

Bi8940 Developmental Biology

Lesson 5

Vertebrate Organogenesis: Endo- and Mesodermal Derivatives

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INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Tato prezentace je spolufinancována
Evropským sociálním fondem
a státním rozpočtem České republiky



Outline of Lesson 5

Organogenesis in Vertebrates: Endo- and Mesodermal Derivatives

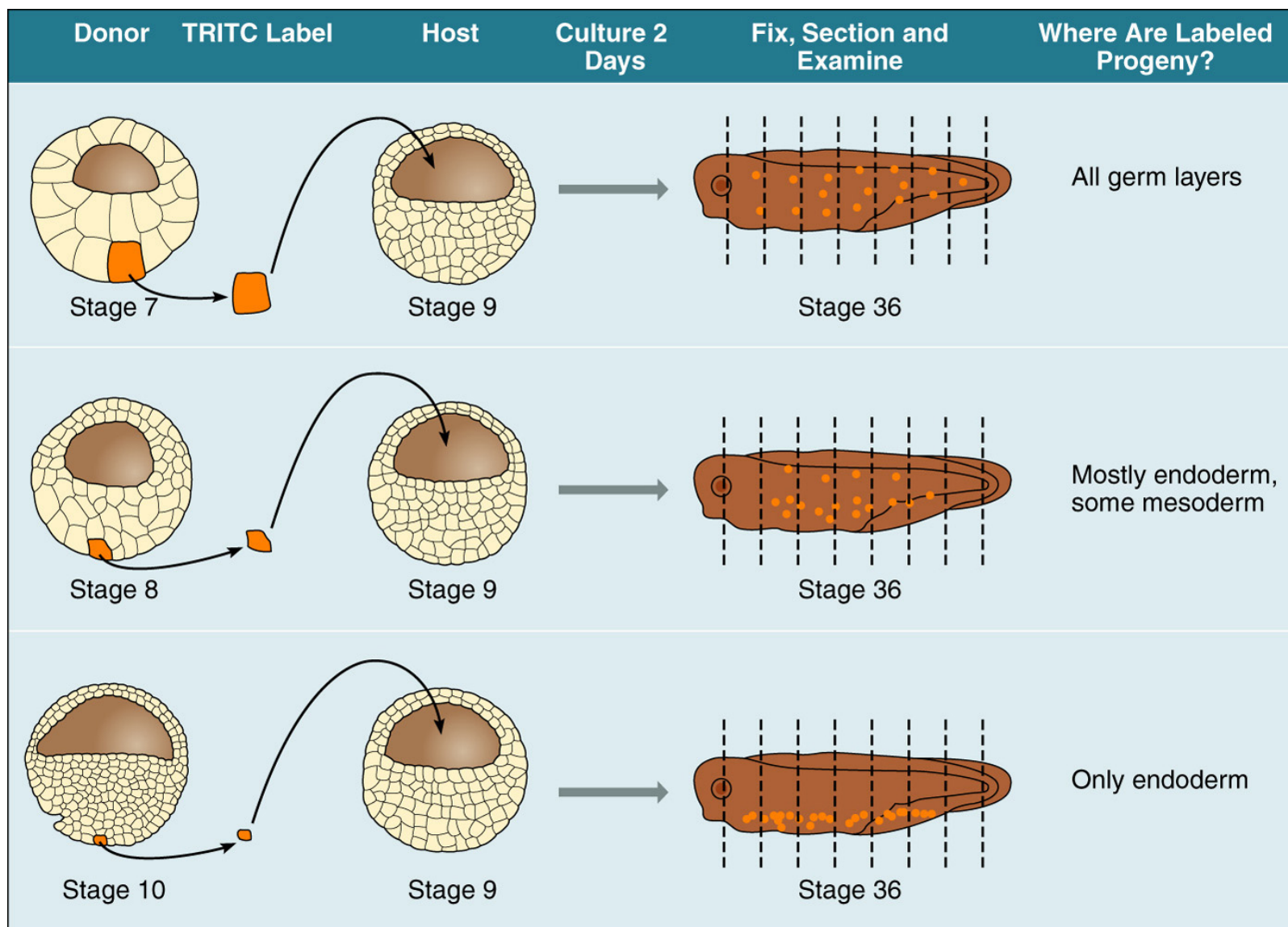
- Mesoderm derivatives development
 - somites formation and signalling
 - formation of muscles
 - endochondral ossification and signalling
 - nephrogenesis
 - formation of gonads
 - hematopoiesis and circular system development
 - limbs formation
- Endoderm derivatives development
 - alimentary canal and its derivatives formation



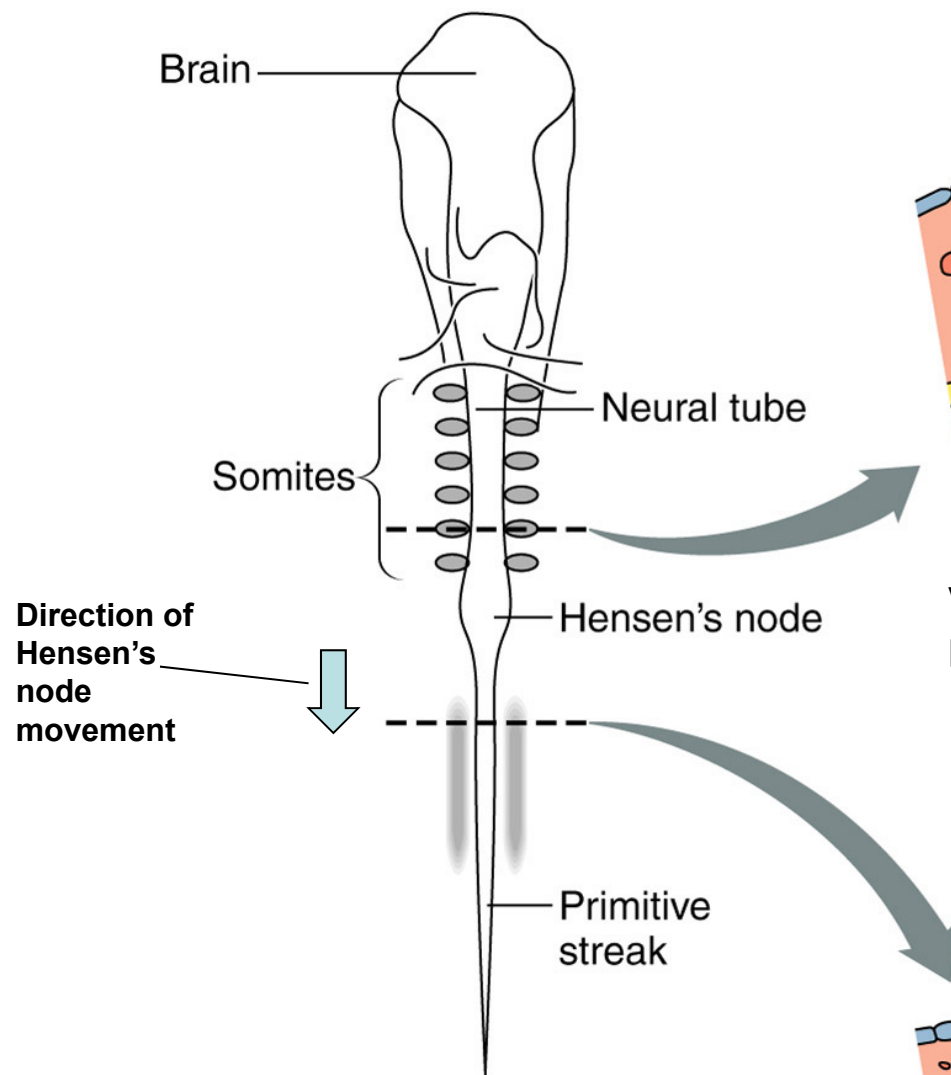
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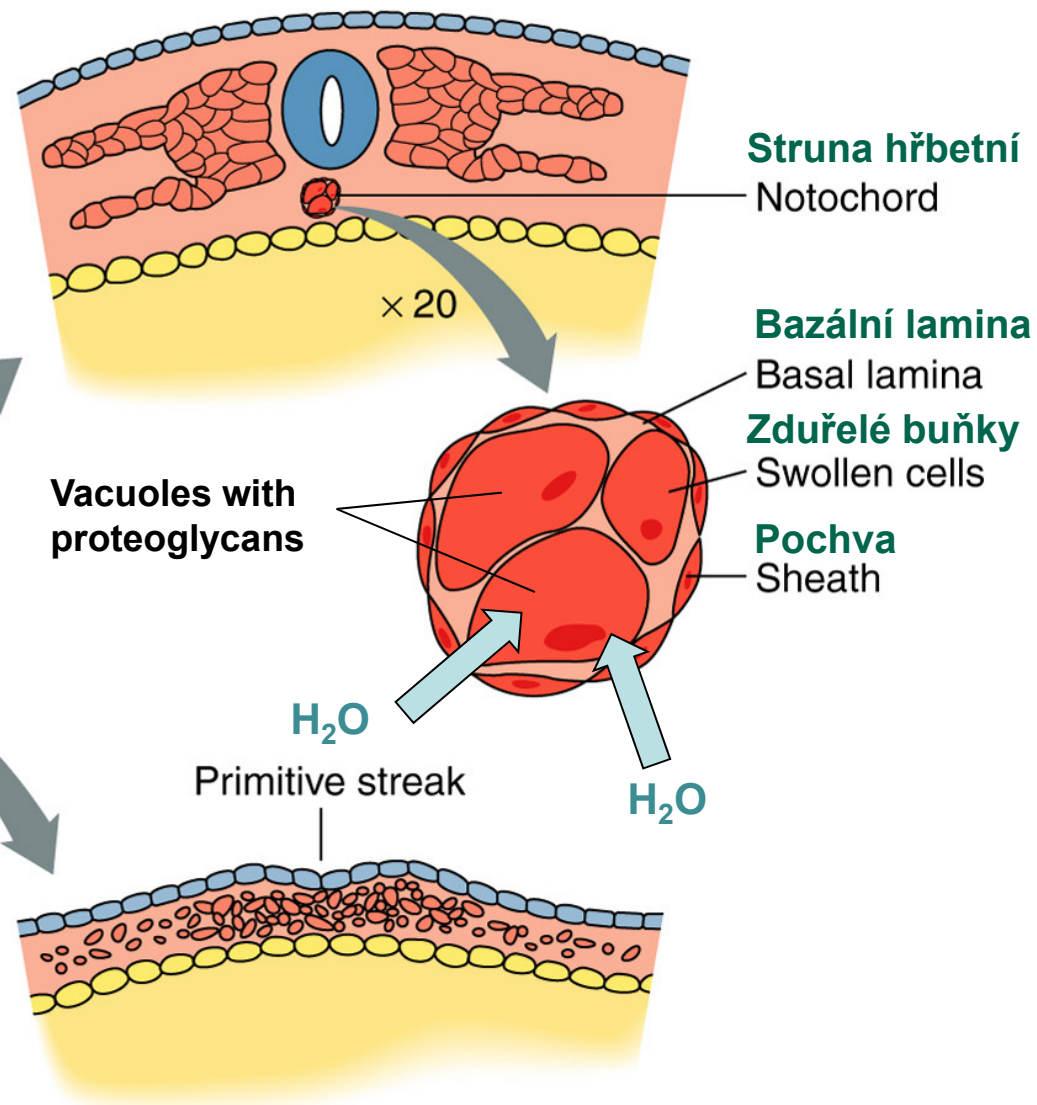
- Mesoderm derivatives development
 - somites formation and signalling



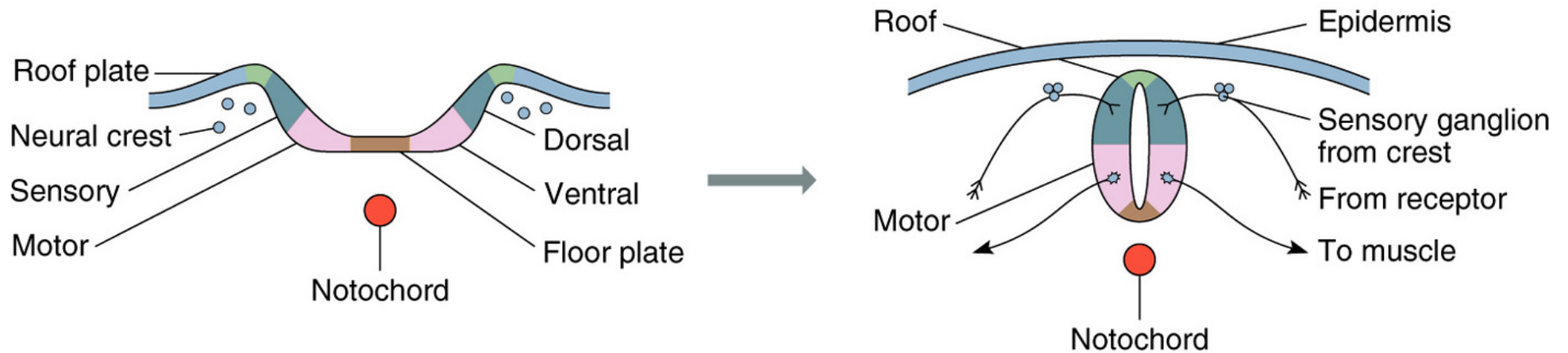
A. Dorsal View



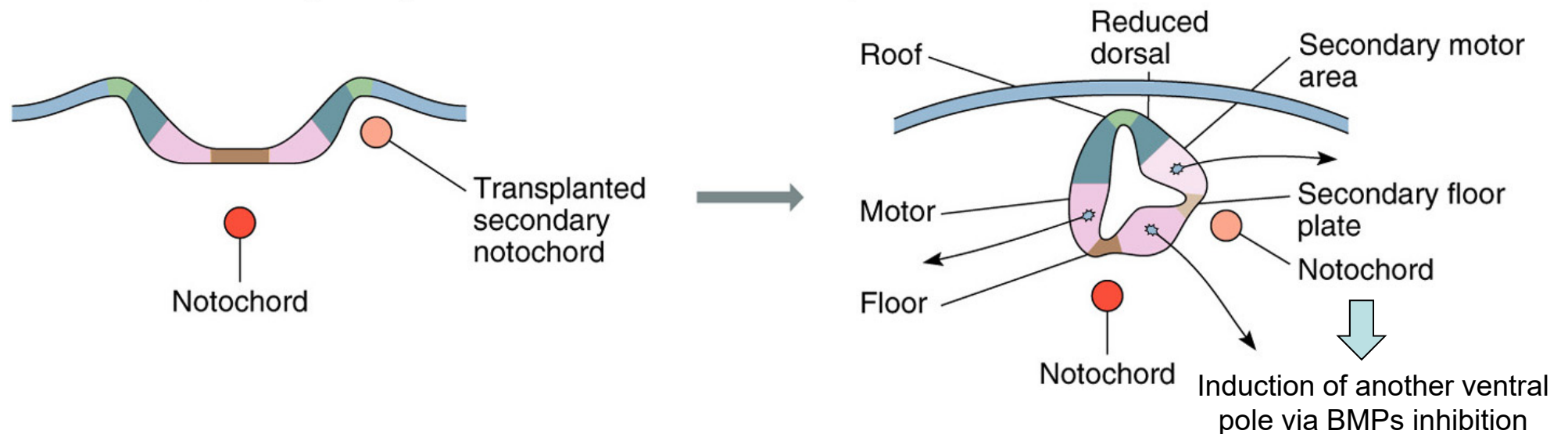
B. Cross-sectional views



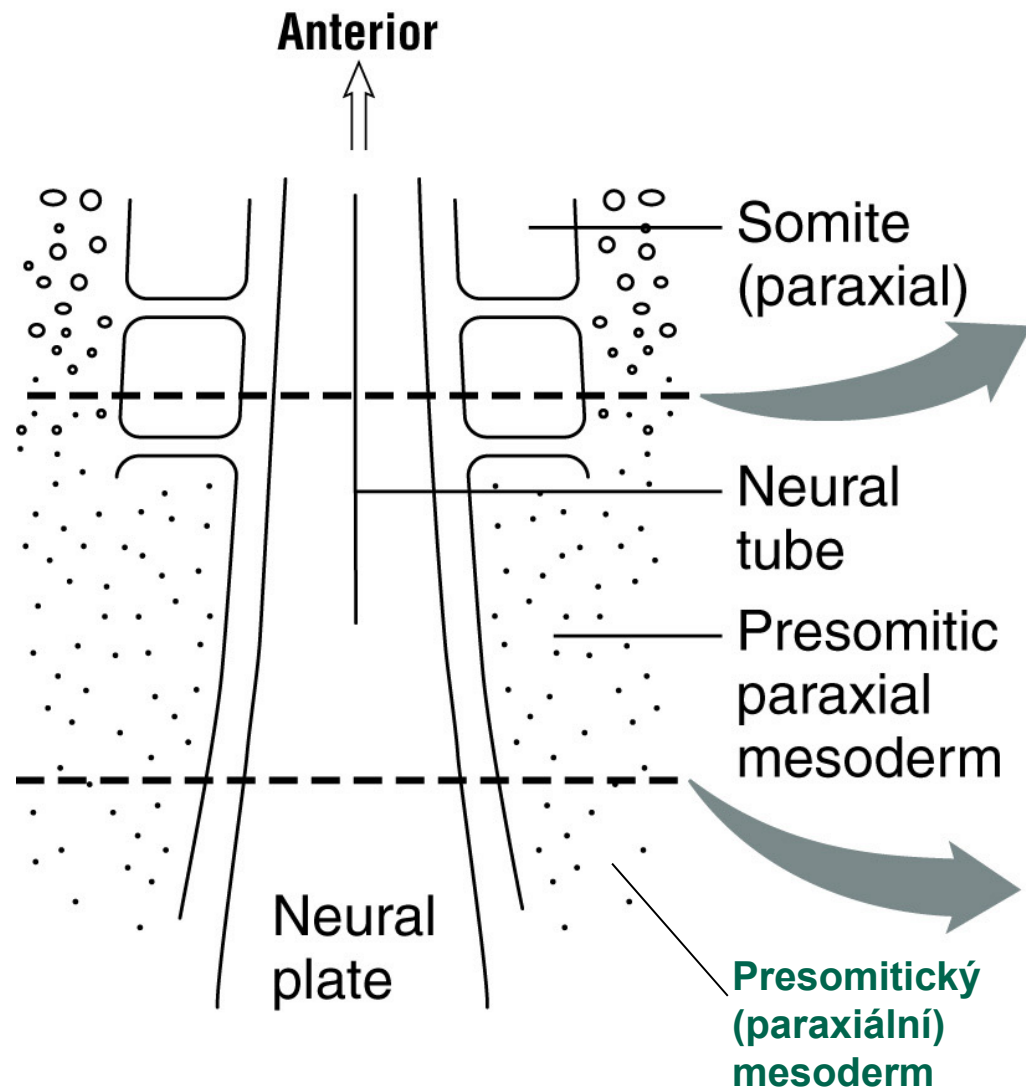
A. The basic situation



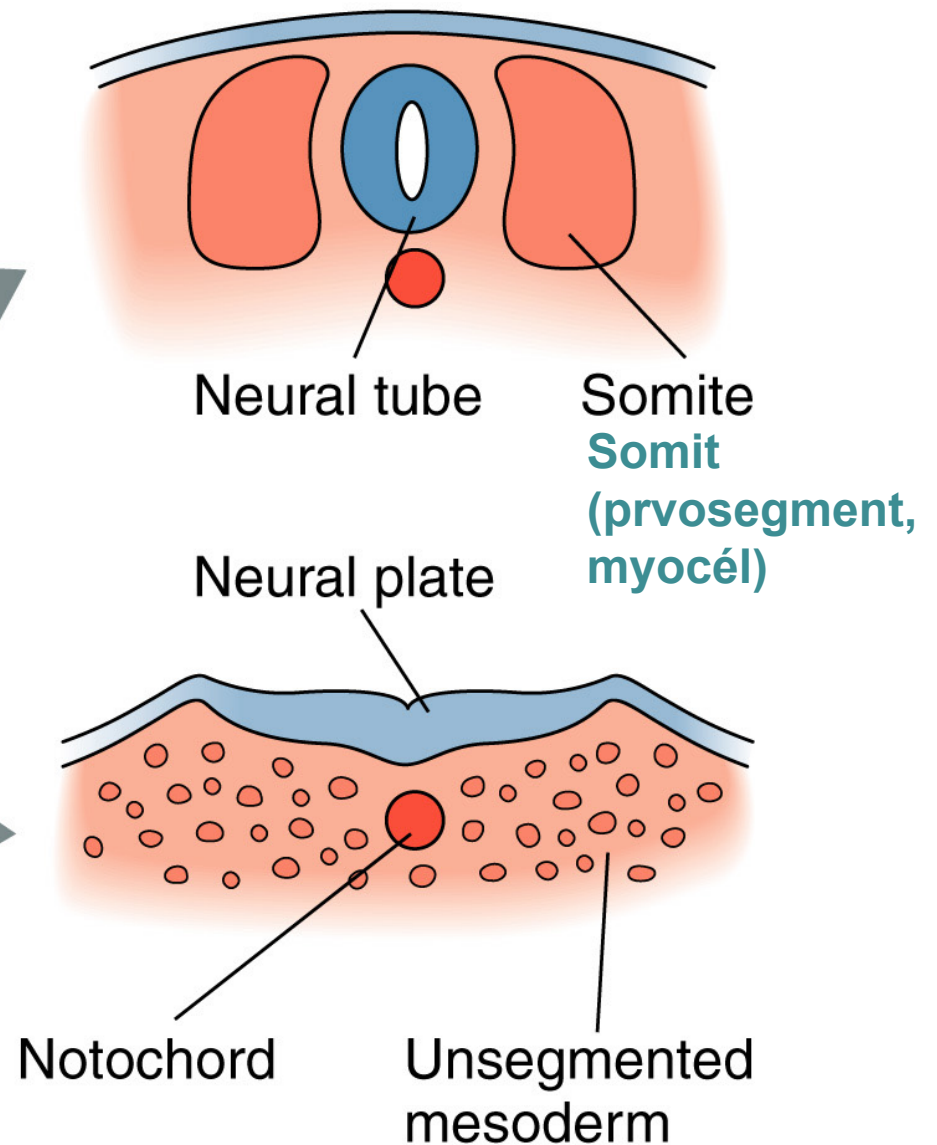
B. Effect of secondary, ectopic notochord under the neural plate

