Embryology III

Kamila Procházková

Stage J 5 (C7-9)

Trilaminar embryo (germ disc) with axial structures

days 15 – 20, MLL 0.5 – 1.5 mm

axial structures: primitive streak, primitive node, oropharyngeal membrane, cloacal membrane, prenotochordal plate, notochordal process and plate, notochord, allantois

Substages

J 5–1	notochordal node and notochordal tubule (prenotochord)	C7
J 5–2	notochordal plate, primitive streak, intraembryonic mesoderm	C8
J 5–3	notochord, neural folds	C9

Third week

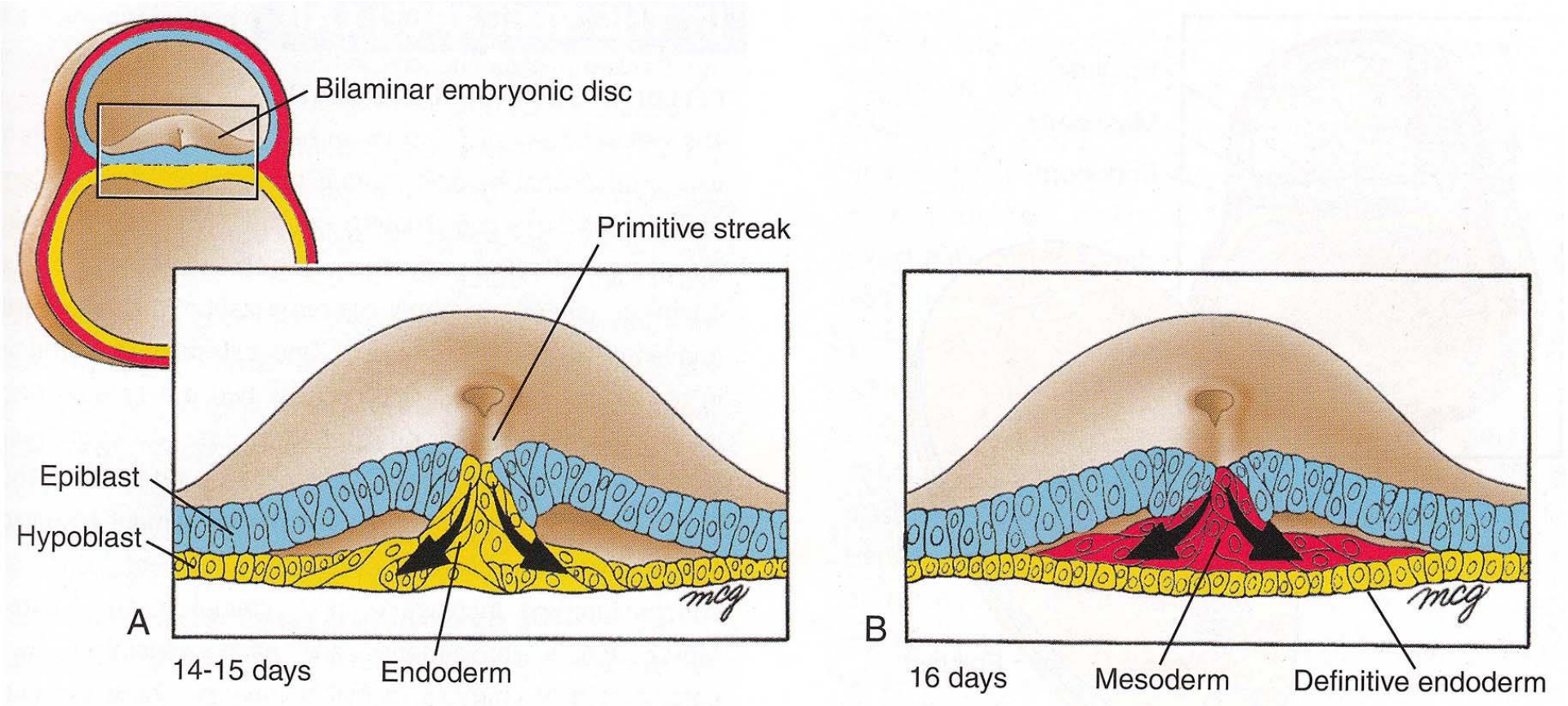
Trilaminar germ disc

days 15 – 20, MLL 0.5 – 1.5 mm

GASTRULATION
NOTOGENESIS
NEURULATION

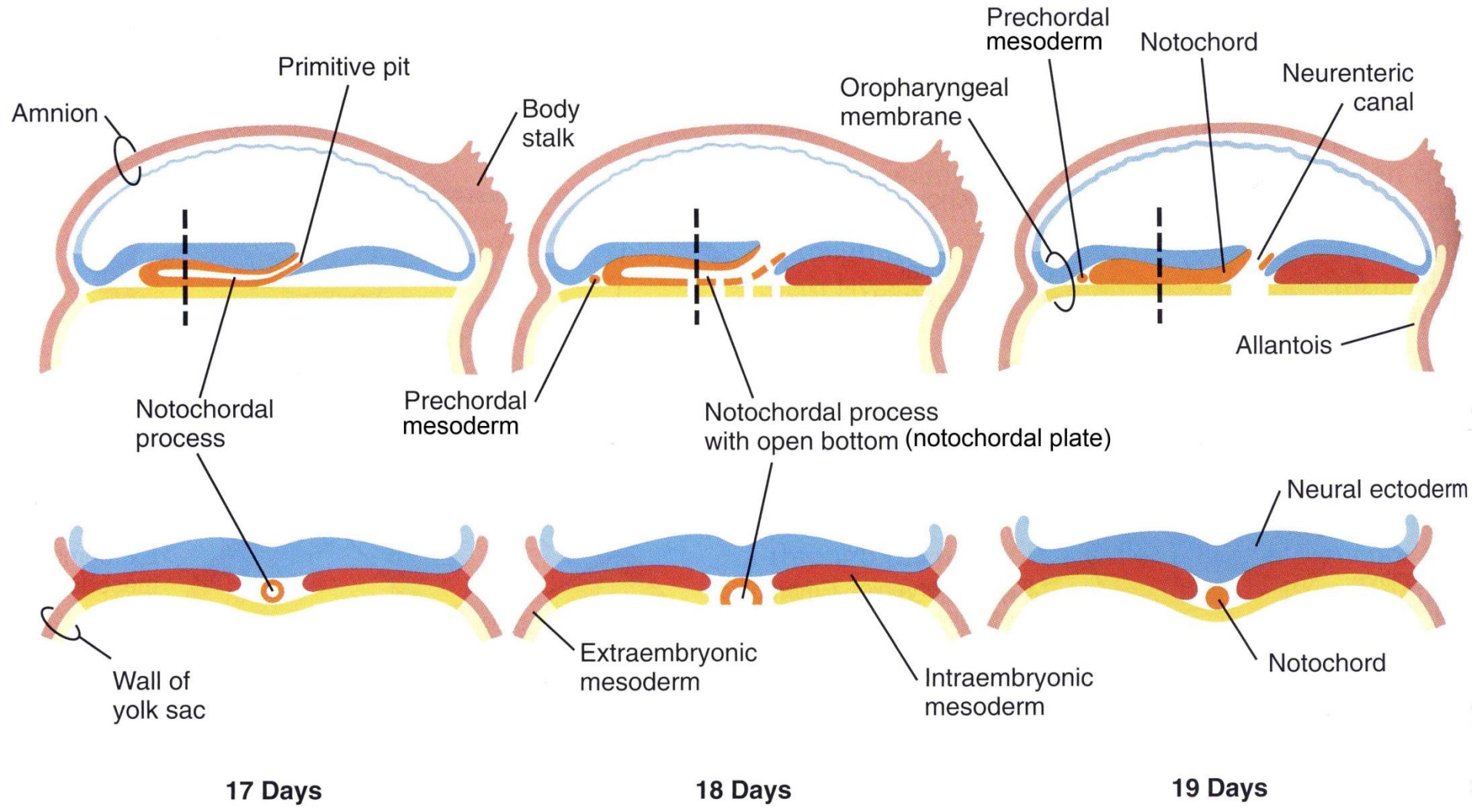
Gastrulation

J5–1/2, C7/8

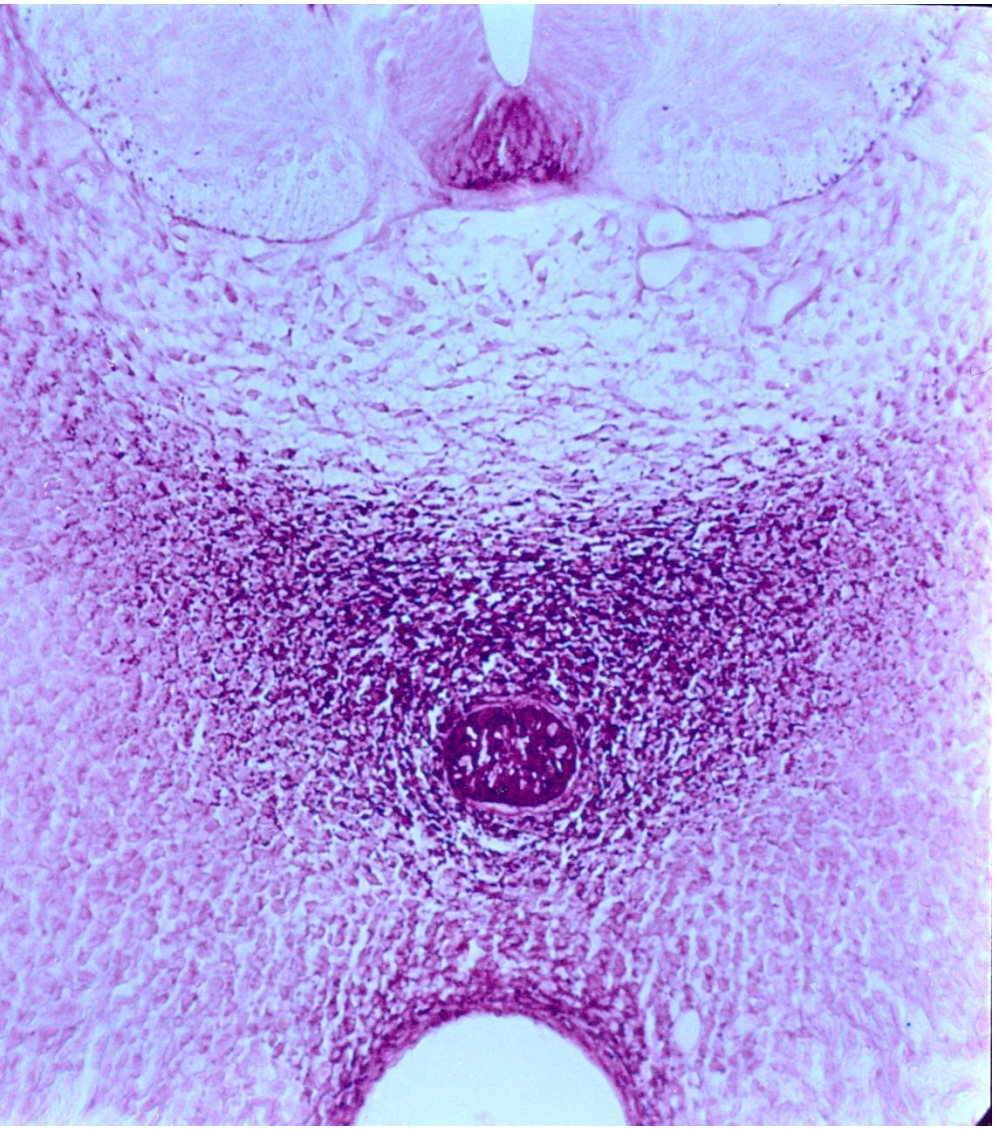


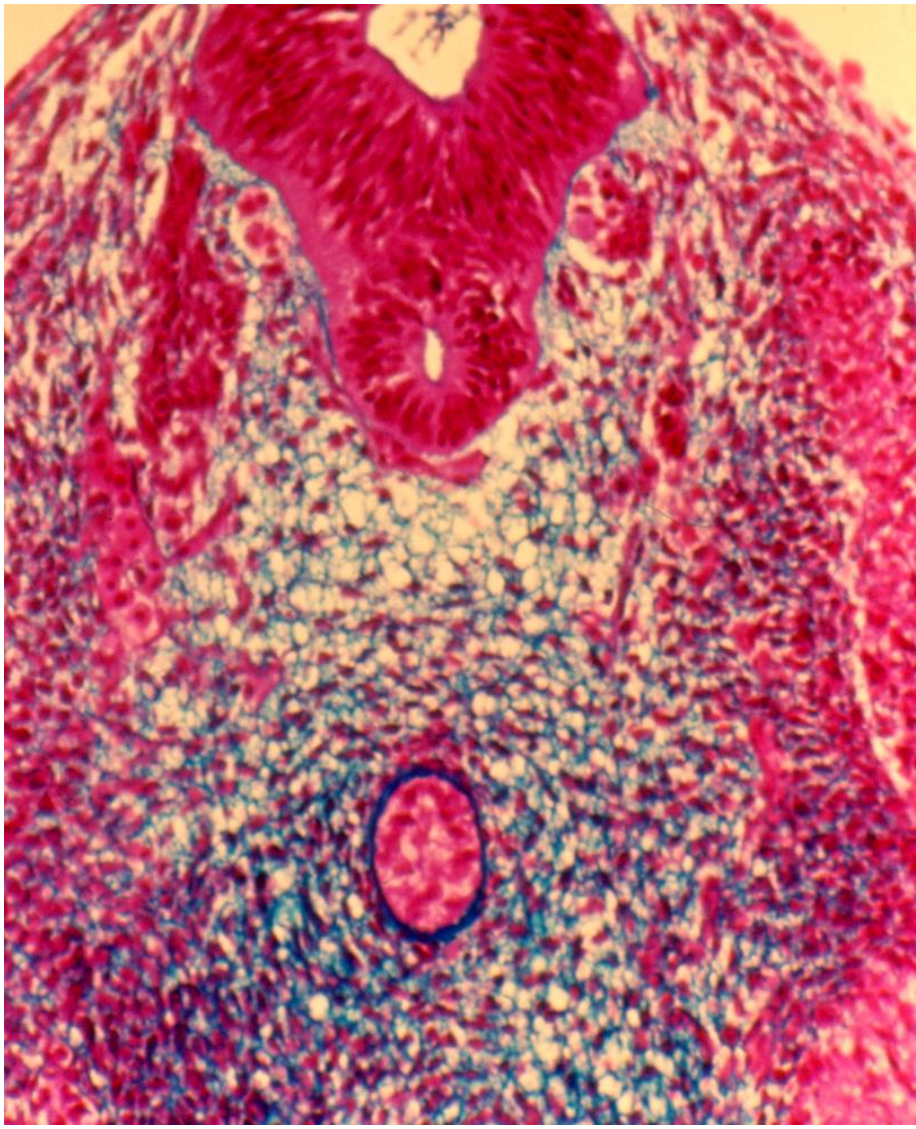
Schoenwolf, G.C. et al: Larsen's Human Embryology, Elsevier 2009

Development of the notochord - notogenesis

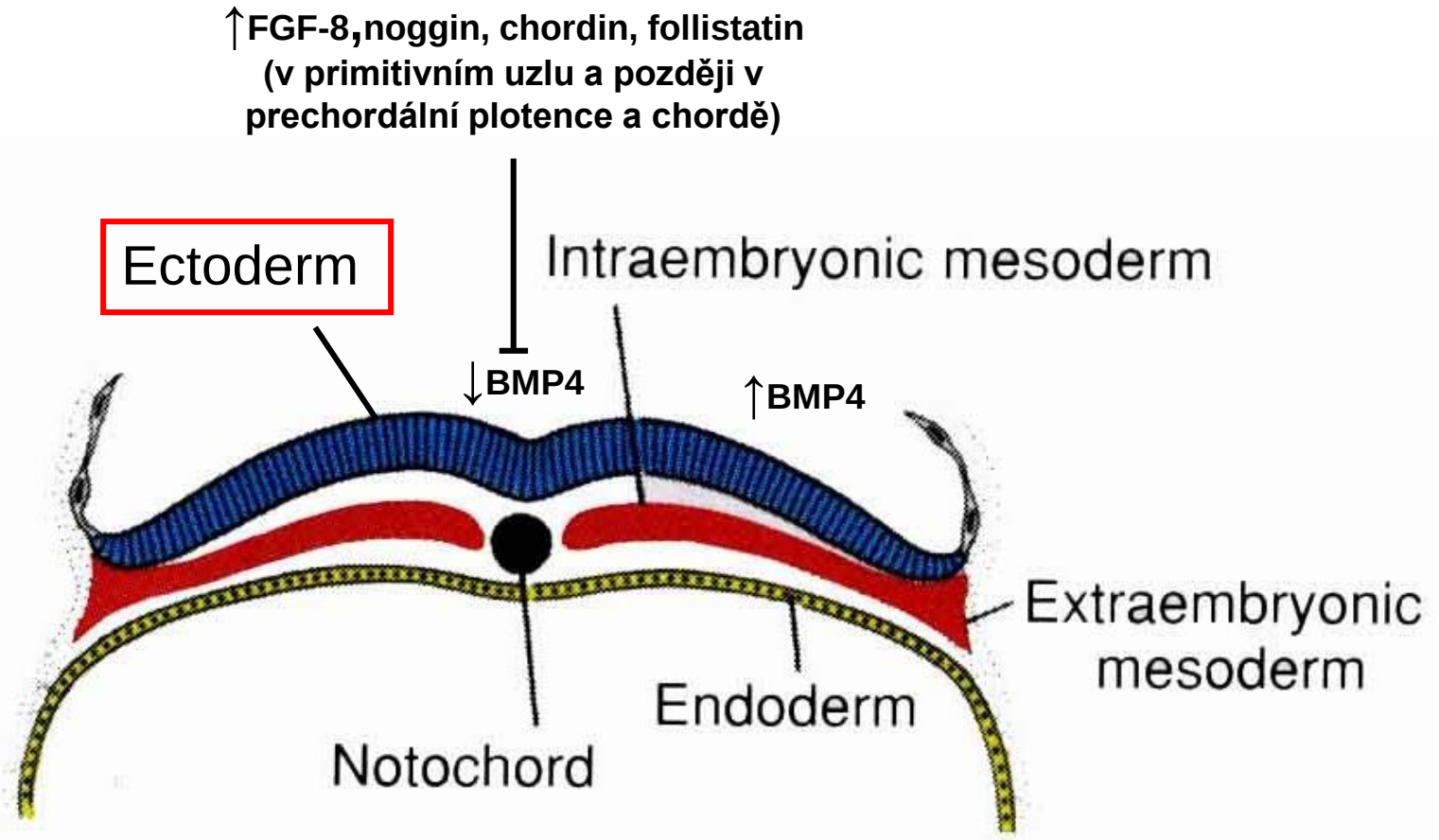


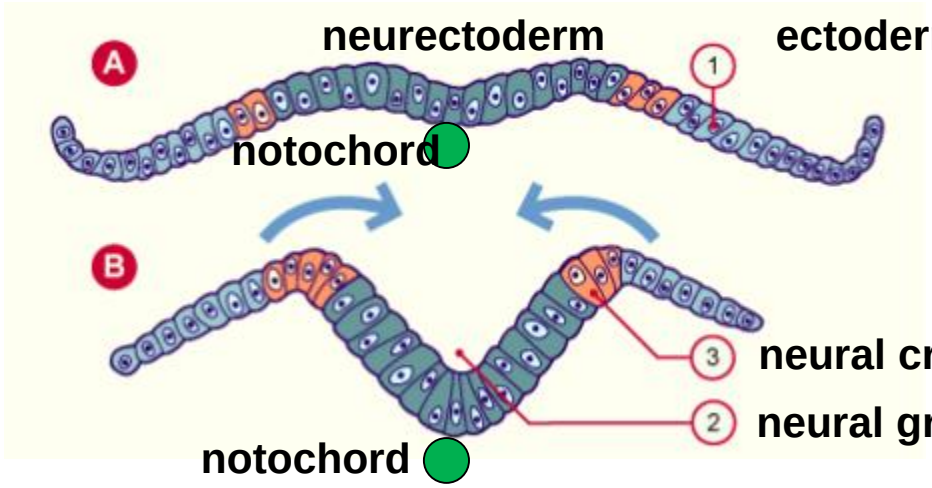
Notochord (Chorda dorsalis)

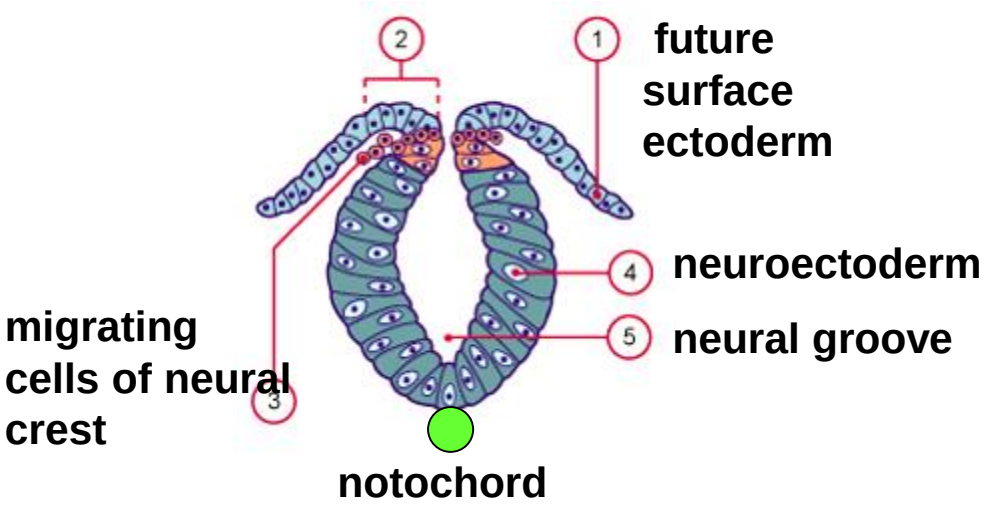


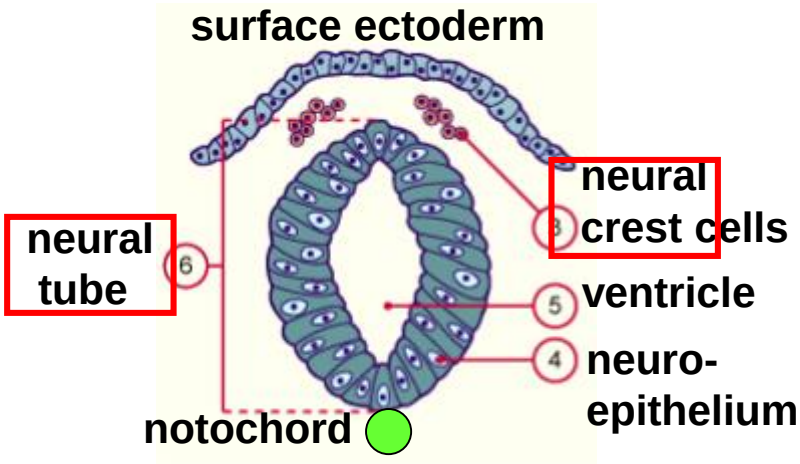


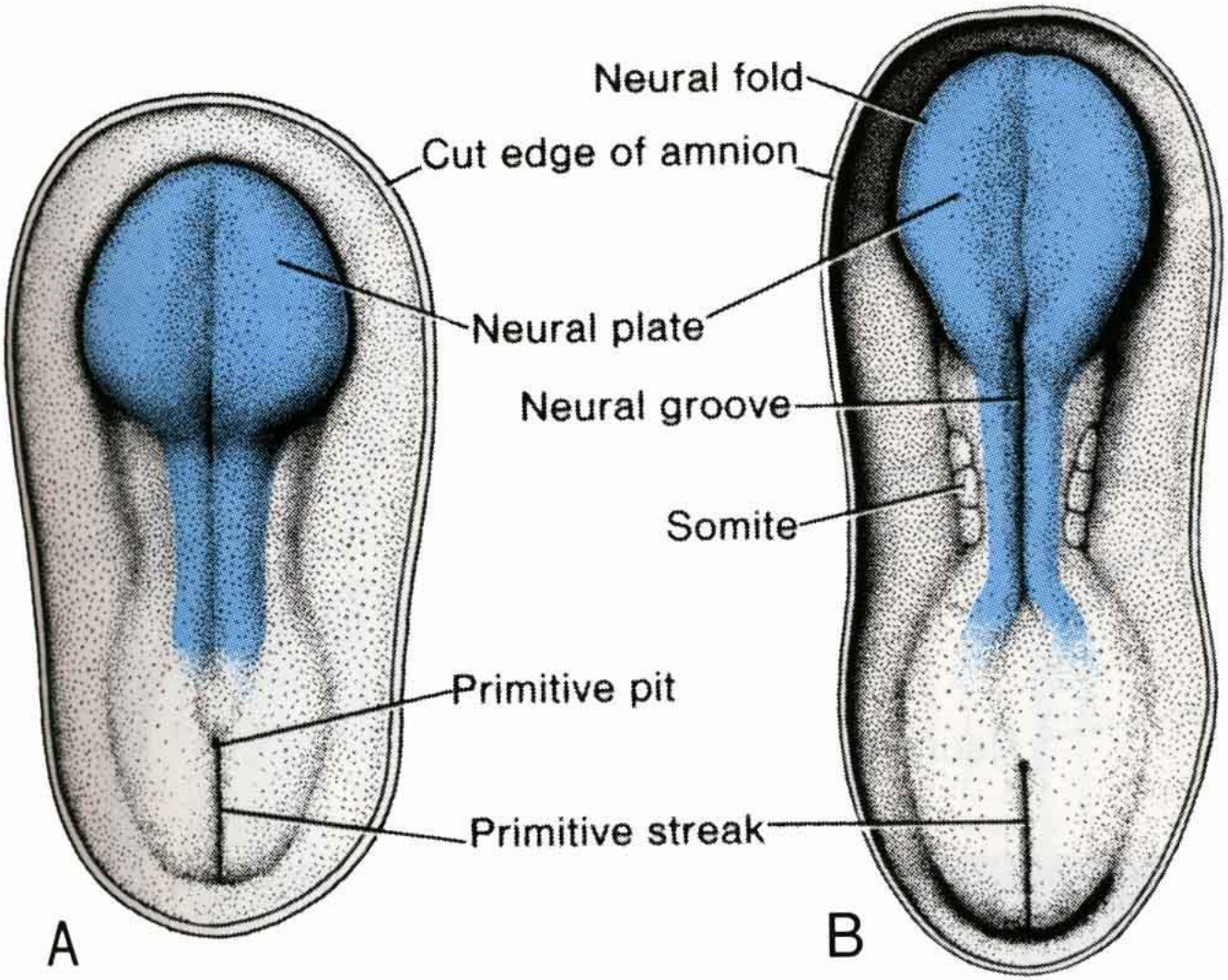
Neurulace

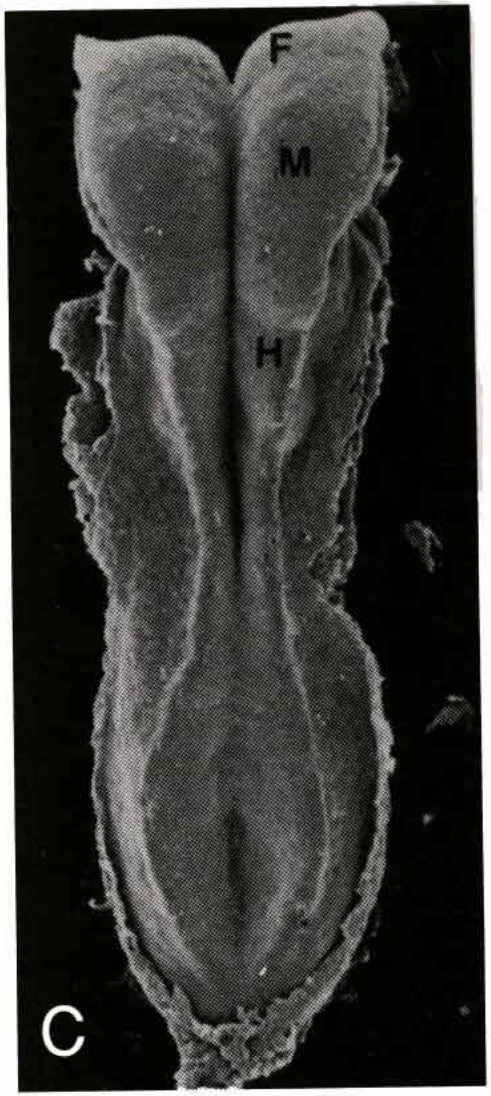

↑FGF-8,noggin, chordin, follistatin
(v primitivním uzlu a později v
prechordální plotence a chordě)
Ectoderm
Intraembryonic mesoderm
↓BMP4
↑BMP4
Extraembryonic
mesoderm
Endoderm
Notochord


A
neurectoderm
ectoderm
1
notochord
B
3
neural crest cells
2
neural groove
notochord


2
1
future surface ectoderm
4
neuroectoderm
5
neural groove
migrating cells of neural crest
3
notochord


surface ectoderm
neural crest cells
neural tube
6
5
ventricle
4
neuro-epithelium
notochord





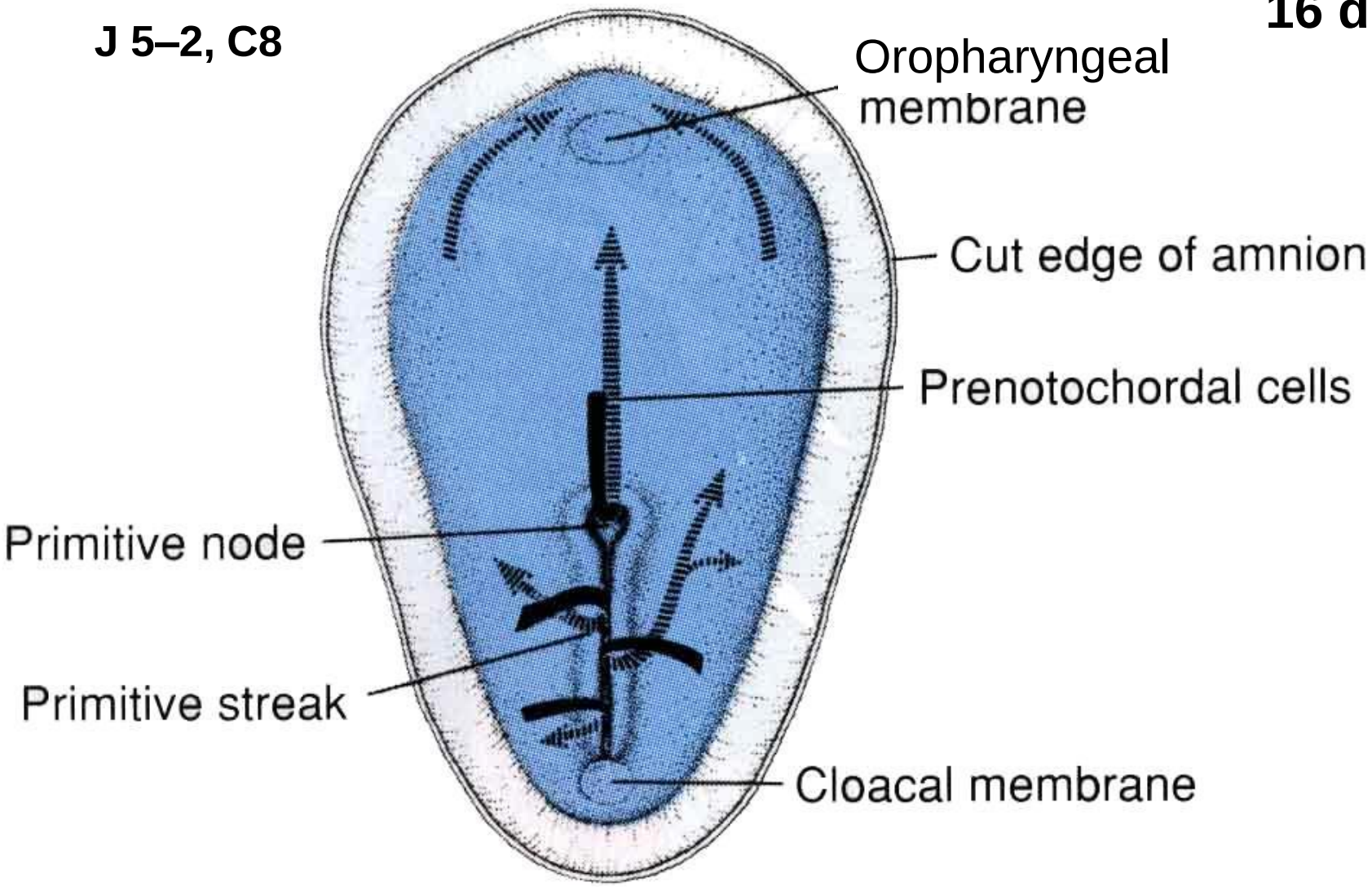
19th day

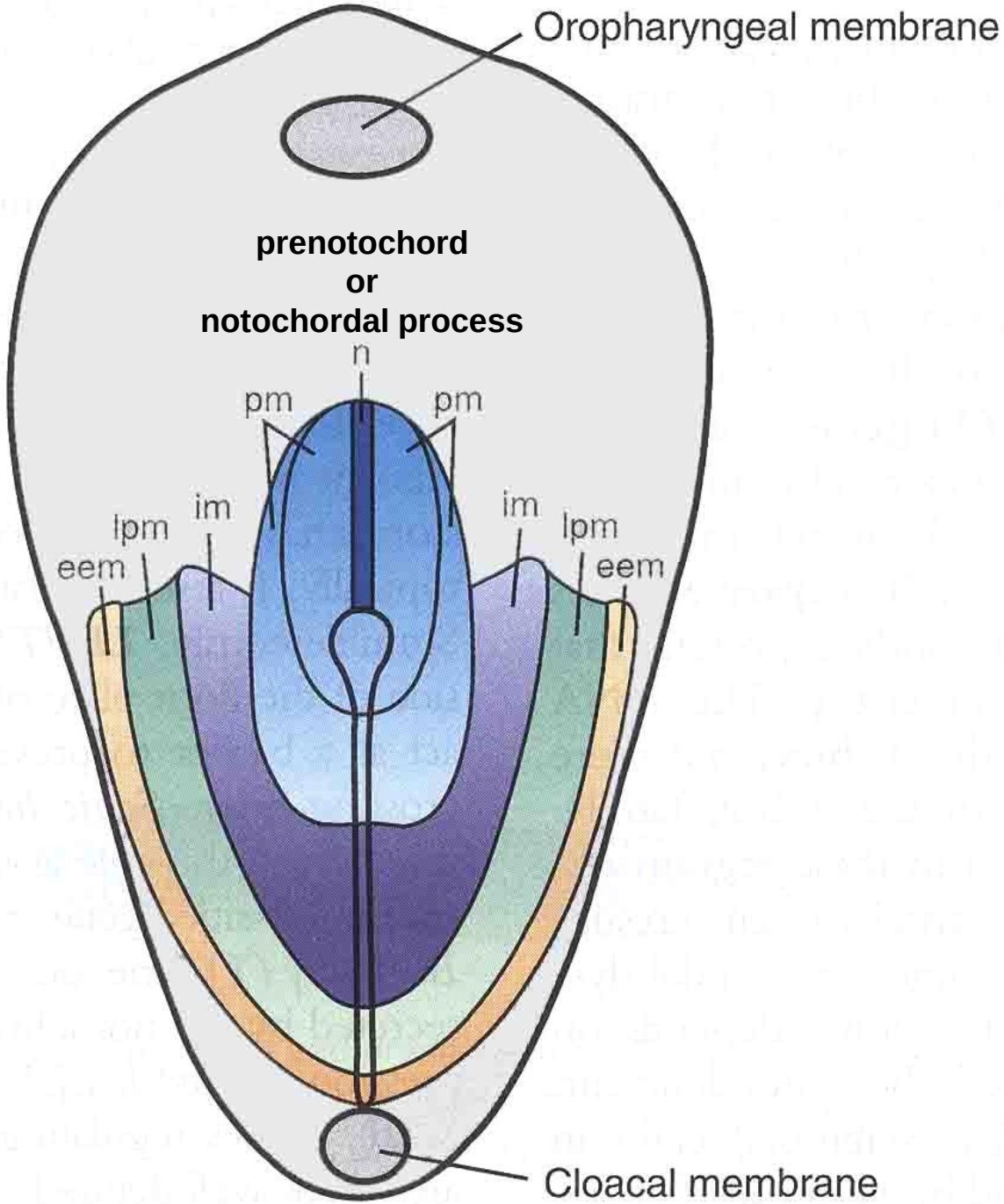
20th day

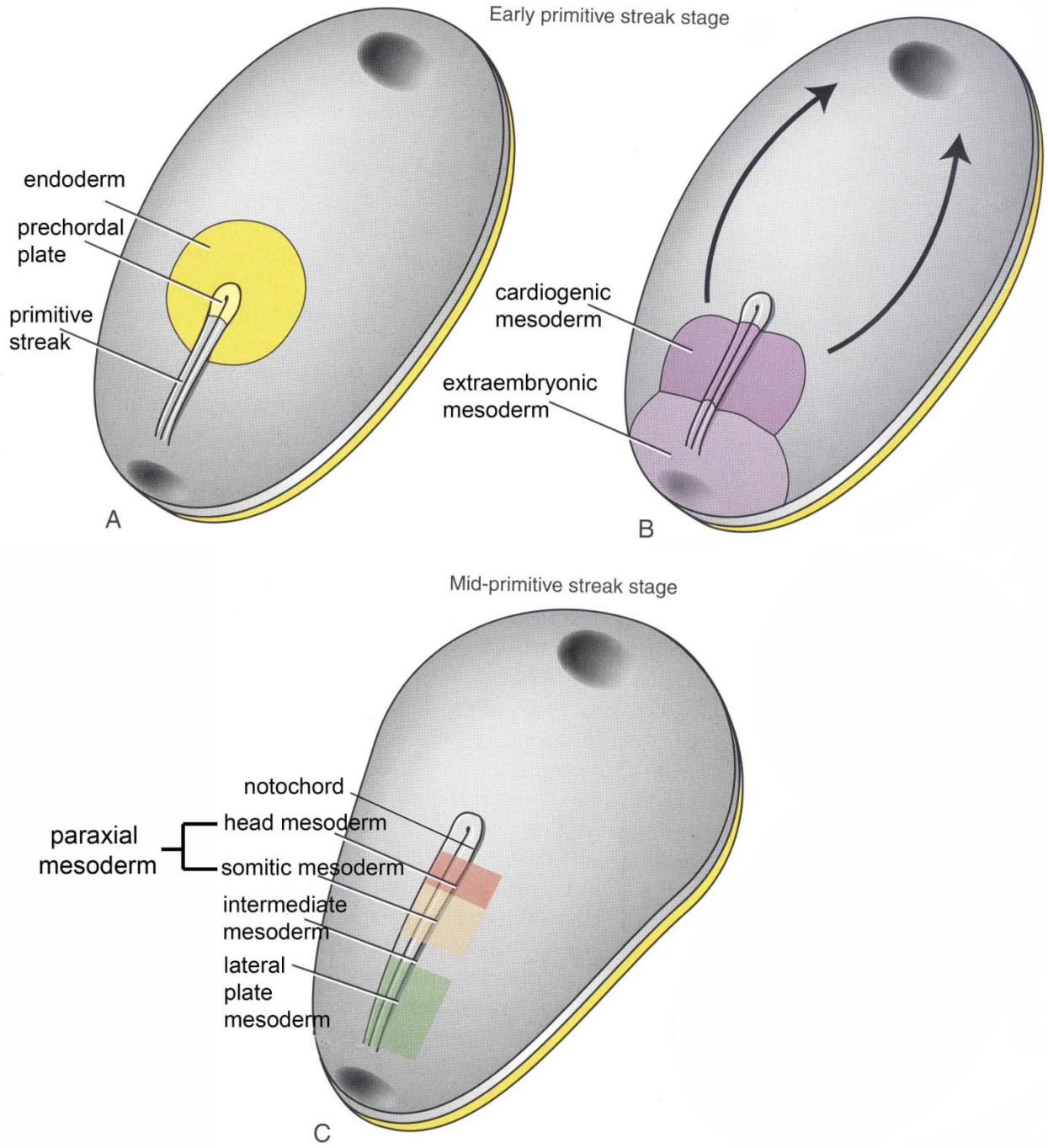
DIFFERENTIATION
OF THE INTRAEMBRYONIC MESODERM

