

The Journal of the American Medical Association

Published under the Auspices of the Board of Trustees

VOL. LIV, No. 6

CHICAGO, ILLINOIS

FEBRUARY 5, 1910

Address

IMAGINATION AND IDEALISM IN THE MEDICAL SCIENCES *

CHRISTIAN A. HERTER, M.D.

Professor of Pharmacology, Columbia University
NEW YORK

The presidential invitation in response to which I am about to address you to-day was welcome to me because it offered a rare chance to express some views of medical progress which I think are too seldom presented to the student. I have in mind the influence of imagination and idealism on the growth of medical discovery. Vividly recalling, as I do, the experiences of my own student days, more than a quarter century past, I fancy you as coming to the acquisition of the myriad facts of medicine with little to tell you of the intellectual forces and historical sequences by which those facts have emerged. If this surmise be correct, it follows that you incline to take a static rather than a dynamic view of the nature of scientific medicine, in the sense that you regard medical lore as something much more fixed than is actually the case. In reality, our science is fortunately plastic, constantly subject to revision of its facts, and ever ready to welcome new interpretations of old facts as well as new discoveries, both great and small. This very plasticity it is that makes progress attainable and fascinates our minds. But our text-books and our lectures are necessarily conservative and dispose us strongly to the notion of fixity of facts, making our minds static in conception. I would like to dispel, in a measure, this retarding conception by telling you something of the ways in which gifted and trained minds have enriched the medical sciences by significant discoveries. And of the qualities underlying such discoveries I would emphasize especially the rôle of imagination and idealism.

The fine humanitarian aim of medicine always has been and always will be one of the features that make men love to practice the art. And the idealism that delights in the relief of human suffering and disability will remain alive so long as the healing art itself. But we must not blind ourselves to the fact that this very attitude of eager desire to help our fellows in distress is a source of weakness as well as a pillar of strength. For he who would answer the calls of the sick must resort to direct methods and must generally tread the paths of the obvious. He has not time to turn aside to the indirect ways of winning the citadel, nor, indeed, is he likely to be in that frame of mind which urges to such an approach; he is preoccupied with the crying needs of

the suffering or dying man committed to his charge. Yet it is growing every day clearer that the progress of the medical sciences depends in a remarkable degree on discoveries made by indirect methods—that is, by methods not looking to the immediate relief of disease.

These discoveries are made chiefly by men who, while in deep sympathy with the humanitarian aims of medicine, nevertheless find time to turn aside to studies and experiments from which the active practitioners are, in general, excluded, by the circumstances of their lives and the intensely practical nature of their vocation. There was a time when the alert physician or surgeon, with little or no training in the experimental method, might make important contributions to knowledge by following rather evident suggestions derived from the study of patients. The Romans, operating for stone in the bladder; Paré, using the ligature to check hemorrhage on the field of battle; McDowell, successfully removing ovarian tumors, give us examples of great advances along rather obvious lines of development. To-day the chances for significant progress in such evident directions, although not exhausted, are far less frequent. The golden nuggets at or near the surface of things have been for the greater part discovered, it seems safe to say. We must dig deeper to find new ones of equal value, and we must often dig circuitously, with mere hints for guides. Our most effective tools are to be found in the experimental laboratory, where the fundamental sciences, physics and chemistry, come to the aid of physiology, biology, pathology and psychology. I should like to tell you of some of the many instances in which these sciences have come to the succor of medicine and have brought her riches of knowledge unattainable had she been limited to resources belonging to the accumulated experience which makes up the accepted material of medical teaching. If I incidentally say something of the personality of the men who have been the living instruments of this progress, it is in order to give you occasional glimpses into the workings of some of the most original and productive of minds.

I like to think of medicine in our day as an ever-broadening and deepening river, fed by the limpid streams of pure science. The river at its borders has its eddies and currents, expressive of certain doubts and errors that fringe all progress; but it makes continuous advances on the way to the ocean of its destiny. Very gradual has been the progress of its widening and deepening, for it is a product of human ingenuity and artifice, and only skilled engineers could direct the isolated currents of science into the somewhat sluggish stream of medical utility. The names of some of the greatest of these engineers are familiar to you—Vesalius, Harvey, Malpighi, John Hunter, Claude Bernard, Helmholtz, Virchow, Metchnikoff, Pasteur, Lister, Koch, Behring, Ehrlich, Emil Fischer, Weigert, Wright, Theobald Smith, Flexner. Different as have been the achieve-

* An address delivered at the College of Physicians and Surgeons, Columbia University, Sept. 23, 1909, at the opening of the Medical School.

* Considerations of space compel the abbreviation of this article in THE JOURNAL. The Complete article is in the author's reprints.

ments of these men, there are some qualities of mind and of heart which nearly all of them have shown in ample measure, and of such qualities none are more evident than imagination, or play of fancy, and personal idealism, using the latter term to mean a readiness to make sacrifices for the sake of lofty achievement. And I think we are quite safe in making the generalization that the discoveries for which we hold these thinkers in honor would have been impossible but for the exercise of these qualities. If this be true, the fact furnishes us with a clue to present tendencies in medicine and shows us to what sorts of gifts we have to look for the significant advances of the future. I, therefore, hope to make good my generalizations by a series of examples.

If we look over any list of the names of the makers of modern medicine, we shall find that they may be classed in two main and definite groups, according to the intellectual trend for which they stand. One group holds the men who look at the problems of medical science largely from the standpoint of structure and arrangement. They have the instincts and interests of the morphologists. They represent anatomy, embryology, pathological anatomy and histology. They have usually been men of powerful and logical minds, craving the positive, the definite and the attainable, either shunning somewhat the speculative aspects of science, or moving uncomfortably in the midst of ill-defined or challengeable facts. In this list belong Vesalius, von Baer, Bichat, Virchow and Weigert, who represent with maximal distinction the group of investigators with dominant morphological tendencies.

