R. B. Haldane the *History of Philosophy* (1896); E. B. Speirs, lectures on the *Philosophy of Religion* (1895); J. Sibree, lectures on *The Philosophy of History* (1852); B. Bosanquet, *Philosophy of Fine Art*, Introduction (1886); W. Hastie, *The Philosophy of Art* (1886); S. W. Dyde, *The Philosophy of Right* (1896). Other recent expositions and criticisms in addition to those mentioned above are W. T. Harris, *Hegel's Logic* (1890); J. B. Baillie, *Origin and Significance of Hegel's Logic* (1901), and *Outline of the Idealistic Construction of Experience* (1906); P. Barth, *Die Geschichtsphilosophie Hegels* (1890); J. A. Marrast, *La Philosophie du droit de Hegel* (1869); L. Miraglia, *I Principii fondamentali e la dottrina eticogiuridica di Hegel* (1873); *Hegel's Philosophy of the State and History* (Germ. Phil. Classics, 1887); G. Bolland, *Philosophie des Rechts* (1902), and *Hegels Philosophie der Religion* (1901); E. Ott, *Die Religionsphilosophie Hegels* (1904); J. M. Sterrett, *Studies in Hegel's Philosophy of Religion* (1891); M. Ehrenhauss, *Hegels Gottesbegriff* (1880); E. Caird, Hegel (1880); A. Seth Pringle-Pattison, *Hegelianism and Personality* (1893); Millicent Mackenzie, *Hegel's Educational Theory and Practice* (1909), with biographical sketch; J. M. E. McTaggart, *Commentary on Hegel's Logic* (1910).

(J. H. Mu.)

HEGEMON OF THASOS, Greek writer of the old comedy, nicknamed Φακῆ from his fondness for lentils. Hardly anything is known of him, except that he flourished during the Peloponnesian War. According to Aristotle (*Poetics*, ii. 5) he was the inventor of a kind of parody; by slightly altering the wording in well-known poems he transformed the sublime into the ridiculous. When the news of the disaster in Sicily reached Athens, his parody of the *Gigantomachia* was being performed; it is said that the audience were so amused by it that, instead of leaving to show their grief, they remained in their seats. He was also the author of a comedy called *Philinne* (*Philine*), written in the manner of Eupolis and Cratinus, in which he attacked a well-known courtesan. Athenaeus (p. 698), who preserves some parodic hexameters of his, relates other anecdotes concerning him (pp. 5, 108, 407). 208

Fragments in T. Kock, *Comicorum Atticorum fragmenta*, i. (1880); B. J. Peltzer, *De parodica Graecorum poesi* (1855).

HEGEMONY (Gr. ἡγεμονία, leadership, from ἡγεῖσθαι, to lead), the leadership especially of one particular state in a group of federated or loosely united states. The term was first applied in Greek history to the position claimed by different individual city-states, *e.g.* by Athens and Sparta, at different times to a position of predominance (*primus inter pares*) among other equal states, coupled with individual autonomy. The reversion of this position was claimed by Macedon (see Greece: *Ancient History*, and Delian League).

HEGESIAS OF MAGNESIA (in Lydia), Greek rhetorician and historian, flourished about 300 B.C. Strabo (xiv. 648), speaks of him as the founder of the florid style of composition known as “Asiatic” (cf. Timaeus). Agatharchides, Dionysius of Halicarnassus and Cicero all speak of him in disparaging terms, although Varro seems to have approved of his work. He professed to imitate the simple style of Lysias, avoiding long periods, and expressing himself in short, jerky sentences, without modulation or finish. His vulgar affectation and bombast made his writings a mere caricature of the old Attic. Dionysius describes his composition as tinselled, ignoble and effeminate. It is generally supposed, from the fragment quoted as a specimen by Dionysius, that Hegesias is to be classed among the writers of lives of Alexander the Great. This fragment describes the treatment of Gaza and its inhabitants by Alexander after its conquest, but it is possible that it is only part of an epideictic or show-speech, not of an historical work. This view is supported by a remark of Agatharchides in Photius (*cod.* 250) that the only aim of Hegesias was to exhibit his skill in describing sensational events.

See Cicero, *Brutus* 83, *Orator* 67, 69, with J. E. Sandys’s note, *ad Att.* xii. 6; Dion. Halic. *De verborum comp.* iv.; Aulus Gellius ix. 4; Plutarch, *Alexander*, 3; C. W. Müller, *Scriptores rerum Alexandri Magni*, p. 138 (appendix to Didot ed. of Arrian, 1846); Norden, *Die antike Kunstprosa* (1898); J. B. Bury, *Ancient Greek Historians* (1909), pp. 169-172, on origin and development of “Asiatic” style, with example from Hegesias.

HEGESIPPUS, Athenian orator and statesman, nicknamed Κρώβυλος (“knot”), probably from the way in which he wore his hair. He lived in the time of Demosthenes, of whose anti-Macedonian policy he was an enthusiastic supporter. In 343 B.C. he was one of the ambassadors sent to Macedonia to discuss, amongst other matters, the restoration of the island of Halonnesus, which had been seized by Philip. The mission was unsuccessful, but soon afterwards Philip wrote to Athens, offering to resign possession of the island or to submit to arbitration the question of ownership. In reply to this letter the oration De *Halonneso* was delivered, which, although included among the speeches of Demosthenes, is generally considered to be by Hegesippus. Dionysius of Halicarnassus and Plutarch, however, favour the authorship of Demosthenes.

See Demosthenes, *De falsa legatione* 364, 447, *De corona* 250, *Philippica* iii. 129; Plutarch, *Demosthenes* 17, *Apophthegmata*, 187D; Dionysius Halic. *ad Ammaeum*, i.; Grote, *History of Greece*, ch. 90.

HEGESIPPUS (fl. A.D. 150-180), early Christian writer, was of Palestinian origin, and lived under the Emperors Antoninus Pius, Marcus Aurelius and Commodus. Like Aristo of Pella he belonged to that group of Judaistic Christians which, while keeping the law themselves, did not attempt to impose on others the requirements of circumcision and Sabbath observance. He was the author of a treatise (ὑπομνήματα) in five books dealing with such subjects as Christian literature, the unity of church doctrine, paganism, heresy and Jewish Christianity, fragments of which are found in Eusebius, who obtained much of his information concerning early Palestinian church history and chronology from this source. Hegesippus was also a great traveller, and like many other leaders of his time came to Rome (having visited Corinth on the way) about the middle of the 2nd century. His journeyings impressed him with the idea that the continuity of the church in the cities he visited was a guarantee of its fidelity to apostolic orthodoxy: "in each succession and in every city, the doctrine is in accordance with that which the Law and the Prophets and the Lord [*i.e.* the Old Testament and the evangelical tradition] proclaim." To illustrate this opinion he drew up a list of the Roman bishops. Hegesippus is thus a significant figure both for the type of Christianity taught in the circle to which he belonged, and as accentuating the point of view which the church began to assume in the presence of a developing gnosticism.

HEGESIPPUS, the supposed author of a free Latin adaptation of the *Jewish War* of Josephus under the title *De bello Judaico et excidio urbis Hierosolymitanae*. The seven books of Josephus are compressed into five, but much has been added from the Antiquities and from the works of Roman historians, while several entirely new speeches are introduced to suit the occasion. Internal evidence shows that the work could not have been written before the 4th century A.D. The author, who is undoubtedly a Christian, describes it in his preface as a kind of revised edition of Josephus. Some authorities attribute it to Ambrose, bishop of Milan (340-397), but there is nothing to settle the authorship definitely. The name Hegesippus itself appears to be a corruption of Josephus, through the stages Ἰώσηπος, Iosippus, Egesippus, Hegesippus, unless it was purposely adopted as reminiscent of Hegesippus, the father of ecclesiastical history (2nd century).

Best edition by C. F. Weber and J. Caesar (1864); authorities in E. Schürer, *History of the Jewish People* (Eng. trans.), i. 99 seq.; F. Vogel, *De Hegesippo, qui dicitur, Josephi interprete* (Erlangen, 1881).

HEGIUS [VON HEEK], ALEXANDER (*c.* 1433-1498), German humanist, so called from his birthplace Heek in Westphalia. In his youth he was a pupil of Thomas à Kempis, at that time canon of the convent of St Agnes at Zwolle. In 1474 he settled down at Deventer in Holland, where he either founded or succeeded to the headship of a school, which became famous for the number of its distinguished alumni. First and foremost of these was Erasmus; others were Hermann von dem Busche, the missionary of humanism, Conrad Goclenius (Gockelen), Conrad Mutianus (Muth von Mudt) and pope Adrian VI. Hegius died at Deventer on the 7th of December 1498. His writings, consisting of short poems, philosophical essays, grammatical notes and letters, were published after his death by his pupil Jacob Faber. They display considerable knowledge of Latin, but less of Greek, on the value of which he strongly insisted. Hegius’s chief claim to be remembered rests not upon his published works, but upon his services in the cause of humanism. He succeeded in abolishing the old-fashioned medieval textbooks and methods of instruction, and led his pupils to the study of the classical authors themselves. His generosity in assisting poor students exhausted a considerable fortune, and at his death he left nothing but his books and clothes.

See D. Reichling, “Beiträge zur Charakteristik des Alex. Hegius,” in the *Monatsschrift für Westdeutschland* (1877); H. Hamelmann, *Opera genealogico-historica* (1711); H. A. Erhard, *Geschichte des Wiederaufblühens wissenschaftlicher Bildung* (1826); C. Krafft and W. Crecelius, “Alexander Hegius und seine Schüler,” from the works of Johannes Butzbach, one of Hegius’s pupils, in *Zeitschrift des bergischen Geschichtsvereins*, vii. (Bonn, 1871).

HEIBERG, JOHAN LUDVIG (1791-1860), Danish poet and critic, son of the political writer Peter Andreas Heiberg (1758-1841), and of the famous novelist, afterwards the Baroness Gyllembourg-Ehrensvärd, was born at Copenhagen on the 14th of December 1791. In 1800 his father was exiled and settled in Paris, where he was employed in the French foreign office, retiring in 1817 with a pension. His political and satirical writings continued to exercise great influence over his fellow-countrymen. Johan Ludvig Heiberg was taken by K. L. Rahbek and his wife into their house at Bakkehuset. He was educated at the university of Copenhagen, and his first publication, entitled *The Theatre for Marionettes* (1814), included two romantic dramas. This was followed by *Christmas Jokes and New Year’s Tricks* 209
(1816), *The Initiation of Psyche* (1817), and *The Prophecy of Tycho Brahé*, a satire on the eccentricities of the Romantic writers, especially on the sentimentality of Ingemann. These works attracted attention at a time when Baggesen, Öhlenschläger and Ingemann possessed the popular ear, and were understood at once to be the opening of a great career. In 1817 Heiberg took his degree, and in 1819 went abroad with a grant from government. He proceeded to Paris, and spent the next three years there with his father. In 1822 he published his drama of *Nina*, and was made professor of the Danish language at the university of Kiel, where he delivered a course of lectures, comparing the Scandinavian mythology as found in the *Edda* with the poems of Öhlenschläger. These lectures were published in German in 1827.

In 1825 Heiberg came back to Copenhagen for the purpose of introducing the vaudeville on the Danish stage. He composed a great number of these vaudevilles, of which the best known are *King Solomon and George the Hatmaker* (1825); *April Fools* (1826); *A Story in Rosenborg Garden* (1827); *Kjöge Huskors* (1831); *The Danes in Paris* (1833); *No* (1836); and *Yes* (1839). He took his models from the French theatre, but showed extraordinary skill in blending the words and the music; but the subjects and the humour were essentially Danish and even topical. Meanwhile he was producing dramatic work of a more serious kind; in 1828 he brought out the national drama of *Elverhöi*; in 1830 *The Inseparables*; in 1835 the fairy comedy of *The Elves*, a dramatic version of Tieck’s *Elfin*; and in 1838 *Fata Morgana*. In 1841 Heiberg published a volume of *New Poems* containing “A Soul after Death,” a comedy which is perhaps his masterpiece, “The Newly Wedded Pair,” and other pieces. He edited from 1827 to 1830 the famous weekly, the *Flyvende Post* (The Flying Post), and subsequently the *Interimsblade* (1834-1837) and the *Intelligensblade* (1842-1843). In his journalism he carried on his warfare against the excessive pretensions of the Romanticists, and produced much valuable and penetrating criticism of art and literature. In 1831 he married the actress Johanne Louise Paetges (1812-1890), herself the author of some popular vaudevilles. Heiberg’s scathing satires, however, made him very unpopular; and this antagonism reached its height when, in 1845, he published his malicious little drama of *The Nut Crackers*. Nevertheless he became in 1847 director of the national theatre. He filled the post for seven years, working with great zeal and conscientiousness, but was forced by intrigues from without to resign it in 1854. Heiberg died at Bonderup, near Ringsted, on the 25th of August 1860. His influence upon taste and critical opinion was greater than that of any writer of his time, and can only be compared with that of Holberg in the 18th century. Most of the poets of the Romantic movement in Denmark were very grave and serious; Heiberg added the element of humour, elegance and irony. He had the genius of good taste, and his witty and delicate productions stand almost unique in the literature of his country.

The poetical works of Heiberg were collected, in 11 vols., in 1861-1862, and his prose writings (11 vols.) in the same year. The last volume of his prose works contains some fragments of autobiography. See also G. Brandes, *Essays* (1889). For the elder Heiberg see monographs by Thaarup (1883) and by Schwanenflügel (1891).

HEIDE, a town of Germany, in the Prussian province of Schleswig-Holstein, on a small plateau which stands between the marshes and moors bordering the North Sea, 35 m. N.N.W. of Glückstadt, at the junction of the railways Elmshorn-Hvidding and Neumünster-Tönning. Pop. (1905), 8758. It has an Evangelical and a Roman Catholic church, a high-grade school, and tobacco and cigar manufactories and breweries. Heide in 1447 became the capital of the Ditmarsh peasant republic, but on the 13th of June 1559 it was the scene of the complete defeat of the peasant forces by the Danes.

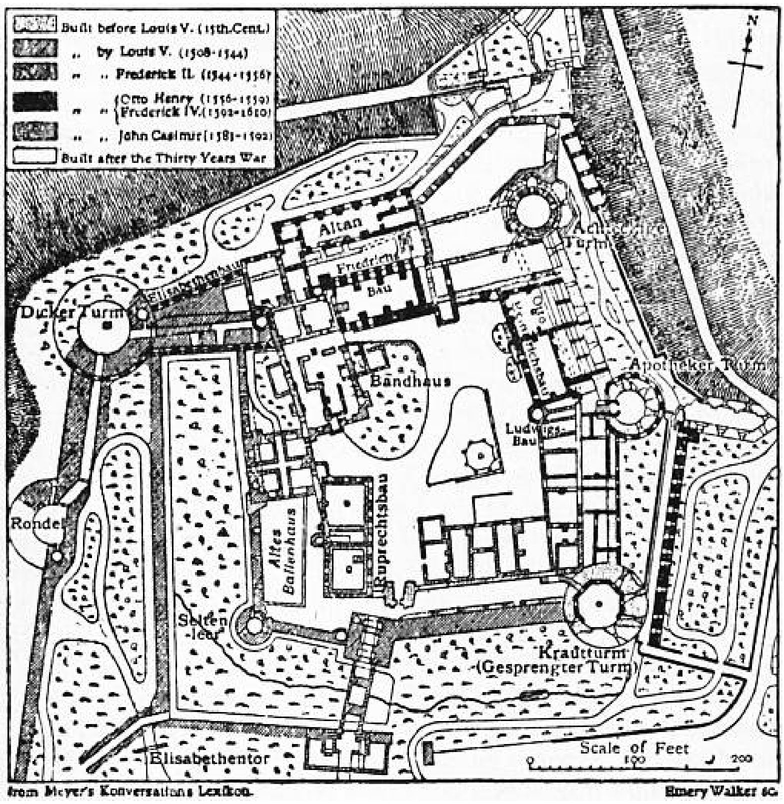
HEIDEGGER, JOHANN HEINRICH (1633-1698), Swiss theologian, was born at Bärentschweil, in the canton of Zürich, Switzerland, on the 1st of July 1633. He studied at Marburg and at Heidelberg, where he became the friend of J. L. Fabricius (1632-1696), and was appointed *professor extraordinarius* of Hebrew and later of philosophy. In 1659 he was called to Steinfurt to fill the chair of dogmatics and ecclesiastical history, and in the same year he became doctor of theology of Heidelberg. In 1660 he revisited Switzerland; and, after marrying, he travelled in the following year to Holland, where he made the acquaintance of Johannes Cocceius. He returned in 1665 to Zürich, where he was elected professor of moral philosophy. Two years later he succeeded J. H. Hottinger (1620-1667) in the chair of theology, which he occupied till his death on the 18th of January 1698, having declined an invitation in 1669 to succeed J. Cocceius at Leiden, as well as a call to Groningen. Heidegger was the principal author of the *Formula Consensus Helvetica* in 1675, which was designed to unite the Swiss Reformed churches, but had an opposite effect. W. Gass describes him as the most notable of the Swiss theologians of the time.

His writings are largely controversial, though without being bitter, and are in great part levelled against the Roman Catholic Church. The chief are *De historia sacra patriarcharum exercitationes selectae* (1667-1671); *Dissertatio de Peregrinationibus religiosis* (1670); *De ratione studiorum, opuscula aurea*, &c. (1670); *Historia papatus* (1684; under the name Nicander von Hohenegg); *Manuductio in viam concordiae Protestantium ecclesiasticae* (1686); *Tumulus concilii Tridentini* (1690); *Exercitationes biblicae* (1700), with a life of the author prefixed; *Corpus theologiae Christianae* (1700, edited by J. H. Schweizer); *Ethicae Christianae elementa* (1711); and lives of J. H. Hottinger (1667) and J. L. Fabricius (1698). His autobiography appeared in 1698, under the title *Historia vitae J. H. Heideggeri*.

See the articles in Herzog-Hauck’s *Realencyklopädie* and the *Allgemeine deutsche Biographie*; and cf. W. Gass, *Geschichte der protestantischen Dogmatik*, ii. 353 ff.

HEIDELBERG, a town of Germany, on the south bank of the Neckar, 12 m. above its confluence with the Rhine, 13 m. S.E. from Mannheim and 54 m. from Frankfort-on-Main by rail. The situation of the town, lying between lofty hills covered with vineyards and forests, at the spot where the rapid Neckar leaves the gorge and enters the plain of the Rhine, is one of great natural beauty. The town itself consists practically of one long, narrow street—the Hauptstrasse—running parallel to the river, from the railway station on the west to the Karlstor on the east (where there is also a local station) for a distance of 2 m. To the south of this is the Anlage, a pleasant promenade flanked by handsome villas and gardens, leading directly to the centre of the place. A number of smaller streets intersect the Hauptstrasse at right angles and run down to the river, which is crossed by two fine bridges. Of these, the old bridge on the east, built in 1788, has a fine gateway and is adorned with statues of Minerva and the elector Charles Theodore of the Palatinate; the other, the lower bridge, on the west, built in 1877, connects Heidelberg with the important suburbs of Neuenheim and Handschuchsheim. Of recent years the town has grown largely towards the west on both sides of the river; but the additions have been almost entirely of the better class of residences. Heidelberg is an important railway centre, and is connected by trunk lines with Frankfort, Mannheim, Karlsruhe, Spires and Würzburg. Electric trams provide for local traffic, and there are also several light railways joining it with the neighbouring villages. Of the churches the chief are the Protestant Peterskirche dating from the 15th century and restored in 1873, to the door of which Jerome of Prague in 1460 nailed his theses; the Heilige Geist Kirche (Church of the Holy Ghost), an imposing Gothic edifice of the 15th century; the Jesuitenkirche (Roman Catholic), with a sumptuously decorated interior, and the new Evangelical Christuskirche. The town hall and the university buildings, dating from 1712 and restored in 1886, are commonplace erections; but to the south of the Ludwigsplatz, upon which most of the academical buildings lie, stands the new university library, a handsome structure of pink sandstone in German Renaissance style. In addition to the Ludwigsplatz with its equestrian statue of the emperor William I. there are other squares in the town, among them being the Bismarckplatz with a statue of Bismarck, and the Jubiläumsplatz.

The chief attraction of Heidelberg is the castle, which overhangs the east part of the town. 210
It stands on the Jettenbühl, a spur of the Königsstuhl (1800 ft.), at a height of 330 ft. above the Neckar. Though now a ruin, yet its extent, its magnificence, its beautiful situation and its interesting history render it by far the most noteworthy, as it certainly is the grandest and largest, of the old castles of Germany. The building was begun early in the 13th century. The elector palatine and German king Rupert III. (d. 1410) greatly improved it, and built the wing, Ruprechtsbau or Rupert's building, that bears his name. Succeeding electors further extended and embellished it (see Architecture, Plate VII., figs. 78-80); notably Otto Henry "the Magnanimous" (d. 1559), who built the beautiful early Renaissance wing known as the Otto-Heinrichsbau (1556-1559); Frederick IV., for whom the fine late Renaissance wing called the Friedrichsbau was built (1601-1607); and Frederick V., the unfortunate "winter king" of Bohemia, who on the west side added the Elisabethenbau or Englischebau (1618), named after his wife, the daughter of James I. of Great Britain and ancestress of the present English reigning family. In 1648, at the peace of Westphalia, Heidelberg was given back to Frederick V.'s son, Charles Louis, who restored the castle to its former splendour. In 1688, during Louis XIV.'s invasion of the Palatinate, the castle was taken, after a long siege, by the French, who blew part of it up when they found they could not hope to hold it (March 2, 1689). In 1693 it was again captured by them and still further wrecked. Finally, in 1764, it was struck by lightning and reduced to its present ruinous condition.



from Meyer's Konversations Lexikon. Emery Walker sc.

Apart from the outworks, the castle forms an irregular square with round towers at the angles, the principal buildings being grouped round a central courtyard, the entrance to which is from the south through a series of gateways. In this courtyard, besides the buildings already mentioned, are the oldest parts of the castle, the so-called Alte Bau (old building) and the Bandhaus. The Friedrichsbau, which is decorated with statues of the rulers of the Palatinate, was elaborately restored and rendered habitable between 1897 and 1903. Other noteworthy objects in the castle are the fountain in the courtyard, decorated with four granite columns from Charlemagne’s palace at Ingelheim; the Elisabethentor, a beautiful gateway named after the English princess; the beautiful octagonal bell-tower at the N.E. angle; the ruins of the Krautturm, now known as the Gesprengte Turm, or blown-up tower, and the castle chapel and the museum of antiquities in the Friedrichsbau. In a cellar entered from the courtyard is the famous Great Tun of Heidelberg. This vast vat was built in 1751, but has only been used on one or two occasions. Its capacity is 49,000 gallons, and it is 20 ft. high and 31 ft. long. Behind the Friedrichsbau is the Altan (1610), or castle balcony, from which is obtained a view of great beauty, extending from the town beneath to the heights across the Neckar and over the broad luxuriant plain of the Rhine to Mannheim and the dim contours of the Hardt Mountains behind. On the terrace of the beautiful grounds is a statue of Victor von Scheffel, the poet of Heidelberg.

The university of Heidelberg was founded by the elector Rupert I., in 1385, the bull of foundation being issued by Pope Urban VI. in that year. It was constructed after the type of Paris, had four faculties, and possessed numerous privileges. Marselius von Inghen was its first rector. The electors Frederick I., the Victorious, Philip the Upright and Louis V. respectively cherished it. Otto Henry gave it a new organization, further endowed it and founded the library. At the Reformation it became a stronghold of Protestant learning, the Heidelberg catechism being drawn up by its theologians. Then the tide turned. Damaged by the Thirty Years’ War, it led a struggling existence for a century and a half. A large portion of its remaining endowments was cut off by the peace of Lunéville (1801). In 1803, however, Charles Frederick, grand-duke of Baden, raised it anew and reconstituted it under the name of “Ruperto-Carola.” The number of professors and teachers is at present about 150 and of students 1700. The library was first kept in the choir of the Heilige Geist Kirche, and then consisted of 3500 MSS. In 1623 it was sent to Rome by Maximilian I., duke of Bavaria, and stored as the Bibliotheca Palatina in the Vatican. It was afterwards taken to Paris, and in 1815 was restored to Heidelberg. It has more than 500,000 volumes, besides 4000 MSS. Among the other university institutions are the academic hospital, the maternity hospital, the physiological institution, the chemical laboratory, the zoological museum, the botanical garden and the observatory on the Königsstuhl.

The other educational foundations are a gymnasium, a modern and a technical school. There is a small theatre, an art and several other scientific societies. The manufactures of Heidelberg include cigars, leather, cement, surgical instruments and beer, but the inhabitants chiefly support themselves by supplying the wants of a large and increasing body of foreign permanent residents, of the considerable number of tourists who during the summer pass through the town, and of the university students. A funicular railway runs from the Korn-Markt up to the level of the castle and thence to the Molkenkur (700 ft. above the town). The town is well lighted and is supplied with excellent water from the Wolfsbrunnen. Pop. (1885), 29,304; (1905), 49,527.

At an early period Heidelberg was a fief of the bishop of Worms, who entrusted it about 1225 to the count palatine of the Rhine, Louis I. It soon became a town and the chief residence of the counts palatine. Heidelberg was one of the great centres of the reformed teaching and was the headquarters of the Calvinists. On this account it suffered much during the Thirty Years’ War, being captured and plundered by Count Tilly in 1622, by the Swedes in 1633 and again by the imperialists in 1635. By the peace of Westphalia it was restored to the elector Charles Louis. In 1688 and again in 1693 Heidelberg was sacked by the French. On the latter occasion the work of destruction was carried out so thoroughly that only one house escaped; this being a quaintly decorated erection in the Marktplatz, which is now the Hôtel zum Ritter. In 1720 the elector Charles II. removed his court to Mannheim, and in 1803 the town became part of the grand-duchy of Baden. On the 5th of March 1848 the Heidelberg assembly was held here, and at this meeting the steps were taken which led to the revolution in Germany in that year.

See Oncken, *Stadt, Schloss und Hochschule Heidelberg; Bilder aus ihrer Vergangenheit* (Heidelberg, 1885); Öchelhäuser, *Das Heidelberger Schloss, bau- und kunstgeschichtlicher Führer* (Heidelberg, 1902); Pfaff, *Heidelberg und Umgebung* (Heidelberg, 1902); Lorentzen,

Heidelberg und Umgebung (Stuttgart, 1902); Durm, *Das Heidelberger Schloss, eine Studie* (Berlin, 1884); Koch and Seitz, *Das Heidelberger Schloss* (Darmstadt, 1887-1891); J. F. Hautz, *Geschickte der Universität Heidelberg* (1863-1864); A. Thorbecke, *Geschichte der Universität Heidelberg* (Stuttgart, 1886); the *Urkundenbuch der Universität Heidelberg*, edited by Winkelmann (Heidelberg, 1886); Bähr, *Die Entführung der Heidelberger Bibliothek nach Rom* (Leipzig, 1845); and G. Weber, *Heidelberger Erinnerungen* (Stuttgart, 1886).

HEIDELBERG, a town and district of the Transvaal. The district is bounded S. by the Vaal river and includes the south-eastern part of the Witwatersrand gold-fields. The town of Heidelberg is 42 m. S.E. of Johannesburg and 441 m. N.W. of Durban by rail. Pop. (1904), 3220, of whom 1837 were white. It was founded in 1865, is built on the slopes of the Rand at an elevation of 5029 ft., and is reputed the best sanatorium in the colony. It is the centre of the eastern Rand goldmines.

HEIDELBERG CATECHISM, THE, the most attractive of all the catechisms of the Reformation, was drawn up at the bidding of Frederick III., elector of the Palatinate, and published on Tuesday the 19th of January 1563. The new religion in the Palatinate had been largely under the guidance of Philip Melanchthon, who had revived the old university of Heidelberg and staffed it with sympathetic teachers. One of these, Tillemann, Heshusius, who became general superintendent in 1558, held extreme Lutheran views on the Real Presence, and in his desire to force the community into his own position excommunicated his colleague Klebitz, who held Zwinglian views. When the breach was widening Frederick, “der fromme Kurfürst,” came to the succession, dismissed the two chief combatants and referred the trouble to Melanchthon, whose guarded verdict was distinctly Swiss rather than Lutheran. In a decree of August 1560 the elector declared for Calvin and Zwingli, and soon after he resolved to issue a new and unambiguous catechism of the evangelical faith. He entrusted the task to two young men who have won deserved remembrance by their learning and their character alike. Zacharias Ursinus was born at Breslau in July 1534 and attained high honour in the university of Wittenberg. In 1558 he was made rector of the gymnasium in his native town, but the incessant strife with the extreme Lutherans drove him to Zürich, whence Frederick, on the advice of Peter Martyr, summoned him to be professor of theology at Heidelberg and superintendent of the *Sapientiae Collegium*. He was a man of modest and gentle spirit, not endowed with great preaching gifts, but unwearied in study and consummately able to impart his learning to others. Deposed from his chair by the elector Louis in 1576, he lived with John Casimir at Neustadt and found a congenial sphere in the new seminary there, dying in his 49th year, in March 1583.

Caspar Olevianus was born at Treves in 1536. He gave up law for theology, studied under Calvin in Geneva, Peter Martyr in Zürich, and Beza in Lausanne. Urged by William Farel he preached the new faith in his native city, and when banished therefrom found a home with Frederick of Heidelberg, where he gained high renown as preacher and administrator. His ardour and enthusiasm made him the happy complement of Ursinus. When the reaction came under Louis he was befriended by Ludwig von Sain, prince of Wittgenstein, and John, count of Nassau, in whose city of Herborn he did notable work at the high school until his death on the 15th of March 1587. The elector could have chosen no better men, young as they were, for the task in hand. As a first step each drew up a catechism of his own composition, that of Ursinus being naturally of a more grave and academic turn than the freer production of Olevianus, while each made full use of the earlier catechisms already in use. But when the union was effected it was found that the spirits of the two authors were most happily and harmoniously wedded, the exactness and erudition of the one being blended with the fervency and grace of the other. Thus the Heidelberg Catechism, which was completed within a year of its inception, has an individuality that marks it out from all its predecessors and successors. The Heidelberg synod unanimously approved of it, it was published in January 1563, and in the same year officially turned into Latin by Jos. Lagus and Lambert Pithopoeus.

The ultra-Lutherans attacked the catechism with great bitterness, the assault being led by Heshusius and Flacius Illyricus. Maximilian II. remonstrated against it as an infringement of the peace of Augsburg. A conference was held at Maulbronn in April 1564, and a personal attack was made on the elector at the diet of Augsburg in 1566, but the defence was well sustained, and the Heidelberg book rapidly passed beyond the bounds of the Palatinate (where indeed it suffered eclipse from 1576 to 1583, during the electorate of Louis), and gained an abundant success not only in Germany (Hesse, Anhalt, Brandenburg and Bremen) but also in the Netherlands (1588), and in the Reformed churches of Hungary, Transylvania and Poland. It was officially recognized by the synod of Dort in 1619, passed into France, Britain and America, and probably shares with the *De imitatione Christi* and *The Pilgrim's Progress* the honour of coming next to the Bible in the number of tongues into which it has been translated.

This wide acceptance and high esteem are due largely to an avoidance of polemical and controversial subjects, and even more to an absence of the controversial spirit. There is no mistake about its Protestantism, even when we omit the unhappy addition made to answer 80 by Frederick himself (in indignant reply to the ban pronounced by the Council of Trent), in which the Mass is described as "nothing else than a denial of the one sacrifice and passion of Jesus Christ, and an accursed idolatry"—an addition which is the one blot on the ἐπιείκεια of the catechism. The work is the product of the best qualities of head and heart, and its prose is frequently marked by all the beauty of a lyric. It follows the plan of the epistle to the Romans (excepting chapters ix.-xi.) and falls into three parts: Sin, Redemption and the New Life. This arrangement alone would mark it out from the normal reformation catechism, which runs along the stereotyped lines of Decalogue, Creed, Lord's Prayer, Church and Sacraments. These themes are included, but are shown as organically related. The Commandments, *e.g.* "belong to the first part so far as they are a mirror of our sin and misery, but also to the third part, as being the rule of our new obedience and Christian life." The Creed—a panorama of the sublime facts of redemption—and the sacraments find their place in the second part; the Lord's Prayer (with the Decalogue) in the third.

See *The Heidelberg Catechism*, the *German Text, with a Revised Translation and Introduction*, edited by A. Smellie (London, 1900).

HEIDELOFF, KARL ALEXANDER VON (1788-1865), German architect, the son of Victor Peter Heideloff, a painter, was born at Stuttgart. He studied at the art academy of his native town, and after following the profession of an architect for some time at Coburg was in 1818 appointed city architect at Nuremberg. In 1822 he became professor at the polytechnic school, holding his post until 1854, and some years later he was chosen conservator of the monuments of art. Heideloff devoted his chief attention to the Gothic style of architecture, and the buildings restored and erected by him at Nuremberg and in its neighbourhood attest both his original skill and his purity of taste. He also achieved some success as a painter in watercolour. He died at Hassfurt on the 28th of September 1865. Among his architectural works should be mentioned the castle of Reinhardsbrunn, the Hall of the Knights in the fortress at Coburg, the castle of Landsberg, the mortuary chapel in Meiningen, the little castle of Rosenburg near Bonn, the chapel of the castle of Rheinstein near Bingen, and the Catholic church in Leipzig. His powers in restoration are shown in the castle of Lichtenstein, the cathedral of Bamberg, and the Knights' Chapel (*Ritter Kapelle*) at Hassfurt.

Among his writings on architecture are *Die Lehre von den Säulenordnungen* (1827); *Der Kleine Vignola* (1832); *Nürnbergs Baudenkmäler der Vorzeit* (1838-1843, complete edition 1854); and *Die Ornamentik des Mittelalters* (1838-1842).

HEIDENHEIM, a town of Germany, in the kingdom of Württemberg, 31 m. by rail north by east of Ulm. Pop. (1905), 12,173. It has an Evangelical and a Roman Catholic church, and several schools. Its industrial establishments include cotton, woollen, tobacco, machinery and chemical factories, bleach-works, dye-works and breweries, and corn and cattle markets. The town, which received municipal privileges in 1356, is overlooked by the ruins of the castle of Hellenstein, standing on a hill 1985 ft. high. Heidenheim is also the name of a small place in Bavaria famous on account of the Benedictine abbey which formerly stood therein. Founded in 748 by Wilibald, bishop of Eichstätt, this was plundered by the peasantry in 1525 and was closed in 1537.

HEIFER, a young cow that has not calved. The O. Eng. *heahfore* or *heafru*, from which the word is derived, is of obscure origin. It is found in Bede’s *History* (A.D. 900) as *heahfore*, and has passed through many forms. It is possibly derived from *heah*, high, and *faren* (fare), to go, meaning “high-stepper.” It has also been suggested that the derivation is from *hea*, a stall, and *fore*, a cow.

HEIGEL, KARL AUGUST VON (1835-1905), German novelist, was born, the son of a *régisseur* or stage-manager of the court theatre, on the 25th of March 1835 at Munich. In this city he received his early schooling and studied (1854-1858) philosophy at the university. He was then appointed librarian to Prince Heinrich zu Carolath-Beuthen in Lower Silesia, and accompanied the nephew of the prince on travels. In 1863 he settled in Berlin, where from 1865 to 1875 he was engaged in journalism. He next resided at Munich, employed in literary work for the king, Ludwig II., who in 1881 conferred upon him a title of nobility. On the death of the king in 1886 he removed to Riva on the Lago di Garda, where he died on the 6th of September 1905. Karl von Heigel attained some popularity with his novels: *Wohin?* (1873), *Die Dame ohne Herz* (1873), *Das Geheimnis des Königs* (1891), *Der Roman einer Stadt* (1898), *Der Maharadschah* (1900), *Die nervöse Frau* (1900), *Die neuen Heiligen* (1901), and *Brömels Glück und Ende* (1902). He also wrote some plays, notably *Josephine Bonaparte* (1892) and *Die Zarin* (1883); and several collections of short stories, *Neue Erzählungen* (1876), *Neueste Novellen* (1878), and *Heitere Erzählungen* (1893).

HEIJERMANS, HERMANN (1864-) , Dutch writer, of Jewish origin, was born on the 3rd of December 1864 at Rotterdam. In the Amsterdam *Handelsblad* he published a series of sketches of Jewish family life under the pseudonym of “Samuel Falkland,” which were collected in volume form. His novels and tales include *Trinette* (1892), *Fles* (1893), *Kamertjeszonde* (2 vols., 1896), *Intérieurs* (1897), *Diamantstadt* (2 vols., 1903). He created great interest by his play *Op Hoop van Zegen* (1900), represented at the Théâtre Antoine in Paris, and in English by the Stage Society as *The Good Hope*. His other plays are: *Dora Kremer* (1893), *Ghetto* (1898), *Het zevende Gebot* (1899), *Het Pantser* (1901), *Ora et labora* (1901), and numerous one-act pieces. *A Case of Arson*, an English version of the one-act play *Brand in de Jonge Jan*, was notable for the impersonation (1904 and 1905) by Henri de Vries of all the seven witnesses who appear as characters.

HEILBRONN, a town of Germany, in the kingdom of Württemberg, situated in a pleasant and fruitful valley on the Neckar, 33 m. by rail N. of Stuttgart, and at the junction of lines to Jagdsfeld, Crailsheim and Eppingen. Pop. (1905), 40,026. In the older part of the town the streets are narrow, and contain a number of high turreted houses with quaintly adorned gables. The old fortifications have now been demolished, and their site is occupied by promenades, outside of which are the more modern parts of the town with wide streets and many handsome buildings. The principal public buildings are the church of St Kilian (restored 1886-1895) in the Gothic and Renaissance styles, begun about 1019 and completed in 1529, with an elegant tower 210 ft. high, a beautiful choir, and a finely carved altar; the town hall (Rathaus), founded in 1540, and possessing a curious clock made in 1580, and a collection of interesting letters and other documents; the house of the Teutonic knights (Deutsches Haus), now used as a court of law; the Roman Catholic church of St Joseph, formerly the church of the Teutonic Order; the tower (Diebsturm or Götzens Turm) on the Neckar, in which Götz von Berlichingen was confined in 1519; a fine synagogue; an historical museum and several monuments, among them those to the emperors William I. and Frederick I., to Bismarck, to Schiller and to Robert von Mayer (1814-1878), a native of the town, famous for his discoveries concerning heat. The educational establishments include a gymnasium, a commercial school and an agricultural academy. The town in a commercial point of view is the most important in Württemberg, and possesses an immense variety of manufactures, of which the principal are gold, silver, steel and iron wares, machines, sugar of lead, white lead, vinegar, beer, sugar, tobacco, soap, oil, cement, chemicals, artificial manure, glue, soda, tapestry, paper and cloth. Grapes, fruit, vegetables and flowering shrubs are largely grown in the neighbourhood, and there are large quarries for sandstone and gypsum and extensive salt-works. By means of the Neckar a considerable trade is carried on in wood, bark, leather, agricultural produce, fruit and cattle.

Heilbronn occupies the site of an old Roman settlement; it is first mentioned in 741, and the Carolingian princes had a palace here. It owes its name—originally Heiligbronn, or holy spring—to a spring of water which until 1857 was to be seen issuing from under the high altar of the church of St Kilian. Heilbronn obtained privileges from Henry IV. and from Rudolph I. and became a free imperial city in 1360. It was frequently besieged during the middle ages, and it suffered greatly during the Peasants’ War, the Thirty Years’ War, and the various wars with France. In April 1633 a convention was entered into here between Oxenstierna, the Swabian and Frankish estates and the French, English and Dutch ambassadors, as a result of which the Heilbronn treaty, for the prosecution of the Thirty Years’ War, was concluded. In 1802 Heilbronn was annexed by Württemberg.

See Jäger, *Geschichte von Heilbronn* (Heilbronn, 1828); Kuttler, *Heilbronn, seine Umgebungen und seine Geschichte* (Heilbronn, 1859); Dürr, *Heilbronner Chronik* (Halle, 1896); Schliz, *Die Entstehung der Stadtgemeinde Heilbronn* (Leipzig, 1903); and A. Küsel, *Der Heilbrunner Konvent* (Halle, 1878).

HEILIGENSTADT, a town of Germany, in Prussian Saxony, on the Leine, 32 m. E.N.E. of Cassel, on the railway to Halle. Pop. (1905), 7955. It possesses an old castle, formerly belonging to the electors of Mainz, one Evangelical and two Roman Catholic churches, several educational establishments, and an infirmary. The principal manufactures are cotton goods, cigars, paper, cement and needles. Heiligenstadt is said to have been built by the Frankish king Dagobert and was formerly the capital of the principality of Eichsfeld. In 1022 it was acquired by the archbishop of Mainz, and in 1103 it came into the possession of Henry the Proud, duke of Saxony, but when his son Henry the Lion was placed under the ban of the Empire, it again came to Mainz. It was destroyed by fire in 1333, and was captured in 1525 by Duke Henry of Brunswick. In 1803 it came into possession of Prussia. The Jesuits had a celebrated college here from 1581 to 1773.

HEILSBERG, a town of Germany, in the province of East Prussia, at the junction of the Simser and Alle, 38 m. S. of Königsberg. Pop. (1905), 6042. It has an Evangelical and a Roman Catholic church, and an old castle formerly the seat of the prince-bishops of Ermeland, but now used as an infirmary. The principal industries are tanning, dyeing and brewing, and there is considerable trade in grain. The castle founded at Heilsberg by the Teutonic order in 1240 became in 1306 the seat of the bishops of Ermeland, an honour which it retained for 500 years. On the 10th of June 1807 a battle took place at Heilsberg between the French under Soult and Murat, and the Russians and Prussians under Bennigsen.

HEILSBRONN (or Kloster-Heilsbronn), a village of Germany, in the Bavarian province of Middle Franconia, with a station on the railway between Nuremberg and Ansbach, has 1200 inhabitants. In the middle ages it was the seat of one of the great monasteries of Germany. This foundation, which belonged to the Cistercian order, owed its origin to Bishop Otto of 213
Bamberg in 1132, and continued to exist till 1555. Its sepulchral monuments, many of which are figured by Hocker, *Heilsbronnischer Antiquitätenschatz* (Ansbach, 1731-1740), are of exceptionally high artistic interest. It was the hereditary burial-place of the Hohenzollern family and ten burgraves of Nuremberg, five margraves and three electors of Brandenburg, and many other persons of note are buried within its walls. The buildings of the monastery have mostly disappeared, with the exception of the fine church, a Romanesque basilica, restored between 1851 and 1866, and possessing paintings by Albert Dürer. The “Monk of Heilsbronn” is the ordinary appellation of a didactic poet of the 14th century, whose *Sieben Graden*, *Tochter Syon* and *Leben des heiligen Alexius* were published by J. F. L. T. Merzdorf at Berlin in 1870.

