THURSDAY, JANUARY 17, 1889.

THE HISTORY OF MATHEMATICS.

A Short Account of the History of Mathematics. By W. W. Rouse Ball. (London and New York: Macmillan and Co., 1888.)

THE quaint words addressed "to the great variety of readers" by the editors of the folio Shakespeare of 1623 are equally applicable to the useful compendium of mathematical history which is the subject of our review. "It is now public; and you will stand for your privileges, we know—to read and censure. Do so, but buy it first: that doth best commend a book, the stationer says. Then how odd soever your brains be or your wisdoms, make your licence the same, spare not." But, as goods are usually "bought by judgment of the eye, not uttered by base sale of chapmen's tongues," we produce our samples in the open market by making a few extracts from Mr. Ball's book.

In the opening chapter, on Egyptian and Phœnician mathematics, we become acquainted with an old Egyptian, "a priest named Ahmes," who, "somewhere between the years 1700 B.C. and 1100 B.C.," wrote, on imperishable papyrus, a book entitled "Directions for Knowing all Dark Things," which "is believed to be itself a copy with emendations, of an older treatise of about the time 3400 B.C." Remembering that this work was written certainly five hundred, and probably more than a thousand, years before the time of Thales, the first of the Greek mathematicians, and founder of the Ionian school, it must be regarded as a most remarkable production; for Profs. Cantor and Eisenlohr have shown that Ahmes had some notion of trigonometry. In his problems on pyramids, "Ahmes desires to find the ratio of certain lines, which is equivalent to determining the trigonometrical ratios of certain angles. The data and the results given agree closely with the measurements of some of the existing pyramids." But perhaps the most interesting feature of this ancient treatise is the algebraic notation employed in it, which our author describes in these words:—"The unknown quantity is always represented by the symbol which means a heap; addition is represented by a pair of legs walking forwards; subtraction by a pair of legs walking backwards, or by a flight of arrows; and equality by the sign /∠." Our own + and − first appeared in Widman's "Mercantile Arithmetic" (published at Leipzig in 1489): with him (see p. 186, Ch. XII.) they "are only abbreviations, and not symbols of operation; he attached little or no importance to them, and would no doubt have been amazed if he had been told that their introduction was preparing the way for a complete revolution of the processes used in algebra." The philosophic conception of the nature of algebra (symbolized by the legs walking forwards and backwards; a notion closely related to, if not identical with, Sir W. R. Hamilton's definition of algebra as the science of pure time) perished with its author: the mere abbreviations (+ and −) lived and flourished—but then Widman was able to print *his* book.

The first date that can be assigned with absolute precision is that of Thales. "It is well known that he predicted a solar eclipse which took place at or about the time he foretold: the actual date was May 28, 585 B.C." It marks the real commencement of the history of mathematics; for the science, now revived in Greece, was at this time neglected and completely forgotten by the Egyptians. When we read that Thales, to the utter amazement of the King and all who were present, showed them how to find the height of a pyramid, by a simple application of the theorem that *the sides of equiangular triangles are proportionals*, we may well wonder why Ahmes did not burst his mummy-case and appear in their midst with his book opened at the problems on pyramids.

From the time of Thales to that of Euclid, the knowledge of mathematical facts acquired in one generation was transmitted to the next, almost exclusively by means of oral tradition. That such was the case is mainly due to the Pythagorean secret Society. "Pythagoras himself did not allow the use of text-books, and the assumption of his school was, not only that all their knowledge was held in common, and secret from the outside world, but that the glory of any fresh discovery must be referred back to their founder: thus Hippasus (*circ.* 470 B.C.) is said to have been drowned for violating his oath by publicly boasting that he had added the dodecahedron to the number of regular solids enumerated by Pythagoras. Gradually, as the Society became more scattered, it was found convenient to alter this rule, and treatises containing the substance of their teaching and doctrines were written. The first book of the kind was composed by Philolaus (*circ.* 410 B.C.), and we are told that Plato contrived to buy a copy of it."

Now Anaximander, the immediate successor of Thales as head of the Ionian school, had the honour of teaching Pythagoras; while Eudoxus, Philolaus, and Plato, all of them received their mathematical training from Archytas of Tarentum, who was one of the most celebrated of the Pythagoreans; and "Menæchmus, who was a pupil of Plato and Eudoxus," was alive as late as 325 B.C., which brings us down to about the time of Euclid. Thus the chain of tradition connecting Thales with Euclid is complete. Its successive links can be traced in the second and third chapters of the work before us.

Among the contemporaries of Plato, Eudoxus of Cnidus deserves special notice. His biography is to be found in Diogenes Laertius, who speaks of him as an astronomer, geometer, physician, and statesman; mentions his great works on astronomy and geometry, and his minor treatises on other subjects; and refers to the fact that he *discovered curved lines.* Modern research has found out what the curves of Eudoxus were, though all his writings are lost: in our author's words, "he discussed some plane sections of the anchor ring," among them the curve which ought in future to be named after him, but is "generally called Bernouilli's lemniscate." Thus, Eudoxus (who died in 355 B.C.) anticipated James Bernouilli (d. 1705 A.D.) by more than 2000 years!

The foundation of Alexandria by Ptolemy marks an epoch in the history of mathematics. Alexander himself did little more than choose the site, and it was entirely due to Ptolemy that the city did not share the fate of at least two others of the same name whose foundation by Alexander is duly recorded by his biographer, Quintus Curtius. What Alexandria actually became, is thus briefly and graphically described :—

> "The earliest attempt to found a University, as we understand the word, was made at Alexandria. Richly endowed, supplied with lecture-rooms, libraries, museums, laboratories, gardens, and all the plant and machinery that ingenuity could suggest, it became at once the intellectual metropolis of the Greek race, and remained so for a thousand years. It was particularly fortunate in producing, within the first century of its existence, three of the greatest mathematicians of antiquity—Euclid, Archimedes, and Apollonius. They laid down the lines on which mathematics were subsequently studied, and, largely owing to their influence, the history of mathematics centres more or less round that of Alexandria, until the destruction of the city by the Arabs in 641 A.D."

It would occupy too much space to discuss, or even to enumerate, the writings of the Alexandrian mathematicians. The most precious relics they have left behind them are: the greater part of the numerous works of Euclid, many of the writings of Archimedes, the "Conics" of Apollonius, the "Almagest" of Ptolemy, the "Mathematical Collections" of Pappus, and the "Arithmetic," or, rather, the "Algebra," of Diophantus. These and other valuable pieces of work, which, like them, have reached us in a more or less mutilated condition, are reviewed in the fourth and fifth chapters of Mr. Ball's "History," in which the best editions of these classical authors are mentioned, and other sources of information concerning them are referred to. We owe the preservation of most of them to the Greek refugees at Constantinople, as will be seen from the following quotation :—

> "After the capture of Alexandria by the Mohammedans, the majority of the philosophers, who had previously been teaching there, migrated to Constantinople, which then became the centre of Greek learning in the East, and remained so for 900 years. But, though its history covers such an immense interval of time, it is utterly barren of any scientific interest; and its chief merit is that it preserved for us the works of the different Greek schools. The revelation of these works to the West in the fifteenth century was one of the most important sources of the stream of modern European thought, and the history of the school may be summed up by saying that it played the part of a conduit-pipe in conveying to us the results of an earlier and brighter age."

Before the fall of Constantinople in 1453, which is alluded to in the above extract, such mathematics as were known in Western Europe were derived from Arabian sources.

The history of Arab mathematics and their introduction into Europe forms the subject-matter of the ninth and tenth chapters of Mr. Ball's book. The first of these excellent chapters tells us, in the beginning, how the Arabs, by their intercourse with Constantinople and India, in the reign of Al Mamun, the successor of the renowned Caliph Haroun Al Raschid, acquired a knowledge of the principal Greek and Hindu authors; it then gives an account of the works of the three chief Hindu mathematicians, Arya-Bhatta, Brahmagupta, and Bhaskara; and finishes with an analysis of the great treatise of Alkarismi, the first Arab mathematician, and an enumeration of the works of the most prominent among his successors from Tabit-ibn-Korra down to Alhazen and Abd-el-gehl. The account of Bhaskara is very much fuller than that given by M. Maximilien Marie in his "Histoire des Sciences Mathématiques et Physiques" (twelve vols. 8vo, 1883–88), and in other parts of the chapter some very interesting facts are mentioned, which we do not find noticed by M. Marie. Among these we may instance the solution of the cubic by Tabit-ibn-Korra, about 650 years before the time of Tartaglia, and, what is even more remarkable, the enunciation by Alkhodjandi of the proposition that the sum of two cubes can never be a cube.

The next chapter begins with the introduction of mathematics into Europe by the Moorish conquerors of Spain in the eighth century; shows how the Christians gained from them some knowledge of Arab science in the twelfth century, and, before the end of the thirteenth, were in possession of "copies of Euclid, Archimedes, Apollonius, Ptolemy, and some of the Arab works on algebra"; and brings the history of European mathematics down to the middle of the fifteenth century. During this long interval there lived only two great mathematicians in all Christendom, both of whom belonged to the thirteenth century. One was the famous Roger Bacon; the other, Leonardo Fibonacci, of Pisa, was the earliest European writer on algebra that we are acquainted with. Their biographies, though concisely written, necessarily occupy a large portion of the chapter.

The three following chapters contain the history of mathematics from the invention of printing to the year 1637, when the "Géométrie" of Descartes made its appearance. In this brief space of time, barely three-quarters of a century, owing to the labours of Pacioli, Recorde, Stifel, Tartaglia, Cardan, Ferrari, Bombelli, Vieta, Harriot, Oughtred, Stevinus, and others, vast improvements in algebra had been effected; trigonometrical and logarithmic tables had been brought to a high state of perfection by Regiomontanus, Rheticus, Napier, and Briggs; Desargues had invented the modern projective geometry; while, in astronomy, Copernicus, Kepler, and Galileo had replaced the old Ptolemaic system by a still older one (propounded by the Pythagoreans), which was now, for the first time, established on a firm basis.

Our author, as he tells us in the preface, has "usually omitted all reference to practical astronomers, unless there is some mathematical interest in the theories they proposed," and, accordingly, the name of Tycho Brahe does not figure in the above list. It would be better, in our opinion, to treat Copernicus in the same manner, rather than to do him the injustice of speaking of "his conjecture that the earth and planets revolved round the sun." Granting that "he advocated it only on the ground that it gave a simple explanation of natural phenomena," we would ask what other, or what better, proof could he have of it? It should be borne in mind that Copernicus spent the best years of his life in testing his "conjecture" by observations, and that nothing short of a firm conviction of its truth could possibly have induced him to publish it in the face of the fierce opposition which he well knew it would provoke.

With this exception, the short sketches of the lives and writings of all the mathematicians we have named are well drawn, and convey a clear idea of the importance of their work, and of the amount contributed by each of them to the advancement of the science.

The remaining portion—about half—of the book is divided into six chapters (numbered XIV. to XIX. inclusive), in which the history of modern mathematics is briefly considered. These are so full of great discoveries and illustrious names that they must be read to be appreciated. We can only, in the limited space at our disposal, quote their titles and add some remarks.

Chapter XIV. "Features of Modern Mathematics." In this chapter, which is a sort of summary of the other five, we read that "five distinct stages in the history of this period can be discerned." Turning to the table of contents, we find the five stages thus described: (1) "invention of analytical geometry and the method of indivisibles," (2) "invention of the calculus," (3) "development of mechanics," (4) "application of mathematics to physics," (5) "recent development of pure mathematics." The mere remark that each of these might be made the title of a bulky volume, will show at once the enormous extent and importance of modern mathematics.

Chapter XV. "History of Mathematics from Descartes to Huygens." The principal names in this chapter are Descartes, Cavalieri, Pascal, Wallis, Fermat, Barrow, and Huygens. In many of their writings may be found the germs of those ideas which have since been developed in the infinitesimal calculus. Especially would we mention Cavalieri's *method of indivisibles*, of which our integral calculus is the modified descendant, and Barrow's method of drawing tangents to curves, substantially the same as that given at the beginning of any modern differential calculus. Full explanations of both methods may be found in the present chapter.

The history of modern mathematics dates from the publication of the "Géométrie" of Descartes, and we wish to call attention to a bibliographical point connected with it. M. Marie ("Histoire," &c., t. iv. p. 20) speaks of "quatre traités separés: 'Le Discours de la Méthode,' 'La Dioptrique,' 'Les Météores,' et 'La Géométrie,'" all of them published in 1637; Mr. Ball (p. 241) says that "Descartes's researches in geometry are given in the third section of the 'Discours.'" We cannot positively say which is correct, but our impression is that we have seen a copy of the separately-published "Géométrie." The point is of small importance, but it should be cleared up in subsequent editions.

Chapter XVI. "The Life and Works of Newton." There are two sections—one devoted to the life, the other to an analysis of the works, of our English Archimedes; his three capital discoveries—fluxions, the decomposition of light, and universal gravitation—will occur to most of our readers. Most of the well-known facts relating to Newton's private and public life are mentioned in this chapter, together with some others that have only recently come to light.

Chapter XVII. "Leibnitz and the Mathematicians of the First Half of the Eighteenth Century." The following sentence occurs in the opening paragraph:—

> "Modern analysis is, however, derived directly from the works of Leibnitz and the elder Bernouillis; and it is immaterial to us whether the fundamental ideas of it were obtained by them from Newton, or discovered independently."

It forms a fitting sequel to the tale told in the preceding chapter of the celebrated controversy between Newton and Leibnitz.

The present chapter is in three sections: (1) "Leibnitz and the Bernouillis," (2) "The Development of Analysis on the Continent," (3) "The English Mathematicians of the Eighteenth Century." The two greatest French names in the chapter are those of Clairaut and D'Alembert; the two greatest English ones, those of Taylor and Maclaurin. Matthew Stewart succeeded Maclaurin as Professor at Edinburgh, and was "almost the only other British writer of any marked eminence in pure mathematics during the eighteenth century." After recounting his chief works, our author proceeds to say:—

> "These prove him to have been a mathematician of great natural power, but, unfortunately, he followed the fashion set by Newton and Maclaurin, and confined himself to geometrical methods."

This sentence gives the history, in epitome, of the decline and fall of British mathematics in the last century.

Chapter XVIII. "Lagrange, Laplace, and their Contemporaries." There are four sections: (1) "The Development of Analysis and Mechanics," (2) "The Creation of Modern Geometry," (3) "The Development of Mathematical Physics," (4) "The Introduction of Analysis into England." The greatest foreign name in this chapter (we single it out from a number of others) is that of Euler; the greatest English one is possibly that of Thomas Simpson, who seems to be rather harshly treated by being allotted only three lines in a footnote, when others of less ability are noticed in the text.

In Section 4 we read: "The introduction of the notation of the differential calculus into England was due to three undergraduates at Cambridge—Babbage, Peacock, and Herschel—to whom a word or two may be devoted."

Doubtless the success of the movement was largely due to their efforts, but the initiative was taken by Woodhouse in 1803 (see J. W. L. Glaisher on the "Tripos," Proc. Lond. Math. Soc., vol. xviii. p. 18). The name of Woodhouse is surely as deserving of mention as the other three.

Chapter XIX. "Recent Times." The author begins with a long list of names well known in the mathematical world. This list, however, "is not and does not pretend to be exhaustive." He then classifies the writers he has enumerated "according to the subjects in connection with which they are best known, arranging the latter in the following order: elliptic and Abelian functions, theory of numbers, higher algebra, modern geometry, analytical geometry, analysis, astronomy, and physics."

The section on the theory of numbers is, in our opinion, the best. It contains biographies of Gauss and the late Prof. Smith (about four pages being allotted to each), and mentions the researches of Cauchy, Liouville, Eisenstein, Kummer, Kronecker, Hermite, Dedekind, and Tchebycheff.

We may now say with old Martial—

> "Ohe jam satis est, ohe libelle:
> Jam pervenimus usque ad umbilicos."

But we have yet to record the impression left by the perusal of the entire work. The most desirable thing in a book of reference is that the reader should be enabled to find his way readily to any part of it. In the one before us this want is met by an admirable index, and an equally complete table of contents, and by the liberal use of clarendon type in the body of the book. The printing is clear and generally correct, but we notice the following errata:—

P. x. line 8 from top, for "1885–1888" read "1883–1888."

P. 110, in the heading of Chapter VI., for "641–1543" read "641–1453."

P. 168, line 4 from bottom, for "Act iv. sc. 3" read "Act iv. sc. 2."

P. 358, line 8 from bottom, for "1728" read "1738."

All the salient points of mathematical history are given, and many of the results of recent antiquarian research; but it must not be imagined that the book is at all dry. On the contrary, the biographical sketches frequently contain amusing anecdotes, many of the theorems mentioned are very clearly explained, so as to bring them within the grasp of those who are only acquainted with elementary mathematics, and there is a very interesting account (in a footnote) of the early history of the Universities of Paris, Oxford, and Cambridge. For those who wish to study mathematical history in detail there is a long list of authorities at the beginning, and many references to other works are made in different parts of the book. We would suggest that in future editions reference should be made to "Les Fondateurs de l'Astronomie Moderne Copernic—Tycho Brahé, Képler, Galilée, Newton," by Joseph Bertrand (8vo, Paris, n.d.), and to the article "Viga Ganita" in the "Penny Cyclopædia" (which contains the opinions of Colebrooke, the translator of the "Lilavati," &c., on many points connected with Hindu mathematics).

Finally, we would suggest that the following motto should be printed on the title-page of the second edition:—

> "Habetis originis ac progressionis mathematicæ historiam brevem. Ex qua matheseos antiquitas, præstantia, ac dignitas apparet."

The quotation is taken from the concluding paragraph of the "Historica Narratio" prefixed to Andrew Tacquet's "Euclid" (2nd ed., by Whiston, 1710). It describes perfectly the contents of the present treatise.

Mr. Ball promises us a supplementary volume containing a list of mathematicians and their works, which is to be as complete as possible. It will be a most important contribution to mathematical bibliography, and we sincerely hope that the reception that this volume meets with will encourage him to write the supplement.

THE BUILDING OF THE BRITISH ISLES.

