himself "the right of examining it further," Hansen observes that "it possesses all the reactions of the usual chlorophyll sauce."[1]

In a second paper[2] Hansen figures the spectra of chlorophyll green and chlorophyll yellow. His researches will, no doubt, be found useful by students of vegetable chromatology.

C. A. MacMunn

RECENT MORPHOLOGICAL SPECULATIONS[3]

II.—*The Origin of Vertebrates*

Fifteen or sixteen years ago Kowalevsky's researches on the development of Amphioxus and of Ascidians seemed to be solving the question of the origin of Vertebrates. The discovery of the larval notochord in Ascidians, and the recognition of the homology of their pharyngeal clefts with the gill-slits of Vertebrates, made it necessary to acknowledge the close relationship of the two, as had been already foreshadowed by Herbert Spencer; while the yet undisputed affinity of Ascidians to Mollusks brought Vertebrates and Invertebrates together in an unbroken line. But as new knowledge brought Ascidians closer to Vertebrates, it undermined their claims to molluscan affinities; and as the doctrine of degeneration grew up, in the hands of Dohrn and Lankester, it taught that Ascidians, and Amphioxus too for that matter, were not really *ancestors* of the higher Vertebrata, but only degenerate descendants of such ancestors, poor cousins, as it were, of the higher Vertebrates. The lines by which Vertebrates had sprung from Invertebrates, the common ancestor of Ascidians, Amphioxus, and the higher Vertebrates, had still to be sought for.

Two leading theories have been formulated, and are still under discussion. The first, identified with the names of Semper and Dohrn, maintains that the nearest allies of the Vertebrates must be looked for among the Chætopod worms, the dorsal surface and spinal cord of the former corresponding morphologically with the ventral surface of the latter, and its gangliated nerve-cord. On the second view, with which we may associate the names of Balfour and Hubrecht, we must take the ancestor of the Vertebrates to have been some segmented worm, descended from the same unsegmented types as the Chætopods, but in which the two nerve-cords, at first lateral like those of Nemertines, had coalesced dorsally instead of ventrally, to form a median nervous system.

Our discussion of the first of these theories may be made clearer if we use the words "neural" and "hæmal" instead of "dorsal" and "ventral," for the gist of the theory is that in the two groups *neural* and *hæmal* surfaces remain constant, but what is dorsal in the one is ventral in the other.

In the Chætopods, say the advocates of this theory, we have a group of regularly segmented animals, not so far specialised but that we might well conceive ancestors like them to have developed into Vertebrates; they point to the relations of the nervous, vascular, and alimentary systems, and to the development of the mesoblast, as being closely parallel in the two groups; and they try to find traces or representatives in Chætopods of such typically Vertebrate possessions as notochord, gill-clefts, and swimming-bladder.

At the very outset a difficulty arises which is perhaps the greatest the theory encounters. The mouth of Chætopods is neurally placed, and surrounded by a nerve-ring; in Vertebrates it is hæmal, and it does not pierce any part of the nervous axis. Dohrn has attempted to overcome this objection. The present mouth of Vertebrates, he says, is not identical with the Invertebrate mouth; it is a distinct and secondary structure; it arises late in development, whereas in other classes the "stomodæum" or primitive oral invagination appears very early. Moreover, in the majority of Vertebrates the mouth does not persist in the position it first appears in; it arises some way off from the anterior end of the body, and in Elasmobranchs, some Ganoids, and Myxinoids it remains there, but in all other Vertebrates it becomes terminal. If we assume, then, that the mouth in existing Vertebrates is secondary, there must have been a time when it did not exist, and when its functions were performed by another or primary mouth. It has been suggested that in the *hypophysis cerebri* or "pituitary body" we have, possibly, a remnant of this primary mouth. The hypophysis cerebri appears first as an ectodermic involution, usually arising from the stomodæum; but in the lamprey, Götte, Scott, and Dohrn have shown that it arises from the ectoderm which lies anterior to the mouth. It is here, in fact, a little pit of ectoderm, placed between those other two ectodermic pits, which are to become the nose and the mouth.