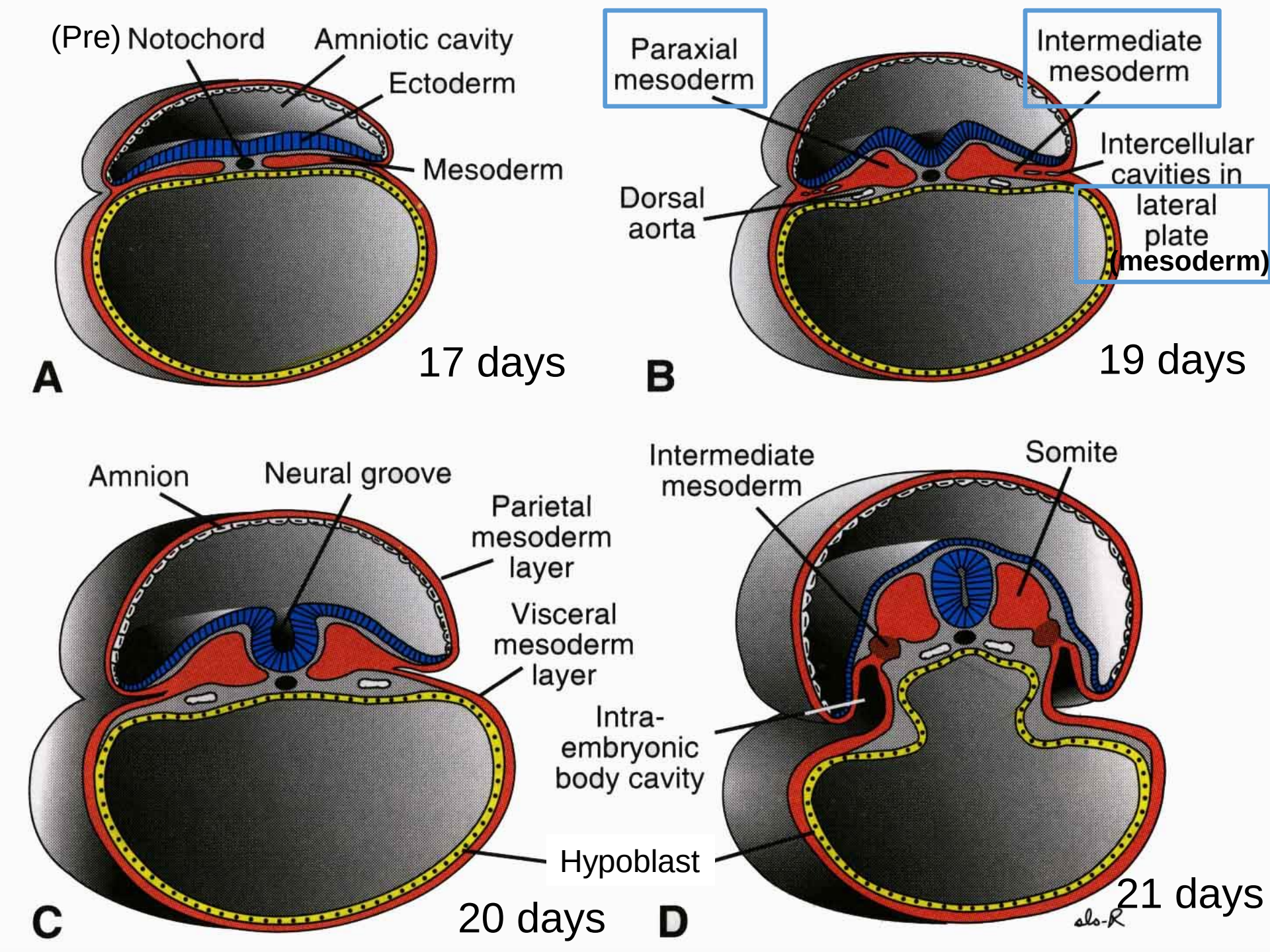
J 5–2, C8

16 d


Oropharyngeal membrane
Cut edge of amnion
Prenotochordal cells
Primitive node
Primitive streak
Cloacal membrane


Oropharyngeal membrane
prenotochord
or
notochordal process
n
pm
pm
im
im
lpm
lpm
eem
eem
Cloacal membrane


Early primitive streak stage
endoderm
prechordal plate
primitive streak
A
cardiogenic mesoderm
extraembryonic mesoderm
B
Mid-primitive streak stage
notochord
paraxial mesoderm
head mesoderm
somitic mesoderm
intermediate mesoderm
lateral plate mesoderm
C


(Pre) Notochord
Amniotic cavity
Ectoderm
Mesoderm
A
17 days
Paraxial mesoderm
Intermediate mesoderm
Intercellular cavities in lateral plate (mesoderm)
Dorsal aorta
B
19 days
Amnion
Neural groove
Parietal mesoderm layer
Visceral mesoderm layer
Intra-embryonic body cavity
Hypoblast
C
20 days
Intermediate mesoderm
Somite
D
21 days

Stage 6 (J–6)
cylindrical embryo

formation of somites, closing neural tube, heart tube and loop

days 20 – 30, length MLL 1.2 – 3 mm

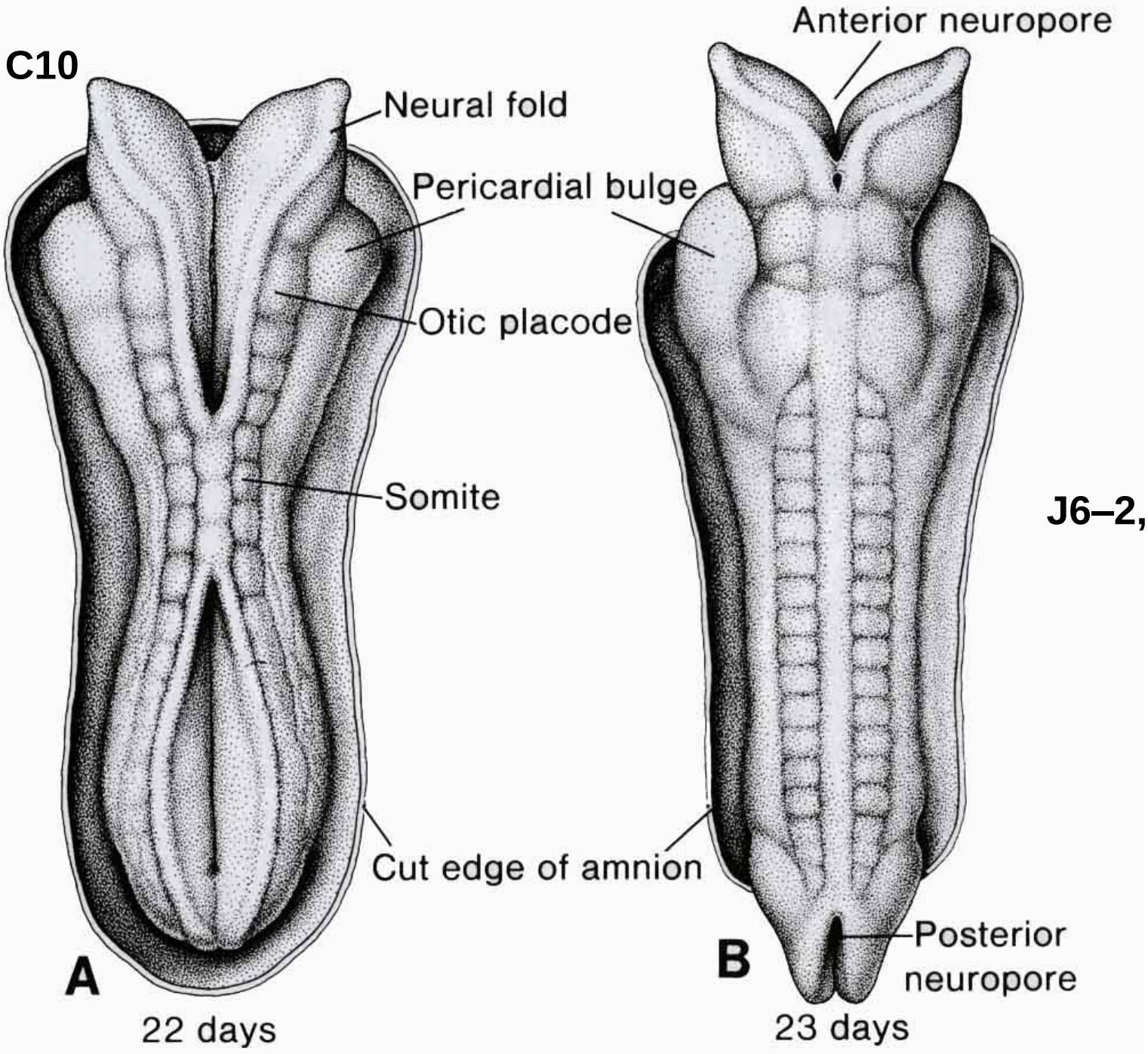
Substages

J6–1 embryos with completely open neural tube and first seven somite pairs (C9/10)

J6–2 embryos with closing neural tube, anterior and posterior neuropores (C10)

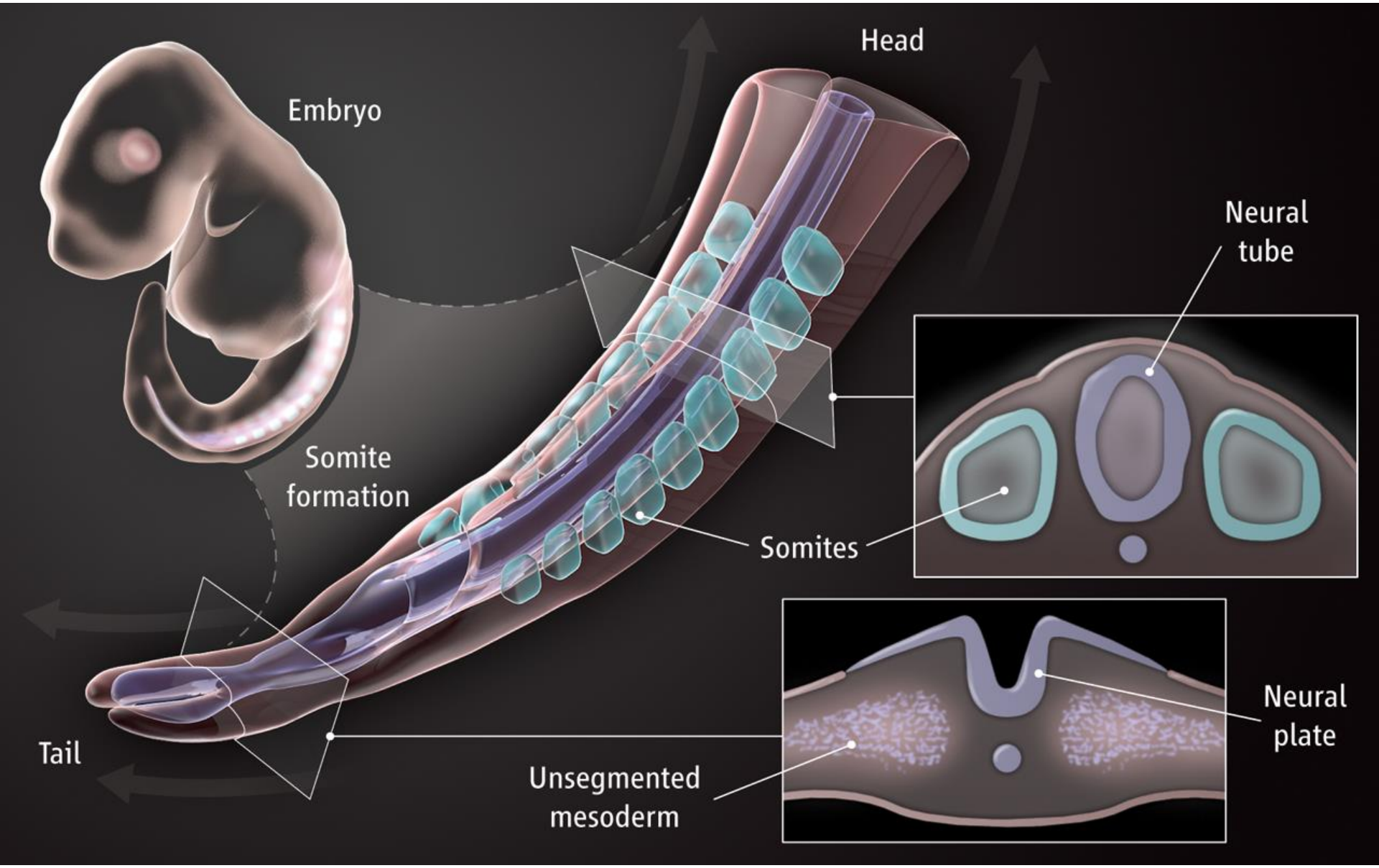
J6–3 embryos with anterior, or both, neuropores closed, no limb buds (C11/12)

J6–1, C10



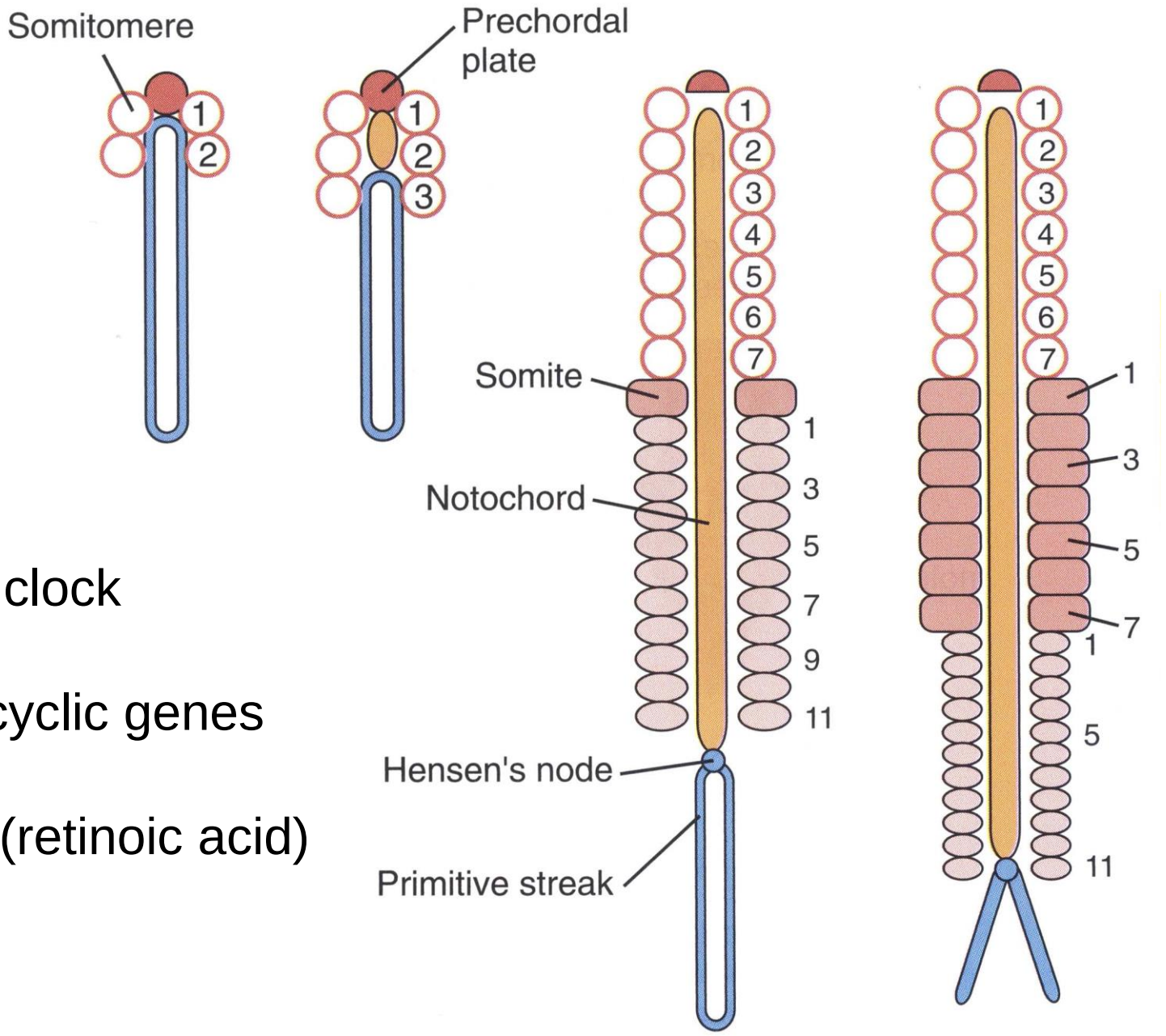
J6–2, C10

J 6–3, C11/12



Wolters Kluwer •Shigeru Kondo , Self-Organizing Somites.*Science***343**,736-737(2014).DOI:10.1126/science.1250245

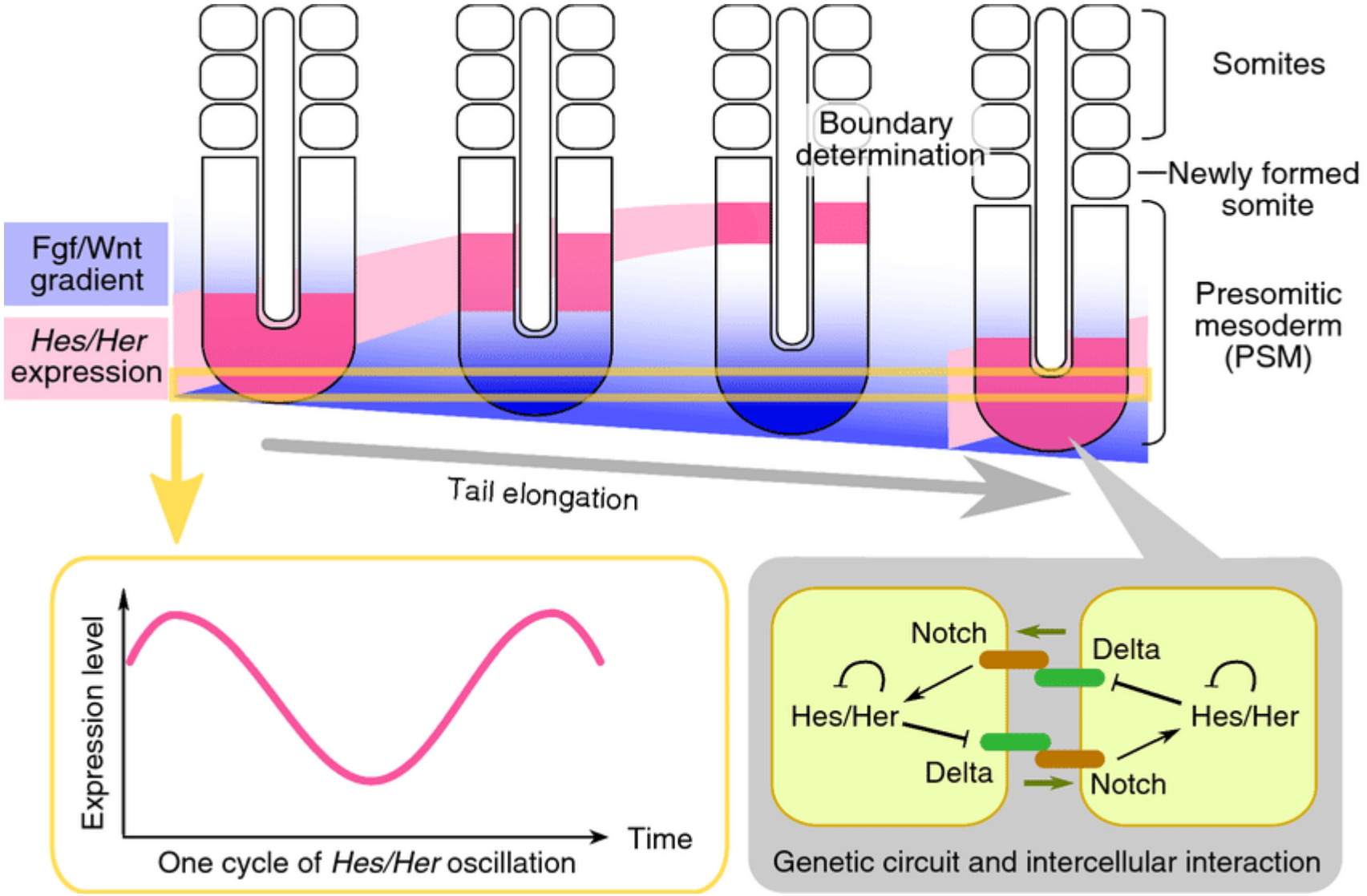
Paraxial mesoderm



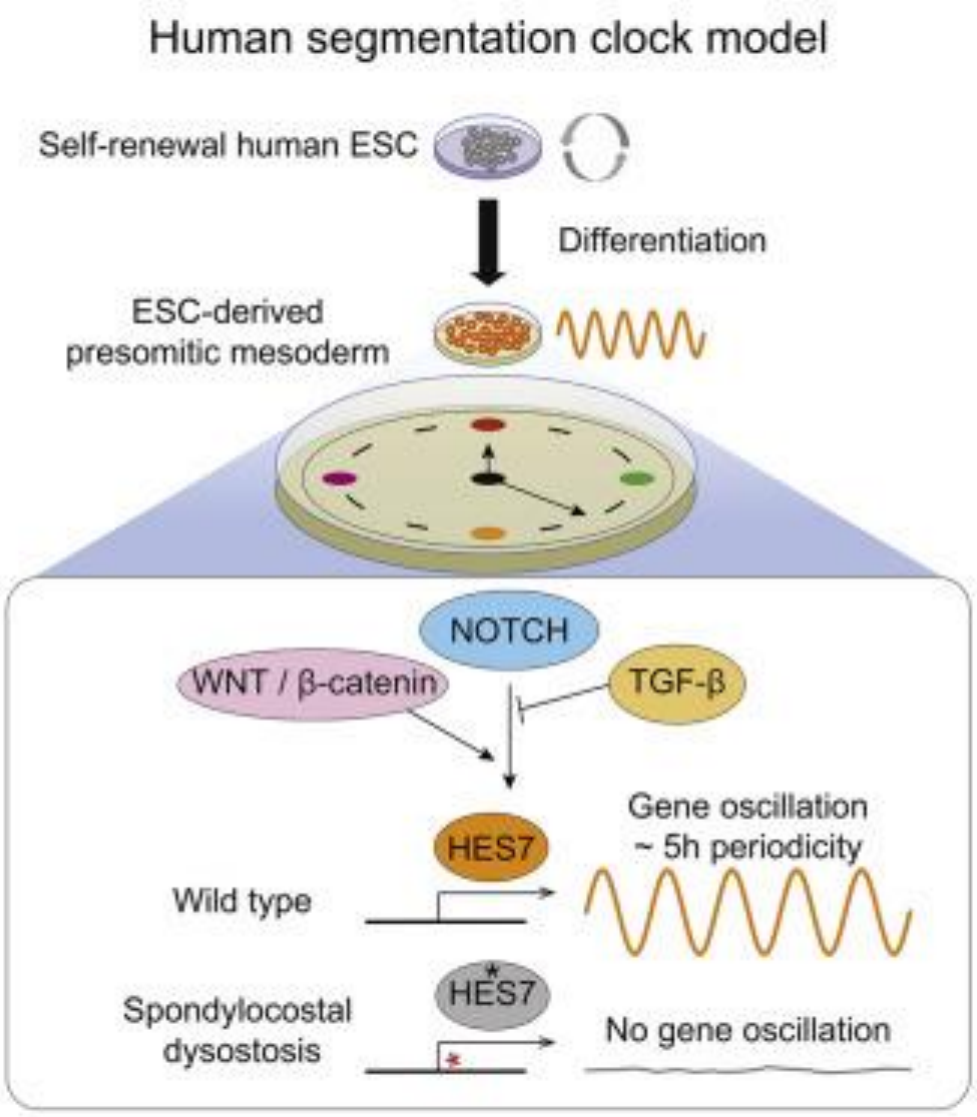
Segmentation clock

Wnt, Notch – cyclic genes

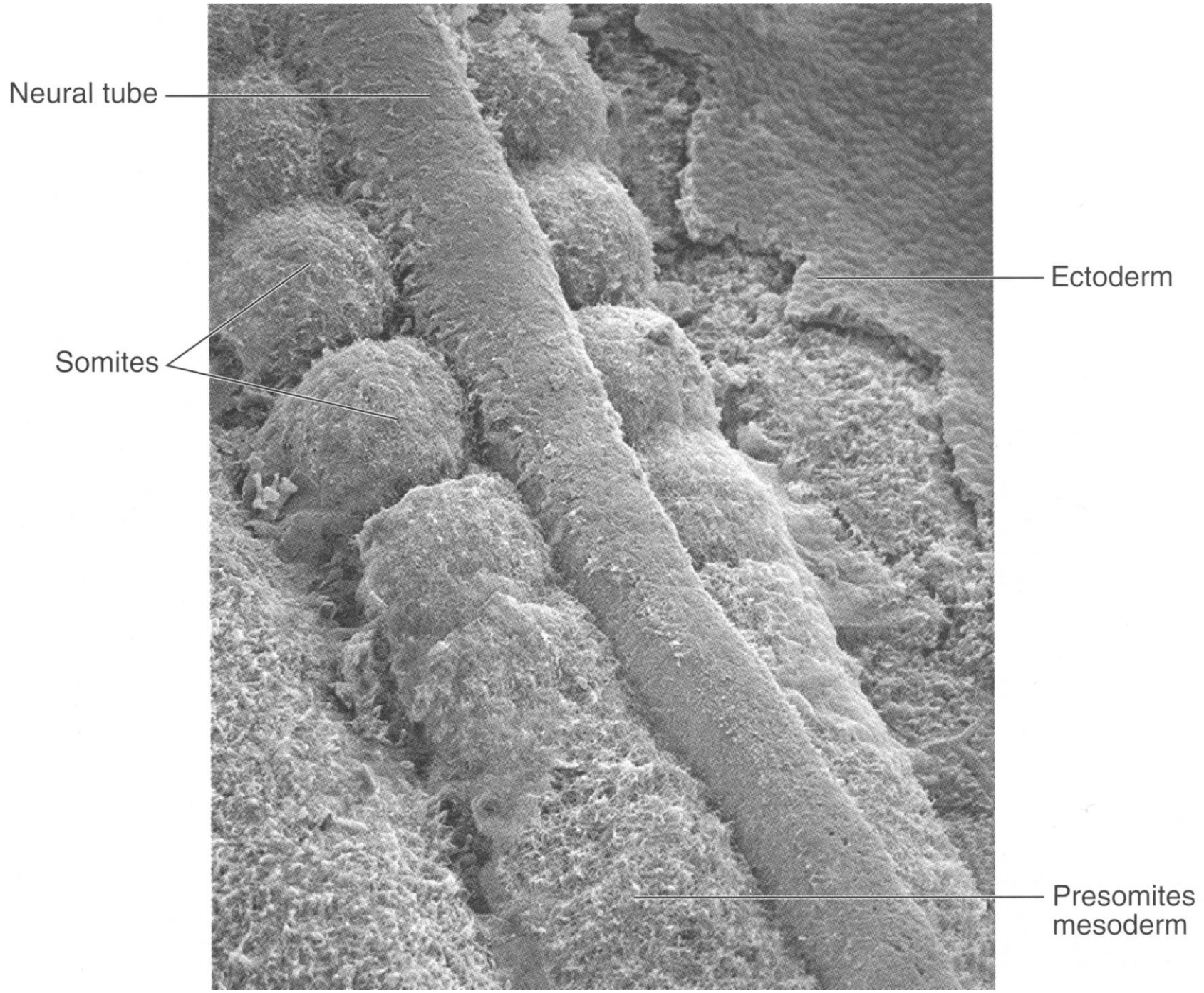
↓FGF8 ↑RA (retinoic acid)



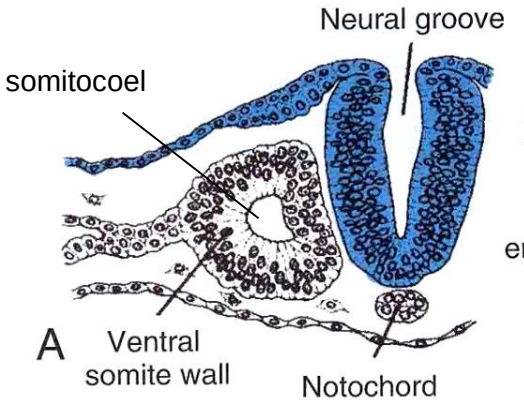
Yoshioka-Kobayashi, Kumiko & Kageyama, Ryoichiro. (2021). Imaging and manipulating the segmentation clock. Cellular and Molecular Life Sciences. 78. 1-11. 10.1007/s00018-020-03655-z.

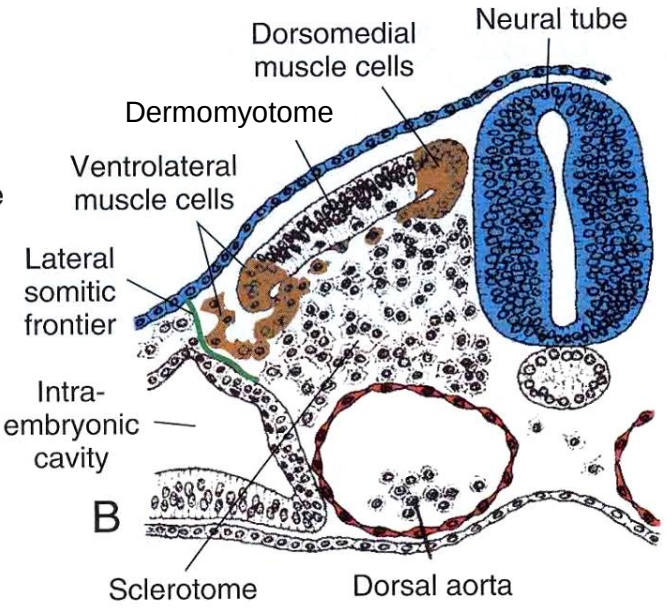


Li-Fang Chu, Daniel Mamott, Zijian Ni, Rhonda Bacher, Cathy Liu, Scott Swanson, Christina Kendziorski, Ron Stewart, James A. Thomson, An In Vitro Human Segmentation Clock Model Derived from Embryonic Stem Cells, Cell Reports, Volume 28, Issue 9, 2019, Pages 2247-2255.e5, ISSN 2211-1247, https://doi.org/10.1016/j.celrep.2019.07.090.

