Cerebrovascular Embryology

Principles:

- Vascular **development** follows:
  - metabolic demand
  - cerebral morphology
- **Organization** of vascular distributing system evolves as the brain grows
  - open neural tube: **diffusion** from amniotic fluid
  - **prechoroidal stage**: neural tube closes, diffusion from **meninx primitiva**
  - **choroidal stage**: invagination of meninx → choroid plexus; diffusion from external and ependymal surfaces; basic arterial pattern persists in later stages
  - **parenchymatous phase**: cerebral mantle thickens: angiogenesis from superficial vascular system

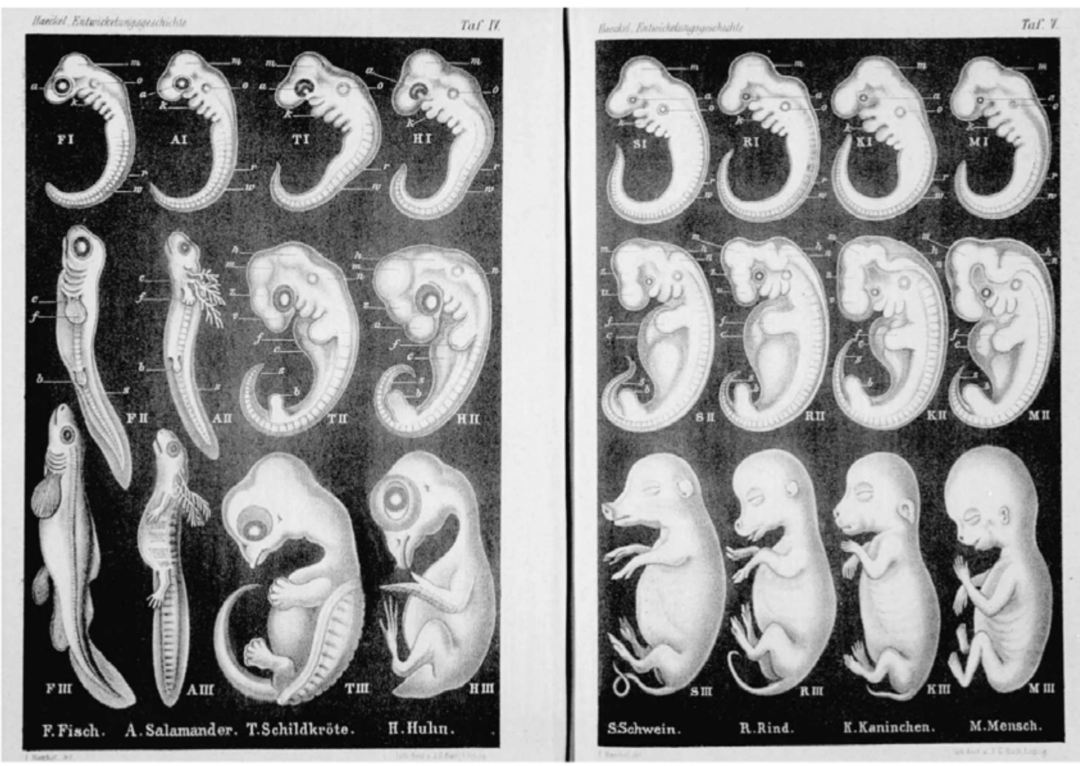
- ventral longitudinal system, circumferential feeders, perforators
- **Phylogenetic similarities, homologous structures** between animal species

Ernst Haeckel (1834-1919):

Ontogeny recapitulates Phylogeny

Biogenetic Law, Recapitulation Theory

Oldest vessels: spinal cord level; segmental art.
Newest vessels: telencephalon (e.g. MCA)
Development of vertebrobasilar system
Shift in role of aCh → PCA territory



Haeckel with his assistant Nicholai Miklukho-Maklai, 1866. (public domain)

Haeckel, *Anthropogenie*, 1874

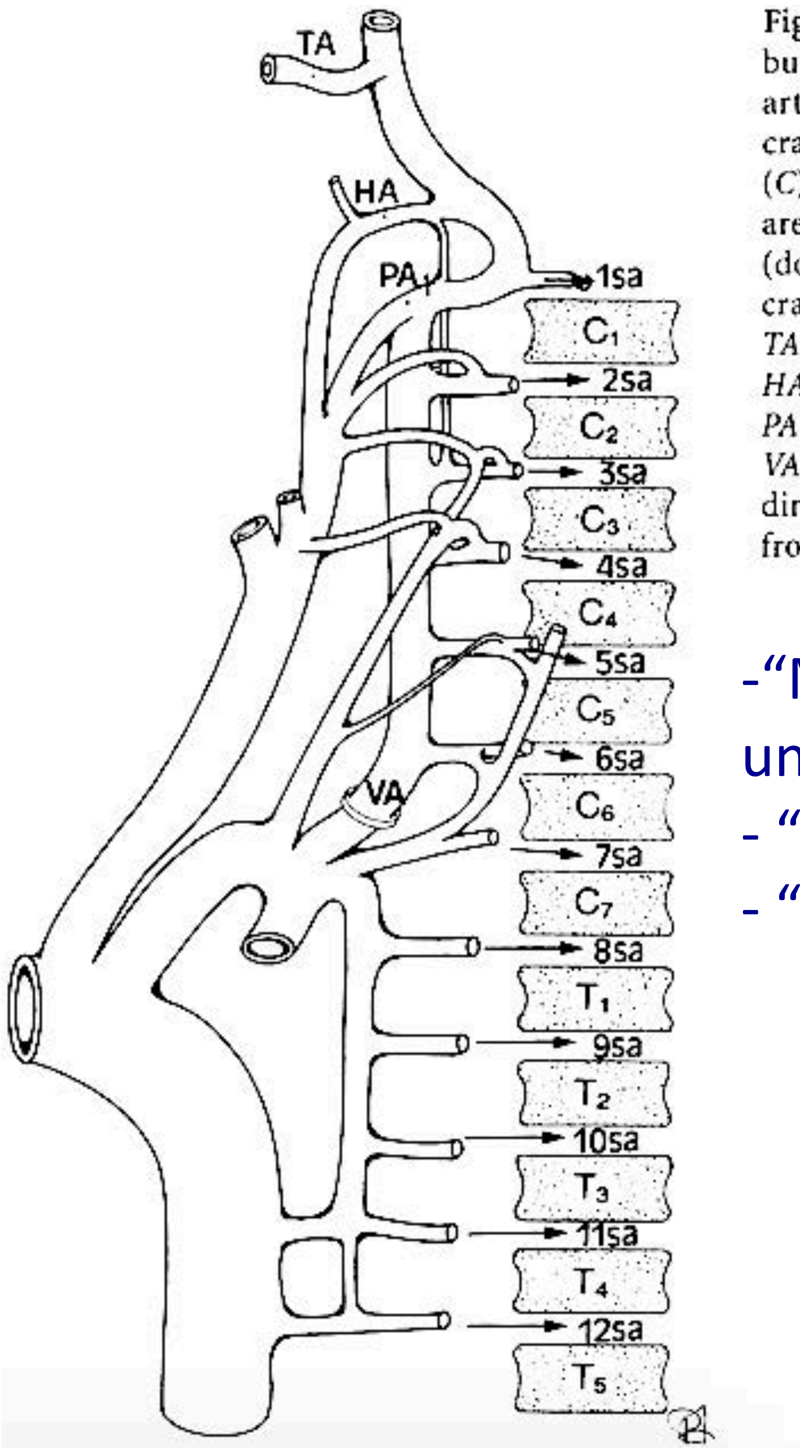


Fig. 2.3. The metameric distribution of the segmental arteries (*sa*) numbered from cranial to caudal; the cervical (*C*) and thoracic (*T*) vertebrae are indicated. Note the carotid (dorsal aortic) origin of the cranial metameric arteries. *TA*, trigeminal artery; *HA*, hypoglossal artery; *PA1*, proatlantal artery, type 1; *VA*, vertebral artery (longitudinal anastomosis). (Modified from Padget 1948 and Lie 1968)

-"Metameric arteries are the basic vascular unit of vertebrates."

- "segmental system" caudal to Trigem. Art.
- "postsegmental system" rostral to TA

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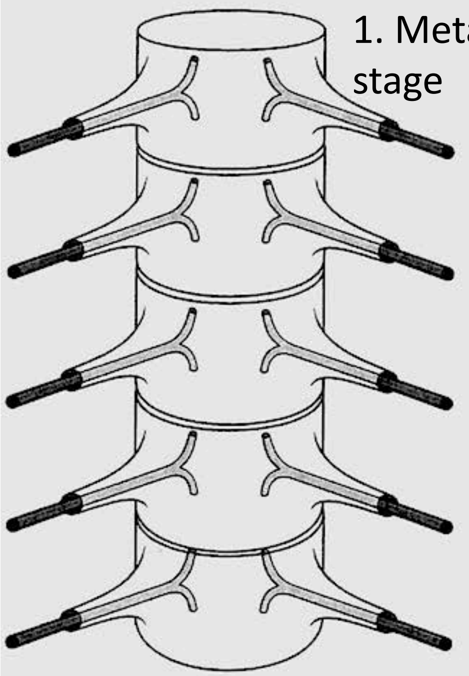
6th week to 4th month



1. Metameric stage

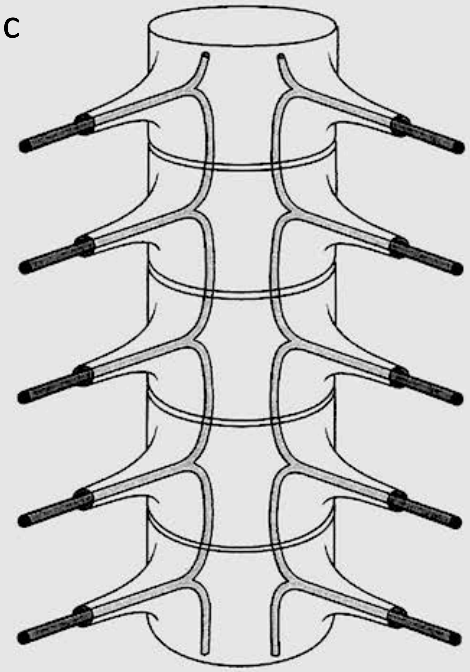
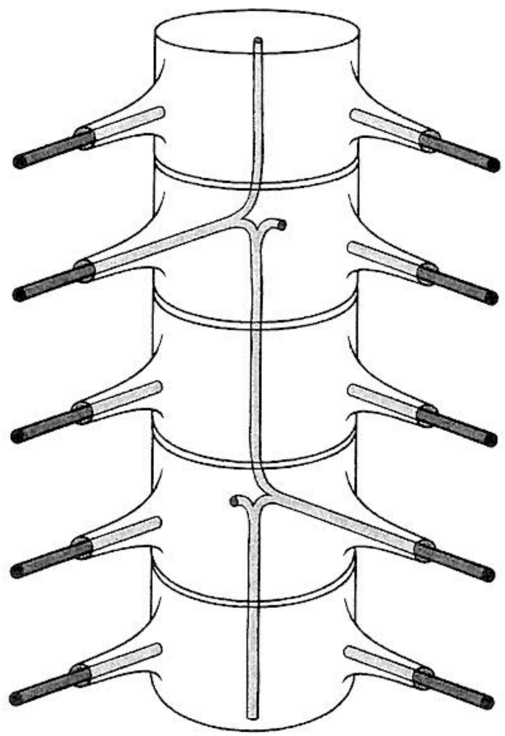


Fig. 2.4 (*left*). Metameric stage: one artery per side follows the spinal nerve to supply the corresponding myelomeric segment of the neural tube

