THE
MONTHLY MICROSCOPICAL JOURNAL.
FEBRUARY 1, 1876.

I.—*Remarks on the Foraminifera, with especial reference to their
Variability of Form, illustrated by the Cristellarians.*

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(Read before the ROYAL MICROSCOPICAL SOCIETY, December 1, 1875.)

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Remarks on the Cristellarians figured in Plates CXXVIII. and CXXIX. in illustration of their Variability.

Introduction.—This paper is not intended to be exhaustive; and, with little that is novel, it aims at giving a general view of the structure and affinities of the Foraminifera and of their extreme variability.

As is well known to Microscopists, foraminiferal shells can be obtained from numerous marine sands, silts, muds, and clays, recent

DESCRIPTION OF PLATES CXXVIII. AND CXXIX.

PLATE CXXVIII.

- FIG. 1.—Max von Hantken's 'Die Fauna der Clavulina-Szabói-Schichten,' 1875, p. 23, pl. 2, fig. 5 (part). *Nodosaria Beyrichi*, *Neugeb.** (= *Nod. radiculula*, Lin.). *a*, side; *b*, end, with radiate terminal orifice.
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[FIG. 7.]

* "*Nodosaria Nengeboreni*, *Reuss*," in the explanation of the Plate.

and fossil, by careful manipulation, and very easily from the sponges of commerce, which often become charged with them when trodden about, in process of drying, on richly foraminiferal beaches. Sometimes half the material of a beach-sand consists of Foraminifera. In some tropical islands, shoals and beaches are formed wholly of the shells of *Orbitolites*, *Tinoporus*, *Operculina*, &c. Fresh seaweeds placed in salt-water aquaria, fresh oyster-ooze and other marine muds washed in sea-water, fine surface-nets and under-water trailing bags, are among the means of obtaining living specimens. In the fossil state Foraminifera constitute great stratified masses, such as the Fusulina limestone of Russia and elsewhere, the Saccaminal limestone of Northumberland, much of the White Chalk, the Nummulitic limestone of Europe, Asia, and North Africa, the Miliolitic limestone of Paris, Alveolina limestone of

- FIG. 7.—v. Hantken, p. 87, pl. 14, f. 4. *Cristellaria elegans*, *Hantk.* *a*, side; *b*, inner edge.
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W. West & Co. Lith.

Gradational Cristellarians.

Scinde, Loftusia rock of Persia, Orbitoidal limestones of the Alps, India, Alabama, Jamaica, and Java, and Amphistegina limestone of Australia; besides vastly adding to the bulk of other limestones and many thick clays, and further, by means of their glauconitic casts, to that of numerous sandy and other strata. Some of the oldest rocks even are largely composed of them, in the forms of *Eozoon*,* *Stromatopora*,† *Receptaculites*,‡ and their allies.

Some kinds of *Orbulina*, *Globigerina*, and *Pulvinulina* have been taken by towing nets at and near the surface of the ocean by Major Owen and others. These constitute also the mass of the abyssal forms. They may have more sarcode in proportion to shell

PLATE CXXIX.

- Fig. 1 a.—Von Hantken, p. 24, pl. 3, f. 1 (part). *Nodosaria spinicosta*, *D'Orb.*
 „ 1 b.—v. Hantken, p. 37, pl. 4, f. 2. *Dentalina Hoernesii*, *Hantk.*
 „ 2.—v. Hantken, p. 48, pl. 5, f. 2 (part). *Marginulina Behmi*, *Reuss.*
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 b, inner edge.
 „ 6.—v. Hantken, p. 57, pl. 6, f. 10. *Robulina gutticostata*, *Gümb.* (= *Cristellaria papillosa*, F. and M.). a, side; b, inner edge.
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 „ 8.—v. Hantken, p. 28, pl. 2, f. 10. *Nodosaria Budensis*, *Hantk.* (= *Nodosaria raphanus*, Lin.). a, side; b, end.
 „ 9.—‘Annals Nat. Hist.,’ ser. 4, vol. viii. “Nomenclature of the Foraminifera,” by Parker, Jones, and Brady; “Species founded by D’Orbigny on figures in Soldani’s ‘Testaceographia,’ &c.,” 1871, p. 163, pl. 10, f. 72. *Marginulina raphanus*, *D'Orb.*
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 „ 13.—Brady’s ‘Foram. Lias,’ p. 110, pl. 2, f. 30. *Planularia Bronni*, *Römer.*
 „ 14.—Brady’s ‘Foram. Lias,’ p. 111, pl. 2, f. 33. *Planularia reticulata*, *Cornuel.* (= *Vaginulina*).
 „ 15.—D’Orbigny’s ‘For. foss. Vien.,’ p. 90, pl. 3, f. 43. *Cristellaria semiluna*, *D'Orb.* (= *Planularia auris*, DeFr.).
 „ 16.—‘Ann. N. Hist.,’ 1871, p. 166, pl. 10, f. 75. *Planularia rostrata*, *D'Orb.*
 „ 17.—v. Hantken, p. 43, pl. 13, f. 13. *Flabellina striata*, *Hantk.* a, side; b, edge.
 „ 18.—‘Ann. N. Hist.,’ 1871, p. 243, pl. 11, f. 101 (part). *Cristellaria navi-
 cularis*, *De Montf.* (= *Flabellina Cristellaria cassis*, F. and M.).
 „ 19.—D’Orbigny’s ‘For. foss. Vienne,’ p. 104, pl. 5, f. 5. *Robulina imperatoria*, *D'Orb.* (= *Cristellaria vortex*, F. and M., keeled).

* Dawson’s ‘The Dawn of Life,’ Svo, 1875. Hodder and Co., London.

† G. Lindström, ‘Kongl. Svenska Vetenskaps Akademiens Handlingar,’ vol. ix., No. 6, 1870.

‡ Gümbel, ‘Transact. Bavarian Acad.’ Munich, 1875.

than the others. Like as the few butterflies rising up to the mountain top, have left the many floating in air among the flowers in the valley, so these float upwards in the higher regions of the water, whilst others remain below,—making their tests of deep-sea sand or of spicula, or of Foraminifera themselves,—or attached to rock, shell, or seaweed,—or lying free on the bottom, with other organisms, to be preyed on by *Dentalium* (S. P. Woodward) or *Ophiura* (at 1260 fathoms, Wallich),—to be used up in the shells of some larger congeners,—to be accumulated in *strata*,—or to be converted into such glauconite as coats the floor of the Mexican Gulf with black-green sand.

The differences of depth at which these Microzoa live, and the concomitant conditions of agitation or repose, of clear or muddy water, much or little nourishment, of relative warmth and light, are easily recognizable. Thus *Polystomella* has a thicker shell in shallow than in deep water; but *Globigerina* is thicker in deep than in shallow; and where it most abounds in abyssal waters, the associated Foraminifera are often few in kind, few as individuals, and very small. Possibly the greater amount of light and warmth that the shallow-water *Polystomellæ* and the floating *Globigerinæ* enjoy, favours their growth beyond that of the more deeply seated and the non-floating forms; but others living even in deep water have thick shells, either meeting with favourable conditions of growth, or having grown thick before they sank to the bottom.

The susceptibility of variation, by relative increase of size, or by modification of shape and mode of growth, or by the thickening and complexity of the shell, belongs to all the systematized groups of Foraminifera.

Systematic Grouping of Foraminifera.—There are said to be 4000 recognizably different forms of these little Rhizopodal shells, such as a “superficial observer can separate by words and a name” (Hooker), and these have been sorted according to their apparent alliances into the several divisions of the appended Table (pages 89–92), copied by permission, with slight modifications, from Henfrey and Griffith’s ‘Micrographical Dictionary,’ new edition, 8vo, Van Voorst, London, 1875. These groupings are based, primarily, on the texture of the shell (whether “porcellaneous,” “hyaline,” or “sandy”), and secondarily on the arrangement of the segments of sarcode, and the form of the shell-chambers. Neither the fixed (parasitic) habit of shell, nor the single-chambered condition, has weight in this classification, as neither is confined to any one group of the Foraminifera.

Arranged on this plan many dissimilar forms are found to be mutual allies, and even more closely akin; whilst, with some, an external resemblance, chiefly from mode of growth, is mimetic only,—or, rather, a real bond of relationship, arising from the

general kinship pervading the whole Foraminiferal family. Nor does relationship end here; for there are among these Rhizopods structures and habits analogous to, if not identical with, those of other *Protozoa*. Thus the spicular contents of *Carpenteria*, *Polytrema*, and *Stromatocerium* (if not accidental), and the internal structure of some old fossil *Patellinæ* (*Orbitolinæ*) and *Dactyloporidæ*, point towards Sponges; whilst the radial shells of *Calcarina* and *Tinoporus*, and the basket-like or pierced shells of others not so well known,* remind us of *Polycystina*, though the material be different. Nor should we forget that the *Porcellana*, protruding their sarcode from one part only of the body, are, *in so much*, more closely allied with their shell-less representatives, than with the *Hyalina* and those Rhizopods which have sarcode processes from the general surface. At the same time we know that it is difficult to define the relative value of pseudopodial characters, which do not coincide with the absence or the development of those more important organs, the "Nucleus" and "Contracting Vesicle," on which Dr. Wallich has based a natural system of classification.† No evidence of either organ having been found in *Foraminifera* and *Polycystina*, they stand (as *Herpnmata*) low in the scale of Rhizopods. A definite nucleus is present in the *Protodermata*, comprising the *Plagiacanthidæ*, *Acanthometrina*, *Thalassicollina*, and *Dactyochidæ*, leading towards *Spongidæ*. Both nucleus and contracting vesicle characterize the *Proteina*, as defined by Wallich, comprising the *Actinophryna* (*Actinophrys*, *Gromia*, *Lagynis*, &c.), and *Amœbina* (*Amœba*, *Diffugia*, *Arcella*, &c.), and leading to *Infusoria*.

A new link between the Foraminifera and the *Polycystina* appears to be indicated in the following extract from one of Dr. Wyville Thomson's Reports on the 'Challenger' Expedition.‡ Off Japan, going eastward [long. 167° E., lat. 35° N.], and before turning south towards Honolulu, "on the 26th of June, we sounded in 2800 fathoms. Several forms were met with [in the towing nets below the surface] which apparently do not occur on the surface, particularly a number of species of a group which is, so far as we know, entirely undescribed. It seems to be intermediate between the Radiolarians and the Foraminifera, resembling the former in the condition and appearance of the sarcode and in the siliceous composition of the test, and the latter in external form." The broken tests were extremely abundant in the red clay of the bottom. §

* Such as a fenestrated, lageniform, porcellaneous Foraminifer, discovered by M. Vanden Broeck, of Brussels, and the pierced Rotalines noticed by Ehrenberg and Joseph Wright. See 'Proceed. Belfast Nat. Field Club,' ser. 2, vol. i., p. 87.

