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Chas. L. Camp
Sept. 1928

Anatomy of the
Nervous System of *Rana pipiens*

J. Wyman

Washington
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Sketch of Lyman

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[ACCEPTED FOR PUBLICATION, MAY, 1852.]

PROFESSOR JEFFRIES WYMAN.

a branching tree. These buds, no doubt, make you think of something you have seen before—the yeast-babies—yes, these are the *baby-hydræ*. Soon their fingers begin to grow; then they loosen themselves from the old mother hydra, and begin to “fish for themselves.” The next time you go wading, you must try and capture some of these

OWLEDGE.

FIG. 42.—OLD HYDRA AND YOUNG ONES.

wonderful little creatures, and see if you can find all that I have described without my help. You are now, I trust, opening your eyes to the great world of living things all around you, in which you have lived and played, as I lived and played—*blindfolded*. And, when once your eyes are really open, wide, there is no telling what wonders they may behold.

Y S T E M

SKETCH OF DR. JEFFRIES WYMAN.

By BURT G. WILDER,

PROFESSOR OF ZOOLOGY IN CORNELL UNIVERSITY.

N S.

WITHIN a year, science has lost two of her greatest leaders, Louis Agassiz and Jeffries Wyman. With the life, the works, and the appearance of the one, all are familiar. But the other was hardly known outside of strictly scientific circles. He rarely gave popular lectures, and never wrote any thing that attracted general attention. Yet his influence upon the progress of science in this country has been very great, and he had for years been regarded by all as the highest anatomical authority in America, and the compeer of Owen, Huxley, and Gegenbauer, in the Old World.

D.

JEFFRIES WYMAN was born at Chelmsford, near Lowell, Massachusetts, August 11, 1814. His father was a physician, as is his surviv-

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ing brother. He was prepared for college at Phillips (Exeter) Academy, entered Harvard University in 1829, and was there graduated. During his last year in college he had an attack of pneumonia, which nearly proved fatal; this doubtless predisposed him to the pulmonary weakness from which he suffered during the latter part of his life, and from which he died on the 4th of September, 1874, at Bethlehem, New Hampshire.

Soon after his graduation he entered the Harvard Medical School, and, in 1836, became "house medical student" in the Massachusetts General Hospital.

In 1837 he received the degree of M. D. His graduation thesis was upon the eye, and accompanied by drawings. It does not appear to have been published, but, in September of the same year, the *Boston Medical and Surgical Journal* contained a paper by him upon the "Indistinctness of Images formed by Oblique Rays of Light." Soon afterward he became Demonstrator of Anatomy in the Medical School under Prof. J. C. Warren, whose chair he was destined afterward to fill.

In 1839 he accepted the curatorship of the newly-founded Lowell Institute. Two years later he delivered therein his first course of public lectures (of which no report has come under our notice), and with the money so earned went abroad for a year to pursue his medical and scientific studies under the great European masters. He had already, since 1838, published, in the *American Journal of Science*, several brief papers upon anatomical and physiological matters.

In 1843 there were published, in the *Journal of the Boston Society of Natural History*, anatomical descriptions of two gasteropod mollusks (*Tebennophorus Carolinensis* and *Glandina truncata*). Likewise a paper on the chimpanzee (*Troglodytes niger*), in which, with characteristic modesty, his account of its organization (though subversive of some of Owen's previous conclusions) is subordinated to Dr. Savage's remarks upon its habits and external characters. The same year he was appointed Professor of Anatomy in the Hampton-Sidney Medical College, at Richmond, Virginia. During his four years' stay his contributions to science included some notes upon fossil remains of vertebrates, and longer papers upon the blind fish of the Mammoth Cave and the teeth of the gar-pike (*Lepidosteus*). The latter paper is illustrated by microscopic sections, showing the close resemblance of the gar-pike's teeth to those of the fossil batrachian *Labyrinthodon*. The article closes with the suggestion that some of the separate teeth then referred by Owen to the latter genus might really belong to Lepidostean forms. This paper alone, though little known and never quoted by its author, would serve to show what manner of man was rising in America.

In 1847, at the age of thirty-three, he was chosen to the Hersey Professorship of Anatomy, at Cambridge. The year of his inaugura-

tion was signalized by his account of the gorilla, based upon specimens forwarded to him by Dr. Savage. This was the first scientific description of the new *Troglodytes*.

From that time forward his scientific progress was rapid and unbroken. He collected, he investigated, he lectured, he wrote. His admirable course of lectures upon Comparative Physiology, before the Lowell Institute, in 1849 (the report of which in pamphlet form has long been out of print), soon caused him to be regarded as the foremost among American anatomists and physiologists.

During this period, and indeed until within a few years of his death, Prof. Wyman published frequent brief notices of new animals, of points of structure and function, the value of which is in no way to be measured by their length. Almost any one of them would have served a less modest man for an extended memoir, while several contain the elements of interesting popular articles. So far from this, Prof. Wyman seemed to attach little personal importance to them, rarely referred to them, or took any pains to have them reproduced elsewhere. Many were, however, copied into European journals.

His first extended paper was "On the Nervous System of *Rana pipiens*" (the bull-frog). It covers fifty quarto pages, with two plates, was published by the Smithsonian Institution in 1853, and should be in the hands of every student of either human or comparative anatomy, as the clearest introduction to the most complex of animal structures.

Somewhat similar to the last, not quite so long, but even more replete with fact and philosophy, is the "Observations on the Development of *Raia batis*" (a skate), published by the American Academy of Arts and Sciences in 1864. This was based upon few materials, but sufficed to convince him, and all naturalists, that the skate ranks higher than the shark, since the latter retains through life a general form resembling one of the stages through which the former passes during its development.

Those who knew Wyman's nature may well imagine how he shrank from any thing like a discussion of two great questions upon which so much has been written during the past fifteen years, namely, the "Origin of Species" and "Spontaneous Generation." But, aside from his natural desire to know and teach the most correct doctrine upon these subjects, his prominent position made it imperative that he should consider them carefully. Respecting evolution, he evidently felt, with Prof. Gray, that, "upon very many questions, a truly wise man remains long in a state of neither belief nor unbelief; but your intellectually short-sighted people are apt to be preternaturally clear-sighted, and to find their way very quickly to one or the other side of every mooted question." In 1863 he wrote as follows: "We must either assume, on the one hand, that living organisms commenced their existence fully formed, and by processes not in accordance with

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the usual order of Nature, as it is revealed to human minds, or, on the other hand, that each species became such by progressive development or transmutation; that, as in the individual, so in the aggregate of races, the simple forms were not only the precursors, but the progenitors of the complex ones, and that thus the order of Nature, as commonly manifest in her works, was maintained."

No one can help seeing that he inclined toward belief in the general doctrine, but he neither indorses "Darwinism" nor denounces those who find themselves unable to accept "derivation" in any sense.

Regarding the appearance of organisms *de novo*, he never allowed himself to express a final opinion. He published two papers embodying the results of numerous and accurate experiments, and, we have reason to know, was still continuing his observations at the time of his death.

The general question to which Prof. Wyman gave most attention, until called from it by the Archæological Museum, was that of Organic Symmetry, especially as manifested in the limbs. Accepting the usual belief in an homology of the front and hind limbs, he associated therewith the idea first put forth by Oken, that the two ends of the body are symmetrical, or reversed repetitions of each other, as are the right and left sides. The application of this doctrine to the limbs makes the ulna the homologue of the tibia, the radius of the fibula, and the thumb of the *little-toe*, instead of the great-toe, as ordinarily believed.

So radically does this interpretation of "intermembral homologies" differ from that of most anatomists, that it is not strange that its acceptance is, at present, confined to a very few (Foltz, in France, and, in this country, Dana, Coates, Folsom, and the writer). But we are encouraged by the reflection that our leader never gave even a qualified assent to any doctrine which did not prove to be in the main correct.

Upon no other single problem did he bestow so much thought. And, as may be inferred, it is in his treatment of this question that his peculiar characteristics appear. In the adoption of new ideas he manifested a wise caution, which, contrasted with the haste of others less well informed, illustrates the maxim, "Fools rush in where angels fear to tread." We recall his freedom in discussion with his students and his kindness in aiding their advancement, even to his own apparent detriment; his modesty, occasioning a lack of reference to his own papers or to unpublished investigations; his critical acumen, which was the more searching and useful from its entire freedom from personality; and, finally, here shine forth in their greatest brilliancy those rare qualities which enabled him, when occasion required, to overlook the delusive charms of teleology, though upheld by popular interest and theological authority, and to regard her plainer but more

reliable sister, morphology, supported by relative position and mode of development.

In 1866 Prof. Wyman was named one of the seven trustees of the Peabody Museum of American Archæology and Ethnology, and became curator. For this work he was peculiarly fitted, both by nature and by his extensive observations upon crania; and his frequent investigations of shell-heaps, etc., during the trips to Florida, which his health had of late years forced him to make. Our space will not permit even a brief sketch of his labors in this new field; the results are modestly recorded in his annual reports. At present, the Museum is very extensive and admirably arranged. Had Prof. Wyman been spared for another ten years, one can hardly predict its importance. Of this, and of his own anatomical collections, the value is wholly out of proportion to the size or actual cost in money, for they represent the constant and skillful labor of a great anatomist during a quarter of a century. The label upon every specimen tells the truth so far as he knew it; and in the descriptive catalogues are rich treasures of fact and thought as yet unrevealed.

Prof. Wyman always shrank from public notice, and from positions in which this was involved. He attended several meetings of the American Association for the Advancement of Science, and served therein as president, treasurer, and secretary. But his communications were few, and comparatively unimportant. He was a member of the American Academy of Arts and Sciences, and was named by Congress one of the original fifty members of the National Academy of Science, but soon resigned. In strong contrast with his slender relations with these organizations is his record in connection with the Boston Society of Natural History. He early became an ardent member, served as secretary, and as curator of several departments, and in 1856 became president. This office he held until 1870, when he offered an unqualified resignation.

Meagre as is the above account of his outer life, we shrink yet more from any such estimate of his abilities and his personal character as the present occasion will permit. Admired and trusted by his associates, by the younger naturalists he was absolutely adored. Ever ready with information, with counsel and encouragement, so far from assuming toward them the attitude of a superior, he on several occasions permitted his original observations to be more or less merged within their productions. The universal regard in which he was held by them is, in the writer's case, intensified by the sense of peculiar obligations, which might cloud his judgment of any ordinary man; but to no man more fitly than to Wyman could be addressed the lines:

"None knew thee but to love thee,
Nor named thee but to praise."

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Nor was any criticism ever made upon him, from any quarter, other than upon his extraordinary freedom from personal ambition, and his aversion to public notice or display.

Wyman's anatomical work was absolutely free from zoological bias, and his statements were always received as gospel by both parties to a controversy. He might not tell the whole truth, for he might not see it at the time; but what he did tell was "nothing but the truth" so far as it went. The hottest partisan felt that a figure or description of Wyman's was, so far as it went, as trustworthy as Nature herself.

Without brilliancy, Dr. Wyman combined qualities rarely found in the same individual. No man of our time has surpassed him in the love of Nature for its own sake, free from the hope of position, power, or profit; in keenness of vision, both physical and mental; in absolute integrity, with the least as well as the greatest things; in industry and perseverance; and in method, whether for the arrangement of collections, or the presentation of an idea. And if to these had been adjoined a tithe of the ambition displayed by smaller men, and had his health and strength been at all equal to his mental powers, no one can doubt that his attainments, his productions, and his reputation, would have been surpassed by none of his contemporaries.

However much we may, for our own sakes, regret that such was not the case, we know that into his mind never entered the shadow of bitterness. His recognition of others' labors was full and generous; his mind was upon the facts and principles of Nature, and regarded not the medium through which they were obtained; and if he ever prayed for health and strength, it was surely not for his own advancement, but because he felt within himself the desire and the ability to learn and to teach the truth.

Dr. Wyman's reputation was less wide than that of some others; but it was deeply rooted. As the years roll on, and as the final estimate is made of the value of what has been done in this century, we may be sure that the name of Jeffries Wyman will stand high among those who have joined rare ability and unwearied industry with a pure and noble life. To use his own words upon a like occasion, "Let us cherish his memory and profit by his example."

SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.

A N A T O M Y
OF
THE NERVOUS SYSTEM
OF
R A N A P I P I E N S.

BY
JEFFRIES WYMAN, M. D.

[ACCEPTED FOR PUBLICATION, MAY, 1852.]

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ERRATA.

Page 20, line 25, for "detached," read "detected."

" 23, " 32, " "Bdelostoma," read "Bdellostoma."

" 44, " 1, " "connected," read "covered."

ON
THE NERVOUS SYSTEM
OF
RANA PIPIENS, LIN.

THE following memoir comprises an anatomical description of the nervous system of a single species of Batrachian Reptiles, one of the largest existing representatives of the Anourous group. The peripheral portion especially is described somewhat in detail; likewise some of the changes which it and the nervous centres undergo during the process of metamorphosis. A comparison is made between the temporary conditions of some of the organs, as observed in the young, with the permanent conditions found in the class of Fishes, from which it appears that there exists a more complete analogy between some of the anatomical conditions of this class and the larvæ of Batrachian Reptiles, than has been generally recognized.

In drawing up the descriptive details of this memoir, there are many which have been already noticed in other and allied Reptiles; nevertheless, they are drawn from a species whose anatomy has not as yet been fully described, and which in some respects differs from that of the closely allied species; it is therefore probable, that the want of agreement between the results contained in this memoir and those of other anatomists whose works are quoted, is dependent upon specific differences.

In the details relating to the cranial nerves, there are some facts noticed, which have not only a bearing on their physiology, as in the case of the facial nerve, but upon the philosophical anatomy of the nervous system, and the reduction of all of the cranial nerves, except those connected with the organs of the special senses, to the common spinal type.

The nervous system of Batrachian Reptiles is worthy the attention of the anatomist, on account of the great simplicity of its structure, presenting a condition intermediate between the two extremes of the Vertebrate series, as exhibited by that of the higher Mammals, on the one hand, and that of the Cyclostome Fishes and

Amphioxus, on the other. The spinal chord in the Anourous species exhibits the general peculiarities of the division, and in addition the enlargements corresponding with arms and legs; while the brain is so far reduced in the relative proportion of its different parts, and so far stripped of the "accessory organs of perfection," as to enable the student to obtain with ease a clear conception of the general plan, a conception always so difficult to acquire when studying the brain of Mammals or of Man. In these, the cerebrum and cerebellum so far transcend all the other organs of the encephalon, that the parts which in a morphological point of view are of equal value have been frequently overlooked, as forming either integral parts or primary subdivisions. In Frogs, in common with the lower Vertebrates, while no one part takes an excessive development, there is at the same time no one of the fundamental ones either wholly deficient, or so far reduced as to deprive the general plan of any of its more important features.

In making a dissection of the cerebro-spinal axis, when the canal in which it is lodged is laid open, one of the peculiarities which first attracts the eye is the existence of a whitish substance deposited in a somewhat irregular manner, but principally on the sides and around the veins, extending through the whole length of the canal and into the cranium, where it is especially abundant in the neighborhood of the optic lobes. Occasionally it will be found in such quantities as materially to embarrass the anatomist in his dissections, and at other times only traces can be detected. Under the microscope this substance is resolved into vast numbers of minute crystalline forms, consisting of calcareous matter, and similar to those hereafter to be described in connection with the spinal nerves, where it is found lodged in peculiar capsules, and in which the quantity is more constant.

After the chord is completely exposed, one of its most striking features, when compared with the same part in other Reptiles, except Anourous Batrachians, is its shortness. (Plate II. Fig. 1.). The point at which the last pair of spinal nerves is given off is just beyond the middle of the trunk, that is, at about the seventh or eighth dorsal vertebra. Beyond this the chord is continued only in the form of a slender thread, which has been compared to a ligament, though it contains the microscopic elements of the chord, but at the same time giving off no nerves, and is lodged and terminates in the long and slender coccyx. In other Reptiles, on the contrary, in Saurians, Chelonians, Ophidians, and Urodel Batrachians, the chord is continued as such to the extremity of the spinal canal, giving off its pairs of nerves nearly opposite to the intervertebral foramina which correspond to them. While it has this exceptional shortness in the adult of the Anourous species, it is of great interest to notice the fact, that, in their embryonic condition, they conform more nearly to the general rule, as was long since shown by Serres,* by numerous other observers after him, and as will be seen in the sequel of these pages; nevertheless, as will be shown hereafter, this caudal portion does not conform precisely to the true spinal type. The subdivisions of the central axis into brain and spinal chord, and of these into subordinate parts, are enumerated in the following tabular view.

* E. R. A. Serres, *Anat. Comp. du Cerveau dans les Quatres Classes des Anim. Verteb.* - Paris, 1829.

CENTRAL AXIS.—PLATE I.

BRAIN.—FIGS. 1-9.

I. OLFATORY LOBES	A.
II. CEREBRAL LOBES	B.
III. CORPORA STRIATA	C.
IV. OPTIC THALAMI	D.
V. PINEAL BODY	E.
VI. PITUITARY BODY	F.
VII. OPTIC LOBES	G.
VIII. CEREBELLUM	H.

SPINAL CHORD.—FIG. 1.

