Embryologie III

Kamila Procházková

Stádium J 5 (C7-9)

Trojvrstevný zárodečný terčík s osovými strukturami

dny 15 – 20, délka 0,5 – 1,5 mm

osové struktury: primitivní proužek, primitivní uzel, orofaryngová membrána, kloakova membrána, prechordální ploténka, chordomesodermový výběžek a ploténka, chorda, alantois

Substádia

J 5–1	primitivní uzel a chordomesodermový výběžek	C7
J 5–2	notochordová ploténka, primitivní proužek, intraembryonální mesoderm	C8
J 5–3	chorda, neurální valy	C9

Třetí týden

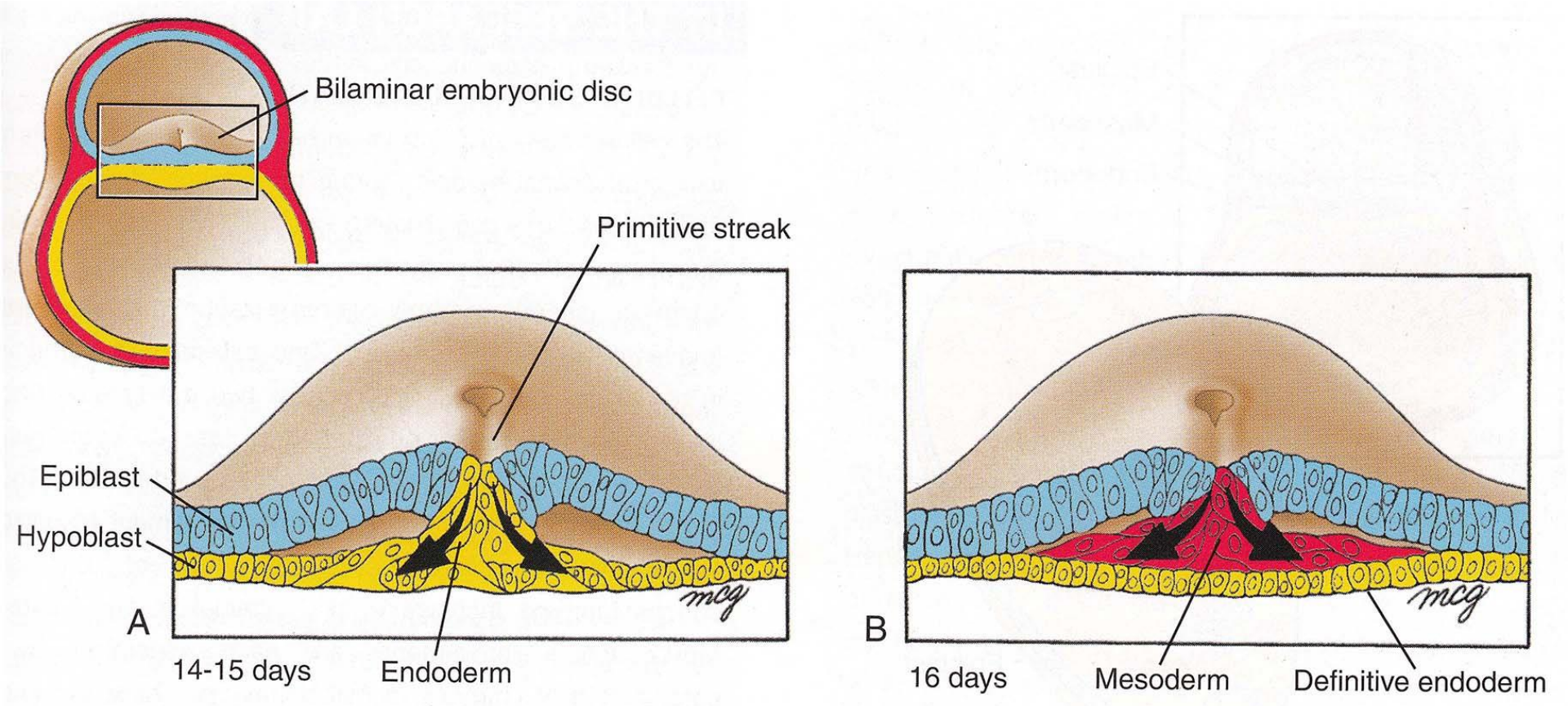
Trojvrstevný zárodečný terčík

dny 15 – 20, délka 0,5 – 1,5 mm

GASTRULACE
NOTOGENESE
NEURULACE

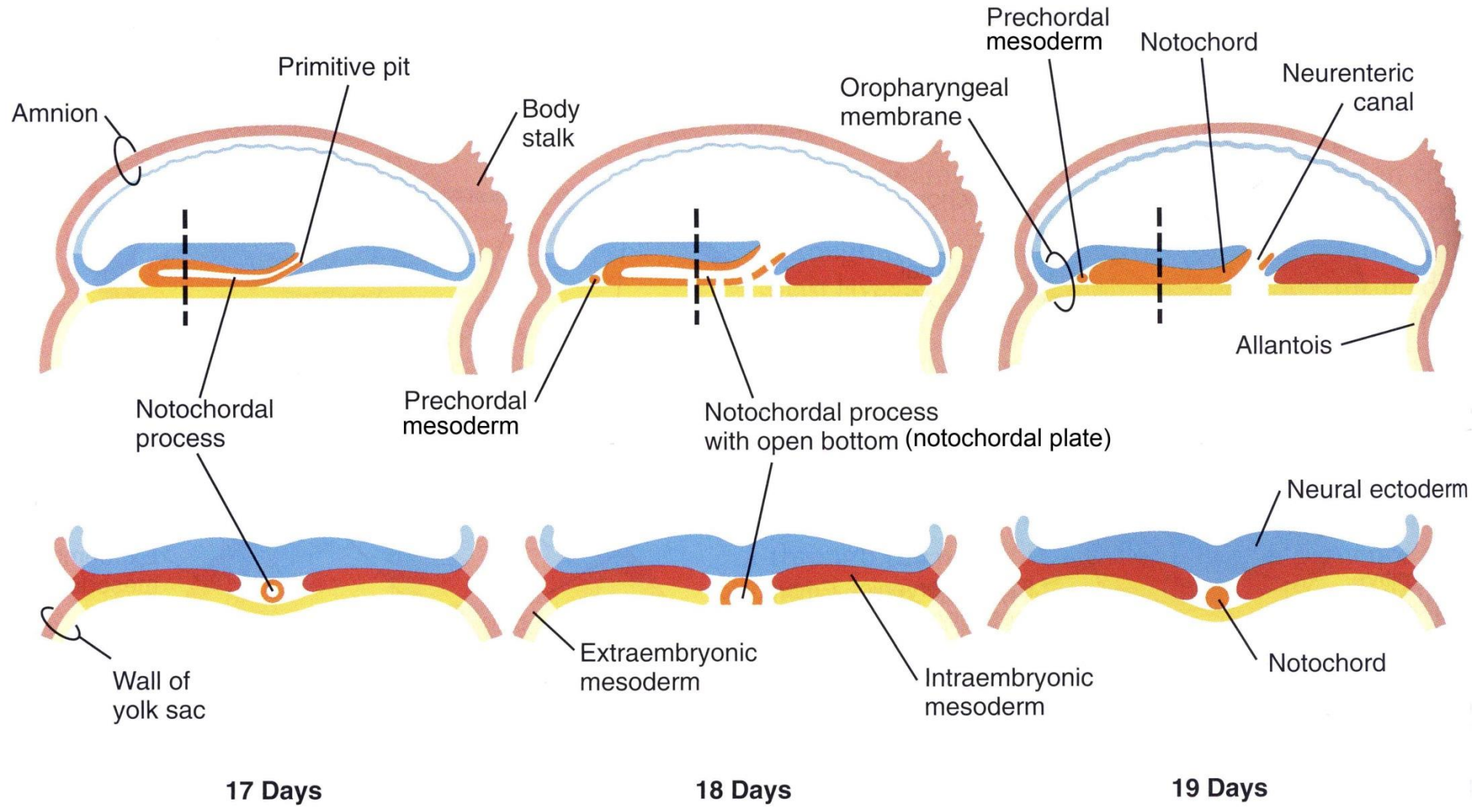
Gastrulation

J5–1/2, C7/8

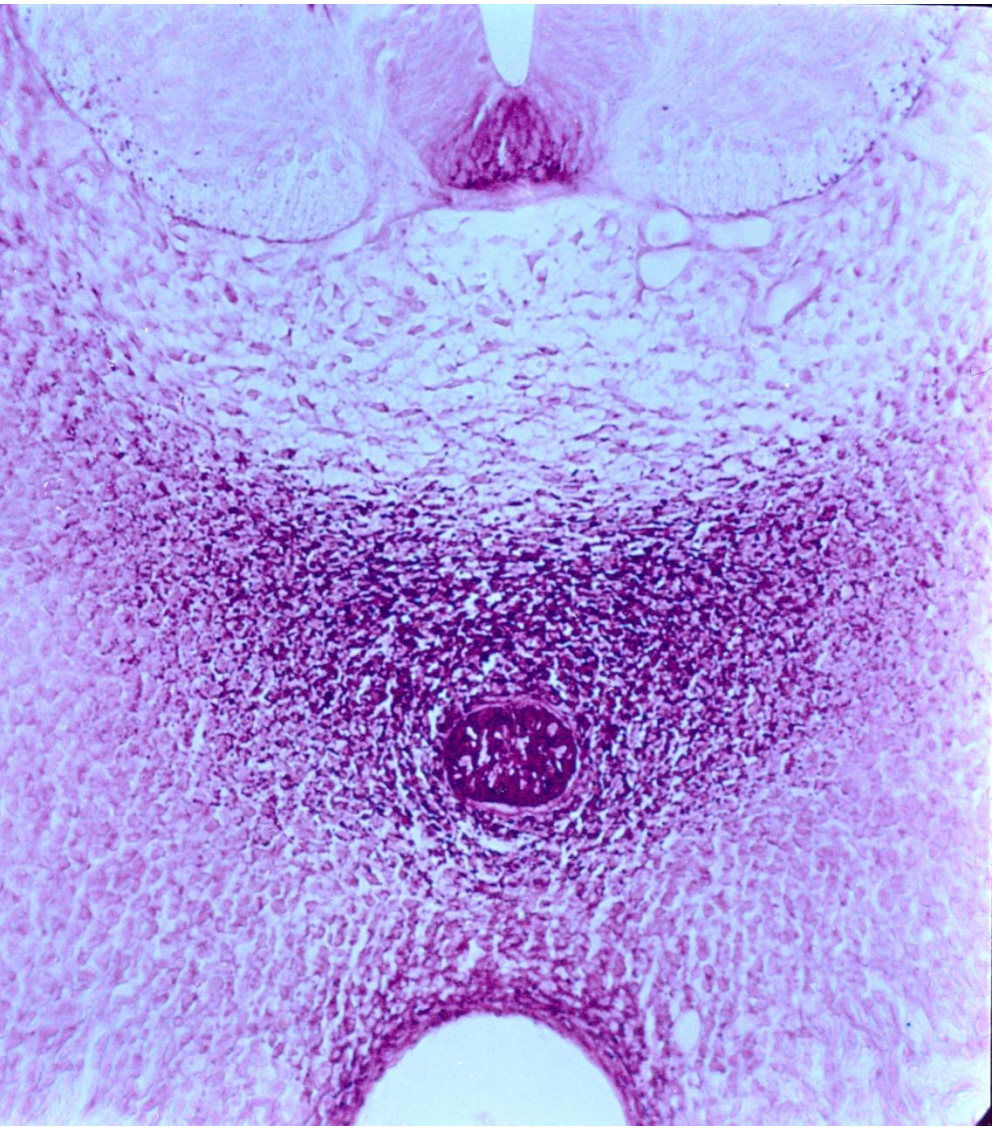


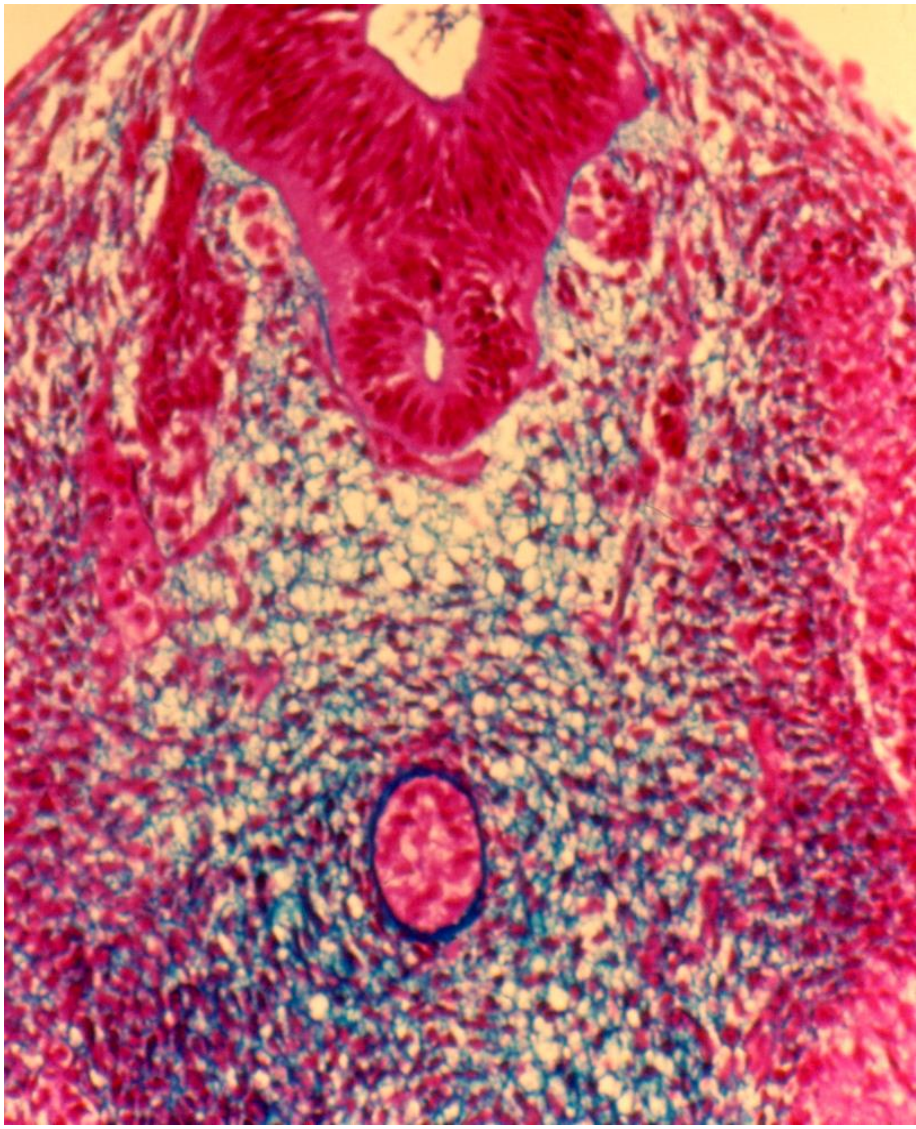
Schoenwolf, G.C. et al: Larsen's Human Embryology, Elsevier 2009

Development of the notochord - notogenesis

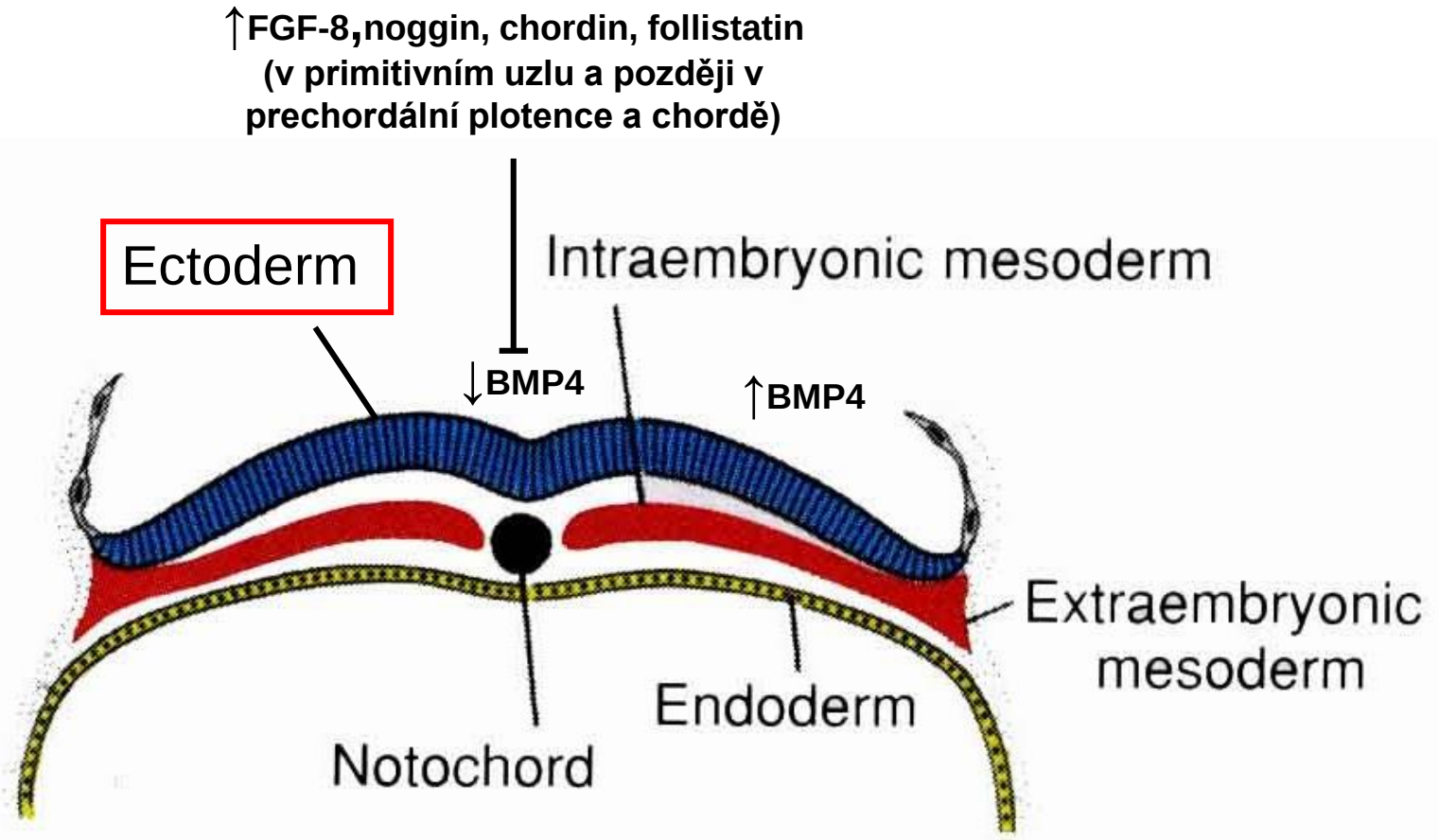


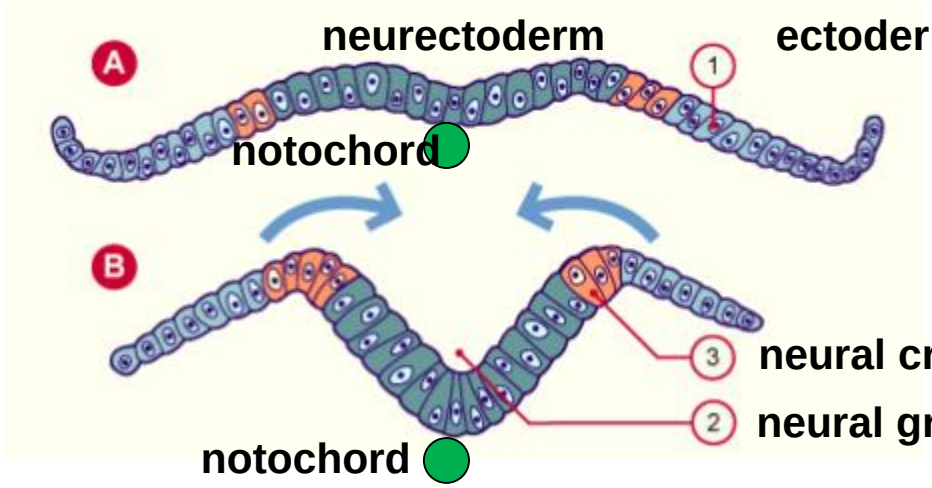
definitivní chorda dorsalis (notochord)

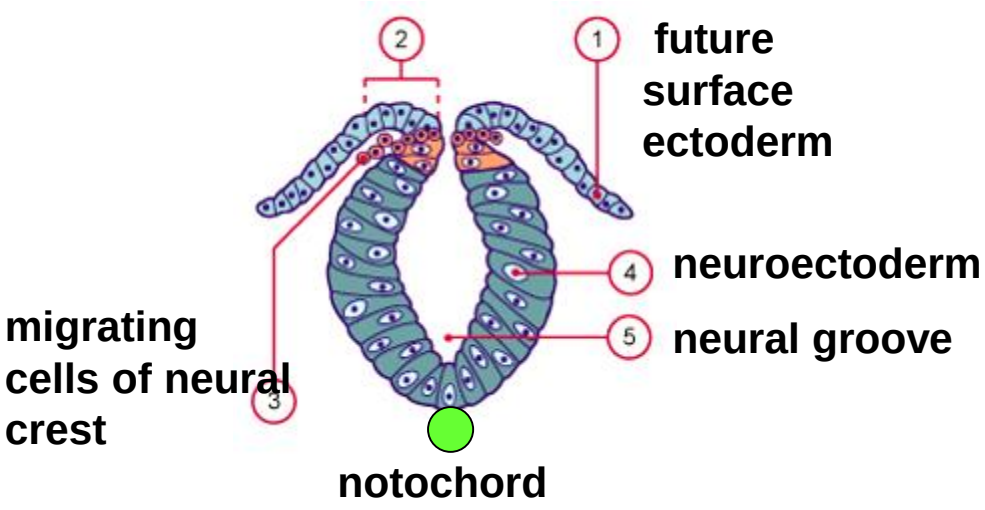


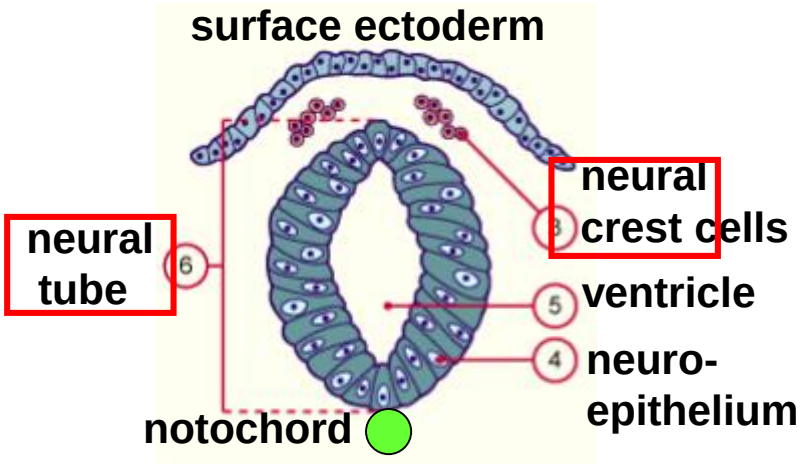


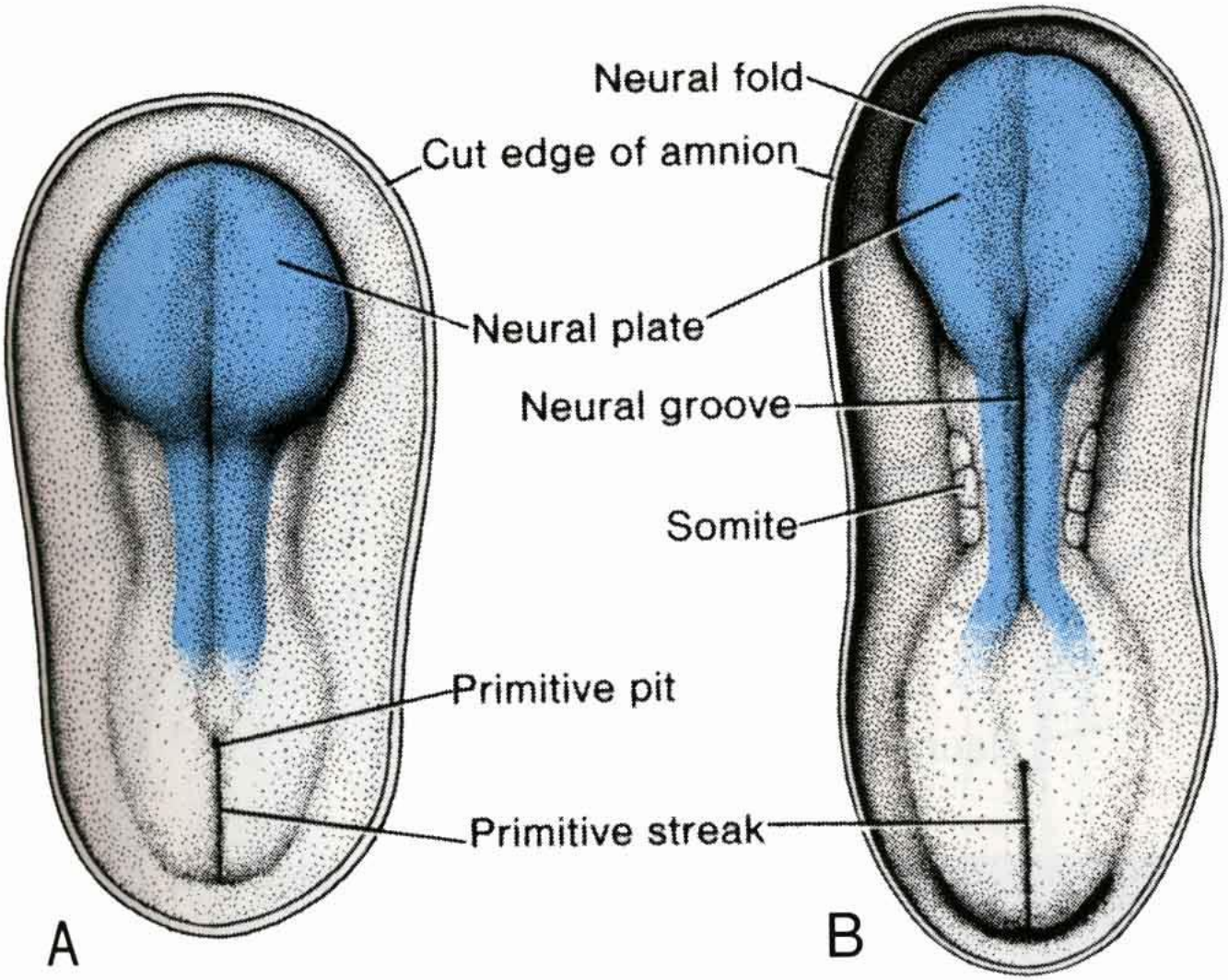
Neurulace

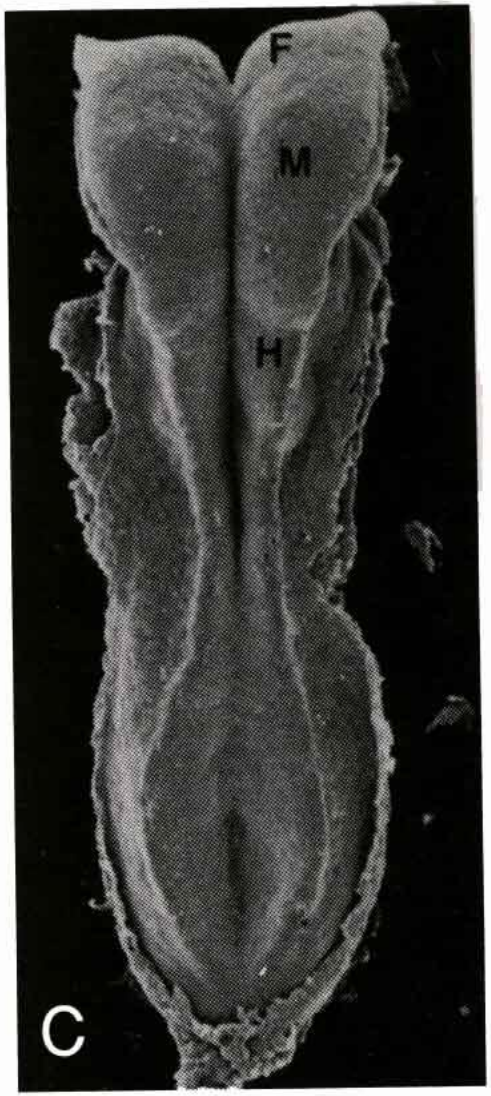

↑FGF-8,noggin, chordin, follistatin
(v primitivním uzlu a později v
prechordální plotence a chordě)
Ectoderm
Intraembryonic mesoderm
↓BMP4
↑BMP4
Extraembryonic
mesoderm
Endoderm
Notochord


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





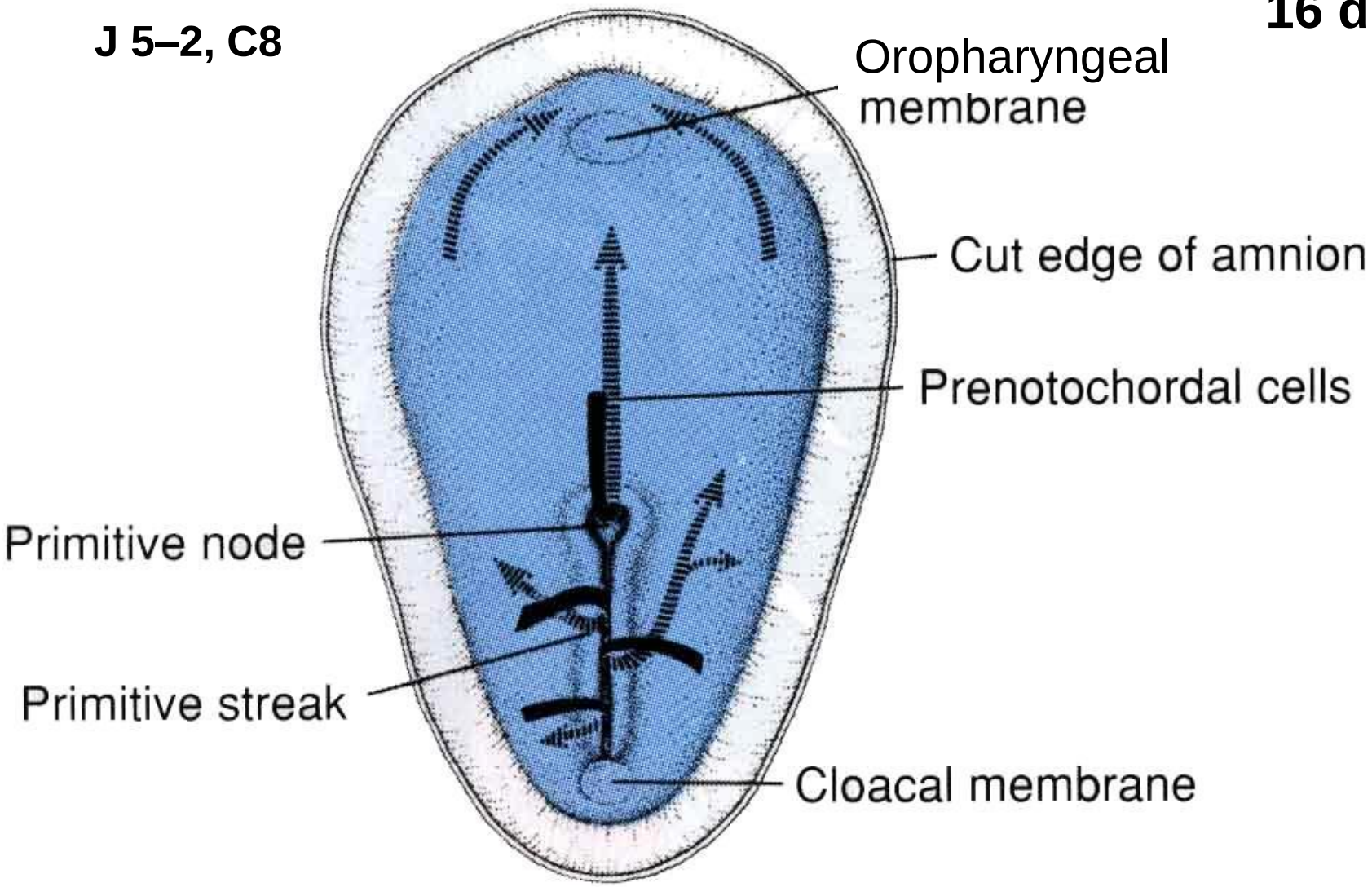
19th day

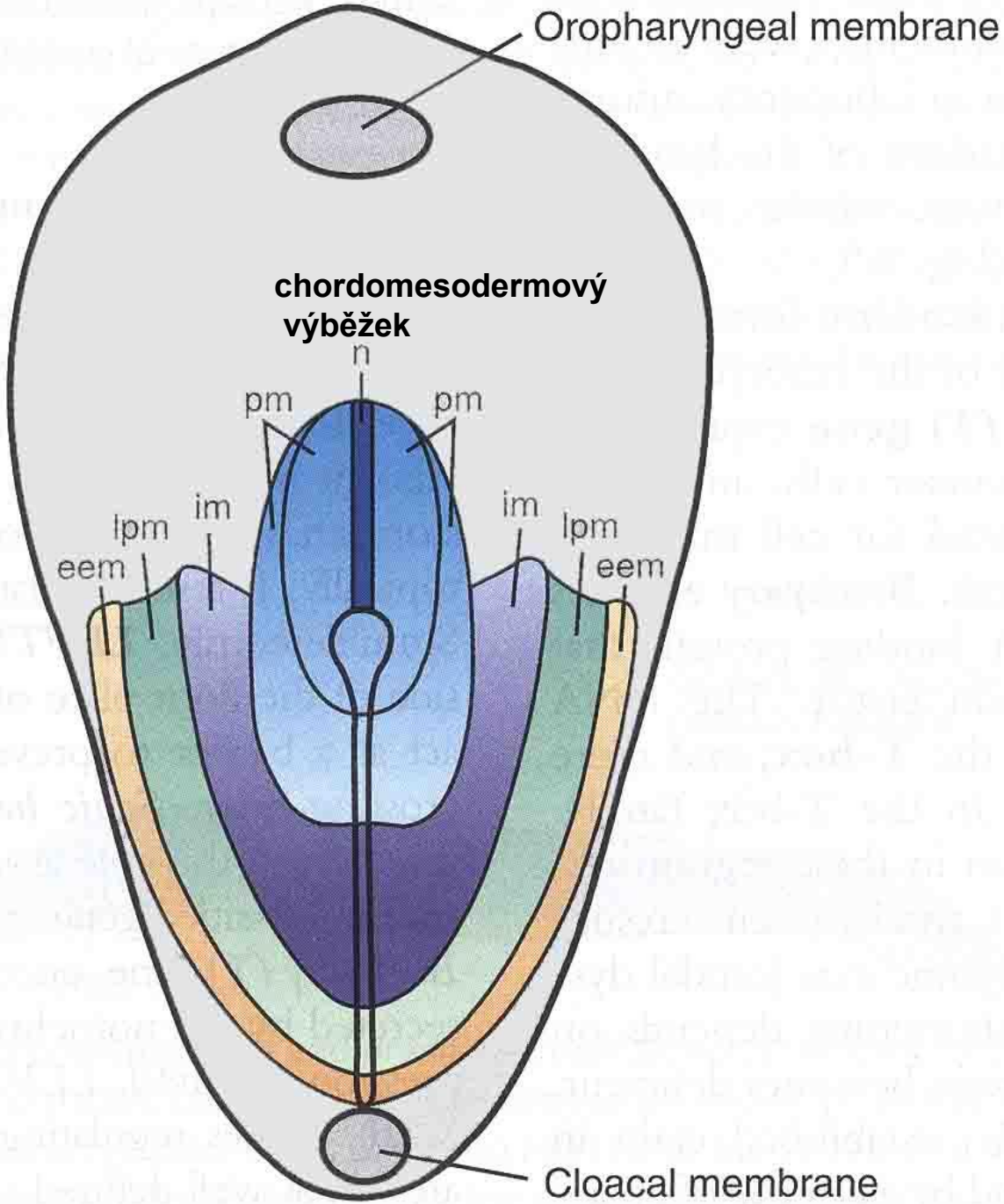
20th day

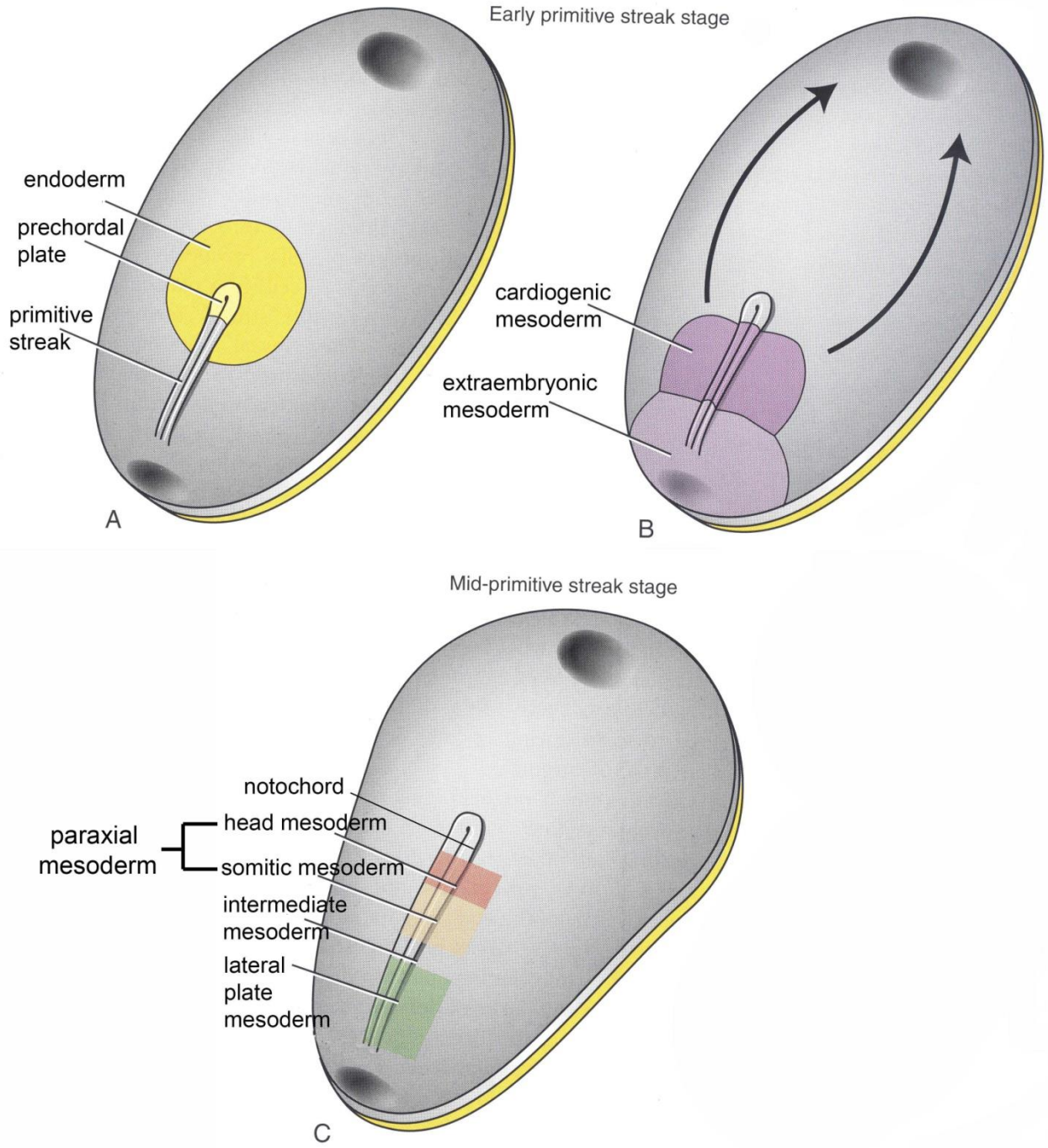
DIFERENCIACE INTRAEMBRYONÁLNÍHO MESODERMU

