The further relations of cramps to the other hyperkineses are shown in the article on *Convulsions*. In this description of cramps we shall limit the application of the term, as is usually done, to the voluntary muscles.

Clinical History.—The voluntary muscles oftenest affected by cramps are those of the extremities, and especially those of the lower extremities. The muscles most susceptible are the gastrocnemii and plantar muscles. The psoas muscle, and flexors of the thigh upon the abdomen, are also at times affected. In the upper extremities it is the muscles of the fingers that are most often attacked. In the special neurosis of which writer's cramp is a type, the muscles of the whole arm may also be involved. Of the trunk muscles, those forming the soft wall of the abdomen are not infrequently affected with slight cramps. After a violent sneeze, for example, part of the rectus may become knotted up in a cramp. In cholera the abdominal muscles are all involved. A sudden "stitch in the side," is due to a cramp of some of the intercostal muscles. A crampy condition of the sterno-cleido-mastoid and of part of the trapezius is observed in the clonic forms of wry-neck. The muscles of the face, of the eye, and of mastication, are not subject to cramps, except in very rare cases.

When the term cramp is used, without further special designation, it refers to painful spasms in the extremities, especially the lower extremities. Attacks of such spasms come on generally at night, or after some violent exertion, such especially as swimming, when the circulation in the extremities is disturbed by the cold water. The pain and contraction come on suddenly, as a rule, though sometimes slight premonitory twinges are felt. The muscle is contracted, and feels hard and knotty, the limb is drawn up, and attempts to straighten it or to relax the muscle give great pain. The patient often feels a sensation of nausea, depression, and even of faintness. Pressure on the affected part gives relief, and forcible rubbing or sudden extension of the muscle will often relax the spasm. No especial change in the electrical relations has been observed. The attack lasts only a few seconds or minutes, as a rule, but it may continue for hours. After one attack has gone, a second and third may succeed. A patient may have to get up half a dozen times a night on account of his seizures.

When the spasms have disappeared, the muscle is left sore and tender to the touch, owing to stretching of the muscle and the irritation and injury to the sensory nerves.

Etiology.—Cramps in the extremities occur as the result of organic disease of the brain and spinal cord, and as the result of certain functional morbid conditions. Pressure on, or irritation of, nerve trunks sometimes causes cramps. The cramps of organic disease I do not purpose to consider here. The causes of the functional cramps are various. In some persons there is an inherited or connate tendency to this trouble. Cramps occur more frequently in the aged and in growing children than at the middle period of life. Gouty and rheumatic conditions, and anæmia, predispose persons to them. In disordered states of the stomach and bowels nocturnal attacks of cramp occur. Cramps in the lower extremities are often an annoying disturbance of pregnancy. In the early months the gastrocnemii and plantar muscles are most affected; later the thighs are drawn up by painful contractions of the psoas and other flexors. These cramps of pregnancy are probably at first reflex in character; later they are due to the pressure of the gravid womb on the nerves which supply the lower limbs.

Cramps of a distressing character occur in Asiatic cholera and cholera nostras. They are also observed in persons of intemperate habits. Arterial sclerosis involving the vascular supply of the legs is a cause of leg cramps of elderly people.

Probably the most frequent of all the exciting causes of ordinary forms of cramps in the extremities is violent exercise, such as swimming, dancing, walking, running, and jumping.

Pathology.—In the ordinary type of cramps the muscle itself is at fault. Through deficient nutrition or over-use its fibres are irritated, an involuntary contraction results which is painful because it is so abnormally powerful that the sensory nerve fibres are pressed upon. Tonic spasms become painful and crampy in character, therefore, simply because of a quantitative excess in muscular contraction. No one can voluntarily knot up his calf muscles as is done in a cramp. The myopathic character of the contraction is shown by the fact that, by the pressure of bands and tourniquets, which alters the blood supply to the muscles, the cramps can often be relieved.

There are, however, certain forms of cramps, like wry-neck, or writer's cramp, that are of purely nervous origin. Here the cramp is due to overstimulation.

Treatment.—The treatment of the ordinary type of leg cramps must be addressed first to the general condition. Rheumatic, gouty, and anæmic tendencies must be corrected, dyspepsia and constipation relieved. If the attacks are unusually severe and obstinate, the question of diabetes or of some organic disease must be investigated. A number of devices have been recommended for preventing the attacks. Among these, one which I have found successful is tying a tape about each thigh just above the knee. This is done just before retiring. Raising the head of the bed by placing one or two bricks under the posts is a measure which I have not found to do any good. A dose of bromide with alkalies at night, or a mixture containing gr. v. each of lupulin and camphor, may be given. In severe cases, especially in pregnancy, codeine or opium may be added to these. Massage and faradization of the limbs will sometimes ward off attacks, and so will small doses of strychnine continuously administered.

