Title: Pearls & Parasites

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Release date: July 15, 2016 [EBook #52580]
Most recently updated: January 24, 2021

Language: English

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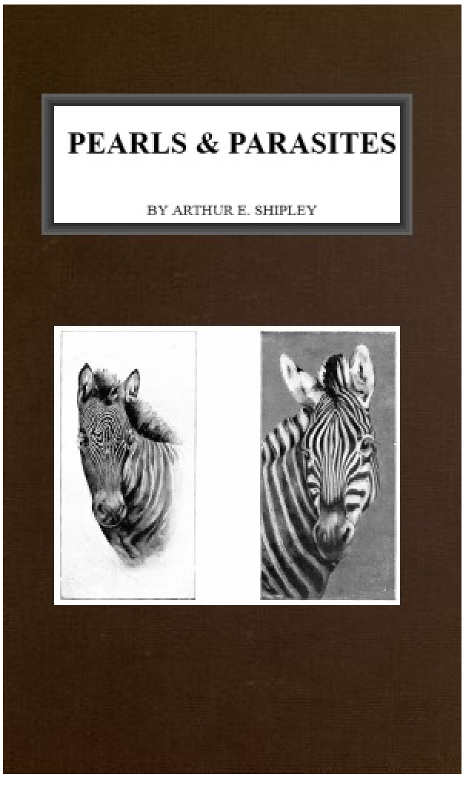

PEARLS AND PARASITES

PEARLS & PARASITES

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WITH ILLUSTRATIONS

LONDON
JOHN MURRAY, ALBEMARLE STREET, W.
1908

TO MY SISTER

E. D. H.

PREFACE

Most of the following essays have appeared in the pages of the *Quarterly Review*, and I am greatly indebted to the editor and to the proprietor of that periodical for permission to reprint them. The article on 'The Infinite Torment of Flies' is an address I delivered before the British Association at Pretoria in 1905, and the eighth essay appeared in *Science Progress*.

As far as possible I have tried to avoid the use of long words, and thus escape the censure of recent critics in the *Times*; but I fear I have not altogether succeeded, and my excuse must be that with new discoveries new conceptions arise, and these conceptions require new names, or we cannot talk or write about them with any precision.

The essay dealing with zebras and hybrids was the first to be written, and appeared before the rediscovery of Mendel's remarkable work, and must be regarded as a pre-Mendelian contribution to a subject which has recently, in connexion with the Deceased Wife's Sister Bill, again aroused attention. Had it been written later the language and the attitude taken would have been modified by recent research.

In the inquiry into the aims and finance of Cambridge University—the only essay which does not deal with questions of economic zoology—I have had the great advantage of the collaboration of Mr. H. A. Roberts, the Secretary of the Cambridge University Association. But for his help I fear I should have lost my way in the intricate mazes of the University accounts.

For the care he has taken in making the Index, I owe thanks to Mr. G. W. Webb, of the University Library.

A. E. S.

Christ's College,
Cambridge.
March 10, 1908.

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BIBLIOGRAPHY

‘Report to the Government of Ceylon on the Pearl-Oyster Fisheries of the Gulf of Manaar.’ By W. A. Herdman, F.R.S. Parts I. and II. Published by the Royal Society. London, 1904.

‘On the Origin of Pearls.’ By H. Lyster Jameson. Proceedings of the Zoological Society of London, 1902.

‘Aus den Tiefen des Weltmeeres.’ By C. Chun. Jena: Gustav Fischer, 1900.

‘Tierleben der Tiefsee.’ By O. Seeliger. Leipzig: Wilhelm Engelmann, 1901.

‘Report of the Scientific Results of the Voyage of H.M.S. *Challenger*.’ Edited by the late Sir C. Wyville Thomson and John Murray. A Summary of the Scientific Results. Published by Order of Her Majesty’s Government, 1885.

‘La Vie au Fond des Mers.’ By H. Filhol. Paris: G. Masson, 1885.

‘The Fauna of the Deep Sea.’ By Sydney J. Hickson. London: Kegan Paul, Trench, Trübner and Co., 1894.

‘British Fisheries: their Administration and their Problems.’ By James Johnstone. London: Williams and Norgate, 1905.

‘An Examination of the Present State of the Grimsby Trawl Fishery, with Especial Reference to the Destruction of Immature Fish.’ By E. W. L. Holt. *Journal of the Marine Biological Association*, vol. iii. Plymouth, 1895.

Journals of the Marine Biological Association of the United Kingdom, vols. i.-vii. Plymouth.

‘Conseil Permanent International pour l’Exploration de la Mer. Rapports et Procès Verbaux,’ vol. iii. Copenhagen.

‘Fishery Board for Scotland. Report on the Fishery and Hydrographical Investigations in the North Sea and Adjacent Waters, 1902-1903.’ [Cd. 2612.] London, 1905.

‘Marine Biological Association. First Report on the Fishery and Hydrographical Investigations in the North Sea and Adjacent Waters (Southern Area), 1902-1903.’ [Cd. 2670.] London, 1905.

‘Annual Reports of the Inspectors of Sea-Fisheries for England and Wales.’ London, 1886-1905.

‘The Penycuik Experiments.’ By J. C. Ewart. London and Edinburgh: A. and C. Black, 1899.

‘Experimental Investigations on Telegony.’ A paper read before the Royal Society, London, June 1, 1899. By Professor J. C. Ewart.

‘La Vie de Pasteur.’ Par René Vallery-Radot. Paris: Hachette, 1900.

‘Pasteur.’ By Percy Frankland and Mrs. Percy Frankland. (Century Science Series.) London: Cassell, 1898.

‘The Soluble Ferments and Fermentation.’ By J. Reynolds Green. (Cambridge Natural Science Manuals.) Cambridge University Press, 1899.

‘Micro-organisms and Fermentation.’ By Alfred Jörgensen. Translated by A. K. Miller and A. E. Lennholm. Third edition. London: Macmillan, 1900.

‘Lectures on the Malarial Fevers.’ By William Sydney Thayer, M.D. London: Henry Kimpton, 1899.

‘On the Rôle of Insects, Arachnids, and Myriapods as Carriers in the Spread of Bacterial and Parasitic Diseases of Man and Animals. A Critical and Historical Study.’ By George H. F. Nuttall, M.D., Ph.D. ‘Johns Hopkins Hospital Reports,’ vol. viii.

‘Instructions for the Prevention of Malarial Fever.’ Liverpool School of Tropical Medicine. Memoir I. Liverpool: University Press, 1899.

‘Report of the Malaria Expedition of the Liverpool School of Tropical Medicine and Medical Parasitology.’ By Ronald Ross, D.P.H., M.R.C.S.; H. E. Annett, M.D., D.P.H.; and E. E. Austen. Liverpool School of Tropical Medicine. Memoir II. Liverpool: University Press, 1900.

‘A System of Medicine, by many Writers.’ Edited by Thomas Clifford Allbutt, M.A., M.D., LL.D., vol. ii., 1897; vol. iii., 1897. London: Macmillan and Co.

‘A Handbook of the Gnats and Mosquitoes.’ By Major George M. Giles, I.M.S., M.B., F.R.C.S. London: John Bale, Sons, and Danielsson, Limited, 1900.

‘Reports to the Malaria Committee, Royal Society, 1899 and 1900.’ By various authors. London: Harrison and Sons, 1900.

Proceedings of the Boston Society of Natural History, vol. xvi., 1874.

U.S.A. Department of Agriculture, Division of Entomology, Bulletin 4, new series.

‘Manchester Memoirs,’ vol. li., 1906, p. 1; *Quarterly Journal of Microscopical Science*, vol. li., 1907, p. 395.

‘Endowments of the University of Cambridge.’ Edited by John Willis Clark, M.A., Registrar of the University of Cambridge. Cambridge: University Press, 1904.

‘Report of a Meeting held at Devonshire House on January 31, 1899, to inaugurate the Cambridge University Association.’ Cambridge: University Press, 1899.

‘Statements of the Needs of the University.’ Cambridge: University Press, 1904.

‘University Accounts for the Year ended December 31, 1904.’ *Cambridge University Reporter*, March 17, 1905.

‘Abstracts of the Accounts of the Colleges.’ *Cambridge University Reporter*, February 10, 1905.

PEARLS AND PARASITES

Know you, perchance, how that poor formless wretch—
The Oyster—gems his shallow moon-lit chalice?
Sir Edwin Arnold.

Certain Eastern peoples believe that pearls are due to raindrops falling into the oyster-shells which conveniently gape to receive them.

‘Precious the tear as that rain from the sky
Which turns into pearls as it falls on the sea,’

as the poet Moore writes. This belief is of ancient origin, and is probably derived from classical sources, since Pliny tells us that the view prevalent in his time was that pearls arise from certain secretions formed by the oyster around drops of rain which have somehow effected an entrance into the mantle cavity of the mollusc. Probably this theory of the origin of pearls has ceased to be held for many centuries except in the East, where tradition has always received more credit than experiment. In the West it has long been known that pearls are formed as a pathological secretion of the mineral arragonite, combined with a certain amount of organic material, formed by the oyster or other mollusc around some foreign body, whose presence forms the irritant which stimulates the secretion. This secretion is of the same chemical and mineralogical nature as the mother-of-pearl which gives the inside of the shell of so many molluscs a beautiful iridescent sheen.

An oyster-shell consists of three layers, the outermost termed the *periostracum*, the middle the *prismatic layer*, and the innermost the *nacreous layer*. Everywhere the shell is lined by the mantle, consisting of a right and left fold or flap of the skin, which is in contact with the nacreous layer all over the inside of the shell. The edge of the mantle is thickened and forms a ridge or margin; and it is this edge which secretes the two outer layers. This permits the shell to grow at its edge whilst the rest of the mantle secretes all over its surface the nacreous or pearly layer. The relative thickness of these three layers varies very greatly. In the fresh-water mussel (*Unio*) the nacreous layer is many times thicker than the two outer layers put together; and such nacreous shells are usually associated with molluscs which are known to represent very ancient or ancestral species. It is also the layer which disappears most readily as the specimens become fossilized; and in fossil Mollusca it is often represented by mere casts, which fill the position it once occupied.

The fact that the nacre is deposited by the whole surface of the mantle has been appreciated by the Chinese. By inserting little flattened leaden images of Buddha between the mantle and the shell, and leaving the oyster at rest for some time, the image becomes coated with mother-of-pearl and incorporated in the substance of the shell; and in this way certain little joss figures are produced. This industry is said to support a large population in some coast districts of Siam.

The nacre, then, is produced by the outermost layer of the mantle or fleshy flap that lines the shell—the external epithelium; and, if a foreign body gets between this epithelium and the shell, the mantle will, in order to protect itself, secrete a pearly coat around it. But valuable pearls are not those which are partially or wholly fused with the shell, but those which lie deep in the tissues of the body; and they are probably formed in the following manner: The intrusive, irritant body forms a pit in the outer surface of the mantle; this pit deepens, and at first remains connected with the outside by a pore; ultimately the pore closes, and the bottom of the pit becomes separated as a small sac free from all connexion with the outside. The sac now sinks into the tissues of the oyster, enclosing in it the foreign body. It will be noticed that the inside of the sac is lined by and is derived from the same tissue or epithelium as covers the outside of the mantle. Now this epithelium continues to do what it has always been in the habit of doing; that is, it secretes a nacreous substance all round the intrusive particle. Layer after layer of this nacre is deposited, and thus a pearl is formed. At first the layers will conform roughly to the outline of the embedded body, but later layers will smooth over any irregularities of the nucleus around which they are deposited, and a spheroidal or spherical pearl is produced. If the irregularities are too pronounced, an irregular pearl is formed; and such pearls, on merely æsthetic grounds, command a lower price.

It is thus clear that pearls are formed around intrusive foreign bodies; and until comparatively recently these bodies were thought to be inorganic particles, such as grains of sand. Recent research has, however, shown that this is seldom the case, and that as a rule the nucleus, which must be present if a pearl is to be formed, is the larva of some highly-organized parasite whose life-history is certainly complicated but as yet is not completely known. The knowledge, however, which we already possess enables us to do much to ensure steady success in a very speculative industry; and with complete knowledge there is no reason why pearl fisheries should not be under as good control as oyster fisheries now are.

It was about fifty years ago (1857-1859) that the problem of the Ceylon pearl-oyster fishery was first attacked in a thoroughly scientific spirit by a certain Dr. Kelaart. His reports to the Government of the island contain the following suggestive sentences:

'I shall merely mention here that M. Humbert, a Swiss zoologist, has, by his own observations at the last pearl fishery, corroborated all I have stated about the ovaria or genital glands and their contents; and that he has discovered, in addition to the Filaria and Circaria (*sic*), three other parasitical worms infesting the viscera and other parts of the pearl-oyster. We both agree that these worms play an important part in the formation of pearls; and it may be found possible to infect oysters in other beds with these worms, and thus increase the quantity of these gems. The nucleus of an American pearl drawn by Möbius is nearly of the same form as the Circaria found in the pearl-oysters of Ceylon. It will be curious to ascertain if the oysters in the Tinnevelly banks have the same species of worms as those found in the oysters on the banks off Arripo.'

Unfortunately Dr. Kelaart died shortly after making this report, leaving his investigations incomplete.

Some seven years before, in 1852, Filippi had shown that the pearls in our fresh-water mussel (*Anodonta*) were formed by the larvæ of a fluke (a trematode), to which he gave the name of *Distomum duplicatum*. Many students of elementary biology, as they painfully try to unravel the mystery of molluscan morphology, must have come across small pearls in the tissues of the fresh-water mussels (*Unio* or *Anodonta*); but these are said to have less lustre and to be more opaque than the sea pearl; so the pearl fisheries of the Welsh and Scotch rivers are falling into disuse. Our ancestors, however, thought otherwise. Less than fifty years ago the Scotch fisheries brought in some £12,000 a year; and a writer of the early part of the eighteenth century describes Scotch pearls as 'finer, more hard and transparent than any Oriental.' British pearls were highly thought of by the Romans. Pliny and Tacitus mention them; and Julius Caæsar is said to have dedicated a breastplate ornamented with British pearls to Venus Genitrix. Fresh-water pearls are still 'fished' with profit in Central Europe; but the Governments of Bavaria, Saxony, and Bohemia watch over the industry and only grant a licence to fish any stretch of water about once in twelve years—a restriction which, had it been imposed on our fisheries, might have saved a vanishing industry.

In 1871 Garner showed that the pearls in the edible mussel (*Mytilus edulis*), which is largely used for bait upon our coasts, were formed round the larvæ of a fluke, a remote ally of the liver-fluke that causes such loss to our sheep-breeders. This origin of pearls has been more completely followed out by Mr. Lyster Jameson. Nor must we forget to mention the researches of Giard (1897) and Dubois (1901) in the same subject. We know the life-history of the organism forming pearls in this edible mussel more completely than we do that of any other pearl-forming parasite; and, before returning to the Ceylon pearls, we will briefly consider it.

Mr. Lyster Jameson finds that the pearls of the *Mytilus* are formed around the cercaria or larval form of a fluke which, in its adult stages, resides in the intestine of the scoter (*Œdemia nigra*), and was originally described from the eider-duck (*Somateria mollissima*) in Greenland and named *Leucithodendrium somateriæ*, after its first known host. The cercaria larvæ of these flukes form the last stage in a complex series of larval forms which occur in the life-history of a trematode or fluke, and they differ from the adult in two points—their generative organs are not fully developed, and they usually have a tail; but this organ is wanting in our pearl-forming cercaria, called a cercariæum by Mr. Jameson. Such a larva has only to be swallowed by a scoter to grow up quickly into the adult trematode capable of laying eggs. Now this bird, called by the French fishermen the 'cane moulière,' is the greatest enemy to the mussel-beds; it is not only common around the French mussel-beds of Billiers (Morbihan), but occurs in numbers at the mouth of the Barrow channel, close to our English pearl-bearing mussel-beds. With its diving habits it destroys and eats large quantities of the mollusc. Those cercariæ which are already entombed in a pearl cannot, of course, grow up into adults, even if they gain entrance to the alimentary canal of the scoter; but those that are not ensheathed may do so. Further, the fluke may possibly live in other hosts where no pearl is formed. At any rate, there seems no lack of larvæ successful in their struggle to attain maturity, for it has been calculated that the alimentary canal of an apparently healthy scoter may harbour as many as six thousand adult flukes.

Thus there are two courses open to the cercaria when it has once found its way into the mussel; it either forms the nucleus of a pearl and perishes, or it is swallowed by a scoter, becomes adult, and prepares to carry on the race. But how do the cercariæ make their way into the mussel, and whence do they come? At present their birth, like that of Mr. Yellowplush, is 'wrapped up in a mistry.' We may presume that the eggs make their way out of the scoter into the sea-water, and that there they hatch out a free-swimming larva, which, after the manner of trematodes, swims about looking for a suitable host. Within this host it would come to rest and begin budding off numerous secondary larvæ, in which stage it may assume considerable size and becomes known as a *sporocyst*. No one, however, has seen the eggs hatch, or the free-swimming larva; but Mr. Jameson produces evidence to show that the sporocyst stage occurs in two other common molluscs—viz., in a clam (*Tapes decussatus*) and in the common cockle (*Cardium edule*). The former mollusc abounds in the black gravelly clay which forms the bottom of the mussel-beds at Billiers; and every specimen out of nearly two hundred examples investigated by Mr. Jameson was found to be infested with sporocysts containing larvæ closely resembling those which act as pearl-nuclei in the edible mussel. Exactly similar sporocysts were found in about fifty per cent. of the common cockles examined in the Barrow channel, where the species *Tapes decussatus* does not occur.

Within the sporocyst certain secondary larvæ are formed, as is habitual with the flukes. These secondary larvæ are the cercariæ; and it is in this stage that the animal makes its way into the pearl-mussel and ultimately forms the nucleus of a pearl. Precisely how it leaves the sporocyst and the first host—*i.e.*, the *Tapes* or *Cardium*—is not known. Certain experiments made by Jameson, who placed mussels which he thought were free from parasites in a tank with some infected *Tapes*, are not quite conclusive, and have been ably criticized by Professor Herdman. It is true that, when examined later, the mussels were well infected; but it was not definitely shown that they were not infected at the start; and further, the numbers used were too small to justify a very positive conclusion. Still, on the whole, it may safely be said that life-history of the organism which forms the pearls in *Mytilus edulis* probably involves three hosts: the scoter, which contains the mature form; the *Tapes* or *Cardium*, which contains the first larval stage; and the mussel, which contains the second larval stage, which forms the pearl.

Recently Professor Dubois has been investigating the origin of pearls in another species of *Mytilus* (*M. galloprovincialis*) which lives on the French Mediterranean littoral. The nucleus of this pearl is also a trematode, but of a species different from that which infests the edible mussel. The interest of Professor Dubois' work, however, lies in the fact that he claims to have infected true Oriental pearl-oysters by putting them to live with his Mediterranean mussels. He fetched his oysters, termed ‘Pintadin,’ from the Gulf of Gabes in Southern Tunis, where they are almost pearlless—one must open twelve to fifteen hundred of these to find a single pearl—and brought them up amongst the mussels. After some time had elapsed they became so infected that three oysters opened consecutively yielded a couple of pearls each. These observations, however, require confirmation, and have been adversely criticized by Professor Giard.

To return to the Ceylon pearls. The celebrated fisheries lie to the north-west of the island, where the shallow plateaux of the Gulf of Manaar afford a fine breeding-place for the pearl-oyster. The pearl-oyster is not really an oyster, but an allied mollusc known as *Margaritifera vulgaris*. It lives on rocky bottoms known locally as paars. The fisheries are very ancient and have been worked for at least 2,500, perhaps for 3,000 years. Pliny mentions them, but he is, comparatively speaking, a modern. The Cingalese records go much farther back. In 550 B.C. we find King Vijaya sending his Indian father-in-law pearls of great price; and there are other early records. From the eighth to the eleventh century of our era the trade seems to have been chiefly in the hands of the Arabs and Persians; and many references to it occur in their literature. Marco Polo (1291) mentions the pearls of the kings of Ceylon; and in 1330 a friar, one Jordanus, describes 8,000 boats as taking part in the fishery. Two centuries later, a Venetian trader named Cæsar Frederick, crossed from India to the west coast of Ceylon to observe the fishery; and his description might almost serve for the present day, so little do habits alter in the East.

The records of the Dutch and English fisheries are naturally more complete than those of their predecessors. The last Dutch fishery was in 1768, and the first English was in 1796, before the fall of Colombo. The fishery is not held every year, but at irregular intervals; and sometimes these intervals have been long. For instance, the oysters failed between 1732 and 1746, and again between 1768 and 1796, under the Dutch régime, and from 1837 to 1854 under the English. On the other hand, the fishing is sometimes annual; recently, it took place with great success in 1887 and the four following years, culminating in the record year 1891, when the Government’s share of the spoil amounted to close upon one million rupees. After this there was a pause till 1903, when the fishery became annual.

The Lieutenant-Governor, Sir Everard im Thurn, now Governor of Fiji, has given a lively account of the fishing scene. He tells us that every year, in November, a Government official visits the oyster-beds, takes up a certain number of oysters, examines them for pearls, and submits his results to certain Government experts. If, as they have done recently, these experts pronounce that there will be a fishing, this information is at once made known; and, partly by advertisement, but probably more by passing the word from man to man, the news rapidly spreads throughout India, up the Persian Gulf, and to Europe. In the meantime preparations on a large scale have to be made.

> ‘On land, which is at the moment a desert, an elaborate set of temporary Government buildings have to be erected for receiving and dealing with many millions of oysters and their valuable if minute contents. Court-houses, prisons, barracks, revenue offices, markets, residences for the officials, streets of houses and shops for perhaps thirty thousand inhabitants, and a water-supply for drinking and bathing for these same people, have to be arranged for. Lastly, but, in view of the dreadful possibility of the outbreak of plague and cholera, not least, there are elaborate hospitals to be provided.’

By March or April some hundreds of large fishing vessels have assembled at Manaar; and a population which varies during the next two months between 25,000 and 40,000 souls has gathered together.

The fishing-boats leave early in the morning for their respective stations; and, on reaching them, the Arab and Indian divers descend, staying under water from fifty to eighty seconds, and eagerly scooping up the oysters and depositing them in baskets slung round their necks. By midday the divers are worn out; and at noon a gun is fired from the master-attendant’s vessel as a signal for return. The run home may take some hours, according to the distance and the wind; and it is during this time that a considerable number of pearls are said to be abstracted. The men on the boats are occupied with the sorting of the oysters and cleaning them of useless stones, seaweed, and other objects which are gathered with them. The finest pearls lie just within the shell, embedded in the edge of the mantle; and these readily slip out and are concealed about the person of the finder. The Government does what it can to check peculation and keep a guard on each boat; but, in spite of all its efforts, there seems no doubt that many of the ‘finest, roundest, and best-coloured pearls’ pass into the possession of those who have no right to them.

On reaching the shore the oysters are carried to the Government building or ‘Kottus,’ a vast rectangular shed, where they are divided into three heaps; two of these fall to the Government, and the third belongs to the divers. This latter share the divers sell as soon as they quit the ‘Kottus,’ sometimes parting with dozens to one buyer, and sometimes selling as few as two or one. In the meantime the Government’s two-thirds have been counted and are left for the night. At nine o’clock in the evening these oysters are put up to auction. The Government agent states how many oysters there are to dispose of, and then sells them in lots of one thousand. Some rich syndicates will perhaps buy as many as 50,000 at prices which fluctuate unaccountably during the evening. Within a short time the price will inexplicably drop from thirty-five rupees to twenty-two rupees a thousand, and may then rise again as suddenly and inexplicably as it sank. Early in the morning each purchaser removes his shells to his own private shed, where for a week they are allowed to rot in old canoes and other receptacles for water, and are then searched for pearls. For a couple of months this great traffic goes on, until the divers are thoroughly exhausted, and the camp melts away.

Owing to the continuous failure of the fishery for ten years from 1891, the Government determined to call in the aid of experts. In the spring of 1901 Professor Herdman of Liverpool was asked by the Colonial Office, then under the direction of Mr. Chamberlain, to visit Ceylon and to report upon the state of the fishery. He reached Colombo early in 1902. He was fortunate in taking out an exceptionally well qualified assistant in Mr. J. Hornell. After a thorough examination of the fishing-grounds, Professor Herdman reported to the Government of Ceylon as follows:

> ‘The oysters we met with seemed, on the whole, to be very healthy. There is no evidence of any epidemic or of much disease of any kind. A considerable number of parasites, both external and internal, both protozoan and vermean, were met with; but that is not unusual in molluscs, and we do not regard it as affecting seriously the oyster population.
>
> ‘Many of the larger oysters were reproducing actively. We found large quantities of minute “spat” in several places. We

also found enormous quantities of young oysters a few months old on many of the paars. On the Periya paar the number of these probably amounted to over a hundred thousand million.

'A very large number of these young oysters never arrive at maturity. There are several causes for this. They have many natural enemies, some of which we have determined. Some are smothered in sand. Some grounds are much more suitable than others for feeding the young oysters, and so conducing to life and growth. Probably the majority are killed by overcrowding.

'They should therefore be thinned out and transplanted. This can be easily and speedily done, on a large scale, by dredging from a steamer at the proper time of the year, when the young oysters are at the best age for transplanting.

'Finally, there is no reason for any despondency in regard to the future of the pearl-oyster fisheries if they are treated scientifically. The adult oysters are plentiful on some of the paars, and seem for the most part healthy and vigorous; while young oysters in their first year, and masses of minute spat just deposited, are very abundant in many places.'

The chief causes of the failure of the fisheries, at any rate the chief causes which can be dealt with by man, are overcrowding and over-fishing. It might be supposed that these factors would counteract each other; but it must be remembered that they become effective at the two opposite poles of the oyster's existence, which is thought to cover five, six, or seven years. The overcrowding takes place when the oyster is quite young and hardly fixed on the submerged reefs, whilst the over-fishing takes place when the animal is fully matured and perhaps growing old. The fact that Professor Herdman and Mr. Hornell conveyed the young oysters from Manaar in the north of the island by boat to Colombo and then on by train to Galle in the south, and there succeeded in rearing them, shows that there would be little difficulty in artificially rearing oysters in convenient localities and then transplanting them to such fishing-grounds as show danger of depletion. With regard to over-fishing, if the grounds are under the charge of a trained zoologist there is no reason why this should go on.

When Professor Herdman was called in to advise the Government, he saw at once that it was the oyster that had failed in the last ten years, not the pearls within the oysters. Microscopic examination of thin sections made through decalcified pearls showed that they are almost in all cases deposited around a minute larval cestode or tapeworm. These larvæ make their way into the oyster, and the irritation they set up induces the formation of the pearl, just as was the case with the cercaria-formed pearls of the mussel. Where do these larvæ come from? We cannot say with absolute certainty. Older specimens of tapeworms belonging to the new species, *Tetrarhynchus unionifactor*, also live in the oyster; and it may be that, were a larva to escape entombment in a pearl, it would grow up into one of these. But even these never become mature in the oyster; to attain sexual maturity they must be swallowed by a second host. What is the second host of the pearl-forming cestode? This question we are only recently able to answer, and here, again, without absolute certainty. I have recently described the adult form of *T. unionifactor* from a large ray, *Rhinoptera javanica*. In this fish, which feeds largely on oysters, the cestodes exist in swarms in the stomach, and the eggs make their way from the fish into the oysters, and there some of them grow up, but most of them perish in their pearly casket. If, as I believe, this is the history of the pearl-forming organism, we must regard the *Rhinoptera* as a friend to the industry, and not, as hitherto, an enemy which helps to destroy the oyster-beds.

The discovery of the cestode larva as a real cause of pearl-formation received an interesting confirmation shortly after it had made it. M. G. Seurat, working independently at Rikitea on the island of Mangareva, in the Gambier group, discovered a very similar larva in the local pearl-oyster around which pearls are formed; this larva, if we may judge from pictures, is almost certainly the same as the one from Ceylon. Professor Giard regards it as belonging to a tapeworm of the genus *Acrobothrium*; and, if he be right, then Professor Herdman's larva is an *Acrobothrium* too. We have so little knowledge of the early forms of cestodes that we cannot accept this attribution as final. We may, however, hope for further information, for a French zoologist, M. Boutan, started some little time ago for the East to work at the problem; Mr. Hornell is still at work in Ceylon; and Mr. C. Crossland, who has had much experience in marine work in the tropics, has been appointed, at the request of the Soudan Government, to investigate the pearl-oyster beds of the Red Sea. Finally Dr. Willey, of the Colombo Museum, has recently described similar larvæ in the pearls of the 'window-pane' oyster, *Placuna placenta*, from the eastern shores of Ceylon.

In 1904 it was again found possible to hold a fishery in Ceylon. It was held at a place called Marichikaddi, also on the north-west coast. In the course of thirty-eight days over 41,000,000 oysters were taken. The trade was very brisk; the prices paid were unprecedented. The 1905 fishery, which began on February 18, promised to beat all records. On February 22 the catch was nearly 4,500,000 oysters; and the Government's share for that day was £9,000. Since this date each year has yielded a bountiful harvest, and in financial circles the London Syndicate, who have obtained a 'concession' of the oyster-beds for twenty years from the Ceylon Government, are understood to be 'doing very well.'

It is perhaps too soon to attribute this success to the efforts of Professor Herdman and Mr. Hornell, the latter of whom, we understand, has been permanently retained as biologist to the syndicate; but we have no doubt that, acting under their advice, the oyster-bed may be made a steady, in place of a most intermittent, source of revenue. In this connexion it may be mentioned that radiography is now being used, and by its means the oysters containing large pearls can be separated from those that do not, and the latter returned to the sea. Besides their valuable work in solving this particular problem, Professor Herdman and his colleague have made a rich collection of marine animals, which are being examined by a number of specialists. The results of their labours have appeared in a handsome series of volumes published under the auspices of the Royal Society; and it is from the first of these that many of the facts contained in this article are derived. The memoirs included in the volumes contain many important additions to our knowledge; but no result is more interesting or more economically important than the confirmation of the fact that, as M. Dubois puts it, 'La plus belle perle n'est donc, en définitive, que le brillant sarcophage d'un ver.'

THE DEPTHS OF THE SEA

Here in the womb of the world—here on the tie-ribs of earth.
RUDYARD KIPLING.

THE first recorded attempt to sound the depths of the ocean was made early in the year 1521, in the South Pacific, by Ferdinand Magellan. He had traversed the dangerous straits destined to bear his name during the previous November, and emerged on the 28th of that month into the open ocean. For three months he sailed across the Pacific, and in the middle of March, 1521, came to anchor off the islands now known as the Philippines. Here Magellan was killed in a conflict with the natives. The records of his wonderful feat were brought to Spain during the following year by one of his ships, the *Victoria*; and amidst the profound sensation caused by the news of this voyage, which has been called 'the greatest event in the most remarkable period of the world's history,' it is probable that his modest attempt to sound the ocean failed to attract the attention it deserved. Magellan's sounding-lines were at most some two hundred fathoms in length, and he failed to touch bottom; from which he 'somewhat naïvely concluded that he had reached the deepest part of the ocean.'

It was more than two hundred years later that the first serious study of the bed of the sea was undertaken by the French geographer Philippe Buache, who first introduced the use of isobathic curves in a map which he published in 1737. His view, that the depths of the ocean are simply prolongations of the conditions existing in the neighbouring sea-coasts, though too wide in its generalization, has been shown to be true as regards the sea-bottom in the immediate vicinity of Continental coasts and islands; and undoubtedly it helped to attract attention to the problem of what is taking place at the bottom of the sea.

Actual experiment, however, advanced but slowly. So early as the fifteenth century, an ingenious Cardinal, one Nicolaus Cusanus (1401-1464), had devised an apparatus consisting of two bodies, one heavier and one lighter than water, which were so connected that when the heavier touched the bottom the lighter was released. By calculating the time which the latter took in ascending, attempts were made to arrive at the depths of the sea. A century later Puehler made similar experiments; and after another interval of a hundred years, in 1667 we find the Englishman Robert Hooke continuing on the same lines various bathymetric observations; but the results thus obtained were fallacious, and the experiments added little or nothing to our knowledge of the nature of the bottom of the ocean. In the eighteenth century Count Marsigli attacked many of the problems of the deep sea. He collected and sifted information which he derived from the coral-fishers; he investigated the deposits brought up from below, and was one of the earliest to test the temperature of the sea at different depths. In 1749 Captain Ellis found that a thermometer, lowered on separate occasions to depths of 650 fathoms and 891 fathoms respectively, recorded, on reaching the surface, the same temperature—namely, 53°. His thermometer was lowered in a bucket ingeniously devised so as to open as it descended and close as it was drawn up. The mechanism of this instrument was invented by the Rev. Stephen Hales, D.D., of Corpus Christi College, Cambridge, the friend of Pope, and perpetual curate at Teddington Church. Dr. Hales was a man of many inventions, and, amongst others, he is said to have suggested the use of the inverted cup placed in the centre of a fruit-pie in which the juice accumulates as the pie cools. His device of the closed bucket with two connected valves was the forerunner of the numerous contrivances which have since been used for bringing up sea-water from great depths.

These were amongst the first efforts made to obtain a knowledge of deep-sea temperatures. About the same time experiments were being made by Bouguer and others on the transparency of sea-water. It was soon recognized that this factor varies in different seas; and an early estimate of the depth of average sea-water sufficient to cut off all light placed it at 656 feet. The colour of the sea and its salinity were also receiving attention, notably at the hands of the distinguished chemist Robert Boyle, and of the Italian, Marsigli, mentioned above. To the latter, and to Donati, a fellow-countryman, is due the honour of first using the dredge for purposes of scientific inquiry. They employed the ordinary oyster-dredge of the local fishermen to obtain animals from the bottom.

The invention of the self-registering thermometer by Cavendish, in 1757, provided another instrument essential to the investigation of the condition of things at great depths; and it was used in Lord Mulgrave's expedition to the Arctic Sea in 1773. On this voyage attempts at deep-sea soundings were made, and a depth of 683 fathoms was registered. During Sir James Ross's Antarctic Expedition (1839-1843) the temperature of the water was constantly observed to depths of 2,000 fathoms. His uncle, Sir John Ross, had twenty years previously, on his voyage to Baffin's Bay, made some classical soundings. One, two miles from the coast, reached a depth of 2,700 feet, and brought up a collection of gravel and two living crustaceans; another, 3,900 feet in depth, yielded pebbles, clay, some worms, crustacea, and corallines. Two other dredgings, one at 6,000 feet, the other at 6,300 feet, also brought up living creatures; and thus, though the results were not at first accepted, the existence of animal life at great depths was demonstrated.

With Sir James Ross's expedition we may be said to have reached modern times: his most distinguished companion, Sir Joseph Hooker, is still living. It is impossible to do more than briefly refer to the numerous expeditions which have taken part in deep-sea exploration during our own times. The United States of America sent out, about the time of Ross's Antarctic voyage, an expedition under Captain Wilkes, with Dana on board as naturalist. Professor Edward Forbes, who 'did more than any of his contemporaries to advance marine zoology,' joined the surveying ship *Beacon* in 1840, and made more than one hundred dredgings in the Ægean Sea. Lovén was working in the Scandinavian waters. Mr. H. Goodsir sailed on the *Erebus* with Sir John Franklin's ill-fated Polar Expedition; and such notes of his as were recovered bear evidence of the value of the work he did. The Norwegians, Michael Sars and his son, G. O. Sars, had by the year 1864 increased their list of species living at a depth of between 200 and 300 fathoms, from nineteen to ninety-two. Much good work was done by the United States navy and by surveying ships under the auspices of Bache, Bailey, Maury, and de Pourtalès. The Austrian frigate *Novara*, with a full scientific staff, circumnavigated the world in 1857-1859. In 1868 the Admiralty placed the surveying ship *Lightning* at the disposal of Professor Wyville Thomson and Dr. W. B. Carpenter for a six weeks' dredging trip in the North Atlantic; and in the following year the *Porcupine*, by permission of the Admiralty, made three trips under the guidance of Dr. W. B. Carpenter and Mr. Gwyn Jeffreys.

Towards the end of 1872 H.M.S. *Challenger* left England to spend the following three years and a half in traversing all the waters of the globe. This was the most completely equipped expedition which has left any land for the investigation of the sea, and its results were correspondingly rich. They have been worked out by naturalists of all nations, and form the most complete record of the fauna and flora, and of the physical and chemical conditions of the deep, which has yet been published. It is from Sir John Murray’s summary of the results of the voyage that many of these facts are taken. Since the return of the *Challenger* there have been many expeditions from various lands, but none so complete in its conception or its execution as the British Expedition of 1872-1875. The U.S.S. *Blake*, under the direction of A. Agassiz, has explored the Caribbean Sea; and the *Albatross*, of the same navy, has sounded the Western Atlantic. Numerous observations made by the German ships *Gazelle* and *Drache*, and Plankton Expedition, the Norwegian North Atlantic Expedition, the Italian ship *Washington*, the French ships *Travailleur* and *Talisman*, the Prince of Monaco’s yachts, *Hirondelle* and *Princesse Alice*, under his own direction, the Austrian ‘Pola’ Expedition, the Russian investigations in the Black Sea, and lastly, by the ships of our own navy, have, during the last five-and-twenty years, enormously increased our knowledge of the seas and of all that in them is. This knowledge is still being added to. At the present time the collections of the German ship *Valdivia* and of the Dutch *Siboga* Expedition are being worked out, and are impatiently awaited by zoologists and geographers of every country. The *Discovery* and the *Gauss*, although primarily fitted for ice-work, have added much to what is known of the sea-bottom of the Antarctic; and amongst men of science there is no abatement of interest and curiosity as to that *terra incognita*.

Before we attempt to describe the conditions which prevail at great depths of the ocean, a few words should be said as to the part played by cable-laying in the investigation of the subaqueous crust of the earth. This part, though undoubtedly important, is sometimes exaggerated; and we have seen how large an array of facts has been accumulated by expeditions made mainly in the interest of pure science. The laying of the Atlantic cable was preceded, in 1856, by a careful survey of a submerged plateau, extending from the British Isles to Newfoundland, by Lieutenant Berryman of the *Arctic*. He brought back samples of the bottom from thirty-four stations between Valentia and St. John’s. In the following year Captain Pullen, of H.M.S. *Cyclops*, surveyed a parallel line slightly to the north. His specimens were examined by Huxley, and from them he derived the *Bathybius*, a primeval slime which was thought to occur widely spread over the sea-bottom. The interest in this ‘Urschleim’ has, however, become merely historic, since John Y. Buchanan, of the *Challenger*, showed that it is only a gelatinous form of sulphate of lime thrown down from the sea-water by the alcohol used in preserving the organisms found in the deep-sea deposits.

The important generalizations of Dr. Wallich, who was on board H.M.S. *Bulldog*, which, in 1860, again traversed the Atlantic to survey a route for the cable, largely helped to elucidate the problems of the deep. He noticed that no *algæ* live at a depth greater than 200 fathoms; he collected animals from great depths, and showed that they utilize in many ways organisms which fall down from the surface of the water; he noted that the conditions are such that, whilst dead animals sink from the surface to the bottom, they do not rise from the bottom to the surface; and he brought evidence forward in support of the view that the deep-sea fauna is directly derived from shallow-water forms. In the same year in which Wallich traversed the Atlantic, the telegraph cable between Sardinia and Bona, on the African coast, snapped. Under the superintendence of Fleeming Jenkin, some forty miles of the cable, part of it from a depth of 1,200 fathoms, was recovered. Numerous animals, sponges, corals, polyzoa, molluscs, and worms were brought to the surface, adhering to the cable. These were examined and reported upon by Professor Allman, and subsequently by Professor A. Milne Edwards; and, as the former reports, we ‘must therefore regard this observation of Mr. Fleeming Jenkin as having afforded the first absolute proof of the existence of highly organized animals living at a depth of upwards of 1,000 fathoms.’ The investigation of the animals thus brought to the surface revealed another fact of great interest, namely, that some of the specimens were identical with forms hitherto known only as fossils. It was thus demonstrated that species hitherto regarded as extinct are still living at great depths of the ocean.

