that the angle is larger in man than in any of the inferior animals and is largest in those races that possess the greatest intellectual development.

Pathological Observations.—It is a fact now generally admitted in pathology, that loss of cerebral substance from repeated hæmorrhage is sooner or later followed by impairment of the intellectual faculties. This point is frequently difficult to determine in an individual instance, but an analysis of a sufficient number of cases shows impaired memory, tardy, inaccurate and feeble connection of ideas, abnormal irritability of temper with a childish susceptibility to petty or imaginary annoyances, easily excited emotional manifestations and a variety of phenomena denoting abnormally feeble intellectual power, following any considerable disorganization of cerebral substance. In short, pathological conditions of the brain all go to show that the intellectual faculties are directly connected with the cerebral hemispheres.

In idiots the brain usually is of small size, although there are exceptions to this rule. In two cases of adult idiots, reported by Tiedemann, the brain was about one-half of the normal weight. The brain of an idiotic woman, forty-two years of age, reported by Gore, weighed ten ounces and five grains (about 284 grammes). It has been observed, also, that the cerebellum is not proportionally diminished in size in idiots (Bradley). In one instance reported, the proportion of the cerebellum to the cerebrum was as 1 to 5·5. In the healthy adult male of ordinary weight, the proportion is as 1 to 8¾. The statements just made with regard to the brains of idiots refer to cases characterized by complete absence of intelligence, and farthermore, probably, by very small development of the body. On the other hand, there are instances of idiocy, the body being of ordinary size, in which the weight of the encephalon is little if any below the average. Lélut has reported several cases of this kind. In one of these, a deaf-mute idiot, forty-three years of age, a little above the ordinary stature, presenting "idiocy of the lowest degree; almost no sign of intelligence; no care of cleanliness," the encephalon weighed 48·32 oz. (1,369·8 grammes). Other cases of idiots of medium stature are given, in which the brain weighed but little less than the normal average. In the *West Riding Lunatic Asylum Reports*, London, 1876, is a report of the case of a congenital imbecile, aged thirty years, height five feet and eight inches (172·7 centimetres), died of phthisis, whose brain weighed 70½ oz. (2,000 grammes). This is heavier than the heaviest normal brain on record. The normal brain-weight is 49½ oz. (1,408·3 grammes).

Reaction-Time.—The time which elapses between the application of a stimulus and its appreciation by the individual experimented upon is known as reaction-time. In experiments with reference to this point, the person observed makes an electric signal when the sensation is perceived. The reaction-time is 0·12 of a second for a shock on the hand, 0·13 for the forehead, 0·17 for the toe and 0·13 for a sudden noise (Exner). The duration is about 0·16 of a second for impressions made on the nerves of special sense. This is the time of conduction of the impression to the brain, its appreciation by the individual, the generation of the voluntary impulse and the conduction of this impulse to the muscles concerned in making the signal. It is probably

subject to variations analogous to those observed in the "personal equation."

Centre for the Expression of Ideas in Language.—The location of this centre depends entirely upon the study of cases of disease in the human subject. It is evident that there must be a comprehension of the significance of words, the formation of an idea more or less complex, and a co-ordinate action of the muscles concerned in speech, as conditions essential to expression in spoken words. One or more of these conditions may be absent in cases of disease; and the general absence of the power of verbal expression, when this depends on cerebral lesion, is known as aphasia. This is quite different from aphonia, which is simply loss of voice. If the comprehension of the meaning of words be absent, the individual is incapable of receiving ideas expressed in language. In cases of aphasia it often is difficult to determine this point. In certain cases it is possible that the individual may understand what is said and may form ideas to which he is unable to give verbal expression. In such instances he can neither speak nor write. There are certain cases in which the written or printed words convey no idea, while spoken words are understood, but there is no loss of intelligence and words are spoken without difficulty. This condition is called word-blindness. If there be simple want of co-ordination of the muscles concerned in speech, words are spoken which may have no connection with the idea to be conveyed, but the individual may be able to express himself in writing. This condition is known as ataxic aphasia. The inability to express ideas in writing is called agraphia, and this is usually an indication of the condition known as amnesic aphasia, in which it is impossible to put ideas into words in any way. Persons affected with purely ataxic aphasia may understand and write perfectly, but they can not read aloud or repeat words or sentences spoken to them. In cases of simple amnesic aphasia, patients can sometimes repeat dictated words. In cases in which hemiplegia is marked, the aphasia usually is ataxic. In cases in which there is no hemiplegia, the aphasia usually is amnesic. The ataxic and amnesic forms of aphasia may be combined. A full description, however, of the many and varied forms of aphasia would be out of place in this work.