† 'Annals Nat. Hist.,' June 1863, p. 439; 'Monthly Microscopical Journal,' 1865, &c.

‡ 'Nature,' November 25, 1875, vol. xiii., p. 70.

§ See also 'Proceed. Roy. Soc.,' vol. xxiv., p. 35.

If the perforated *Rotalinæ* figured by Ehrenberg and Joseph Wright should prove to be *siliceous* (as indeed the Antrim specimen is, though possibly from pseudomorphic change), we have already noticed analogous intermediate examples.* Ehrenberg's original *Spirillina vivipara* is described as being *siliceous*; and is a perfect analogue of our common *Spirillinæ*. Possibly some of the common small Microzoa, passing for Foraminifera, under the microscope, with transmitted light, are really siliceous, and require careful examination with the polariscope.

"I should rather infer," wrote Professor W. C. Williamson, in 1858, "that the hard shells of the Foraminifera do not constitute a sufficiently constant and important element in their organization to justify our trusting to them as guides in the discrimination of species;" and others since then have fully agreed with him, almost, if not quite, to the extent of regarding not only the Foraminifera, but even "the entire group of the Rhizopoda," incapable of *specific* division.† Still the shells have their zoological meaning; for, being variously formed by the sarcode, they refer to some processes of life and some habits of body, some peculiarities of individuals and races, which in higher and more complex animals give *specific* characters,‡ but here, unaccompanied by other fixed features of superadded parts, lose their distinctiveness among imitative repetitions, and are thus lost in changes due to the general adaptability of the sarcodic creature to the varied conditions of its watery life. Certain as it is that the *shells* cannot supply grounds for *specific* distinction, yet their texture and form have the impress of the vital actions of an organism of which frequently little else is tangible; and hence they are important elements in grouping the Foraminifera. It is difficult to appreciate the physiological value of such apparent or presumed organization as is met with in the soft parts of these *Protozoa*, alive or dead, under the microscope, even when well seen; it is difficult to adjudge the relative value of the several methods of producing and using the pseudopodial or other extensions of sarcode; their modes of existence, their individual development and growth, are very imperfectly known. The differences in function and habit and mode of growth may be quite fixed in the several groups of individuals, or not: if fixed, they give *specific* characters; if interchangeable, whether by stages, by

* See 'Proc. Belfast Nat. Hist. Field Club,' ser. 2, vol. i., pp. 87, 88.

† Williamson, 'Recent Brit. Foram.,' p. x.

‡ Professor W. C. Williamson says, "Such differences in the chemical and histological composition of these shells probably indicate correlate physiological differences in the living sarcode, or secreting animal substance, that have at least a specific value" ('Recent Brit. Foram.,' p. xii.). The same *form* of shell (as in *Cornuspira*, *Trochammina*, and *Spirillina*, for instance) being represented in the three groups (Imperforate, Arenaceous, and Perforate), should not invalidate the grounds for specific distinction unless the *structural* differences fail to hold good.

alternations, or less regularly, there is no special grouping. Observations can now be multiplied in these directions, with the help of good aquaria, towards the knowledge of Rhizopodal life.

Shells of the Imperforata.—In the opaque shells of the *Miliolida* (see Table), an important group of the *Porcellana* or *Imperforata*, there is only one outlet for the sarcode, whether as pseudopodia, or sarcoblasts (Wallich), or as a stolon with new segmental growth. The simplest forms of their adult shells are either a mere cell-like shell (*Squamulina*), or a discoidal spiral tube (*Cornuspira*). A similar coil forms the commencement of some *Miliolæ*, which enlarge with half-turns of tubular shell (investing a wire-like sarcode, pinched at the bends), on one or three planes.* By growing out straight, after having made a few of the alternate-sided (agathistegian) turns, the shell becomes a *Ceratospirulina*, linking *Miliola* with *Vertebralina*.

The tooth-like process, or obsolete septum, in the aperture, is sometimes bifid; and by extending as a cribriform plate it becomes the distinguishing feature of *Hauerina*. The inward extension of this oral network, as labyrinthic structure, characterizes *Quinqueloculina saxorum* and *Fabularia*. Another modification of the *Porcellana* is seen in the forms typified by *Orbiculina* and *Peneroplis*, towards which some flat, wide-spread *Hauerinæ* seem to lead us, whilst *Fabularia* and *Alveolina* have a similar internal structure. Further, a *Spiroloculina* (from the Orbitoidal limestone of Java) is figured by Ehrenberg,† which “is very interesting in having lateral stolons from segment to segment, showing a prolepsis of the more complicated and closely related *Orbitolites*, the outside of the quasi-annular segments being multistoloniferous. These supernumerary stolons begin by few, and become many in later segments.”‡

Dr. Carpenter states:§ “I have lately come into possession, through the kindness of M. Munier-Chalmas, of the Sorbonne Museum, of a new fossil type of Foraminiferal structure belonging to the Orbituline group, in which a partial coalescence (or subdivision) of chamberlets, like that of the lamellar portion of *Eozoon*, is very distinctly marked, so as to establish precisely the link of connection which was wanting between the chambers of *Peneroplis* and the completely divided chamberlets of *Orbiculina*.”

* See Williamson's ‘Rec. Brit. Foram.,’ &c., 1858; and W. K. Parker, “On *Miliola*,” ‘Trans. Microscop. Soc.,’ new ser., vol. vi., p. 53. Here I take the opportunity of stating that for facts and views given in this paper I am largely indebted to my friend Prof. W. K. Parker, F.R.S., with whom I have had the pleasure of working on the Foraminifera for twenty years.

† ‘Transact. R. Acad. Berlin’ (for 1855), 1856, pl. 4, fig. xxii.

‡ ‘Annals Nat. Hist.,’ Oct. 1872, p. 265.

§ ‘Annals Nat. Hist.,’ ser. 4, vol. xiii., p. 467.

The now nearly extinct *Dactyloporidæ* are far less evidently allied to the other *Porcellana* above mentioned, than the latter are amongst themselves. Their simplest form of shell (*Haploporella*), however, consists of little sacs, or bottle-shaped chambers, repeated in lateral apposition; and in more complex forms there is a structure approaching that in old *Orbitolites*.

In these points, besides the similarity of shell-tissue, the several groups of the *Porcellana* approach one another; but the *Dactyloporidæ* seem to stand somewhat apart, wanting links, hidden, perhaps lost, in the older rocks. The high-class "hyaline" *Thalamopora* reminds us of some features in the structure of *Dactylopora*.

Shells of the Arenacea.—The *Foraminifera arenacea* divide themselves at first sight into three sets:—1. Those which always have a sandy shell (*Lituola*, *Trochammina*, &c.); 2. Those which have a partly perforate and partly sandy shell (*Valvulina*); and 3. Those which are clear in the young and sandy in the old stages, as *Textularia* and *Bulimina*, and sometimes *Spiroloculina*, *Quinqueloculina*, and *Nubecularia*.

The persistently arenaceous forms are also divisible into two kinds:—1. Those with fine-grained sand in the shell-cement, and mostly smooth (*Trochammina*, &c.); and 2. Those with coarser grains, less cement, and a rough surface (*Lituola*, &c.). In some cases sponge-spicules are partly or wholly used in the construction of these tests. There is great difficulty, however, among the innumerable modifications of the arenaceous Foraminifers, in drawing a line between relative roughness and smoothness of shell, abundance and scarcity of cement, and coarseness and fineness of materials; and we are led from the rough lituate, to the smoother nautiloid *Lituolæ*, and on to the rotaloid *Trochamminæ*, and thence to *Valvulina*, until the whole series becomes apparently indivisible.*

Of the rough-cast sand-shells, with a minimum of cement, *Lituola* is the leading type. It takes the well-known lituate shape; but frequently also it imitates *Lagena*, *Nodosaria*, *Orthocerina*, *Marginulina*, *Flabellina*, *Bulimina* (?), *Nonionina*, and *Globigerina* so closely that, excepting for its internal labyrinthic structure and cribrate septa, the sandy coat would seem to belong as rightfully to these as a hyaline shell. My friend, Mr. H. B. Brady, F.R.S., tells me, indeed, that it is very difficult to say whether or no the earliest (palæozoic) *Nodosariæ* had normally clear, or opaque, or sandy shells.

In his description of *Quinqueloculina fusca*,† Mr. H. B. Brady, F.R.S., points out that it differs from *Q. agglutinans*‡ in having a tough, flexible test with a very little amount of calcareous or earthy

* Brady, 'Annals Nat. Hist.,' ser. 4, vol. x., p. 261.

† 'Annals Nat. Hist.,' ser. 4, vol. vi., pp. 276, 286.

‡ *Op. cit.*, p. 48.

constituents, although still of composite structure. Like *Globigerina* and *Orbulina*, this *Miliola* becomes less calcareous, he remarks, in brackish water. In similar degree, but under marine conditions, *Trochammina* is less arenaceous than *Lituola*.

Dr. Wallich* remarks on the difference in test-structure between the coarse-shelled *Diffugia* and the chitonous *Arcella*, being only of *subspecific* value, at most, in these *Proteina*, which he places much higher among the Rhizopods than the Herpematous *Foraminifera*.

My friend Mr. H. B. Brady, F.R.S., states, in a letter dated December 25, 1875:

"I think I have satisfactorily settled that the dentaliniform Foraminifera from the Carboniferous rocks were all non-porous ('imperforate'),—that those from the Permian were partly true *Dentalinæ* (at Byer's Quarry) and partly imperforate (at Tunstall Hill); the specimens in the latter case are larger and have much thicker shells. Many Palæozoic forms (not *Dentalinæ*) are quite thin-shelled, and, to all appearance, *imperforate*—neither 'porcellaneous' nor truly 'arenaceous.' *Endothyra* is another case in point,—thin-shelled, never porous, and subarenaceous. I believe some of these forms are really and truly the commencement of two series, differentiating, on one side, into a porous (perforate),—on the other, into a truly arenaceous (imperforate) line of organisms. The Carboniferous *Valvulina* is an analogous, smooth, imperforate species.

"*Involutina* (Liassic) has sometimes a perforate undershell, though arenaceous externally. I have some specimens beautifully perforate, but not one in a hundred of those I have worked upon. I am convinced that it runs into *Trochammina incerta* without any gap, though distinct enough in the tuberculate thickened forms. Indeed, the key to the relationship between the Arenaceous and the Perforate forms is to be found in the genera *Trochammina*, *Valvulina*, *Endothyra*, and *Textularia*. The labyrinthic condition of some *Textulariæ* links them with the *Lituolæ*."

