director of research, who makes the following comments:

> Graduates in electrical and mechanical engineering are generally more adaptable than physicists to the problems of industrial research and development relating to physics. They more readily adapt themselves to the handling of apparatus and equipment and are usually more successful in the use of their hands. They have in general a better physical insight and a greater appreciation of practical requirements for carrying through a developmental program.
>
> It probably does not make a great deal of difference what specialized type of training is received by a certain few men with a natural inclination to industrial problems.
>
> We do feel however that too little stress has of late been placed upon the fundamental physics by most American universities, especially in graduate work. The universities are producing physicists who apparently are well qualified to publish worth while researches in spectroscopy and atomic structure, but who have had almost no training in basic mechanics, hydrodynamics, electrical theory and thermodynamics, such as was taught thirty years ago. We believe that in an industrial laboratory, the physicist or engineer who has the fundamental classical background is of greater value than a physicist who has almost exclusively specialized in the modern physical developments.

The qualities that are desirable for successful life are many. Some must be inborn; others, such as attitudes, habits, skills and facts, may be taught. Each combination of qualities fits a man for certain activities.

The qualifications of a research physicist, as I have pictured them, consist mainly of aptitudes and attitudes. The essential aptitudes are, first, a space-sense that will enable him to devise tests, and, second, a retiring personality that gets pleasure from quiet accomplishment, without the need of public applause. The attitudes are, first, an open mind, more anxious to learn the truth than to show its knowledge, which I have called conscious ignorance; and, second, active curiosity, intent on finding out, nerved to spurn delights and live laborious days for the thrill of discovery at the journey's end. President Jewett, of the Bell Laboratories, calls this the spirit of romance. "The thrill," he says, "of adventuring forth intellectually into the unknown and of charting out there paths which others can follow, is equal to that of him who looks on a new land for the first time; and the number of such journeys that can be taken is limitless."[11]

Consciousness of ignorance, combined with active curiosity, is the spirit of youth. Beware of the man who tells you, "I did that 20 years ago." He is old. He is through, either as investigator or as useful teacher.

If knowledge and experience, culminating in judgment, are incompatible with conscious ignorance, then we are better research men without judgment. I believe they are not incompatible. Conscious ignorance and active curiosity are attitudes which may be caught like contagions, cultivated like choice flowers, and retained to old age. We may be young in attitude, though old in experience. To the spirit of youth each observation is a romance, a revelation. This is the spirit of research.

It is in this spirit that we may hope to see the vision of a still greater science. In the words of Dr. Whitney:

> We ought to realize that there may be a more valuable use of knowledge and truth than commercial developments, and by aiming at the full appreciation of creation we may do more than simply conquer and control our local environment. Perhaps industrial uses of new knowledge are after all only by-products or ways of advancing to something better.
>
> We advance more often by finding in Nature that which we may learn to use than by making or forcing from Nature that which we think we want.

[11] "Research and the Individual," *Bull. of Purdue Univ.* 26, July, 1926.

THE PROGRESS OF ROENTGENOLOGY AND ITS CONTRIBUTION TO MEDICAL SCIENCE[1]

By the late Dr. PRESTON M. HICKEY

DR. G. W. C. KAYE prefaces his recent monograph with this passage from Hamlet:

> Come, come, and sit you down; you shall not budge;
> You go not till I set you up a glass
> Where you may see the inmost part of you.
> (*Act III, Sc. 4*).

Little did Shakespeare's world realize that in Hamlet's comment to his mother lay the story of a present-day miracle.

[1] Read before Section N, the American Association for the Advancement of Science, January 1, 1930, by Carleton Barnhart Peirce, A.B., M.S., M.D., of the University of Nebraska College of Medicine. "I regret most sincerely that illness prevents my former preceptor, Dr. Preston M. Hickey, from reading the paper to you. I appreciate more than words can express the honor of presenting for him the initiatory paper of the American Roentgen Ray Society upon its affiliation with the American Association for the Advancement of Science."

The observations of William Conrad Roentgen, professor of physics at Wurzburg, crystallized in large measure the preparatory researches of Hittorf, von Helmholtz, Hertz, Lenard, Crookes, and their colleagues in the study of electrical discharges through partially exhausted gas tubes.

