

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
 - endochordal ossification and signalling
 - nephrogenesis
 - formation of gonads
 - hematopoiesis and circular system development
 - limbs formation

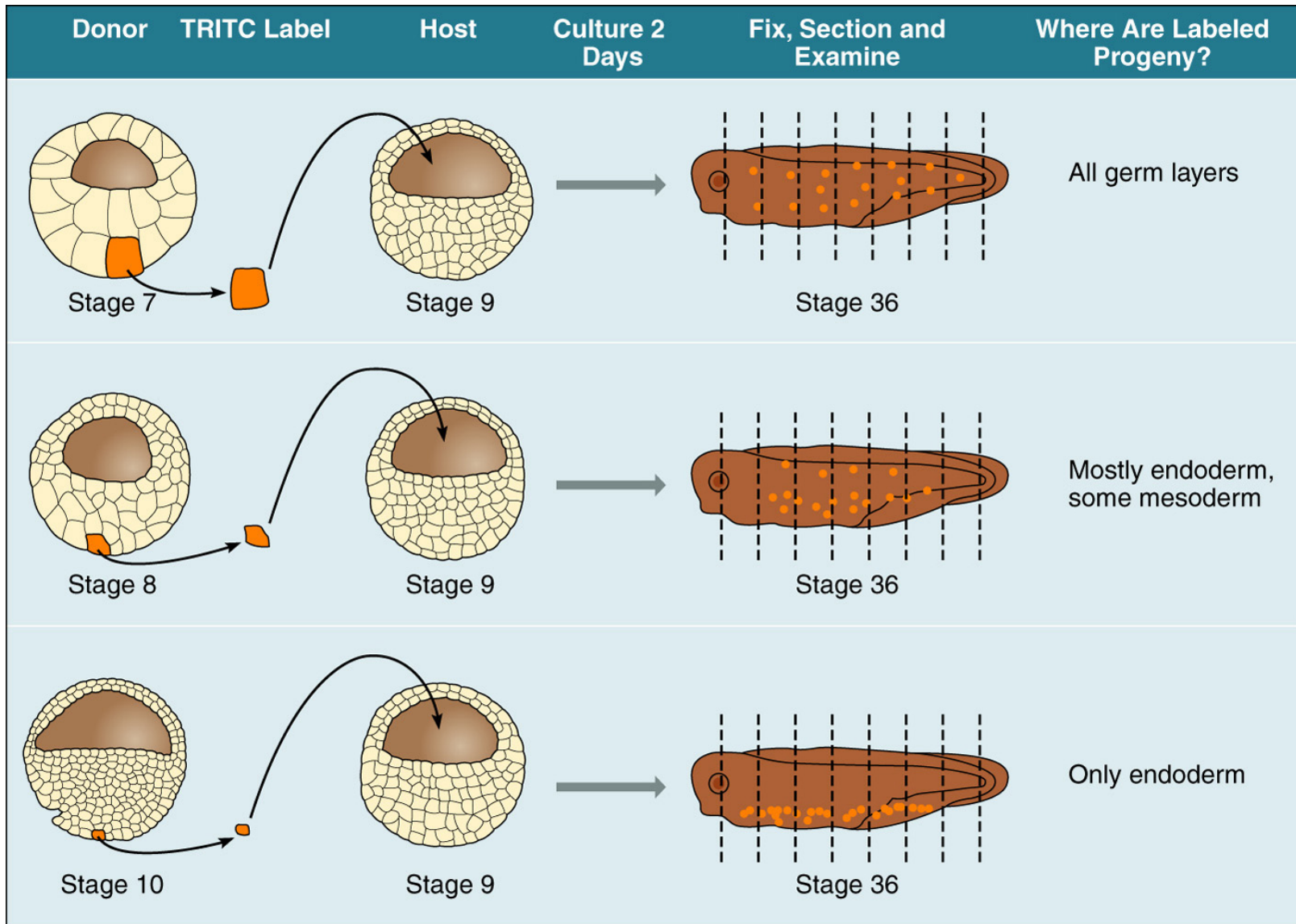
- Endoderm derivatives development
 - alimentary canal and its derivatives formation



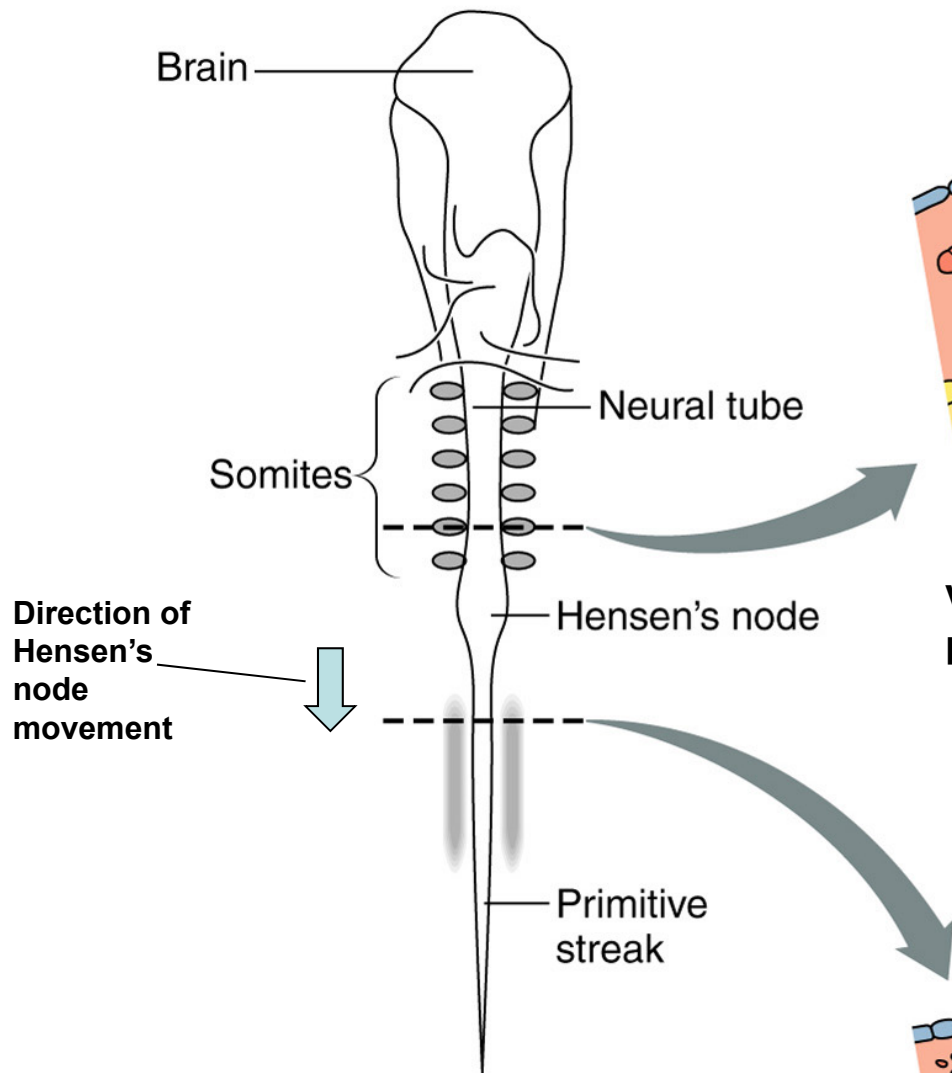
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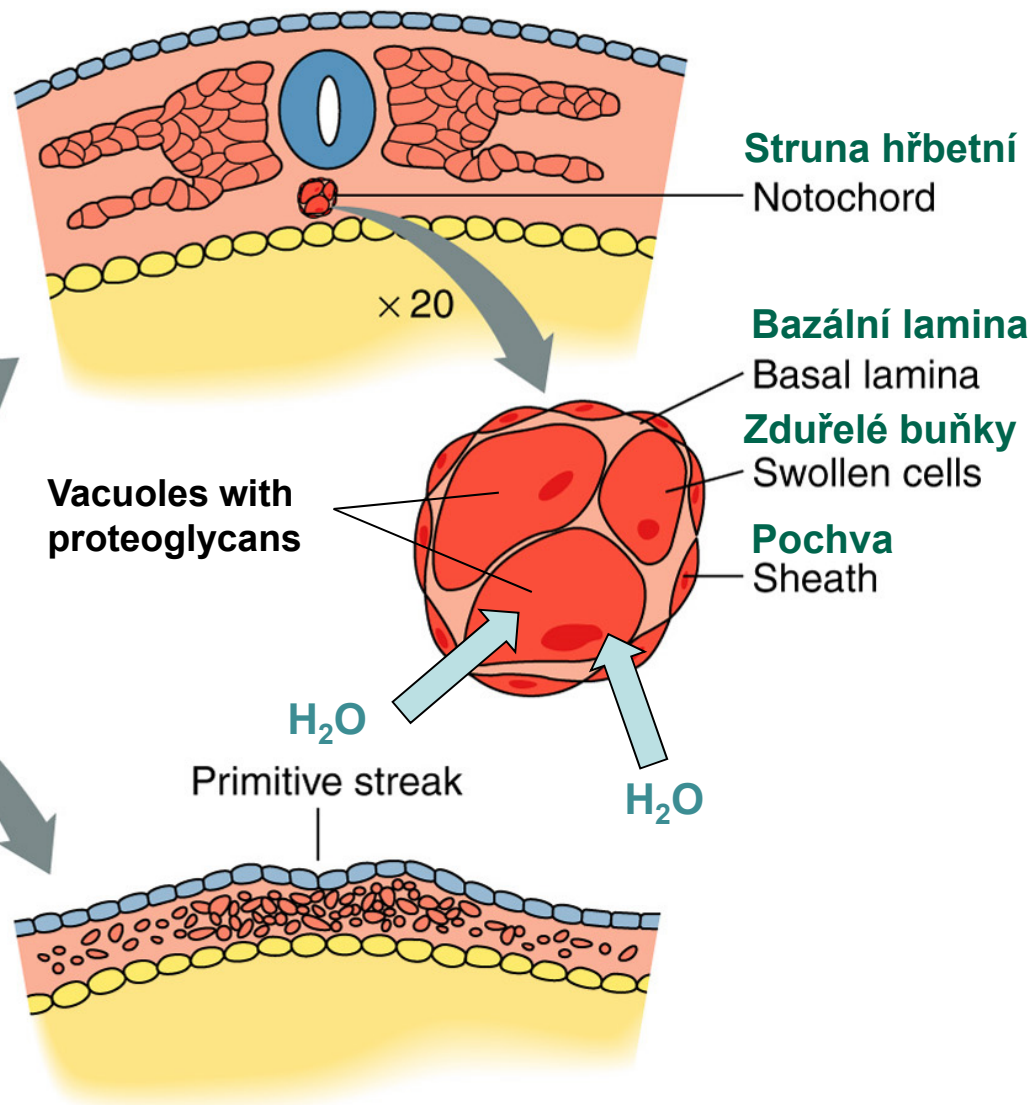
- Mesoderm derivatives development
 - somites formation and signalling



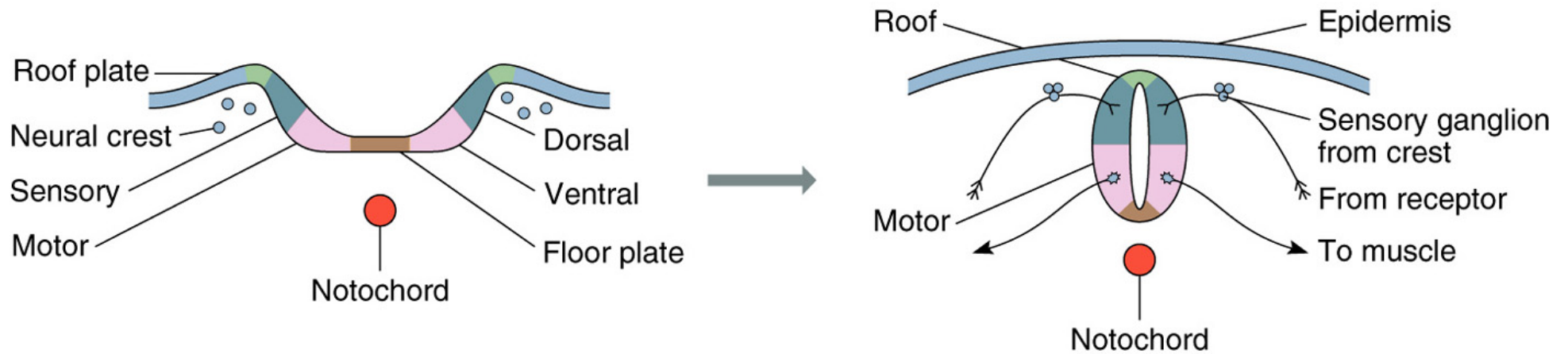
A. Dorsal View



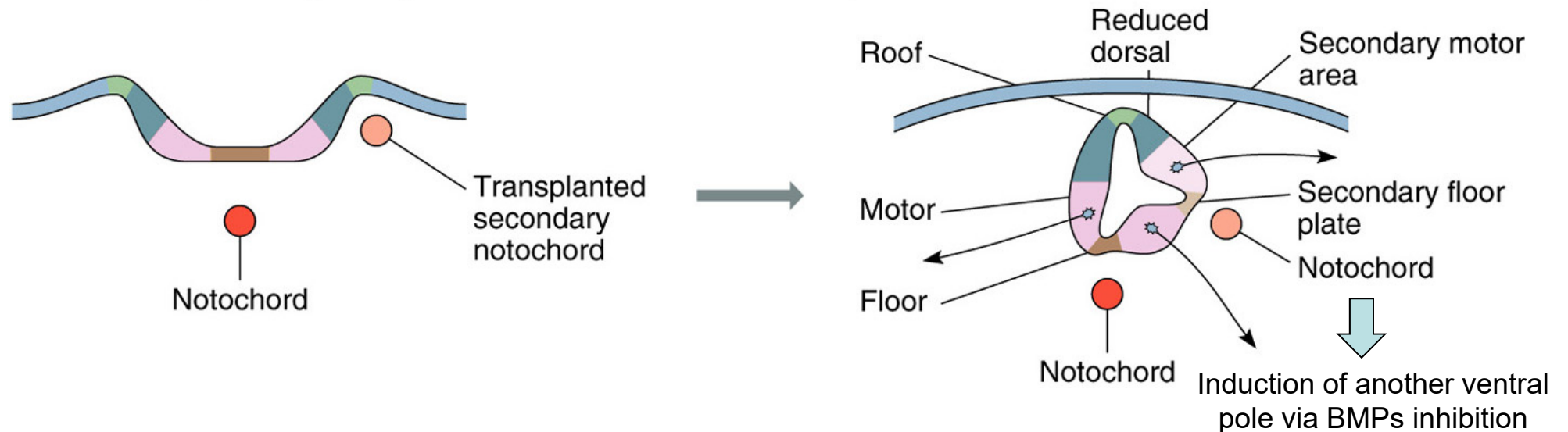
B. Cross-sectional views



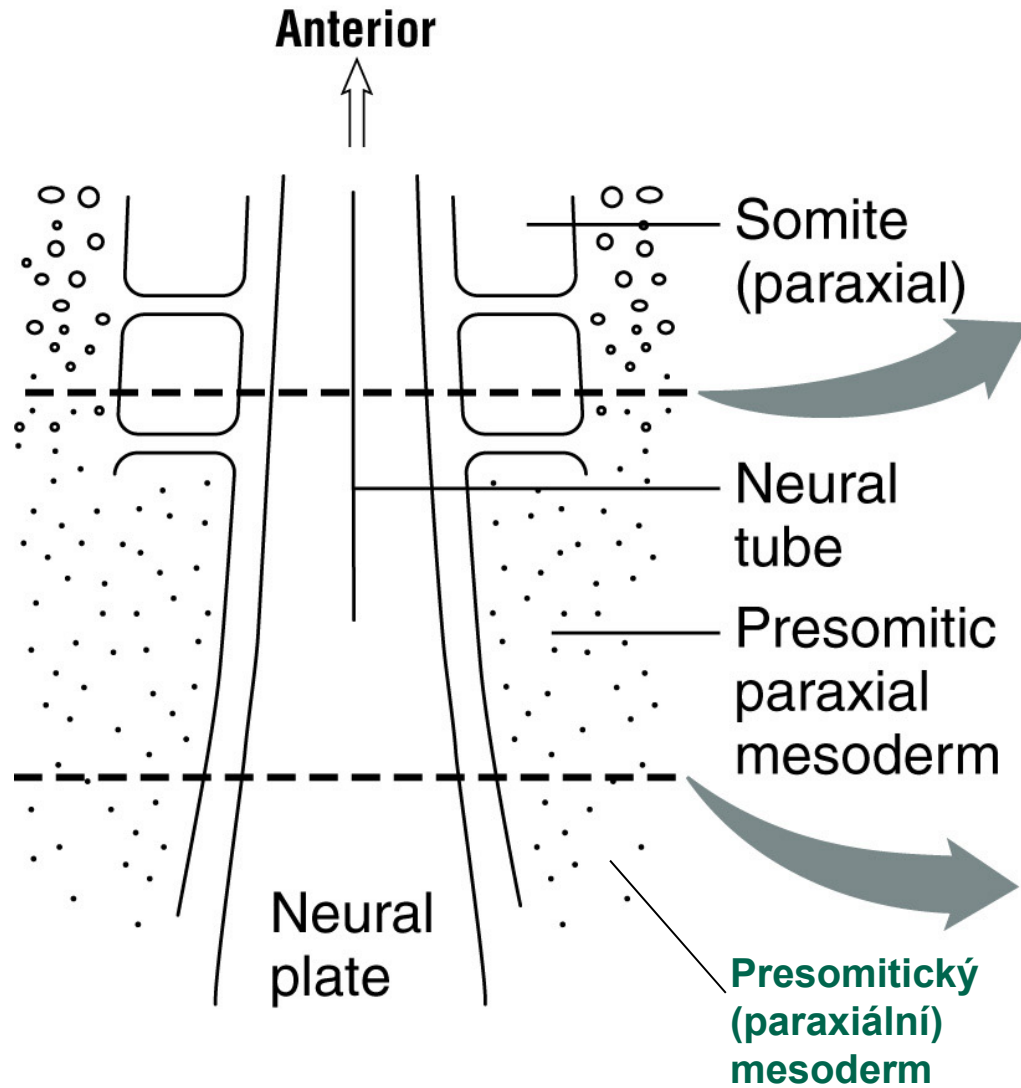
A. The basic situation



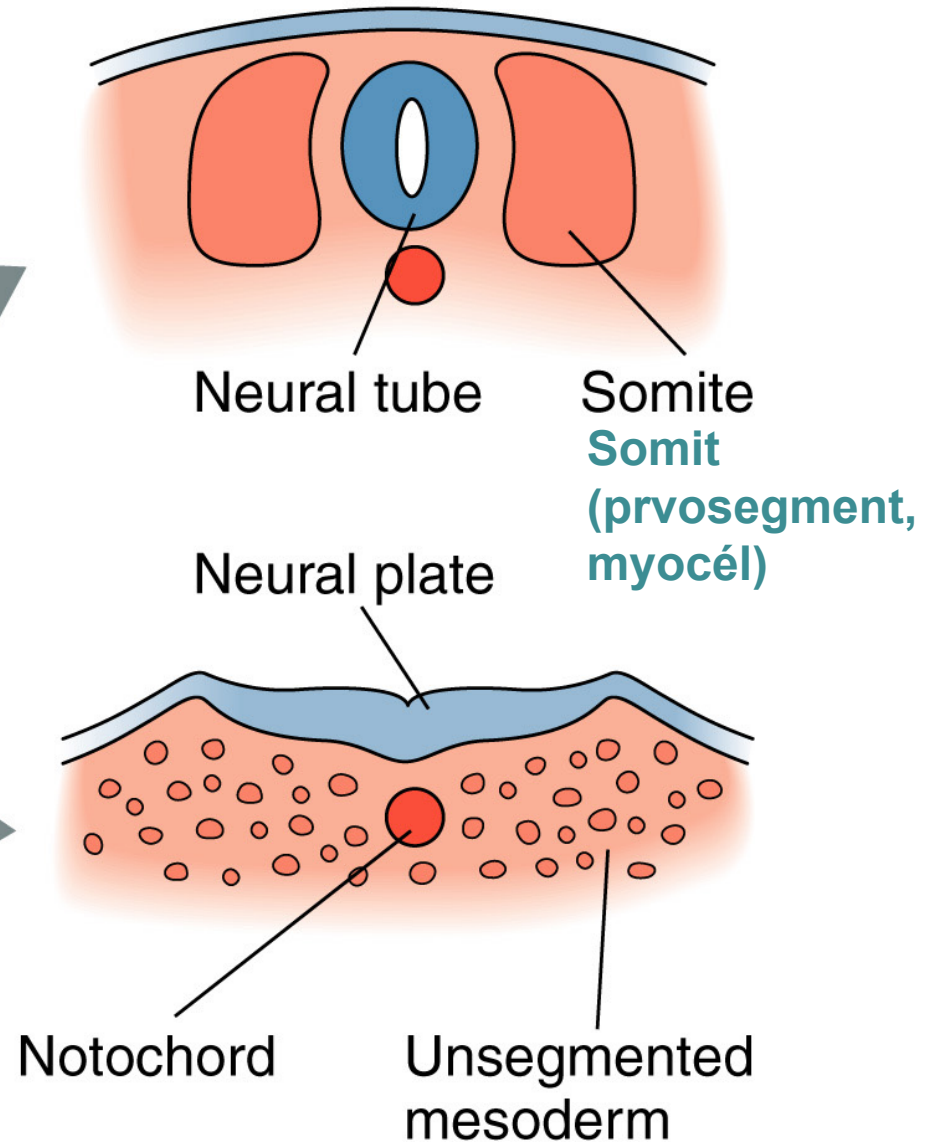
B. Effect of secondary, ectopic notochord under the neural plate