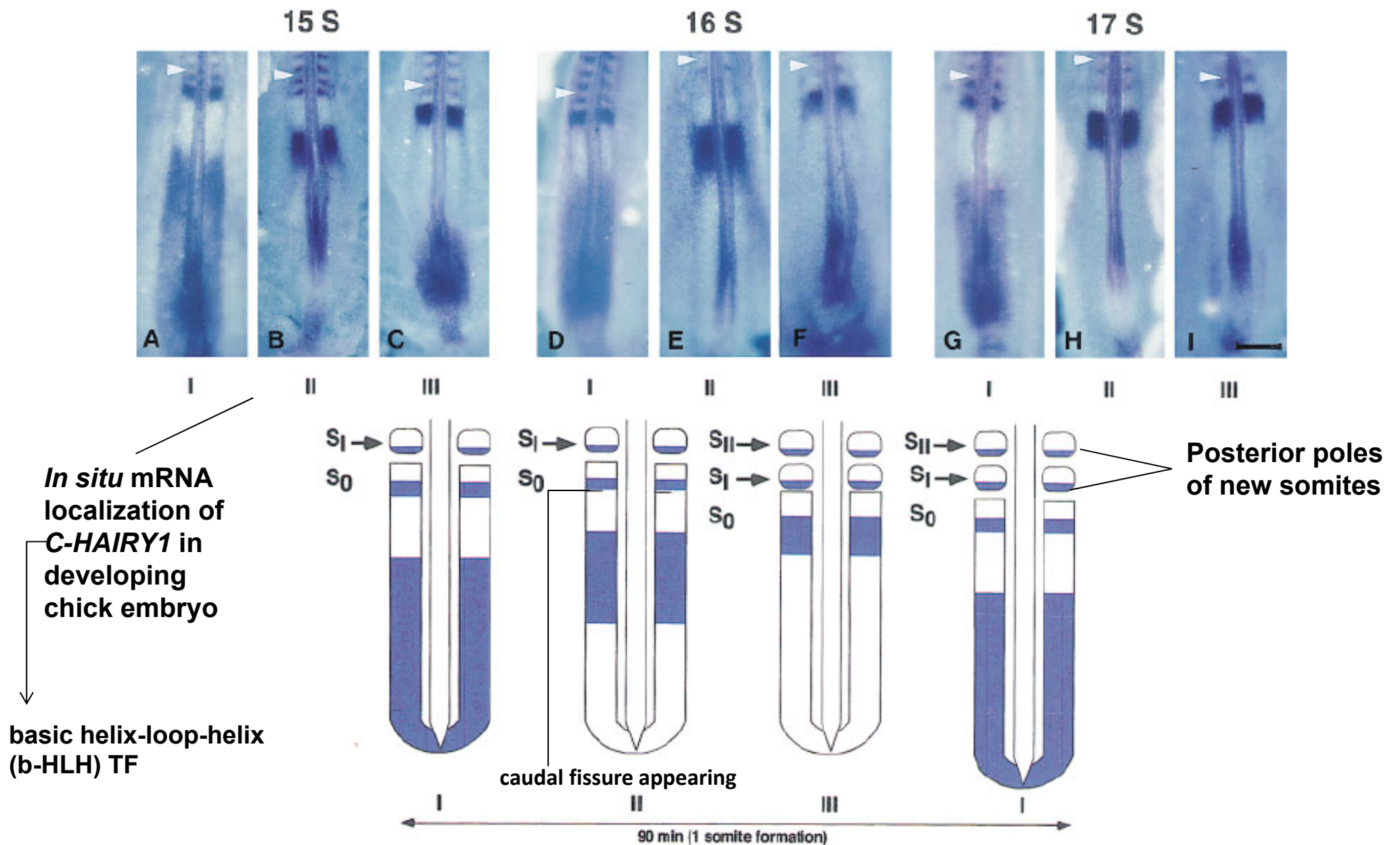


A. Coronal Section

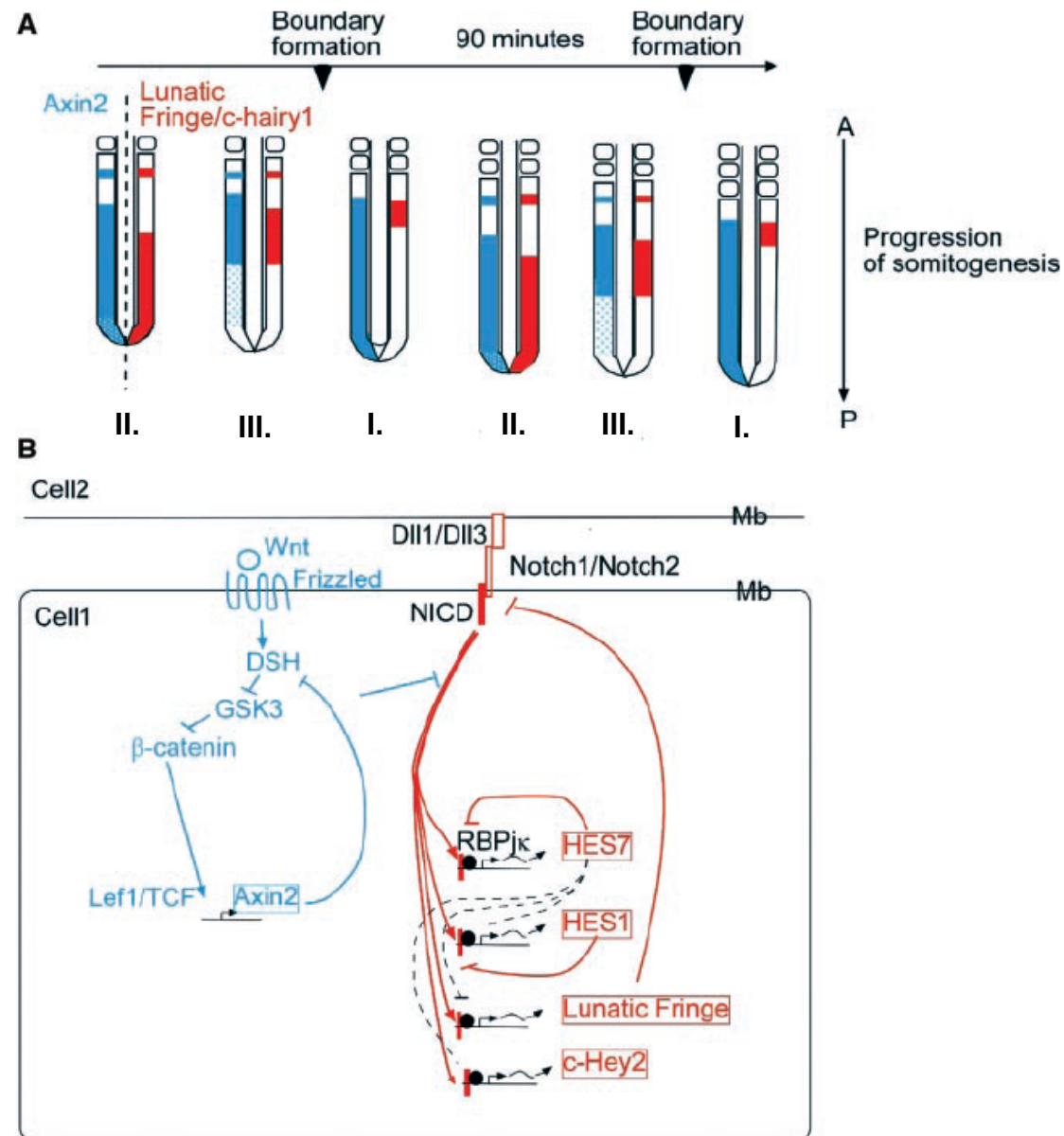


B. Cross Sections

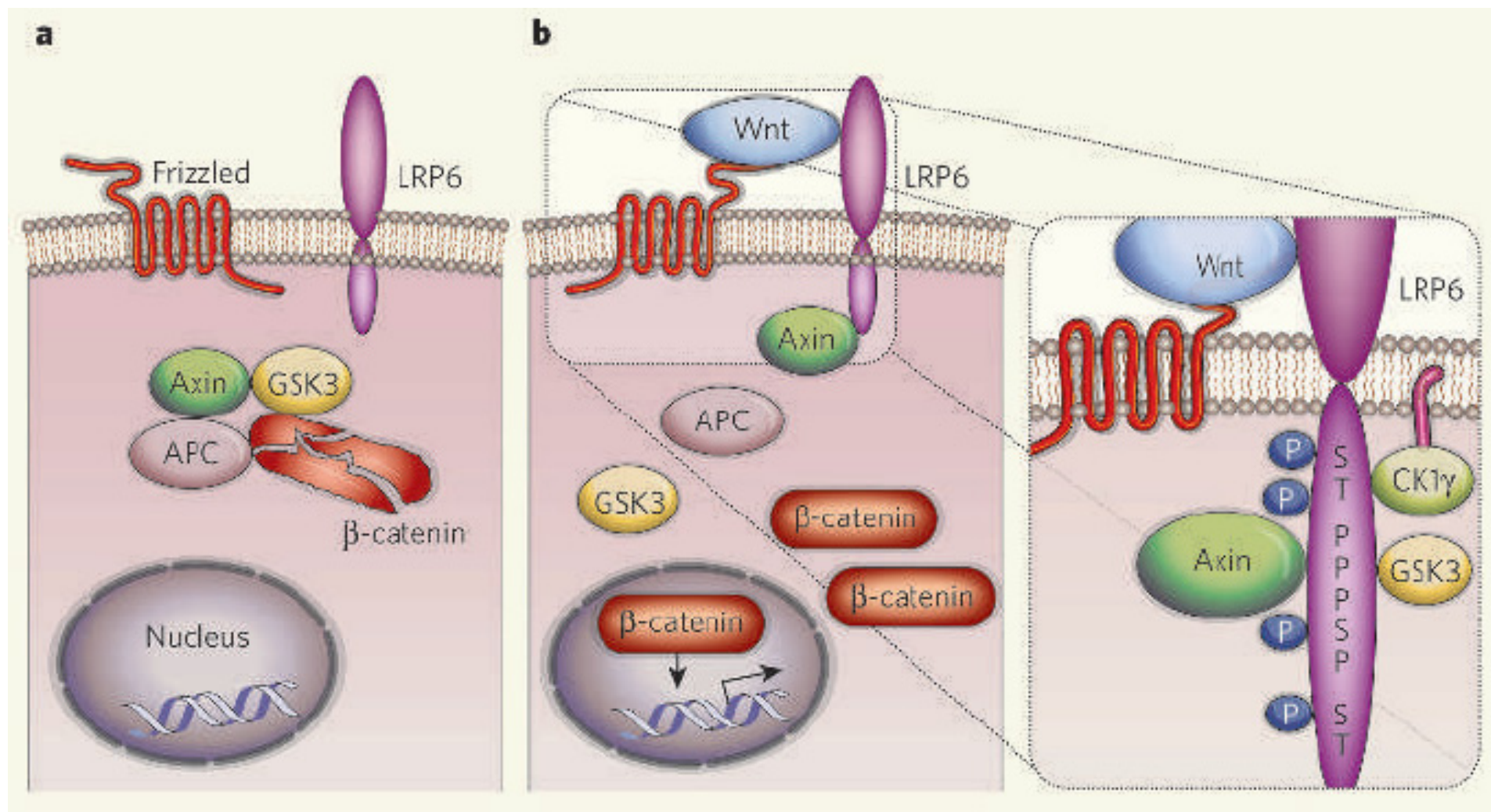




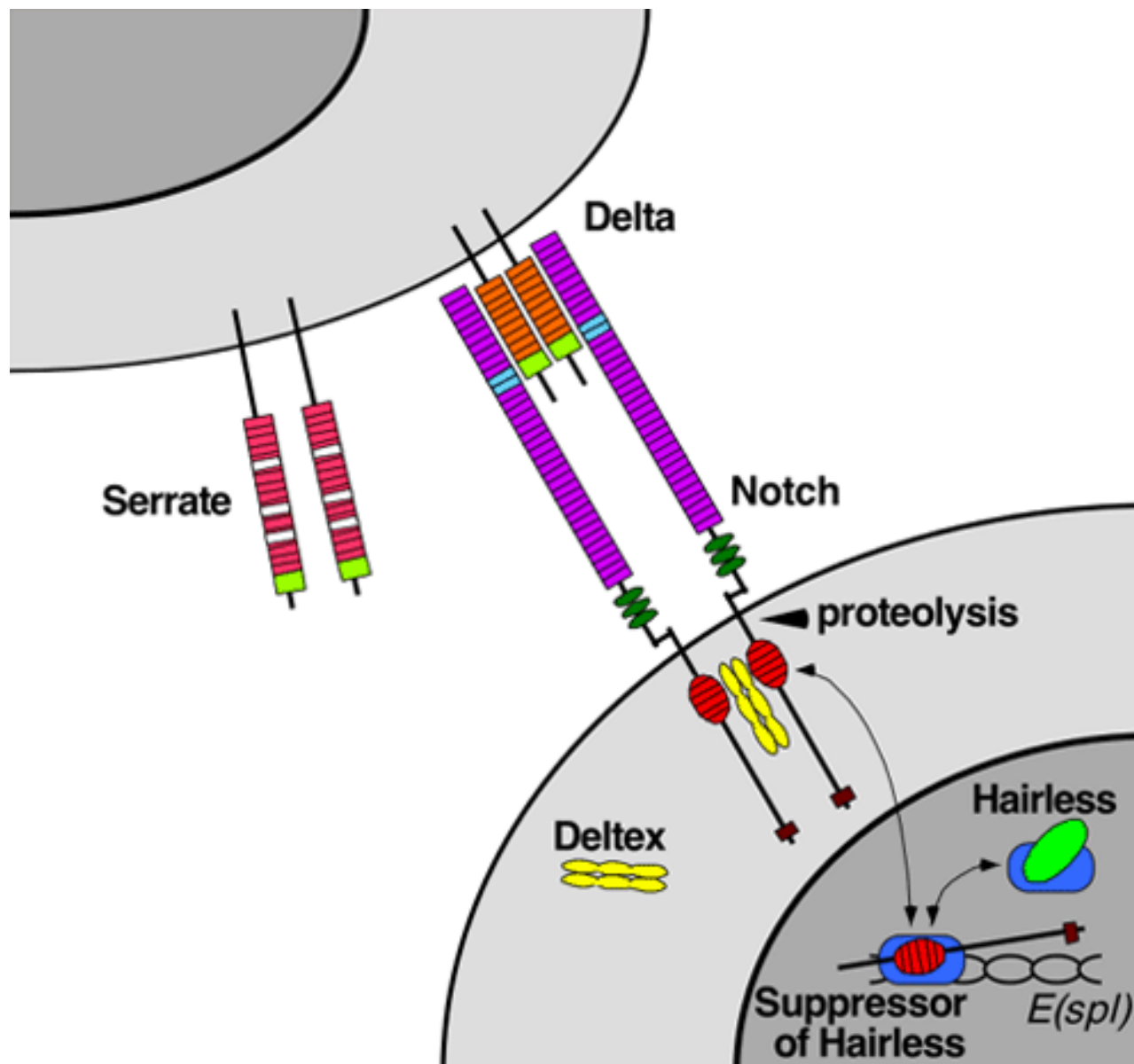
Palmeirim et al., *Cell* (1997)



Pourquie., *Science* (2003)



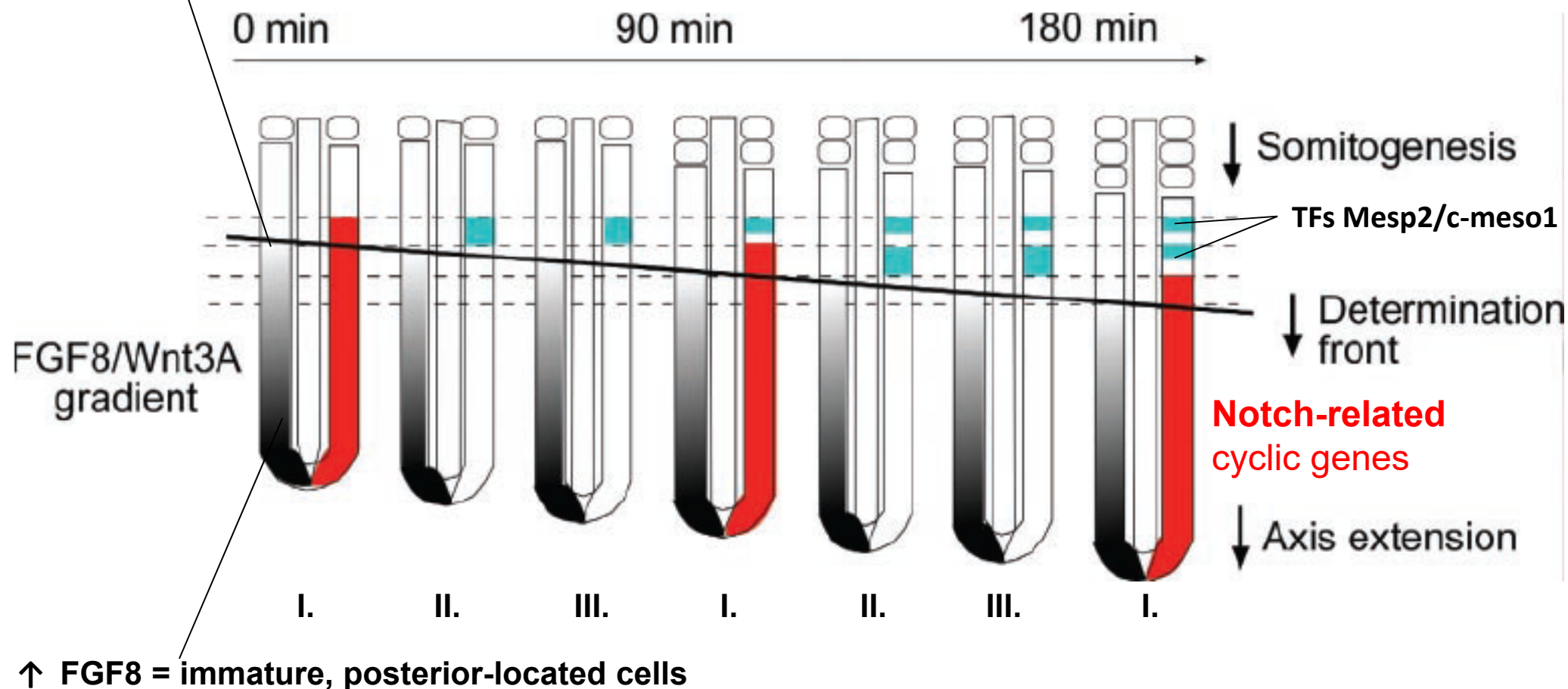
Nusse, *Nature* (2005)



Wikipedia

↓ FGF8 = mature, anterior-located cells - "determination front"

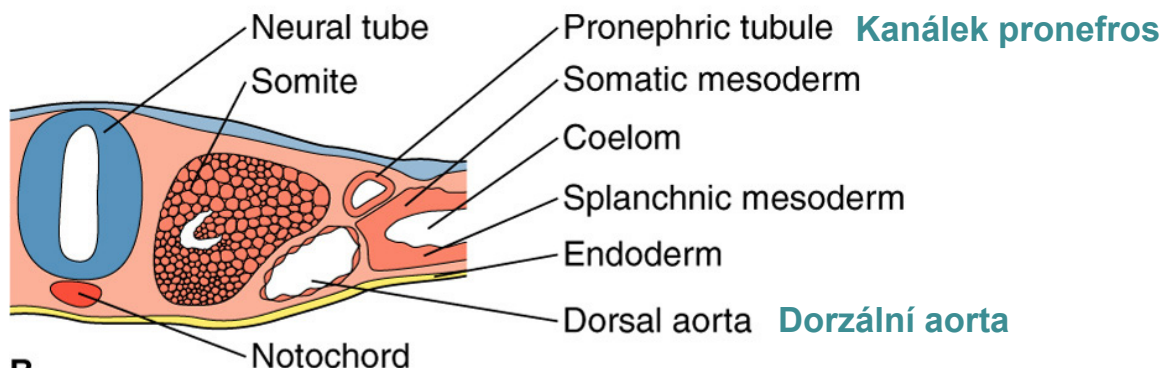
activation of segmentation program, ↑ *Paraxis*, ↓ posterior genes (e.g. *Brachyury*), stopping oscillation genes



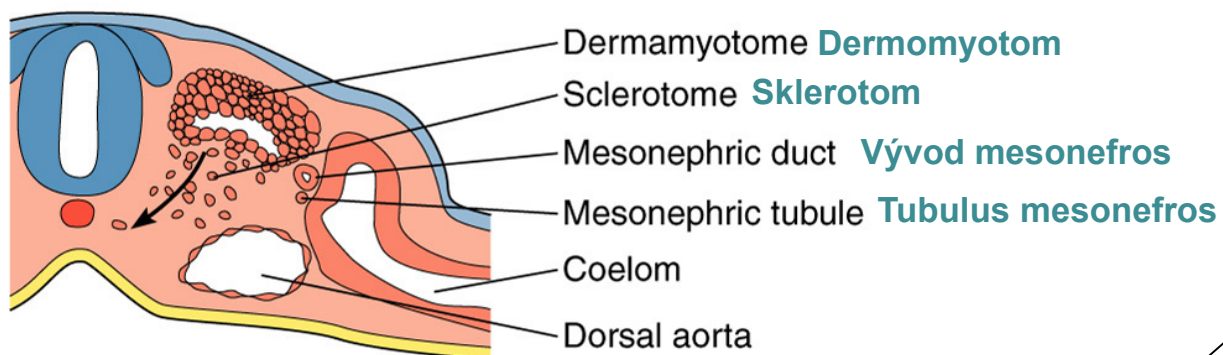
↑ FGF8 = immature, posterior-located cells

Pourquie., *Science* (2003)

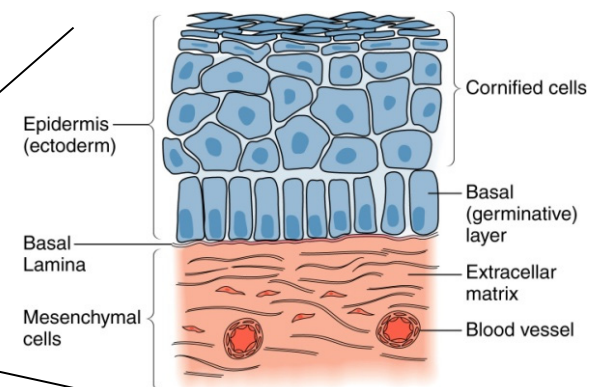
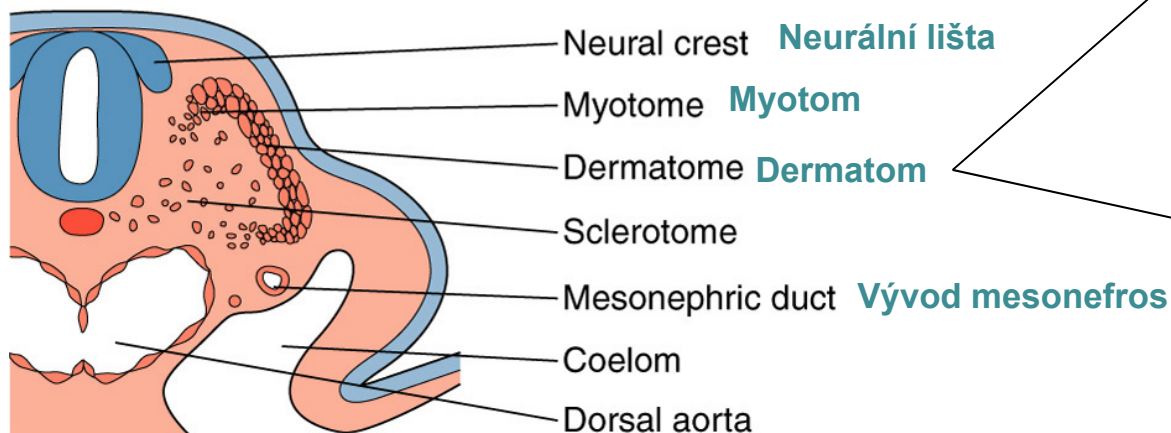
A.

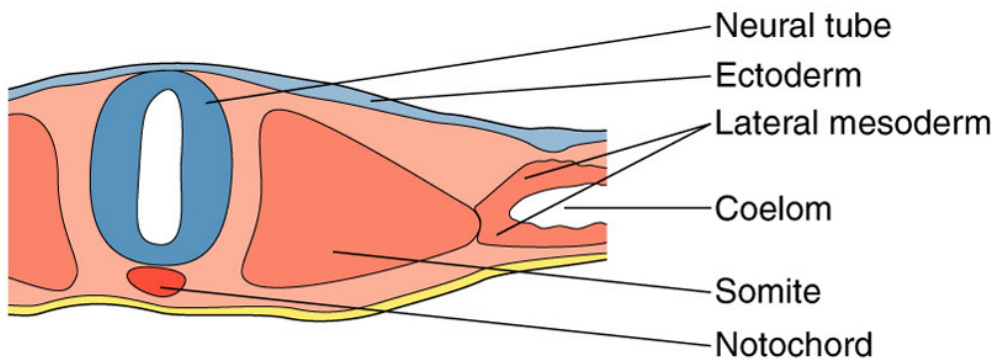


B.




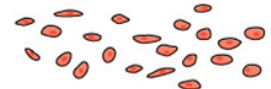

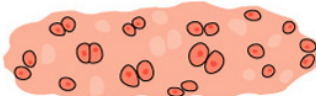

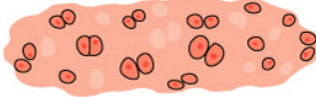

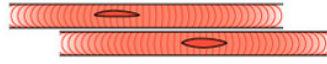

C.





Remove somite and culture:

To get:

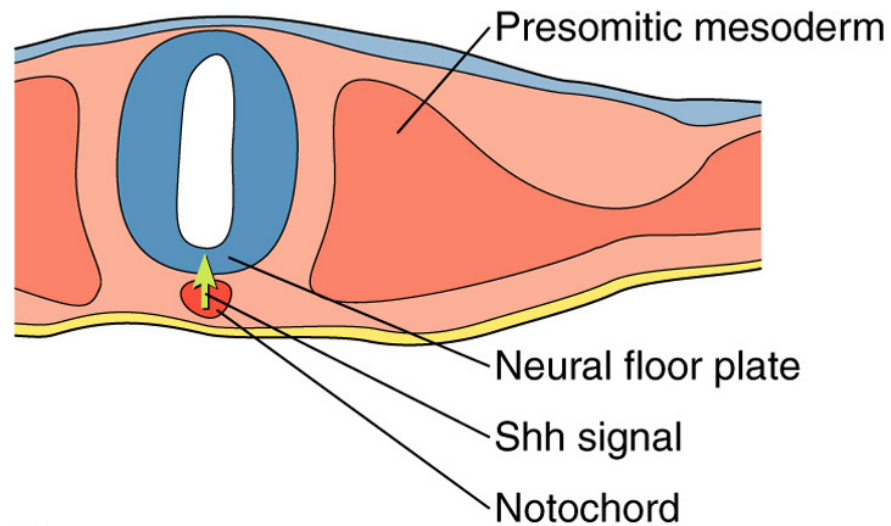
- A. Very young somite alone** → Mesenchyme
 → 
- B. With notochord** → Cartilage
 → 
- C. With ventral neural tube** → Cartilage
 → 
- D. With dorsal neural tube** → Striated muscle
 → 
- E. With ectoderm or lateral mesoderm** → Delayed formation of striated muscle


Importance of intercellular communications

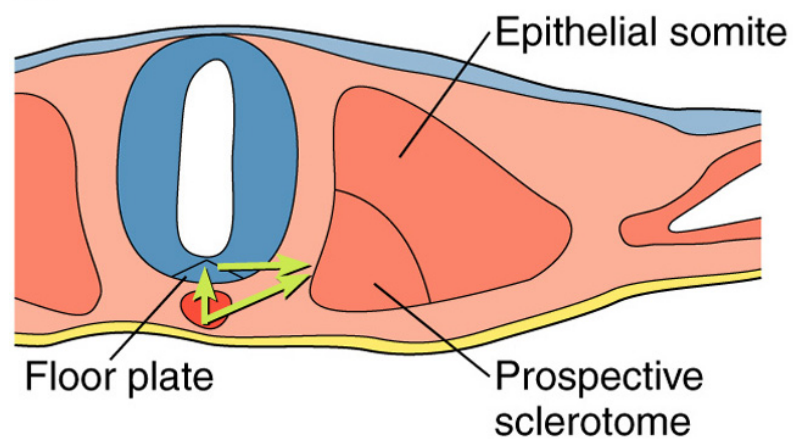


- **MYOD, MYF5**
 - Muscle cells specific TFs
- **Mouse DELTA homologue**
 - Somites segmentation signalling

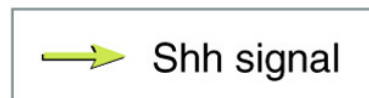
A.



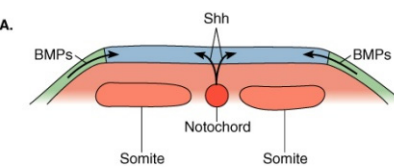
B.



