nance Evaluation, and Field Test Divisions. Under the latter are included field stations at Hiwassee Dam, North Carolina; Fort Monroe, Virginia; Provincetown, Massachusetts; Solomons, Maryland; and Dahlgren, Virginia. Under the Technical Services Department are the Analysis and Publications, Design and Drafting, Industrial Engineering, Library, Technical Museum, Patent, Photographic, Property Control, and Shop Divisions. The General Services Department consists of the Administrative, Communications, Maintenance, Operations, and Plant Engineering Divisions. The Personnel Department is made up of the Employment, Classification, Naval Personnel, Employee Services, Research and Records, and Training Divisions. The last-mentioned division trains naval personnel in ordnance devices, supervises numerous inservice courses, cooperates with universities with graduate courses and theses, and gives training in administration and organization of research laboratories.

One of the duties of the Laboratory will be to maintain continuous and active research and development of new principles and devices. Efforts are being made to incorporate here the best features of industrial and university laboratories in order that the Nation may have the protection of the last word in scientific development.

Fifty Years of Physics—A Study in Contrasts

Gordon Ferrie Hull
Dartmouth College, Hanover, New Hampshire

IN THE DOMAIN OF PHYSICS there have been two transcendent periods during these past 50 years. The first began in 1895–96 with the discovery of X-rays, followed by the discovery of the Becquerel rays in 1896, the electron in 1897, radium in 1898, and the statement of the quantum theory by Planck in 1900. The second period also began in 1896, but, growing slowly, culminated in 1939. Vast vistas were suddenly opened in 1896. There had been no theory or experiment which had foretold or prepared us for the discovery of X-rays. It came out of the blue. A similar statement may be made concerning radioactivity and the quantum idea. The timeliness of the discovery of X-rays and the electron is shown by the fact that two of the three kinds of rays which came from a complex radioactive source could be explained at once. The nature of the third ray, though quickly postulated by the keen intuition of Rutherford, was not convincingly established until the Rutherford and Royds experiment in 1908, when the process of transmutation of the elements as it occurs in nature was made plain and the way opened for all the vast results which have followed.

My purpose is not to attempt to record the progress of physics in all its great domains during these years but to present here only a few contrasts.

Upon a previous occasion[1] I called attention to the fact that no American physicist participated in any of the great discoveries which have been mentioned. Perhaps that statement should be modified, as will later be indicated.

In 1899 Arthur Gordon Webster, a distinguished Harvard graduate and one of our most prominent physicists, called together the leading physicists, chiefly of the East, for the purpose of organizing the American Physical Society. Appropriately, Henry Rowland was elected president, and A. A. Michelson, vice-president. In his address as retiring president, Rowland named, without initials or given names, four American physicists—only four—who in all the preceding history of America had won worldwide fame for their contribution to physics: Franklin, Rumford, Henry, and Mayer.

The many-sided Franklin, a legendary figure, had won fame along various lines. Had he not been famous as a publisher and a statesman, he might never have been heard of as a scientist. Balzac described him as "the inventor of the lightning rod, the hoax, and the republic." It has been maintained that there is no clear evidence that he ever performed the kite experiment, and it is certain that the experiment was performed elsewhere before Franklin wrote of it as a possibility. In any event, Franklin's work in science did not lack for publicity.

Rumford left America as a very young man. He was always a British subject and did all his scientific work in Europe. He could hardly be called an American scientist. He was, however, interested in the development of science in America as is evidenced by the Rumford Medal of the American Academy of Arts and Sciences, the Rumford Fund of that Academy, and the Rumford Professorship at Harvard.

Joseph Henry's work in electromagnetic induction

[1] The second Richtmyer Memorial Address of the American Association of Physics Teachers (*Amer. J. Physics*, 1943, **11**, 23).

Based on an address delivered before the American Physical Society at Cambridge, Massachusetts, 27 April 1946.

was substantial but was overshadowed by the work of Faraday.

But who was Mayer? I have asked many physicists, but only one knew. Henry Crew knew Mayer personally and had visited his laboratory. A. M. Mayer (1836–1897) was professor of physics in Stevens Institute and was the co-author of a very modest text (112 pp.) on Light. His contribution to physics has not been recorded in any history of physics with which I am acquainted.

