So far as the change in mode of life is concerned, their hypothesis is no easier than mine. Professor MacBride has made a number of ingenious suggestions, chiefly dependent on "the fundamental distinction which obtains at the present day between the habits of Eleutherozoa, which in the majority of cases are scavengers, devouring dead animals and organic detritus lying on the bottom, and those of Pelmatozoa, which to this day feed on Plankton captured by currents produced by the cilia covering their tentacles" (1914, *Embryology*, p. 564). Now that Dr. Gemmill has broken down the barrier of this "fundamental distinction" the hypotheses based on it lose much of their probability.

If we imagine an Edrioasteroid with loose attachment, liable to be overturned by currents, just as we know that individuals of *Stromatocystis* were overturned, then all we have to suppose is that some of the overturned individuals were able to survive the accident. This they would be able to do if they had fairly well-developed podia, such as are indicated by the anatomical evidence. Even without the overturning, the podia of such genera as *Edrioaster* and *Dinocystis* might have subserved locomotion; for in them the ends of the subvective grooves were brought into almost direct contact with the sea-floor. Indeed, it is hard to see how locomotion could have been avoided.

As for the alleged directness of individual development (which, as already pointed out, is not direct in some important particulars), this may well be more apparent than real. If it be direct, we are thrown back on 'idiosyncrasy' and 'hemiplegia' and misfits 'somehow displaced'. If, on the other hand, the stalk represents the last trace of a former pelmatozoic stage, we have to imagine that the greater part of that stage has been cut out. But what is more natural? In Ophiuroidea the fixed stage is omitted altogether. In Asteroidea it is not omitted but condensed. The later stage, in which the mouth is already directed downwards, has been pressed back so as to eliminate the supposed stage during which it passed upwards. The preservation of that stage in the ontogeny would have been a useless waste of energy.

Dr. Gemmill says that my view introduces "very serious ontogenetic difficulties". I am unable to see that the main ontogenetic difficulties are any better explained by the Gemmill-MacBride theory, which in its turn seems to me to introduce a fresh set of phylogenetic difficulties.

IV.—THE MORaine WALLS AND LAKE BASINS OF NORTHERN ITALY.

By C. S. DU RICHE PRELLER, M.A., Ph.D., M.I.E.E., F.G.S., F.R.S.E.

THE present paper is the outcome of a number of visits which, during a prolonged professional residence in Italy, I paid to Piémont, Lombardy, and the Italian lakes, and in the course of which I became familiar with the glacial phenomena and the lake basins along the southern base of the Alps.

It is forty years—1874 to 1876—since the 'Moraine Amphitheatre', or series of moraine walls at the foot of the Italian Alps,

suddenly came into prominence through the discovery, chiefly by Stoppani, of several glacial clay, sand, and gravel deposits in the vicinity of Como, which contained marine shells, and therefore demonstrated the presence of the sea in contact with the Alpine glaciers. Stoppani's conclusions, expounded in two brilliant memoirs,¹ were endorsed not only by his Italian confrères, Spreafico² and Sordelli,³ but also by distinguished geologists north of the Alps, notably by Désor of Neuchâtel,⁴ Renevier of Lausanne,⁵ and Rutimeyer of Bâle,⁶ the revealing memoirs more especially of the two last-named being models of classical and closely reasoned exposition. Since then the subject has been enlarged upon chiefly by discoveries of interglacial deposits in various sub-Alpine valleys debouching into the Lombardy plain, and more recently Penck and Brückner have dealt with it from their point of view in their latest monumental work,⁷ whose salient features have been summarized by G. W. Wright.⁸ But the evidence adduced by the various Italian and other writers, including Penck's somewhat laboured endeavour to work out his four glaciations for the Alps *en bloc*, is as yet so conflicting that it is almost refreshing to turn to the earlier and more conclusive views of Stoppani and his contemporaries as a point of departure for considering the subject *mutatis mutandis*, in order to arrive at some independent conclusions from personal observation.