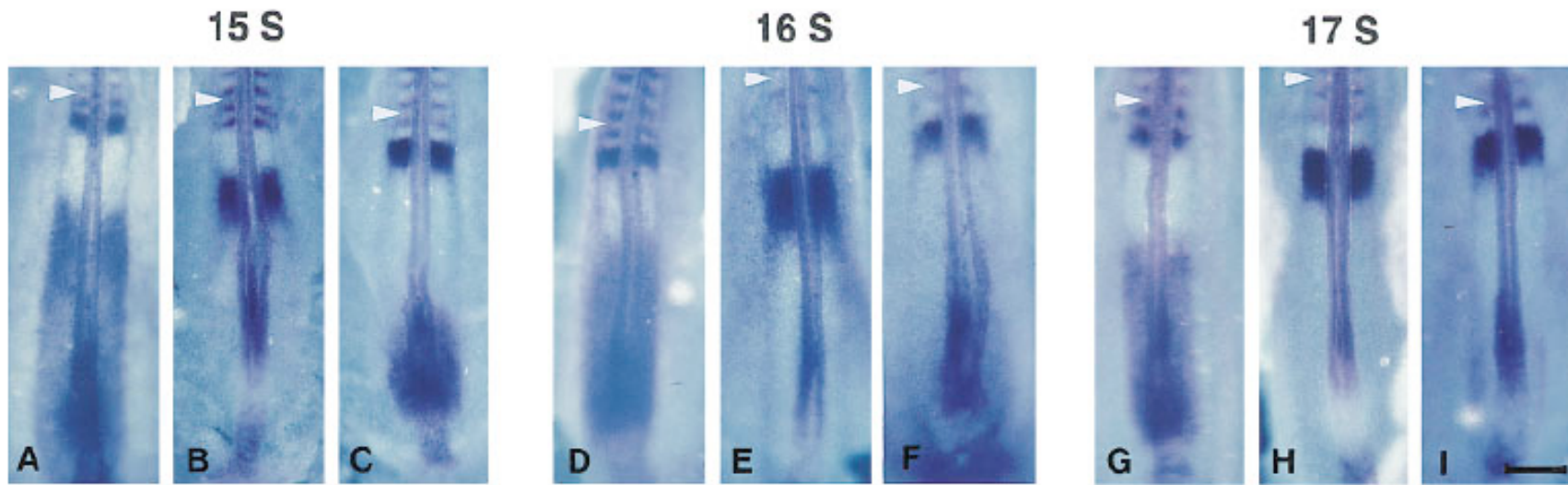


A. Coronal Section



B. Cross Sections

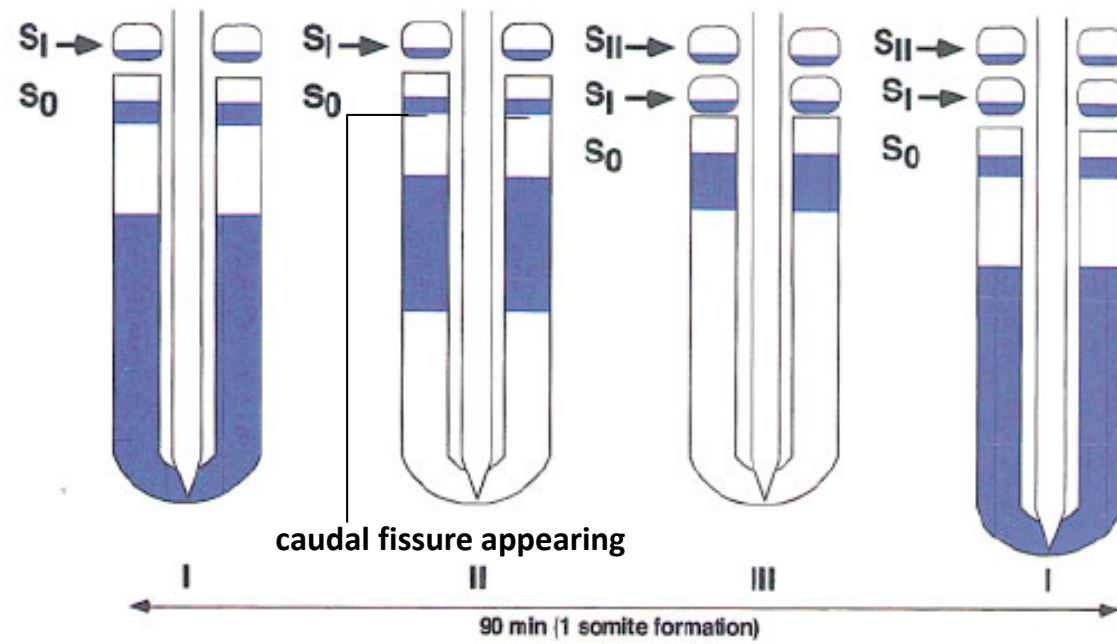




I II III I II III I II III

In situ mRNA localization of *C-HAIRY1* in developing chick embryo

basic helix-loop-helix (b-HLH) TF



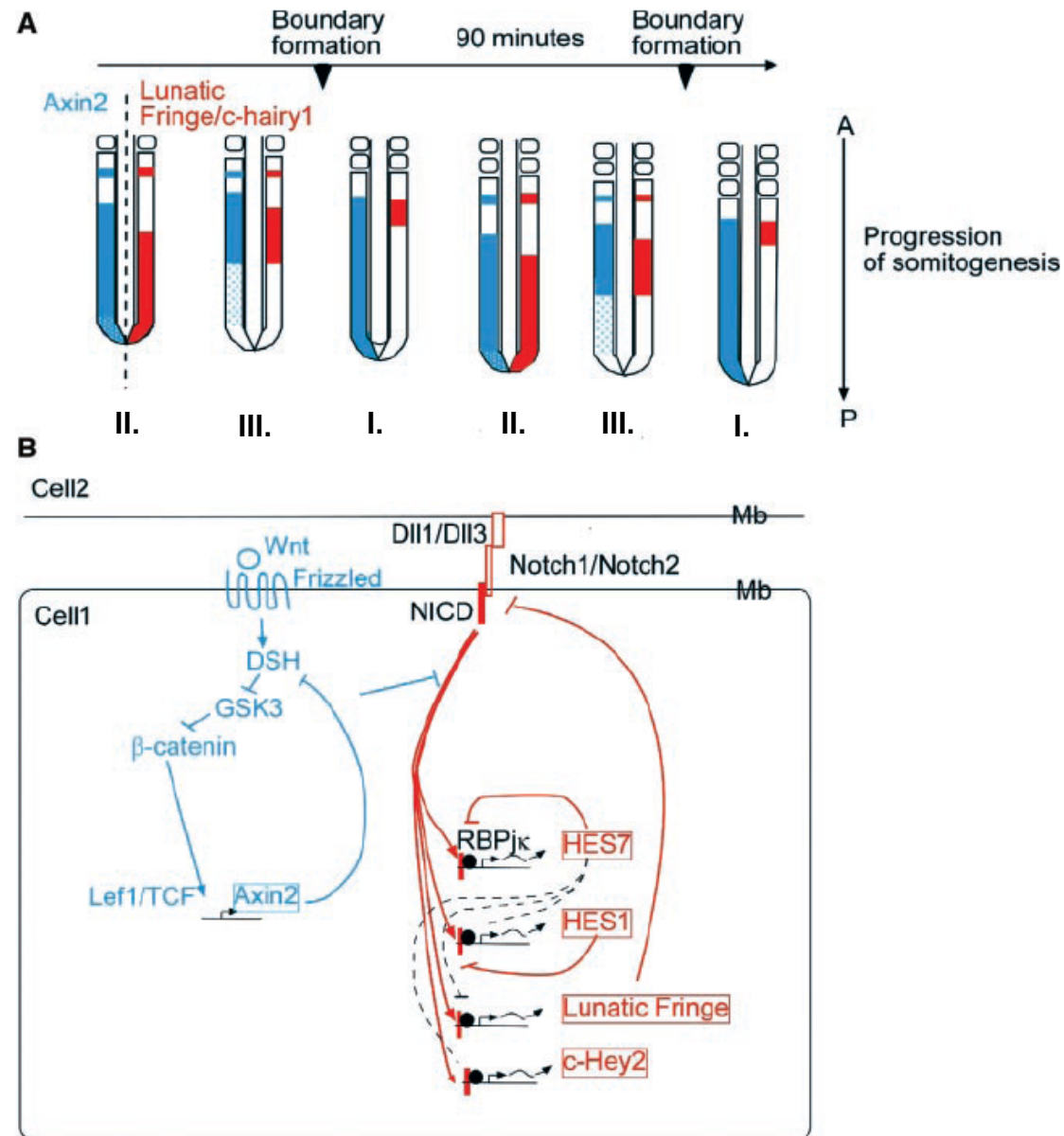
Posterior poles of new somites

Palmeirim et al., *Cell* (1997)

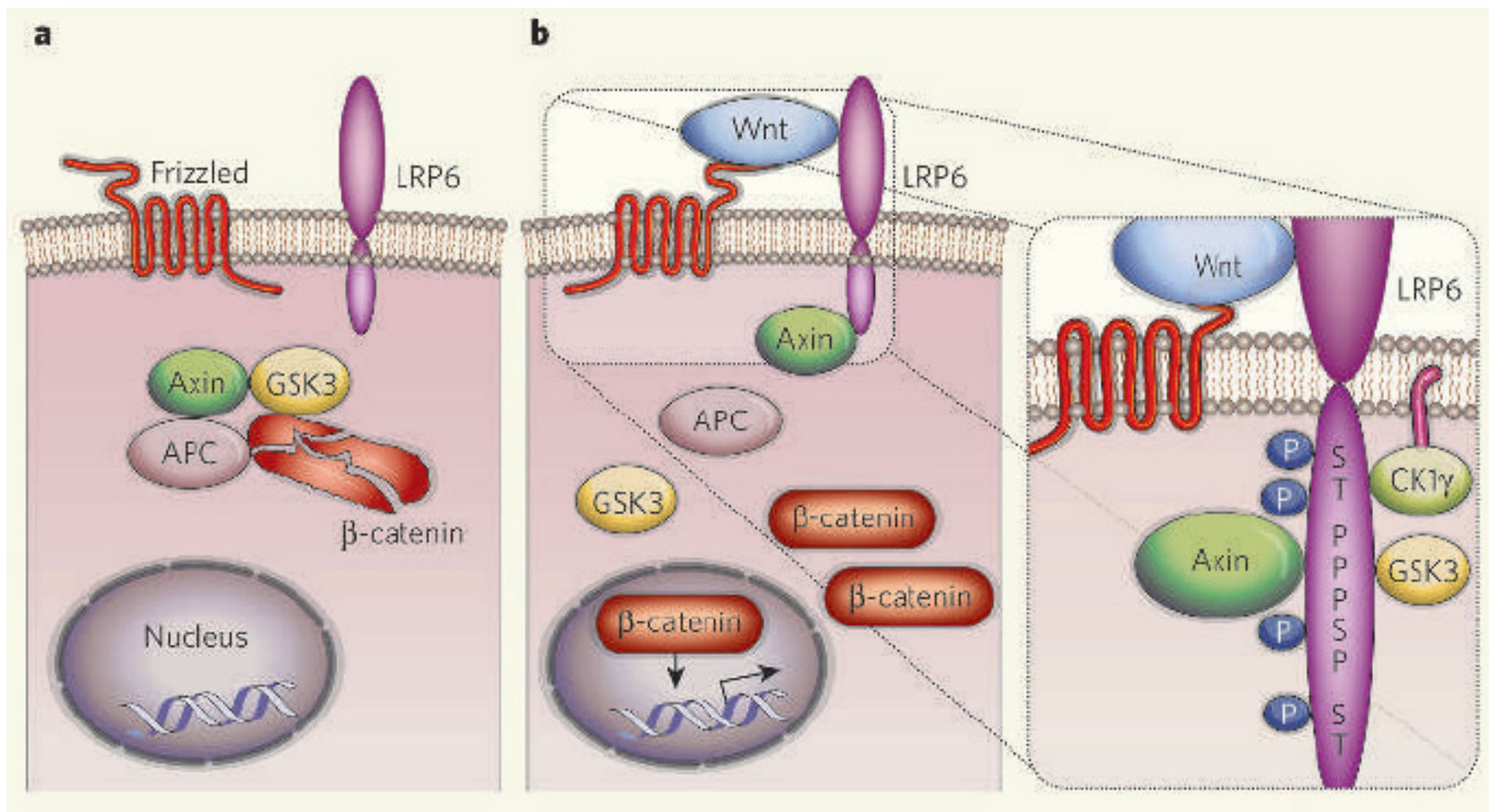


INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

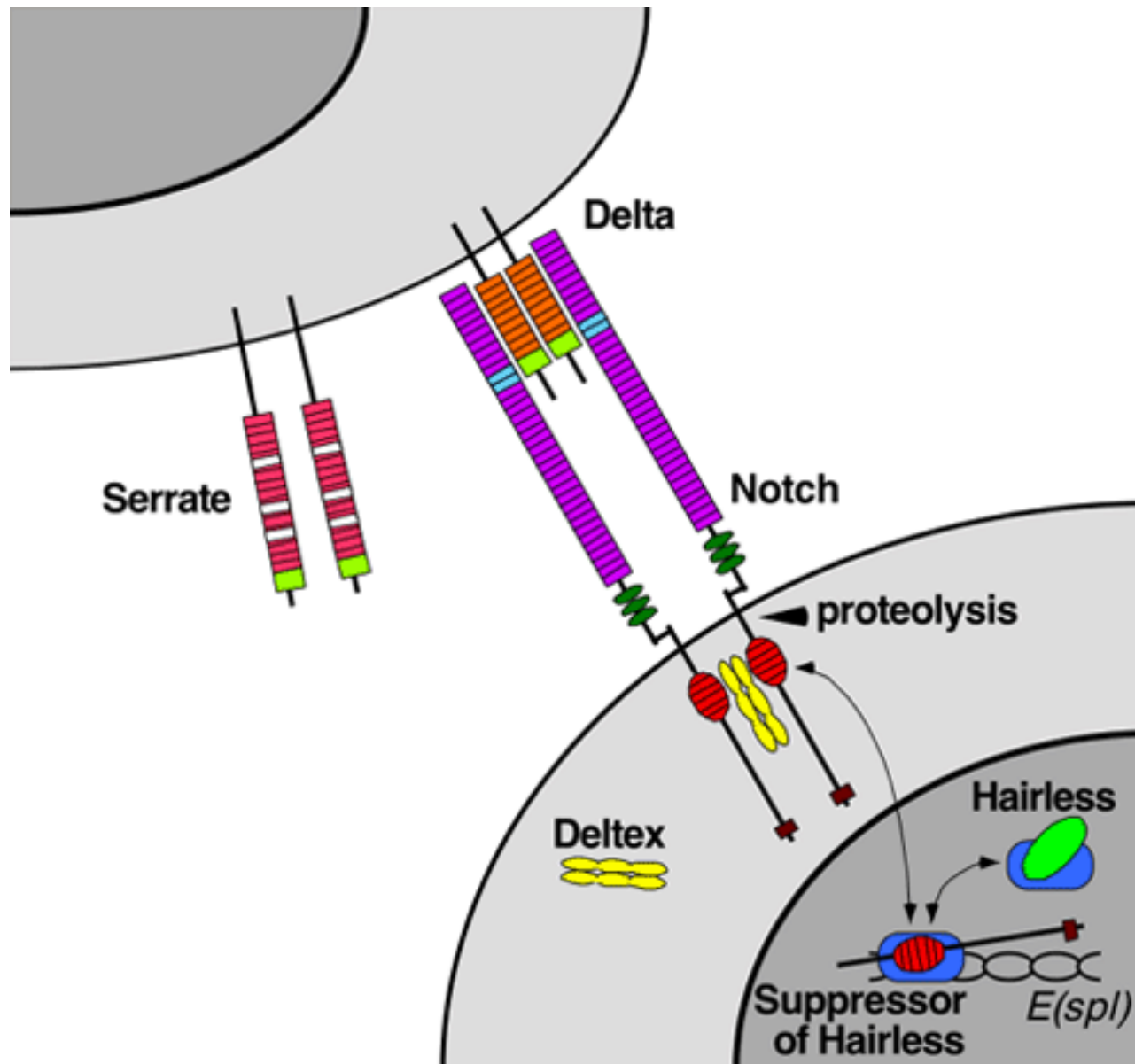
Tato prezentace je spolufinancována Evropským sociálním fondem a státním rozpočtem České republiky



Pourquie., *Science* (2003)



Nusse, *Nature* (2005)



Wikipedia

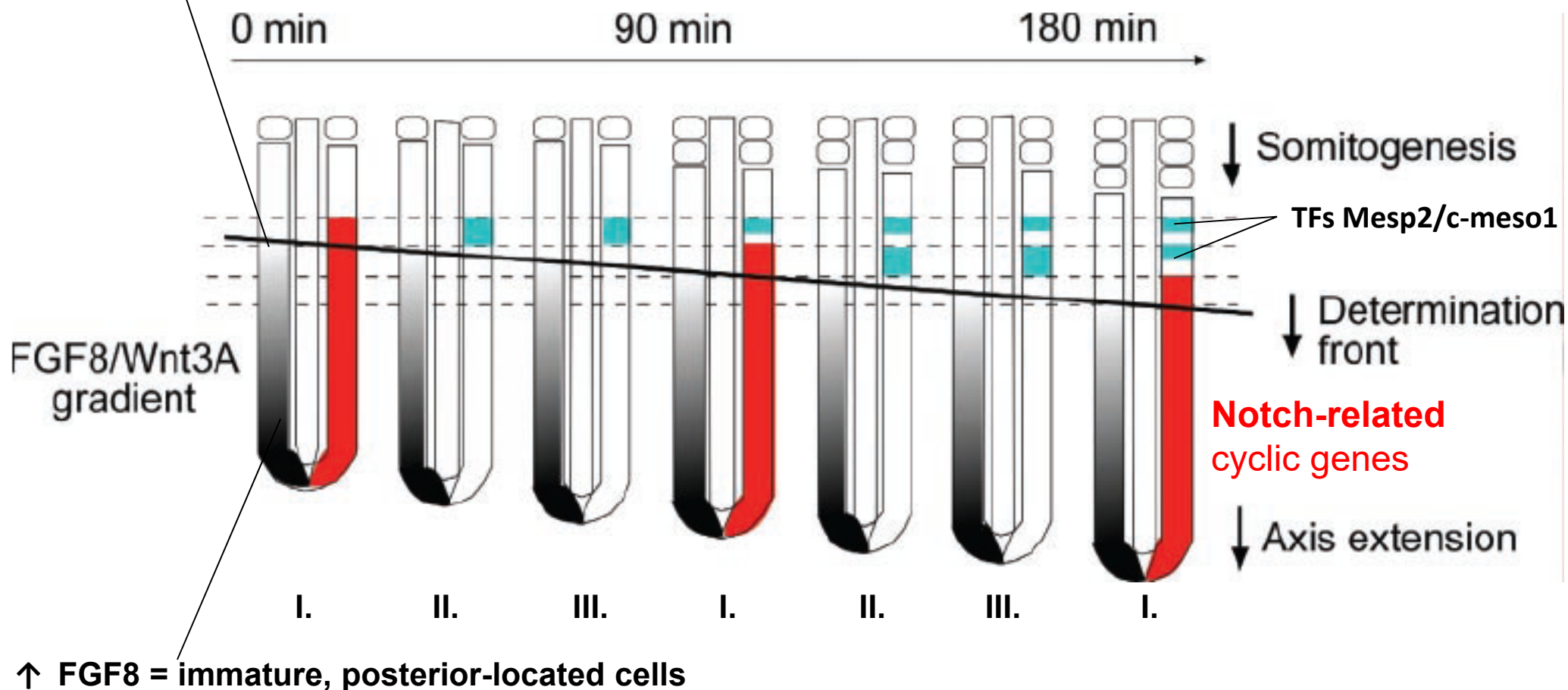


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↓ FGF8 = mature, anterior-located cells - "determination front"

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



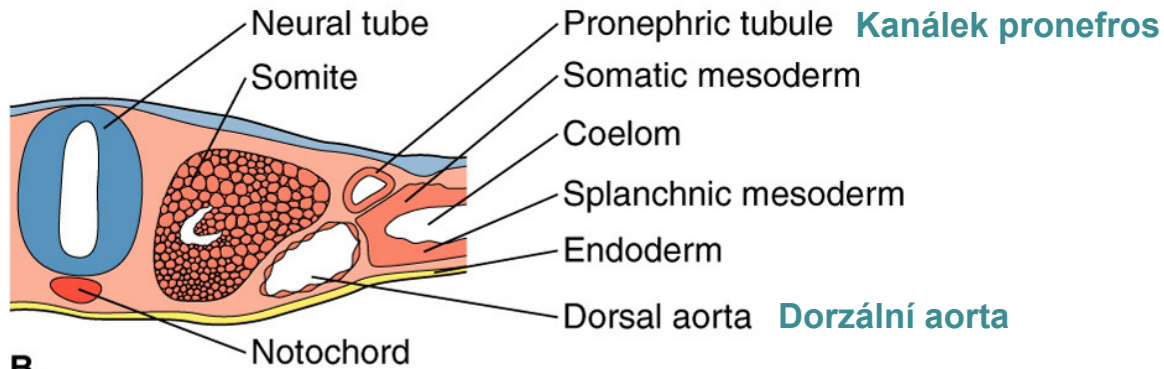
Pourquie., *Science* (2003)



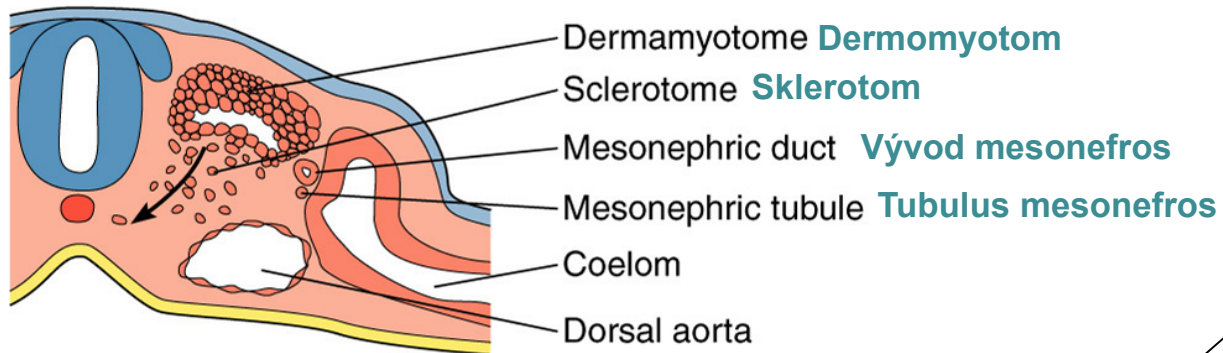
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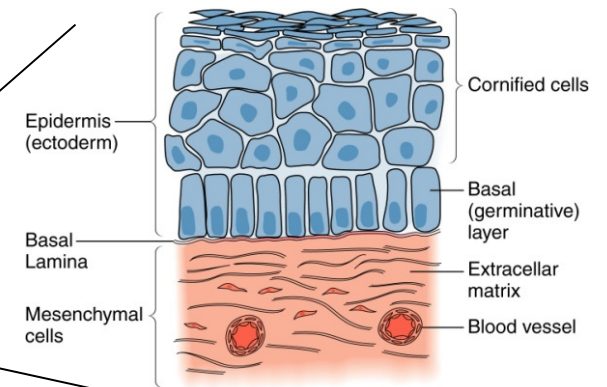
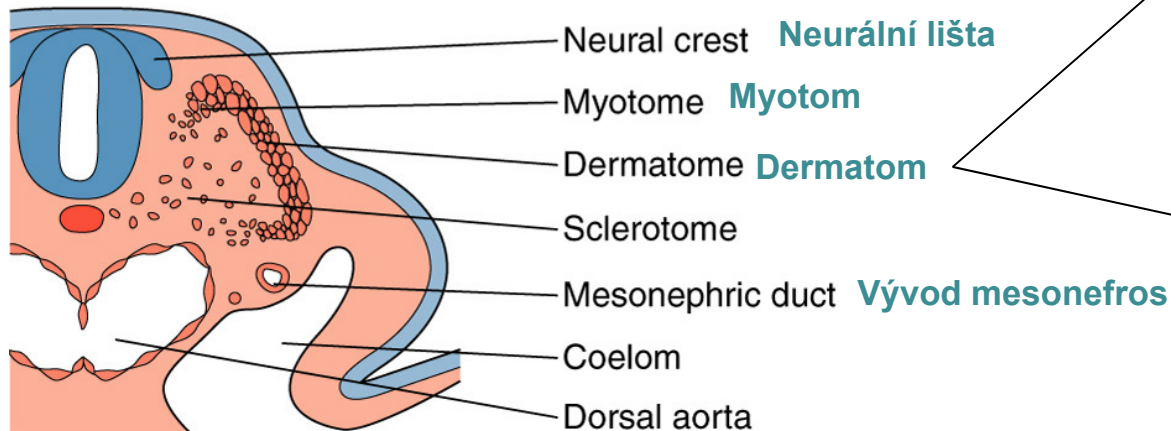
A.

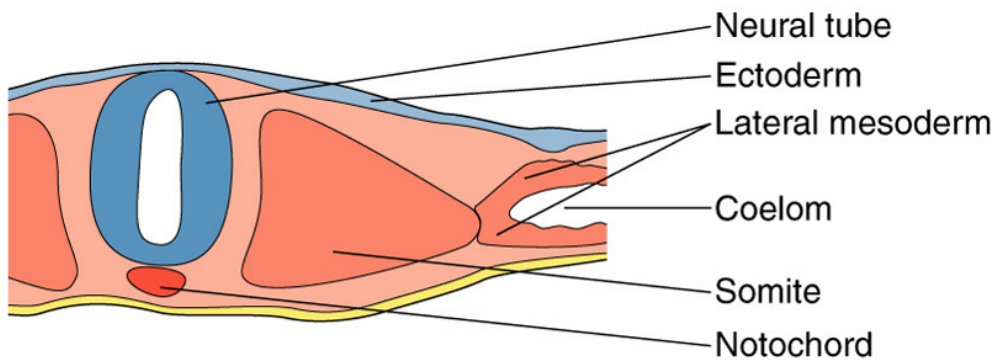


B.



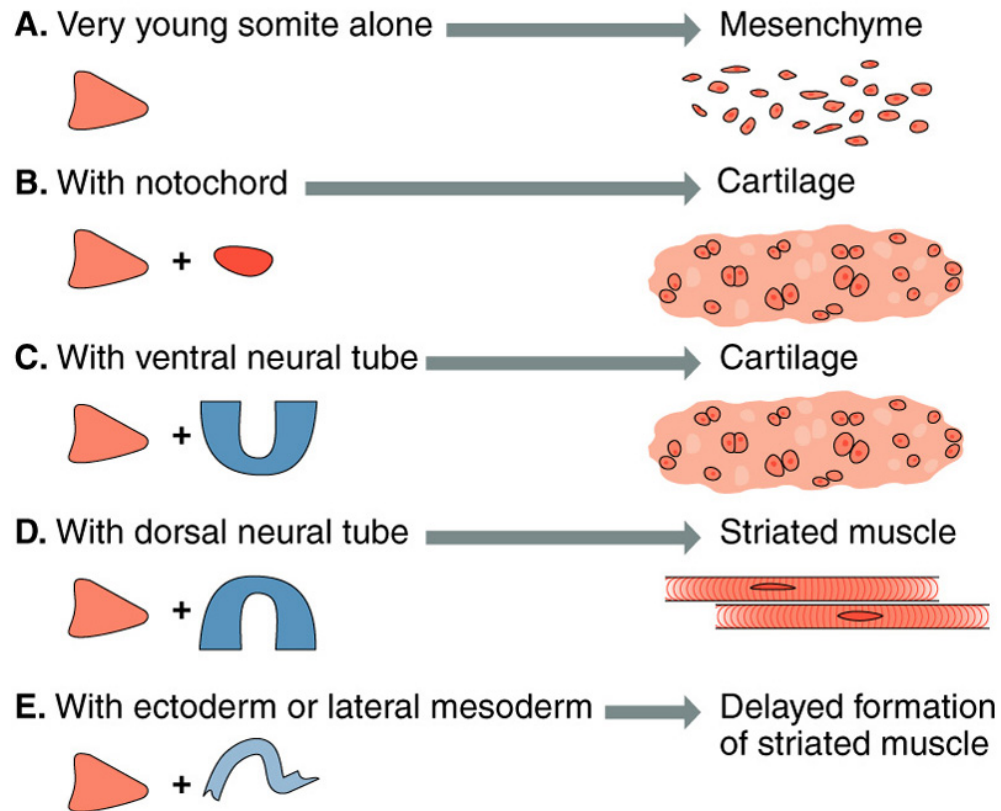
C.





