

On the ASTERIIDÆ found fossil in British Strata. By EDWARD FORBES, Esq., F.R.S., Professor of Botany in King's College, London: Palæontologist to the Geological Survey of the United Kingdom.

DURING the course of the researches of the Geological Survey many remarkable fossil Radiata have been brought to light, some of which involve important considerations both geological and zoological. Of such of those as are most intimately connected with the older palæozoic rocks, I purpose to give a full account in this volume, more especially of the Asteriadæ and Cystidæ; tribes, which, so far as Britain is concerned, have hitherto attracted but little attention in the fossil state.

Not long ago, and until within a very few years past, it was supposed that true starfishes were animals whose appearance in the earth's seas dated from the Oolitic period at earliest. The few fossil species on record had been observed in secondary formations. Their relations with existing forms were uninvestigated, and, indeed, the scientific study of the latter had scarcely commenced. Within the last ten years, however, the attention of zoologists has been strongly directed towards the Echinodermata, and numerous memoirs, both physiological and systematic, have been published upon this interesting order of Radiata.

The structure, habits, and sources of character, generic and specific, of the existing starfishes having been lately extensively investigated, and a good basis for comparison attained, it is time to inquire into the history and generic relations of their fossil allies; the more so, as notices of not a few species are scattered through geological memoirs. Numerous undescribed species exist in collections, and good specimens of many recorded forms, of which slight fragments only have been described or figured. The inquiry is one of great interest, for through it we may hope to attain a knowledge of the earliest features of this important section of radiated animals; to ascertain whether the order as a whole has undergone material changes during its progression in time; whether the earlier forms were rudimentary or equal in perfection of organization with those now living; and whether we can obtain information respecting the conditions of climate or depth under which they lived in the several geological epochs. The last point is especially important, for as we know that the forms of existing Echinodermata have a distribution highly characteristic of regions and conditions in space, we may hope to find an analogical distribution of the fossil species in time.

Whilst a great part of the extinct Zoophyta closely approximate existing types, a large proportion even of the palæozoic species bearing no small resemblance to existing forms, the majority of the higher Radiata which have been preserved exhibit generic, and even sectional differences, separating them from their living allies. These differences are especially conspicuous among the Echinidæ and Crinoideæ. The older genera, and even tribes of the last-named group, became extinct before the epoch of the secondary rocks commenced, and in existing seas there are but few members of the crinoidal type. The group is essentially *chronomorphic*. The Echinidæ are doubtfully indicated as yet among palæozoic forms; but those of secondary formations frequently belong to genera, which have become extinct, and the development of which had an evident relation to points in time, for we find groups of species, presenting peculiar combinations of characters, limited entirely to a few consecutive formations. This centralization of a number of generic types in time among the Echinidæ, whilst the members of others range indifferently through vast epochs, is exactly analogous to the present distribution of sea-urchins, many of the genera of which are confined to limited zoological provinces, whilst the members of others are distributed all over the world.

The knowledge of these facts, and an erroneous and too hasty interpretation of them, led palæontologists to believe that the distribution of the starfishes in time was very limited, and had relation only to recent epochs. They were supposed to have been entirely absent during the Palæozoic epoch—an absence which, if true, would have formed one among the many remarkable negative characters which it apparently presents; but which, it seems to me, have been laid far too much stress upon, when we consider the slight acquaintance we have as yet with comparative geology. But a small portion of the earth's surface has as yet been examined with that minuteness which the palæontologist should require before he infers sweeping conclusions from negative facts. As well might the zoologist or botanist, having thoroughly explored one province, or even a connected group of provinces of distribution, draw from his researches general conclusions respecting the presence or absence of like beings with those which he has examined on other parts of the earth's surface, before they had been explored by competent persons. If many distant points be thoroughly examined, we may hope to come to tolerably correct inferences respecting the phenomena of life in the interspaces; and this is as true in time-investigations as in space-investigations: but in geology, until lately, our knowledge of the fossil faunas and floras of distant regions has been and indeed is still extremely limited, for the parts of the world best examined, viz., Europe and North America, have evidently, in a natural

history point of view, been portions of one province only—vast no doubt, but not vaster than some existing provinces of distribution recognized by those naturalists who have studied that important subject. Yet, this not having been borne in mind, speculations, presented as inferences from extensive series of facts, respecting the universal diffusion of species during the older epochs of the world's history; the evidence they afforded of an universal climate; the progression of organization in time; the development of higher forms from lower; the absence of great classes of organized beings; and the causes of that absence dependent on the existence of peculiar atmospheric or terrestrial conditions, have been rife in geology: and, though probably partially true, yet as the logical process by which many of them were arrived at is not quite clear, whilst the premises were often evidently insufficient, have led many able men, unacquainted with the certainties of our science, too hastily to regard geology as in great part a philosophical romance.

When we consider the enormous lapse of time which has rolled away since the earlier formations were deposited; the changes which have taken place on the earth's surface during the interval; the wear and tear which the hardest rocks must have undergone during their upheavals and depressions; the little that is preserved to us of sea-beds which have been extensively exposed during comparatively recent times, the wonder is, not that we can find no traces of the former existence of numerous tribes of creatures, members of which now live upon our earth and its seas, but that so many types of forms, simulating existing organisms, should be preserved at all as evidences of the most ancient past. It is from positive and not from negative evidences, then, that the palæontologist should draw his conclusions; unless when well-established laws, arrived at by naturalists from the careful study of the full and unmutated chapter of the present, have evidently so strong a relationship of analogy with the phenomena of the past as to warrant their safe application.

Organic remains make their first appearance in British strata abundantly and in considerable variety about the parallel of the Bala Limestone and sandstones and shales associated with it. Much below that geological horizon fossils occur, the oldest known forms appearing to be *Lingulæ*, members of a genus of brachiopodous molluscs, still represented by species which do not vary much in form from their most ancient allies and predecessors. But before the deposition of the Bala rocks, the evidences of life within our own area are comparatively scant. In America corresponding palæozoic phenomena have been described.

The first traces of the appearance of Asteriidæ occur in rocks of the Bala series, or even lower in the geological scale. They were first noticed by Professor Sedgwick, who found them in beds of corresponding

age in Cumberland, where they were also observed by Mr. Daniel Sharpe. The researches of the Geological Survey have brought to light similar fossils in the Bala rocks, near Bala, and in the ashy slates at Drumcannon, near Waterford, where they were found by Captain James. These latter beds probably correspond in age with the former. It is very remarkable that forms of starfishes strikingly similar have been discovered in the Lower Silurian strata of the United States.

The Cumberland, Welsh, and Irish starfishes all belong to one genus. After a very careful examination of all the specimens I have been able to procure (and, through the kindness of Professor Sedgwick and Mr. D. Sharpe, every facility has been afforded), I am induced to refer them to the existing genus *Uraster* (*Asteracanthion* of Müller and Troschel), members of which are at the present day the most abundant starfishes in the British seas and throughout the North Atlantic. The general aspect of the palæozoic starfishes must have been strikingly similar to that of the *Urasteriæ* now living. Indeed, impressions taken from the latter in clay would so closely resemble those which we find in ancient rocks, that the critical eye of a naturalist would be required for the definition of their specific distinctness. Nor does this arise through the obscurity or imperfections of such impressions, for the external characters, so far as contour and sculpture of surface, and even many points of structure, are very completely indicated in them, rude as they may seem.

