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AN ENGINEER'S OUTLOOK[1]

By Sir ALFRED EWING, K.C.B., F.R.S.

LET me make a confession which may also serve as an apology. I have the unwelcome distinction of being the oldest president the association has ever suffered. In its primitive years the average age of presidents scarcely exceeded fifty: one of them, aged only twenty-nine, afterwards founded the Cavendish Laboratory, and so did a service to science which it would be impossible to overvalue. As time went on the choice fell on older men, and now the electors have taken what one hopes may be regarded as an extreme step. But, as it happens, this is not the first time I have read the president's address. At the Edinburgh meeting of 1921 the president, Sir Edward Thorpe, was prostrated by illness and asked me to act as his mouthpiece. The small service so rendered brought an unexpected reward. Some newspaper report must have confused the platform substitute with the real president, for a well-known novelist sent me a copy of one of her romances, which was no doubt meant as a tribute to Sir Edward. It was called "The Mighty Atom"—an arresting title. Perhaps that is why I did not read beyond the title-page. Without close examination it was put by a more orderly hand than mine on a shelf that already held works on like subjects by authors such as J. J. Thomson and Rutherford and Bohr. "The Mighty Atom" was said to be one of the best sellers of its day: in that respect, if in no other, it found congenial company when it was joined on the same shelf by a series of volumes from the fascinating pens of Eddington and Jeans. These, however, I need not tell you I have read and reread, to my entire pleasure and partial understanding.

If "The Mighty Atom" was an arresting phrase, it was also an apt one. For we now know the atom to be indeed mighty in senses that were little suspected by the begetters of atomic theory. It has been mighty in sweeping away ideas that were found inadequate, in demanding fresh concepts, in presenting a new

[1] From the address of the president of the British Association for the Advancement of Science, York, 1932.

world for conjecture and experiment and inference, in fusing chemistry and physics into a single science. It is found to be mighty in the complexity of its structure and the variety of radiations it may give out when excited to activity. It has unravelled for us the bewildering tangle of spectroscopic lines. And, most surprising of all, the atom, however seemingly inert, is mighty in being a magazine of energy which, for the most part, it locks safely away. This is fortunate, for if the secret were discovered of letting loose the atomic store we should invite dissolution at the hands of any fool or knave. And it is also fortunate that in the furnace of the sun, at temperatures far higher than those of our hottest terrestrial infernos, the stored energy of the atom is drawn upon, as we believe, and has been drawn upon for ages, to keep up that blessed radiation which makes man's life possible and is the source of all his power.

In the middle nineties there set in an astonishing renaissance of physical science which has centered in the study of the atom and extends by inevitable logic to the stars. In quick succession came three great discoveries: the x-rays by Röntgen in 1895; radioactivity by Becquerel in 1896, and the electron by J. J. Thomson in 1897. Sensational, puzzling, upsetting, these events inspired every physicist to new activities of thought and equipped every laboratory with no less novel methods of research. A flood of further discovery followed, the flow of which continues unabated. Within the last few months notable items have been announced that well deserve our attention. It may not be inappropriate if I try for a few minutes to touch—however lightly—on one or two aspects of this subject, as it is seen through the eyes of an engineer.

