

# C8545 Developmental Biology

## Lesson 5

### Vertebrate Organogenesis: Endo- and Mesodermal Derivatives

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**Functional Genomics and Proteomics of Plants**

CEITEC

and

**National Centre for the Biomolecular Research**

Faculty of Science

**M U N I**  
**S C I**

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# Outline of Lesson 5

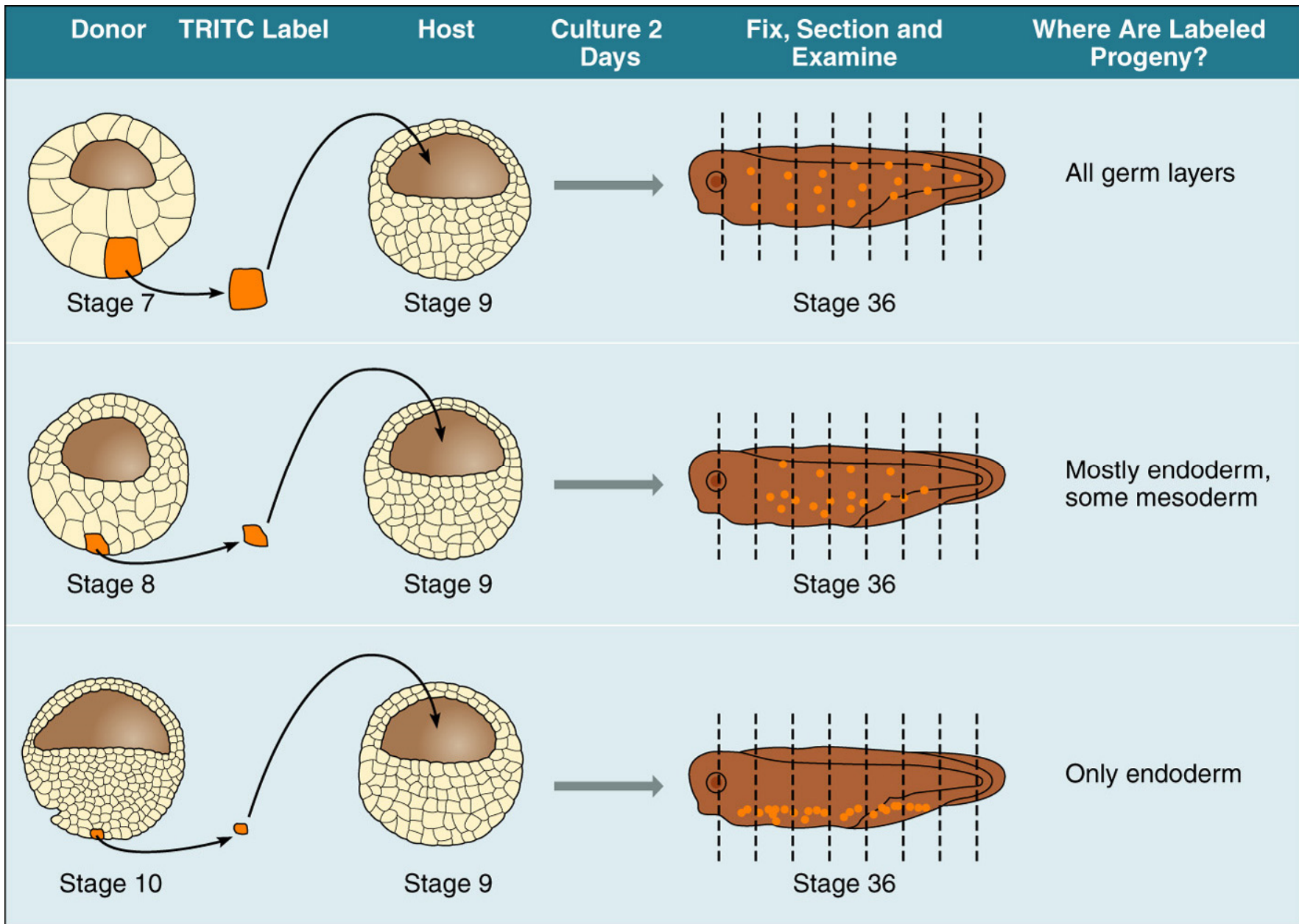
## Organogenesis in Vertebrates: Endo- and Mesodermal Derivatives

- 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

# Outline of Lesson 5

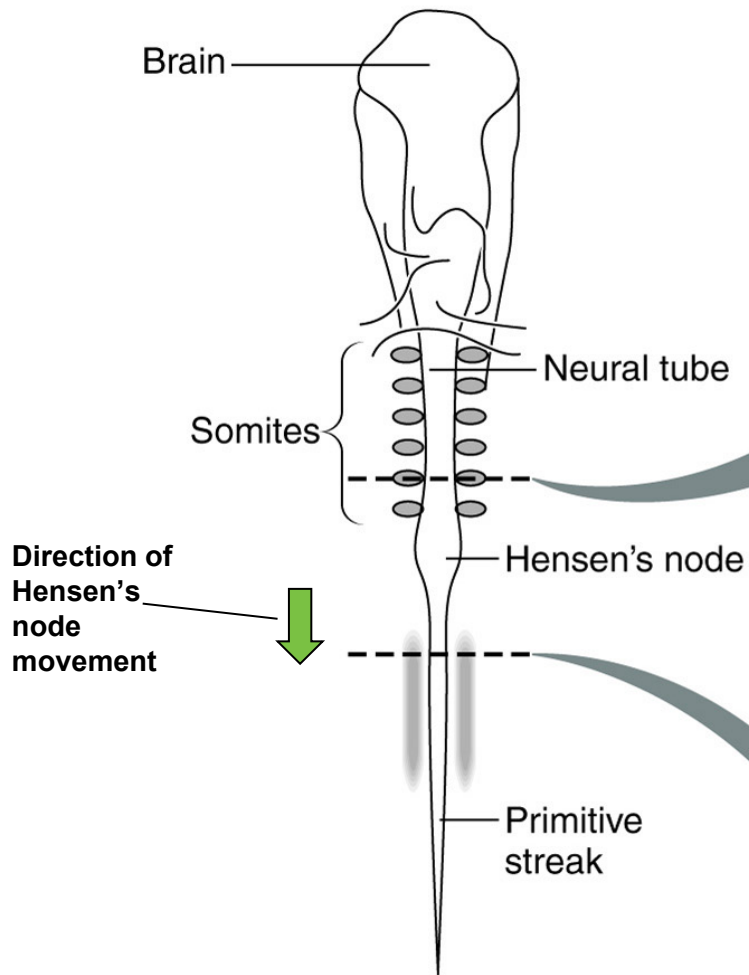
## Organogenesis in Vertebrates: Endo- and Mesodermal Derivatives

