SCIENCE IN THE MAGAZINES.

MR. CHAS. DIXON has discovered a new law of geographical dispersal of species, and he expounds its capabilities in the *Fortnightly*. Here is a statement of his conclusions:—"Species in the northern hemisphere never increase their range in a southern direction; they may do so north, north-east, or north-west, east or west. Species in the southern hemisphere never increase their range in a northern direction; they may do so south, south-east, or south-west, east or west. The tendency of life is to spread in the direction of the poles. Among the six corollaries which I have drawn from this law, mention may be made of the following. By the fourth corollary, species never retreat from adverse conditions. If overtaken by such they perish, or such portion of the species that may be exposed to them. By the fifth corollary, extension of range is only undertaken to increase breeding area. By the sixth corollary, contraction of range is only produced by extermination among sedentary species, and probably also by extermination (through inability to rear offspring) among migratory species that are neither inter-polar nor inter-hemisphere. . . . If this law of geographical distribution be true, polar dispersal of species—in other words, from the direction of the poles towards the equator—is a myth." Mr. Dixon brings forward a number of facts in support of his theory, which will no doubt be given the consideration it deserves.

An address by Mr. Leslie Stephen, on the choice of books, appears in the *National*; but, to prevent misconception, it is just as well to state at once that scientific literature is altogether ignored. Yet it is difficult to understand why this should be, for writings of men of science are apparently included in the definition stated by Mr. Stephen himself. "Literature, in short," he writes, "is one utterance of Matthew Arnold's *Zeitgeist*—the vague but real entity which is a summary of all the sympathies and modes of thought and feeling characteristic of the best minds at a given stage of human progress." A few natural history notes will be found in the *National*, in an account, by Miss Balfour, of a journey through the British South Africa Company's territory, in 1894.

Among other popular articles on natural history in the magazines received by us, we notice "Nestlings," by the Rev. Theodore Wood, in the *Sunday Magazine*, and "Snake-Taming" in *Chambers's Journal*. This periodical also contains a very readable elementary description of the great Indian Trigonometrical Survey. Mr. L. N. Badenoch describes a number of species of Plasmidæ in *Good Words*. In the same magazine Sir Robert Ball writes on the life and works of Copernicus. Under the title, "Tesla's Oscillator and other Inventions," a good account of some of Mr. Tesla's recent electrical work is given in the *Century*, by Mr. T. C. Martin. The article "discloses a few of the more important results he has attained, some of the methods and apparatus which he employs, and one or two of the theories to which he resorts for an explanation of what is accomplished." It is illustrated with fifteen figures, all of which possess points of interest. Mention must be made here of a short biographical sketch of Helmholtz, contributed by Mr. Martin to the March number of the *Century*, but overlooked at the time. The sketch is illustrated by a fine engraving from a photograph of Helmholtz, taken in 1893. A brief note in *Cassell's Family Magazine* describes some curious tubular dwellings constructed against the side of a small aquarium by the species *Amphithoe littorina*. The tubes are semicircular, and composed of sand and small pieces of seaweed, cemented together with a glutinous matter secreted by these shrimps.

The practicability of constructing a railway from the Mediterranean to India is discussed by Mr. C. E. D. Black in the *Contemporary*. Over India proper there are 18,500 miles of lines open to traffic. But westward these lines break off at Peshawur, Chaman, and Kurrachee. It is proposed that a line should be constructed from Port Said, through Northern Arabia, along the edge of the Persian Gulf, to Kurrachee—a distance estimated at 2400 miles.

In addition to the magazines mentioned in the foregoing, the *Humanitarian*, *Scribner*, and *Longman's Magazine* have been received. A portrait of Prof. Bonney accompanies an article on "Science and Faith" in the first of these magazines.

PRECIOUS STONES, AND HOW TO DISTINGUISH THEM.[1]

AMONG the duties which fall to the lot of an official in the Mineral Department of the British Museum, in his otherwise unromantic and sternly studious life, is one which is not altogether devoid of human interest. It may happen, for example, that a lady having inherited a priceless heirloom in the shape of a large emerald, travels from the Antipodes in order to sell it in England for its true value, and desiring to display its charms brings it to the Museum. To inform such a person that the stone is but green bottle glass cannot be a pleasant task.

