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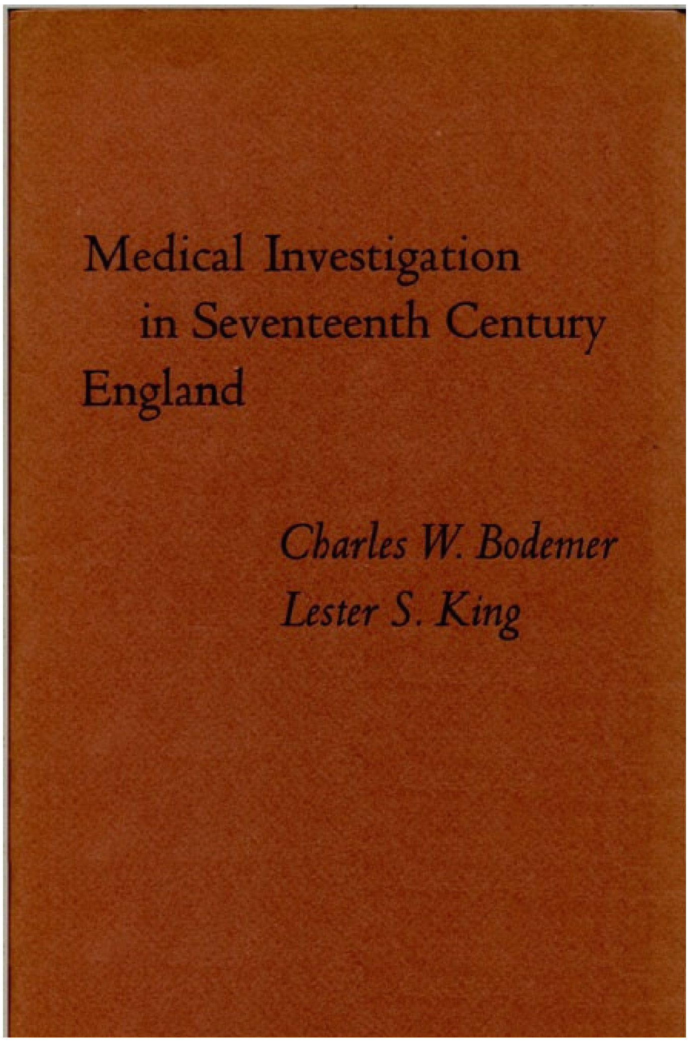

Medical Investigation in Seventeenth Century England

Embryological Thought in
Seventeenth Century England

by Charles W. Bodemer

Robert Boyle as an Amateur Physician

by Lester S. King

Papers Read at a Clark Library Seminar,
October 14, 1967

William Andrews Clark Memorial Library
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Foreword

ALTHOUGH the collection of scientific literature in the Clark Library has already served as the background for a number of seminars, in the most recent of them the literature of embryology and the medical aspects of Robert Boyle's thought were subjected to a first and expert examination. Charles W. Bodemer, of the Division of Biomedical History, School of Medicine, University of Washington, evaluated the embryological ideas of that remarkable group of inquiring Englishmen, Sir Kenelm Digby, Nathaniel Highmore, William Harvey, and Sir Thomas Browne. Lester S. King, Senior Editor of the *Journal of the American Medical Association*, dealt with the medical side of Robert Boyle's writings, the collection of which constitutes one of the chief glories of the Clark Library. It was a happy marriage of subject matter and library's wealth, the former a noteworthy oral presentation, the latter a spectacular exhibit. As usual, and of necessity, the audience was restricted in size, far smaller in numbers than all those who are now able to enjoy the presentations in their present, printed form.

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I

Embryological Thought in Seventeenth Century England

CHARLES W. BODEMER

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TO discuss embryological thought in seventeenth-century England is to discuss the main currents in embryological thought at a time when those currents were both numerous and shifting. Like every other period, the seventeenth century was one of transition. It was an era of explosive growth in scientific ideas and techniques, suffused with a creative urge engendered by new philosophical insights and the excitement of discovery. During the seventeenth century, the ideas relating to the generation and development of organisms were quite diverse, and there were seldom criteria other than enthusiasm or philosophical predilection to distinguish the fanciful from the feasible. Applying a well-known phrase from another time to seventeenth-century embryological theory, "It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness."[1] [Pg 3]

Embryology underwent some very significant changes during the seventeenth century. At the beginning of the century, embryology was descriptive and clearly directed toward morphological goals; by the end of the century, a dynamic, more physiological attitude was apparent, and theories of development derived from an entirely different philosophic base. During this time, English investigators contributed much, some of ephemeral, some of lasting importance to the development of embryology. For this discussion, we will divide the [Pg 4] seventeenth century into three overlapping, but generally distinct, periods; and, without pretence of presenting an exhaustive exposition, we will concentrate upon the concepts and directions of change characteristic of each period, with primary reference to those individuals who best reveal the character of seventeenth-century English embryology.

An understanding of the characteristics of embryological thought at the beginning of the seventeenth century may enhance appreciation of later developments. During the latter part of the sixteenth century, the study of embryology was, for obvious reasons, most often considered within the province of anatomy and obstetrics. From Bergengario da Capri to Jean Riolan the Younger, study of the fetus was recommended as an adjunct of these subjects, and it required investigation by direct observation, as decreed by the "restorers" of anatomy. Embryonic development was, however, also studied independently of other disciplines by a smaller group of individuals, and the study of chick development by Aldrovandus, Coiter, and Fabricius ab Aquapendente laid the basic groundwork of descriptive embryology. In either case, during the last half of the sixteenth century the attempt of the embryologist to break with the traditions of the past was overt, although consistently unsuccessful. When dealing with the fetus, the investigators of this period were, almost to a man, Galenists influenced to varying degrees by Hippocrates, Aristotle, and Avicenna. Each felt compelled to challenge the immediate authority, and yet their intellectual isolation from the past was incomplete, and their views on embryogeny corresponded with more often than they differed from those of the person they railed against.

Embryology emerged as a distinct scientific discipline during the last half of the sixteenth century and early years of the seventeenth century as a result of the aforementioned investigations of Aldrovandus, Coiter, and Fabricius. Concerned with description and [Pg 5] depiction of the anatomy of the embryo, they established a period of macro-iconography in embryology. The macro-iconographic era was empirical and based upon first-hand observation; it was concerned more with the facts than with the theories of development. This empiricism existed in competition with a declining, richly vitalistic Aristotelian rationalism which had virtually eliminated empiricism during the scholastic period. However, the decline of this vitalistic rationalism coincided with the rise of a mechanistic rationalism which had its roots in ancient Greek atomistic theories of matter. The empiricism comprising the *leitmotif* of the macro-iconographic movement then became blended with, or, more often, submerged within, the new variety of rationalism; hence, mechanistic rationalism, divorced entirely or virtually from empiricism, characterizes embryology during the first half of the seventeenth century. It is a particularly vigorous strain of seventeenth-century English embryological thought, well illustrated in the writings of that English man of affairs, Sir Kenelm Digby.

Digby, whose name, according to one biographer, "is almost synonymous with genius and eccentricity,"[2] could claim our attention not only as a scientist of talent, but also as a statesman, soldier, pirate, lover, and a Roman Catholic possessed of sufficient piety and naked courage to attempt the conversion of Oliver Cromwell. Like his father, who was hanged for participation in the Gunpowder Plot, Digby was a political creature, and during the Civil War he was imprisoned for several years. When freed, Digby left England to settle in France. Spending much time at the court of the Queen Dowager, who had been instrumental in securing his release, and exposed to the vigorous intellectual currents of Paris and Montpellier, Digby labored upon a treatise of greater scientific substance and merit than his more famous work on "the powder of sympathy." Published in 1644 under the title *Two Treatises, in the One of Which, The Nature of Bodies; in the Other, the Nature of Mans Soule; is Looked into, in Way of Discovery of the Immortality of Reasonable Soules*, the [Pg 6] book consists of a highly individual survey of the entire realms of metaphysics, physics, and biology.

Digby's cannons were aimed at scholasticism, which, despite "greatly exaggerated" reports, did not die with the Middle Ages. The spirit of scholasticism was alive in many quarters well into the seventeenth century, and although many scholars worked in pursuit of original knowledge, they did not always disturb the scholastic philosophic basis from which their work derived. For example, in his impressive *De formato foetu*, published in 1604, when Sir Kenelm Digby was one year old, Fabricius all too often submerges a substantial body of observations within a dense tangle of philosophical discussion. Thus, in the same treatise that contains the first illustrations and commendably accurate descriptions of the daily progress of the chick's development, Fabricius devotes an inordinate amount of space to tedious discussions of material and efficient causes in development, emphasizing thereby the supremacy of the logical framework to the observations. In 1620, Digby's last year of study at Oxford University, Fienus published a work, *De Formatrice Foetus*, designed to demonstrate that the human embryo receives the rational soul on the third day after conception and to discuss at length such subjects as the efficient cause of embryogeny and the proposition that the conformation of the fetus is a vital, not a natural, action. Various expressions of Aristotelian and scholastic biology were clearly abroad during the first half of the seventeenth century, and there is reason, then, for Digby's attack upon Aristotelian ideas of form and matter and of the persistence of "qualities" in physics and "faculties" in biology.