I. MEDULLA OBLONGATA	I.
II. BRACHIAL ENLARGEMENT	L.
III. CRURAL ENLARGEMENT	N.
IV. COCCYGEAL PORTION	O.

With the exception of the corpora striata, which are lodged and concealed in the cavities of the cerebral lobes, all the parts above enumerated may be seen without dissection, from a merely superficial examination. When stripped of their membranes, and examined in a recent state, there is a striking contrast between the brain and chord as regards color; the first having a grayish semitransparent, almost gelatinous appearance, whilst the second is opaque and whitish, the latter color, however, being traceable to a certain extent in the interior of the cerebral masses. Black pigment-cells are to be seen scattered over the general surface of the brain and spinal chord, but are especially abundant about the optic lobes, which are much darker than the cerebral lobes.

SECTION I.—THE BRAIN.

I. *Olfactory Lobes*. (Plate I. Figs. 1-9, A.)—These form the anterior portion of the cerebral mass, but are so intimately connected with the cerebral lobes, that they might be supposed to form with them one and the same pair of organs, and have been sometimes described as such. The only mark of separation from the cerebral lobes is a slight constriction at the line of contact, visible both on the under and upper surface, though farther back in the latter than in the former; consequently, when seen from below, the olfactory lobes appear relatively larger than from above. A condition of things rarely met with, perhaps only in a few Anouros Batrachians, is the fusion of the right and left olfactory masses, with scarce a trace of any indication that they are double organs. In Toads they are likewise fused, but are separate in *Siren* and *Menobranchus*. (Fig. 5.) This union of the olfactory lobes, however, is analogous to what occurs in the cerebral lobes of Sharks and other Plagiostome Fishes, and in the optic lobes of the *Lepidosiren*, and as it seems in *Menobranchus*. Their fusion is a subject of additional interest, since it tends to show that they are developed from a single embryonic vesicle, and not from a pair of vesicles. If this statement be true, then we have the olfactory lobes arrested in their development, previous to the division of this vesicle. An analogous state of things is easily shown in a chick of the fourth day, where the optic lobes form a single vesicle, though they subsequently become double and widely separated from each other. In *Lepidosiren*, according to Owen, there is but one optic lobe, and that on the median line; we may therefore regard this last as the vesicle

undivided. The fusion, or rather the absence of separation, of the cerebral lobes of Plagiostome Fishes, is undoubtedly to be explained in the same manner.

It should be remembered that the olfactory lobes are not represented in the primitive divisions of the embryonic brain, but are either the result of a transverse subdivision, or perhaps of an offshoot in the form of a hernia from the cerebral lobes. Bearing this in mind, we have an explanation of the union of each olfactory with its corresponding cerebral lobes and with its fellow, in Frogs, which is simply the result of incomplete separation or of arrested development.

II. *Cerebral Lobes.* (Plate I. Figs. 1–9, B.) — Agassiz, in examining the brains of Fishes, has shown that those of the same natural families sometimes, and of genera often, affect forms which to a certain extent are characteristic, and something analogous to this has been observed by Blanchard to exist in the nervous system of Invertebrates. A comparison of the cerebral lobes of *Siren*, *Menopoma*, *Menobranchus*, *Salamandra*, *Triton*, and *Rana* (Plate I. Figs. 2, 4, 5), will show that in them there exist, though perhaps not strongly marked, certain general characteristic peculiarities, which consist mainly in having cerebral lobes with an elongated form, with sides nearly parallel when seen from above, the anterior being but slightly more narrow than the posterior extremity. In other Reptiles, the cerebral lobes have a more triangular form, the transverse diameter being much greater behind than in front. Measured on the upper surface, each cerebral lobe in the Bull-frog is about two and a half times longer than broad, and the breadth of the two lobes together does not exceed that of the medulla oblongata. They are laterally compressed, so that the height of each lobe is greater than its breadth, and its greatest elevation is at its posterior part. (Plate I. Figs. 3–7.) They are separated by a distinct fissure, which may be seen above and below, and which presents this interesting feature, that it extends quite through from the upper to the under surface, being closed in front, however, by the united olfactory lobes, and behind by the mesocerebrum; thus presenting the opposite state of things to that which exists in Rays and some Sharks, where the two are so completely fused, or, perhaps more correctly, have been so little subdivided, still retaining one of their embryonic features, as to have the appearance of a single lobe. This extended separation between the cerebral lobes, though but little noticed, certainly exists in many other Vertebrates. Cuvier speaks of it in Birds, where “it is apparent that they are distinct throughout their whole height, and that they are united to each other behind, near the anterior commissure of the brain.”* Bojanus, in his admirable figures of the anatomy of *Testudo Europæa*, represents a similar separation between the cerebral lobes, though it is not referred to in the descriptions of the plates. His Figs. 88 and 89 show the two hemispheres disjoined as far as the crura cerebri. Agassiz, in the *Anatomie des Salmonés*, Table V. Fig. 5, has represented a longitudinal section of the brain of *Salmo fario*, in which it appears that the “olfactory lobes” (cerebral lobes, cerebral hemispheres of other anatomists), as well as the “olfactory tubercles” (olfactory lobes of others), are likewise wholly separated from each

* Cuvier, *Leçons d'Anat. Comp.*, 3me edit., Tom. III. p. 113.

other. This complete separation of these lobes in the animals above referred to, is certainly an interesting anatomical feature, as bearing upon the physiology of the parts, and tending to prove the existence of complete duality of function; for it can hardly be supposed that two organs so completely separated could be any more mutually dependent than the two eyes or two ears; each is the seat of its own functions and processes, though the functions of the two sides are doubtless precisely similar.

The closing up in front of this fissure between the cerebral lobes, by the united olfactory lobes, leaves an opening through the brain from above downwards, and this might at first sight be compared to the ring which transmits the œsophagus in the Invertebrate animals. If this comparison be allowed, it would afford some support to the doctrine, which assumes a homology between the nervous centres of the Vertebrate and Articulate divisions of the animal kingdom. The question of the correctness of such a comparison will necessarily present itself in the course of the following descriptions, and the remarks we have to make upon it may be not improperly presented here.

Although frequent attempts have been made to homologize the nervous systems of Vertebrates and Articulates, yet in reality there seems to exist no correct basis on which the alleged homology may rest. Among the earlier advocates of this view were Gall and Spurzheim, but a more able advocate was found in Geoffroy St. Hilaire. Still more recently, the doctrine has been revived, at least in part. In the recent edition of his General and Comparative Physiology, Dr. Carpenter seems to recognize the homology of certain portions, at least, of the nervous systems of Articulates and Vertebrates, though in others he admits simply an analogy; after stating that there is nothing in the Articulates homologous with the cerebrum and cerebellum of the Vertebrates, he says, "The first subœsophageal ganglion, which has been likened to the latter (the cerebellum), being really *homologous*, as the distribution of its nerves abundantly proves, with the medulla oblongata."* In speaking of the spinal chord, he says, "It consists of a continuous tract of gray matter inclosed within strands of longitudinal fibres, and it may thus be regarded as *analogous* to the ganglionic chain of the Articulates." If there be any homology, it seems to us as if the whole nervous system of the Articulates, as far as it is developed, should be homologous with a corresponding portion of that of the Vertebrates. If the subœsophageal ganglion is homologous with the medulla oblongata, that which follows it should be homologous with the spinal chord. There seems sufficient ground for the belief, that all homology between the nervous systems of the two divisions is as much contraindicated, as between their skeletons or their muscular systems. If a true homology existed, we ought at least to have representatives from the Articulates and Vertebrates, in which the identity would be obviously proximate, if not absolute. But as yet there has been described no instance where the spinal chord, structurally considered, is fairly and distinctly represented in the Articulates, nor among Vertebrates any true ganglionic chain with an

* Gen. and Comp. Phys., 3d edit., p. 1017.

œsophageal ring through which the œsophagus passes. The existence of separate lateral halves of the spinal chord in the Vertebrate embryo has been adduced as evidence of identity. Has there, however, ever been seen an embryo of a Vertebrate in which there were developed on the lateral halves of the spinal chord itself, distinct and separate ganglionic masses united with the masses above and below them by nervous fibres only? It is true, as already stated, that in many Vertebrates distinct enlargements of the chord correspond with the attachments of the different pairs of spinal nerves; but still, in these instances, the chord never loses its vertebrate type; there is always at least, even in *Amphioxus*, an uninterrupted mass of cell substance occupying the entire length of its centre, and this substance in all other Vertebrates is inclosed in two half-sheaths of longitudinal nerve tubes. The likeness recognized between the subœsophageal ganglion and medulla oblongata is *physiological*, but not anatomical; and physiology, all philosophical observers agree, does not teach us homology. The wings of Birds and Insects, physiologically considered, are corresponding parts; but not so as anatomical structures. On the other hand, the tongue of the Giraffe, of the Woodpecker, the Chameleon, and the Lamprey, anatomically considered, are identical parts, are homologous with the organ ordinarily subservient to taste, but, physiologically studied, are appropriated to widely different uses. Thus the subœsophageal ganglion may be, as regards its functions, the analogue of the medulla oblongata, an analogy, however, which the pure anatomist, independently of experiment, would never discover.

Professor Owen, in speaking of the interspace in Fishes "produced by the divarication of the main lateral columns of the encephalon," through which passes the membranous tube (infundibulum) connected with the hypophysis, asks, "Is this vertical slit homologous with the encephalic ring perforated by the œsophagus of the Invertebrata?"* The homology in this case appears to be opposed by the fact, that the slit in question in the Fish opens *in front* of the optic lobes, which last, if there be any homology between the nervous systems of Vertebrates and Invertebrates, would be the homologues of the suprœsophageal ganglia which give off the optic nerves. The slit should therefore be behind, and not in front of these lobes.

It is contended that the homology between the nervous centres of Vertebrates and Articulates is contraindicated by the following facts:—1st. The brain and spinal chord are enveloped in a common sheath, the vertebral column and its contained membranes, and are never in the same cavity with the viscera, even in the embryo; while the ganglionic chain is lodged and developed in the common cavity with the organs of organic life. 2d. In Vertebrates the spinal chord is always on the back, and the ganglionic chain always on the abdominal side in the Articulates. 3d. One consists of a continuous mass of both tubular and vesicular structure, while in the other the vesicular structure is interrupted. 4th. The œsophageal ring, with the œsophagus inclosed, never exists in Vertebrates, but is always present in the Articulates, in common with nearly all other Invertebrates. 5th. The embryonic conditions of the two systems do not at any period clearly assimilate each other.

* Lectures on Comparative Anatomy, Vol. II., Fishes, p. 181.

6th. Two parts, to be homologous, must be structurally and morphologically similar, and not simply the seat of similar processes.

III. *Corpora Striata*. (Plate I. Fig. 7, C.)—The parts supposed to be homologous with these ganglia are but very imperfectly developed, and present themselves in the form of small nodules in the interior of the cerebral lobes, and will be again referred to in connection with the ventricles and the internal configuration of the brain.

IV. *Optic Thalami*. (Plate I. Figs. 1–9, D.)—Behind the cerebral lobes the encephalon becomes slightly contracted, and its breadth, as seen from above, is formed wholly by two solid bodies, separated from each other by a distinct fissure in front, but behind united by commissural fibres. (Fig. 6, D.) The fissure communicates with a cavity between them. Their position immediately behind the cerebral lobes, as well as their relation to the part next to be described, to the optic lobes and the optic nerves, indicates that they are the homologues of the thalami optici of Mammals and Birds.

V. *Pineal Body*. (Plate I. Figs. 2, 7, 9, 11, 12, E.)—This occupies its usual position between the optic thalami, is situated at their anterior extremity, and almost concealed by the cerebral lobes. It is a small reddish body, the presence of which is not easily determined, since it is covered with a loose areolar tissue, which unites it to the investing membranes, and consequently is usually torn off in removing them. It is sustained by a membranous pedicle, but has no “peduncles.” Its minute structure is quite different from that of the same part in the higher Vertebrates, and might reasonably lead us to doubt as to its homology; in truth, independently of its position, this would not be suspected. Under the microscope it has something of the form of a mulberry, and is highly vascular. Each of the rounded projections on its surface is supplied with a loop of a bloodvessel, all the loops being derived from two or three principal trunks. (Plate I. Figs. 11, 12.) Externally it is invested with a layer of ciliated epithelium. Within the epithelial layer, and apparently among the bloodvessels, are scattered rounded cells containing granules, and these bear a close resemblance to the ganglion cells of other parts of the brain. This corresponds with the description of the same part in Fishes, as given by Professor Owen. It is in them a constant appendage of the encephalon, “but is commonly only a vasculo-membranous pyramidal sac continued from the third ventricle. Some medullary matter mingles with the membranous walls in Clupeoid and Cyprioid Fishes.” *

The existence of vibrating cilia on the surface, and of vascular loops within, are points in which this body resembles the choroid plexus of the brains of Mammals as described by Valentin; but as its position is extra-ventricular, we have no authority for identifying it with that organ. The cilia on its surface seem to indicate that its function, in part at least, is to set in motion the fluids secreted by itself or some of the adjoining parts.†

* Owen, *op. cit.*, Vol. II. p. 180.

† *Comparative Anatomy of the Pineal Body*.—It exists, according to Cuvier, in all Fishes, in the form of a small globe of gray matter, very distinct in the common Eel and the Conger, less apparent in other

VI. *Pituitary Body*. (Hypophysis; Plate I. Figs. 1, 3, 7, 8, F.)—This organ is as universally present in the Vertebrate series as the preceding, and its function is equally unknown. In Frogs it forms a very distinct portion of the encephalon, is situated beneath the optic lobes at a short distance behind the optic nerves, and is of an oval form with its greatest diameter in a transverse direction; it has a short, hollow membranous infundibulum, which is its only attachment to the base of the brain, and is consequently easily separated by very slight force, when the orifice communicating with the ventricular cavity is easily seen. A body which has received the name of *tuber cinereum* is found between it and the decussation of the optic nerves, forms a slight projection from the under surface of the brain, and constitutes the floor of the third ventricular cavity; it is not, however, sufficiently well defined to be regarded as a distinct organ.

VII. *Optic Lobes*. (Plate I. Figs. 1, 2, 6, 7, 8, G.)—In consequence of their form and breadth, the optic lobes are the most conspicuous portions of the brain, and, after the cerebral lobes, the largest. They consist of a pair of oval ganglia flattened on their upper surface, their longest diameter being directed outwards and forwards, and on the median line, where the two come in contact and are united, they are flattened, as it were, by mutual pressure. When seen from beneath (Fig. 1, G), they make a prominent projection on either side of the pituitary body and the tuber cinereum. After the pia mater has been removed, the optic tract can readily be seen in its passage to the optic thalami and optic lobes. (Plate I. Fig. 1.)*

VIII. *Cerebellum*. (Plate I. Figs. 2, 3, 6, 7, 8, H.)—Immediately behind and in part covered by the optic lobes, is the cerebellum; which, when compared with the same organ in the higher Vertebrates, presents a more striking contrast than do either of the other cerebral masses with their respective homologues. In Batrachians generally, the cerebellum does not seem to have passed beyond the minimum of development for the class of Reptiles, an inferiority similar to that met with in *Petromyzon* and *Ammocætes* among Fishes. It consists of a flattened transverse band of cerebral substance, continuous on either side with the medulla oblongata; its posterior border is slightly elevated (Figs. 7, 8, H), and forms the

species, and is inserted between the "hollow lobes" (generally regarded as the optic lobes) and the "anterior (or cerebral) lobes," by two small, either vascular or membranous medullary chords. (*Leçons*, Tom. III. p. 135.) In the *Salmonidæ*, according to Agassiz, the pineal body consists of a plexus of very slender vessels interwoven and anastomosing with each other, so as to form a club-shaped mass attached to a slender pedicle. (*Anat. des Salmonés*, p. 132.) According to Serres (*Anat. Comp. du Cerveau*, Tom. II. p. 483), in *Squalus squatina* "it surpasses all the proportions which it is known to have in the other classes." He also states, that "it is universally present in Fishes, but, in order that it may be detected, it must be examined under water." In Tortoises it is much more distinct than in Frogs, is easily detected, but having apparently the same vascular structure that it has in Batrachian Reptiles. Its presence in Mammals and Birds is beyond a doubt, and in the former especially consists of a more solid mass, having many points of structural resemblance to other parts of the encephalon. The calcareous concretions which Soemmering, the Wenzels, Longet, and numerous other observers, have found to exist so often, perhaps in nearly every instance, in the human body, are seldom or not at all found in the other Vertebrates.

* For pathological facts and physiological inferences with regard to the optic lobes, see the description of the optic nerves.

anterior limit of the triangular opening of the fourth ventricle, and beneath it may readily be seen the passage from the fourth to the third ventricle. Attached to its posterior edge, and formed by the folding of the pia mater, is a vascular valve or plexus, which completely covers in this cavity. According to R. Wagner,* the cerebellum "consists, in naked Amphibia and Ophidia, of a hollow medullary layer." In the dissections of Frogs which I have made, I have in no instance been able to verify this statement; for it has always presented itself in the form of a solid body, though the central portion is more transparent than the cortical.