The Building of the British Isles: a Study in Geographical Evolution. By A. J. Jukes-Browne, B.A., F.G.S. (London: George Bell and Sons, 1888.)

IT is now thirty-three years since Godwin-Austen, in a paper which glows with the instinctive perception that is one of the marks of genius, suggested to geologists an application of their science which lifts it out of the region of technicalities, gives it a human interest, and attracts all those who care to follow the long chain of events of which the present state of things is the outcome. It was an attempt to go back to Mesozoic and Palæozoic days, and mark out the main outlines of the physical geography of Great Britain and the adjoining parts of Europe during those epochs. To enable its conclusions to be more easily grasped, the paper was accompanied by a map, almost bewildering in its complexity and somewhat hazy in its outlines, but full of the masterly generalization that marshals into one compact body a crowd of isolated facts, and of the intuition that foresees the complete meaning of imperfectly ascertained data.

Many a geologist has since been tempted to try his hand at similar tasks, but few have mustered courage, when it came to the point, to embody their conclusions in a map. And no wonder: everyone who has speculated in this direction knows how easy it is to clothe his conceptions in words, and soon finds out how hard verbal descriptions of physical geography are to follow. So he becomes keenly alive to the fact that, if he wishes to be listened to, he must make the road easy by presenting his restorations to the eye in the pictoral form of a map. But if he be haunted by any sense of accuracy, and any horror of vagueness and hasty reasoning, he finds himself beset on all sides, when he begins to plot out his map, with uncertainties and hesitations that give him pause. It may be easy to say that land lay on this side and sea on that, but when a coast-line is actually to be laid down, though it may be possible to fix the limits between which it must lie, these limits are often so wide apart that the feeling of uncertainty as to the actual position of the boundary becomes unbearable, and the prospect of making a map that shall be even approximately accurate grows hopeless. Worse still is it—and this not unfrequently happens—when there are not even bounding limits, and the coast-lines can be no better than such guess-work as rashness delights in and the logical temperament abhors.

But even those who realize most clearly the difficulties of the task of making maps which show the distribution of land and sea during past geological epochs, welcome with keen delight attempts, such as those in the book before us, which are made in the right spirit; and it would ill become me to carp at the author's restorations, even were they less satisfactory than is the case, for I believe that, in noticing a former work of his, I ventured to take him to task for not having appended maps to his verbal descriptions of the old physical geography of our islands.

Mr. Jukes-Browne has explained, in the introduction, the principles which have been his guide; and the words with which he concludes his opening remarks show how fully he is aware of the difficulties that attend the task he has undertaken, and how much uncertainty hangs over many of his results. Even where we cannot agree with him, we feel sure that he has never been hasty and has spared no pains to arrive at the most probable conclusions.

With commendable caution no attempts are made to depict on a map the physical geography of Archæan and Cambrian times; but preference is given to Prof. Hull's conjecture that the great mass of Cambrian land "lay to the north-west of Europe, and occupied a large part of what is now the North Atlantic Ocean." The words "large part" are vague, but a partiality for filling up the

Atlantic on slight provocation is, I fear, rife among us, and ought not to be encouraged.

The Ordovician and Silurian maps are probably as near approximations as the present state of our knowledge allows—maybe as we shall ever attain to. In the Lower Old Red Sandstone map, the Old Red of South Wales is represented as having been formed in a bay of the Devonian sea. This view does get over some difficulties. If we suppose it formed in a fresh-water lake, we must admit that the barrier separating the lake from the Devonian sea was narrow, and, as our author remarks, there is no independent evidence for the existence of such a barrier. The absence, as far as we know, of any marine fossils tells the other way, but the district is yet geologically almost a *terra incognita*, and we must wait before the question can be settled. In the same way it must be confessed that it is hard to see on what grounds the Glengariff Grits are classed as marine; but here again the "retort courteous" might be, "What reason have you for thinking them fresh-water deposits?" It is too large a question to go into here.

The Carboniferous map I turned to with the greatest curiosity, for it so happens that years ago I was rash enough to try my hand at a similar production. The thing has thrust itself upon me many times since, and each time I have seen something in it that dissatisfied me, and it has been touched up and tinkered till now I hardly recognize my own child; and till I know my own mind, it would be hardly fair, even supposing it possible, to attack another man for differing from me. Really, the two maps have more in common than appears at first sight; and on some points of fundamental importance—the land-locked character of the Carboniferous sea for instance—Mr. Jukes-Browne and I are in complete accord. I should not have ventured on this bit of personal reminiscence, if it had not been that it seemed to me that it may possibly be typical. Put a number of equally qualified men to construct one of these geographical restorations, and the result will probably be this: there will be some few points on which all must agree; but the data for settling details will be so vague, that no two maps will be alike in their minor points. Even if this be so, it by no means proves the work to be unprofitable; but it is as well to bear this in mind when comparing two independent restorations.

Space will not allow of detailed criticism of the series of maps with which the book is lavishly illustrated; but all readers will gratefully thank the author for the pains he has taken to render such effectual help to them in following his reasoning. Every chapter bears the mark of patient and conscientious work; and though in a book of this size no more than an abridged and concise statement of many of its facts can find a place, its suggestiveness will insensibly lead the real student to the original papers of which it is an epitome, and open for him a wide field of reading.

The chapter on the Pleistocene epoch is one on which the author has evidently spent much pains, but it seems to me the least satisfactory in the book. With much that he says I heartily agree. I cannot help feeling that some of our most eminent glacialists have ridden their theories rather hard. That the Scotch Till is a *moraine profonde* seems to me the only hypothesis yet put forward which gives anything like a satisfactory explanation of the origin of that deposit; but I am not prepared to admit a like origin for all the so-called Boulder-clays: most of those who have studied on the ground in detail the Boulder-clays of the plains of Lancashire and Cheshire have come to the conclusion that they are submarine, and that their boulders have been supplied by floating ice. Some of the objections which Mr. Jukes-Browne urges against the ground-moraine theory, however, do not seem to me serious. He cannot understand how it is that an ice-sheet could groove and polish the rocks and form a ground-moraine at the same time. There are many ways out of the difficulty. Ice-scratching is most conspicuous on high ground and steep slopes, where there is little or no Till. It is true that it is far from uncommon on lower and flatter ground, where it is covered and indeed preserved by a coating of Till. Here it may be the first work of the ice-sheet before much *débris* had been dragged down from the hill country; but we must also bear in mind the probable character of a ground-moraine: packed closely by the weight of the ice above and frozen hard, it would be very different from the imperfectly consolidated mass we see now: rather it would act as a solid whole, and, as it was dragged along, would be quite capable of effecting a large amount of abrasion. The alternative which is suggested involves the floating of the ice-sheets bodily over wide extents of sea; but, as far as we know, ice-sheets do not float as a whole when they push their way out to sea, they break up into icebergs. We may picture to ourselves the probable action of an ice-sheet somewhat after this fashion. While descending slopes even moderately steep, it would push before it and drag beneath it any loose *débris* that it found ready made to its hand or that it had itself torn off the surface. But here its motive power would be sufficient to carry with it all the loose matter; consequently here no Till would be formed, unless the sheet happened to encounter a gorge in its path. In such a case the stones and dirt would be driven into the hollow till they filled it up, and the ice would then ride over it. When the ice-sheet reached flatter ground, its dragging power would be seriously diminished: it would probably at first heap up the *débris* into a mound or ridge in front of it: this mound after a time it would override, and flatten and spread out its materials; by a continuance of the process a sheet of Till would be spread over the lowlands. Of course here too any valley that lay athwart the path of the ice would be filled up. Thus would be produced exactly the distribution of the Till which occurs: in the hill-country little or none except as filling in valleys; over the plains a broad sheet, and great thicknesses in the valleys of the low country. So that when our author states that Prof. James Geikie's views might be accepted "if the Boulder-clay was found to fill in lake-like hollows," he is describing very nearly an essential feature in the actual manner of its occurrence.

Having now discharged the functions of the critic, and pointed out what appear to me some weak points, I will only add that if I seem to have been scant of praise, it is because there was no need. The book recommends itself.

A. H. GREEN.

OUR BOOK SHELF.

The Civilization of Sweden in Heathen Times. By Oscar Montelius, Ph.D. Translated from the Second Swedish Edition, by the Rev. F. H. Woods, B.D. (London: Macmillan and Co., 1888.)

EVERYONE who knows anything of archæology is aware that a book on the subject by Dr. Montelius is sure to be worth reading. The work translated by Mr. Woods ranks among the best existing summaries of the antiquities of particular countries. The author begins with the Stone age, and passes on, through the Bronze period, to the various stages of the Iron era. For some reasons it might perhaps have been better if he had reversed the order, taking first a group of antiquities the date of which can be approximately fixed, and working his way back to more remote times. This plan has been adopted, with excellent results, by Mr. Anderson, in his study of Scottish antiquities, and by Dr. Lindenschmidt in the work he is writing on the antiquities of Germany. The method chosen by Dr. Montelius is, however, favourable to clear, popular exposition, and he has made excellent use of the opportunities it has provided for him in this direction. He has a dread of far-fetched, fanciful explanations, and, at every stage of the story he has to tell, is careful to show that his statements are in strict accordance with facts. His account of the Bronze age is particularly interesting, but all that is essential to the comprehension of the remains of the Stone and Iron ages in Sweden he also presents with remarkable conciseness and lucidity. The second Swedish edition, of which the present volume is a translation, was published in 1878. Many additions were made by the author to a German translation, which appeared in 1885; and these additions, with others specially provided for the English rendering, have been incorporated by Mr. Woods in his interesting volume. Mr. Woods has done full justice to the original by his vigorous and lucid style, and the notes he has added—especially those relating to the "Corpus Poeticum Boreale," edited by Dr. Vigfusson and Mr. F. York Powell—will be welcome to all serious students of archæology. The work, we may add, is well printed, and the value of the text is greatly increased by a large number of admirable illustrations.

The "Indispensable" Hand-book to the Optical Lantern. Compiled and Edited by W. D. Welford and Henry Sturmey. (London: Iliffe and Son, 1888.)

THIS is mainly a catalogue of lanterns, accessories, and slides, one section of the book being devoted to each. Each section commences with brief general remarks, and is followed by a price list of the various pieces of apparatus concerned, as manufactured by different firms. The details of each piece of apparatus are described, and in some cases special remarks are made. All the important makers are represented, and their full addresses are given.

The classified descriptive catalogue of the various sets of slides in the market will perhaps be the most useful part of the book, seeing that the possessor of a lantern is likely to be most interested in determining what he shall exhibit. This catalogue is such that one can immediately ascertain full particulars relating to any set of slides, without waiting to see them before purchasing.

The illustrations which crowd the book are of a very high class, notwithstanding the fact that most of them are used for advertising purposes by the firms whose productions they represent.

To anyone about to purchase a lantern, or anything concerned with one, the book is fully entitled to its claim to be indispensable. We can further confidently say that it will interest and prove useful to each one of the ever-increasing number of persons who use the lantern either for purposes of instruction or entertainment.

LETTERS TO THE EDITOR.

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of* NATURE. *No notice is taken of anonymous communications.*]

Alpine Haze.

QUESTIONS of nomenclature are of some importance, and of some difficulty, in subjects not thoroughly investigated. M. Antoine d'Abbadie's last letter (NATURE, January 10, p. 247) is so interesting, and, from the linguistic and bibliographical points of view, so exhaustive, that it is with reluctance that I point out why my opinion slightly differs from his on nomenclature, having already indicated a difference of opinion as to the physical nature of the phenomenon itself. I gave, as a matter of course as well as of courtesy, the title of "Alpine Haze" to my last communication, out of deference to Prof. Tyndall, and shall continue to do so until I know Prof. Tyndall's final opinion, but deference to the highest authority cannot alter my belief that this title is not a fortunate one—a belief confirmed by Antoine d'Abbadie's own evidence. Ludolf's definition is good, but what I required was a simple English term for the use of non-scientific observers, and of some careful scientific observers like Dr. Burder. "Dry haze" (together with the specific term, of which it is the translation) begs a more serious question than is begged by "dust haze."

I am also inclined to think that the un-scientific English "dry haze" may be unfortunately applied to the ordinary haze of comparatively dry weather which Dr. Burder describes. There is, I suppose, little doubt that this latter common haze is composed principally of water-particles (usually with some admixture of smoke and dust), *pace* all the hygrometers in the world. It does not differ from mist, and does not differ from fog, except in amount. W. CLEMENT LEY.

A Remarkable Rime.

DURING cold fogs the accumulation of ice on the branches of trees due to the contact of water particles with solid substances, frequently causes damage to timber in the Continental forests: not often, I think, in this country. No snow has fallen here until to-day since October 2, 1888, but anticyclonic frost has been on several occasions accompanied by fogs of unusual density. During the frost of last week, ice-crystals of about 2 inches in length, at first very hard and adhesive, were formed on the windward (south-south-west) side of all exposed objects, but particularly on metal, even at no greater height than 3 or 4 feet above the earth's surface. This is a common sight on the higher hills even in the British Isles, but at this altitude (460 feet above mean sea-level) appears to be rare. The result has been great injury to timber, and a great "wind-fall," without much wind, to the tenant-farmers. Of deciduous trees, the ash seems to have suffered the most, while little damage, so far as I have observed, has been received by the ornamental conifers which usually suffer so much from snow. It is impossible to estimate, with much approach to accuracy, the amount of moisture drawn from the atmosphere in this rime, but during the thaw we measured 4½ inches of ice-crystals on the ground on the leeward side of a rather spare elm-tree 39 feet in height, while the boughs above this surface, on the leeward side, still retained their exquisite robe of rime. ANNIE LEY.

Ashby Parva, Lutterworth, January 12.

Mass and Inertia.

MR. WORTHINGTON is rather unkind in blaming the chemists for perhaps somewhat pedantically doing that which is right, while he encourages his new friends the engineers in continuing to do that which is wrong.

If he could point to a handy and permanent force, independent both of age and position, which could be boxed up in small compass and handed down to posterity with perfect security against alteration, and with complete certainty of precise accuracy in Auckland, or wherever the future capital of the race may be, there might be something to say for his proposal to adopt force as one of the fundamental units instead of mass. Otherwise, there is practically nothing to be said for it.

Mr. Worthington speaks as if we were anxious to do away with a student's familiarity with force as a push or a pull. This shows that he does not appreciate our position.

I even venture to assert that in what he says concerning mass and inertia he is not so absolutely clear in his own mind as it is desirable for a reformer to be. May I suggest to him that the "inertia" or "inertia-reaction" of a lump or mass of matter—that which is measured in an experiment, and the only thing that can be measured in an inertia experiment—is $m\frac{dv}{dt}$; and that the coefficient of the otherwise measurable kinematic factor in this quantity is properly called "the coefficient of inertia," but is, for brevity, styled "mass," and is taken as a measure of the quantity of matter in the body, because, experimentally, it is found to be absolutely unalterable by every physical and chemical process except those which change the amount of matter in the lump. Fancy making our standard of quantity of matter depend upon the approximately determined gravitative attraction of some arbitrarily selected planet at some arbitrarily selected spot near its present surface!

Sometimes, indeed, m is briefly called merely "inertia," just as the coefficient $\frac{V - V^1}{C}$ in Ohm's law is for brevity styled "resistance"; but the full names of these quantities are "coefficient of inertia" and "coefficient of resistance," respectively. In the case of friction the full name is usually given. With junior students it is clearest to give the full names in every case; just as it is much clearer with them to avoid the misleading abbreviation specific heat, and to use the full phrase specific capacity for heat.

OLIVER J. LODGE.

Liverpool, January 14.

A Hare at Sea.

AMONG the notes published in NATURE for December 27, 1888, is an account of a hare swimming across a river; perhaps the following account of a hare taking to the sea may be of interest. In October 1887, I was a member of a shooting party staying near Auchencairn on the Kirkcudbrightshire coast, where for miles the waves of the Solway beat on red sandstone cliffs, broken here and there by small bays, where the burns run down to the sea through little glens. One day I had left the others and was standing among the seaweed-covered boulders of such a bay, when the sounds of a course reached me from a hill-side a quarter of a mile or more away, and presently I saw hare and greyhounds coming down to the shore; they ran close past where I was standing, and then to my astonishment the hare deliberately entered the water and swam out to sea.

I could not persuade the greyhounds to follow, though one was so close that, if she had done so at once, she could have caught the hare without swimming, as the latter was out of her depth directly and swam very slowly. The sun was shining very bright on the water, and it soon became very difficult to keep the hare in sight, as her head only showed now and then on the top of a wave, and about a hundred yards from shore I saw her for the last time, though I stayed about the place a long while.

This hare was perhaps hard pressed, still I could see no reason why she should not have run along the shore to the march dyke, which was close to, and where she would probably have made good her escape.

W. J. BEAUMONT.

Sandiway, Northwich, January 13.

THE ARTIFICIAL REPRODUCTION OF VOLCANIC ROCKS.[1]

ORIGINALLY, the study of the crust of the earth was purely utilitarian: it seems to have been at first forced upon man by the necessity of exploring the strata in order to extract metallic ores, constructive materials, and combustible minerals.

To anyone who glances at the history of the sciences, it becomes evident that they all owe their origin to some useful and practical aim, and that from this initial phase they have passed through a regular development: this progress, so far as geology is concerned, I shall proceed to sketch.

Man, then, commences to explore the depths of the earth in order to extract the materials which may minister to his wants. At first he works without rule; but as the miner's art is developed, method is introduced into the search for mineral wealth, and he observes the conditions under which useful minerals and rocks occur in the bosom of the earth. These observations, at first merely empirical and local, gradually become generalized, and thus lead to a recognition of some of the leading features in the architecture of our planet. On digging into the earth, it soon becomes evident that the world was not made at a single stroke, but owes its formation to a succession of epochs.

It follows, therefore, that, in order to interpret the history of the earth, and the operation of the agencies which have taken part in its formation, it is necessary to study the living world, and to investigate the present condition of our planet. In comparing the various strata of the earth with the deposits which are in course of formation under our own eyes, we realize the conditions which have presided at the formation of the stratified rocks of ancient geological periods. It is thus that, by the analysis of facts, and by induction which generalizes the observations, our knowledge of the crust of the earth enters on a new and truly scientific phase. We start by attempting to discover practical rules for the guidance of the miner, and we are gradually led to decipher the history of the earth.