I. THE MORAINÉ WALLS.

As will be seen from the sketch-map, Sheet No. 1, Fig. 1, the belt of double, in many places triple concentric moraine walls which fringes the southern base of the Alps, forms roughly a semicircle extending from Cuneo in the south of Piémont to Lake Garda in Lombardy, a distance of about 400 kilometres, and from the last-named point to the Frioul, another 200 kilometres. The most striking feature of this belt consists not only in its remarkable extent but in the enormous accumulations of glacial material, compared with which the morainic deposits north of the Alps, notably in Switzerland, almost sink into insignificance. The moraine walls were all formed, like so many bars, in front of the exits of the principal valleys. Thus, near Cuneo we find the terminal moraine of the Stura glacier; west of Savigliano, that of the Po (Monte Viso); at Rivoli, near Turin, that of the Dora

¹ Stoppani, "Il mare glaciale ai piedi delle Alpi": *Rivista Italiana*, Agosto, 1874. "Sui Rapporti del terreno glaciale col Pliocenico nei dintorni di Como": *Atti Soc. Ital. di Scienze naturali*, Aprile, 1875.

² Spreafico, "Conchiglie marine nel terreno erratico di Cassina Rhizzarda (Fino, Prov. di Como)": *Atti Soc. Ital.*, 1874.

³ Sordelli, "La Fauna marina di Cassina Rhizzarda, Fino": *Atti Soc. Ital.*, 1875.

⁴ Désor, *Le Paysage morainique et son origine glaciaire*, Neuchâtel, 1875.

⁵ Renevier, "Relations du Pliocène et du Glaciaire aux environs de Côme": *Bull. Soc. Géol. France*, sér. III, tome iv, 1876.

⁶ Rutimeyer, *Ueber Pliocän und Eisperiode auf beiden Seiten der Alpen*, Bâle, 1876.

⁷ Penck and Brückner, *Die Alpen im Eiszeitalter*, 1909.

⁸ G. W. Wright, *The Quaternary Ice Age*, 1914.

Riparia (Mt. Cenis); at Ivrea that of the Dora Baltea (Mt. Blanc and Mt. Rosa); at the lower end of Lakes Maggiore and Varese, that of the Ticino and Toce (St. Gothard and Simplon); near Como and Lecco that of the Adda; at the lower end of Lake Isco that of the Oglio; and at Lake Garda the terminal moraine of the Mincio glacier.

The most formidable of these moraine walls are those of Ivrea and at the lower ends of Lakes Maggiore, Como, and Garda. South of Ivrea the Monte Rosa glacier, descending through the lower Dora Baltea Valley, has left two stupendous marginal moraine walls, the "Serre" of Andrate and Brosso, which reach a height of no less than 450 metres above the present river-level and, with the frontal moraine broken up into hillocks and interspersed with morainic lakelets, form a circumference of at least 50 kilometres. Again, south of Lakes Maggiore and Varese, the concentric moraine belts of the Ticino and Toce glaciers extend to 10 kilometres from the lake-end, with a circumference of 50 kilometres and a height of 150 metres above Lake Maggiore. South of Como the moraine deposits form, in a distance of barely 10 kilometres, three separate concentric ridges about 20 kilometres in length, rising to 152, 157, and 165 metres above the level of Lake Como. Similarly, at the lower end of Lake Garda, the moraine walls extend in concentric semicircles and an extraordinary agglomeration of morainic hills 12 kilometres into the Lombardy plain, with a circumference of at least 30 kilometres, and rising to 23, 62, and 141 metres above the lake-level.

The points where marine shells were found embedded in glacial deposits are situated about 6 kilometres south and north-west of Como; the former near Fino, on the second of the three concentric moraine ridges, about 160 metres above the present lake-level, and the latter between Chiasso and Mendrisio in the Breggia Valley, by which the former Lugano fiord communicated with that of Como.¹ The most northerly of the latter deposits is that of Pontegana, near Balerna, about 90 metres above the present lake-level, which, being glacial clay, corresponds to similar deposits near Varese and to others in the Ivrea district. In Lombardy the shell-bearing deposits rest directly on Pliocene marl and are overlain by morainic material of sand, gravel, and conglomerate, known as ceppo and ferretto, while in Western and Southern Piémont many of the glacial deposits exhibit intermediate fluvio-glacial alluvia, whose origin was at the time a subject of keen controversy between Stoppani and Gastaldi. These alluvia are, in fact, the southern equivalent of the "alluvion ancienne" and Deckenschotter north of the Alps, and, as such, the product of a pre-maximum glaciation which in Upper Piémont, but not in Lombardy, reached to the foot of the Alps. As regards the stupendous Moraine Amphitheatre of Piémont and Lombardy as a whole, it can only be the product of the maximum glaciation, while any pre-maximum, as also the post-maximum or last glaciation, probably did not descend much beyond the heads of the present lakes, or, roughly, beyond a limit 30 to 40 kilometres distant from the Lombardy

¹ Most of these deposits are now obliterated, but ample specimens of the marine shells are preserved in the Geological Museum of Milan.