Thanks mainly to J. J. Thomson, Rutherford and Bohr, we now recognize the atom of any substance to be a highly complex structure, built up, so to speak, of two sorts of blocks or brickbats—the electrons, which are indivisible units of negative electricity, and the protons, which are indivisible units of positive electricity. It is strangely simple to be taken back, as it were, to the nursery floor and the childish game, and given just two sorts of blocks, exactly alike in each sort, and exactly the same number of each sort, with which to build the universe of material things. The blocks are unbreakable: we can not produce them or destroy them or change them. In respect of electrical quality the two kinds are equal and opposite, but they contribute very unequally to the atom's mass, each proton (for some reason not yet understood) contributing about 1,840 times more than each electron. Every substance is made up of blocks of the same two sorts. If you compare different substances you find that the diversity of their chemical and other properties arises solely from differences in the number and arrangement of the blocks which compose their atoms. Any atom, in its normal or electrically neutral state, must contain an equal number of protons and electrons. All the protons in any atom are gathered close together at the center, along with some of the electrons, forming a compact, dense portion which is called the nucleus. Although the nucleus accounts for nearly the whole of the atom's mass, it occupies no more than a very minute fraction of the atom's volume. Those of the electrons which are within the nucleus doubtless serve to bind the protons together; the other electrons constitute, as it were, a voluminous crinoline, or rather a series of crinolines, extending relatively far away from the center and giving the whole atom an exceedingly open structure. Within that open structure upheavals may be caused by outside agents in various ways. One or more of the electrons in the crinoline may be temporarily removed (as, for instance, by the action of heat or by the incidence of energetic radiation), and the atom is then said to be ionized: for a time the balance between positive and negative is upset. But the missing electron returns to its place, or another comes instead, and when this happens a definite amount of radiation is given out, much as energy is given out when a weight falls from one to another landing of a staircase. We may speak of the landings as energy levels. The radiation which issues when an electron falls from one energy level to another constitutes what is called a photon.[2] It has two aspects, behaving in one like a particle and in the other like a group of waves, and at present we have to accept both, though we can not fully reconcile them. The photon carries a definite quantity of energy and is characterized by a definite frequency of vibration. Its energy depends on the two levels between which the electron falls, and this determines the frequency of the vibration which the photon conveys, for the frequency is equal to the energy divided by that mysterious constant of nature, the quantum of action discovered by Planck. In any element all the atoms have the same set of energy levels: these contribute to the emission spectrum and account for its groups of spectral lines. In heavy atoms there are many energy levels, and consequently very many lines appear in their spectra.

I will not weary you with details that are now fairly familiar. What we have to realize is that all matter consists of the two kinds of electricity, protons and electrons, held apart we do not know how. To the early experimentalists who electrified rods of resin or glass by rubbing them, electricity seemed no more

[2] We owe the name "photon" to Professor G. N. Lewis, of Berkeley, California, who proposed it in a letter published in *Nature* of December 18, 1926.

than a curious attribute of matter: now we regard it as matter's very essence—the ultimate stuff out of which every atom is built. If you ask, What is electricity? there is no answer, save that it is a thing which exists in units of two sorts, positive and negative, with a strong attraction for each other, and that in any atom you find them somehow held apart against that attraction, with a consequent storing of potential energy. They are prevented from coalescing, although the difference of potential between them is nearly a thousand million volts. Why they do not flash together is a mystery—one of the many mysteries which physicists have still to solve.

Engineers are accustomed to the idea of storing energy in a condenser by charging the opposed plates to a potential of a few scores or hundreds or thousands of volts. That is done by transferring some of the crinoline electrons from one to the other plate: it involves only a minute supplementary separation, which disappears when the condenser is discharged. In every atom we have a permanent separation of electricities; the protons and electrons look at one another, so to speak, across an immensely greater dielectric gulf which no laboratory operation ever causes them to bridge. That is why every atom is a magazine of energy, the quantity of which (mc^2) is proportional to the atom's mass.

Any of the usual operations of the electrical engineer, such as charging and discharging a condenser or a storage battery, or driving a dynamo and conducting electricity from it to a distant station where it can actuate a motor or heat the filaments of lamps to incandescence, may be described as the setting up and the breaking down of a comparatively small extra difference of potential between the opposed electricities in some of the atoms of the engineering plant. In every process of industrial electricity, on whatever scale, what happens is a temporary enlargement of the potential difference which always exists between electrons and protons, and then a return to what may be called nature's *status quo*. But those supplementary differences of potential which the engineer first superimposes and then allows to disappear are exceedingly small, even at their greatest, in comparison with the gigantic difference which the normal condition of the atom itself involves.

A notable event of the year is the strong evidence which Dr. Chadwick, of the Cavendish Laboratory, has found for the existence of what is called the neutron—a type of particle in which an electron and a proton are associated in particularly close juxtaposition. There is a like close association between electrons and protons in the nucleus of any heavy element, but it had not previously been discovered in a single isolated pair. Twelve years ago Lord Rutherford conjectured the existence of such a particle and described the properties it should possess. Its excessive smallness and density, together with its lack of an external electric field, give it a unique power of penetrating matter. It is too slim to be confined under pressure in any vessel: it will simply slip through the walls. The normal hydrogen atom has the same two constituents, one proton and one electron, but in nothing like the same intimacy of association, for the hydrogen atom wears its electron as a bulky crinoline which confers on it an immensely greater volume. The neutron, on the other hand, may be said to have taken the crinoline off, folded it up and put it in its pocket. Not to be too fanciful, we may at least describe the partners as clasping one another so tightly that the electron has ceased to be a fender; none the less as a unit of negative electricity it still serves to give electrical balance to the pair. Though so close together, the two constituents of the neutron remain separate and distinct, parted by nearly as many million volts as in a hydrogen atom. In this hitherto unknown particle, whose existence the experiments of Dr. Chadwick seem to have definitely proved, we have a new physical entity of extraordinary interest and a powerful tool for further research.

