

ANOMALIES OF THE ENCEPHALIC ARTERIES AMONG THE INSANE.

A STUDY OF THE ARTERIES AT THE BASE OF THE ENCEPHALON IN TWO HUNDRED AND TWENTY CONSECUTIVE CASES OF MENTAL DISEASE, WITH SPECIAL REFERENCE TO ANOMALIES OF THE CIRCLE OF WILLIS.

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WITH ELEVEN FIGURES.

Minor anomalies of the encephalic arteries are so common that their study and observation have been mainly confined to modifications of the circle of WILLIS and the principal basal trunks. Slight deviation from the normal is very common in my autopsies and probably in most cases unimportant, though it is claimed that anomalies of the basal trunks are more common in the insane, to quote BERKLEY, indicating some defect in the "molding of the vital clay." BERKLEY admits, however, that comparative statistics are wanting, while he states that in four cases out of sixteen the arteries showed anomalies, a very large proportion. It would seem evident that developmental defects in the arteries would in most cases be compensated for by modifications of other trunks; and that under normal conditions functions would be preserved, but under diseased states and possibly unusual circulatory disturbances the abnormality might be of serious importance. The actual ætiological relationship of arterial anomalies to mental diseases other than to defective developmental states, in which it may be inferred, is hard to establish; but the relation they bear to gross cerebral disease, and to surgical operations upon the cervical arteries is easily demonstrated.

It must be borne in mind in the study of these anomalies that

developmental defects should be considered apart from the changes produced by arterial disease. In most cases this is not difficult, and in many instances the acquired condition is clearly inadequate to produce the anomalies present.

In order better to comprehend the significance of the arterial anomalies of the circle of WILLIS and the great basal trunks it is necessary to refer to the normal condition of the circulation as indicated by the diagram, Fig. 1. Normally the carotid system and the vertebral system are separated by a balance, or meeting of the two currents, in the middle of the two posterior communicating arteries, while at the same time the circulation of the two cerebral hemispheres is virtually distinct on account of a normal balance which exists in the anterior communicating artery, and by the direction of the blood current in the first part of the posterior cerebral artery. Under normal conditions of current and pressure it must be extremely improbable for any part of the cerebrum to receive even temporarily any blood supply but from the proper vessels. The separation of the cerebellar circulation from that of the cerebrum under normal conditions is equally distinct, the current from the carotid system being opposed by that in the basilar artery. The pontine and upper cerebellar arteries have a more common blood supply, being in keeping with the fusion of the vertebrals into the basilar, though the two posterior inferior cerebellar vessels must normally receive their blood supply from the corresponding vertebrals. Anastomoses between the cerebellar arteries are also more common than in the cerebral trunks though usually the obstruction of a cerebellar artery results in softening of its proper area.

In abnormal developmental conditions this regulation of circulation is of course disturbed and the direction of the current in a vessel may be permanently reversed, while in disease of the vessels these anomalies may greatly add to the gravity of the situation.

As a basis for this study I have noted the conditions found in 220 consecutive cases of mental disease; and, as a matter of some additional interest I have given the age, sex, pathological condition of the vessels, and the form of mental affection in each case. I must claim, however, as the foundation of my opinion, the examination of over 2220 cases rather than the smaller number given as the basis for the statistics.

I have also given somewhat in detail three cases of anomalies of unusual interest, not included in the list, and have introduced a

number of diagrams of associated anomalous conditions which are for the most part self-explanatory. I would, however, call attention to the number of these in which surgical ligation of the internal carotid, or obstruction of the vessel by thrombosis would endanger the whole hemisphere.

It will be noted in these diagrams, and in a number of the cases in the list, that anomalous conditions are frequently associated. In the sixteen cases diagramed this was strikingly manifested, and at the same time there is a certain correlation between some of the anomalies, notably in enlargement of the anterior cerebral of one side and small size of the opposite vessel; enlargement of a posterior communicating artery with underdevelopment of the corresponding posterior cerebral; and in increased size of the opposite vertebral when one of these is undeveloped.

In the list of cases, 227 were included—Nos. 1968–2194—but in some of these the brain was not examined, leaving 220 consecutive cases in which the vessels were studied. This number and order of cases I think may be taken as fairly representative of the relative frequency of arterial anomalies among the insane, and, though the number is too small for valuable statistics on this question, it may be taken as showing the frequency in the several forms of mental disease.

In the 220 cases studied, 65 showed no anomalies, slight disparity in size of the paired vessels being disregarded, and no anomalous conditions being noted unless presenting a deviation beyond the normal variation.

Professor WINDLE, who studied the vessels in 200 cases among those presumably sane, found 76 cases normal, and disregarding slight difference in the size of the paired vessels he found 119 cases normal in number and arrangement. As I have included the cerebellar arteries in my list, while WINDLE studied only those of the circle of WILLIS, this must be taken into consideration in comparing the two final results.

As I shall have to make frequent reference to the statistics of WINDLE, for comparison with my own, I would here acknowledge my indebtedness.

SUMMARY.

Internal Carotid Artery.—The internal carotid artery has been quite constant in size and development in my cases. It is all the

more remarkable that in several reported cases, a large anomalous branch has been found arising from the cavernous portion of the vessel and turning abruptly backward, joining the basilar. A case of this interesting anomaly is given somewhat in detail in Case No. 1926, Figs. 7 to 9. A case of direct union of the carotids without the intervention of an anterior communicating artery is given by MITCHELL and DERCUM; this I have not met with, though direct fusion of the anterior cerebrals, a closely allied condition, has been seen a number of times. Occasionally some disparity in size of the two vessels is seen, but it was deemed noteworthy in only one case.

Middle Cerebral Arteries.—The middle cerebral artery does not enter into the circle of WILLIS, though the circulation in it is markedly influenced by anomalies of its component vessels. A few abnormal branches were noted, and in one case the inferior external frontal branch was absent and its place was taken by a recurrent vessel from the anterior cerebral. As a result of this a large thrombotic softening of the Sylvian region did not affect the third frontal convolution and speech was preserved. Cases have been recorded of abnormal origin of the vessel itself, and of origin of the post communicating artery and the anterior choroid from this artery, but I have found no case which could not be otherwise explained.

Anterior Cerebral Arteries.—The most common anomaly of the anterior cerebral arteries is the enlargement of one artery and a corresponding small size of the opposite artery. As the result of this the main blood supply comes through the enlarged vessel, the anterior communicating artery is enlarged, and both anterior cerebrals appear to arise from one carotid. Sometimes the anterior communicating artery remains distinct, but it may be completely merged into the anterior cerebrals and the remnant of the small undeveloped anterior cerebral join it at an acute angle. Nos. 2057, 2063, 2066, 2099 and 2137 represent this type of anomaly. Another modification of these arteries is their fusion into a common trunk from the site of the anterior communicating artery onward to the vicinity of the genu callosi, where they commonly again form the two anterior cerebral trunks with a normal distribution. In this condition there is no proper anterior communicating artery. Sometimes the anterior cerebral of one side is very small, in some the vessels are about equal in size.

In a few instances the two arteries have fused anterior to the anterior communicating artery leaving a triangular opening between the vessels. Nos. 2073, 2077, 2139 and 2141 show this type of anomalous development.