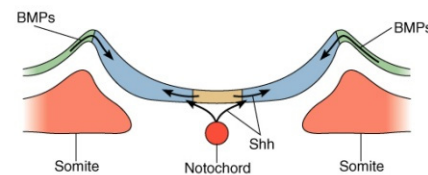
KEY



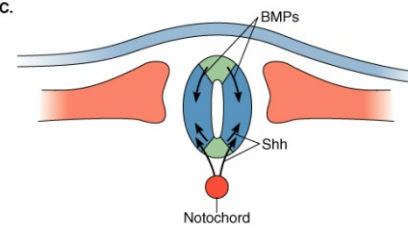
A.



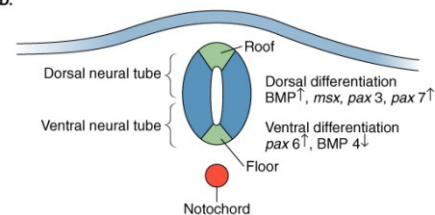
B.



C.



D.



Expression of muscle-specific TFs

Dermamytome differentiation thanks to WNT and BMPs signalling

Ectoderm

Dermamytome

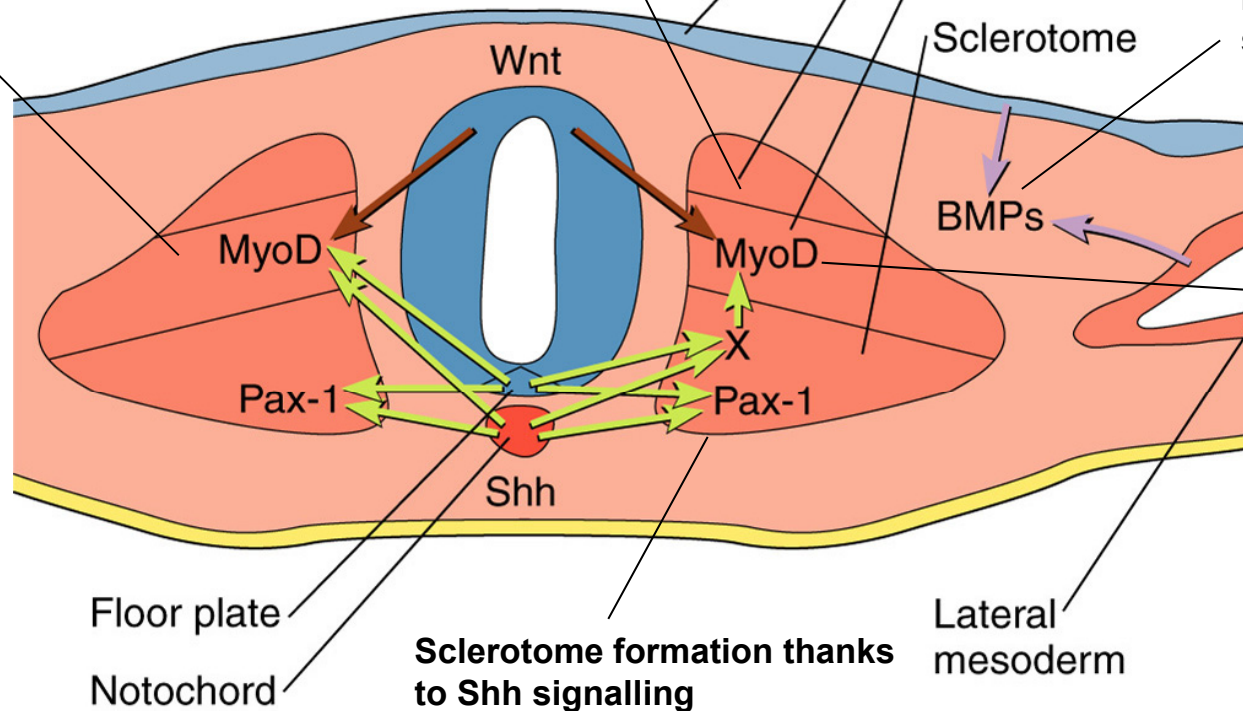
Myotome

Sclerotome

Ectoderm and lateral mesoderm derived signals

BMPs

Muscle-specific TFs



KEY

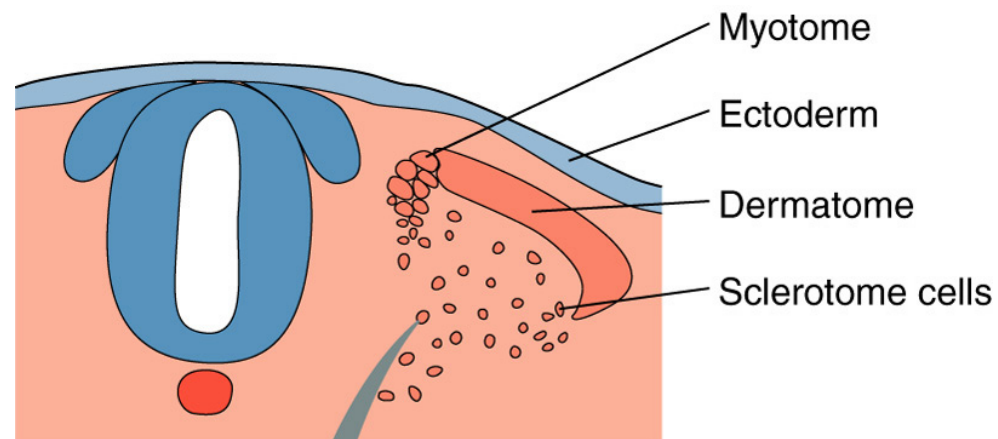




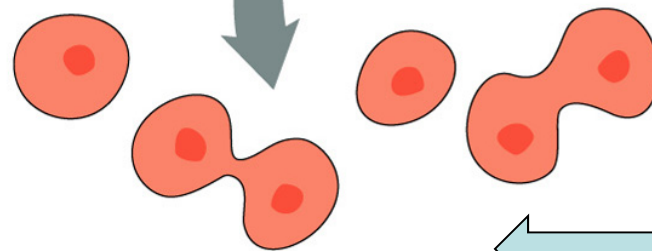
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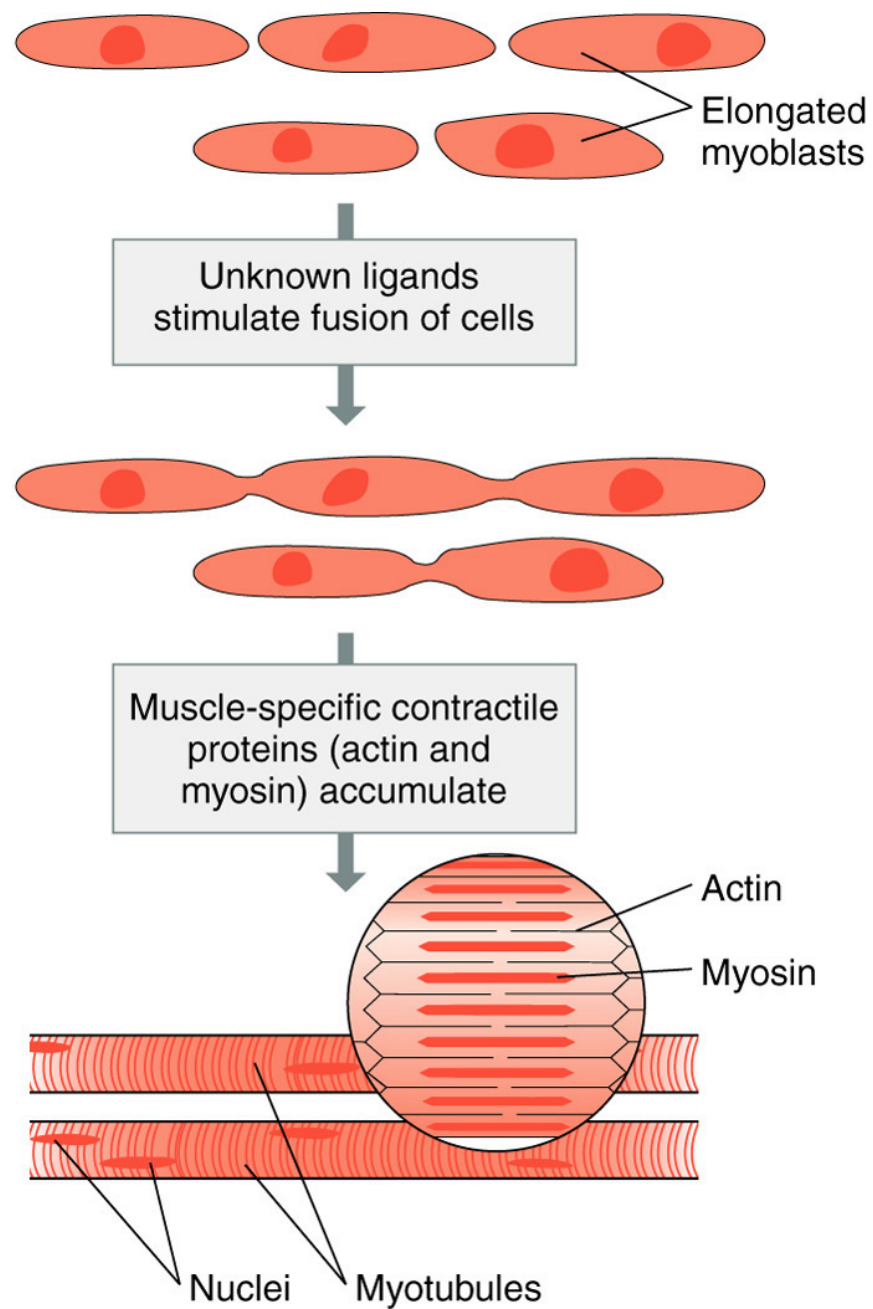


Myoblasts within myotome region proliferate



Cell division ceases

Unknown signal
(e.g. poor medium under *in vitro* conditions)

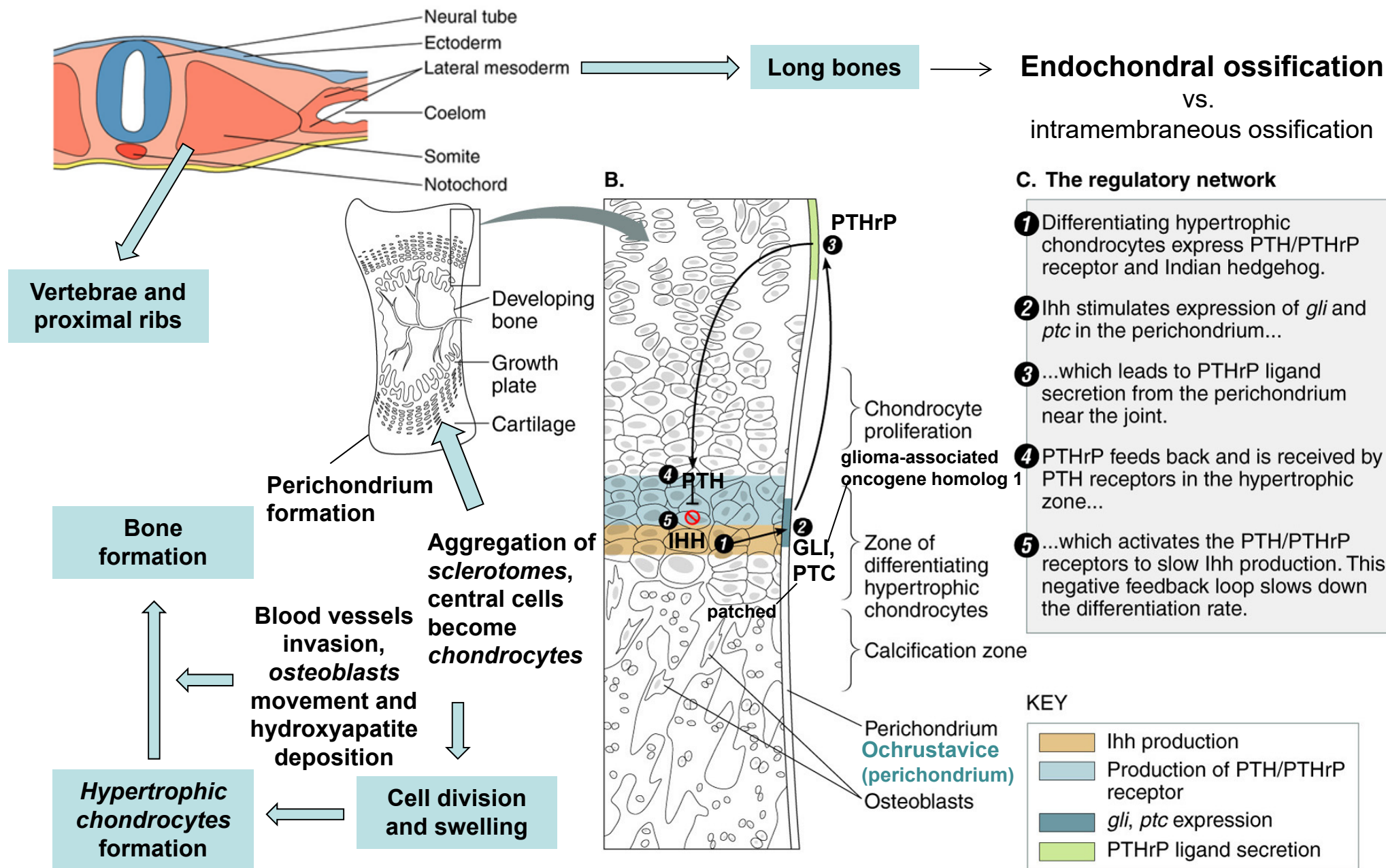




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- Mesoderm derivatives development
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 - formation of muscles
 - endochordal ossification and signalling



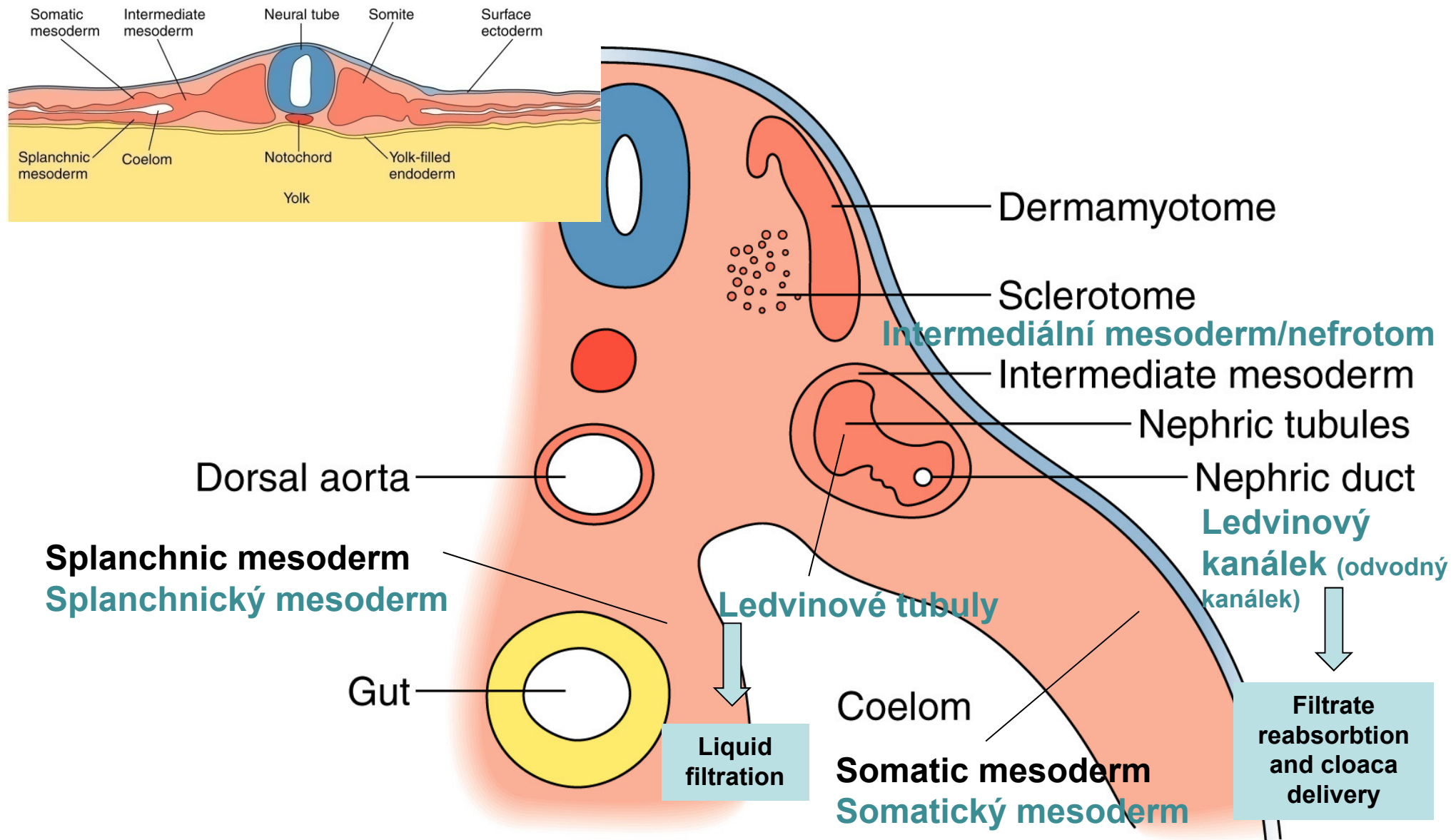


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 - nephrogenesis

B.



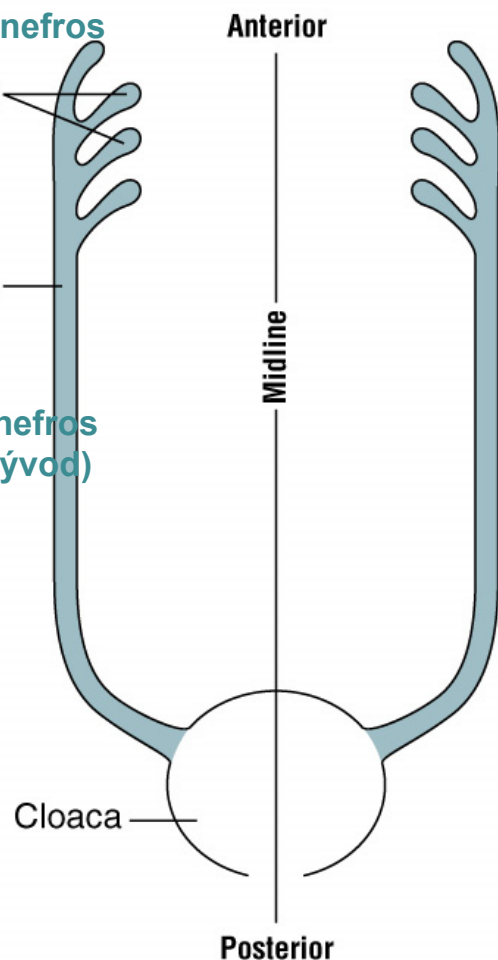
A. Pronephros

Tubuly pronefros

Pronephric tubules

Pronephric (Wolffian) duct

Vývod pronefros (Wolffioho vývod)



sliznatky (bezčelistnatí)
hagfishes (Agnatha)

