other known body. Herr Eder regards the photo-chemical decomposition of silver bromide as the result of partial reduction with loss of bromine.

THE GERMAN ASSOCIATION

THE fifty-fourth meeting of the Association of German Naturalists and Physicians was held at Salzburg on September 18-24. The number of Members and Associates in attendance was 760. There were also present Foreign Members from Switzerland, the Netherlands, Russia, Denmark, and Japan. The first general meeting, on Sunday, September 18, was opened by the First Secretary, Dr. Günthner (Salzburg), who in his hearty address of welcome mentioned the fact that Salzburg was the last retirement of the celebrated physician and naturalist, Theophrastus Paracelsus. After short addresses given by the Governor and Burgomaster, Prof. Pettenkofer (Munich) read a paper "On the Soil and its Connection with the Health of Man." He pointed out that it was previously believed that the state of the air and water exerts an important influence upon the origin and propagation of epidemics, but this view could not be proved by experiments recently made. The contamination of air and water is caused by products of decomposition of bodies putrefying on or in the soil. The progress of epidemic diseases, especially of cholera, is influenced mainly by the soil. The immunity of special localities against cholera is shown by the example of Lyons, which, notwithstanding communication with infected places, remained free from cholera, though filtered Rhone water was used there. Versailles and Salzburg also were exempt from this disease. It is now generally assumed that cholera is due to the action of schizomycetes, which develop at localities where the soil is impregnated with decomposing organic bodies. The contamination is drawn up by diffusion through the porous soil into the interior of houses, where it becomes dangerous to the health of man.

On Monday the work of the sections was commenced. There were twenty-three sections, eleven of them medical. On Tuesday an excursion was made to Reichenhall (Bavaria), with its salt-mines, where the Congress was addressed by Graf Pestallozza. On Wednesday the second general meeting was held. Prof. Weismann (Freiburg-im-Breisgau) read a paper on the duration of life. After enumerating many examples of longer and shorter duration of life among animals, he pointed out that size, constitution, temper, sex, and growth are not critical for the duration of life. In general the duration of life of an individual represents the minimum of time necessary to insure the existence of the species; it is governed by adaptation and heredity. The death caused by wasting and consumption of the cells, of which the (animal) body is composed, is the result of adaptation. The capacity of unlimited life has been lost, since it has become useless. There is no death at the division of lower animals (Amœba). In higher animals the propagating cells are separated from the somatic cells; only the former preserve unlimited productiveness. The limitation of individuals in time and in space is based on the same principle. At the same meeting Prof. Meyners (Vienna) gave an address on the laws which govern human thoughts and actions. In the conclusion of his very interesting discourse, in which he mainly dealt with feelings, sensations, and the experiments of Munk and Goltz, he expressed the opinion that the phenomena of bodies do not disclose to us their essence, and that there is only a phenomenon of freedom of will. Eisenach (Thuringia) was chosen as the town in which the fifty-fifth meeting of the Association should be held.

On Thursday an excursion was organised to Zell-am-See. On Saturday the third general meeting was held. Prof. Oppolzer (Vienna) read a paper on the question: Is Newton's law of gravitation sufficient for the explanation of the motion of heavenly bodies? Are there reasons for regarding it only as approximately true? In consideration of the theories of the moon, of Mercury, and of Encke's comet, he cannot find the theories based on Newton's law in its present form sufficient, but it would suffice under the (hypothetical) assumption of a cosmic matter surrounding the sun. After an address given by Dr. Kirschensteiner (Munich), on Theophrastus Bombastus Paracelsus, the sitting was closed by Dr. Günthner. We give a list of the papers read in the sections of Natural Science.

Section II. Physics: Walter (Tarnowitz), on the molecular kinetic laws of specific heat and the heat of vaporisation of bodies in different states; Sacher (Salzburg), on a direct measure of the attraction between earth and a determined electric current; Kurz (Augsburg), on dispersion of light and measuring the index of refraction; Spörer (Potsdam), results obtained by observations of the sun; Grunmach (Berlin), on the electro-magnetic rotation of the plane of polarisation of radiant heat; Grunmach (Berlin), comparisons of mercury-thermometers with air-thermometers; Sacher (Salzburg) demonstrated some new physical experiments relating to the theory of the formation of the earth (balls of sulphur and spermaceti with crater-formations); Waltenhofen (Prague) spoke on his apparatus for demonstration of the different action of hollow and solid electro-magnets; Günther (Ansbach), on the parallelogram of forces.