Only within the last few months came an Afghan prince who had sold his worldly goods, travelled to the coast of India, and worked his passage to England, having secreted about his person a stone which he supposed to be of enormous value. His story was that as he slept upon the hillside, Mahomet had appeared to him and told him that he would find a rare jewel under his hand. The poor man could not be convinced that a stone with this celestial guarantee could be anything common; for, as he said, "Mahomet cannot lie." Be this as it may, the stone was quartz, and its princely owner could only be advised to repair his fallen fortunes in some Oriental fashion at Constantinople—Kensington.

It is curious that the stones brought by such people are always, in the opinion of their owners, gems of the greatest value and rarity. Could they but have consulted some competent expert nearer home, they would have been saved time and money and bitter disappointment.

But after such interviews, I have always been very forcibly impressed by the fact that even the experts do not seem in the least aware of the simple and certain methods which have been placed at their disposal by recent mineralogical research. There is, perhaps, no subject in which experts have been so slow to take advantage of practical methods supplied by science as in the manipulation and discrimination of precious stones.

The stones brought by these chance visitors have often been bought and sold over and over again under totally false names. There is, I suspect, scarcely a collection, public or private, in which some of the jewels are not wrongly described.

Mistakes are constantly made; and these are sometimes of considerable commercial importance. It may be remembered, for example, that a few years ago much excitement was caused by the discovery of rubies in the Macdonell Range in Southern Australia. Much time and money was wasted in their extraction before it was discovered that, like the so-called Cape rubies, they were merely garnets.

I should be the last person to underrate the great value of that knowledge which results from long experience, or to deny that in ninety-nine cases out of a hundred an expert may be absolutely right. Every one must admire the confidence with which a practised eye can even pick out from several packets of diamonds those which came from a certain mine.

Such a professional expert may in five seconds pronounce a judgment which it might require half an hour to establish by scientific methods, and one which may be equally correct.

But there is a vast difference between "may be" and "is," and scientific men are not satisfied with that sort of judgment, but require actual proof.

One ought to distinguish between two sorts of expert knowledge—that which results from long experience and the training of eye and hand, and that which results from familiarity with scientific methods. To have confidence in the non-scientific expert, one must place reliance upon his personal character and the soundness of his senses, and be sure that his actual experience has included problems similar to the one submitted to him, and even then he may fail in that hundredth case.

But the scientific tests cannot err; moreover, they furnish a proof which carries conviction to all who see it. The opinion of the expert need *convince* none but himself.

An exact parallel is to be found in medical practice. It is no doubt often possible for a doctor of experience to diagnose diphtheria and phthisis by their symptoms. But in recent years new methods have been made available by the discoveries relating to bacteria, and at the present time no diagnosis of diphtheria or of the early stages of consumption would be con-

[1] A lecture delivered at the Imperial Institute, by Mr. H. A. Miers.

sidered complete which did not include the bacteriological evidence; that is to say, the isolation and microscopic examination in each case of the specific bacillus. What is more, such evidence is proof positive of the existence of the disease.

Now the only characters at all generally employed by persons connected with the trade in precious stones are two—namely, the hardness and the specific gravity or weightiness.

If a stone scratches quartz, and is scratched by topaz, it is said to have a hardness between that of quartz and that of topaz; if it scratches topaz, but is scratched by sapphire, it is said to have a hardness between that of topaz and that of sapphire. All minerals, including the gem-stones, have been tabulated according to their hardness with reference to ten standard stones, of which the diamond, the hardest of all known substances, heads the list. If, for example, a red stone, supposed to be a ruby, is found to be only about as hard as topaz, it cannot be a true ruby, but must be a spinel ruby, which is quite a different thing; or if it is sufficiently soft to be scratched by rock-crystal, it is probably a red garnet.