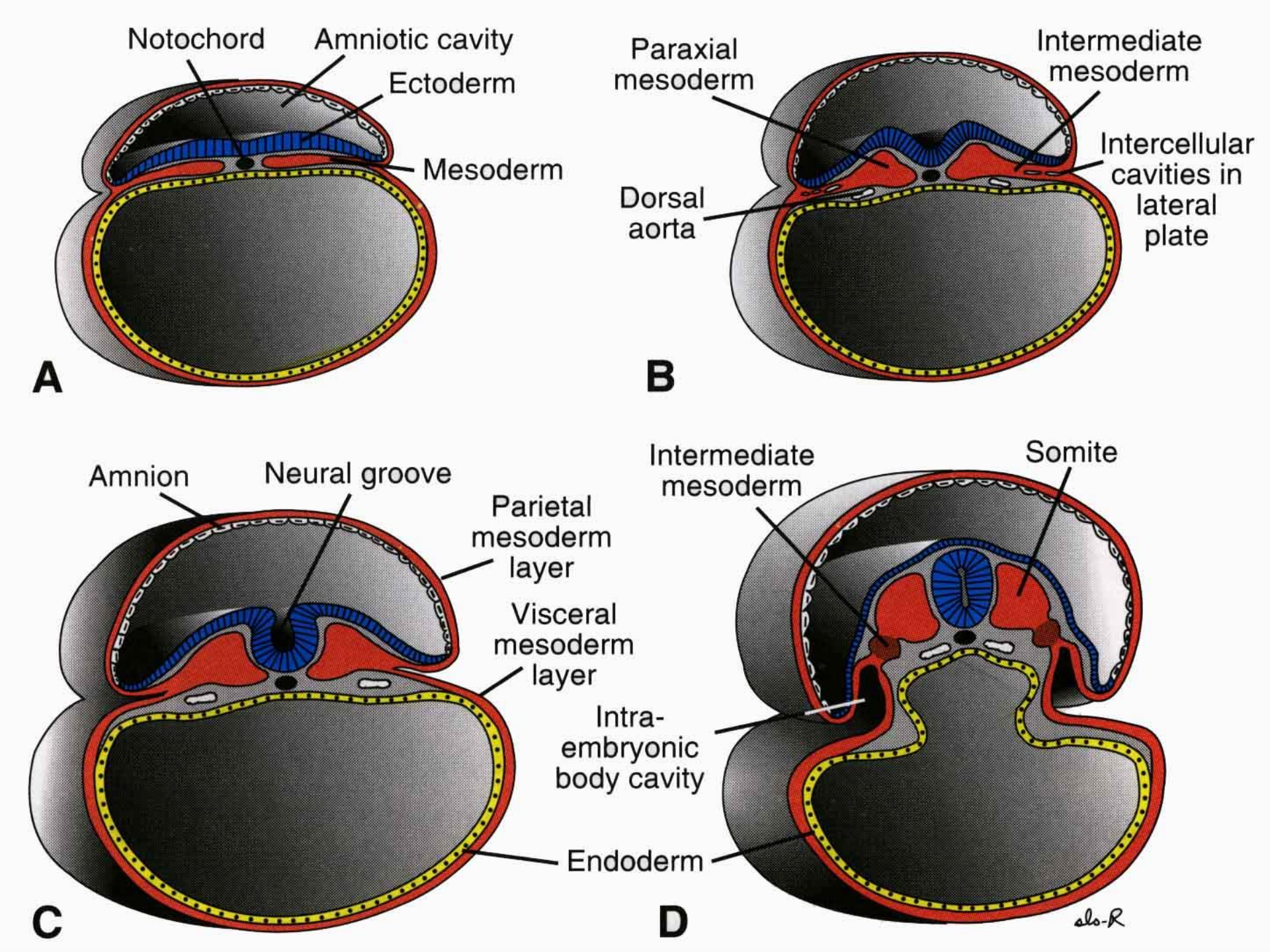
J 5–2, C8

16 d


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


Oropharyngeal membrane
chordomesodermový výběžek
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


Notochord
Amniotic cavity
Ectoderm
Mesoderm
A
Paraxial mesoderm
Intermediate mesoderm
Intercellular cavities in lateral plate
Dorsal aorta
B
Amnion
Neural groove
Parietal mesoderm layer
Visceral mesoderm layer
Endoderm
C
Intermediate mesoderm
Somite
Intra-embryonic body cavity
D
als-R

Stádium J 6 (C9-12) trubicovité embryo

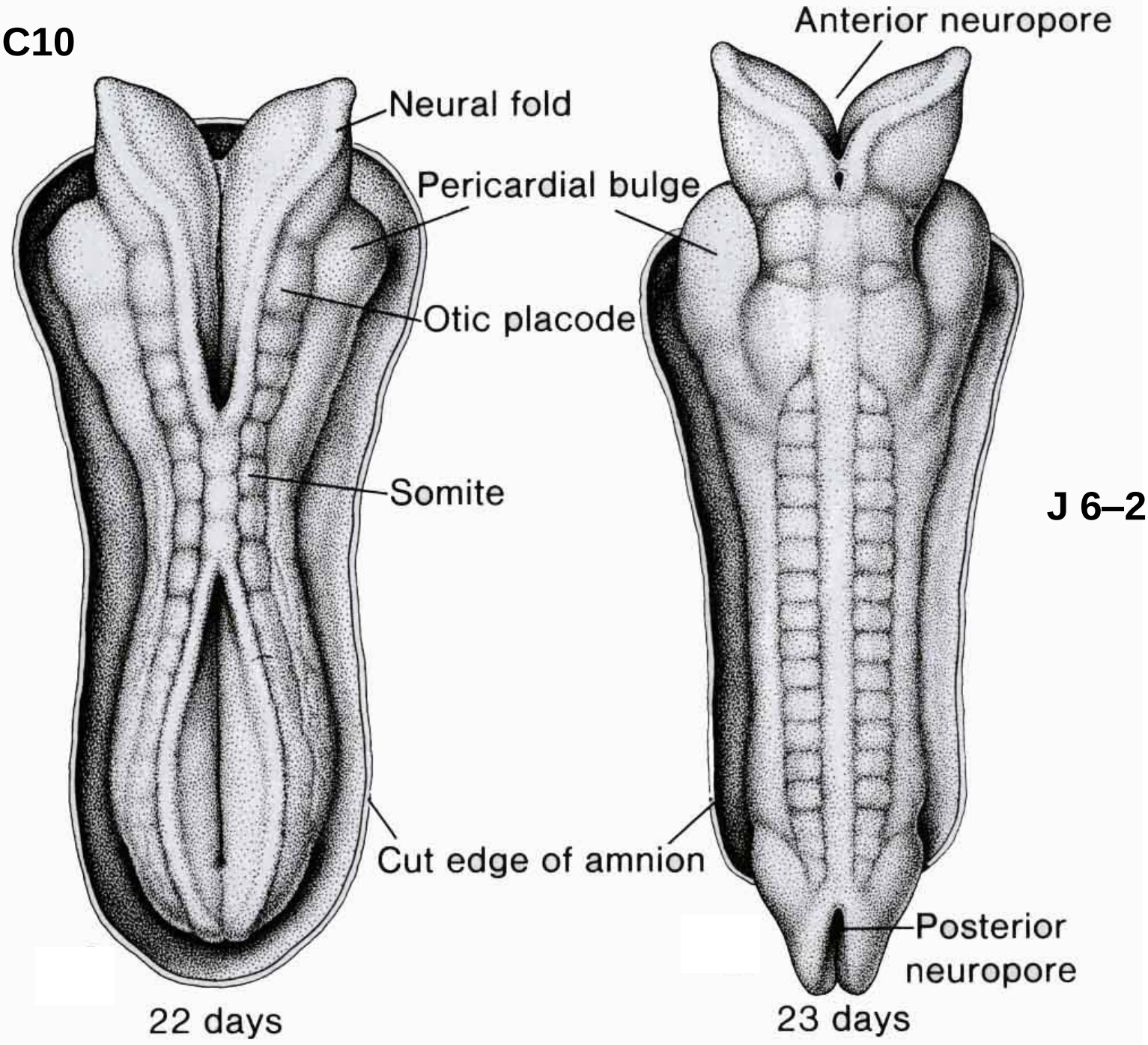
formování somitů, uzavírání nervové trubice, srdeční trubice a klička

dny 20 – 30, délka 1,2 – 3 mm

Substádia

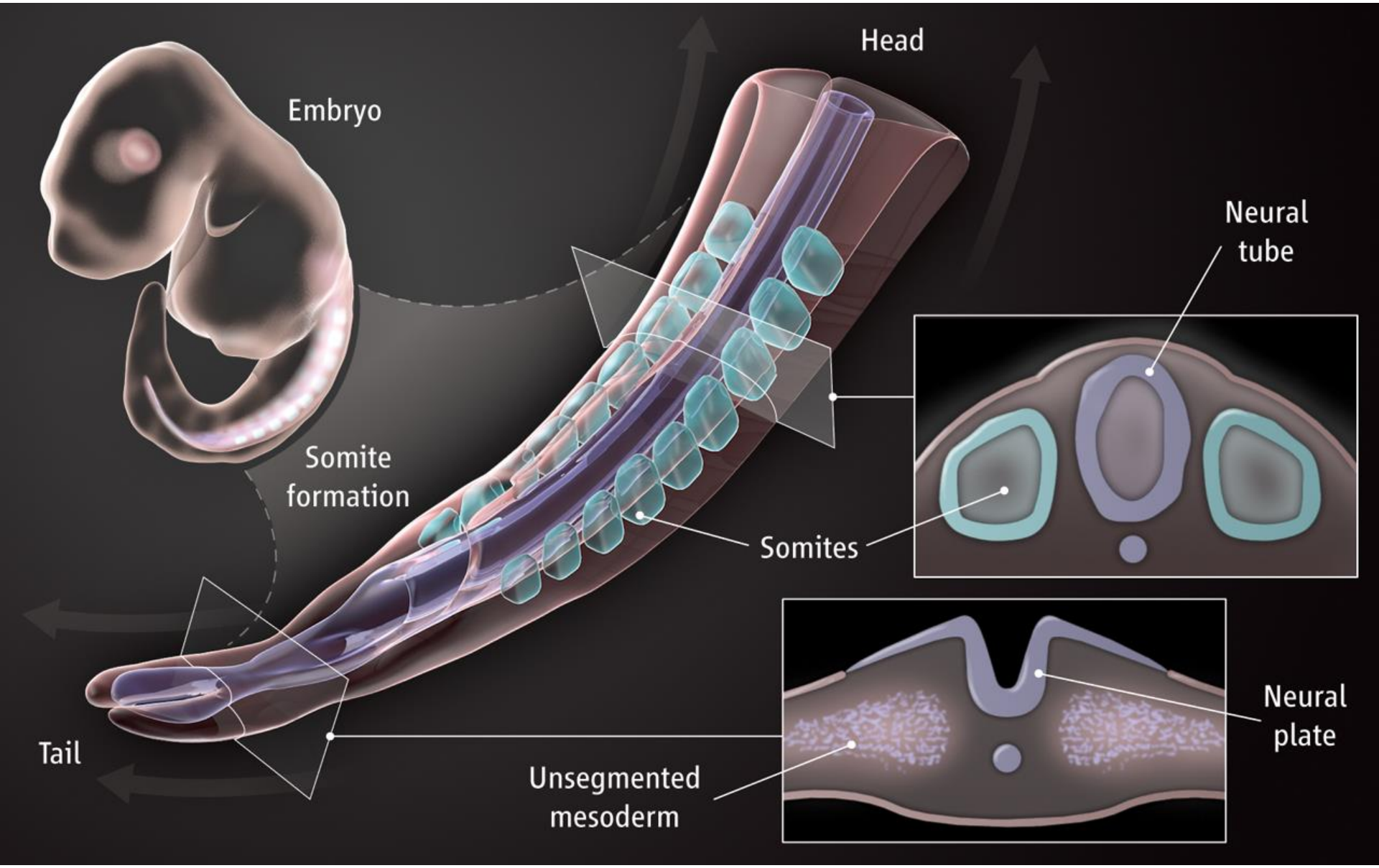
J 6–1	embrya se zcela otevřenou nervovou trubicí a prvními sedmi páry somitů	C9/10
J 6–2	embrya s uzavírající se nervovou trubicí a předním a zadním neuroporem	C10
J 6–3	embrya s uzavřeným předním neuroporem nebo oběma, bez končetinových pupenů	C11/12

J 6–1, C10



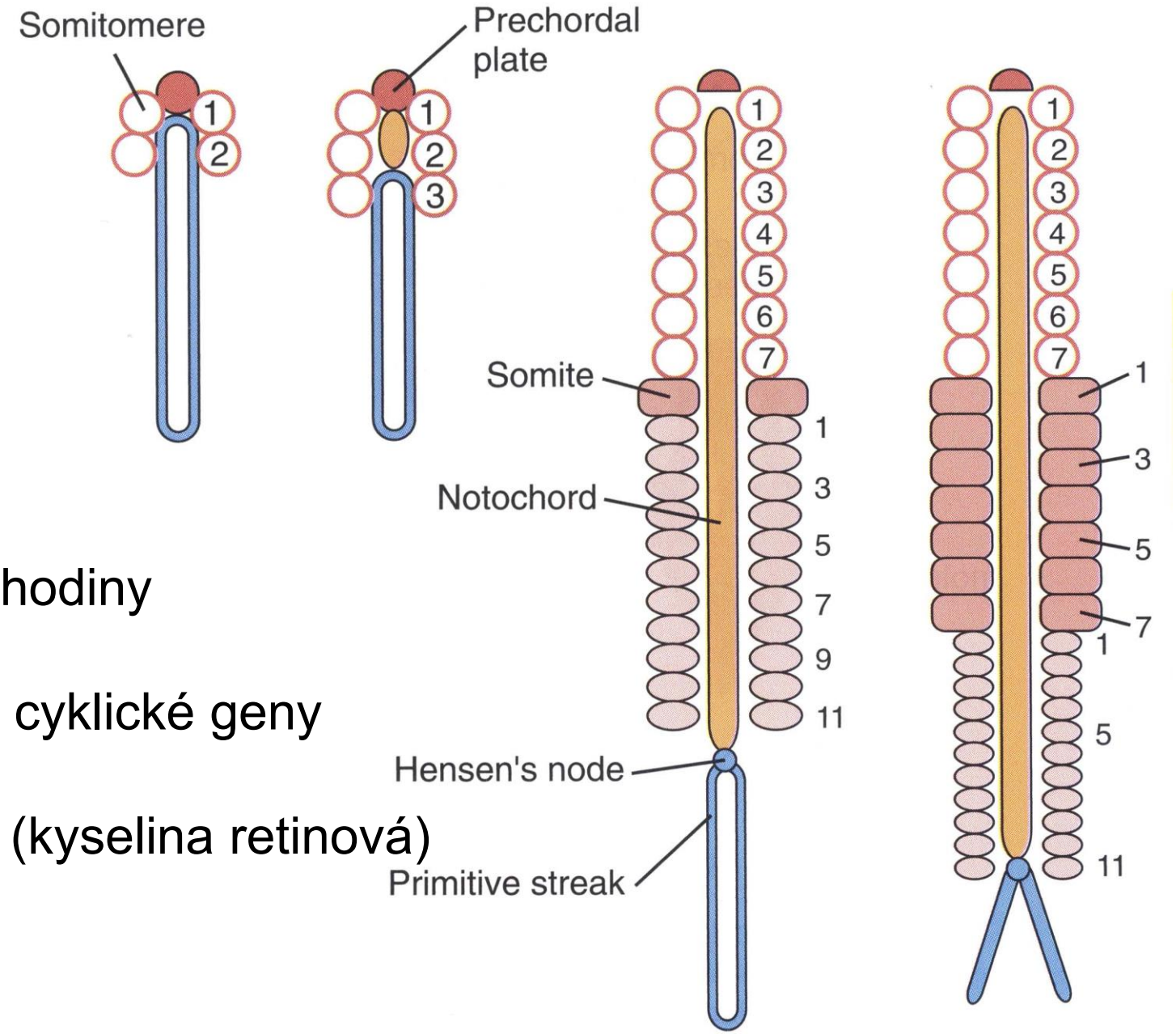
J 6–2, C10

J 6–3, C11/12



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

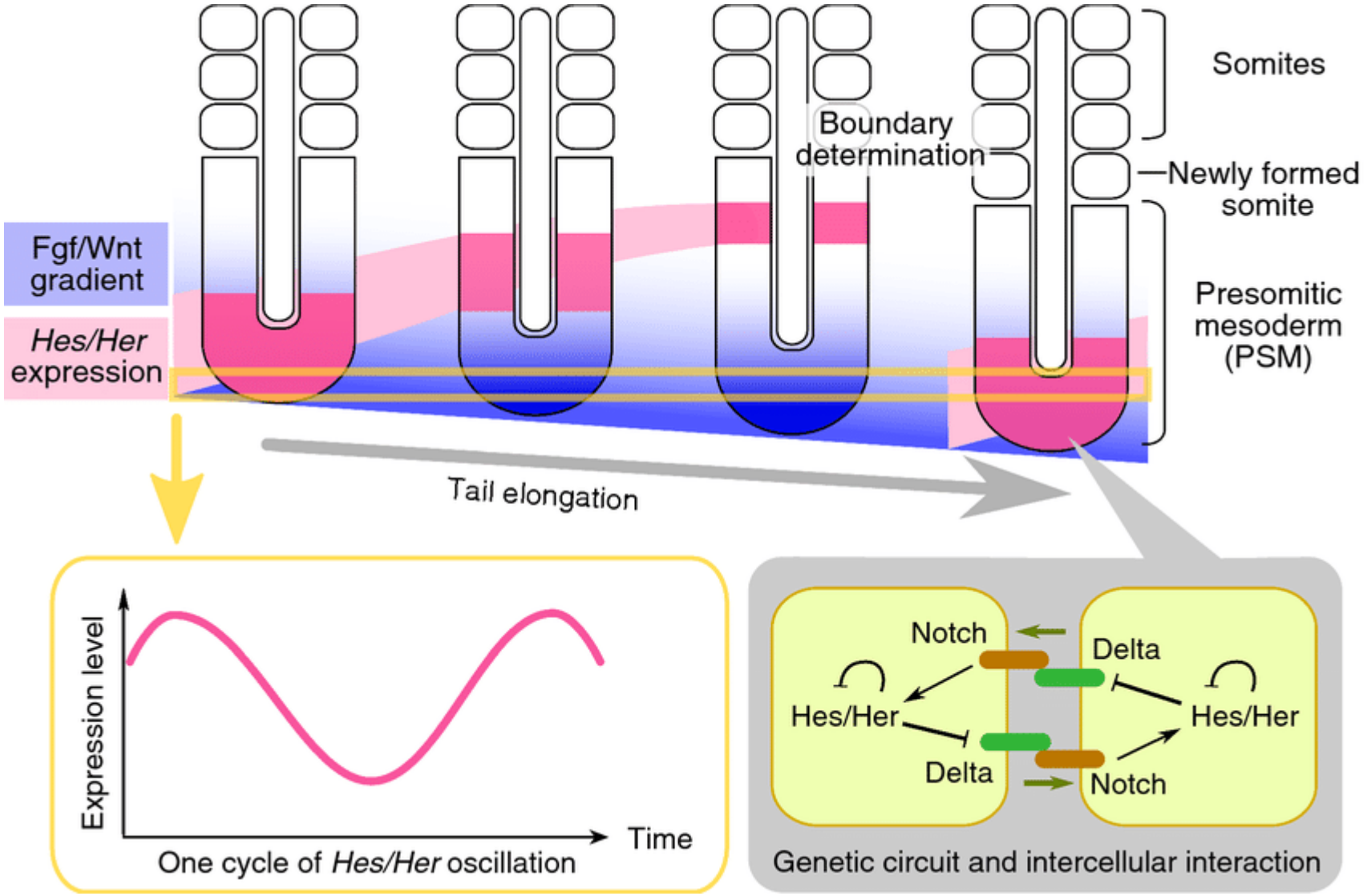
Paraxiální mesoderm



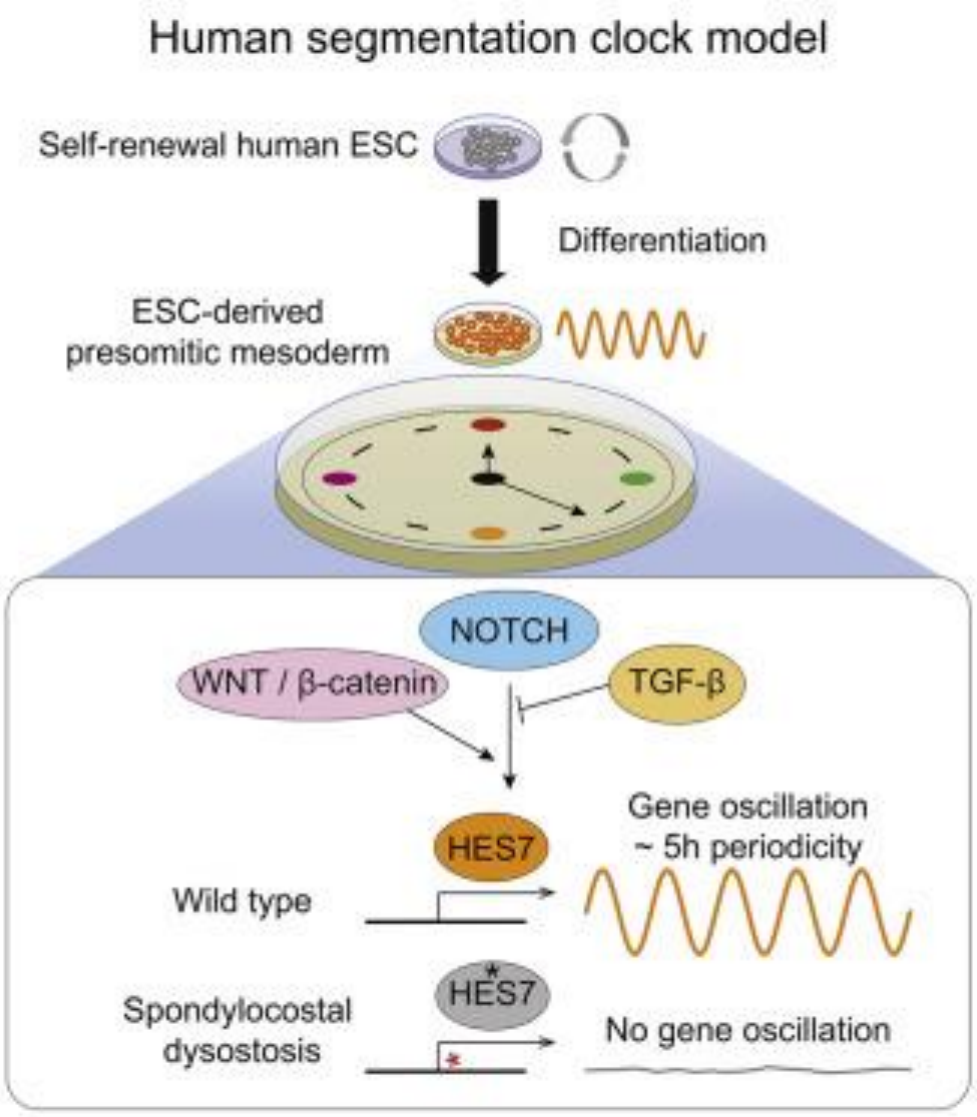
Segmentační hodiny

WNT, Notch – cyklické geny

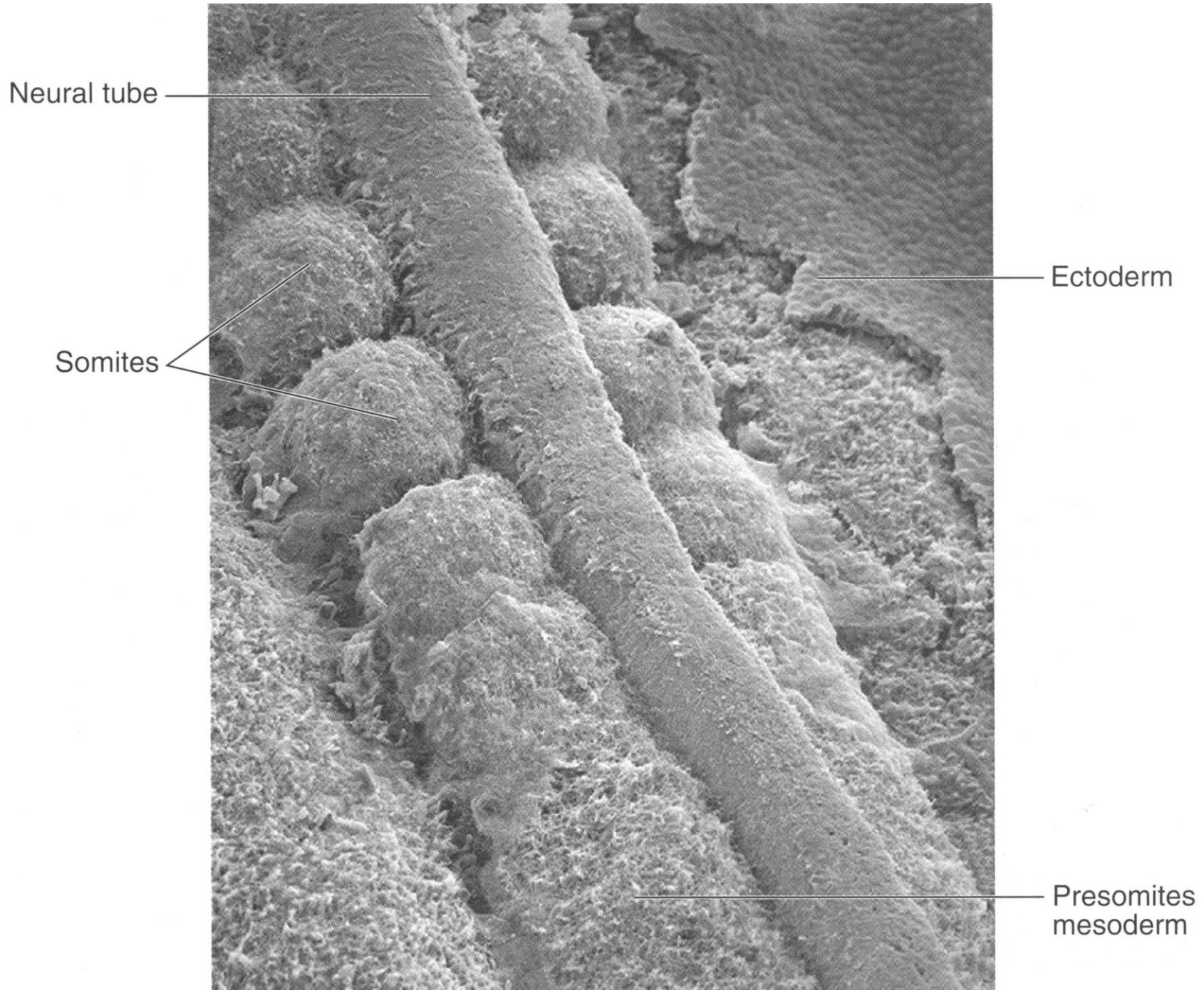
↓ FGF8 ↑ RA (kyselina retinová)



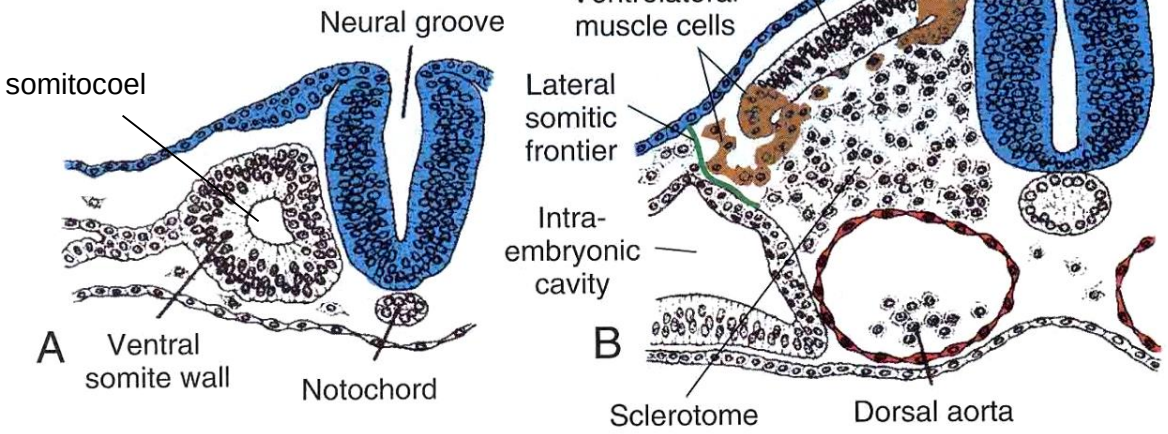
Yoshioka-Kobayashi, Kumiko & Kageyama, Ryoichiro. (2021). Imaging and manipulating the segmentation clock. Cellular and Molecular Life Sciences. 78. 1-11. 10.1007/s00018-020-03655-z.



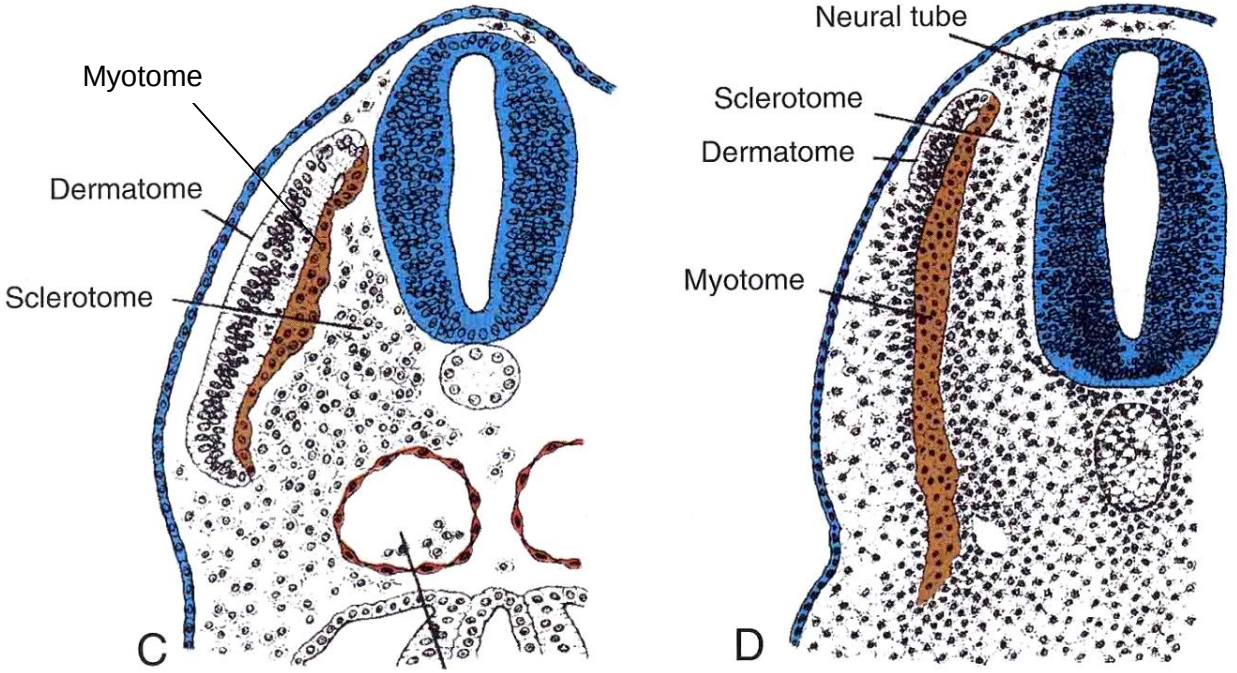
Li-Fang Chu, Daniel Mamott, Zijian Ni, Rhonda Bacher, Cathy Liu, Scott Swanson, Christina Kendziorski, Ron Stewart, James A. Thomson, An In Vitro Human Segmentation Clock Model Derived from Embryonic Stem Cells, Cell Reports, Volume 28, Issue 9, 2019, Pages 2247-2255.e5, ISSN 2211-1247, https://doi.org/10.1016/j.celrep.2019.07.090.


