and in neither case themselves entitled to be called protovertebrates, or else that the protovertebrates referred to were ichthyopsida, that is to say, more simply, allied to the amphibia. I do not object to that latter supposition. I suggested it myself in 1884 (*Journal of Anatomy and Physiology*, xviii. p. 356), as perhaps Prof. Parker is aware. But if birds are developed from amphibians or pre-amphibians, and if Prof. Huxley is right, as I believe he is, in supposing that the connection of mammals with amphibians is neither through reptiles nor birds, we come to this: that amphibians or pre-amphibians have furnished the common stem whence reptiles, birds, and mammals have diverged. In that case there is an end of that group, "Sauropsida," which the birds are alleged by Prof. Parker to "culminate."

But, further, amphibians are certainly more closely allied to reptiles than to either birds or mammals. Cuvier's system may therefore be justly reverted to, and the Amphibia or Batrachia be considered as the lowest division of the Reptilia, which I do not for one moment doubt is the true classification.

University, Glasgow, February 8 JOHN CLELAND

The West Indian Seal (*Monachus tropicalis*)

IT will probably be of interest to the zoological portion of your readers to learn of the re-discovery—or the full discovery—of the West Indian seal (*Monachus tropicalis*). The history of this pinniped is in brief as follows.

It was first noticed by Columbus in his account of his second voyage (1494) as having been found in some numbers on the rocky isle of Alta Vela, off the southern shore of Hispaniola, where his sailors killed eight of them for food. Later—in 1675—Dampier found this seal in abundance on the Alacram reefs, about 80 miles north of Yucatan. At that time it was killed there in great numbers for its oil.

The seal then remained unnoticed for over a century and a half, having no place whatever in the writings of zoologists until 1843. Then Mr. Richard Hill published an account of it in the "Jamaica Almanac," calling it the Pedro seal, from the Pedro Keys, some 60 miles south of Kingston, Jamaica, where he had found it. A few years later Mr. P. H. Gosse obtained an imperfect skin (without skull) which he sent to the British Museum, where it was described by Dr. Gray in the Proceedings of the Zoological Society of London, 1849. Dr. Gray gave it then no name, probably by reason of its imperfect characters. Later—in 1850—(Catalogue of Mammals in the British Museum) he described this same specimen as *Phoca tropicalis*, and afterwards (Catalogue of Seals and Whales, 1866) as *Monachus tropicalis*. But so imperfect was the specimen on which the description was founded, and the animal itself was so little known, that even its generic relations were in doubt, and its reference to the genus Monachus was considered provisional. From thence on to the present, rumours of the existence of this seal have been not unfrequent, but nothing seemed trustworthy and positive, and no specimens were obtained, if we except a young skin, without bones or skull, which came from Cuba to the National Museum at Washington, in 1884, without any indication as to locality.

It has long seemed to the writer—as, doubtless, to many others—that the certain presence in our waters of so important a mammal lying *perdu* in regions which our naturalist collectors are yearly visiting, was the opprobrium of American zoologists. We made inquiries, and collected notes from many sources, which showed clearly that this seal existed at isolated points—on small islands and keys—not only in the Caribbean and among the Bahamas, but also in the Gulf of Mexico. Last summer, while on a visit to the western shore of the Gulf of Mexico, we were so fortunate as to *locate* this seal with much certainty. This was upon the Triangles (Los Triangulos), three little keys, hardly above the water-level at high tide, and lying some 100 miles north-west off the Campeachy coast, in latitude N. 20° 50′, and longitude W. 92° 10′. Following this clue, my son, Mr. Henry L. Ward, last December visited the Triangles in company and partnership with Señor F. Ferrari Perez, naturalist of the Mexican Geographical and Exploring Expedition. His hunt was highly successful, and he has during the present month returned with nearly twenty specimens—skeletons and skins of all ages, from a suckling to the fully adult male, 7 feet in length. This ample material has just been carefully studied by Prof. J. A. Allen, the well-known zoologist, and author of the "Monograph of North American Pinnipeds." Prof. Allen has given a preliminary notice of the specimens in *Science*, January 14, 1887, and promises an elaborate account, with plates, in an early issue of the Bulletin of the American Museum of Natural History, New York.