Other anomalies of these arteries are occasionally met with. The vessels may both arise from one carotid as distinct trunks, one of which may be joined by an undeveloped vessel representing the opposite artery, or this vessel may be completely absent. Sometimes both vessels arise from one carotid by a single trunk which may or may not be joined by an abortive branch representing the opposite vessel. This condition must, however, be carefully analyzed as it is not essentially different from the conditions represented by Nos. 2004 and 2066; especially if the vessels divide at the situation of the anterior communicating artery.

The important surgical complications which would arise in these anomalous developments of the anterior cerebral arteries will be readily comprehended by reference to the accompanying diagrams of combined anomalies.

In my 220 cases the anterior cerebrals were fused into a common trunk in seven cases; see examples Nos. 2073, 2139 and 2141. This condition seemed at first sight to be more frequent as one of the vessels was not infrequently quite small and sometimes practically impervious, so that the vessels appeared as one trunk arising from the carotid. Nos. 2004, 2057, 2063, 2066, 2073, 2099 and 2137 show this type of anomaly.

In the list ten cases showed the right artery small and the blood supply coming from the opposite carotid; in six, the left was the defective vessel. In one case the right artery was unusually large while the left was normal; and in five instances a large recurrent branch originating commonly from the anterior cerebral at its junction with the anterior communicating turned backward and supplied the third frontal gyrus and the insula.

WINDLE found eight cases of fusion of the anterior cerebral arteries; and two instances of absence of one vessel, the place of the missing trunk being taken by a small branch from the opposite carotid. I have not regarded these cases as absence of the vessel in question, but as instances of underdevelopment with compensatory enlargement of the opposite trunk and the anterior communicating artery. See Nos. 2066, 2077, 2099.

Anterior Communicating Artery.—The anterior communicating

artery may be absent, extremely small, double, or treble, or it may be formed of two vessels which join before junction with the anterior cerebral of the opposite side then forming a Y-shaped vessel. When double the anterior is usually the larger trunk. In a number of cases a median anterior cerebral artery arises from this vessel. This trunk is sometimes as large as or even larger than the true lateral trunks, and in some cases it curves around the genu, extends backward along the callosum, and finally divides into two branches which supply the two medial surfaces of the quadrate lobules. In such cases the true anterior cerebral arteries are distributed to the anterior portion of the medial surfaces, and to the orbital gyri.

In normal conditions and in cases of complete fusion of the anterior cerebrals, absence of the anterior communicating artery is of slight importance; in conditions of thrombosis of the carotid its absence may be of serious import.

In my list this vessel was absent in only two cases; it was unusually small in five; large in two; double in thirteen cases; formed a Y-shaped vessel in one; and gave off a large median anterior cerebral in two instances.¹ In quite a large number of cases this vessel was markedly modified by changes in the anterior cerebral trunks as mentioned above; it was also absent or greatly modified in cases of fusion of the anterior cerebrals, as in Nos. 2073, 2077, 2099, 2141 and 2169.

In WINDLE'S cases this vessel was double in fourteen; triple in three; formed a Y in six cases; in six instances it was absent in fusion of the anterior cerebrals; in two it was present under like conditions, as in No. 2139; in two cases he found the vessel absent on account of there being but one anterior cerebral artery; and in one case in complete fusion of these arteries. There were nine instances of a median anterior cerebral artery.

Posterior Communicating Arteries.—The commonest anomalous condition of the posterior communicating arteries is enlargement of one or both of these vessels. In almost every case enlarge-

¹ It is probable that had a more careful search been made this artery would have been more frequently found. Since the above was written an excellent example of this vessel has been found. The artery took its origin from the anterior communicating, and proceeded as a single trunk with a few small branches to the callosum, to about the anterior border of the precuneus, when it divided into two equal sized trunks going to supply both of the quadrate lobules and adjoining portions of the paracentral lobules. The true anterior cerebral vessels were a little smaller than usual and were distributed to the lower and anterior medial surfaces of the hemispheres.

ment of the posterior communicating arteries is correlated with small size of the posterior cerebral trunks at their first part or origin from the basilar. When but one of these arteries is enlarged it is most commonly the right. QUAIN found the right artery enlarged in 5.5 per cent of the cases examined; the left in 4.5 per cent; both in 2 per cent.

In all these cases of enlargement of the posterior communicating arteries the main blood supply to the posterior cerebral territory comes from the internal carotid artery, but I think it a mistake to regard even high degrees of this anomaly as instances of origin of the posterior cerebrals from the carotid system. Often the posterior cerebral is represented by a mere thread, sometimes this may be impervious or even absent, but in none of my cases have I been convinced of the carotid origin of the posterior cerebral.

HYRTLE reports a case in which the middle cerebral was given off by the posterior cerebral a condition not so readily explained, but it must be extremely rare. The posterior communicating artery is not infrequently wanting, fails to join the posterior cerebral, or ends in a few filiform branches about the crus. QUAIN gives it as absent on the right side in 4.5 per cent; on the left in 6.5 per cent; and on both sides in 1.5 per cent.

The origin of the posterior communicating arteries from the middle cerebral rather than from the internal carotid I deem unimportant, as the former vessel is merely a continuation of the latter without definite dividing line, though the posterior communicating arteries arise inside of the origin of the anterior choroids, the latter arising from the terminal part of the internal carotid.

The posterior communicating artery of the left side was abnormally small in seven of my cases; that of the right side in three; both unusually small in four cases. The vessel was totally absent on the right side in one case. The right vessel was enlarged twenty-six times; the left sixteen times; and both were enlarged in twenty-three cases. In all of these cases the corresponding posterior cerebral arteries were below the normal in size. In several instances there were slight and inadequate anastomoses with the basilar through small and abnormal branches representing the posterior cerebral arteries. Nos. 2099, 2159 and 2177.

WINDLE found these arteries normal in 175 of his cases. In twenty-eight cases the right was the larger; in fifteen it was the left; both were abnormally small in seven cases. He gives these

arteries as absent in twenty-five cases; thirteen times the left, the right nine times and both three times. The author states that a partial anastomosis with the basilar was secured in some of these by means of small twigs in the interpeduncular space. It seems possible that some of these may have represented undeveloped posterior cerebral and posterior communicating arteries, as in No. 2177.

Posterior Cerebral Arteries.—The most common abnormal condition of the posterior cerebral arteries is small size of the vessels at their first part before joining the posterior communicating arteries. This, as mentioned above, is the condition which leads to the conclusion that the vessels arise from the carotid. In some cases the vessel joins the posterior communicating artery by a fine practically impervious thread, it may join at an unusual place, or may fail to anastomose with the vessel at all. In case of undevelopment of this vessel it is almost invariably compensated for by enlargement of either the posterior communicating, or the anterior choroid, but in obstruction of the internal carotid of the same side the effects are disastrous. See Case No. 1909.

In my list the posterior cerebral of the right side was noted as smaller than normal in fifteen cases; the left in ten, and both in twenty-one cases. The right artery was absent in one case, and in two instances the main distribution was supplied by an enlarged anterior choroid artery. Nos. 2163 and 2177.

WINDLE claims that in twenty-four of his cases this vessel originated from the *carotid artery*; eleven on the right side; nine on the left; and four on both sides. I have not been able to satisfy myself that this was so in any of my cases, as it seems to me that all may be regarded as compensating enlargements of the posterior communicating and anterior choroid arteries.

