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ROBERT WILLIAMS WOOD

1868—1955

A Biographical Memoir by

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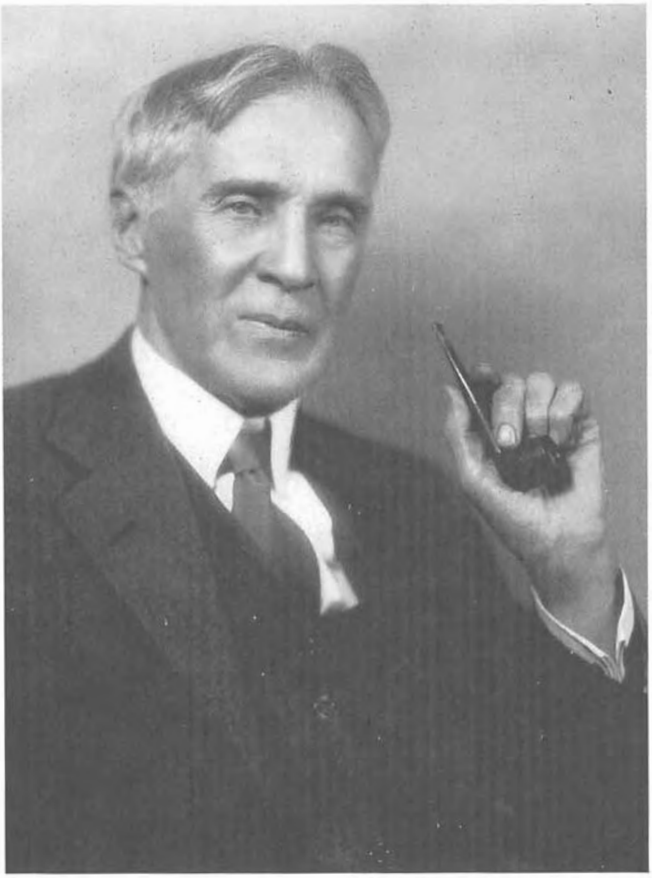

R. W. Wood.

ROBERT WILLIAMS WOOD

May 2, 1868–August 11, 1955

BY G. H. DIEKE

WHEN PROFESSOR R. W. WOOD died on August 11, 1955, he was to the younger generation of physicists a colorful legend, a representative of the past. He was, however, by no means forgotten, as a lesser man might have been at the age of eighty-seven. Many stories were still circulating about him. When I recently paid a visit to the University of Wisconsin, which Wood had left in 1901, his exploits were being discussed there as if they had happened just recently instead of more than half a century before. His solid scientific achievements are now a matter of record. His active mind refused to accept retirement, and he visited his old room in the Physical Laboratory at Johns Hopkins University regularly until nearly the end, even though the infirmities of old age had gradually made themselves felt. He never gave up his curiosity about things and was still actively engaged in the revision of his book *Physical Optics*. Death came to him peacefully; he passed away during his sleep without any severe illness.

Wood's active period of scientific productivity coincided with the rise of atomic physics, and he made important

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contributions to the increasing knowledge of the structure of the atom, chiefly through his experimental research in physical optics. He was, however, far from one-sided and penetrated into many fields. He went wherever his insatiable curiosity led him, whether this was into different branches of physics or into all sorts of other activities such as engineering, art, crime detection, spiritualism, psychology, and archaeology.

Wood may have inherited his interest in scientific matters from his father, Robert Williams Wood, who was born in Massachusetts in 1803, grew up in New England, and was a physician in Maine until 1838. Then he went to the Hawaiian Islands, where he stayed until 1866 as physician and pioneer in the sugar industry, after which he returned to New England. He was active in the American Statistical Association.

From his childhood R. W. Wood, Jr., showed an absorbing interest in all sorts of phenomena in natural science, and he soon started finding out for himself what made things work by trying experiments of his own. He went to Harvard University from which he graduated in 1891 with a bachelor's degree in chemistry. He was apparently bored by the regularly prescribed studies but made up for the poor marks in required subjects like languages and mathematics by extra work in fields that interested him, such as geology, astronomy, and psychology. After graduation he went to Johns Hopkins University for further studies in chemistry. There he found that he was more interested in what went on in Henry Rowland's laboratory in the Department of Physics than what he was supposed to be doing in the Chemistry Department. The following year (1892) he went to the newly founded University of Chicago, intending to get a doctor's degree in chemistry. He was not too well pleased with the routine of chemistry as it was taught there and went to Germany in 1894 for further study of chemistry. In Berlin he once more was attracted by what went on in physics, and under Ruben's influence changed permanently to a career in physics. After two years in Europe, he returned to the United States, spent a short time at the Massachusetts Institute of Technology, and in 1897 accepted an instructorship at the University of Wisconsin.