Neural tube
Somites
Ectoderm
Presomites
mesoderm

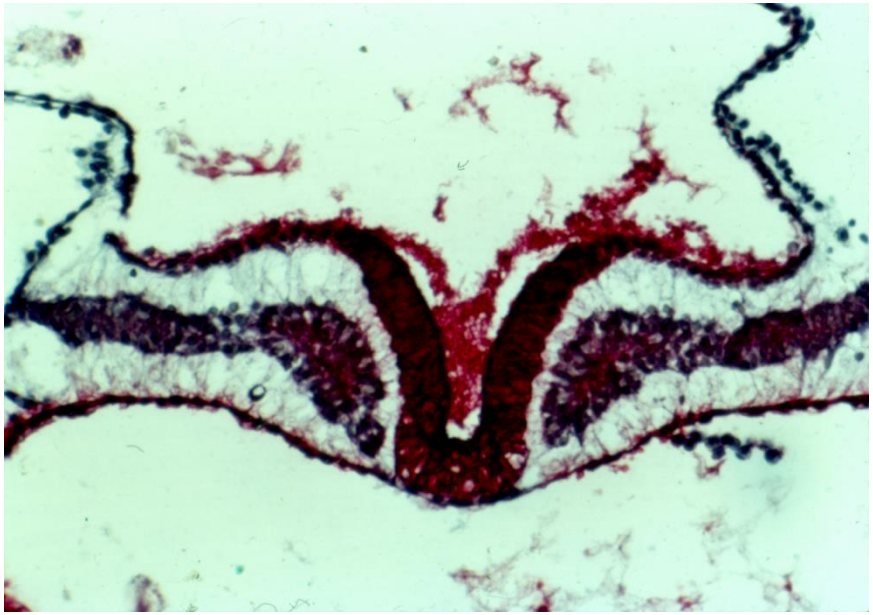
Prvosegment (somit)

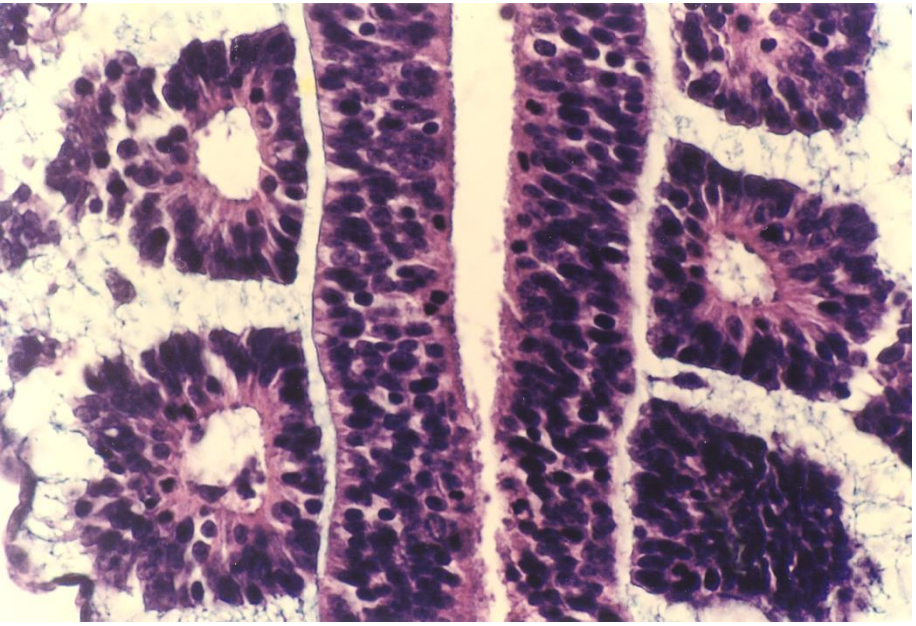


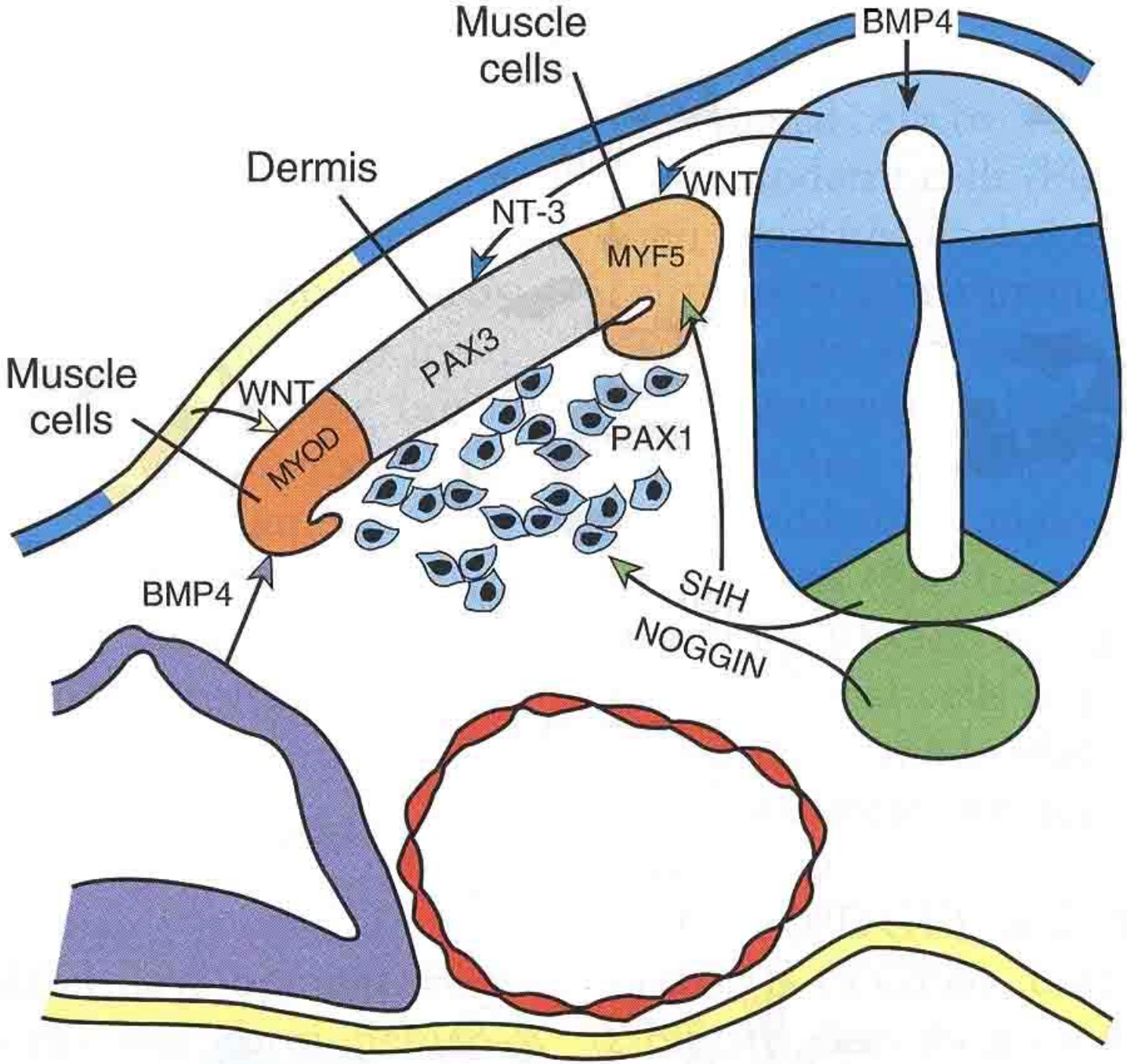
1. somit 20. den
do konce 5. týdne 42-44 somitů



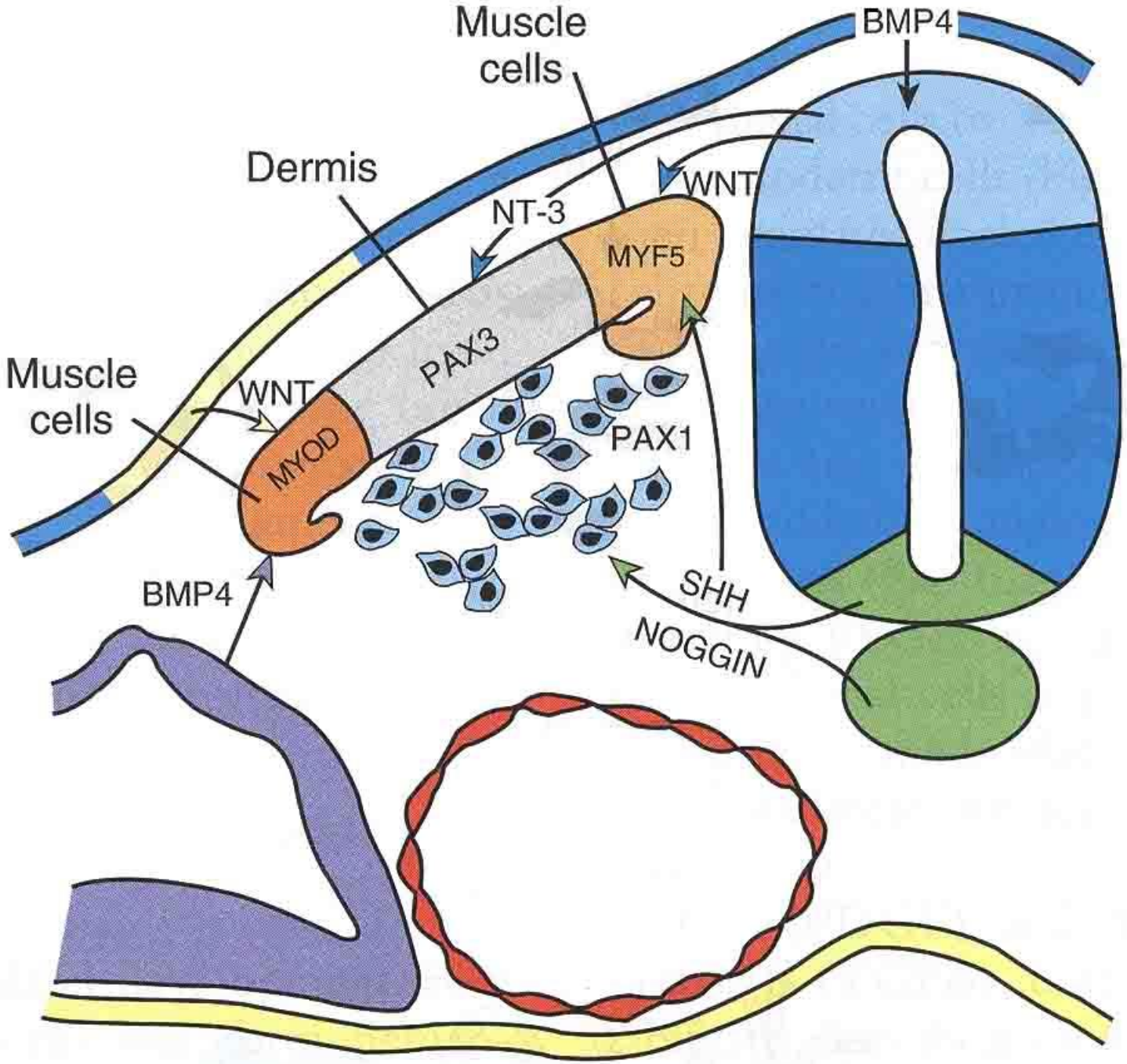
Somity



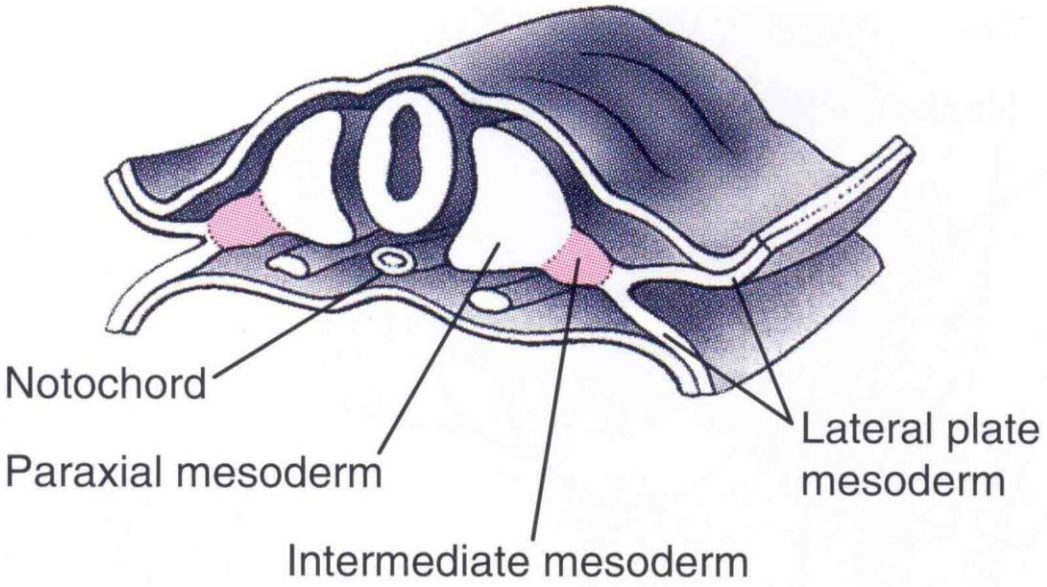


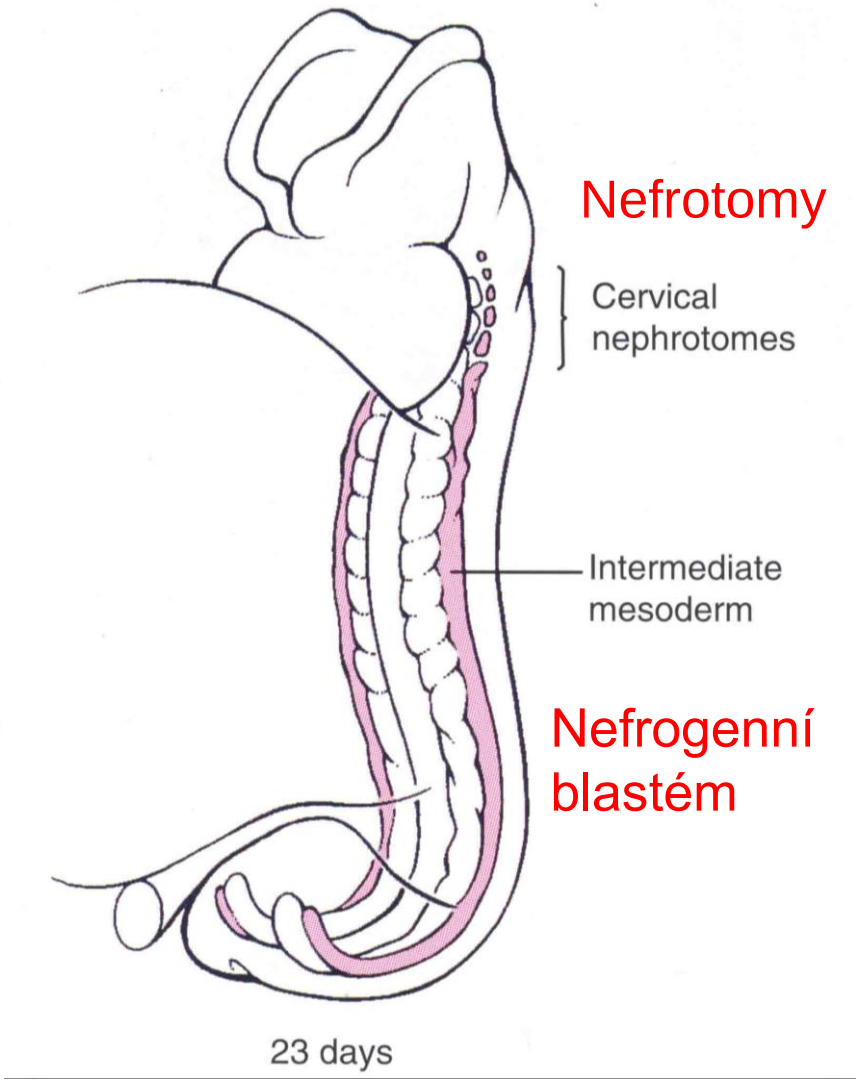

Muscle cells
BMP4
Dermis
WNT
NT-3
MYF5
PAX3
Muscle cells
WNT
MYOD
PAX1
BMP4
SHH
NOGGIN

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

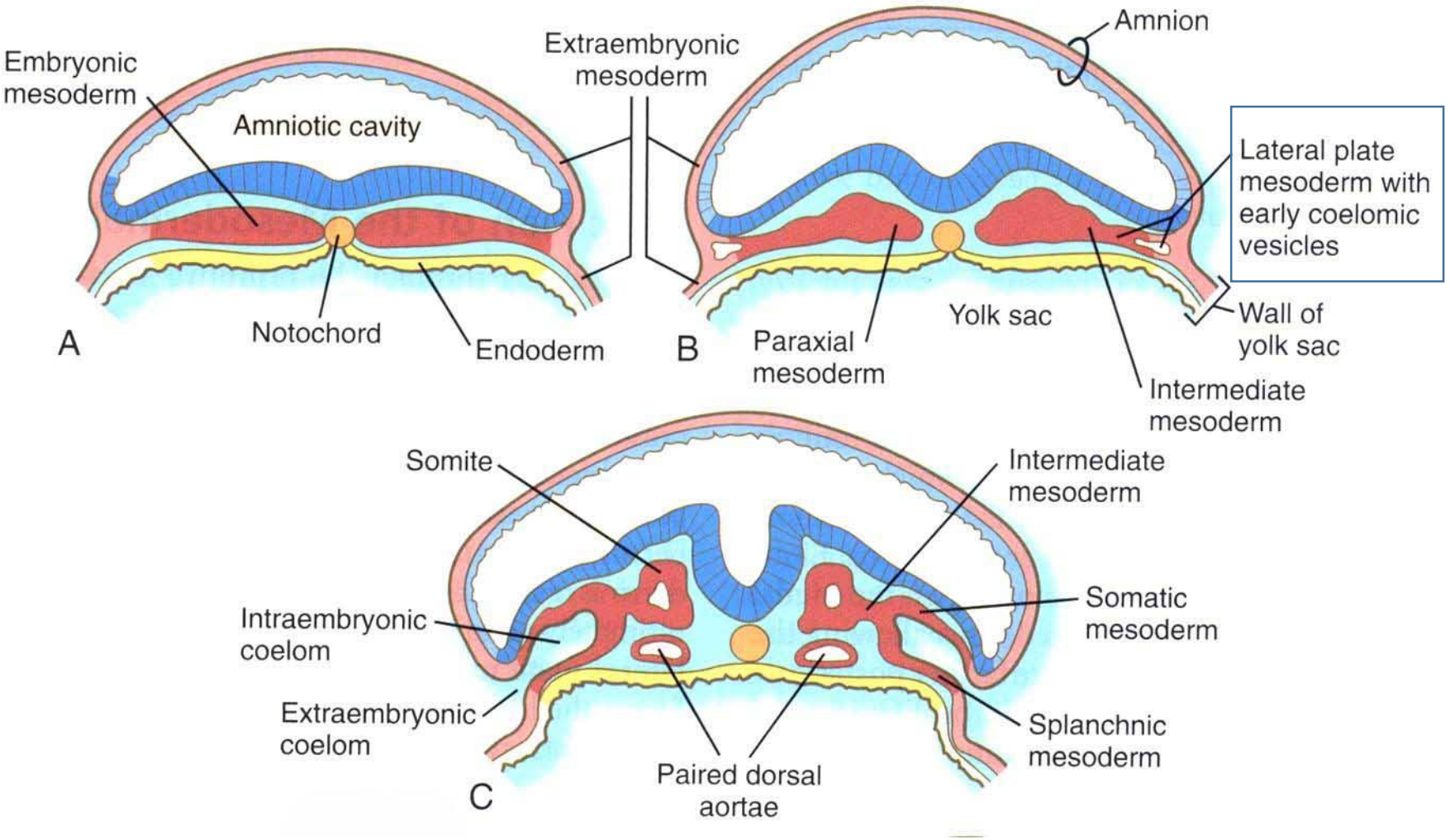

Muscle cells
BMP4
Dermis
WNT
NT-3
MYF5
PAX3
Muscle cells
WNT
MYOD
PAX1
BMP4
SHH
NOGGIN

Intermediární mesoderm



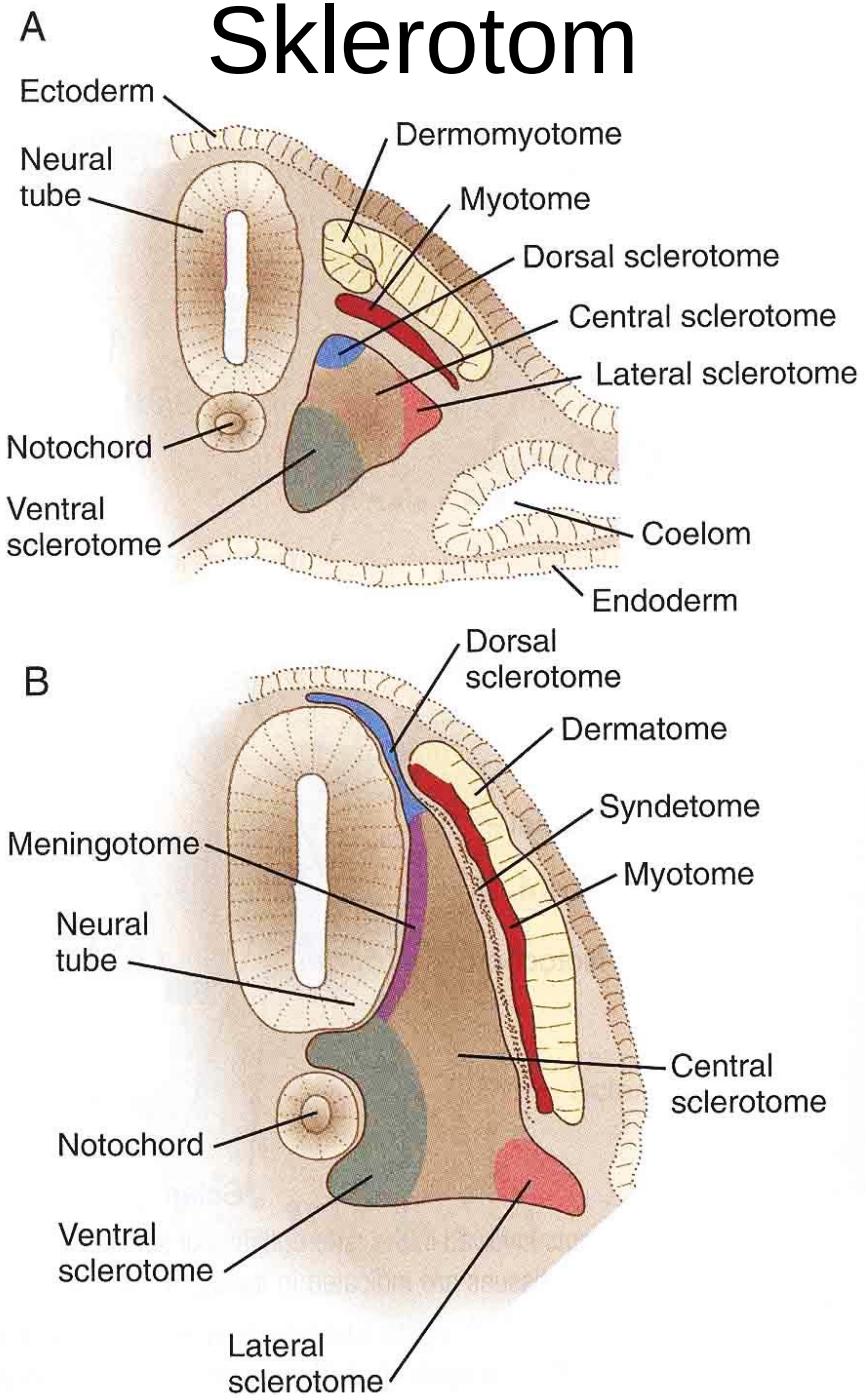


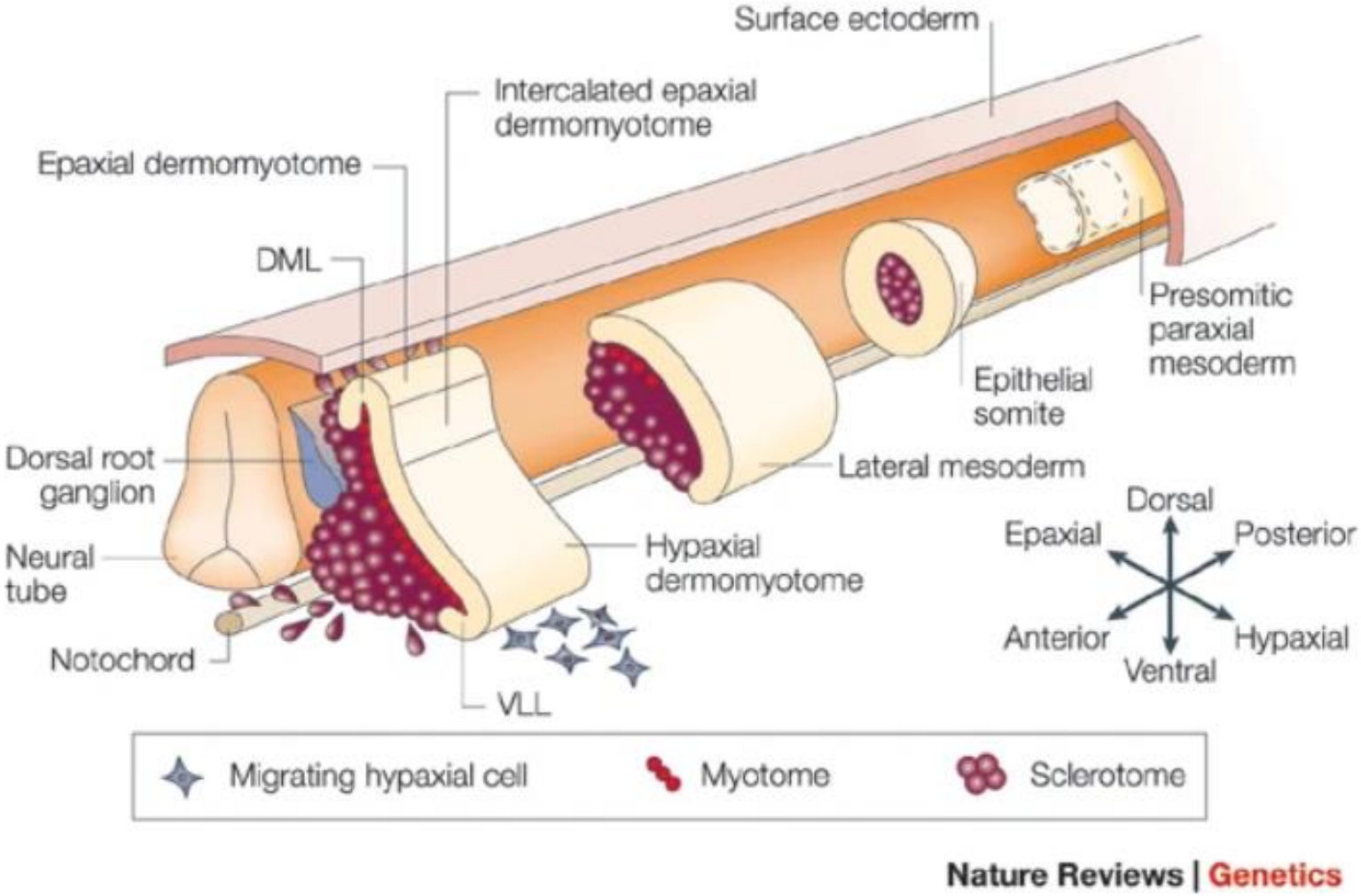
Laterální mesoderm (laterální ploténka)



VÝVOJ KOSTERNÍHO SYSTÉMU

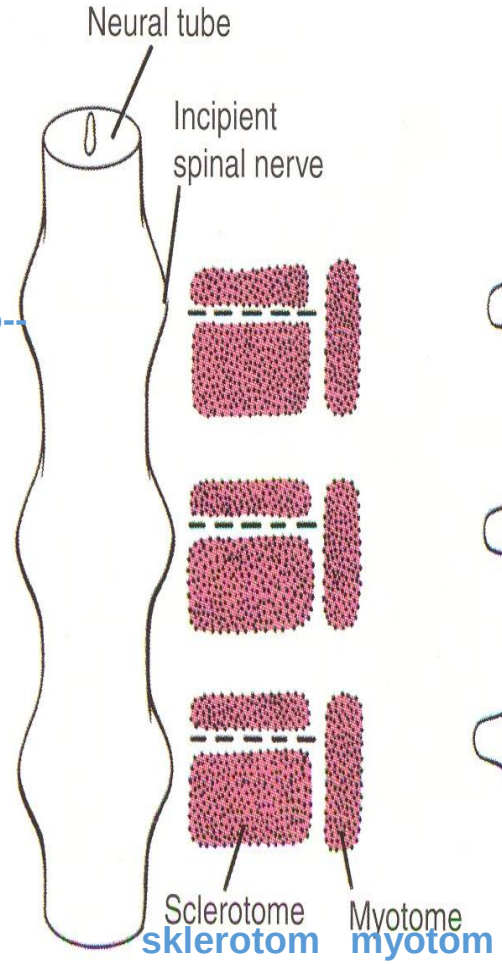
Sklerotom


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

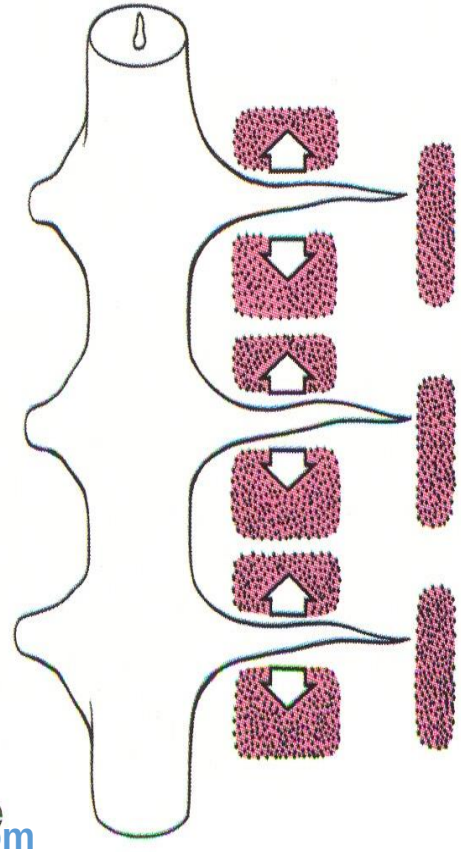
neurální trubice má indukční vliv na vývoj sklerotomu