Lord Rutherford was the first to discover and name the nucleus. It is the inner sanctuary of the atom, the repository of secrets many of which have yet to be disclosed, almost unapproachable, not only because of its smallness but because of the electric field in which it is encased. Recognizing the nucleus to be a richly charged strong-room, Rutherford has spared no effort to break it open. He has submitted it to a furious bombardment, using as missiles the alpha particles which radioactive substances project. These particles, each consisting of four protons and two electrons compactly built together, have the necessary velocity and energy to penetrate to the atom's heart. Rutherford had perforce to fire into the brown: he could not aim his gun, nor even tell when it would go off: the chances of a hit were no more than one in many millions. But hits were in fact obtained—hits so effective that they chipped off protons and caused the missile to be absorbed, thus realizing the dream of the alchemist by making one element change into another. That was a dozen or more years ago: since then his attack has lost none of its severity. It has been taken up under his guidance by a school of workers and many further secrets of the nucleus have been revealed.

Quite recently two of his disciples have gone one better, as disciples sometimes do, to the joy of their lords. Dr. Cockcroft and Dr. Walton have used missiles of their own making, instead of those that come spontaneously and intermittently from substances such as radium or thorium. By beautiful devices they have applied their knowledge of electrical engineering and their mastery of electrical technique to project single protons into the nucleus of lithium, using a steady potential of several hundred thousand volts to give the projectile sufficient penetrating power. An atom of lithium has (usually) seven protons and four electrons in its nucleus; the other three electrons constitute the crinoline. Here again it was a case of firing into the brown—out of millions of shots a few reached their billet. When the projected proton forces an entry into the lithium nucleus it creates a domestic disturbance of the liveliest kind. For with the seven protons already in occupation it makes an eighth; the group then splits into two sets of four, each taking two of the electrons, and they fly violently apart with an energy drawn from the atomic magazine. The result is that two helium atoms are formed. This is a notable achievement, the first artificial splitting of the atom by a laboratory process in which there is no recourse to the violent projectiles which radioactive substances provide. It has been followed up by successfully applying the same method to break up the atoms of other elements.

It is a satisfaction to learn that in all the encounters and emissions and absorptions that are studied among atoms and photons and the parts of atoms there is, so far as we yet know, strict compliance with the accepted principles of conservation in respect of momentum and energy and mass, though matter (in the ordinary sense) is liable to transformation into energy and energy into matter. When radiation is emitted some matter disappears, for the atom that emits it loses a little of its mass; when radiation is absorbed a like quantity of matter comes into being.

But the engineer finds himself obliged to admit that no mechanical model of the atom can be expected to give an adequate picture of that strange new world. Our mechanical ideas are derived from the study of gross matter, which is made up of vast aggregates of atoms, and any model must share the limitations this implies. It is futile to explain the constitution of the atom in terms applicable to gross matter, just as it would be futile to study the psychology of an individual by observing only the movements of crowds. So we must expect to find within the atom and among its parts qualities and actions different in kind from those we know, and paradoxes which without a wider vision we can not interpret. Such a paradox indeed confronts us at the present time, when we try to harmonize the wave aspect and the particle aspect of the photon, of the electron, and indeed of matter itself. These things are still a mystery—a riddle which some day we may learn to read. Meanwhile we do well to remember that any attempt to portray the structure of the atom in the language of ordinary experience is to give undue significance to symbols and analogies that are more or less invalid. Qualifying phrases like "so to speak" or "as it were" can not be escaped. They are confessions that the image is inevitably a distortion of the reality it is intended to suggest.

Let us now glance back to the early days of the association, and trace a little—a very little—of what it has done for the advancement of science, both pure and applied. The two inevitably march together. Between discovery and invention there is, in effect if not always in form, a close partnership with a constant interchange of advantage. No discovery, however abstract, is safe from being turned to practical account; on the other hand, few if any applications fail to react in stimulating discovery and providing the experimentalist with more effective weapons of attack.

