I form a less hopeful prognostication. I think the ocean basins are the scar, which still testify to the place of separation.

The density of the moon is 0·56654 times that of the earth. Putting the mean density of the earth at 5·5, this makes the density of the moon 3·1. The density of granite is about 2·68, and that of basalt 2·96. Consequently the density of the moon is a little greater than that of the basic layer of the earth's surface, which I think we may expect to occur at the sea-board at a depth of about 25 miles. The entire mass of the moon is 0·011364 of the mass of the earth.

Accordingly, it would require a layer of about 31 miles thick, of the density of granite, to be taken off the surface of the primitive mass to make a body of the mass of the moon; and if the mean density of the matter removed was the same as that of the moon, a somewhat thinner layer would suffice. But if we reduce the area of the skin removed to the area of the oceans, it would require to be $\frac{197}{146} \times 31$, or about 41 miles deep. Hence a uniform layer rather less than 41 miles thick taken off the oceanic areas would be sufficient to make the moon.

Of course the layer removed would not, in fact, have been of uniform thickness. But the above estimate gives an idea of the size of the cavity which would be produced. What then would happen? This would depend upon whether the surface had already become at all solid. I conceive this would be the case at a very early stage, judging from the manner in which a solid layer forms on the liquid lava of Kilauea. The hole would therefore fill up by the rise of the liquid from below, rather than by the lateral approach of the edges of the wound. When the raw surface again solidified we should have a crust of greater density over the area in question, because formed from a lower and denser layer, which would have risen not quite to the level of the lighter crust. There would, however, have necessarily been a certain amount of flow in the upper fluid layers towards the cavity, and this would have carried the cooled granitic crust which, floating on it, still remained upon the earth along with it. What was left of the granitic crust would therefore be broken up into fragmentary areas, now represented by the continents. This would make the Atlantic a great rent, and explain the rude parallelism which exists between the contours of America and the Old World.

The sudden rupture of so considerable a fragment from the rotating spheroid, would alter its mass, form, and moment of momentum. It appears then that its axis of rotation would be altered, which might account for the fact, that the approximate pole of the oceanic area is not in the equator.

The volcanic surface of the moon, if volcanic it be, would lend considerable support to the view which I maintain, that the water substance emitted by volcanoes is an integral constituent of the fluid substratum. For when the moon broke away from the earth it would carry with it the aqueous constituent of the magma. Owing to the much smaller force of gravity in the moon, the pressure under which this would there be placed would be much less than in the earth. Consequently it would more easily escape, and the signs of volcanic action would be more pronounced. But the difficulties surrounding terrestrial vulcanism are so great, that one is hardly tempted to add the lunar to them. O. FISHER

CLASSIFICATION OF THE DINOSAURIA[1]

IN the May number of the *American Journal of Science* (p. 423) I presented an outline of a classification of the Jurassic Dinosaurian reptiles of this country which I had personally examined. The series then investigated is deposited in the Museum of Yale College, and consists of several hundred individuals, many of them well preserved, and representing numerous genera and species. To ascertain how far the classification proposed would apply to the material gathered from wider fields, I have since examined various Dinosaurian remains from other formations of this country, and likewise during the past summer have visited most of the museums of Europe that contain important specimens of this group. Although the investigation is not yet completed, I have thought the results already attained of sufficient interest to present to the Academy at this time.

In previous classifications, which were based upon very limited material compared with what is now available, the Dinosaurs were very generally regarded as an order. Various characters were assigned to the group by von Meyer, who applied to it the term *Pachypoda;* by Owen, who subsequently gave the name *Dinosauria,* now in general use; and also by Huxley, who more recently proposed the name *Ornithoscelida,* and who first appreciated the great importance of the group, and the close relation it bears to birds. The researches of Leidy and Cope in this country, and Hulke, Seeley, and others in Europe, have likewise added much to our knowledge of the subject.