As yet, with the exception of the instances already referred to, only one other instance of the discovery of a palæozoic asteriad has come to my knowledge, namely, that of a well-preserved species, apparently also belonging to the genus *Uraster*, by M. Thorent, in the "Terrains anthraxifères" of the department of l'Aisne. It is probable, however, that the progress of research will bring many more to light. In the older secondary strata not a few have been found, both in Britain and abroad. A doubtful form (*Asterias obtusa*) has been figured by Goldfuss from the Muschelkalk, who has also made known a true *Asterias* or *Astropecten* from the lias of Wurtemberg. Several species of *Astropecten* have been observed in the oolites of Yorkshire, and similar forms in corresponding beds in Germany, where *Urasteriæ* have also been found. A single example of a fossil *Luidia* has been made known from the marlstone of Yorkshire, and a *Goniaster* from oolitic beds in Germany. In the upper secondary (cretaceous rocks), numerous fossil starfishes have occurred, especially of the genus *Goniaster*. Representatives of *Oreaster*, *Astropecten*, *Asterina*, and *Arthraster* (n. g.), are also present in the cretaceous series. The few older tertiary starfishes with which we are acquainted belong to the genus *Astropecten*. Arguing from the analogy of their associates, there can be no question that starfishes were abundant in the tertiary seas. Yet how very rare

are the traces of their existence! In the later tertiary strata, the only evidence as yet procured of their presence during the deposition of those beds consists in a few minute fragmentary ossicula of *Urasteriæ*. Yet when we consider the gregarious habits of those starfishes, especially of the species to which the ossicula preserved in all probability belonged, it is very wonderful to mark the almost total disappearance of their exuviæ; and the fact should serve as a caution to those who would unhesitatingly infer the absence of a tribe of organized beings, especially of such as present few facilities for preservation, from the absence of their fossil remains. Even now, when dredging, we very rarely bring up any remains of dead starfishes, whilst the living animals are not only present in the locality explored, but often so abundant as to fill the bag of the dredge, to the exclusion of all other creatures.

Instead of confining this paper to an account of the palæozoic starfishes only, I have thought it desirable to embody in it a synopsis of all our British fossil species, and a notice of all foreign ones which which I am acquainted. This is the more necessary, as no connected account of the fossil Asteriadæ exists, and as the geologist has no text at present by which he may determine the species in his collection. This I could not have done but for the liberality of Mr. Dixon, of Worthing, in whose forthcoming work on the geology, &c., of Sussex, admirable figures are engraved of all the British cretaceous fossil starfishes, the original specimens of which have been submitted for my examination and description. In the course of this inquiry, I have, through the kindness of their possessors, examined the rich collections of Mr. Bowerbank and Mr. Toulmin Smith, and not a few fine specimens from the collections of the Marquis of Northampton, the Earl of Enniskillen, Sir Philip Egerton, and Mr. Stokes. I have especially to thank the Marchioness of Hastings for her kindness in entrusting me with the examination and description of a very interesting new marlstone form, one of many in her valuable cabinet. Through Mr. Charlesworth, and my colleague, Mr. John Phillips, I have also been enabled to complete our knowledge of the oolitic starfishes.

Most of the fossil starfishes described or noticed in geological works are given with the prefix *Asterias*, their describers contenting themselves with referring them to the old Linnæan genus, which has now assumed the rank of an order of Echinodermata. Agassiz, ever active and in advance, when, in his "Prodrome d'une Monographie des Radiaires,"* he endeavoured to marshal existing starfishes into scientific order, (previously meritoriously attempted with less success by Nardo)† endeavoured to reduce such fossil forms as were then upon record into the same ranks.

* Mem. Soc. Sc. Nat. Neuchatel, vol. i. 1835. † De Asteriis in Oken's Isis for 1834.

The invaluable memoirs of Müller and Troschel,* and their great work on the starfishes, omitted the consideration of the fossil species, a catalogue of which was published by F. Dujardin, in the third volume of the second edition of Lamarck's "Animaux sans Vertèbres," in 1840, but without subdivision of the species into genera. In Mr. J. E. Gray's "Synopsis of the Genera and Species of Starfish,"† reference is made to several British fossil species, and a genus (*Comptonia*) constructed for a greensand form. Professor Pictet, in his very useful "Manuel de Paléontologie," has followed Agassiz in his enumeration of the fossil species under various genera.

In the following synopsis, I have endeavoured to arrange all the fossil species under the genera to which they appear to belong. The palæozoic forms I have described as fully as the specimens will admit. Of all the others I have given diagnoses, or, where the materials were not sufficient, brief notices. Fuller descriptions of the British cretaceous species and admirable figures will be found in Mr. Dixon's work already referred to. Plates of the new palæozoic, oolitic, and tertiary forms will be issued by the Geological Survey, and are now in the engraver's hands. The lists of species are prefaced by notices of the characters of the genera to which they belong, especially such as are recognisable in fossil examples.

URASTER.

Asteracanthion, Müller and Troschel. *Asterias*, Gray.

The commonest starfishes in the British seas are members of this genus, distinguished from all others by the presence of four rows of tentacula or suckers in each avenue beneath the long more or less cylindrical arms. Although members of this genus are found in all parts of the globe, their abundance and predominance is certainly characteristic of the approach to the arctic or antarctic regions. In warm climates they are the exception; in cold, the rule. The reverse is the case in some other equally diffused genera, especially in the genus *Goniaster*. It is very remarkable, then, that all the true starfishes, hitherto discovered in a fossil state in the sedimentary deposits of the palæozoic oceans, appear to belong to this genus *Uraster*, whilst the majority of the cretaceous species belong either to *Goniaster* or to genera still more distinctly tropical in character.

All the Urasters have cylindrical and deeply cleft arms, the skeletons of which are composed of small irregular compressed ossicula, articulated with each other in a reticulated fashion. The disk is similarly composed, and is furnished with a minute vent. Both disk and arms are studded

* 'Über die Gattungen der Asteriden,' in Wiegmann's Archiv für Naturgeschichte for 1840, and 'System der Asteriden,' 1842.

† 'Annals of Natural History,' vol. vi. 1841.

with numerous short conical spines, either scattered singly, or grouped in a tuft-like fashion, and on the arms, whether single or fasciculate, arranged more or less distinctly in longitudinal series. The avenues on the under side of the disk and arms are rather wide, and are constructed of closely placed, compressed, more or less femur-shaped ambulacral ossicula, arranged in two series. The peculiar form of these ossicula depends on the peculiar organization of the genus, namely, the presence of four series of tentacula or suckers, a character on account of which *Uraster* is regarded as the type of a distinct family. As this character, so far as it is indicated by the ossicula, is quite preservable in fossilized starfishes, there can be little question that the following palæozoic forms, all of which present the necessary features of ambulacra and disk, are rightly referred to the genus in which I have placed them.

1. *Uraster obtusus*. F.

U. brachiis brevibus, convexis, lanceolatis, obtusis; longitudine brachiarum ad latitudinem disci ut 1.—1½: ossiculis ambulacralibus oblongis, latis, interstitiis linearibus; paginâ superiori reticulato-spinosâ.

A small species, with short obtuse convex arms, and a broad disk. Under surface exhibiting oblong rather broad ambulacral plates, decreasing slowly and nearly equal for two-thirds of the length of the arms. Avenues rather broad. Greatest diameter about an inch and a half.

This interesting form was first noticed in ashy slates at Drumcannon, county of Waterford, associated with *Phacops Jamesii*, and *Orthides*. I cannot distinguish from it a starfish found in the Bala rocks, at Moel y Garnedd, North Wales.

2. *Uraster primævus*. F.

U. brachiis brevibus, triangularibus, acuminatis, disco lato. Paginâ superiori tuberculatâ, reticulatâ (spinosâ? spinis obtusis fasciculatis?) ossiculis ambulacralibus oblongis, latis, geniculatis.

This species is of equal size and proportion of ray and disk with the *U. obtusus*, but the form of the rays is very different. The ambulacral plates are also of a different shape.