From the first the association took cognizance of engineering as one of the subjects it was created to advance. One of its earliest acts, and a very wise one, was to invite reports on the state of science: these were called for in many different fields and were written by the best available experts. In the first batch of such reports were two that dealt with engineering, one on the strength of materials and the other on hydraulics. As it happened, they were of very unequal merit; but they are alike in this, that they demonstrate how conspicuous was the lack of science on the part of early British engineers.

The engineers of those days were big professional figures. They had covered the country with a network of roads and bridges and canals; they had drained the fens; they had built harbors and lighthouses. By multiplying factories, by extending the uses of coal and iron, they were laying the foundations of that commercial supremacy which, so long as it lasted, we took for granted as a sort of national right. They had taught the world how to light towns by gas, and were beginning to drive ships by steam. Above all, they had shown that a new era of locomotion was about to set in. A railway connecting Liverpool with Manchester had been opened: its success was proved, and schemes were projected that would soon utilize labor on a large scale for a host of tunnels and cuttings and embankments, and so relieve the scourge of unemployment which—as we also know—follows the scourge of war. The engineering pioneers were sagacious men who put their faith in experience; they knew little of theory and cared less. Instinct and personality carried them through difficulties of a kind that science might have helped them to solve or to avoid. They had the sense to profit by their own mistakes.

It is significant that in 1832, when the British Association called for a report on the present state of our knowledge of hydraulics as a branch of engineering, the terms of reference included this curious phrase: "Stating whether it appears from the writings of Dutch, Italian and other authors that any general principles are established in this subject."

The report was written by George Rennie, a son of the greater Rennie, who left us a monument of his genius—I wish I could say an imperishable monument—in Waterloo Bridge. After giving a good summary of the work of foreign theorists the reporter remarks:

> It only remains for us to notice the scanty contributions of our own countrymen. While France and Germany were rapidly advancing upon the traces of Italy, England remained an inactive spectator of their progress.

It is clear that there was much need for the scientific leaven which the new association could, and did, provide.

Another of the early concerns of the association was with the performance of steam engines. At the date of our foundation more than fifty years had passed since the inventions of Watt provided an engine fit to serve as a general means of producing power. Its earliest application, and still at that date its most common one, was in the pumping of mines. Engineers took a professional and even sporting interest in what they called its "duty," meaning the amount of water pumped through a given height for each bushel of coal consumed. Nevertheless, it is a remarkable fact that neither they nor the physicists of that period had any notion that the process involved a conversion of heat into mechanical work. It is difficult for us now to imagine a world of physics and engineering where the idea had not yet dawned that there was such a thing as energy, capable of Protean transformations, but in all of them conserving its total amount. Enlightenment was soon to come, and our meeting-rooms furnished the scene. In 1843 Joule brought before one of the sections his first determination of the mechanical equivalent of heat. He spoke with the modesty natural—in those days—to a man of twenty-four. His paper was received in chilly silence. Two years later, after further experiments he reappeared; but again no notice was taken of the heresies of a youthful amateur. Nothing daunted, he prepared a fuller case for the Oxford meeting of 1847, perhaps remembering that Oxford is the home of lost causes. In a narrative written many years later, Joule has told how the chairman suggested that as the business of the section pressed he should not read the paper, but merely give a brief account of his experiments:

> This [he says] I endeavoured to do, and discussion not being invited, the communication would have passed without comment if a young man had not risen in the Section and by his intelligent observations created a lively interest in the new theory. The young man was William Thomson.

But Thomson, though deeply interested, was not at first convinced. Nearly four years more were to pass before he satisfied himself that the doctrines of Joule did not clash with the teachings of Carnot, of which he was then an enthusiastic proselyte. At length he became a convert; he saw, as we should now say, that the first law of thermodynamics was in fact consistent with the second. Then indeed he accepted the principles of Joule in their entirety and was eager in their support. Quickly he proceeded to apply them to every part of the physical domain. Along with Clausius and Rankine he formulated the principles which govern the whole art of producing power by the agency of heat. The steam turbine of Parsons, the gas engines of Otto and Dugald Clerk, the oil engines of Daimler and Diesel, with all their social consequences in making swift travel easy by road and possible by air, are among the practical results. On the same thermodynamic foundation was built the converse art of mechanically producing cold, which we employ in ever-increasing measure for the import and storage of our food. Joint experiments undertaken by Joule and Thomson led to a further discovery which later enabled the process of refrigeration to be carried very near to the limit of coldness which Thomson himself established as the absolute zero. In the hands of Linde and Claude the "Joule-Thomson effect" as a means of producing extreme cold has created new industries through the liquefaction of air and the separation of its constituents by methods of fractional distillation. However cold, however near the absolute zero, was the association's first reception of Joule, we may claim that in effecting a conjunction between him and Thomson it made amends. Their meeting in 1847 ushered in a new era both of scientific theory and of engineering practice.