On the Abrohlos Bank occur *Valvulinæ* with coarse-grained shells, and others of the usual fine-grained consistence. Whether the coarser specimens are *Lituolæ* imitating *Valvulina*, or really *Valvulinæ* with unusually coarse shells, losing their customary hyaline tissue altogether, it is difficult to say. So, on the contrary, as the older (fossil) *Buliminæ* and *Textulariæ* are sandy (*Ataxophragmium* and *Plecanium*, of Von Reuss), it may be surmised that they were at first either persistently sandy and Lituoline forms, or at most only partially "hyaline," as *Valvulina* † is now; and that they have since produced more and more *hyaline* shell (less and less sandy), until their successors have ceased to take up sandy materials until arriving at an adult or old stage.

Of the two gigantic arenaceous Foraminifera, *Parkeria* and *Loftusia*, it is stated that the latter, elongate and biconical, shelled with calcareous cement and fine sand-grains, has a similar relationship to *Alveolina* and *Fusulina* that *Trochammina incerta*

* 'Annals Nat. Hist.,' March 1864.

† Some of the Cretaceous *Valvulinæ* are quite Buliminoid in aspect.

has to *Cornuspira* and *Spirillina*.* With its great size, it has considerable labyrinthic extension of its shell walls within, as in *Lituola*. The great spherical *Parkeria* is sandy with little cement, and, beyond the nucleus of earliest chambers, its walls (highly labyrinthic and Lituoline) are quite concentric and enclosing, unlike any other known Foraminifer.†

In *Valvulina* we have a linking between the *Perforata* and the *Imperforata*; and if *Valvulina* leads to *Trochammina* and *Webbina*, and if these, when poor in sand-grains, are but little distinguished from *Nubecularia*, *Cornuspira*, and *Miliola* (most of which also can at times take up sand into their shellsubstance), there are evidently several points where the differentiation of the three great Foraminiferal groups is by no means absolute.

Shells of the Perforate or Hyaline Foraminifera.—The globular, subglobular, lageniform, and other *primordial* segments, whether simple, or divided off into a secondary semilune, are seen in the *Imperforata*, *Arenacea*, and *Perforata*. The straight, linear, or “stichostegian” growth of segments occurs in all the three groups, though rare in the first, where it is represented only by some attenuate *Articulinae* and *Spirolinae*, with obsolete Milioline or Peneroplid commencements. In the second and third groups it is common, as in *Lituolæ* and *Nodosariæ*. It often occurs too as a “sport,” or wild growth, after other segmental arrangements, giving rise to “dimorphous” *Miliolæ*, *Peneroplides*, *Cristellariæ*, *Polymorphinæ*, *Virgulinæ*, and *Textulariæ*. Both *Lituola* and *Nodosaria* (theoretically straight, but often bent), are so changeable that dimorphism of curved and straight (litate), or of squareness and roundness, in the same individual, is not unfrequent. The only analogous freedom from the restraint of a regular fixed line of growth among the *Globigerinida* is enjoyed by *Planorbulina*, especially in its Truncatuline modifications; but here a single straight line is never attained. The *heaping up* of chambers and chamberlets, as in *Orbitoides*, *Patellina*, *Eozoon*, and others of the *Globigerinida*, is not here in question.

The existence of “canal-system” and “intermediate skeleton” is characteristic of the higher *Rotalina*, but it has been discovered in *Planorbulina* by M. Munier-Chalmas.‡

The simple, tubular, coiled *Cornuspira*, *Trochammina* (*T. incerta*), and *Spirillina* are scarcely distinguishable except by their shell-texture; and though some fossil (Jurassic) *Cornuspiræ* and *Trochamminæ* are so thin, and in the latter case so free from sand, as to be subtranslucent, their habit of growth distinguishes them; whilst *Spirillina* is always perforate.

Alveolina, *Loftusia*, and *Fusulina* represent, in the three several

* H. B. Brady, ‘Phil. Trans.’ 1869, pp. 741 and 751.

† Carpenter, *op. cit.*, p. 728.

‡ ‘Annals Nat. Hist.’ ser. 4, vol. xiii., p. 459, *note*.

groups, a similar form of shell, but with considerable differences of structure.

The "agathistegian" growth of shell, so characteristic of *Miliola*, is represented in the *Perforata* by *Allomorphina* and *Chilostomella*, and among the sandy forms by *Trochammina milioloides*. On the other hand, the nautiloid, or disco-spiral, segmented growth, so characteristic of the *Perforata*, is found in *Lituola* (*L. nautiloidea* and *L. canariensis*), *Endothyra*, and *Trochammina* (*T. inflata*) of the sandy group; but it is only approached in the *Imperforata* by *Hauerina* and *Dendritina*. The *Orbiculinitida* (porcellaneous) correspond, in annular and subdivided chambers, with *Heterostegina*, *Cycloclypeus*, &c. (hyaline).

The alternate arrangement of chambers, seen so frequently in the *Hyalina*, is less common (*Valvulina*) in the *Arenacea* (unless we include the sandy *Textulariæ* and *Buliminæ*), and does not appear among the *Porcellana*.

Thus we see some general features of resemblance between all the three great groups, in the style of growth and arrangement of the segments, as represented by the shell; and occasionally still more binding links, such as the passage from the *Perforate* through *Valvulina* and its arenaceous allies to the *Imperforate* group. We also see very close kinship between some of the so-called "families," and decidedly among the members (so-called "genera") of these subgroups, though we have here looked at only those of the *Porcellana* and *Arenacea*, and that very cursorily. It is well known that the distinctive naming of the members of the so-called "genera" of Foraminifera almost amounts in some cases to naming the individuals themselves; and that "subgenera," "species," "subspecies," and "varieties" are terms easily applied to specimens differing less and less from a chosen type, the characters of which exist for us only in the shape, ornament, and other features of a simple shell. Doubtless the real zoological distinctions (whatever their relative value may be) are to be found in the morphology of these Microzoa: doubtless also their shells have the impress of their original and successional conditions, but these characters are obscured to a very great extent, and wait for further elucidation.

The following extract from a memoir by my friend Prof. W. K. Parker and myself, in the 'Quart. Journ. Geol. Soc.,' vol. xvi., 1860, pp. 293, 294, expresses the views on this subject we then entertained, and which we still hold, looking, however, on "species" of Foraminifera as more comprehensive, and less easily defined, the more exact our acquaintance with them becomes.

"With respect to the nomenclature adopted in our Table (of fossil and recent Foraminifera of the Mediterranean and Euxine areas, *loc. cit.*, p. 302), we have, in the first place, been careful to eliminate all unnecessary binomial terms, such as duplicate names, or names given to but slightly varied individuals; and at the same time we have enumerated many well-marked varieties in each species, because of their

value as indications of peculiar conditions of habitat; and because, many of them presenting at first sight striking differences of form, size, and ornamentation, and being easily mistaken for types of distinct specific groups, they have acquired an importance in the eyes of zoologist and geologist which makes it convenient to give them a sort of subspecific value and a binomial term.

"It has been doubted by some whether in this, the most variable, because simplest, family of the animal kingdom, every variety should not be distinguished by its own binomial appellation,—a plan that has been followed almost to the full by many naturalists. In this, however, we cannot agree, for the unlimited multiplication of quasi-specific names, linked together by pseudo-generic titles, can only weary the catalogue-maker, and throw obstacles in the way of the systematist; for it keeps up a false notion of the value of external characters which are rarely essential, whilst no clue is thereby obtained to the morphological law of each real specific type. Evidences of such law, however, are not wanting when we carefully examine varietal forms as they diverge, and, as it were, radiate, from a given central type.

"Though Linnaeus was somewhat parsimonious in giving names to the microscopic shells which he knew, and though Fichtel and Moll partially indicated their great variability, and were cautious in naming them, yet it was not until Dujardin demonstrated the nature of the Rhizopodous sarcode and its simple, non-differentiated character, and until Williamson and Carpenter, taking up the study of certain species, showed what extreme forms might be connected together by innumerable gentle intermediate gradations, that anything like a really scientific appreciation of these Microzoa may be said to have existed. Our own experience of the wide limits within which any specific group of the *Foraminifera* multiply their varietal forms, related by some peculiar conditions of growth and ornamentation, has led us to concur fully with those who regard nearly every species of *Foraminifera* as capable of adapting itself, with endless modifications of form and structure, to very different habitats in brackish and in salt water,—in the several zones of shallow, deep, and abyssal seas,—and under every climate, from the poles to the Equator. Our principles of nomenclature, and the application of them, may be seen in our papers on *Foraminifera* in the 'Annals and Mag. Nat. Hist.'"

Hyaline or Perforate Foraminifera.—The typical shell of a "hyaline" or "perforate" Foraminifer is, in its simplest form, a very thin, calcareous, perforated tissue, as in an *Orbulina*, or in a young *Globigerina*, or in the primary segments of a *Nummulina*. In the *Lagenida* this early shell is more compact than in some other groups, but still minutely perforate. With the growth of additional segments (whether in straight, curved, or alternate arrangement), the chambers become coated, by the investing sarcode, with successive layers of shell; and the primary layer, whether soft and friable, or relatively hard and glassy, becomes thickened; its perforations, however, are usually kept continuous with the tubules in the succeeding layers by the presence of the pseudopodia, between and around which the little prism-like constituents of the simple shell are formed. According to the number of successional layers, the chamberwalls necessarily vary in thickness, either uniformly or with inequalities.

These latter originate variously; for instance, 1. From the superabundant shellmatter laid down on spots or lines, as pimples and prickles, or as thick and thin ridges, as in the *Lagenida*. 2. Thickenings over certain structures, as over the edges of septa,

as in *Cristellaria*, &c., and of margins, as in *Vaginulina*, &c. ("limbation"); or over the crossing of septa, as in scabrous *Nummulinæ*, and in umbonate *Amphisteginæ*; also in the umbilicus of *Rotalia*. 3. Local hypertrophy of the shellsubstance, with branching tubes, continued from the annular and other canals, in the thicker shells; as in the radiate processes of *Tinoporus*, in the umbones of *Polystomella*, and in the processes and umbones of *Calcarina*. 4. The outward extension of the narrow walls, or intervallation, of the tubuli, making their edges sharp and rugged, as in old *Globigerinæ*, and even prolonging them into thickets of long, thin needles, as in the acerose and hispid *Globigerinæ* and *Orbulinæ*, rivalling *Radiolaria* in their radiate growth. Other modifications of this superficial shellgrowth among the pseudopodia are seen in some *Planorbulinæ*; and the shellmatter sometimes sheaths the roots of the pseudopodia in very hirsute *Calcarinæ*, also occasionally in *Textularia* and *Planorbulina*. In an extreme degree it involves the terminal processes of sarcode in *Polymorphina horrida*; and not unfrequently makes an apertural tube, giving a pouting orifice to *Uvigerina*, &c. 5. The formation of subsidiary flaps, tentlike projections, and chamberlets for umbilical sarcode, is frequent, as in asterigerine *Discorbinæ*. Such secondary segments are neatly packed among the chambers in *Amphistegina*.*

Endless modifications of external appearances are brought about by the various developments of these and other habits of growth; and the *extremes* produced by each kind of growth may seem at first sight to have little or no relation one to another.