An examination of any considerable portion of the Dinosaurian remains now known will make it evident to any one familiar with reptiles, recent or extinct, that this group should be regarded not as an order but as a sub-class, and this rank is given it in the present communication. The great number of subordinate divisions in the group, and the remarkable diversity among those already discovered indicate that many new forms will yet be found. Even among those now known, there is a much greater difference in size and in osseous structure than in any other sub-class of vertebrates, with the single exception of the placental Mammals. Compared with the Marsupials, living and extinct, the *Dinosauria* show an equal diversity of structure, and variations in size from by far the largest land animals known—fifty or sixty feet long, down to some of the smallest, a few inches only in length.

According to present evidence the Dinosaurs were confined entirely to the Mesozoic age. They were abundant in the Triassic, culminated in the Jurassic, and continued in diminishing numbers to the end of the Cretaceous period, when they became extinct. The great variety of forms that flourished in the Triassic render it more than probable that some members of the group existed in the Permian period, and their remains may be brought to light at any time.

The Triassic Dinosaurs, although so very numerous, are known to-day mainly from footprints and fragmentary osseous remains. Not more than half-a-dozen skeletons, at all complete, have been secured from deposits of this period; hence, many of the remains described cannot at present be referred to their appropriate divisions in the group.

From the Jurassic period, however, during which Dinosaurian reptiles reached their zenith in size and numbers, representatives of no less than four well-marked orders are now so well known that different families and genera can be very accurately determined, and almost the entire osseous structure of typical examples, at least, be made out with certainty. The main difficulty at present with the Jurassic Dinosaurs is in ascertaining the affinities of the diminutive forms which appear to approach birds so closely. These forms were not rare, but their remains hitherto found are mostly fragmentary, and can with difficulty be distinguished from those of birds, which occur in the same beds. Future discoveries will, without doubt, throw much light upon this point.

Comparatively little is yet known of Cretaceous Dino-

[1] By Prof. O. C. Marsh. Read before the National Academy of Sciences, at the Philadelphia meeting, November 14, 1881. Communicated by the Author.

saurs, although many have been described from incomplete specimens. All of these appear to have been of large size, but much inferior in this respect to the gigantic forms of the previous period. The remains best preserved show that, before extinction, some members of the group became quite highly specialised.

Regarding the Dinosaurs as a sub-class of the REPTILIA, the forms best known at present may be classified as follows:—

SUB-CLASS DINOSAURIA

Premaxillary bones separate; upper and lower temporal arches; rami of lower jaw united in front by cartilage only; no teeth on palate. Neural arches of vertebræ united to centra by suture; cervical vertebræ numerous; sacral vertebræ co-ossified. Cervical ribs united to vertebræ by suture or ankylosis; thoracic ribs double-headed. Pelvic bones separate from each other, and from sacrum; ilium prolonged in front of acetabulum; acetabulum formed in part by pubis; ischia meet distally on median line. Fore and hind limbs present, the latter ambulatory and larger than those in front; head of femur at right angles to condyles; tibia with procnemial crest; fibula complete. First row of tarsals composed of astragalus and calcaneum only, which together form the upper portion of ankle joint.

(1.) Order SAUROPODA (Lizard foot).—Herbivorous.

Feet plantigrade, ungulate; five digits in manus and pes; second row of carpals and tarsals unossified. Pubes projecting in front, and united distally by cartilage; no post-pubis. Precaudal vertebræ hollow. Fore and hind limbs nearly equal; limb bones solid. Sternal bones parial. Premaxillaries with teeth.

(1) Family *Atlantosauridæ.* Anterior vertebræ opisthocœlian. Ischia directed downward, with extremities meeting on median line.

Genera *Atlantosaurus, Apatosaurus, Brontosaurus, Diplodocus, ? Camarasaurus* (*Amphicœlias*), *? Dystrophæus.*

(2) Family *Morosauridæ.* Anterior vertebræ opisthocœlian. Ischia directed backward, with sides meeting on median line.

