THE HISTORY OF MEDICINE

In its Salient Features

JOHN HUNTER
Painted by Sir Joshua Reynolds

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BY

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PREFACE

In the closing days of 1917 I was asked to give a course of lectures on the history of medicine. This book is the outcome of my attempt to comply with the request made at that time. The course of lectures, given in the first place in the early weeks of 1918, followed the lines of the present table of contents. My auditors were third-year students in one of the American Schools of Medicine, and the plan of presentation was more or less consciously dictated, at the start, by the recollection of what had challenged my curiosity and aroused my attention about the time I had attained a like standing as a student of medicine. Questions and class discussions evoked by the lectures in 1918 and the three subsequent years suggested, however, certain modifications of the initial treatment of the subject and indicated in what directions additions and elucidations were most desirable.

Even at the outset I felt sure that the course would be of greater interest to the men if I could trace the development of medicine, however succinctly, from the earliest times till the present day. I began, therefore, with an account of the dawn of medical science in Egypt and Babylonia, in spite of the imperfect state of the records and their need of interpretation. Nor could I refrain — in April, 1918 — from saying at least something concerning "Medical Science and Modern Warfare," although the time had obviously not arrived for setting forth adequately the medical aspects of the World War. Similarly, the distribution of space as regards ancient and modern medicine, the emphasis of what seemed to me the most important stages in the evolution of medicine, the avoidance of unnecessary details and of needlessly abstruse terminology, as well as the general style of composition, have their explanation in the nature of the audience before whom and of the circumstances in which the course of lectures was given. By the use of simple reading lists, now represented by the References at the ends of the chapters, I hoped so to interest the students that they would soon become capable of constructing their own bibliographies, and that from the perusal of Allbutt, Garrison, Guerini, Hyrtl, Meunier, Osler, Singer, Sudhoff, Withington, and other authorities brought to their particular attention, they might pass to an examination of Baas-Handerson, Buck, Choulant, Daremberg, Diels, Friend, Haeser, Holländer, Ideler, Ilberg, Le Clerc, Littré, Meyer-Steineg, Neuburger, Pagel, Puschmann, Schelenz, Schwalbe, Sprengel, Wellmann, Wickersheimer, and other more or less distinguished writers on the history of medicine. Garrison's *Introduction to the History of Medicine* (third edition, 1921) is a comprehensive and up-to-date work almost indispensable to the serious student of the subject it treats. I am especially conscious of my indebtedness to it, to the *Histoire de la Médecine* of Léon Meunier, to the *Geschichte der Medizin* of Max Neuburger, and to the *Medical History* of E. T. Withington, of whose translations I have made use in the second chapter.

Through an almost inexplicable oversight I failed to mention in the preface of *An Introduction to the History of Science* the "Science Room" at the Bodleian Library, Oxford, where that book was written. Some of the researches there carried on by Dr. Charles Singer and those associated with him have been embodied in two handsome volumes — *Studies in the History and Method of Science* (1917, 1921). I take this opportunity of expressing my sense of obligation to him, as well as to Dr. George Sarton, of the Carnegie Institution, editor of *Isis* and exponent on this continent of the claims of the history of science. I wish also to thank Dr. Edna M. Guest, of Toronto, for advice in reference to all the chapters which she read in manucript, and for substantial help in the revision of the twentieth chapter, — help which her military experience in the East, as well as on the Western front, rendered invaluable. All interested in the history of the medical sciences as well as of science in general will welcome the announcement of a work by Professor Lynn Thorndike on *The History of Magic*, and of a *History of Biology* from the pen of Professor W. A. Locy.

WALTER LIBBY

September, 1922

CONTENTS

ILLUSTRATIONS

THE HISTORY OF MEDICINE

In its Salient Features

CHAPTER I

THE PRIEST-PHYSICIANS OF EGYPT AND BABYLONIA

THE medical lore of a very remote past was handed down from generation to generation by the Egyptian priests, the overseers of the general welfare of the people, to become ultimately known, at least in part, to Hippocrates and other Greeks of the Periclean age. The tendency to perpetuate traditional teachings and practices, natural to the priestly caste everywhere, was enhanced in Egypt through the early development of the hieroglyphic and hieratic systems of writing from the pictorial, and encouraged by the preservative nature of the dry Egyptian climate. The written records of the scribes and clerics, their incantations, spells, exorcisms, prescriptions, and clinical observations, were maintained intact from age to age, and finally embodied in compilations, of which a few specimens survive in the medical papyri of our libraries and museums. At the same time the ease with which the dead could be preserved from putrefaction in the plateaus above the Nile Valley led to improved methods of tomb construction, which culminated in the erection of the pyramids between the thirtieth and twenty-fifth centuries, as well as to the development of the art of embalming, which reached its highest perfection about the middle of the sixteenth century, B.C. It is natural to find that in these circumstances therapeutics and religious superstition were not mutually exclusive, and that the efforts of the Egyptian priest-physicians to promote hygienic living and the attainment of longevity were closely associated with a transcendental vision of a material life everlasting.

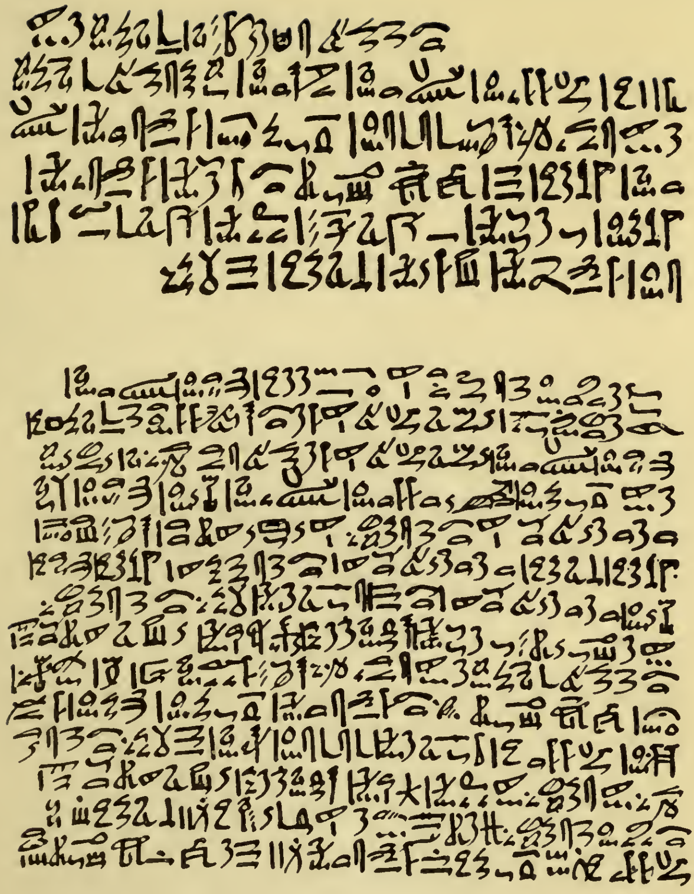
In Egypt more clearly than elsewhere can be traced a rapid advance from barbarism to a high degree of civilization. In the Nile Delta, not far from the pyramids, are still to be seen the graves of neolithic man containing such evidence of his primitive industries as stone implements, pottery, fragments of linen, grains of barley and split wheat. These graves are not unlike those of primitive and prehistoric men elsewhere, as, for example, the graves of some of the aborigines of North America. In fact, the early Egyptian, watering his fields by a simple system of irrigation, living in huts of mud-brick, employing an undeveloped method of chronology, and unacquainted with copper or iron, is in many respects comparable with the ancient Pueblo Indian of New Mexico and Arizona. The transition to a more advanced stage of development came for the Egyptians when in the fifth millennium B.C. they added to the use of gold and the rarer silver that of copper, found native or obtained by smelting from malachite. This acquisition led in turn, about the middle of the thirty-first century, to the employment of prepared stone as building material, and, about the beginning of the thirtieth century, to the erection of the first pyramid. This step-pyramid was designed by Imhotep, the first of the priest-physicians whose name is known to us. In later centuries his memory was held sacred in hundreds of temples, and he became identified in the minds of many Egyptians with Thoth, the god of healing.

It is not strange that some resemblance should exist between the surgery of Egypt, where, in the desert sands, stone tools and flint arrowheads are still to be found, and the surgery of primitive and prehistoric peoples. Before the dawn of history trephining, cupping, circumcision, castration, venesection, the use of the cautery and of splints were known in many parts of the earth; though the motives that led to the employment of these practices were not in each case identical with those of modern surgery. Skulls recovered by the archæologist bear witness that trephining was practiced among prehistoric peoples in the western as well as in the eastern hemisphere. It was performed for a variety and mixture of motives — to relieve headache, to cure epilepsy, to let out the tormenting spirit, to obtain amulets, or to propitiate the gods. Even among primitive peoples to-day trephining is sometimes effected by means of knives of flint or obsidian. A slight link is established between the surgery of barbarian and that of civilized Egypt by some representations of surgical operations of 2500 B.C. They were discovered on the doorpost of a tomb in a necropolis near Memphis. Among the pictures are two of circumcisions, in which the surgeon is shown in the act of operating with a flint knife. The Jews, who learned this adolescent rite from the Egyptians, were still in their ceremonies using the same sort of neolithic instrument centuries later, as we know from the fifth chapter of the Book of Joshua.

On account of the conservatism of the priest-physicians, Egyptian medicine never advanced far beyond primitive medicine with its simple faith in magic spells and the virtue of a rich pharmacopœia, and its belief that the cause of disease was the malice of a demon, the justice of an avenging god, the ill-will of an enemy, or the anger of the dead. The medicine chest of an early Egyptian queen (about 2100 B.C.), with its alabaster bottles containing medicinal roots, is typical of the Egyptian faith in the efficacy of drugs. In the London papyrus, the lesser Berlin papyrus, and the Brugsch papyrus the mystical element predominates, though in the last-named we read of vermifuges, fumigations, treatment of ulcers, of hæmaturia, of diseases of the breast, heart, and ears. The Ebers papyrus, the discovery of which was announced in 1873, though by no means wanting in charms and incantations, is less dominated by the mystical element than the preceding or succeeding medical papyri. It is a compilation of about the middle of the sixteenth century B.C. Much of it reflects, however, the practice of an earlier epoch, and it may be considered as representing the high-water mark of Egyptian medicine.

It is in the main a collection of prescriptions, some of which had been tried frequently, as we learn from marginal notes, and found good, or excellent. It makes mention of some seven hundred remedies, evidently accumulated in the course of the ages, and put on record and preserved for posterity by the priestly scribes. Among the remedies are found poppy, castor-oil, gentian, colchicum, squills, aloes, cedar, mint, myrrh, crocus, hyoscyamus, caraway, elderberries, and many other medicinal herbs, that call to mind the therapy of North American Indians and of all primitive tribes throughout the world. The Egyptian priest-physicians made use also of certain inorganic remedies, such as lead oxide, earthy carbonate of lead, galena, meteoric iron, blue vitriol, crude carbonate of soda, sodium chloride, and sea-salt. Petroleum, bog-water, goose-oil, turpentine, ink (made from charcoal and gum), honey, probably antimony, possibly mercurials, found a place in the Egyptian pharmacopœia. Honey was thought to be terrible to the dead, though sweet to man. It may have been on the complementary principle that what is abhorrent to the patient is pleasant to the perverse demons of disease that many disgusting substances were used as remedies, such as the dung of the gazelle and the crocodile, the fat of a serpent, mammalian entrails, and other excreta, tissues, and organs. In some cases the object seems to have been to wheedle, in other cases to repel, the evil spirits that had taken possession of the patient. The various medicines were given as foods, potions, pills, plasters, inunctions, inhalations, etc.

Among the diseases spoken of in the Ebers papyrus are ailments of the eyes and ears, stomach troubles, worms, dysentery, and other affections of the intestines, arthritis deformans, gout, lumbago, ascites, pemphigus, scurvy, leucorrhœa, asthma, tumors, and a disease which some would



FACSIMILES FROM THE EBERS PAPYRUS IN EGYPTIAN HIERATIC CHARACTERS, THE UPPER CONTAINING THREE, THE LOWER ELEVEN, DENTAL PRESCRIPTIONS

identify as hookworm disease (Egyptian chlorosis), others with bilharziasis. Both of these last-named diseases are very prevalent in Egypt at the present time; both are marked by anæmia and are associated with arrest of mental development; both are now known to be caused by parasitic worms, the former by *Ancylostoma duodenale* (and *Necator americanus*), the latter by *Schistosoma hæmatobium*. Hæmaturia is one of the most constant symptoms of bilharziasis, a fact which may have some bearing on the identification of the disease mentioned in the Ebers papyrus, for the symbol there used for the disease is the phallus. As we shall see in the sixteenth chapter, some of the other diseases treated in the Egypt of the sixteenth century B.C. have in recent times been studied by one of the leading bacteriologists.

A few passages of the Ebers papyrus may bear witness to a knowledge of anatomy, surgery, and diagnosis somewhat beyond the range of primitive and prehistoric peoples. One of these reads: "If the physician place his finger on the head, neck, hands, arms, feet, or trunk, everywhere he will find the heart, for its vessels go to all parts." The vessels of the body are said to run in pairs, and to contain not merely blood, but air, water, milk, and other fluids. Another passage says: "When you find a man with a stoppage, his face pale and heart palpitating, and you find upon examination that his heart is hot and his belly swollen, that is an affection caused by irritant food. Treat it with something that is cooling and aperient, especially with a draught of sweet beer, poured upon dry nequat fruit. Four times shall he eat or drink." A third passage advises operation following diagnosis of fatty tumor: "If you find disease of fat in any part whatsoever of the body of the person, and find that it moves hither and thither under your fingers, and that it trembles when your hand is at rest, then you must say of it, 'It is a fatty tumor; it pains; I will treat it.' Treat it with the knife; dress it as one dresses open wounds."

The Ebers papyrus is not only the most important source of information concerning ancient Egyptian medicine, but the most complete book on any subject that has come down to us from those remote times. The Kahun papyrus consists of two parts, the first gynecological, the second veterinary. The Hearst papyrus, recovered by the Hearst Egyptian Expedition of the University of California, is in content identical with a part of the Ebers papyrus; they belong to the same epoch.

A study of the art of embalming and an examination of mummies and other human remains throw light on the medical science of different periods of Egyptian history, as well as on the various diseases to which the ancient Egyptians were subject. At the same time we are afforded a glimpse of the injuries to which they were especially liable, and of the methods of surgical treatment. Embalming is, of course, of particular interest to us because of the knowledge of anatomy it involved and because it was essentially an antiseptic art. Any brief description of embalming is likely to prove an imperfect or a composite picture, for the procedure was by no means uniform. Evisceration of the dead was to some extent customary before the sixteenth century B.C., and the fact that the ceremonial flint knife was always used to make the incision in the abdomen indicates that the practice had a very early origin. After the embalmer's art had reached its highest development, the brain was sometimes removed by means of an iron or bronze hook, which reached the interior of the skull from the nose by perforating the cribriform plate of the ethmoid bone or by tunneling the sphenoid. The cavity was then cleansed with a solution of drugs. This difficult operation of removing the brain was as a rule quite successful, though the less expert occasionally broke through into the orbital cavities, or even fractured the frontal bone from within. As already implied, the intestines, stomach, liver, and spleen were removed generally through an opening made in the abdominal wall. This was on the left side, probably to allow free play to the right arm of the operator. In some cases the lungs were also removed by piercing the back part of the diaphragm or by removing that muscle. The heart and kidneys might be left *in situ*. After the organs had been removed, the body was rinsed out with wine, myrrh, cassia, etc. At times, instead of making an incision in the abdomen, the embalmer injected a solution of cedar-oil, which acted as a solvent on the viscera, which then were removed through the anus. The body was now kept for seventy days in a saline solution, a solution, for example, of crude carbonate of soda (natron) found native in different parts of Egypt. Finally it was bandaged and wrapped in linen smeared with gums or wax. Resin and pitch were used extensively, as, indeed, the terms "embalm" and "mummy" imply.

During the last few years mummies and other human remains have been examined with the purpose of determining, as far as possible, the diseases and injuries from which the ancient Egyptians suffered. These belated autopsies, numerous as they have been, afford no evidence of syphilis, little or no evidence of rickets (though there are on record cases of distortion difficult to ascribe to any other cause, as well as a case of achondroplasia), and no evidence of tuberculosis except as involved in Pott's disease, an extreme form of which is exhibited in the mummy of a priest of Ammon of about 1000 B.C. Thousands of bodies exhumed in Nubia, in the vicinity of the Assuan Dam, show on examination that the Egyptians suffered but little from pyogenic infections, that the death-rate of children was much lower in ancient than in modern Egypt, and that in the earlier and less luxurious epochs few of the inhabitants of the region suffered from premature decay of the teeth. At no period is there any sign of filled or of artificial teeth, and even as late as the sixteenth century B.C. a large proportion of adults in some districts were able to show perfect sets of teeth.

The examination of bodies belonging to all periods of Egyptian history shows the prevalence of the disease now known as arthritis deformans, of which mention has already been made. It is described as the bone disease par excellence of the ancient Egyptians. It still afflicts the inhabitants along the course of the Nile. Its etiology is uncertain, but, though the view predominates that it is a chronic infection, wet and damp may be among the exciting causes. In the Egyptian cases that have been examined the vertebræ are sometimes involved, as also the shafts of the bones. Cases of vesical calculus of the fourth millennium, renal calculus of the third millennium, gall-stones of the third millennium, variolous eruption and calcareous arteries and atheroma, have also been reported. Pleurisy and appendicitis (Byzantine period) and a case of true gout (sixth century A.D.) belong to a much later time. Bouchard's nodes (indicative of dilatation of the stomach), the enlarged spleen resulting from malarial infection, mastoiditis, and infantile paralysis, have also been proved to have occurred among the ancient Egyptians.

Ribs of date-palm leaves were used as splints in the early centuries of the third millennium, and splints of the same material are still in use in the Egypt of to-day. The ancient Nubian remains exhibit many cases of fractures that had been perfectly set and had healed satisfactorily. Fractures of the ulna near the wrist (as well as of the femur and cranium) are quite common. These injuries were probably sustained in attempting to ward off the blow of the naboot. This weapon was a staff, which was grasped, by the person wielding it, in both hands. Its use was a favorite pastime of the ancient Egyptians, and resembled the old English quarterstaff play. Besides the injuries caused by the naboot, fatal sword-cuts of the skull and cranial ulcerations from carrying water-jars have been noted.

For its skill in medicine Egypt became famous among all the surrounding nations. The Odyssey refers to it as a land producing an infinite number of drugs, where each physician possessed knowledge above all other men. Similarly the Hebrew prophet Jeremiah alludes to it as a land of many medicines. The Greek historian Herodotus, the contemporary of Hippocrates, speaking of the Egyptians of the fifth century B.C., says: "Medicine is practiced among them on a plan of separation; each physician treats a single disorder, and no more; thus the country swarms with medical practitioners, some undertaking to cure diseases of the eye, others of the head, others again of the teeth, others of the intestines, and some those which are not local." He also takes note of the habits, especially among the priestly caste, of personal hygiene, light clothing, frequent baths, purgation, and careful diet, for they have a persuasion that every disease to which men are liable is occasioned by the substances whereon they feed.

It was not till about 2100 B.C. that the City of Babylon, under the leadership of Hammurabi, a Semitic (Amorite) king, gained ascendancy over the Sumerian cities, which lay along the Tigris and Euphrates toward the Gulf of Persia. In the ruins of these cities has been discovered the record of a civilization analogous in its development to Egyptian civilization. Long before 3000 B.C. the Sumerians had learned how to control the freshets of the Euphrates for purposes of irrigation; they cultivated barley and split wheat, reared cattle, sheep, and goats, made use of the ox and ass in ploughing and transportation; they constructed mud-brick dwellings, as well as enormous stage-towers as places of worship and sepulture; they had ornaments of gold and silver, and knives of copper and bronze; they were skilled in pottery and stone-cutting; they developed a phonetic system of writing based on a primitive pictorial system, for it was to these early inhabitants of the land of Shinar that the East was indebted for cuneiform writing. The intellectual and professional life of the Sumerians, as of the Egyptians, was dominated by the priestly caste.

The Amorites of 2100 B.C. were not the first nor the last of the Semitic races to overrun the cities and adopt the system of writing and the general culture of the Sumerians. Many centuries after Hammurabi, the Assyrians, who had from very early times felt the cultural influence of the Sumerians, entered upon a career of conquest, and from about the middle of the eighth till near the close of the seventh century controlled an extensive empire of which Babylonia formed a part. One of the great Assyrian kings, Assurbanipal (668–626 B.C.), established in his palace at Nineveh a cuneiform library. The Code of Hammurabi, a collection of laws inscribed on a large block of black diorite, and the clay tablets of the library of Assurbanipal are the chief sources of information in reference to what may be roughly called Babylonian medicine.

The following sections from this earliest code of laws known to history, the starting-point of medical jurisprudence, throw light on the rights and duties of the surgeon of 2080 B.C.:

"If a physician operate on a man for a severe wound (or make a severe wound upon a man), with a bronze lancet, and save the man's life; or if he open an abscess (in the eye) of a man, with a bronze lancet, and save that man's eye, he shall receive ten shekels of silver (as his fee)."

"If he be a freeman, he shall receive five shekels."

"If it be a man's slave, the owner of the slave shall give two shekels of silver to the physician."

"If a physician operate on a man for a severe wound, with a bronze lancet, and cause the man's death; or open an abscess (in the eye) of a man, with a bronze lancet, and destroy the man's eye, they shall cut off his hands."

"If a physician operate on a slave of a freeman for a severe wound, with a bronze lancet, and cause his death, he shall restore a slave of equal value."

"If he open an abscess (in his eye), with a bronze lancet, and destroy his eye, he shall pay silver to the extent of one half of his price."

"If a physician set a broken bone for a man, or cure his diseased bowels, the patient shall give five shekels of silver to the physician."

"If he be a freeman, he shall give three shekels."

"If it be a man's slave, the owner of the slave shall give two shekels of silver to the physician."

"If a veterinary physician operate on an ox or ass for a severe wound and save its life, the owner of the ox or ass shall give to the physician, as his fee, one sixth of a shekel of silver."

"If he operate on an ox or an ass for a severe wound, and cause its death, he shall give to the owner of the ox or ass one fourth its value."

It is evident that in this translation the term "freeman" indicates a rank intermediate between that of "man" (or gentleman) and that of "slave," and that the term "veterinary" is used in anticipation, since the horse was unknown in Babylonia till some time after the formulation of the Code of Hammurabi.

As already implied, the medical science of the Babylonians was closely associated with their religious beliefs and superstitions. Disease was considered the seizure or attack of the patient by some demon or other, such as the demon of consumption, the demon of liver complaint, and the particularly hideous demon that haunted the bedside of women. Cures were to be effected by charms, incantations, exorcisms, and other magic rites. These led to the use of remedies, like mint, cassia, chicory, sesame, honey, and liquorice, or a green frog, the foot of a small insect, the claw of a black dog, to fortify the patient and to drive or coax out the demon of disease. As the Babylonian priests sought to foretell the future by the study of the heavens, of numbers, and of geometrical forms, so they turned to the inspection of the viscera of sacrificial animals as a means of divination. They believed, like the Jews, that the blood was the vital principle, in some sense identical with the soul; that the blood was elaborated in the liver, and that consequently that organ should be made an object of particular attention. They held it possible, since the deity passed into all animals offered up in sacrifice, to read the disposition of the divine mind by observing the markings and anomalies of a sheep's liver. Clay models of this organ, dating from about 2100 B.C., are as carefully marked off into distinct areas as our modern phrenological charts. The lobes, ducts, depressions, fissures, gall-bladder, etc., on the under side of the liver were minutely scrutinized and definitely named. Pathological conditions were especially studied, because all irregularities seemed to foretell unusual events.

The practice of inspecting the liver for purposes of divination — hepatoscopy — passed from Babylonia as far west as Italy and was not without significance in the development of anatomy and physiology. In a like spirit and with greater results for the progress of science, the Babylonian priests turned their attention to the study of congenital abnormalities in man and animal, and to the interpretation of pathological symptoms. A monstrosity was an evil omen; hysteria and epilepsy and leprosy were special marks of possession or of divine condemnation. In the study of birth-omens and sickness-omens, the Babylonians developed a knowledge of the various parts of the body, and learned to recognize the symptoms of various diseases. Among the latter might be mentioned as finding a place in cuneiform medical literature, colds, indigestion, rheumatism, neuralgia, headache, eye troubles, heart disease, and jaundice.

Some of the early Babylonian prescriptions are half exorcism and half directions for effecting a cure. One cuneiform text, for example, dictates a formula for calling down the wrath of the god Ea on the worm that causes toothache, but advises that while the curse is being uttered thrice, the aching tooth should be treated with a mixture of henbane and resin. Other prescriptions dispensed altogether with the aid of magic: "If a man is sick of a cold, which has turned into stomach pains, let him compound . . . liquorice root . . . these seven drugs let him drink as the star rises and in the morning without food [that is, evening and morning, fasting], and he will recover." The tendency to rely less and less on incantations and more and more on actual remedies seems to have been more pronounced in the later stages of Babylonian medicine. Of course, primitive methods were resorted to in desperate cases; as, for example, if "a man's forehead is affected and the demon in a man's body cries out and does not depart," the traditional treatments may be employed as a last resort. Further evidence of the progress of medicine is afforded by letters written in the seventh century B.C. to Assurbanipal by a doctor called upon to treat the members of the royal family for eye trouble, bleeding of the nose, and other ailments. They read like the communications of a rational, sympathetic, and capable modern practitioner. One of these sends "Hearty greetings to the little chap whose eye causes him trouble" and gives reasons for expecting a speedy recovery. A second letter with similar greetings to the king's son contains excellent directions for arresting persistent hæmorrhage of the nose.

In the textbook literature of the library of Assurbanipal are found long lists of remedies, which are divided into two classes corresponding, it would seem from the particular Sumerian words used, to the distinction of organic and inorganic substances. Among the latter are found alkalies and salts, as well as a number of stones which had probably been thought efficacious as amulets before taking their place in the pharmacopœia. Only a limited number of the drugs that enter into cuneiform prescriptions have as yet been identified, but in addition to those already set down the following might be mentioned; anise, cumin, caraway, colewort, colocynth, coriander, cynoglossum, figs, dates, jasmine, juniper, nard, oleander, willow, and sal ammoniac. Among the therapeutic agents relied on by the Babylonian priest-physicians are found purgatives, diaphoretics, enemata, compresses, salves, poultices, liniments, fumigations, diet, and rest. One might be tempted to ascribe to them the knowledge of a form of massage; but the impression must not be created that the medical science of the Babylonians ever attained to any considerable development. At its best it was obscured by astrology and other superstitious beliefs, and at no time completely emerged from the primitive stage. By the fifth century B.C. it seems, indeed, to have deteriorated; for according to Herodotus no physicians were to be found in the Babylon of the Persian régime and patients were brought into the streets to receive the suggestions of the passers-by.

In Babylonia as in Egypt the conservatism of the priests preserved throughout the ages the medical knowledge of an immemorial past, but the very quality that enabled them to perpetuate traditions prevented their making any marked advance toward a real medical science. Their faith in the virtues of drugs and in the influence of the stars was detrimental to progress, and the distinction of making the first great contributions to scientific medicine was reserved for another people, among whom the healing art was not dominated by the priestly caste.

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CHAPTER II

HIPPOCRATES THE FATHER OF MEDICINE

Three great extraneous influences contributed to the development of Greek medicine — theology, philosophy, and athletics. And to the institutions through which these influences made themselves felt, namely, the temple, the school, and the gymnasium, Hippocrates sustained a well-defined relation.

Even in the early stage of Greek culture represented in the Iliad and the Odyssey the priesthood played a subordinate part in the healing art. These Homeric poems, to be sure, speak of disease as due to the anger of the gods, and tell of the efforts of the priests to arrest epidemics, as well as of the recital of appropriate incantations. But the physicians, cunning in the use of medicines, are evidently distinct from the priests, and form an adjunct of the warrior caste rather than of the sacerdotal.

In the Iliad, Æsculapius, or Asclepios, is a Thessalian chief, who has received from the Centaur Chiron instruction in the use of drugs; while his two sons are warriors and army surgeons. By the beginning of the eighth century B.C., tradition had endowed him with supernatural powers. He became an earth god — especially accessible to his votaries in sleep — and was portrayed with the snake and staff and other attributes of such a deity. Not long after, Æsculapius was recognized as the god of medicine, the son of Apollo, and the father, not only of the surgeon Machaon and the physician Podalirius, but of a younger son, Telesphorus, the god of convalescence, as well as of Hygeia and Panacea. Eventually hundreds of temples arose throughout Hellas, on beautiful and salubrious sites overlooking the sea and beside healing fountains, dedicated to the worship of Asclepios. Among the most famous of these were the Asclepieia of Epidaurus, Cos, Cnidus, Crotona, and Pergamus.

In these healthful places, the strongholds of miraculous medicine, the priests of the temples were credited with cures comparable with the faith cures duly attested to-day at Lourdes, Sainte Anne de Beaupré, and other Christian shrines. In the history of the Greek temples there are some indications of the practice of fraud. The priests of Æsculapius stirred the imaginations and played upon the superstitions of the sufferers by sacrificial rites and purifications, by the presence of tame snakes, contact with which brought healing by the power of the indwelling god, and, in the third place, by temple sleep or incubation. The suppliant, lying down to sleep, after due preparation, by the altar of the god, was at times granted a vision of Æsculapius himself, and was forthwith healed. Sometimes the priest condescended to impersonate the god, offering equally efficacious treatment, or dictating remedies. Again, the suppliant might be permitted to dream by proxy. Those that were benefited by the suggestions, by the remedies, or by the restorative power of nature, left tablets telling of their cure, or other tokens, such as models of the healed parts in marble, or silver, or gold, the priests taking no pains to conceal from their patients the therapeutic virtue of a substantial fee.

Epidaurus, as befitted the reputed birthplace of Æsculapius, was one of the loudest of the temples in proclaiming the benefits of divine healing, and upon the founding of a new temple this mother Asclepieion sent the gift of a snake, symbolic of the god of medicine. Two pillars inscribed with the record of faith cures have been recovered on the site of the ancient shrine. The following translations will indicate how the temple priests sought to overcome the skepticism of the Greek mind.

"A man with the fingers of his hand paralysed, save one. He came a suppliant to the god, and seeing the tablets in the temple he disbelieved the cures, and ridiculed the inscriptions, and sleeping he saw a vision. He seemed to be playing dice, and, as he was about to throw, the god appeared, seized his hand, and stretched out the fingers, then he seemed to bend them up and stretch them out one by one, and when all were straight the god asked if he still disbelieved the inscriptions on the tablets, and he said no. Then he said: 'Fear not for thy former unbelief, but, that thou mayest believe in future, thou shalt obtain what a believer obtains'(?) [the sentence is much mutilated]. And when it was day he went away whole."

"Ambrosia of Athens, blind of one eye. She came a suppliant to the god, and going round the temple ridiculed some of the inscriptions, saying it was incredible and impossible that the lame and blind should be cured by seeing a dream-vision only. But having slept she saw a vision; the god seemed to stand by her and say that he would heal her, but would demand as payment a silver pig to be set up in the temple as a memorial of her stupidity. Having thus spoken he opened her diseased eye and poured medicine on it, and when it was day she departed cured."

The temple priests must not be confused with the Asclepiads (Asclepiadæ), often in attendance at the temples, who formed a guild or brotherhood made up, at first, of physicians claiming descent from Æsculapius. At some of the temples the Asclepiads no doubt long continued to connive at the theurgy and charlatanry of the priests. In other places, however, and notably at Cnidus and Cos, they dissociated themselves from the practice of mystic healing and taught to their sons and disciples medicine as based on rational principles.

Among the philosophers who brought the influence of the schools to bear on the development of early Greek medicine Pythagoras, Alcmæon, Empedocles, and Democritus are especially prominent. Born about 580 B.C. on the island of Samos, Pythagoras traveled extensively, visiting Egypt and probably Babylonia, and settled at Crotona in South Italy. There he founded a sect or society which, to its interest in mathematics, ethics, and other branches of philosophy, added the teaching and practice of medicine and politics. He attended his followers when they were sick, and advocated adherence to a strict diet. In the Pythagorean school there developed a mystical number lore, the elements of which the master may have learned from the Egyptian priests or the Chaldean astrologers. It is difficult to comprehend the peculiar significance this philosophical school attached to certain numbers and number relations. For example, four was of interest to the Pythagorean mind as the square of the first even number, and still more so as symbolizing the perfection of eternally flowing nature. Ten was considered a perfect number. Something of the sentimental value associated with particular numbers by the Pythagoreans, as well as by the Babylonians and other Eastern peoples, still lingers in the attitude of the imaginative to the sacred number three and the mysterious number seven. The number lore of the Pythagoreans is important for us because it later conduced to the Hippocratic doctrine of critical days.

Other schools of philosophy had a more direct interest in medical science. Alcmæon of Crotona, philosopher and physician, the first Greek anatomist, introduced abdominal section, by animal dissections discovered the optic nerve, attempted to explain the sense of hearing and the sense of taste, and recognized the brain as the seat of mental activity. Sleep and waking are due to the ebb and flow of the blood, death to its cessation. Health depends on the harmony of the material elements of the body — cold, warm, moist, dry, bitter, sweet. Empedocles of Agrigentum, Sicily, another philosopher-physician, was the first Greek to think of the universe as composed of four elements.

> "Listen, first, while I sing the fourfold root of creation,
> Fire, and water, and earth, and the boundless height of the æther,
> For therefrom is begotten what is, what was, and what shall be."

Empedocles is said to have freed a town of pestilence by diverting a stream and draining the marshes in its vicinity, and to have improved the climate of his native city by blocking up a cleft in the mountains.

Democritus, a contemporary and friend of Hippocrates, studied the anatomy of animals and the physiology of reproduction and of the senses. He taught that all things are composed of an infinite number of indivisible particles, or atoms, and that the impressions made upon our senses are the source of all knowledge and of all thought.

The influence of athletics on the development of Greek medicine was essentially different from that of philosophy. The gymnasts were the devotees of practice, not of theory. Through experience they acquired skill in the treatment of sprains, dislocations, fractures, and other injuries. They made use of inunctions and fomentations. They controlled the weight and proportions of the athletes by means of purgation, emesis, massage, steam baths, exercise, and diet. These rude empirics were consulted by the sick, and the gymnast Herodicus of Selymbria, with whom Hippocrates came into contact, even undertook to reduce fever by methods borrowed from the gymnasium. Crotona, as famous for athletics as for theurgy and philosophy, was the home of the greatest of wrestlers, Milo, six times crowned victor at the Olympian, six times at the Pythian, games. It is probable that Democedes of Crotona, the first regular Greek physician of whose life we have an account, owed some of his surgical skill to the gymnasium of his native city.

Leaving home as a young man, Democedes became public physician in rapid succession at Ægina, Athens, and Samos, his salary as medical officer mounting from $1200, to $2030, to $2800, at a time when the incomes of officials were generally very low, and the purchasing power of money was very high. Later he found himself a slave at the court of Darius, whose favor he gained by healing a sprained ankle, which had baffled the efforts of the Egyptian physicians in attendance on the Persian king, as well as by treating the queen successfully for abscess of the breast. The one boon of freedom was withheld. Finally, however, Darius permitted Democedes to accompany a band of Persian explorers, the Greek undertaking to guide them in their search for points on the coast of Italy most favorable for the landing of a Persian army. Arrived in Calabria, Democedes delivered his companions into the hands of the king of that region. He then hastened to his native Crotona, where, shortly after, he married the beautiful daughter of Milo the athlete.

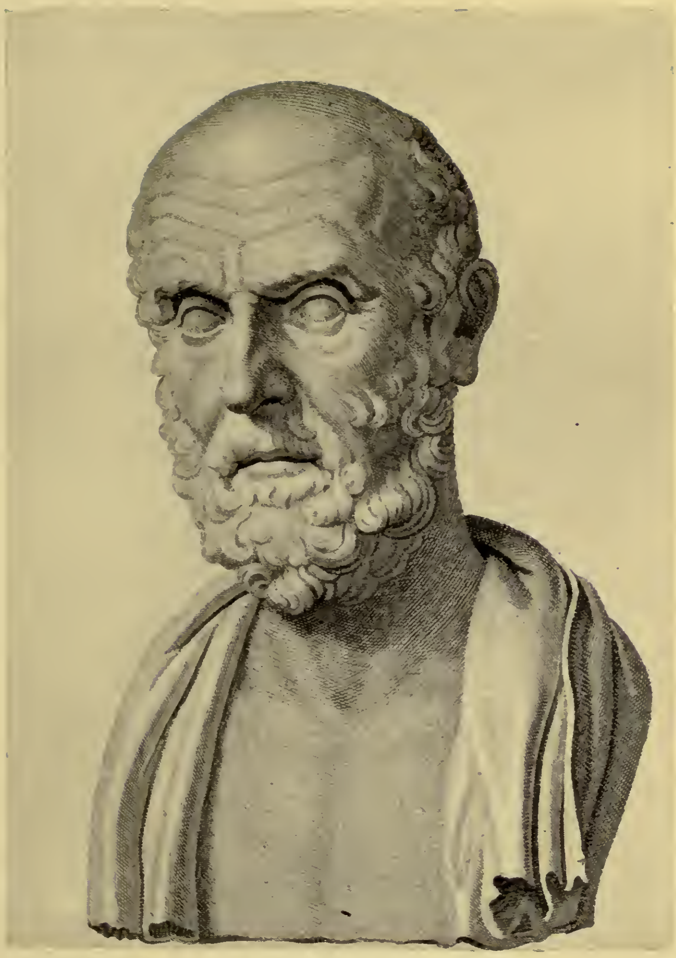
The three influences that affected Greek medicine, namely, the theurgic, the theoretic, and the empiric, though logically distinct, were not always separated in fact. The Pythagoreans cultivated gymnastics as well as dietetics. Milo belonged to the political faction of the Pythagoreans without necessarily sharing their enthusiasm for pure mathematics and an abstemious diet. The temple priests, as we have seen, worked at times in conjunction with the temple physicians, and there is evidence that some of the Asclepieia were provided with gymnasiums, in which tissue change was effected by exercise, diet, and baths. To the combined influence of the priests, the philosophers, and the gymnasts, it was natural that the genius of the greatest physician, bent above all on the successful treatment of the individual patient, should in some way respond.

Hippocrates was born in 460 B.C. at Cos on the island of Cos. His father and grandfather were eminent physicians; and his descent has been traced on the paternal side to Æsculapius, and on the maternal side to Hercules. He received his first instruction in the medical art from his father, and he may have come under the influence of the Asclepiads of the neighboring city of Cnidus, as well as of those of his native place. He traveled extensively, practicing and teaching, and is known to have visited the cities of Thrace, Thessaly, Asia Minor, and the island of Thasus; and he may have been acquainted with Athens, then at the height of its glory, and with Scythia, Egypt, and Libya. He gave instruction at the school of the Asclepiadæ of Cos and trained his sons and son-in-law in the art.

He died at Larissa, Thessaly, at a very advanced age.

An early Hippocratic writing, "The Law," descriptive of the education of an ideal physician, throws light on the training of Hippocrates. "Whoever is to acquire a competent knowledge of medicine," it says, "ought to be possessed of the following advantages: a natural disposition; instruction; a favorable position for the study; early tuition; love of labor; leisure. First of all, a natural talent is required; for, when Nature opposes, everything else is vain; but when Nature leads the way to what is most excellent, instruction in the art takes place, which the student must try to appropriate to himself by reflection, becoming an early pupil in a place well adapted for instruction. He must also bring to the task love of labor and perseverance, so that the instruction taking root may bring forth proper and abundant fruits.

"Instruction in medicine is like the culture of the productions of the earth. For our natural disposition is, as it were, the soil; the tenets of our teachers, as it were, the seed; instruction in youth is like the planting of the seed in the ground at the proper season; the place where the instruction is communicated is like the nourishment imparted to plants by the atmosphere; diligent study is like the cultivation of the fields; and it is time which imparts strength to all things and brings them to maturity."



HIPPOCRATES
The Bust in the British Museum

The ancient Oath of the Asclepiads of Cos, also known to have been written before the time of Hippocrates, indicates the source of his professional ethics:

THE OATH

"I swear by Apollo the physician, and Æsculapius, and Hygeia, and Panacea, and all the gods and goddesses, that, according to my ability and judgment, I will keep this Oath and this stipulation — to reckon him who taught me this Art equally dear to me as my parents, to share my substance with him, and relieve his necessities if required; to look upon his offspring in the same light as my own brothers, and to teach them this Art, if they should wish to learn it, without fee or stipulation; and that by precept, discourse, and every other mode of instruction, I will impart a knowledge of the Art to my own sons, and those of my teachers, and to disciples bound by a stipulation and oath according to the law of medicine, but to none others. I will follow that system of regimen which, according to my ability and judgment, I consider for the benefit of my patients, and abstain from whatever is deleterious and mischievous. I will give no deadly medicine to any one if asked, nor suggest any such counsel; and in like manner I will not give to a woman a pessary to produce abortion. With purity and with holiness I will pass my life and practice my

Art. I will not cut persons laboring under the stone, but will leave this to be done by men who are practitioners of this work. Into whatever houses I enter, I will go into them for the benefit of the sick, and will abstain from every voluntary act of mischief and corruption; and further, from the seduction of females or males, of freemen and slaves. Whatever, in connection with my professional practice, or not in connection with it, I see or hear, in the life of men, which ought not to be spoken of abroad, I will not divulge, as reckoning that all such should be kept secret. While I continue to keep this Oath unviolated, may it be granted to me to enjoy life and the practice of the Art, respected by all men, in all times! But should I trespass and violate this Oath, may the reverse be my lot!"

The tendency shown in the Oath to substitute benevolence, social duty, and moral law for religious superstition is no less marked in the writings of Hippocrates, the contemporary of Socrates. In his treatise "On Airs, Water, and Localities," which deals with disease in relation to geographical and meteorological conditions, or *constitutions*, Hippocrates states that the Scythians attribute the premature impotence of some of their men to a god, but that it appears to him that such affections are just as much divine as all others are, and that no one disease is either more divine or more human than another, but that all are alike divine, for each has its own nature, and that no one arises without a natural cause. The Hippocratic writing "On the Sacred Disease," written by some Huxley among the disciples of the master, deals exclusively with the claim of epilepsy to be considered divine in its origin. If diseases are to be called divine because they are wonderful and ill understood, then the quotidian, tertian, and quartan fevers seem to the author of the treatise no less sacred and divine in their origin than epilepsy. Those who first referred the latter disease to the gods were probably just such people as the conjurors, purificators, mountebanks, and charlatans of his own time. These give themselves out, the treatise proceeds, to be extremely religious, but it is no homage to the gods to see their manifestation in the symptoms of epilepsy — outcries, gnashing of the teeth, foaming at the mouth, contortions, kicking, fever, delirium, fear, and flight. Then, if the epileptics be divinely possessed, why must they be submitted to purification? They should rather be taken to the temple and presented to the god, if a god be the cause of the disease. However, in spite of this vehement controversy, we must not think of Hippocrates and his followers as atheists. While protesting against an unworthy conception of divinity, they respected the traditions, inculcated lofty ideals of professional conduct, dignity of deportment, respect for patients, devotion to universal charity and to medicine. For, as they declared, where love of mankind is, there is also love of the Art.

The Hippocratic respect for tradition led, at the same time, to a just appreciation of the teaching of the gymnasium, much of it inherited, no doubt, from the remote past. The writings of Hippocrates "On Fractures" and "On Dislocations," which have been described (by Malgaigne) as the ablest works ever written by a physician, as well as his treatise "On Injuries of the Head," and his other surgical works, reflect the skill and wisdom resulting from long experience. He was bold in the use of the trephine and raspatory, employed ink and pitch in the manner of the Egyptians, insisted on the necessity of cleanliness and dryness in the handling of fresh wounds, mentioned healing by first intention, referred to exfoliation of the bone, and to the dangers of erysipelas, tetanus, and gangrene, noted the occurrence of fracture by *contre-coup* and of paralysis of the opposite side in cases of lesions of the brain, described the treatment of compound fractures, as well as various methods of bandaging and of reduction with and without apparatus. In his "Aphorisms" Hippocrates remarks that it is not well for athletes to develop tissue to the utmost limit. Once arrived at the maximum, it is impossible to improve or to remain stationary. Instead of slowly deteriorating, it is well to reduce rapidly in order to begin again the process of repair. It is dangerous, however, to carry methods of reduction to extremes. In like manner, medicinal evacuations, if carried to an extreme, are dangerous; and, also, a restorative course, if in the extreme, is dangerous. A slender and restricted diet is always dangerous in chronic diseases, and also in acute diseases, where it is not requisite. Again, as diet brought to the extreme point of attenuation is dangerous, repletion, when in the extreme, is likewise dangerous.

The Hippocratic book "On Ancient Medicine," which ingeniously traces the origin of the Art to the practical study of diet carried on by man from the remotest past, suggests to the physician that advances are still to be made by continuing the study with full knowledge of what has already been achieved. "Wherefore those who devote themselves to gymnastics and training are always making some new discovery by pursuing the same line of inquiry, where, by eating and drinking certain things, they improve and grow stronger than they were." What must be said of those who prosecute their inquiries in the Art by hypothesis rather than by the ancient method of trial? The former procedure has its difficulties. "For if hot, or cold, or moist, or dry, be that which proves injurious to man, and if the person who would treat him properly must apply cold to the hot, hot to the cold, moist to the dry, and dry to the moist — let me be presented with a man, not indeed one of a strong constitution, but one of the weaker, and let him eat wheat, such as it is supplied from the thrashing-floor, raw and unprepared, with raw meat, and let him drink water. By using such a diet I know that he will suffer much and severely, for he will experience pains, his body will become weak, and his bowels deranged, and he will not subsist long. What remedy, then, is to be provided for one so situated? Hot? or cold? or moist? or dry?" Thus the treatise "On Ancient Medicine" passes from a consideration of the empirics, condemned by Hippocrates only when they went beyond their proper sphere, to a criticism of the theorists, or philosophers.

It has frequently been said that Hippocrates, in addition to repudiating the supernatural as a cause of disease, was the first to separate medicine from philosophy. That is indeed true if philosophy be identified with vain speculation. For the fantastic conjectures of Pythagoras and Empedocles, Hippocrates and his followers substituted a common-sense philosophy, still potent in our own time. They held that all general views of the nature of disease must rest on practice and the use of reason. All valid thinking is based on the data supplied by the senses, the understanding giving meaning to these phenomena, noting the manner of their occurrence, their times, and the relation between them of cause and effect. Conclusions must be grounded in observation. The physician should, therefore, hold to facts, so as to acquire mastery in the medical Art. "Theory is the flower, not the root of experience." The famous opening sentences of the "Aphorisms" attest the power of a philosophic mind to rise to general conceptions, while still mindful of the observations and practice from which they were developed. "Life is short, and the Art long; the time is urgent; experiment is dangerous, and decision is difficult. The physician must not only be prepared to do what is right himself, but also to make the patient, the attendants, and externals coöperate."

Diagnosis furnished a solid basis for his generalizations. He observed the color and general state of the skin and mucous surfaces, the eyes, the facial expression, the movements of the body, the quantity and nature of the dejecta and various secretions, the temperature, and, to some extent, the pulse, respiration, rash, spasm, sore throat, chills and fever, localized pains, headache, tenesmus, thirst, appetite, nausea, vertigo, lassitude, deafness, disordered vision, fear, loquacity, delirium, coma, plucking at the bedclothes. He noted the distension of the abdomen, and by palpation determined the enlargement of the liver or the spleen. He took account of the form of the chest, the character of the voice, and, employing succussion and auscultation, detected the signs of pneumohydrothorax or of pleuritic friction. Not content with the mere determination of symptoms, Hippocrates has left us ("Epidemics," Books I and III) forty-two case histories, which remained without parallel in the history of medicine for about two thousand years. The following is one of the briefest in the collection:

"Criton, in Thasus, while still on foot, and going about, was seized with a violent pain in the great toe; he took to bed the same day, had rigors and nausea, recovered his heat slightly, at night was delirious. On the second, swelling of the whole foot, and about the ankle erythema, with distension, and small bullæ (phlyctænæ); acute fever; he became furiously deranged; alvine discharges bilious, unmixed, and rather frequent. He died on the second day from the commencement."

Hippocrates did not rest satisfied with the record of individual cases and their symptoms. In his treatise "On Regimen in Acute Diseases" he admits that the Asclepiads of Cnidus had described accurately the symptoms of various diseases, and even how certain of them terminate; but they had unduly multiplied species. The physician should not make the number of species of disease as great as that of their manifestations. In another treatise ("Prognostics") the Father of Medicine urges upon the physician the need of so knowing the various diseases in their specific tendencies and in their relation to the constitution of the individual patient as to be able to foretell their course and outcome. "He should observe thus in acute diseases: first, the countenance of the patient, if it be like the countenances of persons in health, and more so, if like itself, for this is the best of all; whereas the most opposite to it is the worst, such as the following: a sharp nose, hollow eyes, collapsed temples; the ears cold, contracted, and their lobes turned out; the skin about the forehead being rough, distended and parched; the color of the whole face being green, black, livid, or lead-colored." This is the *facies Hippocratica*, indicative of approaching dissolution. We are, of course, indebted to Hippocrates for the terms acute, chronic, endemic, epidemic, in their application to disease, for the recognition of the tuberculous nature of Pott's disease, for the description of the peculiar respiration "like that of a person recollecting himself," for clinical pictures of various diseases, including puerperal, intermittent and remittent fevers; the latter especially interesting since the decline of Hellenic civilization may have been owing to the ravages of malaria. But a few quotations from the "Aphorisms" will show that, true to his own teaching, he advanced to a knowledge of diseases in their tendencies and outcome. "Those cases of epilepsy which come on before puberty may undergo a change; but those which come on after twenty-five years of age, for the most part terminate in death" (v, 7). "Phthisis most commonly occurs between the age of eighteen and thirty-five years" (v, 9). "When sleep puts an end to delirium, it is a good symptom" (II, 2). In the same spirit of generalization he says: "An article of food or drink which is slightly worse, but more palatable, is to be preferred to such as are better, but less palatable" (II, 38). "Acute diseases come to a crisis in fourteen days" (II, 23). "A true tertian comes to a crisis in seven periods at the furthest" (IV, 59).

As already implied, a trace of Pythagorean doctrine can be detected in the Hippocratic theory of critical days. And a like concession to the four elements of Empedocles is noticeable in the doctrine of the four humors. According to this teaching, for the origin and complete development of which Hippocrates was not responsible, blood is hot and moist like air, phlegm is cold and moist like water, yellow bile is hot and dry like fire, and black bile is cold and dry like earth. As one or other of these humors predominated in an individual, he was supposed to be of a sanguine, phlegmatic, choleric, or melancholy temperament. This view, which persists in scientific and general literature even to the present time, may be illustrated from Shakespeare's "Julius Cæsar," in which play the sanguine Antony, the phlegmatic Octavius, the choleric Cassius, and the melancholy Brutus represent the four temperamental types, while the ideal character is that in which the four humors are naturally and harmoniously mingled. Similarly in the Hippocratic physiology, health depended on the *crasis*, or blending, of the four juices of the body. Unless they duly blend, there is a state of dyscrasia, or *crudity*, the humors, like raw food, acting as irritants. Health must be restored by a process of *coction* (or pepsis) wherein the internal heat of the body cooks the crude humors. Upon this follows a *crisis* — a separation, or elimination — of the superfluous substance. The elements may be restored to a state of harmony and equilibrium by the remedial power of Nature. It was faith in this *vis medicatrix naturæ* which led Hippocrates to adopt an expectant attitude in the treatment of many of his cases, to abstain at times from surgical interference, and to prescribe drugs and cooling drinks as auxiliaries of Nature in the expulsion of the morbific matter after a fever crisis.

However it may have been with his followers, Hippocrates was carried away by no doctrine or theory. Seeing the particular in the general and the general in the particular, he bent his comprehensive genius to the healing of the individual patient. Plato justly compared him to the Athenian sculptor Phidias, who beheld the ideal in the real and impressed upon the rocks of Pentelicus the stamp of an eternal beauty. To enjoy the practice of the Art, to serve as a model for all true physicians, to be respected and honored by all men in all times, was and is the reward and destiny of the greatest of the Asclepiads.

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CHAPTER III

ROMAN ANATOMY AND SURGERY

THAT study of anatomy and practice of surgery which within the bounds of the Roman Empire reached their culmination in the first and second centuries of the Christian era can be traced in their development from the medical science of the age of Hippocrates. Diocles of Carystus, who stood next to the sage of Cos in age and distinction, was a dissector of animals, and in a work on zoötomy described the heart, the large blood-vessels, and a greater number of the smaller vessels than had been recognized in earlier works. He agreed with his contemporary Plato, as well as one of the less authentic Hippocratic writings ("On the Heart"), in looking upon the heart as the source that sent its streams to all parts of the body. Diocles knew the œsophagus, the biliary ducts, the cæcum, the ureters, and the Fallopian tubes. He was the inventor of a bandage for the head, and of the graphiscus, a spoon-like instrument later used in the Roman armies to extract arrows and spears from wounds. He made use of opium as an anodyne, and distinguished pleurisy from pneumonia. Praxagoras of Cos was the first to differentiate veins and arteries, the former filled with blood, the latter with vital air, or *pneuma.* He recorded the local conditions of pleurisy, was the first among the Greeks to recognize the importance of the pulse in diagnosis, and advised laparotomy, as a last resort, in intestinal obstruction, though there is no evidence that this operation was actually put in practice in his age. Diocles and Praxagoras are classed among the Dogmatists, who were under the influence of medical speculations concerning the pneuma (which in the opinion of Diocles was renewed by respiration) and concerning the four humors. For example, both Diocles and Praxagoras attributed epilepsy to a derangement of the humors, as did also the speculative philosopher Plato and the author of "On the Sacred Disease," who was more successful in stating what is not than what is the cause of that malady.