Westmoreland. [Lower Silurians.] Communicated by Professor Sedgwick and Mr. D. Sharpe.

3. *Uraster Ruthveni*. F.

U. brachiis teretibus, longissimis, angustis, subcarinatis; disco parvo; paginâ superiori reticulatâ, spinosa, spinis obtusis fasciculatis. Ossiculis ambulacralibus linearibus, longis, geniculatis.

The rays in this fine species are five times as long as the small disk is broad: they are rounded, tapering, linear-lanceolated, and sub-carinated. The upper surfaces of rays and disk are reticulated

apparently with tufts and spines. The under surface is marked by the impressions of a double series of ambulacral articulations, each of which is slightly curved. Large species are about three inches and a half in diameter.

Communicated by Professor Sedgwick from the Lower Silurians of Westmoreland, where it was first observed by Mr. John Ruthven.

4. *Uraster hirudo*. F.

U. brachiis lineari-lanceolatis, acuminatis, disco minuto: paginâ superiori reticulatâ, decussatâ (spinis fasciculatis, fasciculis spinarum seriebus longitudinalibus dispositis), ossiculis ambulacralibus oblongis, ambulacris latis.

Rays four times as long as the disk, which is extremely small. The arms are tapering and linear-lanceolate, acuminated at their extremities, contracted at their bases. The spinous bundles of the upper surface are arranged in very regular rows, so that each ray appears as if marked by three or four longitudinal furrows, crossed at regular intervals by transverse grooves. Under surface with short ambulacral plates and broad avenues. The largest specimens do not measure more than an inch across. The species is gregarious, and at first glance appears rather like an *Ophiura* than a true starfish.

In the Lower Silurians of Westmoreland. Communicated by Professor Sedgwick.

5. *Uraster rubens*. L.

Mr. Scarles Wood has found ossicula of starfishes in the crag which probably belonged to this well-known living species.

FOREIGN SPECIES.

In the Silurian rocks of North America, several starfishes, probably of this genus, and very possibly closely allied, or even in some cases identical species with the above, have been observed. As no specimens or figures have reached England, it is difficult to judge. The best information respecting them is contained in the following notice, extracted from descriptions of American Silurian fossils, by Mr. Hall, now in the course of publication:—

“*Asterias matutina*.

“Body small, with five radiating arms; arms elongated (length twice and a half the width of the body), teeth acute, composed of three rows of plates, which join above by their lateral margins. Beneath each lateral row of plates there is an inferior lateral range visible, having the sulcus beneath the middle row, which is often depressed. The dorsal plates are somewhat hexagonal,

those of the arms quadrangular; surface punctate or granulate, perhaps from the removal of the spines covering the surface.

“The specimen is considerably crushed, and two of the arms broken off at the base; the madriporiform tubercle upon the back is not visible in our specimen. From its condition, the structure cannot be entirely made out, but it is sufficiently clear to enable any one to recognize the species.

“Three specimens of this highly interesting species are known to me, two of which occur in the Trenton limestone of New York. It bears some resemblance to the one found in Cincinnati; but it would appear, from the figure and description of Professor Locke (Proceed. Acad. Nat. Sci., vol iii. p. 33), that it is a distinct species, being at least twice as large, with the centre proportionally larger, and the plates composing the arms smaller than in our species.

“The name (*Asterias antiqua*) given by Professor Locke, is already appropriated by Troost for a very distinct species, judging from his figure (Trans. Geol. Soc. Penn., vol. i. p. 232, pl. 10, fig. 9), and probably holding a higher geological position. Professor Troost also mentions (p. 235 of the work just cited), having “found five other species of free Asterites; one of them occurring in a lower stratum than that in which the *A. antiqua* is imbedded, and the four others in a higher situation: all, nevertheless, below the coal.” It is, therefore, quite certain that the genus *Asterias* existed during the deposition of the older Silurian rocks, in localities widely separated from each other, and also that the genus is represented by more than a single species.”

In the third volume of the Memoirs of the Geological Society of France, there is a paper, by M. Thorent, on the geology of the department of l’Aisne, in which he gives an account and figure (pl. xxii., fig. 7) of a starfish, evidently of the genus *Uraster*, from the “Terrains anthraxiferes” of that district. He names it *Asterias constellata*, and describes the rays as elongated, acute, and irregular. The figure is not very good.

Goldfuss has figured two oolitic starfishes, specimens of which are not uncommon in English collections, and which may be referred to the genus *Uraster*. Their general aspect is very different from that of the palæozoic species and much more tropical. These are, *Asterias lumbricalis*, the arms of which are terete, long, and linear; and *Asterias lanceolata*, which has lanceolate or petaloid arms, with linear extremities.

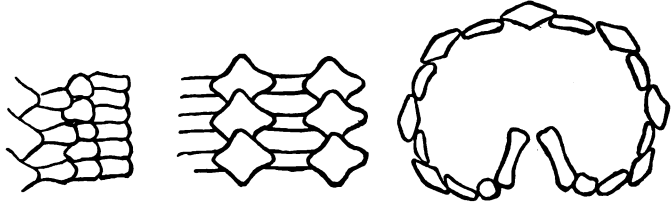
ARTHRASTER.

(*αρθρον*, a joint, *αστηρ*.)

Among the examples of fossil starfishes in the rich collection of Mr. Dickson, and figured by him in his forthcoming work, there is a very beautiful and comparatively well-preserved specimen of an extinct chalk form, generically new, but nearly allied to *Ophidiaster*. It con-

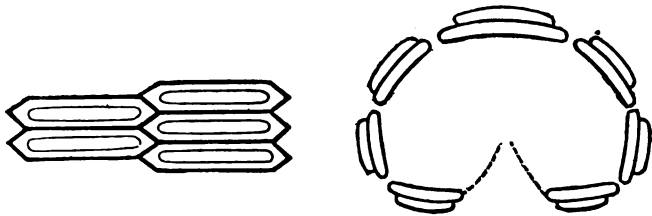
sists of the remains of several long and rounded arms, probably six or seven, radiating from a very contracted disk. The ossicula of which these arms are built are very compactly articulated together, and much fewer in number, besides being different in structure from the correspondent ossicula in *Ophidiaster*.

Fig. 1.



In *Ophidiaster* (fig. 1) the osseous framework of each arm is made up of several series of ossicula, presenting three or four modifications of form: viz., rhomboidal lenticular ossicles, of which there are seven in the transverse section, three belonging to the superior surface of the arm, and two to each of the sides; oblong or linear connecting ossicles, of which there are eight in the section, two linking the rhomboidal ossicles of the upper surface with each other, two linking the superior laterals with the surface plates, two linking the pairs of laterals on each side, and two, rather different in form, joining the inferior laterals to small quadrangular ossicles, which join on to the long femur-shaped ambulacral bones. In all, then, there are 19 ossicles in the transverse section of the arm of *Ophidiaster*.

Fig. 2.



In *Arthraster* (fig. 2) the number of ossicles is much less, and the arrangement different. Exclusive of the ambulacral bones, which are unknown, only seven ossicula enter into the composition of the framework of the arm, as shown in the transverse section, and these alternate in such a way as to form a compact framework without conspicuous interstices. All the seven ossicles are similar in form, consisting each of a transversely oblong expanded though linear base, terminating at each end in an acute angle, and bearing along the centre a linear crest or ridge, with steep sides. The central of the seven is largest; I regard it as equivalent to all the ossicles of the upper surface of the

arm in *Ophidiaster*; whilst the others may be looked upon as the homologues of the lateral and ventral plates, with their connecting ossicula.

The *Ophidiasters* are all tropical, with the exception of two species inhabiting the Mediterranean.

1. *Arthraster Dixoni*. F.