The low degree of the development of the cerebellum in Frogs naturally suggests to us an inquiry as to the nature of its functions, and likewise leads to the conclusion, that, whatever those functions are, they must, on analogical grounds, be supposed to have a low state of activity in comparison with the same organ in those animals in which it is proportionally more largely developed. The low development of this organ in Frogs and Cyclostome Fishes is certainly at variance with either of the more generally received theories entertained by physiologists of the present time; namely, those of Gall and Spurzheim on the one hand, and of Flourens on the other. It would be difficult to reconcile either of them, or perhaps any existing theory, with numerous other facts afforded by comparative anatomy, all of which tend to show a vast disproportion, at least, between the size of the cerebellum and the activity of the functions of which it is alleged to be the seat. As regards the theory of sexual instinct, this function is certainly not less strongly manifested in the Lamprey than in ordinary Fishes, as the Trout or the Herring; yet how widely different is the relative size of the organ in the two! Professor Owen has contrasted Lampreys with the Sharks, showing that the difference in the cerebellum of these animals is entirely disproportioned to any known distinction relating to the sexual instinct.† The well-known experiments of Leuret, though perhaps less extended than could be desired, are, as far as they go, wholly opposed to the hypothesis.

Although the experiments of Flourens and his followers tend to show a connection between locomotion and the cerebellum, disturbance of the former usually attending injuries inflicted on the latter, yet his theory that the cerebellum coördinates muscular motions is opposed by numerous anatomical facts, as well as by some of the results of pathology; for out of *ninety-three* cases of lesions of the cerebellum, Andral found but *one* to sustain the theory of Flourens. The necessity for coördinating motions in Frogs, animals moving with four legs, is as great as, if not greater than, in most Fishes, moving solely by the aid of the vertebral column, all their principal motions being produced by its flexion and extension. In *Petromyzon*, with its still more rudimentary cerebellum, we have the power of coördination as great, and muscular activity as intense, during the breeding season at least, when they stem the most rapid currents and ascend falls of water, as in the Trout, the Sucker, or the Pike, which have the cerebellum proportionally much longer. We will take one

* Elements of the Comparative Anatomy of the Vertebrated Animals, p. 150.

† Lectures on Comp. Anat. and Phys. of Vertebrated Animals, Part. II. p. 188.

more illustration of the inconsistency of this theory (and it equally applies to that of Gall and Spurzheim) with facts; we will contrast the organ in question, as it appeared to us in the recent dissection of a Porpoise (*Delphinus phocaena*) and of a Shark (*Carcharias obscurus*). Both of these animals are predaceous, both pursue their prey in the water, both are endowed with great rapidity of motion, both are capable of readily and suddenly changing their direction, and both move by the alternate flexion and extension of the vertebral column; I know of no reason for supposing that the power of coördination is materially different in the two; and in these instances the mass of the body was in the two nearly the same, and yet the cerebellum of the Porpoise is not only relatively, but absolutely, several times larger than the whole encephalon of any known Fish, however large.

In view of such important opposing facts, derived from comparative anatomy and pathology, and of the contradictory results of experiments, one cannot but entertain a doubt that the problem of the functions of the cerebellum is yet solved. The suggestion of Dr. Carpenter, that the middle lobe may be the seat of the sexual instinct, and the lateral lobes of the power of coördination, loses its force when it is remembered, that in Fishes, Reptiles, and Birds even, the lateral lobes either do not exist, or are in a rudimentary condition, entirely disproportioned to the function of coördination. If the size of the organ is any indication of its functional activity, the cerebellum is not proportional to the amount of muscular fibre set in motion, nor yet to the combinations of motions of which animals are susceptible.

SECTION II. — INTERNAL STRUCTURE OF THE BRAIN.

An indication of imperfect development of the brain in animals is often found in the existence of cavities in one or more of its principal masses. An immature condition of one mass, however, by no means involves that of all the others. In some Sharks the nearly solid cerebral lobes accompany a hollow cerebellum, and in other Fishes a solid cerebellum and cerebral lobes, as in the Cod, are associated with optic lobes, which are hollow. In Frogs, with the exception of the cerebellum and optic thalami, all the principal masses are hollow, and in this respect manifest but little progress beyond an embryonic condition. The cavities of the cerebral and olfactory lobes communicate freely with each other, though there is no communication between those of opposite sides. The two lobes above referred to, being developed from the same vesicle, do not manifest any separation from each other until some time after the tadpole leaves the egg, and subsequently the distinction between them is only indicated by a slight constriction. (Fig. 6.) The walls of the cerebral lobes are quite thin above and externally. On the inner wall may be seen in each ventricle two projections; the upper and longest corresponding with an external furrow, and which may therefore be regarded, perhaps, merely as a convolution (Fig. 7); and the lower an oval ganglionic body (Fig. 7, C), in which may be seen terminating some of the white fibres prolonged forwards from the spinal chord. This body is solid, and its position in the ventricular cavity, its connection with the white fibres, and its relation to the optic thalami, which are directly behind

it, are all strong indications that it is the homologue of the *corpus striatum*. Behind these bodies is an opening which communicates with the third ventricle (Fig. 8, L), and above this another directed towards and above the optic thalami, and which may therefore be regarded as the fissure of Bichat. The *third ventricle* exists in the form of a fissure between the optic thalami (Fig. 8, M), communicating posteriorly with the fourth ventricle, and above is covered over posteriorly only by commissural fibres. The *optic lobes* (Figs. 6, 7, 8, D) are hollow, and their cavities communicate freely with each other. On removing their upper walls we have brought into view two masses, which are seen from above in Fig. 6, and in section in Fig. 8, which nearly fill the cavity, allowing, however, a passage beneath and between them to the fourth ventricle.

The ventricles of both cerebral and optic lobes are lined with ciliated epithelium, which doubtless serves to keep in motion the secreted fluids of the ventricular cavities, a function in all probability performed by the cilia of the choroid plexus in the higher Vertebrates. Thus we have suggested to us again the old hypothesis of the motion of the fluids contained in the brain, not moved, however, by the so-called cerebral pulsations, but by an agency which, when the theory was first propounded on a purely hypothetical basis, was wholly unknown.

One of the more important features indicating perfection in the brain of the higher animals is the existence of commissures between its different segments on opposite sides. The corpus collosum, or great commissure between the cerebral lobes, does not appear to exist in or below the Marsupials, and the pons Varolii or cerebellar commissure is confined to Mammals. The nearly complete separation of the cerebral lobes in Frogs would seem to preclude the possibility of any thing like a corpus collosum passing from the one lobe to the other. The only commissural fibres which I have been able to trace are those between the optic thalami (Fig. 6, D), just in front of the optic lobes; also between the same parts in the base of the brain.

Although great labor has been expended in attempting to unravel the microscopic structure of the brain in Vertebrates, as yet but little has been accomplished beyond the mere demonstration of the histological elements and their general plan of arrangement. The existence of tubular fibres and of vesicular structure is admitted in the nervous system of both Vertebrates and Invertebrates, but the mode of combination, their precise anatomical relationship, is still unsettled; and until that relationship can be determined, but little progress can be hoped for in the explanation of the mode of the origin and transmission of nervous force. Its determination is no less important to the physiology of the nervous system, than the discovery of the circulation of the blood was to the physiology of respiration or nutrition. Some anatomists, as Hanover, describe the vesicular structure as consisting either wholly or in part of caudate cells, the prolongations of which are either the commencement or termination of nerve tubes; this view has also been more recently maintained by Wagner and Robin. Bidder has described and figured nerve tubes, which seem to dilate into ganglion corpuscles or nerve cells, and then revert to the condition of nerve tubes beyond the cell, so that the cell, accord-

ing to this view, is developed, not necessarily at the beginning or end of a tube, but in its course.* I have not been able to detect such a connection in any observations which I have made on the brains of Frogs. The thin walls of the cerebral lobes of these animals, especially when young, seemed to offer a favorable opportunity to test the correctness of this statement. If a piece, comprising the whole thickness of the upper part of the lobes above mentioned, be placed under the microscope, little else can be seen than the vesicular element, though the section is sufficiently transparent to be viewed through its whole thickness. Here and there a questionable tube may be found, but the principal structure, besides the cells, is that of the capillary vessels, which may be identified by their containing blood discs, and may be frequently traced dwindling into minute empty tubes, which are easily mistaken for nerve tubes. If a piece of a lobe which has been macerated in alcohol be transferred to turpentine, the preparation soon becomes transparent, when its minute structure can be determined. In the cerebral lobes of Frogs thus treated, spherical cells and capillary vessels are easily detected, but no nerve tubes. The longest portion of the whole mass obviously consists of cells, and, after repeated examinations both of adults and embryos, not one has been found presenting the caudate condition. Here, then, at least, we have an instance in which the cells and nerve tubes do not come together, — in which they are not immediately connected; and, as will be seen in the spinal chord, continuity is not necessary for the manifestation of nervous force, nor is contact even. In other parts, as the cerebellum, optic lobes, optic thalami, the tubes and cells are more or less intricately combined, the first forming an interlacement, in the meshes of which the cells are inclosed; but even here no continuity between the two was seen, — not a single instance in which a nerve tube arose from or terminated in a cell. The cells (Fig. 10, Plate I.) are quite uniform in appearance, from whatever part of the brain they may be derived. The only variation is that of size. The cell wall is quite thin, and so easily ruptured, that it sustains but little pressure, and, unless great care be taken to protect it, it will be found quite difficult to obtain a fair view of even a single one. Within, the cell contains numerous minute granules, which fill the larger portion of its cavity, leaving a thin transparent space around the circumference. The *nerve tubes*, whether from the base of the brain or from the chord, are varicose in nearly every instance; and whether this condition be accidental or not, when manipulated with the greatest care, whether viewed with or without pressure, even when perfectly fresh and almost living, they were never seen in any other condition. Every attempt to determine the mode of termination of the nerve tube was unsuccessful. If, however, the views of Wagner and some of the more recent writers be correct, — namely, that, before the nerves terminate, the “white substance of Schwann” disappears, so that the tube contracts and becomes invisible, except with the highest powers of the microscope, — we have in part an explanation of the difficulty. Wagner maintains that these minute tubes are lost on the walls

* Zur Lehre von dem Verhältniss der Ganglien-körper zu den Nerven-fasern. Neue Beiträge von Dr. F. H. Bidder. Nebst einem Anhänge von Dr. A. W. Volkmann. Leipzig. 1847.

of the cells. Such, however, cannot be the case in the cerebral lobes, since there are no nerve tubes except at the base of the brain, and these are entirely out of proportion to the cells above them.

Having failed to demonstrate the intimate connection between the tubes and cells, the following general arrangement of the two was nevertheless easily traced, and the more easily from the general absence of commissural fibres in the encephalic masses. The appearance which first of all attracts the eye is the strong contrast of color between the brain and the spinal chord, the first seeming almost gelatinous, and the second of an opaque white, a contrast depending upon the predominance of nerve tubes in the latter and of nerve cells in the former. The white fibres of the chord, as they pass forwards from the medulla oblongata, may be seen entering the different cerebral masses, as indicated in the plan. (Fig. 9, Plate I.) Some of the fibres forming the edge of the fourth ventricle can be traced into the cerebellum, where they extend towards the median line; but few of them reach the posterior edge of this organ, which has the gelatinous appearance of those parts which consist wholly or in a great measure of cells. Other fibres from the lateral portions of the chord are traceable to the optic lobes, on entering which they are crossed by the fibres of the optic nerves, coming from the opposite direction and passing them externally. The remaining portion of the fibres which are continued forwards from the chord pass beneath the optic lobes, and divide into the *crura cerebri*, where they can be more easily followed by slitting the brain longitudinally; some of them terminate in the optic thalami, and others, quite few in number, and only detected by the microscope, are seen to enter the corpora striata and the outer walls of the base of the cerebral lobes, each crus subdividing in order to reach those parts; finally, the last traces of longitudinal fibres are seen following the base of the brain as far forwards as the olfactory lobes. No portion of the brain contains so many nerve tubes as the optic lobes; they are derived from the two sources above mentioned, namely, the chord and the optic nerves, and within the substance of the lobes the two kinds are so completely interwoven and intermixed, as to render abortive every attempt to unravel them, and determine the existence of a definite plan.

The general result, then, which has been obtained from an examination of the minute structure of the brain, is simply this:—1st. That each of the cerebral masses is in direct connection with the spinal chord, by nerve tubes extending from the one to the other. 2d. All the longitudinal fibres of the brain appear to be accounted for, in the species here described, by the fibres prolonged from the chord. 3d. With the exception of the optic lobes, the cerebral masses consist mainly of cells, none of which are caudate, and none of which have any visible connection with the nerve tubes. The cells are all nearly spherical, and their contents are granular. 4th. No longitudinal commissural fibres exist, nor any thing analogous to a fornix. 5th. As regards the functions of the cerebral lobes, their bases excepted, whatever force they originate, whatever impulses they transmit, and whatever impressions they receive, all must be effected by the aid of cells alone; these must be both originators and conductors of nervous force.

SECTION III. — SPINAL CHORD.

As is almost universally the case in the Vertebrate series, this portion of the nervous system consists of a flattened cylinder terminating posteriorly in a conical extremity, and is partially divided lengthwise by two fissures, one on the upper and the other on the under surface; the latter in Frogs is the most easily traced, and when the membranes are stripped off, the right and left halves readily separate as far as the gray substance. By a glance at Plate I. Fig. 1, it will be at once seen, that there exist in the chord three enlargements or bulgings, I, L, N, at nearly equal distances. The first of these, the medulla oblongata, is almost universally present in Vertebrate animals, being perhaps really deficient in *Amphioxus* only; but the second and third are wanting whenever the arms and legs are not developed, or exist in a rudimentary condition. Among Sauria the genus *Bipes* possesses only the third or crural, and *Chirotes* only the second or brachial enlargement; legs only being developed in the first, and arms in the second.

When seen from the abdominal or lower side, as in Fig. 1, these three enlargements have a strong resemblance to each other, and it is at once suggested, that they are serial repetitions of similarly constructed parts. In addition to these, I have noticed in a few instances a slight enlargement of the chord at the origin of each of the pairs of spinal nerves, and from observations made on other animals am inclined to the belief, that a similar condition of the chord exists more generally than anatomists have been disposed to admit, and that there is consequently more truth in the disputed statements of Gall and Spurzheim with regard to this point of anatomy than they have generally received credit for. The enlargements in question are quite obvious in *Menobranchus*; also in *Lophius Americanus*, as stated by Cuvier, though the correctness of this last statement has been called in question by Professor Owen. It is possible, however, that in the European species it may not exist; in the American, it is unequivocally present.

From the second or brachial enlargement is given off a large trunk distributed to the arms, and beyond this a smaller one, which sends a filament to the preceding nerve; the contracted portion of the chord which follows the brachial enlargement gives off the nerves to the walls of the abdomen, and the third enlargement supplies the three lumbar nerves and the minute coccygeal pair. The second and third bulgings present no obvious difference as regards structure, but the principal interest which attaches to them is the proportion between their size and the limbs with which they are connected. It is stated by Cuvier, that they are in proportion to the "force" of their respective limbs. If by force is meant the muscular energy and development of the limbs, this statement does not appear to be sustained in the present instance, nor in many other instances brought to notice by comparative anatomy. In man the brachial enlargement is always larger than the crural, though the legs are so much more powerfully developed than the arms, and the same is true of the greater number of Mammals. In Frogs there is a still greater disproportion between legs and arms, yet

there is not a corresponding difference in the size of the bulgings. They cannot, therefore, be said to be in proportion to the muscular force only of the limbs, but correspond far more nearly to the acuteness of the sense of touch, which in Man and Mammals is more delicate in the hands and arms than in the legs and feet. In Bats, it is true that the muscular force of the arms is greater than that of the legs, and that the brachial far surpasses the crural enlargement; but, at the same time, the sense of touch in the membranes of the wings is exalted to a most extraordinary degree. In Birds the posterior bulging is almost universally the largest, though this condition is in part dependent upon the presence of the rhomboidal sinus. In these animals, while the muscular energy of the wings is the most developed, the sensibility of the feet is the more acute.

A transverse section of the chord, when viewed with a low magnifying power, exhibits the external or white substance forming two crescentic masses, as in Fig. 1, *a*, their concavities turned towards each other and including the gray substance, *b*; this last seems to form the only bond of union between the two sides, (and in this respect agrees with the results of Mr. J. L. Clarke,* from an examination of the chord in Man,) the white columns being quite distinct from each other, and having no commissural fibres either on the anterior or the posterior face. Under the microscope, the white substance is resolved wholly into nerve tubes, and in the gray substance even, these are the most conspicuous element. The largest portion of the white columns consists of longitudinal nerve tubes, intermixed with others which are transverse; some of these last are continuous with the roots of the nerves, and can be seen entering the chord passing towards the centre, and between the longitudinal fibres, but after entering the gray substance are no longer traceable; as shown in Fig. 14, Plate I., some of them appear to join the longitudinal series, but were not traced far enough to determine whether they did not ultimately join the gray substance in their immediate neighborhood.†

The gray substance, besides the white fibres which are intermixed with it, is composed in part of cells more or less spherical or polygonal, such as are met with in the brain, and, in addition, of distinct caudate cells, such as are represented in

* Philosophical Transactions, 1851.

