THURSDAY, OCTOBER 8, 1896.

THE ALTERNATE CURRENT TRANSFORMER.

The Principles of the Transformer. By Frederick Bedell, Ph.D. 8vo. Pp. xii + 400. (New York: The Macmillan Company. London: Macmillan and Co., Ltd., 1896.)

IN a work coming to us from one of the principal technical colleges in the United States, and on a subject which has been occupying the attention of electrical engineers for at least fourteen years, one would naturally expect to find a well-considered treatment based on the concentrated essence of practical experience, and embodied in a form which should definitely guide design and construction. It was therefore with a feeling of disappointment that we found so large a portion of this volume devoted to a class of investigations which are nothing more than elaborate mathematical exercises in the geometry of periodic quantities. The experimental researches of numerous engineers and electricians in the last decade have completely elucidated the general nature of the operations going on in the alternate current transformer, and as a practical art its construction has been brought to a very high degree of perfection. The demand for transformers has developed of late years an entirely new branch of the iron industry, viz. the manufacture of transformer iron, on which much depends, and with a large body of experience to fall back upon, the manufacturer can now work up to a definite and exacting specification. In the presence of other well-known text-books which deal with the properties of periodic currents, the general construction of the transformer, and its employment in electric distribution, there was hardly room for a volume of the size before us unless marked by some distinct novelty of treatment, or the development of a theory strictly brought to the test of experimental confirmation. Unfortunately we find neither of these two requirements here fulfilled. The earlier portions of the book are occupied with an elementary discussion of the properties of simple harmonic currents. It may be assumed that for students beginning to study the properties of alternating currents some amount of this information is necessary, but for the training of engineering students it is above all things necessary that the fundamental definitions should be so laid down as to lead immediately to clear notions of how the quantities concerned are measured, and numerical examples be added. This, however, is just what is not done in this book. The definitions of such leading terms as magnetic induction, magnetic force, inductance, coefficient of self-induction, are given in a way which is likely to produce a considerable amount of obscuration in the mind of a beginner. Take as an instance the definition of the coefficient of self-induction of a circuit. He is told on p. 35, it is the ratio of the induced electromotive force in a circuit to the time-rate of change of the current producing it. He then learns on p. 50, that the practical unit is the Henry, which is 10^9 C.G.S. units. He then discovers that the C.G.S. unit of inductance is one centimetre, and he is left to imagine how a ratio can be measured in centimetres. This method of defining inductance is much more artificial than that which is based on notions of the energy associated with a current. The general properties of simple harmonic currents flowing in inductive circuits are then given, the arrangement and selection of the matter following closely on the lines of other existing English treatises on the same subject.

The body of the book is occupied with the treatment of the theory of the transformer. The author apparently takes the transformer chiefly to be an air-core transformer, with constant coefficients of self and mutual induction, and expends an immense amount of pains in solving various problems about this imaginary instrument, elaborately worked out with polar diagrams and a lavish use of algebra.

The results, however, when done have very little real use. Probably no transformer-maker that ever lived had occasion to measure a coefficient of self-induction, and the merest tyro ought to be told at the beginning of the subject that this method of approaching its treatment with the assumption of constant coefficients of inductance is but little use in connection with the actual iron-core transformer of real life. The theory of the transformer would be simplicity itself if the cyclic value of the induction created in an iron-core transformer by a periodic magnetising force could be simply expressed as a function of the force. In our ignorance of what really goes on inside iron when magnetised, all we are able to do at present is to express the area of the hysteresis curve in terms of its maximum ordinate, and no practical progress is made by raising a whirlwind of mathematical symbols around suppositions or premises not based on experience.

The chapters on alternate current curve tracing, transformer design, and testing, bring us more within touch of practice; but they are handled in a somewhat limited way. The curve tracing is chiefly restricted to the now almost obsolete hedgehog transformer, and the one instance in which the design for a transformer is worked out in complete detail is not confirmed by actual tests of the transformer so supposed to be made. These matters ought really to have formed the bulk of the book.

The good design of a transformer, like that of many other appliances, is largely a matter of compromise and experience. Full and exact details of actual transformers built, and the tests of the same, would have given useful information. As it stands, there is little or nothing which would be the least use in the drawing-office. A student asked to design an impedance coil to pass a current of fifteen amperes, and drop a pressure of sixty-five volts, would find no information in this volume to enable him to attack this simple problem with ease and certainty.

The fact is, that there are two ways of discussing a subject such as that of the treatise before us. One way is to collect all possible data from experiments and practice, and then develop from these a physical theory which shall reconcile all the facts, and be a sufficient guide to future practice. The other is to eliminate the real difficulties by assumptions akin to that of the frictionless pulley of applied mathematical text-books, and then evolve by sheer force of deductive reasoning all possible mathematical consequences. The latter method reduces the subject to mere exercises in algebra and geometry; the former is the only process for advancing true knowledge. It is unfortunately the mathematician's transformer that figures so largely in the present volume. The subject of iron testing, the magnetic qualities of iron, its selection, and the effects of use on it for transformer cores, though fundamental matters of principle in the case of the real transformer, are not so much as mentioned, in spite of all that has been lately done in this matter. The avoidance of eddy current losses in the copper circuits and frames, the effect of magnetic leakage in causing such copper eddy current losses, the processes of ventilating large transformers, and the real difficulties of insulation, and the specialities of design for various purposes, are not named. The practical man, looking for approved principles of design in the case of the transformer, asks for the bread of practical experience; he is here presented with the stones of an artificial theory.

OUR BOOK SHELF.

Mechanics for Beginners. By Linnæus Cumming, M.A. Pp. viii + 247. (London: Rivington, Percival, and Co., 1896.)

TWENTY years ago a Committee of the British Association recommended that the school teaching of physics should begin with a course of elementary mechanics, treated from an experimental point of view, and the opinion expressed in the Physics Section of the Association this year was in support of that view. Mr. Cumming has for some years been endeavouring to act upon the recommendation in the science classes of Rugby School, and the present book contains the course which his experience has proved to be the most suitable for beginners.

The book does not begin with dynamics, for though Mr. Cumming recognises the scientific advantages which this subject offers to the study of mechanics, he has found it too abstract for young students. Statics lends itself to experimental treatment, and is able to appeal directly to the convictions and interests of boys beginning the study of science. The first part of the book is, therefore, devoted to this branch of the subject, dynamics being treated in the second part, and hydrostatics in the third.

Teachers and students who are familiar with the author's books on electricity and heat, will know the character of his work. The present volume is thoroughly practical, is very clearly illustrated, and will doubtless find its way into many schools. It shows how mechanics may be experimentally taught in schools, and the principles demonstrated with simple apparatus; it thus contains the elements of a sound scientific education.

We regret to note the absence of an index, for no text-book is complete without one.

Hints on Elementary Physiology. By Florence A. Haig-Brown. Pp. xii + 121; 20 illustrations. (London: J. and A. Churchill, 1896.)

THESE "Hints" are based upon notes taken by the authoress and her sister while attending lectures and demonstrations given to probationers at St. Thomas's Hospital. They will be found helpful as a means of giving a general idea of the functions of the various parts of our bodies; and nurses who read them will acquire knowledge which will lead to the intelligent performance of duties.

LETTERS TO THE EDITOR.

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of* NATURE. *No notice is taken of anonymous communications.*]

The Utility of Specific Characters.

I AM anxious to avoid prolonging this discussion, but I should like to say a word in answer to Prof. Pearson and Mr. Cunningham. The letters of these gentlemen may lead some readers to infer that I have only just recognised the hypothetical nature of the law of growth of crabs assumed in the report of last year, to which reference has been made. I wish, therefore, to point out that the hypothetical nature of this assumption is recognised in the report itself (*Roy. Soc. Proc.*, vol. lvii. pp. 367-368), and in the remarks which accompany it (*ibid.*, pp. 381-382).

So far as I remember, this point was dwelt upon by at least one speaker in the discussion which followed the reading of the report: and the fact that I have spent the whole of my spare time, since the report was read, in an endeavour to ascertain the actual law of growth, is evidence that I have not been blind to its importance.

I must ask Prof. Pearson's leave to postpone a discussion of the actual law of growth until I have worked out the results of all my observations.

As for Prof. Pearson's second point—that correlations may arise by chance—I altogether fail to follow him; and the data which he gives concerning his hypothetical breed of cows, do not seem to me sufficient to serve as the basis of further discussion.

W. F. R. WELDON.

University College, London, October 3.

An Error Corrected.

WE regret to have to acknowledge a mistake which we have made in a communication to the Paris Académie des Sciences, reproduced in NATURE of Aug. 27. It refers to the densities of helium; it does not affect the experimental results, nor the conclusion that helium has been split into two portions of unequal density; but it affects the figures assigned to these densities. The hypothetical case was stated that a mixture of four volumes of oxygen and one volume of hydrogen would diffuse in equal times, and *therefore could not be separated.* This conclusion is of course wholly wrong, and likewise in consequence the densities calculated for helium on a similar supposition. The densities of the two fractions of helium are therefore those found experimentally, viz. 1·874 and 2·133. It is right to observe that these figures stand for densities calculated from the observed rates of diffusion, and not from direct weighings

WILLIAM RAMSAY.
J. NORMAN COLLIE.

University College, London, October 1.

The Departure of the Swallows.

I DO not know whether the eccentric behaviour of the swallows this year is of sufficient interest to justify me in troubling you with a letter. I am not the only person in this part of the world whose attention it has attracted.

Everybody is familiar with the spectacle of large assemblages of swallows immediately preceding their total disappearance; usually, I think, in early October. This year great multitudes were assembled here on September 1; both flying about this house, and at perch on rails and telegraph wires. On the two next days only one or two were visible, and on the two days succeeding none at all. I concluded that they had antedated their departure by a month, although in this locality the steady sunshine and dryness had not then ceased; but on Sept. 6 large numbers appeared, to disappear again the next morning. Since then their action, or the action of *some* swallows, has varied nearly in accordance with the twelve days' account which is appended. Yesterday (September 30) none were visible, nor are any to-day. But there has been no large assemblage immediately previous.

If you pay any attention at all to these remarks, please to take them with many grains of salt. My observations have not been quite regular, and are wholly unscientific, and are confined to a very narrow area. In fact I cannot distinguish between a swallow and a martin when in flight, nor do I know what may be their differences in the affair of migration. I believe both kinds of swallow (to use the popular term) abound here in normal quantities, and I am told that swifts are comparatively scarce. But my own observation is of the shallowest and loosest character, confined indeed to the æsthetic side—viz. to admiration of the beauty and grace of the birds in dancing their endless reels.

Tuesday, September	1	... multitudes of swallows.
Wednesday ,,	2	... } one or, perhaps, two.
Thursday ,,	3	... }
Friday ,,	4	... } none at all.
Saturday ,,	5	... }
Sunday ,,	6	... multitudes.
Monday ,,	7	... none (reappeared at 3 p.m. in small numbers).
Tuesday ,,	8	... a few.
Wednesday ,,	9	... none in morning; some about 2 p.m.
Thursday ,,	10	... none observable.
Friday ,,	11	... none observable.
Saturday ,,	12	... a few.

After this, the quantities were about normal: not remarkable for multitudes or for paucity. HOBHOUSE.

Charlton House, Portbury, Bristol.

"The Scenery of Switzerland."

BEING away from home, I have only just seen NATURE of September 10, and I should like, with your permission, to make a few remarks on one or two points in Miss Ogilvie's review of my "Scenery of Switzerland."

With reference to the origin of transverse valleys, she says that I first describe them as due to erosion, and afterwards endeavour to explain them as the result of tectonic causes. I fear, therefore, that I have not made my meaning clear.

Some transverse valleys are no doubt entirely valleys of erosion, but in others the original direction is clearly the result of tectonic causes, though the depth may be due to erosion.

Miss Ogilvie goes on to remark that the idea that both longitudinal and transverse valleys "had their primal cause in tectonic movements, by no means finds its first exponent in Sir John Lubbock. It is perfectly familiar throughout the writings of Austrian and German geologists," and she gently blames me for not referring to them. But I made no such claim. Moreover, I quoted Prof. Bonney's interesting remarks on the fact. My suggested explanation is, however, quite different from that of the authors referred to by Miss Ogilvie. Their view was, in her own words, "that the transverse lines of weakness were planes of movement long after the longitudinal folds had ceased to move." My suggestion is, on the contrary, that transverse and longitudinal folds were simultaneous, and due to the same cause.

There is one other criticism on which I should like to say a few words.

Miss Ogilvie observes that "it is the greatest blemish in Sir John Lubbock's book that he nowhere gives a geological insight into the structure of the Monte Rosa massif of mountains from the Simplon Pass to the St. Bernard."

This difficult district was mapped by Gerlach, who was unfortunately killed by an accident before he had completed the letterpress.

No doubt there are several important memoirs on it, which I have read with interest. I had also the advantage of visiting it with Prof. Renevier and Prof. Golliez, and had, in fact, written several pages on the subject.

Certain of the rocks are, however, of such doubtful age, and there is so much difference of opinion, that the time has not yet, I think, arrived when a "geological insight" into this district can be given with confidence.

Under the circumstances, therefore, while regretting the omission, I thought it better not to make the attempt.

St. Andrews, September 21. JOHN LUBBOCK.

THE LIVERPOOL MEETING OF THE BRITISH ASSOCIATION.

VI.—THE EXCURSION TO THE ISLE OF MAN.

A SCIENTIFIC account of the Isle of Man was given as an appendix to the Liverpool "Handbook." This five days' excursion to the island may almost be regarded as a supplementary meeting of the Association. About a hundred members, representative of the more or less Biological Sections C, D, H, and K, left Liverpool on Thursday morning by the *Prince of Wales*, one of the best boats of the Isle of Man Steam Packet Company, and made a rapid passage to Douglas. There they were met on arrival by His Honour Deemster Gill and other leading members of the Natural History Society, and were conveyed to Government House, where His Excellency Lord Henniker gave a reception to the party. Later in the afternoon the Zoologists and Botanists went by train to their headquarters at Port Erin, while the Geologists and Archæologists settled down at Douglas.

The weather throughout has been rather tempestuous and unsettled, and has interfered to some extent with field work. Probably the Zoologists have suffered more than the other Sections, as they have been prevented from carrying out their proposed dredging expeditions. However the storms which rendered work at sea impossible made the shore-collecting more interesting, as vast quantities of *Laminaria* and others of the larger Algæ were cast up, with many animals attached or clinging to them.

The Zoological party included, in addition to the leaders (Prof. Herdman and Mr. Thompson), Prof. Poulton (Oxford), Dr. Hjort (Christiania), Dr. de Man (Holland), Dr. Gilchrist (Cape Town), and others. Both Zoologists and Botanists made considerable use of the Marine Biological Station at Port Erin for the examination and preservation of their specimens. On the Saturday, the Governor of the Island lunched with the party at Port Erin, and afterwards visited the Biological Station. The Botanists were largely engaged in marine work along with the Zoologists, but they also made several excursions into the glens and hills in search of mosses and other land plants. Amongst the more distinguished Botanists in the party were Profs. Weiss, Magnus, Pfitzer, Zacharias, and Chodat. All of them, as well as the foreign Zoologists, expressed themselves as deeply interested in the rich marine fauna and flora at Port Erin, and several made large collections.

The Archæological party was under the leadership of Mr. P. M. C. Kermode and Prof. Haddon. Their programme was carefully arranged so as to include examples of nearly every object of antiquarian interest in the island, and, being practically independent of weather, was completely carried out.

Prof. Haddon reports as follows on the work of this Section of the party:—"On the first day a visit was paid to the church of Braddan, with its interesting Scandinavian and Celtic crosses; and the obscure alignments were inspected. At the Tynwald Hill, near Peel, Deemster Gill gave an account of the promulgation of the laws; the afternoon was spent at Peel Castle, examining the ruins. On Saturday forenoon the Attorney-General took the party round Rushen Castle and its small but interesting museum of Manx antiquities, and in the afternoon Dr. Herdman's Biological Station was visited, and the unique Neolithic grave circle, explored a few years ago by Kermode and Herdman, was carefully inspected, and the probable age and history were discussed by Dr. Montelius, Dr. Munro, and others. The party went to Ramsey on Monday, and on the way ascended the ancient hill fort of Cronk Sumark. At Ramsey, as elsewhere, local collections were exhibited, and the splendid series of casts of early crosses, got together by the enthusiasm of Mr. P. M. C. Kermode, was greatly appreciated; so much was this the case that, in recognition of his services to the study of archæology in the island and of his untiring energy and good nature as an organiser of the excursion, a number of the members of the party collected a contribution towards the expenses of completing this fine series of Manx crosses. The Archæological party was greatly delighted with all the arrangements that had been made for their comfort, and for the facilities that were offered for seeing the wonderfully interesting archæological remains in Man; while the presence of the distinguished Swedish Archæologist, Dr. Montelius, with his genial courtesy and unrivalled knowledge of prehistoric archæology, added greatly to the enjoyment of the excursion."

The leaders of the Geological party were Prof. Boyd Dawkins and Mr. G. W. Lamplugh, of the Geological Survey. Friday was devoted to the investigation of the southern part of the island, including the carboniferous limestone rocks of the Castletown district, the contemporaneous volcanic series of the Stack of Scarlet, the carboniferous conglomerates of Langness, the striking unconformability at their base, and the underlying Skiddaw series. The following day, Saturday, was spent on the northern portion of the Skiddaw "massif," and included the ascent (by electric railway) of Snaefell; the investigation of the curiously partial metamorphism of the slates on that mountain, and of the sections in Sulby Glen, which reveal the breaking up of the bedding and the production of the "crush-conglomerates" described recently by Lamplugh and Watts. On Monday the centre and west of the island were visited, and the sandstones of disputed age at Peel were examined. Stops were made *en route* at Crosby and Rockmount, to see the igneous rocks of different type intrusive into the Skiddaw series at these places. On the return journey the extensive lead mines at Foxdale were visited, and also the granite boss cropping out in that neighbourhood.

On the last evening of the excursion all the parties—Archæological, Geological, Zoological and Botanical—united in a final banquet at Douglas, when they entertained the Governor (Lord Henniker) and some of the leading officials of the island as guests. The company numbered about 120; Prof. Herdman presided, and amongst the seventeen speakers were—the Governor, the Attorney-General, Deemster Gill, the Mayor of Douglas, Profs. Boyd Dawkins, Poulton, Haddon and Pfitzer, Dr. Montelius and Dr. Munro. One subject specially brought forward in several of the speeches was the urgent need of a good museum of local natural history (in a wide sense) in the Isle of Man, and the suggestion was made that the museum might appropriately be erected as a memorial to the great Manx naturalist Edward Forbes.

The opinion seemed to be very generally expressed that this excursion stood out notably amongst British Association excursions, because of the relatively very large number of recognised investigators and authorities in their own branches of science who took part in it, and because of the solid scientific nature of the programme throughout the five days. And it may confidently be added that this "real work" aspect did not in the least detract from the thoroughly enjoyable character of the gathering. W. A. Herdman.

SIR JOHN ERIC ERICHSEN, BART., F.R.S.

SIR JOHN ERICHSEN, who died after a short illness on September 23, was born in 1818. So vigorous was he until the last in mind and body, that few would have suspected that this genial, kindly, and dignified gentleman had attained to the advanced age of seventy-eight. Essentially a practical surgeon, and devoted heart and soul to the advancement of surgery, he was a man of the widest sympathies, and in no way narrowed or restricted to a groove of professionalism. This may have been due in a measure to the early influence of Sharpey, who appears to have inspired the young surgeon with a keen interest in physiology, for we find his name in 1844 as Secretary to the Physiological Section of the British Association. He was also appointed about the same time to conduct an experimental investigation into the phenomena of asphyxia, which resulted in an important essay upon this subject, for which he received the Fothergillian medal of the Royal Humane Society. The claims of his profession soon, however, prevented Erichsen from further development in the direction of physiological science, and required his entire attention to be devoted to surgery. For already in 1850 he was appointed as the successor of Liston, Syme and Arnott, to the chair of Surgery in University College, and subsequently to the chair of Clinical Surgery; and one of these posts he continued to occupy during a quarter of a century. This was a brilliant period for operative surgery, although its brilliancy has been completely eclipsed in the quarter of a century which has succeeded it by the development of the Listerian method. Sir Joseph Lister was himself at one time house surgeon to Erichsen, and is one only, although no doubt the most distinguished, of many eminent surgeons who have left and are leaving their mark upon the scientific progress of their profession, and who owe much for their training to Sharpey and Erichsen.