During the first half of the last century an exaggerated idea of the depth of the sea prevailed, due in a large measure to the defective sounding apparatus of the time. Thus Captain Durham, in 1852, recorded a depth of 7,730 fathoms in the South Atlantic, and Lieutenant Parker mentions one of 8,212 fathoms—depths which the *Challenger* and the *Gazelle* corrected to 2,412 and 2,905 fathoms respectively. The deepest parts of the sea, as revealed by recent research, do not lie, as many have thought, in or near the centres of the great oceans, but in the neighbourhood of, or at no great distance from, the mainland, or in the vicinity of volcanic islands. One of the deepest ‘pockets’ yet found is probably that sounded by the American expedition on board the *Tuscarora* (1873-1875) east of Japan, when bottom was only reached at a depth of 4,612 fathoms. More recently, soundings of 5,035 fathoms have been recorded in the Pacific, in the neighbourhood of the Friendly Islands, and south of these again, one of 5,113 fathoms; but the deepest of all lies north of the Carolines, and attains a depth of 5,287 fathoms. It thus appears that there are ‘pockets’ or pits in the sea whose depth below the surface of the water is about equal to the height of the highest mountains taken from the sea-level. Both are insignificant in comparison with the mass of the globe; and it is sometimes said that, were the seas gathered up, and the earth shrunk to the size of an orange, the mountain ranges and abysmal depths would not be more striking than are the small elevations and intervening depressions on the skin of the fruit.

But it is not with these exceptional abysses that we have to do; they are as rare and as widely scattered as great mountain-ranges on land. It is with the deep sea, as opposed to shoal water and the surface layers, that this article is concerned; but the depth at which the sea becomes ‘deep’ is to some extent a matter of opinion. Numerous attempts, headed by that of Edward Forbes, have been made to divide the sea into zones or strata; and, just as the geological strata are characterized by peculiar species, so, in the main, the various deep-sea zones have their peculiar fauna. These zones, however, are not universally recognized; and their limits, like those of the zoogeographical regions on land, whilst serving for some groups of animals, break down altogether as regards others. There are, however, two fairly definite regions in the sea; and the limit between them is the very one for our purpose. This limit separates the surface waters, which are permeable by the light of the sun and in which owing to this life-giving light, *algæ* and vegetable organisms can live, from the deeper waters which the sun’s rays cannot reach, and in which no plant can live. The regions pass imperceptibly into one another; there is no sudden transition. The conditions of life gradually change, and the precise level at which vegetable life becomes impossible varies with differing conditions. With strong sunlight and a smooth sea, the rays penetrate further than if the light be weak and the waters troubled.

Speaking generally, we may place the dividing-line between the surface layer and the deep sea at 300 fathoms. Below this no light or heat from the sun penetrates; and it is the absence of these factors that gives rise to most of the peculiarities of the deep sea. It is a commonplace, which every schoolboy now knows, that all animal life is ultimately dependent on the food-stuffs stored up by green plants; and that the power which such plants possess of fixing the carbonic acid of the surrounding medium, and building it up into more complex food-stuffs, depends upon the presence of their green colouring matter (chlorophyll), and is exercised only in the presence of sunlight. But, as we have pointed out, 'the sun's perpendicular rays' do not 'illumine the depths of the sea'; they hardly penetrate 300 fathoms. This absence of sunlight below a certain limit, and the consequent failure of vegetable life, gave rise at one time to the belief that the abysses of the ocean were uninhabited and uninhabitable; but, as we have already seen, this view has long been given up.

The inhabitants of the deep sea cannot, any more than other creatures, be self-supporting. They prey on one another, it is true; but this must have a limit, or very soon there would be nothing left to prey upon. Like the inhabitants of great cities, the denizens of the deep must have an outside food-supply, and this they must ultimately derive from the surface layer.

The careful investigation of life in the sea has shown that not only the surface layer, but all the intermediate zones teem with life. Nowhere is there a layer of water in which animals are not found. But, as we have seen, the *algæ* upon which the life of marine animals ultimately depends, live only in the upper waters; below 100 fathoms they begin to be rare, and below 200 fathoms they are absent. Thus it is evident that those animals which live in the surface layers have, like an agricultural population, their food-supply at hand, while those that live in the depths must, like dwellers in towns, obtain it from afar. Many of the inhabitants of what may be termed the middle regions are active swimmers, and these undoubtedly from time to time visit the more densely peopled upper strata. They also visit the depths and afford an indefinite food-supply to the deep-sea dwellers.

But probably by far the larger part of the food consumed by abysmal creatures consists of the dead bodies of animals which sink down like manna from above. The surface layers of the ocean teem with animal and vegetable life. Every yachtsman must at times have noticed that the sea is thick as a *purée* with jelly-fish, or with those little transparent, torpedo-shaped creatures, the *Sagitta*. What he will not have noticed, unless he be a microscopist, is that at almost all times the surface is crowded with minute organisms, foraminifera, radiolaria, diatoms. These exist in quite incalculable numbers, and reproduce their kind with astounding rapidity. They are always dying, and their bodies sink downwards like a gentle rain.[1] In such numbers do they fall, that large areas of the ocean bed are covered with a thick deposit of their shells. In the shallower waters the foraminifera, with their calcareous shells, prevail, but over the deeper abysses of the ocean they take so long in falling that the calcareous shells are dissolved in the water, which contains a considerable proportion of carbonic acid gas, and their place is taken by the siliceous skeletons of the radiolarians and diatoms. Thus there is a ceaseless falling of organisms from above, and it must be from these that the dwellers of the deep ultimately obtain their food. As Mr. Kipling in his 'Seven Seas,' says of the deep-sea cables:

> 'The wrecks dissolve above us; their dust drops down from afar—
> Down to the dark, to the utter dark, where the blind white sea-snakes are.'

In trying to realize the state of things at the bottom of the deep sea, it is of importance to recognize that there is a wonderful uniformity of physical conditions *là-bas*. Climate plays no part in the life of the depths; storms do not ruffle their inhabitants; these recognize no alternation of day or night; seasons are unknown to them; they experience no change of temperature. Although the abysmal depths of the polar regions might be expected to be far colder than those of the tropics, the difference only amounts to a degree or so—a difference which would not be perceptible to us without instruments of precision. The following data show how uniform temperature is at the bottom of the sea.

In June, 1883, Nordenskiöld found on the eastern side of Greenland the following temperatures: at the surface 2·2° C.; at 100 metres 5·7° C.; at 450 m. 5·1° C. In the middle of December, 1898, the German deep-sea expedition, while in the pack-ice of the Antarctic, recorded the following temperatures: at the surface -1° C.; at 100 m.-1·1° C.; at 400 m. 1·6° C.; at 1,000-1,500 m. 1·6° C.; at 4,700 m.-0·5° C. These may be compared with some records made in the Sargasso Sea by the Plankton Expedition in the month of August, when the surface registered a temperature of 24° C.; 195 m. one of 18·8° C.; 390 m. one of 14·9° C.; and 2,060 m. one of 3·8° C. It is thus clear that the temperature at the bottom of the deep sea varies but a few degrees from the freezing-point; and, whether in the tropics or around the poles, this temperature does not undergo anything like the variations to which the surface of the earth is subjected.

There are, however, some exceptions to this statement. The Mediterranean, peculiar in many respects, is also peculiar as to its bottom temperature. In August, 1881, the temperature, as taken by the *Washington*, was at the surface 26° C.; at 100 m. 14·5° C.; at 500 m. 14·1° C.; and from 2,500 m. to 3,550 m. 13·3° C. These observations agree, within one-fifth of a degree, with those recorded later by Chun in the same waters. There are also certain areas near the Sulu Islands where, with a surface temperature of 28° C., the deep sea, from 730 m. to 4,660 m., shows a constant temperature of 10·3° C.; and again, on the westerly side of Sumatra, the water, from 900 m. downwards, shows a constant temperature of 5·9° C.; whilst in the not far distant Indian Ocean it sinks at 1,300 m. to 4° C., and at 1,700 m. to 3° C. In spite of these exceptions, we may roughly say that all deep-sea animals live at an even temperature, which differs by but a few degrees from the freezing-point. Indeed, the heating effect of the sun's rays is said not to penetrate, as a rule, further than 90 to 100 fathoms, though in the neighbourhood of the Sargasso Sea it undoubtedly affects somewhat deeper layers. In the Mediterranean the heat-rays probably do not penetrate more than 50 fathoms. Below these limits all seasonable variations cease. Summer and autumn, spring and winter, are unknown to the dwellers of the deep; and the burning sun of the tropical noonday, which heats the surface water to such a degree that the change of temperature from the lower waters to the upper proves fatal to many delicate animals when brought up from the depths, has no effect on the great mass of water below the 100-fathom line.

Again, in the depths the waters are still. A great calm reigns. The storms which churn the upper waters into tumultuous fury have but a superficial effect, and are unfelt at the depth of a few fathoms. Even the great ocean currents, such as the Gulf Stream, are but surface currents, and their influence is probably not perceptible below 200 fathoms. There are places, as the wear and tear of telegraphic cables show, where deep-sea currents have much force; but these are not common. We also know that there must be a very slow current flowing from the poles towards the Equator. This replaces the heated surface waters of the tropics, which are partly evaporated and partly driven by the trade-winds towards the poles. Were there no such current, the waters round the Equator, in spite of the low conductivity of salt water, would, in the course of ages, be heated through. But this current is almost imperceptible; on the whole, no shocks or storms disturb the peace of the oceanic abyss.

An interesting result of this is that many animals, which in shallower waters are subject to the strain and stress of tidal action or of a constant stream, and whose outline is modified by these conditions, are represented in the depths by perfectly symmetrical forms. For instance, the monaxonid sponges from the deep sea have a symmetry as perfect as a lily’s, whilst their allies from the shallower seas, subject as they are to varying tides and currents, are of every variety of shape, and their only common feature is that none of them are symmetrical. This radial symmetry is especially marked in the case of sessile animals, those whose ‘strength is to sit still,’ attached by their base to some rock or stone, or rooted by a stalk into the mud. Such animals cannot move from place to place, and, like an oyster, are dependent for their food on such minute organisms as are swept towards them in the currents set by the action of their cilia. A curious and entirely contrary effect is produced by this stillness on certain animals, which, without being fixed, are, to say the least, singularly inert. The sea-cucumbers or holothurians, which can be seen lying still as sausages in any shallow sub-tropical waters, are nevertheless rolled over from time to time, and present now one, now another, surface to the bottom. These have retained the five-rayed symmetry, which is so eminently characteristic of the group Echinoderma, to which they belong. But the holothurians in the deep sea, where nothing rolls them about, continue throughout life to present the same surface to the bottom; and these have developed a secondary bilateral symmetry, so that, like a worm or a lobster, they have definite upper and lower surfaces. These bilateral holothurians first became known by the dredgings of the *Challenger*, and formed one of the most important additions to our knowledge of marine zoology for which we are indebted to that expedition.

At the bottom of the sea there is no sound—

> ‘There is no sound, no echo of sound, in the deserts of the deep,
> Or the great grey level plains of ooze where the shell-burred cables creep.’

The world down there is cold and still and noiseless. Nevertheless, many of the animals of the depths have organs to which by analogy an auditory function has been assigned. But it must not be forgotten that even in the highest land-vertebrates the ear has two functions. It is at once the organ of hearing and of balancing. Part of the internal ear is occupied with orientating the body. By means of it we can tell whether we are keeping upright, going uphill or descending, turning to the right or to the left; and it is probably this function which is the chief business of the so-called ears of marine animals. Professor Huxley once said that, unless one became a crayfish, one could never be sure what the mental processes of a crayfish were. This is doubtless true; but experiment has shown, both in crayfishes and cuttlefishes, that, if the auditory organ be interfered with or injured, the animal loses its sense of direction and staggers hither and thither like a drunken man. It is obvious that animals which move about at the bottom require such balancing organs quite as much as those which skim the surface, and it is in no wise remarkable that such organs should be found in those dwellers in the deep which move from place to place.

If we could descend to the depths and look about us, we should find the bottom of the sea near the land carpeted with deposits washed down from the shore and carried out to sea by rivers, and dotted over with the remains of animals and plants which inhabit shoal waters. This deposit, derived from the land, extends to a greater or less distance around our coast-line. In places this distance is very considerable. The Congo is said to carry its characteristic mud 600 miles out to sea, and the Ganges and the Indus to carry theirs 1,000 miles; but sooner or later we should pass beyond the region of coast mud and river deposit, the seaward edge of which is the ‘mud-line’ of Sir John Murray.

When we get beyond the mud-line, say a hundred miles from the Irish or American coast, we should find that the character of the sea-bottom has completely changed. Here we should be on Rudyard Kipling’s ‘great grey level plains of ooze.’ All around us would stretch a vast dreary level of greyish-white mud, due to the tireless fall of the minute globigerina shells mentioned above. This rain of foraminifera is ceaseless, and serves to cover rock and stone alike. It is probably due to this chalky deposit that so many members of the ‘Benthos’—a term used by Haeckel to denote those marine animals which do not swim about or float, but which live on the bottom of the ocean either fixed or creeping about—are stalked. Many of them, whose shoal-water allies are without a pedicel, are provided with stalks; and those whose shallow-water congeners are stalked are, in the depths, provided with still longer stalks. Numerous sponges—the alcyonarian *Umbellula*, the stalked ascidians, and, above all, the stalked crinoids—exemplify this point.

Flat as the Sahara, and with the same monotony of surface, these great plains stretch across the Atlantic, dotted here and there with a yet uncovered stone or rock dropped by a passing iceberg. In the deeper regions of the ocean—where, as we have already seen, occasional pits and depressions occur, and great ridges arise to vex the souls of the cable-layers—the globigerina ooze is replaced by the less soluble siliceous shells of the radiolarians and diatoms. The former are largely found in pits in the Pacific, the latter in the Southern Seas. But there is a third deposit which occurs in the deeper parts of the ocean—the red clay. This is often partly composed of the empty siliceous shells just mentioned; but over considerable areas of the Pacific the number of these shells is very small, and here it would seem that the red clay is largely composed of the ‘horny fragments of dead surface-living animals, of volcanic and meteoric dust, and of small pieces of water-logged pumice-stone.' On whichever deposit we found ourselves, could we but see the prospect, we should be struck with the monotony of a scene as different as can well be imagined from the variegated beauty of a rock-pool or a coral island lagoon.

There is, however, an abundance of animal life. The dredge reveals a surprising variety and wealth of form. Sir John Murray records 'at station 146 in the Southern Ocean, at a depth of 1,375 fathoms, that 200 specimens captured belonged to 59 genera and 78 species.' He further states that this was 'probably the most successful haul, as regards number, variety, novelty, size, and beauty of the specimens,' up to the date of the dredging; but even this was surpassed by the captures from the depths at station 147. The Southern Ocean is particularly well populated. The same writer says: 'The deep-sea fauna of the Antarctic has been shown by the *Challenger* to be exceptionally rich, a much larger number of species having been obtained than in any other region visited by the expedition; and the *Valdivia's* dredgings, in 1898, confirm this.' There seems to be no record of such a wealth of species in depths of less than 50 fathoms, and we are justified in the belief that the great depths are extremely rich in species.

The peculiar conditions under which the Benthos live have had a marked influence on their structure. Representatives of nearly all the great divisions of the animal kingdom which occur in the sea are found in the depths. Protozoa, sponges, cœlenterata, round-worms, annelids, crustacea, polyzoa, brachiopoda, molluscs, echinoderms, ascidians, fishes, crowd the sea-bottom. The *Valdivia* has brought home even deep-sea ctenophores and sagittas, forms hitherto associated only with life at the surface. The same expedition also secured adult examples of the wonderful free-swimming holothurian, *Pelagothuria ludwigi*, which so curiously mimics a jelly-fish. It was taken in a closing-net at 400 to 500 fathoms near the Seychelles. Most of these animals bear their origin stamped on their structure, so that a zoologist can readily pick out from a miscellaneous collection of forms those which have a deep-sea home. We have already referred to a certain 'stalkiness,' which lifts the fixed animals above the slowly deepening ooze. Possibly the long-knobbed tentacles of the deep-sea jelly-fish, *Pectis*, on the tips of which it is thought the creature moves about, may be connected with the same cause. The great calm of the depths and its effect upon the symmetry of the body have also been mentioned; but greater in its effect on the bodies of the dwellers in the ocean abysses is the absence of sunlight.

No external rays reach the bottom of the sea, and what light there is must be supplied by the phosphorescent organs of the animals themselves, and must be faint and intermittent. A large percentage of animals taken from the deep sea show phosphorescence when brought on deck; and it may be that this emission of light is much greater at a low temperature, and under a pressure of 1 to 2 tons on the square inch, than it is under the ordinary atmospheric conditions of the surface. The simplest form which these phosphorescent organs take is that of certain skin-glands which secrete a luminous slime. Such a slime is cast off, according to Filhol, by many of the annelids; and a similar light-giving fluid is exuded from certain glands at the base of the antenna and elsewhere in some of the deep-sea shrimps. But the most highly developed of the organs which produce light are the curious eye-like lanterns which form one or more rows along the bodies of certain fishes, notably of members of the Stomiadæ, a family allied to the salmons. From head to tail the miniature bull's-eyes extend, like so many portholes lit up, with sometimes one or two larger organs in front of the eyes, like the port and starboard lanterns of a ship, so that when one of these fishes swims swiftly across the dim scene it must, to quote Kipling again, recall a liner going past 'like a grand hotel.' Sometimes the phosphorescent organ is at the tip of a barbel or tentacle, and it is interesting to note that the angler-fish of the deep sea has replaced its white lure, conspicuous in shallow water, but invisible in the dark, by a luminous process, the investigation of which leads many a creature into the enormous, toothed mouth of the fish.

A peculiar organ, known by the name 'phæodaria,' exists in the body of certain radiolarians found only in the deep seas. It has been suggested that this structure gives forth light; and, if this be the case, the floor of the ocean is strewn with minute glow-lamps, which perhaps give forth as much light as the surface of the sea on a calm summer's night. There is, however, much indirect evidence that, except for these intermittent sources, the abysses of the ocean are sunk in an impenetrable gloom.

When physical conditions change, living organisms strive to adapt themselves to the changed conditions. Hence, when the inhabitants of the shallower waters made their way into the darker deeps, many of them, in the course of generations, increased the size of their eyes until they were out of all proportion to their other sense-organs. Others gave up the contest on these lines, and set about replacing their visual organs by long tactile tentacles or feelers, which are extraordinarily sensitive to external impressions. Like the blind, they endeavour to compensate for loss of sight by increased tactile perception; and in these forms the eyes are either dwindling or have quite disappeared. An instance in point is supplied by the crustacea, many of whom have not only lost their eyes, but have also lost the stalk which bore them; but amongst the crustacea some genera, such as *Bathynomus*, have enormous eyes with as many as four thousand facets. It is noticeable that this creature has its eyes directed downwards toward the ground and not upwards, as is the case with its nearest allies. On the whole the crustacea lose their eyes more readily, and at a less depth, than fishes. Many of the latter—*e.g.*, *Ipnops*—are blind, and in others the eyes seem to be disappearing. Thus, amongst the deep-sea cod, *Macrurus*, those which frequent the waters down to about 1,000 fathoms, have unusually large eyes, whilst those which go down to the deeper abysses have very small ones. Many of the animals which have retained their eyes carry them at the end of processes. Chun, in his brilliant account of the voyage of the *Valdivia*, has figured a series of fishes whose eyes stand out from the head like a pair of binoculars; and similar 'telescope' eyes, as he calls them, occur on some of the eight-armed cuttle-fish. The larva of one of the fishes has eyes at the end of two stalks, each of which measures quite one-fourth of the total length of the body.

The colour of the deep-sea creatures also indicates the darkness of their habitat. Like cave-dwelling animals, or the lilac forced in Parisian cellars, many of them are blanched and pale; but this is by no means always the case. There is, in fact, no characteristic hue for the deep-sea fauna. Many of the fishes are black, and many show the most lovely metallic sheen. Burnished silver and black give a somewhat funereal, but very tasteful appearance to numbers of deep-sea fish. Others are ornamented with patches of shining copper, which, with their blue eyes, form an agreeable variety in their otherwise sombre appearance. Many of the fishes, however, present a gayer clothing. Some are violet, others pale rose or bright red. Others have a white almost translucent skin, through which the blood can be seen and its course traced even in its finer vessels. Purples and greens abound amongst the holothurians; other echinoderms are white, yellow, pink, or red. Red is, perhaps, the predominant colour of the crustacea, though it has been suggested that this colour is produced during the long passage to the surface, and that some of the bright reds which we see at the surface are unknown in the depths. Violet and orange, green and red, are the colours of the jelly-fishes and the corals.

It thus appears that there is a great variety and a great brilliancy amongst many of the bottom fauna. With the exception of blue, all colours are well represented; but the consideration of one or two facts seems to show that colour plays little part in their lives. Apart from the fact that to our eyes, at any rate, these gorgeous hues would be invisible in the depths, it is difficult to imagine that each of these gaily-coloured creatures can live amongst surroundings of its own hue. Again, it is characteristic that the colour is uniform. There is a marked absence of those stripes, bands, spots, or shading which play so large a part in the protective coloration of animals exposed to light. Although there is no protective coloration amongst the animals of the deep sea, the luminous organs, which make, for instance, some of the cuttlefishes as beautiful and as conspicuous as a firework, may, in some cases, act as warning signals. Having once established a reputation for nastiness, the more conspicuous an animal can make itself the less likely is it to be interfered with. One peculiarity connected with pigment, as yet inexplicable, is the fact that, in deep-sea animals, many of the cavities of the body are lined with a dark or, more usually, a black epithelium. The mouth, pharynx, and respiratory channels, and even the visceral cavity, of *Bathysaurus* and *Ipnops*, and indeed of all really deep-sea fishes, are black. It can be of no use to any animal to be black inside; and the only explanation hitherto given is that the deposit of pigment is the expression of some modification in the excretory processes of the abysmal fishes.

It was mentioned above that the absence of eyes is to some extent compensated by the great extension of feelers and antennæ. Many of the jelly-fishes have long free tentacles radiating in all directions; the rays of the ophiuroids are prolonged; the arms of the cuttle-fish are capable of enormous extension. The antennæ of the crustacea stretch widely through the water, and, in *Aristoeopsis*, cover a radius of about five times the body-length. In *Nematocarcinus* the walking-legs are elongated to almost the same extent; and this crustacean steps over the sea-bottom with all the delicacy of Agag. The curious arachnid-like pycnogonids have similarly elongated legs, and move about, like the ‘harvestmen’ or the ‘daddy-long-legs,’ with each foot stretched far from the body, acting as a kind of outpost. The fishes, too, show extraordinary outgrowths of this kind. The snout may be elongated till the jaws have the proportions of a pair of scissor-blades, each armed with rows of terrible teeth; or long barbels, growing out from around the mouth, sway to and fro in the surrounding water. In other cases the fins are drawn out into long streamers. All these eccentricities give the deep-sea fishes a bizarre appearance; their purpose is plainly to act as sensory outposts, warning their possessor of the presence of enemies or of the vicinity of food.

All deep-sea animals are of necessity carnivorous, and probably many of them suffer from an abiding hunger. Many of the fishes have enormous jaws, the angle of the mouth being situated at least one-third of the body-length from the anterior end. The gape is prodigious, and as the edge of the mouth is armed with recurved teeth, food once entering has little chance of escape. So large is the mouth that these creatures can swallow other fish bulkier than themselves; and certain eels have been brought to the surface which have performed this feat, the prey hanging from beneath them in a sac formed of the distended stomach and body-wall. It has been said of the desert fauna that ‘perhaps there never was a life so nurtured in violence, so tutored in attack and defence as this. The warfare is continuous from the birth to the death.’ The same words apply equally to the depths of the ocean. There, perhaps, more than anywhere else, is true the Frenchman’s description of life as the conjugation of the verb ‘I eat,’ with its terrible correlative, ‘I am eaten.’

Connected with the alimentary tract, though in some fishes shut off from it, is the air-bladder, an organ which contains air secreted from the blood, and which, amongst other functions, serves to keep the fish the right side up. The air can be reabsorbed, and is no doubt, to some extent, controlled by muscular effort; but there are times when this air-bladder is a source of danger to deep-sea fishes. When they leave the depths for shallower water, where the pressure is diminished, the air-bladder begins to expand; and, should this expansion pass beyond the control of the animal, the air-bladder will act as a balloon, and the fish will continue to rise with a rate of ascension which increases as the pressure lessens. Eventually the fish reaches the surface in a state of terrible distortion, with half its interior hanging out of its mouth. Many such victims of levitation have been picked up at sea, and from them we learnt something about deep-sea fishes before the self-closing dredge came into use.

One peculiarity of the abysmal fauna, which, to some extent, is a protection against the cavernous jaws mentioned above, is a certain ‘spininess’ which has developed even amongst genera that are elsewhere smooth. Such specific names as *spinosus*, *spinifer*, *quadrispinosum*, are very common in lists of deep-sea animals, and testify to the wide prevalence of this form of defence. A similar spiny character is, however, found in many polar species, even in those of comparatively shallow water; and it may be that this feature is a product of low temperature and not of low level. The same applies to the large size which certain animals attain in the depths. For instance, in the Arctic and Antarctic Seas the isopodous crustacea, which upon our coasts scarcely surpass an inch in length, grow to nine or ten inches, with bodies as big as moderate-sized lobsters. The gigantic hydroid polyps, *e.g.*, *Monocaulus imperator* of the Pacific and Indian Oceans, illustrate the same tendency; and so do the enormous single spicules, several feet long and as thick as one’s little finger, of the sponge *Monorhaphis*. Amongst other floating molluscs at great depths, chiefly pteropods, the *Valdivia* captured a gigantic *Carinaria* over two feet in length. Of even greater zoological interest were giant specimens of the *Appendicularia*, which were taken at between 1,100 and 1,200 fathoms. This creature, named by Chun, *Bathochordæus charon*, reaches a length of about five inches, and has in its tail a notochord as big as a lamprey’s. All other genera of this group are minute, almost microscopic.

There are two other peculiarities common amongst the deep-sea fauna which are difficult to explain. One is a curious inability to form a skeleton of calcareous matter. The bones of many abysmal fishes are deficient in lime, and are fibrous or cartilaginous in composition. Their scales, too, are thin and membranous, their skin soft and velvety. The shells of deep-sea molluscs are as thin and translucent as tissue-paper; and the same is true of some brachiopods. The test of the echinoderms is often soft, and the armour of the crustacea is merely chitinous, unhardened by deposits of lime. Calcareous sponges are altogether unknown in the depths. This inability to form a hard skeleton—curiously enough this does not apply to corals—is not due to any want of calcareous salts in the bottom waters. It is known that calcium sulphate, from which animals secrete their calcium carbonate, exists in abundance; but those animals which dwell on the calcareous globigerina ooze are as soft and yielding as those which have their home on the siliceous radiolarian deposits. Animals which form a skeleton of silex do not suffer from the same inability; in fact, the deep-sea radiolarians often have remarkably stout skeletons, whilst the wonderful siliceous skeletons of the hexactinellid sponges are amongst the most beautiful objects brought up from the depths.

The second peculiarity, for which there seems no adequate reason, is the reduction and diminution in size of the respiratory organs. Amongst the crustacea, the ascidians, and the fishes this is especially marked. The gill laminæ are reduced in number and in size; and the evidence all points to the view that this simplification is not primitive but acquired, being brought about in some way by the peculiar conditions of life at great depths.

When the first attempts were made to explore the bed of the ocean, it was hoped that the sea would give up many an old-world form; that animals, known to us only as fossils, might be found lurking in the abysmal recesses of the deep; and that many a missing link would be brought to light. This has hardly proved to be the case. In certain groups animals hitherto known only as extinct, such as the stalked crinoids and certain crustacea—*e.g.*, the Eryonidæ—have been shown to be still extant. The remarkable *Cephalodiscus* and *Rhabdopleura*, with their remote vertebrate affinities, have been dragged from their dark retreats. Haeckel regards certain of the deep-sea medusæ as archaic, and perhaps the same is true of the ascidians and holothurians; but, on the whole, the deep-sea fauna cannot be regarded as older than the other faunas of the seas. The hopes that were cherished of finding living ichthyosauri or plesiosauri, or the Devonian ganoid fishes, or at least a trilobite, or some of those curious fossil echinoderms, the cystoids and blastoids, must be given up. Certain of the larger groups peculiar to the deep sea have probably been there since remote times; but many of the inhabitants of the deep belong to the same families, and even to the same genera, as their shallow-water allies, and have probably descended in more recent times. There, in the deep dark stillness of the ocean bed, unruffled by secular change, they have developed and are developing new modifications and new forms, which are as characteristic of the deep sea as an Alpine fauna is of the mountain heights.

BRITISH SEA-FISHERIES

ἄγει
. . . πόντου τ' εἰναλίαν φύσιν σπείραισι δικτυοκλώστοις,
περιφραδὴς ἀνήρ.

Sophocles: *Antigone*.

To contemplate all the legislation concerning English sea-fishing and the administration of this vast industry during the last century is alike to bewilder the reason and to fatigue the patience. The industry is an enormous one, and of the utmost value to the dwellers in these islands. At the present time there are over 27,000 vessels, manned by more than 90,000 seamen, fishing from the ports of Great Britain. They land over 900,000 tons of fish, worth some £10,000,000, during the year. In addition to the fishermen who remove the fish from the sea, a considerable population of packers, curers, coopers, hawkers, etc., is employed. For instance, out of the 20,000 hands employed in the Shetland herring-fishery summer of 1906, 11,000 have been at sea, and 9,120, of whom 7,560 were women, have been employed on shore, not to mention the large number of railway employés who are engaged in the transport of a very perishable article. Apart from the material interests of the trade (the capital invested in steamers, sailing-boats, and gear of all kinds being estimated at more than £11,000,000), the fishing industry is of great importance to the country as a training-ground for sailors and marine engineers, and as affording a means of livelihood to a vigorous and an independent population.

Like any other industry, and—because the life-history of the inhabitants of the sea is still so obscure—perhaps more than any other industry, sea-fishing is liable to arbitrary fluctuations. There was, for instance, a partial failure in the herring-fishery in the summer of 1906 on the north and north-east of the Shetlands. The total number of crans landed was 438,950, as against 632,000 in 1905, a record year; and some of the Shetlanders have been hard put to it to live. Such a failure sets thinking those whose livelihood is threatened; but fishermen, although keen observers in what immediately concerns them, are not widely educated men, and cannot take into account in estimating causes, the many factors of the problems, some of which usually escape even the most talented of marine biologists. Fishermen seek a sign, usually an obvious one; in the present case, the bad season was attributed to the presence of certain Norwegian whaling companies, which a few years ago established themselves in the Shetlands and are destroying the common rorqual, the lesser rorqual, Sibbald’s rorqual, the cachalot, the humpbacked whale, and more rarely the Atlantic right-whale. These are killed for their blubber; the flesh is made into sausages, largely consumed in Central Europe; and the bones are ground up for manure.

It is, however, doubtful if whaling is in any way responsible for the scarcity of the herrings. According to the evidence collected by Mr. Donald Crawford’s Committee on this subject in 1904, it would appear that practically the only point on which the fishermen were then agreed was that the spouting of the whales was often a good guide as to the position of the herring-shoals. But the whales do not bring the herrings; and the fishermen are not even agreed that they serve to concentrate them. It is probable that the general migrations and shoaling habits of the herrings are far more dependent on the physical character of the water—a relation which is particularly clear, as the international investigations have already shown, in areas where sharply contrasted ocean-currents are constantly striving for the mastery as they are in the neighbourhood of the

Shetland Isles. The hydrographical bulletin of the International Council recorded a distinctly lower temperature for the Atlantic current between Iceland and Scotland at the beginning of the year 1906 than at the corresponding season of 1903, 1904, or 1905; and an unusually low temperature has been characteristic of the Shetland waters throughout the summer of 1906. The Gulf Stream could more justly be blamed for the comparative failure of the Shetland fishery in 1906 than the Norwegian whalers, whose operations have probably done no more injury to the herring-fishery than they did in 1905 or the year before. Such failures are often real disasters to a seafaring population—a race who are, as a rule, of small versatility and unable to turn readily to new trades. Their occurrence usually provokes a cry for legislation.

Such an outcry is in this country usually met by the appointment of a Commission, or of a special Parliamentary Committee. Seventeen such inquiries into sea-fisheries have been held since Queen Victoria came to the throne, an average of one every four years. The usual process is gone through; a certain number of more or less influential gentlemen (one of them perhaps an expert) are given a 'wide reference,' and they proceed to take evidence. An energetic secretary, usually a young barrister, collects facts; a great number of witnesses, like Mrs. Wititterly, 'express an immense variety of opinions on an immense variety of subjects.' These are written down and printed; and the Commissioners, with the aid of the energetic secretary, seek to distil wisdom out of the printed evidence of the multitude, and base on it their recommendations. Legislation is sometimes recommended; but in the case of the sea-fisheries of this country it has, perhaps fortunately, seldom followed the presentation of any of these reports.

It seems, indeed, that the time is hardly yet ripe for deep-sea fishery legislation, much as it may be needed; and the reason is that our knowledge of the questions involved, although rapidly increasing, is still too deficient to form a sound basis for law-making. We propose to confine our attention mainly to the North Sea, and, from another point of view, mainly to the English fishing authorities, as opposed to those of Scotland and Ireland, in each of which countries the fishing industry is controlled by a separate Board. The fundamental and central question to be settled is whether there is a diminution in the fish generally, or in any particular species of food-fish in the North Sea area, by far the most productive of our fishing-grounds. If the answer is affirmative, we may ask, What is the cause of this diminution? and, How can it be arrested?

In 1863 Professor Huxley, Mr. (afterwards Sir) J. Caird, and Mr. G. Shaw Lefevre were constituted a Royal Commission to inquire—(1) whether or not the value of the fisheries was increasing, stationary, or decreasing; (2) whether or not the existing methods of fishing did permanent harm to the fishing-grounds; and (3) whether or not the existing legislation was necessary. Three years later the Commission reported; and their Report forms an important milestone on the road of English fishery administration.

Since 1866 great progress has been made in our knowledge of the life-history of food-fishes; yet even to-day we are hardly in a position to answer the questions set to Professor Huxley and his colleagues. At that time nothing was known about the eggs or spawn of the food-fishes. Even while the Commission was sitting, in 1864, Professor G. O. Sars for the first time discovered and described the floating ova of the cod, and succeeded in artificially fertilizing the ova and rearing the young. The following year he did the same with the mackerel; and Professor Malm of Göteborg about this time obtained and fertilized the eggs of the flounder. Since that time we have found out the eggs of all the valuable food-fish, and artificially hatched most of them. But the facts about the cod's eggs appear to have been unknown to the Commission. They had to rely upon such data as the return of fish carried by the railway companies, the current prices of fish in the market, the return on the capital invested, and the impressions of leading merchants and fishermen. They had little scientific knowledge of sea-fisheries to guide them, for the knowledge scarcely existed; and they had no trustworthy statistics. Nevertheless, as was usually the case when Professor Huxley was concerned, they arrived at very definite conclusions—conclusions which subsequent writers have felt to be, for the time when they were formulated, sound. There was no doubt that at that date, both in Scotland and in England, the fisheries were improving; the number and the value of the fish landed at our fishing-ports were annually increasing; the capital invested in the industry yielded a satisfactory return.

The Commissioners strongly opposed the bounty system, which had done so much to build up the herring-fisheries in Scotland. They recommended the policy of opening the ports and the territorial waters to foreign seamen. They regarded the sea as free to all, just as the International Congress of Lawyers in the autumn of 1906 declared the air to be. They found no reason to believe that the supply of fish was diminishing. They were aware of the enormous destruction, especially of immature fish, consequent upon the methods of fishing, but regarded this destruction as infinitesimal compared with what normally goes on in Nature, and held that it did no permanent harm to the fisheries. They recommended that all laws regulating fishing in the open seas should be repealed, and, with two exceptions, that similar laws dealing with inshore fisheries should also be repealed; and they suggested that an Act should be passed dealing with the policing of the seas. The Sea Fisheries Act of 1868 carried these recommendations into effect, removed from the Statute-book over fifty Acts, some dating back for centuries, and rendered it possible for a fisherman to earn his living 'how, when, and where he pleased.'

But since 1868 much has changed. Beam-trawls continued to be increasingly used down to 1893, since which date they have been replaced, in steam-trawlers, by the more powerful otter-trawl. There has been an immense increase in the employment of steam-vessels. In 1883 the number of steamers was 225, with a tonnage of 6,654 tons; in 1892 the steamers numbered 627, with a tonnage of 28,271. During the same time the number of first-class sailing-vessels had sunk from 8,058 to 7,319, whilst the tonnage was practically stationary—244,097 tons in 1883, as compared with 244,668 tons in 1892. The introduction of the use of ice, which took place about 1850, and the invention of various methods of renewing and aerating the water in the fish-tanks, enabled the boats to remain much longer on the fishing-grounds, and to waste much less time in voyaging to and from the ports where the fish is landed. Further, the time spent on the grounds was appreciably lengthened by the employment of 'carriers,' which collect the fish from the fleet of trawlers and carry it to port. This process of 'fleeting,' as it is called, at first confined to the sailing-smacks, is still used by the large Hull fleets of steam-trawlers which provide Billingsgate and more recently, Hull, itself with daily supplies of trawled fish fresh from the fishing-grounds. There has also been a great growth in dock and other accommodation.

With the tendency to use larger vessels and more complex machinery came the tendency to form companies and syndicates. The fisherman ceased to own his boat, and now retains at best a share in it. The increase in size of both the vessel and the gear necessitates increased intricacy in the operations of fishing and increased specialization on the part of the hands. The old fishing community, whose fathers and grandfathers have been fishers, is disappearing before the advance of modern economic forces. The fishing-village is turning into the cheap seaside resort.

The scene of operations of the North Sea fisherman is by no means limited to the area in the map over which the two words wander. Roughly, for purposes of definition, we may say that a North Sea fisherman is one who lands his fish at an eastern port. Should he do so at a southern or western port, even though he hail from Lowestoft or Scarborough, he temporarily ceases, for our purpose, to be a North Sea fisherman. The North Sea codmen work along the Orkneys, the Shetland and Faröe Islands, Rockall and Iceland. The fishing-grounds of East Coast trawlers now range from Iceland and the White Sea to the coasts of Portugal and Morocco. Boats have gradually made their way along the Continental coasts on the eastern side of the North Sea, opening up, about the year 1868, the grounds to the north of the Horn reef off the Danish coast. In this direction, as in the Icelandic grounds, the pioneers have been the codmen and the 'liners,' who catch their fish on hooks attached to long lines—sometimes seven miles in length and carrying 7,000 hooks—which are lowered to near the bottom and attached to buoys. The 'liners' also first exploited the more central portions of the North Sea, fishing the great Fisher Bank for many years before the appearance there, about thirty years ago, of the trawlers, who have only used it as a winter-ground since about 1885. It was not until about 1891 that trawlers visited the Icelandic grounds.

In spite of the increase in the area of the fishing-ground which took place in the last century, the intensity of the fishing has more than kept up with the new areas exploited. Professor Huxley's Commission held the view that not only were there as good fish in the sea as ever came out of it, but that the fish were as many and as large as before, and that there was no reason to suppose their number would diminish. Indeed, when we consider that an unfertilized fish-egg is rarely found in the sea, and that, according to Dr. Fulton, of the Fishery Board for Scotland, the female turbot produces annually 8,600,000 eggs, the cod 4,500,000, the haddock 450,000, the plaice 300,000, the flounder 1,400,000, the sole 570,000, whilst the herring has to be content with the comparatively meagre total of 31,000, optimism seems permissible. On the other hand, the reflection that, if the stock of cod remains about constant, only two out of the 8,600,000 ova attain maturity, gives some idea of the destructive forces at work.

The eggs are expelled into water, whilst a male is 'standing by,' fertilized in the water, and (except in the case of the herring, whose eggs sink) those of the chief food-fishes float to the surface, where they pass the first stages of their development. Except, again in the case of the herring, which has definitely localized spawning-grounds, there has hitherto been little trustworthy evidence as to the existence either of stereotyped spawning migrations or of very definite breeding-grounds in the case of the chief food-fishes. The great Lofoten cod-fishery in spring is based on such a migration, as it is at this time of the year that the cod approach the coast in dense shoals for spawning purposes. During the summer, after the spawning is over, the cod disappear northwards. But with respect to the spawning habits of fishes in the waters most frequented by British fishermen we know little more than that the greater number of fish spawn in relatively deep water and at some distance from land. Light will doubtless be thrown upon this problem by the international investigations now in progress. The brilliant discovery by the Danish investigators of immense numbers of the fry of the common eel in the deep water of the Atlantic, west of Ireland, and the absence of the eggs and fry from the North Sea and Baltic, render it practically certain that the countless hordes of eels which leave the rivers of North Western Europe in autumn migrate to the ocean for spawning purposes; and, more remarkable still, that the delicate young elvers which enter the same streams in autumn have already overcome the perils of their long return migration.