Expressing his disdain of word-spinning, Digby attempts to explain all phenomena by two "virtues" only, rarity and density working by local motion. In discussing embryonic development, Digby writes, "...our maine question shall be, Whether they be framed entirely at once; or successively, one part after another? And, if this later way, which part first?"[3] [Pg 7]
Toward this end, Digby makes some direct observations upon the development of the chick

embryo, incubating the eggs so that the "creatures ... might be continually in our power to observe in them the course of nature every day and houre."[4] His description of chick development is of epigenetic bent:

> ...you may lay severall egges to hatch; and by breaking them at severall ages you may distinctly observe every hourely mutation in them, if you please. The first will bee, that on one side you shall find a great resplendent clearnesse in the white. After a while, a little spott of red matter like bload, will appeare in the middest of that clearnesse fastened to the yolke: which will have a motion of opening and shutting; so as sometimes you will see it, and straight againe it will vanish from your sight; and indeede att the first it is so litle, that you can not see it, but by the motion of it; for att every pulse, as it openeth, you may see it, and immediately againe, it shutteth in such sort, as it is not to be discerned. From this red specke, after a while there will streame out, a number of litle (almost imperceptible) red veines. Att the end of some of which, in time there will be gathered together, a knotte of matter which by litle and litle, will take the forme of a head; and you will ere long beginne to discerne eyes and a beake in it. All this while the first red spott of blood, groweth bigger and solider; till att the length, it becometh a fleshy substance; and by its figure, may easily be discerned to be the hart: which as yet hath no other enclosure but the substance of the egge. But by litle and litle the rest of the body of an animal is framed out of those red veines which streame out all aboute from the hart. And in processe of time, that body incloseth the hart within it by the chest, which groweth over on both sides, and in the end meeteth, and closeth it selfe fast together. After which this litle creature soone filleth the shell, by converting into severall partes of it selfe all the substance of the egge. And then growing weary of so straight an habitation, it breaketh prison, and cometh out, a perfectly formed chicken.[5]

Despite this observational effort, Digby's experience with the embryo is quite limited, and his theory of development relates more to his philosophical stance than to the facts of development. Indeed, the theory he propounds is not necessarily consistent. On the one hand, it posits a strictly mechanistic epigenesis, and on the other hand, it incorporates the notion of "specificall vertues drawne by the bloud in its iterated courses, by its circular motion, through all the severall partes of the parents body."[6] Digby rejects an internal agent, entelechy, or the Aristotelian formal and efficient causes. Similarly, he disposes of the idea that the embryonic parts derive from some part of each part of the parent's body or an assemblage of parts. This possibility is eliminated, he contends, by the occurrence of spontaneous generation. If a collection of parts was necessary, he asks, "how could vermine breed out of living bodies, or out of corruption?... How could froggs be ingendered in the ayre?"[7] Generation in plants and animals must, then, according to Digby, proceed from the action of an external agent, effecting the proper mingling of the rare and dense bodies with one another, upon a homogeneous substance and converting it into an increasingly heterogeneous substance. "Generation," he says, [Pg 8]

> is not made by aggregation of like partes to presupposed like ones: nor by a specificall worker within; but by the compounding of a seminary matter, with the juice which accreweth to it from without, and with the streames of circumstant bodies; which by an ordinary course of nature, are regularly imbibed in it by degrees; and which att every degree do change it into a different thing.[8]

Digby argues that the animal is made of the juices that later nourish it, that the embryo is generated from superfluous nourishment coming from all parts of the parent body and containing "after some sort, the perfection of the whole living creature."[9] Then, through digestion and other degrees of heat and moisture, the superfluous nourishment becomes an homogeneous body, which is then changed by successive transformations into an animal.

Digby is frankly deterministic in his description of embryonic development: [Pg 9]

> Take a beane, or any other seede, and putt it into the earth, and lett water fall upon it; can it then choose but that the beane must swell? The beane swelling, can it choose but breake the skinne? The skinne broken can it choose (by reason of the heate that is in it) but push out more matter, and do that action which we may call germinating.... Now if all this orderly succession of mutations be necessarily made in a beane, by force of sundry circumstances and externall accidents; why may it not be conceived that the like is also done in sensible creatures; but in a more perfect manner.... Surely the progresse we have sett downe is much more reasonable, then to conceive that in the meale of the beane, are contained in litle, severall similar substances.... Or, that in the seede of the male, there is already in act, the substance of flesh, of bone, of sinewes, of veines, and the rest of those severall similar partes which are found in the body of an animall; and that they are but extended to their due magnitude, by the humidity drawne from the mother, without receiving any substantiall mutation from what they were originally in the seede. Lett us then

confidently conclude, that all generation is made of a fitting, but remote, homogeneall compounded substance: upon which, outward Agents working in the due course of nature, do change it into an other substance, quite different from the first, and do make it lesse homogeneall then the first was. And other circumstances and agents, do change this second into a thirde; that thirde, into a fourth; and so onwardes, by successive mutations (that still make every new thing become lesse homogeneall, then the former was, according to the nature of heate, mingling more and more different bodies together) untill that substance be produced, which we consider in the periode of all these mutations....[10]

Digby thus makes a good statement of epigenetic development. He attempts, without success, a physiochemical explanation of the mechanisms of development, finally admitting:

I persuade my selfe it appeareth evident enough, that to effect this worke of generation, there needeth not be supposed a forming vertue ... of an unknowne power and operation.... Yet, in discourse, for conveniency and shortnesse of expression we shall not quite banish that terme from all commerce with us; so that what we meane by it, be rightly understood; which is, the complexe, assemblement, or chayne of all the causes, that concurre to produce this effect; as they are sett on foote, to this end by the great Architect and Moderatour of them, God Almighty, whose instrument Nature is.[11]

Digby's general theory thus represents a strange mixture of epigenesis and pangenesis, and is not entirely devoid of "virtues." It is, however, a bold attempt to explain embryonic development in terms commensurate with his time, and it embodies the same optimistic belief that the mechanism of embryogenesis lay accessible to man's reason and logical faculties that similarly led Descartes and Gassendi to comprehensive interpretations of embryonic development comprising a maximum of logic and minimum of observations.

The traditionalist reaction to the attack upon treasured and intellectually comfortable interpretations of development was not slow to set in. A year after the appearance of Digby's *Nature of Bodies*, Alexander Ross published a treatise with a title indicating its goals and content: *The Philosophicall Touch-Stone; or Observations upon Sir Kenelm Digbie's Discourses of the nature of Bodies, and of the reasonable Soule: In which his erroneous Paradoxes are refuted, the Truth, and Aristotelian Philosophy vindicated, the immortality of mans Soule briefly, but sufficiently proved*.[12] Ross supports the Galenist tradition that the liver, not, as Digby claimed, the heart, forms first in development. It can be no other way, he says, since the blood is the source of nourishment and the liver is necessary for formation of the blood. Furthermore, he contends, "the seed is no part of the ... aliment of the body ... the seed is the quintessence of the blood."[13] Ross is an epigeneticist, to be sure, but so was Aristotle, and Ross prefers to maintain the supremacy of logic and the concepts of the Aristotelian tradition as a guide to the interpretation of development.

In 1651, Nathaniel Highmore, a physician at Sherborne in Dorset, published *The History of Generation*, which, he informs us, is an answer to the opinions expressed by Digby in *The Nature of Bodies*. Highmore's book is an important one in the history of embryology, since it is the first treatment of embryogeny from the atomistic viewpoint and because it contains the first published observations based upon microscopic examination of the chick blastoderm. Admittedly, the drawings illustrating Highmore's observations upon generation are, to use a word often applied to modern art, "interesting," but they do derive from actual observations of developing plant and animal embryos. His observations on the developing chick embryo are quite full, complete, and exact, and he also records some interesting facts regarding development of plant seeds.

Highmore's theory of development appears to have emerged directly out of his observations of development. In this sense, his theory rests upon a more solid base than does the developmental theory of Digby. His theory is a mixture of vitalism and atomism, designed to eliminate the "fortune and chance"[14] resident in Digby's concept. "Generation," he says,

...is performed by parts selected from the generators, retaining in them the substance, forms, properties, and operations of the parts of the generators, from whence they were extracted: and this Quintessence or Magistery is called the seed. By which the Individuals of every Species are multiplied...

From this, All Creatures take their beginning; some laying up the like matter, for further procreation of the same Species.