- Mesoderm derivatives development
  - somites formation and signalling

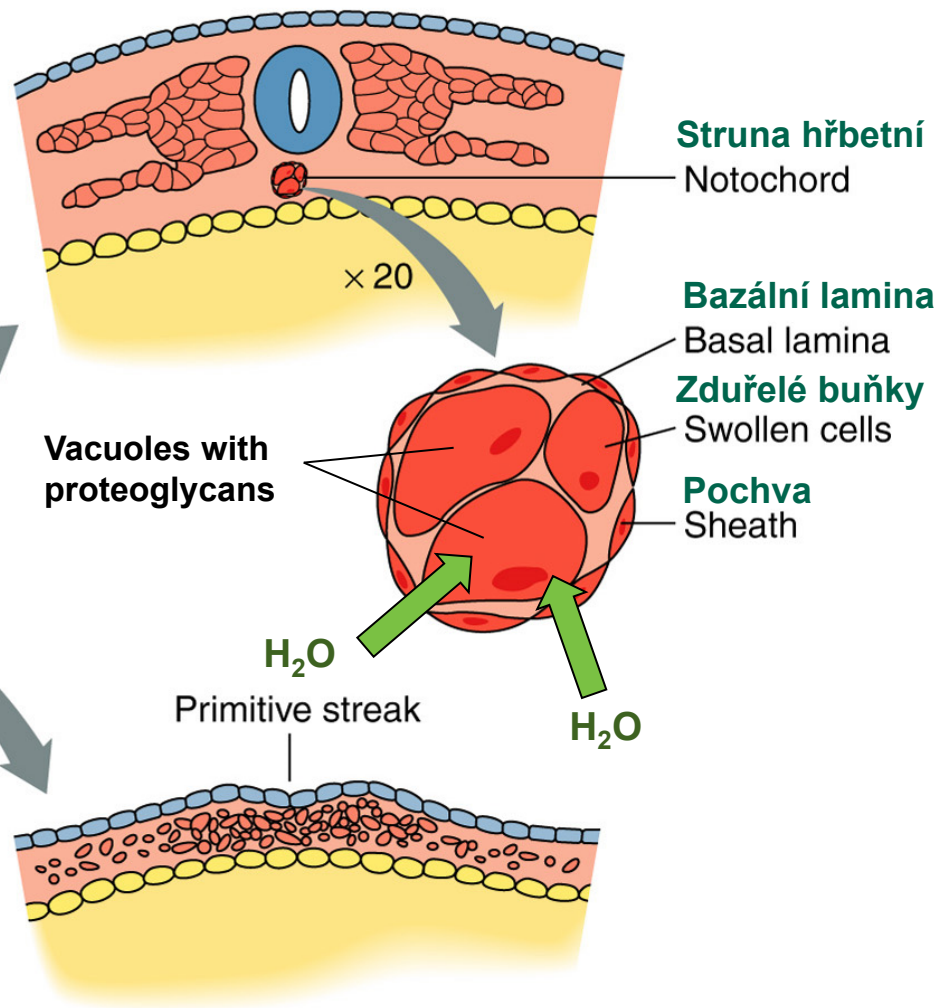




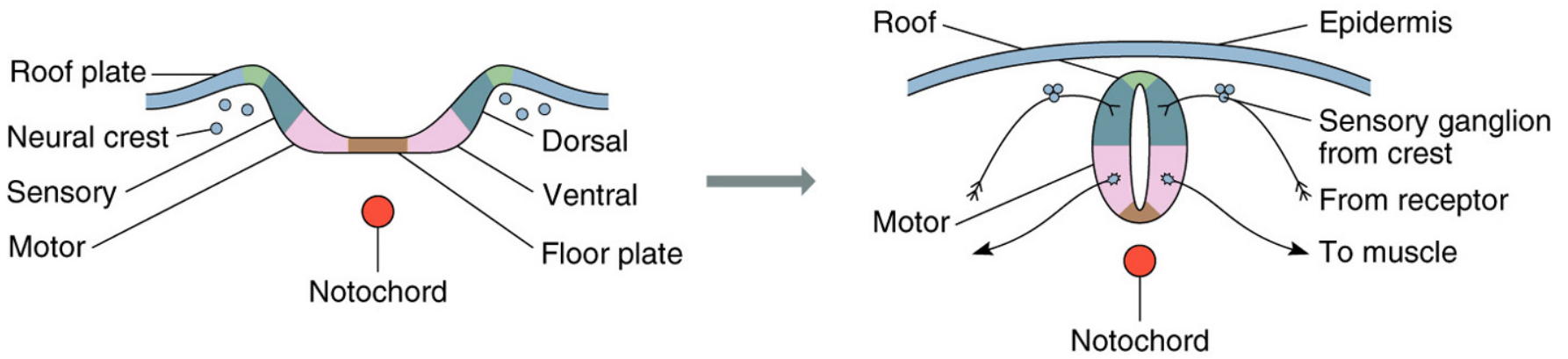
### A. Dorsal View



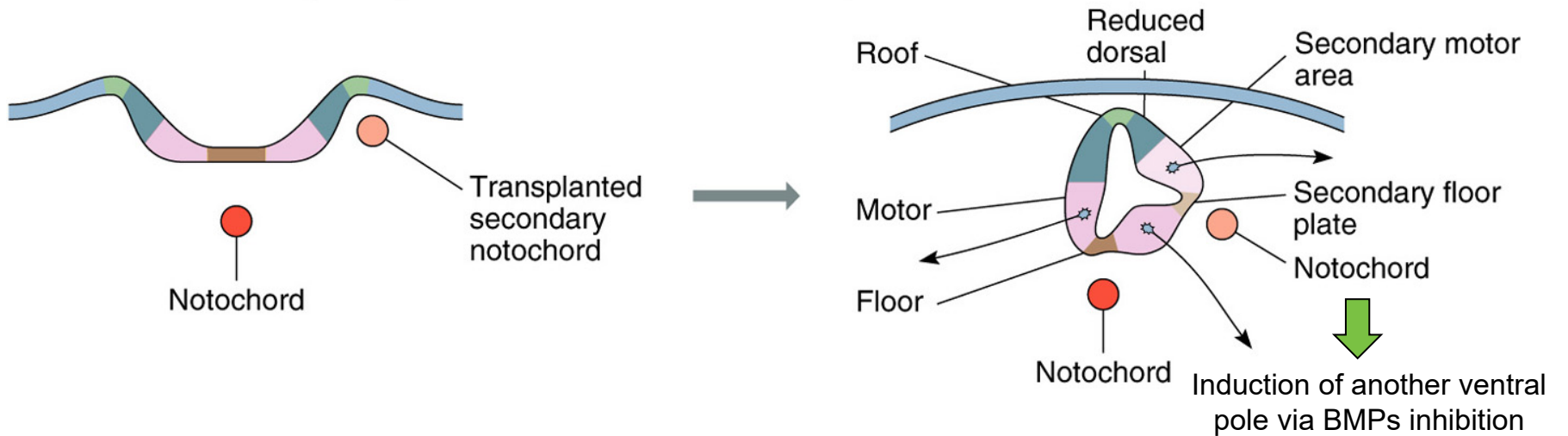
