proper training and a full opportunity of showing whether or not they possessed enough originality to conduct independent research. If they proved capable and sincerely desirous of a career in research, they could look forward to a life position as scientific director of such an institute. Those who found that their chief talents lay in the direction of teaching and administration or of private practice would select other careers. The final result in the clinics would be a diminution in the number and improvement in the quality of publications. I have considered the young men last because they are the most important, since the future development of the clinical subjects in university work lies within their hands.

THE RELATION OF MEDICINE TO THE FUNDAMENTAL SCIENCES

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THE practice, teaching and science of medicine have never been isolated from the other affairs of men, but have modified them and been modified by them. My subject is this interaction, for I have been commanded to speak of it as it exists now and especially as it exists here at Harvard at the end of Dr. Edsall's administration under the influence of changes that he has directed. These changes are the consequence of forces and tendencies that Dr. Edsall has controlled and utilized. The changes are great, the forces strong, the tendencies by no means superficial. All three are manifestations of important intellectual and social processes which concern the university as a whole as well as its parts, and which involve both private affairs and the state itself.

Familiar facts suggest that in order to fix our ideas we may speak loosely of three periods of the interaction from and toward medicine; the first, a very long one when the influence was directed chiefly from medicine outward; the second, a period of transition strikingly marked by the influence of biology, of chemistry and of physics upon medicine; and a third recent period when actions and reactions between medicine and other human affairs are so numerous, so prompt and so intricate that we can hardly follow the chains of cause and effect. These periods are by no means distinct, but it is clear that we are living in the third.

In the beginning and until recent times the action was, as I have said, outgoing; but it took many forms, so many that we can no more than sample the facts. Under the influence of his early medical environment Aristotle turned from the philosophy of his master, Plato. Here at the outset is one action that has never ceased. Like Aristotle, Darwin was the son and grandson of physicians and it is thought that he, too, received the tradition. Also, he, like his cousin Francis Galton, or, to go to another extreme, like the critic Sainte Beuve, pursued medical studies, and in all three the influence of these studies has been noted. Again and again medicine, like the church, has provided a livelihood and so made possible an intellectual life, as it did for Rabelais, for Cardan the mathematician and for Helmholtz.

In an earlier day the path to other fields often led through the study and practice of medicine. Gilbert investigated the magnet, Redi the generation of insects, Stensen geological stratification. John Locke passed from medicine to a psychological epistemology; Sir William Petty, one of the most intelligent of seventeenth century Englishmen, to statistics and economics; Quesnay, the best of the physiocrats, to economic theory guided by an idea of economic circulation borrowed from physiology. In the seventeenth century physicians contributed more than their share to a movement of the first importance in the evolution of science—the founding of academies.

The needs of medicine have created new sciences. They directed the attention of Vesalius to the systematic renewal of the science of human anatomy, of Harvey to his researches on the circulation of the blood and, still farther afield, to embryology. They led to the foundation in Paris of the garden for medicinal plants that finally developed into the Muséum—for one long period the greatest center of natural history in the world. They led Joseph Black, a professor of medicine and chemistry at Edinburgh, to his memorable work on carbon dioxide and on calorimetry. Medicine has also provided the stimulus to new developments. For instance, it was an accidental clinical observation that suggested to Julius Robert Meyer the principle of the conservation of energy.

Medicine has formed the background of the life and thought of humanists like Linacre and of physicists like Young. In other instances, for example, in the political careers of Marat and Clemenceau, we remain in doubt and can but guess about the nature of the influence. Finally, we may note the familiar and characteristic type of the physician-man of letters. At Harvard this brings to mind the elder Oliver Wendell Holmes in the past and, in the present, Harvey Cushing and Hans Zinsser.

