The *massifs* of crystalline schists represented in this zone are large remnants which have remained standing in ruins, the other parts of the primitive rocks having subsided either *en masse*, following great faults, or in detail, by a series of small slides, following the numerous joints, or the divisional planes of bedding. *Not one of them represents a regular and complete anticlinal fold.*

The various types of crystalline schist comprised in the Mont-Blanc zone succeeded one another in the same order as in the *Monte-Rosa zone*. They are also divided into two groups: the upper group—sericitic, chloritic, and hornblendic schists; and the lower group—mica-schists and true gneisses.

In the lower group there is a tendency towards the granitoid structure, and the rocks appear more or less massive, but yet in the main stratiform. They become rich in white mica, and assume a granulitic texture. These phenomena are developed along the anticlinal axes.

The crystalline schists of the upper group have a tendency to become richer in felspar the nearer one approaches the intra-Alpine limit of the zone. It seems that this corresponds with the direction in which alkaline emissions, accompanying the formation of these rocks, took place, the same direction afterwards becoming that of the great limiting fault of the zone. The schists pass thus into chloritic gneisses similar to those occurring near the station at Modane (*third zone*), or to the gneiss of Arolla (*fourth zone*); sometimes also into granitoid gneisses, both chloritic and hornblendic, as, for instance, at Cevins, in Tarantaise.

The tenacity of the chloritic and hornblendic schists, which is generally much superior to that of the mica-schists and true gneisses, and their tendency to develop felspar, which gives them greater consistency, explain the important *rôle* played by these rocks in the constitution of the culminating ridges and steeper *massifs* of the *first zone*. In the Mont-Blanc *massif* and in the eastern portion of the Pelvoux *massif* these "needles" and abruptly culminating ridges characterize the type of rock known as *protogine*. This name, the etymological sense of which must be forgotten, has been created to designate the type of rocks which predominates in the principal ridge of Mont-Blanc. The special character of these rocks consists in the mica being penetrated and partly replaced by chlorite. The granitoid protogine always contains two felspars—orthoclase and oligoclase, part of the orthoclase being usually replaced by microcline.

Prof. Lory thinks the protogine belongs to the upper group—that of the chloritic schists. In that case Mont-Blanc cannot be regarded as a central arch of elevation, and its "fan-structure" becomes simply a very sharp synclinal fold of the crystalline schists of the upper group, isolated by two faults, along which they have subsided, while acquiring a U-shaped fold.

In the Pelvoux-*massif* the protogine is even more largely developed than at Mont-Blanc. Here also it is stratiform, and alternates with chloritic gneisses like those of the western parts of the *massif*. A series of anticlinal and synclinal folds can be made out. The anticlines correspond to the Vallon des Étages, the Barre des Escrins (west slope), and the Combe d'Alefroide; and the synclines to the Combe de la Pilatte, the eastern slope of the Escrins (Glacier Noir), and the summits of Mont-Pelvoux.

From observations made near Bourg-d'Oisans, the author arrives at the conclusion that the *protogine* has originated by a modification of the chloritic schists. During their formation, a considerable increase in their felspathic constituent was produced by granulitic emissions which took place through the gneiss and mica-schists.

Like other important features in the structure of the Eastern Alps this replacement of chloritic schists by protogine follows the intra-Alpine limit of the *Mont-Blanc zone*, which limit is marked by the great fault-line which can be traced over 60 *lieues*, from Vallonise to Airolo. This must have been the direction in which took place those granulitic emissions, which, without giving birth to true eruptive masses, have modified the character of the old gneiss and mica-schists and developed in the chloritic and hornblendic schists the felspathic character which distinguishes the granitoid rock known as protogine.

THE ELECTRIC TRANSMISSION OF POWER.[1]

WHAT is power, and why should we wish to transmit it? Power has one very definite meaning in science, and several rather vague meanings in practice. We speak of a powerful athlete, the power of the law; we sing of the power of love; we say knowledge is power, and so on, using the word in several different senses. Now, in spite of the fact that a general audience feels a little anxious as to what troubles may be in store for it when a lecturer begins by being painfully exact, my telling you that by power an engineer understands the rate of doing work will not, I hope, make you fear that my remarks will bristle with technicalities.