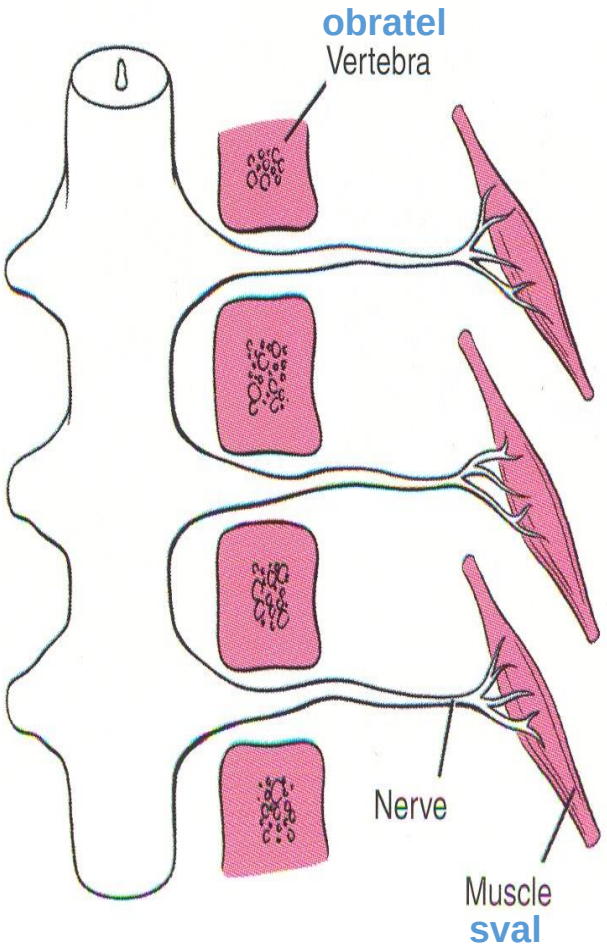
základ spinálního-- nervu

sklerotom

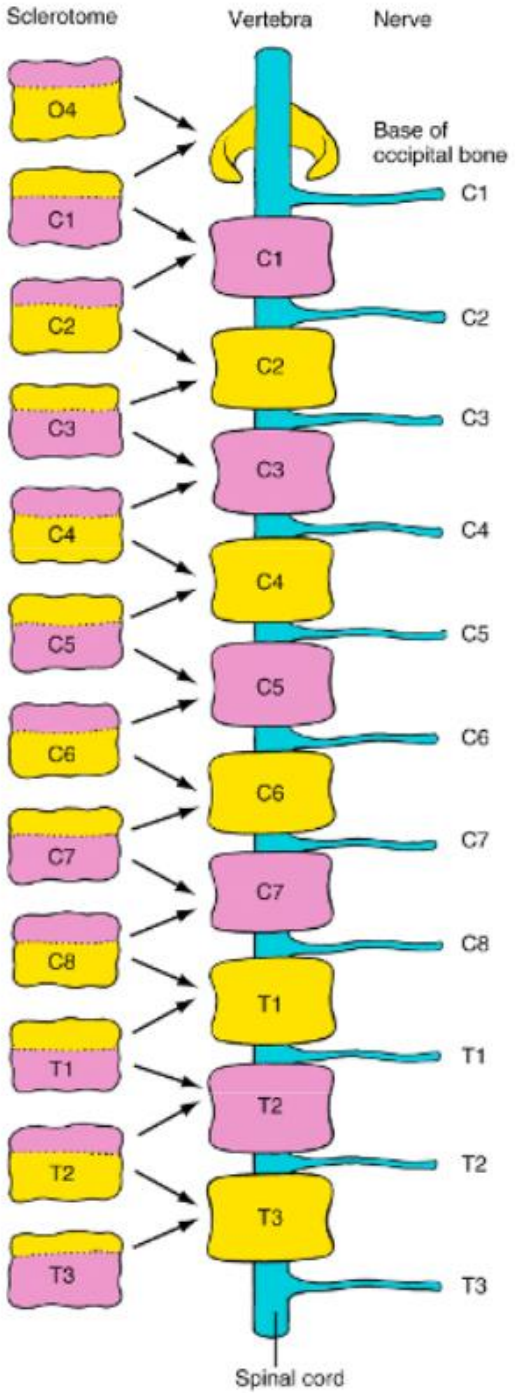
myotom



obratel



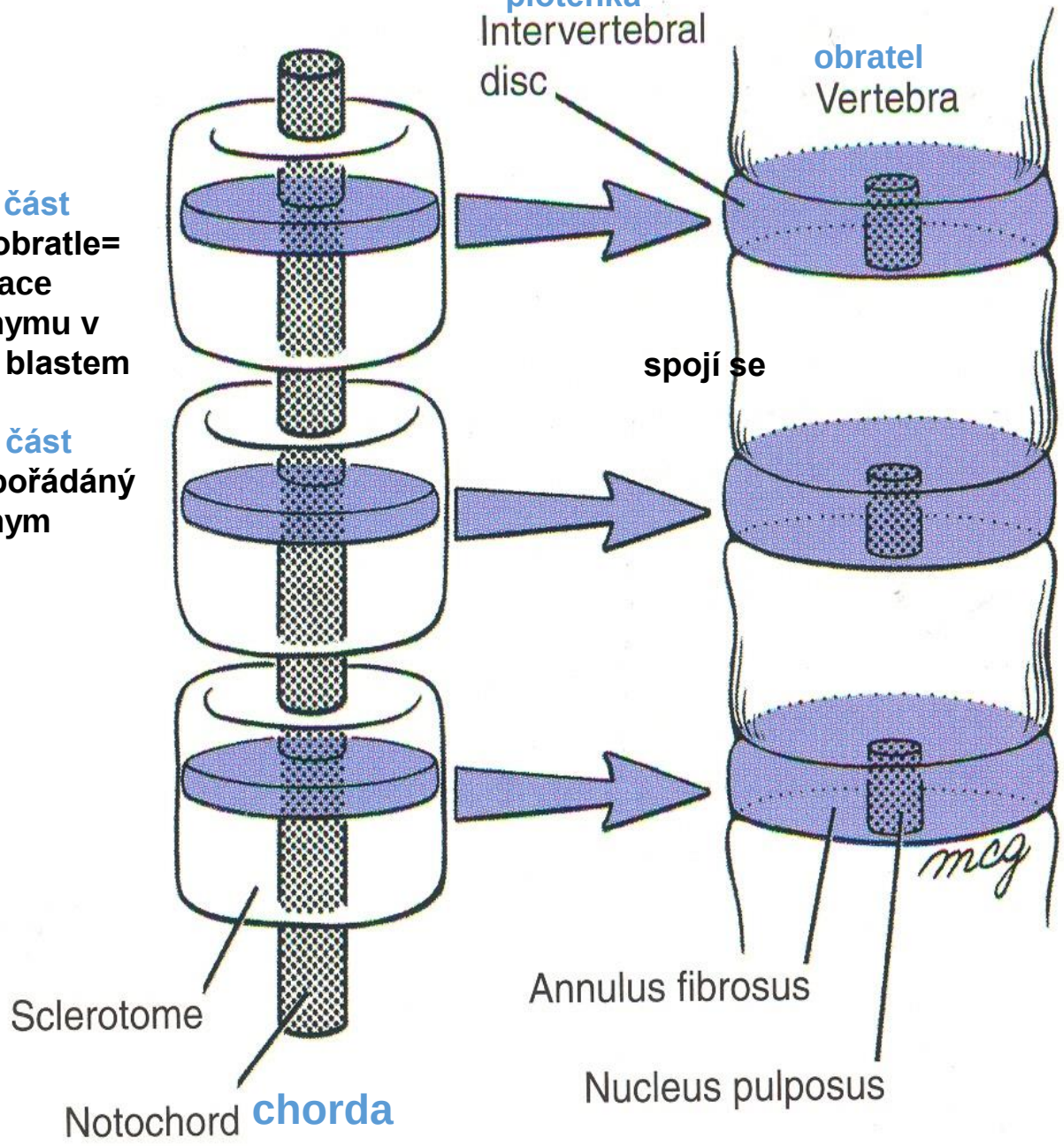
sval

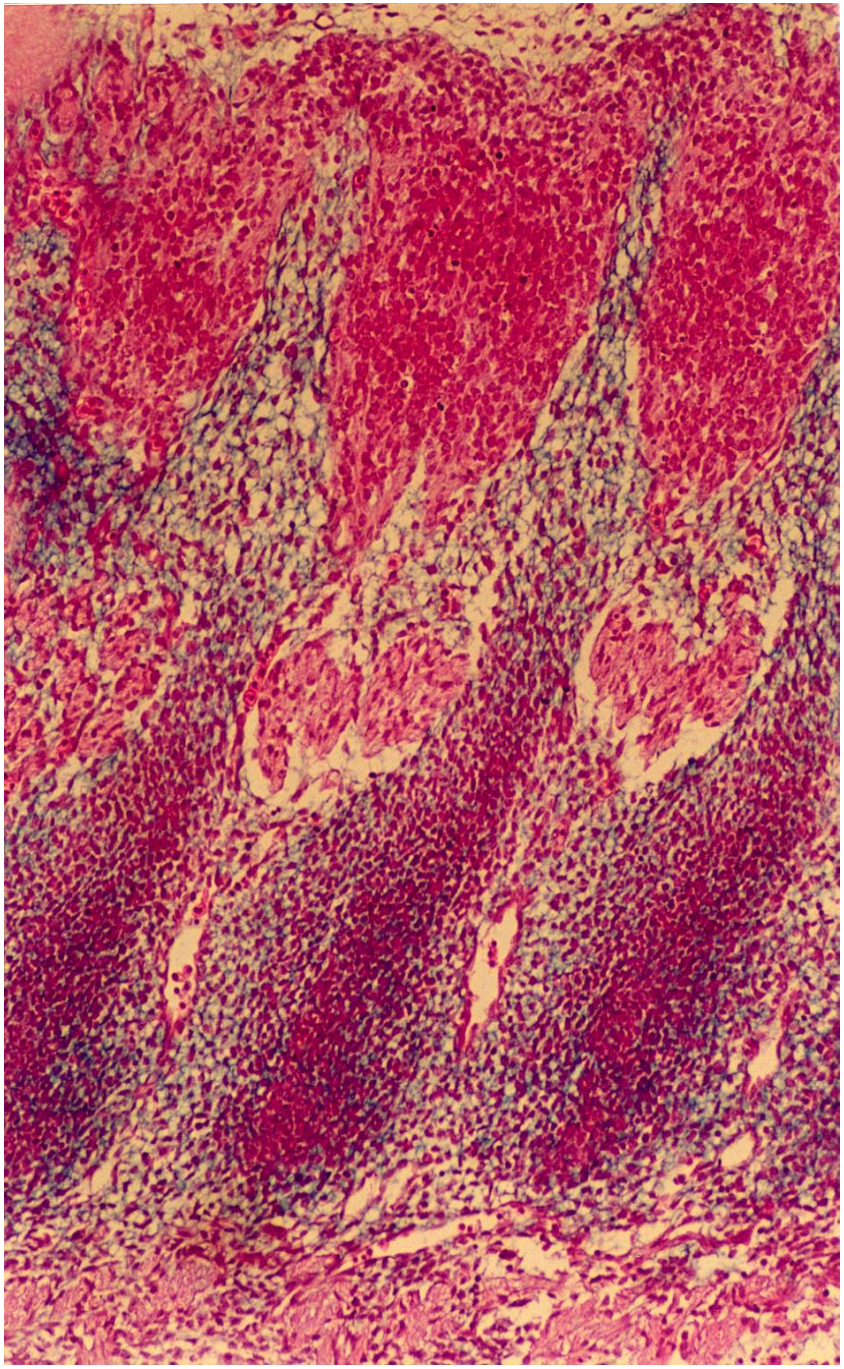

Sclerotome
Vertebra
Nerve
O4
C1
C2
C3
C4
C5
C6
C7
C8
T1
T2
T3
Base of occipital bone
C1
C2
C3
C4
C5
C6
C7
C8
T1
T2
T3
Spinal cord

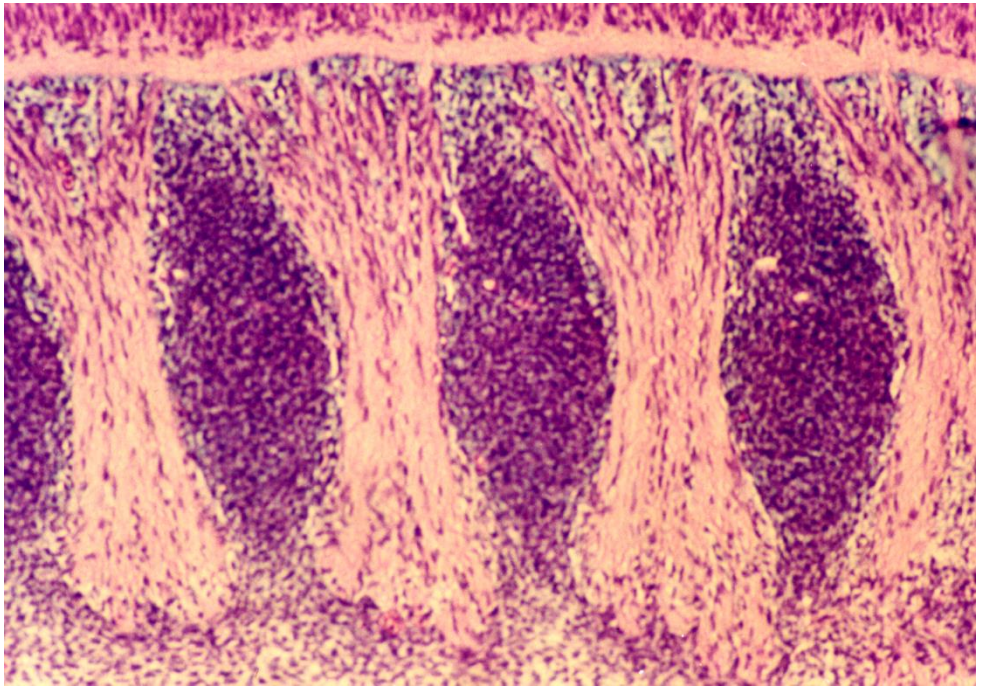
meziobratlová ploténka

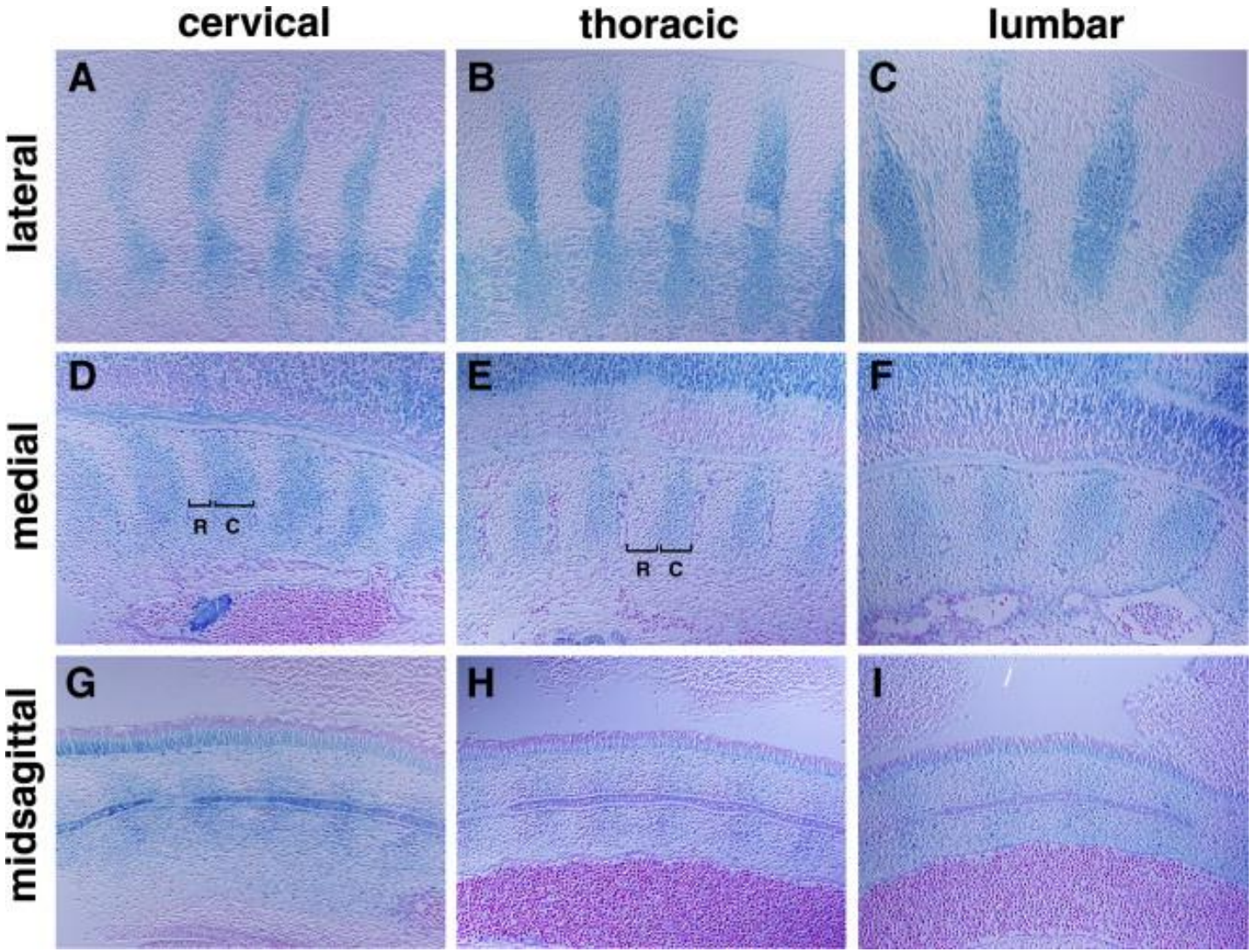
kaudální část základu obratle= kondensace mesenchymu v buněčný blastem

kraniální část řídce uspořádaný mesenchym



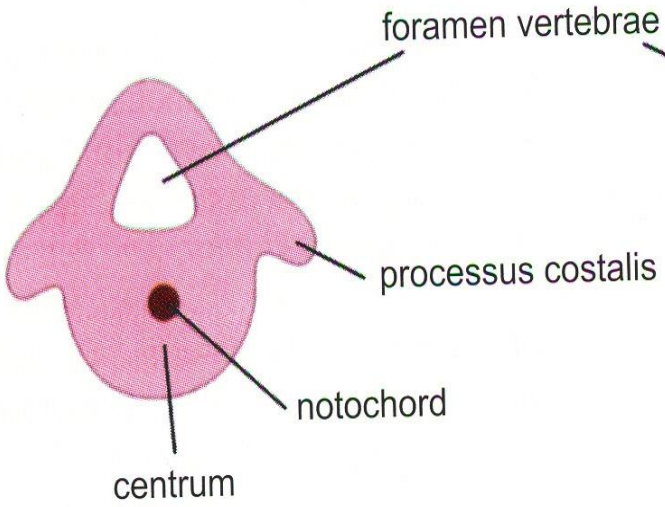


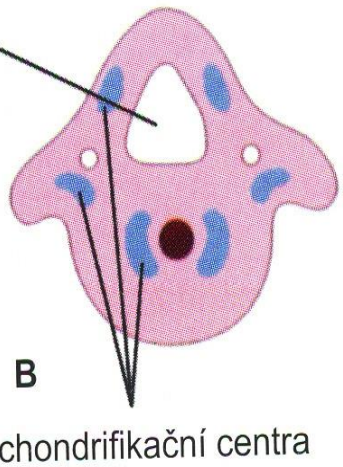


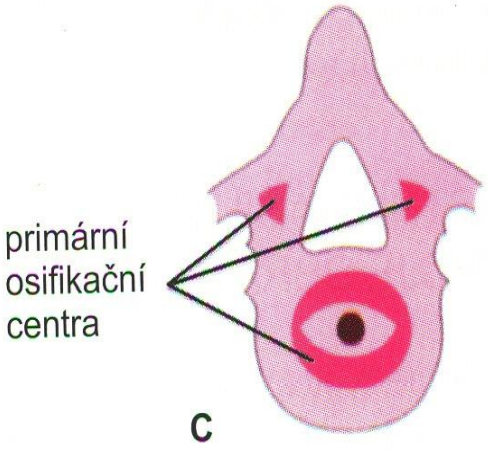


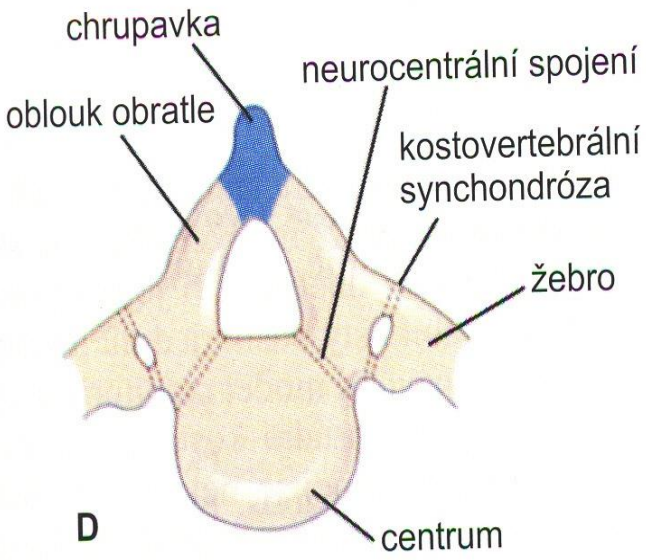
…. rostral (R) and caudal (C) domains within a sclerotome. Anterior to the left, dorsal to the top.

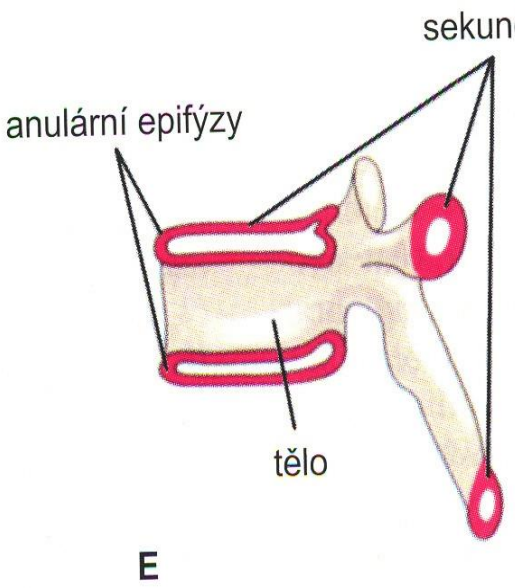
Yu Takahashi, Yukuto Yasuhiko, Jun Takahashi, Shinji Takada, Randy L. Johnson, Yumiko Saga, Jun Kanno, Metameric pattern of intervertebral disc/vertebral body is generated independently of Mesp2/Ripply-mediated rostro-caudal patterning of somites in the mouse embryo, Developmental Biology, Volume 380,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

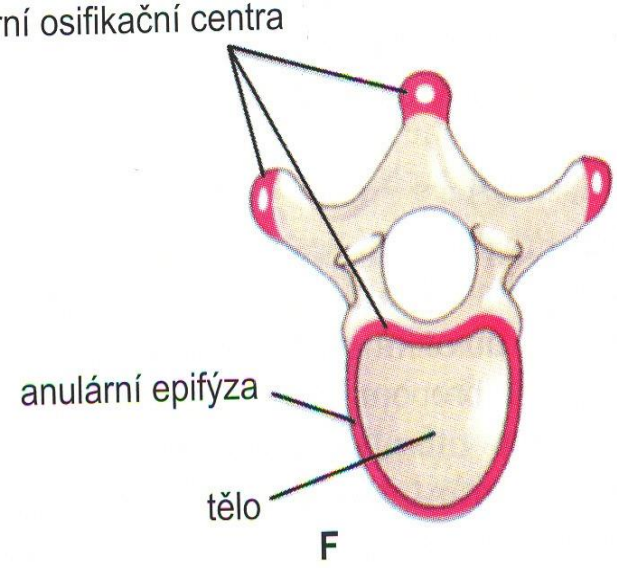

foramen vertebrae
processus costalis
notochord
centrum

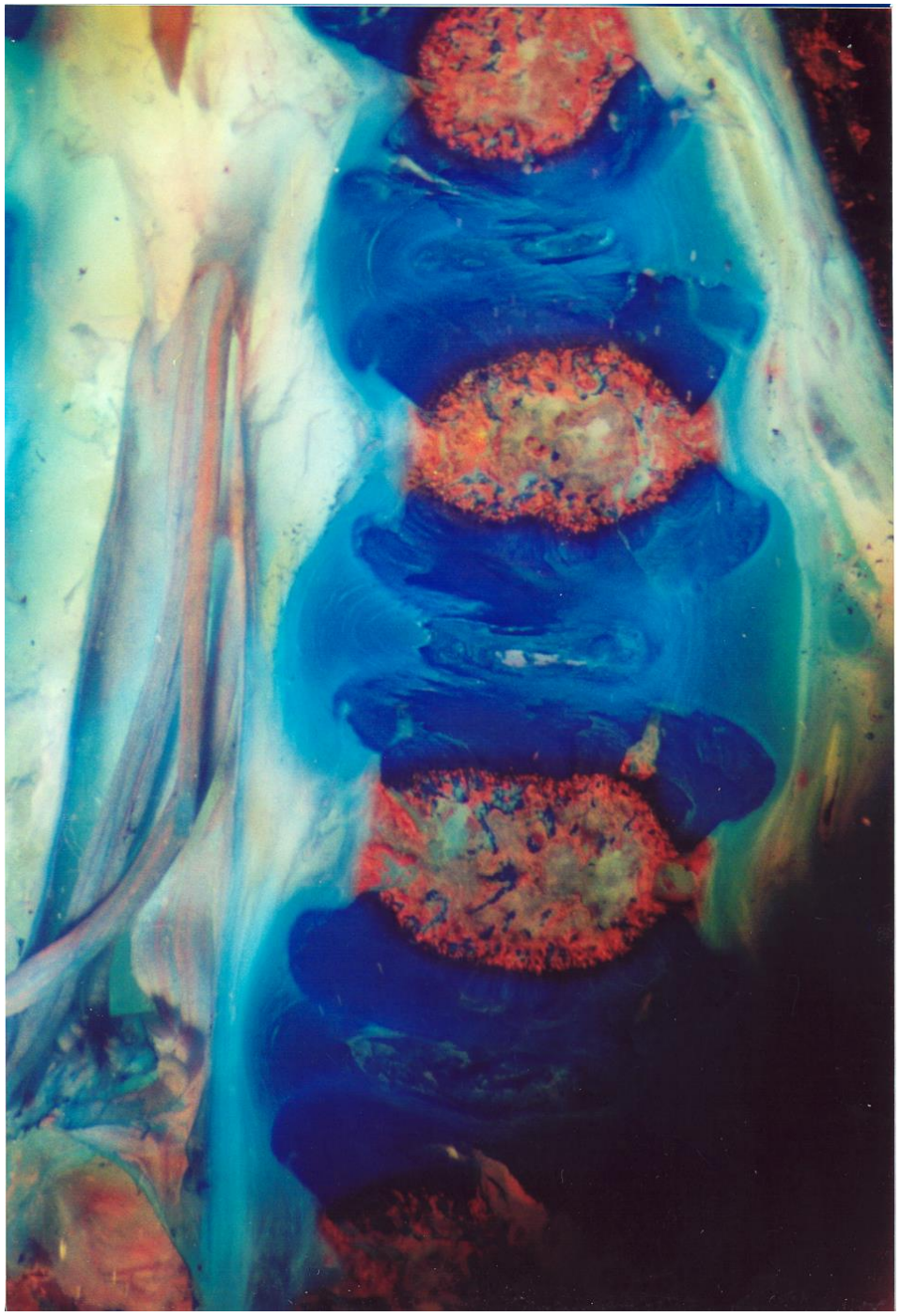

B
chondrifikační centra

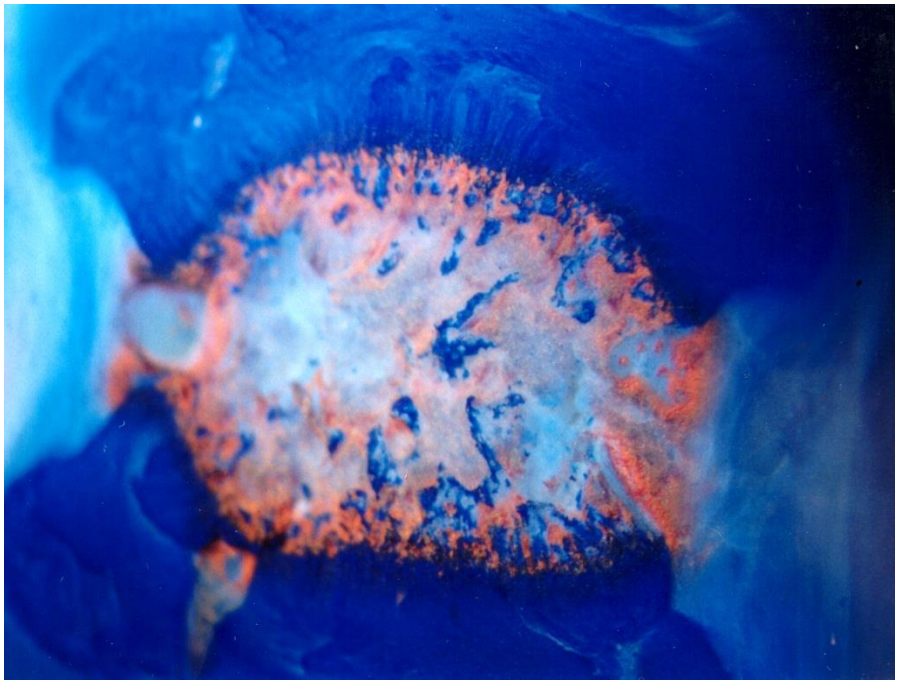

primární
osifikační
centra
C

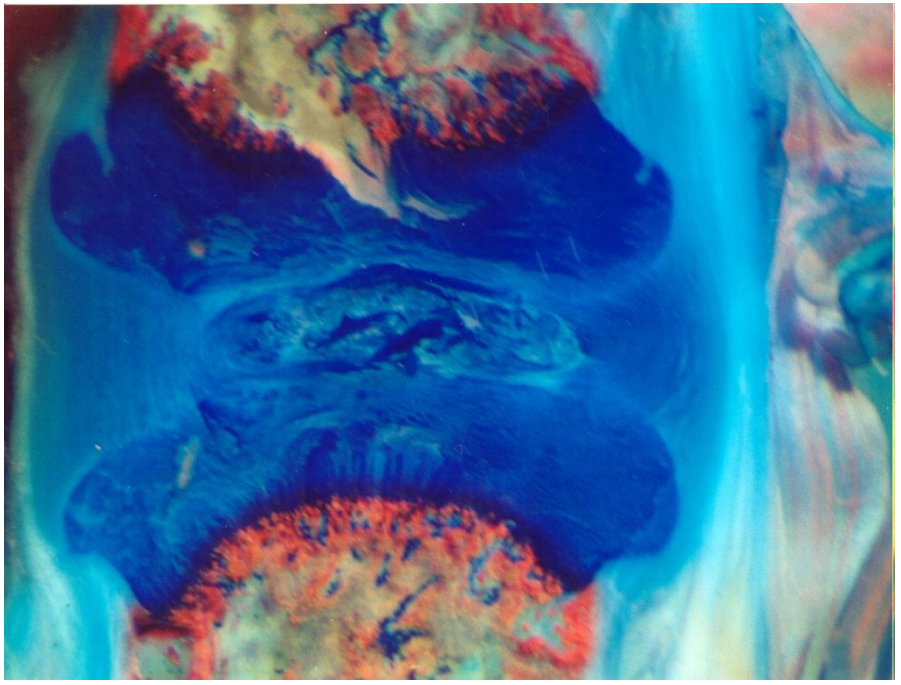

chrupavka
neurocentrální spojení
oblouk obratle
kostovertebrální
synchondróza
žebro
D
centrum