It is a fact of rather peculiar interest that this, the first large mammal ever discovered in America, should, by the strange mishaps of natural history collecting, be the very last one to become known satisfactorily to science. HENRY A. WARD

Rochester, N.Y., January 30

An Abnormal *Hirudo medicinalis*

WHILST dissecting the leech in the class of practical zoology, one of my students directed my attention to an apparent abnormality in the specimen which it fell to his lot to dissect. On careful examination it was found that the vesicula seminalis of the right side had moved forwards into the fifth somite, and there opened into the base of a second and fully-developed penis, which opened to the exterior on the second annulus of the fifth somite. From the vas deferens, however, there passed off to the normal penis a duct which had on it a swelling corresponding in position to the vesicula seminalis, which had been moved forwards. The various parts on the left side, as well as the female organs, were quite normal.

R. J. HARVEY GIBSON

Biological Laboratory, University College, Liverpool,
February 14

Instinctive Action

SOME years ago I was about to drown a terrier pup of about a month old. I held it across the palm of my open hand over a large tub of water. It lay quite still on my hand as I gently lowered it. When within 4 inches of the surface, but not yet touching the water, it deliberately began, and continued as long as I held it there, the paddling motion with its feet peculiar to dogs when swimming, and quite unlike that of walking, although I am perfectly certain this puppy had never seen or touched water before. We know almost all animals swim when first placed in water, but how could this puppy know before it touched the water that this peculiar action would be necessary? Has a similar case been observed by any of your readers?

Birmingham, February 17 D. W. C.

THE RELATIONS BETWEEN GEOLOGY AND THE MINERALOGICAL SCIENCES[1]

I.

THE realm of Nature has been recognised from time immemorial as consisting of three kingdoms: dealing with the affairs of these three kingdoms, respectively, there have grown up side by side three departments of natural knowledge—zoology, botany, and mineralogy. But in recent years new and, I cannot help thinking, regrettable relations have sprung up between these sister sciences. Zoology and botany, having developed a method, a classification, and a nomenclature, based on common principles, have been drawn together by bonds so close and firm that many regard them as indissolubly one—the science of biology. Mineralogy, thus isolated, has been driven to seek new and unnatural alliances—with chemistry, with physics, or with the mathematical sciences. For my own part I confess that I regard this threatened "Repeal of the Union" of the natural sciences as alike a misfortune and a mistake.

It is sometimes assumed that the objects dealt with by zoology and botany are so different in their essential characters from those treated of by mineralogy, that the science of "organic" Nature must always follow a different path from that pursued by the science of "inorganic" Nature. The structures commonly known as *organic*, and the processes usually called *vital*, are asserted to be so entirely different, alike in their origin and in their essence,

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[1] Address to the Geological Society at the Anniversary Meeting on February 18, by the President, Prof. John W. Judd, F.R.S.

from anything existing in the mineral kingdom, as to warrant the establishment and perpetuation of a fundamental distinction between the sciences dealing with "living" and "non-living" matter respectively.

In the year 1854 a very acute thinker, who at one time occupied this chair, made a serious attempt to formulate the distinctions which are supposed to divide living from non-living matter; but at a subsequent date, admitting with characteristic candour that he had altogether outgrown these ideas, Prof. Huxley argued, with great skill and cogency, that "vitality" is merely a general term for a set of purely physical processes, differing only in their complexity from those to which "inorganic" matter is subject.

It is a circumstance of no small significance that no definition of *life* which has yet been proposed will exclude the kind of processes which we can now show to be continually going on in mineral bodies. "Life," said the late George Henry Lewes, "is a series of definite and successive changes, both of structure and composition, which take place in an individual without changing its identity." Mr. Herbert Spencer prefers to define life as "the definite combination of heterogeneous changes, both simultaneous and successive, in correspondence with external co-existences and sequences."

If either or both of these definitions of life be accepted as satisfactory, then, as I hope to demonstrate to you, the minerals which build up the crust of our globe unquestionably live. At all events I am confident of being able to show that "in correspondence with external co-existences and sequences," or, in other words, as the conditions to which they are subjected vary, they undergo "a series of definite and successive changes, both in structure and composition, without losing their identity."

It may seem paradoxical, but it is nevertheless true, that the "vitality" of minerals—I really do not know what other term to use to convey my meaning—is much greater than that of plants, and, *a fortiori*, than that of animals; and this is the direct and necessary consequence of their less complex and more stable chemical constitution.