### B. Cross-sectional views



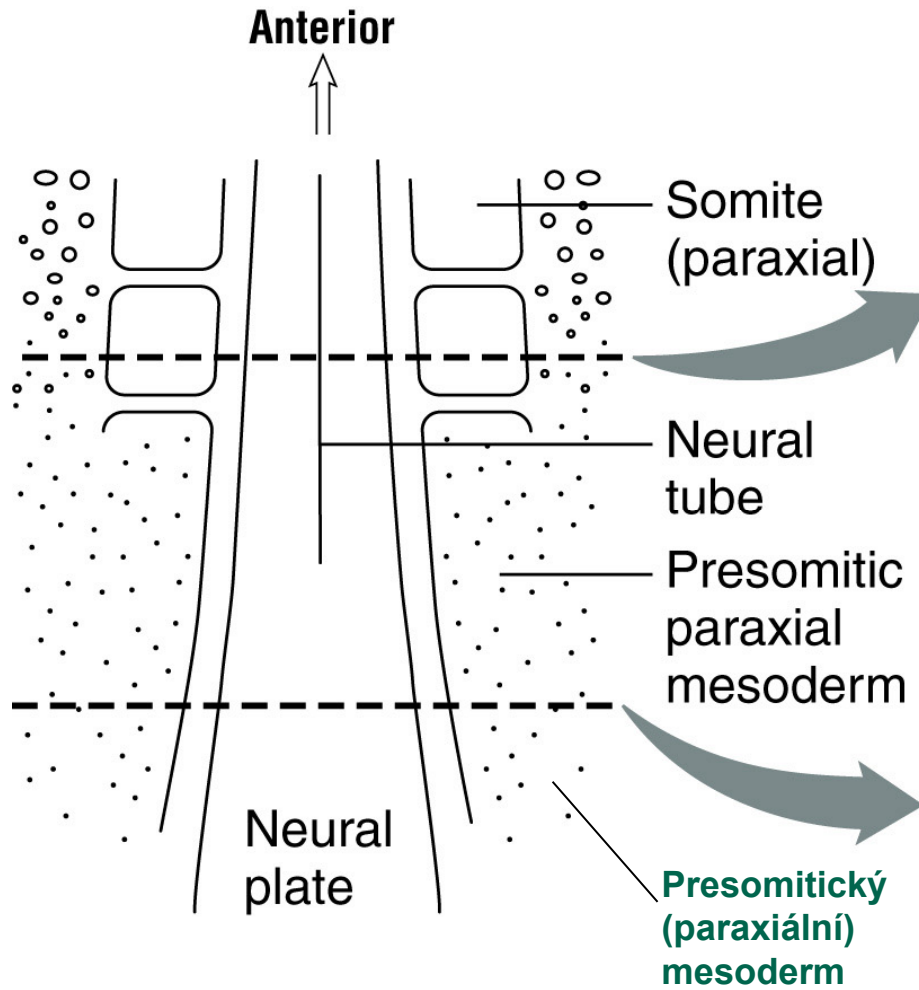
### A. The basic situation



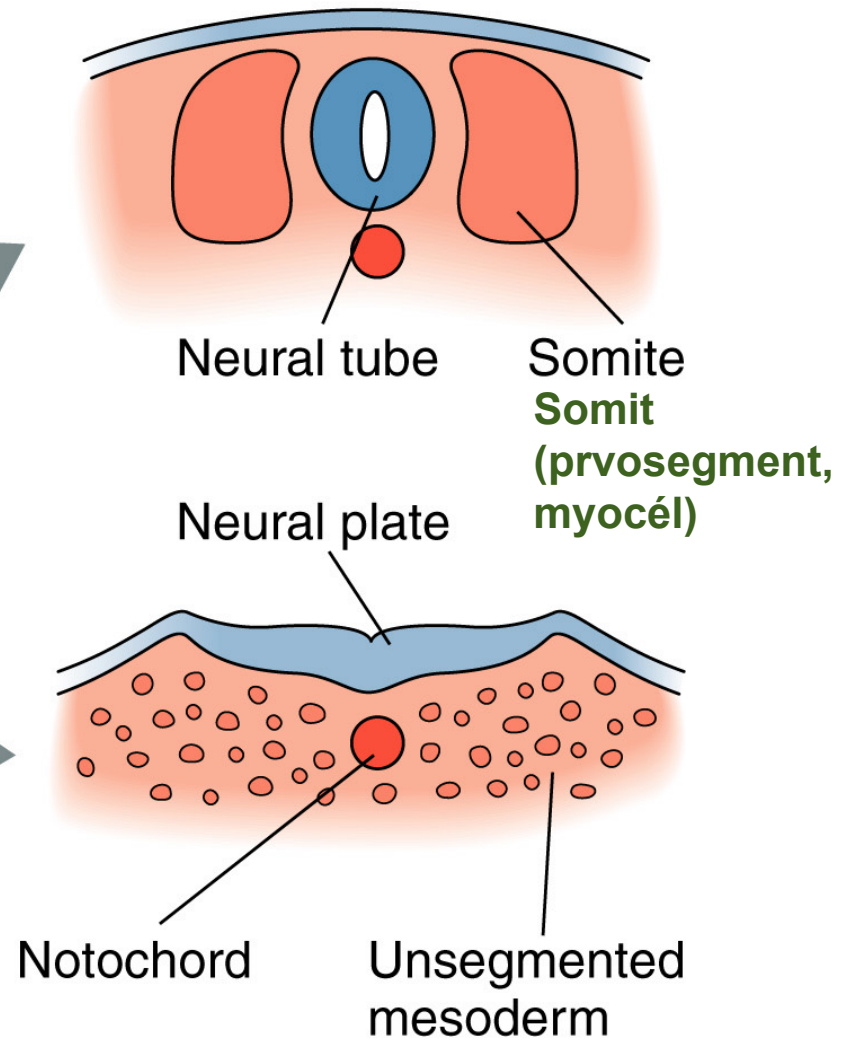
### B. Effect of secondary, ectopic notochord under the neural plate