In others, some diffus'd Atomes of this extract, shrinking themselves into some retired parts of the Matter; become as it were lost, in a wilderness of other confused seeds; and there sleep, till by a discerning corruption they are set at liberty, to execute their own functions. Hence it is, that so many swarms of living Creatures are from the corruption of others brought forth: From our own flesh, from other Animals, from Wood, nay, from everything putrified, these imprisoned seminal principles are muster'd forth, and oftentimes having obtained their freedom, by a kinde of revenge feed on their prison; and devour that which preserv'd them from being scatter'd.[15] Accounting thus for sexual and spontaneous generation, Highmore defines two types of seminal atoms in the seed—"Material Atomes, animated and directed by a spiritual form, proper to that species whose the seed is; and given to such matter at the creation to distinguish it from other matters, and to make it such a Creature as it is."[16] The seminal atoms come from all parts of the body, the spiritual atoms from the male, and the material atoms from the female. The atoms of Democritus are thus transmuted into the "substantial forms" and endowed either with the efficient cause of Aristotle or, permitted to remain material, with Aristotle's material cause. According to Highmore, the atoms are circulated in the blood, which is a "tincture extracted from those things we eat," and these various atoms retain their formal identity despite corruption. The testicles abstract some spiritual atoms belonging to each part and, "As the parts belonging to every particle of the Eye, the Ear, the Heart, the Liver, etc. which should in nutrition, have been added ... to every one of these parts, are compendiously, and exactly extracted from the blood, passing through the body of the Testicles." Being here "cohobated and reposited in a tenacious matter," the particles finally pass out of the testes.[17] A similar extraction of the female seed occurs in the ovaries. The female seed

> ...containing the same particles, but cruder and lesse digested, from a cruder matter, by lesse perfect Organs, is left more terrene, furnished with more material parts; which being united in the womb, with the spiritual particles of the masculine seed; everyone being rightly, according to his proper place, disposed and ordered with the other; fixes and conjoynes those spiritual Atomes, that they still afterwards remain in that posture they are placed in.[18]

The theories of development promulgated by Digby and Highmore reveal the chief formulations of mechanistic rationalism, more or less free of empiricism, that were emerging as the vitalism of the sixteenth and seventeenth centuries waned. There was little new in these theories: both Digby's and Highmore's theories included different combinations of elements of ancient lineage. Digby's concept was essentially free of vitalistic coloring; akin to the embryological efforts of Descartes in its virtual independence from observations of the developing embryo, it was similarly vulnerable to Voltaire's criticism of Descartes, that he sought to interpret, rather than study, Nature. This criticism is not so applicable to Highmore, whose theory of development is more vitalistic than Digby's, and is more akin to the concepts developed by Gassendi than those of Descartes. Highmore had experience with the embryo itself, and his actual contribution as an observer of development, although hardly epochal, is worthy of note. But despite this empirical base, Highmore has final recourse to a hypothesis blending many ancient ideas and substituting the Aristotelian material and efficient causes for the "fortune and chance" he objected to in Digby's hypothesis. It was *not* easy in the seventeenth century to avoid falling back upon some variety of cause or force. [Pg 13]

In 1651, about two months before publication of Highmore's *History of Generation*, a work appeared which marks another period in seventeenth-century English embryology. William Harvey, *De Motu Cordis* almost a quarter of a century behind him, now published *De Generatione Animalium*, the work he said was calculated "to throw still greater light upon natural philosophy."[19] This book is, perhaps, not as well known as Harvey's treatise demonstrating circulation of the blood, but it is an important work in the history of embryology and it occupies a prominent position in the body of English embryological literature.

In *De Generatione*, Harvey provides a thorough and quite accurate account of the development of the chick embryo, which, in particular, clarified that the chalazae, those twisted skeins of albumen at either end of the yolk, were not, as generally believed, the developing embryo, and he demonstrated that the cicatricula (blastoderm) was the point of origin of the embryo. The famous frontispiece of the treatise shows Zeus holding an egg, from which issue animals of various kinds. On the egg is written *Ex ovo omnia*, a legend since transmuted to the epigram *Omne vivum ex ovo*. The legend illustrates Harvey's principal theme, repeated constantly throughout the text, "that all animals were in some sort produced from eggs."[20] [Pg 14]

If Harvey made no contribution beyond emphasizing the origin of animals from eggs, he would deserve a prominent place in the history of embryology. But the work is also significant in its espousal of epigenesis, and, supported as his argument was by observation and logic, it became the prime formulation of that concept of development during the seventeenth and eighteenth centuries. His statement of epigenetic development is clear:

> In the egg ... there is no distinct part or prepared matter present, from which the fetus is formed ... an animal which is created by epigenesis attracts, prepares, elaborates, and makes use of the material, all at the same time; the processes of formation and growth are simultaneous ... all its parts are not fashioned simultaneously, but emerge in their due succession and order ... Those parts, I say, are not made similar by any successive union of dissimilar and heterogeneous elements, but spring out of a similar material through the process of generation, have their different elements assigned to them by the same process, and are made dissimilar ... all its parts are formed, nourished,

and augmented out of the same material.[21]

Actually, Harvey's exposition of epigenesis, albeit clear, is not totally impressive, since it is largely a reflection of Aristotle's influence. The main importance of Harvey's vigorous and cogent defense of epigenesis is that it provided some kind of counterbalance to the increasingly dominant preformationist interpretations of embryonic development.

Harvey did not break with Aristotelianism; on the contrary, he lent considerable authority to it. Unable to escape the past, he was not completely objective in his study of generation. Everywhere the pages of his book reveal his indebtedness to past authorities. Robert Willis, who provided the 1847 translation of *De Generatione*, expresses this well: [Pg 15]

> [Harvey] ... begins by putting himself in some sort of harness of Aristotle, and taking the bit of Fabricius between his teeth; and then, either assuming the ideas of the former as premises, or those of the latter as topics of discussion or dissent, he labours on endeavouring to find Nature in harmony with the Stagyrite, or at variance with the professor of Padua—for, in spite of many expressions of respect and deference for his old master, Harvey evidently delights to find Fabricius in the wrong. Finally, so possessed is he by scholastic ideas, that he winds up some of his opinions upon animal reproduction by presenting them in the shape of logical syllogisms.[22]

Even Harvey's concept of the egg reveals a strong Aristotelian bias. Actually, Harvey attained to his conclusion that all animals derive from eggs by assuming that

> on the same grounds, and in the same manner and order in which a chick is engendered and developed from an egg, is the embryo of viviparous animals engendered from a pre-existing conception. Generation in both is one and identical in kind: the origin of either is from an egg, or at least something that by analogy is held to be so. An egg is, as already said, a conception exposed beyond the body of the parent, whence the embryo is produced; a conception is an egg remaining within the body of the parent until the foetus has acquired the requisite perfection; in everything else they agree; they are both alike primordially vegetables, potentially they are animals.[23]

The ovum, for Harvey, is in essence "the primordium vegetable or vegetative incipience, understanding by this a certain corporeal something having life in potentia; or a certain something existing *per se*, which is capable of changing into a vegetative form under the agency of an internal principle."[24] The ovum is for Harvey more a concept than an observed fact, and, as stated by one student of generation, "The *dictum ex ovo omnia*, whilst substantially true in the modern sense, is neither true nor false as employed by Harvey, since to him it has no definite or even intelligible meaning."[25] [Pg 16]

Harvey's treatise on generation is clearly a product of his time. It advances embryology by its demonstration of certain facts of development, by its aggressive espousal of epigenesis and the origin of all animals from eggs, and by its dynamic approach stressing the temporal factors in development and the initial independent function of embryonic organs. However, the strong Aristotelian cast of Harvey's treatise encouraged continued discussion of long outdated questions in an outdated manner and, combined with his expressed disdain for "chymistry" and atomism, discouraged close cooperation between embryologists of different persuasions. It is perhaps easy to underestimate the impact and general importance of Harvey's work in view of these qualifications, and so it should be remarked that both positive and negative features of *De Generatione* influenced profoundly subsequent embryological thought.

It will be recalled that the title of *The Philosophicall Touch-Stone* identified Digby as the object of Alexander Ross's ire. In comparable manner, the latter's *Arcana Microcosmi*, published in 1652, declares its purpose to be "a refutation of Dr. Brown's Vulgar Errors, the Lord Bacon's Natural History, and Dr. Harvy's book *De Generatione*." Let us pause a brief moment in memory of a man so intrepid as to undertake the refutation of three of England's great intellects in one small volume, and then proceed to examine the embryological concepts of one of the trio, Sir Thomas Browne.