During the four years he spent at Wisconsin, his many-sided talents came into full blossom and he became known as one of the most promising young physicists. When Henry Rowland died in 1901, Wood was appointed his successor at Johns Hopkins University as full professor of experimental physics. Rowland was probably the most eminent physicist in the United States during the final quarter of the nineteenth century, and to be chosen his successor came as a high honor to the thirty-three-year-old Wood.

Wood remained at Johns Hopkins for the rest of his life, although his stay in Baltimore was interrupted by frequent summer trips to Europe and elsewhere and by occasional sabbatical leaves. He was professor of experimental physics until his official retirement in 1938 and was then appointed research professor, a position he held until his death.

When one tries to describe Wood's lifework and his impact on contemporary physics, one is immediately struck by the pure chemistry to contributions in almost every branch of physics, be it acoustics, electricity, heat, or optics. He did not confine himself to the purely academic side of the subject but often came forward with clever practical applications. One of the early examples (and a typical one) is the way he helped to relieve the hardships of the severe winters in Wisconsin. It happened regularly that the water pipes froze. Getting them thawed out was a long, drawn-out, and costly procedure. Wood suggested connecting the leads of a high-current transformer to the water faucets in neighboring houses and letting the electric current produce the heat necessary for the thawing-out process. This extremely simple procedure worked so well that it established Wood's reputation as a person who could be counted on to solve practical problems, something of no small importance in a midwestern state university, one of the chief purposes for the founding of which had been to help the general population meeting all the problems confronting a frontier society.

During his Wisconsin time Wood showed clearly the beginning of the particular genius that later made him famous with physicists all over the world. Here came the start of his studies in physical optics which were to become the main substance of his lifework. The first attack on the problem is typical for Wood. The wave theory of light was, of course, well established by the end of the nineteenth century. The concept of waves, wave fronts, etc., was, however, somewhat abstract. Elegant mathematical methods had been developed for demonstrating all the properties of the waves and could serve for the solution of practically any problem. These, however, meant nothing to Wood, to whom mathematical abstractions were without significance. In order to demonstrate to his students and to his own satisfaction the wave properties of light, he photographed (with the Schlieren method developed by Toepler) the actual wave fronts of sound waves which have analogous properties and demonstrated vividly all the familiar phenomena which are observed when waves are reflected or refracted. These photographs apparently received wide attention, and he was invited by Sir Charles Boys to demonstrate them before the Royal Society in 1900.

When Wood came to Johns Hopkins University, he found a favorable atmosphere for continuing his research in earnest. His teaching duties were light. During the next three decades a series of papers on the optical properties of simple gases appeared, which placed his name among those of the great physicists. The modern theory of the atom was then in its early stages. Scientists realized that the spectra of the elements would form the chief source of information about the detailed structure of the atoms, although the key that would make all this information accessible was not found until the fundamental discoveries by Rutherford and Bohr in 1912. Wood had started on a detailed investigation of the spectra of such simple gases as sodium, mercury, and iodine. He discovered resonance radiation and studied its many puzzling features with great thoroughness and amazing experimental ingenuity. How it was polarized and how it behaved in a magnetic field or in the presence of foreign gases were things at first completely incomprehensible. Wood's experiments stimulated those of many others. During the 1920s the theory had advanced far enough to be greatly aided by these experiments in its further developments. The experimental work of Wood and the increase of our knowledge about the structure of the atom were inseparable. In the late 1920s, after the Raman effect had been discovered, it became apparent that the most significant results would be obtained with gases. The strong background scattering seemed to make experiments with gases impossible. Wood showed that by a ridiculously simple modification the difficulties could be completely overcome.

No one who knew Wood could ever get the mistaken idea that he would confine himself to one subject. Whenever he found something that interested and puzzled him, he went to his laboratory to clear the matter up. He usually could devise some simple experiment that went to the heart of the matter. Wood undoubtedly was one of the greatest experimenters of our time. Nevertheless, he never worked with anything in the least complicated. His apparatus was usually made by himself, often improvised and crude looking but always near perfection in its essentials and capable of extraordinary performances in his own hands. A typical example was the large spectrograph which he used during the summer months. He did amazing things with it, using the sun as his chief light source.