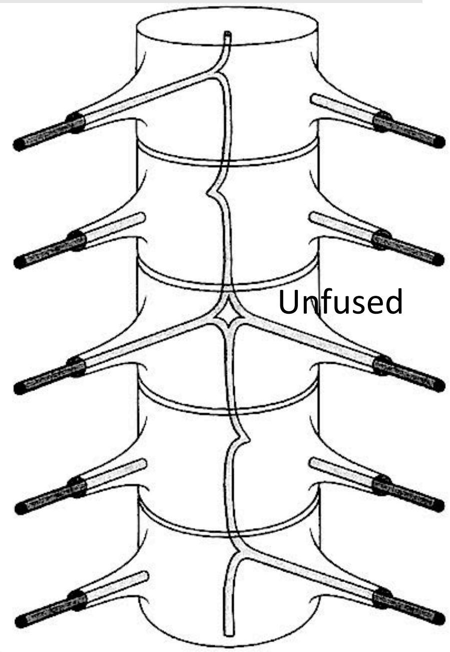
Fig. 2.5 (*right*). Longitudinal anastomosis: each metameric source anastomoses with its caudal and rostral homologue to constitute the ventral paired longitudinal neural arterial axis

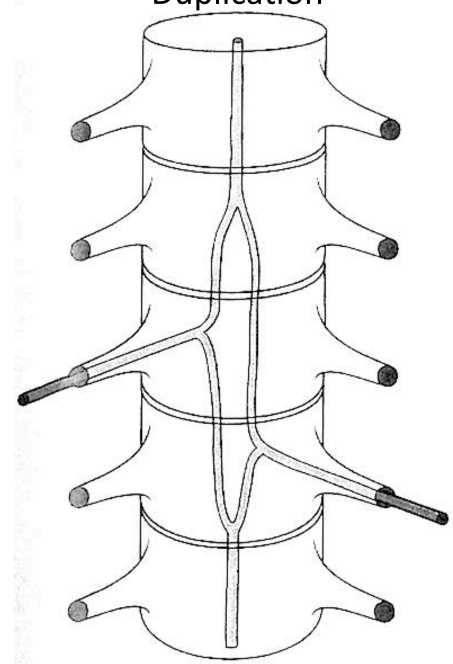
2. Longitudinal anastomosis → ventral paired longitudinal neural arteries

Fig. 2.6. Fusion and desegmentation: the ventral arteries fuse on the midline to become a single artery, the ventral spinal artery. Most of the radicular arterial sources regress. Few of them remain to provide the necessary blood flow to fill the ventral spinal system. The others will remain strictly unimetameric to supply the related nerve, dura, and vertebral body



3. Fusion and desegmentation





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Neural plate forms by day 21

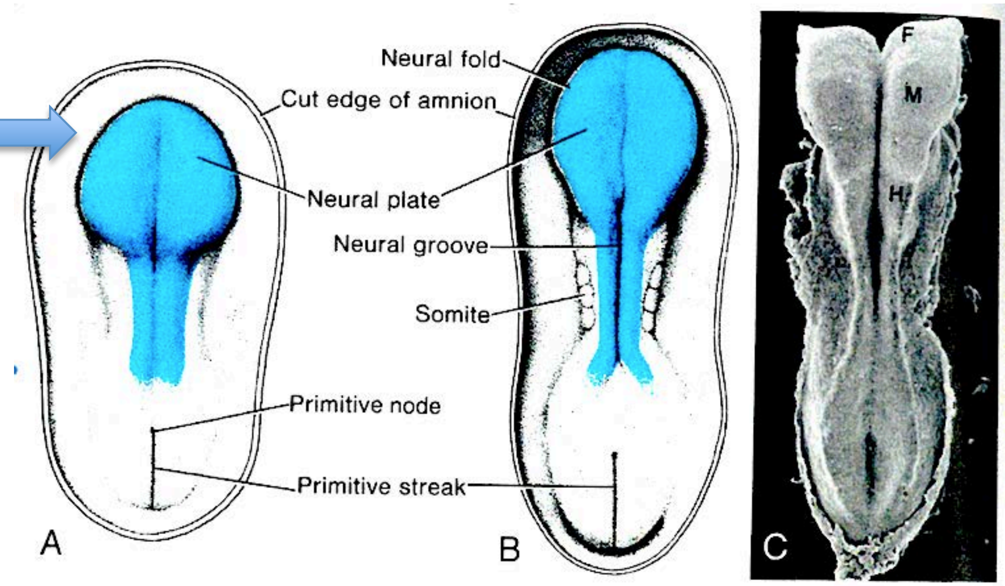
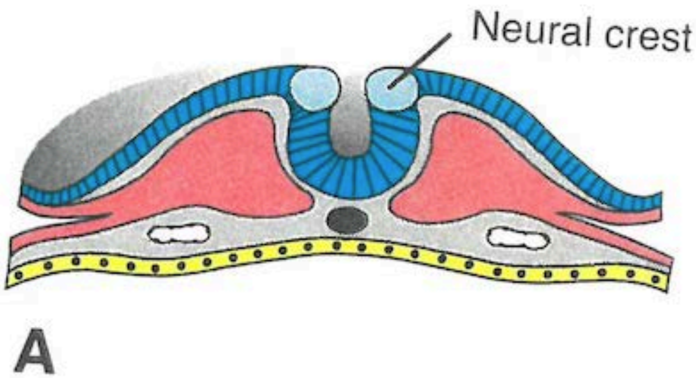
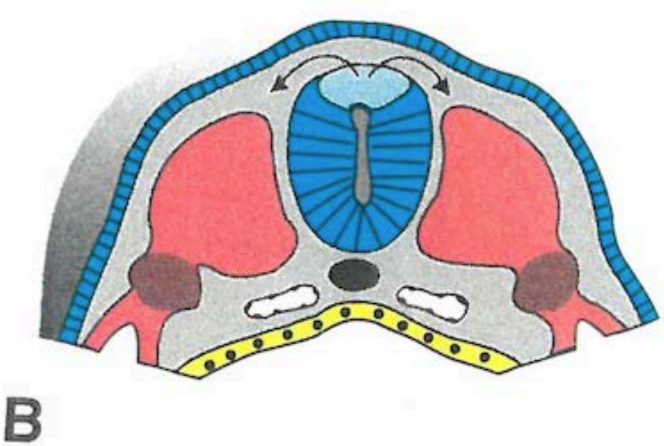


Figure 19.1 A. Dorsal view of a late presomite embryo at approximately 18 days. The amnion has been removed, and the neural plate is clearly visible. **B.** Dorsal view at approximately 20 days. Note the somites and the neural groove and neural folds. **C.** Scanning electron micrograph of a mouse embryo at a stage similar to that in **B.** *F*, forebrain; *M*, midbrain; *H*, hindbrain.





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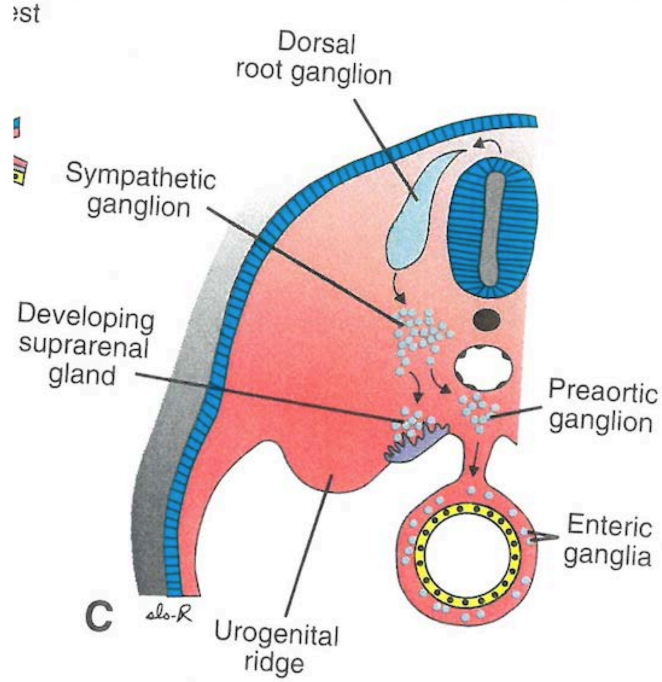

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Cranial neuropore, closes at day 23 becomes the **lamina terminalis**

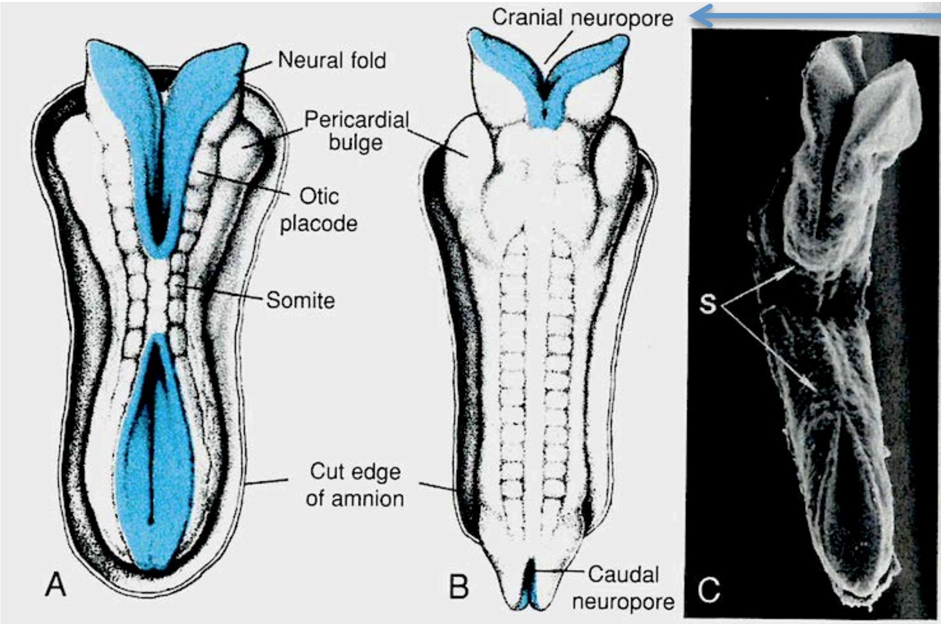

Figure 19.3 A. Dorsal view of a human embryo at approximately day 22. Seven distinct somites are visible on each side of the neural tube. **B.** Dorsal view of a human embryo at approximately day 23. The nervous system is in connection with the amniotic cavity through the cranial and caudal neuropores. **C.** Scanning electron micrograph of a mouse embryo at a stage similar to that in **A.** *S*, somites.

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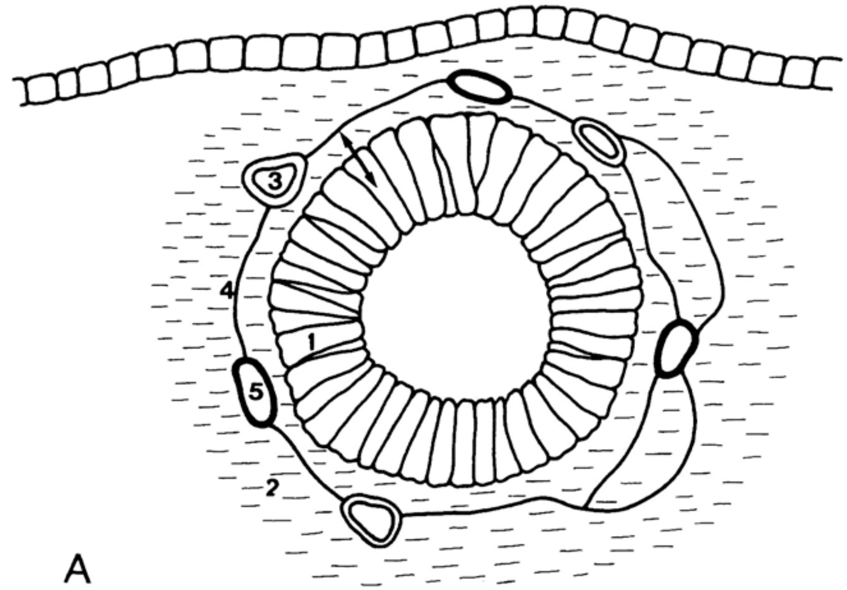