sekundární osifikační centra
anulární epifýzy
tělo
E


anulární epifýza
tělo
F

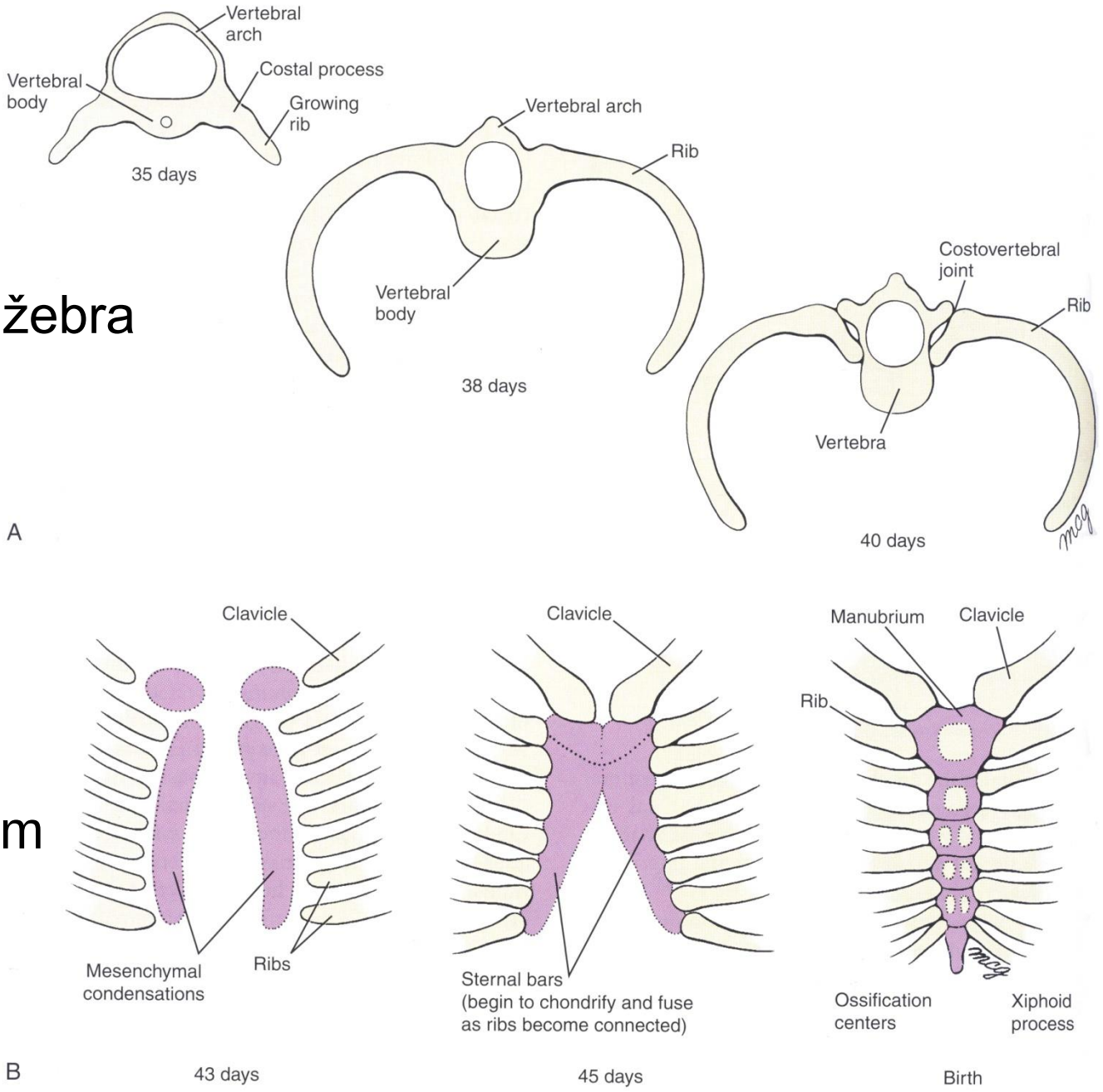




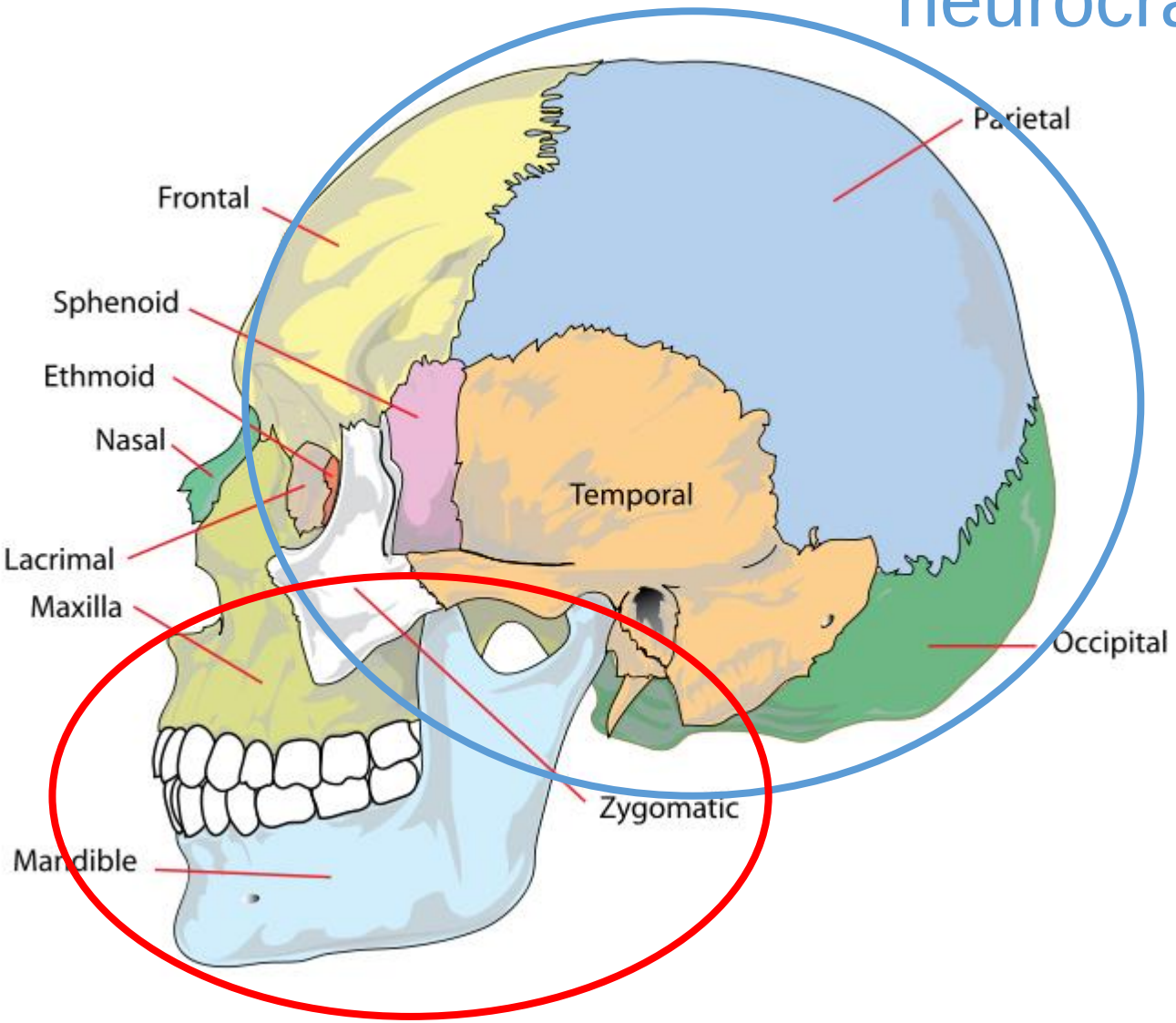


žebra

sternum

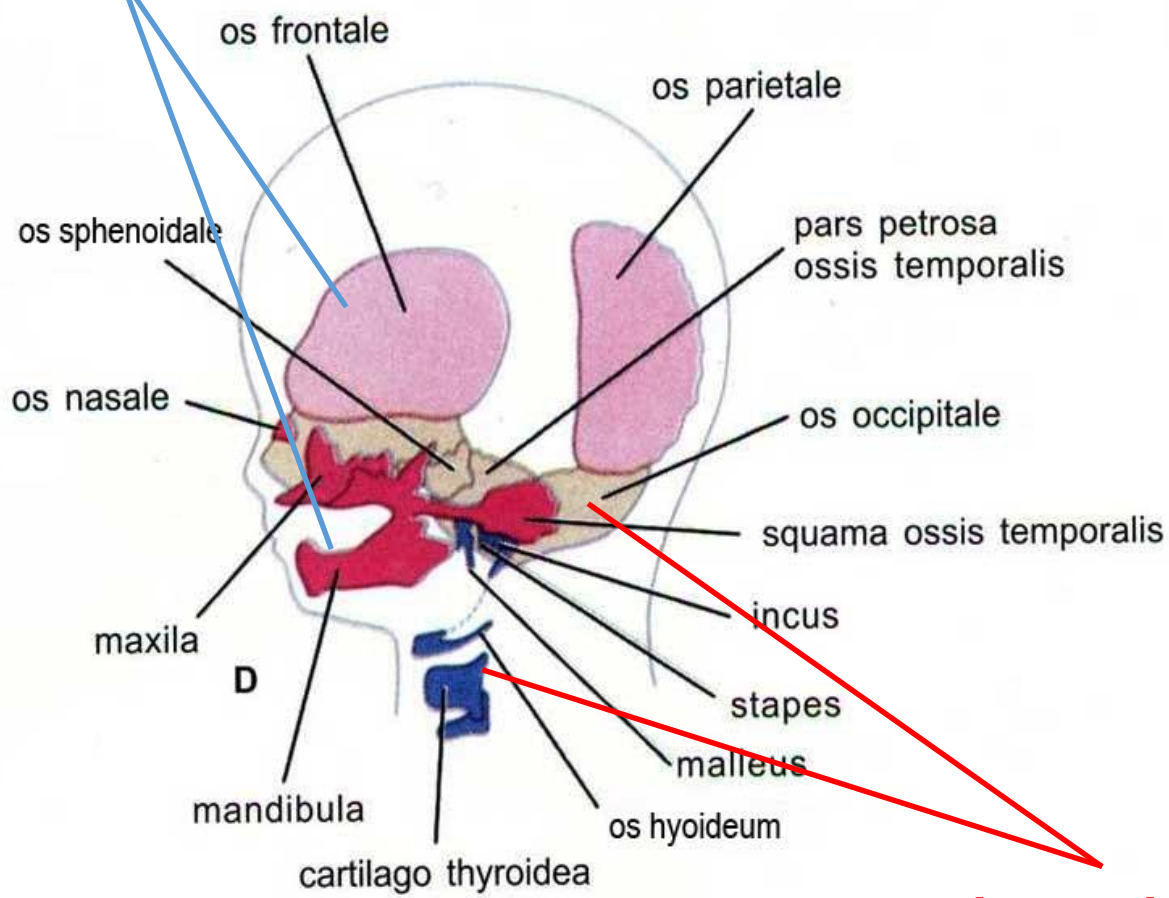


neurocranium

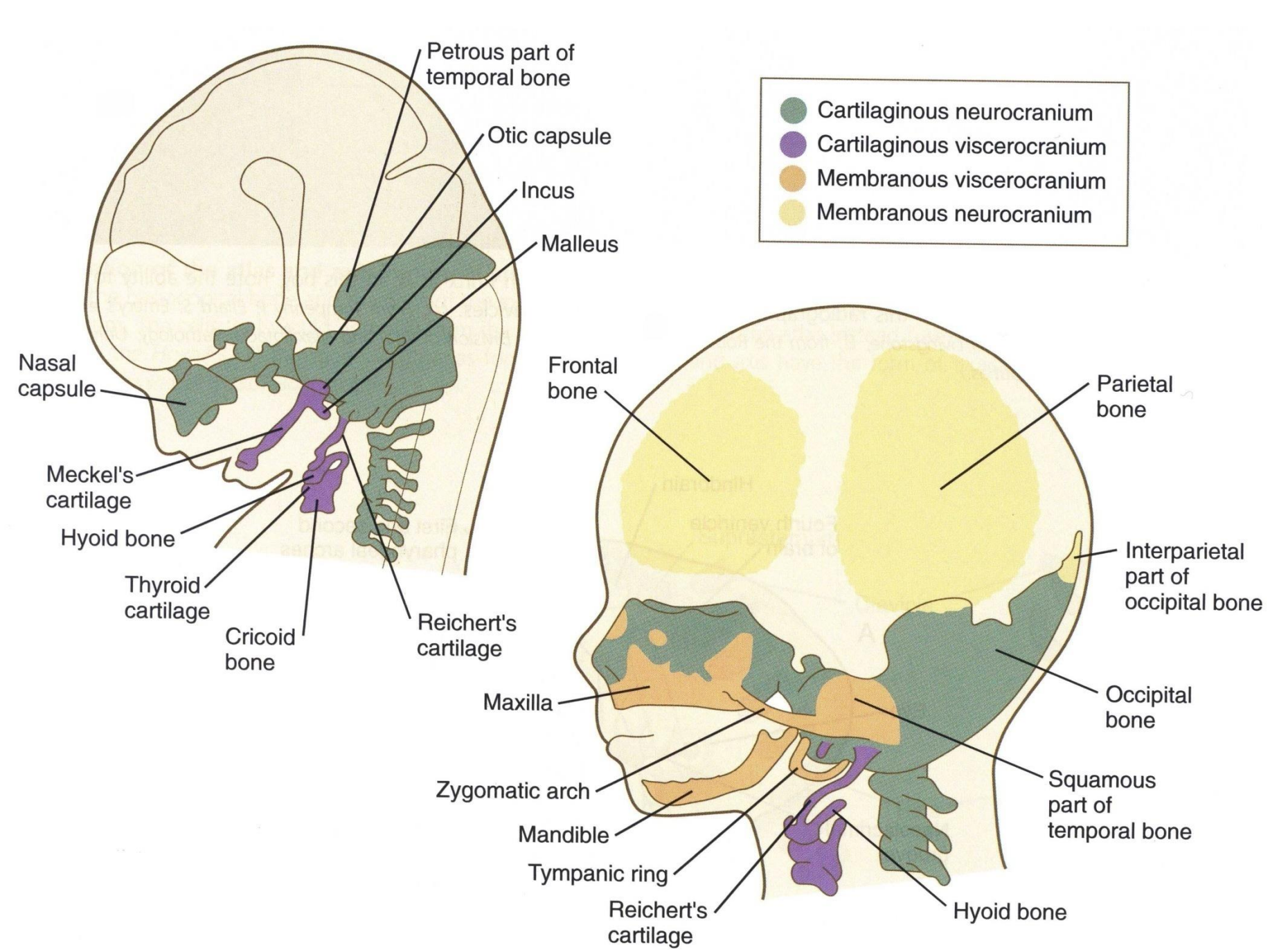


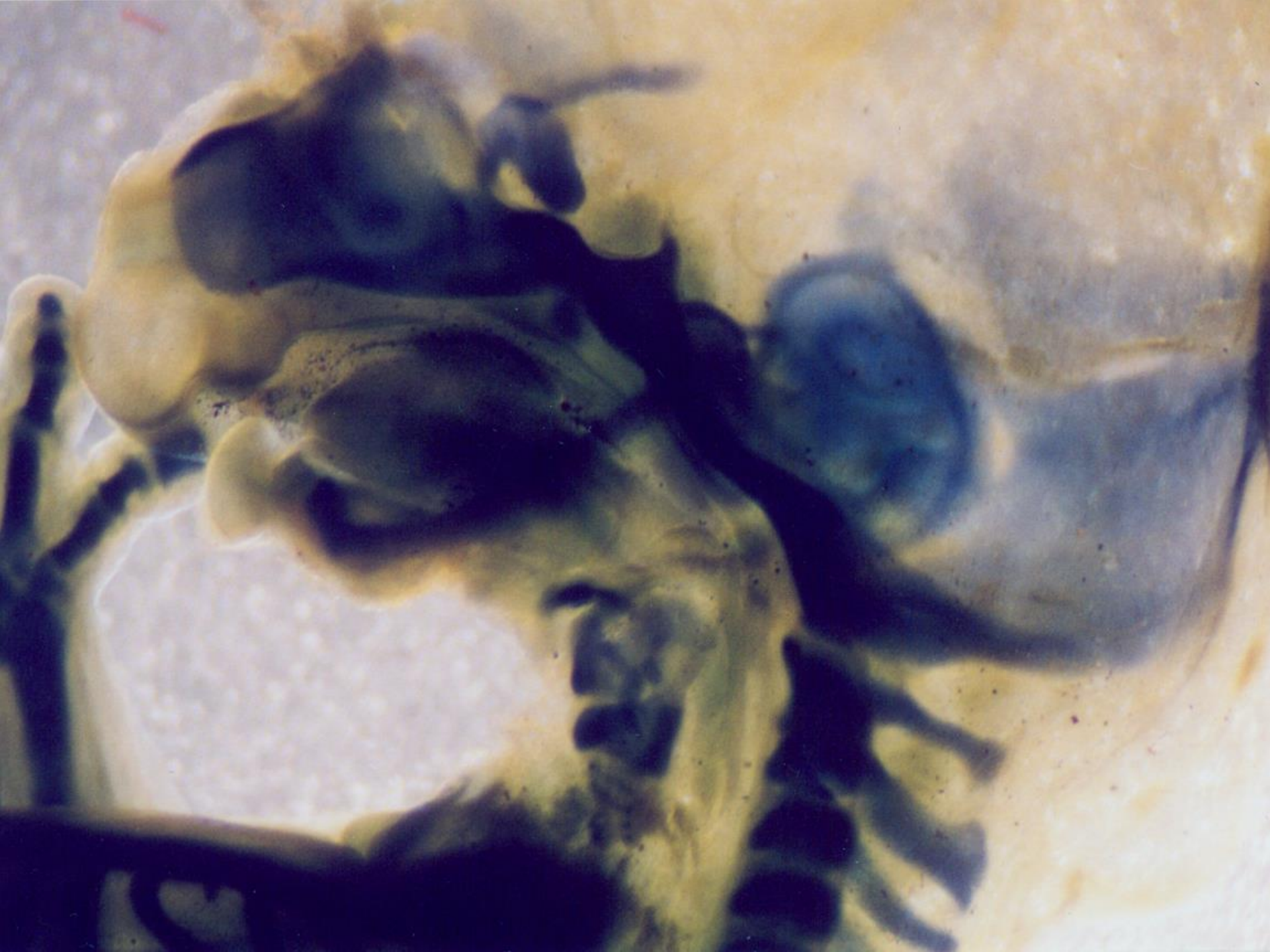
splanchnocranium (viscerocranium)

desmocranium



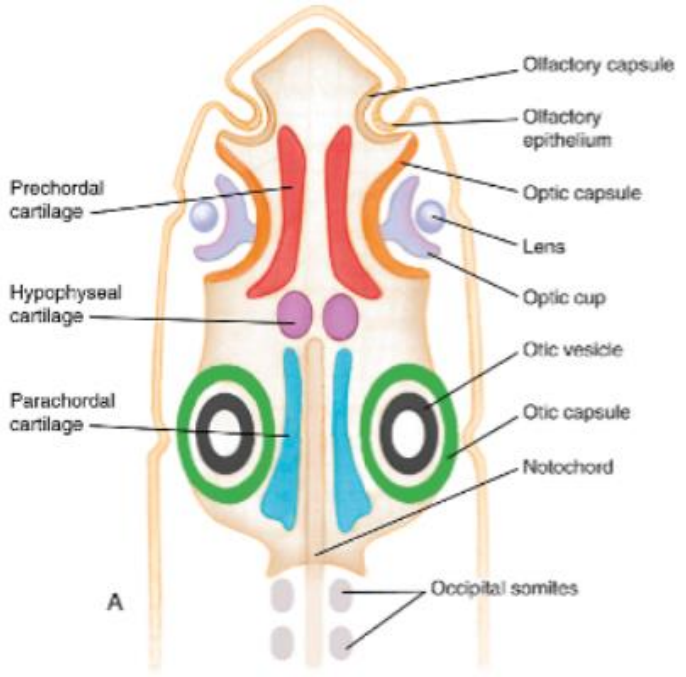
chondrocranium

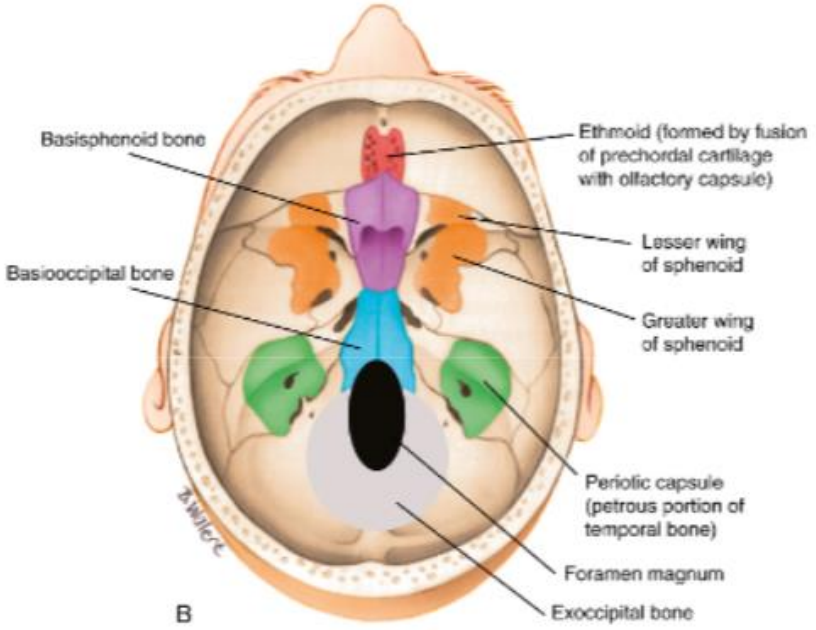

Petrous part of temporal bone
Otic capsule
Incus
Malleus
Nasal capsule
Meckel's cartilage
Hyoid bone
Thyroid cartilage
Cricoid bone
Reichert's cartilage
Cartilaginous neurocranium
Cartilaginous viscerocranium
Membranous viscerocranium
Membranous neurocranium
Frontal bone
Parietal bone
Interparietal part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



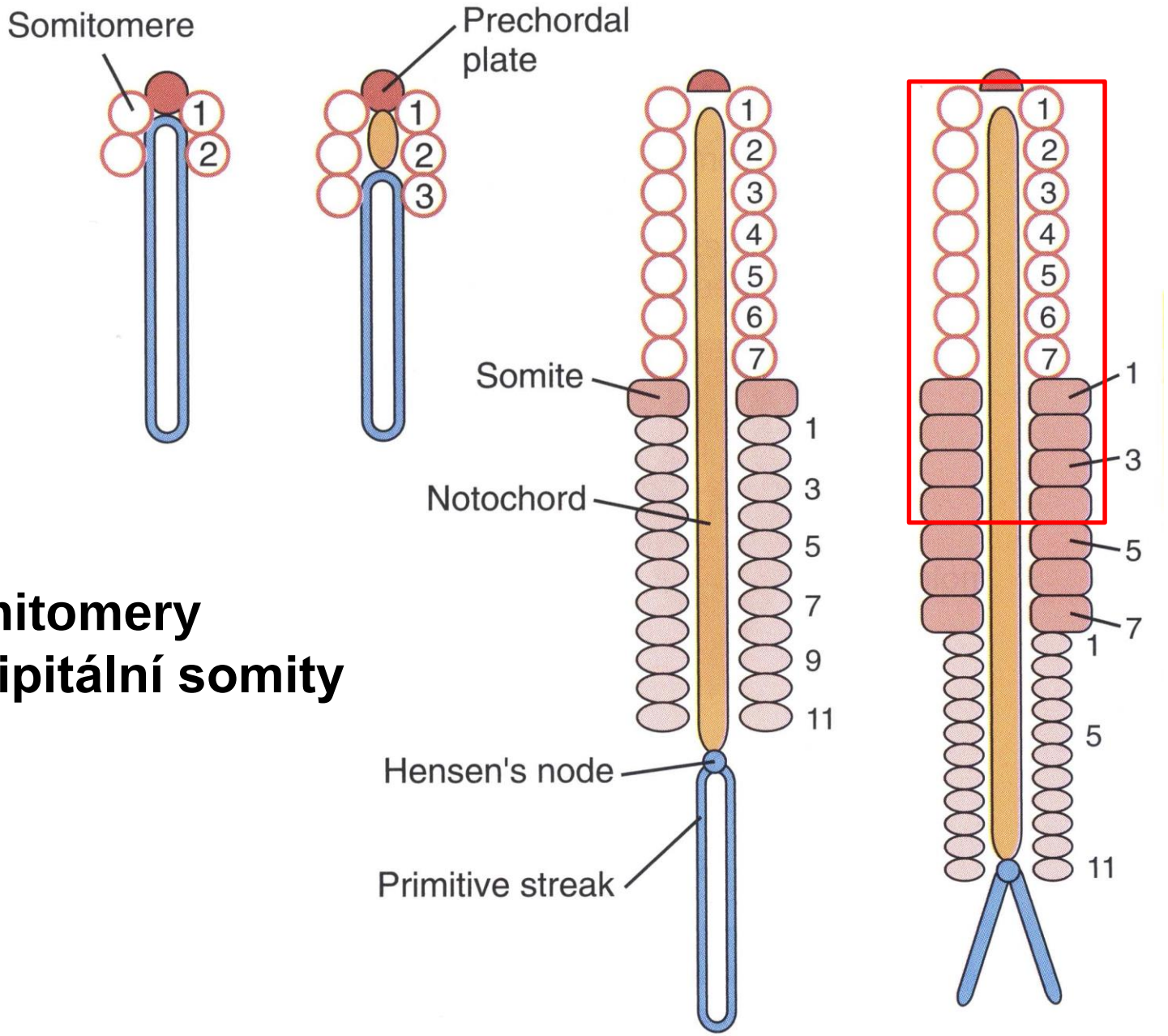
Chrupavčité neurocranium

- Capsula olfactoria
- Prechordální chrup.
- Capsula optica
- Hypofyseální chrup.
- Parachordální chrup.
- Capsula otica



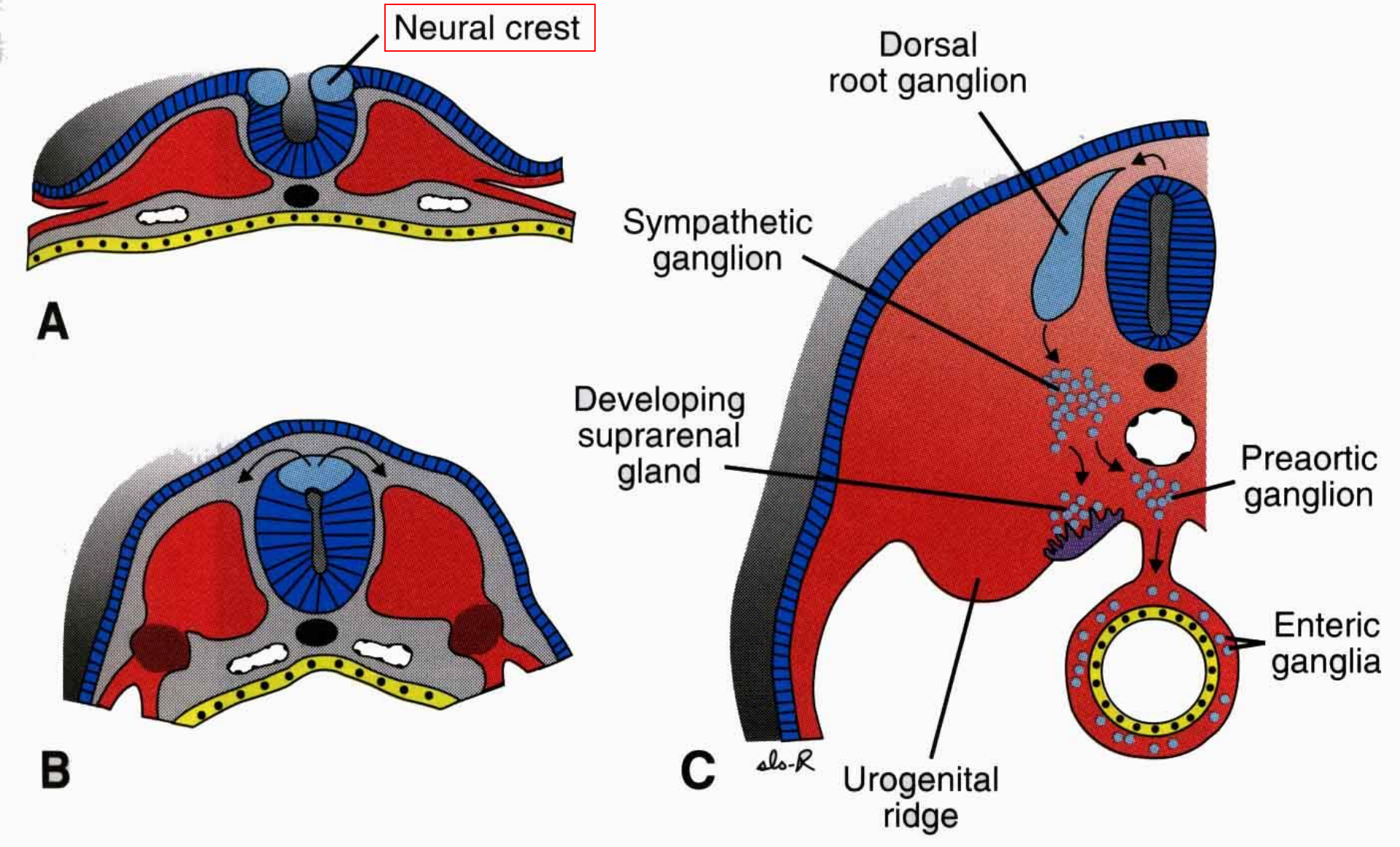


Zdroje mesenchymu:1/paraxiální mesoderm



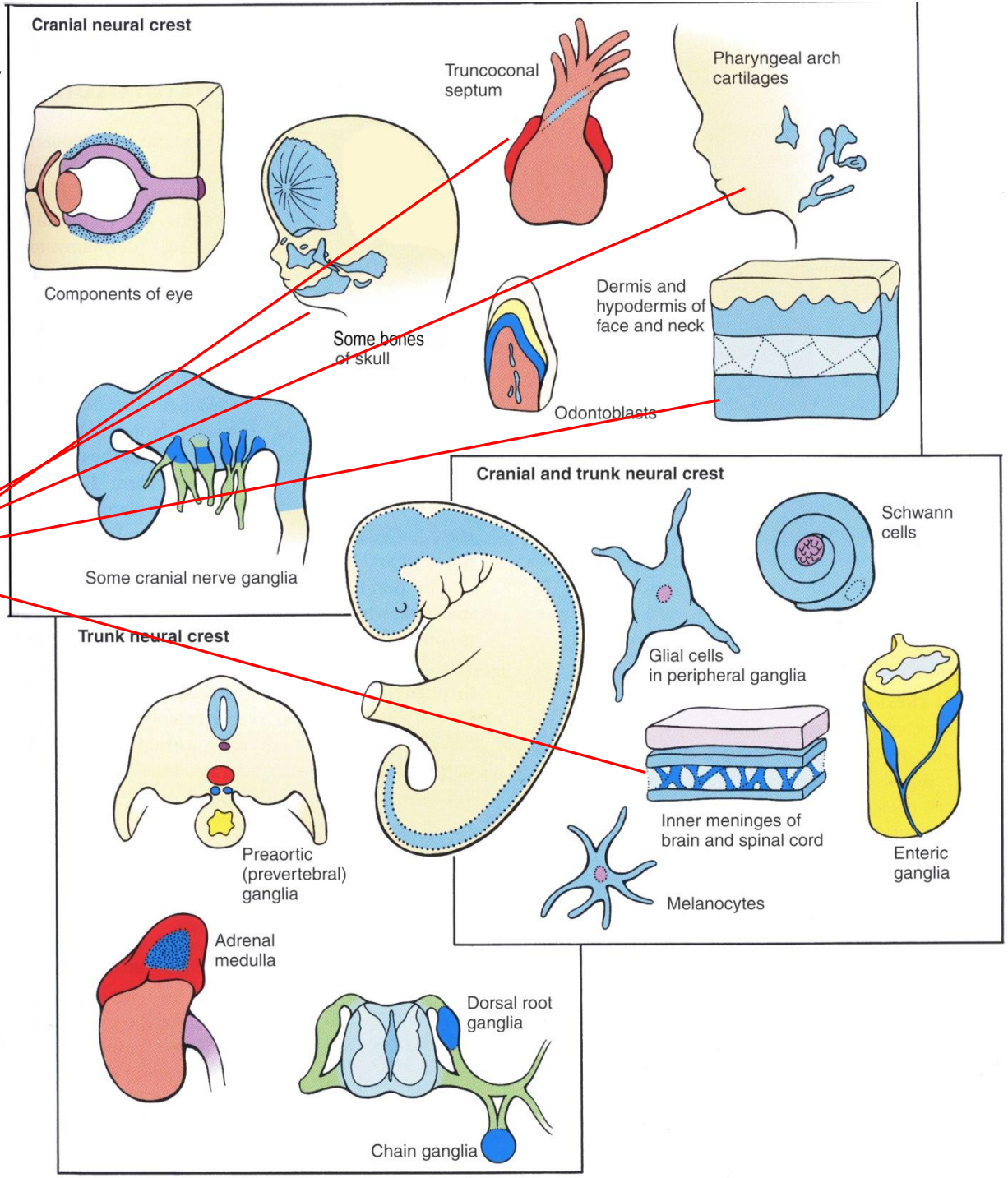
somitomery
okcipitální somity

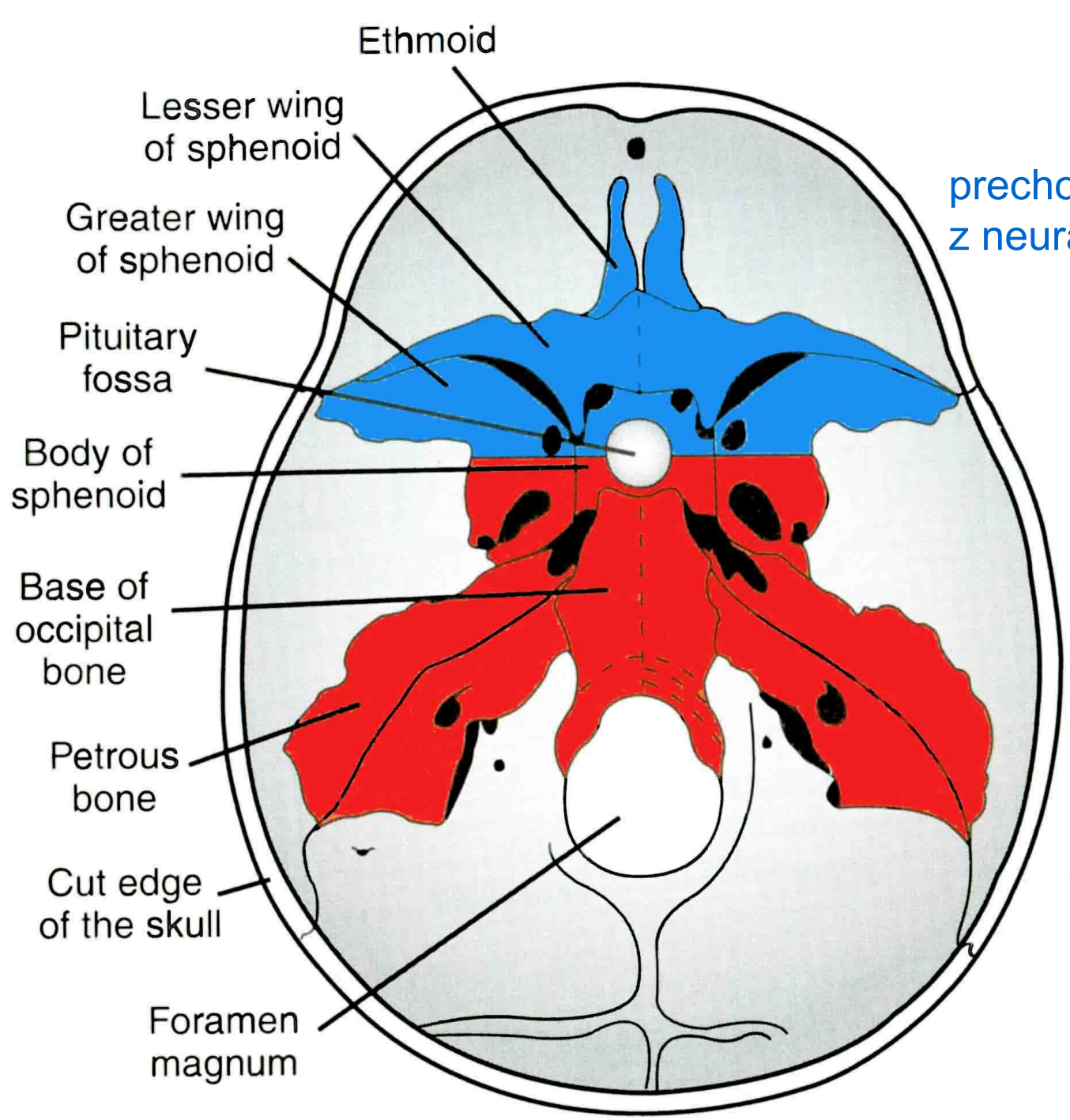
2/ neurální lišta



Deriváty neurální lišty

ektomesenchym



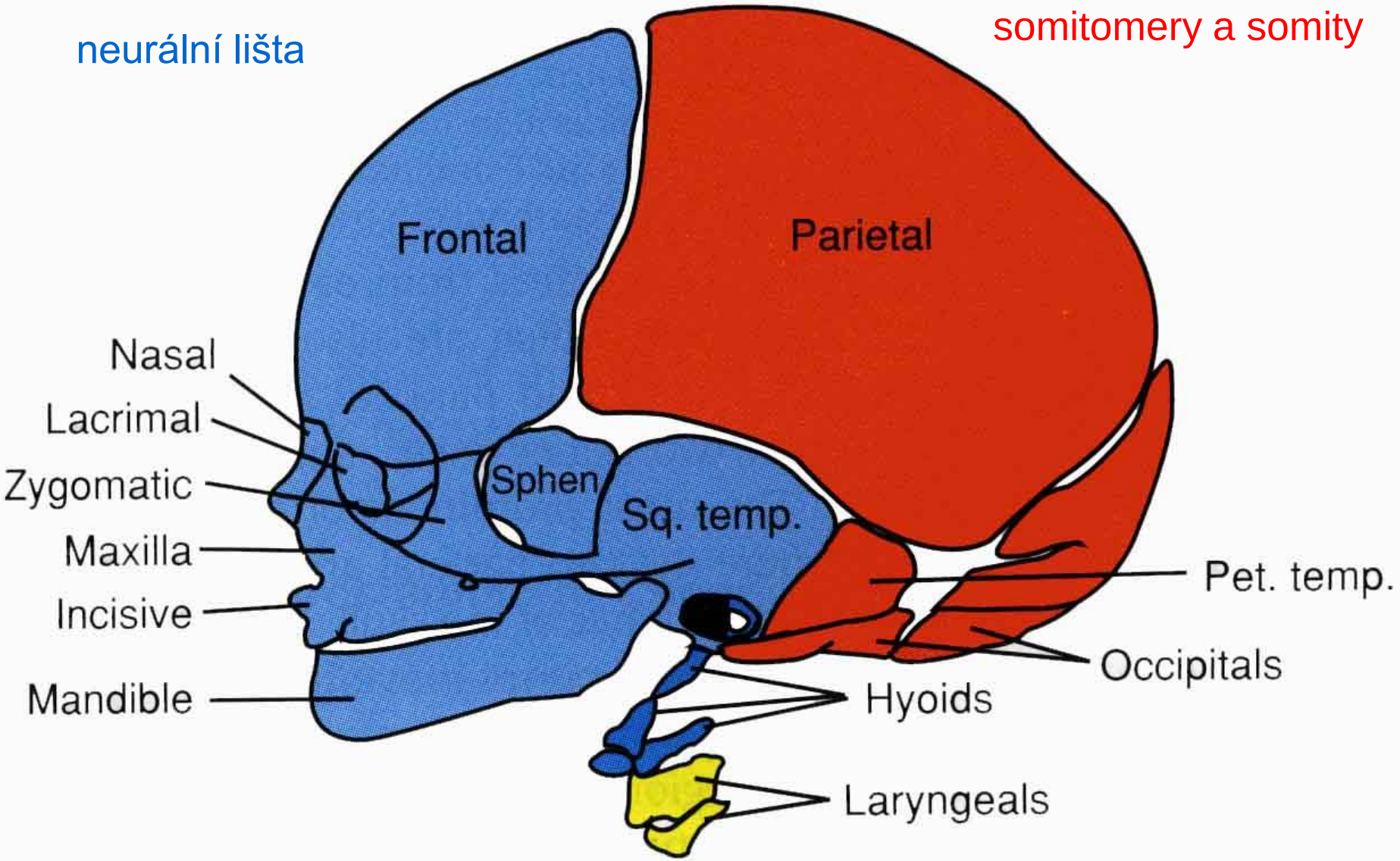


prechordální chondrokranium z neurální lišty

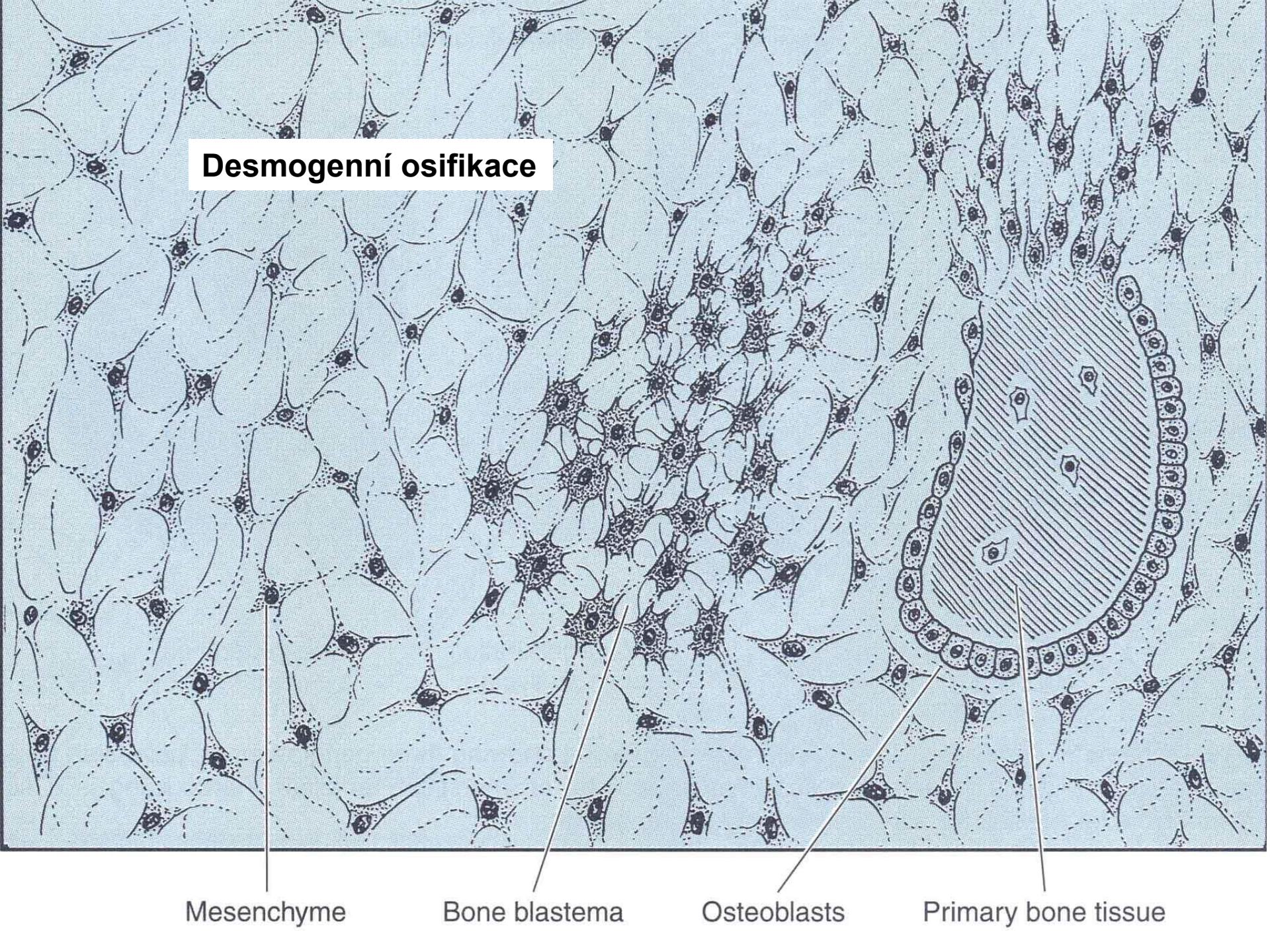
parachordální chondrokranium ze somitomer a somitů

