ATMOSPHERIC ELECTRICITY AND ALLIED PHENOMENA[1]

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ONE of the greatest mysteries of the universe is the tremendous richness of it all and yet the strange concealment of that richness. The sun shines to-day as it probably shone a thousand million years ago in an age when there was no earth, no life and no conditions to support life. Yet in that formless age there existed in the properties of the materials of the sun the wherewithal to fashion in future times a dynamo, an automobile and the countless adjuncts of our civilization of to-day, things which would have had no meaning or place in the fires of the great orb itself.

If the period from the dawn of history be shrunk into a day, we shall find that the first twenty-three hours of that day are barren as far as natural philosophy is concerned; for it is only in the last hour that science was born; and even as the human child develops in its struggle towards manhood, so this child of nature, born to a civilization six thousand years old, has grown, and with such ever-increasing strength that, in the last fifteen minutes of its existence, in the last fifty years of actual time, it has outshone all the achievements of its youth and adolescence and has torn from nature more of her secrets than she had vouchsafed to man in the whole previous history of his existence.

My task this afternoon is to open up for you a small chest in the vaults which store the jewels of the universe and show you a few of those treasures which constitute the science of atmospheric electricity.

From time immemorial, the thunderstorm has symbolized in the mind of primitive man the wrath of the Almighty, and the lightning flashes the decimating bolts of Jove. It was Benjamin Franklin, the founder of the society from whose halls I am now speaking, who, nearly two hundred years ago, in his famous kite experiments performed not far from the spot on which I now stand, showed that the lightning flash is simply the big brother of the ordinary electric spark.

I need hardly remind you that science has come to know two kinds of electricity, called positive and negative electricity because the two kinds possess the power to neutralize each other's effects when they are mixed. When separated, they tend to rush together under their mutual attraction, and may raise to incandescence anything, such as the atmosphere, which impedes them in their paths. It may be of interest to remark that while a piece of iron, for example, is electrically neutral under ordinary conditions, a cubic inch of it contains so much positive and negative electricity that if we could separate these charges and concentrate them at two points an inch apart, they would attract each other with a force of more than a hundred million million million tons.

It is now a universally accepted belief that thunderstorms and lightning are secondary phenomena brought about by the abnormal meteorological conditions which we always find associated with them, and nearly all theories of thunderstorms invoke some mechanism by which falling raindrops, snow or hail become charged with one kind of electricity, while the air and smaller drops capable of being carried up by the rising column of air associated with the storm are charged in the opposite sense. The separation of electricity proceeds until electrical tensions are set up sufficient to result in a lightning flash, sometimes between one mass of air and another, sometimes between a mass of air and the ground. However, while the thunderstorm is the most spectacular manifestation of electrical activity in the atmosphere, that atmosphere is at all times the seat of more modest electrical phenomena of profound interest to the student of science.

Our earth is not an electrically neutral body. Its surface is coated with a layer of negative electricity. The amount of this electric charge is such that there is about one and a half times as much difference of electrical pressure or, to use the technical expression, electrical potential, between the surface and a point one yard above it as there is between the terminals of our lighting circuits. The electrical pressure or potential continues to rise as we mount into the atmosphere but at a decreasing rate, until at an altitude of ten miles or so there is very little further change. However, the net result is that between a point ten miles high and the surface of the earth there is an electrical pressure difference of about a hundred and fifty thousand volts.

Now the atmosphere is a conductor of electricity. As compared with a substance like copper, for example, its conductivity is almost inconceivably small. A column of air one inch long offers as much resistance to the flow of the electric current as would a copper cable of the same cross-section extending from here to the star Arcturus and back several times. In spite of the smallness of this power of the atmosphere

[1] World-wide broadcast of the American Philosophical Society and WRUL, Philadelphia, May 22, 1942.

to conduct electricity, it is sufficient to insure that 90 per cent. of the earth's electric charge would disappear in ten minutes if there were no means of replenishing the loss. The total current flowing from the earth amounts to about 1,000 amperes, that is, enough current to light about 3,000 ordinary incandescent lamps. The total power dissipated in this current is about 150,000 kilowatts. That would be quite a lot to pay for, but it is not very much on the scale of operations of cosmical phenomena, for the sun's radiation delivers to the earth about a thousand million times as much power as this.