Wood and his family spent the summers on an old farm on Long Island. In a barn he had improvised a laboratory, and one of its features was this forty-foot grating spectrograph, probably the largest then in existence and certainly capable of giving better results than anyone had ever seen before. It was constructed from sewer pipe laid by the local stonemason. During the long months between summers when the instrument was not used, all sorts of wildlife used it as a shelter, and the optical path became cluttered up with spider webs. Wood's method of cleaning the tube has become a classic. He put the family cat in one end and closed this end so that the cat, in order to escape, had to run through the whole length of the tube, ridding it very effectively of all spider webs.

Wood's work was certainly not confined to the academic aspects of science. Whenever he saw a practical application, he would pursue it and see to it that others knew about it. The thawing of water pipes in Wisconsin was mentioned earlier. About the same time he invented a process for color photography and later made other contributions to photography. He was also very much concerned with the applications of the invisible ultraviolet radiation to all sorts of problems. During the First World War he developed an efficient filter which, combined with a mercury lamp, suppressed the visible light while transmitting freely the ultraviolet. This filter is still called by many Wood's glass or Wood's filter. During the war such invisible light was used for signalling without the knowledge of the enemy. Many substances fluoresce brightly when subject to ultraviolet light, and the possibility of interesting effects for stage illumination was not lost on Wood. The famous Ziegfeld, who put on spectacular stage shows in New York with a swarm of chorus girls in resplendent costumes (or sometimes without them), was Wood's neighbor on Long Island. Many of Wood's ideas on lighting tricks with ultraviolet light found their way to Ziegfeld's stage.

During the war he became acquainted with high-frequency ultrasonic waves and made many experiments with them. Much of this work was done in the private laboratory of his friend, Alfred Loomis, in Tuxedo Park near New York, to which also his forty-foot spectrograph was transferred (without the sewer pipes, however).

Wood made many inventions, but he was a scientist rather than inventor and did not follow them up with development work and promotion; thus, he rarely reaped any financial benefits from them. His work on the production of hydrogen atoms in discharges, which he had undertaken in order to obtain a well-developed hydrogen spectrum, led in Langmuir's hands to the hydrogen welding process. He was one of the first, if not the first, to make successful photographs in infrared and ultraviolet light and applied them to photographing the moon and the planets in order to discover details on their surface invisible to the eye or ordinary photography. He applied this technique also to the detection of forgeries. He made numerous other improvements in photographic techniques, particularly as they applied to the solution of astronomical problems. He is credited with having been the first to propose the use of tear gas and the use of air spaces around warships to dissipate the destructive power of torpedoes when the ship is attacked.

Another example shows what his combination of curiosity and experimental skill could do to solve a problem completely outside of his own field. In 1931 Wood and his wife took a trip to Egypt, where he saw in the Cairo Museum gold ornaments that had come out of Tutankhamen's tomb. The gold looked decidedly purple, and the reason for this was a mystery. Some thought that the purple color had been produced purposely by the Egyptian goldsmith by a process since lost; others believed that age had affected the gold this way. No one had a clue to the mystery. Wood was allowed to take a few specimens with him and made tests on them when he returned to Baltimore. He found that the purple color was due to a thin surface film and by spectroscopic experiments found that the gold of this film was mixed with iron and some arsenic. He produced evidence that the films were produced purposely either by mixing the necessary ingredients or by using natural gold from a locality where iron and arsenic were present as impurities. Wood was able to reproduce in his laboratory the exact appearance of the purple gold and thus solved an archaeological mystery.

When Wood became seriously interested in physical optics and began to teach this subject, first at the University of Wisconsin and then at Johns Hopkins University, he keenly felt the lack of a book which would approach the subject as he did himself. He therefore set out to write one, and the first edition of *Physical Optics* appeared in 1905. It differed from any other book in this field by the large number of experimental details it included, all from Wood's own experience and therefore original, fresh, and full of interest. Wood admitted in the preface that he had taken the more mathematical parts largely from other books. The experimental parts were what appealed to the reader; a second edition became necessary in 1911, a third was published in 1934, and Wood was working on a revision for the fourth edition when he died. In the preface of the third edition, he stated his aim: "I have attempted to give, in as many instances as possible, a physical picture of the processes usually described by equations." In this he succeeded, spectacularly well in many instances. In others he perhaps overlooked the fact that not everyone had the same aversion to mathematical formulae as he had himself, and in a few cases his physical picture is unnecessarily elaborate, for a simple mathematical derivation would have conveyed the idea quite well.