Rowland's list of American physicists who, before his time, had made substantial contributions boils down then to two names, Benjamin Franklin and Joseph Henry. Had he included living Americans he would have added two more, himself and A. A. Michelson. Rowland's experiment on the magnetic effect of convection currents, begun in Helmholtz' laboratory, made clear to J. J. Thomson the nature of the electron. To that extent an American physicist participated in the discovery of that particle. Rowland's exhaustive experiment on the mechanical equivalent of heat was financed by the Rumford Fund and his extensive paper was published in the proceedings of that Academy. He had had difficulty in finding an American publisher for some of his earlier papers. Clerk Maxwell came to his rescue and had them published in the *Philosophical Magazine*.

Coming then to the year 1900 we find that American physicists had made the contributions just mentioned. In addition, the concave grating had been designed; an excellent machine for ruling gratings (the machine which is still ruling gratings for the world) had been built; and the Michelson-Morley experiment—perhaps America's most important experiment—had been performed. In this, Michelson measured the French meter in wave lengths of cadmium light, carrying the experiment to a precision which has never been exceeded (1 part in 20,000,000).[2]

Fifty years ago graduate training in physics was looking up in America, but it was still true that every young physicist felt it was necessary to spend at least a year in Germany or in the Cavendish Laboratory in Cambridge. Europe was the source of inspiration. Not only our ideas, but 90 per cent of all apparatus in our physical laboratories, came from Europe, chiefly from Germany.

The leading laboratories in the United States were rapidly expanding, and two in Canada, Toronto and McGill, were being heard from. In 1898 the 27-year-old New Zealander, Rutherford, came from Cambridge to McGill as research professor in physics. Soddy, from Oxford, joined him in 1900. Together, in 1902, they put forth the startling theory that radioactivity was a spontaneous natural process of transmutation of certain elements. This idea seemed so preposterous that the authorities of McGill were afraid that the University would be held up to ridicule. But the physicists of the world were presently convinced that the theory was right, and McGill became a mecca for workers in radioactivity. Among those who came was Otto Hahn (1905), who, with Strassmann in January 1939, announced the experimental result which, as you all know, set the world on fire: Uranium atoms bombarded by slow neutrons break up so that barium is produced. Then the second volcanic eruption in physics, which had been gathering force for 40 years, suddenly exploded. The rest has been told in millions of words in our press and journals since 6 August 1945.

Although the "genealogical tree" of the radioactive products of uranium had been set forth in 1902 on the basis that the alpha particle was a helium atom of charge two and mass four, there was still doubt about it when Rutherford left McGill for Manchester in 1907. In a letter to Hahn in 1907 Rutherford writes that "it may yet turn out that the alpha particle is hydrogen and that helium comes from a rayless product." I made this proposal in 1904, when Rutherford lectured at Dartmouth, and doubtless numerous others made it. But within a year after reaching Manchester Rutherford and Royds proved the helium idea the right one. In the same letter to Hahn, Rutherford expressed pleasure at the prospect of getting back to England, for, he wrote: "I shall be glad to be nearer the scientific center as I always feel that America, as well as Canada, is on the periphery of the circle." What would he say now, with at least three-fifths of all the physics activity in the world centered in the United States?

The road from the discovery of radium in 1898 to that of the fission of uranium in 1939 was long. Hans Geiger had been an assistant of Prof. Schuster in Manchester and was retained as Rutherford's assistant. In 1908 we had the Rutherford and Geiger device for counting alpha particles. Later, in Germany, Geiger improved upon this device, and still later (1928) the Geiger-Müller counter was brought out. With this instrument electric currents may be measured to the absolute limit of smallness. A person may be given food containing radioactive atoms, and this counter may be utilized to discover where those atoms are chiefly concentrated at some later time in the body.