Erichsen's "Science and Art of Surgery" is a classical work which appeared in 1853, and at once established the already won reputation of its author as one of the first surgeons of the day. It has run through many editions and been translated into most European languages, and, under the editorship of the late Marcus Beck and of Mr. Raymond Johnson, it is still in 1896 regarded as the best exposition of general surgery that we possess. Than this book no better proof could be forthcoming of the remarkable literary, scientific, and surgical attainments of its distinguished author!

Erichsen became President of the Royal Medical and Chirurgical Society in 1879, and of the Royal College of Surgeons in 1880, and in 1881 he was chosen to preside over the Surgical Section of the meeting of the International Medical Congress in London. He served on the Royal Commission on Vivisection, and was the first Inspector for England under the Act which resulted from the report of that Commission. In 1885 he stood for Parliament, on the Liberal side, for the Universities of Edinburgh and St. Andrews, but was unsuccessful. In 1887 his *alma mater* elected him President of its Council, an honourable post in which he was the successor of Brougham, Grote, Belper and Kimberley, and which he held until his death. The tact and urbanity which he displayed, and the quiet dignity with which he presided over its meetings, and over public meetings at University College during his presidentship, will be remembered by all who have taken part in them of late years. In 1895 he was, somewhat tardily, created a Baronet, at the same time as his life-long friend Russell Reynolds, whom he has only survived a few months. Within so short a time of his death it is not easy to speak calmly of the esteem and affection with which Sir John Erichsen was regarded by all who came under his influence. He was the most judicious of advisers, honourable and straightforward in all his dealings: a thorough gentleman. One of the most pleasing traits in his character was his uniform readiness to assist and encourage younger men in their pursuit of knowledge and in the practice of their profession. Needless to say that he was popular; it would have been difficult for the most cantankerous of mortals to remain unsubdued by his uniform kindness and generosity. Erichsen's death leaves a gap which it will be difficult to fill, and a reputation such as any man may envy. E. A. Schäfer.

NOTES.

THE Council of the British Medical Association are prepared to receive applications for one of the three Research Scholarships which is vacant, of the value of £150 per annum, tenable for one year, and subject to renewal by the Council for another year. Applications should be sent to the General Secretary on or before Saturday, October 10, stating the particulars of the intended research, qualifications, and work done.

FOLLOWING the usual custom, the winter session was commenced on Thursday last, in many of the medical schools in London and the provinces, by the delivery of addresses to the students. At Middlesex Hospital, Dr. W. Essex Wynter alluded to the rapid multiplication of books in modern times, and to the tendency that existed to go to them for information which should be gained at first hand, by direct observation. He described ideas gained from mere verbal accounts as artificial and spurious, and suggested that books should be used to complete and coordinate knowledge previously obtained by practical work. Prof. Sidney Martin inspired the students at University College Medical School with the spirit of investigation by giving a sketch of the advantages which medicine has obtained from the study of bacteriology. He pointed out that development of the experimental method has greatly aided the progress of medical science, and has been the means of improving the treatment of disease. It cannot be too strongly stated that the more that is known of the prime causes of disease, the more is it likely that measures will be discovered to prevent or counteract them. Mr. Morton Smale, at St. Mary's Hospital, dealt largely with quack medicines; and Mr. W. Adams Frost, at St. George's Hospital, discoursed chiefly upon medicine as a career. In the course of his address he referred to the appointment of the Royal Commission on vaccination, and said that, to people knowing the facts, it seemed about as reasonable to appoint a Commission to inquire into the truth of the law of gravitation. The introductory address at Westminster Hospital was given by Dr. Wills, who took for his subject medical practice and practitioners as depicted in the literature of the last two centuries. Mr. Boyce Barrow discoursed upon some of the endowments of the human body, at the London School of Medicine for Women; Sir Henry Littlejohn addressed the students at Sheffield Medical School, on the advantages of a provincial medical school; while Mr. Victor Horsley urged upon the students at the Leeds Medical School the fundamental importance of chemistry in medicine work in all its stages, and discussed matters of medical education, ethics, and politics. Mr. Jonathan Hutchinson delivered the introductory address at Owens College, Manchester, where he pleaded for a wide scope in medical education, and urged the reformation of the examinational system. These and many more were the points dwelt upon at the various medical schools; and if the students pay regard to but a tithe of the advice given them, a high standard of professional ethics will be secured, and future practitioners will abundantly add to the knowledge of the causes of disease and the means of prevention.

WE regret to record the death of Mr. W. C. Winlock, known for his contributions to astronomy. Mr. Winlock was assistant in charge of the office of the Smithsonian Institution. The death is also announced of Dr. J. P. E. Liesgang, a voluminous writer on photographic matters, and the founder of the *Photographische Archiv*; and of Dr. J. A. Moloney, who took a prominent part in the Stairs expedition to Katanga.

LORD SELBORNE took the chair at a meeting, held on Tuesday, to discuss the establishment of an International Submarine Telegraph Memorial. It is proposed to connect the memorial especially with the names of Mr. Cyrus Field, Sir John Pender, and Sir James Anderson. An executive committee was appointed to consider the form which the memorial shall take.

THE South African Museum has recently received a fine mounted specimen of the white or square-mouthed Rhinoceros (*Rhinoceros simus*) which was shot in the Mazoc district of Mashonaland, in June last year, by Mr. A. Eyre. The skin and skeleton were purchased by Mr. C. J. Rhodes, and, after having been sent to England to be set up, were presented by him to the South African Museum.

THE motor-car race from Paris to Marseilles and back, a total distance of 1051 miles, was finished on Saturday last. Twenty-seven of the vehicles which started from Paris on Thursday, September 24, were petroleum carriages, and five were tricycles driven by petroleum motors. There were also four steam carriages. The race was organised by the Automobile Club of France, and was intended entirely as a test of speed. On each day of the ten days the times occupied by the carriages in covering the several stages have been taken, and the winner is the car which travelled the whole distance in the least time. Details of the race have not yet come to hand, but owing to bad roads and obstructions by trees and telegraph-poles blown down by the gale which prevailed early in the contest, the journey was not accomplished under the best conditions.

THE first number has been issued, on September 1, of a new natural history periodical, *Il Naturalista Siciliano*, the organ of the newly-formed Society of Sicilian Naturalists, of which Prof. E. Ragusa is the president, and Sig. T. De Stefani the secretary. The Society is intended to meet monthly in Palermo, and once a year in some other city of Sicily. The first number contains articles, in Italian and in French, on Entomology, Malacology, Botany, and Crustacea. The proposed biological station at Palermo, mentioned in our last number, will be under the management of the Society.

AN interesting note on the influence of the male parent in crossing varieties of carnations, appears in the current number (August) of the *Journal* of the Royal Horticultural Society. Evidence in favour of this prepotency is afforded by experiments, carried out by Mr. Martin Smith, on the fertilisation of "Germania." This is a flower of strong individuality, yet, says Mr. Smith, "Germania (yellow) is swamped by the prepotency of the pollen parent in the great majority of cases. I hardly ever get a yellow worth having; but when I do I find them, as a rule, pure reproductions on a most feeble scale of the mother; and I always regard them as products of Germania fertilised by pollen of flowers on the same plant, or from one in the immediate vicinity." On the other hand, when the pollen of Germania was used to fertilise other plants, extremely few yellow flowers resulted from the cross. It seems to be easy enough in a cross for other colours to overcome yellow, but difficult for yellow to be masterful. Mr. Smith adds the interesting fact that when he crossed violent contrasts of colour, such as purple and yellow, or scarlet and yellow, a large proportion of white flowers appeared among the offspring.

BY common agreement the wasp is accepted as emblematical of irritability and petty malignity; but even this much-abused hymenopterous insect plays a beneficial part in the work of nature, as a note in the *Irish Naturalist* testifies. A number of wasps were seen by Mr. R. M. Barrington, of Bray, buzzing about his cows. Closer inspection revealed that they were all busy catching flies, and pouncing with the rapidity of hawks after birds on the flies as they tried to settle or rest on some favourite part of the cow. One white cow drew more wasps than any of the others, because the moment a fly alighted it was seen at once against the skin. When a wasp catches a fly it immediately bites off both wings, sometimes a leg or two, and occasionally the head. Mr. Barrington saw some of the wasps when laden with one fly catch another, without letting go the first, and then fly away with both. There was a constant stream of wasps carrying away flies, probably to feed the larvæ in their nests, and returning again to the cows to catch more. In about twenty minutes Mr. Barrington estimated that between 300 and 400 flies were caught on two cows lying close to where he stood. Perhaps this narrative of good deeds accomplished will lead people to think more leniently of the vices of the wasp.

"ÜBER LUMINESCENZ" is the title of a small pamphlet of 60 pages (Univ. Buchdruckerei von Fr. Junge, Erlangen, 1896), which we have received from the author, Dr. Wilhelm Arnold. In its pages will be found the results of the investigation which the author has carried out with regard to luminescence phenomena, and this may be said to be continuous with the works done by Herren E. Wiedemann and G. C. Schmidt. Dr. Arnold has examined several inorganic bodies, solutions, and organic substances with regard to their different powers of luminescence, and has found a new series of bodies exhibiting this peculiarity excellently. The apparatus used for exciting the substances by means of the kathode rays was similar to that employed by the above-mentioned experimenters. While engaged in this work, Prof. Röntgen's discovery of the X-rays suggested to the author to make investigations on the behaviour of these rays on "feste Lösungen." These results are also brought together, and they deal, further, with the transparency of different substances to these rays, their power over bacteria, and the sensitiveness of the photographic plate. All those at work on this branch of physics will find this pamphlet an earnest endeavour to advance our knowledge in this particular direction; and its value is further increased by the numerous references which the author has inserted in the form of foot-notes.

FROM the St. Petersburg Municipal Laboratory comes an alarming report, by M. M. P. Sacharbekoff, of the milk supplied to the city. Dr. Bitter has endeavoured to establish a microbial standard for milk, by which the bacterial contents of a so-called good sample of milk are limited to 50,000 per cubic centimetre. If this standard is to be accepted, then it is time St. Petersburg looked into its milk supply, for M. Sacharbekoff finds that the maximum microbial contents in a cubic centimetre of its milk reaches no less than 115,300,000! For the sake of comparison the milk microbial maximum of other cities is cited, amongst which we find Munich figuring with 4,000,000 per c.c., Würzburg with 7,535,000, whilst Giessen even surpasses St. Petersburg with a maximum of 169,632,000. The samples of milk were also tested by means of direct inoculation into animals for the presence of pathogenic bacteria. No less than eighty guinea-pigs were used in these inoculations, out of which four succumbed to the tubercle bacillus, three to the staphylococcus *Pyogenes aureus*, two to *B. coli communis*, and five to other pathogenic microbes. But, besides these bacteria, various saprophytes were isolated out, which it was found were able to elaborate in the milk toxic products of a highly deleterious character. The high rate of mortality from diarrhœa, which prevails amongst young children in St. Petersburg up to five years of age, and which amounts to no less than 43 per cent., is, the writer considers, to a large extent attributable to the impure milk supplied to the city. The worst samples were obtained from the milk-women who buy the milk second-hand, and distribute it to their customers. M. Sacharbekoff ends his report by drawing up a number of suggestions, amongst which is advocated a closer control over the milk supply by competent sanitary authorities.

SOME of the results which the Norwegian traveller Sven Hedin has obtained in his journeys to the northern part of the Kwenlung mountains, and towards the east of the town of Khotan, are summed up in *Globus* (Band lxx., No. 13). It seems that between Kerija and Shahyar, Sven Hedin found the ruins of large towns which had been buried in sand, and his calculations suggest that they were entombed by successive sandstorms about 1000 years ago. The discoveries he made were, considering the difficulties to be contended with, extensive. One of the towns he found was over four kilometres long, and consisted of a great number of house ruins; the separate houses were not built of stone, but constructed of wooden pillars, and the walls consisted of plaited reeds covered with mud. These latter were coated with white plaster, on which were painted human figures, horses, dogs and flowers. Small figures, 10–20 cm. high, representing Budda, were also discovered, besides numerous poplars, apricot and plum trees, which once flourished there when the towns were watered by the canal from the river Kerija. It is suggested that the culture of the inhabitants must have been very considerable, for the copies of the drawings on the walls brought back by Sven Hedin show indications of good execution.

THE *Journal of Botany* gives an interesting account of Herr R. Schlechter's botanical explorations in South Africa, which have been much impeded by the drought. He has collected about 1200 species, of which he estimates at least one-tenth to be new.

ANOTHER of the useful "Hand-lists" issued from the Royal Gardens, Kew, has just been received. It is Part ii. of the list devoted to trees and shrubs grown in the Arboretum, and comprises *Gamopetalæ* to *Monocotyledons*.

A NEW edition (the fourth) of "The Microtomist's Vade Mecum," by Mr. A. B. Lee, has been published by Messrs. J. and A. Churchill. The work is a handbook of the methods of microscopic anatomy, and it constitutes a most complete account of the operations of histological technique. To all who are engaged in histological studies the volume is invaluable.

THE Society for the Protection of Birds is very enthusiastic in the prosecution of the good work it was founded to perform, and has already met with much encouragement in its labours. Its latest, but by no means least important, development is the commencement of a series of leaflets, entitled the "Educational Series," under the editorship of Mr. H. E. Dresser, which aims at supplying to the public, in a not too technical form, authoritative information respecting the seven following points:—Name [of bird], general description, where, when and in what numbers found, food, characteristics, protection, and remarks. The pioneers of the series are "Owls," by Mr. Montagu Sharpe, and "Woodpeckers," by Sir Herbert Maxwell, Bart. We wish for the publications and their successors a very wide circulation, as we feel sure their perusal will remove from the minds of many farmers, gamekeepers, and others, a great deal of misapprehension at present lurking there.

THE additions to the Zoological Society's Gardens during the past week include a Pig-tailed Monkey (*Macacus nemestrinus*) from Java, a Bonnet Monkey (*Macacus sinicus*) from India, presented by Mr. Edward Good; a Patas Monkey (*Cercopithecus patas*) from West Africa, presented by Mr. W. S. Gilbert; a Red-fronted Lemur (*Lemur rufifrons*) from Madagascar, a Serval (*Felis serval*), two Side-striped Jackals (*Canis lateralis*), a Pale Genet (*Genetta senegalensis*), a Vociferous Sea Eagle (*Haliætus vocifer*), a —— Hawk (*Accipiter* sp.?) from British Central Africa, presented by Sir Harry Johnston, K.C.B.; a Black Francolin (*Francolinus vulgaris*) from the Syrian Coast, presented by Admiral Sir M. Culme-Seymour, Bart., K.C.B.; a Kite (*Milvus ictinus*), British, presented by Mr. E. A. Wilson; a Hedgehog (*Erinaceus* sp. ?) from the Erkomit Hills, Eastern Soudan, presented by Mr. J. U. Coxen; a King Parrakeet (*Aprosmictus scapulatus*) from Australia, presented by Mrs. Lyons; three Chameleons (*Chamæleon vulgaris*) from North Africa, presented by Mr. E. Palmer; two Moorish Tortoises (*Testudo mauritanica*) from North Africa, presented by Mr. A. J. Aitchinson; two Black Tortoises (*Testudo carbonaria*) from Granada, W.I., presented by Mr. Thomas Ottway; seven Pratincoles (*Glareola pratincola*), European, deposited; a Levaillant's Amazon (*Chrysotis levaillanti*) from Mexico, a Yarrell's Curassow (*Crax carunculata*) from South-east Brazil, a long-tailed Glossy Starling (*Lamptornis æneus*) from West Africa, purchased; an Asiatic Wild Ass (*Equus onager*), a Great Kangaroo (*Macropus giganteus*), born in the Gardens.

OUR ASTRONOMICAL COLUMN.

COMET GIACOBINI.—Our previous ephemeris of this comet was inclusive up to October 1. A Centralstelle Circular gives us a continuation of this ephemeris, based on new elements (September 5, 8, 11) calculated by Dr. H. Kreutz.

1896.		R.A. h. m. s.	Decl. ° ′	log Δ	B.
Oct. ... 5·5	...	18 22 35	−12 2·5	0·1651	0 9
9·5	...	33 42	12 28·5	0·1706	0·9
13·5	...	45 8	12 51·4	0·1764	0·9
17·5	...	56 51	13 10·9	0·1826	0·9

COMET SPERRA.—With regard to the comet, information about which was communicated by a Science Observer Special Circular (No. 113), a Kiel Circular gives us an ephemeris which Prof. Lamp has calculated from new elements based on observations on September 6, 10, 13. Mr. Sperra describes this comet, as he observed it on August 31, as a nebulous object west of Zeta Ursa Major, an interval of an hour and a quarter showing distinct motion. Mr. Brooks, who had had notice of this discovery on September 4, also found the comet. Various new observed positions are given in *Astronomischen Nachrichten* (No. 3379) by several observers.

Prof. Lamp's ephemeris is given below:—

1896.		R.A. h. m. s.		Decl. ° ′		log Δ		B.
Oct. 6·5	...	16 53 22	...	+43 59·6	...	0·2478	..	0·6
10·5	..	17 11 36	...	41 44·7	...	0·2569	...	0 6
14·5	...	17 28 24		39 29 0	...	0·2671	...	0·5
18·5	...	17 43 56	...	37 14 9	...	0·2785	...	0·5

PROF. LUDWIG PHILIPP V. SEIDEL.—The current number of *Astronomischen Nachrichten* contains a short obituary notice, by Prof. Seeliger, of Prof. v. Seidel, who died recently in Munich, after a long illness. He was born in the year 1821 at Zweibrücken, and studied in the universities of Königsberg, Berlin, and Göttingen, in which he attended the lectures of Bessel, Jacobi, Dirichlet and Gauss, with the two former of whom he became intimately acquainted. Seidel's scientific work was not only restricted to pure mathematics, but also to astronomy. In the former, his researches are well known, and of great importance is his "Note über eine Eigenschaft der Reihen, welche discontinuirliche Functionen darstellen," which contains a beautiful and important conception of regular and irregular convergence in the theory of series. He took no small part in Jacobi's well-known work on the secular perturbations of the major planets, in which he undertook the computations of extensive numerical results. Jacobi's proposal of obtaining by successive approximations the numerical solution of a system of normal equations of several unknowns, was further worked out in detail and extended by Seidel himself. No less interesting are the optical works Seidel completed in conjunction with Herrn C. A. Steinheil; among these may be mentioned his numerous dioptical investigations, which marked a distinct progress in this direction. These and other researches were of great importance in connection with Steinheil's photometric investigations.

THE BRITISH ASSOCIATION.

SECTION I.

PHYSIOLOGY.

OPENING ADDRESS BY W. H. GASKELL, M.D., LL.D., F.R.S., PRESIDENT OF THE SECTION.