Gradually the influence of the more abstract sciences

upon medicine restored the balance of a one-sided action from medicine to other things and then, while some of the older tendencies waned, for a time became preponderant. The ancient world hardly knew this movement, and as late as the beginning of the seventeenth century the pseudo-science of astrology was still studied by medical students and applied in practice. For this reason the medical students of Padua, among them perhaps Harvey, attended the astronomical lectures of Galileo. Thereafter the change is unmistakable. It is implied in the work of Galileo himself and in the theoretical physiology of Descartes. It becomes manifest in the work of Sanctorius and of Stensen, as well as in Borelli's systematic application of Galileo's mechanics to physiology. It appears again and again in the seventeenth and eighteenth centuries; in the applications of the pendulum, of the thermometer and of the microscope, largely under Galileo's influence, and later in the application of the manometer to the study of blood pressure by Stephen Hales. Early in the seventeenth century the physiology of vision was renewed by Kepler and Descartes. Later the physical scientists Boyle and Hooke instituted at Oxford the study of respiration. Meanwhile, step by step, applicable chemical knowledge was acquired, and finally the discoveries of Lavoisier and of Lavoisier and Laplace established the science of metabolism on a secure foundation.

The effect of the abstract sciences on medicine was accelerated in the nineteenth century and at length became, or at least now seems to have become, the most characteristic feature of the time. In its course it has grown too complex for simple description, but I think the historical implications of the single name of Pasteur will bear out my assertion.

When some, I hope I may still say many, of us were students, the words "physics," "chemistry," "botany," "zoology" and "physiology" were safe and comfortable terms that caused no concern. We knew what they meant, and, long before Bridgman had instructed us, even possessed intuitively an operational definition of them. Physics was what B. O. Pierce and others of his guild did and taught and physiology what Henry Bowditch and his guild did and taught. There were indeed signs of change, but they passed unheeded. Thus the growth of the science of physical chemistry seemed to be nothing more than an immigration into a new field that was destined to preserve its independence. Perhaps, among our elders, the word "biology" was already giving some concern to conservatives, for Farlow, a doctor turned botanist and a great Harvard worthy, used to say, wittily and not without feeling, that a biologist is a zoologist who teaches botany or a botanist who teaches zoology. But the sciences still seemed to be independent. They are so no longer; *laissez faire, laissez passer* is the order of the day in science, and the skilful workman may construct what he pleases and seek his materials almost at will. For instance, organic chemists, under the influence of physiology, have returned to the study of natural products. Not without certain temporary inconveniences the guild economy of science is decaying and is being replaced by a system that is more free and, in some few respects, less disciplined. Perhaps the chief cause of this change is that the frontiers of science, formerly several and natural like our early western frontier, have become joint and artificial like those of Europe, and that real interests and prejudices which tend to preserve them are weaker than the opposing forces of initiative and invention.

Nevertheless, the separation of the sciences remains and it is hardly conceivable that it can disappear. The indispensable needs of skill and method endure and I think we may count upon them not only to preserve in the future much that is left of the guild system, but also to restore the discipline that may have been occasionally lost with the disappearance of certain elements of the older traditional training and standards of our fathers.

Let us not, however, prophesy. We are interested in facts, and the novel relations between the sciences are very imperfectly described by what I have said, for these relations are by no means of a random character. On the contrary, they still manifest, with all their increasing complexity, the trend that was so plainly evident during the nineteenth century, and they are in general only weakly transitive.

I am concerned to make this clear and therefore ask you to consider the following list of subjects: mathematics, physics, chemistry, physiology, pathology, medicine, epidemiology, hygiene. Is it not evident, in fact, does not every one know, that on the whole, and saving the exceptions, the influences that now exist are, as they have been in the past, in one direction rather than the other in the order of the list; from chemistry to physiology, pathology and medicine rather than the reverse? Is not the above-mentioned influence of physiology on organic chemistry a little different from the usual run of events? Further, is not the influence frequently from one subject to the *next* following subject, rather than directly to a later subject? Is it not from chemistry to physiology rather than to pathology or to medicine directly? Moreover, is it not in general from a more abstract to a less abstract subject, and again from an older and more highly developed science to one that is younger and less developed, and finally, of course, from a pure science to an applied science?

