the predominantly sandy character of the deposit. It would be difficult to find better evidence of the conformable succession of volcanic rocks on sedimentary than that offered by the Elsburg-Ventersdorp passage beds in that part of Heidelberg so far surveyed in detail."

In this connexion I would point out that coarse boulder beds forming the upper part of the Ventersdorp System and containing large pieces of auriferous conglomerate and quartzite evidently derived from the destruction of Witwatersrand beds have been recorded as resting on Lower Witwatersrand beds at Ratzekaiskraal and Makokskraal to the north-west of Ventersdorp.[1] Molengraaf also, in describing similar boulder beds at Zendelingsfontein to the west of Klerksdorp and at Kroomdraai to the north of Krugersdorp, refers to their unconformable position on Witwatersrand beds.[2]

This evidence of the existence of a break somewhere in the succession of the Ventersdorp system, taken in conjunction with Dr. Rogers' conclusions as to the conformable relation of the volcanic beds, forming the base of the Ventersdorp system, to the Upper Witwatersrand makes it appear probable that further work may show the necessity of placing the division between the two systems at a different horizon.

The Use of Gryphaea in the Correlation of the Lower Lias.

By A. E. Trueman, D.Sc., F.G.S., University College of Swansea.

In the course of recent investigations in the littoral Lias of South Wales and parts of Somerset the writer has frequently found that almost the only fossils in some of these deposits are species of *Ostræa* and *Gryphæa*, which occur in regular sequence and are of considerable value in correlation. On consulting the literature describing these genera it became apparent that the specific names have been frequently misapplied. From correspondence with other students of Liassic rocks it also appeared that there is some difference of opinion concerning the precise horizons at which such species are to be found.

It was therefore necessary to investigate the various forms of *Ostræa* and *Gryphæa* found in the lowest zones of the Lower Lias, and also to examine sections of the zones where they are normally developed in order to correlate the ammonite sequence with the *Ostræa-Gryphæa* sequence. This paper contains a brief account of the results of these inquiries.

[1] Hatch, "The Boulder Beds of Ventersdorp, Transvaal": *Trans. Geol. Soc. S.A.*, vol. vi, 1903, p. 95.

[2] Molengraaf, "A hitherto unrecognized Formation underlying the Black Reef series": *Trans. Geol. Soc. S.A.*, vol. vi, 1903, p. 68.

The relation of *Gryphæa* to *Ostræa* has been noticed by many workers, and it is generally accepted by palæontologists that species of *Gryphæa* have evolved from *Ostræa* by the shortening of the period of attachment and the arching of the left valve.[1]

Numerous workers have published accounts of these fossils, and some have attempted a systematic study[2]; one of the most interesting papers, published by Jones in 1865, is illustrated by plates showing the relation of species to *Gryphæa incurva*.[3] Nevertheless, much research is needed before the relations of the Liassic *Ostræidæ* can be properly determined and before the various species can be usefully employed in detailed stratigraphical work. Dr. F. L. Kitchin has been for some years collecting material with a view to publishing an account of *Gryphæa*; his work, however, has been delayed, and he has generously encouraged me to prepare this account of some of the species from the Lower Lias. Such an account is a necessary preliminary to the publication of the results of the work on the Lower Lias of South Wales.

The writer desires to thank numerous friends for help in the field, particularly Mr. E. Drew and Mr. W. E. Howarth, who have made extensive collections at various localities. Dr. W. D. Lang, Mr. L. Richardson, and Mr. J. W. Tutcher have also assisted by the loan of specimens. The writer also acknowledges a grant from the Royal Society Committee which has enabled him to work in Somerset.

The Lowest Zones of the Lower Lias.

The lineage of *Gryphæa incurva* is represented only in the lowest zones of the Lower Lias, which are commonly known as the *planorbe*, *angulata*, and *bucklandi* zones. Recently these zones have been subdivided by Mr. S. S. Buckman[4] and Mr. J. W. Tutcher,[5] and, although some of the divisions are not found in all areas, the present work has shown the necessity of subdividing the original zones, particularly in Glamorgan, where these zones are unusually thick. For convenience, the subdivisions will be called sub-zones in this paper.