The method in which the shelly coatings of successive segments meet each other,—singly, in the simple tentlike setting-on of the new chamber; doubly, with more or less continuous enwrapping of the new segment in shellmatter; or double with intermediate canaliferous substance,—does not now immediately concern us, though at the foundation of many modifications of form.

Lagenida.—The *Cristellarians*, whose variability we have especially to illustrate, belong to the *Lagenida*. This large group comprises, besides *Ellipsoidina*, of obscure relationship, the *Lagenæ*, the *Nodosarinæ*, and *Orthocerinæ*. *Polymorphinæ* and *Uvigerinæ* have very little distinctive character to separate them from this group.

Lagena.—The very common *Lagenæ* are mere flasklike shells, exquisitely delicate, presenting endless and generally elegant modifications of form. Always of simple construction, *Lagena*, nevertheless, has its surface occasionally beset with rough granules of shellmatter, and even overcast with a coating † which the outer sarcode may be said to have laid down in abortive effort to procure the "supplemental

* The examples here offered for these inequalities of surface are not to be regarded as exhaustive.

† 'Phil. Trans.,' vol. clv., p. 420, pl. 13, fig. 7.

skeleton" so highly perfected in some *Rotalina*. When elliptical in section (compressed) *Lagenæ* lose the roundness of their orifice, which becomes a slit, giving the quasi-subgeneric name of *Fissurina*. The triangular and quadrangular forms of some compressed *Lagenæ* have given rise to other such terms. *Amphorina* is a *Lagena* open at both ends. When the apertural tube is turned inwards, the shell is Entosolenian; when the tube is present and protrudes as usual, it is Ectosolenian. Some *Polymorphinæ* have an inverted tube also. The shells of *Polymorphina* and *Uvigerina* have much in common, one with another, and consist essentially of Lagenoid chambers heaped alternately, with certain habits of growth, but Lagenidal in ornament and aperture. Nor are *Bulimina* and its subgroups far removed from the same series.

Nodosaria, *Cristellaria*, &c.—A succession of Lagenoid chambers, in a straight line, constitutes a *Nodosaria*. The chambers being like a series of bottomless, or at least perforated, flasks, set one on another. They differ considerably in their overlap, from merely encircling the previous apertural tube, or neck, to investing the whole front of the previous chamber. The terminal aperture is either a round hole, with its border cut up into minute radial laminae, or a produced tube, sometimes lipped, and occasionally encircled, as in some *Lagenæ*, with a little spiral cord. The ornament consists essentially of either perfect or intermittent ridges of vitreous shellmatter, rarely joined by cross lines; often produced into prickles, or dying away in granules; sometimes represented by diffused granulation, and sometimes reduced to very few sharp crestlike ribs. Slight excentricity of the axis of growth, in the setting-on of the segments, often takes place, simply curving the shell (especially when it does not begin with a strong growth of relatively large and equal-sized chambers), without altering the relative position of the aperture: but this is easily shifted to one side, generally the outer or convex side of the curve, and the chambers become more or less oblique. "*Dentalina*" comprises both conditions in these usually tapering, bent *Nodosarina*. There is no straight *Nodosaria* without its more or less bent congeners; and these are associated with more and more curved individuals (*Dentalinæ*), until the early chambers are not only excentric in growth, but have a discoidal coil (*Marginulinæ*); and other associates have gone further in this style of growth, until the whole of their shell is nautiloid (*Cristellaria*). Thus the smooth *Nodosaria radricula* has *Dentalina communis*, *Marginulina subarcuatula* and *Cristellaria rotulata* as its congeneric associates or varieties; whilst the ornamented *Nodosaria raphanus*, has *D. acicula*, *M. raphanus*, and *Cr. costata* as varietal associates. *N. radricula* and *N. raphanus*, moreover, are so closely linked by graduated individuals, that they are really but varieties of one species of *Nodosarina*.

As *Lagena*, so *Nodosaria* occurs in a compressed form, and is then known as *Lingulina*; and this bent and partially coiled is *Lingulinopsis*. A *Lingula* much outspread on each side, by the overreaching of the chambers, in stretching backwards, becomes a *Frondicularia*; and if this has an excentric or coiled beginning it is a *Flabellina*, which, without the backward lateral stretch of its later chambers, would be a simple flat *Cristellaria* (*Planularia*). If a *Frondicularia* ceases to have outspread chambers, and grows on as a *Nodosaria*, it is *Amphimorphina*.

A flattened *Dentalina*, with oblique chambers, is *Vaginulina*; and if the aperture be a rift along the front of the chamber, instead of a round hole at the margin, it is *Rimulina*; and a *Vaginulina* with coiled commencement is either nearly or quite a *Marginulina*, which without its straighter portion is a *Cristellaria*.

Trigonal or quadrilateral *Nodosariæ*, known as *Orthocerinæ*, usually have a thick shell; but some take on a Nodosarian or Dentaline growth in advanced age, and are then termed *Dentalinopsis*. Their relationship is indicated by this style of growth; *Cristellaræ*, *Marginulinæ*, and *Vaginulinæ* have the same habit.

Infinite gradations of form connect the "genera" and "subgenera" enumerated above; and the same habit of ornamentation obtains throughout, namely, ridges and riblets, often broken up into prickles, or dying away in granules. In the subdiscoidal and the nautiloid forms a marginal, and often a single dorsal, crest is the reduced, or concentrated, representative of the ridge ornament. The thickening of the septal edges, and of the umbones, is frequent and extremely variable. Lastly, the relative size and proportion of the segments (and consequently their shape in coiled shells) produce some of the greatest differences in the aspect of Nodosarine and especially Cristellarian shells. This variability in the size of the chambers in closely allied individuals seems to rest on the peculiar habits of the animal,—its well- or ill-fed condition, its freedom of growth, and such like; and, if the chambered segments are specially connected with the reproductive processes,* other reasons for relative difference of size may exist; but the gradational conditions are such as to preclude any idea of the proportional size of chamber being a *specific* character.

Cristellaridea.—The many "trivial" names and binomial appellations given to Cristellarians (as indeed to all other congeneric Foraminifera) have been sore troubles to the cataloguist, though of some little use to the collector, and even to the palæontologist, in recognizing the individual kinds of Microzoa, which differ so much in external appearance. In reducing them, however, to zoological order, to which mere external aspect is not the chief

* As Mr. Carter suggests for *Operculina*, 'Annals Nat. Hist.,' ser. 4, vol. xiv., 1875, p. 423.

guide, such a multiplicity of names is a stumbling-block, or at least useless. How the Cristellarians have fared in books, the following Table will show, and at the same time it will help us to fix the few rightful names which the chief varieties can claim, and whereby they may be referred to as recognized typical forms. By "Cristellarians" I mean the more or less coiled varieties of *Nodosarina raphanus* (taking that as the type species), and admitting a limited use of binomial appellations for these varieties.

In the following Table of the bibliography of the *Cristellaridea* from the time of Linné to 1841, a great number of the most important recent and fossil forms of this group are noticed. The range of selected forms takes us from well-developed *Marginulinæ* to *Planulariæ*. Multitudes, however, of weak or merely Dentaline *Marginulinæ* are passed unnoticed. The "*Robulina*" of authors is merged with *Cristellaria* on account of the interchangeableness of the character of aperture in nearly all the nautiloid varieties; as may be seen in some of the best figures given by D'Orbigny, Reuss, and others, the two kinds of aperture are merged in one. Indeed, Dr. Carpenter has of late years found that both the round, radiate aperture and the triangular orifice exist together in some *Cristellarinæ* from the deep Atlantic.

Gradations of the Cristellaridea.—Taking up the partially coiled *Nodosarinæ* (*Marginulinæ*), leading from *Nodosaria* to *Cristellaria*, we find that *Marginulina Webbiana*, D'Orb., *Cristellaria subarcuatula* (W. and J.), and *Cr. gibba*, D'O., are examples of such gradation of form. Various specimens with different degrees of ornamentation have been figured, described, and named. *Cr. rotulata* is the simple, completely discoidal form. Smooth, it is *lævigatula* (W. and J.); subumbonate, *depressula* (Montagu); limbate and umbonate, *querelans* (De M.); limbate and tuberculate, *tuberculata* and *elegans*, D'O. With but few chambers (necessarily triangular), and limbate, it is *virgata*, D'O. If thick and opening out transversely it becomes *Italica*, Defr., *navicula*, D'O., &c., and is liable like others to grow on straightwise and become elongate.

If the simple *Cristellaria* has a marginal ridge, keel, or crest, it is *cultrata* (De M.); large-chambered and umbonate, *cassidata* (De M.); limbate with beads (or granulate on the septa), *papillosa* (F. and M.). If swollen, *cultrata* becomes *acutauricularis* (F. and M.), a large and keeled *Italica*. If the *cultrate* form has many small chambers, it is *carinata*, D'O.; if the many chambers be much curved and rather vorticial, we have D'Orbigny's (*Robulina*) *Soldanii* (his *Crist. Soldanii* is a smooth, limbate *cassis*); if the chambers be very close set, falciform, and vorticial, we have *vortex* (F. and M.), and *orbicularis* and *imperatoria*, D'O., according to the amount of keel and umbones. When the *Cristellaria* retains the

SYNOPTICAL TABLE, SHOWING IN CHRONOLOGICAL ARRANGEMENT, AS NOTICED BY THE EARLIER AUTHORS, THE
VARIETAL MODIFICATIONS OF CRISTELLARIA CALCAR (LINN.), WHETHER KEELESS, KEELED, ROWELLED,
OUTSPREAD, TRIHEDRAL, OR ELONGATE.