In one of WINDLE'S cases and one of my own the third nerve was divided by this artery.

Anterior and Posterior Choroid Arteries.—The anterior choroid artery is fairly constant but may be represented by mere threads. In two instances among my cases I found this vessel in part taking the place of the posterior cerebral. Nos. 2163 and 2177. The posterior choroid arteries sometimes arise from the posterior cerebrals; sometimes from the superior cerebellar arteries. They are somewhat irregular in their development but were not carefully studied.

The Basilar Artery.—This artery, formed originally by coalescence of the two vertebrals, sometimes contains a septum in its interior, and occasionally shows an incomplete fusion, leaving an opening in the vessel as seen in Case 2009 and in Fig. 2. The vessel is sometimes joined by a large anastomotic branch from the carotid artery. See Case 1926. In my list of cases the basilar showed partial separation into its embryonic components in two cases. It was markedly curved in most cases of enlargement of one of the vertebral arteries, the convexity of the curve being opposite to the enlarged vessel. Nos. 2004, 2063 and 2066. Anomalies of origin of the cerebellar arteries arising from the basilar were common.

Superior Cerebellar Arteries.—The superior cerebellar arteries were quite constantly represented, sometimes being duplicated. This occurred on the right side four times; on the left twice; and on both sides in two cases. Occasionally this vessel sends branches to reinforce the anterior inferior cerebellar when it is ill developed.

Anterior Inferior Cerebellar Arteries.—This vessel is quite variable in its place of origin from the basilar. The vessel was duplicate in eight cases; one or the other was absent in seven; and in five instances it sent large branches to take the place of the posterior inferior cerebellar artery when this vessel was small or absent. There seemed to be a constant correlation between the two inferior cerebellar arteries, so that in eighteen cases the two had a common origin in a single trunk arising from the basilar.

Posterior Inferior Cerebellar Arteries.—This vessel was absent on the right side in ten cases; on the left in six. In these cases the place of the vessel was usually taken by branches from the anterior inferior cerebellar. In a few cases the artery took its origin from the basilar just above the junction of the vertebrals.

Vertebral Arteries.—One vertebral artery, according to QUAIN, more frequently the left, is sometimes much smaller than the other. The right vertebral was abnormally small in twenty-one cases; the left in twelve cases; both were small in two instances. An unusually large right vertebral with the left about normal in size was noted twice; the two vessels united by a transverse trunk in two cases. The posterior inferior cerebellar artery was large and received practically all of the blood from the cervical portion of the vertebral, in five cases; three times on the right; twice on the left. In these

and a few other cases the vertebral was almost or quite impervious, but in no instance was either vessel absent.

The Anterior Spinal Artery.—The anterior spinal artery usually shows slight variability in its trunks of origin, depending upon the size of the vertebrals. Occasionally the vessel takes its origin from a short transverse trunk joining the two vertebrals.

The *posterior spinal arteries* have not been studied.

Associated Anomalies.—In many cases the anomalous conditions were so associated that several were present in the same case. I have, therefore, introduced diagrams of a number of the most interesting cases, and have described three somewhat in detail.²

Pathological Conditions of the Arteries.—It was a matter of some surprise and interest to find that no less than 148 of the 220 cases showed some degree of arterio-sclerosis. However, as 138 of the patients were over sixty years of age this may be accounted for. In this connection it is well to bear in mind that arterial thrombosis, one of the most common accidents of arterio-sclerosis in the aged, is most apt to result seriously in these anomalous states of the arteries. BULLEN claims that arterial anomalies are most frequent in paresis; in thirteen cases of this disease in my list, six showed slight anomalous conditions, while some were normal in arrangement and not diseased.

Of the cases studied seventy were of senile dementia; forty, chronic dementia; fifteen, dementia precox; fifteen, epileptic dementia; nineteen, chronic melancholia; fourteen, chronic mania; thirteen, paresis; eight, manic depressive insanity; seven, organic dementia; four, terminal dementia; three, acute mania; three, imbecility; three, acute confusional insanity; two of toxic insanity; two, acute melancholia; and one each of acute confusional insanity and acute febrile delirium. It is perhaps well to state that under a more modern system of classification some of the above diagnoses of the mental diseases, made when the patients were admitted to the hospital, would be materially changed.

Case of Anomalous Circle of Willis.

No. 1926. A. C.; white; male; aged 78; soldier; nativity, Ohio. Mental disease, senile dementia; duration uncertain.

Autopsy partial, only the brain being examined.

² Sixteen of these diagrams, Figs. 3-6, are included among the descriptions of the forty cases abstracted from the complete list of 220 cases. They are, however, sufficiently clear to be understood without reference to the descriptive list.

Skull thick and dense; symmetrical; sutures and bones normal. Over inner surface of dura of the convexity is a thin neo-membrane of internal pachymeningitis.

Brain. Weight, 1420 grams. Slight general shrinkage over the convexity; veins prominent; arterial branches tortuous. The arteries at the base are sclerotic and present the following anomalies.

1. Anterior communicating artery double.
2. At the junction of the upper and middle third of the basilar artery it is joined by a large vessel fully equal to the normal basilar in size, which comes from the left internal carotid just after its emergence from the carotid canal in the temporal bone. This abnormal artery has pierced the dura mater just outside of, and posterior to the posterior clinoid process, and dissection shows that it comes from the internal carotid at the junction of the intra-osseous portion with the cavernous portion of the vessel. The branch is not at all in the bony canal nor does it pierce the dorsum sellæ, though it lies at its origin quite close to the posterior clinoid process. The aberrant vessel curves abruptly backward and inward joining the basilar, which is so altered as to appear a part of the anomalous trunk. The large size of the abnormal branch has diverted the basilar from its course and evidently the main blood supply to the posterior cerebral arteries, and the superior cerebellars, came through the anastomatic vessel from the left carotid, the other portions of the basilar and the whole vertebral system being small. The sixth nerve has the normal relation to the carotid artery and the anomalous branch pierces the dura at its anterior and inner side. The other cranial nerves are not in any way interfered with. Complete dissection of the carotid artery outside of the cranium is not permissible. Two or more minute arteries arise from the anomalous vessel and are distributed to the dura in the vicinity.
3. The vertebral system presents marked deviation from the normal. The left vertebral is unusually small and the main blood supply from below entered a large trunk which represents both the posterior inferior cerebellar artery and the anterior, no trace of the latter arising at the usual place from the basilar. This common trunk is distributed to the territory of both vessels represented. The right vertebral artery is about the usual size and passes without change of size but with marked curvature into the basilaris. There is no artery on this side corresponding to the posterior inferior cerebellar.
4. The basilar artery is so changed that the limits of the vessel can only be determined by the junction of the vertebrales and the division into the posterior cerebrals. At about the junction of the middle and lower thirds of the basilar a large trunk is given off which takes the place of the anterior inferior, and posterior inferior cerebellar arteries, the exact reverse of the condition on the left side. The middle portion of the basilaris is small and on the left side gives off the internal auditory artery and some pontine vessels. The upper part of the vessel, scarcely recognizable as such, gives off the superior cerebellar arteries, divides into the posterior cerebral arteries, and receives the anomalous carotid branch, as above described. The posterior cerebrals give off the posterior choroid arteries and both are distributed as usual.
5. The posterior communicating arteries are rather small but their origin and destination are normal. The anterior choroid arteries are normal in origin and distribution and so far as can be determined the other arterial trunks show no anomalies. (Figs. 7, 8 and 9.)