In this reconstruction of the past history of our planet we are guided by a fundamental principle—namely, that the essence of the forces which have acted upon the earth has never changed. We ought, then, to seek in geological epochs for traces of only such phenomena as are of the same nature as those which we can witness to-day, and submit to direct observation.

Since geologists commenced, towards the close of the last century, to apply the inductive method to the study of the mineral masses which form the crust of the earth, to their architecture, and to the organic remains embedded in the rocks, a vast collection of documents has accumulated, bearing upon the history of our planet. During this period, Geology has made such immense progress that she need not envy the older branches of natural science.

Let us see how, in applying this analytical method and relying on induction, geology interprets the formation of the rocks. Rocks, we know, are the solid mineral masses which constitute the earth's crust. Observation teaches us to recognize two groups. The first are characterized by an arrangement in beds or strata: these are the sedimentary rocks. The second group, which does not present this stratified arrangement, comprises rocks of volcanic character, with a massive structure. These differences in the structure and composition of the two great lithological groups lead us to regard them as having been formed under special conditions, which have left their imprint upon each group.

We see the sedimentary rocks in the course of formation when we observe how detrital matter is rolled about by stream and wave, and how such waters deposit pebbles, sand, and mud upon their beds. After the death of the organisms which inhabit these waters, their skeletons or their shells become mingled with the mineral deposits, and with them build up sedimentary masses. The minerals so deposited assume, by successive accumulation, a stratified arrangement. All their constituent particles were originally isolated grains, and still retain traces of their origin: they are either the *débris* of pre-existing rocks or organic exuviæ, which, by physical and chemical processes, may become subsequently consolidated.

Let us now compare these modern sedimentary deposits, characterized by a stratified arrangement, and

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[1] A Lecture delivered in French at the Royal Institution, on Friday, May 18, 1888, by M. Alphonse Renard, LL.D., Hon.M.R.S.E., Corr.G.S., Curator of the Royal Museum, Brussels. Translated by F. W. Rudler.

by the detrital nature of their constituents, with certain geological strata. We observe on continental surfaces masses of rock of geological antiquity, which offer close analogy in aspect and structure to the materials which are deposited under our very eyes by fluviatile and marine action. This comparison leads us to regard the old stratified rocks as having been formed by the operation of the same causes, and we hence consider them to be deposits of submarine or fluviatile origin. Water is therefore the agent which is everywhere at work in the formation of sedimentary or detrital masses.

The second group, of which we have specially to treat, includes the massive rocks—those which may be observed in course of formation during volcanic manifestations. The molten matter, vomited from the crater or injected into the sedimentary beds, consolidates on cooling. The constituents of the lavas are crystalline individuals developed at the expense of the surrounding magma. These crystals are not detrital, in the sense in which we have just used that term. Speaking in general terms, we may say that the eruptive masses do not present the stratified arrangement of the sedimentary rocks; but in place of the original horizontality and the regular superposition of the stratified beds, the lavas offer an appearance which indicates the thrust from below upwards, to which they were subjected during eruption. Finally, the massive rocks are destitute of organic remains.

Let us now compare the contemporary volcanic rocks with certain ancient crystalline rocks—granites, porphyries, trachytes, and basalts. We observe that these present close analogy in structure and composition to the products of active volcanoes. From the possession of these common characteristic features, we may conclude that the massive rocks, which traverse the strata, have been, like the modern lavas, injected from below, and share with them an eruptive origin.

But while we see the sedimentary rocks in course of formation under our eyes, and can closely follow the conditions which preside at their origin—the work being accomplished, so to say, in broad daylight—the eruptive masses are elaborated in the depths of the earth; their genesis is to some extent enshrouded in mystery, and our vision fails to penetrate the vast subterranean reservoirs where the molten masses are formed, and whence they are projected in volcanic eruptions.

Here the paths of direct observation are partially closed against us. Neither the finest analysis nor the strictest reasoning can supply the missing data; they are powerless to show us all the causes which are at work in the formation of the eruptive rocks.

In order to resolve our doubts, and to control and complete our observations, we therefore attempt to reproduce the volcanic rocks artificially; to form them synthetically. Armed with the results of observation which must serve as our guide, we endeavour by scientific manipulation to imitate the products of Nature. The science of the earth, previously analytical, enters thenceforth upon its final phase—that of synthetic experiment.

These attempts to imitate Nature, guided by the intelligence of man and executed by his hand, enable him, though limited in resource, to obtain results which offer analogy to that which he desires to investigate; he can direct and regulate the progress of the phenomena, can note with exactitude their relations, and can vary at will the conditions under which they arise. The knowledge acquired by observation, analysis, and reasoning, is thus, according to Bacon's expression, "tested by steel, and by the fire of experiment."

We have now indicated in broad outline the three great steps in the progress of our knowledge of the earth's crust. We have watched it at its birth, when it was limited to utilitarian ends; we have followed it later in its course, when, guided by observation and reasoning, it rose to the dignity of a science. Geology, entered now on its last phase, is transformed into an experimental science.

We shall now show, in studying the artificial reproduction of recent volcanic rocks, how powerfully the resources of the laboratory can assist the direct observation of Nature. But before explaining the methods employed in the synthesis of modern volcanic rocks, we must briefly summarize our knowledge of the constitution and formation of these volcanic masses, as derived from analysis and observation. It is to these natural lavas that our synthesis must be directed; they form the models which we must copy, and it is therefore necessary to become thoroughly acquainted with them in order that we may imitate them in their closest details.

Let us, then, recall what we know about lavas and the conditions of their formation. Without dwelling on these grand manifestations of the internal forces of the earth, or the succession of phenomena in an eruption—those formidable disturbances which shake the volcano to its very base, and eject pulverized vitreous matter and red-hot stones—we may remark that in the midst of such a cataclysm, the crater and the flanks of the mountain, rent by pressure of the matter seeking to escape, allow floods of lava to flow forth, and this matter, rolling down the mountain, slowly solidifies upon its slopes.

The chief feature of an eruption is the emission of lava or streams of molten matter escaping from the crater. We may best compare the lava, in general terms, to a glass liquefied under the influence of the high temperature which prevails beneath the solid crust of the earth. Direct observation of the temperature of the liquefied lava at the moment of its emission from the crater is surrounded by dangers which few observers dare to encounter. Hence we possess on this point only approximate observations. But certain volcanoes, where the outflow of lava is never violent, and which are in a state of moderate and permanent activity, as in the Island of Hawaii, have allowed the intrepid observer to approach sufficiently near to estimate the temperature of the molten mass. It has thus been found that the temperature varies between 1000° C. and 2000° C. But on the outflow of the lava the temperature of the surface is rapidly lowered, the liquid sheet becomes incrusted with scoria, more or less thick, beneath which the fused matter flows like a stream, having a temperature of about the melting-point of steel. It is this mantle of scoria which hinders radiation, and enables the subjacent mass to retain for a long time a certain amount of viscosity.

Further on we shall discuss the observations on the phenomena of crystallization presented by this erupted matter, still liquid or viscous, but ready to congeal. Let us, however, first study some of the essential characteristics of the structure and composition of lavas. These erupted products are in many cases vesicular and scoriaceous; while in others they appear as homogeneous vitreous masses, more or less dark-coloured, in which the naked eye fails to detect any isolated mineral. Sometimes, again, this mass is charged with minerals, more or less numerous, which seem to squeeze aside the vitreous paste which cements them together. These embedded minerals, when perfectly developed, present regular polyhedral forms, constant for each species; they are, in fact, *crystals*—that is to say, perfect individuals of the mineral world. They have drawn from the original vitreous magma the chemical elements of which they consist, and which have grouped themselves according to their affinities; just as we observe that in a liquid saturated with a salt, crystals are developed, consisting of the substance which was dissolved in the mother-liquor.

Mineralogy teaches us to determine the mineral species which crystallize in lavas; chemical analysis, in turn, furnishes us with valuable information respecting the composition of volcanic products. If we subject the eruptive rocks to chemical processes, we find that they all contain more or less combined silica, which may reach to upwards of 65 per cent. of the mass: these are the acid or light lavas. Thence we pass, by various gradations, to the basic or dense lavas, in which the proportion of silica, gradually diminishing, does not reach more than 55 or even 45 per cent. This silica does not exist in a free state in modern lavas, but is combined, in the form of silicates, with alumina, iron, lime, magnesia, potash, and soda.

In the slags of metallurgical works we find products which present close analogy to those of volcanoes, both in composition and in mode of formation. These artificial scoriæ are, like lavas, formed of silicates; and another point of resemblance between them lies in the fact that we may regard both as the scum of a metallic nucleus, of which they form the upper zones. The differences in composition result from the fact that they are derived from zones of greater or less depth.

Our knowledge of eruptive rocks came to be enriched in an unexpected manner by the application of the microscope to lithology. We need not here recall the almost marvellous results obtained by this method of investigation, inaugurated by H. C. Sorby; but we may say, in a word, that the microscopic analysis of rocks has changed the face of petrography. Let us confine our attention to some of the conceptions relating to modern volcanic rocks, as revealed by these new methods—methods which, in delicacy, in certainty, and in elegance, are unsurpassed in any other branch of natural science. Not only have they enabled us to verify and control hypotheses, but they have led to the remarkable discoveries to which I am about to refer.

The eye, assisted even by the most powerful lenses, could recognize in lavas only those minerals which appeared in rather large crystals; chemical analysis generally gave merely the composition of the total rock, and its mineralogical composition was only suspected. The intimate texture of the rock remained impenetrable; it was impossible to determine with certainty the order in which the constituents of the molten mass had solidified; neither could we trace the various states through which the crystals had passed—their germs, primordial forms, and skeletons —or the aspect of the rock at different stages of its development.

Let us now apply the microscope to the examination of a thin slice of lava, rendered transparent by polishing. The lavas, as we have said, may be compared to vitreous masses; but whilst in our artificial glasses we seek to obtain a pellucid and homogeneous product, the liquefied matter of volcanoes, when it flows forth, already contains certain differentiated products. The glass which contains these bodies may be regarded as the residue of the crystallization, whence the numerous crystalline individuals have extracted their constituent elements. In the black, brilliant, volcanic glasses, apparently opaque and destitute of crystallization, the microscope discovers a world of mineral forms. It shows us their various states of growth, and the arrest of their development consequent on the more or less rapid consolidation of the mass. It is especially in those rocks which, like obsidian, have preserved almost wholly their vitreous character, and are homogeneous to the naked eye, that we find the rudimentary crystals of curious form, representing the first step in the passage of the amorphous matter to the crystalline condition. Owing to the rapidity with which the vitreous paste consolidated, the crystals were unable to grow, and their development was sharply arrested. Hence the origin of these embryonic crystals which abound in natural glasses, and which we designate as *crystallites*. Analogous crystallites are produced in blast-furnace slags, which have close relations to the matter of lavas. Their common origin is betrayed by certain family likenesses which the microscope reveals. The slags, examined in thin sections, exhibit rudimentary crystalline forms, similar to the crystallites of volcanic glasses.

But usually the crystals have not remained in this embryonic state. If the lava has not been too rapidly cooled, the molecular movements are retained, even in a semi-liquid mass, and the paste develops crystals of minute dimensions, called *microlites*. These microscopic crystals are formed in the heart of the vitreous magma during its slow consolidation. Notwithstanding their infinite minuteness, these small polyhedra exhibit with marvellous exactitude all their specific characteristics, such as we are familiar with in much larger crystals, and which we should not expect to find in lavas. They often form, by their interlacement, a beautiful network in the paste, and give to the rock in which they are developed a *microlitic structure*.

The dimensions of these microlites, invariably microscopic, and their arrangement, prove that they may be referred to a period of disturbance; that they were formed, indeed, at a time when the lava, though still in motion, was solidifying. They separated from the magma during the very act of outflow or eruption.

Besides these microscopic crystals and these groups of crystallites, which belong to the last stage of consolidation, the lava contains also a supply of larger crystals, more fully developed, and in many cases recognizable by the naked eye. These have been formed under calmer conditions, analogous to those presented by a tranquil fluid in which crystallization is proceeding slowly. They were formed in the molten magma when it was still inclosed in the subterranean reservoirs. This slow growth is clearly proved by the formation of the crystals in concentric zones and by their size. These large crystals, existing ready formed in the lava at the time of its eruption, are surrounded by microlites or by a vitreous mass. It was after their slow development in the magma, during an intra-telluric period, that the mass in which they floated was upraised. The period of calm was succeeded by one of agitation, and the lava in its violent ejection carried forth the crystals, breaking them, corroding them, and partially fusing them. The microscope offers distinct evidence of these phenomena. We see the large crystals dislocated and their fragments dispersed, their edges rounded and eroded, and their substance invaded and penetrated by the paste.

While the physical and chemical agencies brought into play by the movement of the lava thus attack the ancient crystals to the verge of demolition, the microlites are in course of formation. This vitreous matter, in which the large crystals float, solidifies as a mass of microscopic individuals. The latter are therefore related to a second phase of crystallization: they are developed in a moving viscous magma, and their further growth is arrested by the rapid cooling which induces solidification *en masse*.

The fluidal arrangement of the microlites distinctly shows, too, that the crystalline action was contemporaneous with the movement of the lava-flow. Indeed, we see in microscopic preparations that the microlites are accumulated around the large sections of crystals, forming wavy trains and presenting the arrangement which micrographers designate as *fluidal structure*. It is marked by the orientation of these infinitely small acicular crystals. When these streams of microlites meet the large embedded crystals, they sweep round them, crowding into the spaces between the large sections, accommodating their flow to these outlines, and preserving for us the last movement of the mass at the very moment of solidification.

The microscope therefore proves that crystallization in lavas belongs to two periods: the first, anterior to the eruption, during which the large crystals already found are suspended in a mass that we may regard as entirely vitreous; and the second period, when the microlites and embryonic crystalline forms are separated, dating from the ejection or outflow, and contemporaneous with the solidification of the rock.

From these microscopic observations on the crystals of the second period, we may conclude that they are formed purely and simply by igneous action, without requiring the hypothetical temperatures and pressures formerly considered necessary, and without that absolute repose regarded as needful for the regular crystallization of minerals. We see, indeed, that the microlites are formed after the outflow, at the normal barometric pressure and at a temperature far from being as high as generally supposed, and we witness the birth of the crystals during the very flow of the lava stream. When the cooling is extremely rapid, the microlites have no time to form, and the lava can produce only crystallites.

But the microscope enables us to determine the chronology of the crystals in lava in a still more detailed manner. We have already distinguished two great periods in their history; let us now indicate in a general way how we may establish to some extent the date at which each species of the two groups is separated from the magma. Data leading to the determination of their relative age are afforded by their inclusions.

A crystal developed in a vitreous mass frequently incloses particles of the medium in which it grows. In this way certain sections under the microscope appear penetrated with vitreous grains, imprisoned in the interior of the crystals and frequently arranged along the zones of successive growth. These inclusions prove that the crystals in question were formed in a vitreous mass, liquefied by heat. In other cases the inclusions are mineral species in the form of microlites; and it is clear that they must have been anterior in date to the mineral in which they are inclosed. Finally, in other cases a species will mould itself around sharply defined crystals, conforming to their outlines, and filling up all the spaces between the minerals; thus showing that the crystals are of earlier origin than the surrounding mineral.

From these facts, which speak for themselves, we have been able to draw up chronological lists indicating the relative date of crystallization of each species of the two great periods. I will not stop to cite these lists, but we shall soon see how the law which governs the successive formation of the crystals, and their relative age, is evolved from synthetic experiments.

I have traced in broad outline the history of a lava, but have sketched only a few of the details which modern researches on lithological phenomena have developed with such startling reality: nevertheless, what we have seen is sufficient to show in a striking manner the power of analysis when supported by reasoning. I think I am not wrong in saying that from this point of view the study of a lava presents one of the finest examples of the application of the inductive method to the natural sciences. We hardly know whether to admire most the analytical processes, or the subtlety of observation, or the logical method by which the observed phenomena have been brought into connection.

Microscopic analysis, powerful as a method of investigation, has enabled us to trace with close exactitude the progress of crystallization in a rock where the unaided eye could discover only an indistinct and uniform mass; to penetrate into this marvellous tissue of volcanic products, where millions of polyhedra occur within the volume of a cubic centimetre; to determine with mathematical precision the nature of each of these infinitely small bodies; to track them to their birth, and follow them throughout their development, tracing all the modifications to which they have been subjected under the influence of physical and chemical agents.

Nevertheless, to the conscientious and modest investigator, how much still remains unknown in connection with the history of volcanic products, though the field seems so narrow, and has already been so well worked! What problems remain unsolved, even by the most refined observation! But when observation can no longer aid us, when we have exhausted all the resources of this method of investigation, there yet remains the method of synthetic experiment. This forms one step more on the road which leads to a perfect knowledge of the phenomena, and may conduct us to their definite solution. But, in order that synthetic operations may attain this end, they must be directed with due intelligence and design.

One of the essential conditions of a geological synthesis, as Sénarmont remarked, is, that each of the artificial operations should be compatible with all the circumstances traceable in the products of the natural operation. The slags and scoriæ of our furnaces, which, as we have shown, are related to certain natural products, are, it is true, the results of synthesis, but synthesis made at haphazard; and thus, notwithstanding their high scientific interest, cannot be placed on the same level with the synthesis of which I am about to speak, where the experimentalist, bearing steadily in view the problem which he desires to solve, attempts to realize in the laboratory the identical conditions which have surrounded the formation of the natural products which he wishes to imitate.

In logical order, the synthetic methods follow the progress of observation and of analysis. But even in the very infancy of geology there were certain powerful minds which foresaw, with the glance of genius, the part which experiment was destined to play in that science. Buffon proved by experiment that granite and the principal crystalline rocks are fusible, and that they were transformed by fusion into a vitreous mass. Some years later, Spallanzani performed an extensive series of experiments on the fusion of lavas, in order to overcome the prejudices which prevailed respecting the cause of the heat of eruptive matter.