In 1766, Pourfour du Petit reported a case of aphasia, with lesion of the left frontal lobe of the cerebrum, in which the patient could pronounce nothing but "*non.*"

Marc Dax (1836) indicated loss or impairment of speech in one hundred and forty cases of right hemiplegia. These observations attracted little attention, until 1861, when the subject was studied by Broca. Since then, many cases of aphasia with lesion of the left frontal lobe have been reported by various writers. In 1863, M. G. Dax, a son of Marc Dax, limited the lesion to the middle portion of the left frontal lobe. It was farther stated, by Broca and Hughlings Jackson, to be that portion of the brain nourished by the left middle cerebral artery (the inferior frontal branch). According to recent observers, the most frequent lesion is in the parts supplied by the left middle cerebral artery, particularly the lobe of the insula, or the island of Reil; and it is a curious fact that this part is found only in man and monkeys, being in the latter very slightly developed.

While the cerebral lesion in aphasia involves the left frontal lobe in the great majority of cases, there are instances in which the right lobe alone is affected, and these occur in left-handed persons. Aside from the anatomical arrangement of the arteries, which seem to furnish a greater quantity of blood to the left hemisphere, it is evident that as far as voluntary movements are concerned, the right hand, foot, eye etc., are used in preference to the left, and that the motor operations of the left hemisphere are superior in activity to those of the right. Bateman has quoted two cases of aphasia dependent upon lesion of the right side of the brain, and consequent left hemiplegia, in which the persons were left-handed; and these, few as they are, are important, as showing that a person may use the right side of the brain in speech, as in the other motor acts. Although most anatomists have failed to find any considerable difference in the weight of the two cerebral hemispheres, Boyd has shown by an "examination of nearly two hundred cases at St. Marylebone, in which the hemispheres were weighed separately, that almost invariably the weight of the left exceeded that of the right by at least the eighth of an ounce (4·5 grammes)."

Broadbent has reported an examination of the encephalon of a deaf and dumb woman. In this case the brain was found to be of about the usual weight, but the left third frontal convolution was of "comparatively small size and simple character."

Taking into consideration all of the pathological facts bearing upon the question, it seems certain that in the great majority of persons, the organ or part presiding over the faculty of language is situated on the left side, at or near the third frontal convolution and the island of Reil, mainly in the parts supplied by the middle cerebral artery. In some few instances the organ seems to be in the corresponding part upon the right side. It is possible that originally both sides preside over speech, and the superiority of the left side of the brain over the right and its more constant use by preference in right-handed persons may lead to a gradual abolition of the action of the right side of the brain, in connection with speech, simply from disuse. This view, however, is purely hypothetical. In some cases of aphasia from lesion of the speech-centre in the left hemisphere, recovery takes place, and occasionally "speech has been again lost when a fresh lesion occurred in this part of the right hemisphere" (Gowers). In the ataxic form of aphasia, the idea and memory of words remain, and there is loss of speech simply from inability to co-ordinate the muscles concerned in articulate language. Patients affected in this way can not speak but can write with ease and correctness. In the amnesic form of the disease, the idea and memory of language are lost; patients can not speak, and are affected with agraphia, or inability to write. The motor tracts from the centre for speech pass to the anterior portion of the posterior division of the internal capsule and thence through the left crus, into the pons Varolii, where they decussate and go to the right side of the medulla oblongata.

The Cerebellum.