This paper, signalizing the recent admission of the American Roentgen Ray Society to affiliation with the American Association for the Advancement of Science, comes at the close of thirty-four years since the discovery of a hitherto unrecognized form of energy by Dr. Roentgen on November 8, 1895.

There appeared in SCIENCE for January 24, 1896, the following news note[2]:

> The *Vienna Presse*, the *London Standard* and other daily papers report what purports to be an extraordinary discovery by Professor Röntgen. It is claimed that he has found that the ultra-violet rays from a Crookes' vacuum tube penetrated wood and other organic substances, whereas metals, bones, etc. are opaque to them. It is said that he has thus photographed the bones in the living body, which would be one of the most important advances that has ever been made in surgery. The photographs have been sent to Vienna and are in the hands of Professor Bolzmann, who has, it is said, accepted the discovery, though he has not succeeded in his attempt to repeat the experiment. In spite of apparently absurd statements concerning the action of the ultra-violet rays it is not impossible that substance such as metals which are good conductors of heat should absorb the ultraviolet rays, while substances such as wood, which are bad conductors of heat, should transmit them. Professor Röntgen is professor of physics at Wurzburg, and any experiments published by him should be accepted without hesitation.

The announcement was followed by much discussion and occasional bitter argument among physicists and investigators the world over. Among the Americans were notably Michael Pupin, Henry W. Cattell, Edwin B. Frost, Thomas Edison, Arthur W. Wright, Arthur W. Goodspeed, Ogden Rood, and William J. Morton. Some fifteen articles in SCIENCE during the first six months of 1896 were devoted to the x-rays. In addition during the same period, the lay magazines, such as *McClure's*, published extensive stories of this new adjunct of science. As occasionally befalls today, this development in the field of pure science obtained earlier and, at first, more notice in the lay press than in the scientific.

You are aware, of course, of the vast development and enlargement of the sphere of roentgenology since then. You also are undoubtedly aware of its varied employment to-day in the physical field with the development of crystallography and its allied phases. More recently, the Roentgen rays have come to be used in the fields of industry and the arts; for instance, in testing fine machines for flaws in metal parts, the consistency of alloys, fine gems in the lapidaries' hands, and the detection of spurious old masters among oil paintings.

But from its inception the major field has been that of the medical sciences. Dr. Roentgen included in his original communication in the *Sitzungsberichte der Wurzburger Physik medizinische Gesellschaft* a note on the observation of the bones of the hand through the flesh. And yet many physicians of that immediate period expressed grave doubt of its usefulness.

The present occasion we consider as a recognition of the importance of roentgenology as a scientific aid in the study, diagnosis and treatment of disease in the human animal. The medical student, who employs the aid of light and sound in the study and treatment of disease, has always paid a tremendous tribute to the importance of the microscope and the stethoscope. These aids, in turn, perhaps unfortunately we venture to say, are beginning to be surpassed by the important applications of the Roentgen ray.

The development of this special adjunct has in large measure been along two lines; one, the refinement of apparatus and technique for the purpose of better differentiation of the nicer gradations in tissue density, and the control of dosage; the other, in the interpretation of the skiagraphic or Roentgengraphic images obtained. In the former we have had the cooperation of the physicist and engineer, and are well launched on a study of biological effect with the collaboration of the biophysicist. In the latter, we must keep closely associated with the fundamental medical sciences of anatomy, physiology and pathology, especially. Perchance we may be able to link more closely morphology and function, under normal and abnormal conditions, than has been accomplished under the current tendency toward compartmentalization of knowledge and "education."

The close relation to anatomy needs little elaboration. One must have primarily the fundamental structure of embryology and anatomy, both microscopic and gross. We are all aware of a certain shock to our freshman ideas of the placement of the stomach as gained from the cadaver, when we observe under the screen an elongated "fish-hook." This is often the occasion for the exclamation of the novice, "Oh! Oh! J-type!"—a sudden realization that "live" anatomy—or a functioning anatomical structure—is not exactly that of the cadaver and has a wide normal variant. In some laboratories, Roentgen studies are being used more and more to afford the student a sense of regional and functional anatomy, which he

[2] SCIENCE, New Series III, No. 56, January 24, 1896, p. 131.

can not procure from his cadaver. This should include both a study of skiagrams of the parts under dissection and fluoroscopic demonstrations of the thorax and gastro-intestinal tract to small groups by a Roentgenologist.