Remove somite and culture:

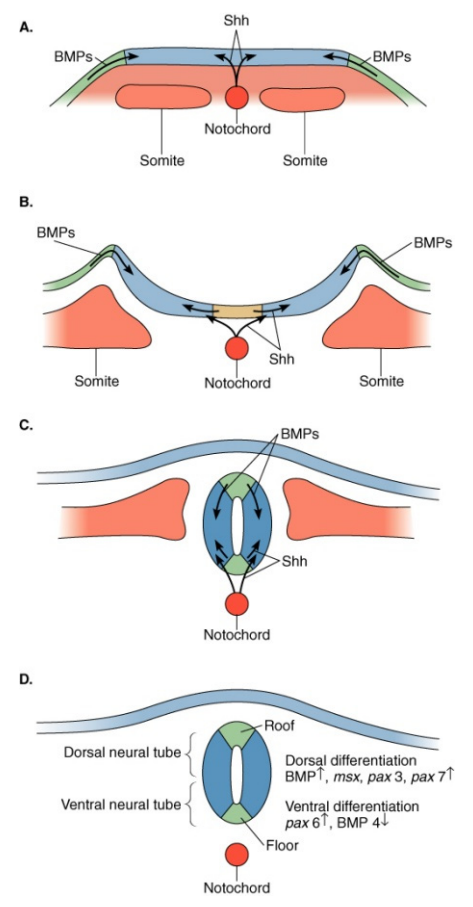
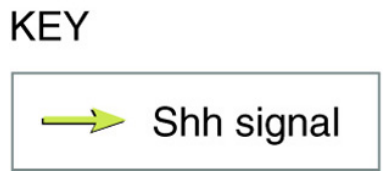
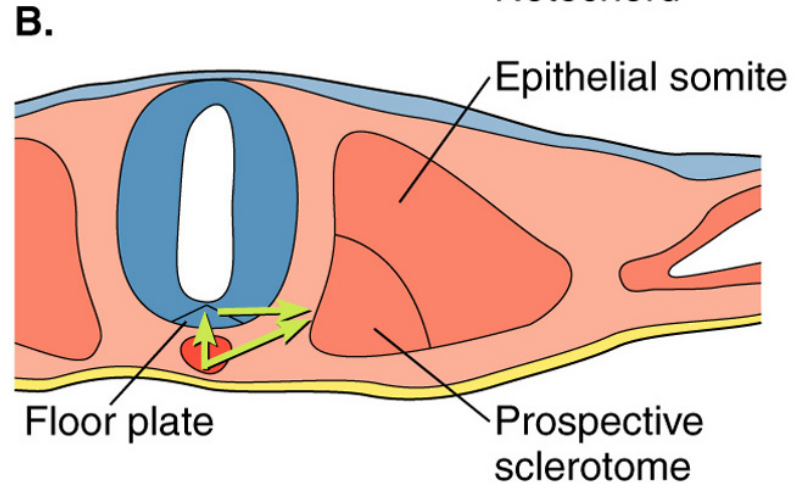
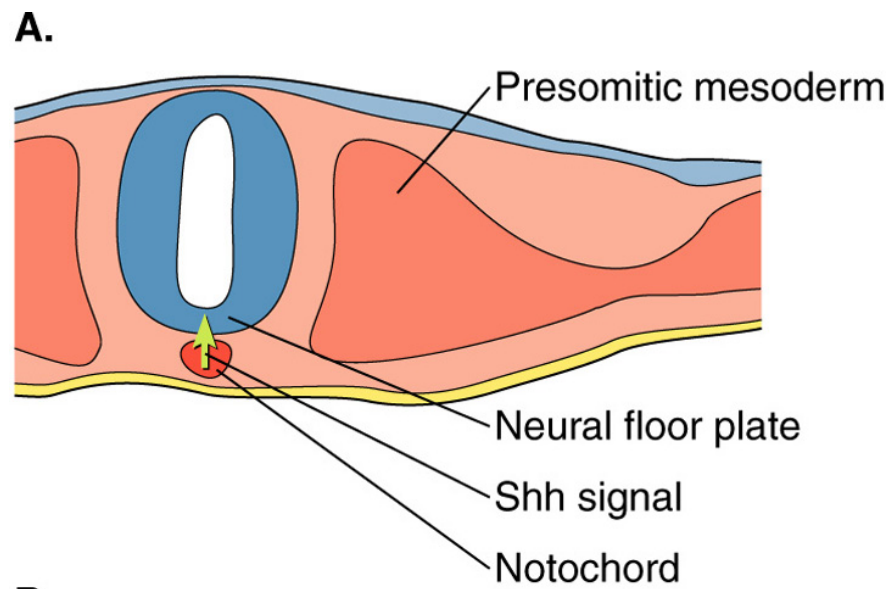
To get:

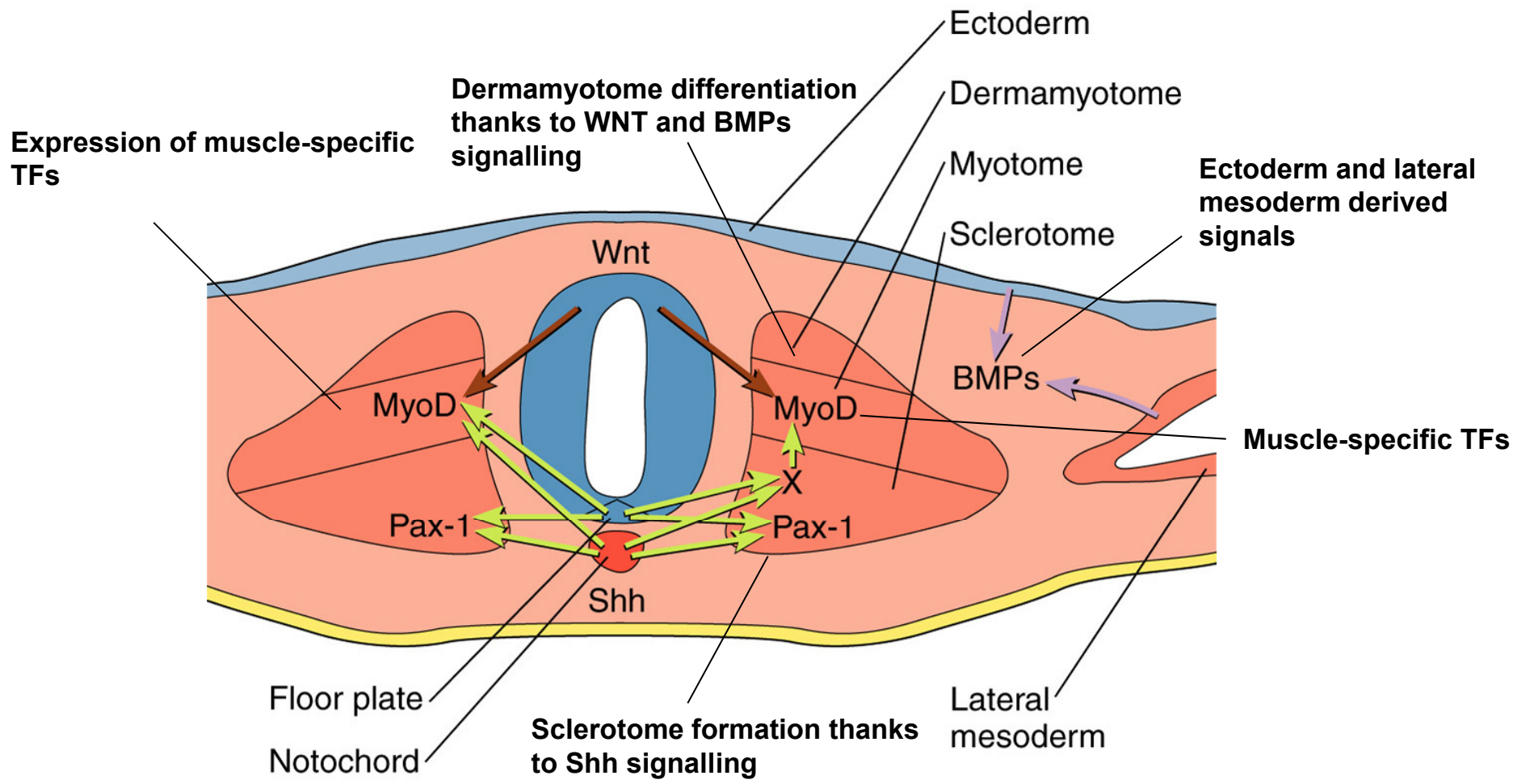


Importance of intercellular communications

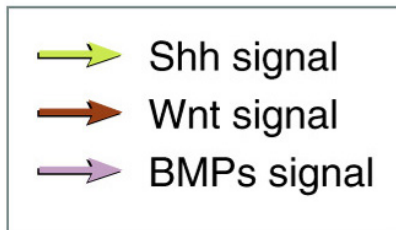


- **MYOD, MYF5**
 - Muscle cells specific TFs
- **Mouse DELTA homologue**
 - Somites segmentation signalling





KEY

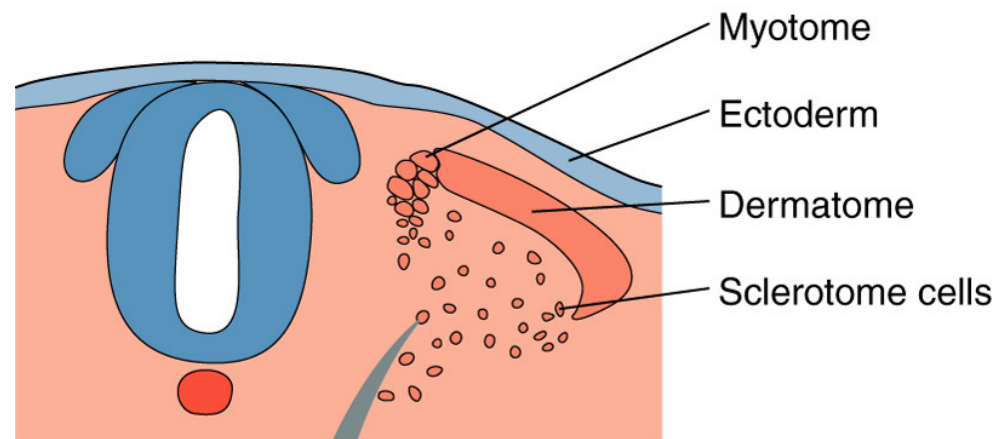




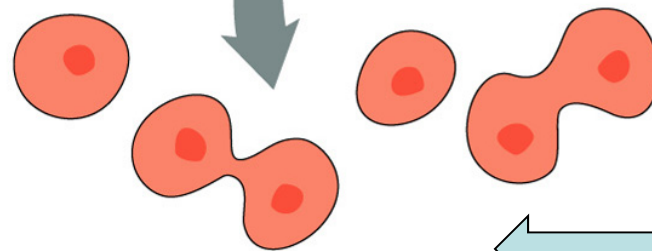
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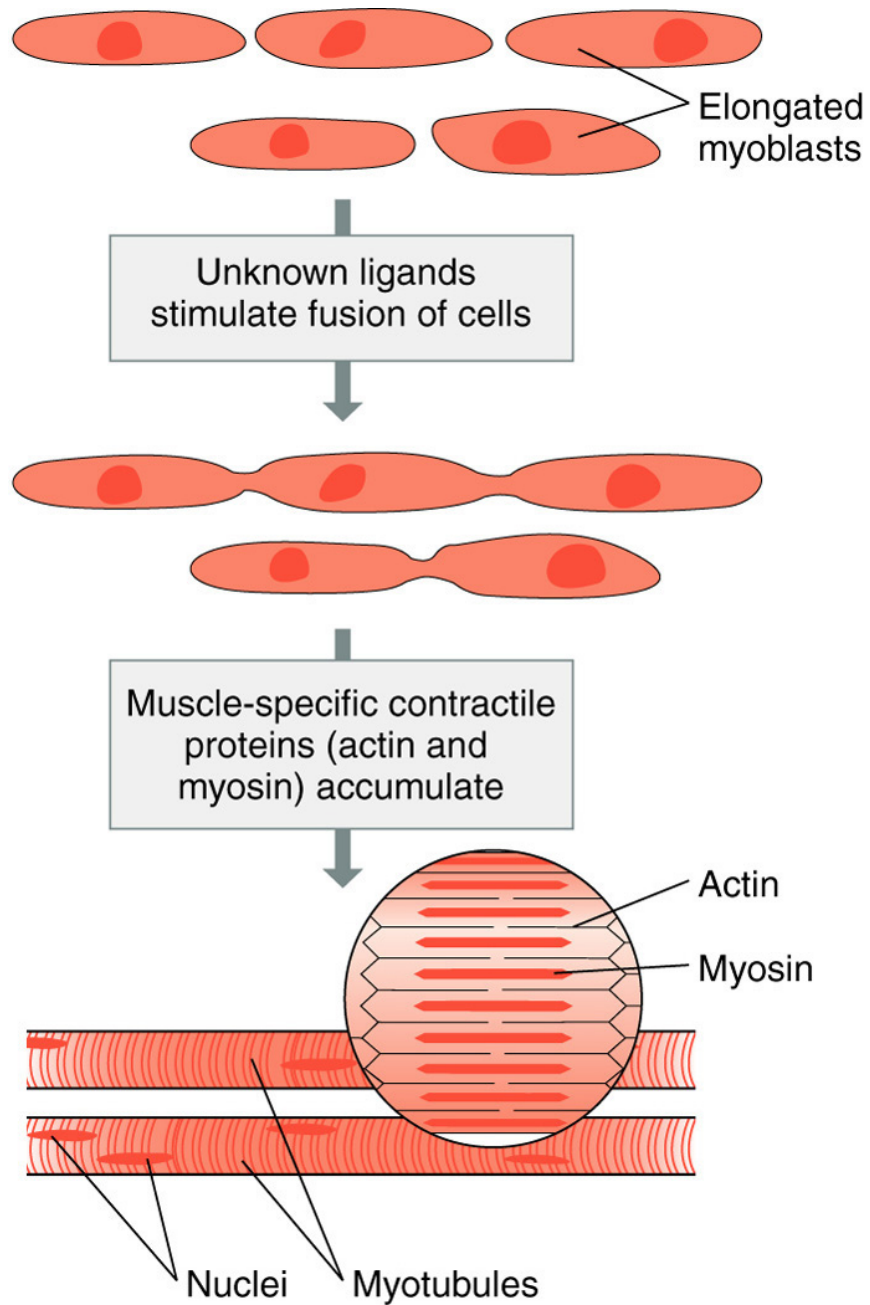


Myoblasts within myotome region proliferate



Cell division ceases

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

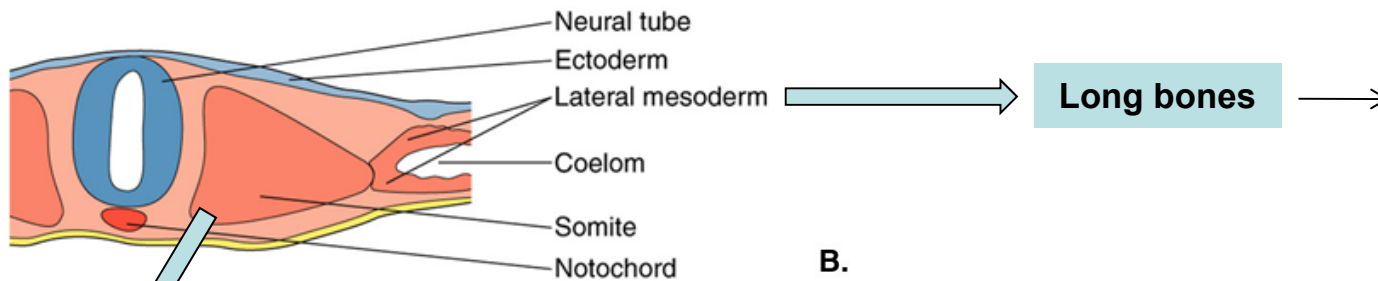




Outline of Lesson 5

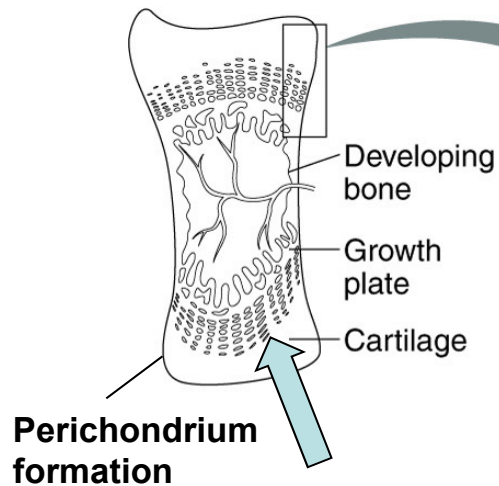
Organogenesis in Vertebrates: Endo- and Mesodermal Derivatives

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 - endochordal ossification and signalling



Endochondral ossification vs. intramembraneous ossification

Vertebrae and proximal ribs



Perichondrium formation

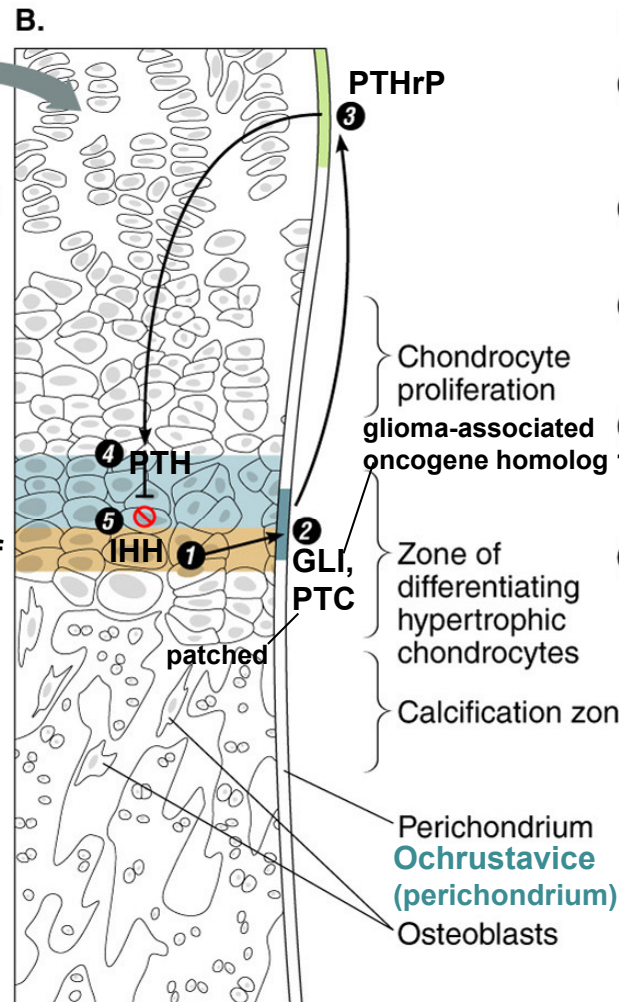
Bone formation

Aggregation of sclerotomes, central cells become chondrocytes

Blood vessels invasion, osteoblasts movement and hydroxyapatite deposition

Hypertrophic chondrocytes formation

Cell division and swelling



C. The regulatory network

- 1 Differentiating hypertrophic chondrocytes express PTH/PTHrP receptor and Indian hedgehog.
- 2 Ihh stimulates expression of *gli* and *ptc* in the perichondrium...
- 3 ...which leads to PTHrP ligand secretion from the perichondrium near the joint.
- 4 PTHrP feeds back and is received by PTH receptors in the hypertrophic zone...
- 5 ...which activates the PTH/PTHrP receptors to slow Ihh production. This negative feedback loop slows down the differentiation rate.

KEY

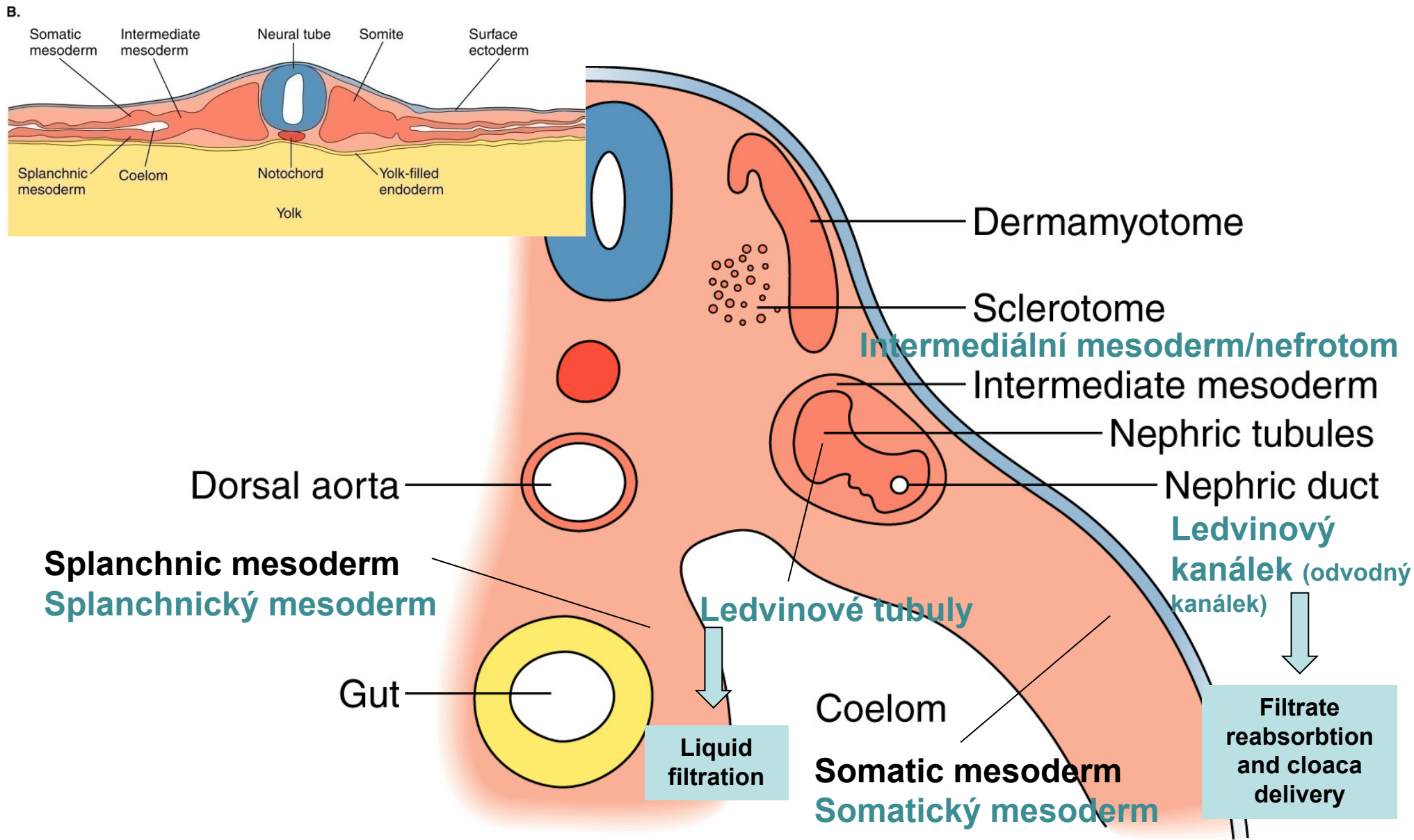
- Ihh production
- Production of PTH/PTHrP receptor
- gli*, *ptc* expression
- PTHrP ligand secretion



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 - nephrogenesis



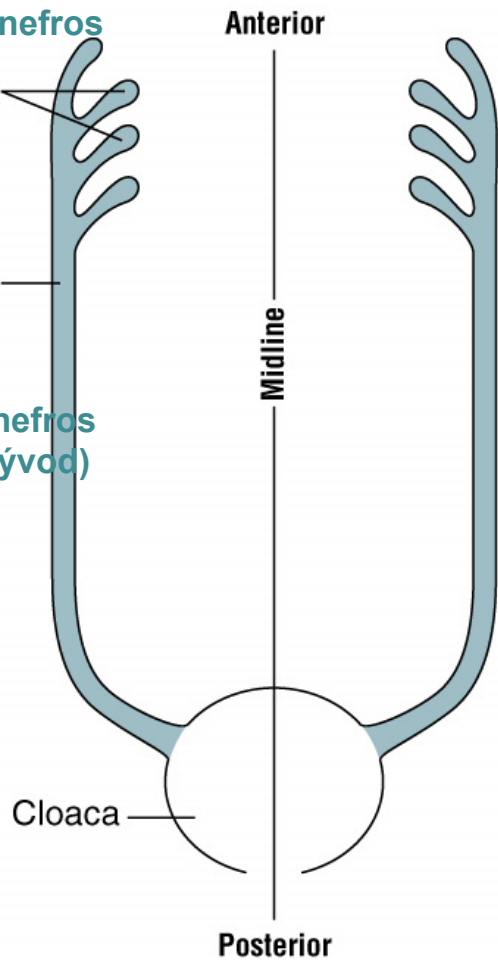
A. Pronephros

Tubuly pronefros

Pronephric tubules

Pronephric (Wolffian) duct

Vývod pronefros (Wolffioho vývod)



sliznatky (bezčelistnatí)
hagfishes (Agnatha)