When the attack comes on, the affected muscles must be vigorously rubbed and kneaded. If the patient jumps up at once and puts the muscles on the stretch, he can often break up the cramp. A little rubbing and exercise will then quiet the muscle. *Charles L. Dana.*

CRANIAL NERVES.—The Doctrine of Nerve Components.—The proper classification and morphological comprehension of the cranial nerves, human and comparative, have remained in an unsatisfactory state because of the difficulty of correlating the several anatomical and physiological data with each other and with the findings of the embryologists. That the arrangement and composition of the twelve pairs of cranial nerves as commonly enumerated have a profound morphological significance is evident from the remarkable constancy with which their main features are repeated throughout the vertebrate phylum. But we are still very far from a complete explanation of the individual peculiarities of the several pairs, and especially of the differences between the cranial and the spinal nerves. During the past decade, however, this field has been very diligently cultivated by the comparative anatomists and much progress has been made toward a better comprehension of the significance of the peripheral nervous system as a whole.

Starting from the undifferentiated nerve tube of the ancestral vertebrate or of the embryo, the morphologist who follows the series of forms presented by the central nervous systems of the animal types from Amphioxus to man will find the problems suggested by this progressively increasing complexity soluble largely in proportion as he realizes that every change in the centre is but the reflection of a corresponding change in the peripheral nervous system, especially the sense organs, which in turn rests upon a new point of contact with the outside environment.

This point of view—the correlation of changes in the centre with those in the periphery—lies at the basis of the recent work on nerve components. To Gaskell belongs the credit of having clearly separated the peripheral nervous system into two great categories: on the one hand, the visceral systems, sensory and motor, which effect the adjustments to the internal environment; and on the other hand, the somatic systems, sensory and motor, which effect the adjustments to the external environment. With this as a foundation to build upon,

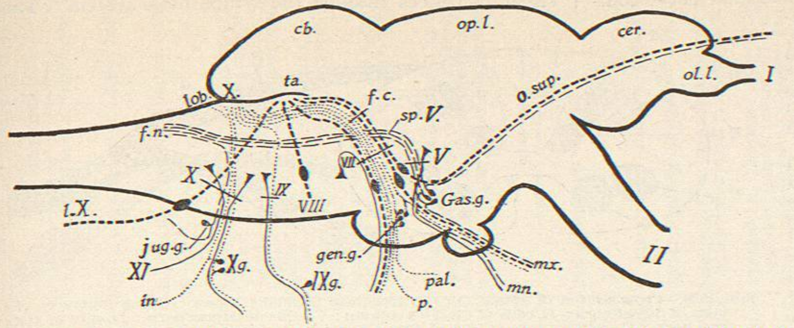

Fig. 1535.—The Cranial Nerves of *Menidia* as seen from the right side, illustrating the central convergence of the sensory components of the several nerves into functional systems. The eye-muscle nerves have been omitted, the superficial origins of the others being indicated by the Roman numerals at the transverse lines drawn across their roots. The viscero-motor roots are drawn as continuous lines, the general cutaneous roots as broken lines, the acustico-lateral system as heavier broken lines, and the communis system (visceral sensory) as dotted lines. The positions of the auditory and of the four lateral line ganglia are indicated, though no special designations are given them. This scheme can be applied with but slight modification to all of the fishes. The student of comparative anatomy will notice that some rami peculiar to the teleosts have been omitted, *e.g.*, the r. lateralis accessorius and the general cutaneous fibres in the hyomandibular trunk. Compare the detailed plot from which this diagram is drawn off, *Journal of Comp. Neurology*, vol. ix., plate xvi., and *Archives of Neurology and Psychopathology*, vol. ii., plate iii. The scheme can be adapted to higher vertebrates (including man) by the suppression of the lateral line roots of the facialis and vagus, leaving the VIII. nerve as the only representative of the acustico-lateral system.

cb., Cerebellum; *cer.*, cerebrum; *f.c.*, fasciculus communis (=fasc. solitarius); *f.n.*, funicular nucleus (terminal nucleus of spinal V. tract); *Gas.g.*, Gasserian ganglion; *gen.g.*, geniculate ganglion; *in.*, ramus intestinalis vagi; *IX.g.*, glossopharyngeal ganglion; *jug.g.*, jugular (gen. cutaneous) ganglion of the vagus; *lob.X.*, lobus vagi (sensory vagus nucleus); *l.X.*, ramus lateralis vagi; *mn.*, ramus mandibularis V; *mx.*, ramus maxillaris V; *ol.l.*, olfactory lobe; *op.l.*, optic lobe; *o.sup.*, superficial ophthalmic branches of the VII. and V. nerves (the latter = frontal nerve of man); *p.*, pretrematic branch of the facialis, corresponding in position with the chorda tympani of man, though not strictly homologous with it; *pal.*, ramus palatinus VII. (= great superficial petrosal); *sp.V.*, spinal V. tract; *ta.*, tuberculum acusticum (terminal nucleus for acustico-lateral system); *thm.*, hyomandibular trunk (= great facial trunk of man); *Xg.*, chief vagus ganglion; *XI.*, motor fibres for trapezius muscle, supposed to represent the accessory nerve.

