THE · ROMANCE OF · MEDICINE

RONALD · CAMPBELL · MACFIE

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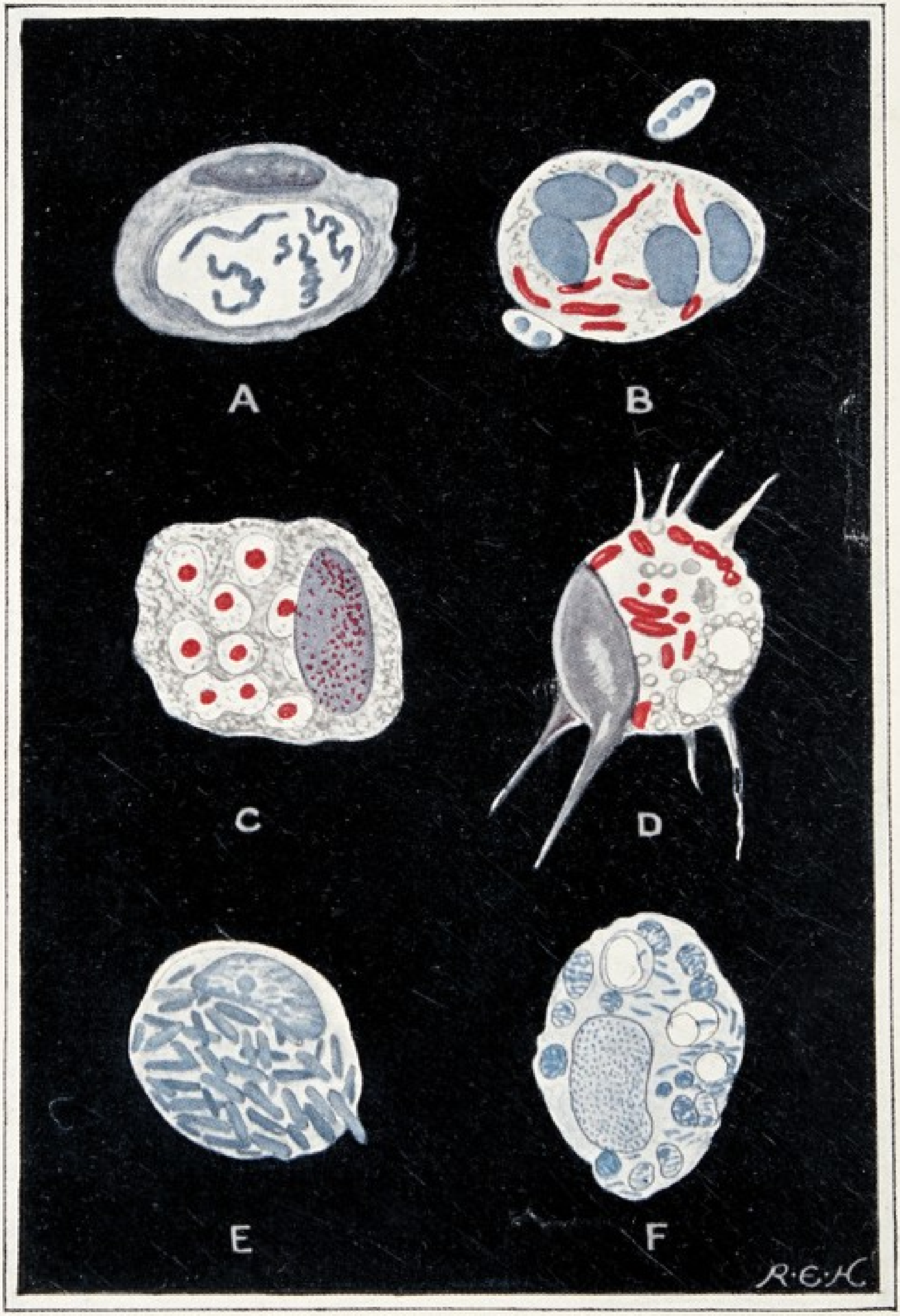

PHAGOCYTES AT WORK (PAGES 168—82)

A, PHAGOCYTE OF A GUINEA-PIG, CONTAINING THE CORKSCREW-LIKE BACTERIA OF RECURRENT FEVER (STAINED BLUE). B, PHAGOCYTE OF A GUINEA-PIG CONTAINING LARGE BACILLI KNOWN AS "PROTEUS BACILLI" (STAINED RED). C, PHAGOCYTE OF RABBIT CONTAINING SPORES OF LOCK-JAW BACILLUS (STAINED RED). D, PHAGOCYTE OF GUINEA-PIG CONTAINING A NUMBER OF BACILLI KNOWN AS "BACILLI COLI" (STAINED RED). E, PHAGOCYTE OF GUINEA-PIG CONTAINING PLAGUE BACILLI (STAINED BLUE). F, PHAGOCYTE OF GUINEA-PIG CONTAINING THE BACTERIA OF CHOLERA.

Selected and adapted from Metchnikoff's "Immunity in Infective Diseases" (Cambridge University Press).

THE ROMANCE OF MEDICINE

BY

RONALD CAMPBELL MACFIE

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To

My Friends

ARTHUR HALLAM LISTER

ASHLEY W. MACKINTOSH

JAMES L. SALMOND

FRANK SIMPSON

PREFACE

THE Romance of Medicine is a romance founded on fact, and it has been the author's endeavour not only to show the imaginative aspect and romantic character of medical discovery, but to present the facts with scientific accuracy and in their correct historical context. He hopes, therefore, that the volume will be of interest to the Profession as well as to the general public.

In the preparation of the book the author has consulted about three hundred volumes, and he finds it, therefore, difficult to acknowledge all the authorities to whom he is indebted. He must, however, specially mention Professor Metchnikoff's "Immunity in Infective Diseases," Sir Michael Foster's "History of Physiology," Professor Monti's "Modern Pathology," Dr. Draper's "History of the Intellectual Development of Europe," Dr. Payne's Harveian oration on "Harvey and Galen," and Dr. R. Caton's articles in the *Lancet* and the *British Medical Journal*.

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CONTENTS

LIST OF PLATES.

THE ROMANCE OF MEDICINE

CHAPTER I.

THE BEGINNINGS OF MEDICINE.

The sense of bodily being—The modern world made by geniuses—Medicine among the Egyptians—In early Greece—Æsculapius—Serpents in treatment—Hippocrates—His anatomy and physiology—High ideals cherished in his time.

General considerations.

MEDICINE is primarily and essentially the healing art, and in its simplest form implies merely the practice of methods to alleviate pain, and to heal obvious mechanical injuries. This practice would, at first, be entirely empiric and instinctive: only in the course of centuries would the great principles of treatment be evolved. The tremendous generalisations on which modern conceptions of health and disease are founded must have been of very slow growth. How could the ancient Briton conceive of his joints as levers, of his heart as a pump, of his lungs as a furnace? How could he guess the complicated mechanism of his eye and ear? How could he imagine that the air was thronged with millions of little invisible ministers of disease and death? He might sacrifice to the gods; he might practise divination from entrails; he might carve and cook his foe, and might thus gain some idea of the rough structure of the human body ; but of the body as a physico-chemical machine, of the body in its relationship to physical laws, he had no conception.

Even subjectively, his body must have meant much less to him than to the modern man ; he must have had a much less definite sense of bodily being. Our subjective conception of our bodily presence is undoubtedly affected by our anatomical and physiological knowledge. We sub-consciously or consciously think of ourselves as made " of flesh and blood, and sinew, and the rest ;" and when we are ill, the conception becomes still more definite, and we say meaningly that we have *a head upon us*, or *a liver*, or *a heart*, or *lungs*. However erroneous our anatomical topography, still we recognise that we are " strangely and wonderfully made."

Even the very clothes we wear, give us a livelier and more definite cutaneous consciousness, and a more emphatic sense of bodily individuality—of the ego contrasted with the non-ego—than had the ancient Briton lightly clad in woad, or in a necklace of his rival's teeth.

And if to the savage the body was a mystery, a half-apprehended possession, how much more mysterious were the body's diseases! The savage might understand that a pain in the region of the stomach, and a heavy helping of sirloin of mammoth were causally connected ; but what could he make of measles and mumps, of smallpox, of cholera? With no very definite conception of his body, either of its material structure, of its material processes, or of its material relationships, with neither facts for generalisation nor capacity to generalise, a bewildered creature in a bewildering environment, now paralysed by an invisible weapon, *now* convulsed by invisible forces, painted now red by measles and *now* white by leprosy, he could not but meet mystery with mystery, and attribute his diseases not to material causes, but to demons and angry gods, and evil eyes, and such-like.

Naturally, diseases with such mysterious causes required mysterious cures, and offerings to the gods, and charms, and incantations must have seemed the appropriate remedies.

We are apt to laugh at the ignorance of the savage, and to imagine that we are intellectually far his superior. But *are* we? In Borneo there is the medicine man; in Boston there is Mrs. Eddy; and perhaps the medicine man is the more scientific, if the less plausible.

The modern world made by geniuses.

The great majority of us are still savages, still intellectual infants, carefully spoon-fed with peptonised facts and pre-digested principles. We flatter ourselves that we are very learned and clever. We know that the world is round, and that it turns on its axis; we know that the heart beats, and that the blood circulates; we know that microbes are as real as mosquitoes, and that if measles is imaginary, so is man. We know many things, but we know them only because we have been taught and told. The great discoveries are not *our* discoveries; *we* could not have made them, and in many cases we do not understand them. The world has been made and interpreted for us by great minds, but we ourselves are really as helpless as the savages. Were we put on the earth under the stars, and left to form our own cosmic and physiological theories, they would be, indeed, very weird and fantastic.

Experiments have been made in bringing up children in total ignorance of religion and ethics. It would be a more interesting experiment still to bring up a child in total ignorance of all science, and then, at the age of reason, introduce him to the phenomena of nature. Where would he be? What would the stars, and the sky, and the wind mean to him? Would he personify the elements? Would he see in the sunrise Hercules on the fiery pile, and in the sunset Orpheus and Eurydice? Would the blue sky be the floor of heaven? Would there be an under-world tenanted by demons? And would unknown lands have their centaurs, and hydras, and gorgons, and unicorns? Or would his mind begin further forward with Thales and Anaximander? Would he, substituting air for Zeus, and water for Poseidon, construct some wonderful cosmogony? Certainly, even after the best business education, the world would be flat to him, and the stars little more than 100 candle-power lights. As recently as the seventeenth century the Muggletonians believed that God was only six feet high, and the sun only four miles off.

And even in these days of education the most grotesque ideas of the universe and of the body may be found.

No; we are not scientists, and to a few great scientific minds we owe all the real science of the world. The history of science is the history of a few great men fighting single-handed to establish truth and to abolish error. Save for Galen, Vesalius, Galileo, Harvey, Newton, what sort of a world should we be in to-day?

When we examine the records of history, we find that medicine in its early days must have presented the characters we have suggested. Surgery apart, we find it, even in historic times, a magic art dealing in charms and amulets and incantations—the natural and inevitable fruit of a fanciful cosmogony.

Egyptian medicine.

The oldest medical treatises known are the medical papyrus discovered by Professor Flinders Petrie near El Lahun, dated about 1600 B.C. (before the time of Moses), the so-called Papyrus Ebers (found between the legs of a mummy), dated about 1500 B.C., the Berlin Medical Papyrus, dated about 1400 B.C., and the British Museum Papyrus, dated about 1100 B.C. Some of the cures mentioned in these documents are said to have originated in the time of Cheops, *i.e.*, 3700 years or so B.C., and in the Berlin Papyrus, King Athosis, who lived six thousand years ago, is said to have written a book of medicine.

All these treatises show that medicine had been theretofore, and was then, essentially a magic art. The world was still a mystery ruled by the caprices of mysterious spirits, and it was inevitable that the body should be conceived as under similar lawless law. Pharmacy, accordingly, was chiefly thaumaturgy, prescriptions mainly incantations, and the physician more or less a priest. The high priest of Sais, indeed, bore the title Chief of the Doctors, and practitioners were compelled to conduct their practices according to the rules in the sacred book of Thoth.

Attitude of the Egyptians towards disease and death.

The attitude of the Egyptians towards disease and death is well described by M. Maspero. "The Egyptians," he says (we quote A. P. Morton's translation), "are not resigned to think that illness and death are natural and inevitable; they think that life once commenced should be indefinitely prolonged. If no accident intervened, what reason could there be for its ceasing? In Egypt, therefore, a man does not die, but someone or something assassinates him. The murderer often belongs to our world, and can be easily pointed out: another man, an animal, an inanimate object, a stone detached from the mountain, a tree falling upon a traveller and crushing him. Often, though, it belongs to the invisible world, and only reveals itself by the malignity of its attacks; it is a god, a spirit, the soul of a dead man that has cunningly entered a living person, or that throws itself upon him with irresistible violence. Once in possession of the body the evil influence breaks the bones, sucks out the marrow, drinks the blood, gnaws the intestines and the heart, and devours the flesh."

Medical disease, accordingly, was conceived by the Egyptians as a kind of demoniac possession, and the treatment was adapted to this belief. Material remedies, chiefly articles of diet, such as beer, milk, dates, oil, incense, were given, but the important matter was the incantation. Indeed, in the earlier times the incantation alone sufficed; the material remedies were additions in later centuries.

The Ebers Papyrus gives the following curious prescription for diseases of the eye: "Let one take a human brain and divide it in half. Let one half of it be added to honey, and the eye be anointed with this in the evening. The other half should be dried and finely ground, and it may then be used for anointing the eye in the morning."

Egyptian prescriptions and incantations.

For cataract a combination of incantation and prescription is recommended: "Come, verdigris ointment! Come, verdigris ointment!" so runs the charm. "Come, thou verdant one! Come, efflux from the eyes of Horus! Come, thou effusion from the eyes of the god Tum! Come, eye stuffs, ye who proceed from Osiris! Come to him (the patient) and take from him the water, the pus, the blood, the pain in the eye, the chemosis, the blindness, the flow of matter which are worked there by the god of the inflammations, of each kind of death, of each kind of pain, and of all evil things which are found in these eyes—so *many of them* there are, too." Directions are given that "it is to be recited over the verdigris ointment, dissolved in beetle honey, with which we should mix cyperus, which should then be laid upon the eyes in the prescribed fashion."

The Papyrus Ebers gives directions that the following words be used in preparing medicines for all parts of the body of the patient: "May Isis cure me, as she cured Horus of all the suffering which his brother Set had inflicted upon him when he killed his father Osiris. O Isis, thou great enchantress, heal me, deliver me from all evil, bad, typhonic things, from demoniacal and deadly diseases, and pollutions of every sort which rush upon me, as thou didst deliver and release thy son Horus; for I have been forced to go into the fire and pass through the waters.

May I not fall into the snare of the day when I shall say I am mean and deplorable. O Ra, thou who hast spoken of thy body; O Osiris, thou who prayest for thy manifestations. Ra speaks of his body, Osiris prays for his manifestation. Deliver me, then, from all possible evils, from bad, wicked, typhonic things, from demoniacal and deadly fevers of every sort." Surely this is quite a prayer.

It will be recognised by these excerpts that the incantations were not mere gibberish, but were of the nature of prayers.

No doubt, as time advanced, pharmacy gradually replaced sorcery; but the beginnings of medicine were founded on a belief in the immaterial character of disease, and in the possibility of curing it by supernatural and immaterial means.

Even in early times drugs were plentiful, and we find that the ancient Egyptians were acquainted with numerous remedies, such as aloes, opium, castor-oil, garlic, pomegranate, peppermint, yeast, absinthe, juniper, squills, turpentine, gentian, myrrh, tamarisk, fennel, hyoscyamus, magnesia, lime, soda, iron, sulphate of lead. The Egyptians made pills, too, and plasters, and powders, and ointments, and injections, and they wrote out long prescriptions, one prescription containing thirty-five different ingredients; and though there was then nothing like a *system* of medicine, yet they had their

Egyptian drugs.

hair restorers, and their hair dyes, and their cosmetics, and their insect powders, their gold fillings for teeth, and even their opiated soothing syrups for infants.

Surgery, as might have been expected, was fairly advanced, and there was some knowledge of hygiene and sanitation—a knowledge which the Hebrews seem to have acquired and developed.

The Egyptians had a god of medicine called I-em-Hotep or I-em-Hetep (He who Cometh in Peace). He is represented as a little bald-headed man: even in those days baldness and learning seem to have been associated. No doubt, the god was originally a learned and celebrated physician. He is described as "the good physician of gods and men, a kind and merciful god, assuaging the sufferings of those in pain, healing the diseases of men, giving peaceful sleep to the restless and suffering: he is called the creative god who giveth life to all men, who cometh unto them that call upon him in every place, and who giveth sons to the childless." He was great "in magic and in all learning." To him many temples were erected, the first temple being at Memphis.

Egyptian god of medicine.

The custom of embalming, which was a religious ritual based on religious beliefs, had much to do not only with the close relationship of priest and physician, of the natural and supernatural, but was obviously a valuable anatomical training.

Possibly the early development of medicine in Egypt was due to the prevalence of this custom. In the process of embalming, the heart was removed and put in a jar, and in another jar were put the viscera, and the priests must thus have acquired a practical knowledge of the general structure of the body. In spite of such practice, however, the anatomical knowledge of the Egyptians was very imperfect, and their knowledge of physiology conspicuous by its absence.

In Assyria, in Babylon, from China to Peru, we find the beginnings of medicine characterised by similar features. To discuss all these, to make a comparative study of the beginnings of medicine, were out of place here; but since for the Western world medicine began in Greece, we will now briefly investigate its beginnings there.

Medicine in Early Greece.

We meet with fragments of contemporary medicine in the earliest Greek literature, and retrospective references, though of course untrustworthy, give us hints of medical conditions even further back. It must, however, be distinctly understood that, even then, the Greek mind and Greek medicine were in the eleventh month of their infancy. The elaborate and poetical theogony of Hesiod and Homer, which arose in great part from a personification of the great natural phenomena, must have taken generations to develop, and the beliefs of the time were centuries beyond the amorphous and trepidant superstition of the primitive man. The infant medicine was millenniums old.

In early Greece, as was natural, medicine was deemed a divine profession, and the first physicians were given divine pedigrees. Apollo was father of Æsculapius, Æsculapius father of Hygeia. By all the legends was the healing art exalted. Were not the great heroes Hercules, Jason, Achilles taught medicine by the centaur Chiron? Did not Melampus of Argus, when he cured the daughters of King Prætus by hellebore and baths and charms, receive as fee one-third of the king's dominions and one of the daughters to wife?

It was good to be a doctor in those days!

Æsculapius.

As Egypt had its god of medicine, I-em-Hotep, so Greece had its god of medicine, Æsculapius. And Æsculapius, like I-em-Hotep, was probably a man, though after his death temples were erected to him, and he was worshipped as a god. According to Homer, his sons, Machaon and Podalirius, were at the siege of Troy, and the latter is said to have been the first to practise blood-letting.

The chief temple of Æsculapius was at Epidaurus. At first its medicine was merely humbug and magic, but in later times practical therapeutics was added.

The sick slept in a chamber known as an *abaton*, and there Æsculapius was supposed to

I-EM-HETEP, THE EGYPTIAN GOD OF MEDICINE.

give them healing dreams and actual treatment. Sometimes, no doubt, the priests gave the patient opium and similar drugs to produce dreams, and to the dreams was attributed relief from pain. Probably in other instances the priests personified Æsculapius, and gave counsel and treatment. Anyhow, the temples were very successful, and their claims and cures put Christian Science quite in the shade.

A man who had only one eye was visited by the god during the night. The god applied ointment to the empty orbit. On awaking he found that he had two sound eyes.

The son of Hermione was blind in both eyes. A dog of the temple licked them, and immediately he regained his sight.

Another man had no hair on his head. He prayed to the god to make it grow again. Æsculapius applied some ointment, and next morning there was a thick growth of hair. We wish we knew that ointment!

To Æsculapius it was quite a simple matter to cure dropsy. He simply cut off the patient's head, held up the patient's body by the heels to let the water run out, and then clapped on the head again. Very simple, no doubt, but requiring a good deal of nerve on the part of the patient.

A very interesting and remarkable feature of treatment at the temple of Æsculapius at Epidaurus, was the prominent part played by serpents. In the valley in which the temple was built were found large, yellow, non-poisonous serpents, and these were trained to lick ailing parts with their forked tongues; hence the fact that Æsculapius is depicted with a serpent round his staff; hence, too, perhaps the later use of viper's flesh as a medicine. The fame of the serpents spread far and wide, and about 300 B.C., when Rome was visited by a pestilence, she applied to Greece for a serpent, and, a serpent being sent, the pestilence at once abated.

Serpents in treatment.

Of course, much in the treatment was ridiculous, but the temples latterly practised good, sound, common-sense therapeutics, prescribing simple food, gymnastics, riding, friction, massage, counter-irritation, baths, poultices; while among the drugs administered were iron, hellebore, squills, lime. For a case of indigestion we read that a diet of bread and curdled milk, milk and honey, lemons boiled in water, parsley, and lettuce was prescribed. Quite recently the great Russian scientist, Metchnikoff, has pointed out the value of sour milk in intestinal disorders.

Common-sense therapeutics.

When we come to the period of Greek philosophy we find that charms and incantations, and magic of all kinds are beginning to play a less important part in medicine. Great geniuses have arisen, and are compelling the multitude into saner conceptions, both of the universe and

The period of Greek philosophy.

of the body. The bond between medicine and theology is loosening; the bond between medicine and philosophy is being formed.

Physics.

To the early Greek thinker φύσις, or physics, meant the science of life, and among living things were stars, and fire, and waves, and winds. Even the meteor was given a mind and healing power. The only criterion of life the Greek knew was motion, and all moving things were to him alive. The study, therefore, of the stars was one with the study of the limbs, and his cosmogony was bound to include the microcosm of the body. Philosophy thus, at its birth, included medical science, and the reductions of the universe and of the body to products and processes of physical law were parallel and correlative achievements.

We are not surprised to learn that Thales, the father of Greek philosophy, wrote a book on medicine; that Democritus, the great originator of the atomic theory, wrote on the nature of man, on pestilential diseases, on prognostics, and on the causes of disease; and that Diogenes, Philolaus, and other philosophers were similarly versatile.

The king of the physicians of the period of Greek philosophy was undoubtedly Hippocrates, who is usually called the Father of Medicine.

In the brilliant age when Pericles ruled Athens, when Socrates walked barefooted about its streets, when Plato wrote his Phædo, and Phidias carved his statues—in that brilliant age Hippocrates laid the foundations of medical science.

Hippocrates and his times.

Medicine was even then a power in Greece: round the pediments of the Parthenon were recorded the birth and the victories of Athene, the goddess of wisdom, and before its gates stood Hygeia, the goddess of health. This age was essentially a transition age: the Greek mind was emerging from the rosy mist of myth and superstition, and, in the dawnlight of reason, was learning to distinguish between fact and fiction. To the foremost minds of the day the old gods were already dead. As the Greek Empire extended, as navigation, and exploration, and conquest widened the boundaries of the natural world, the supernatural necessarily retreated. Myth after myth died. No longer in the garden of the Hesperides grew the apples of gold. No longer did the lotus-eaters lie reclined on beds of amaranth and moly. No longer did the three-headed giant, with the two-headed dog, tend his oxen in Erytheia. The sirens ceased to sing, and the one-eyed Cyclops forgot to hurl his rocks; and as geography dispelled the terrene myths, so reason uprose and shook the foundations of the temples of the gods. Zeus no longer reigned on Olympus, Pan no more roamed the forest, and thinking men demanded a new cosmogony and theogony. Philosopher after philosopher tried to solve the universe. Thales, infected with the Egyptian worship of the Nile, had suggested that water was the origin of all things; Anaximenes contended that the air on which the "very earth itself floats like a broad leaf" was the first principle; while Heraclitus put his faith in fire, and Pythagoras deified number.

In the old gods no thinker believed; but, as usual, thinkers were few, and, as usual, the mass of men clung to their superstitions, and were ready to stone their prophets. Anaxagoras was condemned to die; Euripides was cursed as a heretic; Æschylus narrowly escaped being stoned to death; Pericles was accused of atheism, and Socrates was given the cup of hemlock. What did geography, and history, and logic matter to the mob? Just as little as they matter in the twentieth century.

Such were the age, and the intellectual environment, in which Hippocrates lived and wrote. Even as he was dissecting the body into organs and humours, Democritus was dissecting the universe into atoms; and it is amusing to find that the physician was requested to certify the philosopher insane, and flatly declined to do so, affirming that he was saner than his traducers.

Hippocrates was probably a descendant of Æsculapius, and therefore one of the so-called Asclepiads. He himself claimed to be eighteenth in descent from the physician-god, through his grandson Hippolochus; but for the correctness of this claim we will not vouch. Nor will we vouch that all the Hippocratic writings were by one man. Hippocrates covers a multitude of men—quite a case of

> "I am a cook and a captain bold,
> And the mate of the *Nancy* brig,
> And a bosun tight and a midshipmite
> And the crew of the captain's gig."

Yet though all the Hippocratic writings were not the work of Hippocrates, still Hippocrates was the leader and head of a very remarkable school, and must himself have been a very remarkable man. There is no doubt that he crystallised, and systematised, and developed doctrines and ideas that, up to this time, had been ill-defined and inchoate, and that he did much to separate the chaff from the wheat, and to put medical practice and theory upon a scientific and reasonable basis. He was the heir of the past, offspring of Æsculapius, perhaps of I-em-Hotep; but he was also sower of the future, and lineal ancestor of Harvey, of Lister, of Newton.

Sanity of Hippocrates' views.

When we remember how, in the temples, the spirit of Æsculapius was still putting eyes in empty orbits, and heads on headless shoulders, we are filled with amazement at the sanity and honesty of his medical system. Even when his facts and inferences have been false, his methods have been fertile. The very term "hypothesis," which, in its scientific application, he invented, is a great discovery, a great philosophic instrument, the strong useful hands of a comprehensive idea.

We talk of a *working* hypothesis now, but the essence of all hypotheses is that they do work, that they gather, and compare, and group, and render possible the *chords* of consciousness.

For "the wind-bags" and "street-corner prophets" who dealt in purifications and incantations, and "who sought to conceal their own ignorance and impotence under the mantle of the divine," Hippocrates had nothing but scorn. Yet he was no materialist: he believed in immanent deity, and saw, with the clear insight of a prophet, that rigid natural law was not incompatible with a divine Lawgiver in whom all things lived, and moved, and had their being. Who can forget his fine sayings, "Things are not in varying degree divine or human, but God is in all things"; "Everything is divine and everything human"; and his bold and magnificent generalisation, "The nature and cause of this illness arise from precisely the same *divine* from which all else proceeds"?

His endeavour to base a doctrine of disease on the humours of the body was necessarily unsuccessful; but it was an effort in the right direction. The philosophy of the day was coloured by Empedocles' theory of the four elements, earth, air, fire, and water, and, influenced no doubt by this theory, Hippocrates propounded the doctrine that there are four primary qualities: dry, moist, hot, cold; and four cardinal humours: blood, phlegm, black bile, yellow bile. The tissues and

Hippocrates' doctrine of humours.

combination of tissues were formed by putrefaction and coagulation, by condensation and rarefaction, by melting and boiling, from the warm, the cold, the moist, the dry, the fat, and the gelatinous. Health again, according to his theory, depended on the production and proportionate admixture of the humours. Man, he says, "enjoys health when each humour is in due proportion of quantity and force, but especially when properly commingled." Disease takes place if any humour is excessive or deficient, or if the humours are not duly blended.

The theory of humours was scientific, in so far as it was a generalisation from the more obvious clinical symptoms of certain simple diseases, such as biliousness and cold in the head. As a corollary of his theory, catarrh was the expulsion of a humour which had been formed in excess, and treatment should be directed to assist nature to restore humoral equilibrium.

The theory recalls the well-known definition of disease by Sydenham, the great seventeenth-century physician: "an effort of Nature striving with all her might to restore the patient by the elimination of the morbific matter." Though, of course, inadequate and unsound, the theory was an honest attempt to put pathology and treatment on a basis of broad principles.

In practice, Hippocrates seems to have been a good practical physician in relying more on general measures than on drugs. He poulticed, and bled, and dieted; he gave purgatives and diuretics as required; and, in quite a modern spirit, he prescribed baths and a change of air.

To diet he gave special attention. He realised that everyday diet among civilised people was "a great invention elaborated and perfected in the course of centuries with no mean display of intelligence and imagination," and that differences of diet were due to "original distinctions in constitution and acquired distinctions in habit." Invalid diet he considered should be evolved from civilised diet, as civilised diet had been evolved from the coarse diet of primitive man.

Hippocrates and diet.

Some of the Hippocratic attempts to find first principles of dietetics are very remarkable. Surely the statement that "the performances of work are directed to the consumption of what exists, while food and drink are intended to replenish the void"—surely this statement is a most remarkable generalisation for the time in which it was written. Nor was the Hippocratic school content with mere theory. They made clinical experiments, and the experiment of feeding a man simultaneously with different kinds of food, and thereafter making him vomit in order to see how far digestion had advanced in each case, must be considered the first instance of experimental physiology.

First instance of experimental physiology.

The Hippocratic knowledge of anatomy was very defective. Hippocrates recognised that the blood-vessels were continuous with the heart and with one another, but he did not know the difference between arteries and veins. He did not distinguish between nerves, tendons, and ligaments, and he had no knowledge of individual muscles, but considered them, *en masse,* as *flesh.* Seeing the wonderful precision with which Phidias and the Greek sculptors of the period had indicated individual muscles (even functionally) in their surface anatomy, it is rather strange that the work of deeper differentiation was so long postponed. Even in the labyrinthine palace of King Minos, built by Dædalus before the time of Moses, there are statuettes showing the arrangement and mutual relations of the surface muscles of the forearm, and the manner in which the minute venules on the back of the hand join to form the superficial veins of the arm. That Hippocrates took interest in such anatomico-artistic studies is evident, since Pausanias relates that Hippocrates presented to the Delphi temple of Apollo a brass figure of a man wasted by consumption almost to the bone ; and no doubt the great physician valued this figure on account of the surface anatomy. Still, the fact remains that he was not a great anatomist. His physiology was likewise deficient, though it had in it the germs of great ideas.

Hippocrates rightly located consciousness in the brain, and he had certainly some notion of the circulation of the blood. His experiment, too, to prove the relative digestibility of different articles of diet was, as we have said, probably the first instance of experimental physiology. And is not this an important fact in medical physiology clearly enunciated?—"All parts of the body which are designed for a definite use are kept in health, and in the enjoyment of fair growth, and of long youth, by the fulfilment of that use, and by the appropriate exercise in the employment to which they are accustomed. But when diseased, they grow ill, stunted, and become prematurely old."

Hippocrates' physiology.

A special feature of the Hippocratic system of medicine was its study of symptoms, with a view to diagnosis and prognosis. Inferences were drawn from the expression, from the complexion, from the posture, from the manner, from the voice, from the quality and quantity of the secretions, etc. The inferences were often wrong, but Hippocrates did great service in pointing out how much could be inferred from symptoms, and his descriptions of the symptomatic features of disease are at once picturesque and accurate. To this day the characteristic facial signs of impending death are known as the "facies Hippocrata," because by Hippocrates they were so vividly described.

Hippocrates' study of symptoms.

Not only was medicine intellectually vigorous in the time of Hippocrates, it was also, morally speaking, on a very high level. The so-called Oath of Hippocrates is a witness to all time of the high spirit which inspired the medical profession of the day. The oath enacts that the physician, among other things, is "to help the sick according to his knowledge and power," "to rigidly abstain from every evil, criminal abuse of the means and instruments of his art," "to supply no poison," "to keep an inviolable silence about the secrets which he learnt in his calling or even outside it."

Moral tone of medicine in Hippocrates' time.

And all the Hippocratic writings show a high conception of the duties of the physician quite in keeping with this famous oath. It is enjoined that the physician should have good manners, dress neatly, and avoid perfumes; he must be temperate, honourable, humane, modest, just, affable, and clean; he must oppose fraud and superstition, he must show courage in adversity, and he must have a due sense of the divine power, and recognise that to Heaven he owes success. In addition, he must have a good bedside manner, and must be calm and equable, even when those around him are agitated and excited.

High ideals! But what must we think of these Hippocratic physicians who lived 400 B.C., when we find in their writings sayings like these?—

"Where there is love of humanity, there will be love of the profession"; "I have written this down deliberately, for it is valuable to learn of unsuccessful experiments, and to know the causes of their non-success"; "My opponents' views will be assisted by the following considerations."

High ideals.

Verily, medicine had a magnificent beginning! When Hippocrates died he was promptly deified, and by the irony of fate he who had abjured magic living was reputed to perform magic dead. A pagan physician writes to his friend: "I have a brazen Hippocrates of near a cubit in length, who when the lamp before him is out, takes a tour all round my house, rattling and rummaging over all my boxes, mixing or jumbling together all my medicines, throwing open my doors, etc., and this more especially if we delay the annual sacrifice that is usually made to him. I must therefore declare that Hippocrates the physician still requires sacrifice, and is highly displeased at neglecting the festivals of divine worship to him."

Such is the fate of all geniuses: either to be stoned or misunderstood. Great systems are easily corrupted by small minds.

Contemporary with the school of Hippocrates at Cos was the Empiric school at Cnidos. The Cnidans held that each case must be treated on its own merits, according to individual symptoms, and that great principles of treatment are impossible. This school did some good work. Praxagoras wrote on the pulse; Diocles wrote on hygiene and athletics; Euriphin, the head of the school, wisely conjectured that excess of food was the cause of illness; and Herodicus stated the modern doctrine that "men fall ill when they indulge in food on insufficient exercise."

Contemporary schools.

CHAPTER II.

THE BEGINNINGS OF MEDICINE *(concluded)*.

Aristotle—The Alexandrian school—Galen—An experimental physiologist—His views on the nervous system—On the voice—His investigations of paralyses—Arrested development—The Arabian period—The dark ages—The dawn—Roger Bacon—Paracelsus—The Renaissance—Vesalius—A premature *post-mortem*.

Aristotle.

AFTER Hippocrates came Aristotle, a distinctly retrogressive influence. For centuries he was placed on a pedestal and worshipped. All down the Middle Ages his word was law. Roger Bacon asserts, "Aristotle hath the same authority in philosophy that the apostle Paul hath in divinity." Yet he was not a scientist, not even a trustworthy collector of facts; he represented pseudo-science at its worst, and his influence in science has been almost wholly pernicious.

As Dryden says:

> "The longest tyranny that ever swayed
> Was that wherein our ancestors betrayed
> Their free-born reason to the Stagyrite,
> And made his torch their universal light."

His observations were untrustworthy, and his inferences fantastic. His philosophy, even in his own hands, was, as Hallam says, "like a barren tree that conceals its want of fruit by profusion of leaves." Tyndall sums him up as follows: "As a scientist, Aristotle displayed what we shall consider some of the worst attributes of a modern physical investigator: indistinctness of ideas, confusion of mind, and a confident use of language which led to a delusive notion that he had really mastered his subject; while he had as yet failed to grasp even the elements of it. He put words in the place of things, subject in the place of object. He preached induction without practising it, inverting the true order of inquiry by passing from the general to the particular instead of from the particular to the general."

Tyndall's summing-up of Aristotle.

When we examine his contributions to medicine, we find that he made no experimental researches, and that many of his statements are inaccurate. He held that the heart was the seat of the soul, and that in the heart the nerves originated. He asserted that the heart of small animals had two cavities, and the heart of large animals three. He taught that the brain was cold and bloodless, and that its chief function was to cool the heart; and all his medical writings are full of incorrect statements and fantastic theories.

He was, in all respects, a lesser man than Hippocrates, and he owes his scientific reputation to his garrulity and to the ignorance of his audience. Many reputations are won thus.

What Aristotle professed, the Alexandrian school, founded by his pupil Alexander, actually practised.

The Alexandrian Museum.

Even as we, having conquered the Soudan, started a college at Khartoum in order to sow the seeds of Western civilisation, so did Alexander the Great, encouraged no doubt by Aristotle, found a college at Alexandria, to cement, through culture, Egypt to the Macedonian Empire. The Macedonian Empire vanished, but the city of Alexandria grew, and, under the Ptolemies, the Alexandrian school, the so-called Museum, became a great university, perhaps the greatest the world has ever seen. Here Euclid demonstrated his propositions; here the giant genius Archimedes studied; here Arius and Athanasius nursed their creeds; here the seventy-two scholars translated the Septuagint; here Eratosthenes measured the size of the earth; here Timochares studied the orbit of Venus; here Ptolemy made his immortal discovery of the periodical inequality in the moon's movements; here Hipparchus invented the gyroscope, which has lately attracted so much attention; here, perhaps, Antony and Cleopatra exchanged their sultry kisses; here, under the same roof, were poets, astronomers, engineers, chemists, botanists, biologists, "the literary dandy and the grim theologian." How little most of us knew, when our ships bombarded Alexandria, what a wonderful city they were battering!

In this environment, then, medicine spent the second part of its infancy. With culture in general it had migrated from the Parthenon to the Pyramids. And now in the dissecting-rooms of the Alexandrian Museum it certainly throve.

Although embalming had been practised for thousands of years, popular feeling in Egypt was opposed to dissection of the human body. Nevertheless, Ptolemy Philadelphus authorised his professors of anatomy not only to dissect dead human bodies, but even to vivisect animals and criminals. Whether vivisection, which was certainly pıactised, led to much may be doubted; but dissection undoubtedly put both medicine proper and surgery upon a more scientific basis, and views of the structure of the human body became much more accurate.

The first two anatomists were Erasistratus and Herophilus. Erasistratus established many anatomical facts. He distinguished between nerves of motion and nerves of sensation, and he formulated a theory of the relationship of the liver and heart and blood-vessels, which, though erroneous, held the field for many centuries. We will deal with this theory when we come to Harvey's discovery of the heart. He was aware of the valves of the heart, and seems even to have seen the lacteals

Erasistratus.

(little absorbent vessels in the intestines), which were not re-discovered for nearly two thousand years.

Herophilus, his colleague, who was reputed to have dissected six hundred bodies, and also some live criminals, wrote on the eye and the heart, and also made a special study of the pulse.

Herophilus.

While the anatomical foundations of medicine were thus being laid, surgery and pharmacy were also progressing. In surgery new operations and new instruments, in pharmacy new drugs and new preparations were introduced. New drugs were especially numerous, since the trade of Egypt favoured new importations, especially from the East. Dioscorides, who wrote about 200 B.C., describes more than two thousand drugs, and the preparation called "theriaca" may be taken as typical of the spirit of pharmacy. Theriaca, which had a vogue of nearly two thousand years, was an electuary whose chief constituent was viper's flesh. It contained about sixty-three ingredients, including, besides viper, poppy juice, pepper, rose leaves, iris, liquorice, cinnamon, nardus, cassia, crocus, frankincense, balsam, gum, fennel, cardamoms. Such an electuary shows plainly enough that pharmacy was in its infancy.

It is interesting to know that in 1894 an action was brought to invalidate the patent of lanoline (wool oil) on the ground that Dioscorides had described a process for obtaining fat from wool. Verily, there are few things new under the sun!

Greek medicine in Egypt does not seem to have been much affected by Egyptian medicine, and it continued, though without much marked progress, on its anatomical lines, till the second century A.D., when another great genius appeared.

Again we find the nursery of medicine changed. Though the Alexandrian school lasted till 414 A.D., and ended dramatically with the fanatical monks slaying Hypatia and scraping the flesh off her bones with oyster shells, yet, as a school of science, it had been long moribund. Its glory went with the Ptolemies, and it really perished with Cleopatra.

End of the Alexandrian school.

As Rome became the centre of the civilised world, Alexandria sank to the status of a petty provincial city. Accordingly, when we find in the second century A.D. a great genius appear, his theatre now is Rome.

Galen, the great genius to whom we refer, was by birth a Greek, born at Pergamos and educated at Alexandria, but he naturally gravitated to Rome, and there did the work which has made him famous to all time.

Galen.

He belonged decidedly to the anatomical school of medicine, and, following the traditions of Erasistratus and Herophilus, he dissected chiefly apes, which he killed by drowning; but he also dissected birds, fishes, reptiles, and at least one elephant. In actual anatomy he elucidated little, for before his time anatomy had reached great perfection. It was as an experimental physiologist that he won his fame. Harvey is often spoken of as the first experimental physiologist, but precedence after Hippocrates undoubtedly belongs to Galen, who not only performed physiological experiments, but upon them based clinical diagnosis. Many of his experiments were, of course, imperfect, but some of them were beautifully precise, and he had a complete grasp of the experimental method. He says that his work on the "Use of Parts of the Human Body" is nothing less than a hymn to the Creator. "I hold that true piety is shown, not in the sacrifice of hecatombs of bulls, or in raising clouds of fragrant incense, but in studying myself to know, and in making known to others, the wisdom, the power, and the goodness of God." Truly an admirable spirit, worthy even of his contemporary, Marcus Aurelius, whose friend, indeed, he was.

Galen's work on the nervous system.

His greatest work was done in connection with the nervous system. It must be remembered that the notion of a nerve, as the pathway or as the agent of power, is an extremely difficult and abstract conception; and the discovery and declaration of the Alexandrian school that these white cords and strings among the muscles had motor and sensory functions showed great intellectual audacity. So difficult, and abstract, and audacious was, and indeed is, the idea, that even four hundred years after Erasistratus and Herophilus it had not gained credence.

"A thousand times," complains Galen, "I have demonstrated by dissection that the cords in the heart, called nerves by Aristotle, are not nerves, and have no connection with nerves." But he was demonstrating to blind men! What could he make of men like the Stoic philosopher Chrysippus, who argued that the heart must be the principal seat of the soul, because a man lays his hand on his heart to give emphasis to the assertion of self? What could he make of philosophers who asserted without a shadow of proof that the voice comes from the heart? It seemed a hopeless task to try to knock truth into such thick skulls, but Galen hammered away. He explained that the voice did not come from the heart or from the boots, but that it was produced by the contraction of the chest-wall driving air through the larynx, that the sound was modified by contractions of the larynx, and that the movements of both the chest-wall and the muscles of the larynx were controlled by nerves coming from the brain. Alas! it was no good. "When I tell them this," he says, "and add that all

Galen's explanation of the voice.

voluntary movement is produced by muscles controlled by nerves coming from the brain, they call me παραδοξολογος—*paradoxologos*, a teller of marvellous tales, and have no argument beyond the simple assertion that the trachea is near the heart."

Naturally, with his views of the importance of the brain as centre of the nervous system, Galen studied both the anatomy and the physiology of the brain. At this time many believed the Aristotelian doctrine that the brain was merely a kind of sponge to cool the heart—a doctrine that appears very absurd to us nowadays, but whose very absurdity shows how much the correct anatomical and physiological notion of our bodily structure and function has become part and parcel of our being. There really was nothing very absurd about it. Centuries later Spinoza located the soul in the pineal gland—a little organ in the brain about the size of a pea, and there is really no reason why the seat of the mind should not be in the big toe. As a matter of philosophic and scientific fact the mind, anatomically and physiologically speaking, is contained not only in the brain, but is the sum total of the nerve units, or neurons, which are *focussed* in the brain, but extend to the surface of the body, and therefore the nervous system of the big toe *is* part of the brain as one item in the contents of the central consciousness. The nervous

Aristotelian doctrine of the brain.

system, and therefore the mind, is one and indivisible.

However, this is a digression.

