

Anatomy. — *The Forebrain arteries in Plagiostomes, Reptiles, Birds and Monotremes.* By C. U. ARIËNS KAPPERS.

(Communicated at the meeting of January 28, 1933).

It is generally known that the distribution of the forebrain arteries in man is such that the medial side of the hemispheres is vascularised by the arteriae cerebrales anterior and posterior, which from there for a comparative small distance turn over on the convexity.

The convexity itself is supplied by the arteria cerebri media chiefly, which, though sending also branches to the lateral orbital surface of the brain and to the rhinencephalon posterior (lob. piriformis), is the neopallial artery par excellence. The distribution of these vessels in man (DURET, BEEVOR, SHELLSHEAR, K. H. BOUMAN and LEY), and recently also in Anthropoids (SHELLSHEAR, HINDZE, l.c. infra) is well known.

This cannot be said of the of the phylogenetic development of the art. cer. media and its relation with both other arteries with lower vertebrates, although here also excellent work has been done, specially by HOFMANN (l.c. infra). In the following pages I shall give a short survey of my researches on Plagiostomes, Reptiles, Birds and Monotremes and discuss some points of general interest in the relation of these arteries amongst each other and in regard to the territories they supply.

In Plagiostomes the carotis cerebialis turns backward in an obtuse, nearly right curve along the sidewall of the tweenbrain.

This caudal branch (the communicans posterior of higher vertebrates) is very long and passes backward usually at the outside of the III root (*Acanthias*, *Raja clavata*, HOFMANN), not at the inner side of it, as is the case in mammals and in man.

There are, however, exceptions. So in my specimen of *Laemargus borealis* (see figure) the left carotis caudalis passes mesially to the emergence of the III root, the right one laterally to this root. In a *Rhina squatina* exactly the opposite occurred. It is, however, striking that in both cases the stronger branch was running mesially to the root i.e. the stronger branch took the course characteristic of higher development. Backwards under the midbrain-oblongata border the carotis caudalis joins the caudal carotis branch of the other side thus forming an arteria basilaris, which anastomoses with the two anterior branches of the first spinal artery.

At this place a small branch of each anterior spinal artery runs backwards again and forms an impair tractus arteriosus spinalis anterior in the

ventral midline. As in other animals, a *circulus arteriosus spinalis primus* (HOFMANN¹⁾) may be thus established.

The way in which the frontal branches of the *carotis cerebialis* are distributed in *Laemargus* and *Rhina* is such, that already before the curve the art. *ophthalmica* (O) arises. In the curve itself the *arteriae cerebri* arise, first of all the arteria, named *arteria bulbi olfactorii lateralis* by HOFMANN. This artery runs in a stretched course along the lateral brainwall to the olfactory stalk, which it supplies till the *bulbus olfactorius*. During this course it gives off ventrally and, principally, dorsally small branches to the lateral mantle wall, some of which turn mesially along the olfactory stalk for a short distance on the dorsal surface of the brain. This *arteria olfacto-bulbaris lateralis* to my opinion is the primitive homologon of the art. *cerebri media*. Medially from it the art. *cerebri anterior* arises, which in *Rhina* has no transverse anastomosis (*art. communicans anterior*) with the analogous artery of the other side.

In *Laemargus borealis* a thin *communicans anterior* is present.

The anterior artery is described by STERZI²⁾ as art. *medialis*.

In *Laemargus*, *Rhina* and *Raja batis* the artt. anter. of both sides join at the frontpole of the brain, and turning upwards continue their course on the dorsal forebrain surface, in *Laemargus* for a short distance only.

With my *Rhina squatina* and with *Raja batis*³⁾ this impair artery extends in the midline of the dorsal hemispheres till the posterior border of the pallial area and to the plexus *chorioideus* of the forebrain the parapsyphial sac of these animals.

This difference corresponds with the fact that in *Rhina* and in *Rays* a shifting upwards and backwards of the, in *Laemargus* more frontal area took place, which is also reflected in the more compressed form of the plexus *chorioideus anterior* (dotted area in the figure) and the position of the *commissura anterior*, which in these animals for the greater part lies dorsally and therefore by some authors was erroneously considered as a *corpus callosum*.