Strong carried out the separation of these elements, especially the sensory ones of the cranial nerves, into other components.

Undoubtedly the morphological unit of structure in the peripheral, as in the central, nervous system is the neuromere, or neural segment. This is clearly seen in the peripheral (though not in the central) nervous system in the trunk region of the adult body, each spinal nerve repeating in a metameric way the morphological plan of its predecessors. Both embryology and comparative anatomy show that the head was also primitively segmented, and the present arrangement of the cranial nerves of man undoubtedly has a metameric basis; nevertheless so many disturbing factors have entered that it has thus far been impossible to determine what was the original segmentation of the head in general or of the cranial nerves in particular, so that it is not yet practicable to base a classification of the nerves upon this feature. On the other hand, the numerical designations of Sömmering now generally employed have little significance other than mere convenience in topographical description.

A descriptive unit which is much more generally useful is the functional *system*. Such a system has clearly definable morphological characters, easily demonstrable in the adult, and is immeasurably more useful in clinical neurology, and indeed in all pathological work. Each system may be defined as the sum of all the nerve fibres in the body, which possess certain physiological and morphological characters in common, so that they may react in a common mode. Morphologically, each system is defined by the terminal relations of its fibres—by the organs to which they are related peripherally and by the centres in which the fibres arise or terminate. The fibres of a single system may appear in a large number of nerves, repeated more or less uniformly in a metameric way (as in the general cutaneous system of the spinal nerves), or they may all be concentrated into a single nerve (as in the optic nerve). On the other hand, a single nerve may contain several components, *i.e.*, its fibres may belong to several of these systems. It becomes necessary, therefore, to analyze the root complex of each pair of cranial nerves into its components and to trace not only the central connections of these components within the brain, but also their peripheral courses as well. In other words, the description of any given nervous ramus is not complete when we have given its point of origin from the nerve trunk or ganglion, the details of its devious courses, and the exact points where the several ramuli terminate. In addition to this it is necessary to learn what systems are represented in the ramus, and the precise central and peripheral relations of each system.

The difficulty in determining this latter point is the chief obstacle in the way of researches on the nerve components; for, while the central connections of any nerve can be determined by the microscopical method, the peripheral courses are usually studied by gross methods which reveal nothing of the precise relations of the several components peripherally, and hence do not permit a knowledge of each system as a whole. To trace the components of the more complex cranial nerves continuously from their nuclei of origin or termination within the brain by means of serial sections to their ultimate peripheral termini has never been attempted in the human body. In a few of the lower vertebrates, however,

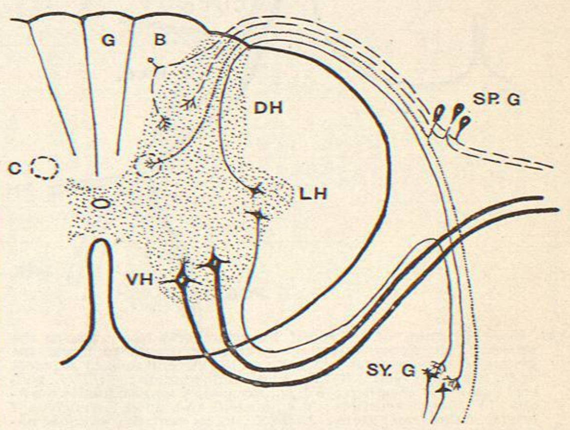

Fig. 1536.—Diagram illustrating the Composition of the Typical Spinal Nerve. The general cutaneous system is represented by broken lines, the visceral sensory by dotted lines, the somatic motor by the heavy continuous lines, the visceral motor by the lighter continuous lines. The visceral motor fibres of the dorsal root are found in lower vertebrates; their presence in the mammals is controverted.

B, Column of Burdach; *C*, Clarke's column; *DH*, dorsal horn; *G*, column of Goll; *LH*, lateral horn; *SP.G*, spinal ganglion; *SY.G*, sympathetic ganglion; *VH*, ventral horn.

this has been accomplished with a fair measure of success. All of the types thus far studied in this way exhibit certain broad general resemblances and permit the establishment of a schematic type of cranial nerve components which is presumably applicable to the vertebrates as a whole. From anatomical, physiological, and clinical data already in hand it is possible to compare the human nerves with this scheme and to infer the composition of most of the peripheral rami with more or less of accuracy.

The composition of the cranial nerves has been most fully worked out by Strong in the tadpole of the frog and by the present writer in the small marine fish called "silver sides" (*Menidia*) and in the codfish. Other notable contributions to the doctrine of the components have been made by Cole, Allis, Kingsbury, Ewart, Pollard, Shore, Gaskell, and others. The accompanying diagram (Fig. 1535) expresses the relations of the components as found in Menidia.

