

constant number of the arms. Infrabasals no longer occur so frequently nor are they so well developed in the Mesozoic as in the Palaeozoic Crinoids; and they are obviously undergoing reduction in the Mesozoic forms.

Turning to the Echinoids, it is evident that the Palaeozoic forms represent a plastic and fluctuating stage of transition in the evolution of the phylum. The inconstancy of the number of the rows of plates of the corona, and the flexibility (in most cases) and variety of form of the test, with its fragile, thin, and loosely articulating plates, which occur in the earliest Echinoids in comparison to the Mesozoic genera, are characteristics which present an analogy to the manifold variety of forms exhibited by most groups near their point of origin, just as we have already seen to be the case in the Mesozoic *Bennettitaceae*, just before a reduction to a working optimum had been arrived at by the early Angiosperms. The Palaeozoic Echinoids displayed a tentative variability in various divergent directions, and the Cidaroids alone out of all these offshoots from the parent stock survived to perpetuate the race. From the Cidaroida all the Mesozoic and modern Echinoids can be derived.

Although the Ordovician *Bothriocidaris* is at present the oldest known Echinoid, it is probable that its single row of plates in each interambulacrum and its rigid test represent an early experiment in reduction. On the other hand, in view of the multiple and inconstant number of rows in the interambulacral areas in other Palaeozoic Echinoids such as *Archæocidaris*, *Melonechinus* (*Melonites*), *Palæechinus*, etc., the latter state of things should presumably be regarded as the more primitive feature. This is all the more probable, seeing that in post-Palaeozoic forms the reduction to the optimum of two rows in each area has become a constant characteristic.<sup>25</sup>

Among the earliest forms a fairly near approach to the Cystids seems to be made by *Echinocystis pomum* of the Upper Silurian, in which the flexible test is composed of a mosaic of numerous (10 in the diameter) irregularly arranged and undifferentiated interradial plates with small spines, each ambulacral area containing four rows of pore-plates united at the upper pole without forming an apical disk. In *Palæodiscus* (also from the Lower Ludlow Shales) a close approximation, on the other hand, is made to the Starfishes, for a series of ambulacral plates like those of the *ASTEROIDEA* occurs inside the plates of the corona, and the tube-feet in the oral portion of the radii apparently passed out between the outer ambulacral plates, but the chief radial water-vascular vessels seem to have run along inside the test; the radioles or movable spines are small and do not differ very greatly from those of some *EDRIOASTEROIDEA* and *ASTEROIDEA*.

In the Devonian *Lepidocentrus*—the earliest and most primitive of the Cidaroida—the test is flexible and this flexibility is still retained to a less extent in the Lower Carboniferous *Archæocidaris* in which there are 4-7 rows of large overlapping plates in each interambulacral area and two rows of ambulacral plates. *Olioporus* has four ambulacral and 4-9 interambulacral rows, while in the Carboniferous *Melonechinus* (*Melonites*) there may be as many as 4-11 columns of interambulacral and 5-14 ambulacral; in *Lepidesthes* there are 8-18 ambulacral and 3-6 interambulacral rows; in *Palæechinus* (also Carboniferous) there are respectively 5-7 rows of interambulacral, decreasing in number toward the poles and only two rows of ambulacral. It is evident that (with the exception of the aberrant *Bothriocidaris*) the reduction to the optimum of two rows took place with greater rapidity in the ambulacral areas than in the intervening zones. The reduction in the number of plates went hand in hand with an increased rigidity and consolidation of the test as a whole, and an increase in the size of the spines.

If, as now seems likely, the Echinoids took their origin from an early offshoot of the Asteroids rather than directly from the Cystids, this would all the more point to the significance of a multiple repetition of similar parts in inducing the evolution of numerous divergent variations; Macbride has suggestively remarked that "when we recollect that some of the oldest *ASTEROIDEA* known to us had very narrow arms and inter-radial areas edged by large square marginals, it does not require a very great effort to imagine how these marginals could be converted into the vertical rows of the interambulacra and the pointed narrow arms, becoming curved, could have formed the ambulacra."

In the organization of the *PELECYPODA* we find a feature which has admitted of an almost inconceivable amount of variety, both of form and arrangement, viz., the manner of the hinge-attachment between the two halves of the shell. It is a matter of some significance for the theory of this paper that the most primitive of the *PELECYPODA* are those forms which exhibit the Taxodont type of hinge, in which the interlocking, comb-like teeth are numerous and similar in

size and form. The primitive nature of the Taxodont class is clearly evidenced by the fact that the embryo shells of many of the higher forms (*Ostreidae*, *Pteriidae*, *Philobryidae*, *Mytilidae*, etc.) pass through the Taxodont stage of a more or less rectilinear or gently curved hinge-line with a considerable number of teeth; and that in still higher forms (*Condylocardia* and *Scioberetia*) this Taxodont stage, "present in the early embryo, is succeeded by the series of folds (characteristic of the young stages of the higher Pelecypods) that subsequently divide off into cardinal and lateral teeth, thus linking the Taxodont with the Heterodont and Desmodont types of hinge."

