If a star, in breaking up by fission, divided its different ingredients proportionally between its two constituents, it is easily shown (*Monthly Notices, R.A.S.*, June 1925) that the fainter constituent would be of earlier spectral type than the brighter. This arrangement prevails in many newly formed binaries, but not in all (cf. Leonard, *L.O.B.* 343, 1923), and it is clear that in many cases, as in that of Sirius already discussed, the more massive constituent must have kept an undue share of highly radiating material; an extreme case of this kind is provided by the sun and earth. The situation is consistent with the supposition that the highly radiating material is of exceptionally high atomic weight and is therefore left in the more massive star when the lighter one is formed by drawing off the outer layers of the original star. Newly created matter probably contains elements of

atomic weights far higher than any known on earth; it may even consist entirely of such elements. Our terrestrial elements are merely a residue of material which is practically non-transformable—dead ashes for the most part, although possibly the radioactive elements still retain some vestige of the powers of primeval matter. For one brief moment it seemed possible that cosmogony might teach us how to obtain almost boundless supplies of energy by the annihilation of quite insignificant fragments of matter, but this apparently is not to be. So far as we can at present see, Nature has arranged that the energy-producing elements shall be kept out of the reach of man; while he may watch the process of transformation going on in the stars, he will never be allowed to operate it himself. Whether this is to his advantage or disadvantage, who shall say?

The Relative Age of Rocks containing Fossils.

By Sir ARTHUR SMITH WOODWARD, F.R.S.

DURING recent controversies as to the evidence for the evolution of life in past ages, it has been stated that geologists arrange the fossil-bearing rocks in a "purely artificial" manner, not necessarily in the order in which they are found superposed. It has even been asserted that when the fossils occur in successive layers in an order which an evolutionist would say is the reverse of that expected, the rocks are assumed from this criterion alone to have been disturbed and turned upside down. The progressive development of life which a geologist recognises, indeed, is said to be imaginary and not proved by the observed order of superposition of the rocks.

Such statements are based on a complete misunderstanding of the facts. The science of geology originated, and the order of nearly all the principal layers of sedimentary rocks was first determined, on the unstable western edge of the continent of Europe. In this region from the beginning of geological time there have been frequently repeated downward and upward movements leaving records in sediments of the successive seas which overflowed and retreated. The sedimentary rocks have been tilted and their edges worn away in such a manner that their order, or relative age, is easily observed. Their succession in fact is so clear that it has been possible in several cases to follow the changes of material in one and the same layer—the sands and gravels which were deposited near the shore, the mud farther out, and the remains of calcareous skeletons forming limestone in the clear water of the open sea. As an illustration may be mentioned the lower Carboniferous deposits, which are open sea limestones in central England but gradually pass into estuarine sands and clays with beds of coal in the south of Scotland, where there are only occasional beds of limestone containing approximately the same fossils as the great marine deposits farther south. More than a century ago, when almost all naturalists believed in "special creation" and there were no accepted theories as to the order of "creation," the succession of the rocks in England and Wales was made out by William Smith from actual observation of their superposition. Later geologists merely elaborated

details, and made more extensive collections of fossils. Geologists on the present European continent found the same general succession in their several countries, only varied by local circumstances; some additional layers being intercalated in the typical British series, others omitted, and some being represented by different rocks. Allowing for the differences in sediment and its amount which would be deposited in different parts of the same sea and adjacent estuaries, the succession was discovered quite clearly by observations in the field.

It was not until the field-work was far advanced that the fossils were studied in detail and found to indicate distinct progress in the development of life on the earth. None but animals without a backbone have ever been found in the oldest fossiliferous rocks; fishes are known to have flourished long before any lung-breathing backboned animals; the cold-blooded amphibians and reptiles came successively before the warm-blooded birds and mammals; man appeared at the end. In several groups, too, fossils collected from rocks of which the relative age is definitely known from observation of the layers in the field, show that the lower grades appeared before the higher grades. This became evident so long ago as 1836, when Buckland in his *Bridgewater Treatise* remarked on the interest of the oldest known mammals from the Stonesfield Slate of Oxfordshire as belonging to the lowly pouched group of marsupials. He stated that "the analogies afforded by the occurrence of the more simple forms of other classes of animals in the earlier geological deposits would lead us to expect also that the first forms of Mammalia would have been marsupial."