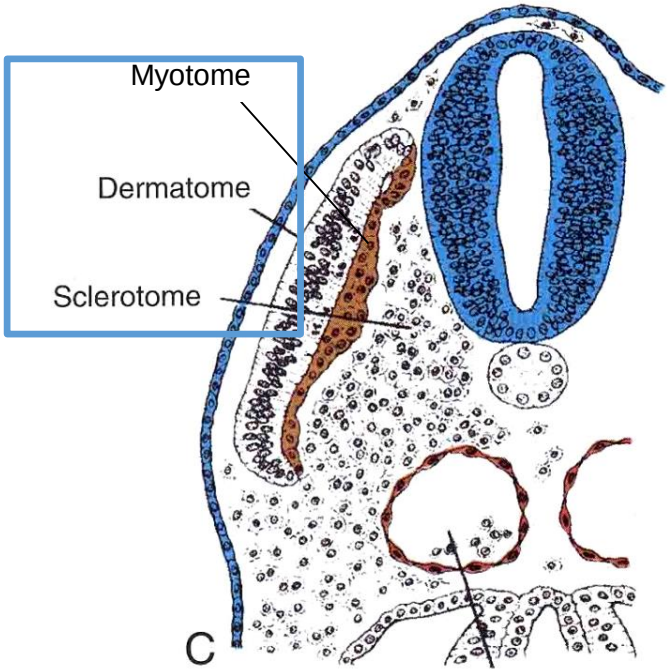

Neural tube
Somites
Ectoderm
Presomites
mesoderm

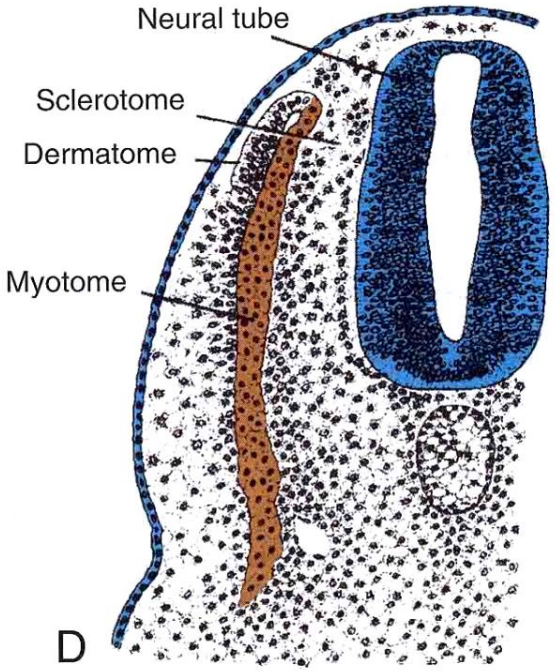
Somites



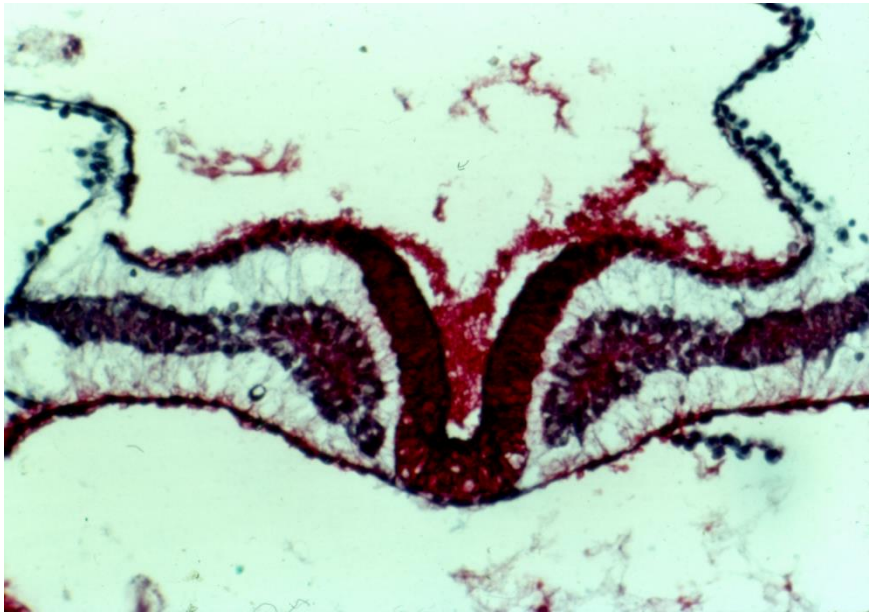


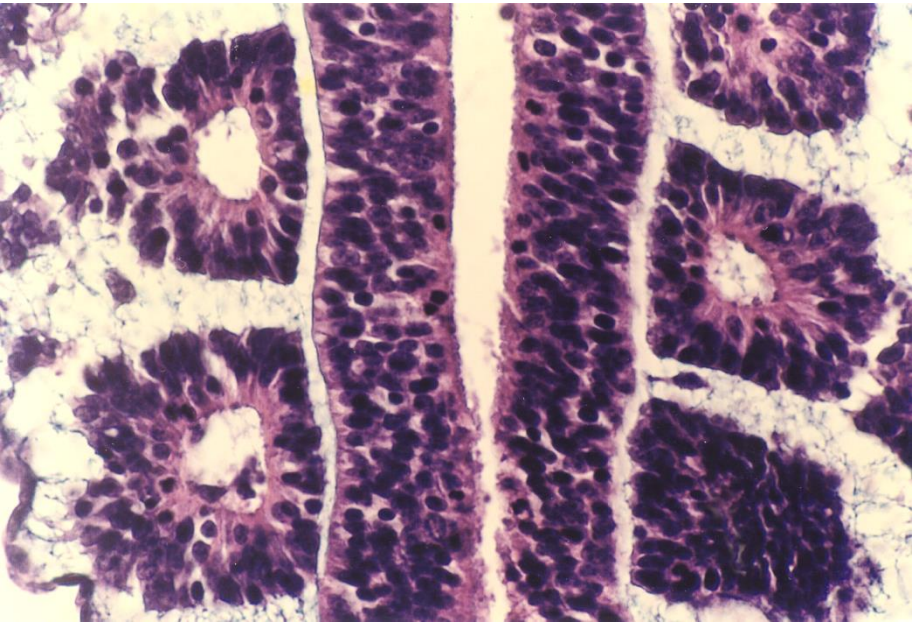
1st pair of somites on the day 20
till the end of the 5th week 42-44 somite pairs

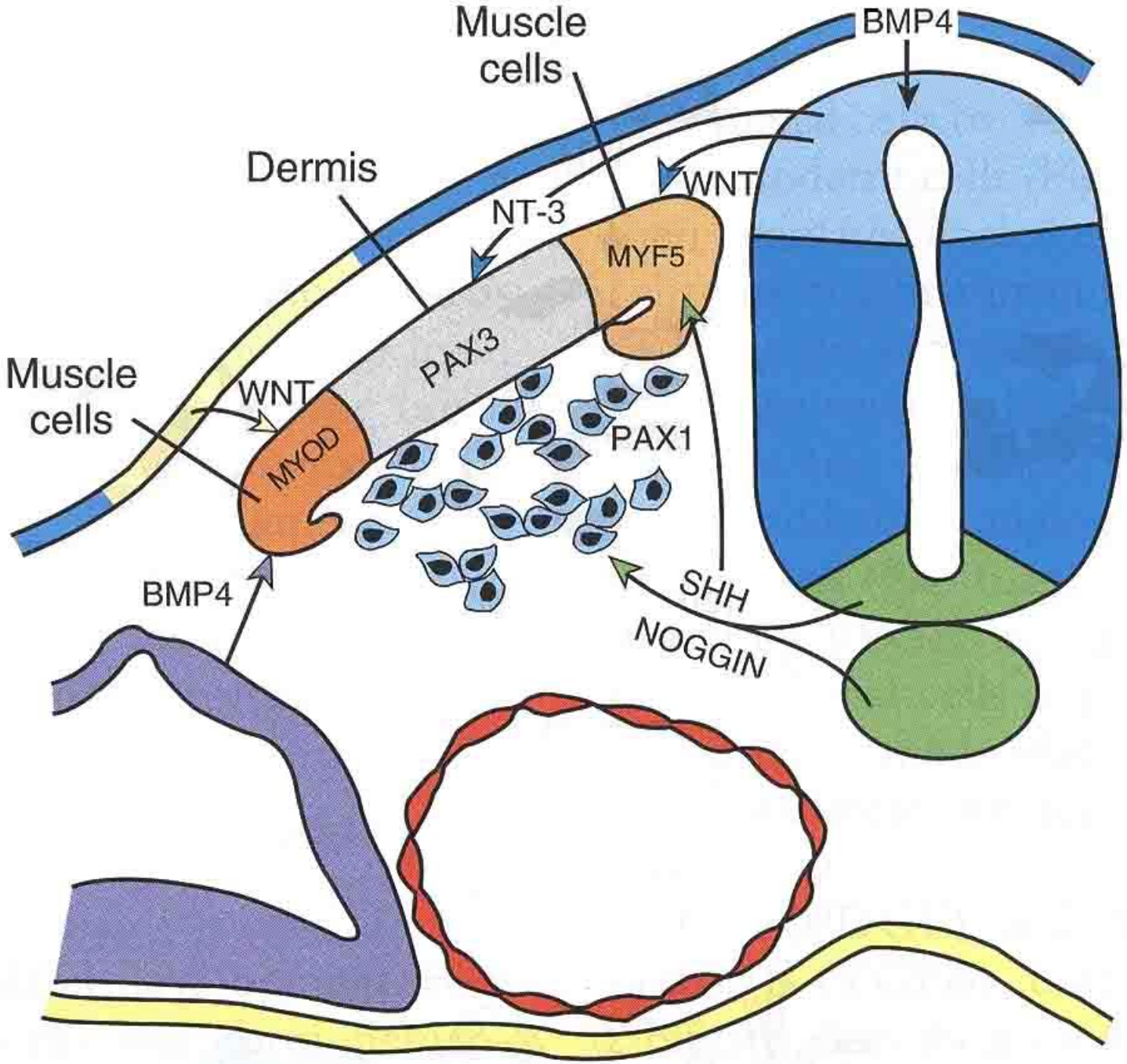




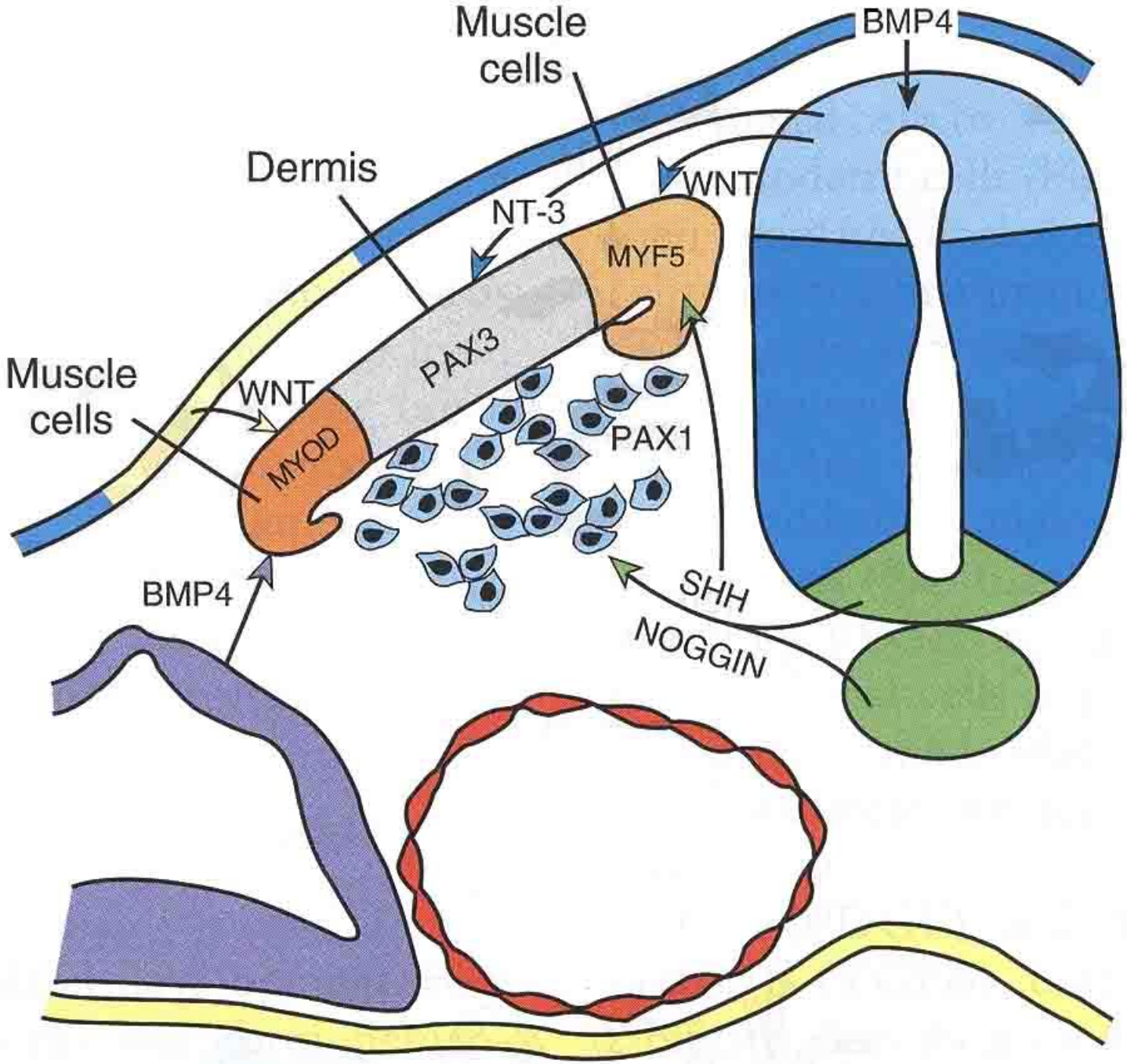
Somites



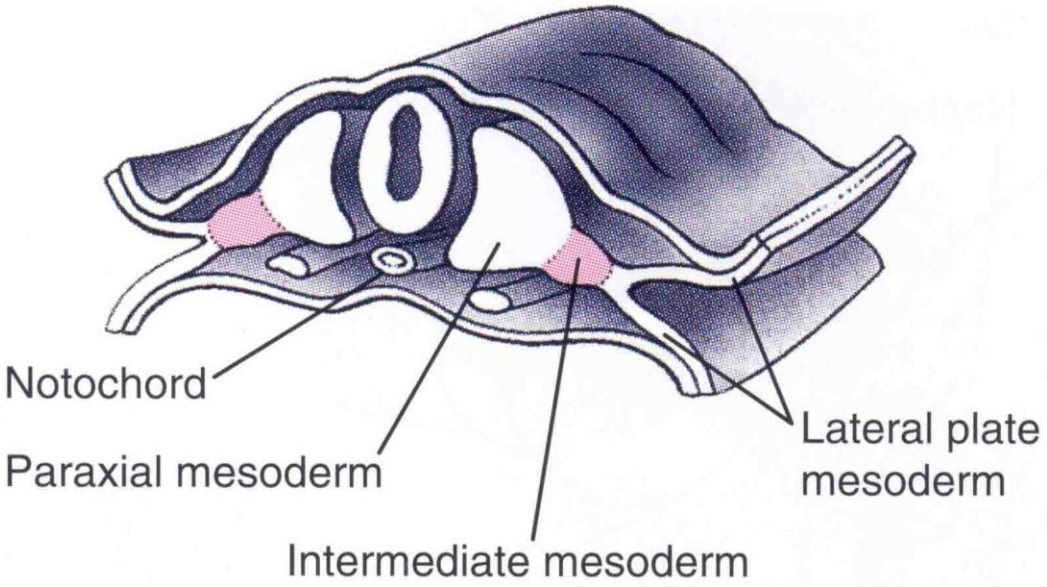


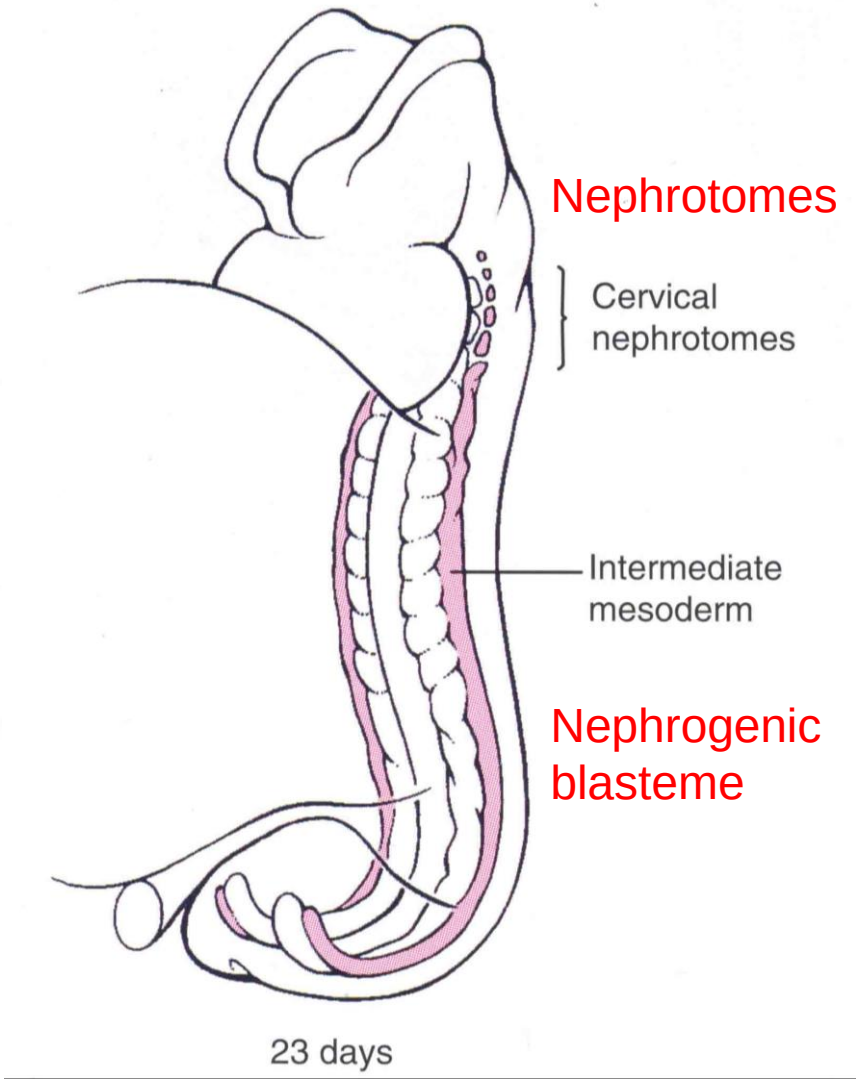

Muscle cells
BMP4
Dermis
WNT
NT-3
MYF5
PAX3
Muscle cells
WNT
MYOD
PAX1
BMP4
SHH
NOGGIN

https://en.wikifur.com/wiki/Sonic_the_Hedgehog_%28character%29

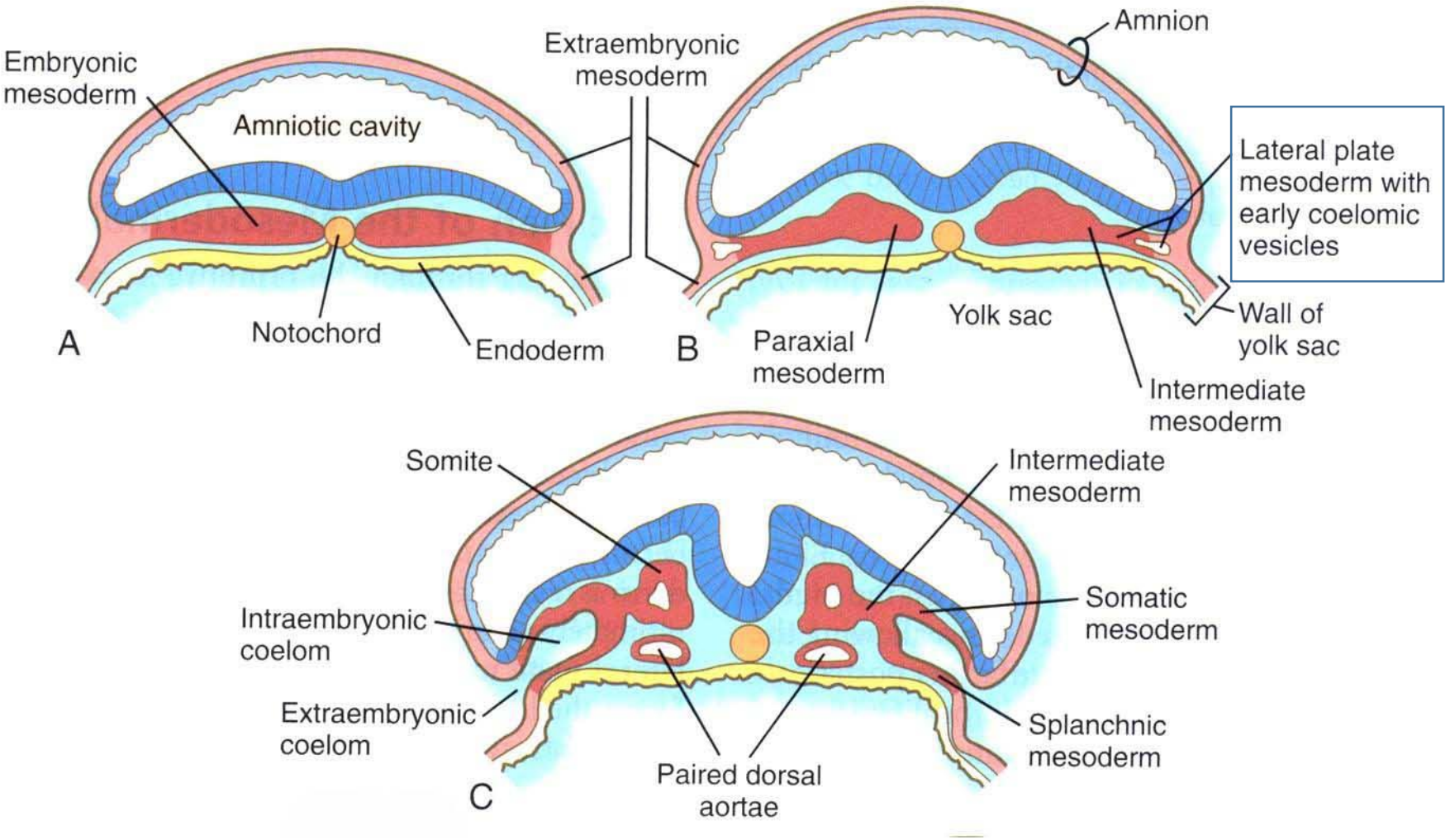

Muscle cells
BMP4
Dermis
WNT
NT-3
MYF5
PAX3
Muscle cells
WNT
MYOD
PAX1
BMP4
SHH
NOGGIN

Intermediate mesoderm



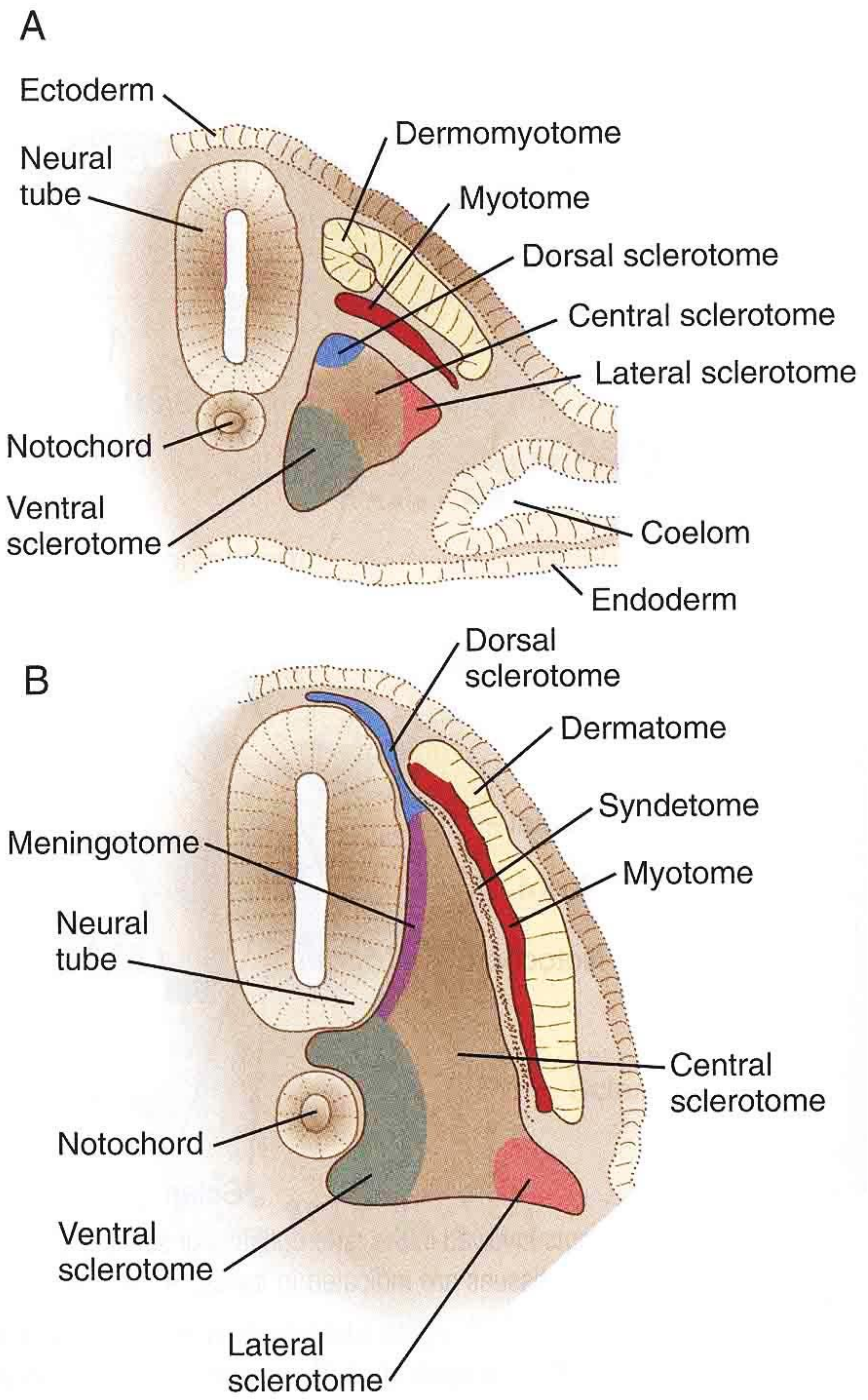


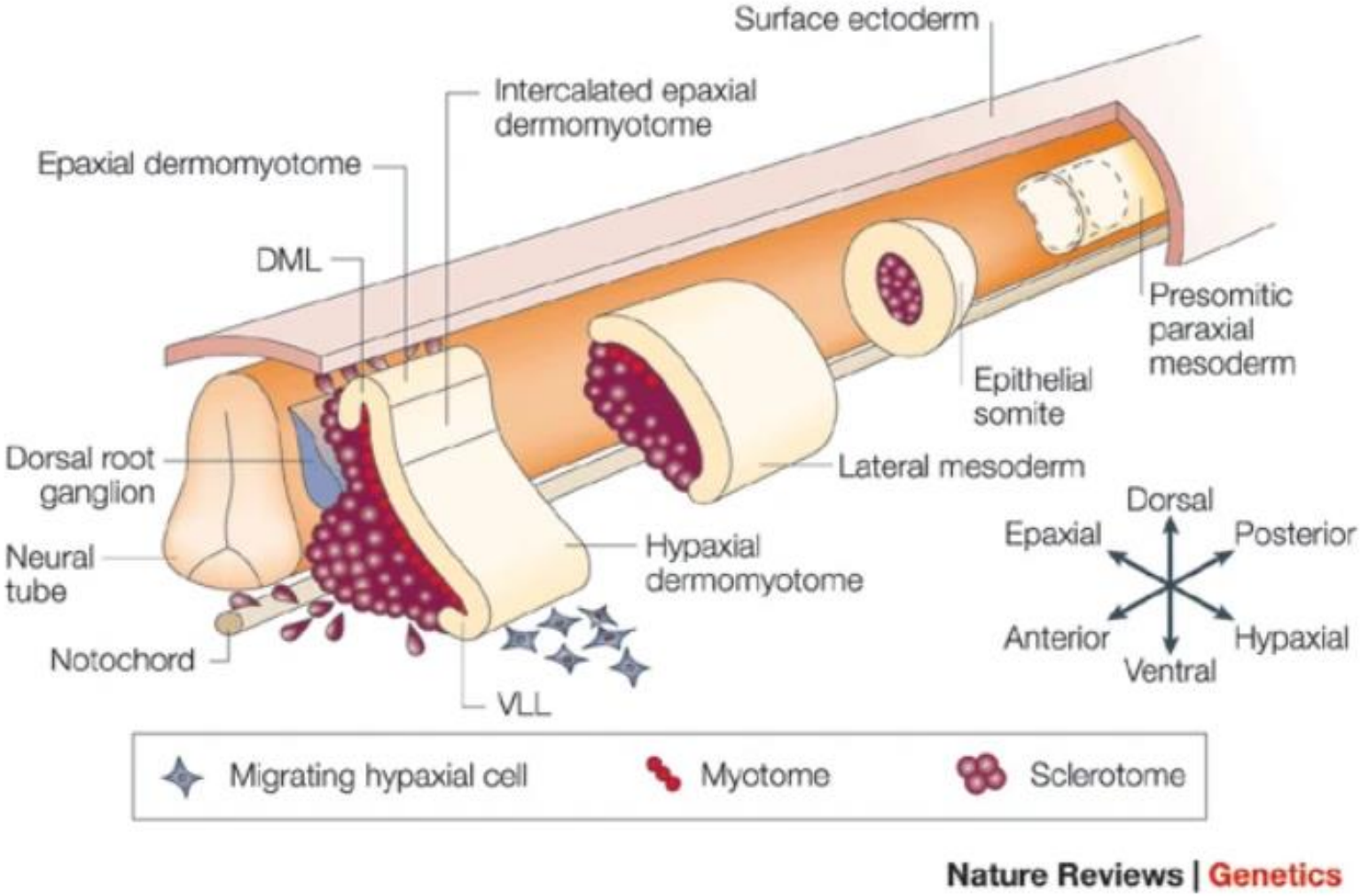
Mesoderm of the lateral plate



DEVELOPMENT
OF THE SKELETAL SYSTEM

Sclerotome

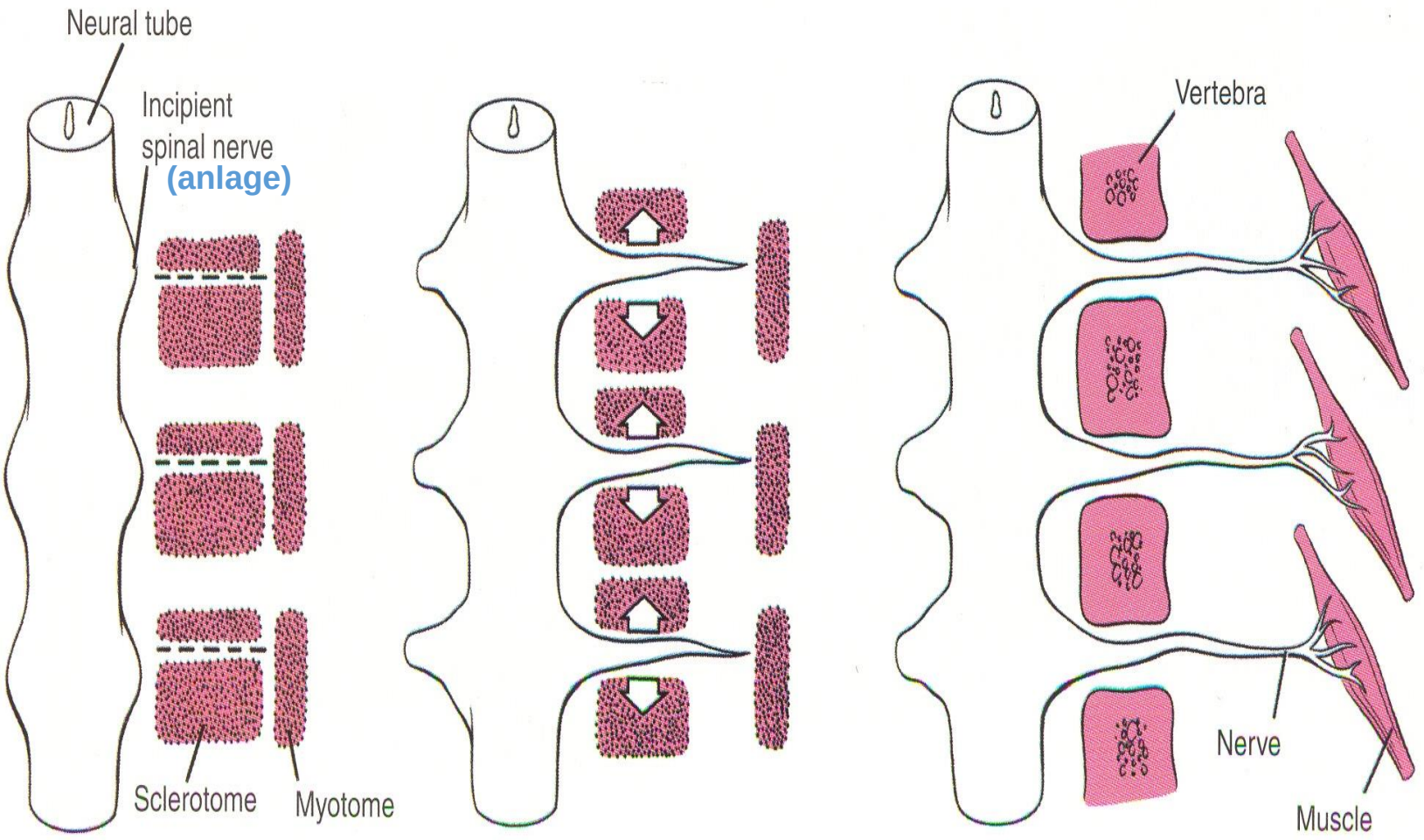

A
Ectoderm
Neural tube
Dermomyotome
Myotome
Dorsal sclerotome
Central sclerotome
Lateral sclerotome
Notochord
Ventral sclerotome
Coelom
Endoderm
B
Dorsal sclerotome
Dermatome
Syndetome
Myotome
Meningotome
Neural tube
Central sclerotome
Notochord
Ventral sclerotome
Lateral sclerotome