It is not necessary in order to comprehend the uses of the cerebellum, as far as these are known, to enter into a full description of its anatomical characters. The points, in this connection, that are most important are the following: the division of the substance of the cerebellum into gray and white matter; the connection between the cells and the fibres; the connection of the fibres with the cerebrum and with the prolongations of the columns of the spinal cord; the passage of fibres between the two lateral lobes. These are the only anatomical points that will be considered.

Physiological Anatomy.—The cerebellum, situated beneath the posterior lobes of the cerebrum, weighs about 5·25 ounces (148·8 grammes) in the male, and 4·7 ounces (135 grammes) in the female. The proportionate weight to that of the cerebrum is as 1 to $8\frac{3}{4}$ in the male, and as 1 to $8\frac{1}{2}$ in the female. The cerebellum is separated from the cerebrum by a strong process of the dura mater, called the tentorium. Like the cerebrum, the cerebellum presents an external layer of gray matter, the interior being formed of white, or fibrous nerve-tissue. The extent of the gray substance is much increased by abundant, fine convolutions and is farther extended by the penetration, from the surface, of arborescent processes of gray matter. Near the centre of each lateral lobe, embedded in the white substance, is an irregularly dentated mass of gray matter, called the corpus dentatum. The convolutions are finer and more abundant and the gray substance is deeper in the cerebellum than in the cerebrum. These convolutions, also, are present in many of the inferior animals in which the surface of the cerebrum is smooth.

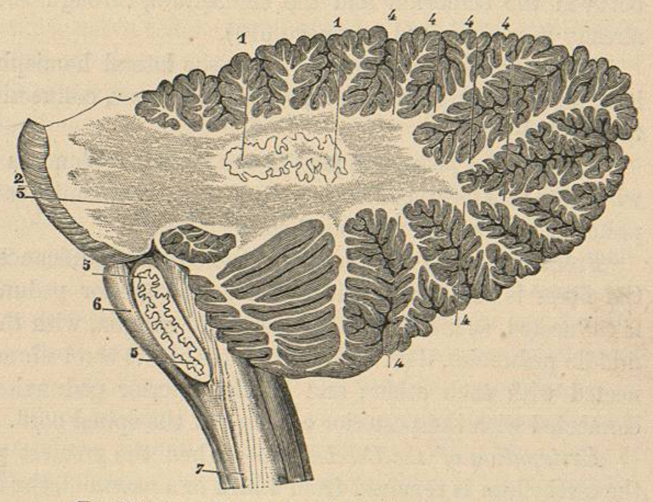

Fig. 230.—*Cerebellum and medulla oblongata* (Hirschfeld).
1, 1, corpus dentatum; 2, pons Varolii; 3, section of the middle peduncle; 4, 4, 4, 4, 4, 4, laminæ forming the arbor vitæ; 5, 5, olivary body of the medulla oblongata; 6, anterior pyramid of the medulla oblongata; 7, upper extremity of the spinal cord.

The cerebellum consists of two lateral hemispheres, more largely developed in man than in the inferior animals, and a median lobe. The hemispheres are subdivided into smaller lobes, which it is unnecessary to describe. Beneath the cerebellum, bounded in front and below by the medulla oblongata and pons Varolii, laterally, by the superior peduncles, and above, by the cerebellum itself, is a lozenge-shaped cavity, called the fourth ventricle. The crura, or peduncles, will be described in connection with the direction of the fibres.

The gray substance of the convolutions is divided quite distinctly into an internal and an external layer. The internal layer presents an exceedingly delicate net-work of fine nerve-fibres which pass to the cells of the external layer. The external layer is somewhat like the external layer of gray substance of the posterior lobes of the cerebrum and is more or less sharply divided into two or more secondary layers. The most external portion of this layer contains a few small nerve-cells and fine filaments of connective tissue. The rest of the layer contains a great number of large cells, rounded or ovoid, with two or three and sometimes four prolongations. The mode of connection between the nerve-cells and the fibres has already been described under the head of the general structure of the nervous system.