This test is obviously a very rude one in more senses than one. Not only does everything depend upon the nature of the scratching part, whether it is a sharp corner or a curved surface, and upon the direction in which the scratch is made; but, to say the least, the surface of a gem is certainly not improved by scratching.

The second test—that of the weightiness—is a really accurate and scientific one, provided that it be made by means of a delicate chemical balance. A stone which is, bulk for bulk, three times as heavy as water, is said to have a specific gravity of 3; one such as topaz, which is three and a half times as heavy as water, is said to have a specific gravity of 3·5. The ordinary method is to weigh the stone, suspended by a thread, first in air, and then immersed in water. The difference is exactly the weight of the water displaced by the stone, and so the specific gravity is easily found.

The objections to this method are, firstly, that it is too laborious; and secondly, that it is not applicable when the stone is very small, because it is then impossible to weigh it with accuracy under water. I should not rely upon the specific gravity of a stone under two carats in weight as determined by this method. A method which I shall presently describe is perfectly free from both these objections.

Incredible as it may seem, the estimation of hardness and the specific gravity are the only attempts at anything like scientific measurement ever made in the ordinary course of business applied to stones; and even then the weightiness is usually estimated merely by poising the stone in the hand. For the rest they are identified by their colour, their fire or sparkle, their lustre and their general appearance.

In a lecture delivered to the Society of Arts in 1881, Prof. Church drew attention to the necessity of scientific methods for this purpose, and has more than once, on subsequent occasions, reiterated his plea. I propose to dwell more particularly on improvements which have been introduced since the date of his lecture, and to indicate how one may, by simple practical tests, which require little special knowledge, distinguish with certainty all gem-stones without in any way injuring them.

Chemical analysis is, by the very nature of the problem, out of the question, for in order to make an analysis, or to apply the simplest chemical test, it is necessary to destroy a part of the material; and this cannot be done, at any rate in the case of a cut stone.

We can begin by dismissing the hardness as a character which it is really unnecessary to determine, except to identify diamond or to distinguish a real stone from paste; here, I know, I shall earn a rebuke from the orthodox mineralogist who, in order to pursue the study of what should be a peaceful science, arms himself with a knife, and proceeds to scratch everything which he comes across.

The weapons which I would recommend are of a milder nature: the microscope, the spectroscope, the goniometer, and the dichroscope.

Among the available characters of gems, first and foremost are the optical properties; that is to say, the appearances seen when we look at them, or through them, in various ways.

The extent to which a ray of light is refracted on entering and leaving a transparent stone, is a characteristic property most useful for determination. As everyone knows, a stick half immersed in water appears bent owing to the refraction of light on passing out of the water; if it is immersed in a more highly refractive liquid, it appears more bent.

To ascertain the refractive power of any transparent substance like glass, a prism-shaped piece is cut from it, and the extent to which a ray of light is refracted on passing through the prism is measured by the goniometer, an instrument found in every physical laboratory.

I have not seen this recommended as a method to be practically used, because it is commonly supposed that a special prism must be cut from the stone for the purpose. For the benefit of those who possess a goniometer, I may say that it is a method which I constantly apply, and find most useful for unmounted cut stones. It is always possible to find two of the facets which form a convenient angle, and, after inking over the remainder of the stone, to trace the ray passing through these two facets, and so to measure with absolute accuracy not only the refraction but the double refraction of the stone; moreover, this method is applicable to any stone, however great its refractive power.

Another simple plan which can be used by any one, but unfortunately only for stones of comparatively low refractive power, has been invented during the last few years. This delightfully simple little instrument, known as the reflectometer, consists of a hemispherical glass lens viewed by an eye-piece containing a graduated scale; it need only be pressed against the plane surface of a cut stone previously touched with a drop of liquid of higher refractive power than the stone itself. On looking into the eye-piece a shade is seen over half the field of view, and its edge crosses the scale at a point which gives the exact refractive index of the stone. The best available liquid is monobromo naphthalene, which has a refractive power higher than that of topaz, and enables one at a glance to distinguish a cut topaz or any less brilliant gem-stone.