Reference will be made to the following:—

[1] See R. T. Jackson, "Phylogeny of the Pelecypoda: The Aviculidæ and their Allies": *Mem. Bost. Soc. Nat. Hist.*, vol. iv, 1890, p. 317. F. L. Kitchin, "Summary of Progress": *Geol. Survey*, 1911. A. Morley Davies, *An Introduction to Palæontology*, 1920, p. 89.

[2] See, for example, M. Hébert, "Observations sur les Gryphées du Lias, etc.": *Bull. Soc. Geol. France*, ser. II, vol. xiii, 1855, p. 213; and O. Terquem, "Paléontologie de l'Etage Inférieur de la Formation Liasique, etc.": *Bull. Soc. d'hist. nat. de la Moselle*, ser. II, vol. v, 1855.

[3] John Jones, "On Gryphæa Incurva and its Varieties": *Proc. Cottes. Nat. Club*, vol. iii, 1865, pp. 81–95.

[4] S. S. Buckman, "Jurassic Chronology: I. Lias": *Quart. Journ. Geol. Soc.*, vol. lxxiii, 1918, p. 274.

[5] J. W. Tutcher, ibid., pp. 278–81.

Zone.	*Sub-zone.*
semicostatum	
bucklandi	*Agassiceras (sauzeanum).* *scipionianum.* *gmuendense.* *vercingetorix.* *bucklandi.* *rotator (rotiforme).* *Vermiceras.*
angulata	*angulata.* *liasicus.* *Wœhneroceras (megastoma).*
planorbe	*Johnstoni (Caloceras).* *planorbe.* *Ostræa.*

It has been found in general that flat oysters of the *Ostræa liassica* pattern are commonest in the lowest part of the *planorbe* zone, and that arched or semi-gryphæate individuals resembling *Ostræa irregularis* are common in the *liasicus* sub-zone. In the *angulata* sub-zone the most typical forms are more gryphæate in appearance, but have generally a fairly large area of attachment and resemble *G. dumortieri* Joly. In the lowest part of the *bucklandi* zone wide open *Gryphæas* (Figs. 1*c* and 2*a*) are found in Somerset and in Glamorgan, while in the upper *Vermiceras* and lower *rotator* sub-zones are very abundant forms resembling *G. obliquata* Sow. The very arched *G. incurva* Sow. is found in the higher sub-zones of the *bucklandi* zone.

Evolution of Gryphæa incurva.

Besides the above-named species of *Ostræa* and *Gryphæa* these lower zones of the Lower Lias are characterized by great numbers of gryphæate and semi-gryphæate forms. These exhibit remarkable variation, but on the whole the individuals may be considered to be members of a series that includes the flat oysters of *O. liassica* pattern and the closely coiled *G. incurva*.

In the opinion of the writer, this represents a true genetic series or lineage, and *G. incurva* has probably evolved through innumerable intermediate stages (including *G. obliquata*, *G. dumortieri*, and *O. irregularis*) from oysters of the type of *O. liassica*. Indeed, it is doubtful whether any better example of a lineage of fossil forms could be found for demonstration purposes, since *Gryphæa* is so abundant that sufficient specimens can be obtained to illustrate the most minute changes.

In such a series various progressive characters may be observed, of which the following appear to be most important:—

1. The arching of the left valve increases until it is coiled through more than one and a half whorls.
2. The area of attachment is progressively reduced.