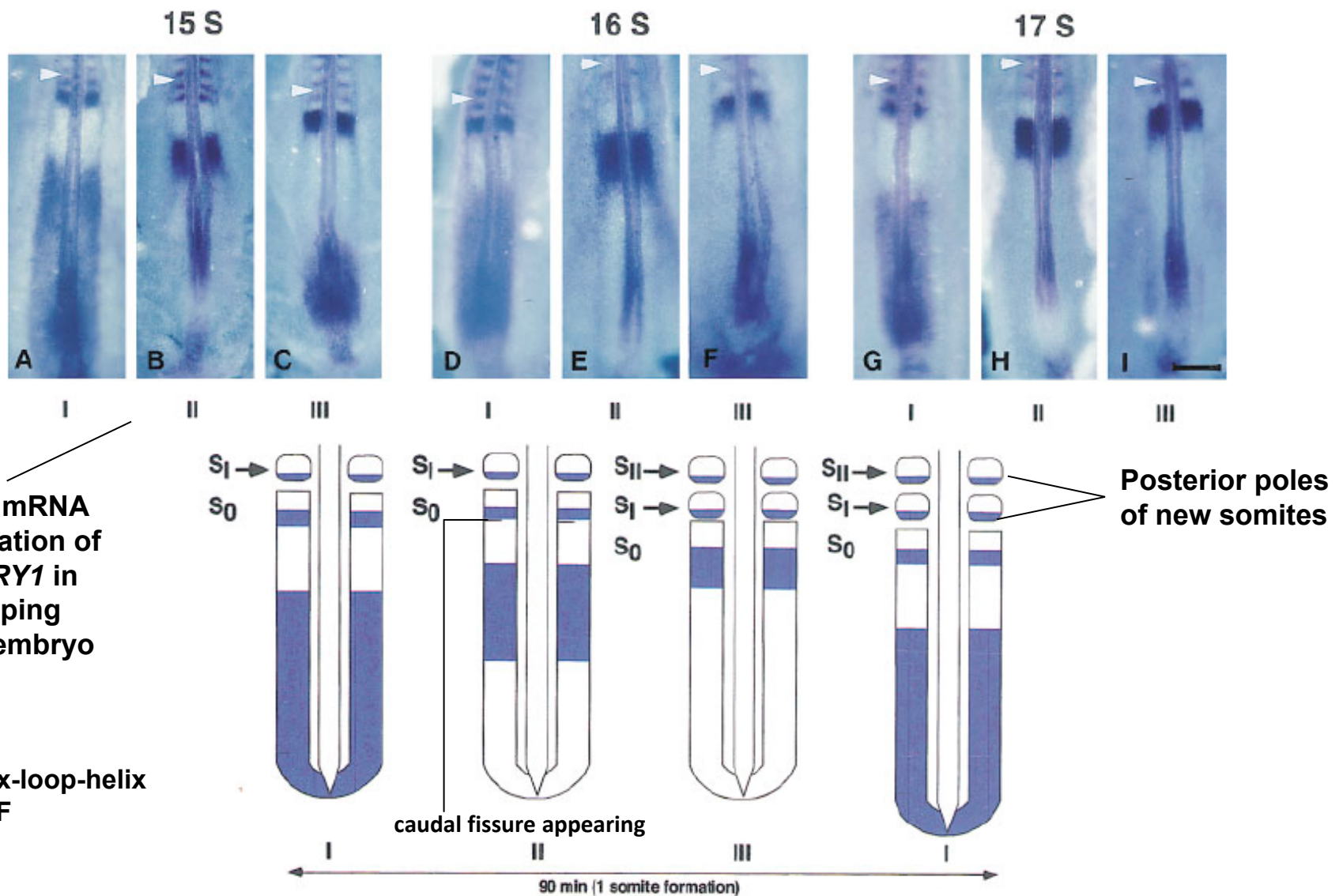


## A. Coronal Section



## B. Cross Sections

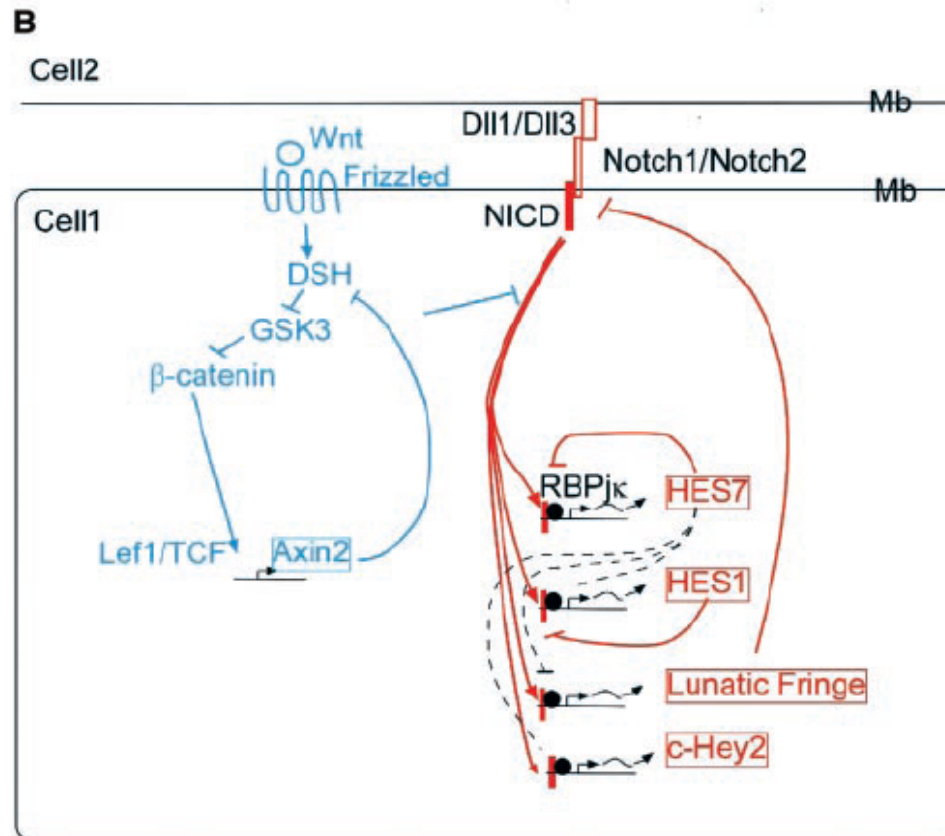
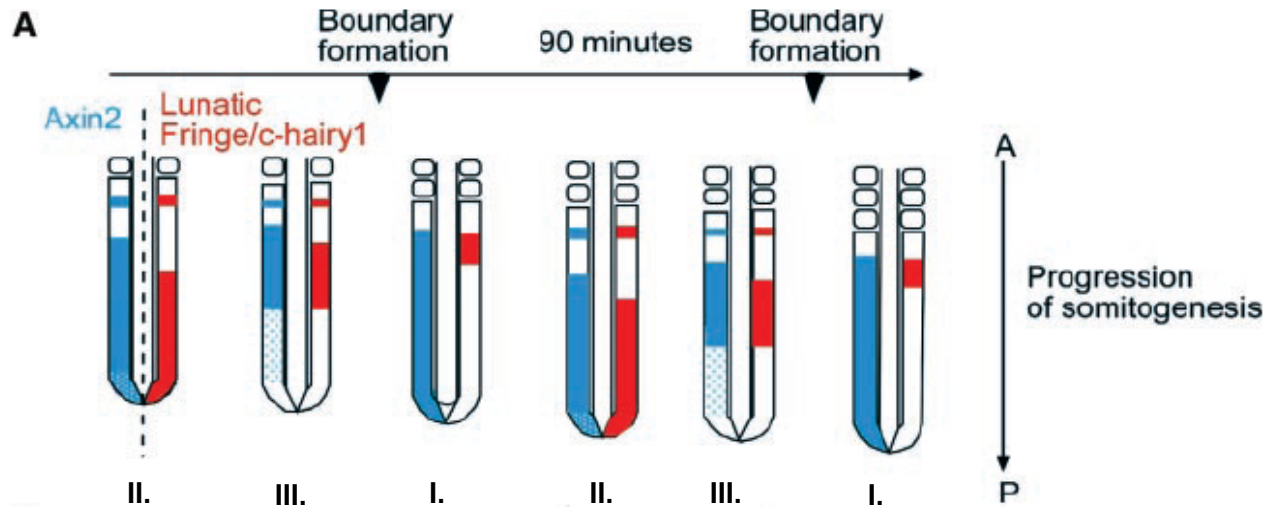




