Birth and Growth of Science in Medicine.¹

By SIR FREDERICK ANDREWES, F.R.S.

THE aim of science is to discover the "laws of Nature," and in its truest, though narrowest, sense it is the pursuit of this knowledge for its own sake, irrespective of any practical use to which it may be put. The primary aim of medicine is the practical one of healing the sick or of preventing disease, and therefore, in the narrower sense, medicine is not a science, but an art. Physiology, pathology, and pharmacology are sciences in the strictest sense; medicine is the art of applying the laws established by these sciences to the prevention or cure of disease. More than this, it is the very human art of treating the patient as well as his disease. But in a broader, and surely more natural, sense we may regard medicine as a science. Pathology may, it is true, be pursued as an abstract subject, but in real life it is inseparable from medicine. Treatment and prevention are so intimately based upon a right understanding of the nature of disease and of the laws which govern its course that I refuse to separate pathology and medicine. It has too long been the fashion to limit the sphere of pathology to the dead-house and the laboratory; its field is equally at the bedside, and, indeed, I would assert that there is no method of studying the natural history of disease which pathology may not claim as its proper province. By Harvey's injunction I am to admonish you to seek out the truths of Nature by observation and by experiment. These are two different ways of pursuing a subject, and, indeed, the concrete sciences have been divided into the "observational" and the "experimental"; anatomy is an observational science, physiology an experimental one. The observational sciences long preceded the experimental, and in pathology and medicine, which partake of the nature of both, the experimental method is of late growth.

My aim is to trace, so far as I may in the allotted span of time, the influences which have governed the growth of our knowledge of disease; to pursue them to their beginnings rather than to record their final results. I cannot, indeed, hope to say anything new; I can only endeavour to place before you the facts to be gathered from literature in the way in which they group themselves in my own mind.

In his suggestive little book entitled "The Revolutions of Civilization" Prof. Flinders Petrie has pointed out that culture is an intermittent phenomenon. No civilisation in the past has proved permanent, and he estimates the average duration of any given period of culture at about 1500 years; in Egypt he traces eight such periods. In Europe we are aware of three great periods of civilisation during the past five thousand years—the Mediterranean or Minoan, with its headquarters in Crete, from 3000 to 1200 B.C.; the Classical, of which Greece was the intellectual fountain-head; and the Modern or Western, in which we are still living.

So far as we are aware, the earliest attempts at science began in Ionia some six centuries before Christ, and the name which I would first commemorate as a spiritual benefactor of this college is that of Thales of Miletus. I might have chosen Empedocles or Pythagoras, but we may let Thales, as the first of the succession of early Greek thinkers, stand as the prototype of the group of men who laid the foundations upon which science was to be built by future generations. Doubtless they had acquired

what they might of the lore of older civilisations, but they seem to have been the first to pursue abstract knowledge. Until their day men had been content to accept any foolish myth about the nature of the world and of the things they saw around them. The service which Thales and his successors rendered to mankind was that they rejected all fabulous tales and began to think for themselves how things had become such as they saw, definitely reaching out after the laws which they felt sure must govern Nature. Their great contribution to science was to establish that atmosphere of intellectual liberty which rendered science possible. It says much for the liberal spirit of that age that these men, who broke with all the cherished traditions of the past, were not, as a rule, reviled for impiety, but received universal honour. Thales was accounted one of the Seven Wise Men of Greece.

But let me now consider what the earlier Greeks did for medical science. Medicine of a sort and rude surgery must have been transmitted even through the dark ages, handed down, it is said, by special families, the Asklepiadæ, just as the epic tradition was passed along by the Homeridæ. Certain rules of surgery and the practices of blood-letting and purgation are known to be of immemorial antiquity, but for the most part the medical practice of those times seems to have been bound up with fetish worship and superstition. There is no evidence that Egypt had any true medical science to impart, and our knowledge of Minoan medicine is limited to the single fact that in the great palace at Cnossus there existed a system of sanitation so good that it was never equalled until the reign of Queen Victoria. We may be quite sure that the inquisitive and receptive Greek mind was quick to pick up what it could from the older civilisations, and then, in accordance with its peculiar genius, it proceeded to develop it out of all recognition.