The Aristotelians, we were saying, held that the brain was only a sponge to keep the heart cool. Metaphorically it may be so, actually it is not so, and Galen astutely inquired, "Why, if the brain is only a sponge, have we this complex structure, these membranes, blood-vessels, cavities, glands, nerves, when for the purpose of cooling only it ought to have been made like a sponge, inert, and shapeless?" Nor did he merely ask awkward questions. He proved, by various ingenious experiments, that serious injuries to the brain immediately abolished sensation and movement, and he was aware of the law that injury to one side of the brain affects the opposite side of the body.

Galen's investigations of paralysis.

Galen cut the spinal cord—the great bundle of nerves that is enclosed in the canal of the backbone—across, and half across, in various places, and noted what parts were paralysed thereafter. Having established his relationship, he could make the inverse inference that paralysis in certain parts was due to injuries to the spinal cord in certain situations, and thus his investigations naturally and inevitably led up to the wonderful achievements of modern nerve diagnosis and of cranial surgery. He is undoubtedly the founder of the physiology of the nervous system and the precursor of Victor Horsley, Ferrier, Head, and Sherrington.

Galen could find no obvious reason why interference with nerves should interfere with motion and sensation, and he assumed that some sort of air or subtle spirit ran down the nerve. The term and metaphysical idea *pneuma* did not, however, originate with Galen, but began among the followers of Hippocrates, and was probably suggested by Plato's philosophy. In Galen's time three kinds of pneuma were distinguished: (*a*) a *pneuma zotikon*, or "vital spirits," having to do with the so-called sphygmical functions, the heart, the heart-beat, the pulse; (*b*) a *pneuma psychikon*, or "animal spirits," having to do with the so-called psychical functions, thinking, feeling, voluntary motions, etc.; (*c*) a *pneuma physikon* or "natural spirits," having to do with the physical functions, nutrition, growth, secretion, reproduction.

The three "pneumas."

The division into three kinds of spirits was distinctly plausible and clever, and, hall-marked with Galen's signature, it continued in vogue for many centuries.

Though Galen's most important work was his interpretation of the nervous system, he did valuable work also in other departments of medicine. He was the first to establish the fact that the kidneys secrete urine, and he proved this by actual experiment. He tied the ureters (the ducts leading from the kidney to the bladder), and showed that under such circumstances no urine was secreted. He even propounded the theory that the blood went to the kidneys in order that the watery part might be filtered off.

Arrested development of medicine.

Seeing the brilliant beginnings of medicine in Hippocrates, Erasistratus, Herophilus, and Galen, its growth ought to have been vigorous and rapid; but, sadly and strangely enough, the development of medicine after Galen's death was arrested for centuries. Greece was no more, Rome seemed unfavourable soil for the growth of science, and Alexandria was in a decline. By the wedding of Christianity and Paganism, of East and West, there sprang, just about the time of Galen's death, the weird monstrosity neo-Platonism, and in a world full of magic and sorcery science could not grow. Neo-Platonism was originated by one Ammonius Saccas; but the best known of the exponents of this wild philosophy were Plotinus and Porphyry. To this school of thought the body was a delusion and a lie—a vile, penitential strait-jacket for the soul. The aim and end of existence was a mystical union with God. It was the creed of the fanatic and the fakir, and its corollaries were a belief in magic, in incantations and demons, and a disbelief in the sane and the scientific. No longer were men interested in the problems of mind and body, for the whole intellectual world—Constantinople, Alexandria, Rome—was seething with theological controversies. Athanasius was anathematising Arius, and the Arians, Semi-Arians, Pelagians, Nestorians, Eutychians, Sabellians, Patripassians, Monothelites, Monophysites, Mariolatrists, *et hoc genus omne,* were busy condemning each other to eternal perdition.

At this period, too, the Fathers arrogated to the Church the right to be arbiter of all knowledge, and enacted that all science must conform with the teachings of the Scriptures. The result was disastrous. Astronomy, history, geography, engineering, all degenerated in such an evil atmosphere, and moral and intellectual progress became almost impossible. The world was dying of dogma!

But help came from a most unexpected quarter. In the year 569 A.D. the great Arab, Mohammed, was born. Through the hubbub of contending creeds sounded his battle cry: "There is but one God, and Mohammed is his prophet." The success of the prophet was phenomenal. Within twelve years after the death of Mohammed the Arabians had reduced thirty-six thousand cities, towns, and castles in Persia, Syria, and Africa; and had destroyed four thousand churches, replacing them with fourteen hundred mosques. In a few years they had extended their rule a thousand miles east and west. Before long all the great cities of Western Asia and Northern

The Arabian period.

Africa were in their hands. Such is the power of a simple rallying cry and a sharp scimitar.

When the Arabs took Alexandria the great libraries were burnt by order of the Khalif, who asserted that if the books agreed with the Koran they were useless, and if they disagreed they were wicked. Legend says that so numerous were the books that they served to heat the baths (forty thousand in number) of the city for six months.

It was a bad beginning; but the Arabs were not opposed to literature, and in a very short time they became patrons and custodians and cultivators of ancient learning, and their esteem of science is shown in sayings of the day, such as, "The ink of the doctor is equally valuable with the blood of the martyr"; "Paradise is as much for him who has rightly used the pen as for him who has fallen by the sword"; "The world is sustained by four things only: the learning of the wise, the justice of the great, the prayers of the good, and the valour of the brave"; "He that knows himself knows his Lord."

From the nature of the Koran, and from the tendency of the Arab to labour in the magical and supernatural, it might have been expected that the wild, fantastic beliefs of the Fathers would find ready soil in the Arabian mind; but the Arabs were saved from such a fate by the antagonism of their creed to the Trinitarian doctrines, and went straight to the ancient Greeks for their science and philosophy. Fortunately, the very schisms of the Church favoured the fostering of Greek learning. The Nestorians had been expelled from Constantinople (A.D. 431) because of their heresies with regard to Trinitarian doctrine, and had removed to the valley of the Euphrates, where they founded a church and a medical school. They were very learned men, and in medicine they took a special interest; and they are said to have been the first to write books dealing, in a systematic way, with the employment of medicine. Their fame soon reached the ears of the Arabs, and when the Khalifs of Bagdad wished for translations of the Greek classics, which were *Greek* to them, they sent for the learned Nestorians, who not only translated Greek works into Arabic, but were entrusted with the education of the sons of important Arabs. Never had a new nation more enlightened rulers. The Khalif Almansor invited all philosophers, astronomers, doctors, poets, mathematicians, quite irrespective of their religious opinions, to his court. His successor, the good Haroun Alraschid, always had a hundred learned men in his travelling retinue, and he enacted that no mosque should be built unless with a school attached to it.

Translation of Greek works into Arabic.

Verily, the infant medicine was having a chequered career. Egypt, Greece, back to Egypt again, and now in the arms of the Arabs, who were developing one of the most magnificent and enlightened civilisations the world has ever seen.

How, then, in its new strange nursery did medicine thrive? In some ways it grew; in some ways it ceased from growing.

Chemistry had a special fascination for the Arab, and though he pursued it chiefly with a view to magic, or in the hope of transmuting metals, or of finding the elixir of life, yet in the course of his wild-goose chase he made valuable chemical discoveries. Djafar discovered nitric acid, and formulated a reasonable conception of gases. By means of nitric acid and sal-ammoniac he dissolved gold, and no doubt the potable gold was much used as an elixir of life. Rhazes discovered sulphuric acid, and Achild Bechil isolated phosphorus.

In pharmacy, too, as might have been expected, the Arabs excelled. They were travellers themselves, and their Nestorian teachers were also travellers, and in their wanderings both Arabs and Nestorians discovered new drugs.

In surgery, also, the Arabs were experts, and yet in medical theory and practice the Arabs did very little. This was due chiefly to the neglect of anatomy and of experimental physiology. To Mussulmans, to touch a corpse was sacrilege, and so Arabian medicine, debarred from dissection, was compelled to be content with writing commentaries, often bizarre, on the ana-

Neglect of anatomy and physiology.

tomy and physiology of the Greeks. Under these circumstances it was not wonderful that the works of Galen found a place in the veneration of the Arabs beside the Koran, and that the great physician was regarded almost as a god. It was only by an uncommon effort of independent thinking that Abdollatif ventured to assert that even Galen's assertions must give way to the evidence of the senses. Such servility was natural, but it led to sterility; and when Europe came back to Galen fifteen hundred years after his death, medical physiology was just as he left it.

Meanwhile, what of Europe? Europe was paralysed, brain and heart, by vain philosophies and theologies. The teachings of the Fathers were still rotting the reason of men. Africa had been saved from the fantasies of Neo-Platonism, from the corruption of a corrupt theology; but Europe was still bound hand and foot to dogma and magic. But the dawn was coming! Soon there was light in the sky. Through the Arabian commentators, by means of Latin translations, a certain amount of the learning of Hippocrates and Galen found its way to Europe. The first translation of Galen into Latin was made by Constantine the African, and the work of translating Arabic authors into Latin was continued in Spain by a band of scholars. By a very roundabout route this learning often came. The Greek, as we have seen, was translated into

Europe in the dark ages.

The dawn.

Syriac, the Syriac into Arabic, and the Arabic again, sometimes with Hebrew between, into Latin. The quality of the science was not improved by the process; but still it was at least as a rushlight in the darkness.

In the tenth, eleventh, twelfth, and thirteenth centuries this light was augmented by the immigration of Jews learned in Arabic medicine. These Jews were clear and independent thinkers, and their treatises were marked by common-sense. In the thirteenth century the Arab influence culminated in the great Friar, Roger Bacon. He had the courage to believe his own senses rather than Aristotle, and his scientific spirit was remarkable for the age. He is said to have invented spectacles, and to have propounded the theory of telescopes and microscopes. He was not a medical scientist, but he was one of the greatest geniuses that ever lived—far greater than his namesake—and he prepared the way for truth; but it was dangerous to be a scientist in those days, and the learned Friar was rewarded for his scientific work by ten years of imprisonment.

Roger Bacon.

Not, however, till the fifteenth century did the dawn really break. Then it became inevitable. In 1453 the capture of Constantinople drove a lingering remnant of learned Greeks to Italian soil, and stimulated the already growing revival of Greek learning. Greek manuscripts, out of

Renaissance of Greek learning.

sight for centuries, reappeared, and the discovery of the original Hippocrates and Galen led to a revolt against the Arabic commentators. It was found that the commentator and the original text did not agree, and men had to use their long-neglected reason, and choose. This spirit of inquiry naturally led to criticism both of the Arabic commentators and of the Greek writers, and helped to create a healthy spirit of scientific scepticism. Strangely enough, the controversy assumed a religious character, Hippocrates and Galen being enlisted on the Christian side, against the pagans Averroës and Avicenna, till in the fourteenth and fifteenth centuries the very name of Averroës was accursed, and he was spoken of as "the mad dog who barked against the Christ," and called by Erasmus "impious and thrice accursed." It was a queer change: the great commentator had become father of infidels. The Greek Renaissance was greatly stimulated by the introduction of the printing-press. Just about the time that the Greek exiles from Constantinople took refuge in Italy, the art of printing was invented, and before the fifteenth century was finished thousands of books and pamphlets were printed.

Even more important, however, than the printing-press, were the great geographical and astronomical discoveries of this and the following centuries. Just as in Greece, more than a millennium before, the horizons of thought had widened with the horizons of the world, just as reason had increased in power with increasing knowledge of the stars, so, now, a truer cosmogony gave birth to a healthier and more courageous science. Authority had attempted to fetter and to deform the world, had attempted even to pervert the orbits of the planets. But the stars in their courses fought for truth, and the world flatly refused to be flattened beneath the heel of dogma. Both earth and sky gave the lie to ignorant and tyrannous authority.

Geographical and astronomical discoveries.

In 1492 Columbus discovered America, much to the discomfiture of patristic geography and ethnology. In 1497 Vasco de Gama doubled the Cape of Good Hope (as a Pharaoh had done two thousand years before). In 1519–1521 Magellan's lieutenant, Sebastian d'Elcano, circumnavigated the globe.

Not only was the world found to be round, but apparently it had the audacity to rotate and gyrate in defiance of all dogma.

In 1543 Copernicus published a work stating that the earth turned on its axis once every day, and gyrated round the sun once every year. Bruno in the next generation repeated the heresy, and in the first decades of the next century Galileo and Kepler further developed it.

In 1526 the great quack, Paracelsus, made a vigorous and vicious attack on the medical dogma of the day. Inspired, perhaps, by Luther's cremation of the Papal Bull six years before, he commenced a course of medical lectures at Basle by setting alight a basin of sulphur and burning in the sulphureous flames the books of Galen, Averroës, and Avicenna, to the words, "*Sic vos ardebitis in Gehenna*" ("So will ye burn in Hell").

Paracelsus.

It has been contended that Paracelsus was a great medical reformer, and that he overthrew Galen and altered the whole course of medicine; but this contention cannot be maintained. Paracelsus was simply an audacious and sensational quack, and his fantastic influence did not long persist. The renaissance and the reformation of medicine must be attributed not to him, but to the revival of anatomy in the middle of the sixteenth century—a revival rendered possible by the various events we have mentioned. An anatomical school was successfully started in Paris, and there, in 1533, Sylvius, a famous miser and anatomist, lectured. Among the pupils of this Sylvius was a young man named Vesalius, and this Vesalius must be counted the originator of modern anatomy, and the layer of the foundations of modern medicine. It is interesting to note that Vesalius's mother was probably English.

The revival of anatomy.

Vesalius.

In Vesalius's student days material for dissection was scanty, but Vesalius had an enthusiasm that would not be denied. He tells how he used to fight with savage, hungry dogs over bones that lay exposed in the Paris cemeteries, and how once at Louvain he climbed a public gibbet and stole a corpse, "which had proved such a sweet morsel to the birds that they had most thoroughly cleaned it, leaving only bones and ligaments." Sometimes he even, like the body-snatchers of more modern days, robbed graves; and a story is told of how he once had to make haste to remove the skin of a corpse in order to prevent its recognition. These are not beautiful anecdotes, but they show the zeal of the man. In later years he was better off, for criminals were given to him to dissect, and executions were sometimes arranged that the corpse might suit his requirements.

Vesalius's zeal.

Five years he worked at anatomy at Padua. "Five years he wrought"—we quote from Sir Michael Foster—"not weaving a web of fancied thoughts, but patiently disentangling the pattern of the texture of the human body, trusting to the words of no master, admitting nothing but that which he himself had seen; and at the end of the five years, in 1542, while he was as yet not twenty-eight years of age, he was able to write the dedication to Charles V. of a folio work, entitled 'The Structure of the Human Body,' adorned with many plates and woodcuts, which appeared at Basle the following year, 1543." Some say

Vesalius's great work.

that the illustrations in the book were done by Titian, but this is unlikely.

Then the storm broke. His old master Sylvius —a wretched old miser who used to keep himself warm in winter by playing ball in his room— thundered against him, and everywhere he met with bitter and bigoted opposition. He had dared to contradict Galen. He had broken up the happy family of the Galenists. He had suggested that men should use their own senses and study Nature, "that true Bible, as we count it, of the human body, and of the nature of man." It was intolerable!

Opposition to Vesalius's reforms.

Disgusted and disappointed, Vesalius burnt his unpublished manuscripts, shook the dust of Padua off his feet, and accepted a post in Spain as Court Physician to Charles V. That ended his career, for in Spain the Inquisition was paramount, and though it tortured the living, it allowed no dissection of the dead. As Vesalius says, "he could not lay his hand on so much as a dried skull, much less have the chance of making a dissection."

Still, till 1561 he endured it. In that year a book of anatomical observations by one Fabricius was put into his hands, and this seems to have awakened all his old anatomical enthusiasm. He wrote a critical review of the book, and, in the course of his criticism, he says that the perusal of the book "had awakened a glad and joyful memory of that most delightful life which, teaching anatomy, I passed in Italy, the true nurse of intellect," and adds, " I live in hope that at some time or other, by some good fortune, I may once more be able to study that true Bible (Nature), as we count it, of the human body and of the nature of man."

Good fortune never came. In 1563 he performed a *post-mortem* on a nobleman—so the tale runs—and, lo and behold, when he laid bare the heart it was still beating. That ought to have seemed a trifling matter to the Inquisition, which, however, imposed on the unlicensed vivisectionist the penance of a pilgrimage to Jerusalem, and on his way back Vesalius died.

Yet he had done his work, and with his work medicine passed from the fairy-tales of the nursery to the realities of the laboratory. We do not mean to say that medical doctrine and practice became at once scientific and systematic. Far from it. Anatomy is merely the foundation of medicine, nothing more, and medicine had to wait on chemistry, and physiology, and bacteriology, and physics for its full development. Still, the foundations were laid fair and square, and from the date of the issue of his work onward, " anatomy pursued an unbroken, straightforward course, being made successively fuller and truer by the labours of those who came after."

CHAPTER III.

HARVEY'S PREDECESSORS.

Harvey's contemporaries—The circulation of the blood—Views of the ancients—Views of Winter, Servetus, Matthew Columbus, Cæsalpinus, and Fabricius.

Harvey's contemporaries.

HARVEY, as Wendell Holmes so happily puts it, was the posthumous child of the Elizabethan period—indeed, though his discovery was not delivered till the time of Charles I., he himself was actually born "in the spacious times of Great Elizabeth." He was a great light in a galaxy of lights. Shakespeare, Milton, Ben Jonson, Dryden, Cowley, Bacon, Lord Napier, Hobbes (of the "Leviathan"), Boyle, Kepler, Galileo, Descartes, Spinoza, Leeuwenhoek, Malpighi, Van Helmont, Torricelli, Mayow, Hooke, Aselli, were all his contemporaries. He may have talked with Milton and Shakespeare, and when he was studying in Padua, Galileo was a professor there. Mahomet's son-in-law, Ali, wisely remarked that we are more children of the age we live in than of our own fathers, and Harvey was a wonderful child of a wonderful age, endowed with all its intellectual ardour.

But, though a child of his age, and inspired, no doubt, by the spirit of the age, his intellectual pedigree was long and cosmopolitan, and it is the greatest mistake to imagine that his doctrine of the circulation of the blood had root and origin in the seventeenth century, and sprang, full-grown, from his brilliant brain. Such an erroneous idea was common even in Harvey's own time. Dryden declares:

"The circling streams, once thought but pools of blood
(Whether life's fuel or the body's food),
From dark oblivion Harvey's name shall save."

And another contemporary poet writes:

"For till thy Pegasus the fountain brake,
The crimson blood was but a crimson lake,
Which first from thee did Tyde and Motion gaine,
And veins became its channel, not its chaine."

That is nonsense! Even the primitive man who chopped an artery with a stone axe must have regarded the crimson stream more as a fountain than as a pool; as a matter of fact, early literature shows that motion was always attributed to the blood. In the Ebers Papyrus, which we have already mentioned, in Chapter I., as the oldest medical document known, there is reference to a flow of blood to and from the heart, and there is also a statement "that the heart is distended and the sick man is short of breath because the blood has stagnated and does not circulate." This last statement is particularly interesting, because it seems to show that the Egyptians recognised that shortness of breath might be due to heart disorders; but the expression "circulate" certainly had no precise significance and meant little more than "move."

When we come to Greek times we see the idea of motion becoming even more pronounced.

Plato speaks of the heart as the origin of the blood-vessels and the fountain of the blood. The terms he uses are remarkably prescient. "The blood," he says, "is forcibly carried round to all parts of the body."

Plato and the circulation.

Hippocrates is equally advanced in his physiology. He affirms that all the blood-vessels communicate with one another and run into one another, "that the vessels which spread themselves over the whole body, filling it with spirit juice and motion, are all of them but branches of an original vessel." "I protest I know not," he says, "where it begins or where it ends, for in a circle there is neither beginning nor ending." And he actually uses the expression, "Circulation of the blood" (αἵματος περίοδον—*haimatos periodon*). We must not, however, make too much of mere words, and "*periodon*," as someone has remarked, had not much more of the idea of physiological circulation in it than has the "*Circulez*" of the French policeman.

Hippocrates.

Aristotle distinguished between arteries and veins, and had a vague idea of a communication between them; but, according to his teaching, the arteries contained air, and air was conveyed to the heart by the windpipe. "Every artery," he says, "is accompanied by a vein; the former are filled with breath or air." He thought that the heart was not only the source of the blood-vessels, but the seat and source of bodily heat, and he imagined that breathing was for the purpose of keeping the heart cool. "The hotter the animal," he explains, "the more vigorously must it breathe in order the more effectually to subdue the heat." Accordingly, he thought that fishes died in air because their hearts were cooled too much, and that animals died in water because, under water, their hearts were cooled insufficiently.

Aristotle.

His theory of the beating of the heart was very ingenious, and extraordinary. He held that the food digested in the stomach went to the heart to be elaborated into blood, and there was expanded by the heat of the heart; and that this expansion made the heart expand. Each fresh supply of nutrient fluid to the heart was expanded by the heat, and thus dilated the heart. The arteries, he thought, dilated when the heart dilated, and the circulation consisted in an *ebb and flow of blood to and from the heart*.

By the Empiric and Hippocratic schools the great idea of "pneuma" was introduced. Praxagoras, of the Empiric school, who was the first to use the term "pulse," taught that arteries took their rise in the lungs and terminated in the nerves, and were full of a *spirituous humour;* but Erasistratus of Alexandria seems to have been the chief teacher of the doctrine of the "pneuma" and of the theory of the circulation, which persisted with modifications for nearly two thousand years.

The "pneuma" of the blood.

Erasistratus taught that the veins contained blood, and that the arteries contained a spiritous principle. He noticed that blood escaped from the arteries when cut; but he explained this away by the supposition that there were communications between the veins and the arteries, and that the blood which escaped came really from the veins. Of the valves of the heart he had some knowledge, but his theory of the circulation was not compatible with their action.

Erasistratus.

When we come to the great Galen we find these theories, more or less modified, still in the field, and by Galen himself they are still further modified.

Galen, as we have seen, was an experimental physiologist, and, like a true scientist, he put theory to experimental proof. He knew of Aristotle's and Erasistratus's theory that the arteries contained air or pneuma, and he opposed the theory both on grounds of logic and on grounds of practical experiment.

Galen.

"That the arteries contain blood," he says, "and when wounded discharge nothing but blood, no one will deny who has seen one of them divided. They, therefore, who with Erasistratus maintain that the arteries contain air are forced to admit that they must have communications or anastomose with the veins, and that the veins have thus a share of spirit."

"When an artery is wounded, we always see blood escape, wherefore one of two things: blood is either contained in the arteries immediately, or it flows into them from somewhere else. But, if from elsewhere, it is obvious that the arteries in their natural state could contain spirit only. Were this the case, however, we should see spirit escape from a wounded artery as a prelude to any flow of blood; but as nothing of this kind occurs, we conclude that the vessel never contained aught but blood." Further: "If we lay bare an artery and include a portion of it between ligatures, and then open it we shall find it full of blood."

Theory that veins and arteries contain different kinds of blood.

But though Galen controverted the idea that the arteries contained not blood, but air, he still held the quite plausible, and, to a certain extent, correct, doctrine that the blood in the arteries and the blood in the veins was different in character and in distribution, the difference being chiefly a difference in the proportion of "pneuma" in each case. "The reason," he explains, " why there are two orders of vessels in the animal body is that the several parts may be supplied with the kind of nutriment appropriate to them. What is so absurd as to suppose that the dense and heavy liver should have nourishment of the same kind imparted to it as the light and spongy lungs? Hence it is that we see the liver furnished almost exclusively with veins, whilst the lungs are provided in large proportion with arteries. Let us, therefore, admire the providence of Nature which ordains a two-fold order of vessels, but arranges mutual openings between the termination of neighbouring branches of each."

Continuity between veins and arteries.

The last sentence of the quotation shows that Galen knew of the continuity of veins and arteries; and in other places he explicitly states the same fact. But the connection, as he conceived it, between arteries and veins, was merely a free intercommunication where artery and vein happened to touch in their course, and he evidently did not regard arteries and veins as a closed system of branching tubes. He could not show the connection between arteries and veins, but he proved, by experiment, that if a large artery be divided both arteries and veins are drained of blood. He thought that the arteries, as they dilated, sucked blood from the veins.

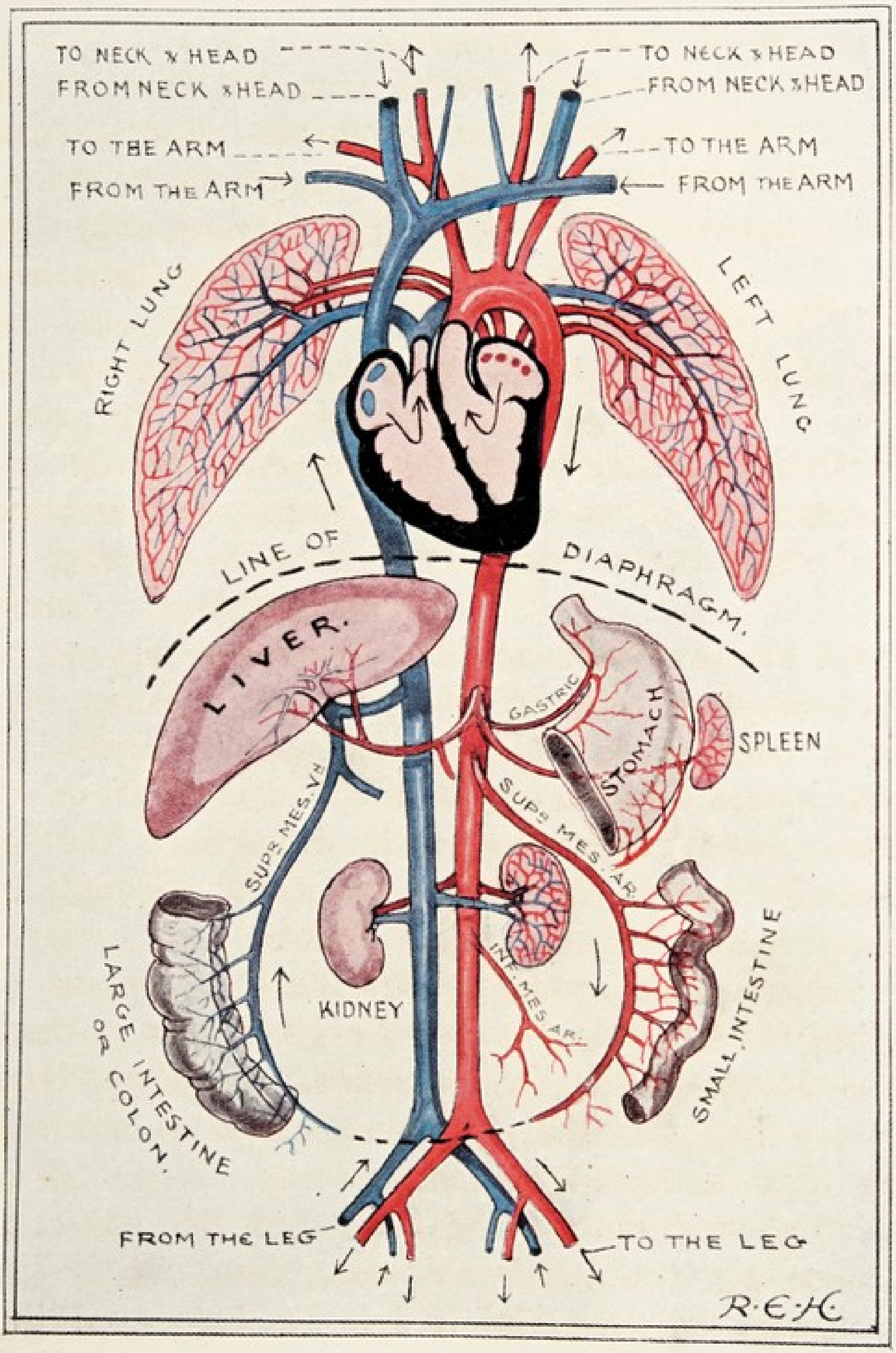
Of the general or systemic circulation, accordingly, Galen had no clear conception. On the other hand, he very nearly discovered the circulation through the lungs.

It may be well here to explain broadly and briefly the manner of the circulation as now understood. The heart is a muscular pouch divided by a partition into right and left halves, and these again are divided by partitions into upper and lower portions. The upper portions are known as right and left *auricles*, and the lower portions as right and left *ventricles*. The left and right sides of the heart are quite self-contained, but each auricle opens into its own ventricle.

Modern doctrine of the circulation.

The right side of the heart, further, contains dark venous blood, and the left side bright arterial blood. Between the two sides of the heart there is a sort of reciprocal relationship. Each time the heart contracts, blood is driven from the right ventricle through the lungs into the left auricle, and from the left ventricle through the body into the right auricle. Now, the circulation from the left ventricle through the body to the right auricle is known as the greater or systemic circulation, while the circulation from the right ventricle to the left auricle is known as the lesser or pulmonary circulation.

The systemic circulation was unguessed by Galen, but the pulmonary circulation, as we have said, was almost discovered by him. He says distinctly, "We cannot suppose that any considerable portion of the blood that is sent to the



DIAGRAMMATIC SCHEME OF THE CIRCULATION OF THE BLOOD.

lungs by the former vessel (vena arteriosa, or pulmonary artery, conveying blood from the right ventricle of the heart) is appropriated by them for their nourishment. It is therefore manifest that it must be transmitted to the left sinus of the heart."

He did not realise that the whole of the blood travelled through the lungs, nor did he understand the mechanism of its impulsion, nor the continuity of the vessels by which it was transmitted. His idea was that *some* of the blood sent from the right side of the heart to the lungs was squeezed, *by the contraction of the chest-wall* (in the act of breathing), through minute pores into the vessels leading to the left auricle. He also rightly perceived that the blood cannot be squeezed back into the right ventricle because of a valve at its entrance. Galen's mechanical theory, therefore, was that spirit was squeezed out of the pulmonary vein, at the same time that blood was squeezed through it to the left ventricle—a not altogether satisfactory conception of the pulmonary circulation.

Galen rightly looked on the heart as a muscular sac, and he even differentiated between longitudinal and circular fibres. He attributed its motion to some innate property associated with its innate heat, and did not agree with Aristotle's theory that it was due to the expansion in the heart of the crude nutriment fluid supplied by the liver.

Galen's greatest mistake was in thinking the expansion of the heart and the suction thus produced was the active working movement of the heart, and on this principle he found it very difficult to give an account of the heart's action consistent with the action of its valves.

Galen's greatest mistake.

This, then, was the state of affairs when Galen wrote his medical works, and, fifteen years later, when the great anatomist Vesalius appeared, we find the Galenical views still prevailing. But the acute anatomist recognised that the Galenical doctrine led to paradoxes, and later he explained that "he accommodated his statements to the dogmas of Galen" "because in such a new work he hesitated to lay down his own opinions, and did not dare to swerve a nail's breadth from the doctrines of the Prince of Medicine."

J. Winter, of Andermach, one of Vesalius's teachers, was probably the first to indicate the part played by the lungs in the arterialisation of the blood. He taught both that blood passed through the lungs from the right to the left ventricle, and that the blood during its passage was elaborated into the pure, subtle, vaporous, and proper aliment of the heart and arteries.

Winter's views of the part played by the lungs.

Not to Winter, however, but to his pupil Servetus, the discovery of the lesser circulation is usually ascribed, and certainly Servetus's exposition of this, the pulmonary circulation, is both clear and precise.

It is interesting to know that he was a pupil of Winter, who speaks of him as "deeply imbued with learning of every kind, and behind none in the knowledge of Galenical doctrine." It would be more interesting still to know how far Servetus owed his theory to Winter.

Servetus was not only a great doctor, but a great theologian and thinker, and, as is well known, he was brutally burnt by Calvin because he refused to believe in the Calvinistic doctrines, and had published in 1553 an heretical work, called "Restitutio Christianismi." Most of the copies of this heretical work were burnt with their author, but one or two copies escaped burning. There is one copy of the work in the British Museum, and one, scorched by the flames, is in the Royal Library of Paris. Sir Michael Foster thinks that Servetus reached his conclusions as to the circulation of the blood "by his own unaided inquiry and thought," but some of Servetus's reasoning, as when he thinks the pulmonary artery too large if its purpose were merely to nourish the lung, is certainly reminiscent of Galen when he says "we cannot suppose that any considerable portion of the blood that is sent to the lungs by the pulmonary artery is appropriated by them for their nourishment"; while it is very unlikely that Servetus was ignorant of his teacher Winter's

Servetus.

views of the circulation. Nevertheless, too much credit cannot be given to Servetus for the part he played in the discovery of the pulmonary circulation. It may be mentioned here that the "Restitutio" was in manuscript in 1546.

Curious is it to find that this courageous and acute thinker was still so much under the dominion of superstition as to believe that the devil could pass with the air up the nostrils to the chambers of the brain, and could thus lay siege to the soul.

The next famous pioneer in the mysteries of the circulation was Matthew Realdus Columbus, whose name is certainly suggestive of discovery.

Matthew Columbus.

Columbus, like Servetus, was a contemporary of Vesalius, and actually acted at Padua as Vesalius's deputy for about two years. A half-educated, vain, and forcible man, Columbus rushed in where angels feared to tread, and was not at all inclined to take all Galen said for gospel.

In his work, "De Re Anatomica," published in 1559, Columbus writes—we quote again from Sir Michael Foster's work, "The History of Physiology": "Between the ventricles there is placed the septum through which almost all authors think there is a way open from the right to the left ventricle; and, according to them, the blood in the transit is rendered thin by the generation of the vital spirits in order that the passage may take place more easily. But these make a great mistake, *for the blood is carried by the artery-like vein to the lungs, and being there made thin is brought back thence together with air by the vein-like artery to the left ventricle of the heart.* This fact no one has hitherto observed or recorded in writing; yet it may be most readily observed by anyone."

And again: "I, for my part, hold a quite different view—namely, that this vein-like artery was made to carry blood mixed with air to the left ventricle of the heart; and this is not only most probable, but is actually the case; for if you examine not only dead bodies but also living animals, you will find this artery in all instances filled with blood, which by no manner of means would be the case if it were constructed to carry air, forsooth, and vapours."

Sir Michael Foster suggests, and there is good ground for the suggestion, that Columbus stole the idea from Servetus, whose manuscript or whose book he may have seen.

All these observers, so far—Galen, Winter, Servetus, Columbus—have propounded more or less clearly the idea of a circulation through the lungs from right ventricle to left auricle. But none of them seems to have had any clear idea of the mechanism which caused this transmission; none of them seems to have grasped the idea of the greater systemic circulation between the left ventricle through the body to the right auricle; and none of them seems to have perceived the incompatibility of the pulmonary circulation with the current and accepted theory of the mechanism of the heart.

In 1571, however, a naturalist, theologian, and physician of Pisa, named Andreas Cæsalpinus, made an effort to get to the root of the matter, and was the first to suggest the true mechanism of the circulation and the completion of the lesser circulation by the greater.

Cæsalpinus adumbrates the systemic circulation.

Cæsalpinus was neither an anatomist nor a physiologist; and yet, by sheer force of logic, he did more to elucidate the circulation than all the scientists before him.

In his "Questiones Peripateticæ" he discusses the inconsistencies of the ordinary doctrine of the circulation, and, from consideration of the valves of the heart, and the general facts of the case, he comes to the conclusion that the arteries dilate when the heart contracts, and that the dilatation of the arteries is due to the blood discharged into them by the contraction of the heart.

He also, from the same considerations and facts, reaches the equally important conclusion that as the heart dilates, it draws blood into its cavity from the veins. This is a tremendous advance. The heart is now conceived as a muscular sac contracting and driving blood out, expanding and sucking blood in, both the influx and the efflux of blood being regulated by valves.

But Cæsalpinus not only enunciated these primary principles of the mechanism of the movements of heart and blood, he also suggested the idea of a systemic circulation. He not only contended that blood was ejected by the arteries, but he also suggested that the blood ejected was returned by the veins. He did not understand the exact mechanism of the return, nor give a precise account of the circulation, but still he had certainly formed a conception of a circular route.

In his "Questiones Medica" he writes: "The passages of the heart are so arranged by Nature that from the vena cava a flow takes place into the right ventricle, whence the way is open into the lung. From the lung, moreover, there is another entrance into the left ventricle of the heart, from which then a way is open into the aorta artery, certain membranes being so placed at the mouth of the vessels that they prevent return. Thus there is a sort of perpetual movement from the vena cava through the heart and lungs into the aorta artery, as I have explained in my 'Peripatetic Questions.'"

Thus Cæsalpinus had quite clearly conceived the greater part of the circulation—from the *vena cava* through the right side of the heart to the lungs, through the lungs to the left side of the heart, and from the left side of the heart to the body. The only "missing link" was that between the arteries and the veins, and this even he at least adumbrated.

Attempts have been made to belittle Cæsalpinus's contribution to the knowledge of the circulation because of his belief that the blood rushes back to the heart lest it should be extinguished ; but this little error of his is quite irrelevant to the accuracy of the general principle he propounded—namely, that there is a flow of blood from the heart through the arteries to the tissues and a return of the blood to the heart through the veins. Cæsalpinus overthrew two of the most vicious and inveterate errors—namely, that the veins carried blood *from* the heart to the tissues, and that the main action of the heart was that of a suction pump. We, nowadays, are so familiar with the action of the heart, and with the function of the arteries and veins, that it is difficult to understand the greatness of the physiological revolution effected by his work ; but a great revolution it undoubtedly was, and Cæsalpinus must certainly share with Harvey the honour of having discovered the circulation of the blood.

Cæsalpinus overthrows two vicious and inveterate errors.

It is extraordinary that, during all these centuries, physicians should have believed that the veins carried blood *from* the heart, for ever since the days of Hippocrates bleeding had been common, and the whole routine and circumstance of blood-letting served to indicate that the blood in the veins flowed towards the heart ; yet an error often grows less eradicable with age, and this aged error persisted for centuries.

The error that the heart and the blood-vessels dilate together is more explicable. When the heart contracts its apex rises against the chest-wall, and this would naturally give rise to the erroneous impression that it was expanding.

Fabricius.

Three years after the "Medical Questions" of Cæsalpinus, Fabricius of Padua published a famous book, "De Venarum Ostiolis," "Concerning Little Doors of the Veins." At intervals in the veins there are valves which prevent any flow of blood from the heart, and this work of Fabricius was a study of these valves. Fabricius was not the discoverer of venous valves. Sylvius Beranger, Stephanus, Vesalius, Eustachius, Porthius, Cannanus, Carpi, all described valves here and there; but Fabricius was the first to make a thorough study of them. Nevertheless, so incorrigible is ancient error, he completely misunderstood the function of the valves in the mechanism of the circulation, and, proceeding on the assumption that the blood flowed *from* the heart and against the valves, he thought that the purpose of the valves was simply to prevent too rapid and too violent a flow.

Thus before Harvey completely elucidated the action of the heart and the mechanism of the circulation, generations of men had worked at the subject, and he had both much to lead and much to mislead him.

CHAPTER IV.

HARVEY AND HIS WORK.

Harvey at Padua—First exposition of his theory of the circulation—Shatters the old Galenic doctrine—His ingenious experiments—How he reached his conclusions—How his work was received—Malpighi discovers the capillaries—Harvey's character—Some of his sayings—Mystery of the action of the heart still unsolved—Practical fruits of Harvey's discoveries.

WE are now in a position to consider Harvey's work, in its relationship to the work of his predecessors and to the beliefs of his time.

Harvey was born in 1578, and, after taking an Arts degree at Cambridge in 1597, he proceeded to Italy to study medicine at Padua.

Harvey at Padua.

The great Fabricius still taught there; Galileo was still "in his turret"; Sylvius, Vesalius, Fallopius, Matthew Columbus were still living influences; no environment could have been more quickening to an ardent and active intellect.

Studying under Fabricius, who about a quarter of a century before had published his book, "De Venarum Ostiolis," Harvey's attention must have been specially directed to problems connected with the function of valves and the action of the heart; and, no doubt, at Padua were sown the seeds that in later years bore such remarkable fruit. True it is that Fabricius still taught the fascinating Galenic doctrine of the concoction of spirits in the left ventricle; but, still, the heretical views of Columbus and Cæsalpinus must also have reached Harvey's ear, and he may even have seen Servetus's book.

Anyhow, Harvey did not remain a Galenist; he became the leader of a new school.

In 1602 Harvey took the degree of Doctor of Medicine at Padua, and returned to England. In 1615 he was appointed Lumleian lecturer. The Lumleian lecturer lectured twice a week; his course lasted for six years, and for each year certain subjects were prescribed. At the end of six years the lectures began again, and the same ground was covered.

Harvey's Lumleian lectures.

During the first year lectures on surgery and on the works of Galen and Oribasius were prescribed, and the lecturer had also "to dissect openly in the reading-place all the body of man, especially the inward parts, for five days together, as well before as after dinner, if the bodies may last so long without annoy." During the second year he had to deliver more advanced works upon surgery and "to dissect the trunk only of the body." It was during the second year's course in 1616 that Harvey first propounded his great theory of the circulation. His notes for his lectures of that year are still extant, and are most interesting reading, even apart from the important principles they maintain. It was, of course, the fashion of the day to write science in Latin, and many of the sentences in Harvey's notes are half English and half Latin, thus "Exempto corde, frogg scipp, eele crawle, dogg ambulat." Even in Harvey's day tight-lacing seems to have been fashionable, for he says one of the causes of difficult respiration in young girls is tight-lacing, "unde cut laces."

But to come to the famous notes on the heart and circulation. They are brief, but to the point. "It is plain," they run, "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.

Harvey's first exposition of his theory of the circulation.

"Whence it follows that the movement of the blood is constantly in a circle, and is brought about by the beat of the heart. It is a question, therefore, whether this is for the sake of nourishment, or rather for the preservation of the blood and the limbs by the communication of heat, the blood cooled by warming the limbs being in turn warmed by the heart."

That is all; yet that is the adumbration of the greatest revolution in medicine.

Not till twelve years later, however, did

Harvey publish his complete work on the motion of the heart. During the interval he was appointed Physician Extraordinary to James I., and was also engaged in private practice, riding "on horseback with a footcloth to visit his patients, his man still following on foot, as the fashion then was." Among his private patients were several noblemen; but his most distinguished patient was Lord Chancellor Bacon. For Bacon, it may be noted, Harvey had no great respect. Indeed, he said, disparagingly, that Bacon wrote philosophy "like a Lord Chancellor."

Publication of Harvey's great book.

In 1628 Harvey's great book, "Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus," appeared. So atrocious was Harvey's handwriting that there is a page and a half of errata. But though his handwriting was erratic, his reasoning was precise, and from first page to last his work is a work of science. Even the preface shows the quality of the book. "Neither do they" (the studious, and good, and true) "think it unworthy of them to change their opinion if truth and undoubted demonstration require them to do so. They do not esteem it discreditable to desert error, though sanctioned by the highest antiquity, for they know full well that to err, to be deceived, is human; that many things are discovered by accident, and that many may be learned indifferently from any quarter, by an old man from a youth, by a person of understanding from one of inferior capacity." Again, "I profess both to learn and to teach anatomy not from books but from dissections; not from the positions of philosophers, but from the fabric of nature!"