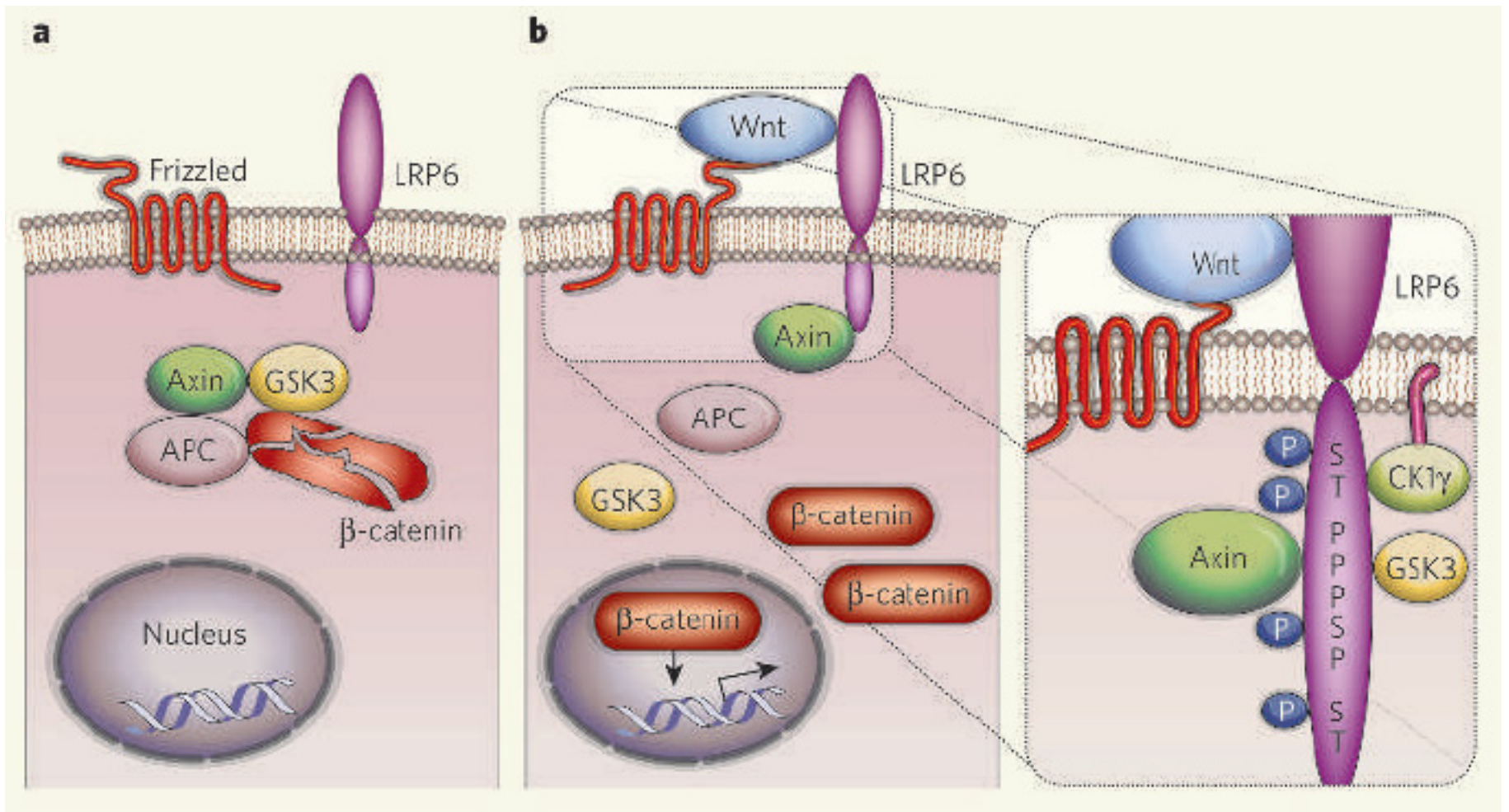
*In situ* mRNA localization of *C-HAIRY1* in developing chick embryo