When you walk upstairs you exert power—only, perhaps, the one-twentieth of a horse when you go up slowly, talking to other people. But when you run upstairs because you have forgotten something that you intended to bring down, then your exertions represent, perhaps, the one-tenth of a horse-power. You only get to the top of the stairs in either case, but the breathless sensation of running fast upstairs tells you that the more quickly you go the harder you are working. A person exercises power in the engineer's sense when he exerts himself physically, and the greater the exertion the greater the power. The exercise of power by the ruling classes, however, is unfortunately not necessarily accompanied by any exertion, physical or mental.

Probably the most familiar example of exerting power at a distance—that is, of transmitting power—is pulling a handle and ringing a bell in another room. I pull the handle, exerting myself slightly, and as the result the bell at the other end of the platform rings. Were not this such a very familiar operation I would call it experiment No. 1. You have doubtless all of you performed this experiment several times to-day, and—what is all important with an experiment—performed it successfully.

And yet it was not until just one hundred years ago that it dawned on people that if one person, A, wanted to attract the attention of another person, B, the place where the bell ought to sound was where B was, and not where A was. Indeed, in many English villages down to the present day the knocker principle of attracting attention is alone resorted to, with the result which you may remember happened when Mr. Pickwick was staying in Bath at lodgings in the Royal Crescent, and Mr. Dowler undertook to sit up for Mrs. Dowler, but "made up his mind that he would throw himself on the bed in the back room and *think*—not sleep, of course. . . . Just as the clock struck three there was blown into the crescent a sedan-chair with Mrs. Dowler inside, borne by one short fat chairman and one long thin one. . . . They gave a good round double knock at the street door. . . . 'Knock again, if you please,' said Mrs. Dowler, from the chair. 'Knock two or three times, if you please.' The short man stood on the step and gave four or five most startling double knocks of eight or ten knocks a-piece, while the long man went into the road and looked up at the windows for a light. Nobody came—it was as silent and as dark as ever." But the tall thin man, you may remember, "kept on perpetually knocking double knocks of two loud knocks each, like an insane postman," till Mr. Winkle, waking up from a dream "that he was at a club where the chairman was obliged to hammer the table a good deal to preserve order," met with the catastrophe which the readers of "Pickwick" will remember.

This episode shows what comes of having plenty of power and no means of transmitting it.

But if some houses can still dispense with mechanical or other methods of transmitting power, even to ring bells, factories cannot. The looms, the lathes, or whatever the machinery used in the factory may be, must either be worked by hand or foot in the old style, or it must be connected with the steam-, gas-, or water-engine in the new. On entering a large factory you see lines of rapidly-rotating shafting, and a net-work of rapidly-revolving belting, all employed in transmitting power. As a contrast to this, I now throw on the screen a photograph of Sir David Salomon's workshop at Tunbridge Wells, in which every machine is worked by a separate electric motor, thus saving to a great extent the loss of power that usually accompanies the mechanical transmission.

In America there are 6000 electromotors working machinery; in Great Britain hardly 100.

But it is not only in transmitting the power from the steam-, gas-, or water-engine of a factory to the various machines working in it, that electricity can be utilized. An incredible amount of power is daily running to waste in this and other countries because many of the rapid streams of water are too far away from towns for their power to have been hitherto utilized.

The holiday tourist, when admiring the splashing water dashing over the stones, hardly realizes that the money loss is as if the foam were composed of flakes of silver.

[1] Lecture delivered by Prof. Ayrton, F.R.S., at the Drill Hall, Bath, on Friday, September 7, 1888.

If we take as a low estimate that a large well-made steam-engine burns only 2 pounds of coal per horse-power per hour, the coal consumption which would be equivalent to the waste of power at Niagara would exceed 150,000,000 tons per annum, which at only 5*s.* or 6*s.* per ton means some £40,000,000 sterling wasted. And descending from big things to small, the River Avon, flowing through Bath, which, so far from being a roaring cataract, especially in dry weather, pursues its course with only a respectable orderly swish, still represents a certain amount of lost power. It has been estimated that from 25 to 130 horse-power runs to waste at the Bathwick Weir behind the Guildhall, depending on the season. If we take as an all-round average that the fall of this weir represents 50 horse-power, and that a steam-engine producing this power burns 150 pounds of coal per hour, it follows that with steam coal at 16*s.* per ton—the price at Bath—the waste at Bathwick Weir represents an income of £450 per annum, not a princely fortune, it is true, but too large to be utterly thrown away as at present.