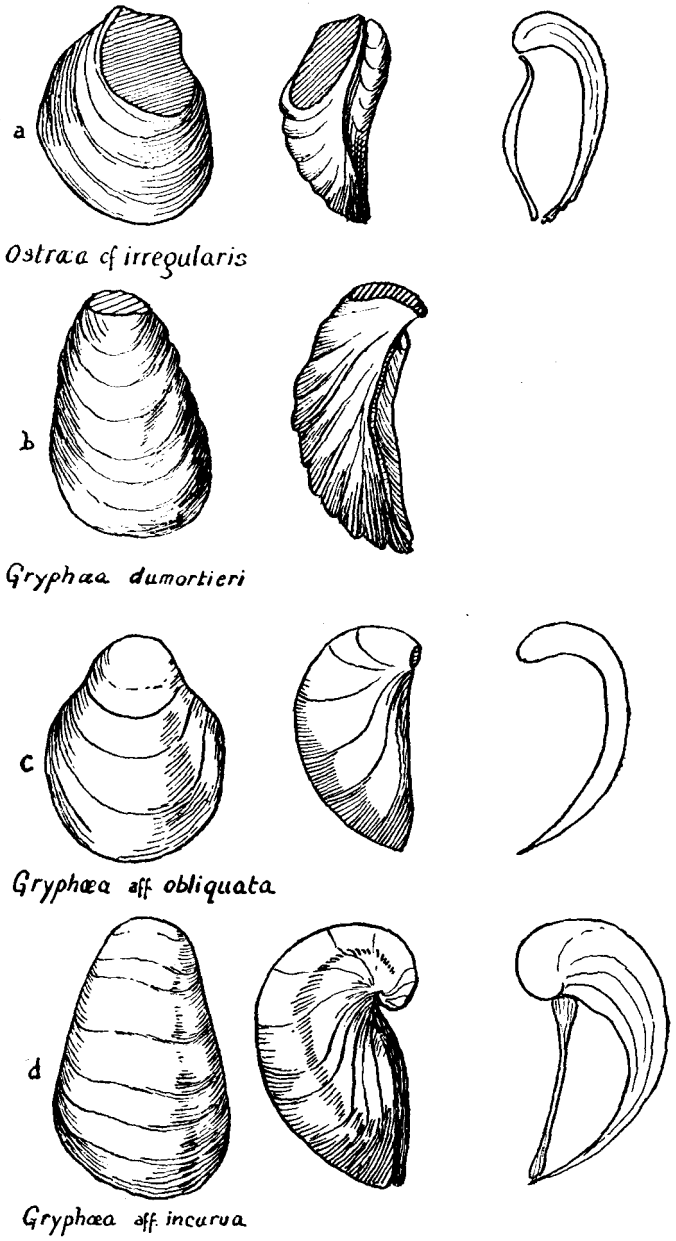

FIG. 1.—Four members of the lineage of *Gryphæa incurva*, showing the left valve, the shell as viewed from the posterior side, and the left valve in section. The area of attachment is shaded. (*a*) *Ostræa* cf. *irregularis* Munst., Lavernock Shales, Lavernock, Glam. (*b*) *Gryphæa* cf. *dumortieri* Joly, *angulata* sub-zone, Dunraven, Glam. (*c*) *G.* aff. *obliquata* Sow., *Vermiceras* sub-zone, Workhouse Quarry, Keynsham, Somerset. (*d*) *G.* aff. *incurva* Sow., ? *gmuendense* sub-zone, near Bridgend, Glam. (slightly reduced).

3. The left (attached) valve is thickened.

4. A sulcus appears on the posterior portion of the left valve; this is developed at a late stage in forms like *G. obliquata*, but at an earlier stage in more advanced forms such as *G. incurva*.

5. The more advanced shells are generally larger.

6. The twist of the left valve seen in *O. irregularis* becomes confined to the apical portion of later species.

The features characteristic of several species are summarized below, and some of the characters named above are illustrated diagrammatically in Fig. 1. The twist of the apical portion of the left valve is shown also in Fig. 2, *a*, *b*; in *G. incurva*, shown in *c* of the same figure, the twist is confined to the apical portion, and is therefore concealed in an adult specimen.

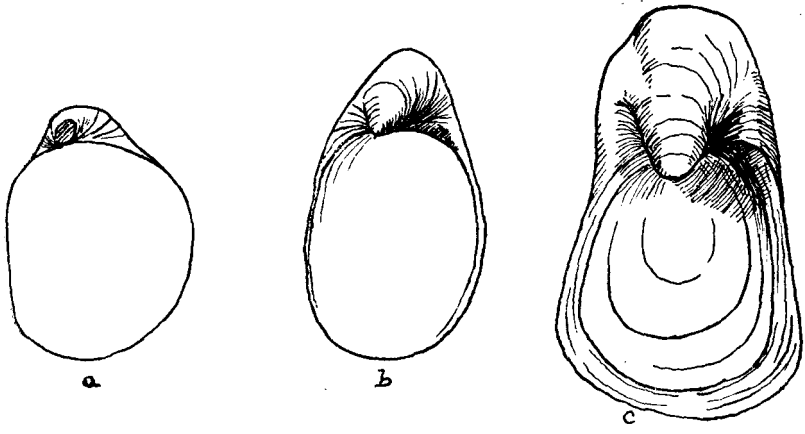

FIG. 2.—Members of the lineage of *Gryphæa incurva*, viewed from the right, to show the twist of the apical portion of the left valve. (*a*) *Gryphæa* aff. *obliquata* Sow., specimen shown in Fig. 1 (*c*). (*b*) *G. obliquata* Sow., a topotype, St. Donats, Glam. (*c*) *G. incurva* Sow., a topotype, Fretherne, Glos.