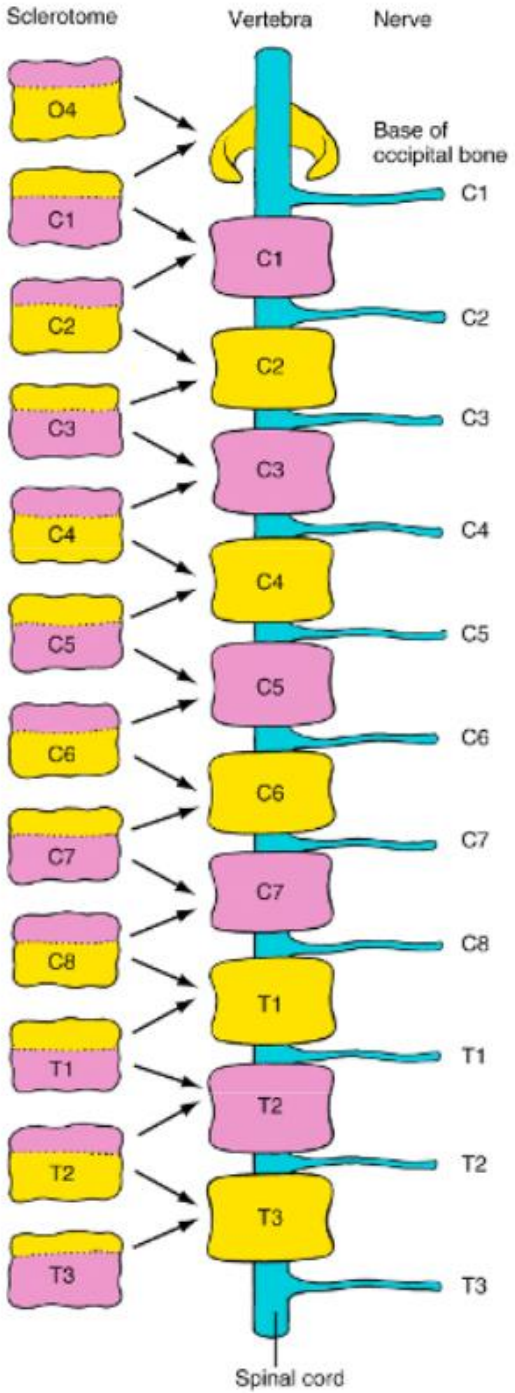


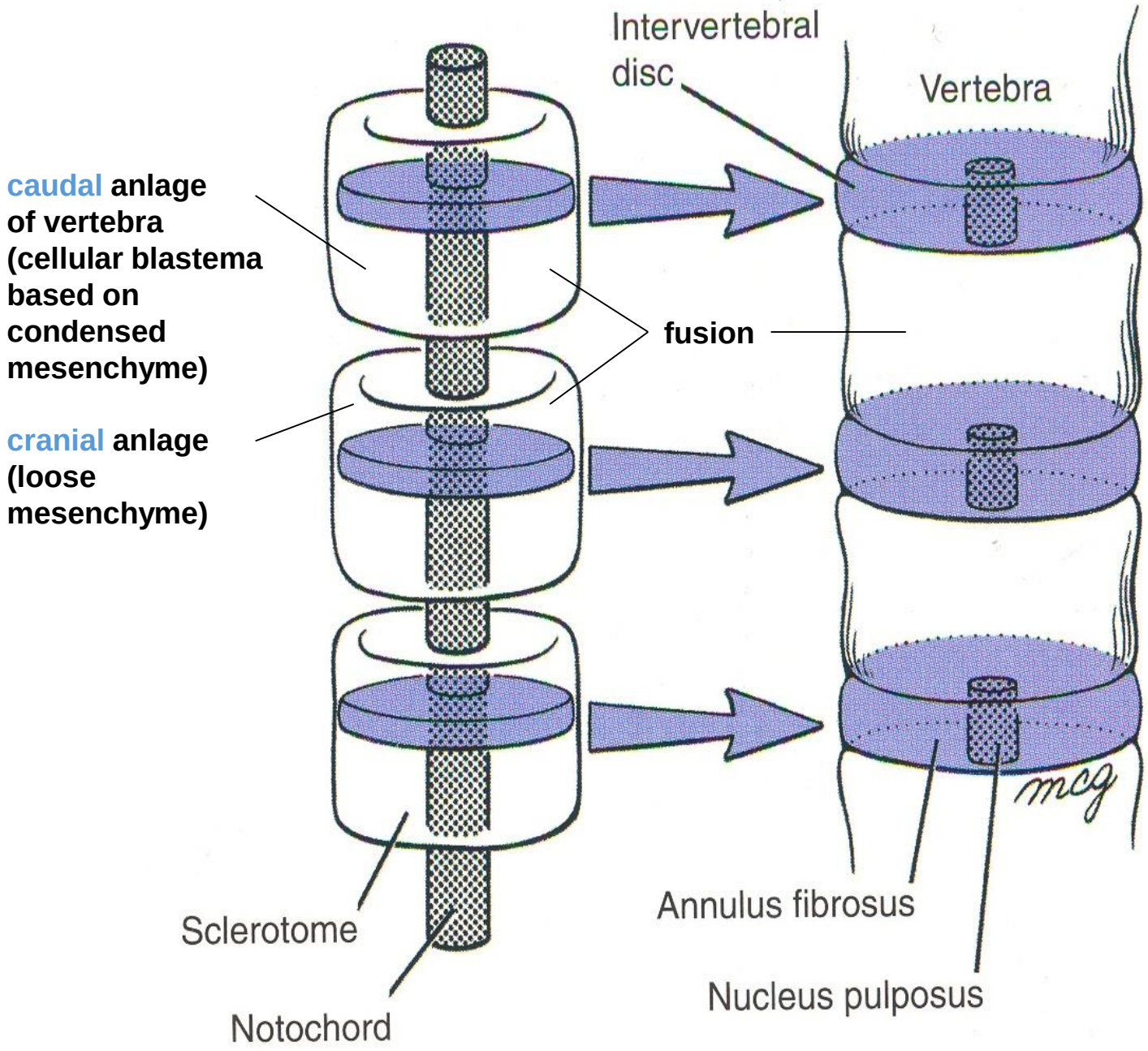
Parker, M., Seale, P. & Rudnicki, M. Looking back to the embryo: defining transcriptional networks in adult myogenesis. *Nat Rev Genet* **4**, 497–507 (2003). https://doi.org/10.1038/nrg1109

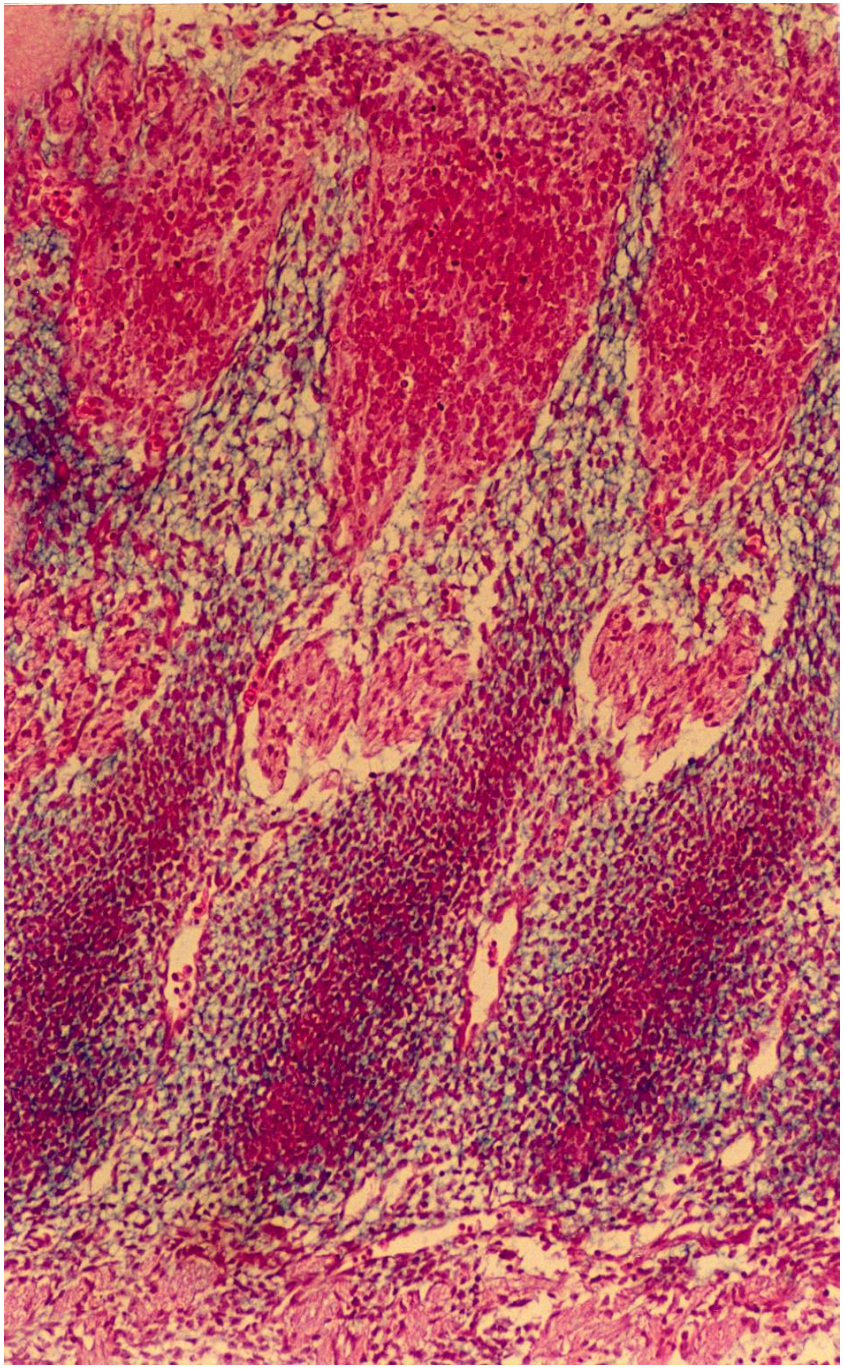
Sclerotome resegmentation

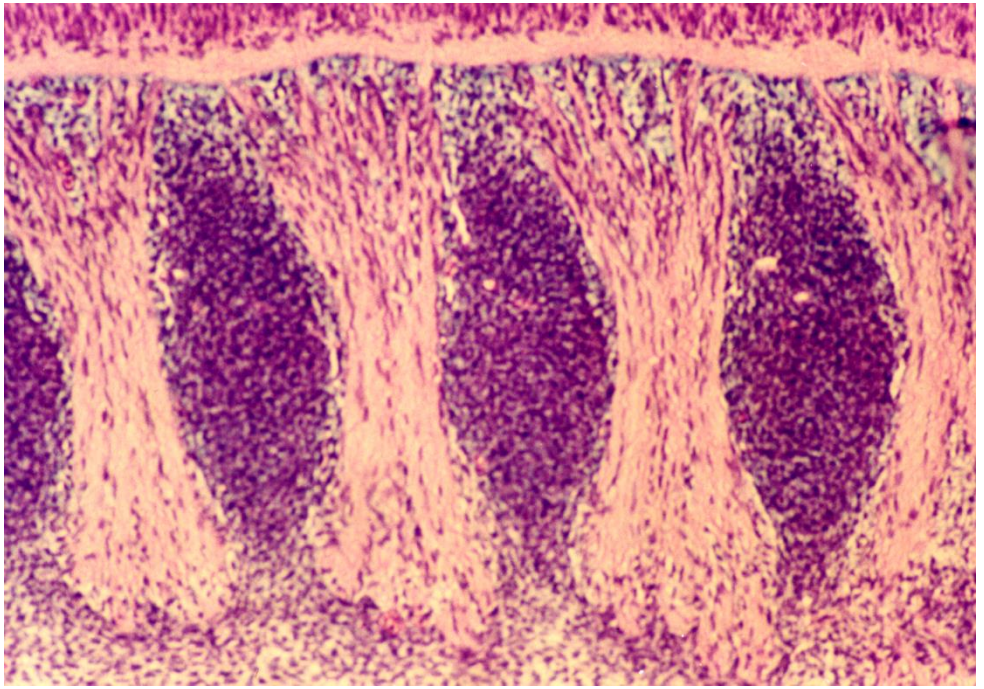
neural tube is inductive to development of sclerotome

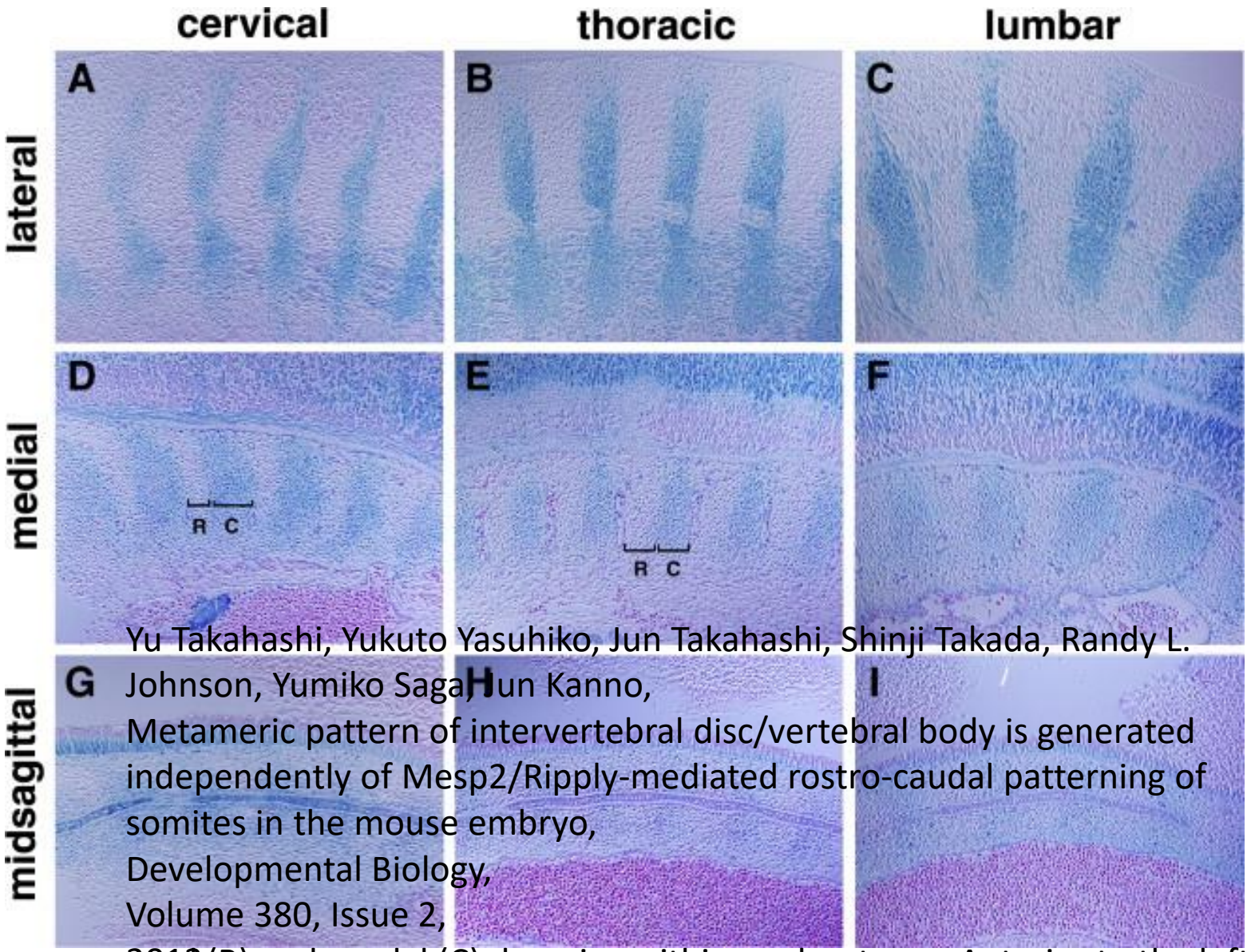



Sclerotome
Vertebra
Nerve
O4
C1
C2
C3
C4
C5
C6
C7
C8
T1
T2
T3
Base of occipital bone
C1
C2
C3
C4
C5
C6
C7
C8
T1
T2
T3
Spinal cord


caudal anlage of vertebra (cellular blastema based on condensed mesenchyme)
cranial anlage (loose mesenchyme)
Intervertebral disc
Vertebra
fusion
Sclerotome
Notochord
Annulus fibrosus
Nucleus pulposus
mcg

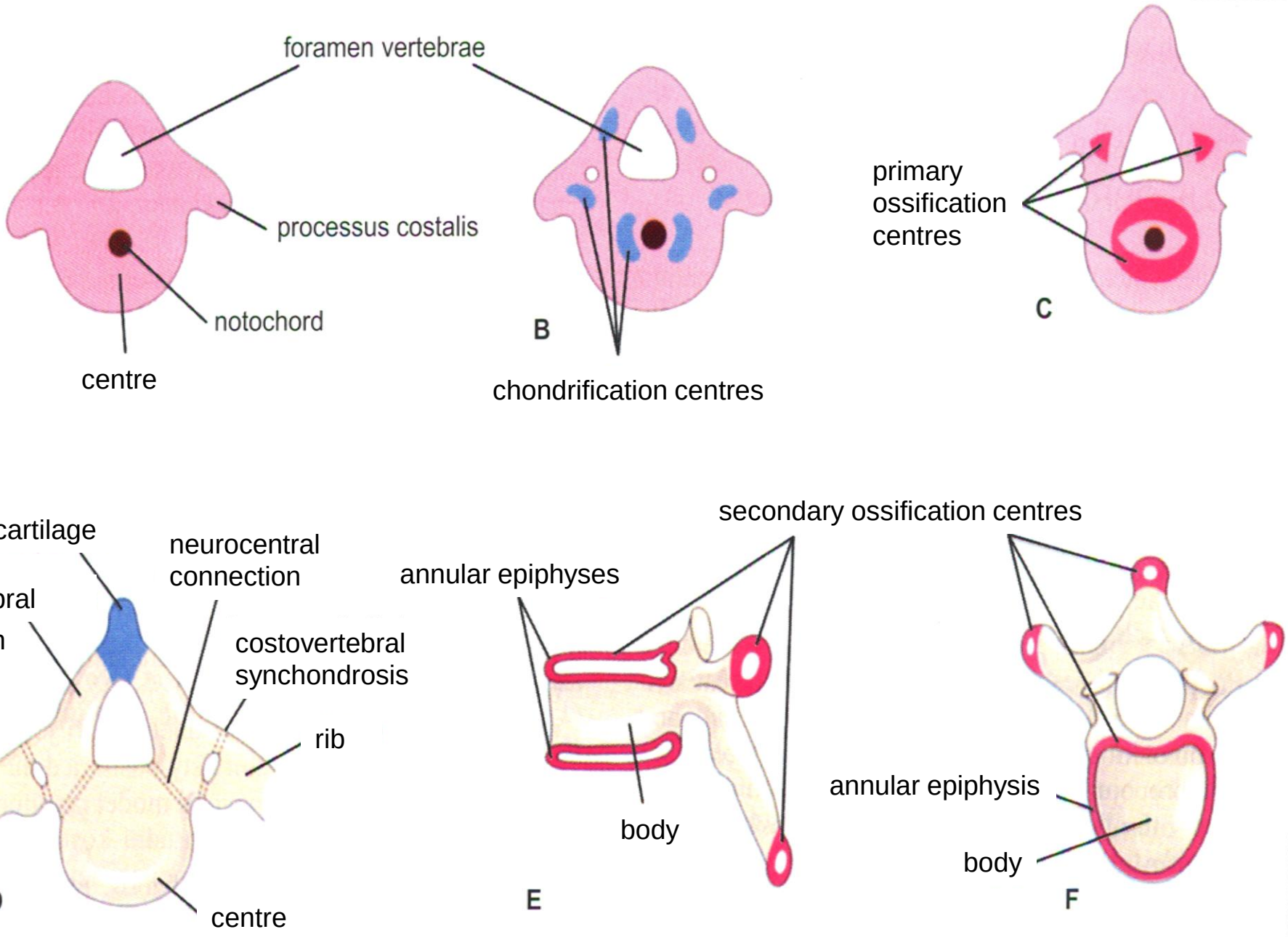


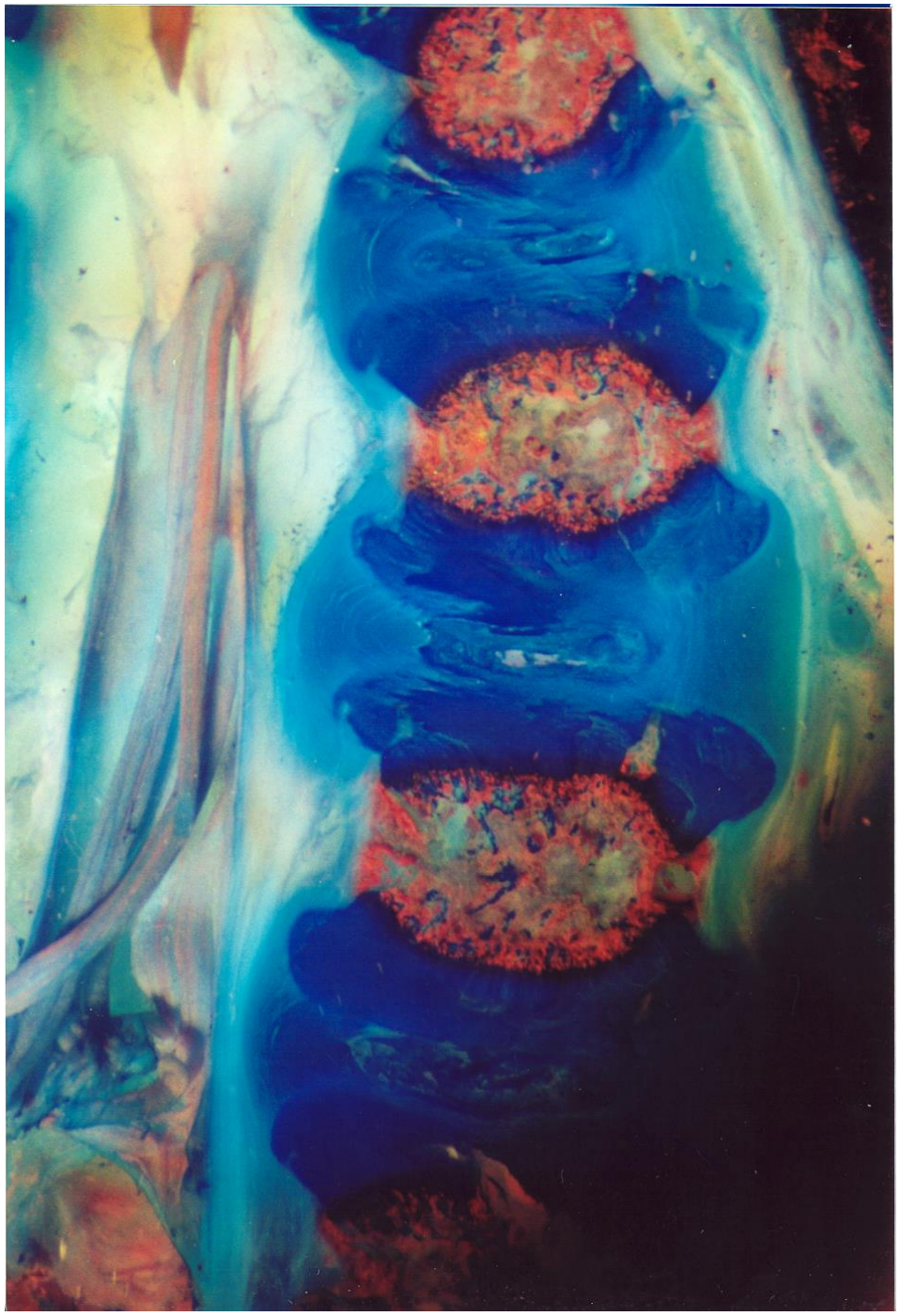


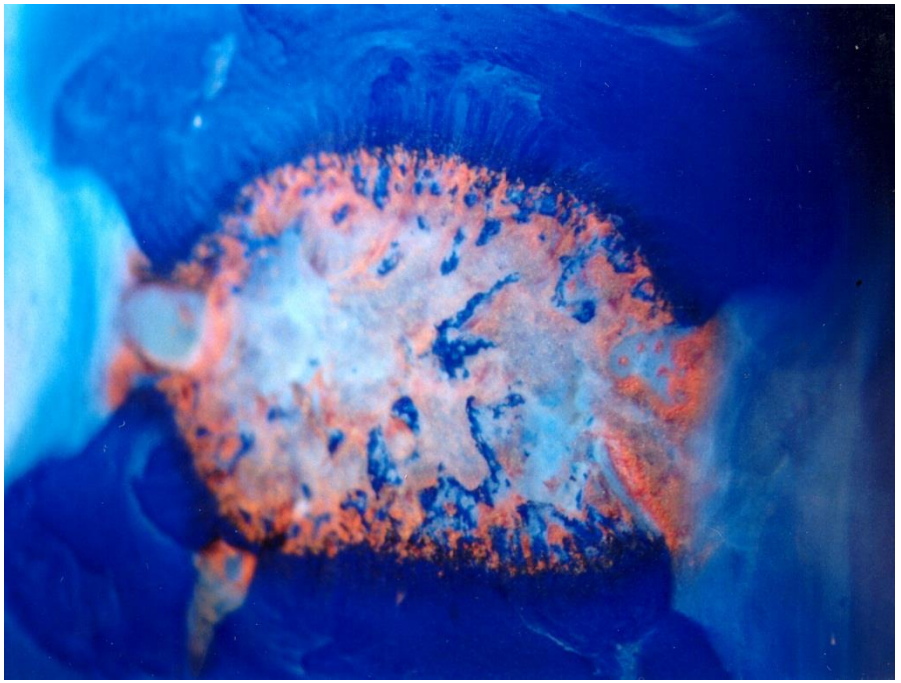


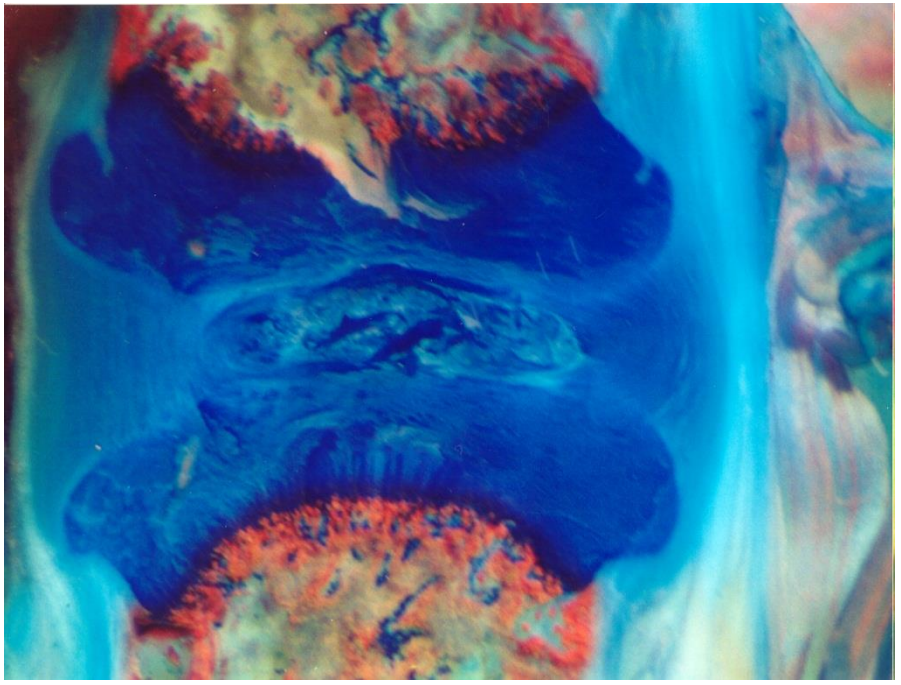
Yu Takahashi, Yukuto Yasuhiko, Jun Takahashi, Shinji Takada, Randy L. Johnson, Yumiko Saga, Jun Kanno,
Metameric pattern of intervertebral disc/vertebral body is generated independently of Mesp2/Ripply-mediated rostro-caudal patterning of somites in the mouse embryo,
Developmental Biology,
Volume 380, Issue 2,
2013,
Pages 172-184,
ISSN 0012-1606,
https://doi.org/10.1016/j.ydbio.2013.05.020.

…. rostral (R) and caudal (C) domains within a sclerotome. Anterior to the left, dorsal at the top.


foramen vertebrae
processus costalis
notochord
centre
B
chondrification centres
primary ossification centres
C
cartilage
neurocentral connection
vertebral arch
costovertebral synchondrosis
rib
centre
D
secondary ossification centres
annular epiphyses
body
E
annular epiphysis
body
F