If this involution ever pierced the brain and opened upon the neural surface, the fore-brain would then be evidently homologous with the supra-œsophageal ganglion of Invertebrates, or ganglion of the præ-oral lobe. A great deal may be said for thus regarding the fore-brain as distinct from the remaining nervous system; it resembles the supra-œsophageal ganglion of the Invertebrata in its close connection with the optic and olfactory organs, and in supplying only organs of sense. There is evidence to show that the third nerve belongs to the cranio-spinal series of segmental nerves, and that the olfactory and optic nerves have a different nature. If this be so, the mid-brain, giving origin to the third nerve, would appear not to have part in the ganglion of the præ-oral lobe. The termination of the notochord directly behind the fore-brain is an additional argument in favour of the morphological distinctness of the latter structure.

Thus if we follow back the genealogical record of the Vertebrates, we find that at one period their ancestors had a mouth upon the neural surface; later, two openings into the alimentary canal appear, one on the neural and one on the hæmal surface; still later the latter gains the ascendancy, and alone remains to the present time. This secondary mouth must have arisen from some pre-existing structure; it could not have originated as a simple depression of the outer skin which deepened and ultimately fused with the alimentary canal; and the only pre-existing organs which could furnish such a passage from the exterior into the alimentary tract are the gill-slits. We must conceive this Vertebrate ancestor as an animal with an intestine which opened anteriorly by a median mouth on its neural surface, and laterally by a series of segmentally situated gill-slits. The mouth took in water, which flowed out over the gill-arches just as it does still in the lower Vertebrates. If from any reason, such as the animal lying like the modern Annelids on its neural surface, it obtained a purer supply of water by taking it in through some of the gill-slits, it is conceivable that a pair of these slits assumed that office, and that by the exercise of this power the gill-slits became gradually larger, and ultimately fused in the middle line. The suctorial power thus acquired to take in water for the purposes of respiration was also of use in obtaining food, and thus a median hæmal suctorial mouth arose, such as the Myxinoids now possess. There is much evidence to show that the ancestral Vertebrate possessed a suctorial mouth which subsequently became modified for biting, and was carried forward to the front of the head. Embryology supplies the following arguments in favour of regarding the mouth as formed from the coalescence of a pair of gill-slits. It lies close against the gill-slits, it is separated from them by a gill-arch, it arises about the same time in the embryo, it opens into the alimentary canal; finally, in some Teleosteans, *Belone*, *Hippocampus*, and *Gobius*, the mouth first appears as two lateral openings, which afterwards fuse in the middle line.

Admitting that the mouth is formed of two gill-slits, we have to see from what structures in an Annelid such gill-slits could be derived. In many Chætopods no part of the body is set apart to perform the function of respiration. Where there are no gills the blood is commonly aërated in the walls of the alimentary canal, water being taken in at either end, and when charged with the waste products of respiration, it is expelled through the same opening. In some cases, as in *Hesione*, the surface with which the water comes in contact is increased by a pair of lateral sacs or diverticula. It is obvious that with such a respiratory apparatus it would be advantageous if there was an exit for the respired water distinct from its entrance, so that the blood should always be in contact with pure water. Such an exit would be formed by fusion of the respiratory diverticula with the body-wall and subsequent rupture of the latter at the points of fusion. And the apertures in the tentacles of Actiniæ and the perforated liver-diverticula of Eolis are adduced as analogous instances of such perforation.

Another suggestion which has been made to account for the origin of gill-slits is that the inner ends of some of the segmental organs gained an entrance into the alimentary tract, and, changing their function, gave rise to gill-slits.

By these steps a Vertebrate has been reduced to an Annelid structure, but certain questions which have arisen in the development of this theory remain to be answered. One is whether the

[1] Tschirsch only obtained his chlorophyll in the form of "blackish-green drops."