B. Mesonephros

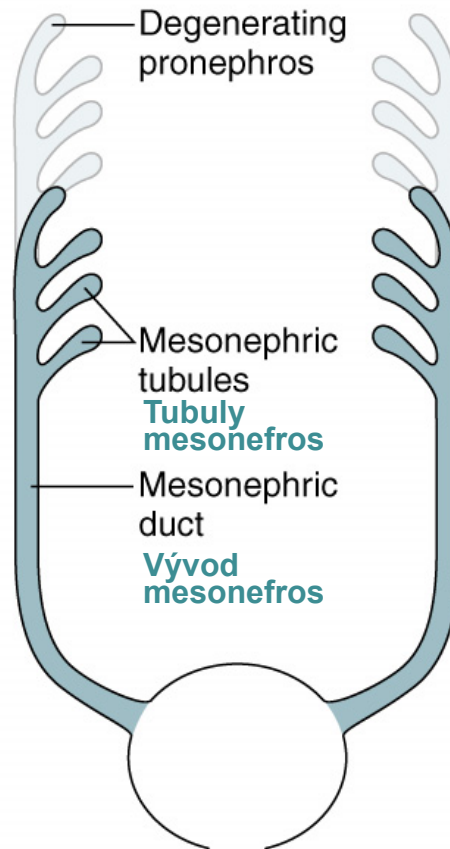
Degenerating pronephros

Mesonephric tubules

Tubuly mesonefros

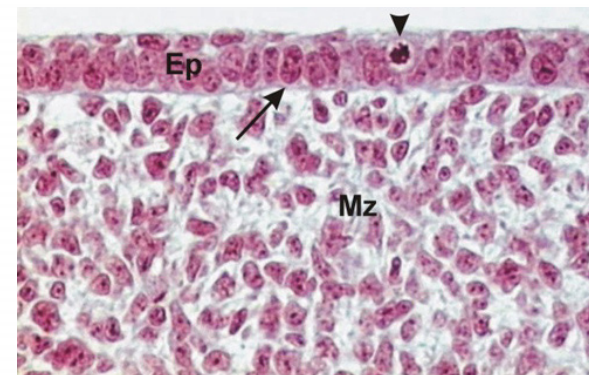
Mesonephric duct

Vývod mesonefros

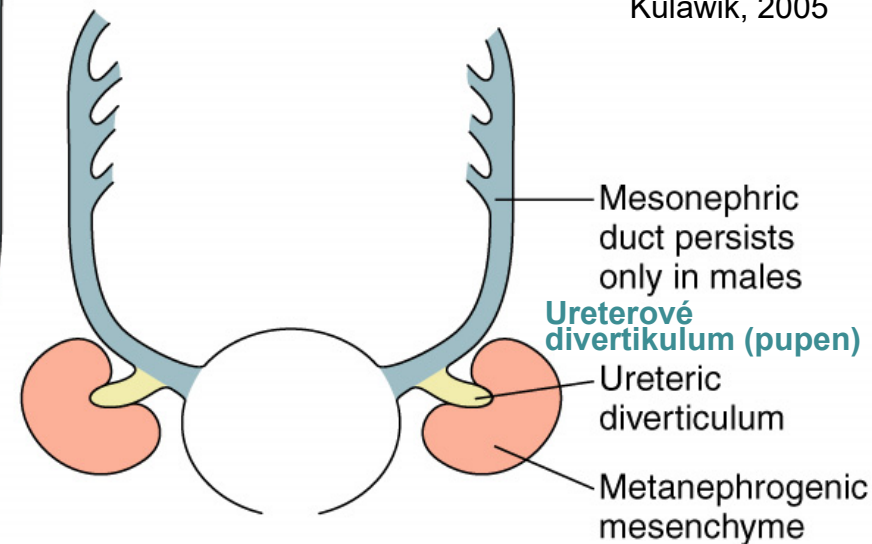


amphibians, fishes

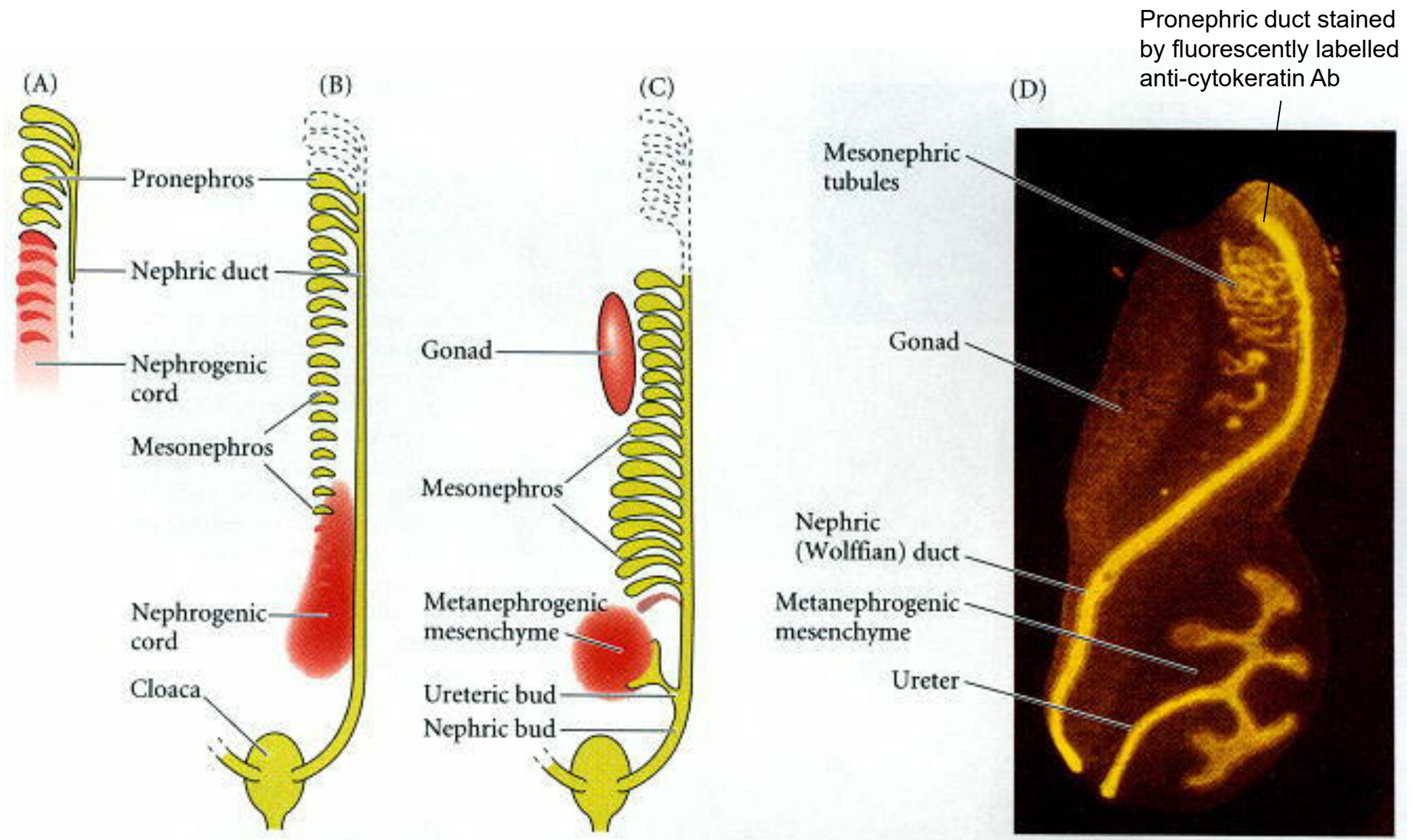
C. Metanephros



Kulawik, 2005

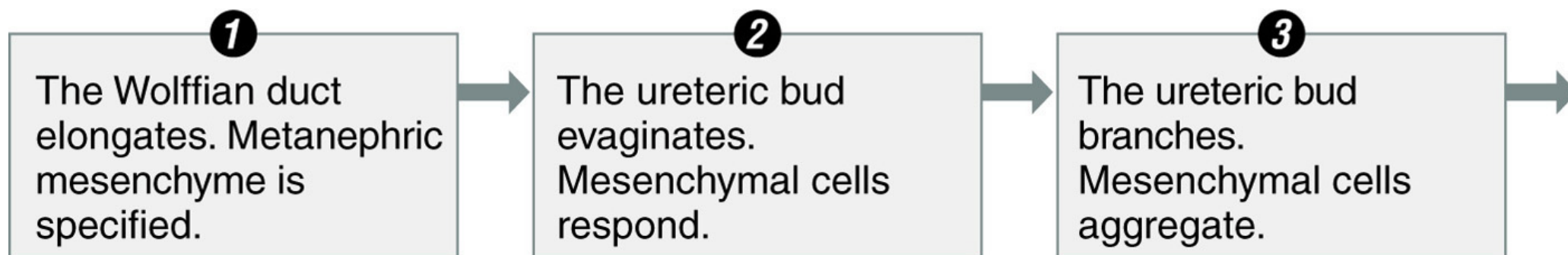
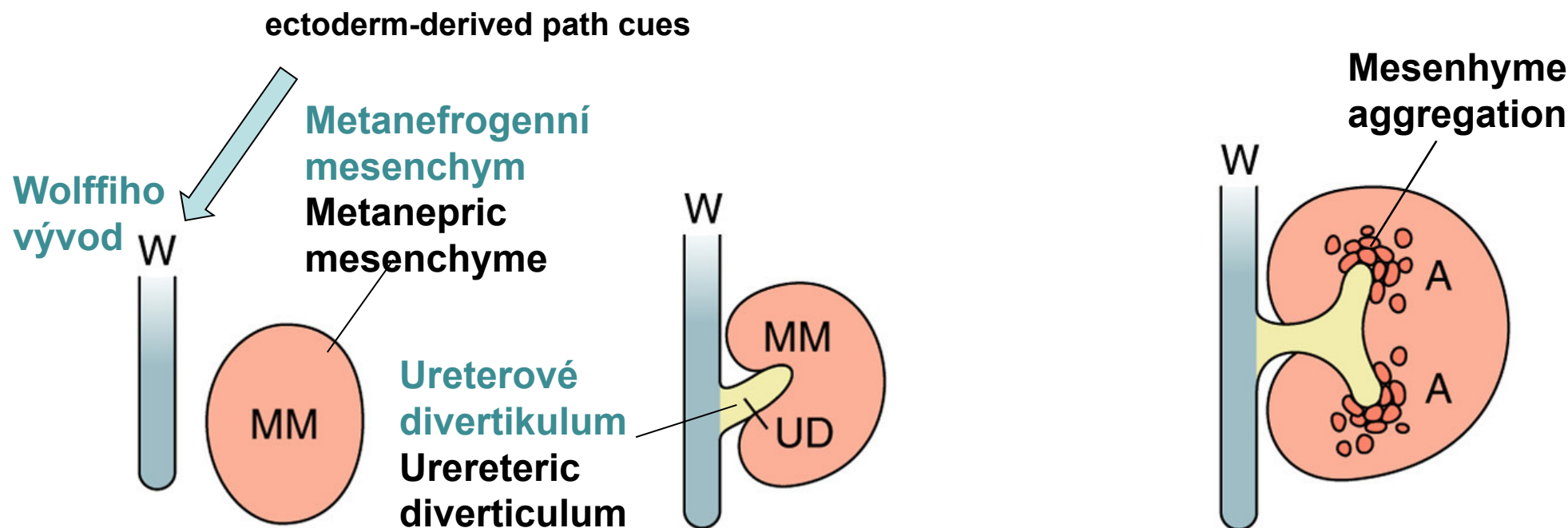


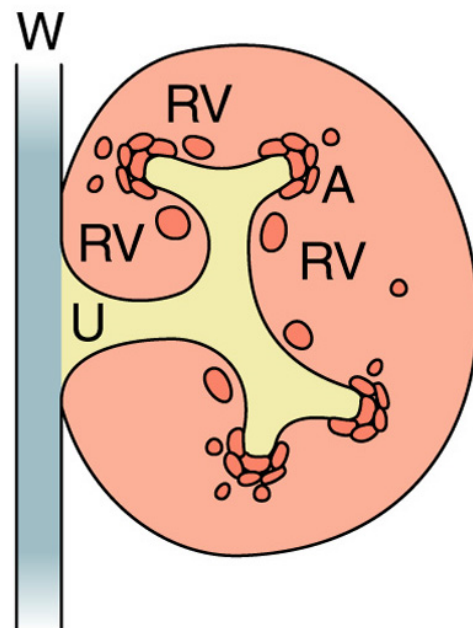
amniotes



Gilbert, SF, Developmental biology

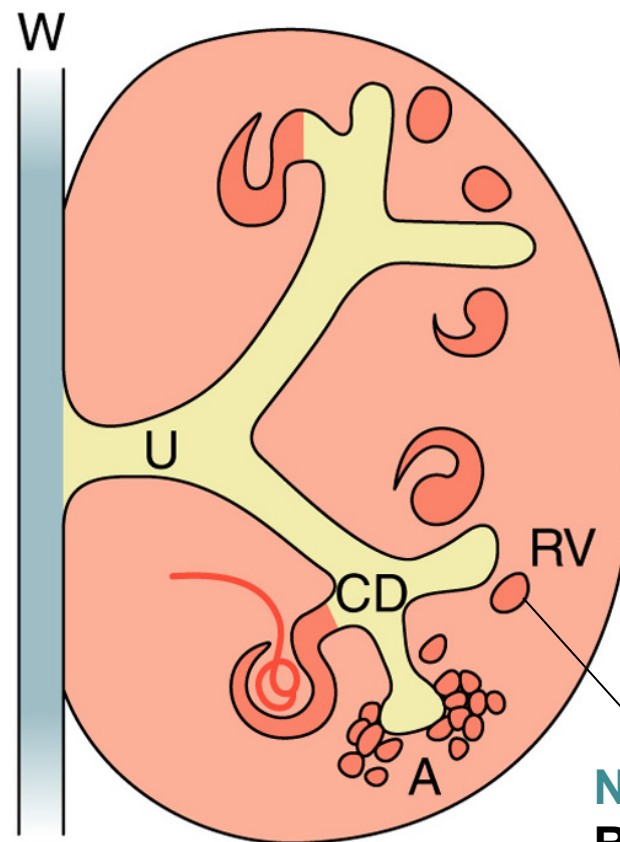
Intermediate mesoderm of a 13-day mouse embryo





4

Renal vesicles form.
Branching and
aggregation continues.

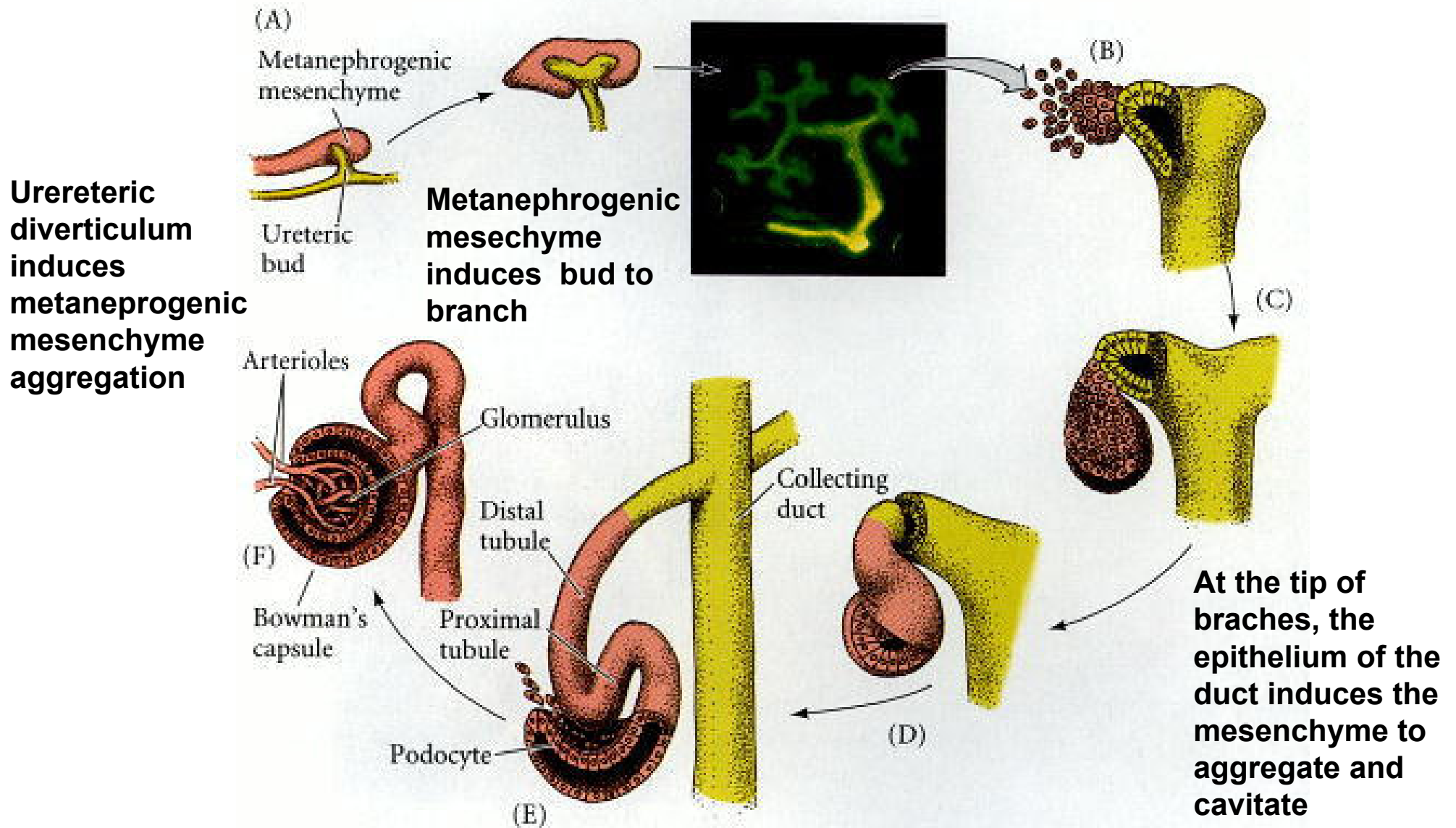


5

Epithelium differen-
tiates and tubules form.
Glomeruli vascularize.
Branching and
aggregation continue.

Nefrogenní váček
Renal vesicle

Reciprocal induction in kidney development



Gilbert, SF, Developmental biology

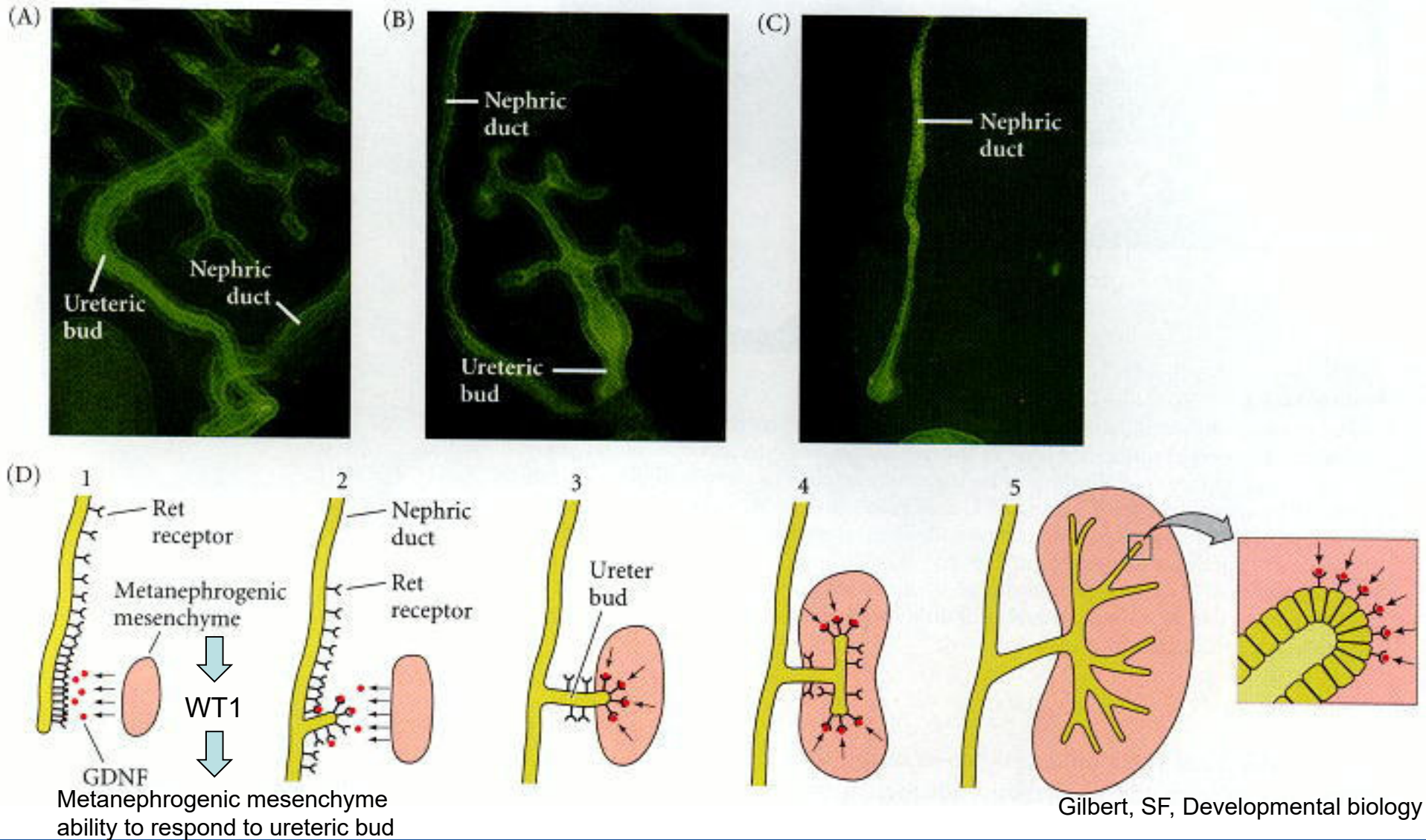
Reciprocal induction in kidney development

The role of glial-derived neurotrophic factor (GDNF)

GDNF/GDNF

GDNF/gdnf

gdnf/gdnf



Metanefrogenní mesenchym

Primární sběrací kanálek
(vzniká větvením ureterického
divertikula)

Nefrogenní váček

Esovitý kanálek

Henle loop
Henleyova klička

Proximální tubulus

Kapiláry glomerulu

Bowmanův váček

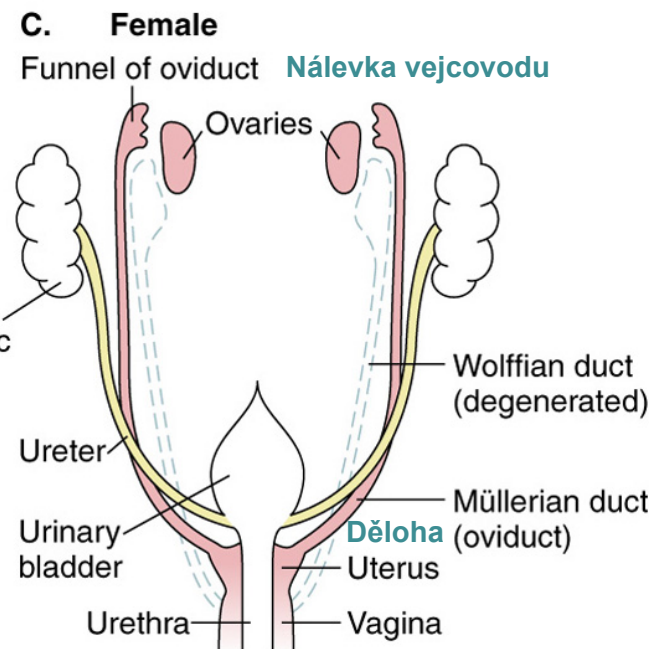
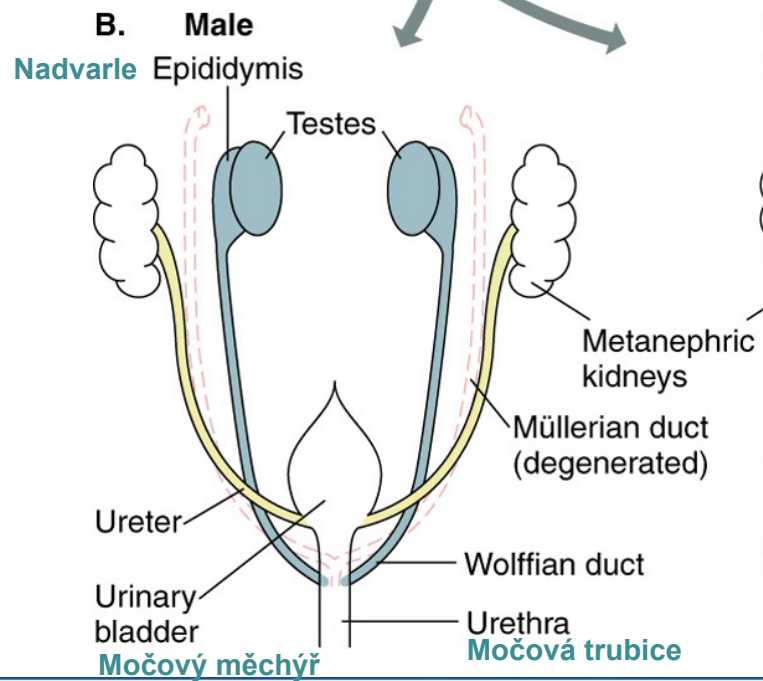
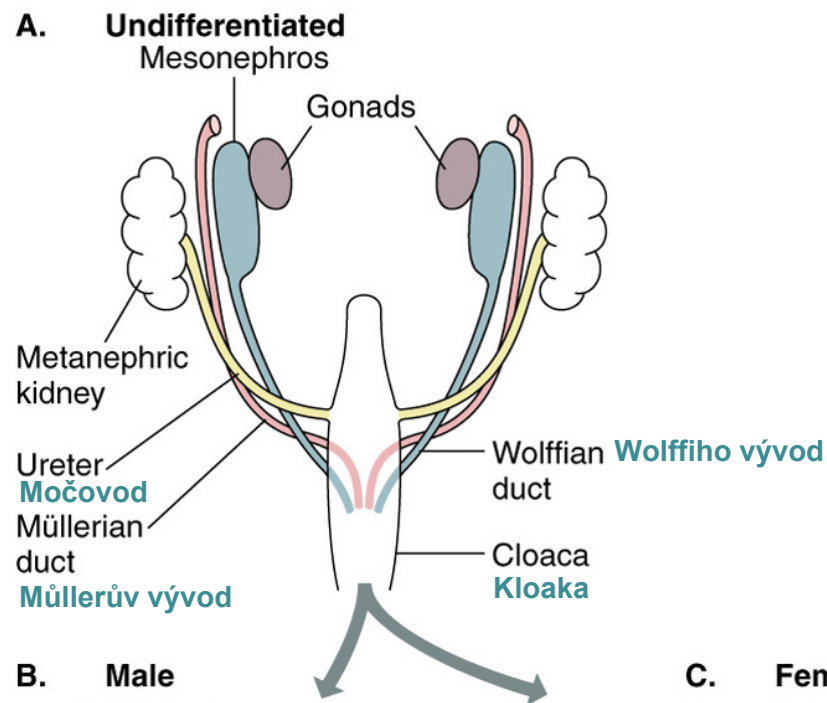
Vacek, Embryologie (2006)



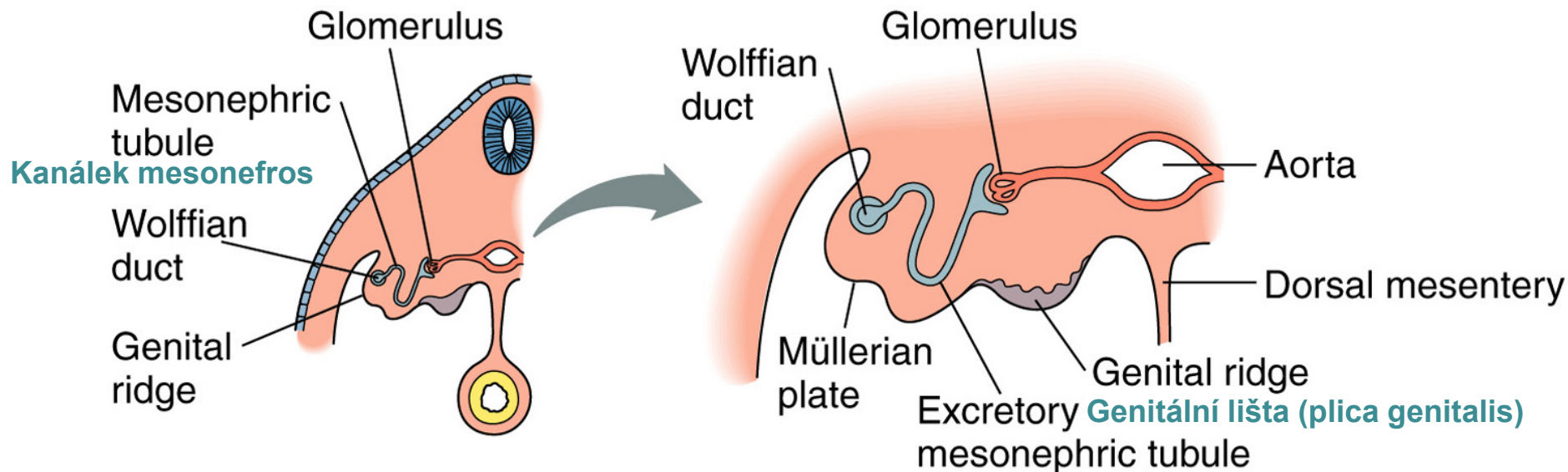
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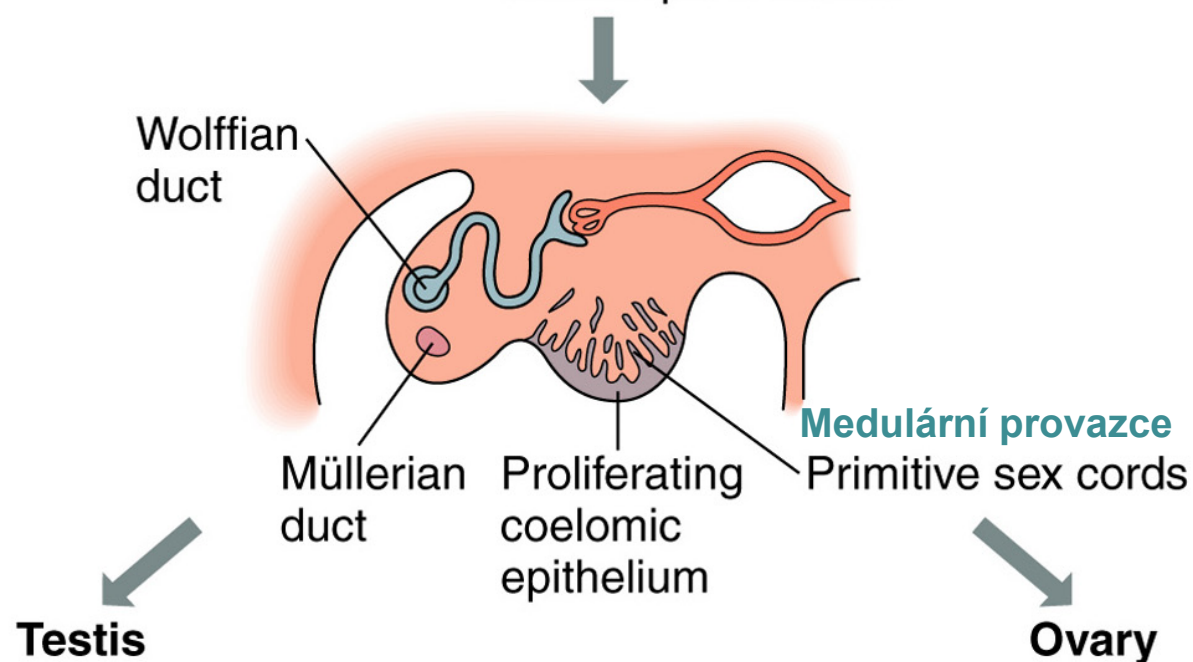
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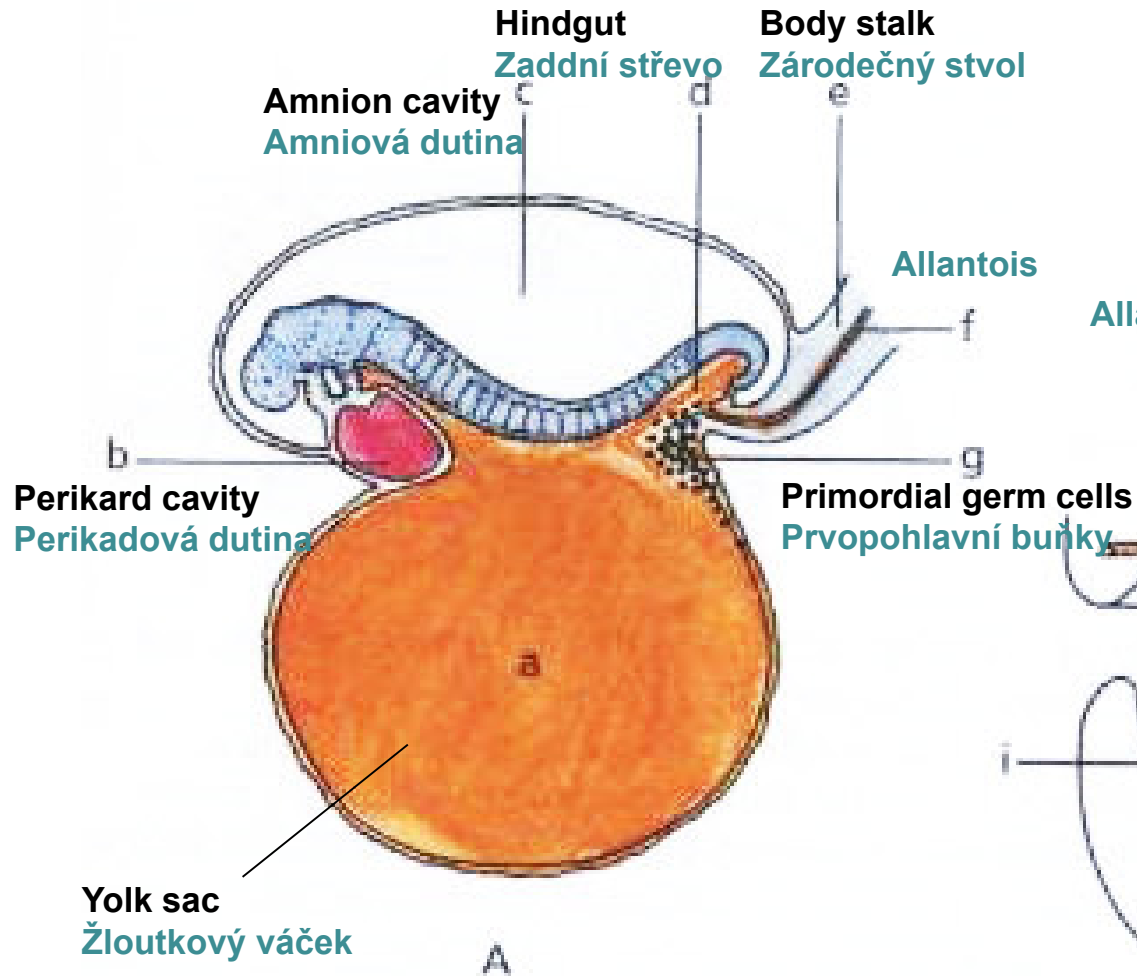
A. 4 Weeks