Directions of the Fibres in the Cerebellum.—Fibres from the gray substance of the convolutions and their prolongations, and from the corpus dentatum, converge to form the three cerebellar peduncles on either side. The superior peduncles pass forward and upward to the crura cerebri and the optic thalami. These connect the cerebellum with the cerebrum. Beneath the tubercular quadrigemina, some of these fibres decussate with the corresponding fibres from the opposite side; so that certain of the fibres of the superior peduncles pass to the corresponding side of the cerebrum and others pass to the cerebral hemisphere of the opposite side. The connections between the cerebrum and the cerebellum, through the pons Varolii, have already been described (see page 610).

The middle peduncles arise from the lateral hemispheres of the cerebellum, pass to the pons Varolii, where they cross, connecting the two sides of the cerebellum.

The inferior peduncles pass to the medulla oblongata and are continuous with the restiform bodies, which, in turn, are continuations chiefly of the posterior columns of the spinal cord.

From the above sketch, the physiological significance of the direction of the fibres is sufficiently evident. By the superior peduncles, the cerebellum is connected, as are all of the encephalic ganglia, with the cerebrum; by the middle peduncles, the two lateral halves of the cerebellum are intimately connected with each other; and by the inferior peduncles, the cerebellum is connected with the posterior columns of the spinal cord.

Extirpation of the Cerebellum.—When the greatest part or the whole of the cerebellum is removed from a bird or a mammal, the animal being, before the operation, in a perfectly normal condition and no other parts being injured, there are no phenomena constantly and invariably observed except certain modifications of the voluntary movements (Flourens). The intelligence, general and special sensibility, the involuntary movements and the simple faculty of voluntary motion remain. The movements are always exceedingly irregular and inco-ordinate; the animal can not maintain its equilibrium; and on account of the impossibility of making regular movements, it can not feed. This want of equilibrium and of the power of co-ordinating the muscles of the general voluntary system causes the animal to assume the most absurd and remarkable postures, which, to one accustomed to these experiments, are entirely characteristic. Calling this want of equilibration, of co-ordination, of "muscular sense," an indication of vertigo, or by any other name, the fact remains, that regular and co-ordinate muscular action in standing, walking or flying, is impossible, although voluntary power is retained. It is well known that many muscular acts are more or less automatic, as in standing, and to a certain extent, in walking. These acts, as well as nearly all voluntary movements, require a certain co-ordination of the muscles, and this, and this alone, is affected by extirpation of the cerebellum. It is true that destruction of the semicircular canals of the internal ear produces analogous disorders of movement, but this is the only mutilation, except division of the posterior white columns of the spinal cord, which produces anything resembling the results of cerebellar injury.

When a portion only of the cerebellum is removed, there is slight disturbance of co-ordination, and the disordered movements are marked in proportion to the extent of the injury. After extirpation of even one-half or two-thirds of the cerebellum, the disturbances in co-ordination immediately following the operation may disappear, and the animal may entirely recover, without any regeneration of the extirpated nerve-substance. This important fact enables one to understand how, in certain cases of disease of the cerebellum in the human subject, when the disorganization of the nerve-tissue is slow and gradual, there may never be any disorder in the movements.

If there be a distinct nerve-centre which presides over the co-ordination of the general voluntary movements, experiments upon the higher classes of animals show that this centre is situated in the cerebellum. If the cerebellum preside over co-ordination, as a physiological necessity, the centre must be connected by nerves with the general muscular system. If this connection exist, a complete interruption of the avenue of communication between the cerebellum and the muscles would be followed by loss of co-ordinating power. From the anatomical connections of the cerebellum, it appears that the main communication between this organ and the general system is through the posterior white columns of the spinal cord. These columns are not for the transmission of the general sensory impressions, and there is no satisfactory evidence that they convey to the encephalon the so-called muscular sense. When the posterior white columns are divided at several points, there is want of co-ordination of the general muscular system. When the posterior white columns are disorganized in the human subject, there is loss or impairment of co-ordinating power, even though the general sensibility be not affected, as in the disease called locomotor ataxia.

