

its surface. To prevent this a small quantity of glycerin or of oil free from oxygen is placed in the thermometer tube above the mercury. If, notwithstanding, the oxide shall accumulate to an inconvenient extent the observer in charge of the instrument will remove the thermometer from its place, and will put the bulb in warm water until the oxide is floated off. He will then supply the loss with pure mercury, determining the proper quantity by immersing the bulb in broken ice, when the mercury column should stand at the mark for 32° .

The whole apparatus, except the thermometer itself, can be enclosed and so protected from the weather and dust, while the thermometer is exposed to the air below.

The system is equally applicable to a barometric record, in which case, on account of the small range of motion, the needle-bar is connected to a lever, thus increasing the range of the record.

ELECTRICITY.

By A. E. OUTERBRIDGE, JR.

[Abstract of a Lecture delivered at the Franklin Institute, March 10, 1882.]

The subject of our lecture is one which offers unusual attractions at the present time, not only to the close student of science, but also to men of every profession or trade. The rapidity with which new discoveries in electrical science have followed each other of late years, together with the numerous practical and economical applications of the force to all sorts of industrial pursuits, and the prescience of still greater advances to come in the near future, has sufficed to render the subject an exceedingly popular one, and to lead many people to believe, whether truly or not, that electricity is the "coming force," which is to prove man's most useful servant, and is even destined, perhaps, to supplant steam power for many mechanical purposes, just as steam superseded human and brute force.

There is, I think, another explanation for the fascination attending, and the popular interest shown in, the study of electricity, which has little to do with its practical phase. I refer to the element of apparent mystery attaching to many of its phenomena.

There would seem to be a natural bias in many minds towards the mysterious, which not infrequently exhibits itself in an extraordinary

development of credulity, giving credence to the puerile teachings of self-elected professors of so-called supernatural agencies, known by various cabalistic names, such as "Psychic Force," "Odie Force," "Animal Magnetism," "Mesmerism," "Spiritualism," etc., but these various "isms," unlike the agency or force which will engage our earnest attention, have not been able to bear the light of careful searching investigation, nor have they been productive of any practical or useful advantage to man. Rather have they tended to befog the weak intellect and to create a doubt in the ill-balanced mind of the stability of nature's laws and the unity of her beneficent purposes, which all true scientific research tends so clearly to reveal.

Electricity as *an entity* was one of the earliest known of nature's agencies, having received its baptismal name more than two thousand years ago, and its sponsor was no less a person than one of the seven wise men of Greece. As *a science* it is the youngest of all her children, and is not yet out of its long clothes, although it is an amazingly precocious infant, having recently learned to talk, and we are astonished to find not only that its voice is strong and lusty, but also that its adaptability for all languages is without limit, reproducing the soft mellifluous tones of the Italian or Spaniard with the same ease that it does the harsher gutturals of the Teuton, the extraordinary syllabic enigmas of the Russian, or the peculiar labials of the "heathen Chinese." So admirable, indeed, are its linguistic accomplishments that it echoes the multitudinous tongues of men with the perfection of one "to the manor born," thus claiming recognition as an infant prodigy without an equal. It is difficult to realize that this youngest electrical child, which we call the "Telephone," is scarcely six years old; for its voice is now heard in all enlightened lands, and it has even become a very necessity of our modern civilization.

Although Thales made his famous experiment with amber more than five hundred years before the Christian era, his observation remained unheeded for twenty centuries. During the long years of the Roman wars, and later, when the Goths and Vandals were overrunning Europe, spreading terror and anarchy in their path, and precipitating the dark age of ignorance and superstition, we can well imagine that the trivial thought of catching feathers with a piece of amber would have no attractions for men, and so we find that it was not until the beginning of the seventeenth century that any further notice was taken of Thales' Amber Spirit. Nevertheless, the little

seed of investigation which had lain buried for so many centuries was neither dead nor wholly forgotten, and from this tiny grain of knowledge has grown the vast tree whose roots reach out to the ends of the earth, and under whose wide-spreading branches thousands of working men now find their daily occupation and sustenance. It is my design to trace out, very rapidly, and of necessity very imperfectly, the gradual development of this germ, to follow the ramifications of its roots, to show the luxuriance of its foliage, and finally to point out a few of its most promising blossoms, some of which are just budding into fruit, while others, though they may seem to flourish for awhile, are doubtless doomed to fall to untimely decay.

The science of Electricity is now passing through a critical period of its development, analogous to that which its sister sciences, heat and light, experienced some years ago, when a famous coterie of eminent investigators (prominent among whom was our countryman, Benjamin Thomson, afterwards Count Rumford) dissected the chrysalis, cleared away the cobwebs which surrounded it, overturned the corpuscular theory, and, by a magnificent series of experiments, proved that heat and light are not material substances, which may be squeezed out of a body, like water from a sponge, but that they are merely "modes of motion" of little molecules of matter.