Of the association's many other services there is little time to speak. When the telegraph developed in the middle of last century and spread itself across the Atlantic, largely under the guidance of that same William Thomson (whom later we knew as Lord Kelvin), there were no accepted units in which electrical quantities could be measured and specified.

The scientific world was as badly off then for a standard of electricity as the commercial world is now for a standard of value. The need of electrical standards was urgently felt, by none more than Thomson himself. He stirred the association to act: a strong committee was set up, and in time its work served as a basis of international agreement. There is no danger that any country will wish to "go off" the standards thus established. To settle them was an incalculable boon to science no less than to technics. It paved the way for the revolution of the eighteen-eighties, when electricity passed, almost suddenly, from being no more than the servant of the telegraph to be master of a great domain. It was then that the electric light and the electric transmission of power gave it a vastly extended application, and the fundamental discoveries of Faraday, the centenary of which we lately celebrated, came into the kingdom for which they had waited nearly fifty years.

Another notable achievement of the association was to promote the establishment of a National Physical Laboratory. Informal talks at our meetings in the nineties led to the appointment of a committee which moved the government of the day to take action. The laboratory was constituted, and Sir Richard Glazebrook was appointed its first head. What it has become in his hands and the hands of his successor, Sir Joseph Petavel, does not need to be told. From small beginnings it has grown to be an influential factor in the world's scientific progress, and a legitimate subject of national pride.

Another by-product of quite a different sort is the memorial to Charles Darwin which we hold as trustee of the nation and of all nations. At our meeting in 1927 the president, Sir Arthur Keith, spoke in his address of the house where Darwin lived and worked, pointing out how admirably it would serve as a monument to the great naturalist. No sooner was the suggestion published than a donor came forward whose devotion to the memory of Darwin expressed itself in a noble gift. Sir Buckston Browne not only bought and endowed Down House, but arranged with pious care that the house and its grounds should exhibit, so far as was possible, the exact environment of Darwin's life. The pilgrims who now visit this shrine in their thousands see Darwin's study as it was when the master thought and wrote, and can reconstruct the habit of his days. There could not be a more appropriate memorial. Its custody by the association involves obligations which are by no means small, and we may claim that they are worthily fulfilled.

One may safely say that there is no department of scientific endeavor our meetings have not aided, no important step in the procession of discovery they have not chronicled. It was at our meeting of 1856 that Bessemer first announced his process of making a new material—what we now call mild steel—by blowing air through melted pig iron. Produced in that way, or by the later method of the regenerative furnace and the open hearth, it soon revolutionized the construction of railways, bridges, boilers, ships and machinery of all sorts, and it now supplies the architect with skeletons which he clothes with brick and stone and concrete. It was at the Oxford meeting of 1894 that Lodge demonstrated a primitive form of wireless telegraph based on the experiments of Hertz, a precursor of the devices that were brought into use a little later through the practical skill and indefatigable enterprise of Marconi. At the same meeting there was an epoch-making announcement by the late Lord Rayleigh. His patient weighings of the residual gas which was found after depriving air of all its oxygen led him to the discovery of argon. That was a surprise of the first magnitude; it was the herald, one may say, of the new physics. Next year his colleague Ramsay presented other members of the family of inert gases. It is curious to recall the indifference and scepticism with which these really great discoveries were received. Some of the chemists of that day seem to have had no use for inert gases. But the stones which the builders were at first disposed to refuse have become head stones of the corner. In the architecture of the elements they fill places that are distinctive and all-important; they mark the systematic sequences of the periodic law. In a metaphor appropriate to atomic physics we may describe them as coy ladies with a particular symmetry in their crinoline of electrons, unresponsive to advances which other atoms are ready to make or to receive. Inert though they be, they have found industrial uses. Helium fills airships; argon fills incandescent lamps; and neon, so modest a constituent of the atmosphere that you might think it born to blush unseen, has lately taken to blushing deliberately and even ostentatiously in the shop-signs of every city street. In the field of pure science it was neon, outside the radioactive elements, that first introduced us to isotopes. And helium has a greater glory as the key to radioactive transformations and historian of the rocks. Disciples of evolution should be grateful to helium for delivering them from the cramping limits of geological time which an earlier physics had mistakenly imposed.