In sharp contrast with this definite type stands the second group, made up of men whose interests lie in the study of function, rather than structure, and whose minds, far from being dismayed by the speculative aspects of their studies, invite such speculation so long as it is severely controlled by frequent appeals to facts won by experiment. The members of this small group are dynamically minded, highly imaginative, delighting in the play of forces. They are essentially experimentalists, and their thoughts in leisure hours, as in the hours of work, turn always restlessly and uncontrollably in the same direction—to the planning of new experiments designed to answer the questions uppermost in consciousness, questions having nearly always to do with the phenomena of living beings. Claude Bernard, Helmholtz, Pasteur and Ehrlich are the unexcelled prototypes of investigators of life-phenomena in medicine, and we shall not go far astray if we fancy them as spirits inspired by

"All that is great and all that is strange
In the boundless realm of unending change."

We have also, I think, to recognize an intermediate group of great investigators who, while highly trained in a morphological way, have shown also a deep and productive interest in the functional aspects of organized nature, without, however, attaining the highest levels of achievement in thought on the dynamical side of medical research. In this category we may place Harvey, Malpighi, John Hunter, Johannes Müller, Cohnheim and Robert Koch. And I think we may safely add that most modern investigators, educated under the influence of the strong trend to physiological thought, belong in this intermediate position.

The examples of medical discovery which I shall first bring to your notice I shall select from the first and intermediate groups of workers, reserving the illustrations from the second group for later consideration.

The first great morphologist of modern times is Vesalius, whose claims to recognition rest not merely on his masterly and precise description of the parts of the human body, but also on his abrupt departure from the Galenic traditions and teachings, forced on him by the objectivity and sincerity of his studies. While we must regard the work of Vesalius as evidence of intellectual and logical power, it would be an error to credit him with the highest type of imagination or with elaborate esthetic reactions. The self-willed, clear-thinking man won his triumphs more by force of character and unswerving purpose than by creative intellect; and we see this type of worker repeated in some of our greatest modern anatomists, as also in some fields in which the experimental method is prominent.

The gain in scientific method, initiated by Vesalius, was fixed and established in England by the spirited, penetrating and imaginative William Harvey, whose monumental work proved that all the blood in the body travels in a circuit impelled by the beating of the heart. That a hugely skilled anatomist should have made this physiological discovery is significant evidence that studies in structure may stimulate a labile mind to serious investigation of the functional side of organic nature. Probably the work which Harvey did with his master, Fabricius, at Padua in the anatomy of the vascular system stimulated his interest in the discovery of experimental methods which should expose the true uses of this elaborate mechanism.

The lofty intellect of Harvey was linked with a generous and idealistic nature. His portraits show a formation of head and face that reminds us of representations of Shakespeare. Like Hunter and Darwin, he had the virtue of being extremely slow in publishing. He forgave his many antagonists, notwithstanding the troubles they brought into his life. He says:

I would not charge with wilful falsehood any one who was sincerely anxious for truth, nor lay it to any one's door as a crime that he had fallen into error. I am, myself, the partisan of truth alone; and I can indeed say that I have used all my endeavors, bestowed all my pains on an attempt to produce something that should be agreeable to the good, profitable to the learned, and useful to letters.

More than a hundred years after the death of Harvey there emerged from obscurity a Scotchman, John Hunter, of such power and versatility as to make him a worthy intellectual successor of the great Englishman. We may take him as our second example of an investigator of our intermediate group, combining the interests of morphologist and physiologist. One example—a celebrated instance—will illustrate the point I wish to make. It was in Richmond Park that Hunter saw the deer whose growing antlers awakened in his mind a singularly fruitful physiological question. What would happen if he shut off the blood-supply of the antler on one side by tying the corresponding carotid artery? Experiment showed that the antler lost its warmth and ceased to grow; but for a short time only was there this check to growth. After a time the horn warmed again and grew. Had he failed to really obstruct the blood flow in the artery? No. Examination showed the carotid to have been securely ligated. Whence, then, came the blood essential for the antler's growth? Through the neighboring arteries that had grown distended, through what we now call the collateral circulation. So was the fact of the collateral circulation revealed. The thoughtful and logical mind of the practical surgeon soon found an important application of this discovery to human pathology. No one had dared to treat aneurism by liga-

tion for fear of causing gangrene. But the existence of a collateral circulation held out a prospect of keeping the parts alive despite the ligation of an important artery. The first trial of the new method on a popliteal aneurism was successful, and the Hunterian operation, as you know it in surgery to-day, came into assured existence. An unimaginative man could not have made this discovery in this manner. Yet Hunter belongs to the logical, independent, matter-of-fact type with fancy well controlled, rather than to the dreamers and poets of science. He was a rough diamond, with an intensely objective nature, and he had corresponding limitations. He is said to have rebelled against the classical teachings of Oxford. "Why, they wanted me to study Greek. They wanted to make an old woman of me!" And when twitted with his lack of knowledge of the "dead languages" he said of his critic: "I could teach him that in the dead body which he never knew in any language, living or dead." The idealism of Hunter showed itself in devotion to work and in fortitude in the adversity of ill health.

I wish now to invite your attention to our second type of investigator—the essentially dynamical or physiological discoverer. The group, as I see it, is a small one. It includes Claude Bernard, Louis Pasteur, Hermann von Helmholtz and Paul Ehrlich.