The zoologist regards as a case of remarkable vitality the recovery of snails which had been long affixed to a museum-tablet, upon their immersion in warm water. The botanist cites the germination of seeds taken from ancient Egyptian tombs as a striking illustration of how long life may remain dormant in the vegetable world. Let us now turn to the mineral kingdom. A quartz-crystal develops to certain dimensions, in accordance with the natural laws of its being, and when the necessary conditions of growth cease to environ it, its increase is arrested. But the crystal still retains its "vitality," that is, the power of further development which is dependent on its particular "organisation" or molecular structure. We may destroy that "organisation" and the "vitality" which is dependent upon it in a single instant, by subjecting the crystal to the action of hydrofluoric acid or of an oxyhydrogen flame. But unless its "organisation" and "vitality" be thus brutally stamped out, the crystal and, indeed, every fragment of it retains, not the "promise" only, but the very "potency of life." It may be worn by wind and wave into a rounded and polished sand-grain; it may be washed from the beds of one formation, to form part of the materials of a new one, and this process may be repeated again and again; but after countless wanderings and unnumbered "accidents by flood and field," extending over millions on millions of years, let but the necessary conditions of growth again environ it, and the battered and worn fragment will re-develop, in all their exquisite symmetry, its polished facets, it will assume once more the form of a quartz-crystal, having at least as much claim to *identity* with the original one, as a man has with the baby from which he has grown.

"Life!" "Vitality!" These terms are but convenient cloaks of our ignorance of the somewhat complicated series of purely physical processes going on within plants and animals. "Organisation!" Why should the term be applied to the molecular structure of an *Amœba* or a yeast-cell, and refused to that of a crystal? But even if we choose to insist on such distinctions as these, must we also make them a basis on which to establish our classification of the sciences?

Unquestionably there are differences between the cycles of change which take place in animals, plants, and minerals respectively. As the animal differs from the plant in not being able to build up its tissues from the simple compounds of the mineral kingdom, so both animals and plants differ from minerals in their power of growth by intussusception.

But perhaps the most striking difference of all between the "vital" processes in animals, plants, and minerals, is found in the *rate* at which they take place. Animals, in consequence of the instability of their chemical constitution, are distinguished by an almost ceaseless activity and a consequent brevity of existence. Plants, in the slower rate at which their vital processes take place, bridge over to some extent the tremendous gap between animals and minerals. In these last the vital processes are so prolonged in their manifestations, owing to the stability of their chemical composition, and they are not unfrequently interrupted by such enormous intervals of time, that they are only recognised by the geologist.

The cycles of change which take place in an ephemera are rapid indeed as compared with those going on in the oak-tree, among the branches of which it lives; but in the rocks among which the oak thrusts its rootlets, other processes are going on compared with which the life of the oak-tree is as "fast" as that of the ephemera compared with its own.

Nevertheless the three forms of life seem to start pretty much on a level. A solution of nitre in which crystallites are uniting, in obedience to the laws of polarity, to build up crystals, with their regular forms, their molecular structure, and their powers of further development; a solution of sugar, in which the cell of a yeast-plant is living and growing; and a third liquid with floating vegetable particles, in which an *Amœba* is increasing and multiplying;—these three may surely be compared with one another, however unlike may appear to be the higher developments in the three kingdoms to which they respectively belong.

I do not, of course, for one moment wish to suggest that it is practicable, or even desirable, to attempt an extension of the conventional use of the terms "life" and "organisation." But I do think that it is of the first importance that we should clearly recognise the fact that the distinctions between living and non-living matter are not essential and fundamental ones, that cycles of change exactly similar in almost every respect to those occurring in the animal and vegetable kingdoms are equally characteristic of the mineral kingdom; though, in the latter, they are more difficult to follow on account of the extreme slowness with which they take place.

When this great truth is fully recognised, the separation of the biological and the mineralogical sciences will be at an end, and mineralogy will begin to profit by that revolution in thought and in method which has already done so much for her sister sciences.

The temporary divorce between biology and mineralogy has arisen, not from any inherent differences between their aims, their methods, or the objects of which they treat, but from the circumstance that, while the former has in the last half century advanced with the stride of a giant, the latter has during the same period tottered on with the feeble steps of infancy. Mineralogy is still in the "pupa-stage" of its development; it is a classificatory science, with its methods imperfect, its taxonomy undeveloped, and its very notation undefined. Its cultivators, absorbed in the Sisyphean task of establishing new species and varieties, too often treat their science, with all its glorious possibilities, as though it were but akin to postage-stamp lore!