I had occasion to discuss with him many parts of his book during the revisions for the third and fourth editions, and the attitude he took was perhaps typical of his relations with science during his whole life. It was only natural that in a subject which had progressed as much as physical optics had done, largely because of his own endeavors, there were some phases with which he had not kept abreast but which he nevertheless wanted to include in the new edition. It would have been easy for him to ask one of his associates to write these parts for him. He never did this. He wrote the parts himself and then went to one of his friends for criticism and suggestions, which he always took freely. He then rewrote the part and had it read again. This would go on until he finally felt that he had absorbed the matter and was reproducing it in his own words. Occasionally this process resulted in something that others felt was more elaborate than the subject warranted, but Wood refused to let others do the thinking for him.

There is an extensive biography of R. W. Wood by William Seabrook (New York: Harcourt, Brace & Co., 1941) which was written in such close collaboration with Wood that large portions of it are nearly autobiographical. This biography gives many details about his career. Much of his experimental work is conveniently assembled in his *Physical Optics.* Space does not permit a presentation here of all details, but one subject should be singled out because through his work in this field he affected the work of many other scientists. This is his work with diffraction gratings.

Henry Rowland, in his early days at Johns Hopkins University, had made the optical diffraction grating into a precision instrument and had invented the concave grating which made possible the modern high-resolution spectrograph. Rowland's engines for the rulings of such gratings were in the Physics Department of Johns Hopkins University. Wood had access to them and later was in complete charge of them. He made many studies of the gratings ruled with these engines. At the same time he made many improvements and saw to it that the machines were kept going so that gratings continued to be produced for other scientists to use. For many years these engines under Wood's care furnished practically the only source of supply for high-quality diffraction gratings, without which precision spectroscopy was virtually impossible. For this reason nearly every spectroscopic laboratory in the world and most astronomical observatories had some of Wood's gratings. Only in relatively recent years have other sources of supply for such gratings become available. Against the expectations of many, the demand for gratings has increased with the years, and now they are used in industry as well as in physical and chemical laboratories and astronomical observatories.

The ruling of 15,000, 30,000 or even more lines per inch, with the highest uniformity of spacing, is no small task, and when there are even minute flaws in the ruling, the resulting grating may be useless. The gratings produce a "spectrum" of light, and the literal meaning of the word is, of course, "ghost." However, use of the English word "ghost" does not refer to the spectrum that is to be produced by the grating but flaws in the spectrum which cause spectrum lines to appear where none are supposed to be. Wood found that one class of such ghosts, the so-called Lyman ghosts, was produced by the shock to the ruling engine caused whenever the seam in the drive belt hit the driving wheel. By designing a more flexible drive, he removed this difficulty entirely.

Wood designed the echelette grating, which is a grating with the grooves ruled with such a shape that they throw practically all the light into one narrow wavelength band. He also experimented with replica gratings so that one successfully ruled grating could provide many replicas with the same properties. The size of a grating is limited by the design of the engine. The astronomers in particular were looking for larger gratings to be placed in front of their large telescope objectives. Wood showed that this problem could be solved by making a composite large grating out of several smaller ones, and he was successful in making several of these mosaic gratings. He made many other improvements in the art of ruling gratings. Perhaps more important than this achievement is the fact that he kept the engines going and supplied a constant stream of gratings without which much of the research that contributed to the progress of physics would have been impossible.

Wood was a fascinating lecturer and a superb showman. This was already manifest during his early days in Wisconsin, where he went out of his way to enliven the teaching of physics by instructive and sometimes spectacular experiments. For Wood no phenomenon became real until he had devised an experiment that clearly demonstrated it. Abstract reasoning never appealed to him; nevertheless everything he did was carefully reasoned out. He never engaged in experimenting at random just to see what would come out but always had a carefully thought out plan. He knew all the tricks of the showman and could prepare carefully and in detail an experiment that was intended to give the impression of being improvised. He knew how to build up to a climax, and it was customary that wild applause would break out even in gatherings where no one would have expected any enthusiasm. He loved stunts such as taking a mouthful of liquid air and spitting it out or breathing in hydrogen and then speaking with a changed pitch to his voice.