The process by which the earth's charge is continually replenished has been for many years a puzzle to the student of atmospheric electricity. From time to time some new fact of physics has seemed the thing necessary to provide a solution of the problem, and then, as we learned more, the explanation appeared inadequate. Frequently we became conscious of the philosophy of the old darky, who remarked: "It ain't what you don't know that gets you into trouble, but what you do know and ain't so."

One of the oldest theories of the replenishment of the charge is a theory proposed by the English physicist, C. T. R. Wilson, who claimed that rain is, on the whole, charged with electricity of the kind to be found on the earth's surface, and that this rain, in descending to the earth, brings its charge with it, leaving the opposite kind in the atmosphere. This theory has had to fight many objections, but it is possible that in the long run it may contain the essentials of the facts.

To return to the electrical conductivity of the atmosphere, we all know that the atmosphere is composed of a large number of molecules of gas. Each of these is in part built up out of particles of electricity of both kinds, so that the molecule is neutral as a whole. By certain agencies it is possible to detach a particle of negative electricity—an electron, we call it—from a molecule, leaving the remainder positively charged. The electron wanders about and soon attaches itself to a neutral molecule so that as a result we have negatively and positively charged molecules. These charged molecules move under the influence of electrical forces, their motion constitutes a current of electricity, and their presence is responsible for the power of the air to conduct electricity. In every cubic inch of the air we breathe there are about 10,000 molecules which have lost or gained an electron. Although this seems a lot, it is very small compared with the five hundred million million million molecules which that cubic inch contains. In fact, if a molecule were to go about saying that it had once seen one of its brothers who had lost an electron, the story would be less likely to be believed by the other molecules than would the assertion by some person that he had seen a man with two heads if he were the only person who had seen such a monstrosity during the whole history of the human race.

Now what agencies are responsible for detaching electrons from molecules? One agency is the radioactive material in the air and in the soil. A substance like radium is continually in a state of disintegration. Any given amount of radium disappears to the extent of 50 per cent. of its original amount in 1,600 years, so that if you have a tenth of an ounce of radium, you are at present losing capital to the extent of about $25 a year. As the radium dies it shoots out atomic particles with tremendous speed. One type of particle, the alpha particle, is a positively charged atom of helium traveling with a velocity of 12,000 miles a second. Then there are electrons traveling with speeds comparable with that of light, 186,000 miles a second, and there are gamma rays which are like very penetrating x-rays. All these particles are responsible for breaking up the molecules of air through which they pass. There is only about ten ounces of radioactive material in the whole of the earth's atmosphere, but this amount is sufficient to play a very important role in determining the power of the atmosphere to conduct electricity. Another agency, and practically the only agency over the great oceans where there is no radioactive material, is the cosmic radiation. Professor Millikan will deal with the nature of this radiation in another of these broadcasts, and it will suffice here to say that it or its progeny gives rise to rapidly moving charged particles in our atmosphere, which particles are responsible to a considerable extent for the origin of atmospheric conductivity. Again we are confronted with a phenomenon which, while readily apparent to our large-scale observations, is a very rare phenomenon from the point of view of the individual molecules. If we should liken the detachment of an electron from an atom by a cosmic ray to a murder in the field of human affairs, then we may say that the chance of a molecule in the atmosphere being murdered is about the same as the chance that one of us would be murdered if, with the earth at its present population, only one murder were committed in 300 years. You see that things are relatively peaceful in the world of molecules.