See Rehm, *Ein Gang durch und um die Münster-Kirche zu Kloster-Heilsbronn* (Ansbach, 1875); Stillfried, *Kloster-Heilsbronn, ein Beitrag zu den Hohenzollernschen Forschungen* (Berlin, 1877); Muck, *Geschichte von Kloster-Heilsbronn* (Nördlingen, 1879-1880); J. Meyer, *Die Hohenzollerndenkmale in Heilsbronn* (Ansbach, 1891); and A. Wagner, *Über den Mönch von Heilsbronn* (Strassburg, 1876).

HEIM, ALBERT VON ST GALLEN (1849-) , Swiss geologist, was born at Zürich on the 12th of April 1849. He was educated at Zürich and Berlin universities. Very early in life he became interested in the physical features of the Alps, and at the age of sixteen he made a model of the Tödi group. This came under the notice of Arnold Escher von der Linth, to whom Heim was indebted for much encouragement and geological instruction in the field. In 1873 he became professor of geology in the polytechnic school at Zürich, and in 1875 professor of geology in the university. In 1882 he was appointed director of the Geological Survey of Switzerland, and in 1884 the hon. degree of Ph.D. was conferred upon him at Berne. He is especially distinguished for his researches on the structure of the Alps and for the light thereby thrown on the structure of mountain masses in general. He traced the plications from minor to major stages, and illustrated the remarkable foldings and overthrust faultings in numerous sections and with the aid of pictorial drawings. His magnificent work, *Mechanismus der Gebirgsbildung* (1878), is now regarded as a classic, and it served to inspire Professor C. Lapworth in his brilliant researches on the Scottish Highlands (see *Geol. Mag.* 1883). Heim also devoted considerable attention to the glacial phenomena of the Alpine regions. The Wollaston medal was awarded to him in 1904 by the Geological Society of London.

HEIM, FRANÇOIS JOSEPH (1787-1865), French painter, was born at Belfort on the 16th of December 1787. He early distinguished himself at the École Centrale of Strassburg, and in 1803 entered the studio of Vincent at Paris. In 1807 he obtained the first prize, and in 1812 his picture of “The Return of Jacob” (Musée de Bordeaux) won for him a gold medal of the first class, which he again obtained in 1817, when he exhibited, together with other works, a St John—bought by Vivant Denon. In 1819 the "Resurrection of Lazarus" (Cathédral Autun), the "Martyrdom of St Cyr" (St Gervais), and two scenes from the life of Vespasian (ordered by the king) attracted attention. In 1823 the "Re-erection of the Royal Tombs at St Denis," the "Martyrdom of St Laurence" (Notre Dame) and several full-length portraits increased the painter's popularity; and in 1824, when he exhibited his great canvas, the "Massacre of the Jews" (Louvre), Heim was rewarded with the legion of honour. In 1827 appeared the "King giving away Prizes at the Salon of 1824" (Louvre—engraved by Jazet)—the picture by which Heim is best known—and "Saint Hyacinthe." Heim was now commissioned to decorate the Gallery Charles X. (Louvre). Though ridiculed by the romantists, Heim succeeded Regnault at the Institute in 1834, shortly after which he commenced a series of drawings of the celebrities of his day, which are of much interest. His decorations of the Conference room of the Chamber of Deputies were completed in 1844; and in 1847 his works at the Salon—"Champ de Mai" and "Reading a Play at the Théâtre Français"—were the signal for violent criticisms. Yet something like a turn of opinion in his favour took place at the exhibition of 1851; his powers as a draughtsman and the occasional merits of his composition were recognized, and toleration extended even to his colour. Heim was awarded the great gold medal, and in 1855—having sent to the Salon no less than sixteen portraits, amongst which may be cited those of "Cuvier," "Geoffroy de St Hilaire," and "Madame Hersent"—he was made officer of the legion of honour. In 1859 he again exhibited a curious collection of portraits, sixty-four members of the Institute arranged in groups of four. He died on the 29th of September 1865. Besides the paintings already mentioned, there is to be seen in Notre Dame de Lorette (Paris) a work executed on the spot; and the museum of Strassburg contains an excellent example of his easel pictures, the subject of which is a "Shepherd Drinking from a Spring."

HEIMDAL, or *Heimdall*, in Scandinavian mythology, the keeper of the gates of Heaven and the guardian of the rainbow bridge Bifrost. He is the son of Odin by nine virgins, all sisters. He is called "the god with the golden teeth." He lives in the stronghold of Himinsbiorg at the end of Bifrost. His chief attribute is a vigilance which nothing can escape. He sleeps less than a bird; sees at night and even in his sleep; can hear the grass, and even the wool on a lamb's back grow. He is armed with Gjallar, the magic horn, with which he will summon the gods on the day of judgment.

HEINE, HEINRICH, (1797-1856), German poet and journalist, was born at Düsseldorf, of Jewish parents, on the 13th of December 1797. His father, after various vicissitudes in business, had finally settled in Düsseldorf, and his mother, who possessed much energy of character, was the daughter of a physician of the same place. Heinrich (or, more exactly, Harry) was the eldest of four children, and received his education, first in private schools, then in the Lyceum of his native town; although not an especially apt or diligent pupil, he acquired a knowledge of French and English, as well as some tincture of the classics and Hebrew. His early years coincided with the most brilliant period of Napoleon's career, and the boundless veneration which he is never tired of expressing for the emperor throughout his writings shows that his true schoolmasters were rather the drummers and troopers of a victorious army than the masters of the Lyceum. By freeing the Jews from many of the political disabilities under which they had hitherto suffered, Napoleon became, it may be noted, the object of particular enthusiasm in the circles amidst which Heine grew up. When he left school in 1815, an attempt was made to engage him in business in Frankfort, but without success. In the following year his uncle, Solomon Heine, a wealthy banker in Hamburg, took him into his office. A passion for his cousin Amalie Heine seems to have made the young man more contented with his lot in Hamburg, and his success was such that his uncle decided to set him up in business for himself. This, however, proved too bold a step; in a very few months the firm of "Harry Heine & Co." was insolvent. His uncle now generously provided him with money to enable him to study at a university, with the view to entering the legal profession, and in the spring of 1819 Heine became a student of the university of Bonn. During his stay there he devoted himself rather to the study of literature and history than to that of law; amongst his teachers A. W. von Schlegel, who took a kindly interest in Heine’s poetic essays, exerted the most lasting influence on him. In the autumn of 1820 Heine left Bonn for Göttingen, where he proposed to devote himself more assiduously to professional studies, but in February of the following year he challenged to a pistol duel a fellow-student who had insulted him, and was, in consequence, rusticated for six months. The pedantic atmosphere of the university of Göttingen was, however, little to his taste; the news of his cousin’s marriage unsettled him still more; and he was glad of the opportunity to seek distraction in Berlin.

In the Prussian capital a new world opened up to him; a very different life from that of Göttingen was stirring in the new university there, and Heine, like all his contemporaries, sat at the feet of Hegel and imbibed from him, doubtless, those views which in later years made the poet the apostle of an outlook upon life more modern than that of his romantic predecessors. Heine was also fortunate in having access to the chief literary circles of the 214
capital; he was on terms of intimacy with Varnhagen von Ense and his wife, the celebrated Rahel, at whose house he frequently met such men as the Humboldts, Hegel himself and Schleiermacher; he made the acquaintance of leading men of letters like Fouqué and Chamisso, and was on a still more familiar footing with the most distinguished of his co-religionists in Berlin. Under such favourable circumstances his own gifts were soon displayed. He contributed poems to the *Berliner Gesellschafter*, many of which were subsequently incorporated in the *Buch der Lieder*, and in December 1821 a little volume came from the press entitled *Gedichte*, his first avowed act of authorship. He was also employed at this time as correspondent of a Rhenish newspaper, as well as in completing his tragedies *Almansor* and *William Ratcliff*, which were published in 1823 with small success. In that same year Heine, not in the most hopeful spirits, returned to his family, who had meanwhile moved to Lüneburg. He had plans of settling in Paris, but as he was still dependent on his uncle, the latter’s consent had to be obtained. As was to be expected, Solomon Heine did not favour the new plan, but promised to continue his support on the condition that Harry completed his course of legal study. He sent the young student for a six weeks’ holiday at Cuxhaven, which opened the poet’s eyes to the wonders of the sea; and three weeks spent subsequently at his uncle’s county seat near Hamburg were sufficient to awaken a new passion in Heine’s breast—this time for Amalie’s sister, Therese. In January 1824 Heine returned to Göttingen, where, with the exception of a visit to Berlin and the excursion to the Hartz mountains in the autumn of 1824, which is immortalized in the first volume of the *Reisebilder*, he remained until his graduation in the summer of the following year. It was on the latter of these journeys that he had the interview with Goethe which was so amusingly described by him in later years. A few weeks before obtaining his degree, he took a step which he had long meditated; he formally embraced Christianity. This “act of apostasy,” which has been dwelt upon at unnecessary length both by Heine’s enemies and admirers, was actuated wholly by practical considerations, and did not arise from any wish on the poet’s part to deny his race. The summer months which followed his examination Heine spent by his beloved sea in the island of Norderney, his uncle having again generously supplied the means for this purpose. The question of his future now became pressing, and for a time he seriously considered the plan of settling as a solicitor in Hamburg, a plan which was associated in his mind with the hope of marrying his cousin Therese. Meanwhile he had made arrangements for the publication of the *Reisebilder*, the first volume of which, *Die Harzreise*, appeared in May 1826. The success of the book was instantaneous. Its lyric outbursts and flashes of wit; its rapid changes from grave to gay; its flexibility of thought and style, came as a revelation to a generation which had grown weary of the lumbering literary methods of the later Romanticists.

In the spring of the following year Heine paid a long planned visit to England, where he was deeply impressed by the free and vigorous public life, by the size and bustle of London; above all, he was filled with admiration for Canning, whose policy had realized many a dream of the young German idealists of that age. But the picture had also its reverse; the sordidly commercial spirit of English life, and brutal egotism of the ordinary Englishman, grated on Heine’s sensitive nature; he missed the finer literary and artistic tastes of the continent and was repelled by the austerity of English religious sentiment and observance. Unfortunately the latter aspects of English life left a deeper mark on his memory than the bright side. In October Baron Cotta, the well-known publisher, offered Heine—the second volume of whose *Reisebilder* and the *Buch der Lieder* had meanwhile appeared and won him fresh laurels—the joint-editorship of the *Neue allgemeine politische Annalen*. He gladly accepted the offer and betook himself to Munich. Heine did his best to adapt himself and his political opinions to the new surroundings, in the hope of coming in for a share of the good things which Ludwig I. of Bavaria was so generously distributing among artists and men of letters. But the stings of the *Reisebilder* were not so easily forgotten; the clerical party in particular did not leave him long in peace. In July 1828, the professorship on which he had set his hopes being still not forthcoming, he left Munich for Italy, where he remained until the following November, a holiday which provided material for the third and part of the fourth volumes of the *Reisebilder*. A blow more serious than the Bavarian king's refusal to establish him in Munich awaited him on his return to Germany—the death of his father. In the beginning of 1829 Heine took up his abode in Berlin, where he resumed old acquaintanceships; in summer he was again at the sea, and in autumn he returned to the city he now loathed above all others, Hamburg, where he virtually remained until May 1831. These years were not a happy period of the poet's life; his efforts to obtain a position, apart from that which he owed to his literary work, met with rebuffs on every side; his relations with his uncle were unsatisfactory and disturbed by constant friction, and for a time he was even seriously ill. His only consolation in these months of discontent was the completion and publication of the *Reisebilder*. When in 1830 the news of the July Revolution in the streets of Paris reached him, Heine hailed it as the beginning of a new era of freedom, and his thoughts reverted once more to his early plan of settling in Paris. All through the following winter the plan ripened, and in May 1831 he finally said farewell to his native land.

Heine's first impressions of the "New Jerusalem of Liberalism" were jubilantly favourable; Paris, he proclaimed, was the capital of the civilized world, to be a citizen of Paris the highest of honours. He was soon on friendly terms with many of the notabilities of the capital, and there was every prospect of a congenial and lucrative journalistic activity as correspondent for German newspapers. Two series of his articles were subsequently collected and published under the titles *Französische Zustände* (1832) and *Lutezia* (written 1840-1843, published in the *Vermischte Schriften*, 1854). In December 1835, however, the German Bund, incited by W. Menzel's attacks on "Young Germany," issued its notorious decree, forbidding the publication of any writings by the members of that coterie; the name of Heine, who had been stigmatized as the leader of the movement headed the list. This was the beginning of a series of literary feuds in which Heine was, from now on, involved; but a more serious and immediate effect of the decree was to curtail considerably his sources of income. His uncle, it is true, had allowed him 4000 francs a year when he settled in Paris, but at this moment he was not on the best of terms with his Hamburg relatives. Under these circumstances he was induced to take a step which his fellow-countrymen have found it hard to forgive; he applied to the French government for support from a secret fund formed for the benefit of "political refugees" who were willing to place themselves at the service of France. From 1836 or 1837 until the Revolution of 1848 Heine was in receipt of 4800 francs annually from this source.

In October 1834 Heine made the acquaintance of a young Frenchwoman, Eugénie Mirat, a saleswoman in a boot-shop in Paris, and before long had fallen passionately in love with her. Although ill-educated, vain and extravagant, she inspired the poet with a deep and lasting affection, and in 1841, on the eve of a duel in which he had become involved, he made her his wife. "Mathilde," as Heine called her, was not the comrade to help the poet in days of adversity, or to raise him to better things, but, in spite of passing storms, he seems to have been happy with her, and she nursed him faithfully in his last illness. Her death occurred in 1883. His relations with Mathilde undoubtedly helped to weaken his ties with Germany; and notwithstanding the affection he professed to cherish for his native land, he only revisited it twice, in the autumn of 1843 and the summer of 1847. In 1845 appeared the first unmistakable signs of the terrible spinal disease, which, for eight years, from the spring of 1848 till his death, condemned him to a "mattress grave." These years of suffering—suffering which left his intellect as clear and vivacious as ever—seem to have effected what 215
might be called a spiritual purification in Heine's nature, and to have brought out all the good sides of his character, whereas adversity in earlier years only intensified his cynicism. The lyrics of the *Romanzero* (1851) and the collection of *Neueste Gedichte* (1853-1854) surpass in imaginative depth and sincerity of purpose the poetry of the *Buch der Lieder*. Most wonderful of all are the poems inspired by Heine's strange mystic passion for the lady he called *Die Mouche*, a countrywoman of his own—her real name was Elise von Krienitz, but she had written in French under the *nom de plume* of Camille Selden—who helped to brighten the last months of the poet's life. He died on the 17th of February 1856, and lies buried in the cemetery of Montmartre.

Besides the purely journalistic work of Heine's Paris years, to which reference has already been made, he published a collection of more serious prose writings under the title *Der Salon* (1833-1839). In this collection will be found, besides papers on French art and the French stage, the essays "Zur Geschichte der Religion und Philosophie in Deutschland," which he had written for the *Revue des deux mondes*. Here, too, are the more characteristic productions of Heine's genius, *Aus den Memoiren des Herrn von Schnabelewopski*, *Der Rabbi von Bacherach* and *Florentinische Nächte*. *Die romantische Schule* (1836), with its unpardonable personal attack on the elder Schlegel, is a less creditable essay in literary criticism. In 1839 appeared *Shakespeares Mädchen und Frauen*, which, however, was merely the text to a series of illustrations; and in 1840, the witty and trenchant satire on a writer, who, in spite of many personal disagreements, had been Heine's fellow-fighter in the liberal cause, Ludwig Börne. Of Heine's poetical work in these years, his most important publications were, besides the *Romanzero*, the two admirable satires, *Deutschland, ein Wintermärchen* (1844), the result of his visit to Germany, and *Atta Troll, ein Sommernachtstraum* (1876), an attack on the political *Tendenzliteratur* of the 'forties.

In the case of no other of the greater German poets is it so hard to arrive at a final judgment as in that of Heinrich Heine. In his *Buch der Lieder* he unquestionably struck a new lyric note, not merely for Germany but for Europe. No singer before him had been so daring in the use of nature-symbolism as he, none had given such concrete and plastic expression to the spiritual forces of heart and soul; in this respect Heine was clearly the descendant of the Hebrew poets of the Old Testament. At times, it is true, his imagery is exaggerated to the degree of absurdity, but it exercised, none the less, a fascination over his generation. Heine combined with a spiritual delicacy, a fineness of perception, that firm hold on reality which is so essential to the satirist. His lyric appealed with particular force to foreign peoples, who had little understanding for the intangible, undefinable spirituality which the German people regard as an indispensable element in their national lyric poetry. Thus his fame has always stood higher in England and France than in Germany itself, where his lyric method, his self-consciousness, his cynicism in season and out of season, were little in harmony with the literary traditions. As far, indeed, as the development of the German lyric is concerned, Heine's influence has been of questionable value. But he introduced at least one new and refreshing element into German poetry with his lyrics of the North Sea; no other German poet has felt and expressed so well as Heine the charm of sea and coast.

As a prose writer, Heine's merits were very great. His work was, in the main, journalism, but it was journalism of a high order, and, after all, the best literature of the "Young German" school to which he belonged was of this character. Heine's light fancy, his agile intellect, his straightforward, clear style stood him here in excellent stead. The prose writings of his French period mark, together with Börne's *Briefe aus Paris*, the beginning of a new era in German journalism and a healthy revolt against the unwieldy prose of the Romantic period. Above all things, Heine was great as a wit and a satirist. His lyric may not be able to assert itself beside that of the very greatest German singers, but as a satirist he had powers of the highest order. He combined the holy zeal and passionate earnestness of the "soldier of humanity" with the withering scorn and ineradicable sense of justice common to the leaders of the Jewish race. It was Heine's real mission to be a reformer, to restore with instruments of war rather than of peace "the interrupted order of the world." The more's the pity that his magnificent Aristophanic genius should have had so little room for its exercise, and have been frittered away in the petty squabbles of an exiled journalist.

The first collected edition of Heine's works was edited by A. Strodtmann in 21 vols. (1861-1866), the best critical edition is the *Sämtliche Werke*, edited by E. Elster (7 vols., 1887-1890). Heine has been more translated into other tongues than any other German writer of his time. Mention may here be made of the French translation of his *Œuvres complètes* (14 vols., 1852-1868), and the English translation (by C. G. Leland and others) recently completed, *The Works of Heinrich Heine* (13 vols., 1892-1905). For biography and criticism see the following works: A. Strodtmann, *Heines Leben und Werke* (3rd ed., 1884); H. Hueffer, *Aus dem Leben H. Heines* (1878); and by the same author, *H. Heine: Gesammelte Aufsätze* (1906); G. Karpeles, *H. Heine und seine Zeitgenossen* (1888), and by the same author, *H. Heine: aus seinem Leben und aus seiner Zeit* (1900); W. Bölsche, *H. Heine: Versuch einer ästhetischkritischen Analyse seiner Werke und seiner Weltanschauung* (1888); G. Brandes, *Det unge Tyskland* (1890; Eng. trans., 1905). An English biography by W. Stigand, *Life, Works and Opinions of Heinrich Heine*, appeared in 1875, but it has little value; there is also a short life by W. Sharp (1888). The essays on Heine by George Eliot and Matthew Arnold are well known. The best French contributions to Heine criticism are J. Legras, *H. Heine, poète* (1897), and H. Lichtenberger, *H. Heine, penseur* (1905). See also L.P. Betz, *Heine in Frankreich* (1895).

(J. W. F.; J. G. R.)

HEINECCIUS, JOHANN GOTTLIEB (1681-1741), German jurist, was born on the 11th of September 1681 at Eisenberg, Altenburg. He studied theology at Leipzig, and law at Halle; and at the latter university he was appointed in 1713 professor of philosophy, and in 1718 professor of jurisprudence. He subsequently filled legal chairs at Franeker in Holland and at Frankfort, but finally returned to Halle in 1733 as professor of philosophy and jurisprudence. He died there on the 31st of August 1741. Heineccius belonged to the school of philosophical jurists. He endeavoured to treat law as a rational science, and not merely as an empirical art whose rules had no deeper source than expediency. Thus he continually refers to first principles, and he develops his legal doctrines as a system of philosophy.

His chief works were *Antiquitatum Romanarum jurisprudentiam illustrantium syntagma* (1718), *Historia juris civilis Romani ac Germanici* (1733), *Elementa juris Germanici* (1735), *Elementa juris naturae et gentium* (1737; Eng. trans. by Turnbull, 2 vols., London, 1763). Besides these works he wrote on purely philosophical subjects, and edited the works of several of the classical jurists. His *Opera omnia* (9 vols., Geneva, 1771, &c.) were edited by his son Johann Christian Gottlieb Heineccius (1718-1791).

Heineccius’s brother, Johann Michael Heineccius (1674-1722), was a well-known preacher and theologian, but is remembered more from the fact that he was the first to make a systematic study of seals, concerning which he left a book, *De veteribus Germanorum aliarumque nationum sigillis* (Leipzig, 1710; 2nd ed., 1719).

HEINECKEN, CHRISTIAN HEINRICH (1721-1725), a child remarkable for precocity of intellect, was born on the 6th of February 1721 at Lübeck, where his father was a painter. Able to speak at the age of ten months, by the time he was one year old he knew by heart the principal incidents in the Pentateuch. At two years of age he had mastered sacred history; at three he was intimately acquainted with history and geography, ancient and modern, sacred and profane, besides being able to speak French and Latin; and in his fourth year he devoted himself to the study of religion and church history. This wonderful precocity was no mere feat of memory, for the youthful savant could reason on and discuss the knowledge he had acquired. Crowds of people flocked to Lübeck to see the wonderful child; and in 1724 he was taken to Copenhagen at the desire of the king of Denmark. On his return to Lübeck he began to learn writing, but his sickly constitution gave way, and he died on the 216
22nd of June 1725.

The Life, Deeds, Travels and Death of the Child of Lübeck were published in the following year by his tutor Schöneich. See also *Teutsche Bibliothek*, xvii., and *Mémoires de Trévoux* (Jan. 1731).

HEINICKE, SAMUEL (1727-1790), the originator in Germany of systematic education for the deaf and dumb, was born on the 10th of April 1727, at Nautschütz, Germany. Entering the electoral bodyguard at Dresden, he subsequently supported himself by teaching. About 1754 his first deaf and dumb pupil was brought him. His success in teaching this pupil was so great that he determined to devote himself entirely to this work. The outbreak of the Seven Years’ War upset his plans for a time. Taken prisoner at Pirna, he was brought to Dresden, but soon made his escape. In 1768, when living in Hamburg, he successfully taught a deaf and dumb boy to talk, following the methods prescribed by Amman in his book *Surdus loquens*, but improving on them. Recalled to his own country by the elector of Saxony, he opened in Leipzig, in 1778, the first deaf and dumb institution in Germany. This school he directed till his death, which took place on the 30th of April 1790. He was the author of a variety of books on the instruction of the deaf and dumb.

HEINSE, JOHANN JAKOB WILHELM (1749-1803), German author, was born at Langewiesen near Ilmenau in Thuringia on the 16th of February 1749. After attending the gymnasium at Schleusingen he studied law at Jena and Erfurt. In Erfurt he became acquainted with Wieland and through him with “Father” Gleim who in 1772 procured him the post of tutor in a family at Quedlinburg. In 1774 he went to Düsseldorf, where he assisted the poet J. G. Jacobi to edit the periodical *Iris*. Here the famous picture gallery inspired him with a passion for art, to the study of which he devoted himself with so much zeal and insight that Jacobi furnished him with funds for a stay in Italy, where he remained for three years (1780-1783), He returned to Düsseldorf in 1784, and in 1786 was appointed reader to the elector Frederick Charles Joseph, archbishop of Mainz, who subsequently made him his librarian at Aschaffenburg, where he died on the 22nd of June 1803.

The work upon which Heinse’s fame mainly rests is *Ardinghello und die glückseligen Inseln* (1787), a novel which forms the framework for the exposition of his views on art and life, the plot being laid in the Italy of the 16th century. This and his other novels *Laidion, oder die eleusinischen Geheimnisse* (1774) and *Hildegard von Hohenthal* (1796) combine the frank voluptuousness of Wieland with the enthusiasm of the “Sturm und Drang.” Both as novelist and art critic, Heinse had considerable influence on the romantic school.

Heinse’s complete works (*Sämtliche Schriften*) were published by H. Laube in 10 vols. (Leipzig, 1838). A new edition by C. Schüddekopf is in course of publication (Leipzig, 1901 sqq.). See H. Pröhle, *Lessing, Wieland, Heinse* (Berlin, 1877), and J. Schober, *Johann Jacob Wilhelm Heinse, sein Leben und seine Werke* (Leipzig, 1882); also K. D. Jessen, *Heinses Stellung zur bildenden Kunst* (Berlin, 1903).

HEINSIUS (or Heins) **DANIEL** (1580-1655), one of the most famous scholars of the Dutch Renaissance, was born at Ghent on the 9th of June 1580. The troubles of the Spanish war drove his parents to settle first at Veere in Zeeland, then in England, next at Ryswick and lastly at Flushing. In 1594, being already remarkable for his attainments, he was sent to the university of Franeker to perfect himself in Greek under Henricus Schotanus. He stayed at Franeker half a year, and then settled at Leiden for the remaining sixty years of his life. There he studied under Joseph Scaliger, and there he found Marnix de St Aldegonde, Janus Douza, Paulus Merula and others, and was soon taken into the society of these celebrated men as their equal. His proficiency in the classic languages won the praise of all the best scholars of Europe, and offers were made to him, but in vain, to accept honourable positions outside Holland. He soon rose in dignity at the university of Leiden. In 1602 he was made professor of Latin, in 1605 professor of Greek, and at the death of Merula in 1607 he succeeded that illustrious scholar as librarian to the university. The remainder of his life is recorded in a list of his productions. He died at the Hague on the 25th of February 1655. The Dutch poetry of Heinsius is of the school of Roemer Visscher, but attains no very high excellence. It was, however, greatly admired by Martin Opitz, who was the pupil of Heinsius, and who, in translating the poetry of the latter, introduced the German public to the use of the rhyming alexandrine.

He published his original Latin poems in three volumes—*Iambi* (1602), *Elegiae* (1603) and *Poëmata* (1605); his *Emblemata amatoria*, poems in Dutch and Latin, were first printed in 1604. In the same year he edited Theocritus, Bion and Moschus, having edited Hesiod in 1603. In 1609 he printed his Latin *Orations*. In 1610 he edited Horace, and in 1611 Aristotle and Seneca. In 1613 appeared in Dutch his tragedy of *The Massacre of the Innocents*; and in 1614 his treatise *De politico sapientia*. In 1616 he collected his original Dutch poems into a volume. He edited Terence in 1618, Livy in 1620, published his oration *De contemptu mortis* in 1621, and brought out the *Epistles* of Joseph Scaliger in 1627.

HEINSIUS, NIKOLAES (1620-1681), Dutch scholar, son of Daniel Heinsius, was born at Leiden on the 20th of July 1620. His boyish Latin poem of *Breda expugnata* was printed in 1637, and attracted much attention. In 1642 he began his wanderings with a visit to England in search of MSS. of the classics; but he met with little courtesy from the English scholars. In 1644 he was sent to Spa to drink the waters; his health restored, he set out once more in search of codices, passing through Louvain, Brussels, Mechlin, Antwerp and so back to Leiden, everywhere collating MSS. and taking philological and textual notes. Almost immediately he set out again, and arriving in Paris was welcomed with open arms by the French savants. After investigating all the classical texts he could lay hands on, he proceeded southwards, and visited on the same quest Lyons, Marseilles, Pisa, Florence (where he paused to issue a new edition of Ovid) and Rome. Next year, 1647, found him in Naples, from which he fled during the reign of Masaniello; he pursued his labours in Leghorn, Bologna, Venice and Padua, at which latter city he published in 1648 his volume of original Latin verse entitled *Italica*. He proceeded to Milan, and worked for a considerable time in the Ambrosian library; he was preparing to explore Switzerland in the same patient manner, when the news of his father's illness recalled him hurriedly to Leiden. He was soon called away to Stockholm at the invitation of Queen Christina, at whose court he waged war with Salmasius, who accused him of having supplied Milton with facts from the life of that great but irritable scholar. Heinsius paid a flying visit to Leiden in 1650, but immediately returned to Stockholm. In 1651 he once more visited Italy; the remainder of his life was divided between Upsala and Holland. He collected his Latin poems into a volume in 1653. His latest labours were the editing of Velleius Paterculus in 1678, and of Valerius Flaccus in 1680. He died at the Hague on the 7th of October 1681. Nikolaes Heinsius was one of the purest and most elegant of Latinists, and if his scholarship was not quite so perfect as that of his father, he displayed higher gifts as an original writer.

His illegitimate son, Nikolaes Heinsius (b. 1655), was the author of *The Delightful Adventures and Wonderful Life of Mirandor* (1675), the single Dutch romance of the 17th century. He had to flee the country in 1677 for committing a murder in the streets of the Hague, and died in obscurity.

HEIR (Lat. *heres*, from a root meaning to grasp, seen in *herus* or *erus*, master of a house, Gr. χείρ, hand, Sans, *harana*, hand), in law, technically one who succeeds, by descent, to an estate of inheritance, in contradistinction to one who succeeds to personal property, *i.e.* next of kin. The word is now used generally to denote the person who is entitled by law to inherit property, titles, &c., of another. The rules regulating the descent of property to an heir will be found in the articles Inheritance, Succession, &c.

An *heir apparent* (Lat. *apparens*, manifest) is he whose right of inheritance is indefeasible, provided he outlives the ancestor, *e.g.* an eldest or only son.

Heir by custom, or customary heir, he who inherits by a particular and local custom, as in borough-English, whereby the youngest son inherits, or in gavelkind, whereby all the sons inherit as parceners, and made but one heir. 217

Heir general, or heir at law, he who after the death of his ancestor has, by law, the right to the inheritance.

Heir presumptive, one who is next in succession, but whose right is defeasible by the birth of a nearer heir, *e.g.* a brother or nephew, whose presumptive right may be destroyed by the birth of a child, or a daughter, whose right may be defeated by the birth of a son.

Special heir, one not heir at law (*i.e.* at common law), but by special custom.

Ultimate heir, he to whom lands come by escheat on failure of proper heirs. In Scots law the technical use of the word "heir" is not confined to the succession to real property, but includes succession to personal property as well.

HEIRLOOM, strictly so called in English law, a chattel ("loom" meaning originally a tool) which by immemorial usage is regarded as annexed by inheritance to a family estate. Any owner of such heirloom may dispose of it during his lifetime, but he cannot bequeath it by will away from the estate. If he dies intestate it goes to his heir-at-law, and if he devises the estate it goes to the devisee. At the present time such heirlooms are almost unknown, and the word has acquired a secondary and popular meaning and is applied to furniture, pictures, &c., vested in trustees to hold on trust for the person for the time being entitled to the possession of a settled house. Such things are more properly called settled chattels. An heirloom in the strict sense is made by family custom, not by settlement. A settled chattel may, under the Settled Land Act 1882, be sold under the direction of the court, and the money arising under such sale is capital money. The court will only sanction such a sale if it be shown that it is to the benefit of all parties concerned; and if the article proposed to be sold is of unique or historical character, it will have regard to the intention of the settlor and the wishes of the remainder men (Re *Hope*, *De Cetto* v. *Hope*, 1899, 2 ch. 679).

HEJAZ (Hijaz), a Turkish vilayet and a province of Western Arabia, extending along the Red Sea coast from the head of the Gulf of Akaba in 29° 30′ N. to the south of Taif in 20° N. It is bounded N. by Syria, E. by the Nafud desert and by Nejd and S. by Asir. Its length is about 750 m. and its greatest breadth from the Harra east of Khaibar to the coast is 200 m. The name Hejaz, which signifies "separating," is sometimes limited to the region extending from Medina in the north to Taif in the south, which separates the island province Nejd from the Tehama (Tihama) or coastal district, but most authorities, both Arab and European, define it in the wider sense. Though physically the most desolate and uninviting province in Arabia, it has a special interest and importance as containing the two sacred cities of Islam, Mecca and Medina (*q.v.*), respectively the birthplace and burial-place of Mahomet, which are visited yearly by large numbers of Moslem pilgrims from all parts of the world.

Hejaz is divided longitudinally by the Tehama range of mountains into two zones, a narrow littoral and a broader upland. This range attains its greatest height in Jebel Shar, the Mount Seir of scripture, overlooking the Midian coast, which probably reaches 7000 ft., and Jebel Radhwa a little N.E. of Yambu rising to 6000 ft. It is broken through by several valleys which carry off the drainage of the inland zone; the principal of these is the Wadi Hamd, the main source of which is on the Harra east of Khaibar. Its northern tributary the Wadi Jizil drains the Harrat el Awerid and a southern branch comes from the neighbourhood of Medina. Farther south the Wadi es Safra cuts through the mountains and affords the principal access to the valley of Medina from Yambu or Jidda. None of the Hejaz Wadis has a perennial stream, but they are liable to heavy floods after the winter rains, and thick groves of date-palms and occasional settlements are met with along their courses wherever permanent springs are found. The northern part of Hejaz contains but few inhabited sites. Muwela, Damgha and El Wijh are small ports used by coasting craft. The last named was formerly an important station on the Egyptian pilgrim route, and in ancient days was a Roman settlement, and the port of the Nabataean towns of el Hajr 150 m. to the east. Inland the sandstone desert of El Hisma reaches from the Syrian border at Ma'an to Jebel Awerid, where the volcanic tracts known as *harra* begin, and extend southwards along the western borders of the Nejd plateau as far as the latitude of Mecca. East of Jebel Awerid lies the oasis of Tema, identified with the Biblical Teman, which belongs to the Shammar tribe; its fertility depends on the famous well, known as Bir el Hudaj. Farther south and on the main pilgrim route is El 'Ala, the principal settlement of El Hajr, the Egra of Ptolemy, to whom it was known as an oasis town on the gold and frankincense road. Higher up the same valley are the rock-cut tombs of Medina Salih, similar to those at Petra and shown by the Nabataean coins and inscriptions discovered there by Doughty and Huber to date from the beginning of the Christian era. To the south-east again is the oasis of Khaibar, with some 2500 inhabitants, chiefly negroes, the remnants of an earlier slave population. The citadel, known as the Kasr el Yahudi, preserves the tradition of its former Jewish ownership. With these exceptions there are no settled villages between Ma'an and Medina, the stations on the pilgrim road being merely small fortified posts with reservoirs, at intervals of 30 or 40 m., which are kept up by the Turkish government for the protection of the yearly caravan.

The southern part of the province is more favoured by nature. Medina is a city of 25,000 to 30,000 inhabitants, situated in a broad plain between the coast range and the low hills across which lies the road to Nejd. Its altitude above the sea is about 2500 ft. It is well supplied with water and is surrounded by gardens and plantations; barley and wheat are grown, but the staple produce, as in all the cultivated districts of Hejaz, is dates, of which 100 different sorts are said to grow. Yambu’ has a certain importance as the port for Medina. The route follows for part of the way along the Wadi es Safra, which contains several small settlements with abundant date groves; from Badr Hunen, the last of these, the route usually taken from Medina to Mecca runs near the coast, passing villages with some cultivation at each stage. The eastern route though more direct is less used; it passes through a barren country described by Burton as a succession of low plains and basins surrounded by rolling hills and intersected by torrent beds; the predominant formation is basalt. Suwerikiya and Es Safina are the only villages of importance on this route.

Mecca and the holy places in its vicinity are described in a separate article; it is about 48 m. from the port of Jidda, the most important trade centre of the Hejaz province. The great majority of pilgrims for Mecca arrive by sea at Jidda. Their transport and the supply of their wants is therefore the chief business of the place; in 1904 the number was 66,500, and the imports amounted in value to £1,400,000.

From the hot lowland in which Mecca is situated the country rises steeply up to the Taif plateau, some 6000 ft. above sea-level, a district resembling in climate and physical character the highlands of Asir and Yemen. Jebel el Kura at the northern edge of the plateau is a fertile well-watered district, producing wheat and barley and fruit. Taif, a day’s journey farther south, lies in a sandy plain, surrounded by low mountains. The houses, though small, are well built of stone; the gardens for which it is celebrated lie at a distance of a mile or more to the S.W. at the foot of the mountains.

Hejaz, together with the other provinces of Arabia which on the overthrow of the Bagdad Caliphate in 1258 had fallen under Egyptian domination, became by the conquest of Egypt in 1517 a dependency of the Ottoman empire. Beyond assuming the title of Caliph, neither Salim I. nor his successors interfered much in the government, which remained in the hands of the sharifs of Mecca until the religious upheaval which culminated at the beginning of the 19th century in the pillage of the holy cities by the Wahhabi fanatics. Mehemet Ali, viceroy of Egypt, was entrusted by the sultan with the task of establishing order, and after several arduous campaigns the Wahhabis were routed and their capital Deraiya in Nejd taken by 218
Ibrahim Pasha in 1817. Hejaz remained in Egyptian occupation until 1845, when its administration was taken over directly by Constantinople, and it was constituted a vilayet under a vali or governor-general. The population is estimated at 300,000, about half of which are inhabitants of the towns and the remainder Bedouin, leading a nomad or pastoral life. The principal tribes are the Sherarat, Beni Atiya and Huwetat in the north; the Juhena between Yambu’ and Medina, and the various sections of the Harb throughout the centre and south; the Ateba also touch the Mecca border on the south-east. All these tribes receive surra or money payments of large amount from the Turkish government to ensure the safe conduct of the annual pilgrimage, otherwise they are practically independent of the Turkish administration, which is limited to the large towns and garrisons. The troops occupying these latter belong to the 16th (Hejaz) division of the Turkish army.

The Hejaz railway.

The difficulties of communication with his Arabian provinces, and of relieving or reinforcing the garrisons there, induced the sultan Abdul Hamid in 1900 to undertake the construction of a railway directly connecting the Hejaz cities with Damascus without the necessity of leaving Turkish territory at any point, as hitherto required by the Suez Canal. Actual construction was begun in May 1901 and on the 1st of September 1904 the section Damascus-Ma’an (285 m.) was officially opened. The line has a narrow gauge of 1.05 metre = 41 in., the same gauge as that of the Damascus-Beirut line; it has a ruling gradient of 1 in 50 and follows generally the pilgrim track, through a desert country presenting no serious engineering difficulties. The graver difficulties due to the scarcity of water, and the lack of fuel, supplies and labour were successfully overcome; in 1906 the line was completed to El Akhdar, 470 m. from Damascus and 350 from Medina, In time to be used by the pilgrim caravan of that year; and the section to Medina was opened in 1908. Its military value was shown in the previous year, when it conveyed 28 battalions from Damascus to Ma’an, from which station the troops marched to Akaba for embarkation *en route* to Hodeda. The length of the line from Damascus to Medina is approximately 820 m., and from Medina to Mecca 280 m.; the highest level attained is about 4000 ft. at Dar el Hamra in the section Ma‘an-Medina.

Authorities.—J. L. Burckhardt, *Travels in Arabia* (London, 1829); ‘Ali Bey, *Travels* (London, 1816); R. F. Burton, *Pilgrimage to Medinah and Mecca* (1893); *Land of Midian* (London, 1879); J. S. Hurgronje, *Mekka* (Hague, 1888); C. M. Doughty, *Arabia Deserta* (Cambridge, 1888); Auler Pasha, *Die Hedschasbahn* (Gotha, 1906).

(R. A. W.)

HEJIRA,[1] or Hegira (Arab. *hijra*, flight, departure from one's country, from *hajara*, to go away), the name of the Mahommedan era. It dates from 622, the year in which Mahomet "fled" from Mecca to Medina to escape the persecution of his kinsmen of the Koreish tribe. The years of this era are distinguished by the initials "A.H." (*anno hegirae*). The Mahommedan year is a lunar one, about 11 days shorter than the Christian; allowance must be made for this in translating *Hegira* dates into Christian dates; thus A.H. 1321 corresponds roughly to A.D. 1903. The actual date of the "flight" is fixed as 8 Rabia I., *i.e.* 20th of September 622, by the tradition that Mahomet arrived at Kufa on the Hebrew Day of Atonement. Although Mahomet himself appears to have dated events by his flight, it was not till seventeen years later that the actual era was systematized by Omar, the second caliph (see Caliphate), as beginning from the 1st day of Muharram (the first lunar month of the year) which in that year (639) corresponded to July 16. The term *hejira* is also applied in its more general sense to other "emigrations" of the faithful, *e.g.* to that to Abyssinia (see Mahomet), and to that of Mahomet's followers to Medina before the capture of Mecca. These latter are known as *Muhajirun*.

For the problems of Moslem chronology and comparative tables of dates see (beside the articles Calendar, Chronology and Mahomet), Wüstenfeld, *Vergleichungstabellen der muhammedanischen und christlichen Zeitrechnung* (2nd ed., Leipzig, 1903); Mas Latrie, *Trésor de chronologie* (Paris, 1889); Durbaneh, *Universal Calendar* (Cairo, 1896); Winckler, *Altorientalische Forschungen*, ii. 326-350; D. Nielson, *Die altarabische Mondreligion* (Strassburg, 1904); Hughes, *Dictionary of Islam*, s.v. "Hijrah."

1 The *i* in the second syllable is short.

HEL, or *Hela*, in Scandinavian mythology, the goddess of the dead. She was a child of Loki and the giantess Angurboda, and dwelt beneath the roots of the sacred ash, Yggdrasil. She was given dominion over the nine worlds of Helheim. In early myth all the dead went to her: in later legend only those who died of old age or sickness, and she then became synonymous with suffering and horror. Her dwelling was *Elvidnir* (dark clouds), her dish *Hungr* (hunger), her knife *Sullt* (starvation), her servants *Ganglate* (tardy feet), her bed *Kör* (sickness), and her bed-curtains *Blikiandabol* (splendid misery).