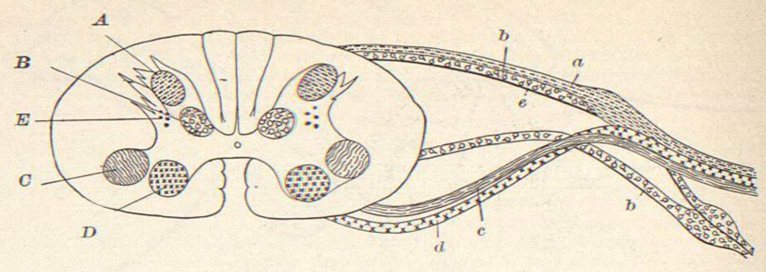

FIG. 1538.—Cross-section of Spinal Cord to Illustrate Gaskell's Views. (Hans Gadow.) *A*, cells of dorsal horn; *B*, cells of Clarke's column; *C*, cells of lateral horn; *D*, cells of ventral horn; *E*, solitary cells at base of dorsal horn; *a*, somatic afferent fibres; *b*, splanchnic ganglionated efferent fibres; *c*, splanchnic non-ganglionated efferent fibres for visceral and enteric muscles; *d*, somatic efferent fibres; *e*, splanchnic afferent fibres.

Following Gaskell and His, we now recognize four systems of components (see Fig. 1536) in the spinal nerves, two motor and two sensory: 1. Somatic motor fibres, arising from cells of the ventral horn and forming the major part of the ventral root, to supply the somatic musculature. 2. Visceral motor fibres, arising from cells in the region of the lateral horn and emerging with the ventral root and (in lower vertebrates, at least) also with the dorsal root. They innervate the visceral or splanchnic musculature via the sympathetic system, forming the preganglionic fibres of Langley. 3. General cutaneous fibres, arising from cells of the spinal

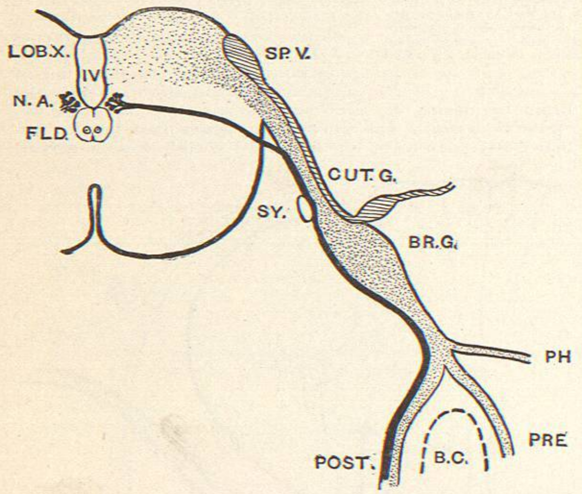

FIG. 1537.—Diagram of a Typical Branchiomeric Nerve among the Fishes. The viscero-motor component is drawn in black, the general cutaneous cross-hatched and the visceral sensory stippled. *B.C.*, Branchial cleft; *BR.G.*, branchial ganglion; *CUT.G.*, general cutaneous ganglion; *FLD.*, fasciculus longitudinalis medialis; *IV.*, fourth ventricle; *NA.*, nucleus ambiguus, the nucleus of origin of the motor fibres; *LOB.X.*, lobus vagi, the terminal nucleus of the visceral sensory fibres; *PH.*, ramus pharyngeus; *POST.* post-trematic ramus; *PRE.* pre-trematic ramus; *SP.V.*, spinal V. tract, associated with the terminal nucleus of the general cutaneous fibres; *SY.*, sympathetic ganglion.

ganglia and forming the greater part of the dorsal root fibres. They comprise the somatic sensory fibres of Gaskell, excluding, however, fibres to special cutaneous sense organs of all kinds. 4. Visceral sensory fibres, arising from cells of the spinal ganglia, entering the spinal cord through the dorsal root to terminate probably in Clarke's column and distributing peripherally to visceral surfaces through the sympathetic system. The number of fibres of this system in most of the spinal nerves is probably small, the visceral sensory function having been largely supplanted by the visceral branches of the vagus. Whether any visceral sensory fibres arise from cells in the sympathetic ganglia is a disputed point.

Each of the spinal nerves typically contains some fibres of each of these four systems; but the relations in the head are complicated by the reduction of some components and the great exaggeration of others, as well as by the introduction of entirely new systems. The somatic motor system is represented in the hypoglossus and the eye-muscle nerves; the motor nuclei of the XI., X., IX., VII., and V. pairs are commonly relegated to the visceromotor system; the general cutaneous system is represented in the vagus, trigeminus, and according to some authorities in the glossopharyngeus, and the visceral sensory system corresponds to what we have termed in the lower vertebrates the *communis system*—*i.e.*, sensory nerves related to the fasciculus communis (= fasc. solitarius) and its associated terminal nuclei, viz., the visceral sensory portion of the vagus, the lingual branch of the glossopharyngeus, and the portio intermedia of the facialis. Associated with the general visceral fibres of these latter nerves are others of a special sensory nature innervating the taste buds. It is not at present possible to differentiate these two types of fibres centrally and they are both included under the designation "communis system." Presumably the special sensory fibres have been derived from the general visceral system in correlation with the differentiation of the special sense organs of the mouth.