Before considering the evidence for the existence of a progressive impoverishment of the fishing-grounds, it should be recorded that the Trawling Commission of 1885 held that the increase of trawling had led to a scarcity of fish in the inshore waters; and that to get good catches it was necessary to go farther to sea. Eight years later, the Select Committee of 1893 held that 'a considerable diminution [had] occurred among the more valuable classes of flat-fish, especially among soles and plaice'; and that of 1900 reported that 'the subject of the diminution of the fish-supply is a very pressing one, and that the situation is going from bad to worse.'

The evidence which induced this change of view rests partly on experiment, partly on statistics. Although the new view may be correct, none of the older sources of evidence are altogether satisfactory. One charge which used to be made against the trawl—that it destroyed the fish-spawn—has been disproved. The ova of all the prime food-fish, as we have seen, with the exception of those of the herring, float on the surface; and the herring is a fish that shows no sign of diminishing in number. In 1886 the Scottish Fishery Board began experiments to determine whether the number and size of fish were diminishing on a certain limited area or not. The Firth of Forth and St. Andrews Bay were closed against commercial trawling, and divided into stations. Once a month the ship employed by the Board visited each station and trawled over a given area. The fish taken were counted and measured. For the first few years the results indicated an increase of food-fish; but, taking a longer period and considering the flat-fishes alone, we find that the numbers of plaice and lemon-sole taken sank from 29,869 for the five years 1885-1890, to 28,044 for the five years 1891-1895. On the other hand, the dab, a comparatively worthless fish, had increased from 19,825 to 29,483.

These figures, it is true, have not been generally accepted as an exact measure of the changes which took place during the period investigated; but independent criticism has corroborated their general tendency. It looks as if protection had been encouraging the wrong sort—a process not unknown elsewhere. The explanation possibly lies in the facts adduced by Dr. Fulton that the plaice and lemon-soles spawn only in the deep water outside the closed areas, where they are subject to continuous fishing, with the apparent result of a decrease in the number of eggs and fry inshore; whilst the dabs spawn to a large extent in the protected waters, and many of them in the offshore waters are able, in consequence of their small size, to escape through the meshes of the commercial trawl, even when mature.

Two further experiments, carried out in 1890 and 1901 by the Scottish Fishery Board and the Marine Biological Association respectively, showed for the first time that the annual harvest of a given area bears a much larger proportion to the stock of fish than had been previously supposed. These were experiments with marked fish, designed originally to trace their migrations. Out of more than 1,200 plaice liberated in the Firth of Forth and St. Andrews Bay, more than 10 per cent. were recovered almost exclusively by hook and line. Owing to these waters being closed against trawlers, there is reason to believe that the number actually recaptured by trawl and line together was very much greater. Again, out of more than 400 marked plaice liberated on the Torbay fishing-grounds, 27 per cent. of those liberated in the bay, and 35 per cent. of those set free on the offshore grounds, were recaptured by trawlers.

The evidence derived from statistics has hitherto been, in many respects, unsatisfactory. In spite of the recommendations of more than one Royal Commission, nothing was done towards a systematic collection of fishery statistics until the late Duke of Edinburgh, at a conference held at the Fisheries Exhibition of 1883, happened to read a paper on some statistics collected by coastguards as to the quantity and quality of fish landed. This paper being sent to the Board of Trade, 'it was decided to establish a collection of fishery statistics for England and Wales on the same lines, and generally by the same machinery, as has been recommended by His Royal Highness.' Unfortunately, neither the lines nor the machinery have proved sound. The officials have also been hampered by want of funds. The Treasury offered £500 (afterwards increased to £700) a year for statistical purposes—a totally inadequate sum when distributed as wages among the 157 'collectors' scattered round our coasts. The duties of these collectors were to send monthly returns of thirteen different kinds of 'wet fish' and three kinds of shellfish, stating the quantities landed and the market value at the port. They had no powers to demand information from anyone, or to examine books or catches or market-and railway-returns; and they were subject to but little if any supervision.

Not only were these statistics untrustworthy, even as a simple record of the quantities of fish landed, but they were rendered practically useless for exact inquiries concerning the decline of the fisheries, through the neglect of any precautions to discriminate between the catches in the home waters and those on distant fishing-grounds of a totally different character. Fish from Iceland, Faröe, and the Bay of Biscay, as these areas were successively exploited, all went to swell the totals in the single column of 'fish landed,' thus rendering it quite impossible to determine the state of the fishery on the older fishing-grounds around our coasts. Taking the statistics as they stand, however, we find that during 1886-1888 the average quantity of fish annually landed on the coasts of England and Wales amounted to 6,263,000 cwt., valued at £3,805,000; during 1890-1892, 6,184,000 cwt., valued at £4,496,000; during 1900-1902, 9,242,000 cwt., valued at £6,543,000.

The average price of fish per cwt. in these periods was consequently 12s. 2d. in 1886-1888, 14s. 6½d. in 1890-1892, and 14s. 3½d. in 1900-1902. The census returns indicate that the population of England and Wales had risen in the meantime from about 28,000,000 in 1887 to 29,000,000 in 1891, and 32½ millions in 1901. We thus see that the people were steadily increasing their expenditure on fish, viz., from 2s. 9d. per head in 1887 to 3s. 1d. in 1891, and to 4s. per head in 1901. The quantity consumed amounted to 25 lb. per head in 1887, 23·9 lb. in 1891, and 38·8 lb. in 1901.

To appreciate the significance of these figures it is necessary to bear in mind that, prior to 1891, the fishing was mostly prosecuted in the North Sea and in the immediate neighbourhood of our coasts. During this period the price rose 20 per cent. and the supply fell—facts which indicate with tolerable certainty that the yield of the older fishing-grounds had reached its limits, if it was not actually declining. But in the following decade the conditions were reversed; the supply increased 50 per cent., and the price fell 3d. per cwt. This was the period of rapid increase in the number of steam-trawlers, of the exploitation of new fishing-grounds in distant waters, and of a great expansion of the herring-fishery.

There was thus no question of a general scarcity of fish. Fishing-boats were multiplying, and supplies increasing by leaps and bounds. Between 1891 and 1901 the average annual catch of plaice rose from 677,000 cwt. to 959,000 cwt., that of cod from 367,000 to 748,000 cwt., and that of herrings from 1,400,000 to 2,800,000 cwt. In the absence of specific information as to the yield of the older fishing-grounds, Parliament and the Government turned a deaf ear to the fishermen's complaints.

But in 1900 it was shown to the Parliamentary Committee on the Sea Fisheries Bill of that year that, during the past decade, characterized (as we have seen) by a general fall in the price of fish, the price of plaice had risen 17 per cent., and that of other valuable flat-fishes from 3 to 6 per cent. It was also shown that, while the catching power had multiplied three-fold in ten years, the catch of trawled fish had only increased 30 per cent. In 1901 the inspectors of fisheries provided a table contrasting for ten years the annual supply of trawled fish at Grimsby, Hull, and Boston (which receive the products of the Icelandic fisheries), with that of other East Coast ports which derive their fish exclusively from the North Sea. In the former ports the supply had increased from year to year, while at the other ports the supply during the years 1895-1900 was in no year so great as in the least productive of the years 1890-1895. The fishermen's case was at last made out; and in 1902 the late Government decided to participate in the investigations recommended by the Christiania Conference in 1901 for the purpose of formulating international measures for the improvement of the North Sea fisheries.

It is satisfactory to turn from the past records of neglect, from the supineness of the authorities, the imperfections of the statistics, the inadequate pittance devoted to investigations, to the progress which has taken place since the Government decided to devote a reasonable proportion of public funds to the improvement of knowledge on fishery subjects. The collection of official statistics has been reorganized on all our coasts on a system which aims at obtaining complete accounts of the results of each voyage of every first-class fishing-boat; the catches of trawlers and liners are now distinguished; the quantities of fish caught in the North Sea are distinguished from those taken beyond that area; the quantities of large, medium, and small fish are separately recorded in important cases; the numbers, tonnage, and landings of different classes of fishing-vessels are separately enumerated.

It is interesting to note the first results of the more exact system introduced in 1903. Considering only the fish caught in the North Sea and landed on the East Coast, we note a marked decline in the total catch of steam-trawlers during the years 1904, 1905, and 1906, and an increase in the catch of sailing trawlers. The former declined from 4¾ million cwt. in 1903 to 3¾ million cwt. in 1905; the latter increased from 277,000 cwt. in 1903 to 296,000 cwt. in 1905. It is shown, however, that these changes were accompanied by a considerable fall in the amount of fishing by steam-trawlers and a rise in the case of the sailing trawlers, so that inferences concerning impoverishment or the reverse would be premature. Nevertheless a fall in the abundance of haddock may be inferred from the fact that not only the total catch of this species, but also the average catch of the boats fell off continuously from 8·4 cwt. per diem in 1903 to 6·1 cwt. per diem in 1905. The fall is also seen to be mainly due to a scarcity of 'small' haddocks in 1904 and 1905 as compared with 1903. With the conclusions to which such data as these are likely to lead we are not now concerned; but these examples are sufficient to show that the official statistics are no longer a confused mass of useless figures, but a rational and fairly accurate system capable of analysis.

We have now to examine those experimental branches of investigation which are equally necessary for the effective solution of fishery problems. The chief possible causes of an impoverishment of the sea are three in number. First, as in the central United States the accumulated richness of a virgin soil produced at first huge crops, so, when fishing began in the North Sea an accumulated wealth, both in the number and in the greater size of the individual fish, was drawn upon. This 'accumulated stock' has been fished out.

Secondly, a given area of the sea, like a given area of land can support but a limited quantity of produce. There is a definite amount of food for fish in a definite volume of sea; a limit is therefore set to the number of fish in that volume of water. Professor Hensen and Professor Brandt, of Kiel, have shown that a square metre of the Baltic produces an average of 150 grammes of dry organic material in the shape of diatoms, copepods, and other floating organisms. A similar area of land produces 180 grammes of ultimate food-substance. The productivity of the sea is judged on this basis to be about 20 per cent. less than that of the land. The actual amount is of less importance than the consequences it entails. If the methods of fishing are more destructive of one species than another, comparatively worthless species may become dominant in areas where they were formerly scarce, and thus consume the food which should be reserved for their betters. It is commonly reported that the dab has tended to usurp the position formerly taken by the plaice, not only in the Scottish firths, but on the Dogger Bank, in the Devonshire bays, and in other localities. Dr. Garstang, of the Marine Biological Association, tells us that small plaice transplanted to the Dogger Bank in 1904 grew three times as much in weight as did their fellows on the coastal banks; but in the following year they grew only twice as much, owing to the presence of vast quantities of small haddocks, which ate the plaice's food and were nevertheless too small and worthless themselves to be landed by the fishermen. Yet formerly the Dogger teemed with large plaice and haddock. It was stated to the Royal Commission in 1863 that the fishermen avoided the Bank as causing gluts of fish and depreciation of price; and witnesses from Yarmouth and Hull assured the Commission that between two and three tons of fish, chiefly haddock and plaice, were frequently taken by smacks in a three hours' haul. As small plaice are confined to the coastal banks, and large plaice are now scarce, it follows that the great food-reserves on the Dogger Bank, which seem providentially designed for the fattening of plaice, are wasted on worthless dabs and baby haddocks. Thus may one cause of impoverishment lead on to another. Perhaps the right remedy in a case like this is to promote the wholesale transplantation of young plaice, as in the case of oysters, mussels, etc. The experiments already made by the Marine Biological Association point strongly in this direction.

Thirdly, the excessive destruction of young fish is another, and perhaps the greatest, cause of the impoverishment of the sea. The destruction is enormous. In the winter of 1882-1883 it was estimated that in the Firth of Forth, the Firth of Tay, and the Moray Firth, 143,000,000 of young herrings and a much greater quantity of sprats were captured. These were mostly sold as manure. Yet the herring does not decrease; it is the flat-fish, the plaice and the sole, that suffer most. In 1896, 368 tons of small fish were seized by the Fishmongers Company at Billingsgate; in 1897, 143 tons; and in 1898, 96 tons. These were sold as manure or destroyed. Mr. Holt estimates that, while over 7,000,000 mature plaice were landed in the port of Grimsby during the year April, 1893, to March, 1894, over 9,000,000 plaice not sexually mature were brought to port; or, taking the trade distinction between 'small' and 'large' fish, over 6,500,000 plaice under 13 inches in length were landed, as against 9,700,000 over 13 inches. So many as 10,407 young plaice have been taken from a single drag of a shrimp trawl. These are but a few instances out of many, showing the great destruction which is going on among the young of our more valuable food-fishes.

The questions they suggest are still a matter of discussion. Whether even this destruction has an appreciable effect on the adult population is debatable. It does not seem to have affected the herring; and we must not forget the prodigious number of offspring given to fish. The taking of immature fish is not in itself uneconomic, unless by that means we so far reduce the total number that the adult stock begins to dwindle. Sardines are more valuable than their adult form, the pilchard; whitebait, mainly composed of young sprats, with from 1 to 20 per cent. of young herrings, fetch more in the market than the parent form; and so long as the adults exist in sufficient number to keep up the stock of fry, sardine and whitebait fishing is perfectly legitimate.

But, assuming impoverishment from one or other or all of the causes enumerated, we should ask what steps can be taken to check it, especially as regards the more valuable flat-fish. It is at this stage that scientific knowledge becomes particularly important. At least nine out of every ten Acts of restrictive legislation have been shown by experience to be futile, or to have produced results absolutely different from those anticipated. It is equally plain that the failure of these attempts to interfere with the natural course of events has been largely due to inadequate knowledge of the complicated factors which affect the growth, multiplication, and distribution of fish, and of the influence which particular modes of fishing exert upon the sources of supply.

Let us examine the first-mentioned cause of impoverishment, the destruction of the 'accumulated stock.' This formula has been eagerly adopted by some who hesitate to admit the existence of any form of over-fishing. It implies that a state of equilibrium is possible between the forces of destruction and the forces of repair; that on virgin territory older individuals tend to accumulate beyond what is necessary for the maintenance of the 'current stock'; and that their removal entails no real injury to the supply. In scientific terms this means that the average age of mature individuals of a natural stock may be reduced by man to a lower point which represents the economic optimum. The Patagonian cannibals seem to have been early converts to the soundness of this theory. The difference between the Patagonian who eats his mother-in-law and the fisherman who destroys the overgrown plaice is that the former's actions are deliberate and limited, while the removal of the accumulated stock is not so much an object of the fisherman as an unpremeditated consequence of the intensity with which fishing operations tend to be conducted. Does the fisherman abate his operations when the economic optimum has been reached? Clearly not. He fishes till it ceases to pay; and no other motive affects him. It is plainly a question for scientific inquiry whether, in a given case, the fishery has been prosecuted to excess, and has reduced the average age too far, or not.

On this question the International North Sea Investigations have already thrown valuable light, for the study of the intensity of fishing by means of definite experiments with marked fish has formed an important part of the programme; and the investigation of the age of plaice, cod, and other species has been vigorously prosecuted. According to the latest report of the Council of the Marine Biological Association, more than 7,000 marked plaice have been set free by their staff, and 24 per cent. altogether have been recaptured. Of the medium-sized fish which, furnish the best test of the intensity of fishing, 30 per cent. in twelve months have been captured in the southern part of the North Sea, where sailing trawlers predominate, and 40 per cent. on the Dogger Bank and adjacent grounds, where the fishing is done by steam-trawlers. It seems, however, that some of the fish lose their labels before being caught again. A still closer idea of the severity of the fishing may perhaps be got from another experiment with weighted bottles, which were specially devised by Mr. G. P. Bidder to act as indicators of bottom currents, and were thrown overboard from the *Huxley* in the winter of 1904-1905, in the southward parts of the North Sea. Out of 600 bottles more than 54 per cent. were returned by trawl fishermen within twelve months. If anything like half the adolescent stock of plaice is taken by our trawlers every year on the deep-sea fishing-grounds, the establishment of the fact must profoundly affect our views as to the causes of depletion and the remedies to be applied; for the fishing in these instances seems not to have been on the so-called ‘small-fish’ grounds or nurseries, but in areas which have always been recognized as legitimate fields of work.

The possibility of determining the age of fish is quite a recent discovery, and is based on the observation that the scales, vertebræ, and especially the ‘otoliths’ or ear-stones of fish, show alternate dark and light rings of growth, corresponding with the summer and winter seasons of the year, exactly like the rings in the wood of trees. Many difficult problems are likely to be cleared up by a knowledge of the age of fish on different fishing-grounds; and, to judge from the scale on which this investigation is being pursued, it will not be long before we may expect something in the nature of an age-census. The Council of the Marine Biological Association have reported no less than 12,000 age-determinations of plaice by their North Sea staff up to June last; and the German and Dutch investigators are working on similar lines.

To conclude our argument, we should now examine the question whether it is possible to determine to what extent and in what manner the destruction of immature fish, which is admittedly enormous, is injurious to the permanent supply. We have already referred to Mr. Holt's statistics, which showed that 40 per cent. of the plaice landed in Grimsby in the year 1893-1894 were below 13 inches in length. In 1904, 30 per cent. of the plaice landed from the North Sea on the whole East Coast were below 11 inches in length. German statistics show that from 1895 to 1904 there was no sensible increase in the total weight of plaice landed in that country, but the proportion of ‘small’ fish (below 14 inches in length) steadily increased from 68 per cent. in 1895 to 87 per cent. in 1904. There can thus be little doubt that the supply is being maintained only by drawing more and more upon the fish of smaller size and of less value.

It seems to have been too readily assumed, however, that this increasing destruction of small plaice is the great cause of the declining catches of better fish. Has the cart not been put before the horse? In view of what has been said above concerning the general severity of the fishing, does it not look as though the capture of increasing quantities of small plaice were a consequence, and not the cause, of the general depletion of the grounds? The people demand plaice. The proprietor of a large fried-fish shop in the East End was a witness before the House of Lords Committee on the Sea-Fisheries Bill of 1904. His customers numbered from 500 to 3,000 daily; and there were 2,000 other establishments of the same kind in London. He told the Committee: ‘Plaice is the most popular fish in our line of business; people do not care for any other.’ Owing to the higher price of plaice, however, he was often compelled to substitute cheaper kinds of fish. In one month he had even made five purchases of small turbot and brill, against only two of plaice, in order to meet the demand. ‘You must understand,’ he added, ‘that amongst the class of people we deal with we do not sell turbot and brill as turbot and brill; we have to sell it as plaice. Plenty of people, if you said you had turbots, would not have them.’ It is obvious that fishermen would not land small plaice if large were plentiful. It was not until the large fish became scarce that fishermen began to take the small.

If these facts are correctly stated, the remedial treatment of the undersized-plaice problem must be taken up from a new standpoint. We must apparently give up the expectation that by merely stopping the destruction of small plaice we shall replenish the sea. The fishing seems to be too severe for that. Every autumn our trawlers fish the waters between the Dogger and the eastern grounds, confident that they will take a good catch of medium-sized plaice averaging 12 to 15 inches in length. These are fish which no fisherman in these days would despise. Though mixed with a considerable proportion of still smaller fish, no possible size-limit will prevent him from reaping this annual harvest. These fish, as has now been shown by the North Sea experiments, are undertaking their first migration from the coastal grounds to the deeper waters. However much we protect the still smaller fish inshore, this wall of nets will be interposed every autumn between the shore and the open sea. The greater the benefits of protection inshore, the denser will be the barrier confronting the fish outside, and the smaller the chances of escape.

To this must be added a new disturbing element, mentioned by Dr. Garstang in his evidence before the House of Lords Committee in 1904. It is generally agreed that the only possible form which protection can take is that of a size-limit, below which it shall be illegal to land or sell fish. In the case of steam-trawlers this limit must be high enough to render it unprofitable for the boats to fish on grounds where the small plaice are most abundant, since the majority of undersized fish are too much injured in the process of capture to be capable of survival if returned to the sea. It is otherwise with the small local sailing-boats (whether Danish, German, or Dutch) which are accustomed to fish on the small-fish grounds. These boats catch the fish alive and throw the undersized fish overboard in a living condition. As they can operate nowhere else, it may be taken for granted that the Governments of their respective countries, however anxious they may be to improve the fisheries, will scarcely consent to impose such a size-limit as to render it unprofitable for their local boats to fish.

The utmost possible protection of the small plaice would consequently be attained by determining (*a*) a high size-limit for steam-trawlers, practically debarring them from fishing on the coastal grounds; and (*b*) the highest size-limit for sailing-boats that would be consistent with the profitable pursuit of their calling. The first pick of the fish would consequently fall to the local boats; and, if protection should result, as it is reasonable to expect, in an increase in the number of plaice on the coastal grounds, there would be every inducement for these local boats to multiply in number, with the laudable object of catching as many as possible of the marketable plaice before they could migrate to the offshore waters. In practice some fish would escape; but, in the absence of any restriction upon the number of local boats, there seems no reason to expect that the number of emigrant plaice would, in the long run, be any greater than at present. Even under existing conditions, the local fishery on the west coast of Denmark has developed from a value of about £40,000 in 1897 to nearly £80,000 in 1904.

If, however, we are right in assuming that a given area of ground can only produce a given weight of fish per annum, it is fairly certain that, under protection, the increased density of the fish inshore will result in a retardation in the average rate of growth, an example of which we have given on a previous page. This must produce one or other of two results: either the small fish will remain longer on the inshore grounds before emigration, or they will emigrate offshore at a smaller size than at present. Judging, therefore, from the evidence available, it seems probable that legislative restrictions on the lines indicated can do little to replenish the offshore fishing-grounds, while such restrictions may lead to a slight, and possibly a substantial, increase in the number of small boats fishing along the coasts affected.

While Great Britain can grudge no benefit to the fisheries of other countries, it is the improvement of the deep-sea fisheries which is the paramount interest of this country. Doubts, it has been said, are resolved by action; but if we have correctly analyzed the complicated factors which affect this problem, we have also shown how essential to right action is the fullest possible knowledge concerning all the factors involved. Grave as the North Sea problem undoubtedly is, it is equally certain that the condition of the fishing industry generally was never more prosperous than at the present time. The figures quoted in an earlier part of this article prove this statement to be no paradox. Interference of some kind, whether by legislation, transplantation, artificial culture, or some combination of all these means, seems ultimately to be inevitable. But, if we are to interfere with the fishing industry more successfully than our predecessors, we should take advantage of the present time of prosperity to increase our knowledge on every side—scientific, statistical, experimental—so as to be able to act with conviction when the whole circumstances are clearer and the adequacy of our proposals is less open to doubt. Moreover, in view of the growing interest of other countries, especially Germany and Holland, in deep-sea trawling, and of the international character of the most critical problems, there can be no two opinions as to the desirability of continuing these investigations on some kind of international basis, a basis which has already been productive of very promising results.

Before turning our attention to the various bodies which administer and investigate the fisheries of England, a short consideration of what is done in the two great countries which have scientifically developed their fisheries may be profitable. In Germany we have the Kiel Commission, and in the United States the Commission of Fish and Fisheries. The Kiel Commission exists for the scientific investigation of the German seas. It was established in 1870 at the suggestion of a German sea-fishery society—an interesting example of the belief which the German layman has in science. It consists of four Kiel professors—Hensen representing physiology, Karl Brandt zoology, Reinke botany, and Krümmel geography—and of Dr. Heincke, director of the biological station on Heligoland. An annual grant of £7,500 is made by the German Government for the maintenance of the laboratories at Kiel, the cost of steamers for investigations, the cost of the handsome reports published under the name of 'Wissenschaftliche Meeresuntersuchungen,' and for salaries; of these the five members of the Commission divide but £270 between them. The German Government has also spent considerable sums on the biological station in Heligoland, and make it an annual allowance of about £1,000.

The American Commission, like that of Kiel, is not an administrative body, but concerns itself with the acquisition and application of knowledge concerning fisheries; like it, too, it is independent of official control. It reports directly to Congress. It was established in 1871. Its work is, however, of a more practical kind; besides general scientific investigation, it collects fishery statistics and undertakes commercial fishery inquiries, assists in finding markets, and generally advises the trade and the Legislature when diplomatic action is indicated; finally, it is by far the most energetic fish-breeding institution in the world. Much of its work is concerned with the vast system of inland waters—rivers and lakes—which traverse the Continent. The work has been carried out on a scale unknown elsewhere, and Congress has supported it with ample funds. The appropriation in 1897-1898 exceeded £97,000, of which £41,000 was spent on salaries, £16,000 on scientific investigations and upkeep of steamers, £37,000 on fish-culture (mostly fresh-water), and £3,000 on administration and statistics. Besides this central body, many of the States possess fish commissions of their own. The commissioners control numerous laboratories and fish-hatcheries, two sea-going vessels, and many railway-cars specially designed for the transport of fish-fry.

Space does not permit our dealing with the Scottish and Irish Fishery Boards. The former has existed for a century, and, being independent of departmental control, while enjoying a moderate income and the advice of such zoologists as Goodsir, Allman, Sir John Murray, Cossar Ewart, W. C. McIntosh—who has done more than anyone in the Empire to elucidate the life-histories of marine fishes—and D'Arcy Thompson, together with an able staff, the Fishery Board for Scotland has done much thorough and useful work. The fisheries of Ireland suffered from the economic disturbances which overtook Ireland during the nineteenth century, and reached, perhaps, their lowest ebb in 1890. The industrial revival, with which the name of Sir Horace Plunkett is so indissolubly connected, has included in its scope the Irish fisheries. The fishery branch of the Department of Agriculture and Technical Instruction receives an annual grant of £10,000, and, under the guidance of the Rev. S. Green and Mr. E. W. L. Holt, is already doing much to promote the fishing of the well-stocked Irish seas.

The English official fishery staff seems to have sprung from the requirements of the Salmon Fishery Act of 1861. To carry out the regulations over fresh-water fisheries recommended by that Act two inspectors were appointed, and these were at first attached to the Home Office; a further Act in 1886 transferred these inspectors to the Board of Trade, and extended their duties so as to include the preparation of annual reports on sea-fisheries. In 1903 another transfer took place; and the inspectors were transferred to the Board of Agriculture, which then became the Board of Agriculture and Fisheries.

At present the central staff consists of an assistant secretary and two inspectors, in addition to a body of statistical experts. Their duties are far too numerous for so small a staff. Much of their time is taken up with the comparatively unimportant fresh-water fisheries; and these are the subject of a separate report. Without actually administering the byelaws of the local committees, they exercise a certain supervision over their actions. They have to attend numerous inquiries all over the country, and to prepare annual reports; and they are responsible for the collection of the statistics which have recently assumed so extensive a development. Besides the central authorities at the Board of Agriculture and Fisheries, there are local fisheries committees established by an Act of 1888. These committees can be established by the county and borough councils on application to the Board of Agriculture and Fisheries, which defines the area over which a committee shall have jurisdiction. One-half of such a committee is chosen by the local councils, and one-half by the central authority. The necessary money is raised by a local rate. A committee may draft byelaws; but these only become operative if confirmed by the Board. These byelaws differ, according to conditions, in different parts of England. They deal largely with restrictions on trawling. No steam-trawler is allowed to trawl within the three-mile limit around the coast of England; even the sailing trawler is forbidden. The byelaws also deal with the sizes of the meshes of nets, shrimping, crabbing, etc.

Neither the central authorities, whose chief function is to administer the law and collect statistics, nor the local committees, whose expenditure is limited to the 'shell-fisheries'—and, stretch the Act to the breaking point, you still cannot make a flat-fish into a shellfish—have either the time or the money for scientific experiment. This has to a large extent been left to local or private enterprise, and is mainly confined to three centres—the Northumberland coast, the Lancashire and western district, and the Channel and North Sea. The first-named area has recently been supplied by a private benefactor with funds for an efficient laboratory at Cullercoats, from which much useful work may be expected.

It is difficult to disentangle the Lancashire and Western Sea-fishery Committee from Liverpool University on the one hand, and from the Liverpool Marine Biological Committee or Society on the other. The Committee owns a handsome marine station at Port Erin, on the Isle of Man; here and at the fish-hatchery at Peel, in Cumberland, the largest fish-breeding experiments in England are carried out. In 1904, 5,000,000 young plaice were reared and put into the sea from Port Erin alone. The Committee publishes annual reports and a series of 'Memoirs.' It is probably to this Committee that the University owes its connexion with the local sea-fisheries authorities. In the laboratories and museums of the University the scientific work of the local districts is carried on by officials paid by the Fisheries Committee; and special rooms in the handsome new zoological department have been assigned to these two organizations. The connecting link between the three bodies is the professor of zoology, Dr. Herdman, who is honorary director of the scientific work, and to whose untiring energy the University and the district owe a large debt. With him work two trained naturalists, Dr. Jenkins, the Superintendent of the District Committee, and Mr. James Johnstone, whose lucid and admirable work is mentioned at the head of this article. From it many of our figures and facts have been taken.

The third and last body occupied with original marine research is the Marine Biological Association of the United Kingdom. It is the most important of these institutions, and aims at a national rather than a local activity. The fine laboratory which dominates the eastern end of Plymouth Hoe was erected at a cost of £12,000, and opened in 1888. The object of the Association is to 'promote researches leading to the improvement of zoological and botanical science, and to an increase of our knowledge as regards the food, life-conditions, and habits of British food-fishes and molluscs.' Although a high average of scientific work has been displayed in the published 'Memoirs' connected with the Plymouth laboratory, great attention has also been paid to matters of practical interest. In a list of some 350 papers published, with the aid or under the auspices of the Association, between 1886 and 1900, nearly one-half deal directly with economic problems. From 1892 to 1895 the officers of the Association carried on at Grimsby extensive investigations into the destruction of immature fish; and it is gratifying to find that the Select Committee of 1893 extended its recognition to the 'facts and statistics' submitted by the Scotch Fishery Board and by the Association. In the summer of 1902 the Association, at the request of the Government, undertook to carry out the English portion of the International Investigation of the North Sea. The scope of this inquiry is immense; and its importance to the largest fisheries available for our fishermen is incalculable. Some idea of the kind of work accomplished has been furnished in the preceding pages.

What now seems to be most required, in addition to the maintenance of the work already in progress, is a closer co-operation of these various bodies with one another and with the central authority now established under the President of the Board of Agriculture and Fisheries. The outlines of some such scheme seem plainly indicated by the existing constitution of these various bodies. The Fisheries Department is responsible for administration, statistics, and general advice to the President of the Board on fishery matters. The Marine Biological Association undertakes general marine investigations of a national as distinct from a local character, as well as such local investigations and experiments as can conveniently be carried out at its laboratories. The Sea-fishery Committees need additional powers to enable them to carry out local scientific investigations more fully in their respective areas. Perhaps an annual conference between the representatives and experts of these bodies and the officials of the Fishery Department, for the express purpose of drawing up plans of work for the ensuing year, would, in the first instance, be the best means of leading up to more intimate co-operation and organization.

The Reports on the North Sea Investigation so far published deal only with the work of the earlier years of the investigations; but already the great prospective value of the results is fully apparent. The Marine Biological Association has carried out the portion of the general scheme entrusted to it with energy and success; and Englishmen have no need to fear comparison with the work done in other countries.

ZEBRAS, HORSES, AND HYBRIDS

This matchless horse
Is the true pearl of every caravan.
Sir F. H. Doyle.

The views and writings of Darwin have influenced in an unexpected way the nature of the work carried on by biological investigators during the past fifty years. To a great extent, whilst generally holding the doctrines he held, they have forsaken his methods of inquiry.

If animals and plants have arrived at their present state by descent with modification from simpler forms, it ought to be possible by careful searching to trace the line of ancestry; and it is this fascinating but frequently futile pursuit which has dominated the minds of many of our ablest zoologists for the last thirty years. To such an extent has this pedigree-hunting been carried that there is scarcely a group of invertebrates from which the vertebrates have not been theoretically derived; and one of the ablest of our physiologists has used his great powers in the attempt to trace the origin of the backboned animals from a spider-like creature, and has exercised his ingenuity in a plausible but unconvincing effort to equate the organs of a king-crab with those of a lamprey. This appeal to comparative anatomy and the consequent neglect of living animals and their habits are no doubt partly due to the influence of Huxley, Darwin's most brilliant follower and exponent. He had the engineer's way of looking at the world, and his influence was paramount in many schools. The trend which biology has taken since Darwin's time is also partly due to a fervent belief in the recapitulation theory, according to which an animal in developing from the egg passes through phases which resemble certain stages in the past history of the ancestors of the animals. For example, there is no doubt that both birds and mammals are descended from some fish-like animal that lived in the water and breathed by gills borne on slits in the gullet, and every bird and mammal passes through a stage in which these gill-slits are present, though their function is lost, and they soon close up and disappear. In the hope, which has been but partially realized, that a knowledge of the stages through which an animal passes on its path from the ovum to the adult would throw light on the origin of the race, the attention of zoologists has been largely concentrated on details of embryology, and a mass of facts has already been accumulated which threatens to overwhelm the worker.

The two chief factors which play a part in the origin of species are heredity and variation, and until we know more about the laws which govern these factors, we cannot hope to arrive at any satisfactory criteria by which we can estimate the importance of the data accumulated for us by comparative anatomists and embryologists. Signs are not wanting that this view is beginning to be appreciated. The publication of 'Materials for the Study of Variation' by Mr. Bateson some years ago shows that there exists a small but active school of workers in this field; and recent congresses on hybridization give evidence that in America, on the Continent, and in Great Britain, one of the most important sides of heredity is being minutely and extensively explored. Professor Cossar Ewart's experiments, which we shall attempt to summarize, deal with heredity and cognate matters, and although they are so far from complete that the results hitherto obtained cannot be regarded as final, they mark an important stage in the history of the subject.

Twelve years ago Professor Ewart began to collect materials for the study of the embryology of the horse, about which, owing to the costliness of the necessary investigations, very little is at present known. At the same time he determined to inquire into certain theories of heredity which have for centuries influenced the breeders of horses and cattle, and the belief in which has played a large part in the production of our more highly bred domestic animals. Foremost amongst these is the view widely held amongst breeders that a sire influences all the later progeny of a dam which has once produced a foal to him. This belief in the 'infection of the germ,' or 'throwing-back' to a previous sire, is probably an old one, possibly as old as the similar faith in maternal impressions which led Jacob to placed peeled wands before the cattle and sheep of his father-in-law Laban. The phenomenon has recently been endowed with a new name—Telegony. Since the publication of Lord Morton's letter to Dr. W. H. Wollaston, President of the Royal Society, in 1820, it has attracted the attention, not only of practical breeders, but of theoretical men of science. The supporters of telegony, when pressed by opponents, having almost always fallen back on Lord Morton's mare, it will be well to recall the chief incidents in the history of this classic animal.

It appears that early in last century Lord Morton was desirous of domesticating the quagga. He succeeded in obtaining a male, but, failing to procure a female, he put him to a young chestnut mare of seven-eighths Arab blood which had never been bred from before. The result was the production of a female hybrid apparently intermediate in character between the sire and the dam. A short time afterwards Lord Morton sold his mare to Sir Gore Ouseley, who bred from her by a fine black Arabian horse. The offspring of this union, examined by Lord Morton, were a two-year-old filly and a year-old colt. He describes them as having

> 'the character of the Arabian breed as decidedly as can be expected where fifteen-sixteenths of the blood are Arabian, and they are fine specimens of that breed; but both in their colour and in the hair of their manes they have a striking resemblance to the quagga.'

The description of the stripes visible on their coats is careful and circumstantial, but the evidence of the nature of the mane is less convincing:

> 'Both their manes are black; that of the filly is short, stiff, and stands upright, and Sir Gore Ouseley's stud-groom alleged that it never was otherwise. That of the colt is long, but so stiff as to arch upwards and to hang clear of the sides of the neck, in which circumstance it resembles that of the hybrid.

This is the classical—we might almost say the test—case of telegony: the offspring resembled not so much the sire as an earlier mate of the dam. The facts related tended to confirm the popular view, and that view is now widely spread. Arab breeders act on the belief, and it is so strongly implanted in the minds of certain English breeders that they make a point of mating their mares first with stallions having a good pedigree, so that their subsequent progeny may benefit by his influence, even though poorly-bred sires are subsequently resorted to.

The evidence of Lord Morton's mare convinced Darwin of the existence of telegony. After a careful review of the case, he says: 'There can be no doubt that the quagga affected the character of the offspring subsequently got by the black Arabian horse.' Darwin, however, latterly came to the conclusion that telegony only occurred rarely, and some years before his death expressed the opinion that it was 'a very occasional phenomenon.' Agassiz believed in telegony. He was strongly of opinion

> 'that the act of fecundation is not an act which is limited in its effect, but that it is an act which affects the whole system, the sexual system especially; and in the sexual system the ovary to be impregnated hereafter is so modified by the first act that later impregnations do not efface that first impression.

Romanes also believed that telegony occasionally occurred. He paid a good deal of attention to the matter, commenced experiments in the hope of settling the question, and corresponded at length on this subject with professional and amateur breeders and fanciers. The result of his investigations led him to the conclusion 'that the phenomenon is of much less frequent occurrence than is generally supposed. Indeed, it is so rare that I doubt whether it takes place in more than 1 or 2 per cent. of cases.' He adds that his professional correspondents regard this as an absurdly low estimate. Tegetmeier and Sutherland believe that telegony exists in dogs and other animals; and Captain Hayes, whose opinion probably coincides with that of the majority of veterinary surgeons, takes for granted that it occurs in horses. A controversy some years ago in the *Contemporary Review* shows us that Mr. Herbert Spencer was a firm upholder of telegony, and that he had a theory of his own as to the mode in which it is brought about.

The explanations put forward by the supporters of telegony as to the mechanism by which it is effected differ widely. It will be well to discuss them here. The view that telegony is due to the mental impression of the dam, held by Sir Everard Home and many others since his day, has nothing to support it; but the other two views, which may be termed (1) the infection hypothesis, and (2) the saturation hypothesis, demand more detailed treatment.

The infection hypothesis supposes that the reproductive organs of the mother are specifically altered or infected by bearing offspring to a previous sire. The method by which this is effected is now most commonly thought to be by a fusion or blending of some of the unused germ-cells of the first sire with the unripe ova in the ovary of the dam. Physiologists, however, regard this as very unlikely. Although at the time that the ovum of a mare is fertilized there are usually other ova almost mature, or approaching maturity, these disappear during gestation. Subsequent offspring arise from successive crops of ova, into whose composition it is most improbable that the earlier spermatozoa could enter. Further, it is known that in the Equidæ the male germinal cells do not live long within the body of the female; they are already disintegrating eight days after insemination, and they probably lose their fertilizing power after three or four days, if not sooner; hence it is not possible for them to remain in the body during the whole of a period of gestation and to fertilize the next succeeding batch of ova.

The second theory which attempts to account for the phenomenon of telegony is termed the saturation hypothesis. In the words of Mr. Bruce Lowe, who has formulated the theory, we may say that, 'briefly put, it means that with each mating and bearing the dam absorbs some of the nature or actual circulation of the yet unborn foal, until she eventually becomes saturated with the sire's nature or blood, as the case may be.' Although not very well expressed, it is obvious what the author means; and if this saturation really takes place, it accounts for a good deal more than telegony. It would affect the whole body and nature of the dam, and not only the reproductive organs, which, according to Romanes and others, are alone influenced. There is no doubt that matter can and does pass from the blood of the embryo into that of the mother—in certain classes of mammalia, at any rate. The published Report of the Fourth International Congress of Zoology, which met in 1898 at Cambridge, contains a paper by Professor Hubrecht, of Utrecht, in which he describes certain blood-corpuscles formed in the embryo which undoubtedly make their way into the maternal bloodvessels and take part in her circulation. That matter can pass from the bloodvessels of the embryo to those of the mother is further demonstrated by the experiments of M. Charrin, who showed that diphtheritic toxins injected into the embryos of a rabbit caused the death of the mother within five days, and further that a rabbit can be rendered immune by injecting anti-diphtheritic toxins into the embryos.