Harvey saw, as Cæsalpinus had seen, the inconsistencies and paradoxes of the Galenic theory. "Good God!" he asks, with pardonable excitement, "how should the mitral valves prevent the regurgitation of air and not of blood?" He points out that the Galenists make the vein-like artery or pulmonary vein perform three or four distinct functions, "for they will have it that air passes through this vessel from the lungs into the left ventricle; that fuliginous vapours escape by it from the heart into the lungs, and that a portion of the spirituous blood is distributed to the lungs for their refreshment; and why," he asks, "if fumes or fuliginous vapours and air permeate this vessel, as they do the pulmonary bronchia, wherefore do we find neither air nor fuliginous vapours when we divide the pulmonary vein? Why do we always find this vessel full of sluggish blood, never of air, whilst in the lungs we find abundance of air remaining?" He shows that even when the lungs are artificially inflated, no air passes along the pulmonary vein to the heart.

Inconsistencies of the Galenic doctrine.

It is difficult to understand at this date what a revolution was implied in the denial of the passage of air to the heart. For nearly two thousand years the formation of vital spirit in the heart had been the popular belief, and it had not only been elaborated into a most far-reaching physiological doctrine, but had become part of the language and the thought of all men. Milton says that Eve, when she ate the apple, had "ampler spirits and dilated heart"; and expressions like "good spirits," "high spirits," "low spirits," "high-hearted," "down-hearted," all show how firmly rooted was the Galenic doctrine. Yet Harvey had the courage to deny this doctrine, flatly, and unflinchingly.

He opposed, too, the old idea that the blood oozed from the right side of the heart to the left, through pores in the partition between the sides.

Harvey's denial of the existence of pores in the septum of the heart.

"By Hercules!" he exclaims, "no such pores can be demonstrated, nor, in fact, do any such exist; for 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 that 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? Why 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? But it is certainly mysterious and incongruous that blood should be supposed to be most commodiously drawn through a set of obscure and invisible ducts, and air through perfectly open passages at one and the same moment. And why, I ask, is recourse had to secret and invisible porosities, to uncertain and obscure channels, to explain the passage of the blood into the left ventricle, when there is so open a way through the pulmonary veins? I own it has always appeared extraordinary to me that they should have chosen to make, or rather to imagine, a way through the thick, hard, dense, and most compact septum of the heart, rather than take that by the open pulmonary vein, or even through the lax, soft, and spongy tissue of the lungs at large."

By such astute and forcible logic, Harvey completely shattered the old Galenic doctrine, and then, with patience and perseverance, he started to find out how the heart *did* work, and proceeded "to contemplate the motion of the heart and arteries, not only in man, but in all animals that have hearts."

The rapidity of the motion, which in many animals "is accomplished in the twinkling of an eye, coming and going like a flash of lightning," greatly bewildered him at first. "I found the task so truly arduous, so full of difficulties," he says, "that I was almost tempted to think with

Frascatorius that the motion of the heart was only to be comprehended by God. . . . I was not surprised that Andreas Laurentius should have written that the motion of the heart was as perplexing as the flux and reflux of Euripus had appeared to Aristotle."

In the course of his researches, he dissected and vivisected numerous animals of all kinds; not only the larger animals, but also frogs, doves, lizards, tortoises, oysters, mussels, serpents, small fishes, slugs, snails, scallops, shrimps, crabs—" nay, even wasps, hornets, and flies," he says. "I have, with the aid of a magnifying glass, and at the upper part of what is called the tail, both seen the heart pulsating myself and shown it to many others." He even watched the development of a chick *in ovo,* and saw the first beginnings of the heart, and his description of what he saw is quite picturesque and imaginative: "I have also observed the first rudiments of the chick in the course of the fourth or fifth day of incubation, in the guise of a little cloud, the shell having been removed and the egg immersed in clear, tepid water. In the midst of the cloudlet in question there was a little bloody point, so small that it disappeared during the contraction and escaped the sight, but in the relaxation it re-appeared again, red and like the point of a pin; so that betwixt the visible and invisible, betwixt being and not being, as it were, it gave by its pulses a kind of representation of the commencement of life."

Through such exhaustive researches and by processes of acute reasoning, Harvey at length discovered the true action of the heart. "The one action of the heart," he writes, "is the transmission of the blood and its distribution, by means of the arteries, to the very extremities of the body; so that the pulse which we feel in the arteries is nothing more than the impulse of the blood derived from the heart. Whether or not the heart, besides propelling the blood, giving it motion locally, and distributing it to the body, adds anything else to it—heat, spirit, perfection—must be inquired into by-and-by and decided upon other grounds. So much may suffice at this time, when it is shown that by the action of the heart the blood is transformed through the ventricles from the veins to the arteries and distributed by the arteries to all parts of the body."

Discovery of real action of the heart.

This explanation of the heart's action seems simple and obvious, but it was quite new, and quite contrary to the physiological beliefs of the time, and even the writers who had most nearly discovered the fact of the circulation of the blood had quite failed to grasp the mechanism of the heart's action; and suction, not impulsion, was considered its dominant action.

Having established the mechanism of the heart, Harvey next proceeded to discover the great fact of the circulation of the blood.

By what route he reached this discovery has been much debated, and some have held that it was reached as a deduction from the arrangement of the valves of the heart and veins. We have no reason, however, to doubt Harvey's own account of the genesis of the idea.

Discovery of the circulation of the blood.

Harvey states quite distinctly that he was led to the idea by the difficulty of accounting for the blood driven through the heart. The heart beats continually, and at each beat a quantity of blood is driven through it. Where did the blood come from, and where did it go to? The circulation of the blood was, indeed, a necessary corollary of his theorem that the blood was driven through the heart to the lungs and the body. Let us quote Harvey's own historical words in his Chapter VIII.: "Thus far I have spoken of the passage of the blood from the veins into the arteries, and of the manner in which it is transmitted and distributed by the action of the heart; points to which some, moved either by the authority of Galen or Columbus, or by the reasonings of others, will give in their adherence. But what remains to be said upon the quantity and source of the blood which thus passes is of a character so novel and unheard-of, that I not only fear injury to myself from the envy of a few, but I tremble lest I have mankind at large for my enemies, so much doth wont and custom become a second nature. Doctrine once sown strikes deep its root, and respect for antiquity influences all men. . . . I frequently and seriously bethought me, and long revolved in my mind what might be the quantity of blood which was transmitted, in how short a time its passage might be transmitted, and the like ; but not finding it possible that this could be supplied by the juices of the ingested aliment without the veins on the one hand becoming drained and the arteries on the other hand getting ruptured through the excessive charge of blood, unless the blood should somehow find its way from the arteries into the veins, and so return to the right side of the heart, I 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 impelled by the right ventricle through the lungs into the pulmonary artery), and that it then passed through the veins, and along the vena cava, and so round to the left ventricle in the manner already indicated."

Precise statement of his doctrine of the circulation.

This is clear and precise enough, but still more clear and precise is his statement in Chapter IX. Here he puts the matter as follows : "First : the blood is incessantly transmitted by the action of the heart from the vena cava to the arteries in such quantity that it cannot be supplied from the ingesta [food], and in such manner that the whole must very quickly pass through the organ. Second: the blood under the influence of the arterial pulse enters and is impelled in a continuous, equable, and incessant stream through every part and member of the body, in much larger quantity than were sufficient for nutrition, or than the whole mass of fluids could supply. Third: the veins in like manner return this blood incessantly to the heart from all parts and members of the body. These points proved, I conceive it will be manifest that the blood circulates, revolves, propelled and then returning, from the heart to the extremities, and thus that it performs a kind of circular motion."

With much ingenuity and detail Harvey works out his point that more blood passes through the heart, in consequence of its action, as explained by him, than the food can supply or the veins contain. He also shows how an animal can be drained of both venous and arterial blood by opening an artery, and thus proves that the blood passes into the arteries from the veins *viâ* the heart. Some of his experiments in proof of his thesis are very convincing. Thus, having exposed the heart of a live snake, he shows that if the big vein going to the heart be nipped between the finger and thumb, some distance from the heart, the vein between the point of compression and the heart will be emptied by the pumping action of the heart; while, on the other hand, if the artery leading from the heart be compressed, the artery between the point of compression and the heart, and also the heart itself, will become distended with blood. This, he points out, not only shows the flow of the blood from the veins through the heart to the artery, but also illustrates two kinds of death: "extinction from deficiency and suffocation from excess."

To deal with all his arguments and experimental proofs would be quite impossible here; but chapter by chapter he confirms his proposition, and finally in his fourteenth chapter he sums up concisely thus: "Since all things, both argument and ocular demonstration, show that the blood passes through the lungs and heart by the force of the ventricles, and is sent for distribution to all parts of the body, where it makes its way into the veins and porosities of the flesh and then flows by the veins from the circumference on every side to the centre, from the lesser to the greater veins, and is by them finally discharged into the vena cava and right auricle of the heart, and this in such quantity or in such a flux or reflux, thither by the arteries, hither by the veins, as cannot possibly be supplied by the ingesta, and is much greater than can be required for mere purposes of nutrition, it is absolutely necessary to conclude 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

Harvey sums up his argument.

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."

From every point of view "De motu cordis" was a great work. Not since the time of Galen had such scientific work been done; and such demonstration might have been expected to carry conviction to the most prejudiced. Yet such is the force of old belief, even when rooted in error, that many scientists remained unconvinced. Riolan, the most eminent of French anatomists, made absurd objections. Reid, Lecturer on Anatomy at the Barber Surgeons' Hall, continued to teach the Galenic doctrine for thirty years after the publication of Harvey's work. Caspar Hofmann, of Nuremburg, remained sceptical, even though Harvey visited him and gave him a personal demonstration. Descartes received the discovery with very qualified approval, admitting the circulation, but denying Harvey's explanation of it, and proposing a fantastic theory of the action of the heart based on the idea that the crude blood, "*un espèce de levain,*" entering the heart from the veins, drop by drop, was expanded by the heat, and caused the heart to dilate. "We know of no kind of fermentation or ebullition," objected Harvey, "in which the matter rises and falls in the twinkling of an eye." Lesser scientists combined in a futile resistance to his doctrines. Indeed, after the publication of his

Reception of Harvey's great work.

work, "he fell mightily in his practice, 'twas believed by the vulgar that he was crack-brained, and all the physitians were against his opinion and envyed him."

Harvey himself writes: "One party holds that I have completely demonstrated the circulation of the blood by experiment, observation, and ocular inspection against all force and array of argument; another thinks it is scarcely sufficiently illustrated—not yet cleared of all objections. There are some, too, who say that I have shown a vainglorious love of vivisection, and who scoff at and deride the introduction of frogs and serpents, flies, and other of the lower animals upon the scene as a piece of puerile levity, not even refraining from opprobrious epithets."

Imperfection of his demonstration.

Only on one point was Harvey's demonstration imperfect: he had not shown the communication between the arteries and the veins, and he had vague and variable theories of the nature of the communication. This hiatus in his theory, however, was not long unbridged; for in 1661, only four years after Harvey's death, the great Italian microscopist, Malpighi, discovered in the lung of a frog the capillaries, or minute tubes connecting the fine terminations of the arteries with the fine beginnings of the veins. "There appears," he declares, "a network made up of the continuations of the two vessels. This network not only occupies the whole area, but extends to the walls, and is attached to the outgoing vessel. . . . Hence it was clear to the senses that the blood flowed along tortuous vessels, and was not poured into spaces, but was always contained within tubules."

A few years later, Leeuwenhoek saw, and described the capillaries in fishes and amphibia. Describing the appearance in the tail of tadpoles, the old Dutchman enthusiastically writes :—"A sight presented itself more delightful than any that my eyes had ever beheld, for here I discovered more than fifty circulations of the blood in different places. I saw that not only the blood in many places was conveyed through exceedingly minute vessels from the middle of the tail towards the edges, but that each of the vessels had a curve or turning, and carried the blood back towards the middle of the tail, in order to be conveyed to the heart. Hereby it appeared plainly to me that the blood-vessels I now saw in this animal, and which bear the name of arteries and veins are, in fact, one and the same—that is to say, that they are properly termed arteries so long as they convey the blood to the farthest extremities of its vessels, and veins when they bring it back towards the heart."

Leeuwenhoek's description of the appearance of the circulation.

And so the fact that the blood circulated in a closed series of tubes and tubules became visible and undeniable. What would old Harvey have given to see the sight! If he had lived only four years longer he might have seen it. Still, he had *foreseen* it as surely as the astronomers Adams and Leverrier had foreseen by their calculations the existence of Neptune, before its actual discovery.

No acknowledgment of the genius of Hippocrates, of Winter, of Cæsalpinus, or of Galen can diminish the honour due to Harvey. By patience, by indomitable mental and moral courage, he overthrew error and set truth upon a rock. It was no mere chance. He won his victory by hard work and fearless courage, and all we know about the man shows that he was worthy of the prize. He was a scientific enthusiast. When he was in Germany he wrote to his friend, Dr. Aveling: "I can only complayne that by the waye we could scarce see a dogg, crow, kite, raven, or any bird or anything to anatomise." Does not that recall the complaint of Vesalius in Spain that "he could not lay his hand on so much as a dried skull, much less have the chance of making a dissection"? On the occasion of the Battle of Edgehill the Prince and the Duke of York were committed to his care, and while the battle was waging, what did this philosopher do? He withdrew with them (the Prince and Duke) under a hedge and "tooke out of his pockett a book and read, but he had not read very long before a bullet of a great gun grazed on the ground neare him, which made him

Character of Harvey.

remove his station." On another occasion, when he was travelling in Austria with the Lord High Marshal of England, Thomas Howard, Earl of Arundel and Surrey, it was recounted that "Dr. Harvey would still be making observations of strange trees, and plants, and earths, etc., and sometimes (he was) like to be lost, for there was not only a danger of thieves, but also of wild beasts."

A man who can read a book under a hedge with bullets flying about, and who is not to be deterred from botanising and geologising by such trifles as thieves and wild beasts, has surely got both the philosophic and the scientific temperaments.

Aubrey, in his gossiping fashion, gives the following description of the great man: "He was, as all his brothers, very cholerique, and in his younger days wore a dagger (as the fashion then was—nay, I remember my old schoolmaster, Mr. Latimer, at 70, wore a dudgeon, with a knife and bodkin, as also my old grandfather Lyte, and Alderman Whitson of Bristowe, which, I suppose, was the common fashion in their young days), but this doctor would be apt to draw out his dagger upon every slight occasion. He was not tall, but of the lowest stature, round-faced, olivaster (like wainscott) complexion; little eie, round, very black, full of spirit; his haire was black as a raven, but quite white twenty yeares before he dyed. . . . He was very communicative and willing to instruct any that were modest and respectful to him."

Some of his sayings, quoted by Aubrey, are rather amusing. "He was wont to say," states Aubrey, "that man was but a great mischievous baboon"; and "He would say that we Europeans knew not how to order or govern our women, and that the Turkes were the only people who used them wisely." Obviously, he would not support the suffragettes!

Some of Harvey's sayings.

He had his eccentricities; but better indications of the real man are found in the inscriptions by him recently found in the Album of Philip de Glarges. In this album Harvey wrote: "Dii laboribus omnia vendunt" (the gods sell all things for labour). Better still in such frequent sayings as incidentally crop up in his great works. Could any but a great man have written: "Nor does God give that which is most excellent and chiefly to be desired—wisdom—to the wicked. . . . To return evil-speaking with evil-speaking, however, I hold to be unworthy in a philosopher and searcher after truth; I believe I shall do better and more advisedly if I meet so many indications of ill-breeding with the light of faithful and conclusive observation"? One can forgive a good deal of choler in a man who can think like that!

And when a mob of citizen-soldiers entered Harvey's lodgings and stole valuable scientific papers, the work of years, he refers to his loss with a quiet dignity. "Let gentle minds forgive me," he writes, "if, recalling the irreparable injuries I have suffered, I here give vent to a sigh. This is the cause of my sorrow: Whilst in attendance on His Majesty the King during our late troubles, and more than civil wars, not only with the permission, but by the command of the Parliament, certain rapacious hands not only stripped my house of all its furniture, but—what is a subject of far greater regret to me—my enemies abstracted from my museum the fruits of many years of toil. Whence it has come to pass that many observations, particularly on the generation of insects, have perished, with detriment, I venture to say, to the republic of letters."

Nor was Harvey merely a doctor and scientist: he was also a man of wide culture, he was a good mathematician, and, like many of the great discoverers in science, he was fond of poetry. Virgil was his favourite poet, and it is said that he looked on his poetry with such astounded admiration that sometimes he would fling the book away and say that Virgil had a devil in him.

Such, then, was the man who discovered the mechanism of the heart and the circulation of the blood—a man with patience, with force, with indomitable courage, with imaginative ardour.

It is almost sad to think of the death of the Galenic doctrine of the heart. Think how it began in Greece in the brain of Plato, how three hundred years before Christ Erasistratus, vivisecting his criminals in Alexandria, was full of it; how Galen at Rome elaborated it; how Vesalius at Padua taught it! It had imaginative value, too, and manifold mystery, and a beautiful plausibility. We are told in the Hebrew Scriptures that God breathed into man's nostrils the breath of life; and, according to this view, the breath was drawn into the heart, and there wonderfully concocted into vital spirits, while some of the blood went to the brain, where the animal spirits which ran down the nerves were manufactured. The heart and the brain as crucibles wherein the spirits were made—that is surely a fine idea, and it is a wonder the poets did not make more of it. Shakespeare's lines: "Dear to me as are the ruddy drops that visit this sad heart," have a new meaning when we realise what mysteries to Shakespeare the blood and the heart were. Did Shakespeare think of these ruddy drops as "*un espèce de levain*"? Did he imagine that there was in the heart a constant ebullition and effervescence? Certainly he knew nothing of the circulation of the blood, and the word he uses, "visit," is more apt when we remember that in his time the circulation was considered a to-and-fro movement. The expression "drops," too, is quite in keeping with the theories of his time, which asserted that the blood distilled into the heart drop by drop.

Imaginative value of the Galenic doctrine of the heart.

Think how much more the terms "high spirits" and "good spirits" and "poor spirits" must have meant in those days!

Harvey cleared up the mystery and "laid" the spirits, and showed the heart simply as a force-pump pumping a red fluid through a system of closed tubes.

Mystery of the action of the heart still remains.

And yet the mystery, the wonder remains! Is there no wonder in the thought of this muscular fist gripping the blood, and forcing it round and round hour after hour, day after day, year after year? It never rests: seventy or eighty times a minute it shuts and opens. Through brains, and hands, and feet, impelled by this living pump, the blood is driven, and yet we are hardly aware that our heart is beating. "Rub-dup" go the valves, and we never hear them; and even when they leak, as they sometimes do, we may be for years unaware of the leakage. Is there no wonder in that? And is there no mystery? *Why* does the heart beat? Galen thought that the vital spirit formed by a mixture of the blood and the air was the cause of its pulsation. Descartes thought its heat made the blood expand, and that the blood's expansion made the heart dilate.

We know more about heat, and more about the nature of the blood, and more about the mechanism of the heart than did Galen and Descartes. We know that air does not enter the heart ; we know that the blood does not expand ; but of the *cause* of the heart-beat we know little more than they. Galen talked of "vital spirits," we may talk of "molecular rearrangement" ; but in both cases the terms merely cloak ignorance. The whole thing is a mighty mystery. Well might old Leeuwenhoek, when he saw the blood flow through the capillaries, say that his eyes had never beheld a more delightful sight.

One thing we have found out, and that is that the heart-beat is not dependent on the brain, though to a certain extent regulated by the brain. Harvey saw the little red point in the ovum of the hen beginning to pulsate ; and this pulsation takes place before there is any nervous system ; and it has been found that the heart in many cases will continue to beat even when it is out of the body, and that in some instances it will continue to beat even after it has been cut into rings. The heart seems almost to have an independent life of its own. Harless observed the heart beating in the body of a decapitated murderer one hour after execution. Margo found the right auricle beating two and a half hours after execution. Dietrich found that both auricles contracted if one were irritated forty minutes after death. Remak observed the rhythmic contractions in the hearts of birds and mammals two days after death, and Ém. Rousseau mentions that a woman's heart had these rhythmic "movements seven-and-twenty hours after she had been guillotined." We have already mentioned how Vesalius, when performing a *post-mortem* on a nobleman, found the heart beating.

Some of the circumstances that affect the heart-beat have been found out. Harvey found that he could cause the heart of a pigeon which had ceased beating to recommence its pulsation, simply by moistening his finger with his saliva, and applying it to the heart. We now know that the stimulating effect was due not merely to the moisture, but to the salts in the saliva, and we can now perform apparent miracles by the application of the principle. It has been found possible to cut a heart out of the body and keep it beating for days, simply by feeding it with a solution of suitable salts! That surely looks like a miracle! The body itself dead and putrid, and yet its heart still alive and beating! It is most uncanny!

But though we can do such marvellous things, the beating of the heart remains a mystery; we do not know why the little red sac in the embryo should suddenly begin to open and shut; we do not know why the heart of a midge and the heart of a mammoth beat, beat, beat day after day, year after year.

It may be asked, what were the practical fruits of Harvey's discovery? Harvey himself made at least one practical application. "Looking back upon the office of the arteries," he writes, "I have occasionally, and against all expectation, completely cured enormous sarcoceles by the simple means of dividing or tying the little artery that supplied them, and so preventing all access of nourishment or spirit to the part affected, by which it came to pass that the tumour, on the verge of mortification, was afterwards easily extirpated with the knife or searing iron."

Practical fruits of Harvey's work.

But at first the practical fruits were very few. The age was not ripe for a medicine of reason: it was still an age of weird prescriptions, of magic, and of witch-burning. Even when Harvey's views were accepted they did not bear at first quite healthy fruit. The overthrow of Galenic doctrine gave rise to a great reaction against treatment based on the "spirits" and the humours—a new school arose which carried the mechanical principles suggested by Harvey's discovery to ridiculous extremes. "The mechanical school," says Oliver Wendell Holmes, "rose in its pride on solid foundations which appealed to practical men with singular force. Very soon that 'beatific epitome of creation,' man, was 'marked out like a spot of earth or a piece of timber with rules and compasses,' and the medical terminology of the day became unintelligible to the older practitioners, who could make nothing of the 'wheels and pulleys, levers, screws, cords, canals and cisterns, sieves and strainers,' and they cracked their jokes on 'angles, cylinders, celerity, percussion,' and such-like terms, which they said had no more to do with physic or the human body than a carpenter has in making Venice treacle or curing a fever."

Despite such exaggerations and extravagances, however, Harvey's doctrine of the circulation eventually became the basis of a large part of modern scientific therapeutics.

Modern doctrines of heart disease—its effects, its treatment—are all based on principles involved in Harvey's discovery. Treatment by transfusion of blood, treatment by hypodermic injection, the principle of the tourniquet, the tying of arteries for hæmorrhage and aneurism, our knowledge of the nature of blood-clot and dropsy, even our conception of the processes of inflammation and suppuration, of respiration and digestion, are all fruits of Harvey's work ; in fact, our whole conception of the body as a physico-chemical machine is based on Harvey's doctrine of the circulation, which became more important as physiology advanced, and as the discovery of the nature of respiration by Lavoisier, the discovery of the vaso-motor nerves by Claude Bernard, and of the vagus and sympathetic action by the Webers, gave it new meanings and wider applications.

Sir Thomas Browne considered Harvey's discovery of the circulation greater than Columbus's discovery of America ; Hunter thought the three great discoveries of modern times were the western hemisphere by Columbus, the constitution of the solar system by Copernicus, and the circulation of the blood by Harvey. Dr. Baas says that Harvey stands alone in respect of the world of life, that his discovery of the inner working of the microcosm takes a place equal to, if not, indeed, higher than those of Copernicus, Kepler, and Newton in respect to the macrocosm.

Voici, Harvey !

CHAPTER V.

THE ROMANCE OF THE CELL: MAN A MENAGERIE.

"Fearful and wondrous is the skill which moulds
Our body's vital plan,
And from the first dim hidden germ unfolds
The perfect limbs of man.
Who, who can pierce the secret—tell us how
Something is drawn from nought—
Life from the inert mass? Who, Lord, but Thou,
Whose Hand the whole hath wrought
Of this corporeal substance, still to be.
Thine eye a survey took,
And all my members yet unformed by Thee
Were written in Thy book."

Invention of the compound microscope—Virchow's doctrine of cellular pathology—Analysis and synthesis—Man as a product of cell-growth—Man both a menagerie and an aquarium—Cells of the blood—Relationship between the different cells—Practical results of the cellular theory—Cancer and the Trypsin treatment—Old age and its cause.

DESPITE the work of Harvey, and the stimulus to clear thinking his discovery had given, medicine in the eighteenth century still wandered in the mists of metaphysics. A few great thinkers like Morgagni insisted upon the necessity of studying the correlations between anatomical conditions and disease; a few great prophets like Planciz foreshadowed the germ-theory of contagions; but, in general, medicine was occupied with transcendental inquiries, with fantastic speculations as to the ultimate constitution of the body; while vague theories of invisible fibres and molecular granules took the place of facts derived from observation and experiment. "Our body, then," said Haller, in his "Physiology" of 1754, "is gradually built up of gelatinous and slimy fluid;" and on the basis of some such "gelatinous and slimy fluid" the theories of medicine were erected!

Medicine in the eighteenth century.

Bichat and his followers had done what they could with the microscope at their command, and had analysed the tissues into twenty-one simple microscopic elements; while such scientists as Brisseau, Mirbel, Treviranus, Turpin, Schleiden, had begun to emphasise the fundamental importance of the cell, foreseen by Hooke in 1665, and actually seen by Malpighi in 1671. But till the microscope was improved, nothing more could be done; and, as someone remarked, the future of anatomy and physiology lay in the hands of Messrs. Schieck and Pistor, the Berlin opticians.

About 1830 the compound microscope became a trustworthy scientific instrument. Up till this time, in the words of Oliver Wendell Holmes, "Nature had kept over all her inner workshops the forbidding inscription, 'No Admittance!' If any prying observers ventured to spy through this magnifying tube into the mysteries of her glands and canals and fluids, she covered up her work in blinding mists, and bewildering halos, as the deities of old concealed their favoured heroes in the moments of danger." Now, however, as the "delusive rainbow" of refraction faded away from the margin of the microscopic field, the rainbow mists of imagination faded away from pathological theory, and men began to see the minute anatomical facts in the *lumen siccum* —in the white light of reason.

Virchow's cellular pathology.

The compound microscope became an efficient weapon of scientific truth about 1830, we have said, and in 1839 Schwann demonstrated that all the higher animals are commonwealths of cells; while in 1858, Virchow published his epoch-making book on cellular pathology. With the publication of this work, a new era in scientific medicine was inaugurated. Observation, which had been gradually narrowing down from the body as a mysterious metaphysical whole, to the body as an aggregate of organs, and to the organs as a patchwork of tissues, became focussed upon the ultimate structural elements, the cells. "Just as a tree," wrote Virchow, "constitutes a mass arranged in a definite manner, in which in every single part, in the leaves as in the root, in the trunk as in the blossom, cells are discovered to be the ultimate elements, so is it also with the forms of animal life. Every animal presents itself as a sum of vital unities, every one of which manifests all the characteristics of life."

Virchow showed further that the cells were the true pathological units, and that all diseases were prefigured and accompanied by cellular changes. He showed, too, by a series of beautiful demonstrations, that the cells could multiply and propagate their species each after its kind. Up till his time, the body cells—as were the microbe cells—were supposed to be capable of being formed by the cohesion of organic particles in the so-called *cyto-blastema;* and the establishment of the law, "*Omnis cellula e cellula*" (Every cell from a parent cell), was in some ways as important as the generalisation, "Every germ from a parent germ," and it has as far-reaching consequences.

To make a mosaic or a menagerie of a man—to teaze out his mysterious tissues into a tesselated multiplicity of cells—to show that his body is composed of little self-contained particles, each living its own life, feeding, growing, multiplying—to demonstrate disease as cellular misdemeanour, was a great analysis; but, like all great analyses, it led to greater syntheses, to novel cosmic correlations. Hitherto man had dared to consider himself a little lower than the angels: now he might venture to consider himself a little higher than the amœbæ. Now might he say to the worm, "Thou art my mother and my sister," and to the tubercle bacillus. "Thou art my brother Cain."

All living creatures, whether roses or reptiles, microbes or men, were shown to be either single cells or colonies of cells, and all cells were shown to be composed of the same material, "protoplasm." King and cabbage were found to be both made of cells, and the cells in both cases were found to be made of identical stuff. Shakespeare had said that we are of such stuff as dreams are made of: Virchow proved that we are also of such stuff as worms are made of.

Thus did Leeuwenhoek's lens pick all life to pieces, and then piece all life together. Thus did the microscope find a least common denominator for all flesh.

Sir James Paget considered the development of ova, through multiplication and division of their cells, as the greatest truth in physiology, and certainly it is the most wonderful. Picture it! Two cells, microscopic particles of protoplasm, so frail that a little sunshine or a trace of carbolic will slay them, meet, and, lo! in the meeting a miracle is wrought: they blend into one and the one cell multiplies in a mysterious way, and becomes a man with an immortal soul. Two other cells, likewise microscopic particles of protoplasm, made of exactly the same material, meet and blend, and, lo, a lily! The one condition of development, the one condition of immortality, a meeting!

How the meeting comes to mean this no one knows.

Man as a product of cell-growth.

Let us consider man as a product of cell-growth. When we look at single-celled organisms such as microbes, we see that they multiply by division, and that each cell is like its parent, and has its parents' structural and chemical characters. When we look at man we see a much more wonderful process.

As a single microscopic cell, the impregnated ovum, man begins; and this cell grows, and buds, and multiplies. Cell is cunningly plastered to cell, and fibre wonderfully interwoven with fibre, till there are eyes, and mouth, and nose; till the little red point becomes a beating heart; till the thing can breathe, and walk, and think, and talk. Each of the cells which go "to the making of man" has its pre-ordained form, and size, and place; each eyelash is predetermined in the ovum. From the one invisible cell has been made, by a process of multiplication and arrangement, the wonderful body of man. The one cell has not produced its like; from the one cell, cells of all kinds and shapes have been made. Over the surface of the body there are plastered about twelve thousand million flattened cells, forming a rainproof panoply—a panoply as soft as silk, and yet tough enough to resist the wear and tear of every-day life. Over the surface of the air-tubes, again, cells more cubical in form are placed, like bricks set on end, side by side, and each cell bears little hairlike appendages which jut into the air-tubes, and, lashing to and fro, protect the lungs from foreign particles. Over the surface of the brain there is a layer of spidery, and starry, and irregular cells, the most wonderful cells in the world ; the centres of sensation and thought. These cerebral cells send prolongations, known as "axis cylinders," down to other cells in the spinal marrow, and these cells again send out prolongations which form nerves of sensation and nutrition and motion. As Dr. Saleeby has pointed out, the nerve which informs one of a corn on a toe, and which controls the growth of a toe-nail, is "a prolongation and continuation of a cell just outside the spinal cord, more than three feet away." And each of the organs has its own special cells, and each cell is a vital unit. Man is, indeed, a regular menagerie.

But man is not only a menagerie, he is also an aquarium. His ancestor was probably a cell that floated in the circumpolar seas ; and some of his cells still prefer a marine and briny habitat.

Man also an aquarium.

Not only is man's body composed of fixed cells—cells fixed to each other to form tissues and organs—but it includes millions of single cells which lead an independent existence. A few of these wander about the tissues ; but there are millions of them in the blood : the blood is simply swarming with them. Some of these cells in the blood are red, and some are white.

The red blood-cells were first seen by Swammerdam in 1658.

Three years later Malpighi saw them in the blood of a hedgehog, but mistook them for globules of fat.

In 1673 Leeuwenhoek discerned them in the human blood, and wrote: "These particles are so minute that one hundred of them placed side by side would not equal the diameter of a common grain of sand, consequently a grain of sand is above a million times the size of one such globule."

All this variety of cells, all the offspring of one cell, is very remarkable, but the strangest thing in the strange constitution of the cell-commonwealth is that not only do the cells differ in appearance, but they differ enormously in their chemical characters, and their different functions are all correlated and collaborative. The cells of the skin of the big toe are three feet away from the cells in the spinal cord, but the skin cells depend for their health on the health of the cord cells. The cells of the liver and the cells of the brain are a good bit from each other, but they cannot say they have no need of each other. Even as the cells are anatomically correlated to make, say, blue eyes and a Roman nose, so are they physiologically correlated to work in complex chemical harmony together. The perfect working of all depends on the perfect working of each, and so exquisite is the adaptation that what one cell-colony eliminates another cell-colony elects—one cell's poison is another cell's meat. The cells in the stomach, for instance, throw on the one side digestive juice, and by various chemical processes assimilate food into their own substance, while they pass on (through the blood and lymph) their leavings to other cells; and these leavings, though really excreta of the stomach cells, exactly suit the requirement of subsequent cells; and so on, seriatim. Even in the act of digestion the cells are working for other cells: no cell lives to itself; each fulfils a useful part in the general economy.

So too the cells that float about in the blood are not "at a loose end"; they fulfil a roving commission. They float about in the blood in their millions, and seem to lead an idle, wanton life; but they are really hardworking citizens of the cell community. They are impelled by the heart, and must journey as the heart desires. Day and night they go hustling through the leathery gates of the heart round the body or through the lungs and back again. Several leagues—or should we say knots?—they voyage every day, and various are the ports at which they call—brain, lungs, liver, spleen—they can be truly said to know every inch of the body. They are the soldiers and sailors, the tinkers and tailors, the police patrol, the scavengers of the body. They fight for the community (as we shall see in another chapter), they carry oxygen, they repair injuries, and some of the white cells occasionally leave the tubes in which they are contained, and wander about in the thickets of the tissues. Moreover, they have much to do with the composition of the blood in which they swim.

It is surely a most remarkable fact that all these cells, so different in appearance, so different in vital habits, should have sprung from one cell. They had all the same origin, the same environment, the same food; yet in the end there are some cells like scales, some like amœbæ; some fixed, some locomotive; some making that mysterious substance which Galen called "animal spirits," some making bile, some making bone; and all, apparently, chemically correlated.

The relationship between the various cells has been conceived in various ways. We have suggested that the cells live partly on each other's leavings, as the natives of the Andaman Islands are said to earn a precarious livelihood by taking in each other's washing; but there are other ways of looking at it. Caspar Friedrich Wolff, for instance, puts it that each single part of the body acts the part of an excretory organ with regard to other parts. Thus, certain substances which feed the cells of the liver would poison, say, the cells of the brain, and so these poisonous substances may be said to be excreted into the liver for the benefit of the other organs and tissues. This conception, however, seems to ignore the fact that each cell not only abstracts from the blood, but also contributes to it.

This brings us to the relationship of the blood to the cells of the cell community. What is the meaning of this rushing red river?

Cells and the blood.

In the centre of the body is the heart, the sun of the microcosm, as Harvey called it. All life long it impels along the red river of blood. In the large arteries the blood rushes at the rate of a foot a second, in the capillaries it loiters at the rate of an inch a minute; but all the tissues, all the cells are irrigated by its waters. In ancient days the blood was a mystery, but so obviously connected with life that it played a part in all religious ceremonies. Homer tells us how blood was poured on Patrocles' corpse, to refresh it, and religious history is full of expiatory bloodshed. What is the real physiological function of this mysterious fluid?

It is partly liquid food, and partly sewage. It is like a great river that carries merchant-ships freighted with provisions, and transports filled with soldiers, and barges laden with coal, and dredgers laden with mud. In its currents it bears the red and white blood-cells, great quantities of waste material, and great quantities of food and fuel. Never was a river so busy, and yet there is no confusion, and no mistake; each cargo goes to the right port, and we, whose conscious life depends on the traffic, know nothing of it, save, perhaps, when shame reddens the cheek, or when fear blanches it, or when some great emotion makes the heart leap. Even the rate, and force, and volume of the river are regulated automatically, without our cognisance.

There are only about ten pints of blood in the whole body, and yet, in the course of the year, its red currents "carry not less," says Lewes, "than three thousand pounds' weight of nutritive material to the various tissues, and three thousand pounds' weight of wasted material from the tissues—salts and metals, and gases, and albumins, and many other substances.

The special relationship between the nerve cells and the other cells of the body we have not space to discuss here, but these, by means of the telegraphic communication their nerves establish between different parts, are of the greatest importance in cellular correlation.

The whole correlation of the cells of the body is almost incredibly perfect, but it must be remembered that it has taken evolution millions of years to elaborate it.

The conception of man as a cellular colony, the conception of disease as cellular disorder, quickly bore fruit.

It was soon seen that many tumours, including cancer, were caused simply by the multiplication of normal tissue cells, and that many illnesses were due to specific misdemeanours on the part of cells in certain regions when irritated in various ways; while with the discovery of the bacteria of disease a few years later the true nature of many diseases, as a combat between cell and cell, became apparent.

Practical results of the cellular theory.

Disease, formerly a huge, mysterious shape —"if shape it might be called which shape had none"—fighting on a vague and vast battle-field, could now be beheld as a little speck in the bright arena of a microscopic field, or could be leisurely studied in a test-tube. Now the fight could be fair and above-board, and every move of the enemy could be watched.

To recognise that disease was the chemical inco-ordination and insubordination of cells, to recognise that in many cases it was a fight between certain cells of the body and marauding invaders, was to recognise at once new methods of treatment. On the one hand, it was found possible to correct the chemical discords of the cells; on the other hand, it was found possible to exclude disease cells (microbes) by simple defensive devices, or to slay them *in situ* by suitable poisons. It was found that in some cases the cells of the body could be gradually educated to resist most powerful disease germs, and that one of the best ways to assist the cells of the body to combat disease was by giving them good air and food. Medicine, in fact, was at once put on a much more scientific basis, and great victories became possible. We cannot here discuss the question in full, but the mutual relationship of the cells of the body, in their nutritional experiences, is becoming more and more evident, and of more and more practical importance. Within recent years it has been shown that if the cells of the thyroid gland (a little gland in the neck under the prominence called "Adam's apple") excrete into the blood too copiously or too scantily, other cells in other parts of the body are seriously affected by the alteration in their diet.

It is well known, too, that many substances which will kill if passed into the blood, are rendered harmless, or even beneficial, if they are acted upon, first, by the cells of the stomach or liver.

Even the terrible disease, cancer, becomes less formidable when regarded in its cellular relationship. Let us look at it in this light. A cancer is a mass of cells, and between the minute structure of a cancer and a man there is no great difference, for a man is also a mass of cells, and each organ may be considered a separate tumour. Indeed, there is nothing incredible in the idea that animals may have died of kidney or liver when Nature first began to introduce them.

Cancer: man the tumour.

But, though man and cancer are cellularly brothers, they are chemically foes.

We have pointed out that when cells live in social communities they must take what is given them by other cells, and make the best of it or die. We shall show, too, later, that when the phagocytes—the white blood-cells, whose business it is to devour hostile intruders—become drunken and dissolute they develop cannibalistic tendencies, and consume their own kin.

Now, the cancer-cells are like the dissolute phagocytes: they not only multiply, but they also devour their neighbours. The kidney tumour assists its neighbours; the cancer tumour slays them. Between the cells of the body and the cells of the cancer, there is no co-adaptation, no give and take: they are quite incompatible in their chemical habits.

This, then, being the cellular position of a cancer, can we discover any way to combat it? One method of treatment, based on cellular pathology, is Dr. Beard's trypsin treatment, which is at present on trial.

Dr. Beard's theory of cancer is intensely interesting, and illustrates most beautifully the inter-nutritional constitution of the body.

Dr. Beard holds that at an early stage in the development of the embryo, certain cells, which he calls *trophoblastic* cells, come into being. These multiply, and thrive, and seem to be quite one of a happy family party; but after a time some new cells, the cells of the pancreas, throw into the blood a new substance which kills and digests the aforesaid trophoblastic cells.

Sometimes, so Dr. Beard maintains, some of the trophoblastic cells are not destroyed, and if in later life these divide and multiply, *the result is a cancer.* As a corollary of his theory, the right treatment of cancer is the injection of the juice of the pancreas cells—*i.e.*, "trypsin," and in some cases good results are reported to have followed such injections. But, as we have said, the theory is at present on trial.

Cancer is a cruel disease, but a disease more fatal even than cancer becomes more hopeful in the light of cellular pathology.

Metchnikoff, the greatest of living scientists, has gone so far as to attribute that most incorrigible of diseases, *old age,* to cellular insubordination, and has suggested means of curing it. His theory is so interesting that, before we leave the fascinating subject of the cells, we must try to sketch it.

According to the views of this great scientist, old age is due to the over-activity and disorderly conduct of the white blood-cells or phagocytes, and the connective-tissue corpuscles. The connective-tissue corpuscles form connective tissue too energetically, and thus on the one hand destroy the elasticity of the blood-vessels, and on the other hand crowd out the *nobler* cells that have to do with nerve action and with secretion. The phagocytes behave even more disreputably. They are at once the mounted police of the body, the scavengers, and the public buildings commissioners; it is their business

Metchnikoff's theory of old age and its cure.

to devour and to poison germs, to build up any tissues destroyed by disease, to remove nuisances, and to perform other equally useful and important public services; but in old age they so far forget themselves as to destroy, instead of to save. When a rebellion reaches the army it is usually a serious matter for the State, and so in this instance these regiments of phagocytes, a multitudinous army, ravage and destroy. Instead of devouring the germs, they devour the pigment of the hair, hence grey and white hair; and they even gnaw the bones, hence the porosity and brittleness of bones in old age; and they do other damage which we need not here detail. The result of this internecine strife is senility.

Now, asks Metchnikoff, what is the cause of this disorderly conduct on the part of the connective-tissue cells and of the phagocytes? *Drink*, he replies. These cells are in a state of chronic intoxication: hence their misdemeanours. Where does the drink come from? Sometimes it comes from the usual place—from a bottle. It is notorious that drunkards become prematurely old. But more often the intoxicant is formed by bacteria in the intestine. In the intestine, according to Strauburger, there are daily about 128,000,000,000 bacteria; these are found chiefly in the large intestine, and there they form toxins, or intoxicants, which are absorbed by the connective-tissue cells and phagocytes, and incite them to evil deeds.

That is Metchnikoff's theory of old age. Now, how does he propose to cure it? Firstly, by abolishing the bottle; secondly, by abolishing the intestinal bacteria; thirdly, by reinforcing, re-invigorating the *noble* cells. To abolish the bottle is an easy matter, but the last two measures are not so easily carried out. Still, Metchnikoff has measures to propose. He proposes to kill the intestinal bacteria on the principle of setting a thief to catch a thief. He would administer sour milk (milk which has been rendered sour by formation of lactic acid by the lactic acid bacillus), since it has been found that lactic acid has an action antagonistic to the intestinal bacteria; and, in addition, he would invigorate the *noble* cells by injections of specially-prepared serums which we cannot here describe.

Metchnikoff's theory of old age and his curative treatment are not yet quite in the sphere of practical medicine, but they serve to show the possibilities of cellular therapeutics.

Nor has the fruit of the cellular pathology been solely new methods of treatment. Even more important has been its influence in overthrowing the empiric treatment based on the conception of organs as isolated units. It is now understood by scientific doctors that the body must be considered as an organic whole, intimately correlated in every cell, and that to give a bottle for this organ, and a bottle for that, is at worst quackery and at best a superficial empiricism. The chemistry of life in the human body took Nature millions of years, cell by cell, to elaborate, and though a few microbes may disturb it, we have not yet learnt to do much to regulate and correct it.

Perhaps the next great step will be to see the arrangement of the atoms in the molecules of the living cells. We can never see them by rays of light: that is impossible; but we may be able to photograph them by ultra-light rays and study their photograph.

But this is far away! Meantime, we have the cell.