WHEN I received the honour of an invitation to preside at the Physiological Section of the British Association, my thoughts naturally turned to the subject of the Presidential Address, and it seemed to me that the traditions of the British Association, as well as the fact that a Physiological Section was a comparatively new thing, both pointed to the choice of a subject of general biological interest rather than a special physiological topic; and I was the more encouraged to choose such a subject because I look upon the growing separation of physiology from morphology as a serious evil, and detrimental to both scientific subjects. I was further encouraged to do so by the thought that, after all, a large amount of the work done in physiological laboratories is anatomical—either minute anatomy or topographical anatomy, such as the tracing out of the course of nerve-fibre tracts in the central and peripheral nervous system by physiological methods. Such methods require to be supplemented by the morphological method of inquiry. If we can trace up step by step the increasing complexity of the vertebrate central nervous system; if we can unravel its complex nature, and determine the original simpler paths of its conducting fibres, and the original constitution of the special nerve centres, then it is clear that the method of comparative anatomy would be of immense assistance to the study of the physiology of the central nervous system of the higher vertebrates. So also with numbers of other physiological problems, such as, for instance, the question whether all muscular substances are supplied with inhibitory as well as motor nerves; to which is closely allied the question of the nature of the mechanism by which antagonistic muscles work harmoniously together. Such questions receive their explanation in the researches of Biedermann on the nerves of the opening and closing muscles of the claw of the crayfish, as soon as it has been shown that a genetic relationship exists between the nervous system and muscles of the crayfish and those of the vertebrate.

Take another question of great interest in the present day, viz. the function of such ductless glands as the thyroid and the pituitary glands. The explanation of such function must depend upon the original function of these glands, and cannot, therefore, be satisfactory until it has been shown by the study of comparative anatomy how these glands have arisen. The nature of the leucocytes of the blood and lymph spaces, the chemical problems involved in the assigning of cartilage into its proper group of mucin compounds, and a number of other questions of physiological chemistry, will all advance a step nearer solution as soon as we definitely know from what group of invertebrates the vertebrate has arisen.

I have therefore determined to choose as the subject of my address "The Origin of Vertebrates," feeling sure that the evidence which has appealed to me as a physiologist will be of interest to the Physiological Section; while at the same time, as I have invited also the Sections of Zoology and Anthropology to be present, I request that this address may be considered as opening a discussion on the subject of the origin of vertebrates. I do not desire to speak *ex cathedrâ*, and to suppress discussion, but, on the contrary, I desire to have the matter threshed out to its uttermost limit, so that if I am labouring under a delusion the nature of that delusion may be clearly pointed out to me.

The central pivot on which the whole of my theory turns is the central nervous system, especially the brain region. There is the *ego* of each animal; there is the master-organ, to which all the other parts of the body are subservient. It is to my mind inconceivable to imagine any upward evolution to be associated with a degradation of the brain portion of the nervous system. The striking factor of the ascent within the vertebrate phylum from the lowest fish to man is the steady increase of the size of the central nervous system, especially of the brain region. However much other parts may suffer change or degradation, the brain remains intact, steadily increasing in power and complexity. If we turn to the invertebrate kingdom, we find the same necessary law: when the metamorphosis of an insect takes place, when the larval organs are broken up by a process of histolysis, and new ones formed, the central nervous system remains essentially intact, and the brain of the imago differs from that of the larva only in its increased growth and complexity.

A striking instance of the same necessary law is seen in the case of the transformation of the larval lamprey, or Ammocœtes, into the adult lamprey, or Petromyzon; here also, by a process of histolysis, most of the organs of the head region of the animal undergo dissolution and re-formation, while the brain remains intact, increasing in size by the addition of new elements, without any sign of preliminary dissolution. On the other hand, when, as is the case in the Tunicates, the transformation process is accompanied with a degradation of the central nervous system, we find the adult animal so hopelessly degraded that it is impossible to imagine any upward evolution from such a type.

It is to my mind perfectly clear that, in searching among the Invertebrata for the immediate ancestor of the Vertebrata, the most important condition which such ancestor must fulfil is to possess a central nervous system, the anterior part of which is closely comparable with the brain region of the lowest vertebrate. It is also clear on every principle of evolution that such hypothetical ancestor must resemble the lowest vertebrate much more closely than any of the higher vertebrates, and therefore a complete study of the lowest true vertebrate must give the best chance of discovering the homologous parts of the vertebrate and the invertebrate. For this purpose I have chosen for study the Ammocœtes, or larval form of the lamprey, rather than Amphioxus or the Tunicates, for several reasons.

In the first place, all the different organs and parts of the higher vertebrates can be traced directly into the corresponding parts of Petromyzon, and therefore of Ammocœtes. Thus, every part of the brain and organs of special sense—all the cranial nerves, the cranial skeleton, the muscular system, &c., of the higher vertebrates can all be traced directly into the corresponding parts of the lamprey. So direct a comparison cannot be made in the case of Amphioxus or the Tunicates.

Secondly, Petromyzon, together with its larval form, Ammocœtes, constitutes an ideal animal for the tracing of the vertebrate ancestry, in that in Ammocœtes we have the most favourable condition for such investigations, viz. a prolonged larval stage, followed by a metamorphosis, and the consequent production of the imago or Petromyzon—a transformation which does not, as in the case of the Tunicates, lead to a degenerate condition, but, on the contrary, leads to an animal of a distinctly higher vertebrate type than the Ammocœtes form. As we shall see, the Ammocœtes is so full of invertebrate characteristics that we can compare organ for organ, structure for structure, with the corresponding parts of Limulus and its allies. Then comes that marvellous transformation scene during which, by a process of histolysis, almost all the invertebrate characteristics are destroyed or changed, and there emerges a higher animal, the Petromyzon, which can now be compared organ for organ, structure for structure, with the larval form of the Amphibian; and so through the medium of these larval forms we can trace upwards without a break the evolution of the vertebrate from the ancient king-crab form. On the other hand, Amphioxus and the Tunicates are distinctly degenerate; it is easier to look upon either of them as a degenerate Ammocœte than as giving a clue to the ancestor of the Ammocœte. It is to my mind surprising how difficult it appears to be to get rid of preconceived opinions, for one still hears, in the assertion that Petromyzon as well as Amphioxus is degenerate, the echoes of the ancient myth that the Elasmobranchs are the lowest fishes, and the Cyclostomata their degenerated descendants.

The characteristic of the vertebrate central nervous system is its tubular character: and it is this very fact of its formation as a tube which has led to the disguising of its segmental character, and to the whole difficulty of connecting vertebrates with other groups of animals. The explanation of the tubular character of the central nervous system is the keystone to the whole of my theory of the origin of vertebrates. The explanation which I have given differs from all others, in that I consider the nervous system to be composed of two parts—an internal epithelial tube, surrounded to a greater or less extent by a segmented nervous system; and I explain the existence of these two parts by the hypothesis that the internal epithelial tube was originally the alimentary canal of an arthropod animal, such as Limulus or Eurypterus, which has become surrounded to a greater or less extent by the nervous system.

Any hypothesis which deals with the origin of one group of animals from another must satisfy three conditions:—

(1) It must be in accordance with the phylogenetic history of each group. It must therefore give a consistent explanation of all the organs and tissues of the higher group which can be clearly shown not to have originated within the group itself. At the same time, the variations which have occurred on the hypothesis must be in harmony with the direction of variation in the lower group, if not actually foreshadowed in that group.

This condition may be called the Phylogenetic test.

(2) The anatomical relation of parts must be the same in the two groups, not only with respect to coincidence of topographical arrangement, but also with respect to similarity of structure, and, to a large extent, also of function.

This condition may be called the Anatomical test.

(3) The peculiarities of the ontogeny or embryological development of the higher group must receive an adequate explanation by means of the hypothesis, while at the same time they must help to illustrate the truth of the hypothesis.

This condition may be called the Ontogenetic test.

I hope to convince you that all these three conditions are satisfied by my hypothesis as far as the head region of the vertebrate is concerned. I speak only of the head region at present, because that is the part which I have especially studied up to the present time, and also because it is natural and convenient to consider the cranial and spinal nerves separately; and I hope to demonstrate to you that not only the nervous system and alimentary canal of such a group of animals as the Gigantostraca—*i.e.* Limulus and its allied forms—is to be found in the head region of Ammocœtes, but also, as must logically follow, that every part of the head region of Ammocœtes has its homologous part in the prosomatic and mesosomatic regions of Limulus and its allies. I hope to convince you that our brain is hollow because it has grown round the old cephalic stomach; that our skeleton arose from the modifications of chitinous ingrowths; that the nerves of the medulla oblongata—*i.e.* the facial, glosso-pharyngeal, and vagus nerves—arose from the mesosomatic nerves to the branchial and opercular appendages of Limulus, while the nerves of the hind brain are derived from the nerves of the prosomatic region of Limulus; that our cerebral hemispheres are but modifications of the supra-œsophageal ganglia of a scorpion, while our eyes and nose are the direct descendants of its eyes and olfactory organs.

In the first place, I will give you shortly the reasons why the central nervous system of the vertebrate must be considered as derived from the conjoined central nervous system and alimentary canal of an arthropod.

Comparison of the Central Nervous System of Ammocœtes with the Conjoined Central Nervous System and Alimentary Canal of an Arthropod Animal such as Limulus.

1. *The phylogenetic test* proves that the tube of the central nervous system was originally an epithelial tube, surrounded to a certain extent by nervous material.

The anatomical test then proves that this epithelial tube corresponds in its topographical relations to the nervous material exactly with the alimentary canal of an arthropod in its relations to the central nervous system; and, further, that the topographical relations, structure, and function of the corresponding parts of this nervous material are identical in the Ammocœtes and in the arthropod.

We see from these diagrams, taken from Edinger, how the greater simplicity of the brain region as we descend the vertebrate phylum is attained by the reduction of the nervous material more and more to the ventral side of the central tube, with the result that the dorsal side becomes more and more epithelial, until at last, as is seen in Ammocœtes, the roof of the epichordal portion of the brain consists entirely of fold upon fold of a simple epithelial membrane, interrupted only in one place by the crossing of the IVth nerve and commencement of the cerebellum. In the prechordal part of the brain this simple epithelial portion of the tube is continued on in the middle line as the first choroid plexus of Ahlborn, and the lamina terminalis round to the ventral side; where, again, in the infundibular region, the epithelial saccus vasculosus, which has been becoming more and more conspicuous in the lower vertebrates, together with the median tube of the infundibulum, testifies to the withdrawal of the nervous material from this part of the brain, as well as from the dorsal region. Further, as already mentioned in my previous papers, the invasion of this epithelial tube by nervous material during the upward development of the vertebrate is beautifully shown by the commencing development of the cerebellar hemispheres in the dogfish; by the dorsal growth of nervous material to form the optic lobes in the Petromyzon; by the occlusion of the ventral part of the tube in the epichordal region to form the raphé, as seen in its commencement in Ammocœtes. Finally, evidence of another kind in favour of the tubular formation being

system of the vertebrate originally consisted of two parts—viz. an epithelial tube and a nervous system outside that tube, which has grown over it more and more, and gives not only no support whatever, but is in direct opposition, to the view that the whole tube was originally nervous, and that the epithelial portions, such

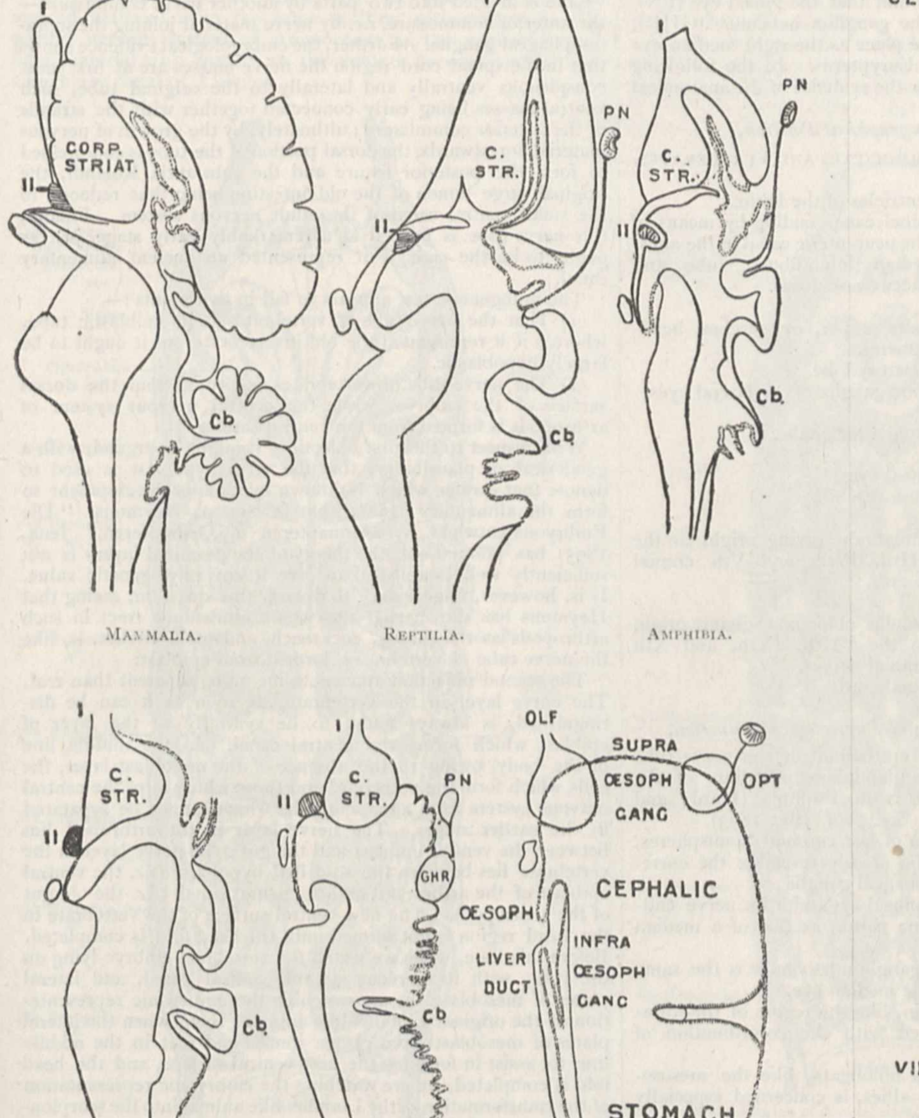


FIG. 1.—Comparison of Vertebrate Brain from Mammalia to Ammocœtes. (Epithelial parts represented by dotted lines.)

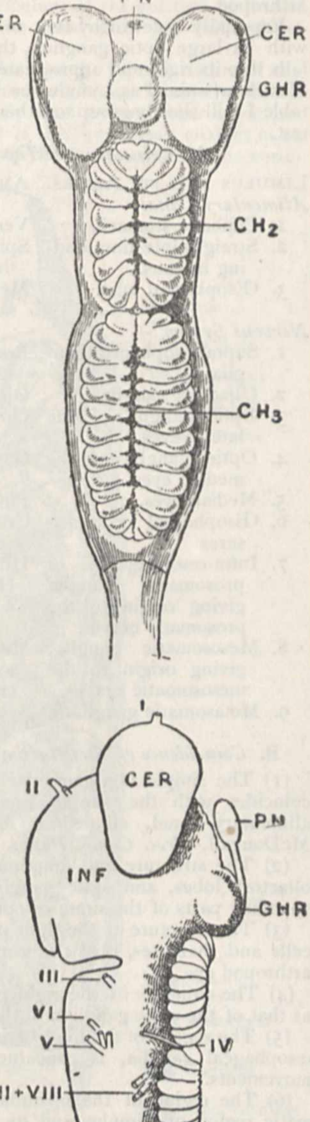


FIG. 2.—Dorsal and lateral view of the Brain of Ammocœtes.

due to an original non-nervous epithelial tube, is given by the frequent occurrence of cystic tumours, and also by the formation of the sinus rhomboidalis in birds.

The phylogenetic history of the brain of vertebrates, in fact, is in complete harmony with the theory that the tubular nervous

as the choroid plexuses and roof of the fourth ventricle, are thinned-down portions of that nerve tube. Passing now to

2. *The anatomical test*, we see immediately why this epithelial tube comes out so much more prominently in the lowest vertebrates, for, as can be seen from the diagrams, and is more fully

pointed out in my previous papers,[1] every part of the central tube of the vertebrate nervous system corresponds absolutely, both in position and structure, with the corresponding part of the alimentary canal of the arthropod, and the nervous material which is arranged round this epithelial tube is identically the same in topographical position, in structure, and in function as the corresponding parts of the central nervous system of an arthropod.

Especially noteworthy is it to find that the pineal eye (PN), with its large optic ganglion, the ganglion habenulæ (GHR), falls into its right and appropriate place as the right median eye of such an animal as Limulus or Eurypterus. In the following table I will shortly group together the evidence of the anatomical test.

A. *Coincidence of Topographical Position.*

LIMULUS AND ITS ALLIES.	AMMOCŒTES AND VERTEBRATES.
Alimentary Canal:—	
1. Cephalic stomach.	Ventricles of the brain.
2. Straight intestine, ending in anus.	Spinal canal, ending by means of the neurenteric canal in the anus
3. Œsophageal tube.	Median infundibular tube and saccus vasculosus.
Nervous System:—	
1. Supra-œsophageal ganglia.	Brain proper, or cerebral hemispheres.
2. Olfactory ganglia.	Olfactory lobe.
3. Optic ganglia of the lateral eyes.	Optic ganglia of the lateral eyes.
4. Optic ganglia of the median eyes.	Ganglia habenulæ.
5. Median eyes.	Pineal eyes.
6. Œsophageal commissures	Crura cerebri.
7. Infra-œsophageal or prosomatic ganglia giving origin to the prosomatic nerves.	Hind brain, giving origin to the IIIrd, IVth, and Vth cranial nerves.
8. Mesosomatic ganglia, giving origin to the mesosomatic nerves.	Medulla oblongata, giving origin to the VIIth, IXth, and Xth cranial nerves.
9. Metasomatic ganglia.	Spinal cord.

B. *Coincidence of Structure and Physiological Function.*

(1) The simple non-glandular epithelium of the nerve tube coincides with the simple non-glandular epithelium of the alimentary canal, ciliated as it is in Daphnia (Hardy and McDougall, *Proc. Camb. Philos. Soc.*, vol. viii., 1893).

(2) The structure and function of the cerebral hemispheres, olfactory lobes, and optic ganglia closely resemble the corresponding parts of the supra-œsophageal ganglia.

(3) The structure of the right pineal eye, with its nerve end-cells and rhabdites, is of the same nature as that of a median arthropod eye.

(4) The structure of the right ganglion habenulæ is the same as that of the optic ganglion of the median eye.

(5) The region of the hind brain, like the region of the infra-œsophageal ganglia, is concerned with the co-ordination of movements.

(6) The region of the medulla oblongata, like the mesosomatic region of Limulus and its allies, is concerned especially with the movements of respiration.

(7) The centres for the segmental cranial nerves resemble closely in their groups of motor cells and plexus substance the centres for the prosomatic and mesosomatic nerves, with their groups of motor cells and reticulated substance (Punkt-Substanz).

3. *The third test is the ontogenetic test.* The theory must be in harmony with, and be illustrated by, the embryonic development of the central nervous system. Such is the case, for we see that the nerve tube arises as a simple straight tube opening by the neurenteric canal into the anus, the anterior part of the tube, *i.e.* the cephalic stomach region, being remarkably dilated; the anterior opening of this tube, or anterior neuropore, is considered by most authors to have been situated in the infundibular region.

Next comes the formation of the cerebral vesicles, indicating embryologically the constricting growth of nervous material outside the cephalic stomach. First, the formation of two cerebral vesicles by the growth of nervous material in the position of the ganglia habenulæ, posterior commissure, and Meynert's bundle, *i.e.* the constricting influence of commissures between the optic part of the supra-œsophageal ganglia and the infra-œsophageal ganglia; then the formation of the third cerebral vesicle by the constricting influence of the IVth nerve and commencing cerebellum. Subsequently the first cerebral vesicle is divided into two parts by another nerve commissure—the anterior commissure, *i.e.* by nerve material joining the supra-œsophageal ganglia. Further, the embryological evidence shows that in the spinal cord region the nerve masses are at first most conspicuous ventrally and laterally to the original tube, such ventral masses being early connected together with the strands of the anterior commissure; ultimately, by the growth of nervous material dorsalwards, the dorsal portion of the tube is compressed to form the posterior fissure and the substantia Rolandi, the original large lumen of the old intestine being thus reduced to the small central canal of the adult nervous system. Finally, this nerve tube is formed at a remarkably early stage, just as ought to be the case if it represented an ancient alimentary canal.