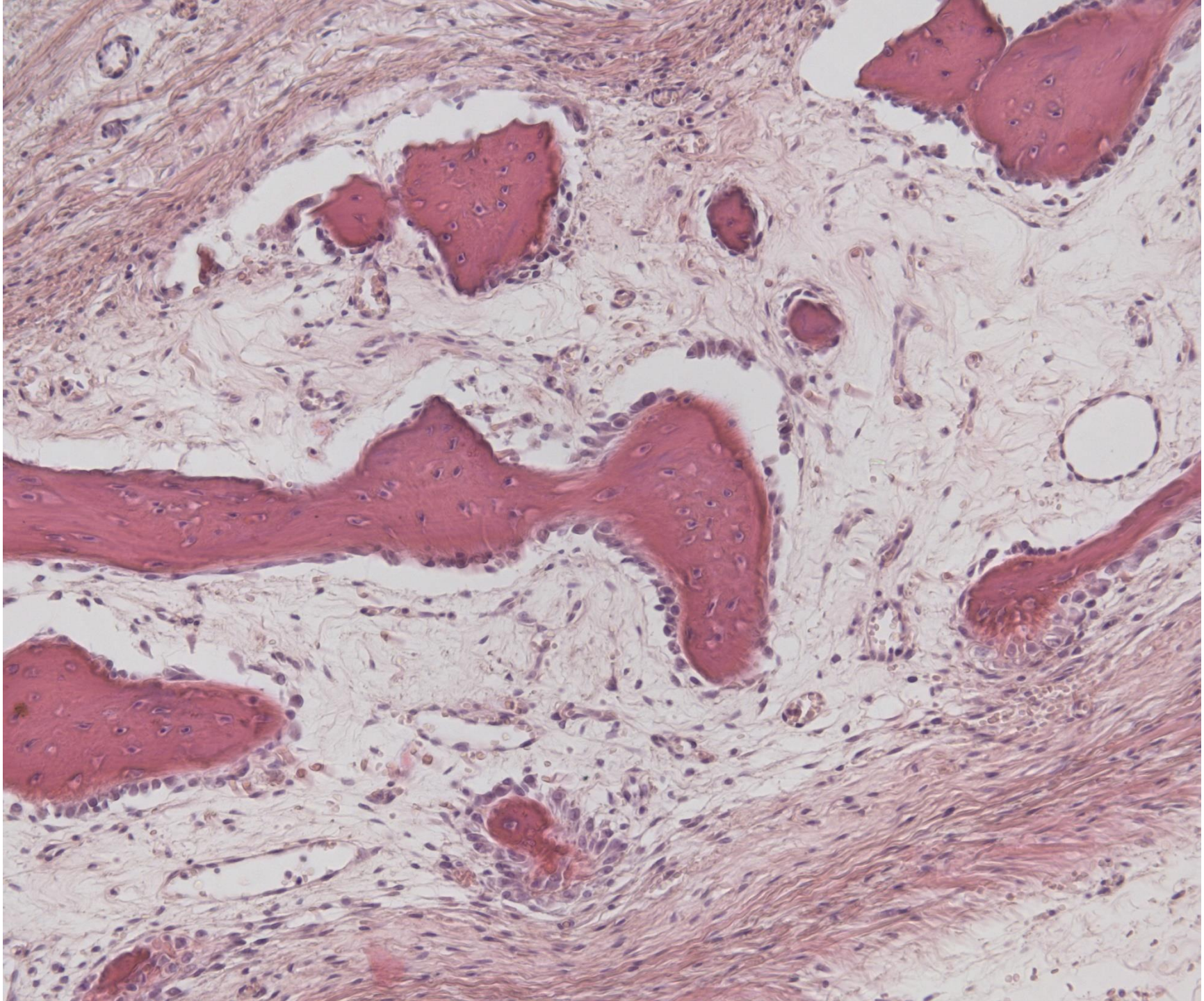
neurální lišta

somitomery a somity

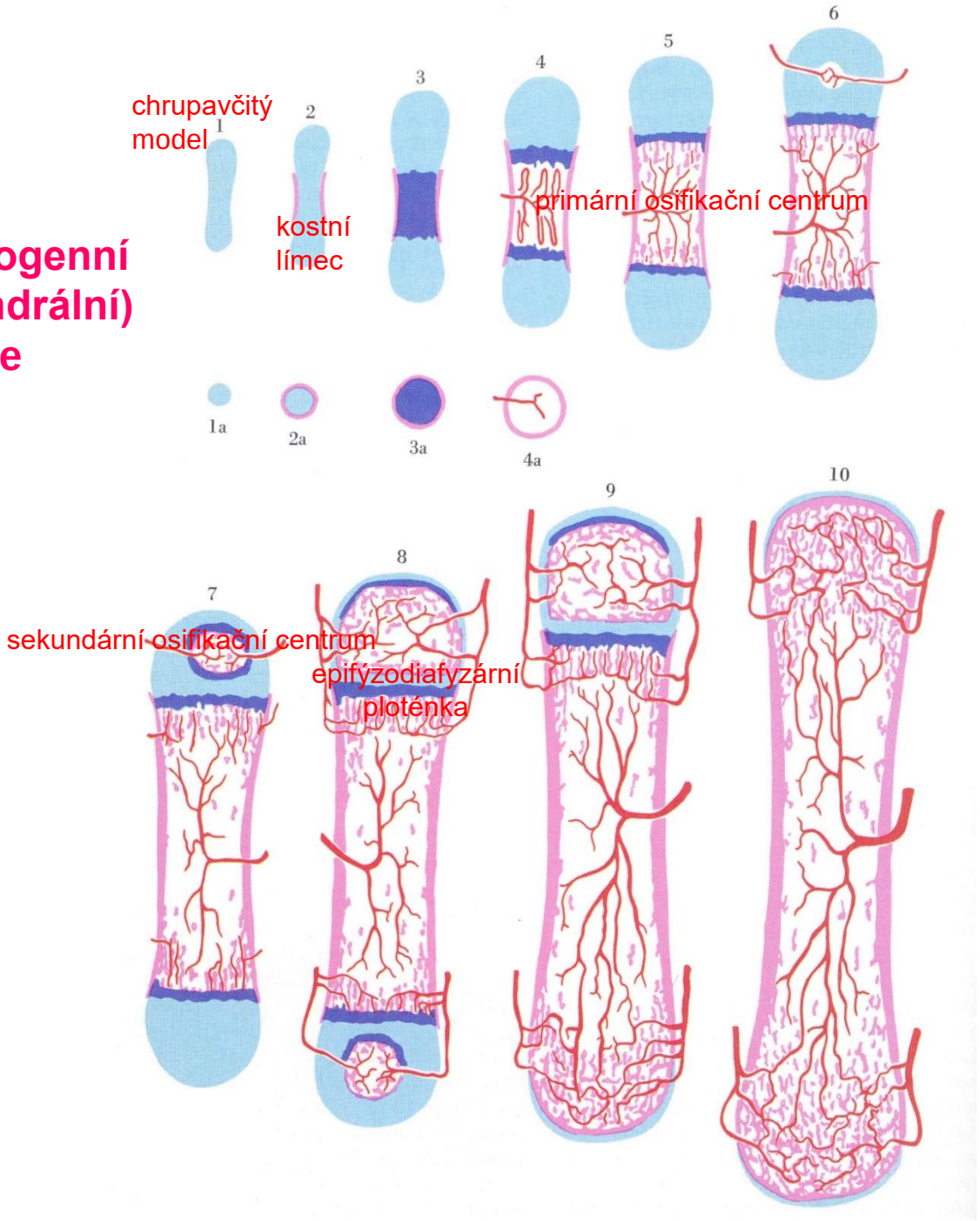


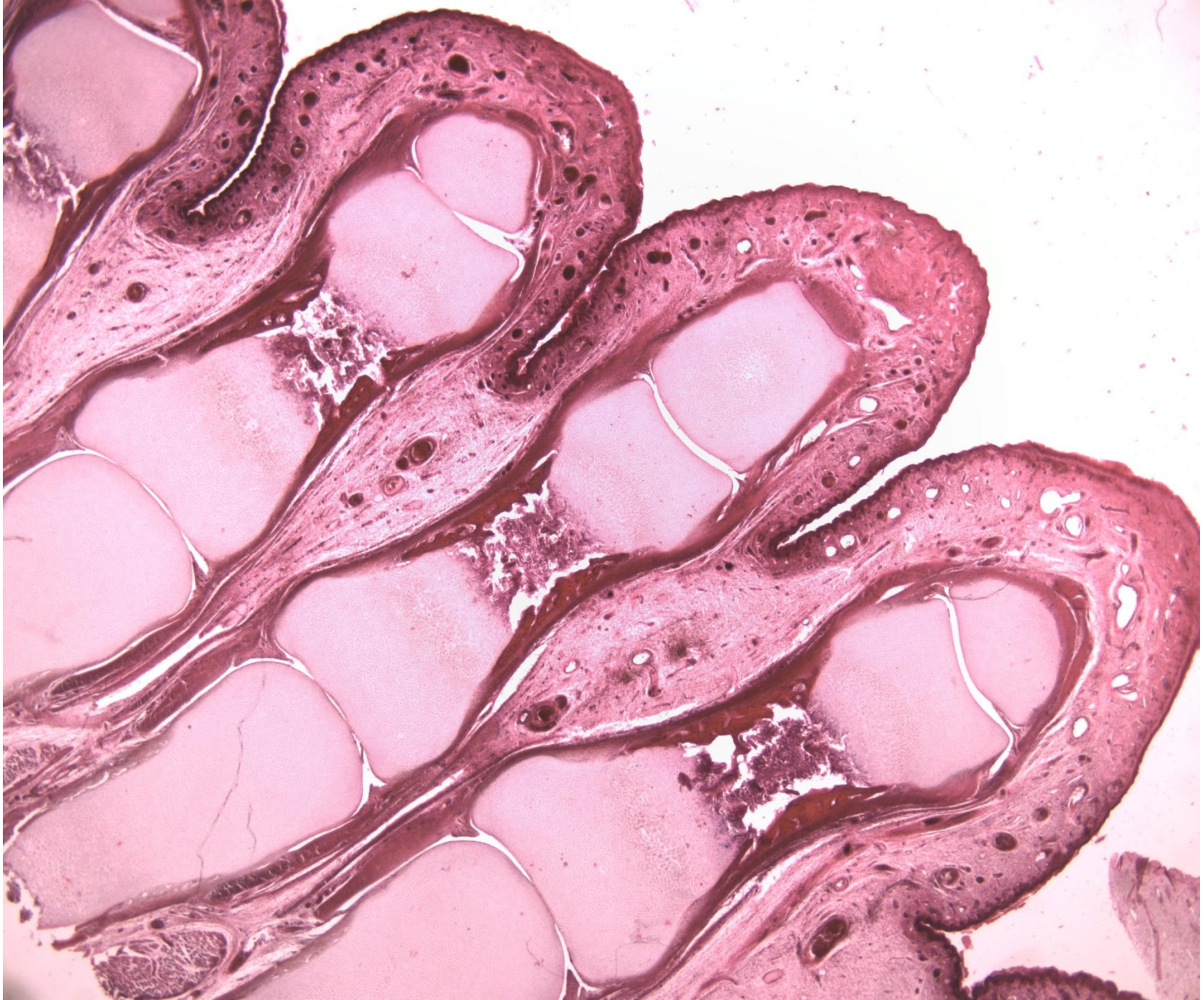
mesoderm laterální ploténky

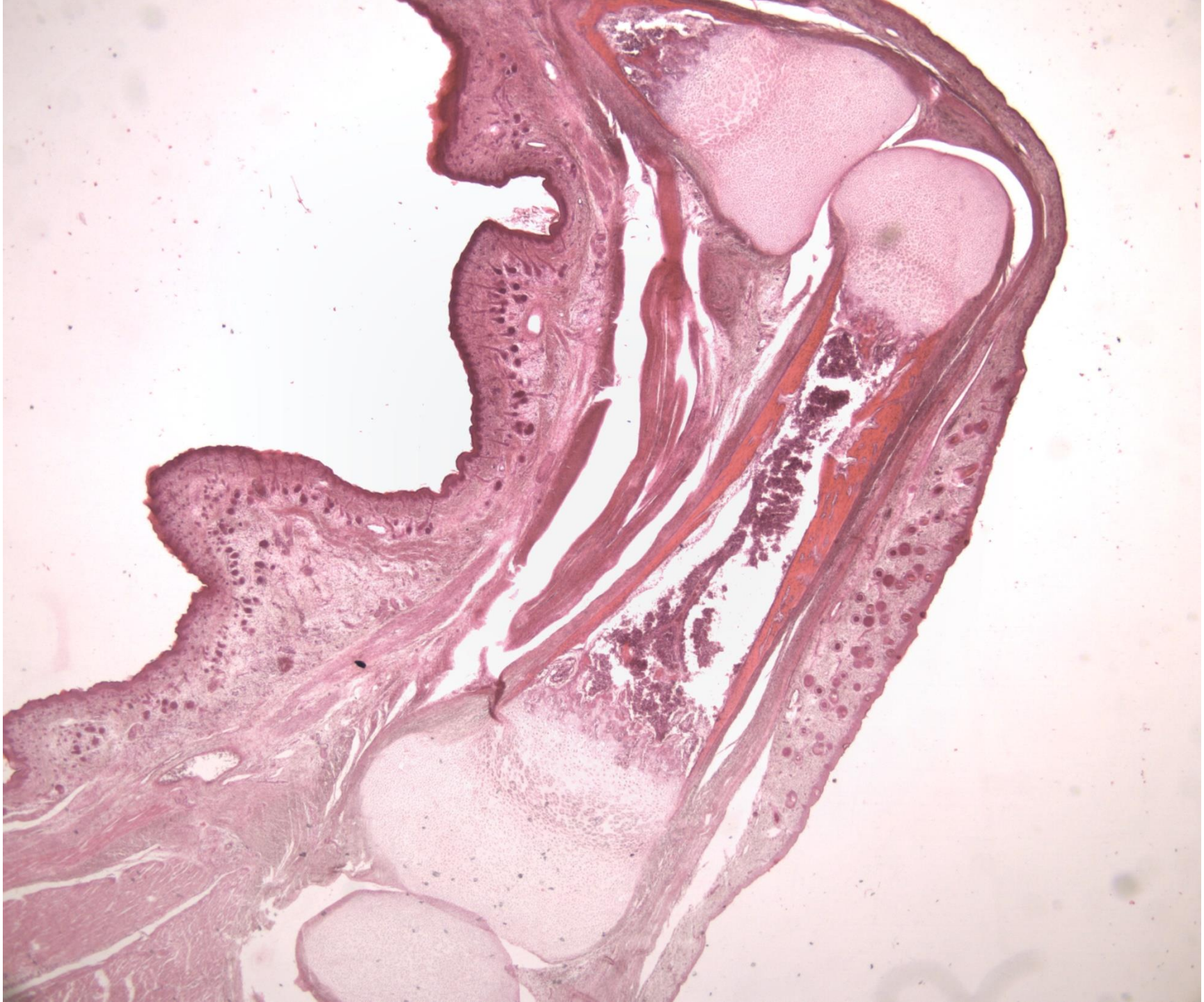

Desmogenní osifikace
Mesenchyme
Bone blastema
Osteoblasts
Primary bone tissue

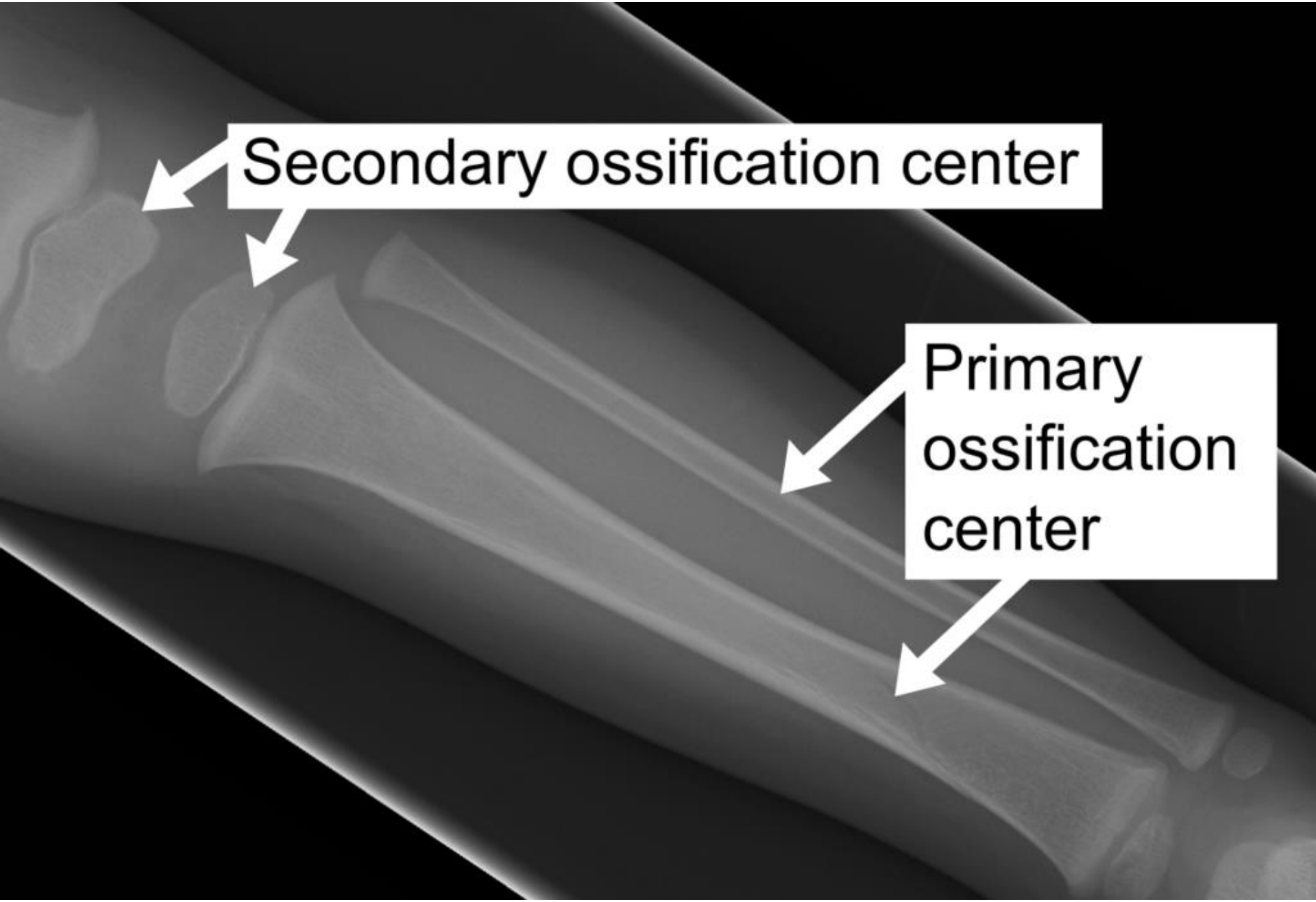


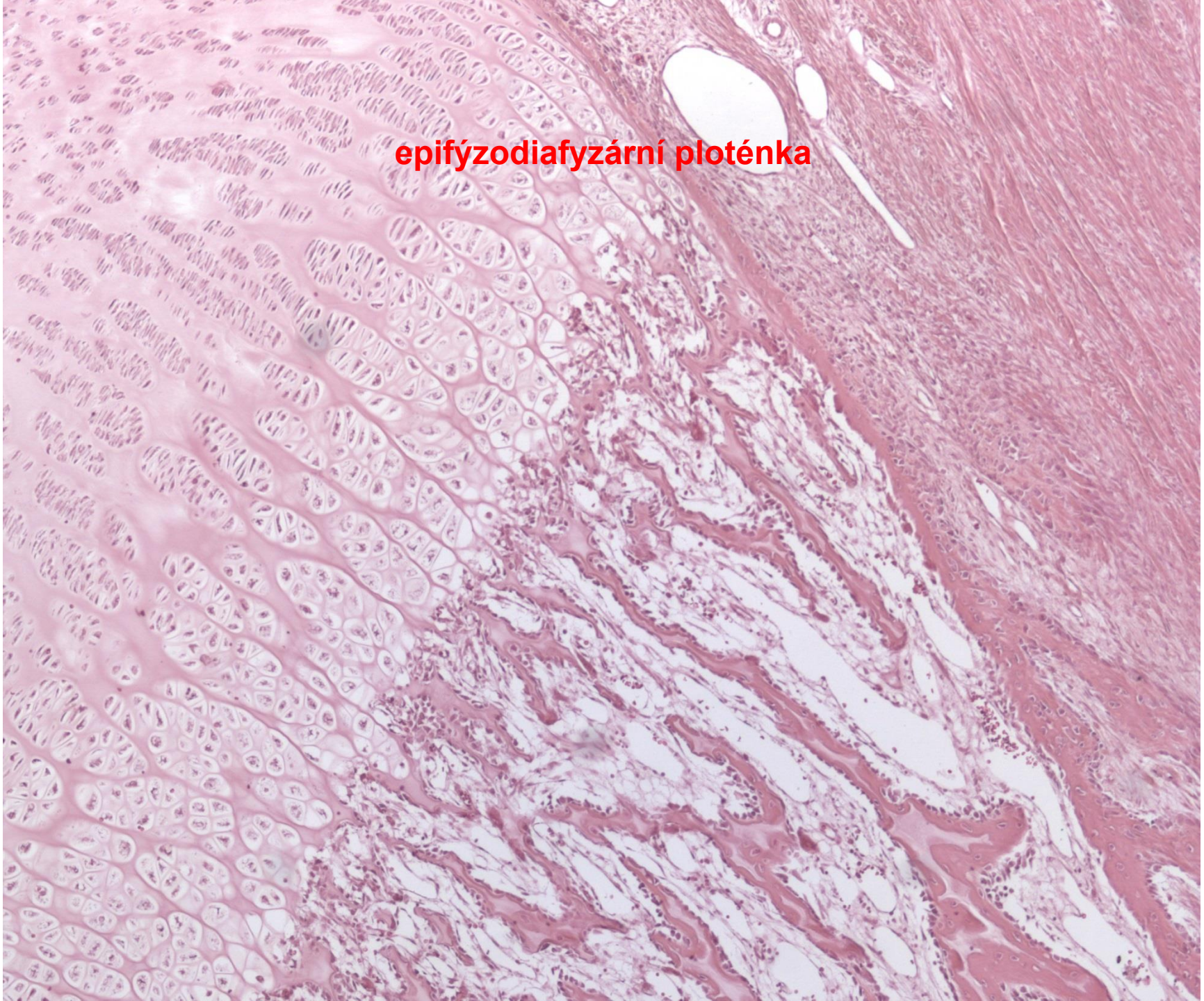
Chondrogenní (enchondrální) osifikace

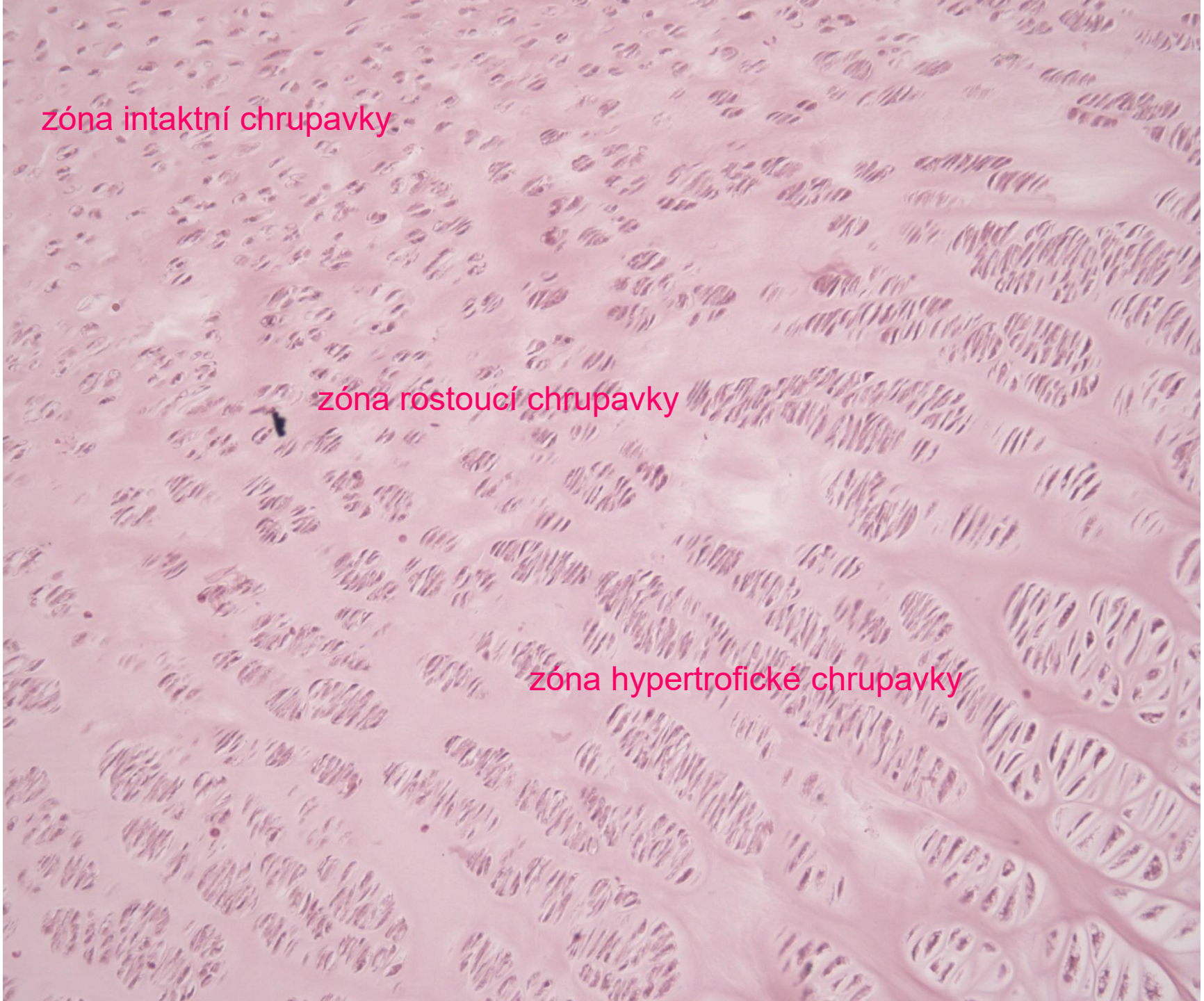


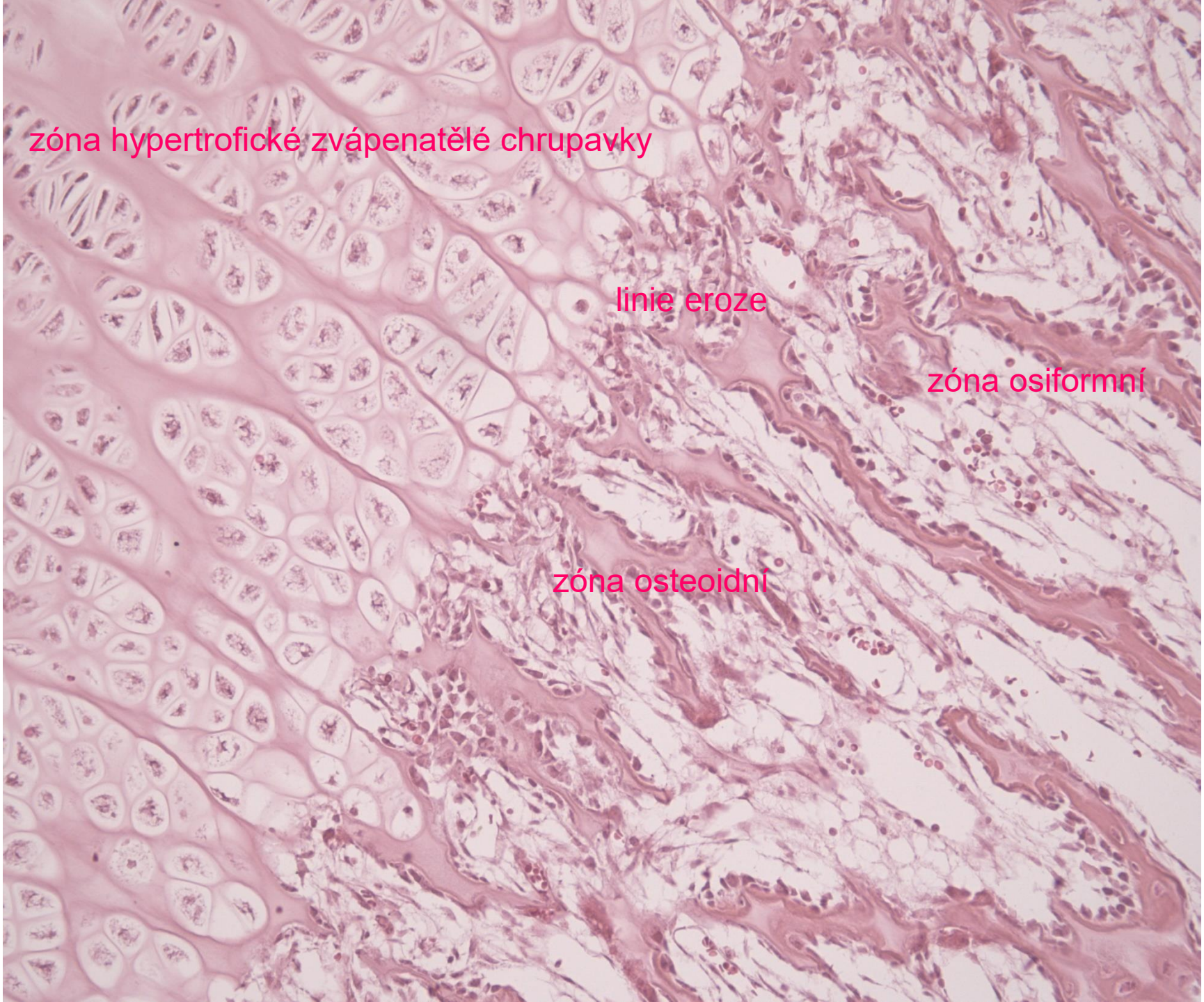







epifýzodiafyzární ploténka


zóna intaktní chrupavky
zóna rostoucí chrupavky
zóna hypertrofické chrupavky


zóna hypertrofické zvápenatělé chrupavky
linie eroze
zóna osiformní
zóna osteoidní

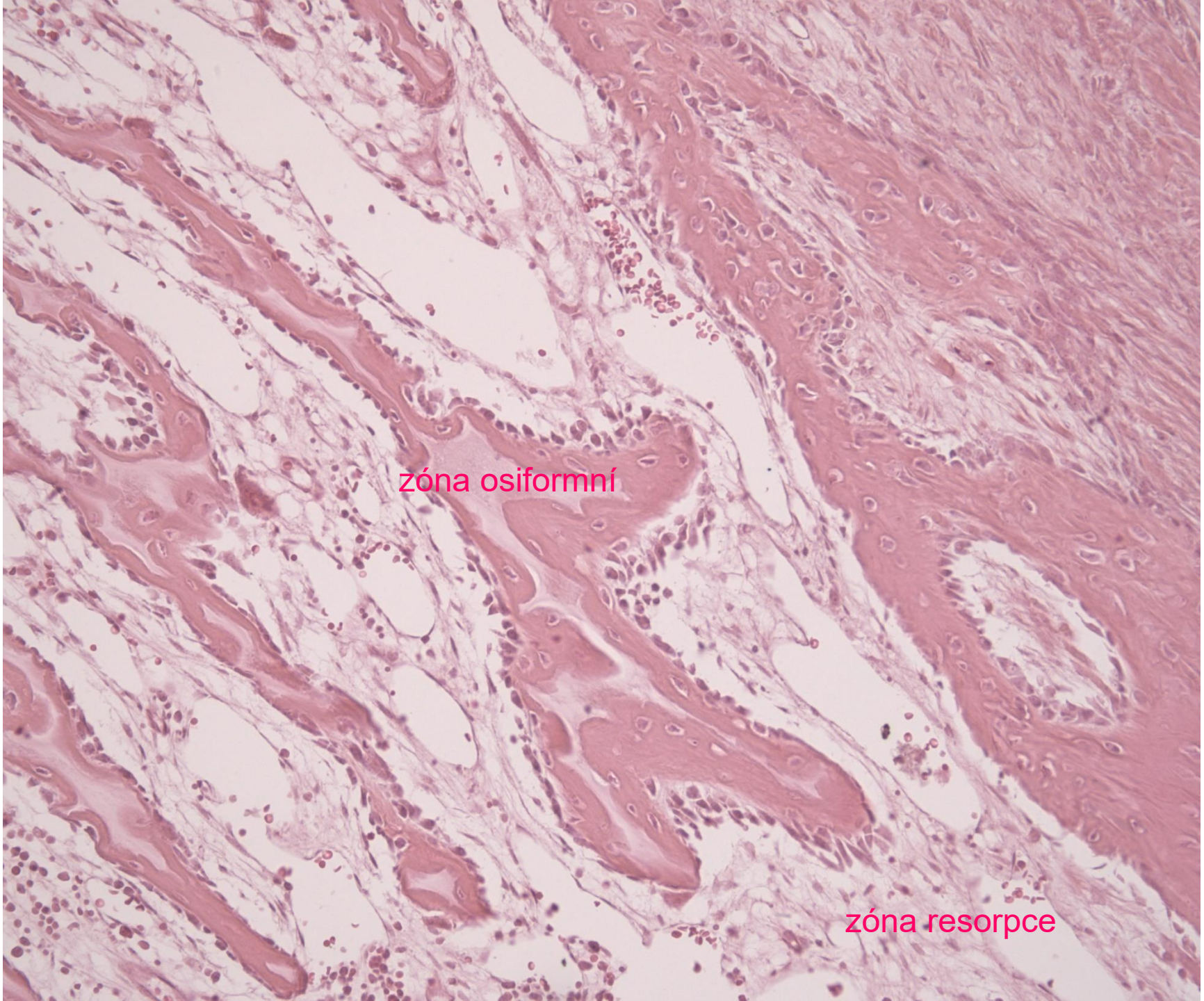
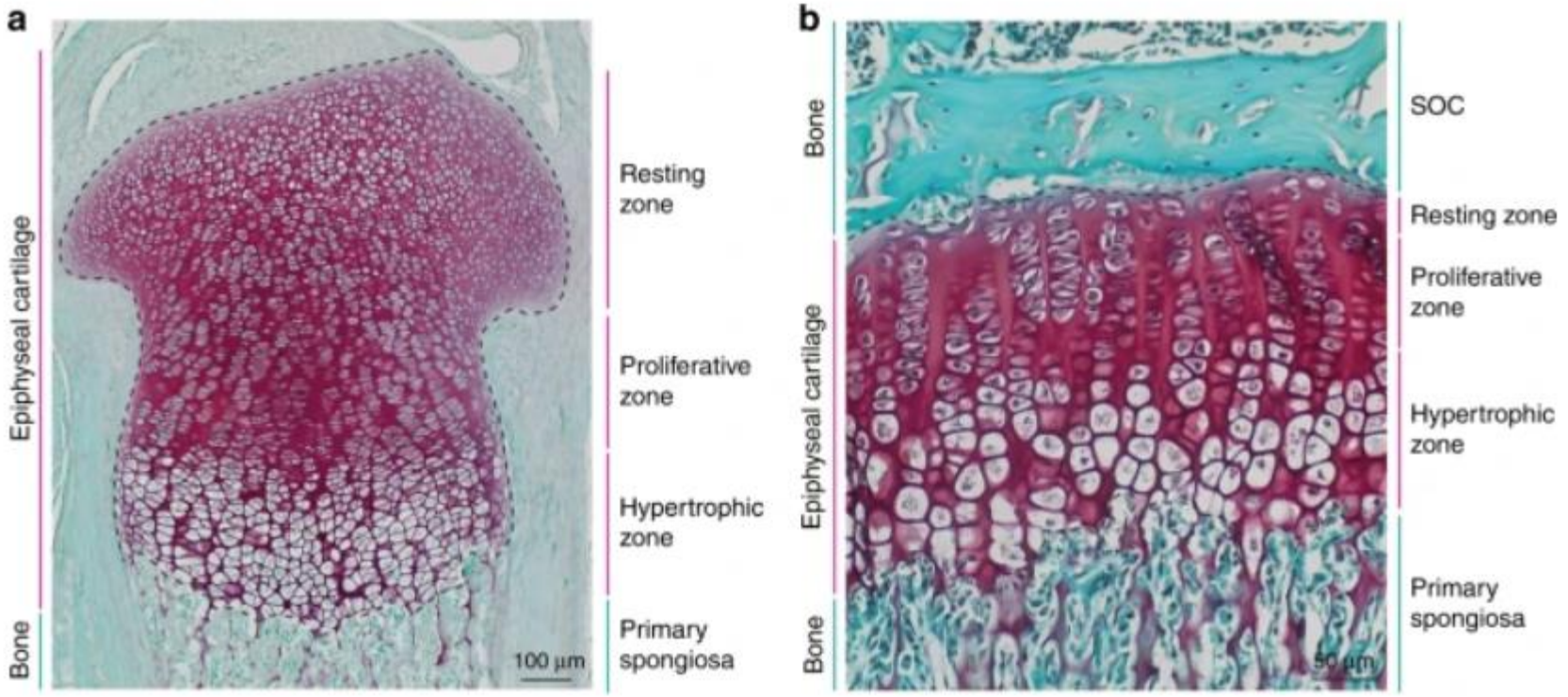
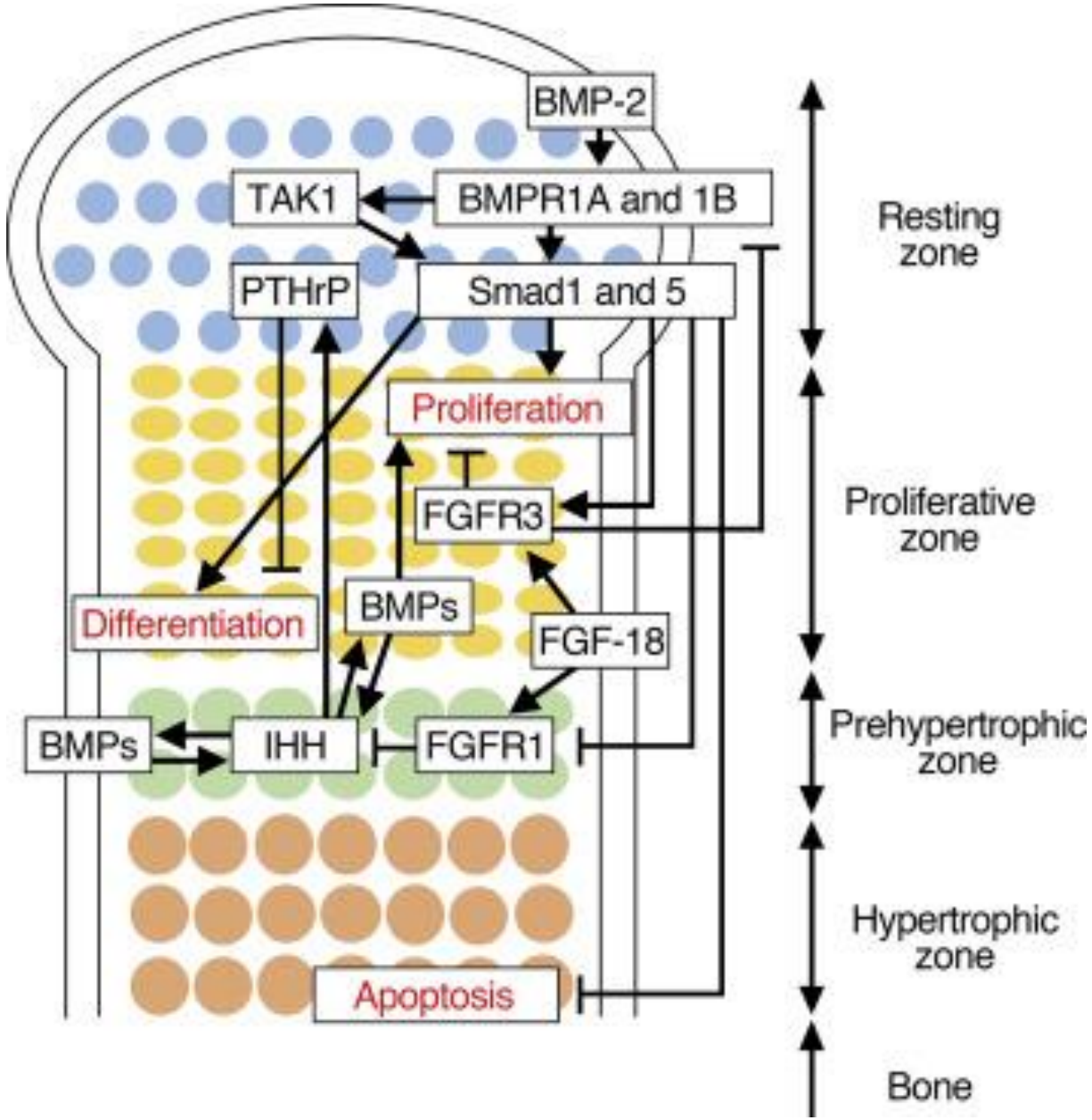

zóna osiformní
zóna resorpce

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).