Although considerable differentiation must have already occurred in pre-Cambrian times, yet the Taxodont shells (*Ctenodonta*=*Tellinomya*, *Glyptarca*, *Redonia*) are relatively numerous in the Cambrian period in comparison with the higher and more differentiated forms, e. g., *Modiolopsis*, and even in the Lower Ordovician a nearly similar disproportion is in evidence. It is therefore apparent that Pelecypods started with a Taxodont hinge; owing to this repetition-series of similar teeth a high degree of variability must have ensued, followed by a rapid reduction to an optimum, i. e., to the Heterodont form of a cardinal tooth and two lateral teeth. Increased specialization has led to still further reduction or even complete suppression. The existing genus *Nucula* is one of those rare instances which have retained many really archaic characteristics, not only in the nature of its hinge-line, but still possessing the primitive Aspidobranch type of gills, the primitive creeping foot and the nacreous type of shell. In the Palaeozoic forms of the *Nuculidae*, however, the ligament is mostly external, while in the recent forms it occurs internally, below the umbo. It is probable that *Tellinomya pectunculoides* of the Ordovician, with its equilateral, nearly circular form of shell, its curved hinge-line, equal adductor-impressions and semicircular, simple pallial line, stands very close to the ancestral form, and that the *Arcidae*, with the straight hinge-line, formed an early specialization.

(To be continued.)

### Ports on the North Pacific

THE changes wrought in the geography of the world by the construction of the Panama Canal, and the consequent changes to be expected in the world's commerce, involve preparations in the form of new harbors, new docks, and additional railways, remarkable alike in extent and in rapidity of construction. Contemplated as a whole, and when the element of time is taken into account, these undertakings constitute an engineering project of variety and magnitude unprecedented in the history of transport development. Nature has been exceptionally kind to builders of ports and harbors on the North Pacific coast, and the statement of conditions in regard to such favored ports as Vancouver, Prince Rupert, and Puget Sound, may well excite envy along less favored coasts.

The dual character of the transport problem is clearly revealed in this awakening of the Pacific trade, for engineers must there concern themselves with difficulties presented by the hinterland and balance them against the advantages of ready-made channels, anchorages, and deep-water basins of natural formation. They must think, in fact, in terms of heights and distances, chains and levels, as well as in terms of tides, fathoms, and quay facilities; for the massive mountain ranges that border the Pacific present an old task in an extended and accentuated form to railway engineers, and all the resources of modern contractors will be requisitioned in the friendly struggle which is now to begin between the Pacific ports for the new trade. Special attention may be directed to the port of Portland with its quay development parallel to the current in contrast to slips or piers projecting into the stream, partly because the works on the bar are ranked among the greatest of the kind ever constructed, and partly because of the probability that in the more or less distant future parallel quays will characterize the development of such ports as London.—*London Times*.

### Aluminium as Flux

By Robert Grimshaw

IRON foundrymen have long known that aluminium is an excellent flux. It oxidizes very easily and removes oxygen from the cast iron and steel, according to the formula  $Al + O_2 = Al_2O_3$ , evolving 391,000 calories, an amount of heat sufficient to raise the temperature of one kilogramme of iron 1,400 deg. Cent., or one pound 5,545 deg. Fahr. This heat causes the sudden foaming of the mass. The energetic movement noticed in the pouring ladle brings the molecules in contact with air, which produces iron oxide; but this oxidation can be avoided by covering the melted iron or steel mass with sand or charcoal. If the melted metal does not attain a high temperature the effect of the addition of aluminium is almost nil. The amount of fluxing metal neces-

sary depends on the quality of steel and the purpose of the casting. For steel with 0.5 per cent carbon there should be added from 160 to 320 grains of aluminium per ton, while for a higher carbon steel only 150 to 250 grains are necessary.—*Journal of the Franklin Institute*.

### A Mnemonic Rule for the Value of the Constant $\pi$

THE following French verse is given by Dr. Gerhard Kowalewski in his text-book of calculus as a mnemonic rule for remembering  $\pi$  to 30 decimals.

"Que j'aime à faire apprendre un nombre utile aux sages!  
Immortel Archimède artiste ingénieur  
Qui de ton jugement peut priser la valeur!  
Pour moi ton problème eut de pareils avantages."

It is much easier to remember these verses than the numbers, derived from counting the letters, of each word, namely—

3.141592653589793238462643383279.

Perhaps some of our readers may want to try their skill at working out an English version.

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<sup>25</sup>The Cretaceous *Tetracidaris* has indeed four rows of plates to each interambulacrum but they are reduced to two rows at the apical region.