Most useful, again, are the so-called interference figures—the appearances seen on looking through a transparent stone by means of a polarising microscope, such as is used by every geologist. There is, of course, nothing new in these figures; they are now employed by geologists in the study of rocks, and even sometimes by those whose business it is to distinguish precious stones.

Without endeavouring to explain the nature of these figures, except to say that they are due to the double refraction of the crystal, it is easy to show that by looking at a stone through a microscope, one may see something very characteristic.

(The interference figures of several minerals were thrown upon the screen by means of a projection apparatus lent by Prof. Ayrton; sapphire, tourmaline, and emerald were shown to give coloured circular rings intersected by a black cross; sphene and chrysoberyl, coloured oval rings intersected by a hyperbola; and quartz, coloured circular rings with a black cross having a tinted centre.)

This beautiful method is not employed nearly so largely as it deserves, because most people find it difficult. In order to see the figure it is necessary to look through any given crystal in one certain direction. (The stones used for projection were plates appropriately cut for the purpose). Now it may happen that a facetted stone is so cut that to look along the required direction would be to look through an angular corner; and every one knows that it is not possible to look through a pointed corner, owing to the refraction of the light. For this reason when an unmounted cut jewel is held under the polarising microscope, and yields no interference figure when turned about into various positions, it is usually given up as hopeless. But obviously we have only to immerse the stone in some liquid having nearly the same refractive power as itself, in order to eliminate the difficulty due to refraction. I find that if the stone be placed in a small tube filled with oil or glycerine, and held in various positions, the interference figure can always be seen. Little more than a year ago, a small facetted stone of peculiar appearance was sent to me, which had deceived the experts to whom it had been shown, although agreeing in some respects with quartz, and was supposed to be a new stone. But by immersing it in oil in a hollow glass sphere, I was able to see the characteristic interference figure of quartz. When a stone has the refraction, the double refraction, the specific gravity, and the characteristic interference figure of quartz—it is quartz and nothing else.

Other optical characters of great value are those resulting from the absorption of the light in its passage through a crystal;

some of the colours contained in ordinary daylight are more absorbed than others, and the light emerges more or less coloured; in consequence of differences of absorption, some gem-stones appear differently coloured according to the direction in which one looks through them. I need not dwell upon this curious property because the instrument used to observe it is the one piece of scientific apparatus sometimes, but by no means generally, used by gem experts—I mean the instrument known as the dichroscope. (A diagram, kindly lent by Prof. Judd, illustrated the appearance seen with this instrument.) Far less familiar is the method of studying the absorption by means of the spectroscope, although the value of this extremely simple method was pointed out many years ago by Prof. Church. Every one knows the colours of the spectrum seen by daylight through a glass prism, and it is also well known that if light transmitted through various vapours be appropriately observed through such a prism by means of the spectroscope, certain black lines are seen in the spectrum, indicating that the vapour has absorbed light of a certain colour; in this way astronomers are able, by merely looking at the sun and stars, to ascertain many of the elements which they contain.

But it is not commonly known that a precisely similar effect is produced by many transparent minerals. It is only necessary to look through a pocket spectroscope in a bright light at any transparent mineral containing the rare element didymium, and certain black bands characteristic of that element are at once seen in the spectrum.

(A diagram of the spectrum of the phosphorescent light emitted by ruby when made to glow in the electric discharge in a vacuum tube, lent by Prof. Crookes, though not a picture exactly of what is here described, served to illustrate the appearance of the black bands in the spectrum of a red mineral.)

Now, there are two gem-stones which give very characteristic black bands when looked at through a spectroscope, namely, the jargoon or jacynth, and the variety of garnet known as almandine, commonly called carbuncle. When a stone, say one set in a ring, is looked at in this way, and gives the characteristic spectrum of zircon, it is at once known to be a jargoon without further trouble.

When one remembers how many pocket spectroscopes are bought by people who wish to see the rain-band and predict the weather, it is surprising that it has not also come into use for the examination of gems.

To pass from optical to other characters, there is a very remarkable property possessed pre-eminently by one mineral which has not, so far as I know, been previously recommended as a practical test.