HELDENBUCH, DAS, the title under which a large body of German epic poetry of the 13th century has come down to us. The subjects of the individual poems are taken from national German sagas which originated in the epoch of the Migrations (*Völkerwanderung*), although doubtless here, as in all purely popular sagas, motives borrowed from the forces and phenomena of nature were, in course of time, woven into events originally historical. While the saga of the Nibelungs crystallized in the 13th century into the *Nibelungenlied* (*q.v.*), and the Low German Hilde-saga into the epic of *Gudrun* (*q.v.*) the poems of the *Heldenbuch*, in the more restricted use of that term, belong almost exclusively to two cycles, (1) the Ostrogothic saga of Ermanrich, Dietrich von Bern (*i.e.* Dietrich of Verona, Theodorich the Great) and Etzel (Attila), and (2) the cycle of Hugdietrich, Wolfdietrich and Ortnit, which like the *Nibelungen* saga, was probably of Franconian origin. The romances of the *Heldenbuch* are of varying poetic value; only occasionally do they rise to the height of the two chief epics, the *Nibelungenlied* and *Gudrun*. Dietrich von Bern, the central figure of the first and more important group, was the ideal type of German medieval hero, and, under more favourable literary conditions, he might have become the centre of an epic more nationally German than even the *Nibelungenlied* itself. Of the romances of this group, the chief are *Biterolf und Dietlieb*, evidently the work of an Austrian poet, who introduced many elements from the court epic of chivalry into a milieu and amongst characters familiar to us from the *Nibelungenlied*. *Der Rosengarten* tells of the conflicts which took place round Kriemhild’s “rose garden” in Worms—conflicts from which Dietrich always emerges victor, even when he is confronted by Siegfried himself. In *Laurin und der kleine Rosengarten*, the Heldensage is mingled with elements of popular fairy-lore; it deals with the adventures of Dietrich and his henchman Witege with the wily dwarf Laurin, who watches over another rose garden, that of the Tyrol. Similar in character are the adventures of Dietrich with the giants Ecke (*Eckenlied*) and Sigenot, with the dwarf Goldemar, and the deeds of chivalry he performs for queen Virginal (*Dietrichs erste Ausfahrt*)—all of these romances being written in the fresh and popular tone characteristic of the wandering singers or *Spielleute*. Other elements of the Dietrich saga are represented by the poems *Alpharts Tod*, *Dietrichs Flucht* and *Die Rabenschlacht* (“Battle of Ravenna”). Of these, the first is much the finest poem of the entire cycle and worthy of a place beside the best popular poetry of the Middle High German epoch. Alphart, a young hero in Dietrich’s army, goes out to fight single-handed with Witege and Heime, who had deserted to Ermanrich, and he falls, not in fair battle, but by the treachery of Witege whose life he had spared. The other two Dietrich epics belong to a later period, the end of the 13th century—the author being an Austrian, Heinrich der Vogler—and show only too plainly the decay that had by this time set in in Middle High German poetry.

The second cycle of sagas is represented by several long romances, all of them unmistakably “popular” in tone—conflicts with dragons, supernatural adventures, the wonderland of the East providing the chief features of interest. The epics of this group are
Ortnit, *Hugdietrich*, *Wolfdietrich*, the latter with its pathetic episode of the unswerving 219
loyalty of Wolfdietrich’s vassal Duke Berchtung and his ten sons. Although many of the incidents and motives of this cycle are drawn from the best traditions of the *Heldensage*, its literary value is not very high.

This collection of popular romances was one of the first German books to be printed. The date of the first edition is unknown, but the second edition appeared in the year 1491 and was followed by later reprints in 1509, 1545, 1560 and 1590. The last of these forms the basis of the text edited by A. von Keller for the Stuttgart *Literarische Verein* in 1867. In 1472 the *Heldenbuch* was adapted to the popular tastes of the time by being remodelled in rough *Knittelvers* or doggerel; the author, or at least copyist, of the MS. was a certain Kaspar von dor Roen, of Münnerstadt in Franconia. This version was printed by F. von der Hagen and S. Primisser in their *Heldenbuch* (1820-1825). *Das Heldenbuch*, which F. von der Hagen published in 2 vols, in 1855, was the first attempt to reproduce the original text by collating the MSS. A critical edition, based not merely on the oldest printed text—the only one which has any value for this purpose, as the others are all copies of it—but also on the MSS., was published in 5 vols. by O. Jänicke, E. Martin, A. Amelung and J. Zupitza at Berlin (1866-1873). A selection, edited by E. Henrici, will be found in Kürschner’s *Deutsche Nationalliteratur*, vol. 7 (1887). Recent editions have appeared of *Der Rosengarten* and *Laurin*, by G. Holz (1893 and 1897). All the poems have been translated into modern German by K. Simrock and others. See F. E. Sandbach, *The Heroic Saga-Cycle of Dietrich of Bern* (1906). The literature of the *Heldensage* is very extensive. See especially W. Grimm, *Die deutsche Heldensage* (3rd ed., 1889); L. Uhland, “Geschichte der deutschen Poesie im Mittelalter,” *Schriften*, vol. i. (1866); O. L. Jiriczek, *Deutsche Heldensage*, vol. i. (1898); and especially B. Symons, “Germanische Heldensage,” in Paul’s *Grundriss der germanischen Philologie* (2nd ed., 1898).

HELDER, a seaport town at the northern extremity of the province of North Holland, in the kingdom of Holland, 51 m. by rail N.N.W. of Amsterdam. Pop. (1900) 25,842. It is situated on the Marsdiep, the channel separating the island of Texel from the mainland, and the main entrance to the Zuider Zee, and besides being the terminus of the North Holland canal from Amsterdam, it is an important naval and military station. On the east side of the town, called the Nieuwe Diep, is situated the fine harbour, which formerly served, as Ymuiden now does, as the outer port of Amsterdam. In this neighbourhood are the naval wharves and magazines, wet and dry docks, and the naval cadet school of Holland, the name Willemsoord being given to the whole naval establishment. From Nieuwe Diep to Fort Erfprins on the west side of the town, a distance of about 5 m., stretches the great sea-dike which here takes the place of the dunes. This dike descends at an angle of 40° for a distance of 200 ft. into the sea, and is composed of Norwegian granite and Belgian limestone, strengthened at intervals by projecting jetties of piles and fascines. A circle of forts and batteries defends the town and coast, and there is a permanent garrison of 7000 to 9000 men, while 30,000 men can be accommodated within the lines, and the province flooded from this point. Besides several churches and a synagogue, there are a town hall (1836), a hospital, an orphan asylum, the "palace" of the board of marine, a meteorological observatory, a zoological station and a lighthouse. The industries of the town are sustained by the garrison and marine establishments.

HELEN, or Helena (Gr. Ἑλένη),in Greek mythology, daughter of Zeus by Leda (wife of Tyndareus, king of Sparta), sister of Castor, Pollux and Clytaemnestra, and wife of Menelaus. Other accounts make her the daughter of Zeus and Nemesis, or of Oceanus and Tethys. She was the most beautiful woman in Greece, and indirectly the cause of the Trojan war. When a child she was carried off from Sparta by Theseus to Attica, but was recovered and taken back by her brothers. When she grew up, the most famous of the princes of Greece sought her hand in marriage, and her father's choice fell upon Menelaus. During her husband's absence she was induced by Paris, son of Priam, with the connivance of Aphrodite, to flee with him to Troy. After the death of Paris she married his brother Deïphobus, whom she is said to have betrayed into the hands of Menelaus at the capture of the city (*Aeneid*, vi. 517 ff.). Menelaus thereupon took her back, and they returned together to Sparta, where they lived happily till their death, and were buried at Therapnae in Laconia. According to another story, Helen survived her husband, and was driven out by her stepsons. She fled to Rhodes, where she was hanged on a tree by her former friend Polyxo, to avenge the loss of her husband Tlepolemus in the Trojan War (Pausanias iii. 19). After death, Helen was said to have married Achilles in his home in the island of Leukē. In another version, Paris, on his voyage to Troy with Helen, was driven ashore on the coast of Egypt, where King Proteus, upon learning the facts of the case, detained the real Helen in Egypt, while a phantom Helen was carried off to Troy. Menelaus on his way home was also driven by stress of winds to Egypt, where he found his wife and took her home (Herodotus ii. 112-120; Euripides, *Helena*). Helen was worshipped as the goddess of beauty at Therapnae in Laconia, where a festival was held in her honour. At Rhodes she was worshipped under the name of Dendritis (the tree goddess), where the inhabitants built a temple in her honour to expiate the crime of Polyxo. The Rhodian story probably contains a reference to the worship connected with her name (cf. Theocritus xviii. 48 σέβου μ᾽, Ἑλένας φυτὸν εἰμί). She was the subject of a tragedy by Euripides and an epic by Colluthus. Originally, Helen was perhaps a goddess of light, a moon-goddess, who was gradually transformed into the beautiful heroine round whom the action of the *Iliad* revolves. Like her brothers, the Dioscuri, she was a patron deity of sailors.

See E. Oswald, *The Legend of Fair Helen* (1905); J. A. Symonds, *Studies of the Greek Poets*, i. (1893); F. Decker, *Die griechische Helena in Mythos und Epos* (1894); Andrew Lang, *Helen of Troy* (1883); P. Paris in Daremberg and Saglio's *Dictionnaire des antiquités*; the exhaustive article by R. Engelmann in Roscher's *Lexikon der Mythologie*; and O. Gruppe, *Griechische Mythologie*, i. 163, according to whom Helen originally represented, in the Helenephoria (a mystic festival of Artemis, Iphigeneia or Tauropolos), the sacred basket (ἑλένη) in which the holy objects were carried; and hence, as the personification of the initiation ceremony, she was connected with or identified with the moon, the first appearance of which probably marked the beginning of the festivity.

HELENA, ST (*c.* 247-*c.* 327) the wife of the emperor Constantius I. Chlorus, and mother of Constantine the Great. She was a woman of humble origin, born probably at Drepanum, a town on the Gulf of Nicomedia, which Constantine named Helenopolis in her honour. Very little is known of her history. It is certain that, at an advanced age, she undertook a pilgrimage to Palestine, visited the holy places, and founded several churches. She was still living at the time of the murder of Crispus (326). Constantine had coins struck with the effigy of his mother. The name of Helena is intimately connected with the commonly received story of the discovery of the Cross. But the accounts which connect her with the discovery are much later than the date of the event. The Pilgrim of Bordeaux (333), Eusebius and Cyril of Jerusalem were unaware of this important episode in the life of the empress. It was only at the end of the 4th century and in the West that the legend appeared. The principal centre of the cult of St Helena in the West seems to be the abbey of Hautvilliers, near Reims, where since the 9th century they have claimed to be in possession of her body. In England legends arose representing her as the daughter of a prince of Britain. Following these Geoffrey of Monmouth makes her the daughter of Coel, the king who is supposed to have given his name to the town of Colchester. These legends have doubtless not been without influence on the cult of the saint in England, where a great number of churches are dedicated either to St Helena alone, or to St Cross and St Helena. Her festival is celebrated in the Latin Church on the 18th of August. The Greeks make no distinction between her festival and that of Constantine, the 21st of May.

See *Acta sanctorum*, Augusti iii. 548-580; Tixeront, *Les Origines de l'église d'Édesse* (Paris, 1888); F. Arnold-Forster, *Studies in Church Dedications or England's Patron Saints*, i. 181-189, iii. 16, 365-366 (1899).

(H. De.)

HELENA, a city and the county-seat of Phillips county, Arkansas, U.S.A., situated on and at the foot of Crowly's Ridge, about 150 ft. above sea-level, in the alluvial bottoms of the Mississippi river, about 65 m. by rail S.W. of Memphis, Tennessee. Pop. (1890) 5189, (1900) 5550, of whom 3400 were negroes; (1910) 8772. It is served by the Yazoo & Mississippi 220
Valley (Illinois Central), the St Louis, Iron Mountain & Southern (Missouri Pacific), the Arkansas Midland, and the Missouri & North Arkansas railways. Built in part upon "made land," well protected by levees, and lying within the richest cotton-producing region of the south, the rich timber country of the St Francis river, and the Mississippi "bottom lands," Helena concentrates its economic interests in cotton-compressing and shipping, the manufacture of cotton-seed products, lumbering and wood-working. The city was founded about 1821, but so late as 1860 the population was only 800. During the Civil War the place was of considerable strategic importance. It was occupied in July 1862 by the Union forces, who strongly fortified it to guard their communications with the lower Mississippi; on the 4th of July 1863, when occupied by General Benjamin M. Prentiss (1819-1901) with 4500 men, it was attacked by a force of 9000 Confederates under General Theophilus H. Holmes (1804-1880), who hoped to raise the siege of Vicksburg or close the river to the Union forces. The attack was repulsed, with a loss to the Confederates of one-fifth their numbers, the Union loss being slight.

HELENA, a city and the county-seat of Lewis and Clark county, Montana, U.S.A., and the capital of the state, at the E. base of the main range of the Rocky Mountains, 80 m. N.E. of Butte, at an altitude of about 4000 ft. Pop. (1880) 3624; (1890) 13,834; (1900) 10,770, of whom 2793 were foreign-born; (1910 census) 12,515. It is served by the Great Northern and the Northern Pacific railways. Helena is delightfully situated with Mt Helena as a background in the hollow of the Prickly Pear valley, a rich agricultural region surrounded by rolling hills and lofty mountains, and contains many fine buildings, including the state capitol, county court house, the Montana club house, high school, the cathedral of St Helena, a federal building, and the United States assay office. It is the seat of the Montana Wesleyan University (Methodist Episcopal), founded in 1890; St Aloysius College and St Vincent's Academy (Roman Catholic); and has a public library with about 35,000 volumes, the Montana state library with about 40,000 volumes, and the state law library with about 24,000 volumes. The city is the commercial and financial centre of the state (Butte being the mining centre), and is one of the richest cities in the United States in proportion to its population. It has large railway car-shops, extensive smelters and quartz crushers (at East Helena), and various manufacturing establishments; the value of the factory product in 1905 was $1,309,746, an increase of 68.7% over that of 1900. The surrounding country abounds in gold- and silver-bearing quartz deposits, and it is estimated that from the famous Last Chance Gulch alone, which runs across the city, more than $40,000,000 in gold has been taken. The street railway and the lighting system of the city are run by power generated at a plant and 40 ft. dam at Canyon Ferry, on the Missouri river, 18 m. E. of Helena. There is another great power plant at Hauser Plant, 20 m. N. of Helena. Three miles W. of the city is the Broadwater Natatorium with swimming pool, 300 ft. long and 100 ft. wide, the water for which is furnished by hot springs with a temperature at the source of 160°. Fort Harrison, a United States army post, is situated 3 m. W. of the city. Helena was established as a placer mining camp in 1864 upon the discovery of gold in Last Chance Gulch. The town was laid out in the same year, and after the organization of Montana Territory it was designated as the capital. Helena was burned down in 1869 and in 1874. It was chartered as a city in 1881.

HELENSBURGH, a municipal and police burgh and watering-place of Dumbartonshire, Scotland, on the N. shore of the Firth of Clyde, opposite Greenock, 24 m. N.W. of Glasgow by the North British railway. Pop. (1901) 8554. There is a station at Upper Helensburgh on the West Highland railway, and from the railway pier at Craigendoran there is steamer communication with Garelochhead, Dunoon and other pleasure resorts on the western coast. In 1776 the site began to be built upon, and in 1802 the town, named after Lady Helen, wife of Sir James Colquhoun of Luss, the ground landlord, was erected into a burgh of barony, under a provost and council. The public buildings include the burgh hall, municipal buildings, Hermitage schools and two hospitals. On the esplanade stands an obelisk to Henry Bell, the pioneer of steam navigation, who died at Helensburgh in 1830.

HELENUS, in Greek legend, son of Priam and Hecuba, and twin-brother of Cassandra. He is said to have been originally called Scamandrius, and to have received the name of Helenus from a Thracian soothsayer who instructed him in the prophetic art. In the *Iliad* he is described as the prince of augurs and a brave warrior; in the *Odyssey* he is not mentioned at all. Various details concerning him are added by later writers. It is related that he and his sister fell asleep in the temple of Apollo Thymbraeus and that snakes came and cleansed their ears, whereby they obtained the gift of prophecy and were able to understand the language of birds. After the death of Paris, Helenus and his brother Deïphobus became rivals for the hand of Helen. Deïphobus was preferred, and Helenus withdrew in indignation to Mount Ida, where he was captured by the Greeks, whom he advised to build the wooden horse and carry off the Palladium. According to other accounts, having been made prisoner by a stratagem of Odysseus, he declared that Philoctetes must be fetched from Lemnos before Troy could be taken; or he surrendered to Diomedes and Odysseus in the temple of Apollo, whither he had fled in disgust at the sacrilegious murder of Achilles by Paris in the sanctuary. After the capture of Troy, he and his sister-in-law Andromache accompanied Neoptolemus (Pyrrhus) as captives to Epirus, where Helenus persuaded him to settle. After the death of Neoptolemus, Helenus married Andromache and became ruler of the country. He was the reputed founder of Buthrotum and Chaonia, named after a brother or companion whom he had accidentally slain while hunting. He was said to have been buried at Argos, where his tomb was shown. When Aeneas, in the course of his wanderings, reached Epirus, he was hospitably received by Helenus, who predicted his future destiny.

Homer, *Iliad*, vi. 76, vii. 44, xii. 94, xiii. 576; Sophocles, *Philoctetes*, 604, who probably follows the *Little Iliad* of Lesches; Pausanias i. 11, ii. 23; Conon, *Narrationes*, 34; Dictys Cretensis iv. 18; Virgil, *Aeneid*, iii. 294-490; Servius on *Aeneid*, ii. 166, iii. 334.

HELGAUD, or Helgaldus (d. *c.* 1048), French chronicler, was a monk of the Benedictine abbey of Fleury. Little else is known about him save that he was chaplain to the French king, Robert II. the Pious, whose life he wrote. This *Epitoma vitae Roberti regis*, which is probably part of a history of the abbey of Fleury, deals rather with the private than with the public life of the king, and its value is not great either from the literary or from the historical point of view. The only existing manuscript is in the Vatican, and the *Epitoma* has been printed by J. P. Migne in the *Patrologia Latina*, tome cxli. (Paris, 1844); and by M. Bouquet in the *Recueil des historiens des Gaules*, tome x. (Paris, 1760).

See *Histoire littéraire de la France*, tome vii. (Paris, 1865-1869); and A. Molinier, *Les Sources de l’histoire de France*, tome ii. (Paris, 1902).

HELGESEN, POVL,[1] Danish humanist, was born at Varberg in Halland about 1480, of a Danish father and a Swedish mother. Helgesen was educated first at the Carmelite monastery of his native place and afterwards at another monastery at Elsinore, where he devoted himself to humanistic studies and adopted Erasmus as his model. None had a keener eye for the abuses of the Church; long before the appearance of Luther, he denounced the ignorance and immorality of the clergy, and, as lector at the university of Copenhagen, gathered round him a band of young enthusiasts, the future leaders of the Danish Reformation. But Helgesen desired an orderly, methodical, rational reformation, and denounced Luther, whose ablest opponent in Denmark he subsequently became, as a hot-headed revolutionist. Christian II. was also an object of Helgesen’s detestation, and so boldly did he oppose that monarch’s measures that, to save his life, he had to flee to Jutland. Under 221
Frederick I. (1523-1533) he returned to Copenhagen and resumed his chair at the university, becoming soon afterwards provincial of the Carmelite Order for Scandinavia. But like all moderate men in a time of crisis, Helgesen could gain the confidence of neither party, and was frequently attacked as bitterly by the Catholics as by the Protestants. From 1530 to 1533 he and the Protestant champion Hans Tausen exhausted the whole vocabulary of vituperation in their fruitless polemics. In October 1534, however, Helgesen issued an eirenicon in which he attempted to reconcile the two contending confessions. After that every trace of him is lost. For a long time he was unjustly regarded as a turn-coat, but he was too superior to the prejudices of his age to be understood by his contemporaries. His ideal was a moral internal reformation of the Church on a rational basis, conducted not by ill-informed fanatics, but by an enlightened and well-educated clergy; and from this standpoint he never diverged. Helgesen was indisputably the greatest master of style of his age in Denmark, and as a historian he also occupies a prominent position. He always endeavours to probe down to the very soul of things, though his passionate nature made it very difficult for him to be impartial. His chief works are *Danmark’s Kongers Historie* and *Skibby Kröniken*.

See Ludwig Schmitt, *Der Karmeliter Paulus Heliä* (Freiburg, 1893); *Danmarks Riges Historie* (Copenhagen, 1897-1905), vol. iii.

1 He wrote his name Heliae or Eliae.

HELIACAL, relating to the sun (ἥλιος), a term applied in the ancient astronomy to the first rising of a star which could be seen after it emerged from the rays of the sun, or the last setting that could be seen before it was lost from sight by proximity to the sun.

HELIAND. The 9th-century poem on the Gospel history, to which its first editor, J. A.

Schmeller, gave the appropriate name of *Heliand* (the word used in the text for “Saviour,” answering to the O. Eng. *hælend* and the Ger. *Heiland*), is, with the fragments of a version of the story of Genesis believed to be by the same author, all that remains of the poetical literature of the old Saxons, *i.e.* the Saxons who continued in their original home. It contained when entire about 6000 lines, and portions of it are preserved in four MSS. The Cotton MS. in the British Museum, written probably late in the 10th century, is nearly complete, ending in the middle of the story of the journey to Emmaus. The Munich MS., formerly at Bamberg, begins at line 85, and has many lacunae, but continues the history down to the last verse of St Luke’s Gospel, ending, however, in the middle of a sentence. A MS. discovered at Prague in 1881 contains lines 958-1106, and another, in the Vatican library, discovered by K. Zangemeister in 1894, contains lines 1279-1358. The poem is based, not directly on the New Testament, but on the pseudo-Tatian’s harmony of the Gospels, and it shows acquaintance with the commentaries of Alcuin, Bæda and Hrabanus Maurus.

The questions relating to the *Heliand* cannot be adequately discussed without considering also the poem on the history of Genesis, which, on the grounds of similarity in style and vocabulary, and for other reasons afterwards to be mentioned, may with some confidence be referred to the same author. A part of this poem, as is mentioned in the article Cædmon, is extant only in an Old English translation. The portions that have been preserved in the original language are contained in the same Vatican MS. that includes the fragment of the *Heliand* referred to above. In the one language or the other, there are in existence the following three fragments: (1) The passage which appears as lines 235-851 in the so-called “Cædmon’s *Genesis*,” on the revolt of the angels and the temptation and fall of Adam and Eve. Of this the part corresponding to lines 790-820 exists also in the original Old Saxon. (2) The story of Cain and Abel, in 124 lines. (3) The account of the destruction of Sodom, in 187 lines. The main source of the *Genesis* is the Bible, but Professor E. Sievers has shown that considerable use was made of the two Latin poems by Alcimus Avitus, *De initio mundi* and *De peccato originali*.

The two poems give evidence of genius and trained skill, though the poet was no doubt hampered by the necessity of not deviating too widely from the sacred originals. Within the limits imposed by the nature of his task, his treatment of his sources is remarkably free, the details unsuited for poetic handling being passed over, or, in some instances, boldly altered. In many passages his work gives the impression of being not so much an imitation of the ancient Germanic epic, as a genuine example of it, though concerned with the deeds of other heroes than those of Germanic tradition. In the *Heliand* the Saviour and His Apostles are conceived as a king and his faithful warriors, and the use of the traditional epic phrases appears to be not, as with Cynewulf or the author of *Andreas*, a mere following of accepted models, but the spontaneous mode of expression of one accustomed to sing of heroic themes. The *Genesis* fragments have less of the heroic tone, except in the splendid passage describing the rebellion of Satan and his host. It is noteworthy that the poet, like Milton, sees in Satan no mere personification of evil, but the fallen archangel, whose awful guilt could not obliterate all traces of his native majesty. Somewhat curiously, but very naturally, Enoch the son of Cain is confused with the Enoch who was translated to heaven—an error which the author of the Old English *Genesis* avoids, though (according to the existing text) he confounds the names of Enoch and Enos.

Such external evidence as exists bearing on the origin of the *Heliand* and the companion poem is contained in a Latin document printed by Flacius Illyricus in 1562. This is in two parts; the one in prose, entitled (perhaps only by Flacius himself) “*Praefatio ad librum antiquum in lingua Saxonica conscriptum*”; the other in verse, headed “*Versus de poëta et Interpreta hujus codicis*.” The Praefatio begins by stating that the emperor Ludwig the Pious, desirous that his subjects should possess the word of God in their own tongue, commanded a certain Saxon, who was esteemed among his countrymen as an eminent poet, to translate poetically into the German language the Old and New Testaments. The poet willingly obeyed, all the more because he had previously received a divine command to undertake the task. He rendered into verse all the most important parts of the Bible with admirable skill, dividing his work into *vitteas*, a term which, the writer says, may be rendered by “*lectiones*” or “*sententias*.” The Praefatio goes on to say that it was reported that the poet, till then knowing nothing of the art of poetry, had been admonished in a dream to turn into verse the precepts of the divine law, which he did with so much skill that his work surpasses in beauty all other German poetry (*ut cuncta Theudisca poëmata suo vincat decore*). The *Versus* practically reproduce in outline Bæda’s account of Cædmon’s dream, without mentioning the dream, but describing the poet as a herdsman, and adding that his poems, beginning with the creation, relate the history of the five ages of the world down to the coming of Christ.

The suspicion of some earlier scholars that the *Praefatio* and the *Versus* might be a modern forgery is refuted by the occurrence of the word *vitteas*, which is the Old Saxon *fittea*, corresponding to the Old English *fitt*, which means a “canto” of a poem. It is impossible that a scholar of the 16th century could have been acquainted with this word, and internal evidence shows clearly that both the prose and the verse are of early origin. The *Versus*, considered in themselves, might very well be supposed to relate to Cædmon; but the mention of the five ages of the world in the concluding lines is obviously due to recollection of the opening of the *Heliand* (lines 46-47). It is therefore certain that the *Versus*, as well as the *Praefatio*, attribute to the author of the *Heliand* a poetic rendering of the Old Testament. Their testimony, if accepted, confirms the ascription to him of the Genesis fragments, which is further supported by the fact that they occur in the same MS. with a portion of the *Heliand*. As the *Praefatio* speaks of the emperor Ludwig in the present tense, the former part of it at least was probably written in his reign, *i.e.* not later than A.D. 840. The general opinion of scholars is that the latter part, which represents the poet as having received his vocation in a dream, is by a later hand, and that the sentences in the earlier part which refer to the dream are interpolations by this second author. The date of 222
these additions, and of the *Versus*, is of no importance, as their statements are incredible. That the author of the *Heliand* was, so to speak, another Cædmon—an unlearned man who turned into poetry what was read to him from the sacred writings—is impossible, because in many passages the text of the sources is so closely followed that it is clear that the poet wrote with the Latin books before him. On the other hand, there is no reason for rejecting the almost contemporary testimony of the first part of the *Praefatio* that the author of the *Heliand* had won renown as a poet before he undertook his great task at the emperor’s command. It is certainly not impossible that a Christian Saxon, sufficiently educated to read Latin easily, may have chosen to follow the calling of a *scop* or minstrel[1] instead of entering the priesthood or the cloister; and if such a person existed, it would be natural that he should be selected by the emperor to execute his design. As has been said above, the tone of many portions of the *Heliand* is that of a man who was no mere imitator of the ancient epic, but who had himself been accustomed to sing of heroic themes.

The commentary on the gospel of Matthew by Hrabanus Maurus was finished about 821, which is therefore the superior limit of date for the composition of the *Heliand*. It is usually maintained that this work was written before the Old Testament poems. The arguments for this view are that the *Heliand* contains no allusion to any foregoing poetical treatment of the antecedent history, and that the Genesis fragments exhibit a higher degree of poetic skill. This reasoning does not appear conclusive, and if it be set aside, the limit of date for the beginning of the work is carried back to A.D. 814, the year of the accession of Ludwig.

Bibliography.—The first complete edition of the *Heliand* was published by J. A. Schmeller in 1830; the second volume, containing the glossary and grammar, appeared in 1840. The standard edition is that of E. Sievers (1877), in which the texts of the Cotton and Munich MSS. are printed side by side. It is not provided with a glossary, but contains an elaborate and most valuable analysis of the diction, synonymy and syntactical features of the poem. Other useful editions are those of M. Heyne (3rd ed., 1903), O. Behaghel (1882) and P. Piper (1897, containing also the Genesis fragments). The fragments of the *Heliand* and the *Genesis* contained in the Vatican MS. were edited in 1894 by K. Zangemeister and W. Braune under the title *Bruchstücke der altsächsischen Bibeldichtung*. Among the works treating of the authorship, sources and place of origin of the poems, the most important are the following: E. Windisch, *Der Heliand und seine Quellen* (1868); E. Sievers, *Der Heliand und die angelsächsische Genesis* (1875); R. Kögel, *Deutsche Literaturgeschichte*, Bd. i. (1894) and *Die altsächsische Genesis* (1895); R. Kögel and W. Bruckner, “Althoch- und altniederdeutsche Literatur,” in Paul’s *Grundriss der germanischen Philologie*, Bd. ii. (2nd ed., 1901), which contains references to many other works; Hermann Collitz, *Zum Dialekte des Heliand* (1901).

(H. Br.)

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1 The term *Volkssänger*, commonly used in German discussions of this question, is misleading; the audience for heroic poetry was not “the people” in the modern sense, but the nobles.

HELICON, a mountain range, of Boeotia in ancient Greece, celebrated in classical literature as the favourite haunt of the Muses, is situated between Lake Copaïs and the Gulf of Corinth. On the fertile eastern slopes stood a temple and grove sacred to the Muses, and adorned with beautiful statues, which, taken by Constantine the Great to beautify his new city, were consumed there by a fire in A.D. 404. Hard by were the famous fountains, Aganippe and Hippocrene, the latter fabled to have gushed from the earth at the tread of the winged horse Pegasus, whose favourite browsing place was there. At the neighbouring Ascra dwelt the poet Hesiod, a fact which probably enhanced the poetic fame of the region. Pausanias, who describes Helicon in his ninth book, asserts that it was the most fertile mountain in Greece, and that neither poisonous plant nor serpent was to be found on it, while many of its herbs possessed a miraculous healing virtue. The highest summit, the present Palaeovouni (old hill), rises to the height of about 5000 ft. Modern travellers, aided by ancient remains and inscriptions, and guided by the local descriptions of Pausanias, have succeeded in identifying many of the ancient classical spots, and the French excavators have discovered the temple of the Muses and a theatre.

See also Clarke, *Travels in Various Countries* (vol. vii., 1818); Dodwell, *Classical and Topographical Tour through Greece* (1818); W. M. Leake, *Travels in Northern Greece* (vol. ii., 1835); J. G. Frazer’s edition of *Pausanias*, v. 150.

HELICON (Fr. *hélicon, bombardon circulaire*; Ger. *Helikon*), the circular form of the B♭ contrabass tuba used in military bands, worn round the body, with the enormous bell resting on the left shoulder and towering above the head of the performer. The pitch of the helicon is an octave below that of the euphonium. The idea of winding the long tube of the contrabass tuba and of wearing it round the shoulders was suggested by the ancient Roman buccina and cornu, represented in mosaics and on the sculptured reliefs surrounding Trajan’s Column. The buccina and cornu[1] differed in the diameter of their respective bores, the former having the narrow, almost cylindrical bore and harmonic series of the trumpet and trombone, whereas the cornu, having a bore in the form of a wide cone, was the prototype of the bugle and tubas.

1 For illustrations of the cornu see the altar of Julius Victor ex Collegio, reproduced in Bartoli, Pict. Ant. p. 76; Bellori, *Pict. antiq. crypt. rom.* p. 76, pl. viii.; in Daremberg and Saglio, *Dict. des antiq. grecques et romaines*, under “Cornu,” the buccina and cornu have not been distinguished.

HELIGOLAND (Ger. *Helgoland*), an island of Germany, in the North Sea, lying off the mouths of the Elbe and the Weser, 28 m. from the nearest point in the mainland. Pop. (1900) 2307. From 1807 to 1890 a British possession, it was ceded in 1890 to Germany, and since 1892 has formed part of the Prussian province of Schleswig-Holstein. It consists of two islets, the smaller, the Dünen-Insel, a quarter of a mile E. of the main, or Rock Island, connected until 1720, when it was severed by a violent irruption of the sea, with the other by a neck of land, and the main, or Rock Island. The latter is nearly triangular in shape and is surrounded by steep red cliffs, the only beach being the sandy spit near the south-east point, where the landing-stage is situated. The rocks composing the cliffs are worn into caves, and around the island are many fantastic arches and columns. The impression made by the red cliffs, fringed by a white beach and supporting the green Oberland, is commonly believed to have suggested the national colours, red, white and green, or, as the old Frisian rhyme goes:—

“Grön is dat Land,
Rood is de Kant,
Witt is de Sand,
Dat is de Flagg vun’t hillige Land.”

The lower town of Unterland, on the spit, and the upper town, or Oberland, situated on the cliff above, are connected by a wooden stair and a lift. There is a powerful lighthouse, and since its cession by Great Britain to Germany, the main island has been strongly fortified, the old English batteries being replaced by armoured turrets mounting guns of heavy calibre. Inside the Dünen-Insel the largest ships can ride safely at anchor, and take in coal and other supplies. The greatest length of the main island, which slopes somewhat from west to east, is just a mile, and the greatest breadth less than a third of a mile, its average height 198 ft., and the highest point, crowned by the church, with a conspicuous spire, 216 ft. The Dünen-Insel is a sand-bank protected by groines. It is only about 200 ft. above the sea at its highest point, but the drifting sands make the height rather variable. The sea-bathing establishment is situated here; a shelving beach of white sand presenting excellent facilities for bathing. Most of the houses are built of brick, but some are of wood. There are a theatre, a Kurhaus, and a number of hotels and restaurants. In 1892 a biological institute, with a marine museum and aquarium (1900) attached, was opened.

During the summer some 20,000 people visit the island for sea-bathing. German is the official language, though among themselves the natives speak a dialect of Frisian, barely intelligible to the other islands of the group. There is regular communication with Bremen and Hamburg.

The winters are stormy. May and the early part of June are wet and foggy, so that few visitors arrive before the middle of the latter month.

The generally accepted derivation of Heligoland (or Helgoland) from *Heiligeland*, *i.e.* "Holy Land," seems doubtful. According to northern mythology, Forseti, a son of Balder and Nanna, the god of justice, had a temple on the island, which was subsequently destroyed by St Ludger. This legend may have given rise to the derivation "Holy Land." The more probable etymology, however, is that of Hallaglun, or Halligland, *i.e.* "land of banks, which cover and uncover." Here Hertha, according to tradition, had her great temple, and hither came from the mainland the Angles to worship at her shrine. Here also lived King Radbod, a pagan, and on this isle St Willibrord in the 7th century first preached Christianity; and for its ownership, before and after that date, many sea-rovers have fought. Finally it became a fief of the dukes of Schleswig-Holstein, though often hypothecated for loans advanced to these princes by the free city of Hamburg. The island was a Danish possession in 1807, when the English seized and held it until it was formally ceded to them in 1814. In the picturesque old church there are still traces of a painted Dannebrog. 223

In 1890 the island was ceded to Germany, and in 1892 it was incorporated with Prussia, when it was provided that natives born before the year 1880 should be allowed to elect either for British or German nationality, and until 1901 no additional import duties were imposed.

Bibliography.—Von der Decken, *Philosophisch-historisch-geographische Untersuchungen über die Insel Helgoland, oder Heiligeland, und ihre Bewohner* (Hanover, 1826); Wiebel, *Die Insel Helgoland, Untersuchungen über deren Grösse in Vorzeit und Gegenwart vom Standpunkte der Geschichte und Geologie* (Hamburg, 1848); J. M. Lappenberg, *Über den ehemaligen Umfang und die alte Geschichte Helgolands* (Hamburg, 1831); F. Otker, *Helgoland. Schilderungen und Erörterungen* (Berlin, 1855); E. Hallier, *Helgoland, Nordseestudien* (Hamburg, 1893); A. W. F. Möller, *Rechtsgeschichte der Insel Helgoland* (Weimar, 1904); W. G. Black, *Heligoland and the Islands of the North Sea* (Glasgow, 1888); E. Lindermann, *Die Nordseeinsel Helgoland in topographischer, geschichtlicher, sanitärer Beziehung* (Berlin, 1889); and Tittel, *Die natürlichen Veränderungen Helgolands* (Leipzig, 1894).

HELIOCENTRIC, *i.e.* referred to the centre of the sun (ἥλιος) as an origin, a term designating especially co-ordinates or heavenly bodies referred to that origin.

HELIODORUS, of Emesa in Syria, Greek writer of romance. According to his own statement his father's name was Theodosius, and he belonged to a family of priests of the sun. He was the author of the *Aethiopica*, the oldest and best of the Greek romances that have come down to us. It was first brought to light in modern times in a MS. from the library of Matthias Corvinus, found at the sack of Buda (Ofen) in 1526, and printed at Basel in 1534. Other codices have since been discovered. The title is taken from the fact that the action of the beginning and end of the story takes place in Aethiopia. The daughter of Persine, wife of Hydaspes, king of Aethiopia, was born white through the effect of the sight of a marble statue upon the queen during pregnancy. Fearing an accusation of adultery, the mother gives the babe to the care of Sisimithras, a gymnosophist, who carries her to Egypt and places her in charge of Charicles, a Pythian priest. The child is taken to Delphi, and made a priestess of Apollo under the name of Chariclea. Theagenes, a noble Thessalian, comes to Delphi and the two fall in love with each other. He carries off the priestess with the help of Calasiris, an Egyptian, employed by Persine to seek for her daughter. Then follow many perils from sea-rovers and others, but the chief personages ultimately meet at Meroë at the very moment when Chariclea is about to be sacrificed to the gods by her own father. Her birth is made known, and the lovers are happily married. The rapid succession of events, the variety of the characters, the graphic descriptions of manners and of natural scenery, the simplicity and elegance of the style, give the *Aethiopica* great charm. As a whole it offends less against good taste and morality than others of the same class. Homer and Euripides were the favourite authors of Heliodorus, who in his turn was imitated by French, Italian and Spanish writers. The early life of Clorinda in Tasso’s *Jerusalem Delivered* (canto xii. 21 sqq.) is almost identical with that of Chariclea; Racine meditated a drama on the same subject; and it formed the model of the *Persiles y Sigismunda* of Cervantes. According to the ecclesiastical historian Socrates (*Hist. eccles.* v. 22), the author of the *Aethiopica* was a certain Heliodorus, bishop of Tricca in Thessaly. It is supposed that the work was written in his early years before he became a Christian, and that, when confronted with the alternative of disowning it or resigning his bishopric, he preferred resignation. But it is now generally agreed that the real author was a sophist of the 3rd century A.D.

The best editions are: A. Coraës (1804), G. A. Hirschig (1856); see also M. Oeftering, *H. und seine Bedeutung für die Literatur*, with full bibliographies (1901); J. C. Dunlop, *History of Prose Fiction* (1888); and especially E. Rohde, *Der griechische Roman* (1900). There are translations in almost all European languages: in English, in Bohn’s *Classical Library* and the “Tudor” series (v., 1895, containing the old translation by T. Underdowne, 1587, with introduction by C. Whibley); in French by Amyot and Zevort.

HELIOGABALUS (ELAGABALUS), Roman emperor (A.D. 218-222), was born at Emesa about 205. His real name was Varius Avitus. On the murder of Caracalla (217), Julia Maesa, Varius’s grandmother and Caracalla’s aunt, left Rome and retired to Emesa, accompanied by her grandsons (Varius and Alexander Severus). Varius, though still only a boy, was appointed high priest of the Syrian sun-god Elagabalus, one of the chief seats of whose worship was Emesa (Homs). His beauty, and the splendid ceremonials at which he presided, made him a great favourite with the troops stationed in that part of Syria, and Maesa increased his popularity by spreading reports that he was in reality the illegitimate son of Caracalla. Macrinus, the successor and instigator of the murder of Caracalla, was very unpopular with the army; an insurrection was easily set on foot, and on the 16th of May 218 Varius was proclaimed emperor as Marcus Aurelius Antoninus. The troops sent to quell the revolt went over to him, and Macrinus was defeated near Antioch on the 8th of June. Heliogabalus was at once recognized by the senate as emperor. After spending the winter in Nicomedia, he proceeded in 219 to Rome, where he made it his business to exalt the deity whose priest he was and whose name he assumed. The Syrian god was proclaimed the chief deity in Rome, and all other gods his servants; splendid ceremonies in his honour were celebrated, at which Heliogabalus danced in public, and it was believed that secret rites accompanied by human sacrifice were performed in his honour. In addition to these affronts upon the state religion, he insulted the intelligence of the community by horseplay of the wildest description and by childish practical joking. The shameless profligacy of the emperor’s life was such as to shock even a Roman public. His popularity with the army declined, and Maesa, perceiving that the soldiers were in favour of Alexander Severus, persuaded Heliogabalus to raise his cousin to the dignity of Caesar (221), a step of which he soon repented. An attempt to murder Alexander was frustrated by the watchful Maesa. Another attempt in 222 produced a mutiny among the praetorians, in which Heliogabalus and his mother Soemias (Soaemias) were slain (probably in the first half of March).

Authorities.—Life by Aelius Lampridius in *Scriptores historiae Augustae*; Herodian v. 3-8; Dio Cassius lxxviii. 30 sqq., lxxix. 1-21; monograph by G. Duviquet, *Héliogabale* (1903), containing a translation of the various accounts of Heliogabalus in Greek and Latin authors, notes, bibliography and illustrations; O. F. Butler, *Studies in the Life of Heliogabalus* (New York, 1908); Gibbon, *Decline and Fall*, ch. 6; H. Schiller, *Geschichte der römischen Kaiserzeit*, i. pt. ii. (1883), p. 759 ff. On the Syrian god see F. Cumont in Pauly-Wissowa’s *Realencyclopädie*, v. pt. ii. (1905).

HELIOGRAPH (from Gr. ἥλιος, sun, and γράφειν to write), an instrument for reflecting the rays of the sun (or the light obtained from any other source) over a considerable distance. Its main application is in military signalling (see Signal). A similar instrument is the heliotrope, used principally for defining distant points in geodetic surveys, such as in the triangulation of India, and in the verification of the African arc of the meridian. It is necessary to distinguish the method of signalling termed heliography from the photographic process of the same name (see Photography).