[2] *Loc. cit.*

[3] Continued from p. 69.

mouth is formed from the most anterior pair of gill-slits. If the trabeculæ cranii are gill-arches, the mouth is not the first. Some authorities consider the nasal sacs as modified gill-slits; they are primitively double, and where we find them single, as in Amphioxus and Cyclostomes, it is due to secondary processes.

In his "Monograph on the Development of the Elasmobranch Fishes," Balfour has pointed out that the histological structure of the spinal cord in Vertebrates is exactly what would be found if, by mechanical folding, the two lateral halves of the nerve-cord of an Annelid became bent toward one another, whilst the external skin was pushed into the groove between them. If this folding were completed, so that the external epithelium formed a canal surrounded by nervous tissues, the white and gray matter would assume the same relative position that they possess in the spinal cord of Vertebrates. The nerves would then arise not laterally, but from the extreme ventral summit, and would thus correspond with the posterior roots of the Vertebrate spinal cord, which, as Balfour has shown, grow out from the extreme dorsal summit of the neural canal, a position comparable with the ventral summit of the Annelid nervous system. In Amphibia the primitive medullary plate (or modified area of dorsal epiblast which is to fold in and form the medullary groove), although elsewhere single, shows signs of being formed of two symmetrical halves, and in both embryo and adult the neural tube has a structure which points to its origin from the coalescence of two lateral cords.

The direction of the blood current, which flows from behind forwards on the hæmal, and from before backwards on the neural, surface, agrees in Chætopods and Vertebrates if the surfaces be reversed, and the hypothesis of reversal presents no great difficulties in the case of a cylindrical animal swimming in the sea.

In connection with this theory it is interesting to note that Eisig has instituted a comparison between the lateral sense-organs in the Capitellidæ (a family of Chætopods) and the lateral line of fishes, and he further compares the "siphon" of the same Chætopods with that obscure rod of tissue split off from the alimentary tract of fishes and Amphibia, the sub-notochordal rod.

The notochord is one of the most characteristic Vertebrate structures, and if the theory propounded above be true, we should expect to find very distinct rudiments of such a structure amongst the Chætopods, but although numerous organs have been interpreted as such, Balfour states that none of these interpretations will bear examination. Quite recently Nussbaum has found in the cockroach a longitudinal string of cells lying upon the nerve-chain, which in its development bears a striking resemblance to the notochord of Vertebrates, and Vejdovsky has described a similar structure in Oligochæta, developed, however, from the mesoderm, under the name of neurochord.

The supporters of the second theory, which we have connected with the names of Balfour and Hubrecht, claim that they have found an organ in one class of the Invertebrata which is comparable to the notochord of Vertebrata.

Balfour in the "Elasmobranch Fishes," whilst combating the Chætopod origin of Vertebrates, suggested that Vertebrates have descended from the same unsegmented stock as the Chætopods, but through some other line which has entirely disappeared. They have thus acquired similar segmental and other organs. In this line of ancestors he imagines that the primitive lateral nerve cords have tended to coalesce dorsally instead of ventrally. In his "Comparative Embryology" he repeats these views, and adds that their probability has been increased by the researches of Hubrecht, who has shown that in some Nemertines the nerve-cords approach each other very closely in the median dorsal line. Hubrecht has quite recently amplified these views by suggesting that "the proboscis of Nemertines, which arises as an invaginable structure, and which passes through a part of the cerebral ganglion, is homologous with that rudimentary organ which is found in the whole series of Vertebrates without exception—the hypophysis cerebri. The proboscidian sheath of the Nemertines is comparable in situation (and development?) with the notochord of Vertebrates."

The first of these two positions is supported by the facts of development. Although the details of the ontogenetic origin of the Nemertine proboscis are still wanting, the broad fact that it arises, like the hypophysis cerebri, as an invagination of the epiblast, has been established.

These organs further resemble each other in the shifting of their external opening, which is in some cases on the outer surface, in others on the dorsal wall of the alimentary canal just within the mouth.