Fig. I.—Sheet No. 1. Sketch-map of Northern Italy.

Figs. II, III, IV.—Sheet No. 2. Moraine Walls.

plain.¹ The extreme limit of the maximum glaciation, as indicated by the outermost moraine walls 10 to 12 kilometres south of the lower ends of the Lakes Orta, Maggiore, Como, and Garda, is shown in Sheet No. 2, Figs. II, III, and IV.

II. THE GLACIERS AND THE SEA IN THE PO VALLEY.

The maximum glaciation south of the Alps presents a striking contrast to that on the north in that it was marked by a uniform general advance of more or less self-contained glaciers of the fan or Piémont type, which invaded the Po Valley to a distance of 10 to 12, in the case of the Dora Baltea (Ivrea) glacier even 20 kilometres, while north of the Alps the glaciers spread all over the Swiss lowlands and deposited their terminal moraines even beyond. Thus the maximum length of the southern glaciers, measured from the crest-line of the Alps to their terminal moraine walls, does not exceed 100 kilometres, while on the north the Rhone and the Rhine glaciers, extending beyond the Jura and Lake Constance respectively, reached a length of 300 kilometres, or three times as much. Inversely, the quantity of material carried and deposited by the southern glaciers having an average fall of 1 in 100, was immensely greater than that of the northern glaciers, the average fall of which was only about half the above. Hence the enormous accumulations of glacial material in Piémont and Lombardy, where, moreover, the glaciers on emerging from the valleys were arrested by the sea as an effectual barrier to their further advance into the Po Valley. This Upper Pliocene sea, an arm of the Adriatic, must have lasted well into the Pleistocene period, and the glaciers washed by it must have been stationery for a very long lapse of time, as is shown by the double and triple concentric frontal moraine walls, each of which marks a long halt in the slow retreat of the ice.² No less certain is it that the sea must have been at a level much higher than the present Po Valley, and higher even than the present levels of the lakes, for the Pontegana marine shell-bearing deposit in the Breggia Valley north of Como is at 300 metres altitude, which is 87 metres above Lake Como, 197 metres above Milan, and 240 metres above the Po at Piacenza, while the Fino deposits south of Como are at an altitude of even 370 metres. It is therefore obvious that at the advent of the maximum glaciation, arms of the sea reached as far as the fjords which constitute the present lake basins—a phenomenon which has an important bearing on the age and origin of the lakes themselves.

¹ The principal localities of interglacial deposits between Lakes Maggiore, Lugano, and Garda, and beyond are the following: at Re, in the Vigizzo Valley, east of Domo d'Ossola; at Calprino, near Lugano; at Lefte and Gandino in the Seriana Valley, north of Bergamo; at Pianico in the Oglio (Lake Isco) Valley; at Valmarino in the Piave Valley, north of Treviso; in the Tagliamento Valley, north of Udine; and in the Isonzo Valley, north of Gorizia.

² It is a striking feature that, of the moraine walls, those of the Como district are continuous, because the Adda eroded its bed marginally from the Lecco arm of the lake, whereas the rivers of Ivrea, Lake Maggiore, and Lake Garda (Dora Baltea, Ticino, and Mincio) found their exit more through the centre of the frontal moraines, which are therefore broken up into agglomerations of hillocks.

III. THE LAKE BASINS.

The following table gives the altitudes and dimensions of the principal six Italian lake basins, which, it will be observed, lie in a zone similar to that of the five Swiss lake basins north of the Alps.

Lake.	Altitude. m.	Length. km.	Mean Width. km.	Area. sq. km.	Greatest Depth. m.	Exit River.
Orta . . .	290	12	2	20	300	Strona ^a
Maggiore . .	194	60	4	212	372	Ticino
Varese . . .	239	9	2	14	380	Bardello ^b
Lugano . . .	274	22	2	83	300	Tresa ^c
Como and Lecco	213	48	3	144	409	Adda ^d
Isco . . .	201	25	2	62	600	Oglio
Garda . . .	65	55	6	490	346	Mincio

^a Drains into Toce, affluent of Lake Maggiore ; ^b drains into Lake Maggiore ;
^c ditto ; ^d exit through Lecco arm.

It will be seen that not one of these lakes reaches the altitude of 300 metres, which, as previously shown, is that of the marine shell-bearing deposit a few kilometres north of Como, nor the altitude of the Fino deposits (370 metres) on the second moraine wall south of Como. The sea in the Po Valley must therefore have communicated with the fjords at a level much higher than that of the present lakes.