Pathological Observations.—Records of cases of lesion of the cerebellum in the human subject have accumulated until the number is very large. A study of cases in which the phenomena referable to cerebellar injury are not complicated by paralysis, coma or convulsions, shows that serious lesion of the middle lobe is almost always attended with marked muscular inco-ordination. Cases in which only a portion of one or of both hemispheres is involved may not present any disorder in the muscular movements. These facts are in accord with the results of experiments upon the lower animals.

The phenomena observed in the few cases of cerebellar inco-ordination which have been carefully observed are notably different from those presented in simple locomotor ataxia. In cerebellar disease, the gait is staggering, much as it is in alcoholic intoxication. The chief difficulty seems to be in maintaining the equilibrium in progression, even with the greatest care and closest attention on the part of the patient. With the idea in mind that there is a co-ordinating centre for the muscles of progression, and that this centre acts imperfectly, it seems as though an efficient effort at co-ordination were impossible. In locomotor ataxia, patients seem to make co-ordinating efforts, but the paths by which these efforts find their way to the muscles are disturbed and the co-ordinating process, which is more or less automatic in health, requires peculiar care and attention. By the aid of the sense of sight and by artificial supports, progression may be safely though irregularly accomplished. The movements are jerky, and each step seems to require a distinct act of volition. It is possible to imagine that in disorganization of the paths of co-ordination in the spinal cord, the co-ordinating centre may act in some degree through the motor paths in the direct and crossed pyramidal tracts of the cord. It is certain that the want of normal co-ordinating power is supplemented by ordinary voluntary acts and by the sense of sight.

Vertigo is not a necessary accompaniment of cerebellar ataxia. Disease of the semicircular canals of the internal ear (Ménière's disease) is attended with vertigo, and this is the main cause of the disturbances of equilibrium.

Connection of the Cerebellum with the Generative Function.—The fact that the cerebellum is the centre for equilibration and the co-ordination of certain muscular movements does not necessarily imply that it has no other office. The idea of Gall, that "the cerebellum is the organ of the instinct of generation," is sufficiently familiar; and there are facts in pathology which show a certain relation between this nerve-centre and the organs of generation, although the view that it presides over the generative function is not sustained by the results of experiments upon animals or by facts in comparative anatomy.

In experiments upon animals in which the cerebellum has been removed, there is nothing pointing directly to this part as the organ of the generative instinct. Flourens removed a great part of the cerebellum in a cock. The animal survived for eight months. It was put several times with hens and always attempted to mount them, but without success, on account of want of equilibrium. In this animal the testicles were enormous. This observation has been repeatedly confirmed, and there are no instances in which the cerebellum has been removed with apparent destruction of sexual instinct. In a comparison of the relative weights of the cerebellum in stallions, mares and geldings, Leuret found that, far from being atrophied, the cerebellum in geldings was even larger than in either stallions or mares.

In certain cases of disease or injury of the cerebellum, irritation of this part has been followed by persistent erection and manifest exaggeration of the sexual appetite, and in others, its extensive degeneration or destruction has apparently produced atrophy of the generative organs and total loss of sexual desire. Serres reported several cases in which irritation of the cerebellum was followed by satyriasis or nymphomania, but in other cases there were no symptoms referable to the generative organs. In the well known case reported by Combette, the patient had the habit of masturbation. Fisher, of Boston, reported (1838) two cases of diseased or atrophied cerebellum, with absence of sexual desire, and one case of irritation, with satyriasis. Similar instances have been given by other writers. The observations of Budge, in which mechanical irritation of the cerebellum was followed by movements of the uterus, testicles etc., have not been satisfactorily explained.

Although there are many facts in pathology which are opposed to the view that the cerebellum presides over the generative function, there are cases which show a certain connection between this portion of the central nervous system and the organs of generation in the human subject; but this is all that can be said upon this point. It is certain that the facts are not sufficiently definite and invariable to sustain the notion that the cerebellum is the seat of the sexual instinct.

It is not necessary to discuss the vague theories with regard to the uses of the cerebellum advanced by writers anterior to the publication of the observations of Flourens. There is no evidence that the cerebellum is the organ presiding over memory, the involuntary movements, general sensibility or the general voluntary movements. The only view that has any positive experimental or pathological basis is that it presides over equilibration and the co-ordination of certain muscular movements, and is, perhaps, in some way connected with the generative function.