How is it, we may profitably ask, that the biological sciences have made such prodigious advances, while the mineralogical ones have lagged so far behind? We must ascribe the result, I believe, to two causes:—

In the first place, improvements in the construction of the microscope, and more especially the perfecting of methods of study by means of thin sections, have immeasurably enlarged the biologist's field of observation; histology and the cell-theory, embryology with all its suggestiveness, and many important branches of physiological research, must have languished, if, indeed, they could ever have seen the light, but for aid afforded by the microscopical methods of inquiry.

In the second place, the growth of geological and palæontological knowledge has been the leading factor in that profound revolution in biological ideas which, sweeping before it the superstition of fixity of species, has endowed this branch of natural science with the transforming conception of evolution.

Now these two causes, which have done so much for biology, are already working out the regeneration of mineralogy; and I doubt not that the fruits brought forth by the latter science will be equally satisfactory with those of the former.

The application of the microscope to the study of minerals has proved less easy than in the case of animal and vegetable structures. More than a century ago, it is true, several French geologists employed the method of crushing a rock, and of picking out from its powder the several minerals of which it was composed, for microscopic study; and in 1816, Cordier endeavoured, by systematising the methods followed by his predecessors, Daubenton, Dolomieu, Fleurian, and others, to elaborate a scheme for the mineralogical analysis of rocks by the aid of the microscope. In recent years the French geologists, with MM. Fouqué and Michel Lévy at their head, have shown how, by the employment of the electro-magnet, of fluids of high density, and of various chemical reagents, this work of isolating the several minerals of a rock for microscopic study or chemical analysis may be greatly facilitated.

But the great drawback to this method of microscopic study of rocks, as devised in France, was found in the circumstance that it began by destroying the rock as a whole, and hopelessly obliterating the relations of its mineralogical constituents. Delesse and other observers, it is true, succeeded in obviating this difficulty, to some extent, by studying the structure of rocks as seen in polished surfaces under the microscope by reflected light.

The greatest step in advance in connection with the microscopic study of rocks was undoubtedly made, however, when it was shown that transparent sections of minerals, rocks, and fossils can be prepared, comparable to those so constantly employed by biologists in their researches. William Nicol, of Edinburgh, was the first to discover, in the year 1827, how the mechanical difficulties in the way of the preparation of such sections could best be surmounted; while Mr. Sorby, in a memorable communication to this Society, in 1858, showed us the first-fruits of the wonderful harvest of results to be obtained by the employment of this method.

But if the birthplace of the one method of microscopic study of rocks was France, and of the other Britain, it must be confessed that a large part of the merit of developing and improving these methods of inquiry is due to the Germans. To the labours of the numerous, patient, and accurate students in that country must be ascribed much of the perfection to which the methods of microscopic mineralogy have now attained; though we must not forget in this connection many most valuable contributions to the study from Scandinavia, Holland, Italy, and the United States.

As in the case of biology the results attained by the geologist have been the means of awakening new interests and inspiring a new philosophy, so in the case of mineralogy other problems have been suggested, and entirely fresh conceptions of the scope of the science have followed from the development of geological thought. We are thus led to regard minerals, not simply as a set of curious illustrations of mathematical and chemical laws, but as important factors in the evolution of the globe. Mineral collections in the past have resembled greenhouses, wherein only beautiful, though often abnormal growths are admitted; but in the future they will be like the herbaria of the botanist, where mere beauties of form and colouring are subordinated to the illustration of natural relationships and to the elucidation of the great problems of origin and development. Far be it from me to undervalue those wonderful crystals, the choice flowers of the mineral kingdom, which adorn our museums; but as there are many plants of extreme scientific interest which happen to possess only inconspicuous flowers, so there are not a few microscopic minerals, the study of which may lead us to the recognition of some of the most important laws of the mineral world.

I believe that what geology has already done for biology she is now accomplishing for mineralogy; it may, indeed, be instructive to point out how, in every one of its departments, the employment of microscopic methods and the suggestion of new lines of thought is causing mineralogy to develop in just the same directions as biology has already taken before her. In this way we may perhaps best convince ourselves that mineralogy is once more asserting her position in the family of the natural sciences.

Every natural-history science presents us with four distinct classes of problems. With respect to the objects of our study, we may make inquiries concerning their forms, their actions, their relations, and their origin. The answers to the first class of questions constitute *Morphology*, to the second *Physiology*, to the third *Chorology* or *Distribution*, and to the fourth *Ætiology*. The great problems of the mineral world, as I shall proceed to show, fall under precisely the same categories; and we may perhaps gather some useful hints by a comparison between the immature results of the mineralogist in each of these departments and those more perfect ones which have been attained by the botanist and zoologist.