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HELIOMETER (from Gr. ἥλιος, sun, and μέτρον, a measure), an instrument originally designed for measuring the variation of the sun’s diameter at different seasons of the year, but applied now to the modern form of the instrument which is capable of much wider use. The present article also deals with other forms of double-image micrometer.

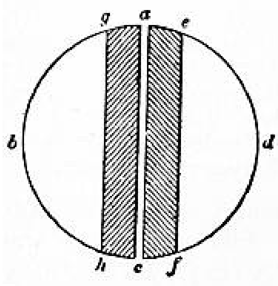

Fig. 1.

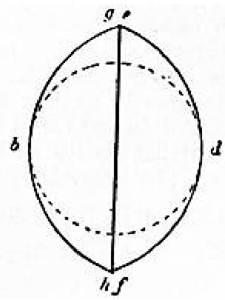

Fig. 2.

The discovery of the method of making measures by double images is stated to have been first suggested by O. Roemer about 1768. But no such suggestion occurs in the *Basis Astronomiae* of Peter Horrebow (Copenhagen, 1735), which contains the only works of Roemer that remain to us. It would appear that to Servington Savary is due the first invention of a micrometer for measurement by double image. His heliometer (described in a paper communicated to the Royal Society in 1743, and printed, along with a letter from James Short, in *Phil. Trans.*, 1753, p. 156) was constructed by cutting from a complete lens *abcd* the equal portions *aghc* and *acfe* (fig. 1). The segments *gbh* and *efd* so formed were then attached to the end of a tube having an internal diameter represented by the dotted circle (fig. 2). The width of each of the portions *aghc* and *acfe* cut away from the lens was made slightly greater than the focal length of lens × tangent of sun’s greatest diameter. Thus at the focus two images of the sun were formed nearly in contact as in fig. 3. The small interval between the adjacent limbs was then measured with a wire micrometer.

Savary also describes another form of heliometer, on the same principle, in which the segments *aghc* and *acfe* are utilized by cementing their edges *gh* and *ef* together (fig. 4), and covering all except the portion indicated by the unshaded circle. Savary expresses preference for this second plan, and makes the pertinent remark that in both these models “the rays of red light in the two solar images will be next to each other, which will render the sun’s disk more easy to be observed than the violet ones.” This he

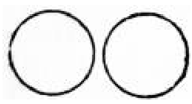
Fig. 3.

mentions "because the glasses in these two sorts are somewhat prismatical, but mostly those of the first model, which could therefore bear no great charge (magnifying power)."

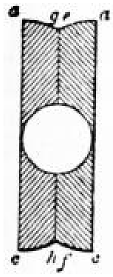

FIG. 4.

A third model proposed by Savary consists of two complete lenses of equal focal length, mounted in cylinders side by side, and attached to a strong brass plate (fig. 5). Here, in order to fulfil the purposes of the previous models, the distance of the centres of the lenses from each other should only slightly exceed the tangent of sun's diameter × focal length of lenses. Savary dwells on the difficulty both of procuring lenses sufficiently equal in focus and of accurately adjusting and centring them.

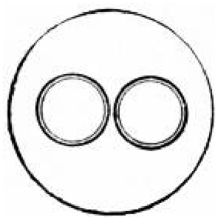

FIG. 5.

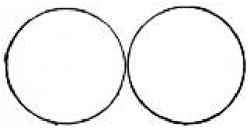

FIG. 6.

In the *Mém. Acad. de Paris* (1748), Pierre Bouguer describes an instrument which he calls a heliometer. Lalande in his *Astronomie* (vol. ii. p. 639) mentions such a heliometer which had been in his possession from the year 1753, and of which he gives a representation on Plate XXVIII., fig. 186, of the same volume. Bouguer's heliometer was in fact similar to that of Savary's third model, with the important difference that, instead of both object-glasses being fixed, one of them is movable by a screw provided with a divided head. No auxiliary filar micrometer was required, as in Savary's heliometer, to measure the interval between the limbs of two adjacent images of the sun, it being only necessary to turn the screw with the divided head to change the distance between the object-glasses till the two images of the sun are in contact as in fig. 6. The differences of the readings of the screw, when converted into arc, afford the means of measuring the variations of the sun's apparent diameter.

On the 4th of April 1754 John Dollond communicated a paper to the Royal Society of London (*Phil. Trans.*, vol. xlviii. p. 551) in which he shows that a micrometer can be much more easily constructed by dividing a single object-glass through its axis than by the employment of two object-glasses. He points out—(1) that a telescope with an object-glass so divided still produces a single image of any object to which it may be directed, provided that the optical centres of the segments are in coincidence (*i.e.* provided the segments retain the same relative positions to each other as before the glass was cut); (2) that if the segments are separated in any direction two images of the object viewed will be produced; (3) that the most convenient direction of separation for micrometric purposes is to slide these straight edges one along the other as the figure on the margin (fig. 7) represents them: "for thus they may be moved without suffering any false light to come in between them; and by this way of removing them the distance between their centres may be very conveniently measured, viz. by having a vernier's division fixed to the brass work that holds one segment, so as to slide along a scale on the plate to which the other part of the glass is fitted."

Dollond then points out three different types in which a glass so divided and mounted may be used as a micrometer:—

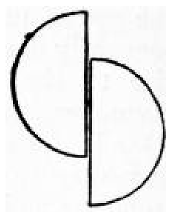

FIG. 7.

"1. It may be fixed at the end of a tube, of a suitable length to its focal distance, as an object-glass,—the other end of the tube having an eye-glass fitted as usual in astronomical telescopes.

"2. It may be applied to the end of a tube much shorter than its focal distance, by having another convex glass within the tube, to shorten the focal distance of that which is cut in two.

"3. It may be applied to the open end of a reflecting telescope, either of the Newtonian or the Cassegrain construction."

Dollond adds his opinion that the third type is "much the best and most convenient of the three"; yet it is the first type that has survived the test of time and experience, and which is in fact the modern heliometer. It must be remembered, however, that when Dollond expressed preference for this third type he had not then invented the achromatic object-glass.

Some excellent instruments of the second type were subsequently made by Dollond's eldest son Peter, in which for the "convex glass within the tube" was substituted an achromatic object-glass, and outside that a divided negative achromatic combination of long focus. In the fine example of this instrument at the Cape Observatory the movable negative lenses consist of segments of the shape *gach* and *acfe* (fig. 1) cut from a complete negative achromatic combination of 8¼ in. aperture and about 41 ft. focal length, composed of a double concave flint lens and a double convex crown. This was applied to an excellent achromatic telescope of 3¼ in. aperture and 42 in. focal length. In this instrument a considerable linear relative movement of the divided lens corresponds with a comparatively small separation of the double image, so that simple verniers reading to $\frac{1}{1000}$ in. are sufficient for measurement.

With one of these instruments of somewhat smaller dimensions (telescope 2½ in. aperture and 3½ ft. focus), Franz von Paula Triesnecker made a series of measurements at the observatory of Vienna which has been reduced by Dr Wilhelm Schur of Strasburg (*Nova Acta der Ksl. Leop.-Carol. Deutschen Akademie der Natursforscher*, 1882, xlv. No. 3). The angle between the stars ζ and g Ursae maj. (708″.55) was measured on four nights; the probable error of a measure on one night was ±0″.44. Jupiter was measured on eleven nights in the months of June and July 1794; from these measures Schur derives the values 35″.39 and 37″.94 for the polar and equatorial diameter respectively, at mean distance, corresponding with a compression 1/14.44. These agree satisfactorily with the corresponding values 35″.21, 37″.60, 1/15.59 afterwards obtained by F. W. Bessel (*Königsberger Beobachtungen*, xix. 102). From a series of measures of the angle between Jupiter's satellites and the planet, made in June and July 1794 and in August and September 1795, Schur finds the mass of Jupiter = 1/1048.55 ± 1.45, a result which accords well within the limits of its probable error with the received value of the mass derived from modern researches. The probable errors for the measures of one night are ±0″.577, ±0″.889, ±0″.542, ±1″.096, for Satellites I., II., III. and IV. respectively.

Considering the accuracy of these measures (an accuracy far surpassing that of any other contemporary observations), it is somewhat surprising that this form of micrometer was never systematically used in any sustained or important astronomical researches, although a number of instruments of the kind were made by Dollond. Probably the last example of its employment is an observation of the transit of Mercury (November 4, 1868) by Mann, at the Royal Observatory, Cape of Good Hope (*Monthly Notices R.A.S.* vol. xxix. p. 197-209). The most important part, however, which this type of instrument seems to have played in the history of astronomy arises from the fact that one of them was in the possession of Bessel at Königsberg during the time when his new observatory there was being built. In 1812 Bessel measured with it the angle between the components of the double star 61 Cygni and observed the great comet of 1811. He also observed the eclipse of the sun on May 4, 1818. In the discussion of these observations (*Königsberger Beobacht*, Abt. 5, p. iv.) he found that the index error of the scale changed systematically in different position angles by quantities which were independent of the direction of gravity relative to the position angle under measurement, but which depended solely on the direction of the measured position angle relative to a fixed radius of the object-glass. Bessel attributed this to non-homogeneity in the object-glass, and determined with great care the necessary corrections. But he was so delighted with the general performance of the instrument, with the sharpness of the images and the possibilities which a kindred construction offered for the measurement of 225
considerable angles with micrometric accuracy, that he resolved, when he should have the choice of a new telescope for the observatory, to secure some form of heliometer.

Nor is it difficult to imagine the probable course of reasoning which led Bessel to select the model of his new heliometer. Why, he might ask, should he not select the simple form of Dollond's first type? Given the achromatic object-glass, why should not it be divided? This construction would give all the advantage of the younger Dollond's object-glass micrometer, and more than its sharpness of definition, without liability to the systematic errors which may be due to want of homogeneity of the object-glass; for the lenses will not be turned with respect to each other, but, in measurement, will always have the same relation in position angle to the line joining the objects under observation. It is true that the scale will require to be capable of being read with much greater accuracy than $\frac{1}{1000}$th of an inch—for that, even in a telescope of 10 ft. focus, would correspond with 2″ of arc. But, after all, this is no practical difficulty, for screws can be used to separate the lenses, and, by these screws, as in a Gascoigne micrometer, the separation of the lenses can be measured; or we can have scales for this purpose, read by microscopes, like the Troughton[1] circles of Piazzi or Pond, or those of the Carey circle, with almost any required accuracy.

Whether Bessel communicated such a course of reasoning to Fraunhofer, or whether that great artist arrived independently at like conclusions, we have been unable to ascertain with certainty. The fact remains that before 1820[2] Fraunhofer had completed one or more of the five heliometers (3 in. aperture and 39 in. focus) which have since become historical instruments. In 1824 the great Königsberg heliometer was commenced, and it was completed in 1829.

To sum up briefly the history of the development of the heliometer. The first application of the divided object-glass and the employment of double images in astronomical measures is due to Savary in 1743. To Bouguer in 1748 is due the true conception of measurement by double image without the auxiliary aid of a filar micrometer, viz. by changing the distance between two object-glasses of equal focus. To Dollond in 1754 we owe the combination of Savary's idea of the divided object-glass with Bouguer's method of measurement, and the construction of the first really practical heliometers. To Fraunhofer, some time not long previous to 1820, is due, so far as we can ascertain, the construction of the first heliometer with an achromatic divided object-glass, *i.e.* the first heliometer of the modern type.

The Modern Heliometer.

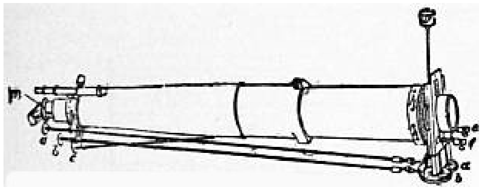

FIG. 8.

The Königsberg heliometer is represented in fig. 8. No part of the equatorial mounting is shown in the figure, as it resembles in every respect the usual Fraunhofer mounting. An adapter *h* is fixed on a telescope-tube, made of wood, in Fraunhofer's usual fashion. To this adapter is attached a flat circular flange *h*. The slides carrying the segments of the divided object-glass are mounted on a plate, which is fitted and ground to rotate smoothly on the flange *h*. Rotation is communicated by a pinion, turned by the handle *c* (concealed in the figure), which works in teeth cut on the edge of the flange *h*. The counterpoise *w* balances the head about its axis of rotation. The slides are moved by the screws *a* and *b*, the divided heads of which serve to measure the separation of the segments. These screws are turned from the eye-end by bevelled wheels and pinions, the latter connected with the handles *a′*, *b′*. The reading micrometers *e*, *f* also serve to measure, independently, the separation of the segments, by scales attached to the slides; such measurements can be employed as a check on those made by the screws. The measurement of position angles is provided for by a graduated circle attached to the head. There is also a position circle, attached at m to the eye-end, provided with a slide to move the eye-piece radially from the axis of the telescope, and with a micrometer to measure the distance of an object from that axis. The ring *c*, which carries the supports of the handles *a′*, *b′*, is capable of a certain amount of rotation on the tube. The weight of the handles and their supports is balanced by the counterpoise *z*. This ring is necessary in order to allow the rods to follow the micrometer heads when the position angle is changed. Complete rotation of the head is obviously impossible because of the interference of the declination axis with the rods, and therefore, in some angles, objects cannot be measured in two positions of the circle. The object-glass has an aperture of 6½ in. and 102 in. focal length.

There are three methods in which this heliometer can be used.

First Method.—One of the segments is fixed in the axis of the telescope, and the eye-piece is also placed in the axis. Measures are made with the moving segment displaced alternately on opposite sides of the fixed segment.

Second Method.—One segment is fixed, and the measures are made as in the first method, excepting that the eye-piece is placed symmetrically with respect to the images under measurement. For this purpose the position angle of the eye-piece micrometer is set to that of the head, and the eye-piece is displaced from the axis of the tube (in the direction of the movable segment) by an amount equal to half the angle under measurement.

Third Method.—The eye-piece is fixed in the axis, and the segments are symmetrically displaced from the axis each by an amount equal to half the angle measured.

Of these methods Bessel generally employed the first because of its simplicity, notwithstanding that it involved a resetting of the right ascension and declination of the axis of the tube with each reversal of the segments. The chief objections to the method are that, as one star is in the axis of the telescope and the other displaced from it, the images are not both in focus of the eye-piece,[3] and the rays from the two stars do not make the same angle with the optical axis of each segment. Thus the two images under measurement are not defined with equal sharpness and symmetry. The second method is free from the objection of non-coincidence in focus of the images, but is more troublesome in practice from the necessity for frequent readjustment of the position of the eye-piece. The third method is the most symmetrical of all, both in observation and reduction; but it was not employed by Bessel, on the ground that it involved the determination of the errors of two screws instead of one. On the other hand it is not necessary to reset the telescope after each reversal of the segments.[4]

When Bessel ordered the Königsberg heliometer, he was anxious to have the segments made to move in cylindrical slides, of which the radius should be equal to the focal length of the object-glass. Fraunhofer, however, did not execute this wish, on the ground that the mechanical difficulties were too great.

M. L. G. Wichmann states (*Königsb. Beobach.* xxx. 4) that Bessel had indicated, by notes in his handbooks, the following points which should be kept in mind in the construction of future heliometers: (1) The segments should move in cylindrical slides;[5] (2) the screw should be protected from dust;[6] (3) the zero of the position circle should not be so liable to change;[7] (4) the distance of the optical centres of the segments should not change in different position angles or otherwise;[8] (5) the points of the micrometer screws should rest on ivory plates;[9] (6) there should be an apparatus for changing the screen.[10]

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Wilhelm Struve, in describing the Pulkowa heliometer,[11] made by Merz in 1839 on the model of Bessel's heliometer, submits the following suggestions for its improvement:[12] (1) to give automatically to the two segments simultaneous equal and opposite movement;[13] and (2) to make the tube of metal instead of wood; to attach the heliometer head firmly to this tube; to place the eye-piece permanently in the axis of the telescope; and to fix a strong cradle on the end of the declination axis, in which the tube, with the attached head and eye-piece, could rotate on its axis.

Both suggestions are important. The first is originally the idea of Dollond; its advantages were overlooked by his son, and it seems to have been quite forgotten till resuggested by Struve. But the method is not available if the separation is to be measured by screws; it is found, in that case, that the direction of the final motion of turning of the screw must always be such as to produce motion of the segment against gravity, otherwise the "loss of time" is apt to be variable. Thus the simple connexion of the two screws by cog-wheels to give them automatic opposite motion is not an available method unless the separation of the segments is independently measured by scales.

Struve's second suggestion has been adopted in nearly all succeeding heliometers. It permits complete rotation of the tube and measurement of all angles in reversed positions of the circle; the handles that move the slides can be brought down to the eye-end, inside the tube, and consequently made to rotate with it; and the position circle may be placed at the end of the cradle next the eye-end where it is convenient of access. Struve also points out that by attaching a fine scale to the focusing slide of the eye-piece, and knowing the coefficient of expansion of the metal tube, the means would be provided for determining the absolute change of the focal length of the object-glass at any time by the simple process of focusing on a double star. This, with a knowledge of the temperature of the screw or scale and its coefficient of expansion, would enable the change of screw-value to be determined at any instant.

It is probable that the Bonn heliometer was in course of construction before these suggestions of Struve were published or discussed, since its construction resembles that of the Königsberg and Pulkowa instruments. Its dimensions are similar to those of the former instrument. Bessel, having been consulted by the celebrated statesman, Sir Robert Peel, on behalf of the Radcliffe trustees, as to what instrument, added to the Radcliffe Observatory, would probably most promote the advancement of astronomy, strongly advised the selection of a heliometer. The order for the instrument was given to the Repsolds in 1840, but "various circumstances, for which the makers are not responsible, contributed to delay the completion of the instrument, which was not delivered before the winter of 1848."[14] The building to receive it was commenced in March 1849 and completed in the end of the same year. This instrument has a superb object-glass of 7½ in. aperture and 126 in. focal length. The makers availed themselves of Bessel's suggestion to make the segments move in cylindrical slides, and of Struve's to have the head attached to a brass tube; the eye-piece is set permanently in the axis, and the whole rotates in a cradle attached to the declination axis. They provided a splendid, rigidly mounted, equatorial stand, fitted with every luxury in the way of slow motion, and scales for measuring the displacement of the segments were read by powerful micrometers from the eye-end.[15] It is somewhat curious that, though Struve's second suggestion was adopted, his first was overlooked by the makers. But it is still more curious that it was not afterwards carried out, for the communication of automatic symmetrical motion to both segments only involves a simple alteration previously described. But, as it came from the hands of the makers in 1849, the Oxford heliometer was incomparably the most powerful and perfect instrument in the world for the highest order of micrometric research. It so remained, unrivalled in every respect, till 1873.

As the transit of Venus of 1874 approached, preparations were set on foot by the German Government in good time; a commission of the most celebrated astronomers was appointed, and it was resolved that the heliometer should be the instrument chiefly relied on. The four long-neglected small heliometers made by Fraunhofer were brought into requisition. Fundamental alterations were made upon them: their wooden tubes were replaced by tubes of metal; means of measuring the focal point were provided; symmetrical motion was given to the slides; scales on each slide were provided instead of screws for measuring the separation of the segments, and both scales were read by the same micrometer microscope;

a metallic thermometer was added to determine the temperature of the scales. These small instruments have since done admirable work in the hands of Schur, Hartwig, Küstner, Elkin, Auwers and others.

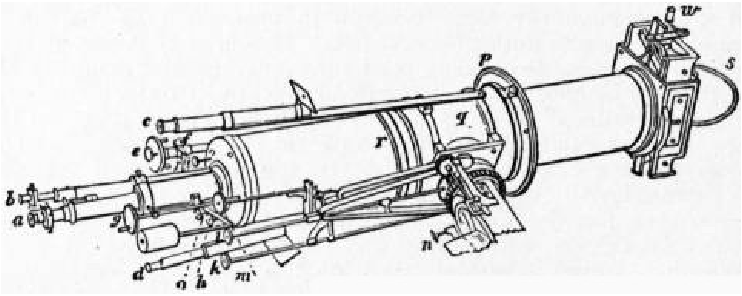


FIG. 9.

The Russian Government ordered three new heliometers (each of 4 in. aperture and 5 ft. focal length) from the Repsolds, and the design for their construction was superintended by Struve, Auwers and Winnecke, the last-named making the necessary experiments at Carlsruhe. Fig. 9 represents the resulting type of instrument which was finally designed and constructed by Repsolds. The brass tube, strengthened at the bearing points by strong truly turned collars, rotates in the cast iron cradle *q* attached to the declination axis, *a* is the eye-piece fixed in the optical axis, *b* the micrometer for reading both scales, *c* and *d* are telescopes for reading the position circle *p*, *e* the handle for quick motion in position angle, *f* the slow motion in position angle, *g* the handle for changing the separation of the segments by acting on the bevel-wheel *g′* (fig. 10). h is a milled head connected by a rod with *h′* (fig. 10), for the purpose of interposing at pleasure the prism π in the axis of the reading micrometer; this enables the observer to view the graduations on the face of the metallic thermometer ττ (composed of a rod of brass and a rod of zinc), *i* is a milled head connected with the wheel *i i* (fig. 10), and affords the means of placing the screen *s* (fig. 9), counterpoised by *w* over either half of the object-glass. *k* clamps the telescope in declination, *n* clamps it in right ascension, and the handles *m* and *l* provide slow motion in declination and right ascension respectively.

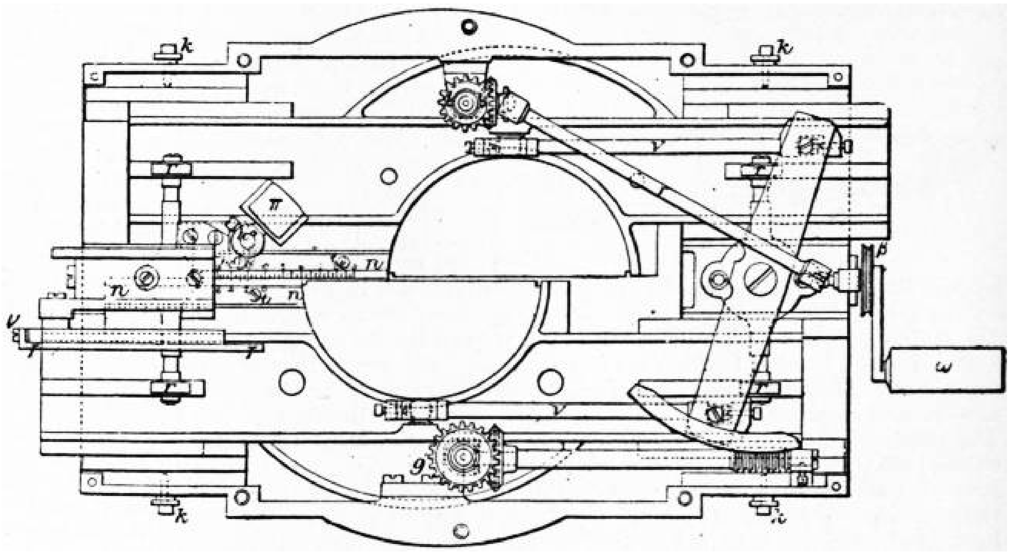


FIG. 10.

The details of the interior mechanism of the "head" will be almost evident from fig. 10 without description. The screw, turned by the wheels at *g′*, acts in a toothed arc, whence, as shown in the figure, equal and opposite motion is communicated to the slides by the jointed rods *v*, *v*. The slides are kept firmly down to their bearings by the rollers *r*, *r*, *r*, *r*, attached to axes which are, in the middle, very strong springs. Side-shake is prevented by the screws and pieces *k*, *k*, *k*, *k*. The scales are at *n*, *n*; they are fastened only at the middle, and are kept down by the brass pieces *t*, *t*.

A similar heliometer was made by the Repsolds to the order of Lord Lindsay for his Mauritius expedition in 1874. It differed only from the three Russian instruments in having a mounting by the Cookes in which the declination circle reads from the eye-end.[16] This instrument was afterwards most generously lent by Lord Lindsay to Gill for his expedition to Ascension in 1877.[17]

These four Repsold heliometers proved to be excellent instruments, easy and convenient in use, and yielding results of very high accuracy in measuring distances. Their slow motion in position angle, however, was not all that could be desired. When small movements were communicated to the handle *e* (fig. 9) by the tangent screw *f*, acting on a small toothed wheel clamped to the rod connected with the driving pinion, there was apt to be a torsion of the rod rather than an immediate action. Thus the slow motion would take place by jerks instead of with the necessary smoothness and certainty. When the heliometer-part of Lord Lindsay’s heliometer was acquired by Gill in 1879, he changed the manner of imparting the motion in question. A square toothed racked wheel was applied to the tube at *r* (fig. 9). This wheel is acted on by a tangent screw whose bearings are attached to the cradle; the screw is turned by means of a handle supported by bearings attached to the cradle, and coming within convenient reach of the observer’s hand. The tube turns smoothly in the racked wheel, or can be clamped to it at the will of the observer. This alteration and the new equatorial mounting have been admirably made by Grubb; the result is completely successful. The instrument so altered was in use at the Cape Observatory from March 1881 till 1887 in determining the parallax of some of the more interesting southern stars. The instrument then passed, by purchase from Gill, to Lord McLaren, by whom it was presented to the Royal Observatory, Edinburgh.

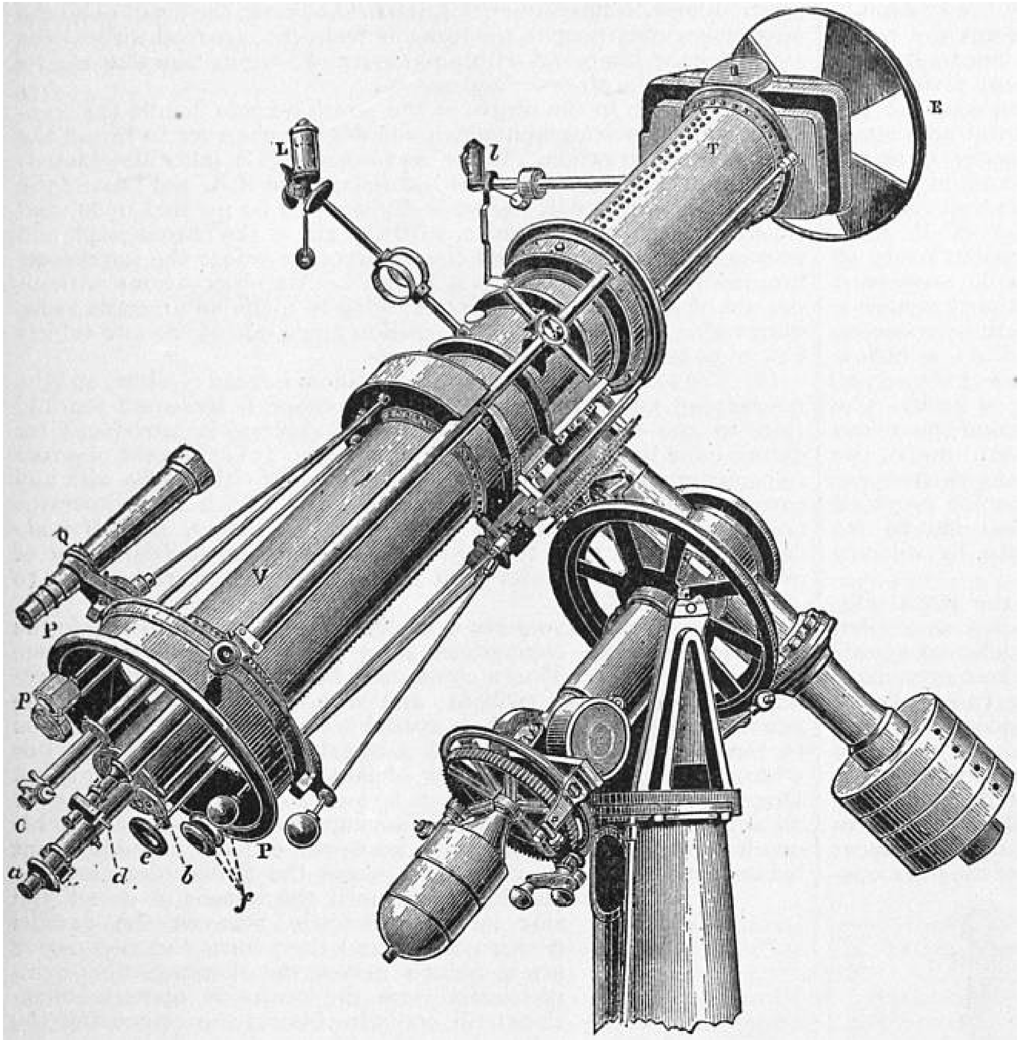


Fig. 11.

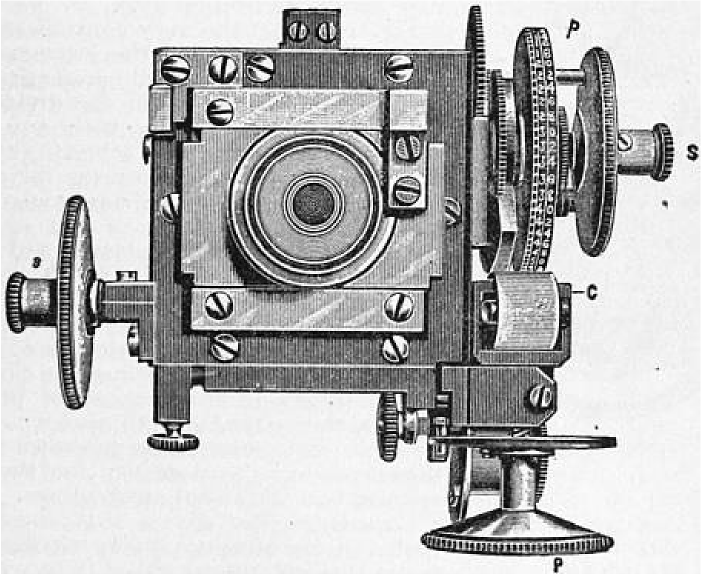


Fig. 12.

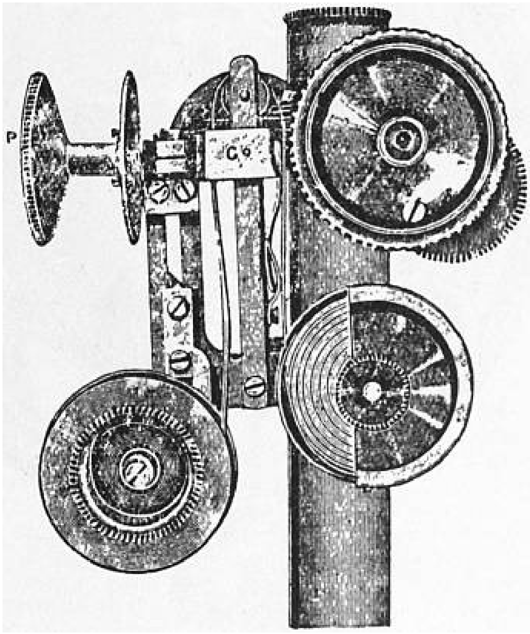


Fig. 13.

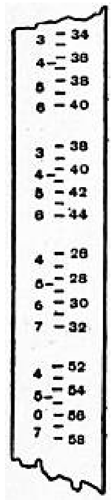
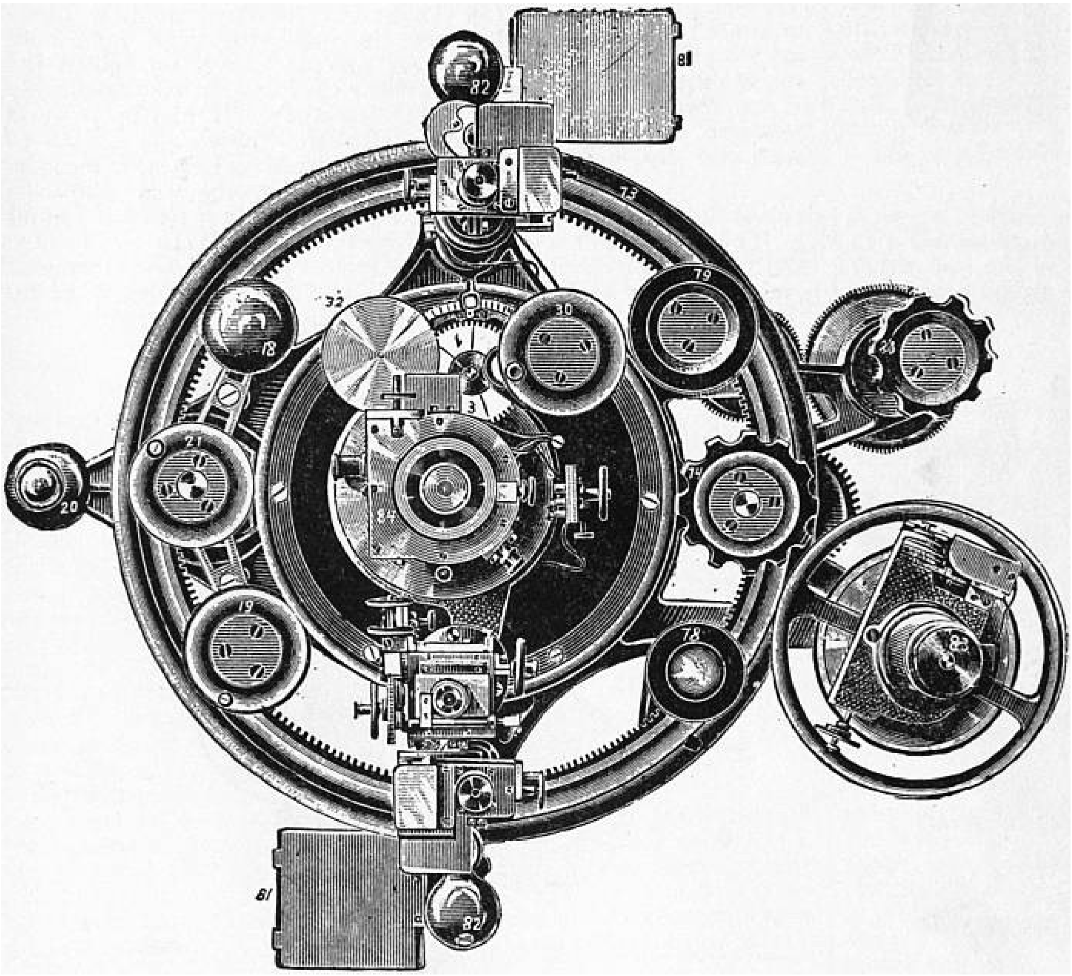


Fig. 14.

Still more recently the Repsolds have completed a new heliometer for Yale College, New Haven, United States. The object-glass is of 6 in. aperture and 98 in. focal length. The mounting, the tube, objective-cell, slides, &c., are all of steel.[18] The instrument is shown in fig. 11. The circles for position angle and declination are read by micrometer-microscopes illuminated by the lamp L; the scales are illuminated by the lamp *l*. T is part of the tube proper, and turns with the head. The tube V, on the contrary, is attached to the cradle, and merely forms a support for the finder Q, the handles at *f* and *p*, and the moving ring P. The latter gives quick motion in position angle; the handles at *p* clamp and give slow motion in position angle, those at *f* clamp and give slow motion in right ascension and declination. *a* is the eye-piece, *b* the handle for moving the segments, *c* the micrometer microscope for reading the scales and scale micrometer, *d* the micrometer readers of the position and declination circles, *e* the handle for rotating the large wheel E which carries the screens. The hour circle is also read by microscopes, and the instrument can be used in both positions (tube preceding and following) for elimination of the effect of flexure on the position angles. Elkin found that the chief drawbacks to speed and convenience in working this heliometer were: (1) The loss of time involved in entering the corresponding readings of the micrometer pointings on two scales. (2) That an additional motion intermediate between the quick and slow motion in position angle was necessary, because, whilst the slow motion provided by Repsolds was admirably adapted for adjusting the pointings in position angle, it was too slow for causing the images to "cross through" each other in the process of measuring distances. To remedy drawback (1) Repsolds devised the form of printing micrometer which is shown in figs. 12

and 13. This micrometer is provided with two pairs of parallel webs. One fixed pair of webs is attached to the micrometer-box, the other pair is moved by the screw S. The whole micrometer-box is moved by the screw attached to the heads. Accordingly, in reading the scales A and B (attached to the slides which carry the two halves of the object-glass), it is only necessary to turn the screws until the fixed double web is pointed symmetrically on one 228
of the divisions of scale A, then to move the other double web by the screw S until it is symmetrically pointed on the adjoining division of scale B. By turning the quick acting screw P (fig. 13) to the right, the cushion C (which is faced with india-rubber) presses the paper ribbon (shown in fig. 13) against the index-edge and type-wheels, and thus the beautifully cut divisions of the micrometer-head, the numbers marking the $^1/_{100}$ parts of the head, the index and the total number of revolutions are all sharply embossed together upon the paper ribbon. Fig. 14 shows the record of several successive paintings on the same scale as that given by the micrometer. The reverse motion of P automatically moves the paper ribbon forward, ready to receive the next impression. It must be mentioned that the pressure of the cushion C on the type-wheels has no influence whatever upon the micrometer-screw, because the type-wheels are mounted on a hollow cylindrical axis, concentric with the axis of the screw, but entirely disconnected from the screw itself. The only connexion between the type-wheel and the screw-head S is by the pin *p* (which is screwed into S), the cylindrical end of which acts in a slot cut in the type-wheel. To remedy drawback (2) Repsolds provided for the Yale heliometer an additional handle for motion in position angle, intermediate in velocity between the original quick and slow motions.



From *Engineering*, vol. xlix.

Fig. 15.

In the 7-in. heliometer, completed in 1887 for the Royal Observatory at the Cape of Good Hope, Repsolds, on Gill’s suggestion, introduced the following improvements: (*a*) Four different speeds of motion in position angle were provided. The quickest movement is given by the hand-ring, 73 (fig. 15). This ring runs between friction wheels and is provided with teeth on its inner periphery, and these teeth transmit motion to a pinion on a spindle having at its other end another pinion which, through an intermediate wheel, rotates the heliometer tube. The transmission spindle, just mentioned, carries at its end a head, 74, which, if turned directly, gives the second speed. The slowest speed is given by means of a tangent screw which is carried by a ball-bearing on the flange of the telescope-sleeve, whilst its nut is double-jointed to a ring that encircles the flange of the heliometer-tube. This ring is provided with a clamping screw, which, through the intervention of bevel-gear and rods, is operated by means of the hand-wheel 78. With similar bevel-gear and rods the tangent screw is connected to the hand-wheel, 79, by which the observer communicates the fourth or slowest motion in position angle. Finally the hand-wheel 80 is connected by gearing to the rod carrying the hand-wheel 79, and it can thus be used to give the latter a more rapid motion than if used direct; this constitutes the third speed of movement.

(*b*) In lieu of oil-lamps, small, conveniently placed incandescent electric 6-volt lamps are employed; and these are fitted with suitable switches and variable resistances. Thus the scales, the position- and declination-circles, the field of view, the heads of all the micrometer-microscopes, the focusing scale, &c., are read without the aid of a hand-lamp and with an amount of illumination that can be regulated at the observer's pleasure.

(*c*) A button in the centre of the position-angle handle (74) connects with a chronograph which enables the observer to record the instant of observation. Little card-holders (81) (also illuminated) enable the astronomer to enter beforehand the R.A. and Dec. of the object to be observed, the scale divisions to be pointed upon, and thus, in measures of distance, with the aid of the chronograph and printing micrometer, enable the observer to adjust the instrument for observation and obtain a record of his observations without the aid of a hand-lamp or the necessity to make any records in his notebook. In observations of position angle one of the two tablets 81 can be used to record the readings.

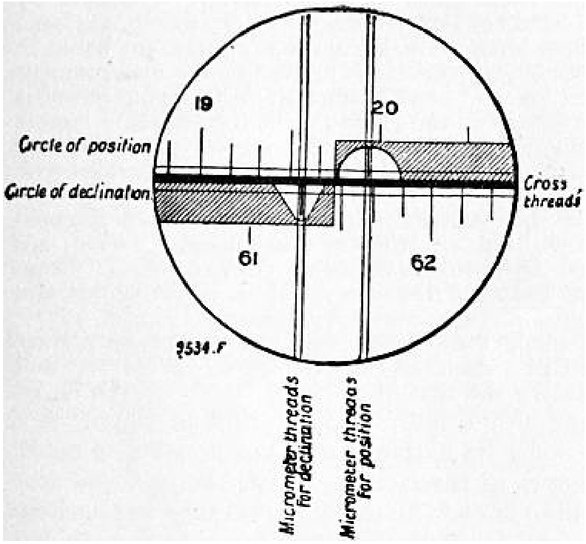
(*d*) The scales are made of iridio-platinum instead of silver, and the magnifying power of the reading microscope is increased fourfold (viz. to 100 diameters). A special microscope is introduced for determining the division errors of the scales. It enables the observer to compare any division-interval on one half of either scale with any corresponding interval on the other scale. With this apparatus Gill was enabled (*Annals Cape Obs.* vii. 29-42, and *Monthly Notices, R.A.S.*, xlix. 105-115) to determine the division error of every line on both scales with a probable error corresponding to ± 0″.0092 arc.

(*e*) A position-micrometer is attached to the finder to enable the observer to select comparison stars for observation with some unexpected object. Thus a comet may be encountered in the morning dawn or evening twilight, and without such an adjunct the astronomer may lose the whole available opportunity for observation in the vain endeavour to find a suitable comparison-star. But with such a position-micrometer of large field he has no difficulty. Directing the finder to the comet, he has at once in the field of view all available comparison stars. Having selected the most suitable one he directs the axis of the finder to the estimated middle point between the comet and the star, turns the finder-micrometer in position angle until the images of comet and star lie symmetrically between the parallel position wires, and then turns the micrometer screw (which moves the distance-wires symmetrically from the centre in opposite directions) till one wire bisects the comet and the other the star. The reading of the position-circle of the finder is then the reading to which the position-circle of the heliometer should be set, and from the readings of the micrometer-screw he finds, by a convenient table, the proper settings of the heliometer scales in distance. When the scales and position-circle of the heliometer have been set to these readings, the comet and the selected comparison-star appear together in the field of view.