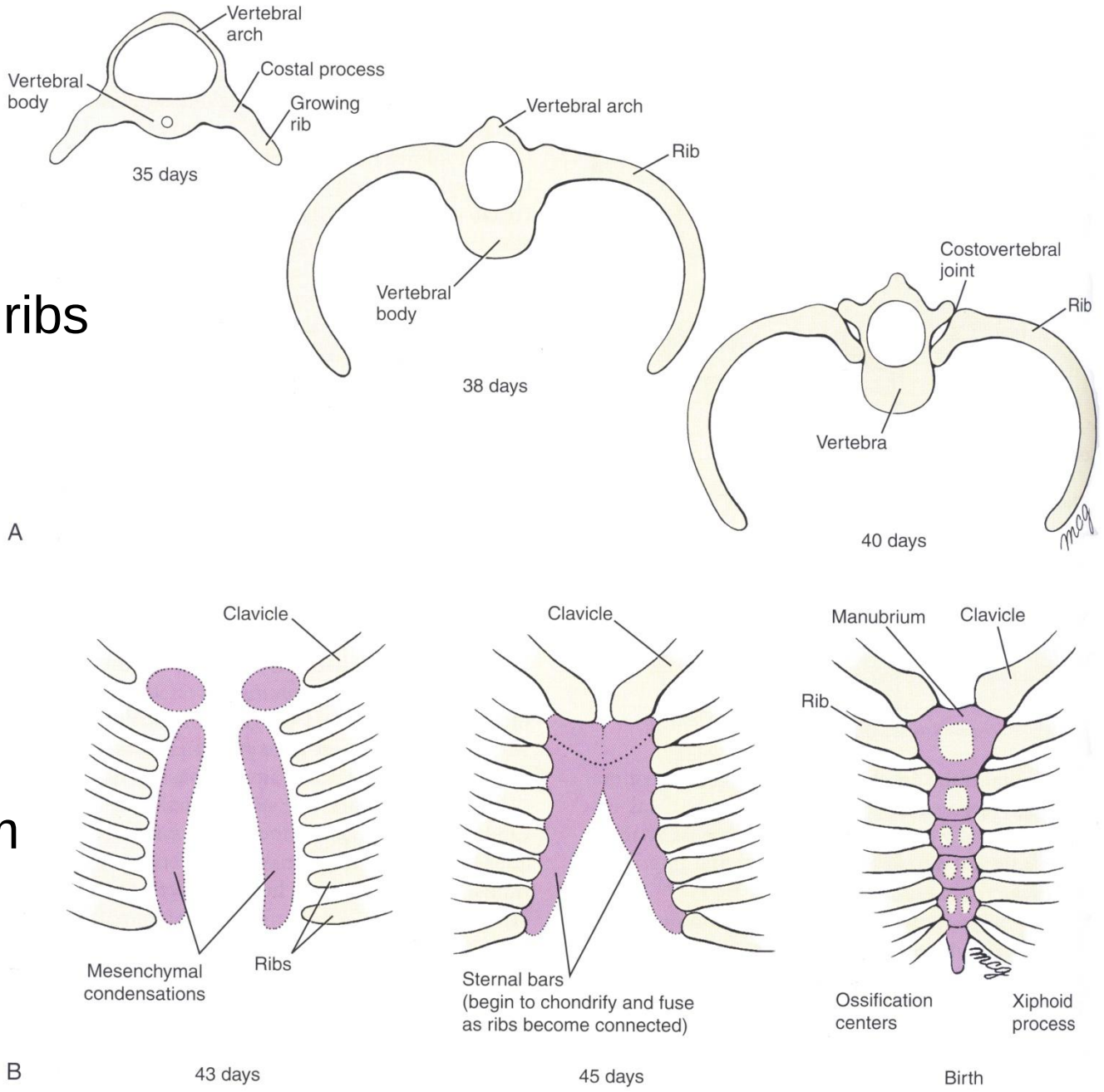




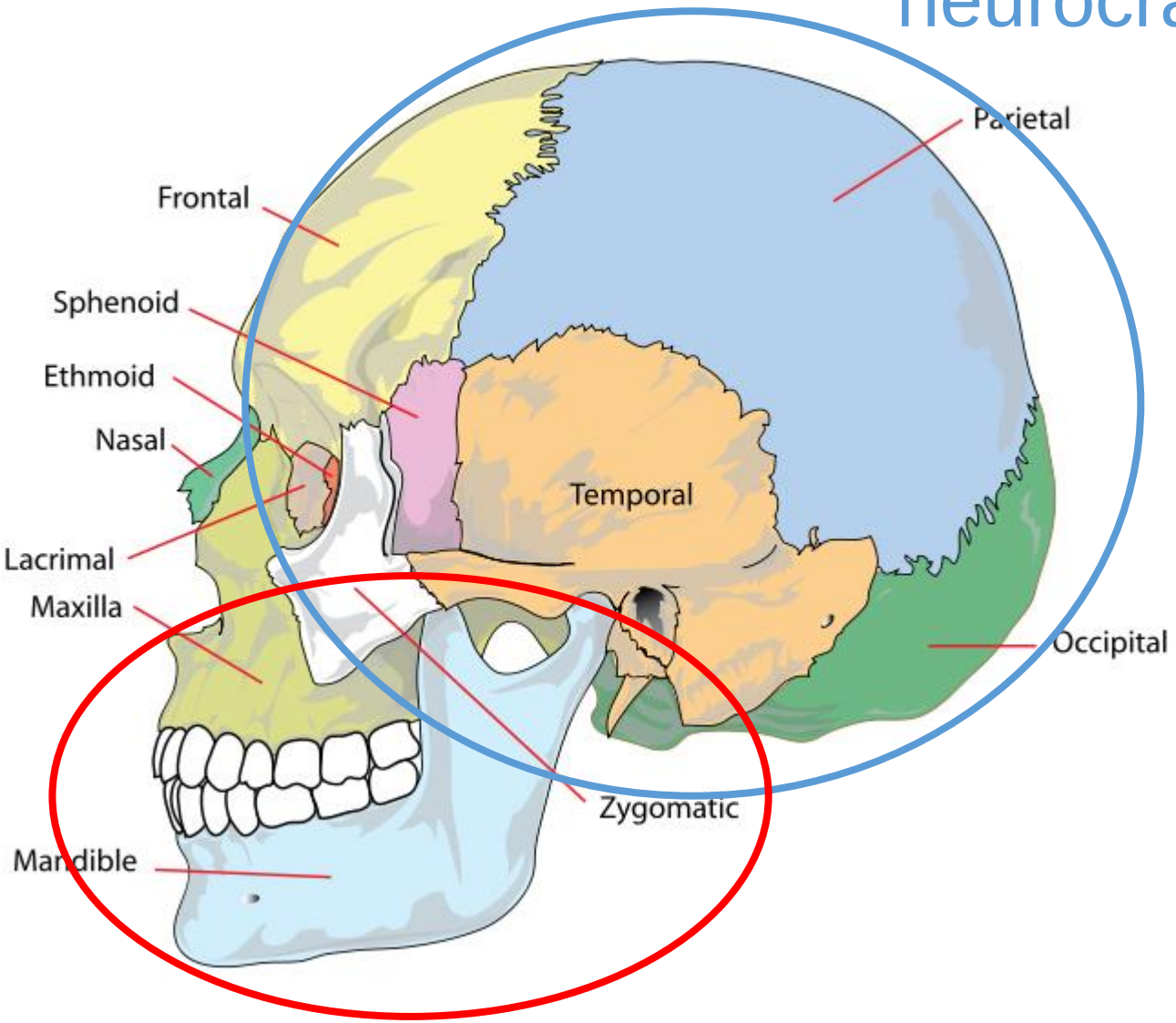


ribs

sternum

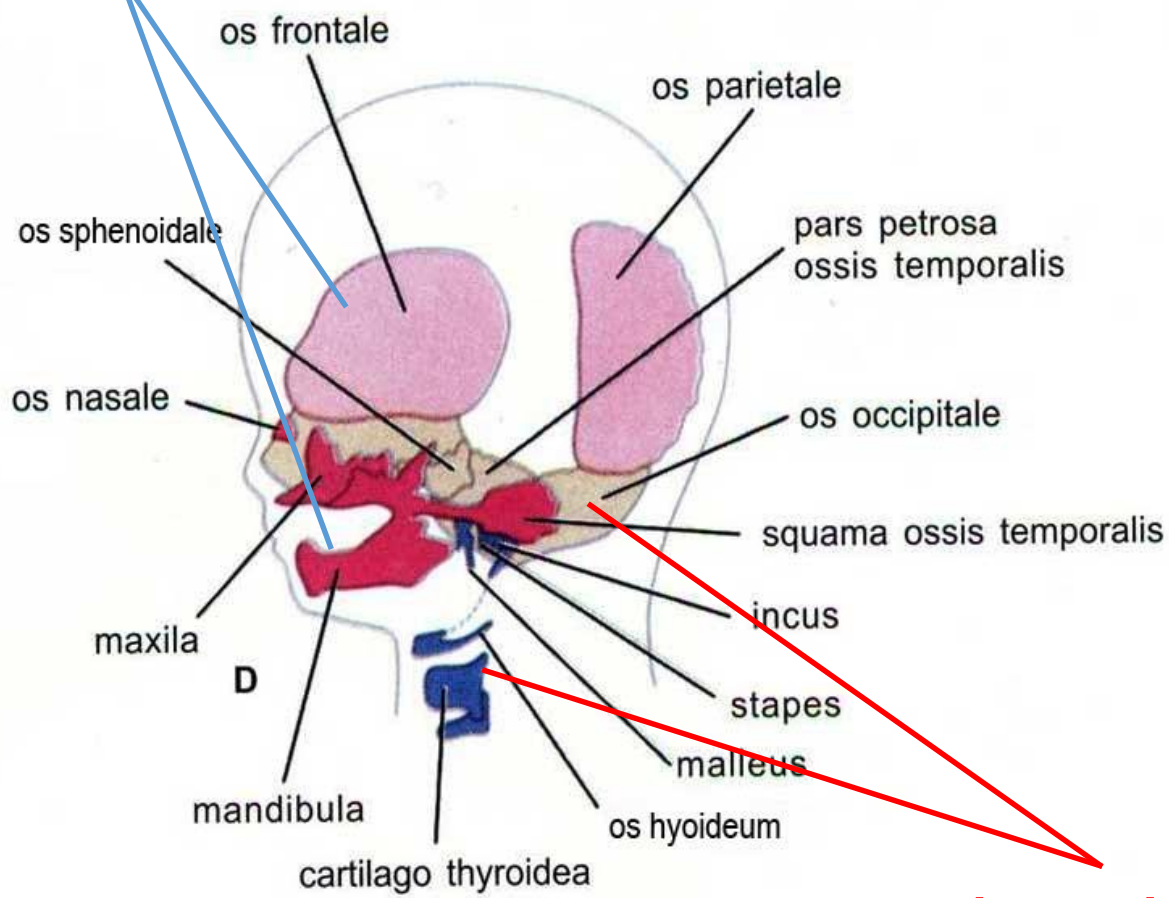


neurocranium

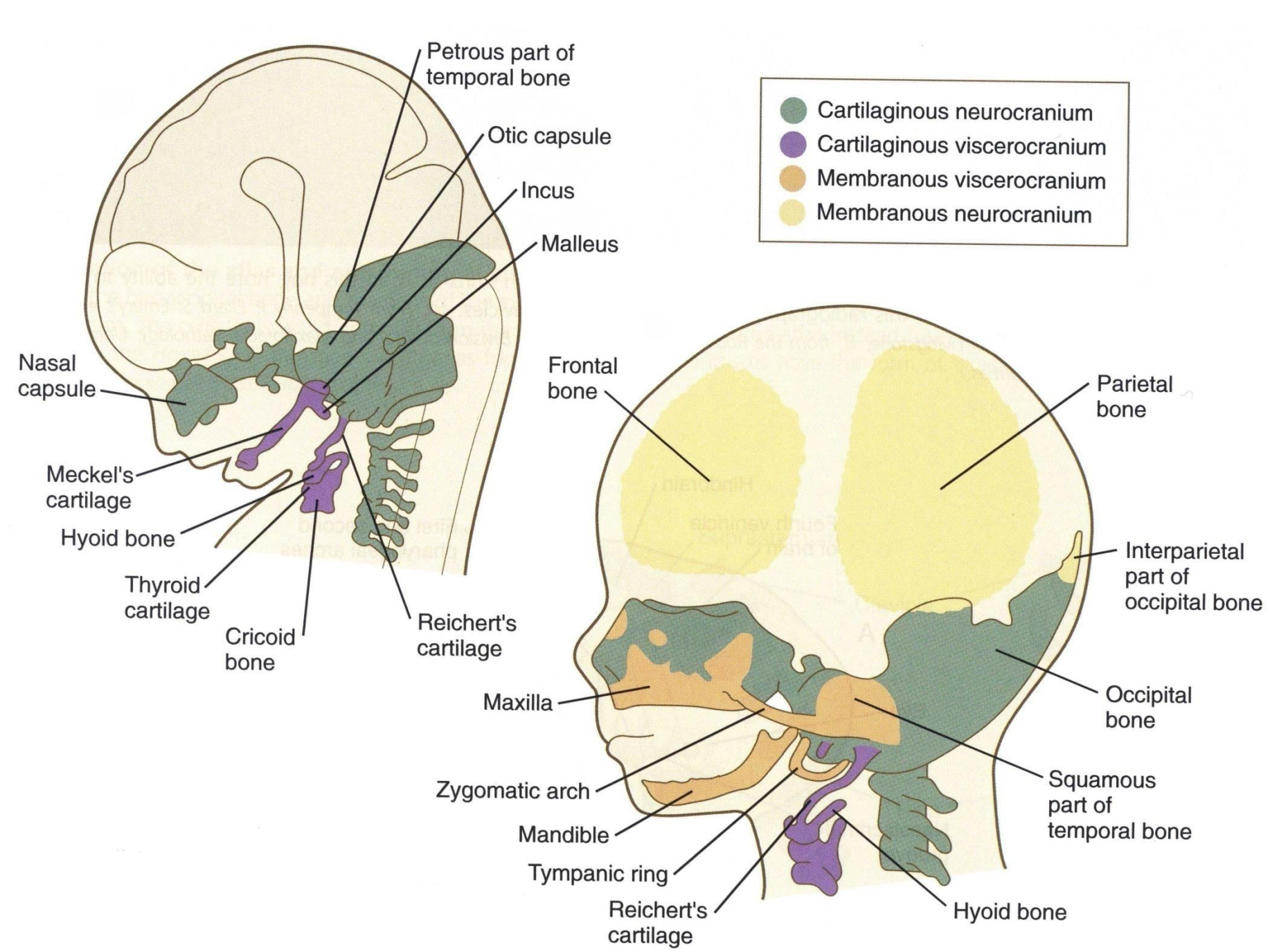


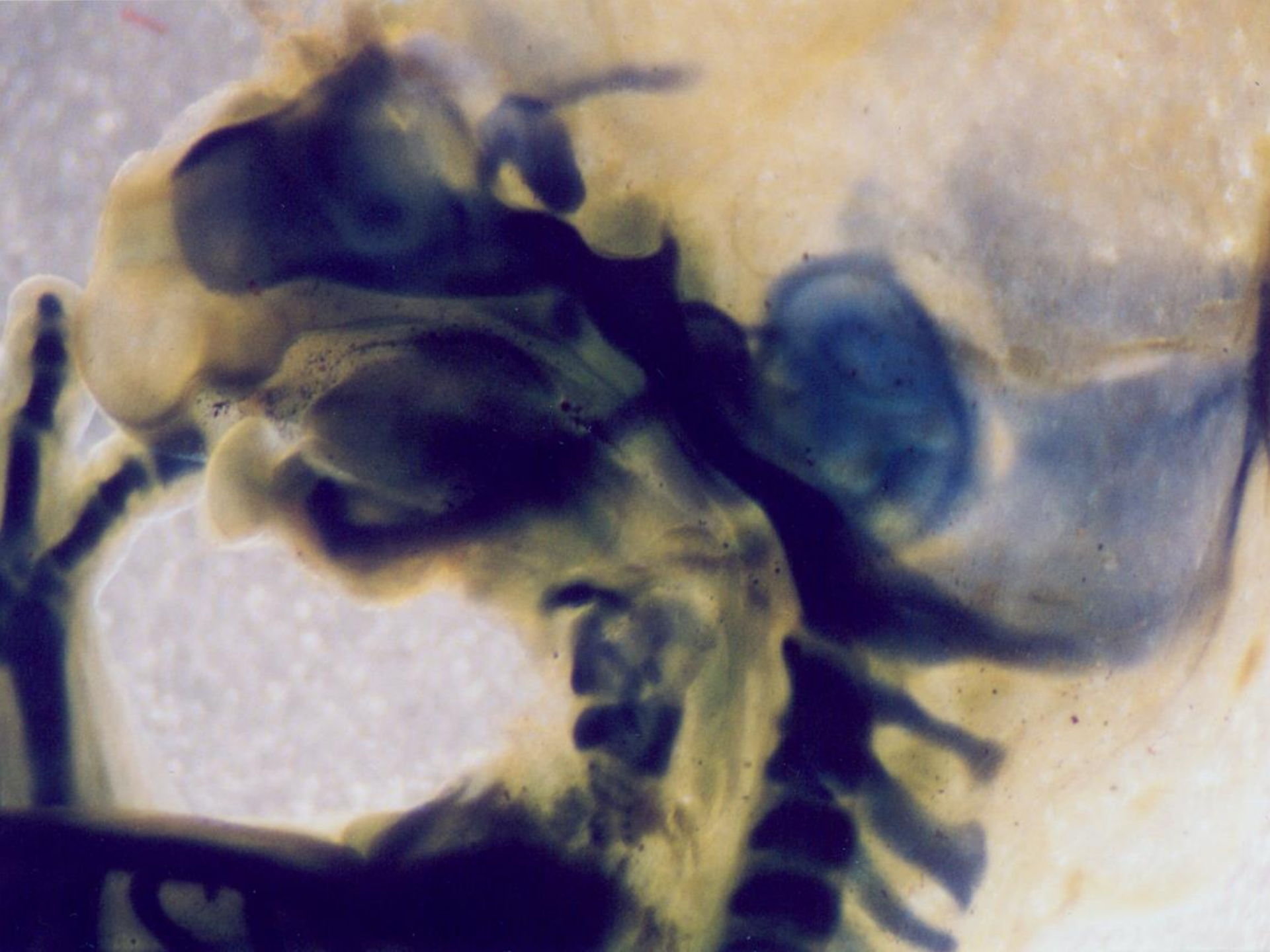
splanchnocranium (viscerocranium)

desmocranium



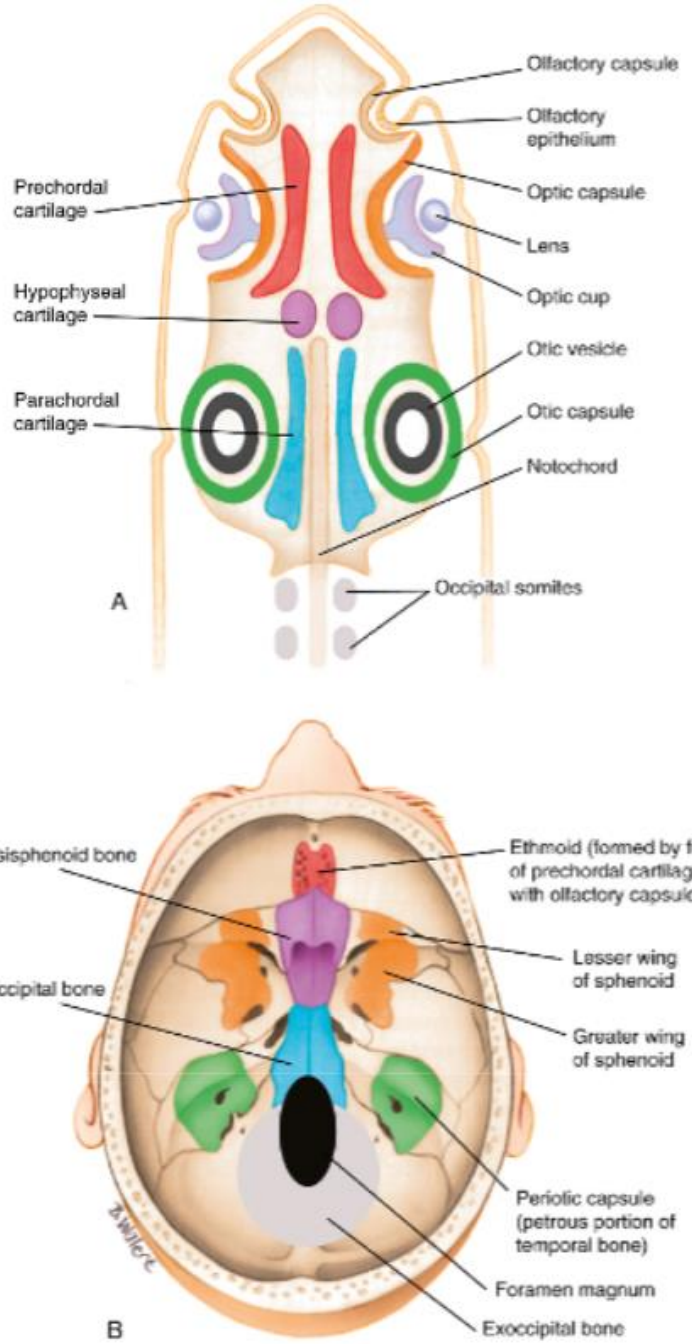
chondrocranium


Petrous part of temporal bone
Otic capsule
Incus
Malleus
Nasal capsule
Meckel's cartilage
Hyoid bone
Thyroid cartilage
Cricoid bone
Reichert's cartilage
Cartilaginous neurocranium
Cartilaginous viscerocranium
Membranous viscerocranium
Membranous neurocranium
Frontal bone
Parietal bone
Interparietal part of occipital bone
Occipital bone
Squamous part of temporal bone
Hyoid bone
Maxilla
Zygomatic arch
Mandible
Tympanic ring
Reichert's cartilage

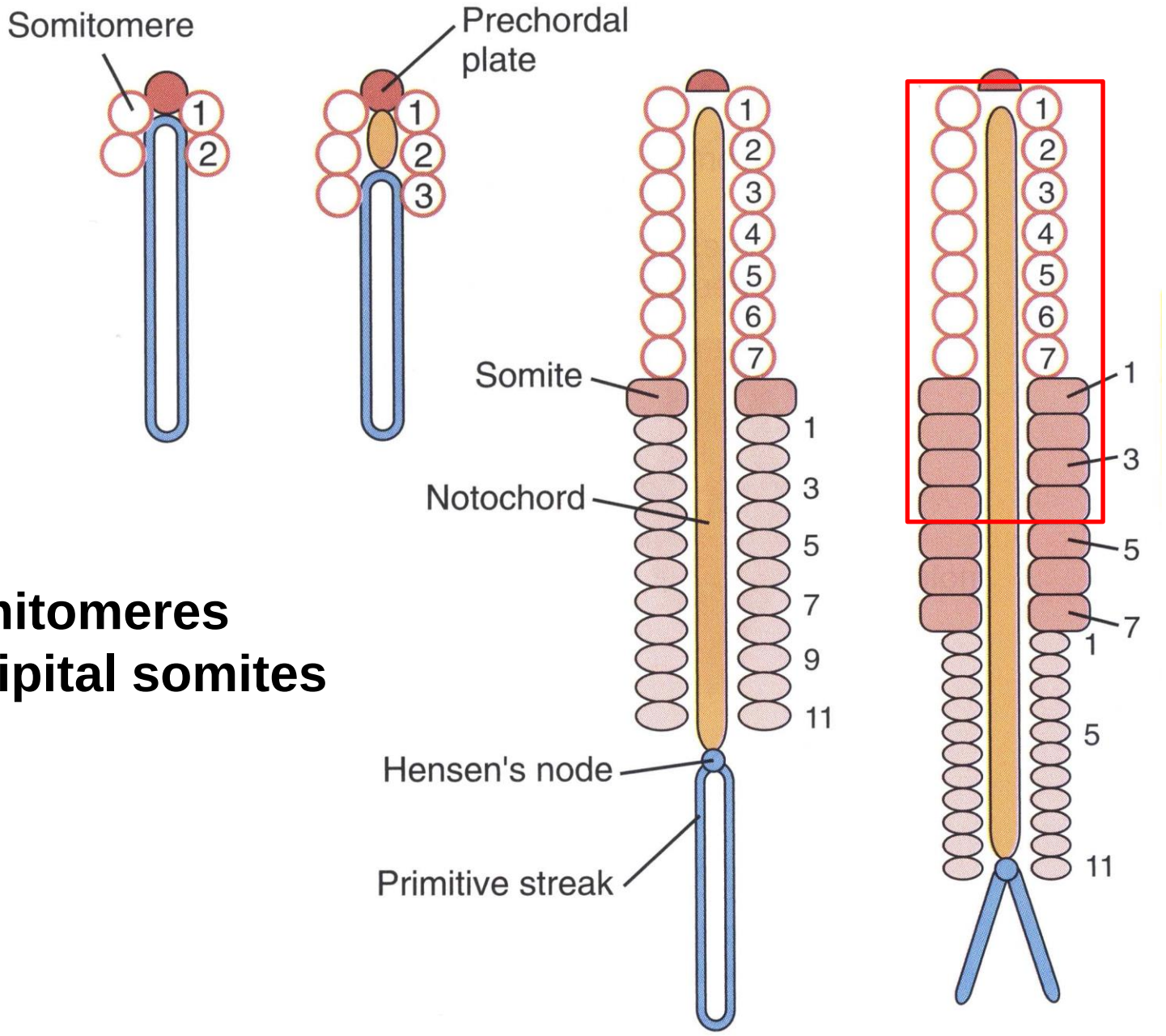


Cartilaginous neurocranium

- Capsula olfactoria
- Prechordal cart.
- Capsula optica
- Hypophyseal cart.
- Parachordal cart.
- Capsula otica