Medicine entered upon its first scientific stage with the Greeks; it became an observational science. More than this; just as in other matters the philosophers had put away the myths and fairy tales of their ancestors, so, too, in medicine they rejected the magic and fetish worship which had hitherto formed so large a part of practice. This was one of the greatest services rendered by the Greeks to medical science. Æsculapius was worshipped at numerous temples, and thither the sick were brought to receive such benefit as they might from the rites of the god. But at such health resorts they were also subjected to other influences—careful diet, pure water, rest, and cheerful associations—and when improvement occurred the physicians had the acuteness to perceive that this simple treatment had probably more to do with the result than the religious rites.

This brings me to the second name which I naturally commemorate to-day—that of Hippocrates of Cos—the first great clinician of whom we have any knowledge, and one whose name will always be associated with the phase which Greek medicine had now reached.

When Hippocrates was born, about 460 B.C., observational medicine had attained a considerable pitch of excellence. He doubtless imbibed the teachings of other good physicians who had gone before him, but the veneration in which Hippocrates was held by the Greeks themselves assures us that he was a man of outstanding character and attainments. We can,

¹ From the Harveian oration delivered before the Royal College of Physicians of London on October 18, 1920.

however, judge of him more directly. It is certain that only a small part of the Hippocratic treatises which have come down to us are from the pen of the master himself, but we may reasonably take them, as a whole, to represent his teaching, and they give us a fair idea of the stage at which the best Greek medical science had arrived in the fifth century B.C. It was a simple and rational medicine based on careful clinical observation and on a watchful study of the results which followed hygienic treatment. The healing powers of Nature formed a leading tenet of the Coan school; we may almost regard Hippocrates as the founder of sanatorium treatment. Perusal of those of the Books of Epidemics which are most certainly by Hippocrates himself shows that he was an admirable case-taker; in the light of our present knowledge we can readily make a diagnosis from many of his descriptions. His medicine shows, of course, the natural limits of a purely observational science; it knows little of anatomy and less of physiology; its crude pathology is based on the doctrine of "opposites"; the idea of experiment as a means of investigation has not yet arisen. Yet in spite of this, the school of Cos is a landmark in the history of rational medicine.

The centre of interest now shifts elsewhere, and especially to Alexandria, but it remains Greek. Alexandrian culture represents a sort of continuation of that of Athens, though, perhaps, in comparison smacking somewhat of Wardour Street. The great creative age in art and poetry had gone by; it was a period of imitation in art, and in literature largely a time of scholiasts and commentators on the better work that had been done before. But here we have an excellent illustration of Prof. Flinders Petrie's dictum that in each period of culture science reaches its prime long after art and literature have begun to decline. For all the branches of science then extant continued to advance in Alexandria. I need scarcely recall how mathematics and astronomy flourished under the Ptolemies, and in medical science the Alexandrian school maintained its premiership for many hundred years.

Anatomy and physiology form a necessary basis for medical science, and much as the earlier Greeks had done for medicine, they had lacked any adequate knowledge of these subjects. The later Greeks proceeded to remedy this defect. The practice of dissection became established, and anatomists must look back to the Alexandrian school for the foundation of their science. I must pass over Herophilus and Erasistratus and commemorate the later Greek school in the person of its most distinguished alumnus, Galen. Roman medicine, like its art, was wholly Greek in origin; its great physicians received their training in Greek schools, and Celsus, the best-known writer on medical subjects, was not himself a practitioner of medicine. Thus, though we associate Galen with Rome, I must commemorate him as a Greek—the last and, in many ways, the greatest of the Greek physicians.

Nearly six hundred years had passed between Hippocrates and Galen, and when we compare the two it must be remembered that Galen had the advantage of that six hundred years of medical experience. It gave him a wider outlook, and thus made him a better physician, though I conceive Hippocrates, considering his times, to have been the bigger man. I do not propose to dwell on Galen's eminence as a physician, though he stood far above all others of his age. His real claim to immortality may be put into a few words: he was the first to make systematic use of the experimental method in medicine, and he founded the science of physiology. His experimental discoveries in physiology, and particularly in the

domain of the nervous system, entitle him to be called the father of that science. Galen must also be credited with a great advance in pathology. The earlier Greeks had regarded internal medicine from a purely humoral aspect; the later Greeks began to recognise affections of certain definite organs, but Galen developed this conception beyond any of his predecessors.

With Galen we come to the end of the great age of classical civilisation, and it will be fitting, before leaving it, to summarise what Greek genius had accomplished in medical science. An atmosphere of intellectual liberty essential to the birth and growth of science had been established by the Greeks; they had developed the love of knowledge for its own sake. Their shrewd observation had transformed medicine from a medley of traditional empiricism and superstition into a natural science; they freed it from magic and laid the foundations of a rational treatment of disease. Towards the close of their epoch they devised the experimental method, and used it to found the science of physiology. Indirectly we owe to them the laws of clear thinking in medicine and in the other sciences, and the development of mathematics and mechanics.