An admirer said sententiously of Bernard: "He is not merely a physiologist; he is physiology itself"; and the saying has the merit of reminding us of the breadth and depth and originality of his researches. With equal skill he worked at the physical and chemical bases of physiology; and we owe to him our knowledge of the glycogenic function of the liver, the enzymes of the pancreatic juice, the vasomotor system of nerves, diabetes from puncture of the fourth ventricle, besides many minor discoveries and researches and a masterly correlation of the general facts of animal and plant life. Bernard was one of the founders of modern pharmacology. He also foreshadowed in a singular manner and under singular circumstances the modern conception of soluble ferments in micro-organisms, a view which unfortunately brought him into an unpleasant antagonism with his life-long friend, Pasteur.

The research that most fully shows the controlled imagination of Bernard is that which, extending over years, culminated in the discovery of the glycogenic function of the liver, a discovery of the very first significance to physiology and pathology. We know the steps which led him to this discovery, and in retracing these steps we get an edifying glimpse of the workings of Bernard's fertile mind. His ambition was to follow the three great classes of foodstuffs, carbohydrates, fats and proteids, through the organism. He soon felt the necessity of limiting himself to the fate of the carbohydrates, which, besides seeming relatively simple to study, especially attracted him on account of their mysterious relation to diabetes. The first step in the research brought out the fact that cane-sugar, when acted on by gastric juice, undergoes a transformation which adapts it for absorption and utilization by the tissues—namely, a change into dextrose (glucose). He knew from the experiments of Tiedemann that starch is changed into dextrose in the digestive tract before absorption. Bernard asked himself what was the fate of this dextrose. He proposed to trace the course of the sugar from the digestive tract, along the portal vein to the liver, from the liver to the lungs by way of the right heart, and finally from the lungs through the left heart to the

various tissues. His idea was that at one of these stations the dextrose disappears, is destroyed or in some manner changed. "If I am able," said he, "to suppress the activity of this station, sugar will accumulate in the blood and a condition of diabetes will be brought about." Here, then, was a highly interesting enterprise. The first thing to do was to feed a dog freely on carbohydrates, kill it at the height of digestion and examine the blood leaving the liver by the hepatic veins to see if any sugar were lost in the liver. Please note that Bernard was helped in this search for sugar in the blood and tissues by the cupric sulphate test for dextrose, just introduced by his friend, Barreswill—a very material help. Sugar was found in abundance in the blood of the hepatic veins; therefore, the liver was not the looked-for place of disappearance of dextrose. "But how do I know," thought Bernard, "that the sugar which I thus find in the hepatic vein is the same sugar as that which I introduced into the portal blood through the food?" To get an answer, Bernard fed a dog on meat only, knowing by experiment that no dextrose would then be present either in the digestive tract or in the portal blood. Then he examined the blood of the hepatic vein for sugar. Great was his surprise to find it loaded with dextrose. His keen intelligence at once drew the correct inference—that the liver is a sugar-making organ and makes sugar out of something which is not sugar, and, furthermore, that within the liver lies the secret of diabetes. Bernard now made a variety of experiments to test the correctness of his inferences. He soon found that sugar was contained in a simple decoction of the liver and that this sugar was dextrose, capable of fermentation and responding to all the known tests. But Bernard did not stop here. His fancy urged him to seek the substance in the liver from which the sugar is produced—the "glycogenic substance" whose existence was inferred from experiment. And in time he isolated the substance which we know to-day as glycogen.

Here, then, was a great triumph of the experimental method in the hands of an imaginative, critical and highly skilled technical worker. The completeness with which the discovery of the glycogenic function of the liver was worked out makes it a model of physiological research for all time. Moreover, the facts elicited by Bernard in this research possess a very broad bearing. They show that the liver has a function as important as, but far less obvious than, the secretion of bile—the first example of an internal secretion. And they prove that animals as well as plants can build up carbohydrate material—glycogen—by means of their own tissues. Finally Bernard very clearly showed that, while the production of glycogen from sugar is a vital act, in the sense of occurring only under conditions of life, the converse process, namely, the formation of sugar from glycogen, is independent of living tissues and may occur as the result of the action of a ferment in the blood.

As Sir Michael Foster said most aptly:

It is in the putting forth of the hypothesis that the true man of science shows the creative power which makes him and the poets brothers. His must be a sensitive soul, ready to vibrate to Nature's touches. Before the dull eye of the ordinary mind facts pass one after the other in long procession, but pass without effect, awakening nothing. In the eye of the man of genius, be he poet or man of science, the same facts light up an illumination, in the one of beauty, in the other of truth; each possesses a responsive imagination. Such had Bernard, and the responses which in his youth found expression in verses, in his maturer and trained mind took the form of scientific hypothesis.

That Bernard well understood the value of imagination in research and also its dangers is well shown by his admirable and memorable advice to his pupils:

Put off your imagination as you take off your overcoat when you enter the laboratory; but put it on again, as you do your overcoat, when you leave the laboratory. Before the experiment and between whiles, let your imagination wrap you round; put it right away from yourself during the experiment itself, lest it hinder your observing power.

Let us now bring to your attention some features of the mental life of another great physiologist, Hermann von Helmholtz, representing a very different phase of physiology from that developed by Bernard. Bernard, though accomplished as a morphologist and skilled in mechanical physiology, leaned strongly to the chemical side. He was essentially the animal experimentalist. Mathematics played only the most simple rôle in his researches. Helmholtz, on the other hand, approached physiology on its physical side, and, one may remark in passing, with a quality and amplitude of success unequalled before or since. He used the higher mathematics constantly and they proved keen tools in his hands. Although an experimentalist of the very first order, Helmholtz was not an animal experimenter except in a very limited way, the nature of his themes making vivisection for the most part unnecessary.