Section III. Chemistry: Brühl (Lemberg), on the connection between the optic and thermic properties of liquid organic bodies; Brauner (Prague), contributions to the chemistry of the rare earths, and on the progress of the system of periodicity of elements; Schwarz (Gratz), short communication on the preparation of nearly perfect alum-cubes by a new method; Zorn (Heidelberg), on hyponitrous acid; Bernthsen (Heidelberg), on the nomenclature of the proper derivates of carbonic acid, taking special notice of isomers.

Sections IV. and V. Geology, mineralogy, palæontology, geography: Bernáth (Budapest), on the mineral waters of Hungary; Gümbel (Munich), on the geological structure of the Untersberg (near Salzburg); Hauer (Vienna) presented a new geological map of Montenegro (designed by E. Tietze); Zittel (Munich), on Spongiæ as rock-forming materials, and on Plicatocrinus; Baltzer (Zurich), on curved strata; Neumayer (Vienna), on fresh-water Conchylia from China; Alth (Krakau), on the Jurassic formation of Niczniow; Hauer (Vienna), on the Arlberg; Tschermak (Vienna), on the definition of species in mineralogy; Hoernes (Gratz), on earthquakes in general; Woehner (Vienna), on the earthquake of Agram; Richter (Salzburg), on observations made at the Obersalzbach glacier; Doelter (Gratz), on the Cape Verde Islands; Dücker (Bückeburg) on the occurrence of petroleum in Northern Germany.

Section VIII. Botany: Kraus (Triesdorf), communications on the sap-pressure of plants; De Bey (Aachen), report on five new and peculiar genera (Coniferæ) of the Aachen chalk-flora; Holzner (Weihenstephan), on agrostological theses; Hildebrand (Freiburg-im-Breisgau), some observations on the flowering and the fruits of plants; Woronin (St. Petersburg), contribution to the knowledge of Ustilagineæ; Kirchner (Hohenheim), on the longitudinal growth of plants.

Sections VIII. and IX. Zoology, comparative anatomy, entomology: Troschel (Bonn), classification of Gastropods; Fraisse (Leipsic), on cell-division and free nucleus-formation; Weidersheim (Freiburg), on the genesis of Jacobson's organ; Grobben (Vienna), on the variation of generations of Doliolum.

BIOLOGY AS AN ACADEMICAL STUDY[1]

I.

IT is told of the late Dr. Norman Macleod that, on paying his first visit in his first parish, he was peremptorily desired to sit down and "go over the fundamentals." I feel that some such demand may, not unreasonably, be made of me to-night.

Five-and-twenty years ago one's position in this respect would have been a comparatively easy one, for then biology may be said to have had no "fundamentals" at all. In spite of the labours of Buffon, Erasmus Darwin, and Lamarck, the great bulk of naturalists at that time believed in the immutability of species; as a natural consequence botany and zoology remained mere "classificatory sciences," and the extraordinary facts of comparative anatomy, of embryonic development, of geographical distribution, of palæontology, were incapaple of rational explanation. Indeed, classification itself was nothing more than a logical expression of likenesses and unlikenesses, and was devoid of all real meaning.

But with the publication of the "Origin of Species," in 1859, a better day dawned for biology. The whole history of science has been a succession of attempts to bring group after group of natural phenomena within the scope of some natural law; and Charles Darwin's great service to science lies in the fact that, although not himself the discoverer of the doctrine of descent, he succeeded, by the immense array of well-arranged facts and sound generalisations contained in his epoch-making book, in

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[1] Inaugural Lecture delivered in the University Library, May 2, 1881, by T. Jeffery Parker, B.Sc., Lond., Professor of Biology in the University of Otago.

bringing those natural phenomena which have to do with living things within the all-embracing law of evolution, thus making belief in the theory of special creation once for all impossible to the student of nature.