Rutherford for some time had been wondering about the structure of the atom—whether it was like the "pumpkin" atom of J. J. Thomson or whether it was a solar nucleus with electrons outside. Nagaoka had suggested a "saturnian" atom, a central massive por-

[2] This precision may in the future be surpassed by using the green line of the new isotope of mercury, but it will require a Michelson to perform the experiment.

tion with a ring of negative electrons. Rutherford worked out the theory of the scattering of alpha particles on the basis of the nuclear idea, and Geiger, later Geiger and Marsden (1912), tested the theory by counting the number of alpha particles scattered at various angles. Their results supported the nuclear idea. Niels Bohr spent some months in Manchester at this time and was quick to use the new picture of the atom in his famous theory of the spectra of hydrogen. Moseley, who was with Rutherford for three years, also confirmed the nuclear view and in 1913 established the concept of the atomic number, the number which has been used ever since to identify chemical elements. Let it be recalled again that Moseley, who had accomplished more in his brief lifetime than most scientists who live to three score years and ten, was killed at Gallipoli in August 1915 at the age of 27.

War now intervened to check ordinary scientific research. Rutherford, Hahn, and Geiger, who had gone back to Germany, corresponded during the war by roundabout methods, all letters showing continued respect and cordial good will. In contrast with this evidence of friendship, I have not heard of any friendly letters during World War II from a German scientist to a scientist outside Germany.

Chadwick carried on research with Geiger in Germany just before World War I. He was interned during the four years but was well treated. Geiger's letters to Rutherford always gave assurances to that effect.

Bohr, in a long letter to Rutherford in November 1918, wrote as follows: "All here are convinced there can nevermore be a war in Europe of such dimensions." Perhaps he was expressing not a conviction but a hope—a hope entertained by all scientists. But scientists in the past have had almost no place in the government of nations.

In 1919 Rutherford found that a nitrogen atom bombarded by an energetic alpha from radium could be transmuted into a new oxygen atom and hydrogen. The laborious method of observing the scintillations of a fluorescent screen was used to detect this result. For the first time in man's history the atom of a stable chemical element—the imperishable element of the chemists—was transmuted into another. The projectile used in this experiment was man directed, but not man made. It was a projectile provided by nature, and its initial energy could not be altered in any way by man. But if we could give great and various energies to various kinds of atoms, what might happen? Cockroft and Walton (1932) in the Cavendish Laboratory were able to speed up hydrogen nuclei to an energy of only 150,000 volts and, directing these against lithium, found that two helium atoms had been formed. Not only were new atoms formed, but apparently energy had been created, for the two helium nuclei together had an energy of 17,000,000 volts. The loss of mass due to the formation of the two new atoms had taken the form of energy—a concept which had been growing for some time. Einstein's historic equation, $E = mc^2$, had been verified. Then the race was on.

Now let us return to the Paleozoic age of physics in America, the formation of the American Physical Society. The Society started with 37 members. Some of these were not physicists but joined to show their good will. Everyone knew pretty nearly everyone else. There were to be four meetings a year, each meeting consisting of a morning and an afternoon session. At the first five meetings there was a total of 28 papers, three or four being given in the morning and three or four in the afternoon. There was plenty of time for the papers and for discussion. Also, a paper could hardly have been said to have received due consideration unless it had been discussed by two men, W. S. Franklin and A. G. Webster. Franklin, the intuitive, always wanted a model to picture the phenomenon under discussion, a model which in imagination he held in his hands and which he stretched, compressed, or twisted. He would quote Goethe to illustrate his point. This would be too much for Webster, who would quote Helmholtz, and also Homer and Virgil in the original, and would end up by giving an explanation completely satisfactory to himself in terms of x, y, and z. At times R. W. Wood, who had succeeded Rowland at Johns Hopkins (1901) and who was known throughout the world as a brilliant experimenter, gave demonstrations of optical phenomena. Here a tribute should be paid to Wood for his many contributions to optics, for his outstanding text on Physical Optics, for his near discovery of the Raman effect, and for his exposure of Blondlot's claims regarding N-rays.[3]

The proceedings and papers of the Society were published in bulletins, four per volume. Volume I, covering the first two years, had a total of 80 pages. But at Cornell University in 1894 E. L. Nichols and Ernest Merritt had started the *Physical Review*. This was taken over by the Society in January 1903. Since then, it has been the chief official publication and has become the foremost physics journal in the world.

Just before Rutherford left Canada in order to be near the center of things, O. W. Richardson came from Trinity College, Cambridge, to Princeton. The

[3] Blondlot, of the University of Nancy, in 1904 received a prize of 50,000 francs for the discovery of the N-rays. Wood visited his laboratory and removed in the semidarkened room some of the "essential" components of the apparatus. Blondlot still saw the screen light up. (See *J. Franklin Inst.*, 1907, **164**, 57, 113, 177.)