1735-67.	LINNÉ. 'Systema Naturæ,' edit. 12, 1767. p. 1162, No. 274	 Nautilus calcar, L.	.. ..	Combining the subtypes C. rotulata, cultrata, calcar, and eassis; after the figures given by Plancus, Gual- tierus, Ledermüller, and Martinus. (See 'Annals Nat. Hist.,' ser. 3, vol. iii. p. 476.)
1784.	WALKER AND JACOB. 'Testac. min. varia.' p. 19, t. 3, f. 66	 Nautilus calcar, L.	.. ..	Slightly oval (produced) C. cultrata. ('Ann. N. Hist.,' ser. 3, vol. iv. p. 338.)
	" " f. 67	 " " lævigatulus, W. & J.	.. ..	The common smooth keelless form; the same as C. rotulata (Lam.), which is the best known name.
	p. 20, t. 3, f. 72	 " " carinatulus, W. & J.	.. ..	Young few-chambered <i>Cristellaria</i> , perhaps C. italica.
	" " f. 73	 " " subarcuatulus, W. & J.	.. ..	Limbate, elongate, or marginuline <i>Cristellaria</i> (C. subarcua- tula as adopted by Williamson 1858), limbate var.
1791.	BATSCH. 'Seebs Kupfertafeln mit Conchylien,' &c. t. 5, f. 14	 Nautilus (Orthoceras) harpa, B.	.. ..	<i>Planularia (auris, DeFrance)</i> , associated with <i>Flabellina</i> and <i>Fronicularia</i> . ('Ann. N. H.,' ser. 3, vol. xv. p. 230.)
1803-8.	MONTAGU. 'Testacea Brit.'			
	p. 189, t. 15, f. 4; and Suppl. p. 76, Nautilus calcar, L.	.. ..	.. ..	Thick C. cultrata. ('Ann. N. Hist.,' ser. 3, vol. iii. p. 348, &c.)
	p. 188, t. 18, f. 7, 8; and Suppl. p. 75	" " lævigatulus, W. & J.	.. ..	Large and thick C. rotulata.
	p. 190, and Suppl. p. 78, t. 18, f. 9	" " depressulus (non W. & J.)	.. ..	Subumbonate C. rotulata, subtype.
	Suppl. p. 80, t. 19, f. 1	" " subarcuatulus, W. & J.	.. ..	Smooth marginuline or elongate <i>Cristellaria</i> . C. subarcua- tula (W. & J.).
	p. 196 and Suppl. p. 80, t. 19, f. 3	" " semilitrus (non Gmel.)	.. ..	<i>Margulinia</i> , limbate with beads; M. Wetherelli, Jones, 1854.
	Suppl. p. 86	" " bicarinatus, M.	.. ..	Elongate or marginuline <i>Cristellaria</i> .
	p. 195	" " carinatulus, W. & J.	.. ..	See above.
1803.	FICHTEL AND MOLL. 'Testac. Microscop.'			
	p. 69, t. 11, figs. a-c	 Nautilus calcar, L.	α	Keeled, rowelled, limbate, and umbonate C. calcar. ('Ann. N. Hist.,' ser. 3, vol. v. p. 111, &c.)
	" " d-f	 " "	β	Limbate and umbonate C. cultrata. Typical.

SYNOPTICAL TABLE—continued.

p. 69, t. 11, figs. <i>g, h</i>	.. ..	Nautilus calcar, L.	γ	..	Keelcd, rowelled, limbate with beads, and umbonate, <i>C. calcar</i> .	<i>C. margaritacea</i> (De Montf.).
" " t. 12, " <i>i, k</i>	.. ..	"	δ	..	Ditto, with small beaded umbo.	
" " " <i>a-c</i>	.. ..	"	ε	..	Ditto, with granulate surface and narrow vortical chambers.	
" " " <i>d-f</i>	.. ..	"	ζ	..	<i>C. rostrata</i> (De M.), <i>C. echinata</i> (D'O.)?	
" " " <i>g, h</i>	.. ..	"	η	..	Like β, but deformed.	
" " " <i>i, k</i>	.. ..	"	θ	..	Limbate and umbonate <i>C. rotulata</i> . <i>C. querelans</i> (De M.).	
" t. 13, " <i>a, b</i>	.. ..	"	ι	..	With short rowels (no keel); limbate and umbonate <i>C. calcar</i> .	
" " " <i>c, d</i>	.. ..	"	κ	..	Like α.	
" " " <i>e, f, g*</i>		"	λ	..	<i>C. calcar</i> , with weak keel and short rowels.	
" " " <i>h, i, k, l</i>	.. ..	"	μ†	..	Umbonate <i>C. cultrata</i> . Chambers large; last septum sunken. <i>C. cultrata</i> (De M. & D'O.).	
p. 82, t. 14, " <i>a-c</i>..	.. ..	"	papillosus, F. & M.	..	<i>C. calcar</i> , with long rowels (no keel), and large umbones.	
p. 33, t. 2, " <i>d-i</i>..	.. ..	"	vortex, F. & M.	..	<i>C. cultrata</i> , thick and limbate with beads. <i>C. papillosa</i> (F. & M.).	
p. 47, t. 4, figs. <i>g, h, i</i>	.. ..	"	N. costatus, F. & M.	..	<i>C. vortex</i> (F. & M.). Thick; with narrow, much curved, subspiral or vortical chambers; no keel. <i>C. orbicularis</i> (D'O.) is keeled and thinner. <i>C. imperatoria</i> (D'O.) is keeled and umbonate, but thinner than Fichtel and Moll's specimen.	
p. 102, t. 18, figs. <i>g-i</i>	.. ..	"	N. acutauricularis, F. & M.	..	<i>C. costatus</i> (F. & M.). Thick, limbate, longitudinally costate, large-chambered, and subcalcarate. A subspecies, <i>C. Arminensis</i> (D'O.) is a weaker form.	
p. 107, t. 19, " <i>g-i</i>	.. ..	"	N. crepidula, F. & M.	..	Elongate, thick, triangular <i>C. cultrata</i> with partial keel. Between <i>C. cultrata</i> and <i>C. italica</i> (Deff.).	
p. 95, t. 17, figs. <i>a-d</i>	.. ..	"	N. cassis, F. & M.	..	Planularia crepidula. A subspecies. <i>Pl. cymboïdes</i> , D'O., 'For. Fos. Vien,' is the same. Keelcd forms are <i>Pl. elongata</i> , <i>lanceolata</i> , &c.	
" " " <i>e-g</i>	.. ..	"	"	..	<i>C. cassis</i> , with beaded umbo.	
" " " <i>h, i</i>	.. ..	"	"	..	with beaded umbo, and partly limbate with beads.	
" " " <i>k, l</i>	.. ..	"	"	..	keel-toothed, and limbate with beads.	
" t. 18, " <i>a-c</i>	.. ..	"	"	..	smooth (= <i>galea</i> , F. & M. <i>subvar.</i> and <i>C. consecta</i> , D'O.†). When Flabelline, <i>C. navicularis</i> (De M.),	
p. 100, " " <i>d-f</i>	.. ..	"	"	..	with umbo slightly beaded.	
	.. ..	"	"	..	smooth and large. <i>C. galea</i> , F. & M. <i>subvar.</i>	

* Fig. *g* (edge view) was taken from a much better specimen than fig. *f*.† α, θ, κ, and μ. These rowelled shells are comprised by D'Orbigny in his *Robulina aculeata*.‡ Not *C. margaritacea*, as stated in the 'Ann. N. Hist., ser. 4, vol. viii, p. 243.

- 1804-6. LAMARCK. ('Ann. Nat. Hist.,' 3 ser., vol. v. p. 286.) 'Annales du Muséum,' v. p. 188, and viii. p. 387, t. 62, f. 11, Lenticulites rotulata, Lam. Cristellaria rotulata. Adopted as a named variety; the same as Walker and Jacob's fig. 67; but the trivial name given by Lamarck is better known.
1807. MATON AND RACKETT. 'Linnean Soc. Transact.,' vol. viii. p. 114. Nautilus rotatus,* M. & R. C. cultrata. Montagu's t. 15, f. 4.
- 1808-10. DE MONTFORT. 'Conchyl. System.,' vol. i. ('Ann. N. H.,' ser. 3, vi. p. 339, &c.)
p. 10, t. 3	.. .. .	Phonemus "tranchant"	.. .. .	C. calcar?
p. 26, t. 7	.. .. .	.. .. .	.. .. .	Planularia crepidula (F. & M.)?
p. 34, t. 9	.. .. .	Chrysolus "perte"	.. .. .	3, F. & M. Above. Cristellaria margaritacea (De M.).
	.. .. .	De M.	.. .. .	
p. 70, t. 18	.. .. .	Antenor diaphaneus, De M.	.. .. .	C. calcar, typical
p. 94, t. 24	.. .. .	Oreas subulatus, De M.	.. .. .	C. acutaucularis (F. & M.).
p. 214, t. 54	.. .. .	Robulus cultratus, De M.	.. .. .	λ, F. & M. C. cultrata. Adopted by D'Orbigny as Robulina.
	.. .. .		.. .. .	η, F. & M.
p. 218, t. 55	.. .. .	Patroclus querelans, De M.	.. .. .	C. costata (F. & M.).
p. 222, t. 56	.. .. .	Sphincterulus costatus, F. & M.	.. .. .	α, F. & M.
p. 226, t. 57	.. .. .	Clisiphontes calcar, L.	.. .. .	ε, F. & M. See also Cr. marginata, D'Orb. 1826.
p. 230, t. 58	.. .. .	Herion rostratus, De M.	.. .. .	C. calcar, typical. (C. aculeata, D'O.)
p. 234, t. 59	.. .. .	Rhinocurus araneosus, De M.	.. .. .	C. cassis without a keel? A cast?
p. 238, t. 60	.. .. .	Macroditis cucullatus, De M.	.. .. .	ζ, F. and M. Deformed C. cultrata.
p. 242, t. 61	.. .. .	Lampas Trihemus, De M.	.. .. .	C. cassis, smooth and passing into Flabellina. Adopted by D'Orbigny as Cristellaria navicularis.
p. 250, t. 63	.. .. .	Scortinius navicularis, De M.	.. .. .	β, F. & M. C. cassis, typical.
p. 254, t. 64	.. .. .	Linthuris cassidatus, De M.	.. .. .	Planularia crepidula (F. & M.).
p. 262, t. 66	.. .. .	Astacolus crepidulatus, De M.	.. .. .	Planularia elongata (De M.). Keel and serrated.
p. 270, t. 68	.. .. .	Periples elongatus, De M.	.. .. .	D'Orbigny's Cristellaria elongata is a keeled Planularia, but not dentate.
1816. LAMARCK. 'Tableau Encyclop. et Method.,' ('Ann. N. H.,' ser. 3, vol. v. p. 287, &c.)
t. 466, f. 5	.. .. .	Lenticulites rotulata, Lam.	Cristellaria rotulata (Lam.).
t. 467, f. 3, a-d	.. .. .	.. .. .	C. cassis, α, F. & M.

* Not the *N. rotatus* in Wood's 'Index Test.,' t. 13, f. 5, which is a variety of *Pulvinulina Partschiana* (D'Orb.).