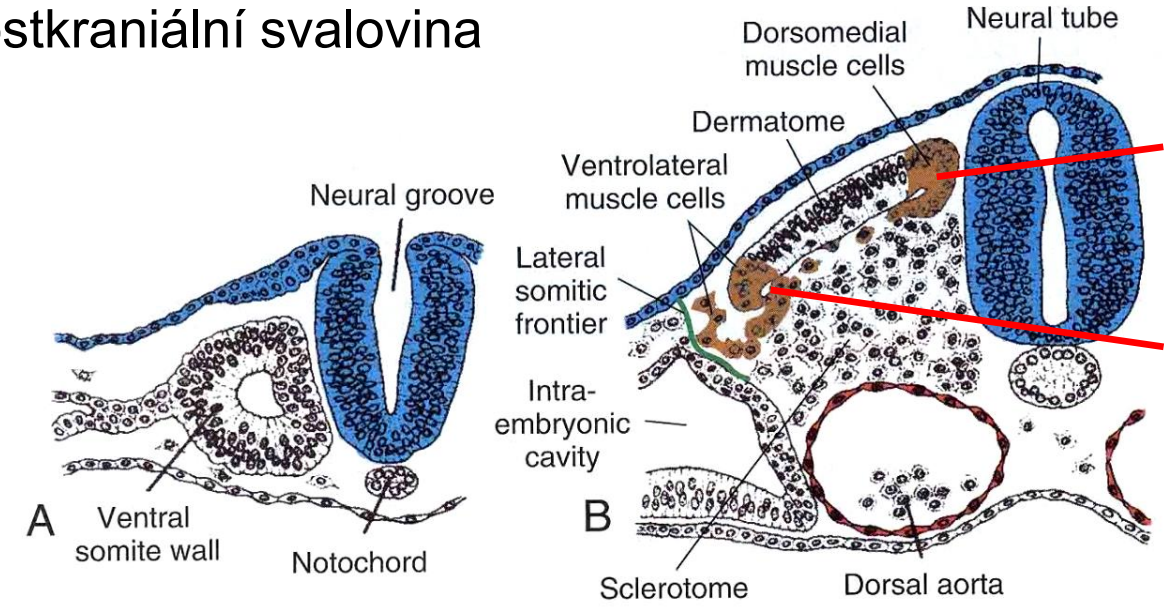
Chagin, A.S., Newton, P.T. Postnatal skeletal growth is driven by the epiphyseal stem cell niche: potential implications to pediatrics. *Pediatr Res* **87**, 986–990 (2020). https://doi.org/10.1038/s41390-019-0722-z



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

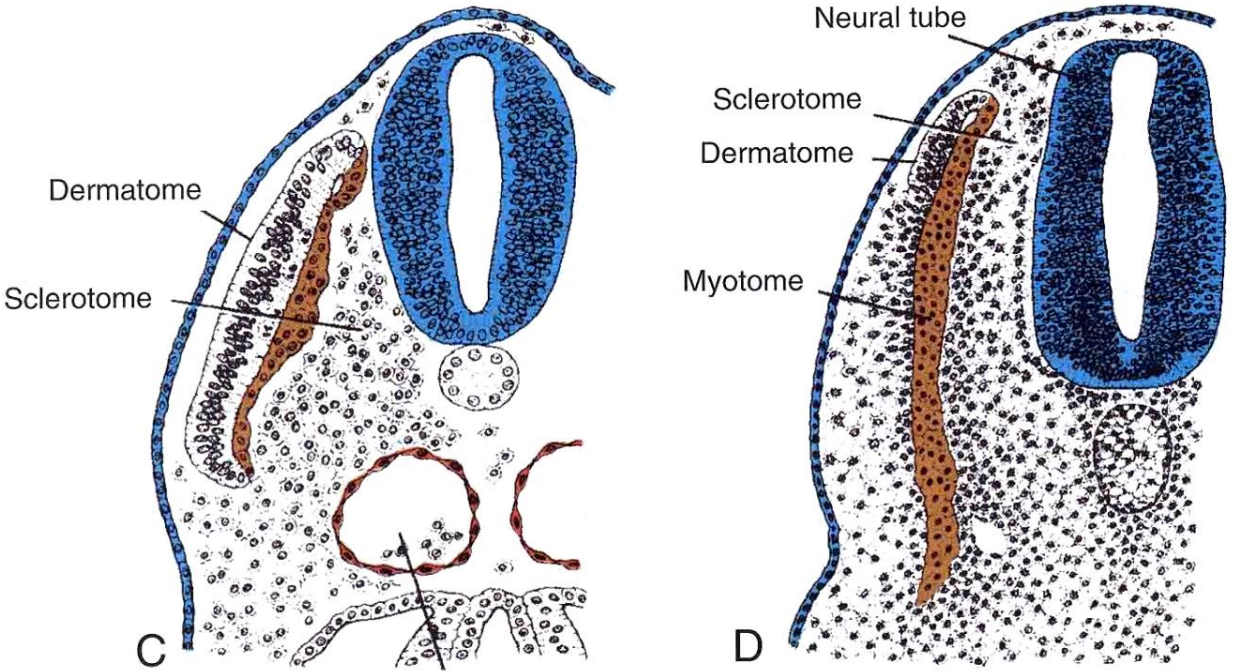
VÝVOJ SVALOVÉHO SYSTÉMU

postkraniální svalovina



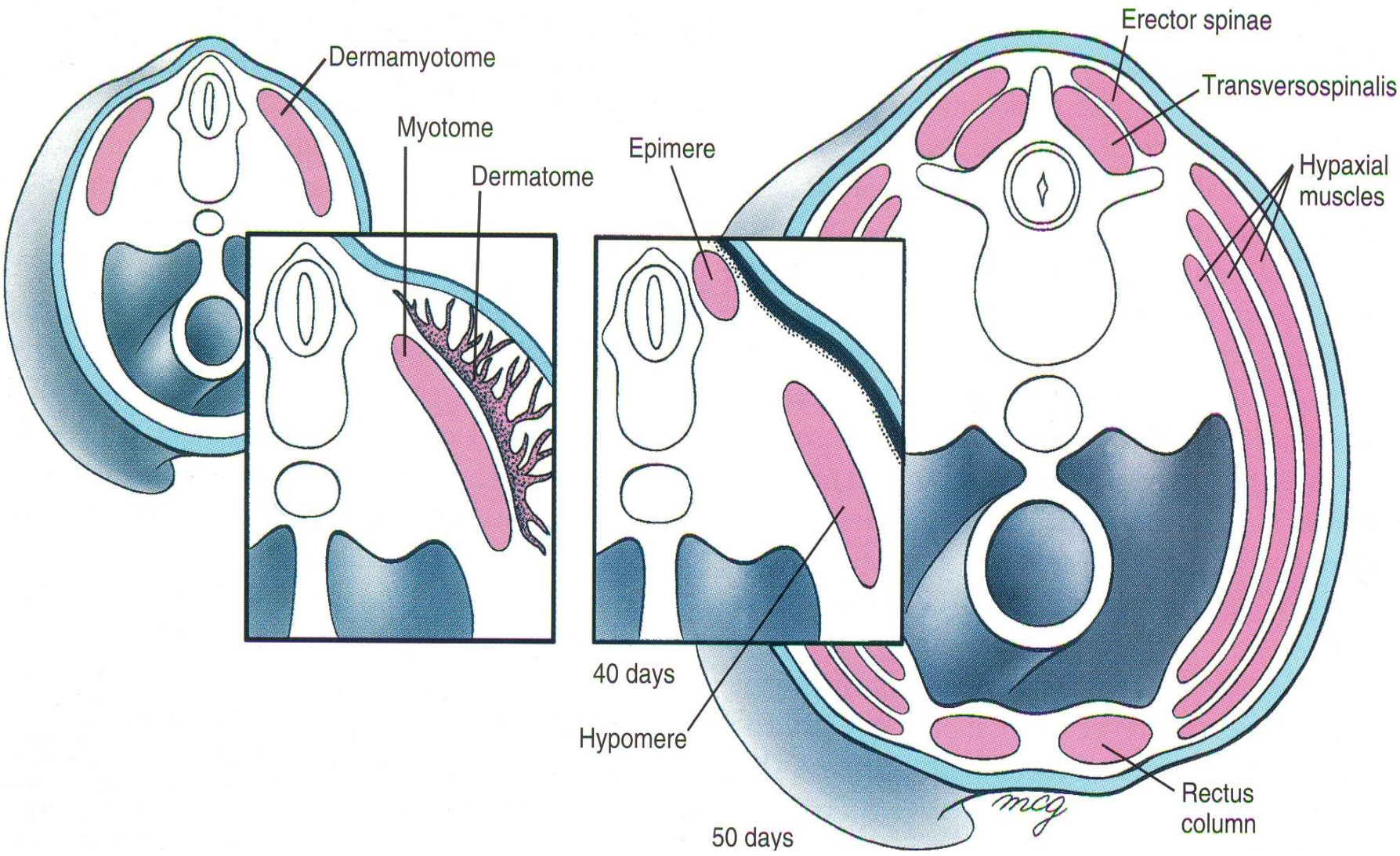
epaxiální svalovina

hypaxiální svalovina

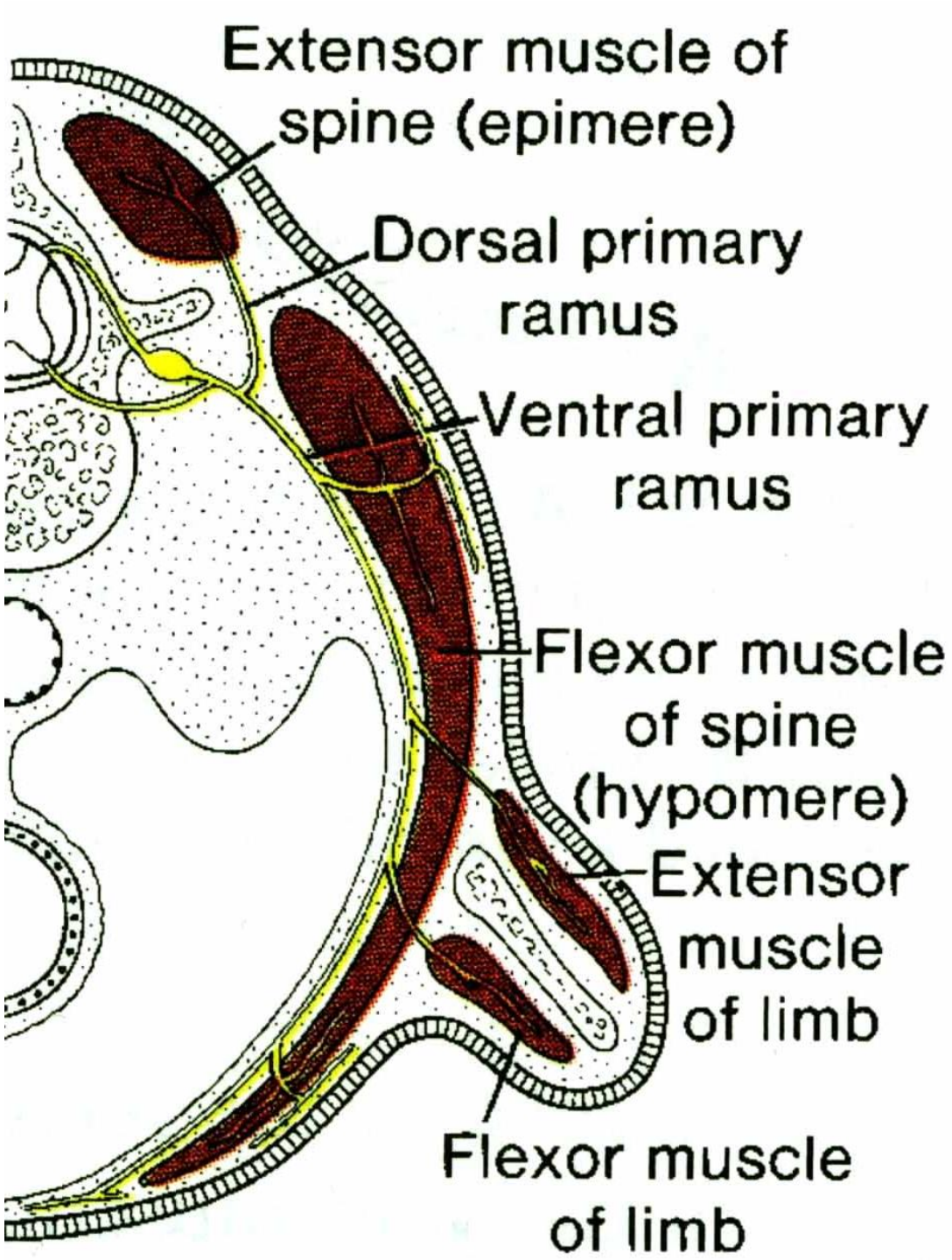


primaxiální svalovina vzniká a vyvíjí se v mesenchymu somitového původu

abaxiální svalovina vzniká v mesenchymu somitového původu, ale vyvíjí se v mesenchymu z mesodermu somatopleury

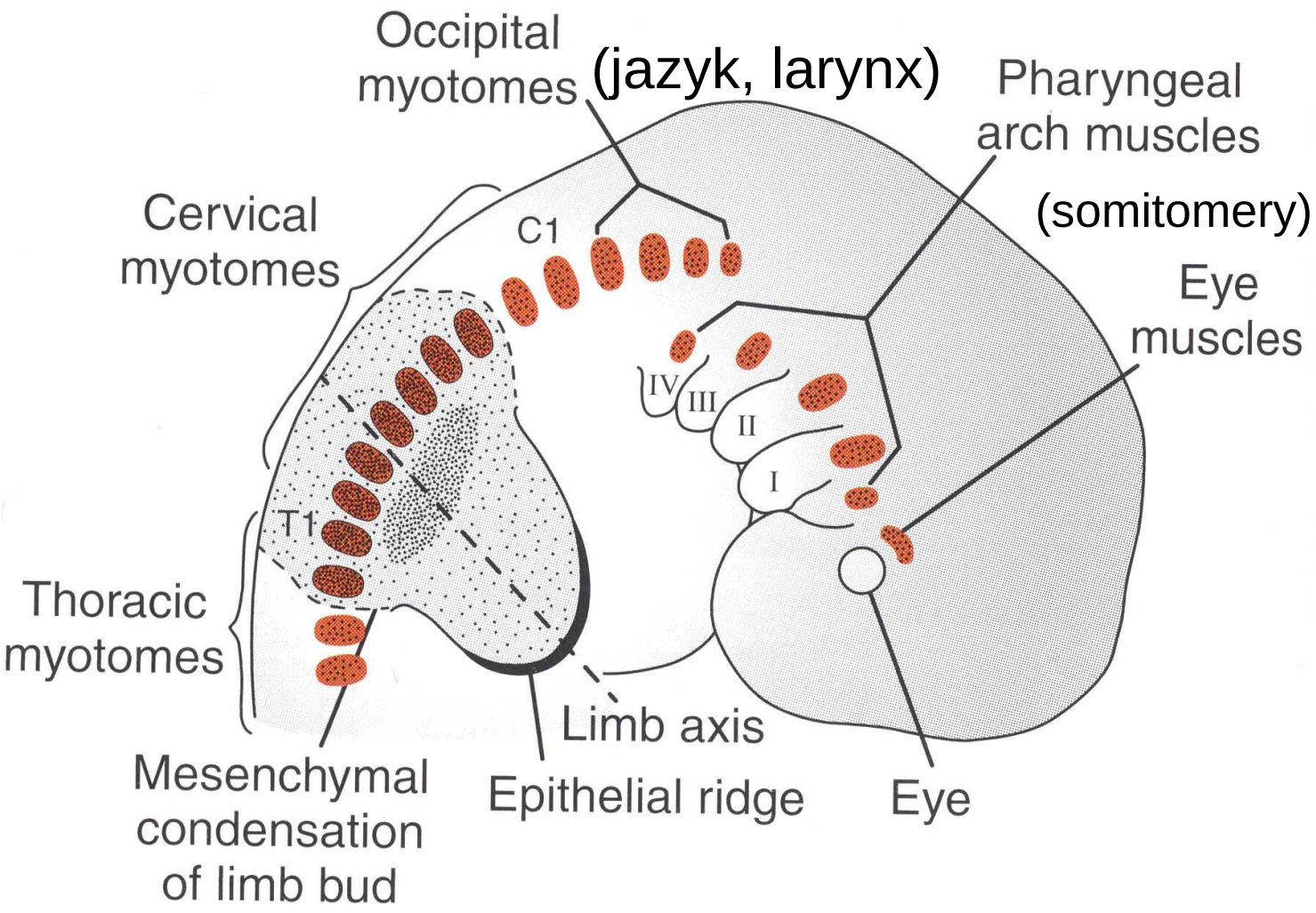

Dermamyotome
Myotome
Dermatome
Epimere
Hypomere
40 days
50 days
Erector spinae
Transversospinalis
Hypaxial muscles
Rectus column
mcg