One hesitates perhaps to urge more of this in the purely anatomical laboratories. The physiologist may feel perhaps that all functional observations should be within his department. We wonder if the majority of our colleagues attempting the instruction of students would not welcome an opportunity to assist the anatomist and the physiologist in demonstrating to the student that anatomical parts are related to each other, and that muscles not only contract on stimulation but move other parts in the process. Furthermore, our information of the growth of the individual, his ossification and subsequent decalcification with age has been increased definitely with the Roentgengram.

Here we must of necessity indicate the relatively inseparable juncture with pathology—pathologic physiology, if you will. For the Roentgenscope and skiagram can offer in large measure the clairvoyance of the necropsy without loss of life of the subject. This clairvoyance is somewhat prognostic—but is essentially valuable in the determination of the past insults of disease heaped on the individual human. One might cite pulmonary damage as a facile example.

Diseases of the respiratory tract, both acute and chronic, may be considered particularly amenable to x-ray examination. The gross tissues of the lung are rendered especially suitable for Roentgen studies because they usually include a graphic background of air. The resultant contrasting shadows emphasized by this background of air demonstrate the density of the gross tissues as well as their relative contour. The x-rays thus bring out the subtractions from, and additions to, pulmonary densities which we have learned differentiate the fine degrees of normal and abnormal tissues. A most important characteristic of this examination is that while the microscope requires a microtome and very thin sections of tissue, the x-ray employs optical sections, leaving the patient intact.

The study of the lungs by means of the x-ray had its beginning in America with Dr. Francis Williams, of Boston, whose early publications on this particular subject date back to 1896 and 1897. Naturally there has been a constant accumulation of new data and new methods of technique. Herein lies a necessarily close correlation of the observations of the clinician, radiologist, and pathologist. One of the very puzzling features in the x-ray study of the chest has been the difficulty of early diagnosis of tuberculosis in children. The early diagnosis of tuberculosis in adults has been very well studied and the characteristic appearance has become quite well known. This is due to the fact that adult tuberculosis is more consistent or typical in its x-ray findings than is tuberculosis in children, where the Roentgen shadows are not so distinctive. It is with pleasure, therefore, that we call attention to the recent work that has been done at the Phipps Institute for Tuberculosis, in Philadelphia. The studies at this institute have added very much to our knowledge of the behavior and appearance of childhood tuberculosis, and in this way has increased our certainty of early diagnosis.

The technique which has been useful in bringing out these helpful points requires the close cooperation of the electrical engineer, and the physiologist, with those already noted above. For it requires the development of a method which will permit very rapid exposures of the chest timed to conform to a particular phase of the cardiac cycle, a mechanical refinement to trip the switch at nearly identical phases. Formerly exposures were made quickly but without being able to choose the cardiac systole or cardiac diastole. We are not able to compare skiagrams made in different parts of the respiratory and cardiac cycles for the reason that the density of the lung shadows depends somewhat upon the quantity of blood in the pulmonary vessels at each different phase of the cardiac cycle. By this we mean that with such refinement of engineering the x-ray exposure can be made either in cardiac diastole or cardiac systole and the changes with the different parts of the cycle can be compared.

Another technical development which has helped much in the study of these cases is the lateral and oblique views of the thorax. The importance of this study, also developed at the Phipps Institute, lies in the opportunity to visualize more clearly the changes in the abnormal bronchial tree, which is usually hidden by the heart shadow, and compare the abnormal with the appearance of the normal. These refinements of x-ray diagnosis in the study of child tuberculosis are destined to be of very great importance as they are compared and studied in the light of pathologic physiology.

Such carefully controlled studies, which must be made, can offer to the fundamental fields of anatomy, pathology and physiology much information, and to clinical medicine a major opportunity for early diagnosis and adequate treatment of such diseases.