But it is especially to Sir James Hall that belongs the honour of having, by his celebrated researches, introduced experiment into geology. He demonstrated its application in a masterly manner, and was led to sound generalizations. We have here to notice in Hall's researches only those which relate to the synthesis of rocks. About the time when Spallanzani studied, by laboratory methods, the conditions of the formation of lavas, the illustrious Scottish geologist was busy fusing the eruptive rocks in a vessel of graphite: he observed that the product of this fusion, if cooled rapidly, became an amorphous vitreous mass, while, if cooled more slowly, crystals were formed. James Hall had already observed by experiment the capital fact for future synthesis that, in order to regenerate the crystals of a rock which has been fused, it is necessary to maintain the glass obtained by the fusion at an elevated temperature, but yet a temperature always inferior to that required for the fusion of the rock. During this process, certain minerals crystallize. These facts may be paralleled with the phenomena which lavas display when their temperature is lowered after their emission.

Towards the commencement of this century, Gregory Watt directed his researches in the same direction. He experimented on masses of basalt, 700 pounds in weight: these he fused, and allowed to cool during eight days beneath a layer of charcoal, which was slowly consumed. During this prolonged *recuit*, spherulitic concretions of fibro-radiated texture, 6 centimetres in diameter, separated in the opaque black glass resulting from the fusion: finally, the glass passed into a stony condition, assumed a granular structure, and became charged with very thin crystalline lamellæ. At the same time, its magnetism was increased, while its density rose from 2·743 to 2·949.

One conclusion from the researches of Watt, which are closely related to those of Hall, is, that crystallization may occur during the period when the fused matter commences to solidify.

At the time when the road to the synthesis of rocks was being thus opened up, analysis and the methods of investigation had not attained to the perfection which they enjoy at the present day; on the other hand, the prejudices which held sway in the infancy of geology increased the obstacles, and these were not surmounted until half a century later. We need not be detained here by the brilliant period of mineral synthesis which followed close on the development of chemistry and mineralogy. It is sufficient to cite the names of Ebelmen, Rose, Mitscherlich, and Sénarmont, to recall those remarkable results in the artifical reproduction of minerals. But the researches of these *savants* related chiefly to the synthesis of isolated species, and not to rocks which are aggregates of mineral species. Speaking generally, it may be said that their researches were essentially mineralogical, and bore but subordinately on lithology. Nevertheless, the researches of these skilful experimentalists shed much light upon geological problems. They also show us that, as the mineral sciences progress, we are led to seek, by experimental methods, the most complete interpretation of the phenomena of Nature. Finally, in 1866, Daubrée led the way to the reproduction of crystalline rocks by simple fusion. This is the method which has been since taken up and developed by MM. Fouqué and Michel Lévy. The researches of Daubrée, to which we refer, are those in which he sought to reproduce by fusion certain meteoric stones characterized by the absence of a felspathic element. By fusing lherzolite, a terrestrial rock which approximates in composition to certain meteorites, he succeeded in obtaining products which, in the details of their structure and composition, resembled the cosmical types which he desired to imitate.

While this eminent geologist thus foreshadowed the researches which some years afterwards shed so brilliant a lustre upon the geological laboratory of the Collège de France, the synthetic methods were still encumbered by hypotheses. It is true we had no longer to struggle against the assumed influence of mysterious forces; but it was held that the reproduction of geological phenomena in the laboratory would be possible only if we had an infinite duration of time at our disposal, and dealt with temperatures and masses far beyond those which we could hope to command in the laboratory. It was still supposed that the mineral associations in Nature were governed by other laws than those which determined the combinations produced by the chemist. Such prejudices would certainly not have hindered Daubrée from proceeding in the path in which he so bravely took the first step by his synthesis of meteorites; for he, indeed, is one of those whose works have largely contributed to banish such prejudices from the realms of geology; but the methods of analysis which then existed did not allow us to probe the nature of the rocks to their very base, and to compare their intimate structure with that of the products of synthesis. Our laboratories were not then in possession of the apparatus by means of which we can command those very high temperatures, maintained during a prolonged period, which such experiments require.

The great improvements in the construction of apparatus, and the application of the microscope to lithology, have at length enabled us to successfully attempt the reproduction of all the modern volcanic rocks. Two French *savants*, MM. Fouqué and Michel Lévy, who introduced into their country the study of micrographic lithology, began in 1877 a series of synthetic experiments destined to be memorable in the annals of science. One of them had already acquired a just reputation by his remarkable researches on volcanic phenomena, carried on in various classical regions; he was familar with all the secrets of the chemical analysis of minerals—a department which he had enriched by the most ingenious and useful methods. The other, prepared by the severe studies of the high French schools, had undertaken, with brilliant success, the examination of minerals by their optical properties: he had carried exact methods into micrography, far beyond what others had done, and he was known by his researches on the eruptive rocks of the older series.

By their joint labours, MM. Fouqué and Lévy have to some extent systematized and co-ordinated the facts relative to the chronological succession of the crystals in eruptive rocks, and have discovered many of the details which we have already noticed in explaining the results of the analyses of lavas. It is to this happy association of talent, to this fruitful collaboration, that we owe those beautiful discoveries which have given such celebrity to the laboratory of the Collège de France, and to which it is an honour for me to render homage before an audience ever ready to welcome scientific progress, and in a place where the immortal Faraday once brought forward, with generous enthusiasm, the admirable researches of Ebelmen in connection with mineral synthesis.

We have already indicated the data upon which these *savants* relied in their researches: they are furnished by chemical and mineralogical analysis. One point, however, not yet touched upon, lies at the base of their general procedure. Theory would predict that the most ancient crystals in an igneous rock should be those which are the least fusible. And this, speaking in general terms, is really what we observe: the minerals of the first period of crystallization are those which occupy the lowest degrees in the scale of fusibility. The constituent mineral species of lavas have appeared at successive periods, as the temperature diminished, according to their relative degrees of fusibility. These facts, proved in detail by microscopic analysis, served as the point of departure in the experiments of MM. Fouqué and Lévy. Their process rests, morever, upon a fact which James Hall foresaw: namely, that the fusion of a rock produces a glass which is more easily fusible than any of the constituent crystalline species of the rock. Now, if we fuse a natural aggregate of minerals and subject the glass produced by this fusion to a series of diminishing temperatures, but always higher than that of the fusing-point of the vitreous mass, the minerals, which can crystallize from this magma should make their appearance one after another, and the less fusible should be the first to separate. These crystals will be united and moulded round by those of which the fusibility is higher, and which will appear in turn as the temperature decreases. Without dwelling on the technical details of the apparatus, it suffices to say that, by aid of the furnaces and bellows, which MM. Fouqué and Lévy employ in their syntheses, we can obtain all degrees of temperature, from a dull red to a dazzling white heat, and can maintain a given temperature constant for an unlimited period.

Into the furnace we introduce a platinum crucible of a capacity of about 20 cubic centimetres, containing the mixture of mineral substances which by fusion and *recuit* are to be transformed into the rock. First, by aid of special arrangements, we subject it for a long time to a glowing white heat, and the mixture is converted into a glass. By regulating the admission of gas and air, and by uncovering the furnace, the temperature is lowered to an orange heat—the fusing-point of steel. By raising the crucible in the furnace, the temperature falls to a cherry-red heat—the melting-point of copper. Finally, if the crucible be completely removed from the furnace, it can still be maintained at a temperature at which copper would fuse with difficulty.

We have thus indicated the broad lines of the operation. These are the successive *recuits* at diminishing temperatures which cause the crystals to be formed in sequence, commencing with the least fusible, and which enable us to impart to the fused matter the texture and the mineral composition of volcanic products.

We proceed to illustrate by examples the method of lithological synthesis. Let us first explain the manipulations for the reproduction of one of the rocks which plays the principal part in the eruptions of Vesuvius—*leucotephrite*. This rock is composed of leucite, labrador-felspar, and augite.

A mixture is formed of silica, alumina, lime, ferric oxide, potash, and soda, corresponding to one part of augite, four of labrador-felspar, and eight of leucite. This mixture is introduced into the crucible, and fused at a glowing white heat to a homogeneous glass. After fusion, the temperature is lowered, and the vitreous mass is exposed for forty-eight hours to the temperature of fused steel. During this first phase, crystals of leucite separate. They evidently correspond to the first period of consolidation in eruptive rocks.

The matter is then subjected during another forty-eight hours to the temperature of fused copper. All the mass, the residue from which the crystals of leucite first separated, is now transformed into microliths of augite and labrador-felspar, with octahedra of magnetite and picotite.

Let us now compare microscopic preparations of the synthetical product of this double *recuit* with those of the natural lava. Not only have the same minerals been reproduced by this dry fusion, but the order of their appearance and the proportion of the constituent species are identical; and their analogy may be pursued even to the details of the crystallographic forms. The leucite, in large crystals, offers all the features of this mineral in the Vesuvian lavas; and around these crystals are grouped the microlites of the second period—the augite and labrador. Finally, as in the natural rock, the leucite contains inclusions of magnetic iron-ore and picotite, which are the most ancient minerals in the rock.

As a second example, let us take the synthesis of *basalt*—one of the most widely-spread types of rock in the volcanic series, and one which, so far as its origin is concerned, has been the subject of numerous hypotheses. It is known that basalt is composed essentially of three minerals—olivine, augite, and labrador-felspar. The olivine in the natural rock appears in crystals of the first consolidation.

As in the case of the leucotephrite, so here, we form a mixture of the chemical constituents, or of the powdered minerals, corresponding to the mean composition of a basalt rich in olivine. Such a mixture is composed of three parts of olivine, two of augite, and three of labrador. This is first transformed into a homogeneous black glass. During forty-eight hours it is maintained at a white heat. If, after this *recuit* at a high temperature, we examine a thin section of the glass, we observe large crystals of olivine. These are as yet embedded in a vitreous mass, in which small octahedra of massicotite and picotite are isolated, as also a few crystals of augite.

It remains now to produce the microlites of the second consolidation, by which the crystals of olivine developed during the first phase ought to be surrounded. To produce these, the mass is maintained at a cherry-red heat for forty-eight hours. After this *recuit* we obtain a paste composed of microlites of labrador and augite, with magnetite and a vitreous substance which is the residue of the crystallization. We have therefore, in this second phase, reproduced the microlithic structure. These manipulations produce basalts which we can scarcely distinguish from the natural rocks, and thus a few grammes of a substance skilfully manipulated furnish us with the most convincing proof of the purely igneous formation of this rock.

We could go on explainng these remarkable series of experiments by MM. Fouqué and Lévy, in the same way as we have dealt with the two preceding syntheses. All the contemporary eruptive rocks have thus been reproduced: andesites, labradorites, basalts, limburgites, nephelinites, tephrites, leucite rocks, peridotites, and labradorites with ophitic structure. We will, however, confine ourselves, as a last example, to those processes by which they have succeeded in directly explaining, by means of synthesis, the eruptive phenomena of the older periods of the globe.

There are certain ancient crystalline rocks, common in the Pyrenees, which are known as *ophites*. The period at which they were formed, and their mode of origin, had not been definitively established, when in 1877 M. Lévy showed that they were eruptive and that they exhibited under the microscope a remarkable structure which he termed the "ophitic structure," the felspar being surrounded by very large plates of augite. It seemed, then, that the ophitic rocks were igneous rocks, in which the cooling had been more slow than in the ordinary rocks of modern eruptions. It was therefore necessary, in attempting to reproduce the ophitic type by synthesis, to cause the augite to crystallize during a phase sharply separated from that in which the felspar was reproduced; and, moreover, to give to the augite sufficient time to crystallize in large plates. For this purpose, a mixture of one part of anorthite and two of augite was submitted, after fusion, to a first *recuit*, in which it was maintained for forty-eight hours at the melting-point of steel: under these conditions the anorthite separated. A second *recuit* of the same duration as the first, but at the fusing-point of copper, led to the crystallization of the augite in large plates, which were moulded round the felspathic element, and to which were added small octahedra of magnetite and picotite. By this remarkable synthesis the eruptive origin of the ophites, and the cause of their structure, were established beyond all doubt.

It is thus seen how synthesis succeeds in explaining the genesis of rocks, and in settling those discussions which until recently were rife with respect to the principal crystalline types of modern date; those relating, for example, to basalt—a rock in whose formation it was argued that water played an important part. Now, the broad conclusion to be drawn from these experiments is that basalt, and, indeed, modern volcanic rocks in general, have been formed by a fusion purely igneous.

But by the side of these magnificent results the *savants* have had to record many fruitless experiments. It is useful to recall these by way of example, as they serve to indicate the paths to be avoided if we would attain success. These failures circumscribe the field of future experiment, and mark the limits within which hypotheses should have play. They demonstrate, moreover, that the rocks which we have not succeeded in forming synthetically by our methods must have been formed under different conditions from those which prevail in the formation of modern volcanic products. This conclusion to which observation and analysis had already pointed, without, however, precisely defining the cause, is thus confirmed by the failure of our synthetic researches. If synthesis has succeeded in reproducing all kinds of lava from modern eruptions, it has failed to imitate those rocks which are no longer formed in contemporary eruptions. It may be said, generally, that up to the present time all the acid rocks have withstood our synthetic efforts, and those which contain among their constituent minerals, quartz, mica, orthoclase, and hornblende.

The processes of Nature involve no occult forces, and it may be that by combining those means which are already at our disposal, and in modifying their application, we may be permitted to witness the production of those rocks which have hitherto eluded our efforts. Such a hope is based on the results already attained, which we may regard as only the presage of others perhaps still more surprising. The failures of the past prepare for the conquests of the morrow.

In this rapid review of the progress of lithological synthesis, I have endeavoured to show the high scientific value of the researches instituted in the geological laboratory of the Collège de France. I could also have explained the successful syntheses, not less remarkable, of minerals and meteorites made by these experimentalists or by their pupils, among whom M. Bourgeois occupies a special position. But I must limit myself; and, indeed, what I have said is sufficient to show how their methods have advanced our knowledge in a domain to which access had previously appeared shut against investigation.

Wherever the experimental method has hitherto carried its torch, it has brilliantly illuminated the most striking phenomena in the science of the earth. It suffices to mention the name of Daubrée, the direct descendant of the illustrious geologists of the Scottish school, to indicate the extent of the field of the mineral sciences already explored by the method of experiment. It has been successfully applied to the interpretation of metalliferous deposits and of metamorphic rocks, and to the study of the fractures and deformation of the earth's crust, of the schistosity of rocks, and of certain features in mountain structure.

Geology, after having passed through the successive phases of observation and analysis, has therefore entered upon that of experiment and synthesis, in which it strives to imitate the creative power of Nature, thus crowning the scientific edifice by processes which allow us to catch a glimpse of the operation of causes the knowledge of which is the final aim of physical and natural science. It was this crowning of the work which Leibnitz foresaw when he wrote, two centuries ago:—"He will perform, in our opinion, an important work, who shall carefully compare the products extracted from the depths of the earth with those of the laboratory; for then will be brought vividly before our eyes the striking resemblance which subsists between the productions of Nature and those of Art. Although the Creator, inexhaustible in resource, has at command divers means of effecting His will, it nevertheless pleases Him to maintain a constancy in the midst of the variety of His works; and it is already a great step towards a knowledge of things to have discovered even one means of producing them; for Nature is only Art on a large scale."

SOME RECENT ADVANCES IN THE THEORY OF CRYSTAL-STRUCTURE.

THE growth of modern theories concerning the structure of crystals is perhaps not so closely followed by English chemists as might be expected from the inherent interest of the subject, in spite of the attention which is now devoted to all questions of atomic and molecular arrangement in space.

It is in the morphology of crystals that the geometrical arrangement of the atoms or molecules (in the solid) finds, if anywhere, a geometrical expression, and yet little or no account is taken of this subject in text-books of chemistry or physics, so that it is difficult for the student to discover what views are held by modern authors. Moreover, crystallographic observations and theories are generally published in journals specially devoted to mineralogy which are not easily accessible to all who are interested in such questions.

It seems, therefore, advisable to draw attention to the progress which has recently been made in the theory of crystal-structure, and more especially to papers by Prof. Sohncke, of Munich, published in Groth's *Zeitschrift für Krystallographie und Mineralogie*, a journal which is a complete storehouse of information relating to the study of crystals.

Sohncke's theory, which was published in 1879,[1] has now emerged from the purifying fire of recent criticism in an emended form in which perhaps it will more readily excite the interest of chemists.

In order to make it clear in what respects the theory of Sohncke in its latest form differs from those which have been previously advanced it will be necessary to give a brief sketch of the theory of Bravais, of which Sohncke's system is an extension.

The Abbé Haüy,[1] having found that all crystals of the same substance may be reduced by cleavage to the same solid figure, whatever their external form, argued that the cleavage solid has the form of the ultimate particles into which any crystal may in imagination be separated by repeated subdivision, and that this is therefore the form of the structural unit: it is not, of course, necessary or even probable that the latter should be identical with the chemical molecule. Hence a crystal is to be regarded as constructed of polyhedral particles, having the form of the cleavage fragment, placed beside one another in parallel positions. A crystal of salt, for example, which naturally cleaves parallel to the faces of the cube, is constructed of cubic particles.

Upon the relative dimensions of the structural unit depends the form assumed by the crystals of a given substance.

It will be found that this theory not only accounts for the existence of cleavage, but further defines the faces which may occur upon crystals of a substance having a given cleavage figure; for, if once it is assumed that a crystal-face is formed by a series of the particles whose centres lie in a plane, it follows that all such planes obey the well-known law which governs the relative positions of crystal-faces.

A natural advance was made from the theory of Haüy, without detracting from its generality, by supposing each polyhedral particle in Haüy's system to be condensed into a point at its centre of mass, so that the positions of the molecules, and therefore of the crystalline planes, remain the same as before; but the space occupied by a crystal is now filled, not by a continuous structure resembling brickwork, but by a system of separate points.

It will be found that in such a system of points, if the straight line joining any pair be produced indefinitely in both directions, it will carry particles of the system at equal intervals along its entire length; in other words, all the structural molecules of a crystal must lie at equal distances from each other along straight lines. The interval between particles along one straight line will in general be different from those along another, but the molecular intervals along parallel straight lines will always be the same.