Fig. 15 shows the very convenient arrangement of the eye-end of the instrument. The disk, 30 with its small projecting handle enables the 2 segments of the divided object to be moved rapidly or with any required delicacy relative to each other. The disk 32 operates the wire gauze screens for equalizing the brightness of the two stars under observation. The dial between 30 and 32 indicates the screen in use. 18 clamps and 19 gives slow motion in declination; 20 clamps and 21 gives slow motion in right ascension. The two handles 82 serve for manipulating the instrument. The microscopes adjoining 82 read the position and declination circles; for, by an ingenious arrangement of prisms and screens, the images of both circles can be read by each single microscope as shown in fig. 16, thus avoiding the necessity for the employment of two additional micrometers.

Experience has shown that there is little that can be advantageously changed to improve this instrument either in convenience or precision of working. A series of observations can be easily and more accurately accomplished with the Cape heliometer in half an hour; with the Oxford heliometer it would occupy 2 hours, and with the 4 in. Repsold heliometer (fig. 9) 1 hour. Heliometers of 6 to 8 in. aperture have subsequently been constructed by Repsolds on these plans for Göttingen, Bamberg, Leipzig and the Kuffner Observatory (near Vienna), and all of them have made important contributions to astronomy of precision.

Heliometer observations of distance in their most refined sense cannot be considered absolute measures of angles. Essentially the scale-value of the instrument depends on the relation of the focal length of the object-glass to the length of the unit of the scale. But *the eye is tolerant of small changes in the focal adjustment which sensibly affect the scale-value*. These changes may and do arise from the following causes: (i.) The focal length of the object-glass and the length of the tube are affected by temperature. (ii.) The focal length is sensibly different for objects of different colour. (iii.) The length of the scale is affected by temperature. (iv.) The state of adaptation of the observer’s eye is dependent on his state of health, on a condition of greater or less fatigue, or on the inclination of the head in consequence of the altitude of the object observed. (v.) The temperature of the object-glass, of the scale and of the tube, cannot be assumed to be identical.



From *Engineering*, vol. xlix.

Fig. 16.

Thus, for refined purposes, it cannot be assumed with any certainty that the instantaneous scale-value of the heliometer is known, or that it is a function of the temperature. Of course, for many purposes, mean conditions may be adopted and mean scale-values be found which are applicable with considerable precision to small angles or to comparatively crude observations of large distances; but the highest refinement is lost unless means are provided for determining the scale-value for each observer at each epoch of observation.

In determinations of stellar or solar parallax, comparison stars, symmetrically situated with respect to the object whose parallax is sought, should be employed, in which case the instantaneous scale-value may be regarded as an unknown quantity which can be derived in the process of the computation of the results. Examples of this mode of procedure will be found, in the case of stellar parallax in the *Mem. R.A.S.* vol. xlviii. pp. 1-194, and in the *Annals of the Cape Observatory*, vol. viii. parts 1 and 2; and in the case of planetary parallax in the *Mem. R.A.S.* vol. xlvi. pp. 1-171, and in the *Annals of the Cape Observatory*, vol. vi. In other operations, such as the triangulation of large groups of stars, it is necessary to select a pair of standard stars, if possible near the middle of the group, and to determine the scale-value by measures of this standard distance at frequent intervals during the night (see *Annals of the Cape Observatory*, vol. vi. pp. 3-224). In other cases, such as the measurement of the mutual distances and position angles of the satellites of Jupiter, for derivation of the elements of the orbits of the satellites and the mass of Jupiter, reference must also be made to measures of standard stars whose relative distance and position angle is accurately determined by independent methods (see *Annals of the Cape Observatory*, vol. xii. part 2).

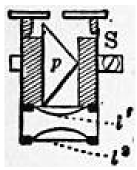


Fig. 17.

Gill introduced a powerful auxiliary to the accuracy of heliometer measures in the shape of a reversing prism placed in front of the eye-piece, between the latter and the observer’s eye. If measures are made by placing the image of a star in the centre of the disk of a planet, the observer may have a tendency to do so systematically in error from some acquired habit or from natural astigmatism of the eye. But by rotating the prism 90° the image is presented entirely reversed to the eye, so that in the mean of measures made in two such positions personal error is eliminated. Similarly the prism may be used for the study and elimination of personal errors depending on the angle made by a double star with the vertical. The best plan of mounting such a prism has been found to be the following. l^1, l^2 (fig. 17) are the eye lens and field lens respectively of a Merz positive eye-piece. In this construction the lenses are much closer together and the diaphragm for the eye is much farther from the lenses than in Ramsden’s eye-piece. The prism *p* is fitted accurately into brass slides (care has to be taken in the construction to place the prism so that an object in the centre of the field will so remain when the eye-piece is rotated in its adapter). There is a collar, clamped by the screw at S, which is so adjusted that the eye-piece is in focus when pushed home, in its adapter, to this collar. The prism and eye-piece are then rotated together in the adapter.

The Double Image Micrometer.—Thomas Clausen in 1841 (*Ast. Nach.* No. 414) proposed a form of micrometer consisting of a divided plate of parallel glass placed within the cone of rays from the object-glass at right angles to the telescope axis. One-half of this plane remains fixed, the other half is movable. When the inclination of the movable half with respect to the axis of the telescope is changed by rotation about an axis at right angles to the plane of division, two images are produced. The amount of separation is very small, and depends on the thickness of the glass, the index of refraction and the focal length of the telescope. Angelo Secchi (*Comptes rendus*, xli., 1855, p. 906) gives an account of some experiments with a similar micrometer; and Ignarjio Porro (*Comptes rendus*, xli. p. 1058) claims the original invention and construction of such a micrometer in 1842. Clausen, however, has undoubted priority. Helmholtz in his "Ophthalmometer" has employed Clausen's principle, but arranges the plates so that both move symmetrically in opposite directions with respect to the telescope axis. Should Clausen's micrometer be employed as an astronomical instrument, it would be well to adopt the improvement of Helmholtz.

Double-Image Micrometers with Divided Lenses.—Various micrometers have been invented besides the heliometer for measuring by double image. Ramsden's dioptric micrometer consists of a divided lens placed in the conjugate focus of the innermost lens of the erecting eye-tube of a terrestrial telescope. The inventor claimed that it would supersede the heliometer, but it has never done anything for astronomy. Dollond claims the independent invention and first construction of a similar instrument (Pearson's *Practical Astronomy*, ii. 182). Of these and kindred instruments only two types have proved of practical value. G. B. Amici of Modena (*Mem. Soc. Ital.* xvii., 1815, pp. 344-359) describes a micrometer in which a negative lens is introduced between the eye-piece and the object-glass. This lens is divided and mounted like a heliometer object-glass; the separation of the lenses produces the required double image, and is measured by a screw. W. R. Dawes very successfully used this micrometer in conjunction with a filar micrometer, and found that the precision of the measures was in this way greatly increased (*Monthly Notices*, vol. xviii. p. 58, and *Mem. R.A.S.* vol. xxxv. p. 147).

In the improved form[19] of Airy's divided eye-glass micrometer (*Mem. R.A.S.* vol. xv. pp. 199-209) the rays from the object-glass pass successively through lenses as follows:

Lens.	Distance from next Lens.	Focal Length.
a. An equiconvex lens	*p*	arbitrary = *p*
b. " "	2	5
c. Plano-convex, convex towards *b*	$1\frac{3}{4}$	1
d. Plano-convex, convex towards *c*	"	1

The lens *b* is divided, and one of the segments is moved by a micrometer screw. The magnifying power is varied by changing the lens a for another in which *p* has a different value. The magnifying power of the eye-piece is that of a single lens of focus = $\frac{4}{5}p$.

In 1850 J. B. Valz pointed out that the other optical conditions could be equally satisfied if the divided lens were made concave instead of convex, with the advantage of giving a larger field of view (*Monthly Notices*, vol. x. p. 160).

The last improvement on this instrument is mentioned in the *Report* of the R.A.S. council, February 1865. It consists in the introduction by Simms of a fifth lens, but no satisfactory description has ever appeared. There is only one practical published investigation of Airy's micrometer that is worthy of mention, viz. that of F. Kaiser (*Annalen der Sternwarte in Leiden*, iii. 111-274). The reader is referred to that paper for an exhaustive history and discussion of the instrument.[20] It is somewhat surprising that, after Kaiser's investigations, observers should continue, as many have done, to discuss their observations with this instrument as if the screw-value were constant for all angles.

Steinheil (*Journal savant de Munich*, Feb. 28, 1843) describes a "heliomètre-oculaire" 230
which he made for the great Pulkowa refractor, the result of consultations between himself and the elder Struve. It is essentially the same in principle as Amici's micrometer, except that the divided lens is an achromatic positive instead of a negative lens. Struve (*Description de l'Observatoire Central de Pulkowa*, pp. 196, 197) adds a few remarks to Steinheil's description, in which he states that the images have not all desirable precision—a fault perhaps inevitable in all micrometers with divided lenses, and which is probably in this case aggravated by the fact that the rays falling upon the divided lens have considerable convergence. He, however, successfully employed the instrument in measuring double stars, so close as 1″ or 2″, and using a power of 300 diameters, with results that agreed satisfactorily amongst themselves and with those obtained with the filar micrometer. If Struve had employed a properly proportioned double circular diaphragm, fixed symmetrically with the axis of the telescope in front of the divided lens and turning with the micrometer, it is probable that his report on the instrument would have been still more favourable. This particular instrument has historical interest, having led Struve to some of

those criticisms of the Pulkowa heliometer which ultimately bore such valuable fruit (see *ante*).

Ramsden (*Phil. Trans.* vol. xix. p. 419) suggested the division of the small speculum of a Cassegrain telescope and the production of double image by micrometric rotation of the semispecula in the plane passing through their axis. Brewster (*Ency. Brit.* 8th ed. vol. xiv. p. 749) proposed a plan on a like principle, by dividing the plane mirror of a Newtonian telescope. Again, in an ocular heliometer by Steinheil double image is similarly produced by a divided prism of total reflection placed in parallel rays. But practically these last three methods are failures. In the last the field is full of false light, and it is not possible to give sufficiently minute and steady separation to the images; and there are of necessity a collimator, two prisms of total reflection, and a small telescope through which the rays must pass; consequently there is great loss of light.

Micrometers Depending on Double Refraction.—To the Abbé Rochon (*Jour. de phys.* liii., 1801, pp. 169-198) is due the happy idea of applying the two images formed by double refraction to the construction of a micrometer. He fell upon a most ingenious plan of doubling the amount of double refraction of a prism by using two prisms of rock-crystal, so cut out of the solid as to give each the same quantity of double refraction, and yet to double the quantity in the effect produced. The combination so formed is known as Rochon’s prism. Such a prism he placed between the object-glass and eye-piece of a telescope. The separation of the images increases as the prism is approached to the object-glass, and diminishes as it is approached towards the eye-piece.

D. F. J. Arago (*Comptes rendus*, xxiv., 1847, pp. 400-402) found that in Rochon’s micrometer, when the prism was approached close to the eye-piece for the measurement of very small angles, the smallest imperfections in the crystal or its surfaces were inconveniently magnified. He therefore selected for any particular measurement such a Rochon prism as when fixed between the eye and the eye-piece (*i.e.* where a sunshade is usually placed) would, combined with the normal eye-piece employed, bring the images about to be measured nearly in contact. He then altered the magnifying power by sliding the field lens of the eye-piece (which was fitted with a slipping tube for the purpose) along the eye-tube, till the images were brought into contact. By a scale attached to the sliding tube the magnifying power of the eye-piece was deduced, and this combined with the angle of the prism employed gave the angle measured. If p'' is the refracting angle of the prism, and n the magnifying power of the eye-piece, then p''/n will be the distance observed. Arago made many measures of the diameters of the planets with such a micrometer.

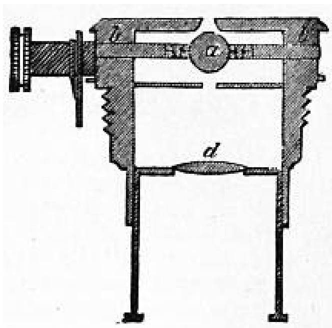


Fig. 18.

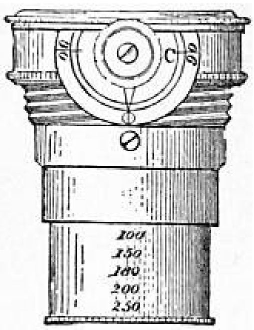


Fig. 19.

Dollond (*Phil. Trans.*, 1821, pp. 101-103) describes a double-image micrometer of his own invention, in which a sphere of rock-crystal is substituted for the eye-lens of an ordinary eye-piece. In this instrument (figs. 18, 19) *a* is the sphere, placed in half-holes on the axis *bb*, so that when its principal axis is parallel to the axis of the telescope it gives only one image of the object. In a direction perpendicular to that axis it must be so placed that when it is moved by rotation of the axis *bb* the separation of the images shall be parallel to that motion. The angle of rotation is measured on the graduated circle C. The angle between the objects measured is = $r \sin 2\theta$, where r is a constant to be determined for each magnifying power employed,[21] and θ the angle through which the sphere has been turned from zero (*i.e.* from coincidence of its principal axis with that of the telescope). The maximum separation is consequently at 45° from zero. The measures can be made on both sides of zero for eliminating index error. There are considerable difficulties of construction, but these have been successfully overcome by Dollond; and in the hands of Dawes (*Mem. R.A.S.* xxxv. p. 144 seq.) such instruments have done valuable service. They are liable to the objection that their employment is limited to the measurement of very small angles, viz. 13″ or 14″ when the magnifying power is 100, and varying inversely as the power. Yet the beautiful images which these micrometers give permit the measurement of very difficult objects as a check on measures with the parallel-wire micrometer.

On the theory of the heliometer and its use consult Bessel, *Astronomische Untersuchungen*, vol. i.; Hansen, *Ausführliche Methode mit dem Fraunhoferschen Heliometer anzustellen* (Gotha, 1827); Chauvenet, *Spherical and Practical Astronomy*, vol. ii. (Philadelphia and London, 1876); Seeliger, *Theorie des Heliometers* (Leipzig, 1877); Lindsay and Gill, *Dunecht Publications*, vol. ii. (Dunecht, for private circulation, 1877); Gill, *Mem. R.A.S.* vol. xlvi. pp. 1-172, and references mentioned in the text.

(D. Gi.)

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1 The circles by Reichenbach, then almost exclusively used in Germany, were read by verniers only.

2 The diameter of Venus was measured with one of these heliometers at the observatory of Breslau by Brandes in 1820 (*Berlin Jahrbuch*, 1824, p. 164).

3 The distances of the optical centres of the segments from the eye-piece are in this method as 1; secant of the angle under measurement. In Bessel's heliometer this would amount to a difference of $^{15}/_{1000}$th of an inch when an angle of 1° is measured. For 2° the difference would amount to nearly $^{1}/_{10}$th of an inch. Bessel confined his measures to distances considerably less than 1°.

4 In criticizing Bessel's choice of methods, and considering the loss of time involved in each, it must be remembered that Fraunhofer provided no means of reading the screws or even the heads from the eye-end. Bessel's practice was to unclamp in declination, lower and read off the head, and then restore the telescope to its former declination reading, the clockwork meanwhile following the stars in right ascension. The setting of both lenses symmetrically would, under such circumstances, be very tedious.

5 This most important improvement would permit any two stars under measurement each to be viewed in the optical axis of each segment. The optical centres of the segments would also remain at the same distance from the eye-piece at all angles of separation. Thus, in measuring the largest as well as the smallest angles, the images of both stars would be equally symmetrical and equally well in focus. Modern heliometers made with cylindrical slides measure angles over 2°, the images remaining as sharp and perfect as when the smallest angles are measured.

6 Bessel found, in course of time, that the original corrections for the errors of his screw were no longer applicable. He considered that the changes were due to wear, which would be much lessened if the screws were protected from dust.

7 The tube, being of wood, was probably liable to warp and twist in a very uncertain way.

8 We have been unable to find any published drawing showing how the segments are fitted in their cells.

9 We have been unable to ascertain the reasons which led Bessel to choose *ivory* planes for the end-bearings of his screws. He actually introduced them in the Königsberg heliometer in 1840, and they were renewed in 1848 and 1850.

10 A screen of wire gauze, placed in front of the segment through which the fainter star is viewed, was employed by Bessel to equalize the brilliancy of the images under observation. An arrangement, afterwards described, has been fitted in modern heliometers for placing the screen in front of either segment by a handle at the eye-end.

11 This heliometer resembles Bessel's, except that its foot is a solid block of granite instead of the ill-conceived wooden structure that supported his instrument. The object-glass is of 7.4 in. aperture and 123 in. focus.

12 *Description de l'observatoire central de Pulkowa*, p. 208.

13 Steinheil applied such motion to a double-image micrometer made for Struve. This instrument suggested to Struve the above-mentioned idea of employing a similar motion for the heliometer.

14 Manuel Johnson, M.A., Radcliffe observer, *Astronomical Observations made at the Radcliffe Observatory, Oxford, in the Year 1850*, Introduction, p. iii.

15 The illumination of these scales is interesting as being the first application of electricity to the illumination of astronomical instruments. Thin platinum wire was rendered incandescent by a voltaic current; a small incandescent electric lamp would now be found more satisfactory.

16 For a detailed description of this instrument see *Dunecht Publications*, vol. ii.

17 *Mem. Royal Astronomical Society*, xlvi., 1-172.

18 The primary object was to have the object-glass mounted in steel cells, which more nearly correspond in expansion with glass. It became then desirable to make the head of steel for sake of uniformity of material, and the advantages of steel in lightness and rigidity for the tube then became evident.

19 For description of the earliest form see *Cambridge Phil. Trans.* vol. ii., and *Greenwich Observations* (1840).

20 Dawes (*Monthly Notices*, January 1858, and *Mem. R.A.S.* vol. xxxv. p. 150) suggested and used a valuable improvement for producing round images, instead of the elongated images which are otherwise inevitable when the rays pass through a divided lens of which the optical centres are not in coincidence, viz. "the introduction of a diaphragm having two circular apertures touching each other in a point coinciding with the line of collimation of the telescope, and the diameter of each aperture *exactly equal* to the semidiameter of the cone of rays at the distance of the diaphragm from the local point of the object-glass." Practically the difficulty of making these diaphragms for the different powers of the *exact* required equality is insuperable; but, if the observer is content to lose a certain amount of light, we see no reason why they may not readily be made slightly less. Dawes found the best method for the purpose in question was to limit the aperture of the object-glass by a diaphragm having a double circular aperture, placing the line joining the centres of the circles approximately in the position angle under measurement. Dawes successfully employed the double circular aperture also with Amici's micrometer. The present writer has successfully used a similar plan in measuring position angles of a Centauri with the heliometer, viz. by placing circular diaphragms on the two segments of the object-glass.

21 Dollond provides for changing the power by sliding the lens d nearer to or farther from *a*.

HELIOPOLIS, one of the most ancient cities of Egypt, met with in the Bible under its native name On. It stood 5 m. E. of the Nile at the apex of the Delta. It was the principal seat of sun-worship, and in historic times its importance was entirely religious. There appear to have been two forms of the sun-god at Heliopolis in the New Kingdom—namely, Ra-Harakht, or Rē'-Harmakhis, falcon-headed, and Etōm, human-headed; the former was the sun in his mid-day strength, the latter the evening sun. A sacred bull was worshipped here under the name Mnevis (Eg. *Mreu*), and was especially connected with Etōm. The sun-god Rē' (see Egypt: *Religion*) was especially the royal god, the ancestor of all the Pharaohs, who therefore held the temple of Heliopolis in great honour. Each dynasty might give the first place to the god of its residence—Ptah of Memphis, Ammon of Thebes, Neith of Sais, Bubastis of Bubastis, but all alike honoured Rē'. His temple became in a special degree a depository for royal records, and Herodotus states that the priests of Heliopolis were the best informed in matters of history of all the Egyptians. The schools of philosophy and astronomy are said to have been frequented by Plato and other Greek philosophers; Strabo, however, found them deserted, and the town itself almost uninhabited, although priests were still there, and cicerones for the curious traveller. The Ptolemies probably took little interest in their "father" Rē', and Alexandria had eclipsed the learning of Heliopolis; thus with the withdrawal of royal favour Heliopolis quickly dwindled, and the students of native lore deserted it for other temples supported by a wealthy population of pious citizens. In Roman times obelisks were taken from its temples to adorn the northern cities of the Delta, and even across the Mediterranean to Rome. Finally the growth of Fostat and Cairo, only 6 m. to the S.W., caused the ruins to be ransacked for building materials. The site was known to the Arabs as *'Ayin esh shems*, "the fountain of the sun," more recently as Tel Hisn. It has now been brought for the most part under cultivation, but the ancient city walls of crude brick are to be seen in the fields on all sides, and the position of the great temple is marked by an obelisk still standing (the earliest known, being one of a pair set up by Senwosri I., the second king of the Twelfth Dynasty) and a few granite blocks bearing the name of Rameses II.

See Strabo xvii. cap. 1. 27-28; Baedeker's *Egypt*.

(F. Ll. G.)

HELIOSTAT (from Gr. ἥλιος, the sun, στατός, fixed, set up), an instrument which will reflect the rays of the sun in a fixed direction notwithstanding the motion of the sun. The optical apparatus generally consists of a mirror mounted on an axis parallel to the axis of the earth, and rotated with the same angular velocity as the sun. This construction assumes that the sun describes daily a small circle about the pole of the celestial sphere, and ignores any diurnal variation in the declination. This variation is, however, so small that it can be neglected for most purposes.

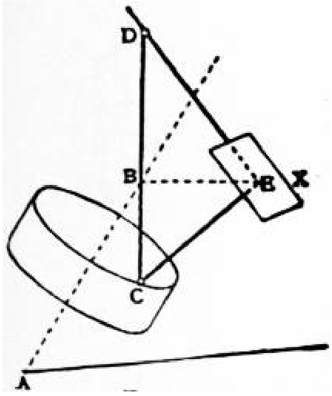


Fig. 1.

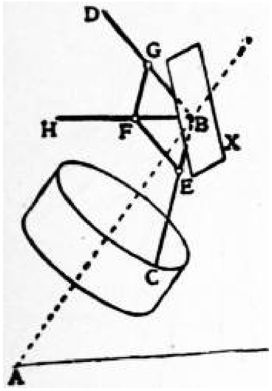
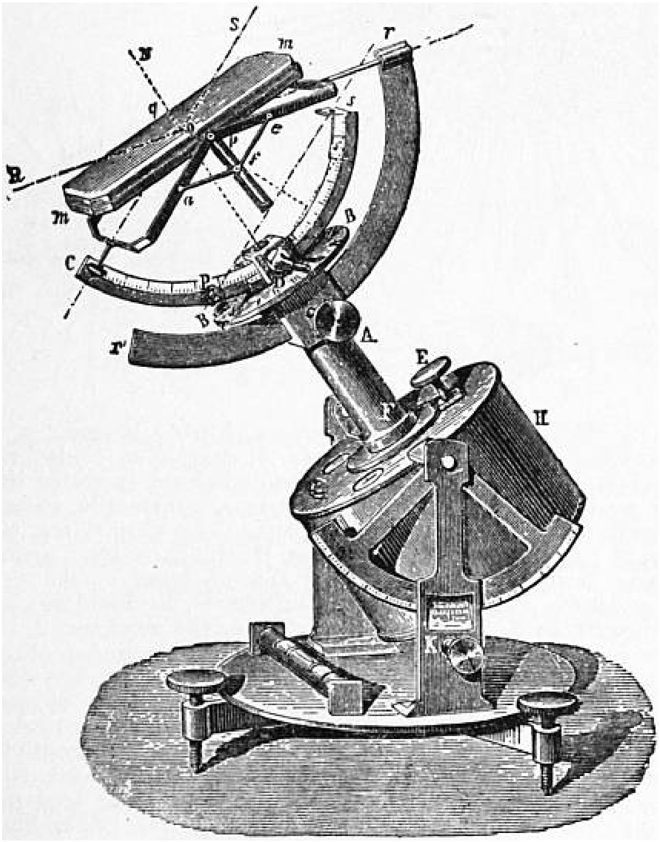


Fig. 2.



From Jamin and Bouty, *Cours de physique*, Gauthier-Villars.
Fig. 3.—Silbermann's Heliostat.

Many forms of heliostats have been devised, the earliest having been described by Wilhelm Jacob s' Gravesande in the 3rd edition of his *Physices elementa* (1742). One of the simplest consists of a plane mirror rigidly connected with a revolving axis so that the angle between the normal to the mirror and the axis of the instrument equals half the sun's polar distance, the mirror being adjusted so that the normal has the same right ascension as the sun. It is easily seen that if the mirror be rotated at the same angular velocity as the sun the right ascensions will remain equal throughout the day, and therefore this device reflects the rays in the direction of the earth's axis; a second fixed mirror reflects them in any other fixed direction. Foucault's heliostat reflects the rays horizontally in any required direction. The principle of the apparatus may be explained by reference to fig. 1. The axis of rotation AB bears a rigidly attached rod DBC inclined to it at an angle equal to the sun's polar distance. By adjusting the right ascension of the plane ABC and rotating the axis with the angular velocity of the sun, it follows that BC will be the direction of the solar rays throughout the day. X is the mirror rotating about the point E, and placed so that (if EB is the horizontal direction in which the rays are to be reflected) (1) the normal CE to the mirror is jointed to BC at C and is equal in length to BE, (2) the rod DBC passes through a slot in a rod ED fixed to, and in the plane of, the mirror. Since CE equals BE these directions are equally inclined to, and coplanar with, the normal to the mirror. Hence light incident along the direction BC will be reflected along CE. Silbermann's heliostat reflects the rays in any direction. The principle may be explained by means of fig. 2. AB is the axis of rotation, BC an adjustable rod as in Foucault's construction, and BD is another rod which can be set to the direction in which the rays are to be reflected. The rods BC and DB carry two small rods EF, GF jointed at F; at this joint there is a pin which slides in a slot on the rod BH, which is normal to the mirror X. The rods EF, GF are such that BEFG is a rhombus. It is easy to show that rays falling on the mirror in the direction BC will be reflected along BD. One construction of the instrument, described in Jamin’s *Cours de physique*, is shown in fig. 3. The mirror *mm* is attached to the framework *pafe*, the members of which are parallel to the incident and reflected rays SO, OR, and the diagonal *pf* is perpendicular to the mirror. The framework is attached to two independent circular arcs C*s* and *rr*ʹ having their centres at O and provided with clamps D and A on the axis F of the instrument. The arc C*s* is graduated, and is set so that the angle COD equals the complement of the sun’s declination. This can be effected (after setting the axis) by rotating C*s* until a needle indicates true time on the hour dial B. The arc *rr*ʹ is set so as to reflect the rays in the required direction. The axis F of the instrument is set at an angle equal to the latitude of the place of observation and in the meridian by means of the screw K, and rotated by clockwork contained in the barrel H. The setting in the meridian is effected by turning the instrument after setting for latitude until a pin-hole aperture s and a small screen P, placed so that Ps is parallel to CO, are in a line with the sun.

Many other forms of heliostats have been designed, the chief difference consisting in the mechanical devices for maintaining the constant direction of the reflecting ray. One of the most important applications of the heliostat is as an adjunct to the newer forms of horizontal telescopes (*q.v.*) and in conjunction with spectroscopic telescopes in observations of eclipses.

HELIOTROPE, or Turnsole, *Heliotropium* (Gr. ἡλιοτρόπιον, *i.e.* a plant which follows the sun with its flowers or leaves, or, according to Theophrastus (*Hist, plant,* vii. 15), which flowers at the summer solstice), a genus of usually more or less hairy herbs or undershrubs of the tribe *Heliotropieae* of the natural order Boraginaceae, having alternate, rarely almost opposite leaves; small white, lilac or blue flowers, in terminal or lateral one-sided simple or once or twice forked spikes, with a calyx of five deeply divided segments, a salver-shaped, hypogynous, 5-lobed corolla, and entire 4-celled ovary; fruit 2- to 4-sulcate or lobed, at length separable into four 1-seeded nutlets or into two hard 2-celled carpels. The genus contains 220 species indigenous in the temperate and warmer parts of both hemispheres. A few species are natives of Europe, as *H. europaeum*, which is also a naturalized species in the southern parts of North America.

Heliotropium suaveolens.

The common heliotrope of English hothouses, *H. peruvianum*, popularly known as “cherry-pie,” is on account of the delicious odour of its flowers a great favourite with florists. It was introduced into Europe by the younger Jussieu, who sent seed of it from Peru to the royal garden at Paris. About the year 1757 it was grown in England by Philip Miller from seed obtained from St Germains. *H. corymbosum* (also a native of Peru), which was grown in Hammersmith nurseries as early as 1812, has larger but less fragant flowers than *H. peruvianum*. The species commonly grown in Russian gardens is *H. suaveolens*, which has white, highly fragrant flowers.

Heliotropes may be propagated either from seed, or, as commonly, by means of cuttings of young growths taken an inch or two in length. Cuttings when sufficiently ripened, are struck in spring or during the summer months; when rooted they should be potted singly into small pots, using as a compost fibry loam, sandy peat and well-decomposed stable manure from an old hotbed. The plants soon require to be shifted into a pot a size larger. To secure early-flowering plants, cuttings should be struck in August, potted off before winter sets in, and kept in a warm greenhouse. In the spring larger pots should be given, and the plants shortened back to make them bushy. They require frequent shiftings during the summer, to induce them to bloom freely.

The heliotrope makes an elegant standard. The plants must in this case be allowed to send up a central shoot, and all the side growths must be pinched off until the necessary height is reached, when the shoot must be stopped and lateral growths will be produced to form the head. During winter they should be kept somewhat dry, and in spring the ball of soil should be reduced and the plants repotted, the shoots being slightly pruned, so as to maintain a symmetrical head. When they are planted out against the walls and pillars of the greenhouse or conservatory an abundance of highly perfumed blossoms will be supplied all the year round. From the end of May till October heliotropes are excellent for massing in beds in the open air by themselves or with other plants. Many florists' varieties of the common heliotrope are known in cultivation.

Pliny (*Nat. hist.* xxii. 29) distinguishes two kinds of "heliotropium," the *tricoccum*, and a somewhat taller plant, the *helioscopium*; the former, it has been supposed, is *Croton tinctorium*, and the latter the ἡλιοτρόπιον μικρόν of Dioscorides or *Heliotropium europaeum*. The helioscopium, according to Pliny, was variously employed in medicine; thus the juice of the leaves with salt served for the removal of warts, whence the term *herba verrucaria* applied to the plant. What, from the perfume of its flowers, is sometimes called winter heliotrope, is the fragrant butterbur, or sweet-scented coltsfoot, *Petasites* (*Tussilago*) *fragrans*, a perennial Composite plant.

Heliotrope, in mineralogy, is the mineral commonly called "bloodstone" (*q.v.*), and sometimes termed girasol—a name applied also to fire-opal. The name, like those of many ancient names of minerals, seems to have had a fanciful origin. According to Pliny the stone was so called because when thrown into the water it turned the sun's light falling upon it into a reflection like that of blood.

HELIOZOA, in zoology, a group of the Sarcodina (*q.v.*) so named by E. Haeckel, 1866. They are characterized by the radiate pseudopods, finely tapering at the apex, springing abruptly from the superficial protoplasm, containing a denser, rather permanent axial rod (figs. 1 (1), 2 (2)); protoplasm without a clear ectoplasm or pellicle, often frothy with large vacuoles, like the alveoli of Radiolaria; nucleus 1 or numerous; skeleton absent, gelatinous or of separate siliceous fibres, plates or spicules, rarely complete and latticed; reproduction by simple fission or by brood-formation, often syngamous; form usually nearly spherical, rarely changing slowly. This group was formerly included with the Rhizopoda; but was separated from it by Haeckel on account of the character of its pseudopods, and its general adaptation to a semipelagic existence correlated with the frothy cytoplasm (fig. 1 (1)). *Actinophrys sol* and *Actinosphaerium eichhornii* (fig. 2), known as sun animalcules to the older microscopists, float freely in stagnant or slow-flowing waters, and *Myriophrys* is able by an investment of long flagelliform cilia to swim freely. The majority, however, lurk among confervae or the light débris of the bottom ooze; and come under the head of "sapropelic" rather than pelagic organisms. The body is usually of constant spherical form in relation to the floating habit. *Nuclearia*, however, shows amoeboid changes of general outline. The pseudopods are retractile, the axial filament being absorbed as the filament grows shorter and thicker and disappearing when the pseudopod merges into the ectoplasm, to be reformed at the same time with the pseudopod. There is often a distinction, clear, but never sharp, between the richly vacuolate, almost frothy ectoplasm and the denser endoplasm. One or more contractile vacuoles may protrude from the ectoplasm. The endoplasm contains the nucleus or nuclei. The nucleus when single may be central or excentric: in the latter case, the endoplasm contains a clear central sphere ("centrosome") on which abut the axial filaments of the pseudopods. The ectoplasm contains, in some species, constantly (*Raphidiophrys viridis*) or occasionally (*Actinosphaerium*), green cells belonging to the genera *Zoochlorella* and *Sphaerocystis*, both probably—the latter certainly—vegetative stages of a Chlamydomonad (Flagellata, *q.v.*) and of symbiotic significance.

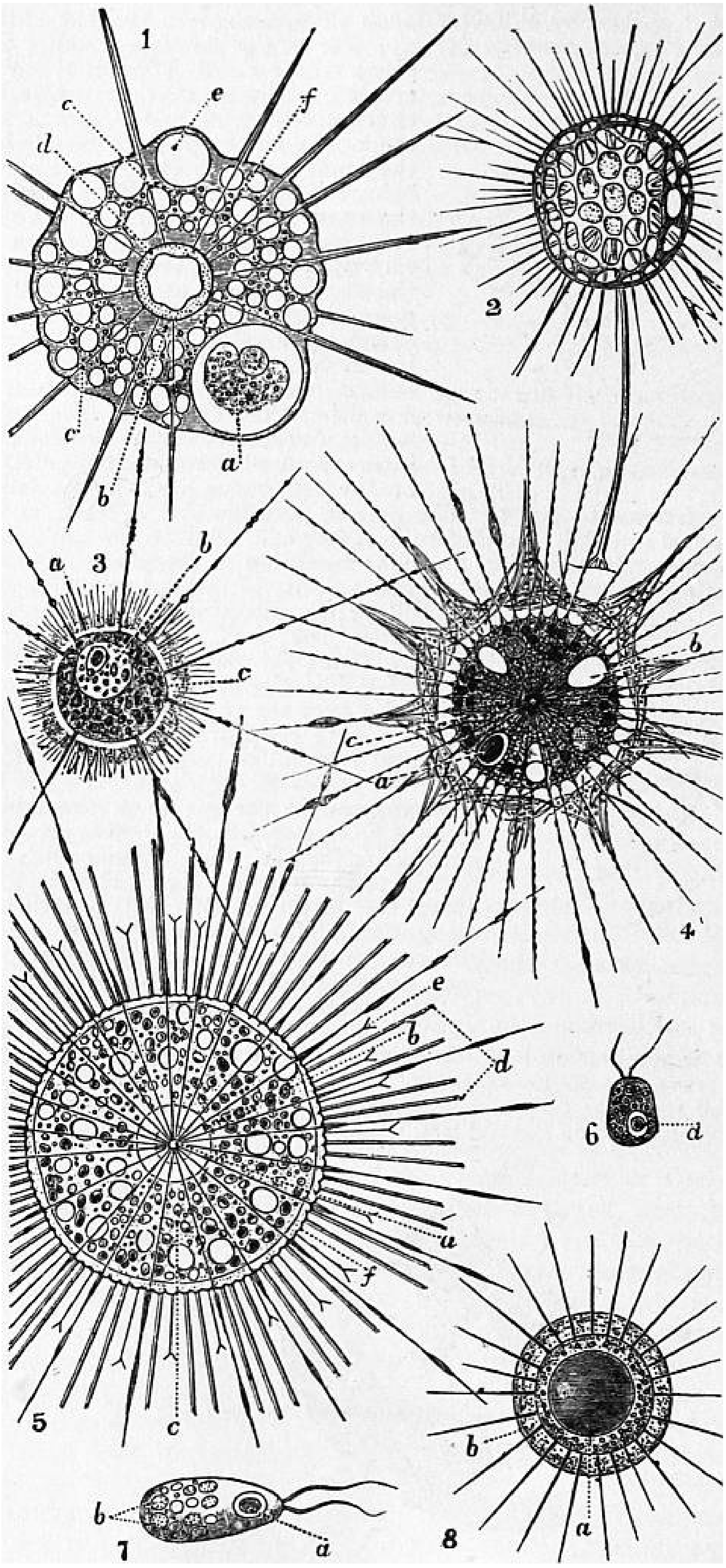


FIG. 1.—Heliozoa. 1. *Actinophrys sol*, Ehrb. *a*, food-particle lying in a large food-vacuole; *b*, deep-lying finely granular protoplasm; *c*, axial filament of a pseudopodium extended inwards to the nucleus; *d*, the central nucleus; *e*, contractile vacuole; f, superficial much vacuolated protoplasm. 2. *Clathrulina elegans*, Cienk. 3. *Heterophrys marina*, H. and L. *a*, nucleus; *b*, clearer protoplasm surrounding the nucleus; *c*, the peculiar felted envelope. 4. *Raphidiophrys pallida*, F. E. Schultze. *a*, food-particle; *b*, contractile vacuole; *c*, the nucleus; *d*, central granule in which all the axis-filaments of the pseudopodia meet. The tangentially disposed spicules are seen arranged in masses on the surface. 5. *Acanthocystis turfacea*, Carter. *a*, probably the central nucleus; *b*, clear protoplasm around the nucleus; *c*, more superficial protoplasm with vacuoles and chlorophyll corpuscles; *d*, coarser siliceous spicules; *e*, finer forked siliceous spicules; *f*, finely granular layer of protoplasm. The long pseudopodia reaching beyond the spicules are not lettered. 6. Bi-flagellate "flagellula" of *Acanthocystis aculeata*. a, nucleus. 7. Id. of *Clathrulina elegans*. *a*, nucleus; *b*, granules. 8. *Astrodisculus ruber*, Greeff. *a*, red-coloured central sphere (? nucleus); *b*, peripheral homogeneous envelope.

The Heliozoa can move by rolling over on their extended pseudopods; *Acanthocystis ludibunda* traversing a path of as much as twenty times its diameter in a minute, according to Penard. Several species (*e.g. Raphidiophrys elegans*) remain associated by the union of their pseudopods, whether into social aggregates (due to approximation) or "colonies" due to lack of separation after fission, is not accurately known. The multinuclear species

Actinosphaerium eichhornii (fig. 2), normally apocytial (*i.e.* the nuclei divide repeatedly without division of the cytoplasm), may increase in size by the fusion (“plastogamic”) of small individuals. If a large specimen be cut up or fragment itself under irritation, the small ones so produced soon approach one another and fuse completely.

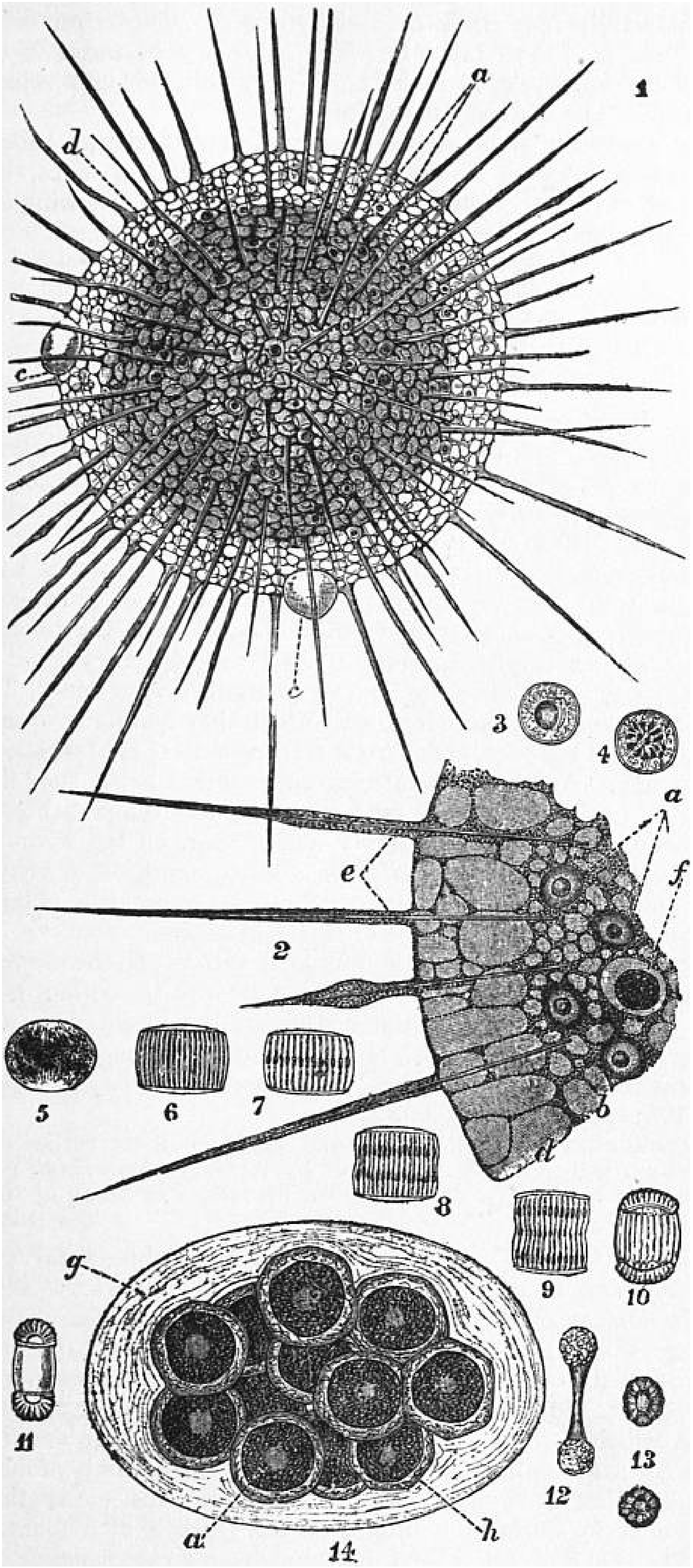


Fig. 2.—Heliozoa. 1. *Actinosphaerium eichhornii*, Ehr.; *a*, nuclei; *b*, deeper protoplasm with smaller vacuoles and numerous nuclei; *c*, contractile vacuoles; *d*, peripheral protoplasm with larger vacuoles. 2. A portion of the same specimen more highly magnified and seen in optical section. *a*, Nuclei; *b*, deeper protoplasm (so-called endosarc); *d*, peripheral protoplasm (so-called ectosarc); *e*, pseudopodia showing the granular protoplasm streaming over the stiff axial filament: *f*, food-particle in a good-vacuole. 3, 4. Nuclei of *Actinosphaerium* in the resting condition. 5-13. Successive stages in the division of a nucleus of *Actinosphaerium*, showing fibrillation, and in 7 and 8 formation of an equatorial plate of chromatin substance (after Hertwig). 14. Cyst-phase of *Actinosphaerium eichhornii*, showing the protoplasm divided into twelve chlamydospores, each of which has a siliceous coat; *a*, nucleus of the spore; *g*, gelatinous wall of the cyst; *h*, siliceous coat of the spore.