Aristotle of Stagira, the son of the Asclepiad Nicomachus and the pupil of Plato, laid the foundations of comparative anatomy by dissecting about fifty species of animals, including the deer, elephant, horse, ox, pig, domestic fowl, chamæleon (which had been made a special study by Democritus), tortoise, frog, sepia, crab, lobster, murex, and sea-urchin. He carried into his investigations the experimental spirit, which, contrary to the teachings of many historians, was never wanting in the medical science of antiquity. He vivisected some of the lower animals, discovered that the tails of saurians would grow again after being cut off, that the chamæleon would continue to breathe for a considerable time after being cut open along its entire length, and he referred to the movements of the heart of the tortoise after the organ had been excised. Aristotle must be credited with a knowledge of the rudiments of histology, as he recognized the various tissues — bone, blood, fat, skin, cartilage, hair, connective tissue, and so forth. He studied the embryos of various animals, observed the early appearance of the chick's heart, its brain and eyes, the rapid growth of the allantois from the fifth day of incubation, and the allantoic and vitelline blood-vessels on the sixth. He was well acquainted in the adult with the liver, spleen, jejunum, colon, sigmoid flexure, rectum, the trachea, the brain membranes and the network of blood-vessels covering the brain, the structure of the lungs and the richness of their blood supply. Perhaps his greatest single contribution was his study of the heart with its chordæ tendineæ, and his attempt to describe the arrangement of the blood-vessels, especially the branches of the *aorta*, as that vessel is called in the writings of this father of science. A brief quotation from the "Historia Animalium" will serve as an example of the many passages in which Aristotle anticipated the investigations of modern scientists. "The ear," he says, "is constructed internally like the trumpet-shell, and the innermost bone is like the ear itself, and into it at the end the sound makes its way, as into the bottom of a jar. This receptacle does not communicate by any passage with the brain, but does so with the palate, and a vein extends from the brain towards it." He failed to understand the function of the nerves that lay before him, and employed the word *neuron* to indicate the material of the tendons, ligaments, and of the fibrin of the blood.

Luckily the structure and functions of the nerves and brain were to a considerable extent elucidated by the investigations of Herophilus and Erasistratus at the beginning of the third century B.C. They were enabled to carry on their investigations at Alexandria through the patronage of the Greek kings of Egypt, Ptolemy Soter and Ptolemy Philadelphus, who placed at their disposal the bodies of condemned criminals for experiment and dissection. Herophilus studied the membranes of the brain, the sinuses of the dura mater, and noted the dilatation of the superior longitudinal sinus now known as the wine-press of Herophilus (*torcular Herophili*). He examined carefully the ventricles of the brain with their choroid plexuses, especially the fourth ventricle, or ventricle of the cerebellum, which he considered as the seat of intelligence, and gave the furrow at the floor of the ventricle a name corresponding to the Latin *calamus scriptorius*. Herophilus also traced a number of the nerves to their connection with the brain and cord, and recognized their function as transmitters of will and sensation. Erasistratus, in turn, compared the convolutions of the cerebrum to the folds of the jejunum, noted their greater complexity in man than in the lower animals, and ascribed the difference in complexity to difference of mental development. He agreed with Herophilus in regarding the cerebellum as the special seat of intelligence, and remarked that the structure of this part of the brain differs from that of the cerebrum. Erasistratus further agreed with Herophilus in dividing nerves into nerves of movement and nerves of sensation. He also taught that the nerves arise from the brain substance and are filled with marrow.

Herophilus contributed to other departments of anatomy. He taught that the arteries arise from the heart, have coats six times as thick as the veins, and that they carry blood and pneuma. He called the pulmonary artery the arterious vein, named the duodenum according to its length, noted the termination of the lacteals in gland-like bodies. He described the liver with some care, comparing the liver of man with that of the lower animals. He examined the salivary glands, the pancreas, the hyoid bone, and named the prostate. We also owe to Herophilus an early account of the testicles, epididymis, vas deferens, seminal vesicles, the uterus, the structure of the ovaries, the spermatic artery, the spermatic vein (even the relation of the left spermatic to the renal), as well as the uterine vessels. He wrote a treatise on the eye, describing the three coats and the vitreous humor, and he improved the operation for cataract. This pioneer in human dissection practiced general surgery and wrote a work on obstetrics. Through his teachers he was in touch with the traditions of both Cos and Cnidus. He developed the diagnostic methods of his master Praxagoras, and was the first to describe the dicrotic pulse. He held the teachings of Hippocrates in reverence, and did not abandon the doctrine of the four humors. In spite of conservatism in this respect, Herophilus preferred observation and experience to theory, and was the first to make post-mortem examinations.

Erasistratus, born about 330 B.C., through his master Metrodorus came under the influence of the teachings of Aristotle and of the school of Cnidus. He was the exponent of a more exact method in medical science than had prevailed before his time, and as an anatomist and surgeon was not inferior to his great contemporary Herophilus. He was more exact than Aristotle or the Hippocratic writings in the description of the heart, its chordæ tendineæ and its valves, and named the tricuspid and sigmoid. He also gave the trachea its name, and explained the function of the epiglottis. He observed the lacteals in lower animals and in man. By post-mortem examination he learned of the hardening of the liver in cases of dropsy, as well as of the anatomical conditions following pleurisy and a certain kind of snake-bite. We are indebted to Erasistratus for a careful description of the normal liver. Though recognizing design in the structure of the body, he regarded some parts — the spleen, for example — as serving no purpose. He failed also to discover the function of the bile, and, rejecting the doctrine of the four humors, greatly developed the doctrine of the pneuma. Like Diocles he taught that the pneuma is renewed by respiration. When the lungs are expanded, and a vacuum thus is created, the air enters by the trachea, bronchi, and bronchial tubes. When the heart dilates, the air advances from the anastomoses of the bronchial tubes to the arterioles, and thence by the pulmonary vein (called by him the "venous artery") to the central organ. On the contraction of the heart the pneuma is forced through the aorta into the general arterial system, that part which feeds the intelligence passing to the brain. Erasistratus denied, in agreement with Praxagoras, the principle of internal heat, and held that the pneuma and the blood are the sources of the body's energy. The blood is formed from food, and digestion is a trituration process, not a coction. Following up his endeavor to reduce physiology to mechanical principles, he tried to prove by experiments with birds that there may occur a loss of body weight other than that due to visible excretions. Disease is generally caused by plethora, an overfilling of the vessels. Inflammation and fever are the result of the plethora of the veins; arthritis is the manifestation of plethora in the joints. The presence of blood in the arteries is pathological, due to the overfilling of the veins or to a vacuum in the arteries following the escape of pneuma. Naturally Erasistratus was unable to anticipate the distinction drawn by modern science between venous blood and arterial, but it is evident that he turned to account the physical science of his own times. In spite of his theory of plethora he seldom resorted to venesection. He likewise abstained from tapping the abdomen in dropsy, because the operation affected merely a symptom and did not strike at the cause of the disease. Erasistratus invented an S-shaped catheter. He employed a hook-shaped knife to extract the dead fœtus, and is said to have opened the abdomen in order to apply medicaments directly to the liver and spleen.

According to the Latin writer, Aulus Cornelius Celsus, Herophilus and Erasistratus "procured criminals out of prison, by royal permission, and, dissecting them alive, contemplated, while they were still breathing, the parts which nature had before concealed, considering their position, color, figure, size, order, hardness, softness, smoothness, and asperity." This hideous practice, already alluded to, found advocates and apologists among the Greeks, some holding "it is by no means cruel, as most people represent it, by the tortures of a few guilty, to search after remedies for the whole innocent race of mankind in all ages." Celsus, however, considered this sort of vivisection both cruel and superfluous, though dissection is necessary for instruction. We learn from him that Ammonius, the Alexandrian lithotomist, was accustomed to split in pieces, by means of an instrument, calculi too large to be removed from the bladder whole. Celsus also makes mention of Heraclides of Tarentum (230 B.C.), to whom it first occurred to adapt to the reduction of dislocations the mechanical inventions of Archimedes. Heraclides was the greatest of the Empirics, a medical sect who thought that success in practice did not depend upon a knowledge of philosophy or science, and that it is more important to heal disease than to know its cause. According to them, physicians, as was obviously the case with farmers and sailors, were in no need of theoretic instruction. To Heraclides, the best product of this narrow school of medical thought, we are indebted for the investigation of the effects of numerous drugs, including opium.

Celsus, who flourished in the early part of the first century A.D., was a Roman patrician and author, who must be considered an enlightened amateur and not a professional physician. Of his encyclopædic writings dealing with the so-called Arts — agriculture, medicine, war, rhetoric, philosophy, and jurisprudence — only one complete work survives, namely, "De medicina, libri octo." It is based on the writings of the Hippocratic and Alexandrian epochs and on the Greek medical works of his contemporaries. It displays a good knowledge of osteology, particularly of the skull with its sutures, foramina, maxillary bones, etc. It shows that its author held a correct view of the part played by cartilage in the articulations, and of the difference in form between the male and female pelvis. Among various other matters Celsus speaks of the carotid arteries, and the cervical glands. In the neck there begin two passages. Of these *alterum asperam arteriam nominant, alterum stomachum. Arteria exterior ad pulmonem, stomachus interior ad ventriculum fertur: illa spiritum, hic cibum recipit.* The œsophagus (*stomachus*) was known to lead to the stomach (*ventriculus*); while the trachea (*arteria*) carries air or spirit to the lungs.

The anatomy found in the "De medicina" is largely incidental, but surgery is the exclusive topic of two of the eight parts into which the work is divided. Very little is known of the practice of surgery at Rome before the time of Celsus, but he makes mention of Asclepiades (about 100 B.C.), who by his tact and urbanity succeeded in gaining for Greek medicine a foothold in the Roman metropolis. Asclepiades advised tracheotomy in certain cases, employed venesection with discretion, and noted two instances of spontaneous dislocation of the femur. However, the distinction between surgeons and physicians was definitely made among the Romans, and Asclepiades was known as a physician rather than as a surgeon. He taught that the body consists of an infinite number of atoms, which surround countless minute tubular spaces or pores, a doctrine that became the fundamental principle of the Methodic school of medical thought.

The pages of Celsus enable us to see the progress made in surgery between the fifth century B.C. and the first century A.D. For example, ligature was unknown in the Hippocratic era, but Celsus, after discussing various methods of arresting hæmorrhage — the application of dry lint, cold, compression, vinegar, corrosives, and caustics — writes: "Finally, if the bleeding continues, the vessels which discharge the blood are to be taken hold of and tied on both sides of the wounded part, and cut through in order that they may retract." In case that such procedure is impracticable, the red-hot cautery is to be applied to the bleeding vessel. Sometimes the application of a cupping instrument near the point of hæmorrhage may prove effective.

Contrary to the supposition of one of our writers of general history the removal of limbs by amputation was practiced by surgeons before Harvey demonstrated the circulation of the blood. In fact, the Father of Medicine, in cases of gangrene, where loss of limb became inevitable, ventured to assist nature by amputating at the line of demarcation. It is to Celsus, however, that we are indebted for the first detailed description of amputation. Speaking of him a great modern surgeon, Lord Lister, who will be the subject of a subsequent chapter, writes: "He directed that the soft parts should be divided with a knife down to the bone, and then dissected up from it for some distance, so as to allow the saw to be applied at a higher level. The rough surface of the sawn bone was then to be smoothed off, and the soft parts, which, as he tells us, will be lax if this plan be pursued, were to be brought down so as to cover the end of the bone as far as possible. This method seems calculated to afford good results;

particularly as it appears probable from his writings that Celsus employed the ligature for arresting hæmorrhage after amputation, and dressed the stump in a manner favorable to the occurrence of primary union."

From the lucid pen of Celsus we have also descriptions of plastic surgery, of lithotomy, the couching of cataract, venesection, trephining, relief of phimosis, urethrotomy, resection, the surgical treatment of hernia, cancer of the lip, vomica of the liver, and many other operative procedures. He mentions suture of the abdominal wall (including the peritoneum) and of the intestines, recognizes the advantage to the surgeon of ambidexterity, and gives the four classical symptoms of inflammation (*Notæ vero inflammationes sunt quatuor, rubor et tumor, cum colore, et dolore*). There have been discovered in the ruins of Pompeii surgical instruments that throw further light on the practice of the first century of the Christian era. These include iron bistouries, bronze forceps and cupping instruments, a lancet with silver blade and bronze handle, probes, a double anal speculum, a three-bladed uterine, and an S-shaped catheter. Pliny, who was a victim of the same eruption of Vesuvius (79 A.D.) as destroyed the city of Pompeii, mentions an artificial iron hand, which was the product, however, of a much earlier period than his own.

The age following that of Celsus was one of the most brilliant in the history of anatomy and surgery, though only a small fraction of the medical literature of the time is now in existence. Marinus, who lived in the time of Nero (54–68 A.D.), was the author of numerous books on anatomy. He is known for his careful study of the muscles, glands, and nerves. He described seven pairs of cranial nerves, including the auditory, facial, and hypoglossal. His knowledge was gained by dissection, as well as by animal vivisection and experimentation. About the time that the warlike Trajan, with the most highly organized armies the Roman Empire had seen, was extending his dominions to their utmost limits and celebrating his triumphs by the exhibition of ten thousand gladiators, there lived among his subjects Leonides, Rufus, Archigenes, Aretæus, Heliodorus, and Soranus of Ephesus. The last-named was the greatest gynecologist and obstetrician of antiquity. He made use of the obstetric chair, practiced version in order to induce head presentation, and he discarded the old rough methods of treating pregnant women (jolting on ladders, etc.) which had been handed down by the Asclepiads of Cnidus. Soranus had, before going to Rome at the end of the first century B.C., been trained in anatomy at Alexandria. He contributed to the development of general surgery, especially the treatment of fractures, and of injuries of the head, as well as to various other departments of the healing art. Unlike his great contemporaries, who were adherents of the Pneumatic or Eclectic schools of medical thought, Soranus was a Methodist, following Asclepiades in medical doctrine and Epicurus, the disciple of Democritus, in philosophy. He was naturally opposed to all forms of superstition, and tried to persuade the midwives to abjure their reliance on dreams and the practice of mystic rites and antiquated customs. The influence of Soranus was greatly extended through the translation and interpretation of Cælius Aurelianus (fifth century A.D), the only distinguished writer on medicine, except Celsus, to employ the Latin language during the period of the Roman Empire.

Rufus of Ephesus was educated at Alexandria, dissected monkeys and other animals, and experimented on live specimens. He knew that all bodily function is under the control of the nervous system. He was acquainted with the recurrent laryngeal nerve, and produced loss of voice and of sensibility by compressing the pneumogastric in the region of the carotid arteries. He discovered the optic chiasma, described the capsule of the lens, and the tortuous course of the uterine artery. As a surgeon Rufus employed torsion of arteries and digital compression, as well as other means, for the arrest of hæmorrhage. He associated *Filaria medinensis* with impure drinking-water, and described leprosy, which at about this time was carried to the West by the returning Roman legions, as well as bubonic plague, traumatic erysipelas, and other diseases.

Flap amputations were performed by Leonides of Alexandria, and by the two greatest surgeons of the time of Trajan — Archigenes and Heliodorus, who, like Rufus, both employed torsion of vessels to arrest hæmorrhage. "Amputation above the elbow or knee," writes Heliodorus, "is very dangerous owing to the size of the vessels divided. Some operators in their foolish haste cut through all the soft parts at one stroke, but it seems to me better to first divide the flesh on the side away from the vessels, and then to saw the bone, so as to be ready at once to check the bleeding when the large vessels are cut. And before operating I am wont to tie a ligature above the point of amputation." Speaking of operating for hernia he writes, "We ligature the larger vessels, but as for the smaller ones we catch them with hooks, and twist them many times, thus closing their mouths." Even more relevant is his description of a minor amputation. "A circular incision," he writes, "is made round the digit near its base. From this two vertical incisions are made opposite one another and the flaps so formed dissected up. The base being thus laid bare, the digit is to be removed by cutting forceps, and the flaps are then brought together and sutured." Heliodorus undertook resections, and the removal of exostoses, and treated stricture by internal urethrotomy. Archigenes performed amputations not only for gangrene and severe injuries, but, in case of malignant tumor or great deformity, constricting the limb above the point of amputation, cutting down upon the chief arteries and ligaturing them. He removed mammary and uterine cancers, employed the vaginal speculum, treated injuries of the head, etc. Heliodorus is known only as a surgeon, but Archigenes excelled in many departments of medicine. Aretæus was probably indebted to Archigenes for his knowledge of the vascular system, of the structure of the kidney and other organs, as well as for much of his clinical wisdom. In the pages of Aretæus are found classical descriptions of phthisis, tetanus, diphtheria, epilepsy with its aura, satyriasis, diabetes, and elephantiasis. These are written in the Hippocratic spirit. They are not case histories, however, but generalized pictures that enable the clinician to know each species of disease in its antecedents, development, and probable outcome in individual cases. Aretæus introduced the term "syncope" into pathology, and established the distinction between paralysis of cerebral origin, involving decussating fibers, and paralysis of spinal origin.

Galen (130–201 A.D.) was the greatest anatomist of antiquity, and, after Hippocrates, the greatest physician. His voluminous writings reflect the spirit of the highly organized Empire of the Antonines, just as the Hippocratic writings reflect the freer spirit of the Periclean age. Galen, born at Pergamus, directed in his early education by a wise and cultured father, was early initiated in the philosophy, medicine, and general learning of his time. By nature and training an Eclectic, he chose what seemed to him best in the teachings of all the schools of philosophy and all the medical sects, and ultimately harmonized all these in a system of his own. He was a professed disciple of Hippocrates, a votary of the Asclepieion of Pergamus, a follower of Aristotle, a student of the works of Plato, and was indebted for parts of his medical doctrine to the dogmatic, empiric, pneumatic. and the methodic schools of medical thought.

Galen received his training in anatomy at Alexandria and other places, and his works on that part of medical science show that he had diligently studied the writings of the great Alexandrian anatomists, of Rufus of Ephesus, and, above all, of Marinus, the expert dissector. Galen himself examined with great care the human skeleton, the muscles of the Barbary ape, the brain of the ox, the nervous system and the viscera of the pig, the blood-vessels of the embryo, and dissected and vivisected many animals — goat, fish, snake, etc. He was particularly intent on the function of each part of the body, and, seeking to demonstrate design in nature and purpose in each structure, he closely correlated anatomy and physiology. As a youth of twenty, he had written three books on the movement of the lungs, as well as a treatise for midwives on the anatomy of the uterus; at the age of twenty-eight, as physician to the gladiators of Pergamus, he showed special skill in the treatment of open wounds and of injuries to tendons; and, leaving his native city for the world's metropolis, he at the age of thirty-two demonstrated before the élite of Roman society by experiments on living animals the mechanism of the nerves and muscles.

Galen's contributions, however, to the knowledge of structure are found in almost every department of the study of anatomy. His descriptions of bones and ligaments approach the standard of the present day. He classified the vertebræ as cervical, dorsal, and lumbar, and employed the terms "apophysis," "epiphysis," "symphysis." He knew in animal dissection the seven muscles of the eye, named the platysma, first described the popliteus and the interossei muscles, and explained the nature of the muscles involved in mastication, respiration, locomotion, etc. He described the branches of the aorta, the ductus arteriosus, the three coats of the arteries, was aware of the anastomoses of the minute veins and arteries, proved, by ligaturing the femoral artery in two places and making an incision between the two ligatures, that the arteries contain blood. He gave directions for the dissection of the brain, recognized the pituitary body and the infundibulum; by dividing the hemisphere exposed the corpus callosum and the fornix; by making sections he studied the ventricles, the corpora quadrigemina, and other parts of the cerebrum; he mentioned the vermiform process of the cerebellum. He carefully traced the course of the trigeminal, auditory, facial, glossopharyngeal, and other cranial, as also the course of the spinal nerves, and the connections of the vagus and sympathetic. Galen described the pleura and the pericardium, lungs, heart, and, very carefully, the abdominal organs, following Herophilus in the description of the genitals. More impressive than even his knowledge of neurology or osteology is the method, systematic and comprehensive, displayed by Galen in his treatises on anatomy.

As already implied, much of his knowledge of anatomy is bound up with physiological discussions. He was able to observe the motion of the exposed heart in two patients, and noted that the heart continued to beat in vivisected animals after the large vessels had been cut. The blood of the right heart is thick and black. Part of it is carried to the lungs by the pulmonary artery, while another part passes through the interventricular septum, permeable according to Galen. This is converted in the left heart into the thinner and redder blood of the arteries by the action of the pneuma, which enters by way of the pulmonary veins after each respiration and the diastole of the heart, the inhaled air acting on the blood like a blast on dying charcoal. From the left heart the blood, mixed with much pneuma, enters the arteries. Galen's investigation of the functions of the nervous system likewise involved considerable knowledge of anatomy. With a sword-like steel scalpel he sectioned the spinal cord of the pig at different levels. Transverse sections above the second cervical vertebra caused sudden death; a section between the third and fourth cervical vertebræ paralyzed respiration; a section between the seventh cervical and the first dorsal was followed by a limitation of the respiratory movement to the diaphragm and the muscles of the thorax. By cutting or constricting the recurrent laryngeal nerves Galen produced aphonia, and by cutting the fifth cervical paralyzed the scapular muscles. He knew that nerve trunks carry motor, or sensory, or motor and sensory, impulses. He cured a patient who had experienced loss of sensation in the fourth and fifth fingers of the left hand by using counter-irritants over the lower cervical and upper dorsal vertebræ. This bold and original experimental physiologist even attempted to determine the functions of parts of the cerebrum, which he regarded as the seat of mental life, by removing the brain of a pig section by section.

After settling in Rome, Galen, like Asclepiades, did very little as a surgeon. As physician to the gladiators in his native city he had made use of red-wine dressings in the treatment of wounds. Besides his early success in the treatment of injuries, he is also credited with the first mention of traumatic aneurism, with the resection of the rib, and with the resection of the sternum for caries (one of the cases of exposure of the heart already mentioned). His works speak of the use of silk and gut ligatures, of bandaging, of the treatment of ulcers, of plastic operations on the nose, lips, and ears, of radical operation for cancer of the breast, etc. By regarding suppuration as the result of the coction of irritant humors, he gave support to the doctrine of laudable pus, which was not seriously challenged till the time of Theodoric of Lucca.

After the time of Galen anatomy and surgery within the bounds of the Roman Empire suffered a rapid decline. Antyllus, noted for his treatment of aneurism and of cataract, for his description of plastic operations and of tracheotomy, is now regarded as a predecessor of Galen. Oribasius (325–403) was the author of an encyclopædia of medicine, which extended the influence of Galen and preserved the memory of Archigenes, Heliodorus, and Antyllus. To Aëtius of Constantinople (sixth century A.D.) we are likewise indebted for information concerning the surgery of Rufus, of Leonides (removal of glandular tumors from the neck, etc.), and, particularly, of Archigenes. His voluminous work gives a definite account of the surgical treatment of aneurism. Alexander of Tralles was the author of a "Practica." With these Byzantine compilers is usually mentioned Paul of Ægina (625–690), who wrote an "Epitome" of medicine in seven books. Paul, however, was an expert surgeon and described a great variety of operations. His treatment of cataract by depression, his failure to perform thoracentesis for empyema, an operation which had been known in Hippocratic times, his neglect of the methods of version followed by Soranus, and his practice of removing the testicles in case of scrotal hernia, indicate that surgery in his time had begun to relapse from a classical to a medieval standard. The pages of the "Epitome" afford some insight into the practice of military surgery in the armies of the Roman Empire.

At the time of Trajan there had been twenty cohorts of garrison troops of one thousand to fifteen hundred men each, with four surgeons to the cohort. Nine cohorts of Pretorian guards were in addition provided with physicians. In the rest of the Empire there were thirty legions of ten cohorts and about sixty-five hundred men each. These troops were attended by surgeons of the legion (*medici legionis*), probably six or more to the legion. They wore the uniform of the legionaries, but were counted as of superior rank. In the fixed camps there were special medical officers. About the same time mention is made of military hospitals, also provided with regular superintendents. In the Roman armies of the sixth century every troop of two hundred to four hundred men was accompanied by eight or ten men on horseback to pick up the wounded. These first-aid men carried each a water flask, and received a gold piece for every man they rescued. In the military hospitals were male nurses. For each vessel in the navy, surgeons were also provided.

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CHAPTER IV

THE TRANSMISSION OF MEDICAL SCIENCE BY THE ARABS

Before the death of Paul of Ægina the translation of Greek and Syriac medical works into the language of the Mohammedan conquerors of Asia Minor had begun, and even before the end of the fifth century the medical science of Constantinople had been carried as far east as the Persian province of Khorasan by the Nestorian heretics. The school and hospital at Gondisapor, controlled for the subsequent centuries by this Christian sect, became the focus from which Greek, Syrian, Persian, and Indian medical teachings were spread among the followers of the Prophet. Here was educated the Arab physician Harets ben Kaladah, who, though a Christian, became the adviser of Mohammed in those hygienic and medical matters which Islam, like Judaism, made a part of religion. When the Arab conquerors overran Mesopotamia and Persia, they left undisturbed their fellow monotheists, the Nestorian physicians of Gondisapor. Among these about the middle of the eighth century certain Syrian families, the Bachtishuas, Messuas, and Serapions, were especially prominent as translators.

In 765 George Bachtishua, whose influence had for a time been supreme in the school and hospital of Gondisapor, was called to the recently founded city of Bagdad by the Abbaside Caliph al Mansur, who induced him to undertake the translation of a number of medical works into Arabic. He returned to Khorasan before his death in 771, but his son was later summoned to the court of Harun al Rashid, and the grandson Gabriel and the great-grandson were famous in the times of that Caliph and his successors.

The Arabian Nights throws a curious light on the medical knowledge and general culture of the Eastern Caliphate at the beginning of the ninth century. Readers of the story of Abu al Husn and his Slave-Girl will recall how the hero "ate and drank, and made merry and took his pleasure, and gave gifts of gear and coin and was profuse with gold, and addressed himself to eating fowls and breaking the seal of wine-flasks and harkening to the giggle of the daughter of the vine as she gurgled from the flagon, and enjoying the jingle of the singing girls; nor did he give over this way of life till his wealth was wasted and the case worsened and all his goods went from him, and he bit his hands in bitter penitence." Then the slave-girl, the last of Abu al Husn's possessions, said: "O my lord, carry me to Harun al Rashid, fifth of the Abbasides, and seek of him to my price ten thousand dinars." When she is brought before the Caliph, her accomplishments and acquisitions are submitted to rigid inquisition. Among the various branches of learning open to students of the time she had not neglected medicine. She proves to be versed in the four elements, the four humors, the three kinds of spirits, the five senses, the three ventricles of the brain. The number of veins is unknown, though some have thought to fix it at three hundred and sixty. There are two hundred and forty bones, and, contrary to the teaching of Galen, the mandible, the sternum, and the sacrum — intermediate between the vertebræ and the coccyx — consist of one bone each. The cause of all sickness is repletion and indigestion. Scurvy may result from eating salt food fasting. The endive is the most excellent of vegetables. Fermented liquor banisheth care and gladdeneth the heart of man, yet its sinfulness is greater than its use. One should not bathe on a full stomach. Yellowness of the whites of the eyes is indicative of jaundice. Medicine is taken to greatest advantage when Jupiter and Venus are in the ascendant. Cupping, like venesection, should be practiced in moderation, and it should be performed in the wane of the moon, and if it fall on a Tuesday and in the spring of the year, it will be the more efficacious, etc. From these fragments it is evident that the Slave-

Girl's medical lore is borrowed from Greek, Hebrew, Babylonian, and other sources. It is probable that the corrections of Galen's osteology, a knowledge of which is attributed in this fourteenth-century tale to the time of Harun al Rashid, are to be credited to Abdollatif (1162–1231), who, invited to visit Egypt in the reign of Saladin, enjoyed greater opportunities of studying the human skeleton than usually came to Mohammedan physicians.

The first of the Messuas to rise to distinction spent the early part of his life as an apothecary at Gondisapor, went to Bagdad as a physician, and, gaining the favor of Harun al Rashid by successful treatment and prognosis, entered into rivalry with Gabriel Bachtishua. Messua's son, usually called Messua the Elder, became the director of a college of translators at the request of the enlightened Caliph al Mamun (813–833), who wished to see translated into the Arabic language the sciences of all the lands under his sway. Messua the Elder and Serapion the Elder dispute the honor of having written the so-called Aphorisms of Damascenus. Greater, however, as a translator than the Bachtishuas, Messuas, or Serapions was Honain ben Isaac (809–873), a Christian Arab who put into his native tongue the works of Hippocrates, Galen, Oribasius, and Paul of Ægina, and who wrote a treatise on ophthalmology and a commentary on

Galen (Isagoge). During the ninth century the writings of Archigenes, Dioscorides, Rufus, Aristotle and other Greeks were likewise made accessible to readers of Arabic. At the same time the Arabs revised Syriac translations from the Greek, which had been made by Sergius in the sixth century, and translated a Syriac work ("Practica") written by Serapion.

The greatest of all the physicians to write in Arabic was the Persian Rhazes (860–932), who studied at Bagdad and was the author of a comprehensive work on medicine, the "Continens," a briefer work, the "Almansor," and a treatise on the smallpox and measles. He taught that inquietude, anxiety, and nausea are more frequent in the measles than in the smallpox; while, on the other hand, pain in the back is more peculiar to the smallpox than to the measles. He considered these diseases (the task of clearly differentiating which was ultimately accomplished by an English clinician) as an inevitable accompaniment of a natural change in the condition of the blood. "Now the smallpox arises," he says, "when the blood putrefies and ferments, so that the superfluous vapors are thrown out of it, and it is changed from the blood of infants, which is like must, into the blood of young men, which is like wine perfectly ripened: and the smallpox itself may be compared to the fermentation and effervescence which takes place in must." And this is the reason why children, especially males, rarely escape being seized with this disease, because it is impossible to prevent must — the nature of which is to effervesce and ferment — from changing into the state that supervenes. In young men, the maturation of the blood having been established, the disease seldom occurs, except in those cases in which a mild form, which has not brought to perfection the transition of the blood from the first state to the second, has been suffered in childhood. Old men are not susceptible except in pestilential, putrid, and malignant constitutions of the air, in which this disease is chiefly prevalent. Rhazes sought by treatment to bring it about that the unavoidable change in the blood "should not be effected all at once and in a short time, with ebullition and fermentation, which are accompanied by frightful and dangerous accidents, but little by little, and in a long time, and gradually, by way of ripening, not putrefaction, and without fevers." He even sought to anticipate the occurrence of the disease.

There is no doubt that Rhazes was markedly original as compared with other writers in Arabic on medicine. He was called the "Experimenter." "I do not suppose," he says, "that any great harm would happen to a man who should drink metallic mercury except severe pains in the stomach and intestines. I gave some to an ape which I had, nor did I see any evil befall him beyond that above mentioned, which I conclude from the fact that he twisted about, and kept biting at his stomach, and pawing it with his hands." He made use of mercurial ointments, and gave the first clear description of spina ventosa. Asked to choose a site for a hospital in Bagdad, Rhazes hung pieces of meat in different parts of the city in order to ascertain the place least favorable to putrefaction. Nevertheless, in spite of the evident independence of his spirit, he insisted on the value to the physician of supplementing personal experience by a knowledge of the history of the medical profession. And when we turn to his larger works, which also treat of smallpox and measles, we find to what an extent he relied on his Greek and Arabic predecessors. In the "Continens" (the ninth book of which was in the sixteenth century translated into Latin by Vesalius) he refers to a dozen writers who had turned their attention to the study of smallpox before his time. These include Aaron, a Christian priest and physician, who had flourished at Alexandria in the first half of the seventh century; Isaac, son of Honain, more distinguished as a physician, no less expert as a translator, than his father; and Messua the Elder, who had anticipated what seemed most original in Rhazes, the view that smallpox is caused by an innate contagion, or ferment, in the blood.

Two other Persian physicians, Haly Abbas and Avicenna, preserved in encyclopædic works written in Arabic the medical science of the ancients. The "Liber Regis" of the former is largely based on Galen, and epitomizes the knowledge of the Arabs of the tenth century. It contains a good account of the symptoms and treatment of diabetes, a disease that had been described by Aretæus and by one of the great physicians of India; it refers to anthrax, which was probably known to Rhazes as well as to Hippocrates, whom Haly Abbas regarded as the prince of the medical art. The book also gives directions for the treatment of melancholy and other forms of mental disorder. Haly Abbas advocated the search for new drugs, the virtues of which should be tested on animals. He held that the student of medicine should not neglect the opportunities offered for observation in hospital and private practice. Avicenna (980–1036) in his "Canon" gave systematic and logical expression to Arabic medical science. He based his doctrines on those of Aristotle and Galen, and he is particularly comparable with the latter as a medical philosopher, whose writings mark the culmination of a long period of development. His book supplanted the "Continens" and the "Liber Regis," and for centuries continued to be the authoritative textbook of medicine in the Western world, as well as in the Eastern, where, indeed, its influence is still dominant. Avicenna described leprosy, already known to Aretæus; treated spinal deformities, as had Hippocrates, by forcible reduction; observed filaria medinensis, as had Leonides of Alexandria, not to mention Agatharcides of Cnidus (second century B.C.), Soranus of Ephesus, and others. Avicenna emphasized the importance of diet and regimen, and paid particular attention to skin diseases and nervous affections. Among other directions for determining the value of drugs, he mentions experiment on human beings. He was bolder than Paul of Ægina in operating for empyema, advocated the use of forceps in obstetrics, and, though addicted to the cautery rather than the knife, employed the ligature as one of the means of checking hæmorrhage.

Isaac Judæus (850–950) was a contemporary of Rhazes rather than of Avicenna, but his mention here will serve to mark the westward migration of Arabian culture. He practiced in Egypt, and later settled in Kairwan (Tunis), the sacred city of Northern Africa. He was known for his treatment of eye troubles, and left treatises on diet, urine, fevers, etc. Besides these writings in Arabic, he is also credited with producing in Hebrew "The Physician's Guide," which reflects the wisdom of an experienced practitioner, as the following quotations bear witness. "He whose business it is to bore pearls must do his work carefully in order not to mar its beauty by haste. Even so he who undertakes the cure of human bodies, the noblest creations on earth, should take thought upon the diseases with which he comes in contact and give his directions after careful reflection, so that he fall into no irremediable error. . . . The chief task of the physician is to prevent disease. . . . The majority of diseases are cured by nature. The more you demand for your treatment and the more highly you esteem your cure, so much the higher will you stand in the eyes of the people. Your art will be held of no account only by those whom you treat gratuitously. . . . Visit not the patient too often, nor remain too long with him, unless the treatment demand it, for it is only the fresh encounter that gives pleasure."

Albucasis (912–1013), Avenzoar (–1162), Averroës (1126–98), and Moses Maimonides (1135–1204) belong to the Western Caliphate. Avenzoar was born in the neighborhood of Seville, Albucasis near Cordova; while the other two were born in that capital, which as early as the tenth century boasted one million inhabitants, hundreds of mosques, numerous and splendid public libraries, and flourishing institutions of higher learning which became the models of the later European universities. Albucasis was the greatest of the Arab surgeons, and fully recognized the value to the surgeon of a knowledge of anatomy. The last part of the "Tasrif," or collected works, is devoted to surgery, and, published separately and illustrated, is the earliest distinct work on that subject. It is based on the sixth book of Paul of Ægina. Albucasis, as was usual with the Arab physicians, emphasized the importance of the cautery, although the use of the ligature was also known to him. He gave directions for the surgical treatment of defective, loose, and irregular teeth. He described a case of extra-uterine pregnancy, anticipated the Walcher position in obstetric cases with presentation of knees and hands, and his illustrations picture forceps with crossed handles. Albucasis employed a more developed form of syringe than the bladder fitted with a reed used in antiquity, and was aware of the occurrence of hæmophilia, and of salivation following the external use of mercury. "Avoid perilous practices," he writes, "as I have already warned you, so shall you have the more praise and profit, if God will."

Avenzoar was the greatest of the Arab physicians after the time of Rhazes, and like him tempered his reverence of the past with a self-respecting reliance on his own clinical observations. The pages of his chief work "al-Teisir" (Assistance) report a number of interesting cases — an abscess of the pericardium which, while Avenzoar was still a student, caused the death of his father, an abscess of the mediastinum from which he himself recovered after coughing up sanious matter, an inflammation of the middle ear, cancer of the stomach, a hernia cured by rest. In the case of a patient suffering from a paralysis of the gullet he poured milk into the stomach by means of a tube passed into the œsophagus and made use of nutrient enemata. He performed tracheotomy experimentally on a goat and recommended resort to that operation in cases of threatened suffocation. He recognized tuberculosis of the intestines, and, like many physicians of antiquity, prescribed milk for phthisis. "Sometimes there arise on the body," he says, "under the external skin, little swellings which are commonly called 'itch,' and if the skin be removed there issues from various parts a very small beast, so small that he is hardly visible." Avenzoar was a surgeon as well as a physician, and justly appreciated the knowledge of osteology and of anatomy in general. He dedicated his great medical work to his friend and disciple Averroës, who was more eminent as a philosopher and as the commentator of Aristotle than as a physician, though he wrote a work — the "Colliget"— on the general principles of medicine. His enthusiasm for the teachings of Aristotle tended to weaken the authority of Galen, who for centuries had been regarded as almost infallible in spite of the independence of Avenzoar and other Arab physicians. As a philosopher Averroës did not believe in personal immortality, and, consequently, he was regarded as a heretic both by the Christians and by the Mohammedans. Toward the end of the twelfth century Arabic culture in Spain was checked by a recrudescence of orthodoxy, and after the death of Averroës the medical science of the Arabs suffered a rapid decline.

The great Jewish Rabbi Moses Maimonides, driven from his native country by the persecution of fanatics, eventually found protection and patronage at Cairo from the hands of the tolerant and enlightened Sultan Saladin. It was in response to Saladin's request for advice on matters of health that Maimonides prepared his most interesting medical treatise, the "Book of Counsel" ("Tractatus de Regimine Sanitatis"). In the preface, addressed to Saladin, the author describes the four parts comprised in the treatise: "The first is a brief explanation of the general rules of health; the second is for those sick persons who cannot find a physician, or, at least, not one whom they can trust; the third contains the regimen proper for my lord's case, as it has been described to me; the fourth treats of matters useful to sick and well in all times and places." Maimonides wrote also a commentary on the "Aphorisms" of Hippocrates, summarized the writings of Galen, prepared a book of "Aphorisms" with quotations from Galen (whose errors and inconsistencies, however, he does not hesitate to expose), as well as treatises on asthma, on poisons, on dietetics, and a translation of a book of Avicenna. Like that Persian physician Maimonides was a disciple of Aristotle and of Galen.

The chief work of Haly Abbas, a book of Galen's, the "Aphorisms" of Hippocrates with the comments of Galen, the treatises on fevers and on urine of Isaac Judæus were translated from Arabic to Latin by Constantine the African in the eleventh century. In the twelfth century Gerard of Cremona did a like service for the "Aphorisms" of Damascenus, the "Practica" of Serapion the Elder, the "Canon" of Avicenna, a part of the writings of Rhazes, Albucasis, and other Arab physicians; while the greater part of Galen and the "Introduction" ("Isagoge") of Honain were likewise translated. The "Colliget" of Averroës and the "Book of Counsel" of Maimonides were made accessible to Christian nations about the middle of the thirteenth century. That very much of the medical science of the Arabs was available in western Europe at the beginning of the fourteenth century is manifest in the pages of the "Rosa Medicinæ" of John of Gaddesden, who drew his materials from translations of Greek, Arabian, and Jewish physicians and from the works of Gilbert the Englishman, who died in 1250, and the French physician Bernard de Gordon, who taught at Montpellier from 1285 till 1307. John of Gaddesden does not refer to the writings of Avenzoar, which were later translated into Latin and printed in Venice (1490). The English physician, however, knows of Avenzoar, and maintains on his authority that the brilliant smaragdus found in the head of the green toad, if triturated with water or wine and given in a nine-grain dose, is an effective emetic in cases of poisoning.

The belief in astrology, which had early prevailed in the Orient, spread throughout the civilized world, and was cultivated at Alexandria and Rome long before the time of the Arab conquests. Galen shared the superstitious views of his contemporaries as regards the influence of the heavenly bodies on one's health and fate, and, though his disciple Avicenna wrote a treatise on the uselessness of astrology, this pseudo-science continued to form a part of medical teaching for centuries. Purging and blood-letting were regulated in accordance with the positions of the planets and the signs of the zodiac. Medicinal plants were gathered under the appropriate planetary influence. The moon was supposed to rule the brain, Mars the bile, Saturn the spleen, etc. Moreover, since among the Babylonians from the very remotest times the sun, moon, and the five known planets were supposed to be in some intimate relation with the seven known metals, there is a natural connection between astrology and alchemy, or the transmutation of metals. The latter owes its real beginnings, however, to the art of dyeing as practiced by the Egyptian priests. It was found possible to color gold, silver, electrum, and other metals and alloys, and, nothing being known at that time of the actual chemical composition of substances, the metal's susceptibility to a certain dye (Tyrian purple in the case of gold) was taken as an index of its purity. Greek philosophy coming to the aid of Egyptian practice in Alexandria taught that the baser metals, copper and lead, partook of the nature of earth, that tin and mercury were of a watery constitution, that silver and gold were clear like air, while pure gold, the penetrative spirit or essence of gold, acted on the other metals like a purifying fire. Like a ferment it was able to transmute a mass of base metal millions of times greater than itself; like a medicine it brought health to the diseased or less perfect copper, lead, tin, etc. By the twelfth century this transforming essence was called the philosopher's stone, because of its resistance to all destructive forces, and later elixir, and it was supposed to be possessed of wonderful healing power.

Geber, who lived and wrote in the eighth century, has been erroneously called the founder of alchemy. His authentic writings show a more definite knowledge of the technique of chemistry — sublimation, calcination, distillation, filtration, crystallization, the coupellation of metals, the use of the water-bath, etc., than found expression in earlier work. Geber and his followers, among whom Rhazes, Avicenna, and a number of Arab physicians are counted, are credited with the discovery of aqua fortis, oil of vitriol, aqua regia, lunar caustic, corrosive sublimate, ammonium chloride, aqua vitæ. They were acquainted with sulphur, carbonate of soda, alum, borax, copperas, pearlash, arsenic, cinnabar, etc. Geber like Avicenna discouraged the belief in astrology, denying the influence of the stars on the formation of the metals; but it would be a mistake to ignore the influence of alchemy on the chemistry of the eighth and the succeeding centuries. The discovery of aqua regia, so called because it dissolved gold, the king of metals, no doubt found its motive in the desire to obtain in *aurum potabile* a sovereign remedy. Though Avicenna doubted the power of art to transmute a metal from the form given it by nature, he named as four mineral *spirits* sulphur, arsenic, sal ammoniac, and mercury, three of which substances had been employed in the Alexandrian art of coloring metals. This teaching was combined with that of Rhazes, that the metals are condensed vapors, in the sixteenth-century doctrine that three invisible substances, sulphur, mercury, and salt, by their coagulation form physical bodies. Even at the present time some trace of the two pseudo-sciences, alchemy and astrology, remains in our use of the terms spirits of wine, spirits of nitre, tincture, martian preparations, saturnine compounds, lunar caustic, jovial disposition, etc.

The pharmacy of the Arabs, interrelated with their chemistry and botany, in the early centuries of Mohammedan civilization had already made a considerable advance. It is at this period that we first hear of trade in drugs, developed from trade in spices, as a distinct vocation. The father of Honain, as well as the founder of the fortunes of the Messua family, was an apothecary. As early as the eighth century public pharmacies were established at Gondisapor and at Bagdad. The Arabs derived a knowledge of drugs from the Egyptians, the Hindus, and even more remote peoples with whom they came into commercial relations. They translated Dioscorides and knew of the Greek in addition to the Indian means of producing anæsthesia. Before the end of the ninth century the first pharmacopœia had issued from the hospital at Gondisapor. We have already noted an inclination among the great Persian physicians to experiment on the effects of drugs. Isaac Judæus advocated care and restraint in the use of remedies. Moses Maimonides, as already implied, showed the interest of his time in the study of toxicology. Avenzoar excelled in a knowledge of drugs, and was opposed to the use of purgatives, but showed himself rather credulous in reference to the virtues of the smaragdus, bezoars, theriacs, and mithridates. Very important in the history of materia medica are the Latin writings of the tenth or eleventh century attributed to Messua the Younger, which went through numerous editions and formed the basis of the European pharmacopœias. The work issued somewhat later under the name of Serapion the Younger was also a very influential book of doubtful authenticity. The most extensive work in Arabic on materia medica was that written by Ibn Baitar in the thirteenth century, who describes some four thousand drugs and draws his material from Dioscorides, Galen, and earlier Arab writers and supplements it with his own observations. Senna, and other mild aperients, orange, lemon, tragacanth, and other adjuvants, syrups, juleps, robs, and other methods of administration, alcohol, and other products of distillation, were known throughout Europe from the Arab treatises on pharmacy. Besides the drugs already mentioned, the following became widely used owing to the influence of the Arabs: aconite, aloes, ambergris, camphor, cannabis indica, cloves, cubebs, gold, manna, mercury, musk, nutmeg, prunes, tamarind, violet-root, rose-water, sandalwood, etc.

Arab institutions for the care of the sick were modeled after the infirmaries and hospitals of other nations. Besides the temples of health the Greeks had had public iatreia, difficult to distinguish from hospitals. Infirmaries for the indigent had existed in India and Ceylon for centuries before the beginning of the Christian era. The Romans provided valetudinaria for slaves and for soldiers. At Edessa in 372 a hospital of three hundred beds was established under Christian auspices, and to this were added in the following century a hospital for women and a school of medicine. The Nestorians, who for a time controlled these institutions, were compelled in 489 to take refuge in Persia. Shortly after their arrival in Persia the Nestorians, as we have already seen, were engaged in the teaching of medicine in the school and hospital at Gondisapor. The latter became the model of institutions founded by the Arabs in more than twenty of their cities. The first of these was established at Damascus in 707. Special provision was there made for the care of lepers and the blind. Before the middle of the ninth century, Bagdad had a hospital of which Messua the Elder became director, and numerous other hospitals arose in that city in the subsequent centuries, and with one of these the great Rhazes was associated, as we have seen. The most famous of the Arab hospitals were the hospital founded at Damascus about 1160 by Nureddin, as a thank-offering for the deliverance of Islam from the menace of the Second Crusade, and the Mansur Hospital of Cairo, erected (1284) for rulers and subjects, freemen and slaves, rich and poor, men and women. At Damascus, Bagdad, and Cairo, provision was made for medical education, libraries were established, and courses of public lectures were given. The knowledge of ophthalmology was particularly advanced, and the insane were treated with much more consideration by the Arabs than by the Christians of the same period. In the Western Caliphate there were numerous hospitals in Cordova and other cities. In the twelfth century Avenzoar was superintendent of a hospital at Seville.

It is true that the Arabs contributed little to the advance of anatomy, for their beliefs made dissection a forbidden practice. They believed that in the world to come the body must be subjected to the examination of two angels, and that the absence of any part might endanger the eternal happiness of the person. Moreover, they held that death was a gradual process only complete with putrefaction, and that contact with a dead body was a contamination. Nevertheless, though it was left for the age following that of the dominance of the Arabs to build upon the foundations laid by the ancients in the department of anatomy, in this field also there is evidence of the transmission of medical science through the channel of Arabic literature. When we use the terms ligamentum nuchae, sagittal suture, dura mater, pia mater, infundibulum, or speak of the cochlea of the ear, or the auricles of the heart, we adopt a nomenclature suggested by the writings of Arab physicians, just as when we use the terms Adam's apple, and cauda equina, we follow the figurative mode of expression of the Jewish physicians, associated at times, as we have seen, with the Arabs.

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CHAPTER V

THE REVIVAL OF ANATOMY AND SURGERY IN THE SIXTEENTH CENTURY

THE rise of modern anatomy and surgery is closely associated with the development of the Italian and French universities. Southern Italy was the natural meeting-place of the influences that contributed to the growth of medical science in the eleventh, twelfth, and thirteenth centuries, and the tradition that the University of Salerno owed its origin to the combined efforts of an Arab, a Jew, a Greek, and a Roman, may be accepted as indicating the sources from which the Salernitan teachers of medicine derived their doctrines. Much of the teaching in the "civitas Hippocratica," as Salerno was called, related to diet and other matters of hygiene, but anatomy and surgery were by no means overlooked. One of the earlier teachers at Salerno, Copho the Younger, a Jew, was the author of "De Anatome Porci," the first modern work on anatomy (about 1100). Toward the close of the twelfth century, another of the Salernitan doctors, Roger of Palermo, wrote a treatise on surgery, " Practica," which was revised by his pupil Roland of Parma in the thirteenth century. In the section dealing with wounds of the intestines, the surgeon is directed to insert in the intestinal canal a small tubular piece of elder and then to stitch the raw edges of the bowel together over it. In the school of Salerno women were admitted both as students and teachers, and one of them, Mercuriada, wrote a treatise on surgery. Nicholas of Salerno, in his "Antidotarium," speaks of a soporific sponge, prepared by saturating a natural sponge with a solution of mandragora, opium, hyoscyamus, lettuce, camphor, and nenuphar. This anodyne was dried, kept till needed, and then moistened with hot water or steam, and held to the patient's nostrils till sleep was induced.

Bologna, the second of the European universities, contributed to the advance of surgery and anatomy through the work of Hugh of Lucca, his son Theodoric, Bishop of Cervia, William of Saliceto, Mondino, and his pupil Bertuccio. Hugh of Lucca, who is known to us through the writings of Theodoric, was appointed city surgeon of Bologna in 1214, a few years later had experience of military surgery with the Crusaders in Egypt and Syria, and died at an advanced age about the middle of the thirteenth century. He observed strict cleanliness in the treatment of wounds, avoided the use of the probe, and employed compresses soaked in wine. Theodoric is quite definite concerning the advance made at Bologna in surgery. "For," he states, "it is not necessary, as Roger and Roland have written, as many of their disciples teach, and as all modern surgeons profess, that pus should be generated in wounds. No error can be greater than this. Such a practice is indeed to hinder nature, to prolong the disease, and to prevent the conglutination and consolidation of the wound." Both Hugh and Theodoric made use of anæsthetic sponges similar to those described by Nicholas of Salerno. William of Saliceto (1201–1277) was, however, the greatest surgeon of the thirteenth century, and the author of a systematic work on surgery ("Cyrurgia"). Like Hugh of Lucca he had had experience on the field of battle. He described wounds of various kinds, the suturing of intestines and nerves, the treatment of fractures and dislocations. His influence tended to restore the use of the knife in surgery, though he devoted considerable space to the discussion of different methods of cauterization. Saliceto distinguished between hæmorrhage from arteries and veins, but his knowledge of anatomy was, like that of all his contemporaries, very limited.

The practice of human dissection, which had been held in abeyance by the force of traditional sentiment and religious prejudice from the third century B.C. was indeed resumed to a certain extent in the thirteenth century, but it was not till 1316 that a treatise on anatomy written by one who had dissected the human cadaver made its appearance. This was the work of Mondino ("De omnibus humani corporis interioribus membris Anathomia"), who had made numerous dissections, two of which (January and March, 1315) are particularly mentioned. In the work of dissection, Mondino was aided by an able prosector, Otto Agenius Lustrolanus, and a devoted girl disciple, Alexandra Galiani. It is further evidence of the enthusiasm for dissection in the University of Bologna at the beginning of the fourteenth century that three years after the appearance of the "Anathomia" four students were brought to trial for having carried off by night the body of a criminal, which they and others of their kind were intent upon dissecting.

Peter of Abano, a friend of Mondino's and also a dissector, but much better known as an exponent of the philosophy of Averroës than as an anatomist, taught at the University of Padua; while Arnold of Villanova, who wrote on surgery as well as on alchemy and general medicine and, like Peter of Abano, was accused of heresy, stood associated with the famous school of Montpellier. More important than either of these from our present point of view was Lanfranchi, a third contemporary of Mondino's and a pupil of Saliceto's, who, about the close of the thirteenth century, carried to Lyons and to the College of Saint Côme at Paris the teaching and practice of Bolognese surgery. He was the author of two works on surgery ("Chirurgia Parva" and "Chirurgia Magna"), and, like his master, protested against the tendency to fix a line between the function of the surgeon and the function of the physician, and between practice and theory. Lanfranchi gave a good account of the symptoms of fracture of the skull, and was the first to describe concussion of the brain. He recommended ligature among the means of arresting hæmorrhage, held that exposure to the air favors the formation of pus in wounds, and advised neurotomy in cases of traumatic tetanus. Henri de Mondeville, the pupil of Lanfranchi and Theodoric, who studied at Montpellier as well as at Paris and Bologna, aided in the introduction of Italian methods of surgery into the French schools. He was the physician of Philip the Fair and frequently attended that monarch and the Count of Valois during their military campaigns. Mondeville lectured on anatomy at the University of Montpellier in 1304, and set forth views of the structure and function of the body strongly reminiscent of the teachings of Galen and the nomenclature of the Arabs. His surgery, however, showed the influence of his Italian masters and contemporaries. "Many more surgeons," he remarks with characteristic incisiveness, "know how to cause suppuration than to heal a wound."