Thrombotic Softening of an Entire Hemisphere.

No. 1909. O. B.; female; white; aged 69; nativity, U. S. Mental disease, chronic melancholia with secondary dementia.

Six days before the patient's death she had a general convulsion from which she did not fully regain consciousness, followed the next morning by another, with hemiplegia and loss of speech; after this she remained comatose until she died four days later.

Synopsis of Autopsy.—Arteries at base of brain sclerotic and tortuous; posterior communicating artery of left side unusually large; posterior cerebral of the same side small and impervious; anterior communicating artery small and impervious; On the right side the vessels were of normal caliber except the posterior communicating which was rather large. A clot had formed at the upper end of the left internal carotid artery, and as result of the above peculiarities of the circulation the whole left hemisphere had undergone acute softening.

The hemisphere was deeply reddened, extremely soft, and the cerebral veins were engorged even to their smallest visible branches. It was in fact, practically a hemorrhagic infraction of the whole hemisphere. The sinuses were not obstructed. The softened hemisphere was generally swollen, presenting a marked contrast with the right, which was moderately atrophied. (Fig. 10.)

Anomalous Condition of the Basal Arteries.

No. 1954. M. J. B.; female; white; aged 64; nativity, U. S. Mental disease, chronic dementia.

The patient had a history of cerebral hemorrhage occurring about six years before her death. This resulted in partial paralysis of the right side, from which she suffered when admitted to the hospital. Her last illness was a sudden attack of left hemiplegia with evidences of disturbance or irritation of the motor region of the left side of the brain.

Synopsis of Autopsy.—The arteries at the base of the brain were extremely sclerotic, calcified and anomalous. The left anterior cerebral was large; the anterior communicating artery large; and the right anterior cerebral was small, thus the main blood supply to the anterior cerebral region came from the left carotid. Both posterior communicating arteries were unusually large; both posterior cerebral vessels small, especially the right. The left superior cerebellar artery double; left vertebral artery as large as the basilar; the right quite small, and the posterior inferior cerebellar, received nearly all of the blood brought by the vertebral.

A small aneurism had formed on the right middle cerebral artery at the point of origin of the principal branches, and a large intra-cerebral hemorrhage had occurred on this side from one of the lenticulo-striate arteries but the actual vessel could not be determined.

A horizontal section of the brain revealed an enormous hemorrhage of the right side which had completely destroyed the basal ganglia and capsules and torn its way into and filled the ventricles. On the left side there was a small brownish lesion in the internal capsule just posterior to the angle, which was supposed to be the remains of the former hemorrhage. The brain was cedematous and soft, and the perivascular spaces were greatly enlarged; some general atrophy of the convolutions of the surface. Other conditions found not important in this connection.

It would seem probable that in this case we had both the formation of the aneurism and the hemorrhage in part dependent upon arterial overstrain consequent to the lack of anastomoses between the right side and the left. The enlargement of the right posterior communicating artery seems to be a direct compensation for the small size of the posterior cerebral, but the small size of the right anterior cerebral and the current in the anterior communicating artery would effectually prevent relief to overstrain in this direction. Certainly the left carotid had a much freer outlet for its contents than the right, but at the same time owing to the compensation present the two hemispheres probably received a normal supply of blood until the complications due to arterio-sclerosis supervened. (Fig. 11.)

CONDITION OF THE ENCEPHALIC ARTERIES IN FORTY OF THE TWO HUNDRED AND TWENTY CASES.

Case 1973. R. M.; colored; male; aged 61; paresis. Arterio-sclerosis. Right anterior cerebral artery small, and the larger portion of the blood came from the left side. From the anterior communicating artery onward, the left anterior cerebral artery forms a large trunk which afterwards divides opposite the genu callosi into two callosal arteries. Left posterior inferior cerebellar artery absent; right small.

Case 1974. E. N.; white; male; aged 76; chronic dementia. Arterio-sclerosis. Right posterior communicating artery very large; the corresponding posterior cerebral small; post choroid artery arises from the right posterior communicating artery. Left posterior communicating artery rather large; posterior cerebral of this side small. Anterior communicating artery small and practically impervious. Right vertebral artery very small and separates into two branches, one of which forms the posterior inferior cerebellar artery; one of which joins the basilar.

Case 1980. L. F.; colored; female; aged 40; manic-depressive insanity. The right posterior communicating artery large and furnishes the main blood supply to the posterior cerebral region, this artery being quite small. The left anterior cerebral artery is larger than normal and sends its blood supply to the opposite artery through an enlarged anterior communicating artery. The right anterior inferior cerebellar is double; the opposite artery comes off the basilar by a common trunk with the posterior inferior cerebellar, and supplies its region, the proper artery being very small.

Case 1985. W. E.; white; male; aged 65; senile dementia. Arterio-sclerosis. Left posterior communicating artery very large and is distributed to the inferior temporal regions. The posterior cerebral artery of this side does not join the former, but is distributed to the parts around the crus and the choroid plexuses. The left anterior cerebral artery rather small, the main blood supply coming from the opposite artery.

Case 1986. D. L.; colored; male; aged 95; senile dementia. Arterio-sclerosis. Both posterior communicating arteries very large; post cerebral arteries extend forward and join them at an acute angle. Anterior communicating artery absent. Right superior cerebellar artery double.

Case 2000. L. T.; colored; male; aged 82; senile dementia. Arterio-sclerosis. The right anterior cerebral artery extremely small both anterior cerebral arteries being supplied from the left side. Anterior communicating artery double. Right posterior communicating artery very large and the posterior cerebral joins it about its middle as a small vessel. (Fig. 3.)

Case 2004. W. L.; colored; male; aged 50; chronic dementia. Arterio-sclerosis. Right anterior cerebral very small at its origin, both anterior cerebral arteries appear to come from the left side. No true anterior communicating artery exists. After turning around the genu callosi the anterior cerebral arteries are distributed as usual. Right posterior communicating artery small; left larger than normal. Right vertebral artery very small; posterior inferior cerebellar artery of this side represented by a small thread and an impervious branch from the common trunk with the anterior inferior cerebellar artery. On the left side a double anterior inferior cerebellar artery is present, and a double superior cerebellar. (Fig. 3.)

Case 2009. S. W.; white; male; aged 66; chronic epileptic dementia. Senile arterio-sclerosis. Both vertebral arteries, about equal in size, join at the upper end of the medulla, and again separate, making a fenestra in the basilar about one-half an inch in length. The right posterior inferior cerebellar artery is normal in position, the left arises at the first point of junction of the vertebrals. The two anterior inferior cerebellar arteries arise from the right and left division of the basilar respectively.

Case 2011. J. W.; colored; female; aged 36; dementia from tumor of the brain. Slight arterio-sclerosis. The left anterior cerebral artery crossed mainly to the right through an enlarged anterior communicating artery, joining with the opposite artery in a common trunk as far as the genu callosi, after which this trunk sends branches to both hemispheres. From the anterior communicating artery onward the left vessel is represented by a small branched vessel.