Even as a child the mind of Helmholtz was unconventional and inquiring, bent on understanding what was going on about him. The boy cut his own path through the mazes of unassimilable educational offerings. His tastes were definite. He obtained notions of geometry from the blocks with which he played, surprised his mother by experimenting on her linen with acids, made telescopes with spectacle lenses, read books on physics and enjoyed greatly his walks in the country. At the university he assimilated ideas with great ease and showed an increasing interest in physics, which he wished to follow as a profession. But his prudent father urged him to study medicine as a surer means of livelihood. And most fortunate it was for medical science that the gifted young man was willing to take up medical studies, for there arose in him a deep interest in the problems of physiology, destined to bear rich fruit. The duties of an army surgeon took only part of his time and the rest he gave to physics. His original researches began at the age of 21 and continued through a long lifetime, covering an extraordinary range of topics in an original and masterly way. Helmholtz contributes to minute anatomy, lays the foundations of physiological optics and acoustics (with all that this means for esthetics, psychology and metaphysics), gives to medicine the specific and golden gift of the ophthalmoscope, enriches physics with an imperishable statement of the doctrine of the conservation of energy and with original studies on vortex motion, on hydrodynamics, on electrodynamics, on dynamics, on meteorological physics. He broadens chemical theory by the influence of his vortex motion hypothesis and, in a somewhat incidental way, brings new theoretical conceptions into the realm of pure mathematics. As students of the psychical forces that have fertilized modern medicine it is interesting for us to note that Helmholtz disclaimed any intention to be practical in his work. If the themes that happened to absorb his attention led to practical and humanely useful results, he was pleased; but he seldom pursued a practical aim simply because of its utility. He chose his themes because they promised to be intellectually satisfying, giving little heed to the nature of the probable outcome. He framed his experiments so that

Nature would have to answer "Yes" or "No" to his questions, thus furnishing him with definite results.

The story of the invention of the ophthalmoscope illustrates the mental processes of Helmholtz in working out an idea. He did not set out to devise an instrument for studying the retina and the ocular refraction, but as he proceeded these important possibilities ripened into definite objects. He says:

I was endeavoring to explain to my pupils the emission of reflected light from the eye, a discovery made by Brücke, who would have invented the ophthalmoscope had he only asked himself how an optical image is formed by the light returning from the eye. In his research it was not necessary to ask it, but had he asked it, he was just the man to answer it as quickly as I did, and to invent the instrument. I turned the problem over and over to ascertain the simplest way in which to demonstrate the phenomenon to my students. It was also a reminiscence of my days of medical study, that ophthalmologists had great difficulty in dealing with certain cases of eye disease, then known as black cataract. The first model was constructed of pasteboard, eye lenses, and cover-glasses used in the microscopic work. It was at first so difficult to use that I doubt if I should have persevered, unless I had felt that it must succeed; but in eight days I had the great joy of being the first who saw before him a human retina.

The basis for this invention was Helmholtz's knowledge of the anatomy of the eye, his mastery of physiological optics, his experimental ability, and, as stated in his own language, his wish to devise an improved method of demonstrating a somewhat obscure phenomenon to his students. Modesty and generous impulse made Helmholtz say that Brücke could equally well have invented the ophthalmoscope had he only asked himself how an optical image is formed by the light returning from the eye. I doubt if it could be successfully contended that Brücke's actual information about the eye was less than Helmholtz's. Helmholtz himself says that Brücke "was just the man" to make the invention, and by this he must refer to equipment in knowledge. In what, then, did Helmholtz excel Brücke? I would answer, in creative fancy, in imagination. The controlled play of fancy, using the facts of the case for its playground, is what made Helmholtz see the possibilities and see them so clearly as also to make it appear worth while to put energy into the effort to see the retina.

It would be easy to multiply examples of the almost playful way in which Helmholtz utilized the children of his rich fancy to extend the bounds of scientific knowledge. The ease with which he made his intellectual progress is one of the most striking features of his wonderfully creative career. Often on solitary walks in the country he experienced ideas that seemed to clarify refractory problems. From the great wealth of his impressions and associated ideas, arising through the operation of active fancy or imagination, there seems to have been a process of controlled selection and rejection by which the finished products, the great ideas, were built up—a conscious selection not without analogies to natural selection in the upbuilding of the physical machinery. In the entire list of the masters of medicine I think there has been only one mind that can be regarded as belonging on the same lofty level as that of Helmholtz, in respect to controlled yet expansive powers of imagination combined with the energy of performance and the technical training necessary to apply those powers. The intellect of Pasteur, and his alone, has revealed associative power and logical sequences of thought culminating in discoveries fairly comparable to those of Helmholtz in respect to the depth of their

psychical basis. And it is probably no accident that the two greatest minds in medicine have entered it on the streams of pure science, Helmholtz as the biological physicist, Pasteur as the biological chemist.