B. Mesonephros

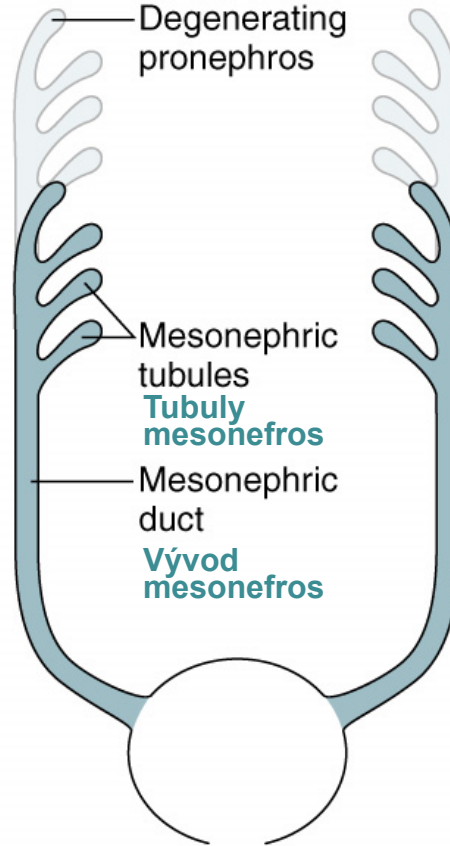
Degenerating pronephros

Mesonephric tubules

Tubuly mesonefros

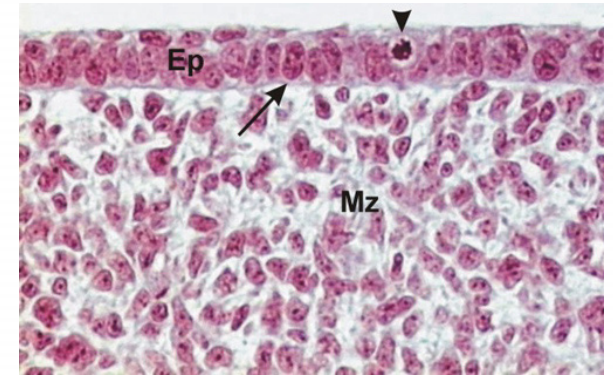
Mesonephric duct

Vývod mesonefros

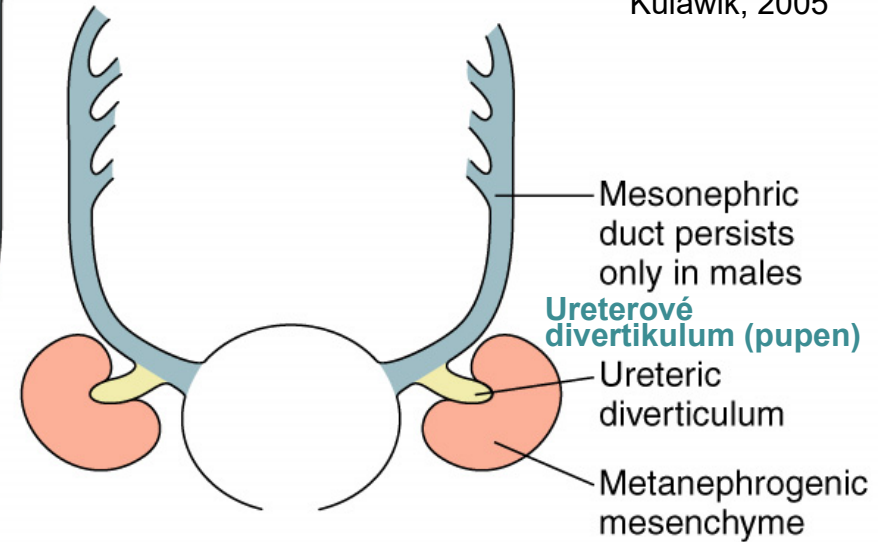


amphibians, fishes

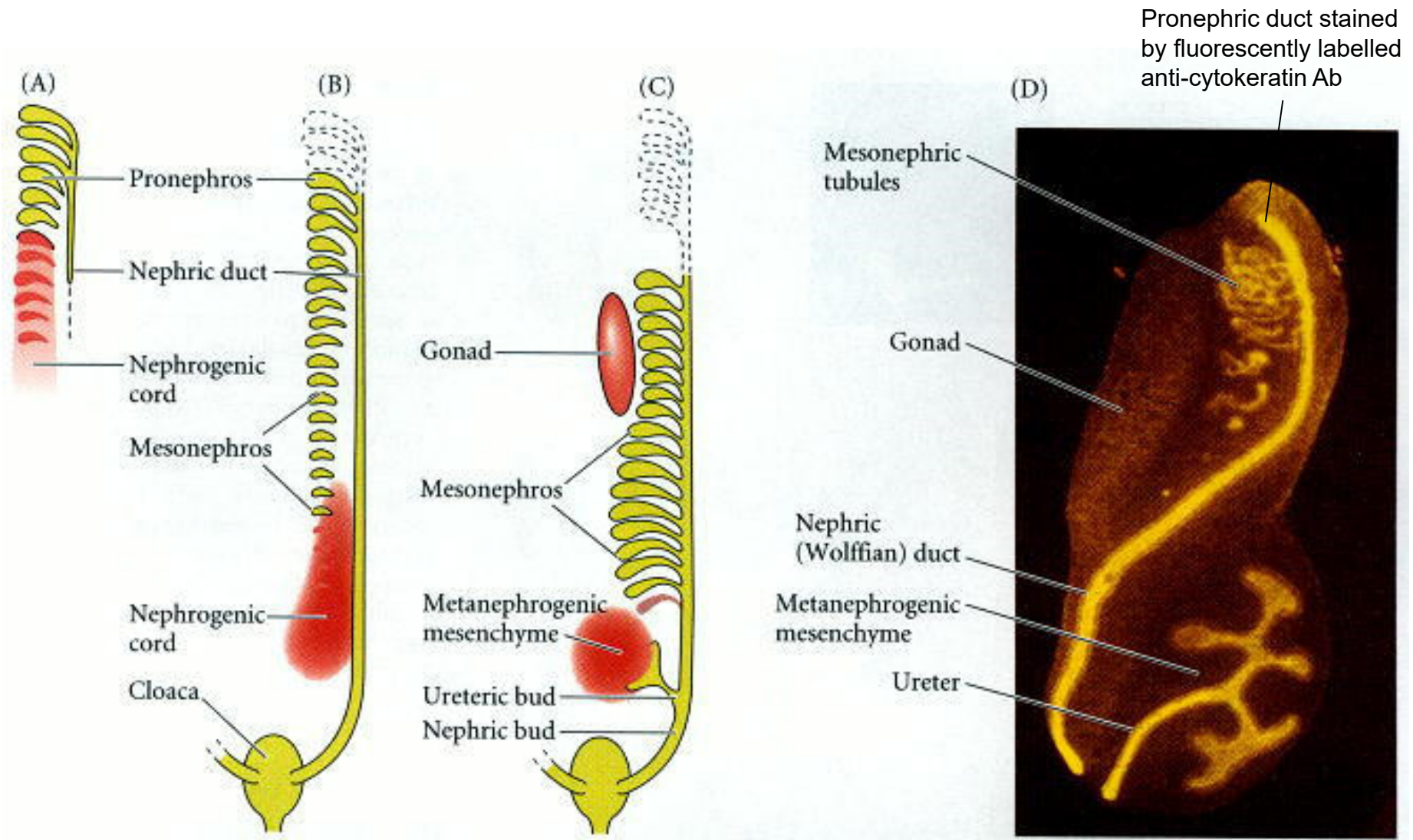
C. Metanephros



Kulawik, 2005



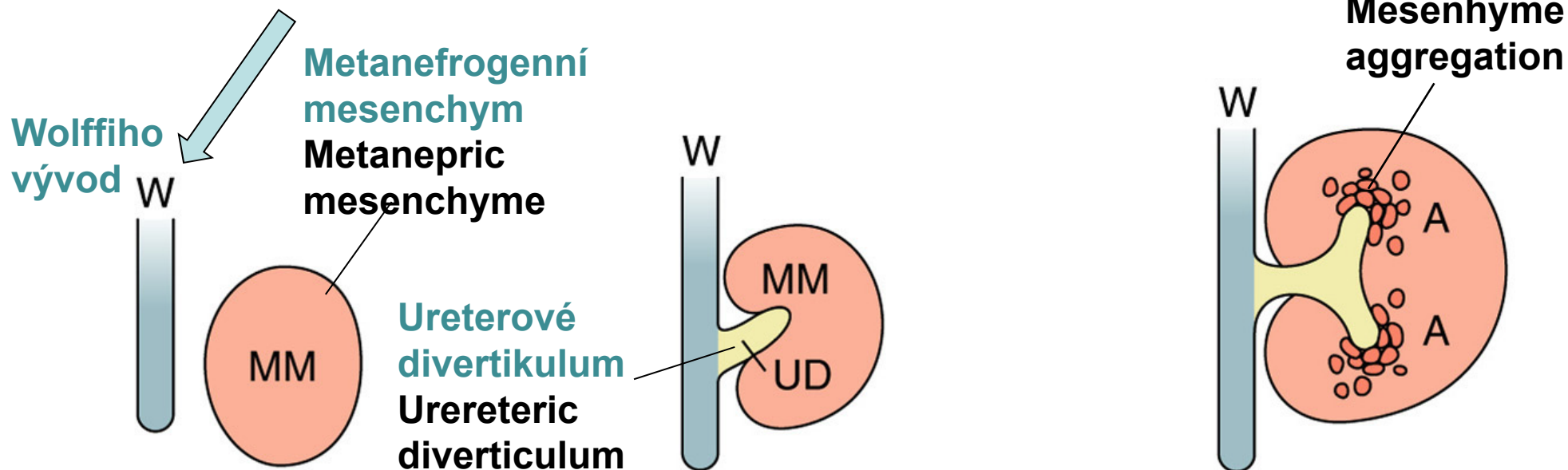
amniotes



Gilbert, SF, Developmental biology

Intermediate mesoderm of a 13-day mouse embryo

ectoderm-derived path cues



1

The Wolffian duct elongates. Metanephric mesenchyme is specified.

2

The ureteric bud evaginates. Mesenchymal cells respond.

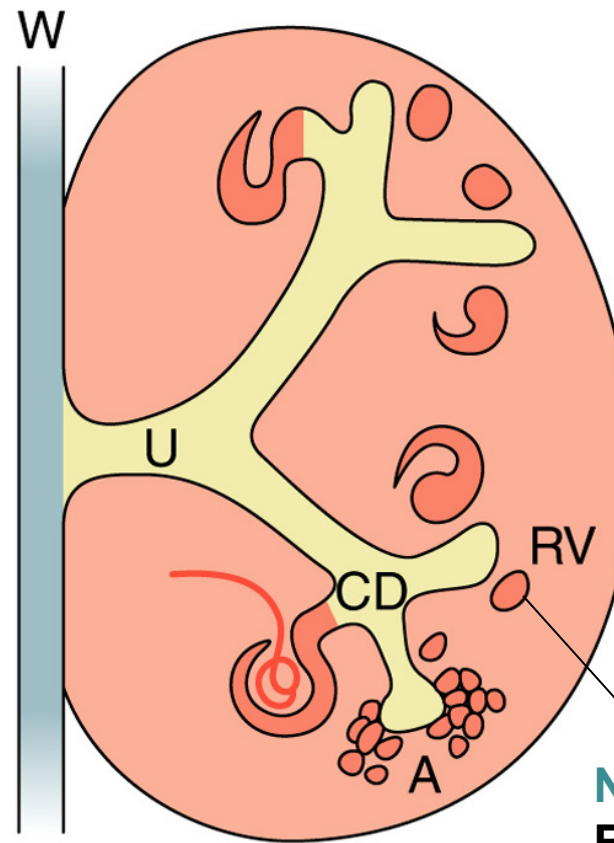
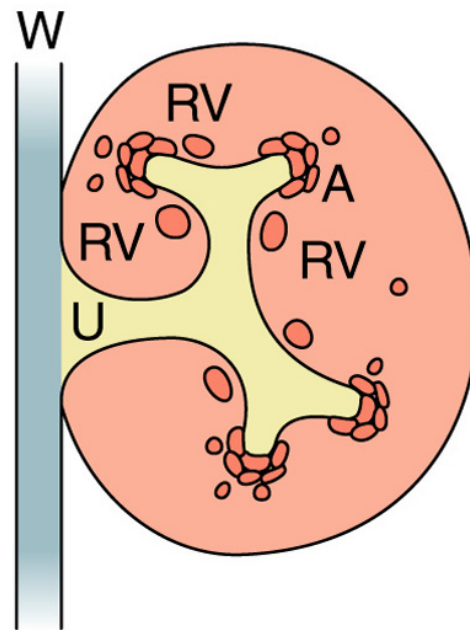
3

The ureteric bud branches. Mesenchymal cells aggregate.



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Nefrogenní váček
Renal vesicle

4

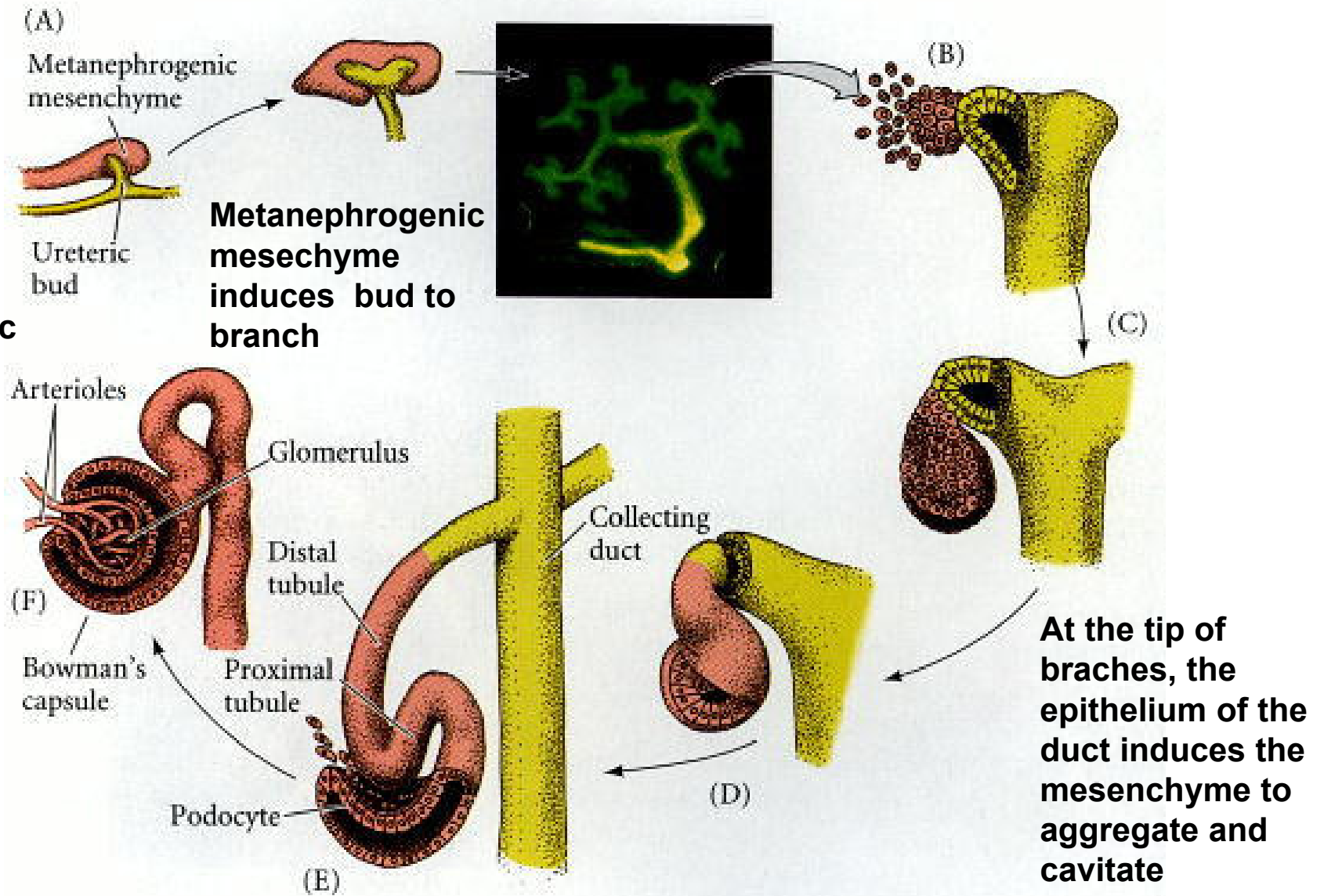
Renal vesicles form.
Branching and
aggregation continues.

5

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

Reciprocal induction in kidney development

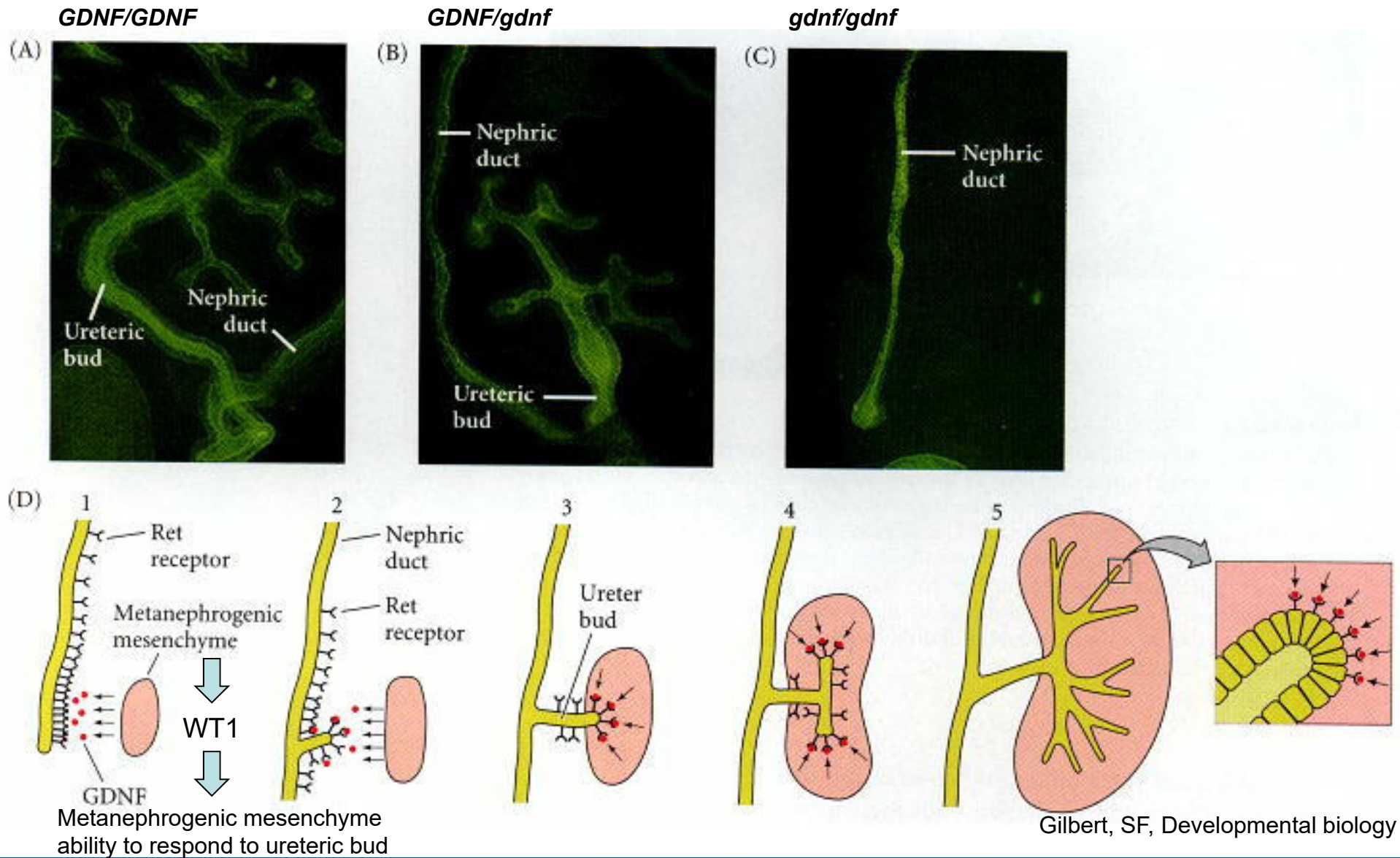
Ureteric diverticulum induces metanephrogenic mesenchyme aggregation



Gilbert, SF, Developmental biology

Reciprocal induction in kidney development

The role of glial-derived neurotrophic factor (GDNF)



Metanefrogenní mesenchym

Primární sběrací kanálek
(vzniká větvením ureterického
divertikula)

Nefrogenní váček

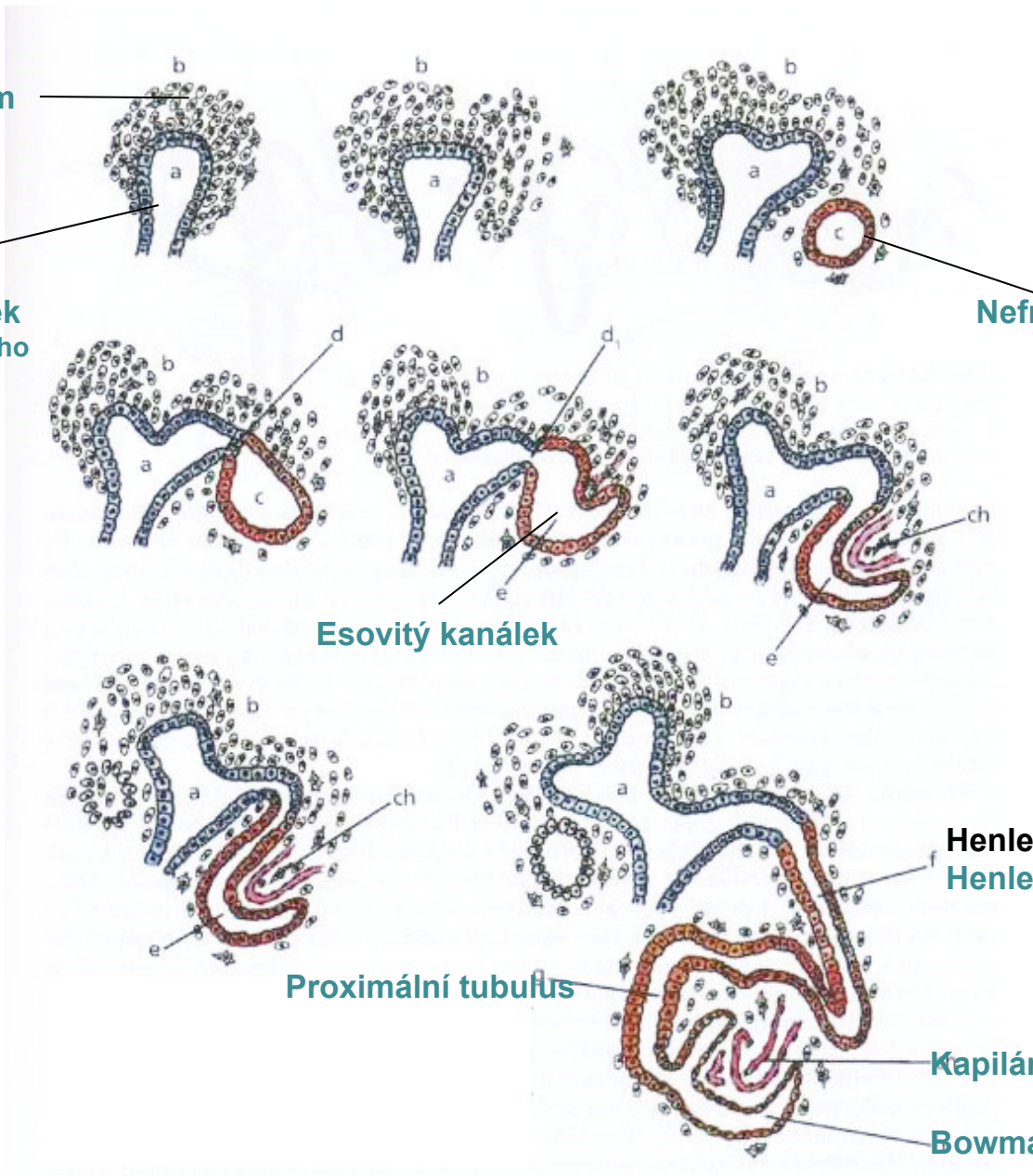
Esovitý kanálek

Henle loop
Henleyova klička

Proximální tubulus

Kapiláry glomerulu

Bowmanův váček



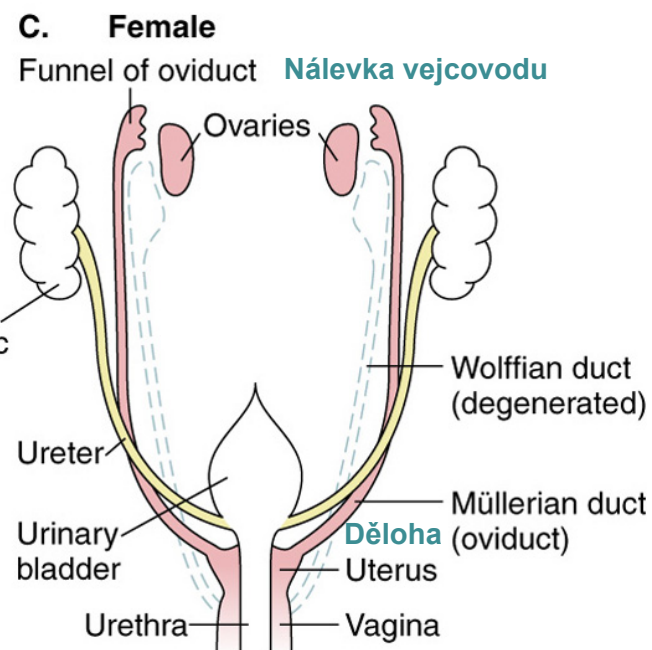
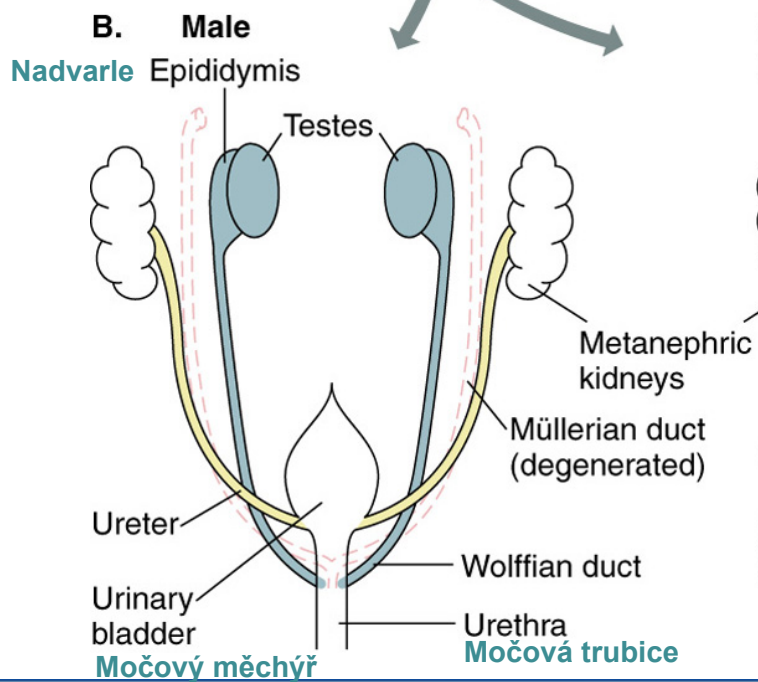
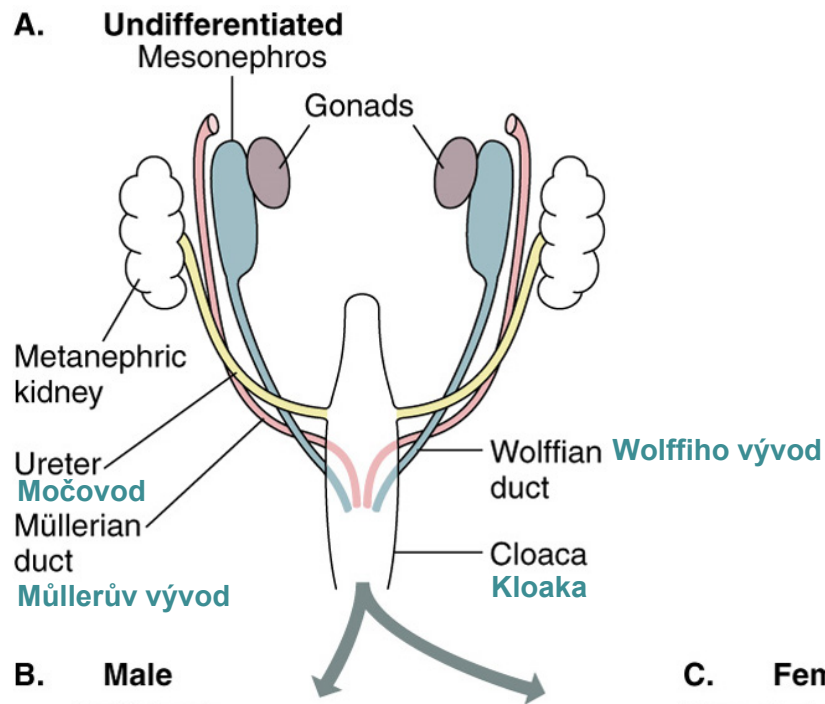
Vacek, Embryologie (2006)