Guy de Chauliac (1300–70) was the greatest surgeon of the fourteenth century. The son of humble country people of the French province of Auvergne, he studied at Toulouse, Montpellier, Paris, and Bologna. He learned anatomy from Bertruccio, who taught dissection in four sessions devoted to the abdomen, thorax, head, and extremities, and made use of dried specimens and bones prepared by boiling. De Chauliac was also indebted to certain anatomical illustrations (eighteen) of Mondeville's. The "Chirurgia Magna" (1363), one of the greatest contributions to the development of surgery, shows that Guy de Chauliac was acquainted with medical history from the time of Hippocrates, and was under special obligation to Galen, Avicenna, Albucasis, and other Arabic writers, as well as to his immediate predecessors in the French and Italian universities. At the same time his extensive knowledge of the practice and theory of others did not deprive him of independence and self-confidence. "For," he said, "we are like children astride the neck of a giant, who see all the giant sees and something besides." In cases of fracture of the femur, in addition to splints reaching to the foot he employed a box or trusses of straw to support the limb and attached to the foot a lead weight by means of a cord passing over a little pulley. He followed Theodoric and others in using narcotic inhalations to produce insensibility to pain, but adopted the theory of coction of irritant humors and laudable pus in the treatment of wounds. Like Saliceto, he believed in restricting the use of the actual cautery, and advocated a close alliance between surgery and medicine. He taught that cancer should be treated at an early stage and preferably with the knife; he gave directions for complete ablation of the gland in case of adenitis, and for suturing the intestines; he made use of the speculum in certain obstetrical operations; he gave an account of the Cæsarean operation following the death of the mother. True to his own principles he did not confine his attention to surgery, but gained acquaintance with all the medical science of his time. He introduced the use of sugar in medicinal preparations, and gave a careful description of the symptoms of leprosy to prevent the isolation of patients unjustly suspected of being lepers and to protect the general public against contagion. Much of Guy de Chauliac's life was passed at Avignon where he was the physician of Pope Clement VI and his successors. In the Black Death epidemics of 1348 and 1360 he took part in combating the pestilence, of the different forms of which he has left descriptions. Some of the manuscripts of the "Chirurgia Magna" contain illustrations of the opening of inguinal and axillary abscesses, of venesection, of the application of the (Gooch) splint, of instruments for trepanning (borers, elevators, rugines, etc.), for fistula operation, and for cauterization (olivary, dactillary, punctuale, etc.).

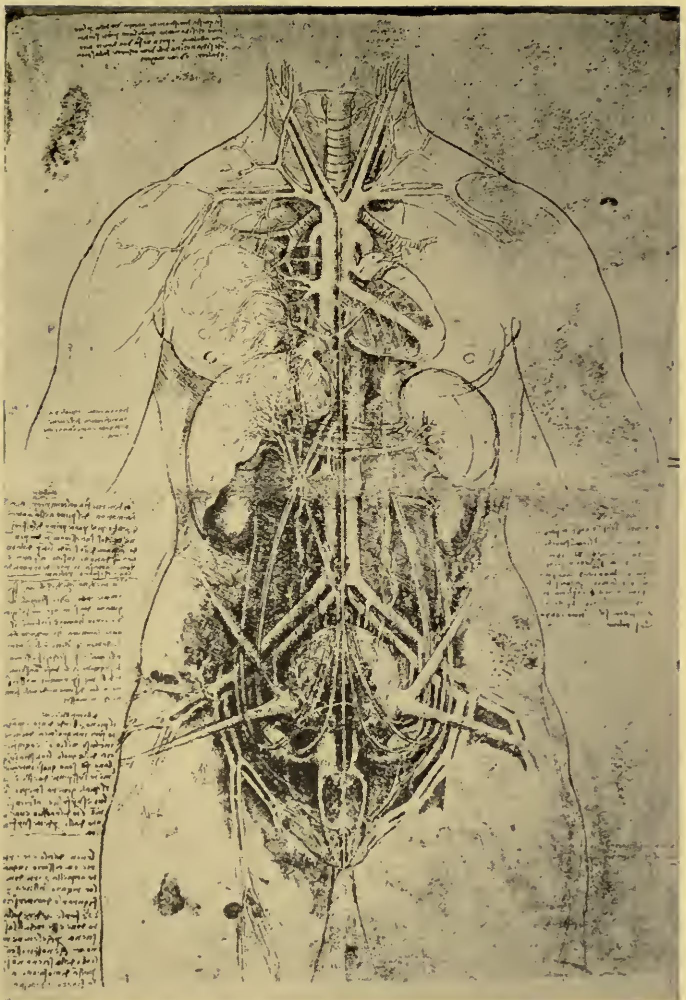
In spite of the foundations laid in anatomy by Mondino and in surgery by Guy de Chauliac and by the other anatomists and surgeons trained at the French and Italian universities, the general European practitioner of the fourteenth century no doubt deserved the satire leveled at him by the English poet Chaucer a few years after the death of Guy de Chauliac. Lines 5–8 in the following quotation are rather obscure, but refer to the attempts of the medical astrologers to bring magic influence to bear by means of diagrams of constellations made at the proper astrological moment. Such diagrams or images were frequently engraved on gems and were supposed to accumulate *influence.*

> With us ther was a Doctour of Phisyk,
> In al this world ne was ther noon him lyk
> To speke of phisik and of surgerye;
> For he was grounded in astronomye.
> He kepte his pacient a ful greet del
> In houres by his magik naturel.
> Wel coude he fortunen the ascendent
> Of his images for his pacient.
> He knew the cause of everich maladye,
> Were it of hoot or cold, or moiste, or drye,
> And where engendred, and of what humour;

He was a verrey parfit practisour.
The cause y-knowe, and of his harm the rote,
Anon he yaf the seke man his bote [remedy].
Ful redy hadde he his apothecaries,
To send him drogges and his letuaries,
For ech of hem made other for to winne,
Hir frendschipe nas not newe to beginne.
Wel knew he the olde Esculapius,
And Deiscorides, and eek Rufus,
Old Ypocras, Haly, and Galien,
Serapion, Razis, and Avicen,
Averrois, Damascien, and Constantyn,
Bernard, and Gatesden, and Gilbertyn.
Of his diete mesurable was he,
For it was of no superfluitee,
But of great norissing and digestible.
His studie was but litel on the Bible.
In sangwin and in pers he clad was al,
Lyned with taffata and with sendal;
And yet he was but esy of dispence;
He kepte that he won in pestilence.
For gold in phisik is a cordial,
Ther fore he lovede gold in special.

In Germany the universities were particularly late in providing instruction in medicine, and the first celebrated German surgeons acquired their skill on the field of battle. Pfolspeundt, a Bavarian army surgeon of the fifteenth century, mentions incidentally the treatment of gunshot wounds (1460). Speaking of the more familiar arrow wounds, he says, in the spirit of Chaucer's Doctour, that recovery depends on the favorable conjunction of the planet that is in the ascendant. His knowledge of rhinoplasty and his use of a narcotic inhalation show that he was somewhat influenced by Italian surgeons. Hieronymus Brunschwig, an Alsatian army surgeon, born at Strassburg in the early part of the fifteenth century, wrote as an old man "Das Buch der Wund-Artzney" (1497). He held that gunshot wounds are poisoned and that suppuration should be induced as a means of purification. He was acquainted with the work of the leading French and Italian surgeons. Hans von Gersdorff, also a native of Strassburg, gained experience of military surgery in the campaigns of Charles the Bold and was present at the battles of Granson (1476) and Nancy (1477). He wrote a "Feldtbuch der Wundtartzney" (1517) illustrated, like Brunschwig's work, with excellent woodcuts. He performed about two hundred amputations, and developed a method of his own. He did not believe that gunshot wounds are necessarily poisoned, but in certain cases followed the practice of pouring hot oil into the wounds. Giovanni da Vigo, in the "Practica Copiosa" (1514), had taught, according to Paré, "that wounds made by firearms partake of venenosity, by reason of the powder; and for their cure he bids you cauterize them with oil of elder-flowers scalding hot, mixed with a little treacle."

In the meantime anatomy had made a great advance in Italy under the influence of the Renaissance spirit. The practice of dissection, which had gained a definite place in medical education through the efforts of Mondino, was continued at Bologna, Padua, and other Italian universities by Zerbi, Achillini, and Marc Antonio della Torre in the brilliant period of scientific and artistic activity at the close of the fifteenth and the beginning of the sixteenth century. The greatest contribution, however, to the advancement of the study of anatomy was made by the supreme genius of the time, Leonardo da Vinci, 1452–1519, who has been described as a painter, sculptor, architect, engineer, musician, poet, philosopher, chemist, botanist, and geologist, and, in addition was referred to by William Hunter as the very best anatomist and physiologist of his time. We learn from an Italian painter and writer of the sixteenth century (Vasari) that Leonardo "filled a book with drawings in red crayon outlined with a pen, all the copies made with the utmost care [from bodies] dissected by his own hand. In this book he set forth the entire structure, arrangement and disposition of the bones, to which he afterwards added all the ligaments, in their due order, and next supplied the muscles. Of each separate part he wrote an explanation in rude characters written backwards and with



DISSECTION SHOWING THE FEMALE VISCERA IN SITU
Drawn by Leonardo da Vinci, *circa* 1510

the left hand, so that whoever is not practiced in writing, cannot understand them, since they are only to be read with a mirror." These invaluable anatomical drawings are still preserved, and within the last twenty-five years have been made accessible in a series of splendid reproductions.

Leonardo thus affords us one of the finest examples of the mutual influence of art and medical science. The Greek sculptors, taught by the observation of naked youth in the palæstra and gymnasium, had depicted the human form with remarkable fidelity, even exhibiting in their statues the contours of the pectineus muscle as developed by gymnastic exercises. For the intuitions of Greek artistic genius Leonardo did not disdain to substitute scientific observation based on the dissection of more than thirty bodies of men and women. He studied human development and deterioration, measured the proportions of the skeleton, and compared with the human foot the foot of the bear, the ape, and the bird. He analyzed the play of the muscles, the expression of the emotions, and movement in general. He not only pictured the muscles as they appear to the eye of the artist, but represented them schematically by straight lines and explained their action as a system of levers. Explaining the mechanism of respiration, Leonardo states: "All these muscles serve to elevate the ribs, and the elevation of the ribs produces a dilation of the chest, and the dilation of the chest involves an expansion of the lungs and, consequently, an attraction of the air which through the mouth enters the lungs now increased in capacity." He did not confine his attention to the bones, ligaments, and muscles, but depicted in his seven hundred and fifty or more sketches, the brain, nerves, blood-vessels, lungs, gravid uterus, heart, stomach, etc. It was Leonardo, who, with an artist's confidence in his own powers of observation, struck from the study of anatomy the fetters fastened upon it for centuries by the authority of Galen. His influence, however, was limited by his failure to bring to completion the projected work on anatomy for which he had made such magnificent preparations. The works of Berengario da Carpi (1470–1530), who wrote extensive commentaries on Mondino, prove that their author, though a dissector and touched by the independent spirit of the Renaissance, did not stand altogether free from the prepossessions of traditional anatomy. It was reserved for the great Vesalius in his systematic and well-illustrated work, "De Humani Corporis Fabrica," to bring that anatomy to the test of observation.

Andreas Vesalius, born at Brussels December 31, 1514, attended the University of Louvain, and in 1533 studied anatomy at Paris under the Galenist

Jacques Dubois (Jacobus Sylvius). Interrupted in his studies by the wars between Francis I and the Emperor Charles V, Vesalius returned to Louvain in 1536. In the following year he went to Venice, and before the completion of his twenty-third year received his doctor's degree at Padua, a city at that time controlled by the enlightened government of the Venetian Republic. In spite of his youth he was immediately appointed professor of surgery. Assuming the responsibility of imparting a knowledge of anatomy to the students of Padua, Vesalius almost at once departed from the established practice of reading Galen in the lecture room, and directed attention to what he afterwards referred to as "that true Bible, as we count it, of the human body and of the nature of man." The lecturer became a demonstrator, appealing from the authority of Galen to the evidence of the senses. The chief results of his observations as a dissector are embodied in the "Fabrica," which, completed and dedicated to the Emperor in 1542, was printed in 1543, in which year also appeared the revolutionary work of Copernicus. Discouraged by the opposition offered to his expositions of the truth, Vesalius relinquished his professorship in the following year, and accepted appointment as physician to Charles V. On the abdication of that monarch, in 1556, Vesalius became physician at the court of the son, Philip II, residing in Spain from 1559 till 1563. From Spain he went as a pilgrim to Jerusalem, probably cherishing the hope of eventually resuming his activities as an anatomist at Padua. Broken in health, however, before he had started on his pilgrimage, further reduced by the privations of a rough and protracted voyage as he was returning from the East, Vesalius landed on the desolate shore of the island of Zante, and there died in 1564.

Vesalius considered Galen as easily first among the students and teachers of dissection and as the greatest physician after Hippocrates. He followed up Galen's physiological experiments on living animals, and even accepted — provisionally at least — the Galenic theories of the circulation and other bodily functions. He did not fail, however, to point out Galen's shortcomings, to many of which he, as a dissector of lower animals, held the clue, and he was particularly severe with those disciples of Galen who contended that the Galenic anatomy described man rather than the ape. He showed that Galen in his description of the suture of the frontal bone, of the division of the inferior maxilla, in his account of the sacrum and coccyx, of the lumbar and abdominal muscles, of the muscles of the leg, foot, and hand, as well as in his account of the vascular system, had been too much influenced by observations made in dissecting apes. He showed that the Galenic description of the occipital bone, of the intestines in general, of the cæcum (the appendix of which he knew to be particularly small in man), was borrowed from the anatomy of the dog; while the structure of both apes and dogs had vitiated the traditional descriptions of the lumbar vertebræ, the lungs, etc. Deluded by the dissection of oxen, the great anatomist of antiquity had falsely attributed to man a complex intracranial plexus of blood-vessels (*rete mirabile*); while his knowledge of the uterus and of the form of the liver had also been obtained by the dissection of brute animals.

Vesalius, moreover, corrected Galen's account of the foramina of the skull, of the processes of the cervical vertebræ, of the tubercles of the humerus, of the shafts of humerus and femur, of the form and consistency of the sphenoid, of the internal structure of the phalanges. The Galenic account of the muscles and movements was subjected to criticism — the dorsal as well as the abdominal muscles, the movements of the head, spine, and upper extremity. Vesalius discovered the semilunar cartilages of the knee-joint, and corrected Galen's mistakes in reference to the cartilage of the patella, the articulations of the ribs, and the ligaments of the arm. Vesalius gave a better description of the brain than had been given before his time, discovered the inferior longitudinal sinus, described the septum lucidum, pointed out Galen's inconsistencies in reference to the ventricles, called in question his account of the meninges, and of the structure and functions of the nerves. He showed the defects in Galen's description of the veins of the upper arm and axilla, mesentery and intestines, and claimed that Galen had been unduly influenced by Aristotle in reference to the vena cava, and the structure of the heart. The attempt of Vesalius to accommodate his statements to Galen's physiological doctrines did not blind him to the fact that the interventricular septum shows no visible perforations. He writes: "The septum of the ventricles, composed as I have said of the thickest substance of the heart, abounds on both sides with little pits impressed in it. Of these pits, none, so far at least as can be perceived by the senses, penetrate through from the right to the left ventricle, so that we are driven to wonder at the handiwork of the Almighty, by means of which the blood sweats from the right to the left ventricle through passages which escape human vision." In somewhat like spirit he treated the questions of the presence in man of an indestructible resurrection-bone, the absence of a creation-rib, and the position of heart and umbilicus.

Among his many other contributions to the development of anatomy, Vesalius is to be credited with the discovery of the ductus venosus, the description of the vena azygos, the seminiferous ducts, the internal pterygoid and lingual muscles, the mediastinum and the pleura, an account of the structure of the pyloris, liver, kidney, and spleen. He made post-mortem examinations, was a successful surgeon, and resisted the tendency to divorce the study of one branch of medical science from another. His great service was to make anatomy a progressive study through his comprehensive volume, which recorded his own observations and contained illustrations, probably reproduced from his own drawings, and marked by a sense of truth and beauty not unlike that of Leonardo.

"Mere knowledge without experience," said Ambroise Paré (1517–90), "does not give the surgeon much self-confidence." The rapidly growing knowledge of anatomy and experience in the wars of Francis I and his successors combined in bringing to perfection the powers of that most illustrious of army surgeons. Born near Laval in Maine, France, Paré received early training as a barber surgeon, and even in his maturity he was treated superciliously, if not by the surgeons of Saint Côme, at least by the doctors of the Faculté. Coming to Paris as a youth, he continued his apprenticeship and served three years as a dresser at the Hôtel Dieu. He had his first experience of military surgery in the Italian campaign of 1536, and soon discarded Vigo's boiling-oil treatment, and further distinguished himself by an exarticulation of the elbow-joint, the first operation of the kind on record. He returned to Paris in 1539, but his services as an army surgeon were soon again in requisition. His pages tell of the successful treatment of wounds inflicted by lance, sword, halberd, stone, arquebus, pistol, culverin, and other firearms. His treatise, "La méthode de traiter les plaies," appeared in 1545. He studied, as opportunity offered, the works of the great surgeons, pursued anatomy under Sylvius, prepared an epitome of the "Fabrica," and in 1549 produced an antomical treatise. In 1552 Paré amputated without cauterization the leg of a gentleman hit by a cannon-ball. "I dressed him, God healed him (Je le pansay, Dieu le guarist). I sent him home merry with a wooden leg." His example fully revived the use of the ligature, and placed further restrictions on the use of the actual cautery. At the close of the same year he smuggled into the city of Metz, besieged by the Emperor, medical supplies from Henry II, and was welcomed by the nobles of the garrison, who said that since he had arrived they would no longer feel in danger of dying in case they should chance to be wounded. Five years later, after the battle of Saint Quentin, he was busy at La Fère-en-Tardenois, and found the wounded particularly difficult to cure. The earth for more than half a league around him was all covered with the dead, and so many green and blue flies arose from them as to hide the sun. "It was wonderful," he continues, "to hear them buzzing; and where they settled, there they infected the air, and brought pestilence with them." In 1559 Paré was consulted, along with Vesalius, in the case of Henry II, accidentally wounded while tilting. The patient in this case succumbed to concussion of the brain. In 1564 Paré courageously fought at Paris an epidemic of the plague, and published an extensive work on surgery copiously illustrated. In 1569 we find him successfully treating a nobleman near Mons, who had been suffering for months from a gunshot wound with fracture of the femur. In addition to local treatment, Paré, as usual, had regard to the general condition of the injured man, and advised the use of a forehead-cloth of oil of roses and water-lilies and poppies and a little opium and rose-vinegar. At the same time the patient must be allowed to smell flowers of henbane and other narcotics.

Paré described various forms of fracture, including fracture of the neck of the femur, and fracture of the parietal bone with extrusion of brain substance; he invented arterial forceps, many other kinds of surgical instruments, as well as artificial limbs, artificial eyes, and feeding-bottles; he encouraged the use of the truss, insisted that regular surgeons should not abstain from the treatment of hernia, cataract, and stone, and followed the practice of the old French lithotomists in employing a grooved director; he suggested syphilis as a cause of aneurism and hypertrophy of the prostate as a cause of strangury; he revived version by the feet, advocated prompt evacuation of the uterus in case of hæmorrhage during labor, and knew of the possibility of the Cæsarean operation during the life of the mother; he performed bronchotomy, neurotomy, staphyloplasty, and made use of the figure 8 suture in cases of hare-lip; he removed articular concretions, refrained from the too frequent dressing of ulcers, improved the method of trepanning, and made advances in eye surgery. Like Guy de Chauliac, Paré did not confine his attention to surgery, but wrote on various branches of medical science and insisted on isolation of those suffering from leprosy.

The work of the father of modern surgery was supplemented by his favorite disciple Guillemeau, by Rousset, by Pierre Franco, by Laurent Colot, by the Italian Tagliacozzi, and by the naval and military surgeon William Clowes (1540–1604). With the father of modern anatomy must likewise be mentioned his contemporaries Vidius, Charles Etienne, the great Eustachius (1524–74), his pupils Fallopius and Columbus, his fellow-student Servetus, as well as Ingrassias, Aranzi, the brilliant Varolius, Andrea Cesalpino, and Fabricius (1537–1619), the teacher of Harvey.

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CHAPTER VI

WILLIAM HARVEY AND THE REVIVAL OF PHYSIOLOGY

We have seen in an earlier chapter the views of Erasistratus and Galen concerning the structure and function of the heart, the arteries, and the veins. The advance in anatomy led by Vesalius prepared the way for a further advance in physiology. His careful study of the structure of the minute ramifications of the veins and arteries must have brought him to the very threshold of the discovery of the circulation of the blood, and the second edition of the "De Fabrica" (1555) shows that he became very skeptical concerning the passage of blood from the right to the left ventricle through the septum of the heart. His incredulity on this score may have been strengthened by the "Restitutio Christianismi" of his fellow student Michael Servetus, published in 1553. In this book Servetus taught that the blood — or, at least, some of it — passes from the right ventricle to the left, not through the cardiac septum, but "is moved in a long passage through the lungs; by them it is prepared; it is made bright; it is transfused from the arterious vein to the venous artery"; in fact, that what we call arterial blood is "a mixture made in the lungs of the inhaled air with the blood which the right ventricle communicates to the left."

Before the death of Vesalius, Eustachius described a large vessel extending downward from the left subclavian vein, provided at its orifice with a semicircular valve, and containing a scanty, watery, fluid. The valves of the veins were known to Charles Etienne, another contemporary of Vesalius, to their master, Jacobus Sylvius, to Cannanus (in 1546), and other anatomists. Fabricius, the pupil of Fallopius and the master of William Harvey, observed the valves of the veins independently in 1574, and published an illustrated treatise on the subject ("De Venarum Ostiolis") the year after Harvey's graduation at Padua. Two other predecessors of Harvey took an honorable part in the discovery of the circulation of the blood. Matheus Realdus Columbus, who had been the assistant and successor of Vesalius at Padua, became in 1545 the first professor of anatomy at the University of Pisa, and in 1548 was called to Rome. In the "De Re Anatomica," which was published after his death in 1559, Columbus states that "the blood is carried by the artery-like vein to the lung and being there made thin is brought back thence together with air by the vein-like artery to the left ventricle of the heart." Harvey indeed acknowledged his indebtedness to Columbus, "that skilful and learned anatomist," as well as to Galen, for guidance in reference to the pulmonary circulation. Andreas Cæsalpinus, 1519–1603, approached even more nearly the modern explanation of the circulation of the blood. In his "Quæstiones Peripateticæ" (1571) he wrote as follows: "Of the vessels ending in the heart, some send into it the material which they carry, for instance the vena cava into the right ventricle, and the vein-like artery into the left; some on the other hand carry material away from the heart, as for instance the aorta from the left ventricle and the artery-like vein, nourishing the lung, from the right. To each orifice are attached little membranes the function of which is to secure that the orifices leading in do not let out and that those leading out do not let in." Cæsalpinus also knew that the arteries dilate as the heart contracts. Moreover, in his "Quæstiones Medicæ" (1593) he explains why, in case of ligature for venesection, the veins swell on the side of the ligature away from the heart, and, in general, that "there is a sort of perpetual movement from the vena cava through the heart and lungs into the aorta."

A year before the appearance of the "Medical Questions," Cæsalpinus left Pisa, where he had been professor of medicine since 1567, for Rome. At the same time Galileo, the father of dynamics, went from Pisa, his native city, to accept appointment in the University of Padua. Though known mainly as a physicist, Galileo exerted a very great influence on the development of medical science. Born in 1564, he had entered the University of Pisa as a student of medicine in 1581, and almost immediately discovered that the time occupied by the oscillation of a pendulum is constant as measured by the pulse. This discovery soon led to the invention of a simple instrument to determine the rate of the pulse (*pulsilogium*). In 1589 Galileo was appointed professor of mathematics at the University of Pisa, and in the following year his treatise on dynamics, "De Motu Gravium," was circulated as a manuscript. Shortly after his removal to Padua Galileo invented the thermoscope, the forerunner of the clinical thermometer, and devised a small but powerful machine for raising water. His lectures attracted to Padua students from all parts of Europe, among them the Archduke Ferdinand (afterwards Emperor Ferdinand II) and Cosimo de' Medici (afterwards Cosimo II, Grand Duke of Tuscany). Before the close of the century Galileo had under his roof twenty resident pupils, including a number of Englishmen. At the same time he was on familiar term with Fabricius, the teacher and friend of Harvey, and there is every reason to believe that the immortal discoverer of the circulation of the blood in 1598–1602 came in contact with the illustrious pupil of Andreas Cæsalpinus.

William Harvey was born at Folkestone, on the south coast of England, in 1578. From his sixteenth till his twentieth year he was in attendance at Gonville and Caius College, Cambridge, which had been refounded by John Kees (Caius), a former pupil and colleague of Vesalius (1539–43) at Padua. During Harvey's undergraduate days Caius College afforded instruction in Latin, Greek, logic, mathematics, and anatomy, and there is evidence in his mature preference for the works of Cicero, Aristotle, and Avicenna, in his interest as an old man in the "Clavis Mathematica" of William Oughtred, and in his lifelong devotion to dissection, that all of these early studies took root in his docile and susceptible mind. He took his degree in Arts in 1597, and a year later went to Padua to study under Fabricius of Aquapendente, who seems to have treated him with marked cordiality. Harvey took a prominent part in the student organizations which governed the University of Padua, gained the friendship of several of Galileo's disciples (Willoughby, Fludd, and others), and graduated with distinction as Doctor of Medicine a few weeks after the completion of his twenty-fourth year.

After his return to England, Harvey took up residence in London, and was admitted to the

College of Physicians, founded by Thomas Linacre — also a Doctor of Padua — in 1518. It was in a lecture at this institution that Harvey gave the first exposition (1616) that has come down to us of his views concerning the movement of the heart and the blood. In this lecture he expressed himself to the following effect:

"It is plain from the structure of the heart that the blood is passed continuously through the lungs to the aorta as by the two clacks of a water bellows to raise water.

"It is shown by the application of a ligature that the passage of the blood is from the arteries into the veins.

"Whence it follows that the movement of the blood is constantly in a circle, and is brought about by the beat of the heart."

Further light is thrown on the genesis of Harvey's views by the following passage from the works of the distinguished chemist Robert Boyle:

"And I remember, that when I asked our famous *Harvey*, in the only discourse I had with him (which was but a while before he died), what were the things that induced him to think of a circulation of the blood? He answered me, that when he took notice, that the valves in the veins of so many parts of the body were so placed, that they gave free passage to the blood towards the heart, but opposed the passage of the venal blood the contrary way; he was invited to imagine, that so provident a cause as nature had not so placed so many valves without design; and no design seemed more probable, than that since the blood could not well, because of the interposing valves, be sent by the veins to the limbs, it should be sent through the arteries, and return through the veins, whose valves did not oppose its course that way."

It was not till 1628 that Harvey published his "De Motu Cordis et Sanguinis in Animalibus," after confirming his views of the motion and function of the heart by the study of the structure of the auricles, ventricles, cardiac valves, the larger and smaller arteries and veins, by experiments in ligaturing, by numerous vivisections, by draining off the blood through a single small vessel, by calculating the quantity of blood passing through the left ventricle in the course of half an hour, by the observation of pathological conditions, by the examination of the vascular system in human embryos as compared with that of fishes, toads, frogs, serpents, and lizards. As a true Aristotelian Harvey held that it was as vain to seek to base the science of anatomy on an examination of the human body alone as to attempt to establish political science on the study of a single commonwealth.

As the title of Harvey's disquisition indicates, it is on the *motion* of the heart that he laid the chief emphasis. In the introductory letter to King Charles, he speaks of the heart of animals as the foundation of their life, and refers to what he has written of the motions of the heart. Similarly, in the dedication to the president and others of the Royal College of Physicians, he makes mention of his new views of the motion and function of the heart, and in the introduction proper Harvey criticizes earlier doctrines as a preliminary to discussing the motion, action, and use of the heart and arteries. These earlier doctrines appear untenable after we have closely studied the structure and mechanism of the heart. The opinion that blood oozes from the right to the left ventricle through pores in the septum is, according to Harvey, not to be tolerated. "For," he proceeds, "the septum of the heart is of a denser and more compact structure than any portion of the body, except the bones and sinews. But even supposing there were foramina or pores in this situation, how could one of the ventricles extract anything from the other — the left, e.g., obtain blood from the right — when we see that both ventricles contract and dilate simultaneously? Wherefore should we not rather believe that the right took spirits from the left, than that the left obtained blood from the right ventricle, through these foramina?" Incidentally, if the septum were permeable, what need would there be of the coronary vessels? The opinion that the diastole of the arteries is simultaneous with that of the heart is also untenable; for how can two mutually connected bodies, simultaneously distended, draw anything from one another? Again, in the opening chapter of the "De Motu Cordis et Sanguinis," Harvey states that he had discovered the motions and uses of the heart after numerous vivisections, and had been led to publish an exposition of his views. This he undertook the more willingly seeing that Fabricius had not written concerning the structure and functions of the heart. In his second chapter, which deals with the motion of the heart as seen in the dissection of living animals, Harvey notes that the heart in its systole — that is, in its essential motion — becomes hard, diminished in size, of a paler color, and so made apt to project or expel its charge of blood. He was later able to supplement this knowledge of the motion of the heart gained through vivisection by direct observation of the human heart in a case of extensive injury of the chest wall. He then demonstrated to King Charles, who was interested in his physiological and embryological investigations, that the heart in diastole is retracted and withdrawn and in systole emerges and is protruded, and also that the diastole of the arteries is simultaneous with the systole of the heart.

Proceeding to a closer scrutiny of the mechanism of the heart, Harvey finds that the heart's motion begins with the auricles and extends to the ventricles, as in a piece of machinery one wheel gives motion to another, yet all the wheels seem to move simultaneously. The blood is thrown into the ventricles by the action of the auricles. The motions of the heart constitute a kind of deglutition, a transfusion of the blood from the veins to the arteries. The valves of the heart have the purpose of preventing regurgitation. Blood continually flows into the right ventricle and is continually passed out of the left, and therefore moves from the vena cava to the aorta. Proceeding on the other hand from the right ventricle into the lungs by the pulmonary artery, and incessantly drawn from the lungs into the left ventricle, it cannot do otherwise than pass continuously by the obscure porosities of the lungs and the minute inosculations of vessels. What is the quantity and source of the blood that reaches the heart by way of the vena cava?

Influenced by the knowledge derived from vivisection, the structure of the ventricles and their valves, the relative size of the conduits leading to and from the heart, the quantity of the blood transmitted, Harvey "began to think whether there might not be *a motion, as it were, in a circle.* Now this I afterwards found to be true; and I finally saw that the blood, forced by the action of the left ventricle into the arteries, was distributed to the body at large, and its several parts, in the same manner as it is sent through the lungs, impelled by the right ventricle into the pulmonary artery, and that it then passed through the veins and along the vena cava, and so around to the left ventricle in the manner already indicated." That there is a circulation of the blood is confirmed, according to Harvey, by the fact that so large a quantity is transmitted by the action of the heart. If only one eighth of an ounce of blood were expelled from the left ventricle of the human heart at each contraction, and if there were two thousand or even one thousand pulsations every hour, a larger quantity would seem to be forced into the aorta in half an hour than is contained in the whole body. "In the same way, in the sheep or dog, say that but a single scruple of blood passes with each stroke of the heart, in one half hour we should have one thousand scruples, or about three pounds and a half of blood injected into the aorta; but the body of neither animal contains above four pounds of blood, a fact which I have myself ascertained in the case of the sheep."

Harvey recognized, as had Cæsalpinus, that the swelling of a limb ligatured as for venesection on the side of the ligature away from the heart proves that the veins carry the blood from the extremities toward the heart. The valves which are found in the cavities of the veins themselves make plain the course of the circulation. Their function is similar to that of the valves of the aorta and the pulmonary artery, namely, to prevent the reflux of the blood. Moreover, the effect of such a ligature as is used to bind a limb for amputation shows that the blood is carried to the extremities by the arteries. The arteries are conduits leading from the heart, while the veins are conduits leading to the heart. The blood passes from the arteries to the veins either immediately by anastomoses, or mediately by the pores of the flesh, or in both ways. It is forced from the capillary veins into the smaller branches, and from these into the larger trunks. It is necessary to conclude, says Harvey, "that the blood in the animal body is impelled in a circle, and is in a state of ceaseless motion; that this is the act or function which the heart performs by means of its pulse; and that it is the sole and only end of the motion and contraction of the heart."

It has frequently been assumed that Harvey failed to demonstrate the passage of the blood from the arterioles to the venuoles, and that the circulation of the blood was fully established only when Malpighi gave ocular demonstration of the capillary circulation. Of course it must be admitted by all that Harvey, in proving that the blood is carried from the heart to the extremities by the arteries and is returned from the extremities to the heart by the veins, gave logical proof of a connection between the minute arteries and the minute veins. But the fact that Harvey in 1651 demonstrated by means of experiment that all of the blood from the right ventricle passes through the pulmonary artery to the pulmonary vein has been disregarded by many. In the presence of a number of his colleagues he injected about a pound of hot water into the right ventricle (of the heart of a man who had been hanged) after having tied the pulmonary artery. Not a drop of water or of blood made its way into the left ventricle. Then, the ligature having been undone, water was injected into the pulmonary artery, upon which a torrent of the fluid, mixed with a quantity of blood, immediately gushed forth from a perforation which had previously been made in the left ventricle. Before making this experiment Harvey had reached the conclusion that *spirit* and *innate heat* are to be thought of only as properties of the blood. "There is, in fact," he says, "no occasion for searching after spirits foreign to or distinct from the blood; to evoke heat from another source; to bring gods upon the scene, and to encumber philosophy with any fanciful conceits. What we are wont to derive from the stars is in truth produced at home. The blood is the only calidum innatum or first engendered animal heat."

Almost immediately after the publication of the "De Motu Cordis," Harvey was drawn into the royal service. In 1629 he was commanded by King Charles to attend James Stuart, Duke of Lennox, who was about to undertake an extensive tour of the Continent. In the following year he received appointment as Physician in Ordinary for His Majesty's Household, and became the personal friend and companion of Charles I. He accompanied the monarch on that journey to Scotland in 1633, which led to the ultimate breach between the King and his Scottish subjects. Two years later, at the command of Charles, Harvey examined the body of Thomas Parr, who had died at the reputed age of one hundred and fifty-two years and nine months. Harvey came to the conclusion that Parr might have lived longer had he not, after being brought to London by the Earl of Arundel, indulged in rather rich fare, "his ordinary diet consisting of subrancid cheese, and milk in every form, coarse and hard bread, and small drink, generally sour whey." In 1636 Harvey accompanied the Earl's embassy to Ferdinand II on behalf of Charles's sister Elizabeth of the Palatinate, mother of Prince Rupert; and before the close of that year was sent to Italy by the Earl about some pictures for His Majesty.

Arundel was famous as an art collector, and interested in medical science, and, we may add, had been seeking to secure a "booke drawne by Leonardo da Vinci." On his way to Venice Harvey was halted at Treviso "to do his *quarantina*," on account of the plague (August 13), and displayed as much testiness as did the choleric Vesalius when held up by extortionate customs officials at the Spanish frontier in 1564. From Venice Harvey passed to Florence (before September 17), where he was entertained by the Grand Duke of Tuscany, Ferdinand II, patron of the sciences and son of Galileo's pupil, Cosimo de' Medici. By December he had returned to his practice in London.

During the struggle between Charles I and his rebellious subjects Harvey was closely associated with the Royalist cause. When in 1639 the King joined the army under the Earl of Arundel in an expedition against the Scottish forces, Harvey accompanied him. He was likewise present when, three years later, Charles raised his standard at Nottingham. It was probably about this time that his lodgings at Whitehall were pillaged, and his papers and specimens scattered or destroyed. At the battle of Edgehill, Harvey had charge of the two young princes and later aided in caring for the wounded. Harvey was in attendance on the King at Oxford, which the Royalist forces entered in triumph October 29, 1642. About a year later he treated successfully Prince Maurice, brother of Rupert, suffering from a slow fever (typhus), "the raging disease of the army." In 1645 Harvey was nominated by the King Warden of Merton College. It was in the Warden's House at Merton that Henrietta Maria, daughter of Maria de' Medici, had her lodging during that stormy time. On June 24, 1646, Oxford surrendered to the Parliamentary forces; whereupon Harvey seems to have retired to private life.

In whatever circumstances he might be placed, his zeal for the advance of medical science was always unabated. Traveling with the Duke of Lennox through regions desolated by war, famine, and plague, he complained of the absence of anything to anatomize. Drawn to Scotland in 1633 in the retinue of King Charles, he studied the flights of gannets on the Bass Rock. While accompanying Arundel in Germany he demonstrated the circulation of the blood at Nuremberg, and, in spite of the unsettled state of the country, "would still be making observations of strange trees and plants, earths, etc., and sometimes like to be lost." The slaughter of does in the royal hunt furnished material for his studies in embryology, and shortly after arriving at Oxford he used to visit George Bathurst of Trinity College, "who had a hen to hatch eggs in his chamber, which they opened daily to see the progress and way of generation." His example had a great influence on Highmore, on Scarborough, his favorite pupil, who "introduced geometrical and mechanical speculations into anatomy," on Wharton, on Willis, and other young men at Oxford interested in scientific investigation, as well as on Glisson, on Ent, and other original fellows of the Royal Society, organized after the Restoration for the promotion of physico-mathematical experimental learning.

In his treatise, "On Animal Generation," following up the studies of Aristotle and Fabricius in no subservient spirit, Harvey declared that the generation of the chick is the result of epigenesis, and that all its parts are not fashioned simultaneously, but emerge in their due succession and order. Like his two great masters he also wrote a treatise on locomotion; he was a worthy successor of Aristotle in the field of comparative anatomy, and had a clearer knowledge than Fabricius of the physiology of respiration. He made use of his discovery of the circulation in surgery, and was not unacquainted with the practice of obstetrics. In 1649 he spoke of publishing a treatise on pathological anatomy based on his numerous post-mortems, and four years later, feeling still vigorous in mind in spite of his bodily afflictions and advanced years, exchanged letters with the Florentine Nardi concerning the problem of contagion. About this time there was completed at Harvey's expense a building for the College of Physicians, to which honorable body he also presented his patrimonial estate in 1656. Toward the close of his life attacks of the gout, from which disease he had long suffered, became more frequent. He was stricken with cerebral hæmorrhage June 3, 1657, and died the same day.

The scientists of Harvey's own time were prepared to accept the mechanical theory of bodily functions. As early as 1604, Kepler had explained the phenomena of vision involved in the refraction of light by the lens; in 1614 Sanctorius had recorded his experiments to determine by weight the insensible perspiration of the human body, and in 1625 had described a pulsilogium and a clinical thermoscope of his own invention; and in 1622 Aselli had observed the lacteals and had recognized the function of the valves discovered in them. After the publication of Harvey's "De Motu Cordis et Sanguinis" the French philosopher Descartes, accepting in the main the doctrine of the circulation of the blood, proceeded to sketch his views of the human machine (1634), man the automaton, which were later developed in his treatise "De Homine." Jan de Wale confirmed (1640), by making incisions in ligatured vessels, Harvey's teaching concerning the direction of the flow of the blood in veins and arteries; Georg Wirsung discovered (1642) the pancreatic duct; Pecquet made known (1651) his discovery that the lacteals pour their contents into the receptaculum chyli, and that the thoracic duct (previously observed by Eustachius) leads thence to the left subclavian vein; the lymphatic vessels were noted by the Cambridge student George Joyliffe in 1652, and, about the same time, Rudbeck traced the connection of the lymphatics of the liver and intestines with the receptaculum chyli and thoracic duct. Before the death of Harvey, Wharton discovered the duct that bears his name, and Glisson gave an accurate description of the capsule of the liver.

Willis was aided in the preparation of his "Cerebri Anatome" (1664) by Sir Christopher Wren and by Richard Lower, who in his "Tractatus De Corde" furthered the work of Harvey by definitely applying the new science of physics to explain the mechanism of the heart. Robert Hooke (the first microscopist to observe the cellular structure of plants) by experiments in artificial respiration (1667) proved that life may be maintained without muscular movement so long as the lungs are supplied with fresh air; and John Mayow in the following year demonstrated that in respiration only part of the air is taken up by the lungs, and that the gas which supports life is identical with that which supports combustion.

In the meantime the influence of Galileo and Harvey had advanced the cause of physiological research in Italy. Much of the progress centers about the name of Ferdinand II of Tuscany, whose brother Leopold de' Medici improved the thermoscope of Galileo and was the first president of the Accademia del Cimento, founded at Florence in 1657. To the University of Pisa, Ferdinand called Borelli, Malpighi, Bellini, and Stensen. For Borelli, the disciple of Galileo, physiology was a part of physics. He recognized that the action of a muscle is a mere contraction of its length, due to the fibers, or muscle substance proper, and not to the tendon. He estimated in pounds the force of the muscles of the jaw and heart. The motion of the heart differs from that of the arm or leg in being non-volitional; it may be automatic, or caused by some organic necessity. The heart is like a wine-press, and, by propelling the blood into the arteries, causes them to distend. The arteries, then contracting, force the blood into their ramifications. By means of the microscope Malpighi, distinguished in embryology, pathology, and histology, observed (1661) the capillaries in the lung, mesentery, etc., of the frog, as well as in the lung of the tortoise. He thus found that the blood is always contained in vessels, and does not escape from the arterioles to be taken up by the venuoles. These observations were confirmed by Leeuwenhoek (1668), by the Irish scientist William Molyneux (1683), and others. In 1665 Malpighi observed the red blood corpuscles, but in this discovery he had been anticipated by Swammerdam. Bellini's study of the minute structure of the kidneys and Malpighi's histological examination of the spleen, liver, brain cortex, lungs, tongue, skin, etc., as well as of the kidneys, became the basis of a more definite knowledge of the physiological action of these parts. The correlation of structure and function was the dominant idea of these investigators. Stenson, the discoverer of the duct of the parotid gland, furthered the investigations of Borelli in reference to the mechanism of the muscles.

It seems almost like a travesty of the mechanical theory of physiological action that in a later generation it was taught, not only that the heart and vessels resemble waterworks and that the chest is like bellows, but that the glands may be compared to sieves, the teeth to scissors, and the stomach to a flask.

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CHAPTER VII

SCIENCE AND PRACTICE: SYDENHAM, BOERHAAVE

Is it possible to be a great physician without an intimate knowledge of up-to-date science? Should the focus of a doctor's attention be something else than anatomy, histology, physiology, embryology, bacteriology, chemistry, etc.? The lives of Thomas Sydenham and Hermann Boerhaave give us occasion to consider these questions.

Sydenham's early life served to develop his practical, rather than his theoretical, tendencies. Born of a family of Puritan gentry at Wynford Eagle, Dorsetshire, September, 1624, he went in 1642 to Oxford, where his eldest brother William — soon to gain distinction as one of Cromwell's officers and councillors — was already in residence. Thomas was enrolled in May at Magdalen Hall, the recognized center of Oxford Puritanism, but he was compelled within a few months, or weeks, to quit the University on account of the impending struggle between the King and the Parliament. He returned to his home in Dorset, where the Sydenham family became, in the bitter local warfare that followed, the leaders of the Parliamentary forces. The father fought with the rank of Captain; William Sydenham became Colonel and Governor of Weymouth; the mother, daughter of Sir John Jeffrey, was killed by a Royalist officer in 1644, and was avenged by one of the elder sons; Francis, a gallant young Major, fell a few months later in the defense of Weymouth; and Thomas, shortly after, was wounded in a cavalry skirmish.

The fortunes of war which caused the departure of Sydenham from Oxford also brought about, as we have seen in the last chapter, the arrival of the Royalist Harvey; and, when peace was restored in 1646 and the University passed to the control of the Parliamentarians, Harvey retired from his post at Merton and the Puritan soldier returned to his studies. Influenced by the advice of William's physician, Thomas Coxe, a Doctor of Padua, and later a Fellow of the Royal Society, Thomas Sydenham now devoted himself to the profession of medicine. No doubt he availed himself of the opportunities afforded at Oxford for the study of anatomy and botany and the reading of Hippocrates and other medical classics, but, though he left Magdalen Hall for Wadham College, soon to become, under the Wardenship of John Wilkins, the center of scientific research and the cradle of the Royal Society, there is no evidence that he was at all attracted to the pursuit of truth merely for the truth's sake. This is all the more striking in view of the line of brilliant devotees of medical science who were at Oxford during the years of Sydenham's prolonged residence — Willis, Wharton, Highmore, Petty, Goddard, Lower, Wren, Locke, Boyle, and others. He was created Bachelor of Medicine in 1648, and probably received also the degree of Master of Arts, some allowance being made, no doubt, for the fact that his studies had been interrupted by four years of civil war.

In October, 1648, Sydenham was made a Fellow of All Souls' College, an appointment he continued to hold for about seven years. In the spring of 1651, however, he was commissioned Captain of cavalry, and during the subsequent months he served in the second Civil War, in which one of his younger brothers, Major John Sydenham, was killed in Scotland, and in which Thomas himself had many stirring adventures, and seems on one occasion to have been left on the field among the dead. In September of the same year, all serious fighting having ended with Cromwell's victory over Charles II at Worcester, Sydenham was free to return to his studies. Before the close of 1653 Christopher Wren was appointed a Fellow of All Souls', but none of the associations of college life could convince the "trooper turned physician" that the discovery of some minute part in the human body, or the search for final causes and the essential nature of disease, was the only way in which a doctor might promote the glory of God and the welfare of the human race. It was thus that he thought of his vocation. In 1655 he relinquished his fellowship, married, and established himself in practice in London.

Although Sydenham was not ambitious of the name of philosopher, and, as a follower of Francis Bacon, sought to avoid premature hypotheses and mere speculation, yet scattered through his writings are passages which outline a sort of philosophy not unknown in the American schools of to-day. In the case of Sydenham it was the outcome of his strongly marked individuality, his concentration of purpose, his Puritan training, his career as a soldier and successful practitioner. In his view practice is the touchstone of theory; the proof of the pudding is in the eating. He thought so little of opinions of any sort that he distrusted his own when they came in conflict with any one else's. And he would distrust them even as regards his best established methods of treatment, were it not that the phenomena of practice support the judgment of reason. We are forced to recognize the limitations of the human mind. There may be beings in those brighter orbs, which are scattered over the infinite expanse of the universe, whose intelligences far exceed those of finite man. "Man, indeed," he proceeds, "may so have his intellectual faculties shaped by Nature [that is, the whole complication of natural causes] as to be enabled to perceive not what is absolute truth, but only that which is necessary for him to know, and fitted to his nature. This applies to those whose medicine consists in vain speculations rather than in that solid experience which rests upon the basis of the senses."

Through his interest in religion, Sydenham was even drawn into the field of metaphysics, as is to be seen in the splendid fragment on "Rational Theology." In this, with the aim of encouraging right conduct, the author develops arguments in favor of the existence of God, the supremacy of the immaterial over the material, and the immortality of the soul, but breaks off when it dawns on his candid mind that a belief in everlasting rapture and torment is not essential to the practice of virtue.

Sydenham's predominant interest in the immediately practical inclined him to turn from problems in medical science for which he saw no prospect of an early solution. "Etiology," he writes, "is a difficult, and, perhaps, an inexplicable affair; and I choose to keep my hands clear of it." The intrinsic or essential nature of the plague and of venereal disease is unknown; and as "to what may be the *essence* of smallpox, I am, for my own part, free to confess that I am wholly ignorant; this intellectual deficiency being the misfortune of human nature, and common to myself and the world at large." It is in Sydenham's opinion impossible for the physician to discover the ultimate causes of the majority of diseases, which are inscrutable, and it is quite sufficient to know whence the mischief immediately arises. In fact, the "whole philosophy of medicine consists in working out the histories of diseases, and applying the remedies which may dispel them; and Experience is the sole guide."

During the first few years of his practice in London, Sydenham had been fully occupied observing the general symptoms of fever. At that time intermittent fever and influenza were epidemic in England. Not far from Sydenham's residence in King Street, Whitehall, there lay a stretch of low and swampy land, and it is interesting to note that he early mentioned that abundant swarms of insects in summer are the precursors of autumnal diseases, and that before the end of his career he believed that a causal relationship existed between a marshy atmosphere and quartan ague. In September, 1658, Oliver Cromwell died at Whitehall of an obscure fever, which his physicians called "bastard tertian." In the following year it is probable that Sydenham visited Montpellier, and his absence from London at the critical period following the Protector's death may have been suggested by the dangers to which his political leanings exposed him; for at the beginning of 1659 he had sought election to Parliament as representative for Weymouth, and having failed in his candidature, received a government appointment. We do not hear of him again in London till the summer of 1660, after the Restoration. Then he was suffering from an attack of gout, to which disease, like Harvey, he was a martyr.

After the summer of 1661 Sydenham was able to pay attention to the more general aspects of the diseases he met in his practice. To be appreciated his writings should be studied in connection with the mortality statistics of London, then a city of about 400,000 inhabitants, and the history of epidemics. His first treatise, "Thomas Sydenham's Method of Treating Fevers, based on his own Observation" (1666), deals with the epidemics of 1661–1664. It was dedicated to Robert Boyle, who in 1660 had published the results of his experiments on air, who was interested in the effects of Peruvian bark and the discovery of other specifics, who had occasionally accompanied Sydenham in visiting the sick, and who had suggested the composition of the "Methodus Curandi Febres." Of the 16,665 deaths occurring in London in the year 1661 the mortality statistics assign fevers as the cause of 3490. Under this class of disease were included, besides intermittents, "spotted fever" (typhus), and, probably, infantile remittent fever and other ailments marked by high temperatures. After some abatement of fevers in 1662–64, there was an increase to 5257 deaths in 1665, but the prevailing epidemic of that year was of course the plague, which claimed no fewer than 68,596 victims. This Great Plague of London was associated by the Puritans with the evils of monarchy. In the first year of the reign of James I an epidemic of plague had caused 33,000 deaths in London, and in the first year of the reign of Charles I, 41,000. Sydenham speaks of it as "the scourge for the enormity of our sins," and considers it as not amenable to ordinary treatment. He withdrew from the city when the epidemic was approaching its culmination, but returned later, and recorded his observations in the second edition of the "Methodus." The appearance of this second book was the occasion of a letter to Boyle, the father of modern chemistry, 1668 (erroneously ascribed by the "Encyclopædia Britannica," Latham, Payne, and other biographers of Sydenham, to the year 1688), which shows his pride in his practice, and contains a little playful irony regarding his knowledge of science. "I have the happiness of curing my patients," he writes; "at least of having it said of me, that few miscarry under me; but cannot brag of my correspondency with some other of the faculty, who, notwithstanding my profoundness in palmistry and chemistry, impeach me with great insufficiency, as I shall likewise do my taylor, when he makes my doublet like a hopsack, and not before, let him adhere to what hypothesis he will."

From this letter we learn also that the physician and philosopher, John Locke, had been attending with Sydenham very many of his variolous patients. In the year 1666 the total number of deaths in London had fallen to 12,738. These included 1998 deaths from plague, and only 741 from fevers, 38 from smallpox, and 3 from measles. In 1667 the mortality from plague had dropped to 35, from fevers had risen to 916, and from smallpox and measles respectively to 1196 and 82. In 1668 there were 14 deaths from plague, 1247 from fevers, 1987 from smallpox, and 200 from measles. In 1669 dysentery and other intestinal diseases, which had been on the increase since 1666, caused 4,385 deaths, plague 3, fevers 1499, smallpox 951, and measles 15. The dysenteric constitution, which Sydenham compares with the epidemics of North Africa (Morocco), was maintained during the next three or four years. Before 1673 smallpox was again on the increase; it continued to gain, and in 1674 became the predominant epidemic. Out of 17,244 deaths in London in the year 1674 there were 2507 from smallpox, 795 from measles, 3 from plague, 2,164 from fevers, and

1777 from dysentery and other intestinal ailments. In 1675, as we learn from Sydenham, there prevailed in London epidemic coughs with pleurisy and pneumonia. "Sometimes," he states, "there supervene upon the cough the following symptoms: a succession of chills and flushes; pains in head, back, and limbs; an occasional tendency to sweats (especially night sweats); sometimes the addition of pain in the side; sometimes a constriction and tightness at the chest; and, as the result of this last, difficulty of breathing, tightness in the cough, and violent fever." In a work with the significant title "Medical Observations Concerning the History and Cure of Acute Diseases" (1676), which may be considered a third, much enlarged, edition of the "Methodus," Sydenham placed before the learned world an account of the history and treatment of the epidemics of fifteen years.

The "Observationes Medicæ" is much more than a contribution to epidemiology. It aims to give graphic and natural descriptions of disease based on well-considered clinical data, and to establish a definite therapeutic procedure. He proposes as a follower of Bacon to advance from the observation of individual cases, and to reduce all diseases to clearly defined "*species*, and that, with the same care which we see exhibited by botanists [like his contemporaries Grew and Ray] in their phytologies." To write the natural history of a disease the physician should hold in abeyance every philosophical hypothesis and prepossession, and imitate "the exquisite industry of those painters who represent in their portraits the smallest moles and the faintest spots." At the same time it is necessary to portray in the clinical picture what is typical and characteristic of the species rather than the adventitious or merely individual phenomena. "No botanist," says Sydenham, "takes the bites of a caterpillar as a characteristic of a leaf of sage." Moreover, diseases must be studied in relation to the time of year in which they occur, for though many are good throughout the twelvemonth, others follow the seasons as truly as plants and birds of passage.

The main part of medicine is the discovery of the indications of the various species of disease. These indications or symptoms furnish a clue to the right treatment, for disease is nothing but Nature's effort to restore the health of the patient by the elimination of the morbific matter or to effect a renovation of the blood. For example, gout seeks to purify the blood of old men, plague to expel those infectious particles which we have taken in along with the air we breathe, just as an abscess may help to remove a thorn. Our natures are the physicians of our diseases, as indeed Hippocrates, that divine old man, taught. In the case of some diseases the practitioner should maintain the expectant attitude, or remain merely passive. He should, however, not hesitate to reënforce the efforts of Nature when she is enfeebled and to coerce her when outrageous, always duly attending to her method and time of working a cure. To develop a system of natural therapeutics, a fixed and consummate method of treating disease, verified by a sufficient number of experiments, must be the result of coöperation. "If, in each age of the world," writes Sydenham, "a single person only had properly treated upon one single disease, the province of the physician, or the art of healing, would long ago have reached its height; and would have been as complete and perfect as the lot of humanity admits." Sydenham recognized that medicine was to be advanced not merely by the preparation of accurate descriptions of diseases and the establishment of a definite method of treating them, but also by the discovery of specific remedies, an interest in which he shared with Robert Boyle.