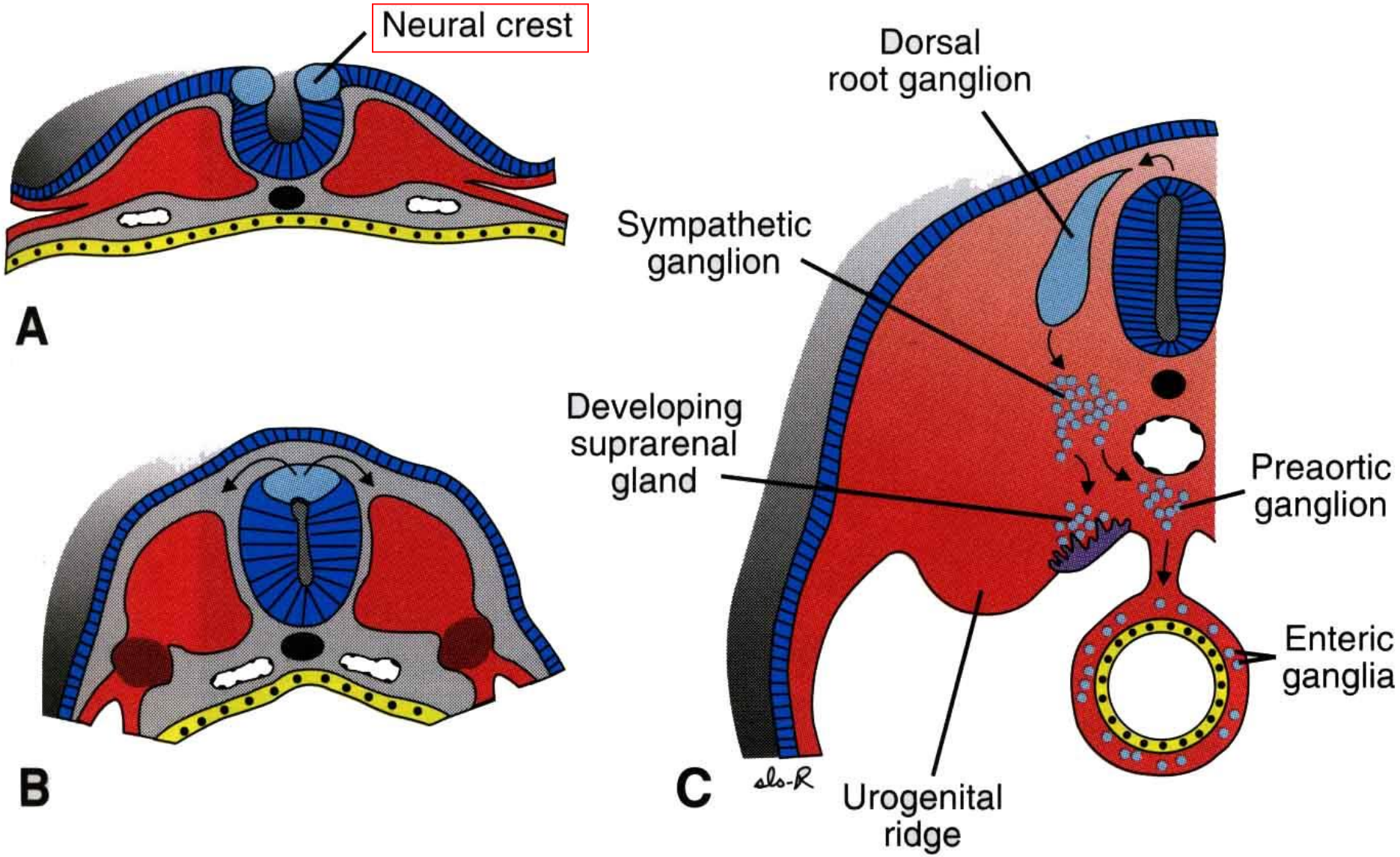


Sources of mesenchyme: 1) paraxial mesoderm



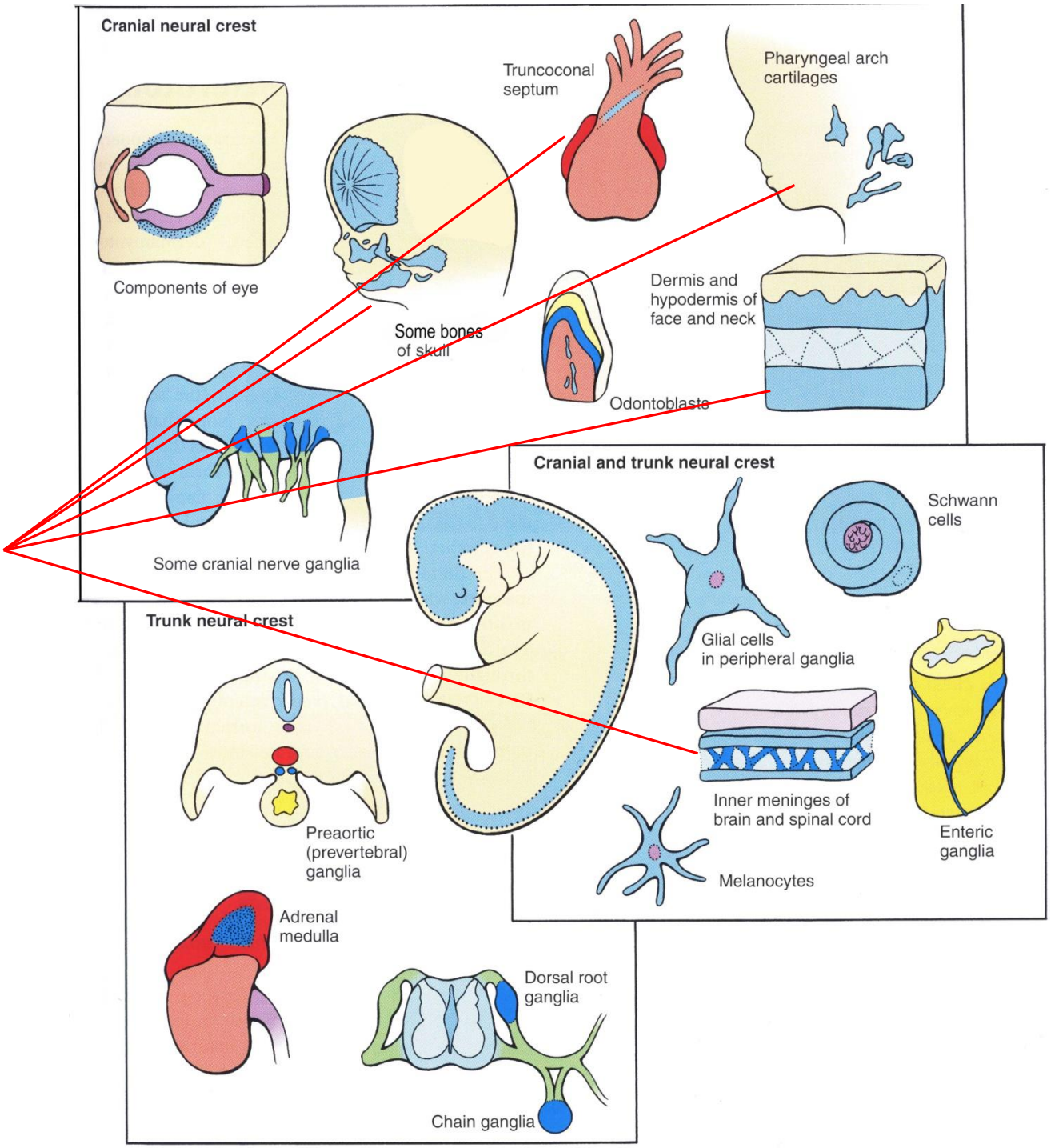
somitomeres
occipital somites

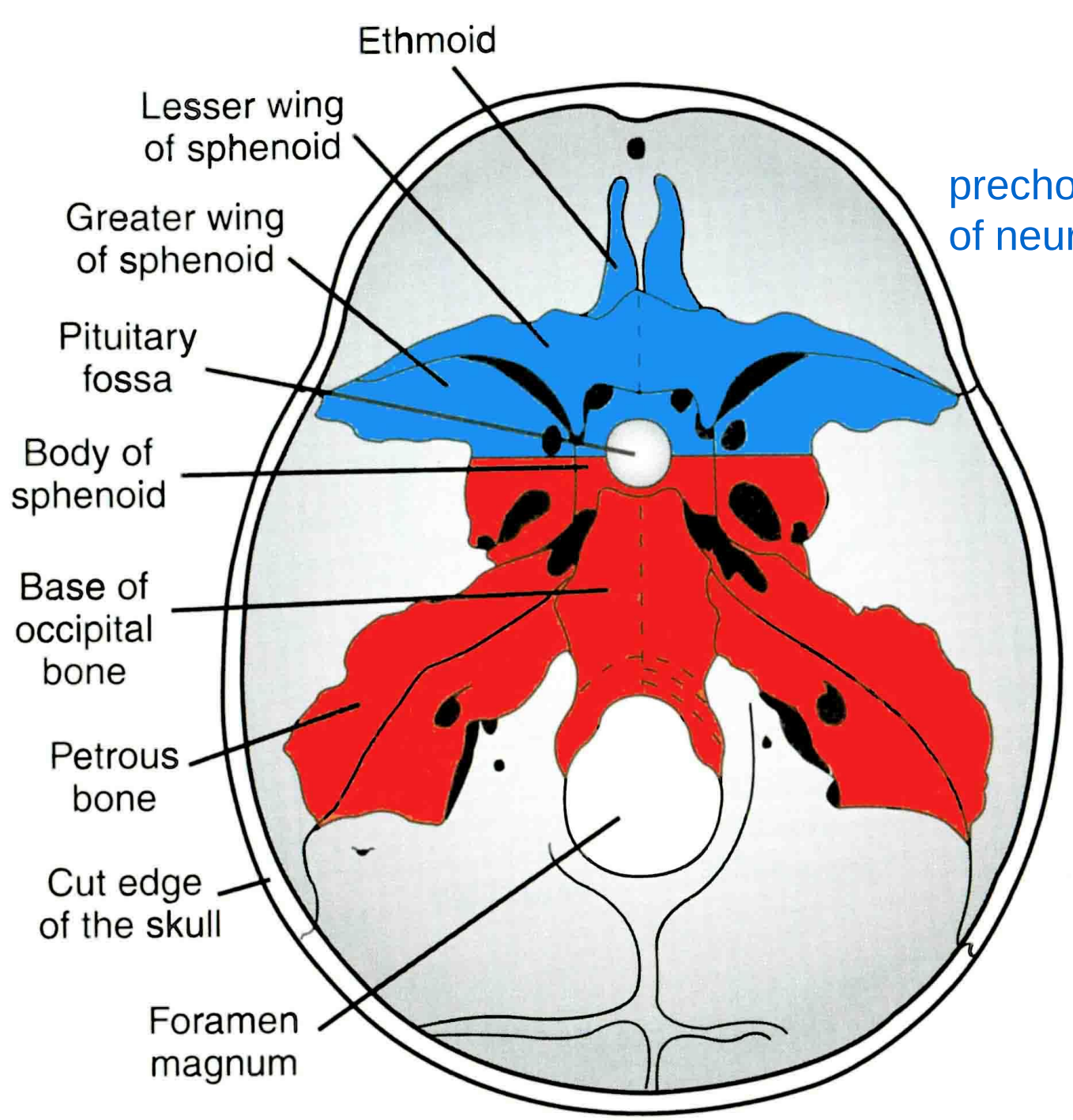
Sources of mesenchyme: 2) neural crest



Derivatives of the neural crest

ectomesenchyme



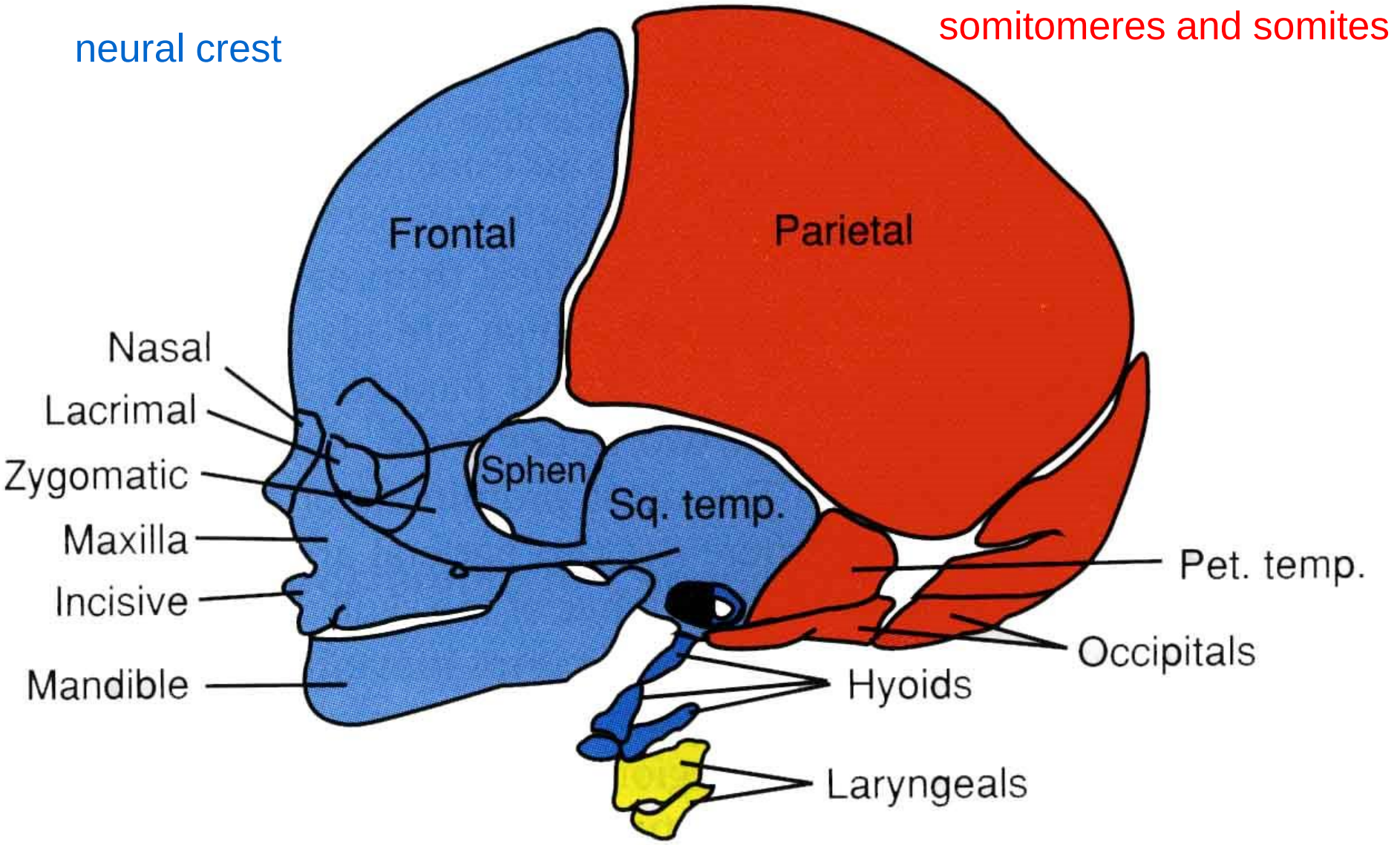


prechordal chondrocranium of neural crest

parachordal chondrocranium of somitomeres and somites

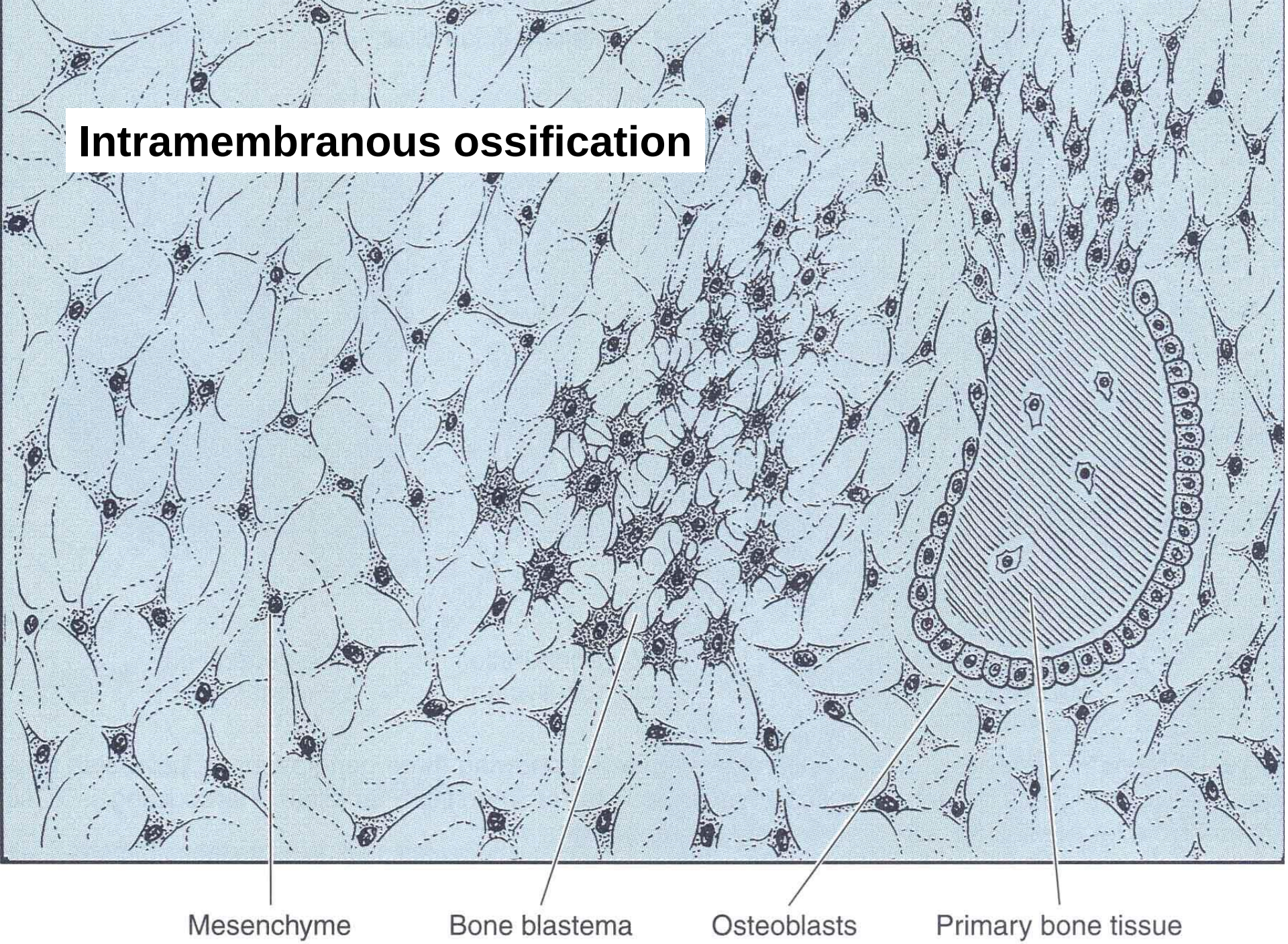
neural crest

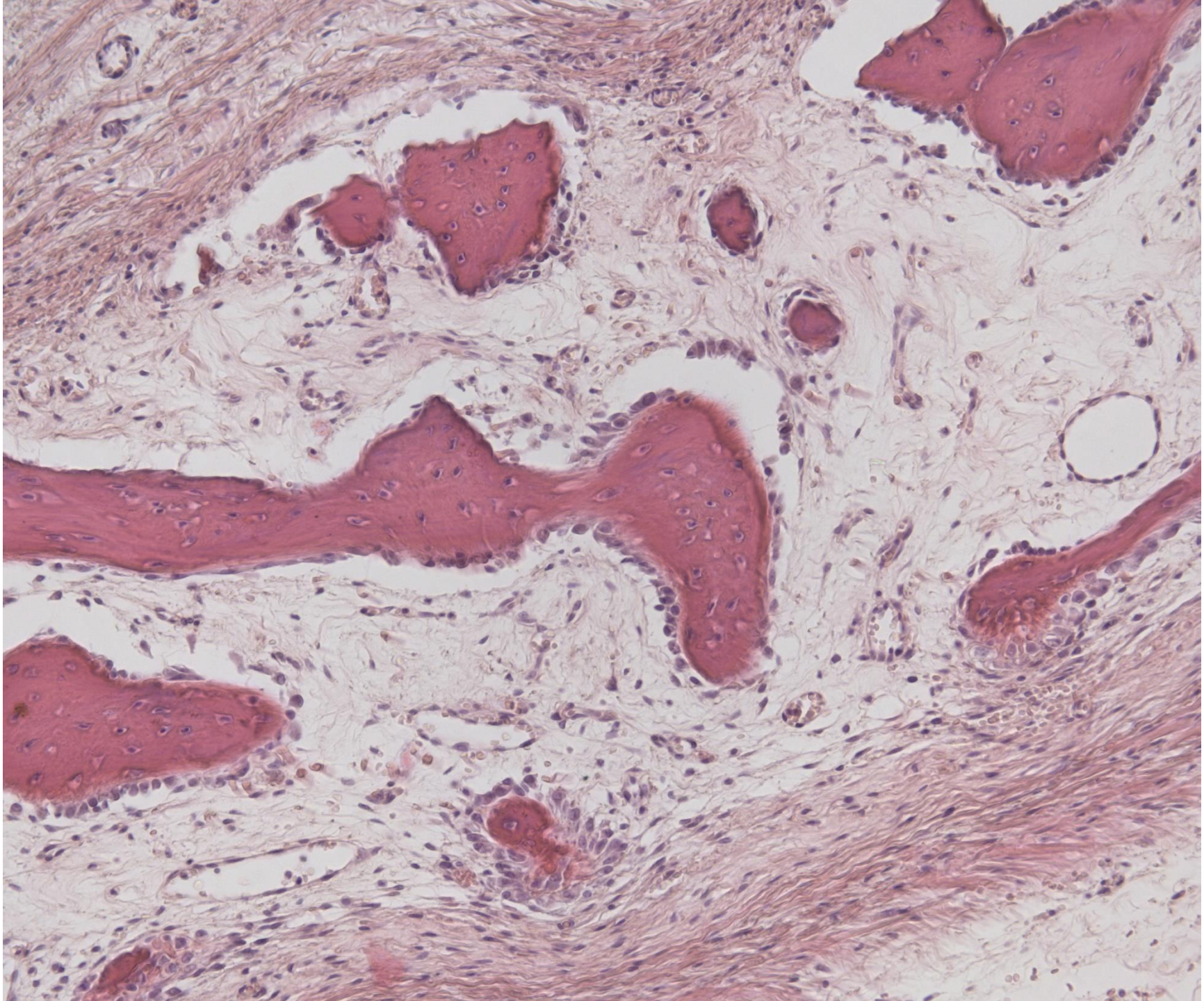
somitomeres and somites



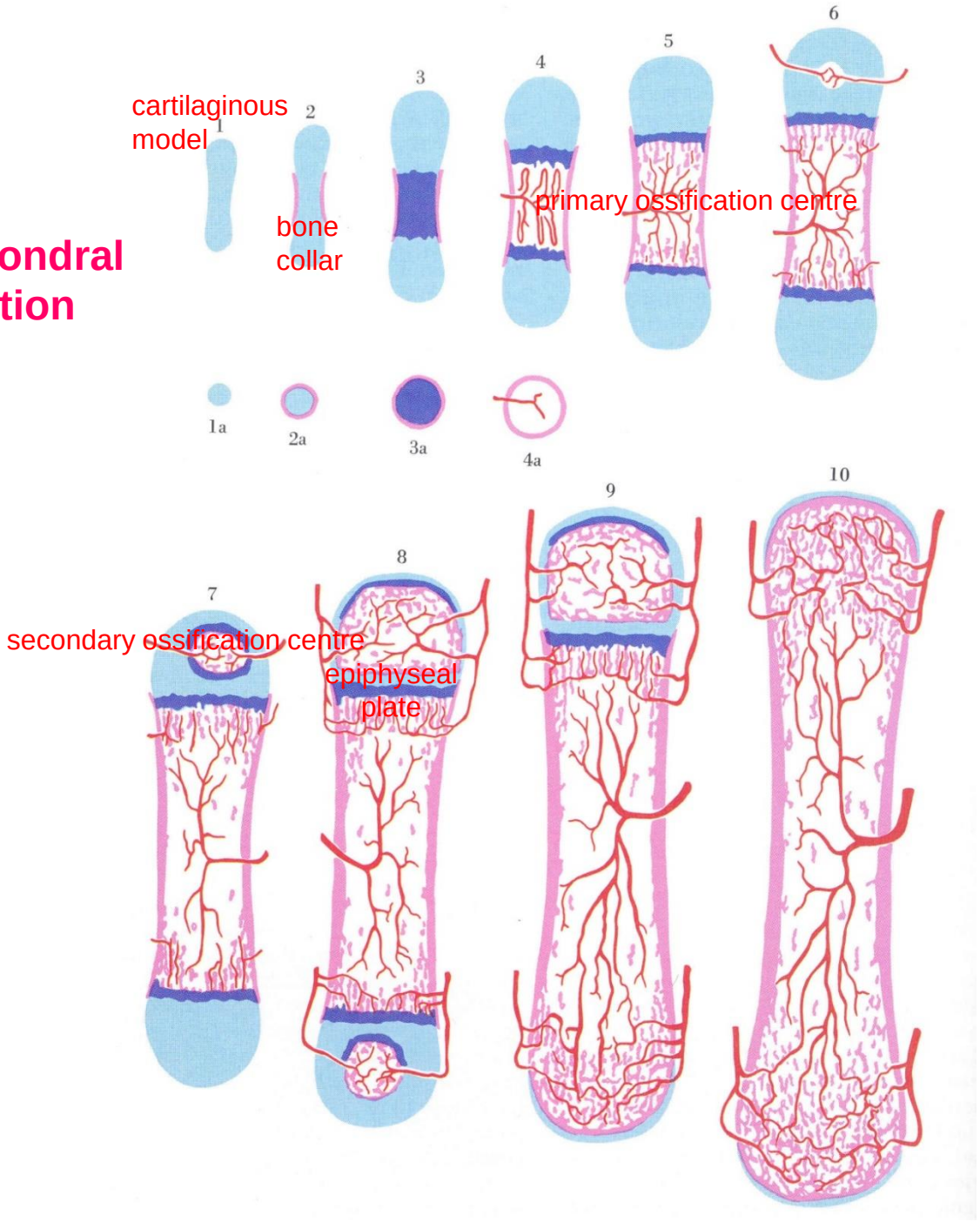
lateral plate mesoderm

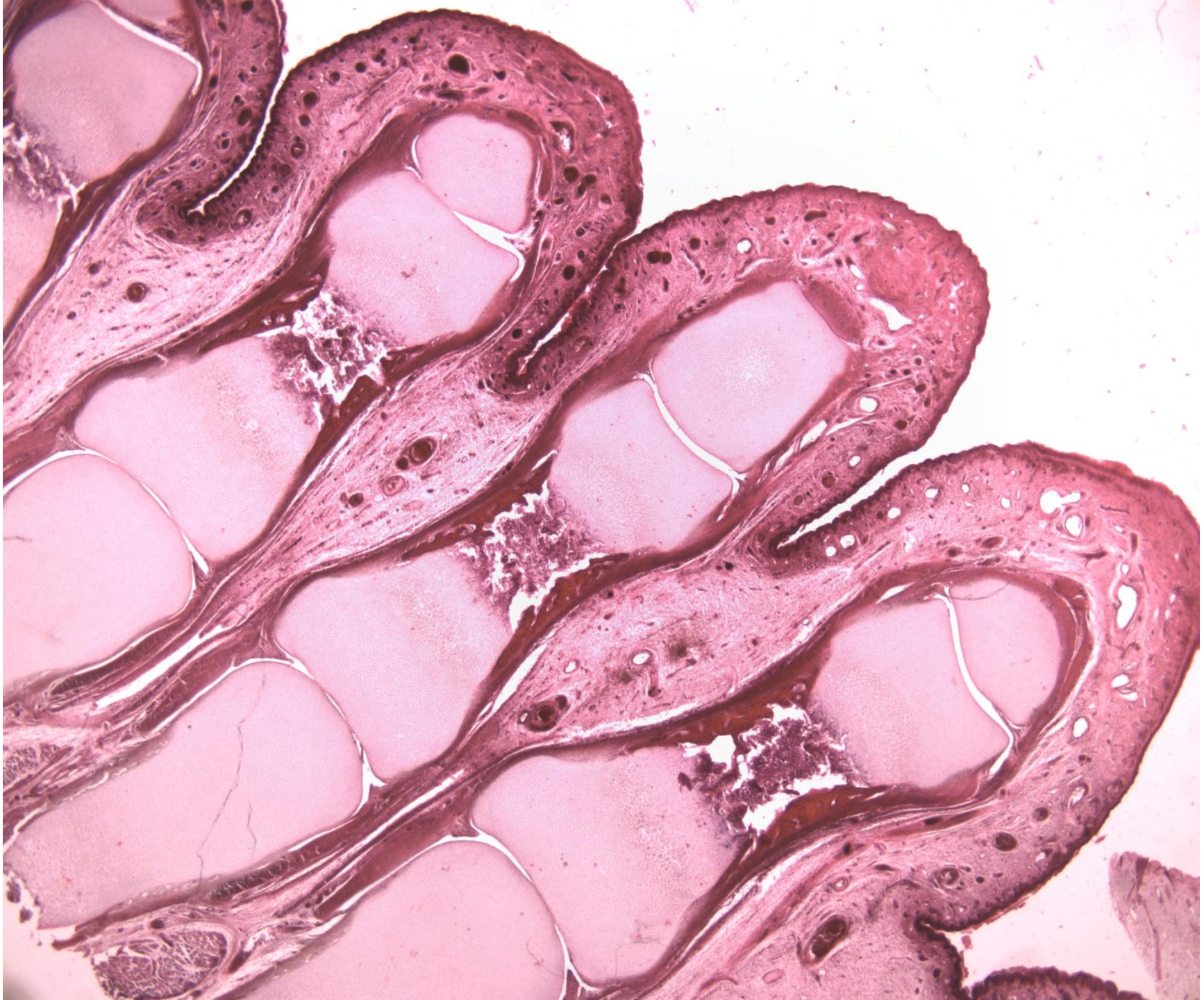
Intramembranous ossification

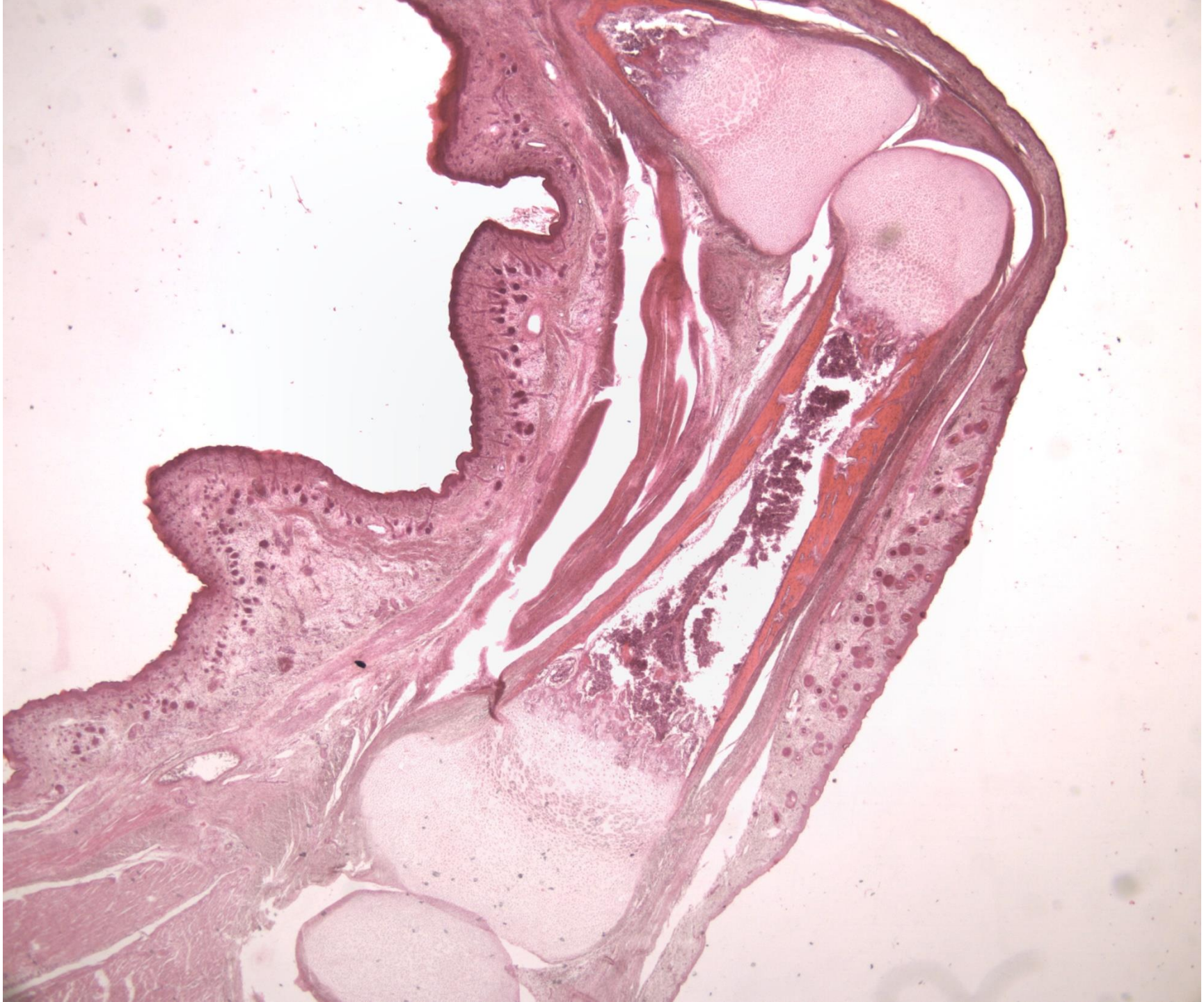


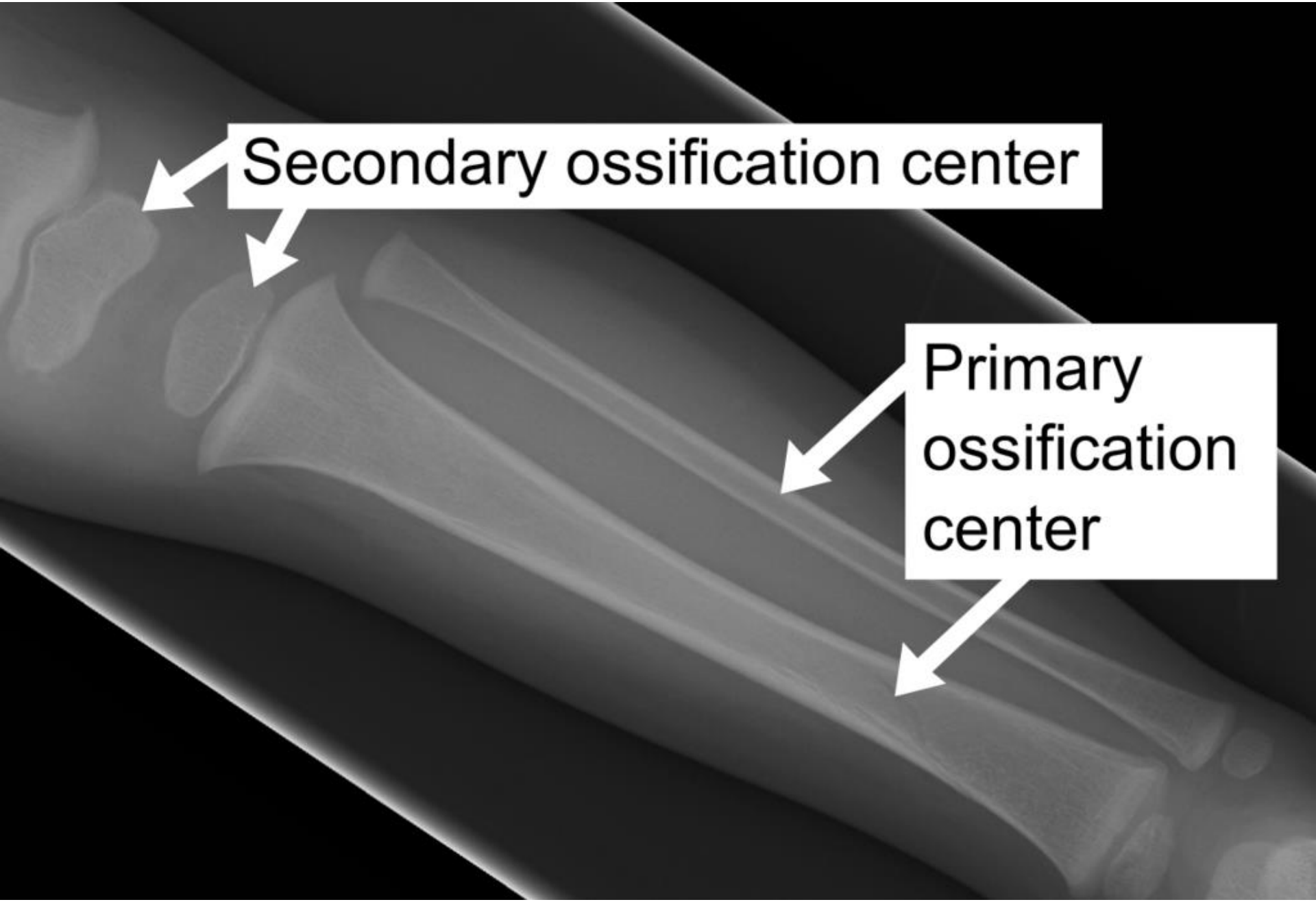


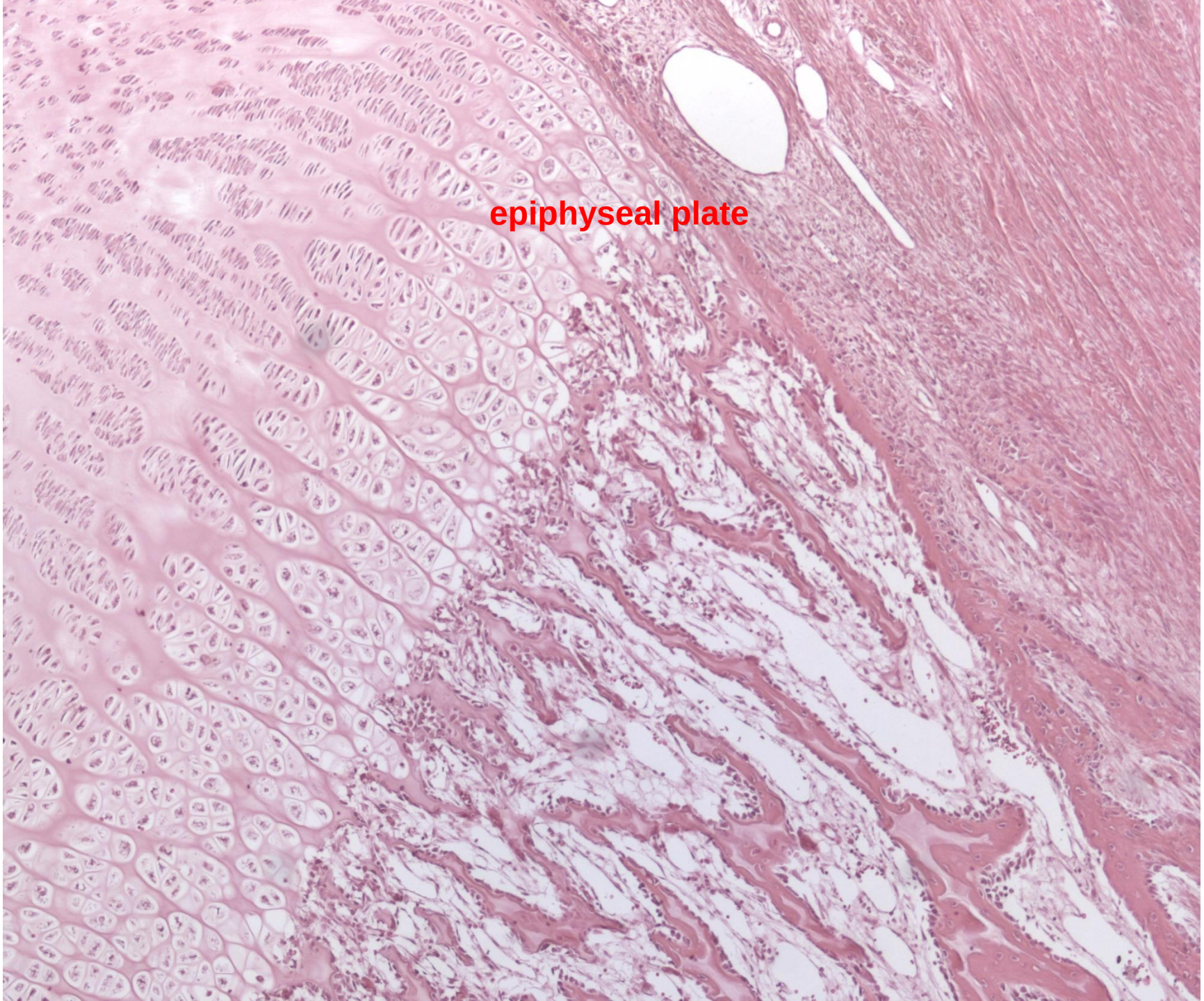
Endochondral ossification

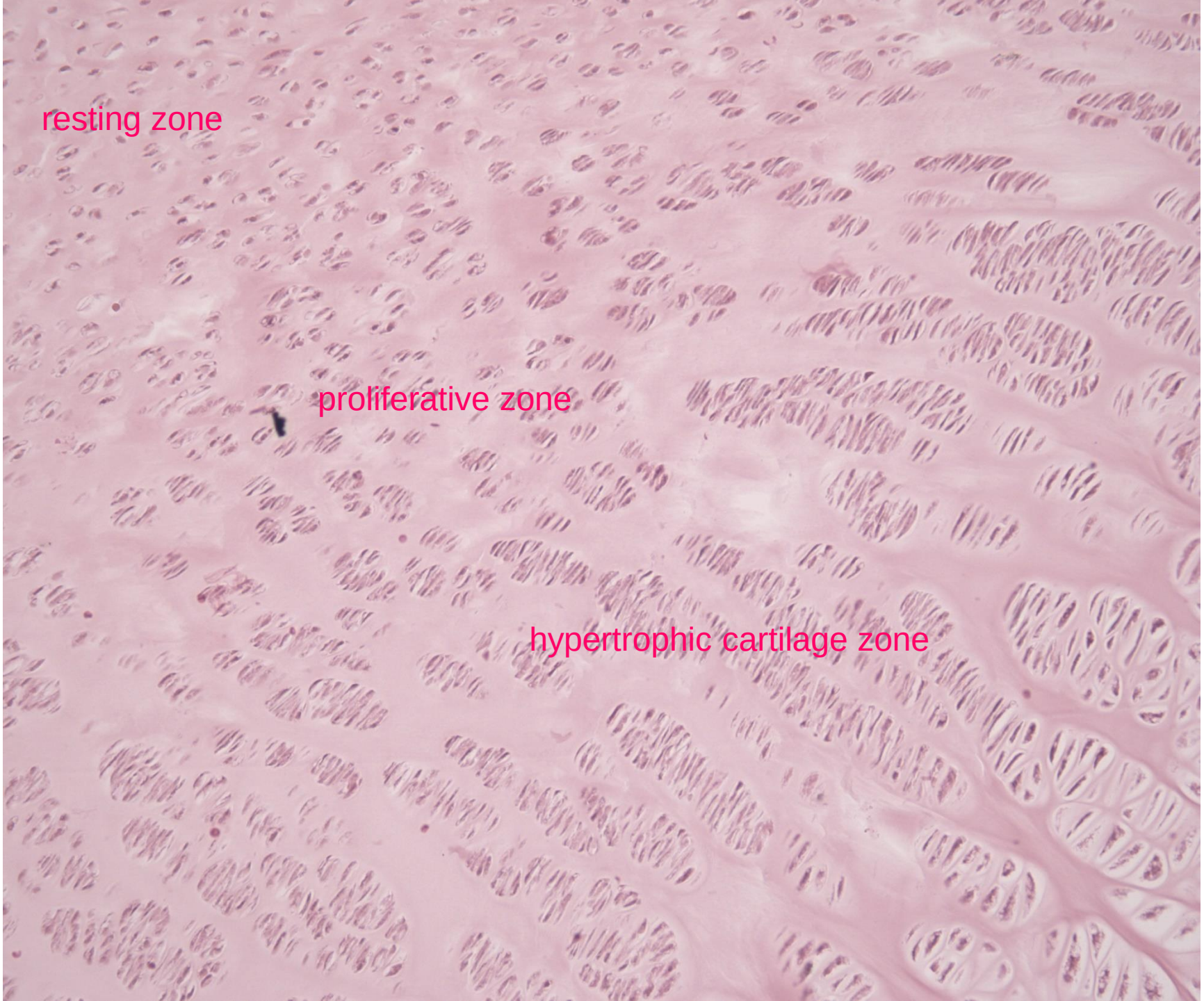


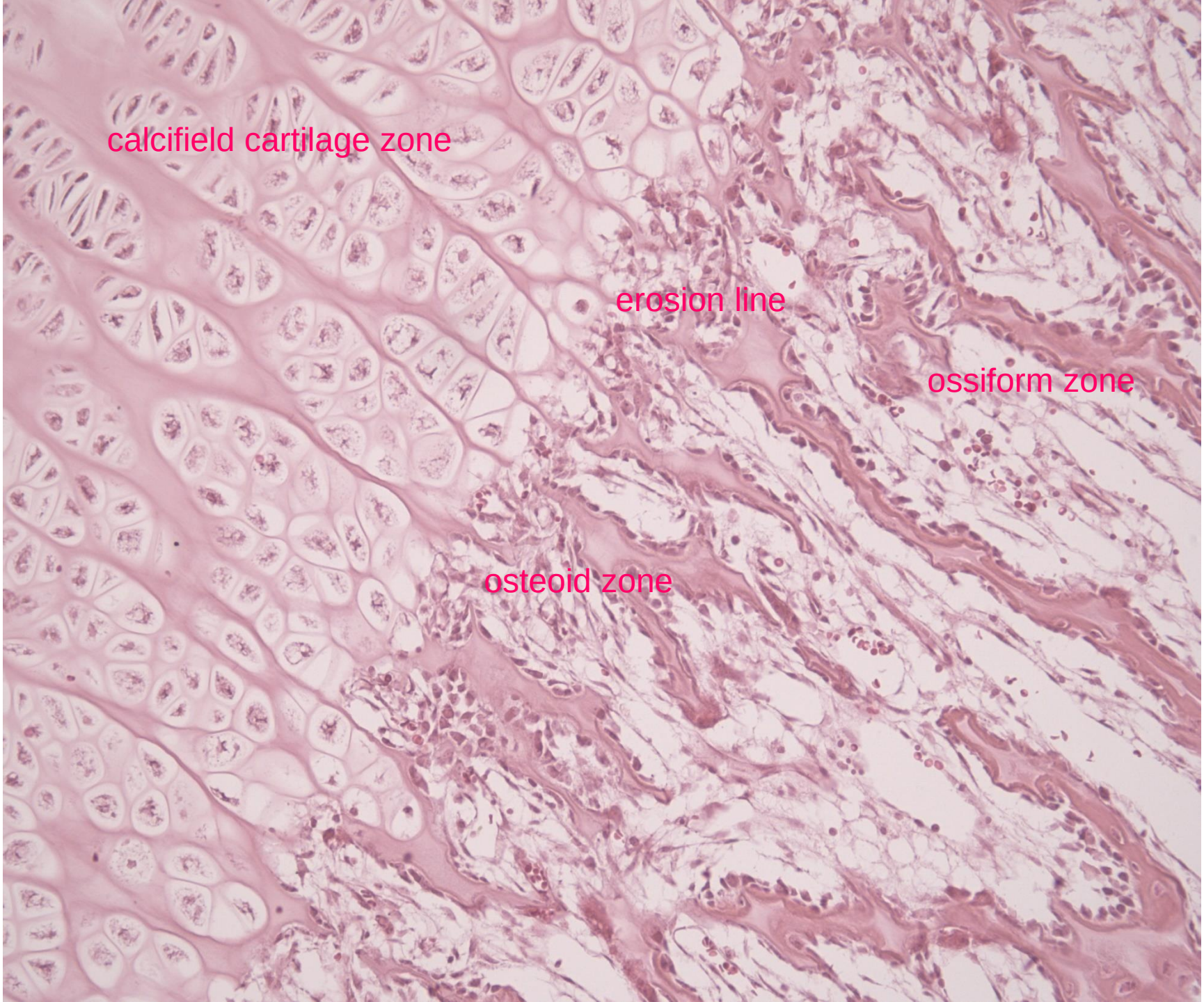







epiphyseal plate


resting zone
proliferative zone
hypertrophic cartilage zone


calcifield cartilage zone
erosion line
ossiform zone
osteoid zone

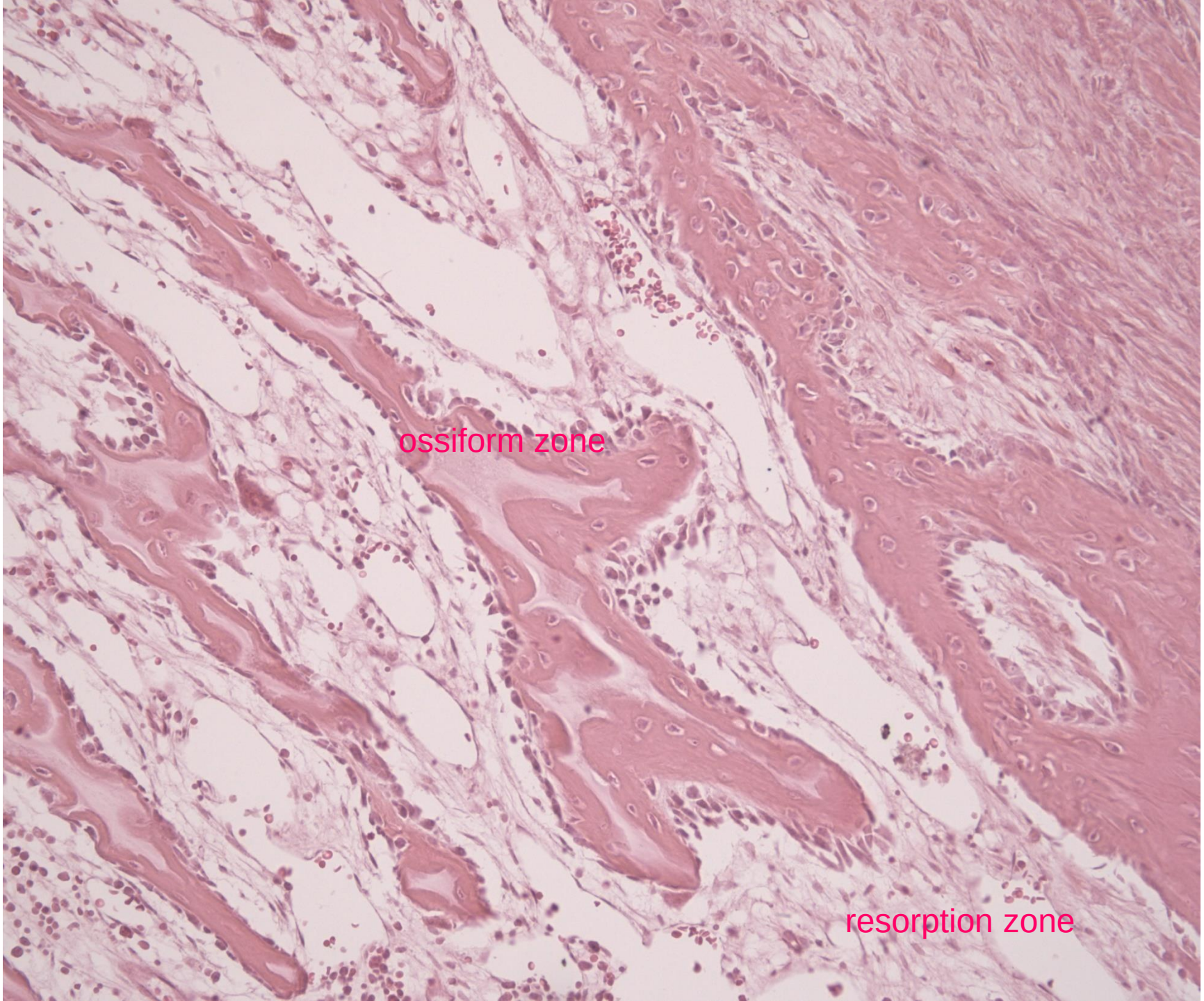
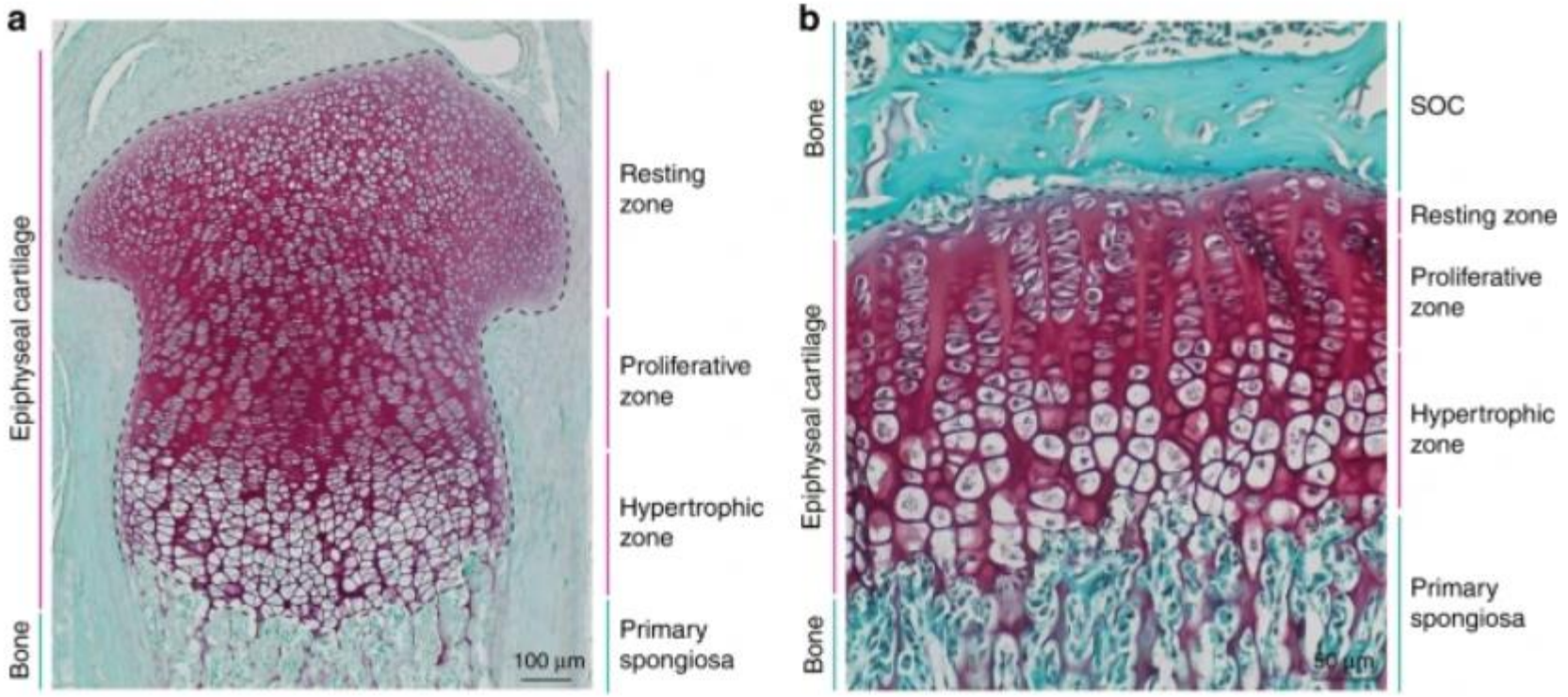
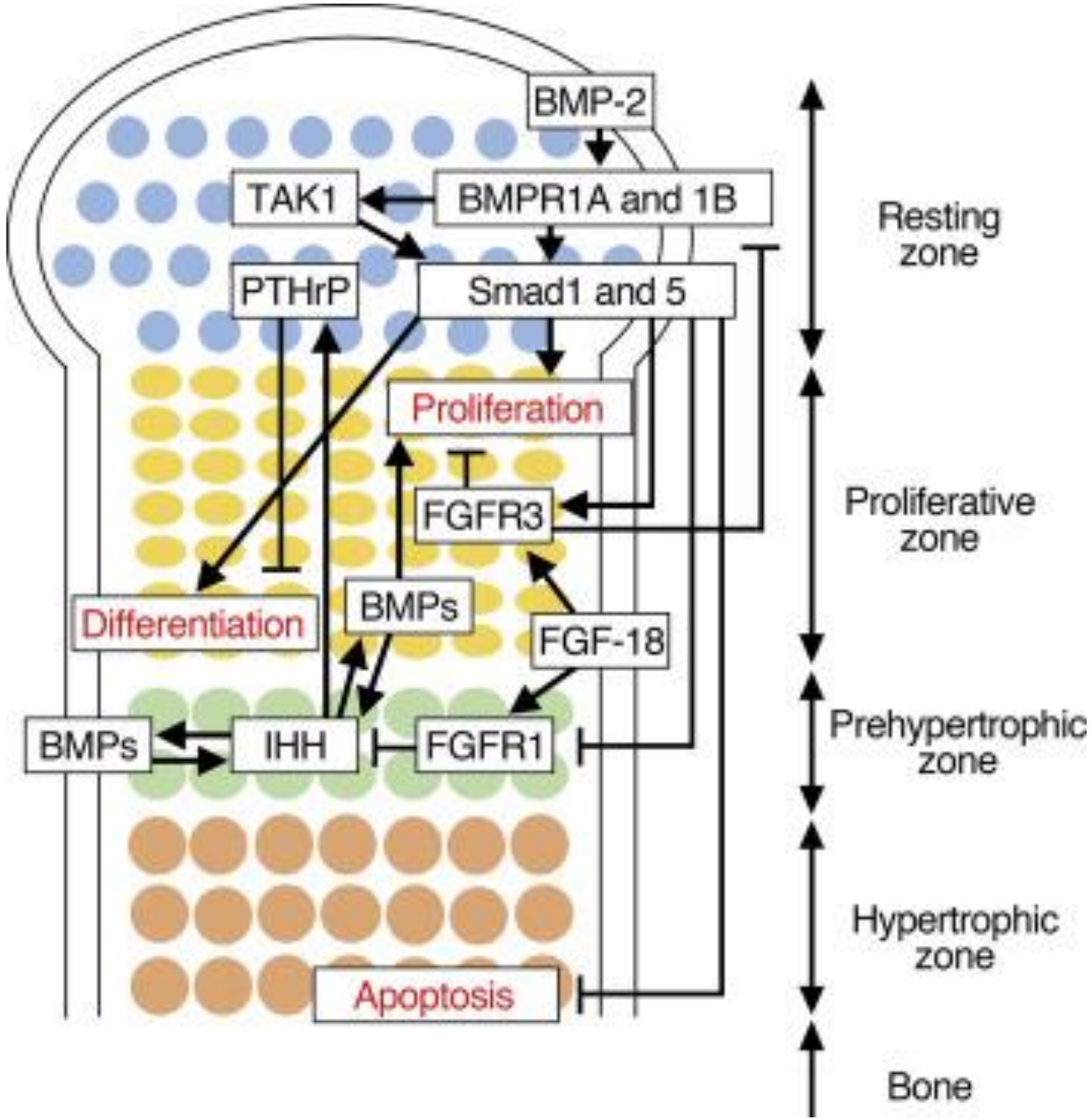

ossiform zone
resorption zone

Fig. 1: Development of the growth plate.



