THE NATURE OF THE EARTH'S INTERIOR*

IN a previous discourse on volcanoes,† I directed attention to the phenomena of volcanic action, specially considered in relation to the part which such igneous or internal forces have played in determining the grand features of the external configuration of the sphere upon which we live.

If now we follow up this subject still further, it will naturally lead to an inquiry into the nature of the internal substance of the globe itself, within which the foci of such agencies must be situated; quite independent of this, however, I have little doubt but that many of you must at some time or other have already asked yourselves the question—What does the central mass of the earth beneath us consist of?

The answer which, in the first instance, would, I imagine, be most likely to suggest itself to your minds, would be that it consisted of solid stone, such as you see forming the body of its mountains, the foundations of its continents, and the rock basins which contain its seas. The belief in such an hypothesis would, however, be rudely shaken by the first personal experience of the shock of an earthquake, the sight of a volcano in eruption, or the consideration of the immense faults which have dislocated many parts of the solid land; since, so far from disposing us to regard the ground under us as entitled to the appellation of the *terra firma*, so commonly used by the ancients, the study of such phenomena could not but suggest grave doubts in our minds as to whether the earth was after all anything like so solid or stable as we at first sight felt inclined to imagine.

But very little inquiry into the subject is necessary, however, to convince any one of the great difficulties in the way of obtaining a satisfactory answer to this question, and to prove that at present we do not have at our command sufficient data or evidence to enable us to arrive at a thoroughly conclusive solution of this most interesting problem.

As the rapid advances made by the natural sciences are, however, daily adding to our information on this subject, and thus enabling us to correct or modify our previous deductions, so as to form a more and more trustworthy opinion on the nature of those parts of our globe, which, from their position, must always remain inaccessible to our powers of direct observation, I have imagined that a short sketch of the present state of our knowledge concerning the probable constitution of the interior of the earth might prove interesting.

In treating this subject, we will first consider what has already been done in the way of direct examination of the earth's substance in depth; yet when it is remembered that the mean diameter of our planet is some 7,912 miles, whilst the greatest depth hitherto attained by man's direct exploration has not even yet reached one mile from the surface downwards; this disproportion appears so enormous as to render it self-evident, in the pursuit of this inquiry, especially as regards the more central portions of the earth, that we must in the main rely upon data furnished by calling in the aid of the natural sciences. The direct examination of the exterior of the earth, even when restricted to this depth, does nevertheless furnish us with many important data from which to start in this to a great degree speculative inquiry, and to some of these we shall now direct attention.

It must first of all be remembered that all the rocks which we meet with at the surface, and which compose so much of the solid exterior of our globe as is actually known to us, may be arranged under two principal heads, viz., the volcanic or endogenous rocks, *i.e.* those formed within the body of the earth itself, and the sedimentary or exogenous, *i.e.* those rocks formed, or rather reconstructed upon its surface, out of the *débris* of previously existing rocks arranged in beds or strata by the mechanical action of water.

It was long taken for granted by geologists that the lowest sedimentary strata, in their normal or in a more or less altered condition, rested directly upon granite, which was for a long time regarded as the foundation upon which they, in the first instance, had been deposited, since this rock was looked upon as the oldest of all, and as representing the primeval or original surface covering of the earth. Later researches, however, have proved this hypothesis to be untenable, since it appears that no instance of a granite has as yet been met with in nature, which if followed up, does not at some place or other break through, and alter or disturb more or less, the stratified rocks in immediate contact with it, so that it naturally follows that such stratified rocks must have preëxisted on the spot, or in other words, that they were older in geological chronology than the granite which came to disturb them.

In the present state of geology, however, it is utterly impossible for us to point out any variety of rock whatsoever as the one which may have served as a foundation upon wh ch the oldest sedimentary rocks were originally deposited, in fact the oldest rocks which we know of at present are themselves sedimentary rocks (mostly in an altered condition) belonging to the Laurentian series in Canada, and as yet it has not been found out what these sedimentary beds may in their turn rest upon, *i.e.*, what is actually below them.