Case 2014. E. B.; colored; female; aged 71; senile dementia. Slight arterio-sclerosis. The left vertebral artery is extremely small, the posterior inferior cerebellar artery taking nearly all the blood that comes through the vertebral artery. Right posterior inferior cerebellar artery very small and a large vessel from the basilar takes its place. Above this vessel is the proper anterior inferior cerebellar artery. Right superior cerebellar artery double.

Case 2016. J. C.; colored; female; aged 61; senile dementia. Arterio-sclerosis of the small-vessel type. The anterior communicating artery has a Y-shape. Both posterior communicating arteries are large and furnish the main blood supply to the posterior cerebral territory, these vessels being small. Right posterior inferior cerebellar artery absent, its place being taken by branches from the anterior inferior artery.

Case 2018. J. H.; white; male; aged 76; senile dementia. Arterio-sclerosis. Right anterior cerebral small; left large. On each side from the anterior cerebral artery a branch turns abruptly backward and is distributed to Broca's convolution in part. The right anterior inferior cerebellar artery large and supplies the posterior inferior cerebellar territory, this vessel being inadequate.

Case 2034. A. W.; colored; male; aged 76; senile dementia. Arterio-sclerosis. Left anterior cerebral artery small. Both posterior communicating arteries are very large and the corresponding posterior cerebral arteries are small at their origin. Both anterior inferior cerebellar arteries are large, and are sent in part to the posterior inferior cerebellar region, these vessels being rather small. Anterior inferior cerebellar of right side is duplicated.

Case 2037. M. G.; white; male; aged 74; chronic melancholia. Arterio-sclerosis. Anterior cerebral of left side small. Left posterior communicating artery very large and supplies the posterior cerebral region as this artery is very small. Anterior inferior cerebellar artery of right side extremely small and its territory is supplied by branches from the superior cerebellar which is unusually large.

Case 2039. J. W.; white; male; aged 50; chronic dementia. Arteries not diseased. The right anterior cerebral artery is small and the main blood supply comes from the opposite vessel. The anterior inferior cerebellar arteries are large and supply the posterior inferior cerebellar regions.

Case 2041. M. H.; white; female; aged 74; chronic dementia. Arterio-sclerosis. The vertebral arteries are joined by a transverse vessel about one-fourth inch from their junction with the basilar, and from this vessel arises the anterior spinal artery. Left posterior communicating artery rather large. Right anterior inferior cerebellar artery supplies the posterior inferior cerebellar region.

Case 2057. A. K.; white; male; aged 77; chronic melancholia. Arterio-sclerosis. Both posterior communicating arteries large; posterior cerebral arteries small. Right anterior cerebral artery large and sends the main blood supply to the opposite side through a large anterior communicating artery, the left anterior cerebral being very small. Anterior inferior cerebellar artery practically absent on left side. (Fig. 3.)

Case 2063. J. B. C.; white; male; aged 65; senile dementia. Arterio-sclerosis. Right anterior cerebral artery small at its origin; left, enlarged and sends the main blood current to the right side through a large anterior communicating artery. Left vertebral artery very small, right unusually large and enters without change of caliber into the basilar. (Fig. 3.)

Case 2066. L. D.; colored; male; aged 34; paresis. Slight arterio-sclerosis. Left anterior cerebral artery large and furnishes the opposite side with blood through a large anterior communicating artery, the right anterior cerebral being very small at its first part. Left vertebral artery small; right about the size of the basilar. (Fig. 4.)

Case 2070. C. J.; colored; female; aged 57; chronic dementia. Arterio-sclerosis. Anterior communicating artery double and from the anterior vessel arises a large artery which supplies the corpus callosum—a median anterior cerebral. Both posterior communicating arteries are very large, and the posterior cerebrals are very small.

Case 2073. A. S.; colored; male; aged 25; dementia præcox. No disease of arteries. Left anterior cerebral artery small and distributed mainly to the inferior surface of the frontal lobe; right artery forms a large trunk which divides an inch posterior to the genu of the callosum and is distributed as usual. Left posterior communicating artery rather large. (Fig. 4.)

Case 2077. A. M. M.; colored; female; aged 72; senile dementia. Arterio-sclerosis. Right anterior cerebral artery small; anterior communicating artery also small; left anterior cerebral artery forms a large trunk which extends as far as the genu callosi where it divides into two large branches, one of which supplies each median surface. Both posterior communicating arteries are large; posterior cerebral arteries small. (Fig. 4.)

Case 2092. H. F.; colored; female; aged 65; senile dementia. Slight arterio-sclerosis. Both posterior communicating arteries very large and supply the posterior cerebral region, the posterior cerebral of the right side being represented by a small thread which was impervious, and the left is a small trunk which curves around the crus but does not join the posterior communicating artery.

Case 2094. S. S. T.; white; male; aged 65; chronic mania. Arterio-sclerosis. The vertebral arteries are connected by a transverse trunk of considerable size, from which arises the anterior spinal artery. Right anterior inferior cerebellar artery absent, and branches from the posterior inferior cerebellar take its place.

Case 2097. P. McC.; white; male; aged 74; chronic dementia. Arterio-sclerosis. Posterior communicating artery of left side very large; the posterior cerebral very small; posterior communicating artery of opposite side very small, posterior cerebral very large. Anterior communicating artery double. Right posterior inferior cerebellar artery large; anterior inferior cerebellar small.

Case 2099. M. D.; white; female; aged 71; senile dementia. Arterio-sclerosis. Right anterior cerebral artery very small; the left is very large, divides into two trunks which correspond to the two anterior cerebral arteries, and there appears to be no true anterior communicating artery. The right posterior cerebral artery apparently arises from the carotid, and is only united to the basilar by a very small branch of a rudimentary vessel which is mainly distributed to the crus and interpeduncular space. (Fig. 4.)

Case 2137. C. N.; white; male; aged 66; senile dementia. Arterio-sclerosis. Right anterior cerebral artery very small, its place being taken by the opposite artery which supplies the two vessels through an enlarged anterior communicating artery. Right posterior communicating artery large, posterior cerebral small. Left posterior inferior cerebellar artery absent, its place being taken by a large branch from the anterior inferior cerebellar artery.

Case 2139. R. W. E.; white; male; aged 48; chronic epileptic dementia. Arterio-sclerosis. The two anterior cerebral arteries join into a common trunk just anterior to the anterior communicating artery leaving a triangular opening between the vessels. The two arteries then form a large vessel about one-half an inch in length after which they again divide and the upper vessel forms a callosal artery, while the other branch is mainly distributed to the medial surface anteriorly. On the left side, opposite the junction of the anterior communicating artery with the anterior cerebral a three branched trunk arises, the anterior branch taking the place of the anterior cerebral artery of this side, the middle branch distributed to the orbital surface, and the posterior branch goes backward to supply Broca's convolution and the insula. The right posterior inferior cerebellar artery is absent, the anterior inferior being rather large. (Fig. 5.) No. 2139; all of the branches not represented.

Case 2141. J. C.; white; male; aged 80; senile dementia. Arterio-sclerosis. The two anterior cerebral arteries join directly into a single trunk without an anterior communicating artery. This trunk extends to the genu callosi where it again divides into two vessels which are distributed normally. A large branch which arises from the junction of the vessels supplies the orbital and medial regions of the left frontal lobe and is possibly the representative of the left anterior cerebral artery. The right posterior communicating artery is very large, corresponding posterior cerebral artery very small at its origin from the basilar. Left superior cerebellar artery is doubled. (Fig. 5.)