With the advancing specialization of the head in vertebrates, the motor systems of this region (especially the segments in front of the gills) have been either reduced or devoted to special functions, and the unspecialized sensory systems of the trunk are largely replaced by nerves of special sense, such as those of the ear, eye, and nose. The increasing relative importance of the sensory nerves as compared with the motor, as we pass cephalad, is illustrated by figures given by Donaldson. Thus, the ratio of motor to sensory fibres entering the spinal cord is estimated as 1:1.6, while the ratio of motor to sensory fibres in the cranial nerves taken as a whole is 1:30. From the point of view of composition, the nerves of the body may be divided into four types, as follows:

1. The spinal type. Its characters are given above. The hypoglossus is the only cranial nerve belonging here. In some of the fishes this is a typical spinal nerve in all respects save that it sends some fibres of its ventral ramus forward into the hyoid (tongue) musculature. In man all the nerve except these latter fibres has disappeared.

2. The branchiomeric type. The nerves of this type in the fishes supply the gill arches and their derivatives, the hyoidean and mandibular arches, comprising the X.,

TABLE OF NERVE COMPONENTS.

System.	Function.	Nerve roots.	Primary nuclei.	Chief secondary connections.	Ganglia.	Chief rami.
I. Somatic motor.	Motor (somatic or skeletal musculature).	1. Ventral spinals..	Ventral horns	Reflex paths from sensory spinal centres; motor zone of cortex via direct and crossed pyramids.	....	Dorsal and ventral rami of spinal nerves.
		2. XII. nerve......	XII. nucleus..........	Reflex paths from sensory cranial nuclei (?) from superior olive and from cortex via pyramids and tract of Hoche in medial fillet.	....	Rami to tongue musculature (speech mechanism).
		3. VI. nerve .... 4. IV. nerve .... 5. III. nerve	VI. nucleus.......... IV. do. .... III. do.	Reflex paths from sensory cranial nuclei and from superior olive; from pregeminum and from spinal centres via fasc. long. medialis; from cortex via pyramids.	....	Rami for the extrinsic and intrinsic eye muscles.
II. Viscero-motor.	Motor (visceral musculature).	1. Ventral and dorsal spinals.	Lateral horns.........	Reflex paths from sensory spinal centres (?) collaterals from pyramids (?).	....	Preganglionic nerves, rami communicantes to sympathetic ganglia, possibly also to sporadic ganglia via dorsal and ventral rami.
		2. XI. nerve.......	(a) Lateral horn...... (b) N. ambiguus ...	Do	....	Accessorius spinalis, for sterno-mastoid and trapezius muscles. Accessorius vagi, joins vagus trunk.
		3. X. nerve........	(a) Chief vagus n .. (b) N. ambiguus....	Reflex paths from sensory cranial nuclei; collaterals from the pyramidal tracts.	....	External laryngeal, inferior laryngeal, cardiac, œsophageal, gastric.
		4. IX. nerve........	N. ambiguus.........			Stylo-pharyngeus muscle.
		5. VII. nerve.......	VII. nucleus	From sensory V. root; corp. trapezoides (cochlear root); fundamental lateral column (lower sensory centres?); pyramidal tracts and tract of Hoche in medial fillet.	....	Stapedius muscle, auricular and scalp muscles, posterior belly of digastric, stylo-hyoid, superficial facial musculature.
		6. V. nerve	(a) Chief motor n., (b) mesencephalic n. and locus cœruleus.	Reflex paths from sensory cranial nuclei; collaterals from pyramidal tracts.	....	Temporal, masseter, external and internal pterygoid, tensor palati, tensor tympani, anterior belly of digastric and mylo-hyoid muscles.
III. General cutaneous.	General tactile sensibility.	1. Dorsal spinals...	Dorsal horns	(1) Dorsal columns, funicular nuclei, medial fillet to cerebral cortex and reflex centres of basal ganglia; (2) lateral fundamental columns to basal ganglia; (3) funicular nuclei to cerebellum via restiforme; (4) Gowers' tract to cerebellum.	1. Spinal ganglia	Dorsal and ventral rami of spinal nerves.
		2. General cutaneous root of X.n.	Substantia gelatinosa of spinal V. tract.	Collaterals of root fibres (of V.) and secondary fibres to all cranial motor nuclei and to cerebellum (?); sec. connections with cerebral cortex and reflex centres of basal ganglia via lateral fillet and to vermis cerebelli via restiforme.	2. Jugular ganglion of X.	Ramus auricularis vagi.
		3. General cutaneous root of IX. nerve (?).	do.		3. Jugular ganglion of IX. (?).	(?)
		4. Sensory V.......	Do. + chief sensory V. nucleus.		4. Gasserian ganglion.	R. ophthalmicus, r. maxillaris, r. mandibularis.
IV. Visceral sensory (including communis system).	Visceral reflexes, taste.	1. Dorsal spinals...	Clarke's column (?) ...	Obscure—possibly Flechsig's dorso-lateral cerebellar tract.	1. Spinal ganglia	Enter sympathetic through rami communicantes.
		2. Visceral sensory root of X.	Spinal nucleus (fasc. solitarius).	Reflex connections with cranial motor nuclei; cerebral cortex via lateral fillet; cerebellar vermis via restiforme.	2. Trunk ganglion of X. (ganglion nodosum).	Meningeal r., r. pharyngeus, internal laryngeal r., inferior laryngeal r., visceral rami.
		3. Visceral sensory root of IX.			3. Petrosal ganglion of IX.	Tympanic r., pharyngeal rami, lingual rami (gustatory, posterior one-third of tongue).
		4. Portio intermedia VII.			4. Geniculate ganglion.	Great superficial petrosal; sensory fibres in main facial trunk; anastomoses with the sympathetic; chorda tympani (mainly gustatory—anterior two-thirds of tongue).
V. Acustico-lateral.	A. equilibrium (static sense).	VIII. vestibular, or median, or anterior (+ lateral line roots of VII. and X. nerves of lower vertebrates)	(a) medial (Schwalbe), (b) spinal or descending, (c) lateral (Deiters), (d) superior (Flechsig, v. Bechterew), probably also (e) ventral cochlear nucleus, (f) cerebellum and other adjacent nuclei.	(1) Cerebellum, (2) fasc. long. medialis for oculomotor nuclei and lower centres, (3) lateral fillet, (4) lateral vestibular bundle.	Vestibular ganglion (ganglion of Scarpa).	Vestibular rami.
	B. audition	VIII. cochlear, or lateral or dorsal.	Ventral and dorsal cochlear nuclei, trapezoid body, superior olive, etc.	(1) Striæ acusticæ and trapezoid body, superior olive, nucleus of lateral fillet, postgeminum, geniculatum mediale, cerebral cortex; (2) cerebellum.	Spiral ganglion (ganglion of Corti).	Cochlear ramus.
VI. Optic.........	Vision	Optic nerve (?)	(a) Geniculatum externum, (b) pulvinar	Optic radiations to occipital cortex..................	(?). Represented in the retina.	
			(c) pregeminum	Reflex connections with lower centres, especially with nuclei of III., IV., and VI. nerves.		
VII. Olfactory....	Smell	Fila olfactoria	Mitral cells of olfactory bulb.	(1) Lateral olfactory striæ to olfactory lobe (collaterals) and cortex of the uncus; (2) medial olfactory striæ to area parolfactoria, trigonum olfactorium, gyrus subcallosus, gyrus fornicatus, hippocampus; (3) ental olfactory tract, to pars anterior of anterior commissure and gyrus hippocampi.	Specific olfactory cells of nasal mucous membrane.	Absent.

