Phylogenesis and Embryology of the Tentorium Cerebelli

No COI

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Osaka City General Hospital
Department of Neuro-Intervention

Development of the human cranial meninges

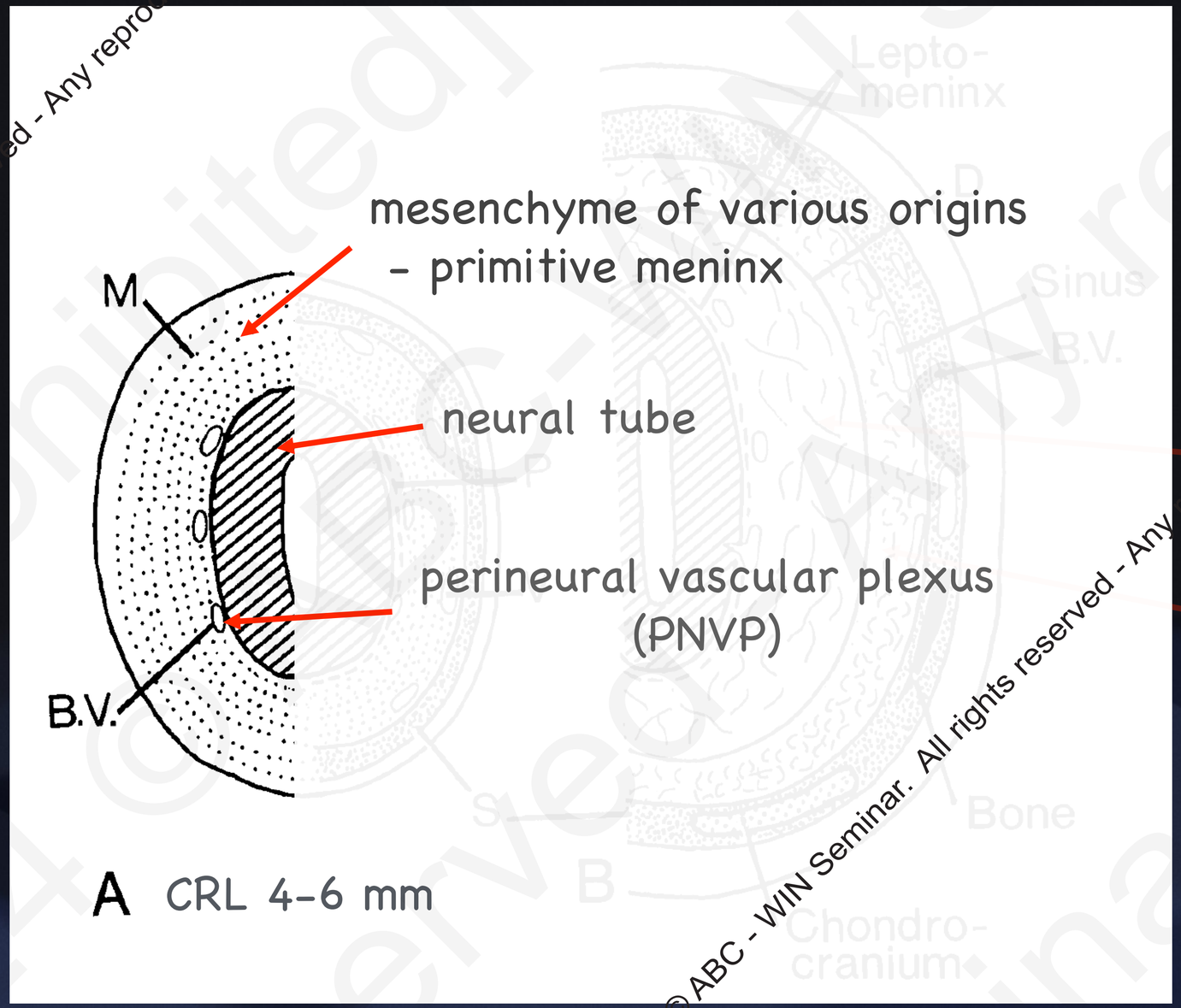
M: mesenchyme

P: pia mater

V: veins

BV: blood vessels

S: skeltogenic layer



D: dural limiting layer

S: dural sinus

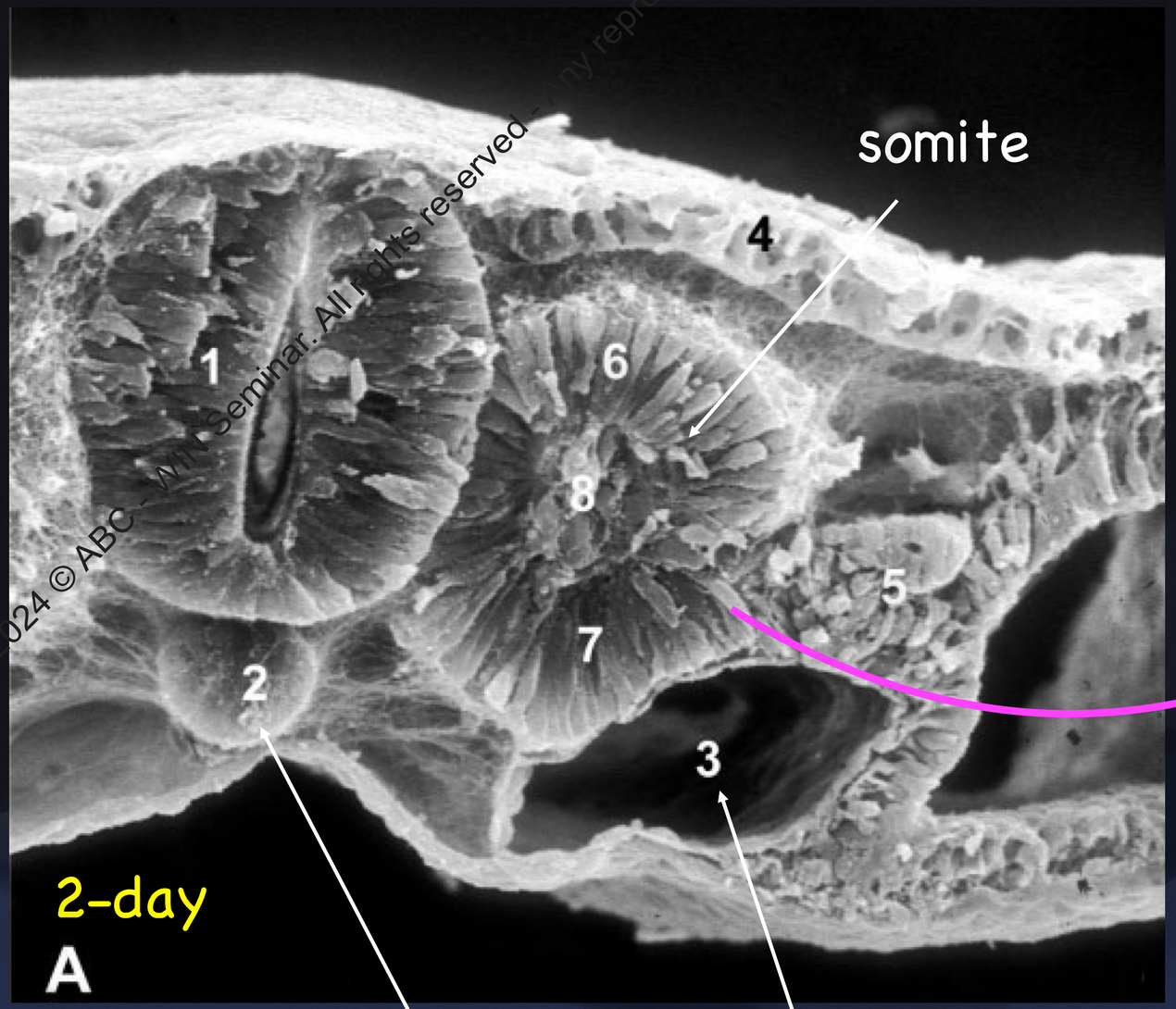
Large meshes
(in the future
subarachnoid space)

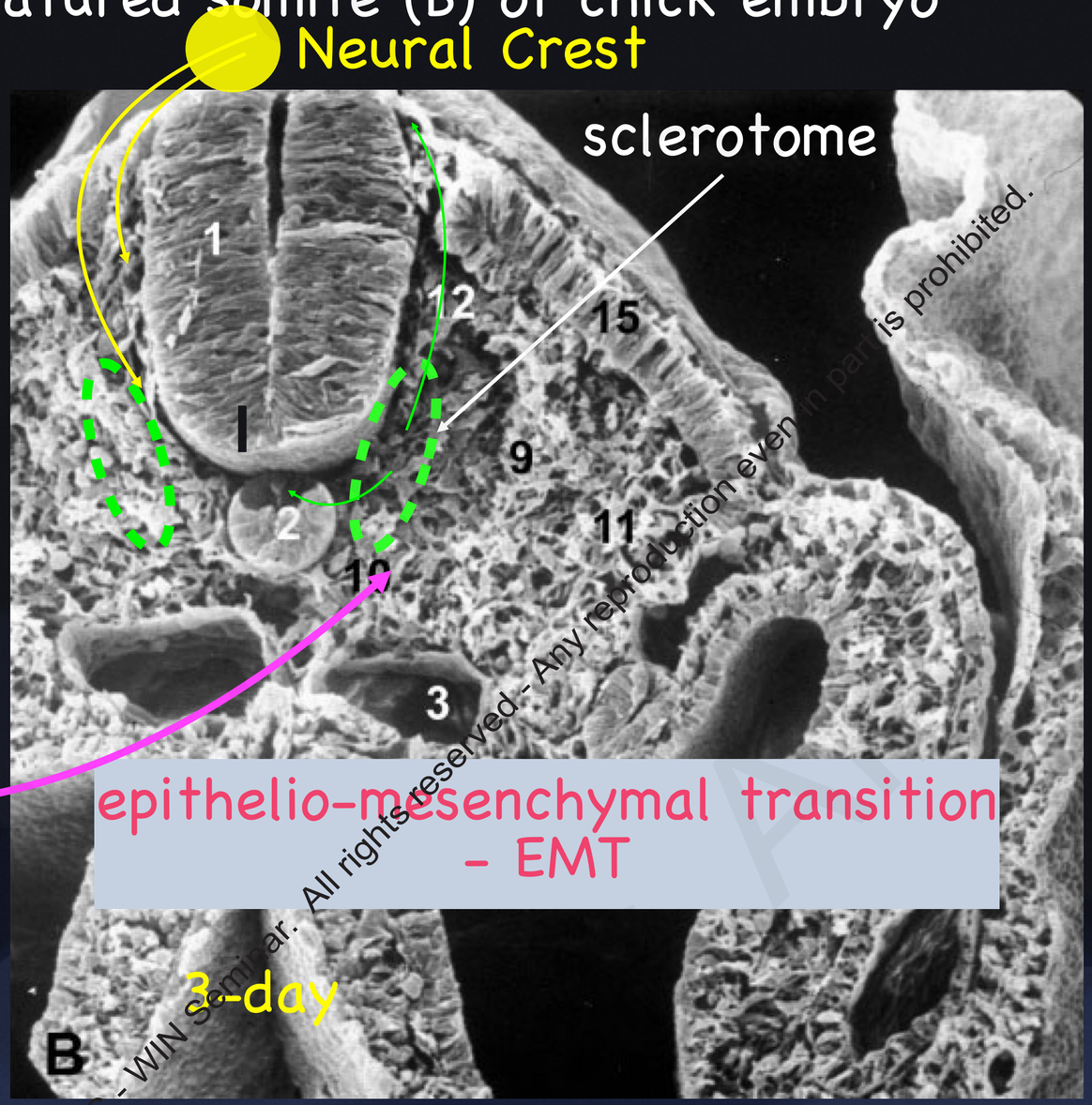
Small meshes
(pachymenix)

B: intramembranous
bone

O'Rahilly R, Müller F: The meninges in human development. J Neuropathol Experi Neural 45:588-608, 1986

An early epithelial somite (A) and a matured somite (B) of chick embryo





Christ B, Huang R, Scaal M: Develop Dynamics 2007

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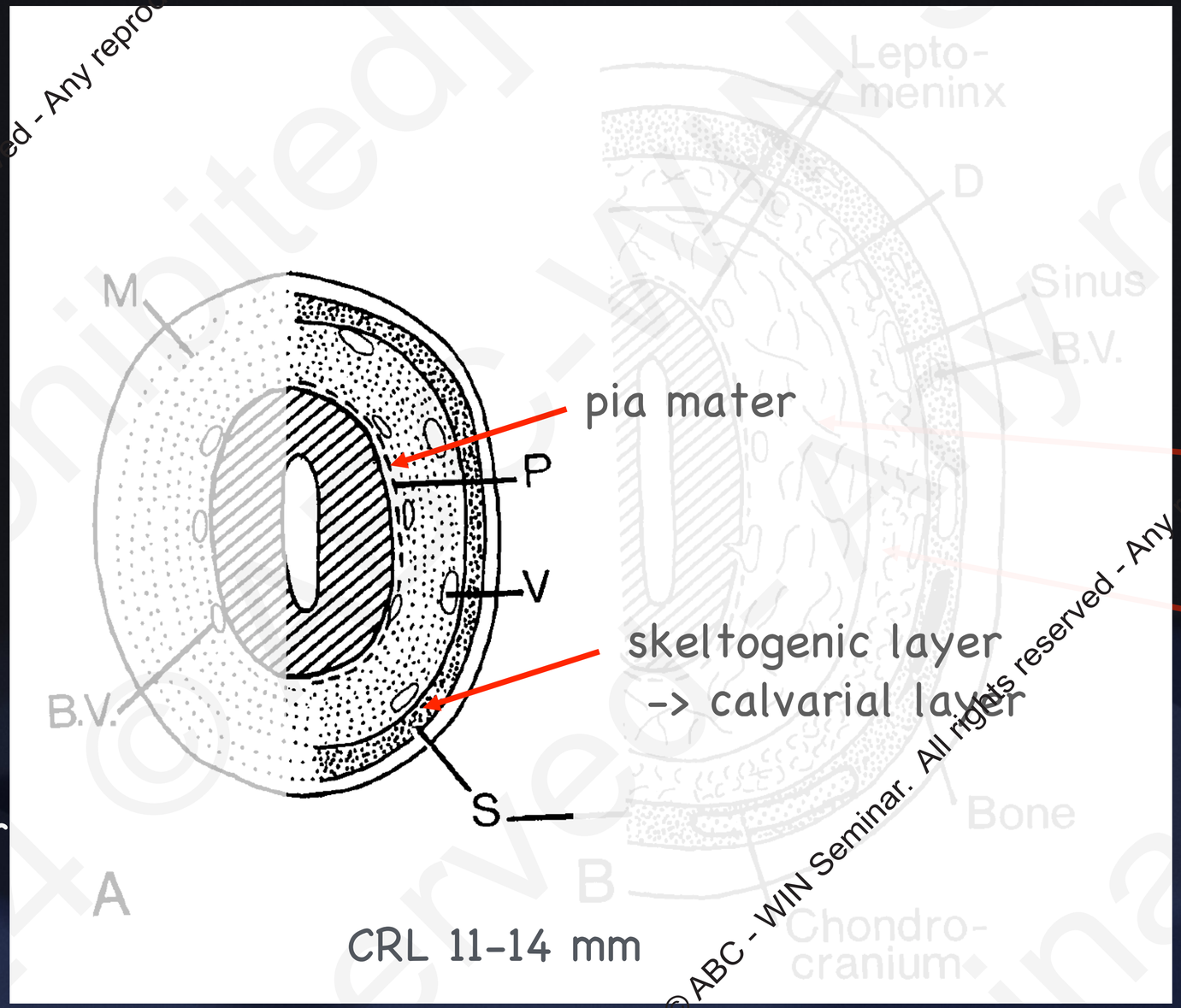

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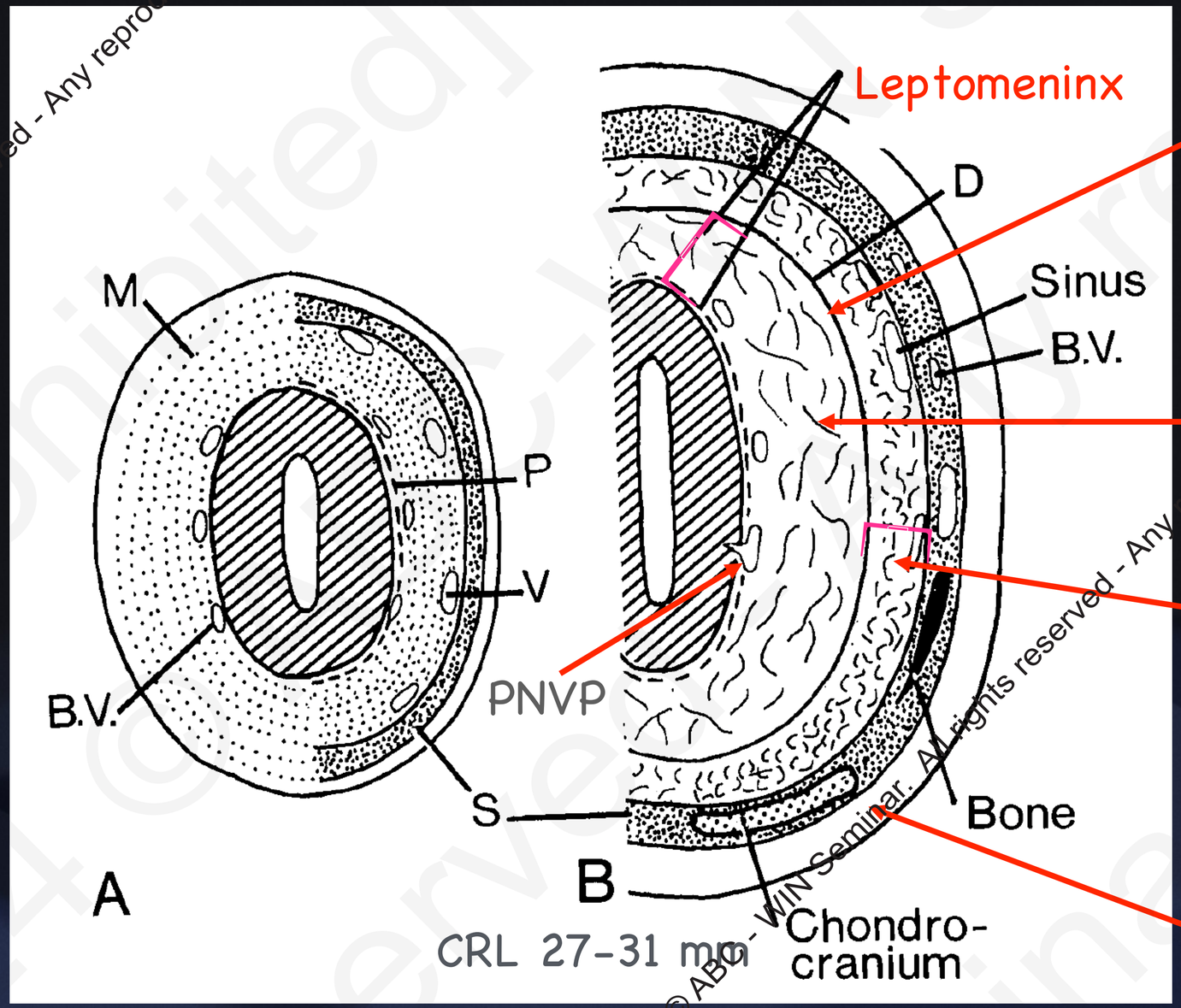


D: dural limiting layer
(dural border cell layer)

S: dural sinus

Large meshes
(in the future
subarachnoid space)

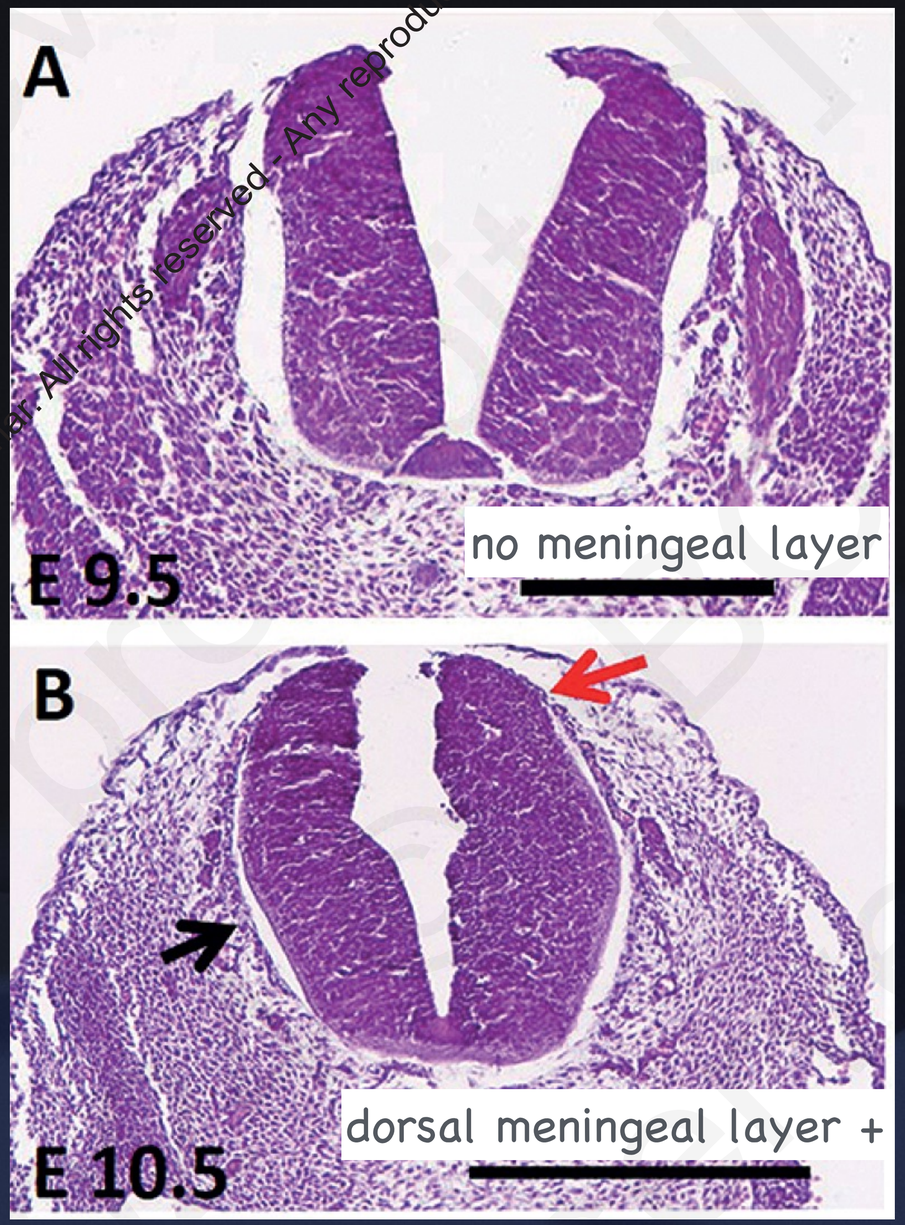
Small meshes
- Pachymeninx
endosteal dura
meningeal dura

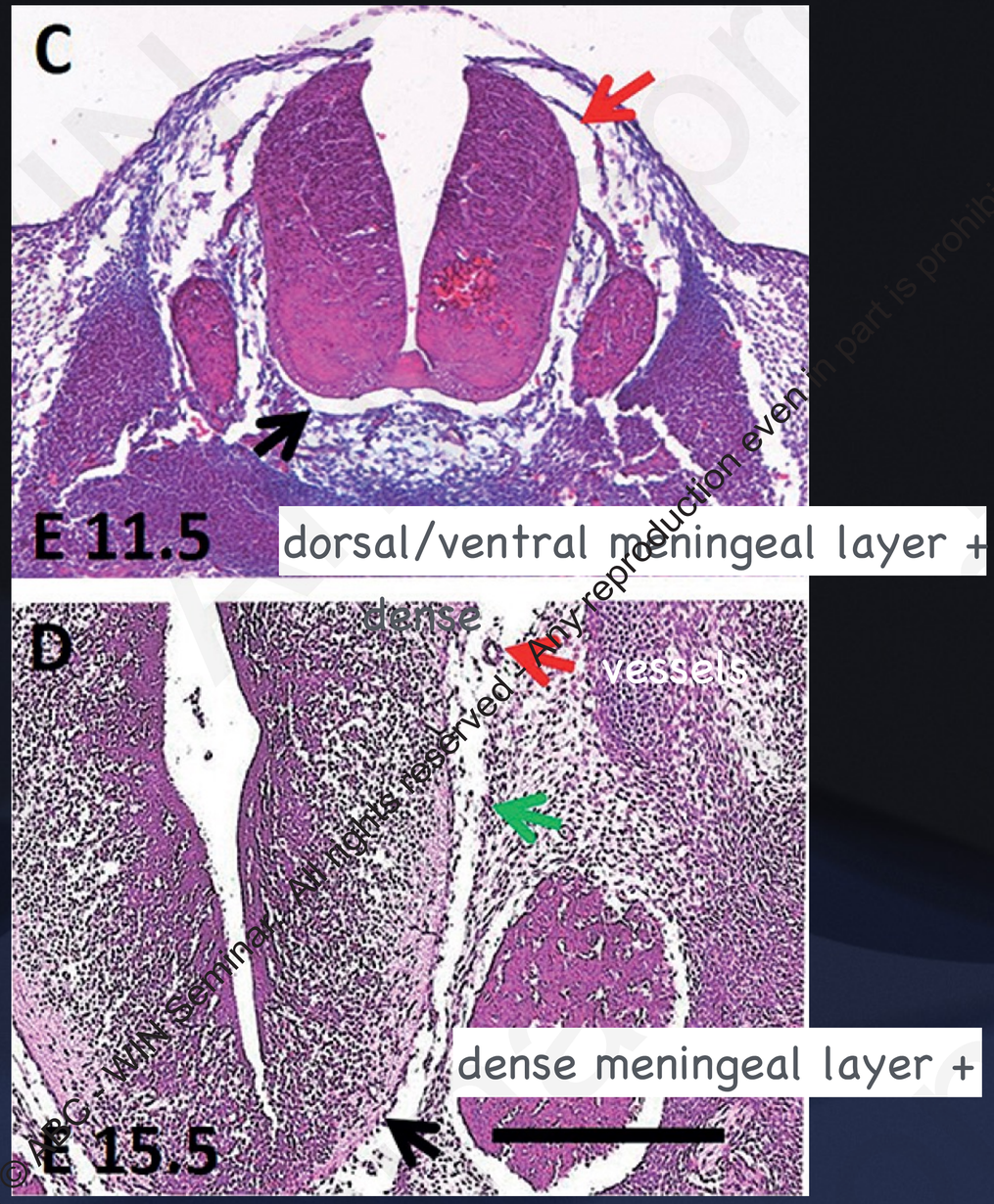
B: intramembranous
bone

dermal layer

O'Rahilly R, Müller F: The meninges in human development. J Neuropathol Experi Neural 45:588-608, 1986

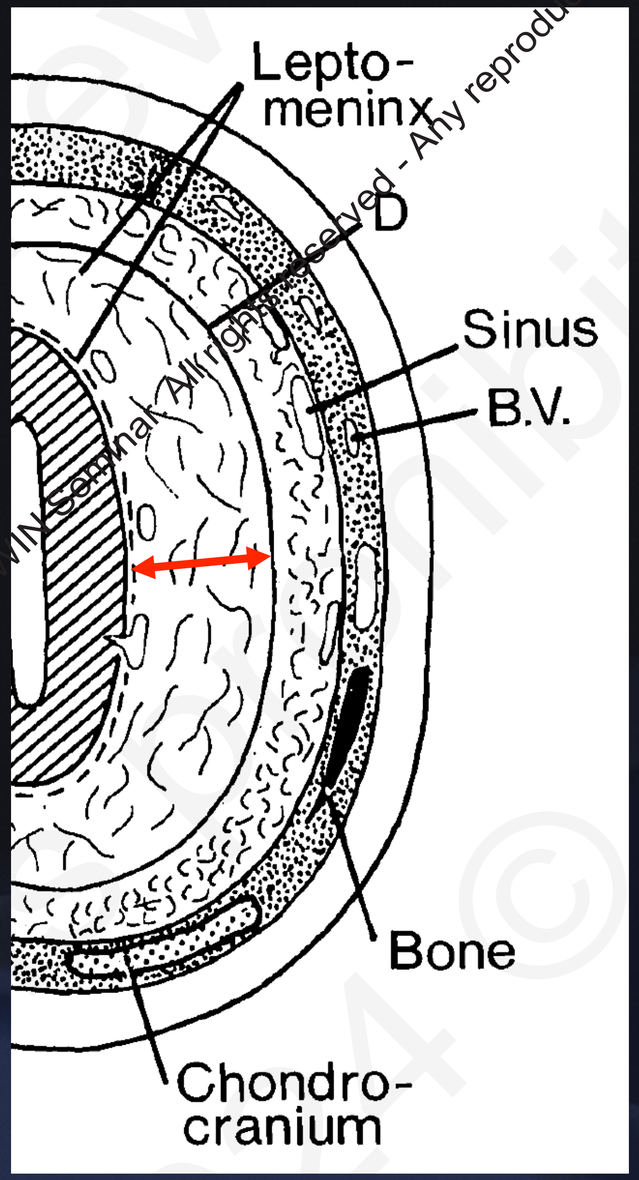
Development of mouse cervical meninges





Batarfi M, Valasek P, Krejci E, et al: The development and origins of vertebrate meninges. Bio Comm 2017

Origins of the meninges



dura mater

arachnoid

pia mater

mesodermal origin

neural crest origin

mixture of both sources

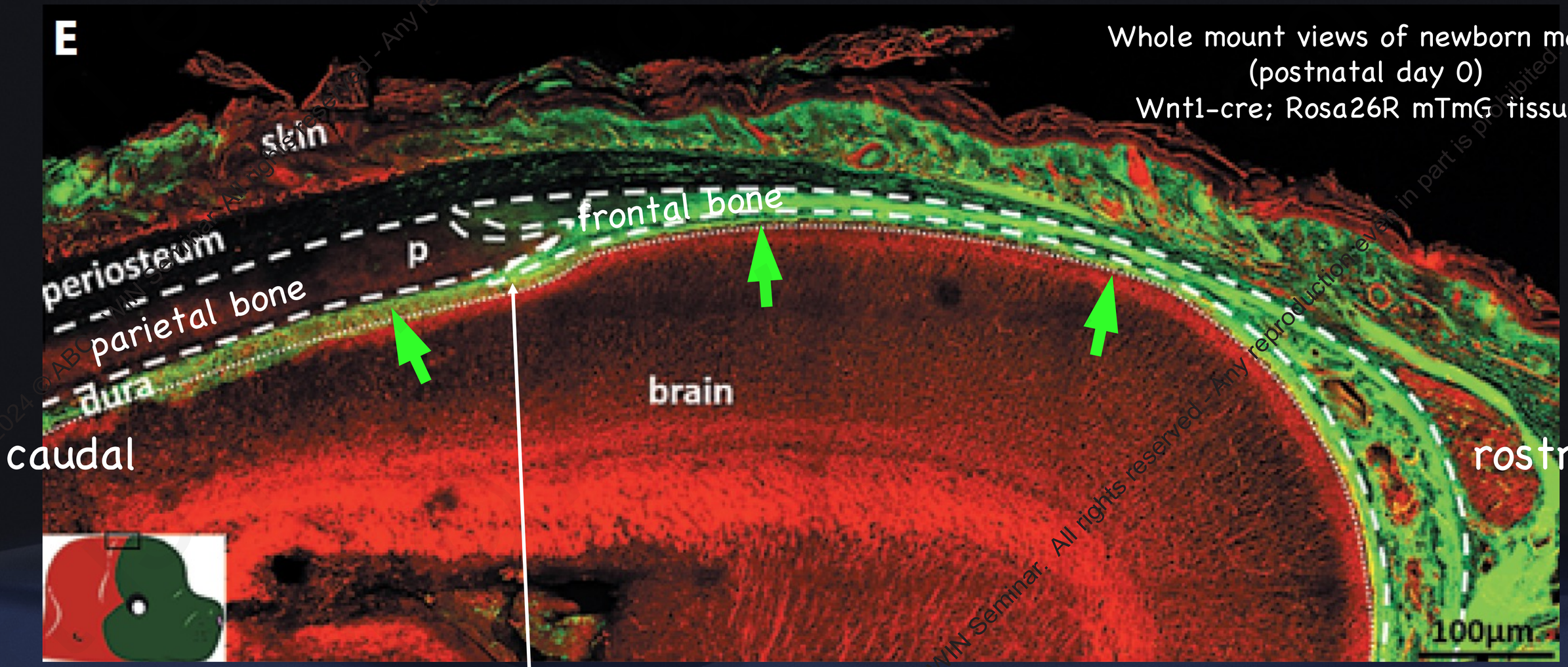
O'Rahilly R, Müller F: The meninges in human development. J Neuropathol Experi Neural 45:588-608, 1986

meninges of the brain

neural crest origin

Jiang X, Iseki S, Maxson, RE, et al: Development Biology 2002
Yoshida T, Vivatbutsin P, Morriss-Kay G, et al: Mech Dev 2008

Neural crest-derived tissues (green) in the mouse cranial vault.