There is nothing in these experiments to show that the nature of the dam is radically altered; and in the Equidæ, in which, as we have seen, the classical case of telegony occurred, there is a strong presumption against any such transference of blood-corpuscles from the embryo to the mother. Still, taking all the facts into consideration, it appears that, if telegony exists, it is more likely to be brought about by saturation than by the direct infection of the ovary; though, if the former method be accepted, telegony must be confined to the mammals and the comparatively few other animals whose young spend some time in the body of the mother and are not hatched out from eggs which have lost their connexion with the body of the mother at an early stage.

Before passing on to consider the views of those who hold that telegony does not exist and to see what light the Penycuik experiments throw on the subject, a word or two may be said about Mr. Herbert Spencer's theory of the mode in which telegony, in which he firmly believed, is brought about. He suggested that some 'germ-plasm' passes from the embryo into the mother and becomes a permanent part of her body, and that this is diffused throughout her whole structure until it affects, amongst other organs, the reproductive glands. This view, which in some respects recalls the pangenesis of Darwin, is intermediate between the saturation and the infection hypotheses. Professor Ewart refers to it as 'indirect infection.'

Weismann, to whom we owe the term telegony, came to consider the facts for and against its existence in connexion with his well-known inquiry into the inheritance of acquired characters. If telegony be true, there is no need to look further for a clear case of the inheritance of a character which has been acquired during the lifetime of the parent. The quagga-ness—if one may be permitted to use such an expression—of Lord Morton's mare was acquired when she was put to the quagga or shortly afterwards, and was transmitted to her foals. A clearer case of a character acquired during lifetime and transmitted to offspring could not be imagined. Weismann does not absolutely deny the possibility of the existence of telegony, but he would like more evidence. In the *Contemporary Review* he writes: 'I must say that to this day, and in spite of the additional cases brought forward by Spencer and Romanes, I do not consider that telegony has been proved.' And further: 'I should accept a case like that of Lord Morton's mare as satisfactory evidence if it were quite certainly beyond doubt. But that is by no means the case, as Settegast has abundantly proved.' He would, in fact, refer the case to reversion, and quotes Settegast to the effect that every horse-breeder is well aware that the cases are not rare when colts are born with stripes which recall the markings of a quagga or zebra. We shall return to this point later.

A considerable number of German breeders support the contention of Weismann that telegony is as yet unproven, and it may be pointed out that in Germany, on the whole, breeders have had a more scientific education than in England, and that in that country science is regarded with less aversion or contempt than is usually the case among so-called practical men in England. Settegast has been quoted above: neither he nor Nathusius, a leading authority on domestic cattle, has ever met with a case of telegony, and the same is true of Professor Kühn, the late Director of the Prussian Agricultural Station at Halle. We may mention one more case of an experienced breeder who was equally sceptical—the late Sir Everett Millais, who was, as is well known, an authority of great weight in the matter of dog-breeding. He writes as follows, in a lecture entitled 'Two Problems of Reproduction':

> 'I may further adduce the fact that in a breeding experience of nearly thirty years' standing, during which I have made all sorts of experiments with pure-bred dams and wild sires, and returned them afterwards to pure sires of their own breeds, I have never seen a case of telegony, nor has my breeding-stock suffered. I may further adduce the fact that I have made over fifty experiments for Professor Romanes to induce a case of telegony in a variety of animals—dogs, ducks, hens, pigeons, etc. —but I have hopelessly failed, as has every single experimenter who has tried to produce the phenomenon.'

It is thus evident that there was a considerable body of opinion, both practical and theoretical, for and against telegony; and that a re-investigation of the subject was urgently needed. Such a re-investigation has been begun by Professor Ewart at Penycuik. Since the clearest and most definite evidence of this throwing back to a previous sire is derived from the crossing of different species of the Equidæ, it was desirable to repeat the experiment of Lord Morton. This is now unfortunately impossible, because the quagga is extinct. The zebra is, however, still with us, and the mating of a zebra stallion with every variety of horse, pony, and ass, and subsequently putting the dam to pure-bred sires, has been the more important part of the numerous experiments carried on in the Midlothian village some ten miles southwest of Edinburgh.

Before considering in detail the result of the experiments it will be necessary to say a few words on the question of the various species of zebra; and since, like Weismann, Professor Ewart explains certain of the phenomena attributed to telegony by reversion, it will be as well to inquire how far reversion is known amongst the Equidæ, and what evidence we have that the ancestor of the horse was striped.

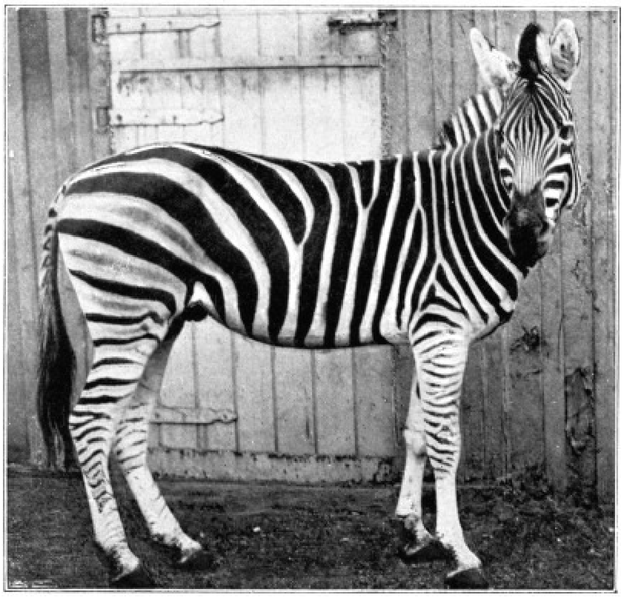
Matopo, the zebra stallion from which Professor Ewart had, some eight years ago, bred eleven zebra-hybrids from mares of various breeds and sizes, belongs to the widely distributed group of Burchell's zebras. Many sub-species or varieties are included in this group, which, as regards the pattern of the stripes, passes —in certain varieties found in Nyassaland—into the second species, the mountain zebra, once common in South Africa. The third species is the Grévy's zebra of Shoa and Somaliland; it is probably this species which attracted so much attention in the Roman amphitheatres during the third century of our era. A pair of Somali zebras were presented to the late Queen some years ago by the Emperor Menelik, and for a time were lodged in the Zoological Gardens, Regent's Park. This species measures about fifteen hands high, is profusely striped, and stands well apart from the other two groups. It is important to note that in Professor Ewart's opinion it is the most primitive of all the existing striped horses.

There is no direct evidence that the ancestors of horses were striped. Certain observers think that some of the scratches on the life-like etchings on bone, left us by our palæolithic cave-dwelling ancestors, indicate such stripes; but little reliance can be placed on this. On the other hand there is much indirect evidence. Every one who has an eye for a horse, and who has travelled in Norway, is sure to have noticed the stripings, often quite conspicuous, on the dun-coloured Norwegian ponies. Colonel Poole assured Darwin that the Kathiawar horses had frequently 'stripes on the cheeks and sides of the nose.' Breeders are well aware that foals are often born with stripes, usually on the shoulders or legs, less frequently on the face. Such stripes as a rule disappear as the colt grows up, but can often be detected in later life for a short time after the coat has been shed; they are sometimes only visible in certain lights, and then produce somewhat the same impression as a watered silk. From the facts that more or less striped horses are found all over the Old World; that in Mexico and other parts of America the descendants of horses which were introduced by the Spaniards and which afterwards ran wild are frequently dun-coloured and show stripes; that foals are frequently striped; and that mules not uncommonly have leg and shoulder stripes, the inference is largely justified that the ancestors of all our horses were striped.

The hypothesis of reversion has recently been called in question, and no doubt the term has been much abused. Animals and plants have been said to revert to some remote ancestor when they have varied in some particular, and this variation has then been described as a primitive character possessed by the ancestor; thus there has been much arguing in and about a vicious circle. But the fact that a term has been illogically applied does not destroy the existence of that which the term signifies, and there can be no doubt that reversion exists. That it exists in the Equidæ is shown by the following proofs: (1) The ancestors of the horse had four premolar teeth in the upper jaw; the modern horse has lost, or is losing, the first of these, and as a rule has only three. When the first is present—the so-called wolf-tooth—it is small, and soon disappears. Zebras usually retain the ancestral number. A few years ago Professor Ewart had a Shetland pony in which the first premolar was relatively nearly as large as it is in hipparion, one of the supposed ancestors of the horse. (2) There is no doubt that the horse is descended through three-toed ancestors from five-toed ancestors. All trace of the latter condition is now lost in development, but an embryo horse six weeks old has three toes as completely formed as those of a rhinoceros. The outer toes then begin to dwindle, and the newly-born foal supports itself on its central digit alone; but horses are occasionally born with two digits, each encased in a hoof, and at very rare intervals with three. Cæsar’s favourite horse was polydactylous, and so was Alexander’s Bucephalus. Major Waddell, in his book on the Himalayas, refers to a creamy fawn-coloured pony, which ‘had a black stripe down the spine ... broad black stripes over the shoulders, flanks, and legs, and dappled spots over the haunches.’ Many other instances might be quoted, but enough has been said to show that reversion is found in the Equidæ, as in other families of animals.

We now pass to the experiments made at Penycuik in crossing the zebra Matopo with various mares of different breeds.

1. Matopo was first mated with Mulatto, one of Lord



MATOPO.
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Arthur Cecil’s black West Highland ponies. The result was the hybrid Romulus, which on the whole, both in mental disposition and bodily form, took more after his father than his mother. His striping was even more marked than that of his sire. He had a semi-erect mane, which was shed annually. The pattern of the markings, on both body and face, resemble the stripes on a Somali zebra—which, as we have seen, is regarded by Professor Ewart as the most primitive type—more than they resembled that of any of Burchell’s zebras. The profuse striping is a point of difference between this hybrid and Lord Morton’s. The quagga-hybrid was less striped than many dun-coloured horses (see illustration).

The mother Mulatto was next mated with a highly-bred grey Arab horse, Benazrek. The offspring agreed in all respects with ordinary foals; it had, however, a certain number of indistinct stripes which could only be detected in certain lights. The stripes were not nearly so clear as in a foal bred by Mr. Darwin from a cross-bred bay mare and a thoroughbred horse, and they disappeared entirely in about five months.

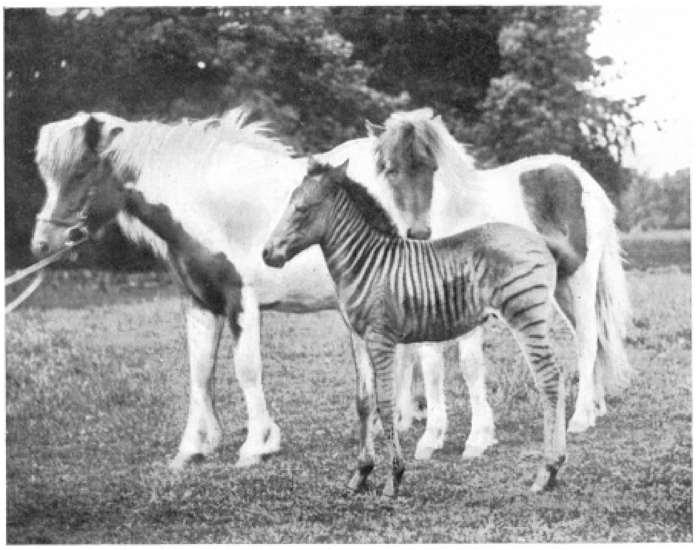
Mulatto has produced a third foal to Loch Corrie, a sire belonging to the Isle of Rum group of West Highland ponies, and closely resembling its mate. This foal was about as much striped as its immediate predecessor. In both cases the pattern of the stripe differed not only from that of Matopo, the previous sire, but from that of the hybrid Romulus. These two foals seem to lend some support to telegony; but the evidence which might be drawn from the second of them is destroyed by the fact that the sire, Loch Corrie, has produced foals from two West Highland mares, one brown and one black, and each of these foals has as many and as well-marked stripes as the foal of Mulatto.

2. Four attempts were made to cross the zebra with Shetland ponies: only one succeeded. The hybrid was a smaller edition of Romulus. The dam Nora had been bred from before, and had produced by a black Shetland pony a foal of a dun colour which was markedly striped. After the birth of the hybrid she was put to a bay Welsh pony; the resulting foal had only the faintest indication of stripes, which soon disappeared. It is a remarkable fact that Nora’s foals were more striped before she had been mated with the zebra than afterwards.

3. Five Iceland ponies were mated with Matopo, of whom one produced, in 1897, a dark-coloured hybrid. The dam, Tundra, was a yellow and white skewbald, which had previously produced a light bay foal to a stallion of its own breed. Her third foal (1898) was fathered by a bay Shetland pony, and in coloration closely resembled its dam. There was no hint of infection in this case. In 1899 Professor Ewart bred from this mare, by Matopo, a zebra-hybrid of a creamy fawn colour, and so primitive in its markings that he believes it to stand in much the same relation to horses, zebras, and asses as the blue-rock does to the various breeds of pigeons (see illustration).

4. Two Irish mares, both bays, produced hybrids by Matopo, and subsequently bore pure-bred foals. One of the latter was by a thoroughbred horse, the other by a hackney pony. The foals were without stripes, and showed no kind of indication that their mother had ever been mated with a zebra.

5. Although Professor Ewart experimented with seven English thoroughbred mares and an Arab, he only succeeded in one case. The mare produced twin hybrids, one of which, unfortunately, died immediately after birth. In the summer of 1899 the same mare produced a foal to a thoroughbred chestnut; ‘neither



TUNDRA (AN ICELAND PONY), HER FOAL, CIRCUS GIRL (BORN 1898), AND HER HYBRID-FOAL, SIR JOHN (BY MATOPO), WHEN A MONTH OLD (BORN 1899).
To face page 86.

in make, colour, nor action' does it in any way resemble a zebra or a zebra-hybrid.

6. A bay mare which had been in foal to Matopo for some months miscarried. Here—if there is anything in the direct infection theory—the unused germ-cells of the zebra had a better chance than usual of reaching the ova from which future offspring are to arise, yet neither of the two foals which this mare subsequently produced to a thoroughbred horse 'in any way suggests a zebra.'

The above is the record of the successful experiments which have been tried at Penycuik, with a view of throwing light on the existence of telegony in the Equidæ. Experiments have also been made with other animals, such as rabbits, dogs, pigeons, fowls, and ducks. Space allows us to quote but one. Six white doe rabbits, all of which had borne pure white offspring to white bucks, were crossed with wild brown rabbits. The result was forty-two young rabbits, all of a bluish-black colour, which in a very short time turned to a brown. These, at the time of writing, were about half grown, and Professor Ewart tells us that it was almost impossible to distinguish them from a full-blooded wild rabbit kept in the same enclosure. The half-breeds, however, were tamer and slightly lighter in colour. The mother does next bred with white bucks again, and in every case bred true. The pure white young showed no trace of throwing back to a previous sire.

A phenomenon somewhat similar to telegony, and one which seems at present quite unexplained, is that a hen which has been crossed with a cock of another breed often lays eggs whose shell is no longer like that of its own breed, but in colour, and frequently in texture, resembles that of the breed with which it has been crossed. Mr. Bulman has recorded a case of this in the pages of 'Natural Science.' Some Orpington fowls which laid eggs of a buff tint were allowed to run loose in a large yard with fowls of various breeds. After a few months they were confined in separate pens again, and for several weeks afterwards they continued to lay white eggs. There seems to be no doubt of the existence of this curious phenomenon; it is mentioned by Gadow in his volume on 'Birds,' in Bronn's 'Thierreich,' by Nathusius in the *Journal für Ornithologie*, and in Newton's 'Dictionary of Birds.' When one calls to mind that the shell is deposited by a special shell-gland which is in no way connected with the ovary, but is a part of the quite distinct oviduct, and that the change in the colour of the eggshell must be caused by some change brought about in this gland by cross-fertilization, we begin to recognize how mysterious and inexplicable are many of the problems which affect breeding.

Throughout his account of his experiments Professor Ewart is extremely cautious in claiming to prove anything, but we think he has justified his claim to have shown that telegony by no means always occurs, as many breeders believe. His experiments so far support the view of Continental mule-breeders that telegony, if it takes place, occurs very seldom. But the experiments are not complete, and it is much to be hoped that they may be continued. If it should subsequently appear that out of fifty pure-bred foals from dams which have been previously mated with the zebra no single instance of telegony be found, the doctrine may surely be neglected by breeders; and if in the experiments which are now being carried out with various other mammals and birds telegony does not occur, the doctrine may be relegated to what the Americans would term the 'dumping-ground' of old superstitions. The present state of the matter may be summed up in the Professor's own words: 'The experiments, as far as they have gone, afford no evidence in support of the telegony hypothesis.' Nothing has occurred which is not explicable on the theory of reversion.

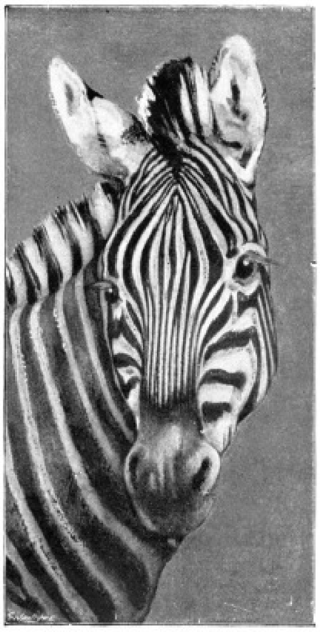
Partly owing to a certain doubt or distrust which has recently been expressed as to the existence of reversion, and no doubt partly because it is reasonable to hold that the phenomena of telegony may all be referred to reversion, Professor Ewart has made some direct experiments on this subject. Darwin, Tegetmeier, and many others have made numerous breeding experiments on pigeons, with the result that we may say that the crossing of extreme forms usually tends to reversion in the offspring. The ancestor of the domestic pigeon is known with tolerable certainty to have been the blue-rock pigeon, *Columba livia*. By crossing a male barb-fantail and a female barb-spot Darwin produced a bird 'which was hardly distinguishable from the wild Shetland species' of blue-rock. In his description of this experiment, Darwin, as Weismann points out, confines himself chiefly to the coloration: he does not inquire how far reversion also appears in the structure of the bird. This question has been answered by one of Professor Ewart's many experiments with pigeons. He crossed a white fantail cock with the offspring of an owl and an archangel. The fantail was pure white, with thirty feathers in its tail, and was so prepotent as to produce white offspring when mated with blue pouters. The owl-archangel was more of an owl than an archangel. One of the young of this complex pair had the coloration of the Shetland rock pigeon, which has a white croup and the wings in front of the bars a uniform blue; the other resembled the Indian rock pigeon in having a blue croup and the front part of the wings chequered. In this second bird there was complete reversion as to colour, and in the first, wherever measurements were possible, there was practically complete reversion also as to form. 'In its measurements it is relatively almost identical with a typical Shetland blue-rock.' The tail feathers are twelve in number, and show but the faintest indications of any colour-inheritance from their immediate parents. An additional point of interest is that in disposition this bird seems wilder and more shy than the domesticated breeds usually are. It is vigorous and hardy, and is much admired by the fanciers.

Another bird whose wild ancestor is known with a high degree of certainty is the barn-door fowl. It has sprung from the jungle fowl, *Gallus bankiva*, and less remotely from the game fowl. Hence, if fowls of different breeds are crossed, the offspring, should reversion occur, ought to resemble either the jungle fowl or their less remote ancestors, the game fowl. A dark red-breasted bantam was crossed with an Indian game Dorking; of the nine chickens which resulted, six resembled Dorkings, and three in both form and colour resembled game birds. Two of the three grew up, and the only visible trace of their parentage was a double comb inherited from their cross-bred father. Here again the reversion does not stop at the colour and form, but extends to disposition; the birds are very shy, and fly about like wild birds. The above are but two instances out of many which might be quoted from the Penycuik experiments; they are, however, unusually clear cases, and should do something to restore confidence amongst recent doubters of reversion.

An animal is said to be prepotent when it strongly impresses its own peculiarities of form, colour, temperament, etc., on its offspring. In the above-mentioned experiment with pigeons the owl had been prepotent over the archangel in the mother of the offspring which showed such marked reversion. There is no factor in breeding of more importance than prepotency, and none which it is more difficult to estimate. The term is necessarily a relative one, and, further, it may affect some characters and not others. Often it must go undetected, as in the case of the leader of a herd of wild cattle, who may be highly prepotent, but whose prepotency, unless he is mated with members of another herd displaying different characters, may pass unnoticed. Breeders claim to be able to produce cattle so prepotent that they will produce their like however mated. A well-known dealer in highly-bred ponies used to boast that he had a filly so prepotent that, though she were sent to the best Clydesdale stallion in Scotland, she would throw a colt showing no cart-horse blood. Prepotency is usually obtained by inbreeding, which up to a certain point fixes the character of a race, and in all cases tends to check variation and reversion—the Jews, for instance, as a race are strongly prepotent—but there is no doubt that it may also arise as a sport, and this is probably its more usual origin in a state of nature. Professor Ewart, however, believes that inbreeding is much commoner among wild animals than has usually been conceded, and he holds the opinion that the prepotency so induced has played a considerable part in the origin of species. This, if true, would to some extent take the place of Romanes' 'physiological selection'; for Romanes also thought that, though of great importance, variation and natural selection were insufficient to account for the origin of species without some factor which would help to mitigate the swamping effect of intercrossing—some such agency as the fences of modern farms and cattle-ranches—without which the famous cattle breeds of the world would soon disappear in a general 'regression towards mediocrity.'

In inbreeding the great difficulty of the breeder is to know when to stop. Carried too far it undoubtedly leads to degeneracy. In the 'Domesticated Animals of Great Britain,' Lowe records the case of a gentleman who inbred foxhounds to such an extent that 'the race actually became monstrous and perished.' Hogs, if too closely inbred, grow hair instead of bristles; their legs become short and unable to support the body; and not only is their fertility diminished, but the mothers cannot nourish the young. That infertility is induced by inbreeding is further shown by some experiments of Ritzema Bos with rats. From seven rats of one family and an unrelated male he continued inbreeding for a period of some six years, and bred about thirty generations. The average of the numbers in each litter fell from $7\frac{1}{2}$ in 1887 to $4\frac{7}{12}$ in 1891 and $3\frac{1}{5}$ in 1892. Further, the offspring of inbred parents are usually weak. Sir Everett Millais estimated that 60 to 70 per cent. of inbred dogs attacked by distemper were carried off.

On the other hand, inbreeding often succeeds even when carried to what the ordinary man would consider excess. The 'Herd-book' contains the following case in point. The bull Bolingbroke and the cow Phœnix were more closely related to one another than half-brother is to half-sister. They were mated, and produced the bull Favourite. Favourite was then coupled with his dam, and produced the cow Young Phœnix; he was then coupled with his daughter Young Phœnix, and the world-famed Comet was the result. Professor Ewart tells us that if there was little crossing in the production of Comet, there was still less in that of Clarissa, the mother of the celebrated Restless. An instance of the faith in close inbreeding which exists in the minds of breeders occurred in a letter which the *Field* published in 1898, in which the writer stated he had heard 'Mr. Joseph Osborne, the ablest authority living on English



ROMULUS. **MATOPO.**
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thoroughbreds, declare that you cannot now get too much of Birdcatcher.'

So far as is known, no direct investigations have been made to test how far inbreeding may be carried in the Equidæ; but, on the other hand, the breeding of racehorses may perhaps be looked upon as a gigantic experiment in this direction. Our English thoroughbreds can be traced back to a few imported sires—the Byerly Turk, imported in 1689; the Darley Arabian, in 1710; and the Godolphin Arabian, in 1730. Since then, by careful breeding and nutrition, they have increased on an average some 8 or 9 inches in height. There is, however, a widely-spread impression that at present there is a marked deterioration in the staying power and in the general 'fitness' of the racer. The falling off is further shown by a fact commented on by Sir Walter Gilbey—viz., 'the smallness of the percentage of even tolerably successful horses out of a prodigious number bred at an enormous outlay.' In support of this he quotes a sentence from the *Times* (December 27, 1897), referring to a sale in which thirty-two yearlings had been sold for 51,250 guineas.

> 'These thirty-two yearlings' (said the *Times*) 'are represented by two winners of five races, Florio Rubattino and La Reine, who have contributed about £2,000 to the total cost; and there is not, so far as can be known, a single one of the thirty others with any prospect of making a racehorse.'

If, then, it is true that the English racehorse is on the down grade, what steps should be taken to arrest this descent? Sir Everett Millais restored a pack of basset hounds by crossing them with a bloodhound, the original forefather of bassets. The resulting pups were bassets in form, but not quite bassets in colour; when, however, these cross-breeds were mated with bassets the majority of the pups turned out to be perfect bassets both in shape and coloration. This indicates that one way to rejuvenate the racehorse would be to have recourse to a new importation of the best Arab mares that the plains of Arabia can produce. Breeders hesitate to adopt this course, because their present breed is not only larger, but, over very short distances, fleeter than its forefathers. The shortening of the course in recent years is probably a further sign of the degeneracy of our present racers. Were new blood introduced, and more three-or four-mile races instituted, we should doubtless soon have a return to the champion form of bygone days. Another method would be to import some of the racers of Australia or New Zealand, and cross them with the home product. Different surroundings, food, etc., soon influence the constitution, and this being so, it would be advisable to select those horses of pure descent which have been longest subjected to these altered conditions. Thus the chance of reversion occurring would be increased.

It has been noticed more than once in the preceding pages that a young animal showing reversion is strong and vigorous. It is the belief of dog-breeders that those members of an inbred litter which show reversion are the strongest and best. Similarly, experience shows that if an inbred sire and dam produce a dun-coloured striped foal it almost always turns out well. Reversion is accompanied by a rejuvenescence; it is as though the young animal had appeared at an earlier period in the life-history of the race, before the race had undergone those changes in the way of deterioration which so often accompany inbreeding.

Wild animals are frequently thought to be prepotent over tame ones, but of the eleven zebra-hybrids bred at Penycuik only two took markedly after their sire, the zebra Matopo.[2] There are other experiments recounted which tell the other way, and at present this matter remains in a state of considerable uncertainty. Further experiment may probably show that though in most cases the oldest type is likely to prevail, the offspring may take after the most inbred of its parents. The matter is not altogether as simple as the above statements would imply. For instance, a sport is often strongly prepotent. Standfuss's experiments in hybridizing butterflies tend to show this, and Mr. Galton even looks upon prepotency as a sport or an aberrant variation. These butterfly experiments also indicate that the male is usually prepotent over the female; but so many questions of nutrition, the maturity of the germ-cells, etc., enter into these intricate problems that it is exceedingly difficult to disentangle the several factors which play a part in the constitution of every living being.

Some years ago it used to be taught that species are infertile *inter se*; nowadays it almost seems that we are giving up the idea of species altogether. No two naturalists take precisely the same view of what constitutes a species, and no one has succeeded in defining shortly and clearly what a species is. The intersterility test has broken down; the common goose and the Chinese goose, the common duck and the pintail duck, various species of pheasant, the ox of Europe and the American bison or the Indian zebu, not only breed together, but yield hybrids which are themselves fertile; and the same is true of many plants. Why the hybrids of Equidæ should prove sterile is not clear.

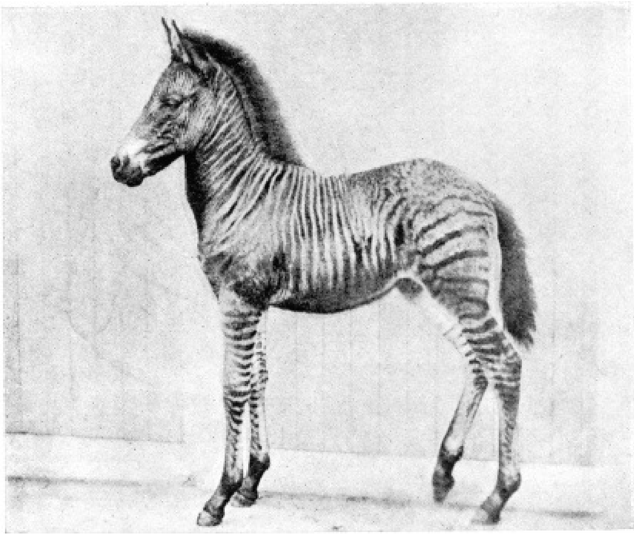
This article must not close without a word or two more about the zebra-hybrids. It is mentioned above that only two out of the eleven which have already been born took strongly after their father. This is no proof that the wilder animal is not prepotent. Recent experiments in hybridizing echinoderms, star-fish, seaurchins, etc., show that the hybrid tends to resemble that species whose germ-cells are most nearly approaching maturity; and thus the nutrition of the germ-cell is but another thread in that complex tangle of heredity which must not be overlooked in attempting to estimate the part played by prepotency and reversion.

Those who have seen the young hybrids playing about in the fields at Penycuik must agree that they are the most charming and compactly built little animals possible; '*marvellous steeds, striped as a melon is, all black and white*,' as the poet has it. Of Romulus, the eldest of the herd, Professor Ewart says:

> 'When a few days old [he] was the most attractive little creature I have ever seen. He seemed to combine all the grace and beauty of an antelope and a well-bred Arab foal.... What has struck me from the first has been his alertness and the expedition with which he escapes from suspicious or unfamiliar objects. When quite young, if caught napping in the paddock, the facility with which he, as it were, rolled on to his feet and darted off was wonderful.'

The writer can fully confirm all the praise Professor Ewart lavishes on his pets; in truth Romulus has been well described as a 'bonnie colt with rare quality of bone ... and with the dainty step and dignity of the zebra.' Remus, the offspring of the Irish mare, was from the first more friendly than his half-brother; he objected less to the process of weaning, and promised to be the handsomest and fleetest of the existing hybrids.

On the whole the hybrids are unusually hardy; at the time of writing only two have been lost—one, a twin, which died almost as soon as it was born, and



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another which lived some three months and then succumbed. It is only fair to say that the dam of the latter, who was only three years old when the hybrid was born, had been much weakened by attacks of the strongylus worm, and that she was the victim of close inbreeding. Both the zebras and the hybrids which have been under observation at Penycuik show a remarkable capacity for recovering from wounds. Accidental injuries heal with great rapidity. On one occasion the surviving twin was discovered with a flap of skin some five inches long hanging down over the front of the left fetlock. The skin was stitched into its place again, during which operation the little hybrid fought desperately, and cried piteously; but it soon recovered, the wound healed, and now scarcely a scar remains. There was no lameness and no swelling either at the fetlock or above the knee. Some time ago four hybrid colts and three ordinary foals were attacked by that scourge of the stable, the strongylus worm. One of the latter died and another was reduced almost to a skeleton: the hybrids, though obviously affected, suffered much less than the others, and soon recovered. It is further noticeable that the hybrids suffer less from colds and other slight ailments than the mares and horses amongst which they live. Thus it seems that Colonel Lugard's hope has to some extent proved true. Some years ago, when administering British East Africa, he strongly recommended the breeding of zebra mules from both the horse and the donkey, believing that they would prove exceptionally hardy and possibly impervious to the tsetse fly. So far as Professor's Ewart's experiments go, the first part of the forecast has proved correct. Unfortunately, the latter half has not been justified.

The much dreaded tsetse fly, which has interfered so seriously with the colonization of whole tracts of South Africa, is now known not to be the direct cause of the disease which follows its puncture, but to be the means by which the organism which causes the disease is introduced into the body. In this respect the tsetse fly resembles the malarial mosquito. It is not thought that the organism—a hæmatozoon—passes through any of the stages of its life-history within the body of the fly, but that the proboscis of that insect merely acts like an inoculating needle. An answer to the important question, Are zebra-hybrids fly-proof or not? has been attempted. Professor Ewart generously allowed an experiment to be tried on two of his hybrids, which were inoculated with the hæmatozoon, supplied from the Pathological Laboratory at Cambridge. The result was unfortunate, for, although the hybrids resisted the disease far longer than a mare which was also inoculated as a control experiment, both ultimately succumbed.

There is no doubt that it is a comparatively easy matter to breed these hybrids, and that they are not only extremely attractive animals to the eye, but hardy and vigorous, possessed of great staying powers, and promising to be capable of severe work. It is recognized that one of the gravest difficulties which the Indian Army Corps has to contend with is the paucity of mules, both for transport and mountain-battery work; and at the time of the South African War a Commission was busily employed purchasing mules both in Italy and in Texas, and elsewhere. Should these hybrids turn out as well as they at present promise, they may fill a want which is acutely felt by those responsible for the conduct of our frequent 'small wars,' and, if bred largely in East Africa, may, as Colonel Lugard suggested, prove a source of wealth and revenue in the future.

We have hitherto said little or nothing about the book itself with which we have been dealing. The larger part consists of three articles reprinted from the *Veterinarian* and one from the *Zoologist*; but the more recent and more important half is the General Introduction, covering a hundred pages, in which Professor Ewart sums up the results of his experiments. The form of the work necessarily involves a good deal of repetition, but in so complex a subject this is on the whole rather an advantage than otherwise. Professor Ewart's style is clear, and his pages abound in apposite illustrations. The book cannot fail to attract both the man of science and the practical breeder.

From what we have said it is evident that the Penycuik experiments are of the highest interest both practical and theoretical, and the public spirit and self-devotion shown by the Edinburgh professor in carrying them out cannot be too widely recognized. The expense of feeding and housing some thirty to forty horses, asses, and zebras is very great, and the initial expenditure in erecting stables, buying land and fencing it, is also considerable. It is, perhaps, not too much to hope that some public body may be willing to undertake at least a part of the burden. The Zoological Society of London possesses, not only the necessary establishment required, including a well-trained staff, but it also has facilities for obtaining all kinds of animals which are far greater than those of any private individual. We hope that the day is not far distant when experiments of this kind will be systematically carried on under the direction of the authorities who control the Gardens in Regent's Park. Probably such experiments would have better prospects of success at a farm in the country than in London, and there is much to be said for such an experimental farm under the management of a body like the Zoological Society. Apart from the more strictly scientific use to which it might be put, it would serve as a convenient sanatorium for those animals which cannot stand the fogs and damp of London.

PASTEUR

Je suis chimiste, je fais des expériences et je tâche de comprendre ce qu'elles disent.—Pasteur.

As one walks down the Rue des Tanneurs, in the small provincial town of Dôle, where the main line from Paris to Pontarlier sends off a branch north-east towards Besançon, a small tablet set in the *façade* of a humble dwelling catches the eye. It bears the following inscription in gilt letters: 'Ici est né Louis Pasteur le 27 décembre 1822.'

Pasteur came of the people. In the heraldic meaning of the term, he was emphatically not 'born.' His forbears were shepherds, peasants, tillers of the earth, millers, and latterly, tanners. But he came from amongst the best peasantry in Europe, that peasantry which is still the backbone of the great French nation. The admirable care with which records are preserved in France has enabled Pasteur's son-in-law and latest biographer to trace the family name in the parish archives back to the beginning of the seventeenth century, at which period numerous Pasteurs were living in the villages round about the Priory of Mouthe, 'en pleine Franche-Comté.'

The first to emerge clearly from the confused cluster of possible ancestors is a certain Denis Pasteur, who became miller to the Comte d'Udressier, after whom he doubtless named his son Claude, born in 1683. Claude in his turn became a miller, and died in the year 1746. Of his eight children, the youngest, Claude-Étienne, was the great-grandfather of Louis Pasteur. The inhabitants of Franche-Comté were, in large part, serfs—'gens de mainmorte,' as they termed them then. Claude-Étienne, being a serf, at the age of thirty wished to enfranchise himself; and this he did in 1763, by the special grace of 'Messire Philippe-Marie-Francois, Comte d'Udressier, Seigneur d'Ecleux, Cramans, Lemuy, et autres lieux,' and on the payment of four *louis-d'or*. He subsequently married and had children. His third son, Jean-Henri, who for a time carried on his father's trade of tanner at Besançon, seems to have disappeared at the age of twenty-seven, leaving a small boy, Jean-Joseph Pasteur, born in 1791, who was brought up by his grandmother and his father's sister.

Caught in the close meshes of Napoleon's conscription, Jean-Joseph served in the Spanish campaign of 1812-1813 as a private in the third regiment of infantry, called 'le brave parmi les braves.' In course of time he was promoted to be sergeant-major, and in March, 1814, received the Cross of the Legion of Honour. Two months later the abdication had taken place; and the regiment was at Douai, re-organizing under the name of 'Régiment Dauphin.' Here was no place for Jean-Joseph, devoted to the Imperial Eagle and unmoved by the Fleur-de-lys. He received his discharge, and made his way across country to his father's town, Besançon. At Besançon he took up his father's trade and became a tanner; and, after one feverish flush during the Hundred Days, and one contest, in which he came off victor, with the Royalist authorities, who would take his sword to arm the town police, he settled down into a quiet, law-abiding citizen, more occupied with domestic anxieties than with the fate of empires.

Hard by the tannery ran a stream, called La Furieuse, though it rarely justified its name. Across the stream dwelt a gardener named Roqui; amongst the gardener's daughters one Jeanne-Étiennette attracted the attention of, and was attracted by, this old campaigner of twenty-five years. The curious persistence of a family in one place, combined with the careful preservation of parish records, enables M. Vallery-Radot to trace the family Roqui back to the year 1555. We must content ourselves with Jeanne-Étiennette, who in 1815 married Jean-Joseph. Shortly afterwards the young couple moved to Dôle and set up house in the Rue des Tanneurs.

Louis Pasteur's father was a somewhat slow, reflective man; a little melancholic, not communicative; a man who lived an inner life, nourished doubtless on the memories of the part he had played on a larger stage than a tannery affords. His mother, on the other hand, was active in business matters, hard-working, a woman of imagination, prompt in enthusiasm.

Before Louis Pasteur was two years old, his parents moved first to Marnoz and then to a tannery situated at the entrance to the village of Arbois; and it was Arbois that Pasteur regarded as his home, returning in later life year after year for the scanty absence from his laboratory that he annually allowed himself. Trained at the village school, he repeated with his father every evening the task of the day. He showed considerable talent, and his eagerness to learn was fostered by the interest taken in him by M. Romanet, principal of the College of Arbois. At sixteen he had exhausted the educational resources of the village; and, after much heart-searching and anxious deliberation, it was decided to send the young student to Paris to continue his studies at the Lycée Saint-Louis. It was a disastrous experiment. Removed so far from all he knew and loved, Louis suffered from an incurable home-sickness, which affected his health. His father hearing this, came unannounced to Paris, and with the simple words, 'Je viens te chercher,' took him home. Here for a time he amused himself by sketching the portraits of neighbours and relatives, but his desire to learn was unquenched, and within a short time he entered as a student at the Royal College of Franche-Comté at Besançon. This picturesque town, situated only thirty miles from Arbois, was within easy reach of his home; and, above all, on market days his father came thither to sell his leather.

At eighteen Pasteur received the degree of Bachelier ès Lettres, and almost immediately was occupied in teaching others; but Paris, although once abandoned, was again asserting its powers of attraction, and by the autumn of 1842 he was once more following the courses at the Lycée Saint-Louis. He also attended the brilliant lectures of Dumas at the Sorbonne, and vividly describes the scene: 'An audience of seven or eight hundred listeners, the too frequent applause, everything just like a theatre.' At the end of his first year in Paris he achieved his great ambition, and succeeded in entering the École Normale, and entering it with credit.

For the last year or two Pasteur had been studying mathematics and physics; at the École Normale he especially devoted himself to chemistry. Under the teaching of Dumas and of Balard his enthusiasm redoubled, and he passed his final examinations with distinction. Balard was indeed a true friend. Shortly after the end of his career at the École Normale, the Minister of Public Instruction nominated Pasteur to a small post as teacher of physics at the Lycée of Tournon. But banishment from Paris meant banishment from a laboratory. Balard intervened, interviewed the Minister, and ended by attaching Pasteur to his staff of assistants.

It must always be remembered that Pasteur was trained as a chemist—*was*, in fact, a chemist. In afterlife he attacked problems proper to the biologist, the physiologist, the physician, the manufacturer; but he brought to bear on these problems, not the intellect of one trained in the traditions of natural science, medicine, or commerce, but the untrammelled intelligence of a richly-endowed mind, 'organized common sense' of the highest order. After the legal, there is, perhaps, no learned profession so dominated by tradition, by what our fathers have taught us, as the medical; and the advances in preventive medicine which will ever be connected with Pasteur's name owe at least something to the fact that he was unfettered by any traditions of professional training or etiquette. Passing from the diseases of the lowest of the fungi to those of a caterpillar, a fowl, a sheep, until he reached those of man himself, it must be acknowledged that he approached the art of healing along an entirely new path.