This state of things will I hope, however, be shortly remedied, for, as you will see from the large map on the wall, it is proposed to put up eighty-one electric arc lamps throughout the streets of Bath, and to supply the 50 horse-power required for these lamps by the fall of the Bathwick Weir, supplementing the fall with a steam-engine at dry seasons.

The next large diagram shows the use that Lord Salisbury has made of the River Lea to electrically light Hatfield House, and to supply electric motive power to the various machines working on his estate. The following diagram shows the course of the Portrush electric railway, six and a half miles long, which is worked by the Bushmill Falls, situated at about one mile from the nearest point of the railway. And lastly, this working model on the table, kindly lent me by Dr. E. Hopkinson, as well as the diagram on the wall, represent the Bessbrook and Newry electric tramway, a little over three miles in length, which is also worked entirely by water power, the turbine and dynamo which convert the water power into electric power being at about three-quarters of a mile from the Bessbrook terminus. [Model electric railway shown in action.]

The newspapers of last week contained a long account of the spiral electric mountain railway that has just been opened to carry people up the Burgenstock, near Lucerne, and worked by the River Aar, three miles away, so that we see electric traction worked by distant water power is extending. But, splendid as are these most successful uses of water power to actuate distant electromotors, it is but a stray stream here and there that has yet been utilized, and countless wealth is still being squandered in all the torrents all over the world.

The familiarity of the fact makes it none the less striking, that, while we obtain in a laborious way from the depths of the earth the power we employ, we let run to waste every hour of our lives many many times as much as we use.

It is also a well-established, time-honoured fact that large steam-engines can be worked much more economically than small ones, and that therefore if it were possible to *economically* transmit the power from a few very large steam-engines to a great number of small workshops there would be a great saving of power, as well as a great saving of time from the workmen in these many small workshops having only to employ this power for various industrial purposes, instead of having to stoke, clean, repair, and generally attend to a great number of small, uneconomical steam-engines.

When delivering the lecture which I had the honour to give at the meeting of the British Association at Sheffield nine years ago, I entered fully into Prof. Perry's and my own views on this subject, and therefore I will not enlarge on them now. You can all realize the difference between the luxury of merely getting into a train instead of having to engage post-horses; of being able to send a telegram instead of employing a special messenger; or being able to turn on a gas tap and apply a match when you want a light, instead of having to purchase oil and a wick, and trim a lamp. Well, a general supply of power to workshops is to the manufacturer what a general supply of light or a general supply of post-office facilities is to the householder: it is all part of the steady advance of civilization that leads the man of to-day to go to the tailor, the shoemaker, the baker, the butcher, instead of manufacturing his own mocassins and lassoing a buffalo for dinner. And in case any of you may be inclined to think that we have gone far enough in these new-fangled notions, and we are all perhaps prone to fall into this mistake as we grow older, let me remind you that while each age regards with justifiable pride the superiority of its ways to those of its ancestors, that very age will appear but semi-civilized to its great-grandchildren. Let us accept as an undoubted fact that a general distribution of power would enable the wants of civilized life to be better satisfied, and therefore would greatly benefit industry.

There are four methods of transmitting power to a distance: (1) by a moving rope; (2) by air compressed or rarefied at one end of a pipe operating an air motor at the other end; (3) by water forced through a pipe working a water motor; (4) by electricity.

We have an example of the transmission of power through a short distance by an endless belt or rope in the machine geared together by belts on this platform, and in the rotatory hair-brushes at Mr. Hatt's establishment in the Corridor, Bath. At Schaffhausen, and elsewhere in Switzerland, the principle is employed on a large scale. Spain and other countries use it in connection with their mining operations; and lastly, wire ropes replace horses on many hilly tramways. Do not look, however, for the wire rope of the Bath cable tramways, for cable is only to be found painted on the sides of the cars.

For short distances of a mile or so there is no system of transmitting power in a *straight line* along the open country so cheap to erect, and so economical of power as a *rapidly*-moving endless rope; but the other systems give much greater facilities for distributing the power along the line of route, are much less noisy, and far surpass wire rope transmission in economy when the rope must move somewhat slowly, as in tramway traction, or when the distance is considerable over which the power is transmitted, or when the line of route has many bends.