† The evidence of the more recent microscopists tends to show that nearly all, perhaps all, of the nerve roots enter the gray substance. A demonstration of this fact, with regard to the posterior roots, is easily made on the spinal chord of a foetal sheep, where they have the peculiarity of passing over the outer surface of the posterior columns until they reach the median line, when (still on the exterior) they descend into the fissure as far as the gray substance, in which they are wholly lost. Their course is easily traced with a low doublet or even the naked eye. The posterior horn of gray substance reaches the surface, and is traceable as a distinct band throughout the whole length of the chord. In the instances which the writer has examined, none of the sensitive roots were traced into the posterior white columns; but all seemed to encircle them, and enter the gray substance at the bottom of the posterior fissure. According to Mr. Clarke, the posterior roots in Man are traceable *through* the posterior columns into the gray substance.

Fig. 2.

Fig. 2. It is not easy, however, to demonstrate the presence of these last in recent specimens. They may be detected readily, by making thin sections after the chord has been hardened in alcohol, and then treating them in the manner followed by Mr. Clarke.* They are more conspicuous in the posterior horns of the gray substance, where they form a well-defined deposit, some of them being fusiform, others with three or more caudate appendages. After the most careful examination, I have not detected any direct connection between these caudate appendages and nerve tubes, and have not therefore been able to confirm the statement of Hanover and others, that nerve tubes originate or terminate in nerve cells. The deposit of caudate cells just referred to seems to extend through the whole length of the posterior horns of the chord; they were not detected in the anterior horns.

On opening the chord from the back longitudinally, two white tracts or columns are traced through its whole length and continued into the fourth ventricle, on the floor of which they may be seen without dissection; they do not, however, appear to be any thing else, as will be seen hereafter, than the lower extremity of each lateral crescent of white substance, as seen in Fig. 1.

In the sections made and examined according to Mr. Clarke's method, I have always found a canal (Fig. 1, *c*) occupying nearly the centre of the chord; it is lined by a well-defined layer of oval or columnar epithelium cells, inclosing a distinct cavity, which in all probability is filled with serum. This canal is continuous with the cavity of the fourth ventricle. Bischoff, Rokitansky, and others, seem to regard the canal as of only temporary existence in the human body; but Mr. Clarke's observations show that it is constant, and it has been detached in many adult animals; it is therefore highly probable that something of the kind exists generally in the Vertebrate division. Consequently, the opinion of Gall and Spurzheim, as to the existence of a central canal, so long disputed, is fully confirmed.

As already stated, the *medulla oblongata*, when seen in front or on the abdominal side, appears to be a serial repetition of the crural and brachial enlargements. Examined on the back, the resemblance is less striking, there being a fourth ventricle to which there is nothing similar in the other portions. If it has been more generally described in connection with the encephalon, it has been rather from its position in the cranial cavity, than from any marked peculiarity as regards structure, or the kind of function of which it is the seat. When morphologically considered, it is reducible to the common type of the chord, and the more complex condition which it has in the higher animals, in consequence of the existence of the olives and pyramids, is lost in the descending scale.

The fourth ventricle is lined with a thin layer of gray substance, *b* (Fig. 3), and this is covered by a layer of epithelium, *c*. The posterior pyramids (Plate I. Fig. 2, *L*)

* This consists in hardening the preparation in alcohol, and then transferring to a mixture of one part of acetic acid and three parts of alcohol, in which it is left for one or two hours; it is then placed for the same period in alcohol, and finally transferred to turpentine, which expels the alcohol and leaves the whole transparent.

are visible on each side of the fourth ventricle, and two pyramidal tracts are continued from them as far as the posterior bulging of the chord, dilating in this last as well as in the brachial enlargement; in comparing the posterior pyramids with the other bulgings of the pyramidal tracts, I am led to the conclusion that they are repetitions of similar parts, and that each tract enlarges in the medulla oblongata, just as it enlarges in the brachial or crural bulging.

The fourth ventricle results from the separation, or perhaps more correctly from the want of union, of the lateral portions of the chord on the back. By a comparison of the adjoining Figs. 1 and 3, it will be seen that the section of the chord and that of the medulla are reducible to the same typical structure. In Fig. 3 the white substance is still presented in the form of two crescents, *a*, but their

concavities, instead of being turned towards each other, are directed upwards, and within them the gray substance, *b*, is spread out, and is covered by an epithelium layer, *c*. This last is continuous with, and is an expansion of, the layer of epithelium which lines the central canal of the chord, and the gray substance is likewise continuous with that of the chord, but is fissured as far as the central canal.

Opposite the origins of the vagus and trigeminus nerves, there are slight ganglionic projections into the cavity of the ventricle; but they are very indistinct, and can only be seen after close examination.

As has already been stated, the fourth ventricle is closed over by a membranous covering, which in its minute structure is reducible to a vascular plexus, like that of the pineal body, or like the plexus choroides of higher animals; the vessels form a series of loops connected with a central vessel, and projecting to the right and left; it is covered with ciliated epithelium. The existence of vibrating cilia on the ventricular side, and of a fluid in the cavity of the ventricle, involves the necessity of the fluid being kept in constant motion. From what has been before stated with regard to vibrating cilia in the cavity of the ventricles of the brain and on the pituitary body, it is rendered highly probable that a circulation of serum exists through the cavities of the ventricles, passing through the passage from the third to the fourth ventricle. If vibrating cilia should hereafter be detected in the central canal of the spinal chord, this last would also be the seat of a similar movement.

The change of form which the spinal chord undergoes during the progress of development is one of its most interesting features, and one which long since attracted attention. The phases are the same that are met with in other Vertebrates in which limbs are developed; but while in these the changes take place with great rapidity, in Frogs generally the ichthyic condition of the chord in which there are no enlargements or bulgings continues for several months, the eggs being hatched in the spring and the complete development taking place in the latter part of the summer. In Bull-frogs, in this latitude at least (42° North), development lasts not less than a year, as the tadpoles hatched in the spring pass the following

winter in the same condition, the metamorphosis occurring during the following spring or summer.

Until the legs begin to be developed, the chord presents the form of an extremely elongated cone, and the bulgings, as was noticed by Serres, are developed simultaneously with the legs. I have not, however, been able to confirm the statement made by him, and repeated by others, that the caudal portion of the chord is shortened as the legs and the bulgings are developed. According to my observations, no shortening takes place until the absorption of the tail commences, and this happens after the bulgings are formed and the legs have acquired their growth. The whole of the caudal prolongation, however, is not absorbed, a portion being persistent, and eventually becoming enveloped by the elongated coccyx.

The caudal portion of the chord in the tadpole is so much reduced in size, that it affords an unusually good opportunity for microscopic examination. It is much flattened, has no fissures, is of an opaque white on the sides, but in the centre a transparent band is visible through its whole length. Examined with a power of one hundred diameters, or even less (Plate I. Figs. 16, 17), it is easily resolved into nerve tubes and cells, the first forming the opaque lateral bands, and the latter a transparent central stripe. The cells are like those described as existing in the brain, spheroidal, filled with granules, the walls attenuated and easily ruptured. None of them are caudate, and no direct connection was noticed between nerve tubes and cells, the former being almost wholly longitudinal, running with great regularity parallel to each other, and giving off nerves to the lateral muscles which form so large a portion of the tail. As the eye traverses the chord from the apex towards the brain, there will be seen, as we approach the former, here and there a nerve tube running more or less obliquely across from one side to the other; a little farther forwards the tubes become more numerous, until at length they are found very abundant in the posterior part of the trunk. Over the transparent central portion of the chord there may be seen, with a very high power, very minute longitudinal fibres (Plate I. Figs. 15, 16), which appear to be solid, and have not the double outline found in nerve tubes caused by the substance of Schwann.

From the description just given, it will be seen that the chord gradually becomes more simple in the caudal portion, that transverse fibres gradually become less numerous, and are eventually omitted, and that the nerve tubes and cells, as elsewhere, have no direct connection. The lateral strands of nerve tubes appear to be continuous with the white columns of the chord proper, and if they anywhere intermix with the nerve cells, it must be in some other place than in the caudal portion.

In one particular, then, the caudal prolongation of the chord in the tadpole differs in structure from that of the true chord, in having the nerve roots all ascending towards the dorsal region of the chord, and none of them passing among the cells of the central portion opposite to the points at which they are attached.

SECTION IV. — PERIPHERAL PORTION OF THE NERVOUS SYSTEM.

The peripheral system, composed of the different nervous trunks, which it is here proposed to describe somewhat in detail, is in Frogs comparatively simple ; far more so than in any Mammals, Birds, or higher Reptiles, and more so even than in most Fishes. This simplicity results in part from the reduction in number both of cranial and spinal pairs of nerves ; in the former it seems as if by suppression of some of them, but in reality it is by the union of two or more pairs which in other animals form so many separate nerves. Another condition in which its simplicity is also manifest is in the absence of those extensive anastomoses and plexuses, which render the whole system of the animals in which they exist so intricate. In consequence of these peculiarities, the nervous system of these animals becomes a matter very interesting to the physiologist and anatomist, enabling him to study the whole in a form almost typical, perhaps as much so as a natural form ever is, and at the same time throwing some rays of light on the subject of philosophical anatomy.

The number of pairs of nerves connected with the central axis and escaping through the walls of the cranium or the vertebral column, does not exceed in all seventeen, of which seven are given off either by the cerebral masses or the medulla oblongata,* and ten from the spinal chord. If we compare the number of pairs of spinal nerves, as indicated by the number of vertebræ in the different species of Vertebrates noticed in the tables of Cuvier, it will be found that in none, a few Batrachians alone excepted, is it reduced so low as in Frogs. According to Cuvier the following species present the smallest number of vertebræ in the classes to which they respectively belong.

Gibbon (Mammal),	31	Vertebræ.
Hoopoe (Bird),	35	"
Chelys anatomata (Reptile),	38	"
Ostracion triangularis (Fish),	15	"
Frogs (Cuvier, 9 pairs),	10	"
Pipa (Surinam Toad),	8	"

With regard to the cranial nerves, there exist among Fishes even, as will be seen hereafter, only the genera *Amphioxus*, *Bdelostoma*, *Myxine*, and *Lepidosiren* in which the number is known to be actually less, the first having but three pairs, *Lepidosiren* five, and the others but six. *Petromyzon*, according to Muller, has nine pairs, and according to Panizza, eight. In the larger portion of the whole Vertebrate division, at least ten or twelve pairs may be made out, the accessory nerve being the one which is most frequently deficient. The following table exhibits an enumeration of the cranial nerves of Man and Mammals contrasted with those of the Frog, showing at the same time what pairs are united in the latter, so as to reduce the whole number from twelve to seven pairs.

* "In the brain of the Frog only eight separate pairs are found, the facial, glosso-pharyngeal, accessory of Willis, and hypoglossal exhibiting no distinct roots"; "the hypoglossal is given off by the first pair of cervical nerves." Wagner, *op. cit.*, p. 151. This statement, as will be seen, is not strictly applicable to the present species.

A. Cranial Nerves:—

MAMMALS.		FROG.
I. Olfactory		I. Olfactory.
II. Optic		II. Optic.
III. Motor communis		III. Motor communis.
IV. Patheticus		IV. Patheticus.
V. Trigemini	} are combined and form	V. Trigemini.
VI. Abducens		
VII. Facial		
VIII. Auditory		VI. Auditory.
IX. Glosso-pharyngeal	} are combined and form	VII. Vagus.
X. Vagus		
XI. Accessory		
XII. Hypoglossal.		

B. Spinal Nerves of the Frog.

I. Hypoglossal.
II. } Brachial.
III. }
IV. }
V. } Abdominal.
VI. }
VII. }
VIII. } Crural.
IX. }
X. Coccygeal.

From this table it will be seen that the hypoglossal nerve in the Frog occupies a position somewhat anomalous, forming as it does the first pair of the spinal series. If this were added to the cranial nerves, to which it belongs in nearly all other Vertebrates, the whole number would be eight; namely, three special sense nerves, and two pairs (viz. the motor communis and patheticus) endowed with common motor properties, and three (viz. the trigemini, vagus, and hypoglossus) having both motor and sensitive filaments combined. To these last Sir Charles Bell applies the term "spinal," and Muller that of "cranio-vertebral." A larger number of cranial nerves has been described by some anatomists in closely allied Batrachians, but after repeated dissections, as will be seen in the sequel, there seems satisfactory reason, as regards the species here under consideration, for adhering to the enumeration given above.

I. *Olfactory Nerves.* (Plate I. Fig. 1, i. and Plate II. Fig. 11, B.)—These arise from the anterior and under portion of the olfactory lobes, their union with which can only be seen distinctly after the membranes have been wholly removed. On the anterior extremity of the lobe they form a kind of cap, but beneath extend in the form of a narrow band, situated near the outer edge, as far as the union of the olfactory with the cerebral lobes, where they terminate in a rounded bulb. From this band extending beneath the lobe, there is given off at its commencement another series of fibres, which are directed inwards, separating from each other and forming a brush. The trunk of the nerve is about two or three lines in length, is directed forwards, and each nerve escapes through a separate opening in the anomalous bone, described by Cuvier as the "*os en ceinture*," and regarded

by him as the representative of the united frontals of serpents, and by others as the ethmoid. The nerve trunks, after passing these openings, divide into two branches, each of which breaks up into a brush of filaments, and are distributed to the upper and under surfaces of the olfactory pouches, but principally to the former.

The minute structure of this nerve, as in other animals, is quite different from that of the other sense nerves. Its fibres have not the appearance of being tubular, are not varicose, and are flattened and closely matted together, resembling the fibres of the nerves of organic life.

II. *Optic Nerves.* (Plate I. Figs. 1 and 3, II.)—These, when stripped of their thick sheath exteriorly to the cranium, or when examined within the cranial cavity, are a little less voluminous than the preceding pair, though the organ of sense with which they are connected is larger and more complex. Behind the decussation, each nerve, as it advances towards its ganglionic centre, divides into two distinct fasciculi of fibres; the anterior fasciculus is directed upwards, its fibres being distributed to the anterior portion of the optic lobe, and in part to the adjoining portion of the optic thalamus, while the posterior, passing beneath the lobe, enters it upon its posterior face. If the brain have been previously macerated in strong alcohol, this demonstration is rendered still more clear by cutting through the optic nerves at the decussation, and on tracing up each nerve towards its origin, it will be found that the only direction in which the fibres may be separated without rupture is towards the ganglionic masses above mentioned. The connection of these nerves both with the optic lobes and optic thalami seems unequivocal, and is a fact of interest bearing on the connection of both these organs with the sense of vision, and this view is supported by the evidence derived from pathology and experiment. Many observers have shown, by dissection, that blindness of long standing is followed by atrophy of the optic lobes (agreeably to the well-known law of atrophy following disuse), and that extensive lesions of the lobes are attended by either impairment or loss of vision. In recent dissections of Frogs, similar results have been observed. One in which the *right* eye had been destroyed had atrophy of the left lobe, which was reduced by nearly one third of the dimensions of that of the opposite side. The condition of the nerve was not examined. In a second instance, there was blindness from destruction of the *left* eye, in which there was atrophy of the left nerve before the decussation, of the right nerve behind the decussation, and of the right optic lobe.* In neither of these cases was there any marked alteration in the proportions of the optic thalami.

The facts furnished by comparative anatomy, however, tend to show that vision is not the sole function of the optic lobes. There are well-known instances of animals, whose lives are passed either in caverns or localities from which the light is excluded; one of the most remarkable of these animals is the Blind Fish (*Amblyopsis spelæus*, Dekay) from the Mammoth Cave of Kentucky. In these no

* American Journal of Medical Sciences, edited by Isaac Hayes, M. D., for October, 1852.

eyes are developed,* and yet the optic lobes do not remain undeveloped to a corresponding degree, but, on the contrary, acquire a proportional size nearly equal to that of other Fishes with normal vision. While, on the one hand, there is sufficient evidence to show that the optic lobes are connected with vision, there is, on the other, evidence to prove that they exist without vision, or entirely out of proportion to the visual organ, as in *Proteus*.

The instances of *Proteus* and *Amblyopsis* naturally suggest the questions, whether one and the same part may not combine functions wholly different in different animals, and whether the same may not hold true with regard to the cerebral organs which is known to obtain with regard to the skeleton, the teeth, the tongue, and the nose, that identical or homologous parts in different animals may perform functions wholly distinct. If the doctrine here suggested can be admitted (and if this were the place facts could be cited in support of it), may we not find in it an explanation of many inconsistencies which now exist between the results of comparative anatomy and physiology?

III. *Motor Communis (oculo-motor)*. (Plate I. Fig. 1, III.) — In the whole Vertebrate series of animals, there is generally but little variety in this nerve; but the exceptional cases have given rise to some difference of opinion as to its true nature, and as to its relationship to the trigeminus. The ordinary distribution of this nerve is as in the human body. On entering the orbit, it divides into two principal branches; a superior, which is distributed to the upper rectus and levator of the upper eyelid, and an inferior, distributed to the rectus internus, and the rectus and obliquus inferior. In Batrachians the distribution is exceptional, and is differently described. Cuvier leaves us to infer that it is the same as in Man. Stannius describes it as dividing into two branches, "and which are distributed to the rectus superior and inferior, and obliquus inferior; at the same time, in Salamanders and Tritons, the rectus superior receives its filaments from the ophthalmic nerve" (ophthalmic branch of the trigeminus).