As therefore we have not as yet been able to reach down to investigate directly any rocks lower in the geological series than those pertaining to the Laurentian formation, we will now turn to the volcanoes, in order to examine the mineral products which they bring up for our consideration, from depths vastly beyond those which we can ever hope to reach directly. What volcanoes teach us with regard to the nature of the earth's interior, at a depth from which they derive their supply of mineral matter, may be summarised as follows:—

That at this depth, the earth's substance exists in a state of perfect molten liquidity, forming as it were a sea of molten rock, analogous in character to the eruptive rocks which have broken through the earth's crust in former times. Secondly, that the mineral products ejected from volcanoes are very similar to one-another in chemical and mineral constitution, no matter from what part of the globe they may emanate from. And, lastly, that from the same volcanic orifice, and during the same eruption, lavas of two totally different classes may be emitted, viz., the light, acid, or trachytic lava, analogous to the granites, felsites, &c., of the oldest period, and the heavy basic or pyroxenic lava, all but identical with the dark basaltic or trappean rocks commonly met with as dykes, &c., disturbing most of the different sedimentary formations.

Another deduction from the study of volcanic phenomena, indicating that at a certain depth below their surface they must be in connection with a continuous sea of molten lava, is based upon the influence which the moon appears to have on volcanic eruptions; this opinion seems to have been confirmed by the observations of Prof. Palmieri made during the last eruption of Vesuvius, on which occcasion he reported that distinct tidal phenomena could be recognised, thereby indicating that the moon's attraction occasioned tides in the central zone of molten lava, in quite a similar manner as it causes them in the ocean. A further corroboration of this view is seen in the results of an examination of the records of some 7,000 earthquake shocks which occurred during the first half of this century, compiled by Perry, and which, according to him, demonstrate that earthquakes are much more frequent in the conjunction and opposition of the moon than at other times, more so when the moon is near the earth than when it is distant, and also more frequent in the hour of its passage through the meridian.

Returning now to the more direct examination of the superficial parts of the earth, we find that the results of mining operations have also thrown considerable light, not only on the mineral nature of the rocks encountered in depth, but also upon some of their physical conditions. A numerous set of experiments made in deep mines in various parts of the world, often far distant from one another, has most conclusively proved that the temperature of the earth, at least as deep down from the surface as has been explored by man, increases in direct ratio as we descend towards its centre. Other observations on the temperature of the water from deep-seated and hot springs, and from artesian wells, fully confirm the experiments made in mines, and show that the temperature of the water furnished by them also becomes higher in proportion to the depth of the source from which it is derived.

As might naturally be expected, the interference of local causes renders it a matter of considerable difficulty to determine the true mean general rate of such increase in temperature of the earth's substance downwards; still, in the main, observers all agree in placing it at somewhere between $1\frac{1}{2}^\circ$ and $2\frac{1}{2}^\circ$ degrees F. for every hundred feet in depth, so that we cannot be far wrong, if for our purpose we estimate it at 2° F. for every hundred feet in depth, or a rate which amounts to 121° for each geographical mile nearer the earth's centre. Since no facts are at the present time known which can in any way invalidate the supposition that this or a somewhat similar rate of increase in temperature holds good in still greater depths, it is perfectly correct and justifiable reasoning to assume that such is actually

* Substance of a Lecture delivered for the Sunday Lecture Society on January 29.

† See NATURE, vol. ii. p. 283.

the case, and therefore a simple calculation will show that at a depth of about twenty-five geographical miles from the surface downwards a temperature of about 3,000° F. should be attained, which would represent a heat at which iron melts, or one sufficient to keep lava in a state of perfect molten liquidity at the surface of the earth. As it must be remembered, however, that at this depth the substance of the earth would be exposed to the pressure of the superincumbent mass, and as it has been shown by experiment that many substances become more refractory—*i.e.*, require a greater degree of heat to melt them—when exposed to pressure than when at the surface, the above calculation will have to be modified considerably in order to meet this condition. Unfortunately, we have not as yet sufficient data at command to enable us to estimate the true ratio in which the melting points of such rocks would become elevated by pressure; yet we may safely take it for granted, after allowing far more than the maximum rate of increase, deduced from the experiments of Bunsen and Hopkins, that we should not require to sink so deep again in order to attain a temperature fully sufficient to keep such substances in a state of fusion, or, in other words, this deduction necessitates the supposition that the solid rock crust of the earth cannot, at the utmost, be more than 50 miles in thickness.