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

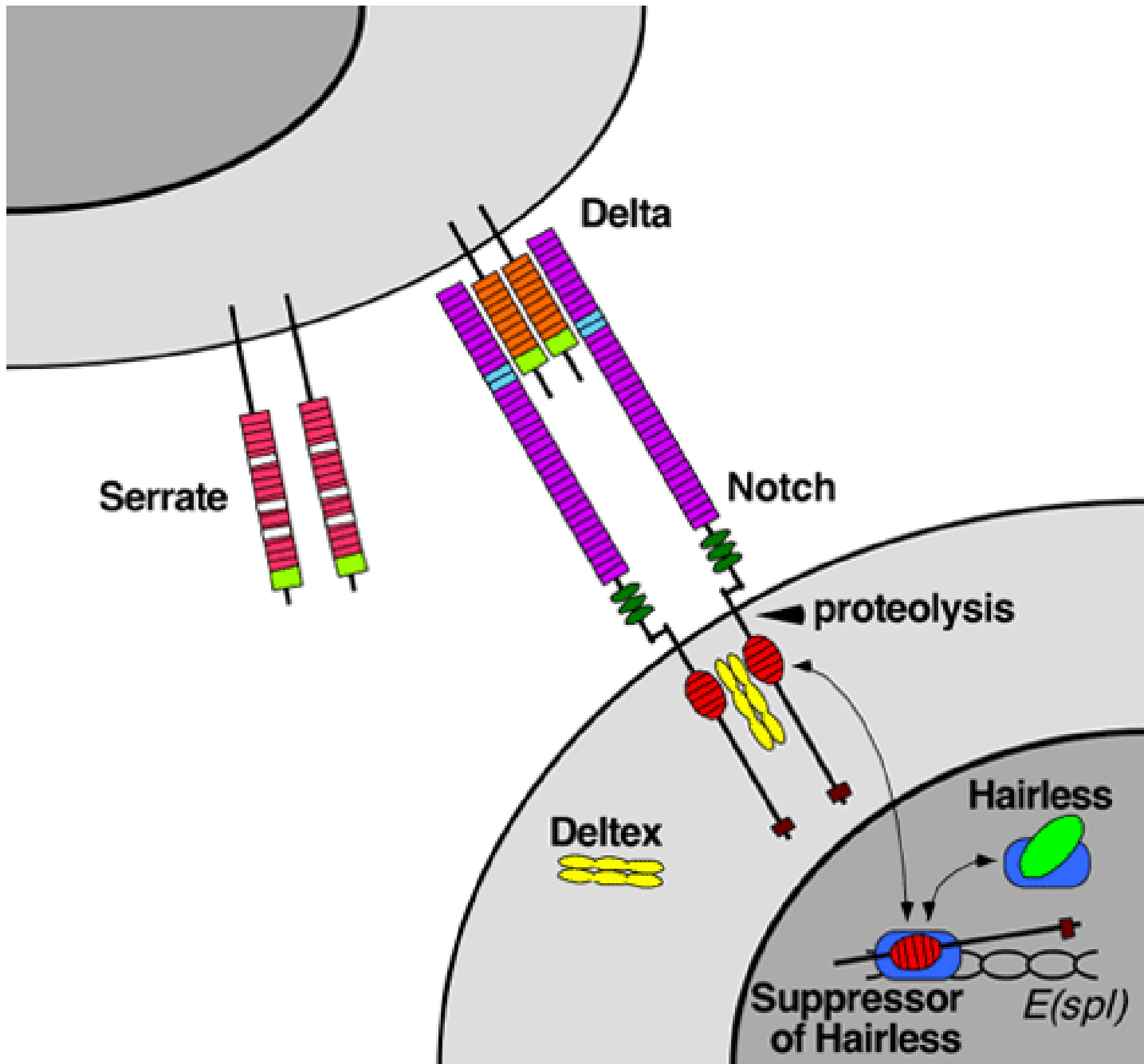
Palmeirim et al., *Cell* (1997)







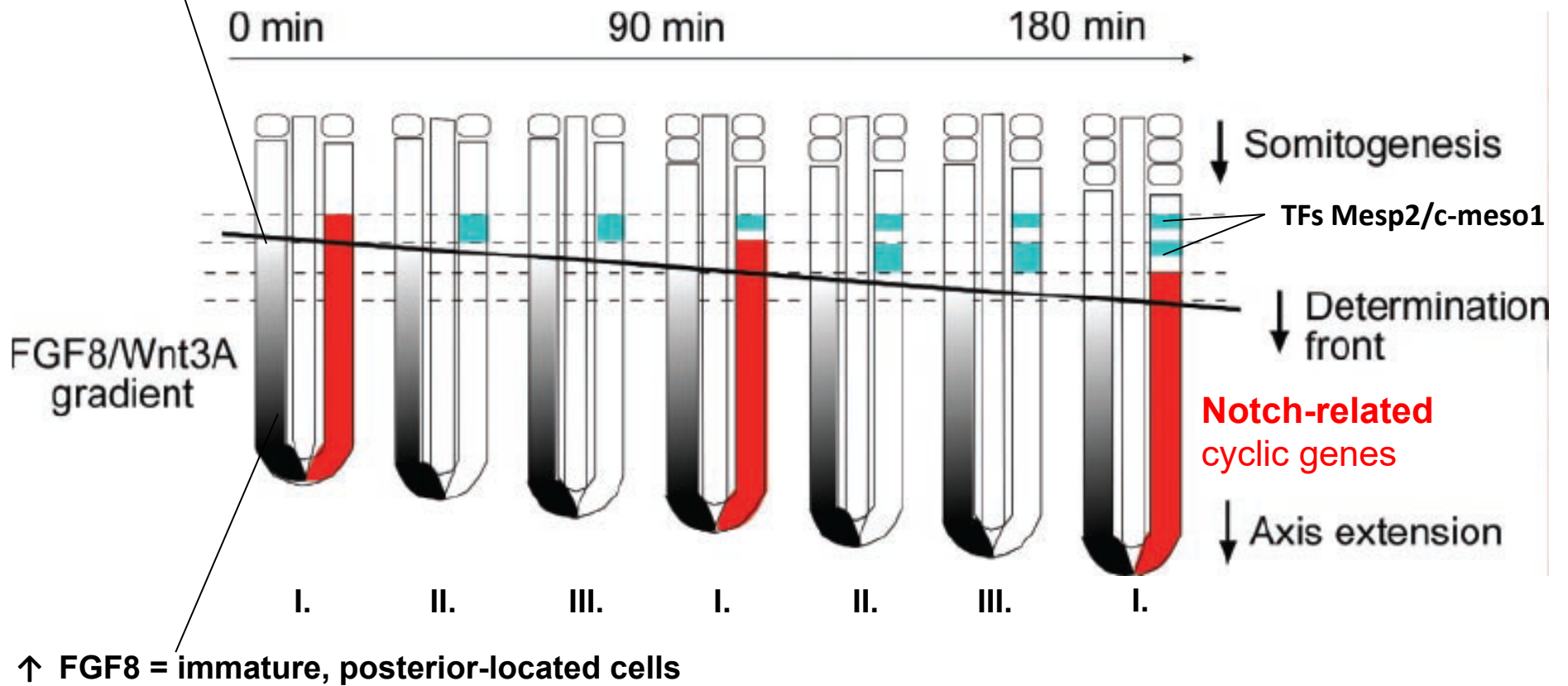
Nusse, *Nature* (2005)