Bravais,[2] therefore, following in the steps of Delafosse and Frankenheim, treated the subject as a geometrical problem, and inquired what are the possible ways in which a system of points may be arranged in space so as to lie at equal distances along straight lines—in other words, so as to constitute what may be called a *solid network* (*assemblage*, *Raumgitter*).

The geometrical nature of a network may be best realized as follows. Take any pair $(\mathrm{O\ C_1})$ of points in space, draw a straight line through them, and place points at equal distances along its entire length $(\mathrm{C_2}, \mathrm{C_3}, \ldots)$; such a line may be called a *thread* of points (*rangée*). Parallel to this line, and at any distance from it, place a second thread of points $(\mathrm{A_1}\ a_1)$, identical with the first in all respects; in the plane containing these two threads place a series of similar equidistant parallel threads $(\mathrm{A_2}\ a_2$, &c.) in such positions that the points in successive threads lie at equal intervals upon straight lines whose direction $(\mathrm{O\ A_1})$ is determined by the points upon the first two threads. Such a system of points lying in one plane may be called a *web* (*réseau*). Now, parallel to this plane, and at any distance from it, place a second web $(\mathrm{B_1}\ b_1)$, identical with the first.

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[1] "Entwickelung einer Theorie der Krystallstruktur." (Leipzig.)

[1] "Traité de Cristallographie." (Paris, 1822.)

[2] "Études cristallographiques." (Paris, 1866.)

Finally, parallel with these, place a series of similar equidistant webs in such positions that the points in successive planes lie at equal intervals upon straight lines whose direction (O B_1) is determined by the points in the first two webs.

In this way a *network* of points is constructed, in which the line joining any two points is a *thread*, and the plane through any three points is a *web*.

The space inclosed by six adjacent planes of the system having no other points of the network between them is a parallelopiped (O A_1 B_1 C_1), from which the whole system may be constructed by repetition, and which may be taken to represent the structural element (*molécule soustractive*) of Haüy.

The complete investigation of all possible solid networks led Bravais to the conclusion that these, if classified by the character of their symmetry, fall into seven groups, which correspond exactly to the seven systems into which crystals are grouped in accordance with their symmetry.

It follows, then, that two (not, however, independent) features of crystals are fully accounted for by a parallelopipedal arrangement of points in space—namely, the symmetry of the crystallographic systems and the law which governs the inclinations of the faces (law of rational indices).

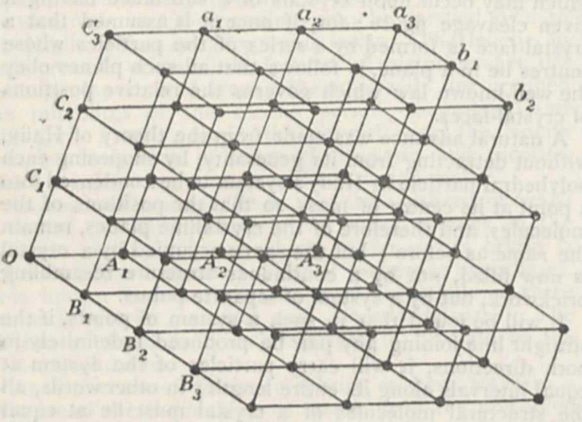

FIG. 1.

There are, however, subdivisions of the various systems consisting of the merohedral or partially symmetrical crystals belonging to them, which are not explained by the geometry of a network; these consequently were referred by Bravais, not merely to the arrangement of the molecules in space, but also to the internal symmetry of the molecule itself.

Hence the theory of Bravais, while able to a certain extent to explain the form of crystals, requires an auxiliary hypothesis if it is to explain those modifications which are partially symmetrical or merohedral.

Sohncke, treating the problem in a different manner, and reasoning from the fact that the properties of a crystal are the same at any one point within its mass as at any other but different along different directions, inquired in how many ways a system of points may be arranged in space so that the configuration of the system round any one point is precisely similar to that round any other. Such a configuration may be called a *Sohncke system* of points in space (*regelmässiges Punktsystem*).

From his analysis of this problem, it appears that there are sixty-five possible Sohncke systems of points, and that these may be grouped according to their symmetry into seven classes corresponding to the seven crystallographic systems; and further that there are within each class minor subdivisions, characterized by a partial symmetry corresponding to the hemihedral and tetartohedral forms of crystallographers.

It may be expected, then, that the theory of Sohncke contains within itself the essential features of a Bravais network of structural molecules, and also the auxiliary hypothesis regarding the arrangement of parts within the molecule which is required to account for merohedrism.

Now, on closer examination the arrangement of Sohncke does prove to be a simple extension of that of Bravais.

Each of Sohncke's arrangements may in fact be regarded as derived from one of the parallelopipedal networks of Bravais if for every point of the latter be substituted a group of symmetrically arranged satellites. It is not necessary that any particle in a group of these satellites should actually coincide with the point of the Bravais network from which the group is derived; and the points of the Sohncke system do not themselves form a network; it is only when all the points in each group of satellites are condensed into one centre that a Sohncke system coincides with a Bravais network.

To any particle of one of the satellite groups corresponds in every other group a particle similarly situated with regard to the point from which the group has been derived. Every such point may be said to be homologous with the first.

It will then be found that each complete set of homologous points is itself a Bravais network in space, and that consequently any Sohncke system may be regarded as a certain number of congruent networks interpenetrating one another: the number of such networks is in general equal to the number of points which constitute each group of satellites.

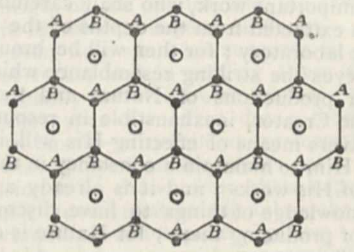

FIG. 2.

The relation of a Sohncke system to the network from which it is derived may be illustrated by a bees'-cell distribution of points in one plane, *i.e.* by points which occupy the angles of a series of regular hexagons. Thus in the adjoining figure the dots form a Sohncke system in one plane, since the configuration of the system round any one point is similar to that round any other; but they do not form a Bravais web, since the points do not lie at equal distances along straight lines.

If, however, points, represented in the figure by the circles O, be placed at the centres of the hexagons, they will by themselves constitute a web, and the hexagonal system may be derived from this web by replacing each of its points by a group of two satellites, A and B. Or, from the second point of view, the arrangement may be regarded as a triangular web, A, completely interpenetrated by a similar web, B.

It is a remarkable feature of the Sohncke systems that some among them are characterized by a spiral disposition of the particles along the threads of a right- or left-handed screw: now this spiral character, which does not belong to any of the Bravais networks, supplies a geometrical basis for the right- or left-handed nature of some merohedral crystals which possess the property of right- or left-handed rotatory polarization.

The theory of Sohncke as sketched above appeared to be expressed in the most general form possible, and to include all conceivable varieties of crystalline symmetry.

It has, however, recently been pointed out by Wulff[1] that the partial symmetry of certain crystals belonging to the rhombohedral system—that, namely, of the minerals phenacite and dioptase—is not represented among the sixty-five arrangements of Sohncke.

Other systems of points in space have also been studied by Haag[2] and Wulff, which do not exactly possess the properties of a Sohncke system, and yet might reasonably be adopted as the basis of crystalline structure, since they lead to known crystalline forms.[3] These, however, and all other systems of points which have been proposed to account for the geometrical and physical properties of crystals, may be included in the theory of Sohncke after this has received the simple extension which is now added by its author.

In Bravais's network all the particles or structural elements were supposed to be identical, and in Sohncke's theory also there is nothing in their geometrical character to distinguish one particle from another.

In Fig. 2, the hexagonal series of dots may, as was said above, be regarded as composed of a pair of triangular webs, A and B; now these, although identical in other respects, are not parallel, for the distribution of the system round any point of A is not the same as that round any point of B until it has been rotated through an angle of 60°.

It is possible, however, to conceive similar interpenetrating networks which differ not only in their orientation but even in the character of their particles. The centre of each hexagon, for example, may be occupied by a particle of different nature from A and B to form a new web, O. The three webs are precisely similar in one respect, since their meshes are equal equilateral triangles; moreover, if the *position* of the points alone be taken into account, the whole system would form a Bravais web, *i.e.* if the particles of O were identical with those of A and B. If, however, as is here supposed, the set O consists of particles different in character from A and B, the distribution round any point of O is totally distinct from that round any point of A or B. The points O are geometrically different from the points A B. The web A is interchangeable with B, but O is interchangeable with neither.

Now, it is precisely an extension of this kind which must be given to Sohncke's earlier theory if it is to embrace all the crystalline arrangements which have been alluded to above. The interpenetrating networks are no longer to be regarded as consisting necessarily of identical particles; the structural units of a crystal may be of more than one kind.

The above figure represents a Sohncke system, A B, of particles of one sort interpenetrated by a Bravais web, O, of another sort; but there is no reason why two or more different Sohncke systems, no one of which is identical with a Bravais network, may not interpenetrate to form a crystal structure.

In its most general form, then, the theory may now be expressed—

A crystal consists of a finite number of interpenetrating Sohncke systems which are derived from the same Bravais network. The constituent Sohncke systems are in general not interchangeable, and the structural elements of one are not necessarily the same as those of another.

Or, since each Sohncke system consists itself of a set of interpenetrating networks, the theory may be thus expressed—

A crystal consists of a finite number of parallel interpenetrating congruent networks: the particles of any one network are parallel and interchangeable; these networks group themselves into a number of Sohncke systems in each of which the particles are interchangeable but not necessarily parallel.

The number of kinds of particles which constitute the crystal may therefore be equal to the number of Sohncke systems involved in its construction.

The structural units are no longer, as they were in the theory of Bravais, necessarily identical, but may represent atomic groups of different nature.

The system in Fig. 2 consists of two sets of particles, A B and O; and, if a large enough number of these be taken, any portion of the system (*i.e.* any crystal constructed in this manner) consists of the particles united in the proportion of two of the first group to one of the second. Such an arrangement, then, may represent the structure of a compound, O A_2.

"When, for example, a salt in crystallizing takes up so-called water of crystallization which is only retained so long as the crystalline state endures, the chemical molecule salt + water cannot be said to exist except in the imagination, for the presence of such a molecule cannot be proved. To obtain an easily intelligible example, without, however, pronouncing any opinion as to whether it may be realized, imagine the centred hexagons in the figure to be constructed in such a way that each corner consists of the triple molecule $3H_2O$, and each centre consists of the molecule R. The chemical formula would then be $R + 6H_2O$, and yet a molecule of this constitution would not really exist; on the contrary, the structural elements in the crystallized salt would be of two sorts—namely, R and $3H_2O$."[1]

Hence it is geometrically possible that the structural elements of a crystal may be different atomic groups which are held in a position of stable equilibrium by virtue of being interpenetrating networks.

Whether such systems are chemically and physically possible must be left for future criticism to decide.

Finally, we may call attention to a remarkable declaration of faith which has recently been made in Germany by one who is a recognized leader in crystallographic and mineralogical science.

Prof. Groth[2] has suggested that there may be something more than a chance similarity between the theory of Sohncke and the views of the eminent French crystallographer Mallard, whose classical research upon the optical anomalies of crystals has been the means of dividing the students of this subject into two adverse camps. The explanation of Mallard has up to the present time found little favour among those German mineralogists who have made similar investigations. Prof. Groth has now, however, declared himself in favour of Mallard, being apparently induced to do so by the support which is given to his views by the theory of Sohncke.

Mallard has ascribed the optical anomalies of various substances to a complete or partial intergrowth of two or more crystals which combine in such a manner as to simulate a symmetry of higher order than that which naturally belongs to them. Now, since Mallard regards each crystal as composed of a Bravais network, it is evident that his views are not far removed from those of Sohncke, whose system is based upon the possible intergrowth of two or more networks. H. A. MIERS.

THE EARTHQUAKE AT BAN-DAI-SAN, JAPAN.

As it may interest our readers to know the present state of matters at the scene of the great earthquake which occurred lately at Ban-dai-san, Japan, we think it well to publish the following narrative just received by Dr. George Harley, F.R.S., in a private letter from his son, who has recently visited the locality of the sad disaster.

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[1] *Zeitschr. f. Kryst.* xiii. (1887) p. 503.

[2] "Die regulären Krystallkörper." (Rottweil, 1887.)

[3] Cf. W. Barlow, NATURE, xxix. (1884) pp. 186, 205.

[1] Sohncke, *Zeitsch. f. Kryst.* xiv. p. 443.

[2] "Ueber die Molekularbeschaffenheit der Krystalle." (Festrede, München, 1888.)

The letter is dated December 2, 1888, from on board the Peninsular and Oriental s.s. *Verona*, while in the Inland Sea on its voyage back from Japan to China.

Mr. Vaughan Harley says that on October 20 last, having procured the services of an interpreter, he started by train from Yokohama to Tokio, where he obtained a permit from the Japanese Foreign Office to visit the Ban-dai-san valley. From Tokio he went by train to Kuragano, where he engaged, for himself and interpreter, a couple of *jinrickshas*, with two coolies for each. On the following morning he started at 4.45 a.m.,—that is to say, before daylight. It being then early winter in Japan, the day did not break till 6.45. The weather at the time was both cold and rainy; but so long as the roads were good, the coolies, running tandem-fashion, managed to get along at an average rate of from 6 to 7 miles an hour, and accomplished 50 miles a day. On arriving at Inawashiro Lake, after having engaged a guide, he proceeded direct to Ban-dai-san, where the scene that met his eyes, though magnificent, was truly awe-inspiring. It was a veritable valley of devastation. For the whole side of a mountain—3 miles in circumference—had been completely blown away, and hurled as if it had been the mere outside wall of a house, into the valley below, completely burying beneath it four villages and their surrounding farms, along with all their inhabitants. Such was the stupendous force of the explosion, that the mere wind-shock produced by its concussion knocked down, as if they had been nothing more than ninepins, the whole of the trees growing on the opposite mountain-side. The river in the valley, too, was so dammed across by the huge mass of detached mountain as to have formed itself into a small lake, the waters of which now occupy the place where formerly well cultivated crops grew.

The catastrophe which brought about these physical changes appears to have been due to the sudden explosion of superheated pent-up steam, either alone or in conjunction with volatile gases, set free by the decomposing chemical action of heat and water on the constituents of the subjacent mineral strata. The whole surrounding ground is at present full of hot springs, giving forth volumes of steam, while from every crack and crevice in the earth issues, either continuously or spasmodically, clouds of hot watery vapour, so that one has to be very careful where he places his feet. Not only the fact of the presence of these hot springs, but likewise of the still frequent occurrence of earthquakes, shows that the same agent or agents that rent the mountain in twain are still actively at work. Even in the morning of the day following his visit (at 5 a.m.) there was a shock of earthquake, which, although it was strong enough to admit of his feeling the earth quiver beneath him, the people spoke of as being such a mild one as to merit no attention. He says, moreover, that the appearance presented by the standing half of the cleft mountain, with its surrounding clouds of steam, was, to his way of thinking, far grander, and vastly more awe-inspiring, than are either the geysers of Iceland or the yet greater and more numerous ones he had seen in the volcanic district of the Yellowstone Park in North America. For here the scene he witnessed not only plainly pointed to the cause, but gave him ocular demonstration of its stupendous power, and made him feel that, if superheated steam could thus easily, apparently, rend asunder a solid mountain of rock, there could be no difficulty in understanding why the live volcanoes scattered over the globe were looked upon as safety-valves for the effects of the various chemical decompositions brought about by heat and water in the molten minerals within the bowels of the earth. For were there no outlets even to the superheated steam—heated by the vast internal fires up to a point when it possibly resolves itself into its elements—he could readily enough imagine, from what he saw, that its sudden explosion might suffice to shatter the earth's crust into fragments—just, perhaps, as takes place in some of the heavenly bodies, fragments from which ever and anon fall, in the shape of meteorites, upon the surface of our globe. Having got back to the tea-house at 7.15 p.m., leg-tired and foot-sore, but thoroughly satisfied with all he had seen and learned, immediately after a hot bath—a natural one, for there is no need of artificially heating bath-water here, Nature does that amply for them—and supper, he went to bed, the bedstead being the floor, as is usual in Japan. Next morning, he started on his return journey to Yokohama, and arrived in good time for the sailing of the *Verona* on the 25th for Hong Kong, where he immediately posted his letter, in order to catch the homeward mail.

NOTES.

THE Vice-Chancellor of Cambridge University has appointed Prof. Stokes, P.R.S., Rede Lecturer for the present year.

MR. ISAAC ROBERTS, the eminent photographic astronomer, has presented to Dunsink Observatory a photographic reflecting telescope with a mirror by With of 15 inches aperture. The generous donor is erecting the instrument at his own expense, and it will be employed in furthering the study of star parallax—a study with which Dunsink has been so long associated.

ON Thursday evening last, the first meeting of the Institution of Electrical Engineers was held in the rooms of the Institution of Civil Engineers, at George Street, Westminster. Mr. Edward Graves, retiring President, occupied the chair. He opened the proceedings by announcing that the last legal steps had been taken to change the name of their body from "Society of Telegraph Engineers and Electricians," by which name it had hitherto been known, to "Institution of Electrical Engineers." Sir William Thomson, President for the year, then delivered his inaugural address on "Ether, Electricity, and Ponderable Matter."

THE forty-second annual general meeting of the Institution of Mechanical Engineers will be held on Wednesday, January 30, Thursday, January 31, and Friday, February 1, at 25 Great George Street, Westminster, by permission of the Council of the Institution of Civil Engineers. The chair will be taken by the President at 7.30 p.m. on each evening. The President, Mr. Edward H. Carbutt, having been in office for two years, will retire, and will induct into the chair the President-elect, Mr. Charles Cochrane.

THE annual general meeting of the Anthropological Institute of Great Britain and Ireland will be held on Tuesday, the 22nd inst., at half-past eight o'clock p.m. Mr. Francis Galton, F.R.S., will take the chair, and deliver the Presidential address.

AT a meeting of the Council of the Sanitary Institute on January 9, Mr. G. J. Symons, F.R.S., in the chair, it was decided that two courses of twelve lectures for sanitary officers should be held, the first course to begin in March, the second in October.