A crystal of tourmaline while being warmed or cooled becomes electrified; one end becomes charged with positive, the other end with negative electricity. The fact has long been known. But a few years ago an extremely pretty and ingenious way of showing the electrification was devised by Prof. Kundt. If a mixture of powdered red lead and sulphur be shaken or blown through a sieve, the particles become electrified by mutual friction, and if it then be dusted upon a crystal of tourmaline which is being warmed or cooled, the positively electrified end of the crystal attracts the negatively electrified yellow sulphur, and the other end attracts the positively electrified red lead; one end of the crystal becomes red, and the other end yellow; and so the difference of electrification is made visible. Now every crystal of tourmaline behaves in this way, and I find it perfectly easy to show the property in an ordinary small jewel, even when mounted in a setting. All that is necessary is to warm the stone, and then, while it is cooling, to dust it with the mixture; at once one part of the stone becomes red, and another part yellow.

(A facetted stone treated in this way was shown upon the screen by reflected light.)

The last character which I have to mention is the one to which I alluded at the beginning, namely, the heaviness or specific gravity. The use of the balance is, as I said, too laborious; but within the last few years an entirely different method has been introduced.

Cork and wood float in water because, bulk for bulk, they are lighter; stone and iron sink because, bulk for bulk, they are heavier than water. But find some substance whose density is exactly that of water, and it will neither rise nor sink, but will remain poised in the water like a balloon in mid-air.

Several liquids have been discovered which are more than three and a half times as dense as water, in which, therefore, amethyst, beryl, and other light stones will actually float. Prof. Church strongly recommended mercuric and potassium iodide; but a still more convenient liquid is now available, namely, methylene iodide. This liquid has a specific gravity of 3·3, so that tourmaline readily floats in it; further, it is not corrosive or in any way dangerous, which is more than can be said for several of the other liquids which have been recommended.

Now it is scarcely possible to prepare a number of liquids, each having the specific gravity of one gem-stone, in order to identify each stone, but methylene iodide is easily diluted by adding benzene to it; each drop of benzene added makes the liquid less dense, and so it may be used to separate tourmaline and all the lighter gem-stones from each other. Nothing can be easier or more satisfactory than this method; no matter how minute the stone may be, it can be identified by its density in a few moments. Suppose it be doubtful whether a certain gem is aquamarine or chrysoberyl, all that is necessary is to place it in a tube of the liquid, together with a small fragment of true aquamarine to serve as an index; if it be a chrysoberyl, which has a specific gravity of 3·6, it will sink like lead; if it be an aquamarine, which has a specific gravity of 2·7, it will float; and if the liquid be then stirred and diluted until the index fragment is exactly suspended, the gem also will neither float nor sink, but will remain poised beside it.

The delicacy and simplicity of the method is marvellous; the only reason why it has not been more generally adopted is that, unfortunately, the greater number of gem-stones are heavier than methylene iodide. What is the use of employing such liquids when they cannot float jargoon, carbuncle, sapphire, ruby, chrysoberyl, spinel, topaz, peridote, and diamond, to mention only those stones whose names are familiar?

But this objection is now entirely removed, thanks to a discovery made quite recently by the distinguished Dutch mineralogist, Retgers. He has found a colourless solid compound which melts, at a temperature far below that of boiling water, to a clear liquid five times as dense as water; and therefore sufficiently dense to float any known precious stone.

This compound is the double nitrate of silver and thallium, and it further possesses a most remarkable property; it will mix in any desired proportion with warm water, so that by dilution the specific gravity may be easily reduced. The fused mass may be reduced in density by adding water drop by drop so as to suspend in succession jargoon, carbuncle, sapphire and ruby, chrysoberyl, and spinel.

This wonderful compound should certainly be employed by all who wish to distinguish gems with ease and certainty.

Let me now remind you how one could apply the methods which I have been describing, to identify with absolute certainty some gem-stone. Take, for example, a cut tourmaline. Dropped into methylene iodide it would just float, and, when the liquid is diluted, it would remain suspended beside an index fragment of tourmaline, and no other gem-stone. Examined with the dichroscope it would show two coloured images, indicating remarkable differences of absorption characteristic of tourmaline, and no other mineral; the absence of absorption bands, when it is viewed through the spectroscope, would show that it is neither garnet nor jargoon; in the polarising microscope it would show the interference figure of tourmaline.