Comptons presently emerged from Princeton, and for a time it looked as though they were going to make the domain of physics a family reservation. Pupin and others were building up Columbia not only by their own work but by capturing prominent physicists for their department. Both J. J. Thomson and Rutherford were asked to join the staff in 1901, but neither would think of going to so isolated a place as New York City.

The sensational discoveries during the closing years of the Nineteenth Century energized the work in physics of all the great universities of America. Perhaps this was especially true of Chicago, where the great name of Michelson and the energy and enthusiasm of Millikan attracted many graduate students. The measurement of the electron charge by the oil-drop method and of Planck's constant by the photoelectric effect brought new precision at that time to those quantities. The graduates from Chicago were destined to fill very responsible positions in the universities and in the great industrial laboratories.

Then Washington University stepped into the limelight. A. H. Compton (1923), measuring the wave length of X-rays scattered by matter, found that the wave length was lengthened slightly and gave an explanation of the effect based on Planck's quantum theory. Both his experimental results and theoretical reasoning were disputed by others, but he proved his case conclusively.

The Compton Effect made it clear that bullets of light, particles of radiant energy, photons, possessed momentum and energy, that waves of light have the properties of particles. At once, by simple mechanics, we could derive the result that light would give momentum to atoms or would exert pressure on a surface on which it fell—a pressure equal to the energy density in front of the surface. This latter conclusion had been derived by Maxwell from his electromagnetic theory and had been discovered experimentally by Peter Lebedew in Moscow and with considerably greater precision by E. F. Nichols and G. F. Hull in the opening years of the century.

One of our great industrial laboratories stepped into the picture when Davisson and Germer (1927), of the Bell Telephone Laboratories, proved that an electron possesses wave-like characteristics. G. P. Thomson, in Aberdeen, arrived at the same result nearly simultaneously. These experiments supplemented Compton's work and proved that particles have the properties of waves. They also confirmed the theoretical work of Louis de Broglie.

All eyes turned toward India when Raman (1928) showed that light scattered by matter might differ in wave length from that of the original beam by amounts which could be explained by the quantum theory but which were completely unintelligible on the basis of the wave theory. India, which had had no place in physics at the beginning of the century, now had, and has continued to have, an honored place.

We come now to 1932, a wonder year in physics. Chadwick discovered the neutron; C. D. Anderson discovered the positron; Urey, Brickwedde, and Murphy discovered heavy water; Cockroft and Walton brought about the transmutation of lithium by firing into it hydrogen nuclei; the latitude effect in cosmic rays was discovered; Van de Graaff devised his generator for high voltages; and the young genius, E. O. Lawrence, with the help of his associates, brought to practical performance the little gadget upon which he had been working for some years—the cyclotron. That gadget has now grown to such dimensions that it may require an entire building to house it and three or four teams of specially trained physicists to operate it by remote control day and night. Compared with Cockroft and Walton's 150,000 volts, the cyclotron may give atom speeds of 60,000,000 volts. It is now installed in many of the great laboratories throughout the world. It may, with its housing, cost as much as $2,000,000.

It should be noted that of the seven discoveries above, two were produced in England and five in the United States. The two English contributions were of very great importance. We now know that neutrons have a large place in nature. In number or mass they are the chief constituents of all atomic nuclei. They are extremely effective bullets in breaking up atoms. They are the detonators in atomic bombs. But the cyclotron is also of importance. By means of it we have transmuted every known element into another.

Continuing the list of discoveries, we have that of artificial radioactivity by the Curie-Joliots in 1934, and of the mesotron in 1936 by Anderson and Neddemeyer, of California Institute of Technology, and by Street and Stevenson, of Harvard.