From the beginning of the caudal branch of the *carotis* (*communicans posterior* of mammalian anatomy), another bloodvessel arises which in *Rhina squatina* chiefly provides the plexus *chorioideus* of the third ventricle and the plexus *chorioidei anteriores*. This artery deserves the name art. *chorioidea anterior*⁴⁾. Since, however, some of its branches bifurcate in the

¹⁾ M. HOFMANN. Zur vergleichenden Anatomie der Gehirn- und Rückenmarksarterien der Vertebraten. Zeitschr. f. Morphologie und Anthropologie. Bnd. 2, 1900, p. 247.

²⁾ STERZI. Il sistema nervoso centrale dei vertebrati, Vol. 2, Pesci, Libro 1 Selaci, Parte 1. Anatomia, Draghi. Padova. 1919.

³⁾ With the two specimens of *Raja clavata* examined by him HOFMANN did not see this dorsal continuation of the art. anterior cerebri. I suppose, however, that it occurs also here.

⁴⁾ More caudally from the posterior *carotis* the artt. *mesencephali* and *cerebellaris superior* arise, from the *basilaris* the artt. *cerebelli inferior anterior* and *posterior*, which I shall not describe here.

hind wall of the brain, the arteria cerebri posterior is also included in this artery. With the more primitive *Laemargus borealis* the dorsal mantle branches of the art. posterior cerebri are distinctly larger and more numerous, the larger part of the dorsal mantle being vascularised by it. Also this difference between *Laemargus* and the *Rhinidae* and *Rajidae* is a result of the less dorso-caudal compression of the frontal mantle area in *Laemargus*.

It is a remarkable fact that in my *Laemargus* specimen the art. chorioidei anterior at the left arises together with the art. posterior cerebri, while at the right the chorioidea anterior arises as a separate artery, the dorsal mantle branches arising as bifurcations of the arteria cerebri media.

Of the reptiles I principally examined the turtles (*Testudo tabulata* and *gigantea*, *Chelone midas* and *Dammonia subtrijuga*) and a Crocodile (*Crocodylus porosus*).

Whereas HOFMANN in *Testudo graeca* found the posterior carotis branch (the communicans posterior of human anatomy) at both sides running medially from the oculomotorius root. I found in my *Chelone midas* the left branch running medially, the right one laterally from the oculomotorius root, the same as in *Laemargus* (cf. figure). Again here it is remarkable that the communicans posterior running medially from the III root is the stronger one, thus showing clearly the hydrodynamic influences acting on the course of this artery.

The frontal carotis branches, run as follows: Before the curve of the carotis the art. ophthalmica¹⁾ arises. It runs under the N. opticus and in *Chelone midas* forms a small art. communicans ophthalmica under the optic chiasma. In the carotis curve itself the art. cerebri media and anterior arise from one stem. This common stem might be called carotis cranialis. It soon bifurcates in an art. media and anterior cerebri. The art. cerebri anterior has no distinct communication with the same artery of the other side (no communicans anterior). Upon the septum a few branches of it turn backward, but for a small distance only²⁾.

The main stem of the art. anterior runs further frontally and bifurcates in the fissura postrhina (which separates the lobus olfactorius anterior from the hemispheres proper) in medial and lateral branches.

It vascularises the lobus anterior and the olfactory stalk (tr. olfactorius), not the hemisphere of the brain. Contrary to the relative diminution of the

1) HOFMANN did not succeed to demonstrate this artery. It is very small even in the much larger Reptiles I examined.

2) RATHKE and HOFMANN found in snakes (*Tropidonotus natrix*) a far backwards running branch of this artery on the dorsomedial wall as an impair artery as I found in *Rhina squatina*, (c.f. RATHKE. Bemerkungen über die Carotiden der Schlangen l.c. infra). — That the artt. cerebri anteriores do not form an impair artery in *Chelone* is probably caused by the fact that the hemispheres in *Chelone* remain more separate, than in snakes.

vascularisation area of the art. anterior cerebri the area of distribution of the art. cerebri posterior has considerably enlarged (see below). This has to be explained by the fact that in reptiles, in contrast with fishes, the greater part of the forebrain (the hemispheres proper) is not a lobus olfactorius anterior but a lobus olfactorius posterior (= lobus piriformis).