In short, there is activity everywhere and in every

direction actions and reactions run on. This is all very confusing, but yet we see clearly enough that the actions, if far from uniformly, are on the whole, or at least in many cases, polarized and that there are several predominant tendencies which result in this polarity: actions from the pure to the applied sciences, from the older to the younger, from the developed to the undeveloped, from the abstract to the concrete, from one neighboring science to another. So much we can see, but we can hardly foresee the particular actions and reactions of even the immediate future, least of all perhaps in the domain of medicine and the medical sciences.

Such conditions make the task of guiding the evolution of medicine in a university difficult. They also impose limits within which it is probably bound to proceed.

In 1918, when Dr. Edsall took over the work of dean, many of these new conditions, especially the immaterial and intellectual conditions, in which the practice, the teaching and the science of medicine are evolving, were already present. But great organizations change slowly, and the formal structure of the University and of the Medical School still corresponded, in part and especially in externals, to the obsolescent guild economy of science. Material signs of this were and still are the isolation of the Medical School from the rest of the University and the planned isolation of the departmental laboratories within the school. But such external obstacles to free intercourse are no more than inconveniences when other conditions are favorable. What was important was the accompaniment of no little intellectual isolation which had already become a sensible disadvantage.

The new dean was well prepared to feel, and therefore to perceive, the effects of this state of affairs, for he had already experienced them concretely in his own work in medicine, especially in the application of chemical methods beyond the routines of diagnosis, in experimental clinical studies in the hospital, and in the application of the methods of experimental medicine to the study of industrial hygiene when pursuing investigations of occupational diseases in the factories and plants where they originate. This experience must have been of good service, while he was making decisions and working out the main lines of an administrative policy that has been from beginning to end realistic, empirical and intuitive, and has therefore led to a continuous adaptation to the changing conditions and needs of the times. Happily the great DeLamar bequest, munificent grants from the Rockefeller Foundation and many other gifts have made possible the execution of this policy.

One of the early results of his action as dean was the School of Public Health, a new department, which from its foundation has borne a relation to the Medical School and other parts of the University that might easily be mistaken for the result of a long period of adaptation rather than of a new establishment. Let us look at the facts. Administratively a separate faculty, this school has never, from the very beginning, been really cut off from the Medical School in respect of staff and researches; for administrative independence, while preventing undesirable constraints, has favored desirable connections and facilitated all sorts of mutual aid. Thus, an ever-changing nexus of connections has grown up. This has extended farther afield, in a manner suggestive of the Hippocratic treatise on "Airs, Waters and Places," to the Children's Hospital, for example, in the study of the hygiene of infants; to the Fatigue Laboratory, for example, in the study of the effects of temperature and pressure; to the Dental School, for example, in the study of nutrition; and, notably, to the Engineering School, where conditions have arisen that well illustrate some of my introductory remarks.

Sanitary engineering has reduced the control and protection of the water supply to a routine, and even in part crystallized the routine in rule of thumb. It is now turning its attention to the air. The problems thus raised have led to a valuable collaboration in research between the Schools of Public Health and Engineering, and in the application of both the physical and the biological sciences to the problems of hygiene in a manner that is obvious enough. But it has also led to other interactions and collaborations of a character that could hardly have been foreseen. Such results, I repeat, depend upon the absence of constraints of the kind imposed by rigid organization and the guild system of science, and upon the presence of connections that grow up spontaneously when conditions favor free intercourse. It is an induction from experience that a necessary condition for the best kind of collaboration in scientific work, except in the relations of master and apprentice, is that those concerned should desire to study a problem and that, because of its nature and scope, they should be unable to do so severally and independently.

In the prosecuton of research the relations between the Medical School and the School of Public Health are similar but far more extensive than those that have been established between the latter school and the School of Engineering. They are the sign of a new period within the Medical School as well as in its wider relations.

For some years there has existed at Harvard a Committee on Industrial Physiology, appointed by the corporation. Dr. Edsall has been the chairman, and among the members have been the dean of the Business School and the former dean of the Bussey Institution.