One may say then that since the publication of the "Origin of Species" evolution has taken its legitimate place as the central doctrine of biology, the key to the infinite number of problems with which the study of animals and plants brings us face to face. Without evolution these problems are incapable of explanation, and any attempt to explain them is little better than a roundabout acknowledgment of ignorance; but with the doctrine of descent as a standpoint, problem after problem yields to patient investigation, biology thereby gradually growing into a perfect and harmonious whole, as did astronomy when once the law of universal gravitation was established.

Not that the real mystery of things is in any way diminished by this, any more than by other great discoveries. As Herbert Spencer finely says: "Positive knowledge does not, and never can, fill the whole region of possible thought. At the uttermost reach of discovery there arises, and must ever arise, the question, What lies beyond? As it is impossible to think of a limit to space, so as to exclude the idea of space lying outside that limit, so we cannot conceive of any explanation profound enough to exclude the question, What is the explanation of that explanation? Regarding science as a gradually increasing sphere, we may say that every addition to its surface does but bring it into wider contact with surrounding nescience."

But the fact that no explanation of natural phenomena can ever be final has no right to diminish our profound thankfulness for every proximate explanation which the genius of a Newton, a Dalton, or a Darwin gives us. To the true man of science these explanations come like a revelation, and he feels that his most cherished beliefs, his most ingrained prejudices, must be brought into harmony with the new light that is in him, or be cast aside as no longer tenable.

A few years ago—even at the time when this University was founded—something more than a bare statement of belief in evolution would have been required from a professor of biology giving his inaugural lecture. For then the doctrine of descent was only just emerging from the fiery trial through which all great truths, scientific or otherwise, have to pass, and it was honestly believed by many estimable persons that "Darwinism" was in direct and necessary opposition to religion and morality, and was the secret ally of atheism, socialism, and the like. But, like the fundamental doctrines of astronomy, physics, and geology, evolution has survived all attacks: I believe I am correct in saying that there is now not a single naturalist of any repute, under the age of sixty, who is not also an evolutionist; indeed, with Louis Agassiz and Von Baer, intelligent opposition to the general doctrine of transformism is practically dead.

Even among the non-scientific public, opinion has undergone a wonderful and rapid change. An evolutionist is no longer looked upon as a dangerous visionary; it is no longer thought necessary to hold "that nature's ancient power was lost" when she had to do with living things, and that the power which could form worlds out of a nebula was unable to evolve a horse from a hipparion, or even a speck of living protoplasm from the elements of the primæval sea.

Under these circumstances it would be superfluous, almost impertinent, for me to make any attempt to repeat the arguments which go to show that the animals and plants living on the earth at any period of its history are the lineal descendants of those which existed during the preceding period, and that the origin of any living thing by direct creation is, in the first place, entirely unsupported by evidence, and, in the second place, unthinkable. I proceed, therefore, to the main subject of this lecture—the position which biology should occupy in the curriculum of our schools and of our University; in other words, its place as one of the natural sciences in a rational scheme of education.

Educational subjects may be divided into two classes, the directly educational—those which serve as a true discipline, which train the mind, leading to clear thought, accurate reasoning, and a high intellectual tone; and the indirectly educational, which primarily serve to impart a certain amount of useful information, and only secondarily, by interesting the student and starting him off on a certain track of thought, serve as an actual means of mental culture. Perhaps the best examples of the two classes are furnished by mathematics on the one hand, and on the other by English history as usually taught in schools. A boy who has once grasped the idea that two and two make four and can never by any possibility add up anything else, has made a long stride in his educational career; but the boy who learns that the battle of Hastings was fought in the year 1066, or that Henry VIII. had six wives, has simply gained two comparatively unimportant concrete facts, the possession of thousands of which would never make him anything more than a well-informed person.

According to the theory of education which was almost universal in the last generation—the English public school system—there were two educational subjects, and two only, Greek and Latin, perhaps with "a shadowy third" in the shape of mathematics, but certainly nothing further than that. As a natural reaction against this time-honoured method of trimming down all minds to one dead level of scholarly dulness came the modern private school system, the principle of which is to try and cram into a boy's head a little of all the subjects of which it is supposed he ought to know something when he arrives at man's estate—divinity, Latin and Greek, modern languages, mathematics, natural science, history, geography, drawing, music, and even bookkeeping. The wretched child is "everything by starts and nothing long"; his masters, chosen for knowing something of as many as possible of these subjects, are usually eminently superficial, and he leaves school well informed perhaps, but profoundly and distressingly ill-educated.