In the same sense that an ordinary house-bell may be considered as a crude example of the transmission of power by a moving rope, the pneumatic bell at the other end of the hall which I now ring by sending a puff of air through the tube is a crude example of the transmission of power by compressed air. [Pneumatic bell rung.] Compressed air is employed to work from a distance the boring-machines used in tunnelling. The continuous vacuum-brakes used on many of the railways are also probably familiar to you, and the pneumatic system of transmitting power to workshops is shortly to be tried on a fairly large scale at Birmingham.

But distribution of power by water pressure is the plan that has hitherto found most favour in this country. That little water motor at the other end of the platform rapidly revolves when I work this garden syringe, and serves as a puny illustration of the transmission of water pressure. [Experiment shown.] Pressure water has been employed for years on a large scale at Hull for distributing power; also by Mr. Tweddle, as a means of communicating a very large amount of power through a flexible tube to tools that have to be moved about; but the grandest illustration of this principle is the vast system of high-pressure mains that have been laid throughout London, as you will see from the photograph that I now project on the screen of the map kindly lent me by Mr. Ellington.

The economy of this system is so marked and the success that has attended its use is so great that, did I not feel sure that electricity offers a grander system still, it would be with fear and trembling that I should approach the subject of this evening, the "Electric Transmission of Power." *Punch* drew six years ago the giant Steam and the giant Coal looking aghast at the suckling babe Electricity in its cradle. That baby is a strong boy now; let the giant Water look to its laurels ere that boy becomes a man. For the electric transmission of power even now bids fair to surpass all other methods in (1) economy in consumption of fuel; (2) more perfect control over each individual machine, for see how easily I can start this electric motor, and how easily I can vary its speed [experiment shown]; (3) ability to bring the tool to the work instead of the work to the tool—this rapidly-rotating polishing-brush, with its thin flexible wires conveying the power, I can handle as easily as if it were a simple nail-brush; (4) in greater cleanliness, no small benefit in this dirty, smoky age; (5) and lastly, there is still one more advantage possessed by this electric method of transmitting power that no other method can lay claim to—the power which during the day-time may be mainly used for driving machinery can, in the easiest possible way, be used during the night for giving light. I turn this handle one way, and the electric current coming by one of these wires and returning by the other works this electromotor; now I turn the handle the other way, and the current which comes and returns by the same wires as before keeps this electric lamp glowing. [Experiment shown.]

It might be said that the transmission of power by coal-gas, which I have excluded from my list, fulfils this condition, but so also does the transmission of power by a loaded coal-waggon. In both these cases, however, it is fuel itself that is transmitted, and not the power obtained by burning the fuel at a distant place.

Let us study this electric transmission a little in detail. I pull this handle, and the bell at the other end of the room rings; but in this case there is no visible motion of anything between the handle and the bell. [Electric bell rung by an electric current produced by pulling the handle of a very small magneto-electric machine.] Whether I ring the bell by pulling a wire, or by sending an air puff, or by generating an electric current by the exertion of my hand, the work necessary for ringing the bell is done by my hand exactly as if I took up a hand-bell and rang it. In each of the three cases I put in the power at one end of the arrangement, and it produces its effect at the other. In the electric transmission how does this power travel? Well, we do not know. It may go through the wires, or through the space outside them. But although we are really quite in the dark as to the mechanism by means of which the electric power is transmitted, one thing we do know from experience, and that is this: given any arrangement of familiar electrical combinations, then we can foretell the result.

Our knowledge of electrical action in this respect resembles our knowledge of gravitation action. The only thing quite certain about the reason why a body falls to the ground is that we do not know it; and yet astronomical phenomena can be predicted with marvellous accuracy. I mention the analogy, since some people fancy because the answer to that oft-repeated question, "What is electricity?" not only cannot be given exactly, but can only be guessed at in the haziest way, even by the most able, that therefore all electric action is haphazard. As well might the determinations of a ship's latitude at sea be regarded as a mere game of chance because we have not even a mental picture of the ropes that pull the earth and sun together.

This power of producing an action at a distance of many yards, or it may be many miles, by the aid of electricity without the visible motion of any substance in the intervening space is by no means new. It is the essence of the electric telegraph; and electric transmission of power was employed by Gauss and Weber when they sent the first electric message. I am transmitting power electrically whether I now work this small model needle telegraph instrument, or whether I turn this handle and set in motion that little electric fan. [Experiment shown.]