SYNOPTICAL TABLE—continued.

t. 467, f. 3, e-g ..	..	..	..	Cristellaria producta, Lam.	C. cassis, β, F. & M.	C. cultrata (De M.).
" " f. 4, a, b ..	..	..	..	serrata, Lam. ..	" " γ, "	C. margaritacea (De M.).
" " " c, d ..	..	..	..	papilionacea, Lam.	" " δ, "	" "
" " f. 5, a-c ..	..	..	..	undata, Lam.	" " ε, "	C. rostrata (De M.).
" " f. 6, a-c ..	..	..	..	galea, F. & M.	" "	" "
" " f. 7, a-c ..	..	..	..	acutauricularis, F. & M.	C. acutauricularis, F. & M.	" "
1816. J. SOWERBY. 'Min. Conch.'						
vol. vi. p. 74, 232 (index) 1829	..	..	..	Nautilus Comptoni, Sow. ..	Cristellaria rotulata (Lam.).	" "
1816-30. DE BLAINVILLE AND DEFRANCE.						
xix. 1821, p. 8; xxxii. 1824, p. 188,	..	..	..	Nummulina Comptoni, Sow. ..	" "	" "
t. 19, f. 8 ..	..	..	..	('Annals Nat. Hist., ser. 3, vol. xii. p. 200, &c.)	'Dict. Sc. nat.'	" "
xxxii. 1824, p. 188 ..	..	..	..	Crepidulina astaculus, De Bl. ..	Planularia crepidula, subvar. partly keeled.	" "
xl. 1818, p. 615 ..	..	..	..	" elongata (De M.)	C. calcar (L.). Rowelled.	" "
" " p. 614, xxxii. 188	..	..	..	Cristellaria calcar (Linn.)	C. cassis (F. & M.). Above.	" "
" " " (1818) ..	..	..	..	cassis (F. & M.)	" "	Probably var. δ.
" " " ..	..	..	..	lævis, DeFr. ..	" "	β (F. & M.).
xxxii. 1824, p. 182 ..	..	..	..	producta, Lam.	C. calcar (L.).	Typical.
" " " ..	..	..	..	Lenticulina araneosa (De M.) ..	C. costata (F. & M.).	" "
" " " ..	..	..	..	calcar (L.) ..	Cristellaria.	" "
" " " ..	..	..	..	costata (F. & M.) ..	C. cultrata (De M.). Umbonate.	" "
" " " ..	..	..	..	cuellata (De M.) ..	C. calcar (L.).	" "
" " " ..	..	..	..	cultrata (De M.) ..	" "	Beaded. C. margaritacea (De M.).
" " " ..	..	..	..	diaphanea (De M.) ..	" "	relans, De M.
" " " ..	..	..	..	margaritacea (De M.)	C. rostrata (De M.).	Var. ε, F. & M.
" " " ..	..	..	..	querelans (De M.)	C. rostrata (De M.).	Var. ζ, F. & M.
xxv. 1822, p. 458, xxxii. p. 181,	..	..	..	rostrata (De M.)	C. rotulata (Lam.).	" "
t. 15, f. 7 ..	..	..	..	" "	trithemus (De M.).	" "
xxxii. 1824, p. 182 ..	..	..	..	" "	C. rotulata, deformed.	" "
xxv. 1822, p. 453 ..	..	..	..	Lenticulites rotulata (Lam.)	C. rotulata (Lam.).	" "
xxvii. 1823, p. 555, xxxii. p. 188,	..	..	..	" "	" "	" "
t. 19, f. 3 ..	..	..	..	Linthuris cassis, (F. & M.)	C. cassis (F. & M.).	" "

- xxxii. p. 178, 1824, xli. p. 244, t. 14, f. 5, *Planularia auris*, Defr... (*Peneropis auris*, De Bl.). *Planularia auris*, Defrance.
Pl. cymba, D'Orb., 1827, is a narrower form.
- xxxii. p. 177, 1824, xlvii. p. 344,
 1827, t. 13, f. 6 *Saracenaria Italica*, Defr.
C. rotulata thickened, trihedral, and passing into *Marguina*.
C. italica (Defr.).
1822. LAMARCK. ('Ann. N. H.,' ser. 3, vol. v. p. 288, &c.) 'Anim. sans Verteb.,' vol. vii.
 p. 607, No. 2 *Cristellaria papillosa* (non F. & M.) *C. cassis*, α , β , γ , ϵ , F. & M.
 p. 608, No. 3 *"* *lævis*, Lam. .. *C. cassis*, δ and *galea*, F. & M.
 p. 608, No. 4 *"* *auricularis*, Lam. .. *C. acutauricularis* (F. & M.)
 p. 608, No. 7 *"* *crepidula* (F. & M.) *Planularia crepidula* (F. & M.)
 p. 620, No. 3 *Lenticulina rotulata*, Lam.
 p. 625, No. 2 *Polystomella costata* (F. & M.) *C. costata* (F. & M.).
1826. ALCOE D'ORBIGNY. 'Annal. Sc. nat.,' vii. ('Ann. N. H.,' ser. 3, vol. xii. p. 429, &c.; vol. xvi. p. 15, &c.; ser. 4, vol. viii. p. 145, &c.)
 p. 292, No. 23 *Cristellaria auricularis*, Lam. *C. acutauricularis* (F. & M.)
 p. 290, No. 3, Modèles 44 and 83 *cassis* (F. & M.) *C. cassis* (F. & M.). Including var. β & ϵ (sublabelline).
 p. 291, No. 6 *"* *galea* (F. & M.) *C. galea* (F. & M.)
 p. 293, No. 26, Modèles 19 and 85 *"* *italica* (Defr.). *C. italica* (Defr.)
 p. 260, No. 5 *"* *Planularia auris*, Defr. *Planularia auris*, Defr.
 p. 260, No. 6 *"* *crepidula* (F. & M.) *Pl. elongata*, D'O. Keel.
 p. 289, No. 12 *"* *Robulina calcar* (L.) .. *Crist. calcar* (L.). Includes keeled, rowelled, and *granu-*
late form (*papillosa*, D'O.), non F. & M., nec Lam. Includes
 var. ϵ , F. & M. *C. rostrata* (De M.). *C. echinata* (D'O.)?
 p. 289, No. 13 *"* *costata* (F. & M.) *C. costata* (F. & M.)
 p. 287, No. 1, Modèle 82 *"* *cultrata* (De M.) *C. cultrata* (De M.)
 p. 288, No. 4 *"* *vortex* (F. & M.) *C. vortex* (F. & M.)
 p. 289, No. 14 *"* *aculeata*, D'O. .. *C. calcar* (L.). Vars. α , ϵ , μ , F. & M. Typical *C. calcar.*
C. araneosa (De M.)
 p. 288, No. 2, t. 15, f. 8, 9* *"* *orbicularis*, D'O. *C. vortex* (F. & M.). Keel and umbonate, sometimes
 slightly.
 p. 260, No. 4, t. 10, f. 9, Modèle 27 *Planularia cymba*, D'O. .. Small *Planularia auris*, Defr.
 p. 290, No. 17, Modèle 14 *Robulina virgata*, D'O. .. *C. virgata*, D'O. Strongly limbate and umbonate; with
 few triangular chambers; keelless.
 p. 292, No. 19, Modèle 47 *Cristellaria levigata*, D'O. .. *C. levigata*, D'O. (Jurassic). Elongate, umbonate, and partially
 limbate. Umbonate *C. subarcuatula*, or *C. rotulata*
 passing into *Marguina*.

SYNOPTICAL TABLE—continued.

p. 292, No. 10, Modèle 84	..	..	Cristellaria costata, D'O. (non F. & M.)	Small or young <i>Planularia auris</i> , DeFr.
p. 260, No. 7	..	..	..	Keelcd and mucronate <i>Pl. cymba</i> , D'O. (var. of <i>Pl. erapidula</i>). <i>Pl. rostrata</i> , D'O.
p. 288, No. 5	..	..	..	<i>C. cultrata</i> , with rather vortical chambers, intermediate to <i>C. vortex</i> . <i>C. Soldanii</i> (D'O.).
p. 288, No. 6	..	..	..	<i>C. cassis</i> (F. & M.). Young.
p. 288, No. 7	..	..	..	<i>C. calcar</i> (L.). Small.
p. 288, No. 8	..	..	..	<i>C. calcar</i> (L.).
p. 288, No. 9	..	..	..	<i>C. calcar</i> (L.).
p. 289, No. 11	..	..	..	<i>C. calcar</i> (L.), with rose-ornament on umbo. <i>C. rosacea</i> (D'O.).
p. 290, No. 23	..	..	..	<i>Cristellaria</i> . Keelless. A cast?
p. 290, No. 24	..	..	..	<i>C. calcar</i> (L.). Keel partial.
p. 290, No. 1	..	..	..	<i>C. cassis</i> (smooth), var. ♂, F. & M. = <i>C. galea</i> (F. & M.).
p. 290, No. 2	..	..	..	<i>C. cassis</i> , smooth, like the last; and <i>Flabellina</i> (growing like <i>Flabellina</i>).
p. 289, No. 15	..	..	..	<i>C. costata</i> (F. & M.). Subvariety with sunken sutures.
p. 281, No. 1	..	..	..	<i>C. ariminensis</i> , D'O.
p. 290, No. 4	..	..	..	Small-chambered <i>C. cultrata</i> . <i>C. carinata</i> (D'O.).
p. 291, No. 4	..	..	..	<i>C. cassis</i> , smooth and limbate.
p. 291, No. 7	..	..	..	<i>C. cassis</i> (= var. ♂, F. & M.). Intermediate to <i>C. cassis</i> and <i>C. calcar</i> .
p. 293, No. 25	..	..	..	<i>C. calcar</i> (L.). Keelcd and rowelled; surface granulate; chambers hidden. Near <i>C. rostrata</i> (De M.).
p. 292, No. 11	..	..	..	<i>C. calcar</i> (L.). Rowelled and granulate; chambers broad. <i>C. marginata</i> , D'O.
p. 292, No. 12	..	..	..	Keelcd. <i>Planularia elongata</i> (De M.).
p. 292, No. 21	..	..	..	<i>Planularia elongata</i> with two-toothed apex.
p. 293, No. 24	..	..	..	Keelless <i>Cristellaria</i> , strongly limbate and tuberculate. <i>C. tuberculata</i> , D'O.
p. 292, No. 17, For. Cub. 1839, p. 63, t. 7, f. 20, 21.	..	..	..	<i>C. tuberculata</i> , weak in limination and umbonal growth. Produced <i>C. rotulata</i> . <i>C. gibba</i> , D'O.

* De Montfort refers to the figure (b b) in Soldani which D'Orbigny includes in his reference.