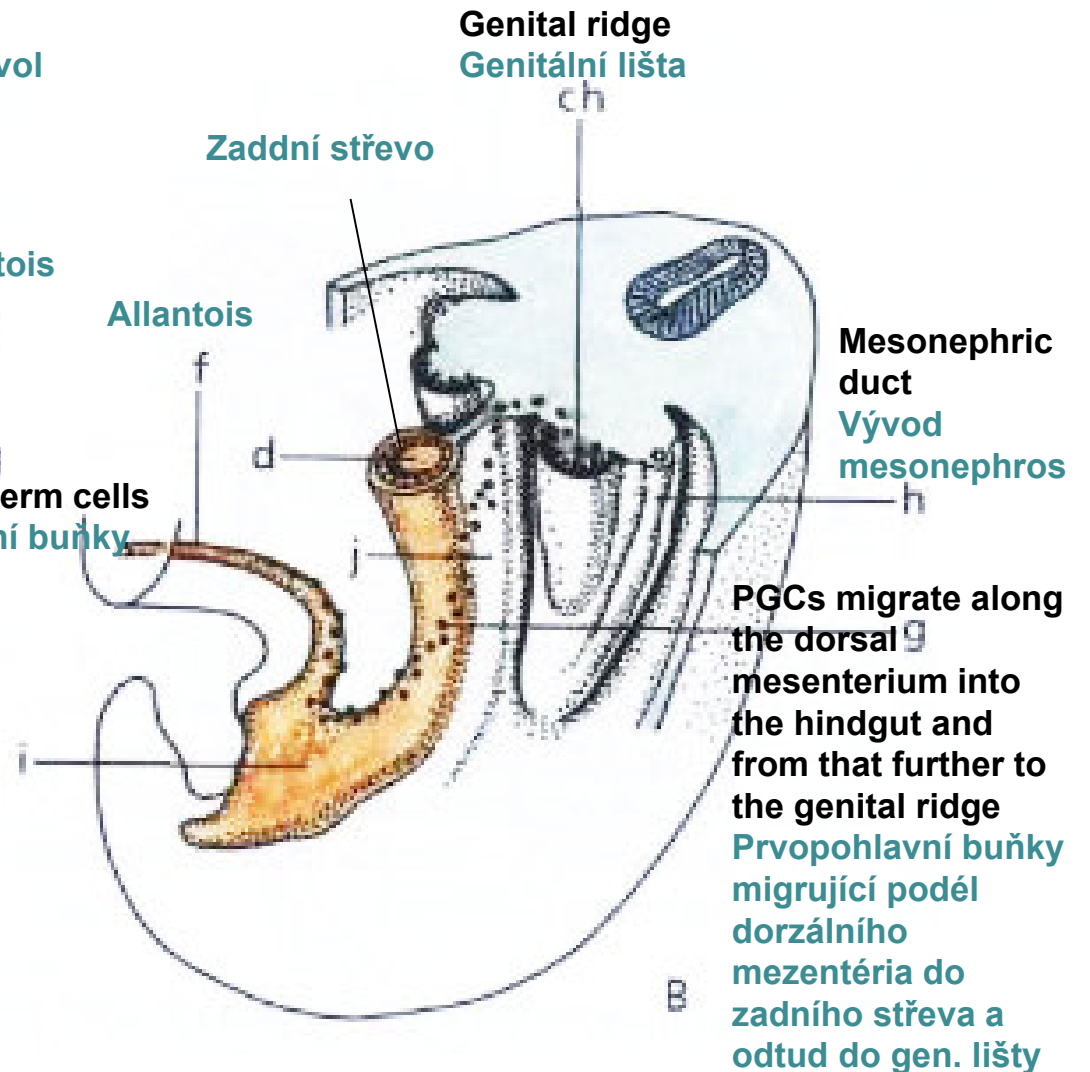
B. 6 Weeks



20-days-old human embryo

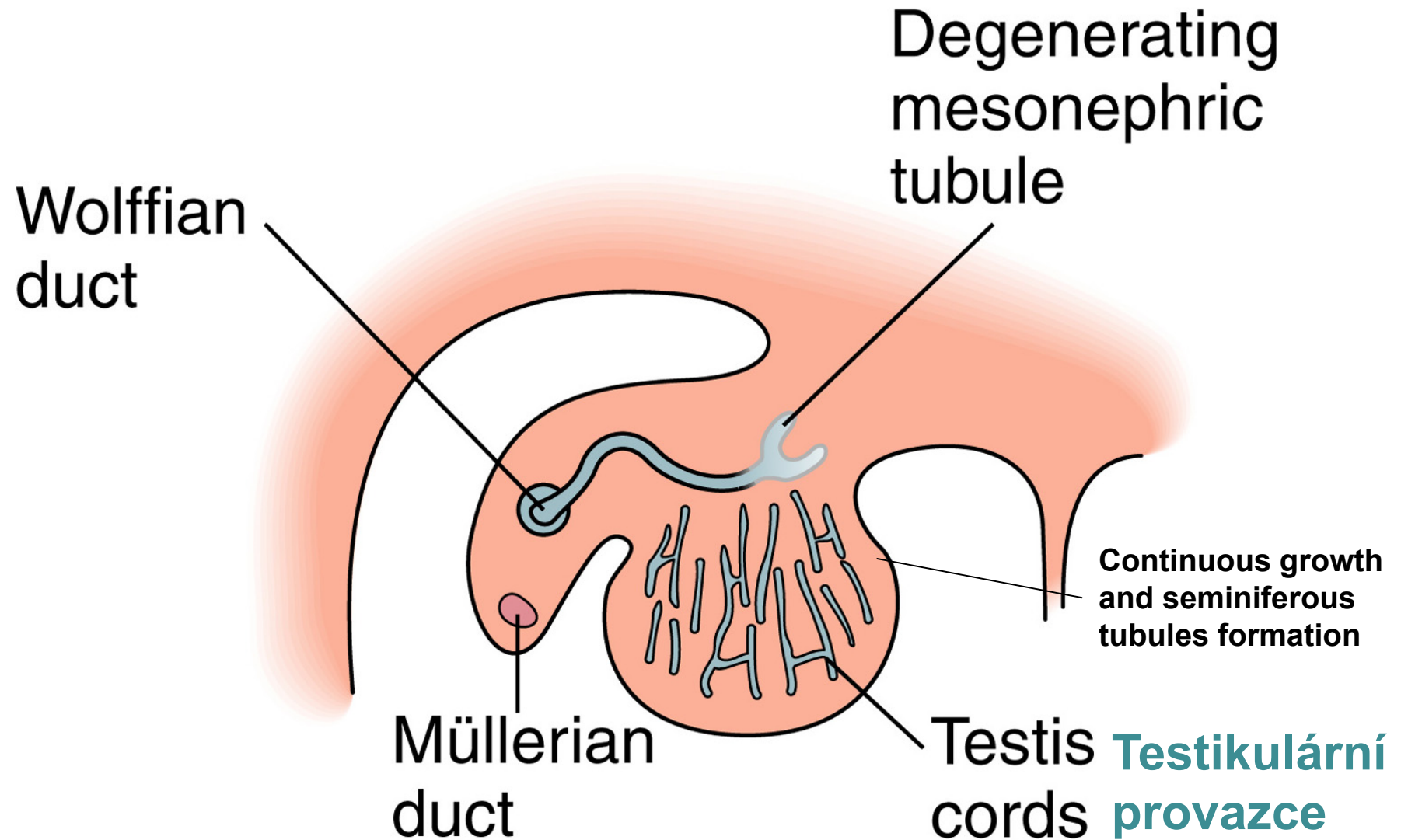


26-days-old human embryo



Vacek, Embryologie (2006)

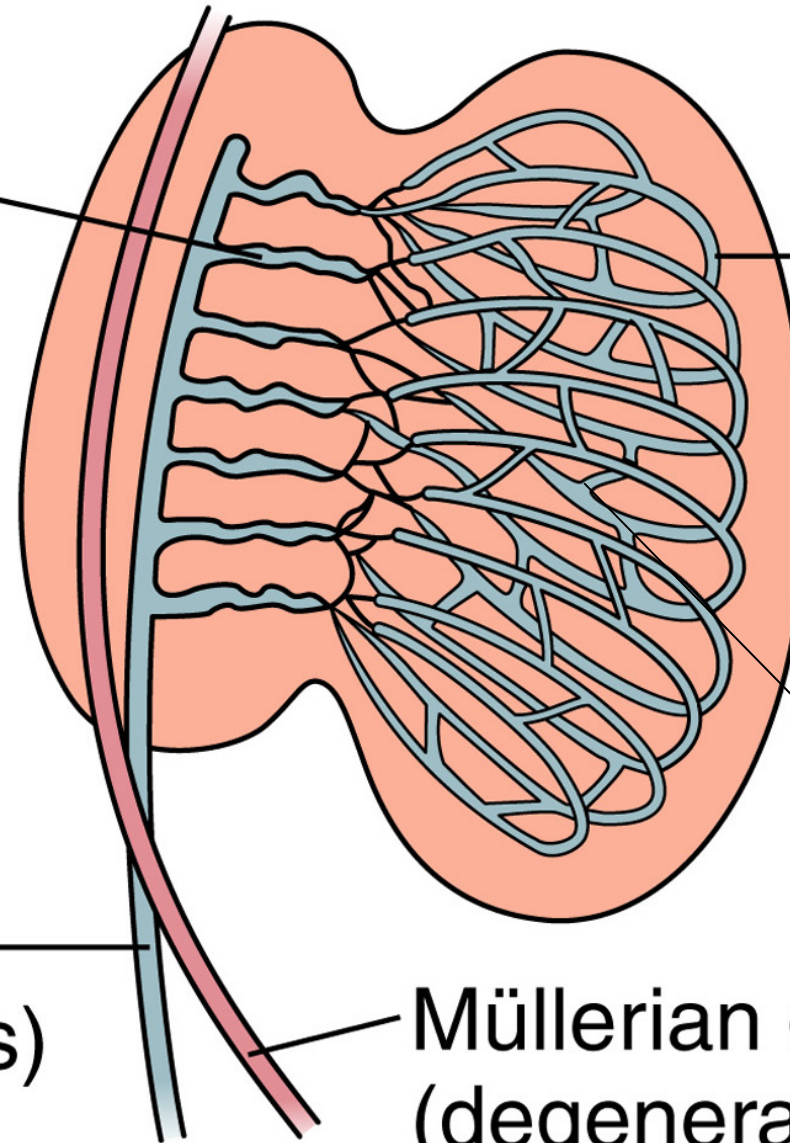
C. 8 Weeks



D. 16 Weeks

Excretory
mesonephric
tubules
(Efferent
ducts)
**Ductuli
efferentes**

Wolffian duct
(ductus deferens)