Further, in the consideration of progress in the medical sciences, particularly as related to pathology, one must give emphasis to the forte of Roentgenology in the cancer problem. It is perhaps a truism to remark that cancer is the most important medical problem which we have to face. Students of cancer are all pretty much in accord with a second truism; namely, that success in the battle against cancer necessitates early diagnosis. We may be permitted to say further, that for this early diagnosis the x-ray is probably our most important agent. Even cursory perusal of the statistics would reveal that cancer of the lip, cancer of the tongue, and cancer of the mouth show a much more favorable outcome than cancer of the esophagus or cancer of the stomach. One does not need to argue that the greater accessibility of these parts to visual inspection is a major factor in this improvement in statistical result.

The use of barium gelatine bougies of varying sizes in the fluoroscopic examination of the esophagus enables the physician to detect very early slight obstructions in swallowing. In this way, without discomfort and without distress to the patient, the physician can ascertain the probable presence or absence of cancer at a much earlier period than he could formerly. Such observations, when critically studied in collaboration with esophagoscopy and cytopathology of the tissue changes presenting, offer a definite advance in the earlier diagnosis and treatment.

The war against cancer of the stomach is being more successfully waged each year. As we study the problem more and more, we realize that here as well the earlier the diagnosis can be made the better will be the result. It follows therefore that the success of our campaign depends to a great extent upon the efficiency of our methods of study. Again may we suggest that these methods of early diagnosis depend largely upon the intelligent use of the x-ray. Patients should be taught the advisability of seeking thorough examinations for the slight but persistent disorders of indigestion commonly called "dyspepsia." The x-ray examination of the stomach causes no discomfort to the patient. There is no reason, therefore, to procrastinate until the symptoms become markedly intrusive. By such delay the seriousness of operative procedure for relief becomes markedly greater. We must remember that the early symptoms of cancer of the stomach are often mild and deceptive, and frequently dismissed, even by the physician, with the general complaint of "indigestion." In these early cases of cancer of the stomach there is found a defect of the gastric outline, manifested either by irregularity or rigidity in the mucous membrane or muscular folds, both departures from normal being presumptive evidence of an early neoplasm. Not only does the x-ray afford a fertile method for the study of the contour and consistency of the lining and wall of the stomach, but also positive means for determining the rate at which the stomach empties. We can then observe an acceleration or retardation of the normal rate, both of which are important in the final conclusion as to the probable condition.

Statistics of the results of the treatment of cancer of the stomach show a marked increase in longevity following operative procedure, so that the older pessimism is now being succeeded by a more optimistic view. If one could insist on an x-ray examination in the average case of so-called indigestion, the brightness of the resultant outlook would certainly become considerably greater. One must, however, bear in mind that merely the use of the x-ray machine is not all that is necessary. Intelligent interpretation of the x-ray shadows, which must be based on fundamental medical knowledge and critical study, is the essential part.

Cancer of the lung must be added to this group of Roentgen diagnostic problems. For some unknown reason cancer of the lung has become much more common in the last few years. A variety of explanations have been offered for this, but so far none have been satisfactory. The diagnosis has usually been made late, and the x-ray has not been of value alone in making an early diagnosis. There is a possibility that the adjuvant of iodized oil for which appreciation must be rendered Doctors Sicard and Forestier, may offer the Roentgenologist assistance by a demonstration of beginning changes in the bronchial lumen, and the patient some hope of relief. This preparation which has been developed within the last few years is easily introduced into the body cavities. And without producing irritation it will give delightfully clear x-ray shadows of the lumen of the cavity. For example, when this oil is introduced into the bronchial tree it causes practically no irritation, and yet will cause shadows which outline that portion of the bronchial tree exactly. In the disease known as bronchiectasis, where there is a very definite enlargement and infection of the bronchi, the physical findings of a tuberculosis and chronic bronchitis are often very difficult to differentiate. However, if the iodized oil is introduced, the size and saculations of the bronchioles are made out with extraordinary accuracy. Many cases of bronchiectasis are in this way diagnosed and treated by methods which are appropriate. Further, this iodized oil is of great value for the injection of small sinuses which, when filled with it, are clearly outlined on the x-ray plate. This same iodized oil may be diluted about 50 per cent. with olive oil and injected into the nasal sinuses such as the antrum, frontal sinuses, etc. A study of the x-ray plates made after injection offers evidences of lack of filling due either to inflammatory diseases or, frequently, to tumors. Comparison with biopsy or surgical specimens may afford us further advance in the correlation of cyto-pathology and physiology with clinical signs.