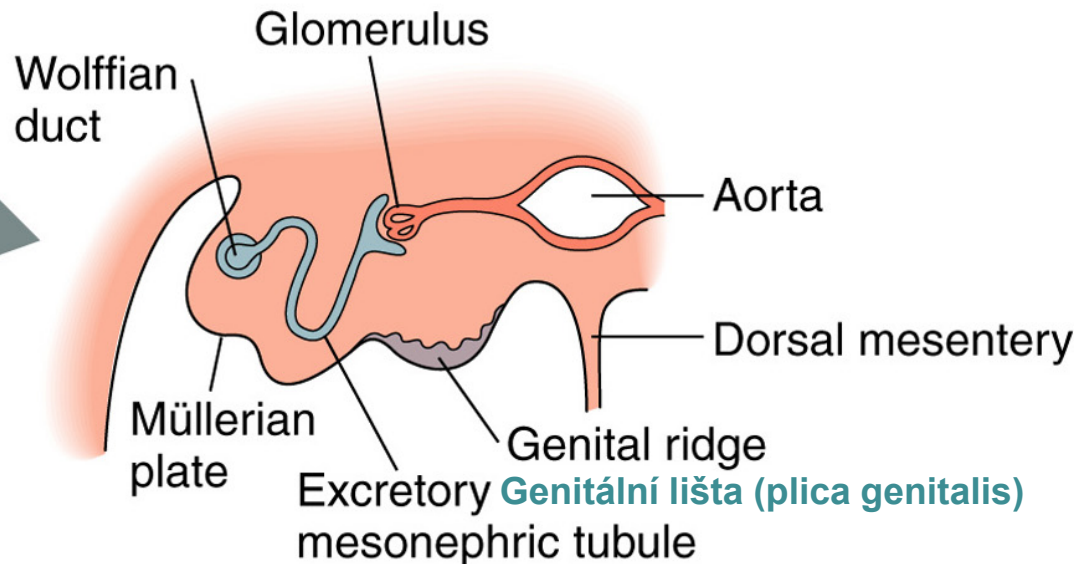
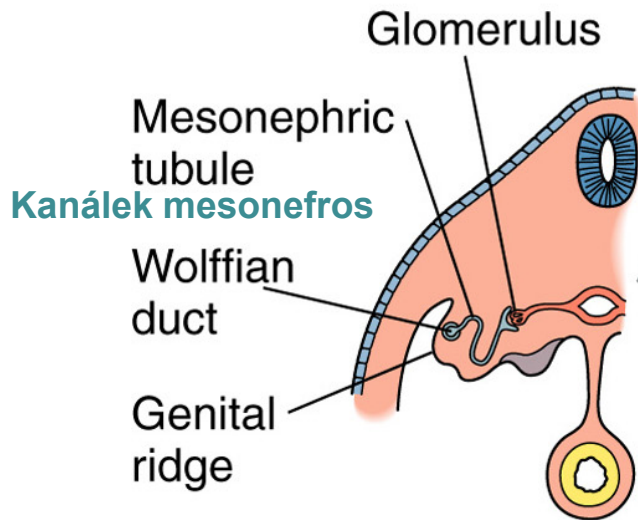
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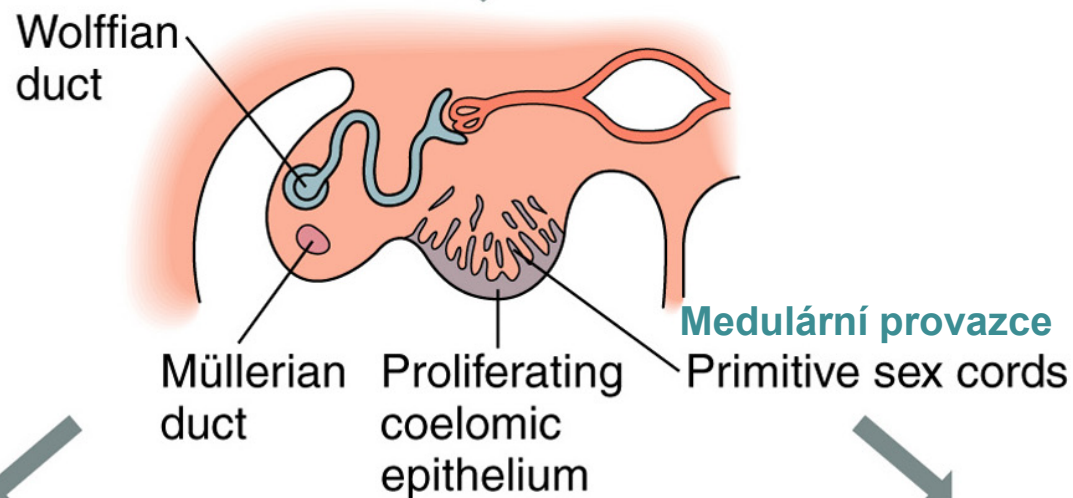
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A. 4 Weeks



B. 6 Weeks

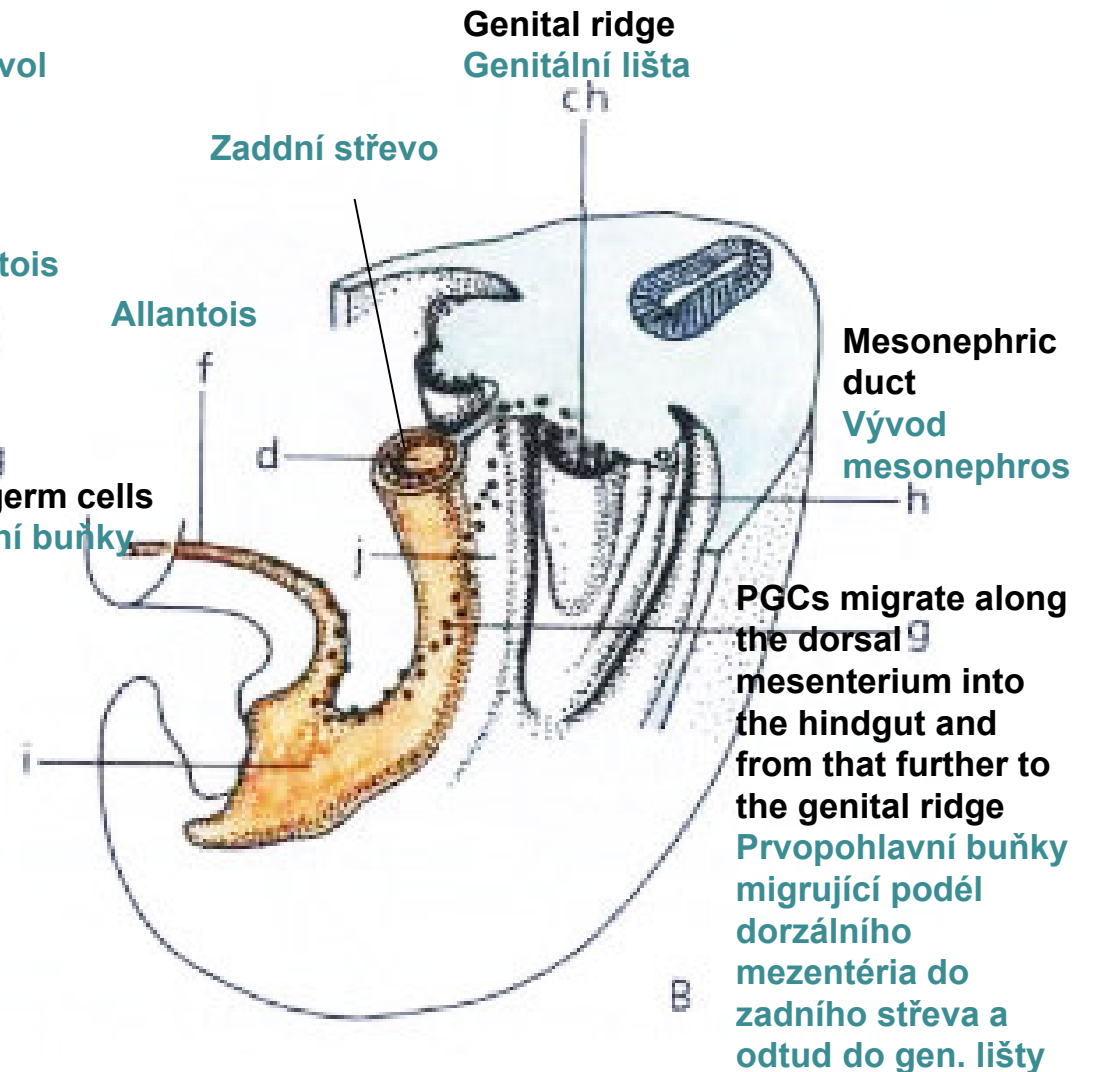
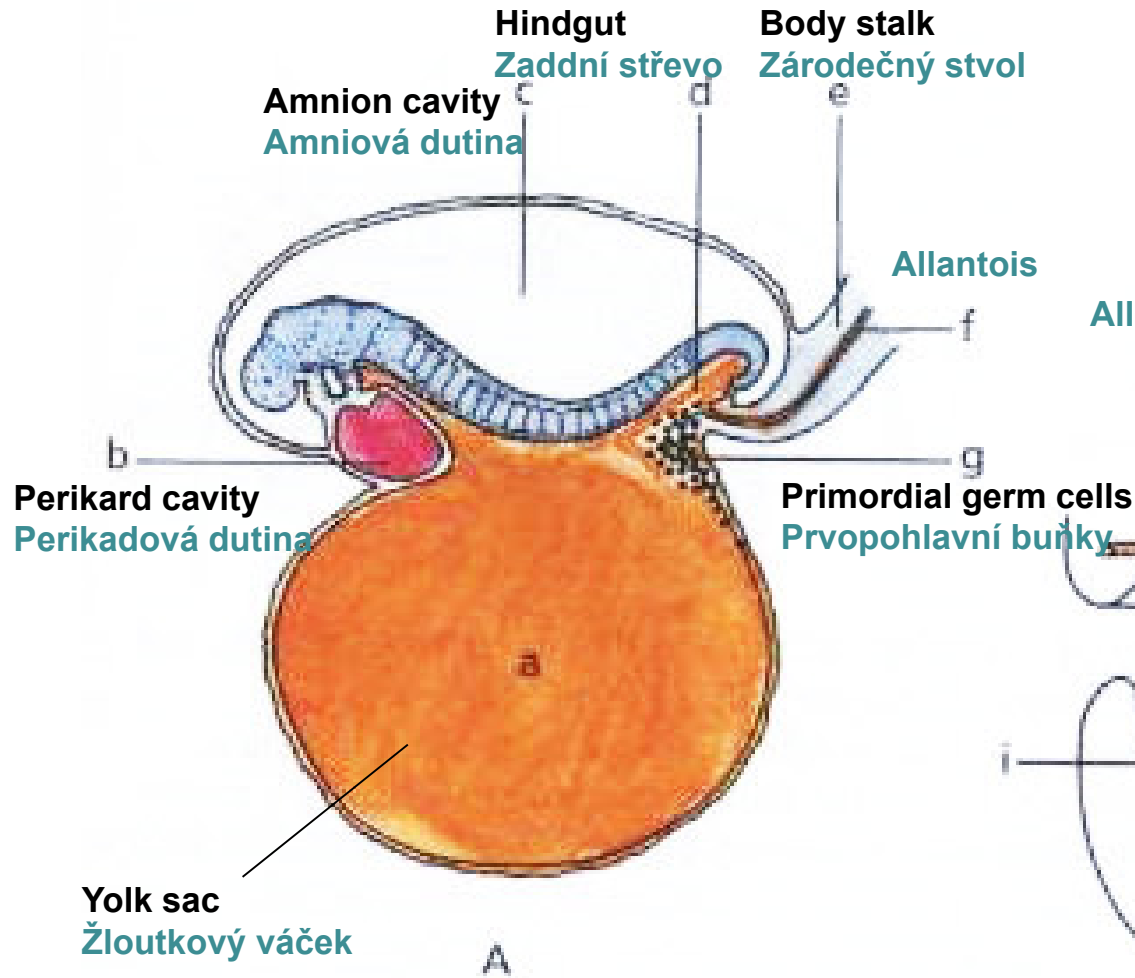


Testis

Ovary

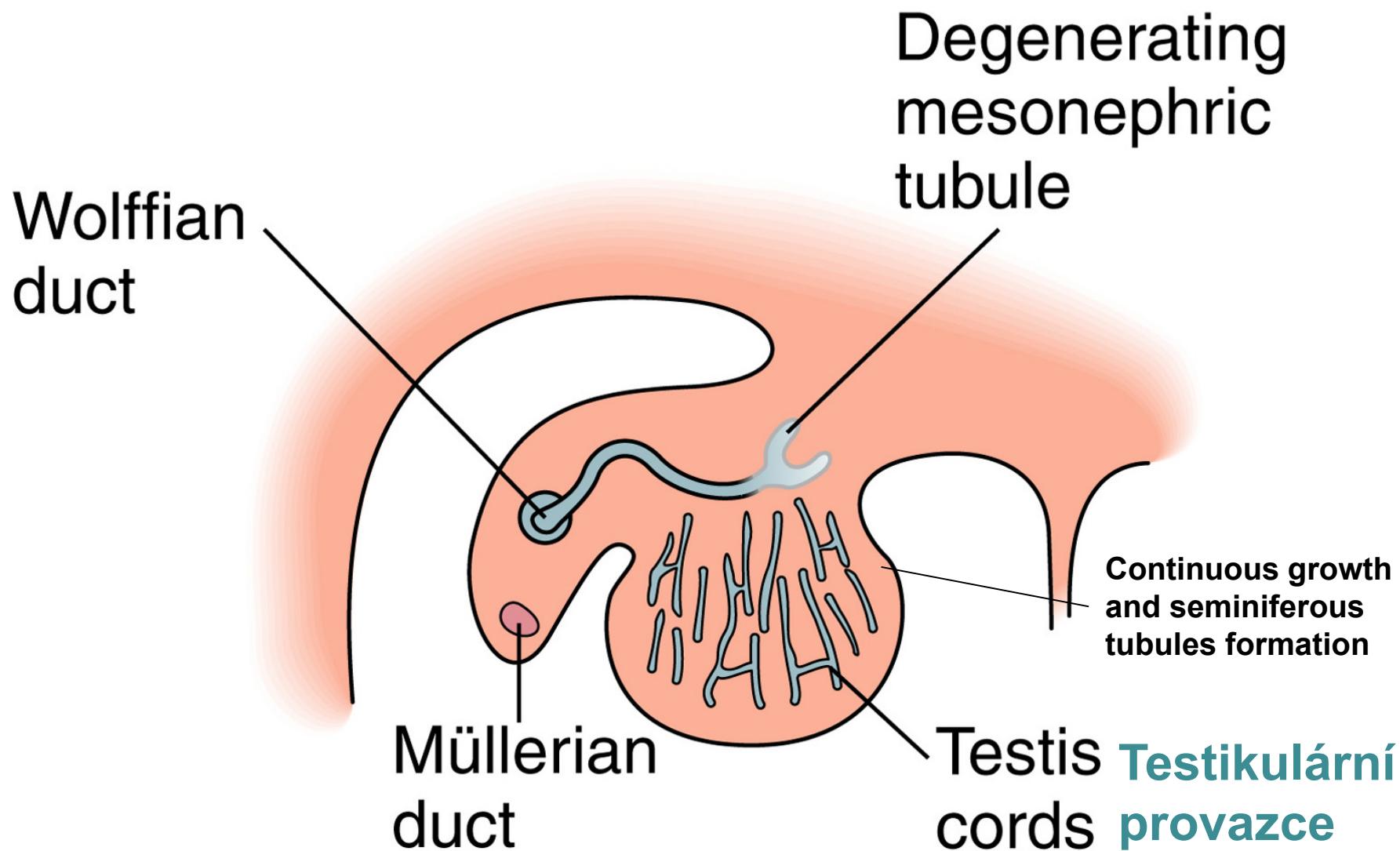
20-days-old human embryo

26-days-old human embryo



Vacek, Embryologie (2006)

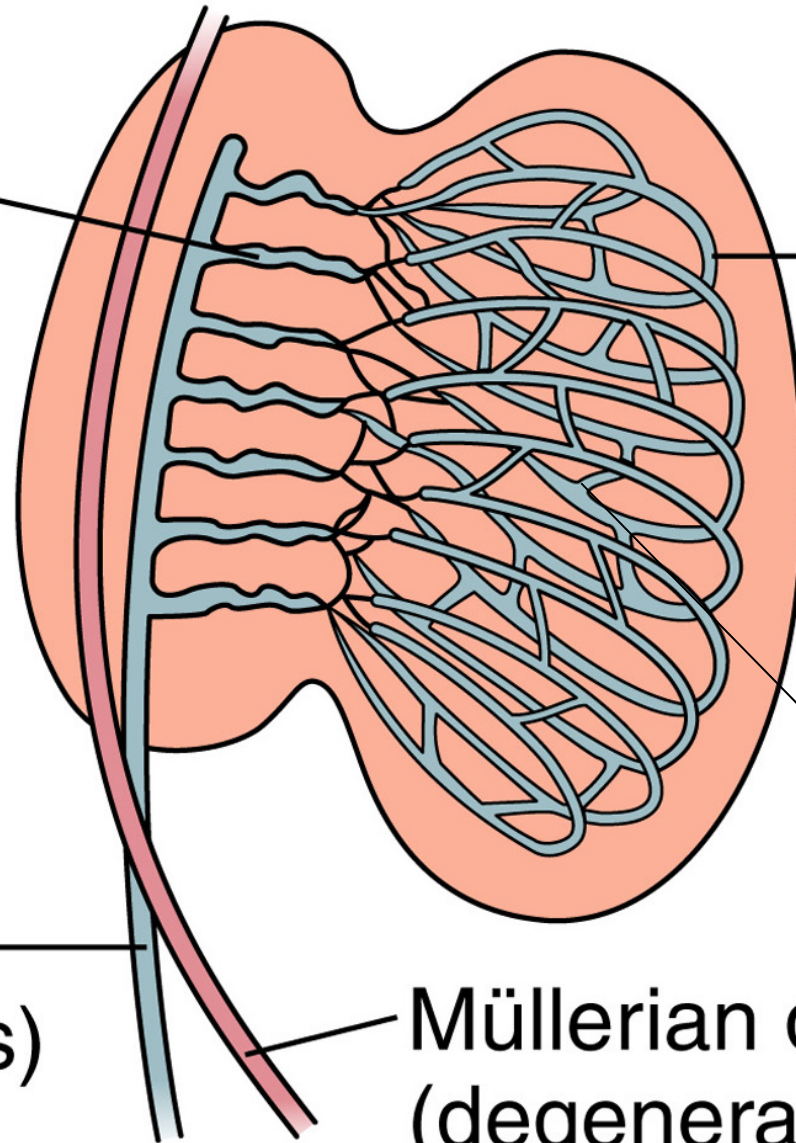
C. 8 Weeks



D. 16 Weeks

Excretory mesonephric tubules (Efferent ducts)
Ductuli efferentes

Wolffian duct (ductus deferens)



Testikulární provazce

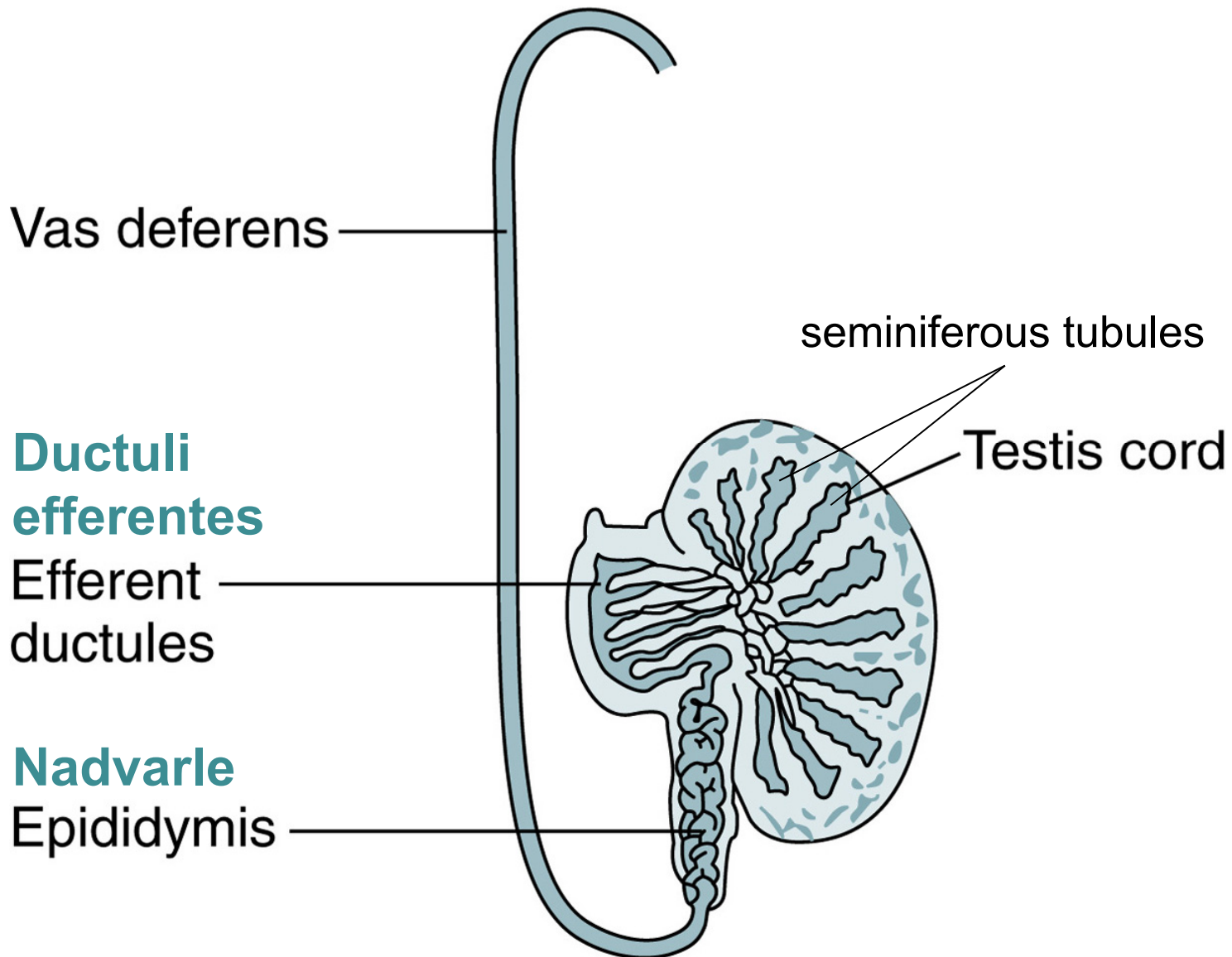
Testis cords

Produkce Müllerovy inhibiční látky

Anti-Mullerian duct factor production by differentiated Sertoli cells

Müllerian duct (degenerating)