Browne's *Religio Medici*, composed as a private confession of faith around 1635, is known to all students of English literature, as is his later, splendid work on death and immortality, *Hydrotaphia, Urne-Buriall*. One of the greatest stylists of English prose, Browne was also a physician and a student of generation who deserves our attention as an early chemical embryologist pointing the way to a form of embryological investigation prominent in the last half of the seventeenth century. [Pg 17]

Browne's embryological opinions are found particularly in *Pseudodoxia Epidemica*, *The Garden of Cyrus*, and in his unpublished *Miscellaneous Writings*. Browne, a well-read man, was educated at Oxford, Montpellier, Padua, and Leyden, and he was thoroughly imbued with the teaching of the prophets of the "new learning." This is evident throughout his writings, as witness his admonition to the reader of the *Christian Morals*:

> Let thy Studies be free as thy Thoughts and Contemplations, but fly not only

> upon the wings of Imagination; Joyn Sense unto Reason, and Experiment unto Speculation, and so give life unto Embryon Truths, and Verities yet in their Chaos.[26]

Browne greatly admired Harvey's work on generation, considering it "that excellent discourse ... So strongly erected upon the two great pillars of truth, experience and solid reason."[27] Browne carried out a variety of studies upon animals of all kinds, in them joining Sense unto Reason, and "Experiment unto Speculation." Thus in his studies of generation, he made observations and also performed certain simple chemical experiments. Noting that "Naturall bodyes doe variously discover themselves by congelation,"[28] Browne studied experimentally the chemical properties of those substances providing the raw material of development. He observed the effects of such agents as heat and cold, oil, vinegar, and saltpeter upon eggs of various animals, recording such facts as the following:

> Of milk the whayish part, in eggs wee observe the white, will totally freez, the yelk with the same degree of cold growe thick & clammy like gumme of trees; butt the sperme or tredde hold its former body, the white growing stiff that is nearest it.... Egges seem to have their owne coagulum within themselves [Pg 18] manifested in the incrassations upon incubation.... Rotten egges will not bee made hard by incubation or decoction, as being destitute of that spiritt, or having the same vitiated.... How far the coagulating principle operateth in generation is evident from eggs wch will never incrassate without it. From the incrassation upon incubation when heat diffuseth the coagulum, from the *chalaza* or gallatine wh. containeth 3 nodes, the head, heart, & liver.[29]

It cannot be said that Browne attained to any great generalizations regarding embryogeny on the basis of his rather naive experiments, but they are indicative of the effects of the "new learning" in one area of biology. Actually, Browne appears more comfortable in the search for patterns conforming to the quincunx, as in *The Garden of Cyrus*, and although he may well have been in search of something like the later Unity of Type, he uses his amassed details of scientific knowledge most effectively in support of nonscientific propositions. Thus, he uses the facts of embryonic development, alchemy, and insect metamorphosis as a part of his argument for the immortality of the human soul:

> ...for we live, move, have a being, and are subject to the actions of the elements, and the malice of diseases in that other world, the truest Microcosme, the wombe of our mother; for besides that generall and common existence wee are conceived to hold in our Chaos, and whilst wee sleepe within the bosome of our causes, wee enjoy a being and life in three distinct worlds, wherin we receive most manifest graduations: In that obscure world and wombe of our mother, our time is short, computed by the Moone, yet longer than the dayes of many creatures that behold the Sunne; our selves being yet not without life, sense, and reason; though for the manifestation of its actions it awaits the opportunity of objects; and seemes to live there but in its roote and soule of vegetation; entring afterwards upon the scene of the world, wee arise up and become another creature, performing the reasonable actions of man, and obscurely manifesting that part of Divinity in us, but not in complement and perfection, till we have once more cast our secondine, that is, this slough of flesh, and are delivered into the last world, that ineffable place [Pg 19] of Paul, that proper *ubi* of spirits. The smattering I have [in the knowledge] of the Philosophers stone ... hath taught me a great deale of Divinity, and instructed my beliefe, how the immortall spirit and incorruptible substance of my soule may lye obscure, and sleepe a while within this house of flesh. Those strange and mysticall transmigrations that I have observed in Silkewormes, turn'd my Philosophy into Divinity. There is in those workes of nature, which seeme to puzzle reason, something Divine, and [that] hath more in it then the eye of a common spectator doth discover.[30]

To affirm that Sir Thomas Browne was the founder of chemical embryology or, indeed, to contend that he made a great impress upon the progress of embryology is to humour our fancy. As Browne himself reminds us, "a good cause needs not to be patron'd by a passion." [31] His work and interpretations of generation are most important for our purposes as an indication of the rising mood of the times and an emerging awareness of the physiochemical analysis of biological systems. Although this mood and awareness coexist in Browne's writings with a continued reverence for some traditional attitudes, they mark a point of departure toward a variety of embryological thought prominent in England during the second half of the seventeenth century.

Browne did no more than analyze crudely the reaction of the egg to various physical and chemical agents. This static approach was later supplanted by a more dynamic one concerned primarily with the physicochemical aspects of embryonic development. This is first apparent in a report by Robert Boyle in the *Philosophical Transactions of the Royal Society* in 1666 entitled, "A way of preserving birds taken out of the egge, and other small foetus's." Boyle, unlike Browne, exposed embryos of different ages to the action of "Spirit of

Wine" or "Sal Armoniack," demonstrating thereby the chemical fixation of embryos as an aid to embryology. A year later, Walter Needham, a Cambridge physician who studied at Oxford in the active School of Physiological Research, which included such men as Christopher Wren and Thomas Willis, published a book reporting the first chemical experiments upon the developing mammalian embryo.[32] Needham's approach and goals are more dynamic than those of Browne, and he attempts to analyze various embryonic fluids by coagulation and distillation procedures. His experiments reveal, for example, that "coagulations" effected by different acids vary according to the fluid; thus, the addition of "alumina" to bovine amniotic fluid produced a few, fine precipitations, whereas the allantoic fluid was precipitated like urine. By such means Needham was able to demonstrate, however crudely, that there are considerable differences in the various fluids occurring within and around the fetus. Furthermore, it is with the results of chemical analyses that he supports his other arguments, such as his contention that the egg of elasmobranchs is not, as believed, composed of only one humour, but has separate white and yolk. [Pg 20]

Needham's book contains many splendid observations, including an accurate description of the placenta and its vessels, the relationship of the various fetal membranes to the embryonic fluids, and rather complete directions for dissection of various mammals. These need not detain us, since the important aspect of Needham's work relevant to our purpose is his continuation of the chemical analysis of the developing embryo and its demonstration that, although Harvey might have despised the "chymists" and been contemptuous of the "mechanical, corpuscular philosophy," this system and approach was not to be denied.

Needham's book is dedicated to Robert Boyle, whose *Sceptical Chymist* set the cadence for subsequent research based upon the "mechanical or corpuscularian" philosophy and quantitative procedures. It is appropriate for us, then, to terminate our discussion with a consideration of this current in English embryological thought. [Pg 21]

John Mayow was the first to realize that "nitro-aerial" vapour, or oxygen, is essential to respiration of a living animal, and he was soon led to inquire "how it happens that the foetus can live though imprisoned in the straits of the womb and completely destitute of air."[33] As a consequence of this interest, the third of his *Tractatus Quinque medico-physici*, published in 1674, is devoted to the respiration of the fetus *in utero*. He shows truly remarkable insight when he concludes therein that

> It is very probable that the spermatic portions of the uterus and its carunculae are naturally suited for separating aerial particles from arterial blood.
>
> These observations premised, we maintain that the blood of the embryo, conveyed by the umbilical arteries to the placenta or uterine carunculae transports to the foetus not only nutritious juice, but also a portion of the nitro-aerial particles: so that the blood of the infant seems to be impregnated with nitro-aerial particles by its circulation through the umbilical vessels in the same manner as in the pulmonary vessels. Therefore, I think that the placenta should no longer be called a uterine liver, but rather a uterine lung.[34]

Although Mayow's attempted analysis of respiration of the chick embryo *in ovo* is less than successful, his views on fetal respiration were soon accepted by many, and his tract stands as a great contribution to physiological embryology.

The studies of such individuals as John Standard reporting the weight of various parts of the hen's egg, e.g., the shell, the yolk, the white, reveal the wing of embryological investigation that was increasingly obsessed with quantification and the physicochemical analysis of the embryo and its vital functions. In this they were following the injunction of Boyle, who used the developing embryo as a vehicle in an attack upon the idea that mixed bodies are compounded of three principles, the obscurities of which operated to discourage quantification:

> How will this hypothesis teach us, how a chick is formed in the egg, or how the seminal principles of mint, pompions, and other vegetables ... can fashion water into various plants, each of them endowed with its peculiar and determinate shape, and with divers specifick and discriminating qualities? How does this hypothesis shew us, how much salt, how much sulphur, and how much mercury must be taken to make a chick or a pompion? And if we know that, what principle it is, that manages these ingredients, and contrives, for instance, such liquors, as the white and yolk of an egg into such a variety of textures, as is requisite to fashion the bones, veins, arteries, nerves, tendons, feathers, blood, and other parts of a chick? and not only to fashion each limb, but to connect them all together, after that manner, that is most congruous to the perfection of the animal, which is to consist of them?[35] [Pg 22]

The emphasis upon quantification and the physicochemical analysis of vital processes was to continue into the eighteenth century and to contribute to the great stress upon precision in that period. It was not, however, destined to become immediately the main stream of embryological investigation. For even as the studies of Mayow were in progress, embryology was embarked upon a course leading to preformationism. By the end of the seventeenth century, the idea that the embryo was encased in miniature in either egg or sperm was elevated to a position of Doctrine, and thereafter there was little encouragement to quantitative study of development. Many embryological investigations were performed during the eighteenth century, but most relate to the controversy regarding epigenesis and preformationism as the true expression of embryonic development. Withal, the seventeenth-century embryologists, and particularly the embryologists of seventeenth-century England, had contributed much to the progress of the discipline. They had introduced new ideas, applied new techniques, and created new knowledge; they had effectively advanced the study of development beyond the stage of macro-iconography; they had freed the discipline from much of its traditional baggage of causes, virtues, and faculties. Various English [Pg 23] embryologists had varying success with developmental theory, but as a group they had made great impact upon the development of embryology. In the course of their century, they had, in the words of one of them, "called tradition unto experiment."[36]

Notes [Pg 24]

[1] Charles Dickens, *A Tale of Two Cities*, London, 1859, p. 1.