Medulla Oblongata (Bulb).

The medulla oblongata, or bulb, connects the spinal cord with the encephalic ganglia. It is composed of white and gray matter and presents, in its substance, a number of important nerve-centres. It is not necessary to give anything like a complete anatomical description of the medulla. Its most important conducting parts are those which are continuous with the columns of the cord and which pass to the cerebrum and cerebellum. The nuclei of origin of certain of the cranial nerves in the floor of the fourth ventricle have already been mentioned.

Physiological Anatomy.—The medulla oblongata is pyramidal in form, with its broad extremity above, and rests in the basilar groove of the occipital bone, extending from the lower border of the pons Varolii to the atlas. It is about an inch and a quarter (31·8 mm.) in length, three-quarters of an inch (19·1 mm.) broad at its widest portion and half an inch (12·7 mm.) thick. It is flattened antero-posteriorly. Like the cord, it has an anterior and a posterior median fissure.

Apparently continuous with the anterior columns of the cord, are the two anterior pyramids, one on either side. Viewed superficially, the innermost fibres of these pyramids are seen to decussate in the median line; but if the fibres be traced from the cord, it is found that they come from the crossed pyramidal tracts of the lateral columns and that none of them are derived from the anterior columns. The fibres of the external portion of the anterior pyramids come from the direct pyramidal tracts of the cord. At the site of the decussation, the pyramids are composed entirely of white matter; but as the fibres spread out to pass to the encephalon above, they present nodules of gray matter between the fasciculi.

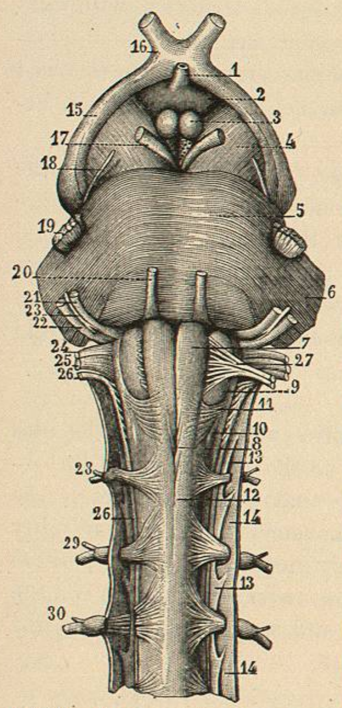

FIG. 231.—*Anterior view of the medulla oblongata* (Sappey).

1, infundibulum; 2, tuber cinereum; 3, corpora albicantia; 4, cerebral peduncle; 5, pons Varolii; 6, origin of the middle peduncle of the cerebellum; 7, *anterior pyramids of the medulla oblongata*; 8, *decussation of the anterior pyramids*; 9, *olivary bodies*; 10, *restiform bodies*; 11, *arciform fibres*; 12, upper extremity of the spinal cord; 13, ligamentum denticulatum; 14, 14, dura mater of the cord; 15, optic tracts; 16, chiasm of the optic nerves; 17, motor oculi communis; 18, patheticus; 19, fifth nerve; 20, motor oculi externus; 21, facial nerve; 22, auditory nerve; 23, nerve of Wrisberg; 24, glosso-pharyngeal nerve; 25, pneumogastric; 26, 26, spinal accessory; 27, sublingual nerve; 28, 29, 30, cervical nerves.

External to the anterior pyramids, are the corpora olivaria. These are oval and are surrounded by a distinct groove. They are white externally and contain a gray nucleus called the corpus dentatum.

External to the corpora olivaria, are the restiform bodies, formed chiefly of white matter and constituting the postero-lateral portion of the medulla. They are continuous with the posterior white columns of the cord. The restiform bodies spread out as they ascend, and pass to the cerebellum, forming a great portion of the inferior peduncles. Some fibres from the restiform bodies pass to the cerebrum.