If we now reason from the above data as premisses, it will follow as a natural consequence that our globe must in reality be a sphere of molten matter surrounded by an external shell or crust of solid matter, of very insignificant thickness when compared to the diameter of the entire globe itself; or, in other words, this deduction represents exactly such a state of things as would ensue in the event of a sphere of molten matter becoming consolidated on its exterior by the cooling action of the external atmosphere; and the figure of the earth itself, which is an ellipsoid of revolution, *i.e.*, a sphere somewhat flattened in at the poles, but bulging out at the equator, being that which a plastic mass revolving round its own axis would assume, is regarded by natural philosophers in general as all but conclusive evidence, that the earth at an early period of its history must have been in a fluid condition.

Although the doctrine that the earth is a molten sphere surrounded by a thin crust of solid matter was all but universally taught by geologists, there have of late years been brought forward several arguments to the contrary, which apparently are more in favour of its being a solid or nearly solid mass throughout, and these arguments are fully entitled to our consideration, as our object is not to defend any particular theory, but to arrive as nearly as we can at the truth. I will, therefore, in the first place proceed to scrutinise all which has been brought forward in opposition to the older hypothesis, and then to consider whether any other explanation yet advanced is more in accordance with the facts of the case.

First of all we have to answer the question as to whether it is possible for such a thin crust to remain solid, and not at once to become melted up and absorbed into the much greater mass of molten matter beneath it? This would doubtless be the case, if the central fluid mass had any means of keeping up its high temperature, independently of the amount of heat it actually possessed when it originally assumed the form of an igneous globe. This question, however, in reality answers itself in the negative, since it is evident that no crust could even commence to form on the surface, unless the sphere itself was at the moment actually giving off more heat from its outer surface to the surrounding atmosphere than it could supply from its more central parts, in order to keep the whole in a perfectly fluid condition, so that when once such a crust, however thin, had formed upon the surface, it is self-evident that it could not again become melted up or re-absorbed into the fluid mass below.

This external process of solidification due to refrigeration would then continue going on from the outside inwards, until a thickness of crust had been attained sufficient to arrest or neutralise (owing to its bad conductibility of heat) both the cooling action of the surrounding air and the loss of more heat from the molten mass within; and thus a stage would soon be arrived at when both these actions would so counterbalance one another that the further cooling down of the earth could be all but arrested: a condition ruling at the present time, since the earth-surface at this moment, so far from receiving any or more than a minute amount of heat from the interior, appears to depend entirely, as regards its temperature, upon the heat which it receives from the sun's rays.

We have next to consider the argument that, if the earth's exterior was in reality only such a thin covering or crust, like the shell of an egg, to which it has often been likened, that such a thickness would be altogether insufficient to give to it that stability which we know it to possess, and that consequently it could never sustain the enormous weight of its mountain ranges, such as, for example, the Himalayas of Asia or the Andes of America, which are, as it were, masses of rock piled up high above its mean surface-level.

At first sight, this style of reasoning not only appears plausible, but even seems to threaten to upset the entire hypothesis altogether. It requires but little sober consideration, however, to prove that it is more, so to speak, sensational in character than actually founded on the facts of the case; for it is only requisite for us to be able to form in our minds some tangible idea of the relative proportion which the size of even the highest mountain bears to that of the entire globe itself, to convince us, if such a crust could once form and support itself, that it could with ease support the weight of the mountains also. The great Himalaya chain of mountains rises to a maximum altitude of 31,860 feet, or six miles above the level of the sea; and if the earth could be seen reduced in scale down to the size of an orange, to all intents and purposes it would look like an almost smooth ball, since even the highest mountains and deepest valleys upon its surface would present to the eye no greater inequalities in outline than the little pimples and hollows on the outside of the skin of an ordinary orange. If this thin crust of the earth can support itself, it is not at all likely to be crushed in by the comparatively speaking insignificant weight of our greatest mountain chains, for in point of fact it would be quite as unreasonable to maintain such a supposition, as to declare that the shell of a hen's egg would be crushed in by simply laying a piece of a similar egg-shell upon its outside.