As seen in my dissections the motor communis arises as a minute filament from the under surface of the medulla oblongata near the median line at its anterior part and just behind the pituitary body; it is then directed outwards and forwards, perforates a little obliquely the cartilaginous sides of the cranium, just in front of the trigeminus; on reaching the orbit, it crosses the ophthalmic nerve in close contact, and has the appearance of becoming incorporated with it, which has led to an erroneous description on the part of some anatomists. The nerves, however, simply cross, there being no intermixture of filaments whatever. The branches given off by the motor communis are, 1st. a branch passing along the border of the rectus internus to the inferior oblique; 2d. a branch to the rectus internus; 3d. to the rectus inferior; and, 4th. to the rectus superior. (Plate II. Figs. 4, 5, 6.)

* Johannes Muller thinks that an eye actually exists; but according to his description, it is "an extremely small black point, without a cornea, of which the pigment forms the external layer, and under which lies a colorless membrane; nothing was determined on with certainty with regard to the contents"; no optic nerves were traced. — Memoir on the Blind Fishes and some other Animals living in the Mammoth Cave, Ky. By Theodore A. Telkampf, M. D. New York Journ. Med., July, 1845.

IV. *Patheticus*. (Plate I. Figs. 2 and 6, iv.) — This is certainly an independent nerve, and at its origin conforms with the general description of the same nerve in other animals. It arises behind the optic lobes, from the part corresponding in position with the valve of Vicussens; it perforates very obliquely the cartilaginous lateral wall of the cranium, in front of the motor communis; it runs parallel to and in company with the ophthalmic nerve, and with a small branch of this last seems to form an anastomosis (Plate II. Figs. 4, 5), and is described as forming one by several writers; it gives no branches, however, until it reaches the obliquus superior muscle, in which it is wholly lost.

Stannius describes this nerve as “distinct in the Anourous Batrachians, and as distributed to the superior oblique; but in Tritons and Salamanders it appears to be entirely incorporated with the trigeminus, so that it is the ophthalmic branch which furnishes filaments to this muscle.”* Cuvier doubts the existence of any communication between this and the ophthalmic nerve, and regards the supposed anastomosis as merely an apposition, “*qu’il ne qu’accole à ce nerf.*”† Vogt has seen a filament of this nerve anastomose with the ganglion of the trigeminus in *Bufo pantherius*. Fischer could not detect the existence of the patheticus in *Salamandra terrestris*, and therefore infers that it is derived from the ophthalmic branch of the fifth, since this last supplies the superior oblique with its motor filaments.

After repeated dissections, I am satisfied that the description of Cuvier is correct as far as it relates to *Rana pipiens*, and that, however close the contact be between the patheticus and the branch of the ophthalmic, no anastomosis really occurs; and am led, therefore, to the conclusion, that the patheticus, which in Tritons and Salamanders is a branch of the trigeminus, is in Frogs a separate and independent nerve.

V. *Trigeminus*. (Plate I. Fig. 1, v.; Plate II. Fig. 2, v.) — This has always attracted the attention of anatomists and physiologists, on account of its extended distribution, its connection with other nerves, and its relations to the organs of sense; also on account of its great resemblance, in the existence of a ganglion, to a common spinal nerve. In Frogs it becomes especially interesting, since, in addition to the three principal trunks found in other animals (namely, the ophthalmic, superior maxillary, and mandibular), it includes the *facial* as well as one of the motor nerves of the eye, namely, the abducens. The different roots which are united in the trigeminus are widely separated from each other, and, as here described, include all the roots arising from the medulla oblongata, and which become connected with the trigeminal ganglion. The *principal* one, and which corresponds with the trigeminus proper, arises from the most convex part of the lateral portion of the medulla oblongata, by several distinct fasciculi, which unite and form a single trunk, that is directed obliquely forwards and enters the ganglion; this trunk includes both motor and sensitive filaments. The *second* is the facial (Plate I. Fig. 1, a), which emerges from the medulla in close contact with the auditory nerve, and, after accompanying it for a short distance, is directed obliquely

* Siebold et Stannius, Nouveau Manuel d’Anatomie Comparée, Tom. II. p. 203.

† Leçons, Tom. III. p. 188.

forwards, and joins the principal root of the trigeminus, into the ganglion of which it enters. The *third (b)* root is equally peculiar, and is longer and far more slender than either of the others; it is so delicate, that, unless great caution be used, it will be torn away in the removal of the membranes. The facility with which it is destroyed offers a probable explanation of the fact, that it has so frequently escaped observation. Its origin is about midway of the medulla on its lower face, and quite near to the median line; this also joins the principal root, and becomes involved in the Gasserian ganglion. The origin of the last-described root corresponds with that of the *abducens*, of which there can be no doubt that it is the homologue, as shown by Vogt.*

We have here, then, one interesting feature of the trigeminus; namely, that all the roots, whether motor or sensitive, pass through the ganglion, a condition not usually found in the same nerve in other animals. All the roots thus united and connected with the ganglion escape from the cranial cavity through *one and the same* foramen in the (wing of the ?) sphenoid. The ganglion is usually quite near to this foramen, may even occupy it, or be exterior to it. The Gasserian ganglion in its shape somewhat resembles the same part in the human body, but has the characteristic yellow color of that of the vagus and spinal nerves. From its convex surface, three large trunks and one smaller one are given off.

A. *Ophthalmic or Orbital Branch.* (Plate II. Figs. 2, 3, *a.*) — After leaving the ganglion of Gasser this nerve is directed forwards parallel to the sides of the cranium, till it reaches the co-ossified frontals or the "*os en ceinture*"; this it perforates, gains its cavity, and is again directed forwards, and divides into two branches; one of these, the superior, crosses the olfactory pouch and branches of the olfactory nerve above, and, inclining towards the median line, is distributed to the skin on the lips over the intermaxillary region; the other, passing externally to the olfactory pouch, is lost in the skin behind the preceding. The upper branch, crossing the olfactory nerve at an acute angle, gives as it passes small branches to the pouch itself. (Plate II. Fig. 11.)

Of the collateral branches of this nerve, the first is quite small, and may be traced as far as the sclerotic, which it perforates near the optic nerve, while other filaments enter it nearer to the cornea, and these may therefore be regarded as *short* and *long ciliary nerves*. The next, which is the longest of the collateral branches, from its distribution might be denominated *palatine* (Plate II. Fig. 2, *b*), though not the homologue of the same nerve in man, since this last is derived from the sphenomaxillary ganglion, which is a dependence of the maxillary branch of the trigeminus. The palatine nerve in Frogs is quite easily detected on raising the mucous membrane of the roof of the mouth, to which it gives numerous filaments, and is directed parallel and runs quite near to the median line, lying just beneath the base of

* "The abducens takes its origin from the anterior end of the medulla oblongata near the median line, runs obliquely forwards towards the *cavitas oculi* under the fifth nerve, passes near the ganglion Gasseri, sending a branch to it, while the greater part passes beyond this ganglion and is lost in the muscles." C. Vogt, *Beiträge zur Neurologie der Reptilien*. Neuchatel, 1840. See Fischer, *Amphibiorum Nudorum Neurologiæ Specimen*, p. 5.

the skull. A little in front of the globe of the eye it divides into two branches, one of which extends forwards as far as the vomerine bones (*c*), where it gives filaments to the internal nasal orifice, and to the neighborhood of the vomerine teeth; while the other, the larger, bends directly outwards (*d*), is situated behind the palatine bones, till it reaches the inner surface of the upper jaw, where it forms a distinct union with the superior maxillary nerve, and after the union of the two their terminal branches are distributed to the neighboring mucous surfaces. The other collateral branches of the ophthalmic nerve are quite minute, one of which is given to the upper eyelid and the skin in front of it, and two others perforate the united frontals, and are distributed to the skin over the nasal cavities, and to that of the nasal orifices.

B. *Upper Maxillary Branch*. (Plate II. Figs. 2 and 3, *e*.)—This and the lower maxillary branch are so closely connected at their origin from the ganglion, that for a short distance they appear to form but a single trunk, though with a little care they may be completely separated. They become disjoined just behind the globe of the eye, where the upper jaw branch gives off some minute filaments, which pass between the muscles of the lower jaw, and are distributed to the sensitive surface of the eye. A small branch is also given to the choanoid muscle, and it is near this point that the *abducens* leaves the trigeminus to reach the external rectus muscle. The terminal filaments, which may be regarded as identical with the infra-orbital nerve of the human body, are lost in the skin beneath and in front of the globe of the eye. A collateral branch extends inwards beneath the eye, and meets with the palatine, as already described, at *d*.

C. *Mandibular or Lower Jaw Branch*. (Plate II. Figs. 2 and 3, *f*.)—The third principal trunk corresponds in its distribution with the same nerve in the higher animals. Near its origin branches are given to the muscles of the lower jaw, but on reaching the angle of the jaw it passes over it to the outside; then, descending beneath, it runs parallel to it as far as the symphysis, where it breaks up into a brush. Its collateral branches are distributed to the skin of the lower jaw and to the mylo-hyoid muscle.

D. *Facialis (Portio dura)*.• (Plate I. Fig. 1, *a*.)—The nerve in Frogs to which this name has been given is quite different, in its mode of origin and of distribution, from that to which the name has been given in the higher animals. The descriptions of it by anatomists are far from coinciding with each other, and will be found somewhat at variance with that which follows.

In describing this nerve, Cuvier does not appear to speak from personal observation when he says, that “it is believed that a branch of the eighth pair (vagus) in tailless Batrachians, as it goes towards the trigeminus, meets with a branch escaping from the semilunar ganglion, and that the two united form the facial.”* Wagner, in speaking of the cranial nerves in Frogs, says that the facial exhibits no distinct roots, and is supplied as a branch of the acoustic.† Muller, referring to Volkman, remarks: “In Frogs Volkman has described a nerve analogous to the facial, which

* Leçons d'Anat. Comp., 2me edit., Tom. III. p. 219.

† Elem. Comp. Anat. Verteb. Animals, New York, 1845, p. 151.

enters the ganglion of the fifth pair, but immediately separates again from it, and is continued as the tympanic branch of the fifth, till it joins the laryngeal branch of the vagus. This laryngeal branch of the vagus is given off by the glosso-pharyngeal branch of the latter nerve, and its anastomosis with the facial may be compared to the similar connection of the glosso-pharyngeal with the facial in the human body." * Vogt, in his excellent memoir on the nervous system of Reptiles, describes this nerve in Toads, after leaving the ganglion, as "winding around the labyrinth to the *cavitas tympani*, behind which it meets with a branch of the glosso-pharyngeus; these two united nerves bend over the articulation of the lower jaw, and branch off to the skin and muscles, just as Volkman has described it." † Stannius describes the nerve somewhat more fully, as follows: "Another peculiarity of Fishes is found in this, that the facial nerve, which corresponds in a great measure with the opercular branch of this class, sends a lower maxillary nerve, which accompanies the alveolar branch of the trigeminus and anastomoses with it. In all Anourous Batrachians, this facial or jugular nerve receives an anastomosing filament from the first branch (analogous to the glosso-pharyngeal) of the vagus. Its first branch is ordinarily destined to the skin comprised between the membrane of the tympanum and the angle of the mouth (auricular branch); the second is the lower alveolar just mentioned, and the third is distributed in part to the sterno-hyoid, and in part to the skin of the thoracic region." ‡ The following may be added to the quotation made above from Cuvier: "In tailless Batrachians, a portion of the facial seems to be furnished by the fifth pair under the form of a fourth branch escaping from the semilunar ganglion." § This, however, he states on the authority of Fischer.

According to my dissections, the following appears to be a true description of the origin, connections, and ultimate distribution of the so-called facial nerve in the species of Frog here noticed. The manner in which it becomes connected with the Gasserian ganglion has already been noticed (p. 27). It is the smallest of the branches derived from the ganglion, which it leaves at its inferior angle, and is directed outwards, passing around the bony walls of the vestibule; it passes backwards over the columella, with which it is in close contact, and, while still beneath the tympanic bony circle, is joined by a branch from the glosso-pharyngeal of the vagus, or by a branch from a common trunk, which is divided into the glosso-pharyngeal and this anastomosing branch. (Plate I. Fig. 1, *c*; Plate II. Fig. 2, *g*.) The single trunk formed by the union of these two branches is directed downwards and backwards behind the tympanic cavity, to just above the angle of the jaw. After it has reached this point, it is far from easy to trace its terminal branches, but after many dissections, both with and without water acidulated with dilute nitric acid, the following distribution has been made out, and it goes to prove, that, although the nerve in question is doubtless the homologue of the facial in Man and Mammals,

* *Physiol.*, Baly's Trans., Vol. I. p. 834.

† Vogt, *Beiträge zur Nevrologie der Reptilien*, p. 52.

‡ Siebold et Stannius, *Man. d'Anat. Comp.*, Paris, 1850, Tom. II. p. 204.

§ Cuvier, *Leçons*, Tom. III. p. 207.

yet its distribution and properties are widely different. The branches from the common trunk resulting from the union of the nerve from the trigeminal ganglion and that from the vagus are three, liable, however, to slight variety, sometimes there being but two, and one of these giving off the third.

a. The first of these (Plate II. Fig. 2, *h*) is directed forwards and outwards, and passes over the tympanic and pterygoid bones just above the articulation of the lower jaw; it gives a small filament to the walls of the cavity of the tympanum, after passing which it divides into two terminal branches, one of which is distributed to the skin behind the angle of the jaw, and to the sides of the throat in the neighborhood of the cicatrices formed by the obliteration of the openings through which the fore legs are protruded when they first appear externally; the second is directed forwards, and is lost on the skin covering the angle and the posterior half of the lower jaw; near its termination this last branch forms an anastomosis with the external lower jaw branch of the trigeminus.

b. The second trunk of the facial (Plate II. Fig. 2, *i*) descends along the horns of the os hyoides, but in its passage no branches were detected until it reached the line of union between the mylo-hyoid muscle and the skin (which occurs on either side, midway between the median line and the branch of the lower jaw); there it passes to and is distributed in the skin covering the throat between the angles of the lower jaw under the larynx and in front of the sternum. No branches whatever were traced to any of the muscles among which it passed.

c. This is the larger of the three (Plate II. Fig. 2, *k*); it passes inside of the angle of the jaw, reaches the inner surface of this last, and follows the line of union between the mylo-hyoid and lower jaw as far forwards as the symphysis. In its course it gives filaments to the mucous membrane of the floor of the mouth, especially at the posterior part, corresponding with the position of the air-sacs of the male; the largest portion of its terminal filaments reach the mucous membrane at the union of this last with the jaw, and are all given off from the convex side of the nerve; all are therefore directed outwards. This branch, however, is not in close company with the lower jaw branch of the fifth, as stated by Stannius, though they run a parallel course.

According to the description just given of the nerves derived from the trunk formed by the union of branches from the trigeminal ganglion and the vagus, it must, reasoning from analogy, be endowed mainly, if not wholly, with *sensitive* properties. No filaments were traced to muscles, though it is not impossible that some minute muscular filaments may have escaped notice; if any do exist, they were too small to be seen with a lens magnifying three diameters, after the preparation had been immersed in dilute nitric acid. The correctness of this investigation by anatomy is confirmed by the evidence derived from galvanism, for the application of this agent when the nerve was fairly insulated produced no muscular contractions; and we might add in evidence the negative fact, that the muscles of mastication and those of the hyoid apparatus are respectively supplied from the lower jaw branch of the trigeminus and the hypoglossus nerves. From what has been said, then, it follows that the so-called facial, even if we admit the existence of motor

properties, is quite different from the same nerve in the human body; in Man it is almost wholly motor, having no sensitive filaments, except such as are derived from anastomosis, and which are intended to give a muscle its ordinary sensibility; thus its distribution is entirely muscular. In Frogs, on the contrary, as far as observed, its distribution is wholly cutaneous, its fibres having been traced to the skin about the tympanum, the angles of the mouth, the submaxillary and lateral jugular region.

The description given above, when compared with those of others which precede it, corresponds with that of Cuvier and of Vogt as to the origin of its vagal and trigeminal branches. Cuvier says nothing of its ultimate distribution, other than would lead to the inference that it has the ordinary distribution of the facialis. Vogt's statement, likewise that of Volkman, that it is distributed to the muscles of the lower jaw, I have not been able to verify. There does not appear any reason from analogy, or from the dissections just described, why Volkman should apply the term laryngeal to the anastomosing branch from the vagus. An anastomosis exists between the facial and glosso-pharyngeal nerves in the human body, but no branch termed laryngeal is given off from them, nor is the nerve in question entitled to that name from its distribution. The only true laryngeal nerve in Frogs, as will be seen, is given off, not by the nerve just referred to, but by the third or visceral trunk of the vagus, and is the homologue of the recurrent in Man. The description given by Stannius is certainly the most complete, and he is almost the only one who seems to have traced the branches to the skin.