[2] Kenelm Digby, *Private Memoirs of Sir Kenelm Digby, Gentleman of the Bedchamber to King Charles the First*, London, 1827, Preface, p. i.

[3] Kenelm Digby, *Two Treatises, in the One of Which, The Nature of Bodies; in the Other, the Nature of Mans Soule; is Looked into*, Paris, 1644, p. 213.

[4] *Ibid.*, p. 220.

[5] *Ibid.*, pp. 220-221.

[6] *Ibid.*, p. 222.

[7] *Ibid.*, p. 215.

[8] *Ibid.*, p. 219.

[9] *Ibid.*, p. 213.

[10] *Ibid.*, pp. 217-219.

[11] *Ibid.*, p. 231.

[12] Alexander Ross, *The Philosphicall Touch-Stone; or Observations upon Sir Kenelm Digbie's Discourses of the nature of Bodies, and of the reasonable Soule*, London, 1645.

[13] Alexander Ross, *Arcana Microcosmi: or, The hid secrets of Man's Body disclosed ... In an anatomical duel between Aristotle and Galen concerning the parts thereof*, London, 1652, p. 87.

[14] Nathaniel Highmore, *The History of Generation, Examining the several Opinions of divers Authors, expecially that of Sir Kenelm Digby, in his Discourse of Bodies*, London, 1651, p. 4.

[15] *Ibid.*, pp. 26-27.

[16] *Ibid.*, pp. 27-28.

[17] *Ibid.*, p. 45.

[18] *Ibid.*, Pp. 90-91.

[19] William Harvey, *Opera omnia: a Collegio Medicorum Londinensi edita*, Londini, 1766, p. 136.

[20] William Harvey, *Anatomical Excercises on the Generation of Animals*, trans. Robert Willis, London, 1847, p. 462.

[21] *Ibid.*, pp. 336-339.

[22] *Works of William Harvey*, trans. Robert Willis, London, 1847, pp. lxx-lxxi. [Pg 25]

[23] Harvey, *op. cit.*, pp. 462-463.

[24] *Ibid.*, p. 457.

[25] F. J. Cole, *Early Theories of Sexual Generation*, Oxford, 1930, p. 140.

[26] Thomas Browne, *The Works*, ed. Geoffrey Keynes, Chicago, 1964, I, 261-262.

[27] *Ibid.*, II, 265.

[28] *Ibid.*, III, 442.

[29] *Ibid.*, III, 442-452.

[30] *Ibid.*, I, 50.

[31] *Ibid.*, I, 14.

[32] Walter Needham, *Disquisitio anatomica de formato foetu*, London, 1667.

[33] John Mayow, "De Respiratione foetus in utero et ovo," in *Tractatus Quinque Medico-Physici*, Oxonii, 1674, p. 311.

[34] *Ibid.*, pp. 319-320.

[35] Robert Boyle, *The Works*, London, 1772, I, 548-549.

[36] Browne, *op. cit.*, II, 261.

[Pg 26]

[Pg 27]

II

Robert Boyle as an Amateur Physician

LESTER S. KING

[Pg 28]

ROBERT BOYLE was not a physician. To be sure, he had engaged in some casual anatomical studies,[37] but he had not formally studied medicine and did not have a medical degree. Nevertheless, he engaged in what we would call medical practice as well as medical research and exerted a strong influence on the course of medicine during the latter seventeenth century, an influence prolonged well into the eighteenth. He lived during the period of exciting yet painful transition when medical theory and practice were undergoing a complete transformation towards what we may call the "early modern" form. The transition, naturally gradual, extended over three centuries, but I wish to examine only a very small fragment of this period, namely, the third quarter of the seventeenth century. [Pg 29]

Boyle's first major work which dealt extensively with medical problems was the *Usefulness of Experimental Philosophy*. This work, although published in 1663, had been written in two parts, the first much earlier than the second. Fulton[38] indicates it had been drafted around 1650, while Hall[39] ascribes it to the period 1647-1648. This first part has relatively little to do with medicine; the references are few and rather incidental, and have significance only for the light they throw on "natural philosophy" and "natural religion." The second part, however, written apparently not too long before publication, has a great deal to do with medicine and constitutes one of the important medical documents of the century. [Pg 30]

Deserving of mention is an earlier and minor work of Boyle, indeed, his first published writing, only recently identified. This work, apparently written in 1649, bore the title "An Invitation to a free and generous communication of Secrets and Receits in Physick," and appeared anonymously in 1655 as part of a volume entitled *Chymical, Medicinal and Chirurgical Addresses Made to Samuel Hartlib, Esquire*.[40] For our purposes, it is significant as emphasizing his early interest in medicine.

Boyle seems to have acquired most of his medical knowledge between, say, 1649 and 1662. It is worth recalling some of the trends and conflicts that formed the medical environment during this period. Among the major trends, first place, perhaps, must be given to Galenic doctrine, which had come under progressively severe attack. Molière, who lived from 1622 to 1673, showed in his comedies the popular reaction to a system which, although dominant, was clearly crumbling. The cracks in the edifice even the layman could readily see. Nevertheless, Galenism had its strong supporters. Riverius, who lived from 1589 to 1655, was a staunch Galenist. An edition of his basic and clinical works[41] was translated into English in 1657, and Latin editions continued to be published well into the eighteenth century.[42]

Galenism, of course, had to withstand the great new discoveries in anatomy and physiology made by Vesalius, Aselli, Sanctonius, Harvey, and others, not to mention the host of great investigators who were more strictly contemporaries of Boyle.

Galenism also faced the rivalry of chemistry. The so-called "antimony war" in the earlier part of the century marked an important assault on Galenism, and the letters of the arch-conservative Guy Patin (who died in 1672) help us appreciate this period.[43] However, even more important was the work of van Helmont, who developed and extended the doctrines of Paracelsus and represented a major force in seventeenth-century thought. Boyle was well [Pg 31] acquainted with the writings of van Helmont, who, although his works fell into disrepute as the mechanical philosophy gradually took over, nevertheless in the middle of the seventeenth century was a highly significant figure. In 1662 there appeared the English translation of his *Oriatrike*,[44] while Latin editions continued to be published later in the century.

In this connection I might also mention the subject of "natural magic," which had considerable significance for medicine. The best-known name is, perhaps, Giovanni Battista della Porta (1545-1615), whose books[45] continued to be published, in Latin and English, during this period when Boyle was achieving maturity.

Profound developments, of course, arose from the new mechanics and physics and their metaphysical background, for which I need only mention the names of Descartes, who died in 1650, and Gassendi, who died in 1655. And then there was also the new methodological approach, that critical empiricism whose most vocal exponent was Francis Bacon, which led directly to the founding of the Royal Society in 1660 and its subsequent incorporation. These phases of seventeenth-century thought and activity I do not intend to take up.

In this turbulent riptide of intellectual currents, Robert Boyle, without formal medical education, performed many medical functions, as a sometime practitioner, consultant, and researcher. Repeatedly he speaks of the patients whom he treated, and repeatedly he refers to practitioners who consulted him, or to whom he gave advice. In addition, through his interest in chemistry, he became an important experimental as well as clinical pharmacologist, and his researches in physiology indicate great stature in this field. If we were to draw a present-day comparison, we might point to investigators who had both the M.D. and the Ph.D. degrees, who had both clinical and laboratory training, and who practiced medicine partly in the clinical wards, partly in the experimental laboratories. [Pg 32]
Boyle, of course, did not have either degree, but he did have a status as the leading virtuoso of his day.

The virtuoso has been the subject of a most extensive literature.[46] He aroused considerable contemporary hostility and satire and his overall significance for medical science is probably slight, with a few striking exceptions. Robert Boyle is one of the great exceptions.

First of all, the virtuoso was an amateur. In the literal sense the amateur loves the activities in which he engages, and in the figurative sense he remains independent of any Establishment. Not trained in any rigorous, prescribed discipline, he was not committed to any set doctrine. Furthermore, he was not restricted by the regulations which all Establishments employed to preserve their status, block opposition, and prevent competition. In many fields the Establishment took the form of a guild organization—in medicine, the Royal College of Physicians.[47]

Boyle was a wealthy and highly talented man who could pursue his own bent without needing to make concessions merely to earn a living. He remained quite independent of the cares which oppressed those less well endowed in worldly goods or native talent. Sometimes, of course, necessity can impose a discipline and rigor which ultimately may serve as a disguised benefit, but in the seventeenth century, when Boyle was active, the lack of systematic training and rigorous background seemed actually an advantage. Clinical chemistry and the broad areas which we can call experimental medicine had no tradition. Work in clinical chemistry, clinical pharmacology, and experimental physiology was essentially innovation. And since innovations are often made by those who are outside the Establishment and not bound by tradition, we need feel no surprise that the experimental approach could make great progress under the aegis of amateurs. Necessarily the work was rather unsystematic and undisciplined, but system and discipline could arise only when the [Pg 33]
new approach had already achieved some measure of success. Through the casual approach of amateurs this necessary foundation could be built.