A. disco parvo; brachiis teretibus, cylindricis, longis; ossiculis cristatis, oblongis, regularibus, sexangularibus, articulantibus.

White chalk of the S. E. of England. [Mus. Dixon.] One specimen only is known: judging from the remains, each ray must have been nearly eight inches in length. It is figured by Mr. Dixon.

OREASTER.

This genus, as defined by Muller, in whose sense I adopt it, includes a group of pentagonal starfishes, with two rows of suckers in each avenue, and a sub-central vent on their dorsal surface, which is greatly elevated and sub-pyramidal. Their skeleton is formed of large variously-shaped irregularly-polygonal plates, disposed on the ridges of the arms in a more or less squamated fashion. Great tubercles or globular spines occupy various parts of the dorsal surface, and coronate its centre. The margins are formed of two rows of granulated overlapping plates. The interior is often strengthened by calcareous pillars. The pedicellariæ are sessile. The plates, pillars, and tubercles of the skeleton are preserved with facility in a fossil state; and as the articulating surfaces are often complicated in this genus, entire specimens or large fragments are likely to be preserved with facility.

These starfishes were styled *Pentaceros* by Linck, a name which has been adopted by Gray. They were included under *Goniaster*, in the first sketch of Agassiz. They constitute a most natural genus, confined to tropical seas. The Indian Ocean is their chief seat. All the fossil species with which I am acquainted are found in the white chalk. Figures of the following species, all of which are British, will be found in Mr. Dixon's work.

1. *Oreaster coronatus*. F.

O. disco pentagonali, crasso, convexo, coronato, brachiis productis; ossiculis disci valde irregularibus, centralibus maximis; tuberculis coronæ polygonalibus nodulosis sub-pyramidalibus.

Brachiis superne planis, ossiculis oblongis, planatis, lobulatis, protectis; ossiculis marginalibus superioribus latis, convexis, polygonatis, marginatis, punctatis, squamatis; inferioribus regularibus, elongatis, arcuatis, marginatis, oblique truncatis: ossiculis minoribus tuberculatis intermediis.

White chalk.

2. *Oreaster squamatus*. F.

O. disco pentagonali, brachiis longe productis; crasso, convexo, tuberculis polygonalibus truncatis, maximis (9), coronato; ossiculis disci lobulatis, convexis, subæqualibus.

Brachiis superne planis, ossiculis tri-lobulatis squamatis protectis; ossiculis marginalibus superioribus subreniformibus.

White chalk.

3. *Oreaster Boysii*. F.

O. disco pentagonali, brachiis productis; ossiculis tuberculisque mediocribus depressis punctatis, inferne cuneatis.

Brachiis superne planatis, ossiculis centralibus parvis, marginalibus oblongis, marginatis, in medio punctatis.

White chalk. [In the collection of the Marquess of Northampton.]

4. *Oreaster bulbiferus*. F.

O. disco pentagonali, crasso, convexo, brachiis productis clavatis; ossiculis disci subexcavatis, polygonatis, punctatis, inæqualibus, sæpe magnis: coronâ disci quinque tuberculorum compositâ; tuberculis conicis, obtusis, punctatis, inferne lobulatis.

Brachiis subcarinatis; ossiculis centralibus rotundatis, marginatis; marginalibus magnis, oblongis, lobulatis, marginatis, punctatis: extremitatibus brachiarum bulbiformibus, ossiculis quinque-serialibus planatis, punctatis, marginatis constructis.

White chalk.

5. *Oreaster obtusus*. F.

O. disco ?

Brachiis crassis, obtusis, extremitatibus oculiferis tumidis, ossiculis arcuatis, convexis, oblongis, punctatis, 4-serialibus constructis.

White chalk.

6. *Oreaster ocellatus*. F.

Ossiculis disci irregularibus, magnis, nodulosis. Tuberculis disci hemisphæricis apicibus truncatis, radiato-striatis; lateribus ocellato-punctatis.

White chalk.

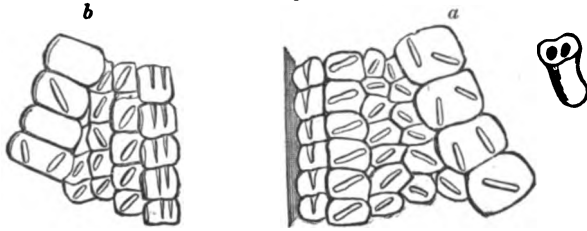
GONIASTER.

I retain this genus nearly in the wide sense given to it originally by Agassiz in his *Prodromus*, and prefer regarding the greater number of minor groups included within it, as subdivisions rather than as genera, whether formed on natural alliances, as in the arrangement of Muller, or upon technical distinctions of slight physiological value, as in that of Gray. Those of Muller still constitute convenient sub-genera, but I can find no characters, sufficiently constant and common to all the species

of each group, to warrant generic separation. The separation of *Asteropsis* from *Goniaster* must, however, be admitted, since the skeletons of the two genera are essentially distinct in structure.

All the members of the genus *Goniaster* have pentagonal bodies, with five angles indicating the extremities of the arms, in some species very slightly projecting, in others much produced. The disk is flat when the animal is taken out of the water, but capable of considerable convexity when alive and active in its native element. Indications of this convexity are seen in the fossil species of the section *Stellaster* (*Comptonia*). The character, "flat on both sides," which has been admitted into the generic distinctions of the *Goniasters*, is therefore adventitious, and founded only on the appearance of preserved specimens in cabinets. At the same time, the specimens of this genus are never so convex as those of *Asteropsis*, or of *Oreaster*. All the species have their margins bounded by two rows of large marginal plates, always larger than those of the back or under side. From the size and constant characters of these plates, they are very important in a palæontological point of view, both because they are capable of very perfect and easy preservation, and because they afford individually sure indications of the species to which they belong. Their surface is variously studded with granules or spines, or large pedicellariæ, and sometimes appears to have been wholly or partially naked. Muller and Troschel attempt to draw distinct lines between their genera *Astrogonium*, *Goniodiscus* and *Stellaster*, on account of the nature and disposition of the spinous appendages of their plates; but, after a careful study of numerous species recent and fossil, I find that such arrangements have no certain relations with the degree of affinity of the forms. Pedicelliferous and spiniferous plates exist equally in *Astrogonium* and *Stellaster*, and many species of the former section have exactly the same structure of marginal plate with that seen usually in species of *Goniodiscus*. At the same time, it must be remembered, that the limitation of characters derived from the structure of the marginal plates and their appendages is apparently much more constant among existing forms than among fossil, and that it is chiefly among the latter we find the connecting species. This is remarkably shown in the following representation of the structure of the marginal plates of an *Astrogonium* (fig. 3 a) taken by Mr. Jukes, on the north-east coast of Australia, contrasted with that of the same parts in a *Stellaster* (fig. 3 b) from the upper green sand of Blackdown (*S. elegans*), preserved in the collection of the Marquess of Northampton. In both we see the marginal plates furnished with large pedicellariæ, variable in number, usually placed obliquely, and fitted into grooves, which remain as if they were impressions on the beautiful siliceous cast of the fossil starfish.

Fig. 3.



Instances like the above show the necessity of excluding, as much as possible, minor characters from generic arrangements; for the very purpose of the institution of genera is, if attainable, the definition of a series of types, round which species should, as it were, be grouped, having a community of structural or major, and a variety of formal, or minor characters. The experience of naturalists goes far to show that such typical groupings have a definite relation to areas in space; and the researches of palæontologists have led us to the inference that there is a constant analogy between distribution in space and distribution in time. It is, therefore, of the greatest consequence that generic groups should be founded on natural and important, and not upon technical and variable characters. The value of palæontology to the geologist depends on the evidences it affords of the continuity of species in time, which is the evidence of unbroken sequence of conditions; and the continuity of the group, which is the evidence of sequence of design. The names of species and genera are the words of the language by means of which such general facts and laws are expressed. If these words be not precise and restricted in their meanings, definitely and not loosely used, this branch of our science can be of little scientific value. Unfortunately, the love of species-making and genus-making is too prevalent among writers on natural history, and likely to cause much confusion in the several departments of that science.