The anatomy of the facialis in *Salmo fario*, as given by Agassiz after his original dissections, shows the existence in this Fish of a condition similar to that of Frogs. "The facial nerve escapes from the brain by the lateral furrow of the medulla oblongata; it is intimately connected with the root of the acoustic, and is separated from the trigeminus, but instead of following the course of the acoustic, its fibres pass obliquely towards the ganglion of Gasser, and, uniting to its inferior face, to the fibres of the trigeminus, and especially to the suborbitar branch of that nerve. Although there is evidently a mixture of these two nerves, we can nevertheless follow a great part of the fibres of the facial, which pass directly to the inferior face of the ganglion, into a single nerve which escapes from the cranium through the hole in the great wing of the sphenoid in company with the trigeminus."* While the ultimate distribution is different in the two, yet Frogs and Trouts have this in common, that the facial becomes an appendage of the ganglion of Gasser, and as in other Fishes it becomes more or less blended with the trigeminus. As it is in no instance bodily combined with any other nerve, we may safely conclude that, philosophically considered, the facial in Man is a dismemberment of the trigeminus.

VI. *Auditory.* (Plate I. Fig. 1, VI.) — This nerve likewise arises from the lateral portion of the medulla oblongata in two portions closely approximated to each other. They enter the vestibule, sometimes still united by a single foramen, at others slightly separated, and then by two foramina. I have noticed one of these conditions on the right and the other on the left of the same individual. After entering the vestibule, the two roots separate from each other, and are distributed

* Agassiz and Vogt, *Anat. des Salmonés*, p. 168; also Table M, Fig. XVI.

to the mass of calcareous crystals occupying the vestibular cavity, and to the semi-circular canals.

VII. *Vagus*. (Plate I. Fig. 1, VII.; Plate II. Fig. 2, VII.) — This is the last of the pairs of nerves escaping through the cranial walls; it arises from the dorsal surface of the medulla oblongata a little behind its lateral portion, by three or four slightly separated roots. The most posterior of these is attached somewhat farther towards the median line on the motor or lower surface than the others, and may therefore be compared to a motor root of a common spinal nerve; if this be identical with any separate nerve in the higher animals, it is with the accessory of Willis, though it has not that peculiar origin, by numerous roots extended for some distance along the medulla, as in higher Reptiles; for example, in the Tortoise.* Reasons for believing in this identity will be found in the description of the ultimate distribution of the nerve. The trunk of the vagus makes its exit from the cranial cavity through a hole in front of the occipital condyles, which, when examining the cranium alone, might from its position be mistaken for the anterior condyloid foramen. Immediately after leaving the cranial cavity it becomes involved in its ganglion, the largest of the whole series of ganglia connected with the cranio-vertebral series of nerves. All the root fibres probably pass through the ganglion. A filament of the sympathetic nerve unites the vagal and hypoglossal nerves with each other, and between the two is a ganglion, the first of the sympathetic series. The vagal trunks are three in number.

A. The first and smallest of the three is given off from the upper portion of the ganglion (Plate I. Fig. 1 and Plate II. Fig. 2, *b*), is directed upwards till it reaches the skin just above the tympanum, as described by Volkman, and is ultimately distributed to the integuments between the tympanic membranes and the eyes, and on the scapular region from above downwards as far as the level of the lower edge of the tympanum. This nerve is supposed by Muller to be the remnant of the nervus lateralis of the tadpoles, a view which does not seem to be confirmed, since they have the nervus lateralis in addition, and the nerve in question is not a branch of the lateralis, but is derived directly from the ganglion. A more probable supposition is to regard it as representing the dorsal branch of a common spinal nerve, a branch which is repeated for every pair of nerves along the back; and here we have additional evidence in favor of the identity of the cranial and vertebral series of nerves.

B. (Plate I. Fig. 1, *g*.) This trunk, after passing outwards one or two lines, divides into two branches, one of which is directed forwards, and, curving around the posterior surface of the vestibule, joins the branch from the trigeminus, with which it forms the so-called facial nerve. The second branch is directed a little backwards, descends along the sides of the neck, where a minute filament is given to the mucous membrane of the oesophagus, passes over the body of the hyoid bone, giving filaments to the mucous membrane of the floor of the mouth, then along the upper surface of the genio-hyoid muscle on the median line till it reaches the symphysis of the lower jaw, where it enters the base of the tongue and is distributed to the mucous membrane alone. When the tongue is retracted, this nerve is thrown into

* See the figures of Bojanus in his *Anatome Test. Europ.*, Plate XXI. Figs. 87 – 92.

numerous zigzag folds, which adapt it to the peculiar extensibility of that organ. This nerve was not traced to any of the muscles among which it passed, nor were any contractions of the hyoid and glossal muscles produced when the nerve was excited by galvanism, proper care being taken to secure its complete insulation.

The distribution of this nerve to the mucous membrane of the tongue pharynx indicates that it is a nerve of sensation, and its connection with the vagus shows that it can be no other than the *glosso-pharyngeal*, which in the higher animals becomes disjoined and forms an independent pair.

Muller says: "The glosso-pharyngeal of the vagus (in Frogs) is the only branch analogous to the glosso-pharyngeal in the human body, and this he regards as supplying the place of the gustatory branch of the fifth." This distribution has an analogical interest, since if it be the seat of the sense of taste (and it is the only sensitive nerve going to the tongue) in these animals, it tends to show that the glosso-pharyngeus in Man, about the function of which so much controversy has existed, may be a gustatory nerve. "The glosso-pharyngeus and vagus are separate at their roots, but unite immediately in the skull into one nerve which swells into a large ganglion outside of the skull. Before the glosso-pharyngeus enters the vagus, it sends off a minute branch, which runs forwards in the pia mater under the acousticus over the cerebral portion of the sympathicus, and penetrates the ganglion Gasseri. According to Volkman's description it does not exist in *Rana*, neither could I convince myself with certainty of its existence in *Bufo cinereus*, for the large collection in the membranes of the brain of masses consisting of microscopical crystals, prevents to a great extent the preparation of so fine a filament. In *Bufo pantherinus*, however, I have it before me so completely prepared, that no doubt can remain of its existence and its course as described above. The glosso-pharyngeus leaves the ganglion of the vagus nearly as large a nerve as the vagus itself, gives the uniting branch to the facialis (which Volkman calls the laryngeal branch of the vagus), then runs downwards, sends a branch to the region of the glottis, and branches in the tongue as far as the tip. The real vagus runs exactly the course described by Volkman, along the œsophagus, with branches to the immediate muscles, and gives off the recurrent and the branches to the skin." *

C. This is the largest of the vagal branches, and corresponds with the *vagus* of the higher animals (Plate II. Fig. 2, *l*), in them the glosso-pharyngeal being a separate nerve; it descends along the sides of the neck, having the glosso-pharyngeal in front and the hypoglossal behind, the latter crossing its course over the stylo-hyoid muscle. The first branch which is given off by it is a minute twig to the stylo-hyoid muscle at its upper part, and may be distinctly traced by the naked eye among its fibres as far as the middle. A little below this a much larger branch leaves, but runs parallel to its course for a short distance, but soon passes in front of the pulmonary artery, then beneath, and ascends a short distance behind it, and is distributed to the muscles of the larynx.† This, therefore,

* Vogt, *op. cit.*

† Weber has shown that even in the Frog a branch of the vagus gives off a filament which takes a retrograde course to the larynx. Muller's *Physiol.*, Baly's *Trans.*, 2d edit., Vol. I. p. 838.

must be regarded as the homologue of the "inferior laryngeal" or "recurrent" nerve of the human anatomist. That this homology is correct is still further indicated by the influence of galvanism, which, when applied high up on the sides of the neck, causes contraction of the laryngeal muscles. No superior laryngeal was detected. A little lower down than the origin of the recurrent branch, the whole trunk divides into two fasciculi of nervous fibres, one of which forms the œsophageal plexus, and the other is readily traced to the heart and lungs.

From the preceding description, it appears that the vagus arises from the lateral portion of the medulla oblongata, the only distinction between its root fibres being the slight separation of the anterior ones from the rest, which arise nearer the median line on the motor side of the chord. All its fibres appear to enter the ganglion; its branches are, — 1. to the skin behind the tympanum and over the scapula; 2. an anastomosing branch to one from the trigeminus forming the "facial"; 3. the glosso-pharyngeal; 4. the splanchnic portion, distributed to the heart, lungs, œsophagus, and stomach. Of the terminal filaments of its different trunks, some are distributed to the skin, others to mucous membranes, as to the œsophagus, tongue, and probably to the respiratory passages; there are also motor filaments to the stylo-hyoid, to the larynx, and to the spinal muscles immediately above its ganglion; these muscles it causes to contract when stimulated by galvanism.

The vagus nerve has been quite differently described by different anatomists, and it is only required that their descriptions should be placed side by side to render evident their occasional inconsistency. Cuvier, whose accuracy is generally so admirable, in describing this nerve seems to speak from analogy rather than personal observation. He speaks of its "accessory branch" as if it were a distinct trunk, when he says, "The accessory is found in all orders of Reptiles, and is arranged as in Birds."* He further states, "From the ganglion of the vagus in Frogs is given off a nerve for the muscles of the jaws, and another for the tongue"; the latter has just been shown to exist, but I have never traced any branches to the muscles of the jaws, nor have these muscles contracted when the vagus has been stimulated by galvanism. Opposed to this statement is the fact that the trigeminal branches are distributed to the muscles of mastication, and that they contract when the trigeminus is galvanized.

Wagner, in speaking of the vagus, says: "Some very delicate nervous radicles, arising from the inferior tracts of the medulla oblongata near to its *anterior* fissure, unite with it and appear to correspond with the glosso-pharyngeal."† This glosso-pharyngeal is one of the principal trunks from the ganglion, and cannot be identified with either of the bundles of roots; it has been shown to be a sensitive and not a motor nerve, as it would be were Wagner's description correct, which makes it arise near the anterior fissure.

Longet states, that "in Frogs there is given off from the ganglion of the vagus a branch which is distributed to the muscles of the jaws."‡ This is a repetition of the statement of Cuvier.

* Leçons d'Anat. Comp., Tom. III. p. 226.

† Syst. Nerveuse, Tom. II. p. 371.

‡ Comp. Anat. of Verteb. Animals, p. 151, Am. ed.

Vogt describes the glosso-pharyngeal as giving a branch to the facial, "after which it runs downwards, sends a branch to the region of the glottis, and branches to the tongue as far as the tip"; the branch to the glottis I have not seen; and as he describes in addition a "recurrent branch," he evidently does not refer to this last.

Wagner leaves us to infer that he finds a part of the accessory nerve of the vagus, when he says, "Some of the roots of the accessory nerve appear to be absent."

Muller, quoting Weber, says: "In Frogs a branch from the ganglion of the vagus goes to the muscles of the lower jaw. It is the jugular branch of Volkman, who has shown its motor influence to be derived from a branch of the facial nerve which has coalesced with it. It is distributed partly to the hyoid muscles and partly to the muscles of the lower jaw." * I have seen no other nerve to which this description is applicable, than that formed by the union of a branch from the vagus and the trigeminus; the latter branch, arising from the side of the acoustic nerve, joins the ganglion of the trigeminus, and afterward the branch from the vagus. According to my dissections, none of its branches are muscular; although they pass among the muscles of the jaw, they were not traced to them, nor do they cause them to contract when galvanized; a small filament is given off behind the tympanum, which I at first thought was distributed to the masseter, but afterwards felt satisfied that I could trace it wholly to the membranous walls of the tympanic cavity. Volkman's statement, that it is distributed partly to the hyoid muscles, is also rendered improbable by the positive demonstration that these muscles get their nervous filaments from the hypoglossus.

Nervus Lateralis. (Plate II. Fig. 9.)—There exists in Fishes, as has long been familiarly known to comparative anatomists, a peculiar nerve, usually a branch of the vagus, though it may sometimes be the result of the union of branches from the vagus and trigeminus; or it may be derived from the trigeminus alone, which, from extending along the side of the body beneath the lateral line, has received the name of lateral nerve. "In *Salmo*, *Clupea*, and *Acipenser* it is formed exclusively by the vagus, but in many Fishes, as *Belone*, *Cottus*, *Cyprinus*, it is formed by a branch of the vagus which receives branches from the trigeminus." † In addition to this, there exists a nerve, first described by Weber, called the dorsal nerve, formed generally by a union of filaments from the fifth and vagus, which, escaping by an especial opening in the parietal and interparietal bones, extends along the whole length of the dorsal fin, receiving filaments from the intercostals, and giving nerves to the muscles of the fin rays. In *Silurus* it is derived from the fifth only, and in some others from the vagus.‡ The use of either of these nerves is unknown; Muller failed to produce muscular contractions by irritating with galvanism the lateral nerve of the carp. It is then in all probability simply a sensitive nerve.

* *Physiol.*, Vol. I. p. 838.

† Owen, *Lects. on Comp. Anat.*, Vol. II. p. 196.

‡ See Cuvier, *Leçons d'Anat. Comp.*, Tom. III. p. 212.

It is an interesting feature in the anatomy of Batrachian Reptiles, which in so many respects resemble Fishes, that they should have, some of them temporarily and others permanently, a nerve which is strictly analogous to the *nervus lateralis* of Fishes. It has been found by Van Deen to exist in *Proteus*, by Meyer in *Menopoma*, and by Kuhn in Tritons, and probably it exists in all the other Urodels. Among the Anourous Batrachians it was first noticed in Frogs, by Van Deen.

Its distribution, as it was presented in the tadpoles of *R. pipiens*, is as follows. (Plate II. Fig. 9.) The vagus escapes through the cartilaginous occiput as a single trunk, and from its ganglion are given off the following branches:—1st. A branch which unites with another from the trigeminus, and forms the facial. 2d. A cutaneous nerve, distributed to the skin of the neck and that of the branchial region. 3d and 4th. Two delicate filaments, which, one of them dividing, furnish three nerves (*d*), one to each of the branchial arches. 5th. The *nervus lateralis* (*c*); at its origin, this, like the preceding nerves, is concealed by the spinal muscles attached to the occiput; having extended outwards as far as the skin, it passes along the side of the abdomen just beneath the edge of the spinal muscles, and is continued along the side of the tail in the groove formed by the union of the upper and lower series of caudal muscular bands. Soon after leaving the vagal ganglion, the *nervus lateralis* gives off a delicate filament (*a, b*), which does not appear to have been noticed hitherto, and which is easily traced, if the parts have been macerated in dilute nitric acid; this branch ascends and is directed backwards till it reaches the base of the fold of skin forming the upper portion of the caudal fin, along the base of which it extends towards its termination.

While no doubt exists as to the identity of the *nervus lateralis*, there can be little that the branch just described is identical with the *nervus dorsalis* of Weber, it being, as in some Fishes, a branch of the vagus; in the case of Frogs it is wholly cutaneous, there being no muscles connected with the skin, and in Fishes it seems questionable whether this nerve is motor or sensitive. In Cuvier's Comparative Anatomy the following remark occurs in connection with the vagus, which it is of interest to mention here: "Up to the present time, no nerve analogous to the dorsal has been found in Reptiles. Nevertheless, the parietal bones of Saurians are pierced with a foramen like those of Fishes." *

The observation of the existence of a dorsal nerve gives additional importance to the discovery of the *nervus lateralis* by Van Deen; and if to these we add those branches of the vagus described above, which pass along the branchial arches, the analogy of the larvæ of Batrachians to Fishes becomes much more striking than there has been reason hitherto to regard it.

SECTION V. — PHILOSOPHICAL ANATOMY OF THE CRANIAL NERVES AND SKULL.

In the table at the commencement of Section IV., the cranial nerves of Man and Mammals, and those of the Frog, are contrasted; it is there shown what nerves in the two correspond, and how it is that, by the union of two or more nerves, the

* Leçons d'Anat. Comp., Tom. III. p. 229.

twelve pairs in the one case are reduced to seven in the other. In the subjoined tabular view of the cranial nerves, as they are presented in some of the different members of the Vertebrate series, it is further seen that there exists a transition from the more simple condition, in *Amphioxus*, *Myxine*, and *Lepidosiren* among Fishes, and in Frogs among Reptiles, where the nerves are less numerous, to the most complex, in Mammals and Man; that the trigeminus and vagus, as we traverse the series, are, as it were, split up and dismembered, so as to make from the smaller number in the one case the larger in the other.

Table of the Number of Pairs of Cranial Nerves found in some of the Members of the Four Classes of Vertebrates.