The art. media cerebri which in the Plagiostomes is represented by the lateral olfacto-bulbar artery, in *Chelone* and the other reptiles examined has much more the character of a real arteria cerebri media, its bifurcations on the lateral mantle wall being more numerous than those on the lateral olfactory bulb. This lateral mantle wall, or pallium, in Reptiles, however, is no neopallium as it is in mammals, but a part of the lobus piriformis and these lateral branches should be considered as the homologues of the artt. piriformes also demonstrated in Mammals (c. f. SHELLSHEAR l.c. infra).

The most dorsal part of the hemispheres is supplied by the art. cerebri posterior. In my Chelonians this artery originates from the caudal carotis branch (or communicans posterior), entirely independantly from the arteria chorioidea ventriculi lateralis and tertii, which arises just before it. The vascularisation area of the art. cerebri posterior in these reptiles extends as far frontally as the hind border of the lobus olfactorius anterior where it anastomoses in the fissura post-rhinica with branches of the art. cerebri anterior (see figure). While thus the area of the arteria anterior cerebri has diminished, that of the arteria posterior cerebri has enlarged, this artery providing the whole dorsal mantle till the fissura postrhinica, i. e. the dorsal side of the hemispheres proper which also contain the amygdala and the hippocampus (= lob. sphenoidalis of CAJAL).

In *Dammonia subtrijuga* both artt. cerebri posteriores are fused to form an impair artery in the dorsal midline as occurs also in Crocodiles¹⁾ (c.f. also RATHKE²⁾ and SHELLSHEAR³⁾).

A remarkable point, with the arteria posterior cerebri in Crocodiles is that it does not arise from the posterior carotis branch (or communicans posterior) but as a branch of the frontal curve of the carotis and that (presumably in connection herewith) it is again united at its origin with the arteria chorioidea anterior. This origin of the art. posterior cerebri from the frontal carotis branch, already observed by RATHKE and SHELLSHEAR in Crocodiles, is found again in birds (*Anser*, *Turdus*, *Gallus* examined by HOFMANN. *Antigone australiasiana* and *Vultur* by myself). Probably this origin of the art. posterior cerebri is no consequence of a frontal

1) This is connected presumably with the lesser space between both hemispheres in *Dammonia* and in the crocodile, see foot note p. 54.

2) RATHKE. Bemerkungen über die Carotiden der Schlangen. Denkschr. Kais. Akad. der Wissensch., Wien. Bnd XI. 1856. Untersuchungen über die Aortenwurzeln der Saurier, Ibidem B. XIII, 1857.

3) SHELLSHEAR. A study of the arteries of the brain of the spiny anteater (*Echidna aculeata*) to illustrate the principles of arterial distribution. Transactions of the Royal Soc. Series B. Vol. 218, 1927.

shifting of its emergence but rather of a more caudal position of the stem of the cerebral carotis ¹⁾ in birds.

In *Anser* the resemblance of the posterior cerebral artery with the homologous artery in crocodiles is still more complete since, according to HOFMANN it arises together with the art. chorioidea anterior and besides fuses in the middle fissure of the forebrain with the corresponding artery of the other side, running frontally as an impair vessel on the medial wall. This is not so in *Gallus*, *Turdus* and *Antigone*.

In *Antigone australiasiana* I was struck by the presence of two arteriae cerebri posteriores at both sides, arising closely behind each other from the frontal carotis bifurcation. The frontal art. cerebri posterior (see figure P. A.) extends far frontally over the medial brainwall, the posterior (P. P.) one supplies the occipital pole only. Both, but especially the former also supplies a part of the convexity.

The art. anterior cerebri in birds has a distinct anastomosis with the anterior of the other side (communicans anterior). The main stem runs over the tuberculum parofactorium and supplies only a part of the basis and a small part of the front pole of the hemispheres including the greatly diminished lobus olfactorius anterior, as it does in reptiles.