His first researches were purely chemical—'On the Capacity for Saturation of Arsenious Acid,' 'Studies on the Arsenates of Potassium, Soda, and Ammonia'—but he had been early attracted to the remarkable observations of Mitscherlich and others on the optical properties of the crystals of tartaric acid and its salts. Ordinary tartaric acid crystals, when dissolved in water, turn the plane of polarized light to the right; but another kind of tartaric acid, called by Gay-Lussac racemic acid, and by Berzelius paratartaric acid—as M. Vallery-Radot remarks, the name does not matter, and each is equally terrifying to the lay mind—leaves it unaffected. In spite of the different actions of the solutions of these two acids on light, Mitscherlich held their chemical composition to be absolutely identical.

This set Pasteur thinking. He repeated the experiments. On examining the crystals of sodium-ammonium salt of racemic acid, he noticed that certain facets giving a degree of asymmetry were always found on the crystals of the optically active salts and acids. On examining the crystals of the racemic acid, he did not find, as he had expected, perfect symmetry; but he saw that, whilst some of the crystals showed these facets to the right, others showed them to the left. In fact, sodium-ammonium racemate consisted of a mixture of right-handed and left-handed crystals, which neutralized one another as regards the polarization of light, and were thus optically inactive. With infinite patience Pasteur picked out the right from the left handed crystals, and investigated the action of their solutions on polarized light. As he expected, the one sort turned the plane of polarization to the left, the other to the right. A mixture of equal weights of the two kinds of crystals remained optically inactive. 'Tout est trouvé!' he exclaimed; and rushing from the laboratory, embraced the first man he came across. 'C'était un peu comme Archimède,' as his biographer gravely remarks.

His work immediately attracted attention. Biot, who had devoted a long and strenuous life to the problems of polarization, was at first sceptical, but, after a careful investigation, was convinced. Pasteur began to be talked about in the circle of the Institute.

In the midst of these researches Pasteur's mother died suddenly, and her son, overwhelmed with grief, remained for weeks almost silent and unable to work. Shortly after this we find the old longing revived, and Pasteur sought at any cost some post near Arbois, somewhere not quite out of the reach of those he loved. Besançon was refused him, but at the beginning of 1849 he replaced M. Persoz as Professor of Chemistry at

Strasbourg.

The newly-appointed Rector of the Academy of Strasbourg, M. Laurent, had already gained the respect and the affection of the professoriate. He and his family were the centre of the intellectual life of the town. Within a few weeks of his arrival Pasteur addressed to the Rector a letter, setting forth in simple detail his worldly position, and asking the hand of his daughter Marie in marriage. The wedding took place on May 29, 1850, and there is a tradition that Pasteur, immersed in some chemical experiment, had to be fetched from the laboratory to take his part in the ceremony at the church. Never was a union more happy. From the first Madame Pasteur, animated by the spirit of the Academy of Science, which always prints 'Science' with a capital letter, not only admitted, but approved the principle that nothing should interfere with the laboratory; whilst, on his side, Pasteur always flew to his wife to confide in her first of all any new discovery, any new advance he had made in his researches. During the five years passed at Strasbourg Pasteur continued to work on the borderline between chemistry and physics. His work on the polarization of light of the tartaric acid crystals led him into the question of the arrangement of the atoms within the molecule. 'Il éclaire tout ce qu'il touche!' exclaimed the once sceptical but now convinced Biot; and it is hardly too much to say that his researches were the starting-point of the new department of physics which, under the name of stereo-chemistry, has attained vast developments during the last quarter of the past century. These researches were rewarded by the French Government, which in 1853 conferred on him the ribbon of the Legion of Honour, and received the recognition of our own Royal Society, which rewarded him in 1856 the Rumford medal.

It was whilst working at his beloved tartrates that he made an observation which first directed his attention towards the problems of fermentation. A German firm of manufacturing chemists, of whom there were many in the neighbourhood of Strasbourg, noticed that impure commercial tartrates of lime, when in contact with organic matter, fermented if the weather were warm. Pasteur tested this, and found that, when racemic acid is fermented under ordinary conditions, it is only the right-handed variety that is affected; and he suggests that this is probably the best way in which to prepare the left-handed acid.

Before dealing with Pasteur's work on fermentation it is well to recall how the matter stood when he began to study it. From the earliest period fermentation had attracted the attention of mankind, but the first record of an attempted explanation is that of Basilius Valentinus, a Benedictine monk and alchemist, who lived at Erfurt during the latter half of the fifteenth century. He was, perhaps, more of a pharmacologist than a chemist, but we owe to him the introduction of hydrochloric acid, which he made from oil of vitriol and salt. In his view alcohol existed in the wort before fermentation began, and fermentation was a process of purification of this alcohol, in which the yeast played the part of the impurities. About a century later van Helmont, a well-to-do physician of Vilvorde, near Brussels, a kind of regenerate Paracelsus, noted that when fermentation occurs 'gas' is set free. It was van Helmont, indeed, who invented the word 'gas.' Of the half-dozen words invented by man—not derived, but created—'gas' is the one which has most surely come to stay. Curiously enough, van Helmont's predecessor, Paracelsus, also invented two words which have, without the permanency of 'gas,' passed into current, though somewhat infrequent, use. They are 'gnome' and 'sylph,' the latter, perhaps, best known as recalling the outline of Miss Henrietta Petowker in her palmier days. By his new term 'gas' van Helmont did not mean an air or vapour, still less did he mean an illuminant. He understood by this term carbon dioxide, and he points out that when sugary solutions ferment, this gas is given off.

About 1700 Stahl, returning to a view put forward by Willis in 1659, propounded the first physical view of fermentation. The ferment was to their minds a body with a certain internal motion which it transmitted to the fermentable matter. Stahl extended this view to the processes of putrefaction and decay. One hundred years later Gay-Lussac taught that the fermentation was set up by the presence of oxygen. The yeast-cells had been seen and described by Leeuwenhoek as far back as 1675, but they seem to have attracted little attention; and it was not until Schwann published his researches, the earliest of which is dated 1837, and until Cagniard de Latour, about the same date, put forward his vitalistic theory—the theory which attributes fermentation to the action of living organisms—that they were recognized as playing an important part in fermentations. Even then they were not allowed to hold the field. Liebig brought the weight of his great authority to oppose the vitalistic theory. In his view the ferment was an unstable organic compound easily decomposed, which in decomposing shook apart the molecules of the fermenting material. This theory and that of Berzelius, who regarded fermentation as a contact action due to some 'catalytic' force, divided between them the allegiance of the chemical world, when, in the year 1854, Pasteur was nominated Professor and Dean of the new Faculty of Science at Lille.

Here, in the centre of the beetroot industry, Pasteur had ample opportunity to study the preparation of alcohol. The father of one of his students owned a distillery, and suffered occasional loss from the fermentations turning sour owing to the formation of lactic acid. He was willing to place material at the disposal of the Professor; and Pasteur made endless experiments, microscopic researches, notes, and at length had the satisfaction of isolating the organism which produces the lactic acid fermentation, and of proving that that, and that alone, was capable of setting up this particular form of fermentation. Whilst in the middle of his investigations on milk and the cause of its turning sour, Pasteur was summoned to return to Paris, and installed as scientific Director at his old college, the École Normale.

This was in 1857. The second Empire was at its zenith, and the Government had little money to spend on science. Pasteur had to install his laboratory in a garret, without even a boy to aid him. In this garret he completed his work on alcohol fermentation, proved it to be 'un acte corrélatif d'un phénomène vital, d'une organisation de globules.' During this work he noted a fact hitherto overlooked. It was that the alcoholic fermentation is accompanied by the formation of small quantities of glycerine and of succinic acid, which had up till that date escaped the notice of chemists.

During the seven years which followed, Pasteur was ceaselessly engaged in investigations on fermentation and on all those processes for which micro-organisms are responsible. Whilst researching on the cause of butyric acid formation, he discovered the remarkable fact that the *Bacillus butyricus*, which causes the unpleasant flavour in rancid butter, will not grow in the presence of free oxygen. Until this discovery it had been accepted as an axiom that all living beings, plants as well as animals, require free oxygen for the manifestation of their energies. Here, however, was a bacillus which not only did without oxygen but was injured by its presence. This observation, it is needless to remark, excited much adverse criticism in the scientific world; but, as usual, Pasteur was in the right. From the conditions under which they grow he suggested the name ‘anaerobic’ for such bacteria as *B. butyricus*; and later observers have shown that many pathogenic micro-organisms are anaerobic. At the present day bacilli are usually divided into two groups, those which grow in the presence of free oxygen (aerobic), and those which will not grow in the presence of oxygen (anaerobic).

Naturally the question of spontaneous generation occupied much of Pasteur’s time. The view, that in certain circumstances living matter originates from non-living, lasted from the classical times until towards the end of the last century. The size of the animal so produced varied, however, inversely with the growth of our era. Van Helmont in the seventeenth century had a recipe for producing mice. Place a piece of linen somewhat soiled in a vessel, add some grains of corn, flavour with a piece of cheese, and in twenty-one days the mice will be there, fully adult and of both sexes.

About the time that van Helmont died there was coming to the front in Florence a young Italian poet, born at Arezzo—in whose cathedral he now lies buried—who had a singular turn for investigating the secret workings of organic nature. Francesco Redi—his name is immortalized in the little larva Redia—was courtier, poet, doctor, above all zoologist; and he belonged to that comparatively small section of teetotallers who have enthusiastically sung the merits of wine.[3] By a series of accurate experiments, such as nowadays are performed by every cook, Redi proved conclusively that meat did not spontaneously produce flies. Shortly afterwards Vallisnieri of Padua demonstrated that fruit did not of itself give rise to grubs. In fact, unless an insect deposited its egg in the fruit, there were no grubs.

The use of the microscope, however, lent a fresh vigour to the believers in spontaneous generation; and, forced to relinquish the mouse and the insect, they still found satisfaction in germs. In the middle of the eighteenth century the doctrine was firmly upheld by an English priest, one Needham, whose experiments, in spite of the keen, and as we now know, unanswerable criticisms of the Abbé Spallanzani, were so convincing that he was early elected a Fellow of the Royal Society. From his time till late in the last century, the question of the spontaneous origin of microscopic life has from time to time troubled the mind of man. Pasteur, Tyndall, and others have at length laid that ghost. It would take too much space to discuss all the experiments made to solve this question. Pasteur’s work did not escape the liveliest criticism; and eventually, in order to settle the matter, he appealed to the Academy of Sciences to appoint a Commission to report on the experiments of himself and his opponents. It is needless to say that when the Committee met and inspected the experiments of Pasteur, and listened to the excuses of his critics, they pronounced absolutely in favour of Pasteur.

In 1862 Pasteur succeeded Senarmont as a member of the Academy of Sciences; and, it is interesting to note, he was presented by the mineralogical section. During this year he had interested himself in the manufacture of vinegar, which is extensively carried on in and around Orleans. He investigated the action of the *Mycoderma aceti*, the mould whose activity converts alcohol into acetic acid; and he taught the manufacturers the importance of pure cultures, showing them how, by a careful manipulation of the temperature, and by artificially sowing the fungus which effects the chemical change, the product they sought could be produced in a week or ten days, instead of requiring two or three months. This problem naturally led on to the acetous fermentation of wine, the cause of great loss to French wine exporters. Pasteur was able to demonstrate that the sourness of wine is caused by various foreign organisms, each of which causes a peculiar flavour to appear in the wine it attacks. The bouquet of wine is notoriously a delicate object, easily disturbed; and the question arose how to check the growth of the organisms without interfering with the bouquet. Pasteur solved it as he solved similar problems with regard to milk. He was able to show that after wine is properly oxygenated, if it be heated to a temperature of some 55° to 60° C. the acid-forming micro-organisms are destroyed, whilst the bouquet is unaffected. Perhaps one of Pasteur’s greatest triumphs was his success in demonstrating this to a representative assemblage of wine-tasters, notoriously a very opinionative class of people.

Pasteur’s researches on micro-organisms further had a profound influence on operative surgery. To the presence of bacteria is due many of the dangers which used to follow on operations. If precautions are taken to exclude the harmful germs much suffering and danger are avoided. It was about this date—namely, in the spring of 1865—that Dr. (now Lord) Lister, who nobly acknowledged the debt he owed to Pasteur, performed his first operations under antiseptic treatment at the Glasgow Infirmary. This date marks an epoch in the history of human suffering.

The chemist Dumas was about this time a member of the French Senate, and in 1865 was charged with the duty of reporting on the petition of some 3,500 ‘propriétaires des Départements séricicoles’ on an epidemic which had for some years been destroying the silkworms of Southern France. Dumas was a native of Alais, a town of the Département Gard, situated in the centre of the silkworm industry, where also the distinguished zoologist Quatrefages was born. Anything that affected Alais affected Dumas; and the epidemic was destroying the prosperity of his native town. The disease was indeed becoming serious. Already in 1849 the silkworms were sickening. The stage at which the symptoms appeared varied—sometimes the eggs were sterile; at other times the silkworms hatched out but to die. If they survived they became shiny; black spots showed themselves; the worms moved with difficulty, refused to eat, and perished; or, if they lived long enough to pupate, the pupa either perished or the moth emerged in an enfeebled state and promptly died.

Efforts had been made to improve the stock by importing eggs from Spain and Portugal, but the Peninsula was soon affected. Eggs were then fetched from Turkey, Greece, and the adjacent islands. These countries too becoming infected, the French cultivators sent further afield and brought eggs from Syria and the Caucasus. Even this resource failed them, and in 1864 every silk-producing country in the world was infected, with the solitary exception of Japan. The loss to commerce was prodigious. In a normal year the value of the cocoons produced in Southern France is, roughly speaking, about £4,000,000; in the years 1863 and 1864 it had fallen below £1,000,000.

When Dumas first asked Pasteur to investigate the disease which was ruining large tracts of the South of

France, the latter not unnaturally hesitated. ‘Considérez, je vous prie, que je n’ai jamais touché un ver à soie. Si j’avais une partie de vos connaissances sur le sujet, je n’hésiterais pas,’ he wrote to his friend; but in spite of his hesitation, he left for Alais, and at once commenced a campaign which lasted during the summers of the next five years. Almost immediately on his arrival he detected in the sick silkworms the corpuscles of Cornalia and Filippi, which we now call the *Micrococcus ovatus*. These micrococci are comparatively large and very bright; they occur in the tissues and blood of the silkworm, and are found even in the eggs of the moth. They cause the disease known as Pébrine. The occurrence of the micrococci in the eggs was one of the most important new facts observed by Pasteur. It was the first recorded instance of a parasitic organism being conveyed from one generation to another by the egg; and, although recently the germ of the Texas fever (allied to the malarial organism) has been shown to pass from one brood to another through the egg of the tick which conveys it, it is satisfactory to record that the cases in which this occurs are restricted in number and comparatively rare. The ease with which *Micrococcus ovatus* could be detected suggested a remedy. A child, when trained, can readily identify the organism. Healthy moths produce sound eggs and healthy larvæ; diseased moths produce diseased progeny. At the present day, throughout the silkworm districts of the South of France, as soon as the moth has deposited her eggs on the piece of linen provided for that purpose, she is pinned up with the cloth; and during the ensuing autumn and winter the women and children are occupied in microscopically examining the body of the moth, crushed in a little water, for traces of the micrococcus. Should any be found, the eggs on the corresponding piece of linen are at once destroyed. Pasteur also showed that the infected stock spread the disease by distributing the micrococci on the mulberry-leaves, whence they enter the silkworm by the mouth; and that the sick inoculate the healthy by crawling over them and piercing the skin with their pointed claws. He therefore emphasized the importance of segregating the sound caterpillars.

The above account conveys no impression of the difficulties under which Pasteur worked. His researches were not only new to himself but to the world. Processes which at the present day are carried out by every medical student had to be devised for the first time. He had to combat the criticism of scientific men, and to overcome the almost invincible ignorance of the agriculturist, an ignorance which at one time advocated the desperate remedy of asperging with absinthe the leaves of the mulberry on which the silkworms fed.

Perhaps Pasteur’s greatest difficulty was the fact that the silkworms did not suffer from Pébrine alone; and it was some time before he recognized that he had to deal, not with one disease, but with two. The second disease, known as the ‘Flacherie,’ is a disease of the digestive system caused by overcrowding and insanitary conditions in the silkworm nurseries. Like Pébrine, it is caused by a micrococcus, *Micrococcus bombycis*. It was whilst investigating this creature that Pasteur discovered that, although the germ itself cannot survive a lengthy period of desiccation, it does in certain circumstances form spores which can survive conditions fatal to the mature organism. This is the first case recorded of a pathogenic organism producing spores, the existence of which has explained so many problems in the spread of disease.

During the period from 1865 to 1870 Pasteur was by no means occupied solely by the silkworm epidemic. In many respects it was a sad epoch in his life. Only nine days after his first arrival at Alais he was summoned to Arbois to see his dying father, but arrived too late. In the autumn of the same year he lost his little daughter Camille, the second who had died. In 1868 he himself was prostrated by a stroke of paralysis, and, although he slowly recovered, it left traces for the remainder of his life.

Few distinguished men of science are left to pursue their investigations undisturbed; and Pasteur was no exception. He had much to do with promoting the publication of the works of Lavoisier, for whose researches he had the profoundest respect. He actively intervened in the elections of the Academy of Science, which appears to consume an infinity of time. He made some preliminary investigations into cholera, an outbreak of which towards the end of the year 1865 carried off 200 victims a day in Paris. He spent a week at Compiègne as the guest of Louis Napoleon, and in a series of *séances* explained the methods and results of his labours. He wrote on the work of Claude Bernard; he drew up schemes for certain reforms in the University; he gave advice on the higher education of the country, and tried to stem the troubles of the École Normale. In fact, he drew lavishly upon his reserve of health and energy until the breakdown of 1868 was inevitable.

After a tedious recovery he recommenced his work. The success of his methods had been acknowledged by the Austrian Government, who conferred on him in 1868 the prize of 5,000 florins offered to anyone who should succeed in discovering the best means of dealing with Pébrine. The same year the University of Bonn conferred on him the honorary degree of Doctor of Medicine; and in 1869 he was elected a foreign member of the Royal Society. As was to be expected, detractors were not wanting: but these were silenced by the campaign undertaken in 1869 by Pasteur on foreign soil. The Master of the Imperial Household, Marshal Vaillant, who devoted his declining years to scientific experiments, had repeated in his apartments in the Tuileries the observations of Pasteur on the silkworm disease, and had verified the accuracy of his conclusions. He suggested to the Emperor that the Villa Vicentina, a property belonging to the Prince Imperial, should be placed at Pasteur’s disposal for further research. This villa, situated a few miles from Trieste, belonged at one time to the Princess Élise, one of the sisters of Napoleon I., who had lived quietly there after the fall of the First Empire. On her death it passed to her daughter, the Princess Baciocchi, and she in turn bequeathed it to the Prince Imperial. It had been a great centre of the silkworm industry; but for some years no cocoons had been produced, owing to the ravages of the disease.

By short stages, owing to his precarious health, Pasteur made his way to Illyria, taking with him some sound silk-moth eggs, and during the winter not only confirmed his previous researches, but re-established the industry on such a scale that in the following spring the sale of cocoons from this estate alone reached the figure of 26,940 francs. During this winter he dictated to his wife the classic book in which he recorded the results of his last five years’ work. Pasteur returned to Paris through Munich, where he had the pleasure of meeting Liebig, one of the most determined of his adversaries. Although he was unable to induce the German savant to discuss scientific affairs, he always dwelt with pleasure on the courtesy and cordiality with which he was received.

On his return the Emperor nominated him a Senator for life; but, before the gazette appeared in which the nomination would have been recorded, war was declared. From his birth Pasteur had been an ardent patriot, and during the progress of the war he suffered acutely. So much did he feel the reverses of his country, and what he regarded as the undue harshness of the victors, that he felt constrained to return the diploma of Doctor of Medicine which two years before he had accepted from the University of Bonn. He did so in a letter which contained some expressions of feeling with regard to the head of the invading army. These had better have been omitted, but were perhaps pardonable under the circumstances; they in no way excuse the terms of reply which Dr. Naumann, Dean of the Faculty of Medicine at Bonn, permitted himself to use—terms which would be discreditable in an ill-bred street *gamin*.

From 1871 to 1876, the year in which he published his 'Études sur la Bière,' Pasteur was again largely occupied with the study of fermentation. Part of his object was undoubtedly to place the French brewers on an equality with the German; and in this he certainly had a large measure of success. To one who knew Paris under the Second Empire and who revisits it under the Third Republic, one of the first changes observable in the life of the *café* is the enormous consumption of 'bocks.' Pasteur's work, however, went far beyond the establishment of a national industry. He started investigations which have changed brewing from an art into a science; and his most fitting memorial in this respect is the bust which decorates the hall of the Carlsberg Institution at Copenhagen, an institution devoted to the study of all problems of fermentation. In his 'Études' Pasteur laid great stress on the fact that every fermentation is brought about by micro-organisms, and he dwells at length on the marked influence which certain bacteria exercise on the nature of the fermentations, and on the character of the beer produced. He did not, however, see, what Hansen demonstrated in 1883, that many of the commonest diseases of beer are caused by certain species of yeast-cell differing specifically from those which cause its normal fermentation. Indeed, he paid but small attention to species, regarding it as waste of time, as it undoubtedly often is, to trouble about names and synonyms.

As Professor Jörgenson and Dr. J. R. Green have shown in two recently-published works, we have learnt much about brewing during the last five-and-twenty years. The nucleus of the yeast-cell has been made visible by appropriate staining; some thirty different species of yeast-cell have been described, and their properties as ferments have been investigated; Buchner, by grinding up the yeast-cells, has produced an extract, called zymase, capable of converting sugar into alcohol; the fact has been established that it is not so much bacteria as other fungi, allied and often congeneric with the yeast-cell, which produce disease in beer; still, allowing a full measure of credit to later workers, we may look back to Pasteur's researches in the early seventies as establishing for the first time a scientific basis for brewing.

The same remarks are applicable to Pasteur's work on the diseases due to specific organisms in the region of preventive medicine. We have built and are building a lordly edifice, but he drew the plan and even laid the foundations. More than two centuries ago Robert Boyle—'the Father of Chemistry and Brother of the Earl of Cork'—had said that he who could solve the nature of fermentations would be without doubt more capable than others of explaining certain phenomena of disease. Towards the end of his 'Études sur la Bière,' Pasteur wrote: 'The ætiology of contagious diseases is on the eve of having unexpected light shed upon it.' He was already thinking of his investigations into the cause and prevention of contagious disease.

There is a certain malady known, when it attacks cattle and sheep, as 'charbon' or 'sang de rate,' and when it attacks man, as 'woolsorter's disease.' The term 'anthrax' covers the disease in both beast and man; and anthrax is produced by a bacterium known as *Bacillus anthracis*, which had been recognized and was accused of causing the disease before Pasteur began to interest himself in such matters. It annually carried off 20 per cent. of the sheep in the agricultural district of La Beauce, and in Auvergne some 10 to 15 per cent. In certain localities the loss was greater, amounting at times to an annual death-rate of 50 per cent. The disease was by no means confined to France; it was spread over Europe. In the government of Novgorod it was responsible for over 56,000 deaths in three years. In Egypt it was regarded as the direct descendant of the plagues of Pharaoh. It ravaged the large sheep farms of the Argentine Republic.

The bacillus which causes this disease, and which at times by inhalation effects a lodgment in the bodies of those engaged in handling wool and hides, was already known when Pasteur took up the study of pathogenic germs. About the same time it was also attracting the attention of the young German physician Dr. Koch, who subsequently became a severe critic of some of Pasteur's work; but in this article we are dealing with Pasteur, and limitations of space compel us to leave unnoticed the brilliant work of many investigators who have made the latter end of the nineteenth century one of the greatest epochs in medical history.

Pasteur and his assistants made many fascinating studies on the behaviour and life-history of the *Bacillus anthracis*. He found it very susceptible to slight variations of temperature. The few degrees by which the temperature of a bird's blood exceeds that of a mammal were sufficient to prove fatal to the bacillus; but by an ingenious experiment he showed that if the temperature of a bird be artificially lowered it becomes susceptible to the disease, though it readily recovers if the artificial surroundings be removed. Pasteur further noted that the bacillus was not equally fatal in all animals, and that it changed its character when passed through the body of certain classes of animals. It was, however, not in studying the *Bacillus anthracis* that he made the far-reaching discovery of the attenuated virus. This he first noted when at work on chicken cholera, a disease very fatal in poultry-yards; and he made the important discovery by one of those happy accidents which only occur to those who possess the genius for observation. During his numerous experiments he one day chanced to inoculate some fowls with a forgotten culture some weeks old. To his surprise the chickens, though made ill, did not succumb; in fact, they rapidly recovered. He immediately tried what the effect would be if these same fowls were inoculated with fresh cultures of a kind so powerful as to be undoubtedly fatal to a healthy bird which had never suffered from the disease. To his delight, the inoculated fowls resisted the poison, and proved, in fact, immune. This simple experiment is the basis of the world-wide prophylactic measures which are now being carried on against all forms of bacterial disease; and, although Pasteur's explanation of the weakening of the virus—which he attributed to oxygenation—has been shown to be erroneous, he must still be regarded as the originator of methods for the production of immunity by means of artificially attenuated organisms.

If the virus of chicken-cholera can be attenuated, and when attenuated produces immunity from later attacks, the same is probably true of other germs which can be cultivated outside the body. Arguing in this fashion, Pasteur returned to his study of anthrax. Here he also succeeded, and in the spring of 1881 he demonstrated the value of his treatment. Out of a flock of fifty sheep one-half were inoculated, the other half were not; the whole flock was then infected with the disease. In less than a month the uninoculated were dead of 'charbon,' the inoculated were perfectly healthy. The telegram announcing the result to Pasteur, anxiously waiting in his laboratory at Paris, ended with the words 'Succès épatant!'

So striking a demonstration naturally had a profound effect. It inspired confidence in the treatment. Since the date of this experiment some millions of sheep have been inoculated against anthrax, and several hundred thousand oxen; and it has been calculated that, within the succeeding twelve years, seven million francs were saved by this means alone to French agriculture. Perhaps the convincing nature of Pasteur's work in this connexion is best shown by the fact that the insurance companies of France insist on inoculation before they will insure sheep and cattle.

We have left ourselves but little space to dwell on the work which occupied the greater part of the last twelve years of Pasteur's life. Already, in the midst of his work on anthrax, he was thinking of rabies; and in 1881 he proved that it was conveyed through the saliva of the mad dog, and that it could be communicated to rabbits. Saliva, however, was not in every case to be depended on. In some cases it failed to convey the disease. Experiment showed that the poison was concentrated in the brain. To this day no one has succeeded in finding the organism—if it be an organism—which causes rabies. Hence it cannot be cultivated on gelatine in test-tubes, and no modified culture of bacteria can be produced, as is now done in the case of diphtheria and other diseases. Other means had to be devised. After countless experiments it became evident that, if the spinal cord of a hydrophobic rabbit be kept dry at a temperature of 25° C. for a couple of weeks, the strength of the virus has so far vanished that, if an emulsion of the cord be injected, it produces no rabies, but has only a slight vaccinating effect. If two days later an emulsion of a twelve-days-old spinal cord be injected, the vaccinating effect is stronger; but the body, already inured to slight doses of the poison, remains unaffected. Thus, by gradually increasing the strength of the dose, a virus may at length be injected which would infallibly produce rabies but for the previous inoculations. When an animal is bitten by a mad dog, the poison transmitted takes some time to develop—some weeks at least, and often many months. If now the artificially introduced virus 'gets the start,' so to speak, of the naturally introduced poison, by the time the latter is at its height the animal has become gradually immunified to the specific poison and suffers little harm. The arsenic-eaters of the Tyrol afford an analogous case. They consume amounts of arsenic which would infallibly produce peripheral neuritis in men unaccustomed to such a diet.

It needed no small courage on Pasteur's part to inoculate his fellow-creatures against hydrophobia. In 1885 a boy some nine years old, from Meissengott in Alsace, was brought by his mother to the laboratory suffering from fourteen wounds inflicted by a mad dog. After long consultations with his assistants and the most anxious deliberations, he consented to the inoculation of the boy. The next fortnight was a time of intense anxiety, but all went well. His second patient is commemorated by the bronze statue which ornaments the front of the Pasteur Institute in Paris. It represents the struggle between a peasant boy, armed only with his sabot, and a mad dog; the boy was terribly bitten, but the treatment saved his life. It is not easy to arrive at an accurate estimate of the death-rate caused by rabies; but the most careful and moderate estimates show that, before this treatment was in use, some fifteen to twenty out of every hundred persons bitten by mad dogs died a most painful and horrible death. During the fourteen years, from 1885 to 1899, over 23,000 persons known to have been bitten by rabid dogs have been inoculated at the Pasteur Institute; and their average mortality has been 0·4 per cent. In 1899, the latest year for which statistics are available, 1,614 cases were treated, with a mortality of 0·25 per cent. Of these, 1,506 were French and 108 were foreigners. Of the 108 foreigners, 12 came from Great Britain and 62 from British India. It is little short of a national disgrace that we should still be dependent on French aid to succour those amongst us who are so unfortunate as to be bitten by a mad dog; but the nation which gave the use of anæsthetics to the world, and which first showed the value of antiseptics, is largely dependent to-day on foreign aid in dealing with great outbreaks of all sorts of diseases within its borders. The German Koch and the Russian Haffkine are called in to cope with the cholera in India; we fall back upon the Swiss Yersin and the Japanese Kitasato to elucidate the true nature of plague, and to devise methods for combating its ravages. When rinderpest broke out in South Africa it was again to Koch that we turned. The unsatisfactory position of Great Britain in these matters is to some extent due to a small but active section of society whose affection for their lapdogs has overpowered their sense of duty to their neighbours. It is, however, we fear, still more due to the unintelligent treatment of men of science by the Government of the country, and to the want of appreciation of the value of science shown by society at large. If, to balance the list given a few lines above, we recall the work of our countryman Major Ross on the malarial parasite, it serves only to remind us of the difficulties placed in the way of his research by the officials of the service to which he belonged and the slightness of the recognition which for many years he received from the Government.

In 1874 the French National Assembly voted Pasteur, as some recognition of his work on seri-culture, a pension of 12,000 francs a year; nine years later this was increased to 25,000 francs, and it was further agreed that the pension should be continued to his wife and children. In 1881 he was nominated to represent France at the International Medical Congress, which met that year in London. The reception accorded him when, with his host, Sir James Paget, he mounted the platform in St. James's Hall, overwhelmed him. 'C'est sans doute le prince de Galles qui arrive,' he remarked to his host, never dreaming that such acclamations could be meant for him. The following year he succeeded to Littré's *fauteuil* at the Academy. In 1888 the President of the Republic opened the Pasteur Institute, which had been erected and endowed by a public subscription from all countries and from all classes; and there in 1892 he received a distinguished collection of scientific men, who had come from all parts of the world to congratulate him on his seventieth birthday.

Three years later his health began rapidly to fail. Two strokes of paralysis followed one another at a short interval, and on September 28, 1895, he died. He lies buried in the Institute he loved so well. A nobler monument, or one more worthy of him who lies therein, has never been erected by man. The benefits which his simple, strenuous, hard-working, noble life conferred on humanity cannot be estimated. They help us, however, to realize the truth of the old Arabian proverb, 'The ink of science is more precious than the blood of the martyrs.'

M. Vallery-Radot has given what will probably prove to be the definitive Life of Pasteur. He has written at length, and he has written well. That he is not a man of strict scientific training in no way detracts from the merit of the work; rather, in many respects, this makes the book more readable. The pupils of Pasteur, who are now carrying on his work, have, out of the abundance of their knowledge, helped in the more technical portions of the book; whilst M. Vallery-Radot, from his intimacy and relationship with the subject of his biography, has been able to supply those personal details which form so essential and so interesting a part of every good biography.

For one who knew Pasteur only during the last decade of his life to attempt any account of his character may savour of impertinence. Still, it is impossible to close this article without some tribute to his simple dignity of manner, and, above all, to his infinite kindness. No man has done more to lessen suffering in this world, both in man and in the lower animals, and probably but few have felt so much sympathy with suffering in others. As a boy—and French country boys are not more thoughtful about the suffering of animals than those of other races—he refused to go shooting. ‘La vue d’une alouette blessée lui faisait mal.’ As an old man it was a touching sight to see him amongst the sufferers under treatment at the Institut Pasteur, patting the little children on the head, heartening up the timid and giving sous to the brave, infinitely tender to the frightened mothers. ‘Men of science, my Sandra, are always the humanest,’ as Laura said in ‘Vittoria.’ Another dominating trait in his character was his unflinching desire for truth; to ‘prove all things,’ and to ‘hold fast that which is good,’ was the motto of his working life. His success was in no small measure due to the rigorous tests he applied at all stages of his investigations; it was also due to the untiring assiduity with which he worked, never sparing himself, never in any way thinking of himself. But, above all, it was due to the intense thought he bestowed upon his researches. Concentrating his intellect upon the problem in question, he thought out all possible solutions, and was prepared for all possible eventualities. It was this power of thought, coupled with a matchless gift of observation and experiment, that enabled him to leave a name which cannot be forgotten whilst civilization endures.

MALARIA

There in a wailful choir the small gnats mourn
Among the river sallows, borne aloft
Or sinking as the light wind lives or dies.

John Keats: ‘To Autumn.’

It has been said that one-half the mortality of the human race is due to malaria. This may very well be an exaggeration, but there can be little doubt that, of all the ills that flesh is heir to, malaria is the most deadly, and exercises the most profound influence on the distribution and activities of man. It will be seen later that the disease is most rife where the densest populations are found, and the mortality of such a closely crowded area as India gives some idea of the enormous loss of life and the widespread suffering caused by this disease. In 1892, out of a total population in India of 217,255,655, the deaths from all causes reached the figure of 6,980,785. Of these, 4,921,583 were ascribed to ‘fever.’ All these fevers were not, of course, malarial, but comparison with other statistics leads to the belief that a high percentage of them was caused by malaria. Major Ross states that in 1897 over 5,000,000 deaths in the same country were recorded as due to ‘fever,’ and that out of a total strength of 178,197 men in the British army in India, 75,821 were treated in the hospitals for malaria. Fifty years ago the loss from malaria amongst the European population of India was 13 per thousand. With improved methods of living and more skilful treatment this has been reduced to 7 per thousand; but the native, who is slow to change his ways, and usually averse to modern methods of treatment, still retains a very high fever death-rate—over 18 per thousand. During the years 1887-1897 the average mortality in Italy attributed to malaria was 15,000 a year, and 2,000,000 patients annually suffered from ‘fever.’

Apart from the mortality due to this disease, the amount of suffering and the decline in human power and activity which it entails deserve careful attention. Compared with the number of patients, the number of deaths is by no means large. In round numbers, out of every thousand soldiers in the British army in India in 1897, 420 men were attacked by malaria, but only one in a thousand died; even in the ‘most malarious’ districts the death-rate only amounted to 6 per thousand. In Sierra Leone, a district much more fatal than any in India, the average death-rate of the white troops, based on hospital records extending from 1892 to 1898, is estimated by Major L. M. Wilson at 42·9 per thousand, whilst that of the coloured troops is 5·9 per thousand. On the other hand, the European troops show an annual number of cases of 2,134 per thousand, and the non-European troops one of 1,056 per thousand. These figures probably under-estimate the amount of fever amongst the troops. It must be remembered that many soldiers who have slight attacks of fever do not present themselves at the hospital, whilst of those who do a considerable number are only detained for slight treatment, and are never entered on the hospital books, and so are not recorded on the returns.

From the statistics quoted above, it appears that of our soldiers in India three out of every seven suffer from an annual attack of malaria sufficiently pronounced to be recorded on the medical books, whilst our soldiers on the west coast of Africa have an average of at least two attacks a year, and a considerable number of them die. There is no reason to believe that the civil population of India or West Africa is in any degree more exempt from the disease than the military, but the statistics in the latter case are more readily accessible.

Malarial fever, when it does not kill, leaves great weakness behind; and all who have watched malaria patients, or patients who are already recovering from an attack, cannot fail to have noticed the listlessness and want of interest in their surroundings and the lack of inclination to work that they all show. Apart from the mortality, the disease probably levies a heavier tribute on the capacity of the officers and officials who administer the British Empire than does any other single agency.

Before describing the organism which causes all this misery a word or two must be said about the distribution of the disease. Roughly speaking, malaria is confined to a broad irregular belt running round the world between the 4th isothermal line north of the Equator and the 16th line south. It is, however, said to occur occasionally outside these limits—for instance, in Southern Greenland and at Irkutsk in Siberia; but until recently the accurate diagnosis of the disease has been difficult, and too much reliance must not be placed on these statements. The chief endemic foci of the disease are along the banks and deltas of large rivers, on low coasts, and around inland lakes and marshes. Malaria is common all round the Mediterranean region: it was well known to, and its symptoms were clearly noted by, the early physicians since the time of Hippocrates. They even recognized the difference between the mild spring and summer attacks and the more pernicious effects of the autumnal fever. In France there are several prominent malarial districts: the valley of the Loire and its tributary the Indre, and the valley of the Rhone; also the sea-coast stretching from the mouth of the Loire to the Pyrenees, and again the Mediterranean sea-board. It occurs in Switzerland, and is found in Germany along the Baltic coasts, and on the banks of the Rhine, the Elbe, and other rivers, and in many other parts. Scarcely a province in Holland is quite free from it, and it is found in Belgium and around Lake Wener, in Sweden. It extends along the Lower Danube and around the Black Sea, and spreads across Russia, being especially prevalent along the course of the Volga and around the Caspian. From Europe it spreads over Asia Minor, and affects all Southern Asia as far as the East Indies, but in Japan it is curiously rare. It is also infrequent in Australia—where it is confined to the northern half of the continent—and in many of the Pacific Islands; and it is unknown in the Sandwich Islands, New Zealand, Tasmania, and Samoa. In America it is more common, and of a more severe type an the Atlantic sea-board than on the Pacific; in the last hundred years its northern limit is said to have retreated in the centre of the continent, though some observers think it is creeping further north in the Eastern States. In a mild form it is known around the Great Lakes, and in Canada and in New England; but it reaches a high degree of intensity in the Southern States, Mexico, Cuba, and Central America, where it probably played a greater part in ruining the projected Panama Canal than all the corrupt financing of the speculators in Paris. It extends throughout the warmer parts of South America, and is known in a virulent form all over Africa except the extreme south.

In Great Britain it used to flourish. The following extract from Graham’s ‘Social Life of Scotland in the Eighteenth Century’ shows what a part it played in the life of the Scottish peasant:

> ‘The one ailment to which they were most liable, and in which dirt had no share, was ague. This was due to the undrained land, which retained wet like a sponge, and was full of swamps and bogs and morasses in which “green grew the rushes.” Terribly prevalent and harassing this malady proved to the rural classes, for every year a vast proportion of the people were prostrated by it, so that it was often extremely difficult to get the necessary work of the fields performed in many districts. In localities like the Carse of Gowrie, which in those days abounded in morasses and deep pools, amongst whose rushes the lapwings had their haunt, the whole population was every year stricken more or less with the trouble, until the days came when drainage dried the soil, and ague and lapwings disappeared.’

In England it was once very prevalent. James I. died of ‘a tertian ague’ at Theobalds, near London, and Cromwell succumbed at Whitehall to a ‘bastard tertian ague’ in 1658, a year in which malaria was very widely spread and very malignant; and it is only within recent memory that the fen districts in Cambridgeshire and Lincolnshire, Romney Marsh in Kent, and the marshy districts of Somerset, have lost their evil reputation for ague. The older chemists in the towns in the fen districts still recall the lucrative trade their fathers carried on in opium and preparations of quinine with the fenmen during the first half of last century; but with the improved drainage of the fens this has all disappeared, and at present cases of endemic malaria appear to be unknown in England, though sporadic cases turn up at rare intervals. It was also very prevalent along the estuary of the Thames, both on the Essex and Kentish marshes. Pip in ‘Great Expectations’ says to his convict:

> ‘ “I think you have got the ague.” “I’m much of your opinion, boy,” said he. “It’s bad about here,” I told him. “You’ve been lying out on the meshes, and they’re dreadful aguish.” ’

Ireland, which appears at first sight peculiarly adapted for the disease, seems to have been remarkably free from it. It may be that the strong antiseptic quality of the peaty bog-water hinders the development of the larval mosquito.