svaly končetin



7. týden

kraniální svalovina



New myoblasts

Myoblasts fusing

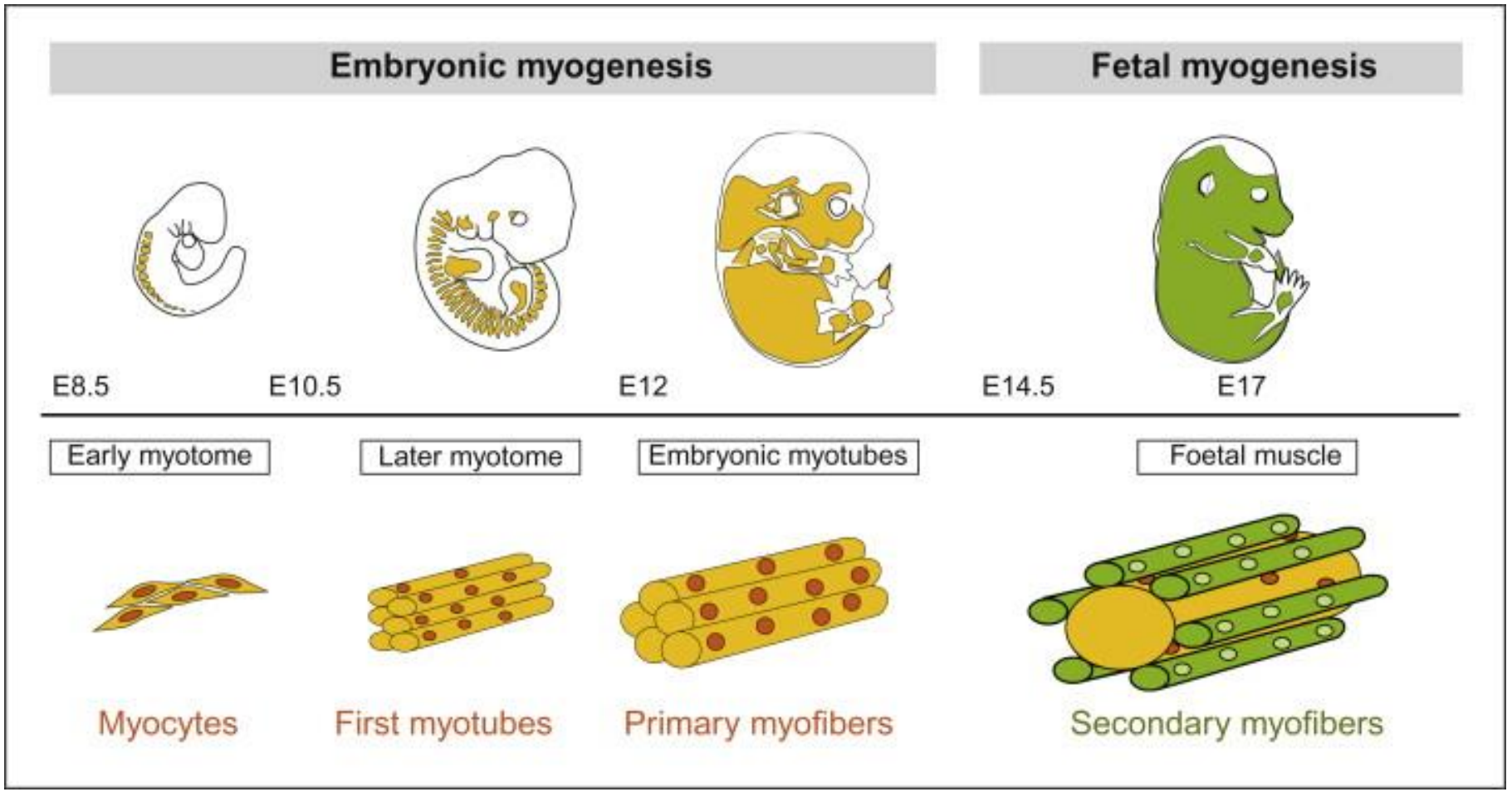
Myoblasts in line

Side views

Cross sections

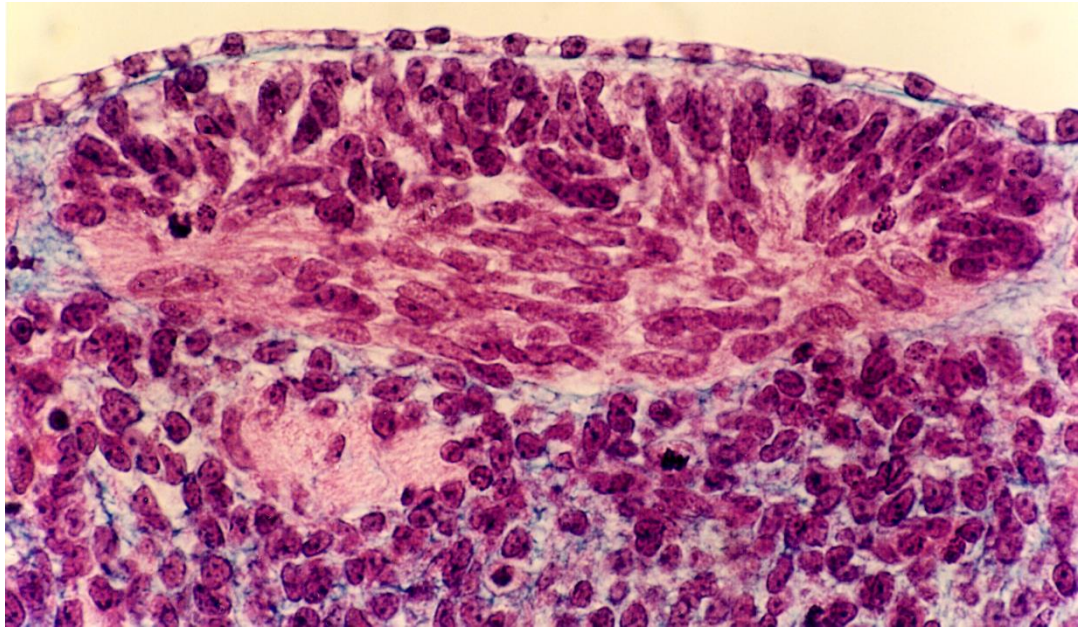
Myoblasts develop myofibrils

Myotube

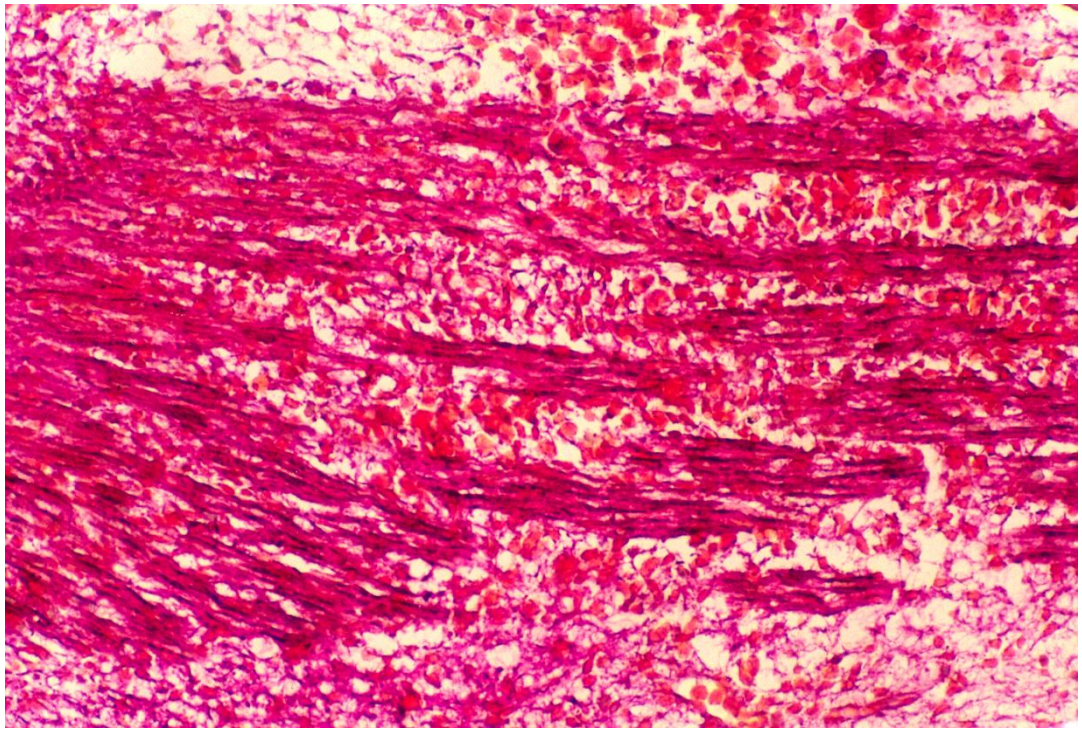


https://www.sciencedirect.com/book/9780123815101/muscle?via=ihub=

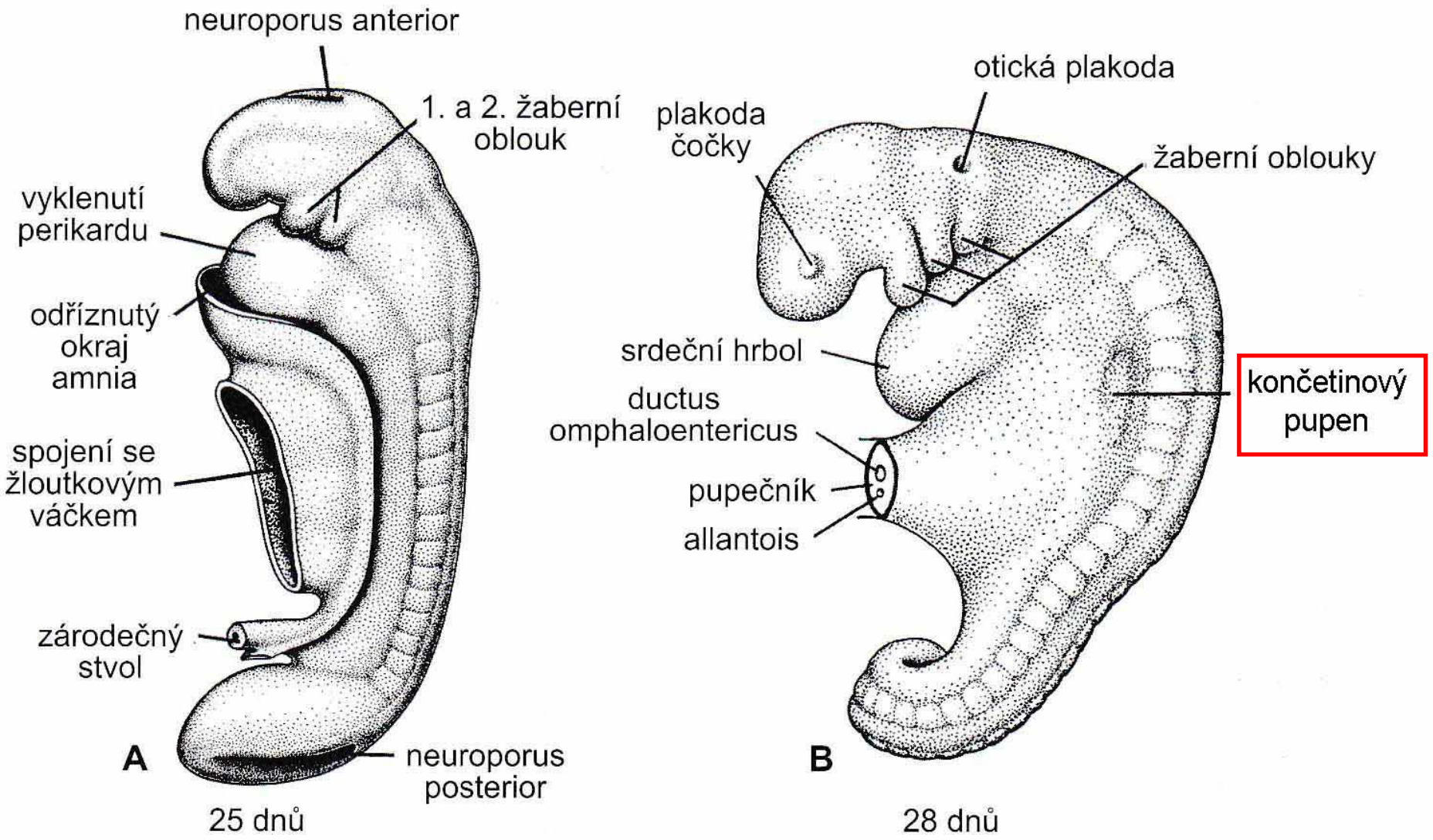
myoblasty



myotuby



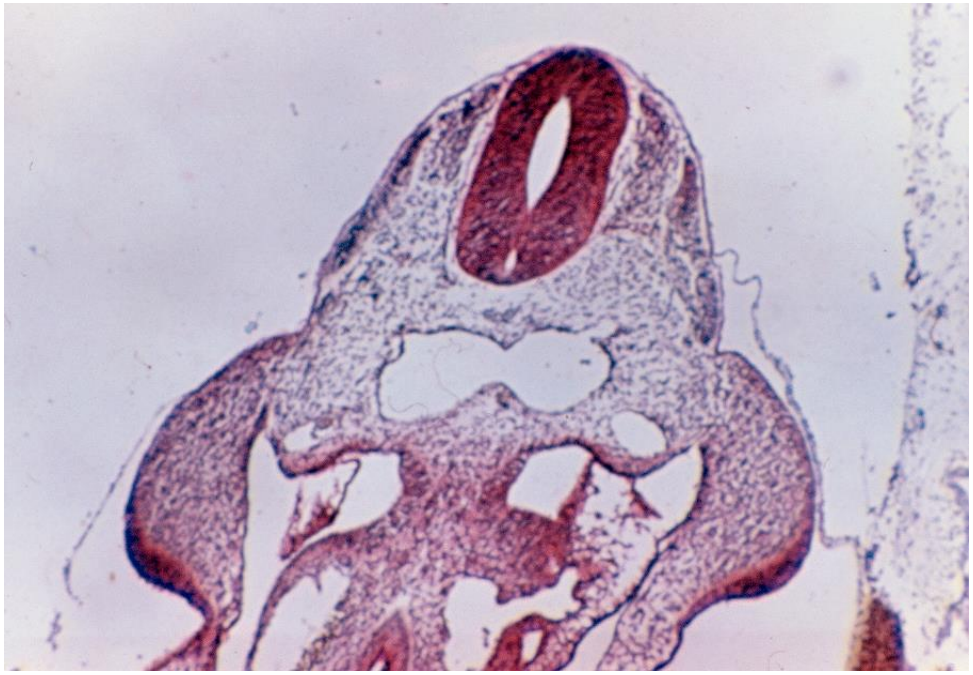
VÝVOJ KONČETIN

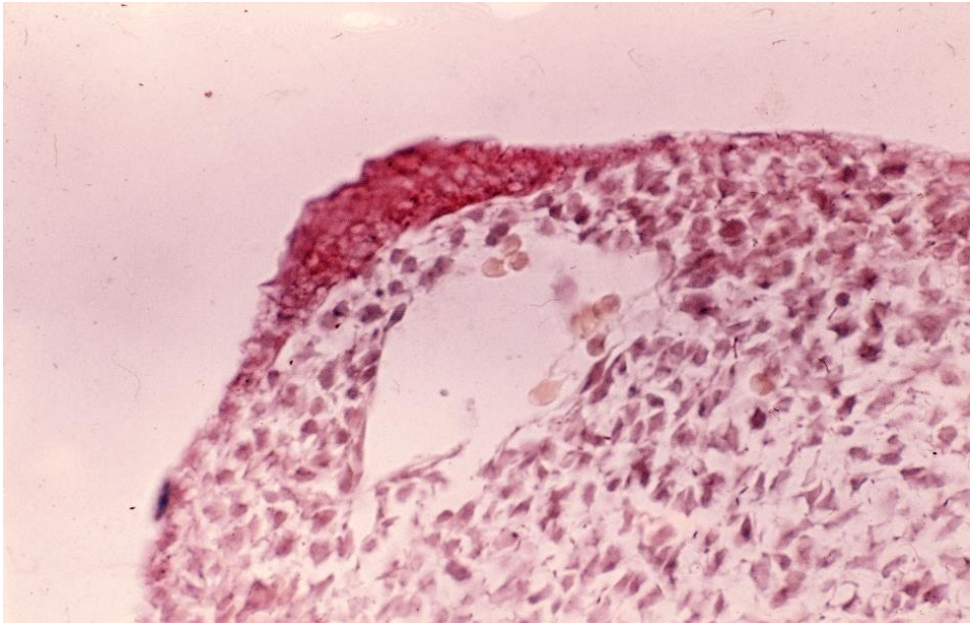


Sadler, T. W.: Langmanova lékařská embryologie, překlad 10. vydání, Grada 2011

Končetinový pupen

5. týden

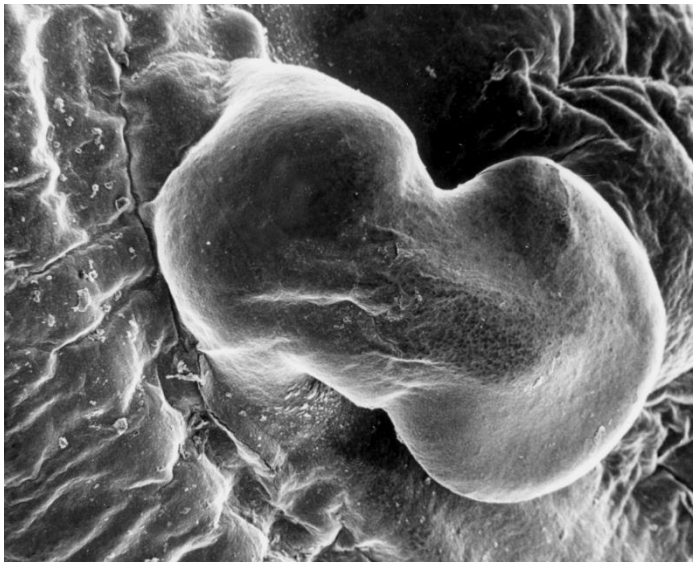


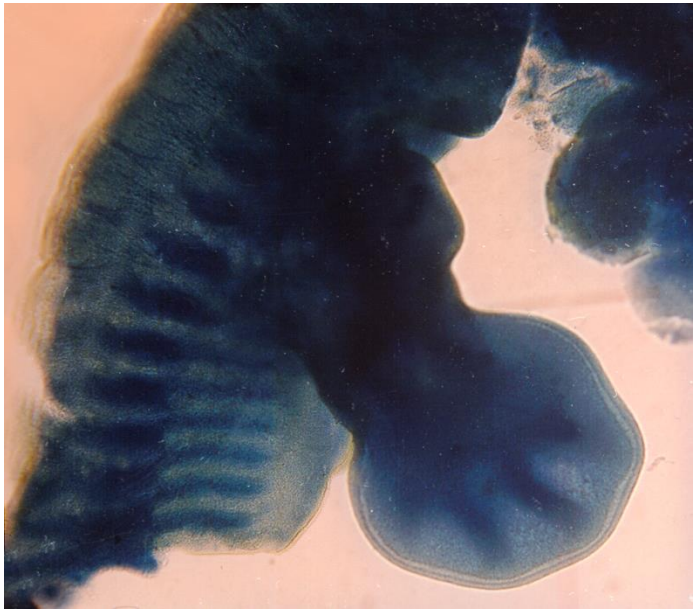


6th week

Končetina se dvěma segmenty, palmární (plantární) ploténka

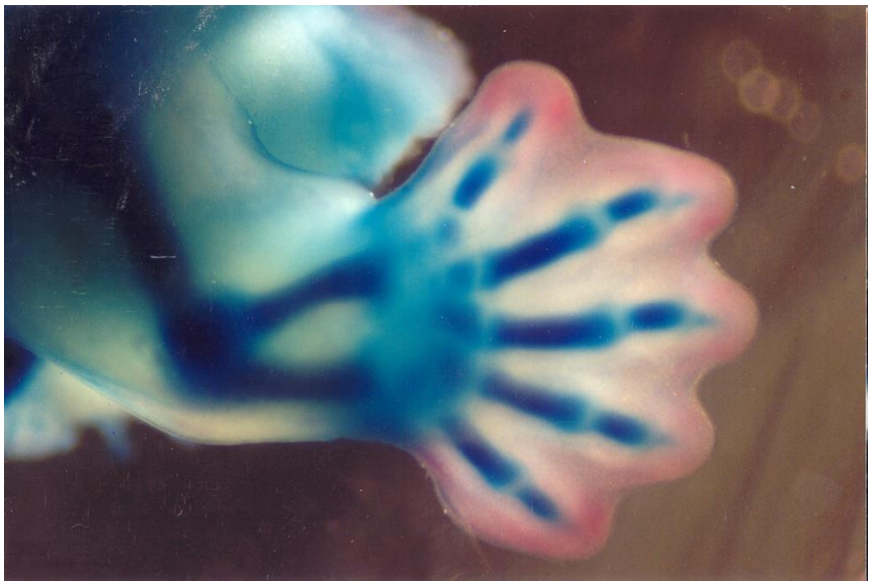
6. týden

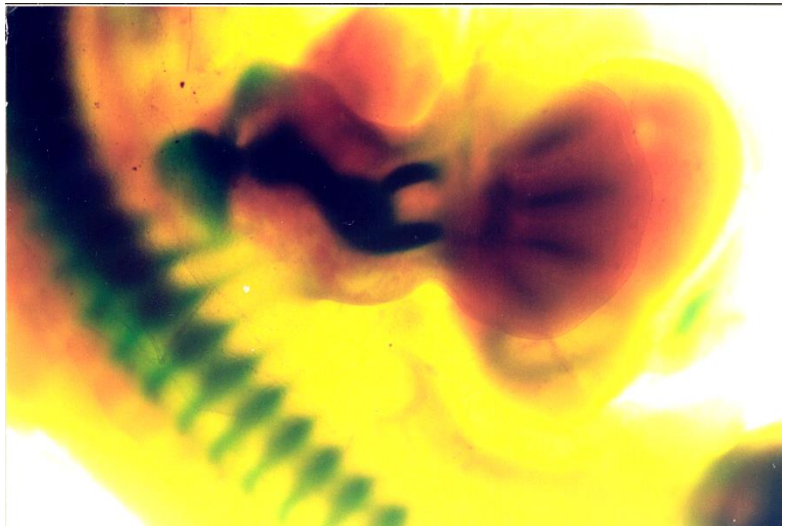


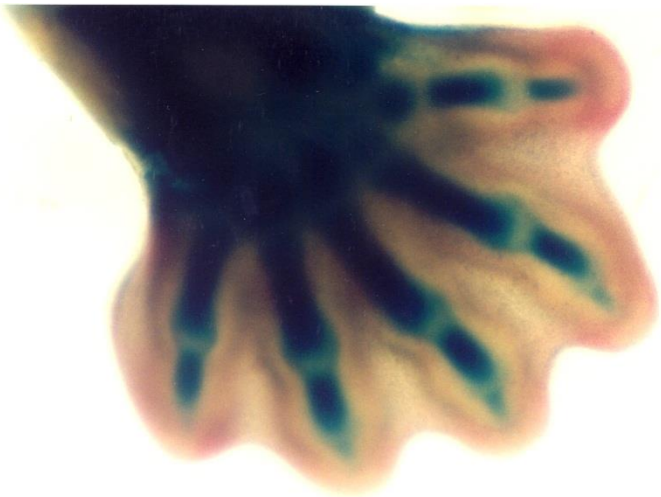


Končetina se třemi segmenty, digitální paprsky a hrbolky

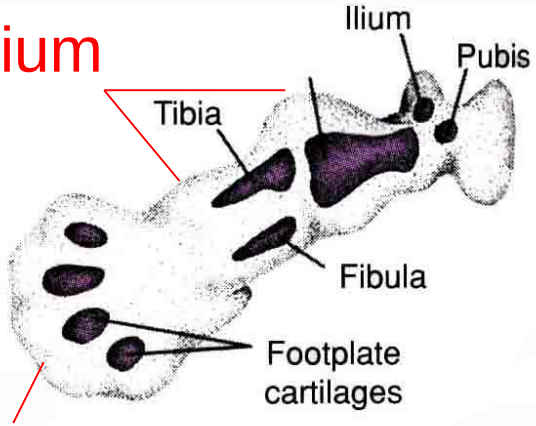
7. týden





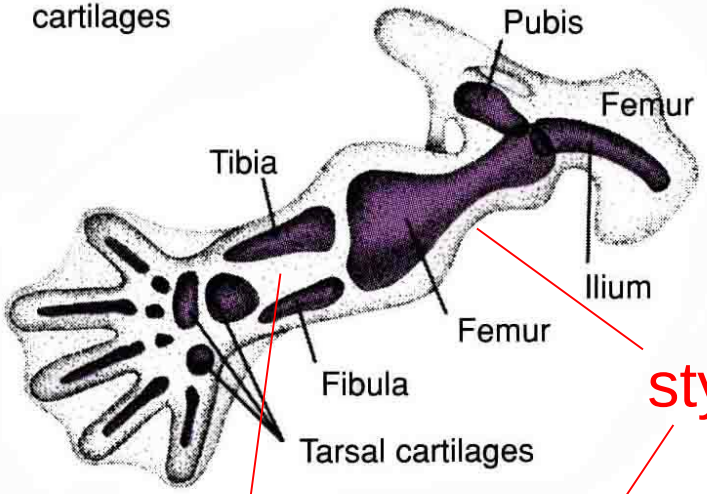


končetina se dvěma segmenty



axopodium

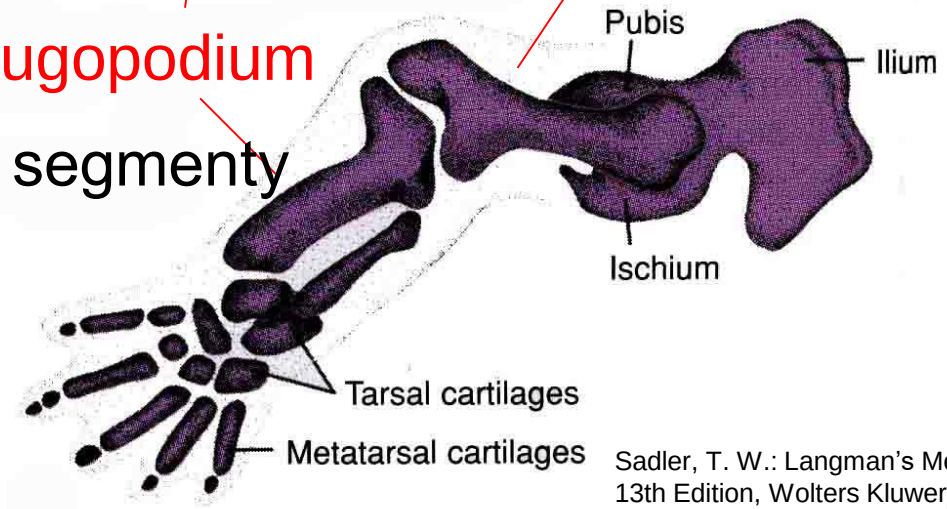
autopodium



stylopodium

zeugopodium

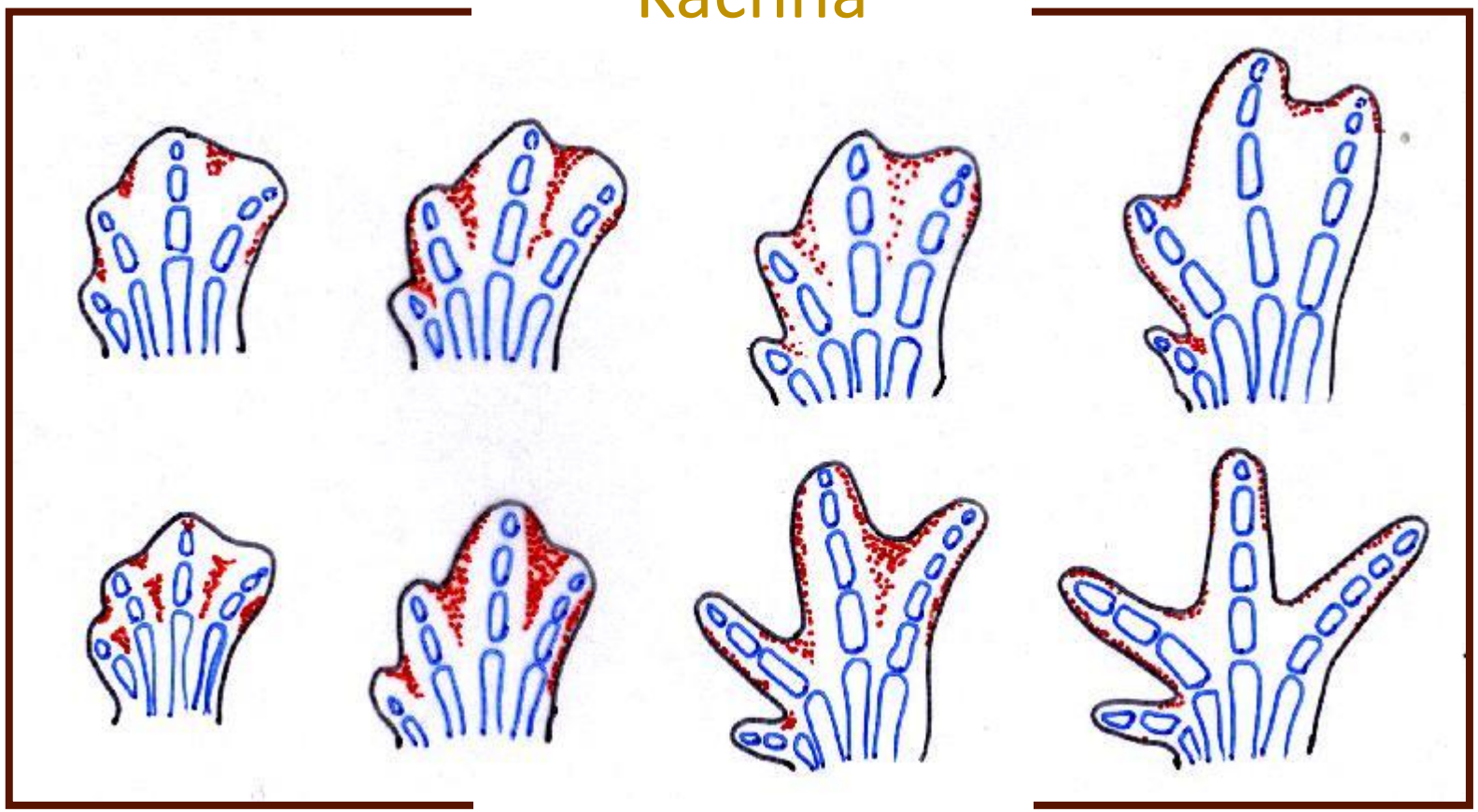
končetiny se třemi segmenty



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

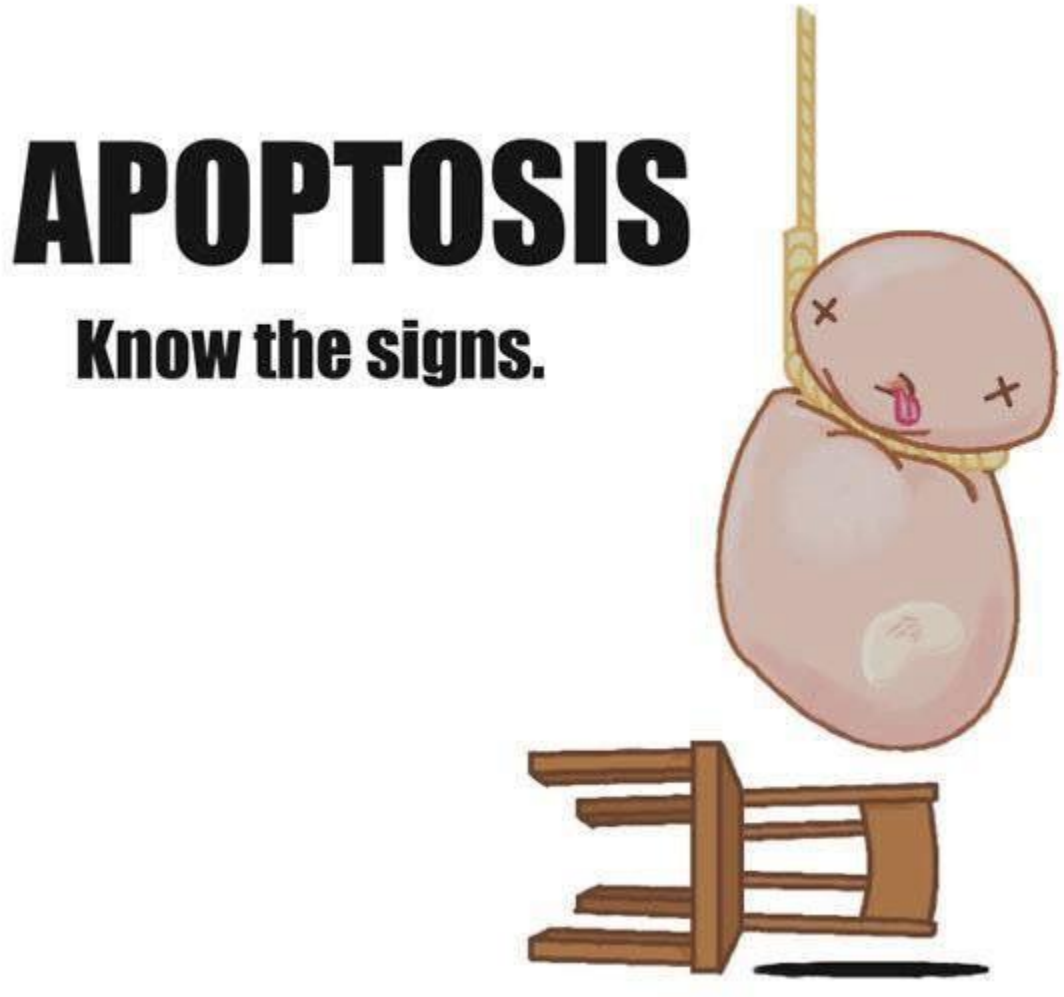
Buněčná smrt ve vývoji končetin

Kachna



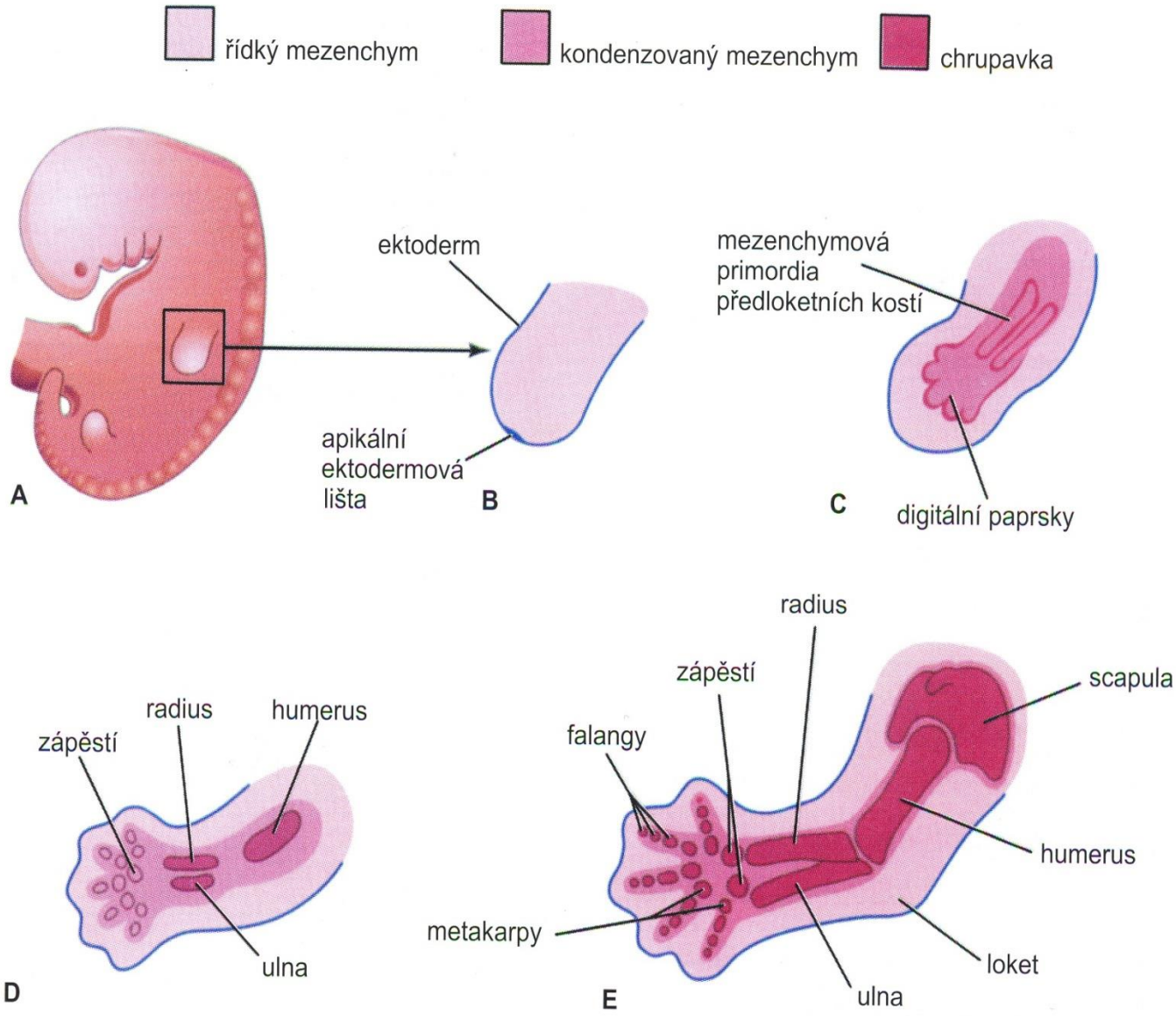
Kuře

Redukce
Buněčná smrt



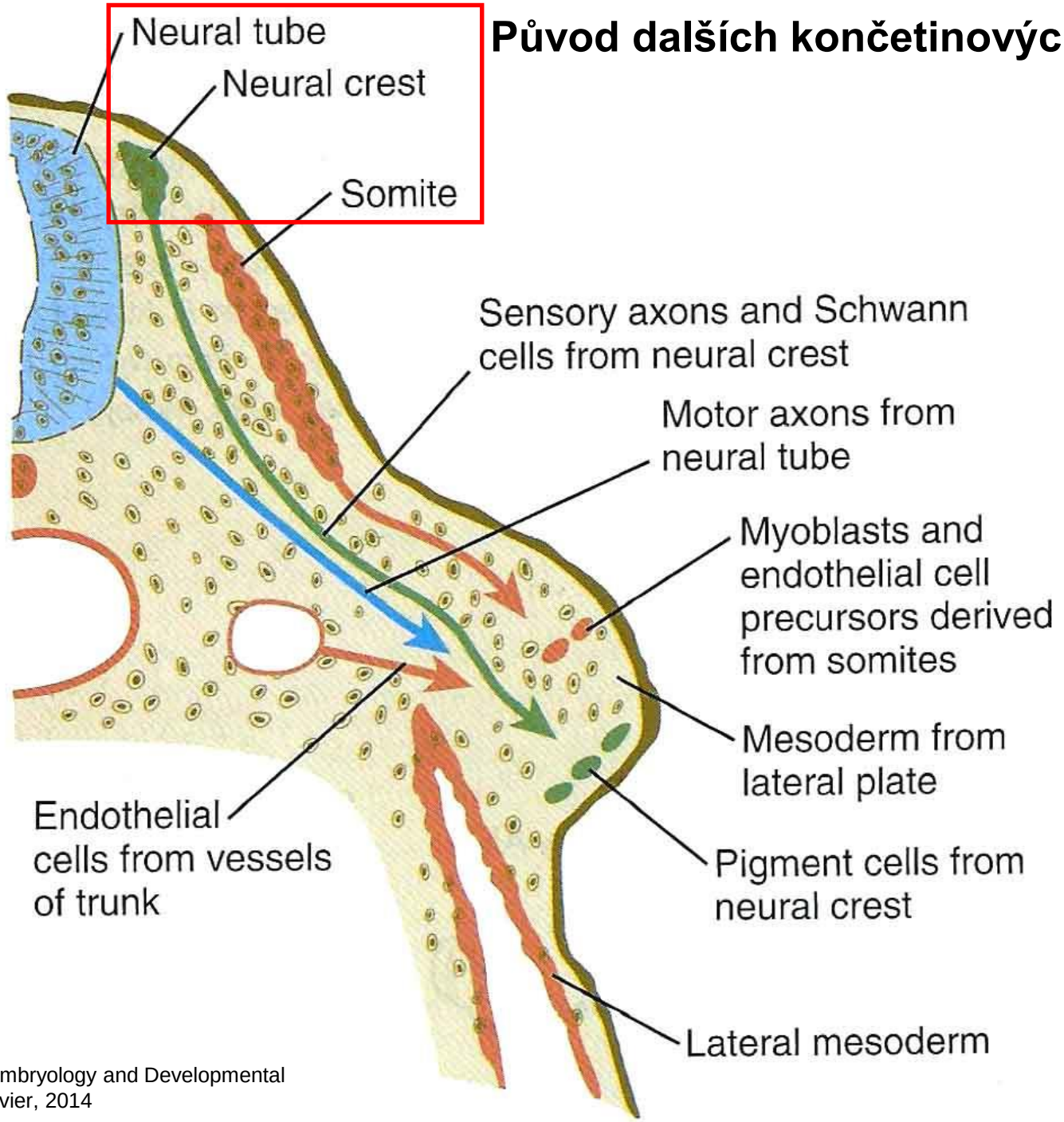
https://www.pinterest.co.uk/sonjasivcev/apoptosis/

Kostra končetiny – parietální list somatického mezodermu

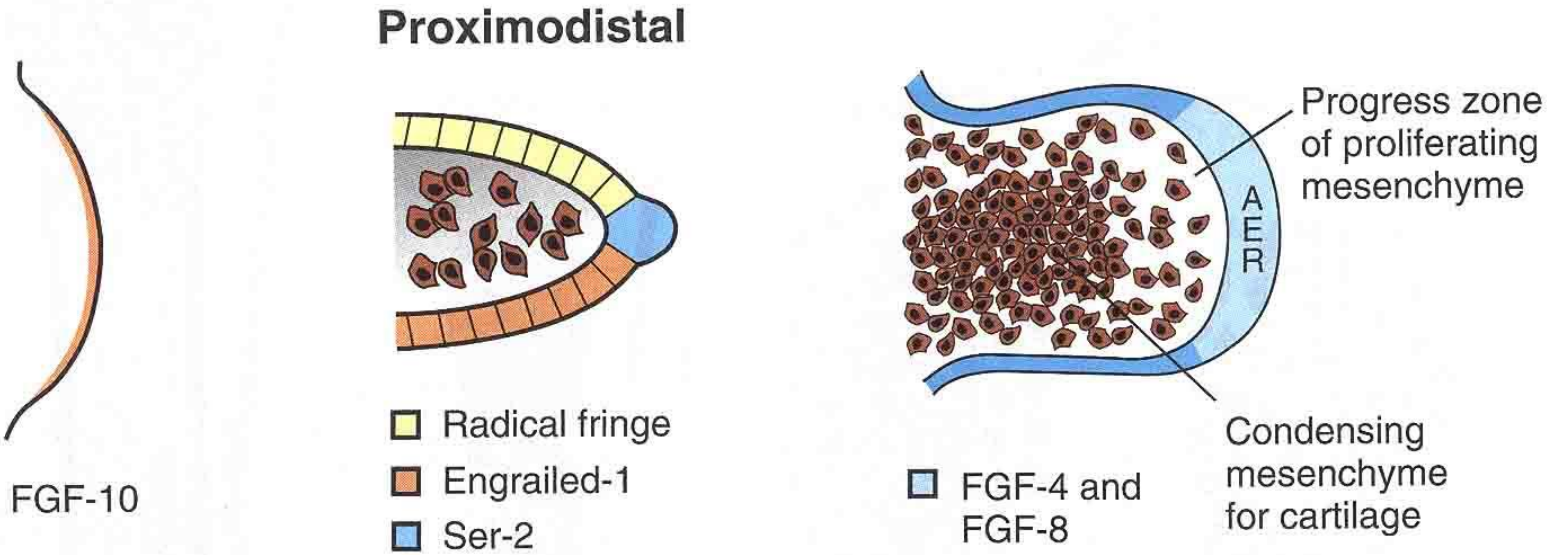


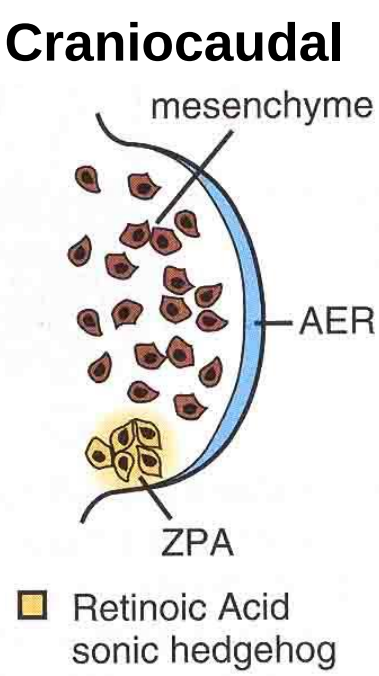
Moore, K. L., Persaud, T. V. N.: Zrození člověka, Embryologie s klinickým zaměřením, překlad 6. vydání, ISV 2002

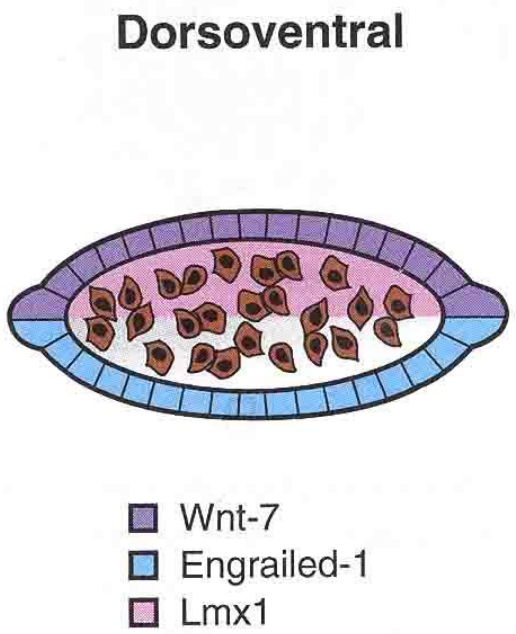
Původ dalších končetinových tkání



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

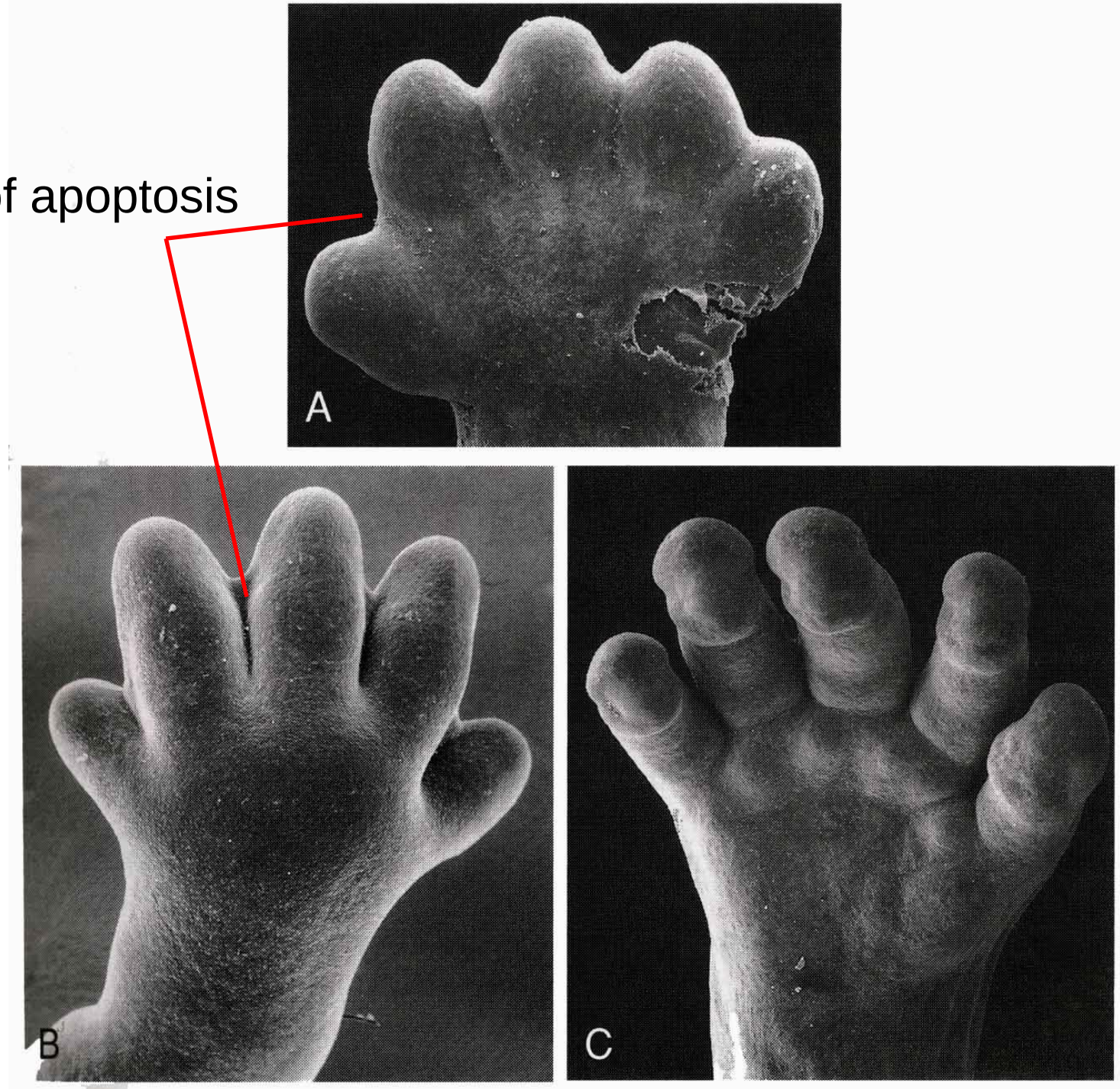

Proximodistal
FGF-10
Radical fringe
Engrailed-1
Ser-2
Progress zone
of proliferating
mesenchyme
AER
FGF-4 and
FGF-8
Condensing
mesenchyme
for cartilage


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



Rotace končetin
(10. týden)