In this comparison between the proboscis of Nemertines and the hypophysis cerebri, the connection of the latter with the brain and its relation to the anterior end of the notochord, must be especially borne in mind. The proboscis passes backward, between the anterior thickenings which form the brain, the two lateral halves of which are connected by a thick nerve commissure ventral to the proboscis, and by a thin strand dorsal to it. Thus the proboscis pierces a ring of nervous tissue, and the proboscis sheath reaches forward to the level of this nervous commissure. This region, then, would correspond to that part of the vertebrate brain to which the hypophysis cerebri is attached and close behind which the notochord terminates, and would thus separate off the fore-brain from the remaining nervous system. In connection with this it is a very significant fact that the superior lobes of the Nemertine brain give rise to the nerves which supply the sense organs, while the strong nerve which supplies the anterior region of the œsophagus originates in the inferior lobes. The one pair of these lobes may thus have been perpetuated as the fore-brain, and the other as the rest of the nervous system.

The sheath of the proboscis corresponds very accurately in its position to the notochord, but unfortunately the knowledge we possess of its development is not great. Barrois and Salensky have attributed a mesoblastic origin to it, the latter, however, noting a connection between the first origin of the œsophagus and proboscis. Hoffman has stated that part of the proboscis is split off the dorsal surface of the alimentary canal, whilst the muscular proboscis sheath is mesoblastic in origin. Hubrecht suggests that possibly the formation of the inner part of the proboscis sheath has been mistaken for the proboscis. If this suggestion prove true, then the proboscis sheath agrees both in position and origin with the notochord of Vertebrates.

The fully-developed notochord is a solid rod, whereas the proboscis sheath is a hollow tube. This, however, is no very serious objection to their homology; and recently Lieberkühn and Braun have shown that the notochord arises at first as a hollow tubiform structure, whilst in old specimens of *Cerebratulus* (a Nemertine) the posterior end of the proboscis sheath is nearly or quite filled up with continuous cellular tissue.

We have unfortunately too little knowledge at present to institute a comparison between the other organs of Nemertines and Vertebrates. Attention should, however, be called to the ciliated lateral pits upon the head. These arise from the most anterior part of the œsophagus in front of the mouth. They bud out from the walls of the œsophagus, and are in this stage directly comparable to similar diverticula which arise in the same region in the larva of *Balanoglossus*, and which there give rise to the first pair of branchial slits. These diverticula become finally cut off from the œsophagus, but enter into connection with epiblastic invaginations, and are thus placed in communication with the sea-water. In Schizonemertines their inner end is in connection with the brain; the latter contains hæmoglobin, and so they subserve respiration. In Hoplonemertines, however, although their development is similar, they apparently are modified for a sensory, possibly an olfactory, function. In connection with these structures, Hubrecht calls attention to some of the results of Hatschek's recent researches on the development of Amphioxus. In this animal there are two lateral hypoblastic diverticula growing out from the anterior part of the œsophagus in front of the mouth. These differ both in their nature and development from the archenteric diverticula, or from the branchial outgrowths. They are at first symmetrical, but have a different fate. They are both constricted off from the hypoblast: the left one communicates with the exterior by a ciliated opening which appears in the epiblast; the right one forms an epithelial lining to the præoral body region. The left one has been looked upon as a special sense organ of the larva.