In 1934 Fermi and his numerous associates in Rome believed that by bombarding uranium by slow neutrons they had produced element 93. But they did not prove their case; indeed, there was great doubt about it. Hahn, Meitner, and Strassmann took up the problem and came to various conclusions, among them that transuranic elements as far out as 97 had been produced. In 1937 Irene Curie and Savitch thought that they had found lanthanum in the material but concluded that it must be a new transuranic element, 93, which had properties similar to lanthanum. (This would be reasonable, since the atomic number of lanthanum is 57. $57+36=93$.) Then, in January 1939, Hahn and Strassmann announced that analysis of the material obtained by bombardment showed that barium was present. *It was not there before the bombardment. It was not a transuranic element; it was barium.* Such a decision required the ultimate in courage. And if barium was present, so probably was krypton. That announcement produced an enormous upheaval in the domain of physics, for never before had a heavy atom been broken up into two atoms roughly equal in mass.

Aston, in his pioneer work with the mass spectrograph, had measured the masses of many atoms and had drawn a curve, called the packing fraction curve, showing the masses of the atoms. This was extended by Dempster so that competent physicists knew the masses of uranium, barium, and krypton; they knew the excess mass of the large atom over the sum of the two smaller masses; and by a simple mental operation they could compute the energy which would result. This computation was made almost immediately by Lise Meitner and Frisch. But early in 1940 A. O. Nier separated by the mass spectrograph U 234, U 235, and U 238. Dunning, Booth, and Grosse proved that it was U 235 that was broken up. Then the great reservoir of power of the physicists of America and England broke loose to bring about in five years a result, the achievement of which was not expected for 100,000,000 years—the production of the atomic bomb. Part of this story—a story that has no counterpart in all man's history—is told in the Smyth report.

There were some discoveries made during the war that call for inclusion. In 1939 in the Berkeley laboratory, Edwin McMillan tentatively identified elements 93 and 94 (of mass 239) in uranium bombarded by slow neutrons. In 1940 he and Abelson made the matter certain. The names proposed by McMillan were "neptunium" (Np) and "plutonium" (Pu). Later in that year uranium was bombarded by 30,000,000-volt deuterons from the cyclotron, and the 238 isotopes of these elements were obtained—indeed, enough of plutonium (0.5 mg., or one-millionth of a pound) to enable Seaborg, Kennedy, and Wahl to make a study of its chemical properties. Had plutonium not been discovered there still would have been no atomic bomb.

Continuing the list of discoveries we note that Seaborg has discovered by physical means elements 95 and 96, for which he has proposed the names "americum" and "curium." During the war eight chemical elements have been discovered by physical means: 43, 61, 85, 87, 93, 94, 95, and 96. Incidentally, all our handbooks of physics and chemistry and all our charts of chemical elements list elements 85 and 87 as alabamine and virginium. These names must be stricken out, since the magneto-optical method of identifying chemical elements, like the N-rays, is an exploded fallacy.

A cyclotron may produce more radioactive atoms and bring about more transmutations than would be produced by all the radium in the laboratories of the world. And in the very near future we may have uranium-plutonium piles or nuclear reactors which may provide neutrons and gamma rays of great intrinsic energy and of unparalleled intensity.

The betatron, a new device for producing high-energy particles—in this case, electrons—has been developed by Kerst. One such instrument in the General Electric Research Laboratory gives to electrons an energy of 150,000,000 volts. The resulting X-rays penetrate a foot of steel. They produce all manner of transmutations and generate mesotrons. Thus we may have man-made cosmic rays generated on the earth. However, both the cyclotron and betatron may be superseded by the synchrotron, which promises to give us energies of 300,000,000 volts. This idea, proposed in 1945 by McMillan in Berkeley, seems to have been proposed in 1944 by V. Veksler, of Moscow, who is building there a 30,000,000-volt instrument.

Let us look at the condition of physics today. In Germany, Japan, and parts of Russia science has been nearly destroyed, and in France and England it has been greatly curtailed; but in the United States physics has reached a pinnacle never before obtained. Note that during the first 20 years of the awards of Nobel Prizes only one American, A. A. Michelson, received the prize, and that was for work done 20 or more years earlier. Of those who received the awards in physics during the past 25 years, 12 are in America; and of the last nine medalists, eight are in America, four of these being native born. Half of our Nobel Prizemen in physics are recent arrivals from Europe, and there are other rather recent arrivals who are not inferior to some of the prizemen. All of these and our own talent have given to research and teaching an unchallenged prestige. Our young men no longer feel that it is necessary to go abroad for thorough training or for opportunities for research. Rather, before the war there was an increasing number of applicants from abroad for admission to our graduate schools. In fact, so great has been the number of applications of students from abroad that some of our universities have had to impose a quota system so that our native-born students would not be crowded out. Attention has already been called to the fact that Russia, Japan, and India were crowding toward the front in science. Now that Japan is badly crippled, the race may easily be won by Russia.