The private school system is now, very naturally, producing in certain quarters a counter-reaction towards the exclusively classical and mathematical method of education, the plea being that the modern plan has been tried and found wanting, that neither natural science nor any of the other recent innovations have any direct educational value whatever, and that these subjects should therefore never form more than a very subordinate part of either a school or a university course.

This cry for a return to the old paths has lately found expression in an article by Dr. Karl Hillebrand,[1] who, however, makes certain very important concessions to his opponents. In the first place, what he is fighting against is not so much scientific education—I mean instruction in the natural sciences—as superficial education; and in this every honest teacher of science will be at one with him. Then again he advocates the postponement of the study of Latin grammar—the chief instrument of culture in his eyes—to the age of twelve or thirteen, and the employment of the first three years of high school life to training the powers of "observation, comparison, memory, and all the elementary functions of the understanding." In this also the advocate of science teaching and the opponent of the English public school system in its purity will be altogether in accordance with Dr. Hillebrand. But when he goes on to advocate as the best training for these "elementary functions of the understanding" the learning of texts and dates by rote, and, by way of science, the "simple classifications of zoology and botany," illustrated by the "exhibition" of real animals and plants, one cannot but wish that before printing such crudities he had tried to understand in what the elementary teaching of science really consists, and how far such teaching would supply the training in observation, comparison, memory, and so forth, to which even he would devote the earlier years of school life. To him, as to many, strict teaching means classical and mathematical teaching, and instruction in science is, if educational at all, only indirectly so.

This opinion as to the educational value of natural science arises, I am inclined to think, from an utter misconception as to what is meant by science teaching: by assuming, in fact, that science can be taught by the ordinary educational apparatus of books and lectures. The fallacy of this is only now beginning to be perceived, even by professed teachers of science. It is true that the chemists have long had their laboratories and the human anatomists their dissecting-rooms; but the notion that no course of lectures on physics, biology, or geology is complete without a corresponding course of practical work, is the product of the last few years, and is even now unrecognised in some British universities and in the large majority of schools.

And yet, one would think, nothing could be more obvious. The whole end and aim of science teaching is to bring the student into direct contact with nature; to insure his knowing, as he knows his multiplication table, the main laws upon which natural phenomena depend, and to make him see, without any possibility of mistake, the relation of those laws to the facts of the universe as he is able to observe them. What would be thought of a mathematical teacher who relied entirely on lectures, and never

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[1] "Half-Culture in Germany," *Contemporary Review*, August, 1880.

dreamed of insisting that his pupils should apply what he had taught by working out examples for themselves? Or what of a teacher of art who ignored the necessity of making his students draw or paint? Every one sees the necessity of practical, and the uselessness of exclusively theoretical teaching in these instances, yet the fact is generally ignored that the case is precisely the same with scientific subjects, and that a man who lectures to beginners day after day and year after year on, for instance, the intricacies of animal structure and the problems connected therewith, without making his students see, by actual dissection, what an animal is, is in great measure spending his strength for naught.

Until this important fact is recognised and proper provision made for it, natural science never will and never can be a power in education. As Mr. Matthew Arnold puts it, "To say that the fruit of classics, in the boys who study them, is at present greater than the fruit of the natural sciences; to say that the realists have not got their matters of instruction so well adapted to instruction as the humanists have got theirs, comes really to no more than this: that the realists are but newly-admitted labourers in the field of practical instruction, and that while the leading humanists . . . have been also schoolmasters, and have brought their mind and energy to bear upon the school teaching of their own studies, the leaders in the natural sciences . . . have not. When scientific physics have as recognised a place in public instruction as Latin and Greek they will be as well taught."[1]

When these remarks were written (in 1868) they were applicable to science-teaching not only in schools, but also, in great measure, in universities and colleges. But since that time great changes have taken place, and in biology, of which science alone I am competent to speak, the improvement is due, first of all, to my honoured master, Prof. Huxley, and next to his co-worker, Dr. Michael Foster, both of them brilliant examples of the fact that an eminent man of science may be at the same time a laborious practical teacher. The classes begun by Prof. Huxley, with the co-operation of Dr. Foster, at South Kensington, and since continued at the School of Mines by Prof. Huxley and Mr. Thiselton Dyer, at Cambridge by Dr. Foster and his pupils, at Oxford and University College, London, by Prof. Ray Lankester, have now fairly put the teaching of biology upon a sound footing, and may be said already to have proved the value of that science as a true mental discipline, an educational instrument of very high order.