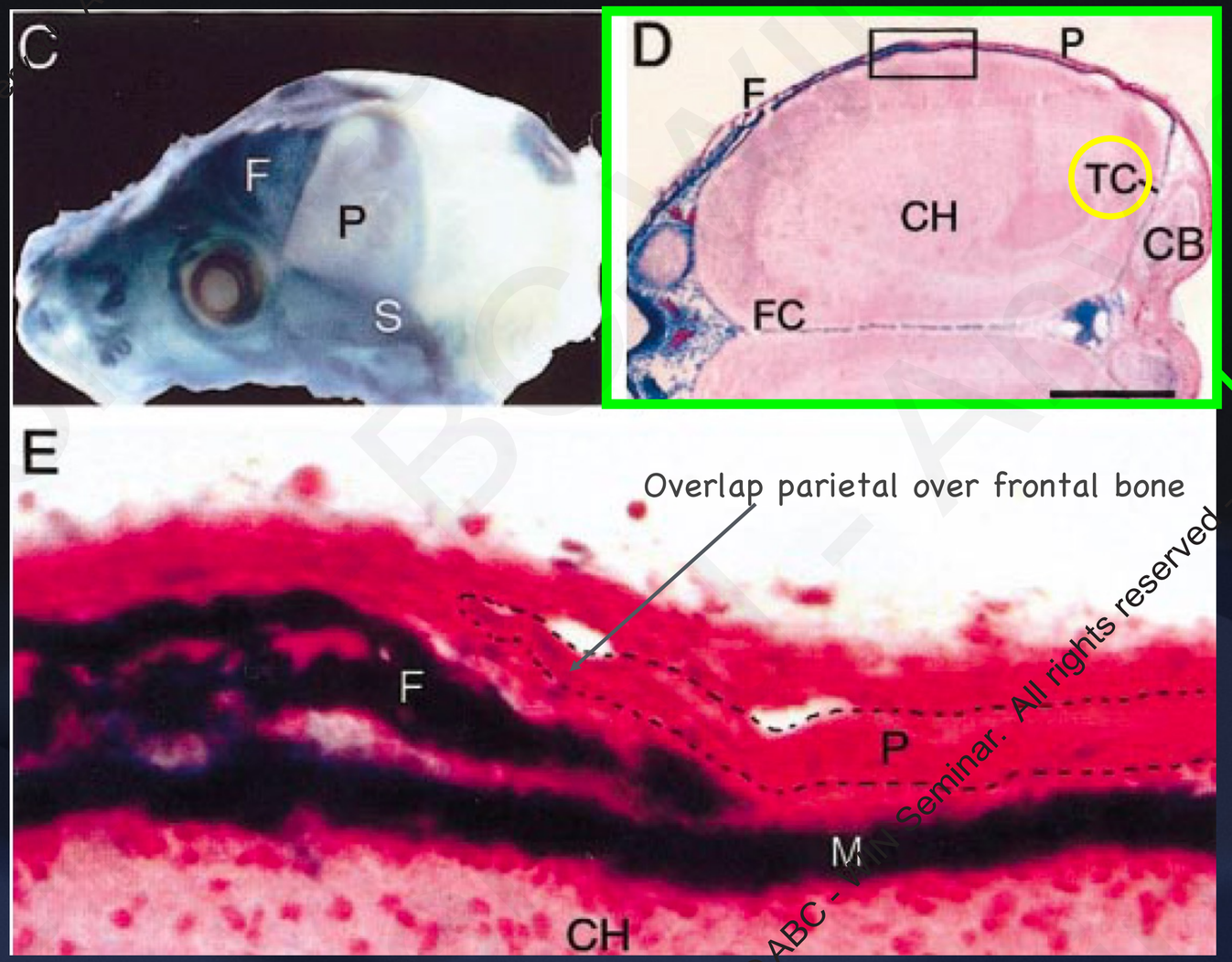
Sagittal section at the coronal suture

Doro D, et al: Mol Syndromol 10:48-57, 2019

Tissue origins of the mouse skull vault

Blue indicates NC origin

F: frontal bone
P: parietal bone
S: squamous bone



CB: cerebellum
CH: cerebral hemisphere
FC: falx cerebri
TC: tentorium cerebelli

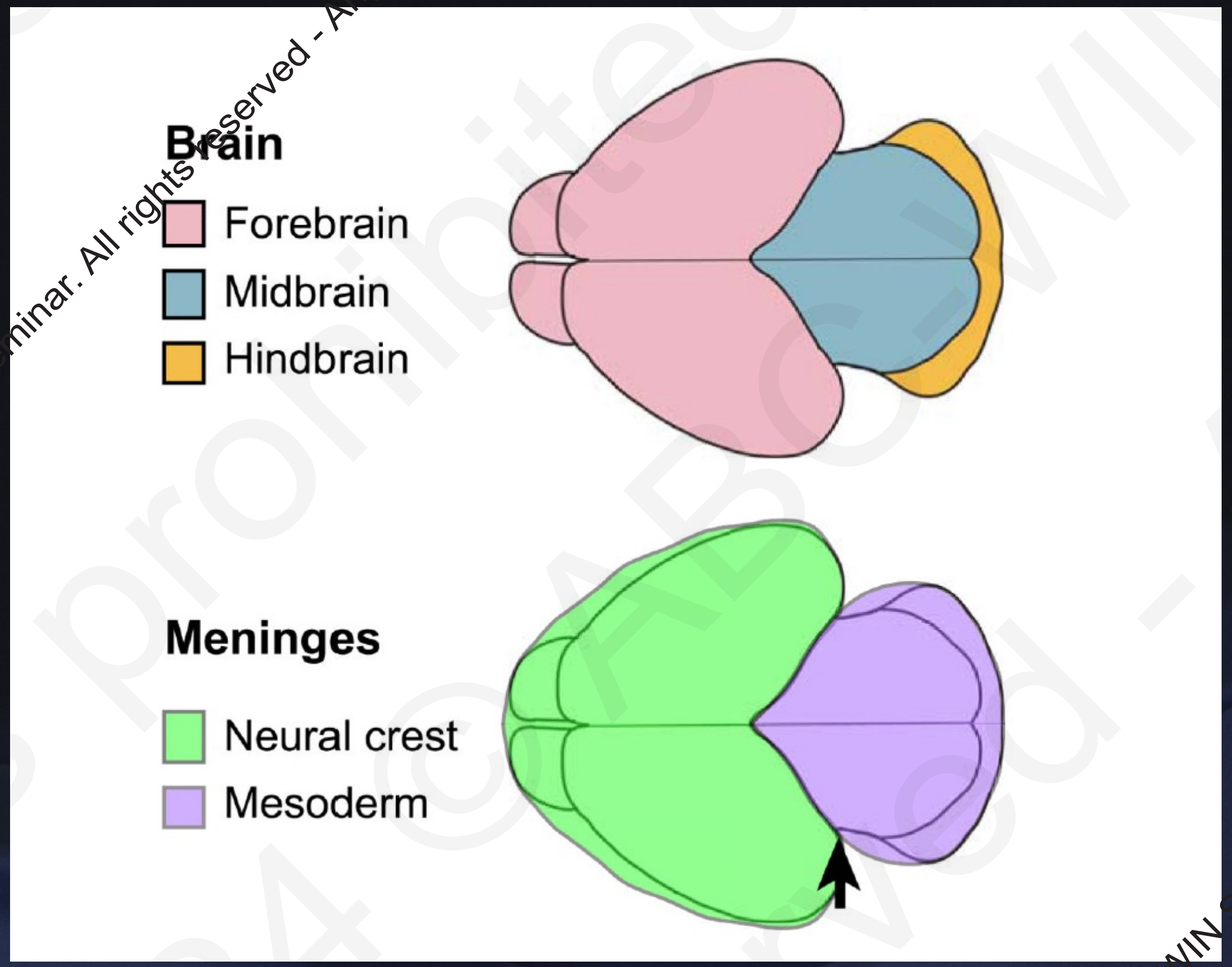
axial section

F: frontal bone
P: parietal bone

M: meninges

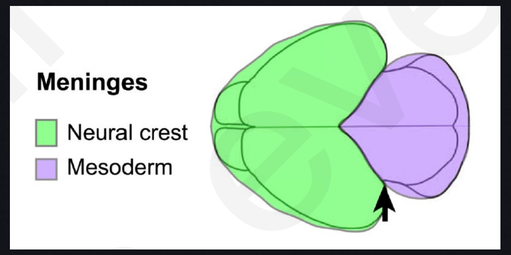
Jiang X, et al: Tissue origins and interactions in the mammalian skull vault. Dev Bio 241:106-116, 2002

Contribution of the cells from the neural crest and the mesoderm to the meninges



Arrow: The rostro-caudal positions of the neural crest-mesoderm boundary

Le Douarin NM and Kalcheim C: The Neural Crest, 2nd ed, Cambridge Univ Press, Cambridge, 1999
Dasgupta K and Jeong J: Development biology of the meninges. Genesis 57(5):e23288, 2019



meninges of the brain

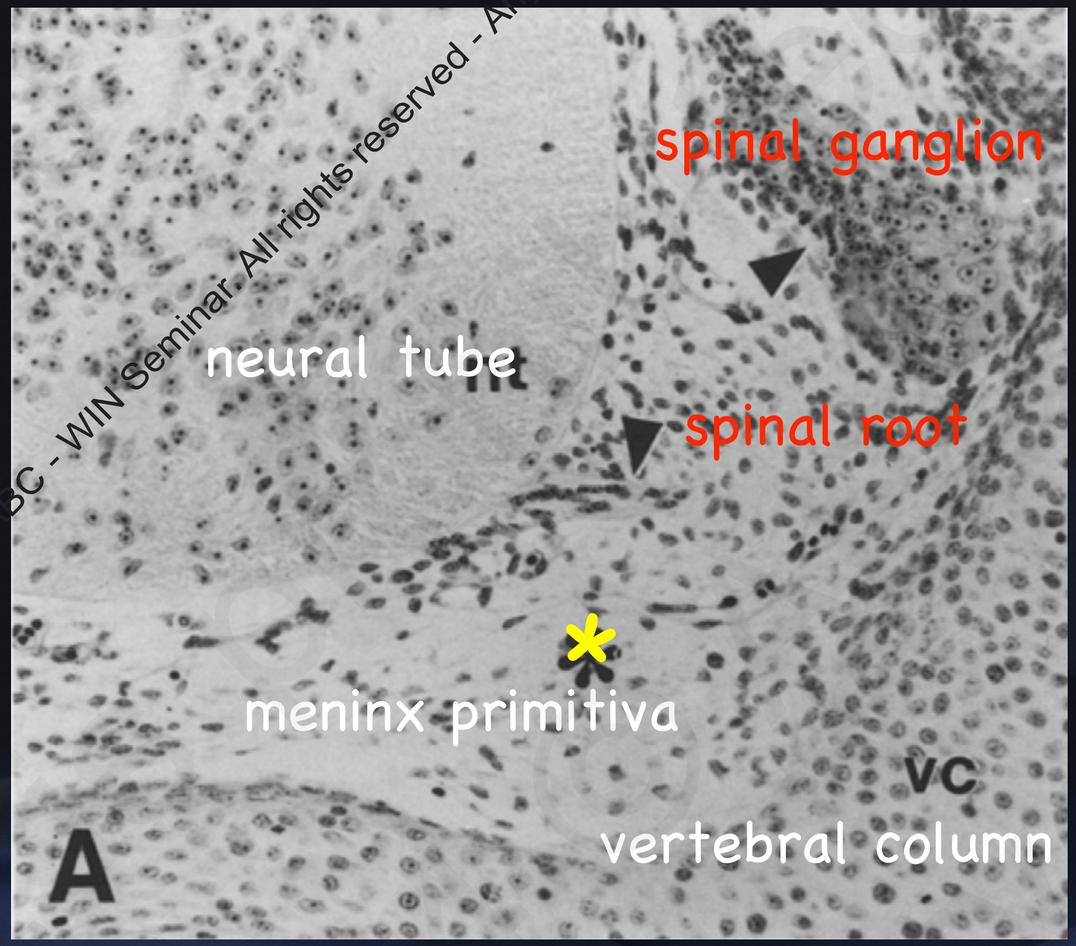
neural crest origin — prosencephalon (tel- and di-encephalons)

mesodermal origin — mes-, rhomb-, and my-encephalons

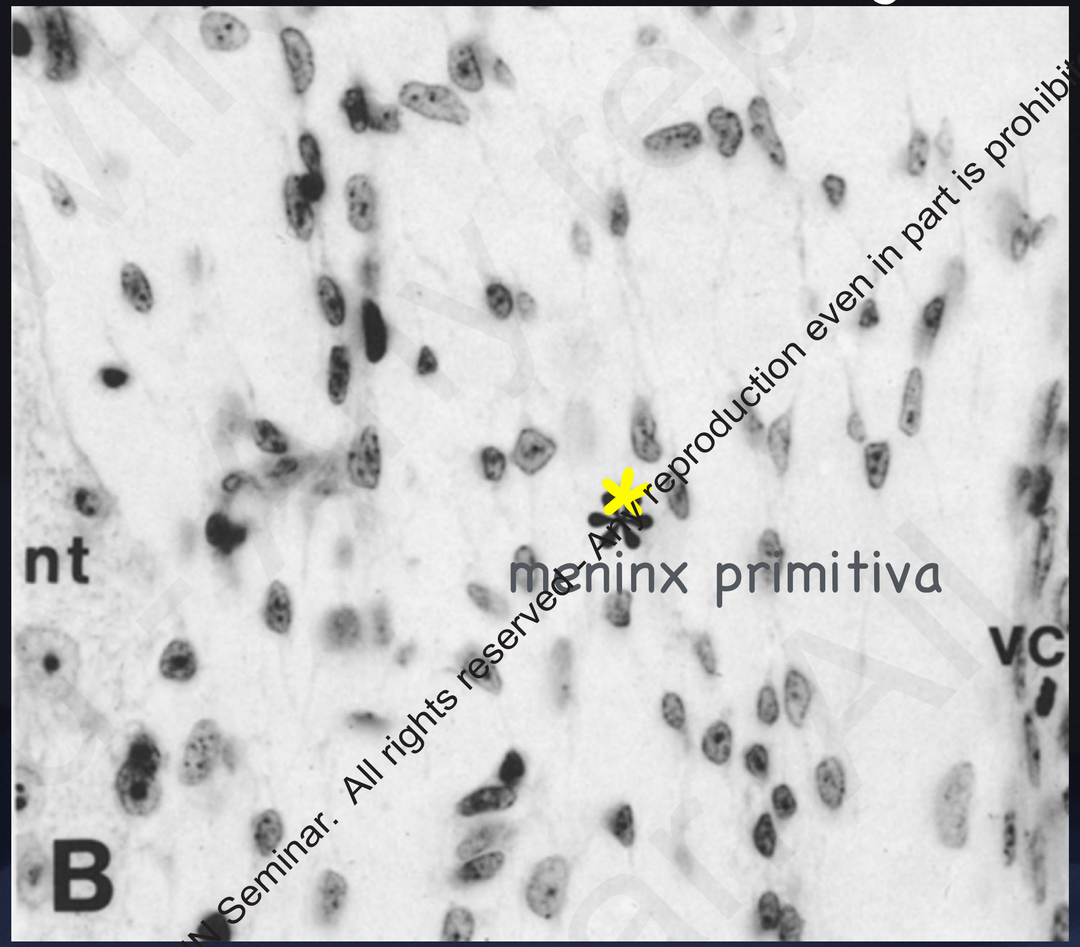
Jiang X, Iseki S, Maxson, RE, at al: Development Biology 2002
Yoshida T, Vivatbutsin P, Morriss-Kay G, et al: Mech Dev 2008

The chick embryo 6 days: Chimera model, quail neural crest transplanted

- Feulgen staining



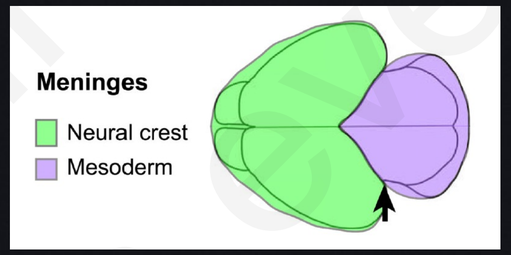
x 260



x 560

The meninx primitiva (asterisk) is formed only by cells of the chick host.

Christ B, Huang R, Scaal M: Develop Dynamics 2007



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meninges of the spinal cord

mesodermal origin

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Halata Z, Grim M, Christ B: Anat Embryol 1990
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Nimmagadda S, Loganathan PG, Wilting J: Anat Embryol 2004
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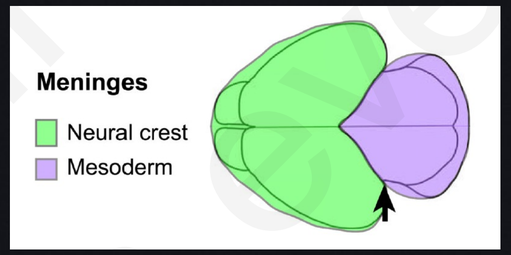

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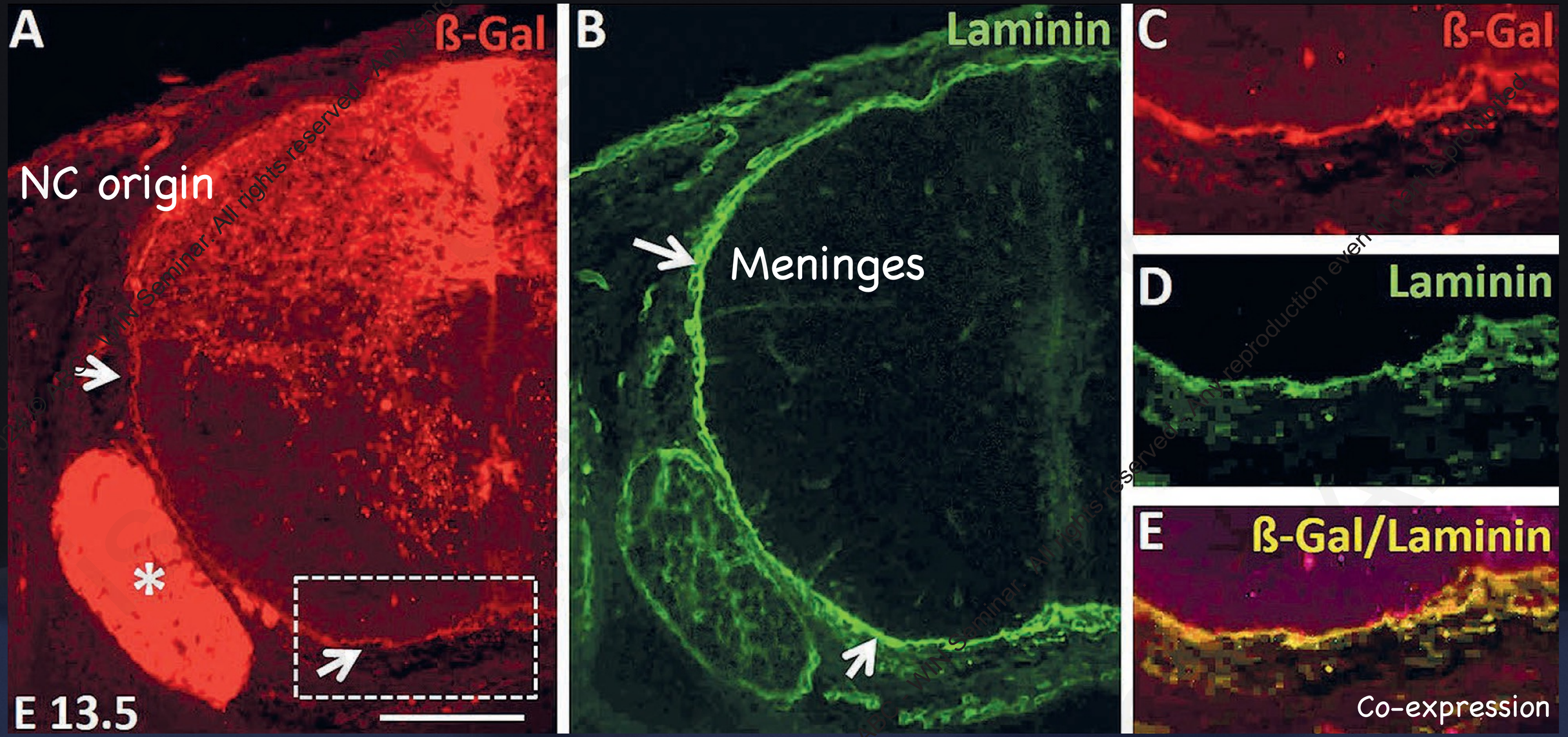
neural crest origin

Batarfi M, Valasek P, Krejci E, et al: Bio Comm 2017

Neural crest origins of mouse meninges at the trunk level



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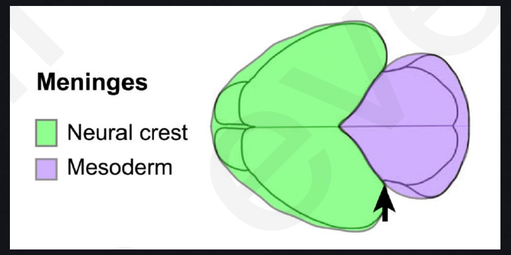

meninges of the brain

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mesodermal origin

Jiang X, Iseki S, M
Yoshida T, Vivatbu

Meningeal epithelial blood vessels may have been mistaken as meninges and led to an erroneous conclusion

meninges of the spinal cord

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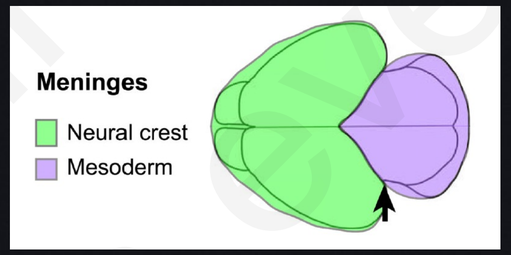
Christ B, Huang

neural crest origin

Entire meninges are of neural crest origin

Batarfi M, Valasek P, Krejci E, et al: Bio Comm 2017



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neural crest origin

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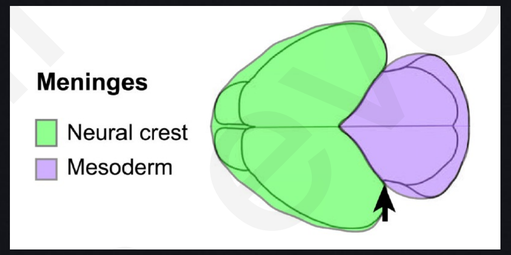
But, still controversial!



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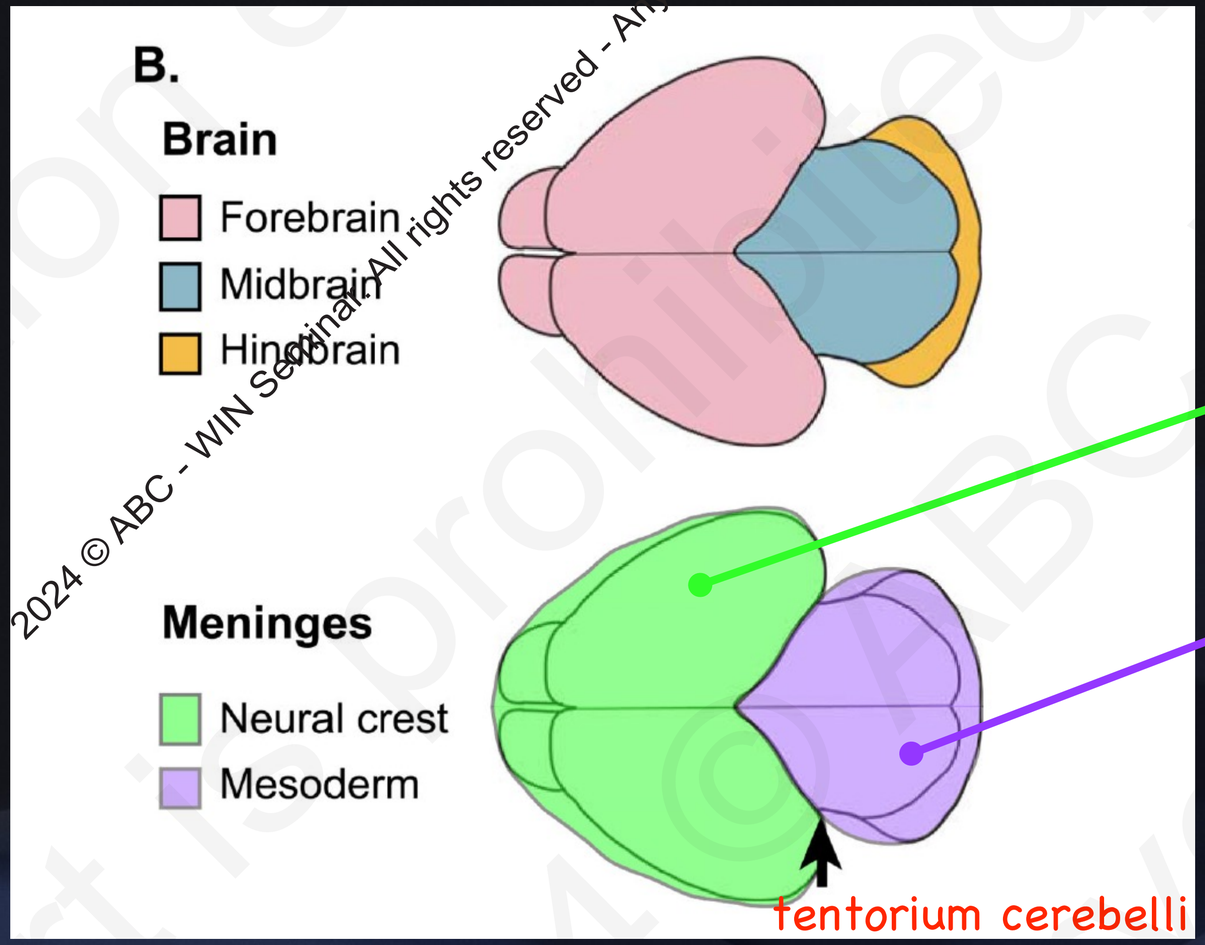
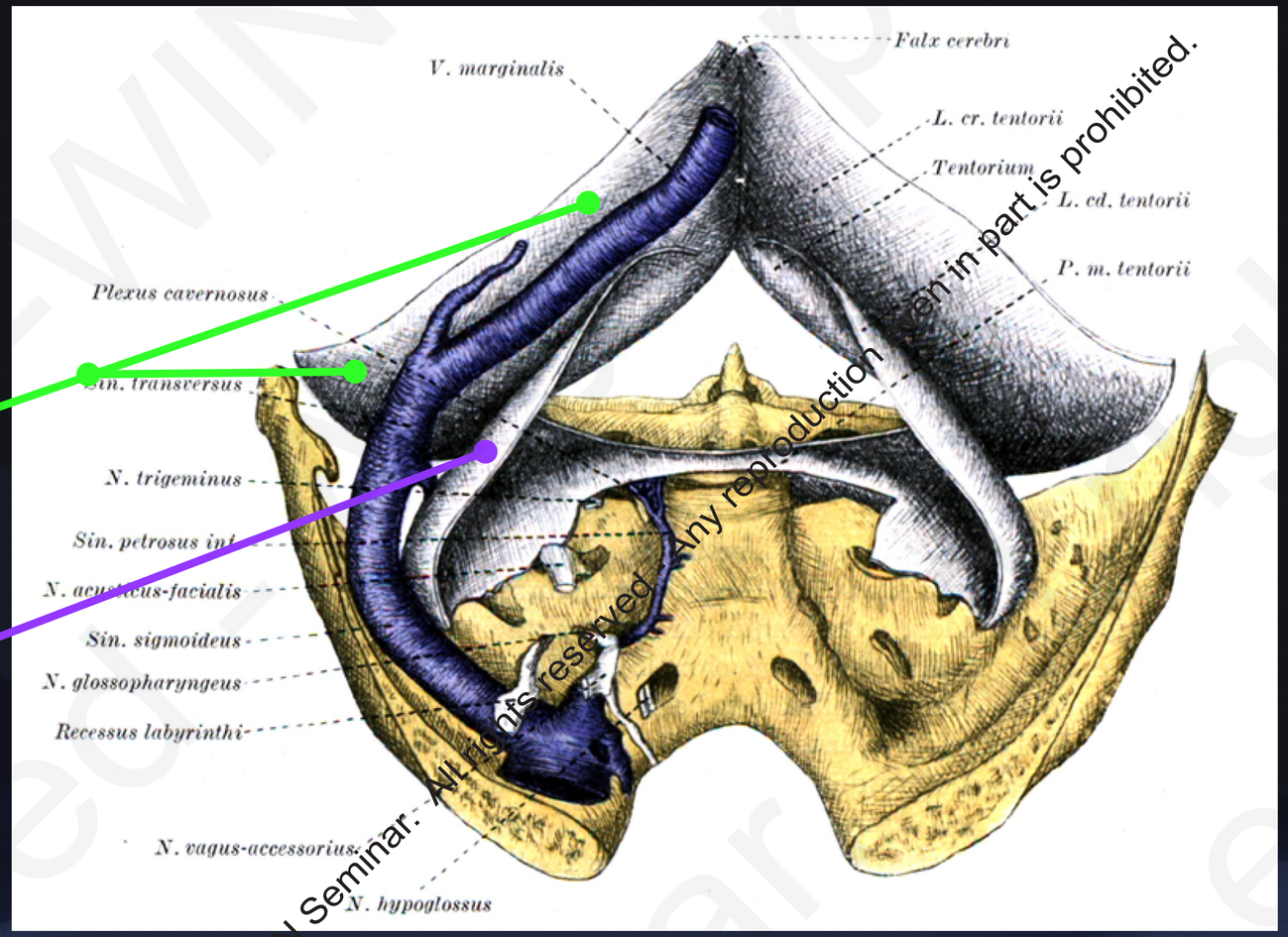
Most common idea on the origins of the meninges at present

Meningeal border between NC and Mesodermal origins



Dasgupta K and Jeong J: Genesis 2019

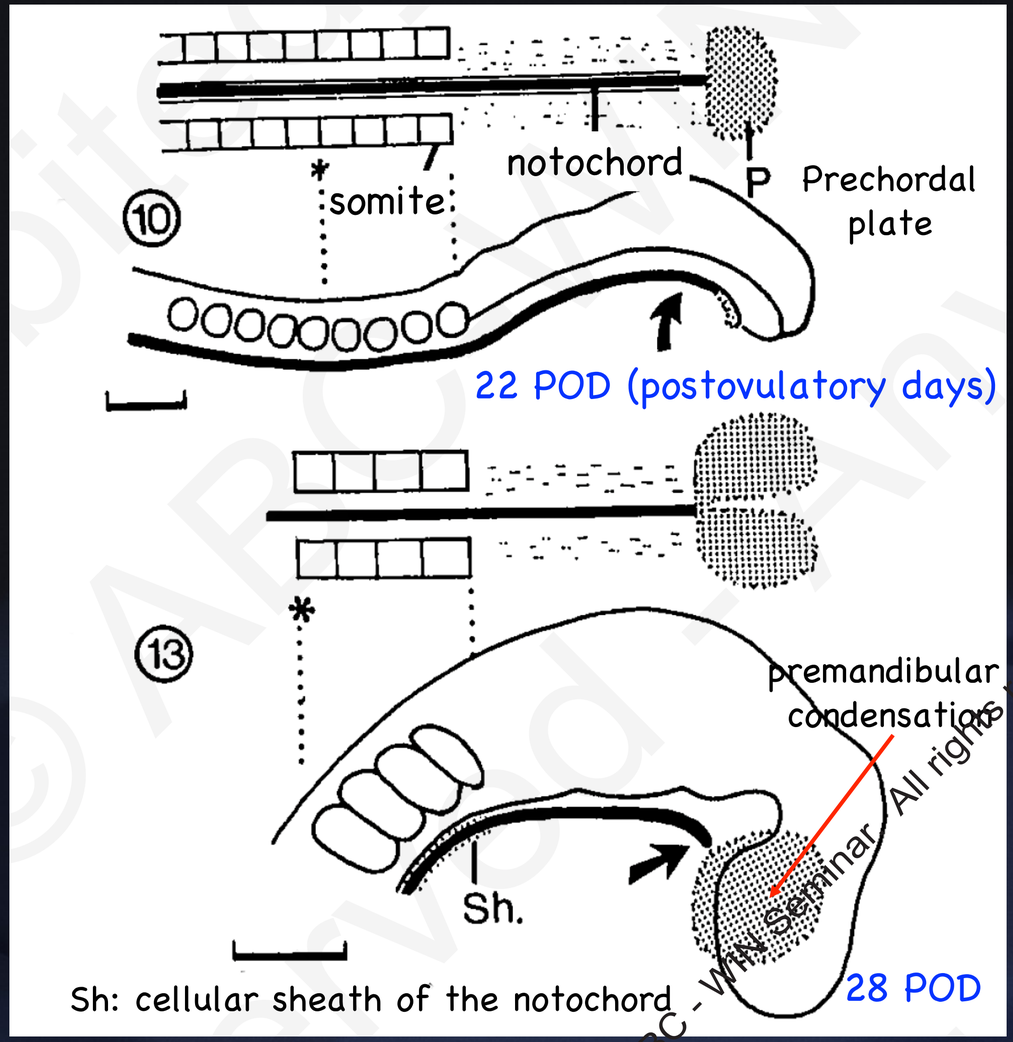


Markowski J: Zeitschrift Anat 1931

Embryology of the medial part of the human tentorium cerebelli

Stages by O'Rahilly R, Müller F:
Anat Embryol 1981

= Carnegie stage



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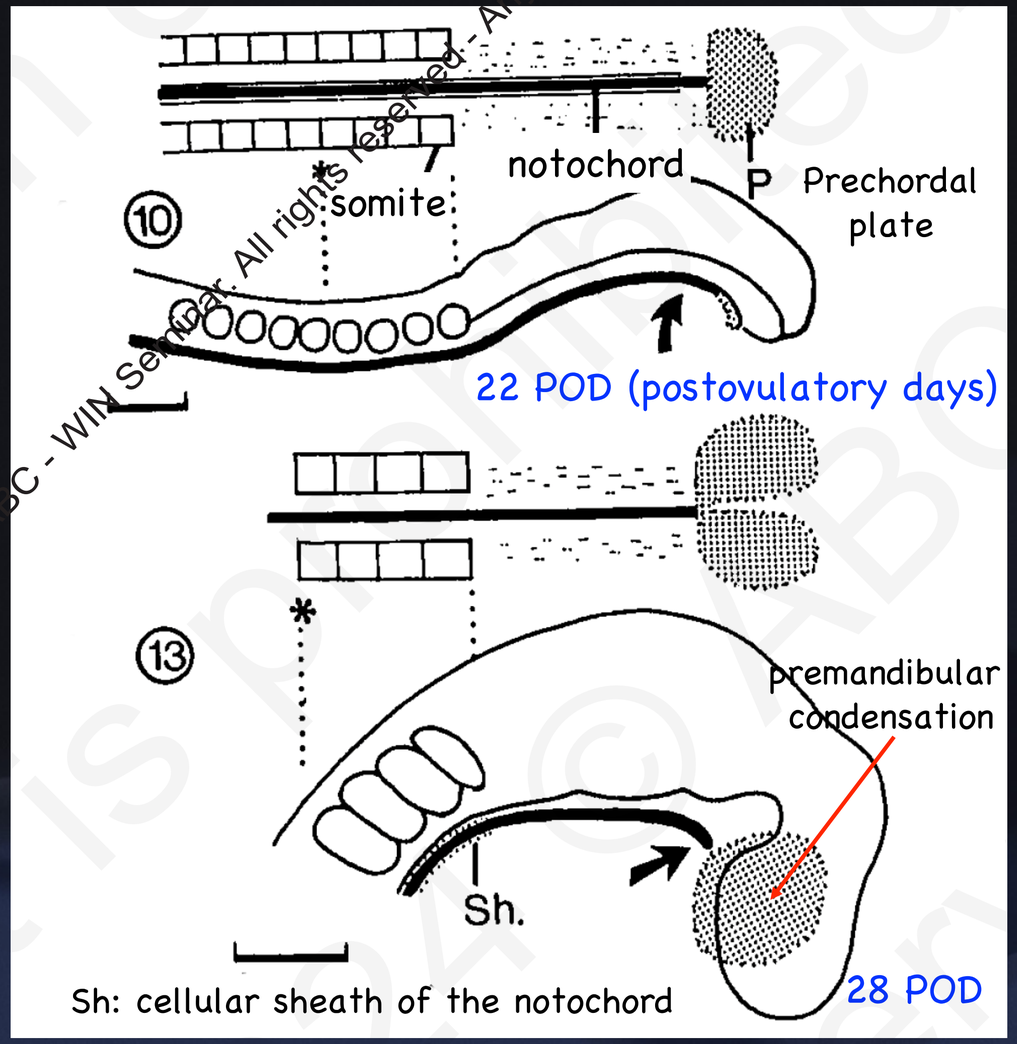