But until about ten years ago the facility that electricity gave for producing signals almost instantaneously at a great distance was the main thing thought of. The electric power consumed for sending the telegraph messages was so small, the amount of power lost *en route* comparatively so valueless, that the telegraph engineer had no need to trouble himself with those considerations that govern us to-day when we are transmitting power large enough to work a factory or an electric tramway. Although there are as many as 22,560 galvanic cells at the Central Telegraph Office, London, which cost some thousands annually to keep in order, what is that compared with the salaries of all the 3089 superintendents, assistants, telegraph-clerks, messengers, and the maintenance of the 1150 telegraph lines that start from the Central Office?

In all the last three systems in my list some form of power, such as flowing water, or the potential energy stored up in coal, wood, zinc, or other fuel, has initially to be utilized. This power is given to some form of air, water, or electric pump, which transfers the air power to the air, water, or electricity, by which it is conveyed to the other end of the system. There it is re-converted into useful mechanical power by means of an air, water, or electric motor.

You will observe that I class together air, water, and electricity; by that I do not mean to imply that electricity is a fluid, although in many respects it acts like a fluid—like a fluid of very little mass, however; or, odd as it may seem, like a fluid moving extremely slowly, for electricity goes round sharp corners with perfect ease, and without any of the phenomena of momentum possessed by rushing water. But what I particularly wish to impress on you by classing air, water, and electricity together is that electricity is not, as some people seem to think, a something that can be burnt or in some way used up and so work got out of it. Electricity is no more a source of power than a bell-wire is, electricity is a marvellously convenient agent for conveying a push or a pull to a great distance, but it is not by the using up of the electricity that electric lights burn or that electromotors revolve. It is by the electricity losing pressure, exactly as water loses head when turning the miller's wheel as it flows down hill, that work is done electrically.

This model shows, in a rough, symbolical way, what takes place in the transmission of power whether by air, water, or electricity. [Model shown.] The working stuff, whichever of the three it may be, is first raised in pressure and endowed with energy, symbolized by this ball being raised up in the model; it then gradually loses pressure as it proceeds along the tube or wire which conveys it to the other end of the system, the loss of pressure being accompanied by an increase of speed or by its giving up power to the tube or wire and heating it. This is shown in the model by the ball gradually falling in its course. At the other end there is a great drop of pressure corresponding with a great transference of power from the working stuff to the motor, and finally it comes back along the return pipe or wire, losing, as it returns, all that remains of the pressure given to it initially by the pump. The ball has, in fact, come back to its original level.

The problem of economically transmitting power by air, water, or electricity is the problem of causing one or other of these working stuffs—air, water, or electricity—to economically perform the cycle I have described.

In each of the four stages of the process—(1) transference of power to the working substance at the pump; (2) conveyance of power to the distant place; (3) transference of power from the working substance to the motor at the distant place; (4) bringing back the working substance—there is a loss of power, and the efficiency of the arrangement depends on the amount of these four losses. The losses may be shortly called (1) loss at the pump; (2 and 4) loss on the road; (3) loss at the motor.

Until 1870 the pump most generally employed for pumping up electricity and giving it pressure was the galvanic battery—scientifically an extremely efficient converter of the energy in fuel into electric energy, only unfortunately the only fuel a battery will burn is so expensive. A very perfect fire-place, in which there was very complete combustion, and very little loss of heat, but which had the misfortune that it would only burn the very best wax candles, would be analogous with a battery. The impossibility of using zinc as fuel to commercially work electromotors has been known for the last half-century, and the matter was very clearly put in an extremely interesting paper "On Electro-magnetism as a Motive Power," read in 1857 by Mr. Hunt before the Institution of Civil Engineers, a copy of which has been kindly lent me by Dr. Silvanus Thompson. Prof. William Thomson (Glasgow)—I quote from the discussion on the paper—put the matter very pithily by showing that, even if it were possible to construct a theoretically perfect electromotor, the best that could be hoped for, if it worked with a Daniell's battery, would be the production of a one horse-power by the combustion of 2 pounds of zinc per hour, whereas with a good actual steam-engine of even thirty years ago, one horse-power could be produced by the combustion of exactly the same weight of the much cheaper fuel coal. This argument against the commercial employment of zinc to produce electric currents is irresistible, unless—and this is a very important consideration, which is only beginning to receive the attention it deserves—unless, I say, the compound of zinc formed by the action of the battery can be reduced again to metallic zinc by a comparatively inexpensive process, and the zinc used over and over again in the battery. If the compound of zinc obtained from the battery be regarded as a waste product, then it would be much too expensive to work even theoretically perfect electromotors, if they were existent, by consuming zinc. Suppose, however, a process be devised by means of which burnt zinc can be unburnt with an expenditure comparable with the burning of the same weight of coal, then it might be that, although coal would still form the basis of our supply of energy, the consumption of zinc batteries might be an important intermediary in transforming the energy of coal, economically, into mechanical energy.