At any rate this is proved as far as University education is concerned. The battle has still to be fought in the secondary schools, and, as every one must see, the circumstances there are so different that victory in the one case is no criterion of victory in the other. It is evident, in fact, that the strict training in observation and experiment, without which, I cannot insist too often, science teaching is valueless as a mental discipline, is very difficult of application in schools, and that the consequences of setting a large class of young boys to make oxygen, or take a specific gravity, or cut up a rabbit each for himself, might prove rather subversive of order than conducive to improvement. But it has been amply proved that there is no difficulty in the case of senior boys taken in comparatively small classes; and even in large classes the practical teaching of elementary botany is quite feasible, as is shown by the experience of our own High School. Botany, indeed, lends itself more than any branch of science to school-teaching, from the simple fact that by its means the pupil can be brought face to face with Nature with comparatively little trouble, with no apparatus beyond a pocket-knife, and perhaps a simple magnifying-glass, and with no mess unremovable by a duster and broom.

For these reasons I am inclined to think that botany should be made the staple science subject for the junior classes in schools. If taught thoroughly, it necessitates the introduction of a good deal of elementary chemistry and physics, since the principles of vegetable physiology, which should on no account be omitted, cannot be explained without reference to the composition of air, earth, and water, the diffusion of gases, capillarity, chemical decomposition, and so on. Theoretically, no doubt, the foundation of a scientific training should be laid with mathematics, physics, and chemistry. As to the first of these there is no difficulty; but unless the two latter can be taught practically, it seems to me that the best thing is to be content with something less than the ideally perfect, and, with mathematics as the necessary introduction to abstract science, to take as our basis for the concrete study of Nature the facts and phenomena of plant-life.[1]

There is one consideration of the first importance, which every science teacher must keep in mind if he wishes his subject to have its proper value as an educational instrument, and that is the absolute necessity for demanding as much and as hard work from his pupils as the classical or the mathematical master. Unless this is done scientific subjects must always hold an inferior position, and the teaching of them can never be followed by adequate results. It behoves every one of us to remember that—

> "Von der Stirne heiss,
> Rinnen muss der Schweiss,
> Soll das Werk den Meister loben,"

and that, if we are satisfied with a minimum of work from our pupils, we must also be content with a minimum of respect for our teaching. As long as in our Matriculation and Junior Scholarship examinations a pupil can pass creditably in a scientific subject by getting up a text-book, while to obtain distinction in classics or mathematics requires prolonged and thoughtful work, so long will science-teaching in schools fail to have any real educational value.

I should like to make it perfectly clear that I am not making the slightest attempt to uphold the absurd notion that science should replace the strict study of language and literature, or of mathematics. All that I plead for is that it should be put on equal terms with them, and should no longer be handicapped by a totally inefficient method of teaching, and then condemned as wanting in the essentials of a strictly educational subject. Those who advocate a return to purely classical instruction because of the acknowledged failure of book-science are comparable to politicians who can see no remedy for the excesses of a revolution save a return to despotism. The whole case as between scientific and literary instruction is so admirably put by Mr. Matthew Arnold that I cannot resist the pleasure of quoting the passage:—"The aim and office of instruction, say many people, is to make a man a good citizen, or a good Christian, or a gentleman; or it is to enable him to do his duty in that state of life to which he is called. It is none of these, and the modern spirit more and more discovers it to be none of these. These are at best secondary and indirect aims of instruction; its primary and direct aim is to enable a man *to know himself and the world*. Such knowledge is the only sure basis for action, and this basis it is the true aim and office of instruction to supply. To know himself a man must know the capabilities and performances of the human spirit; and the value of the humanities, of *Alterthumswissenschaft*, the science of antiquity, is that it affords for this purpose an unsurpassed source of light and stimulus. . . . But it is also a vital and formative knowledge to know the world, the laws which govern Nature, and man as a part of Nature. This the realists have perceived, and the truth of this perception, too, is inexpugnable. Every man is born with aptitudes, which give him access to vital and formative knowledge by one of these roads; either by the road of studying man and his works, or by the road of studying Nature and her works. The business of instruction is to seize and develop these aptitudes." And again: "The grand thing in teaching is to have faith that some aptitudes of this kind every one has. This one's special aptitudes are for knowing men—the study of the humanities; that one's special aptitudes are for knowing the world—the study of Nature. The circle of knowledge comprehends both, and we should all have some notion, at any rate, of the whole circle of knowledge. The rejection of the humanities by the realists, the rejection of the study of Nature by the humanists, are alike ignorant."