Case 2153. R. W.; white; female; aged 66; senile dementia. Arterio-sclerosis. Anterior communicating artery very small and impervious. Left anterior cerebral does not lie close to the genu of the callosum but is distributed to the orbital, and outer anterior medial surfaces of the left side; the opposite artery furnishes a single callosal artery, only one being present. Both posterior communicating arteries are large and supply the territory of the posterior cerebral arteries, these vessels being small at their origin. (Fig. 5.)

Case 2159. P. J.; white; male; aged 66; senile dementia. No disease of arteries. Right posterior communicating artery large; posterior cerebral artery of this side practically absent being joined to the former artery by a small impervious branch. Posterior communicating artery of left side enlarged and the posterior cerebral very small. The basilar, both vertebrals, and the posterior inferior cerebellar arteries are quite small. Anterior communicating artery absent. (Fig. 6.)

Case 2160. J. S. G.; white; male; aged 66; chronic mania. Slight arterio-sclerosis. Left vertebral as large as the basilar; right small and the posterior inferior cerebellar artery receives nearly all the blood brought by the lower part of the vertebral artery. Left posterior communicating artery unusually large. Small aneurism at origin of right anterior choroid artery.

Case 2163. A. H. T.; white; male; aged 68; senile dementia. Arterio-sclerosis. Posterior communicating artery of left side represented by an extremely small vessel. The left anterior choroid artery is unusually large; it lies at its first part deeply in the hippocampal fissure and branches supply the choroid plexus; it finally emerges and forms the parieto-occipital and the calcarine artery. The posterior cerebral of this side is distributed mainly to the inferior temporal region and the crus. On the right

side a small aneurism is situated at the origin of the posterior communicating artery from the carotid, and one at the junction of the right anterior cerebral and anterior communicating artery. (Fig. 6.)

Case 2169. A. J. L.; white; male; aged 72; epileptic dementia. Arterio-sclerosis. Right anterior cerebral artery large, left small; and distributed mainly to the lower medial surface. A large median cerebral artery takes the place of the left anterior cerebral, and after it passes the genu it is distributed to the left upper medial surface and forms a callosal branch. Both posterior communicating arteries are enlarged; left posterior cerebral artery quite small. (Fig. 6.)

Case 2172. F. J. L.; white; male; aged 64; senile dementia. Arterio-sclerosis. Right anterior cerebral artery sends a large callosal branch which afterwards divides and supplies both quadrate lobules, while another branch of this artery forms the callosal branch of the left side. Right vertebral artery small; left continuous with the basilar and of the same size.

Case 2176. P. C.; white; male; aged 66; senile dementia. Marked arterio-sclerosis. Posterior communicating artery of left side large; posterior cerebral small, mainly distributed to velum interpositum, crus, and a small branch which joins the posterior communicating artery about one-half inch from its origin. The posterior communicating artery of this side, therefore, chiefly furnishes the posterior cerebral region.

Case 2177. D. P.; colored; male; aged 63; senile dementia. Arterio-sclerosis. Right posterior cerebral artery very small, and joins the posterior communicating artery by a small impervious branch. This artery is distributed mainly to the crus, and a large artery corresponding with the anterior choroid runs backward in the fissura hippocampi and after supplying the choroid plexus takes the place of the posterior cerebral artery being distributed in the same way. A small branch from this anomalous vessel anastomoses with the posterior choroid artery. The right posterior inferior cerebellar artery arises from the basilar; the opposite artery arises by a common trunk with the anterior inferior cerebellar, Fig. 6.

Case 2179. J. F.; white; male; aged 69; senile dementia. Advanced arterio-sclerosis. Both posterior communicating arteries are large and furnish the region of the posterior cerebral arteries. The left posterior communicating artery communicates with the basilar artery by a small impervious branch; the right anastomoses with the superior cerebellar by a small pervious branch; both posterior cerebral arteries being practically absent. The left anterior inferior cerebellar artery is very small.

Case 2184. W. T.; white; male; aged 57; chronic epileptic dementia. No arterial disease. Both posterior communicating arteries are small and are distributed mainly to parts around the crura. The left anastomoses with the posterior cerebral artery by a small branch, the right has no connection with the posterior cerebral artery. The nutrient arteries of the interpeduncular space are larger than usual, otherwise the posterior cerebrals are normal.

Case 2189. M. J.; colored; female; aged 65; senile dementia. Arterio-sclerosis. Both posterior communicating arteries small; both posterior inferior cerebellar arteries arise in common with the anterior from the basilar. Small impervious trunk connects the two anterior cerebral arteries posterior to the anterior communicating.

LITERATURE CITED.

- BERKLEY.
Mental Diseases. 1900.
- BROWNING.
The Cerebral Circulation. Reference Hand-Book of the Medical Sciences, vol. 2. 1901.
- BULLEN.
Post-Mortem Examination of the Brain, etc. *Journal of Mental Science*, vol. 36. 1890.
- DERCUM.
A Collection of Anomalies of the Circle of Willis. *Journal of Nervous and Mental Disease*, vol. 14. 1889.
- LUCAS, E.
Essai historique, critique et expérimental, sur la circulation, artérielle du cerveau. Thèse de Paris. 1879.
- WILDER.
Encephalic Nomenclature. Arteria Termatica. *New York Medical Journal*, vol. 41, 1885, and *Journal of Nervous and Mental Disease*, vol. 12, 1885.
- WINDLE.
On the Circle of Willis. Reports of the British Medical Association for 1887, *New York Medical Journal*, vol. 2, 1888, and *Journal of Anatomy and Physiology*, 1887-1888.

FIG. 1. Diagram showing the normal direction of the blood current in the basal arteries, and how completely separated are the carotid and the vertebral system by the balance in the middle of the posterior communicating arteries. At the same time in normal conditions the two hemispheres are almost as distinctly supplied, owing to the balance in the anterior communicating artery, and the direction of the current in the posterior cerebral arteries. The cerebellar circulation is not so distinctly separated on the two sides and the anastomoses between the cerebellar arteries are more complete than those of the cerebrum.

FIG. 2. Diagram showing the most common variations in the circle of WILLIS, etc. (*A*) Enlargement of one anterior cerebral artery with corresponding small size of the opposite artery; (*B*) double anterior communicating artery; (*C*) common trunk made by junction of the two anterior cerebral arteries, with division at the genu callosi; (*D*) enlargement of one, or both posterior communicating arteries which then go to supply the region of the posterior cerebral arteries which are abnormally small; (*E*) doubling of the superior cerebellar artery; (*F*) partial doubling of the basilar artery; (*G*) common trunk giving off the anterior, and posterior inferior cerebellar arteries from the basilar; (*H*) common trunk giving off these two arteries from a vertebral artery; (*I*) small size of one vertebral artery with corresponding large size of the opposite artery; (*K*) large size of a vertebral artery before giving off the posterior inferior cerebellar artery.

FIG. 3. Anomalous arrangements of arteries shown by Cases 2000, 2004, 2057 and 2063.