AT the Central Institution, Exhibition Road, during the spring term, Prof. Armstrong will give about ten lectures on some of the more important current problems in chemistry, on Mondays, at 4.30 p.m., commencing Monday, January 21. The following subjects will be dealt with as far as time permits: the nature of chemical change; the interdependence of chemical change and electrolysis; the molecular composition of gases, liquids, and solids; the nature of solutions; physical constants; laws of substitution and isomeric change as bearing on the problem of the nature of chemical change; valency; geometrical isomerism and allo-isomerism.

ZOOLOGISTS will regret to hear of the death of Dr. Heinrich Alexander Pagenstecher. His "Allgemeine Zoologie," in four volumes, the first of which appeared in 1875, the last in 1881, is well known. For a good many years he was a Professor of Zoology at the University of Heidelberg. In 1882, after having retired from public life, he was persuaded to accept the post of Director of the Museum of Natural History at Hamburg. His death—which occurred on January 5—was due to heart disease. He was in his sixty-fourth year.

THE death is announced from Southsea, after a very short illness, of Sir William O'Shaughnessy Brooke, F.R.S., in the eightieth year of his age. From 1852 till 1862 he was Director-General of Telegraphs in India. He was created a Knight Bachelor in 1856 for his distinguished services in establishing the electric telegraph service in our Indian possessions.

THE Rev. Churchill Babington, D.D., F.L.S., died on Sunday morning last at Cockfield Rectory. He was well known as a botanist, and contributed to Sir J. Hooker's *Journal of Botany and Kew Miscellany*. Dr. Babington was one of the honorary Fellows of St. John's College, Cambridge.

AT a meeting of the Royal Botanic Society, held last Saturday, the Secretary reported that the recent fogs had done much damage to the plants in the conservatories, causing many of them to shed both leaves and flower-buds. More especially had this been the case with Australian plants, which, from enjoying in their own country a large amount of sunlight, were found less capable than any others of contending against the vicissitudes of London weather. Mr. G. J. Symons, F.R.S., said he believed that fogs were increasing not only in London, but generally. Plants, however, suffered not only from the absence of light, but from the pores of their leaves becoming filled up with the sulphurous, sooty matters contained in London fogs.

INTELLIGENCE received at San Francisco from Hawaii states that Kilauea, the largest volcano in the island, is in a state of eruption.

A NEW mineral of exceptional chemical interest has been discovered by Mr. Sperry, chemist to the Canadian Copper Company, of Sudbury, Ontario, Canada. It is an arsenide of platinum, $PtAs_2$, and is the first mineral yet found containing platinum as an important constituent, other than the natural alloys with various metals of the platinum group. A considerable quantity of the mineral, which takes the form of a heavy brilliant sand composed of minute well-defined crystals, has been thoroughly investigated by Prof. Wells, who names it "sperrylite," after its discoverer; and the crystals have also been measured and very completely examined by Prof. Penfield. The sand is generally found to contain fragments of chalcopyrite, pyrrhotite, and silicates, which may be removed by treatment first with aqua regia to remove sulphides, and afterwards with hydrofluoric acid to remove silicates. After this treatment the sperrylite sand is seen to have remarkably increased in brilliancy, every grain showing extremely brilliant crystal faces, of a tin white colour, resembling that of metallic platinum itself. It is very heavy, possessing at 20° a specific gravity of 10·6. Strangely enough, however, although so heavy, the sand shows a marked tendency to float upon water, owing to its not being easily wet by that liquid; even when the grains do sink, they almost invariably carry down bubbles of air along with them. This peculiar property is retained even after boiling with caustic potash and washing with alcohol and ether, and cannot therefore be attributed to any surface impurities. Sperrylite is only slightly attacked by the strongest aqua regia, even after boiling for days, and it also remains unchanged when heated in a bulb tube to the temperature of melted glass. Heated in an open tube, however, it gives off a portion of its arsenic as a sublimate of the trioxide, the residue then fusing. When dropped upon a piece of red-hot platinum foil it melts, evolving white fumes inodorous arsenious oxide, and forming a porous excrescence in colour resembling metallic platinum upon the surface of the foil. Analyses show that sperrylite contains 52·5 per cent. of platinum; mere traces of rhodium and palladium, in quantity less than 1 per cent., being also present. Prof. Penfield shows that the crystalline form is cubic, the habit being of the pyritohedral type of hemihedrism, very similar to the various members of the pyrites group, in which an atom of iron, nickel, or cobalt, is united to two atoms of sulphur, arsenic, or antimony. The forms generally developed are the cube $\{100\}$, octahedron $\{111\}$, pyritohedron $\pi\{210\}$, and occasionally the rhombic dodecahedron $\{110\}$. It is very curious that in the treatment with aqua regia, the cube and octahedron faces remain unattacked, while the acids exert a decided action upon the pyritohedral (pentagonal dodecahedral) faces, entirely destroying their power of reflecting light. This similarity between sperrylite and the pyrites of the iron group is rendered all the more important in view of the fact that the platinum and iron groups both occur in the same vertical row (the eighth) in Mendelejeff's periodic classification.

WE referred last week to a proposal for a Meteorological "Congress," to be held in Paris during this year. It should be clearly understood that the meeting in question has originated with the French Meteorological Society, in connection with the Exhibition of 1889, and is quite distinct from the meetings organized by the Committee appointed by the Congress of Rome. This Committee, as stated in Mr. Scott's letter (NATURE, vol. xxxviii. p. 491), has decided to convene a meeting of directors of the meteorological services, at some future time, instead of an official Congress, such as those held at Vienna and Rome; but no such meeting has been arranged by the Committee for the year 1889.

THE Weekly Weather Report issued by the Meteorological Council has been enlarged and considerably improved with the new year. The statistical pages remain unaltered: they refer exclusively to the temperature, rainfall, and sunshine within the United Kingdom. The other portion, which until the end of last year consisted of a brief summary of the weather for each day, accompanied by copies of the daily charts of pressure and temperature over North-Western Europe, has undergone a great change. The area of the charts has been extended so as to cover the whole of Europe, the Mediterranean, Tunis, and Algeria, the hours represented being 8 a.m. for temperature and weather, and 8 a.m. and 6 p.m. for barometer and wind. The enlargement has necessitated the addition of two pages to the Report, the whole forming a most interesting record of the weather over this wide area. The first number is chiefly remarkable for the view it gives us of the Continental anticyclone which spread from Moscow, where the barometer exceeded 31 inches, westward to the Atlantic; the changes in position and intensity being in sympathy with the movements of cyclonic disturbances in the Mediterranean and in the Arctic regions. Towards the close of the week the decreasing intensity of the high-pressure system became favourable to cyclonic weather on our own shores, which afterwards completely dispelled the thick fogs and severe frost. The great cold felt in this country belonged to the same area as that which spread over the Continent, the thermometer being as much as 20° below zero at zero, and gradually rising thence to the shores of the Atlantic.

THE Report of the Smithsonian Institution for the year 1887–88 has been issued. The Secretary, Prof. Samuel P. Langley, refers, as was to be expected, in terms of the highest appreciation, to the character and work of his predecessor, Prof. S. F. Baird. The Institution, as usual, has been doing much excellent work, but Prof. Langley complains that the funds at its disposal are not adequate to its wants. The amount bequeathed by Mr. Smithson, and accepted by Congress, is no longer so valuable as it was half a century ago. "I do not now refer," says Prof. Langley, "merely to the fact that we measure all things by another scale in 1888 from what we did in 1836; or that, owing to the immense increase of public wealth, the capital of the original bequest, which then was greater than any but a few private fortunes, has become relatively so inconsiderable to-day. More than this is meant. It is meant that the actual purchasing power of each dollar is, for our purposes, notably less; that it is being forced upon us that we cannot print as many books, or pay as many *employés*, or make as many researches, as when the scheme of expenditure was first fixed, and that, consequently, a scheme which was wise then, because not only desirable but feasible, is not necessarily so now." Prof. Langley expresses a hope that an increased income may be provided by the Government and by private benefactors.

WE have received the "Bibliography of Astronomy for the Year 1887," compiled by William C. Winlock, and published by the Smithsonian Institution. As a reference list it will be found to be very useful. Most of the various contributions to astronomy published during the year 1887 in the many scientific journals and Transactions of Societies, as well as many more elaborate publications, have been inserted. A few of the titles, as the author says, have been taken from reviews or book-catalogues, and, by means of an alphabetical arrangement of the different subjects of astronomy, references to them can be very easily obtained.

TWO weeks ago we printed a brief account of a method employed by Prof. Pickering for enumerating nebulæ photographed in a given part of the heavens, and comparing them with those given in pre-existing catalogues, and by this means increasing the number of known nebulæ. The following is a rather more detailed account of the subject. The region selected for these experiments extends from 5h. 10m. to 5h. 50m. in right ascension, and from – 10° to 5° in declination. The instrument employed was a Bache telescope, having a photographic doublet, with an aperture of 8 inches and a focal length of 44 inches; and, by means of this, negatives 10° square were obtained, the definition included in a central circular area of 7° in diameter being very good. The work of examining the plates very carefully was intrusted to Mrs. Fleming. Each plate was laid on an inclined plane similar to a retouching desk used in photography, and, by means of a strong magnifying glass, thoroughly studied. Whenever a marking on the negatives appeared to resemble a nebula, the co-ordinates of it were accurately noted, but great care was taken to make sure that the marking was not due to a piece of dust or a defect in the film. The approximate right ascensions and declinations of these objects were next determined from the configuration of the adjacent stars on the charts of the *Durchmusterung*. Then, by comparing the measurements obtained on the plates, and those on the charts, several of the markings coincided, thereby showing that they had been both photographed and catalogued, while in some cases those which had been catalogued had not been photographed, and in other cases some not catalogued were photographed. From the twenty-seven negatives taken fourteen of the objects on them were contained both in the photographs and in the catalogue. Four in the catalogue were not photographed, while twelve, which were not catalogued, were detected on the negatives, and so were probably new. In some instances the back of the plate was covered with a film of shellac and lampblack so as to absorb the light from the rear surface of the plate. The region covered in the above experiments was about four thousandths of the entire sky, so that by photographing the whole heavens a great number of new clusters and nebulæ would be brought to light. From these experiments a very interesting result is disclosed, especially as regards the four nebulæ which were in the catalogue and were not photographed, which suggests that these nebulæ gave different spectra in the ultra-violet from those that were photographed and not catalogued

WE have received Part 4, vol. ii., of the Journal of the College of Science, Imperial University, Japan. It contains papers on the determination of the thermal conductivity of marble, by Kenjirō Yamagawa; on the combined effects of torsion and longitudinal stress on the magnetization of nickel, and on the magnetization and retentiveness of nickel wire under combined torsional and longitudinal stress, by H. Nagaoka; and on the specific volume of camphor of borneol, by Mitsuru Kuhara.

A DESCRIPTIVE Catalogue of the Sponges in the Australian Museum, Sydney, by Dr. R. von Lendenfeld, has been printed by order of the trustees of that institution. Dr. Lendenfeld was intrusted with the compilation of this work in 1885. Early in the following year he changed his residence from Sydney to London, so that some delay was rendered inevitable. He considers, however, that the loss of time was amply made up by the advantage he enjoyed of being able to study the collections in the British Museum, and to compare the types of other authors with the Australian Sponges.

THE Executive Committee for the reception of the British Association on their visit to Bath met on Thursday last, when it was announced that, after paying all expenses, there remained a surplus of £950. It was decided, with one dissentient, to recommend to the subscribers that the balance be retained intact to form the nucleus of a fund for building an art gallery in Bath.

A FEW weeks ago (says the *Cheltenham Examiner*), Mr. Francis Day, of Kenilworth House, Pittville, presented a fine collection of Indian birds to a Museum at Cambridge. Mr. Day has now given the remainder of his zoological collection to the British Museum. The gift consists of about 1500 specimens of Indian fishes, 500 of which are stuffed, and the remainder preserved in spirit. There are also a large quantity of English fishes, both stuffed and in spirit; about 1000 specimens of Crustaceans, collected from all parts of India and Burmah, and some British Crustacea, including some from the collection of Prof. Malm. Among the Indian fishes are specimens from the celebrated collection of Dr. Jordan, and the British fishes include especially interesting hybrid *Salmonidæ*, from Sir James Maitland's fish-farm at Howietoun in Scotland, in which Mr. Day takes great interest. There is, in addition, a miscellaneous collection of zoological specimens from the East, including a large crocodile.

THE following arrangements have been made at the Royal Institution of Great Britain:—On Tuesday next, January 22, Prof. G. J. Romanes will begin the second part of his course of lectures entitled "Before and after Darwin," the subjects being "The Evidences of Organic Evolution and the Theory of Natural Selection." On Thursday next, January 24, Prof. J. W. Judd, F.R.S., will begin a course of four lectures on "The Metamorphoses of Minerals." At the first Friday evening meeting of the season, January 25, at 9 p.m., Prof. G. H. Darwin, F.R.S., will give a discourse on "Meteorites and the History of the Stellar Systems."

THE evening lectures at the Royal Victoria Hall for the next few weeks are arranged as follows:—January 22, Mr. J. D. MacClure, "Shooting Stars"; January 29, Mr. F. W. Rudler, "Coal"; February 5, Prof. Reinold, "Torpedoes"; February 12, Commander Cameron, "Africa and the Horrors of Slavery."

THE additions to the Zoological Society's Gardens during the past week include a Vulpine Phalanger (*Phalangista vulpina* ♂)

from Australia, presented by Mr. F. Buckland; a Common Paradoxure (*Paradoxurus typus* ♀) from India, presented by the Rev. J. De Gruchy; a Tawny Owl (*Syrnium aluco*), European, presented by Mr. T. Gunn; a Stump-tailed Lizard (*Trachydosaurus rugosus*) from New Holland, presented by Mr. C. Elliot; a Grey Ichneumon (*Herpestes griseus*) from India, presented by Mr. C. L. Curtis; a Bonnet Monkey (*Macacus sinicus* ♀) from India, two Red-backed Pelicans (*Pelecanus rufescens*) from West Africa, a Masked Parakeet (*Pyrrhulopsis personata*, yellow var.) from the Fiji Islands, deposited; five Clotbey's Larks (*Ramphocorys clotbeyi*), five Algerian Shore Larks (*Otocorys bilopha*), two Rosy Bullfinches (*Erythrospiza githaginea*) from Algeria, purchased.

ASTRONOMICAL PHENOMENA FOR THE WEEK 1889 *JANUARY* 20–26.

(For the reckoning of time the civil day, commencing at Greenwich mean midnight, counting the hours on to 24, is here employed.)

At Greenwich on January 20

Sun rises, 7h. 56m.; souths, 12h. 11m. 24·4s.; sets, 16h. 26m.: right asc. on meridian, 20h. 11·7m.; decl. 20° 1′ S. Sidereal Time at Sunset, 0h. 27m.

Moon (at Last Quarter January 24, 16h.) rises, 19h. 0m.*; souths, 2h. 29m.; sets, 9h. 45m.: right asc. on meridian, 10h. 27·3m.; decl. 13° 31′ N.

Planet.	Rises.	Souths.	Sets.	Right asc. and declination on meridian.	
	h. m.	h. m.	h. m.	h. m.	° ′
Mercury..	8 42 ...	13 12 ...	17 42 ...	21 12·5 ...	17 44 S.
Venus.....	9 37 ...	15 7 ...	20 37 ...	23 7·3 ...	6 31 S.
Mars	9 24 ...	14 41 ...	19 58 ...	22 42·2 ...	9 11 S.
Jupiter....	5 50 ...	9 46 ...	13 42 ...	17 45·7 ...	23 3 S.
Saturn....	17 55*...	1 26 ...	8 57 ...	9 24·1 ...	16 26 N.
Uranus ...	0 0 ...	5 23 ...	10 46 ...	13 22·2 ...	7 59 S.
Neptune..	12 7 ...	19 50 ...	3 33*...	3 51·2 ...	18 25 N.

* Indicates that the rising is that of the preceding evening and the setting that of the following morning.

Meteor-Showers.

	R.A.	Decl.	
Near κ Ursæ Majoris ...	134° ...	48° N.	
From Coma Berenices ...	180 ...	24 N. ...	Swift; streaks.

Variable Stars.

Star.	R.A.	Decl.		h. m.	
	h. m.	° ′			
U Cephei	0 52·5 ...	81 17 N. ...	Jan. 23,	20 52	*m*
S Persei	2 14·9 ...	58 5 N. ...	,, 26,		*M*
Algol	3 1·0 ...	40 32 N. ...	,, 21,	23 17	*m*
			,, 24,	20 6	*m*
λ Tauri...	3 54·6 ...	12 11 N. ...	,, 25,	1 18	*m*
ζ Geminorum ...	6 57·5 ...	20 44 N. ...	,, 22,	23 0	*M*
R Canis Majoris ...	7 14·5 ...	16 11 N. ...	,, 20,	20 17	*m*
		and at intervals of		27 16	
T Hydræ	8 50·3 ...	8 43 S. ...	Jan. 20,		*M*
W Virginis	13 20·3 ...	2 48 S. ...	,, 22,	22 0	*m*
V Boötis	14 25·3 ...	39 21 N. ...	,, 20,		*M*
R Boötis	14 32·3 ...	27 13 N. ...	,, 22,		*M*
T Vulpeculæ ...	20 46·8 ...	27 50 N. ...	,, 21,	1 0	*m*
			,, 22,	3 0	*M*
Y Cygni	20 47·6 ...	34 14 N. ...	,, 21,	5 40	*m*
		and at intervals of		36 0	
δ Cephei	22 25·0 ...	57 51 N. ...	Jan. 23,	4 0	*M*
			,, 26,	22 0	*m*

M signifies maximum; *m* minimum.

GEOGRAPHICAL NOTES.