The art. cerebri media has enlarged and supplies the greater part of the basis (rami orbitales) and a part of the convexity of the frontbrain (rami piriformes) but also the lateral side of the bulbus olfactorius.

For the Monotremes the data concerning the cerebral vessels of *Ornithorhynchus* are very scanty.

MECKEL ²⁾ and HOCHSTETTER ³⁾ give nothing. HYRTL ⁴⁾ says only about the carotis cerebrialis that she passes through the skull near the upper nasal septum. Of the cerebral vessels proper he says nothing. TANDLER ⁵⁾ gives a drawing of the circulosus arteriosus of *Ornithorhynchus* and says about the cerebral vessels proper only that the art. cerebri anterior fuses to an impair stem that runs backwards along the medial wall as an art. corp. callosi and further that the main stem of the carotis, the media turns backward as an art. Fossae Sylvii. Of the posterior cerebri he says that it is "ganz schwach". This agrees entirely with my own results.

Of *Ornithorhynchus* I had only one somewhat putrified cerebrum fixed in the skull. Nevertheless the following facts could be stated clearly:

The carotis is strongly developed and from its frontal curve the art. cerebri anterior and the art. cerebri media originate ⁶⁾. The art. anterior cerebri, which in my specimen (see figure) is thicker at the left than

¹⁾ While the carotis curve in most animals lies on the level of the chiasma, in birds it lies near the III root.

²⁾ MECKEL. *De Ornithoryncho paradoxi descriptio anatomica*, Lipsiae, 1926.

³⁾ HOCHSTETTER. *Beiträge zur Anatomie und Entwicklungsgeschichte des Blutgefäßsystems der Monotremen*. Semon's Forschungsreisen in Australien. Bnd. II Lief. III 1896.

⁴⁾ HYRTL. *Beiträge zur vergl. Angiologie*, IV. Das arterielle Gefäßsystem der Monotremen. *Denkschr. der Kais. Akademie der Wissensch. Wien*, Bnd. V. 1853.

⁵⁾ TANDLER. *Zur vergl. Anatomie der Kopfarterien bei den Mammaliern*. Bnd. 67, 1899.

⁶⁾ I did not trace the arteria ophthalmica in my specimen.

at the right side penetrates in the median basal fissure (between the tubercula olfactoria) where it joins the contralateral artery (see fig. at +), thus forming a big impair stem, that again bifurcates (see fig. at ×) above the commissures (comm. anterior with the ventral callosum and the dorsal psalterium). On top of this commissural complex it again divides giving a branch to the left and one to the right medial hemisphere wall, running backwards at both sides in a curve as in higher mammals. After having given off a few small frontal branches during this course it has its largest bifurcation behind the posterior half of the hemisphere in a dorsal branch that extends in two or three side branches on the convexity of which they vascularise a rather large part (but not such a large part as in *Echidna* is vascularised by the posterior cerebri, see below). After the emergence of this dorsal branch the original stem — greatly diminished in size — runs further backwards anastomising with a branch of the posterior cerebri, which anastomosis, however, is hardly visible.

The arteria cerebri media has a small orbital branch and 3 or 4 lateral or piriform branches. At the right the third, at the left the second piriform branch (M) is the largest one and probably represents the beginning of an arteria fossae Sylvii. This branch, soon dividing in various side branches, extends, in dorsal and caudal direction on the lateral brain wall, approaching the dorsal main branches of the art. cerebri anterior, that supply the largest part of the dorsolateral mantle.

As already observed by TANDLER the art. posterior cerebri is very small in *Ornithorhynchus*. It arises from the communicans posterior rather far backward, in front of the III root, and principally supplies the medio-ventral surface of the occipital lobe. As stated above it appears (by pulling at the arteries) that there is an anastomosing branch between the anterior and posterior artery. Though this anastomosing branch is very small it forms a closed *arcus arteriosus medialis*.

The communicans posterior is well developed and the arteria basilaris is rather big (about as big as the carotis).