It is possible that the lineage as here defined includes more than one series, differing only in such characters as the size or breadth of the shell, but there does not appear to be any reason for attempting to separate them now.

THE CURVE OF THE GRYPHÆAN SHELL.

It has already been noticed that the curve of the left valve of *Gryphæa* approximates to a logarithmic spiral.[1] In such spirals, it will be recalled, the constant angle for the spiral is the angle between a tangent to the spiral at any point and a line passing through that point and the origin (o) of the spiral. Thus in Fig. 3 *a* is the angle of the spiral.

[1] D'Arcy Wentworth Thompson, *On Growth and Form*, 1917, p. 534.

Measurement of the spirals of the Gryphæas studied has shown that the spiral angle α is the lowest in the most primitive members, and increases to about 80° in *G. incurva*.

In general it also appears that in the development of a gryphæate shell the angle α increases in a corresponding manner. In the early stages of *G. incurva* the angle may be only 60°, as it is in the adult stages of *G. obliquata*.

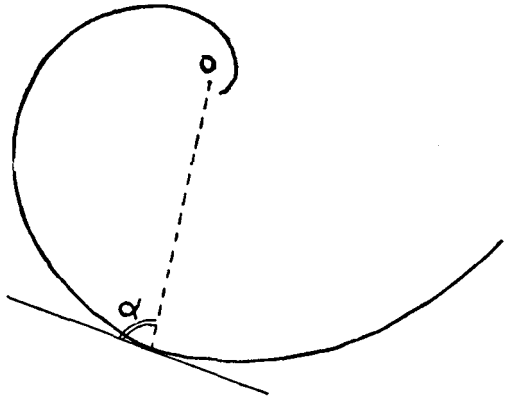

FIG. 3.—Diagram of a gryphæan spiral. Spiral angle, α; origin, o.

THE USE OF GRYPHÆA IN CORRELATION.

As we have noted, the lineage of *G. incurva* ranges from the Oyster Beds at the base of the Lias, where it is represented by flat, oyster-like forms, to the *bucklandi* zone, where it is typically represented by very incurved forms. Consequently the various horizons of the Lower Lias can be identified from a study of the Gryphæas, even when no ammonites are present. For instance, the Gryphæas have proved of considerable value in correlating the littoral Lias of Glamorgan, in which ammonites are very uncommon. In those cases where ammonites have subsequently been found, they have invariably confirmed the conclusions that had been based on *Gryphæa*. It is possible to identify both the zones and the sub-zones in this way.

Some caution is necessary in deciding the precise horizon of beds with *Gryphæa* on account of the variation within the group. Even in the same block of stone they often exhibit marked differences. In a large collection from one horizon it will generally be found that about half the specimens are of similar aspect, with left valves coiled to almost the same extent. Of the remainder, some are less coiled and some are more coiled than the average.[1]

[1] Among Liassic Gastropoda, and some families of Ammonites, it is not uncommon to find adult specimens at the same horizon at somewhat different stages of evolution; some are more "highly accelerated" than others. The differences between the Gryphæas, however, are much more apparent.

The number of whorls forms a measure of the coiling, and also, in a general way, is an indication of the position in the lineage. A curve may be constructed like that in Fig. 4 showing graphically the proportions of specimens from a particular horizon with the various degrees of coiling. It will be noticed from Fig. 4 that the majority of specimens of *G.* cf. *incurva* from the *gmuendense* sub-zone of Bridgend are coiled through more than a whole whorl; a few are coiled for considerably more than a whorl, while others are coiled for only three-quarters of a whorl. The difference in aspect between these two extreme forms is considerable, and it is obviously impossible to determine the horizon represented if only a few specimens are available.