The ontogenetic test appears to fail in two points:—

(1) That the nerve tube of vertebrates is an epiblastic tube, whereas if it represented the old invertebrate gut it ought to be largely hypoblastic.

(2) The nerve tube of vertebrates is formed from the dorsal surface of the embryo, while the central nervous system of arthropods is formed from the ventral surface.

With respect to the first objection, it might be argued, with a good deal of plausibility, that the term hypoblast is used to denote that surface which is known by its later development to form the alimentary canal; that in fact, as Heymons ("Die Embryonalentwickl. v. Dermapteren u. Orthopteren," Jena, 1895) has pointed out, the theory of the germinal layers is not sufficiently well established to give it any phylogenetic value. It is, however, unnecessary to discuss this question, seeing that Heymons has shown that the whole alimentary tract in such arthropods as the earwig, cockroach, and mole cricket, is, like the nerve tube of vertebrates, formed from epiblast.

The second objection appears to me more apparent than real. The nerve layer in the vertebrate, as soon as it can be distinguished, is always found to lie ventrally to the layer of epiblast which forms the central canal. In the middle line of the body, owing to the absence of the mesoblast layer, the cells which form the notochord and those which form the central nervous system form a mass of cells which cannot be separated in the earlier stages. The nerve layer in the arthropod lies between the ventral epiblast and the gut; the nerve layer in the vertebrate lies between the so-called hypoblast (*i.e.* the ventral epiblast of the arthropod) and the neural canal (*i.e.* the old gut of the arthropod). The new ventral surface of the vertebrate in the head region is not formed until the head fold is completed. Before this time, when we watch the vertebrate embryo lying on the yolk, with its nervous system, central canal, and lateral plates of mesoblast, we are watching the embryonic representation of the original Limulus-like animal; then, when the lateral plates of mesoblast have grown round, and met in the middle line to assist in forming the new ventral surface, and the head fold is completed, we are watching the embryonic representation of the transformation of the Limulus-like animal into the scorpion-like ancestor of the vertebrates.

In the Arthropoda, the simple epithelial tube which forms the stomach and intestine is not a glandular organ, and we find that the digestive part of the alimentary tract is found in the large organ, the so-called liver. This organ, together with the generative glands, forms an enormous mass of glandular substance, which, in Limulus, is tightly packed round the whole of the central nervous system and alimentary canal, along the whole length of the animal (represented in Fig. 4 by the dark dotted substance). The remains of this glandular mass are seen in Ammocœtes in the peculiar so-called packing tissue around the brain and spinal cord (represented in Fig. 6 by the dark dotted substance). It satisfies the three tests to the following extent:—

(1) *The phylogenetic test.*—As we descend the vertebrate phylum, we find that the brain fills up the brain-case to a less and less extent, until finally in Ammocœtes a considerable space is left between brain and brain-case, filled up with a peculiar glandular-looking material, interspersed with pigment, which is

[1] Gaskell, *Journ. of Anat. and Physiol.*, vol. xxiii., 1888; *Journ. of Physiol.*, vol. x., 1889; *Brain*, vol. xii., 1889; *Q. J. of Micr. Sci.*, 1890.

not fat tissue, and is most marked in the lowest vertebrates. The natural interpretation of this phylogenetic history is that the cranial cavity is too large for the brain in the lowest vertebrates, and is filled up with a peculiar glandular substance because that glandular substance pre-existed as a functional organ or organs, and not because it was necessary to surround the brain with packing material in order to keep it steady, owing to the unfortunate mistake having been made of forming a brain much too small for its case.

(2) *The anatomical test* shows that this glandular and pigmented material is in the same position with respect to the central nervous system of Ammocœtes as the generative and liver material with respect to the central nervous system and alimentary canal of Limulus.

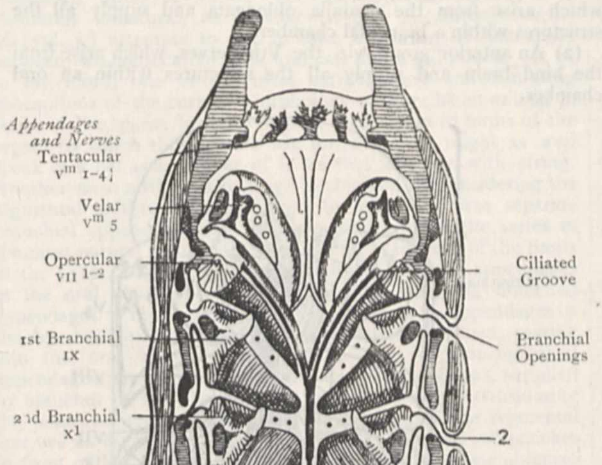


FIG. 3.—Head Region of Ammocœtes, split longitudinally into a ventral and dorsal half. (Ventral Half.)

(3) *The ontogenetic test* remains to be worked out. I do not know the origin of this tissue in Ammocœtes; the evidence has not yet been given by Kuppfer ("Studien z. vergleich. Entwicklungsgesch. d. Kopfes der Kranioten," 2 Heft, München u. Leipzig, 1894). He has, however, shown that the neural ridge gives origin to a mass of mesoblastic cells, the further fate of which is not worked out. The whole story is very suggestive from the point of view of my theory, but incomprehensible on the view that the neural ridge is altogether nervous.

Finally, we ought to find in the invertebrate group in question indications of the commencement of the enclosure of the alimentary canal by the central nervous system; such is, in fact, the case. In the scorpion group a marked process of cephalisation has gone on, so that the separate ganglia, both of the prosomatic and mesosomatic region, have fused together, and fused also with the large supra-œsophageal mass. In the middle of this large brain mass a small canal is seen closely surrounded and compressed with nervous matter, as is shown in this specimen of Thelyphonus; this canal is the alimentary canal. Again, Hardy, in his work on the nervous system of Crustacea, has sections through the brain of Branchipus which demonstrate so close an attachment between the nervous matter of the optic ganglion and the anterior diverticulum of the gut that no line of demarcation is visible between the cells of the gut wall and the cells of the optic ganglion.

For all these reasons I consider that the tubular nature of the vertebrate central nervous system is explained by my hypothesis much more satisfactorily and fully than by any other as yet put forward; it further follows that if this hypothesis enables us to homologise all the other parts of the head region of the verte-

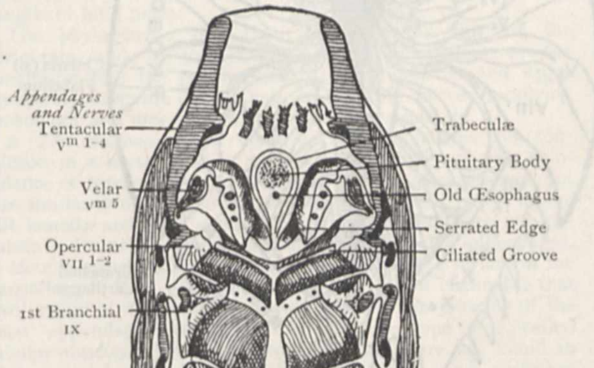


FIG. 3.—Head Region of Ammocœtes, split longitudinally into a ventral and dorsal half. (Dorsal Half.)

brate with similar parts in the arthropod, then it ceases to be an hypothesis, but rises to the dignity of the most probable theory of the origin of vertebrates.

Origin of Segmental Cranial Nerves.

1. *The phylogenetic test.*—It follows from the close resemblance of the brain region of the central nervous systems in the two groups of animals that the cranial nerves of the vertebrate must be homologous with the foremost nerves of such an animal as Limulus, and must therefore supply homologous organs. Leaving out of consideration for the present the nerves of special sense, it follows that the segmental cranial nerves must be divisible into two groups corresponding to two sets of segmental muscles, viz. a group supplying structures homologous to the appendages of Limulus and its allies, and a group supplying the somatic or body muscles; in other words, we must find precisely

what is the most marked characteristic of the vertebrate cranial nerves, viz. that they are divisible into two sets corresponding to a double segmentation in the head region. The one set, consisting of the Vth, VIIth, IXth, and Xth nerves, supply the muscles of the branchial or visceral segments; the other set, consisting of the IIIrd, IVth, VIth, and XIIth nerves, the muscles of the somatic segments. Further, we see that the

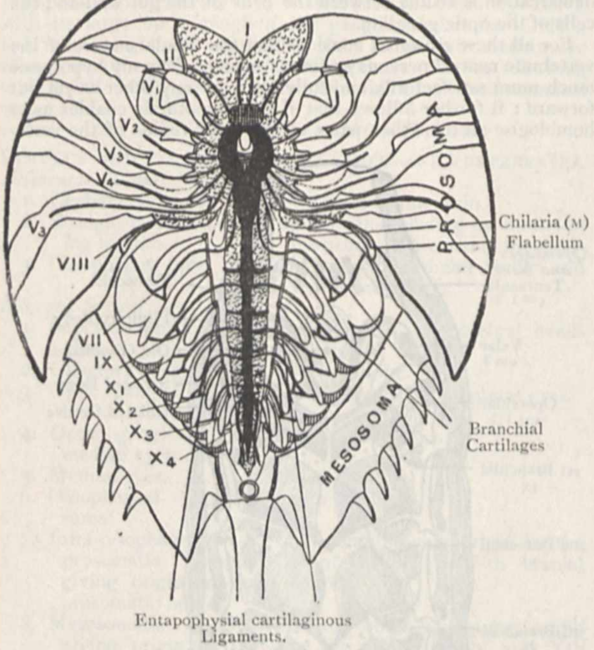


Fig. 4.—Limulus. Nerves of Appendages and Cartilages.

nerves supplying the branchial segments, like the nerves supplying the appendages in Limulus, are mixed motor and sensory, while the nerves supplying the somatic segments are all purely motor, the corresponding sensory nerves running separately as the ascending root of the fifth nerve; so also in Limulus, the nerves supplying the powerful body muscles arise separately

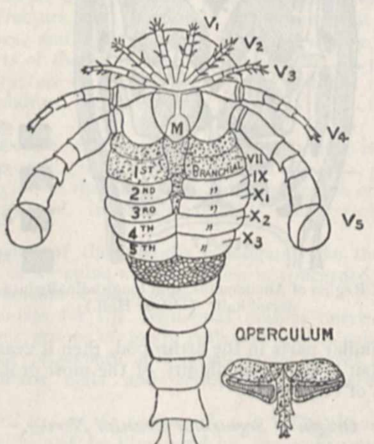


Fig. 5.—Eurypterus.

from those supplying the appendages, and also are quite separate from the purely sensory or epimeral (Milne Edwards, "Recherches sur l'Anatomie des Limulus," *Ann. des Sc. Nat.*, 5th ser.) nerves which supply the surfaces of the carapace in the prosomatic and mesosomatic regions. Finally, the researches of Hardy (*Phil. Trans. Roy. Soc.*, 1894) have shown that the motor portion of these appendage nerves, just like the nerves of the branchial segmentation in vertebrates, *i.e.* the motor part of the trigeminal, of the facial, of the glosso-pharyngeal, and of the vagus, arise from nerve centres or nuclei quite separate from those which give origin to the motor nerves of the somatic muscles. The phylogenetic history, then, of the cranial nerves points directly to the conclusion that the Vth, VIIth, IXth, and Xth nerves originally innervated structures of the nature of arthropod appendages.

We can, however, go further than this, for we find, as we trace downwards throughout the vertebrate kingdom the structures supplied by these nerves, that they are divisible into two well-marked groups, especially well seen in Ammocœtes, viz. :—

(1) A posterior group, viz. the VIIth, IXth, and Xth nerves, which arise from the medulla oblongata and supply all the structures within a branchial chamber.

(2) An anterior group, viz. the Vth nerves, which arise from the hind brain and supply all the structures within an oral chamber.

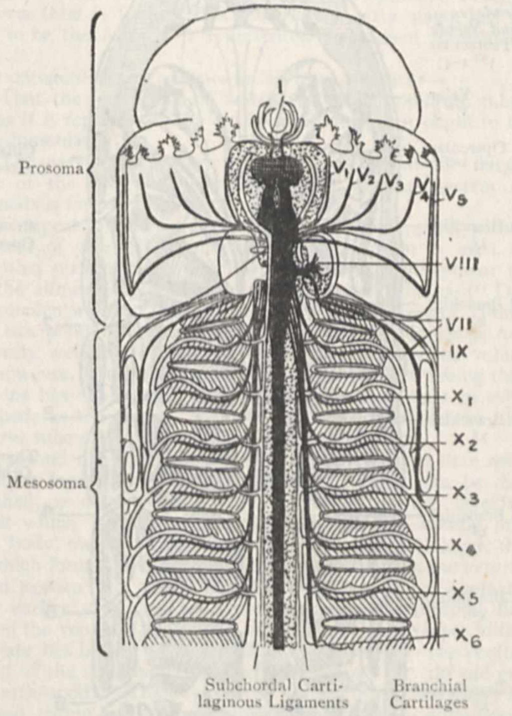


Fig. 6.—Ammocœtes. Nerves of visceral segments and cartilages.

In all three Figures v_1–v_5 = Prosomatic appendages and nerves; vii = 1st mesosomatic appendage or opercular appendage and nerves; ix, x_1 ... = remaining mesosomatic appendages and nerves; m=Chilaria in Limulus, metastoma in Eurypterus.

The reason for this grouping is seen when we turn to Limulus and its allies, for we find that the body is always divided into a prosoma and mesosoma, and that the appendage nerves are divisible into two corresponding well-marked groups, viz. :—

(1) A posterior or mesosomatic group, which arise from the mesosomatic ganglia and supply the operculum and branchial appendages.

(2) An anterior or prosomatic group, which arise from the prosomatic ganglia and supply the oral or locomotor appendages.

Comparison of the Branchial Appendages of Limulus, Eurypterus, &c., with the Branchial Appendages of Ammocœtes. Meaning of the IXth and Xth Nerves.

We will first consider the posterior group—the VIIth, IXth, and Xth nerves—and of these I will take the IXth and Xth nerves together, and discuss the VIIth separately. These nerves are always described as supplying in the fishes the muscles and other tissues in the walls of a series of gill-pouches, so that the respiratory chamber is considered to consist of a series of pouches, which open on the one hand into the alimentary canal, and on the other to the exterior. Such a description is possible even as low down as Petromyzon, but when we pass to the Ammocœtes we find the arrangement of the branchial chamber has become so different that it is no longer possible to describe it in terms of gill-pouches. The nature of the branchial chamber is seen in Fig. 3, which demonstrates clearly that the IXth and Xth nerves supply a series of separate gill-bearing structures or appendages, which hang freely into a common respiratory chamber; each one of these appendages is moved by its own separate group of branchial muscles, and possesses an external branchial bar of cartilage, which, by its union with its fellows, contributes to form the extra-branchial basket-work so characteristic of this primitive respiratory chamber. The segmental branchial unit is clearly in this case, as Rathke originally pointed out, each one of these suspended gills, or rather gill-bearing appendages; it is absolutely unnatural, as Nestler (*Archiv f. Naturgeschich.*, 56, vol. i.) attempts to do, to take a portion of the space between two consecutive gills and call that a gill-pouch. It is, to my mind, one of the most extraordinary and confusing conceptions of the current morphology to describe an animal in terms of the spaces between organs, rather than in terms of the organs by which those spaces are formed. We might as well speak of a net as a number of h les tied together with string. Another most striking advantage is obtained by considering the segmental unit to be represented by each of these separate branchial appendages—viz. that we can continue the series in the most natural manner (as seen in Fig. 3) in front of the limits of the IXth and Xth nerves, and so find a series of appendages in the oral chamber serially homologous with the branchial appendages. The uppermost of the respiratory appendages is the hyo-branchial, supplied by the VIIth nerve, then, passing into the oral chamber, we find a series of non-branchial appendages, viz. the velar and tentacular appendages, supplied by branches of the Vth nerve. In fact, by simply considering the tissue between the so-called gill-pouches as the segmental unit, we no longer get lost in a maze of hypothetical gill pouches in front of the branchial region, but find that the resemblances between the oral and branchial regions, which have led to the endless search for gill-slits and gill-pouches, really mean that the oral chamber contains appendages just as the branchial chamber, but that the former were not gill-bearing.

The study of Ammocœtes, then, leads directly to the conclusion that the ancestor of the vertebrate possessed an oral or prosomatic chamber, which contained a series of non-branchial, tactile and masticatory appendages, which were innervated from the fused prosomatic ganglia or hind brain, and a branchial or mesosomatic chamber, which contained a series of branchial appendages which were innervated from the fused mesosomatic ganglia or medulla oblongata. These two chambers did not originally communicate with each other, for the embryological evidence shows that they are separated at first by the septum of the stomatodæum, and also that the oral chamber is formed by the forward growth of the lower lip.

The phylogenetic test on the side of Limulus and its congeners agrees in a remarkable manner with the conclusions derived from the study of Ammocœtes, for we see that the variation which has occurred in the formation of Eurypterus from Limulus is exactly of the kind necessary to form the oral and branchial chambers of the Ammocœtes. Thus, we find with respect to the mesosomatic appendages that the free, many-jointed appendages of the crustacean become converted into the plate-like appendages of Limulus, in which the separate joints are still visible, but insignificant in comparison with the large branchiæ-bearing lamella; then comes the in-sinking of these appendages, as described by Macleod (*Archiv de Biologie*, vol. v., 1884) to form the branchial lamellæ, or so-called lung-books of Thelyphonus, and the branchiæ of Eurypterus, in which all semblance of jointed and free appendages disappears and the branchiæ project into a series of chamb rs or gill-pouches, each pair of which in Thelyphonus open freely into communication. In this way we see already the commencement of the formation of a branchial chamber similar to that of Ammocœtes.

So also with the innervation of these mesosomatic appendages, originally a series of separate mesosomatic ganglia, each of which innervates a separate appendage; then a process of cephalisation takes place, in consequence of which, in the first place, a single ganglion, the opercular ganglion, fuses with the already fused prosomatic ganglia, as is seen in the stage of Limulus; then, as pointed out by Lankester, in the different groups of scorpions more and more of the mesosomatic ganglia fuse together, and so we find the upward variation in this group is distinctly in the direction of the formation of the medulla oblongata coincidently with the formation of a branchial chamber.

In a precisely similar way, we find the variation which has occurred in the prosomatic appendages leads directly to the formation of the oral chamber and oral appendages of Ammocœtes; for the original chelate and locomotor appendages of Limulus become converted into the tactile non-chelate appendages of Eurypterus (*cf.* Figs. 4 and 5), and the small chilaria (M) of Limulus, according to Lankester, fuse in the middle line and grow forward to form the metastoma of Eurypterus, thus forming an oral chamber, into which the short tactile appendages could be withdrawn, closely similar in its formation to the oral chamber of Ammocœtes. The prosomatic ganglia supplying these oral appendages have already, in Limulus (see Fig. 4), been fused together to form the infra-œsophageal ganglia or hind brain.

The phylogenetic test, then, both on the side of the vertebrate and of the invertebrate, points direct to the conclusion that the peculiarities of the trigeminal and vagus groups of nerves are due to their origin from nerves supplying prosomatic and mesosomatic appendages respectively.

2. *The anatomical test* confirms and emphasises this conclusion in a most striking manner, for we find not only coincidence of topographical arrangement, as already mentioned, but also similarity of structure; thus we see that the blood in the gill lamellæ and velar appendages of Ammocœtes does not circulate in distinct capillaries, but, as in the arthropod appendages, in lacunar spaces, which by the subdivision of the surface of the appendage to form gill lamellæ become narrow channels; that also certain of the branchial muscles and of the muscles of the velar appendages are of the invertebrate type of so-called tubular muscles. These invertebrate muscles are not found in higher vertebrates, but only in Ammocœtes, and moreover disappear entirely at transformation.

Origin of the Vertebrate Cartilaginous Skeleton.