When geologists began to study the marine fossil-bearing rocks in other parts of the world, especially North America, they discovered differences in detail, as might have been expected—differences both in sediment and in fossils. In all cases, however, where the order of superposition of the layers could be clearly observed, the succession of the various groups of fossils was proved to be essentially the same as in western Europe. Rocks containing approximately the same fossils in widely separated regions may not have been contemporaneous in formation; judging by the

distribution of life in the sea at the present day, they were probably not strictly contemporaneous. Always, this rule are comparatively local and in regions which show some signs of disturbance. Among the folded rocks of mountain regions, for example, the layers are sometimes overturned; while in districts where soft deposits have been squeezed by the passage of ice over them, they are sometimes broken up into patches which may be pushed together into heaps, not always in the original order.

The softness or hardness of a deposit is no criterion of its geological age, but depends merely on local circumstances. For example, on the coast of the Baltic Sea near Reval there is a soft clay which looks like a modern deposit; but it contains some of the oldest fossils characteristic of the Cambrian period, and it is shown in some places to be overlain by fossil-bearing limestones which prove that it is really of Cambrian age. Again, in Canton Glarus, Switzerland, there are hard slates of ancient aspect which are shown by their position to be of Tertiary age, and their contained fossil fishes much resemble those of which fragments occur in the Lower Tertiary clays and sands of south-eastern England. There can be no doubt that these two very different series of rocks are at least in part contemporaneous.

There must naturally be numerous gaps in the series of sea-deposited rocks in every part of a continental area, representing periods when the region was dry land or perhaps covered by water in which there was no sediment. Sometimes the elevation or depression of the land occurs without any tilting, and then, unless an old land-surface is marked by remains of vegetation (as in coal seams and in the fossil forest of the Isle of Purbeck and Portland), it can only be recognised by studying the fossils in the rocks above and below. In Morayshire, Scotland, for example, there is a thick regular series of sandstones, the lowest containing Devonian fishes, the uppermost Permian or Triassic reptiles, with no indication of the long coal period which rocks farther south

FIG. 1.—A series of sections of the Tertiary land and freshwater deposits containing fossil mammals in western North America, showing how one section can be correlated with another by noting the successive specially characteristic genera which are enumerated in the column to the right. After Henry Fairfield Osborn (Bull. U.S. Geol. Survey, No. 361, 1909).

however, when sections of the rocks can be studied, the various fossil-bearing deposits are found to be in the same order. The only apparent exceptions to prove to have intervened between the time of deposition of these two directly superposed sandstones. It is only after long and wide experience of the succession

of the rocks in different parts that such "deceptive conformities" can be detected.

It must, indeed, be repeated and emphasised that the whole succession of the marine fossil-bearing rocks in western Europe—the most favourable region in the world—had been clearly ascertained before the idea of organic evolution was accepted by geologists. Fossils were appropriately termed "medals of creation" and were merely used as time-markers in cases where the superposition of the layers was obscured. In spite of earlier discussions, it was only after the publication of Darwin's epoch-making work in 1859 that the meaning of the order in which fossils were known to occur became evident. Group after group was studied from the new point of view, and the study is still in progress. The result is complete confidence in the "evolutionary stages" of all groups of organisms as guides to the relative geological age of rocks which contain them in any part of the world.

This result is important because a large proportion of the land and freshwater deposits of the latest or Tertiary epoch are comparatively limited in extent and thickness, and completely isolated on continental areas which have scarcely been affected by movements since they accumulated. These contain the remains of the ordinary land mammals from their beginning until the present day; and the mammals exhibit the most striking evidence of descent from a common ancestry of any forms of life. At first, especially in North America, it is perhaps true that confidence in the general principles of evolution led to some reasoning in a circle. When collections were made in the terri-

ories of hostile Indians there was not much opportunity for detailed field observations. In later years, however, circumstances have improved and experience has been gained, and not only in North America but also in other countries fossil mammals have been collected from beds which have been definitely observed to repose one on another.