Finally it is impossible to overlook the bearing of Balanoglossus on our subject, although we are not yet in possession of all the facts that Mr. Bateson's (*Q.J.M.S.* No. xciv. April 1884) recent researches seem to have elicited. The pharyngeal slits of Balanoglossus have long been recognised as wonderfully like the gill-slits of Vertebrates, and on the other hand as totally unlike any structures possessed by animals outside the Chordata. But Bateson's researches have already shown that the developmental features of the nervous system and of the mesoblast are not less suggestive of the same kinship. For the mesoblast is developed from an anterior archenteric pouch with two posterior horns (exactly comparable with that described in the last paragraph as existing in Amphioxus) and two pairs of posterior pouches instead of the larger number that Amphioxus possesses. And the fate of the anterior pouch is almost identical in the two forms, for in Balanoglossus its left-hand division becomes lined by cilia and opens to the exterior, whereas its right-hand half degenerates into connective tissue. And as regards the nervous system (which in Balanoglossus contains no mesenteric canal as that of Amphioxus does) "it is only necessary to imagine the invagination of the dorsal nerve-cord to have been extended along the back (instead of being confined to the region of the collar) in order to reproduce the condition which is found in Amphioxus." But however much we may be struck by these relations of Balanoglossus, its own isolated position and the extreme difficulty of allying it to any other Invertebrate groups prevent it from throwing much light upon the Vertebrate pedigree. The claims of the two theories discussed above may be unaffected, however close the correspondence between Amphioxus and Balanoglossus may be shown to be; and as yet Balanoglossus seems to do little more than remind us of how remote a relative of the Vertebrates Amphioxus itself is. Amphioxus occupies such an outlying branch, so far from the main stem of the genealogical tree of Vertebrates, that the demonstration of its likeness to an isolated Invertebrate like Balanoglossus may, like its obvious relationship with the Tunicates, be of little use to us.

It is perhaps premature to judge between these two theories detailed above, or to accept either of them definitely as an indication of the origin of Vertebrates. But we must point out that the Chætopod theory lies under the great disadvantage of assuming as far distant ancestor of Vertebrates a class of animals that seem really to occupy an apical position in a certain line of development. The Chætopods seem to be so highly specialised, that we must be suspicious of taking them to be the origin of another great group, but rather consider them as the ultimate result of evolution in a particular direction. In general it must always, *a priori*, be unsafe to attempt to make the apex of one group the base of the next; and in all cases it must be better, and more consonant with the principles of evolution, to search for the closest relations of one group among the simpler and less specialised members of another. A. E. S.

THE ROYAL SOCIETY OF CANADA

THE annual meeting of this Society was held at Ottawa, May 21-24, under the presidency of the Hon. P. J. O. Chauveau, LL.D., D.-ès-L.