That a very thin spheroidal crust or shell enclosing a body of liquid matter such as an ordinary fowl's egg, does possess in itself an enormous degree of stability and power to resist pressure from without, is easily demonstrated by merely loading a small portion of its surface with weights as long as it does not give way under them. Even when placed on its side (or least strong position) it was found that a portion of the shell only one quarter of an inch square would sustain several pounds weight without showing any symptoms of either cracking or crushing; or, in other words, this simple experiment indicates that if the external crust of the earth was but as thick and strong in proportion as an egg-shell, it would be fully capable of sustaining masses equal in volume and weight to many Himalayas piled up one atop of another, without any danger whatever to its stability.

The next argument which has been advanced against the probability of the major part of the earth's substance being in a fluid condition, is one based altogether upon astronomical considerations. It having been demonstrated when two clocks are set agoing, the pendulums of which are similar to one another in all respects except that whilst the bob of the one is solid, that of the other is hollow and filled with mercury, that the latter will swing somewhat faster, and consequently the clock gain time upon the former. The late Mr. Hopkins, of Cambridge, applied this observation to the consideration of movements of the earth in space, and by a very elaborate course of mathematical reasoning and calculation, demonstrated that the earth, if not quite solid, must be nearly so, since according to his results, if it was merely a comparatively thin shell filled with liquid matter, the ratio of certain of its movements (the precession or nutation) would differ considerably from what they are actually known to be, and these conclusions appeared to be confirmed by the subsequent calculations of Sir William Thomson and Archdeacon Pratt. Although grave doubts suggested themselves as to the correctness of the values used in these calculations for two of their most important elements, viz., the condensing action of pressure and the expanding action of the very high temperatures within the globe—both of which have not as yet been determined with any certainty, and although it might also be surmised that the conditions of a pendulum bob of polished glass filled with heavy slippery mercury swinging at the end of a rod must be extremely different from those of a nearly spherical globe filled with viscid sticky lava revolving around its own axis; still geologists felt themselves quite unable to answer the arguments of the astronomers and mathematicians, and since none of them appeared to be sufficiently versed in either astronomy or mathematics to be able to submit the method of reasoning or the calculations to any strict scrutiny, they felt themselves, reluctantly no doubt, compelled to bow to the decision of such eminent authorities.

So stood the matter until the summer of 1868, when, fortunately for the advancement of this inquiry, M. Delaunay, now Director of the Observatory at Paris, an authority equally eminent as a mathematician and an astronomer, was induced to undertake the reconsideration of this problem; a labour which has not only resulted in altogether reversing the above decision, and demonstrating the complete fallacy of the premisses upon which so much elaborate reasoning had been expended, but which proved conclusively by experiment that a sphere filled with liquid matter would, under circumstances such as are present in the case of the earth, behave in precisely the same manner as an entirely solid one, and, consequently, that the fact of the earth being either solid or liquid in its interior could neither have any influence whatever on the rate of precession or nutation, nor be of any use as a means of deciding as to the real or approximative thickness of the earth's crust.

It may also be added that the conclusions arrived at by Mr. Hopkins, even when supported by Sir William Thomson and Archdeacon Pratt, were not universally acquiesced in; the celebrated German physicist, Helmholtz, amongst others, was not satisfied as to their correctness, and in opposition to the deductions of Sir William Thomson that the earth's crust must be some 1,000 miles in thickness, we have the entirely opposite conclusions of Mr. Henessey, whose calculations tend to show that the earth's crust cannot be less than eighteen miles or more than 600 miles in thickness. We may now, however, fairly conclude that all the objections as yet advanced from an astronomical point of view against the theory of the fluid condition of the interior of our planet, have been invalidated or explained away.

The only other argument in favour of internal solidity is one which bases itself upon the law, announced upon theoretical considerations by Professor Thomson in 1849, that the fusing points of bodies must become more elevated when subjected to pressure, or, in other words, that under the influence of pressure, bodies will require more heat to melt them.

Starting from this, Bunsen argued that the earth could not be other than solid to the core, since the enormous pressure accumulated at the centre would cause its internal substance to become so infusible that it could not remain in a molten state. To a certain extent this law was corroborated by the experimental researches of Bunsen and Hopkins, made upon some of the easily fusible substances like wax, spermaceti, paraffin, and sulphur; but as far as the later experiments went, it was not confirmed either in the case of metallic substances, nor did it appear to hold true with other than the more easily compressible bodies.