Beneath the olivary bodies and between the anterior pyramids and the restiform bodies, are the lateral tracts of the medulla, sometimes called the intermediary or lateral fasciculi, or the funiculi of Rolando. These are composed of an intimate mixture of white and gray matter and have a yellowish-gray color. They receive all that portion of the antero-lateral columns of the cord which does not enter into the composition of the anterior pyramids. They are usually described as parts of the restiform bodies, but they are peculiarly important, from the fact that they contain the gray centre presiding over respiration; and for that reason they are here described as distinct fasciculi.

The posterior pyramids (funiculi graciles) are the smallest of all. They pass upward to the cerebellum, without decussating, joining the restiform bodies above. They are composed chiefly of white matter. As they pass upward in the medulla, they diverge, leaving a space at the fourth ventricle.

The fourth ventricle is the cavity between the pons Varolii, the medulla oblongata and cerebellum. It is lozenge-shaped, the acute angles being above and below. The upper angle extends to the upper border of the pons, and the lower angle, to the lower border of the olivary bodies. The triangles which form this lozenge are of nearly equal size. The superior triangle is bounded laterally by the superior peduncles of the cerebellum, as they converge to meet at the corpora quadrigemina. The inferior triangle is bounded laterally by the funiculi graciles and the restiform bodies of the medulla, which diverge at its lower angle. The arched roof of the ventricle is formed by the valve of Vieussens, which is stretched between the superior peduncles of the cerebellum and covers the anterior triangle, and the cerebellum, which covers the posterior triangle. Beneath the cerebellum, is a reflection of the pia mater. The fourth ventricle communicates above with the third ventricle, by the aqueduct of Sylvius, below with the subarachnoid space, by the foramen of Magendie, and by a small opening below with the central canal of the cord. The floor of the ventricle is formed by the posterior surface of the pons above and the medulla below. It presents a fissure in the median line, which terminates below in the calamus scriptorius. By the sides of the median fissure, are the fasciculi teretes, which correspond to the intermediary fasciculi of the medulla. Little eminences in the floor indicate the situation of nuclei of origin of cranial nerves. The floor is composed mainly of a layer of gray matter, continuous with the gray commissure of the cord. The lower portion of the floor is marked by transverse lines of white matter emerging from the median fissure.

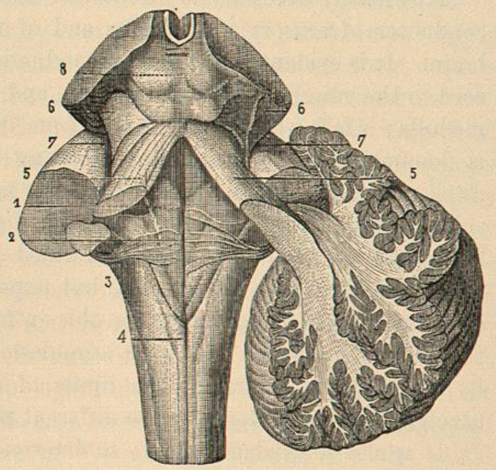

FIG. 232.—*Floor of the fourth ventricle* (Hirschfeld).

1, median fissure, between the fasciculi teretes; 2, transverse, white striæ; 3, inferior peduncle of the cerebellum; 4, posterior pyramid (funiculus gracilis); 5, 5, superior peduncles (divided) of the cerebellum; 6, 6, bands to the side of the crura cerebri; 7, 7, lateral grooves of the crura cerebri; 8, corpora quadrigemina.

The two lateral halves of the posterior portion of the medulla are connected together by fibres arising from the gray matter of the lateral tracts, or intermediary fasciculi, passing obliquely, in a curved direction from behind forward, to the raphe in the median line. There are also fibres passing from before backward, to form a posterior commissure, and fibres arising from the cells of the olivary bodies, which connect the gray substance of the lateral halves. Commissural fibres also connect the gray matter of the lateral tracts with the corpora dentata of the olivary bodies, and the olivary bodies with the cerebellum, their fibres forming part of the inferior peduncles of the cerebellum. In addition it is probable that