**Testikulární
provazce**

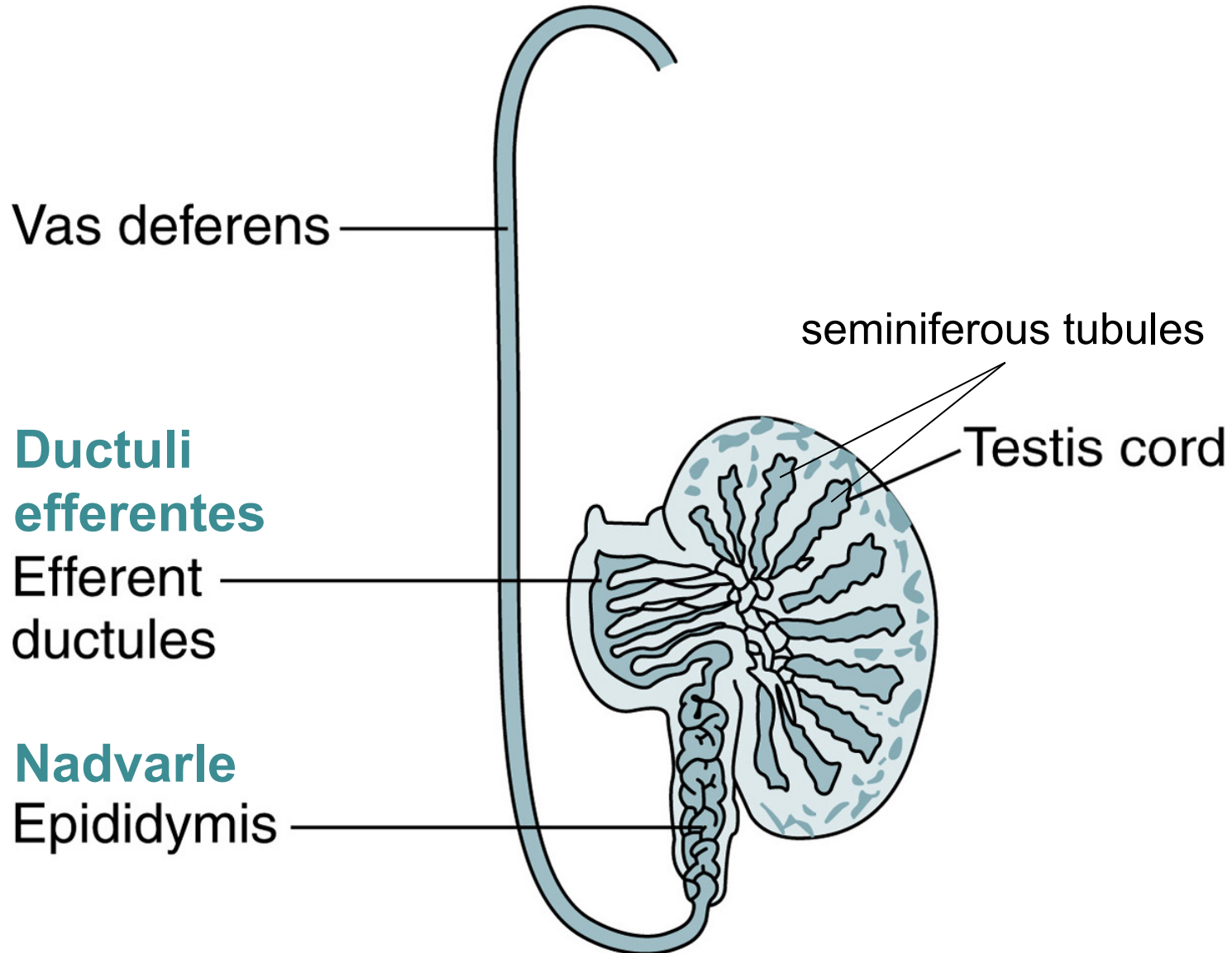
**Testis
cords**

**Produkcce
Müllerovy inhibiční
látky**

**Anti-Mullerian
duct factor
production by
differentiated
Sertori cells**

**Müllerian duct
(degenerating)**

E. Adult



F. 7 Weeks

Degenerating
mesonephric
tubule

Wolffian
duct

Degenerating
medullary
cords

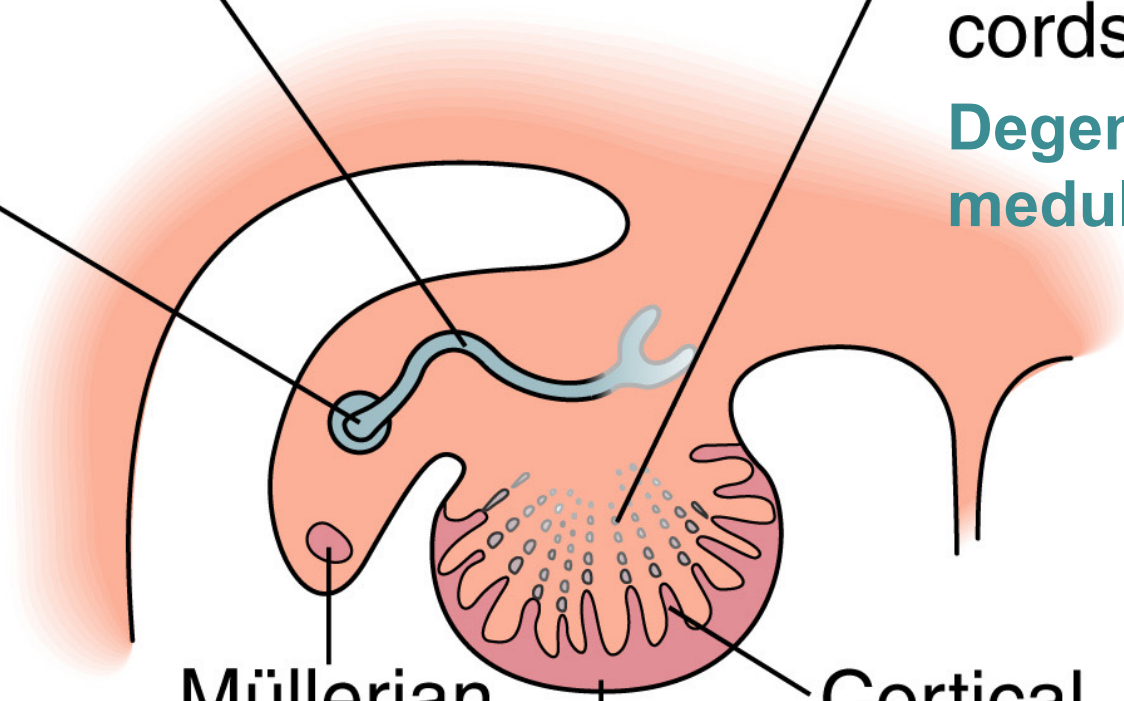
Degenerující
medulární provazce

Müllerian
duct

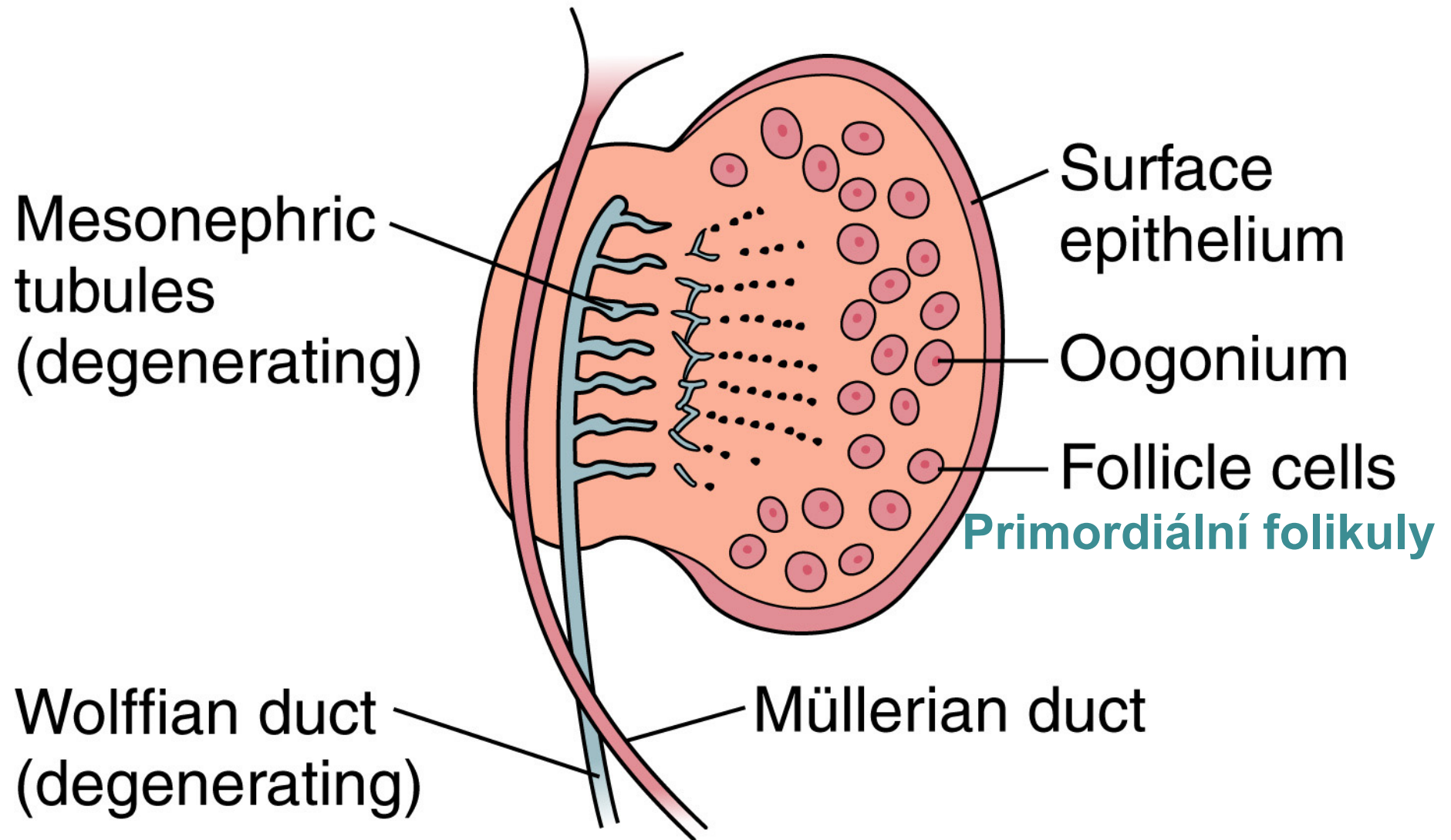
Epithelium

Cortical
cords

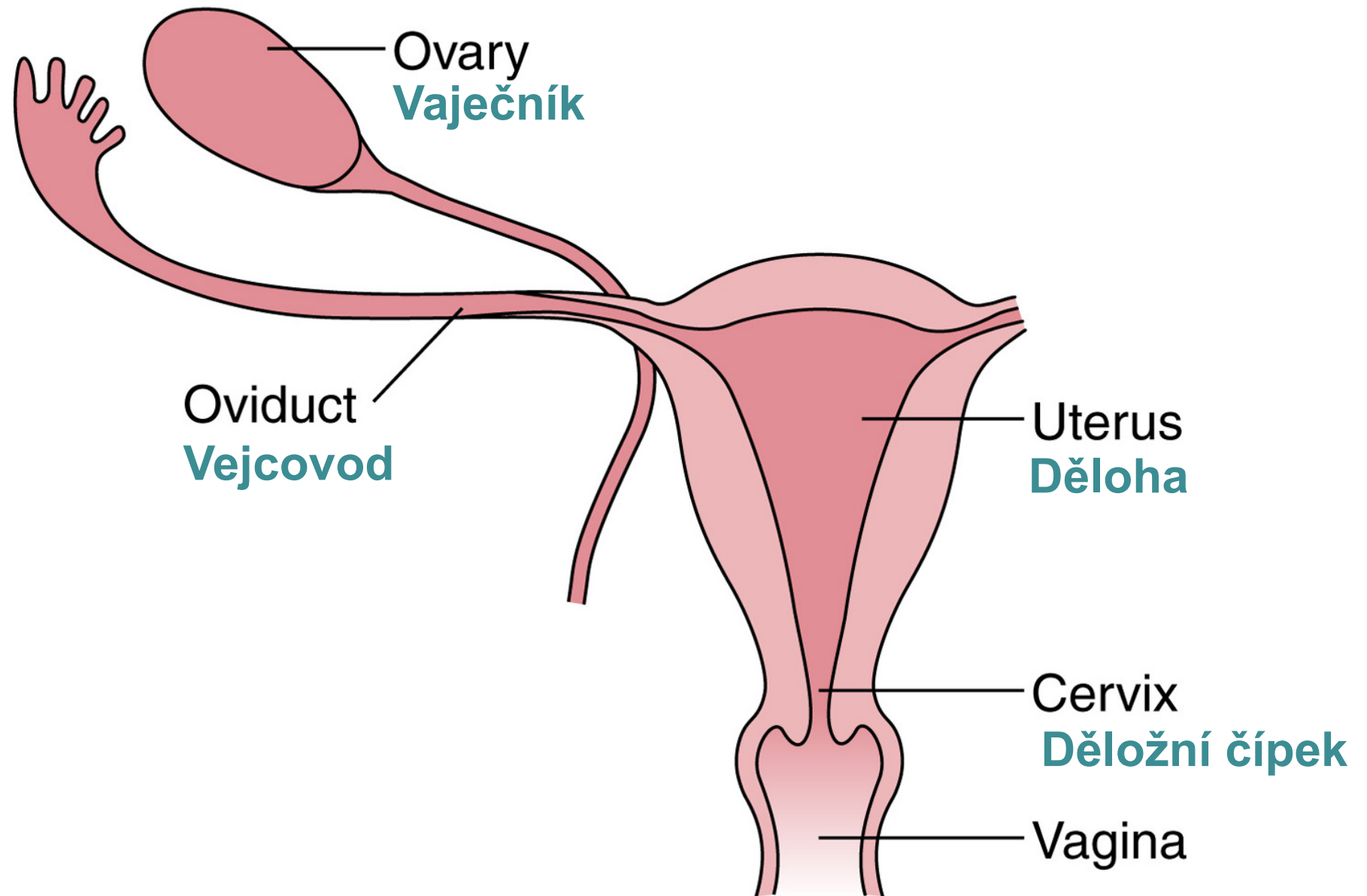
Kortikální provazce



G. 21 Weeks



H. Adult

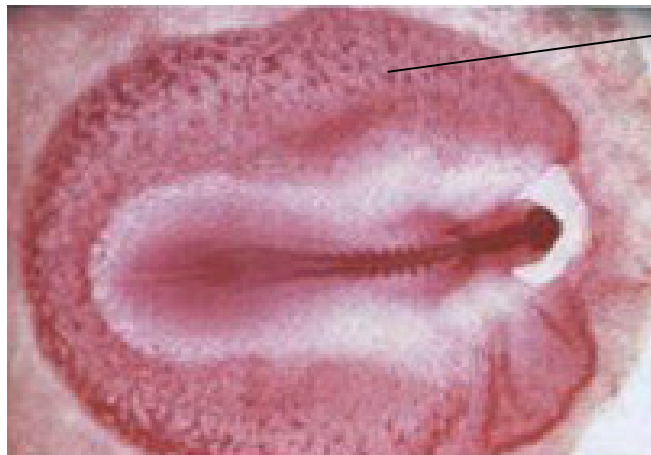




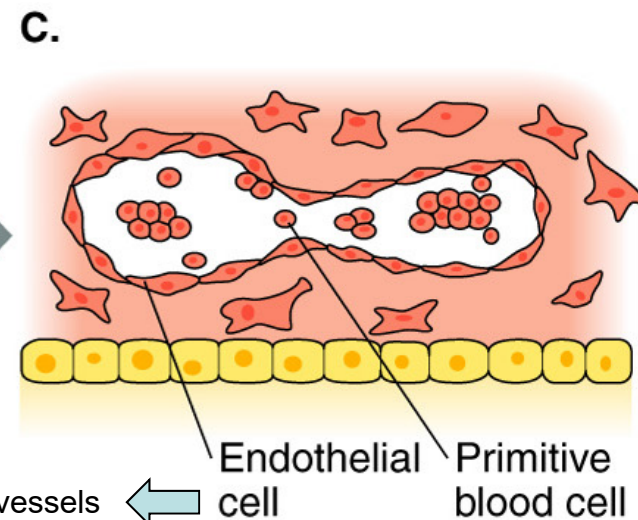
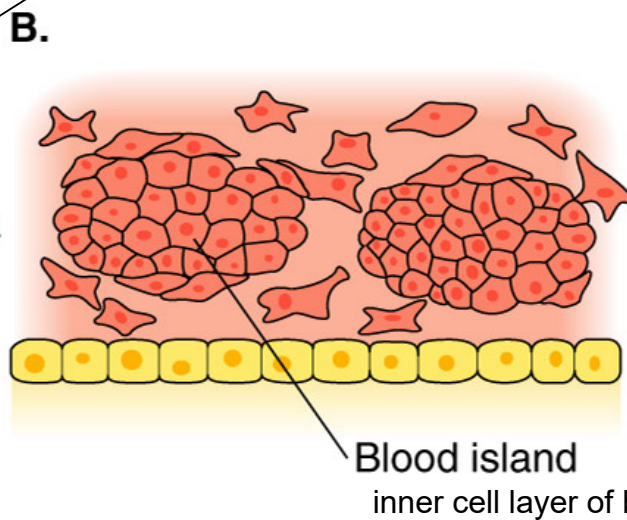
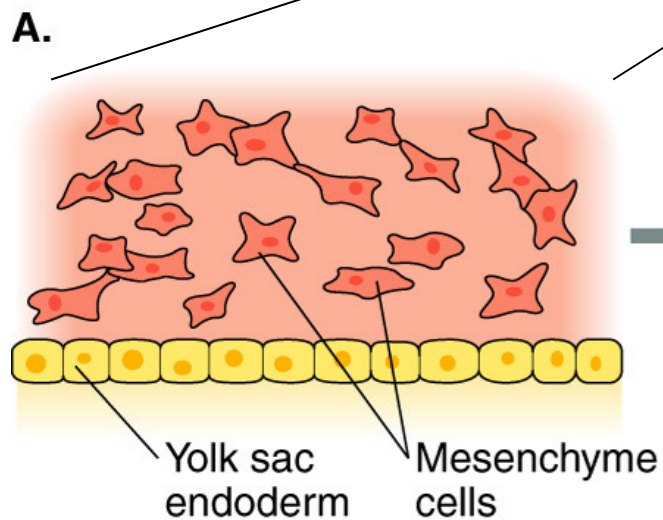
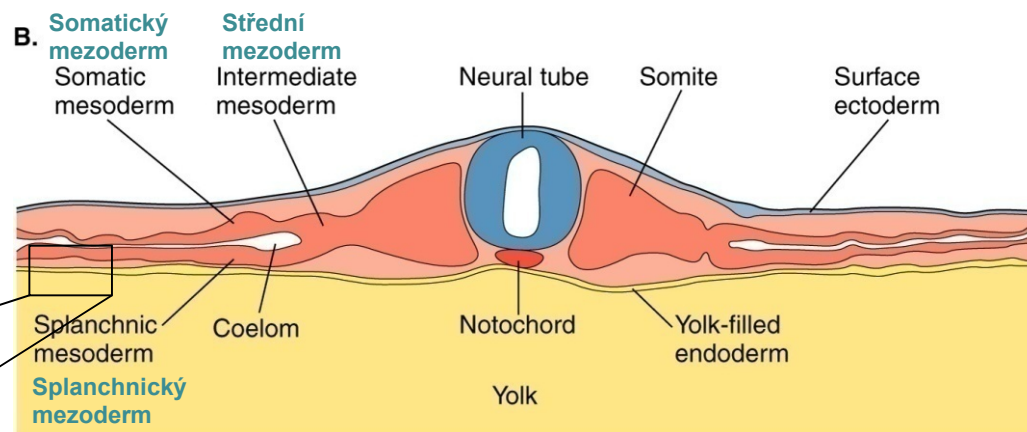
Outline of Lesson 5

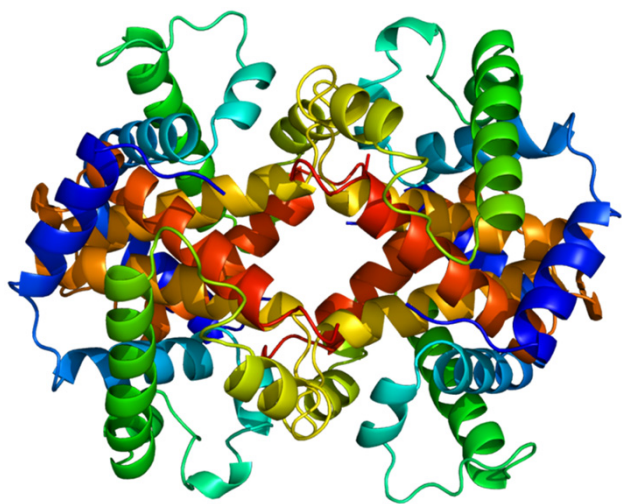
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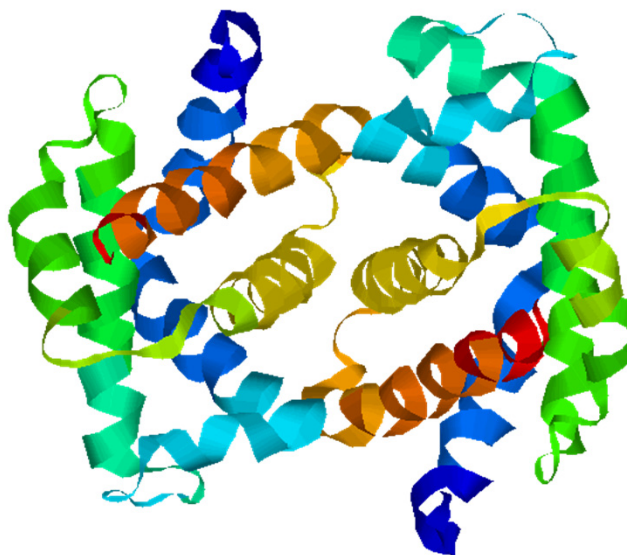


Krevní ostrůvky
Blood islands

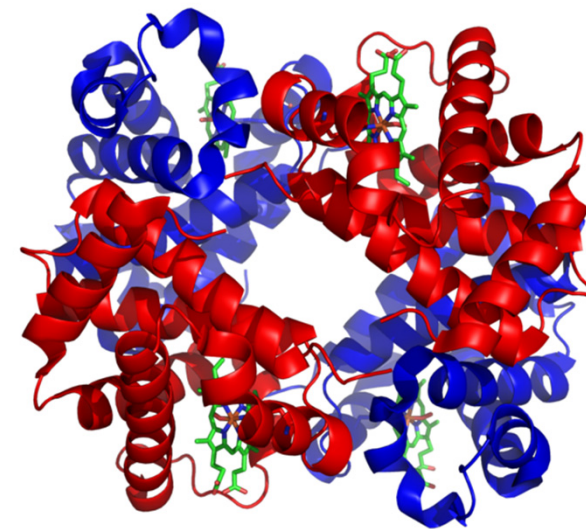




Embryonic hemoglobin $\epsilon\epsilon\zeta\zeta$
yolk sac

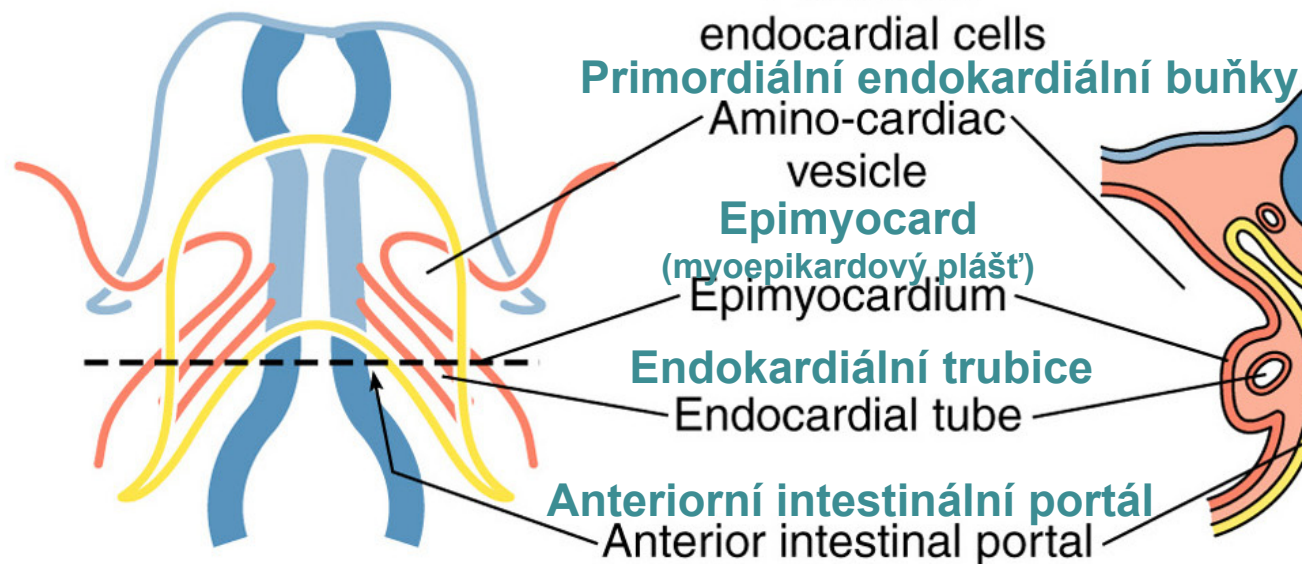
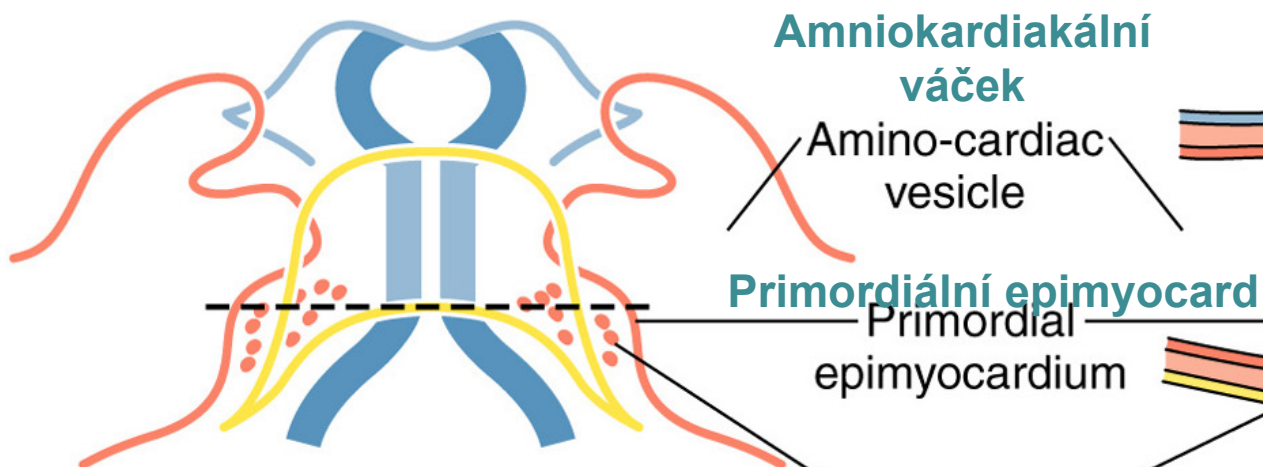


Fetal hemoglobin $\alpha\alpha\gamma\gamma$
liver

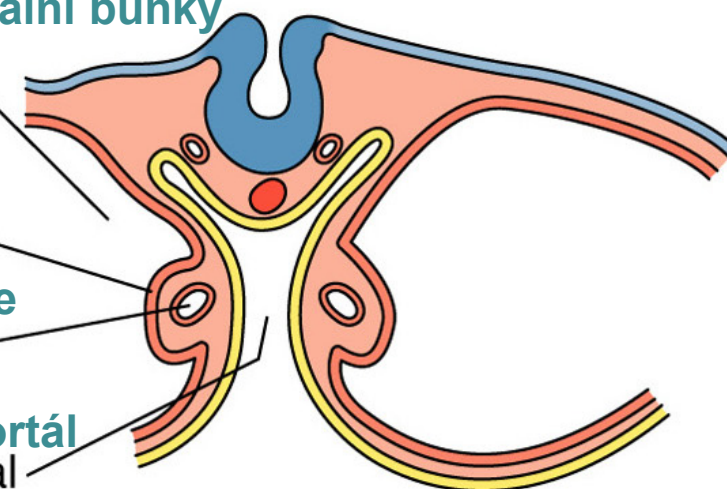
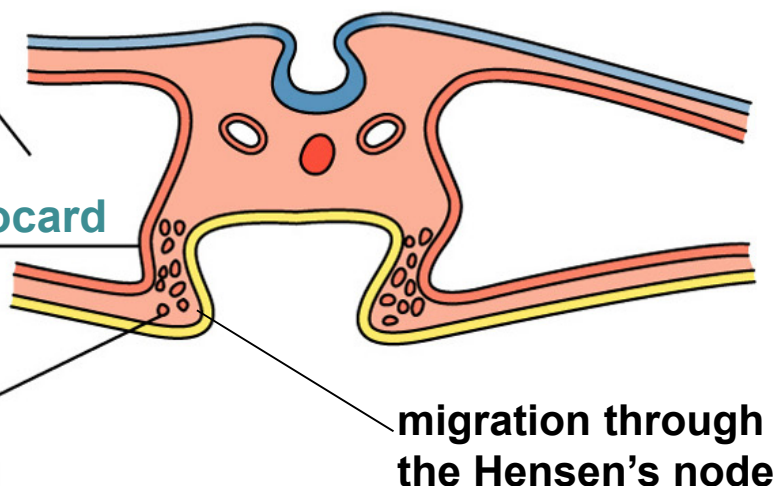


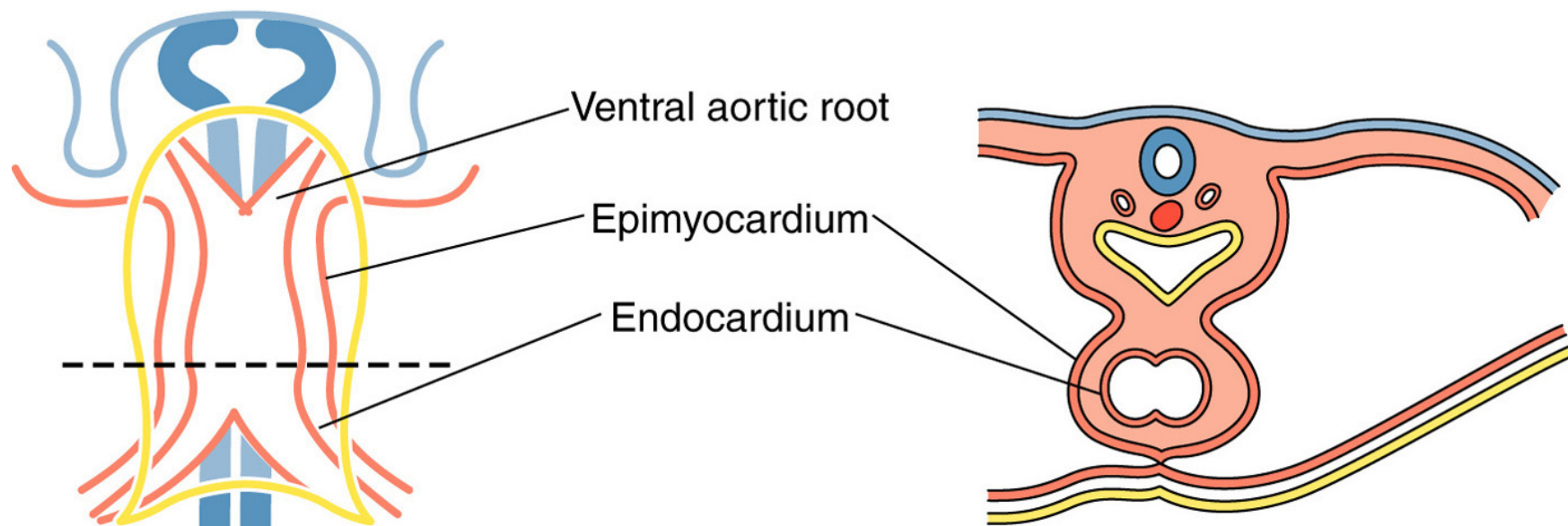
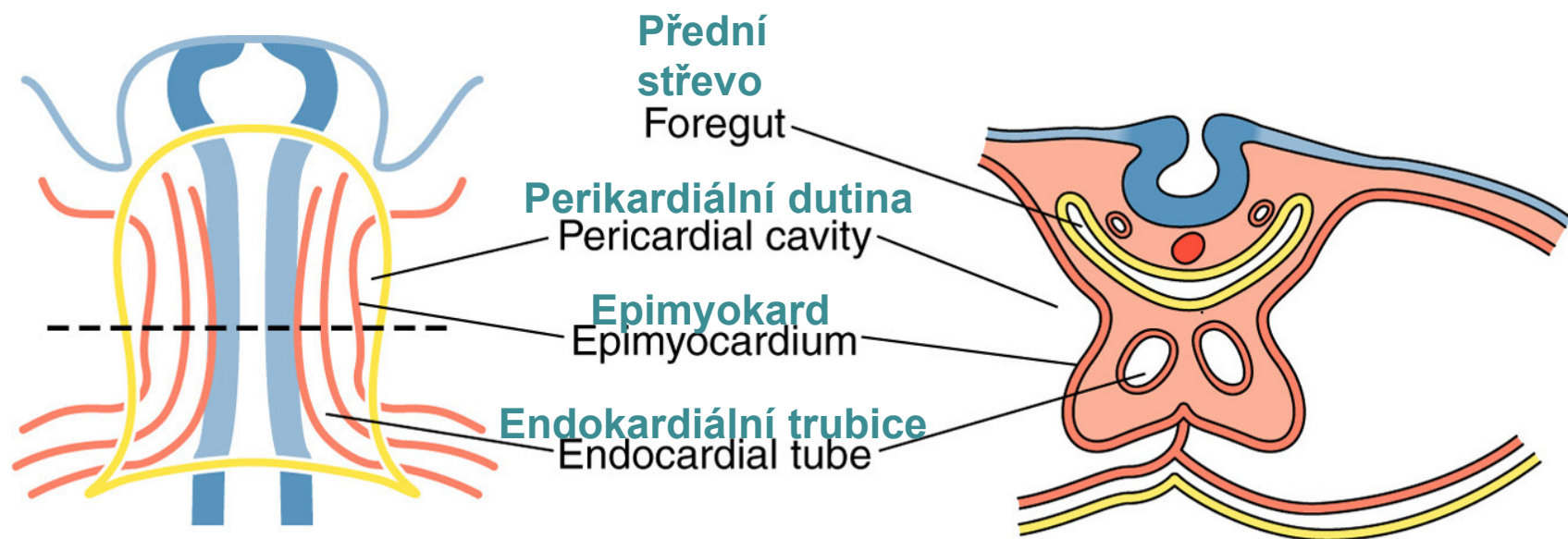
Adult hemoglobin $\alpha\alpha\beta\beta$
bone marrow