My own recollection covers many surprises that are become commonplaces to-day: the dynamo, the electric motor, the transformer, the rectifier, the storage battery, the incandescent lamp, the phonograph, the telephone, the internal combustion engine, aircraft, the steam turbine, the special steels and alloys which metallurgists invent for every particular need, wireless telegraphy, the thermionic valve as receiver, as amplifier, as generator of electric waves. To that last we owe the miracle of broadcasting. Who, a generation ago, would have imagined that a few yards of stretched wire outside the window and a magic box upon the sill should conjure from adjacent space the strains of Beethoven or Bach, the exhortations of many platforms, the pessimism natural to those who forecast the weather and the optimism of orators who have newly dined?

Sounds and sweet airs, that give delight and hurt not.
Sometimes a thousand twangling instruments . . .
And sometimes voices . . . that, when I waked,
I cried to dream again.

I don't know any product of engineering more efficient than that magic box. It needs no attention; it is always ready for service; and when you tire of it you have only to switch it off. A blessing on it for that! Heard melodies may be sweet, but those unheard are often sweeter. Do you ever reflect, when you pick and choose among the multitude of airs and voices, or shut out all from your solitude of thought, that they are still there, physically present, individual, distinct, crowding yet not interfering, besetting you though you do not perceive them, silent until you determine that one or another shall catch your ear? Go where you will, to the ocean or the wilderness or the pole, you can not escape that vast company of attendants; they come to you, unheard, unseen, from every quarter of the globe with a swiftness no other messengers approach. Is any fairy tale so strange as that reality? In all the wizardry of science surely there is nothing more wonderful than this.

THE NEW HYDROBIOLOGICAL LABORATORY ON THE CHESAPEAKE[1]

By Professor JAMES G. NEEDHAM
CORNELL UNIVERSITY

I BRING you the congratulations of the hydrobiological fraternity. This is a fine laboratory in a wonderful environment, with live problems at its very door. It is an undertaking of great promise. It brings research facilities to the problems. In laboratories remote from the sources of experimental materials, far too much work is done with a few weazened specimens and under conditions that put a strain on their very existence. Here one may work in the midst of all the wealth of nature, and may know that he is dealing with natural conditions. Here the training of the university laboratories and the facilities of the field may come together, and practical problems may be met in a practical way.

Here are vast natural resources, and we know right well that there are difficulties in their management. It is time to stop guessing as to what should be done, and time to start fact-finding with adequate facilities. More knowledge is needed. Understanding leads to control.

We marvel to-day at the changes that have come over human affairs in our own time. Science seems to be transforming the world and the rate of its progress is ever accelerating. And why? Is it not because society has become aware of its own intellectual resources and has begun developing them, first, by offering encouragement to invention, and, latterly, by offering encouragement to research? Invention is encouraged by the instrumentality of the patent office; research by the experiment stations and by laboratories such as this one. Science began to make the world over when it became cumulative; when observers began to preserve detailed records of observations and experiments; when its problems were analyzed and split into manageable parts and tackled one at a time; when it organized cooperation and provided for comparison and criticism of results and put these results into economic use.

The spirit of inquiry into the processes of nature lies at the root of all human progress. Scientific curiosity has been called "the divine instinct." It sets us apart from all other creatures. We seek to know. Of all creatures living on the earth, we of the human species are the most inquisitive. We share with animals certain states of mind—joy, fear, anger, curiosity, etc.—and manifest them by like behavior. We probably do not get more frightened or more angry than some other creatures, but we are far more curious to know about things. Therein lies a difference that in its cumulative results sets us so far apart from other living things as to make us seem like another order of things. This desire to know is responsible for the development of all our science.

It is a great pleasure to come to this beautiful spot and to share in these exercises at the founding of a biological laboratory in a place where life does so abound, and where every turn invites to its pleasurable contemplation. How bountiful nature is

[1] Remarks at the dedication of the Biological Laboratory on Solomon's Island, Maryland, July 19, 1932.