Boyle, as a clinician, remained on excellent terms with medical practitioners. For one thing, he took great care not to compete with them. As stated,[48] he "was careful to decline the occasions of entrenching upon their profession." Physicians would consult him freely. As a chemist and experimental pharmacologist, he prepared various remedies. Some of these he tried out on patients himself, others he gave to practitioners who might use them. Boyle seems to have abundantly provided what we today call "curbstone consultations."

In no way bound by guild rules and conventions or by rigid educational standards, Boyle was free to learn from whatever sources appealed to him. Repeatedly he emphasized the importance of learning from experience, both his own and that of others, and by "others" he included not only physicians and learned gentlemen, but even the meanest of society, provided they had experience in treating disease. This experience need not be restricted to treatment of humans but should include animals as well. Thus, in speaking of even the "skilfullest physicians," he indicated that many of them "might, without disparagement to their profession, do it an useful piece of service, if they would be pleased to collect and digest all the approved experiments and practices of the farriers, graziers, butchers, and the like, which the ancients did not despise...; and ... which might serve to illustrate the *methodus medendi*."[49] He was quite critical of physicians who were too conservative even to examine the claims of the nonprofessionals, especially those who were relatively low in the social or intellectual scale. This casts an interesting sidelight on the snobbishness of the medical profession.

Boyle's willingness and ability to ignore the restrictions of an Establishment represent the full flowering of what I might call the Renaissance spirit—the drive to go outside accepted [Pg 34]
bounds, to explore, to *try*, to avoid commitment, and to investigate for oneself.

What internal and external factors permit a successful breakaway from tradition? Rebels there have always been, yet successful rebels are relatively infrequent. The late seventeenth century was a period of successful rebellion, and the virtuosi were one of the factors which contributed to the success. Robert Boyle played a significant part in introducing new methods into science and new science into medicine.

We must realize that Boyle was primarily a chemist and not a biologist. He thought in chemical terms, drawing his examples from physics and chemistry; he did not think in terms of the living creature or the organism, and as a mechanist he passed quite lightly over the concept or organismic behavior. His basic anti-Aristotelianism prevented his appreciating the biologically oriented thought of Aristotle. Instead, Boyle talked about the inorganic world, of water, of metals and elements, of physical properties. He ignored that inner drive which Spinoza called the *conatus*; or the *seeds* of Paracelsus or van Helmont; or the persistence over a time course of any "essence" or "form." Since he dealt with phenomena relatively simple when compared with living phenomena, he could, for this very reason, make progress, up to a point. As a chemist, he could seek fairly specific and precise correlations of various concrete environmental factors, and then assume that living beings behaved as did the inorganic objects which he investigated. However, he always excepted the soul of man, as outside his investigations.

But while Boyle was a skillful chemist, judged by the standards of his time, we cannot call him a skillful medical investigator. This represents, however, the fault of the era in which he lived rather than any fault peculiar to him. Boyle's medical studies fall into at least two categories. These were the purely physiological experiments, such as those on respiration or on blood, and the more clinical experiments, concerned with pharmaceuticals, clinical [Pg 35] pharmacology, and clinical medicine. The purely physiological experiments have great merit and were profoundly influential in shaping modern physiology. The clinical experiments throw great light on the development of critical judgment in medical history, and the relations of judgment and faith.

In 1775, John Hunter wrote a letter to Jenner that has become quite famous. Hunter had just thanked Jenner for an "experiment on the hedgehog." But, continued Hunter, "Why do you ask me a question by way of solving it? I think your solution is just, but why think? Why not try the experiment?"[50] The word "just," of course, in its eighteenth-century sense, means exact or proper, precise or correct. A "just solution" is one that is logically correct. The "think" refers to Hunter's own uncertainty. He is not content with a verbal or logical solution to a problem, he wants empirical demonstration. Why, he is asking, should we be content with merely a logically correct solution when we can have an experiential demonstration. *Try the experiment.* Put the logical inference to the test of experience.

This empirical attitude, not at all infrequent in the latter eighteenth-century medicine, was quite unusual in the seventeenth-century medicine. This was precisely the attitude that Robert Boyle exhibited in his clinical contacts.

Medicine, at least textbook medicine, was rationalistic. Textbooks started with definitions and assertions regarding the fundamentals of health. This we see particularly in a Galenic writer such as Riverius. Medicine, he said, "stands upon the basis of its own principles, axioms and demonstrations, repeated by the demonstration of nature."[51] In his text, Riverius first expounded a groundwork concerning the elements, temperaments and humors, spirits and innate heat, the faculties and functions; then the nature of the diseases which resulted from disturbances of these; and finally the signs of disease and the treatment that was appropriate. All were beautifully interdigitated in a logical fashion, and for any [Pg 36] recommended therapy a good reason could be found. There was, however, a serious difficulty. If anyone were so bold as to ask, *But how do you know?* only a rather lame answer would come forth. The exposition rested in large part on authority or else largely on reasoning from accepted premises—a "just" reasoning. And while much keen observation was duly recorded and a considerable mass of fact underlay the theoretical superstructure, the idea of empirical proof was not current. Riverius chopped logic vigorously and drew conclusions from unsupported assertions in a way that strikes us as reckless.

For a body of knowledge to be a science, it must indicate a logical connection between first principles, which were "universal," and the particular case. The well-educated physician could always give a logical reason for what he did. The empiric, however, was one who carried out his remedies or procedures without being able to tell *why*. That is, he could not trace out the logical connection between first principles and the particular case.

Galenism suffered especially from logical systematization, and the system of van Helmont, while far less orderly, also had its own basic principles on which all else depended. Boyle, however, practiced medicine on a thoroughly different basis. He did not depend on system or logic. In the words that Hunter used to Jenner over a hundred years later, other physicians would *think* the answers to their problems. Boyle, however, preferred to *try the experiment*. He wanted *facts*.

But this attitude, which sounds so modern, so praiseworthy and enlightened, had one serious flaw. What *was* a fact? And how did you know? This important problem, so significant for the growth of scientific medicine, we can study quite readily in the works of Robert Boyle.

The problem, in a sense, resolves around the notion of credulity. What shall we believe?

Boyle makes some distinctions between what he has seen with his own eyes and what other people report to have seen. Thus, he mentions "a very experienced and sober gentleman, who is much talked of" who cured cancer of the female breast "by the outward application of an indolent powder, some of which he also gave me." But, he adds cautiously, he has not yet "had the opportunity to make trial of it."[52] Clearly, since he cannot make the trial himself, Boyle withholds judgment, even though the material came from a "very experienced" gentleman. Or again, he talks about "sober travelers" who made certain claims regarding the treatment of poisons. But, he says, "having not yet made any trial of this my self, I dare not build upon it."[53] [Pg 37]

There are numerous such instances, scattered throughout his works, where he reports an alleged cure but specifically indicates his own mental reservations. Clearly, he is quite cautious in accepting the statements of others, even though they were "sober" or "experienced" or even "judicious." On the other hand, he is extremely uncritical when he himself uses the term "cure" and when he attributes cures to particular medicines.

His skepticism he indicates in references, for example, to Paracelsus and van Helmont. Their specific remedy against "the stone," he says, and their claims that they can reduce stones to "insipid water, is so strange (not to say incredible) that their followers must pardon me, if I be not forward to believe such unlikely things, til sufficient experience hath convinced me of their truth."[54] Here, of course, we see further a feature of critical acumen. A claim is made, but if this claim runs counter to Boyle's own accepted body of knowledge, or to logical doctrines derived from other directions, mere assertion cannot carry conviction. "Sufficient experience" must play its part, and just what constitutes "sufficient" we are not quite sure.

In judging the effectiveness of a remedy or the credibility of a statement, one of the most important weapons was *analogy*. Direct observation of a phenomenon was good. Next best was direct observation of some *analogous* phenomenon whereby one body acted upon another to alter its properties or induce significant changes. Boyle drew his analogies largely from chemistry, but he had no hesitation in applying them to medicine. [Pg 38]

Claims that medicines swallowed by mouth could dissolve stones in the bladder seemed a priori unlikely. Yet there was considerable authority that this took place; many persons had reported that this was a *fact*. Boyle kept an open mind. He might be highly skeptical in regard to the claims for any particular medication, but he did not deny the principle involved. The possibility that some fluid, when swallowed, could have a particular specific action on stones in the bladder, without affecting the rest of the body, he considered quite plausible through the analogy that quicksilver has an affinity with gold but has no effect upon iron. Furthermore, a substance than can corrode a solid body may nevertheless be unable to "fret" a different body which is considerably softer and thinner, if the "texture" does not admit the small particles.[55] Reasoning by analogy served to explain the logical plausibility. In other words, he was very open-minded. He refused to dismiss all such claims, and provided analogy as a reason for keeping his mind open; yet he refused to accept particular claims of medicine that dissolved stones, because the evidence was not convincing. We could scarcely ask for more.