In the case of the earth, therefore, the conclusions of Bunsen cannot be accepted, since we have to deal with materials to which, as yet, this law has not been proved to apply; still, assuming, as seems most probable, that the materials composing the earth's mass do become to some extent more and more infusible according as they approach nearer to its centre, it must, on the other hand, be remembered that this would be more or less neutralised by the expansion which these substances would undergo from the action of the internal heat; and as incontrovertible evidence has been produced to prove that the temperature of the earth downwards from the surface increases in direct ratio with the depth, it seems most probable that the combined effects of expansion and elevated temperatures would more than counteract any tendency to solidification due to the effects of pressure.

Having now taken into consideration the various objections which have been urged against the theory of the earth's internal fluidity, as well as devoted some consideration to the opposing view of its solidity, it will be noticed, if we pass in review some of the distinctive features of the two hypotheses, that the former theory is a legitimate deduction from the data afforded by the direct study of the earth itself, whereas the latter, on the contrary, instead of making the explanation of the earth's phenomena its starting point, devotes itself almost exclusively to the task of proving that it could not be fluid.

Thus, how is it possible, if the earth's mass be solid throughout, to account for the great upheavals or sinkings down of large portions of the rock formations which compose its external crust? Do not these phenomena lead to the direct inference that the external crust cannot, by any possibility, rest in depth upon an unyielding mass of matter in the solid state, but that it must necessarily be superposed upon some more or less fluid substance which by its mobility can, when some one portion of the crust above sinks down, become displaced, and so make room for it by elevating, or, as it were, floating up some other part of the same?

In like manner the hypothesis that the earth is essentially solid necessitated that the phenomena of volcanoes should be explained upon the supposition that they had their sources in numerous small isolated local basins of molten rock scattered over the surface of the globe; a view which is altogether inconsistent with the results of chemical and mineralogical investigation, which proves that the ejected products are identical in constitution even if taken from volcanic vents the most distant from one another, nor does such a theory attempt to explain the tidal phenomena of volcanic outbursts and earthquakes previously alluded to.

So far, therefore, as we have gone into this subject, we may regard the balance of evidence as proving that at a depth of about fifty miles or less from the surface, there exists a continuous zone of molten rock or lava, such as is brought up to the surface by volcanic eruptions. Let us now consider how deep this zone or stratum of molten matter is likely to extend, and also what forms the more central mass of the earth below it.

In order to answer these questions we must look to other than direct evidence, and first of all must inquire whether the consideration of the mean density, or in other words the actual weight, of the earth itself, can throw any light upon these abstruse points. The consideration of the attraction which bodies exert upon one another in the ratio of their magnitude, has enabled the physicist to effect the at first sight apparently impracticable task of determining the entire weight of the earth itself, but it is out of our province to describe the mode of doing so, and we must content ourselves by accepting as a fact the results of such investigations, which prove that the total weight of our planet is as near as possible $5\frac{1}{2}$ times the weight of a similar globe of pure water. Knowing now that the mean density, or specific gravity, as it is also called, of the earth, is $5\frac{1}{2}$, and also from direct experiment that the mean density of the entire solid rock forming its external crust cannot be higher than $2\frac{1}{2}$, or less than half that of the entire sphere, it naturally follows that the central parts must be very much more heavy in order to account for so high a mean figure as $5\frac{1}{2}$, and it has been calculated that if we suppose that the earth was composed of three concentric portions of equal thickness, each in turn increasing in density towards the centre in arithmetical progression, we should then have an outer circle of specific gravity $2\frac{1}{2}$, or as heavy as rock, an intermediate zone of 12, or as heavy as quicksilver, and a central nucleus of about twenty times the density of water, or as heavy as gold.