When the Minoan civilisation passed away the Greeks had been compelled to begin again almost from the beginning. There was no such complete break between the classical period and our modern civilisation; much was handed on by direct tradition, and vastly more by written manuscript. Nevertheless, after the fall of the Roman Empire, Europe had to be remade, and to pass through its dark ages before the dawn of a new culture. The new mixture of races seems to have been incapable of intellectual achievement until the ordained incubation period was over, and that period was at its darkest from the fifth to the tenth centuries A.D. Medicine shared the fate of the other sciences, and what was not forgotten became debased by admixture with Eastern magic and superstition.

The dominant power in Europe during this period was the Church, and, although its conservatism had a wholly deadening influence as regards the advance of science, it did much to preserve the culture of classical times. In the seventh century occurred the last of the four known Arab migrations which have overwhelmed neighbouring peoples; it spread not only over Western Asia, but also round the Mediterranean. Whatever may have been the primitive culture of these Arab invaders, they presently acquired a high degree of civilisation. They were a keen-witted race, quick to assimilate the culture with which they came in contact, and this was largely Greek in origin. For some hundreds of years the Moorish Empire in Spain was far in advance of the rest of Europe in literature, in science, and in medicine. The best medical works of classical antiquity were translated into Arabic, and it is by this strange route that much has come down to us which would otherwise have been irretrievably lost. Their chief share in medicine was to absorb and transmit the knowledge of the Greeks. Medicine reflects the spirit of the Dark Ages in Europe; the traditions of the past were still supreme, and Galen was the god of the medical world. Men felt him to have been a better man than themselves, as in truth he was, and it was enough that Galen said this or that, or that his writings could be interpreted in such and such a sense, and there the matter ended.

Then, in the fullness of time, after more than a thousand years of intellectual slumber, men again began to think for themselves, just as the Ionian Greeks had done twenty centuries before. The Renaissance was at first literally a revival of learning, due to the renewed study of the Greek language and

the discovery of much of the classical literature which had been hidden away in the libraries of the East. The first effect of the revival was to strengthen the position of Galen. With the revival of Greek in the fifteenth century his original writings became accessible, and manuscripts hitherto unknown came to light. It became the aim of the scholars of the time to translate these works into polished Latin for the benefit of those unacquainted with Greek. Amongst the medical humanists, as they are termed, was the founder and first president of this college. There is no more honoured name in scholarship than that of Linacre, but it is instructive to note the difference between his mental attitude and that of Harvey, little more than a hundred years later. Linacre stands for the revival of learning, Harvey for the intellectual quickening that revival was to engender. The avowed aim of the medical humanists was not the advance of medical science, but a return to the uncorrupted knowledge of the Greeks; the thought and science of antiquity were still held so immeasurably superior to anything that modern times could produce that no advance was contemplated. But the seed was sown. Greek literature was the product of an original creative activity and a mental freedom to which Europe had been long unaccustomed. Men could not study it without at the same time drinking in something of the spirit in which it had been conceived and which animates it for all time. This was our true heritage in the Renaissance, and once again imbued with this spirit men felt at liberty to ask whether the ancients were always right and to criticise and test their statements. The reign of mere authority came to an end, and science recommenced that advance which has continued to the present day.

The first science to bear new fruit was anatomy. It was in Italy that the resurrection began, and the book written by Vesalius on "The Structure of the Human Body," published in 1543, set the seal upon the new method—the appeal to fact instead of to dogma. We all know that the truth as to the pulmonary circulation was first ascertained, while it was reserved for Harvey to demonstrate the systemic circuit. The method of experiment as an adjunct to observation, instead of being delayed for hundreds of years, as it had been amongst the Greeks, was now, thanks to Galen, an instrument ready to hand. And thus it came about that when a man arose deeply imbued with the true spirit of science and capable of using this instrument with intelligence and an open mind, his study of the circulation was at once rewarded by a discovery of capital importance.

William Harvey stands as one of the landmarks in the history of medical science. His was the first scientific discovery of absolutely first-rate importance to be made by the application of the methods and spirit now revived from ancient times; he possessed the vision, the power of imagination, as well as the needful industry and patience in gathering his facts and in devising his experiments.