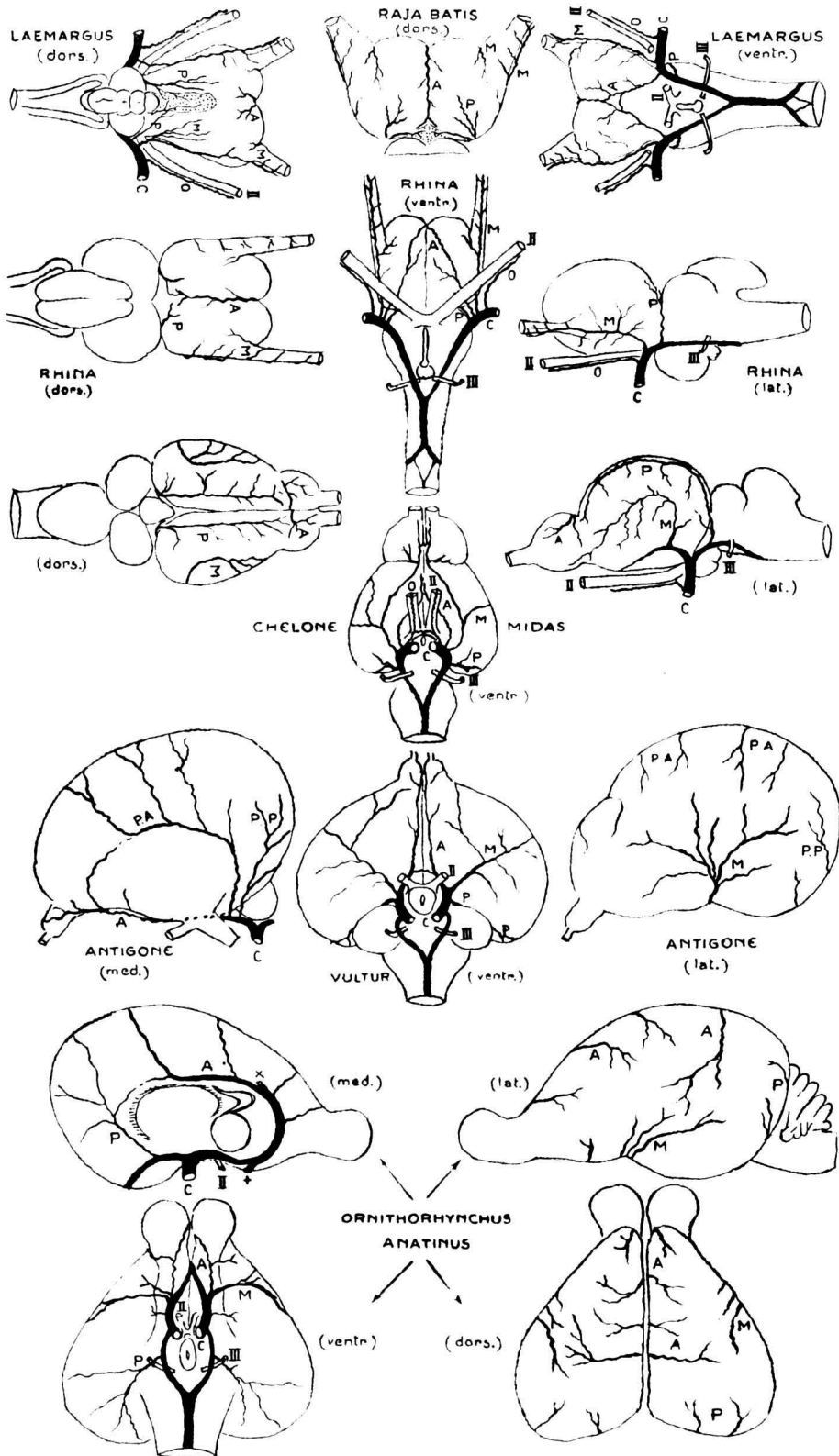
The chief difference with the reptiles and birds thus is that the area of the art. cer. anterior has considerably enlarged in *Ornithorhynchus*. It vascularises nearly the whole medial brainwall and the larger part of the convexity.