This increase of density has sometimes been erroneously represented as entirely due to the effects of the enormous pressure of the superincumbent mass; but this supposition is quite untenable, since the tendency of all the numerous experiments made in this direction has been to prove that no substances can be compressed or condensed to an indefinite extent, since what may be termed their approximative maximum density is soon attained, beyond which the effects of pressure become so much smaller and smaller in proportion to the force applied, that at last the further condensation effected by still greater pressure is all but inappreciable. Besides this, it must not be forgot that the crust of the earth is a species of dome like the shell of an egg, which supports itself without resting or floating upon its fluid centre; and further that the earth's high internal heat, by causing the materials which compose it to expand, must also counteract the effects of superincumbent pressure, so that when all these facts are taken into due consideration, it appears quite evident that the materials which actually form the mass of the interior must be infinitely denser than any of the rocks met with on the surface, and that they must be metallic in their nature, since no other bodies are known which could at all fulfil these conditions of density.

If now we suppose that the earth's interior is composed of a series of concentric zones or layers made up of substances which are of more and more dense nature as they are situated nearer the centre, and that the external one is rock of a density of 2·5, a calculation will show that the centre or nucleus will be about 10, or as heavy as silver. If now we suppose that the zone of molten lava, which we have already concluded must exist at a depth of about 50 miles below the surface, has a density of 3, o say even 4, to give the fullest allowance for the condensing effects of superincumbent pressure, then we should find by calculation that this zone could not extend deeper than about 400 miles, since below this depth the matter would be so heavy that its density can only be explained on the supposition that it is made up of metallic compounds, and as the density of the still lower zones would continue to increase up to the very centre of the earth, the inference is that the whole of this great central mass situated at a distance of some 450 miles or less below the surface, is actually formed of metals and their compounds.

Whether this great central metallic nucleus is fluid or solid may next be inquired into. According to Bunsen's theory previously alluded to, it ought to be solid, for owing to the enormous pressure to which it would be exposed, the solidification of the molten sphere should first commence at the centre. This view would be quite correct if the earth was composed of highly compressible non-metallic materials; but since this is not the case, and since, as before alluded to, the experimental data already obtained indicate that neither the metallic nor the less compressible substances become more refractory in proportion to the increase of pressure, we are more justified in assuming that the central nucleus also must be in a fluid condition, and the more so, not only because we know that metallic compounds are as a rule infinitely more fusible than rock silicates, but also as the well-known high temperature of the earth's interior would, by its expanding action, tend to counteract the effects of the pressure.

In summing up this inquiry, the balance of evidence appears to me to be decidedly in favour of the hypothesis that the interior of our earth is a mass of molten matter arranged in concentric layers or zones according to their respective densities, and the whole enclosed within a comparatively thin external crust or shell.

DAVID FORBES

SCIENTIFIC SERIALS

THE *American Naturalist* for January opens with a long paper by Prof. J. S. Newberry "On the Ancient Lakes of Western America: their Deposits and Drainage," which is stated to be a chapter from Dr. Hayden's forthcoming "Sun-pictures of the Rocky Mountains." Prof. Newberry states that the wonderful collection of fossil plants and animal remains brought by Dr. Hayden from the country bordering the Upper Missouri has been shown, by his observations and the researches of Mr. Meek, to have been derived from deposits made in extensive fresh water lakes, lakes which once occupied much of the region lying immediately east of the Rocky Mountains, but which have now totally disappeared. The sediments that accumulated in the bottom of these old lakes show that in the earliest periods of their history they contained salt water, at least that the sea had access to them, and their waters were more or less impregnated with salt, so as to be inhabited by oysters and other marine or estuary mollusks. In due time the continental elevation which brought all the country west of the Mississippi up out of the widespread Cretaceous sea raised these lake-basins altogether above the sea-level, and surrounded them with a broad expanse of dry land. Between these lakes were the areas of dry land covered with luxuriant and beautiful vegetation, and inhabited by herds of elephants and other great mammals, such as could only inhabit a well-watered and fertile country. Prof. Newberry's explanations throw much light on that remarkable feature of the western side of the great continent, the canons formed by the rivers, like the stupendous one of the Colorado, nearly 1,000 miles in length and from 3,000 to 6,000 feet in depth, with almost perpendicular sides. The Rev. A. P. Peabody contributes an account of the Chinese in San Francisco; Mr. H. Willey, a paper on Lichens under the microscope, with wood-cuts which very well illustrate their mode of vegetation and reproduction; and Dr. A. P. Barnard, a description of a new form of binocular for use with high powers of the microscope. The shorter articles and *Natural History Miscellany* contain, as usual, much interesting information.