The skeleton of the *Goniasters* is composed of ossicula, which, owing to their form being tetragonal or polygonal, do not articulate firmly together. Hence we find even the best-preserved fossil examples almost always partially broken up; and specimens of existing species are very difficult to preserve if their membranous parts be at all loosened by damp. The superior disk is composed of small flat, hexagonal, pentagonal, or, more rarely, tetragonal plates, as are also the spaces between the avenues on the inferior surface. The sides are bordered, and, as it were, framed, by marginal ossicula, mostly quadrate, of considerable dimensions. The ossicula, both of margin or disk, may bear spines usually reduced to a granular form, and pedicellariæ, always sessile. The avenues are bordered by square ossicula, the surfaces of which are

marked by deep parallel grooves, varying in number, and marking the lodging-places of ambulacral spines. The marginal plates, towards the extremities of the rays, especially those of the upper side, are variously modified, often greatly enlarged, for the preservation of the eyes.

The British species of all the sub-genera of *Goniaster* are figured by Mr. Dixon in his work before cited.

Sub-genus.—*Goniodiscus*.

This section includes those species of *Goniaster* that have very short arms, or rather angles, the extreme superior marginal plates of which are modified so as to form a conspicuous eye-protecting apparatus. Were this constant, it would form a good ground for generic distinction; but the degree of its development is so variable, that, as in *Oreaster*, it can only be regarded as a source of specific character: as, however, it is very strongly presented by several species of the group, it may be looked upon as an effort, so to speak, towards the establishment of a type of generic value, and therefore as indicative of a sub-generic section.

The species of this section, besides the greater or less manifestation of the character just mentioned, have usually a definite and constant number of marginal plates between the eye-plates. This number is either 4, or 6, or 8. The eye-plates are modified laterals. In this sub-genus, the two superior laterals, which conspicuously form the angles of the disk, are often greatly enlarged, and always more or less triangular in form. Two minute plates, forming the true termination, and placed above a still minuter eye-plate, are sometimes, though rarely, preserved in fossil specimens. It is probable that these larger superior eye-plates are formed out of several ossicula, as, beneath, three at fewest correspond to them.

A. Species with four intermediate marginal plates on a side.

1. *Goniaster (Goniodiscus) Hunteri*. F.

SYN.—*Goniaster regularis*, Mantell, Medals, vol. i. p. 335, cut 73.

G. corpore pentagonali, angulis obtusis; *ossiculis lateralis superioribus* 4, equalibus, late oblongis, mammillatis, marginatis, lateraliter punctatis. *Inferioribus* similaribus, *ossiculis ocularibus superioribus* magnis, depressis, antice latis, postice truncatis.

White chalk. Two inches in diameter.

2. *Goniaster (Goniodiscus) rugatus*. F.

G. corpore pentagonali, angulis subacutis obtusisve; *ossiculis lateralis superioribus* 4, oblongis, convexis, subgibbosis, centraliter tuberculatis; *inferioribus* lævibus seu minute granulatis. *Ossiculis ocularibus superioribus* triangularibus, abbreviatis, gibbosis, tuberculatis.

White chalk. A small species, the largest specimens measuring about one inch in diameter.

3. *Goniaster (Goniodiscus) uncatu*. F.

G. corpore pentagonali, lateribus sublunatis; *ossiculis lateralibus superioribus* 4, latis, centraliter tumidis rugosisque, marginibus internis impressis, externis obliquis; *inferioribus* planatis, latioribus, lævibus. *Ossiculis ocularibus superioribus* acuminatis, triangularibus, mitratis, tumidis, marginatis.

An inch and a half in diameter. White chalk.

4. *Goniaster (Goniodiscus) sublunatus*. F.

G. corpore pentagonali, lateribus lunatis; *ossiculis lateralibus superioribus* 4, subæqualibus, planis, minutissime punctatis; *inferioribus?* *Ossiculis ocularibus superioribus* magnis, triangularibus, mitratis, tumidis, acuminatis.

Usually under two inches in diameter. White chalk.

B. Species with six intermediate marginal plates on a side.

5. *Goniaster (Goniodiscus) Parkinsoni*. F.

SYN.—*Asterias regularis*, Parkinson, Org. Rem. 3, t. 1, f. 3. *Tosia regularis*, Morris, Cat. p. 60.

G. corpore pentagonali, lateribus sublunatis; *ossiculis marginalibus superioribus* 6, angustatis, oblongis, subarcuatis, punctatis, angustomarginatis; *inferioribus* latioribus. *Ossiculis ocularibus superioribus* triangularibus, angulis obtusis, magnis, gibboso-convexis, punctatis, marginatis.

β. *Ossiculis marginalibus superioribus* latis.

White chalk. Large specimens measure two and a half inches in diameter.

6. *Goniaster (Goniodiscus) Mantelli*. F.

SYN.—*Goniaster semilunatus*, Parkinson, v. iii., pl. 1, f. 1. Mantell, Medals, vol. i. p. 388, cut 75.

G. corpore pentagonali, lateribus valde lunatis; *ossiculis marginalibus superioribus* 6, oblongis, subcuneiformibus, convexis, ocellato-granulatis, lateraliter abruptis; *ossiculis ocularibus superioribus* triangularibus, tumidis, punctatis.

White chalk. Does not grow to the size of the last.

FOREIGN SPECIES.

Goldfuss has figured, under the name *Asterias quinqueloba* (plate 63, fig. 5), fragments which belong to both the above. To prevent confusion, I think it best to reject that name altogether. He refers to Parkinson and also to Schultz (Betr. der Verst. Seesterne, 1760), whose treatise I have not been able to procure. The localities given are England, Westphalia, and Belgium.

C. Species with eight intermediate marginal plates on a side.

7. *Goniaster* (*Goniodiscus*) *Bowerbankii*. F.

G. corpore pentagonali, *ossiculis lateralibus superioribus* 8, anguste oblongis, planatis, punctatis, submarginatis: *inferioribus* similaribus; *ossiculis ocularibus superioribus* triangularibus obtusis, punctatis.

White chalk. In Mr. Bowerbank's collection.

Either to this sub-genus or the next belong certain marginal ossicula of cretaceous starfishes, which have received specific names from Desmoulins and from Agassiz, but which are quite insufficient for the establishment of species.

They are—

A. stratifera,

A. chilipora,

A. punctulata,

Desmoulins, Act. Soc. Lin. Bordeaux, t. v, 1832.

from the white chalk of France.

And—

Goniaster Couloni,

Goniaster porosus.

Agassiz, Notice sur les fossiles du Terrain cretacé du Jura Neuchatelois, in Neuchatel Transactions, vol. i.

Professor Agassiz described the ossicula to which he gives the name of *Goniaster porosus* as being more elongated than those of *quinqueloba*; their outer border broader, flat, and uniformly pitted: and *G. Couloni* as having larger, shorter, and more flattened marginal plates, their outer border much bent, strongly rounded, and ornamented with reticulating cells.

Sub-genus.—*Astrogonium*.

Muller and Troschel formed their genus *Astrogonium* for those discoid *Goniasters* which had their marginal plates partially (centrally) naked; a group of which the *Astrogonium phrygianum*, was the type. The character mentioned is, however, insufficient, and by no means indicates a natural section. Nevertheless, the species brought together in the "System der Asteriden" form a very natural assemblage, and one with which many fossil starfishes may be conveniently associated.