In describing the symptoms of the fevers of 1661–64, Sydenham states that all agues begin with shiverings and rigors, succeeded by heat, and terminated by sweats. In the hot and cold paroxysms the patient has a strong desire to vomit. One may speak of the stage of exhorrescence, the stage of ebullition, and the stage of despumation. The commotion of the blood is Nature's means of bringing about a purification or renovation. For illustration it may be compared with ebullition or fermentation. Vernal intermittents are analogous to the workings of full beer barrels, when, having lain long in cool cellars, they are set near a fire. Depuration occurs by flowers or by dregs. The physician should be guided by Nature in the exhibition of emetics, diaphoretics, or purgatives. Evacuation by means of clysters may act as an oversized vent for beer whilst it is fermenting. If the patient was advanced in years or had been pulled down by evacuations, Sydenham prescribed cordials. "But," he writes, "if the fermentation be neither too active nor too languid, I leave it to itself, and use no remedies." Sydenham, the English Hippocrates, had faith in the *vis medicatrix naturæ*, and resembled the Father of Medicine in his doctrine of atmospheric constitutions, in his avoidance of extremes, in his distrust of speculation and in the inclination to ground philosophy on observation and practice, in his lofty professional ideals, respect for patients, and universal charity, in his humoral physiology, in his diagnosis and prognosis, in the use of cooling drinks, in his resort to hygienic measures (diet, riding and carriage exercise) and in his employment of simple remedies. At the same time Sydenham's name is associated with advances in the use of drugs, with the popularization of Peruvian bark in the treatment of intermittent fever, with its recognition as a tonic, with the introduction of liquid laudanum and other preparations of opium, and with the exhibition of steel and mercury. He found antimonial emetics are not fit for children under fourteen years of age. "I wish, with all my heart," he writes, "that instead of them something more safe, and equally efficacious, could be discovered." For kidney troubles he recommended the waters of different mineral springs, among them the waters of the suburb of London now known by his name.

Among his contemporaries Sydenham was particularly noted for his so-called cooling method of treating smallpox. He certainly held that the danger from cold in this disease is far less than that from a too heating regimen. He burlesqued the treatment then in vogue, and asked whether the subject's life might not be in danger if the stoutest porter in the best of health were, for the sake of experiment, put to bed with the curtains drawn and a large fire in the room to keep him in a sweat for some weeks, there being in attendance a nurse or two, who, if he should shift his position or put a finger out of bed, should correct his error by heaping on more clothes, and who, during all this time, should deny him small beer or other refreshing drinks and continue to ply him with posset and cordials. "From an overhot regimen," he writes, "never good came, any more than from overhasty fruit any profit." The separation of the peccant matter from the humors must be effected before it is eliminated by the skin. We must, however, "not be so intent upon ensuring against an overheated state of the blood, as to expose our patient to any injury from cold, and by so doing arrest the eruption of the pustules." Sydenham, though he clearly distinguished the two diseases, treated measles in much the same way as smallpox, and taught that the former is a disease superinduced upon the blood during an attempt at a new stasis, and that one attack assures as a rule against another. There is much, in fact, in Sydenham's views of smallpox and measles that is reminiscent of Rhazes, as there is also in his view that disease may be explained as a fermentation of the humors. It is probable, however, that the latter conception at least was suggested to Sydenham by the writings of Willis or of some other physician of his own time.

Indeed, although Sydenham focused his attention on the symptoms and treatment, there is sufficient evidence that he did not avoid adopting hypotheses regarding the nature and causation of disease. In harmony with Locke and Boyle he believed that the human frame is adapted to impressions from without, and that maladies are owing in part to mineral effluvia or other occult atmospheric influences — to particles of the atmosphere — and in part to the different fermentations and putrefactions of the humors. He even compares diseases with the mosses, fungi, and mistletoe that grow on trees, the nutritive juice of which may have suffered perversion or depravation. At the same time he was aware that not merely the delicate are subject to infection. A man might be as strong as a wrestler, but if he went to certain parts of the country where fever was raging, he would sicken within a day or two. When in cases of intermittent fever the despumation has been incomplete, the fit may return when the patient seems out of danger; the latent matter presents itself anew, like "broods of bees that grow gradually at stated times." The conditions that produce plague were for Sydenham a special object of curiosity, and the study of them brought him near to a juster view than Boyle's theories afforded of the part played by the atmosphere in the dissemination of disease. He had grave suspicions that the mere atmospheric constitution was insufficient to originate plague. The disease must be perpetuated in *sporadic* cases in the intervals between epidemics, or must continue to survive in some *fomes*, or arise from some infected person from a pestilential locality. Otherwise Sydenham could not account for the fact that through the sanitary measures of the Grand Duke Ferdinand II there had been stopped in 1650 at the borders of Tuscany a plague that had devastated nearly all the rest of Italy. When an epidemic rages, the exhalations from the sick and from the corpses of the victims of the disease spread the contagion through the whole atmosphere of the affected area, so that the air, in itself and of itself, is sufficient to destroy those whose humors are adapted to the receipt of the influence. As regards the treatment of the plague, Sydenham remarks that Nature's method of eliminating the morbific matter by means of abscesses cannot be furthered by means of diaphoresis, and that it is here unsafe for the physician to attempt to follow the path of Nature.

In 1680 appeared Sydenham's fourth book, "Epistolæ responsoriæ duæ," addressed to two physicians connected with the University of Cambridge, from which institution he had received the degree of M.D. in 1676. The first of these letters deals with the epidemics of 1676, of 1678, and the succeeding years (intermittents again prevailing after 1678, and influenza after 1679), with the administration of Peruvian bark, and the treatment of rheumatism by lenitives and by simple, cool, nutritious diet, such as whey. The second letter deals with venereal disease. Sydenham noted that venereal lues had declined in strength since, in 1493, it had first struck root in

Europe, it being in his opinion characteristic of species of disease that they are modified in the course of time, that they become extinct and give rise to new species. He recognized the primary lesion — "shanker"; called buboes the first *stage* of true lues; and spoke of the disease as extending to different parts of the body, attacking the bones, producing phagedænic ulcers, etc. The taint of either parent may be transmitted to the offspring. A child may communicate it to the nurse, or an infected nurse may give it to a healthy child. Sydenham knew that syphilis, which he differentiated to some extent from gonorrhœa, had reached Europe after the discovery of America, but he held that its original home was not the West Indies, but the coast of Guinea or some portion of the negro country thereabout. In fact, he thought it identical with the African disease called the "yaws." Some argue, says Sydenham, "that the cure of the venereal disease should not be taught. With such I disagree. If we reject all cases of affliction which the improvidence of human beings has brought upon themselves, there will be little room left for the exercise of mutual love and charity. God alone punishes. We, as we best can, must relieve. Neither must we be too curious in respect to causes and motives, nor too vexatious in our censorship." According to his experience there was no true instance of this disease having been extirpated except by means of salivation excited by mercury.

Further claims on our admiration of the clinical acumen and skill of the English Hippocrates are made by his recognition of the protean character of hysteria and the relation of hysteria and hypochondriasis, by his account of scarlatina, by his differentiation of chorea from dancing mania, by his riding treatment for phthisis, by his classical description of gout and other chronic diseases. He described a species of insanity following prolonged malaria. Nor should we be misled by exaggerated statements of his indifference to the science of his time; for he refers repeatedly to the circulation of the blood, mentions the lacteals, speaks appreciatively of his English contemporaries who "have done good work in each kind of science that advances medicine," and held it essential for the physician, as for the surgeon, to know thoroughly the structure of the human body. He was not ignorant of contemporary studies of the anatomy of the kidneys, and he was aware of the encystment of renal calculi. He said that coma arises from an obstruction in the cortex of the brain, and that apoplexy may be caused by an extravasation of blood from the capillaries of the cerebral arteries, and in his treatise on dropsy he made mention of the results of post-mortem examination of the abdomen. The special province of the physician, however, is not, in the judgment of Sydenham, scientific research. It is rather comparable with that of a pilot whose only business it is to see that the ship be not sunk, not to speculate on the ebb and flow of the tide. The great English physician's consecration to the welfare of his patients, as well as to the Commonwealth, was a great factor in the establishment of his fame both in Britain and on the Continent of Europe. Boerhaave is said never to have referred to Sydenham without removing his cap in salutation to "Angliæ lumen, artis Phœbum, veram Hippocratici viri speciem."

Hermann Boerhaave himself, born near Leyden, Holland, in 1668, is sometimes called the Batavian Hippocrates. Like his Greek and English models he was discriminating in the use of drugs and made much of hygiene. He was a profound scholar, and served for years as professor and rector in the University of Leyden. His numerous pupils, among whom were Pringle, Haller, Camper, van Swieten, and de Haën, greatly extended the range of his influence. He is especially deserving of remembrance as a clinical instructor. At his demonstrations he concentrated attention on a few patients, made use of a Fahrenheit thermometer, and he also sought to verify his diagnoses by post-mortems, explaining the pathological as a deviation from the physiological. Like Sydenham he condemned philosophers who seek to invent rather than to discover, but he was in closer touch with the science of his own time than the English physician had been with that of the previous epoch. He taught botany and developed the botanical garden at Leyden. He was the author of a work on chemistry ("Elementa Chemiæ," 1732), in which he taught that unlike combines with unlike, not like with like. He studied Boyle, Malpighi, Leeuwenhoek, and edited under the title "Biblia Naturæ" the writings of Swammerdam, who had described red-blood corpuscles and had opposed the ancient doctrine of spontaneous generation. Boerhaave maintained that epidemics of smallpox are owing solely to contagion, and he showed a greater faith than Sydenham in the power of the human mind to arrive at the ultimate causes of disease. "He who," writes Boerhaave, "with the greatest possible exactness, weighs every particular thing which shall happen or has happened to his patient, and which may be learned from the observations of himself or of others, and who then compares all these with one another, and places them in opposition to such things as occur in a state of health, and finally, from all this, with the nicest and strictest control of his speculative powers, rises to the knowledge of the first cause of the disease, and of the remedies fit to remove it, he, and only he, deserves the name of a true physician."

One of his critics regrets that Boerhaave, possessed of remarkable powers of observation, should at times have tied himself to groundless hypotheses, in opposition to the very principles which he advocated so strongly. His works are now little read, but his pupils and the record of his enormous private practice bear witness to his qualities as teacher and physician. A monument raised in his honor by the city of Leyden is inscribed: "Sacred to the Genius of the Health-giving Boerhaave (Salutifero Boerhaavii Genio Sacrum)."

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CHAPTER VIII

COMPARATIVE ANATOMY: JOHN HUNTER

John Hunter, born near Glasgow in 1728, was, like Darwin, an indefatigable collector of natural history specimens. As a boy, instead of going to school, he wandered about the country, observing the ants, the bees, the tadpoles, and the larvæ of caddis-flies, studying the habits of the birds, and making collections of birds' eggs, which he compared in size, color, markings, and in the number characteristic of each species. In his twenty-first year he began at London those studies in anatomy and surgery which formed the basis of his subsequent activities. After eleven or twelve years of almost unremitting work in the dissecting-room and the hospital, he went, as surgeon, with the military expedition to Belle-Ile, where he collected specimens which formed the nucleus of what is now known as the Hunterian Museum. Service in Portugal gave him the opportunity of extending his observations. In 1764 he established at Earl's Court, at that time well to the west of the city of London, a country-seat stocked with ducks, geese, pigeons, fish, frogs, eels, river-mussels, sheep from Turkey, a shawl-goat from the East Indies, buffaloes, leopards, a beautiful little bull presented by the Queen, and specimens of various other species, plant as well as animal. His town house became crammed with natural history specimens, so that, soon after his marriage in 1771, his bride, the accomplished Anne Home, found herself living either in a menagerie in the country or in a museum in the city. In 1783 he set up his famous establishment in Leicester Square. He held that Francis Bacon had been the chief cause of the advance of science since the sixteenth century, and he determined to base his own generalizations on comprehensive and careful observation of natural phenomena. Animals dying at the Tower of London and the city menageries were obtained by Hunter for dissection, and no animal was brought to England during the latter part of his career without his having an opportunity to examine it.

Hunter lacked Darwin's opportunity of extended travel, but the material brought to his door offered an equivalent in some respects, and he lived in an age when men's imaginations were kindled by voyages of discovery as they had been in the Elizabethan. In 1771 Edward Jenner, Hunter's pupil and familiar friend, was chosen at his suggestion to examine and classify the collections brought to England by Captain Cook from Australia, New Zealand, and other islands of the South Pacific.

This incident serves to indicate the kind of influence exerted on Jenner by his master. It is indeed true that Hunter was interested in the problem of immunity and in the rivalry of diseases. He knew that people constantly exposed to the cause of certain diseases become less affected, or less liable to be affected. He recorded the case of two children, in which smallpox, following inoculation, was held in abeyance for a time by an attack of measles. He said that cowpox and smallpox, if inserted at the same time in different parts of the same person, produce each the same effect as if only one of them had been inserted. Nevertheless, Jenner's indebtedness to Hunter has sometimes been put in a false light, and Hunter's famous exhortation to his pupil to rely on experiment rather than on speculation or authority referred to a problem in natural history and not to vaccination. "I thank you," wrote Hunter, "for your experiment on the hedgehog; but why do you ask me a question by the way of solving it? I think your solution is just; but why think — why not try the experiment?" About three years later, that is, in 1778, Hunter turns suddenly from a discussion of Jenner's disappointment in love to stimulate him to undertake fresh experiments on hibernating animals. "I own," he writes, "I was glad when I heard you was married to a woman of fortune; but 'let her go, never mind her.' I shall employ you with hedgehogs." Again he writes: "I have but one order to send you, which is, send everything you can get, whether animal, vegetable, or mineral, and the compound of the two; namely, either animal or vegetable mineralized."

His cupidity for Nature was never satiated. At considerable expense he sent a surgeon to Greenland to examine the anatomical structure of large marine animals and to preserve the more interesting parts. In 1793, the year of his death, his zeal in the study of Nature was still undiminished. Writing to a gentleman in Africa he asked for specimens of the different species of swallows, in order that he might obtain a clue to their migrations, everything respecting the bee tribe, such as wasps with their nests, also hornets with theirs, cuckoos, ostrich-eggs, and chameleons. "If a Foal camell was put into a tub of spirits and sent, I should be glad. Is it possible to get a young tame lion, or indeed any other beast or Bird."

Hunter's writings along with the specimens preserved in his museum show that he had dissected twenty-one species of quadrumana (apes, monkeys, lemurs), ten species of marsupials, fifty-one species of carnivora, twenty species of rodents, five species of edentata, fifteen species of ruminants, ten species of pachyderms, six species of cetacea, and twenty-three other species of mammals scattered through the sub-classes. As regards human anatomy Hunter dissected thousands of cadavers. There is like evidence that he dissected one hundred species of birds, fifty-nine species of fish, thirty-nine species of reptiles, forty-two species of molluscs, over ninety species of "articulate" and "radiate" animals, and, in addition, twenty miscellaneous species of invertebrates. His museum contained 13,682 specimens, including 2773 fossils.

Sir Richard Owen, the leading authority on comparative anatomy in the period following the death of Cuvier, credits Hunter with the first great attempt to arrange in concatenated system the diversified facts of that branch of science. The idea of a graded series is a constant feature of Hunter's studies of the various anatomical structures, as well as of his attempts to lay the foundations of a phylogenetic classification of animals. He considered, for example, whatever is uncommon in the organ of hearing in fishes as only a link in the chain of varieties displayed in the organ of like function in different animals, descending from the most perfect to the most imperfect, in a regular progression. Guided by the same principle he traced the development of the nervous system from the simple filaments of some of the lower organisms to the highly organized masses found in the monkey and in man, the most complex of the animals. In like manner he followed the development of the canine teeth, which he was the first to call cuspids, from the lion to man, noting the similarity in shape, situation, and function. Palmer, who edited Hunter's works in 1837, took him to task for teaching that man was originally constructed for the pursuit and capture of living prey. Though the criticism may have been well founded, it should be recognized that Hunter distinctly taught that man, a more perfect or complicated animal than any other, is not made to come at his food by his teeth, but by his hands, directed by his superior ingenuity; also, that man is able to live in a much greater variety of circumstances than any other animal, has more opportunities of exercising the faculties of his mind, and is possessed of that high degree of sociability which implies superior educability.

In tracing the affinities of the different species of animals Hunter supplemented his special studies of anatomical structure — for example, of the whale as a modified land animal, of the relationship of birds and batrachians, of the weak wings and highly developed legs of the ostrich — by common-sense observation as well as by experiment. He did not overlook the obvious resemblance of the horse, the ass, and the zebra, nor that of the wolf, dog, jackal, and dingo. Does not the natural gradation of animals from one to the other, he asks, lead to the original species? The wolf has a closer resemblance to the fox than has either the dog or the jackal. The shepherd's dog, all over the world, as well as the Esquimaux dog and the dingo, resembles the wolf in shape and disposition. Hunter owned one of a litter of puppies, the offspring of a wolf and a bitch. He described it as easily startled and particularly apprehensive of danger. It had the shape of the wolf refined, and a long coat almost as fine as that of the black fox. The mother was of the Pomeranian breed. A bitch of this same litter had in all thirty-five puppies, some of which were wild and so unruly that they could not be controlled by the most skill-ful dog-trainers. Hunter records another case of four puppies, the offspring of a she-wolf and a grey-hound. Two were like the dog in color — large black spots on white ground; one was black; the fourth was dun, and would probably have been like the mother. Hunter owned a puppy of a second litter of this she-wolf. He also secured a female puppy of a she-jackal and a spaniel. It was of a wild disposition. When mature it gave birth to five puppies. One of these was given to Jenner, who subsequently reported that it was shy and apprehensive, and remarkably fleet.

Hunter's posthumous essays show with what care he compared the anatomical structure of apes, monkeys, and lemurs with that of man. In a species of gibbon he observed the absence of the tail, the length of the appendix, as well as the similarity of the liver and other abdominal viscera to those of a human being. The uterus in form and position is like that of a child. In one species of Macacus he found that the muscles of the eye are as in man, and that the brain is very like the human. In another species of monkey he noted that the prostate gland is similar to the human prostate gland. "The monkey," says Hunter, "in general may be said to be half beast and half man; it may be said to be the middle stage." Again he described the mongoose as an exact degree from the monkey to the brute in its external form.

Hunter supposed that the erect posture in man rendered him more liable to rupture, and contributed to the descent of the testes. When the testes remain in the abdomen in man, as they do normally in the hedgehog and some other species of animals, we have an example of what Hunter was the first to call "arrested development." The erect posture accounted likewise in his judgment for the disposition of the pelvic viscera in man, and affected the curves of the spine and the form of the foot, as well as the structure of the knee-joint. He noted the differentiation of the hand from the foot in man and monkey. He believed that the thumb of the monkey is not so strong as that of man, "and has not that opposing motion." The walk of the monkey is very similar to that of a child who has hardly the power of supporting the center of gravity, he says.

Hunter had observed at Belle-Ile that frogs live upon worms, beetles, grasshoppers, caterpillars, and butterflies. Later he attained to the generalization that the large animals are made as a rule to live upon the less, and he anticipated the doctrines of Malthus so far as to teach that it is necessary "that many animals should be made to prey upon others; else we should be overstocked with the smaller." He also held that modifications that occur in animal structure tend to progression rather than to retrogression. Deviation from the original structure is not necessarily deterioration. It appears, he remarks, just the contrary; therefore we may suppose that nature is improving its works, or, at least, has established the principle of improvement in the body as well as in the mind. Variation furnishes the materials of advance. In the individuals of each species, writes Hunter, varieties are every day produced in color, shape, size, and disposition. Some of these changes are permanent with respect to the propagation of the animal, becoming so far a part of its nature as to be continued in the offspring. In the case of acquired properties, according to Hunter, it is only the susceptibility to certain influences that is inherited. Diseases like gout and scrofula are not really hereditary.

He remarked, in his comparative study of the gizzard and stomach, the difficulty generally encountered by the anatomist of distinguishing the proximate steps in the slow and imperceptible gradations of nature. His recognition of the gradual deviation from type as the rule did not blind him, however, to the possibility of exceptions. "How far," he says, "varieties in animals are gradual, or in what degree they, at once, produce a very distinct variety, is perhaps not to be ascertained." He mentions the case of a white negress who had three children by a white man. One of the children was black, while the two others were tawny. Hunter was interested of course in atavism, and in the variations that occur in domesticated animals. He speaks of latent hereditary dispositions, which pass over one or two generations, and start up again in the second or third. Again, animals living in a free and natural state are subject to fewer deviations from their specific characters than are animals influenced by culture. "From the variations produced by culture, it would appear, that the animal is so susceptible of impression, as to vary nature's actions and this is even carried into propagation."

In 1766, the year preceding that in which Hunter became a fellow of the Royal Society, he wrote a description of the anatomy of an Amphibious Bipes, a species of Siren, which had defied the classificatory skill of Linnæus. It was animals like this and the Southern Chimera, which did not seem to fit into the pigeon-holes of the System of Nature, that particularly fascinated Hunter. He was deeply interested not only in exceptional species of all sorts, but in giants, dwarfs, hermaphrodites, and other monstrosities. According to Owen he anticipated the principles set forth by Isidore Geoffroy Saint-Hilaire in his "Traité de Tératologie" (1832). Hunter observed that the natural hermaphrodite belongs to the inferior and more simple genera of animals, of which there is a much greater number than of the more perfect; and as animals become more complicated, have more parts, and each part is more confined to its particular use [by a physiological division of labor], a separation of the two necessary powers for generation seems also to take place. He raised the question whether there ever occurs in the genera of animals that are natural hermaphrodites, a separation of the two parts forming distinct sexes, and he conjectured that the occurrence of such a variation might account for the distinction of sexes ever having happened.

Darwin begins Part II of "The Descent of Man" with the following statement: "With animals which have their sexes separated, the males necessarily differ from the females in their organs of reproduction; and these are the primary sexual characters.

But the sexes often differ in what Hunter has called secondary sexual characters, which are not directly connected with the act of reproduction." A glance at the table of contents of this work of Darwin's will convince the reader that Hunter's conception is the dominant idea of the last two thirds of it. An introductory chapter on the principles of sexual selection is followed by chapters on secondary sexual characters in the lower classes of the animal kingdom — in insects, in lepidoptera, in fishes, amphibians, reptiles, in birds, and in mammals. The third and last part of "The Descent of Man" consists of two chapters on the secondary sexual characters of man and a general summary and conclusion. "In all animals we are acquainted with," writes Hunter, "we see distinguishing marks between the male and female, exclusive of the parts peculiar to each." Hunter divides sexual characters into principal and secondary, and among the secondary properties which characterize the male and the female he mentions the beard, mane, spurs, horns, voice, etc. He carefully records cases in which the female pheasant had assumed the plumage of the male. He also refers to an interesting case in which the mammary glands were fully functional in a man.

Owen says that Hunter was the first to enunciate the principle of the resemblance of the phases of embryonic life to the series of inferior forms of animal species. "If," wrote Hunter, "we were capable of following the progress of increase of the number of the parts of the most perfect animal, as they first formed in succession, from the very first to its state of full perfection, we should probably be able to compare it with some one of the incomplete animals themselves, of every order of animals in the creation, being at no stage different from some of the inferior orders. Or, in other words, if we were to take a series of animals, from the more imperfect to the perfect, we should probably find an inferior animal, corresponding with some stage of the most perfect." This idea, with which Hunter was struggling, has been neatly expressed in our times by saying that the human embryo in each of its stages of development resembles the mature form of some species lower than itself. Of course this generalization of Hunter's rested on numerous observations. He remarked, as we have seen, that in the hedgehog the testes continue throughout life to be lodged in the abdomen, in the same position as in the human fœtus. The appendix of a species of lemur is like that structure in the human fœtus, which, in turn, Hunter compared with the fœtal appendix of the monkey. The resemblance of the disposition of the abdominal viscera in the lower mammals in general with that in the human fœtus is another case in point. Congenital hernia and certain other abnormalities were explained by Hunter as persisting embryonic conditions.

Geology afforded him another clue to the affinities of the various species and genera of animals, as well as to the interdependence of natural and physical phenomena. He agreed with Hutton that geology has nothing to do with the original formation of the earth itself, but is concerned only with the changes of the earth's crust. Hutton, as Lyell remarks, possessed little information regarding organic remains. Hunter, on the other hand, before the appearance of Hutton's "Theory of the Earth," was attempting to match up fossil animals with those living species with which he was so eminently conversant. He distinctly taught that we should be unable to consider the operations affecting the surface of the earth if we had not the preserved parts of animals to guide us. They enable us to trace the history of the earth's crust just as we should trace the political events in any country by the monuments left. We must judge of the past by the present, supposing from the state of the earth as it now is what must have taken place formerly.

Hunter further agreed with the uniformitarians in believing in the antiquity of the earth. Speaking of one collection of fossil bones he says that there was probably a succession of them for a vast series of years, many thousand years. In what was supposedly the last essay he wrote he used the expression "many thousand centuries." This was criticized and a representative of the Royal Society suggested that he substitute "years" for "centuries," but he withdrew the paper rather than make the change.

Few fossils, says Hunter, correspond with recent specimens. They may not be of different species, but varieties of the same species. If they are really different species, then we must suppose the old are lost and that, therefore, a new creation must have taken place. That many are actually lost seemed plainly shown by the remains of land animals that are not now known. How they became extinct is not easily accounted for. His unexcelled knowledge of dentition enabled him to identify a fossil white bear twice as large as the present white bear, and gave him assurance that the fossil teeth found at Salt Lick, near the Ohio, about 1767, belonged to an animal larger than the elephant.

The teeth of the kangaroo are so singular that it is impossible from them to say what tribe it is of. At the same time Hunter was not unaware of the marsupial character of the Australian fossil mammalia. Darwin, in that part of the "Origin of Species" that treats of geological succession, pays tribute to the work of Hunter by referring to his faithful followers Clift and Owen. "Mr. Clift," writes Darwin, "many years ago showed that the fossil mammals from the

Australian caves were closely allied to the living marsupials of that continent. In South America, a similar relationship is manifest, even to an uneducated eye, in the gigantic pieces of armor like those of the armadillo, found in several parts of La Plata; and Professor Owen has shown in the most striking manner that most of the fossil mammals, buried there in such numbers, are related to South American types." Hunter had dissected of course armadillos, sloths, and ant-eaters, and other specimens of South American species that proved of interest to Owen and Darwin.

William Clift, the last and most devoted of Hunter's pupils, was received as an apprentice and amanuensis on his seventeenth birthday, February 14, 1792. After Hunter's death, in the autumn of the following year, Clift was placed in charge of the establishment in Leicester Square. Almost the sole occupant of the large building during the subsequent six years, he spent his time studying the specimens in the museum and making extensive excerpts from his master's volumes of unpublished manuscripts. When, in 1800, the museum was taken over by the College of Surgeons and the collections were removed to new quarters, Clift was continued in charge with the title of Conservator. The greater part of Hunter's manuscripts were destroyed by his brother-in-law, Sir Everard Home, in 1823. In 1830

Richard Owen, who had studied under Hunter's pupil Abernethy, was appointed Clift's assistant. "From Clift," says the "Dictionary of National Biography," "Owen imbibed an enthusiastic reverence for his great master, John Hunter, which was continually augmented by closer study of his works." Owen married Clift's daughter in 1835, and helped Palmer edit Hunter's works. The paper, already referred to as probably Hunter's last essay, "On Extraneous Fossils and their Relations," was not published till 1859, a few months after the appearance of the "Origin of Species." In 1861 Owen published from Clift's notes two volumes under the title "Essays and Observations in Natural History, Anatomy, Physiology, Psychology, and Geology, by John Hunter, being his Posthumous Papers on these Subjects." It was largely through Clift and Owen, and visitors to the Hunterian Museum, such as the younger Meckel (Johann Friedrich, 1781–1833) and Cuvier, that the influence of John Hunter in comparative anatomy and natural history was perpetuated.

Hunter's attitude toward his profession was somewhat different from Sydenham's. He regarded science as the essential basis of practice, and hoped by his investigations to establish new methods of treatment, or, as he said, to make discoveries in the art itself. He is now recognized as the founder of scientific surgery. Many of the reforms he effected in his profession were the direct result of his comprehensive study of natural phenomena. "It is contrary to the rules of surgery as founded on our knowledge of the animal economy," he writes, "to enlarge wounds simply as wounds," which had been the general practice before the time of Hunter. His observation of tetanus in a deer as the result of a compound fracture stimulated his interest in the conditions of inflammation. He removed one ovary from a young sow, found that it subsequently had numerous offspring, and stated his conviction that there was no reason why the female of the human species should not bear spaying. His seemingly whimsical experiments in the transplantation of tissues have anticipated some of the most striking achievements of modern surgery. In his experiments on the temperature of animals he made use of a thermometer of his own invention very similar to the clinical thermometer of the present day. His studies in comparative odontology enabled him to observe the cause of the retardation and the difficulty in cutting of the wisdom teeth in man, which arise, he says, from the want of room in the jaws for these late teeth. In fact, Hunter's scientific study of the teeth rescued dentistry from a state of crude empiricism and placed it, as surgery in general, on firm foundations. One of the most fruitful of his investigations was his study of the circulation in the antlers of the deer. He ligated the artery supplying the circulation in the antlers of a buck in Richmond Park. The antlers, which were in the velvet, deprived of their blood-supply, grew cold. In two or three days, however, Hunter observed that the temperature had become normal again, and this he attributed to the establishment of a compensatory collateral circulation. Later investigation proved that the ligated artery had become obliterated.

Soon after this experiment he applied his discovery in the hospital in the treatment of a case of popliteal aneurism, tying the femoral artery in the upper part of the thigh. His example opened the way to the triumphs of British and American vascular surgery. One must mention in this connection Hunter's pupil Astley Cooper (the master of John Collins Warren, who played so large a part in the introduction of ether anæsthesia and in the founding of the Massachusetts General Hospital, and of Valentine Mott, who ultimately had one hundred and thirty-eight ligations for aneurism to his credit), Hunter's pupils Abernethy, Wright Post, and Physick, the Father of American Surgery, as well as Physick's nephew, John Syng Dorsey.

It is not altogether irrelevant to mention Hunter's study of gunshot wounds, which gives him a place among the founders of modern military surgery, his study of the repair of tendons and his relation to subcutaneous and orthopædic surgery, his influence on the treatment of hernia, his observations on the inflammation of veins, the clotting of blood, and the communicability of puerperal fever. Hunter discovered the distribution of the olfactory nerves, explained the placental circulation, traced the course of the tubuli uriniferi, advanced our knowledge of the lymphatic system, distinguished Hunterian chancre from chancroid ulcer, invented double bellows for the resuscitation of the apparently drowned and advocated the use of oxygen in the treatment of such cases. He experimented in artificial feeding, made a special study of intussusception, threw light on the nature of alcoholic fermentation, recorded a case of post-mortem digestion of the tissues of the stomach, observed hydatids in the liver of the mongoose, and investigated the motion and the temperature of plants.

Hunter was interested in the mental processes and their development as a part of an interrelated system of natural phenomena. He studied color-blindness ten years before John Dalton, was interested in the accommodation of the eyes, discovered what was later called the specific energy of the nerves, traced the growth of the perception of space, noted the abundance of human instincts, anticipated modern psychology in reference to types of memory and imagination and the physiological phases of the emotions, studied the expression of the emotions in the lower animals, recognized the survival value of anger and fear, and wrote in an enlightened way concerning what is now called the sublimation of the emotions.

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CHAPTER IX

MORBID ANATOMY, AND HISTOLOGY: MORGAGNI, BICHAT

WITHINGTON in his "Medical History" says that local pathology, the study of the tissues, and local diagnosis form the three legs of the tripod upon which the genius of modern medicine took her seat. The early history of these three — morbid anatomy, histology (ἱστός, tissue), and one aspect of local diagnosis — will occupy our attention in this and in the following chapter.

Giovanni Battista Morgagni (1682–1771) has been called the Father of Pathology. His book "Concerning the Seats and Causes of Diseases investigated by Anatomy" ("De sedibus et causis morborum per anatomen indagatis," 1761) gave the results of postmortems known to himself, to his master Valsalva, and to others among their predecessors, such as Bonetus. Morgagni's study of the abnormal was based on a sound knowledge of the normal. He considered the commonest diseases the worthiest objects of investigation, and he was careful to establish the relations between the records of his autopsies and the symptoms of the precedent diseases. His aim was to explain disease by reference to its seat or location rather than to produce a systematic work on morbid anatomy. After his time it became more and more the practice to inquire "Where is the disease?" The old humoral pathology, which had continued to play a large part in the time of Sydenham and in that of Boerhaave, was at last superseded by something better.

Morgagni was particularly definite concerning the location and causes of apoplexy, to which disease his colleague Ramazzini — one of the earliest writers on the pathology of the occupations — as well as Valsalva, and Valsalva's master, Malpighi, had fallen victims. The cases recorded in Morgagni's volumes show that he had observed the suffusion of blood on the surface of the hemispheres (in some cases with rupture of the arteries at the basis of the brain), intraventricular hæmorrhage with laceration of the choroid plexus, and the extravasation of blood between the pia and the dura mater as well as into the substance of the cerebrum. Morgagni noted that the cerebellum is less frequently the seat of apoplexy than is the cerebrum. He confirmed the observation of Valsalva — and of some of the leading authorities of antiquity — that if the left parts of the body are paralyzed the injury is to be found on the right side of the brain; and if the right, on the left. Morgagni records, likewise, a case in which a fracture of the left temple was followed by speechlessness and loss of control of the right hand. Commenting on a case of apoplexy accompanied by a fall, he remarks, "Nor do I attribute it to the accidental fall, but the fall to it."

In several of his cases of apoplexy Morgagni mentioned the excessive use of wine, but among the causes of the disease he was inclined to lay special emphasis on aneurism. Nothing is more natural, he writes, than to call to mind the rupture of aneurisms in the abdomen and thorax, and even to imagine that something similar to this might sometimes occur within the cavity of the cranium; especially as those symptoms often precede the most dangerous apoplexies which would of themselves lead us to imagine such a circumstance. For instance, two aneurisms preceded that apoplexy which in twelve hours carried off the learned and worthy Ramazzini. In fact, Morgagni records the observation, in another case, of those miliary aneurisms, the rupture of which is to-day recognized as the commonest cause of cerebral hæmorrhage. It might be added incidentally that, according to Morgagni, Valsalva and others had known cases in which the circulation in a limb had been adequately restored by collateral arteries after the chief artery had become obliterated following an operation for aneurism.

As Osler notes, Morgagni recognized that *the* infection with which aneurism is especially connected is syphilis. Of the various manifestations of this disease a great many were known to him that were unknown to Hunter and other younger contemporaries of the Italian pathologist. After telling of a rather hurried autopsy in which he had found aneurism of the aorta and a morbid condition of the lungs Morgagni surmises that a further examination might have revealed a diseased state of the kidneys. "For these four parts — the lungs, the aorta, and the kidneys, with their appendages — we have found to be injured in those who have labored considerably, and for a long time, under this lues." He observed, in other cases of venereal disease, caries of the cranium, diseased epiglottis, as well as condylomata and gummata. Morgagni had not himself seen the liver affected, though very learned men reported that this organ was particularly liable to venereal infection. He believed indeed that the lues venerea might vitiate any viscus whatever.

As early as 1743 Morgagni observed the ossification of the coronary arteries. "As I examined," he writes, "the external surface of the heart, the left coronary artery appeared to have been changed into a bony canal, from its very origin to the extent of many fingers' breadth, where it embraces the greater part of the base. And part of that very long branch, also, which it sends down upon the anterior surface of the heart, was already become bony to so great a space as could be covered by three fingers placed transversely." The subject in this case — an old man — had been carried into the hospital suffering from strangulated hernia. Inflammation of the bowels developed soon after his admission, and the patient succumbed almost immediately. Morgagni was able to learn very little about his previous condition. The pulse was reported to have been weak and small, but not intermitting. Speaking of another case recorded by others before 1761, he wished we could know "what disorders, and what kind of death, had preceded in the man, in whom the coronary veins of the heart were found to be bony." He wished we could know, likewise, what particular disturbances had been felt by those in whom the corresponding arteries were bony. One writer had supposed that this condition might be extremely fatal, but that it was so he had been unable definitely to affirm. After the death of Morgagni, Edward Jenner conjectured that the heart disease from which John Hunter suffered for twenty years was caused by the ossification of the coronary vessels. In reference to his master's ailment he consulted Heberden, who had been the first, in 1768, to use the expression angina pectoris. Jenner's conjecture in reference to the condition of the coronary vessels in the case of Hunter was verified by the postmortem made by Everard Home.

Morgagni has been credited with the first description of heart-block (later studied by Adams, 1827, and Stokes, 1836), and with the first recorded case of disease of the mitral valve. He referred cyanosis in congenital heart disease to the general congestion of the venous system due to obstruction. He described lobar pneumonia with hepatization. He treated very fully biliary, renal, and cystic calculi and recorded cases of yellow atrophy of the liver, infantile jaundice, from which all of his fifteen children suffered, and tuberculosis of the liver and kidneys.

According to Morgagni, "In a woman who had not experienced more than dullness of hearing, Valsalva found the membrana tympani on both sides either totally or nearly destroyed by ulceration. On one side all the ossicles were thrown off, except the base of the stapes; and on the opposite side the incus was disjoined from the stapes." Morgagni adds that he had never heard of any one who preserved his hearing long after the stapes had been removed. He differed from his predecessors in reference to the causal relationship between intracranial suppuration and discharge from the ear, and supported his view by citing a case of abscess of the brain which was the "consequence of the suppression of ichor flowing out of the ear." No symptoms of brain abscess had been observed before the occurrence of a diseased condition of the ear.

Hydrophobia, in Morgagni's opinion, is caused by a virus insinuated into the body. "Whoever, therefore, professes to have found out the nature of this disorder, must demonstrate the nature of this poison. But I do not even see that the seat of this disorder is confirmed." He mentions, however, one case of hydrophobia in which the vessels in the meninges were extremely distended with blood. Tetanus was observed by Morgagni to result from apparently trivial injuries, such as the bite of a tame sparrow, or splinters driven into the hand. In one of the cases of tetanus he records, "A cart-wheel passed over the lower part of the left heel of a youth seventeen years of age; but no other injury was apparent except laceration of the common integuments." The first seat of a virulent gonorrhœa, he asserts, is in the larger canaliculi of the urethra. The term "Morgagni's fossa" (fossa navicularis urethræ) and many similar terms preserve his memory as a careful anatomist. "Morgagnian cataract" is a phase of hypermature cataract observed by him. In reference to traumatic cataract Morgagni, with his characteristic care in giving credit to those who have furthered the growth of medical science, quotes Hippocrates as saying that the sight is injured by wounds that are inflicted on the eye-brow or a little above it.

Morgagni was in his eightieth year when he completed the "De Sedibus," the greatest landmark in the history of pathology. His birthplace was Forli, Romagna. At the age of sixteen he had begun his studies at the University of Bologna, where he imbibed the view, once voiced by Malpighi, that systems are ideal and mutable, observation and experience solid and unchangeable. Before he was twenty he had graduated as doctor of medicine and doctor of philosophy. He succeeded his master Valsalva as *demonstrator anatomicus*. He became known as a writer as early as 1706. Six years later he went to Padua, where he was appointed professor of anatomy in 1715. He retained till the time of his death the chair which had been occupied by Vesalius and many other distinguished anatomists. He wrote voluminously on a wide range of subjects, and was celebrated for general erudition and the elegance of his Latin. He had certain foibles, the parsimony that might be expected of a father of three sons and twelve daughters and the vanity that sometimes marks the character of great scholars and writers.

The five books of the "De Sedibus" contain the record of over six hundred dissections made by the author himself and the critical account of a great number of autopsies with which his extended reading had made him acquainted. In the words of Virchow, these books contain all that was known up to that time concerning changes produced by disease in the structure of the human body. This greatest pathologist of the nineteenth century acknowledged the fundamental character of Morgagni's contributions. They furnished a starting point for the progress of modern medicine. "The search for the *sedes morbi* has advanced from the organs to the tissues, and from the tissues to the cells."

It was Marie François Xavier Bichat who made pathology dependent on a study of the tissues. He was born in the village of Thoirette, France, November 11, 1771, and died at Paris July 22, 1802. His father was a doctor of medicine who had received his professional training at Montpellier. The son, Xavier Bichat, after a very thorough general education at Nantua and Lyons, began the systematic study of medicine in the latter city in 1791. The political conditions of the time stimulated among the doctors a special interest in surgery, and Bichat came under the influence of Antoine Petit, the chief surgeon of the Hôtel Dieu of Lyons. The Bichats were not Revolutionists, and, after the siege of Lyons in 1793, Xavier left that city. Before the end of the year he took refuge in Paris, and entered as a student the school of the famous Desault, hoping later to become an army-surgeon. He mingled quietly with the other students of medicine at the Hôtel Dieu of Paris. The fall of Robespierre in

July, 1794, brought to the young man a greater sense of security and a fortunate incident gained for him the friendship and consideration of his master Desault. It was customary in the school for the students to take turns in preparing résumés of the great surgeon's lectures. One day Desault spoke at length on fractures of the clavicle, giving a demonstration of the use of his bandage. When the time came for the résumé, the student who was to have given it was not present and Bichat offered to take his place. Desault's assistant, in whose presence the report was made, was deeply impressed by Bichat's clearness of thought and of expression. He told Desault of the incident, and the master, conscious of Bichat's extraordinary endowments, took the young man into his home and treated him as a familiar friend and disciple.

Henceforth Bichat seemed indefatigable. His only relaxation was change of work. He assisted Desault at the hospital, in his operations, in his private practice, his professional correspondence, his researches in surgery. When, toward the close of his life, Desault gave an extended course of lectures on the diseases of the bones, his tireless assistant prepared a careful statement of the teachings of the various authors from the time of Hippocrates concerning each question taken under consideration. At the same time Bichat continued to dissect. He


FRANÇOIS MAGENDIE


MARIE-FRANÇOIS-XAVIER BICHAT

along with Corvisart and others founded the Société médicale d'émulation, before which he read a number of papers, including one on the synovial membrane and another dealing with the tissues in a more general way. After the sudden death of Desault, in 1795, Bichat edited the fourth volume of his master's "Journal de Chirurgie," compiled two volumes of extracts from the "Journal," and brought out the last volume of Desault's works.

In 1797 Bichat undertook to lecture on anatomy, emphasizing the mutual relation of structure and function, and verifying his views by the experimental study of animals. He followed the course on anatomy with one on surgery, but was forced to desist for a time by a severe attack of hæmoptysis. On his recovery he gave a more extended course on anatomy, establishing a dissecting room and directing the work of about eighty students. In 1800 appeared two works setting forth Bichat's characteristic views concerning structure and function — "Traité des membranes," and "Recherches physiologiques sur la vie et la mort." The former became the basis of Bichat's "Anatomie générale" (1801), which established his claim as the founder of histology; the latter distinguished between the *vie animale* and the *vie organique*. These correspond to the functions which have to do with the external adjustments of the organism on the one hand and to the functions which preserve the automatic activities of the individual on the other hand. According to Bichat the cerebro-spinal nervous system and the ganglionic nervous system are the structures on which the animal functions and the organic functions respectively depend. At the same time he distinguished the muscles of the animal life from the muscles of the organic life.

Before the appearance of Bichat's "Anatomie générale" the study of anatomy had been largely a study of the organs. These, according to Bichat, admit of histological analysis, disentanglement of their component parts. The organs, as he says, are made up of tissues which are of very different kinds and which really constitute its elements. Chemistry, he proceeds, has its simple bodies, which by various combinations, of which they are capable, form compound bodies; likewise anatomy has its simple tissues, which, by their fourfold or sixfold combination, form the organs. Again, he compares the study of general anatomy to that to which an architect applies himself who, before constructing a house, tries to learn in detail the nature of the various materials he has to employ. The study of the general anatomist, as already implied, is analogous to that of the chemist who, before knowing the compound bodies, examines in isolation the elements which compose them, who before investigating, for example, the properties of the neutral salts, wishes to know their radicals. The study of general anatomy, or histology, is in a sense, like chemistry, an abstract study: for no tissue exists in isolation; all tissues are combined in a more or less considerable number.

What are the organic elements, which Bichat, in his search for a morphological unit comparable with the oxygen, nitrogen, carbon, and hydrogen known to the chemists of his time, discovered to be the components of the organs of the body? He mentions twenty-one: cellular, nervous of animal life, nervous of organic life, arterial, venous, tissue of exhalants, that of absorbents and their glands, osseous tissue, medullary, cartilaginous, fibrous, fibro-cartilaginous, muscular of animal life, muscular of organic life, mucous, serous, synovial, glandular, dermal, epidermal, and pilous. It is of interest to find that the father of modern histology in the task of differentiating tissue from tissue considered the microscope of his time a hindrance rather than a help. He chose, instead, to submit them to the action of heat, air, water, the acids, the alkalies, and salts. He observed them under putrefaction and various other conditions, drying, boiling, and macerating them. "The relation," says Bichat, "of properties as causes with phenomena as effects is an axiom in physics, chemistry, and astronomy, almost too hackneyed to repeat to-day. If my work establishes an analogous axiom in physiological science, it will have fulfilled its aim." According to him one must first discover the minute anatomy of the tissues, and the vital functions of the physiological elements. Pathological phenomena involve an alteration of these elements; therapeutics is concerned with restoration of the normal functions of the elements.

At the same time Bichat regarded general anatomy, or the study of the tissues, as an essential introduction to descriptive anatomy as well as to pathology and therapeutics. The twenty-one tissues were the subject of his "Anatomie générale"; their various combinations were the subject of his "Anatomie descriptive." According to Bichat, descriptive anatomy examines the organs just as nature presents them to us. It investigates first their external form, position, size, direction, etc. Then, penetrating more deeply into their structure, it examines the number of systems — nervous, muscular, serous, mucous, etc.— which contribute to the formation of each, and the particular modifications they may undergo in each case; moreover, it must not be indifferent to the relations of the structure to the functions. The stomach, for example, must be studied as an assemblage of tissues — mucous inside, serous outside, organic muscular in the middle. He who attempts to study the organs by means of the scalpel is like the architect who examines each room of a building, or like the chemist who investigates the reactions of the compounds without regard to the elements of which each is made up. Bichat published two volumes of the "Anatomie descriptive"; at the time of his death he had almost completed a third volume and had prepared material for a fourth. Two of his friends brought the work to a conclusion in a fifth volume. Bichat and those with whom he was associated carried into the field of science the ardor and enthusiasm of the Napoleonic age.

He pursued the study of morbid anatomy, especially after his appointment as physician at the Hôtel Dieu in 1800, with an almost incredible vigor and heroism. At the same time he had the opportunity of seeing all the remarkable cases of illness in that metropolitan hospital, where his amiable and magnanimous disposition almost disarmed envy itself. He was natural and spontaneous without being inconsiderate. He was prepossessing, frank and candid, incapable of anger or impatience, quick to welcome the views or recognize the merit of others, generous and tolerant, approachable even when absorbed in work. He held, as we have seen, that disease involves an alteration of the tissues of which the organism is composed. "Let us take for example the lungs," he is reported to have said in his last course of lectures. "These organs are composed of the pleura, of the parenchymatous structure of the lungs, and of the internal membrane. In pleurisy, the pleura only is inflamed, the pulmonary tissue and the mucous membrane remain untouched. In pneumonia, it is, on the contrary, the parenchymatous structure of the lungs that is affected, while its two membranes remain healthy. In the same manner catarrhal cough is exclusively confined to the mucous membrane, while the pulmonary tissue and the serous membrane are sound and healthy. We may reason in the same manner in relation to all the other organs." Thus Bichat, consciously building on the work of Morgagni, whom he considered the founder of pathological science, sought to advance from a pathology of the organs to a pathology of the tissues composing the organs. "It is to him," says Buisson, "that we are indebted for definite ideas concerning diseases of the peritoneum, diseases which had been usually confused with those of the organs covered by that membrane. He proved that each tissue has a special sort of malady, as well as a special character of vitality, and that even in the intestines, the morbid state of one tissue may be associated with the healthy state of the neighboring tissues. Some authors had apprehended this truth; Walter had indeed indicated exactly the nature of peritonitis; but, while all had observed particular facts, none had attached these ideas to a particular point of view."

Bichat's study of therapeutics was, like his study of pathology and descriptive anatomy, based on his early study of the structure and functions of the tissues. In the presence and with the coöperation of more than forty students he examined the action of drugs on the various systems into which he had analyzed the organism. He was still engaged in this investigation when death overtook him. He had worn himself out with almost superhuman exertions. Within a few months he had opened more than six hundred bodies at the Hôtel Dieu and elsewhere. The fatigue resulting from his ceaseless activities had weakened his resistance to the inroads of disease. On July 8, 1802, he examined some macerated tissues which were in such an advanced state of putrefaction that the students were driven out of the laboratory by the odor. When Bichat finally withdrew from his task he fell on the staircase in the hospital, and, hitting his head, was rendered for a time unconscious. On the following day he tried to resume his professional activities, but was seized by a violent headache. He succumbed to typhoid fever July 22.

Corvisart, Napoleon's favorite physician, wrote to the First Consul: "Bichat has just died on a battle-field which has claimed more than one victim; no person, in so short a time, has done so much and so well." Napoleon shortly after gave directions that a tablet be placed in the Hôtel Dieu commemorating the friendship and labors of Desault and Bichat. "Bichat," wrote Bonaparte, "would have greatly extended the domain of this science, so important and so dear to humanity, if pitiless death had not struck him down at thirty years."

Buckle says that, "If we compare the shortness of his life with the reach and depth of his views," he "must be pronounced the most profound thinker and consummate observer by whom the animal frame has yet been studied." He adds: "We may except Aristotle, but between Aristotle and Bichat I find no middle man." We shall be safer, however, in accepting the soberer judgment of the physiologist Carpenter, who says: "Altogether Bichat left an impress on the science of life, the depth of which can scarcely be overrated; and this not so much by the facts which he collected and generalized, as by the method of inquiry which he developed, and by the systematic form which he gave to the study of general anatomy in relation both to physiology and pathology."

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CHAPTER X

LOCAL DIAGNOSIS: AUENBRUGGER, LAENNEC

In the same year as Morgagni's "De Sedibus et Causis Morborum," appeared the "New Invention for Discovering Obscure Thoracic Diseases by Percussion of the Chest." This "Inventum Novum" was the work of Leopold Auenbrugger (1722–1809), the son of an innkeeper of Graz, Austria. He was educated at the University of Vienna, and in 1751 received an appointment in the Spanish Military Hospital of the Austrian capital. It was the age of Maria Theresa. In spite of the struggles of the Empire with Frederick the Great of Prussia and other enemies, Vienna continued to be one of the chief centers of European culture. At the time of the appearance of the "Inventum Novum," the child prodigy Mozart was about to make his début at the Austrian court, Gluck was the Kapellmeister of the Empress, while Haydn held a similar position under the princely patronage of the Hungarian house of Eszterhazy. Into the culture life of Vienna at this time Auenbrugger was fitted by his talents and temperament to enter. He was popular at the imperial court; extremely fond of music, he composed the libretto of an opera, "The Chimney Sweep"

("Der Rauchfangkehrer"), to please the Empress; and later received from her son, Emperor Joseph II, the title Edler von Auenbrug on account of his geniality and other fine social qualities, and not on account of his contribution to the advance of medical science.

In fact, the "Inventum Novum" brought only an inadequate response from Auenbrugger's contemporaries of the Old Vienna School. His teacher, the autocratic Gerard van Swieten, ignored it, as did also Anton de Haën. These two leaders and voluminous writers had studied at Leyden under their fellow countryman Boerhaave, whose influence they perpetuated. Maximilian Stoll (1742–86), however, who succeeded de Haën as clinical teacher at Vienna, recognized the value of Auenbrugger's method both in the diagnosis and treatment of pleurisy and empyema. And of course long after the prophet's death he found honor in his own country; for in 1839 Skoda, the leading clinician of the New Vienna School, wrote a treatise on percussion and auscultation, and "diagnosis confirmed by postmortem" became the watchword in the medical circles of the Austrian capital.

In the preface to the "Inventum Novum" Auenbrugger says: "I here present the reader with a new sign which I have discovered for detecting diseases of the chest. This consists in the percussion of the human thorax, whereby, according to the character of the particular sounds thence elicited, an opinion is formed of the internal state of that cavity." The brief treatise was the outcome of seven years' observation, experiment, and reflection. "What I have written I have proved again and again, by the testimony of my own senses, and amid laborious and tedious exertions." But in spite of his confidence in the results he had achieved, he was far from believing that he had exhausted the possibilities of his method, and he hoped that further observation and experience would lead to the discovery of other truths, in these or other diseases, of like value in the diagnosis, prognosis, and cure of thoracic affections.

The sound obtained on the percussion of certain parts of the healthy chest resembles the stifled sound of a drum covered with a thick woollen cloth or other envelope. The most sonorous region is from the clavicle to the fourth rib anteriorly. "The thorax ought to be struck, slowly and gently, with the points of the fingers, brought close together and at the same time extended." The patient is told at first to breathe naturally; later he is directed to hold his breath after a full inspiration. During the examination the patient must assume such an attitude as will render tense that part of the chest wall which at the moment is being subjected to percussion; for thus a clearer sound is obtained.

Auenbrugger believed that thoracic diseases of the worst description might exist without any symptoms save those revealed by his method of percussion. If a naturally sonorous part of the chest is, on percussion, devoid of the usual resonance — yielding only the sound of a fleshy limb when struck — or if it gives out a sound duller than usual, disease exists in that part. He considered that the deviations from the natural sound are owing to the diminution of the amount of air normally contained in the lungs, a diminution which might arise from the occurrence of solids or liquids. An analogous sound may be obtained by striking a cask partly filled with water. The preternatural sound always accompanies a copious effusion of fluid in the thoracic cavity. Moreover, the "effect of effused liquids in producing the morbid sound is at once proved by the injection of water into the thorax of a dead body; in which case it will be found that the sound elicited by percussion will be obscure over the portion of the cavity occupied by the injected liquid." In addition to the methods of investigation of which Auenbrugger gives here an indication, there is abundant evidence that he made it a practice, where it was feasible, to confirm his diagnosis by post-mortem examination.