Even if the stone were mounted in a setting so that these tests could not be applied, it could be examined with the reflectometer, the boundary of the shade would cross the scale at a point exactly corresponding to the refractive power of tourmaline; and lastly, it could be warmed and dusted with red lead and sulphur, when the two coloured patches would betray the electrical properties of tourmaline. There is enough evidence here to satisfy any one but an English jury hearing expert witnesses, and everything can be done without inflicting even a scratch upon the stone.

Another mineral character of great value in distinguishing gem-stones in the rough I have not alluded to, because it can only be made use of when they are more or less well crystallised; I mean the shape of the crystals. (This feature was illustrated by some very beautiful photographs of gem-stones and other minerals in their natural state, which were taken from specimens in the British Museum by the distinguished photographic expert, Mr. Hepworth.)

It might be asked, with some show of reason, why should we require all these scientific tests which I have described, when the varieties of precious stones are so few in number? In reality, however, gem-stones are far more numerous than is commonly supposed, although they often pass muster under erroneous names. Tourmaline is sold as ruby, cinnamon stone as jacynth, white jargoon and phenacite as diamond, while green garnets are universally known in the trade as olivine or peridote.

That the varieties of available gem-stones are not far more numerous, is due mainly to the prejudice of purchasers, who ring the changes on diamonds, rubies, sapphires, and emeralds, and have heard of nothing else; estimating the stones, as the public estimates popular actors or authors, not by their real excellence, but by their names.

In the mineral gallery of the British Museum are many examples of cut stones which have rarely or never been employed in jewellery, but should certainly win favour on their own merits.

One very curious example is a little gem cut from a crystal of the ordinary tin-stone, the same ore which is worked for tin in the Cornish mines. This is a stone which, when cut from a sufficiently transparent crystal, possesses a most beautiful lustre and colour.

As another example, I may mention a stone which, I suspect from its appearance, would make a very beautiful gem. It was sent with some other fragments from the ruby mines of Burmah; it is only a single rough fragment, and has completely puzzled every one to whom I have shown it. By means of the very tests which I have been describing, and without sacrificing more than a pin's point of the stone, I have been able to identify it as the boro-silicate of lime known as Danburite. This mineral, if it has ever been used in jewellery. which is most unlikely, has certainly never been rightly named.

(A number of facetted stones lent by Mr. Gregory, who has made many interesting experiments in this direction, were thrown upon the screen by reflected light; among these were several of the less familiar gems, such as tourmaline, chrysoberyl, phenacite, felspar, andalusite, axinite, spodumene, sphene, and idocrase.)

I do not know whether the final impression produced by what I have said, is that the determination of stones is an easy or a difficult thing. The impression which I wished to convey, is that where these scientific tests can be applied, it is an absolutely certain thing; and where they cannot be applied, there is no such certainty.

The crystals from which these gems are cut are changeless and imperishable, their beauty has been enhanced by the art of man, but they have lost none of their wonderful properties in the process; in fact, it is only by utilising these very properties that the lapidary converts them from dull stones to flashing jewels, and it is by these properties that we have to recognise them.

The ruby formed countless ages ago in the heart of Burmah, is the same thing in all essentials as the ruby formed to-day in a Paris laboratory.

It is curious to reflect that the diamond which to-day glitters in a London ball-room, may have adorned the crown of some Oriental monarch centuries ago—may have been picked from the shores of an Indian stream in the dawn of civilisation—may have been the silent witness of the growth and decay of empires—but by its own unchanging existence has always borne steadfast evidence to the everlasting laws of nature.

H. A. MIERS.

THE OBSERVATION OF EARTH-WAVES AND VIBRATIONS.

THE object of this communication is to call attention to the apparently high velocity with which motion is transmitted from an earthquake centre to places distant from it a quarter of the earth's circumference, and to the importance of instituting an extended systematic observation of these movements.