Perhaps, however, the most startling evidence in favour of the homology between the branchial segments of Ammocœtes and the branchial appendages of Limulus is found in the fact that a cartilaginous bar external to the branchiæ exists in each one of the branchial appendages of Limulus, to which some of the branchial muscles are attached in precisely the same way as in Ammocœtes. The branchial cartilages of Limulus (see Fig. 4) spring from the entapophyses and form strong cartilaginous bars, which are extra-branchial in position, just as in Ammocœtes; in addition to each branchial bar, a cartilaginous ligament passes from one entapophysis to another, so as to form a longitudinal or entapophysial ligament, more or less cartilaginous, which extends on each side along the length of the mesosoma. In precisely the same way the branchial bars of Ammocœtes are joined together along each side of the notochord by a ligamentous band of more or less continuous cartilaginous tissue, forming a subchordal or parachordal cartilaginous ligament.

Further, we see that this cartilage of Limulus is of a very striking structure, quite different from that of vertebrate cartilage, and that it is formed in a fibro-massive tissue which, like the matrix of the cartilage, gives a deep purple stain with thionin, thus showing the presence of some form of chondromucoid. This fibro-massive tissue is closely connected with the chitinogenous cells of the entapophyses.

Startling is it to find that the branchial cartilages of Ammocœtes possess identically the same structure as the cartilages of Limulus; that the branchial cartilages are formed in a fibro-massive tissue which, like the matrix of the cartilage, gives a deep purple stain with thionin, and that this fibro-massive tissue, to which Schneider ("Beiträge z. Anat. u. Entwicklungsgesch. der Wirbelthiere," Berlin, 1879) gives the name of muco-cartilage, or Vorknorpel, entirely disappears at transformation.

Further, according to Shipley (*Quart. Journ. of Micr. Sci.*, 1887), the cartilaginous skeleton of the Ammocœtes when first formed consists simply of a series of straight branchial bars, springing from a series of cartilaginous pieces arranged bilaterally along the notochord.

The formation of the trabeculæ, of the auditory capsules, of the crossbars to form the branchial basket-work, all occur subsequently, so that exactly those parts which alone exist in Limulus are those parts which alone exist at an early stage in

Ammocœtes. Another distinction is manifest between these branchial cartilages and those of the trabeculæ and auditory capsules, in that the latter do not stain in the same manner; whereas the matrix of the branchial cartilages stains red with picro-carmine, that of the trabeculæ and auditory capsules stains deep yellow, so that the junction between the trabeculæ and the first branchial bar is well marked by the transition from the one to the other kind of staining. The difference corresponds to Parker's (*Phil. Trans. Roy. Soc.*, 1883) soft and hard cartilage.

The new cartilages which are formed at transformation, either in places where muco-cartilage exists before or by the invasion of the fibrous tissue of the brain-case by chondroblasts, are all of the hard cartilage variety.

The phylogenetic, anatomical, and ontogenetic history of the formation of the vertebrate skeleton all show how the bony skeleton is formed from the cartilaginous, and how the cartilaginous skeleton can be traced back to that found in Petromyzon, and so to the still simpler form found in Ammocœtes; from this, again, we can pass directly to the cartilaginous skeleton of Limulus, and so finally trace back the cranial skeleton of the vertebrate to its commencement in the modified chitinous ingrowths connected with the entapophyses of Limulus. A similar explanation of the origin of cartilage from modifications of the chitinous ingrowths of Limulus was suggested by Gegenbauer ("Anat. Untersuch. eines Limulus," *Abhandl. der Naturf. Gesellsch. in Halle*) so long ago as 1858, in consideration of the near chemical resemblances between the chitin and mucin groups of substances.

Comparison of the Thyroid and Hyo-branchial Appendage of Ammocœtes with the Opercular Appendage of Eurypterus, Thelyphonus, &c. Meaning of the VIIth Nerve.

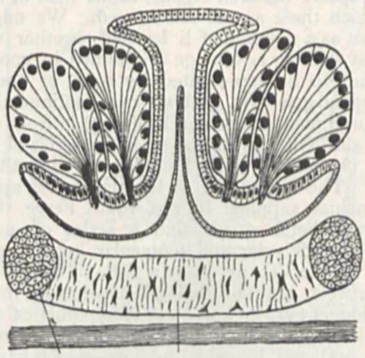
Seeing, then, how easily the IXth and Xth nerves in Ammocœtes correspond to the mesosomatic nerves to the branchial appendages in Limulus, and therefore to the corresponding nerves in such an animal as Eurypterus, we may with confidence proceed to the consideration of the VIIth nerve, and anticipate that it will be found to innervate a mesosomatic appendage in front of the branchial appendages, and yet belonging to the branchial group; in other words, if the VIIth nerve is to fit into the scheme, it ought to innervate a structure or structures corresponding to the operculum of Limulus or of Thelyphonus, &c. Now we see in Figs. 5 and 8 the nature of the operculum in Eurypterus and in Thelyphonus, Phrynus, &c. It is in reality composed of two parts, a median and anterior portion which bears on its under surface the external genital organs, and a posterior part which bears branchiæ; so that the operculum of these animals may be considered as a genital operculum fused to a branchial appendage, and therefore double. It is absolutely startling to find that the branchial segment immediately in front of the glosso-pharyngeal segment in Ammocœtes (Fig. 3) consists of two parts, of which the posterior, the hyo-branchial, is gill-bearing, while the anterior carries on its under surface the pseudo-branchial groove of Dohrn, which continues as a ciliated groove up to the opening of the thyroid gland.

Again, the comparison of the ventral surfaces of Eurypterus and Ammocœtes (*cf.* Fig. 8) brings to light a complete coincidence of position between the median tongue of the operculum in the one animal and the median plate of muco-cartilage in the other animal, which separates in so remarkable a manner the cartilaginous basket-work of each side, and bears on its under surface the thyroid gland. Finally, Miss Alcock has shown that not only the hyo-branchial, but also the thyroid part of this segment, is innervated by the VIIth nerve; so that every argument which has forced us to the conclusion that the glosso-pharyngeal and vagus nerves are the nerves which originally supplied branchial appendages equally points to the conclusion that the facial nerve originally supplied the opercular appendage—an appendage which closed the branchial chamber in front, which consisted of two parts, a branchial and a genital, probably indicating the fusion of two segments: and that the thyroid gland belonged to the genital operculum, just as the branchiæ belonged to the branchial operculum. This interpretation of the parts supplied by the facial nerve immediately explains why Dohrn is so anxious to make a thyroid segment in front of the branchial segments, and why a controversy is still going on as to whether the facial supplies two segments or one.

What, then, is the thyroid gland? Of all the organs found in the vertebrate, with perhaps the single exception of the pineal eye, there is no one which so clearly is a relic of the invertebrate ancestor as the thyroid gland. This gland, important as it is known to be in the higher vertebrates, remains of much the same type of structure down to the fishes, and even to Petromyzon; suddenly, when we pass to the Ammocœtes, to that larval condition so pregnant with invertebrate surprises, we find that the thyroid has become a large and important organ, totally different in structure from the thyroid of all other vertebrates, though resembling the endostyl of the Tunicates.

The thyroid of Ammocœtes may be described as a long tube, curled up at its posterior end, which contains in its wall, along the whole of its length, a peculiar glandular structure, confined to a small portion of its wall.

A section through this tube is given in Fig. 7, and shows how this glandular structure possesses no alveoli, no ducts, but consists of a column of elongated cells arranged in a wedge-shaped manner, the apex of the wedge being in the lumen of the tube;



Thyroid (Ammocœtes).

Thyroid (Scorpion).

FIG. 7.

each cell contains a spherical nucleus, situated at the very extreme end of the cell, farthest away from the lumen of the tube. Such a structure is different from that of any other vertebrate gland. Its secretion is not in any way evident. It certainly does not secrete mucus or take part in digestion, and for a long time I was unable to find any structure which resembled it in the least degree, apart, of course, from the endostyl of the Tunicates.

Guided, however, by the considerations already put forward, and feeling therefore convinced that in Eurypterus there must have been a structure resembling the thyroid gland underneath the median projection of the operculum, I proceeded to investigate the nature of the terminal genital apparatus underlying the operculum in the different members of the scorpion family, and reproduce here (Fig. 8) the figures given by Blanchard ("L'Organisation du Règne Animal") of the appearance of the terminal male genital organs in Phrynus and Thelyphonus. Emboldened by the striking appearance of these figures, I proceeded to cut sections through the operculum of the European scorpion, and found that that part of the genital duct which underlies the operculum, and that part only, contains within its

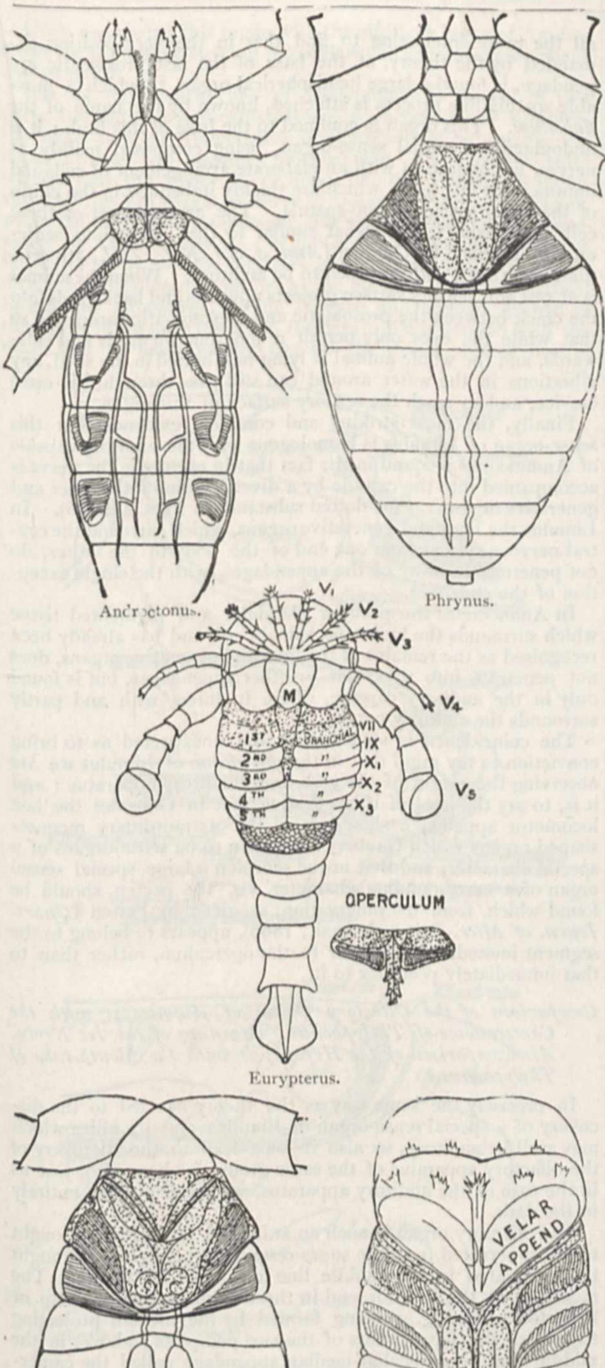


FIG. 8.—Comparison of the ventral surface of the branchial region. In all figures the opercular appendage is marked out by its dotted appearance.

walls a glandular structure which resembles the thyroid gland of Ammocœtes in a remarkable degree. A section is represented in Fig. 7, and we see that under the operculum in the middle line is situated a tube, the walls of which in one part on each side are thickened by the formation of a gland with long cells of the same kind as those of the thyroid; the nucleus is spherical, and situated at the farther end of the cell, and the cells are arranged in wedges, so that the extremities of each group of cells come to a point on the surface of the inner lining of the tube. This point is marked by a small round opening in the internal chitinous lining of the tube. These cells form a column along the whole length of the tube, just as in the thyroid gland, so that the chitinous lining along that column is perforated by numbers of small round holes. This glandular structure is not confined to the male scorpion, but is found also in the female, though not so well developed.

So characteristic is the structure, so different from anything else, that I have no hesitation in saying that the thyroid of Ammocœtes is the same structurally as the thyroid of the scorpion, and that, therefore, in all probability the median projection of the operculum in the old forms of scorpions, such as Eurypterus, Pterygotus, Slimonia, &c., covered a glandular tube of the same nature as the thyroid of Ammocœtes.

We see, then, that the structures innervated by the VIIth, IXth, and Xth nerves are absolutely concordant with the view that the primitive vertebrate respiratory chamber was formed from the mesosomatic appendages of such a form as Limulus by a slight modification of the method by which the respiratory apparatus of Thelyphonus and other Arachnids has been formed, according to Macleod. The anterior limit of this chamber was formed by the operculum, the basal part of which formed a septum which originally separated the branchial from the oral chamber.

Comparison of the Oral Chamber of Ammocœtes with that of Eurypterus. Meaning of the Vth Nerve.

Passing now to the oral chamber—*i.e.* to the visceral structures innervated by the Vth nerve—we find, as already suggested, distinct evidence in Ammocœtes of the presence of the modified prosomatic appendages of the original Eurypterus-like form. The large velar appendage is the least modified, possessing as it does the arthropod tubular muscles, a blood system of lacunar blood-spaces, and a surface covered with a regular scale-like pattern, formed by cuticular nodosites, similar to that found on the surface of Eurypterus and other scorpions. The velar appendages show, further, that they are serially homologous with the respiratory appendages, in that they have been utilised to assist in respiration, their movements being synchronous with the respiratory movements.

The separate part of the Vth nerve which supplies the velar appendage passes within it from the dorsal to the ventral part of the animal, and then, as Miss Alcock has shown, turns abruptly forward to supply the large median tentacle. This extraordinary course leads directly to the conclusion that this median tentacle, which is in reality double, constitutes, with the velum of each side, the true velar appendages.

Again, on each side of the middle line there are in Ammocœtes four large tentacles, each of which possesses a system of muscles, muco-cartilage, and blood-spaces, precisely similar to the median ventral tentacle already mentioned. Each of these is supplied, as Miss Alcock has shown, by a separate branch of the motor part of the Vth nerve (see Fig. 6), and each branch is comparable with the branch supplying the large velar appendage.

That such tentacles are not mere sensory papillæ surrounding the mouth, but have a distinct and important morphological meaning, is shown by the fact that they are transformed in the adult Petromyzon into the remarkable tongue and suctorial apparatus: a modification of oral appendages into a suctorial apparatus which is abundantly common among Arthropods.

Finally, the Vth nerve innervates the visceral muscles of the lower and upper lips of Ammocœtes. In order, then, for the story to be complete, the homologues of the lower and upper lips must also be found in the system of prosomatic appendages of forms like Limulus and Eurypterus. The lower lip, like the opercular or thyroid appendage, possesses a plate of muco-cartilage, and, as already mentioned, falls into its natural place as the metastoma of the old Eurypterus-like form, by the enlargement and forward growth of which the oral chamber of Ammocœtes was formed. The meaning of the upper lip will be considered with the consideration of the old mouth-tube. The comparison of the metastoma of Eurypterus with the lower lip of Ammocœtes demonstrates the close resemblance between the oral chambers of Eurypterus and Ammocœtes. In order to obtain the condition of affairs in Ammocœtes from that in Eurypterus, it is only necessary that the metastoma should increase in size, and that the last oral appendage, the large oar-appendage, should follow the example of the other oral appendages, and be withdrawn into the oral cavity, and so form the velar appendage.

Thus we see that, just as the mesosomatic appendages of Limulus can be traced into the branchial and thyroid appendages of Ammocœtes through the intermediate stage of forms similar to Eurypterus, so also the prosomatic appendages and chilaria of Limulus can be traced into the velar and tentacular appendages and lower lip of Ammocœtes through the intermediate stage of forms similar to Eurypterus.

3. *Lastly comes the ontogenetic test.* The concordant interpretation of the origin of the motor part of the Vth, of the VIIth, IXth, and Xth nerves given by the anatomical and phylogenetic tests must explain and be illustrated by the facts of the development of Ammocœtes.

We see:—

(1) The oral chamber of Ammocœtes is known in its early stage by the name of the stomatodæum, and we find, as might be anticipated, that it is completely separated at first from the branchial chamber by the septum of the stomatodæum.

(2) This septum is the embryological representative of the basal part of the operculum, and demonstrates that originally the operculum separated the oral and branchial chambers.

(3) Subsequently these two chambers are put into communication by the breaking through of this septum, illustrating the communication between the two chambers by the separation of the median basal parts of the operculum.

(4) The velar appendages, the tentacular appendages, the lower lip, all form as out-buddings, just as the homologous locomotor appendages are formed in arthropods.

(5) The branchial bars are not formed by a series of inpouchings in a tube of uniform thickness, but, as Shipley (*loc. cit.*) has pointed out, by a series of ingrowths at regular intervals; in other words, the embryological history represents a series of buddings—*i.e.* appendages within the branchial chamber similar to the buddings within the oral chamber—and does not indicate the formation of gill-pouches by the thinning of an original thick tube at definite intervals.

(6) The communication of the branchial chamber with the exterior by the formation of the gill-slits represents a stage in the ancestral history which is conceivable, but cannot at present be explained with the same certainty as most of the embryological facts of vertebrate development. I can only say that Strübel (*Zool. Anzeiger*, vol. xv., 1892) has pointed out, and I can confirm him, that after the young Thelyphonus has left the egg, and is on its mother's back, before the moult which gives it the same form as the adult, the gills and gill-pouches are fully formed, but do not as yet communicate with the exterior.

(7) The branchial cartilages in the Ammocœtes are formed distinctly before the auditory capsules and trabeculæ, illustrative of the fact that they alone are formed in Limulus.

Comparison of the Auditory Apparatus of Ammocœtes with the Flabellum of Limulus. Meaning of the VIIIth Nerve.

The correctness of a theory is tested in two ways: (1) It must explain all known facts; and (2) it ought to bring to light what is as yet unknown, and the more it leads to the discovery of new facts, the more certain is it that the theory is true. So far, we see that the prosomatic and mesosomatic regions of the body in Limulus and the scorpions are comparable with the corresponding regions of Ammocœtes as far as their locomotor and branchial appendages are concerned, and that, therefore, a satisfactory explanation is given of the peculiarities of the Vth, VIIth, IXth, and Xth nerves. In all vertebrates, however, there is invariably found a special nerve, the VIIIth nerve, entirely confined to the innervation of the special sense-organs of the auditory apparatus. It follows, therefore, that if my theory is true the VIIIth nerves must be found in such forms as Limulus and its allies, and that, therefore, a special sense-organ, probably auditory in nature, must exist between the prosomatic and mesosomatic appendages, at the very base of the last prosomatic appendage. At present we know nothing about the nature or locality of the hearing apparatus of Limulus. It is, therefore, all the more interesting to find that in the very position demanded by the theory, at the base of the last prosomatic appendage, is found a large hemispherical organ, to which a movable spatula-like process is attached, known by the name of the *flabellum*. This organ is confined to the base of this limb; it is undoubtedly a special sense-organ, being composed mainly of nerves, in connection with an elaborate arrangement of cells and innumerable fine hairs, which are thickly imbedded in the chitin of the upper surface of the spatula. The arrangement of these cells and hairs is somewhat similar to that of various sense-organs described by Gaubert (*Ann. d. Sci. Nat., Zool.*, 7th ser., tome 13, 1892), and supposed to be auditory. When the animal is at rest this sensory surface projects upwards and backwards into the crack between the prosomatic and mesosomatic carapaces, so that while the eyes only permit a look-out forwards and sidewards, and the whole animal is lying half buried in the sand, any vibrations in the water around can still pass through this open crevice, and so reach the sensory surface of this organ.

Finally, the most striking and complete evidence that this sense-organ of Limulus is homologous with the auditory capsule of Ammocœtes is found in the fact that in each case the nerve is accompanied into the capsule by a diverticulum of the liver and generative organs. (See dotted substance in Figs. 4 and 6). In Limulus the liver and generative organs, which surround the central nervous system from one end of the body to the other, do not penetrate into any of the appendages, with the single exception of the *flabellum*.