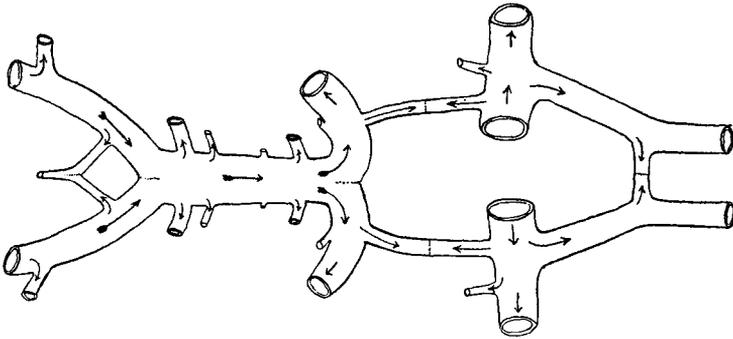


FIG. 1.

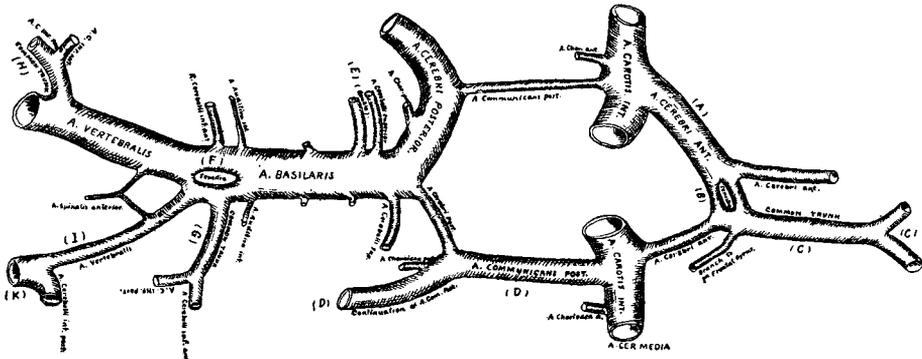
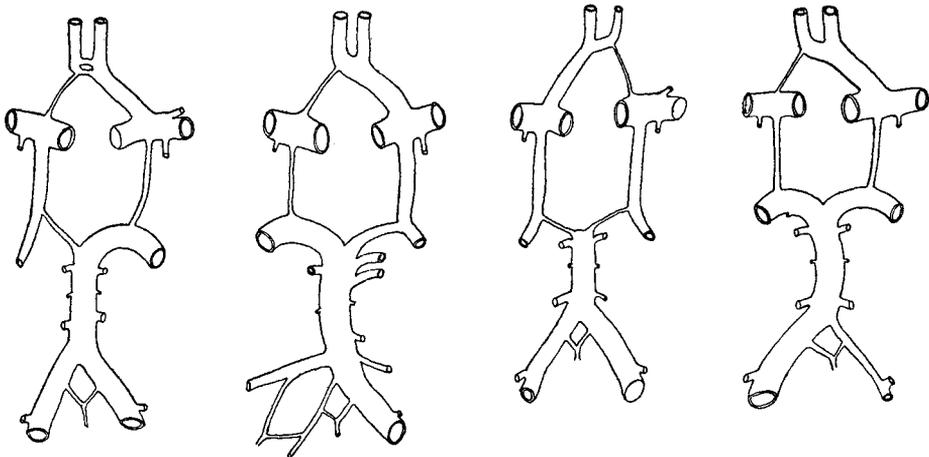


FIG. 2.



No. 2000.

No. 2004.

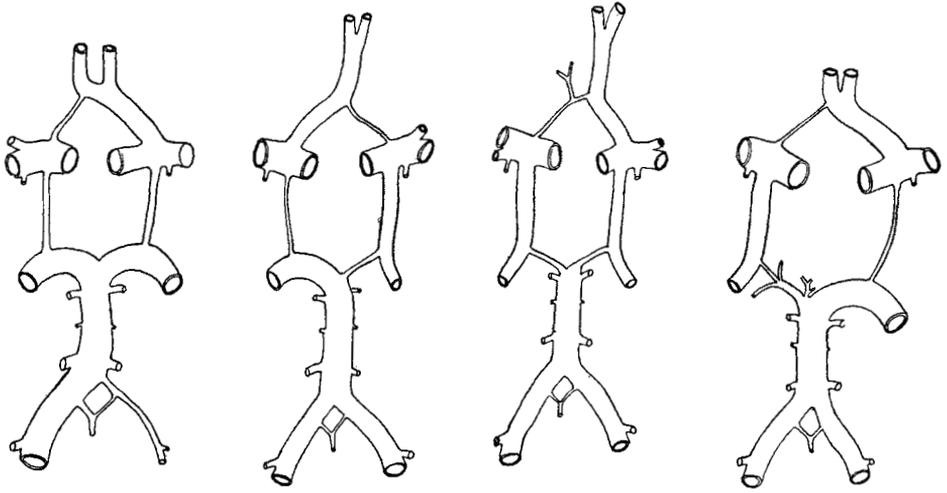
No. 2057.

No. 2063.

FIG. 3.

FIG. 4. Anomalous arrangements of arteries shown by Cases 2066, 2073, 2077 and 2099.

FIG. 5. Anomalous arrangements of arteries shown by Cases 2137, 2139, 2141 and 2153.



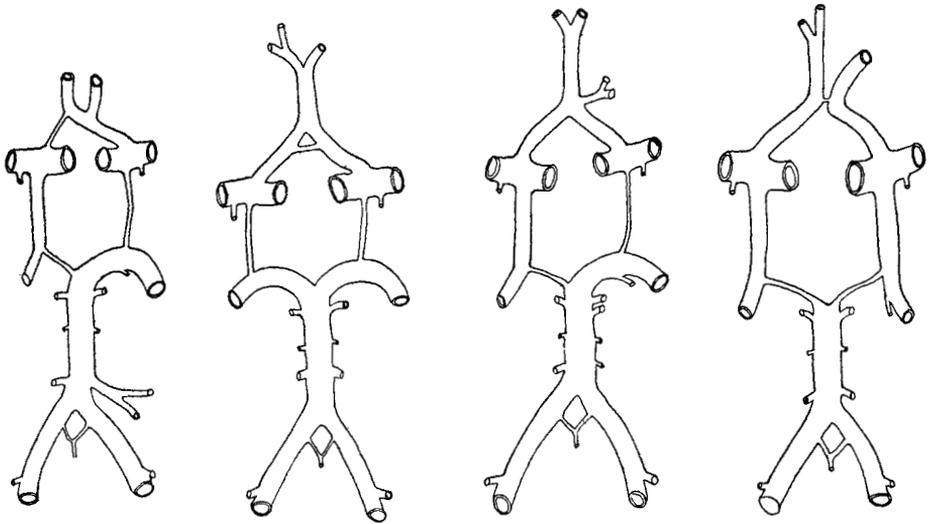
No. 2066.

No. 2073.

No. 2077.

No. 2099.

FIG. 4.



No. 2137.

No. 2139.

No. 2141.

No. 2153.

FIG. 5.

FIG. 6. Anomalous arrangements of arteries shown by Cases 2159, 2163, 2169 and 2177.

FIG. 7. Case 1926. Semidiagrammatic sketch of the circle of WILLIS viewed from the left, partly in profile, showing the point of origin of the anomalous branch from the internal carotid artery and its junction with the basilar. By the origin of the basilar branches it will be seen that the basilar artery is represented by three portions which have been designated upper, middle, and lower portions, and that the vessel is very irregular in caliber owing to the junction with the abnormal branch, and the unusual origin of the cerebellar arteries.