As a human being Helmholtz takes rank with the noblest of men. Considerateness for others and a willingness to help worthy persons were prominent characteristics. He had a calm self-control which still left him natural and simple in human relations, although this fine dignity served as a check to the approaches of shallow and trivial people. Helmholtz was an idealist of the purest type, and never permitted personal interest to interfere with his best aims as a student of science. His was a poetic nature, apt in versification and in music, yet with an intellect so searching that he was not entirely satisfied by esthetic feeling and phantasy, but sought also to understand them. Modesty was one of his greatest charms, and this quality was attractively seen in the sentiment which he expressed on being awarded the von Graefe medal in recognition of his services to medicine through the invention of the ophthalmoscope:

Let us suppose that up to the time of Phidias nobody has had a chisel sufficiently hard to work on marble. Up to that time they would only mold clay or carve wood. But a clever smith discovers how a chisel can be tempered. Phidias rejoices over the improved tools, fashions with them his god-like statues and manipulates the marble as no one has ever before done. He is honored and rewarded. But great geniuses are modest just in that in which they most excel others. That very thing is so easy for them that they can hardly understand why others cannot do it. But there is always associated with high endowments a correspondingly great sensitiveness for the defects of one's own work. Thus, says Phidias to the smith, "Without your aid I could have done nothing of that; the honor and glory belong to you." But the smith can only answer him, "But I could not have done it even with my chisels, whereas you, without my chisels, could at least have molded your wonderful works in clay; therefore I must decline the honor and glory, if I will remain an honorable man." But now Phidias is taken away, and there remain his friends and pupils—Praxiteles, Paionios, and others. They all use the chisel of the smith. The world is filled with their work and their fame. They determine to honor the memory of the deceased with a garland which he shall receive who has done the most for the art, and in the art, of statuary. The beloved master has often praised the smith as the author of their great success, and they finally decide to award the garland to him. "Well," answers the smith, "I consent; you are many, and among you are clever people. I am but a single man. You assert that I singly have been of service to many of you, and that many places teem with sculptors who have decked the temples with divine statutes, which, without the tools that I have given you, would have been very imperfectly fashioned. I must believe you, as I have never chiseled marble, and I accept thankfully what you award to me, but I myself would have given my vote to Praxiteles or Paionios."

If we turn now to Helmholtz's great contemporary, Louis Pasteur, we discern many points of resemblance in the mental endowments and in the careers of these two superlatively eminent masters of medical science. Pasteur, like Helmholtz, was greatly helped in early life by the patient guidance of earnest and capable parents, and, like him, showed a strong interest in poetry and art, the portraits made by Pasteur during his teens showing unmistakable artistic talent. Pasteur's considerable aptitude for mathematics developed later than that of Helmholtz and was of a less original sort, yet served him well, especially in his earlier researches. Both men were endowed with phantasy and associative power of the highest order, but, while Helmholtz seldom departed from the path of strict logical development of

his ideas, Pasteur, with his more impetuous nature, sometimes permitted himself to make speculative excursions of a more random kind. Both found their greatest enjoyment in dealing with the development of general ideas, but Pasteur, on realizing his power to help mankind through his discoveries, deliberately turned his rare gifts to the solution of practical problems in medicine, whereas Helmholtz was satisfied to continue to build the foundations for the physiology of the sense organs and for a better psychology and metaphysics. It is very noteworthy that both Helmholtz and Pasteur were deeply influenced in their outlook by certain conceptions of wide applicability. On the other hand, Pasteur's scientific and philosophical thought was influenced definitely and profoundly by the conception of molecular asymmetry in nature. His interest in this subject was awakened by the study of the salts of tartaric acid, which culminated in 1848 with the famous discovery that the optically indifferent or racemic tartaric acid crystallizes into equal quantities of the ordinary dextrorotary tartaric acid and of the newly recognized levorotary tartaric acid. It was Pasteur's interest in the problem of molecular asymmetry, and especially certain theoretical notions on which we need not linger here, that induced him to experiment on the action of micro-organisms on racemic ammonium tartrate, with the striking result that the living beings converted the optically indifferent solution of salts into a levorotary solution. This showed that the dextrorotary constituent of the indifferent racemic tartrate had been assimilated by the micro-organisms, while the levorotary constituent was unaffected. I emphasize these studies of Pasteur's because they were what excited his interest in the then obscure problem of fermentation, which in turn led him to take up those studies of the causation of disease by micro-organisms and those researches on immunity which have revolutionized the entire science and art of medicine. To do anything like justice to these extraordinarily fertile and original researches of Pasteur is wholly out of question here. I can merely direct your attention to the researches which in the fullest way exemplify Pasteur's gift of imagination and power of experimental control. There are six studies or groups of studies whose histories exhibit Pasteur's genius at its best—the research on the tartrates, the investigations on fermentation, the inquiry into the causes of the silkworm disease, and the methods of its eradication, the research on chicken cholera and immunity to it, the research on anthrax, with the extraordinarily dramatic scenes attending the public test of the immunization methods, and finally the masterly researches on hydrophobia.

In all these different groups of researches were displayed the most active powers of associative thought and phantasy, the most admirable capacity for self-criticism. As Pasteur made his publications in a terse, compact style, we cannot always reconstruct his logical processes by reading them. His method of thought and procedure were, however, well known to his colleagues, with whom he loved to discuss his ideas and plans of experiments. They found him spirited, fertile and imaginative in his conceptions, frankly communicative, generous in giving help and wholly absorbed in his work. Like many intensely serious men, Pasteur lacked somewhat the sense of humor. His feelings of partisanship were so strong that he could never overcome his resentment toward Germany, and he permitted this to color even his relations with German scientific workers. Yet one should dwell but lightly on these slight imperfections

in a nature of such great gifts and such lofty and unselfish purpose.