The following letter from Mr. Stanley to Tippoo Tib has been received in Brussels:—"Boma of Banalya-Murenia, August 17, to the Sheik Hamed Ben Mahomed [Tippoo Tib] from his good friend, Henry Stanley. Many salaams to you. I hope you are in good health, as I am, and that you have remained in good health since I left the Congo. I have many things to say to you but I hope I shall see you face to face before many days. I reached this place this morning with 130 Wangwana, and three soldiers and sixty-six natives belonging to Emin Pasha. This is now the eighty-second day since we left Emin Pasha on the Nyanza, and we have only lost three men all the way. Two of them were drowned, and the other ran away. I found the white men whom I was looking for. Emin Pasha was quite well, and the other white man, Casati, was quite well also. Emin has ivory in abundance, cattle by thousands, and sheep, goats, fowls, and food of all kinds. We found him to be a very good and kind man. He gave numbers of things to all our white and black men, and his liberality could not be exceeded. His soldiers blessed our black men for their kindness in coming so far to show them the way, and many of them were ready to follow me at once out of the country. But I asked them to stay quiet a few months that I might go back and fetch the other men and goods I had left at Yambunga, and they prayed to God that he would give me the strength to finish my work. May their prayer be heard. And now, my friend, what are you going to do? We have gone the road twice over. We know where it is bad and where it is good, where there is plenty of food and where there is none, where all the camps are and where we shall sleep and rest. I am waiting to hear your words. If you go with me it is well. If you do not go it is well. I leave it to you. I will stay here ten days, and then I go on slowly. I move from here to a big island two hours' march from here, and above this place there are plenty of houses and plenty of food for the men. Whatever you have to say to me my ears will be open with a good heart, as it has always been towards you. Therefore if you come, come quickly; for on the eleventh morning from this I shall move on. All my white men are well; but I left them all behind, except my servant William, who is with me.—(Signed) Stanley." This letter, which was brought by a messenger to Stanley Falls, reached Brussels by post on Tuesday evening, and is the only one from Mr. Stanley which has reached the coast. The remainder of the letters brought by the messenger remain at Stanley Falls, and will arrive in Europe two or three months hence.

Another of the few remaining mysteries of African geography has just had a little light shed upon it. For many years a lake has been conjecturally placed upon our maps some 15° to the east of the Cameroons, under the name of Liba. No white traveller has ever seen it. Quite recently, however, Dr. Zintgraff, who has been exploring in the Cameroons interior, has obtained information from some natives of the region in which Lake Liba is placed, that leads him to the conclusion that the so-called Lake Liba is probably only a lake-like expansion of a river of that name which exists in the country of his informants. Should the statements of the natives be confirmed, it would seem that the lake, or rather river, to which it belongs is connected neither with the Congo nor the Shari.

Further light has been thrown upon the important question of the supposed waterway between Macluer Inlet and Geelvink Bay, in New Guinea, the existence of which was reported by Captain Strachan. It appears that Dr. A. Meyer's explorations, the results of which seem incompatible with Captain Strachan's conclusions, have recently received important confirmation from the investigations of certain Dutch officials. Lieut. Ellis, who explored the north and north-east coast of New Guinea from May to November 1887, was unable to find the reported water connection, or to gain any information about it from the natives. His own investigations and the inquiries instituted by him force him to the certain conclusion that no such connection exists; and in this he is supported by the opinion of Dr. Host, another explorer.

Dr. Schweinfurth is at present engaged in exploring the little-known region of the Menakha Mountains. Towards the end of last year he left Aden for Hodeida, on the Red Sea, for the purpose of visiting these mountains and the town of Sana. Dr. Schweinfurth carried letters from the Porte recommending him to the care and protection of the authorities; and as he is liberally supplied with funds from Berlin, he hopes to make a thorough exploration of the district, which has been but little visited by Europeans.

The number of the *Zeitschrift* of the Berlin Geographical Society containing the geographical bibliography of the past year has just been issued. As usual it contains a practically exhaustive list of all publications, papers, and maps that have appeared in the various departments of geography.

THE STRASSBURG BOTANICAL INSTITUTE.

IN the American *Botanical Gazette* for December 1888 (vol. xiii. No. 12) there is a paper by Mr. William R. Dudley on the Botanical Institute at Strassburg. This paper is valuable and interesting as showing the sort of provision for botanical study that is thought right and necessary in Germany. The Institute forms part of the new University buildings of Strassburg. Mr. Dudley gives plans of the ground floor and first floor, and from these it appears that a considerable portion of the building is reserved as a residence for the Director and his family, and that two rooms are allotted to the Director's assistant, usually a young man who has recently taken his degree as a doctor. On the ground floor, besides the living-rooms, are a larger and smaller lecture-room, a "*Lehrsammlung*" or illustrative museum, and a "preparation-room," which is used in the preparation of lectures, and is also found useful by those who wish to carry on work in connection with the museum. On the first floor a large part of the space is given up to laboratories. It includes also an herbarium, a library, a weighing-room, a chemical-room, a dark room, and a small greenhouse.

After some introductory statements, Mr. Dudley continues as follows:—

No doubt the architect who designed this building is accountable for cutting it up into symmetrical squares; any German architect who failed in this would be sure to die unhappy. Nevertheless, for the sequence of the rooms and for the details, De Bary was responsible, and, taking everything into consideration, it is considered in Germany their best single laboratory for botany.

Its chief characteristics are the abundance of all necessary appliances and apparatus, cleanliness and orderly disposition of all its supplies, good light from huge windows and white wall-surfaces. Wall-cases are numerous, and the contained glassware, reagents, &c., nicely arranged. Drawers are abundant—this one containing only reagent tubes, that glass plates, another pipettes, burettes, &c. Running water is convenient, of course, and distilled water and three grades of alcohol where they can be readily obtained by students if necessary. There are several sterilizing boxes in the large laboratories; also constant-temperature boxes provided with thermostats. The chemical-room is provided with a hood for fumes and for the steam generated by the steam sterilizing cylinders. Gas is provided at each table, and a separate room is set apart for delicate instruments, such as balances. Indeed the association and dissociation of rooms and apparatus, the conveniences, the absence of unnecessary things and showy effects, indicate the intelligence and discernment of a worker and a master.

The tables are broad, very heavy, and designed so as to prevent warping or seaming. They are convenient for two beginners or a single special student. Each person is provided, at the outset, with about a dozen common reagents and fluids. The microscopes for laboratory use are chiefly Hartnack. Most of the private microscopes in the laboratory at the time I was there were from Seibert, an excellent Wetzlar manufacturer, not well known in America, and one or two from Zeiss. The stock of reagents in the cases is large, and, if necessary, new ones will be cheerfully ordered. The University requires of special students working every day in the laboratory, a payment of fifteen dollars, which covers all necessary expenses.

Strassburg University had about 1000 students during the winter semester of 1887-88, and 104 professors, *privat-docents*, and assistants. It is, therefore, neither one of the largest, nor one of the smallest, of Germany's twenty-one Universities.

The Botanical Laboratory had six advanced and five beginning students, and I do not think the number was affected by De Bary's illness. To instruct or counsel these were four instructors: the Professor; the associate Professor, Dr. Zacharias; the *privat-docent*, Dr. Wortman; and the assistant, Dr. Jost—all contributors, in a greater or less degree, to science, and of course well-trained men. At least three of the advanced students were working quite independently during De Bary's illness, although it was the latter's custom to inquire nearly every day after the work of the advanced students, when he was in health. But the German Government, which employs and pays these instructors, is not afflicted with that particular kind of malaria which enters into the management of almost every American institution, and gives it alternate chills and fever over fall and rise in numbers. Numbers are a matter of indifference to it. A very distinguished German Professor once said to me: "The truth is, we teach whatever we please, we do as much or as little as we please, and the Government does not interfere with us." Yet these men teach enthusiastically, and accomplish in scientific research ten times as much as the American Professor, who is "personally conducted" by a whole Board of Trustees. The German Government *does* "personally conduct," however, in certain very important matters. In the first place, it provides a suitable *corps* of assistants, and makes it sure, therefore, that the Professor has *not* too great a burden of teaching on his hands. It provides ample appropriations; it appoints its Professors for merit, and it sends up its students from the secondary schools with an excellent and uniform training.

The advanced students were mostly engaged in bacteriological investigations, although one was working out certain biological questions of fern development. Prof. Zacharias was engaged in histological work, Dr. Wortman in physiology, and Dr. Jost completed a paper during the winter on the morphology of certain mistletoes.

In the "*Lehrsammlung*" are numerous beautiful preparations, some made by De Bary, and at once recognizable as the originals of well-known figures in his published works; and some by former pupils, some of whom are now famous men. These preparations are frequently used in illustrating the lectures, all of which were held late in the afternoon or in the evening.

The herbarium collection is not relatively large, and is situated rather remote from the other rooms. Had De Bary been a systematist, he would, no doubt, have placed his herbarium centrally. Instead, the large laboratories, the rooms which have seen so many distinguished investigators, and witnessed so many scientific discoveries under the guidance of the great Director, are the rooms around which the others are clustered.

The library, stocked with a fairly good number of the important serials, together with a few standard works in the principal departments of botany, is placed nearer the laboratory; and in this, every Monday evening, meets the "Botanical Colloquium," made up of the advanced students of the laboratory and the instructors. Certain members give carefully prepared abstracts and reviews of the current botanical literature, which are followed by spirited discussions. After an hour or more of arduous and profitable labour of this kind, by means of which each member is enabled to keep quite abreast of advanced lines of work, they adjourn to a more convivial place, and spend the remainder of the evening in the relaxation natural to the German. By eleven o'clock all their vast learning, and especially the hard facts of the recent Colloquium, are in a state of saturated solution, and by next morning are quite ready for use.

INDUSTRIAL EDUCATION.

MAY I ask you to publish and invite criticism on the inclosed Bill, which has been read a first time in the Kensington Parliament? It is put forward as not antagonistic to, but rather as including (see Clause 8), the academic schemes of technical education with which we are familiar. I write as one who was at a primary school, who has worked at the bench, who has great reason to be grateful to the Science and Art Department, who has been a master at a public school, a manager of works, and an employer of labour. JOHN PERRY.

10 Penywern Road, South Kensington, S.W.,
December 28, 1888.

A Bill for Technical Industrial Education.

Whereas it is expedient to make provision for Technical Industrial Education in England and Wales:

Be it therefore enacted, &c.

(1) This Bill may be cited as the Technical Education Bill 1889, and shall not extend to Scotland or Ireland.

(2) "Apprentice" means any boy of less than 18, or any girl of less than 17 years of age employed, whether under indentures or not, in any place which, under the Factories or Workshops Acts, is denominated a factory or workshop, or in any warehouse, shop, office, or other place of business, or for wages, or other remuneration, in any place of employment. But apprentice so defined shall not include any menial or

domestic servant. "Master" means the employer of any apprentice as hereinbefore defined.

"School Authority" means the School Board exercising jurisdiction in the district in which the place of employment is situated, or any elected body which may take over the powers of such School Board; and in places where there is no School Board, it means the County or Borough Council under the Local Government Act, 1888, or the Municipal Corporations Acts.

"Technical Education" is an education in the scientific and artistic principles which govern the ordinary operations in any industry.

"Technical School" means a place for technical education, whether established and maintained—

(*a*) By the School Authority, and open to all apprentices;

(*b*) By voluntary effort, and open to the apprentices of more than one master;

(*c*) Or by a master for his own apprentices.

"Inspector" means the Inspector of Factories in whose district the place of employment is situated, or if there be no such inspector, then the School Board Visitor for such district.

(3) The Education Department shall forthwith and from time to time prescribe regulations in conformity with the rules for the time being of the Science and Art Department, in the subjects in respect of which Parliamentary grants are made by the Science and Art Department, for the formation and instruction of classes of elementary school children who have passed the Fourth Standard, and thereupon the School Authority may form such science and art classes, and provide such instruction accordingly, and earn such grants, and may assign such grants to the teachers of such classes, or may otherwise provide for their remuneration.

(4) Every master shall provide each of his apprentices with technical education at a technical school.

(5) Every apprentice shall devote at least two hours a day, five days in the week, during working hours, to study at a technical school.

(6) The School Authority shall annually in January prescribe the time for such study, having regard to the usual working hours in places of employment in their district, and shall publish a table of the times so prescribed. A printed copy of such table shall be conspicuously exhibited by the master in every such place of employment in such positions for such times and in such type and form as the School Authority shall prescribe.

(7) The School Authority shall have power to establish and maintain such technical schools as may be necessary to accommodate and provide technical education for all apprentices in their district whose masters do not otherwise efficiently provide for the technical education of their apprentices. The master of each apprentice shall pay the prescribed fees for his tuition at such schools.

(8) The technical schools established and maintained by the School Authority may provide technical education for persons other than apprentices.

(9) The course of studies at such schools, and fees payable for the same, shall be prescribed from time to time by the School Authority, subject to the sanction of the Education Department.

(10) The inspector shall inform himself as to the sufficiency of the technical education given to apprentices in his district, and report thereon to the School Authority and the Education Department at such times and in such manner as they shall respectively prescribe.

The duties, powers, and penalties relating to the office of inspector, specified in the Factories and Workshops Act, 1878, shall be applicable to any inspector under this Act, and to any place of employment within the provisions hereof.

The inspectors shall be paid by the School Authority such remuneration for their services under this Act as the Education Department shall approve.

(11) All offences under this Act shall be prosecuted, and all fines under this Act shall be recovered on summary conviction before a Court of Summary Jurisdiction in manner provided by the Summary Jurisdiction Acts.

The provisions of the Factories and Workshops Act, 1878, and the Acts amending the same as to legal proceedings and appeals, shall be deemed to be incorporated in, and made applicable to, this Act.

The punishment for any offence under this Act shall be a fine not exceeding £5.

(12) The expenses of carrying this Act into execution shall be defrayed by the School Authority, who shall have power to provide for such expenditure by moneys raised, precepts issued, or rates levied under their powers. Separate statements of such expenditure shall be furnished annually to the Education Department.

ZOOLOGICAL NOTES FROM TORRES STRAITS.

CAUDAL Respiration in Periophthalmus.—At the Birmingham meeting of the British Association, in 1886, Dr. S. J. Hickson pointed out that the species of Periophthalmus which he had observed in the Celebes always rested with its tail immersed in water, although the body was out of the same. I do not know whether any experiments have been made on this fish, but I have made a few which tend to show that this remarkable animal largely respires by means of its caudal fin. The experiments were made on specimens obtained from a Mangrove swamp on the Island of Mabuiag (Jervis Islands), and may be summarized as follows:—A specimen totally submerged in the sea was perfectly well and lively after forty-two hours. A second specimen lived a day and a half in a vessel containing just sufficient water to keep the tail-fin submerged, but not enough for respiration by means of the gills. (It is possible that the fish would have lived longer, if the sea-water had been continually renewed.) Fish with the caudal fin coated over with gold size, when put in a vessel of sea-water, only lived, on an average, from twelve to eighteen hours, although they could utilize their gills for respiration; others kept under similar circumstances, but not anointed with gold size, lived a day or two, apparently in perfect health. On submitting the caudal fins to the microscope, the circulation of the blood appeared to be exceptionally vigorous. I hope to be able to further test these observations on a future occasion.

The Employment of the Sucker-fish (*Echeneis*) *in Turtle-fishing.*—The only two references to the employment of the sucker-fish in turtle-fishing which I have by me are those in Dr. Günther's "Introduction to the Study of Fishes," and the "Narrative of the Voyage of H.M.S. *Rattlesnake*," by J. Macgillivray. The latter (vol. ii. p. 21) states that he was informed that the natives of Morulug (Prince of Wales Island), Torres Straits, catch a small species of turtle in the following manner:—"A live sucker-fish (*Echeneis remora*), having previously been secured by a line passed round the tail, is thrown into the water in certain places known to be suitable for the purpose; the fish while swimming about makes fast by its sucker to any turtle of this small kind which it may chance to encounter, and both are hauled in together!" Dr. Günther (*l.c.* p. 461) throws doubt upon the habitual utilization of the *Echeneis* for this purpose. In the Straits there are two periods for turtle-fishing, the one during October and November, which is the pairing season, and when turtle are easily speared owing to their floating on the surface of the water; the other, during the remaining months of the year when the turtle frequent the deeper water and the channels between the reefs. It is then that the sucker-fish—or, as the natives term it, "Gapu,"—is utilized. I have, at present, no means of determining the species of *Echeneis* common in the Straits. I believe it to be *E. naucrata*, as the species here attains a greater length than *E. remora*. When going out turtle-fishing, a Gapu is caught, and the more experienced natives have no great difficulty in procuring one when it is required. A hole is made at the base of the caudal fin by means of a turtle-bone, and the end of a very long piece of string is inserted in the hole and made fast. The end of a second, quite short, piece of string, is passed through the mouth and out by the gills. By means of these two strings the fish is retained, while slung over the sides of the canoe, in the water. When a turtle is sighted deep down in the water, the front piece of string is withdrawn, plenty of slack being allowed for the hind string. The Gapu on perceiving the turtle immediately swims towards it, and attaches itself to the reptile's carapace. A man, with a long rope attached to an upper arm, dives into the water and is guided to the turtle by the line fastened to the Gapu's tail. On reaching the turtle, the man gets on its back, and passes his arms behind and below the fore-flappers, and his legs in front and below the hind-flappers. The man is then rapidly drawn up to the surface of the water bearing the turtle with him. On the arrival of the diver the Gapu usually shifts its position from the carapace to the plastron of the turtle. At the end of the day's fishing the Gapu is eaten. The natives have a great respect for the Gapu, and firmly believe the fish possesses supernatural powers. For example, when there is something the matter with the bow of the canoe, the Gapu is said to attach itself to the neck or the nuchal plate of the turtle; when the lashings of the outrigger to the thwart poles are insecure, the Gapu is believed not to stick fast to the turtle, but to continually shift its position; if the strengthening ties in the centre of the hold of the canoe are faulty, the Gapu is stated to attach itself to the turtle and then immediately to swim away. More than once I was told, "Gapu savvy all the same as man; I think him half devil." The sucker-fish is not used to haul in the large green turtle. I was repeatedly told that it would be pulled off, as the turtle was too heavy. The above information was gathered from several sources, and checked by means of much questioning.