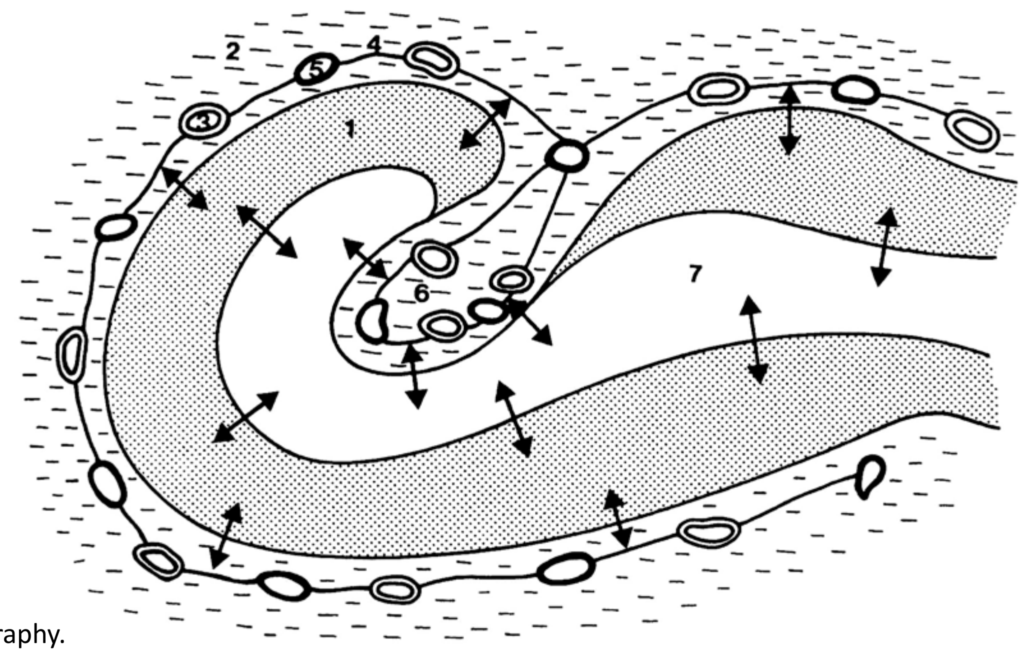

Fig. 6.1. **A, B** Mode of extrinsic supply of nutrients to the neural tube. **A** After it has closed and nutrition from the amniotic fluid has ceased, the neural tube (*1*) is surrounded by the meninx primitiva (*2*) which contains arterial (*3*), capillary (*4*) and venous channels (*5*); metabolites diffuse from the capillary channels to the meninx primitiva and from there to the neural tissue from outside (*arrow*). **B** As the thickness of the neural tube increases, its centripetal diffusion cannot fulfill its metabolic needs. The invagination of the meninx primitiva into the ventricular lumen (choroid plexus, *6)* allows exchanges of metabolites between the capillaries of the meninx and the ventricular fluid (*7*), and between the ventricular fluid and the neural tissue via the ependymal surface. In addition, the exchanges across the external surface of the brain persist

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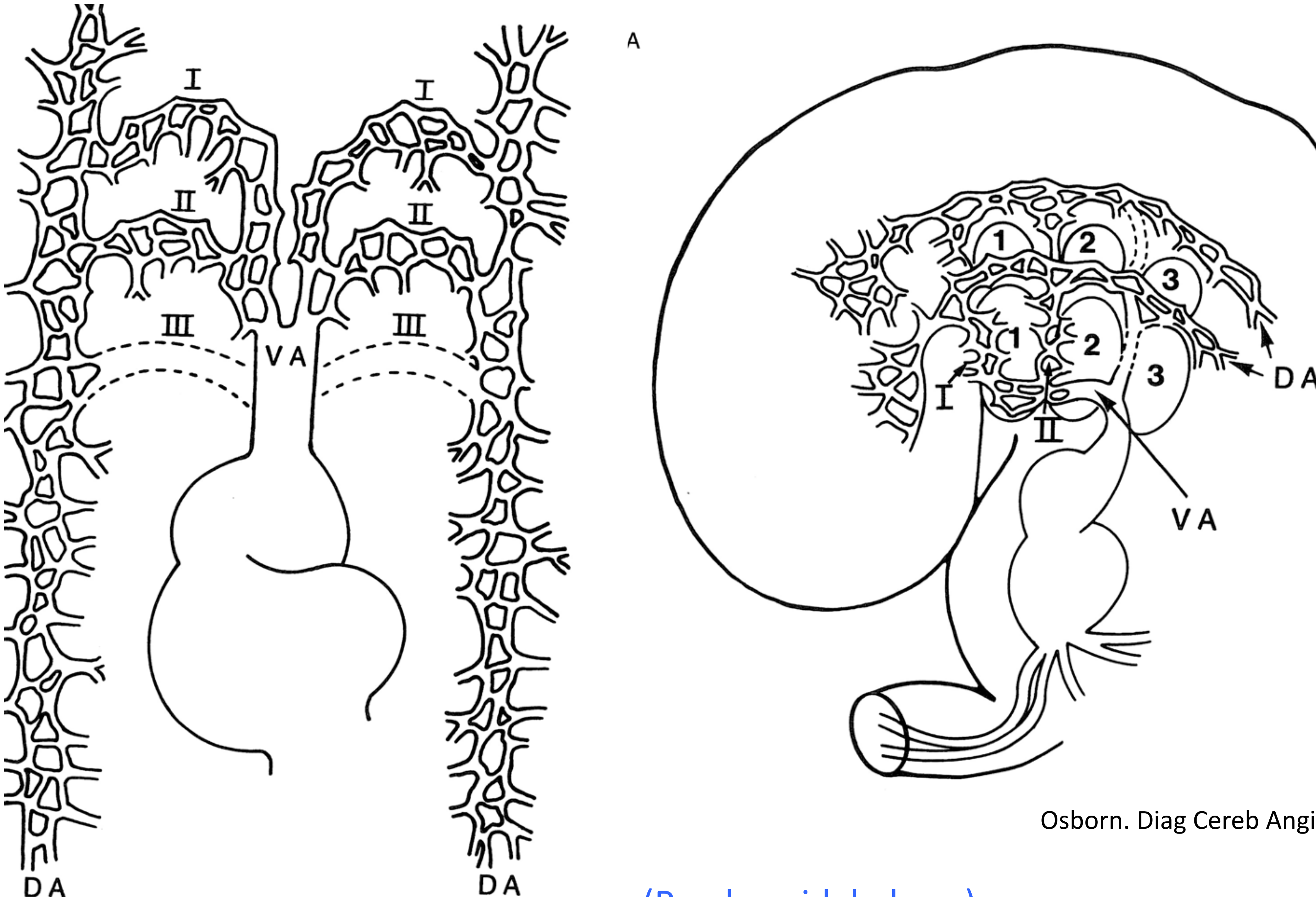
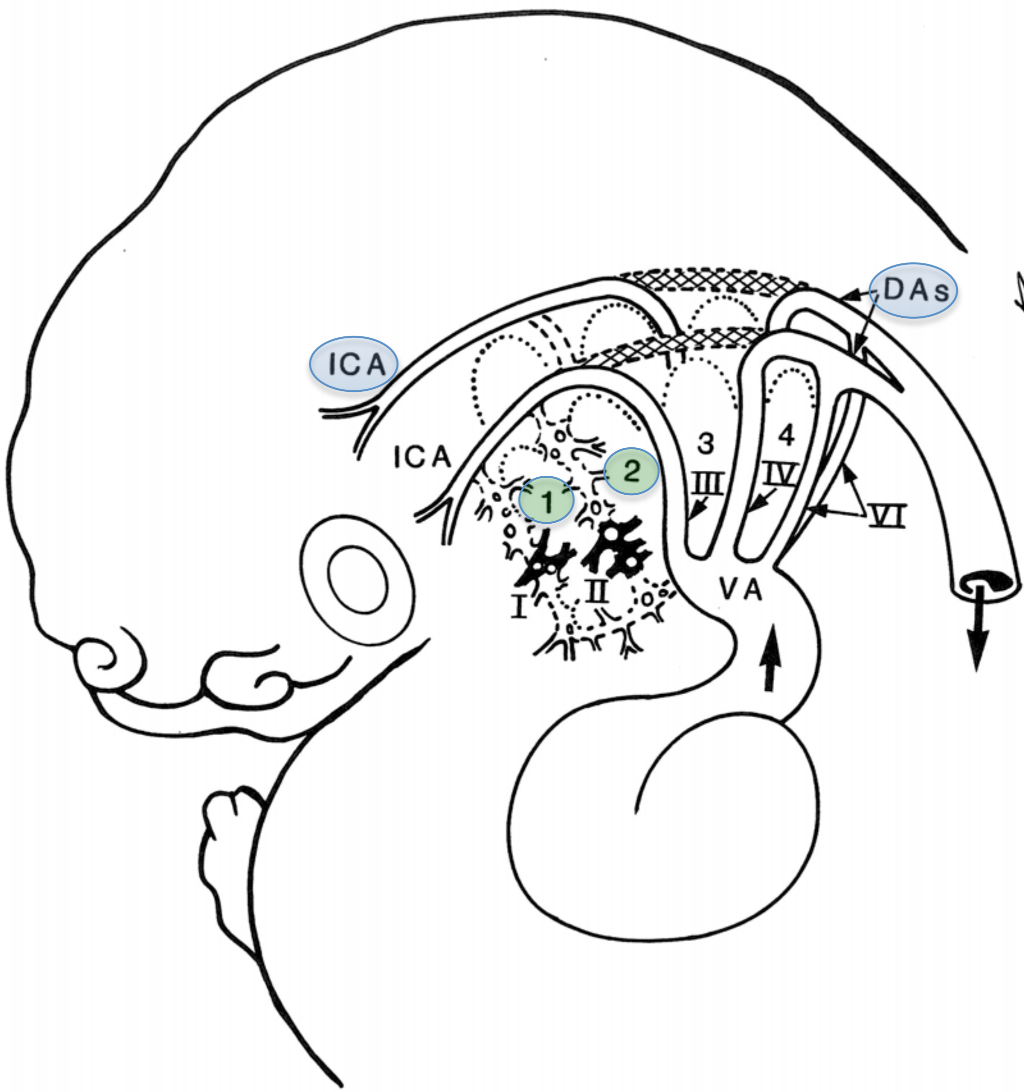