In *Echidna* the relations are different, as appears from the excellent discription given by SHELLSHEAR (l.c. infra), which I can confirm in every detail, thanks to some *Echidna* brains presented to the Institute by Prof. J. P. HILL (London) to whom I am much indebted for this precious material.

The chief difference is that contrary to *Ornithorhynchus*, of both components of the *arcus arteriosus medialis* the art. cerebri posterior is very large and the art. cerebri anterior very small in *Echidna*.

As in *Ornithorhynchus* the latter is partly impair (in the basal median fissure).

The large art. cerebri posterior of *Echidna* arises from the caudal carotis



A = art. cerebri anterior; M = art. cerebri media; P = art. cerebri posterior;
 C = Carotis cerebialis; O = art. ophthalmica; II = optic nerve; III = oculomotor nerve.
 P.A. and P.P. (in Antigone only): art. posterior anterior and art. posterior posterior.
 The dotted area in the forebrain of Laemargus and Raja is the anterior choroid plexus.

branch¹⁾ or communicans posterior close in front of the III root and runs very far frontal as it does in reptiles (and birds), in casu, however, on the medial wall of the brain, near the fiss. chorioidea, anastomosing frontally with a tiny branch of the anterior cerebri.

In addition to most of the medial surface the posterior cerebri vascularises by far the largest part of the convexity which here, as in *Ornithorhynchus*, consists of a proper neocortex. The art. media cerebri (the second piriform continued) takes only a small part in the vascularisation of the neocortex. This is the more remarkable since already in *Chelone* and principally in birds the arteria cerebri media extends over such a large part of the convexity.

I have, however, already called attention to the fact that the convexity of the hemispheres in *Chelonians* practically corresponds with the lobus piriformis of mammals, not with the neopallium. Since in reptiles a neopallium proper does not occur²⁾, the piriform area in these animals is not pressed so much ventrally as in mammals is effected by the growth of the neopallium. Since in *Echidna* the neopallium is more developed (SCHUSTER), than in *Ornithorhynchus* the lobus piriformis is more compressed and lies nearly entirely ventrally in *Echidna*. The lateral orbital area of *Echidna* and the lobus piriformis are supplied by the art. media cerebri, viz. by art. orbitalis lateralis and the artt. piriformes of SHELLSHEAR³⁾.

That the greater part of the convexity is supplied by branches of the circulus arteriosus medialis we observed already in *Ornithorhynchus*, but whereas in the latter the arteria cerebri anterior acts the largest part in it in *Echidna* the art. cerebri posterior is the chief artery for this circle.

Correlating the results of the electric stimulation experiments in *Ornithorhynchus* made by MARTIN⁴⁾ with my findings about the vascularisation, it appears that the motor (probably sensu-motor) neocortex in *Ornithorhynchus* has developed on the border of the vascularisation by the medial arcus arteriosus and of the art. media cerebri, being practically vascularised by the medial arcus arteriosus. That this area corresponds, partly at least, with the areae 4 and 6 of BRODMANN appears from the investigations of ROSE⁵⁾.

In *Echidna* SCHUSTER⁶⁾ the anterior three quarters of the convexity are rather homogeneous. His fig. 4 resembling the motor cortex of lower

¹⁾ The arteria chorioidea has an independent origin.

²⁾ At best a small primordium of a neo- or general cortex (as Dr. CROSBY calls it) is to be found here.

³⁾ Also the first piriform artery extends a small distance on the neopallium (SHELLSHEAR).

⁴⁾ CH. J. MARTIN. Cortical localisation in *Ornithorhynchus*. Journ. of Physiology. Vol. 23, 1898—99.

⁵⁾ Gyrus limbicus and regio retrosplenialis. Journ. f. Psych. und Neurol., 1928 (fig. 1).