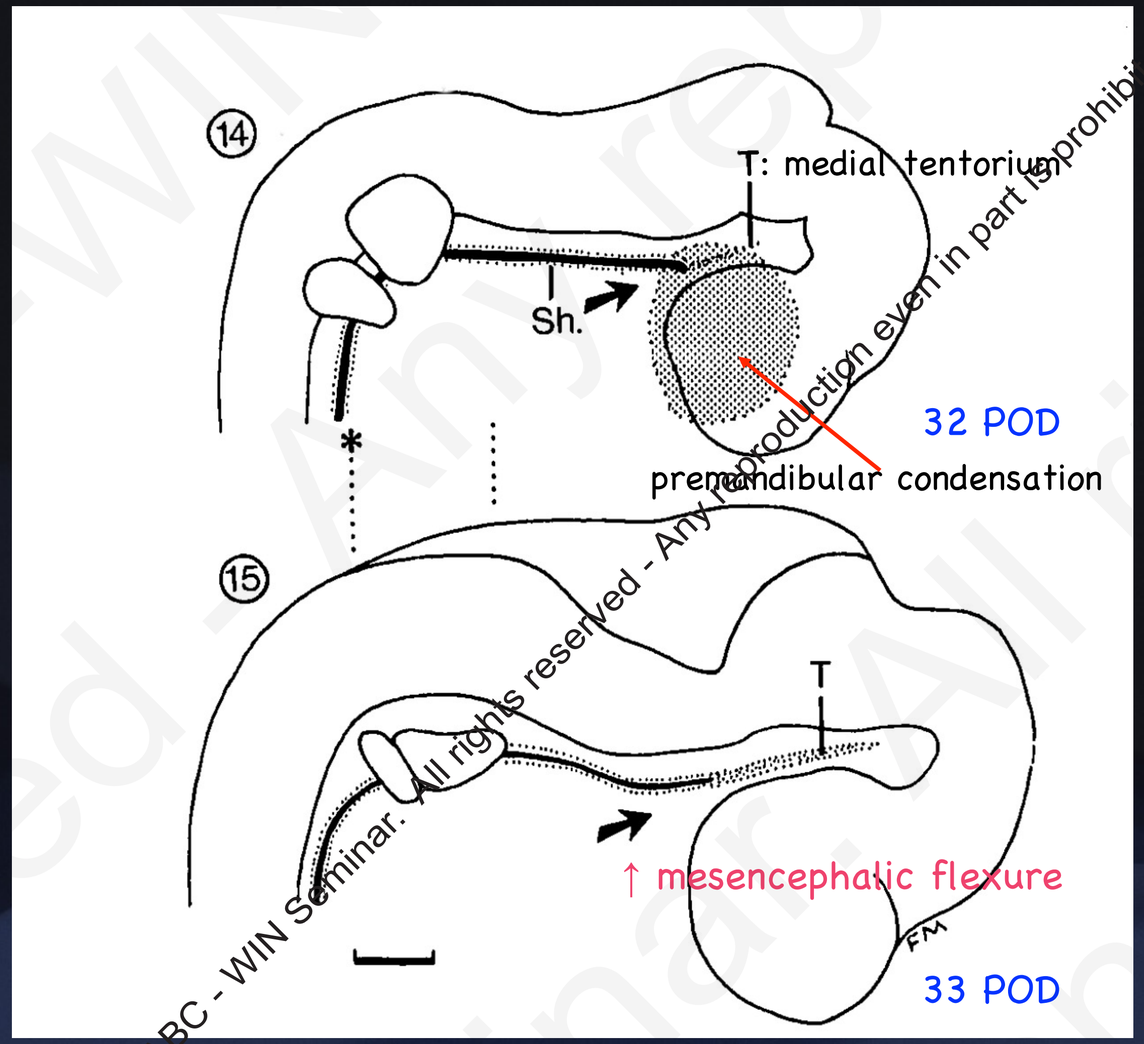

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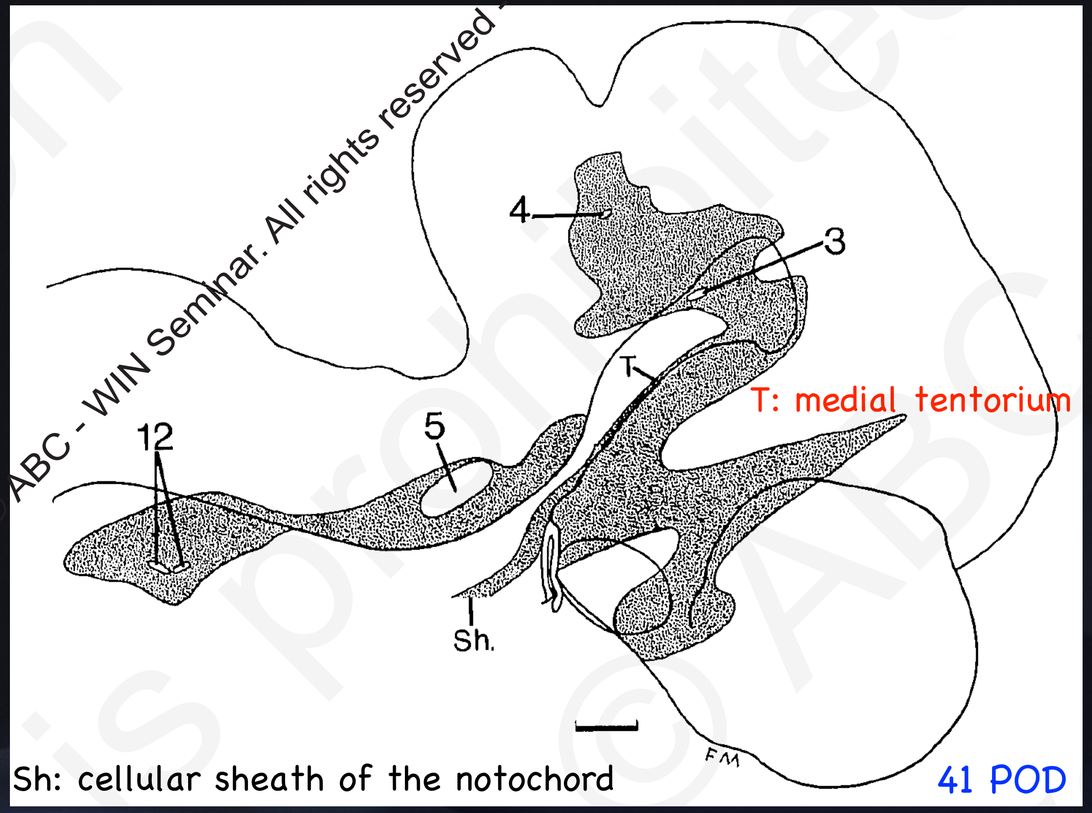
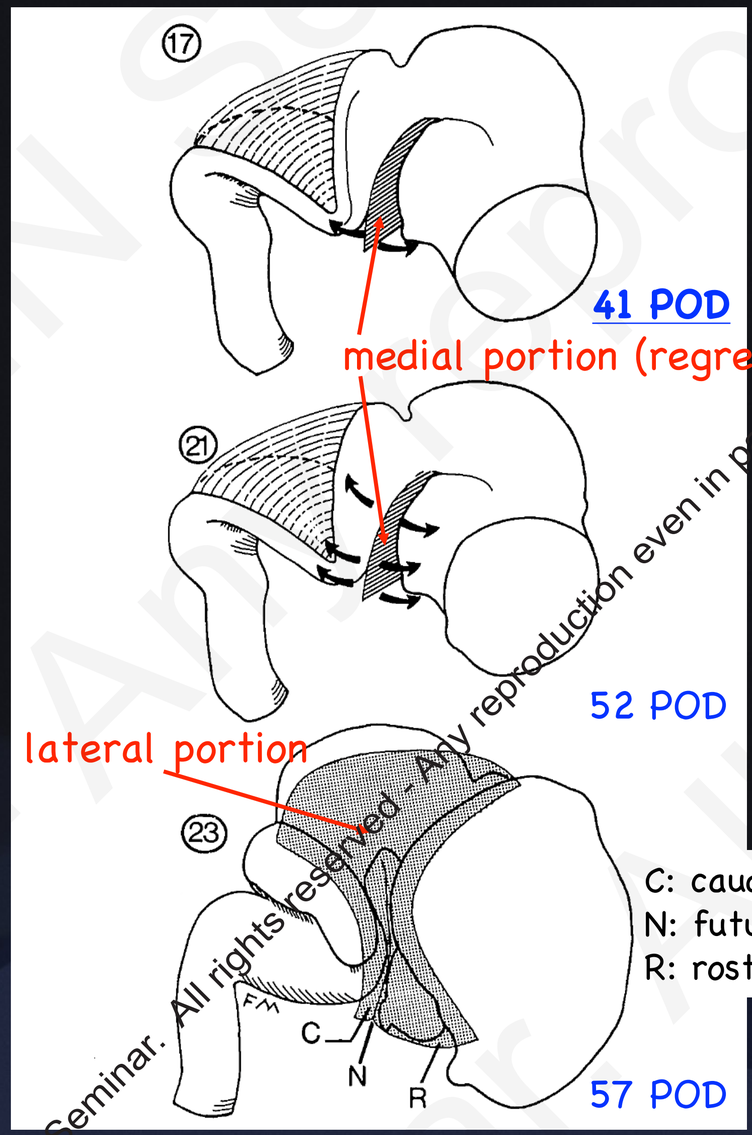


Sh: cellular sheath of the notochord

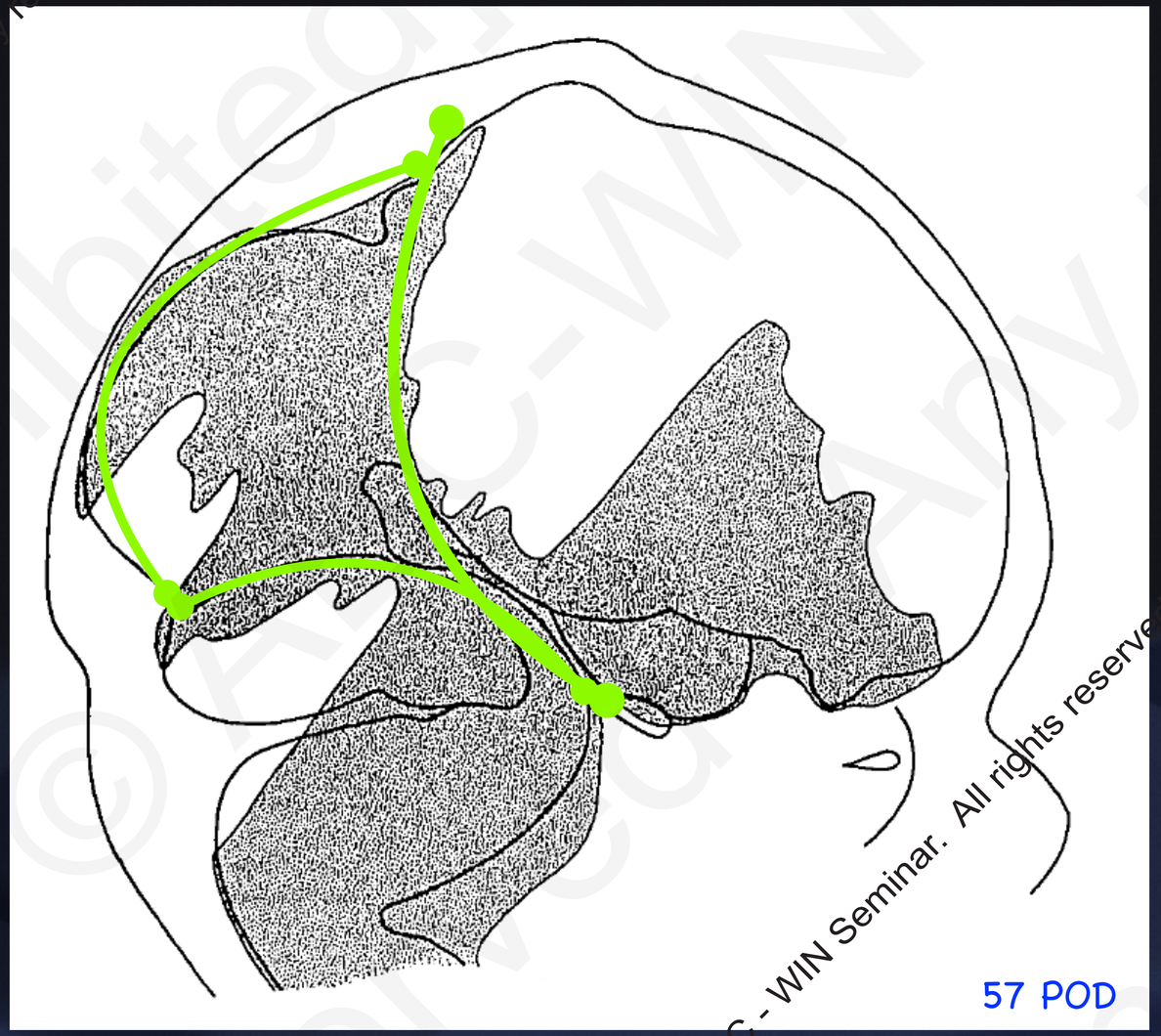
Early formation of the dural limiting layer and lateral part (fold) of the tentorium



Formation of the tentorium

O'Rahilly R, Müller F: The meninges in human development. J Neuropathol Experi Neural 45:588-608, 1986

Embryology of the human tentorium cerebelli

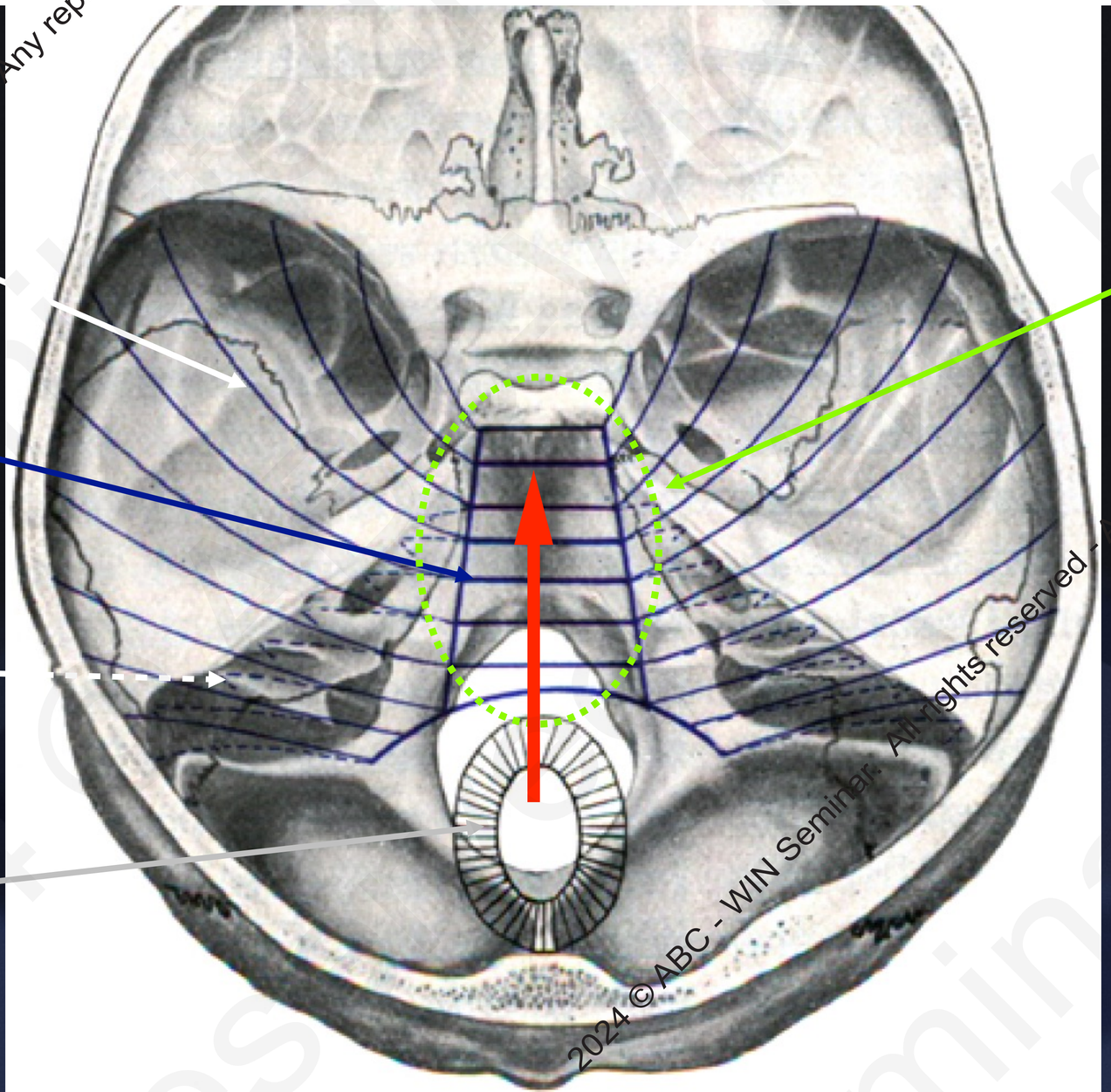


lateral view

O'Rahilly R, Müller F: J Neuropathol Experi Neurol 1986

Most of the dural limiting layer present during the embryonic period is part of the future tentorium cerebelli.

Development of the human tentorium cerebelli



rostral leaf

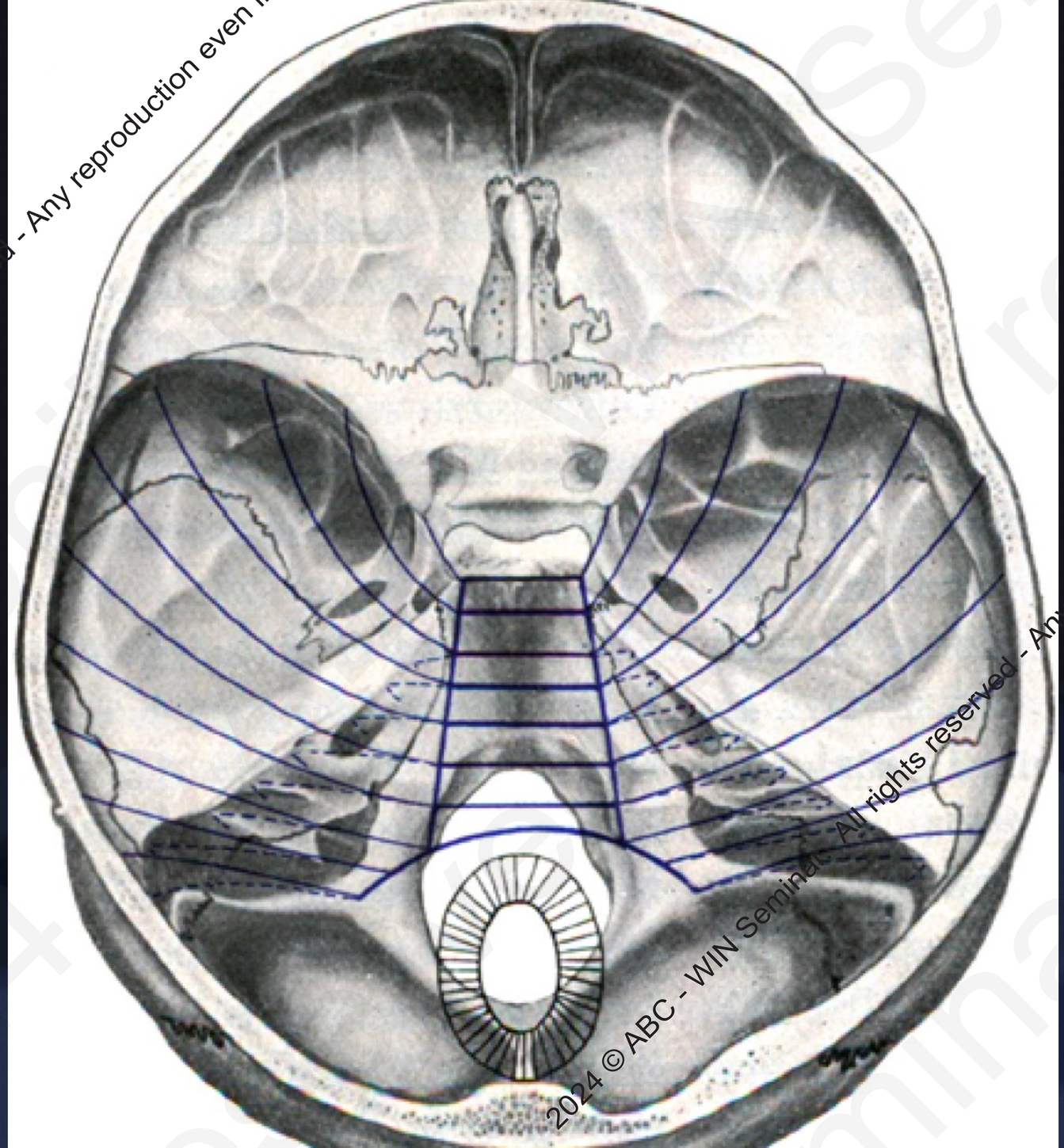
fused two leaves

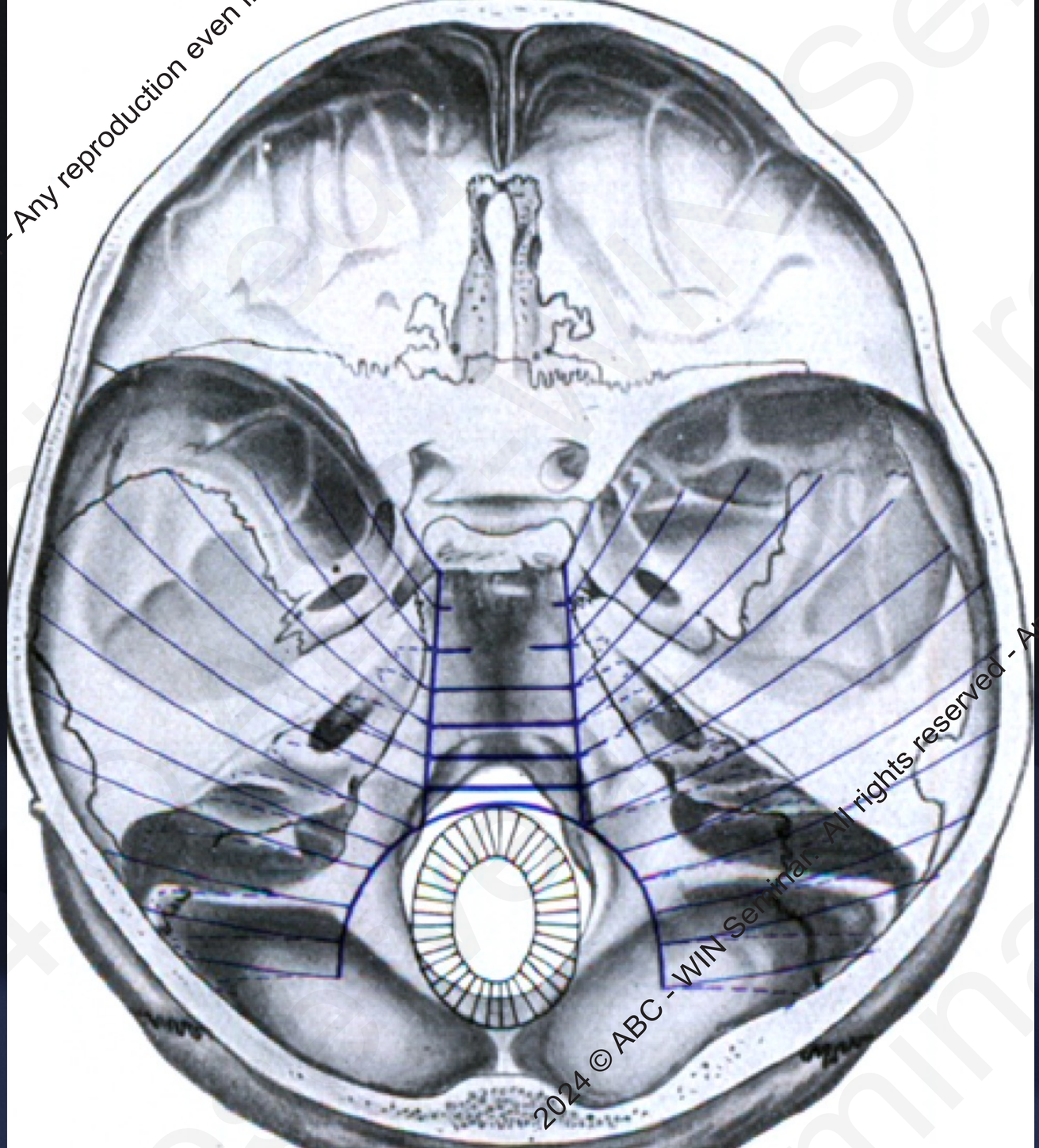
caudal leaf

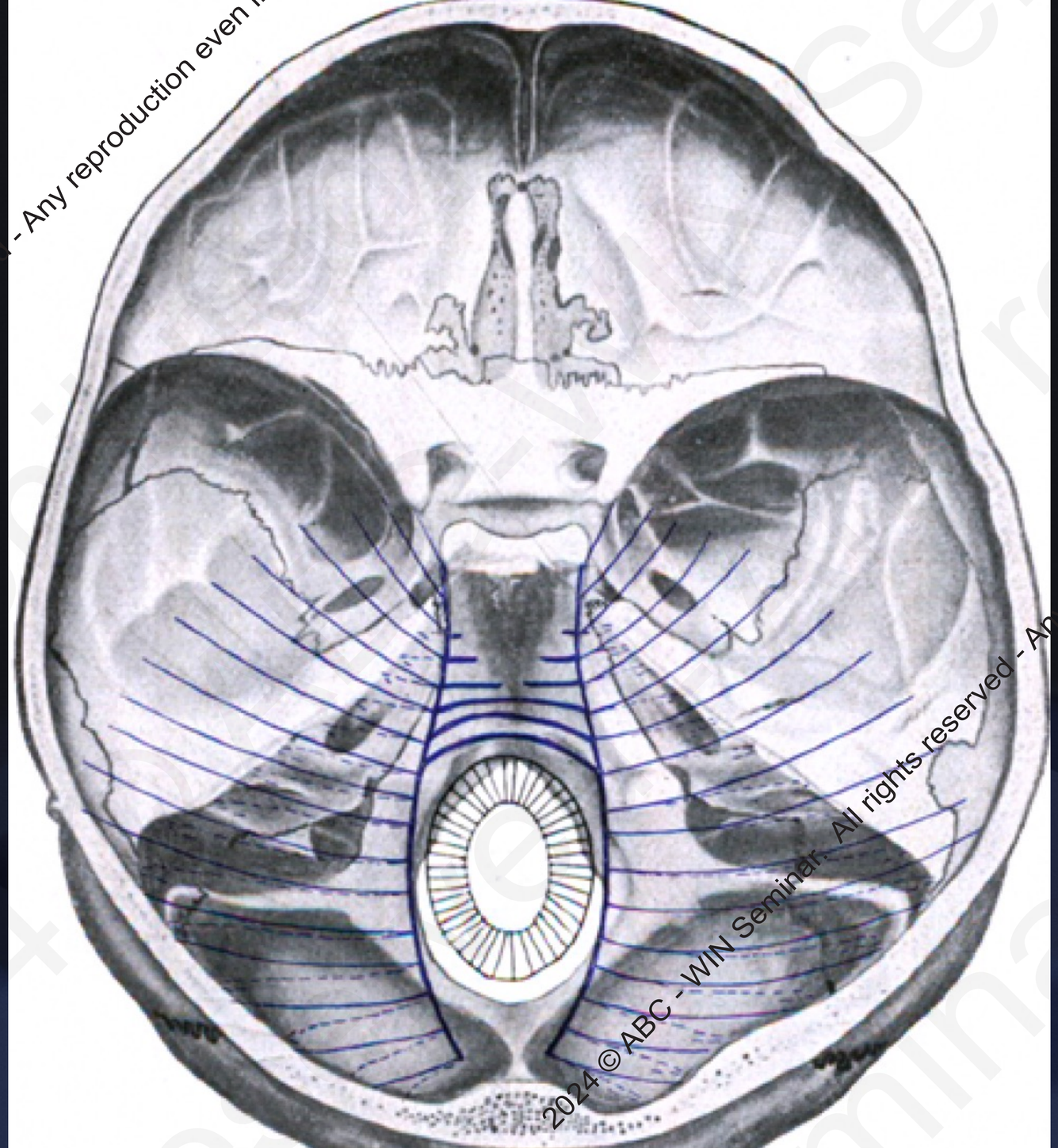
midbrain

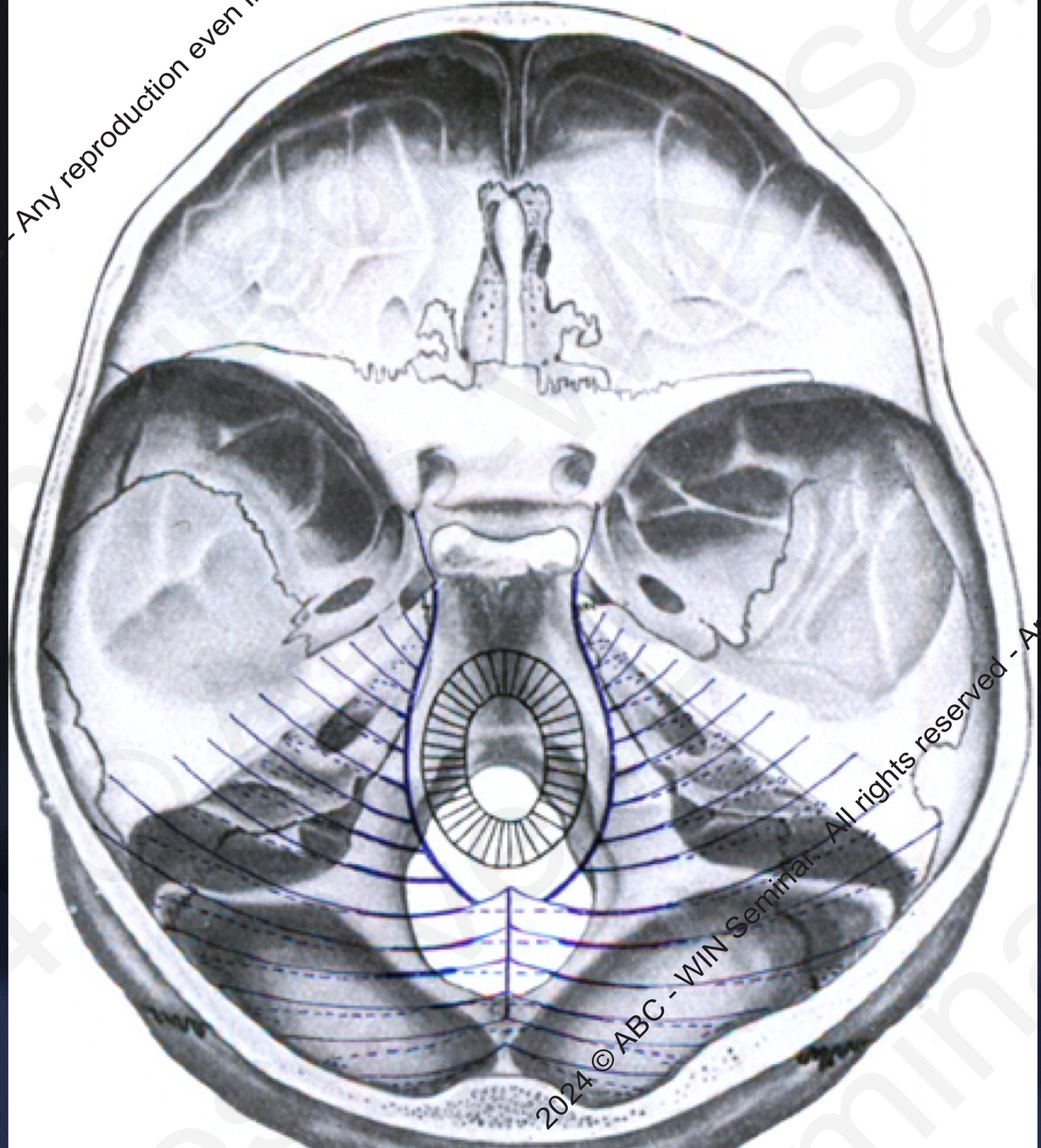
ventral anlage of the tentorium cerebelli

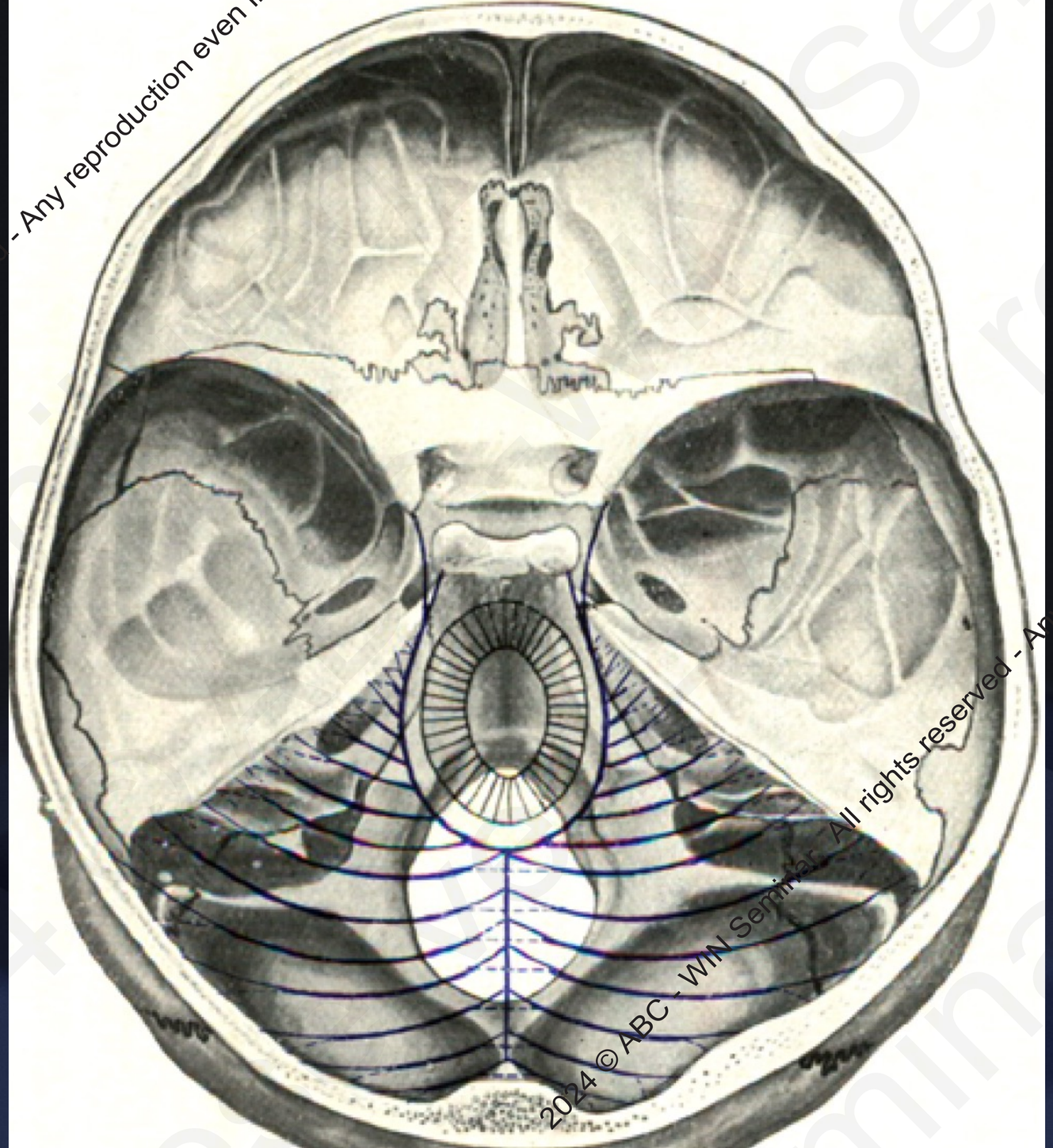
Markowski J: Zeitschrift Anat 94:395-439, 1931