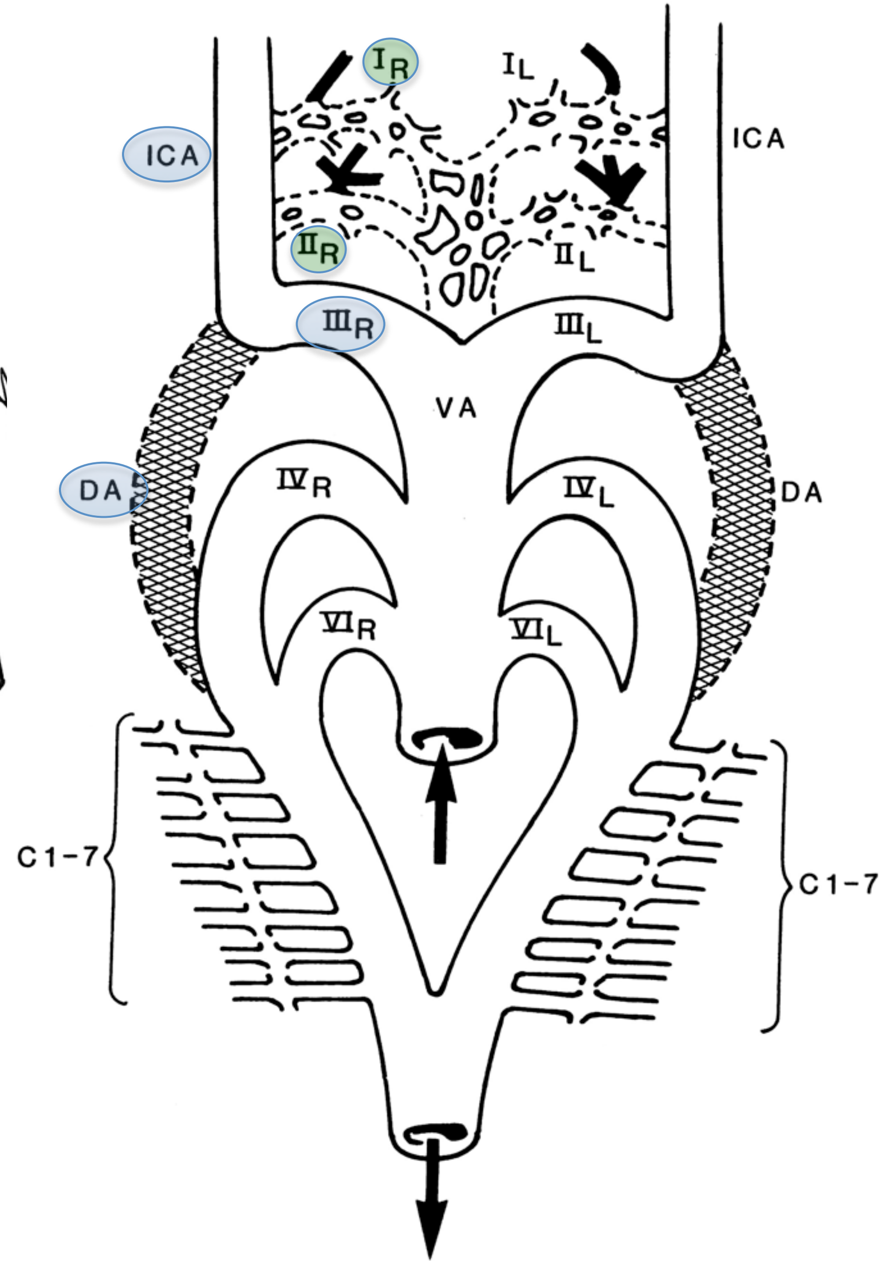
Osborn. Diag Cereb Angio, 2nd Ed.

(Prechoroidal phase)

3 ½ weeks: plexiform channels, aortic arches, dorsal-ventral aortas

4 weeks





- Plexiform 1st, 2nd arches regress (later annexed to the ECA)
- Dorsal Aorta → ICA, supply from 3rd arch from ventral aorta

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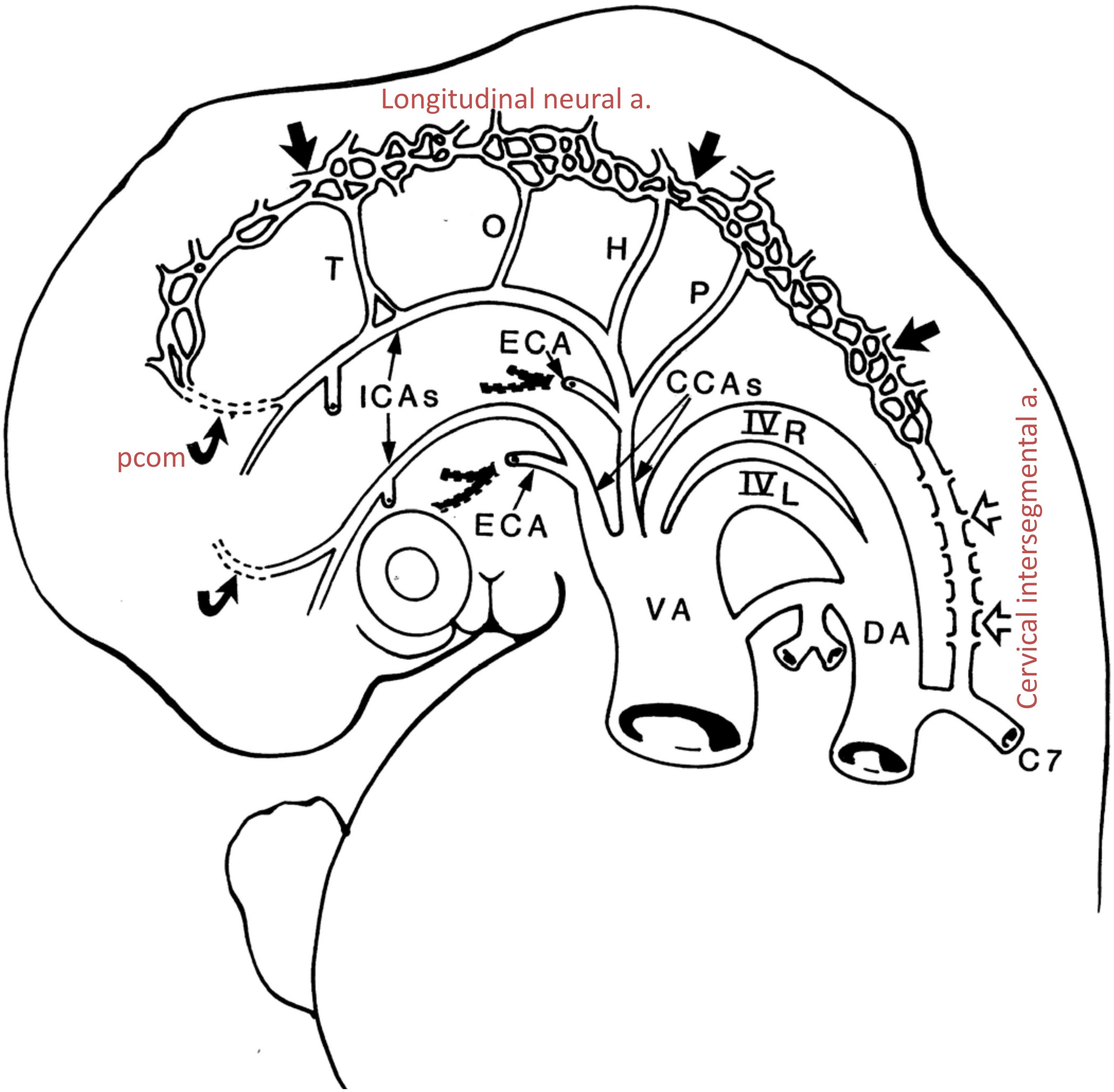
5 weeks



End of 5th week:

- pros- di- mes- met- myel-encephalon are formed

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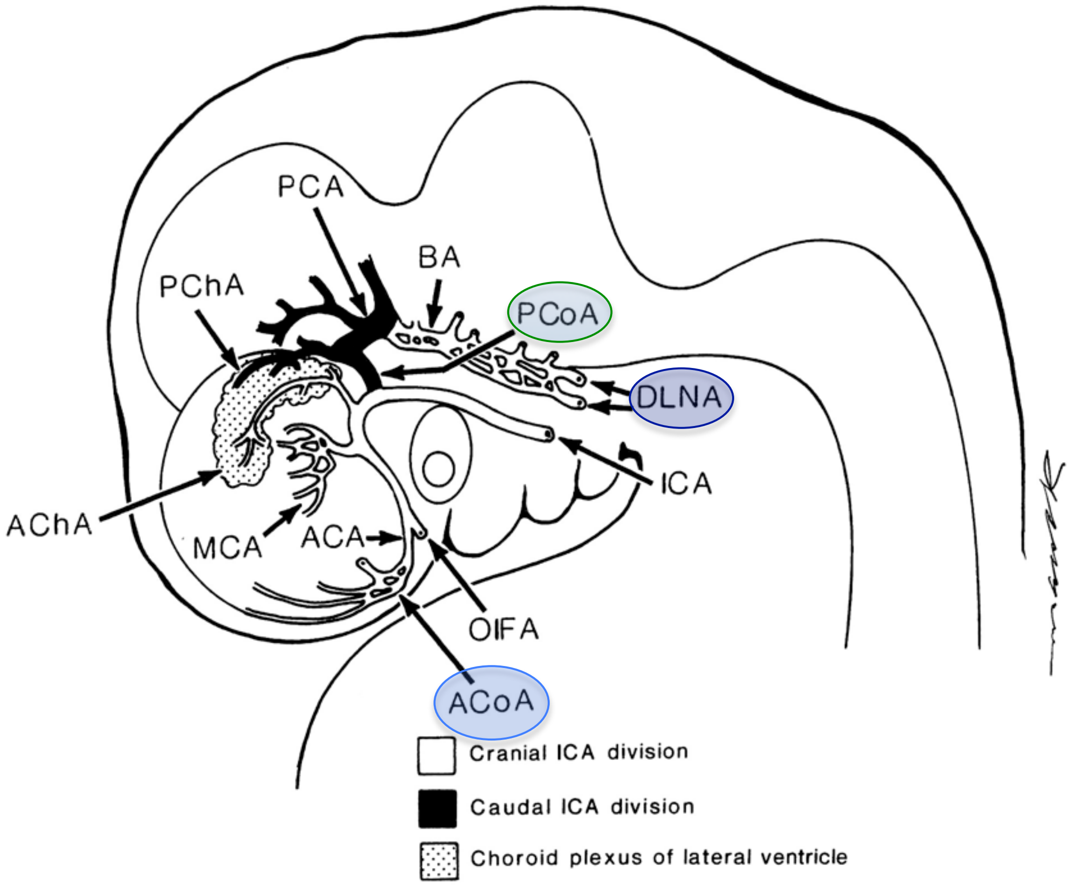
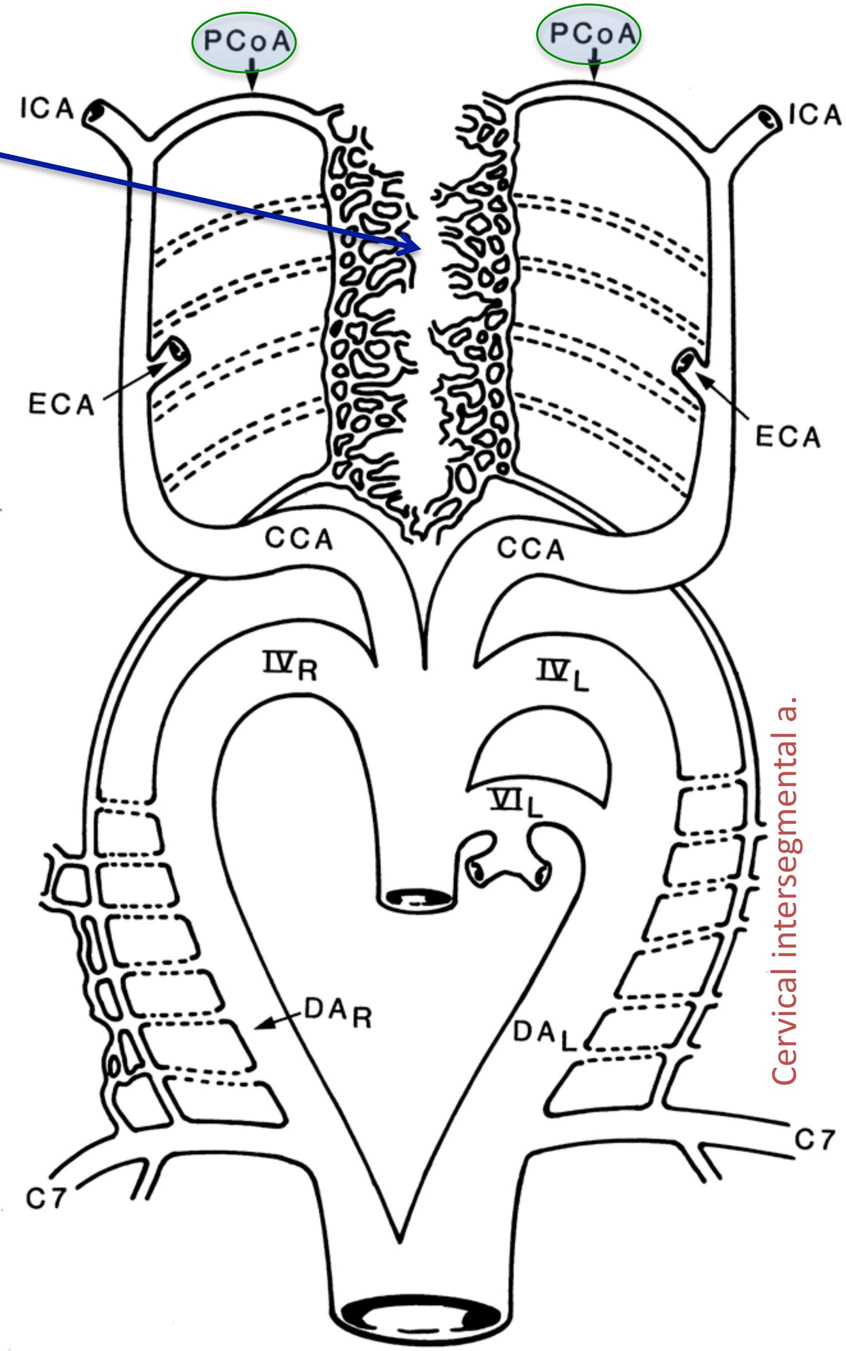
6 weeks