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



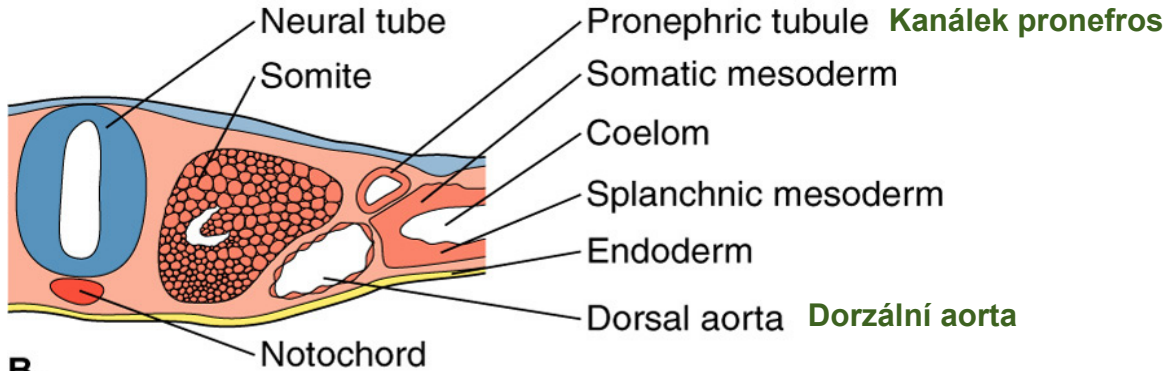
activation of segmentation program, ↑ *Paraxis*, ↓ posterior genes (e.g. *Brachyury*), stopping oscillation genes



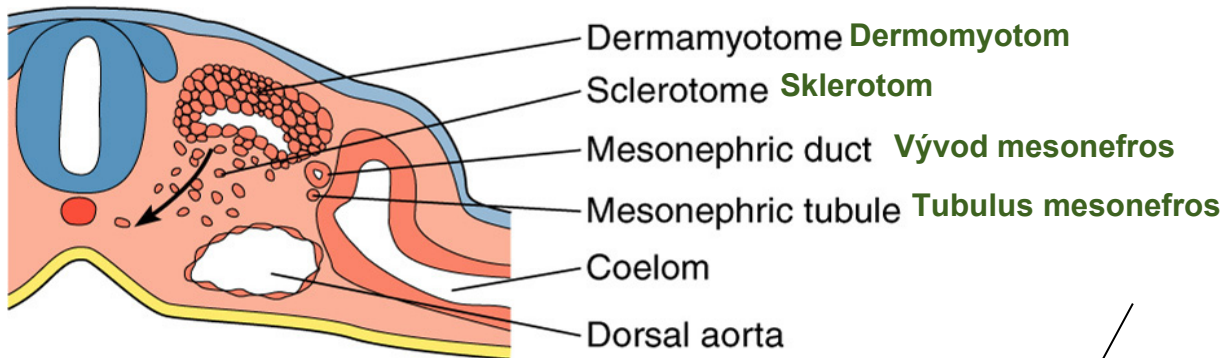
Pourquie., *Science* (2003)



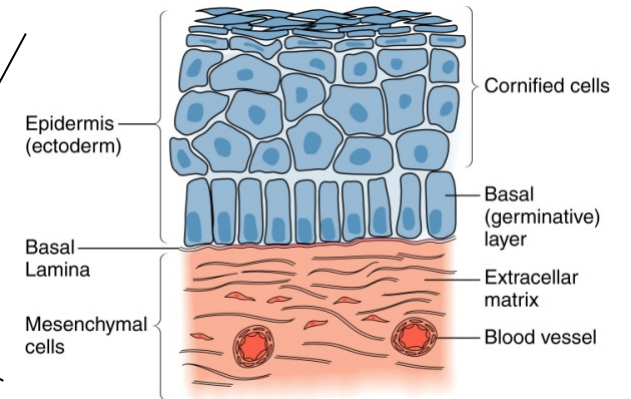
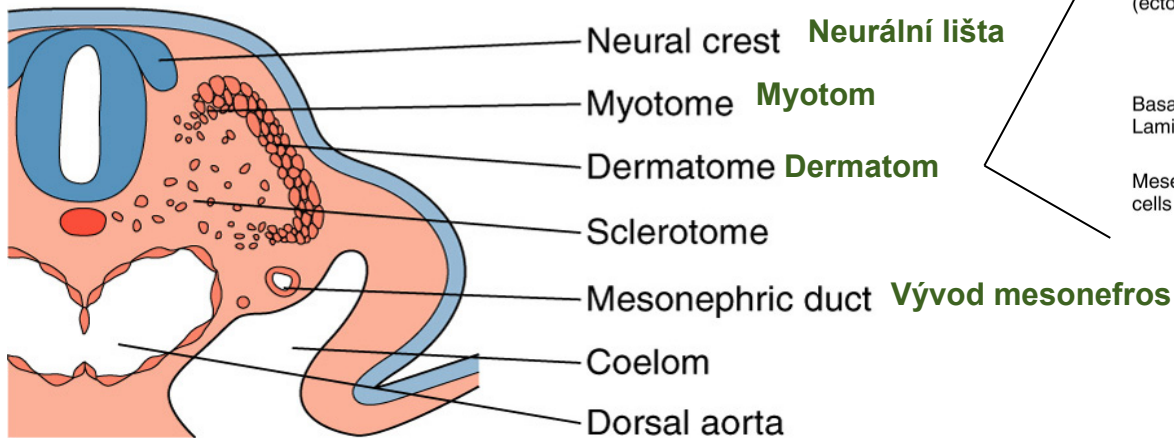
A.

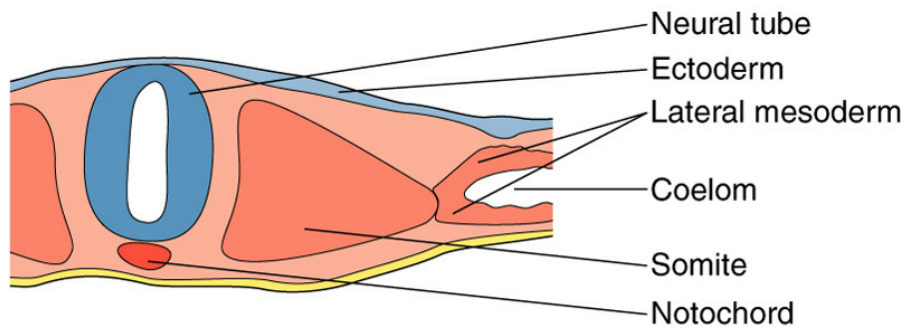


B.