The morphology of minerals was for a long time studied to the exclusion of all other branches of the science; for the problems connected with form and structure were those which naturally first attracted the students of the "inorganic" world.

Few generalisations of science are so beautiful, and at at the same time so suggestive, as those which have been arrived at by a discussion of the accurate measurements of crystal-angles. The constancy, within certain narrow limits, of corresponding angles, amid the almost infinite diversity of form assumed by crystals of the same mineral, is not less striking than the simplicity of the mathematical laws by which all these varied forms can be shown to be related to one another.

But the study of the morphology of minerals, which cannot be carried beyond a certain point by the aid of the goniometer, is capable of being pushed infinitely farther when we investigate the internal structure of their crystals, as illustrated by their optical and other physical properties. Not only do we find the minutest details of their external form to be correlated with peculiarities of molecular structure, as revealed by their action on a beam of polarised light, but delicate differences in internal organisation which the goniometer is powerless to detect, become clearly manifested under the searching tests of optical analysis. For the mineralogist, indeed, the polariscope with its accessories has supplemented the goniometer, in the same way as the spectroscope has the balance of the chemist.

What has been stated concerning the optical characters of minerals is equally true of their other physical properties; for the researches of recent years have shown all these properties to be intimately related to the symmetry of the crystal in which they are displayed. In every crystal, the faces of each group bearing the same relations to its axes exhibit characteristic peculiarities in their lustre, in their hardness, and in the manner in which they are acted upon by solvents; and these serve to distinguish such groups of faces from others in the same crystal having different relations to its axes. The elasticity of crystals, their power of conducting heat and electricity, and their phosphorescent, electric, or magnetic properties, whether natural or induced, are all manifested in varying degrees along certain directions which can be shown to be related to the particular symmetry of the crystal. And the more carefully we study both the forms and the physical properties of minerals, the more are we impressed by the conviction that the most intimate relations exist between these characters and the chemical composition of the minerals.

The phenomenon of "plesiomorphism," as Miller proposed to call it, that is, the slight variation in the angular measurements of crystals in the same species or group, when any of the constituents are replaced by vicarious or isomorphous representatives, very strikingly illustrates this conclusion. And the exact study of the optical properties of minerals shows that the slightest variation in the relative proportions of these vicarious constituents makes its influence felt by changes in their colour, in their pleochroism, in the nature and amount of their double refraction, in the position of their optic axes, and, indeed, in the whole assemblage of the properties of the crystal.

To the admirable investigations of Tschermak on the feldspars, the amphiboles and pyroxenes, the micas, and other groups of minerals, we are largely indebted for the establishment of this conclusion; while Doelter, Max Schuster, and other mineralogists, have contributed many striking observations which serve to extend and fortify it.

The application of the microscope to the study of the internal structure of minerals—their histology—has led to the recognition of many beautiful and unsuspected phenomena. Examined in this way, the seemingly homogeneous masses exhibit many interesting intergrowths and inclosures; and the study of these, as shown by Sorby, Vogelsang, Renard, and Noel Hartley, may serve to throw new and important light upon the conditions under which the crystals were originally developed. Cavities containing carbonic acid and other liquids, with bubbles in constant and, seemingly, spontaneous movement, serve to awaken the interest of the naturalist not less powerfully than the mysterious creeping of protoplasm in the hair of a nettle, or the dance of blood-corpuscles in the foot of a frog!

Others among these histological peculiarities of crystals must be regarded as having a pathological significance; they are abnormal developments resulting from unfavourable conditions to which the crystals may have been subjected during their growth, or in the course of their long and chequered existence.

The variability exhibited in crystals of the same mineral is sometimes very startling. In addition to the varieties due to the combinations of many different forms, or to the excessive development of certain phases at the expense of others, we have the complicated and diversified structures built up by twinning according to different laws. Again, by oscillatory tendencies in the same crystal towards the assumption of different forms, or by the existence of causes calculated to interfere with the free action of the crystallising forces, we may obtain varieties with curiously curved or striated faces. Not unfrequently large quantities of extraneous materials, solid, liquid, or gaseous, may be caught up in the crystal during its growth, and these foreign substances may be so far affected by the polar forces operating around them as to be made to assume definite and symmetrical positions within the crystal.