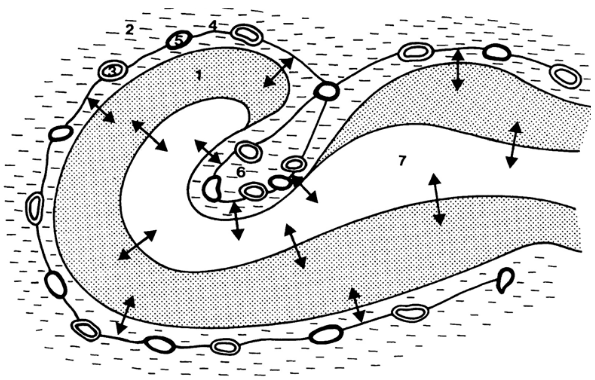


- pcom has formed
- primitive vertebrobasilar anastamoses regress
-ACoa: coalescence of plexiform network
- **vascular supply is meningeal (prechoroidal phase)**

Osborn. Diag Cereb Angio, 2nd Ed.

6th – 8th weeks: invagination of meninx primitiva:

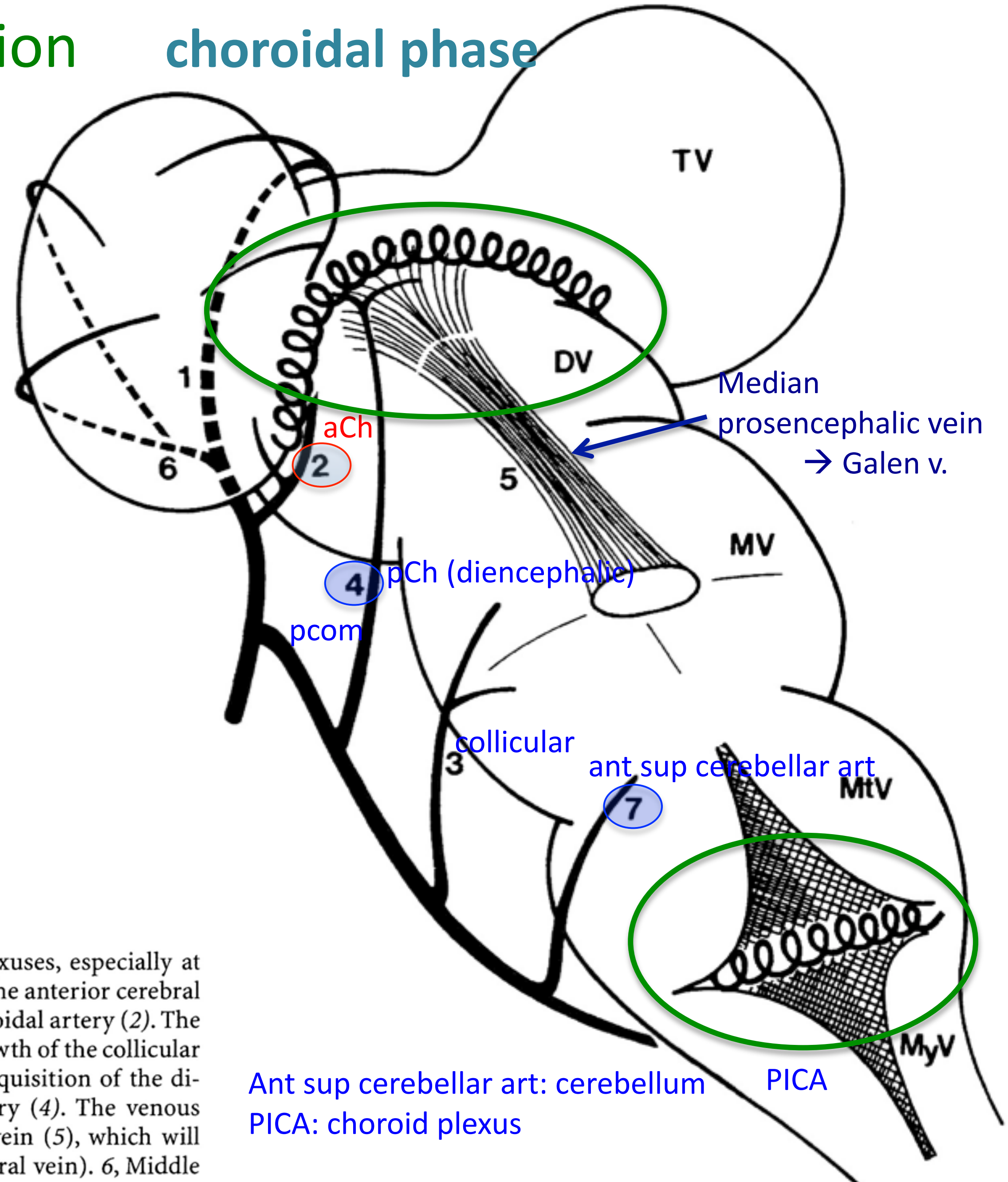
choroidal phase



Choroidal supply:

1. diencephalic-telencephalic junction (velum transversum), choroidal lip
2. Roof of the diencephalic vesicle (3rd ventricle)
3. metencephalic-myelencephalic junction

Fig. 6.3. Choroidal phase. The development of the choroid plexuses, especially at the diencephalic-telencephalic junction, favors the extension of the anterior cerebral artery (*1*), which acts as a choroidal artery, and the anterior choroidal artery (*2*). The prominent growth of the quadrigeminal plates stimulates the growth of the collicular artery (*3*). The growth of the choroid plexus leads to partial acquisition of the diencephalic artery, which becomes the posterior choroidal artery (*4*). The venous drainage is provided by the transient median prosencephalic vein (*5*), which will be later replaced by the system of the vein of Galen (great cerebral vein). *6*, Middle cerebral artery; *7*, anterosuperior cerebellar artery; *TV*, telencephalic vesicle; *DV*, diencephalic vesicle; *MV*, mesencephalic vesicle; *MtV*, metencephalic vesicle; *MyV*, myelencephalic vesicle



Ant sup cerebellar art: cerebellum
PICA: choroid plexus

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7 weeks

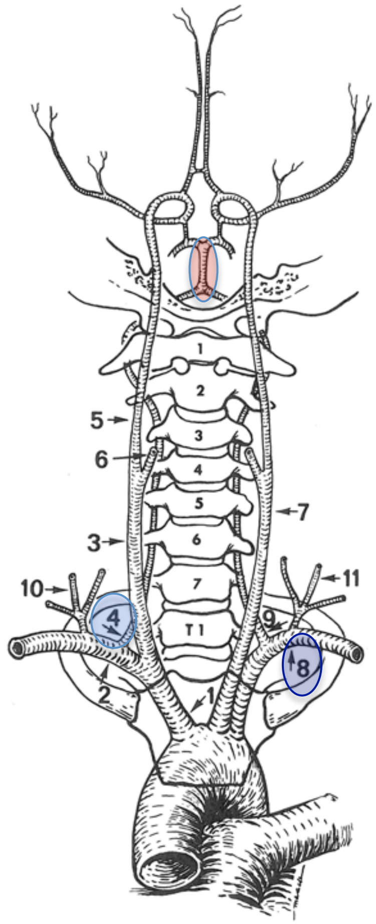
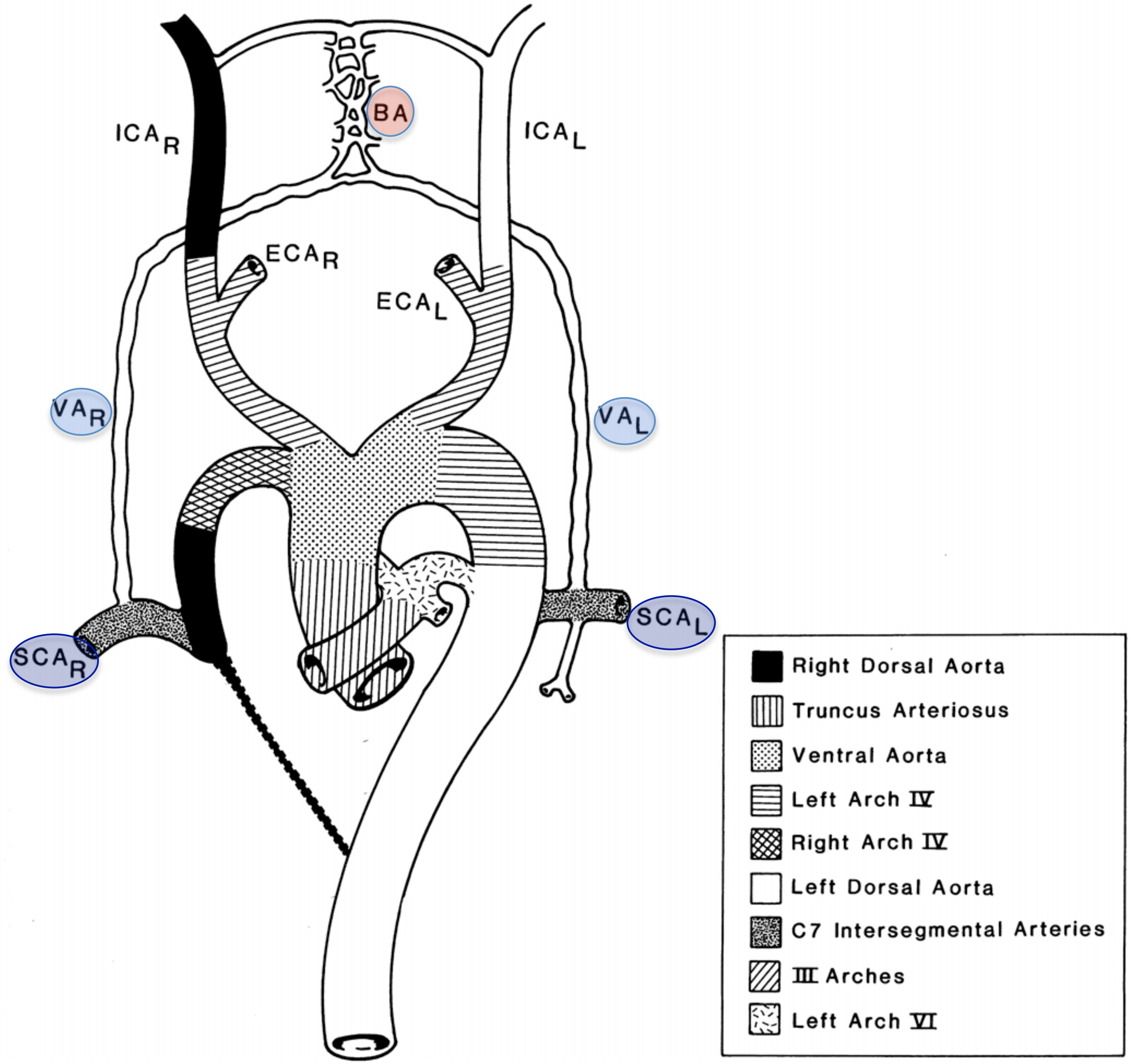


FIG. 1-27. Anatomic sketch of the aortic arch, the great vessels and their major branches (anteroposterior view).