Reproduction.—Binary fission has been repeatedly observed; in some cases one or both of the daughter cells may swim for a time as a biflagellate zoospore (fig. 1 (6, 7)). The process may take place when the cell is naked or after preliminary encystment. Budding has been well studied in *Acanthocystis*; the cell nucleus divides repeatedly and most of the daughter nuclei pass to the periphery, aggregate part of the cytoplasm, and with it are constricted off as independent cells; one nucleus remains central and the process may be repeated. The detached bud may assume the typical character after a short amoeboid (lobose) stage, sometimes preceded by rest, or it may develop 2 flagella and swim off (fig. 1 (6)).

Brood formation is only known here in relation to a syngamic process; this is a sharp contrast to Proteomyxa (*q.v.*) where brood formation is the commonest mode of reproduction, and plasmodium-formation, rare indeed, is the nearest approach to syngamy observed. Indeed, if we knew the life-history of all the species this difference in the life cycle would be a convenient critical character.

Equal conjugation was demonstrated fully by F. Schaudinn in *Actinophrys*; two individuals approach and enter into close contact, and are surrounded by a common cyst wall. The nucleus of either male divides; and one nucleus passes to the surface at either side, and is budded off with a small portion of the cytoplasm as an abortive cell; the two remaining nuclei which are “first cousins” in cellular relationship now fuse, as is the case with the cytoplasts. The resulting coupled cell or zygote divides into two, which again encyst.

Actinosphaerium (fig. 2) shows a still more remarkable process, fully studied by R. Hertwig. The large multinucleate animal withdraws its pseudopods, its vacuoles disappear, it encysts and its nuclei diminish in number to about $\frac{1}{20}$th partly by fusion, 2 and 2, probably by digestion of the majority. Within the primary cyst the body is now resolved into nuclear cells, which again surround themselves with secondary cysts. The cell in each secondary cyst divides (by karyokinesis), and these sister cells, or rather their offspring, pair in much the same way as the individual cells of *Actinophrys*—the chief difference is that after the first division and budding off of a rudimentary cell, a second division of the same character takes place, with the formation of a second rudimentary cell, which is the niece of the first, absolutely in the same way as the 1st and 2nd polar bodies are formed in the maturation of the ovum in Metazoa. The actual pairing cells are thus second cousins, great-granddaughters of the original cell of the secondary cysts. Complete fusion now takes place to form the coupled cell, which is now contracted and forms a gelatinous wall within the siliceous secondary cyst wall (fig. 2 (14)), During a resting stage nuclear divisions occur and finally a brood of young 1-nuclear *Actinosphaerium* leave the cyst.

Classification.

Aphrothoraca. Body naked. Actinophrys Ehrb. (fig. 1 (1)) (nucleate), Actinosphaerium Stein plurinucleate (fig. 2 (1)), Camptonema (plurinucleate) Schaud., Dimorpha Gruber (sometimes 2 flagellate).

I. Chlamydophora. Investment gelatinous. Astrodiscus.

II. Chalarothoraca. Body protected by an investment of spicules or fibre scattered or approximated, never fused into a continuous skeleton.

§ 1. Spicules netted or free in the protoplasm. Heterophrys Arch. (fig. 1 (3)), Raphidiophrys Arch. (fig. 1 (4)), Pinacodocystis, Hertw. and Less.

§ 2. Spicules approximated radially. Pinaciophora Greeff, Pompholyxophrys Arch., Lithocolla F. E. Schultze, Elaeorhanis Greeff (in the two foregoing genera the spicules represented by sand granules), Acanthocystis Carter (fig. 1 (5)), Pinacocystis (?) Hertw. and Less, Myriophrys Penard. (Astrodisculus).

III. Desmothoraca. § 1 attached by a stalk. Clathrulina Cienk. (fig. 1 (2, 7)), Hedriocystis, Hertw. and Less.

§ 2. Free Elaster, Grimin, Choanocystis.

Literature.—The most important English original papers on this group are those by W. Archer, “On some Freshwater Rhizopoda, new, or little known,” *Quarterly Journal of Microscopic Science*, N.S. ix.-xi. (1869-1871), and “Résumé of Recent Contributions to the Knowledge of Freshwater Rhizopods,” *ibid.* xvi., xvii. (1876-1877). See also R. Hertwig and Lesser, “Über Rhizopoda und denselben nahestehenden Organismen,” in *Archiv für mikroscopische Anatomie*, x. (1874), p. 35; R. Schaudinn, “Heliozoa” in *Tierreich* (1896); E. Penard, *Les Héliozoaires d’eau douce* (1904); the two last named contain full bibliographies.

(M. Ha.)

HELIUM (from Gr. ἥλιος, the sun), a gaseous chemical element, the modern discovery of which followed closely on that of argon (*q.v.*). The Investigations of Lord Rayleigh and Sir William Ramsay had shown that indifference to chemical reagents did not sufficiently characterize an unknown gas as nitrogen, and it became necessary to reinvestigate other cases of the occurrence of "nitrogen" in nature. H. Miers drew Ramsay's attention to the work of W. F. Hillebrand, who had noticed, in examining the mineral uraninite, that an inert gas was evolved when the mineral was decomposed with acid. Ramsay, repeating these experiments, found that the inert gas emitted refused to oxidize when sparked with oxygen, 234
and on examining it spectroscopically he saw that the spectrum was not that of argon, but was characterized by a bright yellow line near to, but not identical with, the D line of sodium. This was afterwards identified with the D_3 line of the solar chromosphere, observed in 1868 by Sir J. Norman Lockyer, and ascribed by him to a hypothetical element *helium*. This name was adopted for the new gas.

Helium is relatively abundant in many minerals, all of which are radioactive, and contain uranium or thorium as important constituents. (For the significance of this fact see RADIOACTIVITY.) The richest known source is thorianite, which consists mainly of thorium oxide, and contains 9.5 cc. of helium per gram. Monazite, a phosphate of thorium and other rare earths, contains on the average about 1 cc. per gram. Cleveite, samarskite and fergusonite contain a little more than monazite. The gas also occurs in minute quantities in the common minerals of the earth's crust. In this case too it is associated with radioactive matter, which is almost ubiquitous. In two cases, however, it has been found in the absence of appreciable quantities of uranium and thorium compounds, namely in beryl, and in sylvine (potassium chloride). Helium is contained almost universally in the gases which bubble up with the water of thermal springs. The proportion varies greatly. In the hot springs of Bath it amounts to about one-thousandth part of the gas evolved. Much larger percentages have been recorded in some French springs (*Compt. rend.*, 1906, 143, p. 795, and 146, p. 435), and considerable quantities occur in some natural gas (*Journ. Amer. Chem. Soc.* 29, p. 1524). R. J. Strutt has suggested that helium in hot springs may be derived from the disintegration of common rocks at great depths.

Helium is present in the atmosphere, of which it constitutes four parts in a million. It is conspicuous by its absorption spectrum in many of the white stars. Certain stars and nebulae show a bright line helium spectrum.

Much the best practical source of helium is thorianite, a mineral imported from Ceylon for the manufacture of thoria. It dissolves readily in strong nitric acid, and the helium contained is thus liberated. The gas contains a certain amount of hydrogen and oxides of carbon, also traces of nitrogen. In order to get rid of hydrogen, some oxygen is added to the helium, and the mixture exploded by an electric spark. All remaining impurities, including the excess of oxygen, can then be taken out of the gas by Sir James Dewar's ingenious method of absorption with charcoal cooled in liquid air. Helium alone refuses to be absorbed, and it can be pumped off from the charcoal in a state of absolute purity. In the absence of liquid air the helium must be purified by the methods employed for argon (*q.v.*). If thorianite cannot be obtained, monazite, which is more abundant, may be utilized. A part of the helium contained in minerals can be extracted by heat or by grinding (J. A. Gray, *Proc. Roy. Soc.*, 1909, 82A, p. 301).

Properties.—All attempts to make helium enter into stable chemical union have hitherto proved unsuccessful. The gas is in all probability only mechanically retained in the minerals in which it is found. Jacquerod and Perrot have found that quartz-glass is freely permeable to helium below a red-heat (*Compt. rend.*, 1904, 139, p. 789). The effect is even perceptible at a temperature as low as 220° C. Hydrogen, and, in a much less degree, oxygen and nitrogen, will also permeate silica, but only at higher temperatures. They have made this observation the basis of a practical method of separating helium from the other inert gases. M. Travers has suggested that it may explain the liberation of helium from minerals by heat, the gas being enabled to permeate the siliceous materials in which it is enclosed. Thorianite, however, contains no silica, and until it is shown that metallic oxides behave in the same way this explanation must be accepted with reserve.

The density of helium has been determined by Ramsay and Travers as 1.98. Its ratio of specific heats has very nearly the ideal value 1.666, appropriate to a monatomic molecule. The accepted atomic weight is accordingly double the density, *i.e.* approximately four times that of hydrogen. The refractivity of helium is 0.1238 (air = 1). The solubility in water is the lowest known, being, at 18.2°, only .0073 vols. per unit volume of water. The viscosity is .96 (air = 1).

The spectrum of helium as observed in a discharge tube is distinguished by a moderate number of brilliant lines, distributed over the whole visual spectrum. The following are the approximate wave-lengths of the most brilliant lines:

Red	7066
Red	6678
Yellow	5876
Green	4922
Blue	4472
Violet	4026

When the discharge passes through helium at a pressure of several millimetres, the yellow line 5876 is prominent. At lower pressures the green line 4922 becomes more conspicuous. At atmospheric pressure the discharge is able to pass through a far greater distance in helium than in the common gases.

M. Travers, G. Senter and A. Jacquerod (*Phil. Trans.* A. 1903, 200, p. 105) carefully examined the behaviour of a constant volume gas thermometer filled with helium. For the pressure coefficient per degree, between 0° and 100° C., they give the value .00366255, when the initial pressure is 700 mm. This value is indistinguishable from that which they find for hydrogen. Thus at high temperatures a helium thermometer is of no special advantage. At low temperatures, on the other hand, they find, using an initial pressure of 1000 mm., that the temperatures on the helium scale are measurably higher than on the hydrogen scale, owing to the more perfectly gaseous condition of helium. This difference amounts to about $\frac{1}{10}$° at the temperature of liquid oxygen, and about $\frac{1}{5}$° at that of liquid hydrogen.

The liquefaction of helium was achieved by H. Kamerlingh Onnes at Leiden in 1908. According to him its boiling point is 4.3° abs. (−268.7° C.), the density of the liquid 0.154, the critical temperature 5° abs., and the critical pressure 2.3 atmospheres (*Communications from the Physical Laboratory at Leiden*, No. 108; see also Liquid Gases).

References.—A bibliography and summary of the earlier work on helium will be found in a paper by Ramsay, *Ann. chim. phys.* (1898) [7], 13, p. 433. See also M. Travers, *The Study of Gases* (1901).

(R. J. S.)

HELIX (Gr. ἕλιξ, a spiral or twist), an architectural term for the spiral tendril which is carried up to support the angles of the abacus of the Corinthian capital; from the same stalk springs a second helix rising to the centre of the capital, its junction with one on the opposite side being sometimes marked by a flower. Sometimes the term “volute” is given to the angle helix, which is incorrect, as it is of a different design and rises from the same stalk as the central helices. Its origin is probably metallic, that is to say, it was copied from the conventional treatment in Corinthian bronze of the tendrils of a plant.

HELL (O. Eng. *hel*, a Teutonic word from a root meaning “to cover,” cf. Ger. *Hölle*, Dutch *hel*), the word used in English both of the place of departed spirits and of the place of torment of the wicked after death. It is used in the Old Testament to translate the Hebrew *Sheol*, and in the New Testament the Greek ᾅδης, Hades, and γεέννα, Hebrew *Gehenna* (see Eschatology).

HELLANICUS of Lesbos, Greek logographer, flourished during the latter half of the 5th century B.C. According to Suidas, he lived for some time at the court of one of the kings of Macedon, and died at Perperene, a town on the gulf of Adramyttium opposite Lesbos. Some thirty works are attributed to him—chronological, historical and episodical. Mention may be made of: *The Priestesses of Hera at Argos*, a chronological compilation, arranged according to the order of succession of these functionaries; the *Carneonikae*, a list of the victors in the Carnean games (the chief Spartan musical festival), including notices of literary events; an *Atthis*, giving the history of Attica from 683 to the end of the Peloponnesian War (404), which is referred to by Thucydides (i. 97), who says that he treated the events of the years 480-431 briefly and superficially, and with little regard to chronological sequence: *Phoronis*, 235 chiefly genealogical, with short notices of events from the times of Phoroneus the Argive “first man” to the return of the Heraclidae; *Troica* and *Persica*, histories of Troy and Persia.

Hellanicus marks a real step in the development of historiography. He transcended the narrow local limits of the older logographers, and was not content to repeat the traditions that had gained general acceptation through the poets. He tried to give the traditions as they were locally current, and availed himself of the few national or priestly registers that presented something like contemporary registration. He endeavoured to lay the foundations of a scientific chronology, based primarily on the list of the Argive priestesses of Hera, and secondarily on genealogies, lists of magistrates (*e.g.* the archons at Athens), and Oriental dates, in place of the old reckoning by generations. But his materials were insufficient and he often had recourse to the older methods. On account of his deviations from common tradition, Hellanicus is often called an untrustworthy writer by the ancients themselves, and it is a curious fact that he appears to have made no systematic use of the many inscriptions which were ready to hand. Dionysius of Halicarnassus censures him for arranging his history, not according to the natural connexion of events, but according to the locality or the nation he was describing; and undoubtedly he never, like his contemporary Herodotus, rose to the conception of a single current of events wider than the local distinction of race. His style, like that of the older logographers, was dry and bald.

Fragments in Müller, *Fragmenta historicorum Graecorum*, i. and iv.; see among older works L. Preller, *De Hellanico Lesbio historico* (1840); Mure, *History of Greek Literature*, iv.; late criticism in H. Kullmer, “Hellanikos” in *Jahrbücher für klass. Philologie* (Supplementband, xxvii. 455 sqq.) (1902), which contains new edition and arrangement of fragments; C. F. Lehmann-Haupt, “Hellanikos, Herodot, Thukydides,” in *Klio* vi. 127 sqq. (1906); J. B. Bury, *Ancient Greek Historians* (1909), pp. 27 sqq.

HELLEBORE (Gr. ἐλλέβορος: mod. Gr. also σκάφη: Ger. *Nieswurz*, *Christwurz*; Fr. *hellébore*, and in the district of Avranche, *herbe enragée*), a genus (*Helleborus*) of plants of the natural order Ranunculaceae, natives of Europe and western Asia. They are coarse perennial herbs with palmately or pedately lobed leaves. The flowers have five persistent petaloid sepals, within the circle of which are placed the minute honey-containing tubular petals of the form of a horn with an irregular opening. The stamens are very numerous, and are spirally arranged; and the carpels are variable in number, sessile or stipitate and slightly united at the base and dehisce by ventral suture.

Helleborus niger, black hellebore, or, as from blooming in mid-winter it is termed the Christmas rose (Ger. *Schwarze Nieswurz*; Fr., *rose de Noël* or *rose d’hiver*), is found in southern and central Europe, and with other species was cultivated in the time of Gerard (see *Herball*, p. 977, ed. Johnson, 1633) in English gardens. Its knotty root-stock is blackish-brown externally, and, as with other species, gives origin to numerous straight roots. The leaves spring from the top of the root-stock, and are smooth, distinctly pedate, dark-green above, and lighter below, with 7 to 9 segments and long petioles. The scapes, which end the branches of the rhizome, have a loose entire bract at the base, and terminate in a single flower, with two bracts, from the axis of one of which a second flower may be developed. The flowers have 5 white or pale-rose, eventually greenish sepals, 15 to 18 lines in breadth; 8 to 13 tubular green petals containing honey; and 5 to 10 free carpels. There are several forms, the best being *maximus*. The Christmas rose is extensively grown in many market gardens to provide white flowers forced in gentle heat about Christmas time for decorations, emblems, &c.

H. orientalis, the Lenten rose, has given rise to several fine hybrids with *H. niger*, some of the best forms being clear in colour and distinctly spotted. *H. foetidus*, stinking hellebore, is a native of England, where like *H. viridis*, it is confined chiefly to limestone districts; it is common in France and the south of Europe. Its leaves have 7- to 11-toothed divisions, and the flowers are in panicles, numerous, cup-shaped and drooping, with many bracts, and green sepals tinged with purple, alternating with the five petals.

H. viridis, or green hellebore proper, is probably indigenous in some of the southern and eastern counties of England, and occurs also in central and southern Europe. It has bright yellowish-green flowers, 2 to 4 on a stem, with large leaf-like bracts. O. Brunfels and H. Bock (16th century) regarded the plant as the black hellebore of the Greeks.

H. lividus, holly-leaved hellebore, found in the Balearic Islands, and in Corsica and Sardinia, is remarkable for the handsomeness of its foliage. White hellebore is *Veratrum album* (see Veratrum), a liliaceous plant.

Helleborus niger. 1, Vertical section of flower; 2, Nectary, side and front view.

Hellebores may be grown in any ordinary light garden mould, but thrive best in a soil of about equal parts of turfy loam and well-rotted manure, with half a part each of fibrous peat and coarse sand, and in moist but thoroughly-drained situations, more especially where, as at the margins of shrubberies, the plants can receive partial shade in summer. For propagation cuttings of the rhizome may be taken in August, and placed in pans of light soil, with a bottom heat of 60° to 70° Fahr.; hellebores can also be grown from seed, which must be sown as soon as ripe, since it quickly loses its vitality. The seedlings usually blossom in their third year. The exclusion of frost favours the production of flowers; but the plants, if forced, must be gradually inured to a warm atmosphere, and a free supply of air must be afforded, without which they are apt to become much affected by greenfly. For potting, *H. niger* and its varieties, and *H. orientalis*, *atrorubens* and *olympicus* have been found well suited. After lifting, preferably in September, the plants should receive plenty of light, with abundance of water, and once a week liquid manure, not over-strong. The flowers are improved in delicacy of hue, and are brought well up among the leaves, by preventing access of light except to the upper part of the plants. Of the numerous species of hellebore now grown, the deep-purple-flowered *H. colchicus* is one of the handsomest; by crossing with *H. guttatus* and other species several valuable garden forms have been produced, having variously coloured spreading or bell-shaped flowers, spotted with crimson, red or purple.

The rhizome of *H. niger* occurs in commerce in irregular and nodular pieces, from about 1 to 3 in. in length, white and of a horny texture within. Cut transversely it presents internally a circle of 8 to 12 cuneiform ligneous bundles, surrounded by a thick bark. It emits a faint odour when cut or broken, and has a bitter and slightly acrid taste. The drug is sometimes adulterated with the rhizome of baneberry, *Actaea spicata*, which, however, may be recognized by the distinctly cruciate appearance of the central portion of the attached roots when cut across, and by its decoction giving the chemical reactions for tannin.[1] The rhizome
is darker in colour in proportion to its degree of dryness, age and richness in oil. A specimen

dried by Schroff lost in eleven days 65% of water.

H. niger, *orientalis*, *viridis*, *foetidus*, and several other species of hellebore contain the glucosides *helleborin*, $C_{36}H_{42}O_6$, and *helleboreïn*, $C_{23}H_{20}O_{15}$, the former yielding glucose and *helleboresin*, $C_{30}H_{38}O_4$, and the latter glucose and a violet-coloured substance *helleboretin*, $C_{14}H_{20}O_3$. Helleborin is most abundant in *H. viridis*. A third and volatile principle is probably present in *H. foetidus*. Both helleborin and helleboreïn act poisonously on animals, but their decomposition-products helleboresin and helleboretin seem to be devoid of any injurious qualities. Helleborin produces excitement and restlessness, followed by paralysis of the lower extremities or whole body, quickened respiration, swelling and injection of the mucous membranes, dilatation of the pupil, and, as with helleboreïn, salivation, vomiting and diarrhoea. Helleboreïn exercises on the heart an action similar to that of digitalis, but more powerful, accompanied by at first quickened and then slow and laboured respiration; it irritates the conjunctiva, and acts as a sternutatory, but less violently than veratrine. Pliny states that horses, oxen and swine are killed by eating "black hellebore"; and Christison (*On Poisons*, p. 876, 11th ed., 1845) writes: "I have known severe griping produced by merely tasting the fresh root in January." Poisonous doses of hellebore occasion in man singing in the ears, vertigo, stupor, thirst, with a feeling of suffocation, swelling of the tongue and fauces, emesis and catharsis, slowing of the pulse, and finally collapse and death from cardiac paralysis. Inspection after death reveals much inflammation of the stomach and intestines, more especially the rectum. The drug has been observed to exercise a cumulative action. Its extract was an ingredient in Bacher's pills, an empirical remedy once in great repute in France. In British medicine the rhizome was formerly official. *H. foetidus* was in past times much extolled as an anthelmintic, and is recommended by Bisset (*Med. Ess.*, pp. 169 and 195, 1766) as the best vermifuge for children; J. Cook, however, remarks of it (*Oxford Mag.*, March 1769, p. 99): "Where it killed not the patient, it would certainly kill the worms; but the worst of it is, it will sometimes kill both." This plant, of old termed by farriers ox-heel, setter-wort and setter-grass, as well as *H. viridis* (Fr. *Herbe à séton*), is employed in veterinary surgery, to which also the use of *H. niger* is now chiefly confined in Britain.

In the early days of medicine two kinds of hellebore were recognized, the white or *Veratrum album* (see VERATRUM), and the black, including the various species of *Helleborus*. The former, according to Codronchius (*Comm.... de elleb.*, 1610), Castellus (*De helleb. epist.*, 1622), and others, is the drug usually signified in the writings of Hippocrates. Among the hellebores indigenous to Greece and Asia Minor, *H. orientalis*, the rhizome of which differs from that of *H. niger* and of *H. viridis* in the bark being readily separable from the woody axis, is the species found by Schroff to answer best to the descriptions given by the ancients of black hellebore, the ἐλλέβορος μέλας of Dioscorides. The rhizome of this plant, if identical, as would appear, with that obtained by Tournefort at Prusa in Asia Minor (*Rel. d'un voy. du Levant*, ii. 189, 1718), must be a remedy of no small toxic properties. According to an early tradition, black hellebore administered by the soothsayer and physician Melampus (whence its name *Melampodium*), was the means of curing the madness of the daughters of Proetus, king of Argos. The drug was used by the ancients in paralysis, gout and other diseases, more particularly in insanity, a fact frequently alluded to by classical writers, *e.g.* Horace (*Sat.* ii. 3. 80-83, *Ep. ad Pis.* 300). Various superstitions were in olden times connected with the cutting of black hellebore. The best is said by Pliny (*Nat. hist.* xxv. 21) to grow on Mt Helicon. Of the three Anticyras that in Phocis was the most famed for its hellebore, which, being there used combined with "sesamoides," was, according to Pliny, taken with more safety than elsewhere.

The British Pharmaceutical Conference has recommended the preparation which it terms *the tinctura veratri viridis*, as the best form in which to administer this drug. It may be given in doses of 5-15 minims. The tincture is prepared from the dried rhizome and rootlets of green hellebore, containing the alkaloids jervine, veratrine and veratroidine. It is recommended as a cardiac and nervous sedative in cerebral haemorrhage and puerperal eclampsia. Black hellebore is a purgative and uterine stimulant.

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1 For the microscopical characters and for figures of transverse sections of the rhizome, see Lanessan, *Hist. des drogues*, i. 6 (1878).

HELLENISM (from Gr. ἑλληνίζειν, to imitate the Greeks, who were known as Ἕλληνες, after Ἕλλην, the son of Deucalion). The term "Hellenism" is ambiguous. It may be used to denote ancient Greek culture in all its phases, and even those elements in modern civilization which are Greek in origin or in spirit; but, while Matthew Arnold made the term popular in the latter connexion as the antithesis of “Hebraism,” the German historian J. G. Droysen introduced the fashion (1836) of using it to describe particularly the latter phases of Greek culture from the conquests of Alexander to the end of the ancient world, when those over whom this culture extended were largely not Greek in blood, *i.e. Hellenes*, but peoples who had adopted the Greek speech and way of life, *Hellenistai*. Greek culture had, however, both in “Hellenic” and “Hellenistic” times, a common essence, just as light is light whether in the original luminous body or in a reflection, and to describe this by the term Hellenism seems most natural. But whilst using the term in the larger sense, this article, in deference to the associations which have come to be specially connected with it, will devote its principal attention to Hellenism as it appeared in the world after the Macedonian conquests. But it will be first necessary to indicate briefly what Hellenism in itself implied.

No verbal formula can really enclose the life of a people or an age, but we can best understand the significance of the old Greek cities and the life they developed, when, looking at the history of mankind as a whole, we see the part played by reason, active and critical, in breaking down the barriers by which custom hinders movement, in guiding movement to definite ends, in dissipating groundless beliefs and leading onwards to fresh scientific conquests—when we see this and then take note that among the ancient Greeks such an activity of reason began in an entirely novel degree and that its activity in Europe ever since is due to their impulsion. When Hellenism came to stand in the world for something concrete and organic, it was, of course, no mere abstract principle, but embodied in a language, a literature, an artistic tradition. In the earliest existing monument of the Hellenic genius, the Homeric poems, one may already observe that regulative sense of form and proportion, which shaped the later achievements of the race in the intellectual and artistic spheres. It was not till the great colonizing epoch of the 8th and 7th centuries B.C., when the name “Hellene” came into use as the antithesis of “barbarian,” that the Greek race came to be conscious of itself as a peculiar people; it was yet some three centuries more before Hellenism stood fully declared in art and literature, in politics and in thought. There was now a new thing in the world, and to see how the world was affected by it is our immediate concern.

I. The Expansion of Hellenism before Alexander.—In the 5th century B.C. Greek cities dotted the coasts of the Mediterranean and the Black Sea from Spain to Egypt and the Caucasus, and already Greek culture was beginning to pass beyond the limits of the Greek race. Already in the 7th century B.C., when Hellenism was still in a rudimentary stage, the citizens of the Greek city-states had been known to the courts of Babylon and Egypt as admirable soldiers, combining hardihood with discipline, and Greek mercenaries came to be in request throughout the Nearer East. But as Hellenism developed, its social and intellectual life began to exercise a power of attraction. The proud old civilizations of the Euphrates and the Nile might ignore it, but the ruder barbarian peoples in East and West, on whose coasts the Greek colonies had been planted, came in various degrees under its spell. In some cases an outlying colony would coalesce with a native population, and a fusion of Hellenism with barbarian customs take place, as at Emporium in Spain (Strabo iii. p. 160) and at Locri in S. Italy (Polyb. xii. 5. 10). Perinthus included a Thracian phyle. The stories of Anacharsis and Scylas (Herod, iv. 76-80) show how the leading men of the tribes in contact with the Greek colonies in the Black Sea might be fascinated by the appeal which the exotic culture made to mind and to eye.

The great developments of the century and a half before Alexander set the Greek people in a very different light before the world. In the sphere of material power the repulse of Xerxes and the extension of Athenian or Spartan supremacy in the eastern Mediterranean were large facts patent to the most obtuse. The kings of the East leant more than ever upon Greek mercenaries, whose superiority to barbarian levies was sensibly brought home to them by the expedition of Cyrus. But the developments within the Hellenic sphere itself were also of great consequence for its expansion outwards. The political disunion of the Greeks was to some extent neutralized by the rise of Athens to a leading position in art, in literature and in philosophy. In Athens the Hellenic genius was focussed, its tendencies drawn together and combined; nor was it a circumstance of small moment that the Attic dialect attained, for prose, a classical authority; for if Hellenism was to be propagated in the world at large, it was obviously convenient that it should have some one definite form of speech to be its medium. 237

1. *The Persians.*—The ruling race of the East, the Persian, was but little open to the influences of the new culture. The military qualities of the Greeks were appreciated, and so,

too, was Greek science, where it touched the immediately useful; a Greek captain was entrusted by Darius with the exploration of the Indus; a Greek architect bridged the Bosporus for him; Greek physicians (*e.g.* Democedes, Ctesias) were retained for enormous fees at the Persian court. The brisk diplomatic intercourse between the Great King and the Greek states in the 4th century may have produced effects that were not merely political. We certainly find among those members of the Persian aristocracy, who came by residence in Asia Minor into closer contact with the Greeks, some traces of interest in the more ideal side of Hellenism. A man like the younger Cyrus invited Greek captains to his friendship for something more than their utility in war, and procured Greek hetaerae for something more than sensual pleasure. There is the Mithradates who presented the Academy with a statue of Plato by Silanion, not improbably identical (though the supposition implies a correction in the text of Diogenes Laërtius) with that Mithradates who, together with his father Ariobarzanes, received the citizenship of Athens (Dem. xxiii. 141, 202). Exactly how far Greek influence can be traced in the remains of Persian art, such as the royal palaces of Persepolis and Susa may be doubtful (see Gayet, *L'Art persan*; R. Phené Spiers, *Architecture East and West*, p. 245 f.), but it is certain that the engraved gems for which there was a demand in the Persian empire were largely the work of Greek artists (Furtwängler, *Antike Gemmen*, iii. p. 116 f.).

2. *The Phoenicians.*—As early as the first half of the 4th century we find communities of Phoenician traders established in the Peiraeus (*C.I.A.* ii. 86). In Cyprus, on the frontier between the Greek and Semitic worlds, a struggle for ascendancy went on. The Phoenician element seems to have been dominant in the island when Evagoras made himself king of Salamis in 412, and restored Hellenism with a strong hand. The words of Isocrates (even allowing for their rhetorical colour) give us a vivid insight into what such a process meant. "Before Evagoras established his rule, they were so hostile and exclusive, that those of their rulers were actually held to be the best who were the fiercest adversaries of the Greeks; but now such a change has taken place, that it is a matter of emulation who shall show himself the most ardent phil-hellen, that for the mothers of their children most of them choose wives from amongst us, and that they take pride in having Greek things about rather than native, in following the Greek fashion of life, whilst our masters of the fine arts and other branches of culture now resort to them in greater numbers than were once to be found in those quarters they specially frequented" (Isoc. 199 = *Evag.* §§ 49, 50). Even into the original seats of the Phoenicians Hellenism began to intrude. Evagoras at one time (about 386) made himself master of Tyre (Isoc. *Evag.* § 62; Diod. xv. 2, 4). His grandson Evagoras II. is found as governor of Sidon for the Persian king 349-346. (Babelon, *Perses Achéménides*, p. cxxii.; cf. Diod. xvi. 46, 3).

Abdashtart, king of Sidon (374-362 B.C.), called Straton by the Greeks, had already entered into close relations with the Greek states, and imitated the Hellenic princes of Cyprus (*Athen.* xii. 531; *C.I.A.* ii. 86; *Corp. inscr. Semit.* i. 114). The Phoenician colonists in Sardinia purchased or imitated the work of Greek artists (Furtwängler, *Antike Gemmen*, iii. 109).

3. *The Carians and Lycians.*—The seats of the Greeks in the East touched peoples more or less nearly related to the Hellenic stock, with native traditions not so far remote from those of the Greeks in a more primitive age, the Carians and the Lycians. It came about in the last century preceding Alexander that the first of these peoples was organized as a strong state under native princes, the line founded by Hecatomnus of Mylasa. Hecatomnus made himself master of Caria in the first decade of the 4th century, but it was under his son Mausolus, who succeeded him in 377-376 that the house rose to its zenith. These Carian princes ruled as satraps for the Great King, but they modelled themselves upon the pattern of the Greek tyrant. The capital of Mausolus was a Greek city, Halicarnassus, and all that we can still trace of his great works of construction and adornment shows conformity to the pure Hellenic type. His famous sepulchre, the Mausoleum (the remains of it are now in the British Museum), was a monument upon which the most eminent Greek sculptors of the time worked in rivalry (Plin. *N.H.* xxxvi. 5, § 30; Vitruv. vii. 13). His court gave a welcome to the vagrant Greek philosopher (Diog. Laërt. viii. 8, § 87). Even the Carian town of Mylasa now shows the forms of a Greek city and records its public decrees in Greek (*C.I.G.* 2691 *c, d, e* = Michel 471). In Lycia, which in spite of "the son of Harpagus" and King Pericles, had never been brought under one man's rule, the Greek influence is more limited. Here, for the most part in the inscriptions, the native language maintains itself against Greek. The proper names are (if not native) mainly Persian. But the Greek language makes an occasional appearance; Greek names are borne by others beside Pericles. The coins are Greek in type. And above all the monumental remains of Lycia show strong Greek influence, especially the well-known "Nereid Monument" in the British Museum, whose date is held to go back to the 5th century (Gardner, *Handbook of Gk. Sculp.* p. 344).

4. *South Russia.*—Hellenic influences continued to penetrate the Scythian peoples from the Greek colonies of the Black Sea, at any rate in the matter of artistic fabrication. Our evidence is the actual objects recovered from the soil. (See Scythia.)

5. *Egypt.*—From the time of Psammetichus (d. 610 B.C.) Greek mercenaries had been used to prop Pharaoh's throne. At the same time Greek merchants had begun to find their way up the Nile and even to the Oases. A Greek city Naucratis (*q.v.*) was allowed to arise at the Bolbitinic mouth of the Nile. But the racial repugnance to the Greek, which forbade an Egyptian even to eat an animal which had been carved with a Greek's knife (Hdt. ii. 41), probably kept the soul of the people more shut against Hellenic influences than was that of the other races of the East.

6. *Macedonia.*—In Macedonia the native chiefs had been attracted by the rich Hellenic life at any rate from the beginning of the 5th century, when Alexander I., surnamed "Philhellen," persuaded the judges at Olympia that the Temenid house was of good Argive descent (Hdt. v. 22). And, although their enemies might stigmatize them as barbarians, the Macedonian kings maintained that they were not Macedonians, but Greeks (cf. ἀνὴρ Ἕλλην Μακεδόνων ὕπαρχος, Hdt. v. 20). It was not probably till the reorganization of the kingdom by Archelaus (413-399) that Greek culture found any abundant entrance into Macedonia. Now all that was most brilliant in Greek literature and Greek art was concentrated in the court of Aegae; the palace was decorated by Zeuxis; Euripides spent there the end of his days. From that time, no doubt, a certain degree of literary culture was general among the Macedonian nobility; their names in the days of Philip are largely Greek; the Macedonian service was full of men from the Greek cities within Philip's dominions. The values recognized at the court would naturally be recognized in noble families generally, and Philip chose Aristotle to be the educator of his son. How far the country generally may be regarded as Hellenized is a problem which involves the vexed question what right the Macedonian people itself has to be classed among the Hellenes, and Macedonian to be considered a dialect of Greek.[1] As the literary and official language, Greek alone would seem to have had any status.

7. *In the West: the Native Races of Sicily.*—Italy and the south of Gaul had not remained unaffected by the neighbourhood of the Greek colonies. Under the rule of the elder and younger Dionysius in the 4th century, the hellenization of the Sicels in the interior of Sicily seems to have become complete (Freeman, *History of Sicily*, ii. 387, 388, 422-424; Beloch, *Griech. Gesch.* iii. [i.] 261). 238

The alphabets used by the various Italian races from the 5th century were directly or indirectly learnt from the Greeks. The peoples of the south (Lucanians, Bruttians, Mamertines) show a Greek principle of nomenclature (Mommsen, *Unterital. Dialekt*, p. 240 f.). The Pythagorean philosophy, whose seat was in southern Italy, won adherents among the native chiefs (Cic. *De senec.* 12, cf. Dio Chrys. *Orat. Cor.* 37, § 24). From the Greeks of southern Gaul Hellenic influences penetrated the Celtic races so far that imitations of Greek coins were struck even on the coasts of the Atlantic.

II. After Alexander the Great.—When we review generally the extent to which Hellenism had penetrated the outer world in the middle of the 4th century B.C., it must be admitted that it had not seriously affected any but the more primitive races which dwelt upon the borders of the Hellenic lands, and here it would seem, with the doubtful exception of the Macedonians, to have been an affair rather of the courts than of the life of the people. On the other hand it must be taken into account that Hellenism had as yet only been a very short while in the world. What would have happened had it continued to depend upon its spiritual force only for propagation we cannot say. Everything was changed when by the conquests of Alexander (334-323) it suddenly rose to material supremacy in all the East as far as India, and when cities of Greek speech and constitution were planted by the might of kings at all the cardinal points of intercourse within those lands. The values honoured by the rulers of the world must naturally impress themselves upon the subject multitudes. The Macedonian chiefs found their pride in being champions of Hellenism. Of Alexander there is no need to speak. The courts of his successors in Asia Minor, Syria and Egypt were Greek in language and atmosphere. All kings liked to win the good word of the Greeks by munificence bestowed upon Greek cities and Greek institutions. All of them in some degree patronized Greek art and letters, and some sought fame for themselves as authors. Even the barbarian courts, their neighbours or vassals, were swayed by the dominant fashion to imitation. But by the courts alone Hellenism could never have been propagated far. Greek culture had been the product of the city-state, and Hellenism could not be dissevered from the city. It was upon the system of Greek and Macedonian cities, planted by Alexander and his successors, that their work rested, and though their dynasties crumbled, their work remained. Rome, when it stepped into their place, did no more than safeguard its continuance; in the East Rome acted as a Hellenistic power, and if, when the legions had thundered past, the brooding East "plunged in thought again," that thought was largely directed by the Greek schoolmaster who followed in the legions' train. From our present point of view we may therefore regard this work of Hellenism as one continuous process, initiated by the Macedonians and carried on under Roman protection, and ask in the first place what the institution of a Greek city implied.

The Character of the New Greek Cities.—The citizen bodies at the outset were really of Greek or Macedonian blood—soldiers who had served in the royal armies, or men attracted from the older Greek cities to the new lands thrown open to commerce. To fix their European soldiery upon the new soil was an obvious necessity for the Macedonian chiefs who had set up kingdoms among the barbarians, and the lots of the veterans (except in Egypt) were naturally attached to various urban centres. The cities, of course, drew in numbers beside of the people of the land; Alexander is specially said to have incorporated large bodies of natives in some of the new cities of the Eastern provinces (Arr. iv. 4, 1; Diod. xvii. 83, 2; Curtius ix. 10, 7). It may generally be taken for granted that the lower strata of the city-populations was mainly native; to be included in the city population was not, however, to be included in the citizen body, and it remains a question how far the latter admitted members of other than European origin (Beloch iii. [i.] 414). The statements, for instance, of Josephus that the Jews were given full citizen rights in the new foundations are probably false (Willrich, *Juden und Griechen vor der makkabäischen Erhebung*, 1895, p. 19 f.). The social organization of the citizen-body conformed to the regular Hellenic type with a division into *phylae* and, in Egypt, at any rate, into *demi* (Liban. Or. xix. 62; Satyrus, frag. 21 = *F.H.G.* iii. 164; Sir W. M. Ramsay, *Cities and Bishoprics*, i. 60; Kenyon, *Archiv f. Papyr.* ii. 74; Jonguet, *Bull. corr. hell.* xxi., 1897, 184 f.; Liebenam, *Städteverwaltung*, 220 f.). The cities appear equally Hellenic in their political organs and functions with *boulē* and *demos* and popularly elected magistrates. Life was filled with the universal Hellenic interests, which centred in the gymnasium and the religious festivals, these last including, of course, not only athletic contests but performances of the classical dramas or later imitations of them. The wandering sophist and rhetorician would find a hearing no less than the musical artist. The language of the upper classes was Greek; and the material background of building and decoration, of dress and furniture, was of Greek design. A greater regularity in the street-plans seems to have distinguished the new cities from the older slowly grown cities of the Greek lands, just as it distinguishes the cities of the New World to-day from those of Europe. Alexandria and Antioch were both traversed from end to end by one long straight street, crossed by shorter ones at right angles; Nicaea was a square from the centre of which all the four gates could be seen at the ends of the intersecting thoroughfares (Strabo xii. 565); similar characteristics are noted in the rebuilt Smyrna (*ib.* xiv. 646).

Sometimes the Greek city was not an absolutely new foundation, but an old Oriental city, re-colonized and transformed. And in such cases the old name was often replaced by a Greek one. Thus Celaenae in Phrygia became Apamea; Haleb (Aleppo) in Syria became Beroea; Nisibis in Mesopotamia, Antioch; Rhagae (Rai) in Media, Europus. In some cases the old name was left unchallenged, *e.g.* Thyatira, Damascus and Samaria. Even where there was no new foundation the older cities of Phoenicia and Syria became transformed from the overwhelming prestige of Hellenic culture. In Tyre and Sidon, no less than in Antioch or Alexandria, Greek literature and philosophy were seriously cultivated, as we may see by the great names which they contributed. The process by which Hellenism thus leavened an older city we may trace with peculiar vividness in the case of Jerusalem; we see there the younger generation captivated by its ideals, the appearance of gymnasium and theatre, the eager adoption of Greek political forms (1 Macc. i. 13 f.; 2 Macc. 4., 10 f.).

A. *Characteristics of Hellenism after Alexander.*—To the number of Greek city-states existing before Alexander were now therefore added those which extended Hellas as far as India. With the enormous extension of Greek territory a great shifting took place in the old centres of gravity. What changes in the character of Greek culture did the new conditions of the world bring about?

Government.