⁶⁾ SCHUSTER. Preliminary note upon the cell lamination of the cerebral cortex in *Echidna*. Proceed. Roy. Soc. London. Ser. B. Vol. 82, 1909.

mammals, in absence of stimulation experiments we may accept that this area (type III of SCHUSTER) is homologous with the lateral, sensu-motor cortex of *Ornithorhynchus*. After MARTIN's researches on *Ornithorhynchus* this area has to do with the cortical innervation of the enormous *facialis* musculature, which in both animals extends not only over the head and neck, but also over the shoulder and forelegs ¹⁾. This neo-cortex vascularised in both animals by the *medial arcus arteriosus*, in *Echidna* is obviously still larger than in *Ornithorhynchus* and this may explain that the extension of the dorsal branches of the *arcus arteriosus medialis* on the convexity is also larger in *Echidna* than in *Ornithorhynchus*.

Why, however, in *Ornithorhynchus* principally the art. *cerebri anterior* supplies this neocortical area, whereas in *Echidna* it is supplied by the *arteria posterior cerebri*, in other words why in *Ornithorhynchus* the anterior and in *Echidna* the posterior artery is the most important factor in the *arcus arteriosus medialis*, is difficult to say. One would naturally ask if it may be explained by the fact, that the cerebral carotis in *Echidna* is small and the *communicans posterior* large, while in *Ornithorhynchus* the carotis is strongly developed. Though this is true, in some Rodents the carotis compared with the *communicans posterior*, is still smaller than in *Echidna* and in *Sciurus* (according to my own experience and that of TANDLER and DE VRIESE ²⁾ the carotis *cerebralis* even fails while the art. *anterior cerebri*, though receiving its blood from the *communicans posterior* only, is not smaller here than the *posterior cerebri* and certainly extends further backwards over the medial wall of the brain than it does in *Echidna*.

Considering the frontal compression of the brain in *Echidna*, which according to ELLIOT SMITH ³⁾ acts such a large part in its peculiar fissuration, it cannot be excluded that this factor also acts on the anterior artery, the impair part of which is very much compressed in the narrow interhemispherical fissure of this animal.

With higher mammals ⁴⁾ we find analogous relations as occur in man: the *arteriae anterior* and *posterior*, supplying chiefly the medial brainwall extend for a small part only over the convexity, which is principally supplied by the art. *cerebri media*, that in *Primates* also vascularises the cortical *facialis center*.

¹⁾ E. HUBER. Studies on the organisation of the Monotremes etc. *Morph. Jahrbuch*. Bnd. 66, 1931.

²⁾ BERTHA DE VRIESE. Sur la signification des artères cérébrales chez les mammifères. *Arch. de biologie*. Tome 21, 1905.

³⁾ R. BURNE and ELLIOT SMITH. Catalogue of the Royal College of Surgeons, 1902, p. 145.

⁴⁾ Great variations occur in the origin of the art. *cerebri posterior* (HOFMANN). In some mammals (e.g. deer) it arises very frontal (HOFMANN's art. *cerebri posterior a.*) and coincides with the art. *chorioidea anterior*, in others directly behind this latter from the frontal part of the *communicans posterior* (HOFMANN's type b) but generally still more caudally directly in front of the III root, ascending in front or behind the *geniculatum mediale* (type c. and d of HOFMANN).

In the Ungulates, however, the cortical facialis centre still lies in the vascularisation area of the anterior cerebri (compare the stimulation experiments on sheep by SUTHERLAND SIMPSON and KING¹⁾ with HOFMANN'S investigations about the vascularisation in this animal).

Even in the Carnivora (*Procyon lotor*, SIMPSON)²⁾ this partly occurs, not completely though. The dorsal branches of the art. cerebri anterior extend in these animals till the fiss. coronalis where the vascular area of the arteria media cerebri begins.

We know, however, that in Anthropoids (LEYTON and SHERRINGTON) and in man the cortical facialis centre is vascularised only by the arteria cerebri media. This difference with regard to the vascularisation to my opinion should be explained by the facialis centre being pressed downward by the gradual superposition of other cortical motor centres (trunk and lower limbs chiefly), not yet present in lower mammals. That the arcus arteriosus medialis does not increase in conformity to the motor area, may be due to the fact that the hydrodynamic conditions for the arteria cerebri media, especially for the art. fossae Sylvii are so much better (BOK).

So in this respect there is a great difference between lower and higher mammals.