To this section I would refer those fossil *Goniasters* whose disk, when contracted (as always in the fossil state), becomes quite flat; whose angles are more or less produced into arms; whose marginal plates are numerous, and not regulated strictly by a determinate number; and whose eye-plates are not enormously or even conspicuously developed. The marginal plates and the ossicula of the disk may be in great part smooth, or granulated all over, or spiniferous, or stomatiferous (bearing sessile pedicellariæ), according to the species.

The fossil species of this group appear to be all, with one exception, cretaceous. The majority of existing forms occur in the Pacific and Indian Oceans: two or three distinct and well-marked forms, including the type, however, inhabit the North Atlantic even to the Arctic seas.

8. *Goniaster (Astrogonium) lunatus*. Woodward. (Sp.)

SYN.—*Asterias lunatas*, Woodward, Geol. Norf. t. 5, f. 1. *Tosia lunata*, Morris, cat. p. 60.

G. corpore pentagonali; lateribus lunatis; *ossiculis lateralibus superioribus disci* circa 12, arcuatis, gibbosiusculis, oblongis, minute lineato-punctatis, angustissime marginatis, punctis moniliformibus impressis; *inferioribus* similaribus, subtuberculatis; *ossiculis lateralibus brachiarum* parvis, oblongis.

White chalk. Measures about three inches in diameter.

Mr. Morris refers *Asterias quinqueloba* of Goldfuss to this species; but we have seen that under the name in question several specific forms were included.

9. *Goniaster (Astrogonium) latus*. F.

G. corpore compresso, pentagonali, lateribus rectis, angulis productis; *ossiculis lateralibus superioribus disci* circa 16, anguste oblongis depressis, reticulatis, punctis moniliformibus impressis; *inferioribus* similaribus; *radialibus* latioribus minoribus.

This species seems to have grown larger than the last. White chalk.

10. *Goniaster (Astrogonium) Coombii*. F.

G. corpore stellato-pentagonali, lateribus lunatis; brachiis linearibus, *ossiculis lateralibus superioribus disci* circa 20, oblongis, convexiusculis, rugoso-punctatis; *inferioribus* similaribus; *radialibus* parvis.

Measures above four inches in diameter from angle to angle. White chalk.

11. *Goniaster (Astrogonium) angustatus*. F.

G. corpore pentagonali, angulis valde productis, lateribus profunde lunatis; *ossiculis lateralibus superioribus disci* superne tumidis, punctatis, quadratis, lateraliter altis, planis, lævigatis; *inferioribus* similaribus; *brachialibus* parvis.

About the size of *lunatus*. White chalk.

12. *Goniaster (Astrogonium) Smithii*. F.

G. corpore pentagonali, angulis productis; *ossiculis lateralibus superioribus disci* superne tumidis, arcuatis, tuberculatis, punctatis, spiniferis, centralibus (circa 12) oblongis; *inferioribus* convexiusculis, punctatis; *brachialibus* quadratis.

A very large and splendid specimen, measuring about six inches in

diameter. From the white chalk. In the collection of Mrs. Smith, of Tunbridge Wells.

13. *Goniaster (Astrogonium) mosaicus*. F.

G. corpore pentagonali, angulis lanceolatis productis, lateribus lunatis; ossiculis lateralibus superioribus disci 16 angustis arcuatis, supra abbreviatis, minute punctatis; inferioribus similaribus: brachialibus parvis.

About the size of *lunatus*. From the chalk marl. In Mr. Bowerbank's collection.

14. *Goniaster (Astrogonium) Stokesii*. F.

G. corpore pentagonali, angulis longe productis lateribus profunde lunatis: ossiculis lateralibus superioribus disci oblongo-quadratis depresso seu convexiusculis, brachialibus quadratis tumidis, omnibus punctatis et ad lateras abruptis; inferioribus similaribus.

A species with deeply lunated sides, so that fragments may be mistaken for parts of an *Astropecten*; the arms become suddenly prolonged, and at length so attenuated that the marginal plates come in contact on their upper surfaces. The ossicula of the disk are variable in size, and strongly punctured, like those of the margin. There is a tendency in the ocular plates and their neighbours to become largely developed. Judging from the size of fragments, this species must have grown to six inches in diameter, or possibly still larger. Numerous more or less complete portions have been found in the London clay of Sheppey.

Communicated to the Geological Survey by Charles Stokes, Esq.

15. *Goniaster (Astrogonium) marginatus*. F.

G. corpore? ossiculis lateralibus disci magnis oblongis convexiusculis, rugoso punctatis, marginatis, margine elevato.

Although but a small fragment of this species, consisting of five ossicula and a portion of the disk, has been met with, the characters of the ossicula are so very remarkable that there can be no question as to their claims for specific distinction.

From the London clay of Sheppey. Communicated by Charles Stokes, Esq.

"*Asterias jurensis*" of Goldfuss, plate 63, fig. 6, from the oolitic strata of Wurtemberg, is a *Goniaster* of this section, and apparently distinct from any here described.

Sub-genus.—*Stellaster*.

The genus *Stellaster* was founded by Mr. J. E. Gray* for a well-known Indian Ocean species, which, however, can scarcely (if at all) be distin-

* *Annals Nat. Hist.*, vol. vi. (1841) p. 277.

guished from the type of his genus *Anthenea*, nor do I see how *Hosia* is to be separated.

Stellaster was redefined by Muller and Troschel thus: "Body very pentagonal and flat on both sides, with two rows of granulated marginal plates, which both enter into the formation of the steep margin. Each ventral marginal plate bears a hanging spine: the surface of the disk is studded with granulated plates. The vent is sub-central." *Stellaster Childreni*, Gray, was retained as the type. A close examination and comparison of that species, both in its fresh state (when it is *Stellaster Childreni*), and in its decorticated condition as cast ashore by the waves (*Diagona Reevei*), has convinced me that the fossil starfishes which form the upper green sand of Blackdown are very closely allied to and generically inseparable from the tropical species above mentioned. For these fossils Mr. Gray constituted his genus "Comptonia." I am, moreover, induced to refer *Stellaster* to the rank of a sub-genus of *Goniaster*, for except the habitually convex disk, there is no character by which we can separate it.

16. *Goniaster (Stellaster) Comptoni*. F.

G. corpore pentagonali, lateribus profunde lunatis, brachiis valde productis. *Ossiculis marginalibus* disci angustatis, in brachiis latis, punctatis regularibus, lævigatis.

This species when entire must have measured about 4 inches in diameter.

Green sand of Blackdown: in the collections of the Marquis of Northampton and Mr. Bowerbank.

17. *Goniaster (Stellaster) elegans*. Gray. (Sp.)

SYN.—*Comptonia elegans*, Gray, An. Nat. Hist. 1840, vol. vi. p. 278. Morris, cat. p. 50.

G. corpore pentagonali, brachiis productis, lateribus subrectis. *Ossiculis marginalibus* disci elongato-oblongis, punctatis, in brachiis angustis, irregulariter sulcatis, sulcis linearibus, rectis.

Green sand of Blackdown. Above 4 inches in diameter. In the collection of the Marquess of Northampton, and in the British Museum.

Foreign species. The "*Asterias Schultzii*," Römer (Versteinerungen des Norddeutschen Kreidegebirges, plate 6, fig. 21,) from the Quader of North Germany, comes so very near *Goniaster elegans*, that were it not for the absence of all traces of pedicellarian sulcations on the marginal plates represented in his figure, I should consider it identical.

PALMIPES.

(*Asteriscus*. Muller and Troschel.)