The appearances on dissection in cases where percussion had revealed an abnormal condition fall into two classes — those that involve primarily the respiratory functions, and those found in the heart and pericardium. Under the first class Auenbrugger noted the degeneration of the lung substance, the post-mortem organ being so engorged with blood as to resemble liver in every respect, both as to color and consistency. Among the symptoms exhibited by patients suffering from such a degeneration of the lung substance he mentions the diminution or entire absence of the natural sound over the affected part, and the relative immobility, during inspiration, of the chest on the affected side. Auenbrugger described vomicæ resulting from the degeneration of the lung substance. They are encysted or contained in a sort of capsule; some of them are purulent, some are not; some are closed, others communicate with the bronchi. If, in the case of a patient suffering from a purulent vomica which is discharging into the trachea, while the patient is coughing and spitting the physician places his hand over the site of the vomica, the noise of fluid within the chest will be distinctly manifest. When a vomica discharges its contents into the cavity of the pleura and upon the diaphragm, empyema is produced. "If percussion is now applied, it will be found that the natural sound, which had been nearly lost on the site of the vomica, has in some degree been restored in that place; while it is more or less destroyed — according to the quantity of pus effused — over the posterior and inferior parts of the chest." By dissection Auenbrugger also verified his diagnosis of unilateral and bilateral hydrothorax. Among the symptoms revealed by percussion he mentions a murmuring sound about the hypochondriac region. Moreover, in unilateral hydrothorax, "the affected side, if completely filled with water, is enfeebled and appears less movable during inspiration. In this case, also, the affected side yields nowhere the natural sound on percussion. If the chest is only half filled, a louder sound will be obtained over the parts to which the fluid does not extend, and the resonance will be found to vary according to the position of the patient and the consequent level to which the liquid attains." Auenbrugger mentions hæmothorax with and without an accompanying lesion of the lungs. He had never seen chylothorax, though he believed the disease existed in spite of the fact that the thoracic duct runs outside the pleura.

As regards diseases of the heart and pericardium Auenbrugger's researches contributed to our knowledge of the symptoms and the morbid anatomy. In health the whole sternum yields on percussion as distinct a sound as the sides of the chest, except in the cardiac region, where it is somewhat duller; similarly on the left side of the chest, over the space occupied by the heart the sound loses part of its usual clearness. In hydropericardium the sound is completely deadened as if the percussion were applied to a healthy limb. Post-mortem discloses — in cases of dropsy of the pericardium — either a serous effusion or a purulent effusion, which commonly resembles turbid whey. The same signs are furnished by percussion in either case. "In the first variety the heart is rough, and, as it were, shaggy, with a coating of the purulent matter." In the case of copious extravasation of blood into the pericardium percussion elicits none of the natural sounds over the space occupied by the extravasated blood. Similar results are yielded by percussion in cases of dilatation of the heart.

In spite of such recognition as the "Inventum Novum" early gained in Vienna and other centers of German medicine and its translation into French within a decade of its appearance, it remained for the great French clinician Corvisart (1755–1821) and his pupils to make Auenbrugger's influence at all general. Corvisart was an enthusiastic admirer of the teachings of the Vienna School, and was particularly familiar with the works of Stoll. In 1808, a year before the death of Auenbrugger, he translated the "Inventum Novum" into French and wrote commentaries upon it. In 1806, under the direct encouragement of the Emperor Napoleon, he had published his own masterpiece, "Essai sur les maladies et les lésions du cœur et des gros vaisseaux."

In this work Corvisart directs attention in the first place to diseases of the pericardium, notes the comparative dullness of the sound resulting from percussion of the cardiac region in hydropericardium. and, later, studies the symptoms of dilatation, as well as of aneurism of the thoracic aorta. His diagnoses seemed to his pupils at times the result of intuition, but he was indeed a keen observer with a delicate sense of touch, and an acute sense of hearing that led him to anticipate the discovery of auscultation. He also urged physicians not to neglect post-mortem examination, an injunction carefully heeded by his pupils Bayle and Laënnec.

"Our real knowledge," writes Osler of tuberculosis, "is a nineteenth century contribution, beginning with the work of Bayle on the structure of the tubercle and on its identity in the widely distributed lesions." In his early work, "Phthisie pulmonaire," Bayle spoke, like his predecessors, of types of phthisis other than the tuberculous, but in his later work, "Remarques sur les tubercles," he recognized the specific character of the disease. He defined tubercles as little cysts containing organized solid matter, capable of softening and breaking down. He had found them post-mortem in the lungs, mesentery, liver, kidneys, prostate, and other organs, but he had not observed them in the brain. The fact that they might occur so widely distributed in the one subject seemed to indicate that all tubercles are identical in nature. He even used the expression "tuberculous diathesis" to designate a constitutional tendency to tuberculosis. In the diagnosis of diseases of the chest Bayle resorted to immediate auscultation. The employment of this method by Bayle led to its adoption by his fellow student Laënnec and thus to the discovery of a much better method.

René Théophile Hyacinthe Laënnec was born at Quimper, Finistère (the French Land's End), February 17, 1781. One of his relatives, under whose direction he began his professional education, had been a pupil of John Hunter's. René Laënnec studied medicine as early as 1795 at the Hôtel Dieu at Nantes, accompanied a military expedition against an insurrection in the west of France in 1800, had a little experience in military hospitals, and before the end of 1800 went to Paris for further training in medicine. There he attended the popular clinics of Corvisart at the Unité (Charité), met Bayle, and heard Bichat's last course. His medical education was very thorough. During three years as student at La Charité he wrote up four hundred cases that came under his observation. He discovered the deltoid bursa and the fibrous capsule of the liver; and he became a recognized authority in morbid anatomy. His culture was not confined to narrow professional lines; he was a linguist and something of a poet; he was versed in the writings of Hippocrates and the other great physicians of the past, and he held that discoveries in medical science are made only by those who know its history.

Among the many influences that led to Laënnec's great invention was the work of Chladni in acoustics which had been stimulated in the first place by an intense interest in music. Chladni had given an account of his researches in the presence of some of the leading scientists of Paris; and in 1809 had published a French edition of his work under the title "Traité d'acoustique." The Emperor had drawn general attention to the subject by the terse remark: "Chladni makes tones visible." One day about the middle of October, 1816, Laënnec saw some boys at play in a court of the Louvre, who by listening at the end of a beam were able to hear the sound of the scratching of a pin transmitted from the other end. On the following day there occurred an experience which we shall relate in Laënnec's own words.

"I was consulted in 1816," he writes, "in the case of a young person who showed symptoms of heart disease and in whom palpation and percussion gave poor results on account of her *embonpoint*. The age and sex of the patient forbidding the sort of examination of which I have just spoken, immediate auscultation, I happened to recall a familiar fact in acoustics, namely, that if one places his ear at one end of a piece of timber he can hear very distinctly the scratch of a pin at the other end. It occurred to me that I might take advantage, in the case with which I had to deal, of this physical property. I took a paper notebook, rolled it up tightly, applied one end to the precardiac region and listened at the other. I was as greatly surprised as I was pleased to hear the heart-beats much more clearly and distinctly than I had ever been able to hear them through the immediate application of the ear. From that time I took it for granted that this means might become a method useful and applicable not only in the study of heart-beats, but in the study of all movements which may produce a sound in the thorax, and, consequently, in the examination of the respiration, of the voice, of the râle, and perhaps even of an effusion in the pleura or pericardium."

Under this conviction Laënnec began at once a series of observations at the Necker Hospital (to which he had just been appointed visiting physician) from which he was able to deduce a set of new signs of diseases of the chest, which he considered certain, simple, striking, and calculated, perhaps, to render the diagnosis of diseases of the lungs, pleura, and heart as definite as the indications furnished to the surgeon in the case of a stone in the bladder or of a fractured limb. The first instrument of which he made use was a cylinder of paper, tightly rolled, and kept in shape by means of paste. Later he tried various other materials. Following a series of experiments, he employed in his examinations of the chest sounds "a cylinder of wood, an inch and a half in diameter, and a foot long, perforated longitudinally by a bore three lines wide, and hollowed out into a funnel-shape, to the depth of an inch and a half, at one of the extremities." To this instrument he gave the name "stethoscope" (στῆθος, *chest*, and σκοπεῖν, *explore*).

Laënnec reported some of his results to the Académie des Science in 1818, and in 1819 published the first edition of his work "De l'Auscultation Médiate." In 1820 he retired to Kerlouarnec, where he spent two years resting and recuperating. In 1822 he returned to Paris, and received appointment as professor of medicine at the Collège de France. In the following year he was given the chair of clinical medicine at La Charité. In 1826 appeared the second edition of his great work.

Like Auenbrugger, of whose method of percussion he had made considerable use, Laënnec sought first of all to establish the sounds heard on the examination of a normal subject. "On applying the cylinder," he writes, ". . . to the breast of a healthy person, we hear, during inspiration and expiration, a slight but extremely distinct murmur, answering to the entrance of air into, and its expulsion from, the air cells of the lungs."

Shortly after beginning his observations by means of the newly discovered method, Laënnec, in the case of a woman suffering with a slight bilious fever and a recent cough, applied the cylinder below the middle of the right clavicle while she was speaking. Her voice seemed to come directly from the chest, and to reach the ear through the central canal of the instrument. This peculiar phenomenon was confined, he proceeds, to a space about an inch square. Ignorant of the cause of this singularity, he examined the greater number of the patients in the hospital, and found the same phenomenon in about twenty of them. He began to suspect that it might be caused by tuberculous cavities in the lungs. The subsequent death of the majority of the patients who had exhibited this peculiarity gave him the opportunity to verify his conjecture. In all cases post-mortem examination revealed larger or smaller cavities, which communicated with the bronchial tubes and which were the result of the breaking down of tubercles. "I found the peculiar phenomenon (which I have termed Pectoriloquy) to be perceptible according to the density of the walls of the cavity and its proximity to the surface of the lungs."

Laënnec, though inclined to admit, like Auenbrugger, the possibility of a *phthisis nervosa*, taught that pulmonary consumption is caused by the development in the lungs of tubercles which may appear as isolated bodies or as a tuberculous infiltration. Under the former come miliary tubercles, crude tubercles, encysted tubercles, and tuberculous granules. Under tuberculous infiltration he recognized the gray and the yellow. Laënnec observed tubercles in the peritoneum, testicles, uterus, cervical and mesenteric glands, heart, spleen, brain, bones of skull, ribs, vertebræ and their ligaments. For him scrofula was tuberculosis of the glands; he insisted on the frequency of tuberculous pleurisy; in fact, he supported the doctrine of Bayle in reference to the specific character of tuberculosis. In pulmonary tuberculosis tubercles should be especially suspected at the apex of the lungs, and under the clavicle. The cure of phthisis is possible, since autopsies show us how nature has worked a transformation in the so-called ulcers of the lungs, that is, tuberculous cavities. Laënnec had little faith in the therapeutic value of medicines, etc., in cases of phthisis. He advocated, rather, hygienic treatment — nourishing food, travel, and fresh air, particularly sea air.

In the judgment of Laënnec ægophony (*αἴξ*, *αἴγος*, *wild goat*, *φωνή*, *sound*) was indicative of pleurisy attended by a moderate effusion in the pleura, or of hydrothorax or other extravasation in the chest cavity. Simple ægophony is described by him as a peculiar sound of the voice accompanying or following the articulation of words. He speaks of it as a kind of silvery voice, of a sharper and shriller tone than that of the patient. It seems to vibrate on the surface of the lungs, more like the echo of the voice than the voice itself. "It has, moreover, another character, so constant as to lead me to derive from it the appellation of the phenomenon — I mean a trembling or bleating sound like the voice of a goat, a character which is the more striking because the key or tone of it approaches that of this animal's voice." In another passage Laënnec says that ægophony is characterized by the harsh, tremulous, silvery tones of the voice, which is commonly shriller than the natural voice of the patient, and seems to be quite superficial, and to float, as it were, on the surface of the lungs, instead of coming from the interior, like pectoriloquy or bronchophony. Laënnec sought to produce experimentally the tremulous echo of a voice that seemed to him to occur in pleurisy with effusion, and other forms of thoracic disease. Accordingly, before applying the stethoscope he placed a bladder half filled with water between the scapulæ of a young man with a well-marked natural bronchophony at this point. The stethoscopic sound seemed sharper and also slightly tremulous. A like experiment tried over the larynx seemed to give the like result.

We owe, of course, to the investigations of Laënnec our knowledge of the various râles and their diagnostic significance. In his classic description of lobar pneumonia we find the stages revealed by post-mortem examination coupled with the physical signs — the early crepitant râle, and the mucous râle that accompanies resolution. He held that a metallic tinkle could be heard in hydro-pneumothorax or pyo-pneumothorax. Surpassing the work of Bichat he gave a masterly description of bronchitis with its sonorous and sibilant râles. He described also the *râle humide* and the *souffle.* We are indebted to Laënnec for descriptions of bronchiectasis, oedema of the lungs, pulmonary "apoplexy," hæmorrhagic pleurisy, gangrene of the lungs and emphysema. It seemed to him that vesicular emphysema is, next to hypertrophy, the simplest of all the organic lesions of the lungs, since it consists merely in the dilatation of the air cells. On this account it remained long unknown, and had, he thought, not been correctly described by any author before his time. "I," he continues, "for a long time thought it very uncommon, because I had observed only a few cases of it; but since I have made use of the stethoscope, I have verified its existence as well on the living as the dead subject, and am led to consider it by no means infrequent." In some cases the lung takes on a striking resemblance to the vesicular lungs of Reptilia.

It did not occur to Laënnec to make use of the stethoscope in the diagnosis of pregnancy. This idea came first to his friend Dr. Kergaradec while verifying the facts contained in the first edition of "Mediate Auscultation." Dr. Kergaradec's conclusions are stated in the appendix of the second edition of that work. In putting his idea to the test he observed the fœtal heart-beat, as well as the placental *bruit*, in a woman very near her confinement. The latter he described as an arterial pulsation accompanied by a bellows sound. The fœtal pulse, which is distinctly audible in the sixth month and sometimes a little earlier, is usually twice as rapid as that of the mother. The placental sound, which is usually perceptible about the fourth month, is, on the other hand, isochronous with the pulse of the mother.

"Laënnec," says Osler, "laid the foundations not only of our modern knowledge of tuberculosis, but of modern clinical medicine." By the invention of the stethoscope he brought into play one of the higher senses and armed the profession with the means of a more adequate diagnosis. He did not underrate his own achievement, holding, as he did, to the Hippocratic conviction that theory must rest on observation, and adopting as the motto of his work: An important part of the art is in my judgment to be able to explore (*μέγα δὲ μελός ἡγευμαί τῆς τεχνῆς εἶναιτὸ δυνάσθαι σκοπεῖν*). Very much of

Laënnec's work was so well done that it needs to-day little change in the way either of correction or addition. In the diagnosis of diseases of the heart his endeavors were soon supplemented by the investigations of his disciples of the Dublin School and other great leaders in clinical medicine.

After completing the second edition, which was almost a new work, of the "Mediate Auscultation," Laënnec once more retired to Finistère in the hope of again reëstablishing his health. The sea breezes and outdoor life failed, however, to revive his powers, exhausted by years of constant activity, and August 13, 1826, he succumbed to one of those diseases from which his genius has rescued so many victims.

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CHAPTER XI

ADVANCES IN PHYSIOLOGY

AMONG the many advances in physiology in the nineteenth century must be mentioned above all the progress made in the study of the functions of the nervous system through the investigations of the experimental physiologists, Charles Bell, Magendie, Marshall Hall, Johannes Müller, and Claude Bernard. For this progress the way had been prepared by Albrecht von Haller. Born at Berne, Switzerland, October 16, 1708, Haller was favored by striking natural endowments, as well as by almost unlimited opportunities for education. The accounts of his linguistic, literary, and scientific attainments while he was still little more than a child are not far from incredible. His more advanced education began at Tübingen, where he studied anatomy and, under the direction of Camerarius, botany. From Tübingen he was drawn to Leyden by the reputation of Boerhaave. After graduating at the age of nineteen, he visited England, where he came in contact with some of the leading British scientists. At Paris he came under the influence of the anatomist Winslow, and, at Basel, before returning to his native city, he studied mathematics under Jean Bernouilli. In

1736 Haller, after years of private practice, of a limited sort, and much study, was induced by George II of England to accept a professorship of medicine, anatomy, botany, and surgery in the newly established university of Göttingen. Here as elsewhere he was indefatigable. After seventeen years' activity at this Hanoverian seat of learning he returned to his native Berne, where he spent the remaining twenty-four years of his life.

Of Haller's many claims to distinction his work as a physiologist is the most convincing, though his knowledge of human and animal structure, on which his knowledge of physiological function was based, was very thorough. Haller's influence increased the range of experiments on living animals. He declared that, in spite of its apparent cruelty, vivisection is of more value in the study of physiology than all other methods and that a single experiment of this kind has often cleared up misconceptions soluble by no other means of investigation. The function and structure of mammals, birds, fishes, and still lower forms of life, helped him to explain the anatomy and physiology of man.

Haller laid the progress of physiology under particular obligation by his experiments on muscles and nerves and by the doctrine he based on these experiments. In 1752 they were reported to the Royal Society of Göttingen, of which he was the founder and president. He taught that irritability is the inherent property of muscle, while sensibility is the characteristic property of nerves. He used the term "irritability" in the sense of "contractility"; that is, in a much more restricted sense than Glisson, who in 1677 had spoken of the irritability of all animal tissues. Haller admitted that the usual stimulation which brings about the contraction of a muscle is conveyed by means of the nerves. Yet for this means of stimulation there might be substituted other forms which prove effective even when the connection between the nerve and the muscle is severed. It is the function of the nerves, on the other hand, to transmit to the consciousness the changes called forth by peripheral stimuli; or, in other words, the nerves are exclusively the organs of sensibility. For example, the retina is a network of nerve fibers which serve to transmit sensations of light. The rays of light coming from the object before us produce an impression on the retina which constitutes a stimulus of the optic nerve. What we feel is not the object itself, but the impression which the object makes on the particular nerve in question. It would seem to follow from this that the nerve of each sense has its own special mode of responding to stimulation, and that sensations are subjective in character, though they afford grounds for arriving at a judgment in reference to the nature of the outer world. Irritability may be found in detached parts of the body quite withdrawn from the empire of the soul. It is therefore absurd to seek to identify the soul with mere irritability. The nerves, the true organs of sensibility, contain, Haller was inclined to believe, a subtle, automatic fluid, being influenced no doubt in this belief by the contemporary discoveries in electricity. He also taught that memory is developed through the persistence of impressions on the brain substance.

In 1811 Sir Charles Bell (1774–1842) circulated a privately printed pamphlet, "An Idea of a New Anatomy of the Brain." In this occurred this passage: "On laying bare the roots of the spinal nerves I found that I could cut across the posterior fasciculus of nerves which took its origin from the posterior portion of the spinal marrow without convulsing the muscles of the back, but that on touching the anterior fasciculus with the point of the knife the muscles of the back were immediately convulsed." In his work "The Anatomy of the Human Body" (7th edition) he admitted that sensibility is indeed seated in the nerves, but that is only one of their functions. There are nerves which possess no sensibility at all. He was led to surmise this difference of function by observing beforehand differences of structure, being early struck by the perfect regularity of the spinal nerves as contrasted with the very great irregularity of the cranial nerves. He argued that if the endowment of a nerve depend on the relation of its roots to the columns of the spinal marrow and the base of the brain, then the observation of their roots must indicate to us their true distinction and their different uses. It was necessary to know in the first place whether the phenomena exhibited on injuring the separate roots of the spinal nerves correspond with what was suggested by their anatomy. He hesitated to put the question to the test of experiment because of the cruelty that seemed necessarily involved. It finally occurred to him, however, that it was best to experiment on an animal in a state of insensibility, as otherwise it might be difficult to distinguish between the expression of pain and the effect produced through the motor nerves.

"I therefore," he continues, "struck a rabbit behind the ear, so as to deprive it of sensibility by the concussion, and then exposed the spinal marrow. On irritating the posterior roots of the nerve, I could perceive no motion consequent, on any part of the muscular frame; but on irritating the anterior roots of the nerve, at each touch of the forceps there was a corresponding motion of the muscles to which the nerve was distributed. These experiments satisfied me that the different roots and the different columns from whence these roots arose, were devoted

SIR CHARLES BELL

to distinct offices, and that the notions drawn from the anatomy were correct." In a paper communicated to the Royal Society of London in 1821, we find Sir Charles Bell pursuing a similar line of argument and reporting a similar method of investigation in reference to the function of one of the cranial nerves. He drew attention to the complicated nerve supply of the face, inexplicable on the assumption that the nerves are confined to a single function. He maintained that an organ that has only one function has only one nerve, and assumed that the presence of a number of nerves supplying the same part of the body gave ground for surmising a variety of function. He submitted to special examination the facial nerve (*portio dura*), the branches of which are so largely concerned in the expression of the emotions, and the paralysis of which gives rise to what is now known as Bell's palsy. He produced artificial paralysis in experimental animals by dividing the nerve after its emergence from the stylo-mastoid foramen. The cutting of the nerve called forth no sign of pain. The muscles of the side of the face on which the nerve was cut no longer acted in harmony with the other muscles involved in the act of respiration, and in the expression of emotion so closely associated with respiratory movements. If the facial nerve of one side of the face is cut and that of the other left intact and the animal is bled to death, the contrast in expression between the two sides of the face of the dying animal is most striking.

The different functions of the nerves afford a clue to the functions of the brain and spinal cord. Some of the nerve trunks are made up of filaments that merely convey sensations; while other nerve trunks are made up of filaments that merely convey motor impressions to the muscles: a third class of nerve trunks are made up of the two kinds of filaments, as we have seen in the case of the spinal nerves. The brain and cord in turn are divided into parts concerned respectively with sensations and bodily movements. By many authorities in physiology Bell's contribution to neurology has been compared in value with Harvey's discovery of the circulation of the blood. As early as November 26, 1807, Bell had written to his brother: "I have done a more interesting *nova anatomia cerebri humani* than it is possible to conceive. I lectured it yesterday. I prosecuted it last night till one o'clock; and I am sure it will be well received."

François Magendie, who founded the "Journal de physiologie expérimentale" in 1821, confirmed in the following year, by experiments on a litter of eight puppies six weeks old, the results obtained by Sir Charles Bell in reference to the functions of the roots of the spinal nerves. At that time Magendie had not heard of Bell's experiments to determine these functions. First he cut, in one of the litter of pups, the posterior roots of the lumbar and sacral nerves of one side, leaving the posterior roots on the other side uncut in order that he might have a basis of comparison. The parts of the body to which the cut nerves were distributed were still capable of movement, though their sensibility was wholly extinct. A second experiment of the same description, and a third, showed like results. Magendie then succeeded in another pup in cutting the anterior roots of the lumbar and sacral nerves of one side. The results here also were not hard to interpret, the part of the body concerned becoming completely motionless and lax, while retaining its sensibility. "Finally," writes Magendie, "to neglect nothing, I cut the anterior and the posterior roots at the same time; there was then an absolute loss of sensibility and movement." He concluded from this investigation that the anterior and posterior roots have different functions, in fact, "that the posterior appear more particularly destined for sensibility, while the anterior seem more especially connected with movement."

Just three months later Magendie published an account of further experiments bearing on the functions of the roots of the spinal nerves. Interested in the action of drugs — morphine, strychnine, emetine, veratrine, brucine, piperine, bromine, iodine, and prussic acid — as well as in the functions of the nerves, he gave *nux vomica* to experimental animals and noted the modification of the action of the poison produced by cutting one or the other set of roots of certain spinal nerves. If the posterior roots alone were cut, tetanus was complete. When the anterior roots of the nerves supplying the hind leg were cut, this member remained supple and motionless, while under the influence of the poison all the rest of the body was thrown into convulsions.

In 1833 Marshall Hall read before the Royal Society a paper On the Reflex Function of the Medulla Oblongata and Medulla Spinalis. Consciously basing his investigation on the work with decerebrated animals of certain French physiologists, Hall was particularly interested in phenomena brought about by eccentric, or peripheral, stimulation. He wished to distinguish these phenomena from sensation and volition, the characteristic functions of the cerebrum. Among these phenomena he mentions winking, sneezing, coughing, swallowing, vomiting, tenesmus and the maintenance of equilibrium. In the reflex function the muscles are excited by a stimulus acting along nerves proceeding to the medulla and muscular nerves proceeding from the medulla. The reflex function keeps the glottis open, through the superior laryngeal nerve connected with the cord, and keeps the sphincters closed. Infants born without cerebrum or cerebellum are capable of sucking, grasping, and crying. Strangury may be caused reflexly by the irritation of the rectum. Reflex action is increased by strychnine and opium, decreased by hydrocyanic acid.

In reaching his illuminating conclusions Marshall Hall had experimented with snakes, turtles, frogs, toads, newts, and guinea-pigs. He tells particularly of dividing the spinal marrow of a very lively snake (coluber natrix), between the second and third vertebræ. "From the moment of the division of the spinal marrow, it lay perfectly tranquil and motionless, with the exception of occasional gasping and slight movements of the head." Upon stimulation, however, the body began to move with great activity. When carefully protected "from all external impressions, it moved no more, but died with the precise position and form which it had last assumed." Hall argued that *sensation* can act, in inducing muscular motion, only through the medium of *volition;* that, in the experiments which were performed by him, volition, that is, the will, and not the power, to move, was annihilated; that in such cases — volition being destroyed and the agency of sensation excluded — the influence of external impressions, which might be supposed to induce pain, must have been exerted upon some property of the nervous system different from sensibility. In fine, in Hall's judgment the cerebrum is the source of voluntary emotions, the medulla oblongata the source of respiratory motions, the medulla spinalis the middle arc of the reflex function, the sympathetic nervous system the source of nutrition, secretion, etc.

About ten years after Magendie had given clear experimental proof of the difference in function of the anterior and posterior roots of the spinal nerves, a further confirmation of Bell's view was afforded by the great German scientist Johannes Müller (1801–58), who has been called the founder of scientific medicine in Germany. "The happy thought at length occurred to me," he writes, "of performing the experiment on frogs. The result was most satisfactory. The experiments are so easily performed, so certain and conclusive, that every one can now readily convince himself of one of the most important truths of physiology. . . . It is quite impossible to excite muscular contractions in frogs by irritating mechanically the posterior roots of the spinal nerves; while, on the other hand, the slightest irritation of the anterior roots immediately gives rise to strong action of the muscles. . . . The application of galvanism to the anterior roots of the spinal nerves, after their connection with the cord is divided, excites violent muscular twitchings; the same stimulus applied to the posterior roots is attended by no such effects. . . . If in the same frog the three posterior roots of the nerves going to the hinder extremities be divided on the left side, and the three anterior roots on the right side, the left extremity will be deprived of sensation, the right of motion."

Müller must also be held responsible for formulating the so-called law of the specific energy of the nerves. We find it as an implicit assumption in the works of Haller and other physiologists. John Hunter had stated that the only kind of sensations obtained by stimulating the optic nerve are sensations of light, irrespective of the nature of the stimulus. According to Müller the nature of the sensation depends not on outside objects but on the native substance of the sensory nerve involved in the sensation. For example, the optic nerve cannot be stimulated without giving rise, in accordance with its inherent energy, to sensations of light and color. Light and color do not exist as something fixed and objective which, affecting the sense of sight, calls forth a corresponding sensation; but the mechanism of sight produces always sensations of the same mode whatever may be the nature of the stimulus. Similarly, the auditory nerve cannot be stimulated without giving rise to auditory sensations; the gustatory nerve causes only sensations of taste. The character of the stimulus may be manifold, as we all know in the sense of sight: pressure, percussion, friction, heat, cold, electricity, chemical reagents, the throbbing of an artery, an inflammation of the retina. Whatever stimulates the optic nerve serves to dispel the sensation of darkness and to substitute sensations of light and color, just as by a stimulation of the motor nerves no effect may follow except the contraction of the muscles to which the nerves in question are distributed. It follows, of course, from this doctrine of the specific energy of the sensory nerves that our sensations do not reveal the essential qualities of the objective world. Our knowledge of outside things is limited by our knowledge of the sensations aroused in us by stimuli. At the present time physiologists and psychologists believe as a rule that the nerve fibers are mere conductors, and that the specific differences of sensations depend on the nature of the receptors, the inborn organization of the cortical areas to which the afferent impulses are conducted, or on both of these.

Johannes Müller stands out as one of the greatest leaders in the progress of physiology. The comprehensiveness of his interests as reflected in his two volumes, "Handbuch der Physiologie des Menschen" (1833–40), the comparative character of his physiology, his recognition of the dependence of psychology on physiology (in which he followed the lead of Cabanis, the real founder of physiological psychology), and his striking personality, contributed to make him a wonderfully inspiring influence. Following the example of Virchow, many speakers and writers have said that there was something superhuman about Johannes Müller. Adopting this point of view, one should hasten to add that his was a sort of immanent divinity that wrought its most notable achievements by purely human instrumentality. While no single first-class contribution to physiology stands to his credit, the labors of his pupils bear witness to the commanding character of his genius. Let it suffice here to mention Helmholtz, the inventor of the ophthalmoscope and the ophthalmometer, who measured the velocity of the nervous impulse, and was no less distinguished in acoustics than in optics; Du Bois-Reymond, who brought the apparatus of the physicist to bear on the study of the nerves and muscles; and Brücke, who carried Müller's influence to Vienna.

Claude Bernard (1813–77) advanced the study of the functions of the nerves (to which Bell, Magendie, Hall, and Müller so notably contributed) and furthered remarkably the solution of problems in other departments of physiology. He was born near Lyons, studied medicine at Paris, and, after taking his degree, became an interne at the Hôtel Dieu under the superintendence of Magendie, and in 1841 was appointed assistant (*préparateur*) in Magendie's laboratory at the Collège de France. In 1839

Magendie, on the basis of experiments on the roots of the spinal nerves, claimed that the anterior roots, though motor, were not wholly devoid of sensibility. This claim that there existed in the anterior roots a *sensibilité en retour*, or, as it was afterwards called, *sensibilité récurrente*, was vigorously disputed, and it was only after a long series of experiments on dogs conducted by Magendie and Bernard that the claim was upheld. According to Bernard by means of the sensory fibers from the posterior root which find their way into the anterior root a functional harmony is established in the sensory-motor mechanism. For him the reflex movements, studied as he notes by Hall and Johannes Müller, are the simplest of all. "The excitation carried by the sensory nerve arrives at the cord, it is propagated through the cord to the anterior root, and through the latter to the muscles."

By a series of experiments begun in 1852 he decided the old question of the independent irritability of muscular tissue. He was well aware that the problem of the relation between nervous excitability and muscular contractility had been under discussion since the time of Haller. Curare, however, was in Bernard's hands the means of reaching a clear decision, for it kills completely the motor nervous system without diminishing the range of contraction of muscles. Bernard injected curare under the skin of a frog. He decapitated a second frog, laying bare the lumbar nerves. When the first frog was dead, he stimulated the hind legs of both by means of an electric current applied to the nerves. The muscles of the frog poisoned by curare did not contract under these conditions. When, however, the current was applied, not to the nerve, but directly to the muscles, the contractions were as marked in the one case as in the other.

In 1851 Bernard began to investigate the function of the sympathetic nervous system, starting from the hypothesis that the sympathetic nerves were the producers of heat. On this assumption he cut the cervical sympathetic of a rabbit. Contrary to his expectation there was a decided rise instead of a fall in temperature, and the increased temperature was accompanied by a swelling of the arteries in the external ear. Brown-Séquard, at that time in America, showed that the stimulation of the divided cervical sympathetic had the effect of decreasing the blood supply and the temperature in the ear of the rabbit. Claude Bernard repeated this experiment and verified the results obtained by Brown-Séquard. In 1858 Bernard announced the discovery that the submaxillary gland secretes under the double influence of the chorda tympani and branches of the cervical sympathetic. Both of these nerves are vaso-motor, producing their effects through the unstriated muscles; for example, the unstriated muscular coat of the arteries discovered by Henle in 1840. The function of the cervical sympathetic is as a rule to cause a narrowing or constriction of the vessels, while the function of the chorda tympani is to cause a widening or dilation of the vessels. Thus Claude Bernard completed his discovery of the vaso-motor nerves, that is, the vaso-dilator and the vaso-constrictor. He also opened up the question of the inhibitory functions of nerves by proving (1846) that the stimulation of the vagus arrests the action of the heart, and that respiratory movements are checked by stimulating the superior laryngeal.

Claude Bernard's doctor's thesis (1843) had been on the gastric juice in digestion. He found that cane sugar injected into the veins of a dog is excreted in the urine. If, however, it is first treated with gastric juice, it does not so appear. Seeking, later, to find out at what part of the body the sugar so treated lost its identity, he came upon an unexpected result, namely that sugar occurs in the hepatic vein in greater quantity than in the portal vein. Moreover, if the experimental animal be fed neither sugar nor starch, the sugar in the blood nevertheless persists. He obtained sugar from the liver itself, and, later still, isolated glycogen. It appeared then that the liver has two functions, and that one of its secretions is an "internal secretion." On the false assumption that the vagus nerve might influence the hepatic secretion, he punctured the floor of the fourth ventricle, and produced what he called artificial diabetes (experimental glycosuria), in 1849. He is considered, in consequence of this, the founder of experimental medicine.

About 1848 he found one day on his laboratory table some rabbits, which had been brought in from the market. He noted that their urine was clear and acid, like that of carnivora. He then fed them herbs, and, as he had anticipated, their urine became turbid and alkaline. After they had gone without food for a considerable time, he fed them cold boiled beef, which, *faute de mieux*, they ate readily enough. Again their urine became clear and acid. He concluded that all animals fasting are in a sense carnivorous, since they are nourished on their own tissues. In a later experiment the rabbits were killed after a full meal. He found that the lacteals were white in the lower part of the duodenum about 30 centimeters below the pyloris. This struck his attention, as with dogs in similar circumstances he had noted the whiteness of the lacteals at the upper part of the duodenum. He noted that this difference coincided with the fact that in the dog the entrance of the pancreatic duct is quite near the pyloris, while in the rabbit its entrance is very low. The idea then occurred to him that the pancreatic juice might be the cause of the emulsion of the fatty matter of the food, and thus facilitate its absorption by the lacteals.

Like his master Magendie, Claude Bernard was interested in the action of poisons (for example, curare and carbon monoxide) and had constant recourse to vivisection. Nevertheless, their methods of investigation were in at least one respect contrasted. Magendie called himself a *chiffonnier*, thus comparing himself, working haphazard in the field of knowledge, with those who go about the town picking up rags, etc. Bernard, on the other hand, always had a definite aim in view, holding an hypothesis essential to successful research, though too agile mentally to neglect the clues that chance threw in his way, and too astute to be blinded by prepossessions. "Put off your imagination," he said, "as you take off your overcoat, when you enter the laboratory; but put it on again, as you do your overcoat, when you leave the laboratory." He thought that one had little chance of finding anything unless he knew what he was looking for, yet in his own investigations he was again and again rewarded by the discovery of the unexpected.

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CHAPTER XII

EMBRYOLOGY AND KARL ERNST VON BAER

THE eighteenth century fell heir to two opposed theories concerning the development of the embryo — epigenesis, and preformation or predelineation. They were supported by the authority of the two greatest embryologists of the preceding century, Harvey and Malpighi. Harvey had taught that the organism is built up gradually by the addition of part to part. Malpighi, on the other hand, had held that the chick existed preformed before the beginning of incubation. In the latter view two other early microscopists had concurred, namely, Swammerdam and Leeuwenhoek. The first of these, whose works did not become generally known till 1737, had studied the early stages of the development of the frog, and, interested in the metamorphosis of the caterpillar, had observed the parts of the butterfly in the chrysalis. Leeuwenhoek (1632–1723) was the first to describe the spermatozoa. It would seem that the wonders revealed to these early students of microscopy led them to believe that further revelations of minute structures and minute organisms only awaited the development of better instruments and finer technique.

Moreover, as Professor W. M. Wheeler in his admirable lecture on Wolff has indicated, there is a class of mind predisposed to emphasize the static rather than the dynamic, to view phenomena as being rather than becoming, as stable rather than transitional, and to fasten attention on the fixity of forms and species rather than on their transformations.

The investigations of Charles Bonnet (1720–93), and the authority of Haller, also favored, in the eighteenth century, the inclination to believe in the doctrine of preformation. While still a youth, Bonnet reported his observations concerning parthenogenesis in plant-lice, or Aphides. He had seen a single virgin aphis give birth to ninety-four daughters, which without fertilization continued to produce after their kind. Haller declared that no part of the animal frame was made after the other; that all were made together; and that there was no such thing as epigenesis. It follows logically from the doctrine of preformation that the ovum contains a complete animal that awaits the process of unfolding or evolution, and that the mother of the race bore within her all her posterity, preformed creatures impacted in preformed creatures like a series of boxes enclosed in boxes. This theory of *emboîtement*, was, indeed, definitely taught by Bonnet, Leibnitz and others.

Kaspar Friedrich Wolff (1733–94) opposed the preformation idea in his Theory of Generation, which appeared first as a doctor's thesis in 1759. It maintained that development consists in a series of new formations, and undertook to trace the stages by which the organs are gradually formed. According to Wolff the theory of predelineation merely affirms the fact of generation without offering an explanation of the process. He dealt first with the structure and development of plants in order to discover a clue to the more difficult problems presented by animals. In all plants little globules are to be observed before the appearance of fibers and vessels. The nutrient sap at first follows the path of least resistance; the vessels are formed by virtue of the hardening of the liquid nutriment. This principle of coagulation along with the *vis essentialis corporis*, the force through which the liquids in the organism are distributed and eliminated, is the cause of the process of development in all organic beings, both plant and animal. The primordial kidneys (now frequently called Wolffian bodies in honor of their discoverer) are formed by the urine propelled by the essential force of the body. The globular particles which constitute all animal organs in their inception — heart, blood-vessels, limbs, alimentary canal, kidneys, etc.— may always be distinguished under a microscope of moderate magnification. How, then, can the predelineationists claim that a body is invisible because it is so small, when the parts of which it is composed are easily distinguishable? Wolff's drawings illustrating the development of the chick are, on the whole, inferior to those made by Malpighi in 1672 and sent to the Royal Society of London.

Wolff's opposition to the doctrine of preformation, in which he had no doubt been schooled by his Leibnitzian professor of philosophy Christian Wolff, created a very unfavorable impression. His Theory of Generation implied that the act of creation was an incomplete process, and he became the object of the same sort of criticism as Darwin incurred just one hundred years later. He was warned by Haller of the danger of running counter to the teaching of religion. He was helpless in face of the disapprobation he encountered. During the Seven Years' War he served in the military hospitals in Schleswig and lectured on anatomy in a field hospital in Breslau. But the support that this patriotic service gained for him was not sufficient to overcome the hostility his heresy had aroused. He was refused a professorship, and even forbidden to lecture on physiology in Berlin. In 1766 he accepted an invitation to the Academy of Sciences in St. Petersburg, and he spent the remainder of his life in the Russia of Catherine II.

Wolff's second great contribution to the advance of embryology, "De Formatione Intestinorum," was published at St. Petersburg in 1768 and 1769. Here, speaking of the development of the anterior body wall of the chick, he says: "This is one of the most important proofs of epigenesis. We may conclude from it that the organs of the body have not always existed, but have been formed successively; no matter how this formation has been brought about. I do not say it has been brought about by a combination of particles, by a kind of fermentation, through mechanical causes, through the activity of the soul, but only that it has been brought about." As implied in a correspondence with Haller, Wolff was not interested in proving that anything is true that is not true, and he accepted it as axiomatic that other investigators shared his simple devotion to the truth. This study of the development of the intestines was years after its production referred to by von Baer as "die grösste Meisterarbeit, die wir aus dem Felde der beobachtenden Naturwissenschaften kennen"; that is, the most masterful performance known to us in the field of the observational sciences. In this work Wolff anticipated the embryologists of the nineteenth century by teaching that leaf-like embryonic layers give rise to the intestinal canal, the nervous system, the vascular system, etc. He furthered the study of embryology by applying the method of strict observation in this difficult field, and by establishing a definite antithesis between the doctrine of epigenesis and the theory of predelineation so tenaciously held by his contemporaries.

In 1812 the "De Formatione Intestinorum" was translated into German, under the title "Ueber die Bildung des Darmkanals im bebrüteten Hühnchen," by Johann Friedrich Meckel, sometimes called the younger to distinguish him from his grandfather, J. F. Meckel, whose name is associated with the sphenopalatine ganglion. The younger Meckel is famous as the discoverer of Meckel's diverticulum of the intestines, which represents the remains of the vitelline duct, and as the author of an extensive work on comparative anatomy. He has already been mentioned in these pages as having some acquaintance with the work of Hunter. He is credited with an early statement of the recapitulation theory, namely, that the development of each higher animal is "an epitome of the ancestral stages which preceded it" (Garrison). This theory, foreshadowed, as we have seen, in the writings of Hunter, was not accepted by von Baer without limitation, he, indeed going so far as to say that the embryos of higher forms never resembled the adult stages of the lower forms but merely the embryos of such forms (Balfour). This theory, severely criticized by the embryologists of to-day and all but annihilated, has served to stimulate countless investigators, especially since Darwin's "Origin of Species" seemed to lend it a new significance.

Karl Ernst von Baer was born at the family estate of Priep in the Russian province of Esthonia, February 28, 1792. He passed a free and happy childhood in the country. At the age of eight he had not learned the alphabet, but this fact did not hamper his later progress. He attended school at Reval, and spent four years at the University of Dorpat, where he received his degree as doctor of medicine in 1814. Following his graduation he went to Vienna to complete his professional studies, but his inclination for more general biological research was stimulated by a chance meeting with the botanist Martius in the spring of 1815. He decided to put himself under the instruction of Professor Ignaz Döllinger of Würzburg, who in the previous year had published works on the value and significance of comparative anatomy and on the development of the brain ("Beiträge zur Entwickelungsgeschichte des Gehirns"). Döllinger was a disciple of the philosopher Schelling. At the same time he was a keen observer, known to have improved the microscope, and a skillful teacher. Under his direction von Baer pursued the study of comparative anatomy for two years. Before the expiration of that time, Döllinger having expressed the wish to have somebody undertake a detailed study of the development of the chick, Christian Heinrich Pander, a friend of von Baer's, was induced to come to Würzburg and devote himself to the investigation.

In 1817 Pander set forth the results of his research in a Latin thesis, which before the end of the year appeared in a German translation, "Beiträge zur Entwickelungsgeschichte des Hühnchens im Ei." It was illustrated by sixteen excellent copperplate engravings, the work of the anatomist and archæologist E. J. D'Alton. Pander describes the formation, within the first twenty-four hours of incubation, of the three layers of what he was the first to name the "blastoderm." All subsequent development is nothing else than "a metamorphosis of this membrane, endowed with an inexhaustible supply of creative force, and of the three layers that compose it." The outer layer he called the "serous," the middle layer he called the "vascular," and the inner, the "mucous." The metamorphosis by which these three layers are transformed into the various organs and systems of the body is more precisely described by Pander, then a young man of twenty-four, than it had been by Wolff, whose theory and observations he in the main confirmed. In fact, it was not till the appearance of Pander's dissertation that students of embryonic development found the clue to the descriptions and the generalizations of his eighteenth century predecessor.

Von Baer, in the meantime, after spending a few months in Berlin, had gone to Königsberg as prosector to Professor K. F. Burdach, under whom he had studied at Dorpat. He was appointed professor of zoötomy in 1819. In the same year, stimulated by the results of Pander's investigation, he began his special studies in embryology, which he pursued with intense energy for the subsequent seven years. In 1827 he began to publish statements of the results of his researches. He had discovered as present in all vertebrate animals the notochord, the key, as Sedgwick has called it, to the whole of vertebrate morphology. He sprang into special prominence by the announcement of the discovery of the mammalian ovum — "Epistola de ovi mammalium et hominis genesi." He had verified the conjecture of Prévost and Dumas by finding the human ovum in a Graafian follicle. This capital discovery gave a new meaning to Harvey's dictum, *omne vivum ex ovo*, confirmed man's place in relation to the lower animals, and established human embryology as a branch of general biology. Some of von Baer's more general results appeared, also in 1827, in Burdach's "Physiologie," which contained, in addition, contributions on the development of invertebrates by Professor Rathke, and on the Entozoa in particular by the youthful K. T. E. von Siebold.

In 1828 appeared the first volume of the work which established the fame of Karl Ernst von Baer as the greatest embryologist of the nineteenth century —"Ueber die Entwickelungsgeschichte der Thiere — Beobachtung und Reflexion." The title is doubly significant, in the first place as indicating the beginning of comparative embryology, in the second place as indicating von Baer's unique combination of accurate observation and unerring powers of generalization. Following up the results of his friend Pander, to whom the book was dedicated, von Baer traced carefully the development of the chick day by day, and at the same time took account of other embryos. He recognized two chief layers in the blastoderm, the animal and the vegetative, Pander's vascular layer consisting, in von Baer's judgment, of derivatives from the so-called serous and mucous layers. These layers were in no sense ordinary tissues, but true germinal layers, the source of all the systems and organs of the body. From the animal layer come the external skin, the sense organs, and the nervous system in general; from its derivative the muscular and osseous systems. From the vegetative layer come the internal lining of the alimentary canal and all its dependencies — salivary glands, lungs, liver, etc.; while from its derivative come the heart, blood-vessels, kidneys, spleen, sexual glands, etc. The germ-layers, observed in the embryos of all species of animals except the very lowest, produce the fundamental systems by forming tubular cavities, from which the special parts and organs are in turn evolved. The formation of the central nervous system by the folding of the outer germ-layer is an example familiar to all. As far as the development of the alimentary canal is concerned Wolff had anticipated the observations of von Baer. In a similar way the walls of the body and the bony skeleton arise from muscular and osseous tubes.

By 1834 von Baer had added through continued research to his data concerning the development of animals. His publisher pressed him to complete the material for a second volume, and finally, having waited in vain, proceeded to publication in 1837 without receiving the consent of the author. Von Baer in 1835 contributed a paper on the embryology of fishes—"Untersuchungen über die Entwickelungsgeschichte der Fische"—and put on record the observation of the segmentation of the yolk in the ovum of the fish. The remainder of his long life was, however, given up to other scientific interests. As early as 1827 he had been invited to the Academy of Sciences at St. Petersburg; he had gone to the Russian capital to live in 1829, only to return to Königsberg the following year. But in 1834 he took up permanent residence in his native country as zoölogical member of the St. Petersburg Academy.

Von Baer traveled extensively, sometimes at the instance of the Russian government, sometimes at the dictate of his scientific curiosity. He visited North Cape, Nova Zembla, the Volga, the Caspian Sea, the Sea of Azov. He was interested in the physical features of the country, in its resources, especially in its fisheries, and in the distribution of plants and animals. He had early written on the subject of fossils. In 1845 he published a paper on teratology. In 1858–61 he visited the museums of London and other European cities. He made a special study of anthropology, particularly craniology, and in 1861, in conjunction with another embryologist, Rudolf Wagner, called together the first Congress of Anthropologists. One is impelled to ask whether after 1834 von Baer felt that further progress in embryology must depend on a fundamental reconstruction of biological conceptions. In 1862 he resigned his position as an active member of the Russian imperial Academy. A few years later he wrote his Autobiography at the suggestion of his admirers among the Baltic nobility, and on November 28, 1876, he died at Dorpat in his eighty-fifth year.

Von Baer's special training and his opportunities for comprehensive observation would seem an almost ideal preparation for the appreciation, if not indeed the discovery, of the doctrine of organic evolution. On the basis of his embryological studies he sought to classify animals under certain types, between which he recognized a distant kinship. In fact, according to von Baer, for one brief moment in the course of embryonic development there is a degree of conformity between vertebrate and invertebrate animals. The further we go back in development, he says, the more we find agreement in animals of very different sorts. We are thus led to ask, he continues, whether in the beginning of development all animals are not essentially alike, and whether there is not for all a common original form. It need not, however, greatly surprise us to find that von Baer raised his voice in opposition to the teachings of Charles Darwin ("Reden und kleine Aufsätze," 1864–77). In this respect he may be compared with Sir Richard Owen, from whom Darwin and his friends hoped to gain support for their doctrines. The severest critics of a new theory are not unlikely to be men who have long cherished views only slightly dissimilar to those they feel called upon to discuss, and who thus bring to the discussion a special knowledge of the data and a keen sense of the danger of the generalizations involved.

Professor Locy, referring to the period in the history of embryology between the work of von Baer and that of Francis Balfour states that there were great general advances in the knowledge of organic structure that brought the whole process of development into a new light. "Among the most important advances," he continues, "are to be enumerated the announcement of the cell-theory, the discovery of protoplasm, the beginning of the recognition of germinal continuity, and the establishment of the doctrine of organic evolution." In a passage dealing with the last item in this enumeration the same author says: "The general acceptance of the doctrine, which followed after fierce opposition, had, of course, a profound influence on embryology. The latter science is so intimately concerned with the genealogy of animals and plants, that the newly accepted doctrine, as affording an explanation of this genealogy, was the thing most needed."

These great advances in the knowledge of organic structure were all made before the death of von Baer. At the same time there was a marked improvement of the technique of investigation, and, of course, a steady accumulation of results. The principles set forth by J. J. Lister in a paper read before the Royal Society in the beginning of 1830 led to a much-needed improvement of the microscope both in England and on the continent of Europe. About 1855 von Gerlach made use of carmine as a nuclear stain, and before 1876 Golgi had introduced the use of silver nitrate in the study of the nervous system.

A further improvement in technique came through the introduction of the microtome in the preparation of histological sections by Purkinje, by Lister, and by Wilhelm His, famous for his study of the development of nervous tissue.

Among the contributions to embryology before the discovery of the cell-theory mention should be made of the work of von Baer's colleague at Königsberg, Martin Heinrich Rathke, who observed the branchial clefts and the visceral arches in the embryos of abranchiate animals, and by the application of the germ-layer doctrine in the investigation of lower species established his claim to be called the founder of invertebrate embryology. Von Siebold has already been associated with him. Herold's early study of the embryonic development of spiders should not be overlooked in this connection. Von Baer's discovery of the mammalian ovum, as his confirmation of the germ-layer doctrine, stimulated a series of special studies. As early as 1825 Purkinje had described the germinal vesicle in the ovum of the bird. In 1833 Coste reported the discovery of the germinal vesicle in the mammalian ovum, and a year or two later Wagner discovered the germinal spot. Bischoff, early interested in human embryology, ultimately traced the development of the ovum in four species of mammals, namely, the rabbit, dog, guinea-pig, and deer.

Johannes Müller contributed to the progress of embryology personally and through the work of his pupils. In 1829–30 he investigated the development of the genito-urinary organs, and the name Müllerian duct is still applied to the duct of the pronephros, which in the adult becomes converted into the genital passages. Müller's "Handbook of Physiology" by its statement of the results of investigations in embryology helped (along with the books of Wagner and Valentin) to make the teachings of that branch of biological science widely known. We must defer till the next chapter the consideration of the work of two of Müller's most distinguished pupils, Schwann and Virchow. A third pupil, Reichert, by his volume "Histology and Embryology," brought to bear on the study of embryonic development the method and point of view suggested by the formulation in the preceding year (1839) of the cell-theory. In 1837 he had made a special study of the transformation of the visceral arches. The work of Reichert was followed by that of a fourth pupil of Müller's, von Kölliker, who in 1841 explained the cellular origin of the spermatozoa, their nature and function. In 1843 he published a paper on the development of invertebrates, and in 1861 he wrote the first book on comparative embryology. Robert Remak, also a pupil of Johannes Müller's, in a study of the chick and frog, 1851–55, reviewed and clarified the origin of the germ-layers from the blastoderm, and indicated to some extent their relation to the formation of the body cavities. A few years before (1849), Huxley had put forward the view that the ectoderm and the endoderm of the Cœlenterata are analogous to the serous and mucous germ-layers observed by Pander in the development of the chick.

A few examples must suffice to show the nature of some of the advances made in embryology between the appearance of Darwin's "Origin of Species" and the death of von Baer. In 1861 Gegenbaur showed that the vertebrate ovum consists of a single cell, and in 1865 he turned his attention with like results to the examination of the spermatozoon. That the embryo is formed from these unicellular elements and that development takes place through cell-division became the natural presuppositions of subsequent theories of heredity. The study of Amphioxus by Kowalevsky in 1866 tended to break down the sharp distinction that had been made between the vertebrates and the invertebrates, and his doctrine that all animals pass through a gastrula stage — a doctrine elaborated by Haeckel — went further toward establishing the unity of the development of all organisms. At about the same time, Fritz Müller, one of the earliest German converts to the teachings of Darwin, gave a new formulation to the theory of recapitulation, to which reference has already been made, and which assumes that all animals of complex structure are the descendants of simpler forms. In 1874 another disciple of Darwin's, Francis Maitland Balfour, who had pursued some of his inquiries at the newly established Zoölogical Station at Naples, made report before the British Association at Belfast of some of those investigations which culminated in his volumes on Comparative Embryology (1879–81). And in 1875 Oscar Hertwig, known to the twentieth century as the author of a monumental work on vertebrate embryology (1901, *et seq.*), published his discoveries concerning the process of fertilization.

In his lecture on "Embryology and Medical Progress" Charles Sedgwick Minot says: "Embryology supplies facts which are directly valuable to the practitioner. It supplies explanations and interpretations of many anatomical structures and relations which would otherwise remain incomprehensible. It supplies the clues to many common and rare anomalies, and it supplies to pathology a series of fundamental conceptions, without which our actual present pathological knowledge could not have been upbuilt. These claims of embryology to recognition are very great, but nevertheless they do not include her greatest claim to a preëminent place among the medical sciences. That greatest claim is established in my opinion by the contribution of embryology to the solution of the problem of organic structure."