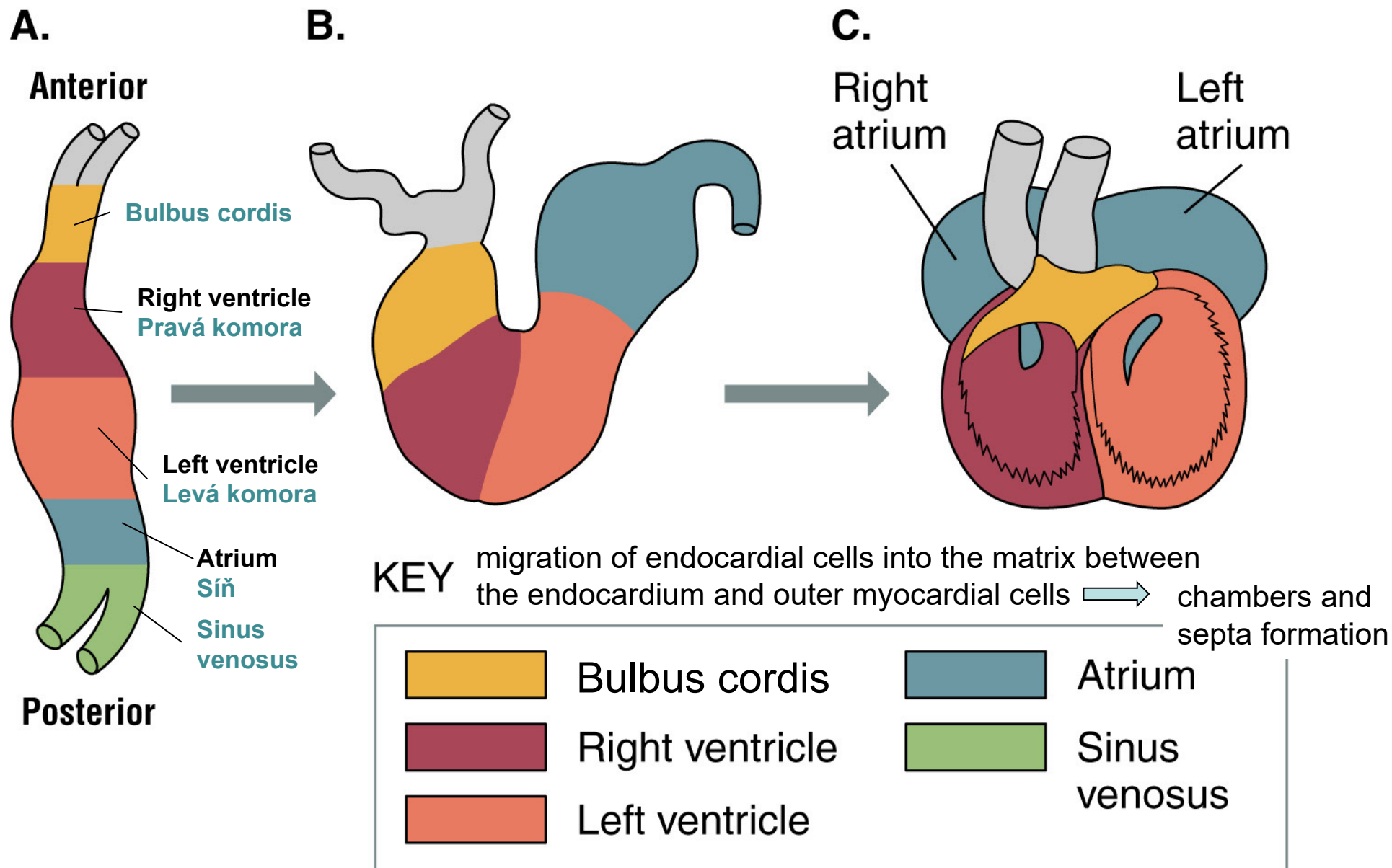
A. Ventral views



B. Transverse views





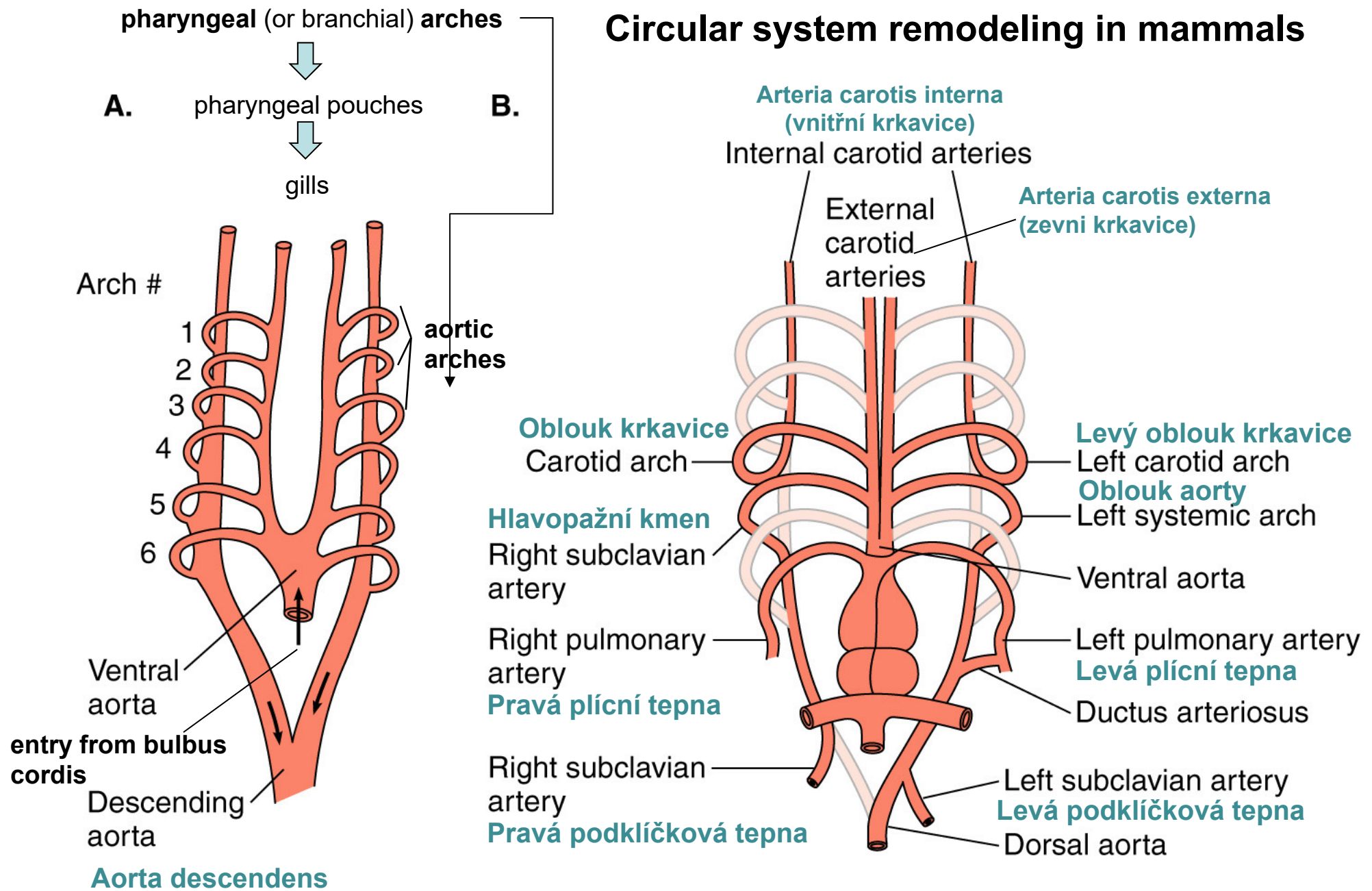




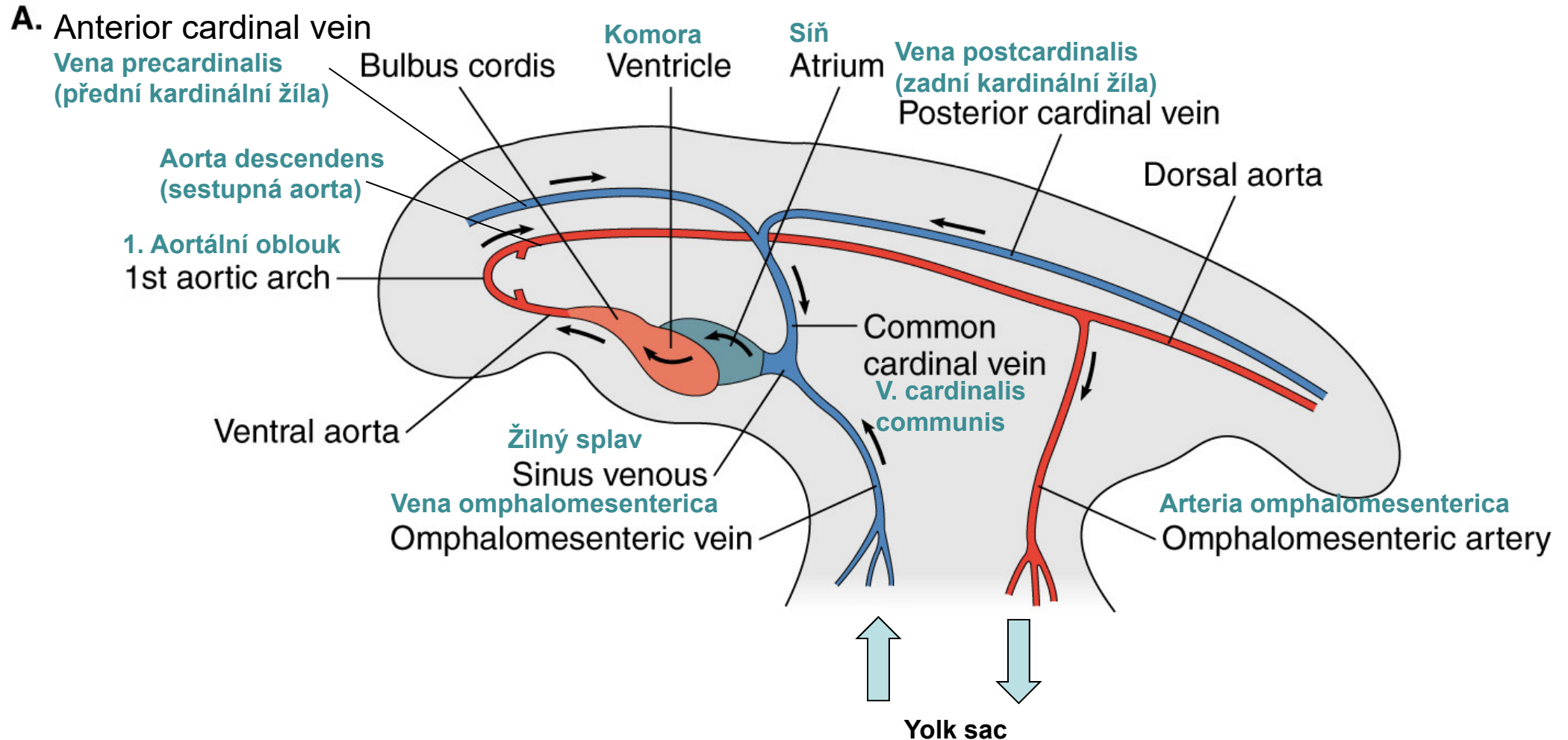
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Tato prezentace je spolufinancována
Evropským sociálním fondem
a státním rozpočtem České republiky

Circular system remodeling in mammals

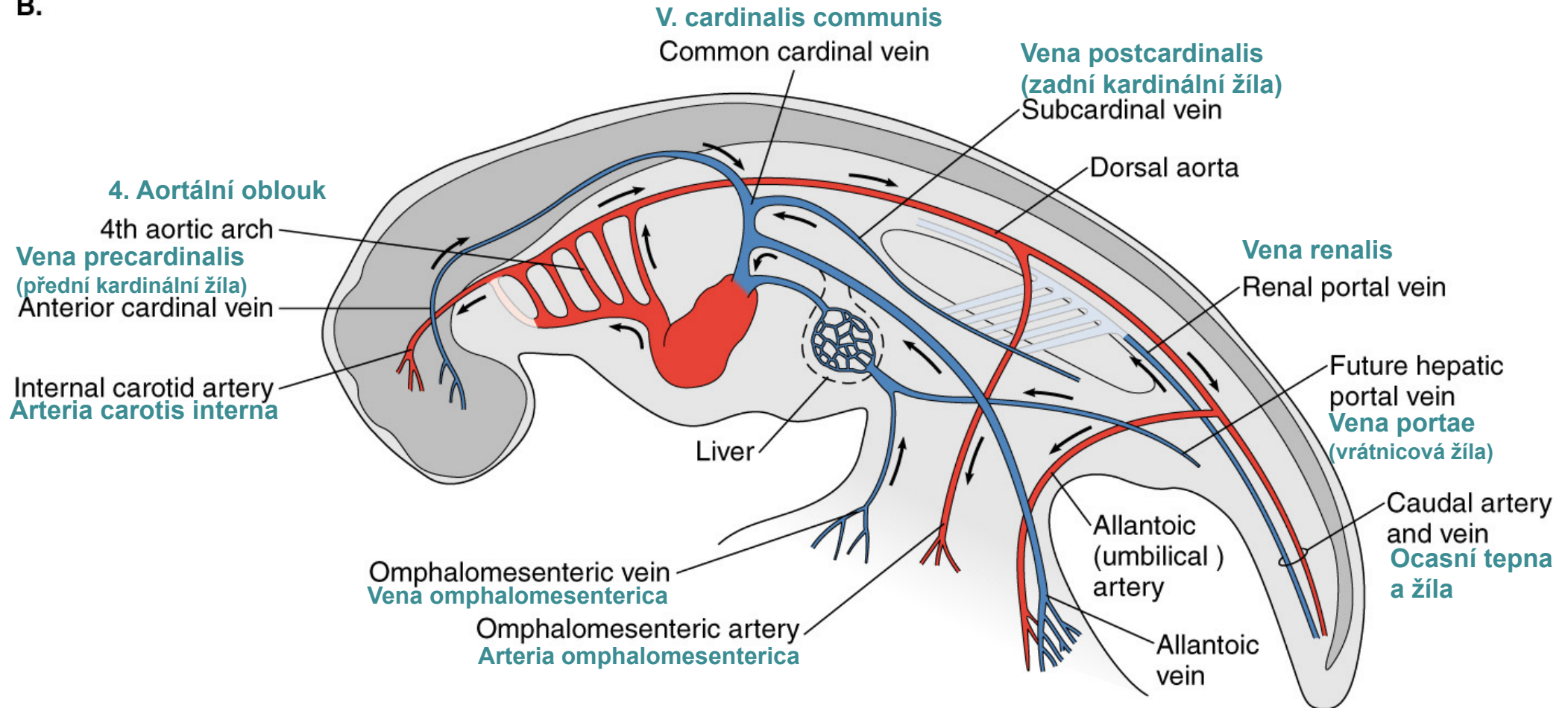


Blood streaming in the initial circular system in amniote embryo



Blood streaming in the remodeled circular system in amniote embryo

B.





Outline of Lesson 5

Organogenesis in Vertebrates: Endo- and Mesodermal Derivatives

- Mesoderm derivatives development
 - somites formation and signalling
 - formation of muscles
 - endochordal ossification and signalling
 - nephrogenesis
 - formation of gonads
 - hematopoiesis and circular system development
 - limbs formation

Neurální trubice
Neural tube

Křídelní pupen
Wing bud

Nožní pupen
Leg bud

Ocas
Tail

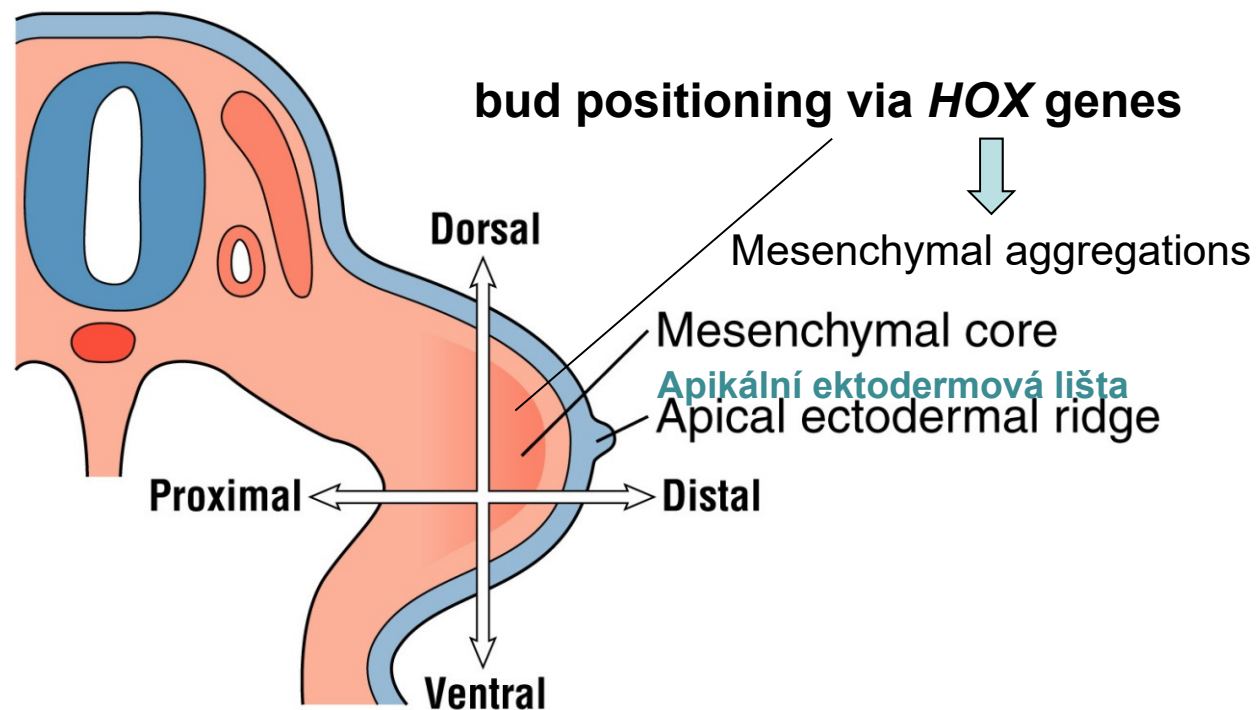


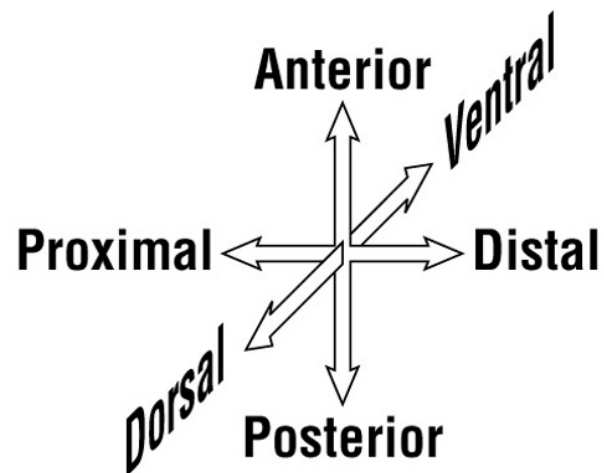
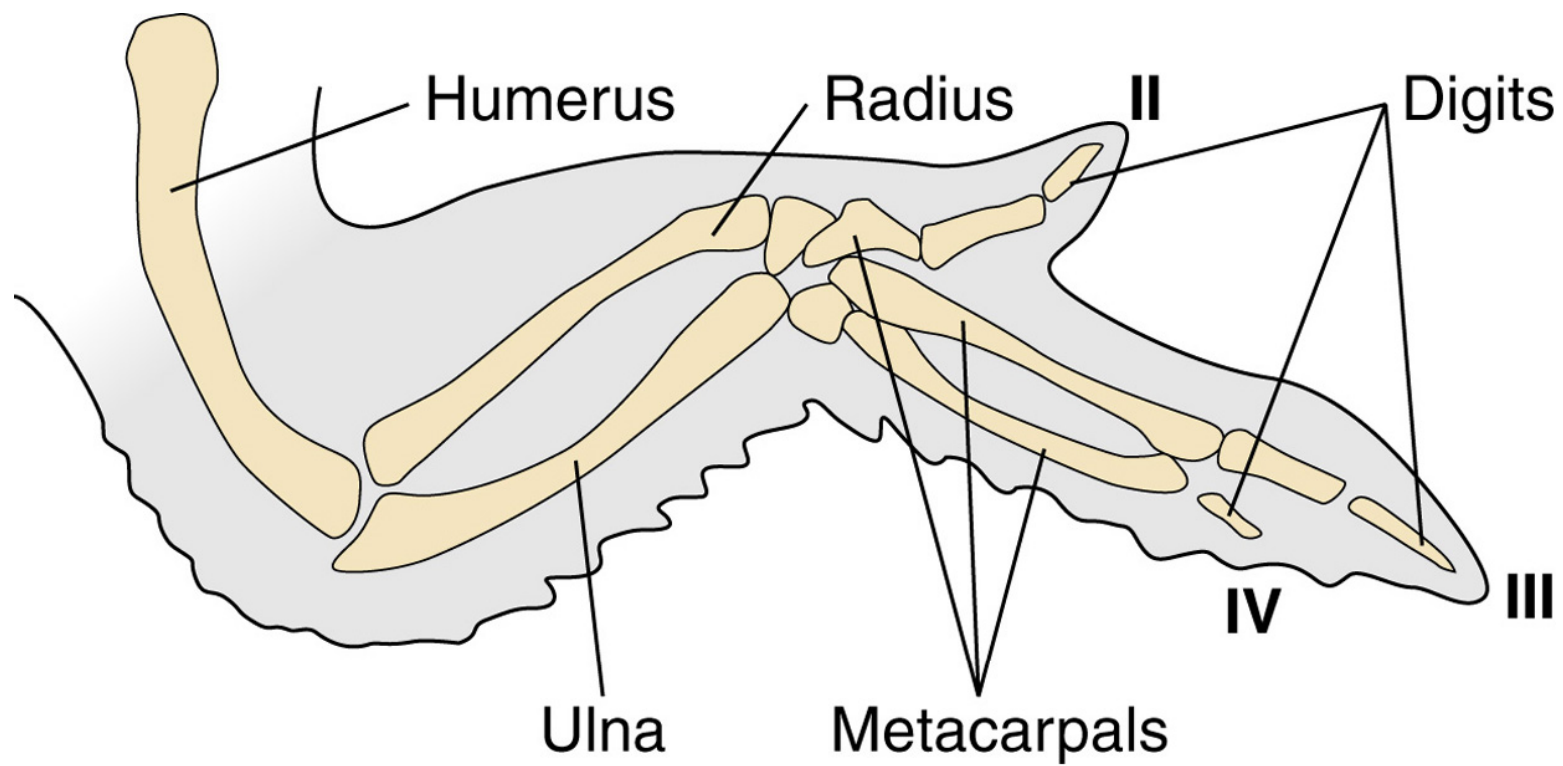
Střední mozek
Midbrain

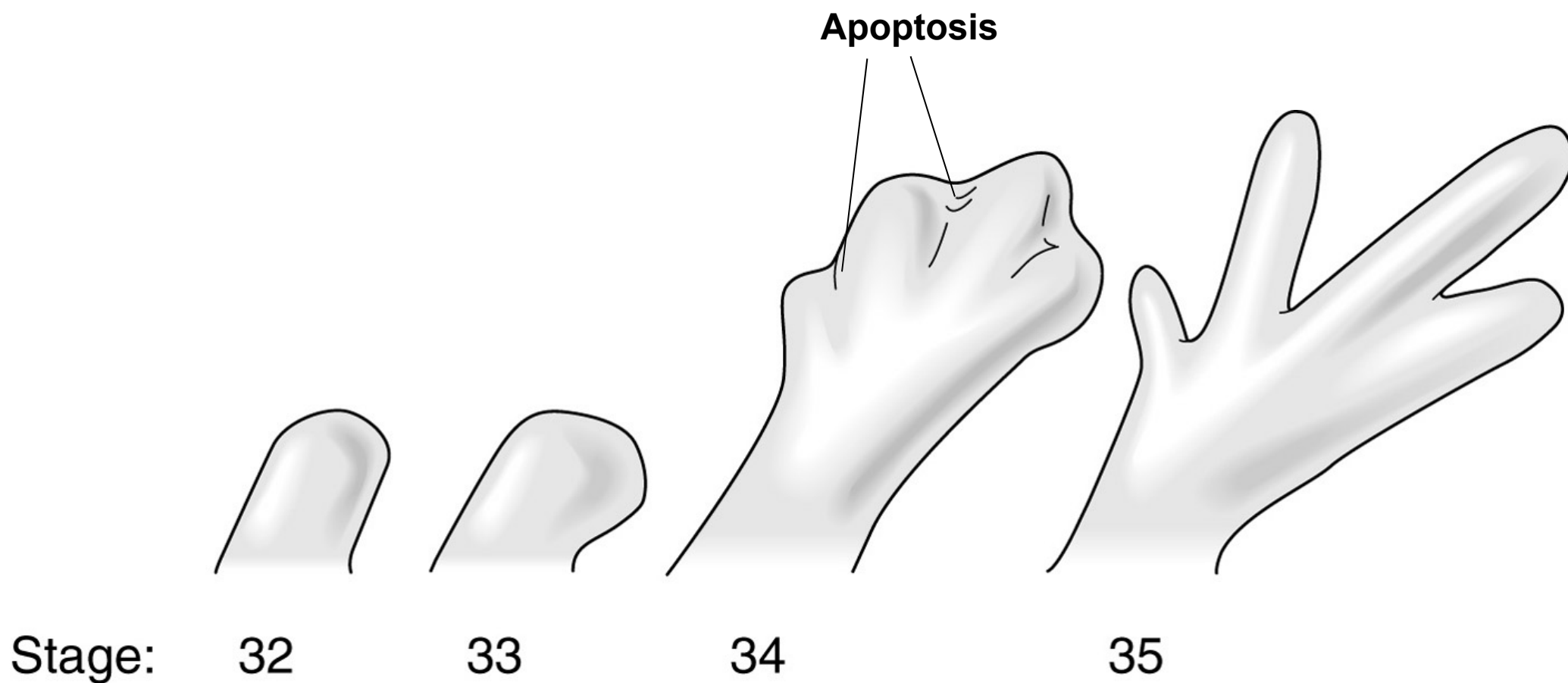
Oko
Eye

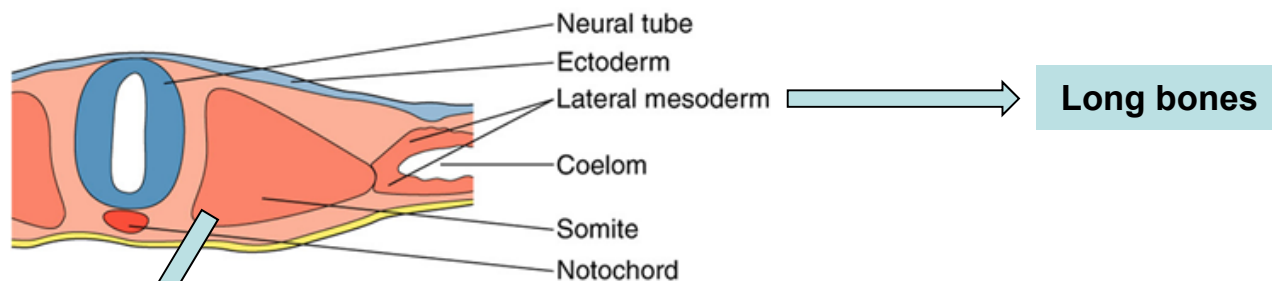
Somity
Somites

B. Cross section of a chick wing bud

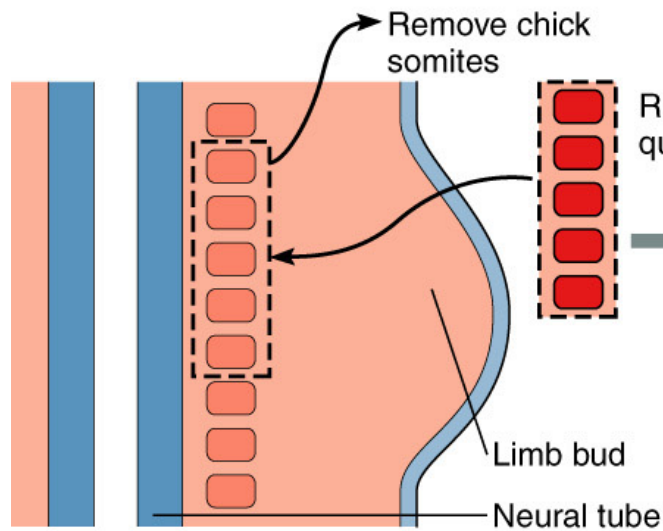






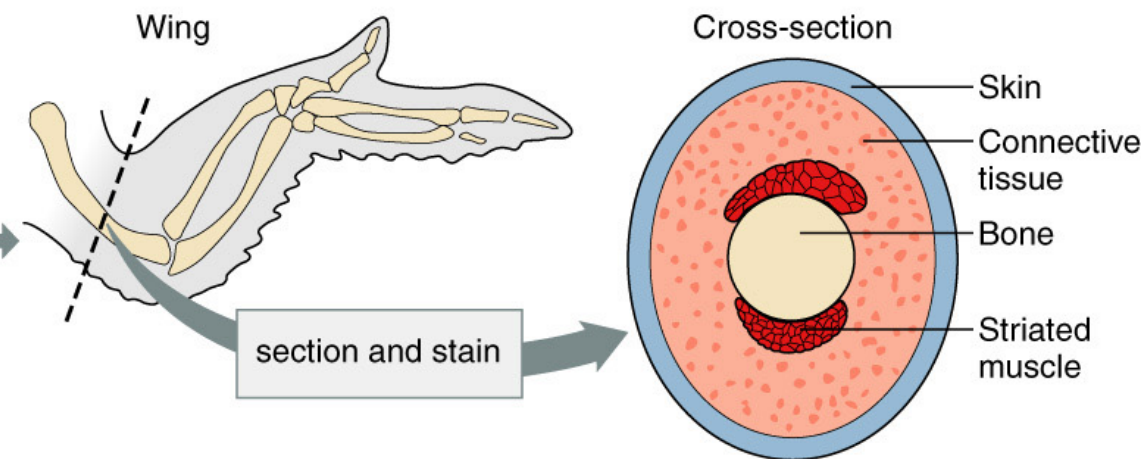


A.