Histological images of mouse epiphyseal cartilage before (**a**) and after (**b**) the growth plate is defined by the maturation of the secondary ossification center. Tissue sections from 3 days old (**a**) and 30 days old (**b**) mouse proximal tibiae are stained with Safranin O (red, cartilage) and Fast Green (green, bone and connective tissue).

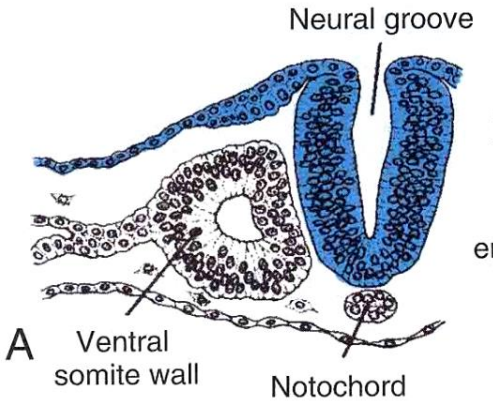
Chagin, A.S., Newton, P.T. Postnatal skeletal growth is driven by the epiphyseal stem cell niche: potential implications to pediatrics. *Pediatr Res* **87**, 986–990 (2020). https://doi.org/10.1038/s41390-019-0722-z

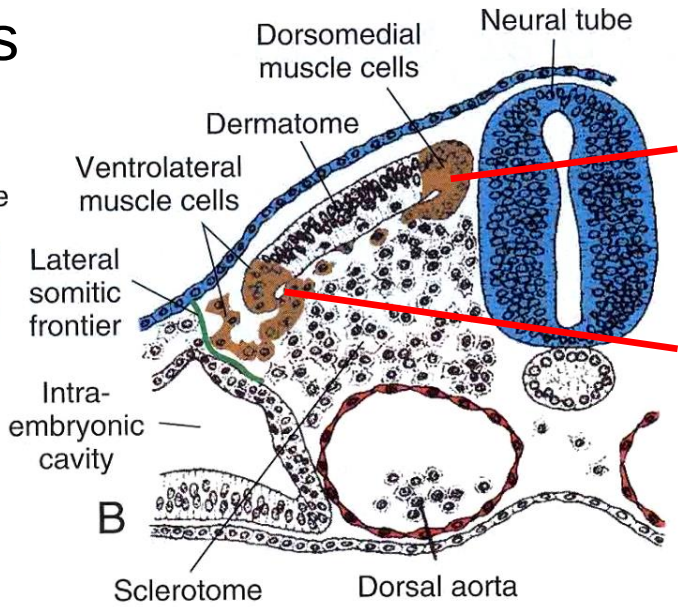


https://www.sciencedirect.com/referencework/9780128140826/encyclopedia-of-bone-biology

DEVELOPMENT
OF THE MUSCLE SYSTEM

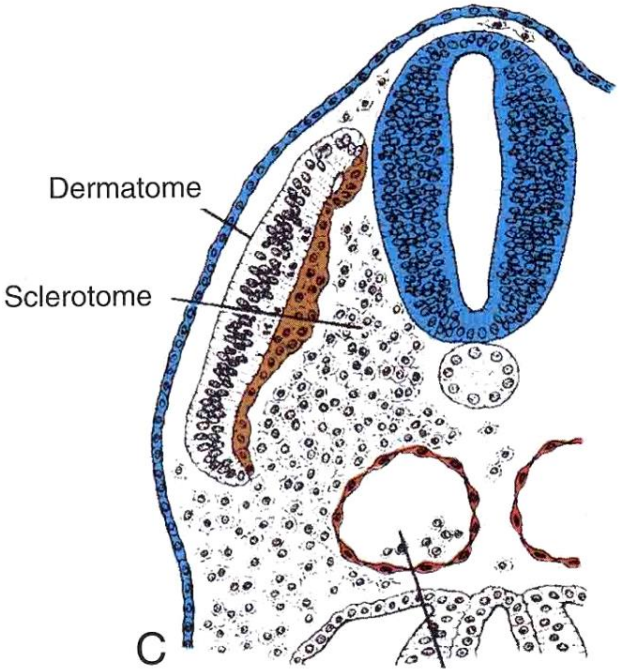
postcranial muscles

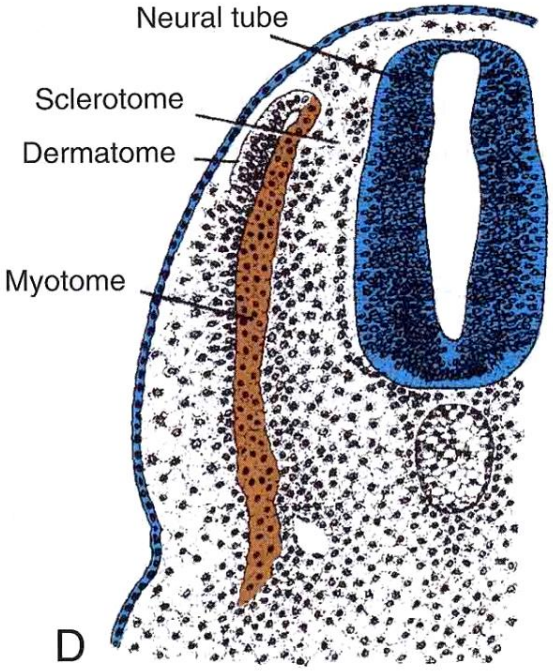




epaxial muscles

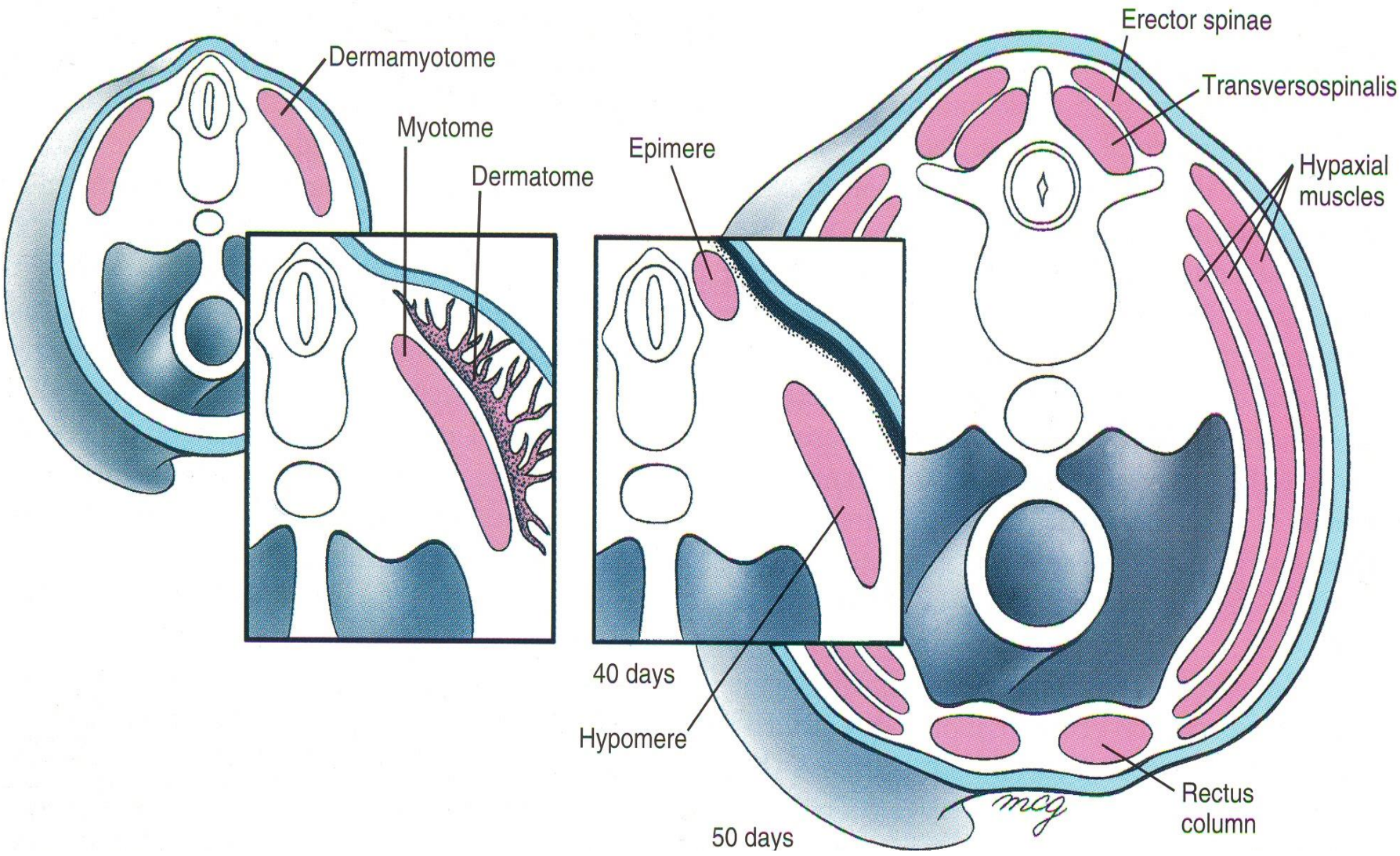
hypaxial muscles



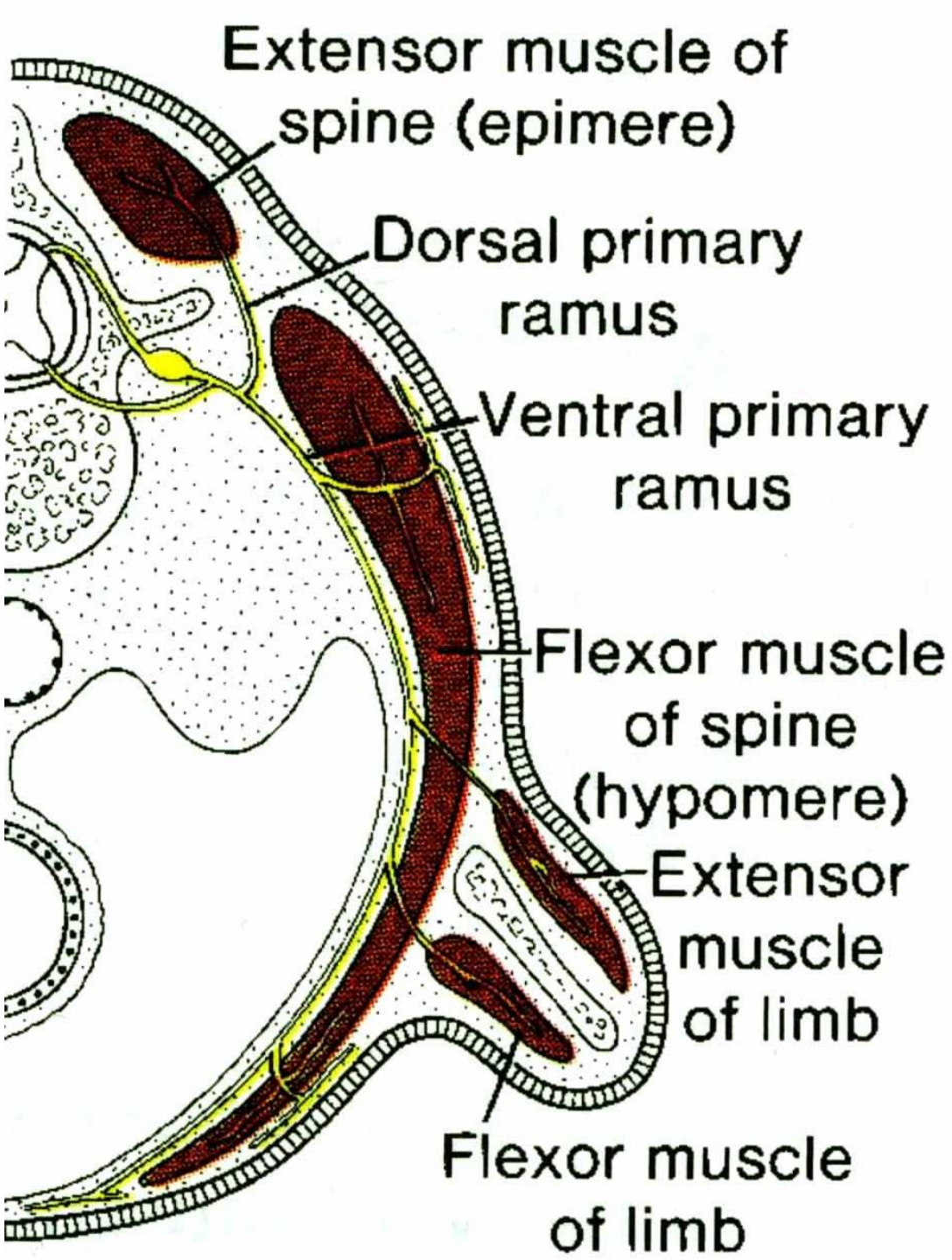


primaxial muscles
arise and develop
withn somitic mesenchyme

abaxial muscles
arise within somitic mesenchyme
but develop withïn mesenchyme
of somatopleuric mesoderm

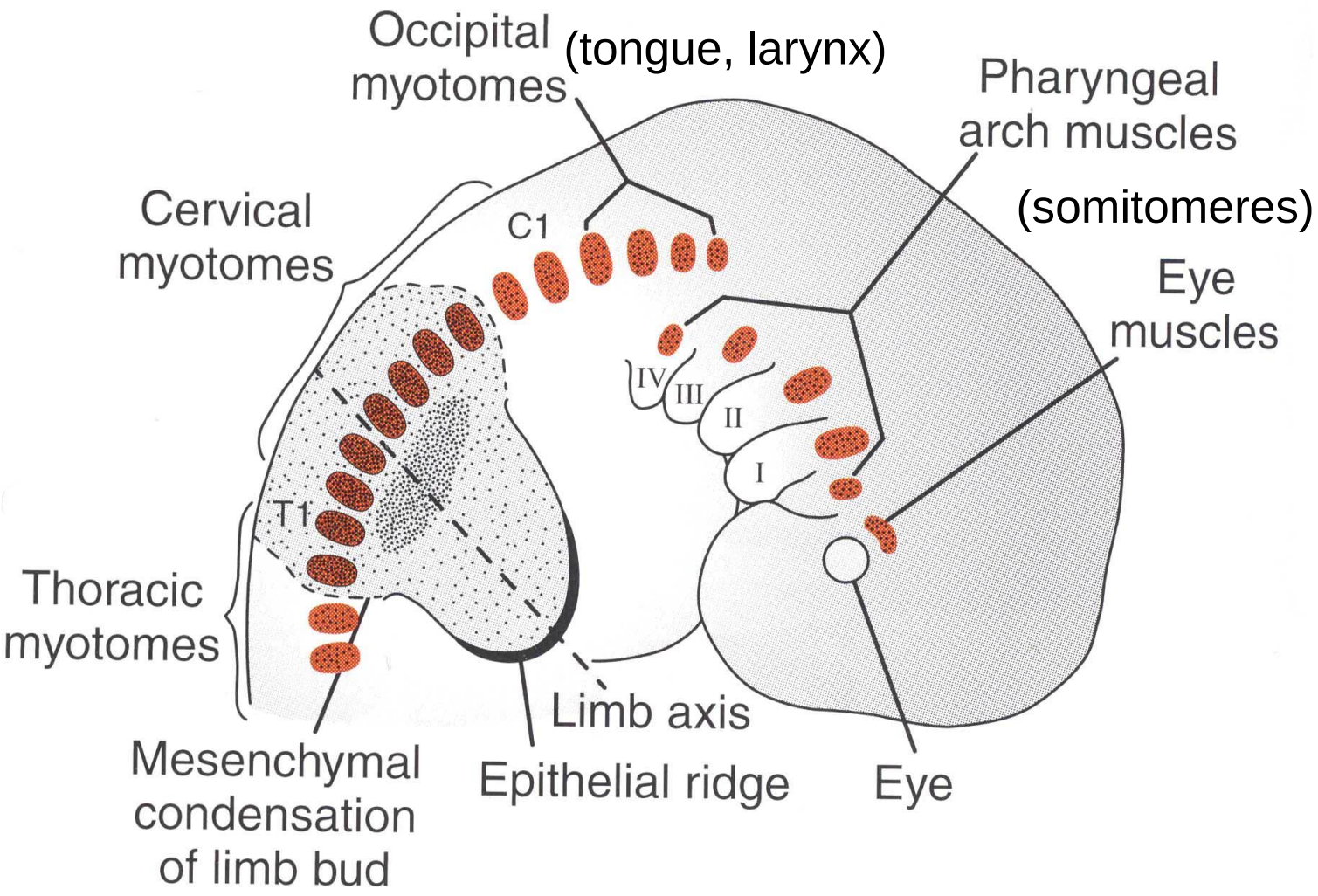

Dermamyotome
Myotome
Dermatome
Epimere
Hypomere
40 days
50 days
Erector spinae
Transversospinalis
Hypaxial muscles
Rectus column
mcg

muscles of limbs



7th week

cranial muscles



7th week

New myoblasts

Myoblasts fusing

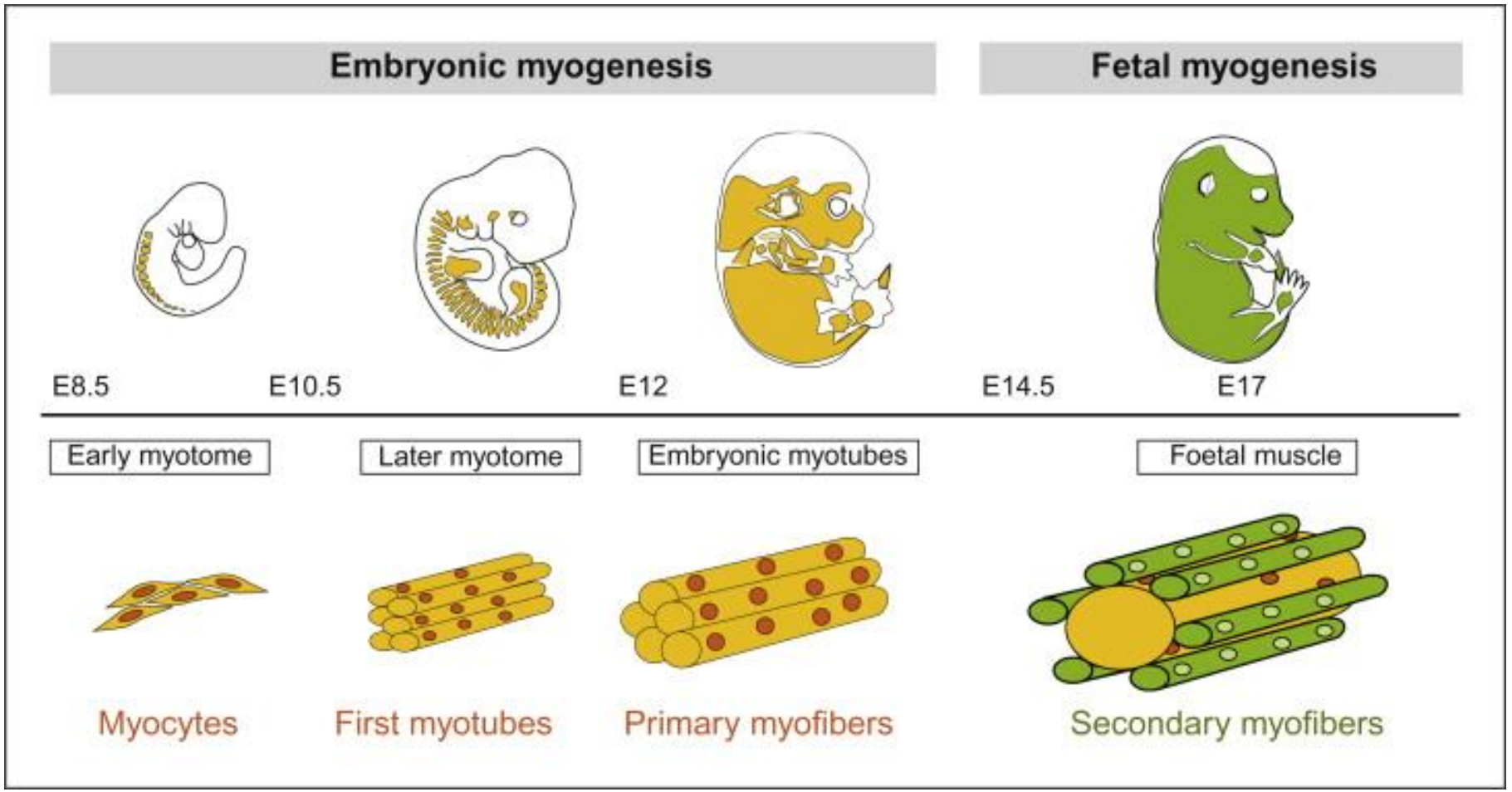
Myoblasts in line

Side views

Cross sections

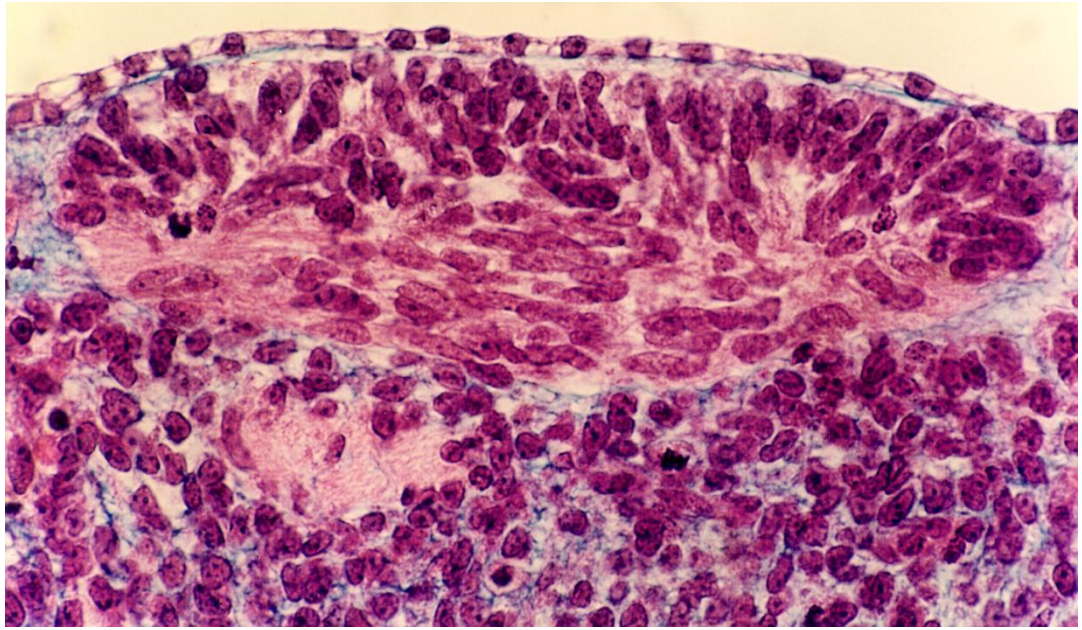
Myoblasts develop myofibrils

Myotube

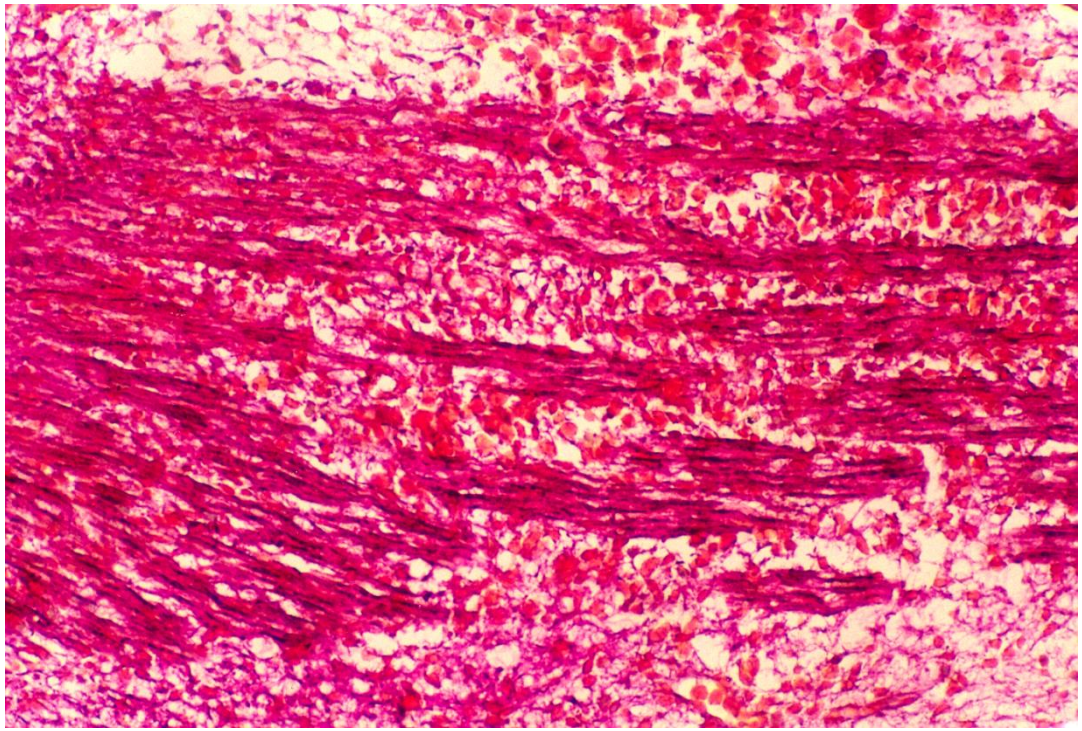


https://www.sciencedirect.com/book/9780123815101/muscle?via=ihub=

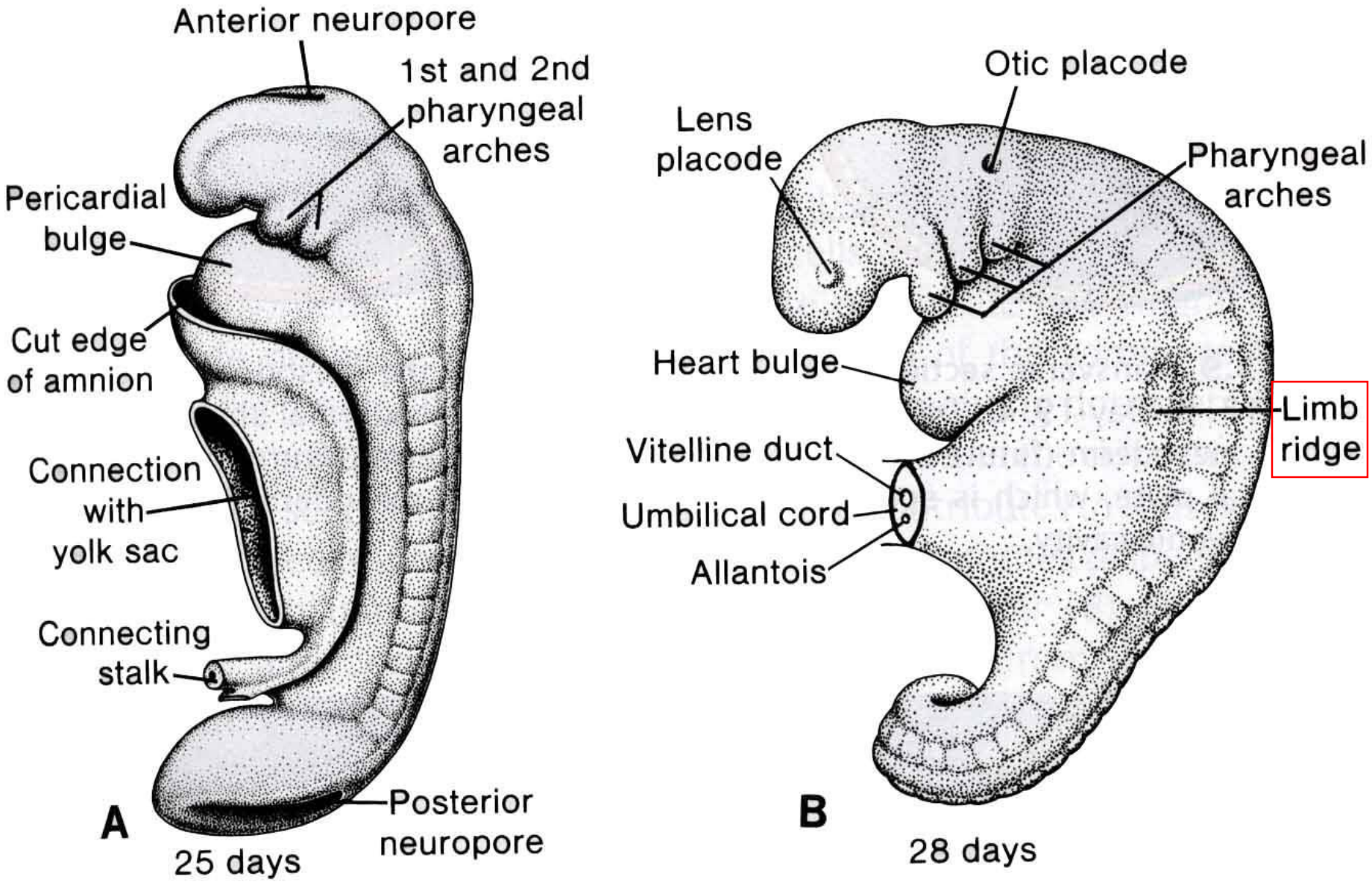
myoblasts



myotubes



DEVELOPMENT OF LIMBS



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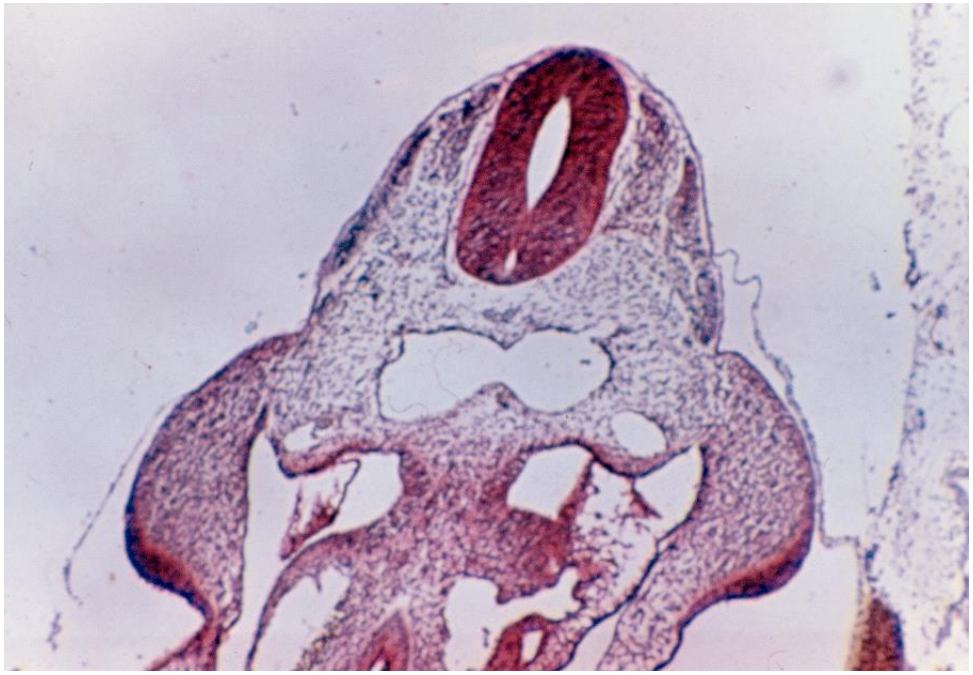
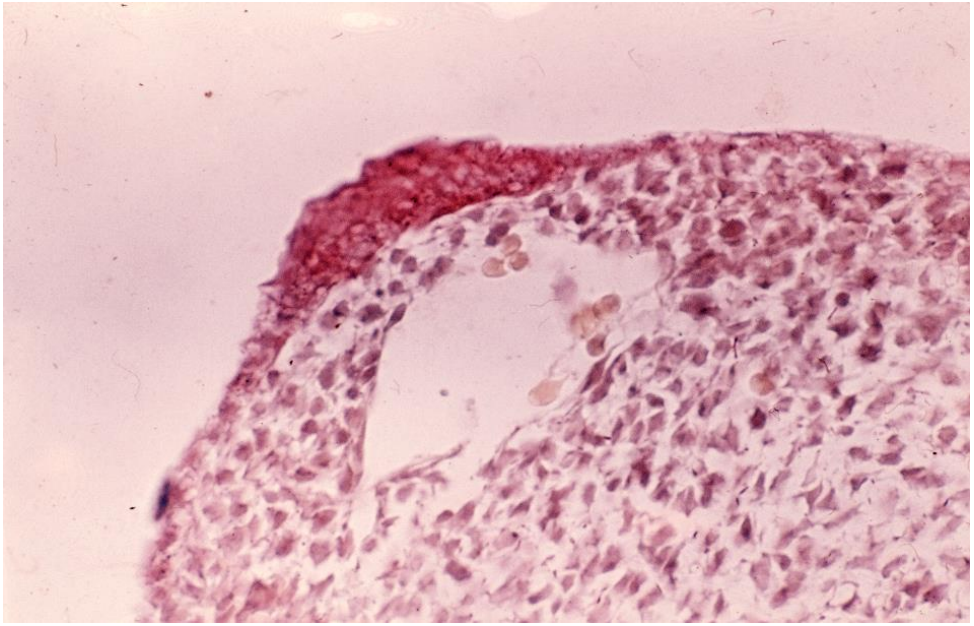
Limb buds