The power of the atmosphere to conduct electricity increases with altitude many times up to altitudes which have been attained, and we have indirect evidence to support the view that at altitudes comparable with 150 or 200 kilometers the conducting power is enormous compared with what it is at the earth's surface. When radio waves pass out from the broadcasting antenna and encounter these highly conducting

regions, they set up electrical currents therein, and these currents emit other radio waves of the same kind as the original ones, but so ordered in their relationship to these original waves that they cancel them as regards their progression towards outer space and reinforce them in regions below. The net result is that we obtain what we call reflection of the waves from these conducting layers. The United States Bureau of Standards keeps continual track of changes in these layers, since their power to reflect radio waves back to the earth is responsible for the whole success of radio broadcasting and particularly for short-wave broadcasting through which you hear my voice at this moment.

Through the efforts of the Carnegie Institution of Washington, atmospheric electric observations have been extended all over the earth, including the great oceans, and several permanent observatories have been set up by the Institution, by the U. S. Coast and Geodetic Survey, and by other organizations, not only in the United States of America, but in Australia, and several other parts of the world. Not only in peace but also in periods of war some collaboration has been maintained even among the warring nations, particularly by the astronomers whose minds, so well attuned to see richness everywhere, find everywhere some good in the world. If only political collaboration among nations were as harmonious as scientific collaboration, how greatly would the brotherhood of man benefit, and how much nearer should we be to that millennium which, through the ages, has been the goal of all mankind.

OBITUARY

VERNON ORLANDO BAILEY

1864–1942

THE achievement in personality that characterized Vernon Bailey, who died at his Washington, D. C., home on April 20, was suggested at his funeral services by the Reverend Dr. John Van Schaick, who quoted from the Eighty-fifth Psalm: "Mercy and truth have met together."

Mr. Bailey, who had lived for almost 78 years, had devoted his most strenuous efforts to the advancement of knowledge about natural history and to the development of kindliness toward wild animals. Truth he honored and discovered in field investigations in every State of the Union and in Mexico and Canada, in studies that formed the basis for writings that are now listed in a bibliography of 244 titles. Mercy, in its most practical forms, he practiced through many years of work for conservation and gentle, patient, but persistent agitation, years that included his own accomplishments in designing and promoting the use of traps that make their captures "alive and unhurt."

The influences of such a character for good are, of course, inevitable, yet they were all the more effectively exerted by Mr. Bailey because by inclination he was a guide to other men and to women and boys and girls. Whether these influences, aside from those perpetuated within his writings, are considered as they were felt by other members of his profession, by the Boy Scouts of America, for whom he was a great leader, by his numerous audiences or only by his casual acquaintances and the general public, they must be valued most highly. As his colleague, Edward A. Preble, has pointed out, "even the ablest naturalists" had seen only by accident many of the small mammals that became well known when Vernon Bailey had discovered and shown others how these animals might be taken. Cumulatively in many other small ways Mr. Bailey changed the world in which he lived more than can be realized, and changed it for the better.

To many who knew him personally, and surely to some others also to whom he was known only at a distance, he will be remembered all the more preciously because of the companionship which, with the help of Florence Merriam Bailey, he created and perpetuated for forty years. The reassuring and enrichening influences of this companionship have a precious reality for many who must now only remember it, but the remembrance is enduring and is most fittingly treasured up in the writings in collaboration that were among its benefits.

Rated since 1910 among the leading thousand of the country's scientists by "American Men of Science," Mr. Bailey had achieved his widest professional recognition as a mammalogist and an authority on the geographic distribution of mammals, birds and plants, yet the unqualified term "naturalist" was peculiarly appropriate to him. He was born on June 21, 1864, in Manchester, Mich., and at about the age of 6 moved with his pioneer parents to Elk River, Minn., where he laid the basis of his self-education in his own observations of natural history on his father's farm. It was the collection of specimens that he forwarded from there to Washington which led to his employment by Dr. C. Hart Merriam, founder of the agency that was later to become the Bureau of Biological Survey and the present Fish and Wildlife Service. First appointed as a special field agent in 1887, he soon became prominent among the corps of biologists then laying the foundations of a new governmental activity, and in 1890 he gained the title of chief field naturalist, which he cherished until his retirement in 1933 and which no other has had since. Practically every season of