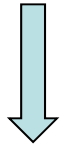


allow to develop

B.

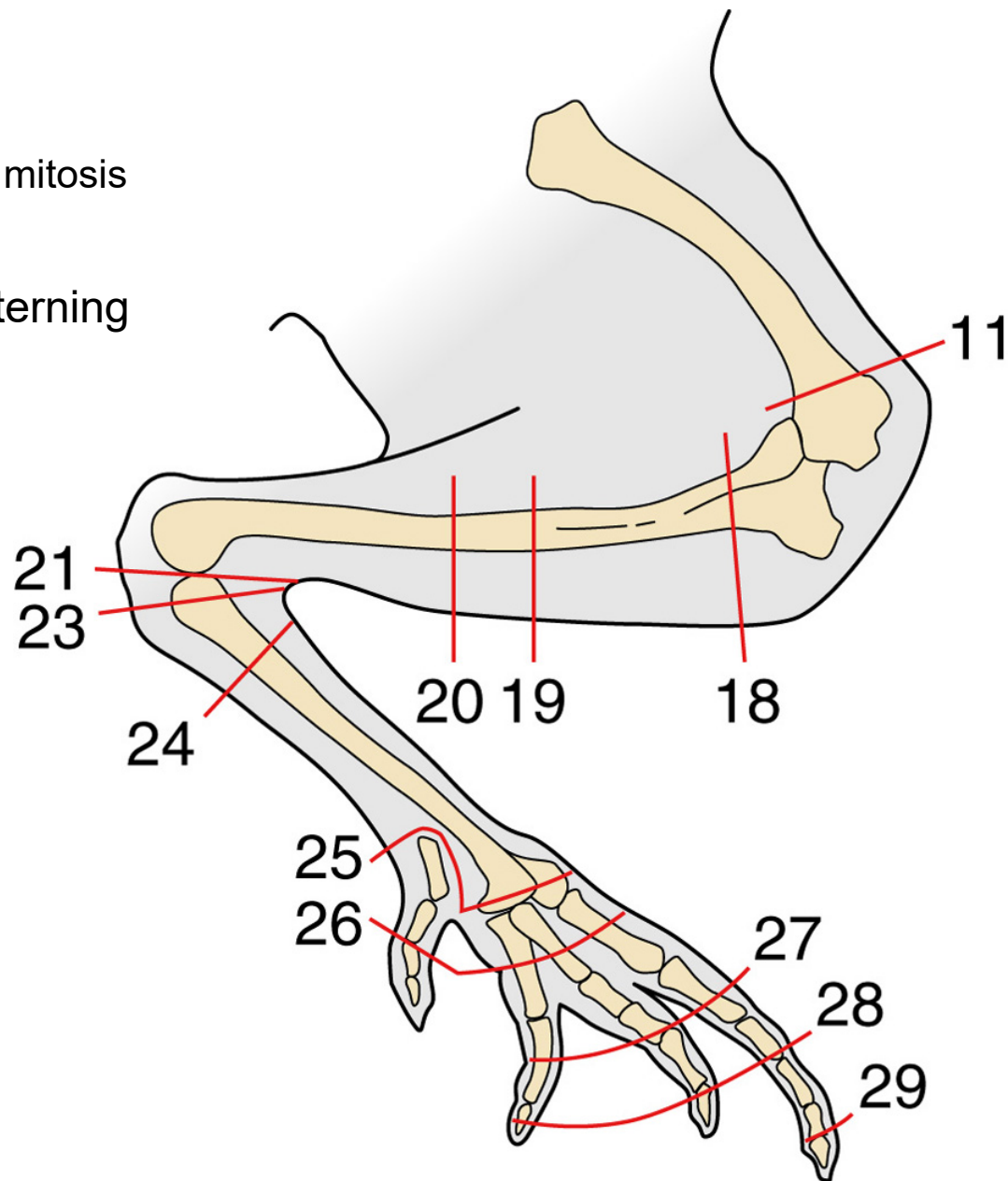


AER



7 rounds of mitosis

Proximodistal limb patterning



Chicken embryo as a developmental model

Hamburger & Hamilton Stage 4 (15 hours)



HH Stage 9 (31 hours 8 somite)



HH Stage 10 (33 hours)



HH Stage 16-17 (56 hours)



HH Stage 38 (12 days)

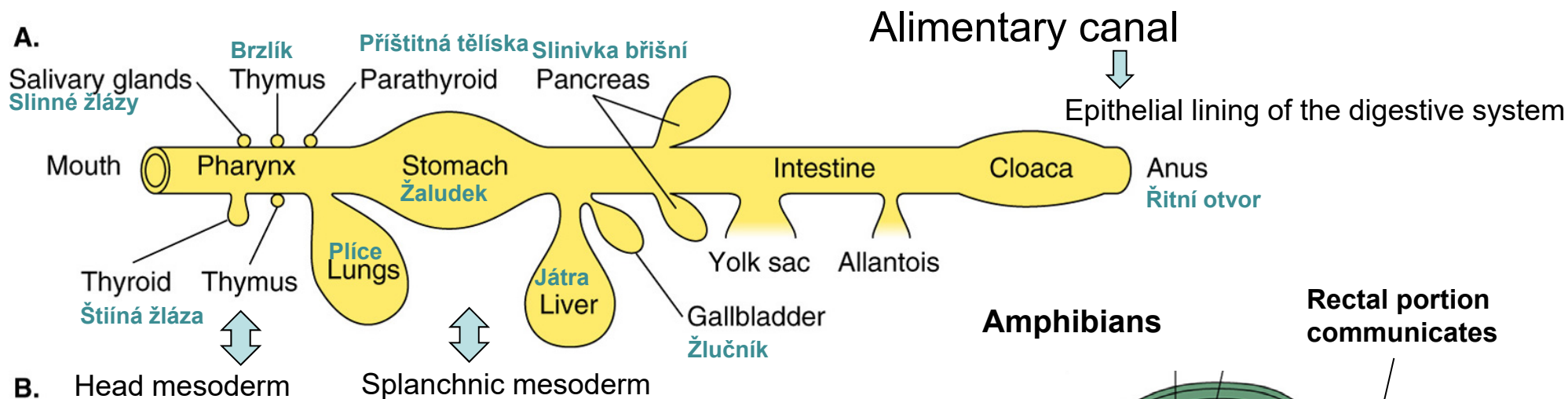




Outline of Lesson 5

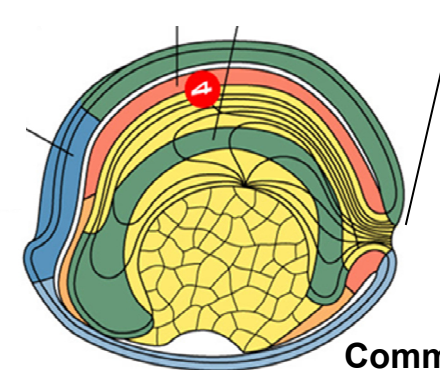
Organogenesis in Vertebrates: Endo- and Mesodermal Derivatives

- Mesoderm derivatives development
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 - nephrogenesis
 - formation of gonads
 - hematopoiesis and circular system development
 - limbs formation
- Endoderm derivatives development
 - alimentary canal and its derivatives formation



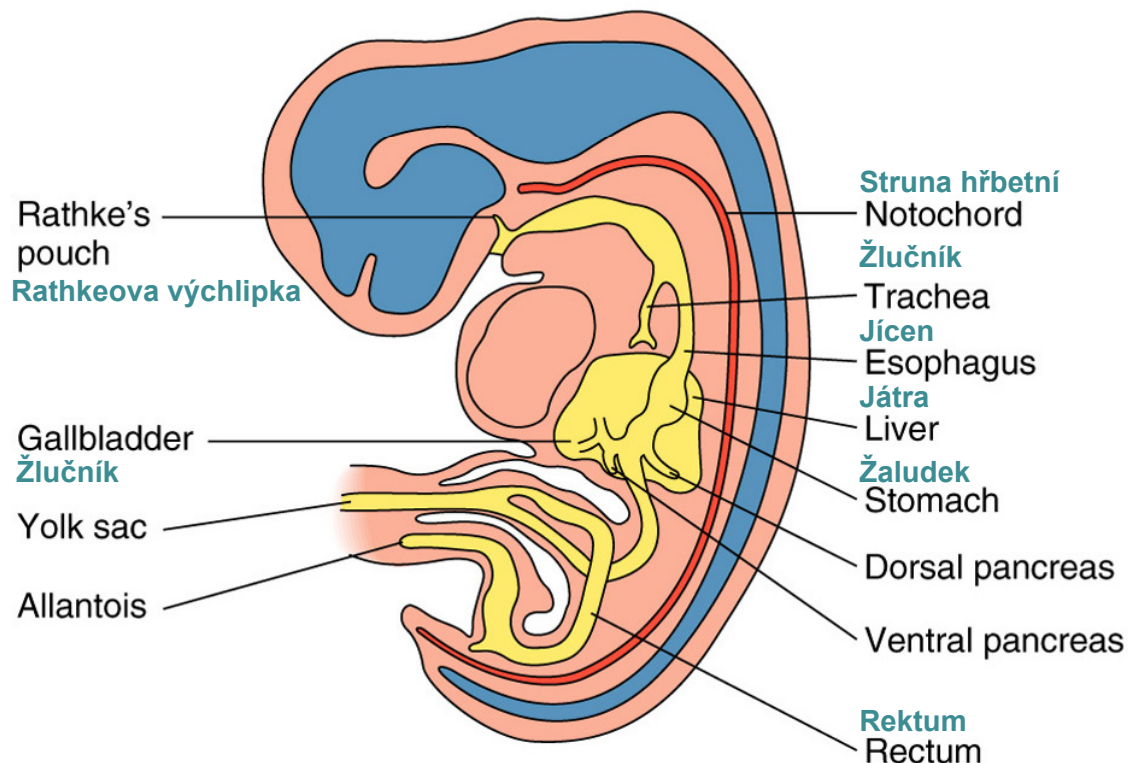
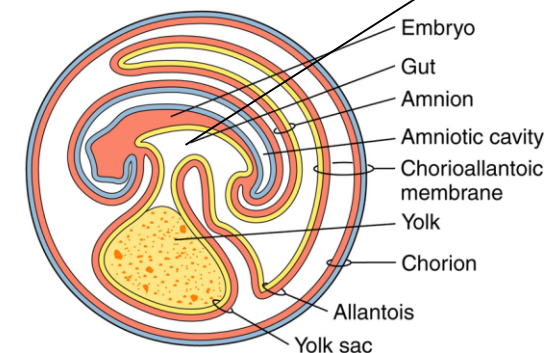
Amphibians

Rectal portion communicates

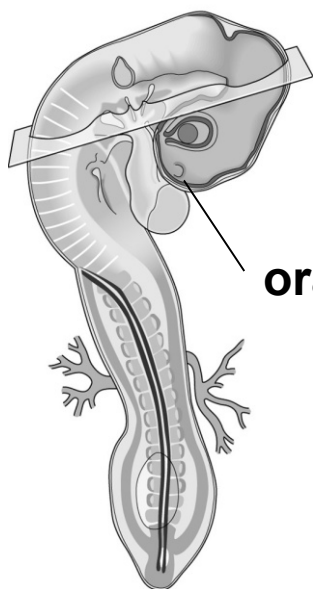


Communication only with yolk sac

Amniotes

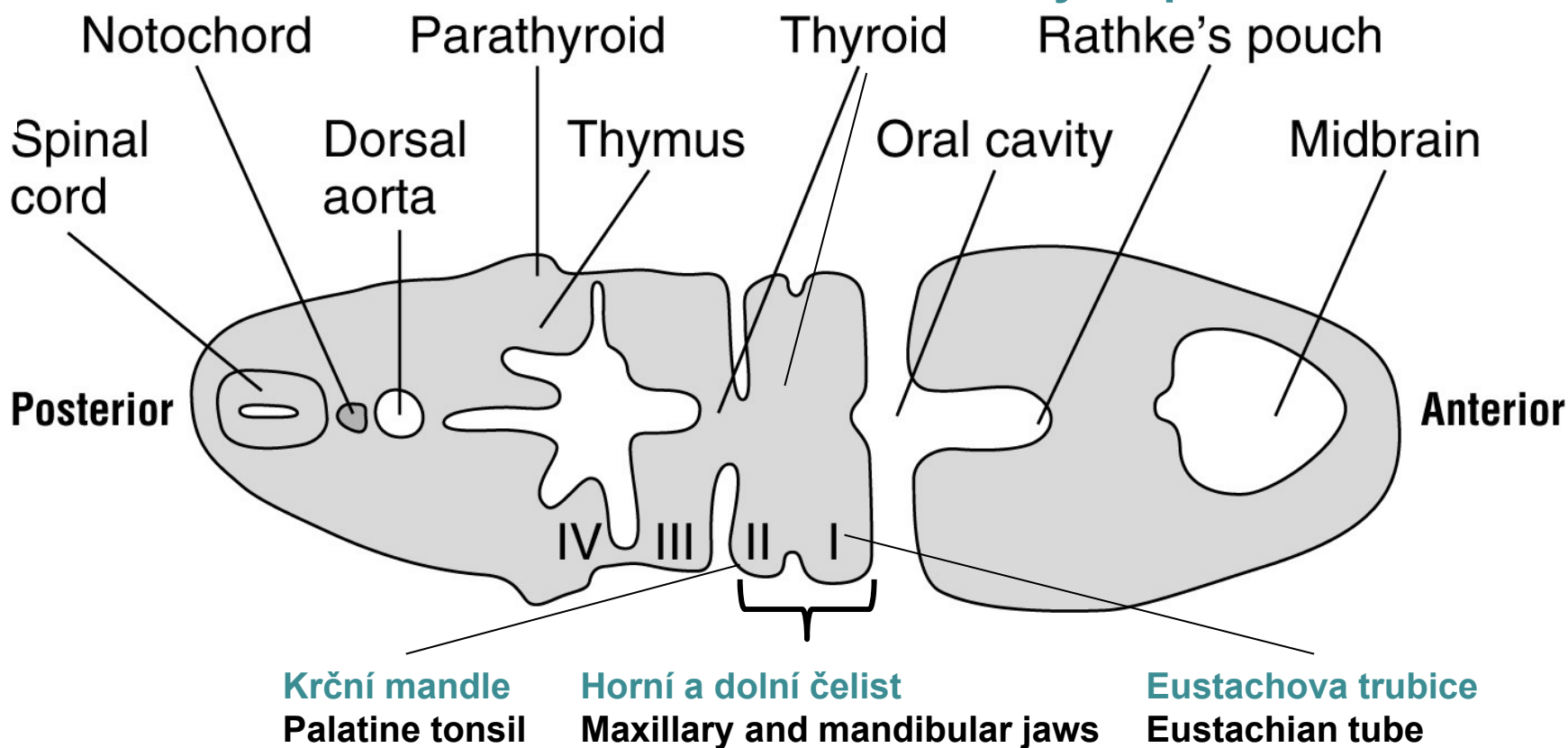


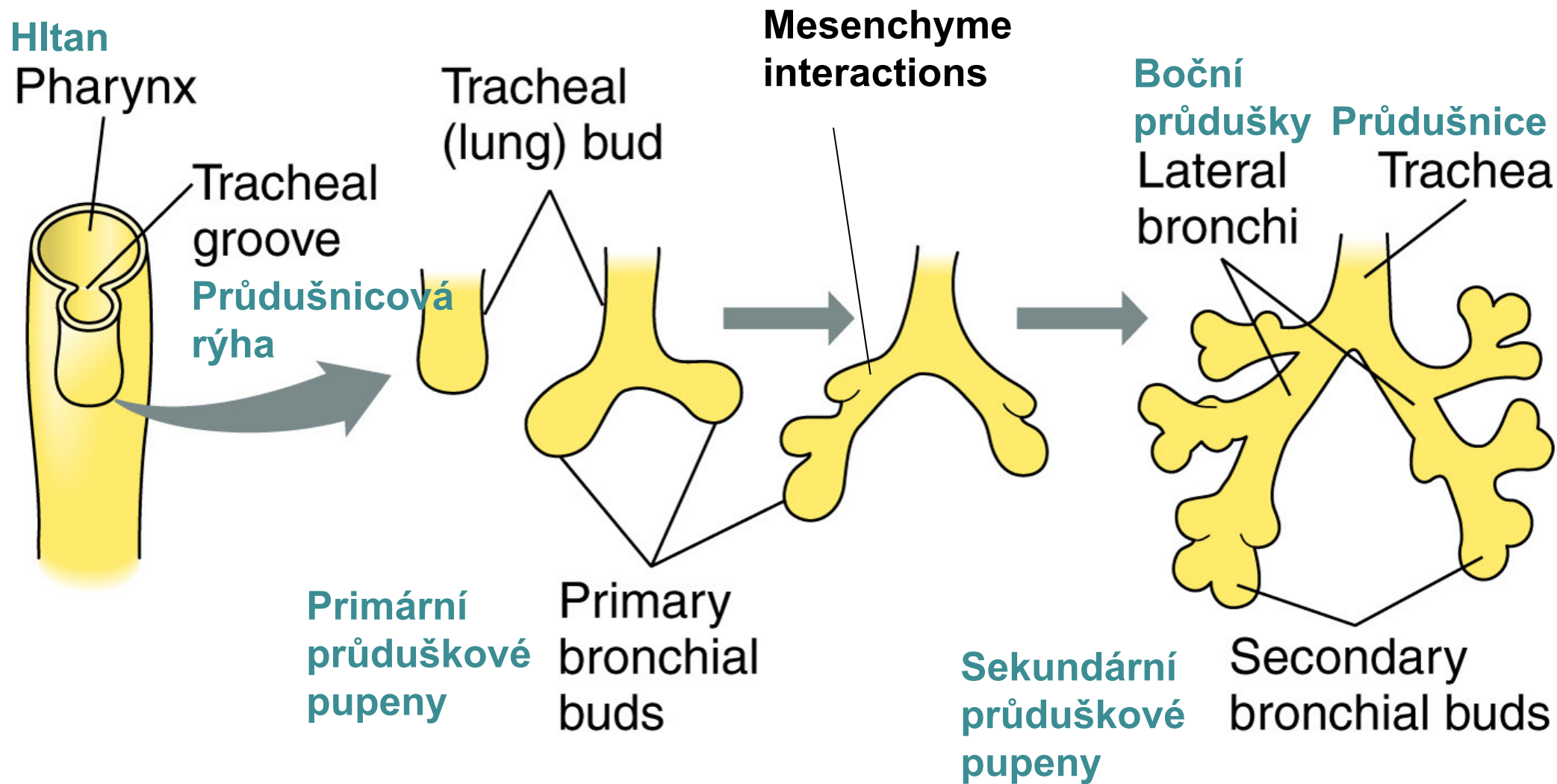
A.

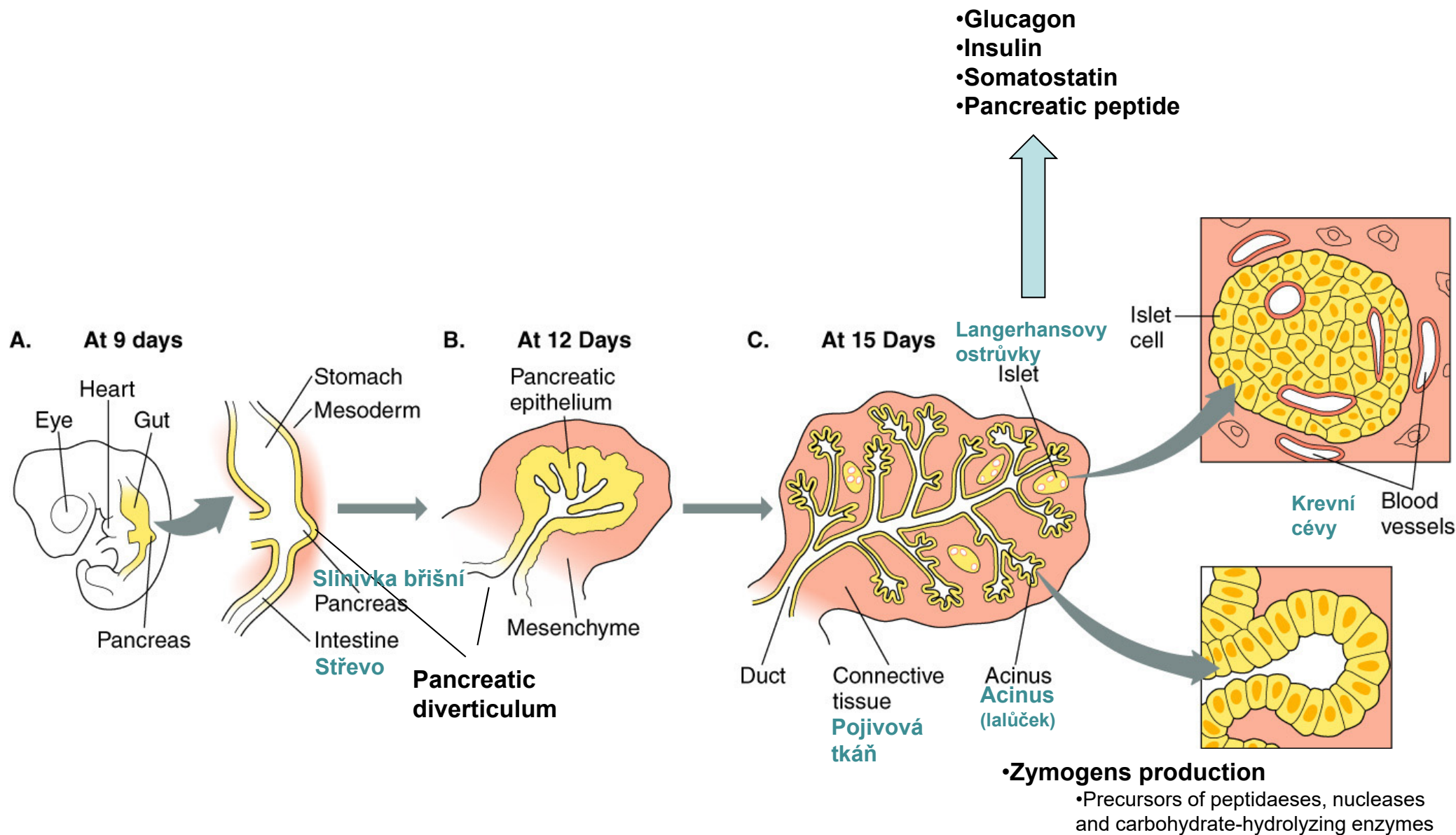


oral plate

B.







Key Concepts

- **Developmental potential** is studied via e.g. **transplantation experiments**, while **developmental fate** is best studied using modern **molecular techniques** in a normal embryo.
- Vertebrate embryos have a **conservative axial organization** proceeding from the midline to the periphery: **notochord**, **somite**, **nephrotome**, or **gonad** and **lateral mesoderm** (limb buds).
- **Iterative oscillations** of the gene expression in a combination with **gradient of gene expression** allow **proper body segmentation** during embryonic development. **Underlying molecular mechanisms** are at least **partially conserved** in *Drosophila* and vertebrates.
- Normal tissue and organ formation depends not only on the **presence of signalling molecules**, but also on the **appropriate timing of ligand-receptor interactions**. Such communications can establish **feed-back loops**, as demonstrated e.g. in case of cartilage and bone formation.
- **Cell aggregation/disaggregation** is one of the **key developmental mechanisms** guiding new organ formation.
- **Some structures** are **transient during development**, e.g. pronephros, some, e.g. circular system are **extensively remodelled** during development.