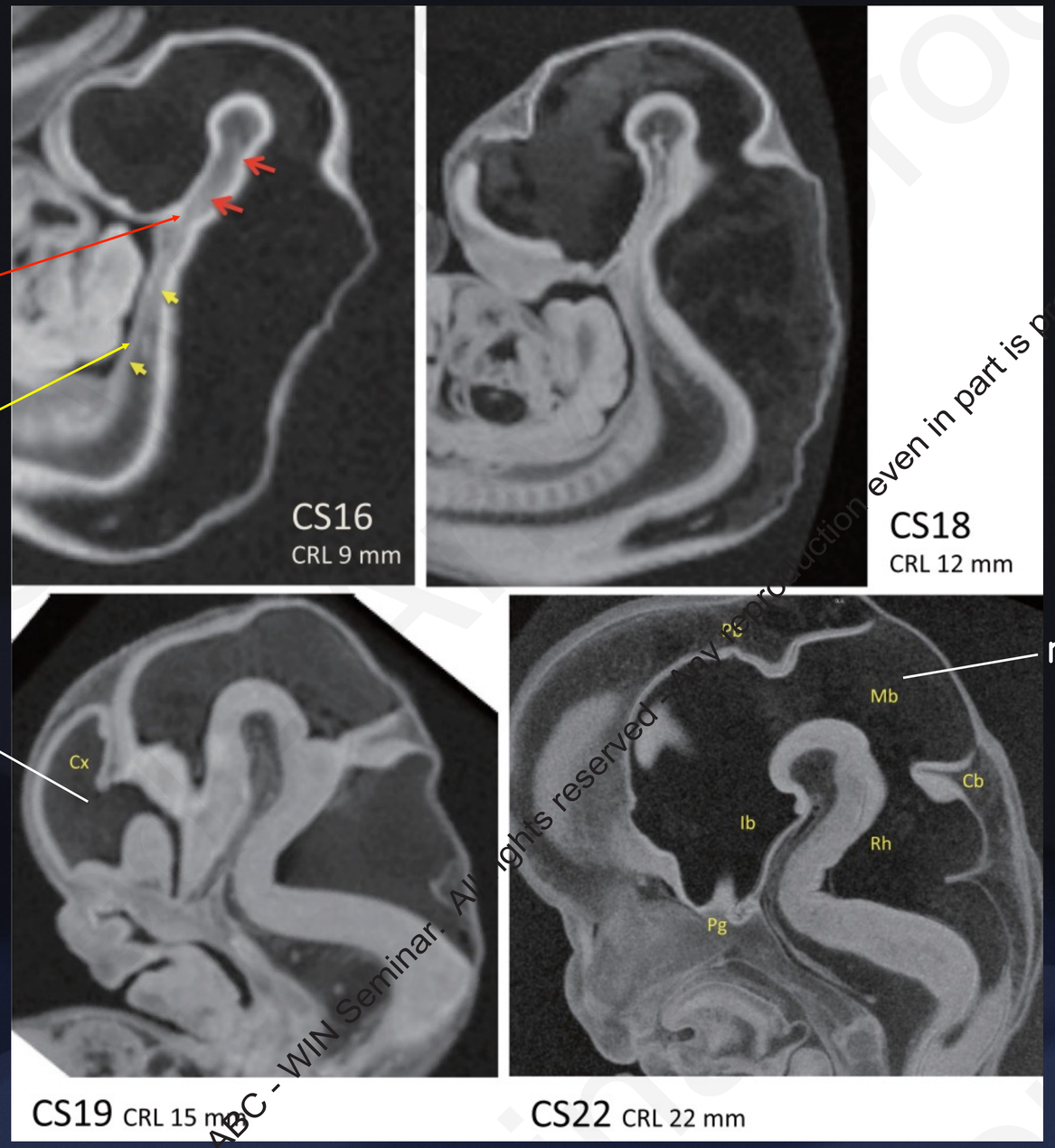




Median plains on MRI

Median (ventral) tentorium

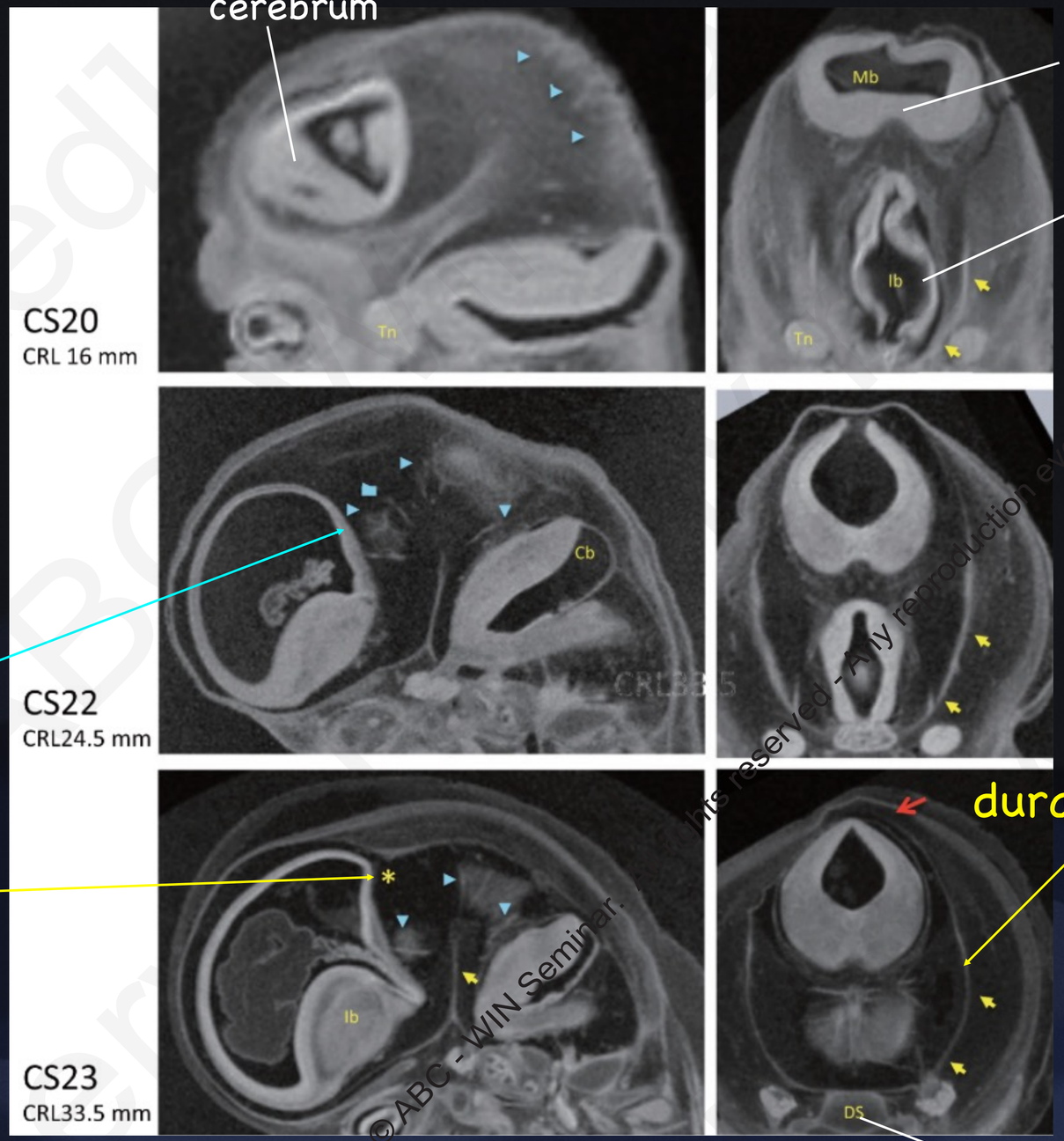
Notochordal cellular sheath



Embryological period

Mitsunari C, et al: Anat Rec 306:515-526, 2023

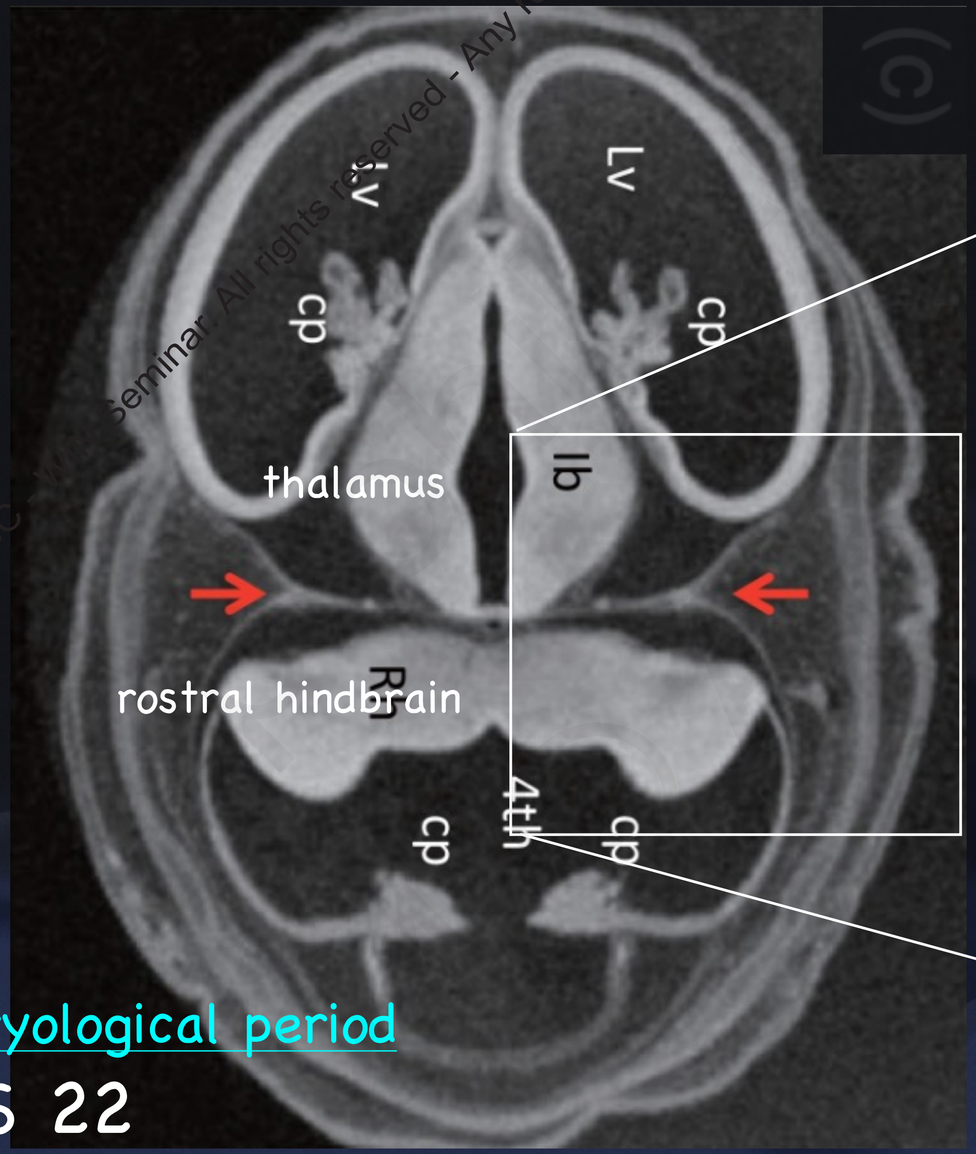
Parasagittal and Coronal plains on MRI

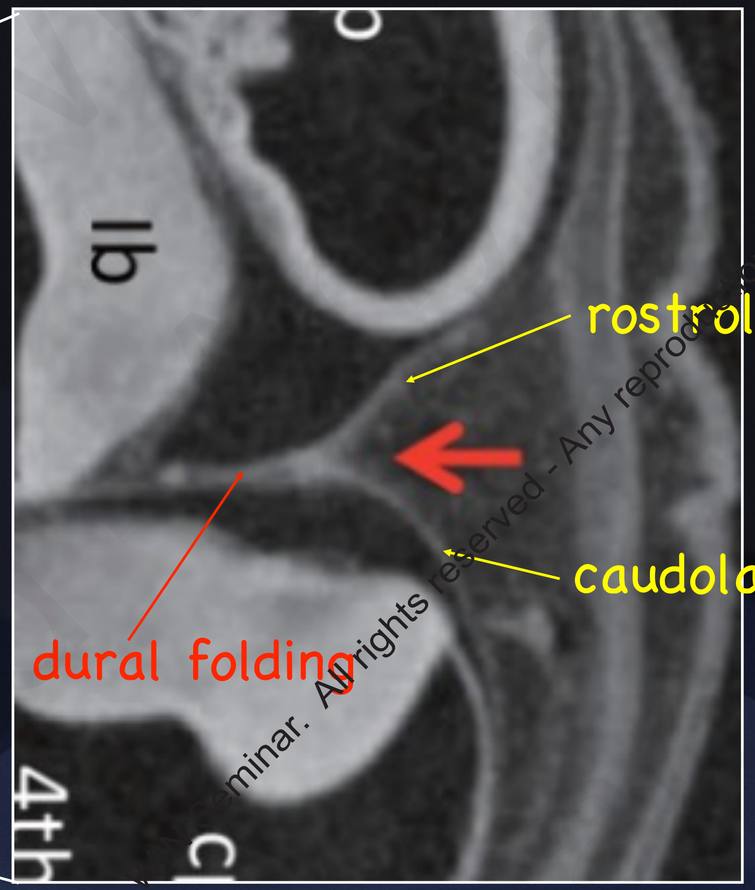


Embryological period

Mitsunari C, et al: Anat Rec 306:515-526, 2023

Axial plain on MRI





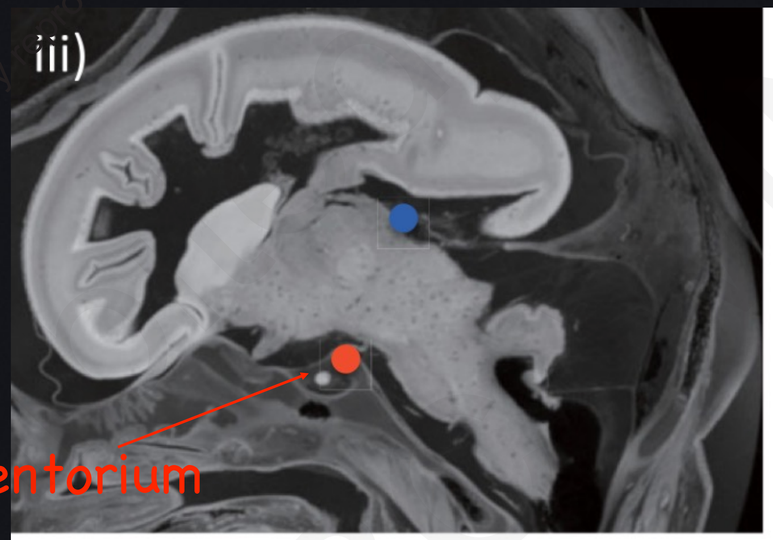
Embryological period

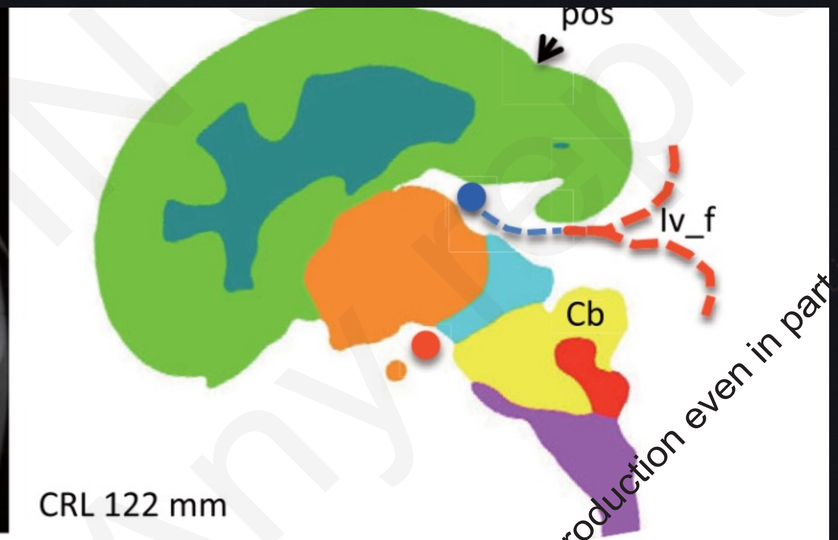
CS 22

Mitsunari C, et al: Anat Rec 306:515-526, 2023

Median and Parasagittal plains on MRI

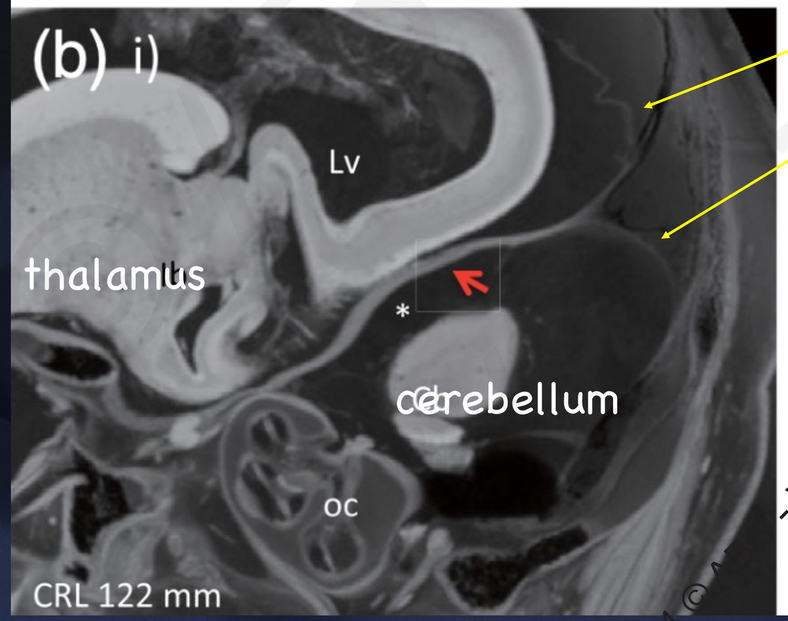
lack of medial (ventral) tentorium

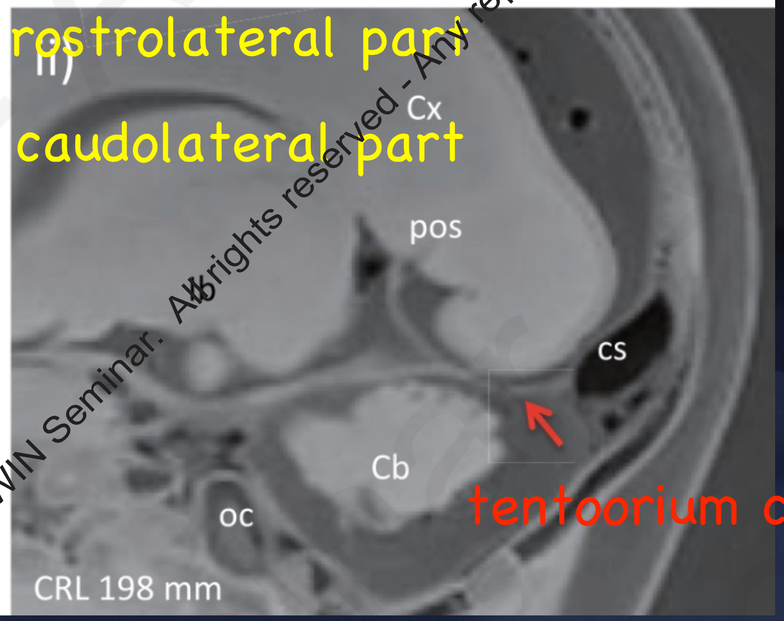




rostrolateral part

caudolateral part



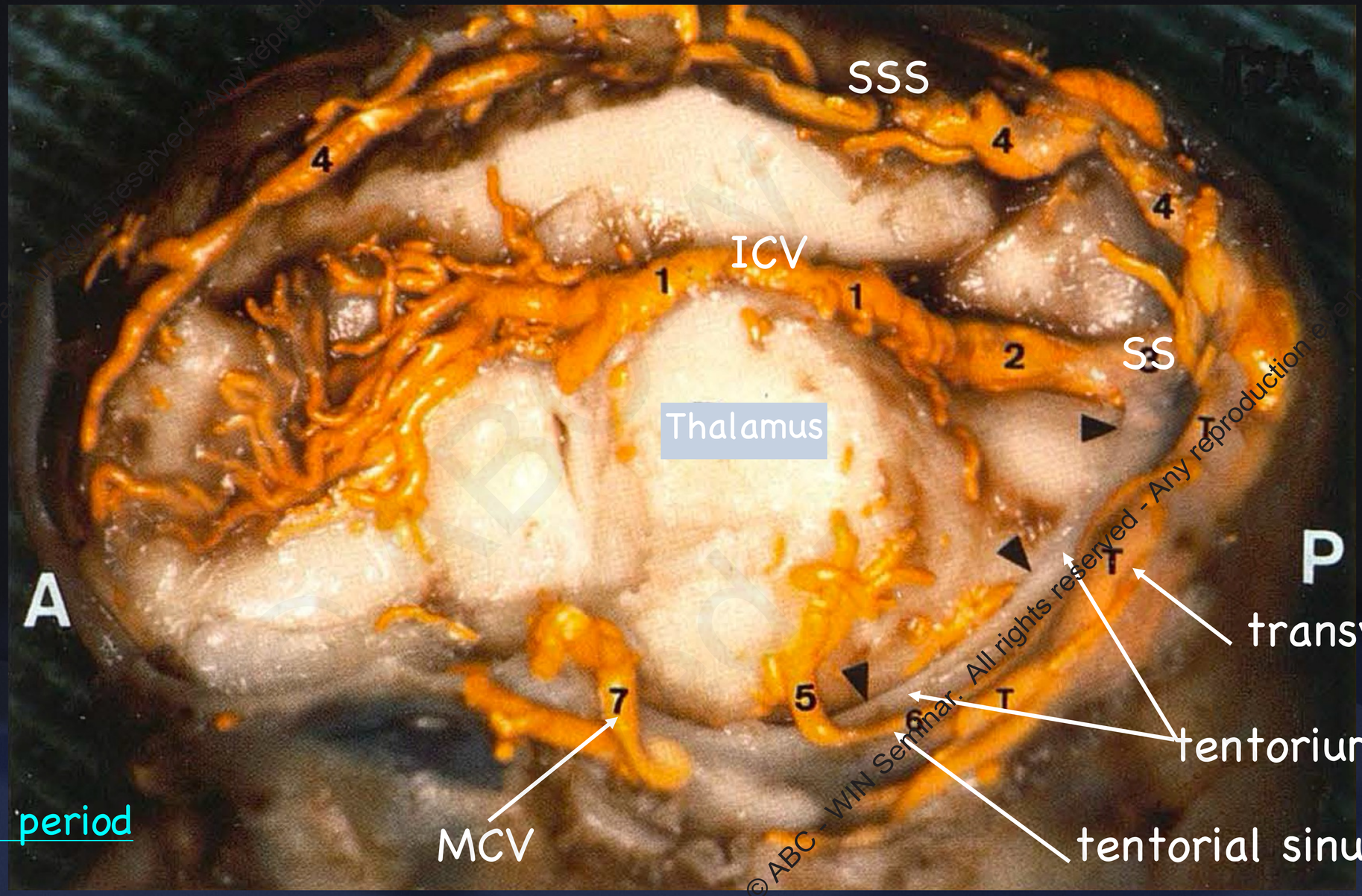


Middle fetal period

tentoorium cerebelli

Mitsunari C, et al: Anat Rec 306:515-526, 2023

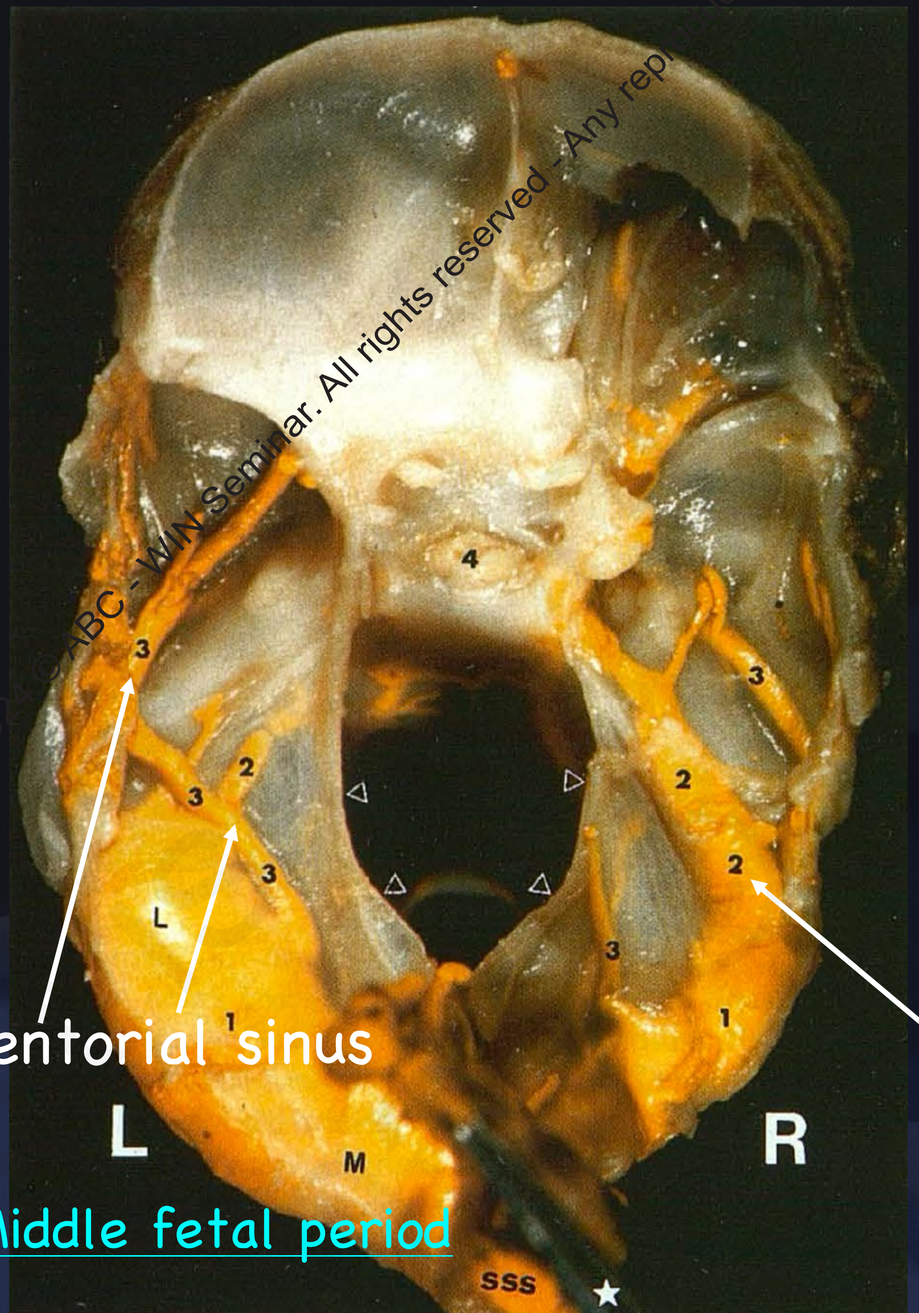
12-week-old fetus (65-mm crown-rump length)

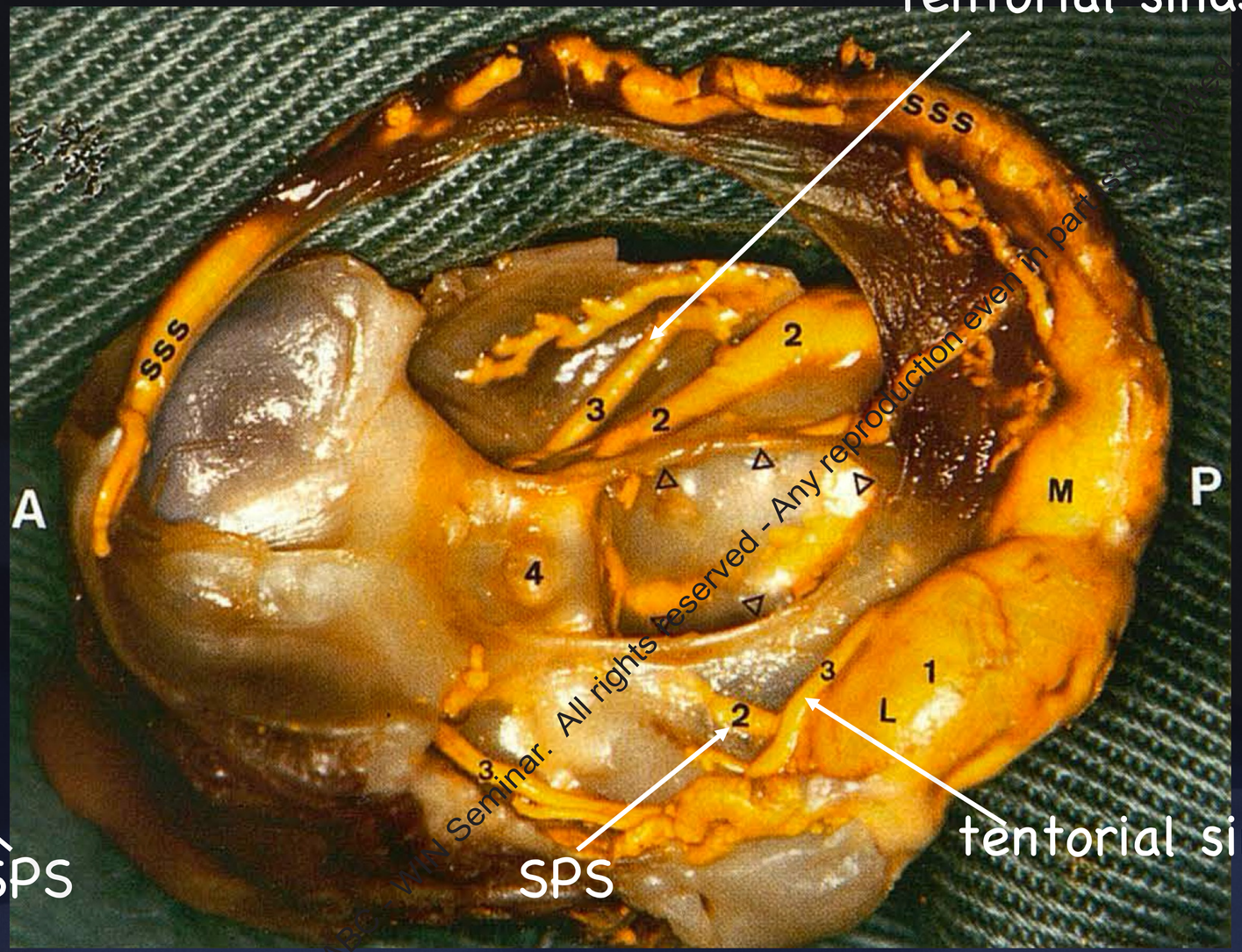


Early fetal period

Okudera T, et al: AJNR 15:1871-1883, 1994

A 16-week-old fetus (115-mm crown-rump length)

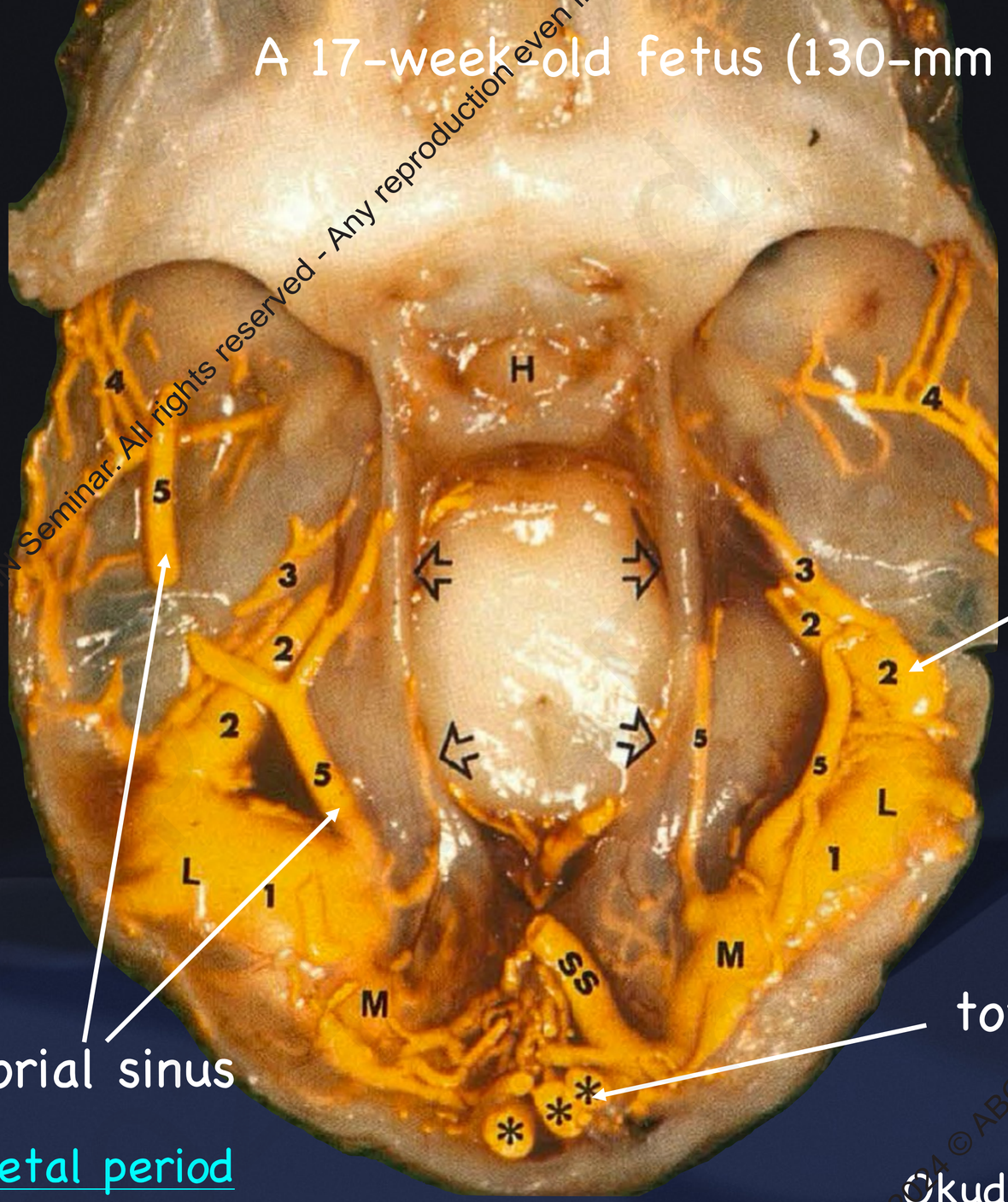




Middle fetal period

Okudera T, et al: AJNR 15:1871-1883, 1994

A 17-week-old fetus (130-mm crown-rump length)