At the time when Pasteur was beginning his research on anthrax, a young student of medicine at the University of Strassburg, Paul Ehrlich, was laying the foundations for that uniquely fertile and versatile career of medical research which has made him the most original and picturesque of living investigators of medical science. Although at this time Ehrlich was especially under the direction of the anatomist, Waldeyer, he rapidly developed a capacity for chemistry which was a surprise both to himself and to the chemist, Adolf von Beyer, whose lectures had been systematically cut by the gifted but unconventional student. For unconventional he then was and ever has been, neglecting what he did not like and throwing himself with fervor and intense energy into the solution of the themes that attracted him. From the outset it was clear that Ehrlich would make a career as an experimental investigator. Much of the time he was supposed to spend in taking the usual medical courses he devoted to experiment. When Robert Koch was shown through the laboratory at Breslau by one of the professors his attention was called to a young student working at a desk covered with bottles of dyestuffs. "There is our little Ehrlich," said the professor; "he is a first-rate stainer of tissues, but he will never pass his examinations." The prediction about the examinations came perilously near fulfilment; Ehrlich made bad flunks and it is hinted that he would never have received his degree had not he made a discovery—namely, the existence of the peculiar type of leucocyte which is known to us as the "plasma-cell." The faculty reasoned that it would be improper to keep so promising and original a worker indefinitely in an undergraduate position, and it is suspected that they mitigated the rigor of the examinations in order to relieve their own embarrassment.

A noteworthy example of Ehrlich's free-lance method is seen in his peculiar way of working at chemical problems. Though a highly accomplished organic chemist, both as to theory and a singularly rich acquaintance with the properties of substances, Ehrlich rarely uses any but the simplest methods and quite refuses to work quantitatively. His personal experiments are almost exclusively test-tube experiments, most ingeniously contrived to yield a rich fund of knowledge. He says:

For the pure chemist, who proceeds analytically or synthetically, my way is only an unending *pons asinorum*. The chemist starts from two substances, *a* and *b*, both of which he knows, and by synthesis derives substance *c*. Through this procedure a sure insight into the nature of the process becomes possible. This is exactly as if one drew a circle with the calipers. On the other hand, one may define a circle by means of a large number of tangents, and the chemistry which I practice is a kind of tangent chemistry. Through my schooling in this tangent chemistry I have had a great advantage in dealing with immunity problems. If one cannot define chemically the components entering into action, as is frequently the case in immunity problems (for example toxin and antitoxin) one cannot draw the circle in the usual chemical way and the nature of the reaction process must remain a closed book. But for one who has worked for decades, as I have done, at tangent chemistry, the task is no longer so difficult; and I think that in this way, through the recognition of toxoids and their quantitative formation from toxins, I have succeeded in correctly bringing out the two functional groups, the toxophore and the haptophore, which indeed furnish us with the key to the entire doctrine of immunity.

Ehrlich's dominant interests during the student days were histology and chemistry, but his attitude toward these subjects was even then highly individual, original

and laden with the dynamic spirit—the spirit that seeks to gain a conception of what goes on in the living cells. Throughout his career Ehrlich has sought to use his knowledge of histology and of chemistry to gain light on the processes of life. The clarity of his visual perceptions and the tenacity of his visual memories have enabled him to cultivate a sort of chemistry peculiarly suited to this aim. Ehrlich early recognized that he had a peculiar gift of being able to recall and represent mentally the constitution of a large variety of substances and with little effort to picture vividly their interactions. He definitely states that he considers this chemioplasmic memory his greatest scientific endowment, and it is clear that the long line of his investigations is founded on this faculty and on his taste for rational therapeutics. Like Helmholtz and Pasteur, Ehrlich has been guided in his experiments by certain well-defined general conceptions. The most important of these in Ehrlich's case is the idea that the living cells have many different kinds of definite chemical affinities, by virtue of which they are able to enter into combination with some compounds and not with others. This idea is at the foundation of Ehrlich's well-known researches on the basophilic, acidophilic and neutrophilic leucocytes, on the distribution of dyestuffs in the so-called "intravital" staining, on the cell affinities of the different alkaloids, on the side-chain theory of immunity and the measurement of the strength of antitoxin, and on the organic chemical compounds of arsenic in relation to the trypanosomes of the sleeping-sickness.

The recital of Ehrlich's achievements in medicine would demand a voluminous space, for his activities have been intense and varied. The pharmacological studies, the work on immunity in its different phases (including the action of hemolysins), the experimental studies on carcinoma—each of these deserve the most careful study, not merely because of actual results gleaned, but on account of the luminous ingenuity of the methods employed.

It is in the field of immunity that Ehrlich has won his brightest laurels. The discovery that vegetable poisons like abrin and ricin excite antitoxicity, the development of a method of measuring the activity of the diphtheria antitoxin—a standard method the world over—the extremely ingenious studies of hemolysins, the recognition of the laws of transmission of immunity from mother to child, and the discovery of immunity in trypanosomes exposed to the action of arsenical poisons, are all contributions of far-reaching import. And cementing all Ehrlich's special investigations of immunity, relating them also with his work on the distribution of dyestuffs, alkaloids and nutritive materials generally, stands the famous "side-chain" theory. This bold, elaborate and refined hypothesis of the nature of immunity, this offspring of rich phantasy and fertile experimentation, was long the source of discord and strife among bacteriologists and pharmacological theorists. At the height of the controversy Ehrlich once remarked: "They are shooting into my antitoxin tower and I will reply vigorously." To-day a welcome peace—perhaps merely a truce—has succeeded the sometimes heated contest, and only an occasional stray shot is heard. However widely the rival camps may disagree on certain points, there seems now to be a common ground. The centrally emergent conception in immunity appears to be the existence of a specific binding or anchoring avidity between the immunity-excitant or antigen and certain substances belonging to the living cell—the so-called receptors. This conception and the