There are in effect two theories of electricity now extant; the older one, although actually repudiated by practical electricians, still lingers in our text-books, and is, unfortunately, still taught in many of our schools. The other is the new science which has been the outcome of the labors of such men as Sir Wm. Thomson, Professor Maxwell, Dr. Siemens and many others of eminence and ability.

The first of these two sciences, which must, we hope, soon be eradicated from our school curriculum, is founded on the theory that electricity is a fluid, or that there are two fluids, commonly called positive and negative or vitreous and resinous. We must discard the old notion of electric fluids or currents flowing along a wire, as water flows through a pipe, and learn to realize that there is no passage of any material substance whatever when the circuit is closed on a wire in Philadelphia and the click is heard almost instantly in the receiving instrument in New York.

We no longer believe, as did our ancestors, that there is any transfer of material substance along the beams of light and heat which proceed from the sun to the earth. We know that there is simply a transfer

of motion from particle to particle of the intervening, highly attenuated medium, called for the want of a better name, the "luminiferous ether."

If you cast a stone into a pond and watch the ripples radiating outwards, growing larger and larger, until they strike the opposite shore, you do not imagine that the actual particles of water which were displaced by the stone have traveled to the other side of the pond. You know, on the contrary, that they have given up their motion to their nearest neighbors and these again have passed the impulse to their neighbors, and so on until there has been a transfer of motion through the whole of the water and the wave strikes the distant shore. So we believe that when a body is "charged with electricity" its molecules are thrown into a new state of vibration, not very different in character, perhaps, from that which shows itself as light in the little filament of carbon, enclosed in a vacuum bulb, which we will cause to become brilliantly incandescent by means of the electric force obtained from the dynamo-machine operated by the engine in the laboratory.*

Let us then once and for all discard the antiquated notion that electricity is a fluid and regard it henceforth as a form of energy or a mode of motion; we will then find that many hitherto vague and confused ideas in regard to its character may be reduced to definite and clear terms and that the most delicate phenomena of electricity may be measured with mathematical accuracy and precision.

Those of us who have gained clear ideas of the nature of matter and its properties will find little difficulty in conceiving the possibility of a vibration of molecules, under electrical excitation, or rather of such vibration *causing* electrical excitement. We know that the molecules constituting even the most dense solid substances, like lead or platinum, are not in actual contact, but that they are free to move, and, in fact, are constantly and forever vibrating with enormous velocities within certain boundaries. It is even believed that if this molecular motion should stop, "matter, as we know it, would cease to exist."

We know that the mere change in temperature of a few degrees is sufficient to visibly alter the length of a bar of iron or other metal, and we can easily realize that, as the temperature of all bodies is incessantly changing, its molecules are forever in motion from this disturb-

* The lecture room was illuminated with Edison and Maxim incandescent lights.

ing cause alone. We know that the change in condition of a substance from the solid to liquid and thence to the gaseous form is a visible expression of the increased motion of its molecules under the influence of heat vibration. We know that sound, heat and light, have all been resolved into "modes of motion," and now we believe that electricity also is henceforth to be included in the study of the laws of motion. Thus we see that the most widely separated phenomena and the most complex of nature's operations emanate from one common cause, showing a "unity in diversity" which is in itself a strong and logical argument in favor of the new theory.

There is one point which investigators in this field of research too often fail to fully recognize, viz.: that you can no more create electricity from nothing than you can create steam-power without the expenditure of fuel; for, although the various forces of nature are mutually interchangeable, they are so nicely balanced and controlled by unchanging law, that man with all his ingenuity cannot add to, or subtract one tittle from, the sum total of force in the world; the most he can ever hope to do is to utilize these ready-made forces for his special purposes, with the least waste possible.

The theory that electricity is a form of energy, which can only be developed by an equivalent expenditure of work of some kind or other, is quite a modern notion, and as it becomes more fully understood it will tend to eradicate many of the vague ideas and fallacious expectations which now prevail in regard to the future possibilities of utilizing electricity for lighting, heating, driving machinery and countless other useful purposes for which it seems so well adapted.

The general acceptance of the idea that electricity is a form of energy and not a form of matter has been somewhat retarded, hitherto, by the lack of adequate terms in which to express its dicta, for scientists do not coin new standard words as rapidly as the mint coins its new "standard dollars," which are, however, false measures of value, even though they may be of true standard fineness. This difficulty is gradually becoming eliminated, and the obsolete expressions which convey the idea of fluids and currents are giving place to more exact definitions; thus, the word *potential* is used to express the difference between a body in a state of electrical tension and another in its normal condition of molecular equilibrium; it does not commit us to any preconceived theories, and possesses another great merit in that the difference of potential (or electro-motive force, which is an equiva-

lent expression) between two dissimilarly electrified substances may be accurately measured and their comparative values may be stated in terms which we can all understand, and may even be reduced to the ordinary mechanical unit of work, the foot-pound.