IX., VII., and V. pairs. In the mammals, the true gill arches having disappeared save for slight vestiges in the laryngeal region, the primitive characters of these nerves have been profoundly modified. The spinal accessory

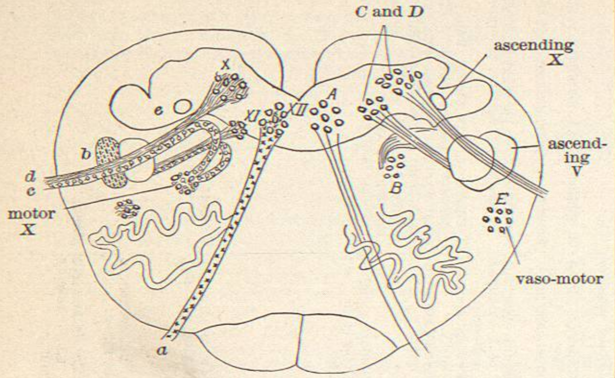

FIG. 1539.—Schematic Cross-section of the Medulla Oblongata. (Gaskell.) *A*, cells corresponding to those of ventral horn; *B*, cells corresponding to those of lateral group of ventral horn; *C*, cells corresponding to those of Clarke's column; *D*, cells corresponding to the solitary cells at base of ventral horn; *E*, cells corresponding to those of lateral horn; *a*, somatic efferent fibres; *b*, somatic afferent fibres; *c*, splanchnic non-ganglionic efferent fibres; *d*, splanchnic ganglionated efferent fibres; *e*, splanchnic afferent fibres.

nerve is a complex, belonging in part to the first type and in part to the second. The composition of a typical branchial nerve of the bony fishes is illustrated by the accompanying diagram (Fig. 1537).