	Olf.	Op.	M. c.	Path.	Trig.	Abd.	Fac.	Aud.	Gl. p.	Vagus	Access	Hyp.	Total.
Man (Soemmering),	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	12
Testudo Europæa (Bojanus),	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	12
Goose (Swan),	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	?	XII.	11
Boa (Swan),	I.	II.	III.	IV.	V.	?	VII.	VIII.	IX.	X.		XII.	10
Salmo (Agassiz),	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.		XII.	11
Raia (Swan),	I.	II.	III.	IV.	V.	VI.		VIII.	IX.	X.		XII.	10
Bufo palmarum (Fischer),	I.	II.	III.	IV.	V.	VI.		VIII.		X.	XI.	XII.	10
Petromyzon (J. Muller),	I.	II.	III.	IV.	V.		VII.	VIII.		X.		XII.	9
“ (Panizza),	I.	II.	III.		V.		VII.	VIII.		X.		XII.	8
Gadus morrhua (Swan),	I.	II.	III.	IV.	V.	VI.		VIII.		X.		XII.	9
Rana pipiens (J. W.),	I.	II.	III.	IV.	V.			VIII.		X.			7
Bdellostoma (Muller),	I.	II.			V.		VII.	VIII.		X.			6
Myxine (Muller),	I.	II.			V.		VII.	VIII.		X.			6
Lepidosiren (Owen),	I.	II.			V.			VIII.		X.			5
Amphioxus,*	I.	II.			V.								3

The instances in which the nerves are reduced to the lowest degree of numerical simplicity are very few, in comparison with those in which the larger portion, if not the whole series, of twelve exists. This simplicity is not, however, regulated by the zoölogical position of the animal; for in Frogs there exist but seven pairs of cranial nerves, whilst in most Fishes eleven are found, — the whole series, in fact,

* This enumeration of the nerves of *Amphioxus* deviates from that of Quatrefages, in his admirable memoir on the anatomy of this interesting Vertebrate. By reference to the figures of Quatrefages, it will be seen that the five pairs described by him may be easily reduced to three, if we regard the branches *l* and *m* (Plate XI.) as forming but one nerve, and corresponding to the ascending and descending branches of a common spinal nerve in the same animal, and the branches *o* and *p* (Figs. 4 and 5) as accessory filaments to the nerve *l*. The branch *m* does not vary materially in its size and distribution from the corresponding part in the pairs which precede it. The great size of the branch *l* is at once explained when compared with the greater amount of surface which it supplies, and the more acute sensibility which exists about the head. The branches *l*, *m*, *o*, *p*, would therefore form but a single nerve, which may be compared with the trigeminus; and if to this we add the optic and olfactory, we have two pairs of special sense nerves and one of cranio-spinal nerves. Rathke regards all the nerves as true spinal ones, and the brain as wholly deficient. See Quatrefages, *Annales des Sci. Nat.*, p. 197. Oct., 1845.

which is met with in Man, except the spinal accessory. It does not appear, that in one and the same animal the number of cranial nerves is reduced so low as six pairs, except in the lowest of Fishes, namely, in the genera *Amphioxus*, *Myxine*, *Lepidosiren*, and *Bdellostoma*.*

While the cranial nerves of Frogs are less simple than in the genera just mentioned, they are more so than in any Mammals, Birds, or Reptiles, except the allied Batrachians; and they are especially interesting as showing the greatest reduction met with in any air-breathing Vertebrates. By tracing out the distribution of some of the branches of the trigeminus and vagus, we are enabled to identify them with the separate pairs of nerves into which they are resolved in the ascending series. The branch from the vagus distributed to the tongue is easily identified with the glosso-pharyngeal, and the branch to the muscles of the shoulder with the spinal accessory; thus we have a demonstration of the fact, that the vagus is made up by the union of three nerves, which in Man are so many independent pairs. In like manner, some of the branches of the trigeminus are identified with separate pairs of nerves in the higher Vertebrates, as, for example, the facial, and the motor externus; in Salamanders, the patheticus, and some (as the rectus superior, pp. 26, 27), if not all, of the branches of the motor communis. Thus the theory which makes the typical number of cranial nerves (independently of the special sense nerves) three pairs, namely, trigeminus, vagus, and hypoglossus, becomes highly probable.

As regards the special sense nerves, they have some peculiarities which seem to indicate that they are of a different order from all the rest of the nerves connected with the cerebro-spinal axis. Their peculiarities relate, — 1st, to the fact that they are connected with special organs of sense; 2d, to their development.

According to the ablest embryologists of the present day, common spinal nerves, and the same is true of the cranio-spinal nerves, do not shoot out from the respective portions of the chord to which they are attached, but are developed in the tissues where they are respectively found, and this independently of the central axis, just as the bloodvessels of the germinating membrane are developed independently of the central organ of circulation. This view, or something very near it, was maintained by Gall, and more recently has been presented by Bischoff, Kölliker, and others.

Such is not the mode of the development of the special sense nerves. According to Reichert and the more recent observers, the special sense nerves, as well as a portion of the organ of sense itself, are the result, in the first instance, of a kind of hernia, or protrusion of a portion of the embryonic cerebral vesicles, which are evolved and prolonged outwards, until they meet an involution of the common integument, and from the two results the organ of sense. The sense nerve at first seems to be formed by the contraction of the evolved tube, forming a hollow pedicle, but is subsequently filled up with nerve fibres.

One other difference may be referred to in connection with the special sense

* For the anatomy of the brain of Myxinoid Fishes, see Johannes Muller, Berlin Trans., 1837.

nerves; namely, that in the animal series they are never seen combined with motor roots, are never presented under the aspect of a true spinal or vertebral nerve. It has been maintained by Blainville and others, that the motor nerves of the eyeball are the nerves, of which the optic is the sensitive portion, and that they are separated in consequence of the high degree of specialization of function. This assumption is readily disproved by the fact, that, of these same motor nerves, the pathetic, abducens, and some, if not all, of the branches of the motor communis, can be shown to be dismemberments of the trigeminus. The opinion of Oken, which considers the special sense nerves as appendages of the brain, is far more rational, and has the merit of being more in accordance with facts.

Cranial nerves may therefore be divided into two groups; namely, into

1. Special sense nerves:

- I. Olfactory,
- II. Optic,
- III. Auditory;

2. Cranio-spinal nerves:

- A. Trigeminus,
- B. Vagus,
- C. Hypoglossus;

the second including the only true serial repetitions of spinal nerves.

The determination of the typical number of cranial nerves becomes a matter of importance, in consequence of its bearing upon the philosophical anatomy of the skull. On the hypothesis that the cranium is made up of a series of vertebræ, one of the first questions which is presented is as to the number which enter into its composition. Throughout the vertebral column, as ordinarily understood, the pairs of nerves equal the number of vertebral pieces. If the cranium is reducible to the vertebral type, we might from analogy expect that there would be found a series of nerves corresponding in number to the vertebræ of which the cranium is made up. If we admit only such nerves as present the true spinal character to be indicative of the number of vertebræ, that is, those which have motor and sensitive roots, are provided with ganglia, and have a similar mode of development, then, according to the analysis given above, there being three pairs of nerves conforming to the spinal type, we should infer the existence of three vertebræ.

Anatomists, however, have not generally followed these indications, and it is a singular fact, that, in establishing the number of cranial vertebræ, they have rested their conclusions on such widely different foundations. Oken, in his latest publication, admits the existence of four vertebræ, based on the organs of sense and the lower jaw, and which he designates as the "nose vertebra," the "eye vertebra," the "ear vertebra," and the "jaw vertebra." Bojanus also recognizes four, and substitutes the "tongue vertebra" for Oken's jaw vertebra. Agassiz admitted but a single cranial vertebra, since the chorda dorsalis of the embryo did not extend beyond that portion of the base of the skull which corresponds with the basilar portion of the occiput. Professor Owen, the most recent writer on the subject, who has investigated it very minutely, and has worked out his system with admirable skill, bases his vertebral theory upon the principal subdivisions of the encephalon, from which he deduces a "rhinencephalic," "prosencephalic," "mesencephalic," and "epencephalic" vertebra. A larger number has been admitted by others, as Geoffroy St. Hilaire, Carus, and MacIise, based mainly on an unsound determination of the different osseous elements.

If we apply the analogies of the spinal chord and vertebral column to the cranium and its nerves, we ought to base our determinations on the repetitions of true spinal nerves and of the true vertebral elements. If the theory be true which reduces the cranial nerves (exclusive of the special sense nerves) to three, namely, the trigeminus, vagus, and hypoglossus, then we ought, *à priori*, to detect at least three vertebral segments. This conclusion agrees perfectly well with the determination from osteology. For the larger part of modern anatomists admit at least three vertebræ, though some admit more, but are not precisely agreed as to the exact number of elements which enter into the composition of each. These vertebræ may be designated as follows: 1st, the occipital, of which the basilar bone is the body; 2d, the parietal, of which the posterior sphenoid is the body; 3d, the frontal, of which the anterior sphenoid is the body. Professor Owen admits a fourth, of which the vomer is the body, and as this vertebra is associated with the organs of smell, he designates it as the rhinencephalic vertebra. It is through or between these three vertebræ enumerated above, that the trigeminus, vagus, and hypoglossus have their exit from the cranial cavity, and it is likewise through or between these same vertebræ that the special sense nerves make their escape. If the number of pairs of nerves of both kinds is to regulate the number of vertebræ, then, instead of three pairs, we must admit six for the cranium alone, leaving wholly out of view the face. But if the special sense nerves, for reasons already stated, can be rejected as indications of vertebræ, the cranio-spinal nerves will give us just the number which accords with osteology. In this conclusion we are supported by both osteology and neurology. Johannes Müller admits the existence of three vertebræ, and argues from them the number of pairs of cranio-spinal nerves. "According to my view, there are three vertebral nerves of the head, just as there are three cranial vertebræ. The first is the fifth or trigeminus, the second is the vagus with the glosso-pharyngeal and accessory, and the third is the hypoglossus."

The three-vertebra theory given above relates simply to the bones constituting the walls of the cranial cavity which include the brain; no account is taken of the jaws and other bones of the face, nor of the os hyoides. Professor Owen, in his system, regards these, with the scapular arch, as forming a series of four inferior or "hæmal" arches to the four cranial vertebræ, with their "neural arches," that they in fact are serial repetitions of ribs.

It would be foreign to the purpose of this paper to discuss the grounds on which these conclusions rest. Another hypothesis seems to us worthy of consideration, but which can only be stated in general terms, as follows. The teeth in the early embryonic conditions are developed from, and are dependences of, the mucous membrane of the mouth; in many Fishes these conditions are permanent; in Rays, Sharks, and other cartilaginous Fishes, the jaws or other bones which support teeth are equally developed in the internal integument or mucous membrane, and are never closely connected with the cranium except by ligament; the hyoid apparatus is likewise developed in the walls of the alimentary canal. If to these facts we add another, namely, that primarily the mouth and nostrils form a single

cavity, and are only separated after development has advanced to a certain stage, we have a strong ground for the hypothesis, that all the bones of the face which are developed in the walls of the primitive cavity of the mouth which they surround, are in their anatomical and physiological relations splanchnic, connected either with digestion or respiration, rather than parts of the endo-skeleton of animal life.

The conclusions which have been drawn from the statements made above are as follows: that in Frogs the *vagus* comprises the glosso-pharyngeal and accessory nerves; that the *trigeminus* comprises the facial, the abducens, and in the Salamanders the patheticus and portions of the motor communis; that other evidence sustains the hypothesis, that the whole of the motor communis is a dependence of the trigeminus; if to these we add the *hypoglossus* (which in Frogs is exceptionally a spinal nerve), we shall have three pairs of cranial nerves, each having all the characters of a common spinal nerve, namely, motor and sensitive roots and a ganglion; that there are no nerves to indicate a fourth vertebra, unless the special sense nerves are considered; if these are admitted as indications, then we must presuppose either two pairs of nerves to each vertebra, or the existence of six vertebræ, which is a larger number than can be accounted for on an osteological basis. The functions and mode of development of the special sense nerves we have taken as affording sufficient grounds for considering them as of a peculiar order, and not to be classified with common spinal nerves.

SECTION VI. — SPINAL NERVES.

I. *Hypoglossus*. (Plate I. Fig. 1, 1.) — Another remarkable feature in the nervous system of Frogs, and one which has been noticed in other tailless Batrachians also, is the fact that the hypoglossal nerve (the ninth pair of Willis, and the eleventh of Soemmering), is not, as in most Vertebrates, one of the cranial nerves, but the first of the dorsal or true spinal series. Its origin is at the extreme portion of the medulla oblongata, just in front of the contraction of the chord which precedes the brachial enlargement. In reference to the determination of its true affinities, it is of consequence to notice the fact, that it is provided with two kinds of roots, of which the anterior or motor are the most numerous, consisting of a bundle of filaments attached a little nearer to the median line than the corresponding ones from the *vagus*. The posterior or sensitive root is quite small and scarcely perceptible; it does not appear to have been noticed, except by Volkman. Its minuteness is such, that in removing the membranes, unless especial care be taken, it will be torn away with them, and therefore easily escape detection. The presence of this dorsal or sensitive root serves to identify it with a true spinal nerve; and the identification is rendered complete by the existence of a minute ganglion near its junction with the motor root. The two kinds of root fibres, just after escaping from the spinal canal between the first and second vertebræ, unite and form a single trunk, which almost always is provided with a small sacculated appendage filled with calcareous crystals. The trunk of the nerve descends along the sides

of the neck, crosses the vagus and its laryngeal branch, and, running nearly parallel to the glosso-pharyngeal, passes along the genio-hyoid muscle as far as the symphysis of the lower jaw; it then ascends, in company with the last-mentioned nerve, into the substance of the tongue, and is lost among its muscular fibres. This description applies to the principal trunk; in its progress, however, it gives off numerous branches, repeating very nearly the distribution of the same nerve in the human body; in other words, it is distributed to the muscles which move the os hyoides and tongue. The following branches were traced: 1st, a branch to the muscles attached to the vertebral column in its immediate neighborhood and to the omo-hyoid; 2d, to the sterno-hyoid; 3d, to the hypoglossus; 4th, genio-hyoid; 5th, genio-glossus. Galvanism proves still further the relation of these muscles to the hypoglossal nerve; if this agent be applied to the main trunk near the vertebral column, convulsions are simultaneously produced throughout the whole hyoid and glossal group; but nothing of the kind is noticed, as has already been stated, when it is applied to the glosso-pharyngeal, which has a direction so nearly parallel with it.* On entering the base of the tongue, the hypoglossus, like the glosso-pharyngeal, is thrown into zigzag folds, which adapt it to the peculiar extensibility of that organ.

The descriptions of this nerve by different anatomists are somewhat discordant, and it is therefore a matter of some interest that they should be compared. Vogt, in the memoir already referred to, says: "Volkman describes this nerve as the first nerve of the neck, which it is according to its exit, but not according to its origin and its course. He also represents its origin as at some distance from the vagus, and the nerve as if it were provided with a ganglion. I thought I could at least find the last in Frogs, but was soon convinced of my error." "The hypoglossus takes its origin close to the vagus, but nearer to the median line, from the under surface of the medulla oblongata, and, instead of going directly outwards, bends backwards close to the under side of the medulla within the pia mater, and when opposite to the foramen makes a sudden bend outwards, so that, if the pia mater is untouched, it has the appearance of having its origin opposite to the hole, and at some distance from the vagus. Has Volkman been deceived by this disposition?" "That, as Volkman says it does in Frogs, it takes its origin with two roots, and has, as he draws it, a ganglion, is certainly not the case in Toads, and I believe that no error on my part exists." Stannius distinctly, but incorrectly, asserts, that the hypoglossus has no posterior roots. "The spinal nerves always arise by two roots; the first two cervical nerves appear to form an exception to this rule, not only in the naked Reptiles, where they take the place of the hypoglossus, but also in some of the scaly ones."†

According to the dissections which form the basis of this memoir, Volkman's description is quite correct, both as to the existence of two kinds of roots and of the ganglion; also as to the position on the side of the medulla. The roots of the

* The same result, as regards its function, is shown by the experiments of Dr. Waller. — Philosophical Transactions, 1850.

† Stannius, Manuel d'Anatomie Comparée, Tom. II. p. 200.

hypoglossus are in part connected by the arachnoid. In *Bufo Americanus* I have found the hypoglossus arising very nearly as Vogt has described it.

Vogt's classification of this nerve among the true cranial nerves does not seem to be satisfactorily sustained, and certainly will not hold as regards Frogs. In them it certainly has all the characters of a common spinal nerve; viz. two kinds of roots, a ganglion on one of them, a mass of crystals attached as in the spinal nerves, and making its exit at an intervertebral foramen. There is still another anatomical character, though perhaps not an important one, which allies it to the spinal more than the cranial nerves; this is the primitive direction of the nerve roots backwards instead of forwards, as is the case with the cranial nerves.

II. *Brachial Nerves*. (Plate II. Figs. 1, 2.)—These are comparatively simple. In most of the higher Reptiles which have limbs, they consist of three or more pairs, which subsequently unite and form the brachial plexus, which in turn gives its branches to the upper extremity. In Frogs, however, only a small filament is given by the third spinal to the brachial nerve, and thus an approach merely to a brachial plexus exists. All the nerves to the arms, with the exception of the above-mentioned branch, are supplied by the single trunk of the second pair, which is attached to the spinal chord by several distinct motor and sensitive filaments. The trunk passes to the upper part of the arm before it divides, giving off, however, collateral branches to the muscles of the scapular and clavicular regions; also a branch to the pectoral muscles and a circumflexus humeri. The remaining portion of the nerve forms the ulnar and radial branches.

III. IV. V. VI. are the smallest pairs of the spinal nerves. They all arise by single anterior and posterior roots, and are mainly distributed to the muscles and skin of the back and the abdomen. The distribution of the cutaneous nerves will, however, be described hereafter.

Lumbar Nerves, VII. VIII. IX. These likewise all arise by single anterior and posterior roots from the spinal chord, but they are very much longer than those of the preceding pairs, in consequence of the greater distance of their origins from the intervertebral foramina, where the anterior and posterior filaments unite. The three lumbar nerves thus formed descend to the neighborhood of the hip joint, where the eighth and ninth pairs become intimately blended (*c*), and at the same time receive an anastomosing branch from the seventh (*b*). After giving off the branch just referred to, the seventh pair makes a turn outwards and upwards, so as to give its terminal filament to the posterior walls of the abdomen; from the convex side of its curved portion are given off numerous branches, which descend in a parallel series and are distributed to the skin of the thigh (*g*). This nerve, from the fact that it escapes at the inguinal region, and in consequence of its distribution to the leg, may be regarded as identical with the *cruralis*.