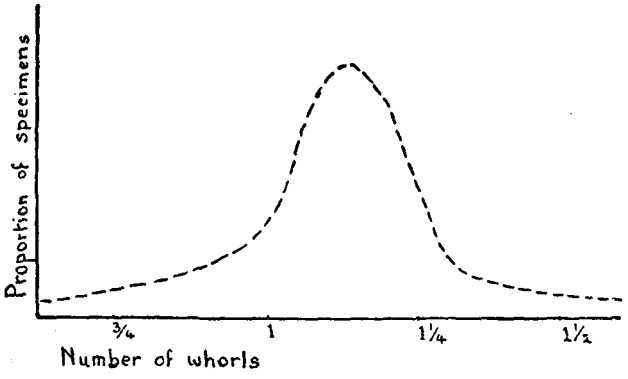

FIG. 4.—Graph based on a collection of *Gryphæa* aff. *incurva* from a horizon in the *gmuendense* sub-zone, Bridgend, Glam., to show the proportions of specimens in various stages of coiling.

When these facts are remembered it is easy to understand the confusion that has arisen concerning the horizons at which various species are found. For example, *G. incurva* has been recorded by various writers from the *planorbe* zone, the *angulata* zone, and the *bucklandi* zone, and although many of the records probably refer to specimens that are really less advanced than the true *G. incurva*, it should be noted that quite curved forms of *Gryphæa* occur somewhat rarely in the *angulata* zone, and not uncommonly in the lower part of the *bucklandi* zone.[1]

In Fig. 5 are shown graphs representing the proportions of specimens in the various coiling stages from several horizons of the Lower Lias. In the lower portion of the *angulata* zone (*liasicus* sub-zone) *Ostræa irregularis* represents the *G. incurva* lineage, and rarely shows a curve of more than a quarter of a whorl. The Gryphæas of the *Vermiceras* sub-zone are typically curved through

[1] The very curved forms from the *angulata* zone generally differ from *G. incurva* in having a feeble sulcus (if any) and a larger area of attachment. They are, therefore, accelerated in some characters only.

more than half a whorl and occasionally more than three-quarters, while the Gryphæas of higher zones may rarely be less curved than three-quarters of a whorl, but are generally a whole whorl or more. In other words, some specimens, perhaps five per cent, in the lower *Vermiceras* sub-zone are as advanced as those in the *gmuendense* sub-zone, but the majority of specimens at each horizon illustrate the trend in the evolution of the group.

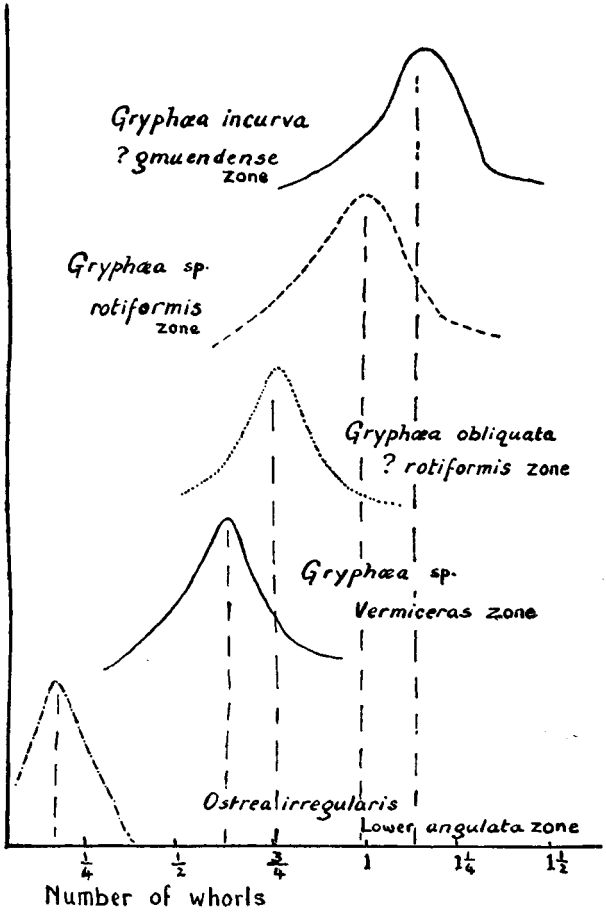

FIG. 5.—Graphs based on collections of gryphæate specimens from several horizons to show the proportions of specimens at each horizon in the various stages of coiling.

[*For* "zone" *read* "sub-zone."]