Turning now to the cause of the disease, it is interesting to note that the discovery of the organism which produces all this misery and death took place just about the time when Koch was making his far-reaching investigations into the cause of tuberculosis. In 1880 Koch was at work on the tubercle bacillus; and in the same year a French army surgeon, named Laveran, looking down a microscope in a remote military station in Algiers at a preparation of blood taken from a malarious soldier, recognized for the first time the small organism which has played a larger part in human affairs than the greatest politician or general that ever lived. This small organism is an animal, not a plant. It belongs to the great group of single-celled organisms, mostly microscopic in size, called Protozoa, and it lives as a parasite inside the body of other animals, from which it abstracts what nutriment it needs. Before describing its structure and life-history, a word or two must be said about its surroundings in the body of man.

That blood consists of a fluid in which enormous numbers of cells called blood-corpuscles float is now a matter of common knowledge. These corpuscles are of two main kinds, the red and the white, but the red surpass the white in number, in proportions ranging from 300 up to 700 to 1. A cubic millimetre of blood contains about 5,000,000 red corpuscles; and since these act as the carriers of oxygen from the lungs to the tissues all over the body, and on their return journey carry away the carbon dioxide from the tissues to the lungs, where it is given off, it is obvious that the presence of a parasite in the red corpuscle will have a most serious effect upon the welfare of the body.

Before Laveran’s discovery, Lankester had described a parasitic organism living in the blood-cells of a frog, and within the last twenty years numerous other organisms have been discovered and described by various investigators living in the blood-corpuscles of reptiles, birds, monkeys, and bats. There are at least three species of Hæmatozoa, as they are called, which live in the blood of man, and these three correspond to the three kinds of malaria—the tertian, the quartan, and the æstivo-autumnal, or, as it is often termed, the irregular type of malarial fever, which occurs so frequently in the late summer and autumn in Italy and elsewhere. The hæmatozoön causing the last-named fever has been especially studied by the Italian observers, and it differs more markedly from those causing the tertian and quartan fevers than the latter do *inter se*. It is not universally conceded that the differences between these three forms of organism are such as to establish a difference of species, but the weight of opinion is in favour of this view. Ross even places the parasite of the æstivo-autumnal fever in a separate genus, and we have throughout this article adopted his nomenclature. Zoologically he groups all the three species infesting man in Wassielevski's family Hæmamœbidæ, which, besides the human parasites, includes a species found in monkeys, three species in bats, and two in birds. The species causing tertian and quartan fevers are grouped by Ross in the genus *Hæmamœba*, the former being called *Hæmamœba vivax*, the latter *Hæmamœba malariæ*. The parasite causing the æstivo-autumnal fever is called *Hæmomenas præcox*.

With the exception of a few details the life-history of all these forms is practically identical, although the time which is occupied by different phases of their life-cycle varies in the different species. The account given here applies in the main to them all.

The organism which Laveran saw living in the blood-corpuscles of his malarious patient was a minute cell of irregular shape whose nucleus can be demonstrated by the use of appropriate reagents. The cell constantly but slowly changes its outline, pushing out and withdrawing blunt rounded processes; in fact, the cell resembles the lobate forms of one of the simplest microscopic animals we know, the Amœba (Fig. 1). The movements and change of shape consequent on them are termed amœboid, and the organism in this stage is known as an amœbula. These amœbulæ whilst in the blood-cell grow rapidly, and in some way they collect the hæmoglobin, or colouring matter of the red corpuscle, within their own bodies, and convert it into a number of dark brown or black pigment granules, which crowd around the nucleus of the parasite. This pigment, the so-called malarial pigment or melanin, had been recognized by Virchow and others about the middle of the nineteenth century as a characteristic product in the blood of malarial patients. The amœbulæ continue to grow rapidly, at the expense of their cell-host, until, after a definite period, which varies from one to several days, they become mature, and by this time they have completely filled up the red corpuscle, whose scanty remains form a tight skin round the fully-grown parasite (Fig. 1, 1-8). When mature, one of two things happens—either they become (1) gametocytes, whose meaning and fate we will consider later, or they become (2) sporocytes. In the latter case the nucleus of the amœbula breaks up into a number of small nuclei, and each surrounds itself by a small mass of protoplasm and forms a spore (Fig. 1, 5-8). The result of this process of division may be roughly realized if we imagine an orange with

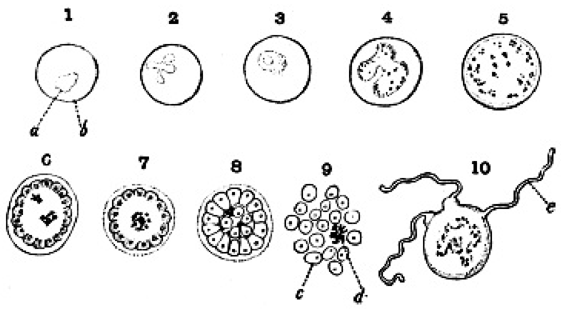

FIG. 1.—THE PARASITE OF TERTIAN FEVER, HÆMAMŒBA VIVAX (ROSS). HIGHLY MAGNIFIED.

Nos. 1, 2, 3, 4, show the growth and the changing shape of the parasite within the blood-corpuscle; Nos. 3, 4, etc., show the aggregation of the pigment, melanin, in the parasite; No. 5 is a sporocyte, which in Nos. 6, 7, and 8, shows the several stages of sporulation; No. 9 shows the spores derived from a single sporocyte, escaped from the blood-corpuscle and free in the blood-plasm, ready to infect new corpuscles; No. 10 is a male gametocyte, removed from the body of man, and either in the stomach of Anopheles or on a microscope-slide, forming there flagella or spermatozoa, a, Parasite; b, red blood-corpuscle; c, spore; d, granules of pigment, melanin; e, flagellum or spermatozoön. (From Thayer.)

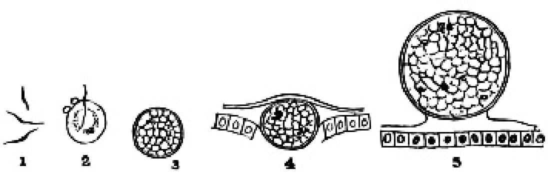

FIG. 2.—VARIOUS STAGES WHICH THE PARASITE OF THE ÆSTIVO-AUTUMNAL FEVER, HÆMOMENAS PRÆCOX (ROSS), PASSES THROUGH IN THE BODY OF THE MOSQUITO ANOPHELES. MAGNIFIED 2,000 TIMES. AFTER ROSS AND FIELDING-OULD.

No. 1, Flagella or spermatozoa from male gametocyte (see Fig. 1 above); No. 2, flagellum or spermatozoön entering and fertilizing the female gametocyte; No. 3, the fertilized cell or zygote; Nos. 1, 2, 3, are found in the blood in the stomach of the Anopheles; No. 4, the fertilized cell piercing the wall of the stomach of the mosquito to come to rest at No. 5, between the epithelial lining of the stomach and the muscular sheath.

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but one pip in each quarter. Then the skin of the orange will represent what is left of the red blood-corpuscle, the flesh will represent the divided sporocyte, each quarter will represent a spore, and the pip will represent its nucleus.

At this stage the skin to which the red corpuscle has been reduced breaks, and the spores fall into the liquid part of the blood (Fig. 1, 9). The pigment granules which escape at the same time also pass into the liquid of the blood, and are eaten up and removed by those scavengers of the vascular system, the white corpuscles. Each of the spores, after remaining a short time in the fluid of the blood, attaches itself to a new red corpuscle, penetrates its body, and becomes a small amœbula, which repeats the life-history described above. In this way a few organisms will soon produce enough spores to infect a very large number of blood-corpuscles; as many as 60 per cent. are in some cases infected. The severity of the attack naturally depends in a great degree on the number of corpuscles infected. Laveran not only first recognized and described the organism[4] we are dealing with, but he definitely connected its presence with malaria; but it was not until some time later, in 1885, that Golgi described the sporulation of the sporocyte and pointed out that the moment of the escape of the spores from the red corpuscle coincides with the paroxysm of the fever. Since all the amœbulæ of one crop are at about the same stage of growth in any one host, millions of spores in a well-infected patient are thrown into the liquid of the blood at about the same time; and it is clear that this must be accompanied by a profound disturbance of the system. This disturbance manifests itself in a feverish attack. The period when the spores have left the corpuscles and are free in the liquid of the blood is also the time at which the administration of quinine is said to be most effective. Further, it is only at this stage that the disease can be artificially transferred from one man to another. All efforts to transmit the gametocytes have ended in failure.

Hæmamœba vivax, which causes the tertian fever, passes through the various stages of its life-history in man in forty-eight hours; hence the febrile paroxysm occurs every second day. Malaria is usually of the tertian type, and this is certainly the most common form in temperate climates. Occasionally the infection has been repeated, and we may find that there are two groups of the parasite present in the blood, which arrive at the sporulating stage on alternate days; in this case the febrile symptoms manifest themselves every day, and the type of malaria is designated ‘quotidian intermittent fever.’ In this case, if a single dose of quinine be administered at the right time, one group of parasites is killed off and the quotidian fever is reduced to a tertian. There may occasionally be more than two groups present, or the parasites may for some reason have failed to arrange themselves in groups, in which case the fever becomes irregular or continuous.

In the quartan fever the parasite *Hæmamœba malariæ* takes seventy-two hours to complete its cycle in man, and the paroxysms occur every three days—that is, there are two days without febrile symptoms, followed by a day when there is a paroxysm. This form is common in Sicily and in certain parts of Italy—for instance, around Pavia. Just as in the tertian fever, so in quartan there may be a second infection, in which case paroxysms arise on two successive days, followed by a day of intermission of the fever. If a third group be present, we have a quotidian fever. The æstivo-autumnal fever, due to *Hæmomenas præcox*, is noted by a marked irregularity in its clinical symptoms. It usually sets in during August, September, or October, and is attended by much more serious results than are the regular intermittent fevers. The pernicious or malignant form of malaria, rarely seen in temperate climates, but common in the tropics, is caused—in many cases, though perhaps not in all—by the same parasite.

From what has been above described, it is evident that when once the parasite has obtained entrance to the blood it may remain and multiply for years. The parasite is, however, very susceptible to the poisonous action of quinine, and this is especially the case at the time when sporulation has just taken place and the spores are being set free in the blood. Quinine seems to have little or no effect on the organisms whilst they are inside the blood-corpuscle, but shortly before the paroxysm is due it should be administered. Quinine is amongst the very few absolutely trustworthy specifics known to medical science. It seems to have been introduced into Europe in the year 1640 by the Countess of Chinchon, a small town south-east of Madrid. The Countess was Vice-Queen of Peru, and in 1638 was cured of a tertian fever by the use of Peruvian bark. Shortly afterwards she started for Europe with a supply of the drug, but unfortunately died on the voyage. About a hundred years later Linnæus named the plant after this lady, but acting on erroneous information omitted the first ‘h’ in the name, and called the plant Cinchona. According to some authorities the word ‘quinine’ is derived from ‘quina,’ the Spanish spelling of the Peruvian word ‘kina,’ which signified bark.

But to come back to the parasite. It was mentioned above that the amœbulæ become either sporocytes or gametocytes. We have followed the fate of the former and must now turn our attention to the latter. In the genus *Hæmamœba* the gametocyte has a general resemblance to the sporocyte before its nucleus divides and it begins to form spores; and it is impossible to predict which amœbulæ will become sporocytes and which will become gametocytes. In *Hæmomenas*, however, the gametocyte can be recognized at an early stage. In this genus some of the amœbulæ become globular and ultimately form spores, whilst others become elongated and slightly curved; in fact, they assume the shape of minute sausages. These are the gametocytes. It is on this difference in shape that Ross has founded his new genus for the parasite of the æstivo-autumnal fever, all the essential characters of which had, however, been previously recognized by Italian and American observers.

So long as the gametocytes remain in the blood of the patient they undergo no further development; on being liberated from the cell into the fluid of the blood, they degenerate and die; but if they be removed, even only on to a microscope-slide, they begin to develop. They escape from the red corpuscle in which they have hitherto been confined, and some of them—the male gametocytes—are then seen suddenly to emit long filaments (Fig. 1, 10). These filaments can be watched under a high power struggling violently to free themselves from the cell which has given rise to them. Ultimately they succeed, and breaking loose, at once dart away amongst the corpuscles and other debris on the slide. So long ago as 1880 Laveran had seen these bodies, but until 1897 their nature was quite misunderstood. This formation of the filaments or flagella, sometimes called ‘flagellation,’ can only take place at comparatively high temperatures. This has an important relation to the seasonal variation in the prevalence of the disease.

Hitherto in this article we have only studied the malarial parasite inside the body, with the exception that we have just seen that, should it get out, certain cells undergo a further development and produce mobile filaments. It occurred to many that these filaments might be spores, which were in some way carried into the blood of man. Later research showed that this is not their true meaning; but, acting on some such belief, Dr. Patrick Manson propounded the hypothesis that the spores may be conveyed to man by the intervention of some blood-sucking insect; and the brilliant and laborious researches of Major Ross, undertaken with the view of establishing the truth or falsehood of this hypothesis, have within the last few years cleared up the whole question of the transmission of the disease from one patient to another.

It is a well-established belief in many malarious countries that the mosquito plays a part in the infection. The negroes of the Usambara Mountains, who acquire the disease when they descend to the plains, even use the same word to denote the disease and the mosquito. In Assam, in Italy, and in Southern Tyrol, the belief in the mosquito origin of malaria obtains. Experienced travellers, like Livingstone, Emin Pasha, and General Gordon, insisted on the importance of mosquito-nets, thinking that the netting 'acted as a filter against the malarial poison,' and knowing by experience that its presence diminished the tendency to the disease. The whole epidemiological evidence was put together in a masterly essay on the mosquito theory, read before the Philosophical Society of Washington in 1883, by Professor A. F. A. King. There was thus a considerable body of opinion in favour of the mosquito-malaria theory, when, in 1894, Manson explained his views to Major Ross, at that time a surgeon in the Indian Medical Service.

Manson's own epoch-making researches on *Filaria*—another human parasite whose intermediate host is the mosquito—no doubt strengthened his faith and helped to encourage Major Ross, who in 1895 began in Secunderabad a series of investigations, which, after much weary work, were crowned with brilliant success. The difficulties of the work were very great. Hardly anything was known about the great number of gnats and mosquitoes which are found all over India, and it was often impossible to have them accurately determined. Then no one could predict the appearance of the parasite within the body of the mosquito—if it were there—or in what part of the body it should be looked for. The mosquito had to be searched cell by cell. The difficulty of dissecting a mosquito is great even in temperate climes, and when we recollect that hundreds of all the available species were dissected in the most malarious districts in India, we must recognize that it was only a faith akin to that which moves mountains which sustained the courage and stimulated the perseverance of the tireless worker. For nearly two years and a half Major Ross searched in vain. No matter what species of mosquito he worked at, the results were negative. A less determined man would long ago have abandoned the research; Major Ross only tried new methods. At Sigur Ghat, near Ootacamund, a peculiarly malarious district, he noticed for the first time a mosquito with spotted wings which laid boat-shaped eggs. Shortly afterwards he was able to feed eight specimens of this mosquito on a patient whose blood contained the parasites in the gametocyte stage—and it should have been mentioned above that all mosquitoes dissected were first fed upon the blood of malarious patients. Six of these insects were searched through and through, organ by organ, but without result. The seventh showed certain unusual cells in the outer surface of the stomach, which contained a few granules of the characteristic black pigment or melanin of malarial fever. The eighth and last specimen showed the same characteristic cells with the same characteristic pigment; but the peculiar cells, quite unlike anything hitherto met with in the mosquito's body, were larger and further developed. 'These fortunate results practically solved the malaria problem.'

Without following in detail the various stages of the further investigations carried on by Major Ross, we must endeavour to give an account of the final results obtained by him and later investigators. Being unable to obtain material for the study of malaria in man owing to the scare caused by the outbreak of plague amongst the natives, Ross worked out the life-history of an allied organism which causes malaria in birds. It is to the brilliant researches of the Italian school—prominent among whom are Grassi, Bastianelli, and Bignami—that we owe the first complete accounts of the life-history of the human parasite. It has already been explained that some of the parasites do not form spores, but persist in a more or less unchanged condition whilst in the blood of man as gametocytes. We have also seen that when removed from the human body some of these gametocytes throw off actively mobile filiform bodies. In 1897 MacCallum of Baltimore showed what these filiform bodies really are. Certain of the gametocytes do not produce them, but lie passively still on the microscope-slide, or in the blood within the mosquito's stomach. These are destined to form the female cell; the filamentous bodies which break off from the first-named gametocyte were seen by MacCallum to fuse with them, and, in fact, to play the part of the male cell or spermatozoön. This, in fact, happens when a mosquito feeds on a malarious patient. The gametocytes, unchanged in the blood of man, as soon as they reach the stomach of the insect, swell and burst from their red corpuscle. The male gametocyte throws off the filiform bodies, which actively swim about seeking a female gametocyte (Fig. 2, 1). When found they fuse with it, and thus produce a fertilized cell or zygote (Fig. 2, 3). This zygote is produced on the microscope-slide, and in the alimentary canal of certain mosquitoes, but so far as is known at present it undergoes further development only in the stomach of the various species of the mosquito genus *Anopheles*. In all other cases it dies or is digested. In *Anopheles*, however, the zygote travels to the walls of the stomach, pierces the inner coats and comes to rest underneath the muscular tunic which ensheaths that organ (Fig. 2, 4 and 5).

At first the zygote is very small, about the size of a red blood-corpuscle; but it grows, and in the course of about a week it has, roughly speaking, increased to five hundred times its original bulk (Fig. 3, 1 and 3). Its contents have not only increased, but have divided into some eight or twelve cells, called meres; and each of these meres has given off round its periphery a number of filiform cells, called blasts (Fig. 3, 2). The structure of the mere, with its coating of blasts, may be easily understood by a zoologist when it is mentioned that it very closely resembles that stage in the formation of the spermatozoa of the earth-worm just before the spermatozoa separate themselves from the blastophor; the lay mind may gain a better idea of its appearance by recalling the head of a mop. As the zygote, still resting on the outside of the mosquito's stomach, matures, the cells which are giving rise to the blasts diminish in size and disappear, leaving the capsule packed with thousands of minute filiform slightly spindle-shaped blasts (Fig. 3, 3). Then the capsule bursts and the blasts make their way into the body-cavity, or space between the stomach and the wall of the mosquito's body. It is not known whether they have any movement of their

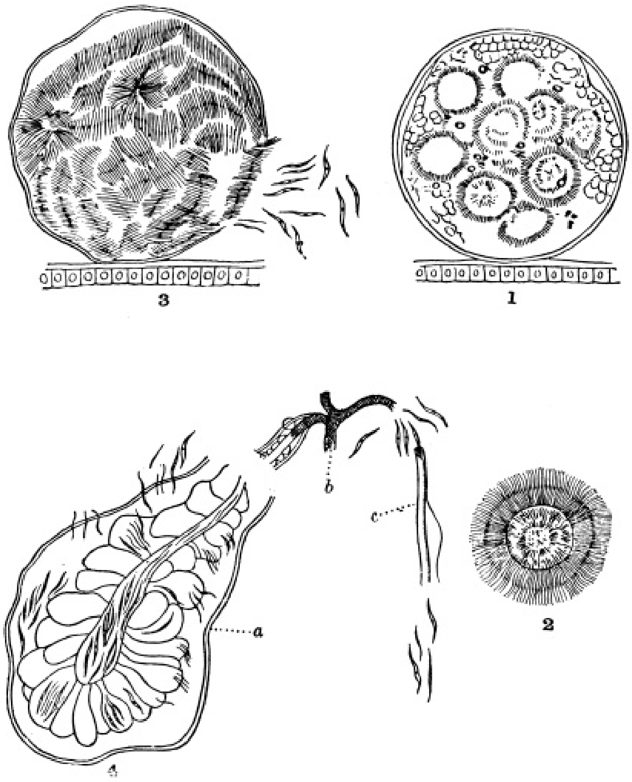


FIG. 3.—FORMATION OF THE BLASTS OF HÆMOMENAS PRÆCOX (ROSS) WITHIN THE BODY OF THE MOSQUITO ANOPHELES. MAGNIFIED 2,000 TIMES. AFTER ROSS AND FIELDING-OULD.

No. 1, The full-grown zygote dividing up into meres; No. 2, an isolated mere which has developed its filiform bodies or blasts; No. 3, the zygote crammed with blasts is bursting; No. 4, the blasts are making their way into the salivary gland of the mosquito a, through it into the œsophagus b, and finally into the proboscis c.

To face page 144.

own, but in some way or another they make their way into the salivary glands of the insect and accumulate in the cells which secrete the saliva. Thence the blasts pass into the salivary duct and down the grooved proboscis of the insect (Fig. 3, No. 4). The next time the mosquito has a meal off a man, some of these blasts will be washed into the man's blood by the saliva which causes the irritation set up by a mosquito's bite. It is known that when an infected insect bites a healthy man malaria ensues; and though the blasts have not hitherto been seen to enter the blood-corpuscles, they certainly give rise to the disease, and it can hardly be doubted that they force their way into the red corpuscles and form the young amœbulæ which we described at the beginning of this article.

The appended scheme will perhaps make clear the very diverse phases of the somewhat polymorphic organisms. Those stages which occur in the blood of man are printed in ordinary type, but those which occur in the mosquito are in italics:

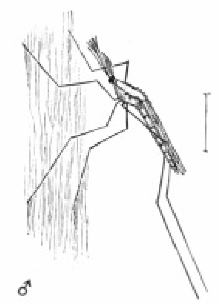
Amœbulæ.

Sporocyte.	Female Gametocyte.	Male Gametocyte.
Spores (in liquid of blood).		
Amœbulæ.	*Female Gametocyte.*	*Filamentous bodies* or *Spermatozoa.*
Sporocyte.	*Zygote.*	
Spores and *da capo*.	*Meres.*	
	Blasts.	
	Amœbulæ.	

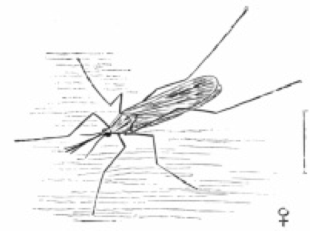
Sporocyte.	Female Gametocyte.	Male Gametocyte.

The foregoing account of this varied and romantic life-history is no hypothetical one. With the exception that, so far as we know, no one has yet seen the blasts enter the corpuscles and become amœbulæ, every stage in the story has been verified over and over again by competent observers, and their observations are now accepted by all whose opinion in such matters has weight. Further, the facts here recorded are not peculiar to parasites in man. Allied forms of Protozoa attack other vertebrates, and, in fact, the first hæmatozoön whose life-history was thoroughly worked out by Ross was the *Hæmamœba (Proteosoma) relicta*, which causes a malaria-like disease in birds, and is conveyed from one bird to another by means of the common gnat, *Culex pipiens*. Again, the parasite which causes so much loss to stock-owners, the Texas fever organism, *Pyrosoma bigeminum*, is, thanks to the researches of Smith and Kilborne, now known to be conveyed from one ox to another by the cattle-tick, *Boöphilus bovis*. Thus, however strange the life-history of the malarial parasite may seem to the unscientific, it is very much what might have been expected by zoologists who have worked on allied organisms, and it is vouched for in its main features by the most expert workers in England, France, America, Italy, and Germany. The whole literature of the subject of transmission of disease by insects has been ably sifted and brought together by Dr. Nuttall in a monograph whose title is mentioned in the Bibliography.

For two years and a half Major Ross dissected mosquitoes, looking for traces of the malaria organism and finding none, but at last found what he sought in a species of mosquito that had hitherto escaped his attention. This means that, like most other parasites, the Hæmamœbidæ will develop in one kind of animal and in one kind only. If taken up by another kind they are simply digested. The mosquito with the



ANOPHELES MACULIPENNIS.
MALE, IN CHARACTERISTIC ATTITUDE.



ANOPHELES MACULIPENNIS.
FEMALE.
To face page 146.

spotted wings and boat-shaped eggs undoubtedly belonged to the genus appropriately named *Anopheles*; and only the species of this genus, so far as we know, are capable of conveying the infection from man to man. In their bodies only will the gametocytes develop. If swallowed by other biting insects or by leeches, etc., they disintegrate, and are no more.

The word mosquito has no scientific import; derived from the Spanish or Portuguese, it simply means ‘little fly’; it is used popularly to denote a gnat which bites, and most gnats bite when they have a chance. The word is sometimes extended to include certain midges. The Dipterous family, Culicidæ, to which the gnat belongs, contains, according to Major Giles, some 242 species, divided amongst 8 genera. The great majority of species, some 160, however, belong to the genus *Culex*; *Anopheles* includes 30; whilst the remainder are divided amongst the other 6 genera, none of which are large. The collections which have been made at the British Museum, and which were worked out by Mr. Theobald, contain many species of *Anopheles* new to science; so that we have now some half hundred species of the genus ‘which has been hopelessly convicted of being the medium by which the malaria parasite is transmitted from person to person.’ According to the last-named authority, we have in England 17 species of *Culex*, and 2 of *Anopheles*, *A. bifurcatus* and *A. maculipennis (claviger)*, though some authorities are inclined to add a third, *A. nigripes*. Five other species, belonging to the smaller genera of Culicidæ, make a total of some 24 species of gnat or mosquito found in England. *Culex pipiens*, probably the commonest gnat the wide world over, conveys the parasite *Proteosoma*, or, as Ross now calls it, *Hæmamœba relicta*, of the avian malaria from bird to bird; but it will not carry the parasite of human malaria. Indeed, 14 different species of *Culex* have been tried in this respect, and in each case with negative results. The same nice adjustment of parasite to host is found in *Anopheles*. It will not convey the bird malaria, that is to say, the gametocytes are destroyed in its body, but it is readily infected by the human parasite, and at the present date a considerable number of species have been successfully tried, and this not only in Europe, but in Africa, India, and the United States.

Anopheles is obviously worth studying. It has now been found very commonly distributed in England, *A. maculipennis* abounding in the eastern counties. Its boat-shaped eggs, laid, not as are those of the genus *Culex*, in little rifts, but singly, give rise to a charming little larvæ, whose diet of minute algæ gives a greenish tint to the centre of the body, which elsewhere is of a brownish hue. When at rest, these small larvæ float on the water parallel with the surface, and not hanging down into the water as does the larval *Culex*. They have a most beautiful arrangement of minute hairs, arranged like the ribs of an umbrella turned inside out, along the upper surface of their backs, and by the action of these hairs they hang on to the surface-film.

Their breathing organs open near the tail, but are not produced into the long respiratory tube by which the *Culex* larva can be so easily recognized. They possess the most marvellous arrangements on the head for setting up currents conveying food to the mouth, and, in fact, they afford one of the most charming objects of ‘animated nature’ that one could desire to watch. After some days, varying in number according to the temperature, the larva turns into one of those curious active Dipterous pupæ which are well known in the case of other gnats. Like the larva, the pupa floats at the surface of the water. When mature its integument splits along the back; then the perfect insect steps out, rests a moment to dry its wings, and sails away into the air.

It is very doubtful if the male *Anopheles*, which can easily be distinguished from the female by its bushy feathered tentacles, quite visible to the naked eye, ever sucks blood. The habit in the female is possibly prompted by a desire to obtain material for the growth of the ova. Out of the numerous genus *Culex* only four species are known in which the male bites; and it is probable that malaria is always conveyed from man to man by the activity of the female. It is difficult to say how long mosquitoes live in the imago state—certainly, if fed, for many weeks. The earlier collectors, not knowing how to feed them, used to cork them up in glass tubes, and then, noticing in a day or two that the poor insect had died, retired to their studies and wrote moral essays on the brevity of life, or learned treatises on the duration of life in relation to the methods of ovipositing. Now we feed the imagos—as a rule, on bananas—and they live well in confinement. The fertilized female survives the winter, hibernating in some dusky corner, and it is probable that some of the eggs also carry the species over the cold months from autumn to the following spring.

It should, perhaps, be mentioned that the infected mosquito does not transmit the parasites to its offspring. This was an important point to ascertain, because it is known that the tick which causes Texas fever does transmit its parasite to the young ticks, and they in turn communicate the disease to the oxen. A somewhat similar case of the transference from parent to offspring of an organism causing disease is that of the Pébrine, caused by a parasite which attacks silkworms, and which is conveyed by the infected ova from one generation to another.

The above short résumé of the life-history and habits of *Anopheles* has been given as a prelude to the important question: What can be done to diminish malaria? A few years ago, before we understood the cause of the disease, much had been done to lessen it. While aiming at other objects, we drove malaria out of England by draining. Now that we know the secret of the disease we can direct our efforts more intelligently. There are two points exposed to attack. The first is the sporulating organism in the blood of man, the second is the insect. If we could eliminate the organism from man, the mosquito would be saved much suffering, and would be powerless to infect man; or, if we could prevent the mosquito from access to man, either by guarding him against its bites or by killing off the insect, the hæmotozoön would, in the course of time, gradually die out.

Both methods should be tried. Malarious patients should, so far as possible, be treated with quinine, and no effort should be spared to free their system from the parasite. Special precautions, such as hanging up mosquito curtains, etc., should be taken to prevent the access of the mosquito to the patient; otherwise he acts as a centre of infection. It is almost equally important to protect the healthy man living in a malarious place. The mosquito net must be carefully made, and let down over the bed well before sunset; its free edges should be tucked under the mattress, and the greatest care should be taken to prevent the ingress of a mosquito, especially when slipping within the curtains. Punkahs should be employed as much as possible; they certainly tend to keep the *Anopheles* at a distance. In the summer of 1899 an experiment was initiated by Sir Patrick Manson which must convince even those least open to conviction that malaria is preventable if proper precautions be taken. That the bite of an infected mosquito can convey malaria may be taken as proved by the voluntary submission of Mr. T. P. Manson to the experiment, as recounted in the *Times*.[5] This gentleman allowed himself to be bitten, in this country, by insects previously fed on malarious patients; and in due course the disease—tertian ague—showed itself in him. To prove the other side of the case required even more courage and endurance. During the spring of 1899, Dr. Low and Dr. Sambon, of the London School of Tropical Medicine, with Signor Terzi, an Italian artist, and two servants, have been living in a mosquito-proof hut, near Ostia, in the Roman Campagna, and remained in perfect health. The spot selected for this experiment is so malarious that the Romans regard spending a single night there as equivalent to contracting a virulent type of malaria. Yet, when Professor Grassi and several other experts visited the mosquito-proof hut on September 12, 1900, they found the inhabitants in perfect health—a fact which they telegraphed, with their salutations, to Sir Patrick Manson, ‘who first formulated the mosquito-malarial theory.’ The conditions under which Dr. Low and Dr. Sambon and their Italian companions lived were all directed to the avoidance of being bitten by mosquitoes. During the daytime they were allowed out of their hut, because the chance of being bitten in broad daylight is so small that it may be neglected; but they were ‘gated’ an hour before sunset, and were not allowed out until an hour after sunrise. The mosquitoes were kept out of the hut by the use of wire-gauze doors and windows. By these precautions contact between mosquito and man has been avoided, and man has now lived for months in one of the most malarious spots in Europe without acquiring a trace of malaria. It is most satisfactory to record that a similar success has attended the efforts of the Italian authorities to improve the state of things in the great plain of Salerno. Visitors to Paestum and Battipaglia cannot fail to have noticed how malaria has marked that district as its own. By taking such precautions as are indicated above, the peasants and railway signalmen have, during the last few years, for the first time, escaped the disease; whilst for the first time newcomers to the district have failed to contract it. The intelligent activity of the Italian Government, and the well-known interest taken in the question by the King and Queen of Italy, cannot fail to have a profoundly beneficial effect upon the lives of some of the poorest and most hard-working of European peasantry.

The problem in Africa is more complex, owing to the fact that the native population is thoroughly permeated with the parasite. Mr. Christophers and Dr. Stephens, in their ‘Further Reports to the Malaria Committee,’ have shown that the children of natives are in the great majority of cases infected with malaria. In one village where the *Anopheles* was found in ‘considerable numbers,’ 90 per cent. of the babies suffered, 57 per cent. of the children up to eight years, 28 per cent. of the children up to twelve years, after which age the children were ‘very rarely infected.’ This is but one example out of many, all tending to show that after a time a certain immunity to the disease is acquired, and, further, that travellers should as far as possible avoid the neighbourhood of native villages, and, above all, decline to sleep in native huts.

The destruction of the mosquito, at any rate in neighbourhoods inhabited by man, is a matter of difficulty, but is worth attempting. To expect to destroy the mature insect seems a vain thing, but the larva can be more easily dealt with. *Anopheles*—unlike the common gnat, which breeds close to houses, in cisterns, garden fountains, old tubs, drains, etc.—prefers rain-water puddles, natural hollows by the roadside, small ponds, and rice-fields. We have occasionally found the larvæ of *Anopheles* and *Culex* in the same water in England, but this is probably exceptional. In England, so far as our experience goes, the *Anopheles* larvæ are usually met with in shallow water easily heated by the sun's rays; and we have always found them in association with the common green water-weed *Spirogyra*, though they are not known to eat this.

Attention to the standing water round houses or near towns will do much to diminish the scourge of mosquitoes. All pots and pans containing water should be regularly turned out once a week, and puddles should be brushed out. The larva takes some seven days to develop, so that once a week suffices to destroy each brood. All useless water should be drained away and stagnant ponds filled up. The introduction of fish has markedly diminished the number of mosquitoes around the late Mr. Hanbury's celebrated garden at La Mortela on the Riviera. They eagerly devour the larvæ, and should be made use of in all large areas of water. For smaller areas some 'culicide' should be tried, and more experiments in this direction are urgently needed. One of the simplest remedies known is kerosene oil. A piece of rag tied to a stick should be dipped into the oil, and then applied to the surface of the water. The oil diffuses in a fine film over the surface and clogs the breathing tubes of the larval insect; it possibly interferes with the action of the surface tension—at any rate, the larvæ die. Fresh tar has the same effect. This 'painting' of the water must be renewed once a week. Wells and cisterns should be kept closed. A more careful selection of the site for houses, and a more liberal use of wire-netting mosquito shutters, will do much to minimize the risk to Europeans in malarious districts.

The various remedies suggested above have been tried with success in different parts of the world. The writer has been assured by an old inhabitant of Colombo that the mosquitoes have distinctly diminished in number in parts of that town since the custom of storing water near the houses was abandoned. During the summer of 1900 the authorities at Sassari in Sardinia claim to have 'practically exterminated the mosquitoes … by killing the larvæ in the swamps with petroleum, and the flies with chlorine and other destructive chemicals.'[6]

The extinction of malaria in England is a kind of by-product of the draining operations which restored to the agriculturist large tracts of land in the fen districts and elsewhere. The breeding-places of the mosquitoes were dried up and their numbers materially lessened; at the same time the parasite was killed in an increasing number of patients. Thus the mosquitoes which survived had fewer opportunities of infecting themselves, and as time went on the parasite was ultimately eliminated. *Anopheles*, though in diminished numbers, is still with us, and is especially to be found in those parts of England once infested with the malaria; but the parasite has disappeared.

'INFINITE TORMENT OF FLIES'

Where the water is stopped in a stagnant pond,
Danced over by the midge.
R. Browning: 'By the Fireside.'

The last few years of the nineteenth and the first few years of the present century are marked in the annals of medicine by a great increase in our knowledge of certain parasitic diseases, and, above all, in our knowledge of the agency by which the parasites causing the diseases are conveyed from host to host.

Chief among these agencies in carrying the disease-causing organisms from infected to uninfected animals are the insects, and, amongst the insects, above all the flies. Flies—*e.g.*, the common house-fly (*Musca domestica*)—can carry about with them the bacillus of anthrax, and, if brought into contact with a wounded surface, may thus set up an outbreak of woolsorter's disease. Flies, ants, and other even more objectionable insects, are not only capable of disseminating the plague bacillus from man to man, and from rat to man, but they themselves fall victims to the disease, and perish in great numbers. They are active agents in the spread of cholera, and the histories of the South African and Cuban wars definitely show that flies play a large part in carrying the bacilli of enteric fever from sources of infection to the food of man, thus spreading the disease. They are also accused of conveying the inflammatory matter of Egyptian ophthalmia, and of the 'sore-eye,' so common in Florida, from one human being to another.

The diseases already mentioned are caused by bacteria. But flies also play a part in the conveyance of a large number of organisms which are not bacteria, but which, nevertheless, cause disease, and cause it on the largest scale.

Of all the twenty-two orders into which the modern entomologist divides the class Insecta, that of the Diptera, or true flies, is, perhaps, the easiest to recognize, for it is characterized by one very obvious feature, the presence of the fore-wings only. The hind-wings are replaced by a pair of small-stalked, club-shaped 'balancers,' which are readily visible in some kinds of fly—*e.g.*, the daddy-long-legs—but in others are by no means conspicuous. Thus it is an easy matter to determine whether an insect be a fly or not. To determine what particular kind of fly it be is, however, a very different affair. At present some forty thousand species of Diptera are known, and have been more or less completely described or figured; and Mr. D. Sharp estimates that this number is 'only a tithe of what are still unknown to science.' Further, the group has been rather neglected. Flies, speaking generally, are neither attractive in their appearance nor engaging in their habits, and it is a cause for no astonishment that entomologists have preferred to work at other groups.

In considering the part played by flies in disseminating diseases not caused by bacteria, we can neglect all but a very few families, those flies which suck blood having alone any interest in this connexion.

From the point of view of the physician, by far the most important of these families is the Culicidæ, with over three hundred described species and five sub-families, of which two, the Culicina and the Anophelina, interest us in relation to disease. The gnats or mosquitoes—the name is indifferently used, and has no scientific application—are amongst the most graceful and most beautiful insects that we know, but they have been judged by their works, and undoubtedly are unpopular, and we shall see that this unpopularity is well deserved. Gnats belong both to the genus *Culex* and to the genus *Anopheles*. The genus *Culex*, from which the order takes its name, includes not only our commonest gnat, often seen in swarms on summer evenings, but some hundred and thirty other species. Members of this genus convey from man to man the *Filaria nocturna*, one of the causes of the widely-spread disease filariasis, one variety of which is the elephantiasis, so common in parts of the tropics. In patients suffering from this disease minute embryonic round-worms swarm in the bloodvessels of the skin during the hours of darkness. Between six and seven in the evening they begin to appear in the superficial bloodvessels, and they increase in number till midnight, when they may occur in such numbers that five or six hundred may be counted in a single drop of blood. After midnight the swarms begin to lessen, and by breakfast-time, about eight or nine in the morning, except for a few strayed revellers, they have disappeared from the superficial circulation, and are hidden away in the larger bloodvessels and in the lungs.

In spite of their incredible number—some authorities place it at thirty to forty millions in one man—these minute larval organisms, shaped something like a needle pointed at each end, seem to cause little harm. It might be thought that they would traverse the walls of the bloodvessels and cause trouble in the surrounding tissues; but this is prevented by a curious device. It is well known that, like insects, round-worms from time to time cast their skins, and the young larvæ in the blood cast theirs, but do not escape from the inside of this winding-sheet; and thus, though they actively wriggle and coil and uncoil their bodies, their progress is as small and their struggles as little effective as are those of a man in a strait-waistcoat.

The causes of the periodicity of the appearance of these round-worms in the superficial bloodvessels are not completely understood, but they appear to have more relation with the usual sleeping hours of humanity than with day and night. In individuals who sleep by day and work by night the *Filaria nocturna* is found in the bloodvessels of the skin during the day. Thus, whilst between 5 p.m. and 7 or 8 a.m. the vessels of the skin of Cox the Hatter would be well peopled by the round-worms, they would only come to the surface in Box the Printer during the daytime, whilst he was sleeping in the lodgings of Mrs. Bouncer.