Genus *Morosaurus.*

European forms of this order: *Bothriospondylus, Cetiosaurus, Chondrosteosaurus, Eucamerotus, Ornithopsis, Pelorosaurus.*

(2.) Order STEGOSAURIA (Plated lizard).—Herbivorous.

Feet plantigrade, ungulate; five digits in manus and pes; second row of carpals unossified. Pubes projecting free in front; post-pubis present. Fore limbs very small; locomotion mainly on hind limbs. Vertebræ and limb bones solid. Osseous dermal armor.

(1) Family *Stegosauridæ.* Vertebræ biconcave. Neural canal in sacrum expanded into large chamber; ischia directed backward, with sides meeting on median line. Astragalus co-ossified with tibia; metapodials very short.

Genera *Stegosaurus* (*Hypsirhophus*), *Diracodon*, and in Europe *Omosaurus*, Owen.

(2) Family *Scelidosauridæ.* Astragalus not co-ossified with tibia; metatarsals elongated; four functional digits in pes. Known forms all European.

Genera *Scelidosaurus, Acanthopholis, Cratæomus, Hylæosaurus, Polacanthus.*

(3.) Order ORNITHOPODA (Bird foot).—Herbivorous.

Feet digitigrade, five functional digits in manus and three in pes. Pubes projecting free in front; post-pubis present. Vertebræ solid. Fore limbs small; limb bones hollow. Premaxillaries edentulous in front.

(1) Family *Camptonotidæ.* Clavicles wanting; post-pubis complete.

Genera *Camptonotus, Laosaurus, Nanosaurus,* and in Europe *Hypsilophodon.*

(2) Family *Iguanodontidæ.* Clavicles present; post-pubis incomplete. Premaxillaries edentulous. Known forms all European.

Genera *Iguanodon, Vectisaurus.*

(3) Family *Hadrosauridæ.* Teeth in several rows, forming with use a tesselated grinding surface. Anterior vertebræ opisthocœlian.

Genera *Hadrosaurus, ? Agathaumas, Cionodon.*

(4.) Order THEROPODA (Beast foot).—Carnivorous.

Feet digitigrade: digits with prehensile claws. Pubes projecting downward, and co-ossified distally. Vertebræ more or less cavernous. Fore limbs very small; limb bones hollow. Premaxillaries with teeth.

(1) Family *Megalosauridæ.* Vertebræ biconcave. Pubes slender, and united distally. Astragalus with ascending process. Five digits in manus and four in pes.

Genera *Megalosaurus* (*Poikilopleuron*), from Europe. *Allosaurus, Cœlosaurus, Creosaurus, Dryptosaurus* (*Lælaps*).

(2) Family *Zanclodontidæ.* Vertebræ biconcave. Pubes broad elongate plates, with anterior margins united. Astragalus without ascending process; five digits in manus and pes. Known forms European.

Genera *Zanclodon, ? Teratosaurus.*

(3) Family *Amphisauridæ.* Vertebræ biconcave. Pubes rod-like; five digits in manus and three in pes.

Genera *Amphisaurus* (*Megadactylus*), *? Bathygnathus, ? Clepsysaurus*; and in Europe, *Palæosaurus, Thecodontosaurus.*

(4) Family *Labrosauridæ.* Anterior vertebræ strongly opisthocœlian, and cavernous. Metatarsals much elongated. Pubes slender, with anterior margins united.

Genus *Labrosaurus.*

Sub-Order CŒLURIA (hollow tail).

(5) Family *Cœluridæ.* Bones of skeleton pneumatic or hollow. Anterior cervical vertebræ opisthocœlian, remainder bi-concave. Metatarsals very long and slender.

Genus *Cœlurus.*

Sub-Order COMPSOGNATHA.

(6) Family *Compsognathidæ.* Anterior vertebræ opisthocœlian. Three functional digits in manus and pes. Ischia with long symphysis on median line. Only known specimen European.