extensions that follow from it—including, for example, the now familiar view that the antitoxin freed in the blood represents excessively multiplied receptors disengaged from the stimulated cells—are peculiarly original with Ehrlich. His mind reached this central idea, because it is a mind beset by chemical phantasy, a mind seeking to explain all biological phenomena in medicine by means of chemical principles. In the special case of the side-chain theory, Ehrlich's intimate knowledge of the chemical and biological properties of the dyestuffs played a very large part, and it should be noted that the theory is in this sense a hybrid, that it originates not from a purely chemical conception, but from a chemical and a biological idea. Slowly that theory grew to its present full proportions and its somewhat bewildering intricacies of superstructure. In this elaborate form there is doubtless much in the hypothesis that can be criticized if we turn to it in the hope of learning the absolute truth in respect to immunity. It is perhaps just to say that the value of the theory lies largely in the fact that it expresses relationships. Time and experiment will doubtless mold it anew. But whatever changes in form it may suffer, the data collected by Ehrlich and correlated by him will long remain a monument to his experimental genius and creative imagination. And the fair-minded critic will remember the great practical services which this theory has rendered and is still rendering to medicine, in enabling investigators to pursue their experiments in new territories of research in immunity by giving them points of attack and lines of advance. It is stated by Wassermann, the discoverer of the serum reaction of syphilis, that he could never have worked out this biological reaction had he not possessed the side-chain hypothesis as a guide. It seems clear, too, that the intelligent use of this hypothesis is destined to aid us greatly in learning something of the seat and mode of action of many drugs of which we now know but little. And, again, there are unmistakable signs that the side-chain conception will give many a clue to the understanding of the nutrition of cells.

Ehrlich's mind is singularly labile, playful and restless. It passes quickly and casually from one subject to another, yet without the least confusion. It is always on the alert, ready to dally with a new fact or a new idea, in the hope that it will illumine one of the many experimental interests with which consciousness ever teems. Ehrlich reads medical literature rapaciously but selectively, ignoring all but the themes in which he has a special interest, as one reads who reads for his pleasure and not for duty's sake. This unusual method is extremely effective and gives a highly serviceable command of facts likely to be helpful in extracting from Nature new facts by experiment. Even during holiday seasons, this spirituelle, penetrating mind knows no real rest, for the time is beguiled by the reading of detective stories, even second-rate ones, in the hope of finding some new and complicated situation, for which an ingenious solution can be invented.

It is a cheering sign of the times that the cultivated classes are beginning to recognize the essential rôle of imagination in the progress of the biological and medical sciences. President Eliot remarks that the nineteenth century has taught us that, on the whole, the scientific imagination is quite as productive for human service as the literary or poetic imagination. "The imagination of Darwin or Pasteur, for example, is as high and productive a form of imagination as that of Dante, or Goethe, or even Shakespeare, if we regard the

human uses which result from the exercise of imaginative powers and mean by human uses not merely meat and drink, clothes and shelter, but also the satisfaction of mental and spiritual needs." The history of medical discovery is a long chain of imaginative experiences whose links have been welded and fixed by passing through the fiery ordeal of appeal to experimental tests. And could we but set forth, in fitting language, the true story of these mental experiences, with all their vicissitudes of hope and despair, success and failure, we should certainly dispel for all time the wide-spread notion that medical research is a dry and painful task, to which only an unimaginative mind can turn with satisfaction.

There is a phase of imaginative thought and feeling which expresses itself in a strong desire to pursue ideal ends, even at the cost of the ordinary prizes of life, wealth, material power and physical comfort. This idealism has been a very pronounced attribute of the great masters of medicine. In a noteworthy degree they have all possessed it and some, like Helmholtz and Pasteur, have led lives of unpretentious, simple self-sacrifice in admirable harmony with the illustrious and superlative service they have rendered mankind. This idealism, while clearly a moral trait in the conventional sense, seems to be the offspring of the creative intellectual attitude and especially of an absorption in work, which leaves the mind neither time nor inclination to seek the petty advantages for which most men at some time in their lives find themselves struggling. For these reasons, indifference to vulgar aims and aloofness from commonplace interests are apt to be found where there is preoccupation in productive work of a high order, whether this be concerned with science or not. But in the medical sciences the rewards are so great, in the sense of personal satisfaction from superior achievement, that there is an especial and peculiarly potent incentive to repress those exaggerations of the self-preservative instinct which show so insistently in the selfish conduct of commonplace persons.

There is a special quality pertaining to the greatest masters of medicine which arrests our attention when we survey their life work. This is the wonderful variety and number of their discoveries. We are struck with this quality of productivity in the works of Hunter, Malpighi, Johannes Müller, Claude Bernard, Helmholtz, Pasteur, Koch and Ehrlich. In some instances the range of topics is relatively narrow, as in the case of Koch, or extraordinarily wide, as in the case of Helmholtz, but in nearly all instances the great masters have been repeatedly productive, and this varied productivity on a high plane is an unfailing mark of genius. On the other hand, it is necessary to recognize that very important discoveries in medicine have been made by men who once in their lives, and once only, have attained a high level of achievement. There are two examples of this singularity in discovery which I would bring particularly to your notice—one the discovery and development of the antiseptic method by Lister and the discovery of general anesthesia by Morton.