There are other terms, which have been devised, to express the units of intensity, resistance, etc., with which the student must familiarize himself; their elucidation does not come within the legitimate scope of a "popular lecture," which should aim, first, to awaken interest in the subject of which it treats, and then to point the way in which it should be pursued to its ultimate goal. The student of electricity will find a permanent investment for his intellectual capital, never failing in interest, for the fund of knowledge is growing larger day by day.

In view of the modern developments in electrical science only a foolish man would venture to define the boundaries of its future progress, for if we allow our imagination the smallest liberty in the contemplation of such subjects we are sure to be almost startled at the vast possibilities for practical and useful applications of this force which suggest themselves; and yet, when we consider the actual accomplishments of the searchers in this field during the past few years, the most daring flights of fancy seem hardly more than natural sequels to events which have already outstripped all calculation.

It is not unlikely that some of my hearers may remember the years when Morse was wearily striving to obtain a small grant of money from an unwilling Congress, to enable him to lay his experimental telegraph line from Washington to Baltimore. He was derided as a crazy visionary, and Congress was ironically advised, by jeering wise-acres, to appropriate money from the public coffers to project a telegraph line to "the man in the moon." Most of us, doubtless, well remember the time, not very far distant, when the idea of an Atlantic cable was generally regarded as an impracticable and absurd scheme, yet there are now "more than seventy thousand miles of sub-marine cable," and the overland wires threading the earth to-day are long enough, if they should be stretched in a straight line, to reach our satellite!

The present magnitude of the telegraph business is a favorite theme for writers on these subjects, and has been well set forth by Mr. Preece in his lecture on the "Recent Wonders of Electricity." It is matter of history that on the day of President Lincoln's funeral no less than

seventy thousand words were transmitted from Washington to New York in the short time of six hours and a half, and this was before the use of the quadruplex system, by means of which four messages are now sent over one wire, in different directions, at the same time, and it was also prior to the invention of the automatic system, which has increased the speed of transmitting words more than one hundredfold.

The telephone, in its practical form, is not yet six years old, and yet there is scarcely a business community of any importance in this country or in Europe to which it is a stranger.

The electric light is no longer a scientific curiosity, and the manufacture of the plant used in its production has grown into a large industry, giving employment to hundreds of workmen, and representing millions of dollars capital invested.

The art of the electro-plater is another vast industry, and the statistics of the amount of gold and silver annually consumed in the process of gilding and silvering the baser metals seem almost incredible, especially when we reflect that a single grain of precious metal will cover several square feet of surface.

The admirable "block system" of operating railroad trains, which has greatly reduced the danger of accidents from collision, calls in the aid of this force, or rather depends upon it for its very existence, and even trains themselves have been propelled in Europe for several months past by this force alone. The idea of employing electricity as a motive power for machinery is by no means a novelty, but it has assumed new importance in the light of the recent improved methods of developing and utilizing the force economically.

It is a stupendous thought that our great natural curiosity, Niagara, is freely offering to our use its mighty arm, which is strong enough to turn every loom, operate every machine shop or other manufactory throughout this broad land, and that this may be accomplished by the intervention of means which we already possess of converting the headlong force of the cataract into the quieter channel of dynamical electricity, or, as we might otherwise say, *by changing its mass motion into molecular motion*. The calculations made by Sir Wm. Thomson, Dr. Siemens and other eminent scientists, show that this is no mere poetical fancy or impracticable idea; it is certainly quite within the bounds of rational discussion, if not of actual possibility, at the present time. It has been shown that a copper cable of no unwieldy dimensions would carry one thousand horse-power of electrical energy a distance

of one hundred miles without a very enormous loss, and it is even predicted that the time will come when our factories will be operated during the day, and our shops and houses illuminated at night, by the giant power of Niagara or some other less water-fall nearer home.

It would seem a curious and beneficent provision of nature that when the coal and wood, with which we are as yet well supplied, shall have become comparatively scarce and dear, the future race of men may find their substitute in water, not merely as a source of mechanical power, but also of light and heat.

It may be that our descendants will look back with curiosity to the time when their ancestors discussed with caution the possibility of thus utilizing the waste forces of nature, and they may well wonder at our extravagance in consuming black diamonds in our furnaces in order to obtain therefrom a mere modicum of their stored energy in the form of mechanical power.

As an ever watchful detective against our common enemies, fire and thieves, this agency has proved its fidelity time and again, never compounding with felons, and, if properly attended to, never failing to perform its duty.