Of course, membership in our physical societies has increased. In 1899 there were only 30 or 40 members of the parent Society, whereas now there are 5,300, and in it and the related societies (optical, acoustical, X-rays, electron microscope, and physics teachers) a total of 10,000, or about 300 times the original membership. Instead of the 20 or 30 papers a year there are now a few thousand.

There has been a corresponding increase in the research activities in our great universities and technical schools. It ought to be recorded that during these 50 years the number of students in our colleges and universities has increased by a factor of seven. Consider, for example, the M.I.T. (Every scientist in the world knows the meaning of those letters.) Originally it was purely an undergraduate technical institution. Now it is the foremost institute of technology in the world. Originally research in pure science was out of bounds. Gradually its field broadened. During the first 20 years of this century it gave a total of four Master's degrees and two Doctor's degrees in physics. Now it has 150 graduate students including those in three groups: the Research Laboratory in Electronics, the Laboratory of Nuclear Science, and the Acoustics Laboratory. During the war it cosponsored the Radiation Laboratory, which, next to the Manhattan Project, was the greatest enterprise of the war. Its operating expenses were about $3,000,000 a month. In that laboratory numerous radar devices were designed and brought to perfection. These included the H_2X air-borne set carried by heavy bombers so that targets could be found at night or through overcast; the Loran sets for long-range navigation, so that any vessel or airplane carrying a receiver could locate its position without chronometer or astronomical observation; and the powerful MEW (Microwave Early Warning) set which played so large a part in the invasion of Europe. Contracts placed with manufacturers by the Radiation Laboratory totaled about $2,000,000,000. Here we should note that the multicavity, multiresonant magnetron essential in very many of our radar devices is due to Oliphant, of Birmingham. The idea of the original magnetron is due to A. W. Hull, of the General Electric Research Laboratory.

Let us go across the continent to the Pacific Coast. In the University of California there are about 4,000 students in the undergraduate physics courses—3,000 different students. There were 120 graduate students when I last heard, and 100 were clamoring for admission. This does not include the famous Radiation Laboratory—the laboratory of the monster cyclotrons. At present I can get no information regarding that laboratory. It is under government control. Think of a laboratory with 200 graduate students in physics. Think of the apparatus required and of the guidance that is necessary. Then shed a tear for the physics instructors at Berkeley!

Let us consider the California Institute of Technology. It has risen from nearly nothing to be perhaps the foremost physics research laboratory in the world. It has 300 undergraduates in physics and 80 graduates. Fifty years ago these numbers were 12 and 0. In its physics faculty of 13 full professors there are two Nobel Prize winners, one-third of all the native-born American prize winners in physics. Its great growth and prestige is due, of course, to the abounding energy of R. A. Millikan, who has been its chief for 25 years.

In this brief survey I have named a few men and thereby may have offended many. I have not mentioned the contributions of Theodore Lyman and Bridgman; of Harrison and Slater; of Aston, Dempster, and Bainbridge; of Boltwood, Bumsted, and Swann; of C. T. R. Wilson, Dirac, Schroedinger, Heisenberg, and Bethe; of J. A. Wheeler; and of many others. But the workers in physics find joy in their work without the stimulus of publicity. They know well that "full many a flower is born to blush unseen" and are content.

The wonders of radar in all its forms, completely unknown 50 years ago, the discovery of the fission of uranium by Hahn and Strassmann, the production of the Atomic Bomb by the combined scientific power of the United States and England, by the Canadian contribution of the essential materials, and by the vast industrial power of the United States, have given to American physicists a prestige never before enjoyed. They are actually consulted by Congress regarding some matters. In fact, some of them are constantly shouting their advice from the housetops, but they can never expect to attain the prominence occupied by the rulers of the country, the so-called labor leaders, who, when the situation is right, make war on the rest of the Nation and who, at times of national emergency, hold up the Nation and demand its money or its life.