When Lister visited Pasteur in 1865 he was much impressed by the attitude of the great master in regard to the wide part played by micro-organisms in fermentation and disease. As a surgeon he had a deep interest in the diseases of wounds, and the idea established itself in his mind that such diseases might be due to a kind of fermentation which might be checked or prevented by the use of antiseptics. This idea, worked out by Lister with the utmost patience and superior intelligence, gave

the wonderfully far-reaching results with which we are all familiar. The important results of Lister's methods are not limited to the surgical diseases of human beings. By making it possible to experiment on animals in wholly new ways, these methods have placed in the hands of the physiologist a powerful instrument for the extension of medical and biological knowledge along most significant lines of progress. We have, therefore, to concede that Lister's discovery is one of such rich fertility as to make it rank among the great discoveries of medicine. Yet it cannot be claimed that Lister was a great scientist. In training, in originality, in versatility and in imagination he is far from being the peer of the great masters of whom we have spoken. And we see here, again, that the practical import of a discovery is no arbitrary measure of the scientific attainments of the discoverer.

Hardly less valuable an asset of practical medicine is the discovery of general anesthesia, but it appears that the qualities of mind revealed by Morton belong to a level less high than those of Lister. Morton was an alert, enterprising young dentist in Boston, who, while educating himself in medicine, successfully practiced his calling and invented an improved system of dental plates. The use of this system required the free removal of carious and otherwise diseased teeth, and this caused great pain. To relieve this pain, Morton pertinaciously sought an efficient anesthetic. After many unsatisfactory trials with different substances, he experimented with sulphuric ether, given him by Jackson, the professor of chemistry in the Harvard Medical School. In 1846 he succeeded in demonstrating the efficacy of sulphuric ether as a general anesthetic and thus gave to mankind a precious, almost unequalled boon.

This great discovery cannot be reckoned as one of high fertility, since, aside from anesthesia, it has not opened new lines of thought or practical service. Neither can it be said to have sprung from a scientific mind of exalted qualities and attainments. It has the earmarks of a child of empiricism. Morton's scientific knowledge was slight, and his mind had a strong commercial bent. The singularity of his discovery, the only one of his life, points neither to fertility of resource nor to lofty imagination, but to the fortunate combination of conditions under which he insistently exercised his ingenuity.

Having told you something of the qualities distinguishing the modern masters of medicine, I now ask your permission to speak of certain aspects of these qualities as they seem related to the career of the thoughtful student of medicine. And first of all I would correct in your minds any impression I may have made of a discouraging nature. Having drawn our examples of medical advance so largely from the work of supremely gifted men, workers in laboratories, many of whom have not been practitioners of medicine, or have only casually practiced, it may possibly appear that you are confronted with the paradox that an essential condition of the loftiest success in medical science is to abstain from the practice of medicine. There is, indeed, a measure of truth in this, for, as I have already tried to show you, entire absorption in the practical problems of medicine unfits men to pursue with the highest success the career of discovery. In this there is naught of real discouragement, but only a sign that the problems of disease, as we meet them by the bedside, are far too complex to permit solution there. There was a time when all medical discovery was based directly on observation at the bedside. Then, with the growth of anatomy, the invention of the microscope and the coming of the twin

hand-maids of medicine, physics and chemistry, the laboratories spring into existence. Much there was that could be discovered only by laboratory methods, and so it happened that some men were justified in working at medicine, and able to become masters of medicine, though they scarcely left their laboratories. But I would have you note well that we have now entered on a time when the clinics and the laboratories must work more and more closely together, aiding each other at every step to bridge the wide chasms of our ignorance. And just here lies one of the greatest opportunities for the alert student of medicine, undergraduate and post-graduate to do something worth while. For the problems are so many, so varied and so widely graded as to difficulties that for almost every earnest student there is at hand a theme suited to his powers and training.

I have intimated my belief that the powerful and controlled imagination is generally associated with a strong vein of idealism. The explanation is not remote; the imagination separates the wheat from the chaff in the realm of ideals, picturing vividly what will yield enduring satisfaction. In persons of average capacity and imagination, idealism is more halting because the perceptions of what is permanently worth while are less definite and carry less firm conviction. Hence in such persons idealism of conduct is less spontaneous and calls for conscious effort to sustain it. It is, indeed, a quality which may be deliberately cultivated if the germ exists in the character.

What I would like particularly to impress on your minds is that without idealism of purpose, without the willingness to make sacrifices of material comfort and much that the world overprizes, the career of the student and practitioner of medicine is almost certain to be pitifully limited and mediocre. He will do well who has the character to run his course in a strong spirit of independence, satisfied during the long years of professional preparation with the slender means that permit the prolongation of some phase of the student life long after graduation from the medical school. There is no surer road to hopeless mediocrity than that which leads the young physician to assume an active practice before he is ripe for it. On the other hand, the student physician who waits patiently, year by year, to strengthen his intellectual grip on the processes of disease, if possible under the guidance of some master of medicine, is laying the unshakable foundations of a telling and distinguished career. He need have no anxiety as to the future either on the score of professional recognition or the ability to earn a sufficient income. For the world needs and must ever seek the serious, well-trained, idealistic physician whose first thought is to render a high grade of service. The superior type of student will not dread the long years of preparation in laboratory and clinic. He will eagerly seek them and will count it the greatest privilege of his life to be able to utilize and develop his powers. The fascinating interest of his problem and the elevation of his ideals will keep him buoyant under circumstances of discouragement. If he be blest with a fair share of imagination and idealism he will never falter in the struggle to make a worthy career, for he will know that he is treading in the footsteps of the great masters of medical science and that in doing so he is helping to assuage human suffering, perhaps also to illuminate some of the dark problems in the baffling mystery of life. And in this consciousness will he find ample compensation for the self-abnegation which such a career must necessarily exact from its votaries.

819 Madison Avenue.