Furthermore, there has been much certain correlation by the deposits of one isolated area, as shown by the fossils, overlapping in time the deposits of another isolated area. In illustration of this, Prof. Osborn has published the accompanying diagram (Fig. 1), which explains itself. The general evolution of the horses and camels in North America has thus been revealed, not by assuming the relative age of the beds of different areas in which their fossil remains occur, but by actual correlations made by geologists in the field. Similarly, the relative ages of the primitive ancestors of the elephants in Egypt have been ascertained by examination of perfectly clear geological sections. So many observations of this kind have now been made in various parts of the world, that palæontologists have no longer any hesitation in determining the age of an isolated Tertiary deposit by the state of evolution of the fossil mammals which it contains. They are perfectly justified in doing so, in view of the definite geological evidence which is forthcoming in so great a multitude of cases.

The evolution of life as revealed by fossils is not, therefore, a phantom arising from excess of zeal in pursuing a fascinating idea. It is as strictly the outcome of purely inductive science as any other great generalisation.

Obituary.

MR. W. P. HIERN, F.R.S.

WILLIAM PHILIP HIERN, whose death took place at the Castle, Barnstaple, on November 29, was best known for his work on systematic botany. The son of J. G. Hiern, he was born at Stafford on January 19, 1839, and entered St. John's College, Cambridge, in 1857, where he graduated B.A. as ninth wrangler in 1861, proceeded to M.A. in 1864, and was a fellow of his college from 1865 until 1868. In 1868 he incorporated as M.A. at Christ Church, Oxford, about which time he became interested in botany, and in 1873 published in the *Transactions of the Cambridge Philosophical Society* a monograph of the Ebenaceæ. He then went to the Royal Botanic Gardens, Kew, where he worked out the Meliaceæ and Sapindaceæ for Hooker's "Flora of British India," and was responsible for the greater part of volume 3 of the "Flora of Tropical Africa" in 1877, the Umbelliferae, Araliaceæ, Rubiaceæ, Valerianaceæ and Ebenaceæ of which he worked out alone, and the Compositæ with Prof. D. Oliver.

A law suit, which had been commenced in 1873 by the King of Portugal against the executors of Dr. Friedrich Welwitsch, who had made botanical collections in Angola on behalf of the Portuguese Government, terminated in a compromise in 1875, and Hiern was appointed by the Court to separate a set and to copy the field notes on behalf of the British Museum. This he proceeded to do, and between 1896 and 1900 published in four parts a "Catalogue of the African Plants

collected by Dr. Friedrich Welwitsch in 1853-1861." This completed the account of the dicotyledons, and the remainder of the catalogue was published by members of the British Museum staff. In the *Journal of Botany* for 1895, pp. 139-141, he published a note on the "Plants of Welwitsch's Apontamentos." In conjunction with C. Ficalho he worked out a collection of African plants on which a report, entitled "On Central African Plants collected by Major Serpa Pinto," was published in the *Transactions of the Linnean Society* in 1881.

Having completed his work on the Welwitsch collection, Hiern again went to Kew, where he elaborated the account of the Scrophulariaceæ of South Africa, which in 1904 occupied pp. 121-420 of volume 4, part 2, of the "Flora Capensis," after which he found himself unable to undertake further work on African botany, which was offered to him at Kew. He then retired to Barnstaple and kept the botanical records for Devon, and published in the Botanical Exchange Club Report, 1918, p. 414, a "Clavis to Devonian Sedges," based on the structure of the stems and leaves. During this period he devoted his attention to public affairs and became a Justice of the Peace and County Alderman for Devon.

Mr. Hiern was elected a fellow of the Royal Society in 1903 and of the Linnean Society in 1873; he was also a corresponding member of the Royal Academy of Lisbon. He was a widower, and his only son died some years ago.

C. H. W.