The scientists of this Nation are not likely to make war on this or any other nation. We are not combative or competitive. We should unite with the scientists of all other nations to outlaw war. No iron curtain should be allowed to enclose and segregate the scientists of any nation.

Science has come to have a prominent place in the life of our Nation, but the methods of science have not greatly changed. True, there is emphasis on teamwork in contrast with the efforts of an individual. Great laboratories supplied with very powerful and expensive apparatus can dwarf the work of ordinary college laboratories.

But what kind of people are you going to put into the large laboratories? What ideals are you going to place before them? Merely bringing a lot of men together in one building or center is not necessarily going to bring about progress in science. How did it happen that Chadwick discovered the neutron? He knew from Compton's work what a photon would do if it struck an atom. He knew from long-established principles what an atom would do if it struck another atom. He could identify atoms by their ranges from the abundant data established by the long labors of Rutherford, Blackett, and himself. He possessed a great fund of knowledge and experimental skill, and he was a tremendous worker. Would he have been helped or hindered by a lot of clock punchers? I think it is of vast importance that we impress every teacher of physics in our colleges and universities with the view that progress in science depends on *his* knowledge of the domain in which he works, *his* scientific curiosity, *his* scientific imagination, *his* experimental skill and analytical ability, and that progress is likely to be accompanied by the scientific analogues of blood, sweat, and tears.

Technical Papers

The Similarity of the Effect of Podophyllin and Colchicine and Their Use in the Treatment of Condylomata Acuminata

MAJOR LESTER S. KING and
MAJOR MAURICE SULLIVAN[1]
Wm. Beaumont General Hospital, El Paso, Texas

The drug podophyllin, after having been dropped from the official list of cathartics in the *Pharmacopeia*, has become of renewed interest in dermatology. Kaplan (*1*) reported the use of podophyllin in oil as a topical application in the treatment of condylomata acuminata, with very satisfactory clinical results. Clinical trials have fully confirmed the efficacy of the drug. Its mode of action, however, has hitherto received no attention.

The application of podophyllin to normal human and rabbit skin reveals unusual changes affecting the epidermis. There is alteration of nuclear pattern, leading to the breakup of chromatin masses and the production of varying-sized pycnotic fragments. In other cells the disintegration of chromatin resembles markedly distorted mitotic figures, principally but not exclusively of the metaphase. There are corresponding cytoplasmic changes consisting, in different cells, of spongy swelling, shrinkage from the cell membrane, hydrops, delicate fibrillation, and alterations of standing reactions. We designate such altered cells as "podophyllin cells."

In many rabbits practically every cell in the epidermis discloses these severe nuclear and cytoplasmic alterations. The changes are transitory, and an essentially normal epidermis is re-established four to six days after a single application. Repeated applications show no increase in effect. On the contrary, a resistance seems to be established, and the histologic appearance following 20 applications is less striking than that following a single application. There is no evidence of cumulative effect in the experiments thus far undertaken.

Histologic examination of condylomata in the process of undergoing involution following applications of podophyllin shows numerous "podophyllin cells" of the type readily observed in the experimental material. In addition, there are widespread, nonspecific, degenerative changes in the epithelial cells.

The "podophyllin cells" were found to resemble the so-called "colchicine figures" described in the literature (*2, 3*). Consequently, suspensions of colchicine in oil were applied to condylomata acuminata, with clinical results superior to those of podophyllin. Similar colchicine suspensions applied to rabbit skin also resulted in pathologic alterations identical with the podophyllin effect, but more intense and of briefer duration.

Previously, in the experimental use of colchicine the drug has been injected parenterally, and its effect on various organs has been widespread. Its action has been considered to be to arrest mitosis in the metaphase. In the present work, colchicine and podophyllin, applied to the unbroken skin, do not suggest this mode of action. There is some direct, immediate, degenerative action, with resultant cell death. Other changes can be interpreted as a preliminary stimulation of mitosis, with marked distortion of the resulting pattern.

The differences between colchicine injected subcutaneously and colchicine applied locally can probably be attributed to the greater local concentration attainable with the latter method. It is of interest that podophyllin and colchicine are essentially without effect when applied to verrucae vulgares or other

[1] Present addresses, respectively: 836 Wellington Avenue, Chicago 14, Illinois, and 3301 North Charles, Baltimore 18, Maryland.