During the last few years Dr. E. von Rebeur-Paschwitz and other observers in Europe have recorded earth movements which had their origin in Japan or in other distant countries. Beyond a radius of a few hundred miles from their origin these disturbances are often too feeble to be sensible or to be recorded by ordinary seismographs. Their presence is, however, made known by the use of specially contrived nearly horizontal pendulums, and by these and other instruments we find that they usually have a duration of from ten to thirty minutes, though now and then they last one or two hours. On June 3, 1893, the writer obtained a record lasting 5 hrs. 24 min. In Europe what was probably the same disturbance indicated a movement which continued for about fifteen hours. From observations hitherto made, it seems extremely likely, as Dr. E. von Rebeur-Paschwitz has suggested, that these earth-waves could be recorded at almost any point upon the surface of our globe, while the phenomena they present are such that it is probable that their extended study would throw light, not only upon the manner in which motion is transmitted through the superficial portions of the earth, but also across its interior.

As illustrative of the results to which these records lead, I take those derived from diagrams of several seismographs in Tokyo, and from that of a long pendulum seismograph at Rocca di Papa in Italy, which on March 22, 1894, together with many other instruments in Europe, exhibited considerable motion. The origin of the disturbance was off the N.E. coast of Yezo (Lat. 42° N., Long. 146° E.).

From observations made in Tokyo, distant about 600 miles from the epicentrum, not only upon the initial disturbance, but also four after-shocks, it seems that motion was propagated at an average rate of about 2·3 km. per second. Inasmuch as the instruments from which these records were obtained, are not capable of recording movements of small amplitude, probably this velocity was that of the pronounced vibrations of the quasi-elastic nature characteristic of most earthquakes. There are reasons for believing that such waves outside an epifocal area are practically confined to the surface of the earth. A movement which from the manner in which it slowly affected ordinary or horizontal pendulum seismographs, had probably a similar character, travelled from Japan to Italy with a velocity of from 2·7 to 3 km. per second, the larger waves travelling at the slower rate.

Preceding these decided motions, minute tremors were observed, which, if they originated at the epicentrum and travelled on the surface of the earth, must have done so at a rate of 11·5 km. per second, while if they were created by the transformation of the energy of the partially elastic undulations as they passed from medium to medium, then their velocity of propagation must have been still more abnormal. If it is assumed that they reached Italy by direct radiation through the earth, or that in consequence of refraction they followed curvilinear paths, the observations indicate a velocity of 9 or 10 km. per second.

Considering the influence of gravity upon the propagation of surface undulations, the observed velocities may possibly be a little lower than what might have been expected. The minute tremors, however, seem to have a velocity which is roughly twice that for a condensational rarefactional wave in glass.

Observations upon other earthquakes, although none of them can claim any great degree of accuracy, point to the same general results.

At present, the diversity of instruments employed in Europe, and the various degrees of sensibility given to the few instruments which are approximately similar, apparently results in the recording of different phases of motion, and it is not likely that our knowledge will be increased or made more accurate until there is greater uniformity in the methods of observation.

Now to determine whether the disturbances created by large earthquakes are propagated to distant localities in the manner suggested, much might be learned by establishing twelve or fourteen similar instruments at an equal number of selected stations round the northern hemisphere. It is yet premature to indicate the class of instruments to be employed, but if their chief function is to record the time of arrival and the different phases of these wide-spreading movements, it is the writer's experience that many difficulties may be avoided in installation, adjustment and management, by using a type that is not too sensitive to extremely minute changes of level, such as accompany fluctuations in temperature and changes in atmospheric conditions. All of them should admit of adjustment to a similar degree of sensibility, and so far as possible be attached to similar foundations in localities or places where the effects of tremor storms, which often eclipse the effects due to earthquakes, are not likely to be pronounced. Photographic surfaces on which records are received, should move at a rate of *not less* than two inches per hour, which will enable an observer to determine time intervals to within 30 seconds.

It would seem advisable that the first attempt to make a seismic survey of the world should be tentative. Having ob-