3. The oculomotor type. Illustrated by the VI., IV., and III. pairs, commonly regarded as somatic motor nerves.

4. Nerves of special sense. These comprise the olfactory, optic, and auditory nerves, and should doubtless in-

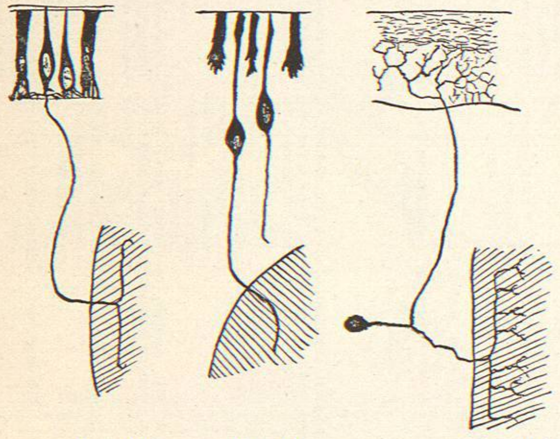

FIG. 1540. FIG. 1541. FIG. 1542.

FIGS. 1540, 1541, AND 1542.—Diagrammatic Representations of the Migration of the Peripheral Sensory Ganglion Cells from the Epidermis toward the Central Nervous System in Different Animals. (After Retzius.) Fig. 1540, Lumbricus; Fig. 1541, Limax; Fig. 1542, vertebrates.

clude also the gustatory nerves (related to the fasciculus solitarius), though these latter, as stated above, cannot as yet be separated anatomically in their intracranial courses from the associated nerves of general visceral sensation.

The account here given, though based largely on Gaskell's scheme, differs from his in important respects. The main features of his analysis of the cranial and spinal nerves can be gathered from the accompanying figures and their legends (Figs. 1538 and 1539).

The accompanying table expresses the chief relations of the several components so far as known in the human body. Compare the more detailed exposition of the several nerves beyond. It should be borne in mind that the analysis here given is in several respects theoretical rather than demonstrated fact. In particular, the distribution of the cerebral motor roots in the somatic and visceral groups, as here indicated, is greatly in need of confirmation. The table is intended to present the views now most generally accepted, and must be held subject to revision and further analysis as our knowledge advances.

PHYLOGENY AND EMBRYOLOGY.—The peripheral nervous system (including probably the whole of the sympa-

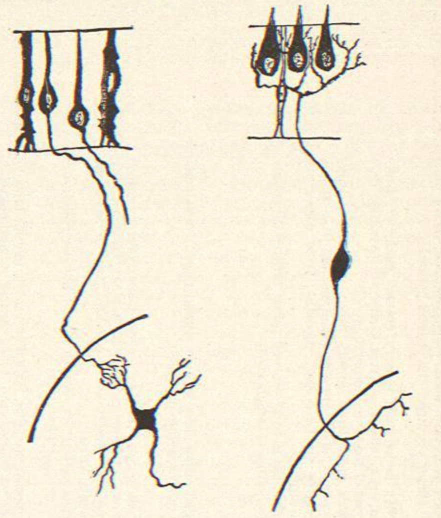

FIG. 1543. FIG. 1544.

FIG. 1543.—Diagram of the relations of the Specific Olfactory Cells of the Nose with the Central Nervous System. (After Retzius.)
FIG. 1544.—Diagram of the connections of the Auditory Ganglion Cells. (After Retzius.)

thetic system) is exclusively ectodermal in origin. In some lowly invertebrates the entire nervous system lies close under the epidermis, or even in this layer. But with the increasing demand for the correlation and integration of nervous impulses, the central system is in early phylogenetic stages specialized off to lie in the deeper layers of the body. On the other hand, the cell bodies of the peripheral nervous system may retain their peripheral position in the epidermis in animals of a much higher grade. Thus, in the earthworm the epidermis is composed of a single layer of columnar epithelium cells, among which in the cephalic region of the body are scattered spindle-shaped sensory cells, each giving rise to a nerve fibre which terminates in the central nervous system (Fig. 1540). In other invertebrates (as in the slugs) the cell body has retired a longer or shorter distance from the surface, being provided, in addition to its central process, with a peripheral process extending to the periphery (Fig. 1541). Finally, in the vertebrates the typical arrangement is given by the general cutaneous nerves, whose cell bodies have sunken as far as possible below the surface until they lie in the spinal ganglia adjacent to the spinal column (Fig. 1542). In this case, too, it will be noted that the cell body, instead of lying in the path of the fibre (bipolar), has been crowded off to one

side and become unipolar. This arrangement is characteristic of the spinal ganglion cells and of most of the cranial ganglia, viz., those of the X., IX., VII., and V. nerves.

Not all of the nerves of the human body, however, have been specialized so far in this direction. The olfac-

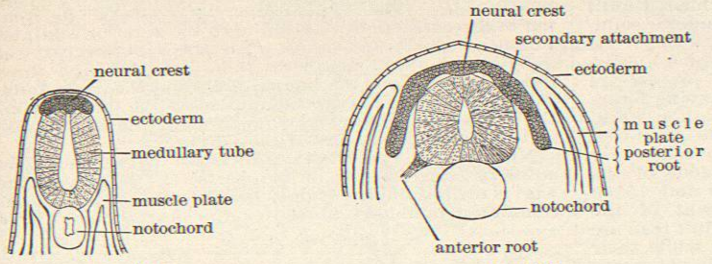

FIG. 1455. FIG. 1546.