While, then, some experimenters are aiming at possibly increasing the working power of a ton of coal to eight times its present value by earnestly seeking for a method of converting the energy it contains directly into electric energy without the intervention of a wasteful heat engine, it should not be forgotten that in the cheap unburning of oxidized metal may lie another solution.

The solution of this latter problem is quite consistent with the principles of the conservation and dissipation of energy, since the heat required to theoretically unburn 1 pound of zinc is only one-seventh of that given out by the burning of 1 pound of coal. Further, it involves no commercial absurdity like that found in the calculations given in the prospectuses of many primary battery companies, which are based on zinc oxide, a material used in the manufacture of paint, maintaining its present price even if thousands of tons were produced. Unless all those who use primary batteries on this expectation intend to have the painters doing up their houses all the year round, they will find themselves possessed of the stock-in-trade of an oil and colourman on a scale only justified by a roaring business in paint.

Now about waste No. 3, the waste of power at the motor. That also is gone into fully in the discussion on Mr. Hunt's paper, and Mr. Robert Stephenson concluded that discussion by remarking "that there could be no doubt, from what had been said, that the application of voltaic electricity in what ever shape it might be developed was entirely out of the question commercially speaking. . . . The power exhibited by electro-magnets extended through so small a space as to be practically useless. A powerful electro-magnet might be compared for the sake of illustration to a steam-engine with an enormous piston, but with an exceedingly short stroke. Such an arrangement was well known to be very undesirable."

And this objection made with perfect justice against the electromotors of thirty years ago might also have been made to all the machines then existing for the mechanical production of electric currents. I have two coils of wire at the two sides of the platform joined together with two wires. I move this magnet backwards and forwards in front of this coil, and you observe the magnet suspended near the coil begins to swing in time with my hand. [Experiment shown.] Here you have in its most rudimentary form the conversion of mechanical power into electric power, and the re-conversion of electric power into mechanical power; but the apparatus at both ends has the defects pointed out by Mr. Hunt and all the speakers in the discussion on his paper—the effect diminishes very rapidly as the distance separating the coil from the moving magnet increases.

As long as electromotors as well as the machines for the production of electric currents had this defect, the electric transmission of power was like carrying coals to Newcastle in a leaky waggon. You would pay at least 16*s*. a ton for your coals in Bath, lose most of them on the way, and sell any small portion that had not tumbled out of the waggon for, say, 2*s*. a ton at Newcastle —a commercial speculation not to be recommended.

A very great improvement in electromotors was made by Pacinotti in 1860, but although his new form of electromotor was described in 1864 it attracted but little attention, probably because any form of electromotor, no matter how perfect, was commercially almost useless until some much more economical method of producing electric currents had been devised than the consumption of zinc and acids. Pacinotti's invention removed from motors that great defect that had been so fully emphasized by the various speakers at the reading of Mr. Hunt's paper in 1857. When describing his motor in the Nuovo Cimento in 1864, he pointed out that his principle was reversible, and that it might be used in a mechanical current generator. This idea was utilized by Gramme in 1870, who constructed the well-known Gramme dynamo for converting mechanical into electric power—a machine far more efficient than even Pacinotti had contemplated —and gave the whole subject of electrical engineering a vigorous forward impulse. Every subsequent maker of direct-current dynamos, or motors, has followed Gramme's example in utilizing the principle devised by Pacinotti, which was as follows. In all the early forms of dynamos or motors there were a number of magnets and a number of coils of wire, the magnets moving relatively to the coils, or the coils relatively to the magnets, as you see in this rather old specimen of alternate-current dynamo. To produce magnetism by a large number of little magnets is not economical, and Pacinotti's device consisted in arranging a number of coils round a ring in the way shown in the large wooden model [model shown], so that they could all be acted on by one large magnet. Instead of frittering away his magnetism, Pacinotti showed how it could be concentrated, and thus he led the way to dynamos and motors becoming commercial machines. Pacinotti's science, engineered by Gramme, not only made electric lighting commercially possible, but led to electricity being used as a valuable motive power. It was in their work that the electric transmission of power in its modern sense sprang into existence.