Wood never formed a school; he was too individualistic for that. He had, however, many students from all over the world, and even now whenever two of them come together they can spend hours telling anecdotes about their former teacher. He was very fond of practical jokes. As a student he had a landlady who he felt showed too much interest in his affairs. One day when the streets were muddy, he took his shoes and placed footprints in his room beginning at the window, up the wall, across the ceiling, and down the other wall. The reactions of the landlady are not recorded.

When he gave demonstrations with ultraviolet light, often before gatherings with ladies present, he used to call attention to how brightly teeth fluoresce in ultraviolet light. Everyone would open his mouth for a demonstration until Wood remarked casually, "And you notice that all the false teeth remain black"; suddenly the mouths would snap shut again.

Wood, who worked over his own experiments until whatever he wanted to show became crystal clear, had no patience with scientific quackery and frauds. He occasionally went to considerable lengths to set matters straight. This he sometimes did by unconventional means and often with dramatic results.

Perhaps the most famous of these cases was that of the "N-rays," discovered by a reputable French physicist, which caused a considerable stir in 1903 and 1904 because of the remarkable properties attributed to them. Other investigators appeared to confirm the original findings, and a whole series of papers appeared in reputable scientific journals dealing with these sensational rays. In fact, the French Academy awarded a gold medal and a large prize to the discoverer. Other investigators, among them Wood, could not duplicate any of the experiments. At the request of other scientists, but undoubtedly also because the subject appealed to him, Wood went to France to investigate the matter. The rays were supposed to be deflected by an aluminum prism. While the inventor was demonstrating the effects in a darkened room, Wood took the prism out of the apparatus and put it in his pocket without any change being observed by the inventor. Wood published this finding immediately in *Nature* and thus ended the N-rays for good.

As far as I know, no one ever suggested that fraud was involved in the affair of the N-rays. It apparently was a case of self-delusion on the part of the inventor and the other scientists who claimed that they could observe them.

Wood also had ample experience with outright frauds and fakers. Some claimed to have secret inventions for which they sought financial backing, others claimed a cure for strange ailments, and still others could communicate with the spirits of the departed. Wood had no patience with any of them; he used much ingenuity to trap them and had spectacular success in many cases. Mediums soon became wary and after such experiences did not want to have anything to do with Wood.

The following example has all the imprints of Wood's method, though I cannot vouch that it originated with him. During the Second World War there was a self-styled inventor who claimed to have discovered a powerful explosive which in his opinion would supersede all hitherto used explosives, while the military experts considered it worthless. The inventor had, however, powerful friends among the politicians in Washington, and therefore the Aberdeen Proving Ground, where Wood was a consultant, could not refuse to give the inventor the opportunity for a demonstration. It was agreed that the effect of the explosive should be tested with goats to be tethered at various distances from the explosion. The day of the test arrived, with senators and generals present and the newspapers full of the importance of the occasion. The explosion went off but the goats, even the nearest ones, calmly continued to graze as if nothing had happened. Nothing more was ever heard of this particular explosive.

What had not been made public was that on Wood's advice the goats had been made to graze for weeks in the immediate vicinity of the big guns that were tested at Aberdeen so that noise did not startle them. While undoubtedly the worthlessness of the explosive would eventually have been demonstrated the more usual methods, Wood's way presented a shortcut which saved a great deal of time, which the explosives experts could then use for better purposes.

Wood could attack, with the same zest that he bestowed on the most important problems in physics, other questions that caught his fancy whether they were on the fringes of science or had nothing to do with it.

He started as a boy and kept it up until his death. As a student at Harvard he became interested in hallucinations. To gain firsthand experience he secured a quantity of hashish, swallowed it, and recorded in minute detail the visions and hallucinations he experienced; and he reported the results as a thesis in a course of psychology he was then taking. He also sent the account to a New York newspaper and was disappointed when it was published without sensational headlines.

As to the matter of publication, Wood was never a publicity seeker but was so interested in whatever he was doing that he felt others should be just as interested to read about it. He often sent his scientific papers simultaneously to journals in the United States, Britain, and the Continent and saw to it that the daily press was also informed. When he was very impatient, he sent communications to *Nature* by cable.