The following papers were read in Section III. (Mathematical, Physical, and Chemical Sciences):—Electrical induction in underground and aërial metallic conductors, by F. N. Gisborne, C.E. The author proposed, in order to get rid of induction phenomena in telephone circuits, to connect sending and receiving telephones by means of pairs of twisted and insulated wires. He described experiments made with a section of cable about 3000 feet in length and laid underground between two of the Departmental Buildings at Ottawa. The cable contained twenty indifferently insulated wires, which were divided into pairs, two wires being twisted together in each case, each pair constituting a metallic circuit, and one wire of each pair being used as a "return" instead of the earth plates usually employed. The experiments showed that if one of these pairs was used as a telephonic circuit, no induction effects could be observed in the others. The absence of induction effect he attributed to the equidistance of the two wires of a pair from any third wire and the equality and opposition of the currents flowing in them.—A particular case of the hydraulic ram or water hammer, by C. Baillargè, C.E.—On the form of the contracted liquid vein affecting the present theory of the science of hydraulics, by R. Steckel. Communicated by C. Baillargè, C.E.—The origin of crystalline rocks, by T. Sterry Hunt, LL.D., F.R.S. The author began by remarking that the problem of the origin of those rocks, both stratified and unstratified, which are made up chiefly of crystalline silicates, is essentially a chemical one. He then proceeded to review the history of the once famous dispute between the vulcanist and the neptunist schools in geology as to whether granite and other crystalline rocks were formed by igneous or by aqueous agencies, and showed from recent writers that the controversy is not yet settled. He noticed of the igneous school both the plutonic and the volcanic hypotheses of the origin of these rocks, and then considered the so-called metamorphic and metasomatic hypotheses, which would derive them by supposed chemical changes from materials either of igneous or of aqueous origin. The hypothesis of Werner was next discussed. This conceives all such rocks to have been successively deposited in a crystalline form from a chaotic watery liquid, which surrounded the primitive earth, and at an early time held in solution the whole of the materials of these rocks. The inadequacy of all of these hypotheses was pointed out, though it would appear that Werner's was the one nearest the truth. The author conceives that the crystalline rocks were formed by deposition from waters which successively dissolved and brought from subterranean sources the mineral elements. Their formation is illustrated by that of granitic veins, and that of zeolites—processes regarded as survivals of that which produced the earlier rocks. The true zeolites are but hydrated feldspars, while the minerals of the pectolitic group correspond to the protoxyd-silicates of the ancient rocks. The source of the elements in these rocks, according to the new hypothesis here proposed, was in the superficial layer which was the last-congealed portion of an igneous globe consolidating from the centre. In this primitive stratum, porous from contraction and impregnated with water, resting upon a heated anhydrous nucleus, and cooled by radiation, an aqueous circulation would be set up, giving rise to mineral springs. The waters of these dissolved and brought to the surface, there to be deposited, the quartz, the feldspars, and other mineral silicates, which, through successive ages, built up the great groups of crystalline stratified rocks, often so markedly concretionary in aspect. Exposed portions of the primitive silicated material would be subject to atmospheric decay and disintegration, giving rise to sediments of superficial origin, which would become intercalated with the deposits from subterranean sources. The reactions between the mineral solutions from below and the superficial materials were important in this connection, probably giving rise to certain common micaceous minerals; while dissolved silicates allied to pectolite, by their reaction with the magnesian salts, which then passed into the ocean waters, generated species like serpentine and pyroxene. This process of continued upward lixiviation of the primitive chaotic stratum would result in the production of a great overlying body of stratified acidic rocks, leaving below a basic residual and much diminished portion, the natural contraction of which would cause corrugations of the superincumbent stratified mass, such as are everywhere seen in these ancient rocks. The source of volcanic rocks is partly in this lower and more or less exhausted stratum of comparatively insoluble and basic ferriferous silicates, whence come melaphyres and basalts; partly in the secondary or acidic mass, which, softened by the combined agency of water and heat, may give rise to granitic and trachytic rocks; and partly also, it is conceived, in later aqueous deposits of superficial origin, which also may be brought within the influence of the central heat. This attempt to explain the genesis of crystalline rocks by the continued solvent action of subterranean waters on a primitive stratum of igneous origin the author designates the crenitic hypothesis, from the Greek κρήνη, *fons*. A preliminary statement of it was made by him to the National Academy of Sciences at Washington, April 15, 1884, and appears in the *American Naturalist* for June.—On the density and thermal expansion of aqueous solutions of copper sulphate, by Prof. J. G. MacGregor, D.Sc. The author gave the results of extended observations of the density of solutions of different concentration and at different temperatures. They show that the rate of variation of density with temperature increases with the temperature and with the percentage of salt in solution; that the density of any solution at low temperatures (below 20° C.) diminishes, as the temperature increases at a greater rate than that of water; that the ratio of the density of a solution to the density of water at the same temperature diminishes as the temperature increases; and certainly for many solutions, probably for all, attains a constant value within the temperature limits of the experiments (below 35°-50°); that, therefore, at about 40° C. the thermal expansion of solutions is the same as that of water at the same temperature. The experiments also substantiated a result formerly reached by Prof. Ewing and the author that very weak solutions of this salt have a smaller volume than the water used in making them. If then these solutions are made by the addition of anhydrous salt to water contraction must occur. The experiments show that the greatest contraction occurs in the case of a solution containing 1·34 per cent. of anhydrous salt, in which case the contraction is 0·0048. The solution containing 5·95 per cent. of anhydrous salt has the same volume as the water required to make it.—Blowpipe reactions in plaster of Paris tablets, by Prof. E. Haanel, Ph.D. This paper was a continuation of that presented to the Society last year. The author described the result of the treatment of copper with hydrobromic acid, and of iron and