Until within the last few years the position of science, and especially of biology, in universities and colleges, was quite as unsatisfactory as in schools. In the days when zoology was taught merely by lectures, and a man to insure success in examinations had only to "cram" his notes or a text-book and perhaps be able to tell a mammal's skull from a bird's, or a bivalve shell from a coral, it was not unnatural for the votaries of the older forms of culture to look upon "science" as a sort of academic Alsatia—a useful-enough refuge for the stupid, the lazy, and the eccentric, but something quite

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[1] "Higher Schools and Universities in Germany."

[1] For this reason I cannot but regret that in the regulations for Junior Scholarships approved by the Senate at their recent meeting, biology is only counted as of equal examination value with a single branch of physics; so that while a candidate can take up physics alone of science subjects, he is obliged, if he select biology, to take in addition either chemistry or a branch of physics or mechanics.

beneath the notice of a man with a fair share of intellect and diligence.

And this opinion was quite justified by the facts. In my own University—London—until quite recently, there was no evidence of practical knowledge required in any branch of science except botany, for the degree of Bachelor of Science. A fair amount of mathematics and mathematical physics were demanded; but the chemical standard was miserably low, and the zoology, physiology, botany, and geology were such that no experienced examinee would wish for more than a month's reading for each, with perhaps an extra fortnight in the case of botany to enable him to learn enough of the art of describing plants. But now that a searching practical examination is enforced in these subjects, the degree has a real value—it is evidence that a man has done real work.

The case is very similar at Cambridge. Formerly, the Natural Science Tripos was a bye-word—a sort of back-door to a university degree. Now, thanks in great measure to Dr. Foster, the chances are that a man who takes high honours in that Tripos will be the intellectual equal of a high wrangler or of a high classic.

Considering that this regeneration of biological teaching began only about ten years ago in London and Cambridge, I think New Zealand is distinctly to be congratulated upon the fact that the first professor of biology in the Colony—my predecessor in this Chair, Captain Hutton—was also the first to inaugurate the true method of teaching that science in the Australian Colonies. It is by no means the least important debt which the Colony owes to Prof. Hutton, that he, having made his reputation as a systematic zoologist, voluntarily undertook the labour—no light one—of organising, in connection with his lectures, a class for regular practical instruction in comparative anatomy. I must confess to a slight feeling of disappointment at finding, on my arrival here, that the revolution I had expected to initiate was already well under weigh.

(*To be continued.*)

THE ELECTRICAL DISCHARGE, ITS FORMS AND ITS FUNCTIONS[1]

I.

If we knew as much about electricity as we know about sound or light, we should be still a long way from having learnt all that we could wish, but we should know far more than we do now.

For instance, in the matter of sound, we know, in most cases, the nature of the air-disturbance to which it is due, and the mechanism whereby that disturbance is effected; and we have ascertained the magnitude and character of the aërial waves on which sound is carried. We know, in fact, what it is which is transmitted, and the velocity and direction in which that transmission takes place.

Again, in the matter of light, although we do not know the exact nature of the disturbance to which luminosity is due, nor the mechanical process by which that disturbance is effected; although we are not even certain whether the ætherial waves, to which light is attributed, have an actual existence or not, we nevertheless do know that something which is capable of being represented by wave motion is transmitted along a ray of light; its direction is a matter of simple observation, and we have determined the velocity with which it travels.