FIGS. 1545 and 1546.—Two Stages in the Development of the Neural Crest and Spinal Ganglion in the Embryo Chicken. (After Marshall.)

tory nerve, in fact, has retained the primitive invertebrate arrangement with but slight modification. It is the most archaic nerve of the body. The specific olfactory cells are scattered among the indifferent cells of the olfactory membrane and are provided each with a fibrous prolongation directed centrally, which pierces the basement mem-

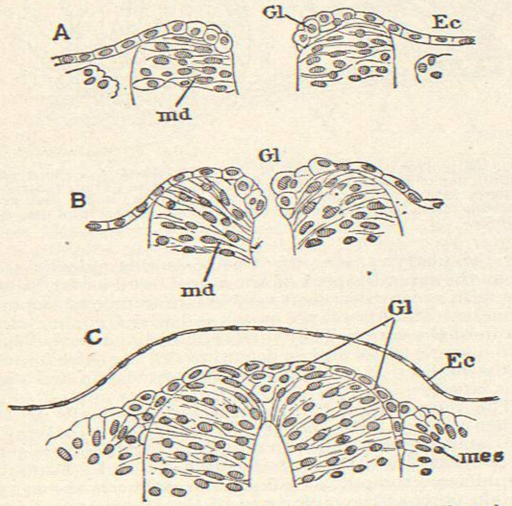

FIG. 1547.—The Formation of the Neural Crest. Sections through the cervical region of a human embryo of fourteen to sixteen days. (After v. Lenhossék.) *Ec*, Ectoderm; *mes*, mesoderm; *Gl*, neural crest; *md*, medullary plate, closing in to form the neural tube.

brane of the epithelium and forms one of the fibres of the olfactory nerve, finally to terminate in an arborization in one of the glomeruli of the olfactory bulb. The olfactory "nerve," therefore, really corresponds to the radix of a spinal sensory nerve in that it is made up of root fibres, *i.e.*, fibres passing from the ganglion to the centre. Another evidence of the primitive character of the olfactory nerve is found in the absence of medullary sheaths upon its fibres. The fibre corresponding to the peripheral process of a spinal ganglion cell never develops, since the cell body itself lies in the periphery (Fig. 1543).

The auditory nerve is intermediate between this type and that of the spinal nerves, since the cell body is bipolar and lies in the spiral ganglion midway between the periphery and the oblongata (Fig. 1544). It is therefore in this respect a more primitive type of nerve than the spinal nerve. In other respects, however, it is more highly specialized. For instance, instead of ending free in the periphery among unaltered cells, it, like the gustatory nerves, ramifies about specially modified epithelial cells which serve as receptive organs for these nerves of special sense.

There is some evidence that these nerves of special sense arise in the periphery, their ganglion cells being specialized in the ectoderm at the site of the future sensory organ. The optic nerve belongs to a distinct category, since the ectodermal rudiment of the eye and its nerve is formed on the cephalic plate before its invagination into the nerve tube, then to be secondarily evaginated from the nerve tube into its definitive position.

The other sensory nerves (and, according to the researches of His, Jr., the sympathetic system also) are derived from cells which migrate out from the ectoderm at the time of the invagination of the nerve tube at the seam, or line of contact, between the nerve tube and the unmodified ectoderm from which the latter is derived. These cells arise in some cases apparently from the ectoderm just after the neural tube has been pinched off, in other cases from the dorsal wall of the tube at a corresponding period. In either case they form a ridge or heap of cells between the dorsal edge of the tube and the overlying ectoderm, which is termed the "neural crest." Its cells now migrate down on either side of the neural tube into the definitive position of the spinal ganglion, meanwhile becoming bipolar by the growth of a fibrous process from each pole of the spindle-shaped cell body. One of these processes grows outward toward the periphery, the other inward to form the sensory root of the nerve in question. Two stages in the development of

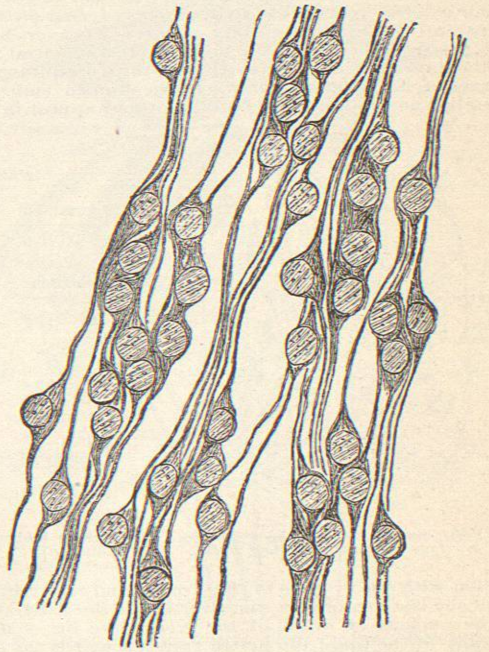

FIG. 1548.—Bipolar Spinal Ganglion Cells from a Human Embryo. (After His.)