Genus *Compsognathus.*

DINOSAURIA?

(5.) Order HALLOPODA (leaping foot).—Carnivorous?

Feet digitigrade, unguiculate; three digits in pes; metatarsals greatly elongated; calcaneum much produced backward. Fore limbs very small. Vertebræ and limb bones hollow. Vertebræ biconcave.

Family *Hallopodidæ.*

Genus *Hallopus.*

The five orders defined above, which I had previously established for the reception of the American Jurassic Dinosaurs, appear to be all natural groups, well marked in general from each other. The European Dinosaurs from deposits of corresponding age fall readily into the same divisions, and, in some cases, admirably supplement the series indicated by the American forms. The more important remains from other formations in this country and in Europe, so far as their characters have been made out, may likewise be referred with tolerable certainty to the same orders.

The three orders of Herbivorous Dinosaurs, although widely different in their typical forms, show, as might be expected, indications of approximation in some of their aberrant genera. The *Sauropoda*, for example, with *Atlantosaurus* and *Brontosaurus*, of gigantic size, for their most characteristic members, have in *Morosaurus* a branch leading toward the *Stegosauria.* The latter order, likewise, although its type genus is in many respects the most strongly marked division of the Dinosaurs, has its

Scelidosaurus, a form with some features pointing strongly towards the *Ornithopoda*.

The Carnivorous *Dinosauria* now best known may all be placed at present in a single order, and this is widely separated from those that include the herbivorous forms. The two sub-orders defined include very aberrant forms, which show many points of resemblance to Mesozoic birds. Among the more fragmentary remains belonging in this order, but not included in the present classification, this resemblance appears to be carried much farther.

The order *Hallopoda*, which I have here referred to the *Dinosauria*, with doubt, differs from all the known members of that group in having the hind feet specially adapted for leaping, the metatarsals being half as long as the tibia, and the calcaneum produced far backward. This difference in the tarsus, however, is not greater than may be found in a single order of Mammals, and is no more than might be expected in a sub-class of Reptiles.

Among the families included in the present classification, I have retained three named by Huxley (*Scelidosauridæ*, *Iguanodontidæ*, and *Megalosauridæ*),[1] although their limits as here defined are somewhat different from those first given. The sub-order *Compsognatha*, also, was established by that author in the same memoir, which contains all the more important facts then known in regard to the *Dinosauria*. With the exception of the *Hadrosauridæ*, named by Cope, the other families above described were established by the writer.

The *Amphisauridæ* and the *Zanclodontidæ*, the most generalised families of the *Dinosauria*, are only known from the Trias. The genus *Dystrophæus*, referred provisionally to the *Sauropoda*, is likewise from deposits of that age. The typical genera, however, of all the orders and sub-orders are Jurassic forms, and on these especially the present classification is based. The *Hadrosauridæ* are the only family confined to the Cretaceous. Above this formation, there appears to be at present no satisfactory evidence of the existence of any *Dinosauria*.