Harvey has left us two treatises of unequal greatness. The "De Motu Cordis" has no need of any introductory disquisition on scientific method, for it itself is the method incarnate. It is the mature work of a master who is sure of his ground; it sweeps us along from one short chapter to another, each filled with accurate observation and close reasoning, so that no doubt or hesitation is possible to the reader.

But he also essayed to solve other biological problems, for which his means were not adequate, and the "De Generatione," which he was reluctant to publish, is reading of a different kind. The most instructive part of this treatise is perhaps the introduction on scientific method, "Of the Manner and Order of Acquiring Knowledge." Here Harvey in

his later age sets forth the principles which had guided him, with Aristotle as his leader, in his life's work, and we realise how truly scientific were his methods.

With Harvey, we feel that medical science has fairly entered the right path. The conditions essential to scientific progress—freedom of thought, accuracy of observation, imagination, experimental verification, and logical reasoning—all are exemplified in Harvey's work.

There is room for difference of opinion as to the impulses from external sources which have had the most far-reaching effects upon medicine since Harvey's day, but I would name four as of exceptional importance. They are the invention of the compound microscope, the development of chemistry, the acceptance of the doctrine of evolution, and the discovery of the relation of micro-organisms to disease. The microscope was invented in Holland late in the sixteenth century, but its possibilities as an aid to anatomy were not at first grasped, and it was not until after Harvey's death that Malpighi actually saw the capillaries and the contrary direction of the blood-flow in arteries and veins. The rise of histology from that time forward has transformed our ideas of the structure of the body, and with each improvement in the microscope our horizon has widened. We have passed from the organ to the units of which it is built up, and Virchow's "Cellular Pathology" marks an epoch in medicine. To-day we are a stage further, for the inquiry is being pushed into the more intimate structure of the cell itself, in the hope of revealing the nature of the processes by which it carries on its work.

The rise of physics and chemistry has been even more fruitful for medicine. We cannot nowadays consider them separately, so closely merged have they become. We recognise the fundamental importance of these sciences for the right understanding of physiology and pathology by placing them at the root of medical education.

Chemistry has influenced medicine from the days of alchemy onwards; Paracelsus and Van Helmont stand out as picturesque figures in its history. In England the rise of physics and chemistry began in Harvey's lifetime with those meetings of scientific men which later gave birth to the Royal Society. It must not be forgotten that the work of such men as Boyle, Hooke, Lower, and Mayow practically solved the problem of respiration not long after Harvey's death—a problem second only in importance to that of the circulation—though a century was to elapse for its full meaning to become clear with the discovery of oxygen. Every advance in physics and chemistry has borne fruit for us in its turn; to-day we can almost affirm that the chief issues in physiology and pathology are to be sought in the chemical activities of the human body. These, again, are bound up with physical conditions, and there is one recent branch of chemistry the possibilities of which are only beginning to be appreciated in medicine. If we reflect that the body, from a chemical point of view, consists almost entirely of colloids, the behaviour of which is still imperfectly understood, it will be realised that advances in colloidal chemistry are destined to throw a flood of light upon the processes of vital activity.

The doctrine of evolution has scarcely received the attention it merits as a factor in modifying the opinions of medical science. So long as it was believed that the body, with all its natural functions, had been created from the first in its present condition, there was little room for inquiry into the origin of those functions, and still less into that of morbid processes. Darwin has changed all this, as a single instance will suffice to show. Metchnikoff's studies on the comparative pathology of inflammation have

taught us that this is not a diseased state, but a purposeful reaction against injury, gradually perfected in passing up from the lower to the higher animals. Almost without our being conscious of it, the idea of evolution has gradually effected a great change in the point of view from which we regard a large number of diseases, the symptoms and morbid changes in which we now understand as efforts of the body to maintain its integrity in face of the injurious agencies which threaten it. One might almost rewrite pathology from the evolutionary point of view.

Last, but not least, of the great changes which have swept over medical science is that which was due in the first place to Pasteur, carried on by Koch, and brought to triumphant practical application by Lister. The discovery of the true nature of infection has of necessity transformed the outlook of medicine and surgery, but bacteriology and its daughter science immunology would demand a Harveian oration to themselves.