SPS

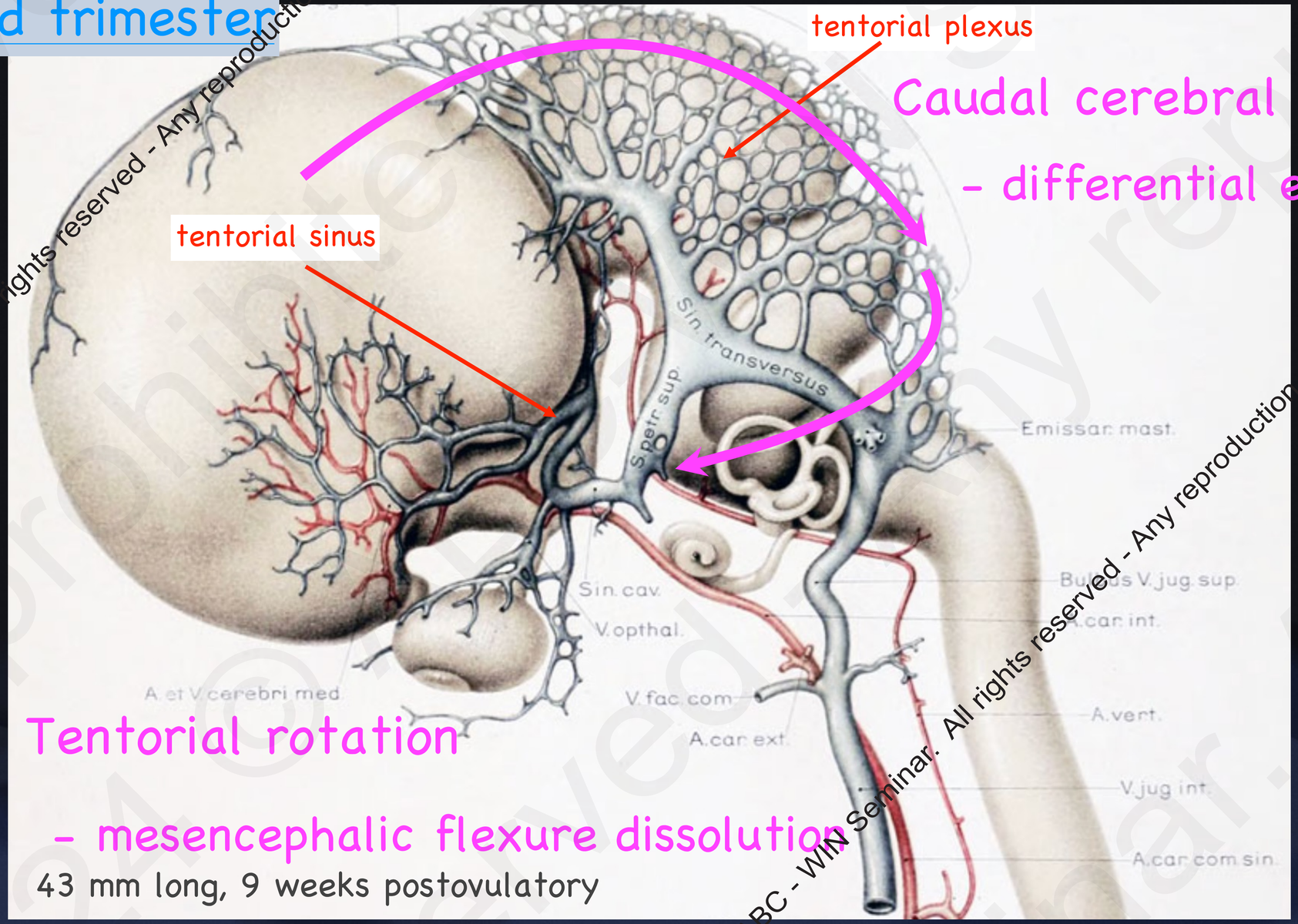
tentorial sinus

torcular (plexiform)

Middle fetal period

Okudera T, et al: AJNR 15:1871-1883, 1994

After second trimester



Caudal cerebral expansion

- differential encephalization

Tentorial rotation

- mesencephalic flexure dissolution

43 mm long, 9 weeks postovulatory

Streeter GL: Contrib Embryol, Carnegie Inst. 8:7-38, 1921

J. Anat. (2002) **200**, pp135–144

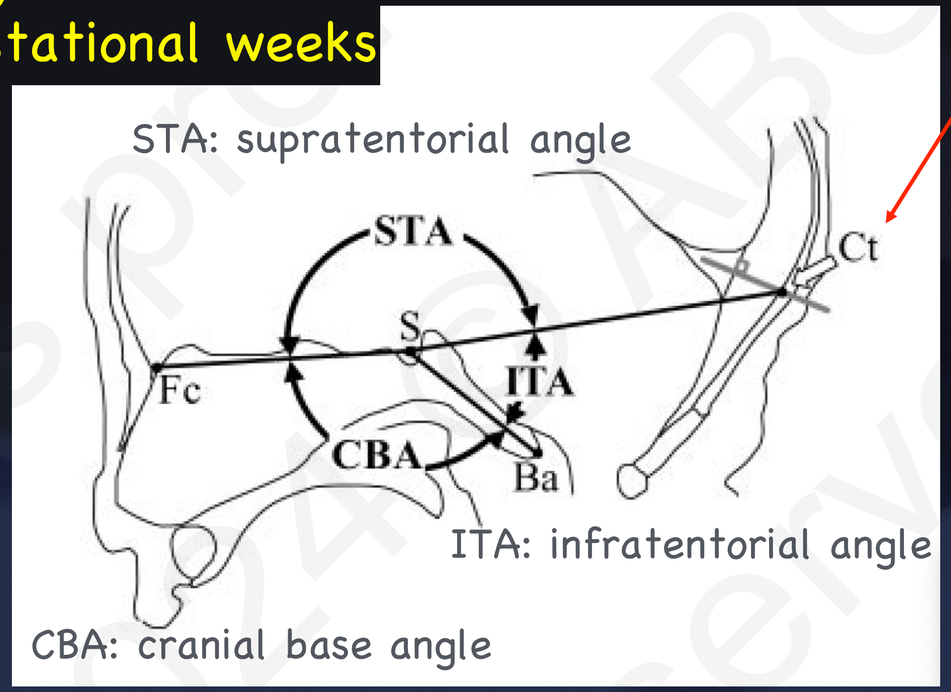
Differential regional brain growth and rotation of the prenatal human tentorium cerebelli

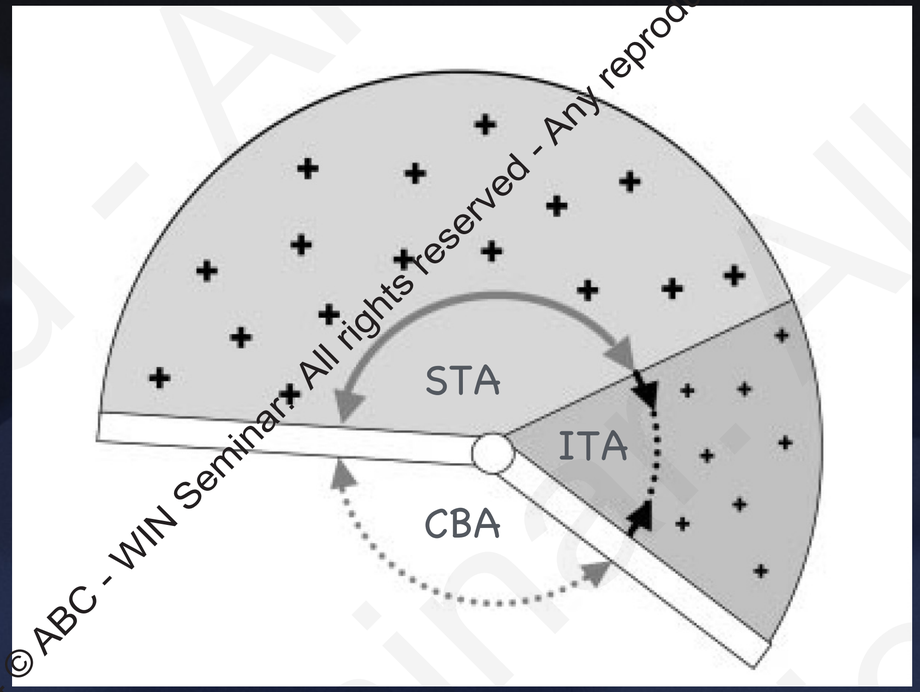
Nathan Jeffery

Evolutionary Anatomy Unit, Department Anatomy and Developmental Biology, University College London, Rockefeller Bld., University St., London WC1E 6JJ, UK

MR study: 46 fetuses
10-29 gestational weeks

Ct: calvarial attachment of tentorium,





F. Ceacum

IDE: index of differential encephalization = cerebellum volume / cerebrum volume

J. Anat. (2002) **200**, pp135–144

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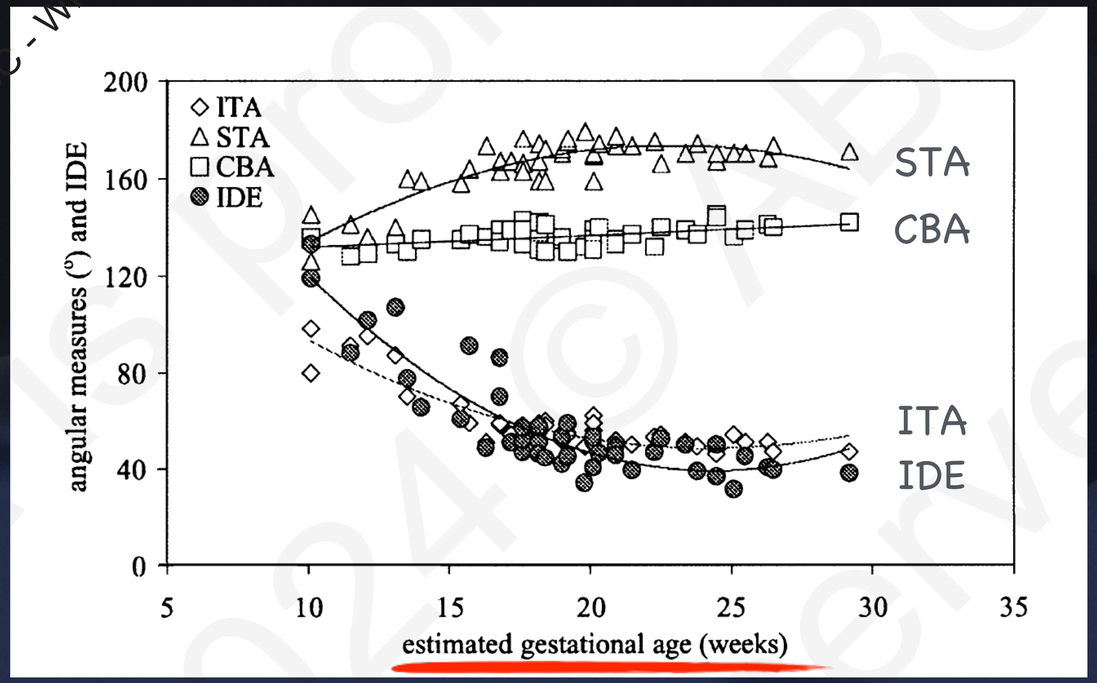
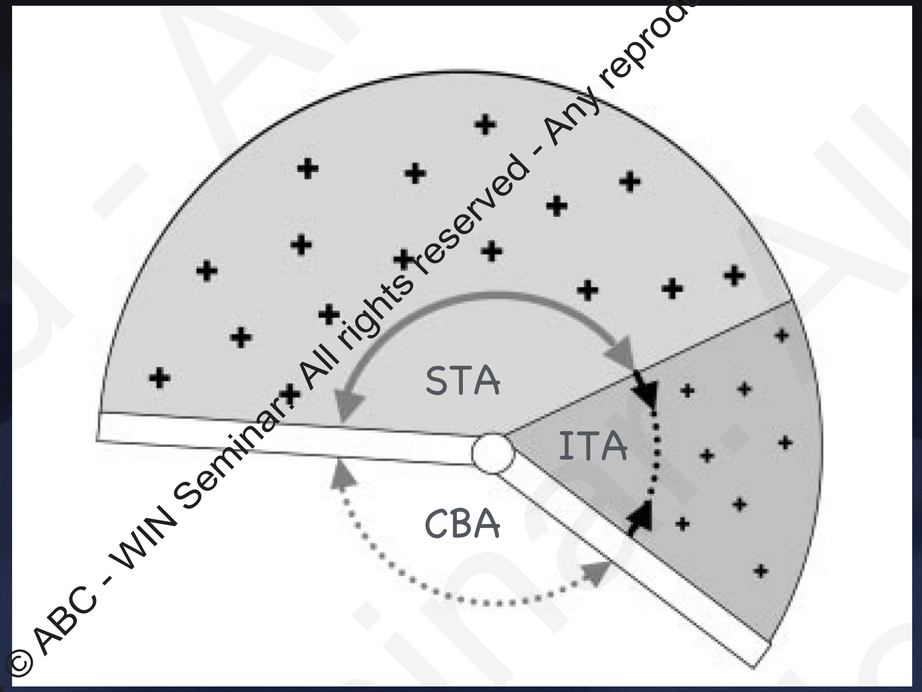
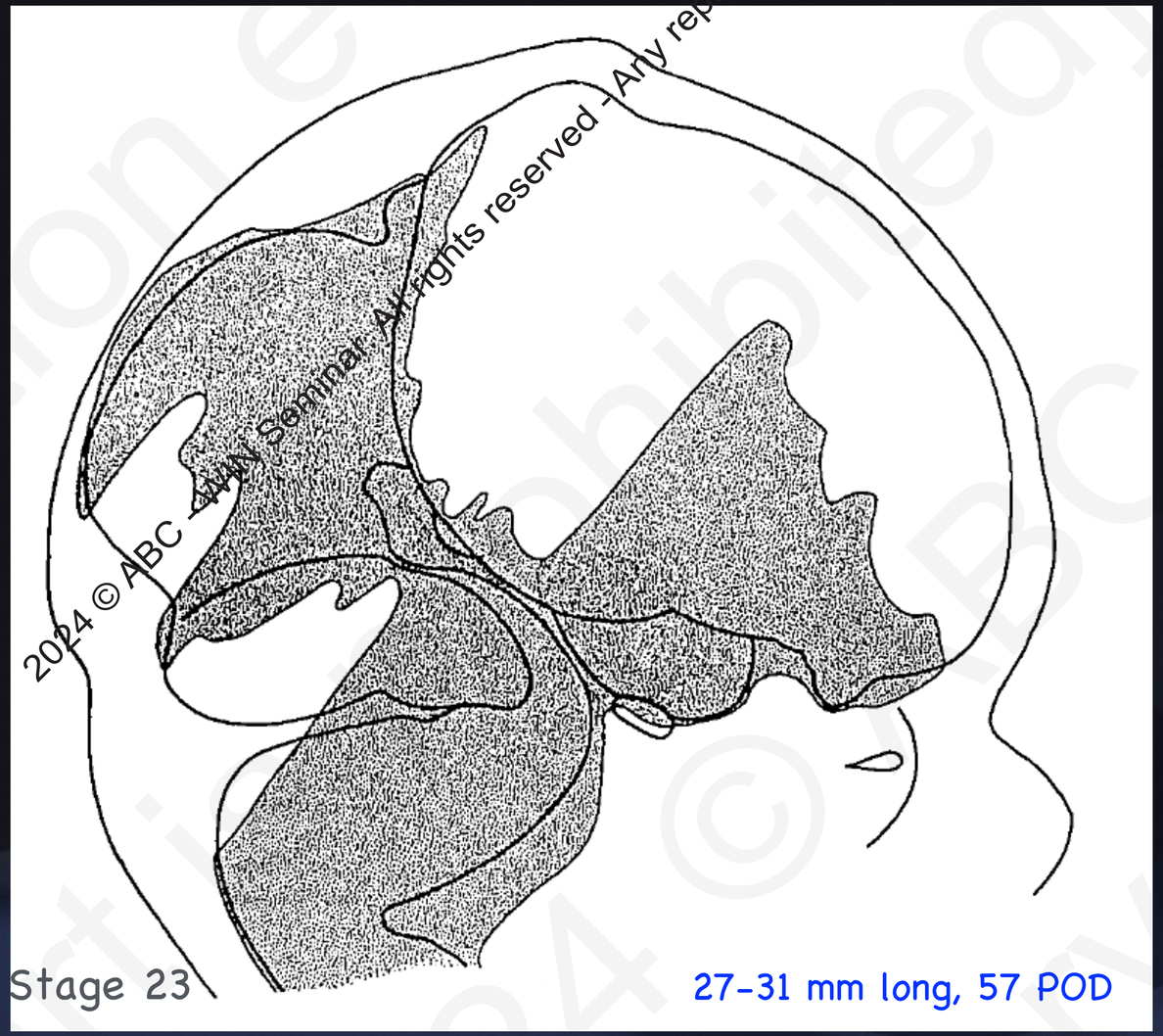
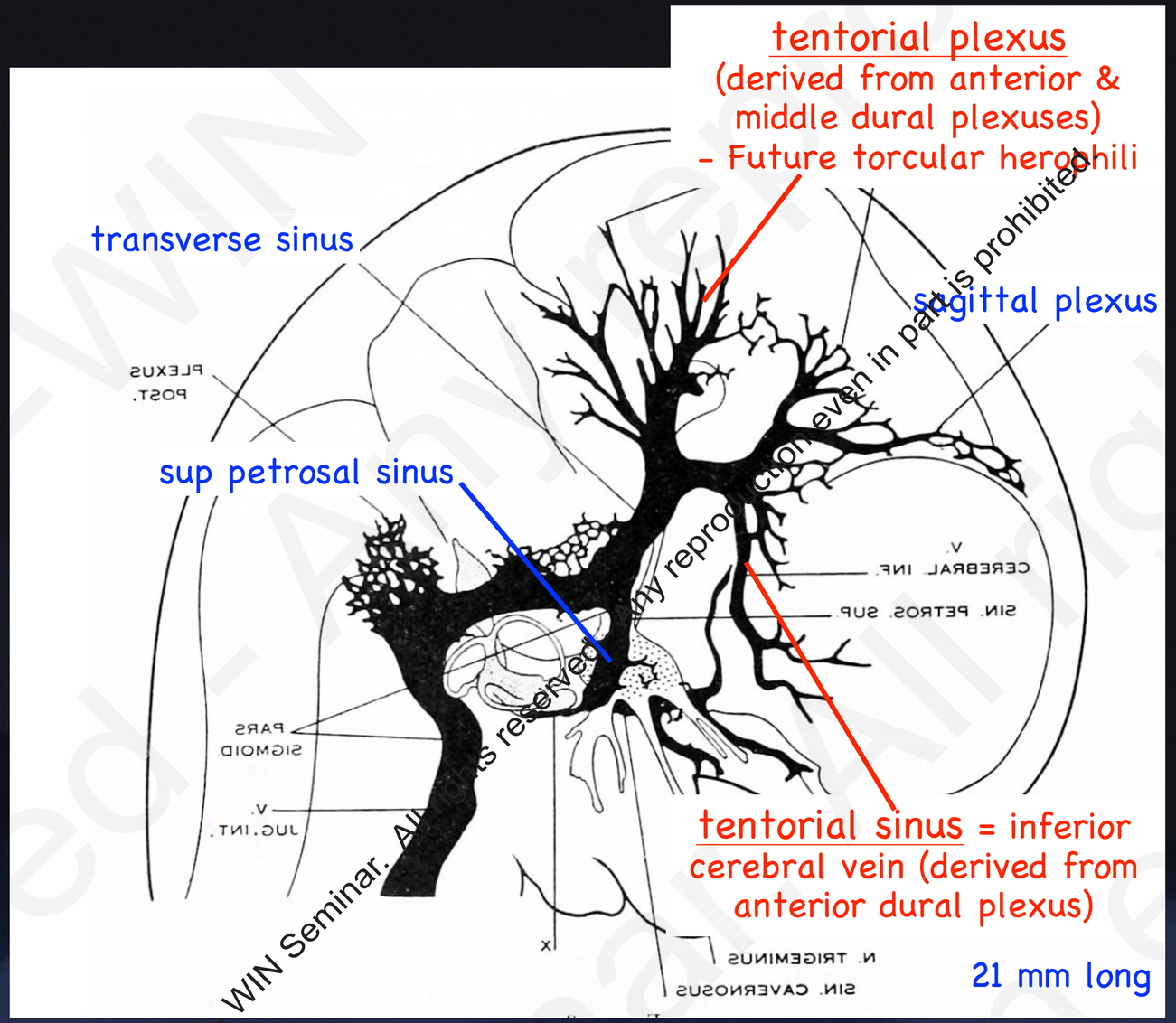




IDE: index of differential encephalization = cerebellum volume / cerebrum volume

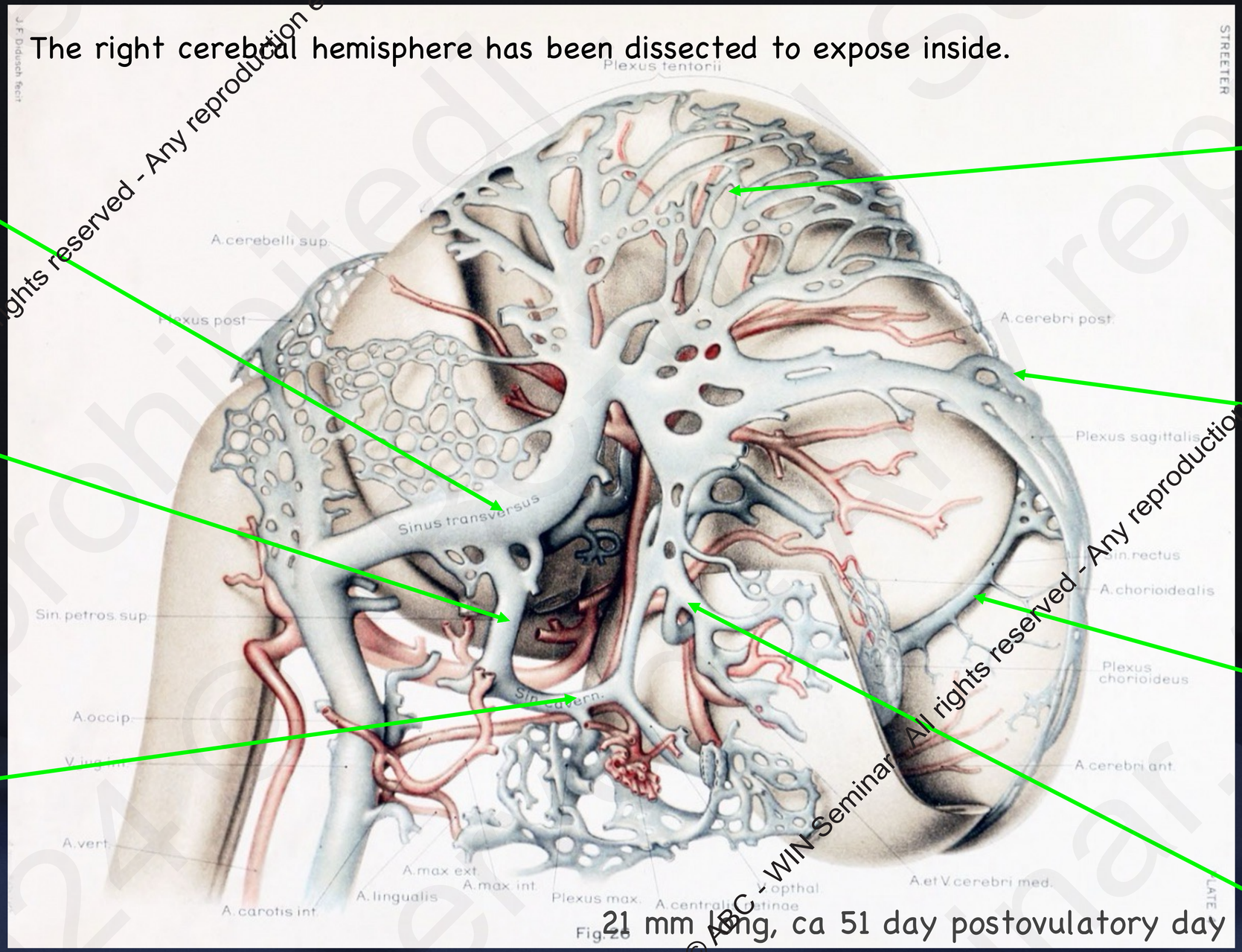




O'Rahilly R, et al: J Neuropathol Experi Neural 1986

Streeter GL: Am J Anat 1915

The right cerebral hemisphere has been dissected to expose inside.



21 mm long, ca 51 day postovulatory day

transverse sinus

superior petrosal sinus

cavernous sinus

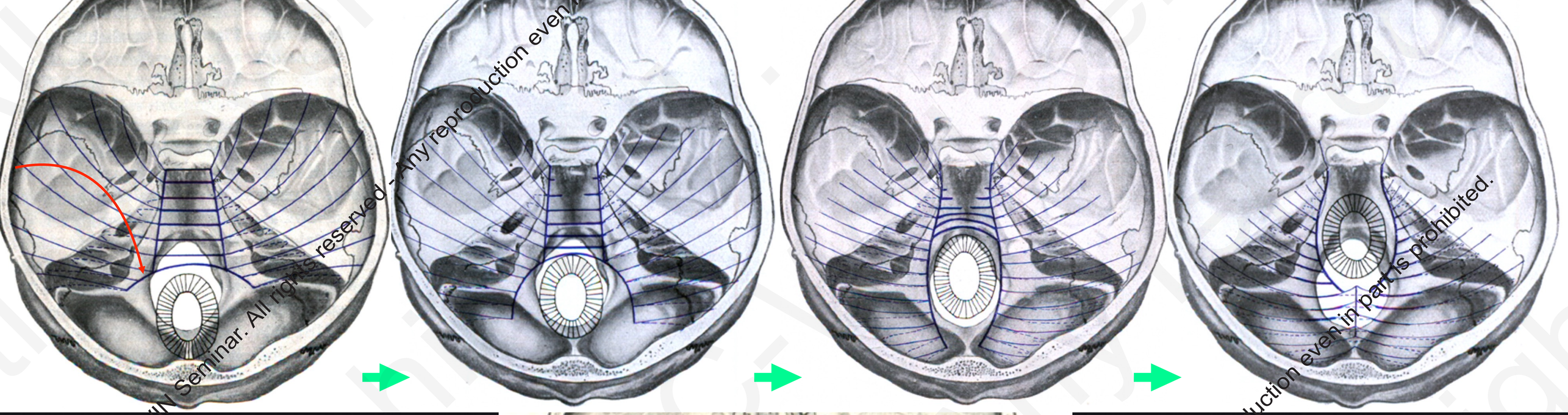
tentorial plexus

sagittal plexus

straight sinus

tentorial sinus

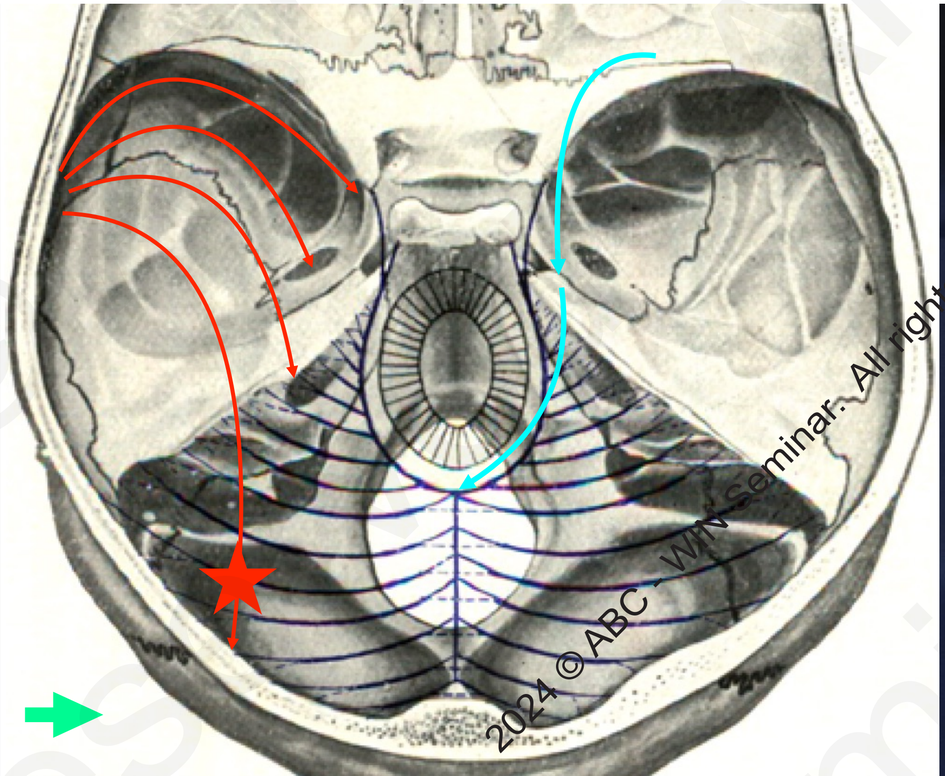
Streeter GL: Contrib Embryol, Carnegie Inst. 8:7-38, 1921



anterior dural plexus -
primitive tentorial sinus

Primitive tentorial sinus

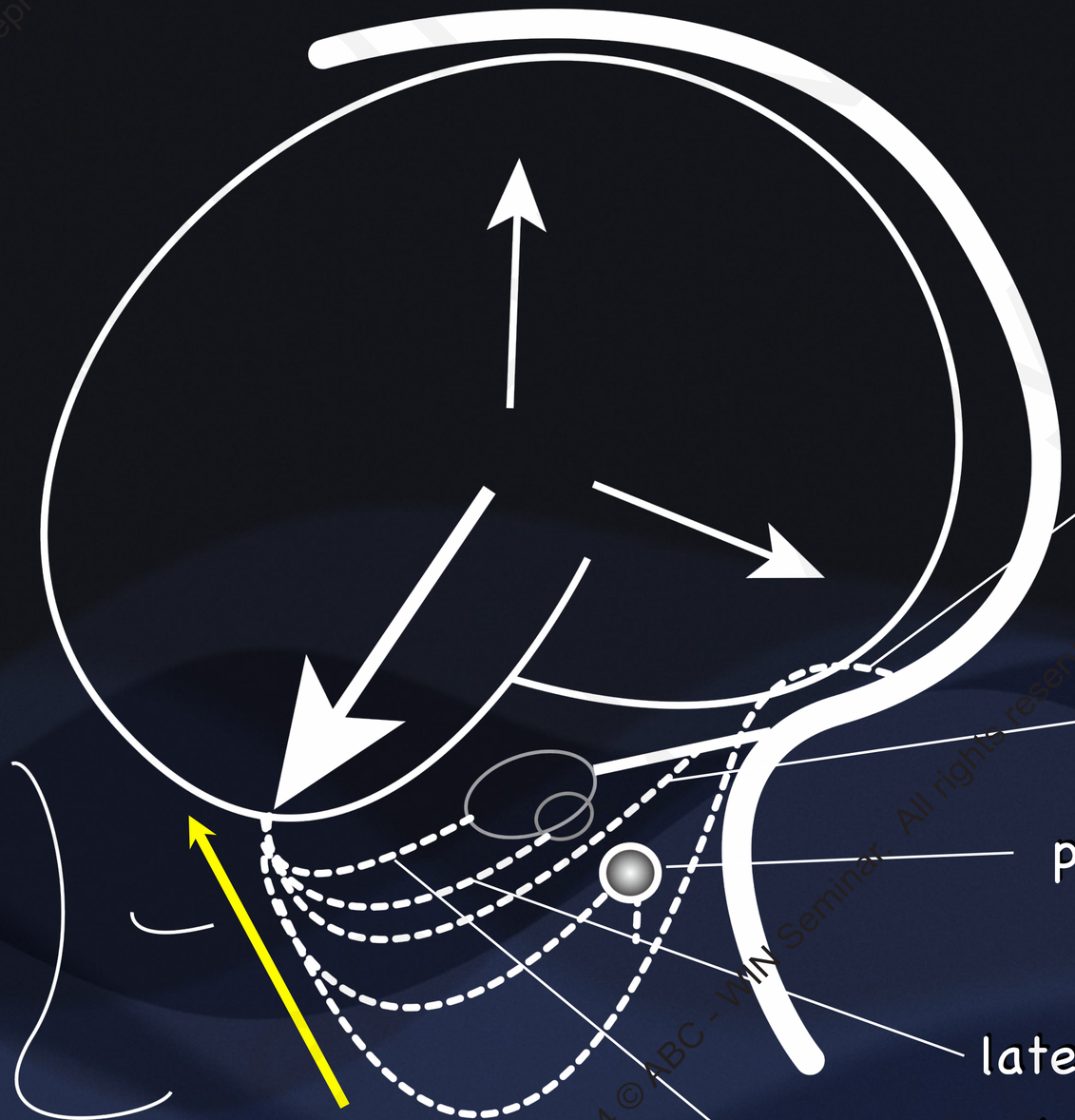
SMCV - possible drainages



basal vein of Rosenthal

Markowski J: Zeitschrift Anat 94:395-439, 1931

Development of the primitive tentorial sinus



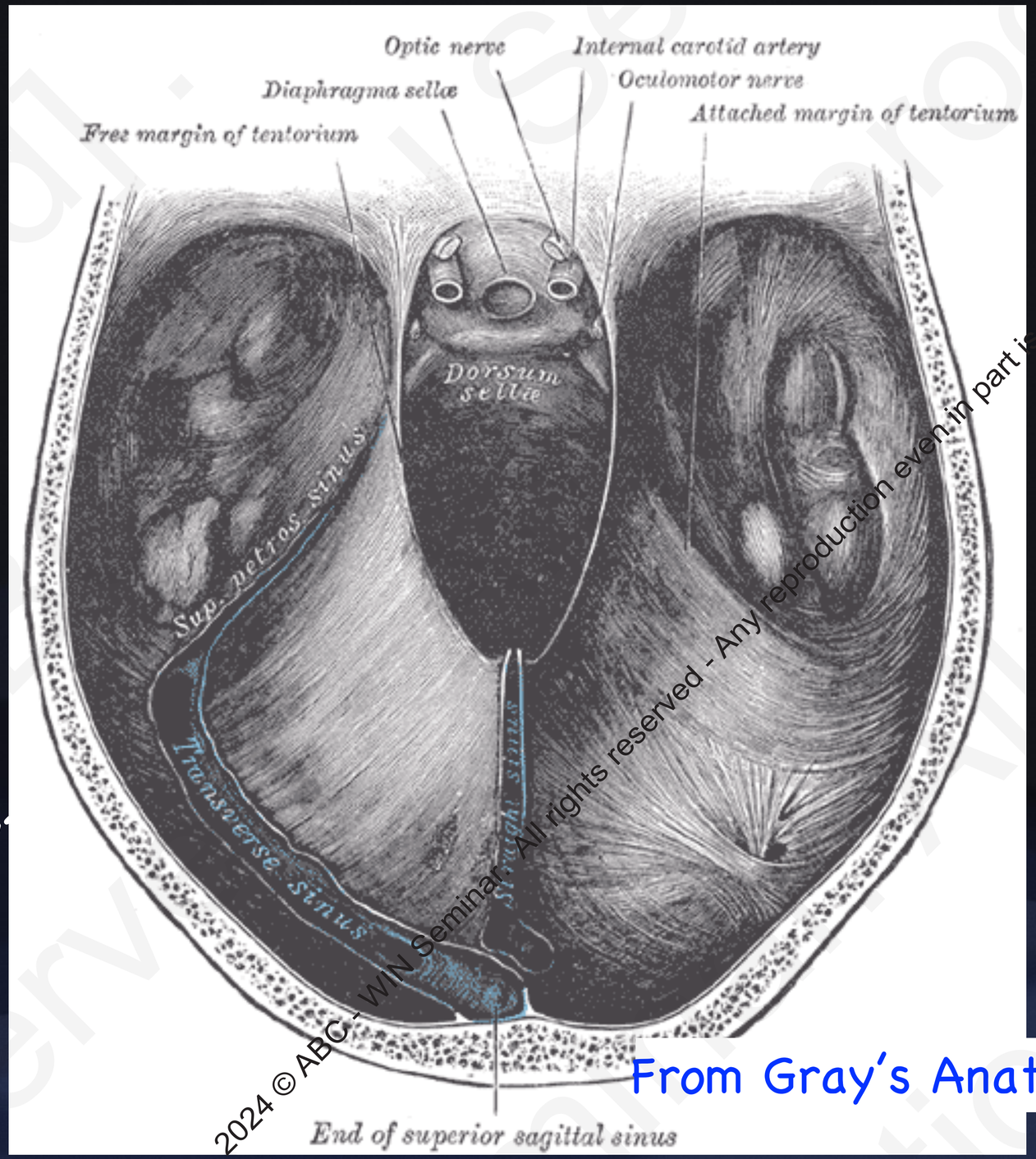
phylogenic ascent

Tentorium Cerebelli

What is the role?