By the union of the eighth and ninth, with a portion of the seventh, a large sciatic trunk is formed, and this descends nearly to the knee without division, giving off, however, as collateral branches, a glutæal nerve (*e*), and two larger muscular nerves to the thigh (*f*). At the knee the sciatic is divided into two branches, the tibial and peroneal nerves (*h* and *i*).

X. *Coccygeal Nerve*; 10. This is the last of the series of spinal nerves, and from its minuteness does not appear to have attracted notice; consequently, the number of pairs is usually enumerated as nine. It is most easily detected on either side of the coccyx beneath the muscles extending from it to the ilia. If traced from its termination towards the chord, it will be found entering the cavity of the coccyx by a foramen pierced quite obliquely in its walls at a short distance from the anterior extremity of the bone. This nerve is attached to the chord by both kinds of roots, just beyond the third crural or ninth pair of spinal nerves. The detection of this nerve has especial interest, since it demonstrates conclusively the homology of the anomalous-shaped coccyx with a true vertebra, and also makes the number of nerves and vertebral pieces equal.

Cutaneous Branches of the Spinal Nerves.—The skin of Frogs, it will be remembered, is attached only to a very limited extent to the parts beneath, so that there is a series of large subcutaneous cavities, which are for the most part separated from each other. The first or dorsal subcutaneous cavity covers the whole region of the back, extending from the occiput to the posterior part of the trunk, and limited on the sides by the union of the skin with the muscles beneath, on a line extending from behind the eyes as far as the pelvis. The lateral cavities, one on each flank, are limited by the lines described above, and two others, one on each side, extending from the axilla to the pelvis. The fourth or abdominal cavity is comprised between the two last, and extends over the whole abdominal region.

The cutaneous nerves escape through the muscles to the skin, mainly in three directions; namely, on each side of the median line on the back, and at the upper and lower lines which limit the lateral subcutaneous cavities. The dorsal branches are in pairs, nine in number, and corresponding with the first nine vertebræ. In front of the scapula is a minute branch of this series, which is derived from the hypoglossus, and to this same series should be added the cutaneous filament from the vagus distributed to the skin near the occiput. On the upper lateral line eight pairs are given to the skin; on the sides in the lateral cavity five pairs descend to the lower lateral line, where, with three others given off more posteriorly, they enter the skin. These last branches seem to be the ones liable to the greatest irregularity. The existence of a dorsal cutaneous branch from the vagus and hypoglossus both, added to the facts already stated under another head, go still further to show their identity with common spinal nerves.

Crystal Capsules attached to the Spinal Nerves. (Plate I. Fig. 1, *i, i.*)—The existence of certain white bodies on either side of the vertebral column in Frogs seems for a long time to have attracted attention. They are referred to by Blasius, in his *Anatome Animalium*,* and are figured by Swann,† though he gives no descriptions. Wagner mentions them as follows:—“The ganglia admit of being very readily

* “Ab utraque spinalis medullæ parte, substantia quædam albicans calcis instar adhærescit, quam vasa plurima perreptant; substantia hæc sali volatili est analoga, cum ex observatione Swammerdamii affuso spirito acido effervescat. Cui usui tot vasorum plexibus inserviat admodum obscurum est.”—*Gerardi Blasii Anatome Animalium*, Amstellodami, 1681, p. 291.

† *Comp. Anat. Nerv. Syst.*, Plate VII. Figs. 5, 6.

demonstrated, lying upon the sides of the vertebral column; they are situated near those small white vesicles, which protrude by becoming swollen, chiefly during the spring of the year, and contain numerous microscopic calcareous crystals." * Stannius describes them as an accumulation of the white substance which covers the pia mater around the nerves where they escape from the spinal canal, and which, under the microscope, has the appearance of a mass of crystals. † Professor Owen has usually called attention to them in his annual Hunterian lectures, though he has published nothing in relation to them.

As I have seen them in dissections, they are subject to some variety, but exist on the trunks of all the true spinal nerves, the hypoglossus included, and invest them more or less completely at their exit from the spinal canal, occupying the space between the transverse processes of two adjoining vertebræ. The capsule is a very thin membrane, sometimes having a diameter of two or three lines; its surface is minutely lobulated, an appearance which results from the existence of numerous partitions within, forming many small cavities, which communicate, though not very freely, with each other. The contents of these pouches are vast numbers of exceedingly minute crystals of a somewhat oval form (Plate I. Fig. 18), pointed at their extremities, and comparable in shape to a lemon-seed, but sometimes presenting well-defined angles.

These capsules are not in any definite proportion to the size of the nerves to which they are attached, those of the brachial, for example, which is one of the largest pairs of nerves, being much smaller than those connected with the dorsal nerves, which are of less size. As to the statement by Wagner, that they are found more swollen in the spring, this condition has not been noticed in the instances which have fallen under my observation. I have detected them of nearly equal dimensions at all seasons of the year, whether examined in spring, summer, late in the autumn, or even in midwinter. They do not belong exclusively to the adult period, but, as stated by Stannius, I have found them in the larvæ at different periods, even before the development of arms and legs. Dissections of other than Raniform Batrachians have not led to their detection; I have not found them in *Siren*, *Menobranchus*, *Bufo*, or *Salamandra*, but have seen them in *Rana fontinalis*, *R. halcina*, and *R. palustris*. They seem to be in these species constant appendages to the spinal nerves. The crystals which these capsules include are similar in size and form to those contained in the vestibule of the ear; in the latter case they are in contact with the extremity of the nerve, but in the former they are simply attached to its sheath.

SECTION VII. — SYMPATHETIC NERVE.

The small number to which pairs of spinal nerves are reduced involves, as a matter of course, a sympathetic nerve of a corresponding degree of simplicity. It is connected with all of the nerves from the trigeminus to the third lumbar nerve in-

* Comp. Anat. Verteb., Part. I. p. 151.

† Manuel d'Anat. Comp., Tom. II. p. 200.

clusive; at its anterior extremity, no filament was traced to the motor communis, though analogy would lead us to expect one; nor at the other extremity was any

V. Trigeminus.

VI. Auditory nerve.

VII. Vagus.

a and b. Right and left aortas at their union.

c. Mesenteric artery.

d. Descending aorta.

e, e, e. Renal and genital ganglia.

traced to the coccygeal pair. The filament from the ganglion of the trigeminus to the vagus is very minute, and, as will be seen by reference to the figure, no sympathetic ganglion is developed upon it. Precisely similar conditions exist, according to Fischer, in *Bombinator igneus*, *Pelobates fuscus*, and *Hyla arborea*; also, according to Vogt, in *Bufo pantherinus*. From the posterior extremity of the vagal ganglion, the nerve extends backwards as far as the fourth dorsal, receiving filaments from the hypoglossal, brachial, and the two succeeding spinal nerves, and where each of these filaments joins the sympathetic trunk, a distinct ganglion is formed. After it receives its fibres from the fourth spinal nerve, it is enlarged, leaves the side of the vertebral column, and forms, with the nerve from the opposite side, a plexus around the mesenteric artery, from which it is distributed to the spleen, stomach, and intestines.

The branches of the fifth and sixth pairs unite and form a ganglion, from which a small branch goes to the splanchnic plexus, and another backwards to the ganglion of the next nerve (seventh), which is the first of the crural or lumbar pairs; this last ganglion in turn sends a branch back to the ganglia of the eighth and ninth pairs, e, e, e. The filaments given off from the group just mentioned are distributed almost entirely to the kidneys and neighboring viscera, following the course of the bloodvessels which ramify upon them.

It is seldom that we have a more favorable opportunity offered for studying the minute structure of the ganglia than in the sympathetic system of

Frogs, where they are both small and transparent. I have not been able to determine any thing different from what was previously known with regard to their minute structure. Fig. 10, Plate II. represents the ganglion just behind the third spinal nerve; a, b is the principal trunk of the nerve; c is the sympathetic branch; d, d, the sympathetic trunk in front of and behind the ganglion. Some of the fibres of the sympathetic pass through the ganglion without separating; others, leave the principal fasciculus, and become more or less mixed up with the nerve cells entering into the composition of the ganglion. The branch c divides into two

principal fasciculi, one of which goes towards the head, and the other backwards; but some of the same fibres leave the principal bundles and run irregularly among the cells. The sympathetic nerve fibres are more minute than the spinal, and some of the latter may be readily traced into the sympathetic, where they are distinguished by their size. A portion of the root *c* is, however, made up of the more minute sympathetic fibres. The ganglion cells are well defined, lightly pressed together, so that their spherical form is but slightly interfered with, and contain a few granules of a yellowish color. In no instance was a caudate cell noticed, nor any connection between the cells and the nerve tubes. The latter passed among, but not into, the cells. Each ganglion formed by the union of the spinal and sympathetic nerve may therefore be described as consisting of the following elements: 1st, a mass of ganglion cells; 2d, a fasciculus of sympathetic fibres, some of which last become detached from the principal bundle, and, after passing irregularly among the cells, either return to the fasciculus from which they came, or join one of the other fasciculi; 3d, a double series of filaments from a spinal nerve, one series passing forwards and the other backwards; some of the fibres of each series become detached from their fasciculi, and pass irregularly among the ganglion cells.

Besides these ganglia connected with the spinal nerves, others more minute appear to be formed wherever two sympathetic branches cross each other, in which case the fibres of the different fasciculi separate and form an open but irregular series of meshes, in which ganglion cells are deposited. In the formation of each ganglion, it seems to be a general rule that there is an interchange of filaments between the two or more trunks which enter into its formation; also a deposit of ganglion cells in the meshes formed by the separated fibres. In this last respect it differs from a plexus, which consists merely in the interchange of filaments of two adjoining nerves, without any deposit of nerve or ganglion cells.

From what has been stated with regard to the relation of nerve tubes and nerve cells in the brain, in the spinal chord, and sympathetic, it seems almost certain that continuity of structure between the two histological elements of the nervous system is in the species here described not essential to nervous action. The only conditions which direct observation gives evidence of is close proximity, but not absolute continuity.

EXPLANATION OF THE PLATES.

P L A T E I.

IN Figs. 1 to 9 inclusive, corresponding parts are indicated by the same letters.

Olfactory Lobes	A.
Cerebral Lobes	B.
Corpora Striata	C.
Optic Thalami	D.
Pineal Body	E.
Pituitary Body	F.
Optic Lobes	G.
Cerebellum	H.

FIG. 1. Cerebro-spinal axis seen from beneath, enlarged four times, linear measurement, showing the origins of the cranial and spinal nerves.

I. Olfactory nerve ; II. Optic nerve ; III. Motor communis ; IV. Patheticus ; V. Trigemini.

a, portio dura, or facial, which joins the ganglion of the trigemini ; *b*, motor externus or abducens, which also joins the ganglion of the trigemini ; *c*, "facial," a nerve formed by the union of a branch from the trigemini with another, *d*, from the vagus.

VI. Auditory nerve.

VII. Vagus. *d*, branch joining the "facial" ; *e*, motor root ; *f*, cutaneous branch ; *g*, *h*, glosso-pharyngeal.

I. First enlargement, or medulla oblongata.

L. Brachial enlargement.

N. Lumbar, or crural enlargement.

O. Coccygeal portion.

i, *i*. Crystal capsules connected with all of the spinal nerves, except the tenth pair.

k, *k*. Ganglia of the spinal nerves.

FIG. 2. Dorsal view of the cerebro-spinal axis, enlarged two diameters, linear measurement. A, B, D, E, G, H, the same as in Fig. 1. K, fourth ventricle. L, posterior pyramidal tract, enlarged at each of the bulgings of the chord ; the posterior pyramids form a similar enlargement for the medulla oblongata, but are separated by the fourth ventricle.

FIG. 3. Side view of the cerebro-spinal axis. Letters indicate the same parts as in the preceding figures.

FIG. 4. Brain and spinal chord of *Bufo Americanus*. References as before.

FIG. 5. Brain of *Menobranchius lateralis*. The optic lobes, G, are fused, as in *Menopoma*, and as are the olfactory lobes in Frogs and the cerebral lobes in some Plagiostome Fishes.

FIG. 6. Transverse section of the brain, showing the cavities of the olfactory, cerebral, and optic lobes.

FIG. 7. Longitudinal section of the brain, a little to the left of the median line. The corpus striatum, C, is here exposed to view, also the body within the optic lobes, G.

FIG. 8. Longitudinal section of the same on the median line; the cut surfaces are shaded. L is the entrance to the lateral ventricle, and the space between this opening and the olfactory lobes, A, indicates the extent of the fissure which extends from the upper to the under surface, completely separating the cerebral lobes from each other.

FIG. 9. A plan, showing the connection between the spinal chord and the different portions of the brain.

FIG. 10. Nerve cells or vesicles from the cerebral lobes.

FIG. 11. Pineal body, consisting almost wholly of loops of bloodvessels; the whole surface is covered with ciliated epithelium, as at *a*.

FIG. 12. A small portion of the pineal body, magnified, showing an inclosed loop of bloodvessel, and the epithelial covering.

FIG. 13. A small portion of chord from the median line, showing the nerve tubes which pass from one side to the other in the gray substance.

FIG. 14. A small portion of the chord highly magnified, showing the entrance of one of the roots of a spinal nerve, as seen on the surface.

FIGS. 15 and 16. Portions of the chord from the tail of a tadpole, showing the existence of a central mass of cells with white columns on each side; the nerve roots enter these last, and ascend towards the trunk. A few transverse fibres only are seen.

FIG. 17. The under surface of the lower jaw, and sublingual region of a Frog. M, lower jaw; V and V', branches of the facial portion of the trigeminus; the same as *i*, *k*, and *h*, Fig. 2, Plate II.

FIG. 18. Calcareous crystals from the crystal capsules of the spinal nerves.

PLATE II.

FIG. 1. General view of the spinal nerves, of the natural size. 2, brachial nerves. *a*, anastomosing filament from the third spinal nerve, forming a simple brachial plexus. The three following nerves are distributed to the walls of the abdomen. 7, 8, 9, lumbar nerves; *c*, union of the 8th and 9th with a branch from the 7th, forming the single sciatic trunk; *e*, gluteal nerve; *f*, nerve to muscles of the thigh; *g*, branches of the crural nerve, distributed to the skin of the thigh; *h*, tibial, and *i*, peroneal nerves.

FIG. 2. Some of the details of the distribution of the trigeminus (V.) and vagus (VII.) nerves. *a*, orbital branch of trigeminus; *b*, palatine branch; *c*, terminal branches to vomerine teeth and internal nasal opening; *d*, anastomosing branch to upper maxillary nerve; *e*, upper and lower maxillary nerves united; *g*, "facial," formed by the union of a branch from the trigeminus and vagus nerves; *h*, tympanic branch; *i*, jugular branch; *k*, lower jaw branch; the last two are the same as V and V', Plate I. Fig. 17; *l*, *n*, branch of vagus to heart, lungs, and stomach; *m*, glosso-pharyngeal.

FIG. 3. Side view of the branches of the trigeminus. *a*, orbital branch; *b*, palatine branch; *c*, filaments to inner nasal orifice; *d*, union of palatine and upper maxillary branches; *e*, upper maxillary nerve; *f*, lower maxillary nerve; *g*, "facial."

FIG. 4. Right eye seen from above. III. Motor communis entering superior and internal rectus muscles. IV. Patheticus distributed to the superior oblique muscles. V^a. (on the left of the figure), orbital branch of trigeminus (should be marked V.); V^a. (on the right), the *abducens*, which is a branch of the trigeminus, distributed to the external rectus.

FIG. 5. IV. Patheticus. V. Orbital branch of the trigeminus, from which a filament is given off, crossing the preceding, and which appears to communicate with it.

FIG. 6. Right eye seen from below. III. Motor communis giving branches to rectus inferior and rectus internus, also to the obliquus inferior muscles. V. Branch of trigeminus to the external rectus, *abducens*.

FIG. 7. Tadpole, showing general form of the chord previous to the development of legs.

FIG. 8. Tadpole, showing changes in the form of the chord after the development of the legs and before the absorption of the tail.

FIG. 9. Tadpole, showing the temporary branches of the vagus; *a*, branch of vagus giving off dorsal branch, *b*, distributed to the fin of the tail, and the lateral nerve, *c*; *d*, branches of vagus passing along the branchial arches. The descending branches along the side of the abdomen are spinal nerves, which escape from beneath the muscles, and pass beneath the lateral nerve, but do not communicate with it.

FIG. 10. Ganglion of the sympathetic nerve. *a*, trunk of the third spinal nerve; *b*, muscular and cutaneous portion; *c*, branch to the ganglion, dividing into ascending and descending filaments, which become separated from each other, and inclose ganglion cells; *d*, *d*, sympathetic fibres, which extend through the ganglion, in passing which their filaments separate and include ganglion cells.

FIG. 11. A, olfactory pouch; B, olfactory nerve; C, olfactory lobe; D, cerebral lobes; V, V, orbital branches of the trigeminus, crossing the olfactory nerve, sending filaments to the olfactory pouch, and terminating in the skin of the upper lip.

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