One reason of the normal appearance of the creatures in the blood at night is undoubtedly connected with the habits of its second host, the gnat or mosquito. Two species are accused of carrying the *Filaria* from man to man—*Culex fatigans* and *Anopheles nigerrimus*. Sucked up with the blood, the round-worms pass into the stomach of the insect. Here they appear to become violently excited, and rush from one end to the other of their enveloping sheath, until they succeed in breaking through it. When free, they pierce the walls of the stomach of the mosquito, and come to rest in the great thoracic muscles. Here the *Filarias* rest for some two or three weeks, growing considerably, and developing a mouth and alimentary canal; thence, when they are sufficiently developed, they make their way to the proboscis of the mosquito. Here they lie in couples, and it would be interesting to determine whether these couples are male and female. Exactly how they effect their exit from the mosquito and their entrance into man has not yet been accurately observed, but presumably it is during the process of biting. Only inside man they work their way to the lymphatics, and very soon the female begins to pour into the lymph a stream of young embryos, which reach the bloodvessels through the thoracic duct. It is, however, the adults which are the source of all the trouble. They are of considerable size, three or four inches in length, and their presence, by blocking the channels of the lymphatics, gives rise to a wide range of disease, of which elephantiasis is the most pronounced form. We can consider later how the disease can be averted by keeping down the number of gnats and by preventing their access to infected patients.

We now pass to the second of the diseases carried by gnats, that of malaria.

The parasite which causes malaria is a much more lowly organized animal than the *Filaria*. It is named *Hæmamœba*, and it, too, is conveyed by an insect, and, so far as we know, by one genus of mosquito only, the *Anopheles*. Hence, from the point of view of malaria, it is important to know whether a district is infected with *Culex* or *Anopheles*. The former is rather humpbacked, and keeps its body parallel with the surface it is biting, and its larva hangs at an angle below the surface of the water, by means of a respiratory tube. *Anopheles*, on the other hand, carries its body at a sharp angle with the surface upon which it rests, and its larva lies flat below the surface-film and parallel with it. The malarial parasite lives in the blood-cells of man, but at a certain period it breaks up into spores, which escape into the fluid of the blood, and it is at this moment that the sufferer feels the access of fever. The presence and growth within the blood-cells result in the destruction of the latter, a very serious thing to the patient if the organisms be at all numerous. If the spores be sucked up by an *Anopheles*, they undergo a complex change, and ultimately reproduce an incredible number of minute spores or ‘blasts,’ each capable of infecting man again if it can but win entrance into his body.

Under normal circumstances, for each *Filaria* larva which enters a mosquito, one *Filaria* issues forth, longer, it is true, and more highly developed, but not much changed. The malaria-parasite undergoes, in its passage through the body of the *Anopheles*, many and varied phases of its life-history. As the Frenchman said of the pork, which goes into one end of the machine in the Chicago meat factories as live pig, and comes out at the other in the form of sausages, ‘Il est diablement changé en route.’ The mosquito is as truly a host of the malarial parasite as man, and is as necessary for its full development as is man. Judging by the number and extent of the lesions in the insect’s body, it must suffer far more than man, and it is undoubtedly killed at times, and perhaps fairly frequently, by the parasite.

Whoever has watched under a lens the process of ‘biting’ as carried on by a mosquito, must have observed the fleshy proboscis (*labium*) terminating in a couple of lobes. The labium is grooved like a gutter, and in the groove lie five piercing stylets, and a second groove, or *labrum*. It is along this labrum that the blood is sucked. Between the paired lobes of the labium, and guided by them (as a billiard cue may be guided by two fingers), a bundle of five extremely fine stylets sinks slowly through the epidermis, cutting into the skin as easily as a paper-knife into a soft cheese. Four of these stylets are toothed, but the single median one is shaped like a two-edged sword. Along its centre, where it is thickest, runs an extremely minute groove, only visible under a high power of the microscope. Down this groove flows the saliva, charged with the spores or blasts of the malaria-causing parasite. Through this minute groove has flowed the fluid which, it is no exaggeration to say, has changed the face of continents, and profoundly affected the fate of nations.

It is an interesting fact that, amongst the Culicidæ, it is the female alone that bites. The mouth-parts of the male are weaker, and seem unable to pierce the skin. It has been suggested that a meal of blood is necessary for the development of the eggs; but the evidence for this is not conclusive. There must be millions and millions of mosquitoes in sparsely inhabited or uninhabited districts, in Africa, in Finland, in Northern Asia, and America, which never have a chance of sucking blood; and it is impossible to believe that these millions do not lay eggs.

The female is undoubtedly greedy. If undisturbed, she simply gorges herself until every joint of her chitinous armour is stretched to the cracking-point. At times even, like Baron Munchausen's horse after his adventure with the portcullis, what she takes in at one end runs out at the other. But she never ceases sucking. The great majority of individuals, however, can never taste blood, and subsist mainly on vegetable juices. In captivity they cannot last longer than five days without food and drink; but they can be kept alive for weeks on a diet of bananas, pineapples, and other juicy fruits.

Anopheles is often conveyed great distances by the wind, or in railway trains or ships; but of itself it does not fly far; about five or six hundred yards—some authorities place it much lower—is its limit. Beyond this distance they do not voluntarily stray from their breeding-places. Both *Anopheles* and *Culex* lay their eggs, as is well known, in standing water, and here three out of the four stages in their life-history—the egg, the larva, and the pupa—are passed through. The larva and the pupa hang on to the surface-film of the water by means of certain suspensory hairs, and by their breathing apparatus. Anything which prevents the breathing tubes reaching the air ensures the death of the larva and pupa. Hence the use of paraffin on the pools or breeding-places. It, or any other oily fluid, spreads as a thin layer over the surface of the pools and puddles, and clogs the respiratory pores, and the larvæ or pupæ soon die of suffocation.

In Ismailia the disease has been reduced to an amazing extent, and quite recently remarkable results have followed the use of these preventive measures at Port Swettenham, in the Federated Malay States. Within two months of the opening of the port in 1902, 41 out of 49 of the Government quarters were infected, and 118 out of 196 Government servants were ill. Now, after filling up all pools and cleaning the jungle, no single officer has suffered from malaria since July, 1904, and the number of cases amongst the children fell from 34·8 to 0·77 per cent. The only melancholy feature about this wonderful alleviation of suffering due to the untiring efforts of the District Surgeon, Dr. Malcolm Watson, is that his fees for attending malarial cases have dropped to zero.

Thus a considerable degree of success has attended the efforts of the sanitary authorities, largely at the instigation of Major Ross, all over the world, to diminish the mosquito plague. It is, of course, equally important to try and destroy the parasite in man by means of quinine. This is, however, a matter of very great difficulty. In Africa and in the East nearly all native children are infected with malaria, though they suffer little, and gradually acquire a high degree of immunity. Still, they are always a source of infection; and Europeans living in malarious districts should always place their dwellings to the windward of the native settlements. Knowing the cause, we can now guard against malaria; mosquito-nets and wire windows and doors are a sufficient check on the access of *Anopheles* to man. If they could only be kept permanently apart, we might hope for the disappearance of the parasite from our fauna. In relieving man from the pest, all lovers of animals will rejoice that we are also relieving the probably far more acute sufferings of one of the most delicate and beautiful insects that we know.

Another elegant little gnat, *Stegomyia fasciata*, closely allied to *Culex*, with which, until recently, it was placed, is the cause of the spread of that most fatal of epidemic diseases, the yellow fever. Like the *Culex*, but unlike the *Anopheles*, *Stegomyia* has a humpbacked outline, and its larva has a long respiratory tube at an angle to its body, from which it hangs suspended from the surface-film of its watery home. It is a very widely distributed creature; it girdles the earth between the Tropics, and is said to live well on shipboard. It breeds in almost any standing fresh water, provided it be not brackish. The female is said to be most active during the warmer hours of the day, from noon till three or so, and in some of the West Indies it is known as the 'day-mosquito.'

The organism which causes yellow fever has yet to be found. It seems that it is not a bacterium, and that it lives in the blood of man. It evidently passes through a definite series of changes in the mosquito, for freshly infected mosquitoes do not at once convey the disease. After biting an infected person, it takes twelve days for the unknown organism to develop in the *Stegomyia* before it is ready for a change of host. The mosquitoes are then capable of inoculating man with the disease for nearly two months. The period during which a man may infect the mosquito, should it bite him, is far shorter, and extends only over the first three days of the illness.

Very careful search has hitherto failed to reveal the presence of the parasite of yellow fever. By its works alone can it be judged. It seems that, like the germ of rinderpest and of foot-and-mouth disease, it is ultra-microscopic, and our highest lenses fail to resolve it. From the course of the disease and the nature of its host, it will probably prove to be something like the organism which causes malaria. The means of warring against *Anopheles* and *Culex* are equally applicable in the case of *Stegomyia*, but, since the last-named flies by day, they are more difficult to carry out, and more irksome to endure. By the intelligent application of these preventive measures the Americans have freed Havana for the first time from yellow fever, and have materially reduced the amount of malaria, and they have been equally successful at Panama.

King Solomon sent to Tarshish for gold and silver, ivory, and apes and peacocks, and at the present day people mostly go to Africa for gold, diamonds, ivory, and game. These are the baits that draw them in. Of the great obstacles, however, which have for generations succeeded in keeping that great continent, except at the fringes, comparatively free from immigrants, three—and these by no means the least important—are insignificant members of the order Diptera. We have considered the case of *Culex* and *Anopheles*; the third fly we have now to do with is the tsetse fly (*Glossina*), which communicates fatal diseases to man and to cattle and domesticated animals of all kinds.

There are at least seven species of the genus which received its name as long ago as 1830, when Wiedemann first described it. Perhaps the best known species is *Glossina morsitans*, which was named by Westwood.

The members of the genus *Glossina* are unattractive insects, a little larger than our common house-fly, with a sober brownish or brownish-grey coloration. When at rest the two wings are completely superimposed, like the blades of a shut pair of scissors; and this feature readily serves to distinguish the genus from that of all other blood-sucking flies, and is of great use in discriminating between the tsetse and the somewhat nearly allied *Stomoxys* and *Hæmatopota*.

The tsetse flies rapidly and directly to the objects it seeks, and must have a keen sense of smell or sight, or both, making straight for its prey, and being most persistent in its attacks. The buzzing which it produces when flying is peculiar, and easily recognized again when once heard. After feeding, the fly emits a higher note, a fact recalling the observation of Dr. Nuttall and the present writer on the note of *Anopheles*, in which animal they observed that, 'the larger the meal, the higher the note.' The tsetse does not settle lightly and imperceptibly on the sufferer as the Culicidæ do, nor does it alight slowly and circumspectly after the manner of the house-flies, but it comes down with a bump, square on its legs. Like the mosquito, the tsetse is greedy, and sucks voraciously. The abdomen becomes almost spherical, and of a crimson red, and in the course of a few seconds the fly has exchanged the meagre proportions of a Don Quixote for the ampler circumference of a Sancho Panza. There is a good deal of discrepancy between the reports of the various sufferers as to the pain of the bite. No doubt different persons are very differently affected, and suffer to very varying degrees. Unlike so many of the blood-sucking Diptera, in which the habit is confined to the females, both sexes of *Glossina* attack warm-blooded creatures.

The fly always seems to choose a very inaccessible portion of the body to operate on—between the shoulders in man, or on the back and belly in cattle and horses; even inside the nostrils in the latter, or on the forehead in dogs. According to Lieutenant-Colonel D. Bruce, R.A.M.C., to whom we owe so much of our knowledge of this fly and its evil work, the female does not lay eggs, but is viviparous, and produces a large active yellow larva, which immediately crawls away to some secluded crevice, and straightway turns into a hard, black pupa, from which the imago emerges in some six weeks. Thus two stages, the egg and the larva, both peculiarly liable to destruction in the Culicidæ, are practically skipped in the tsetse—at any rate, in some species. On the other hand, this advantage is probably to a great extent counterbalanced by the smallness of the number of the larvæ produced, compared with the number of the eggs laid by the oviparous Diptera.

The genera of the Culicidæ which we have considered are found practically all over the world, but the genus *Glossina*, except that it just reaches Arabia, is fortunately confined to Africa. From the admirable map of the geographical distribution of the fly compiled by Mr. Austen we gather that its northern limit corresponds with a line drawn from the Gambia, through Lake Chad to Somaliland, somewhere about the 13th parallel of north latitude. Its southern limit is about on a level with the northern limit of Zululand. The tsetse, of course, is not found everywhere within this area, and, though it has probably escaped observation in many districts, it seems clear that it is very sporadically distributed. Mr. Austen further thinks that it may occur outside the boundary above laid down, and suggests that the great mortality amongst the horses in the Abyssinian campaign against King Theodore may have been caused by it.

Even where the tsetse is found it is not uniformly distributed, but occurs in certain localities only. These form the much dreaded 'fly-belts.' The normal prey of the fly is undoubtedly the big game of Africa, including crocodiles, but they are not the only factor in its distribution; the nature of the land also plays a part. There are the usual discrepancies in the accounts of travellers, especially of African travellers, as to the exact localities the *Glossina* affects; but most writers agree that the tsetse is not found in the open veld. It must have cover. Warm, moist, steamy hollows, containing water and clothed with forest growth, are the haunts chosen. Even within the fly-belt there are oases, due, perhaps, to an absence of shrubs or trees, where no flies are.

The tsetse fly belongs to the family Muscidæ, the true flies, a very large family, which also includes our house-fly, blue-bottle fly, etc. These flies, unlike *Anopheles* and *Culex*, are day-flies, and begin to disappear at or about sunset, a fact noted centuries ago by Dante:

> 'Nel tempo che colui, che il mondo schiara,
> La faccia sua a noi tien meno ascosa,
> Come la mosca cede alla zanzara.'[7]

The practical disappearance as the temperature drops has enabled the South African traveller to traverse the fly-belts with impunity during the cooler hours of the night. At nightfall the tsetse seems to retire to rest amongst the shrubs and undergrowth, but, if the weather be warm, it may sit up late; and some experienced travellers refrain from entering a fly-belt, especially on a summer's night, until the temperature has considerably fallen.

The sickness and death of the cattle bitten by the tsetse were formerly attributed to some specific poison secreted by the fly, and injected during the process of biting. It is now, largely owing to the researches of Colonel Bruce, known to be due to the inoculation of the beasts with a minute parasitic organism conveyed from host to host by the fly. The disease is known as 'nagana,' and the organism that causes it is a species of *Trypanosoma*, a flagellate Protozoon or unicellular organism, which moves by means of the lashing of a minute, whip-like process. Since Bruce's researches a number of *Trypanosomas* have been found causing diseases in various parts of the world. Thus *T. evansii* causes the 'surra' disease of cattle, horses, and camels in India. *T. equinum* produces the 'mal de caderas' of the horse-ranches of South America, and *T. equiperdum* is responsible for the North African disease called by the French the 'dourine.' *T. theileri* causes the gall-sickness, and there are others. These parasites were first seen by Gruby, who named them in 1843, in the blood of a frog; they live, not as does the malaria parasite, in the blood-cells, but in the fluid of the blood. The particular species of *Trypanosoma* which causes nagana is *Trypanosoma brucei*, and it does not attack man, and some goats and donkeys seem also immune; but, with these exceptions, all domesticated animals suffer, and in a great percentage of cases the disease terminates in death. Just as the native children in Africa form the source of the supply of the malarial parasite without appearing to suffer much, so the big game of the country abound in *Trypanosoma* without appearing to be any the worse. They are, in Lankester's phrase, 'tolerant' of the parasite, and a harmony between them and the parasite has been established, so that both live together without hurting one another. Under a more natural condition of things than at present obtains in South Africa, the big game formed the natural prey of the tsetse; and, indeed, so dependent is the fly on the antelopes, etc., that, in places where the game has been exterminated, the fly has also disappeared. It is from the big game that the disease has spread. In their bodies the harmful effect of the parasite has through countless generations become attenuated, but it leaps into full activity again as soon as the *Trypanosoma* wins its way into the body of any introduced cattle, horse, or domesticated animal. Whether the *Trypanosoma* does any harm to the fly, or whether it passes through any stages of its life-history in the body of the fly, is still a debatable point. Possibly it does not, and the proboscis of the fly acts then simply as an inoculating needle.

The Report of Colonel Bruce, which was issued three years ago, shows that the sleeping-sickness which devastates Central Africa, from the West Coast to the East, is also conveyed by a species of tsetse fly. Writing over a hundred years ago of Sierra Leone, Winterbottom mentions the disease. 'The Africans,' he says, 'are very subject to a species of lethargy which they are very much afraid of, as it proves fatal in every instance.' Early last century it was recorded in Brazil and the West Indies; and in all probability the deaths which our slave-owning ancestors used to attribute to a severe form of home-sickness, or even to a broken heart, were in reality caused by sleeping-sickness. The severity of the disease, which always terminates fatally, is shown by the fact that in a single island—Buvuma—the population has recently been reduced by it from 22,000 to 8,000, whilst whole districts have been almost depopulated. In one year the deaths in the region of Busoga reached a total of 20,000; and it is calculated that although the disease was only noticed in Uganda for the first time in 1901, that by the middle of 1904 100,000 people have been killed by it. The disease is caused by the presence of a second species of *Trypanosoma* in the blood and in the cerebro-spinal fluid. The existence of this parasite has now been proved in all the cases recently investigated. Apparently the *Trypanosoma* can live in the blood without doing much harm, and only when it reaches the cerebro-spinal canal does it set up the sleeping-sickness. It is also found in great numbers in the lymphatic glands, especially those of the neck, which in patients infected by the parasite are usually swollen and tender. From the similarity of the parasite to that causing the cattle disease of South Africa, the idea at once arose that the *Trypanosoma* was conveyed from man to man by a biting insect. Along the lake shores a species of tsetse (*Glossina palpalis*) abounds; and it was noticed that if the fly, having fed off a sleeping-sickness patient, bit a monkey, the monkey became infected. Further, flies which were captured in a sleeping-sickness district were also capable of conveying the disease to healthy monkeys. The proof that sleeping-sickness is due to a *Trypanosoma* known as *T. gambiense* present in the cerebro-spinal fluid of the patient, and that it is conveyed from man to man by *Glossina palpalis*, seems now complete. Fortunately, like its congener, *G. palpalis* is confined to certain districts. The knowledge of these, and of the habits of this species of fly, will suggest preventive measures; and the brilliant research of Colonel Bruce and his colleagues, Captain Grieg and Dr. Nabarro, may yet save the much-tried African continent from the most fatal of recent diseases.

Finally, we come to a last class of disease which is of the utmost interest to the agriculturist and settler, and yet at present is but little understood. These diseases are caused by various species of a Protozoon named *Piroplasma*, and the diseases may collectively be spoken of as piroplasmosis. When they are present in cattle they are spoken of in various parts of the world as Texas fever, tick fever, blackwater, redwater, and many other French, German, Italian, and Spanish names. Heartwater in sheep is a form of piroplasmosis. Horses also suffer, and the malignant jaundice or bilious fever, which makes it impossible to keep dogs in certain parts of this country, is also caused by a *Piroplasma*. Finally, under the name of Rocky Mountain fever, spotted or tick fever, the disease attacks man throughout the west half of the United States.

The organisms which cause the disease live for the most part in the red blood-corpuscles, but they are sometimes to be found in the plasma or liquid of the blood. Unfortunately, we know but little about the life-history of the *Piroplasma*, or of the various stages it passes through, but we do know how it is transmitted from animal to animal and from man to man.

We have seen that the carrier or 'go-between' in the case of the malaria is the mosquito, and in the case of the sleeping-sickness is the tsetse fly. The *Piroplasma*, however, is not conveyed from host to host by any insect, but by mites or ticks, members of the large group of Acarines, which include beside the mites the spiders, scorpions, harvestmen, and many others.

The ticks differ from the insect bearers of disease inasmuch as the tick that attacks an ox or a dog does not itself convey the disease, but it lays eggs—for I regret to say here, as with the *Anopheles*, it is the female only that bites—and from these eggs arises the generation which is infective, and which is capable of spreading the disease. The tick which conveys the *Piroplasma* from dog to dog is called *Hæmophysalis leachi*. The brilliant researches of Mr. Lounsbury have shown that even the young are not immediately capable of giving rise to the disease. The female tick gorges herself with blood, drops to the ground, and begins laying eggs. From these eggs small six-legged larvæ emerge. These larvæ, if they get a chance, attach themselves to a dog, gorge themselves, and after a couple of days fall off. If their mother was infected they nevertheless do not convey the parasite. After lying for a time upon the ground the larval tick casts its skin and becomes a nymph, a stage roughly corresponding with the chrysalis of a butterfly. This nymph, if it has luck, again attaches itself to the dog and has a meal, but it also fails to infect the dog. After a varying time it also drops to the ground, undergoes a metamorphosis, and gives rise to the eight-legged adult tick. Here at last we reach the infective stage; the adult tick is alone capable of giving the disease to the animal upon which she feeds, and then only when she is descended from a tick which has bitten an infected host. Think what a life-history this parasite has! Living in the blood-corpuscles of a dog, sucked up by an adult tick, passed through her body until it reaches an egg, laid with that egg, being present while the egg segments and slowly develops into the larva, living quiescent during the larval stage and the nymph stage, surviving the metamorphosis, and only leaping into activity when the adult stage is reached. This most remarkable story probably indicates that the *Piroplasma* undergoes a series of changes comparable to those of the malaria organism when it is inside the mosquito; what these stages are we do not at present know, but Dr. Nuttall and Mr. Smedley at Cambridge, and many other observers elsewhere, are at work on the problem, and soon we shall have more light.

With regard to bovine piroplasmosis, Koch, and others have distinguished redwater fever, which is conveyed by *Rhipicephalus annulatus*, and in Europe probably by *Ixodes reduvius* from the Rhodesian fever, which is conveyed by *Rhipicephalus appendiculatus*, and I regret to say by a species dedicated to myself, *Rhipicephalus shipleyi*.

The heartwater disease of sheep and goats is similarly conveyed by *Amblyomma hebræum*, the Bont tick, and many farmers accuse *Ixodes pilosus* of causing the well-known paralysis from which sheep suffer in the early autumn; and there are many others, diseases such as the chicken disease of Brazil, which is so fatal to poultry yards, and which is conveyed by the *Argas persicus*.

I will not weary you with more diseases. I think I have said enough to show that within the last few years a flood of light has been thrown upon diseases not only of man and his domestic animals, but upon such insignificant creatures as the mosquito and the tick. I have tried to show how these diseases interact, and how both hosts are absolutely essential to the disease. We can now to a great extent control these troubles; the old idea that there is something unhealthy in the climate of the Tropics is giving way to the idea that the unhealthiness is due to definite organisms conveyed into man by definite biting insects. We have at last, I think, an explanation of why Beelzebub was called the Lord of Flies.

THE DANGER OF FLIES

And Moses said, Behold, I go out from thee, and I will entreat the Lord that the swarms of flies may depart from Pharaoh, from his servants, and from his people, to-morrow.—Exodus.

It is one of those facts which not unfrequently occur in science that we know less about the life-history and habits of the commonest insects than we know about scarce and remote species. For instance, the life-history of the common house-fly, one of the most widely distributed insects in the world, is as yet very incompletely known.

It was Linnæus who first described this insect and named it *Musca domestica*, and de Geer who, in the middle of the eighteenth century, first described its transformation. In 1834 Bouché described the larva of the insect as living in the dung of horses and fowls. In 1873 the well-known American entomologist, A. S. Packard, reinvestigated the question, and L. O. Howard has recently written on the subject. In our own country C. Gordon Hewitt is publishing a monograph on the house-fly, which will, when completed, fill a long-felt want. Packard noted that in the August of 1873 the house-fly was particularly abundant, especially in the neighbourhood of stables. He was able to observe the insects laying their ova in clumps containing some 120 eggs in the crevices of stable manure, ‘working their way down mostly out of sight.’ The eggs hatched in about twenty-four hours, but he noticed that those hatched in confinement required from five to ten hours longer, and that these larvæ when hatched were smaller than those hatched out in the open. The eggs are oval and cylindrical, one twenty-fifth to one-twentieth of an inch long and about one-hundredth of an inch wide, and of a dull, chalky-white colour.

The little larva has not been seen emerging from the egg-case, but probably, as in the case of the meat- or blow-fly, *Musca vomitoria*, the eggshell splits longitudinally and the maggot pushes its way out. The length of the newly-hatched larva in its first stage (or instar) is seven-hundredths of an inch, and it remains in this stage about twenty-four hours, when it casts its skin and appears as a larger maggot three-twentieths of an inch long. In this condition it remains from twenty-four to thirty-six hours. After a second moult the maggot attains the length of one-quarter of an inch, and in this stage it remains five or six days. During its life the larva moves actively about amongst its surroundings, eating up the decaying matter, but avoiding bits of straw and hay. There is some evidence to believe that, if pressed for food, larvæ may devour one another. After living altogether some five to seven days, the larva somewhat suddenly turns into a dark brown pupa or chrysalis. The transition takes place very rapidly—in the course of a few minutes—and the pupa remains enclosed in the last larval skin. After another period of five to seven days in normal circumstances the insect hatches out, at first running around with soft and baggy wings, which, however, soon stretch out, harden, and dry. It is worthy of note that whereas Howard found the complete metamorphosis to take ten days, and Packard from ten to fourteen days, in the cooler climate of Manchester Hewitt finds it takes from twenty to thirty days. The last named gives some interesting particulars as to the effect of the weather upon the rate of development. It is believed that many flies pass the winter in the pupa state; the adult fly also survives the cold weather hidden away in cracks and crevices, from which it may from time to time emerge when the sun shines warmly.

When the larvæ are reared in too dry manure, they attain only one-half their usual size. Too direct warmth and the absence of moisture and available semi-liquid food also tend to dwarf them.

A word may be said about the distribution of the insect. It is practically cosmopolitan. As Mr. Austen records:

> ‘The British Museum collection, though very far from complete, includes specimens from the following localities: Cyprus; North-West Provinces, India; Wellesley Province, Straits Settlements; Hong Kong; Japan; Old Calabar; Southern Nigeria; Suez; Somaliland; British East Africa; Nyassaland; Lake Tanganyika; Transvaal; Natal; Sokotra; Madagascar; St. Helena; Madeira; Nova Scotia; Colorado; Mexico; St. Lucia; the West Indies; Pará, Brazil; Monte Video, Uruguay; Argentine Republic; Valparaiso, Chili; Queensland; New Zealand.’

It is carried all over the world in ships and trains, and seems to be equally at home in the high latitudes of Finmark or in the humid heat of Equatorial Brazil.

The diseases which flies convey from man to man—which rendered them by no means the least formidable of the plagues of Egypt, and fully justified Beelzebub's title of the 'Lord of Flies'—are for the most part conveyed mechanically. The proboscis acts as an inoculatory needle. No part of the life-history of the disease-causing organism must necessarily be carried on in the body of the fly; it is conveyed mechanically and without change from an infected to a healthy subject. The mouth parts can pick up the anthrax bacillus, and if the fly then alight upon a wounded surface it will set up woolsorter's disease. It, together with the flea, is accused of transmitting the plague bacillus, not only from man to man, but from rat to man. Flies are active agents in disseminating cholera; and anyone who has watched them clustering around the inflamed eyes of the children in Egypt, or in Florida, will not readily acquit them of being the active agents in the spread of inflammatory ophthalmia or of 'sore eye.'

It is worthy of note that after exhaustive experiments on the tsetse fly (*Glossina palpalis*), which conveys that most fatal of diseases, sleeping-sickness, Professor Minchin and his colleagues, Mr. Gray and Mr. Tulloch, have come to the conclusion that the Protozoon (*Trypanosoma gambiense*) which causes the disease does not—as might be expected—pass through certain stages of its life-history in the fly, but is mechanically conveyed upon the biting mouth parts of the insect. The deadly parasite is, indeed, so easily cleaned off these appendages that a single bite is sufficient to wipe them off. A tsetse fly which has bitten an infected person will set up the disease in the next person (or monkey) it bites; but the insertion of the proboscis, quick and instantaneous as it is, serves to clean it—to wipe off adhering trypanosomes, and if it now bite a second person (or monkey), it fails to convey the disease. This is a most important discovery, and contrary to what we should have expected; but our knowledge of the history of the genus *Trypanosoma* is still too small to justify generalization, difficult as it is to avoid it. The diseases which in our country are disseminated by flies are all bacterial and all mechanically conveyed.

In passing, it is worth recording that, contrary to the usual statement that tsetse flies are confined to the continent of Africa, Captain R. M. Carter[8] has recently brought some back from the Tabau River and from other localities in South Arabia. Mr. Newstead has recognized the specimens as belonging to the species *Glossina tachinoides*. It evidently does not live on big game here, since, except the gazelle, game is absent. The Bedouins say that it bites donkeys, horses, dogs, and man, but not camels or sheep. It is at times so troublesome as to force the natives to shift their camps.

The common house-fly has been known for some time to be an active agent in the dissemination of bacterial diseases. In intestinal disorders—such as cholera and enteric fevers, which are caused by micro-organisms, the flies convey the bacteria from the dejecta of the sick to the food of the healthy. In the recent war in South Africa they are described in the standing camps as dividing their activities 'between the latrines and the men's mess-tins and jam rations.'[9] In the Spanish-American War in Cuba, and in the South African War, and in several recent outbreaks of enteric fever in the British army in India, flies have been proved to be the carriers of the *Bacillus typhosus*. Dr. Veeder[10] writes:

> 'In a very few minutes they may load themselves with dejections from a typhoid or dysenteric patient, not yet sick enough to be in hospital or under observation, and carry the poison so taken up into the very midst of the food and water ready for use at the next meal. There is no long roundabout process involved. It is very plain and direct; yet when thousands of lives are at stake in this way the danger passes unnoticed.'

Similar records come from the Boer camp at Diyatalawa in Ceylon. The bacilli are conveyed direct, just as they might be by an inoculating needle. They do not pass into the body of the fly, neither do they undergo any part of their life-history in its tissue.

Dr. Sandilands[11] has recently investigated outbreaks of epidemic diarrhœa. He points out that the prevalence of diarrhœa follows the earth's temperature, and does not follow the temperature of the atmosphere. It is a well-known fact that this illness is more prevalent in the houses of the poor than in the mansions of the rich. As Dr. Newsholme, late Medical Officer of Health for Brighton, said:

> 'The sugar used in sweetening milk is often black with flies which have come from neighbouring dust-bins or manure heaps; often from the liquid stools of diarrhœa patients in the neighbouring houses. Flies have to be picked out of the half-emptied can of condensed milk before it can be used for the next meal. When we remember the personal uncleanliness of some mothers, and that they often prepare their infants' food with unwashed hands, the inoculation of this food with virulent colon bacilli of human origin ceases to be a matter of surprise.'

Compared with cow's milk, which nourishes a very numerous progeny of bacteria, the bacterial content of Nestlé's milk is very low, according to Dr. Sandilands. In certain seasons the cow's milk is exposed to temperatures which favour an enormous multiplication of bacteria, and yet it is not then a frequent source of diarrhœa—in fact, mere numbers have little or no influence on the incidence of the illness. The greater number of cases are due to infection conveyed from some patient in the near neighbourhood and conveyed mechanically by flies.

The great attraction of the sweetened condensed milk for flies to some extent explains the greater prevalence of infantile diarrhœa among children fed on this preparation.

As was stated above, one of the most remarkable features in the prevalence of infantile diarrhœa is that it follows the rise and fall of the earth's temperature, and not that of the air. In the same way the number of house-flies does not reach its maximum with the first burst of hot weather. The prevalence of these insects follows rather than coincides with periods of great heat. The flies, in fact, lag behind the air temperature and persist for a time after the hot weather has ceased. In other words, the meteorological conditions associated with an increase or a diminution of the prevalence of diarrhœa exercise a similar influence on the prevalence of flies.

The transference of the *Filaria bancrofti*, whose presence in the human body in the adult stage is associated with various diseases of the lymphatics, the most pronounced of which is the terrible elephantiasis, is due to more than one species of gnat or mosquito. It is true that no one has ever seen the actual transference of the *Filaria* from the biting organs of the *Culex*, *Anopheles*, *Panoplites*, or *Stegomyia* into the human body, but the circumstantial evidence is so strong that on it any jury would convict. Noè and

Grassi have demonstrated a similar mode of infection for the *Filaria immitis*, which exists in the adult stage in such incredible numbers in the cavity of the right side of the heart of dogs, especially in tropical and in sub-tropical countries, that it is difficult to see how the circulation can be maintained at all. It is therefore interesting to note that the proboscis of our common house-fly frequently harbours a larval nematode which has been described by Carter[12] under the name of *Habronema muscæ*; and again (if it be the same species) by Generali[13] under the name *Nematodum sp.* (?), and again by Piana,[14] who is inclined to think it is the larval form of *Dispharagus nasutus* (Rud.). What the further history of this parasite is we do not conclusively know, but, judging by analogy—and in the case of the grosser parasites it is not always wise to do that—the nematode probably develops in some higher animal which eats the fly. Piana brings forward a good deal of evidence that this is the domestic fowl.

Another parasite which attacks flies is the fungus or mould *Empusa muscæ*, whose growth is fatal to the insect. The hyphæ penetrate into the body, and as they grow weaken the fly until it is unable to lift a leg, but remains glued by its viscid feet to the object upon which it rests. The fungus spreads and radiates out in all directions, covering the fly as with a velvety pile, and giving off countless minute spores, which are blown away, to alight, if they are lucky, on a further victim.

I think enough has been said to prove that flies are a very real danger to our community. I have refrained from giving the appalling statistics of our infant mortality, partly because of the difficulty of discriminating between the claims of the flies and those of other agencies which affect the lives of our babies—*e.g.*, the insurance companies which do a large trade in insuring infants. Legislation has not attempted to control the latter. Sanitation might do much to destroy the former. In well-administered towns slaughterhouses no longer ‘fill our butchers’ shops with large blue flies’; they have been replaced by abattoirs, under proper inspection. Stables should also be segregated or controlled. The practice of backing the mansions of Berkeley Square by stable yards should either be given up, or the manure-heaps in which the flies breed should be under cover so close as to prevent the access of the fly. A layer of lime spread over the manure effectively prevents the fly laying. Creolin, in its cheap commercial form, is also recommended, sprayed over the manure-heaps every two or three days. It not only deters flies from ovipositing, but should they succeed in doing so it kills the resulting larvæ.[15]

Ross has shown us how to clear Ismailia of malaria; the Americans have rid Havana, for the first time in a century, of yellow fever; the same could be done with flies, if only the people liked to have it so. The motorcar, with all its destruction of nervous tissue, its prevention of sleep, its danger to life and to limb, has one great merit—it affords no nidus for flies.

CAMBRIDGE

‘*Our dear Cambridge.*’
Cowley:
‘On the Death of Mr. William Hervey.’

The grant of a charter to the Victoria University in 1880 marked the beginning of a new era in English education. Not to speak of Scotland and Wales, there are in England to-day six Universities which bring the new learning and the old to the very doors of the vast populations which surround their seats. Birmingham claims the Midlands; Manchester, Liverpool, Leeds, and Sheffield instruct the manufacturing and commercial centres of the North; while the University of London, full of new aspirations, does its best for the huge and somewhat apathetic population of the capital. The calculated prodigality of the State endowments of Germany, the individual generosity of the citizens of the United States, the vigour of the young Universities of Canada, have smitten the national conscience, if not with shame, at least with fear. But, while so powerful a lever as the dread of industrial decay may have been necessary to overcome the intellectual inertia of the country, the consequent impetus given to the study of science and (it may be hoped) of letters is not dying away, but rather taking permanent shape; and it is now impossible to say, as was said in 1903 by one of the members of the Mosely Educational Commission, that ‘in this country ... we seem to be doing nothing for its own sake, and least of all in education.’

The new edition of the ‘Endowments of the University of Cambridge’ suggests other, though kindred, reflections. The book has for its basis a series of documents, beginning with the year 1293, and ending with the year 1904. The learned Registrary has prefaced the account of each bequest with an explanation, and, by his discriminating comment, has invested his material with something of that charm which characterizes all his work. In one aspect his book serves, and is intended to serve, as a history of the progress of education in Cambridge; and the large amount of new matter which has been incorporated since the previous edition of the ‘Endowments’ in 1876 is, in this aspect, highly satisfactory. Yet, though it is a mistake to suppose that the flow of benefactions to the ancient Universities has entirely ceased, the fact remains that Cambridge has twice appealed—once in 1898, and once again in the spring of 1904—for help, without which she cannot meet her national responsibilities. Oxford has at last been constrained to confess that she is in a similar, if not yet so dire, a strait; and it is easy to understand the effort which it has cost her, as well as her sister University, to sue *in formâ pauperis*.

In truth, the neglect, almost absolute, of Oxford and Cambridge, while the new Universities are finding generous benefactors, either leads to the conclusion that the old Universities are condemned and found wanting, or has its origin in a profound misconception of their efforts and resources. It may be urged that neither alternative is true; that the needs of the new Universities are more urgent, and that the needs of Oxford and Cambridge will in turn receive attention. But a delay of a few years may in these days involve damage which will not be repaired for more than one generation. Of Cambridge, at any rate, it is asserted that she is at the end of her means, that in the last forty years she has, in her efforts at development, strained her resources to the utmost, and that without assistance, which, to be effectual, must be both prompt and generous, no further advance is possible. Science has emptied the University chest, yet, as the late master of

Trinity Hall said, ‘Science is still hungry and aggressive.’ As the result of her straitened resources Cambridge can no longer satisfy the just demands either of science or of letters. When we compare this state of things with that in Germany, where the University of Berlin enjoys a State endowment of £170,000 per annum, or in the United States, whose Universities have received from private benefactors alone £42,000,000 sterling in the last thirty years, apart from large funds provided by the State, we are forced to recognize that much yet remains to be done in England.

It is not difficult to suggest some reasons for the comparative neglect of the older Universities in the matter of benefactions. In the first place, neither of them can appeal to local patriotism; and an appeal on the wider ground of national efficiency is not so easily nor so effectively pushed home. Next, it is hard to imagine that a University whose colleges enjoy a corporate income of something like £300,000 a year can be in serious want of funds. Moreover, if this deficiency really exists, it is generally regarded as the result of the squandering of revenue on an extravagant system of ‘prize fellowships’—that is, fellowships given as the reward merely for a high place in examination, and held by barristers, doctors, and civil servants, professors and lecturers in other Universities, and even successful men of business—persons who do not contribute in any way to the efficiency of the University as a teaching or as an investigating body.

We propose briefly to examine the University balance-sheet, the college system, and the question of the fellowships, and to endeavour to give the candid inquirer some ground for a judgment on the claims of Cambridge. But we must first discuss what is perhaps the most serious obstacle to the satisfaction of her needs. This obstacle is the belief, apparently ineradicable, that the older Universities teach and care for nothing but the ancient languages, theology, and mathematics. For the persistence of this belief the daily press and public speakers are in a great measure to blame. Scarcely a week passes without an allusion which betrays, if not a culpable levity, a most unfortunate ignorance. Cambridge men have listened with amazement to the covert attacks on Cambridge science, and have wondered how long it may be before Cambridge letters are also disparaged. Of late, too, another note has been heard; and, notwithstanding the just aspiration of the new Universities to a many-sided activity, alike in the literary and scientific fields, an attempt, which must be stigmatized as ungenerous and illiberal, has been made in the press and on the public platform to limit the functions of the ancient Universities, and to drive them back into the grooves of the thirties and forties, from which Cambridge, to say nothing of Oxford, has so completely escaped. Whatever the reason may be, it is at least certain that Cambridge is frequently written and spoken of as if she were still the Cambridge of 1850.

It has been suggested, even in responsible journals, that Oxford and Cambridge would do well to keep to the older lines of education, and to leave newer studies to their younger rivals. The obsession of men’s minds by an ideal which passed away half a century ago can alone account for the impression that the policy of restriction to the ancient learning is in any way possible, or has been possible for these fifty years. Those who know Cambridge may well be astonished that responsible persons should gravely speak of the University of Newton and Charles Darwin, of Maxwell and Rayleigh, as still shrouded in medieval shadow.

It cannot be too often repeated that since the Commission of 1850, or rather since the promulgation of the new statutes in 1856, the University has advanced without pause to claim as her own the whole field of modern knowledge; and that it is the rapidity of her advance which has depleted her treasury. The state of things before 1850 need here be referred to only for purposes of contrast. The only avenue to an honours degree was then the Mathematical Tripos, or, for students of classics, the Mathematical combined with the Classical Tripos. Science formed no part of the regular course of instruction. Adam Sedgwick himself, pre-eminent geologist as he afterwards became, knew nothing of geology when admitted to his professorship. When he was appointed to his chair, classics, mathematics, and, in a less degree, theology and law, were well endowed; but effective provision for modern studies or for science there was none. In 1851 was founded the Disney professorship of archæology, and the creation of this chair may fairly be considered to be the first step towards the recognition of the sciences of ethnology and anthropology. The imperial value of ethnological and anthropological research is incontestable, and to this research no more important contribution has been made than by the bands of Cambridge travellers and students.