The *Journal of Botany* for February commences a series of papers which will be very useful to systematic botanists; an alphabetical catalogue of the new genera and species of plants published during 1870 in the English botanical and gardening journals, not including the "Journal of the Linnean Society." The present number only carries the list down to *Dracontium*. Mr. J. G. Baker continues his monograph of the genus *Xiphium*, and Dr. Hance contributes an article on the so-called "olives" of Southern China, which he states to be produced by two species of *Canarium*, trees from twenty to thirty feet high, largely grown in the neighbourhood of Whampoa. The stones are beautifully and elaborately carved by the Chinese as ornaments, and, when set in gold, form exceedingly handsome brooches or bracelets. Two articles of special interest to systematists are Prof. Dyer and Dr. Trimen on *Polygonum nodosum*; and Mr. W. P. Hiern on the form and distribution over the world of the Batrachian (or aquatic) section of *Ranunculus*. There is also the usual section of short Notes and Queries.

SOCIETIES AND ACADEMIES

LONDON

Chemical Society, February 2.—Prof. Williamson, F.R.S., President, in the chair. The following gentlemen were elected Fellows: R. J. Friswell, R. F. Humiston, M.D., A. H. Mason, I. R. Justin. Prof. Frankland, F.R.S., read a paper "On the Development of Fungi in Potable Water." He began by alluding to the experiments Dr. Heisch had made some months back with waters contaminated with sewage matter. When to such waters some sugar was added, very soon a kind of fermentation ensued, and a rich fungoid growth made its appearance. Prof. Frankland has now repeated and extended these experiments and arrived, with one or two exceptions, at the same results. But in the course of his researches he encountered some reactions which revealed to him that the presence of sewage matter in saccharic water is in itself not sufficient to produce fungoid growth, but that the presence of phosphates in some form is indispensable to such production. Prof. Frankland further found that the germs which give rise to the development of fungi need not necessarily come from sewage contamination, but that they may be derived from the atmosphere. Finally, he found that animal charcoal does not remove those germs. Dr. Frankland thinks that the sugar test of Dr. Heisch for the detection of traces of sewage contamination may be turned into a very delicate reagent for the detection of minute quantities of phosphates; for when these defy the power of the usual laboratory tests, they yet are capable of feeding those germs and thus giving rise to the fungoid growth. From all his observations Prof. Frankland drew the following conclusions:—1. Potable water mixed with sewage, urine, albumen, and certain other matters, or brought into contact with animal charcoal, subsequently develops fungoid growth, and other organisms, when small quantities of sugar are dissolved in them and they are exposed to a summer temperature. 2. The germs of these organisms are present in the atmosphere, and every water contains them after momentary contact with the air. 3. The development of these germs cannot take place without the presence of phosphoric acid, or a phosphate or phosphorus in some form of combination. Water, however much contaminated, if free from phosphorus, does not produce them. A German philosopher has said "ohne Phosphor kein Gedanke." The above experiments warrant the alteration of this dictum to "ohne Phosphor gar kein Leben."

Anthropological Society January 31.—Dr. Charnock, President, in the chair. A paper was read by Mr. Joseph Kaines, on some of the Racial Aspects of Music. The author, in a very brief glance at the characters of the music of the various races of men on the globe, drew particular attention to a striking anthropological fact—namely, that the music of the people of the north-east of Europe, unlike that of all the rest, was pervaded by a settled melancholy. He sought to account for this phenomenon physically and psychically. He drew attention to the climatal and general physical conditions under which the peoples of the north-east of Europe live, and suggested that, in the constant war with Nature, and the endeavour to modify Nature's laws, they acquired a gravity, awe, and sadness, of which the peoples of the sunny south knew nothing, as their music showed, Nature having used them more kindly. The author contrasted the biographies (as well as the music) of the German and Italian composers, and showed that the men differed as widely; sadness and sorrow marking the one, brightness and gladness characterising the other. He commented upon the introspectiveness of the northern peoples, and the rapt attention and morbid analysis they give to the great problems of Life, Death, God, and Immortality; and stated that the contemplation of these and such sublime mysteries saddened and brightened by turns all their thoughts and impressions. It was curious to note that even the dance tunes and popular airs of the Germans, Norwegians, and Swiss, as has been remarked by Mr. H. F.