In Ammocœtes the peculiar glandular and pigmented tissue which surrounds the brain and spinal cord, and has already been recognised as the remains of the liver and generative organs, does not penetrate into the velar or other appendages, but is found only in the auditory capsule, where it enters with and partly surrounds the auditory nerve.

The coincidence is so startling and unexpected as to bring conviction to my mind that in the *flabellum* of Limulus we are observing the origin of the vertebrate auditory apparatus; and it is, to say the least of it, suggestive that in Galeodes the last locomotor appendage should carry the extraordinary racquet-shaped organs which Gaubert has shown to be sense-organs of a special character, and that in the scorpion a large special sense-organ of a corresponding character, viz. the pecten, should be found which, from its innervation, as given by Patten (*Quart. Journ. of Micr. Sci.*, vol. xxxi., 1890), appears to belong to the segment immediately anterior to the operculum, rather than to that immediately posterior to it.

Comparison of the Olfactory Organ of Ammocœtes with the Camerostome of Thelyphonus. Meaning of the Ist Nerve. Also comparison of the Hypophysis with the Mouth-tube of Thelyphonus.

In precisely the same way as the theory has led to the discovery of a special sense-organ in Limulus and its allies which may well be auditory, so also it must lead to the discovery of the olfactory apparatus of the same group, for here also, just as in the case of the auditory apparatus, we are at present entirely in the dark.

The olfactory organ in such an animal as Thelyphonus ought to be innervated from the supra-œsophageal ganglia, and ought to be situated in the middle line in front of the mouth. The mouth is at the anterior end in these animals, the lower lip or hypostoma (see Fig. 9) being formed by the median projecting flanges of the basal joints of the two pedipalpi; above, in the middle line, is a peculiar median appendage called the camerostome. Still more dorsal we find in the median line the rostrum, with the median eyes near its extremity, and laterally on each side of the camerostome, and dorsal to it, are situated the powerful chelicerae, which are considered by some authorities to represent antennæ. Of these parts the camerostome is certainly innervated from the supra-œsophageal ganglia, and upon cutting sagittal transverse sections in a very young Thelyphonus we find that the surface is remarkably covered with very fine sense-hairs, arranged with great regularity and connected with a conspicuous mass of large cells. Upon making transverse sections through this region we see that the camerostome projects into the orifice of the mouth, and that its sense-epithelium forms, together with a similar epithelium on the lower lip, a closed cavity surrounded by a thick edge of fine hairs. Here, then, in the camerostome of Thelyphonus is a special sense-organ which, from its position and its innervation, may well be olfactory in function, or at all events subserve the function of taste.

Upon comparing this organ with the olfactory organ of Ammocœtes we see a most striking resemblance in general arrangement and structure.

Just as the mouth tube of Thelyphonus is formed of two parts, the pedipalp and camerostome, so, according to Kuppfer, the nasal tube of Ammocœtes is composed of two parts, the upper lip and the olfactory protuberance. Of these two parts we see that the upper lip, or hood, like the pedipalp, is innervated by the Vth nerve, or nerve of the prosomatic appendages, while the olfactory protuberance, like the camerostome, is innervated by the Ist nerve. Kuppfer's investigations show us further (Fig. 9) how the olfactory protuberance is at first free, is directed ventralwards, and lies at the opening of the hypophysial tube; how afterwards, by the forward and upward growth of the upper lip to form the hood, the nasal tube is formed with the result that the nasal opening lies on the dorsal surface just in

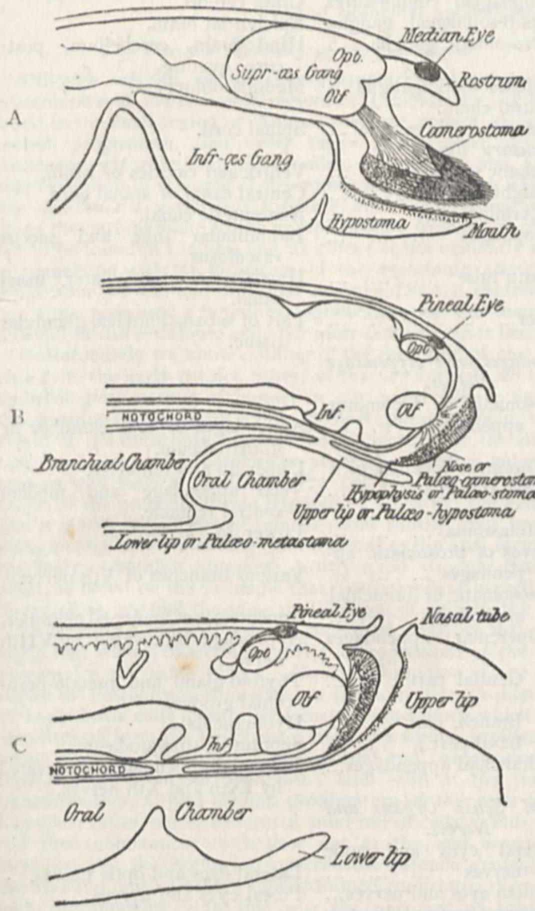


FIG. 9.—A, median sagittal section through head of young Thelyphonus; B, ditto, young Ammocœte (after Kuppfer); C, ditto, full-grown Ammocœte (after Kuppfer).

front of the pineal eye. Kuppfer, like Dohrn and Beard, looks upon this hypophysial tube as indicating the palæostoma, or original mouth of the vertebrate, a view which harmonises absolutely with my theory, and receives the simplest of explanations from it, for, as you see on the screen, sections through the mouth tube of Thelyphonus correspond absolutely with sections through the nasal tube of Ammocœtes; here in the one section is the projecting camerostome, there is the corresponding projection of the olfactory protuberance, here is the sense-epithelium of the lower lip or hypostoma, there is the sense-epithelium of the upper lip or hood. Here, as Fig. 9 shows, the mouth tube passes in the ventral middle line to where it turns dorsalwards into the middle of the conjoined nervous mass of the supra- and infra-œsophageal ganglia. There the nasal tube ends blindly at the spot where the infundibular tube lies on the surface of the brain.

Further, the topography of corresponding parts is absolutely the same in the two animals: in the dorsal middle line the rostrum, with the two median eyes near its extremity; in the corresponding position the two pineal eyes; below this, in the middle line, the camerostome; corresponding to it in the Ammocœtes the olfactory protuberance; then the modification of the median projections of the foremost ventral appendages—the pedipalpi—to form the hypostoma. in the corresponding position the upper lip or hood of Ammocœtes, which forms the hypostoma as far as the hypophysial tube or palæostoma is concerned, but an upper lip as far as the new mouth is concerned. The muscles of this upper lip belong all to the splanchnic and not to the somatic group, and are innervated by the appropriate nerve of the prosomatic appendages, viz. the motor part of the Vth. Ventral to the pedipalpi in Thelyphonus there is nothing, ventral to the corresponding lip in the Ammocœtes is the lower lip, and we have seen that, although such a structure is absent in the land scorpions of the present day, it was present in the sea scorpions of old time, was known as the metastoma, and is supposed to be a forward growth which started at the junction of the prosoma with the mesosoma. Precisely corresponding to this we see from Kuppfer that the lower lip of Ammocœtes is a forward growth from the junction of the stomatodæum with the respiratory chamber.

We see then, so far, that the comparison of the vertebrate nervous system with the conjoined central nervous system and alimentary canal of the arthropod has led to a perfectly consistent explanation of almost all the peculiarities of the head region of Ammocœtes. We have solved the segmentation of the skull and the mysteries of the cranial nerves, for we have found that the cranial segmentation of the vertebrate can be reduced to the segmentation of the prosomatic and mesosomatic regions of the Limulus, that the cranial skeleton arose from the modified internal chitinous skeleton of the Limulus, that the new mouth was formed by the forward growth of the metastoma, leading to the formation of an oral chamber, while the old mouth remained as the hypophysial tube, guarded by its olfactory and taste organs.

Search as we may in the prososomatic and mesosmatic regions of scorpion-like animals, there are but few points left for elucidation; among these the most important are: (1) the fate of the cœlomic cavities and coxal gland; (2) the fate of the heart; (3) the fate of the external chitinous covering.

Comparison of the Head Cavities of the Vertebrate with the Prosomatic and Mesosomatic Cœlomic Spaces of Limulus.

A recent paper by Kishinouye (*Journ. of Coll. of Sci. Tokio*, vol. v., 1891) on the development of Limulus enables us to compare the cœlomic cavities in the head region of a vertebrate with those of the prosomatic and mesosomatic segments of Limulus, and we see that the comparison is wonderfully close; for whereas each mesosomatic segment possesses a cœlomic cavity, just as each of the segments of the branchial chamber supplied by the vagus, glossopharyngeal, and facial nerves possesses a cœlomic cavity, this is not the case with the prosomatic segments. In these latter the first cœlomic cavity is a large præoral one, common to the segment of the first appendage and all the segments in front of it; the segments belonging to the second, third, and fourth appendages have no cœlomic cavities formed in them, the second cœlomic cavity belongs to the segment of the fifth appendage. Similarly in the vertebrate in the region corresponding to the prosoma there are only two head cavities recognised, viz. the 1st præoral head cavity of Balfour and V. Wijhe; and 2nd or mandibular head cavity, associated especially with the Vth nerve. According to my view the motor part of the Vth nerve represents the locomotor prosomatic appendages of Limulus, and we see that already in Limulus the three foremost of these appendages do not form cœlomic cavities.

In fact, the agreement in the formation and position of the cœlomic cavities in the head region of the vertebrate and in the prosomatic and mesosomatic regions of Limulus could not well be more exact; further, these cavities agree in this, that in neither case are they permanent; both in the vertebrate and in the arthropod they are supplanted by vascular spaces.

Comparison of the Pituitary Gland with the Coxal Gland of Limulus.

In connection with the second cœlomic cavity in Limulus is found an ancient gland, partially degenerated according to some views, which was probably excretory in function, and has been considered as homologous to the crustacean green glands. In a precisely corresponding position, and presenting a structure fairly similar to that of the coxal gland of Limulus, we find in Ammocœtes and in other vertebrates the pituitary gland. How far this gland tissue is developed in connection with the mandibular head cavity I do not know, but I venture to suggest that the complete evidence of its homology with the coxal gland will be found in its developmental connection with the walls of the 2nd or mandibular head cavity.

Comparison of the Vertebrate Heart and Ventral Aorta with the Ventral Longitudinal Branchial Sinuses of Limulus and its Allies.

The heart of the vertebrate presents two striking peculiarities, which make it different from all invertebrate hearts; first, its developmental history is different; and, secondly, it is at first essentially a branchial rather than a systemic heart. The researches of Paul Mayer (*Mitth. a. d. Zool. St. zu Neapel*, vol. vii.) have shown that the subintestinal vein, from which in the fishes the heart and ventral aorta arise, is in its origin double, so that in all vertebrates the heart and ventral aorta arise from two long veins which are originally situated on each side of the middle line. By the formation of the head fold these come together ventrally, coalesce into a single tube to form the subintestinal vein and heart, still remaining double as the two ventral aortæ with their branchial branches into each gill, as is well shown in the case of Ammocœtes.

It is a striking coincidence that in Limulus and the Scorpions two large venous collecting sinuses are found situated in the same ventral position, for the same purpose of sending blood to the branchiæ, as already described for the vertebrate; still more striking is it to find, according to the researches of Milne Edwards and Blanchard, that these longitudinal sinuses have already begun to function as branchial hearts, for they are connected with the pericardium by a system of transparent muscles, described by Milne Edwards and named by Lankester venopericardiac muscles. These muscles are hollow, both near the vein and near the pericardium, so that the blood in each case fills the cavity, and, as they contract with the heart, that part of them in connection with the venous collecting sinus already functions, as pointed out by Milne Edwards and Blanchard, as a branchial heart.

By this theory, then, even the formation of the vertebrate heart is prevised in Limulus, and I venture to think that in Ammocœtes we see the remnant of the old dorsal single heart of the arthropod in the form of that peculiar elongated organ composed of fattily degenerated tissue which lies between the spinal cord and the dorsal median skin.

Comparison of the Cuticular and Laminated Layers of the Skin of Ammocœtes with Chitinous Layers.

The external epithelial cells of Ammocœtes possess a remarkably thick cuticular layer. The striated appearance of this layer is due to a number of pores through which the glandular contents of the cells are poured when the surface is made to secrete. That this striated appearance is due to true porous canals, just as in chitin, and not to a series of rods, is easily seen by the inspection of sections, and also by watching the secretion through them of rose-coloured granules when the living cell is stained with methylene blue. The surface layer of this cuticular layer, according to Wolff (*Jen. Zeitschr.*, vol. xxiii.) resists reagents in the same manner as chitin.

Internal to the epithelial cells of the skin of Ammocœtes is a remarkable layer of tissue, generally called connective tissue. It resembles, however, histologically, in the Ammocœtes, a section through chitin most closely; the layers are perfectly regular and parallel; cells are found in it with great sparseness, and it is not until after transformation, when it is altered and invaded by new cell elements, that it can be looked upon as at all resembling connective tissue. It resembles chitin in its reaction to hypochlorite of soda. In order to completely dissect off this laminated layer from an Ammocœtes, all that is necessary is to place the animal in a weak solution of hypochlorite of soda, and in a short time it entirely disappears, bringing to view the muscles, branchial cartilages, pigment, front dorsal part of the central nervous system, &c., in a most striking manner. At present I am puzzled that so manifest a chitinous covering should lie internal to the epithelial cells of the surface; such a position is not, however, unknown among invertebrates, and may be accounted for in various ways.

For the sake of clearness I will sum up before you in the form of a table the corresponding parts in Ammocœtes and in Limulus and its allies, as far as I have discussed them up to the present, from which you will see that there is not a single organ which is present in the prosomatic and mesosomatic regions of Limulus and its allies which is not found in the corresponding situation and of corresponding structure in Ammocœtes.

Table of Coincidences between Limulus and its Allies, and between Ammocœtes and Vertebrates.

LIMULUS AND ITS ALLIES.	AMMOCŒTES AND VERTEBRATES.
Central Nervous System.	
Supra-œsophageal ganglia	Cerebral hemispheres.
Optic part	Optic thalami, ganglia habenulæ, &c.
Olfactory part	Olfactory lobes.
Œsophageal commissures	Crura cerebri.
Infra-œsophageal ganglia	Epichordal brain.
Prosomatic ganglia ...	Hind brain, cerebellum, post-corp. quadrig.
Mesosomatic ganglia ...	Medulla oblongata.
Ventral chain.	
Metasomatic ganglia ...	Spinal cord.
Alimentary Canal.	
Cephalic stomach	Ventricular cavities of brain.
Straight intestine	Central canal of spinal cord.
Terminal part	Neurenteric canal.
Œsophagus	Infundibular tube and saccus vasculosus
Mouth tube	Hypophysial tube, later nasal canal.
Liver...	Part of subarachnoideal glandular tissue.
Appendages and Appendage Nerves.	
Prosomatic or locomotor appendages	Appendages of oral chamber or stomatodæum.
Foremost appendages...	Upper lip and tentacles.
Last appendages	Velar appendage and median ventral tentacle.
Metastoma	Lower lip.
Nerves of prosomatic appendages	Various branches of Vth nerve.
Mesosomatic or branchial appendages	Appendages of branchial chamber.
Opercular appendages	Appendage innervated by VIIth nerve.
Genital part	Thyroid gland and pseudo-branchial groove.
Branch. part	Hyobranchial.
Basal part...	Septum of stomatodæum.
Branchial appendages...	Branchial appendages innervated by IXth and Xth nerves.
Special Sense Organs and Nerves.	
Lateral eyes and optic nerves	Lateral eyes and optic nerves.
Median eyes and nerves...	Pineal eyes and nerves.
Camerostoma and olfactory nerves	Olfactory organ and Ist nerve.
Flabellum and nerve ...	Auditory organ and VIIIth nerve.
Epimeral nerves to surface of prosoma and mesosoma	Sensory part of Vth nerve.
Internal and External Skeleton.	
Internal skeleton.	
Branchial cartilages ...	Branchial cartilages.
Entapophysial cartilaginous ligaments ...	Subchordal cartilaginous ligaments.
Fibro-massive tissue (forerunner of cartilage or "Vorknorpel")	Muco-cartilage or "Vorknorpel."
External skeleton.	
Chitinous layer	Cuticular layer on surface of body and subepithelial laminated layer.

Excretory Organs and Cœlomic Cavities.	
Coxal gland	Pituitary gland.
1st head cavity, præoral...	1st head cavity, præoral.
2nd head cavity. Cavity of prosomatic segments	2nd head cavity, mandibular.
Cavities to each mesosomatic segment... ...	Cavities of hyoid and branchial segments.
Heart and Vascular System.	
Dorsal heart	Column of fatty tissue dorsal to spinal cord.
Longitudinal venous sinuses	Heart and ventral aorta.
Lacunar blood spaces of appendages	Lacunar blood spaces in velar and branchial appendages.

The Possible Meaning of the Notochord.

Although we can say that every structure and organ in the prosomatic and mesosomatic regions of Limulus, &c., is to be found in the head region of Ammocœtes, we cannot assert the reverse proposition, that every organ in the head region of Ammocœtes is to be found in Limulus, &c., for we find a notable exception in the case of the notochord, a structure which is *par excellence* a vertebrate structure, and has in consequence given the current name to the group. Such a structure is clearly not to be found in Limulus and its allies; it has evidently arisen in connection with the formation of the vertebrate alimentary canal from the oral and branchial chambers, and it evidently at one time possessed a functional significance, for the lower we descend in the vertebrate scale the more conspicuous it becomes.

Unfortunately we know nothing of the condition of the notochord in the early extinct fishes, so that we are reduced to the embryological method of inquiry in our endeavours to find out the meaning of this organ. This method appears to point to the origin of the notochord from a tube connected with the alimentary canal, originally therefore an accessory digestive tube; the reasons why such a view has been put forward are, first, the origin of the notochord from hypoblast; secondly, the evidence that it is to a certain extent tubular; and thirdly, that it is an unsegmented tube extending from the oral to the anal regions of the body. Another argument, to my mind stronger than any other, is based on the principle that nature repeats herself, and if, therefore, we find the same proliferation of cells in the same place forming a series of solid notochordal rods, we may fairly argue that we are observing a series of repetitions of the same process for the same object. Now the formation of the head region of Petromyzon shows that at first a median proliferation of hypoblastic cells occurs to form the notochord, which then separates off from the hypoblast; later on a similar proliferation takes place to form the subnotochordal rod, which similarly separates off from the hypoblast; later still, at the time of transformation, a third median proliferation of the cells of the hypoblast takes place, to form a solid rod of cells. This solid rod then commences to hollow out at the end nearest the intestine, and the hollowing out process extends gradually to the oral end, until a hollow tube is formed connecting the mouth with the intestine. In this way the new gut of the adult Petromyzon is formed from a solid median rod of cells closely resembling in its formation the original notochord.

I put it forward therefore as a suggestion, that in the ancient times when the Merostomata were lords of creation and the competition was keen among these ancient arthropod forms, in which the nervous system was so arranged that increase of brain substance tended more and more to compress the food channel, and therefore to compel to the suction of liquid food instead of the mastication of solid, accessory digestive apparatuses were formed, partly in connection with the formation of the oral respiratory chambers, and partly by means of the formation of the notochord. Of these accessory methods of digestion the former became permanent, while the latter becoming filled up with the peculiar notochordal tissue became a supporting structure, still showing by its unsegmented character its original function. That a tube formed from the external surface either as notochord or as the respiratory portion of the alimentary canal in Ammocœtes should be capable of acting as a digestive tube is clear from the researches of Miss Alcock (*Proc. Camb. Phil. Soc.*, vol. vii., 1891), for she has shown that the secretion of the skin of Ammocœtes easily digests fibrin in the presence of acid. Such a secretion, like the similar secretion of the carapace of Daphnia and other crustaceans, was originally for the purpose of keeping the skin clean.