5th week

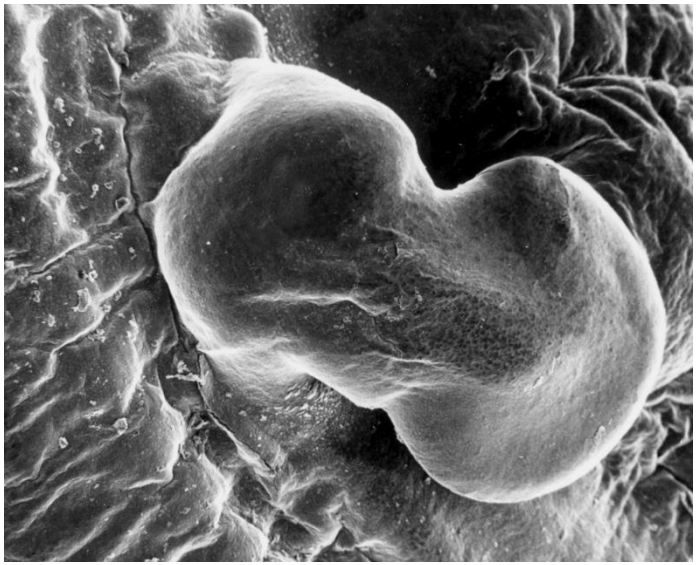


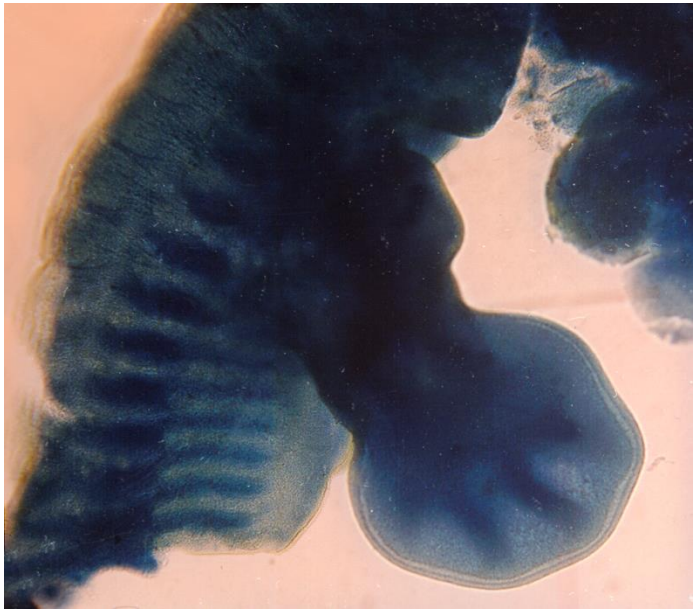


6th week

Two-segment limb; palmar plate and plantar plate, respectively

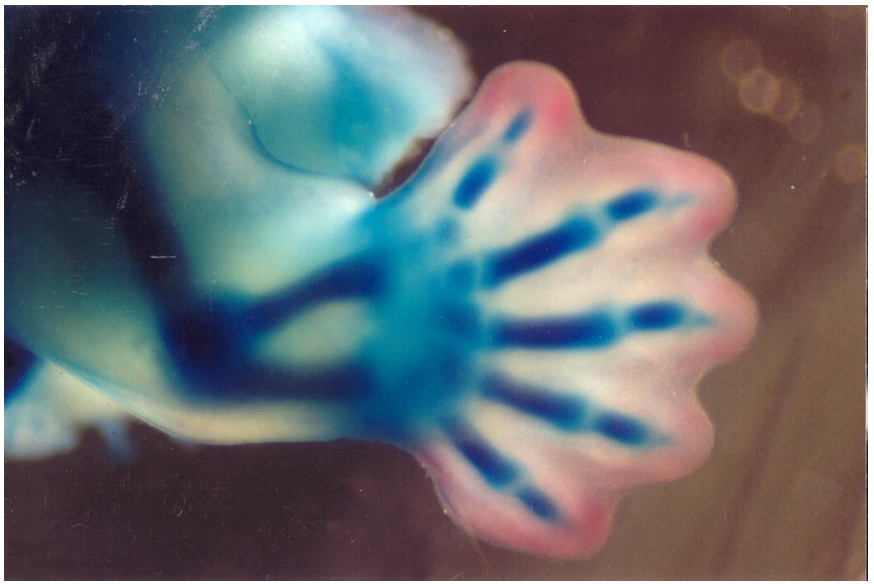
6th week

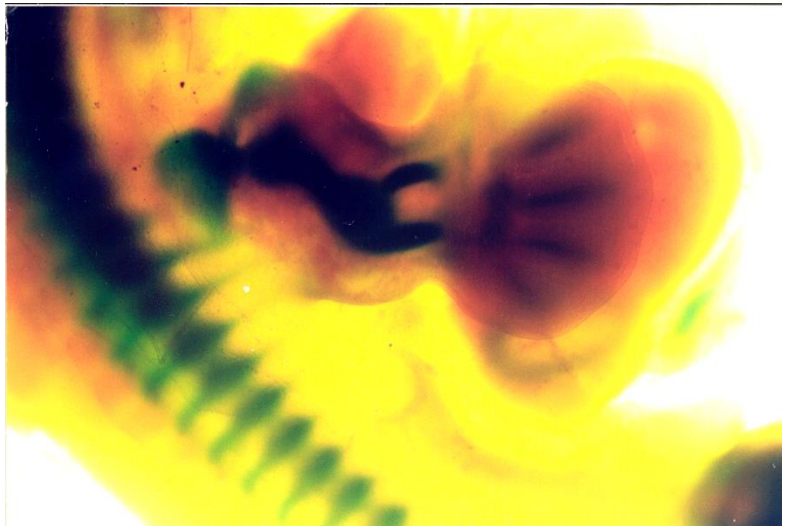


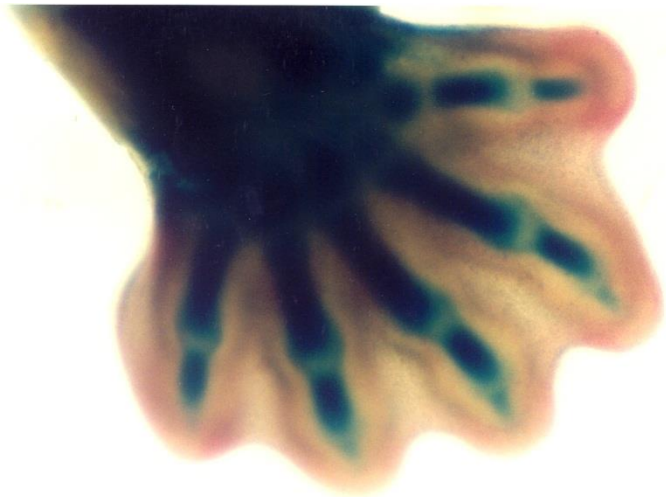


Three-segment limb; digital rays and tubercles

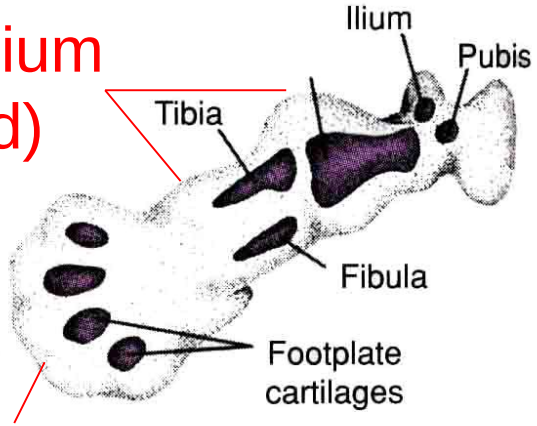
7th week





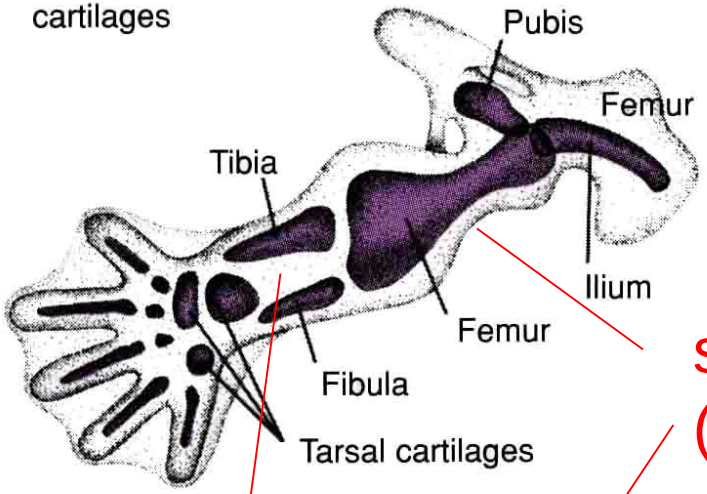


axopodium
(axopod)



two-segment limb

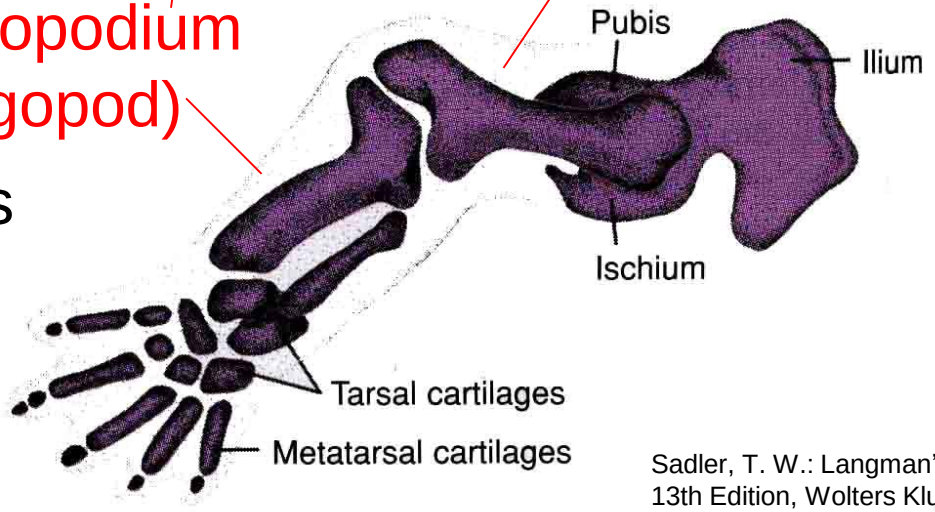
autopodium
(autopod)



stylopodium
(stylopod)

zeugopodium
(zeugopod)

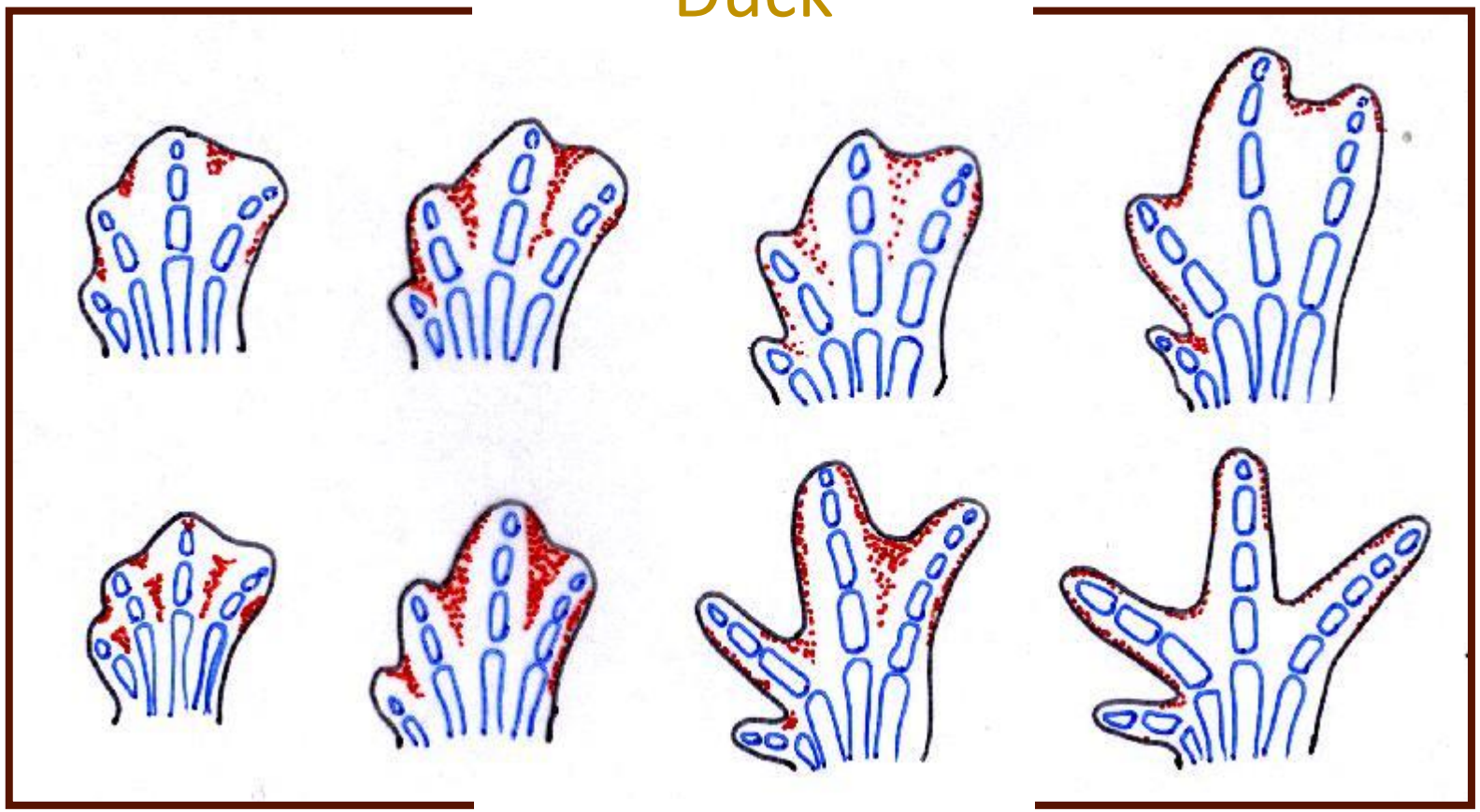
three-segment limbs



Sadler, T. W.: Langman's Medical Embryology,
13th Edition, Wolters Kluwer 2015

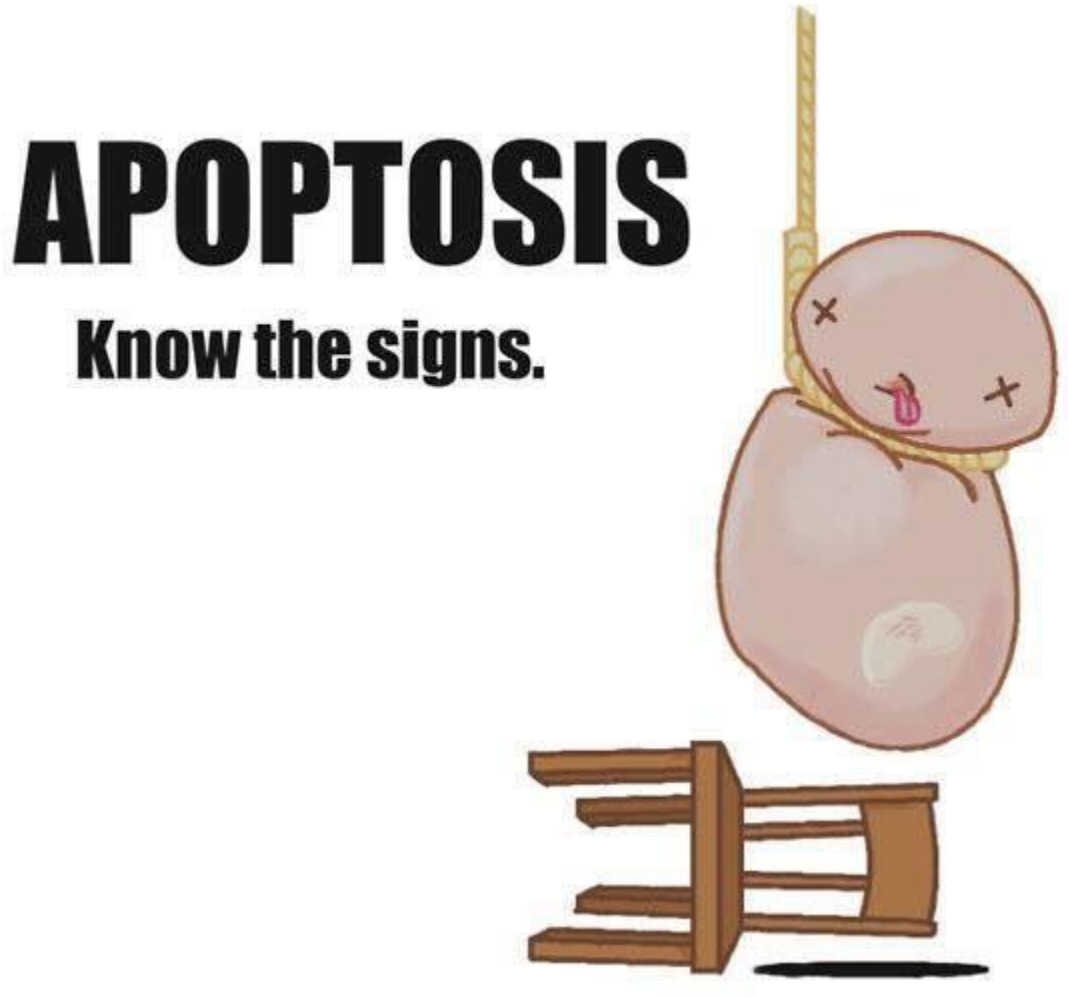
Programmed cell death in the limb development

Duck



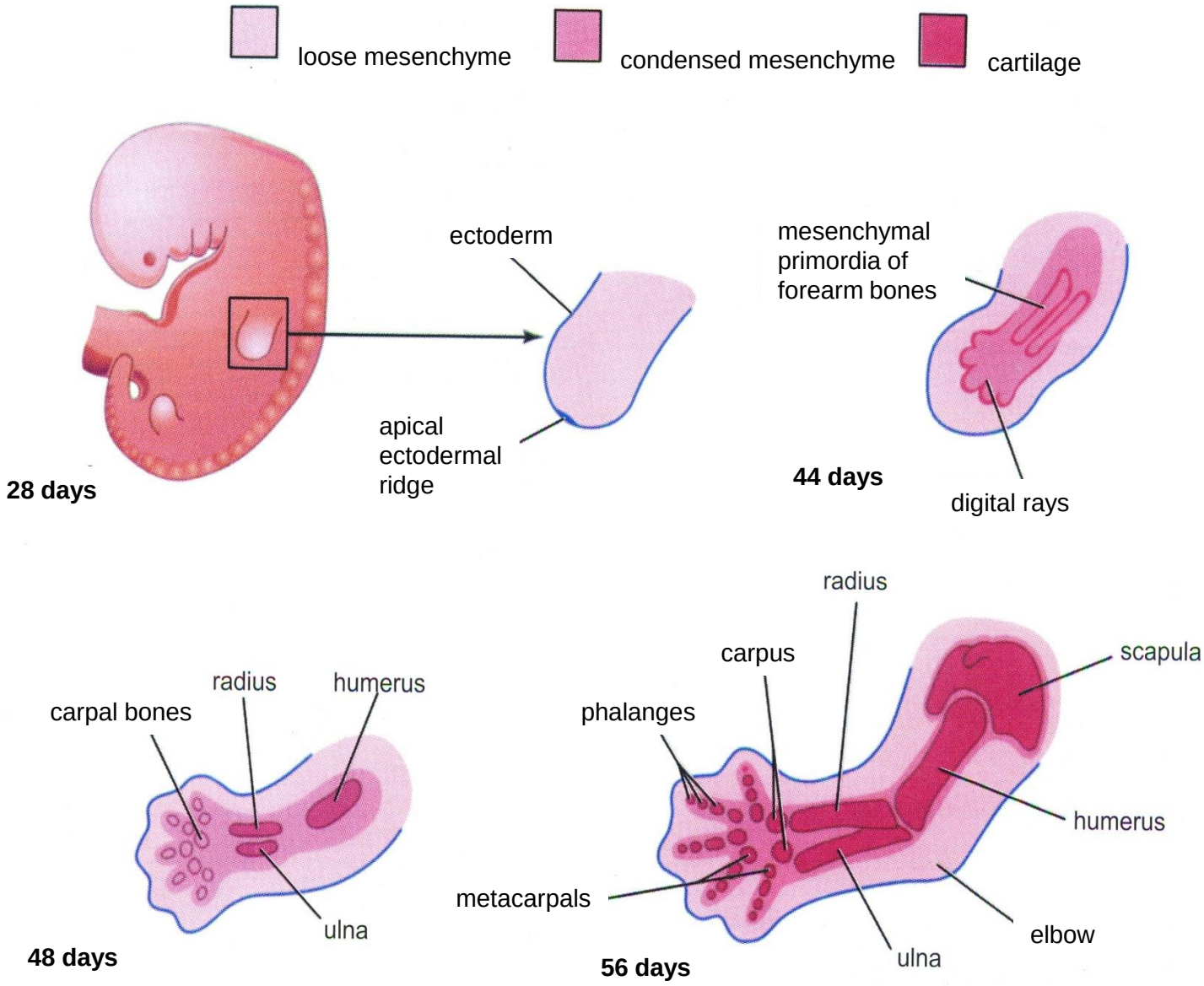
Chicken

Reduction
Cell death



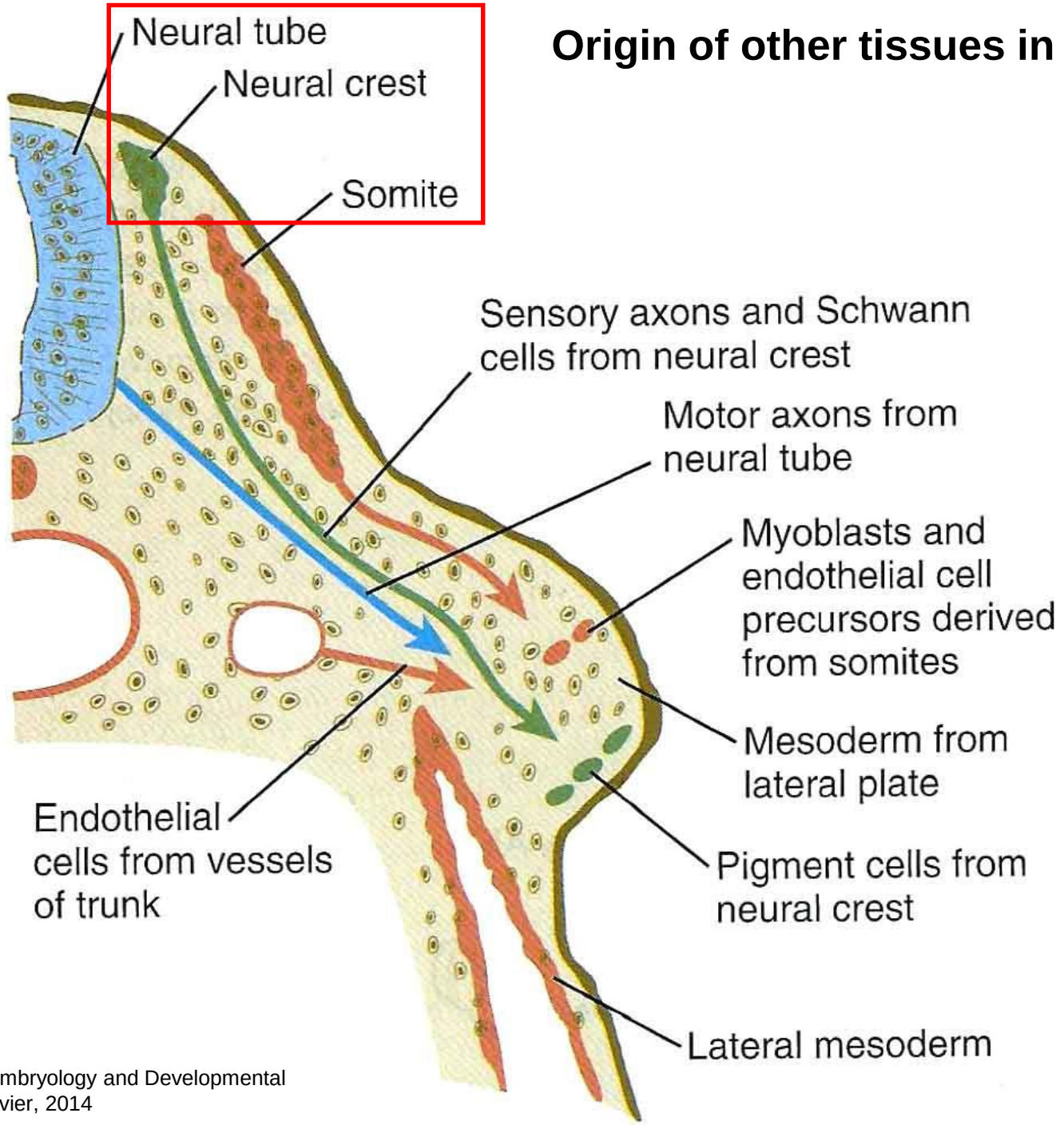
https://www.pinterest.co.uk/sonjasivcev/apoptosis/

Limb skeleton – somatopleura

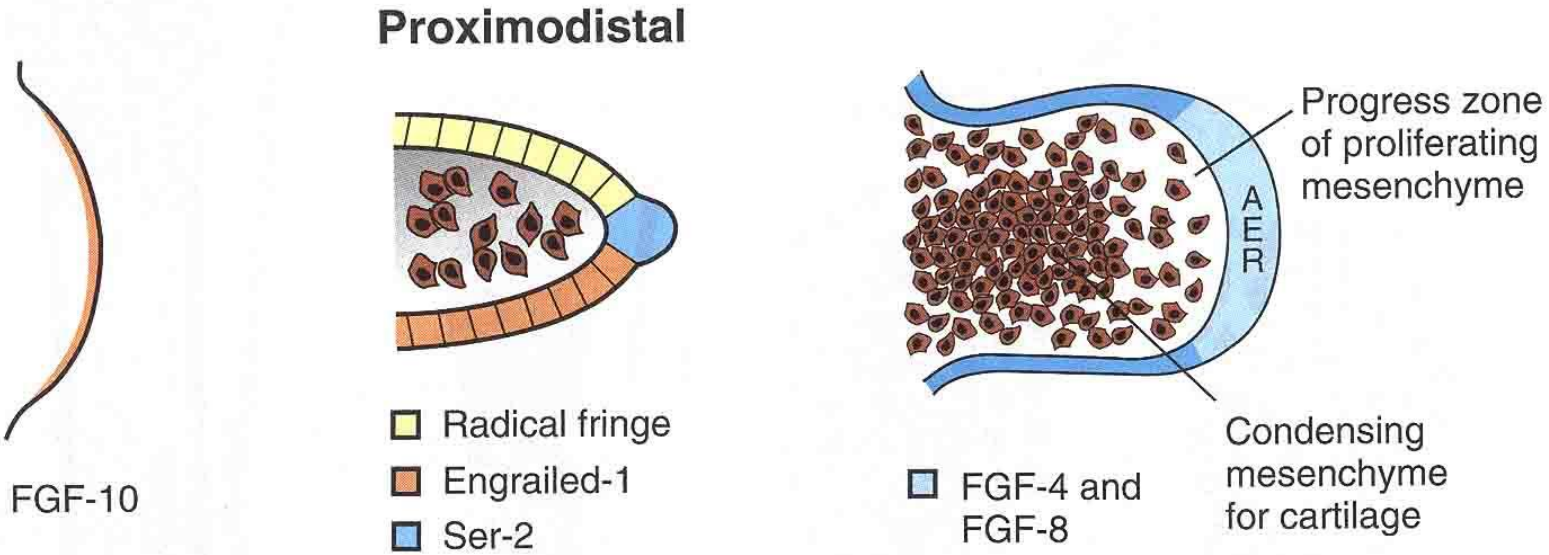


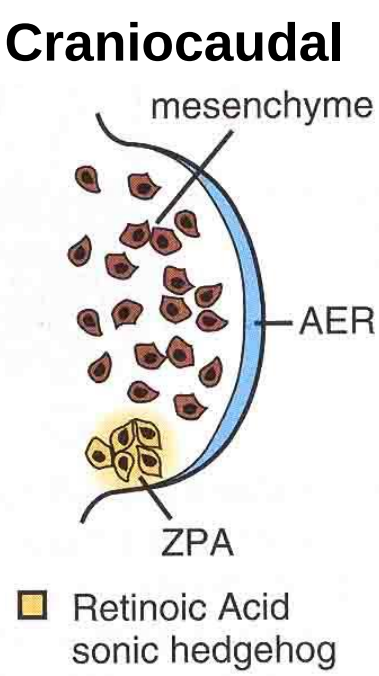
Moore, K.L., Persaud, T.V.N.: The Developing Human. Clinically Oriented Embryology. 7th ed. 2003.

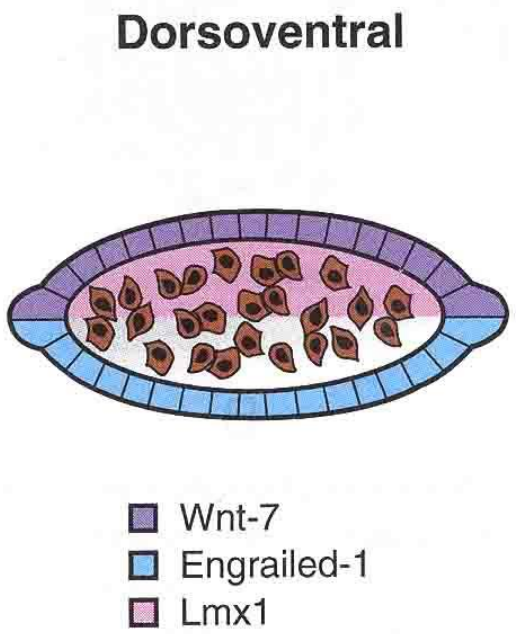
Origin of other tissues in limbs



Carlson, B. M.: Human Embryology and Developmental Biology, 5th Edition, Elsevier, 2014

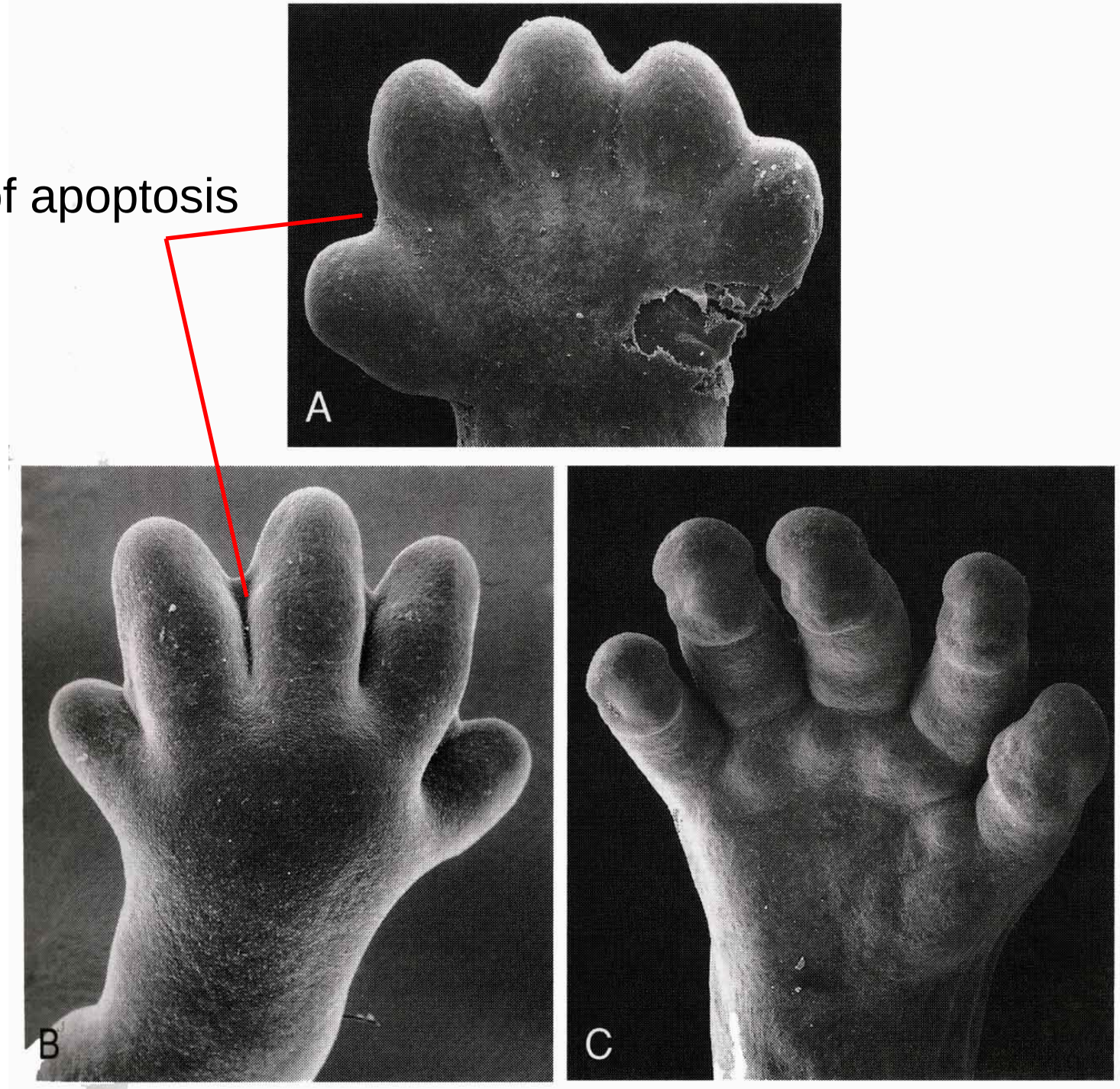

Proximodistal
FGF-10
Radical fringe
Engrailed-1
Ser-2
Progress zone
of proliferating
mesenchyme
AER
FGF-4 and
FGF-8
Condensing
mesenchyme
for cartilage


Craniocaudal
mesenchyme
AER
ZPA
Retinoic Acid
sonic hedgehog


Dorsoventral
Wnt-7
Engrailed-1
Lmx1

https://en.wikifur.com/wiki/Sonic_the_Hedgehog_%28character%29

areas of apoptosis



Limb rotation
(10th week)