An important seventeenth-century medical document was the report of Sir Kenelm Digby, regarding the so-called "weapon salve." The essay describing this famous powder was written in 1657, and I have discussed it at some length elsewhere.[56] Here again Boyle keeps an open mind, saying, "and if there be any truth in what hath been affirmed to me by several eye-witnesses, as well physicians as others, concerning the *weapon-salve*, and *powder of sympathy*, we may well conclude, that nature may perform divers cures, for which the help of chirurgery is wont to be implored, with much less pain to the patient, than the chirurgeon is wont to put him to."[57]

One great advantage of chemistry, thought Boyle, lay in the help it provided in investigating the *materia medica*. Chemistry, he thought, could help to purify many of the inorganic medicines and make them safer, without impairing their medicinal properties. Furthermore, chemistry could help investigate various medications customarily employed in medicine, where "there hath not yet been sufficient proof given of their having any medical virtues at all."[58] Boyle believed that by proper chemical analysis he could isolate active components, or, contrariwise, by failing to extract any valuable component, he could eliminate that medicine from use. While a major interest, perhaps, was a desire to provide inexpensive medicines, he was well aware that much of what went into prescriptions probably had no value. Furthermore, he felt that his chemical analysis could indicate whether value and merit were present or not. [Pg 39]

The same skepticism applies to remedies that, far from being expensive, were common and yet rather disgusting. The use of feces and urine as medication was widespread. The medical virtues of human urine represent, he believed, a topic far too great to be considered in a brief compass. But he declared that he knew an "ancient gentlewoman" suffering from various "chronical distempers" who every morning drank her own urine, "by the use of which she strangely recovered."[59] Boyle was quite skeptical of the reports of others, which he had not had opportunity to try himself. But in therapeutic trials that he himself had witnessed, he seemed utterly convinced that the medication in question was responsible for the cure and was quite content to accept the evidence of a single case.

He discussed the "efficacy" of millepedes, which he found to be "very diuretical and aperitive." And he indicated, on the evidence of a single patient whom he knew, that the millepedes had great medicinal value in suffusions of the eyes.[60]

Many remedies of this type, the so-called old wives' remedies, were those of empirics. As mentioned previously, Boyle felt deeply concerned because physicians tended to ignore the alleged remedies of those who had not had formal training in medicine. He believed that great specific virtue probably lurked in many of these remedies, and he maintained that the chemists should investigate them without the prejudice that the medical professions exhibited. As part of this view, he felt that "simples" should be more carefully studied, because medicinal virtues inhered in single substances and that complicated combinations were unnecessary.

We find innumerable examples scattered through Boyle's writings regarding the relations between chemistry and medication, numerous descriptions of cures, and skepticism regarding other alleged cures. As an important example, I would indicate Boyle's discussion of one of van Helmont's alleged cures.[61]

Van Helmont described the remarkable cures brought about by a man identified only by the name of Butler. Apart from van Helmont's discussion, we can find no trace of him in medical annals, and van Helmont's own account is extremely skimpy. There are no dates given, and the only temporal clue is that Butler apparently knew King James—King James I, naturally. Butler was an Irishman who suddenly came into world view while in jail. A fellow prisoner was a Franciscan monk who had a severe erysipelas of the arm. Butler took pity on him, and to cure him took a very special stone which he had and dipped it briefly in a spoonful of "almond milk." This he gave to the jailer, bidding him convey a small quantity of it into the food of the monk. Almost immediately thereafter, the monk, not aware of the medicine, noted an extremely rapid improvement.

Van Helmont related other cures. For example, a laundress who had a "megrim" [migraine] for sixteen years was cured by partaking of some olive oil, into a spoonful of which Butler dipped the stone. Other cures for which van Helmont vouched included a man who was exceedingly fat; he touched the stone every morning with the tip of his tongue and very speedily lost weight. Van Helmont's own wife was cured of a marked edema of the leg. Similarly, a servant maid who had had severe attacks of erysipelas which were "badly cured," and the leg leaden colored and swollen, was cured almost immediately. An abbess, whose arm had been swollen for eighteen years, partly paralyzed, was also cured. Van Helmont, however, indicates that he himself, when he thought he was being poisoned by an enemy, did not secure any benefit from the use of the stone. Later, however, it turned out that, because of the nature of the illness, he should have touched the stone with his tongue, to take its virtue internally, rather than merely anointing the skin with oil into which the stone had been dipped.

Van Helmont makes it very clear that this is not magic or sorcery; there is no diabolic influence, no necromancy. He drew attention to the overwhelming effects which might result from a cause which was so minute that it could not be perceived by the senses. We cannot here go into the theoretical background which underlay van Helmont's conceptions, but we must mention at least briefly his idea of a basic mechanism. Van Helmont considered the action to be that of a ferment, where an extremely minute quantity can produce a tremendous effect. He gives the analogy of the tooth of a mad dog, which, although any saliva has been carefully wiped off, can nevertheless sometimes induce madness. The effect of the stone seems to be comparable. Its power becomes manifest even in enormous dilution and can multiply, for it can import its remedial virtue to a vast quantity of oil. Moreover, the stone had a sort of universal power against all diseases. Such a virtue could not be vegetable in its nature, but was, he thought, connected with metals. He pointed to the well-accepted medicinal virtues which inhered in gems. Metals also had great medicinal potency. Antimony, lead, iron, mercury, were well known, and of special importance was copper, the *Venus* of the early chemists.

The medicinal virtue which inhered in Butler's stone and in other powerful fermental remedies, van Helmont designated as "drif," which he said means, in the vernacular, virgin sand or earth. This virtue requires a metallic body in which to inhere. The general concept is not unfamiliar, of a virtue or power or ferment which was attached to a material object, and it is this type of explanation which was so preponderant in, for example, Porta's *Natural Magick*. Van Helmont speaks of the "first being," which translates the Latin *Ens*, of Venus or copper. Vitriol is the basic substance, and for purification of the virtue we require a "sequestration of its Venus from the dregs of the vitriol."[62]

This was the background from which Boyle set about to secure a potent remedy. Van Helmont had discussed his experiments whereby he tried to create a medicine which would have the virtues of Butler's stone. Boyle attempted to improve on van Helmont's technique. Copper—Venus—was the basic metal, and Boyle started with vitriol or copper sulfate. He gave fairly explicit directions for the preparation, including calcination, boiling, drying, adding sal armoniack, subliming twice. The resulting chemical represented a purified medicine which he prescribed in variable dosage, from two or three grains, up to twenty or thirty at the maximum. He declared it to be a "potent specifick for the rickets," since he, and others to whom he had given it for use, had "cured" a hundred or more children of that disease. The medicine he also prescribed in fevers and headache, and he thought it "hath done wonders" in obstinate suppressions of the menses. It also improved the appetite. It worked, he declared, through the sweat and, to some extent, the urine.[63] It is noteworthy that Boyle did not claim to have cured the same illnesses than van Helmont reports as having been cured by Butler's stone.

As another example, he gave directions for preparing essence of hartshorn—prepared, literally, from the horn itself. The preparation, strongly alkaline, he prescribed in small doses of eight to ten drops. The medicine "resists malignity, putrefaction, and acid humours," for it destroys the acidity. He used it "in fevers, coughs, pleurisies, obstructions of the spleen, liver, or womb, and principally in affections of the brain...."[64] [Pg 43]

While Boyle was a far more skillful chemist than van Helmont, he did not have any greater diagnostic acumen. And clearly, from the standpoint of scientific method, he lacked any sharp criterion of cure. Various patients were ill with various diseases; he gave them one or another preparation; the patients recovered. Controls there were none. Boyle, with great enthusiasm, believed that through natural philosophy we would eventually discover "the true causes and seats of diseases" and also find out effective remedies which would quickly free the patient from the disease.[65] But faith and enthusiasm did not compensate for the *post hoc propter hoc* attitude.

According to Galenic concepts, if diseases are due to alterations of humors either in their quality or in their proportions, then the suitable remedy will restore the appropriate quality or proportion. In Galenic doctrine, the disturbance of the humors should be perceptible, and a sound Galenic remedy should work by perceptibly changing the nature and proportion of the humors back to normal. However, side by side with the Galenic medical doctrines, there were the other prevalent doctrines, among which I can mention the idea of "specifics." I can emphasize three features: the specific remedy was active against a particular disease, in a quite specific fashion, in the same way that an antidote acted against a specific poison; second, the effectiveness was a matter of direct experience, based on empirical observation; and third, the mode of action remained relatively obscure, but nevertheless the medicines did not seem to behave as did the so-called "Galenicals." Thus, whether they acted by "sympathy," or by a special hidden virtue, or by a peculiar microcosmic energy, we cannot say. But the *fact* remains that many people asserted the specific effectiveness[66] of this or that remedy against a specific disease—e.g., that snakeweed was an effective cure for the bite of a serpent. [Pg 44]

Learned physicians, unfortunately, refused in large part to accept the validity of these alleged cures. Their hesitancy rested not on statistical evidence or on niceties of scientific method, but on the grounds that the alleged mode of operation was quite unintelligible and not at all in accord with accepted doctrine.