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CHAPTER XIII

THE CELL-THEORY AND CELLULAR PATHOLOGY

THE cell-theory resulted from the investigations of the botanist Schleiden and the anatomist and physiologist Schwann. It teaches that the tissues of developing plants and animals are composed of cells, and it may be compared with earlier attempts to discover a morphological unit in the organism, such as Haller's theory of fibers, Milne Edward's theory of globules, or Bichat's doctrine of elementary tissues. Cells had been observed by microscopists as early as the seventeenth century, notably by Robert Hooke (1665), who examined sections of cork under his compound microscope, and found them made up of little boxes or cells. He described the sections as "all cellular or porous in the manner of a honeycomb, but not so regular." His drawings of these cork cells were reproduced in his book "Micrographia," one of the very early publications of the Royal Society. The observations made at this time by means of the microscope seemed to confirm speculations concerning atoms and pores which had persisted among medical philosophers from the time of Democritus. In the eighteenth century Wolff, as already implied, recognized common elements in the minute structure of developing plants and animals. Huxley gives the following statement of Wolff's views: "Every organ, he says, is composed at first of a little mass of clear, viscous, nutritive fluid, which possesses no organization of any kind, but is at most composed of globules. In this semifluid mass cavities (Bläschen, Zellen) are now developed; these, if they remain round or polygonal, become the subsequent cells; if they elongate, the vessels; and the process is identically the same, whether it is examined in the vegetating point of a plant, or in the young budding organs of an animal."

Mathias Jakob Schleiden (1804–81) was interested in the development of plants, their anatomy and physiology, rather than in their classification under barbarous Latin names. He studied the relation of the cell-nucleus, which had been discovered by Robert Brown in 1831, to the development of the cell. Moreover, he attained to the view that the cell is the elementary organ of the plant. The development of plant tissues depends on the nucleated cell. For Schleiden the *development* of the cells of plants was a matter of supreme interest. His treatment of this question appeared under the title "Ueber Phytogenesis" in Müller's "Archiv" (1838).

Theodor Schwann (1810–82) was a pupil of Johannes Müller at Bonn, and later (1834–38) at

Berlin. Besides the formulation of the cell-theory a long list of triumphs stands to his credit, including the discovery of the sheath of the axis-cylinder of nerves, and the recognition of the organic nature of yeast and its rôle in fermentation. In 1837 Schleiden told Schwann of his observations of the nuclei of plant cells. Schwann had himself noted (under Müller's direction) the nucleated cells of the notochord. The two friends compared the results of their investigations, and Schleiden recognized in Schwann's sections of the notochord nucleated cells similar to those he had himself observed in plants. Subsequently Schwann included in his investigation the cellular origin and development of various tissues, and arrived at the generalization that "There is one universal principle of development for the elementary parts of organisms, however different, and that principle is the formation of cells." In 1839 appeared his "Microscopical Researches concerning the Harmony in Structure and Growth of Animals and Plants." In this work he says: "The development of the proposition that there exists one general principle for the formation of all organic productions, and that this principle is the formation of cells, as well as the conclusions which may be drawn from this proposition, may be comprised under the term *cell-theory*."

The views of biologists concerning the nature and origin of cells were soon modified by further discoveries. In 1835 Dujardin had observed a semi-fluid, jelly-like substance in protozoa, endowed with all the qualities of life. The term "protoplasm" was first used by Purkinje in 1839, to designate the germinal ground-substance of the embryo. In 1846 von Mohl observed a jelly-like substance in plants to which he applied the name "protoplasma." A few years later Cohn noted the similarity, if not identity, of animal and plant protoplasm. In 1852 Remak established the fact that it is by cell-division that the tissues develop from the three embryonic layers. Two years later Virchow was making the cell-theory the basis of his system of pathology.

Rudolf Virchow (1821–1902) was born in Pomerania, began the study of medicine at Berlin in the year in which Schwann's Microscopical Researches appeared, and received his degree during the deanship of Johannes Müller, who was his model and ideal. In the following year he was demonstrator of anatomy at the Charité Hospital (Berlin). Here he had special charge of chemical and histological investigations, and his work in microscopic pathological anatomy suggested to his mind the need of studying the relationship between pathology and physiology. In 1847 he established the "Archiv" (für pathologische Anatomie und Physiologie und für klinische Medizin") since known by his name. About the same time he was appointed by the Prussian government to investigate an epidemic of typhus fever in Upper Silesia. His report not only recommended certain hygienic measures but took the government to task for the deplorable social conditions in that province, and advocated complete and unlimited democracy, and "education, with her two daughters, freedom and prosperity." He was already showing the personal spirit and political tendencies that later made him the vigorous opponent of Bismarck. Some years later he wrote: "I uphold my own rights, and therefore I also recognize the rights of others. This is the principle I act upon in life, in politics and in science. We owe it to ourselves to defend our rights, for it is the only guarantee for our individual development, and for our influence upon the community at large." From the summer of 1848, the year of the attempted revolution in Prussia, till the summer of the year following he published a weekly on Medical Reform, which ultimately had a great effect on the sanitation of Berlin. But the government could not tolerate his activity as an agitator. His pay was suspended for a time in the spring of 1849, and Virchow took advantage of a call to Würzburg to withdraw from Prussian territory. At the University of Würzburg he was closely associated with von Kölliker, who had treated the segmentation of the egg, and, as we have seen, other phases of embryonic development.

In 1854 Virchow began to edit a six-volume "Handbuch der speciellen Pathologie und Therapie." In the first volume he states that there is no essential difference between physiological and pathological laws. The human body, like all organisms, is composed of minute elements, each of which can be ultimately traced to a single cell and its sphere of influence. These organic cellular elements and elementary precincts are anatomically recognizable. They are at the same time morphological and vital units, differing from inorganic matter both in their composition and in their power to reproduce themselves. It would be a mistake, however, to regard the body as a mere aggregation of these vital units. They are parts of a higher unity. Some would describe this higher unity as a vital principle or constructive vital spirit, which in consistency they are bound to postulate in plants as well as in animals. According to Virchow the expression "constructive vital spirit" is purely figurative, like the expression "Landesvater" as applied to a monarch. The unity of the living body consists only in the interdependence of its living elements. The harmonious interaction of these elements, all derived originally from one simple element, is the condition of life. "Life does not proceed discontinuously, or by fits and starts, but in the regular, legitimate succession of generations." Pathological derangement must, to begin with, involve definite elements. Every disease has therefore a local, anatomical starting point or seat.

In 1856 Virchow was recalled to Berlin as professor of pathology and director of a new Pathological Institute. In 1858 he gave a series of twenty lectures to members of the medical profession. These were published under the title "Cellular Pathology as Based upon Physiological and Pathological Histology." After pointing to the advances in medicine which in the past had followed the work of the Alexandrian anatomists, of Vesalius, and of Bichat, who developed the principles of general anatomy, Virchow says: "What Schwann, however, has done for histology, has as yet been but in a very slight degree built up and developed for pathology, and it may be said that nothing has penetrated less deeply into the minds of all than the cell-theory in its intimate connection with pathology." In a relatively short time Bichat came to exercise an extraordinary influence on the state of medical opinion. The hesitancy to build upon the discoveries of Schwann was owing, according to Virchow, to the continued incompleteness of knowledge in the medical profession of the intimate structure of the tissues. Particular difficulty had been found in deciding which parts of the body are the source of action — what parts are active, what passive. "The chief point in this application of histology to pathology is to obtain a recognition of the fact that the cell is the ultimate morphological element in which there is any manifestation of life, and that we must not transfer the seat of real action to any point beyond the cell."

At the same time the idea of the cell was in need of restatement. Hooke and other early observers were inclined to magnify the importance of the cell-wall and to minify the importance of the cell-contents. Indeed, the very name "cell" tended to fix upon the enclosing membrane as the characteristic feature. Virchow held that Schwann in his observations had been unduly influenced by the botanist Schleiden. Schleiden was particularly prone to exaggerate the importance of the cell-wall because he thought that the nucleus never lay free in the interior of the cell but was always enclosed in the cell-wall. The typical plant cell was thought to consist of an extraneous membrane of cellulose, generally found to be destitute of nitrogen, and nitrogenized contents differing from it. To this type of plant cell the cartilage cell with its capsule seemed to be comparable, but the capsule is not an essential part of the cartilage cell; it is really the result of excretion, and in the young cell may be observed to be very thin. Virchow came to the general conclusion that when we separate from the cell all that has been added to it by an after-development, "we obtain a simple, homogeneous, extremely monotonous structure, recurring with extraordinary constancy in living organisms. But just this very constancy forms the best criterion of our having before us in this structure one of those really elementary bodies, to be built up of which is eminently characteristic of every living thing — without the pre-existence of which no living forms arise, and to which the continuance and maintenance of life is intimately attached."

In this opening lecture of the series Virchow also restated his view of 1854 in reference to the relation of cell to cell within the organism, making more explicit the analogy between the cells in the body and the citizens in the State. The highly developed organism, whether plant or animal, must be regarded as made up of a larger or smaller number of similar or dissimilar cells. Every animal is a sum of vital elements, each of which manifests all the characteristics of life. Life cannot be especially attributed to one particular seat or organ, such as the brain of man, but it must be recognized in each individual cell, the constantly recurring structure, or morphological and vital unit. "Hence it follows that the structural composition of a body of considerable size, a so-called individual, always represents a kind of social arrangement of parts, an arrangement of a social kind, in which a number of individual existences are mutally dependent, but in such a way, that every element has its own special action, and, even though it derive its stimulus to activity from other parts, yet alone effects the actual performance of its duties."

In his second lecture on "Cellular Pathology" Virchow enunciated what Lord Lister has described as the true and fertile doctrine that every morbid structure consists of cells which have been derived from pre-existing cells as a progeny. His earlier study of parasitic organisms had not converted him to a belief in spontaneous generation. In the first volume of the "Handbook of Special Pathology and Therapeutics," already referred to, he had written a section on plant and animal parasites. We are indebted to him for the first good descriptions of some of the nonbacterial fungus infections (mycoses); and this volume of 1854 gives a list of thirty metazoan parasites, classified as trematodes, cestodes, nematodes, etc. In this list are found the *Tænia solium*, *Trichina spiralis* (to which Virchow at a later date directed his attention to the great benefit of the public health), *Ancylostoma duodenale*, *Filaria medinensis*, as well as the parasitic causes of hepatic distomiasis, and of bilharziasis. In 1858 he was prepared to maintain that even in pathology no development of any kind begins *de novo*, and that the theory of spontaneous generation is to be rejected just as decisively in the history of individual parts as in that of entire organisms. A tænia solium does not owe its origin to the intestinal mucus nor a fungus take its life from decomposing animal or vegetable matter; "equally little are we disposed to concede either in physiological or pathological histology, that a cell can build itself up out of non-cellular substance. Where a cell arises, there a cell must have previously existed (*omnis cellula e cellula*), just as an animal can spring only from an animal, a plant only from a plant. In this manner, although there are still a few spots in the body where absolute demonstration has not yet been afforded, the principle is nevertheless established, that in the whole series of living things, whether they be entire plant or animal organisms, or essential constituents of the same, an eternal law of *continuous development* prevails. There is no discontinuity of development of such a kind that a new generation can of itself give rise to a new series of developmental forms. No developed tissues can be traced back either to any large or small simple element, unless it be to a cell." This clear statement of the law of the genetic continuity of cells was based of course in part on the studies of von Kölliker, Remak, and other embryologists.

Karl Blind is the authority for an anecdote intended to throw light on Virchow's view of his own contribution to the development of the cell-theory. At a party given in honor of Virchow on the eve of his departure for Cambridge, where he was to give an address at a Harvey celebration, Blind broached the question of Harvey's claim to be the first discoverer of the circulation of the blood. Professor Hecker of Berlin had given proofs of the worthlessness of Harvey's claims in the early part of the nineteenth century, and Blind himself had found additional evidence in the writings of Leonardo da Vinci. Virchow in a conversation lasting nearly half an hour made eager attempts to convince Blind of his mistake, and finally observed (according to Blind): "It might as well be contended, and it has even been contended, that the cellular theory was not my own." This remark seemed, to the narrator of the story, directed against those who had pointed out the claims of Schleiden and Schwann. Blind's own judgment was that Virchow had worked out a cellular theory of his own, correcting the mistakes of his predecessors, and giving a demonstration of his aphorism, *Omnis cellula e cellula.*

The pathology of Morgagni was a pathology of the organs; that of Bichat a pathology of the tissues composing the organs; cellular pathology in turn fixed attention on the elements that go to the formation of the tissues. Naturally the cell-theory enabled Virchow to review the work of Bichat, and to make a more thorough analysis of the components of the various organs and systems. As constituting one class of normal tissues he recognized those composed exclusively of cells. Of this class the epithelial formations are typical — the epidermis, the rete Malpighi, the nails, the crystalline lens, the mucous and serous membranes, and the active elements of the glands, which, Remak showed, owe their origin to the proliferation of epithelial structures. A second class of normal tissues includes those in which the cellular elements are separated by a certain amount of intercellular matter. To this class belong those to which Johannes Müller gave the name "connective tissues." (In the earlier medical literature they had been called "cellular," that is, "areolar"; which indicates very definitely how the term "cell" had shifted its meaning.) To Virchow's third class belong the highly specialized tissues, under which class come the nervous and muscular systems, the vessels and the blood. In considering the physiology and pathology of the brain, we must take into account not only its nervous tissue, but its membranes, vessels, and interstitial substance. (We owe to Virchow the term "neuroglia," as well as "mycosis," "embolism," "arthritis deformans," "heterotopia," etc.). Similarly a long bone is to be regarded as an organ consisting of at least three tissues besides the osseous.

Do the general types established for the physiological tissues hold good for the pathological? Yes, every pathological structure has its physiological prototype. At times the new formation (neoplasm) corresponds to the type of tissue in which it occurs as a pathological phenomenon, as when a fatty tumor develops in adipose tissue. The neoplasm is then said to be homologous. In contrast with homology heterology is the occurrence of a new formation in a type of tissue from which it differs, as, for example, in fatty degeneration of muscular tissue, or amyloid degeneration of the kidneys. Pathological conditions may arise not only from the misplacing of tissues (heterotopia) but also from their retarded or premature development (heterochronia), as, for example, when bone is invaded by a cartilaginous tumor, and, lastly, from the mere variation of their quantity (heterometria). Under heterometria is included hyperplasia, involving an increase in the number of the cells. Hypertrophy may result merely from the enlargement of the individual cells, as, for example, in the enlargement of the hepatic cells in hypertrophy of the liver. Pathological states may be caused also by intracellular changes.

Virchow included in his "Cellular Pathology" the consideration of the diseases of the blood and the blood-vessels. He describes the minute crystals of haematoidin, discovered by him, and mentions their occurrence in the cicatrix following cerebral hæmorrhage. Leukæmia, first observed and named in 1845, is here spoken of as "a permanent, progressive leucocytosis." Virchow distinguishes it from pyæmia, notes the hæmorrhagic tendency associated with it, and connects it causally with the lymphatic glands and the spleen. Chlorosis, which usually involves imperfect development of the aorta, and frequently of the heart and sexual organs, is not to be confused with leukæmia. Perhaps, however, Virchow's greatest individual triumph in pathology was his doctrine of embolism, and the consequent clearing-up of the nature of thrombosis and phlebitis. Setting aside the speculations of the French pathologist Cruveilhier (1791–1873), with whom the idea of phlebitis had become almost an obsession, Virchow inquires in reference to the facts concerning the composition and the origin of the thrombus. Microscopic examination reveals that the coagulated mass consists of broken-down cells, of disintegrated fibrin, and of white and red blood-corpuscles undergoing disorganization, and, in the case of the last-named, in process of discoloration. Though it may look like pus, it should never be regarded as pus. The pathological condition begins with the coagulation, the formation of the thrombus in the blood. Virchow readily admits that at times phlebitis, as well as arteritis and endocarditis, may give rise to thrombosis; but real phlebitis is an inflammation of the walls, and not of the contents of the vein. Moreover, he finds that not infrequently the small branches of the peripheral veins become quite filled with masses of coagulum. The greater number of these thrombi become prolonged beyond the mouths of the branches, and greatly enlarged. From these prolonged thrombi particles (emboli) are carried along by the blood stream. Minute fragments may hence be wedged tightly into the nearest system of arteries or capillaries. "Thus we see that as a rule all the thrombi of the periphery of the body produce secondary obstructions and metastatic deposits in the lungs." It is also noted that embolism in certain cases occasions sudden occlusions of the vessels of the eye or brain.

To Johannes Müller, who had laid down the law of the correspondence between embryonic and pathological development, Virchow owed no doubt some of his interest in the pathology of the fœtus, in what he called "agenesia" (aplasia cerebri), as well as in allied subjects, such as the structure of the umbilical cord, and tubal pregnancy. Müller's histological study of tumors exerted a no less decisive influence on Virchow's uncompleted work of three volumes, "Die Krankhaften Geschwülste" (1863–67), one of his greatest contributions to pathology.

In this work is maintained the point of view of the Cellular Pathology. It must be ever realized, said Virchow, that tumors, whether they are parasitic in origin or not, are always portions of the body, and do not develop from some morbid humor of the organism, nor independently through some special force of their own substance. He held that tumors owe their origin as a rule to the less highly specialized tissues, to the connective tissue, and, more particularly, the epithelial. At one time he was inclined to trace the derivation of cancers to the mesoblast, but, probably influenced by investigators who thought these growths were also of epithelial origin, he left this part of his work unfinished. He gave the first description of hematoma of the dura mater, and of glioma.

Virchow was also the first to describe leontiasis ossea; he discovered the lymphatic sheaths of the cerebral arteries; in his doctor's thesis he treated the topic of the inflammation of the cornea (keratitis), and noted that wounds of the cornea repair without the presence of plastic exudations; he maintained that Peyer's patches are only lymphatic glands, and that in disease they play a part comparable with that of axillary and inguinal glands; he set forth in detail the pathology of syphilis; he investigated tuberculosis, and established the relation to it of lupus; and he explained the forms of parenchymatous inflammation. Virchow was not disdainful of therapeutics, and his attitude in this regard may have influenced his student Hoppe-Seyler, and others closely associated with him. He is also mentioned in connection with the investigation of septicæmia, leprosy, cholera, smallpox, diphtheria, pellagra, the pearly disease of cattle, Addison's disease, exophthalmic goitre, and cretinism. He was interested in the composition of adipocire. He was active in municipal, as well as national politics, and instituted in Berlin a system of sewage disposal and other sanitary reforms. In what was named, by him, the "Kulturkampf," he considered himself the champion of liberal culture against the forces of obscurantism. On the eve of the Franco-Prussian War he stood as the advocate of European disarmament, but during the conflict he took a very prominent part in the organization of the ambulance and hospital service. He also contributed to the improvement of civil hospitals and of nursing. Along with his varied pursuits he made extensive collections, labeling over twenty-three thousand specimens, which he presented to the Pathological Museum.

In the judgment of Virchow medicine as an applied science must rest on the firm basis of the natural sciences. At the same time he looked upon the classical literatures as the source of European culture. He encouraged the archæological researches of Schliemann, and in 1879 was with him in the Troas, and, nine years later, in Egypt, Nubia, and the Peloponnesus. Like von Baer he devoted a great deal of energy to the study of anthropology, particularly craniology. He followed the genetic method of seeking the explanation of things in their origins. He applied that method to the study of medicine. "For me," he said, "medicine does not begin to-day, and I hold it impossible to be completely at home in it, if one does not interpret it genetically." He was the first to write on the relation of medicine to the fine arts. Perhaps it was his sense of historical perspective that made him contemptuous of the trace of humoral pathology that survived in the teachings of the great Viennese pathologist Rokitansky, and made him at the same time distrustful of the doctrines of Darwin, of Koch and von Behring.

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CHAPTER XIV

THE INTRODUCTION OF ANÆSTHETICS

The title of Priestley's work, "Experiments and Observations on Different Kinds of Air" (1774, *et seq.*), gives some indication of how little was known concerning the chemistry of gases in the latter part of the eighteenth century. The composition of the atmosphere had remained undetermined; marsh gas, carbon dioxide, as well as oxygen, nitrogen, and hydrogen, were kinds of air. The names by which we know them had to wait upon their differentiation, upon their analysis, or upon the analysis of the compounds of which they formed parts, such as water, nitric acid and other acids. A great step forward was made when, on August 1, 1774, Priestley in an apparatus from which air was excluded ignited litharge by means of a burning-glass. He tested the *factitious air* thus obtained by placing in it a piece of lighted charcoal. In the belief that the supporter of combustion is also the supporter of life he put two mice into the newly isolated gas. He then inhaled some of the gas, and observed an exhilarating effect. "Who can tell," he writes, "but in time this pure air may become a fashionable article in luxury?

Hitherto only two mice and myself have had the privilege of breathing it."

Before the end of the century the investigations of Priestley, Scheele, and others inspired Dr. Thomas Beddoes to found in one of the suburbs of Bristol the Pneumatic Institution to carry on experiments, and to treat patients by means of the newly discovered factitious airs. This enterprise has been described as a scientific aberration, but Beddoes was fortunate in choosing as an assistant to superintend the experiments Humphry Davy, then (1798) nineteen years old. Davy experimented for months with nitrous oxide, which had been discovered some time previously and which in 1793 was produced by heating ammonium nitrate; that is, the process still in use to-day. The fact that it supports combustion like pure oxygen may have directed special attention to it, but it had been declared poisonous, and had even been described as the "principle of contagion." Davy, however, finally ventured on the crucial experiment of inhaling large quantities of the gas. After being subjected to nitrous oxide in an air-tight chamber for an hour and a quarter he inhaled twenty quarts of the pure gas.

"A thrilling," he says, in describing the experience, "extending from the chest to the extremities, was almost immediately produced. I felt a sense of tangible extension highly pleasurable in every limb; my visible impressions were dazzling, and apparently magnified; I heard every sound in the room, and was perfectly aware of my situation. By degrees, as the pleasurable sensations increased, I lost all connection with external things; trains of vivid visible images rapidly passed through my mind, and were connected with words in such a manner, as to produce perceptions perfectly novel. I existed in a world of newly connected and newly modified ideas: I theorized, I imagined that I made discoveries. When I was awakened from this semi-delirious trance by Dr. Kinglake, who took the bag from my mouth, indignation and pride were the first feelings produced by the sight of the persons about me. My emotions were enthusiastic and sublime, and for a minute I walked round the room perfectly regardless of what was said to me. As I recovered my former state of mind, I felt an inclination to communicate the discoveries I had made during the experiment. I endeavored to recall the ideas: they were feeble and indistinct; one collection of terms, however, presented itself; and with the most intense belief and prophetic manner, I exclaimed to Dr. Kinglake, '*Nothing exists but thoughts! The universe is composed of impressions, ideas, pleasures and pains!*'"

The discovery of the properties of "laughing gas" appealed to the popular imagination, and inhaling nitrous oxide became a regular form of entertainment. Davy, made famous by this and other brilliant discoveries, was appointed assistant lecturer in chemistry at the Royal Institution, London, where his youth, scientific acumen, and wonderful powers of expression soon drew upon him the attention of the fashionable world. In 1800, the year preceding his appointment at London, there appeared his "Researches, Chemical and Philosophical, chiefly concerning Nitrous Oxide," which sets forth the following conclusion: "As nitrous oxide in its extensive operation appears capable of destroying physical pain, it may probably be used with advantage during surgical operations in which no great effusion of blood takes place." Davy's suggestion led to no immediate effects in the practice of surgery. Between the years 1820 and 1828 Hickman, a young surgeon of Shropshire, England, excruciated by the sufferings of those upon whom he was called to operate, carried on a series of experiments on animals in order to discover a method of inducing insensibility to pain by means of inhalations. His early experiments were concerned with the study of asphyxiation, animals being rendered unconscious by enclosing them in glass and preventing the access of air or by exposing them to carbon dioxide prepared from calcium carbonate and sulphuric acid. Rebuffed by the profession in his own country, he succeeded in 1828 in having his methods of producing anæsthesia investigated by the Academy of Medicine in Paris. He failed to gain the approbation of that body, though there is evidence that by that time he was using nitrous oxide and that his claims were supported to some extent by the distinguished army-surgeon Baron Larrey. Ethyl ether was destined to be employed before nitrous oxide in surgical operations.

Ethyl ether had been described as a preparation before the middle of the sixteenth century. As an inhalation it was used in Birmingham, England, as early as 1785, in the treatment of asthma and other respiratory affections. Dr. John Collins Warren, of Boston, Massachusetts, employed it in 1805 in the treatment of the advanced stages of phthisis. In 1818 there appeared a brief article in the "Journal of Science and the Arts," London, containing the following statement: "When the vapour of ether mixed with common air is inhaled, it produces effects very similar to those occasioned by nitrous oxide." It had already evidently been considered a source of fun, for the writer, after describing the method of inhalation and the effects, gives expression to a warning, one gentleman after inhaling a large quantity having been thrown into a "lethargic state, which continued with occasional periods of intermission for more than thirty hours." This brief article, or note, was probably written by the celebrated chemist Michael Faraday, then a young man of twenty-seven acting as Davy's assistant at the Royal Institution.

In spite of the warning concerning its imprudent use, ethyl ether, like nitrous oxide, continued to furnish entertainment both in England and in the United States (where the anæsthetic effects of ether inhalation were soon recognized by Godman (1822) and other physicians). In 1839 at an "ether frolic" at Anderson, South Carolina, a colored boy, who had been forced to inhale a considerable amount of ether, after remaining unconscious for an hour, showed no subsequent ill effects. This may have encouraged the others. At all events, one of the young men present on that occasion became in 1842 a pupil of Dr. C. W. Long, of Jefferson, Georgia, and here the sport of inhaling ether was maintained. Dr. Long observed that he and the others did not experience pain from any blows and bruises they received while under the influence of the intoxicant. This led him to think it might be of value in surgery, and on March 30, 1842, he administered ether to James Venable and removed a small tumor from the patient's neck. Venable, the first person to undergo an operation under etherization, was somewhat addicted to inhalation as a pastime, and his bill from Long, which is still preserved, shows that ether with operation cost two dollars and ether without operation twenty-five cents. Dr. Long continued to use the anæsthetic in his limited country practice; but he did not publish an account of his experiences with it, and there is no evidence that he exerted any influence in bringing about the general use of ether in surgery.

Two or three years after this occurrence, an itinerant lecturer, G. Q. Colton, entertained an audience at New Haven, Connecticut, by a lecture on "Laughing Gas," demonstrating on a few of his hearers the effects of inhaling nitrous oxide. A young dentist, Dr. Horace Wells, who was among those present, made an observation — similar to Long's in the case of ethyl ether — that those exhilarated by the inhalation of laughing gas seem to experience no pain from even rather severe injuries. Impressed by this fact, and hoping to turn it to account in his practice, he determined to submit himself to a decisive test. Accordingly, on the day following the lecture, Wells had one of his own teeth extracted while under the influence of the anæsthetic administered by Colton. He felt no pain. Henceforth Wells made constant use of nitrous oxide in his practice as a dentist. He foresaw not only the part anæsthesia was to play in dentistry, but also its value to surgery in general. In the autumn of 1845 he visited Boston in order to direct the attention of the medical profession to the virtues of nitrous oxide. He seized an opportunity to give a demonstration before the Harvard Medical College; but on this public occasion he failed. At this time he was thrown in contact with Dr. Charles T. Jackson and with William T. G. Morton (1819–1868). Wells and Morton had been partners for a short time in Boston in 1843. They were both interested in a new method of making false teeth, and, therefore, had a special motive for discovering a means of painless extraction.

In 1844 Morton, without relinquishing his very lucrative practice as a dentist in Boston, had entered the office of Dr. Jackson as a student of medicine, and had matriculated at the Harvard Medical College. In that same year he had begun to experiment with ether as an anæsthetic. He continued his experiments, both on animals and human beings, in the summer of 1846. From Jackson he learned the different kinds and preparations of ether, the effects of the inhalations (as observed by his preceptor in the case of college students), and the necessity of making use of ether free from impurities. Finally Morton had the courage to try the effects of ethyl ether inhalation on himself, in September, 1846. He relates his experience in the following words: "I shut myself up in my room; seated myself in the operating chair and commenced inhaling. . . . It partially suffocated me but produced no decided effect. I then saturated my handkerchief and inhaled it from that. I looked at my watch and soon lost consciousness. As I recovered I felt a numbness in my limbs with a sensation like a nightmare and would have given the world for some one to come and arouse me. I thought for a moment I should die. . . . At length I felt a slight tingling of the blood in the end of my third finger, and made an effort to touch it with my thumb, but without success. . . . I pinched my thigh, but . . . sensation was imperfect. . . . I immediately looked at my watch. . . . I had been insensible between seven and eight minutes."

Before the end of the month, Morton, with characteristic boldness, made successful use of ether in extracting a tooth. The patient was given a handkerchief saturated with the anæsthetic, and was directed to inhale. He lapsed into unconsciousness almost immediately. A firmly rooted bicuspid was removed, and in about a minute the patient recovered consciousness. This was on September 30th. Within less than a week the enterprising Morton, then a young man of twenty-seven, called on Dr. Warren, senior surgeon of the Massachusetts General Hospital, told of his success, and asked for an opportunity to give a public demonstration of his method of rendering insensible to pain patients about to undergo surgical operations. He did not have to wait long for an invitation to be present at an operation, and to put his method to the test.

At the appointed time, ten o'clock on the morning of October 16, 1846, Morton was not present. This increased the skepticism of those assembled to witness the test, and raised a doubt in the minds of some concerning the good faith of the young dentist. Dr. Warren, the operating surgeon, seemed to share to some extent the general feeling of incredulity. Indeed, after waiting for a time, he was about to begin the operation without Morton's assistance when the latter appeared on the scene. He had been delayed in securing some apparatus he thought desirable in administering the ether, namely, an inhaler provided with a stop-cock and fitted into a glass vessel containing the ether. He now adjusted the apparatus, and in about three minutes the patient sank into a state of insensibility. The operator made an incision about three inches long in the neck, and proceeded to extirpate a tumor just below the jaw on the left side. The patient, when he recovered from the effects of the ether, said that he had suffered no pain during the operation, though he had had the feeling that a blunt instrument was passing roughly across his neck. Warren, as well as the others present, was convinced that Morton had made good his claim, though the patient soon after the first incision had begun to speak incoherently, and had appeared to give indications of suffering, his agitation continuing till the operation was over. On the following day Dr. Hayward removed a tumor from the arm of a woman while she was under the influence of the inhalation. In this case the anæsthetic was administered throughout the operation, and the patient remained unconscious except for a disagreeable dream toward the close. Morton's triumph was complete.

The use of ethyl ether as an anæsthetic soon gained the recognition it deserved. Every successful operation under etherization increased the confidence of the profession and strengthened the public faith in Morton's innovation. Three weeks after his first success with the anæsthetic, Dr. Hayward amputated a lower extremity above the knee, the patient remaining unconscious throughout the operation. The prestige of the Massachusetts General Hospital, and the support of such leaders in the medical world as Warren, Hayward, and Bigelow, account for the rapid headway of surgical anæsthesia throughout all civilized countries. Henry J. Bigelow, considered at that time one of the best surgeons in America, who had been appointed to the staff of the Massachusetts General Hospital and professor of surgery in the Harvard Medical College in the year of the great discovery, did his utmost to encourage Morton. As early as November 3d he read a paper dealing with the new anæsthetic before the Academy of Arts and Sciences. He published this paper in the "Boston Medical and Surgical Journal" November 18th. Three days later Dr. Oliver Wendell Holmes suggested the terms "anæsthesia" and "anæsthetic" in the sense in which they are still employed.

In the following weeks Bigelow carried a sample of ether to London, arriving in that metropolis December 17th. Two days later it was there used by a dentist in extracting a tooth, and on December 21st Robert Liston, the famous surgeon, employed it in an amputation of the thigh. Syme, his cousin and sometime partner, used it in his Edinburgh practice the following year. On January 19, 1847, Simpson, who had discussed with Liston in the preceding Christmas holidays the use of ethyl ether, led a notable advance by introducing the anæsthetic into the practice of midwifery. After several months, referring to his experience with ether, he wrote: "I have employed it with few and rare exceptions, in every case of labor that I have attended; and with the most delightful results. . . . I have never had the pleasure of watching over a series of better or more rapid recoveries; nor once witnessed any disagreeable result follow to either mother or child; whilst I have now seen an immense amount of maternal pain and agony saved by its employment." Among the European apostles of surgical anæsthesia must also be mentioned Pirogoff, the illustrious Russian military surgeon. It seems almost incredible that in the year following the use of ethyl ether for the first time in an American hospital he could have written his "Practical and Physiological Researches concerning Etherization." Two years later appeared a medical report of his experiences in the Caucasus containing interesting statistics of the results of amputating under the new conditions.

On November 4, 1847, Professor (later, Sir) James Young Simpson of Edinburgh [1] discovered the anæsthetic effects of chloroform on human beings. This compound had been discovered almost simultaneously, in 1831, by Guthrie in America, Liebig in Germany, and Soubeiran in France. In 1834 the great French chemist J. B. Dumas correctly described its composition and gave it the designation "chloroform." In the March preceding Simpson's discovery, its anæsthetic effects on lower animals had been recorded by the noted French

[1] "Chloric ether"— that is, an alcoholic solution of chloroform — had been tried by Morton before his success with ethyl ether. Warren had used "chloric ether" by preference after October 16, 1846. It had also been employed at St. Bartholomew's Hospital, London, in the summer of 1847.

physiologist Flourens. In his search for an anæsthetic inhalation less irritant than ethyl ether, Simpson had been advised to try chloroform ("perchloride of formyle") by Waldie, described as a chemist of Liverpool, but born, like Simpson himself, in the county of Linlithgow. Simpson, after examining with the assistance of his colleagues, Keith and Duncan, a great variety of chemicals in the hope of finding a substitute for ethyl ether, decided to put chloroform to the test. The three friends inhaled it one evening from tumblers in the dining-room of Simpson's home in Edinburgh. They became exhilarated, and the members of the household enjoyed the liveliness of the ensuing conversation. Then the three became suddenly insensible. Nothing daunted, however, by this first experience, they inhaled the chloroform repeatedly that same evening. Simpson's niece was inclined to try it also. Folding her arms across her breast and inhaling the chloroform, she fell asleep crying, "I'm an angel! Oh, I'm an angel!"

Within the following week Simpson tried the new anæsthetic on upwards of thirty people, using it in extracting teeth, opening abscesses, to annul the pain of dysmenorrhœa, neuralgia, etc. Moreover, he employed it with conspicuous success in obstetric practice. The lady to whom it was first administered in child-birth had previously been delivered in the country, after prolonged labor, only by sacrificing the life of the child. In this, her second confinement, she was worn by anxiety and sleeplessness, and pains supervened a fortnight before full time. Three hours and a half after the occurrence of the first pains, at the beginning of the first stage of parturition, she inhaled from a handkerchief on which a teaspoonful of chloroform had been poured. Ten or twelve minutes later a like amount was administered, and the child was born twenty-five minutes after the beginning of the first inhalations. The patient was not aroused by the crying of the child nor at the coming away of the placenta. When she did regain consciousness she remarked to Simpson that she had had a very comfortable sleep, that she had needed it having been so tired, but that she would now be able for the work before her. Simpson made no haste to set her right, and when the nurse came back into the room with the child, the mother could hardly believe it was her own living baby, as she said.

Before the middle of November chloroform was used as an anæsthetic in three operations at the Royal Infirmary of Edinburgh in the presence of Dumas, who chanced to be visiting Scotland at the time. The notes of the operating surgeon, Professor Miller, supply the following account of the first case. "A boy, four or five years old, with necrosis of one of the bones of the forearm. Could speak nothing but Gaelic. No means, consequently, of explaining to him what he was required to do. On holding a handkerchief, on which some chloroform had been sprinkled, to his face, he became frightened and wrestled to be away. He was held gently, however, by Dr. Simpson, and obliged to inhale. After a few inspirations he ceased to cry or move, and fell into a sound, snoring sleep. A deep incision was now made down to the diseased bone; and, by the use of the forceps, nearly the whole of the radius, in the state of sequestrum, was extracted. During this operation, and the subsequent examination of the wound by the finger, not the slightest evidence of the suffering of pain was given. He still slept on soundly, and was carried back to his ward in that state. Half an hour afterwards he was found in bed, like a child newly awakened from a refreshing sleep, with a clear, merry eye and placid expression of countenance. . . . On being questioned by a Gaelic interpreter who was found among the students, he stated that he had never felt any pain, and that he felt none now. On being shown his wounded arm, he looked much surprised, but neither cried nor otherwise expressed the slightest alarm."

In the other operations performed at the Royal Infirmary at this time Simpson made use of a hollow sponge in administering the anæsthetic. In one of these cases — a soldier who had an opening in the cheek, the result of exfoliation of the jaw — Miller recognized that it would have been impossible to employ any complicated inhaling apparatus applied to the mouth of the patient. In the other case Dr. Duncan operated on a young man suffering from necrosis of the first phalanx of the great toe and ulceration of the integuments. On November 15th Miller removed from a private patient an encysted tumor beneath the angle of the jaw. At that date Simpson had administered chloroform to fifty persons.

As the acknowledged champion of surgical anæsthesia he was very successful in meeting the arguments and beating down the prejudices of his opponents. Many of his contemporaries in Scotland and elsewhere considered pain as a punishment that should be received in a spirit of meekness, and the resort to anæsthetics seemed to them an impious attempt to thwart the divine will. Simpson was attacked from the pulpit and passages from the Bible were quoted to prove the wickedness of his undertakings. But he met arguments of this sort by appealing to the same authority. "My opponents forget," he said, "the twenty-first verse of the second chapter of Genesis; it is the record of the first surgical operation ever performed, and that text proves that the Maker of the universe, before he took the rib from Adam's side for the creation of Eve, caused a deep sleep to fall upon Adam." Enlightened clergymen gave him of course their support, and the opposition to the use of anaesthetics in midwifery, which had been particularly bitter — pointing to the wickedness of trying to remove a part of the primal curse on woman — broke down when Queen Victoria gave her countenance to the use of chloroform on the occasion of the birth of Prince Leopold in 1853.

Anæsthesia was not only, as it has been called, the death of pain; it did away to a considerable extent with shock, and, by obviating the necessity of great speed in the performance of operations, made the introduction of antiseptic methods possible. Before ethyl ether and chloroform came into use haste was one of the recognized criteria of good surgery. One reads of Cheselden performing a lithotomy in less than a minute; of Langenbeck, surgeon general of the Hanoverian army in the Napoleonic era, amputating a shoulder while one might take a pinch of snuff; of Sir William Fergusson, the founder of conservative surgery, who was at times so speedy that the onlookers had to keep on the alert for fear of missing the whole operation through one moment's inattention; of Pirogoff, who was so rapid and dexterous in the use of the knife as to challenge comparison with a sleight-of-hand artist. When, on

December 21, 1846, an anæsthetic was first used in England in a major operation, the surgeon, Robert Liston, proceeded as expeditiously as usual, removing the limb of the patient at the thigh in twenty-five seconds, according to the statement of the dresser. Among the onlookers on this occasion at the University College Hospital, London, was a young student of nineteen still working for his degree in arts, Joseph Lister, whose contributions to surgery about twenty years later were no less the consequence of the introduction of anæsthesia than of the development of bacteriology.

Within those twenty years the study of anæsthetics continued to advance. Ethyl chloride, the anæsthetic effects of which on animals had been reported by Flourens in 1847, was tried in surgery in 1848. Improved methods of administration arose from the work of John Snow who invented an inhaler in 1847 and published the results of his various experiments in 1858. His successor, J. T. Clover, invented his chloroform inhaler in 1862. This was followed by the Junker inhaler in 1867. Nunneley investigated in 1849, and the years following, the anæsthetic properties of carbon dioxide, ethyl bromide, and other compounds. In 1853 Alexander Wood invented the hypodermic syringe and thus prepared the way for the triumphs of local anæsthesia; while in 1866 Sir Benjamin Richardson added to his numerous contributions to anæsthesia the use of the ether spray. In 1864 a committee of the Royal Medical and Chirurgical Society recommended the mixture of alcohol, chloroform, and ether first used by Harley. In the years following 1863 the use of nitrous oxide, which had been allowed to lapse after the death of Horace Wells in 1848, was greatly stimulated through the advocacy of Colton both in America and Europe; and in 1868 Edmund Andrews proved that the anæsthetic effects of nitrous oxide do not depend on partial asphyxiation. He thus cleared up a misconception of long standing. His mixture of oxygen and nitrous oxide gave very satisfactory results.

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CHAPTER XV

THE THEORY OF ORGANIC EVOLUTION

WHEN Charles Darwin, in October, 1836, returned to England from his voyage round the world, which had occupied nearly five years, he had arrived at no theory concerning the origin of species. In 1837, however, he made the following note: "In July opened first note-book on Transmutation of Species. Had been greatly struck from about the month of previous March on character of South American fossils, and species on Galapagos Archipelago. These facts (especially latter) origin of all my views." In the months intervening between October, 1836, and July, 1837, he had been thrown into close contact with the great geologist Sir Charles Lyell, the champion of the uniformitarian doctrine.

This doctrine, that the changes that have taken place in the earth's crust in the past were owing to agencies still in operation, had been splendidly stated by the Scotch geologist James Hutton in 1785. Hutton's views, however, had been ignored by some scientists, and decried by others because of their alleged anti-religious tendency. The hostility to Hutton's teaching in 1822 was thus expressed by one of the leading English geologists, who was willing to concede some recognition to the facts gathered by the Scotch geologist in reference to granite and other rocks: "The wildness of his theoretical views, however, went far to counterbalance the utility of the additional facts which he collected from observation. He who could perceive in geology nothing but the *ordinary* operation of actual causes, carried on in the same manner through infinite ages, without the trace of a beginning or the prospect of an end, must have surveyed them through the medium of a preconceived hypothesis alone." Professor Sedgwick, under whom Darwin had studied geology at Cambridge, in a similar vein eloquently denounced the unscriptural tenets of Hutton and Hutton's disciples. Both Sedgwick and Henslow, the botanist, Darwin's chief masters at Cambridge, were clergymen, and Darwin, till the time of his appointment as naturalist to the Beagle expedition, planned to take orders ultimately in the Established Church of England.

Sir Charles Lyell (1797–1875) had been an early convert to the uniformitarian view, but fully conscious of the strength of the opposition, and naturally kindly and sympathetic as regards the opinions of his intellectual inferiors, his public utterances were of the most tactful sort. A careful study of Gibbon had convinced him that the frontal attack is not the most effective method of combating religious prejudice, and had helped him to develop further a pleasing style of composition, which an early acquaintance with the classics and the constant example of a father of scholarly tastes had already made second nature. At the age of twenty he observed on the coast of East Anglia the action of the sea in the formation of new land as well as in the wearing down of the cliffs; and in the following years he found abundant evidence in his native Forfarshire, in the action of rain and rivers and the formation of limestone, that all observable changes in the earth's crust were not owing to the Noachian deluge.

By 1825 Lyell was a convinced uniformitarian, and was considering how he could express his convictions without rousing unnecessary opposition and without giving offence to his older contemporaries. In 1827 he had completed the first sketch of his Principles of Geology, and two years later, in preparing the book for the press, he made a preliminary statement, in a letter to a friend, of his doctrine "that *no causes whatever* have from the earliest time to which we can look back to the present, ever acted, but those that are *now acting*, and that they never acted with different degrees of energy from that which they now exert." The first volume appeared in 1830 with the subtitle "An Attempt to Explain the Former Changes of the

Earth's Surface by Reference to Causes now in Operation." Lyell was not oblivious to the logical outcome of applying the uniformitarian doctrine to the study of the organic world, and when Sedgwick and others charged him with holding that the creation of new species is going on at the present day he readily admitted it. He thought it impossible that any one should read his work without perceiving that the notion of uniformity in the existing causes of change implies that "they must for ever produce an endless variety of effects, *both in the animate and inanimate world.*"

When Darwin was leaving England in 1831 the extremely orthodox Henslow advised him to take Lyell's first volume with him, but to pay no attention to it, except in regard to facts, for it was altogether wild as far as theory goes. Needless to say it made a very deep impression on the mind of the young naturalist. Lyell's second volume appeared in 1832, and a copy of it was sent to Darwin at Montevideo. This second volume was full of facts concerning variations, hybridism, and the struggle for existence; and it no doubt had a great effect on Darwin's subsequent observations and on his maturer generalizations. In fact, in dedicating the second edition of "A Naturalist's Voyage" to Lyell the author with characteristic generosity writes: "This edition is dedicated with grateful pleasure as an acknowledgment that the chief part of whatever scientific merit this journal and the other works of the author may possess, has been derived from studying the well-known and admirable 'Principles of Geology.'"

Darwin was very slow and systematic in arriving at his generalizations. Soon after he began to collect data relating to the transmutation of species, he turned particular attention to the different species and varieties of plants and animals under domestication, and to the success of the horticulturist and the breeder attained by a careful selection of certain strains for purposes of propagation. Admitting that species might arise in nature by the perpetuation of chance variations he was at a loss to discover any causative influence corresponding to what he saw at work in the improvement of domestic plants and animals. In the autumn of 1838 he read Malthus's "Essay on Population," which developed the teaching that it is a constant tendency among all living things to increase more rapidly than the means of subsistence; the resultant disproportion between the two rates of increase was the occasion of wars, vice, and misery. The idea flashed into Darwin's mind of a *natural selection*, comparable in its effects to the *artificial selection* he had noted in his study of the improvement of cultivated plants and domesticated animals. Natural selection might occur in such hard conditions as would cause organisms to compete with one another for their very existence. It occurred to Darwin that under these circumstances "favorable variations would tend to be preserved, and unfavorable ones to be destroyed. The result of this would be the formation of new species. Here, then, I had a theory by which to work."

He deliberately refrained from making a written statement of his own views till 1842, when he wrote out a sketch, which he expanded two years later to a manuscript of 231 folio pages. He explained his theory in a letter to the American botanist Asa Gray in 1857. He stated that his belief that species have really changed depended "on general facts in the affinities, embryology, rudimentary organs, geological history, and geographical distribution of organic beings." He maintained that if such a selective agency as has developed our breeds of domestic animals, had, during the long ages revealed by the study of geology, exerted an influence on the organic world in general, it would have produced the miracles of design and adjustment in plants and animals that had hitherto baffled his powers of explanation. Such an agency he now finds in natural selection. He mentions also the slowness of the changes in species, the struggle for life, and the spontaneous occurrence of favorable variations.

Darwin had begun, in this year, at the urgent request of Lyell, who feared the new theory might be forestalled by some other naturalist, the composition of a treatise. When he had written about a half of it, he received a manuscript from Alfred Russel Wallace setting forth a theory almost identical with his own.

Wallace's experience had corresponded in different respects with Darwin's. He had spent many years in scientific exploration in South America and in the Malay Archipelago; he had come under the influence of Lyell; he had long considered the problem of the origin of species; and he had finally been led to a solution by Malthus's "Essay on Population." He had learned from the "Principles of Geology" that the inorganic world was and always had been in a continual state of slow modification. Consequently forms of life must have become modified and constantly adjusted to the new conditions in order to survive. The slowness of the changes revealed by the examination of fossils was such as to afford opportunity for the continuous automatic adjustment of organic beings to the inorganic environment. In 1855 he arrived at the conclusion that each species has come into existence in the same environment as a closely allied species and in succession to it. This indicated the fact of evolution, but failed to explain the process. "In February, 1858," he writes, "I was suffering with a rather severe attack of intermittent fever at Ternate, in the Moluccas; and one day, while lying on my bed during the cold fit, wrapped in blankets, though the thermometer was at 88 Fahr., the problem again presented itself to me, and led me to think of the 'positive checks' described by Malthus in his 'Essay on Population,' a work I had read several years before, and which had made a deep and permanent impression on my mind. These checks — war, disease, famine, and the like — must, it occurred to me, act on animals as well as man. Then I thought of the enormously rapid multiplication of animals, causing these checks to be much more effective in them than in the case of man; and while pondering vaguely on this fact, there suddenly flashed upon me the *idea* of the survival of the fittest — that the individuals removed by these checks must be on the whole inferior to those that survived. In the two hours that elapsed before my ague fit was over, I had thought out almost the whole of the theory; and the same evening I sketched the draught of my paper, and in the two succeeding evenings wrote it out in full, and sent it by the next post to Mr. Darwin."

In the "Origin of Species" (1859), which the majority of scientists regard as exerting a greater influence on the development of ideas than any other book produced in the nineteenth century, Darwin turns his attention first to the occurrence of variation under domestication. He is not, as has been supposed by some of his critics, unaware of the occasional occurrence of sudden deviations from the parental type, such as in the well-known case of ancon sheep, to which he makes reference. He also speaks of sporting plants, and recognizes that a seedling may exhibit remarkable deviation from type. But his main concern here is with those slight variations of which the horticulturist takes advantage in the improvement of cultivated plants, and which afford the material that enables the breeder of horses, or cattle, or dogs to produce such distinct types of domestic animals. He was reluctantly inclined to believe that all the different breeds of horses were derived from one wild stock. Domestic dogs on the other hand he thought had probably descended from several wild species, though one could not think that a parent type at all resembling the Italian greyhound, the Blenheim spaniel, the bull-dog, the bloodhound, etc., had ever existed freely in a state of nature. Many of the remarkable breeds and varieties are of course undergoing constant modification through a purposeful process of artificial selection.

Darwin made a particularly close study of the breeds and sub-breeds of pigeons, keeping every breed he could purchase or otherwise obtain, securing specimens of skins from India and Persia, consulting eminent pigeon-fanciers, and noting the references to domestic pigeons in the ancient literatures. He was convinced that the English carrier, the tumbler, the runt, the barb, the pouter, the turbit, the Jacobin, the trumpeter, the laugher, the fantail, etc., all draw their descent from the rock-pigeon (*Columba livia*). When two birds belonging to two distinct domestic breeds are crossed the mongrel offspring are liable to show the characteristic color and markings of the ancestral rock-pigeon. "I crossed," writes Darwin, "some uniformly white fantails with some uniformly black barbs, and they produced mottled brown and black birds; these I again crossed together, and one grandchild of the pure white fantail and pure black barb was of as beautiful a blue colour, with the white rump, double black wing-bar, and barred and white-edged tail-feathers, as any wild rock-pigeon!" In spite of their common ancestry the breeds are so different among themselves that an ornithologist seeing them for the first time would describe them as belonging to well-defined species, the differentiation depending not only on their general appearance, but on the character of their voice and disposition, on the shape and size of their eggs, and on their anatomical structure, for example, the shape of the skull, the number of the ribs, and the number of the caudal and sacral vertebrae. How have these differences been established? By accumulative artificial selection, the pigeon-fancier retaining for breeding purposes the birds that showed certain desirable characteristics. "Some variations useful to him have probably arisen suddenly, or by one step." But in general the variations put at the disposal of man's choice have been limited in range, and the development of new breeds has, consequently, been a slow process. Of this fundamental part of his theory, so directly an outcome of the personal observations of an Englishman of Darwin's class and associations, he gave a fuller treatment in a later work — "The Variation of Animals and Plants under Domestication" (1868).

"Why if man can by patience select variations most useful to himself, should nature fail in selecting variations useful, under changing conditions of life, to her living products?" Even in the same species no two individuals are cast in precisely the same mould. This holds true of plants and animals in a state of nature as in those under domestication. Owing to the struggle for life, the fierceness of which had in Darwin's judgment not been fully appreciated by Lyell and others who had treated of it, any variation, however slight, in any degree profitable to the individual, "will tend to the preservation of that individual, and will generally be inherited by his offspring. The offspring, also, will thus have a better chance of surviving, for, of the many individuals of any species which are periodically born, but a small number can survive. I have called this principle, by which each slight variation, if useful, is preserved, by the term of Natural Selection, in order to mark its relation to man's power of selection." This process of natural selection Darwin considered the main but not the exclusive means of modification.

What are the proofs that the one million and more living species now found on the earth owe their origin to development from other species, that is, to Evolution, rather than to acts of Special Creation? Darwin helps us to answer this question by indicating that in spite of the incompleteness of the geological record it is evident that all extinct organic beings fall into the same system with living beings, and that a continuity may be observed to exist between classes of extinct and classes of living plants and animals, as, for example, between the fossil and the recent marsupials of Australia, and between the fossil and the recent edentata of America. The facts of geographical distribution prove that, besides this succession or continuity in time, there is between like groups of living beings a degree of contiguity in space. Just so far as they are not liable to the invasion of plants and animals continents have their own characteristic faunas and floras. The species of oceanic islands are related to the species of that mainland from which they are most accessible to the immigration of plants and animals. In addition to the lines of proof suggested by the facts of geological succession and geographical distribution Darwin points out the interrelationship of all organic beings. This is the argument from classification.

On this subject he writes as follows: "It is a truly wonderful fact — the wonder of which we are apt to overlook from familiarity — that all animals and all plants throughout all time and space should be related to each other in group subordinate to group, in the manner which we everywhere behold — namely, varieties of the same species most closely related together, species of the same genus less closely and unequally related together, forming sections and sub-genera, species of distinct genera much less closely related, and genera related in different degrees, forming sub-families, families, orders, sub-classes, and classes. . . . On the view that each species has been independently created, I can see no explanation of this great fact; but, to the best of my judgment, it is explained through inheritance and the complex action of natural selection, entailing extinction and divergence of character." Moreover, the doctrine of common inheritance enables us to explain the likenesses among organisms revealed by the study of rudimentary organs, embryology, and morphology in general.

It is with the consideration of these likenesses that Darwin begins his volume on "The Descent of Man" (1871), which undertakes to make good the prediction contained in the "Origin of Species" that through the principles laid down in that work light would be thrown on the origin of man and his history. The general anatomical structure of man is analogous to that of other mammals. The human skeleton may be compared bone for bone with the skeleton of the monkey, bat, or seal. The "Origin of Species" had mentioned the structural resemblance of the hand of man, the wing of the bat, the fin of the porpoise, and the leg of the horse, as well as the likeness in the number of cervical vertebræ of creatures so different as the elephant and the giraffe. A similar correspondence is found in the muscles, blood-vessels, viscera, and nerves of man and the lower mammalia. The chief fissures and convolutions of the human brain are comparable to those in the brain of the orang-outang. Moreover, the fact that man is liable to certain communicable and incommunicable diseases that affect the lower animals seemed to Darwin to indicate a close similarity of tissues and blood.