E. Adult



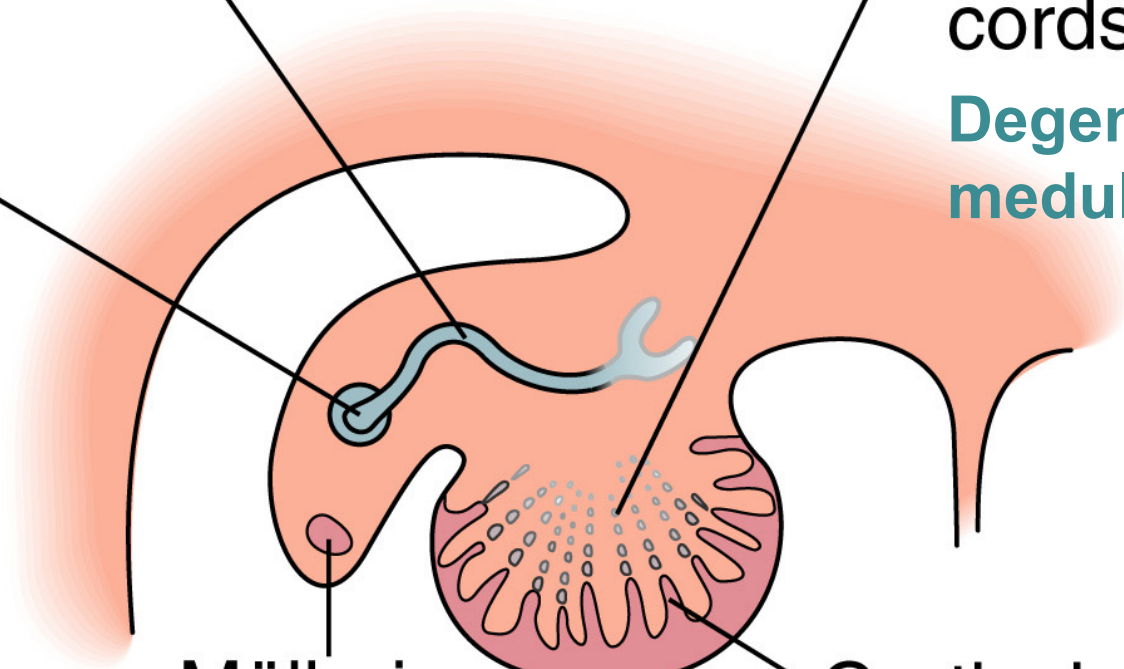
F. 7 Weeks

Degenerating mesonephric tubule

Wolffian duct

Degenerating medullary cords

Degenerující medulární provazce



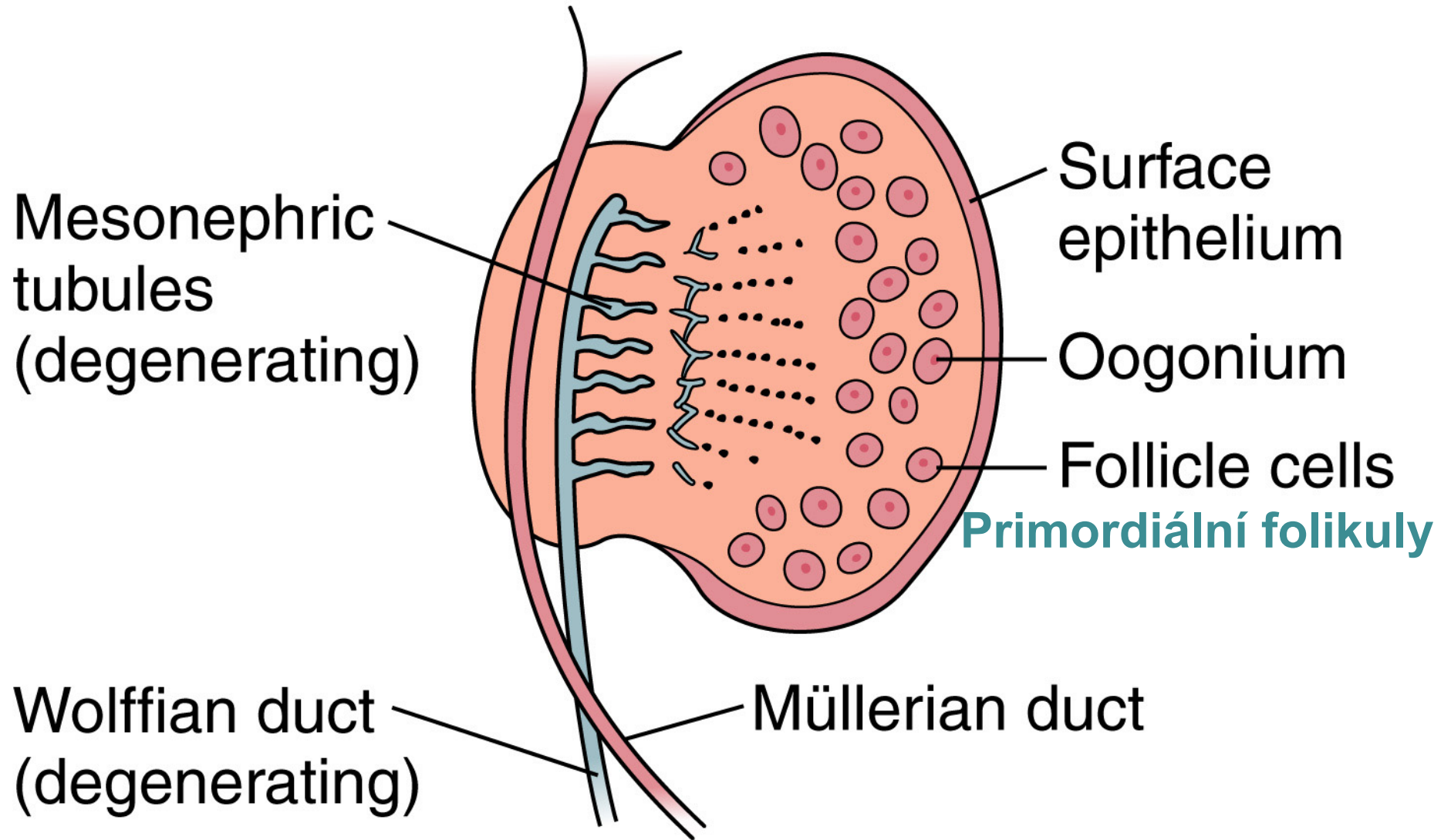
Müllerian duct

Epithelium

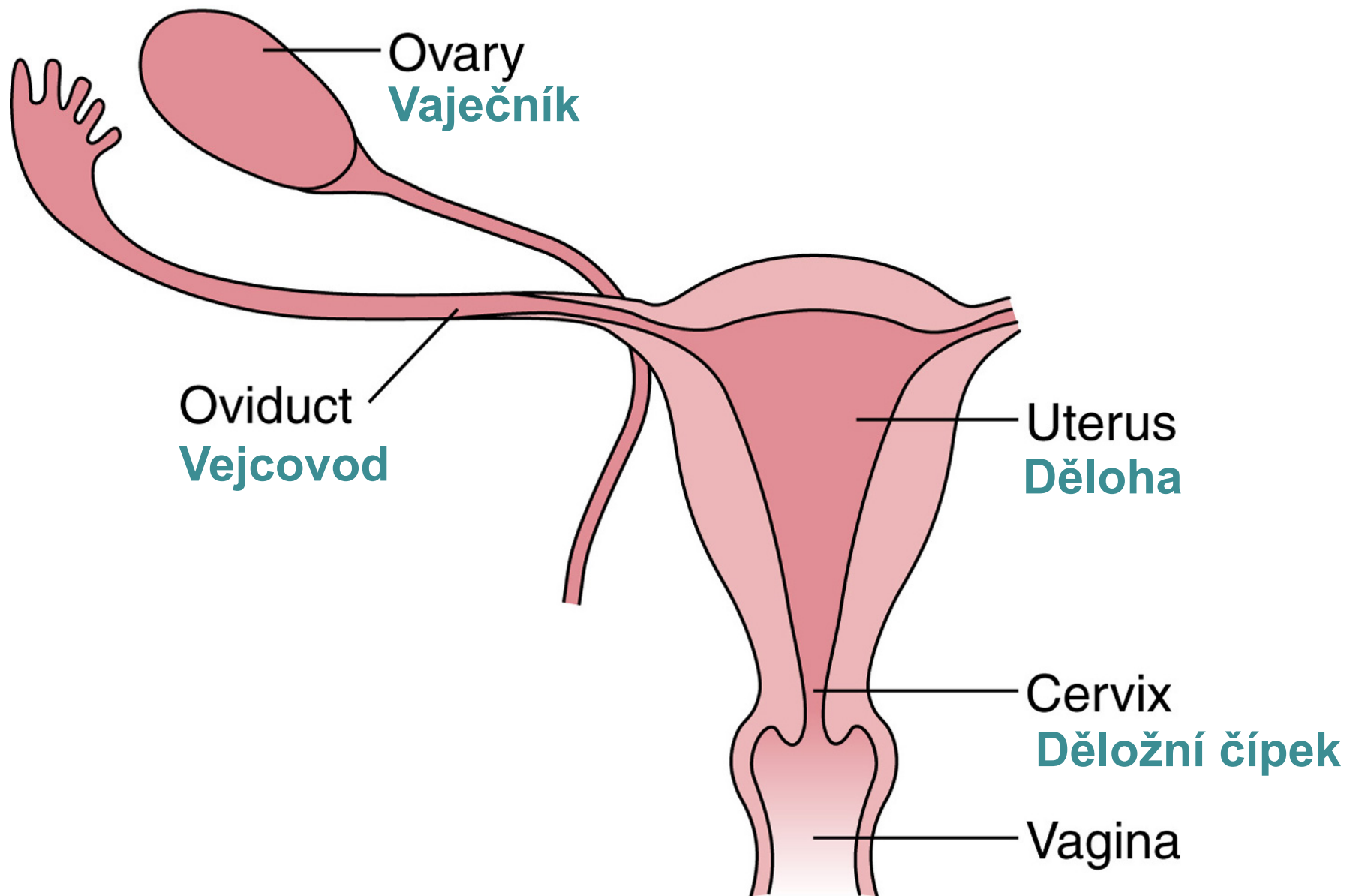
Cortical cords

Kortikální provazce

G. 21 Weeks



H. Adult

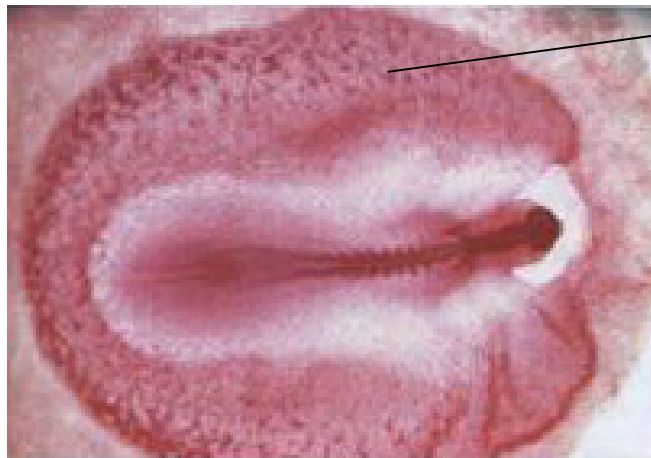




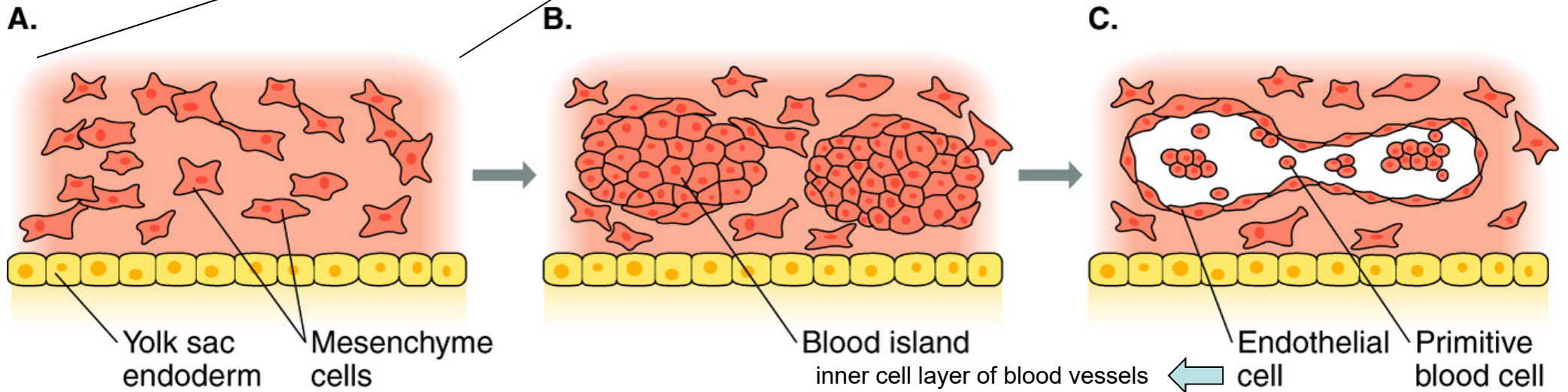
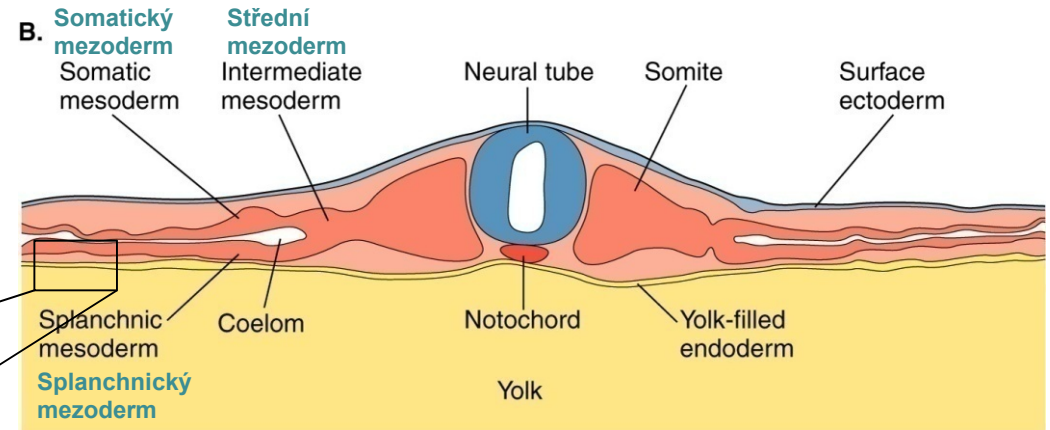
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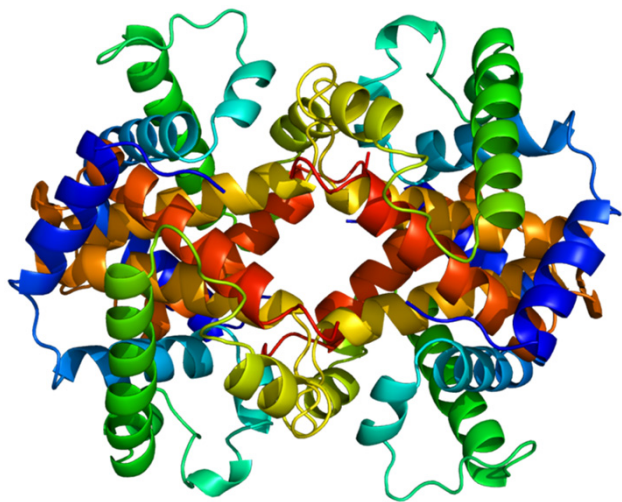
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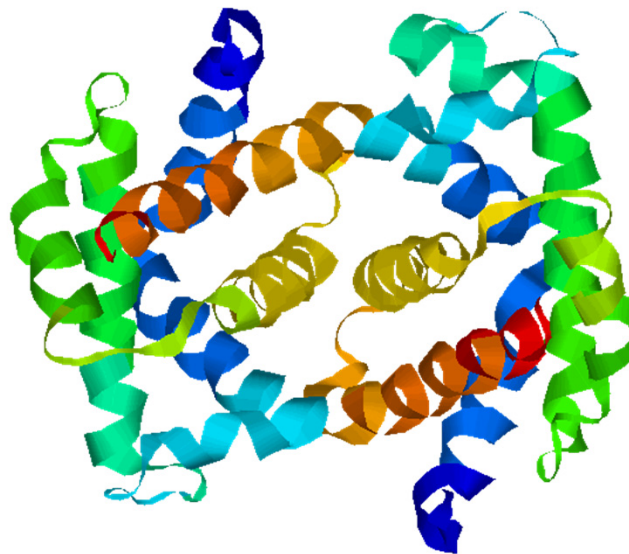


Krevní ostrůvky
Blood islands

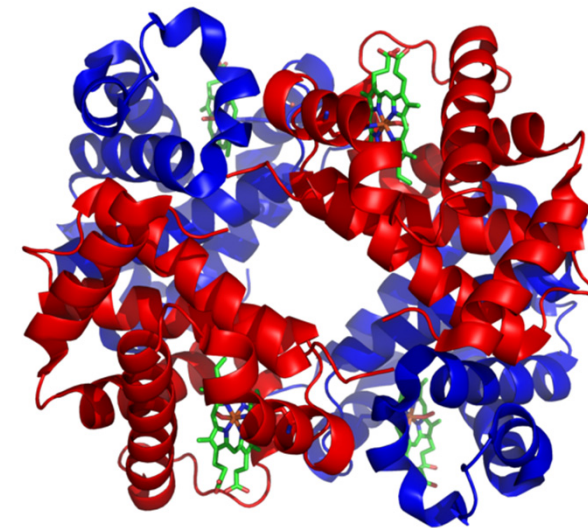




Embryonic hemoglobin $\epsilon\zeta\zeta\zeta$
yolk sac

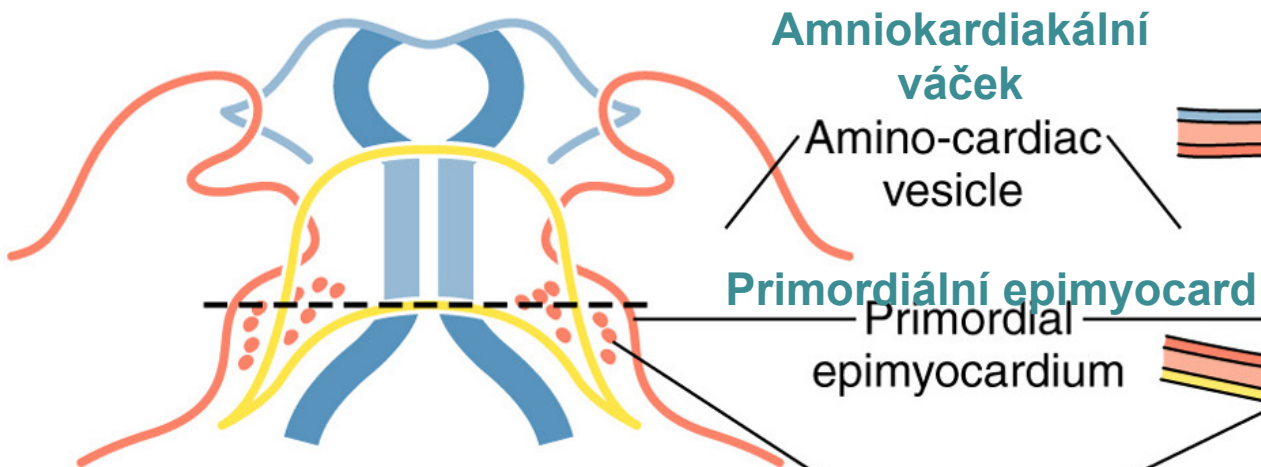


Fetal hemoglobin $\alpha\gamma\gamma\gamma$
liver

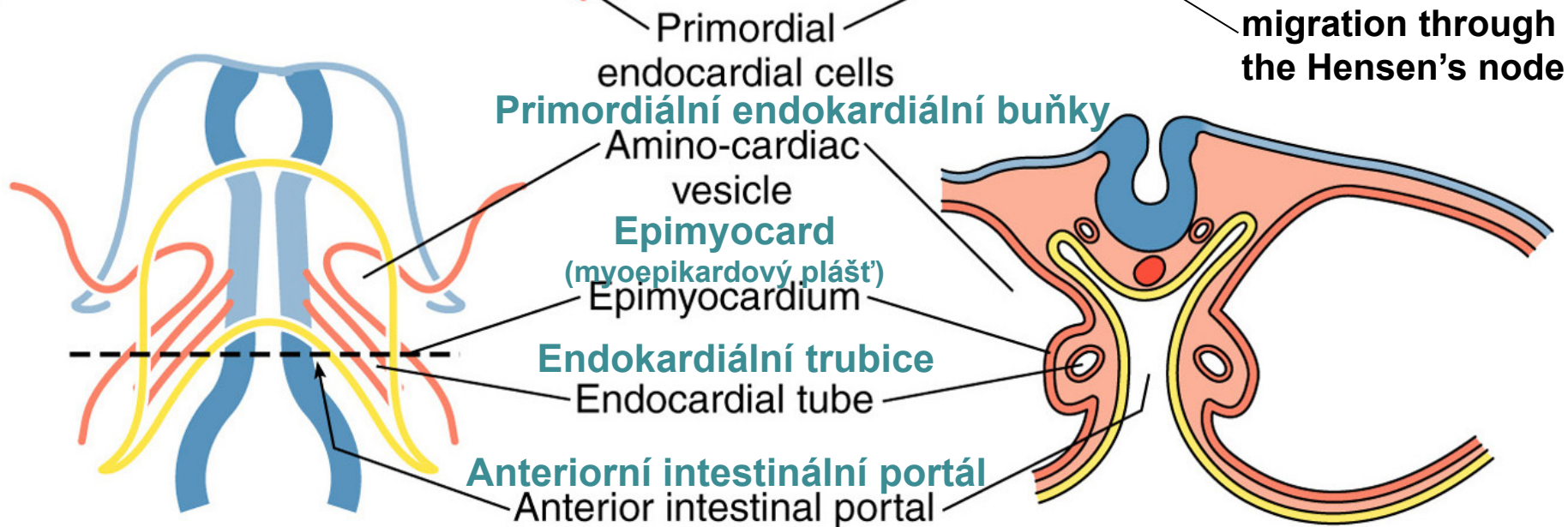
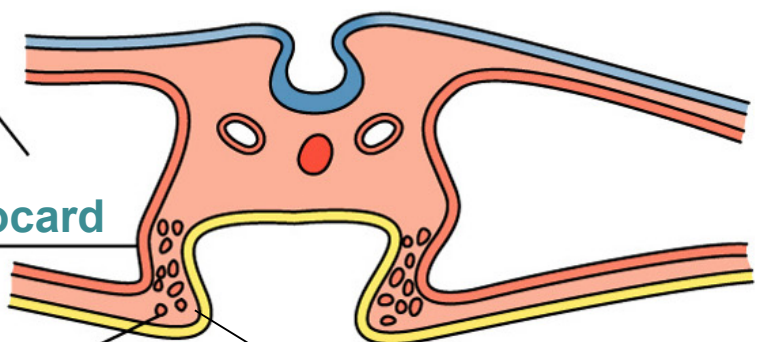


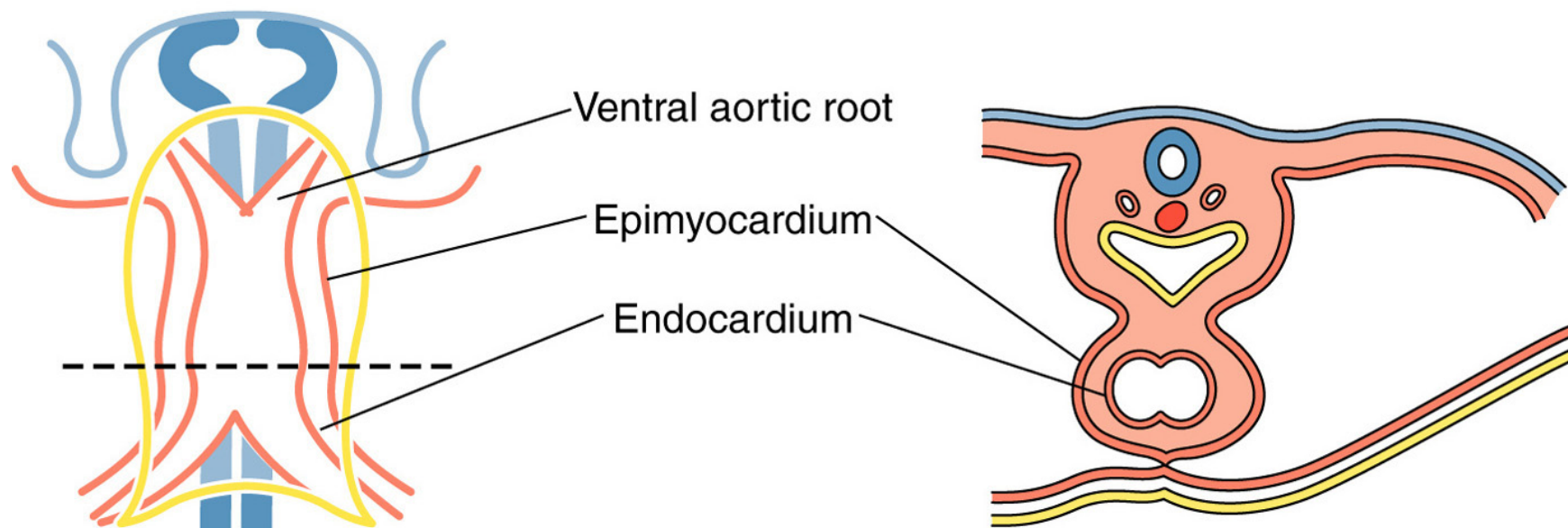
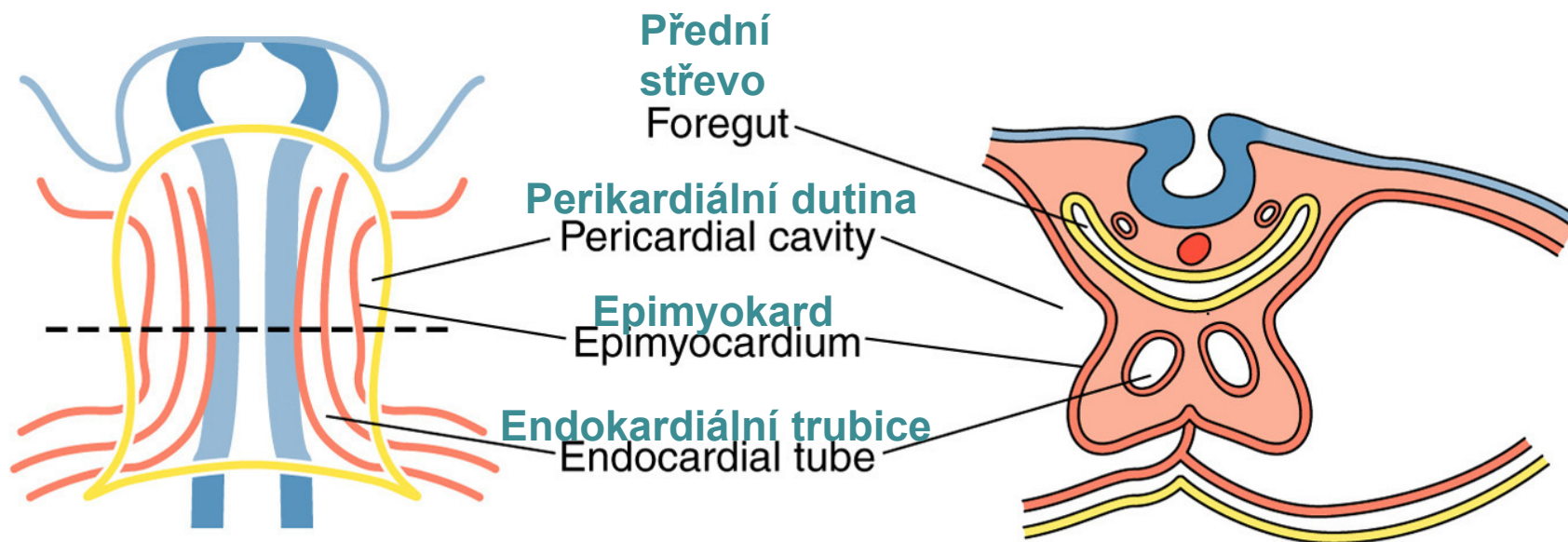
Adult hemoglobin $\alpha\beta\beta$
bone marrow