On the other hand among Anthropoids and man the arteriae cerebri show a great fundamental conformity in their branchings. This conformity lies not in the extent of the areas which these branches supply, for, as shown by SHELLSHEAR³⁾, whose work — as far as the Chimpanzee is concerned — was confirmed by HINDZE⁴⁾, this varies with the different size of the cytotoxic regions, which they supply. The constancy meant is in the number and origin of the different branches of the art. cerebri media in Primates and the nature of the regions which they supply.

Similarly we may state that among the Monotremes the difference, occurring between *Ornithorhynchus* and *Echidna* in the part of the art. anterior and posterior cerebri in the vascularisation of the dorso-lateral neocortex, is surpassed by the fact, that in both cases this vascularisation is effected mainly by the arcus arteriosus medialis and hardly by the art. media cerebri.

1) SIMPSON and KING. Localisation of the motor area in the sheep. Quart. Journ. of experiments. Phys. Vol. 4, 1911.

2) SIMPSON. The motor cortex in the raccoon (*Procyon lotor*) Bub. Soc. f. exper. biol. and med. Vol. 10, 1912.

3) SHELLSHEAR. The arteries of the brain of the Orang-oetan. Journ. of Anatomy. Vol. 61, 1927.

SHELLSHEAR. A contribution to our knowledge of the arterial supply of the cerebral cortex in man. Brain. Vol. 50, 1927.

SHELLSHEAR. The arterial supply of the cerebral cortex in the chimpanzee (*Anthropopithecus troglodytes*). Journ. of anat. Vol. 65, 1930.

4) HINDZE. Die Hirnarterien des Chimpansen. Zeitschr. für Morphologie und Anthropologie, Bnd. 27, 1930.

Nevertheless the different vascularisation of the cortical facialis centre in lower mammals (Monotremes, Ungulates) at one side and the Primates at the other side shows that the constancy of relation between bloodvessels and cortical centra is no more valid, when comparing phylogenetically remote animals.

Physics. — *The cosmic corpuscular ultra-radiation. V. Ionisation in the Stratosphere and in the highest layers.* By J. CLAY. (Communicated by Prof. P. ZEEMAN.)

(Communicated at the meeting of January 28, 1933).

§ 1. After having found, in our previous communication IV ¹⁾, a basis for an explanation of the variation of intensity of the ultraradiation in the Earth's magnetic field and of the variation in hardness, we now wish to discuss, in how far the remaining phenomena are in agreement with this explanation. In the first place REGENER's ²⁾ splendid measurements in the stratosphere should be considered, the more so, since at first sight one might think, that for lower magnetic latitudes an ionisation as high as found by REGENER could not be expected, the reason being that, according to STÖRMER's theory, no electrons of lower energy could be incident. We expect, however, that this ionisation near the magnetic equator will be somewhat less, corresponding to the smaller number of primary rays, but that apart from this the ionisation curve will have about the same shape as found by REGENER at 50° magnetic latitude.

In the first place we may convince ourselves, that the high ionisation of e.g. 90 ions which REGENER found at an altitude of 10 km can only to a small extent be due to an increase of the intensity of the primary rays, for the following reason.

Rays from outside penetrating the atmosphere to an altitude of 10 km. have already passed through $\frac{1}{4}$ of the atmosphere and therefore originally had a minimum energy which is $\frac{1}{4}$ of the minimum energy required to reach the earth's surface or 10^9 e. Volt. But this shifting of the lowest energy limit from 4×10^9 to 10^9 e. Volt does not seem capable of causing an increase of primary rays by a factor 25, as would be necessary if we wish to attribute the ionisation observed by REGENER to primary rays only.

It appears, however, that the existence of such a large increase of ionisation with altitude may be expected on account of the influence of the secondary rays, if we take into account the influence which the pressure in the atmosphere should have.

In dealing with this matter, we shall not enter into the question as to in how far collisions of primary rays in the atmosphere might give rise to

¹⁾ Proc. Royal Acad. of Amsterdam, **35**, p. 1282, 1932.

²⁾ E. REGENER. Die Naturwissenschaften, **20**, p. 695, 1932.