CHAPTER VI.

THE MICROBE: ITS DISCOVERY AND ORIGIN.

Galileo's telescope and Leeuwenhoek's microscope—Leeuwenhoek's discoveries—His opposition to the doctrine of spontaneous generation—The germ theory of diseases—How it was demonstrated—Theories of the origin of life—Pasteur gives the spontaneous generation theory its quietus.

NOTHING seems less romantic than a microbe. To the man in the street it means little more than the mumps or the measles. Yet the story of the microbe is perhaps the most romantic chapter in the romantic history of medical science.

The seventeenth century—the century of Shakespeare, of Milton, of Bacon, of Malpighi, of Harvey—was a century of discoveries, a century of expanding horizons, a century of visions of the unseen. In this century Galileo put his eye to a telescope and discovered suns, and Leeuwenhoek put his eye to a microscope and discovered microbes; and Leeuwenhoek saw the farther, though he knew it not. "Galileo in his turret" saw the valleys and the mountains of the moon, but Leeuwenhoek in his shop looked beyond the stars into the arsenal of life and death.

It is interesting to think that Galileo invented, in a sense at least, both microscope and telescope, and, with the choice of two worlds to explore, chose to investigate the infinitely large, leaving the Dutch lens-maker to be pioneer in the world of the infinitely small. It is interesting, too, to find that the discoveries of both were met, as had been the discovery of Columbus, with scepticism and disbelief. New worlds had been discovered, but few would credit the discoveries.

What Leeuwenhoek saw.

Leeuwenhoek discovered little enough—merely the animalcules in water and saliva, and such-like; but his writings show that he had the true scientific spirit, and certainly he was the Columbus of a new world: he crossed the ocean between the seen and the unseen, and he laid bare the secrets of Nature—"*arcana naturæ*," as he himself expresses it. The magnitude of the new world he did not guess, and he was more concerned with the infinitesimal size of his animalcules than with the infinite possibilities they hinted. He boasts that there are no less than 100,000 animalcules in a single grain, but he does not realise that his little animalcules are cousins of the captains of the cohorts of life and death.

Nevertheless, he was a shrewd and accurate observer, and it is most interesting to read of his early investigations. He examined the tartar of the teeth, for instance, and he says, "I found, to my great surprise, that it contained many very small animalcules, the motions of which were very pleasing to behold. . . . The motion of these little creatures, one among another, may be likened to that of a great number of gnats or flies disporting in the air." He also observed the circulation of the blood in a cock's comb, in a rabbit's ear, in a bat's wing, in an eel's tail and fins, and he found the vessels in the intestines of flies and other insects. "On examining the intestines of flies and other insects," he writes, "I have discovered vessels conveying the blood and juices, the extreme ramifications and branches whereof appeared to be more than 200,000 times less than a hair of my head." On discovering animalcules in rain in a gutter he shrewdly surmises, "They may be carried thither with the particles of dust blown about by the winds." Even more interesting are his remarks on the origin of the animalcules. He is no believer in the doctrine that life can originate spontaneously. "As to the production and propagation of these animalcules," he says, "I consider as idle tales what some writers assert of their being generated by putrefaction or decayed substances, immoderate wet or heat, and other equally senseless imaginations, and I lay it down as a certain truth that these, as well as all other small living creatures, are produced from their like by means of eggs, seeds, or spawn according to the nature implanted in them at their first creation." Elsewhere he remarks, "It is my fixed and settled opinion that no leaf, no tree, no root, ever did or ever can produce or breed any animal endued with life or motion." And again, "Surely no one will be so absurd as to retain the notion that any animal, however contemptible in our eyes, can be produced spontaneously or bred from corruption." Here we have the enunciation of the two great biological principles, *Omne vivum ex ovo*, and *Omne vivum ex vivo*.

It is rather remarkable that so careful an observer, so shrewd a reasoner as Leeuwenhoek, should have failed to see the relevance of his discoveries to the then dubious doctrine that germs were the cause of disease; yet so it was, and not till nearly a hundred years later did the full significance of his work dawn upon the world.

The germ theory of disease sounds quite modern; but there is nothing new under the sun, and the theory is really more than two thousand years old. One of the oldest references to it occurs in the treatise, "*De Re Rustica*," of Tarentius Rusticus, who writes: "If there are any marshy places, little animals multiply which the eye cannot discern, but which enter the body with the breath through the mouth and nose and cause grave diseases." Lucius Moderatus Columella propounds the same theory, and all down the Middle Ages the doctrine survived, and was more or less logically maintained. In 1641, even before Leeuwenhoek's discoveries, Athanasius Kirscher reported that he had seen little insects in the air and water and earth, declaring:

The germ theory of disease.

"It is so true that the air and the water and the earth swarm with innumerable, very minute insects, that nowadays it can be proved by the human eye." And in the year 1656, when there was a plague epidemic in Italy, he thought he had discovered tiny worms in the blood and pus which were the cause of the disease. But Kirscher could not have seen pathogenic bacteria with the primitive microscope he used; the objects he saw were probably blood-cells and infusoria; and there can be little doubt that Leeuwenhoek was the first to see, describe, and depict actual bacteria, even though he did not deal with the great question of their being the cause of disease. Indeed, even after the time of Leeuwenhoek, men's ideas of germs were both vague and fantastic. One quotation from a medical writer of 1721 may be given to show what germs meant to the physicians of that date. This writer, talking of the Plague, explains: "The infecting particles that are immediately the pestilential matters' officers of execution are made of Nature's noblest materials, fire and blood, a composition truly military; and, as we may infer from their birth and quality, as well as activity, must be of the most beautiful form, gaudy and glorious colours, a flying army of the richest dress and finest livery; and one may think that the symptom of the plague of seeing beautiful and glorious colours, took notice of by Mr. Boyle, was not merely fantastical apparition."

A germ theory of this kind is little better than a dream.

Leeuwenhoek's microscopic discoveries, however, offered a new and substantial basis for the germ theory; and, though they were not at once utilised, yet numerous writers of the next century, such as Andry, Lancisi, Linnæus, Nyssander, were firm believers in the bacterial origin of disease; while in 1762, a great genius, Marcus Antoninus Plenciz, of Vienna, propounded in the most full, precise, and prescient way the modern germ-theory of disease. Plenciz's prevision was most remarkable. He maintained that every disease had its own particular micro-organism; he believed that decomposition was caused by micro-organisms, and he even suggested the possibility of air-borne infection. But Plenciz only theorised, and it was not till seventy years later that his prophecy received its first proof in Agostino Bassi's demonstration that silk-worm disease was due to a minute cryptogamic plant. Agostino Bassi not only demonstrated the parasitic nature of silkworm disease, but, with genius and prevision as great as those of Plenciz, he anticipated the discoveries of later science, declaring: "Not only am I of the opinion that the contagions, such as variola, petechia pest, etc., are produced by vegetable or animal parasitic entities, but also that many, not to say all, of the cutaneous diseases are due to

Plenciz.

Bassi.

the same cause; that is, that these also are generated and maintained by the said vegetable and animal parasitic entities of different species; and I am also of the opinion that some, though deep, if they are not caused, are at least maintained, and for a long time, by parasitic entities, and that even gangrene is caused by such entities." Agostino Bassi's name is not well known, but there is no doubt that he was the direct precursor of Pasteur, Lister, and Koch, and that "to him belongs the great merit of having been the first to demonstrate the parasitic nature of the contagions, of having established the fundamental lines of the whole doctrine of pathogenic microbes . . . of having, in fine, inaugurated the hygienic school to which nowadays we all belong." But Bassi, like Plenciz, believed more than he could prove, and not till 1863 was the first bacterium of human disease discovered. In that year Davaine and Rayer captured the anthrax bacillus, seen and suspected by Pollender fourteen years previously. Davaine announced his discovery in the following words: "We find in the blood little filiform bodies about twice the length of a blood-corpuscle."

From 1863 proofs of Plenciz's and Bassi's propositions have come in quick succession. In 1866 were found the bacteria causing suppuration; in 1873 were found the spirilla of relapsing fever; in 1880 the typhoid bacillus; in 1882 the tubercle bacillus; in 1884 the cholera bacillus;

and now a million microscopes are exploring the New World of Leeuwenhoek.

The origin of life.

Parallel with this question of the pathogenicity of germs, has run the great relevant problem of their origin. From earliest times this problem has had a fascination for scientists and dreamers; and even as the seventeenth century was an epoch in the history of the problem of the pathogenicity of germs, so also was it an epoch in the history of the problem of biogenesis.

The early Greeks and Romans were believers in the spontaneous generation of animal life. Thales of Miletus held the theory that animals were formed from moisture. Anaximander believed that life had origin in inorganic mud. Aristotle believed that frogs and eels could be developed from dead matter, and lays down the law, "Every dry body becoming moist, and every moist body becoming dry, engender animals." Virgil in the "Georgics" gives instructions how to produce bees, and the majority of scientists in the beginning of the seventeenth century seem to have agreed with the ancients. Philippo Buonanni, for instance, a learned Jesuit of the seventeenth century, maintained that animalcules or small living creatures—*e.g.*, mussels—could be produced out of inanimate substances, such as mud or sand, by spontaneous generation, and announced that certain timberwood, after rotting in the sea, produced worms, which engendered butter-flies, which became birds. And Van Helmont, a distinguished scientist of the same century, who invented the word "gas," gives a prescription for producing mice. He says that if soiled linen be squeezed into the mouth of a vessel containing some grains of wheat, the grains are transmuted into adult mice in about twenty-one days. He also gives the following recipe for producing scorpions: "Scoop out a hole in a brick. Put into it some sweet basil crushed. Lay a second brick upon the first so that the hole may be perfectly covered. Expose the two bricks to the sun, and at the end of a few days the smell of the sweet basil, acting as a ferment, will change the herb into real scorpions." No doubt few scientists held the doctrine of spontaneous generation in such a crude form, but most believed that living organisms were produced from dead, decaying matter; or maintained that there was no real death of organised creatures, but simply a change of vital shape—*e.g.*, that the living matter of so-called dead sheep changed into live maggots.

In 1686, however, Francesco Redi (by an experiment which Huxley considered the foundation of later bacteriological technique) proved that maggots never invaded putrid meat if flies were prevented from depositing their eggs on it, and thus gave the first blow to the doctrine of spontaneous generation. But maggots are one thing, and microbes another, and long after Redi's experiment, well into the eighteenth century, the leading scientists of the time, such as Francesco Needham, Comte di Buffon, O. F. Müller, were firm believers in the origin of life from dead matter, or, at least, from the organic matter of dead bodies. Buffon held that there were certain primitive and incorruptible parts common to animals and to vegetables, which mould themselves into different beings. At death these particles become free, and then are reunited into worms and vegetables and eels and so forth.

"It is very strange," said Voltaire, "that men should deny a Creator and yet attribute to themselves the power of creating eels."

Not, indeed, till the middle of the nineteenth century was the doctrine of the spontaneous generation of life completely and conclusively refuted. In 1858 Pouchet published a "Note on Vegetable and Animal Proto-organisms Spontaneously Generated in Artificial Air and in Oxygen Gas"; and as late as 1862 we find Dr. William Budd, a famous English physician, writing: "A very large, and by far the most influential school in this country—a school which probably embraces the great majority of medical practitioners and the whole of the *sanitary public*—holds and teaches that sundry of these poisons (of specific contagious diseases) are constantly being generated *de novo* by the material conditions which surround us."

The controversy which raged in the eighteenth and nineteenth centuries between those who believed that life could be spontaneously generated and those who believed that living creatures, large and small, could be generated only by living progenitors, is one of the most interesting and momentous controversies in the history of mankind. Upon no war have so many lives depended, for the question had not merely enormous theoretical interest; it affected the practical question of the origin and treatment of disease. Pasteur saw the tremendous practical importance of the question, and said: "It is in the power of man to make parasitic diseases disappear from the surface of the globe, if, as in my opinion, the doctrine of spontaneous generation is a chimera."

To discuss this great controversy in detail is unnecessary and undesirable; but some of its stages may be briefly indicated.

In 1748 Father Needham, an Irish priest, put putrescible material in hermetically sealed vessels and submitted the vessels to heat. On examination thereafter abundance of micro-organisms was found, and it was reasonably argued that since the heat must have killed all the micro-organisms in the tube, therefore those found afterwards must have been spontaneously generated.

In 1765 Abbé Spallanzani repeated Needham's experiments and found that if the vessels were heated for a longer time and more thoroughly, no micro-organisms could be discovered, and he, in turn, reasonably argued that micro-organisms were not spontaneously generated.

Needham retorted that the additional "torture" had enfeebled, or perhaps totally destroyed the vegetative force of the substance, and entirely corrupted the air.

In 1811 a French confectioner, called Appert, discovered that animal and vegetable substances could be preserved in hermetically sealed vessels; and the well-known chemist, Lussac, finding no oxygen in the air of the vessels, formulated a theory that oxygen in contact with dead organic matter generated micro-organisms.

Schwann endeavoured to disprove this oxygen theory by showing that if air were passed through a tube heated nearly to boiling point so as to destroy any germs contained in it, no micro-organisms were then generated by the oxygen. Helmholtz and others, by passing air through chemicals; Schroeder and Dusch, by filtering it through cotton-wool, afforded similar disproof. But their disproof was unsatisfactory and inconclusive, since on some occasions micro-organisms appeared in the tubes even after the air had been filtered.

Not till 1862 can the question be said to have been definitely settled. In that year Pasteur afforded to the French Academy of Sciences final and conclusive evidence that spontaneous generation never occurs. His opponents on that occasion were completely confounded, and though the question has been recently reopened, it is now almost universally admitted as a biological axiom that "*la génération spontanée est une chimère.*"

In 1864 Pasteur, lecturing at the Sorbonne before a large and distinguished audience, spoke the following dramatic words:

"And therefore, gentlemen, I could point to that liquid and say to you, I have taken my drop of water from the immensity of creation, and I have taken it full of the elements fitted for the development of inferior beings. And I wait, I watch, I question it, begging it to recommence for me the beautiful spectacle of the first creation. But it is dumb—dumb ever since these experiments were begun several years ago; it is dumb because I have kept it from the only thing which man cannot produce—from the germs which float in the air: from Life; for Life is a germ and a germ is Life. Never will the doctrine of spontaneous generation recover from the mortal blow of this simple experiment."

The first microbe, then, was seen by Leeuwenhoek towards the end of the seventeenth century.

The first microbe of disease.

The first microbe of disease was caught and convicted in 1863, and about the same date the ancient doctrine of the spontaneous generation of germs was overthrown. Each of these events marks an epoch in the history of mankind as important as Sedan or Waterloo. With the establishment of the great biological principle that every germ springs from a preceding germ, and that without parent germs the germs of putrefaction and fermentation and disease cannot occur—with the establishment of that great principle, and with the discovery of the first bacterium of disease, bacteriology acquired a practical importance that cannot be exaggerated, for it was at once obvious that if germs did not arise spontaneously, then germ-diseases might be prevented by preventing the entrance of microbes, or cured by destroying the microbes after entrance.

CHAPTER VII.

BACTERIA AND THEIR CHARACTERISTICS.

Bacteria—Their littleness—Their ubiquity—How they multiply—Their voracity—Their versatility—Their indispensability—their vitality.

THE most important of microbes are the bacteria. Bacteria are the most minute, ubiquitous, and versatile of vegetables. So minute are they as to be invisible to the naked eye, so ubiquitous as to be found almost everywhere, so versatile as to be capable of almost anything.

Bacteria.

The liliputian dimensions evade even imagination and "dodge conception to the very brink of heaven." To such pigmies a pin-point is a plateau, and a pin-hole an abyss. Ten thousand of the sturdiest of them, shoulder to shoulder, do not extend an inch; billions of them do not weigh a grain; and their little cousins, the moulds and the mushrooms, seem in comparison inconceivably colossal. A microbe is to a mushroom as a comma to a cathedral, and if a midge and a bacterium could be magnified, *pari passu*, under the same microscope, the midge would out-measure Sindbad's

Their dimensions.

roc or Gargantua's mare before the bacterium would be well visible.

And the ubiquity of the bacteria is as amazing as their insignificance. Earth, air, water, are full of them. We swallow and breathe them in countless multitudes. A pint of milk contains innumerable millions of them. Cream, butter, and many other substances swarm with them. In a glass of good water they are "thick as autumnal leaves that strow the brooks in Vallombrosa," and it has been shown "that even the ice upon the summit of Mont Blanc has its complement of bacterial flora," that hailstones as they descend upon the earth contain bacteria, and that snow, the emblem of purity, "is but a whited sepulchre and will on demand deliver up its bacterial hosts." Nay more, our mouths and our nostrils harbour hundreds of them, and our skin is a regular hotbed of them. It has been calculated that each inhabitant of London inhales, on an average, fourteen thousand microbes an hour.

Their ubiquity.

> "Der Luft, dem Wasser, wie der Erde
> Entwinden tausend Keime sich
> Im Trocken, Feuchten, Warmen, Kalten."

Pouchet, a distinguished opponent of Pasteur, was so impressed with the evidence of the ubiquity of germs that he said the air ought to be a regular fog of microbes dense as iron.

Our forefathers believed the world peopled with invisible fairies, and gnomes, and sylphs, and pixies, and naiads, but we have found an invisible host more potent and more marvellous than the creatures of their dreams.

As we have said, it was demonstrated about the middle of last century that every germ arises from a preceding germ—*omne vivum ex ovo*—and the ubiquity of bacteria is proof of their mobility and fecundity. Their method of multiplication is straightforward and expeditious. Though they occasionally form seeds or *spores*, they usually multiply without sentiment or ceremony simply by each dividing into two. Each new-born bacterium is thus literally "a chip of the old block," and "it is a wise bacterium that knows its own father."

Their mode of multiplication.

Division and multiplication can occur every half-hour, and thus one individual might in twenty-four hours become 16,613,376. The cholera bacillus, for instance, can duplicate every twenty minutes, and might thus in one day become 5,000,000,000,000,000,000,000, with a weight, according to the calculations of Cohn, of about 7,366 tons. In a few days, at this rate, there would be a mass of bacteria as big as the moon, huge enough to fill the whole ocean. Pasteur once said he would undertake to çover a surface of wine equal in extent to the area of the hall in which he was speaking with the *Mycoderma aceti* in the space of twenty-four hours, by sowing in various places little specks hardly visible to the naked eye. On another occasion Pasteur said: "The hall of the Academy of Sciences is very large; it has a capacity of hundreds of cubic metres. I am sure I could fill it with a liquid of such a nature that on planting in it a parasitic microscopic organism of the fowl, the whole immense mass would in the course of a few hours be troubled by the presence of an organism."

Luckily, competition, limited food-supply, and other factors prevent such enormous increase; but still one bacterium has been actually observed to rear a small family of 80,000 within a period of twenty-four hours; and 20,000 bacteria injected into a rabbit have been found to multiply into 12,000,000,000 in one day.

Such figures and illustrations will give some idea of bacterial fecundity, and render their ubiquity somewhat less surprising.

And if bacterial fecundity is prodigious, no less prodigious is bacterial voracity, for the reproductive performance of a bacterium cannot outstrip its digestive capacity. *Ex nihilo nihil fit,* and if a bacterium divide every twenty minutes into two bacteria, each almost as large as its original self, it must obviously assimilate about its own bulk of food in the same time, or about seventy-two times its own bulk in twenty-four hours, a digestive feat that not even Gargantua could emulate.

Their voracity.

Verily the miracle of the widow's cruse and that of the loaves and fishes are quite eclipsed by this eternal miracle of digestion and duplication. Think of it! By the reservoir of life in one infinitesimally small cell, tons of dead matter can be transmuted into living organisms.

What is this strange, apparently transmissible, and apparently inexhaustible force—

> "Transforming the dull clod, compelling there
> All new successions to the forms they wear"?

What is this mysterious essence which can make the dead alive, and yet can be seemingly annulled "with a bare bodkin," with a drop of carbolic, and in a hundred other ways? Certainly it is not ponderable matter, and it is almost incredible that such tremendous energy can be annihilated by such trivial interference.

The enormous digestive capacity of bacteria, shown in their power of multiplication, is of great economic importance. Where bacteria abide there they digest, and where they digest they cause various chemical changes according to their various physiological idiosyncrasies, and according to the nature of their food and environment, and this chemical versatility, though sometimes vicious, can often be turned to profitable account.

Their versatility.

Thus, millions of bacteria are engaged in the jute and flax industries. They digest the cement-substance between the fibres of plants, and are of invaluable assistance to the manufacturers. Save for these industrious little mill-hands, Belfast and Dundee would be mere villages to-day. Other bacteria, again, assist the tanner to tan; others give aroma to tobacco; others turn beer into wine; others turn wine into vinegar; others flavour luscious fruits; others flavour cheese and butter; and so valuable is bacterial co-operation in this last respect that special bacteria are now sown and grown just like ordinary visible vegetables, and are used, as required, to give favourite flavours to cheese and butter. Some bacteria for flavouring cheese and butter have actually been patented. Thus, if we desire a butter with a strong flavour, we add to Pasteurised cream such a bacterium as "Conn's Bacillus No. 41"; while if we desire a butter with a mild flavour we add a few of the bacteria known as "Hansen's Danish Starter." In Denmark almost every important dairy uses special cultures of bacteria as butter-starters, and dairy bacteriology is quite an important branch of science. Even without much bacterial refinement, it has been found possible to utilise the flavouring properties of bacteria, and "new cheese factories may sometimes be stocked with the proper micro-organisms by rubbing the shelves and vessels with fresh cheeses imported from localities where the desired variety is nominally made."

One of the most interesting of micro-organisms is that known as the *Mycoderma aceti*. It is the "toper" of bacteria; it lives in alcohol, and drinks it with avidity, changing it into vinegar.

And, as if to atone for the mischief of this germ, another micro-organism, the well-known yeast-plant, makes alcohol even as its brother destroys it. This yeast-plant, found some sixty years ago, is a "sweet-tooth"; it digests starch and sugar, forming glycerine, succinic acid, carbon dioxide, and alcohol. And it not only assists brewers, and makes beers and peers, it also works for bakers, raising the dough and rendering the bread more digestible. Altogether a very useful, versatile, and accomplished microbe.

It is strange to think that the flavour of our butters, and cheeses, and Burgundies, and cigars, is due to the vital chemistry of these little organisms.

But, stranger still, we are now beginning to use microbes as soldiers to slay our enemies.

It has several times been suggested that microbes might be employed to destroy the rabbits which are such a pest in Australia. I do not know whether this suggestion has ever been actually carried out; but microbes are now being used to exterminate a cousin of the rabbit, the rat, by means of microbes; and a special breed of microbes for the purpose is now in the market.

Microbes are also being used to massacre moths. In certain parts of the New England States moths multiplied to a tremendous extent, and devastated orchards and even forests; so Congress has voted £20,000 for the importation of microbes known to be destructive to moths, and millions were imported from the laboratories of Japan and of Buda-Pesth.

So far, microbes have not been found able to combat the microbes that cause disease in man; but it is quite possible that some may presently be found.

But even though microbes are not yet available to fight against our microbe foes, yet to microbes we owe the food we eat. Without microbes there would be a famine in the land.

These minute creatures, invisible to man for thousands of years, are yet the very basis and condition of his existence; for bacteria decompose dead organic matter, and elaborate nitrogen to form nitrates for plants. Without bacteria there would be no decay, and decay is the jackal of life. Save for decay, dead matter would cumber the planet; save for decay, there would be no food for plants, and so no food for animals. Bacteria are the commissariat department of life.

Suppose that suddenly every bacterium were killed. Then plants would perish from lack of food manufactured for them by the putrefying and nitrifying bacteria, and their seeds would be abortive. Herbivorous animals would accordingly starve, and carnivorous animals, including man, would die of famine. The dead would not decay, they would simply lie and dry on the last lichens of the exhausted soil, and the face of the earth would be like a museum or charnel-house with

Their indispensability.

undecaying leaves and flowers and with mummied corpses. No Shelley then could sing:

> "The leprous corpse, touched by the spirit tender,
> Exhales itself in flowers of gentle birth."

For without the invisible cohorts of bacteria the sun and the rain and the wind are impotent to evolve a single rose. Without bacteria no flora, without flora no fauna.

In the arctic and antarctic regions, where intense and prolonged cold has killed bacteria, there is no decay; and Dr. Hertz found in Siberia a mammoth which had died probably eight thousand years before. The mammoth was in good condition. "Most of the hair on the body had been scraped away by ice, but its mane and near foreleg were in perfect preservation and covered with long hair. The hair of the mane was from four to five inches long, and of a yellowish brown colour, while its left leg was covered with black hair. In its stomach was found a quantity of undigested food, and on its tongue was the herbage which it had been eating when it died. This was quite green."

Is not this a romance? This colossal creature kept for thousands of years like canned lobster or pickled tongue! Yet let the microbes reach it, and they will devour it as surely as carrion is devoured by the dogs of Constantinople. Some foolish people, who call themselves Christian Scientists, declare that microbes exist only in imagination. What an imagination it must require to tear down a mammoth which has outlasted empires! Nay, the microbes are as real as man, and are made of the self-same protoplasm.

Though most microbes have been classified, for sound scientific reasons, as vegetables, they are very unlike the conventional visible vegetable. They have no leaves nor roots, nor specialised organs; but, like Milton's angels, they—

> "Live throughout,
> Vital in every part, not frail like man
> In entrails, head or heart, liver or veins.

Bacteria, which are the most important of the microbes, occur either as round bodies called *cocci*, or as rod-shaped bodies called *bacilli*, or as spiral bodies called *spirilla;* while some are pleomorphic—*i.e.*, occur in more than one form.

Few things are more surprising than the vital tenacity of microbes. Typhoid bacilli have been frozen in ice for 103 days and have come forth alive and kicking. The spores or seeds of the anthrax bacillus have been frozen at a temperature of 36° F. for months, and have survived the ordeal. The bacillus of tuberculosis has been exposed to 370° F. for six weeks, and has retained vitality and virulence. Other bacilli have endured a temperature of 480° F., and have emerged alive from a bath of liquid air. Microbes can also withstand great pressure, and the bacilli of typhoid anthrax and tuberculosis have been

Their vitality.

uninjured by a pressure of 500 atmospheres—*e.g.*, about 7,500 pounds to the square inch.

Most microbes have no means of locomotion; but some have whip-like appendages, with which they propel themselves through fluid, and the spiral forms can wriggle and dart about like eels.

Such, then, are microbes: drunkards and dairymen, tobacconists and tanners, scavengers and cooks, brewers and florists, philanthropists and homicides, spirits of health and goblins damned.

CHAPTER VIII.

SOME REPRESENTATIVE MICROBES OF DISEASE.

The anthrax microbe—Pasteur's vaccine—The tetanus or lock-jaw microbe—The tubercle bacillus—The microbe of malaria—The mosquito its transmitter—Experiments in the inoculation of malaria—The mosquito and yellow fever—The political importance of microbes.

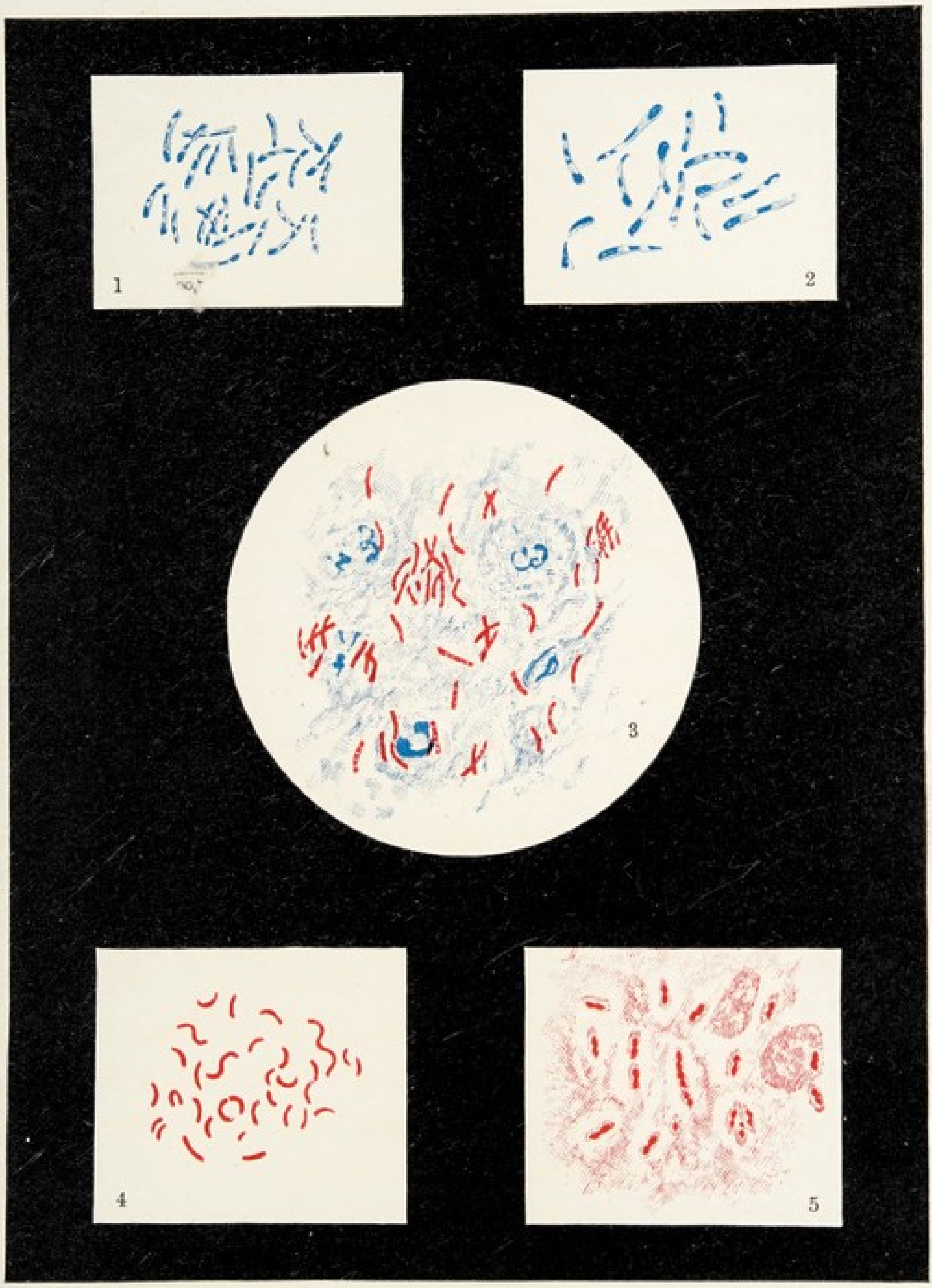
As we have already stated, the first bacterium actually convicted of homicide was the so-called anthrax bacillus, the microbe which causes the disease known as anthrax, carbuncle, malignant pustule, or splenic fever. Seen and suspected by Pollender in 1849, and by Davaine and Rayer in 1850, it was caught red-handed, *in flagrante delicto*, by the last two observers in 1863. To prove the accused guilty had been by no means easy, and for years the verdict was not proven; but now its criminality is clearly proven, and every laboratory keeps it in solitary confinement.

Anthrax.

It takes several shapes, but usually occurs as a rod-shaped bacterium, and though, comparatively speaking, large, yet 150,000,000 might find elbow-room on a postage-stamp. Since it often occurs in sheep's wool and attacks wool-sorters, the disease it causes is sometimes called wool-sorters' disease. Sometimes it invades the body through the skin and causes carbuncles; and sometimes it is inhaled by the breath and destroys the lungs. Its poison is so potent that a rabbit can be killed by an injection of $\frac{1}{500,000}$th of its body-weight. No sooner was the venomous vegetable identified than laboratories all over the world began to cultivate it, and to study its habits, in order to find the best means of killing it or of resisting its assaults. The problem was of great economic importance. In France the disease amounted to a plague; whole flocks and herds perished, and it cost the country millions of francs annually. In a single district in Russia, during three years, 56,000 horses and cattle and sheep and 528 men died of anthrax. Not, however, till 1881 was an efficacious remedy discovered. In that year Pasteur announced that

Pasteur's vaccine against Anthrax.

he had discovered a protective vaccine (whose nature we will afterwards discuss), and in May he gave an experimental demonstration of his method. We will quote his own description of the demonstration. He writes: "On the 5th of May, 1881, we inoculated by means of a Pravaz syringe twenty-four sheep, one goat, and six cows, each animal with five drops of an attenuated culture of the anthrax bacillus. On the 17th of May we inoculated these animals with a second virus, also attenuated, but more virulent than



SOME BACTERIA OF DISEASE.

1. Diphtheria bacilli, after one day's growth, stained blue.
2. The same after five days' growth.
3. Tubercle bacilli, stained red.
4. Cholera bacterium, stained red.
5. Pneumonia bacterium, stained red.

the first. On the 31st of May we proceeded to make a very virulent inoculation, in order to test the efficacy of the preventive inoculations made before. For this experiment we inoculated the thirty-one vaccinated animals, and also twenty-four sheep, one goat, and four cows which had not received any previous treatment. . . When the operation was finished all those present were invited to re-assemble on June 2nd—*i.e.*, forty-eight hours after the virulent inoculation was made. Upon the arrival of the visitors on June 2nd all were astonished at the result. The twenty-four sheep, the goat, and the six cows which had received the attenuated virus all presented the appearance of health. On the other hand, twenty of the sheep and the goat which had not been vaccinated were already dead of anthrax, two more of the non-vaccinated sheep died before the eyes of the spectators, and the last of the series expired before the end of the day. The non-vaccinated cows were not dead. We had previously proved that cows are less liable than sheep to die of anthrax ; but all the non-vaccinated cows had an extensive œdema at the point of inoculation behind the shoulder."

Was ever a sensational discovery more sensationally demonstrated ?

The economic value of the discovery was enormous. Anthrax inoculations became the order of the day, and have been the order of the day ever since. The results of anthrax inoculations in France were compiled by Chamberlan in 1894. During twelve years 1,788,677 sheep and 200,962 cattle were inoculated. Before inoculation 10 per cent. of sheep and 5 per cent. of cattle died. After inoculation only .94 per cent. of sheep and .34 per cent. of cattle died, representing a total saving of five million francs for sheep and two million francs for cattle.

Verily a remarkable victory to be won so early in the war against the newly-discovered hosts of death.

Another interesting and representative demon of disease is the tetanus or lockjaw bacillus. This little organism has a very wide distribution, having been found even in the mud at the bottom of the Dead Sea. It is shaped like a drum-stick, with a seed or spore at the head; but the drum-stick is so small that a thousand drums to fit it might be dispersed on the dot of an "i." Yet its power is prodigious, and well can it beat the tattoo of death. It forms a poison so potent that the three-hundredth part of a grain is probably sufficient to kill a man. A few drops injected into the veins of a mastodon would distort its colossal frame with terrible convulsions, and finally grip its heart in the vice of death.

Tetanus.

The bacillus sometimes occurs in the mud of swamps, and certain savages, though knowing nothing of bacteriology, dip their arrows in such mud to make them more deadly.

It is interesting to know that a Japanese scientist, Kitasato, was the first to make a pure culture of the bacillus.

Perhaps the most formidable bacillus of all is the bacillus of tuberculosis, discovered by Koch in 1882. This is the most deadly weapon of death. Samson slew a thousand with the jawbone of an ass, but with this little sabre Death has slain his millions. In comparison with its massacres, Maxims and melinite are meek and merciful; and the mouth of a consumptive may scatter more deaths than the muzzles of many guns. Slender, and dainty and dandy, it is quite an aristocrat among bacilli—a *beau sabreur* of death; but, nevertheless, it is more ruthless than a Thug, more ravenous than any beast of prey—a very Beelzebub of bacilli. Though it devours chiefly the poor, yet no class of society is exempt from its ravages, and it has numbered among its victims many distinguished persons, such as Spinoza, Schiller, Laurence Sterne, Henry Kirke White, John Keats, Chopin, Robert Louis Stevenson, Marie Bashkirtseff, Thoreau, Grace Darling, George Gissing.

Tuberculosis.

Almost as important as the microbe of tuberculosis, and fully as interesting, is the microbe of malaria. The microbes we have mentioned so far have all belonged to the vegetable kingdom; but the microbe of malaria is an animalcule. It belongs to the animal order known as Protozoa, an order that contains many murderers among its numbers.

Malaria.

To this order belong the microbes of tsetse fly disease and of dysentery. The microbe of the mysterious disease known as sleeping sickness is also a protozoon, a microbe so murderous that it slew in Uganda alone, between 1901 and 1905, no less than 100,000 natives. A noted criminal of the same family is the *Glugea bombycis*, which attacks the silkworm, and in 1853 appeared in such force and played such havoc that in seventeen years it cost the silk-growers £30,000,000. The *Glugea bombycis* has the distinction of being the first micro-organism that was subdued by the methods of modern bacteriology.

Popular beliefs concerning malaria.

The microbe of malaria has had an interesting history. Long before it was discovered it was an article of popular faith. Ancient writers like Tarentius Varro believed in marsh microbes of some kind or other; Lancisci considered that effluvia of marshes was harmful, chiefly because of animalcules contained therein and capable of entering into the blood of man. Rasori wrote: "I have held the opinion for many years that intermittent fevers are produced by parasites, which renew the access during the act of their reproduction that follows more or less quickly according to their different species," and many other writers promulgated similar doctrines. But though the microbe was long surmised, it was never seen till the nineteenth century. In the thirties of that century Meckel described in the human blood certain black particles, which he found in the white blood-cells and in certain pale bodies like white blood-cells whose nature he did not know. Later on, Frerichs, Heschl, and Virchow corroborated his description; but it was left to Laveran to establish the real nature of these mysterious bodies, and to introduce to the world the microbe of malaria.

Laveran identified and convicted the microbe in 1880, and in his discovery "there lay the promise of benefits more potent than any gift the laboratory had ever offered to mankind, viz., the possibility of the extermination of malaria."

The discovery of the microbe in the blood was one step; the next question arose, How did it get there? Was it inhaled by the breath or swallowed with the food, or how did it get entrance?

Its mode of entrance was long a puzzle, but a few years ago Surgeon-Major Ronald Ross solved the problem. He showed that a certain genus of mosquito (the Anopheles) imbibes the microbe from marshes or from infected blood. The microbe lives for a while in the intestine of the mosquito, marries there, and multiplies there, and its offspring, reaching the salivary gland, is inoculated into any animal the insect may bite. Verily this microbe makes murder a fine art.

How the microbe of malaria enters the blood.

In the blood the microbe lives in the red blood corpuscles, and feeds upon them; and the different stages of the disease correspond with the different stages in the life-history of the parasite, the paroxysms of the disease depending on the sporulation (the process of breaking up into spores) of the microbes.

The whole life-history of the microbe has been beautifully worked out, and all the events of its chequered and adventurous career, from its marriage in the intestine of a mosquito to the setting free of its spores in the blood of man, have been carefully demonstrated, and the result is a romance in microscopy such as has rarely been equalled.

Well might Dr. Ronald Ross, when he made this mighty discovery, opening up millions of miles of country to the white man, and saving thousands of lives—well might he break into poetry and sing:

"This day relenting, God
Hath placed within my hand
A wondrous thing; and God
Be praised. At His command,

Seeking His secret deeds,
With tears, and toiling breath,
I find thy cunning seeds,
O million-murdering Death.

I know this little thing
A myriad men will save.
O Death, where is thy sting?
Thy victory, O Grave!"

DR. RONALD ROSS, C.B., THE HERO OF THE MOSQUITO THEORY OF MALARIA.

Dr. Ronald Ross investigated the process of infection by inoculating healthy birds by the bite of infected mosquitoes; but to make his conclusions doubly sure experiments were made on men in various ways.

For instance, in July and August, 1900, Dr. (now Sir) Patrick Manson (whose suggestions had greatly helped Dr. Ronald Ross) had consignments of live infected mosquitoes sent from Rome to London. These—forty in all—were allowed, between August 29th and September 12th, to bite his son, the late Dr. Thurburn Manson, who had never suffered from malaria. Mr. Manson duly developed the disease, and parasites were found in his blood.

Experiments in the inoculation of malaria.

At the same time a hut was erected in an intensely malarious part of the Roman Campagna, and Dr. Sambon, Dr. G. C. Low, Signor Terzi, and two Italian servants entered into residence. All these went about all day, but retired to the hut at night, when the mosquitoes feed. They took no quinine, and the only precaution against malaria was mosquito netting over the windows and mosquito netting round the beds. None of them developed malaria, though there were cases in all the adjacent huts. At the end of three months the following instructive report was issued:

"After living for three months on the edge of a pestiferous swamp, through the hottest and most unhealthy time, they are now leaving the deadly Campagna, looking as fit and bronzed as if their summer had been spent in the Swiss Alps or the Scottish Highlands. In sad contrast with this pleasing picture is the condition of the inmates of the nearest peasant's house, little more than 100 yards distant from the mosquito-proof hut. Here live seven persons, all of whom have suffered from malaria during the past summer. The four whom I saw presented the sickly, anæmic, cachectic appearance characteristic of the chronic forms of that blighting disease. A very cursory examination of their dwelling sufficed to reveal the source of their ills, for in the cobwebs on the walls, under the tables, in every dark corner of the house lurked numerous specimens of the fever-giving Anopheles."

Could there be a more dramatic object-lesson ?

It is curious to find that popular and medical opinion accused the mosquito even before science proved its blood-guiltiness.

In a Sanscrit work called "Susruta," written 1,400 years ago, and said to have been compiled from one of the lost Vedas, it is stated that mosquitoes are of five kinds: Sanusdra, Parimandala, Hastimasaka, Krishna, Parwatiya, and that a bite from the mosquito Parwatiya is followed by fever, pain in the limbs, goose-skin, vomiting, shivering, and an intense feeling of cold. Peasants, too, in Italy had for centuries blamed the mosquito; and certain savages in German East Africa call malaria and the mosquito by the same name, "*mbu.*" The Jeevas of the Punjaub, who fish and catch wild fowl in malarial marshes, and who spend the whole night in boats among the reeds, found that they could keep themselves free from malaria by completely enveloping themselves at sunset in a special costume, and by burning a fire in the boat. Emin Pasha told Stanley that a good mosquito net was the best preventive of malaria. As early as 1807, a Dr. John Crawford published a paper on the mosquital origin of malarial disease; in 1848 Dr. Josiah Nott suggested the mosquito of the lowlands as the probable cause of malaria and yellow fever; in 1871 Angelo Alessandrino wrote: "The mosquito, with the vehicle of unhealthy air, passes from the Campagna to inhabited places, invades habitations, hides itself by day to hum during the night in search of man in repose, and by means of its bite inoculates him with its poison"; while the arguments in favour of the mosquito theory were most ably set forth by Dr. A. F. A. King in a paper written in 1883. Dr. King's advice is so sound that we cannot refrain from quoting it. He recommended personal protection by walls, trees, electric light, smoke, etc.; domiciliary protection by curtains, screens, etc.; municipal protection by draining of swamps and pools, and by cordons of electric light.

In face of these suggestions of medical and popular opinion, it is strange that the mosquito remained so long unconvicted; but so it was, and only a few years ago did Dr. Ronald Ross succeed in demonstrating the interesting and remarkable details of the infection. Not more surely could a doctor inoculate disease with a hypodermic syringe than the little mosquito inoculates the microbes with its fine proboscis.

Yellow Fever.

No sooner was the mosquito convicted of malarious deeds than it began to be suspected of causing yellow fever, and steps were soon taken to see whether the suspicion was well founded.