1, Innominate artery (brachiocephalic trunk)
2, Right subclavian artery
3, Right common carotid artery
4, Right vertebral artery
5, Right internal carotid artery
6, Right external carotid artery
7, Left common carotid artery
8, Left subclavian artery
9, Left vertebral artery
10, Right thyrocervical trunk
11, Left thyrocervical trunk



- **longitudinal neural art. → basilar art. (still plexiform)**
- cervical intersegmental art. (C1-6) → vertebral art.
- C7 intersegmental art. → subclavian art.

Osborn. Diag Cereb Angio, 2nd Ed.

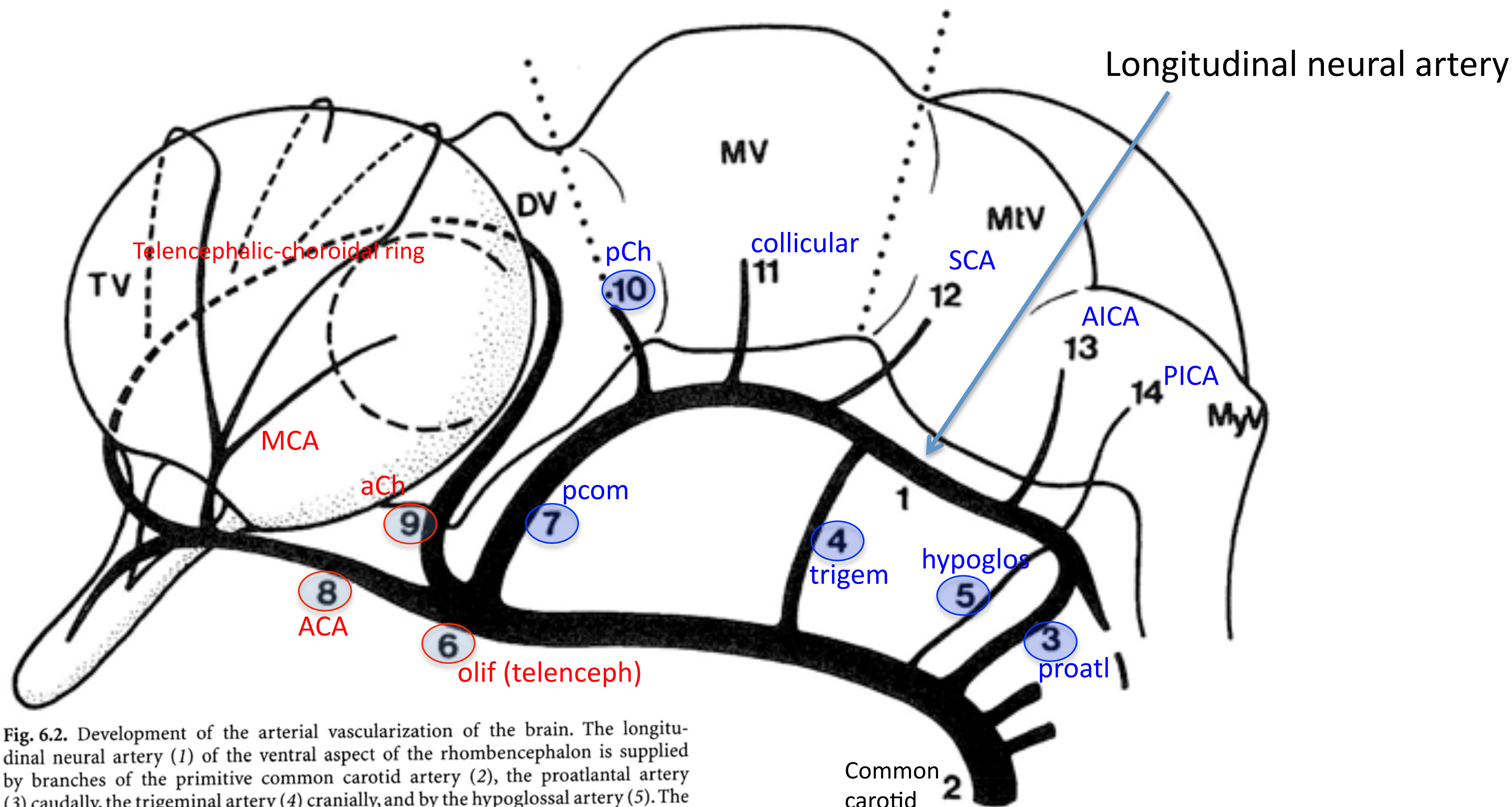


Fig. 6.2. Development of the arterial vascularization of the brain. The longitudinal neural artery (*1*) of the ventral aspect of the rhombencephalon is supplied by branches of the primitive common carotid artery (*2*), the proatlantal artery (*3*) caudally, the trigeminal artery (*4*) cranially, and by the hypoglossal artery (*5*). The longitudinal system of anastomoses between the cervical intersegmental arteries has not yet evolved into the vertebral arteries. More cranially, the primitive carotid artery ends as a rostral (*6*) (olfactory artery) and a caudal (*7*) (posterior communicating artery) division. The anterior branch subdivides into the anterior cerebral (*8*) and future anterior choroidal (*9*) arteries, and both encircle the neck of the telencephalic vesicle (*TV*) and anastomose with each other. Their lateral branches form the pericerebral arterial network of the hemispheres, including what is to become the middle cerebral artery. The posterior branch of the primitive carotid artery sends secondary branches toward the diencephalon (*DV*) (posterior choroidal arteries, *10*), the mesencephalon (*MV*) (collicular arteries, *11*) and the metencephalon (*MtV*) (superior cerebellar artery, *12*). It connects with the longitudinal neural artery, thereby causing the trigeminal artery to regress, while the development of the vertebral artery supplies the caudal artery system place of the proatlantal artery, which then also regresses. *13*, Anteroinferior cerebellar artery; *14*, posteroinferior cerebellar artery; *MyV*, myelencephalic vesicle

The MCA develops from the ACA as the phylogenetically newer telencephalic vesicle develops into the cerebral hemisphere.

Transdural vert. corresponds to proatlantal art.

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8 weeks

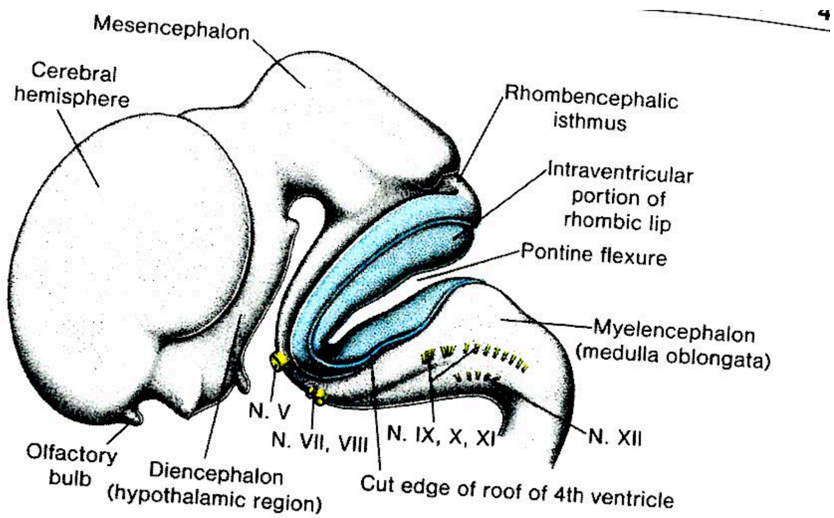

Figure 19.17 Lateral view of the brain vesicles in an 8-week embryo (crown-rump length approximately 27 mm). The roof plate of the rhombencephalon has been removed to show the intraventricular portion of the rhombic lip. Note the origin of the cranial nerves.

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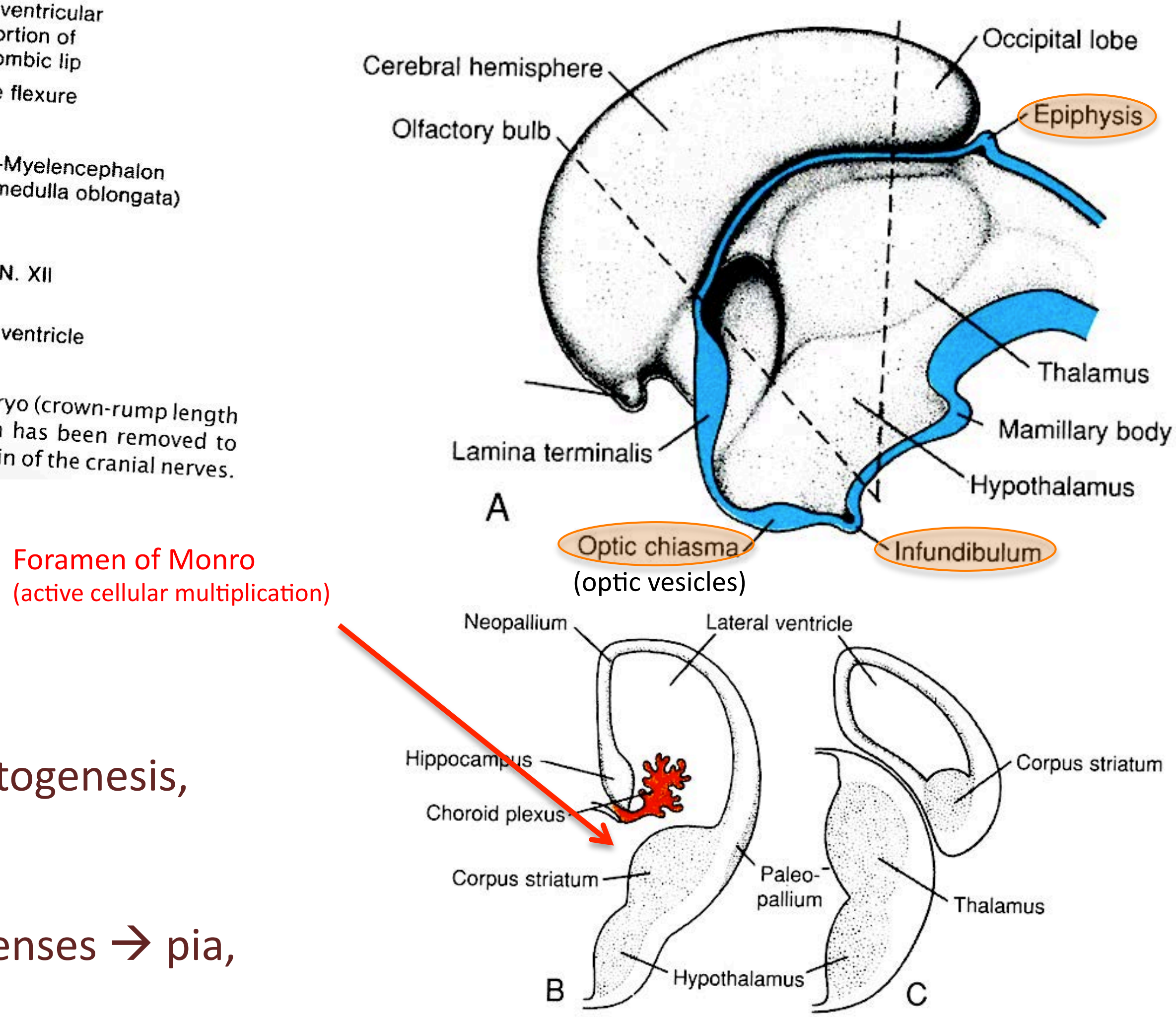

Figure 19.25 A. Medial surface of the right half of the telencephalon and diencephalon in an 8-week embryo. **B** and **C.** Transverse sections through the right half of the telencephalon and diencephalon at the level of the *broken lines* in **A.**