Even in the case of minerals of identical chemical composition and similar crystalline form, marked variations in physical properties may result from differences in the conditions under which they have originated. In lustre, density, and other characters, adularia differs from sanidine, and elæolite from nepheline. Dr. Arthur Becker has shown that quartz exhibits marked variations in its specific gravity, according to the particular conditions under which it has been formed.

There is one kind of morphological variability in minerals which has during recent years attracted a great amount of attention, and excited much discussion among mineralogists. Soon after his memorable discovery of the relations between the crystalline forms of minerals and their optical properties, Brewster detected certain apparent exceptions to his important generalisation; and since his day many additions to these curious anomalies in the optical behaviour of minerals have been made by other observers. So greatly, indeed, have these been multiplied in recent years, that it is doubtful whether any mineral crystallising in the cubic, the tetragonal, or the hexagonal system could be cited in which the optical properties are precisely what they ought to be according to theory; and similar anomalies are also found in crystals possessing lower degrees of symmetry.

The attempts which have been made by some crystallographers to account for these optical anomalies in crystals, by assuming that they possess only a pseudo-symmetry, the result of very complicated twinning, ingenious as they undoubtedly are, remind one of the wonderful addition of eccentrics and epicycles by which astronomers so long sought to maintain the credit of the Ptolemaic theory. But as, in the latter case, complexities and difficulties alike vanished when the centre of the system was shifted from the earth to the sun, so have the discoveries of Klein, Rosenbusch, and others removed the necessity for the painfully elaborate crystallographic hypotheses to which we have referred.

Most mineralogists will now be prepared to admit, as the result of these researches, that the perfection alike of form and of optical properties which characterises a crystal when first formed, is liable to slight modification, as the conditions of temperature and pressure under which it exists vary. In consequence of this, almost all natural crystals are found, when we study them with sufficient care, to exhibit slight but very striking and significant differences in form and optical behaviour from what they ought theoretically to possess.

While our knowledge of the ordinary mineral varieties promises to be vastly extended by the improvements which have been made in the methods of optical and chemical diagnosis under the microscope, there is, at the same time, reason to hope that the relationship of these numerous varieties will, by the same means, be made more clearly apparent. As the existence of well-defined natural groups of minerals becomes more clearly established, through the study of interesting though inconspicuous links, we shall obtain a basis for a much-needed reform in mineral taxonomy and nomenclature.

The more carefully we pursue our researches among the diversified forms of the mineral world, the more are we impressed by the conviction that each mineral, like each plant or animal, possesses its own individuality. Nature does not make *facsimiles* in the mineral, any more than in the vegetable or the animal kingdoms. All the sciences of Nature must be content to recognise individuals as the only real entities, and to accept species, like genera, families, and orders, as convenient but purely artificial conceptions.

The geological study of minerals leads us to regard each specimen that we examine as possessing a distinguishing combination of properties, some of which are impressed upon it by causes operating when it came into being, while others are no less clearly the result of the long series of vicissitudes through which it has since passed.

Of all the branches of mineral morphology there is none from the study of which the geologist has gained more in the past, or from which he has greater reason to look for future aid, than that of the embryology of crystals.

In the year 1840 Link showed that the first step in the formation of crystals in a solution consists in the separation of minute spherules of supersaturated liquid in the mass; and subsequently Harting in Holland, and Rainey and Ord in this country, obtained a number of interesting experimental results, by allowing crystallisation to take place slowly in mixtures of crystalloids and colloids.

Valuable contributions to the same subject were made by Frankenheim, Leydolt, and others; but it is to Hermann Vogelsang that we owe the greatest and most important contributions to mineral-embryology. By the ingenious device of adding viscous substances to solutions in which crystallisation was going on, he succeeded in so far retarding the rate at which the operation took place as to be able to study its several stages. He thus showed how the minute "globulites," gathering themselves into nebulous masses or ranging themselves according to mathematical laws, gradually build up skeleton-crystals, by the clothing of which the perfect structures arise.

Since the early and regretted death of Vogelsang, the subject of the development of crystals from their embryos, the so-called *crystallites*, has been successfully prosecuted by Behrens, Otto Lehmann, Wichman, and other investigators.