When using *Gryphæa* in the field for determining the zone it is advisable whenever possible to record the coiling of not less than

fifty, and preferably more than a hundred, adult specimens, from a particular horizon. It will generally be sufficient to note the coiling and any other prominent characters, and it is not usually necessary to preserve large numbers of specimens. There is frequently some difficulty in judging exactly the number of whorls present in uncleaned specimens, particularly in the more advanced members of the series. If all the records are made by the same observer, however, any small inaccuracies do not appear to be of very great practical importance. From these data a graph may be constructed and the zone may be determined by comparison with graphs made from known horizons.

Relation of G. incurva to other Gryphæate Series.

It is not necessary in this paper to describe other gryphæate forms, but it may perhaps be usefully noted that other Gryphæas, such as *G. cymbium* and *G. maccullochi*, have probably been evolved from oysters. Indeed, it is extremely likely that these gryphæiform shells have been evolved repeatedly during the Jurassic and

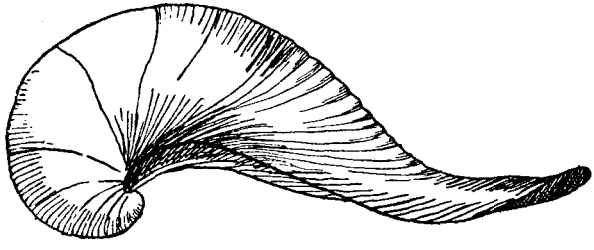

Fig. 6.—A large specimen of *Gryphæa* cf. *incurva* from the *Agassiceras* subzone, Kilmersdon Colliery Quarry, Radstock.

Cretaceous from species of *Ostræa* that are similar and are presumably closely related. In other words, "*Gryphæa*" is a polyphyletic group, containing species evolved along many different lines.[1] Therefore, the name *Gryphæa* can only be applied strictly to *one* of these series, and each such series should receive a separate generic name; but until more of their characteristics are known, at least, it appears undesirable to add to the existing confusion by creating new names for each group. Indeed, as homœomorphs in some of the series are almost or quite identical, it would probably be impossible to distinguish many of the genera even though names were available.

Some of these gryphæate series may be distinguished by the measurement of the angle of the spiral (see Fig. 3) and by the form of the beak.

[1] The parallel evolution of these numerous series, each passing almost inevitably through comparable stages, and following what may be regarded as a pre-determined "programme", affords an example of what Dr. F. L. Kitchin has called "programme-evolution". (See W. D. Lang, *Catalogue Cret. Bryozoa*, vol. iii, 1921, p. xviii.)

Many of these offshoots from the oyster family continued to progress in the characters named, particularly in the curving of the left valve, until a stage was reached when the coiled apical portion pressed against the opercular right valve.[1] Thus in such advanced Gryphæas the shell would be kept closed, and consequently this stage marks the limit of evolution in that direction. Occasionally large adult specimens show a tendency to avoid this calamity by reducing the coiling in the later stages (Fig. 6).

It is only necessary here to refer briefly to the interesting biological aspects of the evolution of gryphæan lineages. Although it may be conceded that the earliest stages in such a lineage may have been of some advantage to the animal, it is obviously difficult to account for evolution in a direction that inevitably leads to the extinction of the lineage, if evolution is the result of the operation of natural selection. Dr. W. D. Lang has taken a different view of the relative importance of natural selection, and has suggested that these lineages became extinct through the secretion of a superfluity of calcium carbonate.[2]

Notes on Species.

Ostræa liassica Strickland.

This name conveniently covers the typical oysters of the base of the Lias. A flat form, usually attached by the whole surface, or nearly the whole surface, of the left valve. Commonly about 1 inch to 1½ inches in length.

These shells are most abundant in the *Ostræa* Beds at the base of the Lias, and are also found in the overlying *planorbe* and *Caloceras* sub-zones. In the latter, the oysters are not infrequently moulded on the shells of ammonites. Oysters somewhat similar to this species, frequently of larger size and less regular form, are also found in several higher zones of the Lower Lias.

Some small specimens of *O. liassica*, collected at Lavernock, near Cardiff, and at Owthorpe and Barnstone, near Nottingham, show the initial shell or prodissoconch (Fig. 7). In these young shells the umbo is prominent in the free valve and is directed posteriorly, as in *Ostræa edulis*.[3]

Ostræa irregularis Münst.