Another striking use of the iodized oil is the injection of such bland media into the uterine cavity to demonstrate its outline or the possible inclusion of tumors and to display the size of the lumen and the patency of the Fallopian tubes.

In a discussion of the function of Roentgenology in the study of neoplasms one must not overlook the advances which have been made in the field of neurology. Many brain tumors are very frequently without localizing symptoms. One can frequently feel quite sure of the presence of a brain tumor without being positive as to upon which side it is located, and what particular nerve tracts are involved. In conditions of the brain where there has been a disturbance of the circulation in the ventricles and in the lymphatic system, the x-ray is often of the greatest help. Inasmuch as many brain tumors are attended with disturbance of the collection of fluid in the ventricles, and its evacuation, there follows that many brain tumors could be delineated by the demonstration of this disturbance in a graphic method using the x-rays. The way in which this is effected, in general, is that the ventricles of the brain are tapped under very stringent aseptic precautions and the ventricular fluid is replaced by air. Films are made in different positions so as to show the air-filled ventricles in different angles. These studies of the brain oftentimes show the dilated or distorted ventricles by means of this change in density due to the injected air. Tumors, therefore, which encroach upon the ventricles to produce pressure or distortion are demonstrated. This procedure of ventriculography is one which is not used unless the symptoms are urgent. When, however, an experienced neurologist is confronted with the symptoms of a brain tumor the location of which is not certain, one feels that there is ample justification for an injection of air, which will usually be absorbed in a few days without great risk. It is a procedure which is not, of course, to be undertaken by any one who is not thoroughly familiar with all the various minutiae of the new technique. This must entail careful preliminary laboratory investigation, as has been done by Dandy, Cushing, and others.

The injection of air by way of the spinal column is also one of the newer procedures which is adding much to the study of many of our obscure brain cases. This means, like the one just referred to, is not one to be undertaken except by a thoroughly experienced investigator of the conditions and who has exhausted all the simpler methods of diagnosis. In this the cerebrospinal fluid is replaced by air, the amount of spinal fluid withdrawn being balanced very carefully by the amount of air which is being introduced so that a nearly constant pressure is maintained. X-ray plates are then made with the patient in different positions so as to study the places where the air collects or is blocked. The injection of air directly into the ventricles is spoken of as ventriculography. The injection of air into the spinal column is spoken of as encephalography, and is frequently resorted to now in the study of epilepsy, and for the demonstration of spaces resulting in the brain from previous injury.

We would like to refer briefly to the examinations of the urinary tract. When one compares the difficulties of examinations of a generation or of two generations ago with what is being done at the present time, he feels that there has indeed been great progress made. Careful clinical study, cystoscopic examination, laboratory examination of the excretions of the urinary tract, together with x-ray plates of the involved organs, either with or without the injection of an opaque solution into these viscera, detecting distortions or areas of calcification, have increased the reliability of diagnosis of tumors and dysfunction of the urinary tract manyfold. The skiagrams in such studies offer most conclusive information.

Notable among recent advances in medical science is the linkage of Roentgenology with physiology, pharmacology and biochemistry in the work of Graham and his associates, first published in 1923, on the function of the liver and biliary passages, and their Roentgengraphic demonstrations. The study and development of the utilization of halogen compounds of phenolphthalein as a test of liver and gall-bladder functions has a definite remarkable importance in the entire field of medicine to-day. With this adjunct—cholecystography—the physician is able to visualize and evaluate the function of another of the important viscera in the problem of human illnesses. The collaboration of the chemist in the production of an isomer of the salt of lessened toxicity and greater value as an index of function is most notable. Related work is being carried on in the study of the effects of various drugs on the movements of the intestinal tract in the laboratory animal, a procedure which heretofore necessitated surgical technique and often loss of the animal, together with considerable outlay in apparatus. With the fluoroscope and serial skiagrams the animal may be studied time and again under many variants in conditions. Such study under adequate experimental control will offer the most opportunity for further progress in diagnosis and intelligent therapy.