The chief investigations were conducted by Dr. Reid, of the American Army Medical Service, and no investigations in the history of science have been more heroic and fearless.

Heroic investigations.

The investigations were carried out at Cuba in the summer of 1900. Eleven individuals who volunteered for the experiment were bitten by infected mosquitoes—*i.e.*, by mosquitoes which had previously been allowed to fill themselves with blood from yellow fever cases. Two of these volunteers, Dr. W. Lazear and Dr. James Carroll, contracted the disease, and Dr. Lazear fell a victim to the cause of science and humanity.

In a later report Dr. Reid states: "We have thus far succeeded in conveying yellow fever to twelve individuals by means of the bites of contaminated mosquitoes." Further, Dr. Reid in four cases directly inoculated from man to man. The blood was taken from a vein at the bend of the elbow and was injected subcutaneously into four non-immune individuals. Three of these individuals contracted the disease.

Having demonstrated the fact that yellow fever is propagated by mosquitoes, Dr. Reid and his associates endeavoured to ascertain whether it might also be propagated, as was commonly supposed, by clothing, bedding, and other articles which have been used by those suffering from the disease.

Everything was done to favour death. A special experimental building was erected. All through ventilation of air was prevented. Heavy wooden shutters were put up to keep out the sunlight; heating apparatus was provided to keep the temperature high, and measures were taken to keep the air humid.

The building was finished on November 30th, 1900, and into this melancholy house of death experiments such as the world had never before seen were conducted. We will quote Dr. Reid's account of the proceedings, and the wonder seems to be not so much that the inmates escaped yellow fever as that they escaped a madhouse, for the conditions of the experiment were ghastly and loathsome.

"Three large boxes, contaminated by yellow-fever patients and their discharges, were received and placed in the building. The majority of articles had been taken from the beds of patients sick with yellow fever at Las Animas Hospital, Havana, and at Columbia Barracks. Many of them had been purposely soiled with a liberal quantity of black vomit, etc.

"A dirty 'comfortable,' and a much-soiled pair of blankets, removed from the bed of a patient sick with yellow fever in the town of Quemados, were contained in one of these boxes. The same day, at 6 p.m., Dr. R. P. Cooke, Acting Assistant Surgeon, U.S.A., and two privates of the hospital corps, all non-immune young Americans, entered this building and deliberately unpacked these boxes, which had been tightly closed and locked for a period of two weeks. They were careful, at the same time, to give each article a thorough handling and shaking, in order to disseminate through the air of the room the specific agent of yellow fever if contained in these fomites. These soiled sheets, pillow-cases, and blankets were used in preparing the beds in which the members of the hospital corps slept. Various soiled articles were hung around the room and placed about the bed occupied by Dr. Cooke.

"From this date until December 19th, 1900, a period of twenty days, this room was occupied each night by these three non-immunes. Each morning the various soiled articles were carefully packed in the aforesaid boxes, and at night again unpacked and distributed about the room. During the day the residents of this house were permitted to occupy a tent pitched in the immediate vicinity, but were kept in strict quarantine.

"*December 12th.*—A fourth box of clothing and bedding was received from Las Animas Hospital. These articles had been used on the beds of yellow-fever patients, but, in addition, had been purposely soiled. . . . As this box had been packed for a number of days, when opened and unpacked by Dr. Cooke and his assistants on December 12th, the odour was so offensive as to compel them to retreat from the house. They pluckily returned, however, within a short time, and spent the night as usual.

"On December 19th these three non-immunes were placed in quarantine for five days, and then given the liberty of the camp. All had remained in perfect health, notwithstanding their stay of twenty days amid such unwholesome surroundings.

"During the week, December 20th to 27th, the following articles were placed in the house, viz., pyjama suits, 1; under-shirts, 2; nightshirts, 4; pillow-slips, 4; sheets, 6; blankets, 5; pillows, 2; mattress, 1. These articles had been removed from the persons and beds of four patients sick with yellow fever, and were very much soiled, as any change of clothing or bed-linen during their attacks had been purposely avoided, the object being to obtain articles as thoroughly contaminated as possible.

"From December 21st, 1900, till January 10th, 1901, this building was again occupied by two non-immune young Americans under the same conditions as the preceding occupants, except that these men slept every night in the very garments worn by yellow-fever patients throughout their entire attacks, besides making use exclusively of their much-soiled pillow-slips, sheets, and blankets. At the end of twenty-one nights of such intimate contact with these fomites, they also went into quarantine, from which they were released five days later in perfect health.

"From January 11th till January 31st, a period of twenty days, 'Building No. 1' continued to be occupied by two other non-immune Americans, who, like those who preceded them, have slept every night in the beds formerly occupied by yellow-fever patients, and in the nightshirts used by these patients throughout their attack without change. In addition, during the last fourteen nights of their occupancy of this house they have slept each night with their pillows covered with towels that had been thoroughly soiled with the blood drawn from both the general and capillary circulation on the first day of the disease in the case of a well-marked attack of yellow fever. Notwithstanding this trying ordeal, these men have continued to remain in perfect health."

A second building had by this time been made —"Building No. 2," divided by a wire-screen partition into two rooms.

On December 21st, 1900, at 11.45 a.m., there were set free in one of the rooms fifteen mosquitoes, which had previously been contaminated by biting yellow-fever patients. "At twelve noon on the same day, a non-immune young American (J. J. Moran) entered the room where the mosquitoes had been freed, and remained thirty minutes. During this time he was bitten about the face and hands by several insects. At 4.30 p.m. the same day he again entered and remained twenty minutes, and was again bitten. The following day, at 4.30 p.m., he, for the third time, entered the room, and was again bitten." Moran contracted the disease.

Meanwhile, two non-immunes in the same building, protected by the wire-screen partition, remained in perfect health.

Such, then, is the romantic story of the mosquito and yellow fever, and surely such scientific determination and heroism are worthy to be styled romantic.

The result of the conviction of the mosquito is almost incalculably great; it means the extermination of at least two deadly diseases, and it opens continents to the conquest of the Caucasian.

Microbes of disease have more than medical—they have vast political importance.

The political importance of microbes.

The two most important microbes of disease, the bacillus of tuberculosis and the hæmamœba of malaria, not only slay individuals, but build empires. Though the bacillus of tuberculosis slays annually 100,000 Anglo-Saxons, yet it is the Prince of Imperialists. To it England owes her security and supremacy, while the walls of many Jerichos have been laid low by the trumpetings of the little mosquito. As Dr. Archdall Reid has pointed out, Columbus discovered America, but the bacillus of tuberculosis conquered the northern half for the Anglo-Saxon, and the hæmamœba defended the southern half against the Spanish and Portuguese. The microbes "have connived at our designs," and germs "have plotted for us."

The civilised man takes with him not only missionaries and Maxims, but also civilised diseases, and these it is that sweep Caribs, and Tasmanians, and Red Indians from his path. Save for civilised diseases the "black problem" would have checkmated us all over the world. The savage may anoint his arrows with the tetanus bacillus; but the civilised consumptive has merely to cough to kill. We have conquered in many lands through the dandy tubercle bacillus and the sweet-tooth yeast plant; and now we are proceeding to capture darkest Africa with a mosquito net, and our best ammunition is not gunpowder but quinine.

The ravages of infectious diseases, among those unprepared by evolution for their assaults, is almost incredible. Robert Louis Stevenson gives the following instances of the deadliness of small-pox and tuberculosis among the Polynesians. "The tribe of Hapaa is said to have numbered some four hundred when small-pox came and reduced them by one-fourth. Six months later a woman developed tubercular consumption. The disease spread like fire about the valley, and in less than a year two survivors, a man and a woman, fled from the newly-created solitude. Early in the year of my visit, for example, or late the year before, a first case of phthisis appeared in a household of seventeen persons, and by the end of August, when the tale was told me, one soul survived, a boy who had been absent at his schooling."

More terrible still were the ravages of small-pox among the Red Indians. Whole tribes were destroyed. George Catlin, who in the first half of the nineteenth century travelled for eight years through the tribes then remaining, gives a graphic account of the extermination by small-pox of the Mandan tribe. The small-pox attacked the tribe in the autumn of 1838, and in the course of two months almost all perished. "Utter despair," he writes, "seemed to possess all classes and all ages, and they gave themselves up to despair as entirely lost. There was but one continual crying, and howling, and praying to the Great Spirit for His protection during the nights and days; and there being but few living, and those in too appalling despair, nobody thought of burying the dead, whose bodies, whole families together, were left in horrid and loathsome piles in their own wigwams, with a few buffalo robes, etc., thrown over them, there to decay and to be devoured by their own dogs. . . . From the trader who was present at the destruction of the Mandans, I had many most wonderful incidents of the dreadful scene, but I dread to recite them. Amongst them, however, there is one which I must briefly describe relative to the death of that noble gentleman of whom I have already said so much, and to whom I became so much attached—Mah-to-toh-pah, or the Four Bears. This fine fellow sat in his wigwam, and watched every one of his family die about him—his wives and his little children—after he had recovered from the disease himself, when he walked out around the village and wept at the final destruction of his tribe; his braves and warriors, on whose sinewy arms alone he could depend for a continuance of his existence, all laid low! Then he came back to his lodge, where he covered his whole family in a pile with a number of robes, and wrapping another round himself, went out upon a hill at a little distance, where he lay several days, despite all the solicitations of the traders, resolved to starve himself to death. He remained there till the sixth day, when he had just strength enough to creep back to the village. He then entered the horrid gloom of his wigwam, and, laying his body alongside of the group of his family, drew his robe over him and died on the ninth day of his fatal abstinence."

On this occasion the disease spread to other tribes, and twenty-five thousand died in a few months.

In other countries the disease has been equally deadly. In the West Indies, in 1507, whole tribes were exterminated. In Mexico 3,500,000 were suddenly slain, and none left to bury them. In Brazil whole races of men were extirpated. In Quito a hundred thousand Indians died. In 1590 all the Indians in the cities of Potosi and De la Paz were swept away.

Such are the hecatombs of the microbes!

But it has not always been on behalf of civilisation that microbes have fought. The civilisation of ancient Greece, the civilisation which gave us our modern science and art and philosophy, the highest civilisation the world has ever seen, owed its downfall probably to mosquitoes. According to Dr. Ronald Ross, who personally investigated the matter, half the blood of modern Greece swarms with hæmamœbæ, and in some places all the children are infected in autumn. During 1905, out of a population of 2,433,806 there were 960,048 cases of malaria. The mosquito is everywhere. In the gorge where once sounded the Oracle of Trophonius its bugle is heard, and at the springs of Lethe and Mnemosyne it quenches its thirst. In pools by Thebes near the dwelling-place of Pindar and Epaminondas its wriggling larva is found, and Ross remarks: "I am not certain whether the little wriggler of the puddles has not been a worse enemy to Thebes than was the great conqueror." Even in the fountain of the Graces, where they were wont to bathe, were discovered "the shameless insects" desecrating the divine spot.

Blood so impoverished, so poisoned, must mean national degeneracy. The children are often miserably ill, emaciated and anæmic, and the results of malaria are often lifelong.

How great a part the mosquito has played in the downfall of Greece may be questioned, but that it has been an important factor cannot be denied.

Let us quote some extremely interesting paragraphs from Ronald Ross's paper on Malaria in Greece. "People," he writes, "often seem to think that such a plague strengthens a race by killing off the weaker individuals; but this view rests upon the unproven assumption that it is really the weaker children that cannot survive. On the contrary, experience seems to show that it is the strange blood which suffers most—the fair northern blood which Nature attempts constantly to pour into the southern lands. If this be true, the effect of malaria will be constantly to resist the invigorating influx which Nature has provided, and there are many facts in the history of India, Italy, and Africa which could be brought forward in support of this hypothesis. . . .

"In prehistoric times Greece was certainly peopled by successive waves of Aryan invaders from the north—probably a fair-haired people—who made it what it became, who conquered Persia and Egypt, and who created the sciences, arts, and philosophies, which we are only developing further to-day. That race reached its climax of development at the time of Pericles. Those great and beautiful valleys were thickly peopled by a civilisation which in some ways has not since been excelled. Everywhere there were cities, temples, oracles, arts, philosophies, and a population vigorous and well-trained in arms. Lake Kopais, now almost deserted, was surrounded by towns whose massive works remain to this day. Suddenly, however, a blight fell over all. Was it due to internecine conflict or to foreign conquest? Scarcely, for history shows that war burns and ravages, but does not annihilate. Thebes was thrice destroyed, but thrice rebuilt Or was it due to some cause entering furtively and gradually sapping away the energies of the race by attacking the rural population, by slaying the new-born infant, by seizing the rising generation, and especially by killing out the fair-haired descendant of the original settlers, leaving behind chiefly the more immunised and darker children of their captives won by the sword from Asia and Africa? . . .

"Could it (the malaria) not have been introduced into Greece about the time of Hippocrates by the numerous Asiatic and African slaves taken by the conquerors? Supposing, as is probable, that the Anophelines were already present, all that was required to light the conflagration was the entry of infected persons. Once started, the disease would spread by internal intercourse from valley to valley, would smoulder here and blaze there, and would, I think, gradually eat out the high strain of the northern blood.

"I can't imagine Lake Kopais, in its present highly malarious condition, to have been thickly peopled by a vigorous race, nor, on looking at those wonderful figured tombstones at Athens, can I imagine that the health and power people represented upon them could have ever passed through the anæmic and splenomegalous (to coin a word) infancy caused by widespread malaria. . . . The whole life of Greece must suffer from the weight which crushes its rural energies. Where the children suffer so much, how can the country create that fresh blood which keeps a nation young?"

The Turk and the mosquito together have destroyed Greece, and perhaps the mosquito has been the more destructive.

Little did the Greeks know that in the blood of the slaves they imported, swarmed microbes that would devour their mighty civilisation. Yet so it seems it was. Nemesis in a gnat!

With the growth of science, however, microbes become less and less important as an evolutionary factor. The microbes have finished their political career, and now mankind is engaged in subjugating, and breeding, and abolishing them.

CHAPTER IX.

MAN VERSUS MICROBE.

The war with microbes—Davaine's theory—How does the body conquer germ disease—Pasteur's theory—Metchnikoff's theory—The white blood-cells—Metchnikoff's experiments—Opposition to the theory—Immunity—Ehrlich's theory—" Opsonin."

MAN is usually master of his voluntary muscles: he walks, he talks, he eats, yet the movements of the cells of which he is made are quite beyond his jurisdiction. The cells live their own lives and fight their own battles, and when he is dreaming in his bed they may be grappling with the cohorts of death. Still, by watching their warfare, and by analysing their victories, man may sometimes assist them in their battle against disease. For man has, at least, the commissariat department in his hands; he can feed his cells with good food and fresh air, he can keep them warm, and to some extent he can provide them with ammunition.

The war with microbes.

Let us examine the manner of the war. With what weapons do cells fight? They fight with their chemical affinities, with their digestive juices, with *poisons*. Not even the Medici, not even the Borgias, were more expert toxicologists than are the cells. As we have mentioned, the tetanus bacillus secretes a poison so potent that a three-hundredth part of a grain is sufficient to kill a man; and the poison of the anthrax bacillus is still more virulent. How, then, do the cells of the human body resist such poisons—poisons that would break them up, as a yeast-cell breaks up the molecules of sugar? How do they resist such poisons, and how can their resistance be increased? What is the natural history of microbic disease and of the recovery therefrom? What decides the issue of the battle?

It is a matter of Greek meeting Greek, of thief catching thief, of poison antagonising poison. If certain bacteria form poisons fatal to the cells of the body, the cells of the body in turn form poisons fatal to bacterial cells; they have the power of neutralising the bacterial toxines by means of substances known as "alexins" and "antitoxins" and "opsonins."

That is a very general statement of the situation; but modern science has investigated the whole subject with marvellous patience and ingenuity; and many most suggestive facts and important principles have been elicited, so it will be interesting to examine the question of bacterial disease in greater detail.

The magnificent generalisation, that bacterial disease is of a fermentative nature, was born in beer, and we may almost say that to beer we owe bacteriology. In 1675 Leeuwenhoek discovered the yeast-cells in beer; he *saw* them, but naturally he did not recognise them as living vegetables. In 1836, however, Cagniard Latour, and in 1837 Schwann (whom we mentioned as one of the pioneers of the cellular pathology), happened to notice that the yeast-cell budded, and came to the bold conclusion that the cells were living vegetables, and that the fermentation of the wine and beer were due to their vital processes. But Liebig, who was then a power in the land, disputed these conclusions, and their discovery remained unutilised and dormant for nearly twenty years. Then Pasteur, who was engaged in studying the fermentation of beer, proved that not only the fermentation of beer, but also the fermentation of wine, the souring of milk, the ammoniacal decomposition of urine, and, indeed, all the so-called fermentations, were due to the vital action of living cells. He himself saw the inferences of his discovery, and wrote, "The etiology of infectious diseases is on the eve of having unsuspected light shed upon it," and, indeed, the step, from his generalisation to the conception of decay and disease as similar fermentative processes, was inevitable, and was soon taken. It was taken first, as is not generally known, by Davaine, the discoverer of the bacillus of anthrax. This keen-minded man, speaking of the thread-like corpuscles which he had seen in the blood of sheep attacked with anthrax, declared: "In the

Davaine's theory.

present state of science, no one would think of going beyond these corpuscles to seek for the agent of contagion. This agent is visible, palpable; it is an organised being endowed with life, which is developed and propagated in the same manner as other living beings. By its presence, and its rapid multiplication in the blood, it without doubt produces in the constitution of this liquid, after the manner of ferments, modifications which speedily destroy the infected animal."

Davaine was right; and further researches proved that decay and suppuration—that is, the formation of pus—and most forms of contagious disease were fermentative processes, analogous in all respects to the fermentation which takes place in milk, or wine, or beer. All flesh is as grass. Alcoholic fermentation is a putrefaction of sugar, suppuration is a fermentation of flesh; both processes are equally due to the chemical action of living cells (or, perhaps more accurately, to the chemical action of a ferment produced by living cells), and both fermentation and suppuration can be prevented by preventing the access of cellular ferments.

This, then, is the first fact in the study of bacterial disease: the process is a species of fermentation—the wine-making of death.

Let us look at the process of infection more particularly. Suppose an anthrax bacillus, vicious and virulent, invades the blood, what happens? The anthrax bacillus will feed and multiply in the blood, just as the lactic acid bacillus feeds and multiplies in milk, or the yeast-cell feeds and multiplies in beer; it will break up the blood, and it will so change it with its excretions, etc., that it will poison the cells of the body instead of nourishing them; the red river of life will become a river of death. Now, the anthrax bacilli will find the blood good, fattening food, well-flavoured, salted, and served warm; and, feeding on such good food, why should they not become as the stars of the sky, as the sands of the sea, for multitude? Why should they not increase as we have shown in an earlier chapter microbes are capable of increasing? Why do many diseases after a time die out, and leave the body more resistant to future attacks? That is a very important question, for if we can find how the body wins its victories we may be able to assist it to win them.

How does the body conquer germ disease?

At first it was thought—I think Pasteur first proposed the theory—that the invaders perished, as did Napoleon's Russian army, of famine. It was held that there was only a certain amount of food in the blood, and that when this became exhausted, the raiders died of starvation. But this theory, though fascinating in its simplicity, was soon shown to be unsound: it under-estimated both the foraging facilities of the

Pasteur's theory.

invaders and the resisting capacity of the home army. And it implicitly made the rather bold assumption that for each disease germ there was special pabulum in the blood.

Metchnikoff's theory.

Then it was suggested that the germs were "stewed in their own juices," "hoist with their own petard," that they were poisoned by their own secretions, even as the victims of Surajah Dowlah who perished in the Black Hole of Calcutta. This explanation sounded quite plausible, but it was not correct, for it is found that an accumulation and concentration of secretions, sufficient to kill the secreting germs, does not take place under natural conditions; and so this theory, in turn, was superseded, and gave place to Metchnikoff's famous theory of *phagocytosis*. In his presidential address in 1896, Lord Lister said: "If ever there has been a romantic chapter in the history of pathology, it is the story of phagocytosis." And certainly this theory of Metchnikoff's appeals to the imagination in no common degree.

As we mentioned in the chapter on the Romance of the Cell, there are certain cells of the body which live a morphologically independent existence—cells that are self-contained, and that paddle their own canoes. Of these cells the most numerous and active are the red and the white blood corpuscles; and according to Metchnikoff's theory the latter, the white blood-cells, are the defenders of the body. They defend it by consuming the invading microbes, and he therefore called them phagocytes (cell-eaters).

The white blood-cells.

The white blood corpuscles, or leucocytes, are the most extraordinary of all the cell-members of the cellular community. They are most extraordinary in their behaviour, and most extraordinary in their appearance.

In the slime of ponds and ditches a little organism, known as the *Amœba proteus*, is usually found. This is little more than a mass of naked, jelly-like, semi-fluid protoplasm. It changes shape constantly (hence its name *proteus*), and it has the power of throwing out prolongations of its substance like arms, "pseudopodia," and of crawling about by means of these, the movement being known as amœboid movement. It has the power, too, of enveloping foreign bodies in its substance, and of digesting such substances as it finds digestible. It has power of multiplying, and, as a living creature, it must, of course, breathe.

Now, the white blood-cells are just like these amœbas: each is a little bit of naked protoplasm with power of amœboid movement. The blood is full of them. Each time the heart beats it drives millions and millions of them through the arteries and veins. Each has power of locomotion, and can breathe and digest; it is quite free to go as it pleases and to do what it likes; it has no nervous restrictions, and no family ties.

What is the purpose of this swimming, swarming multitude, thicker than salmon in a Canadian river? What is their business? Are they parasites, or philanthropists, or gentlemen at large?

It required much investigation to settle the question, and the history of the investigation is briefly as follows. In 1858 Haeckel (the same Haeckel whose works are so well known today) discovered that indigo he had injected into a mollusc was taken up by the white blood-cells.

In 1867 Cohnheim made the important and astounding discovery that the white blood-cells had the power of passing through the walls of the blood-vessels and of wandering about in the tissues. This was a most remarkable fact; the white corpuscles actually passed through the wall of the blood-vessels as ghosts are reputed to pass through closed doors. But more remarkable facts were soon to be discovered.

About 1871–2 various scientists—Hayem, Klebs, Waldeyer, and others—noticed that the white blood-cells frequently contained micro-organisms. In 1876 Koch, the discoverer of the tubercle bacillus, reported that after he had inoculated frogs with anthrax bacilli he found therein the bacilli in the white blood-cells.

At first, however, the idea prevailed that this presence of bacteria in the white blood-cells was due to aggression on the part of the bacteria, and this was Koch's view of the phenomenon; but gradually the idea began to dawn that the position was really reversed, and that it was not a case of bacteria invading the white blood-cells, but of the white blood-cells devouring the bacteria. This idea was first hinted by Panum in 1874. In 1877 Grawitz noticed that when a fungus which grows upon lily-of-the-valley was introduced into the blood of mammals, it was seized by the white blood-cells. In 1881 the idea of phagocytosis seemed rapidly to ripen. In that year Gaule, Roser, and Sternberg all gave more or less precise expression to the notion. Gaule, as quoted in Metchnikoff's work on Immunity, described how parasites in the blood of a frog were devoured by white blood-cells. "He happened on one occasion to observe a white blood-cell of the spleen of the frog, which in a short time ingested three little worms, and then went briskly away without leaving any trace of where it had been. Following its movements, he was able to make out within the contents of the blood-cells the body of this little worm; but this body became paler, and half an hour later it had been completely assimilated."

Roser was even more advanced in his theory. He stated that the "immunity of animals and plants in complete health depended, in his opinion (1) on the relative quantity of salt contained in their fluids, (2) *on the property of their cells* *of consuming the enemy which enters the animal body.*"

And more advanced still was Sternberg, who stated the theory more in detail, thus: "It has occurred to me that possibly the white blood-cells may have the office of picking up and digesting bacterial organisms which by any means find their way into the blood. The propensity exhibited by the leucocytes (white blood-cells) for picking up inorganic granules is well known, and that they may be able not only to pick up, but to assimilate and so dispose of the bacteria which come in this way does not seem to me very improbable in view of the fact that amœbæ, which resemble them so closely, feed upon bacteria and similar organisms."

In 1883 he added: "It requires no great stretch of credulity to believe that they may, like amœbæ, digest and assimilate the protoplasm of the captured bacterium, thus putting an end to the possibility of its doing any harm."

Sternberg is not mentioned by Metchnikoff in his work, but there is no doubt that he was one of the first to formulate the theory of phagocytosis.

Meantime, the Russian biologist himself had been engaged in investigating the nature and function of these white cells; and his investigations constitute one of the most interesting researches in the history of science. He went to the root of the matter. He showed, firstly, that the white blood-cells originated from the same layer of embryonic tissue which formed the digestive region of the lower organisms, and thus he established a presumption that their digestive faculty would be retained. He next proceeded to show that the presumption was verified by fact.

Metchnikoff's experiments.

Having read Cohnheim's description of the emigration of the white blood-cells, he commenced to make experiments on their behaviour in simple organisms. Into the larvæ of star-fish he inserted rose prickles—surely suitable material for so poetical and imaginative a research! These larvæ were quite transparent, and he was able to see that the rose prickles were quickly surrounded by crowds of white blood-cells, thus showing that the cells were actually mobilised to repel the invasion of foreign bodies.

Then he selected a small transparent crustacean, the daphnia (used by Cohnheim in his experiments), and showed that if it were inoculated with the spores of a fungus, the white blood-cells rushed, or at least crawled to the rescue, and saved the crustacean by devouring the spores. Finally, he demonstrated that in the higher vertebrates anthrax bacilli and other germs were consumed and destroyed by the white blood-cells. In the course of his researches he investigated the phenomena of phagocytosis most exhaustively, examining a great variety of animals, from goldfish to alligators. He also fed white blood-cells of one animal with red blood corpuscles of another, and showed conclusively that the red blood-cells were digested by a process of intercellular digestion.

He thus reached his famous theory that the "amœbæ cells are defensive elements of the body, capable of guaranteeing to it immunity and cure."

Metchnikoff's theory was fascinating. According to his contentions, the white blood corpuscles were the army and navy of the body—a vast multitude of free cells maintained by the State, that they might repel invasion by other unicellular organisms. The white cells floated, as a rule, in the blood-stream; but they were also massed in the lymph glands, which were thus a kind of blockhouse, and they had the power of rapidly mobilising to repel invaders.

Infectious disease, then, was depicted as a struggle between cells—between the phagocytic cells and the cells of disease.

What, it might be asked, guided the phagocytes to this prey? Did they scent the battle from afar? Did they descry carrion in the distance like flies or vultures? Why did they throng about the rose prickle? Why did they swarm around the hostile germs?

The exact nature of the process could not be elucidated; but it was soon shown by a series of beautiful experiments that the phagocytes had minds of their own, and tastes, and distastes, and that they could distinguish, even at a distance, between different substances. Ingenious experimenters introduced into the bodies of rabbits, guinea-pigs, and frogs, fine glass tubes containing different solutions—*e.g.*, broth, salts, bacterial products—and it was found that the phagocytes crowded into some of the tubes and studiously avoided others. Further, it was shown that the larger white cells and the smaller white cells had different dietaries, and it was suggested that the immunity acquired by an individual was due to a gradual gastronomic education of the phagocytes, to *acquired* phagocytic tastes, while failure to conquer an infective disease was due to phagocytic inadequacy and ineducability.

Though so plausible and complete, though so patiently and laboriously built on such a scientific foundation, Metchnikoff's theory met with fierce opposition. It could not be denied that the phagocytes did consume foreign particles and bacteria, but it was contended that the white blood-cells acted merely as scavengers, and simply cleared away dead cells.

Opposition to Metchnikoff's theory.

In reply to this criticism, Metchnikoff proved conclusively that the germs consumed were really alive. By making cultivations of germs taken from the interior of phagocytes, he showed that the germs were alive when devoured, and lived for a time, but were eventually killed by the digestive action of the cells.

Still, the opponents of the phagocytic theory were not convinced, and when (in 1886) a Hungarian scientist, Fodor, discovered that the ordinary blood of a rabbit was bactericidal and had the power of killing anthrax bacilli, there arose the great rival theory, the *humoral* theory, which maintained that immunity, whether natural or acquired, was due to the ferments of the blood and had little or nothing to do with phagocytes and phagocytosis.

Immunity.

The power of the body, then, to resist disease is probably due to the phagocytic action of the white blood-cells, and this, again, is probably assisted by bactericidal (bacteria-killing) substances in the serum (the fluid part of the blood), these bactericidal substances being sometimes sufficient in themselves to kill the bacteria.

When the microbes are few or feeble, they are easily killed by the serum and phagocytes, without constitutional disturbance, or noticeable alteration in the qualities of the serum. This is called natural immunity. When, however, the microbes are numerous or virulent, there are constitutional disturbances (*i.e.*, signs of disease), and alteration in the qualities of the serum.

The alteration in the qualities of the serum is of great importance, for it is found that if the organism recovers from the disease, there are substances produced in the serum which render the animal immune to future attacks. This is called *acquired* immunity, and it is with acquired immunity that medical science is specially concerned.

In the course of experiments further to elucidate the subject, Buchner, one of the leaders of the *humoral* school, demonstrated that the bactericidal property of the altered blood is due to an albuminoid substance which he called "alexin," and which is destroyed by heating to 55° C.; and it was afterwards shown by Bordet and others that alexin cannot destroy bacteria until the bacteria have been acted upon by another substance in the blood—the so-called "sensibilising substance." Thus the bactericidal qualities of the blood were shown to be due to two substances in it—one rendering the germ vulnerable, and the other slaying it.

Ehrlich's Theory.

Professor Ehrlich, of Frankfort, has explained this double character of the bactericidal process by a theory which has taken a great hold of the scientific world, and which has proved a useful working hypothesis. He maintains that between the microbe and the alexin in the serum which poisons the microbe there is no direct structural connection; they do not fit together. The sensibilising substance, however, acts as a link between them and brings them into connection: it has one end attachable to the alexin and the other end attachable to the microbe, and can thus bring the two into chemical relationship. Only by this connecting link, which Ehrlich calls the "amboceptor," can the alexin or bactericidal substance act on the microbe. The blood may be full of alexin, but unless there be also present sensibilising substance, or amboceptors, the alexin cannot reach the microbe. Natural immunity, therefore—in so far, at least, as the death of the microbe is concerned—is due to a triple alliance. The relationship between microbe, amboceptor, and alexin has been illustrated by the relationship between a lock, a key, and a hand.

How the "amboceptors" are formed.

The amboceptors, according to Ehrlich, are formed by cells which have been attacked by the microbe poison. The microbe poison combines with molecular groups in the cells, which are really intended to combine with nutrient molecules. The cell, thus deprived of its food, is stimulated to form more molecular groups for nutrient purposes, and some of these, thrown off into the serum, act as amboceptors or go-betweens, and bring the alexin into contact with the microbes floating in the serum. So long as the amboceptor is attached to the cell it merely acts as a mediator to connect the toxin (poison) molecule of the microbe with the cell; and is thus a danger to the cell; but when it breaks off from the cell, and has thus two free hands, so to speak, it takes the microbe in one hand and the alexin in the other and brings them into contact, to the detriment of the microbe.

It will be seen that Ehrlich holds that the destruction of the microbe takes place in the serum, and cannot be effected directly by the phagocyte.

Metchnikoff at once frankly admitted the importance of the substances in the serum; but he held and holds that the substances are really the digestive substances in the interior of the phagocytes which overflow from the phagocytes, or are thrown into the blood when the phagocytes are dissolved.

"Opsonin."

Within the last few years Sir A. E. Wright has brought forward a new theory involving a new conception of the mutual relationship of the fluids of the body and of the phagocytes to immunity. He holds that the blood contains a substance which he calls "opsonin," a substance which semi-digests or cooks the microbes, and prepares them for the palate of the phagocytes, and he contends that immunity and resistance to diseases depend on the amount and potency of the substance; while on the condition, and character, and chemistry of the phagocytes little or nothing depends. He has shown, to the satisfaction of most, that it does not matter what kind of phagocytes are present in a blood-serum—that in the *same* serum they will all devour the bacteria equally well; and he has also shown that in *different* serums the same phagocytes will show different degrees of phagocytic activity.

Thus, when he put phagocytes from different individuals, A, B, C, into portions of the same serum containing bacteria, he found that A's and B's and C's phagocytes all devoured about equal numbers of bacteria. When, on the other hand, he put phagocytes from one individual, A, into different serums, X, Y, Z, each containing microbes, he found that A's phagocytes varied in their phagocytic power with the serum in which they were immersed.

While admitting, then, phagocytosis as a final step in the mechanism of immunity, Wright considers the phagocytes passive and unimportant agents, and maintains that the serum is the essentail factor in immunity ; and he proves his theory further by showing that if a serum is heated to a certain temperature so as to destroy the opsonin, the phagocytes then lose almost all power of ingesting germs.

According to Wright's views, moreover, each microbe requires its own special opsonin, and a serum which is very rich in opsonins that digest tubercle bacilli may yet be very poor in opsonins that deal with anthrax bacilli, and *vice versâ*.

Wright estimates the amount of opsonin in serums by adding to them bacteria, and by comparing the bactericidal power of the serums as shown by the number of bacteria ingested by phagocytes immersed in each. By means of such a comparison he obtains what he calls the "opsonic index" of each serum.

Thus, if the average number of microbes devoured by phagocytes immersed in normal blood-serum be twenty-four, and if the average number of microbes devoured by phagocytes immersed in A's serum be twelve, and if the average number of microbes devoured by phagocytes immersed in B's serum be forty-eight, then A's serum is said to have an "opsonic index" of ·5, and B's an "opsonic index" of 2. In other words, A's serum has only half the normal bactericidal potency, while B's has double the normal bactericidal potency.

The bacteria are stained so that they may be clearly seen in the interior of the phagocytes, and a fair number of phagocytes are counted so as to get a correct average.

Wright claims to have established a relationship between resistance to bacterial disease and the "opsonic index," and he takes special measures to raise the "opsonic index" in order to combat various diseases.

On *a priori* grounds, Sir A. Wright's theory seems improbable. It is surely improbable that the blood-serum should be unaffected by the vital chemistry of the millions of active amœboid cells which swarm in it. It is surely improbable that the phagocytes should play no part in the preparation of their own food. But antecedently improbable as his theory may seem, he has established it to the satisfaction of most scientists, and has based upon it a new system of bacterial therapeutics.

Whether his theory be wrong or right, his methods of investigation are beautiful, and it is a wonderful thing to know that we can actually count the bacteria inside our own phagocytes, and can take measures to give our white blood-cells a more voracious appetite.

But there is still another way in which natural immunity is attained. The microbes slay, as we have seen, by means of their poisons, and in some cases the cells become invulnerable to their attacks simply by forming antidotes to these poisons.

In diphtheria, for instance, this is the case. The diphtheria microbe does not itself live in the blood; it lives in the tissues of the throat, and there manufactures poisons which circulate in the blood. It is found that the cells in such a case do not form substances to kill the microbe, but substances known as "anti-toxins," which neutralise the microbic poison. This anti-toxin is formed in just the same way as the amboceptor—in fact, it is an amboceptor. The toxins, or poisons, attack the nutrient molecules of the cells, and the cells, in self-defence, form an excess of nutrient molecules, and some of these, cast off into the blood-stream, constitute the anti-toxin.

Anti-toxins.

These, then, are some of the facts of natural immunity. We shall see later (Chapter XV.) the application of these facts in practical therapeutics.

CHAPTER X.

SOME VICTORIES OVER THE HOSTS OF DEATH.

Early antiseptic practices—Antisepsis in the Middle Ages—Discoveries of Leeuwenhoek and Redi—Place's prophecy—Pringle's investigations—Bassi's anticipations—Semmelweiss and puerperal fever —A disheartened pioneer—The irony of fate.

THE question may be asked, To what extent have the researches into the nature of contagious disease led to victory over the hosts of death? We have mapped out the enemy's positions, we have unmasked his batteries, but have we silenced his guns? No doubt it is interesting to watch the military manœuvres of microbe and phagocyte through the field glass of a microscope, and to make flower-pots of bombs, and ornaments of cartridges; but what has been done to help suffering humanity? The air is still full of the emissaries of death; they ride on the snowflakes, they make aëroplanes of the dust, and injection-syringes of the mosquitoes. The little tubercle bacillus alone kills its thousands daily. What have we done? What victories have we won?

The first great victory—the victory of Jenner over small-pox—was largely empiric in its character, and will be separately considered.

The first scientific victory of note was really the victory of antisepsis and asepsis; and even this was at first empirical in character, and had a long empirical pedigree.

Long before the days of the microscope there were nibblings at the notion.

The first practitioners of antiseptic chemistry were the embalmers, who found means of preserving dead bodies of animals and men. Their methods were rough, but so effectual that mummies two or three thousand years old have been found with the soles of their feet still soft and elastic, and their joints still flexible. The preservatives used were chiefly pitch, natron, palm-oil, myrrh, cassia, cedar-oil, and sometimes wax and honey; all over the world this branch of antisepsis was practised. Jacob and Joseph, as we read in the Scriptures, were embalmed; and Alexander the Great was preserved in wax and honey. In Egypt the practice dates back to at least four thousand years B.C., and it has been calculated that over 7,000,000 bodies were embalmed in Egypt alone. In view of the wide extent of the custom, it is strange to think that the idea of applying the same principle to *living* flesh never occurred to the ancients.

Early antiseptic practices.

Other instances of early antiseptic practice are seen in the ancient customs of preserving wine by the addition of pitch, of smoking fish, of salting pork; and no doubt other examples of empirical antisepsis in general putrefactions could be found;

but in medical practice the growth of antiseptic methods, even as an empirical practice, was surprisingly slow.

Hippocrates recommends that wounds should be permitted to bleed freely, and should be carefully cleaned. Celsus makes the same recommendation, and suggests that a sponge, moistened with wine or vinegar, should be laid upon the wounds.

We read in the Scriptures how the good Samaritan went to the man who was waylaid by robbers, and bound up his wounds, "pouring in oil and wine," and we could quote many other instances from ancient literature of mild antiseptic treatment. But these applications were quite unscientific and the ancients had no true conception of antisepsis or asepsis.

Antisepsis and asepsis in the middle ages.

In succeeding centuries disinfectants of various kinds were used, and antiseptic and aseptic measures of varying stringency had an occasional vogue; but, as a rule, a pernicious disbelief in the *vis medicatrix naturæ* prevailed, and Nature was more hampered by tents, and plugs, and empirical applications than helped by antiseptic precautions.

Even as late as the thirteenth century suppuration was considered a salutary process which should be artificially provoked and encouraged; and the protests of more enlightened physicians, such as Theoderic, Bourgogni, Lanfranc, and

Henri de Mandeville did little to establish the true pathological nature of the discharges. At no time was the true relationship between germs and suppuration clearly conceived, and the antiseptics used were employed merely to stimulate healing, without any definite theory as to their action. Most of the antiseptics used had little antiseptic power. Hot wine fomentations were perhaps most common; Paracelsus, who lived in the fifteenth century, used solution of lead acetate; Ambroise Paré, a famous surgeon of the next century, used boiling oil and turpentine; while his contemporary, Jean André Delacroix, used pitch (the substance employed to preserve mummies and wine).

In Ambroise Paré's writings many interesting sidelights are thrown on the surgical treatment of the time. He describes how he cauterised wounds, according to the method then in vogue, "with oil of elders, scalding hot, mixed with a little treacle." "At last," he says, "my oil ran short, and I was forced instead thereof to apply a mixture of the yolks of eggs, oil of roses, and turpentine"—a mixture which produced such good results that he "resolved never more to burn thus cruelly poor men with gunshot wounds."

He also tells how at Turin he found a surgeon who had a famous balm wherewith he treated gunshot wounds, "and," he says, "he made me pay court to him for two years before I could possibly draw the recipe from him. In the end, thanks o my gifts and presents, he gave it to me, which vas to boil, in oil of lilies, young whelps just born ınd earth-worms prepared with Venetian turpen- ine. Then I was joyful, and my heart made ;lad, that I had understood his remedy, which was ike that which I had obtained by chance."

Paré advises the following treatment of a suppurating thigh: "Then the thigh and the whole of the leg must be fomented with a decoc- tion made of sage, rosemary, thyme, lavender, flowers of chamomile and melilot, red roses boiled in white wine, with a drying powder made of oak ashes and a little vinegar, and half a handful of salt"; and when he had a compound fracture himself, white of egg, flour, soot from the chim- ney, and fresh butter melted were applied to the wound. Such was surgery in the sixteenth century!

Discoveries of Leeuwenhoek and Redi.

In the seventeenth century there was little advance in surgical antisepsis, though Sir John Colbatch invented a patent antiseptic with which he claimed to have obtained very successful results. Nevertheless, to this century belonged two great advances in the direction of antiseptic principles: the discoveries of microbes by Leeuwenhoek, and the experiments of Redi, the Tuscan poet. Redi, as we have seen, disproved the notion that maggots are spontaneously generated, by showing that, if meat be protected by a piece of fine wire gauze, so that flies are prevented from depositing their eggs, maggots do not appear. It was a crude and rough experiment, but it was considered by Huxley the foundation of modern bacteriological technique, and Redi's wire gauze was the father of the cotton-wool plug of the modern test-tube, and of the antiseptic gauze of modern surgery. Every butcher, indeed, who covers his carcases with gauze is practising a rough kind of asepsis.

Neither the biological and bacterial suggestions, however, of Leeuwenhoek's discovery, nor the technical suggestions of Redi's experiment were realised till centuries later.

In the eighteenth century drainage of wounds was practised, and some attempts at antiseptic treatment were made by such well-known men as Boerhaave, Percival Potts, Benjamin Bell; and about this date, too, the scientific basis of antiseptic treatment began to be suspected. The germ nature of various obscure internal diseases had frequently been surmised, and now the hypothesis began to be broadened so as to include surgical suppuration. In 1721 a Mr. Place, writing about the plague, observes: "However, as this Phenomenon shows the Motion of the Pestilential Poison to be putrefaction, it makes the Use of Antiseptics a reasonable way to oppose it, and whatever resists and is preservative against Putrefaction and admits not of the generation of Insects—if this hypothesis is proceeded upon—

Place's prophecy.

are proper and promising Materials to yield Medicine, and for physical preparations against it, such as Cedar, Irish Oak, Cinnamon, Spices, and what was used by the Ancients in their Embalmments of dead Bodies; *for the same Vertues that preserve dead Bodies from Insects and Putrefaction, I know no reason why they should not preserve the same Bodies living from the same thing.*"

This seems to me a most brilliant generalisation, hinting at both surgical and medical antiseptic practice.

Asepsis, the principle of preventing access of germs, as contrasted with *antisepsis,* the principle of destroying germs, finds one of its first prophets in a book entitled, "Medicine and Surgery for the Poor," published in 1749. In this book it is recommended to keep the wound from contact with air, and to avoid touching the wound with fingers or instruments. "It is also salutary," so runs the advice, "when uncovering the wound in order to dress it, to begin by applying over its whole surface a piece of cloth dipped into hot wine and brandy."

A beginning in a different direction to lay a scientific basis for antiseptic treatment is found in the investigations of John Pringle and Dr. Short into the action of antiseptic substances. Pringle's experiments dealt exclusively with dead organic matter subject to putrefaction, and with the comparative antiseptic power of various salts, and he suggests

Pringle's investigations.

no surgical application. Still, he indicated the scientific basis on which the art of antisepsis was afterwards erected, and he must be held as a pioneer.