Expanded, compressed, mostly pentangular starfishes, having two

rows of suckers in each avenue, and no vent in the dorsal surface. Their skeleton is composed of small more or less pentagonal plates, those of the margin scarcely differing from and not larger than those of the disk. Most of the living species (there are about 20) are natives of tropical seas; but there is one not uncommon on the British coast, and another confined to the Arctic zone. They range to considerable depths.

No fossil starfish found in British strata can be referred to this genus; but Hisinger has figured (*Lethæa Suecica*, t. xxvi. f. 6) a starfish from the green sand of Gotland in Sweden, which appears to be a true *Palmipes*. He names it *Asterias antiqua*, and describes it as "A. quinqueloba angulis brevibus, apicæ obtusis, pagina inferiori reticulato-striata, radiis quinque lanceolatis." By the reticulato-striated inferior surface, he means the arrangement of the ossicula in linear series; and by the five lanceolate ridges, the peculiarly broad ambulacra presented by this apparently well preserved fossil.

It is not improbable that species of *Asterina*, a genus which closely resembles *Palmipes* in form, will be found fossil in the white chalk, judging from some loose ossicula. In *Asterina*, the ossicula of the disk are unusually trilobate and crescentic.

ASTROPECTEN.

(*Asterias* of Agassiz: *Stellaria* of Nardo.)

This genus belongs to the starfishes furnished with two rows of suckers in each ambulacrum, and having no vent. All the species are characteristically starlike; the number of rays is typically four. The upper and under surfaces are both nearly flat, but very dissimilar. Two rows of regular plates border the arms, often bearing spines, especially at their sides. The intermediate spaces and upper disk are covered with paxillæ. The ambulacral borders occupy the under surface, and are studded with numerous flattened spines.

Such a structure when fossilized is apt to present an appearance very similar to that seen in the fossil *Goniasters* of the sub-genus *Astrogonium*. But in *Astropecten*, the arms proper are not merely productions of the angles of the disk as in the former group, but occupy and form the whole border, so that the points of junction of the bases of the arms form acute angles, and not more or less lunated intermediate spaces.

Many living species of *Astropecten*, difficult to define on account of their variations, are described. They have been found in all parts of the world, but the majority live in warm climates. They live for the most part on sandy bottoms.

1. *Astropecten arenicolus*. Goldfuss.

Charlesworth, London Journ. Geol., No. 3, pl. 17.

A. radiis lanceolatis, longis, acuminatis, ad origines contractis; angu-

lis intermediis acutis; *ossiculis marginalibus* angulorum brevibus, in parte latiori radiorum maximis, angustè oblongis, in apicibus radiorum quadratis.

This species measures nearly a foot in diameter. The peculiar form of the rays, which, united by their bases at an acute angle (where the marginal plates are narrowest), then swell out into a petaloid shape, and again contract into long linear-lanceolate extremities, distinguishes it from all its congeners. Each ray is to the diameter of the disk as 3 to 1. There are about 70 plates on each side of each ray.

Marlstone of Yorkshire. It was first described and figured from the oolites of Germany.

2. *Astropecten Hastingsiæ*. F.

A. radiis brevibus, lanceolatis, acutis, lateribus rectis, angulis intermediis obtusis; *ossiculis marginalibus* quadratis subæqualibus.

About 2 inches in diameter. A very beautiful star-like species, remarkable for the uniformity of the quadrate marginal plates, of which there are about 18 on each side of each ray. The length of, as compared with the diameter of, the disk, is as 1 to 1.

Marlstone? Yorkshire. Discovered by the Marchioness of Hastings, by whom it has kindly been communicated to the Geological Survey.

3. *Astropecten Orion*. F.

A. radiis lineari-lanceolatis, longis, lateribus rectis, angulis intermediis obtusis; *ossiculis marginalibus* omnibus (ossiculis angulorum exceptis) plus-minus ve quadratis, spiniferis.

Measures 8 or more inches in diameter. A very regularly stellate species, having gradually tapering arms, bordered by square plates, which decrease regularly and gradually towards the apices. Each ray is to the diameter of the disk as $3\frac{1}{2}$ to 1. There are about 40 ossicula on each side of each ray.

In the collections of the Marchioness of Hastings, the Marquess of Northampton, and Mr. Bowerbank. All the specimens are from the oolites of Yorkshire.

Astropecten Phillipsii. F.

A. radiis lanceolatis, lateribus rectis, angulis intermediis valde obtusis; *ossiculis marginalibus* oblongo-quadratis, spiniferis.

A small species, measuring about $3\frac{1}{2}$ inches in diameter, and strikingly resembling, in general appearance, the *Astropecten aranciæ*, var. *Mulleri*, of our seas. The rays are to the diameter of the disk as $1\frac{1}{2}$ to 1. There are about 28 ossicula on each side of each ray.

From the marlstone of Yorkshire. Communicated by Mr. John Phillips.

5. *Astropecten Cotteswoldiæ*, Buckman.

Buckman and Strickland's Ed. of Murchison's Geology of Cheltenham, p. 94, t. 3. p. 8.

A. radiis lineari-lanceolatis, lateribus rectis, angulis intermediis obtusiusculis; *ossiculis marginalibus* quadratis, magnis.

Ray to disk as 2 to 1. About 20 marginal plates bound each side of each ray. "Arms, five: composed of small striated joints, elongatéd and pointed at the extremity; disk, small. This is a very elegant Asterias, and varies in size from 1½ to 3 inches in the length of its arms. Locality: Eyeford, near Stow-on-the-Wold, in the Stonesfield slate beds. A very rare fossil, first discovered by the Rev. E. J. Witts, of Stanway."—Buckman, loc. cit.

The figure represents an *Astropecten* about 4 inches in diameter.

5. *Astropecten crispatus*, F.

Ansted, Geology, vol. ii. p. 66.

A. radiis late-lanceolatis, angulis valde obtusis; *ossiculis marginalibus* anguste oblongis, numerosis, spiniferis; disco lato.

About 4 inches in diameter (specimen in Mr. Bowerbank's collection). A very broad species with short arms, their length being to the diameter of the disk as rather less than 1½ to 1. On each side of each arm there were about 36 plates. A strong spine is attached to each plate in perfect specimens.

London clay of Sheppey. In many collections. Communicated to the Geological Survey by Mr. Stokes.

6. *Astropecten armatus*. F.

A. radiis lanceolatis, angulis valde obtusis, *ossiculis marginalibus* oblongis carinatis, externé longé spinosis.

A fragment of a species, about the size of the last, easily distinguished by the characters of the marginal plates.

From Sheppey; in Mr. Bowerbank's and other collections. Communicated by Mr. Dixon.

FOREIGN SPECIES.

1. *Astropecten Mandelshohi*, Munster.

Beitrag, 1st Heft. (1846), t. xi. f. 1, p. 98.

This species is figured very beautifully; it is described as having oblong lanceolate arms; the marginal plates oblong arcuated, slightly convex, and gradually decreasing. It approaches *A. arenicolus*, and was found in oolitic sandstone by Aalen.

2. *Astropecten priscus*, Goldfuss (sp.).

Asterias prisca, Goldfuss, Pet. Germ. pl. 63, p. 3.

An *Ophiura*-like species, with linear-lanceolate arms, from the lias of Wurtemberg. Very distinct.

3. *Astropecten propinquus*, Munster (sp.).

Asterias propinqua, Phillippi, Beitrage, a. kennntnis der Tert. Verstein. Nordw. Deutsch p. 70 (no figure).

From the cretaceous system in Northern Germany. This species is not sufficiently described.

Desmoulin has given the names of *A. poritoides*, *A. levis*, and *A. adriatica*, to loose marginal plates of species, probably of this genus, from the tertiaries of the south of France (Act. Linn. Soc. Bourdeaux, T. V. 1832).

LUIDIA.