O. irregularis Quenstedt. Der Jura, 1858, t. iii, 15*a*, *b*.

Cf. *O. sublamellosa* Dunker, Dumortier. Dépôts jurassiques du Bassin du Rhône, pt. ii, pl. i, 10, 11, 12.

This name is applied to oysters of the Lower Lias that are in a semi-gryphæate condition. The size of the area of attachment varies, but is typically about half the total length of the shell. The left (attached) valve is thickened (Fig. 1*a*).

O. irregularis is characteristic of the *liasicus* sub-zone, and is

[1] As in the type of *G. incurva*.

[2] W. D. Lang, *Catalogue of Cretaceous Bryozoa*, vol. iii, 1921, p. x.

[3] R. T. Jackson, loc. cit., p. 312.

extremely common in the Lavernock Shales in the Cardiff district [1] and in the lower *angulata* zone near Keynsham, Somerset.[2]

Gryphæa cf. *dumortieri* Joly. (Fig. 1*b*.)

G. dumortieri Joly. Les Fossiles du Jurassique de la Belgique, 1908, pl. i, figs. 4–7.

G. sp. Dumortier. Dép. jur. Bass. Rhone, pt. ii, p. 83, pl. xv, 1, 2.

This species is distinguished from *O. irregularis* by its smaller area of attachment, which is not usually more than one-sixth the length of the shell. The curve of the left valve amounts to about one-half of a whorl. This species was described by Joly from the Hettangian of Belgium; specimens which appear to be identical are found not uncommonly in the *angulata* sub-zone of Glamorgan and around Radstock, Somerset.

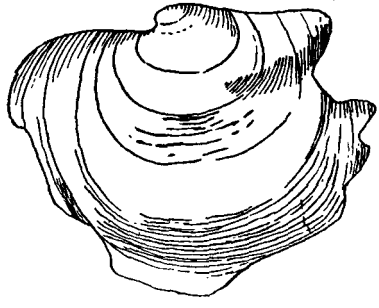

FIG. 7.—Prodissoconch of *Ostræa liassica* Strick. × 8 approx. From the *Ostræa* Beds, Owthorpe, Notts.

Gryphæa obliquata Sow.

Cf. *G. arcuata* var. *rugosa* Munst. Goldfuss, Petref. Germ., pl. lxxxiv, fig. 2*c* only.

This specific name has been applied to many gryphæate forms from various horizons in the Lias. It is necessary therefore to emphasize the characters by which it is distinguished.

Sowerby pointed out that in his species—

1. The attached valve does not form a complete whorl.
2. The beak is twisted to the posterior side (Fig. 2*b*).
3. The area of attachment is small.
4. The shell is broader in proportion than in *G. incurva*.

It may be added that the holotype of Sowerby's species (in the British Museum of Natural History) shows a faint sulcus appearing on the later part of the shell. The shell is not free from matrix, but the apex of the shell appears to be broad and not detached

[1] A. E. Trueman, "The Liassic Rocks of the Cardiff District": *Proc. Geol. Assoc.*, vol. xxxi, 1920, p. 102.

[2] A. Vaughan & J. W. Tutcher, "The Lias of the Neighbourhood of Keynsham": *Proc. Brist. Nat. Soc.*, N.S., vol. x, 1903.

or beak-like. The shell is broken, but at the length of 42 mm. has a breadth of 32 mm.

The holotype is beekitised and was collected in the Blue Lias near St. Donats Castle. Beekitised Gryphæas, agreeing with Sowerby's specimen in size and character, are exceedingly abundant in the limestone reefs forming the shore just west of St. Donats Bay, Glamorgan.

It is likely that these are topotypes of Sowerby's species; ammonites are not commonly found in those beds, but the horizon is the lower part of the *bucklandi* zone (the *Vermiceras* or *rotator* sub-zone). Comparable forms are found on the Dorset coast at approximately the same horizon (W. D. Lang Coll. 4143–6).

Gryphæa incurva Sow.

Cf. *G. arcuata* Lamarck.

The chief characters of this species are the following:—

1. The arched valve makes much more than one complete turn; it frequently represents one and a half whorls.

2. The area of attachment is very small and is concealed in adult shells by the curving of the valve.

3. The shell increases very slowly in breadth, and the breadth is little more than a half the total length (measured across the whorl). In the holotype, the breadth of the arched valve at its widest point is 41 mm.; the diameter or greatest length is 73 mm.