Hellenism had been the product of the free life of the Greek city-state, and after Chaeronea the great days of the city-state were past. Not that all liberty was everywhere extinguished. Under Alexander himself the Greek states were restive, and Aetolia unsubdued; and, with the break-up of the empire at Alexander's death, there was once more scope for the action of the individual cities among the rival great powers. In the history of the next two or three centuries the cities are by no means ciphers. Rhodes takes a great part in *Weltpolitik*, as a sovereign ally of one or other of the royal courts. In Greece itself the overlordship to which the Macedonian king aspires is imperfect in extent and only maintained to that extent by continual wars. The Greek states on their side show that they are capable even of progressive political development, the needs of the time being met by the federal system, by larger unions of equal members than the leading cities of the past would have tolerated, with their extreme unwillingness to forego the least shred of sovereign independence. The Achaean and Aetolian Leagues are independent powers, which the Macedonian can indeed check by garrisons in Corinth, Chalcis and elsewhere, but which keep a field clear for Hellenic freedom within their borders. Sparta also is a power which can cross swords with the Macedonian king, and Cleomenes III. aspires to unite the Peloponnesus under his headship. As to the cities outside Greece, within or around the royal realms, Seleucid, Ptolemaic or Attalid, their degree of freedom probably differed widely according to circumstances. At one end of the scale, cities of old renown, *e.g.* Lampsacus or Smyrna, could still make good their independence against Antiochus III. at the beginning of the 2nd century B.C. At the other end of the scale the cities which were royal capitals, *e.g.* Alexandria, Antioch and Pergamum, were normally controlled altogether by royal nominees. At Pergamum indeed and (at any rate after Antiochus IV.) at Antioch, forms of self-government subsisted upon which, of course, the court had its hand, whilst at Alexandria even such forms were wanting. Between the two extremes there was variation not only between city and city, but, no doubt, in one and the same city at different times. In Syria the independent action of the cities greatly increased during the last weakness of the Seleucid monarchy. With the extension of the single strong rule of Rome over this Hellenistic world, the conditions were changed. Just as the Macedonian conquest, whilst increasing the domain of Greek culture, had straitened Greek liberty, so Rome, whilst bringing Hellenism finally into secure possession of the nearer East, extinguished Greek freedom altogether. Even now the old forms were long religiously respected. Formally, the most illustrious Greek states, Athens, for instance, or Marseilles, or Rhodes, were not subjects of Rome, but free allies. Even in the case of *civitates stipendiariae* (tribute-paying states), municipal autonomy, subject indeed to interference on the part of the Roman governor, was allowed to go on. *Boulē* and *demos* long continued to function. The old catchword, "autonomy of the Hellens," was still heard and indeed was solemnly proclaimed by Nero at the Isthmian games of A.D. 67. But during the first centuries of the Christian era, this municipal autonomy, by a process which can only be imperfectly traced in detail, decayed. The *demos* first sank into political annihilation and the council, no longer popularly elected but an aristocratic order, concentrated the whole administration in its hands. By the end of the 2nd century A.D., claims made by the imperial government upon the municipal senate are more and more changing membership of the order from an honour into an intolerable burden, and financial disorganization is calling on imperial officials in one place after another to undertake the business of government. After Diocletian and under the Eastern Empire the Greek world is organized on the principles of a vast bureaucracy. 239

Social changes.

With this long process of political decline from Alexander to Diocletian correspond the inner changes in the temper of the Hellenic and Hellenistic peoples. There were, of course, marked differences between one region and another. But certain general characteristics distinguished at once Greek society after the Macedonian conquests from the society of the earlier age. When the vast field of the East was opened to Hellenic enterprise and the bullion of its treasuries flung abroad, fortunes were made on a scale before unparalleled. A new standard of sumptuousness and splendour was set up in the richest stratum of society. This material elaboration of life was furthered by the existence of Hellenistic courts, where the great ministers amassed fabulous riches (*e.g.* Dionysius, the state secretary of Antiochus IV., Polyb. xxxi. 3, 16; Hermias, the chief minister of Seleucus III., and Antiochus III., Polyb. v. 50. 2; cf. Plutarch, *Agis* 9), and of huge cities like Alexandria, Antioch and the enlarged Ephesus. It is significant that whereas the earlier Greeks had used precious stones only as a medium for the engraver's art, unengraven gems, valuable for their mere material, now came to be used in profusion for adornment. Already before Alexander pan-hellenic feeling had in various ways overridden the internal divisions of the Greek race, but now, with the vast mingling of Greeks of all sorts in the newly-conquered lands, a generalized Greek culture in which the old local characteristics were merged, came to overspread the world. The gradual supersession of the old dialects by the Koinē the common speech of the Greeks, a modification of the Attic idiom coloured by Ionic, was one obvious sign of the new order of things (see Greek Language).

In its artistic, its literary, its spiritual products the age after Alexander gave evidence of the change. In no department did activity immediately stop; but the old freshness and

Art and literature.

creative exuberance was gone. Artistic pleasure, grown less delicate, required the stimulus of a more sensational effect or a more striking realism, as we may see by the Pergamene and Rhodian schools of sculpture, by the bas-reliefs with the *genre* subjects drawn from the life of the countryside, or, in literature by the sort of historical writing which became popular with Cleitarchus and Duris, by the studied emotional or rhetorical point of Callimachus, and by the portrayal of country life in Theocritus. At the same time, artists and men of letters were now addressing themselves in most cases, not to their fellow-citizens in a free city, but to kings and courtiers, or the educated class generally of the Greek world. In those departments of intellectual activity which demand no high ideal faculty, in the study of the world of fact, the centuries immediately following Alexander witnessed notable advance. Scientific research might prosper, just as poetry withered, under the patronage of kings, and such research had now a vast amount of new material at its disposal and could profit by the old Babylonian and Egyptian traditions. The medical schools, especially that of Alexandria, really enlarged knowledge of the animal frame. Knowledge of the earth gained immensely by the Macedonian conquests. The literary schools of Alexandria and Pergamum built up grammatical science, and brought literary and artistic criticism to a fine point. If indeed the earlier ages had been those of creative and spontaneous life, the Hellenistic age was that of conscious criticism and book-learning. The classical products were registered, studied, assorted and commented upon. Men travelled and read more. Books were in demand and were multiplied. Libraries became a feature of the age, the kings leading the way as collectors, of books, especially the rival dynasties of Egypt and Pergamum. The library attached to the Museum at Alexandria is said to have contained at the time of its destruction in 47 B.C. as many as 700,000 rolls (Aul. Gell. vi. 17. 3). Even smaller cities, like Aphrodisias in Caria, had public libraries for the instruction of their youth (Le Bas, III. No. 1618).

With the general decay of ancient civilization under the Roman empire, even scientific research ceased, and though there were literary revivals, like that connected with the new Atticism under the Antonine emperors, these were mainly imitative and artificial, and even learning became at last under the Byzantine emperors a jejune and formal tradition (see GREEK LITERATURE).

Religion and philosophy.

The diffusion of the Greek race far from the former centres of its life, the mingling of citizens of many cities, the close contact between Greek and barbarian in the conquered lands—all this had made the old sanctions of civic religion and civic morality of less account than ever. New guides of life were needed. The Stoic philosophy, with its cosmopolitan note, its fixed dogmas and plain ethical precepts, came into the world at the time of the Macedonian conquests to meet the needs of the new age. Its ideas became popular among ordinary men as the older philosophies had never been. The Stoic or Cynic preacher, attacking the ways of society, in pungent, often coarse, phrase, became a familiar figure of the Greek market-place (P. Wendland, *Beiträge zur Gesch. d. griech. Philosophie*, 1895).

Although the cults of the old Greek deities in the new cities, with their splendid apparatus of festivals and sacrifice might still hold the multitude, men turned ever in large numbers to alien religions, felt as more potent because strange, and the various gods of Egypt and the East began to find larger entrance in the Greek world. Even in the old Greek religion before Alexander there had been large elements of foreign origin, and that the Greeks should now do honour to the gods of the lands into which they came, as we find the Cilician and Syrian Greeks doing to Baal-tars and Baal-marcod and the Egyptian Greeks to the gods of Egypt, was only in accordance with the primitive way of thinking. But it was a sign of the times when Serapis and Isis, Osiris and Anubis began to take place among the popular deities in the old Greek lands. The origin of the cult of Serapis, which Ptolemy I. found, or established, in Egypt is disputed; the familiar type of the god is the invention of a Greek artist, but the name and religion came from somewhere in the East (see discussion under SERAPIS). Before the end of the 2nd century B.C. there were temples of Serapis in Athens, Rhodes, Delos and Orchomenos in Boeotia. Under the Roman empire the cult of Isis, now furnished with an official priesthood and elaborate ritual, became really popular in the Hellenistic world. King Asoka in the 3rd century B.C. sent Buddhist missionaries from India to the Mediterranean lands; their preaching has, it is true, left little or no trace in our Western records. But other religions of Oriental origin penetrated far, the worship of the Phrygian Great Mother, and in the 2nd century A.D. the religion of the Mithras (Lafaye, *Culte des divinités alexandrines*, 1884; Roscher, articles "Anubis," "Isis," &c.; F. Cumont, *Mystères de Mithra*, Eng. trans., 1903; *Les Religions orientales dans le paganisme romain*, 1906). 240

The Jews, too, by the time of Christ were finding in many quarters an open door. Besides those who were ready to go the whole length and accept circumcision, numbers adopted particular Jewish practices, observing the Sabbath, for instance, or turned from polytheism to the doctrine of the One God. The synagogues in the Gentile cities had generally attached to them, in more or less close connexion a multitude of those "who feared God" and frequented the services (Schürer, *Gesch. d. jüd. Volks*, iii. 102-135).

Christianity.

Among the religions which penetrated the Hellenistic world from an Eastern source, one ultimately overpowered all the rest and made that world its own. The inter-action of Christianity and Hellenism opens large fields of inquiry. The teaching of Christ Himself contained, as it is given to us, no Hellenic element; so far as He built with older material, that material was exclusively the sacred tradition of Israel. So soon, however, as the Gospel was carried in Greek to Greeks, Hellenic elements began to enter into it, in the writings, for instance, of St Paul, the appeal to what "nature" teaches would be generally admitted to be the adoption of a Greek mode of thought. It was, of course, impossible that speaking in Greek and living among Greeks, Christians should not to some extent use current conceptions for the expression of their faith. There was, at the same time, in the early Church a powerful current of feeling hostile to Greek culture, to the wisdom of the world. What the attitude of the New People should be to it, whether it was all bad, or whether there were good things in it which Christians should appropriate, was a vital question that always confronted them. The great Christian School of Alexandria represented by Clement and Origen effected a durable alliance between Greek education and Christian doctrine. In proportion as the Christian Church had to go deeper into metaphysics in the formulation of its belief as to God, as to Christ, as to the soul, the Greek philosophical terminology, which was the only vehicle then available for precise thought, had to become more and more an essential part of Christianity. At the same time Christian ethics incorporated much of the current popular philosophy, especially large Stoical elements. In this way the Church itself, as we shall see, became a propagator of Hellenism (see Hatch, *Hibbert Lectures*, 1888; Wendland, "Christentum u. Hellenismus" in *Neue Jahrb. f. kl. Alt.* ix. 1902, p. 1 f.; and *Die hellenistisch-römische Kultur in ihren Beziehungen zu Judentum u. Christentum*, 1907).

B. *Effect upon non-Hellenic Peoples.*—Hellenism secured by the Macedonian conquest *points d'appui* from the Mediterranean to India, and brought the system of commerce and intercourse into Greek hands. What effect did it produce in these various countries? What effect again in the lands of the West which fell under the sway of Rome?

Greek cities.

(i.) *India.*—In India (including the valleys of the Kabul and its northern tributaries, then inhabited by an Indian, not, as now, by an Iranian, population) Alexander planted a number of Greek towns. Alexandria "under the Caucasus" commanded the road from Bactria over the Hindu-Kush; it lay somewhere among the hills to the north of Kabul, perhaps at Opian near Charikar (MacCrindle, *Ancient India*, p. 87, note 4); that it is the city meant by "Alasadda the capital of the Yona (Greek) country" in the Buddhist Mahavanso, as is generally affirmed, seems doubtful (Tarn, loc. cit. below, p. 269, note 7). We hear of a Nicaea in the Kabul valley itself (near Jalalabad?), another Nicaea on the Hydaspes (Jhelum) where Alexander crossed it, with Bucephala (see Bucephalus) opposite, a city (unnamed) on the Acesines (Chenab) (Arr. vi. 29, 3), and a series of foundations strung along the Indus to the sea. Soon after 321, Macedonian supremacy beyond the Indus collapsed before the advance of the native Maurya dynasty, and about 303 even large districts west of the Indus were ceded by Seleucus. But the chapter of Greek rule in India was not yet closed. The Maurya dynasty broke up about 180 B.C., and at the same time the Greek rulers of Bactria began to lead expeditions across the Hindu-Kush. Menander in the middle of the 2nd century B.C. extended his rule from the Hindu-Kush to the Ganges. Then "Scythian" peoples from central Asia, Sakas and Yue-chi, having conquered Bactria, gradually squeezed within ever-narrowing limits the Greek power in India. The last Greek prince, Hermaeus, seems to have succumbed about 30 B.C. It was just at this time that the Graeco-Roman world of the West was consolidated as the Roman Empire, and, though Greek rule in India had disappeared, active commercial intercourse went on between India and the Hellenistic lands. How far, through these changes, did the Greek population settled by Alexander or his successors in India maintain their distinctive character? What influence did Hellenism during the centuries in which it was in contact with India exert upon the native mind? Only extremely qualified answers can be given to these questions. Capital data are possibly waiting there under ground—the Kabul valley for instance is almost virgin soil for the archaeologist—and any conclusion we can arrive at is merely provisional. If certain statements of classical authors were true, Hellenism in India flourished exceedingly. But the phil-hellenic Brahmins in Philostratus' life of Apollonius had no existence outside the world of romance, and the statement of Dio Chrysostom that the Indians were familiar with Homer

in their own tongue (*Or.* liii. 6) is a traveller's tale. India, the sceptical observe, has yielded no Greek inscription, except, of course, on the coins of the Greek kings and their Scythian rivals and successors. To what extent can it be inferred from legends on coins that Greek was a living speech in India? Perhaps to no large extent outside the Greek courts. The fact, however, that the Greek character was still used on coins for two centuries after the last Greek dynasty had come to an end shows that the language had a prestige in India which any theory, to be plausible, must account for. If we argue by probability from what we know of the conditions, we have to consider that the Greek rule in India was all through fighting for existence, and can have had "little time or energy left for such things as art, science and literature" (Tarn, *loc. cit.* p. 292), and it is pointed out that a casual reference to the Greeks in an Indian work contemporary with Menander characterizes them as "viciously valiant Yonas." How long is it probable that Greek colonies planted in the midst of alien races would have remained distinct? Mr Tarn builds much upon the fact that the descendants of the Greek Branchidae settled by Xerxes in central Asia had become bilingual in six generations (Curt. vii. 5, 29). But the Greek race before Alexander had not its later prestige, and we must consider such a sentiment as leads the Eurasian to-day to cling to his Western parentage, so that the instance of the Branchidae cannot be used straight away for the time 241
after Alexander. Certainly, had the Greek colonies in India been active political bodies, we could hardly have failed to find some trace of them, in civic architecture or in inscriptions, by this time. Perhaps we should rather think of them as resembling the Greeks found to-day dispersed over the nearer East with interests mainly commercial, easily assimilating themselves to their environment. A notice derived from Agatharchides (about 140 B.C.) possibly refers to the activity of these Indian Greeks in the sea-borne trade of the Indian Ocean (Müller, *Geog. Graeci min.* i. p. 191; cf. Diod. iii. 47. 9). As to what India derived from Greece there has been a good deal of erudite debate. That the Indian drama took its origin from the Greek is still maintained by some scholars, though hardly proved. There is no doubt that Indian astronomy shows marked Hellenic features, including actual Greek words borrowed. But by far the most signal borrowing is in the sphere of art. The stream of Buddhist art which went out eastwards across Asia had its rise in North-West India, and the remains of architecture and sculpture unearthed in this region enable us to trace its development back to pure Greek types. It remains, of course, a question whether the tradition was transmitted by the Greek dynasties from Bactria or by intercourse with the Roman empire; the latter seems now almost certain; but the fact of the influence is equally striking on either theory. How far to the east the distinctive influence of Greece went is shown by the seal-impressions with Athena and Eros types found by Dr Stein in the buried cities of Khotan (*Sand-buried Ruins of Khotan*, p. 396), and according to Mr E. B. Havell, there exist "paintings treasured as the most precious relics and rarely shown to Europeans, which closely resemble the Graeco-Buddhist art of India" in some of the oldest temples of Japan (*Studio*, vol. xxvii. 1903, p. 26).

Greek art.

See A. A. Macdonell, *History of Sanskrit Literature* (1900) p. 411 f., and the references on p. 452; V. A. Smith, *Early History of India* (1904); Grünwedel, *Buddhist Art in India* (Eng. trans., edited by Dr Burgess, 1901); W. W. Tarn, "Notes on Hellenism in Bactria and India" in *Journ. of Hell. Studies*, xxii. (1902); Foucher, *L'Art gréco-bouddhique du Gandhâra* (1905).

(ii.) *Iran and Babylonia.*—The colonizing activity of Alexander and his successors found a large field in Iran where, up till his time, hardly any walled towns seem to have existed. Cities now arose in all its provinces, superseding in many cases native market places and villages, and holding the vantage-points of commerce. Media, Polybius says, was defended by a chain of Greek cities from barbarian incursion (x. 27. 3); in the neighbourhood of Teheran seem to have stood Heraclea and Europus. In Eastern Iran the cities which are its chief places to-day then bore Greek names, and looked upon Alexander or some other Hellenic prince as their founder. Khojend, Herat, Kandahar were Alexandrias, Merv was an Alexandria till it changed that name for Antioch. When the farther provinces broke away under independent Greek kings, a Eucratidēa and a Demetrias attested their glory. Even in a town definitely barbarian like Syrinca in 209 B.C. there was a resident mercantile community of Greeks (Polyb. x. 31). The bulk of Greek historical literature having perished, and in the absence of both archaeological data from Iran, we can only speculate on the inner life of these Greek cities under a strange sky. One precious document is the decree of Antioch in Persis (about 206 B.C.) cited in a recently discovered inscription (Kern, *Inschr. v. Magnesia*, No. 61; Dittenberger, *Orient. gr. Inscr.* i. No. 233). This shows us the normal organs of a Greek city, *boulē*, *ecclesia*, *prytaneis*, &c., in full working, with the annual election of magistrates, and ordinary forms of public action. But more than this, it throws a remarkable light upon the solidarity of the Hellenic Dispersion. The citizen body had been increased some generations

Greek cities.

before by colonists from Magnesia-on-Meander sent at the invitation of Antiochus I. The Magnesians are instigated by pan-hellenic enthusiasm. And we see a brisk diplomatic intercourse between the scattered Greek cities going on. It is especially the local religious festivals which bind them together. Antioch in Persis, of course, sends athletes to the great games of Greece, but in this decree it determines to take part in the new festival being started in honour of Artemis at Magnesia. The loyalty, too, expressed towards the Seleucid king implies a predominant interest in pan-hellenic unity, natural in colonies isolated among barbarians. A list is given (fragmentary) of other Greek cities in Babylonia and beyond from which similar decrees had come.

Greek kingdoms.

In the middle of the 3rd century B.C. Bactria and Sogdiana broke away from the Seleucid empire; independent Greek kings reigned there till the country was conquered by nomads from Central Asia (Sacae and Yue-chi) a century later. Alexander had settled large masses of Greeks in these regions (Greeks, it would seem, not Macedonians), whose attempts to return home in 325 and 323 had been frustrated, and it may well be that a racial antagonism quickened the revolt against Macedonian rule in 250. The history of these Greek dynasties is for us almost a blank, and for estimating the amount and quality of Hellenism in Bactria during the 180 years or so of Macedonian and Greek rule, we are reduced to building hypotheses upon the scantiest data. Probably nothing important bearing on the subject has been left out of view in W. W. Tarn's learned discussion (*Journ. of Hell. Stud.* xxii., 1902, p. 268 f.), and his result is mainly negative, that palpable evidences of an active Hellenism have not been found; he inclines to think that the Greek kingdoms mainly took on the native Iranian colour. The coins, of course, are adduced on the other side, being not only Greek in type and legend, but (in many cases) of a peculiarly fine and vigorous execution; and excellence in one branch of art is thought to imply that other branches flourished in the same *milieu*. Tarn suggests that they may be a "sport," a spasmodic outbreak of genius (see BACTRIA and works there quoted). In these outlying provinces the national Iranian sentiment seems to have been most intense, and it is interesting to see that under Alexander Hellenism appeared as "belligerent civilization," in the attempt to suppress practices like the exposure of the dying to the dogs (an exaggeration of Zoroastrianism) and, possibly also, abhorrent forms of marriage (Strabo xi. 517; Porphyr. *De abstin.* 4. 21; Plut. *De fort. Al.* 5).

The west of Iran slipped from the Seleucids in the course of the 2nd century B.C. to be joined to the Parthian kingdom, or fall under petty native dynasties. Soon after 130 Babylonia too was conquered by the Parthian, and Mesopotamia before 88. Then the reconquest of the nearer East by Oriental dynasties was checked by the advance of Rome. Asia Minor and Syria remained substantial parts of the Roman Empire till the Mahommedan conquests of the 7th century A.D. began a new process of recoil on the part of the Hellenistic power. In Babylonia, also, in Susiana and Mesopotamia, Hellenism had been established in a system of cities for 200 years before the coming of the Parthian. The greatest of all of them stood here—almost on the site of Bagdad—Seleucia on the Tigris. It superseded Babylon as the industrial focus of Babylonia and counted some 600,000 inhabitants (*plebs urbana*) according to Pliny, *N.H.* vi. § 122 (cf. Joseph. *Arch.* xviii. § 372, 374; for coins, probably of Seleucia, with the type of Tychē issued in the years A.D. 43-44 see Wroth, *Coins of Parthia*, p. xlvi.). The list of other Greek cities known to us in these regions is too long to give here (see Droysen, *loc. cit.*, and E. Schwartz in Kern's *Inschr. v. Magnesia*, p. 171 f.). In Mesopotamia, Pliny especially notes how the character of the country was changed when the old village life was broken in upon by new centres of population in the cities of Macedonian foundation (Pliny, *N.H.* vi. § 117; cf. K. Regling, "Histor. geog. d. mesopot. Parallelograms," in Lehmann's *Beiträge*, i. p. 442 f.).

Hellenic-Iranian culture.

We do not look in vain for notable names in Hellenistic literature and philosophy produced on an Asiatic soil. Diogenes, the Stoic philosopher (head of the school in 156 B.C.), was a "Babylonian," *i.e.* a citizen of Seleucia on the Tigris; so too was Seleucus, the mathematician and astronomer, being possibly a native Babylonian; Berossus, who wrote a Babylonian history in Greek (before 261 B.C.) was a Hellenized native. Apollodorus, Strabo's authority for Parthian history (*c.* 80 B.C.?), was from the Greek city of Artemita in Assyria. When the Parthians rent away provinces from the Seleucid empire, the Greek cities did not cease to exist by passing under barbarian rule. Gradually no doubt the Greek colonies were absorbed, but the process was a long one. In 140 and 130 B.C. those of Iran were ready to rise in support of the Seleucid invader (Joseph. *Arch.* xiii. § 184; Justin xxxviii. 10.6-8). Just so, Crassus in 53 B.C. found a welcome in the Greek cities of Mesopotamia. Seleucia on the Tigris is spoken of by Tacitus as being in A.D. 36 "proof against barbarian influences and mindful of its founder Seleucus" (*Ann.* vi. 42). How important an element the Greek population of their realm 242 seemed to the Parthian kings we can see by the fact that they claimed to be themselves champions of Hellenism. From the reign of Artabanus I. (128/7-123 B.C.) they bear the epithet of “Phil-hellen” as a regular part of their title upon the coins. Under the later reigns the Tychē figure (the personification of a Greek city) becomes common as a coin type (Wroth, *Coins of Parthia*, pp. liii., lxxiv.). The coinage may, of course, give a somewhat one-sided representation of the Parthian kingdom, being specially designed for the commercial class, in which the population of the Greek cities was, we may guess, predominant. The state of things which prevails in modern Afghanistan, where trade is in the hands of a class distinct in race and speech (Persian in this case) from the ruling race of fighters is very probably analogous to that which we should have found in Iran under the Parthians.[2] That the Parthian court itself was to some extent Hellenized is shown by the story, often adduced, that a Greek company of actors was performing the *Bacchae* before the king when the head of Crassus was brought in. This single instance need not, it is true, show a Hellenism of any profundity; still it does show that certain parts of Hellenism had become so essential to the lustre of a court that even an Arsacid could not be without them. Artavasdes, king of Armenia (54?-34 B.C.) composed Greek tragedies and histories (Plut. *Crass.* 33). Then the prestige of the Roman Empire, with its prevailingly Hellenistic culture, must have told powerfully. The Parthian princes were in many cases the children of Greek mothers who had been taken into the royal harems (Plut. *Crass.* 32). Musa, the queen-mother, whose head appears on the coins of Phraataces (3/2 B.C.-A.D. 4) had been an Italian slave-girl. Many of the Parthian princes resided temporarily, as hostages or refugees, in the Roman Empire; but one notes that the nation at large looked with anything but favour upon too liberal an introduction of foreign manners at the court (Tac. *Ann.* ii. 2).

Such slight notices in Western literature do not give us any penetrating view into the operation of Hellenism among the Iranians. As an expression of the Iranian mind we have the Avesta and the Pehlevi theological literature. Unfortunately in a question of this kind the dating of our documents is the first matter of importance, and it seems that we can only assign dates to the different parts of the Avesta by processes of fine-drawn conjecture. And even if we could date the Avesta securely, we could only prove borrowing by more or less close coincidences of idea, a tempting but uncertain method of inquiry. Taking an opinion based on such data for what it is worth, we may note that Darmesteter believed in the influence of the later Greek philosophy (Philonian and Neo-platonic) as one of those which shaped the Avesta as we have it (*Sacred Books of the East*, iv. 54 f.), but we must also note that such an influence is emphatically denied by Dr L. Mills (*Zarathushtra and the Greeks*, Leipzig, 1906). Outside literature, we have to look to the artistic remains offered by the region to determine Hellenic influence. But here, too, the preliminary classification of the documents is beset with doubt. In the case of small objects like gems the place of manufacture may be far from the place of discovery. The architectural remains are solidly *in situ*, but we may have such vast disagreement as to date as that between Dieulafoy and M. de Morgan with respect to domed buildings of Susa, a disagreement of at least five centuries. It is enough then here to observe that Iran and Babylonia do, as a matter of fact, continually yield the explorer objects of workmanship either Greek or influenced by Greek models, belonging to the age after Alexander, and that we may hence infer at any rate such an influence of Hellenism upon the tastes of the richer classes as would create a demand for these things.

For gems see “Gobineau” in the *Rev. archéol.*, vols. xxvii., xxviii. (1874); Ménant, *Recherches sur la glyptique orientale*, ii. 189 f.; E. Babelon, *Catalogue des camées de la Bibl. Nat.* (1897), p. 56; A. Furtwängler, *Die antiken Gemmen*, pp. 165, 369 ff.; Figurines: Heuzey, *Fig. ant. du Louvre* (1883) p. 3; J. P. Peters, *Nippur*, ii. 128; Military standard: Heuzey, *Comptes rendus de l’Acad. d. Inscr.* (1895) p. 16; *Rev. d’Assyr.* v. (1903), p. 103 f. Alabaster vase: Sykes, *Ten Thousand Miles in Persia*, p. 445. In the case of the architectural remains, the Greek tradition is obvious at Hatra (Jacquerel, *Rev. archéol.*, 1897 [ii.], 343 f.), and in the relics of the temple at Kingavar (Dieulafoy, *L’Art antique de la Perse*, v. p. 10 f.).

Sassanian empire.

If any vestige of Hellenism still survived under the Sassanian kings, our records do not show it. The spirit of the Sassanian monarchy was more jealously national than that of the Arsacid, and alien grafts could hardly have flourished under it. Of course, if Darmesteter was right in seeing a Greek element in Zoroastrianism, Greek influence must still have operated under the new dynasty, which recognized the national religion. But, as we saw, the Greek influence has been authoritatively denied. At the court a limited recognition might be given, as fashion veered, to the values prevalent in the Hellenistic world. The story of Hormisdas in Zosimus is suggestive in this connexion (Zosim. *Hist. nov.* ii. 27). Chosroes I. interested himself in Greek philosophy and received its professors from the West with open arms (Agath. ii. 28 f.);

according to one account, he had his palace at Ctesiphon built by Greeks (Theophylact. Simocat. v. 6).

But the account of Chosroes’ mode of action makes it plain that the Hellenism once planted in Iran had withered away; representatives of Greek learning and skill have all to be imported from across the frontier.

For Hellenism in Babylonia and Iran, see the useful article of M. Victor Chapot in the *Bull. et mémoires de la Soc. Nat. des Antiquaires de France* for 1902 (published 1904), p. 206 f., which gives a conspectus of the relevant literature.

(iii.) *Asia Minor.*—Very different were the fortunes of Hellenism in those lands which became annexed to the Roman Empire.

Greek cities of the Diadochi.

In Asia Minor, we have seen how, even before Alexander, Hellenism had begun to affect the native races and Persian nobility. During Alexander’s own reign, we cannot trace any progress in the Hellenization of the interior, nor can we prove here his activity as a builder of cities. But under the dynasties of his successors a great work of city-building and colonization went on. Antigonus fixed his capital at the old Phrygian town of Celaenae, and the famous cities of Nicaea and Alexandria Troas owed to him their first foundation, each as an Antigonia; they were refounded and renamed by Lysimachus (301-281 B.C.). Then we have the great system of Seleucid foundations. Sardis, the Seleucid capital in Asia Minor, had become a Greek city before the end of the 3rd century B.C. The main high road between the Aegean coast and the East was held by a series of new cities. Going west from the Cilician Gates we have Laodicea Catacecaumene, Apamea, the Phrygian capital which absorbed Celaenae, Laodicea on the Lycus, Antioch-on-Meander, Antioch-Nysa, Antioch-Tralles. To the south of this high road we have among the Seleucid foundations Antioch in Pisidia (colonized with Magnesians from the Meander) and Stratonicea in Caria; in the region to the north of it the most famous Seleucid colony was Thyatira. Along the southern coast, where the houses of Seleucus and Ptolemy strove for predominance, we find the names of Berenice, Arsinoë and Ptolemais confronting those of Antioch and Seleucia. With the rise of the Attalid dynasty of Pergamum, a system of Pergamene foundation begins to oppose the Seleucid in the interior, bearing such names as Attalia, Philetaeria, Eumenia, Apollonis. Of these, one may 243
note for their later celebrity Philadelphia in Lydia and Attalia on the Pamphylian coast. The native Bithynian dynasty became Hellenized in the course of the 3rd century, and in the matter of city building Prusias (the old Cius), Apamea (the old Myrlea), probably Prusa, and above all Nicomedia attested its activity. While new Greek cities were rising in the interior, the older Hellenism of the western coast grew in material splendour under the munificence of Hellenistic kings. Its centres of gravity to some extent shifted. There was a tendency towards concentration in large cities of the new type, which caused many of the lesser towns, like Lebedus, Myus or Colophon, to sink to insignificance, while Ephesus grew in greatness and wealth, and Smyrna rose again after an extinction of four centuries. The great importance of Rhodes belongs to the days after Alexander, when it received the riches of the East from the trade-routes which debouched into the Mediterranean at Alexandria and Antioch. In Aeolis, of course, the centre of gravity moved to the Attalid capital, Pergamum. It was the irruption of the Celts, beginning in 278-277 B.C., which checked the Hellenization of the interior. Not only did the Galatian tribes take large tracts towards the north of the plateau in possession, but they were an element of perpetual unrest, which hampered and distracted the Hellenistic monarchies. The wars, therefore, in which the Pergamene kings in the latter part of the 3rd century stemmed their aggressions, had the glory of a Hellenic crusade.

Native dynasties.

The minor dynasties of non-Greek origin, the native Bithynian and the two Persian dynasties in Pontus and Cappadocia, were Hellenized before the Romans drove the Seleucid out of the country. In Bithynia the upper classes seem to have followed the fashion of the court (Beloch iii. [i.], 278); the dynasty of Pontus was phil-hellenic by ancestral tradition; the dynasty of Cappadocia, the most conservative, dated its conversion to Hellenism from the time when a Seleucid princess came to reign there early in the 2nd century B.C. as the wife of Ariarathes V. (Diod. xxxi. 19. 8). But Hellenism in Cappadocia was for centuries to come still confined to the castles of the king and the barons, and the few towns.

Hellenism

When Rome began to interfere in Asia Minor, its first action was to break the power of the Gauls (189 B.C.). In 133 Rome entered formally upon the heritage of the Attalid kingdom and became the dominant power in the Anatolian peninsula for 1200 years. Under Rome the process of Hellenization, which the divisions and weakness

under Roman sway.

of the Macedonian kingdoms had checked, went forward. The coast regions of the west and south the Romans found already Hellenized. In Lydia "not a trace" of the old language was left in Strabo's time (Strabo xiv. 631); in Lycia, the old language became obsolete in the early days of Macedonian rule (see Kalinka, *Tituli Asiae minoris*, i. 8). But inland, in Phrygia, Hellenism had as yet made little headway outside the Greek cities. Even the Attalids had not effected much here (Körte, *Athen. Mitth.* xxiii., 1898, p. 152), and under the Romans, the penetration of the interior by Hellenism was slow. It was not till the reign of Hadrian that city life on the Phrygian plateau became rich and vigorous, with its material circumstances of temples, theatres and baths. Among the villages of the north and east of Phrygia, Hellenism "was only beginning to make itself felt in the middle of the 3rd century A.D." (Ramsay in Kuhn's *Zeitsch. f. vergleich. Sprachforschung*, xxviii., 1885, p. 382). Gravestones in this region as late as the 4th century curse violators in the old Phrygian speech. The lower classes at Lystra in St Paul's time spoke Lycaonian (Acts xiv. 11). In that part of Phrygia, which by the settlement of the Celtic invaders became Galatia, the larger towns seem to have become Hellenized by the time of the Christian era, whilst the Celtic speech maintained itself in the country villages till the 4th century A.D. (Jerome, Preface to Comment, in *Epist. ad Gal.* book ii.; see J. G. C. Anderson, *Journ. of Hell. Stud.* xix., 1899, p. 312 f.). Cappadocia at the beginning of the Christian era was still comparatively townless (Strabo xii. 537), a country of large estates with a servile peasantry. Even in the 4th century its Hellenization was still far from complete; but Christianity had assimilated so much of the older Hellenic culture that the Church was now a main propagator of Hellenism in the backward regions. The native languages of Asia Minor all ultimately gave way to Greek (unless Phrygian lingered on in parts till the Turkish invasions; see Mordtmann, *Sitzungsb. d. bayer. Ak.* 1862, i. p. 30; K. Holl in *Hermes*, xliii., 1908, p. 240 f.). The effective Hellenization of Armenia did not take place till the 5th century, when the school of Mesrop and Sahak gave Armenia a literature translated from, or imitating, Greek books (Gelzer in I. v. Müller's *Handbuch*, vol. ix. Abt. i. p. 916.)

(iv.) *Syria.*—In Syria, which with Cilicia and Mesopotamia, formed the central part of the Seleucid empire, the new colonies were especially numerous. Alexander himself had perhaps made a beginning with Alexandria-by-Issus (mod. Alexandretta), Samaria, Pella (the later Apamea), Carrhae, &c. Antigonus founded Antigonia, which was absorbed a few years later by Antioch, and after the fall of Antigonus in 301, the work of planting Syria with Greek cities was pursued effectively north of the Lebanon by the house of Seleucus, and, less energetically, south of the Lebanon by the house of Ptolemy. In the north of Syria four cities stood pre-eminent above the rest, (1) Antioch on the Orontes, the Seleucid capital; (2) Seleucia-in-Pieria near the mouth of the Orontes, which guarded the approach to Antioch from the sea; (3) Apamea (mod. Famia), on the middle Orontes, the military headquarters of the kingdom; and (4) Laodicea "on sea" (*ad mare*), which had a commercial importance in connexion with the export of Syrian wine. Of the Ptolemaic foundations in Coele-Syria only one attained an importance comparable with that of the larger Seleucid foundations, Ptolemais on the coast, which was the old Semitic Acco transformed (mod. Acre). The group of Greek cities east of the Jordan also fell within the Ptolemaic realm during the 3rd century B.C., though their greatness belonged to a somewhat later day. The whole of Syria was brought under the Seleucid sceptre, together with Cilicia, by Antiochus III. the Great (223-187 B.C.). Under his son, Antiochus IV. Epiphanes (175-164), a fresh impulse was given to Syrian Hellenism. In 1 Maccabees he is represented as writing an order to all his subjects to forsake the ways of their fathers and conform to a single prescribed pattern, and though in this form the account can hardly be exact, it does no doubt represent the spirit of his action. Other facts there are which point the same way. We now find a sudden issue of bronze money by a large number of the cities of the kingdom in their own name—an indication of liberties extended or confirmed. Many of them exchange their existing name for that of Antioch (Adana, Tarsus, Gadara, Ptolemais), Seleucia (Mopsuestia, Gadara) or Epiphanea (Oeniandus, Hamath). At Antioch itself great public works were carried out, such as were involved in the addition of a new quarter to the city, including, we may suppose, the civic council chamber which is afterwards spoken of as being here. With the ever-growing weakness of the Seleucid dynasty, the independence and activity of the cities increased, although, if, on the one hand, they were less suppressed by a strong central government, they were less protected against military adventurers and barbarian chieftains. Accordingly, when Pompey annexed Syria in 64 B.C. as a Roman province, he found it a chaos of city-states and petty principalities. The Nabataeans and the Jews above all had encroached upon the Hellenistic domain; in the south the Jewish raids had spread desolation and left many cities practically in ruins. Under Roman protection, the cities were soon rebuilt and Hellenism secured from the barbarian peril. Greek city life, with its political

Seleucid empire.

Roman period.

forms, its complement of festivities, amusements and intellectual exercise, went on more largely than before. The great majority of the Hellenistic remains in Syria belong to the Roman period. Such local dynasties as were suffered by the Romans to exist had, of course, a Hellenistic complexion. Especially was this the case with that of the Herods. Not only were such marks of Hellenism as a theatre introduced by Herod the Great (37-34 B.C.) at 244
Jerusalem, but in the work of city-building this dynasty showed itself active. Sebaste (the old Samaria), Caesarea, Antipatris were built by Herod the Great, Tiberias by Herod Antipas (4 B.C.-A.D. 39). The reclaiming of the wild district of Hauran for civilization and Hellenistic life was due in the first instance to the house of Herod (Schürer, *Gesch. d. jüd. Volk.* 3rd ed., ii. p. 12 f.). In Syria, too, Hellenism under the Romans advanced upon new ground. Palmyra, of which we hear nothing before Roman times, is a notable instance.

Greek culture in Syria.

As to the effect of this network of Greek cities upon the aboriginal population of Syria, we do not find here the same disappearance of native languages and racial characteristics as in Asia Minor. Still less was this the case in Mesopotamia, where a strong native element in such a city as Edessa is indicated by its epithet μιξοβάρβαρος. The old cults naturally went on, and at Carrhae (Harran) even survived the establishment of Christianity. The lower classes at Antioch, and no doubt in the cities generally, were in speech Aramaic or bilingual; we find Aramaic popular nicknames of the later Seleucids (K. O. Müller, *Antiq. Ant.* p. 29). The villages, of course, spoke Aramaic. The richer natives, on the other hand, those who made their way into the educated classes of the towns, and attained official position, would become Hellenized in language and manners, and the "Syrian Code" shows how far the social structure was modified by the Hellenic tradition (Mitteis, *Reichsrecht und Volksrecht in den öst. Provinzen des röm. Kaiserreichs*, 1891; Arnold Meyer, *Jesu Muttersprache*, 1896). Of the Syrians who made their mark in Greek literature, some were of native blood, *e.g.* Lucian of Samosata.

One may notice the great part taken by natives of the Phoenician cities in the history of later Greek philosophy, and in the poetic movement of the last century B.C., which led to fresh cultivation of the epigram. Greek, in fact, held the field as the language of literature and polite society. Possibly at places like Edessa, which for some 350 years (till A.D. 216) was under a dynasty of native princes, Aramaic was cultivated as a literary language. There was a Syriac-speaking church here as early as the 2nd century, and with the spread of Christianity Syriac asserted itself against Greek. The Syriac literature which we possess is all Christian.

But where Greek gave place to Syriac, Hellenism was not thereby effaced. It was to some extent the passing over of the Hellenic tradition into a new medium. We must remember the marked Hellenic elements in Christian theology. The earliest Syriac work which we possess, the book "On Fate," produced in the circle of the heretic Bardaisan or Bardesanes (end of the 2nd century), largely follows Greek models. There was an extensive translation of Greek works into Syriac during the next centuries, handbooks of philosophy and science for the most part. The version of Homer into Syriac verses made in the 8th century has perished, all but a few lines (R. Duval, *La Litt. syriaque*, 1900, p. 325).

The Jews.

(v.) *The relation of the Jews to Hellenism* in the first century and a half of Macedonian rule is very obscure, since the statements made by later writers like Josephus, as to the visit of Alexander to Jerusalem or the privileges conferred upon the Jews in the new Macedonian realms are justly suspected of being fiction. It has been maintained that Greek influence is to be traced in parts of the Old Testament assigned to this period, as, for instance, the Book of Proverbs; but even in the case of Ecclesiastes, the canonical writing whose affinity with Greek thought is closest, the coincidence of idea need not necessarily prove a Greek source. The one solid fact in this connexion is the translation of the Jewish Law into Greek in the 3rd century B.C., implying a Jewish Diaspora at Alexandria, so far Hellenized as to have forgotten the speech of Palestine. Early in the 2nd century B.C. we see that the priestly aristocracy of Jerusalem had, like the well-to-do classes everywhere in Syria, been carried away by the Hellenistic current, its strength being evidenced no less by the intensity of the conservative opposition embodied in the party of the "Pious" (Assideans, *Ḥasīdīm*).