Boyle, as a chemist, insisted on keeping an open mind in regard to so-called specifics. He objected strongly to the argument that simply because we cannot account for their mode of action, we should conclude that they were not effective. In a passage of great importance, he declared, "Why should we hastily conclude against the efficacy of specificks, taken into the body, upon the bare account of their not operating by any obvious quality, if they be recommended unto us upon their own experience by sober and faithful persons?" Thus, his chain of reasoning is, first of all, these remedies work, as attested by direct experience; we are not able to explain why or how they work; we must not, however, fly in the face of experience and deny their effectiveness simply because of our inability to explain the workings. He gives the example of a "leaven," which in minute amounts is able to "turn the greatest lump of dow [dough] into leaven."[67]

Boyle strongly supported the well-known quotation of Celsus, that the important thing is not what causes the disease but what removes it. In strong terms he criticized "many learned physicians" who rejected specifics on the ground "that they cannot clearly conceive the distinct manner of the specificks working; and think it utterly improbable, that such a medicine, which must pass through digestions in the body, and be whirled about with the mass of blood to all the parts, should, neglecting the rest, shew it self friendly to the brain (for instance) or the kidneys, and fall upon this or that juice or humour rather than any other."[68] Boyle then went into considerable detail to show how this can take place through the action of ferments, combined with a theoretical exposition of atomistic philosophy, which we do not have time to go into at present. He gave in great detail an exposition of how these specifics *may* operate, but did not in any way produce cogent evidence that they do in fact operate in such fashion. [Pg 45]

As a physician, Boyle insisted on facts over theory. He was constantly pleading for physicians to enlarge their experience, to try new medicines, even though these were not based on traditional doctrine. Where observed fact conflicts with theory, the fact cannot be ignored. Credulity of physicians, he indicated, may do the world "more mischief" than any other profession, but nevertheless he condemned those who would try to "circumscribe, or confine the operations of nature, and not so much as allow themselves or others to try, whether it be possible for nature, excited and managed by art, to perform divers things, which they never yet saw done, or work by divers ways, differing from any, which by the common principles, that are taught in the schools, they are able to give a satisfactory account of."[69] Surely, this is not a model of elegant English style, but the message is clear. Boyle was emphasizing the message taught earlier in the century by Francis Bacon, that we must judge the theory by the fact, and not the facts by the theory. It is the same philosophy that Hamlet expounded, that there are more things in heaven and earth than are dreamed of in our philosophy.

We see, thus, that Boyle had taken a mighty step toward modern scientific medicine, but he covered only a small part of the total distance. He insisted that we should accept facts, but he did not realize the difficulties attendant on defining a fact and making it credible. He indicated that when strange results are alleged, "these need good proof to make a wary man believe so strange a thing,"[70] but what constitutes proof was a problem which he was not able to wrestle with and, indeed, a problem which he did not clearly perceive.

I would emphasize that Boyle was in essence a man of great faith. He had great faith in religion, and was a deeply religious man. He was a great supporter of so-called "natural religion" and tried to reconcile the doctrines of natural philosophy with those of traditional religion. Westfall[71] has considered in detail the religious attitudes of late seventeenth-century writers, Robert Boyle in particular. The "proofs" alleged by the proponents of natural religion have, of course, little cogency. As Westfall points out, they examined nature in order to find what they already believed. [Pg 46]

Nevertheless, religious faith was only one part of the total faith which Boyle exhibited. He had as much faith in the capabilities, the future progress, and the promise of science as he did in traditional religion. Throughout all his works we see great evidence of his religious piety. But his faith in science, particularly as it affected medicine, we see with utmost clarity in the essay "The Usefulness of Natural Philosophy." He had great vision of the benefits that science would eventually bring to the healing arts. Unlike many of his contemporaries, particularly persons such as Glanvill or Spratt, he realized that many anatomical discoveries, for example, were of little practical value, but he felt that such discoveries would, "in process of time (when the *historia facti* shall be fully and indisputably made out, and the theories thereby suggested clearly established) highly conduce to the improvement of the therapeutical part of physick...."[72] And with extraordinary perceptiveness he indicated the different ways in which he expected progress to be made through the proper application of mechanical philosophy. He was clear-sighted enough to realize that the discoveries made hitherto were not of great practical value but that the future was indeed bright, and he provided a remarkable blueprint of progress to come.

The measure of progress is, perhaps, the quantity of faith which moves mankind. The study of Robert Boyle emphasizes some divisions among mankind. Some are content to look [Pg 47] backward, to be satisfied with the achievements of the past, to rely on accepted systematization, doctrine, and explanation. Others, while dissatisfied with the past, have no guide to lead them anywhere. Still others, however, have a strong faith in the new course which they are pursuing, a faith which can guide them over great difficulties. Boyle was such a man of faith—a word which is really synonymous with "attitude." He marked the transition between the old and the new, and pointed up the difficulties which transition always involves.

Notes [Pg 48]

[37] Thomas Birch, *The Life of the Honourable Robert Boyle*, in Robert Boyle, *The Works of the Honourable Robert Boyle*, ed. Thomas Birch, London; 1772, I, liv, reprinted Hildesheim, 1965, I, Introduction, viii-ix; Marie Boas Hall, *Robert Boyle on Natural Philosophy: An Essay with Selections from His Writings*, Bloomington, Indiana, 1965, p. 16.

[38] John F. Fulton, *A Bibliography of the Honourable Robert Boyle*, 2nd ed., Oxford, 1961, p. 37.

[39] Hall, *op. cit.*, p. 47.

[40] Margaret E. Rowbottom, "The Earliest Published Writing of Robert Boyle," *Annals of Science*, VI (1950), 376-389; R. E. W. Maddison, "The Earliest Published Writing of Robert Boyle," *Annals of Science*, XVII (1961), 165-173.

[41] Lazarus Riverius, *The Universal Body of Physick, in five books,... Exactly translated into English by William Carr*, London, 1657.

[42] Lazari Riverii, *Opera Medica Universa*, Geneva, 1727.

[43] J.-H. Reveillé-Parise, ed., *Lettres de Gui Patin*, Paris, 1846.

[44] Jean Baptiste van Helmont, *Oriatrike or Physick Refined ... faithfully rendered into English by J. C.*, London, 1662, and *Ortus Medicinae*, Editio Quarta, Lugduni, 1667.

[45] Giovanni Battista della Porta, *Natural Magick*, London, 1658, reprinted New York, 1957, and *Magiae Naturalis Libri Viginti*, Rothomagi, 1650.

[46] Richard F. Jones, *Ancients and Moderns: A Study of the Rise of the Scientific Movement in Seventeenth-Century England*, 2nd ed., St. Louis, 1961; Richard S. Westfall, *Science and Religion in Seventeenth-Century England*, New Haven, 1958; Marjorie Hope Nicolson, *Pepys' Diary and the New Science*, Charlottesville: The University Press of Virginia, 1965;

Walter E. Houghton, "The English Virtuoso in the Seventeenth Century," *Journal of the History of Ideas*, III (1942), 51-73, 190-219; and Dorothy Stimson, *Scientists and Amateurs: A History of the Royal Society*, New York, 1948. See also, for an entertaining primary source, Thomas Shadwell, *The Virtuoso*, ed., Marjorie Hope Nicolson and David Stuart Rodes, London, 1966. [Pg 49]

[47] Sir George Clark, *A History of the Royal College of Physicians of London*, Oxford, Volume I, 1964, Volume II, 1966.

[48] Boyle, "Memoirs for the Natural History of Human Blood," *Works*, IV, 637.

[49] Boyle, "On the Usefulness of Natural Philosophy," *Works*, II, 169.

[50] Stephen Paget, *John Hunter*, London, 1897, p. 126.

[51] Riverius, *Opera*, trans. Lester S. King, p. 1.

[52] Boyle, "Usefulness," pp. 74-75. See also pp. 115-116.

[53] *Ibid.*, p. 87.

[54] *Ibid.*, p. 97.

[55] *Ibid.*, p. 98. See also "Of the Reconcileableness of Specific Medicines to the Corpuscular Philosophy," *Works*, V, 85-86.

[56] Lester S. King, "The Road to Scientific Therapy: 'Signatures,' 'Sympathy,' and Controlled Experiment," *Journal of the American Medical Association*, CXCVII (1966), 250-256.

[57] Boyle, "Usefulness," p. 115.

[58] *Ibid.*, p. 127.

[59] *Ibid.*, p. 130.

[60] *Ibid.*, p. 131.

[61] Van Helmont, "Butler," *Ortus Medicinae*, pp. 358-365, and *Oriatrike*, pp. 585-596. See also Boyle, "Usefulness," p. 102.

[62] Van Helmont, *Ortus*, p. 365; *Oriatrike*, p. 596.

[63] Boyle, "Usefulness," pp. 135-136.

[64] *Ibid.*, p. 138.

[65] *Ibid.*, p. 144.

[66] Boyle, "Reconcileableness of Specific Medicines," pp. 80-81.

[67] Boyle, "Usefulness," p. 183.

[68] *Ibid.*, p. 190.

[69] *Ibid.*, p. 194.

[70] *Ibid.*, p. 195.

[71] Westfall, *op. cit.*

[72] Boyle, "Usefulness," pp. 163-164.

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