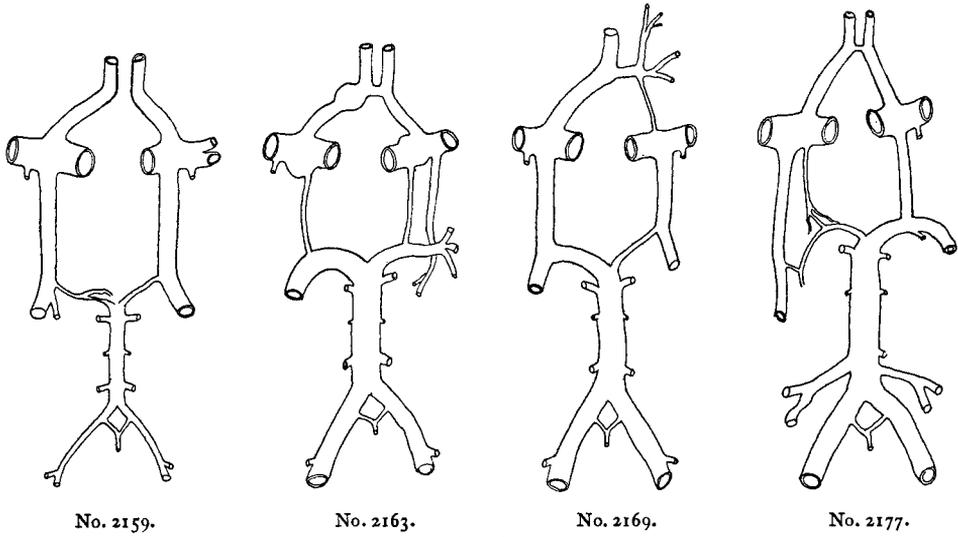


FIG. 6.

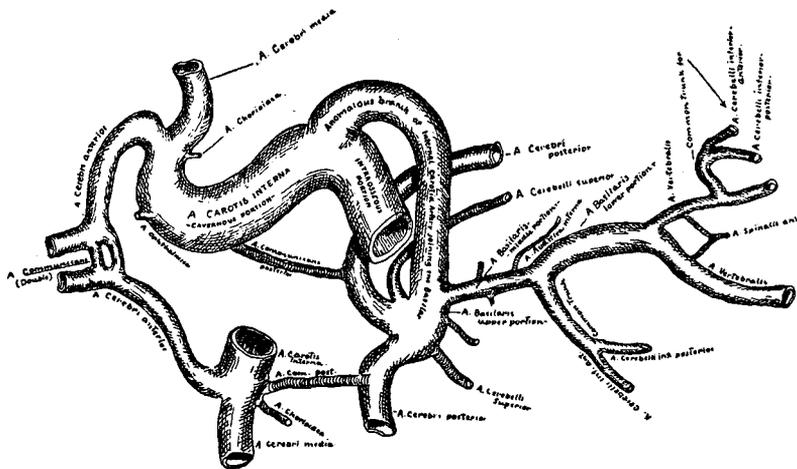


FIG. 7.

FIG. 8. No. 1926. Diagram of the cerebral arteries viewed from above, as they lie at the base of the skull. The cavernous portions of the carotid arteries are exposed, and the dotted line shows the position of the anomalous carotid branch.

FIG. 9. No. 1926. Diagram of the arrangement of the arteries of the base of the brain in Case 1926, viewed from below as they lie on the brain. The point of origin of the anomalous branch and its junction with the basilar artery are shown.

FIG. 10. Case 1909. Thrombotic softening of the left hemisphere from a thrombus, situated in the intracranial portion of the left carotid artery; the anterior communicating artery and the posterior cerebral artery of the same side being small, partly obstructed by arterio-sclerosis, and insufficient to maintain the circulation. Thrombosis of the right carotid would not have so resulted on account of the large size of the posterior cerebral and the normal size of the posterior communicating artery.

FIG. 11. Case 1954. Set of cerebral arteries showing almost all of the common anomalies, with their compensatory relationships. 1, The anterior communicating is large and modified by enlargement of the left anterior cerebral; 2, left anterior cerebral large, right small; 3, both posterior communicating large, corresponding posterior cerebral arteries small, especially the right; 4, left superior cerebellar artery double; 5, right vertebral artery small, and the posterior inferior cerebellar receives nearly all of the blood brought by the vertebral; 6, left vertebral artery as large as the basilar. An aneurism on the right middle cerebral artery at the origin of its principal branches.

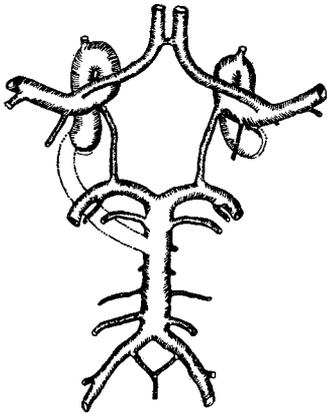


FIG. 8

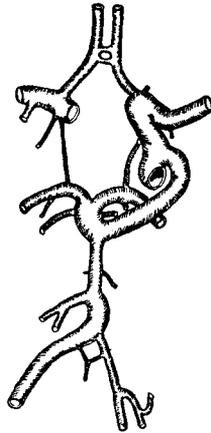


FIG. 9.

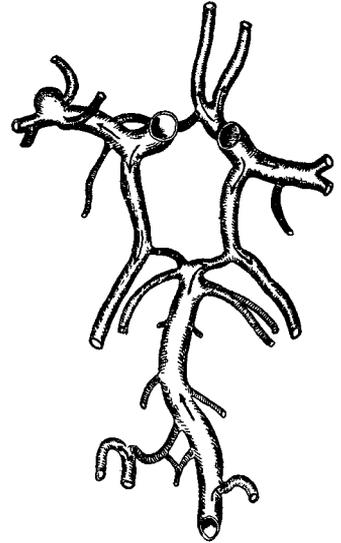
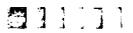


FIG. 11. 

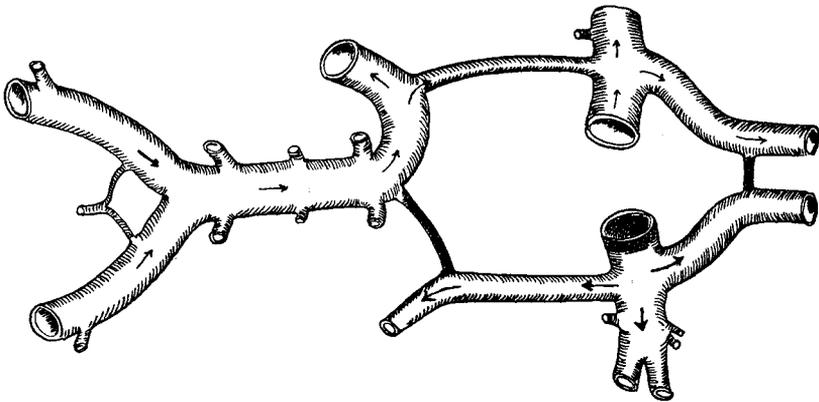


FIG. 10.