Mention has been made in the first place of the studies more closely related to the ‘humanities,’ because it does not seem generally to be realized how thoroughly even the ancient learning is to-day imbued by the scientific spirit. But, so early as the year 1851,[16] new avenues to an honours degree were opened by way of the Moral Sciences Tripos (embracing at present psychology, logic and methodology, political economy, ethics, metaphysical and moral philosophy and psychophysics), and the Natural Sciences Tripos (embracing chemistry, physics, mineralogy, geology, botany, zoology, human anatomy, and physiology). In 1857 the Sadlerian professorship of pure mathematics was founded by the consolidation of an old endowment; and Cayley was the first occupant of the chair. In 1863 the block of buildings known as ‘The Museums’ was commenced, with a view to providing accommodation for the professors of the natural sciences; additions were made to the original buildings in 1877, 1880, 1882, 1884, and 1890, as new branches of science became important. In 1858 the ‘Civil Law Classes’ were replaced by the Law Tripos; the professor of civil law and the Downing professor of the laws of England were given a colleague by the creation of the Whewell professorship of international law in 1867; and the Law School has since 1904 possessed a worthy habitation, built partly at the expense of the University, partly by the help of eminent Cambridge lawyers, and completed by the generous donation of the law library by Miss Squire. In 1866 the professorship of zoology was founded.

The School of Medicine has grown continuously; and its progress is associated with the great names, to mention no others, of Sir George Humphry, Sir George Paget, and Sir Michael Foster. In 1883 were founded the professorships of surgery, physiology, and pathology. The diploma of public health was instituted in 1875, and the diploma in tropical medicine—the first of its kind in the kingdom—in 1904. The latter diploma is destined to a brilliant future in Cambridge; and the University, together with the schools of tropical medicine in London and Liverpool, is doing much to raise the scientific standard of research in a study so vitally important to the teeming populations of our tropical possessions. The students attending the School of Medicine in Cambridge number nearly four hundred, despite the high standard of the attainments necessary for qualification. In 1904 important new buildings, with provision for bacteriology, pathology, and public health, were opened by the King.

The year 1869 was marked by the foundation of the Slade professorship of fine art, and the professorship of Latin. The endowment of the latter chair is but £300 a year, half provided by the University and half by the friends of the late Dr. Kennedy, the famous headmaster of Shrewsbury School. That the University should have had to wait till 1869 for the foundation of a chair of Latin, and that the parsimonious contribution of £150 a year was all that could be spared towards the stipend of the professor, scarcely lends colour to the prevailing belief that the University, kindly and naturally as she may be disposed towards the old learning, squanders on the teaching of ancient languages resources which ought to be otherwise employed. In 1875 the Historical Tripos was founded; and the School of History, starting under the influence of Seeley, has become one of the most popular avenues to an honours degree. A professorship of ancient history was founded in 1898.

The Historical Tripos already provided in some measure for the study of political science and political economy as component parts of a liberal education. But latterly the need for a more thorough study of economic conditions has been felt to be imperative for those who look forward to a career in the higher branches of business or in public life; while, as regards the professional economist, it has been realized that his work as a student must be carried much farther than has hitherto been customary, if he is to attack with success those problems which bring his science close to reality and to the needs of the practical man. A Tripos in Economics has therefore been established, the first examination for which was held in 1905. The advanced portion of it includes such subjects as modern methods of production, transport and marketing, trusts, the recent development of joint-stock companies, railway and shipping organization and rates, banking systems, stock exchanges, investment markets, international aspects of credit and currency, tariffs and bounties; and it is expected that, as in the second parts of most other triposes, a mass of new work, the result of current research, not yet available in text-books, will be placed before the students.

The Medieval and Modern Languages Tripos dates from 1886. It provides for the study of English, French, German, Spanish, Italian, and Russian. A colloquial test has recently been added. The Semitic Languages Tripos was established in 1878; the Indian Languages Tripos was founded in 1879, and merged in the Oriental Languages Tripos in 1895. The University founded a professorship of Sanskrit in 1867; and a chair of Chinese has existed since 1888. The University possesses the finest Chinese library in the world outside of China, the gift of Sir Thomas Wade. Provision is made for the teaching of Arabic, Persian, Turkish, Hausa, Burmese, and the Indian vernaculars of Bengali, Hindustani, Marathi, and Tamil. The teaching of living Oriental languages for the benefit of practical students is carefully co-ordinated under a recently appointed director of studies; and not only are the most necessary languages taught in their living forms by competent scholars, but these latter are assisted by a staff of carefully selected native *répétiteurs*. Towards the expenses of this work the University contributes about £2,800 a year. A professorship of Anglo-Saxon was founded in 1878.

In 1871 the chair of experimental physics was founded, a chair held in succession by Clerk Maxwell, Lord Rayleigh, and J. J. Thomson; and in 1874 the famous Cavendish laboratory, the munificent gift of its late chancellor to the University, was opened. The laboratory was designed by Maxwell; and the chancellor himself, soon after its completion, provided all the instruments which were immediately required. In 1894 the area of the laboratory was increased, the cost being defrayed, in part, by a sum of £2,000 saved by Professor Thomson out of fees received from students; but the constant pressure on the available space by research students coming from all quarters of the globe rendered further extension urgently necessary, an extension which Lord Rayleigh’s generous gift of the Nobel Prize has now enabled the University to undertake. Astronomy has a traditional home in Cambridge; and the observatory, which in 1706 found a strange temporary site over the gateway of Trinity College, began to be built on its present site in 1822. The observatory, which takes its regular share of the work mapped out for the observatories of Europe, has received important additions in the shape of both building and equipment in recent years.

In 1875 the professorship of mechanism and applied science was established; and in 1878 the first engineering workshops were built in the University, and fitted with machine tools and other necessary equipment. In 1894 the new engineering laboratories were opened during the tenure of the professorship by Dr. Ewing, now director of naval education. In 1894, also, the first examination for the Mechanical Sciences Tripos, which gives a degree in honours to students of engineering, was held. In 1899 the generosity of Mrs. Hopkinson and her family made possible the addition of a much needed new wing to the laboratory. The buildings of the department now contain lecture-room accommodation which seats about 360 students simultaneously, a drawing-office for a class of ninety, two rooms for elementary heat and mechanics, a boiler-room, an engine-room with ten heat-engines of different types, arranged so that the measurement of all quantities concerned may be systematically made by the students, a large room for dealing with strength of materials and with hydraulics, a dynamo-room fitted with various kinds of dynamos, a motor-room fitted with motors of all the usual types, and several other rooms for special purposes. The greater part of the staff have had practical engineering experience of some kind; and it is usual during the long vacation for one or two members of the staff, as well as a number of the students, to go into a drawing-office or into works in order to keep in touch with practice. The school numbers at present more than 250 students, and supplies young engineers with a scientific training to various public services, as well as to mechanical and electrical firms.

The University chemical laboratory was built in 1887; and, while planning it, the professor of chemistry spent some months in visiting the newest laboratories on the Continent and in America. The importance of botany has of late years so greatly increased that its study is represented in Cambridge by a professor, a reader, and two University lecturers, besides demonstrators, assistant demonstrators, and attendants. In 1904 botany was housed in a separate building of its own, the finest devoted to that science in the United Kingdom, and one of the finest in Europe. The physiology of plants, bacteriological research, and the cultivation of hybrids and seedlings, are completely provided for. The extensive botanic garden belonging to the Senate is at the disposal of the staff and the students, the more distinguished of whom, after completing their degree course in Cambridge, start on a course of research in this country or abroad. The importance of the department as touching agriculture on its scientific side can hardly be overestimated.

The professorship of agriculture was founded in 1899, and endowed for a term of years by the munificence of the Worshipful Company of Drapers, a body which, with commendable breadth of view, recognizes alike the importance of applied scientific instruction for the artisan and of scientific investigation in all forms of the national activity. The department of agriculture is conducted on the most practical and progressive lines. It provides instruction in the principles of agriculture for the sons of landowners, farmers, and others. It conducts experiments on crops and live stock, making every effort to secure the intelligent co-operation of farmers. The University experimental farm, for the use of which the department is indebted to the generosity of a member of Clare College, has an area of 140 acres. The County Councils of Cambridgeshire and nine neighbouring counties co-operate in the work and assist it by subsidies. The field experiments of the department extend over ten counties. Parties of farmers visit the experimental plots every season in order to see the results of the experiments and to discuss them with members of the staff; and reports which summarize these results are widely distributed in the districts concerned. Of the suitability of Cambridge as a site for a school of agriculture, and of the importance of the work undertaken by the school, it may be well to leave the late professor to speak for himself.

> ‘I have but recently become a member of the University, and, like a good many others, I at one time doubted the possibility of founding a thoroughly satisfactory school of agriculture in one of the old English Universities. But I no longer doubt; and as one who, before coming to Cambridge, was a teacher or student in five British Universities, I will venture to say that nowhere else do such opportunities exist. Apart altogether from the exceptional facilities for the study of science possessed by the University, and apart, too, from the exceptional practical skill of the farmers in the surrounding counties, the old University appears to me to be more disposed to extend a helping hand to agriculture than many of her younger sisters; and nowhere has a more friendly reception been given than at Cambridge to the new organization fostered by the activity of the Board of Agriculture....
>
> ‘American experience leaves no room for doubt that modern scientific methods are capable of greatly increasing the prosperity of agriculture, and that the farmer has no better ally than the laboratory worker. But, if we wish to make these benefits ours, we must cease to be satisfied with imported information; ... we must aim at securing for agriculture the services of British specialists, men who will give their whole time to the study of one subject under the conditions which prevail in our own country. To the extent of our resources this has been the policy of our agricultural department in Cambridge.
>
> ‘We are in the centre of the finest land in England; we already have an organization by which we reach the farmer; we know his wants; and the University has supplied us with well-qualified teachers of applied science. If we were in possession of suitable laboratories, properly equipped for research, we should find competent investigators and willing assistants among the younger members of the University who are always ready to engage in original work, either with the view of gaining knowledge or in order to qualify themselves for appointments.’

In considering the development of all these departments, and the foundation of the chairs and other teaching posts made necessary by them, it must be remembered that the professorships already existing before 1850 included, among others, those of chemistry, anatomy, botany, geology, mineralogy, medicine, physic, political economy, moral philosophy, modern history, Arabic, and music; that these chairs had, before the Commission of 1850, no very important duties attached to them; and that in the last fifty years each has been adapted to its place in the University system, and each has in turn become a new centre of activity round which, to use a convenient term unfamiliar in Cambridge, a ‘faculty’ has crystallized. To many important developments it has been possible to allude only in the most cursory manner. The merest mention must suffice for the diploma in geography; the diploma in mining engineering, with its provision for practical experience in mines in this country or abroad; the diploma in forestry, which is a logical outcome of the development of the botanical and agricultural schools; the provision for military studies, and the Day Training College for teachers. The latter has both a primary and a secondary department, and the certificate given by the University in the theory, history, and practice of education, and for practical efficiency, attracts teachers in great numbers from all parts of the country.

Development so wide and so rapid as that which we have sketched has been of necessity costly. The expenditure since 1862 on buildings devoted to science alone must have considerably exceeded £300,000, the greater part having taken place in the latter years of the period; and it must be remembered that the University has had also to equip and maintain the observatory, the cost of which is not included in the amount just mentioned, and to spend large sums on the University library. Except in one or two cases, in which a special benefaction fund had been appropriated to adornment by the desire of the benefactor, these buildings have been erected with the strictest regard to economy. The amount expended cannot be said to be an inordinate sum for a modern University to have spent on scientific buildings and equipment. Yet even this expenditure would have been impossible without external help.

The cost of the maintenance of the buildings erected and of the very inadequately paid staffs, now presses on the limits of the available income; and it is contended that but little more can be attempted for many years, if ever, without external aid. We will proceed, then, to a rough analysis of the resources of the University and colleges, and of the allotment of these resources. Before doing so, however, it may be well to state that the colleges provide adequately, but not extravagantly, for the teaching of classics and mathematics, for elementary teaching in many other subjects, and for individual assistance to the student and supervision of his work in the subjects taught in the University. The collegiate system also ensures a close contact and intercourse between teacher and student not otherwise or elsewhere attainable. The University, in its teaching aspect, may be regarded as an organization for providing instruction in all those branches of knowledge the teaching of which cannot be economically undertaken by the colleges. Thus, for the teaching of science, and for the provision of costly laboratories, the University is responsible; and the higher and more specialized teaching in most other departments is also provided by the University. The ancient endowments are, in the main, college endowments; but the history of the development of modern subjects is also the history of the development of the University; and it is the University rather than the colleges which is at present in need of substantial financial help. But to suppose that the colleges do not heartily co-operate in the University teaching would be erroneous; at the present time one college may be better organized than another for this particular purpose, but the colleges may safely be trusted soon to come into line.

The corporate income of the seventeen colleges is, roughly, £310,000 per annum. This, with a sum of about £52,000 (called the Tuition Fund), received annually from the lecture and laboratory fees of the 3,200 students, and £30,000 received annually by the University for degree and other fees, constitutes the whole available income for college as well as University purposes, if we except certain Trust Funds for the endowment of some professorships, and those funds of the nature of charities of which the colleges are merely administrators.

The corporate income of the colleges consists of (1) endowments, usually in the form of estates, which bring in £220,000 a year; (2) fees, rent of rooms, profits on kitchens, and so forth, which bring in £90,000. But the colleges are great landowners and have the outgoings of landowners. Though the expenses of the estate management are only about 7 per cent. of the revenues arising from the estates, yet £130,000 a year are spent on management, repairs, and improvements on the estates, rates and taxes,[17] interest on loans, and the maintenance of the costly college buildings in Cambridge. Many of the latter are national monuments of surpassing interest, the proper care of which is a duty to the nation. When allowance has been made for the inevitable expenditure under these heads, there is left only £180,000 for all other purposes. The fellowships and the stipends of the heads of houses absorb £78,000; and the contributions of the colleges towards scholarships, as determined in the main by statute, and as distinct from any separate endowment, account for £32,000.

An analysis of the distribution of the fellowship money may conveniently be deferred for the moment; but it may be stated that the sum spent on scholarships finds, inside the University at least, many critics. The expenditure on scholarships is undoubtedly, however, in the main, a fulfilment of the intentions of their founders, and, if we may judge by the recent expenditure of County Councils, is in accordance with public feeling. After deduction of fellowships and scholarships, there is left of the corporate income a sum of £70,000. Of this sum, £32,000,[18] or nearly one-half, is paid as a direct contribution to the University; but, as will be seen immediately, the colleges contribute to the University in many other ways. Of the £38,000 remaining, £4,000 goes to supplement the Tuition Fund of £52,000 received from the students as fees; the sum of £56,000 so obtained is applied to the provision of college and University lecturers. A large proportion of these fees is paid to the scientific departments of the University; and of the fees so paid the greater part is assigned as a contribution to the maintenance of the several departments, and not, directly at least, to the payment of lecturers.

Deducting the sum of £4,000, contributed by the colleges to the Tuition Fund, we have left over of the corporate income a sum of £34,000, or about £2,000 per college, available for the payment of college officers and servants, the expenses of the college libraries, printing, and other expenses. If, then, it can be shown that the £78,000 spent on the fellowships is not extravagantly allotted—and of this more below—it is clear that the colleges can contribute but little more than they do at present to the University teaching.

An idea of the serious effect of the fall of agricultural rent on the college incomes may be gathered from the fact that one of the larger colleges has in the last thirty years suffered a loss of revenue amounting to £10,000 a year.

We now turn to the question of the fellowships. The sum of £78,000 was in 1904 divided among seventeen heads of houses and about 315 ordinary fellows. Of this sum the heads of houses received among them, as far as can be ascertained, the not excessive amount of £15,000, very unequally divided. The average stipend of a fellow is thus about £200 per annum. When the last Commission sat, the maximum stipend of a fellow was fixed at £250; and it was thought that this sum would usually be reached. But, except in the case of one or two colleges, which are the fortunate possessors of town property, the maximum is now never reached; and in certain cases the value of a fellowship has fallen to less than £100 per annum. Of the 315 fellows, some 245 were in 1904 resident and some 70 non-resident. Of the residents, about 225 were holding some University or college office, educational or administrative. Of the non-residents, and of the residents who were holding no office, the greater number had earned their fellowships by holding some qualifying position, such as a lectureship for a given number of years, usually twenty. Among the non-residents, in addition to fellows who hold their fellowships as a pension, were to be found students who are prosecuting research away from Cambridge; such students are, as a rule, liable to be summoned to reside, as college exigencies may demand. Several other non-residents are fellows who have but recently received appointments away from Cambridge; their fellowships will, under the new statutes, lapse in a year or two.

The analysis shows that the number of ‘prize fellowships’ is small; and it is believed that they are steadily vanishing. To assist the reader in obtaining a general idea of what is done with the fellowships, the combined result in the case of two colleges is here given. The two colleges in question have been chosen because the writers happen to be in a position to account for the occupant of every fellowship in each college. As will be seen, the two colleges render most valuable assistance to the University; and they have practically rid themselves of the burden of prize fellowships imposed on them by the Commission of 1856. The two colleges dispose, according to the University calendar of 1905-6, of forty fellowships between them. Of these, five are pension fellowships; five are held by professors in the University, as part of their stipend; twelve are held by University lecturers, demonstrators, or other University officers; eleven are held by college officers or lecturers; five are held by research students in Cambridge; two junior fellowships are held by non-residents. One of the latter was recently appointed to a professorship in another University, and his fellowship has just lapsed; the other holds a prize fellowship. It is unlikely that, when his fellowship lapses, another prize fellow will be elected in his place. There are in residence at each of the two colleges a number of University lecturers and officers, and of college lecturers, for whom no fellowship can be found. Speaking generally of the fellowships allotted to college teaching, it may be said that, with the help of a portion of the Tuition Fund, they enable the colleges to provide the college lecturers with stipends on which an unmarried man, occupying rooms in college, may comfortably live. When we turn to the University lectureships, there is often another tale to tell.

The University income, which has to bear almost the whole cost of modern developments, is made up of the following items: matriculation, degree, examination, and other fees, £30,000; direct contributions from colleges, £32,000; income from endowments, £2,000—£64,000 in all.

In 1904 the University, in the course of its ordinary work, expended £65,300, distributed roughly as follows:

	£
Officers, secretaries, and servants	4,100
Maintenance of business offices, registry, senate house, and schools	1,300
Rates and taxes	3,400
Obligatory payments from income	1,300
Stipends of professors	12,400
Stipends of readers, University lecturers, demonstrators, and other teachers	9,100
Maintenance and subordinate staff of scientific departments (including the botanic garden and observatory)	9,600
University library, staff, and upkeep	6,300
Examiners' fees, etc.	5,900
Debt on buildings, sites, sinking fund, and interest on building loans	8,500
Printing and stationery	2,600
Pension funds (professors, £200; servants, £150)	350
Miscellaneous expenses	450
	£65,300

There are forty-four professors, very few of them receive £800 or more a year (including fellowships), while the lowest limit of a professor's stipend, unless he holds a fellowship, is about £90 a year. The average annual income of a professor is not more than £550, and of the yearly revenue of £24,000 required to produce this average, £7,000 are paid in the shape of fellowships by the colleges, and about £4,600 from the income of special trust funds and other benefactions, one payment of £800 a year being for a term of years only. One or two professors at most receive a proportion of the fees paid for lectures and laboratories in their respective departments. There are twelve University readers (or sub-professors). The new statutes contemplated for a reader the salary of £400 a year, but, owing to the inadequacy of the University income, none receives more than £300, and in several cases only £100 is paid. There are fifty-three University lecturers whose stipends range from £200 a year to £50, and it is melancholy to note how many of these receive the lower sum, without any assistance from endowments, such as fellowships or the like. There are thirteen University teachers, almost all of them appointed by the Board for Indian Civil Service studies, and occupied, in the main, in teaching eastern dialects; and there are forty-four demonstrators, curators, and superintendents of museums, whose stipends range from £200 a year to nothing at all.

The incomes of some of these gentlemen are supplemented by fellowships, of others by a share of lecture fees; a few, too, may hold two such offices as curator and lecturer simultaneously. But, when the addition from all sources (about £8,000 from fees or special funds, and £13,000 from fellowships) has been made to the annual sum (£9,100) which the University has to give, we arrive at a total of about £30,000, giving the surprisingly low average income of £250 a year for any University teacher other than a professor. A few of the older teachers may hold some college office which adds a little to their income, but these are rare exceptions. There are no resources from which these incomes may be increased according to the service of the holder, and there is practically no provision for pension, except in the case of those teachers (less than one-half of the whole number) who hold fellowships, and may expect, after many years of service, to earn the right to retain them permanently.

In these circumstances it is not surprising that the University finds a difficulty in retaining many of its abler teachers. At the beginning of 1904 it was estimated that over two hundred professors and lecturers at other Universities (as distinct from University colleges) in the United Kingdom had been educated at Cambridge, and, though that is by no means a matter for regret, yet it is not too much to say that, in supplying this demand for teachers, the University has done a great national work for which she is poorly requited by her difficulty in retaining a sufficient staff for herself. Fortunately, when all other funds are exhausted, the fund of patriotism remains inexhaustible. It is not known how many fellows, possessed of some private means, and attached to the University through sheer love of their work, return their stipends to their colleges to be employed for the general good; such men are always anxious that their names should be concealed, but the present writers know of three in the restricted circle of their immediate personal friends. The special correspondent of the *Times* writes, on the occasion of the royal visit in 1904:

> 'I may be permitted to say, as the result of my personal inquiries, that the amount of work done either gratuitously or for very inadequate remuneration by professors, readers, lecturers, demonstrators, and other teachers in many departments of study and instruction, really constitutes a very substantial endowment, freely contributed by men who have no worldly goods to give, but who give lavishly of their time, their energy, their intellectual capacity, their acquired knowledge, and their disinterested devotion to the advancement of learning. If this asset were evaluated in pounds, shillings, and pence, the University balance-sheet would wear a very different aspect.'

On a consideration of the analysis just made, and of the additional facts that the Reserve Fund set aside by the University for building and equipment during the years of her development is now exhausted, and that her borrowing powers have been seriously reduced, it would appear that further progress is almost entirely dependent on an increase of endowment.

A few years ago certain of the University authorities, foreseeing the approach of a financial crisis, put away their pride, and, with the countenance of the chancellor, boldly begged for help. Their appeal resulted in the collection of about £100,000, which has been expended on the erection and equipment of various buildings devoted to science, such as the museum of geology and the botany school, the University itself contributing a large proportion of the expense incurred. In the list of contributors occur the names of no fewer than 500 Cambridge men, past and present, out of a total of 620 names. This number is a sufficient retort to the suggestion which has been made that Cambridge does not help herself. It must be remembered, too, that a sum of about £14,000 a year is contributed by members of the Senate to the funds of the University and of the colleges for the privilege of continued membership, and that these fees are often paid out of very slender incomes on grounds which are, as a rule, purely patriotic.

In enumerating the needs of the various departments it is fitting that the older studies and their modern developments should be first passed in review, for, though in certain respects these studies are well equipped, and though the provision of what is necessary would not be so costly as in the case of science, yet, in the deficiency of income available for development, there is real danger that the humanities may be starved.

Theology is well endowed by the piety of former generations. Yet the present Bishop of Winchester, when Hulsean Professor of Divinity, pleaded for an increased stipend for the professors which would permit them to save enough to retire upon; and, in view of the small sum, £200 a year, which the University is able to pay to its pension fund, such an increase cannot be said to be unreasonable. In law, a new post for the teaching of jurisprudence, or of jurisprudence combined with Roman law, is the chief requirement. The teaching of Latin and Greek is largely and effectively supplemented by the provision made by the colleges, but the demand for a professorship instead of a readership in classical archæology cannot be called extravagant, while it is little short of scandalous that the University possesses no professor, and can make no permanent provision for the study of ancient philosophy.

The teaching of Oriental languages is perhaps more dependent than that of any other subject on the self-sacrificing generosity of the staff. Though but a nominal stipend and a nominal duty attach to his chair, the Lord Almoner's professor of Arabic voluntarily undertakes a large share of the teaching. The payment of the Talmudic reader, depending mainly on the generosity of a private person, is guaranteed only during the tenure of the present reader. The cost of the colloquial teaching of spoken Arabic, Turkish, and Persian by native instructors is guaranteed, and sometimes in part provided, by the Sir Thomas Adams professor of Arabic. The professor of Chinese has the inadequate stipend of £200; and the professorship terminates with the tenure of the present holder. Apart from the necessity of providing teaching for practical students, the proper care of the Chinese library alone renders the permanence of the professorship a necessity. There is no professorship or readership of Japanese. The stipend of the present lecturer in Persian is inadequate. Egyptology is not provided for, although there is a fine collection of mortuary objects in the Fitzwilliam Museum; and Assyriology, although the professor of Assyriology at King's College, London, lives in Cambridge, is wholly unrepresented. No provision is made for the teaching of the Iranian dialects. Altogether some £2,000 a year could well be spent in Oriental languages alone.

There is no chair of English literature in the University. The professorship of Anglo-Saxon is a recent endowment. By the exertions of the occupant of that chair a sum of £2,100 has been collected, which yields an endowment of £60 a year for an English lectureship. To this small stipend the University adds £50 a year. It is not surprising that the distinguished student who has so long occupied the post should at last have been attracted to London by a higher stipend.

French and German are represented by two readers, who in the last twenty years have taken a large share in the development of a sound and growing school. In the provision for the teaching of modern languages, Cambridge ought not to be behind the northern Universities; and it is most desirable that professorships should be established in at least French and German. The University is indebted to a private fund for a small endowment for the lectureship in Russian and other Sclavonic tongues. This lectureship should be made permanent; and lectureships should be established in Spanish and Italian.

As in the case of classics and mathematics, the University teaching in history is largely supplemented by the colleges; but the Regius professor pleads for an additional reader and two lecturers. A central building with professors' rooms and lecture-rooms and accommodation for the professorial library is urgently required.

The newly-established school of economics and politics is in urgent need of three or four lectureships, to which definite duties in research should be attached, in order to extend the present range of economic study, and to bring it close to the great problems of modern industry. While in the Universities of Edinburgh, London, Manchester, Leeds, North and South Wales, and Montreal, political economy is taught by economists trained at Cambridge, their *alma mater* is starved of the means necessary to produce their successors.

The anthropological collections are, for want of space, in a chaotic state. The University is fortunate in possessing many ardent workers; and its collections are most valuable. The existing museum of archæology and ethnology is, however, quite inadequate for their display, or even for their storage; and a disused warehouse has been hired at Newnham to accommodate the further collections which generous donors continue to present. To such an extent has it been necessary to carry the economy practised in this department that the shelves of the warehouse have been made from old boxes. A site for a new museum has been provided by the University, and plans have been prepared; but without the help of extraneous benefactions it is impossible to build at present. An adequate building would cost perhaps £25,000. The removal of the museum to a new site would set free space greatly needed for other purposes. The Disney professor of archæology and the curator of the archæological museum plead also for the foundation of a chair, or at least a readership, for the comparative study of religions; and, in view of the relations of the Empire to every kind of cult, it is scarcely creditable that neither of the older Universities makes any provision for this study.

The present staff consists of the Disney professor of archæology, and a lecturer on ethnology with a salary of £50 a year. The only accommodation for the latter is a room in the basement of the medical school, where he takes classes in practical work. Physical anthropology is associated more directly with the department of human anatomy, and is represented by another lecturer at £50 a year. The collection of skulls brought together by Professor Macalister affords unrivalled material for demonstrations; and, as two recent volumes from the pen of Dr. Duckworth show, good use is made of the material. The University has recently recognized the importance of anthropology by adopting a scheme for granting degrees for research in this subject.

The growing importance of the architect's profession, and the widespread recognition of the fact that the young architect must have a preliminary scientific training, point to the desirability of establishing a school of architecture at Cambridge, resting on the one hand on the engineering school, and on the other on the Slade professorship of fine arts, and the school of archæology. The school might be organized on lines similar to those of the medical school; and the young architect would pass his early years of professional study on thoroughly practical lines, in the midst of admirable examples of almost all the different styles.

In 1877 Cambridge led the way in that difficult science called sometimes physiological psychology, sometimes experimental psychology, and sometimes psychophysics. In that year the present professor of mental philosophy and logic, and Dr. Venn, made a vigorous effort to establish a psychophysical laboratory. They unfortunately failed; had they succeeded, Cambridge would have possessed the first laboratory of this kind in the world. In 1878 Wundt opened his laboratory at Leipzig; and there are now some seven psychophysical laboratories in Germany, two in Russia, ten in the United States, one in Copenhagen, one in Paris, one in Geneva, and one in Canada. It is not that psychophysics is not studied in Cambridge, for Dr. Rivers, the lecturer on the subject, and Dr. Myers, have formed a school there which is second to none in Great Britain; this school has recently supplied a reader to Oxford. But the work is done under most discouraging circumstances. The laboratory is at present established in a dilapidated cottage in Mill Lane and in an adjacent disused granary. Further and better provision for this growing subject is urgent; and the present lectureship should be converted into a readership. The interest which is taken in the subjects under the control of the Board of Moral Science is shown by the successful launching of the *Journal of Psychology*, the first number of which was published by the University Press in 1904. Lecture-rooms and a departmental library are wanted; and the establishment of a readership in pedagogy should not be long delayed.

In mathematics two new professorships are needed, one in pure mathematics and one in applied mathematics; two of the present lecturers should be made readers; and the salaries of all the lecturers should be raised to £100 a year. One pressing need is that for two lecture-rooms, with an adjacent library and a museum of mathematical models. Cambridge is perhaps the most renowned mathematical school in the world; yet its provision for the accommodation of the staff is far behind that of the chief American Universities. A munificent benefactor has recently left a sum of £5,000 for repairs, etc., to the Newall telescope; but there is no stipend forthcoming for Mr. Newall, who for sixteen years has discharged the duties of observer without remuneration. The Lowndean and Plumian professors pay the salary of a demonstrator.

The Cavendish laboratory, owing to the position it has for years taken in the promotion of physical research, is overcrowded with students and researchers. Lord Rayleigh has most generously given to the University the Nobel prize gained by him in 1904. Of this benefaction, £5,000 have been assigned as a contribution towards the desired new wing; but money will be required for maintenance; and the professor estimates that a sum of £7,500 is now wanted for instruments, machinery, and laboratory fittings. The professor of chemistry asks for more apparatus and higher stipends for his teachers. He draws attention to the need for a metallurgical laboratory, the provision of which, in view of the recent establishment of a diploma in mining engineering, is urgent. Mineralogy asks only for a trained attendant and £35 a year; but for meteorology there is no real provision.

The Sedgwick museum, in which the department of geology is now housed, has involved much expense in furnishing. Although the existing furniture was all retained, there is still a demand for more cabinets; and Professor Hughes would like to spend £2,800 on these alone, while a large sum should be set apart for maintenance, wages, and the increase of stipends. The demands of botany are not yet completely satisfied. A readership to deal with the newly recognized study of scientific forestry has recently been created.

In zoology, if we leave out of account the need for higher stipends for teachers and higher wages for attendants, which runs like a thread through all the departments, there are two chief requirements. The first is for a new or, at any rate, a greatly enlarged museum. It is doubtful if the existing site is large enough to allow an adequate increase to the present structure; and to build a new building on another site would probably cost £30,000; nevertheless, with the ever-increasing collections housed in rooms already overstocked, this expenditure must soon be faced.

A branch of experimental science dealing with the study of variation and heredity in plants and animals has recently arisen, and has already attained very considerable proportions in Cambridge. It seems, indeed, that we are entering on a period when such studies will absorb the energies of most of the younger biological students. Under Mr. Bateson some twelve researchers are already at work following out Mendel’s law in many varieties of plant and animal. The extreme importance of these studies, which, if they prove a key to heredity, will place in man’s hands an instrument as powerful as Watt’s application of steam, is shown by the fact that Mr. Biffen has already discovered that susceptibility to rust in wheat is Mendelian, and is thus a property which may be eliminated by breeding. For all these studies land is required, as well as a greenhouse, outbuildings, and a trained gardener. None of these is as yet attainable.

The recent discoveries of the protozoic origin of malaria, sleeping-sickness, and other human and many other animal diseases, has directed attention both to the protozoa, with their complicated life-histories, and to the insects which convey them from one creature to another. Both protozoa and insects are highly specialized groups of animals. The establishment, by the aid of the Quick bequest, of a chair of protozoology will do something to meet the necessities of the case, so far as the protozoa are concerned; but some provision for the study of the insects is still needed.

A chair of physiological chemistry is urgently wanted. The pressing problems of the day in physiology require a chemical solution. Remarkable strides have already been made in this subject; the interaction of the various tissues of the body by means of the blood, the functions of the ductless glands, the problems of immunity, are all being worked out upon a chemical basis. In this country there are but two professors of physiological chemistry, whereas in Germany there are eleven, in Austria eight, in France six. That Great Britain is lamentably behind in this branch of learning is even more markedly shown when we consider the output of original memoirs. In 1903 over 3,000 papers, written by some 2,500 workers, were published; to this total the United Kingdom contributed no more than seventy. Cambridge has produced many brilliant physiologists; but the school cannot afford the outlay for even a necessary piece of apparatus costing £10; and the demonstrators pay, out of their pittances, part of the wages of their attendants.

The new medical schools, opened by the King in March, 1904, are but a portion of the original plan; and, until the remaining laboratories can be erected (at a probable cost of about £12,000), the various departments must necessarily be cramped. Many more teachers in special subjects are wanted, and the need of a professorship, or at least a readership, in hygiene is pressing. A new lecture-room is wanted in the department of human anatomy, which at present shares a room with physiology. A considerable sum is also needed for instruments, fittings, attendants, and libraries.

The school of engineering needs provision in metallurgy, mining subjects, and naval architecture; of the latter, in the greatest shipbuilding country of the world, but two chairs—one at Glasgow, and one at Newcastle-on-Tyne—exist. New workshops and engine-rooms are also greatly needed. The present workshops date from 1878, and are far too small for the demands on them. The provision of a sum of money which can be expended by the professor on the encouragement of research is much needed.

The department of agriculture is fairly well staffed, but at present is obliged to carry on its indoor work in four rooms in the basement of the chemical laboratory. The amount of research carried on by the staff has fully justified them in establishing the *Journal of Agricultural Science*, which appeared for the first time in 1904. This is the only periodical in the country devoted entirely to scientific agriculture. A laboratory for agriculture is a most pressing necessity; a site is available, but at present there is not sufficient money for the building, which, including provision for maintenance, would cost £20,000. The Drapers' Company has generously promised a conditional £5,000 towards this sum, and some £12,000 has been collected from other sources.

Besides numerous smaller needs, there are two of primary importance which have not yet been mentioned. The first is that for the provision of examination rooms. The University examinations are at present held in the Guildhall, the Corn Exchange, and other hired rooms, often badly lighted, badly heated, and badly ventilated, and in no case well adapted to the purpose of conducting examinations. The hiring and arranging of the rooms costs the University at least £450 a year.

The other great need is some adequate provision for that priceless national treasure, the University library. Mr. J. W. Clark has himself inaugurated an appeal on its behalf. The list of donors which he is already able to print is headed by His Majesty the King; and a sum of over £18,000 has already been collected. This sum includes a donation of £5,000 from the Goldsmiths' Company, and £2,700 assigned by Lord Rayleigh from the Nobel prize; to the remainder, resident masters of arts have largely contributed. When it has been shown by their contributions how keenly the residents feel on the subject of the library, it is hoped that some generous measure of help may be forthcoming from hands more able to give it. The library is the mainspring of University activity; and its well-being and good organization are important to all departments alike. Every member of the Senate, and every other person entitled to use the library, have access to the shelves; and no serious student, whether a member of the University or not, is refused.

But, in its restricted area, the library cannot expand further; and the result is congestion and inevitable disorder. The furniture and fitting up of the rooms recently rendered available for the library will cost some £15,000. Towards this expenditure the Financial Board has been able to grant only £5,000, spread over three years. The cost of furnishing a reading and reference-room is estimated at from £800 to £1,000. Further, an increase of the staff is urgently needed. The library grows at the rate of about 11,000 books per annum; and there are considerable arrears of cataloguing to be overtaken. The magnificent gift of Lord Acton's library, for which the University is indebted to Mr. Carnegie and Mr. John Morley, has involved considerable outlay. The number of volumes presented is about 59,000; the binding, cataloguing, printing of titles, and the provision of bookcases will cost about £8,000, to which the University has contributed £6,900. Gifts such as these are of priceless value to Cambridge; but they entail heavy expenditure. Additional assistants, moreover, are needed to look after them; and every new room added to the library increases the cost of maintenance. Altogether, it is estimated that a sum of £21,200 is required for present use; and that £3,800 a year is required for additions to the staff, the purchase and binding of books, and for the additional expense entailed by the Acton library. This annual income, if capitalized, represents a sum of £126,700.

Modern education is a costly thing; and when, in 1904, the heads of departments in the University made an estimate of the outlay necessary to place their several provinces in a state of efficiency, their deliberate and responsible calculations showed that a sum of £270,000 was required for building and equipment, and an additional annual income of £38,000 for the increase of salaries on the very moderate scale suggested, and for maintenance; in all, say a capital sum of a million and a half. Even this estimate takes no account of the desirability of providing pensions for professors who have reached the age of seventy. As the published list of benefactions shows, Cambridge has reason to be grateful to her recent benefactors. But to raise an endowment comparable to that of £1,400,000 which the Johns Hopkins University received from private munificence seems in this country to be hardly within the bounds of possibility.

Had an appeal such as that issued by Cambridge been made in the United States, there is little doubt that it would have met with a prompt response. There is in Montreal a University, officered largely by Cambridge men, and equipped with a princely magnificence of which Cambridge dares not even dream. Dr. Ewing's comment is pertinent. 'It is good,' said he, 'to see the colonial daughter sitting down to so lavish a table; but is it well that the *alma mater* at home should be left looking wistfully at the crumbs?' Nearer home, Mr. Carnegie has shown what a large-minded liberality can do for the Scottish Universities. A great benefactor who would free the University of Cambridge from a sordid struggle, in which every pound spent on development has to be laboriously begged, would earn an enduring fame in the annals of British education. It has been the earnest desire of the authors of this paper to show that the University is not unworthy of such generosity; that she has displayed great courage and great self-denial in facing modern conditions; and that her reputed wealth is a fiction, while her poverty is a grim fact.

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BILLING AND SONS, LTD., PRINTERS, GUILDFORD.

FOOTNOTES:

[1] Owing to the comparative absence of bacteria in deep-sea water their bodies undergo little decay.

[2] The illustration shows the difference between the facial marks of the zebra and those of the hybrid. The latter, in this respect, bears much the same relation to the former as a blue-rock pigeon does to a fancy type.

[3] A volume of Redi’s poems, entitled ‘Bacco in Toscano,’ was published in 1804. Longfellow says of him:

> ‘Even Redi, when he chanted
> Bacchus in the Tuscan valleys,
> Never drank the wine he vaunted
> In his dithyrambic sallies.’

[4] It had been seen before by Virchow and others, who, however, did not recognize its importance.

[5] The *Times*, September 21, 1900, and medical papers.

[6] *Vide* p. 162.

[7] 'Inferno,' xxvi. 26-28.

[8] *Brit. Med. Journ.*, No. 2,394, November 17, 1906, p. 1393.

[9] Austen, *Journal of the Royal Army Medical Corps*, vol. ii., 1904, pp. 651-667.

[10] *Medical Record*, vol. liv., 1898, pp. 429, 430.

[11] *Journal of Hygiene*, vol. vi., 1906, pp. 77-92.

[12] *Ann. Nat. Hist.*, ser. 3, vii., p. 29.

[13] *Atti Soc. Modena*, ser. 3, ii., *Radiconte*, p. 88.

[14] *Atti Mus. Milano*, xxxvi., 1896, p. 239.

[15] Theobald, 'Second Report on Economic Entomology,' British Museum (Natural History), London, 1904, p. 125.

[16] The dates given for the triposes are those of the first public examinations held.

[17] Rates, taxes, and tithe *alone* swallow up £45,000.

[18] Including about £10,000 capitation tax.