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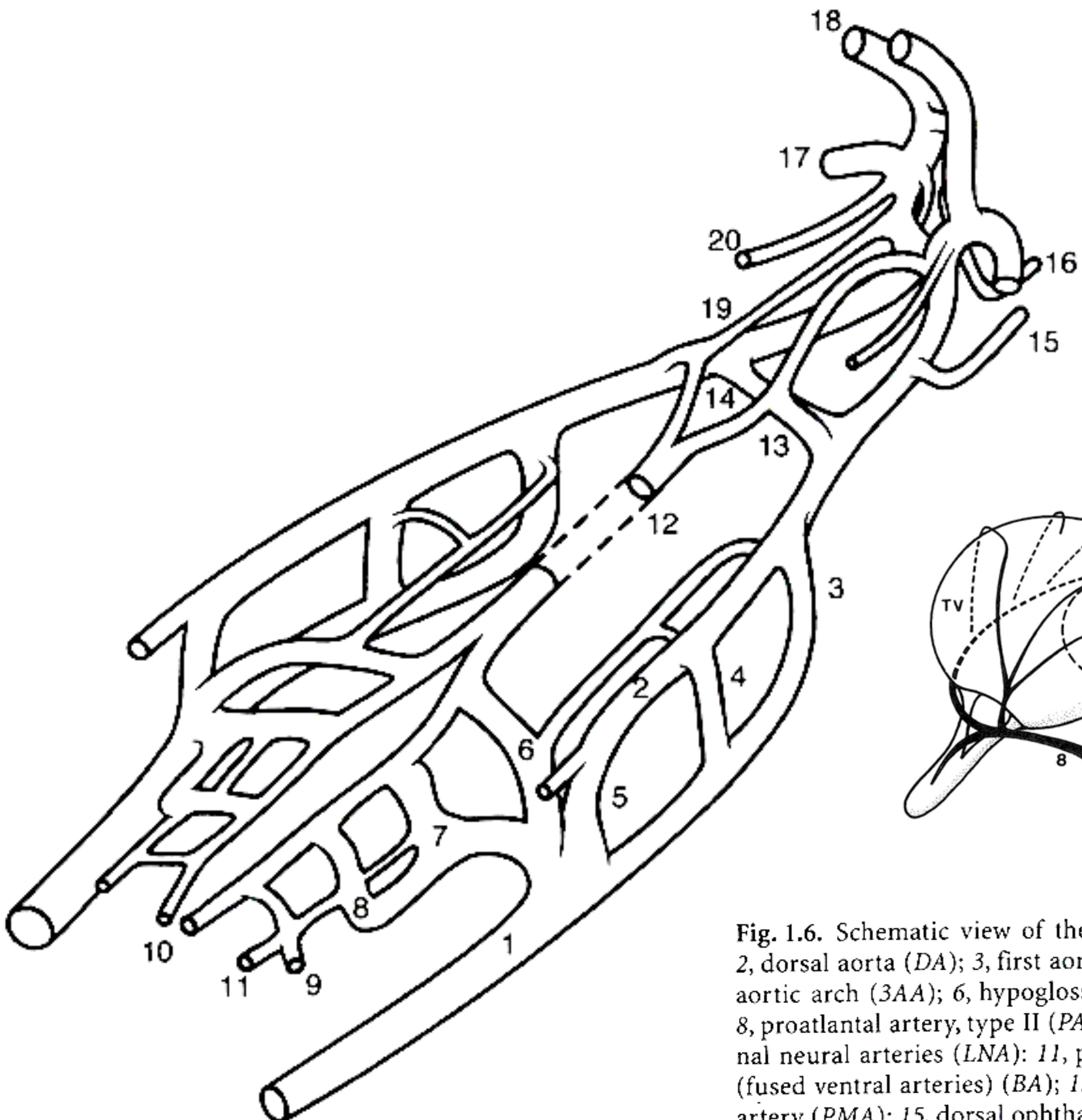
Embryonic period ending

Fetal period beginning: intense histogenesis, periventricular germinal matrix

- **parenchymatous phase**

Meninx primitiva vacuolates/condenses → pia, arachnoid, dura, bony vault



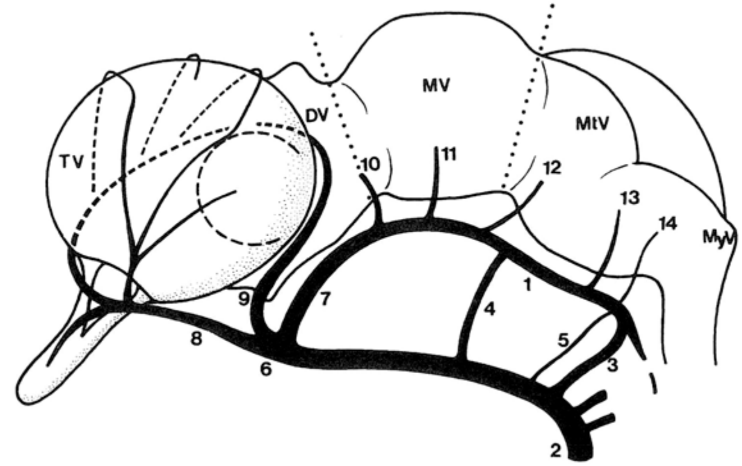


Fig. 1.6. Schematic view of the embryonic cranial arteries: *1*, ventral aorta (*VA*); *2*, dorsal aorta (*DA*); *3*, first aortic arch (*1AA*); *4*, second aortic arch (*2AA*); *5*, third aortic arch (*3AA*); *6*, hypoglossal artery (*HA*); *7*, proatlantal artery, type I (*PA 1*); *8*, proatlantal artery, type II (*PA 2*); *9*, third cervical segmental artery; *10*, longitudinal neural arteries (*LNA*): *11*, paraventral (lateral) neural artery; *12*, basilar artery (fused ventral arteries) (*BA*); *13*, trigeminal artery (*Trig.A*); *14*, primitive maxillary artery (*PMA*); *15*, dorsal ophthalmic artery (*DOPHA*); *16*, ventral ophthalmic artery (*VOPHA*); *17*, middle cerebral artery (*MCA*); *18*, anterior cerebral artery (*ACA*); *19*, internal carotid posterior (caudal) division (*ICA Cd*); *20*, anterior choroidal artery (*AChA*). (Reprinted by permission from Lasjaunias P, Interv Neuroradiol 6:113–124, 2000)

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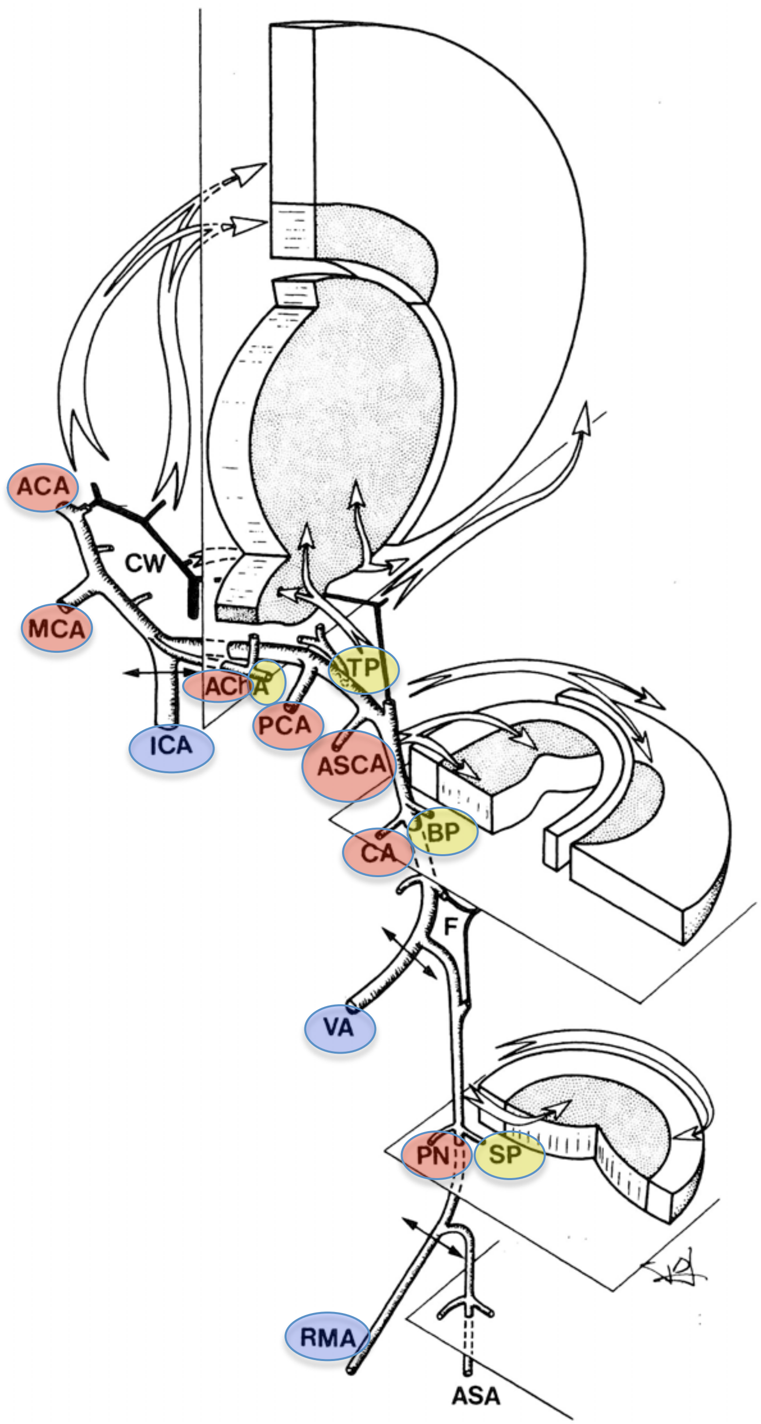

Fig. 2.11. Representation of the similarities between the arterial supply to the spinal cord, brain stem, cerebellum, and cerebrum. A ventral, midline arterial axis runs from caudal to rostral direction (*ASA*, anterior or ventral spinal artery). Fenestration occurs at the vertebral artery (*VA*) fusion (*F*) at the midline and reopens again at the circle of Willis (*CW*) rostrally. The radiculomedullary artery (*RMA*), the vertebral artery (*VA*), and the internal carotid artery (*ICA*) can be considered as similar contributors from metameric sources to the same distributing system. The pial network main channels (*PN*), the circumferential artery (*CA*), and the cerebellar arteries – such as the anterior superior cerebellar artery (*ASCA*), the posterior cerebral artery (*PCA*), the middle cerebral artery (*MCA*), and the anterior cerebral artery (*ACA*) – can be regarded as a similar system. It travels superficially around the neural tube derivatives (*long open curved arrows*). The sulcal perforators (*SP*), basilar perforators (*BP*), and thalamoperforators (*TP*) are similar and belong to the same midline centrifugal system. The anterior choroidal artery (*AChA*) is linked to both systems at the same time, and its specificity is discussed in Chap. 6

Common vascular structure:

Spinal cord
Brain stem
Cerebellum
Cerebrum

Ventral, midline arterial axis

"Metameric" contributors

Superficial, circumferential distributing system

Perforators

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PCA / AChA homology

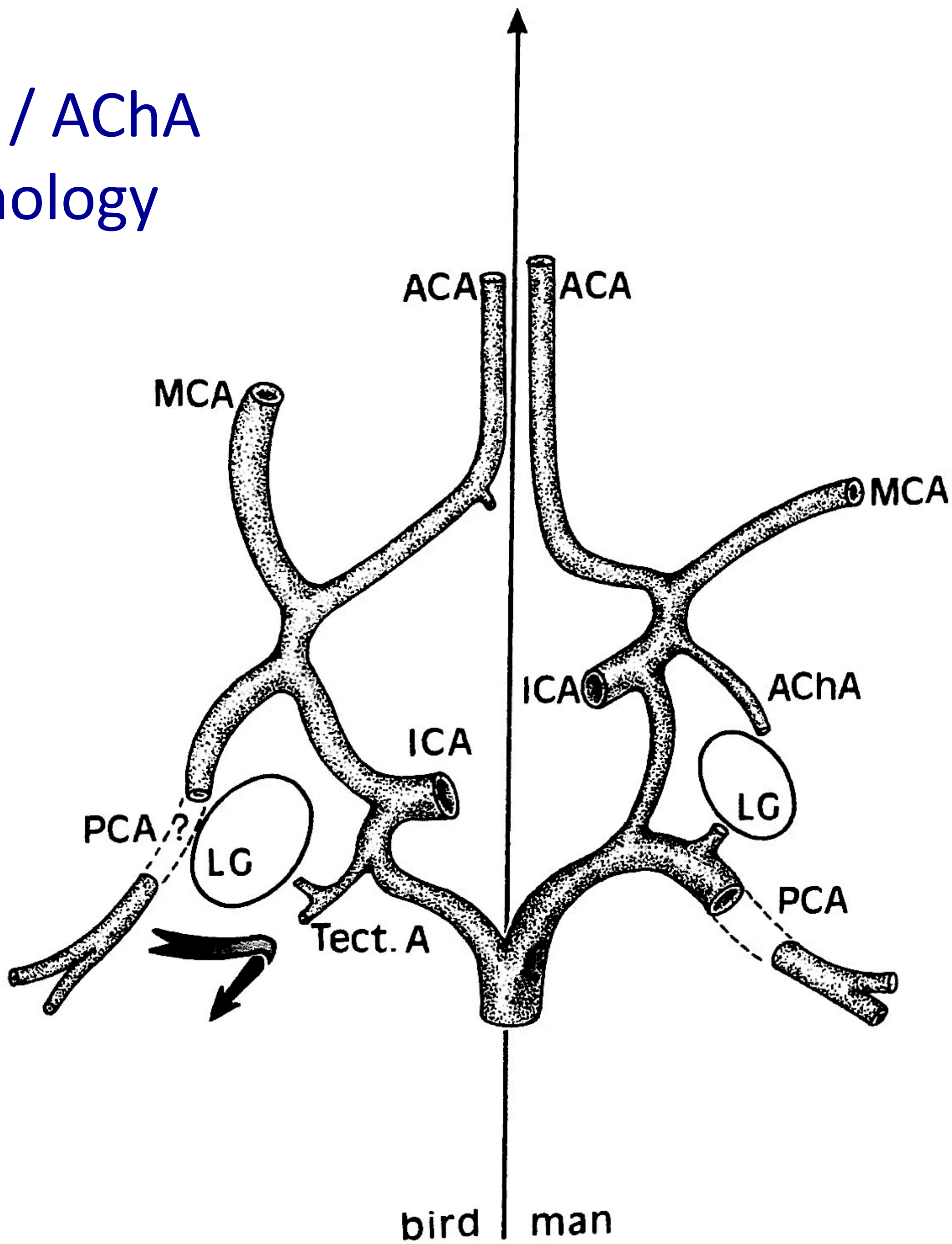

Fig. 6.14. The pattern of the circle of Willis in birds and man. The position of the so-called posterior artery in birds shows its complete homology with the anterior choroidal artery in man. The relationship between both vessels and the lateral geniculate body confirms the identity of both systems. The *broken arrow* points to the distal transfer of territory from the pseudo "PCA" of the bird to the tectal artery to become the PCA in man. *ACA*, Anterior cerebral artery; *MCA*, middle cerebral artery; *ICA*, internal carotid artery; *AChA*, anterior choroidal artery

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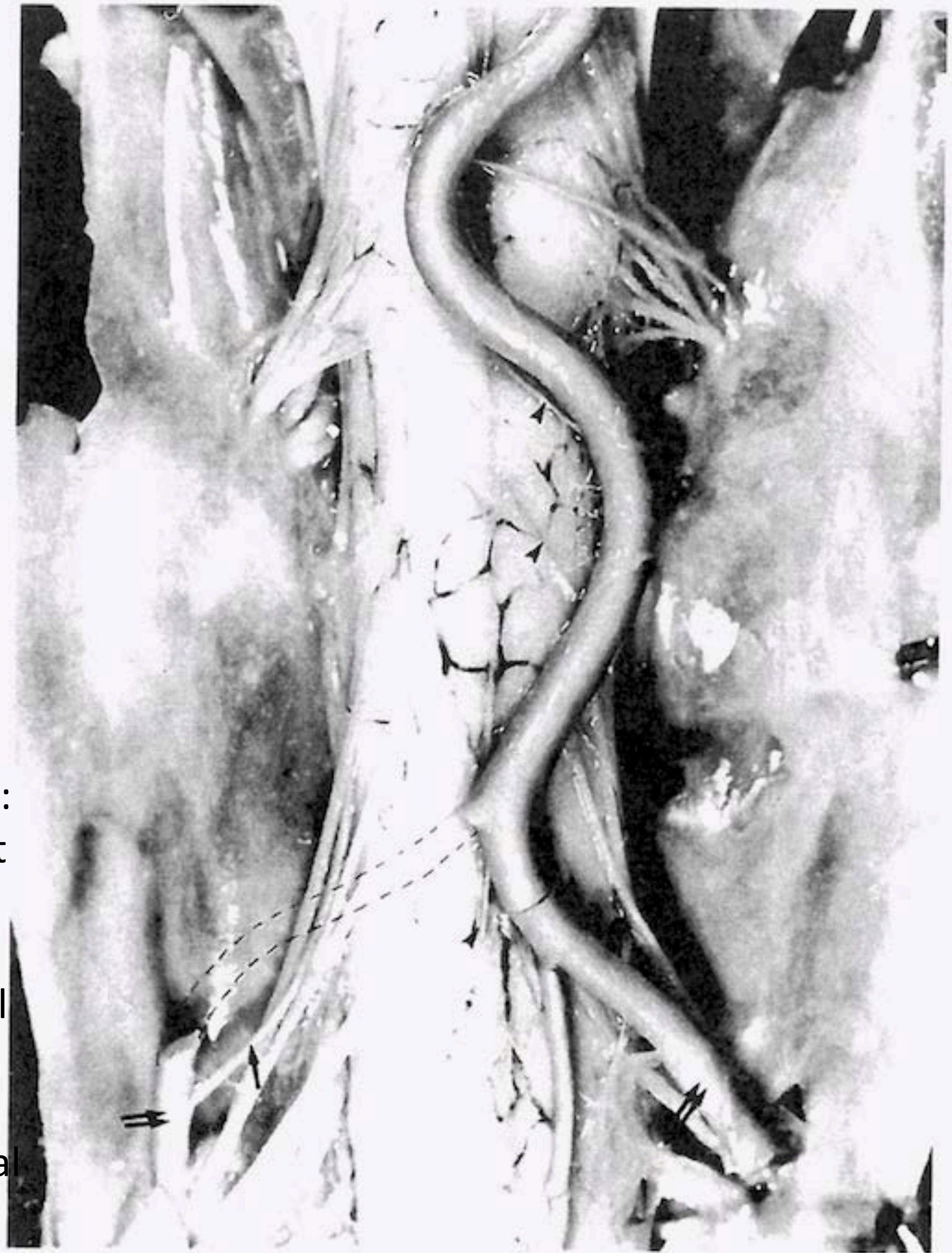
ig. **2.10.** Ventral view of the
ervical spinal cord of the dog.
adiculomedullary arteries
(*louble arrows*) join on the
idline at the C-4 level. Small
erforators (*arrowheads*) pene-
ate the ventral midline fissure
supply the cervical spinal
ord. These radiculomedullary
teries are homologues of the
ertebral artery in man, and
is large ascending ventral
inal axis is equivalent to the
asilar artery. Note a radiculop-
l artery joining the lateral
spect of the cord (*arrow*)



Vertebral channels (human):

phylogenetically recent

Dog:

fusion of paired ventral longitudinal axis with major radicular contrib. at C4/5

No vertebral art. Rostral to C4/5.

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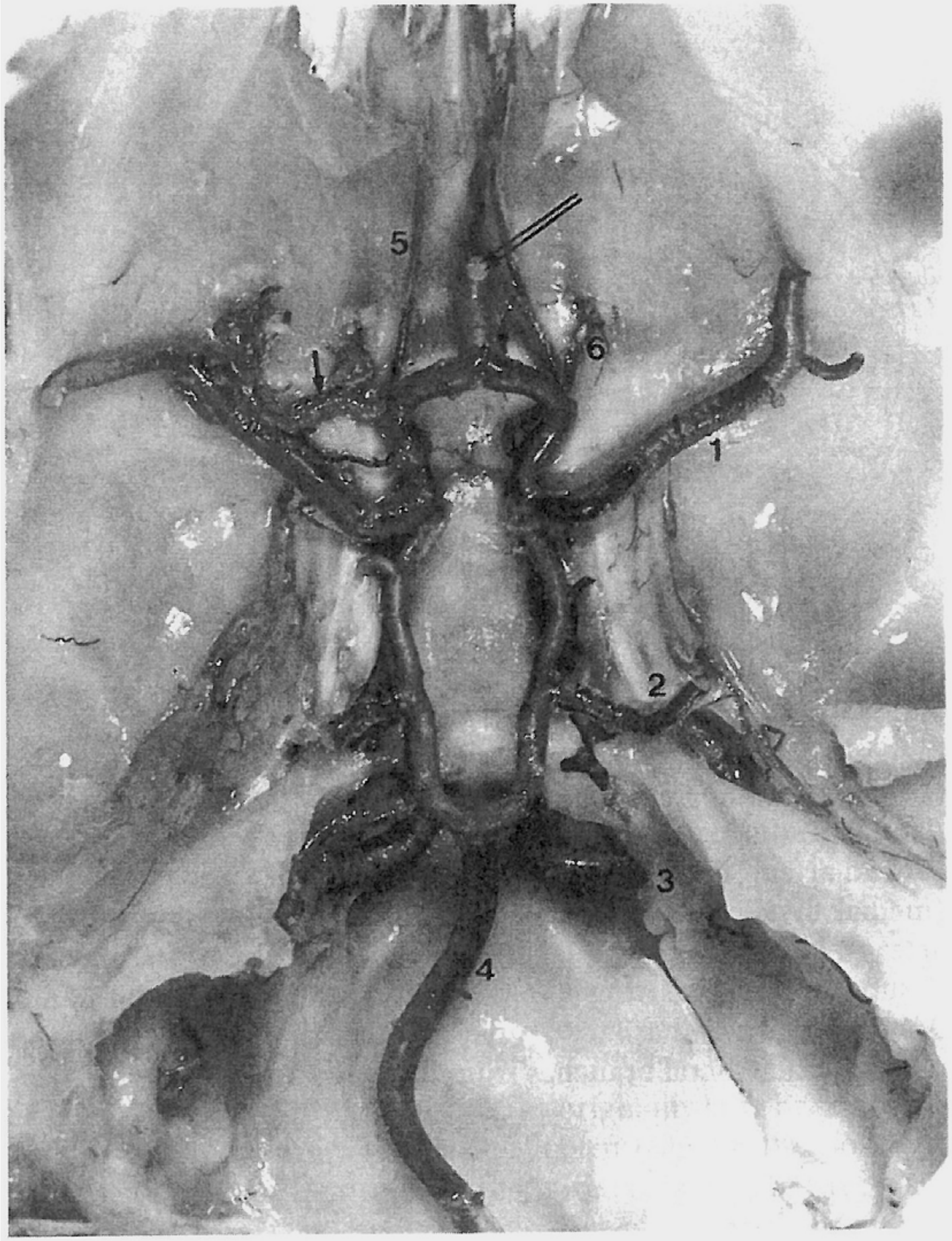

Fig. 6.16. Circle of Willis in the dog. The middle cerebral (*1*) and posterior cerebral (*2*) arteries are clearly seen. Note the large size of the superior cerebellar artery (*3*) and the relatively small size of the basilar artery (*4*). The circle of Willis is largely open and fuses distal to the origin of the superior cerebellar artery. The olfactory artery (*5*) originates from the homologue of the recurrent artery of Heubner (*arrow*). The ophthalmic artery (*6*) arises from the A1 segment of the anterior cerebral artery. It fuses in the midline to form an azygos arrangement (*double arrow*)

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