In the same way Appert, the French confectioner who discovered in the beginning of last century the art of preserving meats, and fruits, and other edibles by means of heat and hermetical sealing, must be considered not only as a pioneer in the culinary and commissariat departments of civilisation, but also as a worker in the fields of antiseptic science and art.

With the labours of Agostino Bassi, the Italian physician, however, antisepsis as a practical medical science may be said to commence, though not till the time of Cagniard Latour was it on a safe scientific footing.

We have seen how the cellular theory of Schwann and Virchow lengthened man's histological pedigree, so that he could say to the worm, "Thou art my mother and my sister," and it was on behalf of this mother and sister of his that man won his first scientific victory. Not for a common or garden worm, however, did he win it, but for its more aristocratic cousin, the silkworm.

Man has certain carnal luxuries: silk, wine, beer; and it is very extraordinary to find how investigation into the sicknesses of wine and beer, and into diseases of the silkworm, have led to the discovery of remedies for the diseases of the flesh.

Bassi was led to study a disease in silkworms known as "muscardine." He showed that the disease was caused by a parasite, and he showed, too—what was much more important—that the parasite could be killed by certain substances.

Bassi's work, "Del Mal del Segno, Calcino, Moscardine," was published in 1835, twenty-five years before the discovery of the first pathogenic bacterium; but Bassi was a mighty genius, and he undoubtedly anticipated many of the methods and discoveries of modern science, and was the greatest forerunner of Pasteur and Lister and Koch. He tested the pathogenic properties of the parasite of silkworm by inoculations; he tested the disinfectant value of various substances by methods still in use, and he even suggested the principle of "fractional cultures," a bacteriological idea that has since borne much fruit. Moreover, he realised the relevance to human diseases of his discoveries, and wrote the following remarkable prophecies and propositions:—

Bassi's anticipations.

"This production of mine ought to interest not only the breeder of silkworms, but also all the cultivators of the natural sciences, it being capable, perhaps, of removing some of the many anomalies which the doctrine of contagions in general presents, and of shedding new light—of announcing, perhaps, the dawn of new discoveries." . . . "Not only am I of the opinion that the contagions, such as smallpox, pest, etc., are produced by vegetable or animal parasitic entities, but also that many—not to say all—of the cutaneous diseases are due to the same cause—that is, that these also are generated and maintained by the said vegetable or animal parasitic entities of different species, *and I am also of the opinion that some ulcers, though deep, if they are not caused, are at least maintained, and for a long time, by parasitic entities, and that even gangrene is caused by such entities.*" . . . "Observation and experiment demonstrate to us that all contagions disappear or cease to act in the individual whom they assail, when agents or means are used capable of destroying the life of the animal or vegetable organism of the lowest classes, the producers, so to speak, of contagious diseases." . . . "Hydrophobia, Arabian smallpox, Asiatic cholera, and other contagions, caused by the work of parasites, disappear or cease to act, with the use of substances or agents capable of killing these parasites."

These are remarkable statements, and they were not merely lucky hits: they were founded on scientific grounds.

And Bassi not only preached: he also practised antiseptic and aseptic treatment, and practised it, not as an empiricist, but as a scientific bacteriologist. He actually cured certain ulcerations by injections of corrosive sublimate, one of the most powerful and most extensively used of modern antiseptics, and he introduced aseptic precautions into vaccination methods.

In 1839, four years after the publication of Bassi's work, Schönlein discovered the fungus of a skin disease called tinea favosa, and suggested the use of parasiticides.

A few years later a great victory was won by an Austrian physician, Ignatius Philippus Semmelweiss, who, by adopting antiseptic measures, succeeded in greatly lowering the death-roll in Vienna from puerperal fever, that saddest of all diseases, which attacks women after child-birth, and only too often puts a coffin beside the cradle.

Semmelweiss and puerperal fever.

Semmelweiss's views were narrow. He made no broad generalisations. His doctrine was little better than empirical, yet his inferences and his practice were sound, and he gave an object lesson to the whole world in the possibilities of antiseptic principles. Never before had Death met with such a reverse.

The story of Semmelweiss's success is also the story of his failure, and his triumph has a background of tragedy. In 1846 he became one of the staff of the General Hospital at Vienna. About this time the death-rate from puerperal fever in the maternity department had reached alarming proportions. Semmelweiss talks of "hecatombs like a Chimborazo," and, indeed, during one outbreak 829 out of 5,139 cases died, giving a death-roll of about 1 in every 6. In the department under a Dr. Klein the rate of mortality was particularly high, and it is recorded that when patients found themselves in Klein's wards they "fell on their knees and with clasped hands begged to be allowed to return to their homes." Almost every day the sound of bells intimated that the priest was administering the last sacrament to the dying. Semmelweiss writes: "I myself was terror-stricken when I heard the sound of bells at my door, and a deep sigh rose in my breast for the unfortunate mother who was victim to a cause hitherto unknown. This worked on me as a fresh incentive that I should to the best of my ability endeavour to discover the mysterious agent, and a conviction grew day by day that the prevailing fatality in Clinique No. I. could in no wise be accounted for by the hitherto adopted etiology of puerperal fever." Unsatisfied, then, with the hitherto adopted theory as to the cause of puerperal fever, he tried expedient after expedient, and considered possibility after possibility; but the cause of the great mortality remained undiscovered until the death of his colleague, Professor Kolletschka, finally gave him a clue. Professor Kolletschka fell a victim to blood poisoning caused by a dissection wound, and Semmelweiss says, "Kolletschka's fatal symptoms unveiled to my mind an identity with those I had so often noticed in the death-bed of puerperal cases."

At length Semmelweiss came to the conclusion that puerperal fever was due to infection borne from the dissecting room on the hands of medical students, and he accordingly gave orders that every person, before proceeding to examine any patient, should thoroughly wash his hands with liquid chlorine or chlorinated lime-water.

The result of these antiseptic precautions was that the death-rate fell, in a few months, from 12.24 per cent. to 3.04 per cent., and in the second year of the experiment it further fell to 1.27 per cent.

But, convincing as the facts seemed, they fell on stony and barren soil, and bore no fruit. Whether owing to the political prejudices or to professional jealousy, Semmelweiss's discovery was not appreciated, and he received such unfriendly treatment that in 1850 he left Vienna, and took up his abode at Pesth. In spite of his vehement advocacy his doctrines made little headway, and, depressed and disappointed, his fortitude gave way, and ultimately his mind broke down. On July 21st, 1865, he was removed to an asylum, and within a month—such is the irony of Fate—he died there of blood poisoning, the very disease he had done so much to combat.

A disheartened pioneer.

Thus all down the centuries, directly and indirectly, slowly, intermittently, the doctrine and practice of antisepsis were evolved—from the mummies of Egypt, to the maggots of Redi, to the meat of Appert; but not till the coming of Pasteur and Lister were they carried to their logical and scientific conclusions.

With the establishment of the germ theory in its various aspects by Pasteur and his co-workers, with the introduction of carbolic acid as an antiseptic, the battle reached its final stage; indeed, the history of the final conflict is largely the history of the application of carbolic acid.

CHAPTER XI.

LISTER AND ANTISEPSIS.

Basis of antisepsis—Cagniard Latour's discovery—Pasteur—Davaine—Carbolic acid—Lemaire's experiments—Bottini—Lister—State of things when he appeared—Alphonse Guérin tries to keep out the germs—Lister's results—Reception of his doctrines—Why he succeeded—From antisepsis to asepsis.

THOUGH Lord Lister was the first to perceive the full surgical purport of the antiseptic theory, and the first to realise the full possibilities of carbolic acid, he neither established the theory nor discovered the acid. He sharpened the sword, but he did not forge it ; he slew the foe, but he did not discover him. In order, therefore, to understand Lister's achievement, we must glance at the final development of antiseptic theory and the history of carbolic acid.

The theory of antisepsis and asepsis is based on the theory of *ferments*—the theory that all putrefaction is due to living germs.

We have seen how Robert Boyle and Mr. Place foresaw different aspects of the truth ; how Robert Boyle foresaw that the man who should discover the true nature of fermentation would shed light on infective disease, and how Mr. Place made the brilliant generalisation—" For the same Vertues that preserve dead Bodies from Insects and Putrefaction, I know no reason why they should not preserve the same Bodies *living* from the same thing." We have seen, too, how Bassi based antiseptic treatment on sound antiseptic theory, and how Semmelweiss, without much theory at all, saved thousands of lives by antiseptic principles. But the real seed of scientific antiseptic theory —of theory based on indubitable facts—will be found in Cagniard Latour's discovery that yeast consists of living cells, and that the fermentations of wine and beer are due to the vital chemistry of these cells. When, in 1836, Cagniard Latour wrote that the ferment of beer, called yeast, was composed of cells "susceptible of reproduction by a sort of budding, and probably acting on sugar through some effort of their vegetation," he made a Lister inevitable.

Cagniard Latour's discovery.

Pasteur, in the course of his investigations into diseases of wines, beer, and silkworms, and into the question of spontaneous generation, rapidly established some great and pregnant generalisations. He showed not only that the fermentation of beer and wine was due to living organisms, but that many other fermentations and that all putrefaction were due to the same cause. The step from this generalisation to the further generalisations that suppuration and infective diseases are likewise fermentative processes due to germs was soon taken.

Pasteur.

Davaine, as we have seen, suggested that anthrax was due to a fermentation of the blood, caused by the anthrax bacilli; the principle was soon extended to cover suppuration.

The principle that suppuration is a fermentation of the flesh, even as alcohol is a fermentation of sugar, suggested at once that suppuration might be prevented by destroying the germ that caused it, or by preventing its entrance; and the history of antisepsis thereafter became the history of efforts to apply to surgery this corollary of the germ theory. Pasteur himself saw the relevance of his discoveries to practical medicine and surgery, and several times lamented that he had not opportunity and time to apply them; but by the very tide of his own successes he was carried whither he would not, and others reaped where he had sown; he led Science to the Pisgah peak, but did not himself enter the promised land. Yet in one instance at least he actually proposed antiseptic treatment; in 1864 he advised M. Guyon to wash out a bladder affected by germs with boracic acid.

And even though Pasteur did not carry his discoveries to their great life-saving conclusions, and though he was engaged in investigating the diseases of silkworms, while Lister was studying the suppuration of wounds, yet, with Lister, he must share the chief honours in the great victory over disease.

While the theory of antisepsis was being established, carbolic acid, the most important of modern antiseptics, was being evolved, and its action upon suppuration was being studied.

Carbolic acid.

As we have seen, one of the first antiseptics known was pitch or tar. With pitch or tar the ancients preserved their corpses and their wines, and carbolic acid, the antiseptic of antiseptics, was, strange to say, a derivative of coal-tar.

Coal-tar itself was recommended as a preservative by Chaumotte in 1815. In 1844 a Dr. Bayard invented a powder containing coal-tar, sulphate of iron, etc., which he used to kill insects and to preserve wood. In 1858 a French surgeon, named Demeaux, used for the treatment of wounds a patent powder made of coal-tar and plaster, and stated, as a result of his clinical experiments: "The action of this disinfectant substance seems to arrest the work of decomposition." This powder was much used in France and Italy, but met with little success, and soon fell into disuse.

Much more successful, and based much more on sound theory, were Lemaire's experiments with coal-tar saponic, an emulsion of coal-tar and tincture of saponic, invented in 1850 by M. Ferdinand Le Bœuf.

Lemaire made his first experiment in August, 1859, in a case of gangrene. The results were very striking, and Lemaire accordingly continued his experiments in other cases, and finally, in 1863—

Lemaire's experiments.

the date of the discovery of the first microbe of disease—he published his book on carbolic acid.

With true scientific insight Lemaire apprehended the similar nature of fermentation, germination, and suppuration. "With coal-tar emulsion," he writes, "I can arrest and produce at will the formation of pus, as I can arrest and produce fermentation and germination." And again he writes: "With the coal-tar emulsion one can diminish to a very great degree the formation of pus, and one can prevent its decomposition."

Lemaire not only used coal-tar; he analysed and studied it, and he made extensive experiments with its constituent, carbolic acid, which had been discovered by Lange in 1834, and which had been investigated previously, in its disinfectant properties, by Liebig in 1844, and by Calvert in 1851. Lemaire showed that a very small quantity of carbolic sufficed to kill vibrios, spirilla and other micro-organisms; he showed, too, that various forms of fermentation and putrefaction (*e.g.*, the fermentation of beer) were abolished by the same acid, and he suggested numerous applications of its antiseptic properties.

Lemaire must thus be accorded a place of honour as one of the great pioneers of antisepsis, as a chemist who investigated the properties of carbolic acid, as a thinker who knit the correlations of the antiseptic theory, and who saw the relationship between fermentation, suppuration, and disease; but on the other hand it must be recognised that in the practical exposition of the surgical possibilities of antisepsis he played only a small part. He held no surgical appointment; and when we examine his treatment of surgical cases, we find that his material was inadequate, and his methods inchoate. He did not recognise, as did even Bassi, the prophylactic side of antisepsis, and the aseptic idea was beyond his ken.

Bottini.

A greater pioneer of carbolic antisepsis was Bottini, an Italian surgeon, who in 1866 published an article on the use of carbolic acid in surgery and taxidermy. With regard to his researches, he wrote—we quote from Monti's "Modern Pathology": "My investigations extended to more than six hundred patients, watching with the greatest diligence the changes occurring in ulcers dressed with carbolic acid, comparing this medication with others furnished by remedies of the same nature, suspending purposely the carbolic medication to discover how much was to be attributed to the action of this poison, finally not admitting any treatment, in order to be able, with full knowledge of the cause, to deduce these corollaries, which are the fruit of the pure and simple observation of the fact."

Inquiring, "What is the mode of action of carbolic acid in arresting putrid decomposition?" he answered, showing a sound scientific conception of antisepsis: "If it be true that fermentation is the phenomenon produced by the action of a ferment or fermentible matter, and that this erment is a living organism, as Schultz and Schwann have held, and as Pasteur with much ardour has recently confirmed, then the explanation is easy, since we know in a positive way the morbific action of carbolic acid on microphytes and zoophytes."

Considering the number of cases Bottini treated, and his evident grasp of antiseptic principles, he must share with Lister the honour of having put antiseptic theory to practical proof.

In 1865 Lister commenced his immortal work. Heir of all the ages, heir of all the tentative antiseptic doctrine and practice of preceding centuries, heir of Redi, of Bassi, of Latour, Lister was especially heir of Pasteur, whose theory was a sure and firm foundation for his practice. In 1874 Lister frankly and gratefully acknowledges his indebtedness to Pasteur, writing: "Allow me to take this opportunity to tender to you my most cordial thanks for having, by your brilliant researches, demonstrated to me the truth of the germ theory of putrefaction, and thus furnished me with the principles upon which alone the antiseptic system can be carried out."

Lister.

In view of all the preliminary steps of theory and practice already taken, the step taken by Lister might seem both inevitable and small, but it required a giant to take it. Old prejudices are difficult to cross, and even Pasteur's convincing experiments and Lemaire's and Bottini's clinical successes had not carried conviction to conservative minds. Ridoux's doctrine, "Disease is in us, of us, by us," was hard to kill, and the microbic origin of suppuration was not a popular doctrine.

State of things when Lister appeared.

In 1863, the year in which Davaine found the anthrax bacillis and suggested its fermentative action—in 1863, when Pasteur had proved antiseptic principles to the hilt, antisepsis was so inadequately understood and practised that ten women in succession were sent for operation to a house in Paris, and left it in coffins. In their terrified ignorance the neighbouring inhabitants called the house the "House of Crime," yet the only criminals were the microbes, who might have been destroyed with a few drops of carbolic acid.

Despite Semmelweiss's work, too, puerperal fever slew thousands, and in some maternity hospitals there was an attempt to hide the great death-rate from the public by putting two bodies in one coffin.

In hospitals and ambulance wards of every kind the fatal germs of pyæmia and septicæmia (varieties of blood poisoning), of gangrene, of erysipelas were rampant. In the Krankenhaus at Munich "80 per cent. of the wounds became affected with gangrene, and filled the surgical wards with horror."

In 1868 the death-rate, after amputation in hospitals, was over 60 per cent., and, as Velpeau remarked, "a pin-prick was a door for death." Lingo Porto, a well-known Italian surgeon, was so accustomed to deaths that he regarded his patients chiefly as material for his famous museum.

In the American Civil War almost all abdominal and head wounds proved fatal; and when the driver of an ambulance wagon was asked if he knew how to treat wounded men, he replied: "Oh, yes; if they are hit here"—pointing to the abdomen—"knock 'em on the head: they can't get well." This reminds one of the story of Ambroise Paré, who one day during a battle saw three desperately wounded soldiers placed with their backs against a wall. An old campaigner inquired, "Can these fellows get well?" "No," answered Ambroise. Thereupon the old campaigner went up to them and cut all their throats "sweetly and without wrath" (*doucement et sans colère*).

During the Franco-German War of 1870, the ambulance wards were infernos of suffering. Sédillot writes: "Places where are those that are wounded are recognisable by the fœtor of suppuration and gangrene." Vallery-Radot, in his "Life of Pasteur," declares: "It was a perpetual agony; the wounds of all the patients were suppurating, a horrible fœtor pervaded the place, and infectious septicæmia was everywhere." "Pus seemed to germinate everywhere," said a student of the time—M. Landouzey, who became a Professor at the Faculty of Medicine—"as though it had been sown by the surgeon." This M. Landouzey also relates how M. Denonvilliers, a surgeon of the Charité Hospital at Paris, used to say to his pupils: "When an operation seems necessary, think ten times about it, for too often when we decide upon an operation we sign the patient's death-warrant."

The remedy was at hand. Reason and experience both pointed to it, yet death was permitted to pile up his hecatombs.

It was only at the end of the Franco-German War that a surgeon, Alphonse Guérin, began to think that the cause of all the suppuration and gangrene might possibly be due to the germs Pasteur had made such a fuss about. With this idea on his mind Guérin imagined that he might protect the wounded from the fatal assault of the germs by filtering the air through cotton-wool, even as Pasteur had filtered the air entering his test-tubes by filling their mouths with plugs of cotton-wool. Not a bad idea! "After arresting the bleeding," says Vallery-Radot, "ligaturing the blood-vessels, and carefully washing the wound with carbolic solution or camphorated alcohol, Alphonse Guérin applied thin layers of cotton-wool, over which he placed thick masses of the same, binding the whole with strong bandages of new linen. This dressing looked like a voluminous parcel, and did not require to be removed for about twenty days. This

Alphonse Guérin tries to keep out the germs.

vas done at the St. Louis Hospital to the wounded ɔf the Commune from March till July, 1871. Other ;urgeons learnt with amazement that out of :hirty-four patients treated in that way nineteen ıad survived operation."

Such were the Augean stables Lister had to :leanse with his rivers of carbolic acid; but by :raining, by tradition, by character, he was fitted or his great mission. He married the daughter ɔf a great surgeon, and his father, Joseph Jack-;on Lister, was a scientist and Fellow of the Royal Society, whose improvements of the microscope, ınd whose investigations into certain character-stics of the red blood-cells must have been an nspiration and an example.

Graduating in medicine in London in 1852, Lister at once showed his scientific bent. In 1853 ıe published papers on the muscular tissue of he skin and the contractile tissue of the iris, and ɔetween 1857 and 1862 he published remarkable ınd illuminating treatises dealing with inflamma-ion and the coagulation of the blood.

Nor was he only a theorist; he was also a ɔractical surgeon, and in 1860 he was appointed Professor of Surgery in Glasgow University. A plendid picture of him as surgeon was drawn by Henley in his well-known lines "The Chief":

"His brow spreads large and placid, and his eye
Is deep and bright with steady looks that still;
Soft lines of tranquil thought his face fulfil—
His face at once benign, and proud, and shy."

The poet also speaks of his "wise, rare smile" as being "bright with certainties," and as seeming "in all his patients to compel such love and faith as failure cannot quell."

Lister, as we have said, began his antiseptic experiments in 1865, and in a series of papers communicated to the *Lancet* in 1867, and entitled, "On a New Method of treating Compound Fracture, Abscess, etc., with Observations on the Conditions of Suppuration," he describes his first cases. He lays down at once as the basis of his methods the principles established by the philosophical researches of Pasteur. "Bearing in mind," he says, "that it is from the vitality of the atmospheric particles that all the mischief arises, it appears that all that is requisite is to dress the wound with some material capable of killing these septic germs, provided that any substance can be found reliable for the purpose, yet not too potent a caustic." He next relates how he was led to choose carbolic acid as his antiseptic, because he had been "much struck by an account of the remarkable effects produced by carbolic acid upon the sewage of the town of Carlisle, the admixture of a very small proportion not only preventing all odour from the lands irrigated with the refuse material, but, as it was stated, destroying the entozoa which usually affect cattle fed upon such pastures. . . . I saw that such an antiseptic was peculiarly adapted for experiments with a view to elucidating that subject [suppuraon], and while I was engaged in the investiga-on the applicability of carbolic acid for the treat-ent of compound fracture naturally occurred me."

Carbolic acid had been used in wounds y Cruveilhier, Follet and Rigault as far back 1859. In 1860 it was used by Barrican id Petit for compound fractures; in 1861 it as extensively used by the celebrated French rgeon, Maisonneuve; while in 1866, as we have en, Bottini published remarkable results ob-ined by its use. It had also been used by Dr. R. Wolff of Aberdeen, and by Dr. John Wood Edinburgh, before Lister commenced his experi-ents.

Of these previous experiments, and of the re-arches of Lemaire, Declât, Demeaux, etc., Lister parently knew nothing, and he selected carbolic id for the rather empirical reasons we have stated.

An attempt is sometimes made to diminish ster's fame, by pointing to the work of these evious experimenters; but Lister's claim to ne rests not upon the discovery of carbolic acid, t upon his conclusive demonstrations of its anti-otic utility, by successful antiseptic methods.

His original methods were crude, and were adually modified, and improved, in the light of perience, but from the first his science and his art were allies, and from the first his results were remarkable. At asgow Infirmary, before the introduction of his

er's results.

methods, the death-rate in his wards following amputations was 45.7 per cent.; while during the first three years of antiseptic treatment it fell to 15 per cent., and he was able to state that his wards were the healthiest in the world, while other wards, separated from his "only by a passage a few feet broad, where former modes of treatment were for a while continued, retained their former insalubrity."

Lister's results and theories met with a mixed reception; some received them with welcome, others with scorn. Professor Nussbaum, of the Krankenhaus at Munich, where, as as we have seen, 80 per cent. of the wounds became affected with gangrene, introduced Lister's antiseptic treatment, with the result that "from that day hospital gangrene ceased in the Krankenhaus."

Reception of Lister's doctrines.

Professor Sédillot, too, welcomed the new surgery with enthusiasm, and it had many other ardent supporters; but, on the other hand, the new treatment had its bitter foes. "People," writes Dr. Auguste Réaudin, of Geneva, "turned into ridicule Lister's minute precautions in the dressing of wounds, and those who had lost nearly all their patients by poulticing them, had nothing but sarcasm for the man who was so infinitely superior to them." Pouchet admitted that a few germs did fly about here and there, but he considered the germ theory and its corollary, the antiseptic treatment, as ridiculous fiction. Chas-

Photo: Elliott & Fry.

THE RIGHT HON. LORD LISTER, O.M.

saignac, a well-known surgeon, ridiculed Lister's treatment as "laboratory surgery which has destroyed very many animals and saved very few human beings."

Despite sarcasms and opposition, however, Lister's treatment fought its way and won.

It may be asked, Why did Lister succeed where so many had failed?

Why Lister succeeded.

Lister succeeded because his surgical methods were the fruit at once of science and of art; he had confidence in his scientific doctrines, and technical skill to carry those doctrines to their practical logical conclusions. Some failed through lack of the courage of their opinions; some through lack of scientific imagination; some through lack of technical skill: Lister alone had the combination of qualities that ensured success.

To believe that suppuration is due to germs is one thing; to see all that that belief involves is another thing; and to base on the belief successful surgical practice still another thing.

It seems easy nowadays to realise the slimness of the microbes, to realise that a speck on a polished knife may be large enough to slay a city; that pyæmia sufficiently virulent to rot a strong man may lurk under a little finger-nail; and that the pores of an unclean sponge may be Stygian caves of disease. It seems easy to realise that, and to understand that the methods of surgery must therefore be as minute, and meticulous, and scrupulous, as the experimental methods of Pasteur, which laid their scientific foundations. Yet even *now* some nurses, and Christian Scientists, and even doctors are found who lack the imagination to realise the unseen, and *then* the idea was new and strange, and it required courage to accept it; and it required a man of "faultless patience, of unyielding will," of indomitable faith in the invisible, of powerful yet delicate imagination, to carry the extraordinary scientific discovery to its surgical conclusions.

Goethe said of Englishmen that they have a masterly power of quickly utilising discovery, and of proceeding to new discovery and fresh achievement. And Lister had the Englishman's practical common-sense combined with a rare amount of imaginative vision. What others attempted, Lister achieved; where others failed, he succeeded; and the result was the birth of the new antiseptic surgery, a daughter of Science and Art, which has saved mankind incalculable suffering. Operations, formerly deadly, are now hardly dangerous; operations formerly impossible are now of daily occurrence.

When Ambroise Paré, the greatest surgeon of his time, was asked if the wound of the King of Navarre was mortal he said, "Yes; because all wounds of great joints, and especially contused wounds, are mortal, according to all those who have written about them." Yet to-day these great joints are constantly opened.

No longer is a pin-prick a door to death; now, even the great cavities of the chest and abdomen are boldly explored. No longer are wards full of the odour of suppuration and of sour poultices. No longer do old campaigners slit the throats of wounded soldiers; no longer do ambulance men knock on the head those with abdominal wounds; for nowadays, under antiseptic treatment, the most desperately wounded often recover.

From antisepsis to asepsis.

It is interesting to trace the development of antiseptic surgery, from its first conception by Lister. At first the dominant idea was to slay the germs in the wounds. This is called the *antiseptic* idea, and with this idea Lister actually cauterised the tissues with pure carbolic acid; but gradually this idea was replaced by the wiser idea—the aseptic idea—to prevent the approach of any germs. Surgery is now essentially *aseptic*. The modern surgeon's chief endeavour is to prevent the access of germs to surgical wounds. So far as possible all the germs on the surgeon's and patient's skin are killed before the commencement of the operation by a suitable antiseptic, and all instruments and sponges and everything likely to be in contact directly or indirectly with the wound are sterilised by heat or chemicals. Some surgeons wash their entire body and change their whole clothes before an operation. Some shave off their moustache, others merely disinfect it. Some surgeons disinfect their mouths or wrap rolls of gauze round their mouths and nostrils. In some cases the precautions taken seem excessive; but the responsibility is now tremendous, for every wound that suppurates means that the surgeon has permitted the access of germs, and sometimes a little suppuration may mean the difference between a stiff and a useful limb, between a blind and a useful eye, even between life and death. After operation there should be no necessity to apply any strong antiseptic to the wound, and in some cases nothing is used in the dressing except distilled water. Hence the *Times*' famous remark that Lister's arguments grew stronger as his solutions grew weaker.

Lister's antiseptic surgery has probably saved more lives than have died on the battlefields of the world since its discovery, and so long as the world lasts his name must be immortal.

CHAPTER XII.

INOCULATION AND VACCINATION.

History of inoculation—Inoculation of small-pox—Introduced from Europe into England—Lady Mary Wortley Montagu's letter—Sermons against inoculation—Progress—Dangers of the practice—Jenner—His first crucial experiment—Vaccination before Jenner—Farmer Jesty—Opposition—Award to Jenner from Parliament—Fame—A paradox—What vaccination has achieved.

History of inoculation.

INOCULATION, though generally considered a modern invention, is really a defensive device of ancient and empiric origin. Among savage and primitive peoples there are many interesting instances of inoculation to be found.

A Portuguese soldier, Colonel Serpa Pinto, relates in a letter written to M. Abbadie how he was inoculated against serpent venom by the savages in North-east Africa. They mixed the venom of serpents with certain vegetable juices, and then rubbed the brown paste so obtained into incisions in the skin of his arm. The inoculation was followed by pain and swelling, and seemed to produce an immunity to certain poisons, since the Colonel was afterwards bitten by a serpent without bad effect. How the savages could have found out this method of treatment it is difficult to guess. Still, they practised it, and apparently obtained good results from the practice.

The Moors and Pouls of Senegambia have, as De Rochebrune reported, for ages inoculated their cattle against pleuro-pneumonia. "The point of a knife of primitive form or of a dagger is plunged into the lung of an animal that has died of the disease, and an incision, sufficient to allow the virus to penetrate below the skin of the healthy animal, is made into the supra-nasal region." Experience has demonstrated the success of this protective inoculation.

At Berne, in the eighteenth century, similar inoculation against pleuro-pneumonia was practised.

Inoculation against small-pox, though introduced into England only in 1721, had been in vogue amongst Oriental nations for centuries, usually by introducing small-pox crusts into the nostrils—a process known as "sowing" the small-pox. In Hindostan inoculation seems to have been practised before the Christian era. In China, and probably in Persia and Ashanti, it was certainly practised in the eleventh century. According to Caffen Aga, Ambassador from Tripoli in the eighteenth century, it had been practised in Tripoli, Tunis, and Algiers so long "that nobody remembers its first rise," and it is "generally practised, not only by the inhabitants of the towns, but also by the wild Arabs." His description of the operation as carried out there is rather

Inoculation of small-pox.

interesting. "If anyone," he writes, "hath a mind to have his children inoculated, he carries them to one that is ill of the small-pox, at the time when the pustules are come to full maturity. Then the surgeon makes an incision upon the back of the hand between the thumb and forefinger, and puts a little of the matter, squeezed out of one of the largest and fullest pustules, into the wound. This done, the child's hand is wrapped up with a handkerchief to keep it from the air, and he is left to his liberty till the fever arising confines him to bed, which commonly happens at the end of three or four days. After that, by God's permission, a few pustules of the small-pox break out upon the child. All this I can confirm by domestic proof, for my father carried us five brothers and three sisters to the house of a girl that lay ill of the small-pox, and had us all inoculated the same day. Now he that had most of us all had not above twenty pustules, otherwise this practice is so innocent and so sure that out of a hundred persons that are infected with the small-pox the natural way there die commonly about thirty."

In Circassia, and Greece, and Turkey, the practice was very common. In Circassia the women were specially inoculated, for if they escaped without a scar it increased their market value. In the days of the slave trade, too, it was customary to inoculate the negroes that they might fetch higher prices. And the negroes also voluntarily inoculated themselves.

Dr. Cotton Mather, a famous witch-hunter of Boston, states that even before he had heard of Lady Mary Wortley Montagu's experiment, he had heard of the practice of inoculation from an African servant of his own, who bore the scar. "I have since," he says, "met a number of these Africans, who all agree in one story—'that in their country grandy many die of small-pox; but now they learn this way: people take the juice of small-pox and cutty skin and put in a drop; then by-and-by a little sicky sicky, then a few little things like small-pox, and nobody die of it, and nobody have small-pox any more.' Thus," remarks Dr. Cotton Mather, "in Africa, where the poor creatures die of small-pox like rotten sheep, a merciful God has taught them an infallible preventative."

Inoculation in Europe.

When we come to Europe we find that it was practised here and there in a sporadic way even before its historical introduction into these islands in 1721. In Wales, according to the testimony of Dr. Perrot Williams, writing in 1722, it had been practised for a long time before. "However new," he writes, "the method of communicating the small-pox may appear in this kingdom, yet I am to acquaint you that it has been commonly practised by the inhabitants of this part of Wales (Pembrokeshire) times out of mind, though by another name, viz. that of 'buying the disease.' . . . There is a married woman in the neighbourhood of this place who practised it on her own daughter about a year and a half ago, by which means she had the small-pox favourably, and is now in perfect health, notwithstanding she has, ever since, without reserve, conversed with such as have had that distemper this last summer. In order to procure the distemper to themselves they either rub the matter taken from the pustules, when ripe, on several parts of the skin of the arms, or prick those parts with pins, or the like, first infected with the same matter." And this same Dr. Williams reports that various schoolboys inoculated themselves.

In Scotland also inoculation was sometimes practised. In England, however, small-pox inoculation seems to have been almost quite unknown till in 1713 Dr. Emanuel Timonins, a Fellow of the Royal Society, sent home an account of inoculation as practised in Constantinople. About the same time Dr. Jacobus Pylarnius sent a communication to the Royal Society entitled, "A new and safe method of exciting the small-pox by transplantation."

Inoculation introduced into England.

But these papers, though attracting considerable attention, led to nothing, and the credit of introducing the inoculation method into England must be given to that brilliant woman, Lady Mary Wortley Montagu. Lady Mary Wortley Montagu began her public life at the age of eight at the Kitcat Club. Brought to the club by her father, Lord Kingston, in a merry moment, she was received with acclamations, and feasted with sweetmeats, and was passed from the arms of one poet, or patriot, or statesman, to the arms of another. In later life she was the friend of Addison and Steele and Pope, and many other well-known men; and her letters, especially her letters to Pope, have a famous place in literature.

An historic letter.

One letter is famous not only in literature but in science—the letter written from Constantinople in 1717 to Miss Sarah Chiswell, telling her of the practice of inoculation for small-pox as carried out at Constantinople. "*A propos* of distempers," she writes, "I am going to tell you a thing that I am sure will make you wish you were here. The small-pox, so fatal and so general among us, is here entirely harmless by the invention of ingrafting, which is the term they give it. There is a set of old women who make it their business to perform the operation every autumn, in the month of September, when the heat is abated. People send to one another to know if any of their family has a mind to have the small-pox; they make parties for this purpose, and when they are met (commonly fifteen or sixteen together) the old woman comes with a nut-shell full of the matter of the best sort of small-pox, and asks what vein you pleased to have open. She immediately rips open that you offer to her with a large needle (which gives no more pain than a

ommon scratch) and puts into the vein as much
enom as can lie upon the head of a needle, and
fter binds up the little wound with a hollow bit
f shell, and in this manner opens four or five veins.
he Grecians have commonly the superstition of
pening one in the middle of the forehead, in
ach arm and on the breast, to mark the sign of
he cross; but this has a very ill effect, as all
hese wounds leave little scars, and it is not done
y those who are not superstitious, who choose
o have them in the legs or that part of the arm
hat is concealed. The children or young patients
lay together all the rest of the day, and are in per-
ect health to the eighth. Then the fever begins to
eize them, and they keep their bed two days—
ery seldom three. They have very rarely above
wenty or thirty on their faces, which never mark,
nd in eight days' time they are as well as before
he illness. Where they are wounded there remain
unning sores during the distemper, which I
on't doubt is a great relief to it. Every year
housands undergo this operation; the French
mbassador says pleasantly that they take the
mall-pox here by way of diversion, as they take
he waters in other countries. There is no ex-
mple of anyone that has died in it, and you may
elieve I am very well satisfied of the safety of
he experiment since I intend to try it on my dear
ttle son."

Lady Mary Wortley Montagu *did* have her
boy "engrafted," and about a year later she

writes: "The boy was engrafted last Tuesday, and is at this time singing and playing, and very impatient for his supper. The boy was inoculated by an old Greek woman with a rusty blunt needle in one arm, and by Dr. Maitland with a lancet in the other."

At this time small-pox was a curse to the country: it slew, it disfigured, it blinded thousands, and an unspotted face was seldom to be seen. So universal was it that Sydenham, a famous physician, thought that it was a natural process and arose "from a desire the blood hath to change its state."

Accordingly the introduction and recommendation of inoculation by so distinguished a lady obtained for it at once public notice, and interest in the method increased when Lady Montagu's daughter and a son of a Dr. Keith were successfully inoculated.

And yet, in spite of such illustrious examples, the public fought shy of inoculation, and in some quarters the method met with fierce opposition. Some clergymen asserted that inoculation was a "horrid murder of the little unoffending innocents," that it was "suicide," and that it was at once impious and unavailing to counteract the visitations of an all-wise Providence." Others, both in England and America, preached and practised inoculation.

In the medical profession opinion was divided. Some doctors, such as Dr. Wagstaffe, M.D., F.R.S., of St. Bartholomew's, and Dr. Dolbonde, of Boston, condemned the practice as dangerous and uncertain. Others approved it. On the whole, public opinion was in favour of the treatment.

In 1722 the Princess of Wales, after experiments on some charity children, had two of her own children inoculated. The Princess of Wales also begged the King to pardon some Newgate criminals under sentence of death on condition that they should consent to be inoculated, with the result that successful experiments were made on six condemned criminals.

Strangely enough, though Lady Mary Montagu influenced royalty, she failed to influence her own friends, and her own nephew and the very friend to whom she wrote from Turkey died of small-pox.

Progress of inoculation.

In spite of opposition, the practice made steady headway. In 1746 an inoculation hospital was established; in 1754 the College of Physicians issued the following declaration of faith: "The College, having been informed that false reports concerning the success of inoculation in England have been published in foreign countries, think proper to declare their sentiments in the following manner, viz.: That the arguments which at the commencement of the practice were argued against it have been refuted by experience, that it is now held by the English in greater esteem, and practised among them more extensively than ever it was before, and that the College thinks it to be highly beneficial to the human race."

So prevalent was the practice that in two years one famous inoculator, Sutton, inoculated no less than 13,792 subjects, and this operator denied that a single patient had died *fairly* of the inoculation. Another famous inoculator, Dimsdale, went across to Russia, and after experiments had been made on six cadets, he was permitted to inoculate the Empress of Russia and her own son Paul. Dr. Dimsdale remarks, rather quaintly, "The Empress and the Grand Duke were pleased to permit several persons to be inoculated from them, and by that condescension the prejudice which has reigned among the inferior ranks of people—that the party would suffer from whom the infectious matter was taken—was most effectually destroyed."

There can be no doubt that inoculation "softened the virulence and diminished the dangers of small-pox"; but small-pox still continued, and indeed—since no precautions against infection were taken—each person inoculated served to disseminate the disease. One of Dr. Maitland's earliest cases, a child of the name of Mary Butt, infected six servants who had caressed her.

Dangers of inoculation.

In a report of the diseases of London, 1796–1800, Dr. Willan records: "A child was inoculated in April, whose parents kept a shop in a court consisting of about twenty houses. As the inhabitants repaired every day for necessary articles to the source of infection, the consequence was that seventeen persons were affected with the small-pox in the natural way, within a fortnight after the child's recovery, and eight of them died of the disease."

In Boston seven hundred and sixty persons died during the first three months of inoculation, and the town became "a mere hospital."

So far did inoculation fail that at the end of the eighteenth century one child out of each fourteen died of small-pox, while the average annual death-rate for small-pox for Europe was 210,000. During epidemics the death-rate from small-pox was still higher, and in Russia during one year no less than two million died.

Dr. Lettson reported to a Parliamentary Committee in 1802 that during the thirty years preceding the introduction of inoculation the death-rate from small-pox averaged 72 per thousand, and that during the thirty years following the introduction of inoculation it rose to 89 per thousand; and this Parliamentary Committee found that though by inoculation "individual lives are certainly preserved, and it is true that a smaller loss happens in equal numbers who undergo small-pox now than there was formerly, yet it must be admitted that the general prevalence of inoculation tends to spread and multiply the disease itself, of which, though the violence be much abated by the present mode of treatment, the contagious quality remains in full force."

It was evident, therefore, that unless in conjunction with a careful system of quarantine such as was ably advocated by Dr. Hayward in 1777, or unless universally practised, inoculation saved individuals, but endangered the community, and that its abolition would be for the greater good of the greater number; and, indeed, in France and Spain it was soon suppressed.

It was very disappointing, but yet the conquest of small-pox was at hand. In 1749 in the vicarage of Berkeley, in Gloucestershire, Edward Jenner, the conqueror of the vile disease, was born. At that time inoculation was in vogue, and Jenner, after a preliminary period of bleeding and starving and purging, was duly inoculated.

Jenner.

When still a child, Jenner showed a distinctly scientific bent, collecting eggs and fossils with great enthusiasm; and it was only natural, therefore, that medicine should be chosen as his profession. Medicine he studied under a Dr. Ludlow, at Sodbury, near Bristol, and under the celebrated John Hunter, in London. There can be little doubt that his association with John Hunter stimulated his scientific zeal, and indirectly led to his world-famous researches; but it was at

Sodbury that he had the first inkling of the idea he afterwards developed. The idea occurred to him by chance, as it must have occurred to others before him; but in his case it fell on fruitful soil.

It came to him in this way, as told by his biographer, John Baron:

When he was at Sodbury "a young country woman came to seek advice; the subject of small-pox was mentioned in her presence, and she immediately observed: 'I cannot take that disease, for I have had the cow-pox.'" The remark made a great impression upon him, and when he went to John Hunter he mentioned the idea to the great anatomist; and, even though inquiries made among country doctors threw doubt on the protective properties of cow-pox, he still kept the theory in view; and in 1780, as the result of investigations, which must at that date have been very meagre, he confided to a friend that he had great hopes of being able to extirpate small-pox by vaccinating cow-pox.

It may be explained here that cow-pox is a pustular disease of the udders of cows, which causes sores on the hands of those employed in milking.

In 1789 we find Jenner making experiments on his eldest son, then only a year and a half old, with swine-pox. He inoculated the child with swine-pox; and then, at various times, inoculated small-pox. Whether owing to the swine-pox or not, the child seemed immune to the small-pox.

Not till 1796, however, did Jenner make his first crucial experiment. In that year he selected a healthy boy about eight years old, by name James Phipps, for the purpose of inoculation for the cow-pox. The matter was taken from the sore on the hand of a dairymaid. The boy developed a pustule on one of his arms, and when inoculated a few weeks later with the small-pox virus he was found to be immune to that disease.

Jenner's first crucial experiment.

In 1796 or 1797 Jenner sent a paper to the Royal Society with an account of this case, and of the important general conclusions he had reached; but the paper was returned, to be afterwards published in 1798, with additions, as a private pamphlet, with the title, "Inquiry into the Causes and Effects of Variolæ Vaccinæ, a Disease discovered in some of the Western Counties of England, particularly Gloucestershire, and known by the name of the cow-pox."

The paper is undoubtedly light to bear such immense conclusions, and a good deal consists of erroneous and irrelevant matter trying to trace cow-pox to a disease of the horse's heel. Still, it was the first scientific attempt to show the connection between cow-pox and small-pox, and it did much to establish the proposition that cow-pox protects the human constitution from the infection of small-pox.

It must, however, be admitted that though Jenner was the first to endeavour to put the popular belief on a scientific basis, he was not the first to put the belief to experimental proof. With such a tradition prevailing, it would be strange if there were not instances of intentional vaccination for purposes of protection; and we find that there were cases prior to Jenner's experiments where children and adults were intentionally infected with cow-pox as a preventive of small-pox. The best authenticated and the most famous case of vaccination before Jenner is the case of Farmer Benjamin Jesty. It has been proved conclusively that in the spring of 1774 Farmer Benjamin Jesty, of Yetminster, in Dorset, alarmed for the safety of his family during an epidemic of small-pox, inoculated with the vaccine of his own cows his wife and two sons. "Fifteen years afterwards (1789) the sons were inoculated for the small-pox by Mr. Trowbridge, surgeon, of Cerne Abbas, along with others who had not had the cow-pox. The arms of the former inflamed, but the inflammation soon subsided, and there was no fever or other variolous symptom; the latter went through the fever, eruption, and the usual course of the inoculated small-pox."