The evidence which I have put before you is in agreement with the conclusion that the fore gut of the vertebrate arose gradually from a chamber formed by the lamellar branchial appendages, which functioned also as a digestive chamber. By the growth of the lower lip, or metastoma, and the modification of the basal portion of the last locomotor appendage, which basal part was inside the lower lip, into a valvular arrangement like the velum, the animal was able to close the opening into the respiratory chamber and feed as blood sucker in the way of the rest of its kind, or when living food was scarce, keep itself alive by the organic material taken into its respiratory chamber with the muddy water in which it lived.

The Possible Formation of the Vertebrate Spinal Region.

It remains to briefly indicate the evidence as to the formation of the rest of the alimentary canal and the spinal region of the body.

The problems connected with the formation of this region are of a different nature from those already considered in connection with the cranial region.

In the cranial region the variation that has taken place within the vertebrate group and in course of the formation of the vertebrate is, on the whole, of the nature called by Bateson substantive, *i.e.* increase or suppression of parts, while throughout the parts remain constant in their relations to each other. It matters not whether it is frog, fish, bird, or mammal we are considering; we always find the same cranial nerve supplying the same segments. When we consider the spinal cord and its immediate junction with the cranial region, this is no longer so; here we find a repetition of similar segments, with great variation in the amount of that repetition; here we find the characteristic feature is meristic variation rather than substantive, and so indetermined is the vertebrate in this respect that even now the same species of animal varies in the number of its segments and in the arrangement of its nerves. In this part of the vertebrate body this repetition is seen not only in the central nervous system and its nerves, but also in the excretory organs, so that embryology teaches us that the vertebrate body has grown in length by a series of repetitions of similar segments formed between the head end and the tail end; such lengthening by repetition of segments has been accompanied by the elongation of the unsegmented gut, of the unsegmented notochord, and of the unsegmented neural canal.

To put it shortly, all the evidence points to and confirms the view so strongly urged by Gegenbauer, that the head region is the oldest part and the spinal region an afterthought, that the attempt so often made to find vertebræ and spinal nerves in the cranial region is an attempt to put the cart in front of the horse—to obtain youth from old age. We may, it seems to me, fairly argue from the sequence of events in the embryology of vertebrates that the primitive vertebrate form was chiefly composed of the head region, and that between the head and the tail was a short body region. In other words, the respiratory chamber and the cloacal region were originally close together, just as would be the case in Limulus if the branchial appendages formed a closed chamber. According, then, to my view, there would be no difficulty in the respiratory chamber opening originally into the cloacal region, *i.e.* the same cloacal region into which the neurenteric canal already opened. The short junction tube thus formed would naturally elongate with the elongation of the body, and, as it originally was part of the respiratory chamber, it equally naturally is innervated by the vagus nerve. This, then, is the explanation of that most extraordinary fact, viz. that a nerve essentially branchial should innervate the whole of the intestine except the cloacal region. Whether this is the true explanation of the formation of the mid-gut of the vertebrate cannot be tested directly, but certain corollaries ought to follow: we ought to find, on the ground that the sequence of the phylogenetic history is repeated in the embryo, that (1) the growth in length of the embryo takes place between the cranial and sacral regions by the addition of new segments from the cranial end; (2) the formation of the fore-gut and hind-gut ought to be completed while the mid-gut is still an undifferentiated mass of yolk cells; (3) the cloacal region ought to be innervated from the sacral nerves, while the stomach, mid-gut and its appendages, liver and pancreas, ought to be innervated from the vagus.

The first proposition is a well-known embryological fact. The second proposition is also well known for all vertebrates, and is especially well exemplified in the embryological development of Ammocœtes, according to Shipley. The third proposition is also well known, and has received valuable enlargement in the recent researches of Langley and Anderson (*Journ. of Physiology*, vols. xviii., xix.).

Further, we see that in this part of the body the ancestor of the vertebrate must have had a cœlomic cavity the walls of which were innervated, not from the mesosomatic nerves or respiratory nerves, but from the metasomatic group of nerves; and in connection with this body cavity there must have existed a kidney apparatus, also innervated by the metasomatic nerves; with the repetition of segments by which the elongation of the animal was brought about the body cavity was elongated, and the kidney increased by the repetition of similar excretory organs. All, then, that is required in the original ancestor in order to obtain the permanent body cavity and urinary organs characteristic of the vertebrate is to postulate the presence of a permanent body cavity in connection with a single pair of urinary tubes in the metasomatic region of the body. As yet I have not worked out this part of my theory, and am therefore strongly disinclined to make any assertions on the subject. I should like, however, to point out that, according to Kishinouye (*Journ. of Coll. of Sci. Tokio*, vol. iv. 1890, vol. vi. 1894), a permanent body cavity does exist in this part of the body in spiders, known by the name of the stercoral pocket; into this cœlomic cavity the excretory Malphigian tubes open.

The Palæontological Evidence.

It is clear, from what has already been said, that the palæontological evidence ought to show, first, that the vertebrates appeared when the waters of the ocean were peopled with the forefathers of the Crustacea and Arachnida, and, secondly, the earliest fish-like forms ought to be characterised by the presence of a large cephalic part to which is attached an insignificant body and tail.

Such was manifestly the case, for the earliest fish-like forms appear in the midst of and succeed to the great era of strange proto-crustacean animals, when the sea swarmed with Trilobites, Eurypterus, Slimonia, Limulus, Pterygotus, Ceratiocaris, and a number of other semi-crustacean, semi-arachnid creatures. When we examine these ancient fishes we find such forms as Pteraspis, Pterichthys, Astrolepis, Bothriolepis, Cephalaspis, all characterised by the enormous disproportion between the extent of the head region and that of the body. Such forms would have but small power of locomotion, and further evolution consisted in gaining greater rapidity and freedom of movements by the elongation of the abdominal and tail regions, with the result that the head region became less and less prominent, until finally the ordinary fish-like form was evolved, in which the head and gills represent the original head and branchial chamber, and the flexible body, with its lateral line nerve and intestine innervated by the vagus nerve, represents the original small tail-like body of such a form as Pterichthys.

Nay, more, the very form of Pterichthys and the nature of its two large oar-like appendages, which, according to Traquair, are hollow, like the legs of insects, suggest a form like Eurypterus, in which the remaining locomotor appendages had shrunk to tentacles, as in Ammocœtes, while the large oar-like appendages still remained, coming out between the upper and lower lips and assisting locomotion. The Ammocœtes-like forms which in all probability existed between the time of Eurypterus and the time of Pterichthys have not yet been found, owing possibly to the absence of chitin and of bone in these transition forms, unless we may count among them the recent find by Traquair of Palæospondylus Gunni.

The evidence of palæontology, as far as it goes, confirms absolutely the evidence of anatomy, physiology, phylogeny, and embryology, and assists in forming a perfectly consistent and harmonious account of the origin of vertebrates, the whole evidence showing how nature made a great mistake, how excellently she rectified it, and thereby formed the new and mighty kingdon of the Vertebrata.

Consideration of Rival Theories.

In conclusion I would ask, What are the alternative theories of the origin of vertebrates? It is a strange and striking fact how often, when a comparative anatomist studies a particular invertebrate group, he is sure to find the vertebrate at the end of it: it matters not whether it is the Nemertines, the Capitellidæ, Balanoglossus, the Helminths, Annelids, or Echinoderms; the ancestor of the vertebrate is bound to be in that particular group. Verily I believe the Mollusca alone have not yet found a champion. On the whole I imagine that two views are most prominent at the present day: (1) to derive vertebrates from a group of animals in which the alimentary canal has always been ventral to the nervous system; and (2) to derive vertebrates from the appendiculate group of animals, especially annelids, by the supposition that the dorsal gut of the latter has become the ventral gut of the former by reversion of surfaces. Upon this latter theory, whether it is Dohrn or van Beneden or Patten who attempts to homologise similar parts, it is highly amusing to see the hopeless confusion into which they one and all get, and the extraordinary hypotheses put forward to explain the fact that the gut no longer pierces the brain. One favourite method is to cut off the most important part of the animal, viz. his supra-œsophageal ganglia, then let the mouth open at the anterior end of the body, turn the animal over, so that the gut is now ventral, and let a new brain, with new eyes, new olfactory organs, grow forward from the infra-œsophageal ganglia. Another ingenious method is to separate the two supra-œsophageal ganglia, let the mouth tube sling round through the separated ganglia from ventral to dorsal side, then join up the ganglia and reverse the animal. The old attempts of Owen and Dohrn to pierce the dorsal part of the brain with the gut tube either in the region of the pineal eye or of the fourth ventricle have been given up as hopeless. Still the annelid theory, with its reversal of surfaces, lingers on, even though the fact of the median pineal eye is sufficient alone to show its absolute worthlessness.

Then, as to the other view, what a demand does that make upon our credulity! We are to suppose that a whole series of animals has existed on the earth, the development of which has run parallel with that of the great group of appendiculate animals, but throughout the group the nervous system has always been dorsal to the alimentary canal. Of this great group no trace remains, either alive at the present day or in the record of the rocks, except one or two aberrant, doubtful forms, and the group of Tunicates and Amphioxus, both of which are to be looked upon as degenerate vertebrates, and indeed are more nearly allied to the Ammocœtes than to any other animal. This hypothetical group does not attempt to explain any of the peculiarities of the central nervous system of vertebrates; its advocates, in the words of Lankester, regard the tubular condition of the central nervous system as in its origin a purely developmental feature, possessing no phylogenetic importance. Strange power of mimicry in nature, that a tube so formed should mimic in its terminations, in its swellings, in the whole of its topographical relations to the nervous masses surrounding it the alimentary canal of the other great group of segmented animals so closely as to enable me to put before you so large a number of coincidences.

Just imagine to yourselves what we are required to believe! We are to suppose that two groups of animals have diverged from a common stock somewhere in the region of the Cœlenterata, that each group has become segmented and elongated, but that throughout their evolution the one group has possessed a ventral mouth, with a ventral nervous system and a dorsal gut, while in the other—the hypothetical group—the mouth and gut have throughout been ventral and the nervous system dorsal. Then we are further to suppose that, without being able to trace the steps of the process, the central nervous system in the final members of this hypothetical group has taken on a tubular form of so striking a character that every part of this dorsal nerve-tube can be compared to the dorsal alimentary tube of the other great group of appendiculate animals. The plain, straightforward interpretation of the facts is what I have put before you, and those who oppose this interpretation and hold to the inviolability of the alimentary canal are, it seems to me, bound to give a satisfactory explanation of the vertebrate nervous system and pineal eye. The time is coming, and indeed has come, when the fetish-worship of the hypoblast will give way to the acknowledgment that the soul of every individual is to be found in the brain, and not in the stomach, and that the true principle of evolution, without which no upward progress is possible, consists in the steady upward development of the central nervous system.

In conclusion I would like to quote to you a part of the last letter I ever received from Prof. Huxley, in which, with reference to this very subject, he wrote as follows: "Go on and prosper, there is nothing in the world of science half so good as an earthquake hypothesis, even if it only serve to show how firm are the foundations on which we build." I have given you the earthquake hypothesis; it is for those of you who oppose my conclusions, to prove the firmness of your foundations.

PHYSICS AT THE BRITISH ASSOCIATION.

PERHAPS Section A does not discuss the question of science teaching in schools so often as Section B does. But the many teachers of science who listened to the address of the President (Prof. J. J. Thomson) on Thursday, must have heard with pleasure the testimony of so competent an authority that the teaching of physical science in schools has greatly improved in recent years. Very welcome, too, was his advice as to the importance of experimental work and method in teaching, and his warning as to the danger of trying to cover too much ground. The Section was favoured with the presence of physicists from various foreign countries, including Profs. Kohlrausch (Director of the Reichsanstalt), Lenard (Aachen), Bjerknes (Stockholm), J. E. Keeler (Pittsburg), Max Wolf (Heidelberg), and Elster and Geitel (Wolfenbüttel). The mention of Prof. Lenard's name in the President's address was the signa for very hearty applause.

After the President's address, the Section adjourned from the Arts Theatre to the Physics Theatre. The Report of the Committee on the Establishment of a National Physical Laboratory was presented by Sir Douglas Galton, who gave details of the cost of the Reichsanstalt, where the capital expenditure has amounted to £200,000, and the annual working expenses are £14,500. The Committee was appointed last year (see NATURE, September 26, 1895) to consider—or rather to reconsider—a suggestion made by Prof. Oliver Lodge at the Oxford meeting. It now proposes that the Kew Observatory at Richmond be extended so as to include a nucleus for the suggested National Physical Laboratory, and that the Government be approached with a request for the modest sum of about £20,000 for buildings and equipment, and £3000 per annum for maintenance. The control of the laboratory should be vested in a Council of Advice appointed by the Royal Society, either alone (like the present Kew Committee) or in conjunction with one or more of the chief scientific bodies in the country; but the immediate executive and initiative power should be vested in a paid chief or director of the utmost eminence attainable. The functions of the institution would include an extension of certain branches of work now performed by the Kew Observatory, such as the verification of standards and comparisons of length, weight, capacity, gravity, sound, light, &c., and variations of conditions due to temperature, vibrations, or other causes, as well as quality of materials. Research work of the following types should also be undertaken: (1) observations of phenomena, the study of which must be prolonged through periods greater than the average duration of life; (2) testing and verification of instruments for physical investigation, and the preservation of standards for reference; (3) systematic determination of physical constants and numerical data which may be useful for scientific or industrial purposes. In the discussion which followed, Lord Kelvin, Profs. Lodge, Ayrton, Fitzgerald, Rücker, and S. P. Thompson, and the Director of the Reichsanstalt took part. Dr. Isaac Roberts read a paper, in which he dealt with the analytic and synthetic methods of tracing the evolution of stellar systems. Very beautiful photographs of stars and nebulæ (taken with about four hours' exposure) were projected on the screen. Prof. G. H. Darwin read a paper on periodic orbits, which Lord Kelvin characterised as a monument of skilful and painstaking calculation. In the afternoon Prof. McKendrick gave a most interesting demonstration of a method of transcribing wave forms from a phonograph cylinder to paper, with other experiments illustrating his researches on the phonograph. During the week a number of instruments and exhibits were on view in the physical laboratory. These included the apparatus with which Dr. Lodge has sought to determine whether a moving body sets the ether in its neighbourhood in motion; X-ray tubes and photographs taken with them; a large influence machine; Prof. Lodge's electrostatic model; and Mr. Barlow's model illustrating the nature of homogeneity in crystals.

On Friday there was a joint discussion with Section B on Röntgen rays and allied phenomena. The interest felt in these was evidenced by the large attendance, many members having to content themselves with seats in the gallery of the large lecture theatre of University College. The subject was appropriately introduced by Prof. P. Lenard, who described his researches on kathode rays, and his views as to their nature. The separation of these rays was made possible by Hertz's discovery that they can pass through thin plates or films, *e.g.* of aluminium. Lenard's discharge tube had an aluminium window at the end opposite the kathode. Aluminium is a turbid medium for these rays, so that in passing through the window they are diffused. They are almost invisible in air, which is only very faintly illuminated by them; they are also largely absorbed by air, so that their intensity diminishes very quickly. If the tube is continued beyond the aluminium window, and the pressure of the air in this second chamber is reduced, the rays travel much further. This favours the view that they are not due to projected matter, but are of the nature of ether-waves. By placing a second screen with a diaphragm beyond the aluminium window a more distinct beam is obtained, and this is allowed to fall upon a phosphorescent screen. By introducing plates of metal in the path of the rays, it is found that their opacity is roughly proportional to their superficial density (gm. per sq. cm.). The same is true for gases; air can be made as transparent as hydrogen by reducing its pressure. Kathode rays exhibit differences in degree analogous to those of differently coloured lights; these differences can be exhibited by varying the pressure in the discharge tube, and observing the different amounts of deflection produced by a magnet. By reducing the pressure we get less deflectible rays; these are the least absorbed by ordinary matter, and are the easiest to investigate. X-rays are of this nature; they travel easily through air, and may be regarded as kathode rays which can only be very slightly affected by a magnet. They were probably present in Lenard's experiments, but must have been very faint, for the aluminium window was small and (on account of the pressure) not very thin. Prof. Lenard subsequently exhibited his experiments in the physical laboratory.

In the discussion which followed, Sir George Stokes maintained the view that the rays are due to projected matter. The inside of the aluminium window is bombarded by molecules of gas or by particles discharged from the electrode. Why should not this bombardment give rise to a corresponding projection of molecules from the outside of the window? It is not necessary to suppose that they pass through the window. We have an analogue in the electrolysis of copper sulphate between copper electrodes. If a third (idle) electrode is introduced between them, we find that copper ions are deposited on one side of it and removed from the other. The absence of diffraction effects and other properties favour the view that X-rays are due to sudden and non-periodic disturbances. Prof. Fitzgerald congratulated Prof. Lenard on his skilful investigation, and pointed out that, whereas Röntgen's experiments had soon been repeated by hundreds of observers, Lenard's earlier experiments were of such a difficult nature that no one had since repeated them. Although Hertz held that the kathode rays were due to ethereal vibrations, his own suggestion that their deflection by a magnet may be analogous to the Hall effect tells against this view; for the Hall effect only occurs when matter is present. Again, Hertz found support for his views in his remarkable discovery that a magnet was not deflected by kathode rays. He does not seem to have considered that corresponding to the direct conduction current in the tube there must be a reverse convection current outside. Would not this back current neutralise the effect of the first convection current? Or the explanation may simply be that the effect upon a magnet is so slight that we cannot detect it. Prof. J. J. Thomson gave an account of experiments, made by himself and Mr. E. Rutherford, on the laws of conduction of electricity through gases exposed to the Röntgen rays. These rays convert gases into conductors, and the gas retains its conducting power for some time after the rays have ceased to pass. When the gas is forced through a wire gauze or muslin strainer into another vessel, it still conducts; but filtering through glass wool removes the conducting power, and so does bubbling through water. It is remarkable that the passage of a moderate electric current through the gas entirely destroys the conductivity; even very small currents reduce it considerably. This seems to indicate that the conduction is electrolytic. A theory based on this assumption has been tested by quantitative measurements, and the results are in satisfactory accordance with the theory. For an E.M.F. of 1 volt per cm. the ionic velocity is between 1 mm.

and $\frac{1}{3}$ mm. per sec. (or of that order). There are extraordinary differences between the rates of leakage in different gases; roughly they follow a density law. Thus mercury vapour (which is one of the best insulators) is here found to become the best conductor. Chlorine, bromine, and iodine come next. Sulphuretted hydrogen conducts better than oxygen. But the rates depend on the slope of potential used, and the order may even be reversed (as in the case of air and hydrogen). Another remarkable result of the experiments is to show that the conductivity under the action of X-rays increases when the length of the column of gas between the electrodes is increased; this is intelligible on the electrolytic theory just referred to and is, indeed, required by it. Prof. Ayrton pointed out that a similar phenomenon is observed in arc lamps worked at a constant potential; when the length of the arc is increased, the current at the same time increases. Prof. Rücker made a preliminary communication on measurements of transparency of glass and porcelain to Röntgen rays, made by himself and Mr. Watson. A colour-patch photometric method was employed, in which the light produced by the rays on a phosphorescent screen was compared with light from an arc lamp which had passed through two thicknesses of cobalt glass. Assuming the law of inverse squares, it is found for glass that the intensity of the transmitted light is given by $I = I_0 (A + B^t)$ where I_0 is the intensity of the incident light and t the thickness of the glass. Certain kinds of china are almost as transparent as glass; but others, in the manufacture of which bone ash is used, are very opaque. This method of examination may prove of service to collectors of porcelain and china. Lord Kelvin made a preliminary communication on measurements (by himself, Dr. Bottomley, and Dr. Maclean) of electric currents through air at different densities down to one five-millionth of the density of ordinary air. At a distance of 1·5 mm. between needle-points an E.M.F. below 1000 volts produces no current. 2000 volts produces an appreciable current which increases rapidly from 2000 to 8000 volts. A curve having volts as abscissæ, and galvanometer readings as ordinates, is always convex to the axis of abscissæ. The above measurements were made at the ordinary pressure; at a pressure of one-thousandth of an atmosphere (0·75 mm.) a few score of volts would start a current. Dr. F. T. Trouton communicated the results of experiments on the duration of X-radiation at each spark, made by rotating a wheel between the discharge tube and a sensitive plate. The duration varies between 1/300th and 1/10,000th of a second, but the results are dependent on the nature of the plate used. Prof. S. P. Thompson read a paper on the relation between kathode rays, X-rays, and Becquerel's rays. Interesting experiments were described in which various screens and obstacles were introduced inside a Crookes tube. In one of these the discharge from a concave kathode was allowed to fall on a flat anti-kathode inclined at 45°, and then on to two aluminium wires as obstacles in front of the wall of the bulb. At a low degree of exhaustion kathode rays are produced which throw shadows of the wires on the bulb, but no shadow on a fluorescent screen outside. The position of the shadows on the bulb can be shifted by a magnet. At a high degree of exhaustion we get X-rays which throw shadows on a fluorescent screen outside. These are not shifted directly by a magnet, excepting that the magnet shifts the hot point of the kathode rays on the anti-kathode. At an intermediate degree of exhaustion both shadows can be seen simultaneously. The kathode shadows contract when the wires are electrified positively, and expand when they are electrified negatively; the X-shadows are not affected by electrifying the wires.