THE TAY AND THE FORTH BRIDGES

THE reconstruction of the Tay Bridge (if it really go on) by Mr. W. H. Barlow and the re-designing of the Forth Bridge by Mr. John Fowler and Mr. B. Baker will undoubtedly mark a new point of departure in the practice of British engineers. With the advent of railways there arose a generation of engineers who for some inexplicable reason ignored the traditions of their predecessors and gave no thought to wind pressure. Previous to this the question was always considered of vital importance by constructors. For example, Tredgold, writing some sixty years ago about roofs over building slips, directed special attention to the fact that such structures were "much exposed to be racked and strained by high winds," and recommended certain proportions, based upon the assumption of the actual weight of the roof being 16 lbs. per square foot, and the pressure of the wind 40 lbs. per foot. He thus clearly warned engineers that in some instances the pressure of the wind and not the load governs the strength of the structure. Nevertheless so completely have British engineers ignored this condition that it may safely be said at least three-fourths of the railway bridges in Great Britain and Ireland have no lateral bracing or provision of any kind to enable them to resist wind pressure. Even metallic arched bridges, which from their form must, in the absence of cross bracing, be necessarily in a state of more or less unstable equilibrium, form no exception to the rule. At Richmond, for instance, and at Kingston also, there are cast-iron arches about 100 feet in span, the lateral stability of which is dependent solely upon the 8 inches or 10 inches wide flanges of the arched ribs. There is no lateral bracing nor are there any iron cross-girders to bind the arched ribs together, and the lateral stiffness of a 10-inch flange over a span of 100 feet is more easily imagined than calculated. Within a few hundred yards of the Richmond Bridge is an anemometer which, according to the official returns, has not infrequently recorded a pressure of 27 lbs. per square foot, but it is hardly necessary to say that no wind pressure even approximating to that amount could ever have taken effect on the bridge.

Since the fall of the Tay Bridge the principles and practice of Telford's day have been reverted to by British engineers, and the question of wind pressure has been most influential in determining the design and proportions of the new Tay and the proposed Forth Bridges.

In the original Tay Bridge the type of pier foundation finally developed was, it may be remembered, a single cylinder of 31 feet diameter. This was satisfactory enough as regards vertical pressure, but in the new design it was lateral and not vertical pressure which governed the form of the pier's foundation, and the latter will consist not of a single 31 feet cylinder but of two 23 feet cylinders spread 32 feet apart centre to centre, and affording correspondingly increased lateral stability. Similarly, as regards the metallic piers resting on these foundations: originally these consisted of a group of cast iron columns, and as regards vertical pressure nothing could be better, for, as we have recently ascertained by tests, a hollow cast-iron column of ordinary proportions will carry more load than either a wrought iron or a steel tube of equal weight. When the bending action of the wind upon a bridge pier is taken into consideration, however, the steady vertical pressure due to the load becomes of comparatively little moment, and Mr. Barlow has very properly adopted wrought iron for the piers of the new Tay Bridge, and the Board of Trade have with no less propriety intimated, in their recent "Memorandum of Requirements," that piers made up of a group of small cast-iron columns will no longer be passed by the inspecting officers.

The superstructure of the new Tay Bridge, no less than the piers, affords evidence of the provision which it is now thought necessary to make against the consequences of high wind pressures. Thus Mr. Barlow has provided three lines of defence against a train being hurled into the Tay, firstly, a guard balk of considerable height outside each rail; secondly, a ballasted floor of sufficient strength to hold up a derailed locomotive at any point; and thirdly, a strong iron parapet. Most of these provisions will in all probability be insisted upon by the Board of Trade in future railway bridges.

Turning now to the gigantic Forth Bridge, the influence of wind pressure in determining the design is beyond all precedent. The assumed lateral pressure of the wind upon the 1700 feet span girder is in fact no less than 50 per cent. greater than the maximum rolling load, so that were it not for the influence of gravity on the mass of the bridge, the required strength would be greater laterally than vertically to the extent of one-half. The weight of steel in the 1700 feet girder is, however, so considerable, that the stresses both for rolling load and wind pressure are relatively less than in smaller bridges.

The original design for the Forth Bridge by Sir Thomas Bouch was, it will be remembered, on the suspension principle. Except as regards the enormous drop in the suspension chains and the consequent unprecedented height of the piers, there was little to distinguish the proposed structure from an ordinary suspension bridge with stiffening girder, and without the inclined stays characteristic of American suspension bridges. During the past forty years the suspension principle has been universally rejected by engineers of all countries as unsuitable to the conditions of high-speed railway traffic, and the only reason for introducing it in the case of the Forth Bridge was the assumption that no other plan was commercially

[1] Quarterly Journal Geological Society of London, vol. vxvi. p. 34. 1870.