Treatment of disease by means of x-radiation is entering upon a period in which, with the collaboration of the biophysicist, we may be able to offer relief, if not cure, to the patient. The translation of amounts of radiation energy into terms of quantity usable on all types of generators has been a serious problem. The biological dose has been in general the only "measuring stick," and there a human error in interpretation has vitiated much work. The development of a biophysical quantity will afford some further knowledge of the process which has taken place in irradiated tissue. With the establishment in the last year by the International Congress of a physical unit of the *r*, or Roentgen unit, there is in sight a standardization of x-radiation dosage on a uniform scale. This is of value both in diagnostic exposures and in therapy. The collaboration of the Bureau of Standards in maintaining a standard scale is a further step forward toward a universal standard of measurements.

With the continuance of the interest and the close cooperation and enthusiasm of the physicist, the biologist, and the Roentgenologist in the study of the effect of x-radiation on tissue, and its relation especially to the combat of the neoplasm, we may anticipate much of value to medicine and *"les malades,"* and of interest to science as a whole.

OBITUARY

MATTHEW FONTAINE MAURY[1]

FINE Virginia blood flowed in the veins of Matthew Fontaine Maury. His grandfather, James Maury, was an Episcopal clergyman who kept a small school in Albemarle County, which numbered among its pupils Jefferson, Madison and Monroe, three distinguished presidents of the United States who had much to do with starting out the University of Virginia in the way that it should go. Born in 1806, the fourth son in a large family, he soon imbibed among pioneer surroundings courage and self-reliance, a love of honor and independence of thought, and, best of all, a burning desire to know and to achieve. In a curious manner he became interested as a boy in the study of mathematics, which was to play such an important part in his future life. He relates the incident in these words, "My first ambition to become a mathematician was excited by an old cobbler, Neal by name, who lived not far from my father's house, and who used to send the shoes home to his customers with the soles all scratched over with little x's and y's."

At the age of nineteen, he became a midshipman in the United States Navy, and his first cruise was on the *Brandywine,* which carried back to France the great Lafayette after his memorable visit to the United States. Maury started his career with a determination to overcome all obstacles, no matter how disagreeable the task. The success he had in life was attained not so much by a great brilliancy of mind but rather as the result of sheer hard work. In his own words, he says:

> When I became old enough to reflect, it was the aim at which all my energies were directed to make myself a useful man. I soon found that occupation, for some useful end or other, was the true secret of happiness. . . . When I went on board ship, I set out to make everything bend to my profession. I was required to study Spanish; and that nothing might be lost, I got a Spanish work in navigation and studied that. . . . I used to draw problems in spherical trigonometry with chalk on the shot, and put them in the racks where I could see them as I walked the deck.

So well did he school himself by these methods that when his book on navigation was published in 1836, the first nautical work ever to come from the pen of an American naval officer, it soon became the standard treatise on the subject.

The navy of one hundred years ago was unfortunately in a condition of dry rot, and some one with courage was needed to come forward and point out the remedies. Maury accepted the challenge and wrote a series of articles dealing with reforms. At first he wrote under a pseudonym, but he soon won the sympathy and approval of the officers of the Navy. So excellent were the reforms suggested that when the author became known, the President of the United States had all but decided to allow him to put his theories into practice by making him the Secretary of the Navy, in spite of the fact that his rank was but that of lieutenant.

So famous had his writings made him by this time that he was appointed in 1842 as head of the Depot of Charts and Instruments. Here was the opportunity for Maury to show his worth. When he took charge, the office was a very small one, but it grew quickly in size and importance until its name was changed to that of the United States Naval Observatory. The superintendent, although a naval officer, knew little of the science of astronomy. With characteristic determination he immediately started out to teach himself. To those of us who are familiar with telescopes vastly greater than he had ever dreamed of, it is interesting to read the enthusiastic manner with which he describes the passage of a star through the field of view of a transit instrument. His enthusiasm and his love of work affected his subordinates to such a degree that soon the Naval Observatory took rank with the two national observatories of

[1] Address given on the occasion of the unveiling of his bust at the Hall of Fame of New York University, May 14, 1931.