Why is it necessary?

Who has it, phylogenetically?



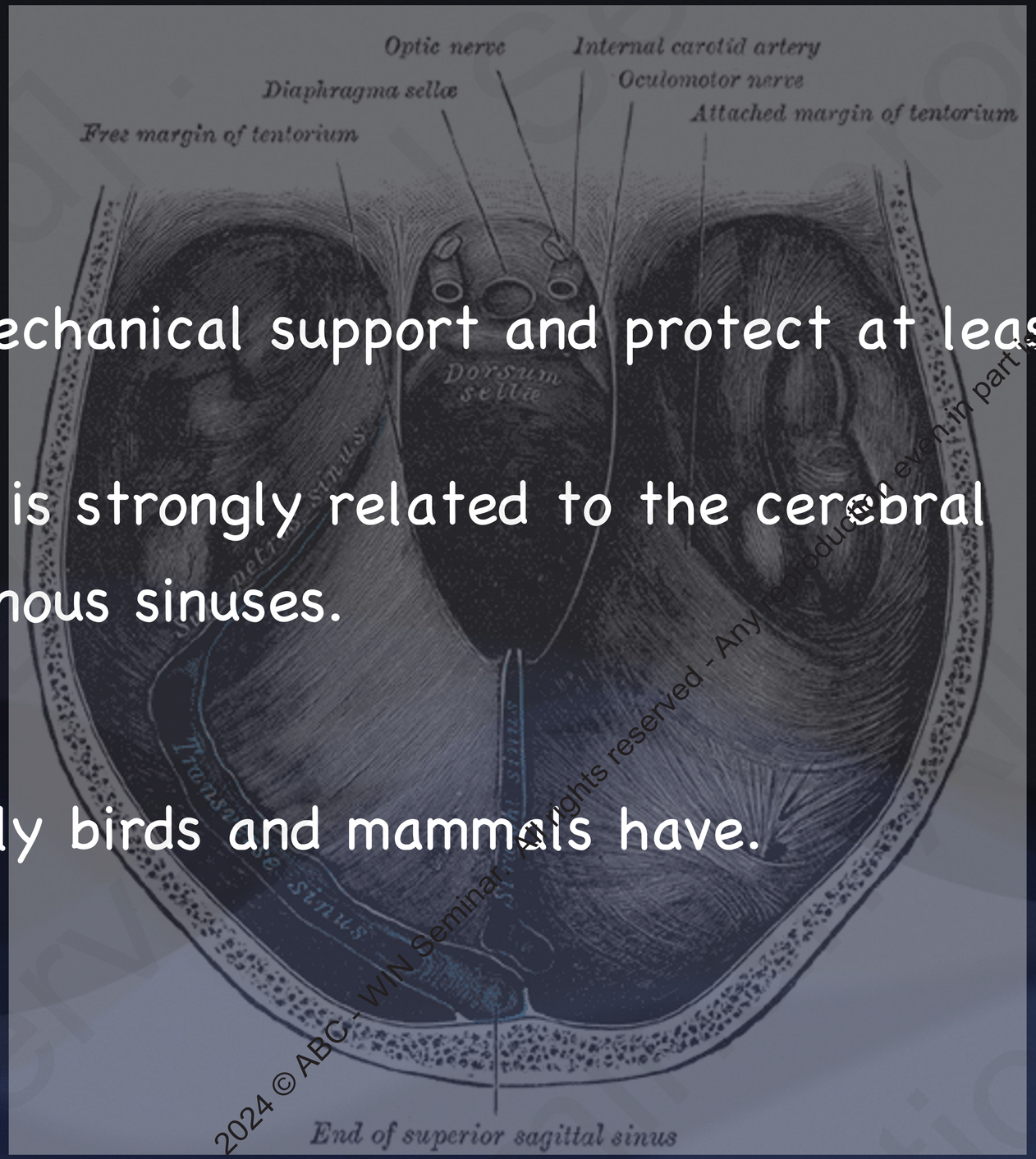
From Gray's Anatomy

Tentorium Cerebelli

What is the role? - mechanical support and protect at least

Why is it necessary? - It is strongly related to the cerebral venous sinuses.

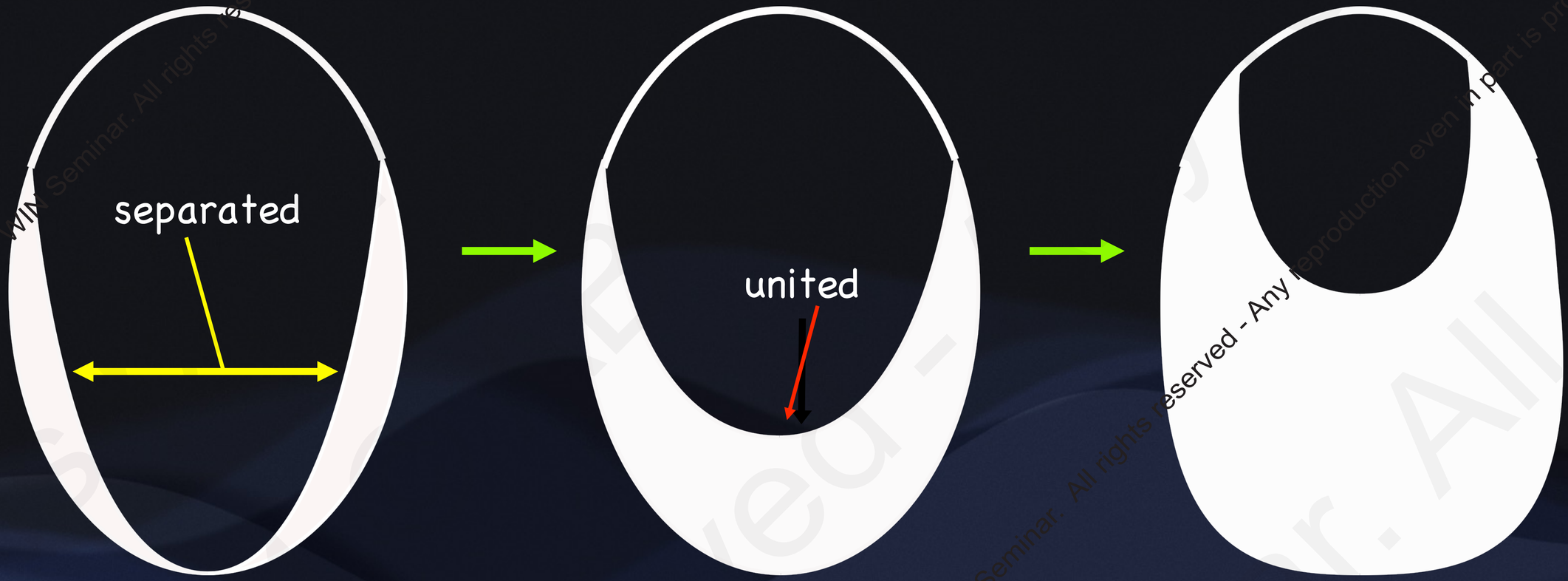
Who has it? - Only birds and mammals have.



Ontogeny of the tentorium cerebelli

Klintworth GK: The comparative anatomy and phylogeny of the tentorium cerebelli. Anat Rec 160:635-42, 1968

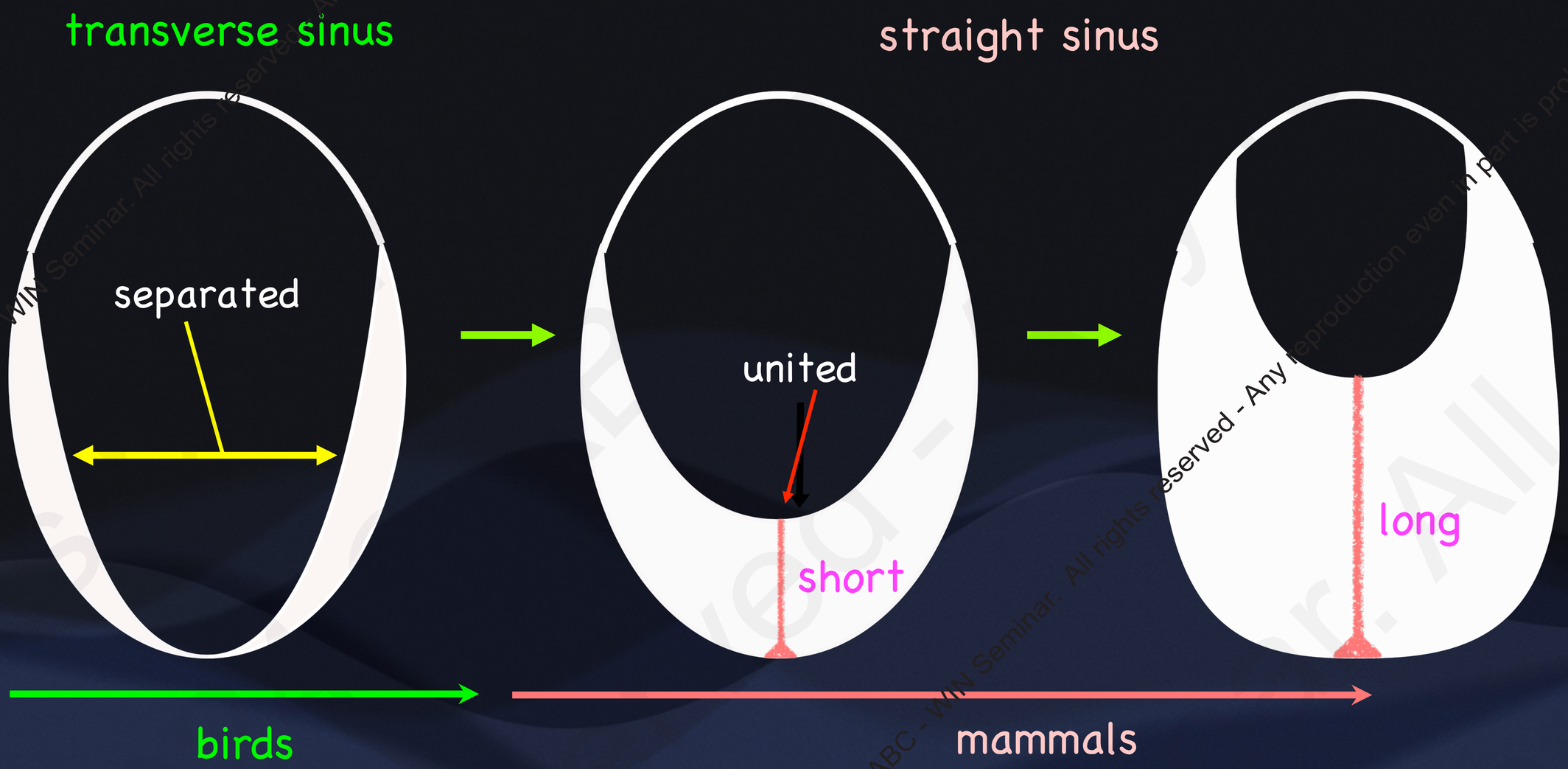
Ontogeny of the tentorium cerebelli



primitive type intermediate type fully developed type

Klintworth GK: The comparative anatomy and phylogeny of the tentorium cerebelli. Anat Rec 160:635-42, 1968

Phylogeny of the tentorium cerebelli



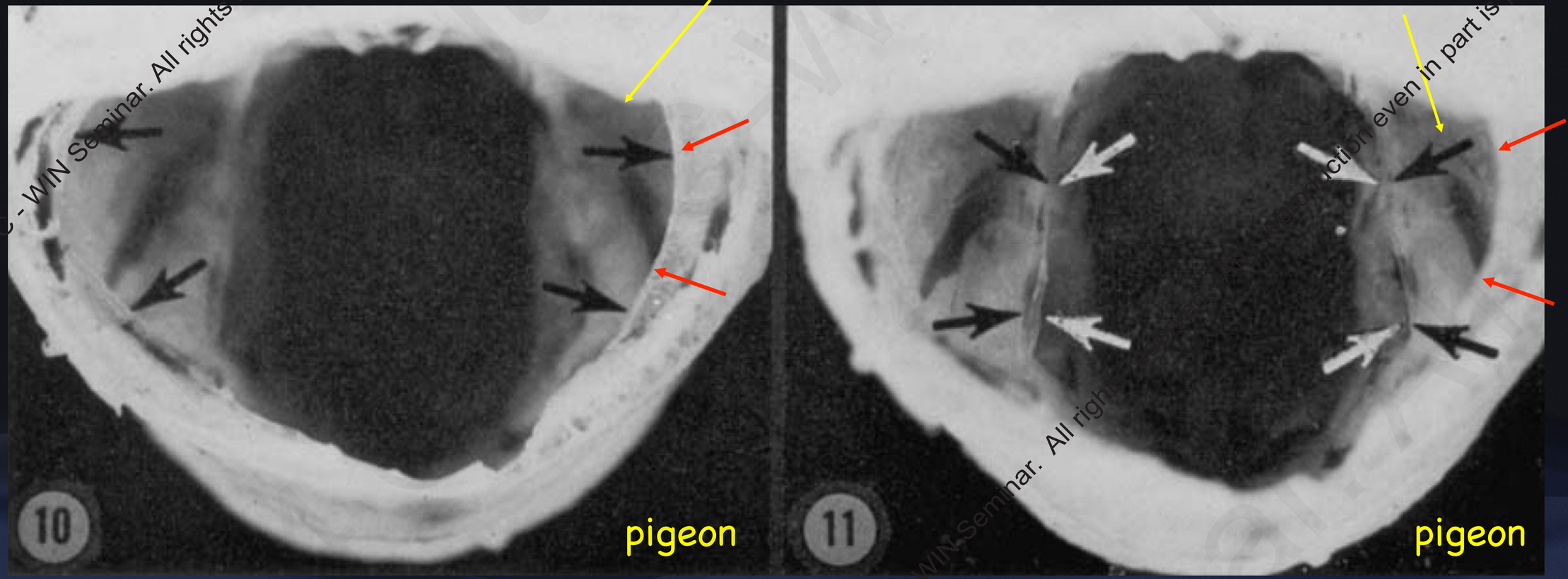
Klintworth GK: The comparative anatomy and phylogeny of the tentorium cerebelli. Anat Rec 160:635-42, 1968

dural partition

dural septa found in some birds

lesser wing

petrous temporal bone

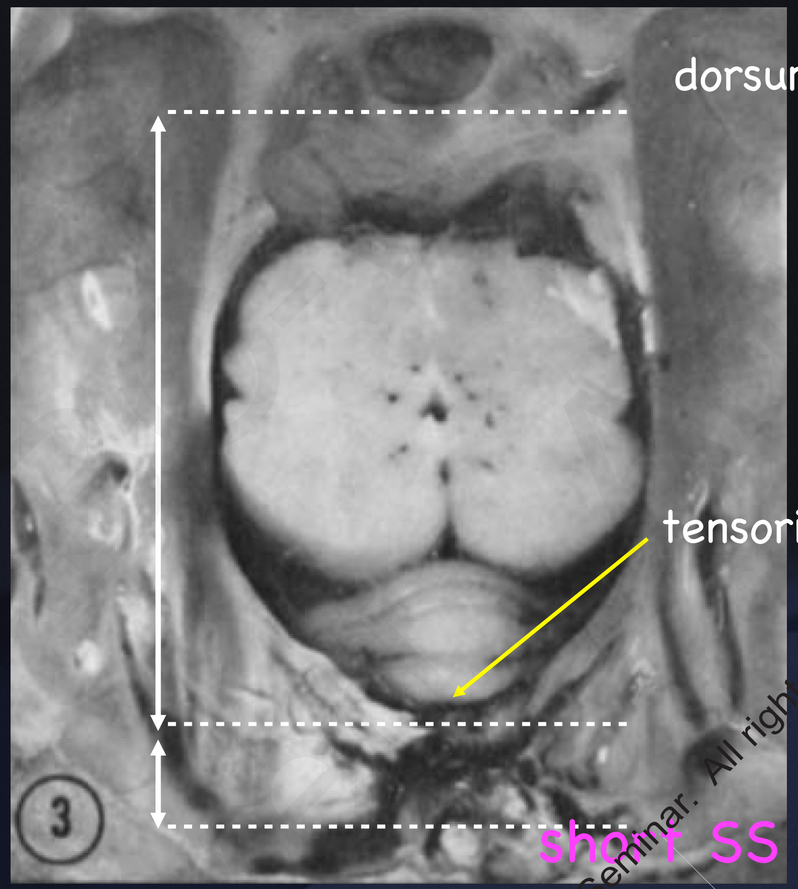


Klintworth GK: The comparative anatomy and phylogeny of the tentorium cerebelli. Anat Rec 160:635-42, 1968

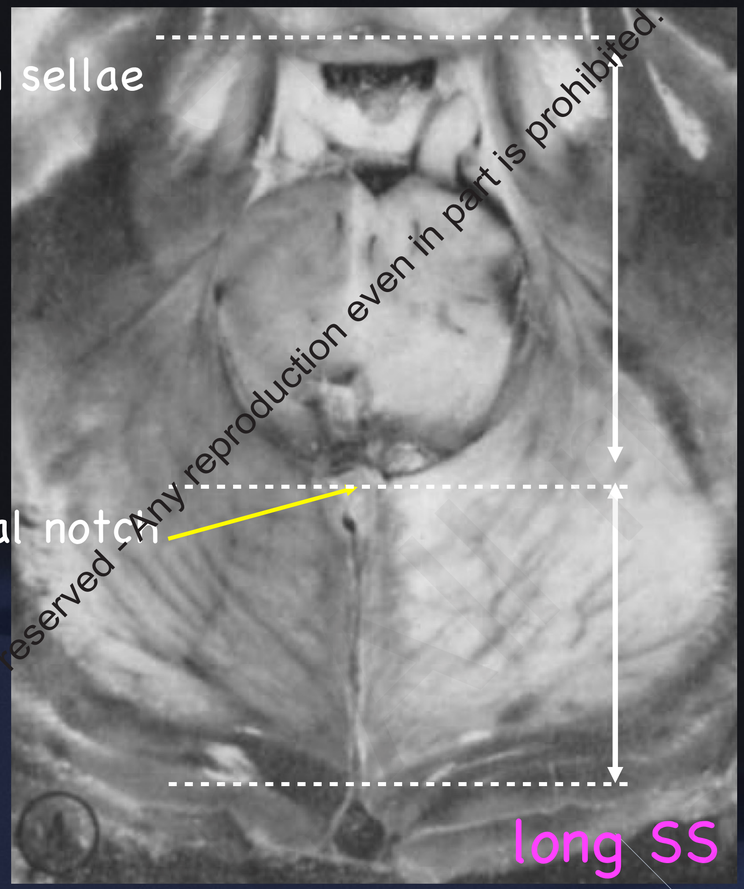
tentorium cerebelli

symmetrical dural partition

Opossum



Goat



Rhesus monkey

Klintworth GK: The comparative anatomy and phylogeny of the tentorium cerebelli. Anat Rec 160:635-42, 1968

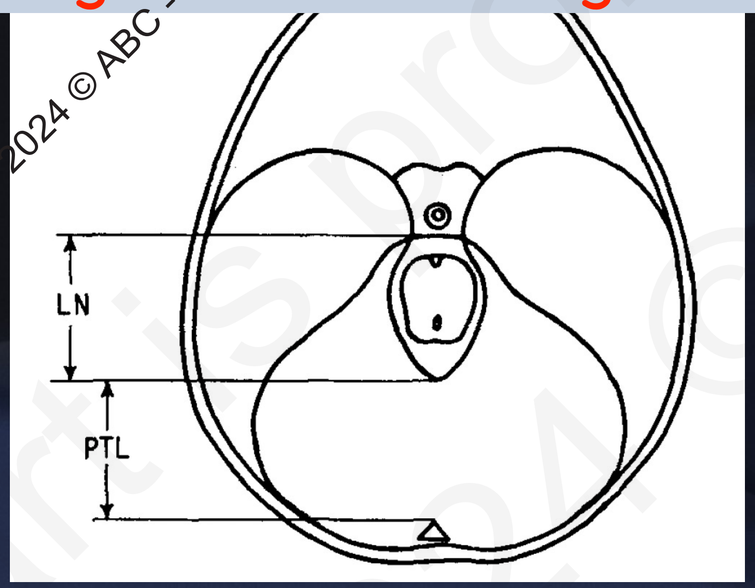
Tentorial index

= PTL/LN x 100

LN: notch length

PTL: posterior tentorial length

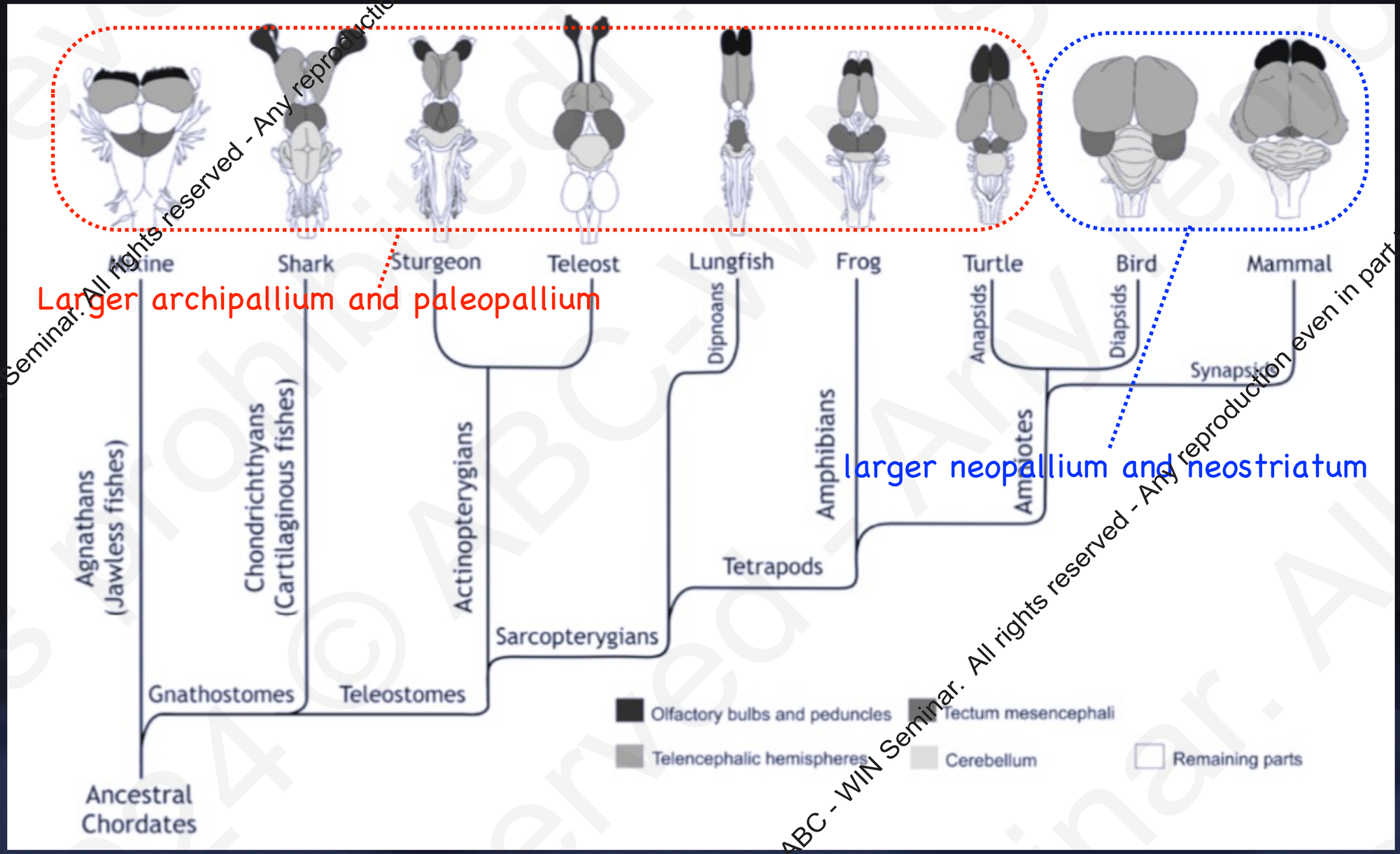
Large TI means long straight sinus.



Animal		TI
Order Primates:		
Suborder Anthropoidea:	Hussar monkey (*Erythrocebus patas*)	87
	Man (*Homo sapiens*)	52–131 (76) [1]
	Rhesus monkey (*Macaca mulatta*)	115
	Squirrel monkey (*Saimiri sciurea*)	122
	Vervet monkey (*Cercopithecus aethiops*)	68–143 (95)
	Western baboon (*Chaeropithecus papio*)	100
Suborder Lemuroidea:	Angwanatibo (*Arctocebus calabarensis*)	14
Order Carnivora:		
Suborder Fissipedia:	Domestic cat (*Felis domestica*)	50
	Domestic dog (*Canis familiaris*)	61
	Mink (*Mustela vison*)	50
Order Artiodactyla:		
Suborder Ruminantia:	Domestic goat (*Capra hircus*)	11
	Domestic swine (*Sus scrofa*)	17
	Sheep (*Ovis aries*)	17
	White-tailed deer (*Odocoileus virginianus*)	13
Order Chiroptera:	Evening bat (*Nycticeius humeralis*)	0
Order Cetacea:	Pacific bottle nose dolphin (*Tursiops gilli*)	63
	Pacific common dolphin (*Delphinys bairdi*)	66
Order Rodentia:		
Suborder Hystricomorpha:	Guinea pig (*Cavia porcellus*)	0
Suborder Myomorpha:	Gerbil (*Gerbillus paeba*)	0
	Golden hamster (*Mesocricetus auratus*)	0
	House mouse (*Mus musculus*)	0
	White rat (*Rattus norvegicus albinus*)	0
Order Lagomorpha:	Rabbit (*Oryctolagus cuniculus*)	7
Order Marsupialia:	Opossum (*Didelphus virginiana*)	0
	Wallaby (*Marcopus brownii*)	19

Klintworth GK: The comparative anatomy and phylogeny of the tentorium cerebelli. Anat Rec 160:635-42, 1968

Fish ⟶ Amphibians Reptiles Aves Mammals

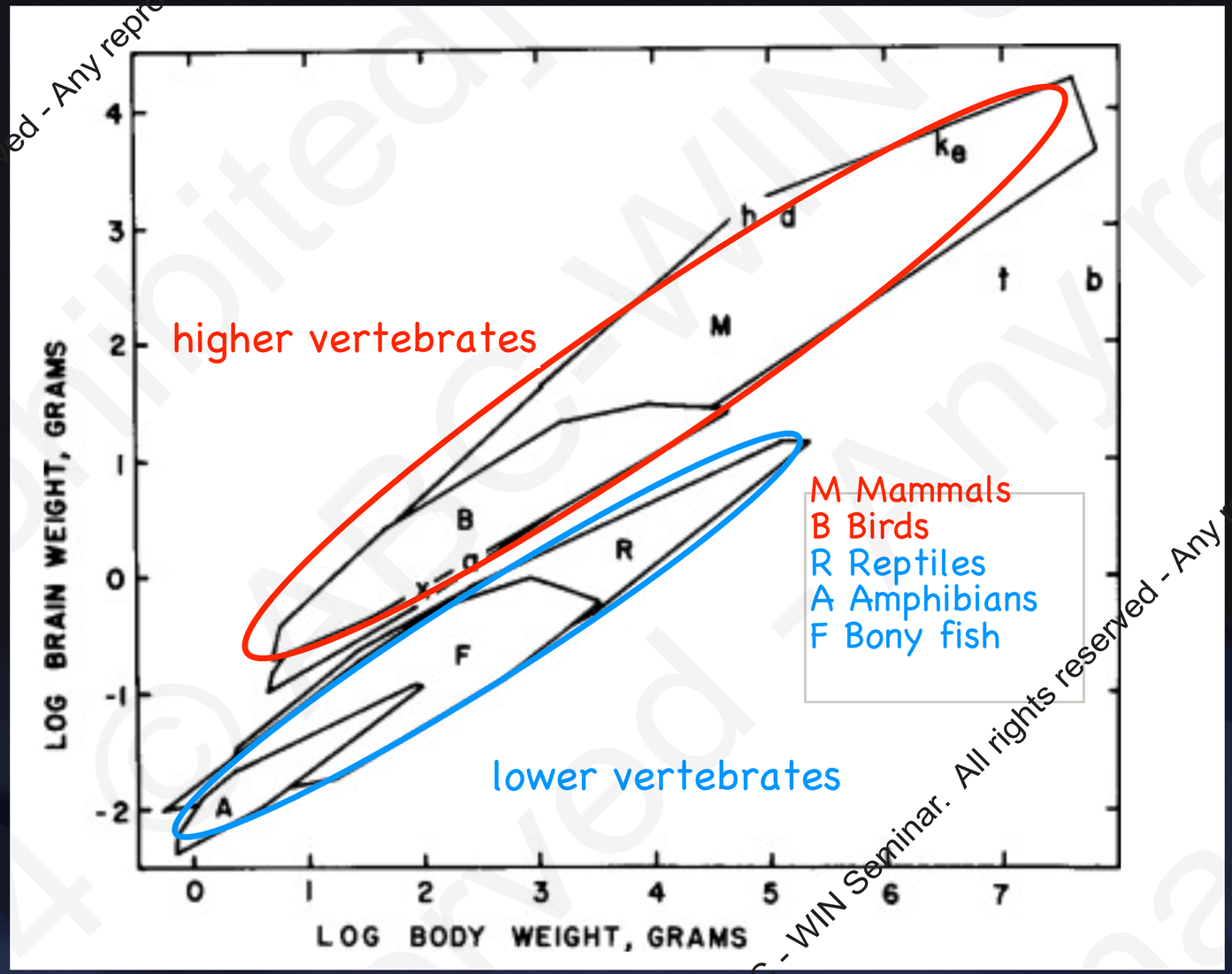


Phylogenetic tree

Broglio C, et al: J Behavioral Brain Sci 2015

Evolution of the Brain

Brain weight

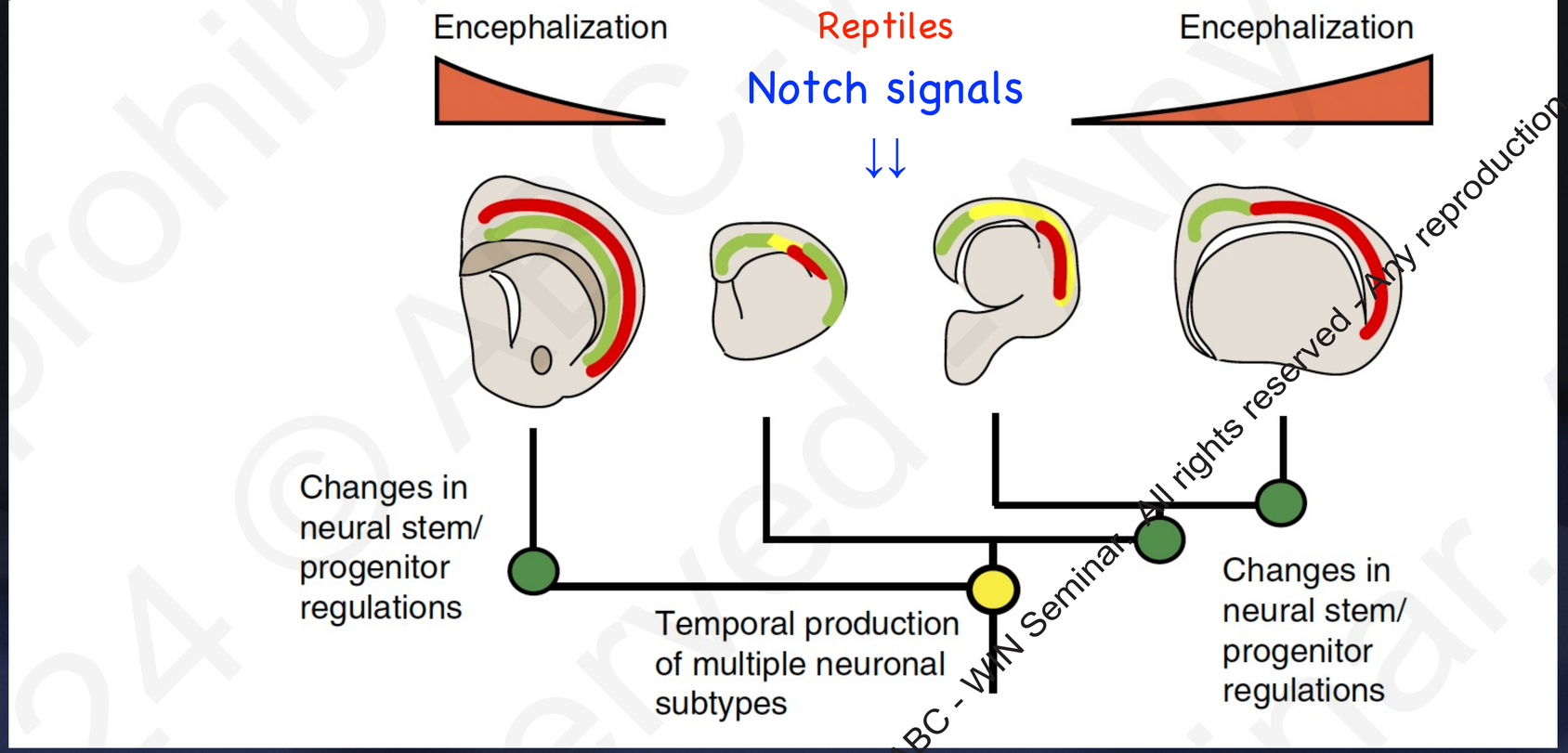


Body weight

Jerison HJ: Evolution of the Brain and Intelligence. New York, Academic Press, 1973

Parallel encephalization had occurred independently?