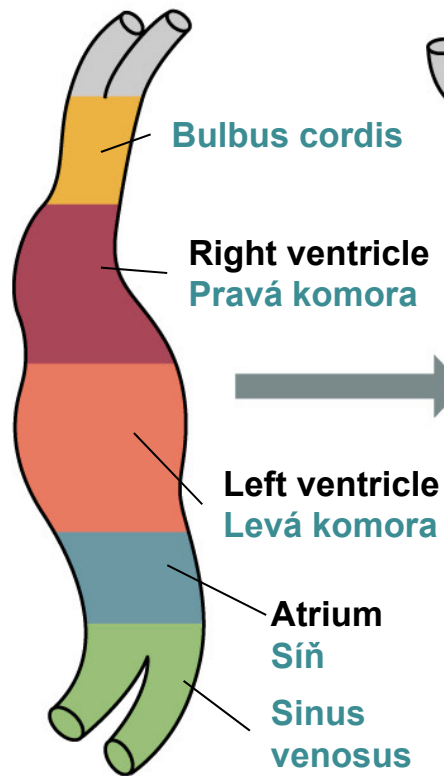
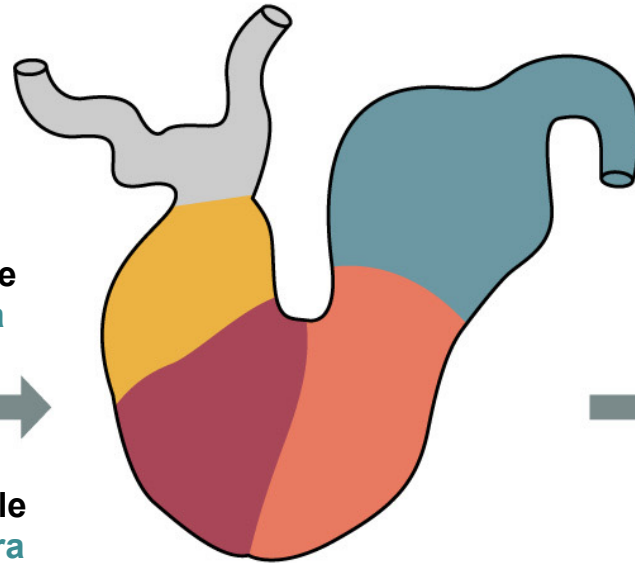
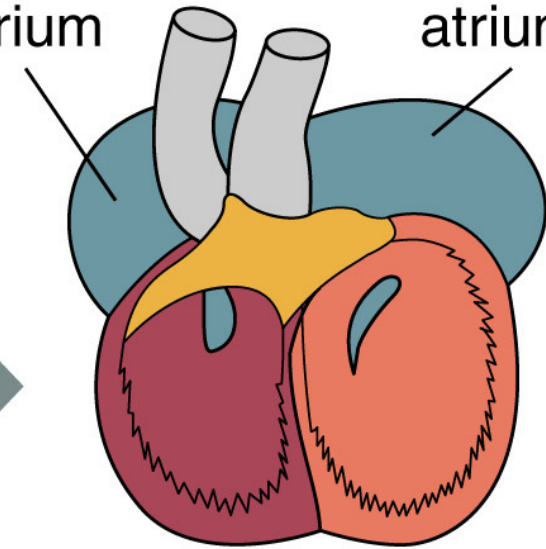
A. Ventral views



B. Transverse views





A.**Anterior****Posterior****B.****C.****Right atrium****Left atrium****KEY**

migration of endocardial cells into the matrix between the endocardium and outer myocardial cells → chambers and septa formation

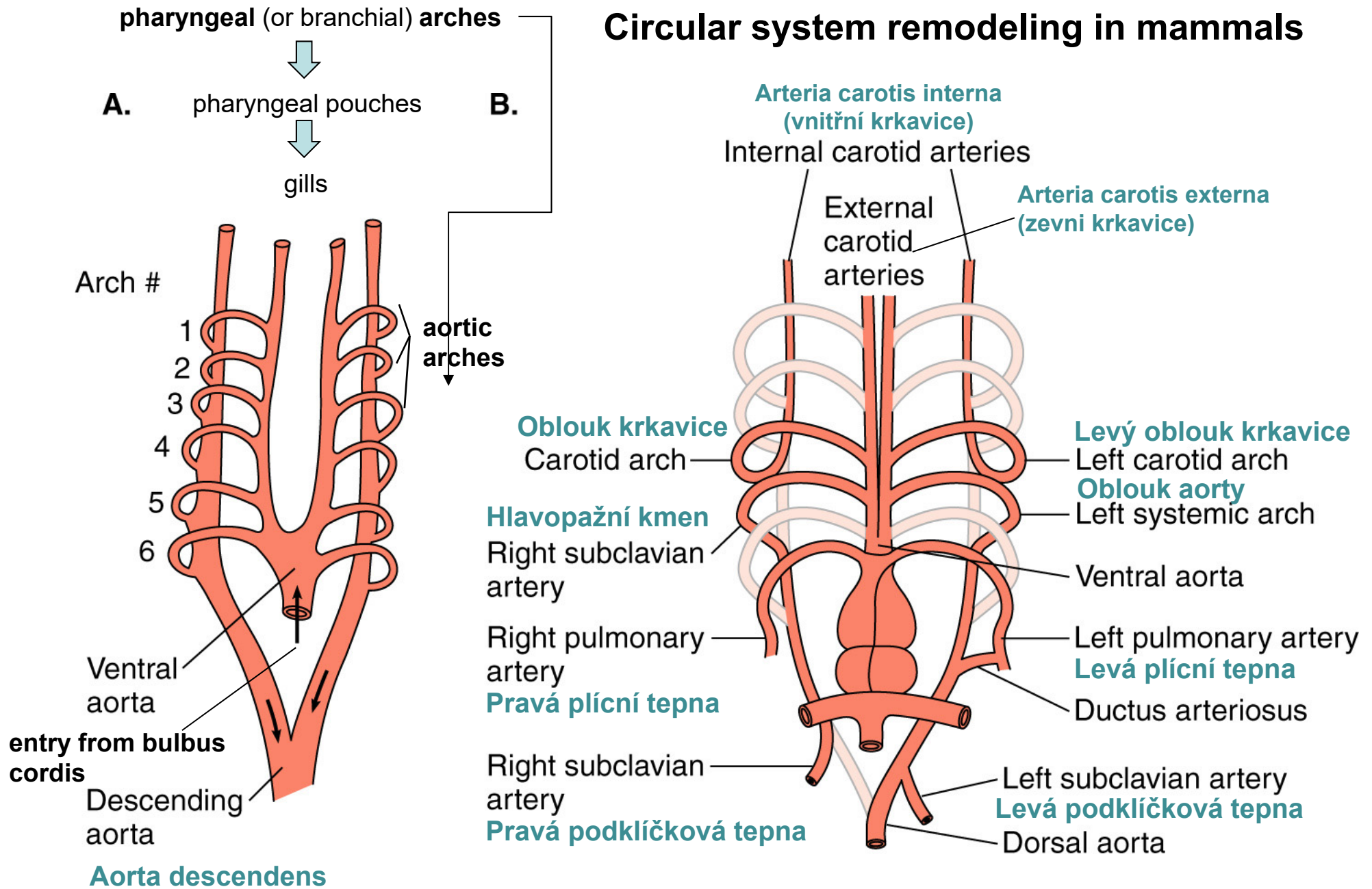
**Bulbus cordis****Atrium****Right ventricle****Sinus venosus****Left ventricle****Left atrium**



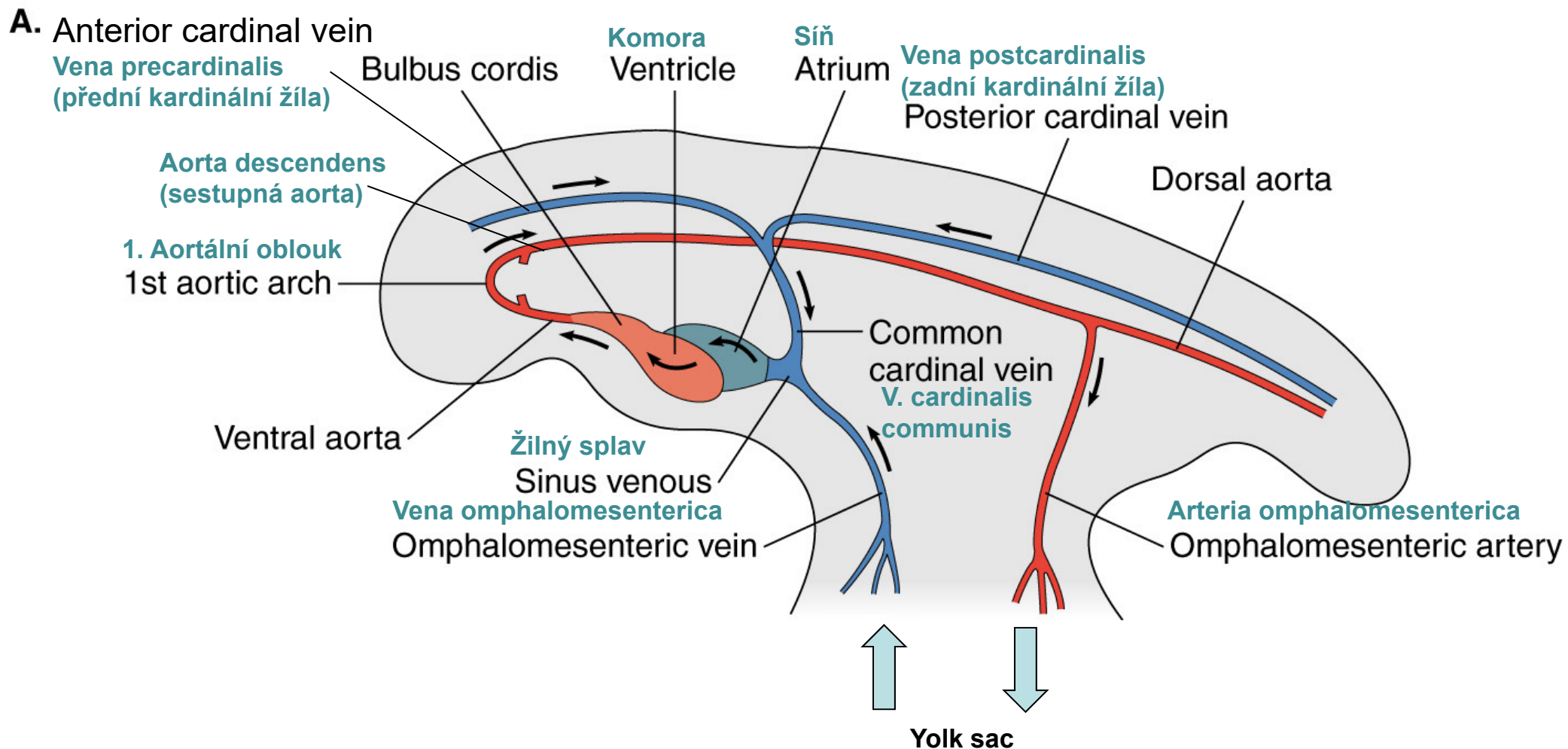
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

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

Circular system remodeling in mammals

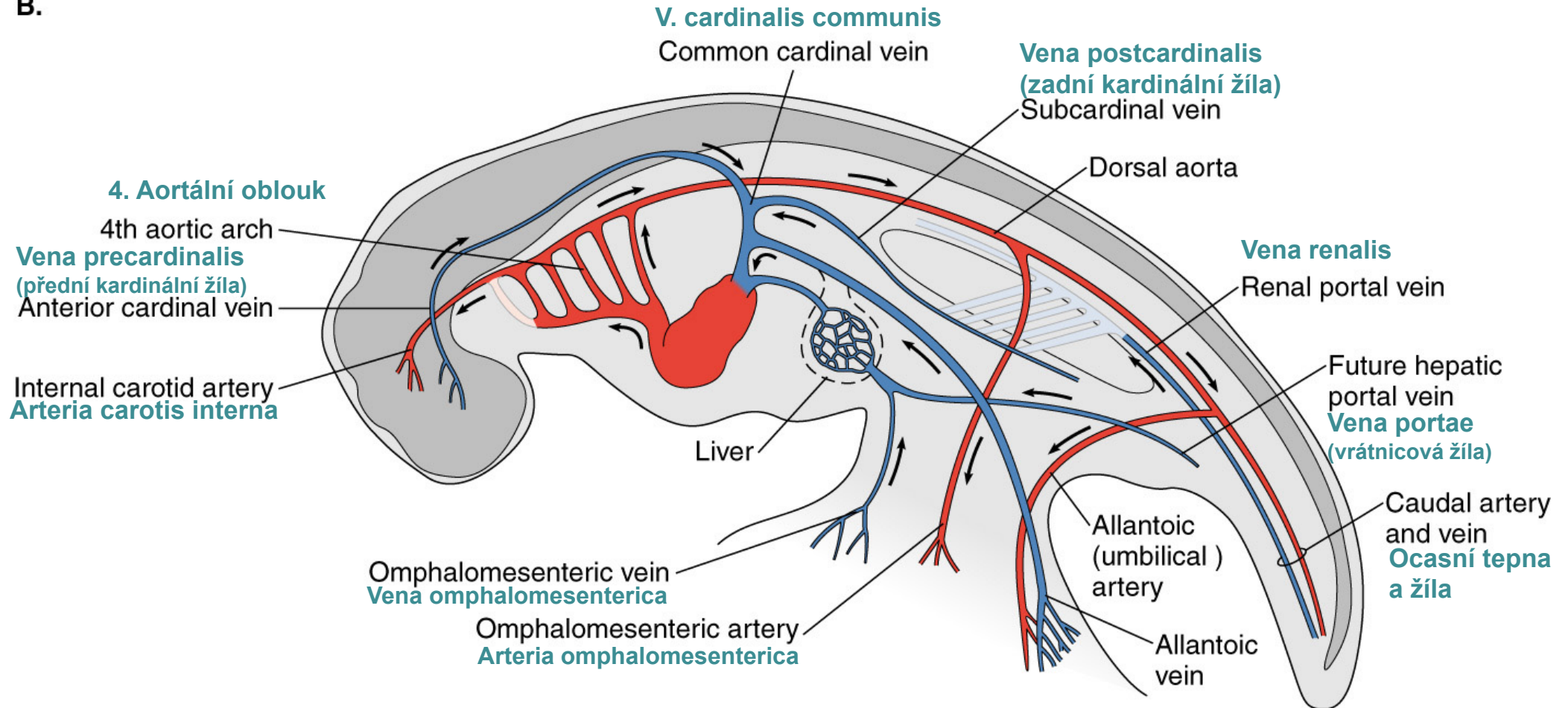


Blood streaming in the initial circular system in amniote embryo



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

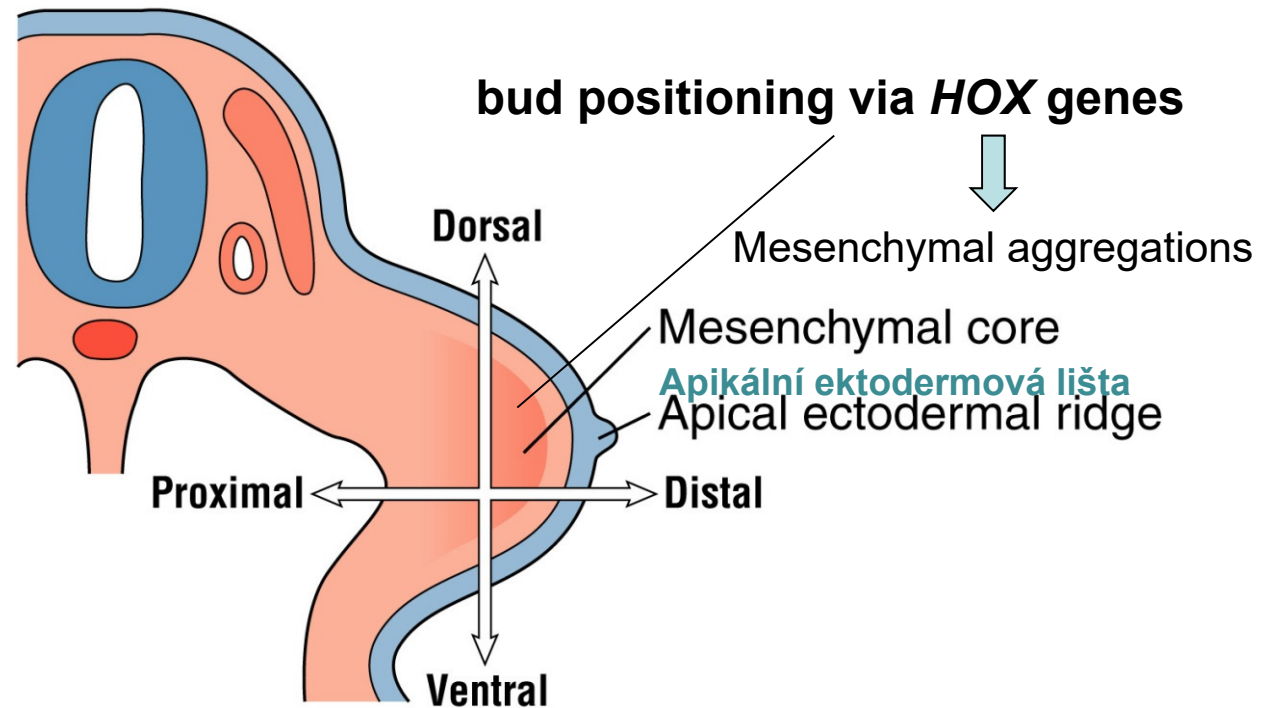


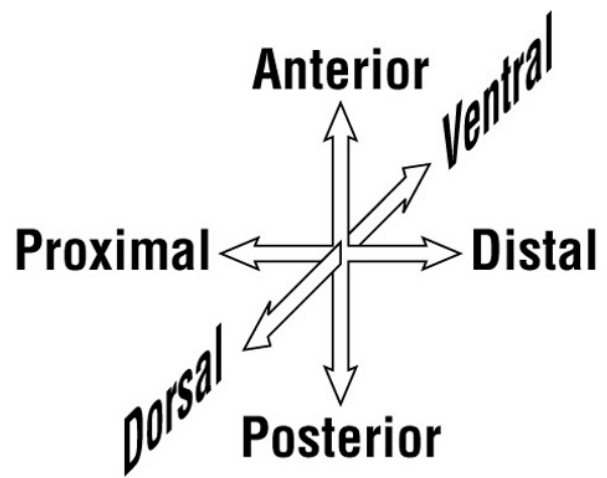
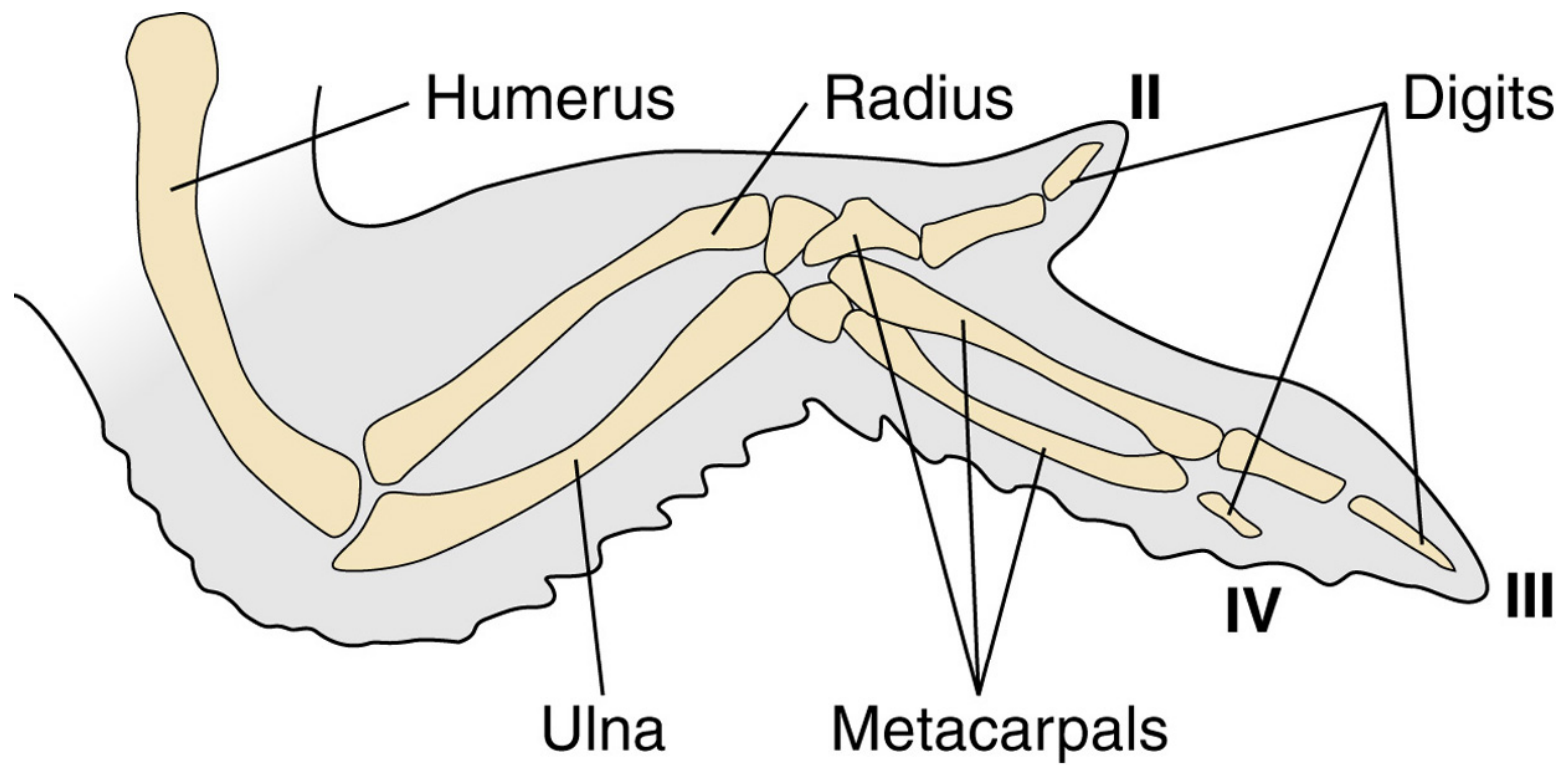
Střední mozek
Midbrain