Embryonic development begins in man as in the lower animals with the ovum. In the human embryo the arteries run in arch-like branches as in animals with functioning gills; the heart exists as a simple pulsating vessel; the os coccyx projects like a true tail. "In the embryos of all air-breathing vertebrates, certain glands, called the corpora Wolffiana, correspond with and act like the kidneys of mature fishes." The convolutions in the brain of the human fœtus at the end of the seventh month correspond in their development to those of the adult baboon. In the embryo the great toe is shorter than the other toes, and projects at an angle from the side of the foot, as in the adult simian. In 1859 Darwin had explained the similarity of the embryonic forms of mammals, birds, and reptiles on the principle of common ancestry.

The study of rudimentary organs, vestigial structures, arrested developments, and reversions, furnished Darwin with further evidence of man's humble origin. In this connection he mentions the vermiform appendix, the os coccyx and *filum terminale*, traces of a supra-condyloid and an inter-condyloid foramen, the mammæ of males (sometimes fully developed and functioning), supernumerary mammæ, the nictitating membrane, cleft-palate, and the imperfectly developed wisdom-teeth. As regards the canine teeth he cites Haeckel's observation that in every large collection of human skulls some may be found with the canine teeth projecting considerably beyond the others as in the anthropomorphous apes, but in a less degree. "He," writes Darwin, "who rejects with scorn the belief that the shape of his own canines, and their occasional great development in other men, are due to our early forefathers having been provided with these formidable weapons, will probably reveal by sneering, the line of his descent. For though he no longer intends, nor has the power, to use these teeth as weapons, he will unconsciously retract his 'snarling muscles' (thus named by Sir C. Bell), so as to expose them ready for action, like a dog prepared to fight." (At the time Darwin wrote this passage — rather exceptional in its tone — he was planning to publish his work "The Expression of the Emotions in Man and Animals," a subject suggested to him by Bell's work "Anatomy of Expression.")

The *panniculus carnosus*, and the structures associated in the same system with it, especially the functionless muscles of the ear, are not overlooked by Darwin. The frequency of deviations from the so-called "normal" musculature is a commonplace observation in every dissecting room. One anatomist has recorded two hundred and ninety-five muscular variations in thirty-six subjects. Many muscles found occasionally in the human subject correspond to muscles usually found in monkeys and other mammals. Darwin's tubercle, malformations of the external ear, the arrested brain-development of idiots, the persistence and distribution of hair, support the evidence afforded by the muscles, teeth, etc. Moreover, monstrosities are "so similar in man and the lower animals, that the same classification and the same terms can be used for both, as has been shown by Isidore Geoffroy St. Hilaire."

A great deal of space in "The Descent of Man" is given to the development of the intellectual and moral processes in man and the lower animals, and, as we have seen in a previous chapter, to a consideration of secondary sexual characters. Darwin thus affords a biological basis for the psychology of the cognitions, volitions, and emotions. Into the choice of a mate, influenced by voice, brilliant plumage, and other secondary sexual characters, a conscious — æsthetic — element enters. Since sexual selection involves consciousness, it may be viewed in relation to artificial selection; in fact, sexual selection as between man and woman is a matter of artificial selection. Therefore it is not surprising that Darwin should reach the following conclusion: "Man scans with scrupulous care the character and pedigree of his horses, cattle, and dogs before he matches them; but when he comes to his own marriage he rarely or never takes any such care. He is impelled by nearly the same motives as the lower animals, when they are left to their own free choice, though he is in so far superior to them that he highly values mental charms and virtues. On the other hand he is strongly attracted by mere wealth or rank. Yet he might by selection do something not only for the bodily constitution and frame of his offspring, but for their intellectual and moral qualities. Both sexes ought to refrain from marriage if they are in any marked degree inferior in body or mind; but such hopes are Utopian and will never be even partially realized until the laws of inheritance are thoroughly known."

Darwin's doctrine of pangenesis (1868), which he put forward as a tentative hypothesis which could be given up as soon as any better might be found, has been described by Weismann (1834–1914), the spokesman of the Neo-Darwinians, as the first theory of heredity worthy of the name. Weismann's own theory of the continuity of the germplasm (1885) was anticipated to some extent by Francis Galton in the year following the appearance of "The Descent of Man." Haeckel, another early German disciple of Darwin, speaks of the English naturalist's influence in every branch of biology, especially in comparative anatomy and ontogeny, and in zoölogical and botanical classification. It was indeed revolutionary. "Darwin's extraordinary marshalling of facts," says Garrison, "in evidence of the survival of the fittest by natural selection in the struggle for existence, had the same far-reaching influence upon biological speculation that the discoveries of Copernicus had upon astronomy. . . . It created the sciences of comparative physiology and pathology, by pointing to the close structural and functional relationship between human tissues and those of animals and plants."

It is important that the student of medicine should recognize that many problems concerning the relation of inheritance to pathology still await solution. How shall we explain the facts of hereditary immunity, such as Darwin noted in negroes as regards malaria and yellow fever, or such as have been observed in individuals in epidemics of cholera and other deadly diseases? How shall we account for the transmission of familial diseases like Friedreich's ataxia, or of such hereditary defects as hæmophilia, color-blindness, deaf-mutism, and polydactylism? Has pathology solved the problems of hereditary predispositions and diatheses? What vestigial structures are pathogenic? What diseases or malformations have resulted from the assumption of the erect posture?

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CHAPTER XVI

THE FOUNDERS OF BACTERIOLOGY

In 1820 Ozanam, a French historian of epidemic and infectious diseases, wrote that many writers had dealt with the animal nature of infectious materials. Several had maintained not only that these develop from animal substance but that they are themselves organic and living beings. Varro, Columella, Lucretius, Father Kircher, Lancisi, Vallisneri, Réaumur, Christ, Long, Plenciz, Menuret, Rasori, and others had supported this view. Frémont had maintained that infectious materials arise and develop in the body through fermentation. "I will not waste time," adds Ozanam, "in refuting these absurd hypotheses."

Leeuwenhoek, by means of an excellent lens, ground and mounted by himself, had observed bacteria as early as 1683. In 1701 Nicolas Andry expressed the conviction that air, water, vinegar, fermenting wine, beer, cider, and sour milk are full of germs; that germs exist also in blood, urine, and the pustules of smallpox patients; and that mercury cures venereal disease because it kills the invisible pathogenic organisms. By the year 1726 the doctrine of the causal relationship between micro-organisms and disease was so notorious as to be made the subject of a French satire ("Système d'un médecin anglais sur la cause de toutes les espèces de maladies"), in which the fainter, the belly-nipper, etc., were playfully described.

More serious attempts at classification appeared before the close of the eighteenth century. Linnæus, in the last edition of his "Systema Naturæ" (1768), classed bacteria along with other microscopic forms in the category "chaos." In spite of his distrust of the observations of the microscopists, however, he recognized that organic beings might be the cause of fevers, venereal lües, and exanthemata. In fact, in an earlier work he had expressed the belief that parasites cause measles, dysentery, plague, small-pox, etc. In 1786 was published the "Animalcula infusoria fluviatilia et marina" of Otto Friedrich Müller, of Copenhagen, who under the general name of "infusoria" sought to classify, according to form, movement, and habitat, the microscopic beings so inadequately treated by Linnæus. Müller made use of the terms "monas," "bacillus," "vibrio" "spirillum"; though he laid the chief emphasis on differences of form, he noted the serpentine and other movements characteristic of some kinds, and the inclination of others to form filaments, pellicles, and clusters, and, above all, he furnished well-executed illustrations of the organisms he had observed.

For a considerable time, however, the attention of biologists was fixed on the problem of the origin of the infusoria rather than on that of their classification. Were they produced by other living beings like themselves, or did they arise from inorganic substances by spontaneous generation? As regards creatures visible to the naked eye the Italian physician Francesco Redi had settled the question of spontaneous generation by his experiments on the putrefaction of meat in 1668. The discovery of micro-organisms, however, revived the hopes of the opposition. By some they were regarded as the beginnings of life, the link between the organic and the inorganic. In 1745 Needham, an English priest living on the Continent, reported an experiment that seemed to support the doctrine of spontaneous generation. He had boiled meat juice in bottles, which he had then carefully sealed; nevertheless, after some time, animalcula were observed to have developed in great numbers within the closed bottles.

Bonnet indicated two lines of attack on the conclusiveness of this experiment: creatures so minute as infusoria might find their way into even carefully sealed bottles; and it was possible a few living forms might survive within the bottles even after the contents had been boiled. These purely theoretical criticisms were supported by the experiments of Spallanzani (1729–99), one of the most distinguished experimenters of the eighteenth century. In the particular experiments in question he made use of flasks which could be sealed hermetically. If it were true, he argued, that living organisms could be found in preparations that had been boiled in vessels from which the outside air was excluded, then they must have arisen from germs or eggs on the sides of the container, in the decoction, or in the air within the container. He heated his flasks in the fire, poured into them well boiled meat and seeds, and sealed the flasks hermetically. Notwithstanding this procedure, living infusoria were present in the flasks after a few days. He now supposed that some germs might have remained alive in the air contained in the flasks. Therefore, he next poured nineteen different infusions into as many flasks, sealed the flasks, and allowed them to stand for an hour in a large vessel of boiling water. Microscopic examination of the contents of the nineteen flasks failed subsequently to reveal the presence of any living organism. Other experiments showed that if a flask were slightly cracked the air might penetrate to the contents bearing with it the living germs. These experiments were reported in 1767. It is upon the principles thus established by Spallanzani that modern canning industries are based.

Two objections were raised against his experiments — that an insufficient quantity of air had been allowed for the support of life in the infusoria, and that the conditions of the experiments had robbed the air of its life-supporting quality. In 1836 Franz Schulze tried to meet these criticisms by filtering the air in a flask (containing an infusion) through concentrated sulphuric acid. He renewed the air in this way for over two months. The infusion remained free from micro-organisms. When at the end of that time, however, unfiltered air was admitted to the infusion, various living forms developed. In 1837 Schwann used molten metal or a spirit flame for the same purpose as the concentrated sulphuric acid served in Schulze's experiment. Both Schulze and Schwann were open to the criticism of having subjected the air to vitiating influences. In 1854, however, Schröder and von Dusch showed that a thick layer of cotton wadding sufficed to exclude all germs, while permitting free access of air. In 1861 Pasteur found an even simpler means of excluding germs while freely admitting air. The infusion was placed in a flask the neck of which terminated in a long stem, curved down and then up somewhat like the letter "S." This stem was left open, and the outside air allowed to enter. After the infusion in the flask had been boiled, the germs from the outside air would at first be killed by the steam, while, later, as the apparatus cooled, such germs as found their way into the end of the open stem would be arrested in its curves.

It was urged by Pasteur's opponents that if alterations occurring in infusions, after they had been duly boiled, were brought about solely through the agency of germs in the air, then these germs must everywhere be present in great abundance and variety. Pasteur replied that they were much more abundant in some localities than in others, and he proceeded to secure experimental proof of his contention. He filled a large number of flasks with infusion, heated them to the boiling point, and then hermetically sealed them. He opened twenty of these flasks, sealing them again immediately, at the foot of the Jural Alps; twenty others at an altitude of eight hundred and fifty meters above sea-level; and an additional twenty at an altitude of two thousand meters. On examining the contents of these sixty flasks after some days, it was found that eight out of the first twenty, five out of the second twenty, and only one out of the third twenty showed the presence of microscopic beings. Other objections to his doctrine of biogenesis he proved to be based on careless experimentation. "No," he said at the end of his communication to the Académie des Sciences in 1864, "there is no circumstance known to-day that permits us to assert that microscopic beings have come into the world without germs, without parents similar to themselves."

Several years before the final overthrow of the theory of spontaneous generation, Pasteur had demonstrated the part played by germs in various kinds of fermentation. We have seen in previous chapters that an analogy had been traced by the predecessors of Rhazes between fermentation and at least one form of disease, and that a like comparison was familiar in the time of Sydenham. Robert Boyle had declared that "He that thoroughly understands the nature of ferments and fermentations shall probably be much better able than he that ignores them to give a fair account of divers phenomena of certain diseases (as well fevers as others) which will perhaps be never properly understood without an insight into the doctrine of fermentations." In 1836 Cagniard de la Tour, the French physicist, observed that yeast plays a part in alcoholic fermentation, that it seems to be a living plant, and that its growth keeps pace with the process of fermentation. About the same time Schwann arrived independently at like conclusions.

Pasteur was interested in 1856 in fermentation in connection with the manufacture of beetroot alcohol, and examined the globules of the ferment by means of the microscope. In the years following he succeeded in showing that lactic (1857), tartaric (1858), butyric (1861), and acetic (1862) fermentations depend likewise on the presence of definite living organisms. For example, if *Penicillium glaucum* grows in a racemate solution, the solution gradually becomes lævo-tartaric. (Pasteur's masterly analysis of racemic acid into dextro-tartaric and lævo-tartaric laid the foundation-stone of stereo-chemistry in 1848.) In his study of the different kinds of fermentation Pasteur first determined in which constituent of the fermentable substance the characteristic change occurred. In the second place he studied under the microscope such organisms as invariably accompanied the fermentation in question. He then made a solution of the fermentable constituent, added such ingredients as he conceived necessary for the growth of the organism, boiled the solution so as to render it free of germs, and placed in the solution thus prepared a trace of the essential ferment. In this way he put to the test his hypotheses concerning the organic causes of fermentation. The cause of butyric fermentation he found to be a micro-organism that could live only in the absence of oxygen, in fact, an anaërobic vibrio. Pasteur followed up these studies of fermentation by investigating the ammoniacal decomposition of urine and the part played in so-called putrefaction by micro-organisms.

He now turned his attention to the diseases of wine. He soon found that wine becomes sour through the activity of *Mycoderma aceti*, the presence of which is betrayed by the appearance of a pellicle on the surface of the liquor, that the bitterness of wine is owing to an organism that shows under the microscope branching and twisted filaments, while the turning and ropiness of wine result from the development of other micro-organisms.

At the time of these investigations Pasteur had become fully conscious of his purpose to arrive, as he expressed it to the Emperor in 1863, at the knowledge of the causes of putrid and contagious diseases. After treating what he called the spontaneous alterations or diseases of wines, he undertook, at the urgent request of Dumas (now a Senator and particularly influential in the Ministry of Agriculture), to investigate the diseases of silkworms. In 1836 Bassi had made the remarkable discovery that one communicable disease of silkworms, muscardine, is caused by a fungus, the minute spores of which are transferred from the diseased to the healthy worms through the atmosphere or by actual contact. In 1857 Naegeli had described the micro-organism of the disease, *pébrine*, that Pasteur was now especially called upon to investigate. After five years of arduous labor Pasteur succeeded in tracing out the history of this infection, devised means of eradicating it, and discovered the cause of a second disease of silkworms, *flacherie*, which he ascribed to an organism that developed in the intestinal canal of the worm.

In 1871 he resumed his study of alcoholic beverages, and undertook to discover the causes of the diseases of beer. Why does it become thick, sour, slimy, or putrid? He came to the conclusion that every "marked alteration in the quality of beer coincides with the development of micro-organisms foreign to the nature of true beer yeast." Beer is unalterable so long as it contains no living germs; disease ferments will not develop in bottled beer after being heated to a temperature of from 50° to 55° C. When, says Pasteur, we see beer and wine undergo marked alterations because they harbor micro-organisms, which gain an entrance unnoticed and then increase enormously in numbers, we must be convinced that similar experiences must befall in the case of the lower animals and of man.

A number of important advances in bacteriology prepared the way for Pasteur's study of anthrax in 1877. The *Bacillus anthracis* was observed as a little rod-like structure in the blood of animals that had died of anthrax, or splenic fever, by Delafond in 1838. In 1850 a like observation was made by Davaine (as well as by Rayer), who came to recognize the importance of the discovery only after reading Pasteur's paper on butyric fermentation. In 1863 he inoculated some rabbits with the blood of a sheep that had died of anthrax, and upon the death of the inoculated animals concluded that they also had succumbed to anthrax. In that same year Delafond studied the organisms under a watch glass, saw the little rods grow into filaments, and attempted to discover "the mechanism of fructification." Even before the observations of Davaine and Rayer, Pollender had observed the bacillus in the blood of cows that had died of anthrax (1849). Important as are these observations of this pathogenic micro-organism, the cause of widespread infection, they are less deserving of emphasis in the history of bacteriology than the achievements of Ferdinand Cohn (1828–98) and of Robert Koch.

Cohn's discovery, in 1857, of the sporulation of microscopic organisms led to the clearing up of a number of difficulties, such as the persistence of living forms in infusions of hay, milk, and cheese, which had baffled experimenters from the time of Spallanzani. Cohn's researches concerning bacteria furnished a system of classification, which, retaining what was of value in earlier systems — such as the Hallier's concept of the micrococcus and Ehrenberg's concept of the spirillum and the spirochæta — still dominates to-day the grouping and the nomenclature of schizomycetes. Cohn recognized that all bacteria are plants. He classified the micrococci as chromogenic, zymogenic, and pathogenic. Among the bacilli he mentioned of course the bacillus anthracis. He showed, moreover, by striking calculations the marvelously rapid increase of bacteria under conditions favorable to their development, and thus drew attention to the part they play in the struggle for existence. In 1876 he observed the germination of the spores of certain bacteria. In April the same year Koch announced to Cohn the results of his study of the anthrax bacillus. To this brilliant investigation and to Koch's other achievements we shall return presently.

At the beginning of 1877 the French physiologist Paul Bert maintained that by the use of compressed oxygen he could destroy the bacillus anthracis in the blood of animals that had died of anthrax, and, then, by inoculating the blood so treated, cause death in the inoculated animals without the appearance of fresh bacilli. Therefore, he argued, the bacillus anthracis is neither the cause nor the necessary effect of anthrax. Pasteur, assisted by Joubert, tackled the subject. He found it possible to obtain a pure culture of the organism in urine rendered neutral or slightly alkaline. The inoculation of a trace of this culture produced a typical case of anthrax. How then account for the results of Bert's experimentation? In the first place Pasteur stated that the spores of bacillus anthracis could resist for three weeks the action of pure oxygen under a pressure of ten atmospheres. In the second place the death of animals, following the inoculation of the blood of anthrax victims, without the appearance of bacilli was really owing to septicæmia, which in turn owed its development to pathogenic micro-organisms. He was able to point out in the blood of animals that had died of anthrax, in addition to bacillus anthracis, the *vibrion septique* (bacillus of malignant œdema), which he had himself discovered. Nevertheless, he did not believe that septicæmia is a specific infection, and he later discovered Staphylococcus pyogenes and Streptococcus pyogenes. Pasteur also discovered the pneumococcus.

Until Pasteur's study of chicken cholera in 1880, Edward Jenner's great success in the production of artificial immunity remained an isolated phenomenon. Some years before this the micro-organism of chicken cholera had been described. Toussaint established the causal relationship between the organism and the disease. Pasteur found that the best culture medium was a broth of chicken gristle neutralized with potash, and that the smallest drop of a recent culture would kill a chicken. When, however, hens were given an old culture, which had been put away and forgotten for a few weeks, though they were affected by the disease they did not succumb to it. If these hens were then exposed to the unattenuated virus, they were either unaffected, or they experienced the disease in a mild form. "Was not this fact," writes Vallery-Radot, "worthy of being placed by the side of the great fact of vaccination, over which Pasteur had so long thought and pondered?" Was it possible to develop an animal's resistance to other infectious diseases? By the beginning of 1881 Pasteur was able to announce the essentials of his preventive treatment for anthrax. He had found that bacillus anthracis could be cultivated in neutralized chicken broth at 42° to 43° C. without developing spores, and that by being kept for ten or twelve days the culture became so attenuated as to give rise merely to a benignant form of the disease. Moreover, the weakened culture can be cultivated at 30° to 35° C. and yet yield spores of the same degree of virulence as the bacilli that formed them. The bacilli may recover their original virulence by being passed through a series of guinea-pigs, the second being inoculated with the blood of the first, and so forth. (Similarly, the micro-organism of chicken cholera, after it has become weakened through contact with oxygen, may be strengthened by being passed through a series of sparrows or canaries.)

It was the methods and principles established by these studies that led to Pasteur's successful treatment of hydrophobia in 1885, and to the subsequent founding of the Pasteur Institute. "Here," says Garrison, "Pasteur labored almost to the end of his life, with such brilliant pupils as Metchnikoff, Roux, Yersin, Calmette, Chamberland, and Pottevin."

Robert Koch (1843–1910) born in the Kingdom of Hanover, was a pupil at Göttingen of the distinguished histologist Henle, who in 1840 had revived the doctrine of a *contagium animatum.* Koch took his degree in 1866, the year in which Hanover was conquered and annexed by Prussia. In the Franco-Prussian War he served as a volunteer army surgeon. After the war was over, he was appointed district physician of a small place (Wollstein) in Posen. There he devoted himself to the study of infectious diseases.

In 1876 Koch began to publish the results of his investigations concerning the etiology of anthrax ("Die Aetiologie der Milzbrand-Krankheit, begründet auf die Entwickelungsgeschichte des Bacillus anthracis"). He showed in the first place that mice develop anthrax when inoculated with blood containing the bacilli; that by successive inoculations the disease may be passed from one to another of a long series of mice. At the same time he noted the rapid growth of the organisms in the blood, lymph, etc., and the presence of countless numbers of them in the spleens, of the inoculated animals. He then proved that in a suitable culture medium, such as fresh ox blood serum or the aqueous humor of an ox's eye, at a temperature of from 18° to 40° C. and with free access of air the anthrax bacilli grow to great length and develop numerous spores. He had been able to observe this process, by means of the microscope, in a drop of aqueous humor to which a small portion of fresh spleen containing bacilli was added. In a fresh drop of aqueous humor he also saw these spores develop into typical anthrax bacilli. This beautiful piece of work, which of itself entitles Robert Koch to a place beside Pasteur as one of the great founders of bacteriology, placed in his hands an absolutely pure culture of a pathogenic micro-organism, and gave him the means of proving that the bacillus anthracis is the sole cause of splenic fever. The spores on account of their resistance to the action of prolonged moisture or dryness play of course an important part in the dissemination of the disease.

In 1878 Koch published his investigations concerning the etiology of wound infections. He believed that the "parasitic" nature of these diseases is probable, "but that an adequate proof therefor had not been given and that such proof would not be forthcoming till we succeed in discovering the parasitic micro-organisms in all cases of the disease under investigation, till we succeed in showing them, moreover, in such numbers and distribution as to explain all the morbid phenomena, and, finally till we succeed in establishing for every kind of wound infection a definite, morphologically distinct, micro-organism as the parasite." He sought to discover the characteristic organisms in septicæmia, pyæmia, erysipelas, etc., by experiments on animals, injecting into mice and rabbits such substances as putrescent meat infusion or blood. He was able to study the effects of injecting, into mice, blood impregnated with chain-forming micrococci, and to produce in rabbits a disease markedly resembling erysipelas in man. The main result of this investigation seems to have been to strengthen Koch's conviction of the indubitable differences of pathogenic micro-organisms and of their inalterable constancy of behavior.

Koch always laid great stress on the value for the progress of medicine of improved technique and new methods of investigation. In 1877 he had advocated the use of photography as practiced by himself in the identification of microscopic organisms. He adopted Weigert's method of staining with aniline dyes, especially methyl violet and fuchsin, and he sought means to overcome the constant movement of the micro-organisms recognized by him as one of the chief obstacles of the investigator. In 1881, a year after he was called to the Imperial Health Bureau in Berlin, he devised his method of obtaining pure cultures with fixed, coagulable, culture media. After he had developed his method, discoveries fell into the lap of the investigator like ripe fruit, as Koch himself said.

In 1882 he announced the discovery of the *Bacillus tuberculosis*, thus confirming the views of others in relation to the specific and communicable character of tuberculosis. In the course of his experiments carried on in the hope of discovering a cure for tuberculosis Koch found that tuberculous guinea-pigs differ from healthy guinea-pigs in their manner of reacting to inoculations of tubercle bacilli, alive or dead. From this fact he inferred that there was in the bacilli a soluble substance which would prove a means of diagnosis and of control. His tuberculin — a glycerine extract of pure culture of bacilli — was announced at the International Medical Congress held at Berlin in 1890. Later he produced a new tuberculin, which has become recognized as of great value in diagnosis. He held that the bacilli of bovine tuberculosis do not cause tuberculosis in man.

In 1883 Koch went to Egypt and India as leader of the German Cholera Commission: recognized in amœbæ the cause of tropical dysentery; discovered in the comma bacillus the cause of Asiatic cholera; and in another bacillus the cause of infectious conjunctivitis. In 1885 he received appointment at the University of Berlin as professor in the faculty of medicine and director of the newly established Hygienic Institute. In 1891 his great powers as an organizer were called into play in connection with the new Institute for Infectious Diseases. In the following year cholera broke out in the city of Hamburg, but the menace to the fatherland was averted by the medical science of Koch, always alive to the dangers of water-borne infections. He further served Germany by fighting typhus in the southwestern part of the country, as well as by suggesting sanitary legislation, and organizing conferences. In 1896 at the request of the British government he investigated Rinderpest in South Africa, and developed a method of preventive inoculation. In 1897 he studied bubonic plague at Bombay. He had recognized in 1883 that blood-sucking insects are transmitters of disease, and a considerable part of the last fifteen years of his life was spent in the study of tropical medicine. In 1906 he was again in Africa as head of the Sleeping Sickness Commission.

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See also references on page 230 of the author's *Introduction to the History of Science.*

CHAPTER XVII

ANTISEPTIC SURGERY: LORD LISTER

Joseph Lister, the story of whose achievements in surgery is so closely associated with that of the development of bacteriology, was born in the London district (Upton) April 5, 1827. He received his early schooling at two Quaker institutions (his family belonging to the Society of Friends), took his bachelor's degree at University College, London, proceeded at the age of twenty-one to his professional education at the University College Hospital and Medical School, and at the age of twenty-five received the M.B. and F.R.C.S. He had already come in contact with several men whose names are known in the history of science: Joseph Jackson Lister, his father, already referred to as contributing to the production of the achromatic lens; Thomas Graham, who formulated the law of the diffusion of gases; W. B. Carpenter, whose work on "Mental Physiology" has had a great effect on the progress of psychology; William Jenner, who during Lister's early years as a student of medicine was working out the distinction between typhus fever and typhoid; William Sharpey, the distinguished teacher of physiology; and Wharton Jones, noted as an ophthalmic surgeon and as one of the pioneers, in England, in the study of embryology. Before taking his degrees in medicine Lister had served six months as house physician and nine months as house surgeon (to Erichsen) at the University College Hospital.

Among the results of his extended education were a considerable command of ancient and modern languages, skill as a draughtsman and microscopist, love of scientific truth and a taste for research. In 1853, the year following his graduation in medicine, he published two papers in the "Quarterly Journal of Microscopical Science." The first of these recorded the discovery of the sphincter and the dilator of the iris as distinct muscles, and confirmed the views of Kölliker as regards the nonstriated and the cellular structure of the tissue in question. The second paper, illustrated like the first by delicate drawings, dealt with the *arrectores pili*, especially those of the scalp. He prepared his sections by tying the tissue to be examined between two thin slips of pine and allowing it to dry for twenty-four hours, by which time the piece of scalp having adhered to one of the slips could be cut, by means of a sharp razor, in very fine shavings along with the wood in any plane desired. This was an original form of microtome.

In the autumn of 1853 Lister went to Edinburgh, on the advice of Sharpey, in order to attend the surgical clinics of Syme, an excellent teacher and the foremost surgeon at that time in Great Britain. The young man was very cordially received. He became a frequent visitor in Syme's home, where he met a large number of agreeable and cultured people, among them Dr. John Brown, the author of "Rab and his Friends." In the congenial society of Edinburgh, a city more beautiful then even than now, Lister threw off much of his natural shyness and restraint, though, in spite of the favor his accomplishments and admirable disposition gained for him, he never lost his native modesty. He soon became Syme's house surgeon at the Royal Infirmary, where in this period following the introduction of the use of anæsthetics, he had abundant opportunities to develop skill as an operator. About this time he wrote home: "If the love of surgery is a proof of a person's being adapted for it, then certainly I am fitted to be a surgeon; for thou canst hardly conceive what a high degree of enjoyment I am from day to day experiencing in this bloody and butcherly department of the healing art." The young house surgeon had twelve dressers, who called him "The Chief," a title he retained for life among his many loyal disciples. In the autumn of 1855 he gave an extra-mural course of lectures on surgery. In the following spring he married Syme's daughter Agnes. A three months' tour of the Continent followed, during which the young couple met Rokitansky, Albrecht von Graefe, and other distinguished people. In the autumn of 1856, after their return to Edinburgh, Lister was appointed assistant surgeon at the Royal Infirmary.

Among the many papers prepared by him during these early years in Edinburgh the most important is that on "The Early Stages of Inflammation," read before the Royal Society of London in 1857. It was the product of a long series of investigations, probably suggested by some studies of Wharton Jones. Lister's conclusions were based on an experimental study of the circulation in the web of the frog's foot and of the bat's wing. He had begun his experiments on the frog in September, 1855. In a letter written at that time he says: "Mr. Sparshott, the most intelligent of the last set of dressers, and who is to attend my lectures in the winter, kindly assisted me, and a glorious night I had of it. I had the frog so placed and fixed that I could inject anything upon the web under the microscope from a syringe, and it so happened that the frog was not only perfectly healthy, but with remarkably little pigment, and exceedingly quiet. By using a 2/3 object-glass I had a fine large field of view, and had under observation always the same artery, with the field of capillaries into which it divided and the two veins which returned the blood from them; and thus was able to watch with great precision the effects produced; the animal rarely struggling at all." Under these conditions he began by applying to the web warm water, which first checked and then stimulated the circulation. He followed up this procedure by applying water of higher and higher temperature till the boiling point was approached. Finally the capillaries were greatly "distended and stuffed with the red corpuscles, and the blood was first retarded, then stagnant."

Lister continued these studies of the circulation by a series of obervations and experiments concerning a closely related subject, namely, the coagulation of the blood. A case of so-called spontaneous gangrene, in which he had been forced to resort to amputation, led him to the conclusion that obstruction to the circulation had been caused primarily by a diseased condition of the vessels. This case was reported in the early part of the year 1858 (just when Virchow was giving his lectures in Berlin on "Cellular Pathology"). At the same time Lister reported that he had drawn off the blood of a sheep into a vulcanized rubber tube, which he then divided into a number of closed compartments, and that the blood remained fluid for three hours. When the blood was allowed to escape from the tube, it coagulated, of course, in about three minutes, just as if it had been drawn fresh from the veins of the animal. Moreover, by ligating the vessels in the amputated leg of a sheep or a cat he could keep blood uncoagulated for several days. After other papers dealing with the coagulation of the blood Lister delivered the Croonian lecture on that subject before the Royal Society of London in 1863. Though he had been considerably influenced by the work of Hunter, he refused to commit himself to the vitalistic hypothesis as regards coagulation, nor, as he said, "to any particular theory of the nature of life, or even to the belief that the actions of living bodies are not all conducted in obedience to physical and chemical laws." He was more and more inclined to emphasize the influence on coagulation of foreign solids, and of diseased tissues which acted like foreign solids.

At the beginning of 1860 Lister had been appointed professor of surgery at the University of Glasgow. At that institution he was the colleague of Allen Thomson, the anatomist and embryologist, to whom he was largely indebted for his appointment, of Sir William Thomson (afterwards Lord Kelvin), professor of physics, and of other men distinguished in letters and science. He sent his father an interesting account of his induction as a member of the Faculty. The ancient rite demanded that the new professor should give a dissertation in Latin;

but Lister was summoned to the ceremony on very short notice, did not set pen to paper till the morning of the day on which he was to appear before his colleagues, and wrote the last third of his disquisition while on the train from Edinburgh to Glasgow. He acquitted himself creditably, and was soon busy with his large classes and considerable private practice. He faced additional responsibilities when in the following year he received appointment as surgeon in the Glasgow Royal Infirmary.

In order to appreciate the benefits Lister conferred upon surgery one must know something of the condition of the hospitals before the introduction of the antiseptic system. After the use of ether and chloroform had become general, operations gradually increased both in number and range. Although deaths from shock grew less frequent, the presence of septicæmia, pyæmia, erysipelas, and hospital gangrene, etc., caused an alarming mortality. Worst of all, writes Sir Rickman Godlee, Lister's nephew and biographer, "was the appearance of the moist grey slough surrounded by an angry blush, which heralded the onset of hospital gangrene. The limits of the original wound were then lost sight of. What might be the shape or size or even the position of the scar in the event of the patient's recovery became a matter of the greatest uncertainty, because it was impossible to foresee the amount of tissue which would perish from the destructive effects of the disease and the heroic measures taken to combat it." These diseases were particularly rife in the large hospitals. Sir James Simpson led the attack on "Hospitalism" (1869). A statistical inquiry conducted by him showed that out of 2098 amputations in country practice 226 had proved fatal, and that out of 2089 amputations in hospital practice 855 had proved fatal; and that the larger the hospital the greater the mortality. "Most hospital surgeons," he said, "ever remain content with losing one-third to one half of *all* their amputation cases, and nine tenths of some." Institutions which had been developed through centuries of philanthropic endeavor were proving a curse, unable to meet the needs of the cities ever increasing in size as a result of the industrial revolution.

Lister in his new appointment had to face the practical problems of controlling these diseases, the only solution of which had seemed to many able surgeons the demolition of the hospitals. Glasgow, with a population of 390,000, was then, as now, one of the industrial centers of Great Britain, and in 1861 the Glasgow Royal Infirmary was no better than other city hospitals. Sir Hector Cameron, at one time Lister's house surgeon and assistant, says that every wound discharged pus freely, and putrefactive changes occurred in the discharges of all.

"Secondary hæmorrhage, tetanus, erysipelas, septicæmia, pyæmia, and hospital gangrene," he proceeds, "were never all absent from the hospital wards, and at times pyæmia and hospital gangrene became alarmingly epidemic." Lister, though he had for some time past taught that suppuration is a form of putrefaction, was still without the clue to a real explanation of putrefactive changes. Even after his successes had begun, a terrible state of affairs was discovered at the Royal Infirmary. "A few inches below the surface of the ground," he writes, "on a level with the floors of the two main accident wards, with only the basement area, a few feet wide, intervening, was found the uppermost tier of a multitude of coffins, which had been placed there at the time of the cholera epidemic of 1849, the corpses having undergone so little change in the interval that the clothes they had on at the time of their hurried burial were plainly distinguishable." He was horrified also by the custom of the "pit burial" of paupers still practiced in the old cathedral churchyard adjoining the Infirmary, more particularly as he associated infectious disease with a contaminated state of the atmosphere. Such were the circumstances in which Lister developed his method of antiseptic surgery.

In 1864 he was especially interested in the study of suppuration (in relation to decomposition), a subject to which he had given considerable attention since his student days. He was therefore very deeply interested in the fact that carbolic acid had proved effective at Carlisle not only in deodorizing the sewage, but even in destroying the entozoa that had infested the cattle in the fields fertilized by the sewage. It occurred to him that carbolic acid might prevent suppuration in cases of compound fracture. He had long felt that to make an open wound behave like a closed one would be a notable advance in scientific surgery. The first attempt to use carbolic acid in the treatment of compound fracture was not successful. This was in the spring of 1865, the year in which Lister's attention was first directed to Pasteur's studies of fermentation and putrefaction. In August of the same year, however, the new method was employed with complete success in a case of compound fracture of the tibia. The patient was a boy of eleven, who had been run over by a wagon. Lister felt that recovery was as rapid and satisfactory as if the fracture had been merely a simple one.

In announcing this and other successes Lister said: "In the course of an extended investigation into the nature of inflammation, and the healthy and morbid conditions of the blood in relation to it, I arrived, several years ago, at the conclusion that the essential cause of suppuration in wounds is decomposition, brought about by the influence of the atmosphere upon blood or serum retained within them, and, in the case of contused wounds, upon portions of tissue destroyed by the violence of the injury.

"To prevent the occurrence of suppuration, with all its attendant risks, was an object manifestly desirable; but till lately apparently unattainable, since it seemed hopeless to attempt to exclude the oxygen, which was universally regarded as the agent by which putrefaction was effected. But when it had been shown by the researches of Pasteur that the septic property of the atmosphere depended, not on the oxygen or any gaseous constituent, but on minute organisms suspended in it, which owed their energy to their vitality, it occurred to me that decomposition in the injured part might be avoided without excluding the air, by applying as a dressing some material capable of destroying the life of the floating particles."

At the time of this statement — March, 1867 — the list of successful cases of compound fractures, abscesses, contused and lacerated wounds, amputations, strangulated inguinal hernias, etc., had grown so great that Lister felt impelled to impart the knowledge of his procedure to the profession. His wards in the Glasgow Royal Infirmary had become the healthiest in the world.

In 1869 Lister was called to Edinburgh as professor of clinical surgery on the retirement of Syme, and at first found himself in a very critical atmosphere. He gave in his first lecture a history of the germ theory, referring to the work of Schwann, Pasteur, and others. He had repeated Pasteur's experiment in which putrescible fluids remained pure in the presence of atmospheric air, and he showed to his audience flasks in which the contents, kept free from dust, were still sweet and clear after a space of two years. As Lister said in later life, from the beginning of his campaign in favor of the antiseptic method he had the youth on his side. He was idolized by the Edinburgh students, and his classes were very large. The poet Henley, who was one of Lister's patients at the Royal Infirmary, has expressed in a sonnet his sense of the surgeon's influence and personality.

THE CHIEF

His brow is large and placid, and his eye
Is deep and bright with steady looks that still.
Soft lines of tranquil thought his face fulfill —
His face at once benign and proud and shy.
If envy scout, if ignorance deny
His faultless patience, his unyielding will,
Beautiful gentleness and splendid skill,
Innumerable gratitudes reply.
His wise, rare smile is sweet with certainties,
And seems in all his patients to compel
Such love and faith as failures cannot quell.
We hold him for another Heracles,
Battling with custom, prejudice, disease,
As once the son of Zeus with Death and Hell.

LORD LISTER

At Edinburgh, where Lister spent eight years in teaching, practicing, demonstrating and developing his method and technique (as previously at Glasgow, and later at London), surgeons from the continent appeared, eager to sit at the feet of the master of modern scientific surgery. Dr. Saxtorph, professor of surgery in the University of Copenhagen, visited Edinburgh in the summer of 1869. In the following year he wrote to Lister: "Formerly there used to be every year several cases of death caused by hospital diseases, especially by pyæmia, sometimes arising from the most trivial injuries. Now, I have had the satisfaction that not a single case of pyæmia has occurred since I came home last year, which result is certainly owing to the introduction of your antiseptic treatment."

In the same month in which these words of commendation were written, the Franco-Prussian War began. The Prussians felt convinced that the sanitary organization of their armies could compete with the best in the world. A large medical division was provided, which on occasion could be broken up into smaller units. There were twelve light hospitals for every thirty thousand combatants. Each soldier carried a tin of dressings. One soldier in eight had been especially trained for emergency duties. Instructions had been given concerning the safety of the open air and the dangers of infection in crowded rooms. Many of the surgeons were aware of the antiseptic value of carbolic acid. Lister's treatment was, however, not in use; though he published at the beginning of September, 1870, a brief statement of "A method of antiseptic treatment applicable to wounded soldiers in the present war." Stromeyer, who has been called the father of modern military surgery in Germany, in one series of thirty-six amputations through the knee-joint recorded one hundred per cent failures; von Nussbaum amputated in thirty-four successive cases without a single success. In the lower limb scarcely an amputation recovered, death resulting from exhaustion, sloughing of the flaps, and frequently from pyæmia. Hospitals became hotbeds of pyæmia in spite of what had seemed perfect arrangements. Among the French forces conditions were much worse. Their hospitals surpassed in horror the records of the Crimean War. Out of 13,173 amputations of all kinds, including those of fingers and toes, 10,006 proved fatal.

Before the end of the war, von Nussbaum was a convert to the Lister method. In the years following he was at the head of the Allgemeines Krankenhaus in Munich. It was overcrowded, partly on account of the industrial growth of the city, and a severe epidemic of hospital gangrene occurred. In 1872, 1873, and 1874 the percentage of wounded or operated that were attacked by that disease — to-day almost unknown — mounted to twenty-six, to fifty, to eighty. Von Nussbaum was in despair. He appealed to Lister for help, and dispatched one of his assistants to Edinburgh to learn the antiseptic method. It was soon put into effect at Munich. Henceforth hospital gangrene was banished from the Allgemeines Krankenhaus. Von Nussbaum's book, with an account of the antiseptic treatment went through four German editions in six years, and was translated into French, Italian, and Greek. Thiersch of Erlangen (later of Leipzig) was, however, Lister's first disciple among the surgeons of Germany, and Richard von Volkmann his most redoubtable champion. Von Mikulicz-Radecki, who was Billroth's assistant at Vienna, was sent by his master to visit Lister at London in 1879. Lucas-Championnière, the French pioneer of the antiseptic method, had visited Glasgow as early as 1868; and he published his "Chirurgie antiseptique" in 1876. In the previous year Lister in response to urgent invitations had visited a number of German university centers — Munich, Leipzig, Berlin, Halle, and Bonn. According to the "Lancet," his progress through Germany took on the character of a triumphal march.

While the antiseptic treatment was making rapid headway throughout Europe, Lister felt that he still had before him the task of converting his native place to the truth of the new doctrine. The opportunity came in 1877 when he was invited to accept the post of professor of clinical surgery in King's College, London. He reluctantly consented to do so. He was received with a considerable show of skepticism. He and those who had accompanied him from Edinburgh felt helpless for a time in facing a conservatism and inertia that seemed hostile to every innovation. In about a month, however, a patient appeared who had broken his knee-cap. Lister cut down, and united the two pieces of the fractured patella by means of a silver wire. He operated successfully in cases refused by the leading London surgeons. Some who had been set up as his rivals and competitors became his pupils and followers. It was soon realized that through the introduction of the antiseptic method the scope of surgery was greatly extended. Both in London and elsewhere operations on the brain, as well as on the thoracic and abdominal viscera, were undertaken with ever-increasing freedom. Orthopædic surgery extended its range. Albrecht von Graefe, the most famous of eye surgeons, recognized the added power that came from the antiseptic method. Moreover, surgeons now took courage to interfere in the early stages of an affection, an advantage particularly notable in the treatment of cancer.

One of Lister's old students at London writes

(1918), in answer to a recent critic: "From the day of Lister's entry we never saw the temperature rise after an operation in any of his patients, and never saw a blush on a wound. To us who had been taught that inflammation was necessary for healing . . . it was a miracle, the more so that Lister immediately did operations that hitherto we had learned must always prove fatal." It is true that a formidable list of achievements, some preceding the development of the antiseptic method, may be placed to Lister's credit. For example, in 1861 he described an original amputation in the neighborhood of the knee. In 1862 he recorded the successful use of a tourniquet of his own invention to control the abdominal aorta. In 1864 Syme told with pride that Professor Lister of Glasgow had succeeded in the excision of the wrist for caries. In 1868 he tested the value of catgut ligatures by tying the carotid artery of a young calf, and found a month later (January, 1869) that the ligatures had been replaced by living tissue. He devoted much time to the study of ferments, such as the lactic ferment, and the relation of micro-organisms to the blood; and came to the conclusion about 1881 that the spray of carbolic acid solution, which he had long used in his operating-room to destroy the pathogenic organisms in the air, was not essential to the antiseptic method. He also experimented with the double cyanide of mercury and zinc and other antiseptic preparations. Nevertheless, it was not to these particular achievements, not to any of his later operations, such as the excision of the knee-joint, that Lister owed his fame, but to the steadfast vigilance with which he applied a great principle.

Lister received a baronetcy in 1883. In the same year he visited Austria and Hungary, but did not hear for some time later of the work of Semmelweiss, frequently regarded as his forerunner. In 1892 he attended the Pasteur jubilee at Paris and with his usual magnanimity ascribed all his own triumphs in surgery to the work of the founder of bacteriology. In 1895 he became President of the Royal Society. In 1896 he was chosen President of the British Association for the Advancement of Science, and in the following year he was raised to the peerage. In 1902 was celebrated the fiftieth anniversary of his entrance into the medical profession. At a banquet given in honor of Lord Lister by the Royal Society, Mr. Thomas Bayard, the American Ambassador, addressing the great surgeon, said: "My Lord, it is not a profession, it is not a nation, it is humanity itself which with uncovered head salutes you." Lord Lister died in 1912. A public funeral service was held in Westminster Abbey, where a marble medallion now commemorates him. But, in accordance with special instructions he had given, he was buried beside his wife in a simple tomb in the West Hampstead Cemetery.

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CHAPTER XVIII

THE HISTORY OF SYPHILIS

The term "syphilis" was first used, so far as we know, by the distinguished Italian physician Fracastoro, who in 1530 wrote a poem "Syphilis sive Morbus Gallicus." But the synonymous expression and its many equivalents — "French pox," "Gallische Krankheit," "mal francese," etc.— were extensively used before the close of the fifteenth century, and were soon translated into some of the languages of Africa and Asia. In France syphilis had a great many names, but only one of these had any geographical reference, namely, "mal de Naples," a term that found echoes in three or four other languages. In England the disease was called, among other things, "Spanish pox"; and similar expressions were used in Scotland, Holland, Germany, and in the western part of North Africa. The Russians called it at times the "Polish disease"; and the Persians knew it as the "Turkish disease." The Portuguese, turning their eyes to the east rather than to the west, spoke of the "Castilian disease." The Spaniards, however, used occasionally the term "Indian measles," and, also, "disease of the island of Hispaniola" (that is, Santo Domingo).

There was a fierce epidemic of syphilis in Europe near the end of the fifteenth century. Its diffusion is associated with the military expedition in Italy, under the leadership of Charles VIII of France, in 1494 and 1495. The army of the French king, made up of adventurers from various countries, and accompanied by a dissolute train of camp-followers, met with little opposition. There was a slight engagement with a force of Spaniards and Neapolitans at Rapallo (near Genoa) in September, 1494. Charles halted for a short time in Florence on his triumphal progress south; lingered four weeks in Rome, then governed by Alexander Borgia; and entered Naples February 22, 1495. Here he stayed for about three months. Some historians attribute the epidemic to Spanish mercenaries in the army of Charles; others put it down to the Spaniards in Naples, which had for some time been a possession of the House of Aragon, and particularly to the garrison of a fortress in the harbor, who held out for three weeks after the French troops had entered the city, and who then for the most part went over to the service of Charles. Professor Robinson mentions as one of the momentous results of this campaign that the intellectual leadership of Europe passed from Italy to England, France, and Germany. However that may be, the venereal plague ran within a few months through the Italian cities, and reached the borders of France, Switzerland, and Germany.

There is evidence to show that syphilis had appeared along the line of march in 1494, that is, before Charles had reached Naples, namely, in the camp at Rapallo, in the neighboring city of Genoa, and in Rome. It developed into a virulent epidemic at Naples before May, 1495, and, it seems reasonable to suppose, hastened the retirement of the French northwards. We hear of its breaking out in 1495 at Florence, at Bologna (at which center of learning, as elsewhere, it was regarded as a new and unheard-of disease), at Cremona, Verona, and Novara, where a part of the retreating army was besieged for several months. The epidemic seems not to have reached Modena, Ferrara, and Venice till the following year. Syphilis at the time of this European epidemic was extremely malignant, a fact explained by Bloch, who maintains that this was the first appearance of the disease in the Old World, on the ground that it here found virgin soil, as he expresses it. The secondary symptoms appeared very early — often in a few days; the patients had high fever; they suffered intense pains (especially in the joints) and severe skin affections; they fell into general decline, and very frequently died.

Charles reached Lyons in November, 1495, but the greater part of his forces, after leaving Italy, had scattered in all directions. The disease was soon prevalent in the south of France, and by the beginning of 1497 had become so general that the Parliament of Paris issued regulations in the hope of controlling "la grosse vérole," which for two years had afflicted the kingdom, as well Paris as other places. The Emperor Maximilian I, in an edict dated August 7, 1495, recognized the danger for his dominions of the new and unheard-of scourge. Some of his troops had taken part with the enemies of France at the protracted siege of Novara, where the epidemic had prevailed; and German, Hungarian, and Slav mercenaries had formed part of the army of Charles. The fact that six thousand Swiss mercenaries also accompanied the French accounts for the early appearance of syphilis in Switzerland. The disease reached Great Britain in 1497 from French and, probably, Spanish ports. It was carried to the Netherlands in 1496 by the retainers of a Spanish princess. It appeared in Russia in 1499 coming by way of Poland. The latter country is said to have got the infection from an individual woman, who had made her way from Rome to Cracow as early as 1495.

When we turn to Spain, we find new light is thrown on the history of the syphilis epidemic by the evidence of reliable witnesses. The most important of these is the physician Ruy Diaz de Isla, who at the age of thirty-one was practicing at Barcelona at the time of the return of Columbus from the West Indies in 1493. Before 1521 this physician wrote a book dedicated to the King of Portugal — "Against the Reptilian Disease, Commonly Called in Spain the Buboes." The first chapter deals with the birth and origin of the disease on the island of Hispaniola. He states that it made its appearance in Spain in the city of Barcelona in the year 1493. The city became infected, and from it all Europe and all the known and accessible parts of the earth. It had its birth and origin in the island of Hispaniola. When the island had been discovered by the Spaniards, they had had intercourse with the natives, and the disease being readily contagious it presently appeared on the ships. At the time Columbus returned to Spain, Ferdinand and Isabella were in the city of Barcelona, and while they were receiving accounts of the voyage and the discoveries the disease began to infect the people and to spread through the city. According to de Isla a great many Spaniards infected with the disease joined the army of Charles in the following year and thus infected the main body of the French army. The Indians of Hispaniola called the disease "Guaynaras," and applied other names to it. As for the physician's own name for it, he considered it appropriate; because a reptile is a hideous, fearful, and dreadful animal, and the disease is likewise hideous, fearful, and dreadful. It is a severe disease, forming abscesses and corrupting the flesh, breaking and rotting the bones, and shortening and drawing up the sinews. And, since de Isla knew that the disease from remote times had existed in Hispaniola, whence it had spread throughout the world, he called it the reptilian disease of the island of Hispaniola. He also insisted that the disease had never been seen and never known before the voyage of Columbus, and that nothing like it could be found described in medical works.

De Isla's conviction that the reptilian disease had existed from time immemorial on the island of Hispaniola rested on the fact that the natives had developed a complete system of therapy in its treatment — the use of guaiac, balata, and other vegetable remedies, the regulation of diet, care regarding water and air, and abstention for a certain time from sexual intercourse. With an eye on the difficulties experienced in his own time by civilized peoples in dealing with an unknown disease, de Isla argued that the very stupid natives of Hispaniola must have known guaynaras for very many generations before arriving at their clever and orderly treatment of it. The Spanish physician maintained that mercury was the only reliable remedy for the reptilian disease as it existed in Europe; he employed it as an inunction. He advocated a well considered plan for the state control of syphilis. Besides his experience in treating at Barcelona some of the crew accompanying Columbus (among them the pilot Vicente Pinzon), as well as other people in the city infected with the disease, de Isla saw practice at Seville (where Columbus had passed four weeks or more before reaching Barcelona), and, subsequently, had served many years in All Saints' Hospital at Lisbon, where he had abundant opportunities of studying syphilis.

The American origin of syphilis is likewise upheld by Oviedo, the author of the "General and Natural History of the Indies," who crossed the Atlantic many times, spent over forty years in America, and was particularly well acquainted with the island of Hispaniola. As a boy of fifteen he had been present at the landing of Columbus at Barcelona, where he made friends with the sons of the discoverer and with Vicente Pinzon. In 1501 Oviedo spent six months in Sicily with Gonsalvo de Cordova, who in 1495 had been sent from Spain with an army to oppose Charles VIII, and whose secretary Oviedo became in 1512. On a visit to Italy the young man was much amused to hear that the Italians called syphilis "mal francese" and that the French called it "mal napolitain," for he was well aware it should be called "mal de las Indias." According to him some of the companions of Columbus had become infected at the time of the first voyage to America, and, after their return to Spain, the infection passed to Italy and other countries. It had not been known in Spain until the return of Columbus in 1493. Immediately it had spread among the lower classes, and later had found its way among the gentry and nobility. Oviedo knew that some of the soldiers under the command of Gonsalvo de Cordova in 1495 were infected before quitting Spain.

Oviedo believed that syphilis was found not only in Hispaniola, but throughout the West Indies and on the American mainland. It was less dangerous, he said, in those regions than in Spain and the other countries of the Old World. The Indians knew how to cure it by the use of guaiac (which was fresher and consequently more efficacious in the Indies than in Europe), and other vegetable remedies. Of the Christians who had intercourse with the native women few escaped with impunity.

The statements of Oviedo in reference to the comparative mildness of the disease among the American natives and the marked susceptibility of Europeans to the infection are fully corroborated by Las Casas, known as "the Apostle of the Indies," who also refers, like Oviedo and de Isla, to the success of the native therapy. Moreover, he is able to support by the testimony of the aborigines the theory of de Isla regarding the antiquity of the disease in the island of Hispaniola. He took great pains, he says, to question the Indians as to whether the disease had long existed on the island. They answered in the affirmative; it had been present so long among them before the coming of the Christians that there was no memory of its beginning. Of the truth of this, Las Casas felt there could be no doubt. Indeed, we know from other sources that the presence of guaynaras in Hispaniola was implied in the earliest traditions of the natives.

Las Casas was born in Seville in 1474. His father accompanied Columbus in 1492, and the young man was present when the discoverers in 1493 brought ten Indians from Hispaniola to Seville, where they remained for about a month before proceeding to Barcelona. He went to the West Indies in 1498, and was ordained as a priest in 1510 on the island of Hispaniola, where he passed altogether twenty years of his life. He was appointed Bishop of Chiapa, Mexico, in 1543. He lived to the age of ninety-two, and left a manuscript "History of the Indies." In the judgment of this well-informed witness the disease known to the Italians as "mal francese" was carried to Europe by the Indians Columbus took to Spain in 1493 or by the Spaniards who had been infected in Hispaniola at the time of its discovery.