Quite recently an improvement in the same direction has been introduced into alternate-current dynamos by Mr. W. N. Mordey, for he has replaced the many magnets of the ordinary alternate-current dynamos with one large magnet, and so with his alternator weighing 41 hundredweight, which you see in this hall, he has succeeded in obtaining at a speed of 650 revolutions per minute an output of 53·6 horse-power with a high efficiency.

It may be convenient to mention at this stage the very valuable work that has been done by the Drs. Hopkinson, Mr. Crompton, Mr. Kapp, and others, in the improving of dynamos and motors by applying scientific principles in the construction of these machines. Were I lecturing on dynamos and motors instead of on the electric transmission of power, I would explain to you how, by putting more iron into the rotating armature, as it is called, and less wire on it, by shortening the stationary magnet, and generally by concentrating the magnetic action, these constructors have raised the commercial efficiency of these machines to actually as high as between 93 and 94 per cent.; further, how, by recognizing the force of the general principles laid down by Prof. Perry and myself, as to the difference that should exist in the construction of a motor and a dynamo, Messrs. Immisch have succeeded in constructing strong, durable electromotors weighing not more than 62 pounds per effective horse-power developed.

The subject is so entrancing to me, the results commercially so important, that I am strongly tempted to branch off, but the inexorable clock warns me that I must concentrate my remarks as they have concentrated the magnetic action.

87½ per cent. of the power put into an Edison-Hopkinson dynamo has actually been given out by the motor spindle when 50 horse-power was being transmitted. How does this compare with the *combined* efficiencies of an air-pump and an air-motor, or of a water-pump and a water-motor? I understand that in either of these cases 60 per cent. is considered a very satisfactory result. As far, then, as the terminal losses are concerned, electric transmission of power is certainly superior to air or water transmission.

(*To be continued.*)

SCIENTIFIC SERIALS.

THE Proceedings of the American Academy of Arts and Sciences for the year May 1887-88 contains many important papers. Among them we may mention one on the relative values of the atomic weights of hydrogen and oxygen, by Prof. J. P. Cooke and Mr. Richards, and a catalogue of all recorded meteorites, by Prof. Huntington. The volume also contains papers on the existence of oxygen, carbon, and certain other elements in the sun; the first two of these papers are chiefly remarkable for the absence of reference to the literature of the subjects, and it is charitable to suppose that this proceeds from the authors' ignorance.

Bulletin de l'Académie Royale de Belgique, June 30.—On the physical aspect of Mars during the opposition of 1888, by L. Niesten. An image of the planet taken by the author on May 5 shows that the so-called continent was again visible, which M. Perrotin had reported as having disappeared during the opposition of 1886. Analogous though less marked modifications in the form and colour of the spots seem to imply that these changes are periodical. The paper is illustrated by two successful photographs of the planetary disk, showing its appearance on April 29 and May 5, 1888.—Fresh researches on the optic origin of the spectral rays in connection with the undulatory theory of light, by C. Fievez. A new interpretation of the spectral rays is here offered by the author, who regards spectral phenomena as a particular case of optical interferences. According to this view luminous rays would produce at a given point of the spectrum a vibratory movement, whose intensity might be maximum or minimum according as one of the rays follows another by an even or uneven number of half wave-lengths. A spectrum presenting dark or bright rays would always proceed, not from a luminous source, but from at least two different sources. It would thus indicate the nature of the rays, whose undulatory movement was disturbed by the simultaneous action of the various luminous sources. M. Fievez concludes that Kirchhoff's absorption theory does not alone suffice to explain the observed facts, which may also be interpreted by means of the undulatory theory of light. His views are supported by a number of ingenious and skilfully executed experiments in spectral analysis.