We loosely speak of such fundamental discoveries as those I have just mentioned as producing a revolution in medical science. It is not revolution, but upward growth. With the establishment of each

great principle we gain a fresh height from which the field of science takes on a new and wider aspect, and we may be confident that we shall reach yet greater heights to reward us with an even ampler range of vision. There is no sign that the vitality of science in our civilisation is in any way spent; on the contrary, its fertility is unchecked. During the late war we saw for the first time the scientific forces of this country fully mobilised, and no previous five years have seen so many scientific problems brought to a successful issue. So forcible has been the lesson that science has gained mightily in public estimation, and research is on the lips of everyone. New facts are being gathered in, old facts are coming to be seen in a new light; we are almost bewildered by our own progress. The workers in the field of medical science are many, and it may not be given to any one of us to make an immortal discovery, such as that of the circulation of the blood. But the humblest of us can work in Harvey's spirit and bring his contribution to the building up of knowledge in the full assurance that even a single stone, if honestly and truly squared, will in due time find its proper place in the fabric.

Wheat from Seed-bed to Breakfast-table.

THE History of a Grain of Wheat from the Seed-bed to the Breakfast-table" formed the subject of the concluding evening discourse given by Sir Daniel Hall at the Cardiff meeting of the British Association, and an account of it appeared in the October issue of the *Journal of the Ministry of Agriculture*. Of all industries there is not one which is older, more universal, or more essential than the growing, grinding, and baking of wheat and its kindred food-grains. Yet, in spite of the extreme age of the industry, the various processes involved in the passage of the wheat-grain from its seed-bed to the breakfast-table still demand the close attention of the best obtainable research men of the day; for it is only by research and by the utilisation of the results so obtained that the increased food production necessary for supplying the needs of the world's growing population can be attained.

Many experiments have been made to try to bring about an increase in yield by treating the seed either by electricity or by soaking it in some nutrient fluid. The results of these experiments are very doubtful, and it is improbable that such treatment can affect the ultimate yield. Attention has also been paid to the influence on the wheat yield of the rate of sowing. Ordinarily, wheat sown at the rate of $2\frac{1}{2}$ bushels per acre gives a thirteenfold yield, but isolated wheat-plants are capable of giving more than a hundredfold yield. It is hoped that by using a suitable machine a perfectly effective seeding can be attained with 1 bushel per acre, and such a reduction in the amount of seed sown would mean a considerable gain to the country. Improvement in the quality of wheat grown has been brought about by careful breeding work. Prof. Biffen, working on Mendelian principles, has obtained a variety of wheat, "Little Joss," which produces very good crops on certain soils because of its resistance to rust attacks, the rust-resistance power having been introduced into the grain by careful selection and breeding. Another wheat, "Yeoman," has been bred for the high milling quality of the grain, and on soils to which it is suited the "Yeoman" wheat yields a very heavy crop, while the quality of the flour is almost equal to that obtained from the best Canadian grain. At the present time millers are compelled to mix strong foreign wheat with our home-

grown wheat in order to produce bread of the spongy type desired by the public, but it is hoped that extension of Prof. Biffen's work will ultimately supply strong wheats of the "Yeoman" type suited to the varying conditions of all our different wheat-growing districts, and in this way the millers may be rendered independent of foreign wheats.

Although wheat is the crop for breaking in virgin land, yet it will not stand competition; at Rothamsted a wheat crop left unharvested to sow itself without further cultivation entirely disappeared in a grassy wilderness in three years. Wheat, though thus dependent on cultivation, possesses a remarkable power of yielding a good crop upon all sorts of soil. One of the Rothamsted plots has carried wheat for seventy-seven successive years without any manure, and the yield is still about 12 bushels per acre—approximately the average crop for the wheat-lands of the world. The manurial requirements of a wheat crop have long since been decided, and the problem now is to prevent the lodging which occurs with big crops on good soils. It may be possible to breed varieties with stiffer and shorter straw, or it may be that manurial treatment, time of sowing, width of rows, and spacing of the seed have some effect on the lodging, or, again, there may be some actual disease factor involved. All these points are being investigated.

The growth of the wheat-plant, so far as gathering material from the air and from the soil is concerned, is practically completed about five weeks before the grain is harvested. This latter period is occupied by the transference of stored-up food from the leaves and stem to the seed. The transference, however, is never complete, and the straw still retains about half of the valuable material manufactured by the plant. Since the amount of such material depends largely on conditions of soil and water-supply, which are outside our control, one line of development must be to increase the migration into the seed. This is especially urgent in drier countries where insufficient water-supply sets a definite limit to the amount of growth. With regard to the flour, considerable differences in milling operations have been brought about under the stress of war. The miller's object is to crack the wheat "berry" with the least possible