	Mammals	Geckoes	Turtles	Birds
Apical proliferation	High	Low	Low[b]	High[c]
Basal progenitors	Exist[a]	Not exist	Exist[b]	Exist[b]
Neuronal differentiation	Fast	Slow	Moderate	Fast
Multiple neuronal subtypes	Exist	Exist	Exist[c]	Exist[c]



Nomura T, et al: Nature Communications, 2013

Phylogeny of the tentorium cerebelli

encephalization (-)	encephalization (+)
tentorium cerebelli (-)	tentorium cerebelli (+)
brain / body weight (↓)	brain / body weight (↑)
venous sinuses (-)	venous sinuses (+)
Fish, Amphibian, Reptile	Bird, Mammal

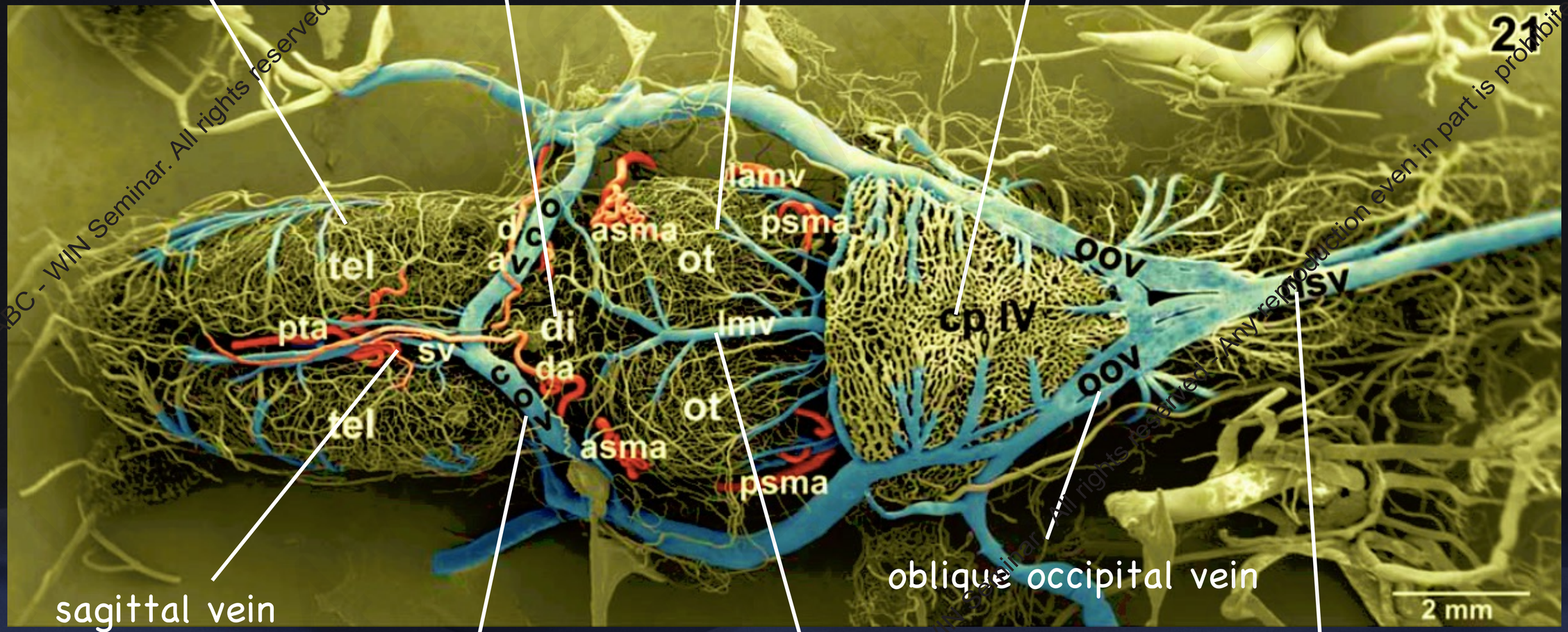
Phylogeny of the tentorium cerebelli

encephalization (-)	encephalization (+)
tentorium cerebelli (-)	tentorium cerebelli (+)
venous sinuses (-)	brain / body weight (↑)
	venous sinuses (+)
Fish, Amphibian, Reptile	Bird, Mammal

Development of tentorium cerebelli can be evaluated by development of the cerebral venous sinuses

Xenopus laevis (pipid frog)

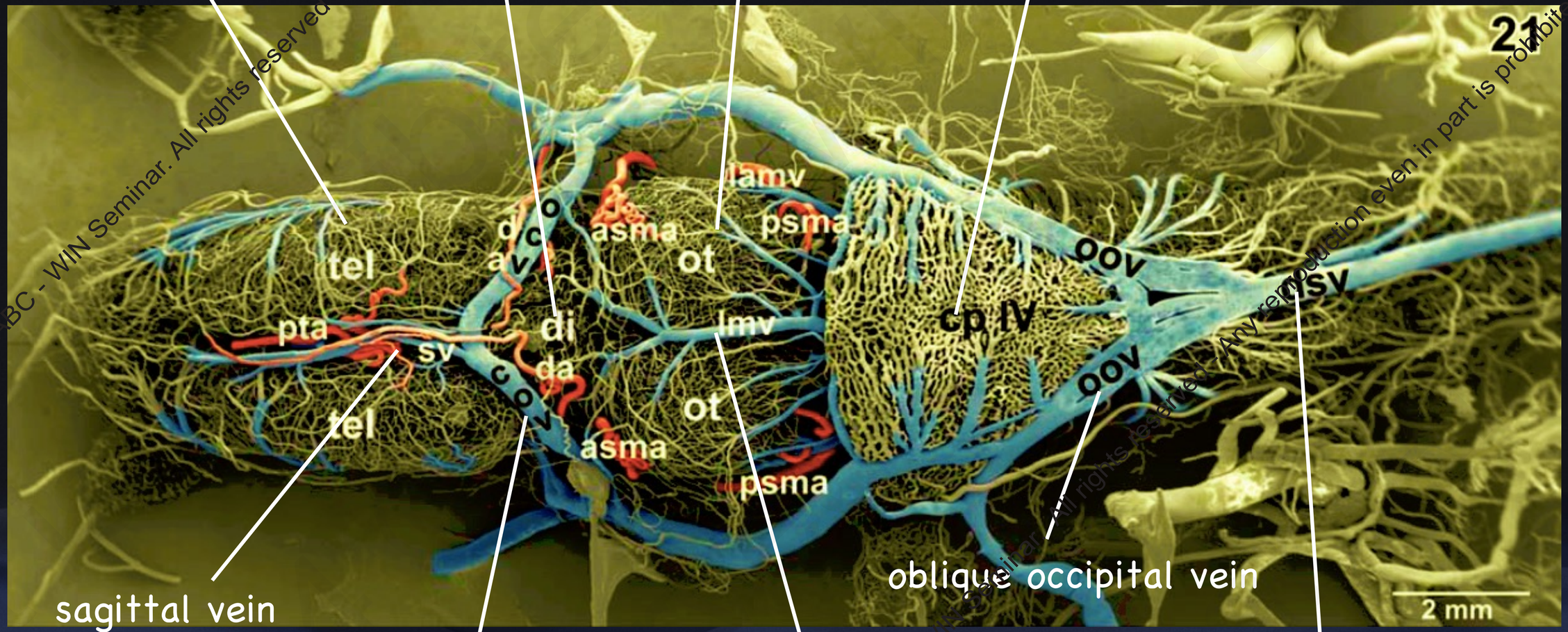
dorsal view



Lametschwandthner A, et al: J Morphol 2018

Xenopus laevis (pipid frog)

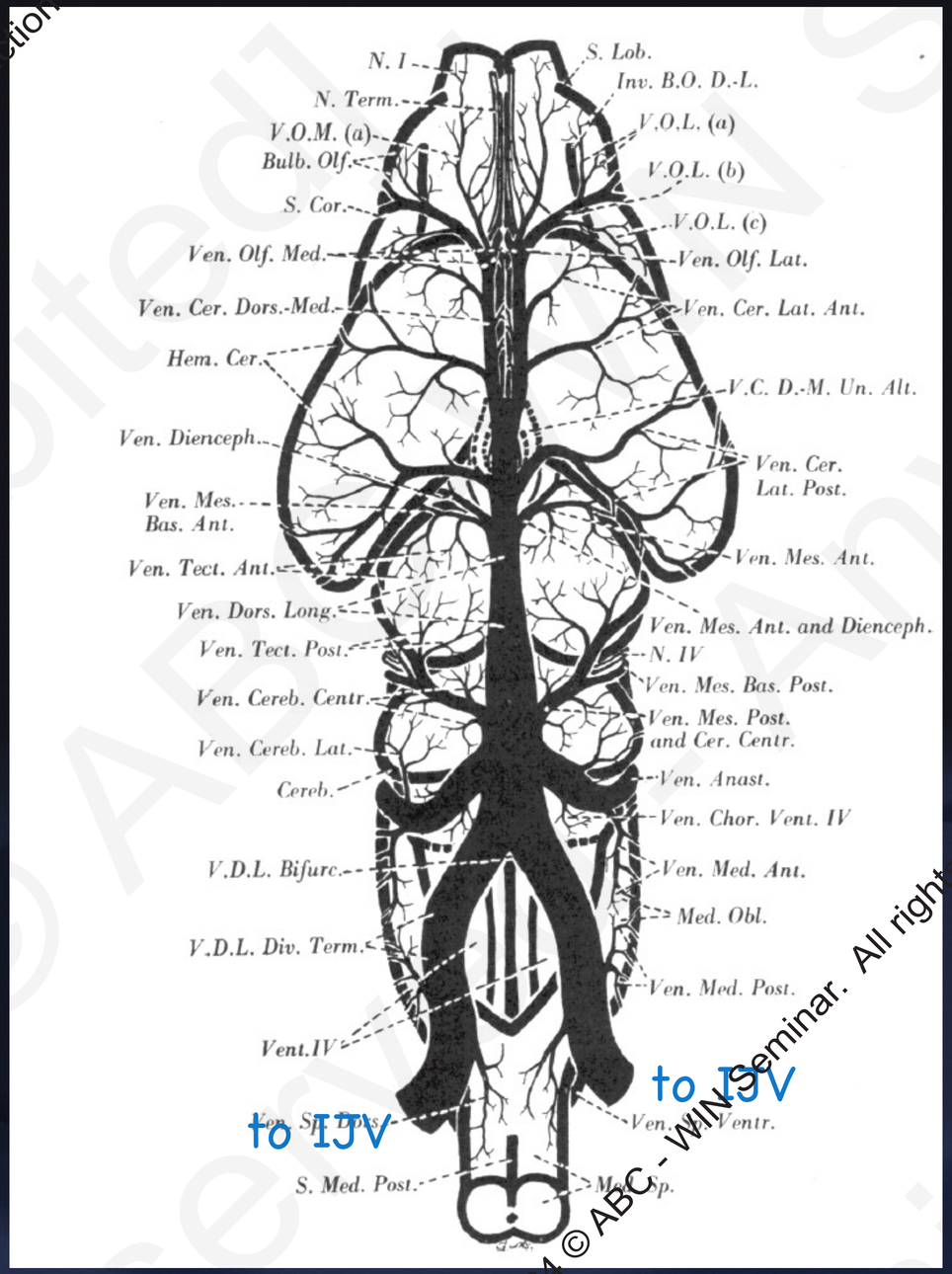
dorsal view



Lametschwandthner A, et al: J Morphol 2018

Tortoise

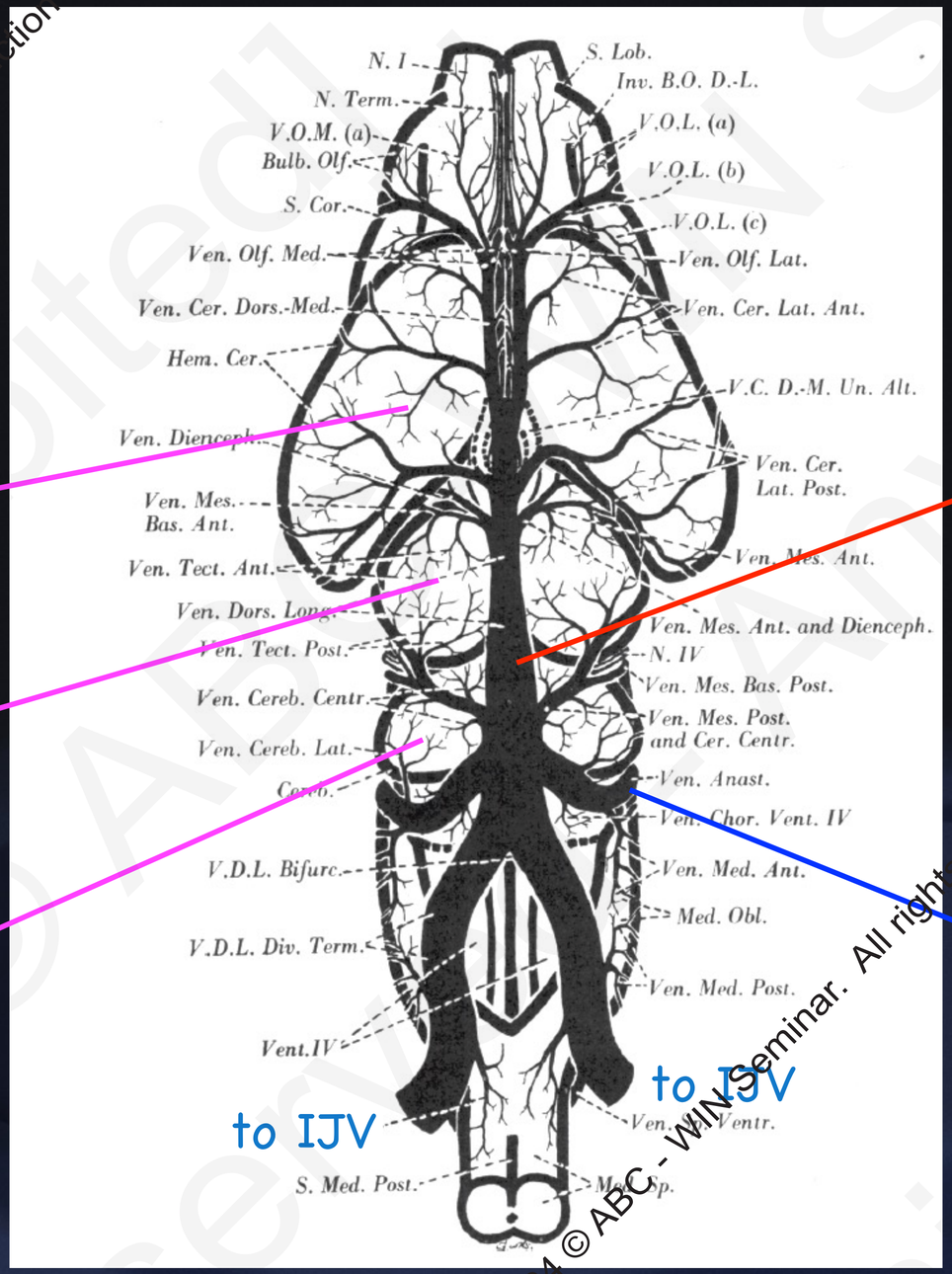
dorsal view



Schepers GWH: J Anat 1939

Tortoise

dorsal view



telencephalon

midbrain

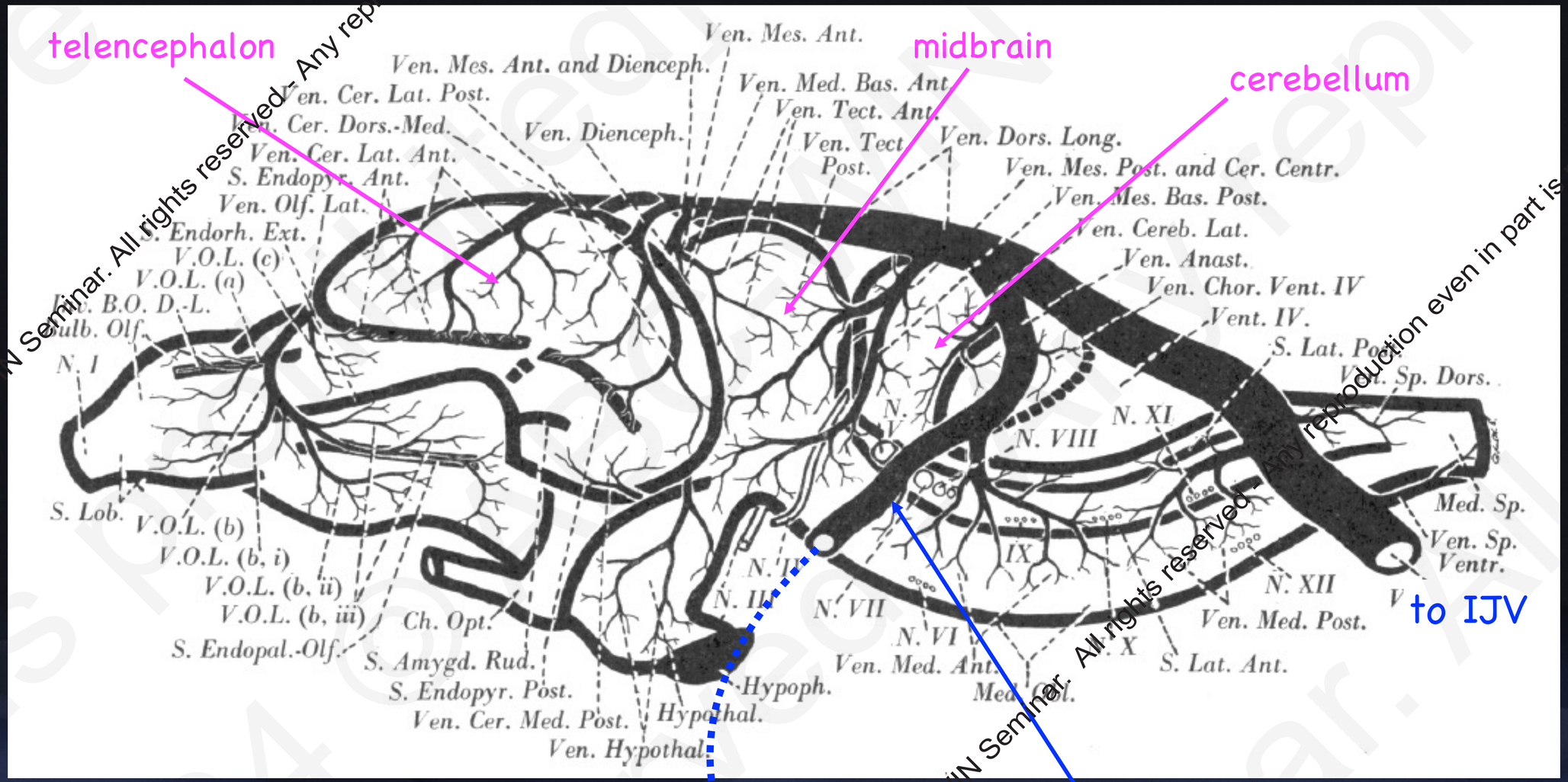
cerebellum

dorsal longitudinal vein

anastomotic vein

Schepers GWH: J Anat 1939

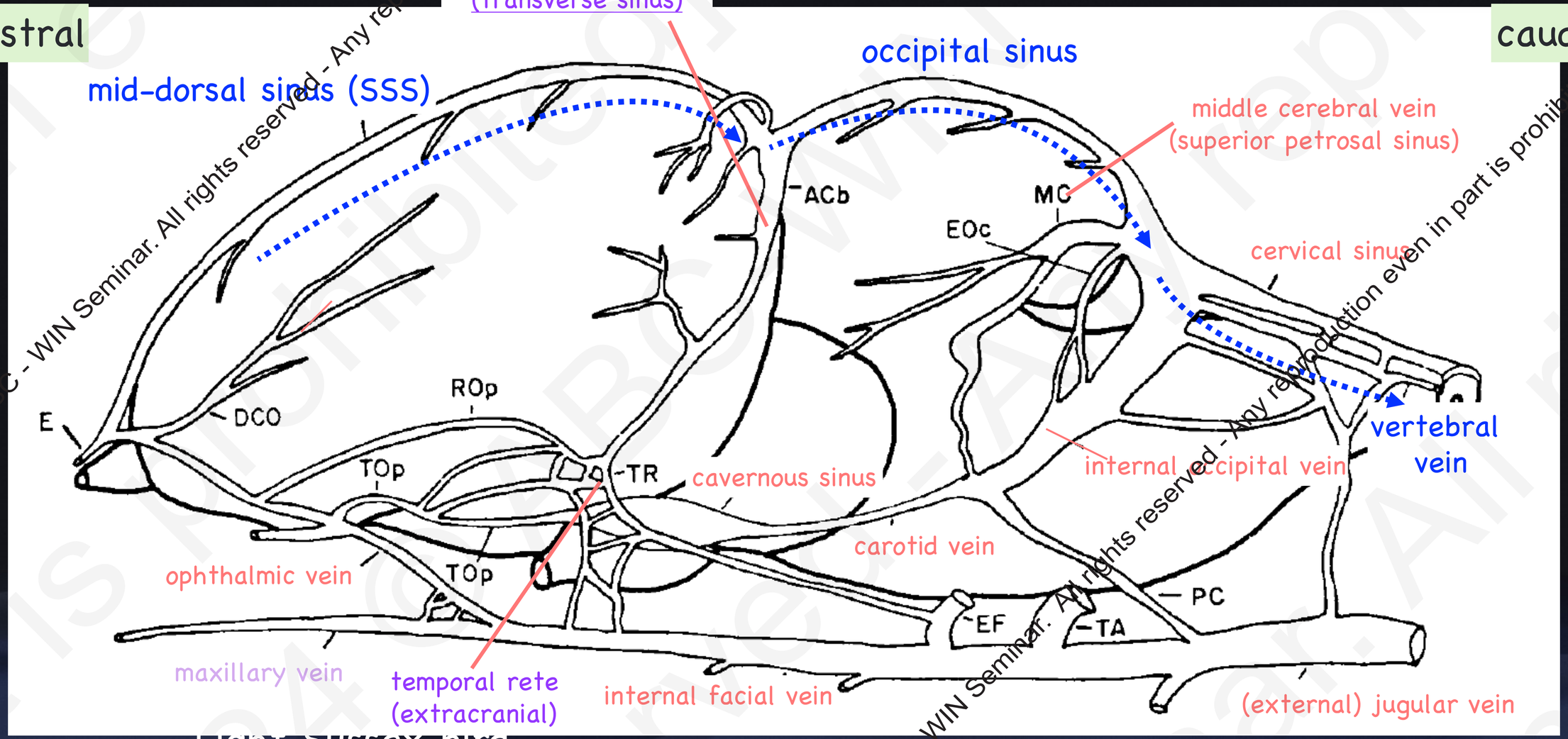
Tortoise



Schepers GWH: J Anat 1939

Light Sussex bird

Dural sinus drains cerebral blood



Light Sussex bird

hards SA: J Zool, Lond 1968

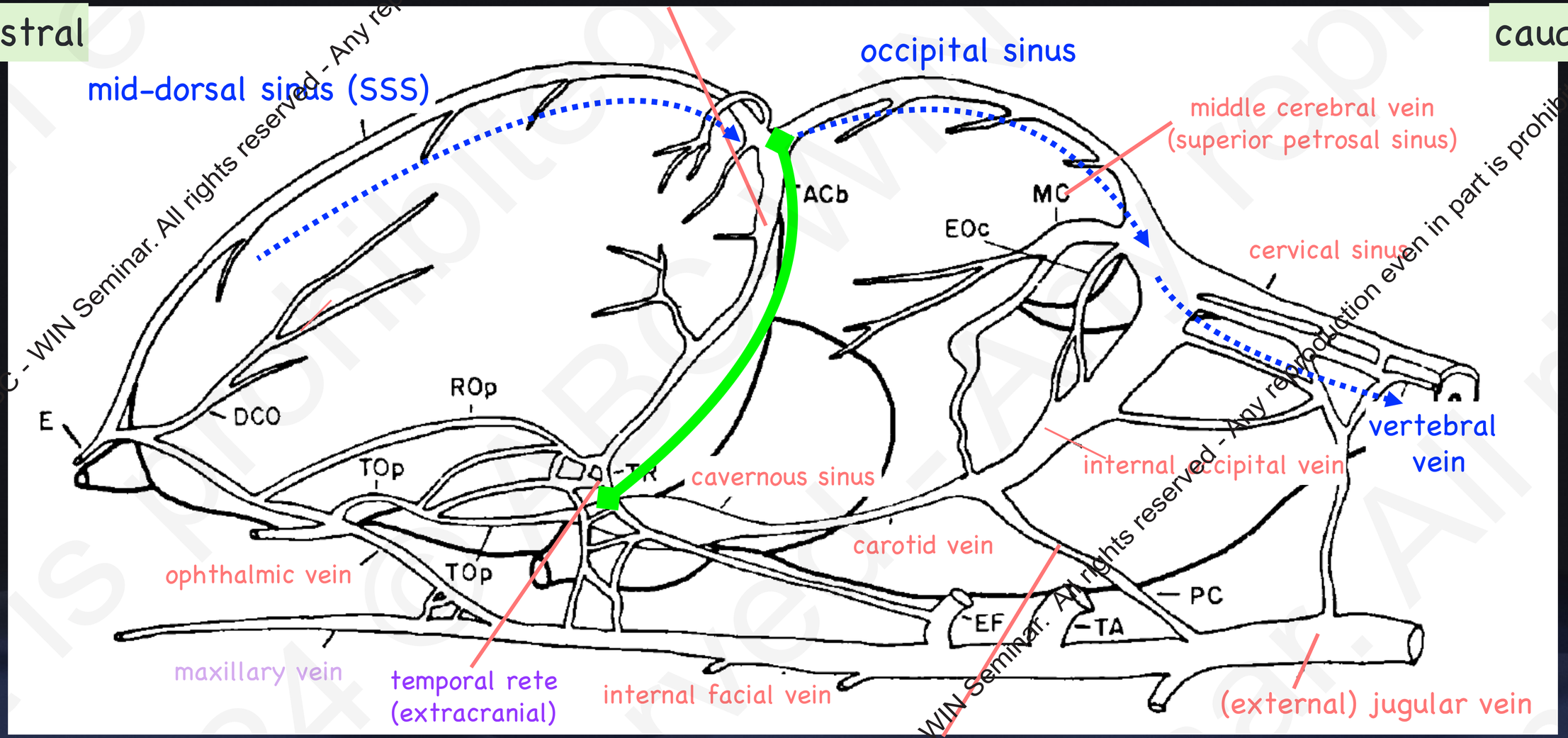
Light Sussex bird

Dural sinus drains cerebral blood

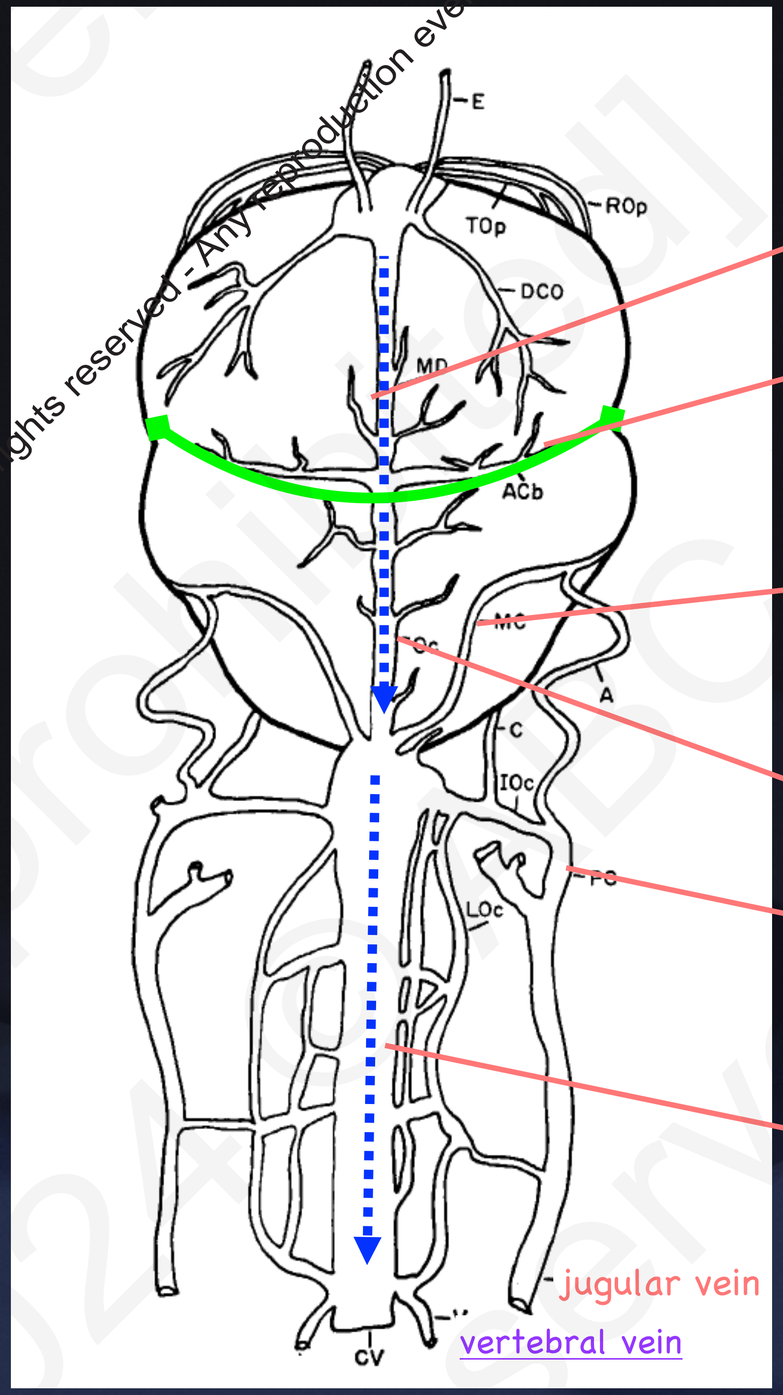
anterior cerebral vein
(transverse sinus)

← rostral

caudal →



Richards SA: J Zool, Lond 1968



mid-dorsal sinus (superior sagittal sinus)

anterior cerebral vein (transverse sinus)

middle cerebral vein (superior petrosal sinus)