Under Antiochus IV. Epiphanes (176-165) the Hellenistic aristocracy contrived to get Jerusalem converted into a Greek city; the gymnasium appeared, and Greek dress became fashionable with the young men. But when Antiochus, owing to political developments, interfered violently at Jerusalem, the conservative opposition carried the nation with them. The revolt under the Hasmonaean family (Judas Maccabaeus and his brethren) followed, ending in 143-142 in the establishment of an independent Jewish state under a Hasmonaean prince. But whilst the old Hellenistic party had been crushed the Hasmonaean state was of the nature of a compromise. The Mosaic Law was respected, but Hellenism still found an entrance in various forms. The first Hasmonaean "king," Aristobulus I. (104-103), was known to the Greeks as Phil-hellen. He and all later kings of the dynasty bear Greek names as well as Hebrew ones, and after Jannaeus Alexander (103-76) the Greek legends are common on the coins beside the Hebrew. Herod, who supplanted the Hasmonaean dynasty (37-34 B.C.) made, outside Judaea, a display of Phil-hellenism, building new Greek cities and temples, or bestowing gifts upon the older ones of fame. His court, at the same time, welcomed Greek men of letters like Nicolaus of Damascus. Even in the neighbourhood of Jerusalem, he erected a theatre and an amphitheatre. We have already noticed the work done by the Herodian dynasty in furthering Hellenism in Syria (see Schürer, *Gesch. des jüdisch. Volkes*, vols. i. and ii.). Meanwhile a great part of the Jewish people was living dispersed among the cities of the Greek world, speaking Greek as their mother-tongue, and absorbing Greek influences in much larger measure than their brethren of Palestine. These are the Jews whom we find contrasted as "Hellenists" with the "Hebrews" in Acts. They still kept in touch with the mother-city, and indeed we hear of special synagogues in Jerusalem in which the Hellenists temporarily resident there gathered (Acts vi. 9). A large Jewish literature in Greek had grown up since the translation of the Law in the 3rd century. Beside the other canonical books of the Old Testament, translated in many cases with modifications or additions, it included translations of other Hebrew books (Ecclesiasticus, Judith, &c.), works composed originally in Greek but imitating to some extent the Hebraic style (like Wisdom), works modelled more closely on the Greek literary tradition, either historical, like 2 Maccabees, or philosophical, like the productions of the Alexandrian school, represented for us by Aristobulus and Philo, in which style and thought are almost wholly Greek and the reference to the Old Testament a mere pretext; or Greek poems on Jewish subjects, like the epic of the elder Philo and Ezechiel's tragedy, *Exagogē*. It included also a number of forgeries, circulated under the names of famous Greek authors, verses fathered upon Aeschylus or Sophocles, or books like the false Hecataeus, or above all the pretended prophecies of ancient Sibyls in epic verse. These frauds were all contrived for the heathen public, as a means of propaganda, calculated to inspire them with respect for Jewish antiquity or turn them from idols to God.

For Jewish Hellenism see Schürer, *op. cit.* iii.; Susemihl, *Gesch. der griech. Lit. in der Alexandrinerzeit*, ii. 601 f.; Willrich, *Juden und Griechen* (1895), *Judaica* (1900); Hastings' *Dict. of the Bible*, art. "Greece"; *Encyclop. Biblica*, art. "Hellenism"; Pauly-Wissowa, art. "Aristobulus (15)"; also the work of P. Wendland cited above.

Through the Hellenistic Jews, Greek influences reached Jerusalem itself, though their effect upon the Aramaic-speaking Rabbinical schools was naturally not so pronounced. The large number of Greek words, however, in the language of the Mishnah and the Talmud is a significant phenomenon. The attitude of the Rabbinic doctors to a Greek education does not seem to have been hostile till the time of Hadrian. The sect of the Essenes probably shows an intermingling of the Greek with other lines of tradition among the Jews of Palestine.

See Schürer ii. 42-67, 583; S. Krauss, *Griech. u. latein. Lehnwörter im Talmud* (1898); *Jewish Encyclopedia*, art. "Greek Language."

Ptolemaic kingdom.

(vi.) *In Egypt* the Ptolemies were hindered by special considerations from building Greek 245
cities after the manner of the other Macedonian houses. One Greek city they found existing, Naucratis; Alexander had called Alexandria into being; the first Ptolemy added Ptolemais as a Greek centre for Upper Egypt. They seem to have suffered no other community in the Nile Valley with the independent life of a Greek city, for the Greek and Macedonian soldier-colonies settled in the Fayum or elsewhere had no political self-existence. And even at Alexandria Hellenism was not allowed full development. Ptolemais, indeed, enjoyed all the ordinary forms of self-government, but Alexandria was governed despotically by royal officials. In its population, too, Alexandria was only semi-Hellenic; for besides the proportion of Egyptian natives in its lower strata, its commercial greatness drew in elements from every quarter; the Jews, for instance, formed a majority of the population in two out of the five divisions of the city. At the same time the prevalent tone of the populace was, no doubt, Hellenistic, as is shown by the fact that the Jews who settled there acquired Greek in place of Aramaic as their mother-tongue, and in its upper circles Alexandrian society under the Ptolemies was not only Hellenistic, but notable among the Hellenes for its literary and artistic brilliance. The state university, the "Museum," was in close connexion with the court, and gave to Alexandria the same pre-eminence in natural science and literary scholarship which Athens had in moral philosophy.

Probably in no other country, except Judaea, did Hellenism encounter as stubborn a national antagonism as in Egypt. The common description of “the Oriental” as indurated in his antagonism to the alien conqueror here perhaps has some truth in it. The assault made upon the Macedonian devotee in the temple of Serapis at Memphis “because he was a Greek” is significant (*Papyr. Brit. Mus.* i. No. 44; cf. Grenfell, *Amherst Papyr.* p. 48). And yet even here one must observe qualifications The papyri show us habitual marriage of Greeks and native women and a frequent adoption by natives of Greek names. It has even been thought that some developments of the Egyptian religion are due to Hellenistic influence, such as the deification of Imhotp (Bissing, *Deutsche Literaturzeitung*, 1902, col. 2330) or the practice of forming voluntary religious associations (Otto, *Priester und Tempel*, i. 125). The worship of Serapis was patronized by the court with the very object of affording a mixed cultus in which Greek and native might unite. In Egypt, too, the triumph of Christianity brought into being a native Christian literature, and if this was in one way the assertion of the native against Hellenistic predominance, one must remember that Coptic literature, like Syriac, necessarily incorporated those Greek elements which had become an essential part of Christian theology.

Ethiopia.

From the Ptolemaic kingdom Hellenism early travelled up the Nile into Ethiopia. Ergamenes, the king of the Ethiopians in the time of the second Ptolemy, “who had received a Greek education and cultivated philosophy,” broke with the native priesthood (Diod. iii. 6), and from that time traces of Greek influence continue to be found in the monuments of the Upper Nile. When Ethiopia became a Christian country in the 4th century, its connexion with the Hellenistic world became closer.

Greek culture in the Roman world.

(vii.) *Hellenism in the West.*—Whilst in the East Hellenism had been sustained by the political supremacy of the Greeks, in Italy *Graecia capta* had only the inherent power and charm of her culture wherewith to win her way. At Carthage in the 3rd century the educated classes seem generally to have been familiar with Greek culture (Bernhardy, *Grundriss d. griech. Lit.* § 77). The philosopher Clitomachus, who presided over the Academy at Athens in the 2nd century, was a Carthaginian. Even before Alexander, as we saw, Hellenism had affected the peoples of Italy, but it was not till the Greeks of south Italy and Sicily were brought under the supremacy of Rome in the 3rd century B.C. that the stream of Greek influence entered Rome in any volume. It was now that the Greek freedman, L. Livius Andronicus, laid the foundation of a new Latin literature by his translation of the *Odyssey*, and that the Greek dramas were recast in a Latin mould. The first Romans who set about writing history wrote in Greek. At the end of the 3rd century there was a circle of enthusiastic phil-hellenes among the Roman aristocracy, led by Titus Quinctius Flamininus, who in Rome’s name proclaimed the autonomy of the Greeks at the Isthmian games of 196. In the middle of the 2nd century Roman Hellenism centred in the circle of Scipio Aemilianus, which included men like Polybius and the philosopher Panaetius. The visit of the three great philosophers, Diogenes the “Babylonian,” Critolaus and Carneades in 155, was an epoch-making event in the history of Hellenism at Rome. Opposition there could not fail to be, and in 161 a *senatus consultum* ordered all Greek philosophers and rhetoricians to leave the city. The effect of such measures was, of course, transient. Even though the opposition found so doughty a champion as the elder Cato (censor in 184), it was ultimately of no avail. The Italians did not indeed surrender themselves passively to the Greek tradition. In different departments of culture the degree of their independence was different. The system of government framed by Rome was an original creation. Even in the spheres of art and literature, the Italians, while so largely guided by Greek canons, had something of their own to contribute. The mere fact that they produced a literature in Latin argues a power of creation as well as receptivity. The great Latin poets were imitators indeed, but *mere* imitators they were no more than Petrarch or Milton. On the other hand, even where the creative originality of Rome was most pronounced, as in the sphere of Law, there were elements of Hellenic origin. It has been often pointed out how the Stoic philosophy especially helped to shape Roman jurisprudence (Schmekel, *Philos. d. mittl. Stoa*, p. 454 f.).

Whilst the upper classes in Italy absorbed Greek influences by their education, by the literary and artistic tradition, the lower strata of the population of Rome became largely hellenized by the actual influx on a vast scale of Greeks and hellenized Asiatics, brought in for the most part as slaves, and coalescing as freedmen with the citizen body. Of the Jewish inscriptions found at Rome some two-thirds are in Greek. So too the early Christian church in Rome, to which St Paul addressed his epistle, was Greek-speaking, and continued to be till far into the 3rd century.

III. Later History.—It remains only to glance at the ultimate destinies of Hellenism in West and East. In the Latin West knowledge of Greek, first-hand acquaintance with the Greek classics, became rarer and rarer as general culture declined, till in the dark ages (after the 5th century) it existed practically nowhere but in Ireland (Sandys, *History of Classical Scholarship*, i. 438). In Latin literature, however, a great mass of Hellenistic tradition in a derived form was maintained in currency, wherever, that is, culture of any kind continued to exist. It was a small number of monkish communities whose care of those narrow channels prevented their ever drying up altogether. Then the stream began to rise again, first with the influx of the learning of the Spanish Moors, then with the new knowledge of Greek brought from Constantinople in the 14th century. With the Renaissance and the new learning, Hellenism came in again in flood, to form a chief part of that great river on which the modern world is being carried forward into a future, of which one can only say that it must be utterly unlike anything that has gone before. In the East it is popularly thought that Hellenism, as an exotic, withered altogether away. This view is superficial. During the dark ages, in the Byzantine East, as well as in the West, Hellenism had become little more than a dried and shrivelled tradition, although the closer study of Byzantine culture in latter years has seemed to discover more vitality than was once supposed. Ultimately the Greek East was absorbed by Islam; the popular mistake lies in supposing that the Hellenistic tradition thereby came to an end. The Mahommedan conquerors found a considerable part of it taken over, as we saw, by the Syrian Christians, and Greek philosophical and scientific classics were now translated from Syriac into Arabic. These were the starting-points for the Mahommedan schools in these subjects. Accordingly we find that Arabian philosophy (*q.v.*), mathematics, geography, medicine and philology are all based professedly upon Greek works (Brockelmann, *Gesch. d. arabischen Literatur*, 1898, vol. i.; R. A. Nicholson, *A Literary History of the Arabs*, 1907, pp. 358-361). Aristotle in the East no less than in the West was the “master of them that know”; and Moslem physicians to this day invoke the names of Hippocrates and Galen. The Hellenistic strain in Mahommedan civilization has, it is true, flagged and failed, but only as that civilization as a whole has declined. It was not that the Hellenistic element failed, whilst the native elements in the civilization prospered; the culture of Islam has, as a whole (from whatever causes), sunk ever lower during the centuries that have witnessed the marvellous expansion of Europe.

The middle ages.

Islam.

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Authorities.—For the inner history of Hellenism after Alexander, the general historical literature dealing with later Greece and Rome supplies material in various degrees. See works quoted in articles Greece, *History*; Rome, *History*; Ptolemies; Seleucid Dynasty; Bactria, &c.

Different elements (literature, philosophy, art, &c.) are dealt with in works dealing specially with these subjects, among which those of Susemihl, Wilamowitz-Moellendorff, Erwin Rohde and E. Schwartz are of especial importance for the literature; those of Schreiber and Strzygowski for the later Greek art.

Sketches of Hellenistic civilization generally are found in J. P. Mahaffy’s *Greek Life and Thought* (1887), *The Greek World under Roman Sway* (1890); *The Silver Age of the Greek World* (1906); Julius Kaerst, *Gesch. d. hellenist. Zeitalters* (Band ii., publ. 1909); and in Beloch’s *Griechische Geschichte*, vol. iii. (for the century immediately succeeding Alexander). R. von Scala’s “The Greeks after Alexander,” in Helmolt’s *History of the World* (vol. v.), covers the whole period from Alexander to the end of the Byzantine Empire. P. Wendland’s *Hellenistisch-römische Kultur in ihren Beziehungen zu Judentum u. Christentum* (1907) is an illuminating monograph, giving a conspectus of the material. For Hellenistic Egypt, Bouché-Leclercq, *Histoire des Lagides*, vol. iii. (1906).

(E. R. B.)

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1 See, among recent writers, on one side Kaerst, *Gesch. des hellenist. Zeitalters*, pp. 97 f., and on the other Beloch, *Griech. Gesch.*, iii. [i.] 1-9; Kretschmer, *Einleitung in die Gesch. d. griech. Sprache*, p. 283 f.; O. Hoffmann, *Die Makedonen, ihre Sprache u. ihr Volkstum* (1906).

2 “Ce sont les Tadjik de l’Afghanistan qui constituent les trente-deux corps de métier, qui tiennent boutique, expédient les marchandises, représentent, en un mot, la vie industrielle et commerciale de la nation. Ce sont aussi les Tadjik des villes qui forment la classe lettrée, et qui ont empêché les Afghans de retomber dans la barbarie.” (Reclus, *Nouvelle Géograph. univ.* ix. p. 71.)

HELLER, STEPHEN (1815-1888), Austrian pianist and composer, was born at Pest on the 15th of May 1815. (Fétis's dictionary says 1814, but this is almost certainly wrong.) He was at first intended for a lawyer, but at nine years of age performed so successfully at a concert that he was sent to Vienna to study under Czerny. Halm was his principal master, and from the age of twelve he gave concerts in Vienna, and made a tour through Hungary, Poland and Germany. At Augsburg he had the good fortune to be befriended when ill by a wealthy family, who practically adopted him and gave him the opportunity to complete his musical education. In 1838 he went to Paris, and soon became intimate with Liszt, Chopin, Berlioz and their set, among whom was Hallé, throughout his life an indefatigable performer of Heller's music. In 1849 he came to England and played a few times, and in 1862 he appeared with Hallé at the Crystal Palace. He outlived the great reputation he had enjoyed among cultivated amateurs for so many years, and was almost forgotten when he died at Paris on the 14th of January 1888. His pianoforte pieces, almost all of them published in sets and provided with fancy names, do not show very startling originality, but their grace and refinement could not but make them popular with players and listeners of all classes.

HELLESPONT (*i.e.* "Sea of Helle"; variously named in classical literature Ἑλλήσποντος, ὁ Ἕλλης πόντος, *Hellespontum Pelagus*, and *Fretum Hellesponticum*), the ancient name of the Dardanelles (*q.v.*). It was so-called from Helle, the daughter of Athamas (*q.v.*), who was drowned here. See ARGONAUTS.

HELLEVOETSLUIS, or HELVOETSLUIS, a fortified seaport in the province of South Holland, the kingdom of Holland, on the south side of the island of Voorne-and-Putten, on the sea-arm known as the Haringvliet, 5½ m. S. of Brielle. It has daily steamboat connexion with Rotterdam by the Voornsche canal. Pop. (1900), 4152. Hellevoetsluis is an important naval station, and possesses a naval arsenal, dry and wet docks, wharves and a naval college for engineers. Among the public buildings are the communal chambers, a Reformed church (1661), a Roman Catholic church and a synagogue.

HELLÍN, a town of south-eastern Spain, in the province of Albacete, on the Albacete-Murcia railway. Pop. (1900), 12,558. Hellín is built on the outskirts of the low hills which line the left bank of the river Mundo. It possesses the remains of an old Roman castle and a beautiful parish church, the masonry and marble pavement at the entrance of which are worthy of special notice. The surrounding country yields wine, oil and saffron in abundance; within the town there are manufactures of coarse cloth, leather and pottery. Sulphur is obtained from the celebrated mining district of Minas del Mundo, 12 m. S., at the junction between the Mundo and the Segura; and there are warm sulphurous springs in the neighbouring village of Azaraque. Hellín was known to the Romans who first exploited its sulphur as Illunum.

HELLO, ERNEST (1828-1885), French critic, was born at Tréguier. He was the son of a lawyer who held posts of great importance at Rennes and in Paris, and was well educated at both places, but took to no profession and resided much, for a time, in his father's country-house in Brittany. A very strong Roman Catholic, he appears to have been specially excited by his countryman Renan's attitude to religious matters, and coming under the influence of J. A. Barbey d'Aurevilly and Louis Veuillot, the two most brilliant crusaders of the Church in the press, he started a newspaper of his own, *Le Croisé*, in 1859; but it only lasted two years. He wrote, however, much in other papers. He had very bad health, suffering apparently from spinal or bone disease. But he was fortunate enough to meet with a wife, Zoe Berthier, who, ten years older than himself, and a friend for some years before their marriage, became his devoted nurse, and even brought upon herself abuse from gutter journalists of the time for the care with which she guarded him. He died in 1885. Hello's work is somewhat varied in form but uniform in spirit. His best-known book, *Physionomie de saints* (1875), which has been translated into English (1903) as *Studies in Saintship*, does not display his qualities best. *Contes extraordinaires*, published not long before his death, is better and more original. But the real Hello is to be found in a series of philosophical and critical essays, from *Renan, l'Allemagne et l'athéisme* (1861), through *L'Homme* (1871) and *Les Plateaux de la balance* (1880), perhaps his chief book, to the posthumously published *Le Siècle*. The peculiarity of his standpoint and the originality and vigour of his handling make his studies, of Shakespeare, Hugo and others, of abiding importance as literary "triangulations," results of object, subject and point of view.

HELMERS, JAN FREDERIK (1767-1813), Dutch poet, was born at Amsterdam on the 7th of March 1767. His early poems, *Night* (1788) and *Socrates* (1790), were tame and sentimental, but after 1805 he determined, in company with his brother-in-law, Cornelis Loots (1765-1834), to rouse national feeling by a burst of patriotic poetry. His *Poems* (2 vols., 1809-1810), but especially his great work *The Dutch Nation*, a poem in six cantos (1812), created great enthusiasm and enjoyed immense success. Helmers died at Amsterdam on the 26th of February 1813. He owed his success mainly to the integrity of his patriotism and the opportune moment at which he sounded his counterblast to the French oppression. His posthumous poems were collected in 1815.

HELMERSEN, GREGOR VON (1803-1885), Russian geologist, was born at Laugut-Duckershof, near Dorpat, on the 29th of September (O.S.) 1803. He received an engineering training and became major-general in the corps of Mining Engineers. In 1837 he was appointed professor of geology in the mining institute at St Petersburg. He was author of numerous memoirs on the geology of Russia, especially on the coal and other mineral deposits of the country; and he wrote also some explanations to accompany separate sheets of the geological map of Russia. His geological work was continued to an advanced age, one of the later publications being *Studien über die Wanderblöcke und die Diluvialgebilde Russlands* (1869 and 1882). Most of his memoirs were published by the Imperial Academy of Sciences at St Petersburg. He died at St Petersburg on the 3rd of February (O.S.) 1885.

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HELMET (from an obsolete diminutive of O. Fr. *helme*, mod. *heaume*; the English word is "helm," as in O. Eng., Dutch and Ger.; all are from the Teutonic base *hal-*, pre-Teut. *kal-*, to cover; cf. Lat. *celare*, to hide, Eng. "hell," &c.), a defensive covering for the head. The present article deals with the helmet during the middle ages down to the close of the period when body armour was worn. For the helmet worn by the Greeks and Romans see ARMS AND ARMOUR.

FIG. 1.—Casque with Neck-guard.

The head-dress of the warriors of the dark ages and of the earlier feudal period was far from being the elaborate helmet which is associated in the imagination with the knight in armour and the tourney. It was a mere casque, a cap with or without additional safeguards for the ears, the nape of the neck and the nose (fig. 1). By those warriors who possessed the means to equip themselves fully, the casque was worn over a hood of mail, as shown in fig. 2. In manuscripts, &c., armoured men are sometimes portrayed fighting in their hoods, without casques, basinets or other form of helmet. The casque was, of course, normally of plate, but in some instances it was a strong leather cap covered with mail or imbricated plates. The most advanced form of this early helmet is the conical steel or iron cap with nasal (fig. 2), worn in conjunction with the hood of mail. This is the typical helmet of the 11th-century warrior, and is made familiar by the Bayeux Tapestry. From this point however (*c.* 1100) the evolution of war head-gear follows two different paths for many years. On the one hand the simple casque easily transformed itself into the *basinet*, originally a pointed iron skull-cap without nasal, ear-guards, &c. On the other hand the knight in armour, especially after the fashion of the tournament set in, found the mere cap with nasal insufficient, and the *heaume* (or "helmet") gradually came into vogue. This was in principle a large heavy iron pot covering the head and neck. Often a light basinet was worn underneath it—or rather the knight usually wore his basinet and only put the heaume on over it at the last moment before engaging. The earlier (12th century) war heaumes are intended to be worn with the mail hood and have nasals (fig. 3). Towards the end of the 13th century, however, the basinet grew in size and strength, just as the casque had grown, and began to challenge comparison with the heavy and clumsy heaume. Thereupon the heaume became, by degrees, the special head-dress of the tournament, and grew heavier, larger and more elaborate, while the basinet, reinforced with camail and vizor, was worn in battle. Types of the later, purely tilting, heaume are shown in figs. 4 and 5.

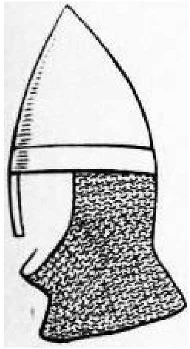

Fig. 2.—Casque with Nasal and Mail Hood.

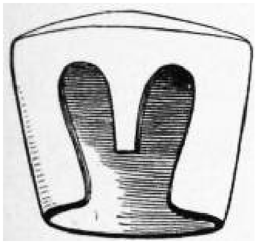

Fig. 3.—Heaume, early 13th century.

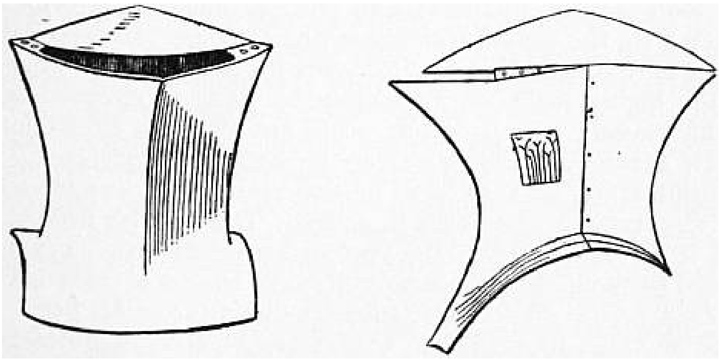

Fig. 4.—Heaume, 15th century.   Fig. 5.—Heaume, 15th century.

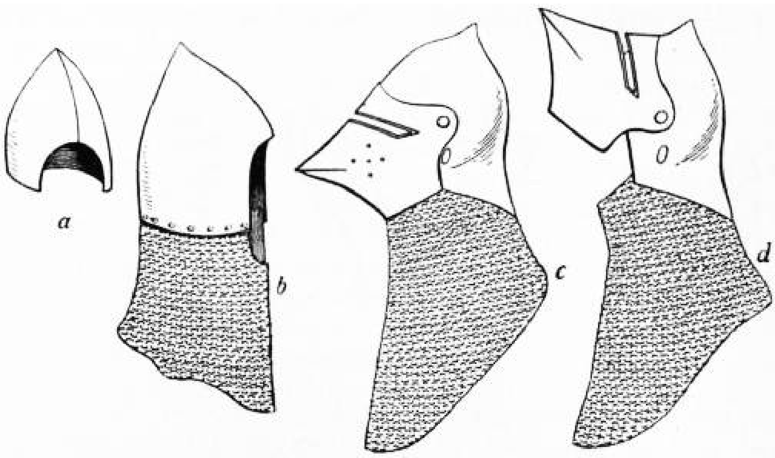

Fig. 6.—Basinets.

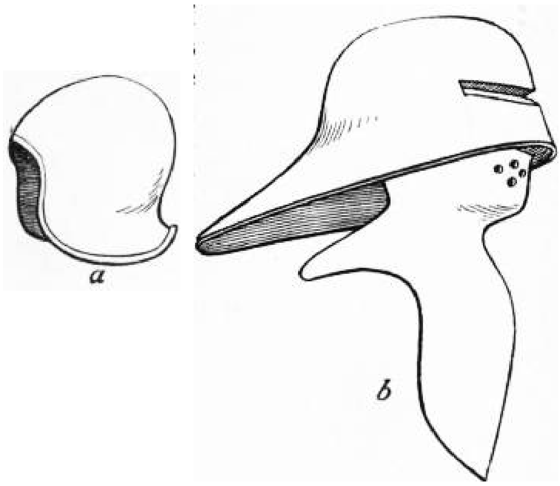

Fig. 7.—Salades or Sallets.

The basinet, then, is the battle head-dress of nobles, knights and sergeants in the 14th century. Its development from the 10th-century cap to the towering helmet of 1350, with its long snouted vizor and ample drooping “camail,” is shown in fig. 6, *a*, *b*, *c* and *d*, the two latter showing the same helmet with vizor down and up. But the tendency set in during the earlier years of the 15th century to make all parts of the armour thicker. Chain “mail” gradually gave way to plate on the body and the limbs, remaining only in those parts, such as neck and elbows, where flexibility was essential, and even there it was in the end replaced by jointed steel bands or small plates. The final step was the discarding of the “camail” and the introduction of the “armet.” The latter will be described later. Soon after the beginning of the 15th century the high-crowned basinet gave place to the *salade* or *sallet*, a helmet with a low rounded crown and a long brim or neck-guard at the back. This was the typical headpiece of the last half of the Hundred Years’ War as the vizored basinet had been of the first. Like the basinet it was worn in a simple form by archers and pikemen and in a more elaborate form by the knights and men-at-arms. The larger and heavier salades were also often used instead of the heaume in tournaments. Here again, however, there is a great difference between those worn by light armed men, foot-soldiers and archers and those of the heavy cavalry. The former, while possessing as a rule the bowl shape and the lip or brim of the type, and always destitute of the conical point which is the distinguishing mark of the basinet, are cut away in front of the face (fig. 7 *a*). In some cases this was remedied in part by the addition of a small pivoted vizor, which, however, could not protect the throat. In the larger salades of the heavy cavalry the wide brim served to protect the whole head, a slit being made in that part of the brim which came in front of the eyes (in some examples the whole of the front part of the brim was made movable). But the chin and neck, directly opposed to the enemy’s blows, were scarcely protected at all, and with these helmets a large volant-piece or beaver (*mentonnière*)—usually a continuation of the body armour up to the chin or even beyond—was worn for this purpose, as shown in fig. 7 *b*. This arrangement combined, in a rough way, the advantages of freedom of movement for the head with adequate protection for the neck and lower part of the face. The *armet*, which came into use about 1475-1500 and completely superseded the salade, realized these requirements far better, and later at the zenith of the armourer’s art (about 1520) and throughout the period of the decline of armour it remained the standard pattern of helmet, whether for war or for tournament. It figures indeed in nearly all portraits of kings, nobles and soldiers up to the time of Frederick the Great, either with the suit of armour or half- 248
armour worn by the subject of the portrait or in allegorical trophies, &c. The armet was a fairly close-fitting rounded shell of iron or steel, with a movable vizor in front and complete plating over chin, ears and neck, the latter replacing the mentonnière or beaver. The armet was connected to the rest of the suit by the gorget, which was usually of thin laminated steel plates. With a good armet and gorget there was no weak point for the enemy’s sword to attack, a roped lower edge of the armet generally fitting into a sort of flange round the top of the gorget. Thus, and in other and slightly different ways, was solved the problem which in the early days of plate armour had been attempted by the clumsy heaume and the flexible, if tough, camail of the vizored basinet, and still more clumsily in the succeeding period by the salade and its grotesque mentonnière. As far as existing examples show, the wide-brimmed salade itself first gave way to the more rounded armet, the mentonnière being carried up to the level of the eyes. Then the use (growing throughout the 15th century) of laminated armour for the joints of the harness probably suggested the gorget, and once this was applied to the lower edge of the armet by a satisfactory joint, it was an easy step to the elaborate pivoted vizor which completed the new head-dress. Types of armets are shown in

fig. 8.

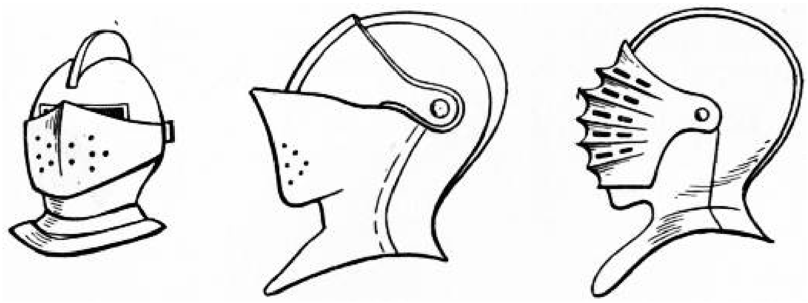

FIG. 8.—Armets.

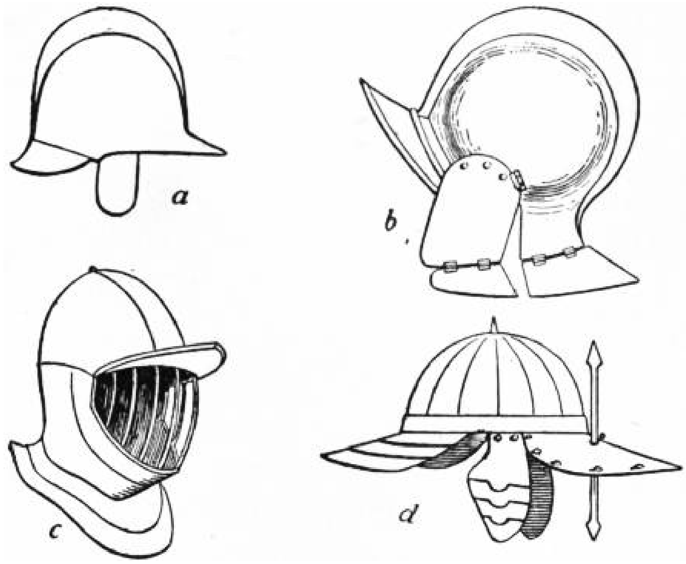

FIG. 9.—Burgonets.

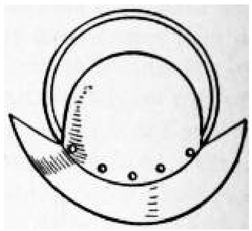

FIG. 10.—Morion.

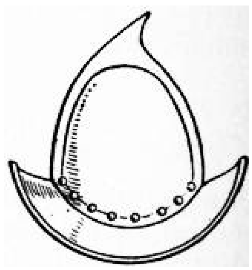

FIG. 11.—Cabasset.

The *burgonet*, often confused with the armet, is the typical helmet of the late 16th and early 17th centuries. In its simple form it was worn by the foot and light cavalry—though the latter must not be held to include the pistol-armed *chevaux-légers* of the wars of religion, these being clad in half-armour and vizored burgonet—and consisted of a (generally rounded) cap with a projecting brim shielding the eyes, a neck-guard and earpieces. It had almost invariably a crest or comb, as shown in the illustrations (fig. 9). Other forms of infantry head-gear much in vogue during the 16th century are shown in figs. 10 and 11, which represent the *morion* and *cabasset* respectively. Both these were lighter and smaller than the burgonet; indeed much of their popularity was due to the ease with which they were worn or put on and off, for in the matter of protection they could not compare with the burgonet, which in one form or another was used by cavalry (and often by pikemen) up to the final disappearance of armour from the field of battle about 1670. Fig. 9 *b* gives the general outline of richly decorated 16th-century Italian burgonet which is preserved in Vienna. The archetype of the burgonet is perhaps the casque worn by the Swiss infantry (fig. 9 *a*) at the epoch of Marignan (1515). This was probably copied by them from their former Burgundian antagonists, whose connexion with this helmet is sufficiently indicated by its name. The lower part of the more elaborate burgonets worn by nobles and cavalrymen is often formed into a complete covering for the ears, cheek and chin, and connected closely with the gorget. They therefore resemble the armets and have often been confused with them, but the distinguishing feature of the burgonet is invariably the front peak. Various forms of vizor were fitted to such helmets; these as a rule were either fixed bars (fig. 9 *c*) or mere upward continuations of the chin piece. Often a nasal was the only face protection (fig. 9 *d*, a Hungarian type). The latest form of the burgonet used in active service is the familiar Cromwellian cavalry helmet with its straight brim, from which depends the slight vizor of three bars or stout wires joined together at the bottom.

The above are of course only the main types. Some writers class all remaining examples either as casques or as “war-hats,” the latter term conveniently covering all those helmets which resemble in any way the head-gear of civil life. For illustrations of many curiosities of this sort, including the famous iron hat of King Charles I. of England, and also for examples of Russian, Mongolian, Indian and Chinese helmets, the reader is referred to pp. 262-269 and 285-286 of Demmin’s *Arms and Armour* (English edition 1894). The helmets in brass, steel or cloth, worn by troops since the general introduction of uniforms and the disuse of armour, depend for their shape and material solely on considerations of comfort and good appearance. From time to time, however, the readoption of serviceable helmets is advocated by cavalrymen, and there is much to be said in favour of this. The burgonet, which was the final type of war helmet evolved by the old armourers, would certainly appear to be by far the best head-gear to adopt should these views prevail, and indeed it is still worn, in a modified yet perfectly recognizable form, by the German and other cuirassiers.

HELMHOLTZ, HERMANN LUDWIG FERDINAND VON (1821-1894), German philosopher and man of science, was born on the 31st of August 1821 at Potsdam, near Berlin. His father, Ferdinand, was a teacher of philology and philosophy in the gymnasium, while his mother was a Hanoverian lady, a lineal descendant of the great Quaker William Penn. Delicate in early life, Helmholtz became by habit a student, and his father at the same time directed his thoughts to natural phenomena. He soon showed mathematical powers, but these were not fostered by the careful training mathematicians usually receive, and it may be said that in after years his attention was directed to the higher mathematics mainly by force of circumstances. As his parents were poor, and could not afford to allow him to follow a purely scientific career, he became a surgeon of the Prussian army. In 1842 he wrote a thesis in which he announced the discovery of nerve-cells in ganglia. This was his first work, and from 1842 to 1894, the year of his death, scarcely a year passed without several important, and in some cases epoch-making, papers on scientific subjects coming from his pen. He lived in Berlin from 1842 to 1849, when he became professor of physiology in Königsberg. There he remained from 1849 to 1855, when he removed to the chair of physiology in Bonn. In 1858 he became professor of physiology in Heidelberg, and in 1871 he was called to occupy the chair of physics in Berlin. To this professorship was added in 1887 the post of director of the physico-technical institute at Charlottenburg, near Berlin, 249
and he held the two positions together until his death on the 8th of September 1894.

His investigations occupied almost the whole field of science, including physiology, physiological optics, physiological acoustics, chemistry, mathematics, electricity and magnetism, meteorology and theoretical mechanics. At an early age he contributed to our knowledge of the causes of putrefaction and fermentation. In physiological science he investigated quantitatively the phenomena of animal heat, and he was one of the earliest in the field of animal electricity. He studied the nature of muscular contraction, causing a muscle to record its movements on a smoked glass plate, and he worked out the problem of the velocity of the nervous impulse both in the motor nerves of the frog and in the sensory nerves of man. In 1847 Helmholtz read to the Physical Society of Berlin a famous paper, *Über die Erhaltung der Kraft* (on the conservation of force), which became one of the epoch-making papers of the century; indeed, along with J. R. Mayer, J. P. Joule and W. Thomson (Lord Kelvin), he may be regarded as one of the founders of the now universally received law of the conservation of energy. The year 1851, while he was lecturing on physiology at Königsberg, saw the brilliant invention of the ophthalmoscope, an instrument which has been of inestimable value to medicine. It arose from an attempt to demonstrate to his class the nature of the glow of reflected light sometimes seen in the eyes of animals such as the cat. When the great ophthalmologist, A. von Gräfe, first saw the fundus of the living human eye, with its optic disc and blood-vessels, his face flushed with excitement, and he cried, “Helmholtz has unfolded to us a new world!” Helmholtz’s contributions to physiological optics are of great importance. He investigated the optical constants of the eye, measured by his invention, the ophthalmometer, the radii of curvature of the crystalline lens for near and far vision, explained the mechanism of accommodation by which the eye can focus within certain limits, discussed the phenomena of colour vision, and gave a luminous account of the movements of the eyeballs so as to secure single vision with two eyes. In particular he revived and gave new force to the theory of colour-vision associated with the name of Thomas Young, showing the three primary colours to be red, green and violet, and he applied the theory to the explanation of colour-blindness. His great work on *Physiological Optics* (1856-1866) is by far the most important book that has appeared on the physiology and physics of vision. Equally distinguished were his labours in physiological acoustics. He explained accurately the mechanism of the bones of the ear, and he discussed the physiological action of the cochlea on the principles of sympathetic vibration. Perhaps his greatest contribution, however, was his attempt to account for our perception of quality of tone. He showed, both by analysis and by synthesis, that quality depends on the order, number and intensity of the overtones or harmonics that may, and usually do, enter into the structure of a musical tone. He also developed the theory of differential and of summational tones. His work on *Sensations of Tone* (1862) may well be termed the *principia* of physiological acoustics. He may also be said to be the founder of the fixed-pitch theory of vowel tones, according to which it is asserted that the pitch of a vowel depends on the resonance of the mouth, according to the form of the cavity while singing it, and this independently of the pitch of the note on which the vowel is sung. For the later years of his life his labours may be summed up under the following heads: (1) On the conservation of energy; (2) on hydro-dynamics; (3) on electro-dynamics and theories of electricity; (4) on meteorological physics; (5) on optics; and (6) on the abstract principles of dynamics. In all these fields of labour he made important contributions to science, and showed himself to be equally great as a mathematician and a physicist. He studied the phenomena of electrical oscillations from 1869 to 1871, and in the latter year he announced that the velocity of the propagation of electromagnetic induction was about 314,000 metres per second. Faraday had shown that the passage of electrical action involved time, and he also asserted that electrical phenomena are brought about by changes in intervening non-conductors or dielectric substances. This led Clerk Maxwell to frame his theory of electro-dynamics, in which electrical impulses were assumed to be transmitted through the ether by waves. G. F. Fitzgerald was the first to attempt to measure the length of electric waves; Helmholtz put the problem into the hands of his favourite pupil, Heinrich Hertz, and the latter finally gave an experimental demonstration of electromagnetic waves, the "Hertzian waves," on which wireless telegraphy depends, and the velocity of which is the same as that of light. The last investigations of Helmholtz related to problems in theoretical mechanics, more especially as to the relations of matter to the ether, and as to the distribution of energy in mechanical systems. In particular he explained the principle of least action, first advanced by P. L. M. de Maupertuis, and developed by Sir W. R. Hamilton, of quaternion fame. Helmholtz also wrote on philosophical and aesthetic problems. His position was that of an empiricist, denying the doctrine of innate ideas and holding that all knowledge is founded on experience, hereditarily transmitted or acquired.

The life of Helmholtz was uneventful in the usual sense. He was twice married, first, in 1849, to Olga von Velten (by whom he had two children, a son and daughter), and secondly, in 1861, to Anna von Mohl, of a Würtemberg family of high social position. Two children were born of this marriage, a son, Robert, who died in 1889, after showing in experimental physics indications of his father's genius, and a daughter, who married a son of Werner von Siemens. Helmholtz was a man of simple but refined tastes, of noble carriage and somewhat austere manner. His life from first to last was one of devotion to science, and he must be accounted, on intellectual grounds, one of the foremost men of the 19th century.

See L. Königsberger, *Hermann von Helmholtz* (1902; English translation by F. A. Welby, Oxford, 1906); J. G. McKendrick, *H. L. F. von Helmholtz* (1899).

(J. G. M.)

HELMOLD, an historian of the 12th century, was a priest at Bosau near Plön. He was a friend of the two bishops of Oldenburg, Vicelin (d. 1154) and Gerold (d. 1163), who did much to Christianize the Slavs. At Bishop Gerold's instigation Helmold wrote his *Chronica Slavorum*, a history of the conquest and conversion of the Slavonic countries from the time of Charlemagne. For the life and times of Henry the Lion, duke of Saxony, Helmold's chronicle, as that of a contemporary who had exceptional means for gaining information, is of first-rate importance. The history was continued down to 1209 by Abbot Arnold of Lübeck.

The *Chronica* were first edited by Siegmund Schorkel (Frankfort a. M., 1556). The best edition is by J. M. Lappenberg in *Mon. Germ. hist. scriptores*, xxi. (1869). For critical works on the *Chronica* see A. Potthast, *Bibliotheca hist. med. aevi*, s. "Helmoldus."

HELMOND, a town in the province of North Brabant, Holland, on the small river Aa, and on the canal (Zuid-Willems Vaart) between ’s Hertogenbosch and Maastricht, 24½ m. by rail W.N.W. of Venlo. It is connected by steam tramway with ’s Hertogenbosch (21 m. N.W.), a branch line northwards to Osch being given off at Veghel. Pop. (1900) 11,465. The castle of Helmond, built in 1402, is a beautiful specimen of architecture, and among the other buildings of note in the town are the spacious church of St Lambert, the Reformed church and the town hall. Helmond is one of the industrial centres of the province, and possesses over a score of factories for cotton and silk weaving, cotton printing, dyeing, iron founding, brewing, soap boiling and tobacco dressing, as well as engine works and a margarine factory. There is an art school in the town.