To come back to Wood's extrascientific activities: they were too numerous for all to be mentioned here, because he was interested at one time or other in practically everything. He was a skilled boomerang thrower and introduced the Hawaiian surfboard to the Long Island beaches. He traveled before 1900 through the Wisconsin countryside in one of the first automobiles seen in that part of the country. He was a gifted painter in watercolors. For a time he tried his hand at science fiction in collaboration with Arthur Train, an author of popular stories, but after getting a few stories published he gave up this sideline.

He was, however, very successful with a series of poems, first published in 1907, and probably many who never heard of Wood the physicist know him as the author of *How To Tell the Birds from the Flowers*, for this volume went through about twenty editions. He had written these nonsense verses to amuse his children and illustrated them by clever drawings.

It is not surprising that Wood with all of his scientific curiosity should be fascinated by crime detection, and he lent a hand in the solution of a number of criminal cases in New York and Baltimore.

The scientific curiosity which he showed in all matters manifested itself even when, a few years before his death, he suffered a heart attack. As these things go it was not a very severe attack, but he must have driven his doctor to distraction by the intense interest he showed in his own symptoms. It was a great disappointment to him when he realized that he was not the first one to go through this experience.

Wood always had close ties with British scientists. These dated from 1900, when he was invited to lecture on his process of color photography before the Royal Society of Arts and received at the same time an invitation for a demonstration of his photographs of sound waves before the Royal Society. In 1904, in connection with the Cambridge meeting of the British Association for the Advancement of Science, he was the guest of Lord Rayleigh at his country house and private laboratory, and there was from then on a frequent exchange of ideas between the two great scientists. In 1919 he was elected Foreign Member of the Royal Society. He received his first honorary degree from the University of Birmingham and one of his last from Oxford University, with one from the University of Edinburgh in between. He was an honorary member of the Royal Institution and of the London Optical Society and an honorary fellow of the London Physical Society. He received in 1899 a medal of the Royal Society of Arts for his invention of the diffraction color process in photography and in 1938 the Rumford Gold Medal of the Royal Society for his achievements in physical optics, a distinction which he valued perhaps most of all. The *Philosophical Magazine* and later the *Proceedings of the Royal Society* were his favorite journals for his own publications.

Thus Britain, perhaps more than any other country, showed appreciation for Wood's genius, although he did not lack distinctions in his own country and abroad. He was a member of the National Academy of Sciences in Washington, the Academia dei Lincei in Rome, the Russian Academy of Science in Leningrad, the Royal Swedish Academy in Stockholm, and the Indian Association for Science in Calcutta, among many others. The University of Berlin awarded him an honorary doctor's degree in 1934, and Johns Hopkins University honored him in the same way when in 1951 he had finished his fiftieth year as professor at that institution.

During that same year his closest associates in Baltimore honored him at an intimate dinner to which the wider circle of his friends had been invited to send messages. The messages poured in from all corners of the world. They showed how much Wood and his achievements were still in the minds of physicists.

From the foregoing, the reader will have gathered that Wood was by no means a one-sided scientist but that he had wide interests and made contributions to many diverse fields.

In his private life he was far from being a recluse. In 1892 he married Gertrude Ames, who also came from a New England family and who was his constant companion for more than sixty years, although she herself had no interest in scientific things. The Woods led a very active social life in Baltimore, at their summer place near Easthampton on Long Island, and during their travels abroad. They had a very wide and interesting circle of friends. Mrs. Wood provided the family the stability without which a man of Wood's temperament might have found life occasionally very difficult. He is survived by Mrs. Wood, their three children, and many grandchildren.

His biographer, Seabrook, called him "a small boy who never grew up," and there is probably a good deal of truth in that statement, for though he had much sophistication, his fundamental approach to everything was that of a small boy fascinated by something new that he wants to take apart so he can see what makes it work.

The secret of Wood's greatness is probably that he could recognize a problem that could be dealt with by experimental methods, that he could then reduce the experimental technique to something very simple, and that in carrying out the experiment he could distinguish the essential points from the confusing details. Physicists will look back with nostalgia to this era when one person working practically by himself could make major contributions to the frontier fields of his science, and they will think of R. W. Wood as the protagonist of this era.

Perhaps techniques in physics, like so many other things, have changed since the two world wars. Now we have become accustomed to a state of affairs where even a moderate effort to get beyond what is already known often involves the expenditure of millions of dollars and requires the cooperation of many persons, scientists, technicians, and engineers, and an organization that will make such cooperation effective. Many will think back to the times of R. W. Wood as the good old days. Perhaps there will again be persons who can make this era revive.

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