Vaccination before Jenner.

Farmer Jesty.

In the churchyard of Worth Matravers, near

Swanage, there is a tombstone, with the following inscription :—

Sacred
to the Memory
of
Benjn. Jesty (of Downhay)
who departed this life
April 16th, 1816,
aged 79 years.

He was born at Yetminster in this country, and was an upright, honest man, particularly noted for having been the first person (known) that introduced cow-pox by inoculation, and who, from his great strength of mind, made the experiment from the cow on his wife and two sons in the year 1774.

Thus did common-sense anticipate science!

To Jenner, nevertheless, must be given the honour of having converted the world to the doctrine and practice of vaccination. From 1796 till his death in 1823 he was the recognised champion of vaccination; and not without much fighting did his discovery find a place in preventive medicine. His was a new idea, and the world is afraid of new ideas, and inclined to stone their prophets. The idea had certainly, too, its repulsive side. To inoculate man with a disgusting disease of a cow was certainly not a beautiful practice, even though Coleridge wrote to Jenner: "I have planned a poem on this theme, which, after long deliberation, I have convinced myself is capable in the highest degree of being poetically treated according to our own divine bard's

(Milton's) own definition of poetry as simple, sensuous (*i.e.*, appealing to the senses by imaginary sweetness of sound), and impassioned;" and even though Jenner, himself a poet, was wont to describe the vaccination pustule as "a pearl on a roseleaf."

No; the idea was certainly repulsive, and it is amusing to read the opinions of the day. Dr. Rowley, a well-known doctor of the day, published a long treatise, entitled: "Cow-pox Inoculation no Security against Small-pox Infection, to which are added the Modes of treating the beastly new Diseases produced from Cow-pox."

Opposition.

In this pretentious treatise Dr. Rowley gives a picture of a cow-poxed, ox-faced boy, and writes: "Dr. Moxley, who sensibly first exposed the errors of vaccination, saw the case of the ox-faced boy by desire. He observed to me that the boy's face seemed to be in a state of transforming and assuming the visage of a cow."

"Various beastly diseases," he asserts, "common to cattle have appeared among the human species since the introduction of cow-pox—cow-pox mange, cow-pox abscess, cow-pox ulcer, cow-pox gangrene, cow-pox mortification, and enormous hideous swellings of the face, resembling the countenance of an ox with the eyes distorted and eyelids forced out of their true situation." "Small-pox," he asserts, "is a visitation from God, but the cow-pox is produced by presumptuous man; the former was what Heaven ordained, the latter is perhaps a daring violation of our holy religion."

Mr. Ring, in a treatise on cow-pox, tells of a "lady who complained that since her daughter was inoculated she coughs like a cow, and has grown hairy over her body"; and Mr. Blair was told, on a late excursion into the country, "that the inoculation of the cow-pox was discontinued there because those who had been inoculated in that manner bellowed like bulls."

"The vaccine," exclaimed one anti-vaccinator, "was the damnedest thing ever proposed; he wished the inventors were all hanged, and he would give his vote for its being done." "The most degrading relapse of philosophy that ever disgraced a civilised world" cried another. "Who would marry into any family at the risk of their offspring having filthy, beastly diseases?" inquired still another.

Despite such opposition, however, vaccination became more and more general, and in 1802 Jenner petitioned Parliament to grant him such remuneration for his discovery as "to their wisdom shall seem meet." The petition was referred to a committee which, after a searching investigation of Jenner's claims, reported in his favour, and obtained for him an award of £10,000. The report of the committee was emphatic: "The result, as it appears to your

Award to Jenner from Parliament.

committee, which may be collected from the oral testimony of these gentlemen (with the exception of three of them), is that the discovery of vaccine inoculation is of the most general utility, as it introduces a milder disorder in the place of the inoculated small-pox, which is not capable of being communicated by contagion; that it does not excite other humours or disorders in the constitution; that it has not been known in any one instance to prove fatal . . . and that it tends to eradicate, and, if its use becomes universal, must absolutely extinguish one of the most destructive disorders by which the human race has been visited."

Even after this report the battle raged between the vaccinists and the anti-vaccinists, but all reasonable men were convinced.

In 1802, when Jenner presented his petition, 100,000 had been vaccinated, and year by year the number multiplied. Even women became vaccinators, and one woman vaccinated some thousands of cases. Within a few years vaccination had spread over the whole world.

His rich reward of fame.

Rarely has a scientific discoverer reaped richer reward than did Jenner. "Every extension of the vaccine practice in foreign countries was followed by increasing respect and veneration for the author." In 1803 a ship was sent by the King of Spain to introduce vaccine into the various Spanish colonies. On the ship were twenty-two unvaccinated children, who were to be vaccinated on the voyage and preserve the vaccine, passing from arm to arm. The expedition was received with the utmost enthusiasm, and thousands were vaccinated.

From Pekin to Peru—or, in Jenner's own expression, "from Greenland to the Cape, from the Mississippi to the Ganges"—the treatment spread, and as it spread his fame grew. Poems (one of no less than 286 pages), addresses, diplomas, poured in upon him from all parts of the world. He received the freedom of Dublin, Edinburgh, Glasgow. At Berlin, in 1812, the anniversary of the cow-pox inoculation or the Jennerian Feast was celebrated "very solemnly." Even the Red Indians sent an address and a belt and string of wampum. The address of the Red Indians is so pretty and quaint that we cannot refrain from quoting it: "Brother! Our Father has delivered to us the book you sent to instruct us how to use the discovery which the Great Spirit made to you, whereby the small-pox, that fatal enemy of our tribe, may be driven from the earth. We have deposited your book in the hands of a man of skill whom our great Father employs to attend us when sick or wounded. We shall not fail to teach our children to speak the name of Jenner, and to thank the Great Spirit for the bestowing upon him so much wisdom and so much benevolence. We send with this a belt and string of wampum in token of our acceptance of your precious gift, and we beseech the Great Spirit to take care of you in this world, and in the land of spirits."

Among the most enthusiastic of Jenner's proselytes and proselytisers were the crowned heads of Europe. The Empress of Russia zealously urged vaccination, and ordered that the first child vaccinated should be christened "Vaccinoff." The young Vaccinoff was then conveyed to St. Petersburg in one of her Imperial Majesty's coaches and placed in the Foundling Hospital with a pension for life. Not content with such proof of her favour, the Empress afterwards sent Jenner a valuable diamond ring. The King of Spain and the Emperor of Austria actually released prisoners on Jenner's application. Even Napoleon honoured the great physician in similar fashion by releasing prisoners at his petition, saying on one occasion to Josephine: "Jenner! Ah, we can refuse nothing to that man." Napoleon also issued a decree that 100,000 francs should be at the disposal of the Minister of the Interior for the propagation of vaccination.

So great was Jenner's influence and reputation that persons left our shores, not with a passport countersigned by a Minister of State, but with a simple certificate bearing the name of Edward Jenner; and his biographer, Baron, remarks that probably there was not a civilised nation in the world that would not have paid respect to such a document.

In 1823, while still at the height of his fame, Jenner died of apoplexy.

He was in all respects a lovable man, with many interests and many friends. He had energy and imagination, he wrote clever verses and interesting letters, and during the vaccination controversy he showed good temper, good taste, much firmness of purpose, and much self-reliance. Still, Jenner was not a great scientist, and we are apt to wonder that he should have been the man to make so great a discovery. How did this little dapper practitioner in his blue coat with yellow buttons, and buckskins, and well-polished jockey boots, and broad-brimmed hat—how did this man alight on so great a discovery?

Verily, it is a lesson in the mystery of things! For century upon century Death had been slaying, and blinding, and maiming his millions with this loathsome disease, when one morning a medical apprentice in a country village hears a young woman make a casual remark, and lo! the remark gives birth to a great idea, and the apprentice becomes the bearer of good tidings to the whole suffering world, and the saviour of countless lives!

A paradox.

It is difficult nowadays to conceive the full benefit conferred upon humanity by Dr. Jenner's discovery. The very success of vaccination has made us forget its achievements. Nowadays an outbreak of small-pox is usually parochial and limited; it means to most merely a piece of ribbon round a swollen arm, with a few jests, and a few hours' indisposition; but before the days of vaccination it meant death, and deformity, and blindness to thousands. For centuries small-pox was the greatest captain of Death: it depopulated cities, it exterminated nations: it killed in Europe alone, where its ravages were comparatively slight, hundreds of thousands yearly. In most European countries the yearly death-rate from small-pox was about two thousand per million. In London during the third quarter of the seventeenth century the annual mortality was four thousand per million, and between 1770 and 1780, when inoculation was in vogue, it rose to five thousand.

Ravages of small-pox.

And now? Well, now the death-rate from small-pox is almost negligible. In Sweden the death-rate one year was .2. In Prussia, where compulsory vaccination is thoroughly carried out, the total deaths in one year from small-pox were only four in a population of 16,000,000; while between 1874 and 1896 there was but one death in the whole German army. In Scotland and Ireland the death-rate has been reduced to about four or five per million.

And if, in face of figures like these, sceptics can still be found who doubt the efficacy of vaccination, even more convincing comparative statistics can be produced. During the Franco-Prussian war Prussia had 216,426 of her soldiers vaccinated, while France had only 40,000. In the French army, accordingly, 23,469 soldiers died of small-pox, while in the German army only 316 died.

In the epidemic at Sheffield, again, in 1887–88, among 68,236 vaccinated children there were 353 attacks and six deaths, while among 2,259 un-vaccinated children there were 228 attacks and 100 deaths.

Surely figures like these are quite conclusive, and Jenner must be considered one of humanity's greatest benefactors, worthy of a place beside Lister, and Harvey, and Pasteur.

CHAPTER XIII.

THE DISCOVERY OF ANÆSTHETICS.

Pain—Haschish—Mandragora—Mechanical methods of producing insensibility—Laughing gas—The first tooth extracted under gas—Ether—Dr. Morton and his spaniel—Dr. Jackson anæsthetises himself—The "Yankee dodge" tried in England—The discoverer of chloroform—Objections to anæsthesia—Theology *v.* Chloroform—Operations without anæsthesia.

Pain.

ONE of the great mysteries in life is pain. It has a thousand shapes—hunger, heartache, toothache. It may be merely discomfort, or it may be intolerable agony; but in one form or another, from the cradle to the grave, it dogs and threatens man. In many cases it is salutary and conservative, preventing action that would be detrimental to the organism; but in other cases it appears wholly wanton and purposeless, sapping vitality and even destroying life.

Pain of the most agonising character is often caused by surgical operations, and surgeons of all times have tried to find means of modifying the anguish.

We read in the first chapter of Genesis how, when God made Eve from one of Adam's ribs, he anæsthetised Adam before the operation: "And the Lord God caused a deep sleep to fall upon Adam, and He took one of his ribs and closed up the flesh thereof;" and drugs capable of producing a deep sleep seem to have been known to the surgeons of antiquity.

Haschish.

The drug chiefly used was haschish or Indian hemp. This drug causes hallucinations of space and time, and dulls sense of pain, and diminishes fear of death. "The wine of the condemned," mentioned by Amos, who wrote 700 B.C., was probably haschish, and at various times among various nations haschish was taken or administered before death or torture, and seems to have been very efficacious in deadening pain; indeed, a case is credibly recorded where a criminal of gigantic stature on the rack had toes torn off both feet without suffering. A certain famous Arab chief used to drug his followers with haschish so that they became invulnerable to pain and fear; and the feats of these haschish-eaters gave origin to the word "assassin." Haschish was not only eaten, but, as Herodotus relates, it was also sometimes inhaled, and anæsthesia by inhalation of haschish was probably the first instance of anæsthesia by inhalation.

Mandragora.

Another drug much used to deaden pain was mandragora. Dioscorides, the ancient botanist and physician, writes: "Some boil down the roots in wine to a third part, and preserve the juice thus procured, and give one cyathus of it to cause the insensibility of those who are to be cut or cauterised." Apuleius, writing about 200 A.D., says: "If anyone is to have a member mutilated, burned, or sawed, let him drink half an ounce with wine, and let him sleep till the member is cut away without any pain or sensation."

Preparations of opium were also used. Theoderic, a well-known surgeon of the thirteenth century, used a "spongia somnifera," containing opium, hyoscyamus, hemlock, etc.; and Baptista, in the sixteenth century, used a "pomum somnificum," of similar composition, "the smelling of which binds the eyes with a deep sleep."

These latter were, of course, instances of anæsthesia by inhalation.

There were also various secret remedies, some of which seem to have been very potent. A secret remedy was surreptitiously administered to Augustus II. of Poland, so strong that a diseased foot was amputated without his knowledge, and he did not know his foot was off till the following morning.

A secret remedy.

Shakespeare's references to anæsthetics are very interesting. In *Romeo and Juliet* there are the well-known lines:

> "This distilled liquor drink thou off,
> When presently through all thy veins shall run
> A cold and drowsy humour, which shall seize
> Each vital spirit, for no pulse shall keep
> His natural progress, but surcease to beat," etc.

In *Cymbeline,* also, occur the lines :

> "Those she has
> Will stupefy, and dull the sense awhile,
> Which first, perchance, she'll prove on cats and dogs,
> Then afterward up higher, but there is
> No danger in what show of death it makes,
> More than the locking up the spirits a time,
> To be more fresh reviving."

Middleton, too, in his play, *Women Beware Women,* written in 1657, has the following interesting reference :

> "I'll imitate the pities of old surgeons
> To this lost limb who, ere they show their art,
> Cast me asleep ; then cut the diseased part."

Mechanical methods.

Besides drugs, mechanical means were also employed to cause insensibility. In the fifteenth and sixteenth centuries it was discovered that men and animals might be rendered insensible by pressing on the big arteries that carry the blood to the brain, but this method of anæsthesia was not much used. In the sixteenth century, too, Ambroise Paré suggested compression, and in 1784, a Dr. Moore put the idea into practice, with a fair measure of success.

The beginning, however, of the modern science and art of anæsthetics dates from the discovery of the properties of nitrous oxide, or "laughing gas," by Sir Humphry Davy. Sir Humphry Davy discovered not only that the gas had the exhilarating qualities which its popular name implies, but also that it produced insensibility to pain. In 1800 he writes: "The power of the immediate operation of the gas in removing intense physical pain I had very good opportunity of ascertaining. In cutting one of the unlucky teeth, called the *dentes sapientiæ*, I experienced an extensive inflammation of the gums, accompanied with great pain, which equally destroyed the power of repose and of consistent action. On the day when the inflammation was most troublesome I breathed three large doses of nitrous oxide. The pain always diminished after the first four or five inspirations, the thrilling came on as usual, and uneasiness was for a few moments swallowed up in pleasure. As the former state of mind returned, the state of the organ returned with it, and I at once imagined that the pain was more severe after the experiment than before." Because of its effect in abolishing pain, Sir Humphry Davy suggested that it might be used in surgical operations, but his suggestion bore no fruit for many years, and "laughing gas" was made merely as a chemical curiosity, and its effects were shown merely to amuse.

Laughing gas.

In the month of December, 1844, however, the anæsthetic effects of laughing gas were practically proved. In that month a Mr. G. Q. Colton gave an exhibition at Hartford, in the United States, of the intoxicating effects of laughing gas; and it occurred to a dentist in the audience that the gas might be used to prevent patients feeling pain, and he proceeded to put the idea to the test of actual experiment by having a tooth of his own pulled under laughing gas. The story will perhaps be best told in the actual words of Dr. Riggs, a dentist of Hartford, who pulled the tooth:

The first tooth extracted under gas.

"In the month of December, 1844," he testified, "Mr. G. Q. Colton delivered a course of lectures in this city, on which occasion he exhibited the nitrous oxide, sometimes called 'laughing gas.' On the evening of the 10th of said December, Dr. Wells came into my office after Mr. Colton's lecture, and said that he and others had taken the above gas, and remarked that one of the persons had injured himself and stated, after recovering from the effects of the gas, that he did not know at the time that he had sustained such injury. Dr. Wells then said, 'He did not feel it. Why cannot the gas be used in extracting teeth?' A long discussion then followed between Dr. Wells and myself on that subject, the result of which was, Dr. Wells concluded to try on himself the ensuing day the experiment of having a tooth extracted while under the influence of this gas. He said he had a tooth that occasioned him some inconvenience, and he would take the gas and have the tooth extracted, if I would perform the operation. And I agreed to do so the next morning, remarking that it would be fair to commence the experiment upon ourselves. Accordingly, the next morning Dr. Wells came with Mr. Colton and his bag of gas to his, Dr. Wells', office, and called me in. There were present, besides Dr. Wells and myself, Mr. Colton, Mr. Samuel A. Colley, and some others whose names I cannot now recall. Dr. Wells, after seating himself in the operating chair, took the bag and inhaled the gas, and after he had been brought sufficiently under its influence, he threw back his head and I extracted the tooth. It was a large molar tooth in the upper jaw, such as is sometimes called a 'wisdom tooth.' It required great force to extract it. Dr. Wells did not manifest any sensibility to pain. He remained under the influence of the gas some time after, and immediately upon recovering from it, he swung his hands and exclaimed, 'A new era in tooth-pulling!' He remarked he did not feel any pain from the operation."

Dr. Riggs, during official examination in 1852, further stated: "A few minutes after I went in, and after conversation Dr. Wells took a seat in the operating chair; I examined the tooth to be extracted with a glass, as I usually do; Wells took a bag of gas from Mr. Colton, and sat with it in his lap, and I stood by his side; Wells then breathed the gas until he was much affected by it; his head dropped back, I put my hand to his chin; he opened his mouth and I extracted the tooth; his mouth still remained open some time ; I held up the tooth in the instrument that the others might see it ; they, standing partially behind the screen, were looking on. Dr. Wells soon recovered from the influence of the gas, so as to know what he was about, discharged the blood from his mouth, swung his hand, and said, 'A new era in tooth-pulling!' He said it did not hurt him at all."

Dr. Wells afterwards gave laughing gas in other cases, and, though he had unsuccessful exhibitions in New York and Boston, the anæsthetic value of the gas was quickly established.

But laughing gas has a very transitory effect, and other doctors and dentists began to seek for an anæsthetic more suitable for operations requiring some time to perform.

Among other seekers were a Dr. Jackson and a Dr. Morton, of Boston. The former was a chemist, the latter was a dentist and had been a pupil and afterwards, for a time, a partner of Dr. Wells.

Both Dr. Jackson and Dr. Morton claimed to have discovered the anæsthetic qualities of ether, and for years an interesting controversy raged between the partisans of each. It was a great and important discovery, and it was natural that both should claim to have been the discoverer. The truth probably is that both about the same time obtained a knowledge of the anæsthetic properties of ether, and that Dr. Morton, *encouraged* by Dr. Jackson, pro-

Ether.

ceeded to apply his knowledge to his dental practice. Both told very interesting stories of their discovery, and both sent statements to the French Academy of Science and Art.

It must, however, be recognised that long before Morton made practical use of ether as an anæsthetic, its anæsthetic properties were known. In the *Lancet* of February 13th, 1847, Dr. J. Gorringe states that he had a distinct recollection of two cases of insensibility produced by inhaling ether in the chemical lecture-room in the year 1838–39, the students falling flat upon their backs; and, no doubt, during preceding centuries, similar cases of accidental insensibility must have occurred. Therefore the point at issue between Dr. Morton and Dr. Jackson was not priority in the discovery of the anæsthetic properties of ether, but priority in the application of the discovery.

Dr. Morton and his spaniel.

Dr. Morton, to whom the chief credit and honour are probably due, states that he began his experiments in the spring of 1846. His first really successful experiment was made upon a spaniel. He poured some ether upon some cotton placed at the bottom of a tin pan, and held the dog's head over the cotton. In a short time "the dog wilted completely away in his hands, and remained insensible to all his efforts to arouse him by moving or pinching him," and yet, after the removal of the pan, it quickly recovered. In

August of the same year, when he again tried to anæsthetise the spaniel the dog sprang against the jar and broke it and spilt the ether. Morton thereupon soaked his handkerchief in the spilt ether, and succeeded in anæsthetising himself. "I am firmly convinced," he says, "that at that time a tooth could have been drawn without feeling of pain or consciousness." Encouraged by these results, Morton next experimented on two students, but in these cases he failed to obtain satisfactory anæsthesia.

On September 30th, however, he both anæsthetised himself, and, later in the day, a patient. He gives the following account of the experiment in his report sent to the Academy of Arts and Sciences at Paris: "Taking the tube and flask, I shut myself up in my room, seated myself in the operating chair, and commenced inhaling. I found the ether so strong that 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 nightmare, and would have given the world for someone to come and arouse me. I thought for a moment I would die in that state, and the world would only pity or ridicule my folly. 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. At a second effort

I touched it, but there seemed to be no sensation. I gradually raised my arm and pinched my thigh, but I could see that sensation was imperfect. I attempted to rise from my chair, but fell back. Gradually I regained power over my limbs, and full consciousness. I immediately looked at my watch, and found that I had been insensible between seven and eight minutes.

"Delighted with the success of this experiment, I immediately announced the result to the persons employed in my establishment, and waited impatiently for someone upon whom I could make a fuller trial. Toward evening, a man, residing in Boston, came in, suffering great pain, and wished to have a tooth extracted. He was afraid of the operation, and asked if he could be mesmerised. I told him I had something better, and saturating my handkerchief, gave it to him to inhale. He became unconscious almost immediately. It was dark, and Dr. Hayden held the lamp while I extracted a firmly-rooted bicuspid tooth. There was not much alteration in the pulse, and no relaxation of the muscles. He recovered in a minute, and knew nothing of what had been done to him."

This is Dr. Morton's account to the French Academy, and it certainly sounds quite plausible, and this statement is corroborated by certificates from the patient on whom he operated, and from witnesses of the operation.

That Dr. Morton was the first to perform an operation under ether there can be little doubt; but he was not a particularly veracious man, and the details he gives of the genesis of the idea must be taken with a grain of salt. To the Academy of the Arts and Sciences he gives a plausible, moderate statement; but on other occasions he did not hesitate to decorate his facts.

In October, 1846, Morton was invited to give ether to a patient at the Massachusetts General Hospital. He was late in arriving, and those who were waiting for him began to wax sarcastic. However, just in the nick of time, he entered dramatically, and, according to the records of the hospital, "after four or five minutes the patient appeared to be asleep, and the operation (the cutting out of a tumour) was performed. . . . . To the surprise of Dr. Warren and the other gentlemen present, the patient did not shriek or cry out, but during the insulation of the veins he began to move his limbs and to utter extraordinary expressions. These movements seemed to indicate the existence of pain, but after he had recovered his faculties he said he had experienced none, but only a sensation like that of scraping the part with a blunt instrument, and he ever after continued to say he had not felt any pain."

A man capable of performing such a dangerous experiment, in such a public fashion, must have been a man of indomitable courage and of iron nerve. He was late for the operation; on the success of his experiment depended his own career, and perhaps the life of a fellow-man; he had seen Dr. Wells hissed for his unsuccess on a similar occasion, yet it is recorded that he was cool and calm and collected.

Like Dr. Morton, Dr. Jackson sent a memoir to the Academy of Arts and Sciences in Paris. This is its text:

"*Nov. 13th,* 1846.

Dr. Jackson.

"I request permission to communicate through your medium to the Academy of Sciences a discovery which *I* have made, and which I believe important for the relief of suffering humanity, as well as of great value to the surgical profession. Five or six years ago I noticed the peculiar state of insensibility into which the nervous system is thrown by the inhalation of the vapour of pure sulphuric ether, which I respired abundantly, first by way of experiment, and afterwards when I had a severe catarrh caused by the inhalation of chlorine gas. I have latterly made a useful application of this fact by persuading a dentist of this city to administer the vapour of ether to his patients when about to undergo the operation of extraction of teeth. It was observed that persons suffered no pain in the operation, and that no inconvenience resulted from the administration of the vapour."

It will be noticed that Dr. Jackson says he persuaded a dentist to administer the vapour of ether to his patients, and it is quite possible that he *did* persuade Dr. Morton to make the experiments, though Dr. Morton strenuously denied it. Certainly Dr. Morton and Dr. Jackson afterwards took out a conjoint patent, and it is hardly likely that Dr. Morton would have agreed to share the material fruits of the discovery with Dr. Jackson unless to Dr. Jackson he, to some extent at least, owed the idea.

In a letter dated May 19th, 1848, written to one Joseph Hale Abbot, Dr. Jackson gives an interesting account of how he anæsthetised himself with ether even before Dr. Morton had experimented upon himself: "Having taken," he writes, "a bottle of pure sulphuric ether from my laboratory, I went into my office, soaked a folded cloth with it, squeezed it out slightly, and seated myself in a rocking-chair. Having laid my head back against the rocking-chair, with my feet supported in another, so as to give me a fixed position, I placed the cloth over my mouth and nostrils, and commenced inhaling the ether. The effects perceived by me were at first a little coughing, a sensation of coolness, then warmth and fulness of the head and chest, exhilaration and giddiness, numbness or want of feeling in the feet and legs, a swimming sensation as if I had been afloat in the air, together with a loss of all feeling of the rocking-chair in which I was seated, loss of all sensation of pain in the throat and chest, a state of reverie, and soon entire unconsciousness for a space of time unknown to me. Recovering, I felt a sense of giddiness, but with no desire to move; found the cloth I had moistened with ether had dropped from my mouth; had no feeling of pain in the throat and chest, but began to feel a strange thrilling in the body. In a short time, I felt the soreness in the throat gradually returning, and the distress in the chest also, though much less than it had been before. From the cessation of all pain, and the loss of all feeling of external objects, a little while *before* and *after* the loss of entire consciousness, I was led to infer that the paralysis of the nerves of sensation would be so great during the continuance of the unconsciousness and the total loss of feeling, that a surgical operation could be performed upon the patient under the full influence of ether, without causing him any pain, and, therefore, I prescribed it with full confidence in the result."

We may sum up the matter, therefore, as follows: In 1844 Horace Wells, of Hartford, in Connecticut, established the anæsthetic properties of laughing gas, and two years later Dr. Morton, of Boston, probably encouraged, if not inspired, by Dr. Jackson of the same city, established the anæsthetic properties of ether.

Oliver Wendell Holmes suggested that statues of Morton and Jackson should be set up on the same pedestal, with the inscription "*To E(i)ther.*"

Before leaving the subject of ether it will be interesting to quote an account of the first administration of ether in England. Sir R. Reynolds writes: "The first operation in this country under an anæsthetic was witnessed in University College Hospital. Liston had consented to try the anæsthetic. I can see him now as he said to his students: 'Gentlemen, we are now going to try a Yankee dodge for making men insensible.' . . . At length Peter Squire said, 'He is ready now, sir.' Liston's knife flashed in the air. I took out my watch to count the time, and the leg was on the floor in six-and-twenty seconds. Liston turned to his students and said, 'This Yankee dodge, gentlemen, beats mesmerism hollow.'"

Ether tried in England.

But a greater man than either Wells or Jackson or Morton was soon to discover a greater anæsthetic than either laughing gas or ether.

In the 'forties there was studying in Edinburgh a student called James Simpson, son of a village baker. When this student saw Liston operate on a poor Highland woman without an anæsthetic, he found the sight so terrible that for a time he renounced his medical studies, and though he afterwards returned to medicine he was haunted by the spectre of pain, and never ceased trying to discover some means of alleviation. When ether was introduced, he at once adopted it, and was the first to use it in obstetric practice,

The discoverer of chloroform.

yet finding it in some respects unsatisfactory, he set himself to discover another substance which would have more reliable anæsthetic effects. He was a busy man then, with a huge practice; but when his day's work was done—and often it was not finished till after midnight—he would sit down and inhale various vapours and gases. His assistants, Dr. George Keith and Dr. Matthews Duncan, also risked health and life with similar experiments.

For months no discovery rewarded the brave experimenters, but on a November evening of 1847, Dr. Simpson and his assistants tried the substance chloroform and discovered its wonderful anæsthetic properties. It is right to record that a Linlithgow chemist, Waldie, had suggested the trial of chloroform, and that a French chemist, Flourens, had, a few months before, written on its effects on animals.

The story of the discovery of chloroform is well told by Simpson's colleague, Professor Miller. He writes: "Late one evening—it was the 4th of November, 1847—on returning home after a weary day's labour, Dr. Simpson, with his two friends and assistants, Drs. Keith and Duncan, sat down to their somewhat hazardous work in Dr. Simpson's dining-room. Having inhaled several substances, but without much effect, it occurred to Dr. Simpson to try a ponderous material which he had formerly set aside on a lumber-table, and which, on account of its great weight, he had hitherto regarded as of no likelihood whatever. *That* happened to be a small bottle of chloroform. It was searched for and recovered from beneath a heap of waste paper. And with each tumbler newly charged, the inhalers resumed their vocation. Immediately an unwonted hilarity seized the party: they became bright-eyed, very happy, and very loquacious—expatiating on the delicious aroma of the new fluid. The conversation was of unusual intelligence, and quite charmed the listeners—some ladies of the family and a naval officer, brother-in-law of Dr. Simpson.

"But suddenly there was a talk of sounds being heard like those of a cotton mill, louder and louder; a moment more and then all was quiet—and then, *crash!* On awakening, Dr. Simpson's first perception was mental: 'This is far stronger and better than ether,' said he to himself. His second was to note that he was prostrate on the floor, and that among the friends about him there was both confusion and alarm. Hearing a noise, he turned round and saw Dr. Duncan beneath a chair—his jaw dropped, his eyes staring, his head bent half under him, quite unconscious and snoring in a most determined and alarming manner. More noise still—much motion. And then his eyes overtook Dr. Keith's feet and legs making valorous attempts to overturn the supper table, or, more probably, to annihilate everything that was on it. By-and-by, Dr. Simpson having regained his seat, Dr. Duncan having finished his uncomfortable and unrefreshing slumber, and Dr. Keith having come to an arrangement with the table and its contents, the *sederunt* was resumed. Each expressed himself delighted with this new agent, and its inhalation was repeated many times that night—one of the ladies gallantly taking her place and turn at the table—until the supply was exhausted."

The lady mentioned by Professor Miller was a niece of Mrs. Simpson, and report says that she fell asleep with her arms folded across her breast, crying, "I'm an angel! Oh, I'm an angel!"

Simpson had so much material in his own practice that within a fortnight he had administered chloroform to no less than fifty patients and had established its safety and reliability.

Thus, within a few years, three great anæsthetics were discovered, and the human race was liberated from an intolerable servitude to pain.

Yet, such is human nature, even this great discovery of anæsthesia was received with carping criticism and opposition. Some said anæsthesia was dangerous, others said it was unnatural, others wrong; and Simpson had to fight, as Jenner and Harvey had fought before him, to force mankind to believe, and to take what is good for it.

Objections to anæsthesia.

Certainly, to meddle with consciousness—to poison even temporarily the wonderful nerve-cells of sensation and motion, is an heroic and audacious proceeding; but such a terrible thing as agonising pain surely justifies bold measures

Some of the criticism was easily answered, and a shrewd, pawky Scotsman like Simpson easily killed it with a little commonsense. When an Irish lady exclaimed to Simpson, "How unnatural it is for you doctors in Edinburgh to take away the pains of your patients!" he completely confounded her by retorting, "How unnatural it is for you to have swum over from Ireland to Scotland against wind and tide in a steamboat!"

But the theologians were not so easily crushed, and many of the clergy, both in Britain and America, protested against anæsthesia, even as the clergy in the days of Jenner had protested against vaccination. Their arguments, nowadays, seem puerile and absurd, but those were the days of dogma, and to many of the laity the reasoning seemed right.

"What right have we," asks one clergyman, "to say to our brother man, 'Sacrifice thy manhood—let go thy hold upon that noble capacity of thought and reason with which God hath endowed thee, and become a trembling coward before the presence of mere bodily pain?'" "What right have we," asks another, "as baptised men . . . . what right have we, ungratefully or unbelievingly, to forget all this, and be willing to go under the deep stupor of a *power* the influences of which, and connected with which, we know so exceeding little?"

Another talks of chloroform as "a decoy of Satan apparently offering itself to bless women; but in the end it will harden and rob God of the deep, earnest cries that should rise to Him in time of trouble for help."

When a clergyman is able to talk of robbing God of deep, earnest cries, he is surely beyond the reach of any argument save the toothache or a thumb-screw.

As a rule, the medical profession welcomed the anæsthetics, but even here there were exceptions. Thus we find one doctor writing: "If one death took place out of every 500, and that one was caused by the remedy, would it not be something to meditate upon? Besides, there might be other consequences—one greatly feared—*insanity*." "Should I," writes a Dr. Greig, "exhibit it to a thousand patients merely to prevent physiological pain, and *for no other motive*; and should I, in consequence, destroy only one, the least of them, I should feel disposed to clothe me in sackcloth and cast ashes on my head for the remainder of my days. What sufficient motive have I to risk the life and health of one in a thousand in a questionable attempt to abrogate one of the general conditions of man?"

A midwifery professor in Dublin foolishly wrote that "he did not think any one in Dublin had as yet used anæsthetics in midwifery; that the feeling was very strong against its use in ordinary cases, merely to avert the ordinary amount of pain which the Almighty had seen fit—and most wisely, no doubt—to allot to natural labour; and with this feeling he (the writer) most heartily concurred." Simpson's private comment on this remarkable epistle at once showed his opinion of it, and ridiculed the objection out of existence. He skilfully parodied the letter thus: "I do not believe that anyone in Dublin has as yet used a carriage in locomotion; the feeling is very strong against its use in ordinary progression, merely to avert the ordinary amount of fatigue which the Almighty has seen fit—and most wisely, no doubt—to allot to natural walking; and in this feeling I heartily and entirely concur."

But most of the doctors who opposed anæsthetics were mental weaklings: the kind of man who tried to treat the pains of child-birth by hanging the husband up by his feet in the next room till the labour was over. This was actually sometimes done.

Simpson answered even the most absurd objections with patience and logic and wit; and when he failed to convince, sometimes pain came and personally clinched his arguments.

Dr. Rice, of New York, relates a good story of theology *versus* chloroform. He tells how he attended in 1850, with Professor Morill Wyman, of Cambridge, an operation on a respectable farmer, who had, by some accident, divided one of the arteries in the palm of his hand. As it had been

Theology *v.* chloroform.

found impossible by any method to stop the bleeding, it was deemed necessary to tie at the wrist the artery which supplied the blood. "The operation is not by any means a grave one, and only in a moderate degree painful, as the incision through the skin required is but small. Nevertheless, to obviate even this degree of pain, the precaution was taken to carry a small vial of ether.

"The patient had been previously warned of the necessity of the operation, and that something would be given him to prevent any pain. But on arriving at the house, we were met by his wife, who, calling us aside, informed us that her husband, after a conversation with her, had decided not to inhale the ether, the reason being that they both considered it wrong; she added that, having fortified himself by prayer, he felt himself sufficiently prepared, and would not endeavour to escape any of that punishment which had been ordained man for his sin.

"Of course, to this information no answer was to be made, and preparations were accordingly commenced for the operation, while the good wife adjourned once more to her husband's room to further strengthen his resolution by an additional prayer.

"When all was ready and with a last kiss his wife had left the room, the good farmer's hand was placed in the proper position upon a small table. Then the surgeon, with one clean, quick cut, divided the skin immediately over the artery.

This was actually the only painful part of the operation, the sensitive nerves lying almost wholly in the skin. But the good farmer was hardly as much fortified as he supposed, for with a terrific yell which could have been heard almost as far as a steam-whistle, he broke from the hands which endeavoured to restrain him, and ordered a discontinuance of the operation.

"'Phew!' said he, 'that was awful. Why, doctor, I didn't know it was to hurt like that.'

"'Certainly,' said Dr. Wyman, 'I told you it would pain some. How do you expect any cutting can be done and you not feel it? Come, my good friend, sit down and let me finish; it will soon be through.'

"'But wait—is it going to hurt like that all the rest of the time?'

"Dr. Wyman, with a severe struggle to keep his countenance, at the peculiar appearance and disordered air of the worthy man, answered that it would in some degree, but not nearly as much.

"'Yes, doctor; but I can't stand it. You say that the stuff you have in that little bottle will keep me from feeling it? You do? Well now, doctor, do you think it would be really wrong to take it? Say just a little, enough to keep off the worst of the pain, but still let me feel it some—of course, you don't. You are a good man, doctor, and you wouldn't do anything wrong, I know. Besides, if you recommend it to me, the blame ought to fall upon you!' After pausing a moment in deep agitation, he suddenly brought his huge fist with a loud thump upon the table, and, with a preliminary specimen of *muscular English*, exclaimed: 'Well, wicked or not wicked, doctor, I guess I'll go the ether.' With the action of the ether his religious scruples entirely vanished, and a few moments later saw him completely insensible and the operation finished.

"The amazement and quiet look of reproach of his wife, when on entering the room she was informed of what had been done, was inimitable. The poor husband, still half tipsy from the effects of the anæsthetic, conscious that he had offended the good opinion of his better half, yet sure that she would have done the same had she been in his place, endeavoured to reason with her. But his tongue was a little too much out of his control for him to be very intelligible, and his brain was quite too much affected for the excuses to be other than of the lamest kind. The scene was particularly amusing to all spectators."

What anæsthetics mean to surgery it is difficult to realise. One has become so accustomed to the spotless peace of the modern operating theatre that one forgets how it was formerly a very chamber of horrors —that the patient, instead of lying still and motionless, with his senses lost "in the thick, sweet mystery of chloroform, the drunken dark, the little death in life," used to writhe in agony. In olden days only men of

Operations without anæsthesia.

iron will and coarse nervous system could face the terrible scenes of the operating room. The great French surgeon, Ambroise Paré, though he did not mind pouring boiling oil on wounds, was sickened by the aspects of surgery, and, as we have mentioned, Simpson was fain to give up medicine when he first saw the sufferings of a woman in the hands of a skilful operator. When we think of all the torture inflicted on sensitive women, or tender children, before the days of anæsthetics—when we think of Nelson's brave sailors, with their bleeding stumps plunged in boiling pitch, in the gloom of the orlop deck, it makes our blood run cold. To an imaginative patient, the waiting for an operation must have been almost indescribably terrible. Some patients, indeed, died of fear before the operation began.

A doctor patient of Simpson's, who had undergone an operation without chloroform, wrote to Simpson: "Before the days of anæsthetics a patient preparing for an operation was like a condemned criminal preparing for execution. He counted the days till the appointed day came. He counted the hours of that day till the appointed hour came. He listened for the echo in the street of the surgeon's carriage. He watched for his pull at the door-bell, for his foot on the stair, for his step in the room, for the production of his dreaded instruments, for his few grave words and his last preparations before beginning; and then he surrendered his liberty and, revolting at the necessity, submitted to be held or bound, and helplessly gave himself up to the cruel knife."

Sometimes the patient's courage completely gave way. On one occasion a patient, horror-stricken by the implements of torture he beheld, fled from Liston's operation-table, rushed shrieking down the corridor, and locked himself into a room. But Liston, a big, powerful man, rushed after him, burst open the door, half-dragged, half-carried him back, and successfully performed the operation.

Here are two descriptions of surgery in old days: "Big drops of perspiration, started by excess of agony, bestrew the patient's forehead; sharp screams burst from him in peal after peal; all his struggles to free himself and escape the horrid torture are valueless, for he is in the powerful hands of men as inexorable as death." "At the first crisp cut of the scalpel agonising screams burst from her, and with convulsive struggles she endeavours to leap from the table. But the force is nigh. Strong men throw themselves upon her, and pinion her limbs. Shrieks upon shrieks make their horrible way into the stillness of the room. At length it is finished, and, prostrated with pain, weak from her exertions, and bruised by the violence used, she is borne from the amphitheatre to her bed in the wards to recover from the shock by slow degrees."

These are not overdrawn, sensational pictures. They are descriptions by unemotional surgeons.

Such was surgery *then*. And *now?* Let us hear the words of a poet, Sir Edwin Arnold, who himself went under the knife on an operating table:

"Not till 1847," he writes (1844 would be the more precise date)—"not till 1847, although Humphry Davy had been so near the revelation, did the anæsthetic age commence, giving to your art a sure control of anguish, to its boldest practice confidence, quiet, and leisure, and to those who have to lie under that knife a sweet and complete oblivion. I have myself known what it is to pass fearless of the kind steel into that world of black velvet tranquillity of which your magic drugs now keep the gate, and to awake as good as healed, grateful beyond words for the soft spell of enchanted peace and the sure and faithful skill."

That is surgery *now*—a world of black velvet tranquillity from which the patient awakens to find that a leg, or an arm, or a kidney is gone.

Whether to anæsthetics or antiseptics the world owes the greater debt it would be difficult to say, but certainly since the world was created it has received no greater blessings than these two discoveries. They are the two great practical romances of medicine!

CHAPTER XIV.

HYDROPHOBIA AND PASTEUR.

Quaint methods of treatment—Suffocation—A brain-storm—Pasteur's investigations—Pasteur and the mad bull-dog—From dog to human being—Pasteur's hopes and fears—A little hero—A great-minded scientist.

THERE is perhaps no disease, not even leprosy, so terrible to the popular imagination as hydrophobia.

The malady has certainly existed for many centuries. Ancient literature has many references to it. One of Homer's warriors, Teucer, calls Hector a "mad dog," and Aristotle clearly describes the disease. Celsus also describes it, and advises that the wound be cauterised, and that the patient be "suddenly, without warning," thrown into a fish-pond, "alternately, if he has no knowledge of swimming, plunging him under the water that he may drink, then raising his head, or, if he can swim, forcing him under it, and keeping him below till he is filled with the water; so that the thirst and the water-dread may be distinguished at the same time." After this Celsus advises a warm oil bath. The bolder practitioners carried out this treatment,

Quaint methods of treatment.

advised by Celsus, very vigorously, believing that the more nearly they suffocated the patient the better. Thus, the distinguished scientist, Van Helmont, the same who made mice out of basil, was wont to keep his wretched patient under water till the whole Psalm *Miserere* was sung, a proceeding which, as Dr. Good quaintly remarks, took a varying time, according to the choristers. And M. Morin relates a case of even more drastic treatment: he tells how a young woman suffering from symptoms of hydrophobia was plunged into a tub of water in which was dissolved a bushel of salt, and was dipped and dipped "till she became insensible, and at the point of death, when she was still left in the tub, sitting against its sides." When she recovered her senses "she found herself (according to accounts) capable of looking at the water, and even of drinking it without choking."

The water-cure seems to have had much reputation for a time, and Sir Thomas Browne (author of "Religio Medici") writes of those suffering from hydrophobia "who are afraid of their proper remedy, and refuse to approach any water, though that has often proved a cure unto the disease."

Other doctors, however, preferred bleeding to drowning, and patients were bled almost to death. One miserable patient, we read, was bled nearly to death, and was then given nothing but bread and water for a year; and another man was bled to the extent of six pints in a week.

Besides such drastic treatment, medicinal treatment was also used, and some remarkable remedies were proposed. Pliny the elder advised the liver of mad dogs. Galen thought crayfish eyes better. Certain plants, too, had for a time a vogue, and their name still bears witness to their repute—*e.g.*, Lichen caninus, Madwort, or Alyssum. An interesting treatment seems to have prevailed about the beginning of the nineteenth century—*i.e.*, the drinking of the blood of a rabid animal; and Dr. Good makes an interesting suggestion, quite prophetic of serum treatment, that since distemper seemed to prevent hydrophobia in dogs, the inoculation of the catarrhal fluid of distemper might have a curative effect.