This committee is charged with the administration of a large grant from the Rockefeller Foundation. Its authority is derived directly from the corporation. It carries on independently of all faculties and departments of the University and its sole responsibility is to see to it that the work done under its supervision shall be well done and that it shall be of such a character as to conform to the liberal terms of the gift.

This committee has voted funds in support of certain researches that are now going on in the University, such as those of the functional anthropologists, of the Psychological Clinic and of the International Expedition to Chile led by Dr. Dill. The committee administers all the funds of Professor Mayo's Department of Industrial Research in the Business School and all those of the Fatigue Laboratory.

In making plans that led to the establishment of this broad undertaking Dr. Edsall took a decisive part and I think that we can see how these plans are the outgrowth of his earlier policies and experiences. His own studies of industrial medicine were a first step in the direction of sociology and the foundation of the School of Public Health went much further in the same direction. Now these are the common features of the studies that have been supported by the Committee on Industrial Physiology; they are all concerned with problems that may be considered, in the broadest sense, sociological, or else with problems whose solutions appear to be necessary as a means of making progress in understanding the conditions within which social phenomena occur. In each instance the work is carried on by men who have acquired some special skill in the use of appropriate scientific methods, including statistical, chemical, physiological, psychological, anthropological and clinical methods. In every case these men have come, independently, to desire to investigate the problems in question. In general, each is interested in the work of many of the others, so that there is much intercourse and every useful mutual aid and collaboration. Evidently all this work is, on the one hand, the outcome of the special scientific interests of those concerned and, on the other hand, a result of the many unforeseeable interactions between the different sciences that are so striking a feature of our times. Also, it is, so far as I know, in no single instance something imposed as a deduction from a great rationalized project. I believe that it is for these reasons that the results have been thus far satisfactory to the investigators and not uninteresting to others. The influence of this work has extended into the Business School and into the Cambridge departments of anthropology, psychology and sociology.

Meanwhile, the opportunity for direct influence of the more abstract sciences on those of the Medical School has been provided. Ever since the foundation of the School of Public Health a professional mathematician and mathematical physicist has held the chair of vital statistics. Also, an experimental physicist has been a regular officer of the Cancer Commission. Many other factors have strengthened the influence of the abstract sciences. A department of physical chemistry has been established in the Medical School, Professor Fiske's laboratory has become almost a laboratory of organic chemistry and chemistry has infiltrated at other points. Finally, there has been no little collaboration with members of the Division of Chemistry of the Faculty of Arts and Sciences.

The relations between the Medical School and the Division of Biology of the Faculty of Arts and Sciences are somewhat different, because the various fields of biology at Harvard, as in most other universities, were formerly divided between the two faculties. This separation, which long remained as an anachronism, has now been largely overcome. The growth of medical zoology and the importance of the ecological and other aspects of tropical medicine on the one hand, and, on the other hand, the presence of Professor Redfield, for years a professor in the Medical School and now director of the Biological Laboratories in Cambridge, the presence of others from the Medical School and the rapid growth of physiology in Cambridge have established intimate relations where once there was almost none. Lastly, we may note the recent addition of an economist to the Faculty of Medicine.

Meanwhile the relations between the laboratories of the Medical School and those of the great Boston hospitals have been almost transformed. Where formerly little more than routine pathological anatomy supplemented clinical observations, now clinical researches employing refined chemical and physiological methods are the rule. To mention only one instance, the investigations of Professor Gamble have contributed not only to medicine and human physiology, but also to general physiology.

The influence of these developments upon the practice of medicine is great. They are known to most of you better than to me. But what of medical education? From the beginning of his administration President Lowell was interested in changes in the course of study and methods of teaching and examining in the Medical School which have been slowly adopted and which are the expression of the very tendencies that we have been considering. To this I can testify because I clearly remember parts of a conversation with him that is now more than a quarter of a century old. Some of these changes were accomplished before Dr. Edsall became dean. The others, entirely accordant with the dean's sentiments and

opinions, were accomplished with the president's support, for here as in other respects, there was perfect accord between the two executives.