Now in all glasses—whether of natural or artificial origin—in which the process of primary devitrification is going on, we have examples of the growth of crystals in a viscous and retarding mass, and in these, as Leydolt, Zirkel, and Vogelsang clearly saw, admirable opportunities are afforded to us for studying the formation of crystallites, and the laws which govern the union and growth of these into crystals. Two years ago, my predecessor in this chair submitted to you the interesting results of his own researches upon the devitrification of artificial glasses and slags; and the subject has since been pursued by Velain in France, and by Hermann and Rutley in this country.

The igneous rocks supply us with admirable opportunities for studying mineral embryology. In the same rock-mass we may sometimes find every possible graduation, from an almost perfect glass to a holocrystalline aggregate. By the study with the microscope of the several transitions in different parts of the mass, we obtain data for the most important conclusions concerning the phenomena of crystal-development.

There is another line of research in connection with mineral-embryology, which appears to be full of promise, and which has not yet received all the attention it deserves. In the "contact-zones" around great igneous intrusions, we find the curious so-called "spotted slates," which under the microscope are seen to contain nebulous patches, the mere ghostly presentments of crystals, struggling into being in the amorphous mass. The development of these nebulous masses into perfect crystals, exhibiting the characteristic external forms and optical properties of andalusite and kyanite, of garnet and epidote, of hornblende and mica, may be traced in some cases with the greatest facility.

More complicated still are the phenomena exhibited along the foliation-planes of the rocks, which have been made to flow in the act of mountain-making. There, as the old minerals are destroyed, new ones build themselves up from their elements. The study of all the steps of this process is an undoubtedly difficult one, but the results already obtained by Reusch, Lossen, Heim, and Lehmann, by Lapworth, Teall, Roland Irving, and Williams, lead us to look hopefully forward to the full solution of the grand but complicated problems of regional metamorphism.

The field of mineral-embryology is indeed a promising one, and its diligent cultivators may hope to gather a harvest no less rich than that which has been reaped by the workers in the same department of the biological sciences.

(*To be continued.*)

TABASHEER

I HAVE often wondered that this curious substance has never attracted more attention. But scanty references to it are to be found in books, and yet it seems to me that few more singular things are to be met with in the vegetable kingdom.

In Watts's "Dictionary of Chemistry" (vol. v. p. 653), exactly six lines are devoted to it. It is defined to be: "Hydrated silica, occurring in stony concretions in the joints of the bamboo. It resembles hydrophane, and when thrown upon water does not sink till completely saturated therewith." It is further stated to be the least refractive of all known solids, and an analysis by Rost von Tonningen of a specimen from Java gives a composition of 86·39 per cent. silica soluble in potash, 4·81 potash, 7·63 water, with traces of ferric oxide (to which I suppose its occasional yellowish colour to be due), lime, and organic matter.

There are several specimens in the Kew Museums, partly derived from the India Museum. All consist of small irregular angular fragments, varying from the size of a pea downwards, and opaque white in colour. It is obvious that these fragments are the debris of large masses.

Now, the presence of considerable solid masses of so inert a substance as hydrated silica in the plant-body is a striking fact. At first sight, one might compare it do the masses of calcium phosphate which form the endo-skeleton in the higher animals. These, however, serve an obvious mechanical purpose, which cannot be attributed to the lumps of tabasheer in the hollow joints of a bamboo. The presence of silica may sometimes serve an adaptive purpose, as in the beautiful enamelled surface of canes. And according to Dr. Vines ("Physiology of Plants," p. 21), "Struve found that it constitutes 99 per cent. of the dry epidermis of *Calamus Rotang*."[1]

In a few other groups of plants, such as *Equisetum* and the *Diatomaceæ*, it is a characteristic constituent. In all cases it principally occurs in the cell-wall (Vines, *l.c.* p. 137. This has suggested the highly ingenious speculation that, seeing the intimate chemical relationship which obtains between silicon and carbon, there might be a silicon-cellulose. I notice that Count Castracane, in his Report on the *Diatomaceæ* collected by the *Challenger*, speaks of its "having been already shown that silica is sometimes substituted for carbon in the formation of cellulose" (p. 7). Judging from ash-analyses it might be supposed that silica was an essential constituent of gramineous plants. But by the method of water-culture Sachs has found that maize, for example, will grow with only a trace of silica. I must confess to ignorance of all that may have been done in the matter recently. But Ladenburg thought, and I think with reason, that the indifference of the plant to silica was a

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[1] Sachs remarks ("Text-book," second edition, p. 700) that silica accumulates chiefly in the tissues exposed to evaporation, though this clearly does not apply to the case of diatoms.