SYNOPTICAL TABLE—continued.

p. 127, t. 1, figs. 14, 15	..	..	Cristellaria Berthelotiana, D'O.	Flatter than <i>Margulina Webbiana</i> : almost <i>Planularia crepidula</i> . Planularian <i>Cristellaria</i> , near Montagu's t. 19, f. 1, and the same as Williamson's fig. 56, grouped together as <i>C. subarcuata</i> (W. & J.).
p. 126, t. 3, " 7-9	..	..	Saulcyi, D'O.	Limbate <i>C. rotulata</i> passing into smooth <i>Margulina</i> . The same as <i>C. lævigata</i> , D'O. (Caen Oolite), Model 47.
p. 127, t. 3, " 3, 4	..	..	Robulina Canariensis, D'O.	<i>C. eultrata</i> , umbonate.
1839. A. D'ORBIGNY. 'Foram. de l'Amér. mérid.'				
p. 26, t. 5, figs. 19, 20	..	..	Robulina subeultrata, D'O.	Umbonate <i>C. eultrata</i> , with sunken sutures. (" <i>R. eultrata</i> " in the plate.)
1839. A. D'ORBIGNY. 'Foram. de Cuba.'				
figs. 20, 21	..	..	Cristellaria gibba, D'O.	<i>C. rotulata</i> , with sunken sutures, and becoming elongate.
" 17, 18	..	..	crepidula, (F. & M.)	Planularia crepidula (F. & M.). Above.
1840. AL. D'ORBIGNY. 'Mém. Foram. Craie blanche.'				
figs. 15-18	..	..	Cristellaria rotulata, Lam.	<i>C. rotulata</i> : umbonate, figs. 17, 18; not umbonate, f. 19.
" 19, 20	..	..	navicula, D'O.	Elongate, thick <i>C. rotulata</i> . <i>C. Italica</i> (Defr.).
" 21, 22	..	..	triangularis, D'O.	Trihedral <i>C. rotulata</i> .
" 23-25	..	..	recta, D'O.	Very narrow elongate <i>C. rotulata</i> ; or narrow, thickish <i>Planularia</i> .
" 26, 27	..	..	Gaudryana, D'O.	Young <i>Flabellina</i> ; or Flabelline limbate <i>Planularia</i> .
1840-1. F. A. RÖMER. 'Verstein. Norddeutsch. Kreidegeb.' (Cretaceous).				
f. 14	..	..	Planularia Bronni, R. . .	Thick, simple Marginuline (produced) <i>Cristellaria</i> . Thick <i>C. subarcuata</i> ; or thick, short <i>Margulina Webbiana</i> , D'O., or <i>glabra</i> , D'O.
f. 15	..	..	Margulina comma, R. . .	" " " " " " with sunken sutures.
f. 30	..	..	Robulina Muensteri, R. . .	<i>C. eultrata</i> (De M.).
f. 31	..	..	Ehrenbergii, R. . .	<i>C. eultrata</i> ?
f. 32	..	..	crassa, R. . .	Umbonate <i>C. rotulata</i> (Lam.).
f. 33	..	..	Comptoni, Sow. . .	Umbonate <i>C. rotulata</i> (Lam.).
f. 34	..	..	Nonionina compressa, R. . .	<i>C. rotulata</i> ?

longitudinal ribbing of *Nod. raphanus*, we have the thick *costata* (F. and M.), and the weaker *ariminensis*, D'O. In *C. ornata*, D'O., this ornament is dying out.

An excessive crest, accompanied with thinness (compression) of the chambers, gives rise to the large and elegant *Crist. cassis* and its subvarieties.

When the keel is subdivided into spines, like the rowels of a spur, *cultrata* becomes *calcar* (Lin.); and *margaritacea*, *rosacea*, *rostrata*, and *marginata* are among the names given to subvarieties. Granules on umbones and septa, or all over, are frequent in the subvarieties of *C. calcar* and *C. cassis*.

Some of the above-mentioned features and conditions are evidently gradational; the others are related by many similar gradations not here mentioned, but some of which are indicated in the Table.

The long, flat *Cristellariæ*, retaining something of the *Marginulina* growth, but with the posterior or downward angle of the chambers reaching almost or quite down to the excentric umbilicus, are known as *Planulariæ*, very delicate and pretty shells. *Pl. crepidula* (F. and M.) is little more than a *Marginulina* and rather less than a *Cristellaria* of the *rotulata* group, but thin and imperfectly coiled; its modifications are endless; when keeled, it is *elongata*, D'O.; *rostrata*, D'O., when mucronate also. With bolder convexity and better development of the apertural margin, with more numerous and neater chambers, and some trace of costate ornament, we have *Pl. auris*,* DeFrance, and its smaller forms *cymba* and *auricula*, D'O.

Conclusion.—Without having exhausted the subject, I think that these remarks may be usefully suggestive to beginners and students. One good piece of work that promises satisfactory results would be the careful copying and collating of all the figured forms of each "genus" and "species" of Foraminifera, so that their gradations and their distinctions might be seen at a glance, and the right appellation, according to priority and worth, be awarded to the types and subtypes. These appear to have come from very early times, increasing their varieties under every new set of modifying conditions to which they were introduced. These varieties have sufficient fixedness to give a peculiar *facies* to the several local groups of Foraminifera, fossil or recent; and, inasmuch, their chief forms require a nomenclature for reference and identification.

The remarkable persistence of Foraminiferal types, in general character, has been often noticed; and their conservative tendencies, due to their simplicity and universal adaptability, has been com-

* Batsch figured this shell, together with *Frondicularia* and *Flabellina*, calling them all *Nautilus harpa*, an appropriate name, had he defined the separate form.

pared with the susceptibility of living on under very various conditions, shown by man, the dog, &c., but, of course, the terms of comparison are not really equal. The extreme variability of Foraminifera, of both great groups (Porcellaneous and Vitreous), is doubtless governed by some systematic life-properties which we do not at present recognize in their totality. A wide field for research opens here. As far as we can see at present, as far as we understand the nature and growth of these Microzoa, there seem to be but relatively few links wanting to make the gradations, from one group to another, in form and structure, so evident and so close that all the Foraminifera might be placed in the close union of a specific group, modified by conditions of habitat, feeding, climate, and hereditary peculiarities of growth. But I am not yet prepared to avow a belief in their unispecific relationship.

Remarks on the Cristellarians figured in Plates CXXVIII. and CXXIX. in illustration of their Variability of Form and Ornament.

Taking examples, as much as possible, from among contemporaneous and local groups, we have the associated forms, whether varying from an original stock by long series of differences, in collateral races, or showing new varieties, resulting from the peculiar conditions of place and time.

The beautiful illustrations of Herr Max von Hantken's Monograph* on the Foraminifera of those Tertiary strata in Central Hungary, which he terms the "Clavulina† Szabó-bedes," supply us with a fine series of variations of well-known forms from one geological deposit.

Alcide D'Orbigny's Monograph on the Tertiary Foraminifera of Vienna, known to all Rhizopodists, has also been applied to for some good typical forms. Thirdly, the Liassic and Lower Oolitic Foraminifera, with their innumerable variations of *Nodosarinæ*, illustrated by M. O. Terquem and Mr. H. B. Brady, F.R.S., supply us with two sets of Rhizopods living about the same time and having similar developments.

The few figures taken from the reduced outlines of some of Soldani's illustrated Italian Tertiary (Pliocene) Foraminifera, belong to forms not very far removed in time from those figured by D'Orbigny and Von Hantken (Miocene).

Fig. 1 (Pl. CXXVIII.) is one of the simplest forms of *Nodosarina* (*Nodosaria* proper). In Fig. 2 it is no longer quite straight, but

* From the 'Mittheilungen aus dem Jahrbuche der kön. ung. geologischen Anstalt,' vol. iv., 8vo. Budapest, 1875.

† The term *Clavulina* is here applied to the elongated *Tritaxia* (Reuss), or dimorphous *Verneuilina*, D'Orb., allied to *Clavulina communis*, D'Orb.

is a *Dentalina* with excentric orifice.* In Figs. 3 and 4 it has lost more and more of its bilateral symmetry, becoming a *Marginulina*; and its curvature becomes extreme and discoidal in Fig. 5. Here the newest chamber is still simple, but the older part of the shell has received a crest or keel—essentially a single, medial riblet. Returning to the bent form of *Nodosaria*, in Figs. 6, 7, and 8, we have stronger, neater, and more compact *Marginulinæ*; the last one with a crest. By the transverse lengthening and obliquity of the chambers, with corresponding lateral compression, we are led to Figs. 9, 10, and 11, which end in the flat form of elongated *Cristellaria*, termed *Planularia*; whose close relation to the discoidal type is beautifully shown by Fig. 12.

The coiling of early chambers (as in Fig. 7) is often succeeded, not by linear, but by continued spiral growth (*Cristellaria*), leading ultimately to Figs. 13, 14, 15, and 16, with their various conditions of keel, limbation, and umbones, and very changeable proportions (and hence shape) of their chambers, see Pl. CXXIX., Figs. 18 and 19, besides the more ornamented forms. Fig. 17 is another ultimate *Cristellaria* of the same breed; but Fig. 18 has still an elongate shape, leading, on one hand, to the nearly discoidal, but arrested, Fig. 19; and, on the other, to the very thick forms (Figs. 20 and 21), which are known as DeFrance's *Saracenaria Italica*.

Referring to Fig. 1, we lose its roundness in the flatter Fig. 22 (*Lingulina*). The chambers, beginning to overlap at the edges in Fig. 23, become chevron-shaped in Fig. 24 (*Frondicularia*). Even in Fig. 23, however, the early chambers are not simply linear in growth, and this, increased in Fig. 24 to a subspiral arrangement, leads through many gradations in these flat shells to a spiral system of early chambers, as seen in Figs. 25 and 26; and this Planularian growth remains free, without the overriding or saddle-like chambers, in Fig. 27, essentially the same as Fig. 10 and its allies, and, excepting its relative thinness, equivalent to Fig. 18, &c. One of its ornamented colocal varieties is shown in Pl. CXXIX., Fig. 12.

Plate CXXIX. exhibits some of the ornamented analogues of the above-mentioned varietal forms of *Nodosarina*. Fig. 1*a* is a *Nodosaria* with characteristic ornamental ridges, but they end abruptly on each chamber, forming little spikes. In Fig. 1*b* several small spines or prickles are produced on each ridge or riblet of the chambers of a slightly bent (Dentaline) *Nodosaria*.

In Figs. 2–6 the riblets are represented by granules on some allied *Marginulinæ*.† In some individuals (as in fig. 1, pl. 6, of Von Hantken's Monograph) they become gradually confined to the

* If the shell were flattened it would be a *Vaginulina*.