But when we come to electricity our knowledge is much more at fault. We know, it is true, how to produce electricity or electrical action, as well as how to transmit it, by means of wires, to a distance; we know also that there is a dissymmetry at the two ends or "terminals" of a battery or machine, or other source of electricity, implying a directional character either in that which is transmitted, or in the mode of its transmission. But we know neither what electricity really is, nor the process whereby it is transmitted. And although, on account of the dissymetry above mentioned, we cannot divest ourselves of the idea of direction, yet we have as yet no certain clue to the actual direction in which the transmission can be said to take place. It has, indeed, been shown, by the late Clerk Maxwell and others, that the mathematical expressions for the properties of a medium, whose vibrations are capable of representing the phenomena of light, are the same as those of a medium whose vibrations are capable of representing those of electro-magnetism; and that, on the supposition that light is an electro-magnetic phenomenon, the velocity of propagation of electro-magnetic disturbances is the same as the velocity of light. But an identity in the mode of mathematical representation does not decide anything about the physical facts in either case, nor does it even prove that the facts are the same in both cases. And lastly, even granting that there is actual motion along the wires, neither the mathematical formulæ nor the experimental facts can as yet decide whether the motion, or "current" of electricity, is to be considered as starting from one terminal and arriving at the other, or as starting from the second and arriving at the first; or, indeed, whether the motion may not be in some sense double, in both directions at once.

In this somewhat unsatisfactory state of ignorance we approach the subject of this evening's discourse. And although I cannot hope in any adequate sense to resolve these difficulties, I propose to explain what progress has been made towards a solution of them, and to indicate the direction which appears to offer the best promise of success in the prosecution of further research.

Into the various modes of producing electricity it is not my intention now to enter. I shall use them indifferently as may be most convenient, explaining only in general terms any differences which may be of consequence for understanding the various experiments shown in illustration of my argument. It will, in fact, be assumed that electricity has been produced by some known means or other, and our object will be to examine it in the course of its passage, with a view of obtaining some information as to its nature and its mode of transmission.

As a matter of fact we have here as our sources of electricity, first, a Holtz machine, or, rather, Prof. Töppler's modification of it), which produces electricity in a condition similar to that given off by the ordinary frictional machines, although it effects this by a different method; secondly, a battery, or arrangement of metallic plates and acid, wherein a flow or "current" of electricity is produced by the action of the acid upon the metal; thirdly, a dynamo-machine, such as those invented by Gramme, Siemens, Brush, or others, which produces a current similar to that from the battery, but by means of the expenditure of mechanical force in moving coils or other closed circuits of wire within the influence of an electro-magnet, or, as it is usually termed, within a magnetic field; fourthly, a magneto-machine by De Meritens, producing, on a principle similar to that involved in the dynamo-machine, a series of currents, but with permanent magnets, and in this case in alternate directions; fifthly, an instrument called an induction-coil, the object of which is to produce from currents of one character currents of another, in a way to be presently described; and, lastly, we have Leyden jars or condensers for accumulating large charges in a manner which will allow of their being discharged all at once.

Now, in the first place, suppose we make use of the battery, or of the dynamo-machine, producing a direct and practically uniform current; then, if the wires carrying the current be closed, no directly visible effect is produced. I say "directly visible" because indirectly we can prove that a wire carrying a current is in a condition different to one not carrying a current. One way in which this may be shown is the following:—If we bring an ordinary piece of copper wire into the neighbourhood of some iron filings, the filings are indifferent to its presence when it is in its natural state; but as soon as the wire is made part of a circuit through which a current is flowing, the filings are attracted by it as if by a magnet. When the circuit is broken, so that the current is interrupted, the filings drop, and the wire resumes its ordinary condition. This property of a wire carrying a current is, however, beside our present purpose, and I mention it only in order to show that the passage of an electric current is not without its effect on a closed circuit, even when no result is directly visible.

The magnetic effect which we have just seen is not, however, the only effect which a current produces in a closed circuit. If in a galvanic circuit, supposed to consist otherwise of copper wire, we interpose a piece of different metal of a kind called refractory on account of its bad conductive power, such as platinum or iron, or a sufficiently thin piece of the same wire, we shall find that when the current is passing, the interposed wire becomes hot; and if we increase the strength of the current, or reduce the thickness of the wire—in other words, if we increase the quantity of electricity flowing through the platinum, or diminish the size of the platinum conductor which has to carry it—we shall find that the temperature is proportionally increased. A similar increased temperature will be produced by

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[1] A Lecture delivered before the British Association at York on September 5, 1881, by William Spottiswoode, D.C.L., LL.D., President of the Royal Society.