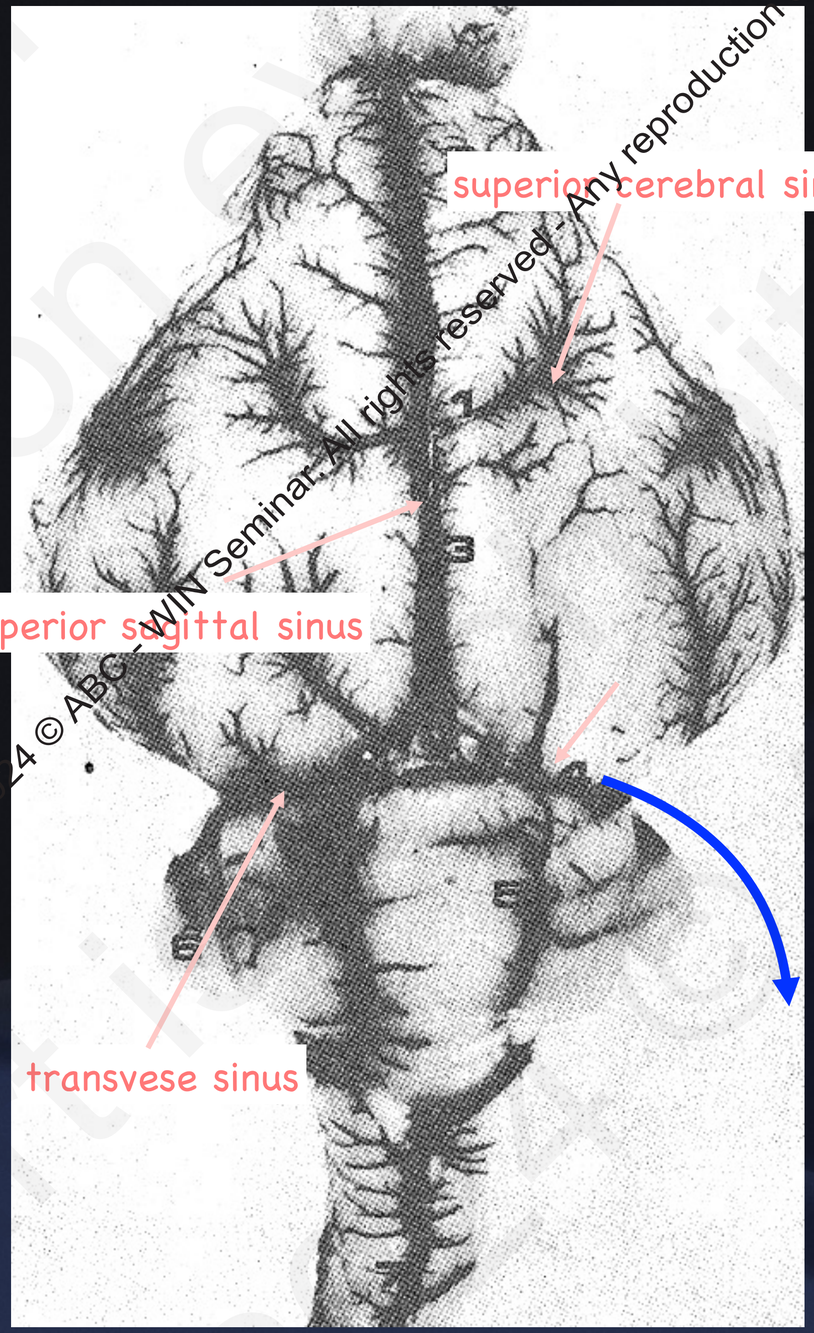
occipital sinus

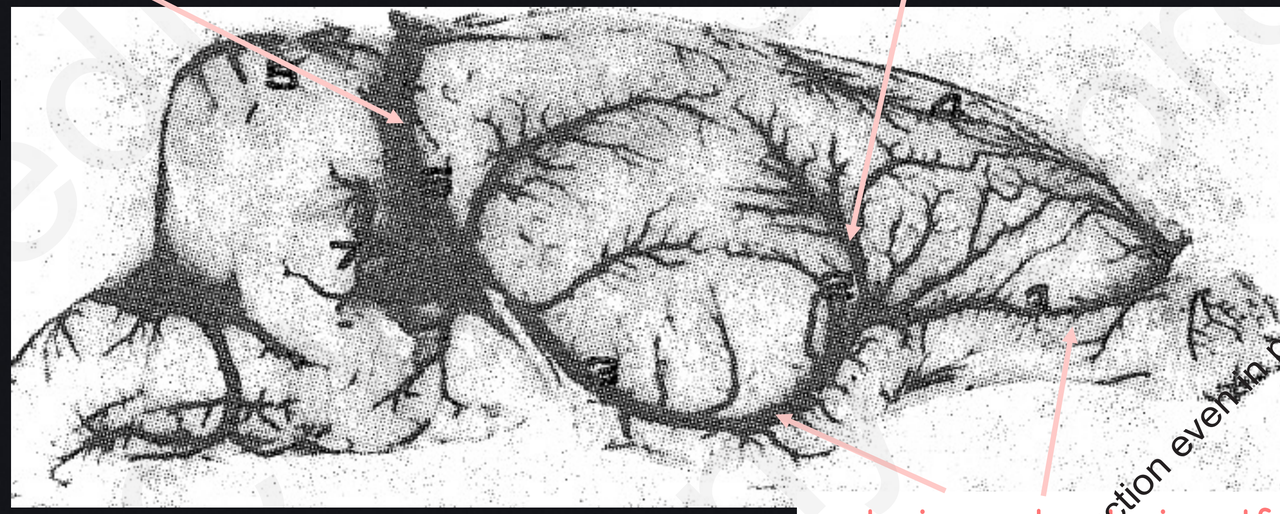
posterior cephalic vein

cervical sinus

Richards SA: J Zool, Lond 1968

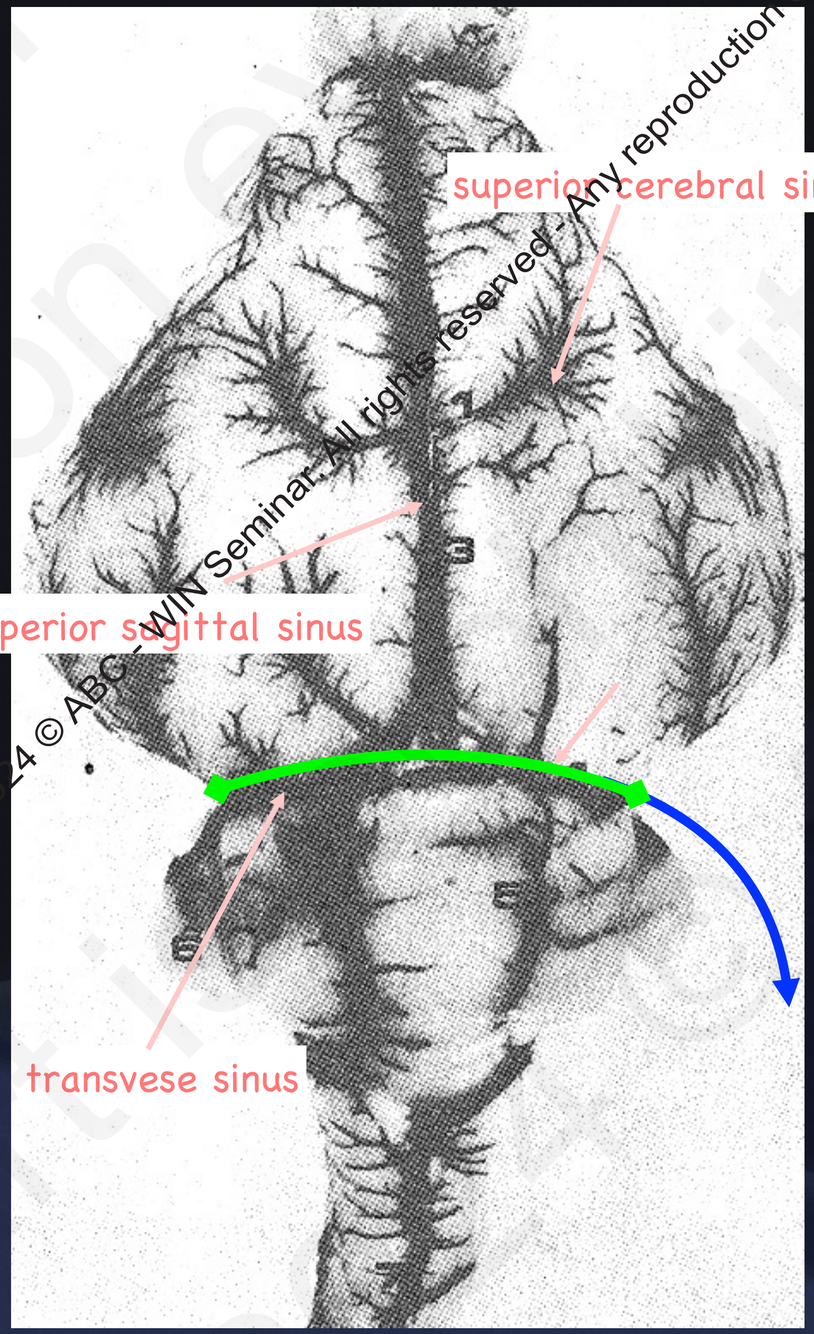
Guinea Pig



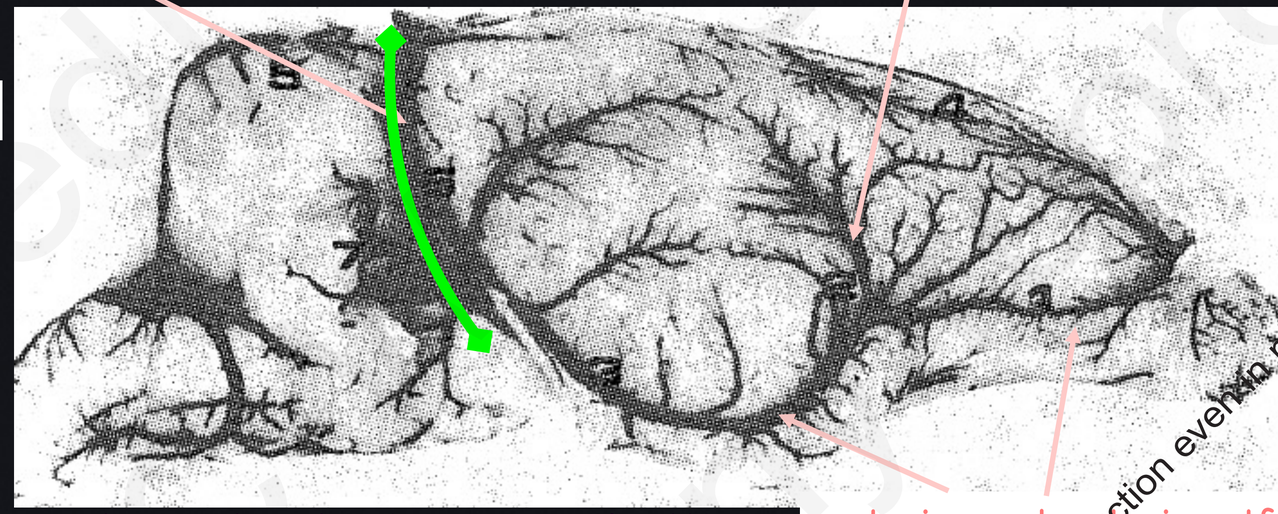


To IJV
similar to man

Majewska-Michalska E: Folia Morphol 1994



Guinea Pig

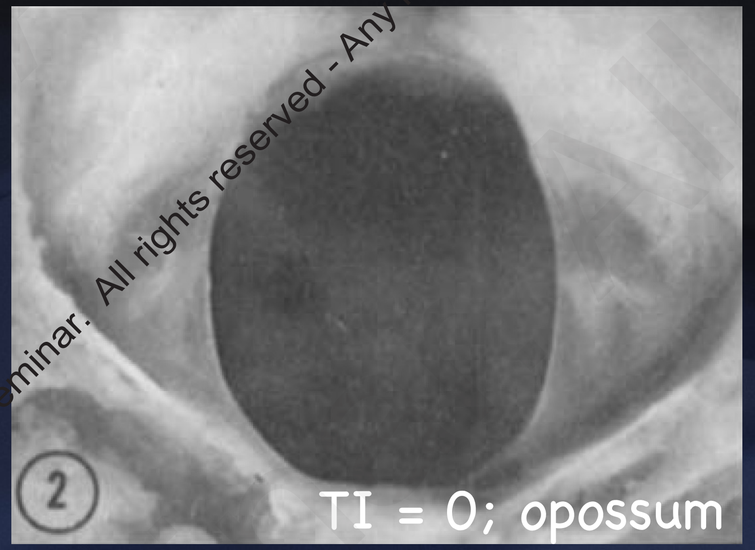


Immature tentorium cerebelli

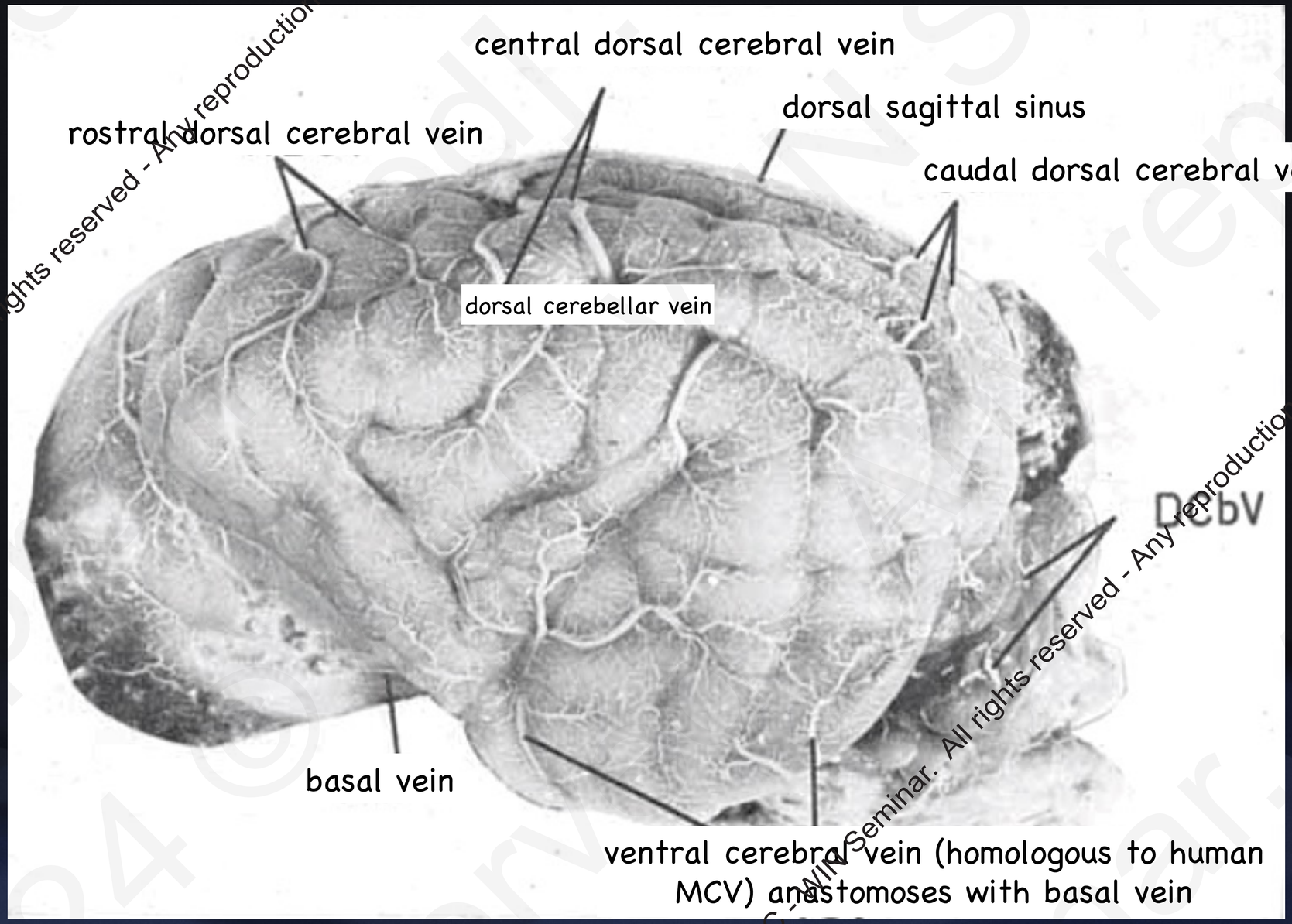
To IJV
similar to man

Tentorial Index = 0

primitive type



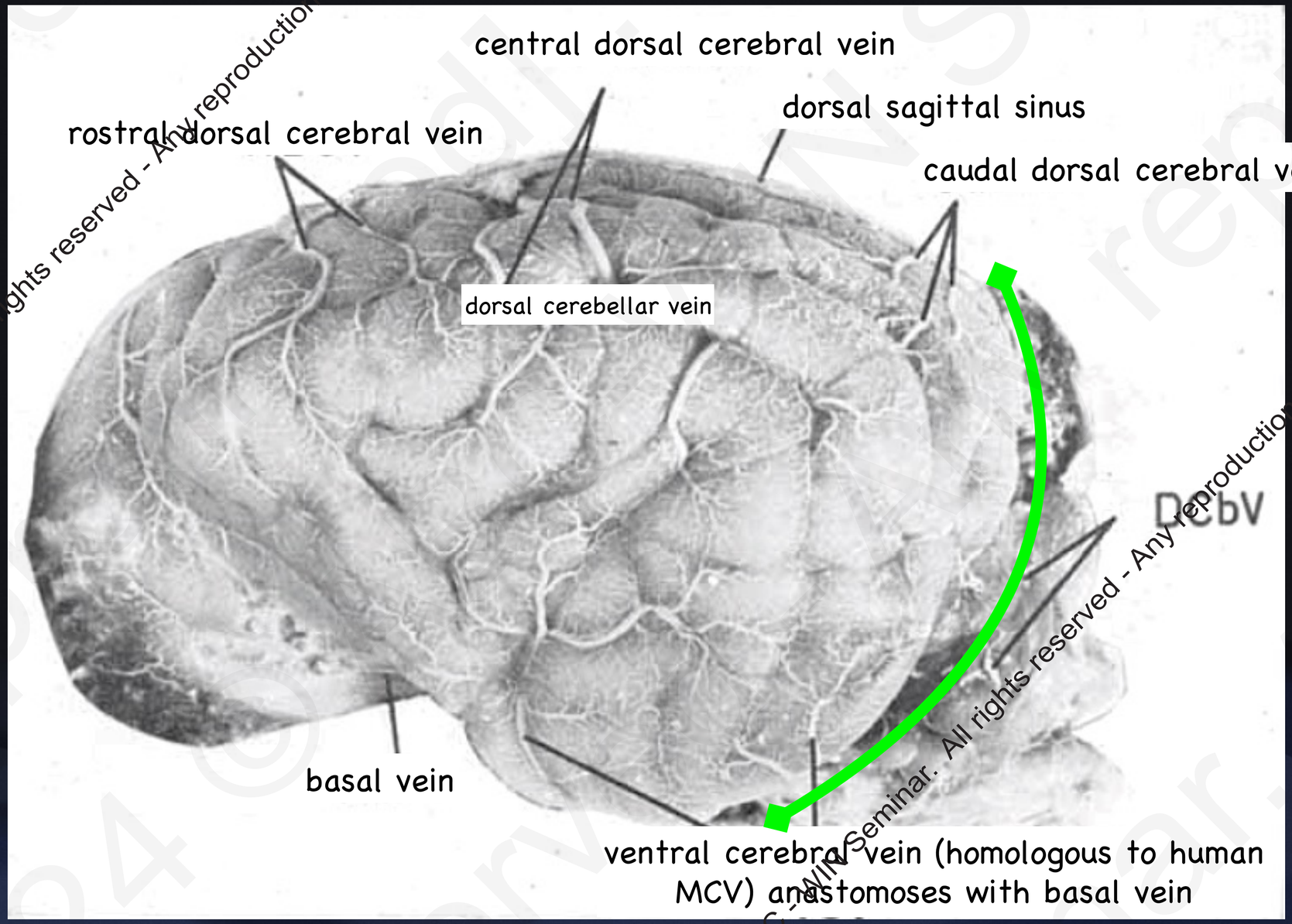
Majewska-Michalska E: Folia Morphol 1994



← rostral

caudal →

Armstrong LD, et al: Adv Sci 1971

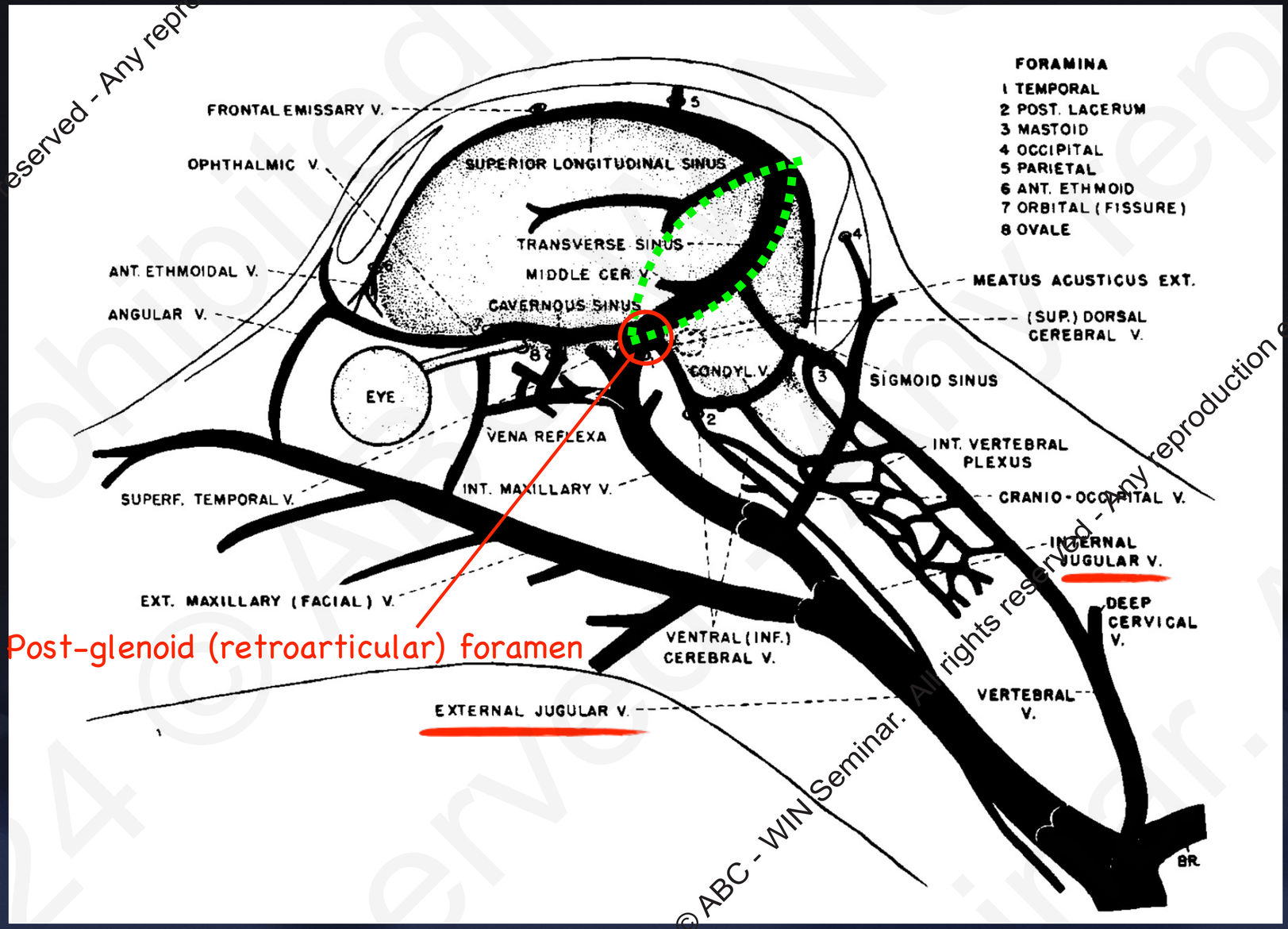


← rostral

caudal →

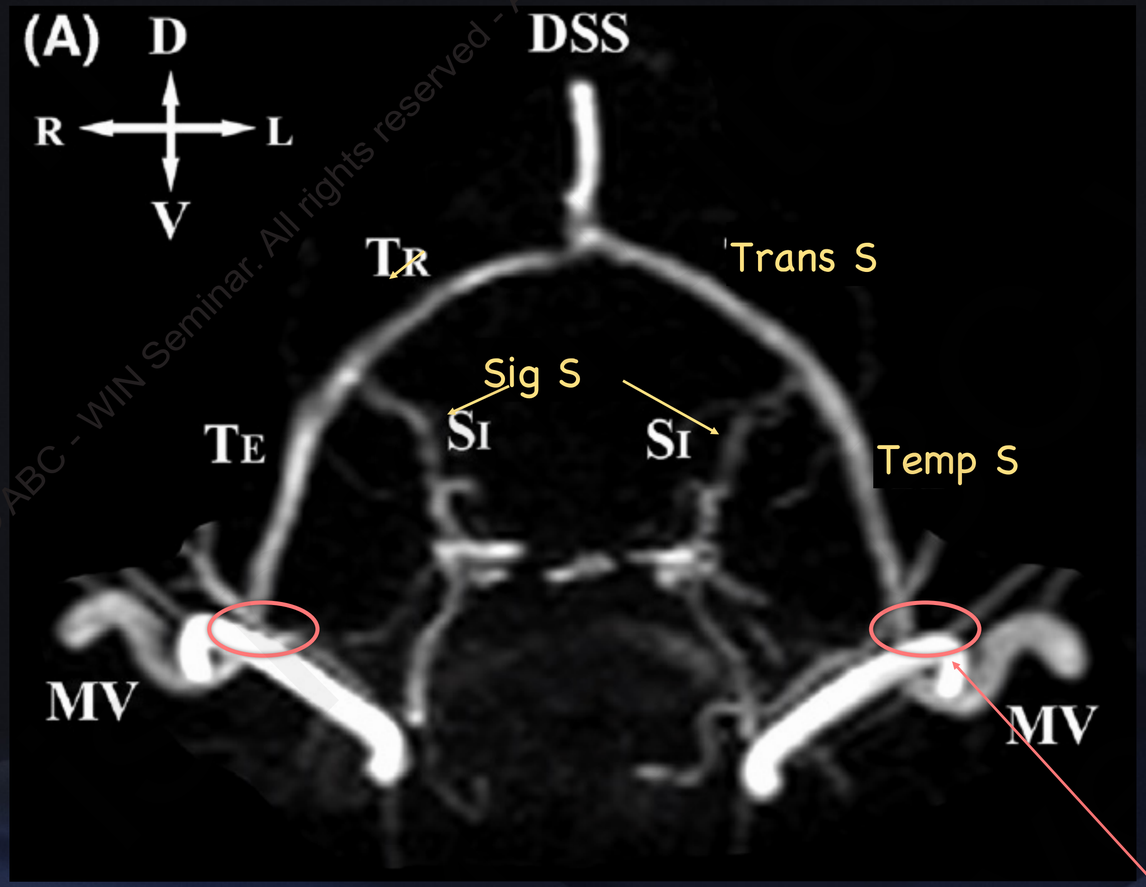
Armstrong LD, et al: Adv Sci 1971

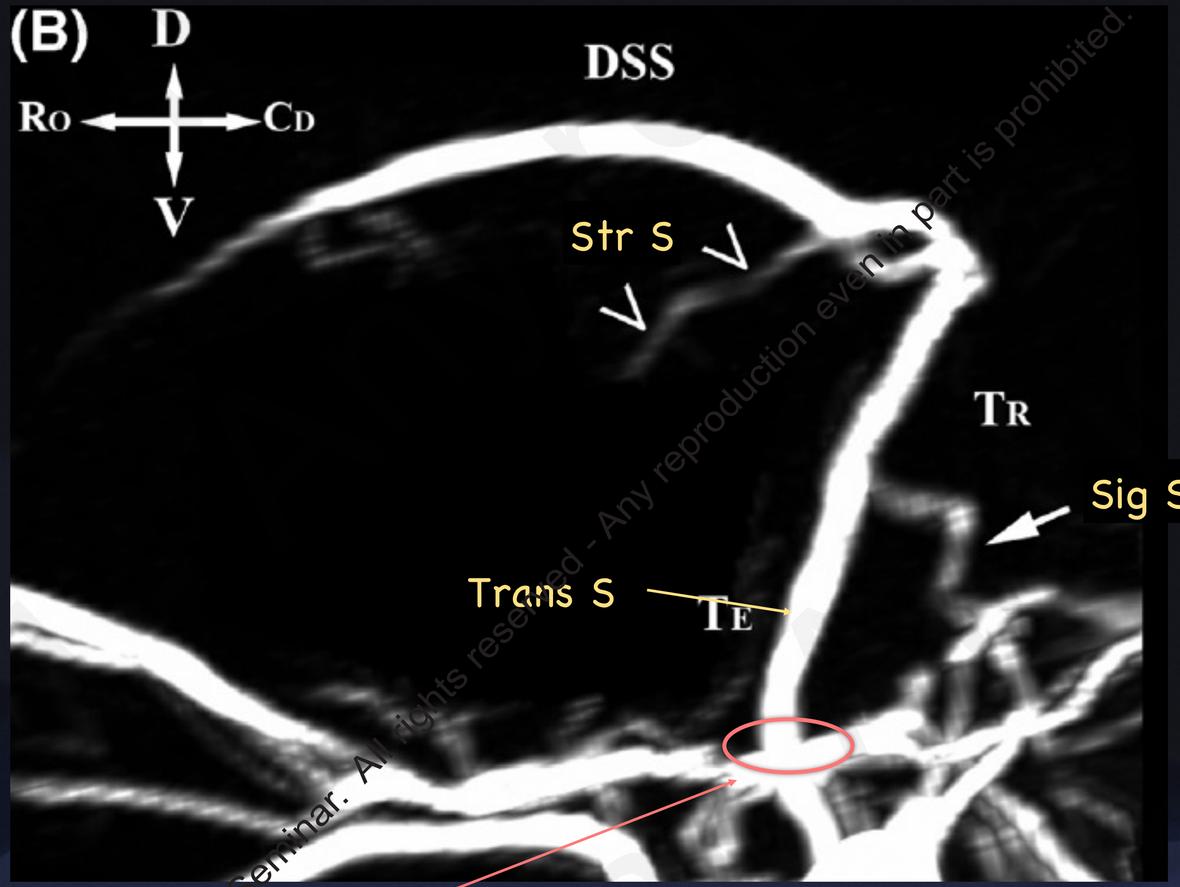
Cranio-cervical venous system in dog



Hegedus SA, et al: Am J Anat 1965

MR venography of the dog at 1.5 Tesla





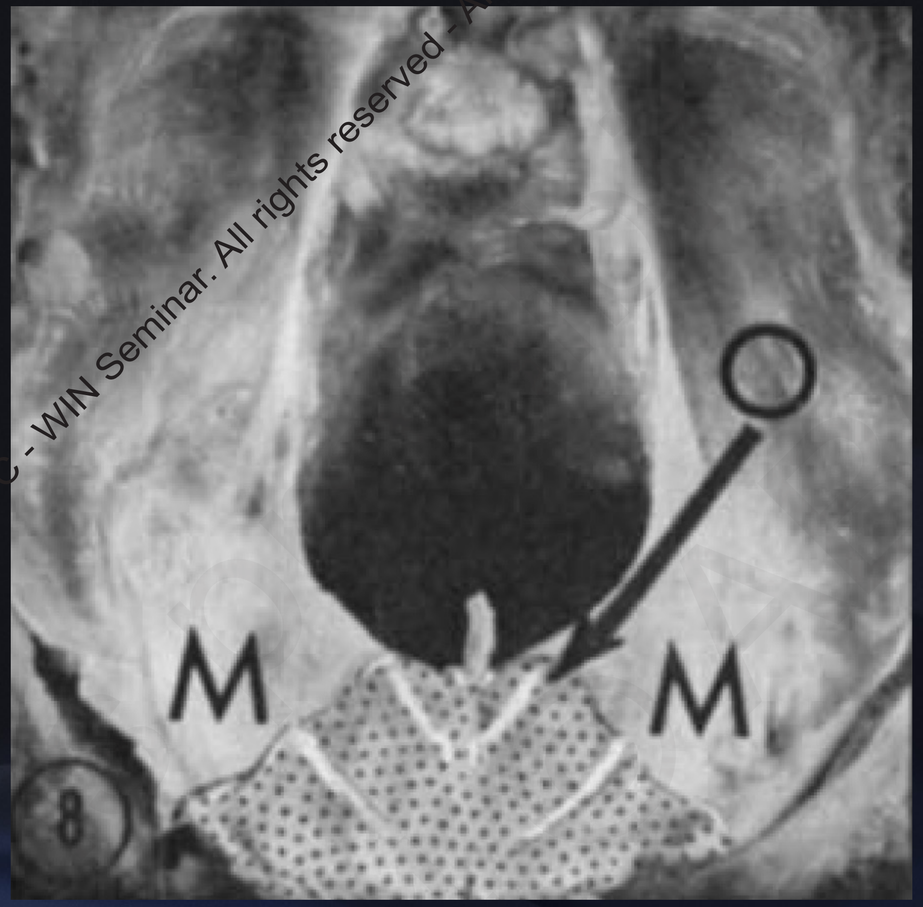
AP view

Post-glenoid (retroarticular) foramen

Lateral view

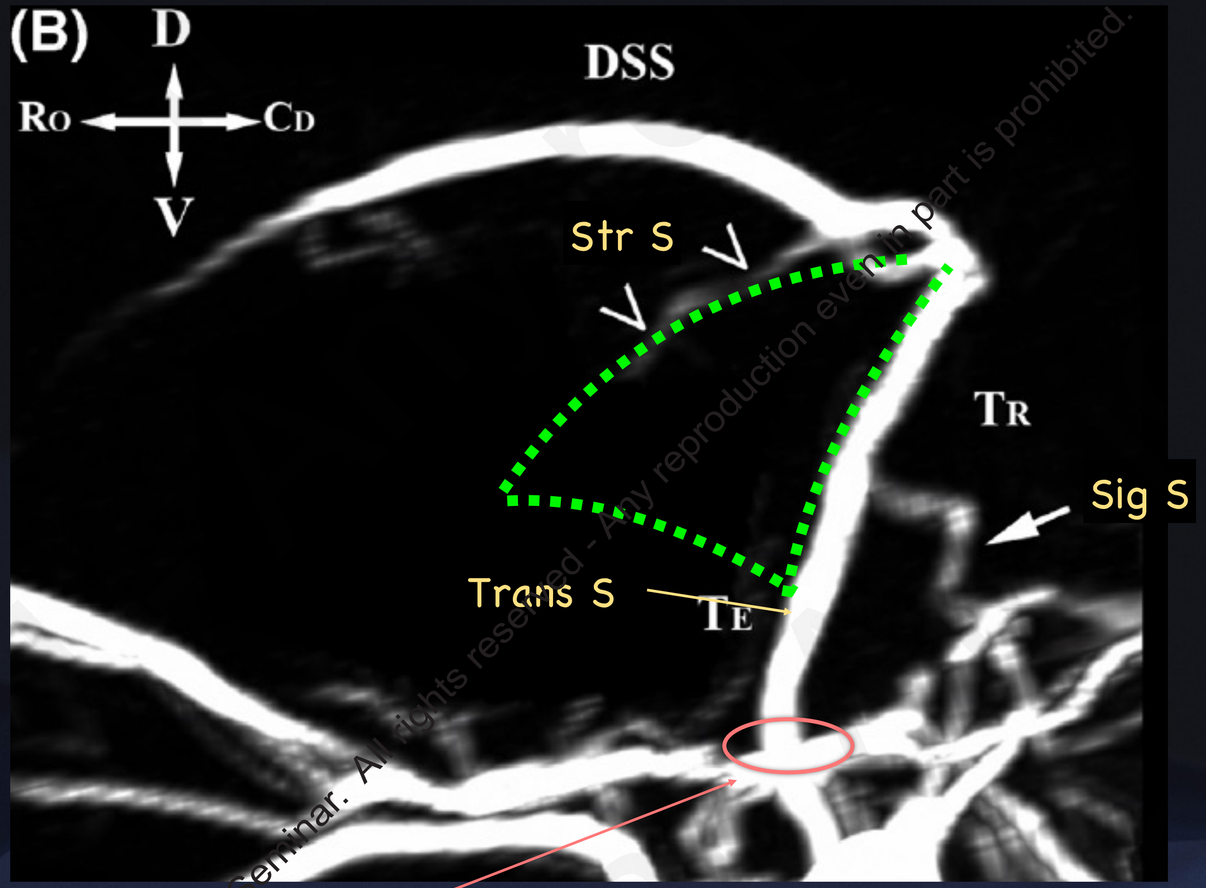
Fenn J, et al: Vet Radiol Ultrasound 2013

MR venography of the dog at 1.5 Tesla



Tentorial Index = 61
fully developed type

Klintworth GK: T Anat Rec 160:635-42, 1968



Post-glenoid (retroarticular) foramen Lateral view

Fenn J, et al: Vet Radiol Ultrasound 2013

Conclusions

In the vertebrate phylogeny, tentorium cerebelli has developed solely in avians and mammals due to progressive encephalization.

Embryologically, tentorium cerebelli develops first ventro-medially, which regresses soon. Then, dorso-lateral portions develop bilaterally.

Dura mater of the forebrain is of the neural crest origin while that of the hindbrain is of the mesodermal origin. Tentorium cerebelli is located between them.