On Saturday the Section divided into two departments. In the department of Physics the Report of the Committee on the Comparison and Reduction of Magnetic Observations was presented. Prof. Rücker presented the Report of the Committee on Magnetic Standards. A survey instrument previously compared with Kew has been taken to three observatories and compared with the instruments at these. Prof. Rücker visited Falmouth, and Mr. W. Watson Valencia and Stonyhurst. The differences from Kew are given below:

	Falmouth.	Stonyhurst.	Valencia.
Declination	− 0·2 ...	+ 1·1 ...	± 0·0
H × 10^{-5} C.G.S. ...	− 18 ...	− 6 ...	+ 29
Dip	− 1′·6 ...	+ 2′·2 ...	− 1′·8

In the course of the adjourned discussion on Prof. S. P. Thompson's paper (read on Friday), Prof. V. Bjerknes stated that M. Birkeland (of Kristiania) had recently observed a discontinuous line spectrum of kathode rays produced by magnetic deflection. The rays are allowed to pass through an aperture in a metallic screen inside the tube, and their position, after deflection, is observed by means of the fluorescence on the wall of the tube. When the pressure is high only a single line is observed, but when the pressure is reduced new lines make their appearance. The spectrum is not continuous, as Lenard had supposed, but is discontinuous like the line spectrum of a gas. This supports the view that the rays are due to ethereal vibrations. The observations are rather difficult on account of flickering. Three or four bright lines are distinctly seen, but probably there are thirty or forty present. Prof. S. P. Thompson read a further paper on "hyper-phosphorescence"—the term hyper-phosphorescent being applied to bodies which, after due stimulus, exhibit a persistent emission of invisible rays not included in the hitherto recognised spectrum. In endeavouring to shorten the time of exposure in photographing with X-rays, the action of fluorescent substances, such as calcium sulphide, zinc sulphide, and fluoride of uranium and ammonium, was tested. The plates were found to become fogged by these materials, although they had been kept in the dark long enough for all visible phosphorescence to disappear. Even after being kept in the dark for six weeks calcium sulphide actively emits rays that affect a photographic plate. Experiments were made to test whether sunlight, or the light from an arc lamp, contains any radiation which will pass, like the X-rays, through opaque bodies. From an arc lamp, with an exposure of two hours, photographic shadows of pieces of metal were obtained through pine-wood several millimetres thick; but aluminium was quite opaque to everything radiated from the arc and to sunlight. Fluorescent substances were next placed on top of an aluminium plate below which was a photographic plate; and the whole was exposed to dull sunlight for several hours. Photographic action was found to have taken place (through the aluminium) behind the portions where uranium nitrate and uranium ammonium fluoride had been placed. These effects are inconsistent with a law enunciated by Stokes—but which he has since modified. When they were communicated to Sir George Stokes, he drew the speaker's attention to the remarkable results obtained by Becquerel in the same direction. The Becquerel rays differ from the X-rays in that they can be refracted and polarised; they are probably transverse waves of an exceedingly high ultra-violet order.

In the department of Mathematics a Report was presented on the G (r, ν) Integrals; also the Report of the Committee on Bessel Functions and other Mathematical Tables. Papers were read by the Rev. R. Harley, on results connected with the theory of differential resolvents; by Lieut.-Colonel A. Cunningham, on the connection of quadratic forms; by Mr. H. M. Taylor, on great circle sailing; by Mr. S. H. Burbury, on the stationary motion of a system of equal elastic spheres; and by Mr. G. H. Bryan, on some difficulties connected with the kinetic theory of gases.

On Monday the Section again met in two departments. In the Physics Theatre, Lord Kelvin gave an account of experiments made by himself, Dr. Maclean and Mr. Galt, on the communication of electricity from electrified steam to air; and also contributed a paper on the molecular dynamics of hydrogen gas, oxygen gas, ozone, peroxide of hydrogen, vapour of water, liquid water, ice, and quartz crystal. Taking hydrogen and oxygen and their compounds first, it is assumed that there are two kinds of atom, h, o, with the distinction that the force between two h's and the force between two o's and the force between an h and an o are generally different. The mutual force between two h's is always the same at the same distance; so is the force between two o's and between an h and an o. The atoms are considered as points acting on one another with forces in the lines joining them; no further assumption is made beyond the conferring of inertia upon these Boscovich atoms. It is shown that the known chemical and physical properties of the substances named can be explained by making H consist of two Boscovich atoms (h, h) and O of two others (o, o). This makes H_2 consist of four h's at the corners of an equilateral tetrahedron, and O_2 a similar configuration of four o's. It naturally shows ozone as six o's at the corners of a regular octahedron; and peroxide of hydrogen as a tetrahedron of h's symmetrically placed within a tetrahedron of o's. It makes H_2O (gaseous) consist of two o's, with two h's attached to one of them and two other h's to the other; the h's of each o getting as near to the other o as the mutual repulsion of the h's allows. Models of this configuration and of the modification which it experiences in the formation of ice-crystals were shown; also of right- and left-handed quartz molecules and rock-crystal. The crystalline molecule of quartz is supposed to consist of three of the chemical molecules (OSiO). Mr. E. Rutherford exhibited, by a number of interesting experiments, a method of detecting electro-magnetic waves. The detector consists of a group of fine steel wires about 1 cm. long, insulated from each other by shellac. These are first magnetised, and then inserted in a coil of many turns of wire provided with a suspended magnet and mirror. The passage of Hertzian waves alters the magnetism of the group of magnets, and shifts the position of the spot of light. For long waves the detector is very sensitive, and has been found to respond to waves produced half a mile away (with houses between); but for short waves a coherer is much more sensitive. The method has been used for measuring the resistance of a spark-gap: for short sparks this is very slight, but increases much more rapidly than the length of the gap. The apparent resistance of iron wires to Hertzian waves is found to be from 10 to 100 times that for steady currents. Prof. J. Chunder Bose exhibited a very neat and compact apparatus for studying the properties of electric waves. With this he has verified the laws of reflection and refraction, determined refractive indices and wave-lengths (by curved gratings), and exhibited polarisation and double refraction by pressure and unequal heating. The gratings used consist of tinfoil strips on ebonite. Between crossed gratings tourmaline exhibits little or no depolarising effect; the difference of transparency for the two vibrations at right angles is nothing like what it is for light. Very good depolarisation is produced by beryl and by serpentine; the latter makes a good electrical tourmaline. So also does a block of jute compressed by hydraulic pressure. Vegetable fibres and locks of human hair produce very striking polarisation effects, the vibrations along the fibres being absorbed, and those at right angles transmitted.

Department II. met in the Physics class-room to consider reports and papers on Meteorology. Reports of four Committees were submitted: on Meteorological Observations on Ben Nevis; on Solar Radiation; on Seismological Observations; and on Meteorological Photographs. Mr. A. W. Clayden's report on the application of photography to the elucidation of meteorological phenomena stated that the work of the Committee during the past year had been almost entirely confined to the determination of cloud altitudes by the photographic method. The two observing cameras are stationed 200 yards apart, and are electrically connected by telegraph wires. Exposures of quarter of a second and less are used. Each negative contains an image of the sun. The altitude and azimuth of this are first determined, and the coordinates of a selected point in the cloud-image are measured with reference to this. Among the greatest altitudes measured are the following (in miles):—Mackerel sky, 7·25; cirro-stratus, 9·63; cirrus, 11·62; upper level cirrus, 17·02. The results show that clouds forming exhibit a general tendency to rise, and this is also true of the ascent of general cloud-levels towards the early afternoon. Papers were read by Prof. Rambaut, on the effect of refraction on the diurnal movement of stars, and a method of allowing for it in astronomical photography; by Mr. G. H. Bryan, on the sailing flight of birds; by the Rev. R. Harley, on the Stanhope arithmetical machine of 1780; and by Mr. A. L. Rotch, on the exploration of the upper air by means of kites.

In the adjourned discussion on Prof. Bose's paper, on Tuesday, Prof. Oliver Lodge exhibited the coherer, "copper hat," &c., which he had used in studying electric waves some three years ago. He characterised his apparatus as being rather unmanageable and very cumbersome as compared with that of Prof. Bose; but members who were present at the Oxford meeting will remember with gratitude Prof. Lodge's interesting address, and the very successful experiments with which it was illustrated. Mr. W. H. Preece made a brief statement as to telegraphy by Hertzian vibrations. Signals have been transmitted (by Signor Marconi, working with Mr. Kempe) across a distance of one and a quarter miles on Salisbury Plain; further experiments are to be made on the Welsh hills. Reports were submitted by the Committee on Electrolysis and the Electrical Standards Committee. At the Ipswich meeting (see NATURE, September 26, 1895) the choice of a thermal unit was referred to this Committee, which has since communicated with physicists in various foreign countries on the matter. For many purposes heat is most conveniently measured in ergs. The name Joule has been given to 10^7 ergs. A certain number of Joules may be selected as a secondary or practical thermal unit, and called a Calorie. According to the best determinations made, 4·2 Joules are required to raise the temperature of 1 gm. of water from 9°·5 C. to 10°·5 C., measured by a hydrogen thermometer. The Committee recommend that this be adopted as the secondary thermal unit. More accurate determinations of J, and of the variations of the specific heat of water, may necessitate a slight alteration in the mean temperature at which the rise of 1° takes place; but the definitions and the number (4·2) of Joules in a Calorie would otherwise remain unaltered. It is now proposed to issue a circular requesting international co-operation and agreement. Mr. W. N. Shaw read a paper on the total heat of water. Rowland's measurements give us data for finding the specific heat of water from 0° to 35°; and his measurements, together with those of Regnault, enable us to calculate it from 100° to 180°. What is now needed is a series of determinations from 35° to 100°. Mr. E. H. Griffiths exhibited a special form of resistance box (which admits of easy recalibration of all the coils in the box without requiring any other special instruments), and briefly communicated the results of his measurements of electrical resistance. It is of extreme importance that no shoulders should form on the brass plugs. Standard coils of the B.A. pattern (with wires imbedded in paraffin) only acquire the temperature of the surrounding medium very slowly; it is impossible to make accurate determinations with them when the temperature of the room differs from that of the bath by more than the fraction of a degree. In Mr. Griffiths' box all the coils are of naked wire wound on mica, and immersed in a hydrocarbon oil which is stirred from the outside. Mr. S. A. Sworn communicated the results of long and careful researches on absolute mercurial thermometry, and emphasised the importance of capillary corrections.

On Wednesday the Section again divided into two departments. In the Physics class-room the Report of the Committee on the sizes of pages of periodicals was presented, and papers were read by Mr. W. H. Preece, on disturbance in submarine cables; by Mr. W. M. Mordey, on carbon megohms for high voltages, and on an instrument for measuring magnetic permeability; by Mr. A. P. Trotter, on a direct-reading form of Wheatstone Bridge; and by Prof. F. Bedell, on the division of an alternating current in parallel circuits with mutual induction.

In the Physics Theatre Prof. J. E. Keeler described his method of measurements of the velocity of rotation of the planets by the spectroscopic method. Profs. Elster and Geitel described their investigations as to the cause of the surface colourisation of colourless salts (KCl, NaCl) by the kathode rays discovered by Goldstein. In this process the inside of the exhausted tube becomes coated with a layer which looks as if it might be metallic potassium or sodium. If so, it should be incapable of retaining a negative charge under the influence of violet light; this was tried, and found to be the case. In the case of rubidium and cæsium, gas-light was enough to cause leakage. But Goldstein finds that the salts retain their superficial tints in air for months; so the effect can scarcely be due to free alkali-metals on the surface. Probably the molecules of the metal are driven by the kathode rays into the salt, forming a solid solution in van 't Hoff's sense. It has been shown that the salts become alkaline after kathodic radiation, and this indicates that chlorine has been driven off. No chemical test has shown the presence of free chlorine; but this is not surprising when we consider the difficulty of proving its presence after light has acted upon silver chloride. A paper by Mr. J. Burke, on change of absorption accompanying fluorescence, dealt with a number of experiments made with the view of detecting whether the coefficients of absorption of uranium glass, and some other substances for the rays they emit, are altered in the act of fluorescence. The experiments, which were described at length, showed that a marked difference existed in the two cases, the absorption being greater when fluorescing and when not. Comparisons were made photographically as well as photometrically. Mr. W. Barlow read a paper on homogeneous structures and the symmetrical partitioning of them, with application to crystals.

The interest of the sectional meetings was much enhanced by the discussions following the papers, in which the President, Lord Kelvin, Sir George Stokes, and Prof. G. F. Fitzgerald frequently took part. So also did Prof. Oliver Lodge, who placed at the disposal of the Section all the conveniences of his lecture-rooms and laboratories, and also attended to the comfort and convenience of members in other ways.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

Cambridge.—By the resignation of Dr. A. Sheridan Lea, F.R.S., the University Lectureship in Chemical Physiology is vacant. Candidates are instructed to send in their applications to the Vice-Chancellor not later than October 19.

Mr. W. T. N. Spivey, of Trinity College, has been appointed Jacksonian Demonstrator of Organic Chemistry, in succession to Dr. A. Scott; and Mr. Stanley Dunkerley has been appointed Demonstrator in Mechanism and Applied Mechanics, in the place of Mr. Dalby.

The following candidates have passed the Examination in the Science and Art of Agriculture, and are entitled to receive the University Diploma:—W. Burkitt, T. R Robinson (Downing), J. T. Smith (Downing), J. P. Wilton.

The King of the Belgians has presented to the Museum of Zoology a series of casts from the famous Wealden *Iguanodon bernissartensis* preserved in the Royal Museum of Natural History at Brussels, constituting an entire skeleton. This has been mounted in the Comparative Anatomy Lecture Theatre, standing erect; it measures 15½ feet in height, and over 23 feet horizontally. The group of *Dinosauria* has hitherto been unrepresented in the Cambridge Museum.

The election to the Professorship of Surgery, vacant by the death of Sir George Murray Humphry, has been postponed till after the middle of the term. This will enable new arrangements to be made as to the tenure and the emoluments of the chair. Dr. Joseph Griffiths is to carry on the official duties of the Professorship in the interval.

The London School of Medicine for Women has received a gift of £1000 from a lady who a short time since attended as a student some of the classes held in the school. The interest on this sum is to be divided between bursaries to promising students, and an annual contribution to the library and common room funds. The Helen Prideaux prize, value £50, has been awarded to Miss Edith Knight, M.B. (London), for an essay on the Pseudo-Bacillus of Diphtheria, and its relations to the Klebs-Lœffler Bacillus. The research work upon which the essay is based was carried on in the laboratory of the Institute of Preventive Medicine, Great Russell Street.

For the following announcements of extended opportunities for scientific work in America, we are indebted to *Science*:—Mrs. Edward Roby, Mr. E. A. Shedd and Mr. C. B. Shedd have offered the University of Chicago a large tract of land around Wolf Lake and the channel connecting it with Lake Michigan, for the purpose of a lake biological station, and it is also understood that they will erect the buildings for the purpose if the offer is accepted. The gift is valued at £100,000.—The Lewis Institute, the new Chicago school of technology, the foundation-stone of which was laid two years ago, has now been dedicated. The late Allan G. Lewis left, in 1877, £100,000 for the purpose, which has now accumulated so as to make the value of the endowment £333,000.—The Ohio State University is now erecting two new buildings, viz. Townshend Hall, for the accommodation of agriculture and agricultural chemistry, to cost £15,000; and a hall for physiology, zoology, and entomology, to cost £7000.

The following are among the entrance scholarships in science awarded at the London Medical Schools:—Guy's Hospital Medical School: Myers Coplans, scholarship £150; John Ford Northcott, scholarship £60. London Hospital Medical College: Epsom Scholarship, £126, Mr. E. F. Fisher; Price Scholarship in Science, £120, Mr. H. E. Ridewood; Entrance Science Scholarship, £60, Mr. A. B. Lindesey; Entrance Science Scholarship, £35, Mr. C. E. Ham; Price Scholarship in Anatomy and Physiology, open to students of the Universities of Oxford or Cambridge, £60, Mr. E. W. A. Walker. St. Mary's Hospital Medical School—Natural Science Scholarships: £105, Mr. C. C. C. Shaw; £52 10*s*., Mr. W. J. Morrish; £52 10*s*., Mr. J. Gay-French; University Scholarship, £52 10*s*., Mr. A. G. Witson. St. Thomas's Hospital—Entrance Scholarships in Natural Science: £150, Alfred Barton Lindsey; £60, Robert Ellis Roberts; Entrance Scholarship for University Students, £50, Mr. Raymond J. Horton Smith, of St. John's College, Cambridge.

SOCIETIES AND ACADEMIES.

Paris.

Academy of Sciences, September 28.—M. A. Cornu in the chair.—Cryoscopy of precision; application to solutions of sodium chloride, by M. F. M. Raoult. The data given for weak solutions of common salt show that the expression previously proposed by the author, $C_1 = C_0(1 + q)$, where C_1 is the apparent lowering of the freezing-point, C_0 the true lowering, and q a very small constant (·002), holds within the limits of experimental error. The criticism of this expression by M. Ponsot is thus shown to be incorrect.—Observations of the Brooks comet (September 4), made with the Brunner equatorial, and of the Giacobini comet, made also with the large Gautier telescope at the Observatory of Toulouse, by M. F. Rossard.—Observations of the Giacobini comet (September 4), made at the Observatory of Lyons, by M. G. Le Cadet.—Solar observations made at the Observatory of Lyons during the third quarter of 1896, by M. J. Guillaume.—Sun-spots in relation to time, by M. Marcel Brillouin.—On the laws of reciprocity, by M. X. Stouff.—On the distribution of deformations in metals submitted to strain, by M. G. Charpy. A reply to a paper on the same subject, by M. Hartmann.—On the absorption of ultra-violet light by crystallised bodies, by M. V. Agafonoff.—On a spectrum from the kathode rays, by M. Birkeland.—On the existence of acid properties of nickel dioxide, by M. E. Dufau.—Researches on double bromides, by M. R. Varet.—On the immunity conferred by some anti-coagulating substances, by MM. Bosc and Delezenne.—On the presence of the agglutinating property in the plasma, and other liquids from the organism, by MM. Ch. Achard and R. Bensaude.—Influence of rest, physical exercise, intellectual work, and the emotions upon the capillary circulation in man, by MM. A. Binet and J. Courtier.—On the structure of the body-wall of Plathelminthus parasites, by M. Léon Jammes.—On the existence of "epitoque" forms in Annelids, by MM. F. Mesnil and Caullery.—Experiment establishing the preservation of venomous properties of the venom of serpents, by M. P. Maisonneuve.—On the results of researches on mineral coal recently made in Siberia, by M. Venukoff.

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