† *Marginulina Wetherellii* of the London Clay is the same form.

septal lines; they are often wanting on the newer chambers of the shell. In the further developed *Cristellaria*, Fig. 6, the granulated septal lines continue the above-described character; and in Fig. 7 the aspersions of shellmatter in the form of pimples or granules over all the older portion of the shell is a character fore-shown by the somewhat irregular granulation in some specimens of *Marginulina fragaria* (*Wetherellii*), and in the grouped granules on the umbo of Fig. 7. Soldani figured several highly granulate *Cristellarie* of this kind.*

Fig. 8 is the common and variable *Nodosaria raphanus*, with characteristic ribbing; Fig. 9 is its *Marginulina*, individuals of which present gradual (though rare) passages to *Cristellaria costata* (F. and M.) and its feeble representative, Fig. 10. The flat form of *N. raphanus* is *Lingulina costata*, D'Orb., Fig. 11; and its *Flabellina* (Fig. 17) is *Fl. striata*, Hantken.

Taking up Fig. 12 again, referred to above, we see its further development in its colocal ally, Fig. 13, which may be said either to fade away into, or to have come from, the *Vaginulina*, Fig. 14, which is the flat asymmetrical, one-sided form of *Nodosaria raphanus*. Fig. 15, one of the delicately elegant, flat *Cristellarie* (*Planularie*), is related by gradation to Fig. 11, &c., in Pl. CXXVIII., and wears the usual costulate ornament of the *Nodosarinæ*. One of its extreme forms is shown in Fig. 16.

Fig. 18 is an explanate, broadly spiral *Cristellaria* (*C. cassis*, F. and M.), putting on overriding chambers, and thus becoming *Flabellina*, like Figs. 25 and 26, Pl. CXXVIII., and thousands of similar and analogous varieties. Fig. 19, a *Cristellaria*, with very narrow, curved, vorticial chambers, has been already noticed.

Besides the above selections, very many others might easily be made. Thus, in Von Reuss's beautiful plates of the Foraminifera of the Westphalian Chalk,† the following might be arranged in succession:—Pl. 4, f. 1; pl. 3, f. 6; pl. 2, f. 8; and pl. 1, f. 5; pl. 5, f. 6; pl. 7, f. 4; and pl. 6, f. 5: also pl. 7, f. 3, 5; pl. 5, f. 7; pl. 8, f. 6; pl. 9, f. 4; pl. 10, f. 3, 4, 1. In Von Reuss's Memoir‡ on the 'Tertiären Foraminiferen-Fauna,' &c., the following series may be studied:—Pl. 3, f. 30, 36, 33, 37, 39; pl. 4, f. 47, 49, 50, 53, 54; pl. 5, f. 59, 65. From f. 53 to pl. 5, f. 62; pl. 6, f. 68; and pl. 8, f. 91. From f. 59 to pl. 6, f. 63, 64, and 66. Hundreds of other gradational figures may easily be selected, but the above are sufficient.

* See 'Annals Nat. Hist.,' ser. 4, vol. viii., pl. 10 and 11, figs. 96-99, &c.

† Sitzungsber. math.-nat. Cl. k. Akad., Wiss. Wien, vol. xl., 1860.

‡ *Op. cit.*, vol. xlviii., 1863.

I. FORAMINIFERA IMPERFORATA VEL PORCELLANA.

I. NUBECULARIDA.

Squamulina, Schultze. Monothalamous.
Nubecularia, DeFrance. Fixed.

II. MILIOLIDA.

Vertebralina, D'Orb. Dimorphous usually.
a. Articulina, D'Orb. Dimorphous.
Cornuspira, Schultze (restricted). Monothalamous.
Miliola, Lamarck.
a. Uniloculina, D'Orb. Monothalamous.
b. Biloculina, D'Orb.
c. Triloculina, D'Orb.
d. Quinqueloculina, D'Orb.
e. Crueiloculina, D'Orb.
f. Spiroloculina, D'Orb.
g. Ceratospirulina, Ehrenberg. Dimorphous.
Hauerina, D'Orb.
Fabularia, DeFrance.

III. PENEROPLIDA.

Peneroplis, De Montfort.
a. Spirolina, Lamarck (restricted). Dimorphous.
b. Dendritina, D'Orb.

IV. ORBICULINIDA.

Orbiculina, Lamarck.
Orbitolites, Lamarck.
a. Pavonia, D'Orb.
Alveolina, D'Orb.

V. DACTYLOPORIDA.

Haploporella, Gümbel.
Dactyloporella, Gümb. (*Dactylopora auctorum in parte.*)
Thyrsporella, Gümb.
Gryroporella, Gümb.
Cylindrella, Gümb.
Uteria, Michelin.
Acicularia, D'Archiac.
Verticillipora (?), Mantell.
Receptaculites, DeFrance.
Archæocyathus, Billings.

II. FORAMINIFERA ARENACEA.

I. PARKERIADA.

Parkeria, Carpenter.
Loftusia, Brady.

II. LITUOLIDA.

Endothyra, Phillips.
Involutina, Terquem.
Trochammia, Parker and Jones. Monothalamous in some forms.
a. Webbina, D'Orb. (restricted). Fixed.
Valvulina, D'Orb. Sometimes dimorphous.
Tetrataxis, Ehrenberg.
Ataxophragmium, Reuss (sandy *Bulimina*).
Plecanium, Reuss (sandy *Textularia*).

- Saccammina, Sars. Monothalamous in one form.
a. Psammospæra, F. E. Schulze. Monothalamous?
b. Storthospæra, F. E. Schulze. Monothalamous.
 Pilulina, Carpenter.* Monothalamous.
 Astrorbiza, Sandahl. Monothalamous.
a. Astrodiscus, F. E. Schulze. Monothalamous.
 Rhabdammina, Carpenter. Monothalamous?
 Botellina, Carpenter. Monothalamous.
 Proteonina, Williamson. Monothalamous?
 Lituola, Lamarck. Often dimorphous.
a. Placopsilina, D'Orb. Fixed.
b. Haplophragmium, Reuss. Often dimorphous.
c. Haplostiche, Reuss.
d. Hippocrepina, Parker.
e. Polyphragma, Reuss.
f. Conulina (?), D'Orb.

III. FORAMINIFERA PERFORATA VEL HYALINA.

I. LAGENIDA.

- Ellipsoidina, Seguenza.
 Lagena, Walker and Jacob. Monothalamous.
a. Entosolenia, Ehrenberg.
b. Fissurina, Reuss.
 Ramulina, Jones. Slightly segmented, branching.
 Nodosarina, Parker and Jones.
a. Glandulina, D'Orb.
b. Nodosaria, Lamarck.
c. Dentalina, D'Orb.
d. Lingulina, D'Orb.
e. Lingulinopsis, Reuss. Dimorphous.
f. Rimulina, D'Orb.
g. Vaginulina, D'Orb. Dimorphous usually.
h. Marginulina, D'Orb. Dimorphous.
i. Pseudium, Reuss. Dimorphous.
j. Cristellaria, Lamk. Sometimes dimorphous.
k. Planularia, DeFr.
l. Flabellina, D'Orb. Dimorphous.
m. Frondicularia, DeFrance.
n. Amphimorphina, Neugeb. Dimorphous.
 Orthocerina, D'Orb.
a. Dentalinopsis, Reuss. Dimorphous.

II. POLYMORPHINIDA.†

- Polymorphina, D'Orb.
a. Dimorphina, D'Orb. (restricted). Dimorphous.
 Uvigerina, D'Orb.
a. Sagrina, D'Orb. (restricted). Dimorphous.

III. BULMINIDA.

- Bulimina, D'Orb.
a. Ataxophragmium (sandy), Reuss.
b. Bolivina, D'Orb.

* For this and some other allied forms, see Dr. Carpenter's 'Descriptive Catalogue of Objects from Deep-sea Dredgings exhibited at the Soirée of the Royal Microscopical Society, King's College, April 20th, 1870.' 8vo. London, 1870.

† The *Polymorphinida* are separated from the *Lagenida* only on account of their alternate arrangement of chambers.

- c. *Virgulina*, D'Orb.
- d. *Bifarina*, P. and J. Dimorphous.
- e. *Robertina*, D'Orb.
- Cassidulina*, D'Orb.
- a. *Ehrenbergina*, Reuss. Dimorphous.

IV. TEXTULARIDA.

- Textularia*, DeFrance.
- a. *Plecanium* (sandy), Reuss.
- b. *Bigenerina*, D'Orb. Dimorphous.
- c. *Spiroplecta*, Ehrenb. Dimorphous.
- d. *Gaudryina*, D'Orb. Dimorphous.
- e. *Verneuilina*, D'Orb.
- f. *Tritaxia*, Reuss. Dimorphous.
- g. *Clavulina*, D'Orb. (restricted). Dimorphous.
- h. *Heterostomella*, Reuss. Dimorphous.
- i. *Vulvulina*, D'Orb.
- j. *Venilina*, Gumbel. Dimorphous.
- k. *Candeina*, D'Orb.
- l. *Cuneolina*, D'Orb.

V. GLOBIGERINIDA.

- (1.) *Globigerinina*.
 - Ovulites*, Lamarek. Monothalamous.
 - Orbulina*, D'Orb. Monothalamous usually.
 - Globigerina*, D'Orb.
 - Pullenia*, Parker and Jones.
 - Sphæroidina*, D'Orb.
 - Carpenteria*, Gray. Fixed.
 - Allomorphina*, Reuss.*
 - Chilostomella*, Reuss.*
- (2.) *Rotalina*.
 - Spirillina*, Ehrenb. (restricted). Monothalamous.
 - Discorbina*, Parker and Jones.
 - Planorbulina*, D'Orb. Fixed in some cases.
 - a. *Planulina*, D'Orb.
 - b. *Truncatulina*, D'Orb. Fixed.
 - Pulvinulina*, Parker and Jones.
 - Rotalia*, Lamarek (restricted).
 - Cymbalopora*, Von Hagenow.
 - Thalamopora*, Reuss.
 - Calcarina*, D'Orb.
 - Tinoporus*, De Montfort (restricted).
 - Patellina*, Williamson.
 - Conulites*, Carter.
 - Polytrema*, Risso. Fixed.
- (3.) *Polystomellina*.
 - Polystomella*, Lamarek (restricted).
 - a. *Nonionina*, D'Orb.
- (4.) *Nummulinina*.
 - Nummulina*, D'Orb.
 - a. *Operculina*, D'Orb.
 - b. *Assilina*, D'Orb.
 - Amphistegina*, D'Orb.
 - Heterostegina*, D'Orb.

* The systematic place of these two forms is not well understood.

Cyclotypeus, Carpenter.
Orbitoides, D'Orb.
Fusulina, Fischer.
Archæosphærina (?), Dawson.
Archædiscus, Brady.
Eozoon, Dawson. Fixed.

(The systematic place of the following is not yet determined.)

Caunopora, Phillips.
Cœnostroma, Winchell.
Sparsispongia, D'Orb.
Stromatocerium, Hall.
Stromatopora, Goldfuss.