In the more recent centuries treatment very often took the form of suffocating the patient. According to the popular superstition, the disease transformed the nature of a man into the nature of a dog, and the victims of this most terrible calamity were promptly suffocated—sometimes at their own request. Indeed, as late as 1810 the following Bill was proposed in France: "It is forbidden, under pain of death, to strangle, suffocate, or bleed to death, or in any other way, murder individuals suffering from rabies, hydrophobia, or any disease causing fits, etc."; and the French papers of 1819 report the suffocation between two mattresses of a victim of hydrophobia.

Suffocation.

Dreadful in reality, the terrors of the disease have been magnified by ignorance and superstition. As a matter of fact, hydrophobia does not change the character of a man into the character of a dog, and the barkings are really efforts to clear the throat of tough phlegm, or are due to spasms of the diaphragm and of the muscles of the throat.

A brain-storm.

Regarded scientifically, hydrophobia is essentially a "brain-storm." The expression "brain-storm" has passed into the current coin of the language, and, using the term in a broad and general sense, we may say that hydrophobia is a fierce and fatal brain-storm. The poison of the disease, inoculated into the blood, affects chiefly the nerve centres, and the result is a series of fierce spasms. As a rule, the intellect remains clear to the end, and the storm rages solely in the motor centres. Till the later decades of the nineteenth century, no man had suffered from hydrophobia and lived. Cases of recovery, it is true, had been from time to time reported; but these were almost certainly cases in which hysteria had simulated the disease; and, indeed, the success of the water-cure points to such confusion.

Pasteur's investigations.

In 1880 Pasteur turned his attention to hydrophobia. It seems rather strange that with cancer, consumption, malaria still waiting solution, he should have chosen this comparatively rare disease; but perhaps he had personal reasons for the choice. When he was a child of nine a rabid wolf appeared

PASTEUR IN HIS LABORATORY. (FROM THE PAINTING BY A. EDEFELT.)
(By permission of Messrs. Goupil & Co., Paris.)

was known about the disease, and crayfish eyes and other empiric remedies were still under consideration. At once he began by scientific experiment to put the problem on a scientific basis. By patient investigation he established that the poison of the disease was to be found not only in the saliva of the rabid animal, but also, and chiefly, in its nervous system.

Pasteur and the mad bull-dog.

The picture of the preliminaries of one of Pasteur's experiments is most dramatic. We will give it in the words of his biographer, Vallery-Radôt: "One day Pasteur, having wished to collect a little saliva from the jaws of a rabid dog, so as to obtain it directly, two of Bourrel's assistants undertook to drag a mad bull-dog, foaming at the mouth, from its cage. They seized it by means of a lasso and stretched it on a table. These two men, thus associated with Pasteur in the same danger with the same calm heroism, held the struggling, ferocious animal down with their powerful hands, whilst the scientist drew, by means of a glass tube held between his lips, a few drops of the deadly saliva." Surely that is a dramatic picture—the grey-bearded, furrowed old man sucking the saliva from the jaws of a mad dog.

Pasteur's father had received the Cross of the Legion of Honour for bravery on the battlefield: surely the son deserved a similar honour for bravery in the laboratory.

Fearlessly, indefatigably, confidently, Pasteur prosecuted his investigations, and, fact by fact, he established a series of important conclusions.

By making an emulsion of part of the brain of a rabid dog, and inoculating therewith the brain of a healthy dog, he succeeded in transferring the disease to the healthy animal, so that fourteen days after inoculation characteristic symptoms appeared. He found, further, that the poison could be cultivated in the brains of living rabbits, and that as it was transferred from brain to brain, it became more virulent, till finally it reached a degree of virulence sufficient to cause hydrophobia seven days after inoculation.

These were important facts, but far more important was his discovery that if the nervous tissue were dried, the poison decreased in virulence, till at the end of fourteen days it was harmless, *and that by inoculations of poison growing consecutively stronger, animals could be, so to speak, educated to resist the disease.*

About this time, when Pasteur had succeeded in rendering dogs immune to hydrophobia, and when a Commission was engaged in testing his results, Madame Pasteur writes: "Your father is absorbed in his thoughts, talks little, sleeps little, rises at dawn, and, in a word, continues the life I began with him this day thirty-five years ago."

The Commission we have mentioned made many experiments. They trephined (*i.e.*, cut a circular piece of bone out of the skull) normal and immune dogs, and injected into their brains poison from rabid animals; they let mad dogs bite normal dogs and immune dogs; they experimented upon dozens of dogs; and finally, after some months' investigations, they sent a report stating that magnificent results had been obtained.

By March, 1885, Pasteur had established another important fact, for he writes that he has proved it possible to give such protection that dogs can be vaccinated, and rendered immune to rabies, even if inoculated after they have been bitten by mad animals.

And now came the great question, Was the principle applicable to man? Writing to a friend, Pasteur says: "I have not yet dared to treat human beings after bites from mad dogs; but the time is not far off, and I am inclined to begin with myself—inoculating myself with rabies and then arresting the consequences, for I am beginning to feel very sure of my results."

From dog to human being.

On May 29th, 1885, he had no less than 125 dogs under treatment, and he regrets that he has not more kennels.

Not, however, till July did he make an experiment on a human subject. On July 6th a little Alsatian boy, terribly bitten on the thighs, legs, and hands by a mad dog, was brought to him, and, after consultation with his colleagues, he decided to make the experiment. The child was given a bedroom at Rollin College, and made happy there with the chickens, rabbits, white mice, and guinea-pigs kept there for experimental purposes; and every day he was given an inoculation of the virulent nerve-tissue of a mad dog. At first the injection contained weak poison, but day by day stronger virus was injected. A more dramatic situation can hardly be conceived, and one can imagine the anxiety of Pasteur as the potency of the injection increased. "My dear children," writes Madame Pasteur, "your father has had another bad night; he is dreading the last inoculation on the child; and yet there is no drawing back now."

Pasteur's biographer, Vallery-Radôt, gives a sympathetic account of this time: "Pasteur was going through a succession of hopes and fears, and an ardent longing to snatch little Meister from death. He could no longer work. At nights feverish visions came to him of this child, whom he had seen at play in the garden, suffocating in the mad struggles of hydrophobia, like the dying child he had seen at a hospital in 1880. Vainly his experimental genius assured him that the virus of that most terrible of diseases was about to be vanquished, that humanity was about to be delivered from this dread horror—his human tenderness was stronger than all; his

Pasteur's hopes and fears.

accustomed ready sympathy for the sufferings and anxieties of others was for the nonce centred in the dear lad.

"The treatment lasted ten days. Meister was inoculated twelve times. The virulence of the medulla (brain-substance) used was tested by trephinings on rabbits, and proved to be gradually stronger. Pasteur even inoculated on July 16th, at 11 a.m., some medulla only one day old, bound to give hydrophobia to rabbits after only seven days' incubation; it was the surest test of the immunity and preservation due to the treatment.

"Cured of his wounds, delighted with all he saw, gaily running about as if he had been in his own Alsatian farm, little Meister, whose blue eyes now showed neither fear nor shyness, merrily received the last inoculation. In the evening, after claiming a kiss from 'dear Monsieur Pasteur,' as he called him, he went to bed and slept peacefully. Pasteur spent a terrible night of insomnia. In those slow, dark hours of night, when all vision is distorted, Pasteur, losing sight of the accumulation of experiments which guaranteed his success, imagined that the little boy would die."

But the little boy did not die, and three months later Pasteur described the case to the Academy of Sciences as a "*tentative heureuse*."

The second hydrophobia case treated by Pasteur is worth mentioning, because of its dramatic *mise-en-scène*. The victim of the mad dog's bite, a boy of fourteen, stood up to protect the flight of his comrades. "Armed only with a whip, he confronted the infuriated animal, who flew at him and seized his left hand. After a tremendous struggle, during which his hand was badly bitten, the boy succeeded in overpowering the dog, bound its jaws together with the whip, battered in its head with his wooden *sabot*, and finally dragged it to a stream and held its head under water till it was undoubtedly dead."

A little hero.

It must have been a special satisfaction to Pasteur to save, as he did, the life of this boy; and a very interesting letter, written by Pasteur to his patient, may be given to show the warm heart and practical human side of the great scientist. "My dear Jupille," he writes, "I have received your letter, and I am much pleased with the news you give me of your health. Madame Pasteur thanks you for remembering her. She, and everyone at the laboratory, join with me in wishing that you may keep well, and may improve as much as possible in reading, writing, and arithmetic. Your writing is already much better than it was, but you should take some pains with your spelling. Where do you go to school? Who teaches you? Do you work at home as much as you might? Do you know that Joseph Meister, who was first to be inoculated, often writes to me? Well, I think he is improving more quickly than you are, though he is only ten years old. So mind you take pains, do not waste your time with other boys, and listen to the advice of your teachers, and of your father and mother. Remember me to M. Perret, the Mayor of Villers-Farlay. Perhaps, without him you would have become ill, and to be ill of hydrophobia means inevitable death. Therefore, you owe him much gratitude. Good-bye. Keep well."

A great-minded scientist.

And Pasteur was not only kind; he was also noble and magnanimous. When his treatment for hydrophobia was still *sub judice*, when his reputation depended on its success, a little child was brought to him bitten, thirty-seven days before, by a rabid dog. It was almost certainly too late to save the child, and Pasteur's assistants pointed out to him that if the child died the death would be laid to his account and would discredit his discovery. They begged him, therefore, to make no attempt to save the child's life. "No," said he; "if the child have one chance in ten thousand of recovery I ought to try everything." And he gave the child the chance and bore without flinching the opprobrium which her death brought to him.

To a man with a heart so human, so sensitive, and so sympathetic, the scenes he had to face in connection with his work were most harrowing and harassing, and he suffered greatly; but, nevertheless, he did his duty faithfully and indefatigably.

During a series of ten years 18,645 persons were treated at the Institut Pasteur, with an average mortality of under 5 per thousand, and patients came for treatment from far and wide—Brazil, Egypt, Greece, Morocco, India, the United States.

Thus did Pasteur, to quote the words of his friend M. Velpeau, make "one of the finest discoveries ever made, both from the scientific and the humanitarian standpoint."

Well might the President of the Students' Association say to him, with touching simplicity: "You have been very great, and very good; you have given a beautiful example to students."

CHAPTER XV.

CONCERNING ANTI-TOXINS.

Difficulties of attacking germs of constitutional diseases—Preventive medicine—Dr. Maguire's heroic experiments—Quinine in malaria—Ways in which Nature may be assisted—Diphtheria anti-toxin—Some well-known defensive serums.

We have seen how Lord Lister, building antiseptic treatment on the theory of microbic fermentation, completely routed the germs of surgical suppuration. We have seen, too, how Davaine applied the same theory of fermentation to the disease called anthrax, and suggested that the anthrax germs acted in the blood just as other germs acted in other fermenting fluids. And it might be thought that the treatment which prevented or cured suppuration would be equally practicable in internal germ diseases. But that is not so. To protect wounds from infection by germs, or to kill germs in accessible places, is a much simpler matter than to exterminate the germs in infectious diseases. The germs of infectious diseases do not, as a rule, fight in the open; they are slim and strategic; they dig trenches; they hide behind kopjes; and once they gain entrance to the tissues it is

Difficulties of attacking germs of constitutional diseases.

very difficult to get at them, and the best we can do, in many cases, is just to feed well our own fighting cells, our phagocytes, etc. The germs of consumption, for instance, are barricaded in the lungs; the germs of anthrax swarm in the tissues; the germs of typhoid are entrenched in the bowels and glands; the germs of anthrax and of malaria swarm in the blood; the germs of small-pox have never been discovered.

It is obviously a difficult problem. Still, something can be done.

Preventive medicine.

In the first place, something can be done to prevent the access of germs; we can practise asepsis. This is the principle of preventive medicine. We know that the germs of tuberculosis are found in the matter coughed up by consumptive patients, and we take measures to destroy the expectorated matter, and to prevent infection from this source. We know that typhoid fever germs are contained in the excreta of typhoid patients, and may infect drinking water, and we take steps to disinfect the excreta and we further boil or filter the water. We have recently found that the germ of Mediterranean fever is conveyed by goats' milk, and by giving up goats' milk we can almost put an end to the fever. We have found that the germ of malaria is inoculated by the bite of mosquitoes, and by killing the larvæ of the mosquito and by warding off the mosquito by netting we can baffle the germ.

In the case of consumption even we can practise a sort of asepsis. We cannot actually kill the consumption germs in the tubercular ulcers, but by keeping the patient in a dustless, pure atmosphere, as is done in sanatoriums, we can prevent the access of the germs of suppuration to the raw surfaces, and can thus greatly diminish the danger of the disease.

Quarantine and disinfection in the case of scarlet fever, and measles, and small-pox, and other infectious diseases, are also effective measures in combating the germs.

Enough has been said to show that prevention, which is better than cure, is a valuable weapon in the battle against disease.

But sometimes, in spite of all precautions, the germs of disease gain entrance. What is to be done *then* ? Why not do, as Lister did, it may be asked ? Why not kill the germs *in situ* with bactericidal substances ?

Alas ! in most cases the germs are out of reach. When the germs are localised and within reach it *is* sometimes possible to kill them by bactericides. A cold in the head, a septic sore throat, even consumption of the throat, can be treated by antiseptics ; but in many cases such treatment is quite futile, either because the germs are "ungetatable" or because antiseptics strong enough to kill the germs would also kill the cells of the body.

It might seem possible, for instance, to reach the germs of consumption in a lung by means of inhalations of antiseptic vapours; but, as a matter of fact, it is found that the antiseptic vapour does not reach the microbes.

A more promising idea was to attack the germs in the lungs by means of germicidal substances injected into the blood. A few years ago Dr. Maguire, of Brompton Hospital, made heroic experiments upon himself to discover how strong solutions of a powerful antiseptic, called formaldehyde, might be injected into the veins without danger; and, having decided this point, he proceeded to inject solutions of the antiseptic into the blood of consumptives. He selected a vein of the arm, and by means of a hollow needle injected into it a quantity of the antiseptic. From the vein of the arm the solution was carried by the current of the blood right through the right auricle and ventricle into the heart. The lung was thus saturated with the antiseptic, and, according to theory, all the tubercle bacilli ought to have been killed. It was a brilliant idea, but, alas! the tubercle bacilli remained alive and kicking. They were probably so well entrenched that the antiseptic never touched them, and so the treatment has fallen, more or less, into desuetude.

Heroic experiments.

Dr. William Ewart, of St. Thomas's Hospital, tried similar intra-venous injections with a solution of a silver salt; and Dr. Thomas Dewar has tried injections of iodoform dissolved in ether; but the results are inconclusive.

And as in consumption, so in most other constitutional germ diseases: it has not been found possible to kill the germs in the tissues with ordinary antiseptics.

A notable exception, however, may be mentioned. When the mosquito succeeds in injecting the malaria germ into the blood, it is found possible to kill the germs in the blood by means of quinine. True, the quinine is not usually injected straight into the blood-vessels, but it gets there all the same, and completely paralyses the germs that are browsing so happily upon the blood. But with this exception there is, perhaps, no instance of successful treatment of constitutional germ diseases by antiseptics.

Quinine in malaria.

Ordinary antiseptic treatment being thus inapplicable when germs have gained entrance to the tissues, what other steps can be taken to defeat the invaders?

We have seen in Chapter IX. that when the body throws off an infectious disease it does so either by killing the microbes, or by forming anti-toxins to neutralise the microbic poisons.

Now it has been found that there are several ways in which we may assist Nature in her defensive measures.

Firstly, we may, by means of certain drugs (nuclein, cinnamic acid, etc.), increase the number of the phagocytes, which are also probably the most important source of the germicidal and anti-toxic substances.

Secondly, we may, by giving injections of weakened germs (germs rendered less virulent by artificial means—heat, etc.), gradually fill the blood with anti-toxins sufficiently strong.

Thirdly, we may inject anti-toxins from other sources into the blood to act either as anti-toxins or as germicides.

The first method has not been found of great practical service. The second has been found useful in only a few instances. Vaccination for small-pox is an instance of this method, and Pasteur found it possible to protect animals against strong microbes of anthrax by inoculating them with weak ones.

Diphtheria anti-toxin.

The third method—the injection of serums containing anti-toxins—has been found useful in several instances, notably in the instance of diphtheria; and this instance we will now describe as perhaps the most striking victory of serum treatment.

As we explained in a previous chapter, the microbes of diphtheria live in the mucous tissue of the throat, and from their headquarters there fill the blood with their toxins. The toxins attack the cells of the body, and the cells of the body respond by throwing off anti-toxins into the blood serum which, so to speak, meet the toxins half-way and neutralise them.

In 1890 a Japanese scientist, Kitasato, working with a German scientist, Von Behring, found that if the serum of an animal which had recovered from diphtheria were injected under the skin of another animal which had never had diphtheria, this other animal became invulnerable, or, as the technical term is, *immune* to the poison of the diphtheria. The theory of this is quite simple. The blood of an animal which has recovered from diphtheria contains quantities of unused anti-toxin, and when its serum is injected into a non-immune animal, this unused anti-toxin is, of course, also injected, and confers immunity.

This was obviously a most important discovery, and it became more important still when it was demonstrated that this injection of anti-toxic serum would not only protect an animal against diphtheria, but would even cure an animal already affected.

The whole process was quickly elaborated, and the preparation of anti-diphtheritic serum has become an exact science.

We now manufacture anti-toxin in the blood of the horse with as great certainty as we can make wine out of grape-juice.

The process is this: The microbes are grown in special beef-teas or *bouillons*. After a time the microbes, which have multiplied by millions, are filtered off, and a highly poisonous fluid, filled with the toxins manufactured by the microbes, is left. This bouillon is so poisonous that a few drops may be sufficient to kill a horse.

Well, this bouillon is cautiously injected into a horse. At first small doses are given, and then larger and larger, till as much as two pints may be injected at a time. The result of these progressive injections is that the blood of the horse becomes full of anti-toxins ready for injection into non-immune individuals or into individuals already suffering from diphtheria. A hollow tube is then inserted into the jugular vein of the horse, and blood is drawn off, and after it has coagulated the clear serum is decanted off and used for injection.

Could anything be more ingenious, or more wonderful? The horse poisoned, and made to form anti-toxins in its blood, and these then taken to save the lives of the children of men?

Both the preventive and the curative powers of the anti-diphtheritic serum have been established beyond doubt. If the anti-diphtheritic serum be injected on the first day of illness death almost never occurs and improvement at once follows, while if the injections be given as a preventive, the protection is almost invariably efficacious.

Many other curative and protective serums are now known. Some act by neutralising the toxins of the microbe, some by destroying the microbe. Among the better-known serums may be mentioned the anti-tetanic serum, which neutralises the toxin of tetanus or lock-jaw; the anti-typhoid serum, which kills the microbes of typhoid; the anti-plague serum, which kills the microbe of plague; the anti-venene serum, which neutralises the toxin of serpents' venom; and the anti-streptococcic serum, which destroys certain of the microbes of suppurative conditions. None of these, however, is so certain in its action as the anti-diphtheritic serum.

Some well-known defensive serums.

Strenuous attempts have been made to find a serum to cure tuberculosis, but so far none has been found.

In 1890 Koch extracted some of the toxins from bacilli of tuberculosis and made a preparation which he called tuberculin, and which he supposed exercised a curative influence on consumption. The excitement at the time was intense; but, alas! the tuberculin proved a failure.

In 1897 Koch brought forward a new tuberculin, the so-called "tuberculin R," obtained by grinding up living tubercle bacilli in agate mortars; but this tuberculin also proved disappointing.

Serum treatment is still in its infancy, and though its discoveries and achievements have already been marvellous, its possibilities are even greater.

CHAPTER XVI.

SURGERY AND MEDICINE: THEIR PRESENT AND FUTURE.

Modern surgery—Excision of stomach—Stitching the heart—Operations on the brain—How the surgeon makes noses—Transplanting skin—Progress of medicine—Old prescriptions—Mummy as medicine—Modern specifics—Organic extracts as medicine—Myxœdema and the thyroid gland—A cure discovered—Advance in diagnosis.

We have traced, in the preceding chapters, the growth of medicine from the days of I-em-Hotep onwards through Hippocrates, Galen, Vesalius, Harvey, and Jenner, to Pasteur and Lister and Kitasato and Koch. We have seen the dawn of the great discoveries of medicine—circulation, vaccination, antisepsis, anæsthetics, anti-toxins. Now let us see where medicine now is, and whither medicine is going. The boy is always father of the man, and we see in present-day surgery and medicine simply the developments of the doctrines and practices of earlier dates. The growth is largely inevitable evolution. Let us glance first at surgery.

Antisepsis, in its first beginnings, was crude. Lister cauterised wounds with raw carbolic. In its first beginnings anæsthesia was timid and tentative, so that patients were known to rise and threaten the surgeon with a bloody fist. *Now,* both antiseptics and anæsthetics are elaborate sciences: we know exactly what strength of carbolic will kill germs, and what strength of chloroform will not kill patients.

Modern surgery.

The motto of surgery has ever been "*Toujours l'audace.*" Even in prehistoric times the operation of trepanning was performed; and, as is well known, Cæsar was cut out of his mother's womb; and the discovery of antiseptics and anæsthetics, diminishing the patient's danger, has doubled the surgeon's audacity.

Nowadays the surgeon opens the abdomen with as much *sangfroid* as a tailor slits up a seam; and at the time when appendicitis was in fashion, most fashionable people had their appendices removed. Dr. Henry Grey, of Aberdeen, opened the abdomen simply to squeeze the heart. He was called once to a suffocating woman *in articulo mortis,* and having first slit her windpipe with an ordinary pocket-knife, he opened her abdomen, and, inserting his hand, squeezed and massaged the heart, and thus saved the woman's life, even when she had all the appearance of being dead.

In more than one instance the whole stomach has been cut out, and the intestine joined to the œsophagus, the tube which conveys food from the mouth to the stomach. It is strange to learn that none of the patients without stomachs seemed much to miss that organ, and that some of the patients actually increased in weight.

Excision of stomach.

So unimportant, in fact, does the stomach seem, and so audacious is surgery, that it has been actually proposed to cut out the stomach simply on the ground that it is superfluous!

In other cases sections of the bowel—sometimes several feet in length—have been cut out, and then the two ends of the severed coil sewn together.

These facts seem wonderful enough, but even more wonderful things have been done; for in several cases wounds of the heart have been stitched up, and the patient has recovered.

Stitching the heart.

The well-known surgeon, Pagenstecher, put four stitches in a wound of the left ventricle about an inch and a half long, and saved his patient's life. And a Dr. E. G. Tchernyachoff sewed up a wound in the heart of about the same length, also with a successful result.

In one case a boy fell upon some iron railings, and was impaled. A big torn wound in the heart, large enough to hold three fingers, resulted, yet a skilful surgeon, Dr. Travers, sewed the wound together, and the boy lived for eleven days.

Even the brain can be moulded and amended by the modern surgeon. Bullets are located by the X-rays and extracted; tumours are located by the methods suggested by Galen, and cut out, so that the surgeon can literally make the lame walk and the dumb talk. The diagnosis of the position of a tumour in the brain has been perfected to such a degree that from the twitching of a toe or a finger it is possible to locate it. And the art of cranial surgery has become so daring that as soon as the tumour is located the surgeon saws through the skull and cuts it out. In former days a man who was attacked by convulsions, and who foamed at the mouth, was thought to be possessed by a devil; now we know that the devil is often a clot, or growth, or foreign body irritating the brain, and the surgeon simply makes a round hole in the skull and cuts the "devil" out. A little nodule in the brain, the size of a pea, may throw the whole body into terrible convulsions, or may cause paralysis, or blindness, or dumbness, or madness, and its extraction means recovery of health and sanity. The writer knows of a case where the extraction of a bullet altered the whole moral character of a man, and a lady of his acquaintance wears a silver plate to cover a hole in her skull which bears witness to an operation that gave her back her sight when she had become blind.

Operations on the brain.

Nay, sometimes the surgeon can do still more miraculous things: he can make the congenital idiot an intelligent man.

Sir Victor Horsley once came across a congenital idiot with a very small head, and concluded that the idiocy was due to the prevention of the development of the brain by the smallness of the skull. He accordingly cut a strip of bone out of one side of the skull in order to allow the brain to expand, and thereafter the boy became much more intelligent. This last operation, however, it should be mentioned, can be of service only in very exceptional cases, since, as a rule, the skull is small because the brain has not developed, and not *vice versâ*.

How the surgeon makes noses.

Not content with clipping off appendices, and stitching up hearts, and enlarging heads, and curtailing intestines, the modern surgeon also beautifies. He can smooth wrinkles, he can make dimples, he can correct squints, he can epilate hairs, he can straighten crooked limbs and crooked noses. He can, indeed, actually make noses. A man with only a wart for nose is rather handicapped in the race of life; and ingenious surgeons have contrived various means of improving his nose for him. One plan is to cut two flaps out of his forehead. The flaps are shaped like leaves, and are cut away from the forehead, but are left attached above the bridge of the nose by stalks so that they may get blood supply. The place where the nose ought to be is then scarified and rendered raw, and is otherwise prepared, and the flaps are turned down to make a nose. One flap is turned straight down, and the skin, therefore, is in the position of the nostrils. The other flap is twisted on its stalk, so that the skin lies outside, and this second flap is applied over the raw surface of the first. A scar is, of course, left on the brow.

Another plan is to bind the patient's arm over the site of his nose and cut a piece of flesh almost quite out of his arm, and when the flesh has become attached to the rawed site of the nose, to cut it wholly away from the arm and let it remain on the face as a nose. Very fair imitations of noses have been made in this way.

Still another plan of improving the shape of noses by injecting paraffin under the skin was introduced a few years ago. The paraffin is injected in a liquid condition, and can be moulded as it solidifies. Mr. Stephen Paget, who has practised this art, wrote: "It is not possible to make perfect Greek noses . . . but, short of perfection, an immense amount of good might be done. The skin between the eyes can be so raised and moulded that a fairly good-looking upper part of the nose can be made, improving the whole character of the face and the look of the eyes." In some cases it was "perfectly easy in a few minutes to make a very fairly good-looking nose." "A nose that had been perfectly flat and ape-like for many years might be made at least unnoticeable, so that it would not destroy and hinder a man all through life."

A discovery of recent years is the art of transplanting skin. It has been found possible to slice off pieces of skin, and to put them on a raw surface so that they will grow there. Not only do the pieces of skin become attached, but the cells of which they are composed divide and multiply and spread over the raw surface. We can, in fact, sow cells of skin, just as we might sow a germ on a nutrient surface.

Trans-planting skin.

In what direction surgery can progress further it is difficult to see, for already it seems a perfect science and a finished art.

When we look at medicine proper, on the other hand, we find great room for improvement. It was swaddled, as we have seen, in superstition, and though the character of the superstition changes, superstition still clings to it.

Progress of medicine.

What Sir Frederick Treves has called "the extraordinary habit" of taking drugs when ill is still prevalent, and medical practice still consists largely in prescribing pills and potions. No longer is an incantation given with the prescription, but still in many cases the efficacy of the drug depends more on the faith of the patient than on the potency of the medicine.

It is quite true that this kind of pious fraud is often defensible: often the patient suffers from a *maladie imaginaire,* and often, too, the imagination acts as powerfully on the body as a pill. We all know the story of the man who had a clinical thermometer (which he had never seen before, and whose use he did not know) placed under his tongue, and who, at the end of three minutes, exclaimed: "Eh, doctor, I feel better already." But such treatment, though successful and defensible, can hardly be considered legitimate medical practice, and the habit of promiscuous prescription is certainly discreditable to the profession. And not only is it discreditable to the profession, but it is detrimental to the public health. Every daily paper is full of advertisements of nostrums; and the public, who have been taught to put their faith in bottles, are preyed upon by the patent-medicine-monger. Enough patent medicine is consumed by the British public to float a warship, and enough pills to pave Piccadilly. Is it any wonder that Christian Science is having a passing vogue?

Still, even in the department of the bottle, modern medicine is advancing. However foolish may be the talk of liver tonics, and gastric tonics, and blood purifiers, etc., doctors no longer "pour drugs of which they know little into bodies of which they know less." The action of most drugs has been carefully studied, and, at least, the superficial symptoms they provoke are known.

Comparison of old with modern prescriptions.

When we compare the medicines of the day with medicines of earlier centuries, we see a distinct advance. Just look at the prescriptions of distinguished doctors in the seventeenth and eighteenth centuries. Look at some of

Dr. R. Lower's prescriptions! (Dr. R. Lower, it may be mentioned, was the first to practise transfusion of blood.)

To cure dropsy. "Take a good quantity of black snails, stamp them well with bay salt, and lay to the hollow of the feet, putting fresh twice a day."

"A receipt brought out of Turkey to cure a wound by anointing the weapon: Take a piece of rusty bacon, melt it with a pair of tongues in a dish and anoint the weapon with it, wrap it in a woollen cloth, and set it with the point upward; anoint the weapon twice a day. This will cure any wound that is curable."

To cure ill eyes. "Take two or three lice, and put them alive into the eye that is grieved, then shut it close. The lice will certainly suck the web out and afterwards, without any damage to the patient, come out."

For sinews that are shrunk. "Take twelve young swallows out of the nest, of rosemary, lavender and strawberry leaves, of each a handful; bruise the swallows with their guts and feathers, then boil them all in a sufficient quantity of fresh butter after you have strained it. Rub the part with it very well by the fire."

Or take some of the famous Robert Boyle's recipes:

For an ague. "Take of the bone call'd patella of the knee of a dead man, and having reduced it to fine powder, give of it as much as will lie upon a groat or a sixpence for one dose, in any proper conserve or fit vehicle at a convenient time."

For dysentery. "Take the bone of the thigh of a hanged man (perhaps another will serve, but this was made use of). Calcine it to whiteness. Dose: a dose of white powder in some red cordial."

Earthworms, wood-lice, human skull, and other loathsome things were favourite prescriptions of the time.

Mummy as Medicine.

One of the most extraordinary medicines of olden days was mummy, and we really cannot refrain from quoting Sir Thomas Browne's delicious discourse thereupon: "That mummy is medicinal the Arabian doctor, Haly, delivereth, and divers confirm; but of the particular uses thereof there is much discrepancy of opinion. While Hofmannus prescribes the same to epileptics, Johan de Muralto commends the use thereof to gouty persons; Bacon likewise extols it as a styptic; and Junkenius considers it of efficacy to resolve coagulated blood. Meanwhile, we hardly applaud Francis the First of France, who always carried mummies with him as a panacea against all disorders, and, were the efficacy thereof more clearly made out, scarce conceive the use thereof allowable in physic, exceeding the barbarities of Cambyses, and turning old heroes into unworthy potions. Shall Egypt lend out her ancients unto chirurgeons and apothecaries, and Cheops and Psammitticus be weighed unto us for drugs? Shall we eat of Chamnes and Amosis in electuaries and pills, and be cured by cannibal mixtures? Surely such diet is dismal vampirism, and exceeds in horror the black banquet of Domitian, not to be paralleled except in these Arabian feasts wherein ghoules feed horribly. . . . But the common opinion of the virtues of mummy bred great consumption thereof, and princes and great men contended for this strange panacea, wherein Jews dealt largely, manufacturing mummies from dead carcases and giving them the names of kings, while specifics were compounded from crosses and gibbet-leavings. There wanted not a set of Arabians who counterfeited mummies so accurately that it needed great skill to distinguish the false from the true. Queasy stomachs would hardly fancy the doubtful potion wherein one might so easily swallow a cloud for his Juno and defraud the fowls of the air while in conceit enjoying the conserves of Canopus."

No doubt, some of the prescriptions of empiric medicine had a scientific basis. Thus, Lower's prescription for baldness—"Shave the head, rub it with brandy and honey, and anoint it with bear's-grease"—and Boyle's prescription for fits—"Take the feathers of partridges (it matters not from what part of the fowl), and burn them for a competent time under the patient's nose "—had certainly some sense in them. Even Joanna Baillie's remedy for the stone and gravel purchased by Parliament for the nation, and found to consist of calcined eggshells and snail-shells, was not so absurd as it seemed; for the calcined shells consisted of oxide of lime, and oxide of lime is recognised to be beneficial in gravel. So we must not indiscriminately condemn the prescriptions of empiric medicine as foolish and futile.

Yet foolish and futile they usually were, and modern medicine, despite its perpetual pills and potions, is much more scientific than the medicine of the seventeenth and eighteenth centuries.

Modern specifics.

Now we know certain specifics, and have some idea how they act. We know that iron cures anæmia, that quinine cures ague, that sodium salicylate relieves rheumatism, and nitrite of amyl relieves the agonising pain of angina pectoris.

The discovery of the action of amyl nitrite may be cited as one of the triumphs of scientific medicine. Sir Lauder Brunton came to the conclusion that the pain was due to the efforts made by a diseased heart to drive the blood through the contracted smaller blood-vessels, and, knowing that amyl nitrite dilated the smaller blood-vessels, he gave the drug to inhale, and it acted like a charm. This is surely a remarkable instance of scientific mechanical therapeutics.

Not in ordinary pharmacy, however, but in serum-therapy, whose methods we have already described, and in treatment by organic extracts, have the greatest victories of modern medicine been achieved, and along these two lines will medicine probably progress in the future.

Organic extracts as medicine.

Of serum-therapy we need say nothing more. We have already sufficiently discussed it in Chapter XV., but it will be well now to give a brief sketch of the methods and principles of treatment by means of organic extracts.

Organo-therapeutics is the branch of medicine which deals with the medicinal effects of extracts of various organs given as drugs. It is the direct outcome of the cellular conception of the body, and depends on the principle of the inter-relationship of the chemical products of the different cells which are thrown into the blood-stream. No cells live to themselves, and each group of cells is just what the other cells make it. If one group of cells—liver cells, or kidney cells, or pancreas cells, or whatever they be—shirks its work, the whole organism suffers. Organo-therapeutics, then, seeks to supplement cellular products, when deficient, by adding to the blood extracts obtained from cells of a like nature.

We have already mentioned that Dr. Beard contends that cancer may be cured by injecting the juice of the pancreas (the "sweetbread") under the skin; but a proved and more famous instance of organo-therapeutics is to be found in the treatment of a strange disease called myxœdema by doses of thyroid extract—*i.e.*, by doses of extract of the thyroid gland.

Myxœdema and the thyroid gland.

Myxœdema is a disease as ugly and weird as its name. It is described vividly in a text-book of medicine edited by Dr. G. A. Gibson as follows: "The skin begins to get rather dry, and gradually the deposit of solid œdema can be detected under it. It is earliest observed in the face, which gradually acquires a stupid, heavy, apathetic, swollen look. All the features become coarsened, swollen, and enlarged; the lower eyelids have a baggy look, the upper eyelids are swollen and hang down over the eyeballs; the cheeks are pendulous, the nose is broadened, and the lips and chin coarsened. . . . The hair of the scalp and eyebrows falls out. . . . The subcutaneous swelling [*i.e.*, the swelling of the tissues under the skin] gradually spreads to the root of the neck, and appears in the abdomen, hands, feet, and other parts, giving the person a clumsy, bulky appearance. The gait is deliberate, waddling, and awkward, and no movement of any kind is performed nimbly and neatly. The hands become more square in shape, or 'spade-like,' owing to the fingers being swollen and non-tapering, and they are used clumsily; the feet also become swollen, and larger gloves and boots are required. The soft tissues of the mouth, throat, and larynx [voice-box] also become infiltrated [*i.e.*, filled with a material causing swelling], hence the tongue is enlarged, swallowing may be slightly interfered with, and the tones of the voice become thick, harsh, and monotonous. . . . The hair, nails, and teeth all suffer greatly from malnutrition, the two first becoming dry and brittle, the last carious [decayed] and loose. . . . There is marked muscular weakness. The nervous system is very distinctly affected. . . . There is great deliberation, both in speech and movement, and a disinclination for mental and bodily exertion. Memory becomes weakened, ideas are very slowly grasped and responded to, and there is sometimes an overpowering tendency to sleep at odd times. . . . One or all the special senses may be dulled. Most patients are contented and good-natured, not to say apathetic; but occasionally a morose, unsocial temper is developed, or depression, delusions, and mental alienation may ensue."

This is obviously a most distressing and terrible disease, and for a long time its cause was unknown, and it was considered incurable. But towards the end of last century it began to be noticed that the disease was associated with disease or absence of the gland in the front of the neck below "Adam's apple." This thyroid gland is very like the pancreas, and is often sold for it by butchers. It has no duct to convey secretions to the blood, and its function was long obscure.

As soon as the relationship of the thyroid to the disease myxœdema became known, doctors began to make practical use of the knowledge.

Discovery of cure for myxœdema.

Some surgeons transplanted the thyroid gland of the sheep into the human subjects suffering from myxœdema, and thus obtained some temporary improvement. In 1891 Dr. Murray, of Newcastle, tried the effect of injecting an extract of thyroid gland under the skin of a myxœdematous patient, and was so fortunate as to obtain a cure. In the following year it was shown that if the gland was given by mouth, either raw or cooked, it exercised a similar curative effect. Now the thyroid is given dry or powdered in tabloid form.

This is certainly one of the most wonderful discoveries ever made. The effect is almost miraculous. In a few days signs of improvement appear: the patient feels better and looks brighter, and the swelling diminishes, and in a few weeks he is quite restored to health. Mental and bodily activity return; the skin grows soft and smooth, the hair grows thick again, and the countenance keen and bright.

A terrible form of idiocy called cretinism is also due to lack or absence of the thyroid secretion in the infant, which causes stunting and deformity of mind and body; and this disease can also be greatly alleviated, if not cured, by administration of thyroid gland.

A third terrible disease, known as exophthalmic goitre, characterised by protrusion of the eyeballs, palpitation, and great nervousness, is also caused by disease of the thyroid gland; but in this case the gland is enlarged and its secretion too copious; and the disease can be cured by excising part of the thyroid gland, and thus diminishing the amount of thyroid secretion thrown into the blood.

Nothing could exemplify more dramatically and forcibly the principle of the inter-relationship of the cells of the body than these diseases and their cures. A few cells lazy or lacking, or too active, and the life of the whole individual marred! A few little tabloids of the deficient secretion, or the excision of a few cells, and health and vigour restored! Is not that a romance of medicine?

We have dwelt at length on the thyroid and its diseases because they afford a typical instance of organo-therapy, even as the anti-toxin of diphtheria is a typical instance of serum-therapy; but other instances have been found where extracts of organs are beneficial, and there are great unfulfilled possibilities in this branch of modern therapeutics.

One of the most interesting branches of modern medicine is treatment by means of light.

Light treatment.

The general and constitutional effects of light are well known. On a sunny day life burns more brightly; in dull, cloudy weather vitality is depressed. During the winter in Polar regions life is at a low ebb. One of Nansen's party writes as follows: "The last winter in the ice was simply awful. We had our fill of the darkness. We got sleepy and indifferent, and shaky on our legs. We were not ill, but weak and dead beat, and the doctor was anxious about our brains. When the day came with the sun, it was like a resurrection for us all. We were electrified when we saw him. Nobody knows how fine the sun looks but those who have been six months in darkness. Then we came to strength again."

When we investigate the manner of the action of light we find that it acts largely by stimulating tissue change. Animals exposed to light absorb much more oxygen and give out a much greater quantity of carbonic acid than do animals in darkness. We find, too, that the action of light varies with the colour of the light-rays. Ordinary sunlight, as is well known, can be analysed into violet, indigo, blue, green, yellow, orange, red rays; and it is the violet rays and invisible rays beyond the violet rays that have chemical power. It is the violet and ultra-violet rays that tan the skin and that cause chlorophyll (the green-colouring matter of plants) to split up carbonic acid; it is the violet and ultra-violet rays that kill germs.

In July, 1893, a Danish scientist, Professor Finsen, proposed to treat small-pox by excluding violet rays. He argued that the chemical rays had an irritating and stimulating effect on the skin, and that the eruption would be less severe if the chemical rays were excluded. He placed patients, accordingly, in rooms from which the chemical rays were excluded by interposing red glass, or thick red cloth, and he reports that "out of a total of 140 to 150 cases of small-pox, some very severe ones, chosen specially for this trial, which have been thus treated, it can be affirmed that in one case only, that of Dr. Benckert, was the method inefficacious."

It is interesting to note that as far back as the ninth century a famous Arab physician, Rhazes, treated small-pox with red light.

A year or two later Finsen made a still more important application of light to treatment.

We have spoken in previous chapters of the tubercle bacillus. The tubercle bacillus, as we know, usually attacks the lungs, causing the disease consumption; but it also attacks other organs, and in some cases it attacks the skin, generally the skin about the face, producing a terrible and loathsome skin disease known as lupus. By this disease the lips and nose are sometimes gnawed away, producing hideous deformity. It is a disease very difficult to cure. Even when the diseased parts are scraped away the disease is apt to recur, and terrible scars are left.

Well, it occurred to Finsen to use the chemical rays of light, which have great bactericidal power, to kill the bacilli *in situ*. He used either the light of the sun or the light of an arc lamp, and he concentrated the light by means of lenses. The violet rays are not very penetrating, and one difficulty was to secure sufficient penetration; and Finsen found that by squeezing the blood out of a part, the penetrative power of the rays could be increased. Thus, he found that if a photographic film were placed behind the ear, and light thrown upon it through the ear, the film was unaffected even after five minutes' exposure, whereas if the blood were squeezed out of the ear by compressing it between two plates of glass the film was speedily affected. We cannot here enter into the details of the treatment, but its results have been marvellous. The disease usually disappears in a few weeks, and the scar left is often hardly noticeable. If any method of treatment may be considered more divine than others, surely this method by light may be selected. Yet the writer once attended a Christian Science meeting, and there, among the poor dupes, was a girl with her face attacked by lupus. Her face was being as surely eaten away by the tubercle bacilli as if it were being gnawed by rats, and yet the poor creature was being prevented from finding a cure in the sunlight of God. For rats arsenic and strychnine, for wolves and tigers rifle-bullets, and yet for tubercle bacilli not even sunlight. Surely the height of absurdity!

X-rays, otherwise known as Röntgen rays, also have been found to exercise a curative effect on lupus, and not only on lupus but also on various cancerous diseases, especially on a dreadful disease called rodent ulcer, which slowly but surely eats into any part it attacks, forming a gradually increasing cavity. Ringworm, acne, eczema, psoriasis, and other skin diseases are also benefited by X-rays.

Advance in diagnosis.

Not in treatment alone has medical practice advanced. Even more has it advanced in the art of diagnosis. The chemist, the physicist, the optician have all been enlisted in the service of Æsculapius. The body is made to tell the tale of its disorders through the stethoscope. Even before there are any marked constitutional signs of heart disease or consumption, the trained ear of the physician can hear the feet of death. With the laryngoscope he can look right into the patient's windpipe even down to where it branches to the lungs. With a similar instrument he can look right into the bladder. With the X-rays he can see right through the patient's body: he can see the bullet in his brain, the stone in his kidney, and can watch his diaphragm rise and fall. With the ophthalmoscope he can see the blood-vessels within the eyeball, and the delicate retina where light is focussed, and can sometimes see there the signature of death so undeniably written that he can say to a man, apparently in good health, that his days, or even his hours, are numbered.

Sometimes disease seems so strong, and men's best efforts to combat it seem so weak, that the heart despairs; but no one who studies the history of medicine can fail to be impressed by the slow but certain progress of medicine, by its increasing sanity and power. Century after century, by offensive and defensive warfare, disease is being conquered, and the story of the combat is a long romance which will have a happy ending.

INDEX.

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