4. The beak does not appear to be oblique at the apex in a complete specimen.

5. A prominent sulcus is present on the shell from an early stage in development.

It must be pointed out again that this name has been frequently misapplied, and emphasis must be laid on the extreme curvature of the left valve of this species.

The holotype (British Museum of Natural History, No. 43343) is a specimen from Fretherne, Glos. The horizon is the *bucklandi* zone (probably the *Agassiceras* sub-zone). Identical forms are known from Purton Passage, Glos. (J. W. Tutcher Coll.); from Bengeworth, near Evesham, Glos. (L. Richardson Coll., L.L. 16 and L.L. 11); and from the railway cutting near Bridgend, and other parts of Glamorgan.

It is, perhaps, desirable to explain why Sowerby's specific name is used here in place of *G. arcuata* Lam., which is supposed to be synonymous. Notwithstanding the similarity between the two, there is no proof of identity. Even if the two species can scarcely be distinguished it does not necessarily follow that they are members of the same lineage, and it is therefore preferable to use Sowerby's name for the specimens from the English Lias.

NOTE ON THE CLIFF SECTION AT FRETHERNE, GLOS.

The low river cliffs at Hock Crib, Fretherne, about 8 miles south of Gloucester, were examined primarily in order to determine the

precise horizon of *G. incurva* Sow., of which this is the type locality. An account of this section was published by Mr. L. Richardson in 1908.[1] It is unnecessary to repeat the details given by him.

That writer discovered several ammonites and concluded that the zones from *megastoma* to *semicostatus* were present. Ammonites are not now abundant at Fretherne, but it appears from recent observations that no beds lower than the *bucklandi* zone are present. Large *Arietid* ammonites are found in the lowest reef on the foreshore (No. 24 on Mr. Richardson's section). In the same bed the Gryphæas are only slightly arched, with feeble sulcus and with fairly large area of attachment. Gryphæas in the succeeding beds (Nos. 20 and 18) show a more incurved left valve and are generally small. Specimens that are scarcely distinguishable from *G. incurva* are found occasionally in beds 15 and 13, but in the same bands are less coiled specimens. Large specimens resembling the holotype are most abundant in bed 11.

The precise horizon of this cannot easily be determined, but in bed 9, some 5 feet higher, *Arnioceras bodleyi* is present, and presumably the typical *G. incurva* occurs near the top of the *bucklandi* zone at Fretherne. Fragments resembling *Coroniceras gmuendense* were found just below bed 11, and it is certain that the type of *G. incurva* is from the upper part of the *gmuendense* sub-zone or a little higher.

Notes on the Fauna of the Lower Devonian Beds of Torquay.

By F. R. Cowper Reed, Sc.D., F.G.S.

(PLATE XII.)

Part III: Mollusca.

Pterinea (*Cornellites*) *costata* Goldfuss.

In spite of Frech's detailed work on the Devonian *Aviculidæ*, the application of the specific name *costata* to certain members of the genus *Pterinea* is even now a matter of some dispute, and Drevermann [2] considers that Frech [3] included under this name some shells which properly belong to *Pt. Pailletei* De Vern. Walther [4] and Fuchs [5] have more recently described the internal characters. Williams [6] has chosen the species as the type of his new subgenus *Cornellites*.

The one fairly good example from the Torquay district with which

[1] L. Richardson, "The Section of Lower Lias at Hock Crib, Fretherne, Glos.": *Proc. Cottes. Nat. F.C.*, vol. xvi, 2, 1908, pp. 135-42.

[2] Drevermann, *Palæontographica*, Bd. L, 1904, p. 237.

[3] Frech, "Devon. Aviculidae": *Abh. geol. spec. Kart. Preuss.*, Bd. ix, iii, p. 71, t. viii, fig. 2; t. ix, figs. 4–8.

[4] Walther, *Neues Jahrb. f. min. Geol., Beil.*, Bd. xvii, 1903, p. 36.

[5] Fuchs, *Abh. kön. preuss. geol. Landesanst.*, N.F., Heft 79, 1915, p. 31, t. viii, figs. 12–18.

[6] Williams, *Proc. U.S. Nat. Mus.*, vol. xxxiv, 1908, p. 89.