Amphioxus.—A species of Amphioxus, apparently very similar to *A. lanceolatus*, was not uncommon at one spot at Mabuiag, at a depth of from 3 to 4 fathoms. A species of this animal is catalogued as follows by Mr. Krefft, in his list of "Australian Vertebrata, Fossil and Recent": "*Branchiostoma lanceolatum.* Dredged in Bass's Straits, by H.M.S. *Herald*, at a depth of from 10 to 12 fathoms." I am not aware whether it has been found elsewhere in Australian waters.

ALFRED C. HADDON.

Thursday Island, November 12, 1888.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—The Sedgwick triennial prize has been awarded to Mr. Alfred Harker, Fellow of St. John's College. The subject of the essay is "The Petrology of the Igneous Rocks associated with the Cambrian (Sedgwick) of Carnarvonshire."

SCIENTIFIC SERIALS.

IN the number of the *Journal of Botany* for December 1888, Mr. S. Le M. Moore has an interesting article on photolysis in *Lemna trisulca*, in which he contests some of Stahl's conclusions as to the effect of day and night on the relative positions of the chlorophyll-grains on the cell-walls. The remaining articles, both in this number and in that for January 1889, are chiefly of interest to geographical or systematic botanists. Messrs. Britten and Boulger's "Biographical Index of British and Irish Botanists" has now advanced as far as the letter G.

IN the *Botanical Gazette* for November 1888, Miss E. L. Gregory completes her account of the development of cork-wings on certain trees, the trees described in the present instalment being species of *Acer* and *Liquidambar*.

SOCIETIES AND ACADEMIES.

LONDON.

Royal Society, November 22, 1888.—"Report of Researches on Silicon Compounds and their Derivatives. Part I." By J. Emerson Reynolds, M.D., F.R.S., Professor of Chemistry, University of Dublin.

The present investigation was undertaken some years ago with a view to examine the action of the silicon haloids—but more especially of silicon tetrabromide—on various compounds containing nitrogen, as our knowledge of the relations of silicon and nitrogen is extremely limited.

It was ascertained at an early stage of the inquiry that the bromide of silicon is much superior to the chloride as a reagent with nitrogenized compounds, but since the bromide had apparently not been obtained in any quantity even by its discoverer, Serullas, considerable time had to be devoted to working out a method for the production of a sufficiently large supply of this material. The method adopted is described in the full paper.

In the purification of the crude tetrabromide a new *chlorobromide*[1] *of silicon* was discovered, which boils at 141° C. This proved to be the compound $SiClBr_3$, which was required to complete the series of possible chlorobromides of silicon.

The first group of nitrogen compounds subjected to the action of silicon tetrabromide included the primary thiocarbamide or sulphur urea, obtained by the author in 1869, and the allyl-, phenyl-, and diphenyl-thiocarbamides.

All these are shown to unite with silicon tetrabromide, and afford the highly condensed compounds—

$$(H_4N_2CS)_8SiBr_4,$$
$$(C_3H_5,H_3N_2CS)_8SiBr_4,$$
$$(C_6H_5,H_3N_2CS)_8SiBr_4,$$
$$((C_6H_5)_2H_3N_2CS)_8SiBr_4.$$

These are more or less vitreous solids, with the exception of the allylic compound, which is a transparent and singularly viscous liquid. All are dissolved and decomposed by water and by alcohol.

The action of alcohol on the compound $(H_4N_2CS)_8SiBr_4$ was studied in detail, and it was shown that not only do ethyl bromide, thiocyanate, and diethylic silicate result, but that the representatives of two new classes of thiocarbamide derivatives are formed.

The first of these is a beautiful *tetrathiocarbamide* compound whose formula proved to be—

$$(H_5N_2CS)_4NBr,$$

which may obviously be written—

$$(H_4N_2CS)_4H_4NBr.$$

This body separates from alcohol in fine masses of crystals resembling sea anemones in appearance, which melt at 173°–174°, and begin to decompose at 178°–180°. The synthesis of this substance was effected by heating ammonium bromide with thiocarbamide.

Several homologues of the above *tetrathiocarbamidammonium bromide* were produced by synthetic methods; some of these contain chlorine or iodine instead of bromine. The following are examples of the compounds found in the course of this part of the investigation:—

$$(H_4N_2CS)_4H_4NBr,$$
$$(H_4N_2CS)_4H_4NCl,$$
$$(H_4N_2CS)_4H_4NI,$$
$$(H_4N_2CS)_4(CH_3)H_3NBr,$$
$$(H_4N_2CS)_4(C_2H_5)_2H_2NBr,$$
$$(H_4N_2CS)_4(C_2H_5)_3HNCl.$$

By the action of silver nitrate on the tetrathiocarbamidammonium bromide the crystalline *dithiocarbamide* compound with silver bromide was obtained—

$$(H_4N_2CS)_2AgBr.$$

This was subsequently produced by the direct union of thiocarbamide with the pure silver haloid. The compound—

$$(H_4N_2CS)_2AgCl$$

was also obtained in fine crystals, as were other similar substances.

A *trithiocarbamide* compound is also formed during the action of ethyl alcohol on $(H_4N_2CS)_8SiBr_4$, but it is much more soluble than that which first separates. It is also crystalline, and its analysis and reactions lead to the formula—

$$(H_5N_2CS)_3Br,C_2H_5Br.$$

Hitherto only mono- and di-thiocarbamide derivatives have been known, but the results above stated in outline prove that tri- and tetra-thiocarbamide compounds are formed in presence of silicon tetrabromide and certain other agents, which latter form addition products with the condensed amide.

So far, cases were only dealt with in which silicon tetrabromide combined with nitrogenized groups without loss of its halogen. The next stage of the inquiry involved the investigation of certain interactions in which the tetrabromide loses *all* its halogen. One of the chief results obtained in that direction forms the subject of a separate communication.

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[1] The chlorine required for the production of this compound was derived from the crude bromine (which always contains chloride of bromine) used in preparing the tetrabromide.

Mathematical Society, January 10.—J. J. Walker, F.R.S., President, in the chair.—Mr. Basset made a few remarks on the steady motion and stability of dynamical systems.—Dr. Glaisher, F.R.S., gave several forms of expression of Bernoulli's numbers derived from the consideration of lemniscate functions.—The President (Sir J. Cockle, F.R.S., in the chair) read a paper on results of ternary quadratic operators on products of forms of any orders.—Mr. Jenkins communicated a note by Mr. R. W. Christie on a theorem in combinations.

EDINBURGH.

Royal Society, December 3, 1888.—A restatement of the theory of organic evolution, by Prof. Patrick Geddes. In the introduction to this paper Prof. Geddes gives to the four customary divisions of biology more general meanings. He considers that morphology, besides being a description of individual forms, deals with specific and generic ones. Taxonomy is thus the higher and more generalized morphology. Embryology includes the description of the development of species and genera in addition to that of individuals. Morphology and embryology, then, deal with the descriptions of the form, and the development of the form, not only of individuals but of races. Similarly, physiology is applied to the description of the functions of the individual, and also to those of species, genera, and higher groups. As the description of the relations of organs characterized the physiology of the individual, so that of interspecific adaptations is the physiology of the race. As morphology and embryology are related, so are physiology and ætiology. Ætiology gives the laws of variation of individual and race. It deals not merely with functions in a balanced state in the individual, and perfected adaptation between races, but also with the origin of both of these in the temperament of the unit organism, and of the sum of organisms. This question has to be separated from the deeper one of the origin of organismal temperament in the influence of environment or otherwise. The following diagram shows these relationships:—

	Structure.		Function.	
	Embryology.	Morphology.	Physiology.	Ætiology.
Group ...		Linnæus	Darwin	
Class ...			↑	
Order ...				
Genus ...				
Species ...				
Species unit (pair, &c.)			....	......>
Individual				
Organ ...				
Tissue ...				
Cell ...				

From this division of the field of biology, a clearer and more exact estimate of Mr. Darwin's position can be had. It is plain that the theory of natural selection, which Mr. Romanes rightly describes as rather that of "the origin of adaptations," is part of the higher physiology, or the relation of races to one another. It is thought by many that Mr. Darwin dealt with problems of ætiology—that he described the origin of the functions in the individual. But he openly deferred the consideration of the laws of variation, and confessed entire ignorance of them. He, indeed, at different times, had two impressions of the import of natural selection. Like others, he sometimes makes the mistake of thinking that an account of adaptations, which species acquire, explains their origin. At other times he clearly sees that there must be a science of variation—an ætiology—which shall tell of the origin of variations acted on by natural selection to form the raw material of adaptations. Both pre- and post-Darwinian writers have dealt with the explanations of variations as arising from temperament. The former have theorized in a general way; the state of their knowledge not allowing them to prove that variation is definite. This point of view must again be taken, and all recent results read from it. The object of the present paper is to show how this may be accomplished throughout the organic world, as the author has already done in finding a definite *rationale* of sex and reproduction. Prof. Geddes then took up the matter in detail for the vegetable world, under such headings as: inflorescence; floral structure; floral colour; the antithesis between floral and grassy types; variations in the leaf; thorns and spines; evergreens; corelations between the reproductive and vegetative systems. The classes of the animal kingdom were treated *seriatim*, the definite lines of variation being traced from the synthetic types in each. He next showed, and illustrated with masses of detail, that throughout a great number of species there are individuals with vegetative and others with reproductive diathesis; and similarly in every genus. Some species are more vegetative, some more reproductive in character; and so, further, of orders and large groups. The vegetative or self-maintaining activities are opposed to, and balanced by, the reproductive or species-maintaining ones. The history of the individual life, or of the development of the race, is a series of alternations between predominating vegetation with subordinate reproduction, and prevailing reproduction with diminished vegetation. The differentiation of sex, the development of parental care and of sociality, are the most obvious results of the reproductive, the race-maintaining diathesis; and these play at least as important a part in organic progress as struggle for individual advantage. In conclusion, Prof. Geddes contrasted his own views of the process of nature, as a materialized ethical process, with that of Prof. Huxley, expressed in his *Nineteenth Century* article, where he considers organic evolution an intellectual but not a moral process. A second paper is to follow, carrying out the argument into the ethical, social, and economic relations of humanity.

BERLIN.

Meteorological Society, December 4, 1888.—Dr. Vettin, President, in the chair.—Dr. Andries developed an original theory as to the constitution of the sun, by which he explained a large number of phenomena. During the discussion which ensued, the theory was attacked from various sides.—Prof. von Bezold made a report on Prof. Kiessling's book, "Untersuchungen über die Dämmerungserscheinungen" ("Researches on the Phenomena of Twilight"), after he had briefly alluded to the recent and more comprehensive work of the English Commission on the Krakatão eruption, which had appeared simultaneously with that of Prof. Kiessling. He pointed out that these two works complement each other, inasmuch as Prof. Kiessling had confined himself entirely to the optical phenomena arising out of the eruption, describing them fully, and illustrating them by physical experiments, while the Commission had dealt comparatively briefly with these phenomena.—Dr. Less spoke on falls of snow during high temperatures. On the morning of November 20 the temperature was 9° C.; it reached a maximum of a little over 11° between 9 and 10 a.m., and then fell irregularly with repeated showers of rain to about 3° C. At 9.45 a.m., when the temperature was above 11°, one of the watchers in the Meteorological Institute announced that he had observed some few flakes of snow falling with the commencing rain. Since the speaker could not find anybody from among his acquaintances who could confirm the above observation, he addressed himself to the public at large by means of the newspapers: he thus obtained very valuable and reliable reports, not only from various parts of Berlin, but also from outlying districts, of snow having fallen, either in solitary large flakes or in larger quantities, at temperatures as high as 9° to 11° C. Dr. Less had once before in this year (1888) observed the same phenomenon, on May 8, when the temperature of the air was 12° C. On going over the literature of this subject in the synoptic weather reports for Germany for the years 1876 to 1888, he came upon twenty-eight cases in which snow had fallen, either in larger quantities or as solitary flakes, when the temperature was above 5° C. He explained the formation of the snowflakes as the result of low-lying currents of air whose temperatures were much lower than those at the earth's surface. Out of the twenty-eight cases quoted above, eleven were accompanied by marked and wide-spread thunder during the ensuing twenty-four hours. This circumstance may be taken as supporting Sohncke's theory of aërial electricity, according to which the electricity during a storm results from the friction of drops of ice and water, and this can only take place when cold currents of air at comparatively low levels flow over warm, moist masses of air.

Physical Society, December 14, 1888.—Prof. von Helmholtz, President, in the chair.—Dr. Thiessen gave an account of experiments which he had carried out in order to measure the amount by which gravity varies at different heights. The method he employed was that of Jolly, but with the introduction of a modification, in order to eliminate the irregularities due to differences of temperature at the higher and lower stations. Scale-pans were attached to each arm of the balance—one close up to the beam, the other some distance below it—and the weight was interchanged between the pans, both at the upper and lower stations, thus eliminating the influence of differences of temperature and of any inequality of the balance. The upward force of the air had no influence on the results, notwithstanding the varying volumes of the weights used. The distance between the upper and lower scale-pans was 11·5 metres, and the weight used was 1 kilogramme. Twenty-four determinations were made, which gave as a result that the kilogramme, when in the lower pan, weighed 2·8 milligrammes more than when it was weighed in the upper pan. After making some corrections, and, among these, one necessitated by the fact that the weight in its lower position was 4 metres below the general surface of the earth, it was found that the weight of 1 kilogramme varies by 0·28 milligramme for each 1 metre of difference in altitude.—The President gave an account of a paper by Prof. Hertz, which he had yesterday communicated to the Berlin Academy. It contained a description of further experiments on electrodynamic waves, and their analogy with waves of light. Weak induction discharges between small metallic cylinders with rounded ends were employed, and a similar apparatus for the detection of the electrodynamic waves. The action was not propagated more than 2 or 3 metres through space; when it fell on a metallic surface it was reflected, interference phenomena were observed, and from these the length of half a wave was found to be 30 centimetres. When a metallic parabolic mirror, 1 metre across its opening, was placed behind the apparatus used to produce the discharge, the action was propagated to a distance of 8 metres; and the action was greatly increased when a second concave mirror was placed behind the receiving apparatus. When a conductor was interposed, the action ceased, while non-conductors allowed the waves to pass. By interposing perforated metallic screens, it was found that the waves are propagated in straight lines; the waves passed through a dry wooden partition. Polarization of the waves could be determined in several ways. When the receiver was placed at right angles to the apparatus producing the waves, no action between them could be detected, the vertically-produced waves not being picked up by the horizontally-placed receiver. When the two pieces of apparatus were placed parallel to each other, and a wooden cube, with a number of insulated metallic wire rings wrapped round it, was placed in the path of the electrodynamic waves, it produced the same effect as does a tourmaline plate on polarized light. When the wires were vertical—that is to say, parallel to the exciting apparatus—the action was not propagated through the cube; but it was, on the other hand, when the wires were horizontal. When the receiver with its mirror was placed horizontally, so that it did not record any action as reaching it, and the wire arrangement, described above, was placed in the path of the waves, no change took place in the receiver when the wires on the cube were either vertical or horizontal, but the receiver was affected when the wires were placed at an angle of 45°. The laws of reflection of electrodynamic waves at metallic surfaces were found to be the same as those for the reflection of light at plane mirrors. Finally, Prof. Hertz has determined the refraction which the waves undergo in a prism made of pitch, and finds that the refractive index of this substance for electric waves is 1·68.—Dr. Ritter demonstrated by experiments the action of the ultra-violet rays of light on electric discharges in accordance with the experiments of Hertz, Wiedemann, and Eberts.

STOCKHOLM.

Royal Academy of Sciences, January 9.—On the researches and studies made at the zoological station of the Academy at Christineberg in Bohuslan, during the past year, by Prof. S. Lovén. He gave an account of papers by Dr. Aurivillius on the disguise amongst the Oxyrhynchous Crabs, by Dr. Virén on a Nereid Annelid (*Nereis fucata, forma inquitina*), by Herr Lönnberg on cestodes in marine fishes and birds.—Researches on the periodic system of the elements, by Dr. T. R. Rydberg.—Baron Nordenskiöld exhibited some uncommonly large crystals of magnetic iron from the Nordstjerne mine near Vestanfors, and gave an account of some remarkable Swedish localities with crystallized magnetite. He also showed four meteorites, for the collection of the State Museum, received from the British Museum. Amongst these were (1) a sample of a small, highly-interesting block of iron, which fell near Rowton, in Shropshire, August 20, 1876; (2) a fragment of a meteorite which fell in Hisen, in Japan.—On some transcendents, which appear at the repeated integration of rational functions, by Dr. A. Jonquière, of Bern.—On natural etching figures and other phenomena of solution on beryllium, from Muovinsk, by Herr W. Peterson.—Researches on minerals from Fiskernæs, in Greenland, by Herr N. V. Ussing.—Mineralogical notes, II., 3-4, by Herr G. Flink.—Anatomical studies on Echidna, by Miss C. Westling.—On the dimorphism of the *Rhizopoda reticulata*, by Dr. A. Goës.—The insect fauna of Greenland; I. Lepidoptera and Hymenoptera, by Prof. Chr. Aurivillius.

BOOKS, PAMPHLETS, and SERIALS RECEIVED.

Memoirs and Memoranda in Anatomy, vol. i.: Cleland, Mackay, and Young (Williams and Norgate).—Molekularphysik, Erster Band: Dr. O. Lehmann (Williams and Norgate).—Thomas Jefferson and the University of Virginia: H. B. Adams (Washington).—Transactions of the Sanitary Institute of Great Britain, vol. ix. (Stanford).—Life Register (West, Newman).—Essai d'une Théorie du Soleil et des Étoiles Variables: A. Brester (Delft).—Industrial Education in the South: Rev. A. D. Mayo (Washington).—Kew Observatory, Richmond, Report for the year ending December 31, 1888 (Harrison).—L'Écoulement des Glaciers: Dr. A. A. Odin (Lausanne).—Arnold Toynbee: F. C. Montague (Baltimore).—Journal of Physiology, December (Cambridge).—Journal of Chemical Society, December (Supplementary Number) and January (Gurney and Jackson).—Himmel und Erde, 1 Jahrg. Heft 2, 3, 4 (Berlin, Paetel).—Annalen der Physik und Chemie, 1889, No. 1 (Leipzig, Barth).

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