By the simple addition to the ordinary ship's compass of two platinum pins, forming the terminals of a wire connected with a little battery and a call-bell, the captain of the vessel may retire to rest in security, knowing that if the man at the wheel allows the ship to wear away more than the fixed allowance the little bell will sound its note of warning in the cabin or stateroom; it is even possible to make the arrangement automatic, so that the same controlling force shall open steam valves which operate the mechanism of the rudder, and so the vessel may be kept on one undeviating course without the further intervention of human agency. The same principle has been applied to steam and water gauges, to sound a timely warning in the office of the large manufacturer when the pressure of steam in the boiler exceeds a certain limit or the level of water falls below a safe point.

The doctor and surgeon have found electricity a most valuable auxiliary in their efforts to alleviate human suffering, and new fields of usefulness in this direction are almost daily opened up to the profession.

In the physicist's sanctum electricity reigns supreme, for it is equally adapted to perform the coarsest work and to assist in the most refined investigations.

At the various meteorological stations throughout the country, the finger of electricity is at work, day and night, recording the hourly and even momentary changes of atmospheric conditions, and the same agent transfers these records to the central bureau in Washington in order that the mariner and the farmer may be forewarned of the approach of tornadoes, rain-storms or biting frost.

At the government arsenal may be seen a beautiful apparatus for recording, by a little spark of electricity, the velocity of projectiles, thus affording a means of measuring the explosive force of different samples of gunpowder. The whole distance the bullet is allowed to travel is only a few feet and the time consumed in its flight is inappreciable to the ordinary perception, yet the record made by the spark (which passes from a vibrating tuning fork to a cylinder of metal coated with lamp-black, revolving at a known speed), tells at a glance the exact time consumed, which is so infinitesimal that its expression in decimal fractions of a second requires a prefix of several ciphers.

At a recent scientific entertainment in London luscious fruits, which were grown by the aid of the electric light, were served to the guests. I dare say, many of you have read with interest Dr. Siemens' account of his experiments in electrical horticulture, the practical possibilities of which are, no doubt, more apparent to the inhabitants of that land of perpetual fog than to our more fortunate selves, where the sun is so generous of his beams and so constantly "shines free for all."

The astronomer, whose gaze is fixed on the heavenly bodies, does not scorn to avail himself of terrestrial electricity, and he, too, has found this force an invaluable aid in his most abstruse researches.

Applying the principle of varying resistance of metals at different temperatures to the passage of electricity he has recently been enabled to construct an apparatus for measuring the heat of the stars,* a sort of celestial thermometer "which will promptly indicate a change of less than one fifty-thousandth of one degree Fahrenheit, and will even measure these extremely minute amounts of heat and compare their differences with each other, though the whole quantity involved would produce no change whatever in the most sensitive thermometer."

These are but a very few of the useful applications of this ubiquitous agent, which seems to be the only one of man's possessions that he can employ in two places at practically the same time. To indicate the various other directions in which electricity may be utilized in the

* Professor Langley's *Bolometer*.

future would require both a vivid imagination and a careful sense of discrimination, and would occupy far more time than we have to devote to such speculations. We can only allude, in conclusion, to the probability of telegraphing without wires, which has already been done experimentally, and to the more remote possibility of transmitting the power of vision to a distance through the peculiar electrical properties of selenium when acted on by light.

Whether these beautiful experiments, which are the very quintessence of refinement in physical research, may produce practical results or not, they will undoubtedly serve as indicators to future generations of the intellectual and scientific attainments of the human mind in our day, and each new step forward enlarges the scope of our mental vision and smoothes the path for those who are to come after us.

As we stand on our vantage ground to-night and look back over these recently explored regions, we have reason to feel proud of all that has been accomplished and to rejoice that we are living in an age of such activity and progress in useful and ennobling scientific pursuits.*

Pulverizing Rocks by Dynamite.—Major Lauer claims that his method of pulverizing rocks in the beds of rivers, by exploding dynamite on their surface, leaves them in a condition to be removed by the current. When the cartridges are inserted in drill holes, the rock is broken into large fragments, which must be removed mechanically and often at great cost.—*Ann. des P. et Chauss.* C.

* The technical portion of the lecture, which is not reported herein, was illustrated with apparatus, both of historical interest and of recent invention. In the former list was Dr. Benjamin Franklin's frictional electrical machine, by means of which he sent electric flashes across the Delaware river, between Philadelphia and New Jersey, through a submerged cable, one hundred years before the invention of the Morse Telegraph.

An original working model of Bains' electro-chemical telegraph; also, an original Morse apparatus, all of which are preserved in the museum of the Franklin Institute.

In the latter category were induction coils, Geissler & Crookes tubes, Toepler-Holtz machines, etc., contributed by Messrs. Queen & Co.

A Brush dynamo-machine, operated by a six-horse power engine which supplied arc and incandescent lights, the Maxim lamps being contributed by the Company and the Edison lights by the Baldwin Locomotive works, where they have been in practical operation for some months past.