In another direction the initiative came from Dr. Edsall. Since it is the growth of the sciences that has given rise to all the changes that we have considered, it is not surprising that the same cause should have modified the problems of college education for the future medical student. Signs of the new conditions became clear long ago, and I remember a still earlier conversation with President Eliot, when as a young instructor I tried, prematurely and probably with little success, to argue that college undergraduates had need of information about the new relations between chemistry and biology and medicine. At the beginning of the century little was to be done, but by the twenties the problem had become serious. Nearly ten years ago it led, on the initiative of Dr. Edsall, to the establishment in Harvard College of tutorial instruction that was carefully designed to meet the need. This experiment has prospered, and from the early years of college to the end of their medical education, it has already enabled many students to prosecute and organize their studies more broadly and with a better understanding of their needs and of their intellectual interests. Moreover, the presence of a group of young and able medical men among the corps of tutors in Harvard College has greatly strengthened the interactions between the two faculties. It has also established a balance among the biological activities of the Faculty of Arts and Sciences that American physiologists have long admired and envied in the University of Cambridge and that formerly was unattainable here. The appointment of one of the tutors, Professor Ferry, as Master of Winthrop House, is a significant result of this change.

So much by way of chronicle. But the chronicle is not enough, for in ending we must try to seize the continuous threads that run through the events.

Edsall's administration is a period of transition. I have tried to suggest that it is especially marked by the application to University policy of the two principles of *laissez faire* and of *laissez passer* that were already evident in the evolution of medical science. A conspicuous result has been the strengthening of old relations and the formation of many new relations within the University. The influences of *laissez faire* are, perhaps, chiefly attributable to spontaneous forces, but it is in great part the dean who, by applying the principle of *laissez passer,* has made the intercourse and the interrelations possible and, above all, it is the man himself who has promoted that spirit of good will and mutual aid in collaboration which is to-day one of the most fortunate traits of Harvard.

OBITUARY

CARL BARUS—1856–1935

IN the death of Carl Barus on September 20, 1935, Brown University lost a brilliant scholar and investigator, long internationally famous, and a beloved colleague who for forty years had ever been among us a source of inspiration. Although he had attained to nearly fourscore years he walked in our last commencement procession. But during that very week he underwent an operation from which after a gallant summer-long struggle he appeared to rally; the end finally came with startling suddenness.

Both of the parents of Professor Barus were Germans, who at different times had come to this country and finally settled in Cincinnati, where they were married. Their eldest child, Carl, was born there on the nineteenth of February, 1856. His early years were spent in an atmosphere of music, since his father, a leading musician of Cincinnati for more than twenty-five years, was director of numerous musical organizations and undertakings. Rehearsals were constantly held in his home, and his knowledge of certain operas and other music became minute; already before his teens he improvised much on the piano and composed sonatas in the style of Mozart. Later in life he devoted considerable time to composition, and the forty resulting works included a "March to Pembroke Hall," which was published in 1905. In 1874 he graduated as the silver medallist from the then notable Woodward High School, in the same class with William Howard Taft. Already his seethingly active mind was reaching out in various directions. With books and a telescope he acquired wide knowledge of the stars; an elaborate plumber's establishment offered the opportunity for considerable acquaintance with machinery and the tempering of steel; he experimented in a chemical laboratory which he had set up in his own home; he and a chum explored the flora cincinnatiensis and had a herbarium of about a thousand plants; he obtained a basic command of literary and scientific German, later to stand him in good stead.

In 1874 he became a student of mining engineering at Columbia University, but towards the end of his second year, his interest in pure science had become intense in the same degree that the allurements of engineering had waned. A college physical laboratory had not been thought of at Columbia at that time. For the next four years he carried on research in physics under Kohlrausch at Würzburg and received

[1] Minute spread on the Faculty Records of Brown University, October 1, 1935.