The question of how and when the present lakes were formed is obviously and closely allied with the retreat of the sea from the Po Valley. Désor ¹ held that from the time of the glaciers coming into contact with the sea the littoral of the Lombardy and Piémont plain was gradually raised ; but this would only account for the high level of the Fino and the other marine shell-bearing deposits. It appears much more likely that a simultaneous lowering took place on the one hand in the floor of the Po Valley, ² while the sea gradually receded, and on the other along the base of the Alps, which converted the fjords into lakes in addition to the fjords being choked by the moraine bars of the retreating glaciers. The formation of the lakes would, therefore, be due to the same two concurrent causes which operated in the formation of the lake basins north of the Alps—a zonal flexure and a moraine barrier behind which the river valleys or fjords became lakes during the recession of the glaciers.

The cross-section of the triple moraine walls south of Como shown in Sheet No. 2, Fig. II, which Rutimeyer gave for another purpose in his memoir already quoted, exhibits a striking reverse dip from the outermost wall to Lake Como of no less than 165 metres. The third moraine wall, which rests upon considerably bent strata of Molasse, thus constitutes, in my view, the anticline of the flexure whose syncline to the north follows the deepest points of the lakes, while the syncline to the south lies along the lowered floor of the Po Valley. The conditions in respect of Lake Maggiore and of Lake Garda are precisely similar, the reverse dip to the former being 150

¹ *Paysage morainique*, p. 72.

² The deposition of the rich alluvia which cover the floor of the Po Valley, and to which it owes its wonderful fertility, began with the retreat of the glaciers when the rivers resumed their erosive energy, and continued throughout the long interglacial period after the maximum glaciation.

and to the latter 140 metres. The two last-named lakes afford, moreover, at their lower ends, typical examples of the formation of lake basins behind the terminal moraines of retreating glaciers, for in both cases the widened basins at the lower ends are appendages of the original fjords, and their contours conform strikingly to those of the concentric moraine walls behind which they were formed.

The zonal flexure also accounts for the extraordinary depth of the present lake basins as the result of overdeepening by the lowering of their floors, as against the theory of overdeepening by the direct action of glacial erosion, as if such steep, long, and narrow basins could be formed by the vertical scooping of a glacier in the same way as a cirque or corrie. The indirect action of the glaciers was more probably confined to the widening of the fjords and of the tributary valleys of the Dora Baltea, Ticino, Adda, and others.

The simultaneous operation of the zonal bending and the retreat of the glaciers on the one hand, and the recession of the sea from the Po Valley on the other, must have been of very long duration, probably till the end of the Ice Age, including the period of the last glaciation, which did not reach, and therefore did not directly affect, the contact zone of the sea and the moraine walls in the Po Valley.

Such extraordinary phenomena as the natural exit of the Como fjord being choked and its drainage reversed, so that the present lake has its only exit through the Lecco arm; or the former connexions between the Como and Lugano fjords at Menaggio and Porlezza, and through the Breggia Valley at Chiasso being severed by the lowering of fjord levels, and the Lugano fjord finding its exit through the Tresa into Lake Maggiore; or again, Lake Orta having its southern outlet barred and its drainage reversed to the north into the Toce; or, similarly, Lake Varese draining reversely into Lake Maggiore,—all these phenomena, as well as the labyrinth of erratic and tortuous watercourses throughout the morainic littoral and the whole lake district, are only some of the direct and indirect effects of that great maximum glaciation which has left its impress along the base of the Italian Alps both in Piémont and Lombardy by a morainic landscape in magnitude, grandeur, and variety unequalled in any other part of the Alps or of Europe.

V.—ON THE EVIDENCE AS TO THE GEOLOGICAL STRUCTURE OF CUMBERLAND BORDERING THE SOLWAY.

By T. V. HOLMES, F.G.S., F.R. Anthropol. Inst.

(PLATE XIV.)

WHILE no doubts have existed among geologists that the rocks of this district are of Permo-Triassic age, that they are surrounded by older formations of the Carboniferous Series, and capped by a small Lias outlier, unanimity as to the relations of the local Permo-Triassic rocks to each other has never yet prevailed. Hence when the Geological Survey Memoir, by the present writer, on this district was published in 1899, Sir Archibald Geikie stated in the preface that the delay in its appearance was due to the hope that additional deep borings might have settled certain questions as to the relations to