This genus was instituted by the author in 1839,* for one of the most interesting and extraordinary radiata of the European seas. It belongs to the third family of starfishes in the arrangement of Muller and Troschel, viz., those which have two series of tentacles in each avenue, but in which no vent is present. The rays are always very long and flat. A double row of large plates borders the margin, which is fringed with long spines. Paxillæ cover the disk in the living species, but these bodies (coronated spines, possibly transformed pedicellariæ) cannot be expected to be found preserved in the fossil state. The living Luidiæ are remarkable for the facility with which they can break their bodies into fragments. The known species are inhabitants of northern and tropical seas.

An unique fossil starfish appears to belong to this genus; it is figured and described by Mr. Williamson in the 9th vol. of Loudon's Magazine of Natural History for 1836. Not having seen the specimen, I extract the description entire. The species will stand as *Luidia Murchisoni*. Williamson (sp.) :—

“ This fossil was found in the marlstone at the point where it is carried up into the cliff, to the north of the great fault, at the Peak Hill near Robin Hood's bay, near the lower part of the stratum, where it blends with the lower lias. The figure represents the object reduced to two-thirds of the real size. The slab on which the fossil is preserved is of a rather micaceous nature, a matrix, generally unfavourable for preserving minute characters; and a portion of the fossil having adhered to the upper part of the rock, which fell in pieces, the view presented is rather that of the internal than the external structure of the animal. The central circle, the situation of the mouth, is preserved very distinctly; and proceeding with considerable regularity from this, is a series of rays 20 in number. Those rays near their base bear the sulcus (furrow), which runs under those of recent Asteriæ; but towards their apex they become more worn and thin, showing, in several places, a small wiry line, with short ribs branching off at right angles, appa-

* Wernerian Memoirs, vol. viii. pt. 1.

rently a species of appendage, resembling what represents the vertebral column and ribs in the turtle, and which is observable in recent Asteriæ. There are also slight traces of transverse grooves on the whole surface of each ray; but these are generally almost obliterated. Along the margins are extremely regular rows of small rhomboidal perforations, or cells, from which proceed a series of lateral filaments, or delicate lengthened papillæ; but on the surface of the fossil, it merely presenting to us the interior, no papillæ are preserved. The apex of such rays as have not been broken off prior to the animal being entombed are obtusely pointed."

Table of Fossil Asteriadae.

	Genus.	Species.	Formation.	Locality.	Reference.
PALÆOZOIC	Uraster .	obtusus, n. s. . . .	Lower Silurian	{ Ireland. N. Wales. Westmoreland.	
	_____ .	primævus, n. s. . . .	_____	_____	
	_____ .	Ruthveni, n. s. . . .	_____	_____	
	_____ .	hirudo, n. s. . . .	_____	_____	
	_____? .	matutina, Hall . . .	_____	United States	Hall, Pal. N. Y. { Proc. Ac. N. S. Phil. vol. 3.
	_____? .	antiqua, Locke . . .	_____	_____	{ Tr. Geol. Soc. Pen. vol. 1.
	_____? .	antiqua, Troost . . .	_____?	_____	Ditto.
	_____ .	{ "five other species," Troost }	_____?	_____	{ Tr. Geol. Soc. Fr. vol. 3.
	_____ .	constellata, Thorent. . .	{ Terrains an- thraxiferes. }	N. of France	
	LOWER SECONDARY.	Uraster .	lumbricalis, Goldf.	Germany .
_____ .		lanceolata, Goldf.	Germany .	_____
Goniaster .		jurenensis, Goldf.	Wurtemberg	Petrif. Germ.
Astropecten		arenicolus, Goldf. . . .	Marlstone .	{ Yorkshire . Germany .	Charleow. Journal.
_____ .		Hastings, n. s. . . .	Marlstone .	Yorkshire.	
_____ .		Cotteswoldian, Buckman.	_____	_____	
_____ .		Orion, n. s. . . .	Marlstone .	Yorkshire.	
_____ .		Phillipsii, n. s. . . .	Marlstone .	Yorkshire.	
_____ .		Mandelshohi, Munster.	Oolites . . .	Aalen . . .	{ Munst. Beitr. 1st Heft.
_____ .		priscus, Goldfuss	Lias	Wurtemberg.	
Luidia .	Murchisonii, Williamson	Marlstone .	Yorkshire .	Mag. N. Hist.	
UPPER SECONDARY.	Arthraster	Dixonii, n. s.	White Chalk .	S. of England	Dixon.
	Oreaster	coronatus, n. s.	White Chalk .	_____	_____
	_____ .	squamatus, n. s.	_____	_____	_____
	_____ .	Boysii, n. s.	_____	_____	_____
	_____ .	bulbiferus, n. s.	_____	_____	_____
	_____ .	obtusus, n. s.	_____	_____	_____
	_____ .	ocellatus, n. s.	_____	_____	_____
	Goniaster .	Hunteri	_____	_____	Mantell, Medals.
	_____ .	rugatus, n. s.	_____	_____	Dixon.
	_____ .	uncatus, n. s.	_____	_____	_____
	_____ .	sublunatus	_____	_____	_____
	_____ .	Parkinsoni	_____	_____	Parkinson.
	_____ .	Mantelli	_____	_____	_____
	_____ .	Bowerbankii, n. s.	_____	_____	Dixon.
	_____ .	lunatus, Woodward	_____	_____	{ Woodward, Geol. Norfolk.
	_____ .	Coombii, n. s.	_____	_____	Dixon.
	_____ .	angustatus, n. s.	_____	_____	_____
	_____ .	latus, n. s.	_____	_____	_____
	_____ .	Smithii, n. s.	_____	_____	_____
	_____ .	mosaicus, n. s.	Chalk Marl	_____	_____
_____ .	elegans, Gray	Green Sand	Blackdown .	Dixon.	
_____ .	Comptoni, n. s.	_____	_____	_____	
_____ .	Schultzei, Römer	Quader	Germany .	Römer. Kr.	
Palmipes .	antiquus, Hisinger	Green Sand .	Sweden . . .	Leth. Suecica.	

Table of Fossil Asteriadae—continued.

	Genus.	Species.	Formation.	Locality.	Reference.
	Astropecten (Doubtful sp. or repetitions)	propinquus, Phillippi .	Green Sand ? .	Germany .	Phill. Beitr.
	Goniaster .	quinqueloba, Gold. . .	White Chalk .	Germany, &c.	Petr. Germ.
	_____ .	Couloni, Agassiz . . .	Chalk Marl ? .	Neuchatel .	Neuf. Mem. 1.
	_____ .	porosus, Agassiz . . .	_____ .	_____ .	_____ .
	_____ ? .	stratifera, Desm. . . .	Chalk	} France .	Bourdeaux Tr. t. v.
	_____ ? .	chilipora, Desm. . . .	_____		
	_____ .	punctulata, Desm. . . .	_____		
TERTIARY .	Uraster .	rubens, Lin. ?	Crag	Suffolk	S. Wood.
	Goniaster .	Stokesii, n. s.	London Clay .	Sheppey .	
	_____ .	marginatus, n. s. . . .	_____ .	_____ .	
	Astropecten	crispatus, n. s.	_____ .	_____ .	Ansted, Geol.
	_____ .	armatus, n. s.	_____ .	_____ .	
	(Doubtful species)				
	Astropecten	poritoides, Desmoulins .	} Tertiaries .	S. of France.	Bord. Tr. vol. 5.
	_____ .	levis, Desmoulins			
	_____ .	adriatica, Desmoulins . .			

Note.—CÆLASTER, Agassiz, appears to me not to belong to the Asteriadae, nor do the bodies named by Goldfuss, *Asterias scutata*, *A. stellifera*, and *A. tabulata*.