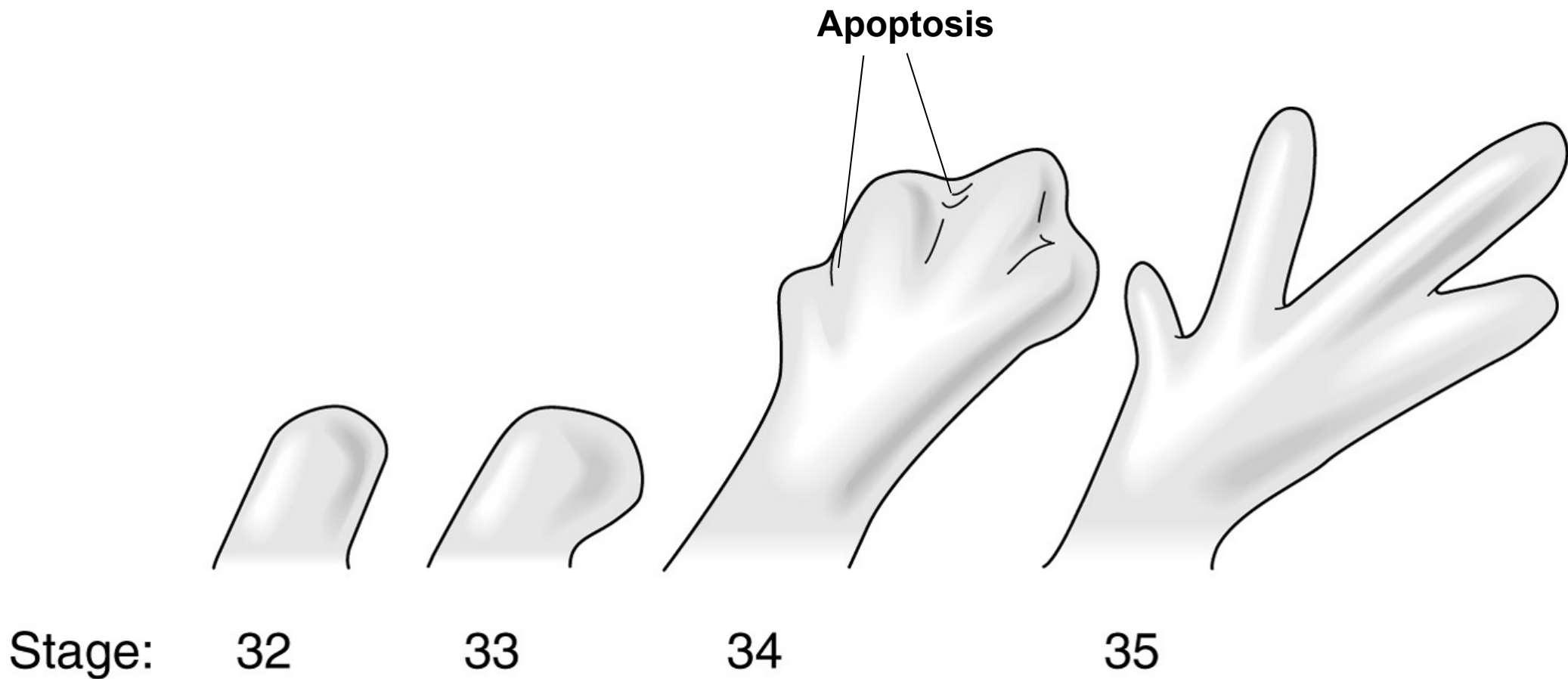
Oko
Eye

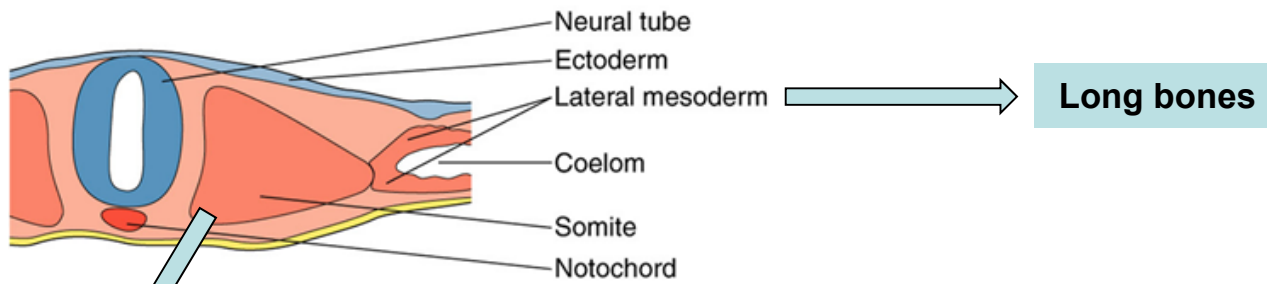
Somity
Somites

B. Cross section of a chick wing bud

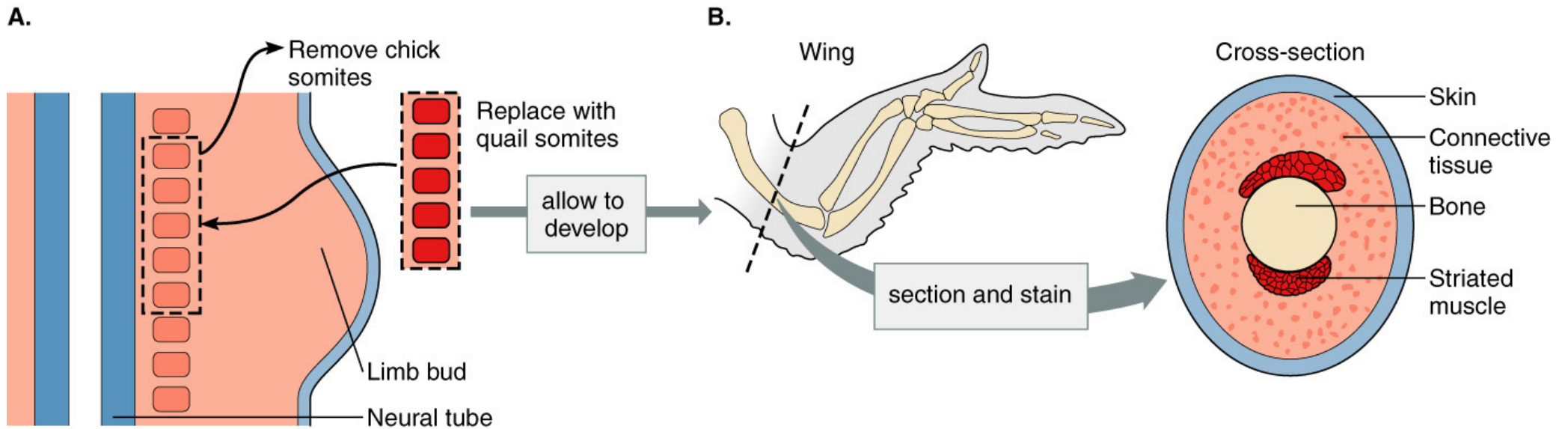




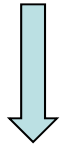




Vertebrae and proximal ribs

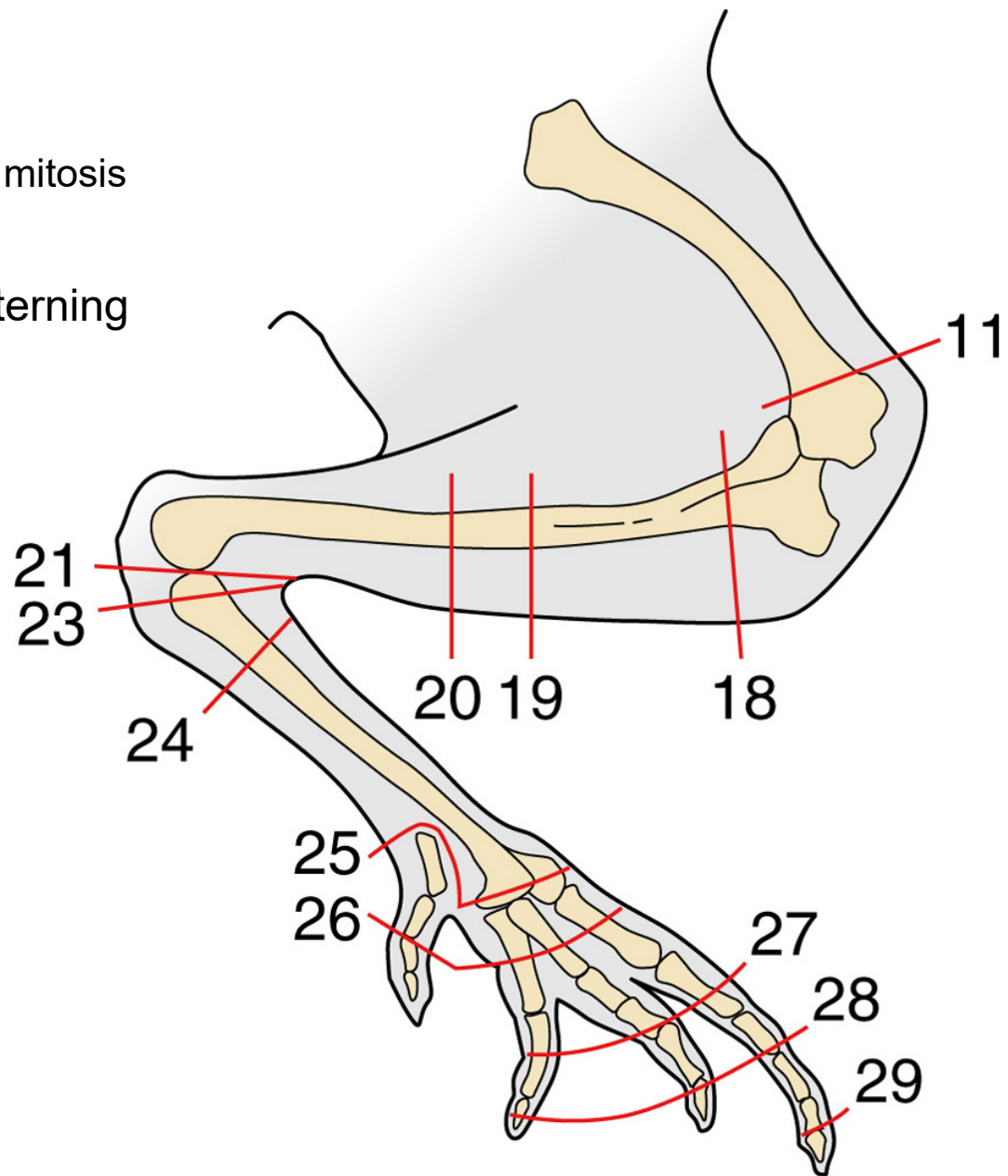


AER



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)



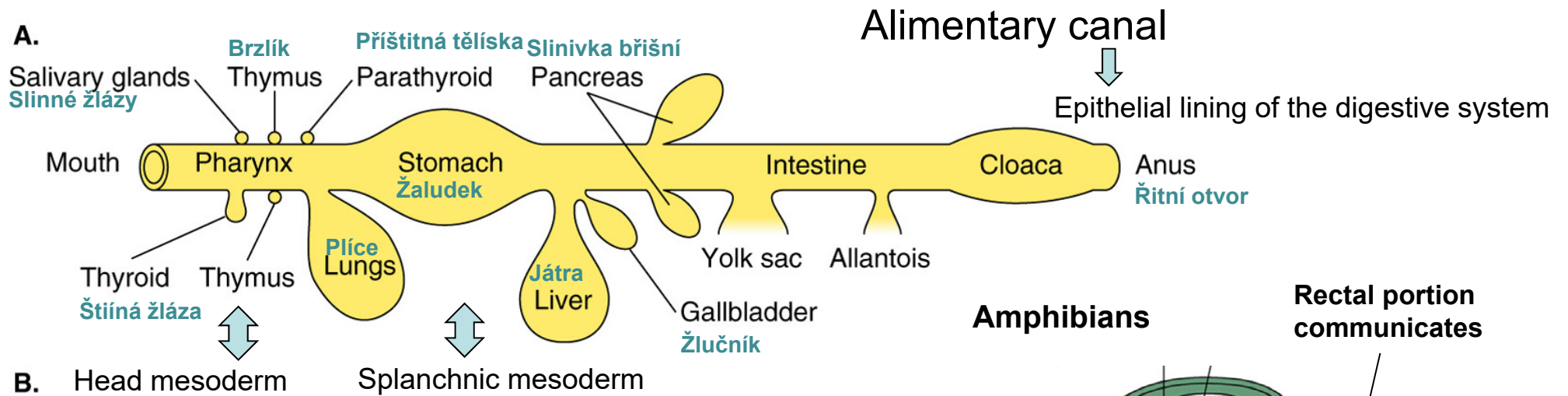


Outline of Lesson 5

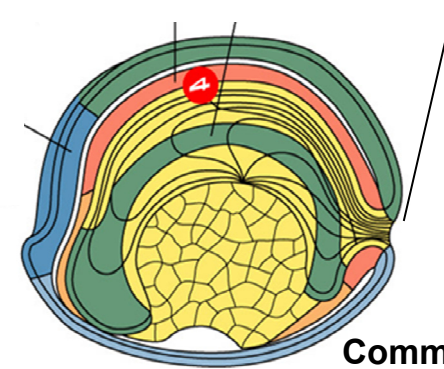
Organogenesis in Vertebrates: Endo- and Mesodermal Derivatives

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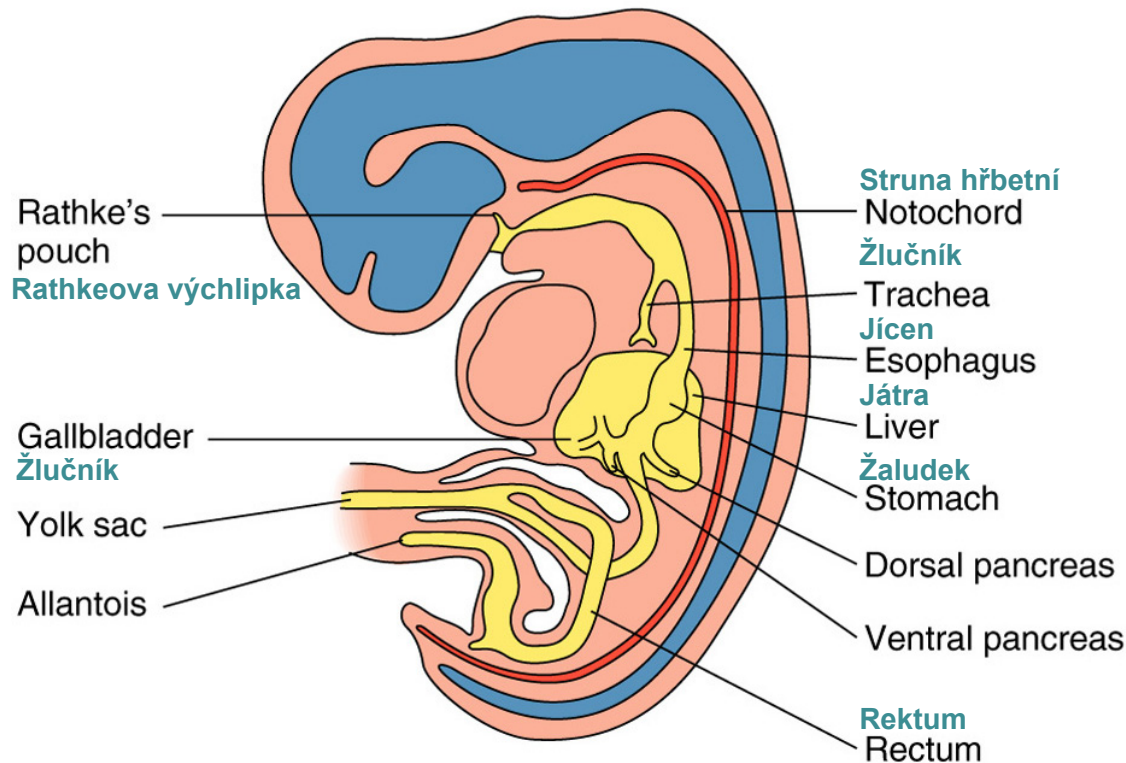
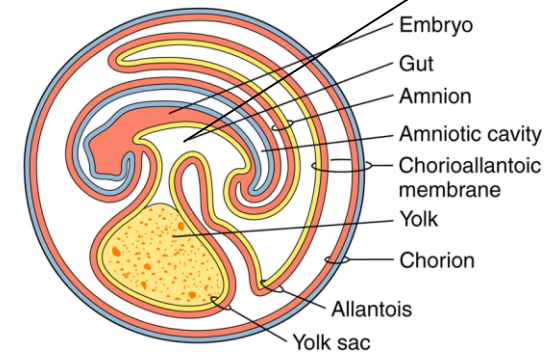
- Endoderm derivatives development
 - alimentary canal and its derivatives formation



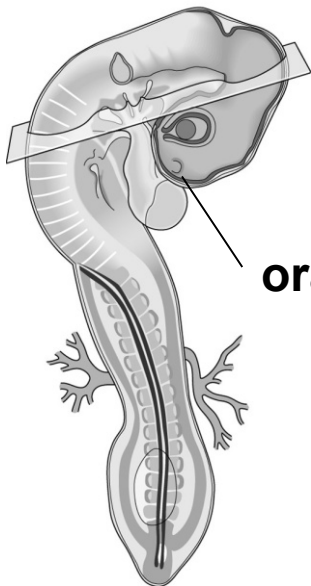
Amphibians Rectal portion communicates



Amniotes Communication only with yolk sac



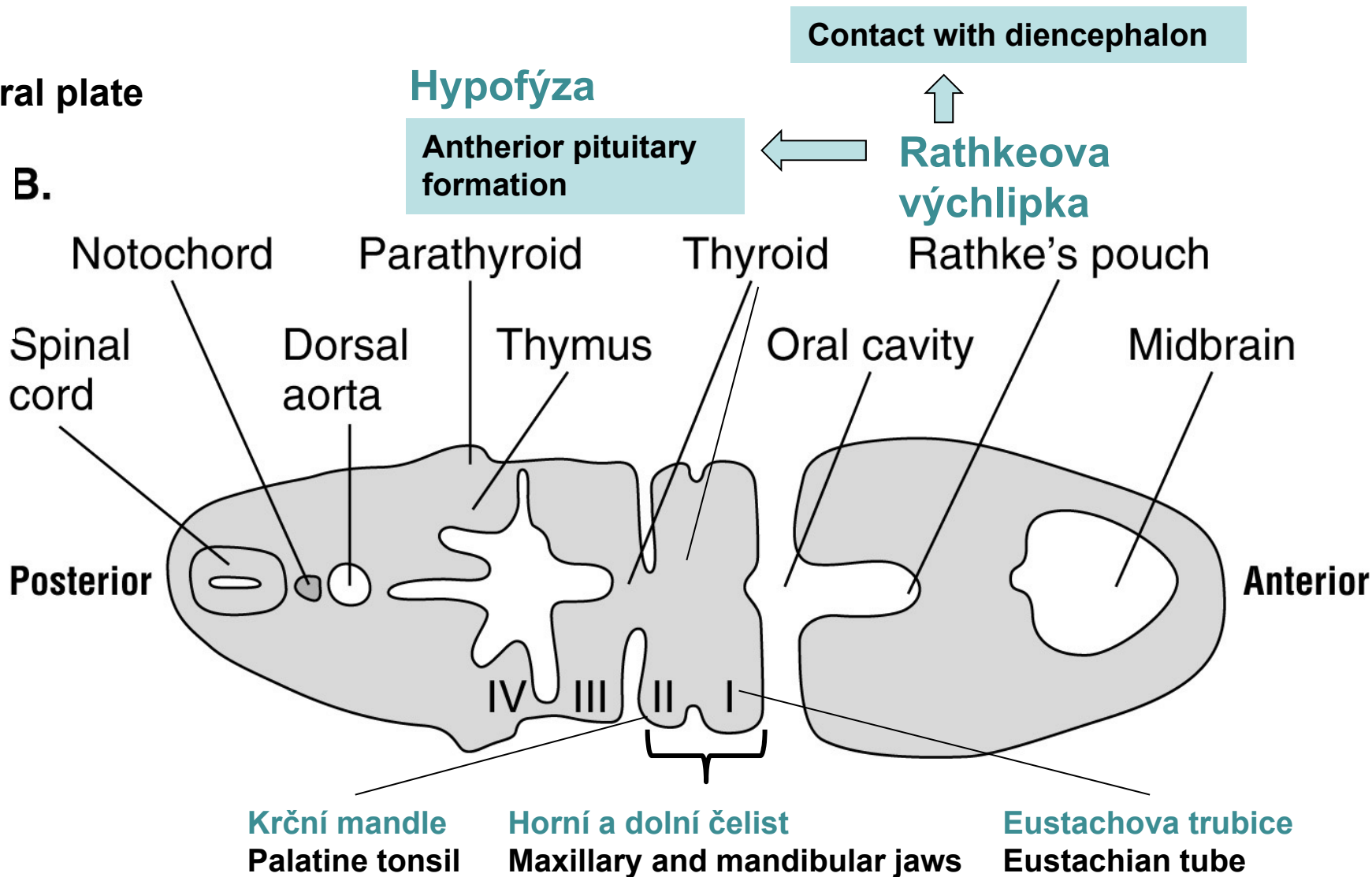
A.

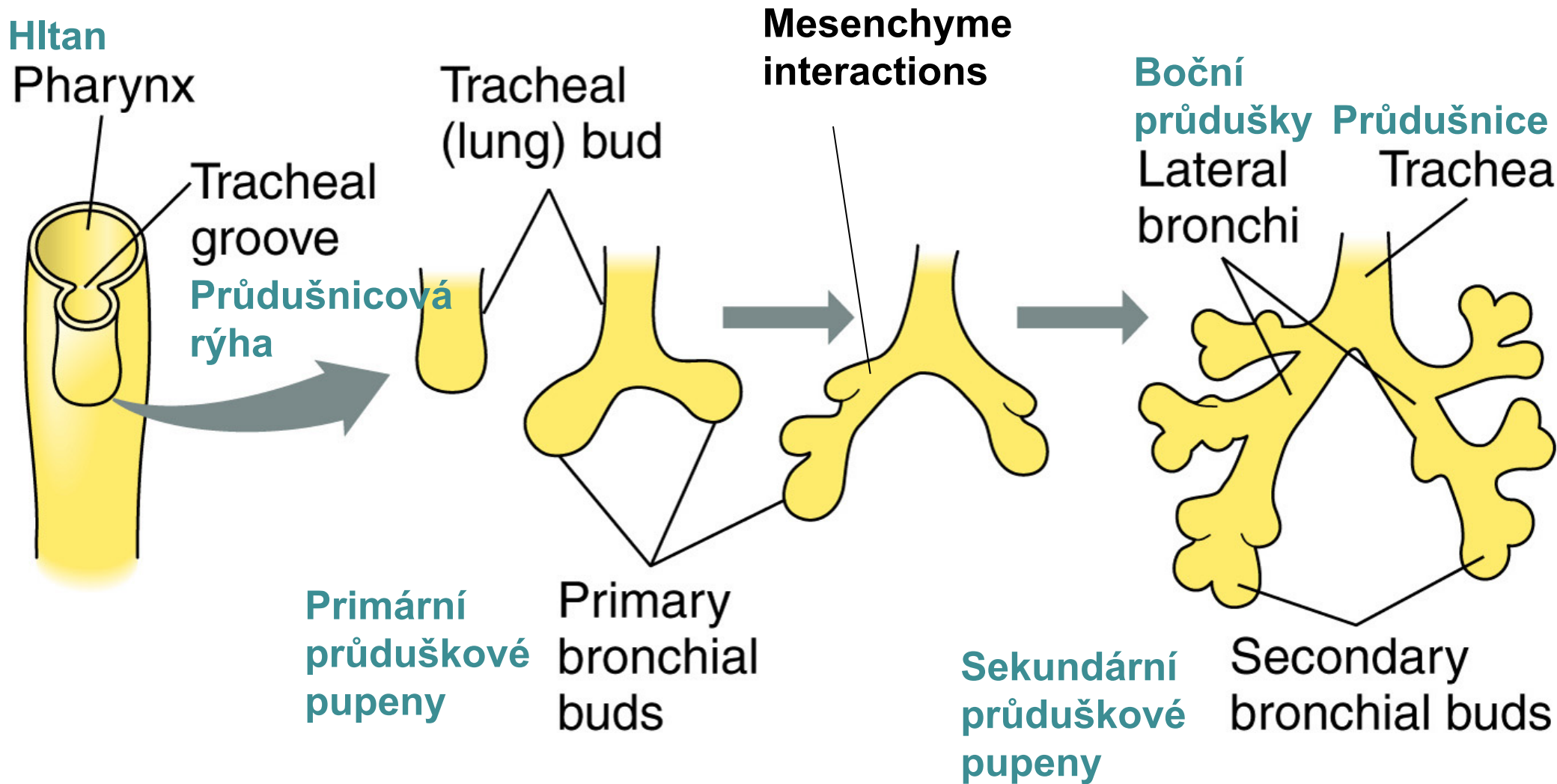


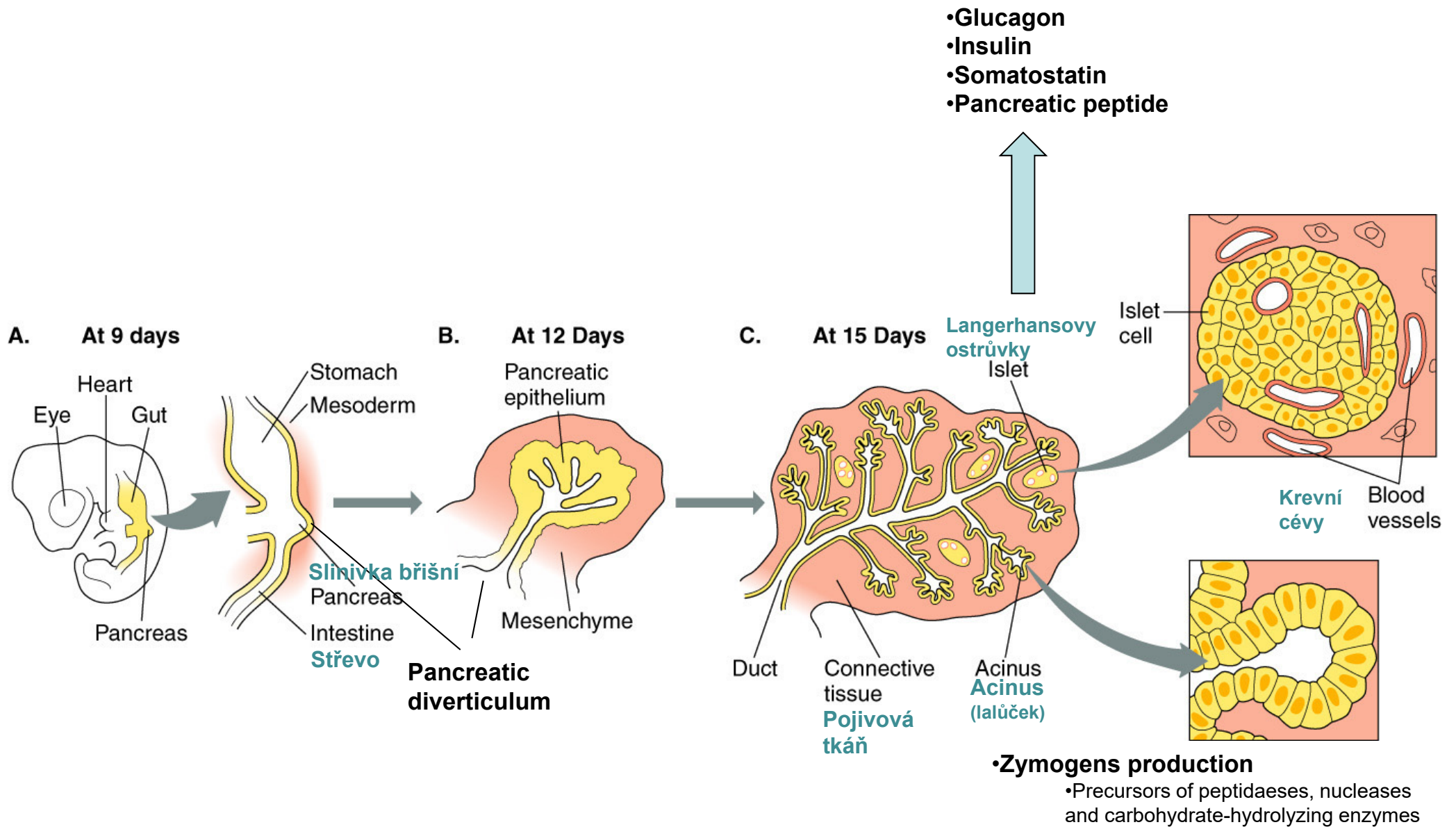
Pharyngeal arch-specific endoderm derivatives development

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.