As regards the epidemic in Barcelona, following the return of Columbus from his first voyage to the West Indies, we have valuable corroborative evidence in a letter written in June, 1495 (printed in the following March), by the Sicilian physician Nicolò Scillaccio. The letter is addressed to his former teacher at Pavia, Ambrogio Rosato, physician to Ludovico Sforza (who a few months later overcame the French resistance at Novara). Scillaccio had left Italy for Spain in February, unaware of the imminent epidemic. It is with some gusto he announces to his master the advent of a new disease. Among the symptoms he had observed in those infected in Barcelona were purulent pustules, intense fever, arthritis with severe pains, dermal crusts, and swellings colored at first blue and later blackish. The disease begins most frequently in the genitals, but spreads to the whole body. According to the statement of Scillaccio this new species of malady had but recently invaded Spain. The disease does not run longer than a year in an individual case (*annum morbus non excedit*). This statement gives us reason to affirm that it had been under observation in Barcelona for a year or two.

According to Osler, "writers who contend for the antiquity of the disease in Asia and Europe rely on certain old Chinese records, on references in the Bible and in old medical writers to diseases resembling syphilis and on suggestive bone lesions in very old skeletons. The balance of evidence, according to the best syphilographers, is in favor of the American origin." No European bones belonging to a date earlier than 1493 show satisfactory indications of the disease; though skeletons belonging to a later period have been found with the characteristic signs wherever the infection has been carried — even in regions so remote from Europe as the Philippines, New Caledonia, and Australia. In America, on the other hand, this sort of negative evidence is not so decisive. For example, two skulls have been found in Tennessee, one of which shows signs of syphilitic caries, the other the thickening of the nasal bones indicative of syphilis. Their discoverer thought them probably the most ancient syphilitic bones in the world. It is not positively known, however, that they belong to the pre-Columbian period.

The outbreak of syphilis in Europe at the end of the fifteenth century was a challenge to the medical science of the time. The problems it raised could not be answered by consulting the volumes of Galen and his commentators. Its extreme virulence seems to have prevented its early observers from confusing it with gonorrhœa. Berengario da Carpi treated it with inunctions of mercury as early as 1500, and, therefore, disputes with Diaz de Isla, the honor of introducing this form of treatment. Before the middle of the sixteenth century Mattioli employed mercury internally. Mercurial plasters came into use, as well as fumigations, sulphur baths, and guaiacum. Sarsaparilla, which had been used in America in the treatment of syphilis, was used by the Portuguese even on the coast of India as early as 1535. In addition to the symptoms already referred to, the physicians of the sixteenth century took note of the primary lesion, the falling out of the hair, affections of the internal organs, and disorders of the nervous system. Paracelsus recorded the observation of congenital syphilis. The venereal nature of the disease and its special mode of transmission were soon generally recognized, and in 1557 Fernel stated definitely that the disease always gave rise to a little sore and pustule at the point of the primary inoculation. Paré noted, as we have seen, the connection between aneurism and syphilis, and wrote in detail concerning hereditary syphilis.

After the beginning of the seventeenth century there was a clearer recognition of the minor causes of infection — the communication of the disease to physicians and midwives by lying-in women, infection from drinking-vessels, inoculation by kissing, and the transmission of the disease through the operation of cupping, the infection of the child by the nurse and of the nurse by the child. The list of syphilitic affections was gradually increased —

chancre of the tonsil, nasal syphilis, lesions of larynx, windpipe, and lungs, gummata of the brain, syphilitic neuralgias, and diseases of the spinal cord. As we have seen in the seventh chapter, Sydenham noted the lessened virulence of the disease in the seventeenth century as gauged by the records of the end of the fifteenth century, held that this species of disease is not immutable, attempted to trace the stages passed through in individual cases, and considered syphilis identical with yaws.

In the eighteenth century Lancisi described cardiac syphilis, and supported the observations of Paré by giving syphilis as one of the causes of aneurism. We have seen in the ninth chapter that Morgagni held syphilis to be not only one of the causes but the preponderating cause of aneurism, that he had observed syphilitic lesions in nearly all of the thoracic and abdominal viscera and believed that venereal disease might vitiate any viscus whatever. "At last, John Hunter came and laid the true foundations of the science of venereal affections" (Ricord). It is true that Hunter, in spite of his numerous post-mortems, failed to observe syphilis of the viscera, and that he confused syphilis and gonorrhœa; but he based his generalizations in this field, as elsewhere, on observation and experimentation, and had the courage to inoculate himself with venereal virus and to study the results over a long period before knocking the disease down with mercury, as he expressed it. It is not improbable that this was the cause of the angina pectoris from which he suffered for many years and which resulted in his death. As mentioned in the eighth chapter he succeeded in differentiating Hunterian chancre from chancroid ulcer. Before the end of the eighteenth century Benjamin Bell taught that there is a difference between the virus of gonorrhœa and that of syphilis.

At the beginning of the nineteenth century Hernandez confirmed the views of Bell by inoculating with the poison of gonorrhœa seventeen convicts at Toulon. Hunter and Hernandez in their resort to experiment in investigating venereal disease may be regarded as forerunners of Philippe Ricord (1800–89) who in the years 1831 to 1837 made at Paris twenty-five hundred inoculations, and proved that gonorrhœal secretion never produces chancre nor constitutional syphilis. He established the three stages of syphilis, held that the induration of the chancre is subsequent to the passage of the poison into the general system, and that in its third stage the disease is non-communicable. Virchow, as already stated in the thirteenth chapter, set forth in detail the pathology of syphilis. In considering the various phases of the subject he of course did not overlook the histological. He noted, for example, the resemblance of the indurated chancre to all gummatous formations. He observed that a syphilitic cicatrice in the bones of the cranium gives evidence of a diminished growth in the center and an increased growth in the periphery. This and other indications of syphilis he maintained are not to be found in skeletons of a date earlier than the closing years of the fifteenth century. Further advances in the knowledge of venereal disease followed the development of the science of bacteriology. Neisser's discovery of the micro-organism of gonorrhœa in 1879, Ducrey's isolation of the bacillus of venereal ulcer in 1889, and the success of Metchnikoff and Roux in inoculating monkeys with syphilis in 1903, cleared the way for the discovery by Fritz Schaudinn in 1905 of the protozoon *Treponema pallidum* as the cause of syphilis.

Schaudinn (1871–1906), born at a small place in East Prussia, received his training as a zoölogist at Berlin, attaining the doctorate at the age of twenty-three. Four years later he was an instructor in his specialty, and in 1904 he was engaged at the Imperial Health Bureau as an expert in protozoölogy. Under the auspices of this institution he pursued investigations at Rovigno on the Istrian coast. In the year of his death he accepted an appointment in the Institut für Schiffs- und Tropen-hygiene at Hamburg. He studied the hookworm recognized as the cause of anæmia among the miners of Westphalia, and confirmed the discovery of Looss in reference to the life-history of that parasite. Schaudinn made important contributions to the classification of protozoa (such as *Spirochæta* and *Trypanosoma*) as well as their mode of reproduction, including the mechanism of cell-division. Although he had not studied medicine, the control of disease soon became one of the main purposes of his work in science. He insisted on the necessity of knowing the complete history of microscopic parasites, and traced satisfactorily the life cycles of a number of pathogenic protozoa that infest man and the lower animals, such as *Plasmodium vivax* (the relation of which to the human blood-vessels he established) and *Trypanosoma noctuæ*. He distinguished *Entomœba histolitica* from *Entomœba coli*. Moreover, he established a method of studying protozoan infections which helped to guide the investigations of others. Five years after Schaudinn had determined the causative agent of syphilis, Ehrlich announced the discovery of a specific.

Paul Ehrlich (1854–1915) was born at Strehlen, Silesia; received his early education in his native place and in the neighboring city of Breslau; after spending a semester at the University of Breslau, proceeded to Strassburg, where he began the study of medicine; and later visited as a student at two other German universities. He took advantage of the freedom of German university life and pursued intensively those studies that laid claim on his interest. Although at Strassburg he had the privilege of the instruction of Julius Cohnheim, Ehrlich was more influenced by Carl Weigert, his cousin, with whom he was closely associated. He was soon distinguished for his contributions to hæmatology, based on improved methods of staining. In 1882 he employed fuchsin red in staining tubercle bacilli. His investigations were early guided by the hypothesis that the molecules of living tissue combine with foods, poisons, dyes, and other chemicals by virtue of selective affinities. In 1885 he reached the conclusion that cell protoplasm takes up oxygen as benzene takes up bromine. That is, the elements of the protoplasm that enter into combination with the extraneous molecules are analogous to the side-chain of the benzene ring. In 1886 he injected methylene blue in the blood of a rabbit and discovered that the nervous tissue has a special affinity for that particular dye. In 1891 the phenomena of immunity of mice to gradually increased quantities of vegetable poison gave Ehrlich ground for the extension of his principles. By the exercise of what he called his "chemical imagination" he pictured a poisonous substance as made up of two kinds of parts, the actual carriers of the poison, or toxophores, and the effecters of the connection with the protoplasm, or haptophores. When the poison is administered in small quantities, the side-chain elements — chemo-receptors — of the protoplasm break away from the ring and render the toxin harmless by combining with the haptophore. At the same time the protoplasm is stimulated to produce a very great number of chemo-receptors, which neutralize the poison when administered in larger quantities. Ehrlich on the basis of further experiments eventually established an international standard for the administration of diphtheria antitoxin.

The fact that pathogenic micro-organisms share with the living tissues of the human body the property of combining with certain chemical substances, as their specific affinity for certain aniline dyes bears witness, suggested means for their destruction. The pathogenic protozoa revealed by the micro-biological studies of Schaudinn and others offered a special field for a therapy based on micro-chemistry. Ehrlich had something of Sydenham's faith regarding the discovery of specifics. Quinine is a specific for a disease caused by a protozoön. We must learn to destroy all pathogenic protozoa without injuring the tissues of the patient. The ideal was a *therapia sterilisans*, one injection of which would destroy all the microbes, which, otherwise, might become immune to the poisonous influence of the injected chemical substance. In trypan red Ehrlich discovered such a specific for sleeping sickness in mice. This is, of course, a trypanosome disease. In 1894 Thomas and Breinl, of the Liverpool School of Tropical Medicine, had discovered that injections of atoxyl destroy the parasite in human beings suffering from sleeping sickness. It was found, however, that there are grave objections to its administration. Atoxyl was found to be para-amino-phenylarsenic acid, and Ehrlich discovered (as he thought) in one of its derivatives — arsenophenylglycin — a remedy for all trypanosomiases. Would one of these complex arsenic compounds prove effective against *Treponema pallidum*, the protozoön of syphilis? After a long series of experiments carried out by Ehrlich and his Japanese assistant Hata a specific was found in "606" — Salvarsan, or dioxydiamido arsenobenzol. The discovery was announced in the early part of 1911. It is interesting to note, in connection with the conjecture of Sydenham regarding the identity of syphilis and yaws, that "606" acts as an ideal remedy in the latter disease, which is caused by a parasite — *Treponema pertenue* — hardly distinguishable from *Treponema pallidum*.

The veteran Sir Jonathan Hutchinson (1828–1913), who had seen over a million cases of syphilis, wrote shortly before his death: "For the student of pharmacology syphilis has many important lessons.

The marvel which we witness in the certain and speedy disappearance under the influence of mercury of a large sclerosis as hard as cartilage, is more than equalled by the melting away of a big tumour-gumma under that of iodide of potassium." The record of Hutchinson and others may serve to remind us that the successful treatment of syphilis had its beginnings before the advent of recent chemotherapy.

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See also obituary notice of Paul Ehrlich in the *Proceedings* of the Royal Society, series B, vol. 92 (1921), pp. i–vii.

CHAPTER XIX

PREVENTIVE MEDICINE IN THE TROPICS

More than a century before the appearance of syphilis in Europe the eastern hemisphere was ravaged by another disease which had its origin in the tropics. The Black Death, or Plague, which even since the beginning of the twentieth century has carried off millions of the inhabitants of India, in the fourteenth swept to the northwest and claimed about sixty million victims. This was not its first nor its last visitation of Europe. We have already seen its disastrous effects in London and elsewhere in the time of Sydenham; and within the last twenty-five years this dreaded disease has threatened the ports of Italy, France, Germany, and Great Britain, as well as those of America both on the Atlantic and the Pacific. The virulent outbreak at Hong-Kong in 1894 led to the study of the pestilence in the light of modern bacteriology and parasitology. Within a few months Kitasato and Yersin had discovered the *Bacillus pestis*. Of the two forms of the disease — the pneumonic and the bubonic — the former may be conveyed from one person to another by means of bacilli borne by the air. Bubonic plague is transmitted to man from the rat by fleas. The chief preventive measure is the extermination of diseased rats. Haffkine's prophylactic vaccine has a marked effect both in decreasing the chances of infection and in increasing the chances of recovery in cases in which infection takes place.

It was Dr. (afterwards Sir Patrick) Manson who prepared the way for the greatest triumphs of preventive medicine in the tropics by demonstrating thoroughly, in 1879, that the mosquito is the intermediate host of *Filaria sanguinis hominis*, the parasite in certain particularly hideous forms of filariasis. Manson traced the life-cycle of the nematode in the mosquito and in the definitive host, man. He observed the filariæ in the stomach of the mosquito after it had sucked the blood of a patient suffering from filariasis, found that within a few hours they broke down the blood corpuscles in the abdomen of the insect, the escape of the hæmoglobin bringing about a thickening of the plasma. The viscosity of the plasma seemed to stimulate the filariæ to wriggle out of their sheaths. Once rid of these they moved about freely and found their way into the thoracic muscles of the mosquito, where they underwent metamorphosis, the young parasites showing a remarkable increase in size. The mosquito, about a week after sucking the blood of the filariasis patient, lays her eggs on the surface of stagnant water, and then dies. The filariæ find their way into the water from the dead body of the intermediate host, and thence into the stomach of the definitive host, and from the stomach reach the lymphatic trunks. There they attain sexual maturity, and give birth to a new generation of filariæ, which eventually pass by way of the lymphatic vessels into the blood stream.

In the year following Manson's discovery of the life-history of *Filaria sanguinis hominis*, Alphonse Laveran, a French army surgeon on service in Algeria, observed in the blood of patients suffering from malaria parasites which he considered the cause of the disease, a judgment that was soon confirmed by Dr. Richard and others. These protozoa were accurately described by Marchiafava and Celli in 1885. There are three varieties of this group of hæmocytozoa, *Plasmodium vivax*, *Plasmodium malariæ*, and *Plasmodium falciparum*, the parasites respectively of tertian, quartan, and æstivo-autumnal fevers. Golgi, the histologist, who as early as 1885 had shown that the paroxysms of malarial patients occur at the same time as the sporulation of the parasites, took the first step (1889) toward establishing the relationship between the varieties of the parasite and the various forms of malarial fever. Golgi's discovery of the coincidence between the malarial paroxysms of the patient and the sporulation of Plasmodia was confirmed by Dr. (afterwards Sir William) Osler, while the task of determining the exact casual relationship between pernicious, tertian, and quartan fever on the one hand, and *P. falciparum*, *P. vivax*, and *P. malariæ* on the other hand, was immediately completed by Marchiafava and Celli.

In 1886 Dr. G. M. Sternberg directed the attention of the medical profession in the United States to the views of Laveran concerning the etiology of malaria, and these soon gained support from the investigations of Councilman, Abbott, Thayer, and others, including Osler. As early as 1883 Dr. A. F. A. King had put forward as worthy of observation and experiment the supposition that mosquitoes (rather than marsh vapor) are the source of malarial infection. In 1889 Theobald Smith demonstrated that Texas fever is caused in cattle by a hæmatozoan parasite, later (1893) shown to be carried by an insect. It remained for Manson to formulate a definite verifiable hypothesis concerning the relation of the mosquito to the malaria parasite. With his studies of filaria in mind he proceeded on the supposition that the protozoa, after undergoing sexual reproduction, complete their life-cycle in the body of an insect host. Laveran had observed in the blood of malarial patients withdrawn from the circulation that some of the gametocytes put forth motile filaments. These processes, mistaken by Manson for spores (and later shown to be of the nature of spermatozoa), he correctly supposed to play an essential part in maintaining the life of the protozoa in the body of some suctorial insect. In 1894 Manson communicated his hypothesis to Major (now Sir) Ronald Ross, who undertook its verification in the malarial districts of India, where he was on service.

This was a very difficult task; for the species of mosquito that might prove the intermediate host of the protozoön and the form the latter might bear in the body of the insect were alike unknown at that time. Ross, in the course of an investigation extending about two and a half years, fed hundreds of mosquitoes of different species on persons suffering with malarial fever, and then examined the tissues of each insect in the hope of discovering the parasite. As he stated in 1900, "nothing but the most convincing theory, such as Manson's theory was, would have supported or justified so difficult an enterprise." Finally eight mosquitoes of a species with spotted wings were fed on a malarial patient. On dissecting the seventh of these specimens the investigator achieved his first success.

"The tissues of the stomach (which was now empty owing to the meal of malarial blood taken by the insect four days previously being digested) were reserved to the last. On turning to this organ I was struck by observing, scattered on its outer surface, certain oval or round cells of about two or three times the diameter of a red blood corpuscle — cells which I had never seen in the hundreds of mosquitoes examined by me. My surprise was complete when I next detected within each of these cells *a few granules of the characteristic coal-black melanin of malarial fever* — a substance quite unlike anything usually found in mosquitoes. Next day the last of the remaining spotted-winged insects was dissected. It contained precisely similar cells, each of which possessed the same melanin; only the cells in the second mosquito were *somewhat larger than those in the first*. . . .

"These fortunate observations solved the malarial problem. As a matter of fact the cells were the *zygotes of the parasite of remittent fever growing in the tissues of the gnat;* and the gnat with spotted wings and boat-shaped eggs in which I found them belonged (as I subsequently ascertained) to the genus *Anopheles*. Of course it was impossible absolutely to prove at the time, on the strength of these two observations alone, that the cells found by me in the gnats were indeed derived from the *hæmamœbidæ* sucked up by the insects in the blood of the patients on whom they had fed; — this proof was obtained by subsequent investigations of mine; but . . . the clue was obtained: it was necessary only to follow it up — an easy matter."

The *zygote*, which is the ovum of the female gametocyte fecundated by the motile filament of the male gametocyte, gives rise to spores or *blasts*, which are found distributed in various parts of the insect. "Beyond this it was difficult to go, but at last, after examining the head and thorax of one insect, I found a large gland consisting of a central duct surrounded by large grape-like cells. My astonishment was great when I found that many of these cells were closely packed with the *blasts*, which are not in the least like any normal structure found in the mosquito. Now I did not, at this time, know what this gland is. It was speedily found, however, to be a large racemose gland consisting of six lobes, three lying on each side of the insect's neck. The ducts of the lobes finally unite in the common channel which runs along the under surface of the head and enters *the middle stylet, or lancet, of the insect's proboscis*. It was impossible to avoid the obvious conclusion. Observation after observation showed that the *blasts* collect within the cells of this gland. It is the salivary or poison gland of the insect, similar to the salivary gland found in many insects, the function of which in the gnat had already been discovered — although I was not aware of the fact. *That function is to secrete the fluid which is injected by the insect when it punctures the skin*, fluid which causes the well-known irritation of the puncture, and which is probably meant either to prevent the contraction of the torn capillaries or the coagulation of the ingested blood. . . . The *blasts* must evidently pass down the ducts of the salivary gland into the wound made by the proboscis of the insect, and thus cause *infection in a fresh vertebrate host.*"

Ross's investigations were carried on from 1895 to 1899. In 1897 Dr. W. G. MacCallum discovered the function of the motile filaments already referred to, and in 1898–99 Bignami and others demonstrated that all mosquitoes acting as hosts of malarial parasites belong to the genus *Anopheles*. In 1900 Dr. Sambon, accompanied by friends and servants, succeeded in living in a malarial district near Rome (Ostia) without contracting fever — and that from the beginning of July till October 19th — exercising the sole precaution of remaining within a well-screened hut from sunset to sunrise. It was also shown that mosquitoes that had bitten malarial patients in Italy could, when carried to England, transmit the infection to people who had never been in a so-called malarial district. Mr. Manson, the son of Dr. Manson, submitted to the experiment necessary to establish this fact.

Methods of sanitation, developed largely by Ross, were soon extensively employed in the control of malaria. These included the use of nets and wire screens, the protection of tanks and other water receptacles, the clearing away from the neighborhood of human habitations of empty tins, broken bottles, gourds, buckets, and bits of pottery in which mosquitoes might lay their eggs, the drainage of swamps, the filling-in of pools and puddles, the extirpation of undergrowth, the oiling of stagnant waters, the killing of mosquitoes by fumigations, and the destruction of the larvæ by means of fish and other natural enemies. At the same time the systematic use of quinine as a preventive was greatly extended in the tropics through the influence of Koch. Ross visited the west coast of Africa in 1899, and before the close of 1901 encouraging results of sanitary measures suggested by the discovery of the part played by *Anopheles* in malarial infection were reported from Sierra Leone, Lagos, Hong-Kong, certain points in the Malay Peninsula, as well as from Italy, India, North Africa, and the American Tropics. In 1902 Ross received the Nobel Prize for his efforts to control malaria, the scourge of the tropics, and of all diseases whatsoever probably the most detrimental to the health and efficiency of man. At Ismailia, on the Suez Canal, where Ross was in charge of sanitation, the number of cases of malaria was reduced from 1551 in 1902 to 37 (all cases of relapse) in 1905.

It was by the ingenuity and resolution of Major Walter Reed, an American army surgeon, that another great triumph over tropical disease was made possible. Born in Virginia in 1851, he succeeded by severe application to study in securing the doctor's degree at the University of Virginia before he had completed his nineteenth year. He continued his medical studies in the Bellevue Hospital Medical College, New York, had considerable hospital experience in that city and in Brooklyn, became district physician in one of the poorest parts of the metropolis, and was appointed one of five inspectors on the Brooklyn Board of Health. He soon gave up the idea of general practice, and, having passed the examination of the Medical Corps of the United States Army, he married, and at the age of twenty-four entered upon his garrison duties in the West. He had an extended experience of frontier life — Arizona, 1876–80, Nebraska, 1882–87, and Dakota, 1891–93. For a short time in 1881 he was stationed at Fort McHenry, Baltimore, and was able to pursue at the Johns Hopkins University the study of physiology, but a greater opportunity, which he seized with avidity, came in 1890–91, when he served as examiner of recruits at Baltimore. He now devoted himself to pathology and bacteriology, and was in close relation with Welch, Councilman, Abbott, Thayer, Nuttall, and other leaders in medical science, at the Johns Hopkins Hospital. He undertook an investigation into the so-called lymph nodules of the liver in typhoid fever, and gave further evidence of an aptitude for research.

After his two years of service in Dakota, Reed was appointed curator of the Army Medical Museum at Washington and professor of bacteriology in the Army Medical School. He was deeply interested in the discovery of the Klebs-Löffler bacillus, and was the champion of the antitoxin treatment of diphtheria. He made numerous contributions to professional periodicals, and prepared reports on malarial fevers at Washington Barracks and Fort Myer, and on serum diagnosis in typhoid fever. In 1897 Reed and Dr. James Carroll were appointed by Surgeon-General Sternberg to investigate the claim of Professor Sanarelli of Bologna that *Bacillus icteroides*, found by the Italian scientist in the blood of yellow-fever patients in Brazil, was the cause of yellow fever. It was especially desirable that the organism observed by Sanarelli should be compared with *Bacillus X*, which had been observed ten years previously, by Sternberg himself, in yellow-fever patients. In a preliminary report in 1899 Carroll and Reed stated that *Bacillus icteroides* (ultimately shown to be identical with *Bacillus X*) is really a variety of the hog-cholera bacillus, with which Reed had become familiar while working with Welch and Clement at the Johns Hopkins Hospital. After the beginning of the Spanish-American War of 1898, Reed was made chairman of a committee to investigate the origin and spread of typhoid fever in the United States military camps, but his great opening came, when, in 1900, yellow fever having broken out among the American troops in Cuba, he was made chairman of an Army Board, composed of Carroll, Lazear, Agramonte, and himself, appointed to investigate the cause of the disease.

How little was known, at the time of the Spanish-American War, concerning the cause of yellow fever and its mode of transmission is shown by a report of the officers of the United States Marine Hospital Service, which declared that it was spread by the infection of places and articles of bedding, clothing, and furniture. "More recently," this report of 1898 continues, "the idea has been advanced that probably the germ of yellow fever enters the general circulation through the respiratory organs in some obscure manner, and incubating in the blood directly poisons this life-giving stream. However this may be, the present opinion is that one has not to contend with an organism or germ which may be taken into the body with food or drink, but with an almost inexplicable poison so insidious in its approach and entrance that no trace is left behind." The American army in Cuba almost succumbed to its unseen enemies. After two months' campaigning it "was utterly used up and of no value whatever as a fighting machine," at least four fifths of the troops being incapacitated by tropical diseases and typhoid. When Gorgas took control of the sanitation of Havana he was influenced by the rather vague assumption that yellow fever was a filth disease. Though he was thrown into daily contact with Dr. Carlos Finlay, Gorgas took very lightly the mosquito hypothesis which the Havana doctor had been maintaining stoutly since 1881. By the middle of 1900 Gorgas had made Havana, in his judgment, the cleanest city in the world, but there were more cases of yellow fever than for several years previously, and the inhabitants twitted him with the fact that the disease was particularly prevalent in the cleanest sections of the Cuban capital.

Reed, who arrived at this juncture — June, 1900 — soon found his way, with the able support of Carroll, Lazear, and Agramonte, through the welter of misconceptions concerning the etiology and transmission of yellow fever. Some time was spent by the Board in giving the *coup de grâce* to Sanarelli's hypothesis. Agramonte had previously — at Santiago — found *Bacillus icteroides* in thirty-three per cent of the yellow-fever patients examined by him. Now, however, eighteen cultures from as many yellow-fever patients failed to show the presence of the hog-cholera bacillus. At the end of July Reed went to the Pinar del Rio Barracks, where a number of cases of yellow fever had occurred, and there he made two very important observations. He noted in the first place that several non-immunes had come into intimate contact with clothing and bedding contaminated by yellow-fever patients without any apparent deleterious effects. He noted in the second place that a prisoner confined with eight others in a cell of the guardhouse had contracted the disease, while his companions had escaped infection, and that it had been surmised at the time that the victim had been bitten by an insect, perhaps by a mosquito. Very soon after his arrival in Cuba Reed had taken account of Finlay's hypothesis, as well as of the attempts to put it to experimental proof, and had obtained from Finlay eggs of the *Stegomyia*, the supposed carrier of the pathogenic organism. Moreover, Reed had been impressed by the work of Ross, Bignami, and others concerning the dissemination of malaria. He declared it to be "of the highest importance that the agency of an intermediate host, such as the mosquito, should either be proven or disproven."

Ross's belief in an intermediate host had been influenced by the report of Dr. H. R. Carter's observations in Mississippi (1898) concerning the time that elapsed between the arrival of cases of yellow fever in isolated farmhouses and the occurrence of secondary infections. Finlay's attempts to produce yellow fever by the bite of *Stegomyia* had failed because he did not know that the insect does not become infectious till about twelve days or more after feeding on a yellow-fever patient, and that the blood of the patient does not infect the insect except in the first three days of sickness. The first experiments of Lazear with supposedly infected mosquitoes failed for similar reasons, but on August 27th, Dr. Carroll allowed himself to be bitten by mosquitoes that had fed on yellow-fever patients, and one of the insects was able to produce the desired result. After some slight premonitory symptoms he developed a severe case of yellow fever August 31st. On September 13th Lazear, while working among yellow-fever patients at Las Animas Hospital, Havana, observed a mosquito biting his hand. He allowed it to take its fill. He was attacked by yellow fever September 18th, and died of the disease a week later. On the basis of these and other cases Reed stated in the following month — "The Etiology of Yellow Fever: A Preliminary Note" — that the mosquito acts as the intermediate host for the parasite of yellow fever. The task remained by a series of well-controlled experiments to support this statement and to test the claims of other possible means of infection besides the bite of the mosquito. Accordingly a quarantined camp, named in honor of Dr. Lazear, was established about a mile from Quemados, Cuba.

"It was now proposed," writes Reed, "to attempt the infection of non-immune individuals in three different ways, namely, first, by the bites of mosquitoes which had previously bitten cases of yellow fever; second, by the injection of blood taken during the early stages from the general circulation of those suffering from the disease; and, third, by exposure to the most intimate contact with fomites. For this purpose, in addition to the seven tents provided for the quartering of the detachment, two frame buildings each 14 x 20 feet in size were constructed. These buildings, having a capacity of 2800 feet, were exactly similar, except that one of them, known as the 'Infected Mosquito Buidling,' was divided near the middle by a permanent wire screen partition and had good ventilation; while the other, designated as the 'Infected Clothing Building,' was purposely so constructed as to exclude anything like efficient ventilation. These houses were placed on the opposite sides of a small valley, about eighty yards apart, and each seventy-five yards distant from the camp proper. Both houses were provided with wire screen windows and double wire screen doors, so that mosquitoes could be kept within or without the buildings as the experimenters might desire."

On December 5th Private Kissinger, who (with Moran) had volunteered without pecuniary reward, "solely in the interest of humanity and the cause of science," to submit to the experiment, was bitten by infected mosquitoes, and in about three and a half days suffered an unmistakable attack of yellow fever. During the week following the onset of his illness four other cases of the disease were produced by the same means in the Infected Mosquito Building. On December 21st and 22d Moran was bitten, and on Christmas morning he had a sharp attack of the fever; but two other volunteers, who slept for fifteen nights on the other side of the wire screen partition, by which the building was divided, remained in good health because they were protected from the mosquitoes. A building is infected only in as much as it harbors infected mosquitoes. In the Infected Clothing Building Dr. Cooke and Privates Folk and Jernigan slept every night from November 30th till December 19th in close contact with blankets, sheets, pillow-slips and pyjamas polluted beyond description by yellow-fever patients in Las Animas Hospital and other institutions. The three remained in perfect health in spite of passing twenty nights in hot, ill-ventilated, and noisome quarters. In a later experiment — January 4, 1901 — Jernigan was inoculated with blood drawn from a yellow-fever patient in the early stage of the disease. He developed yellow fever in about four days. Blood taken from him within the first three days of his illness and injected into a non-immune proved capable of transmitting the disease, a fact which was taken to indicate that the casual agent is a living organism and not merely a chemical toxin. It was further proved by experiment that the blood of a yellow-fever patient remains infectious after passing through a fine filter, but that it loses its virulence after being heated to 55° C.

The general conclusions announced by the Army Board were: That yellow fever is conveyed from the sick to the well solely by the bite of the female *Stegomyia* mosquito; that the insect can become infected only after sucking the blood of a patient within the first three days of the sickness; that the period of extrinsic incubation is from twelve to twenty days; that the period of intrinsic incubation is from three to six days; that yellow fever may be produced artificially by injecting a non-immune with the blood of a patient in the early stage of the disease; and that the causal agent of yellow fever is a sub-microscopic parasite. "These discoveries," writes Gorgas, "have been of enormous benefit to mankind, and upon them has been based the sanitary work against yellow fever which has been so successful."

To the splendid efforts of Major (later Surgeon-General) Gorgas, who at the time of the Army Board's report — February, 1901 — was chief sanitary officer of Havana, the practical success of controlling yellow fever was due. All cases of the disease occurring in the city were required to be reported immediately to the Health Department. The patients were carefully screened from mosquitoes in order that they might not become the source of further infection. A war was carried on against the insects by the use of fumigations of sulphur and of pyrethrum powder, by the destruction of larvæ, and by the protection of barrels, cisterns, etc., and by the removal of tin cans and other breeding-places. Any ship with yellow fever on board was fumigated in order to kill infected mosquitoes, and the non-immune passengers or members of the crew were detained at a quarantine station for a period of six days. There had been three hundred and ten deaths from yellow fever in Havana in 1900; there were only eighteen in 1901. Of these eighteen cases, seven occurred in the month of January, five in February, one in March, one in July, two in August, and two in September. For the first time since the capture of Havana by the British during the Seven Years' War, the city became free from yellow fever. "For two hundred years before this time [1762]," writes Gorgas, "Havana had been subject to epidemics of yellow fever, but from 1762 up to the year 1901, there was probably not a single day when Havana did not have a case of this disease within its bounds." Gorgas attacked the *Anopheles* mosquito, as well as the *Stegomyia*, and the number of deaths from malaria in Havana was reduced from three hundred and twenty-five in 1900, to one hundred and fifty-one in 1901, to seventy-seven in 1902, and to four in 1912.

Early in 1902 Gorgas called the attention of Surgeon-General Sternberg to the value of applying the principles established by the Reed Board to the sanitation of the Isthmus of Panama in case the United States should take over the construction of the Canal. He was soon relieved of duty at Havana, and ordered to the United States in order that he might be in touch with preparations for work on the Isthmus. In the spring of 1904 he, as sanitary adviser accompanied the Commission (Isthmian Canal) on a visit of inspection to Panama. His organization began in June. Finding "that the French had lost yearly by death from yellow fever about one third of their white force," he made an onslaught on the mosquitoes, principally by the use of fumigations in the city of Panama. Success was not immediate. There was a great deal of yellow fever within the ensuing twelve months, but in the autumn of 1905 the number of cases rapidly declined. After November the disease ceased to exist in the city of Panama. One case occurred at Colon in the spring of 1906, but since then not one case of yellow fever has originated on the Isthmus.

"Of the six important tropical diseases," says Osler, "plague, which reached the Isthmus one year, was quickly held in check. Yellow fever, the most dreaded of them all, never recurred. Beri-beri, which in 1906 caused sixty-eight deaths, has gradually disappeared. The hookworm disease, ankylostomiasis, has steadily decreased. From the very outset, malaria has been taken as the measure of sanitary efficiency. Throughout the French occupation it was the chief enemy to be considered, not only because of its fatality, but on account of the prolonged incapacity following infection. In 1906, out of every 1000 employees there were admitted to the hospital from malaria 821; in 1907, 424; in 1908, 282; in 1912, 110; in 1915, 51; in 1917, 14. The mortality from the disease has fallen from 233 in 1906 to 154 in 1907, to 73 in 1908 and to 7 in 1914. The death rate for malarial fever per 1000 population sank from 8.49 in 1906 to 0.11 in 1918. Dysentery, next to malaria the most serious of the tropical diseases in the Zone, caused 69 deaths in 1906; 48 in 1907; in 1908, with nearly 44,000 only 16 deaths, and in 1914, 4."

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CHAPTER XX

MEDICAL SCIENCE AND MODERN WARFARE

THE achievements of medical science in the emergency created by the outbreak of war in 1914 were owing in no inconsiderable degree to officers imbued with the spirit of research and with the enterprise that had checked the ravages of yellow fever and malaria, discovered the cause and the mode of transmission of Malta fever and trypanosomiasis, developed a treatment for amœbic dysentery, adopted measures for the cure of beri-beri, and dealt successfully with hundreds of thousands of cases of hookworm disease.

Preventive measures against typhoid, the application of which to millions of men was one of the important successes of the World War, were made possible by the work of Sir Almroth Wright and others. The *Bacillus typhosus* had been discovered by Eberth in 1880. In 1896 Pfeiffer and Kolle succeeded in inoculating two volunteers with the disease. In this same year Wright devised his preventive inoculation — an emulsion of dead typhoid bacteria. With this he inoculated British troops in India to about the number of four thousand in 1898–1900. During the Boer War Wright, in coöperation with Sir William Leishman, extended the prophylactic treatment to 100,000 troops in South Africa. It was adopted by the medical officers of the French and German colonial troops. The prevention of typhoid among the Japanese soldiers was one of the outstanding features of the Russo-Japanese War of 1904. Of 12,801 men of the United States army, who during the Mexican border troubles of 1912 had received preventive treatment under the direction of Major Russell, only two developed typhoid. This result is all the more striking when we recall that at the time of the Spanish-American War there had been among 107,973 men in the United States encampments 20,738 cases of typhoid fever and 1580 deaths. During the World War preventive measures, including the chlorination of waters and the control of carriers, were made more and more effective. The technique of prophylactic inoculation was developed among the British by officers working under the direction of Leishman. From the beginning of 1916 the triple vaccine, for the prevention of the paratyphoids — the bacteriology of which had been set forth by Buxton in 1902 — as well as of typhoid proper, came into use, and was followed by other polyvaccines. Among the millions of United States troops, in the two years subsequent to the declaration of war in April, 1917, there were only 227 deaths from typhoid fever.

The labors, toward the close of the nineteenth century, of the Prussian army surgeon Emil von Behring and others had prepared the way for the successful employment of serums in the World War. The *Bacillus tetani* had been discovered by Nicolaier in 1884. Five years later Kitasato had succeeded in growing the organism in pure culture. In 1890 von Behring in collaboration with Kitasato published an article concerning the production of diphtheria immunity and tetanus immunity in animals. His serum therapy (as explained in *Die Blutserumtherapie*, 1892) is founded on the principle that the serum of animals rendered immune to a disease acts, if introduced into a living organism, as an antidote to the virus of the bacteria concerned. In the first part of the World War there were a great many losses through tetanus — so many, in fact, among the allied troops in the weeks following the first battle of the Marne as to give rise to the most serious apprehensions. In the month of October, 1914, the ratio of cases among the wounded was 32: 1000. This was quickly reduced to 2: 1000 by the use of anti-tetanus serum. During the war the serum treatment was used also to control cerebrospinal meningitis. The pathogenic organism had been isolated by Weichselbaum in 1887. Dr. Simon Flexner had undertaken the investigation of the disease in 1905 and after a series of experiments had produced a prophylactic serum. In 1914–15 a severe epidemic broke out among the Canadian troops and (according to Osler) the infection was carried by them to England. It was particularly rife in the camp on Salisbury Plain. In 1915 it was discovered that a better serum could be prepared by injecting into animals different strains of the menigococcus, the differentiation of which is still under investigation. It was also found desirable to isolate soldiers suspected of being carriers, as the infection is readily conveyed from person to person by coughing and sneezing.

Influenza, another disease disseminated through discharges from the mouth and nose, baffled the resources of medical science, and became very deadly in the armies, as well as in the civil populations throughout the world. For example, it began to attract special attention among the British troops on the northern part of the western front about April, 1918, that is, a few weeks after the beginning of the final campaign. It was soon known to be pandemic and extremely infectious. The earlier cases were quite mild, but the disease became, as it spread, more and more virulent. June 23d a committee which had been appointed to study influenza reported to the Director General of the Medical Services that the contagion of this disease appears to be air-borne. "The main principle to be followed, therefore, is to spread troops as widely as possible, avoiding the crowding of men in tents, billets, messrooms, etc." Whenever the military situation permitted, the troops were to sleep in the open air in individual blanket-shelters. Influenza patients were to be kept separate from other patients. Of course it was frequently impossible to live up to the sanitary suggestions contained in this British report. This was notably the case in the transportation of troops. In September the American transport Nestor left the United States for England with 2807 soldiers on board. Two or three days later she was forced to land 660 patients and contacts at Sydney, Cape Breton. But, in spite of this precaution, 1000 more men were taken ill before the ship reached Liverpool. The military camps in the United States were severely smitten, and the deaths from influenza and its complications outnumbered the country's total losses in battle.

The stimulating influence of war on research in the various sciences is obvious to every student of history. The effect of the World War on the progress of medical science was early recognized and is becoming every day more manifest. At the beginning of 1917 Sir F. W. Andrewes expressed the opinion "that in pathology, no less than in the other sciences, advances have been made, under the stress of national necessity, during the two years and a half of war which could hardly have been expected in twenty years of ordinary work; and although it has been 'war work,' it represents a solid contribution to science which will be valid for the years of peace to come." The occurrence of dysentery among the troops in Gallipoli, Egypt, Mesopotamia, and other regions led to a renewed investigation of the causative agents of both the bacillary and amœbic forms of the disease, and to a modification of the use of emetine and emetine bismuth iodide in the treatment of amœbic dysentery. Ailments like trench foot, trench nephritis, and trench fever, incident to life at the front under new and peculiar conditions, were a challenge to the medical science of the twentieth century as syphilis had been to the less highly developed medical science of the sixteenth century. Trench fever, named toward the end of 1915, was proved by investigations to be transmitted by the louse, and this discovery suggested as a means of control such a crusade against the insect carriers as had proved effective in combating typhus in Serbia and elsewhere. Trench fever is probably not only a newly recognized disease but an absolutely new disease, caused by a micro-organism which has now for the first time invaded the tissues of man. Trench nephritis, on the other hand, had been described during the American Civil War. Soldier's heart, closely studied by J. M. Da Costa among the Federal troops, had been observed in the Crimean War. After the outbreak of the World War disordered action of the heart (investigated by Allbutt and others) as well as pyrexias of uncertain origin, became familiar to every medical officer. Infective jaundice, which was no doubt rife among the American soldiers in 1861–65, and is now known to be caused by a parasite (*Spirochæta icterohæmorrhagiæ*), was epidemic at times during the recent war; while toxic jaundice was of frequent occurrence in munition factories.

Observations made during the World War give considerable promise of advance in our knowledge of psychiatry. Some of the methods of testing the mental fitness of the men and of rating the officers were rather crude and illogical, and the statistical methods applied to the data led at times to results which the scientific mind will receive with caution. Nevertheless, great enterprise was shown — notably in America — in the task of taking stock of the mental equipment of millions of young men. It has been claimed as the result of extensive investigation that a very large percentage of twelve-year-old minds is found among American men of military age. The records of the discharge of soldiers from the British armies as permanently unfit on account of nervous or mental diseases have, similarly, been regarded as indicating that a considerable proportion of the male population of a highly civilized country possesses a neurotic or neuropathic predisposition.

The British War Office recognized three forms of war neurosis — shell shock, hysteria, and neurasthenia. Needless to say, the symptoms described under each of these categories show that the classification was not wholly satisfactory. Some cases included under shell shock were definitely known to be the result of the percussion of explosives, to the direct effect of which organic changes, like the rupture of the tympanic membrane and the alteration of the spinal fluid, bore witness. Other cases of shell shock seemed more purely psychic in their manifestations. Both types contributed to corroborate the teachings of Darwin and James concerning the intimate relations between the emotions — fear, for example — and the physiological concomitants of the emotions. Does the shattering effect, on the body, of air-vibrations constitute the agitation we call fear, or does the recognition of danger provoke the physiological symptoms? The well-attested fact that a cold wind playing upon a sleeper may give rise to a dream of fear seems to support the view that it is the bodily state that gives substance and character to the emotion.

Colonel Mott holds that in any case there is a vicious circle, the perceptual feeling of fear stimulating the physiological symptoms and these in turn giving reinforcement to the psychic condition. In his patients he found evidence of a persistence of the bodily changes characteristic of a state of fear. About ten per cent of the cases of severe neurasthenia showed some of the symptoms of Graves's disease, among the exciting causes of which fright, worry, and mental shock have long been recognized. Other cases gave evidence of an unusual amount of adrenin in the blood, an increase of which secretion occurs as a result of fright, as has been shown experimentally by Cannon. The view here taken concerning the importance for the emotional life of the internal secretions — of the thyroid as well as the adrenals — might be supported by referring to Addison's disease, in which the atrophy of the adrenals may give rise to languor, anæmia, and cardio-vascular asthenia. Fear, including the increased heart rate, is a preparation for fight or flight; but, as Mott remarks, in trench warfare, which is particularly prolific of war neuroses, the emotions are deprived of their natural functions. The soldier can neither fight nor take refuge in flight; he can only adopt the crouching attitude of immobility. The result may be a deep-seated emotional derangement.

"In the dreams of soldiers, ideas of past war experiences are revived with great vividness in the great majority of cases, even in those who are unable to recollect their dreams. For besides those patients who wake up in a fright and cold sweat, there have been numerous instances of soldiers who have walked in their sleep, and many others have talked, shouted out orders, and cried out in alarm as if again engaged in battle (not a few of these have been mutes). But the strangest phenomena of forgotten dreams of soldiers suffering from shock are observed in those who in their sleep act as though they were engaged in battle, and go through the pantomime of fighting with bombs, with bayonet, with machine gun and with rifle, and yet remember none of these things when they wake. Evidently during their sleep vivid imaginings of their previous experiences are arousing defensive and offensive reactions in face of the imaginary enemy." Neuropathic patients who show symptoms, in the early morning, of nervous exhaustion and irritability are not infrequently the victims of dreams of a highly emotional sort which may be beyond the power of recall of the waking consciousness.

In the treatment of war hysteria persuasion, suggestion and psychoanalysis proved effective. It was found advisable to explain the symptoms and the nature of the neurosis to a few of the more intelligent patients and to employ their powers of persuasion to induce a new mental attitude in the others. Grateful patients already on the highroad to recovery thus became very helpful in bringing about cures. Any form of treatment that inspired in the patient the confidence that something effective was being done in his behalf had a therapeutic value. Even where no bodily derangement was suspected a thorough physical examination was necessary in order to establish the physician in the confidence of the patient. The physician's personality and the surroundings generally had a powerful influence on the suggestible minds of the patients. In addition to its suggestive value electricity enabled the physician to prove to patients suffering from hysterical paralysis that their muscles had not lost the power of contraction. It also restored sensibility in cases of hysterical anæsthesia, and thus renewed the patients' consciousness of the affected parts. Passive movements of an apparently paralyzed limb might afford the kinæsthetic cue for active, voluntary movements. The method of psychoanalysis — breaking down dissociations and inducing an integration of consciousness by the revival of repressed emotional experiences — found many champions among those who succeeded in the treatment of war hysteria. The revival of the repressed experience — such as remorse in connection with the death of a comrade — must be emotional in character in order to bring about a satisfactory catharsis; and the revived experience should be recalled again and again till the memory loses its dramatic vividness. The fact that an anxiety neurosis may supervene on the removal of the hysterical symptoms should warn us that dissociation is after all a means of defense against unbearable mental strain. "My dearest wish," wrote a young correspondent towards the close of the war, "is to forget the whole grewsome business." What Culpin calls "the ever-growing sense of horror" led at times to prolonged amnesias, the treatment of which by the method of psychoanalysis had to be undertaken with the utmost caution.

In reporting on the surgical developments of the World War Dr. W. S. Bainbridge writes: "In the many hospitals and casualty clearing stations visited, the method of treating war wounds varied greatly. There were those who believed in the use of the strongest antiseptics, as at the Grand Palais, where phenolization was employed, while others favored incising freely with drainage and practically no antiseptics. More and more the two extremes are being emphasized; on the one hand, the Carrel treatment with its scientific laboratory control and systematic use of strong antiseptic solutions, and on the other, *débridement* and immediate closure." The failure of the ordinary antiseptic methods to meet the conditions of warfare on the western front, where the heavily manured soil was charged with organisms, soon led to modifications, such as the use of drainage with antiseptics, and the use of hypochlorites. The Carrel method, which attracted general attention in 1916, soon found rivals in other essentially antiseptic methods. In 1917–18 the method of primary wound suture, immediate or delayed, came into special prominence. "Under favorable conditions," continues Bainbridge, "primary union by immediate or delayed suture of war wounds which have been operated on and properly purified, is now the last word in this branch of surgery. Experience in the World War has taught entirely new lessons to the surgeons who found themselves confronted with unprecedented conditions both in regard to the masses and classes of war wounds they were expected to handle. Perhaps the most important lesson of all, with the closest bearing on wound treatment in general, consists in the recognition of the fact that antiseptics are inefficient without the most careful and thorough mechanical purification of the wound, including the complete removal of all dead or nonviable tissue."

Sir Henry Gray expresses a similar conclusion. "Much discussion," he writes, "took place during the early periods of the war as to the best form of dressing and the most effective lotions to be employed in the treatment of wounds. It was hoped that by the early use of suitable disinfectants much would be done to combat the onset of sepsis. It has been found that antiseptics *per se* have but little influence in this direction, and that the best hope of averting the danger of severe sepsis lies in early and efficient operation. The use of ordinary disinfectants and impregnated dressings is of little or no value in most cases until such operation has been carried out." He adds that eusol and similar solutions are too evanescent in antiseptic action when in contact with the tissues to make their use worth while, and Carrel's method is out of the question in the early treatment of war wounds. The experience of the twentieth century has confirmed the judgment of the sixteenth that all gunshot wounds are necessarily infected, and for Gray sepsis, shock and hæmorrhage are interdependent phenomena. The wounded must be carefully guarded against all emotional and sensory stimuli liable to provoke shock, and the loss of every additional ounce of blood is of the utmost importance. "Nothing," as Gray says, "has been more striking than the rapid spread of the use of blood transfusion as a therapeutic measure for the combating of shock-hæmorrhage. During the first two years of the war transfusion was performed only by a few specially experienced surgeons, and was regarded more as an interesting curiosity than as a practical measure in the treatment of shock. It is only during the last two years that its scope has been realized, and that it has been adopted as a recognized part of the treatment of the severely wounded man."

War surgery was greatly facilitated by improved methods of anæsthesia, as well as by radiography and other means of determining before operation the nature of the injury and the exact location of bullets, shrapnel, or other foreign bodies. Local or regional anæsthesia was frequently employed even in major operations. Nitrous oxide and oxygen came into very general use. Sometimes these inhalations were combined with small quantities of ether, or administered after preliminary injections, nerve blocking, etc. There occurred a revaluation of the various anæsthetics and combinations of anæsthetics, and an increased discrimination in their use. Moreover, professional opinion was rendered so unsettled in reference to the worth of the various methods of inducing surgical anæsthesia that the search for new drugs and anæsthetic preparations has been greatly stimulated.

In the localization of foreign bodies, as well as of fractures and other injuries, radiography was indispensable. Unless the cases suffering from bullet or shrapnel wounds were screened, it was as a rule impossible to conjecture the location of a projectile. A bullet entering the back above the scapula might lodge in the anterior wall of the abdomen without its passage through the lungs being revealed by any remarkable symptoms. Small fluorescent screens that could be closely applied to the skin of the patients were used by some radiographers. Fractures and other injuries that could not be detected on the screen were often revealed by an examination of the plates. In many cases stereoscopic radiographs proved invaluable to the operator. Besides radiography, other ingenious devices were used in the localization of bullets and other projectiles.

The exigencies of the World War entailed a very great extension of orthopædic surgery. Through the activity of Sir Robert Jones — exponent of the practice and principles of Hugh Owen Thomas and John Hunter — the British Orthopædic Centers with only two hundred and fifty beds at the start developed into the Special Military Surgical Hospitals with thirty thousand beds. In these institutions the general surgeon, the orthopædic surgeon, the neurologist, as well as the experts in hydrotherapy, massage, gymnastics, vocational training, etc., coöperated in the repair of injuries and the restoration of the functions of nerves and muscles. To obtain the best results it was essential to secure continuity of treatment. The importance of the work of the advanced units in the prevention of deformities was very clearly recognized. At the earliest possible moment after the occurrence of a fracture it became the practice to adjust a suitable splint, such as a Thomas leg splint or a swiveled Thomas arm splint. Fractures of the femur at the beginning of the war frequently resulted in serious deformities; later, Jones was able to report a series of five hundred cases of compound fracture of the femur with an average shortening of less than half an inch. Remarkable successes were gained by the patient treatment of comminuted septic fractures. In the judgment of Sir Robert Jones "the weight of the body should not be allowed on the unsupported femur for at least six months after the recumbent treatment of the fracture." A badly sprained ankle, however, should make a complete recovery in fourteen days: whereas immobilization for weeks in plaster would indefinitely perpetuate weakness and disability. The theory of the Belgian surgeon Willems that joint lesions should be treated on the principle of immediate active mobilization led of course to a procedure far more drastic than any employed in the British Special Military Surgical Hospitals, where an opposed principle in the main prevailed.

One of the outstanding successes in restorative work was the plastic surgery at Queen's Hospital, Sidcup, at Val-de-Grâce (Paris), at Boulogne, at Le Mans, and at the American Ambulance at Neuilly. The general surgeons and the dentists here entered

PLASTIC SURGERY OF THE FACE

1 and 2: Condition on admission. 3: Adjustable intranasal support carried from a metal cap splint cemented to the upper teeth. 4: Improvement obtained by operation and insertion of nasal splint. 5 and 6: Result of insertion of cartilage graft from rib. (At Queen's Hospital, Sidcup, by Major H. D. Gillies.)

into the closest coöperation. As early as 1916 Delagénière reported a number of cases in which defects of the skull after trephining and defects in bones that had failed to unite after fracture had been successfully treated by means of osteoperiosteal grafts from the tibia. In the following year he applied his method in the treatment of the inferior maxilla and other parts of the bony framework of the face. Indeed, he soon recognized that any part of the skeletal system may be repaired by means of grafts. The restoration of the faces of soldiers mangled by the instruments of modern warfare is rightly regarded as one of the finest achievements of the art of surgery. In their endeavors to enable the mutilated man to resume his place among his fellow-men the surgeons were supported by those who used their talents in the modeling of masks.

Successes gained by means of bone grafting — the most important development of modern orthopædic surgery — by ligating the upper part of the femoral artery and other large vessels in accordance with the fundamental principles of vascular surgery, by the suture of nerves and the transplantation of tendons, by the treatment of burns with solutions of paraffin-resin, by resection, by the coöperation of the surgeon and the bacteriologist as in the treatment of gas gangrene, etc., convince us that there were a great many unnecessary amputations in the early stages of the war. Moreover, Tuffier found that a considerable number of those whose limbs had been amputated in 1914–15 had to undergo a further operation before they could take advantage of prosthetic devices of recent invention. However, the severity of our criticism of the medical and the surgical treatment of the soldiers in the opening years of the World War may be considered in some sense a measure of the progress that has been made in the medical sciences in general, not only in the special fields here emphasized but in the development of the treatment of venereal disease, in brain and heart surgery, and in various other departments of the healing art.

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INDEX

INDEX

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