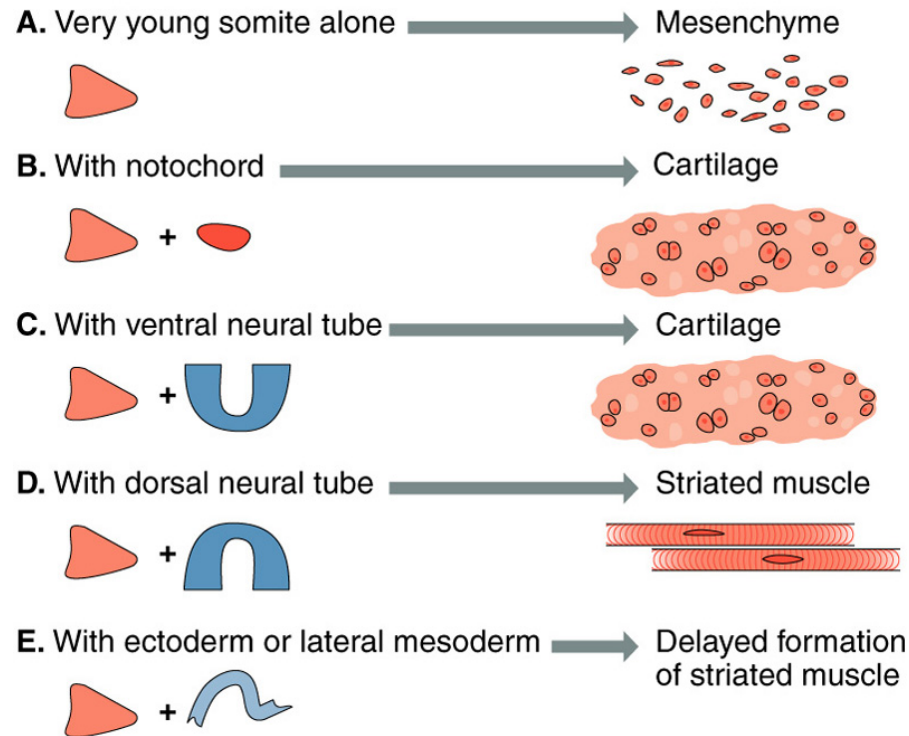
C.





**Remove somite and culture:**

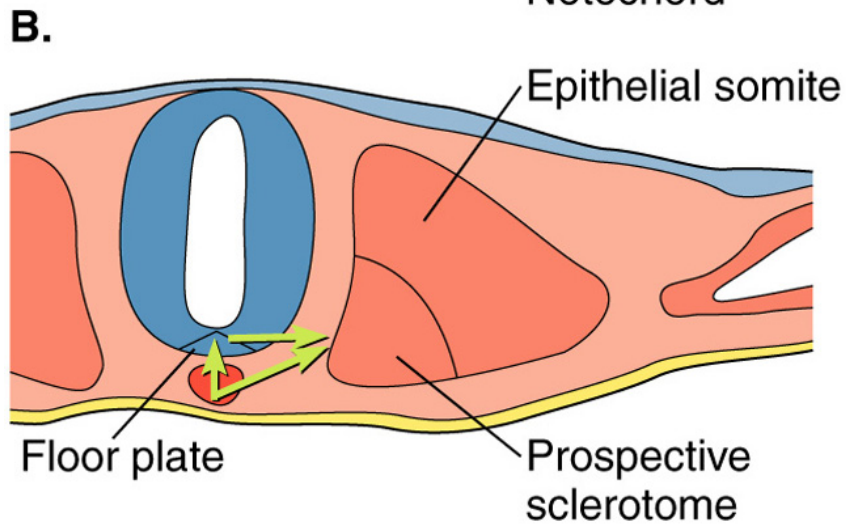
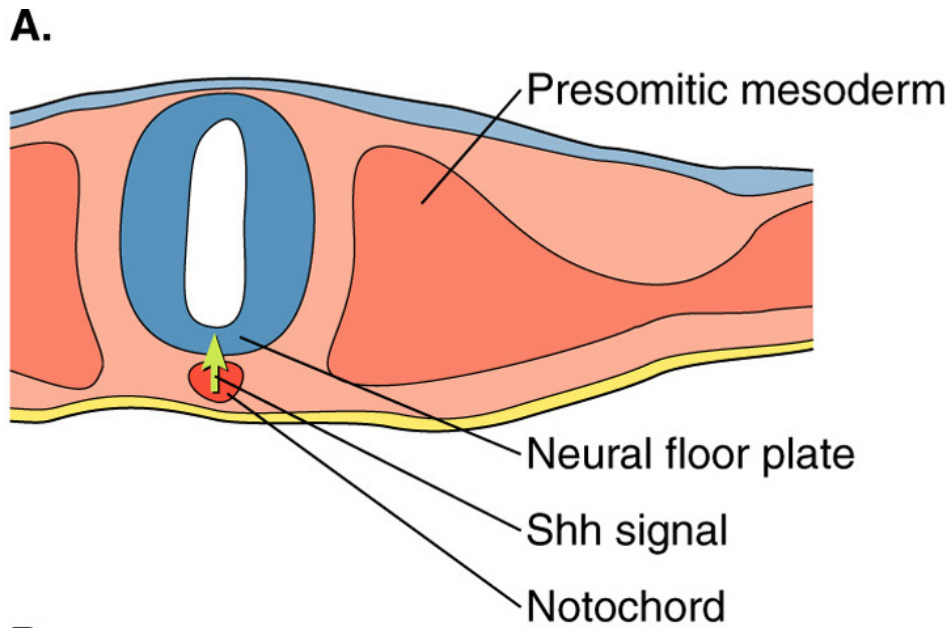
**To get:**



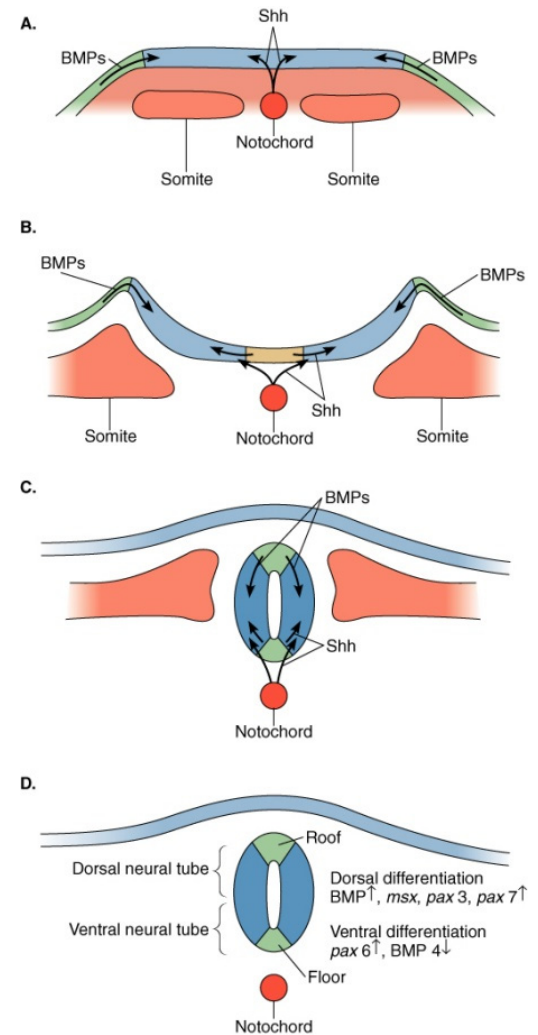
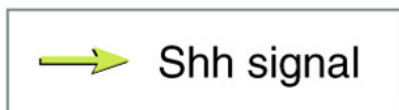
**Importance of intercellular communications**

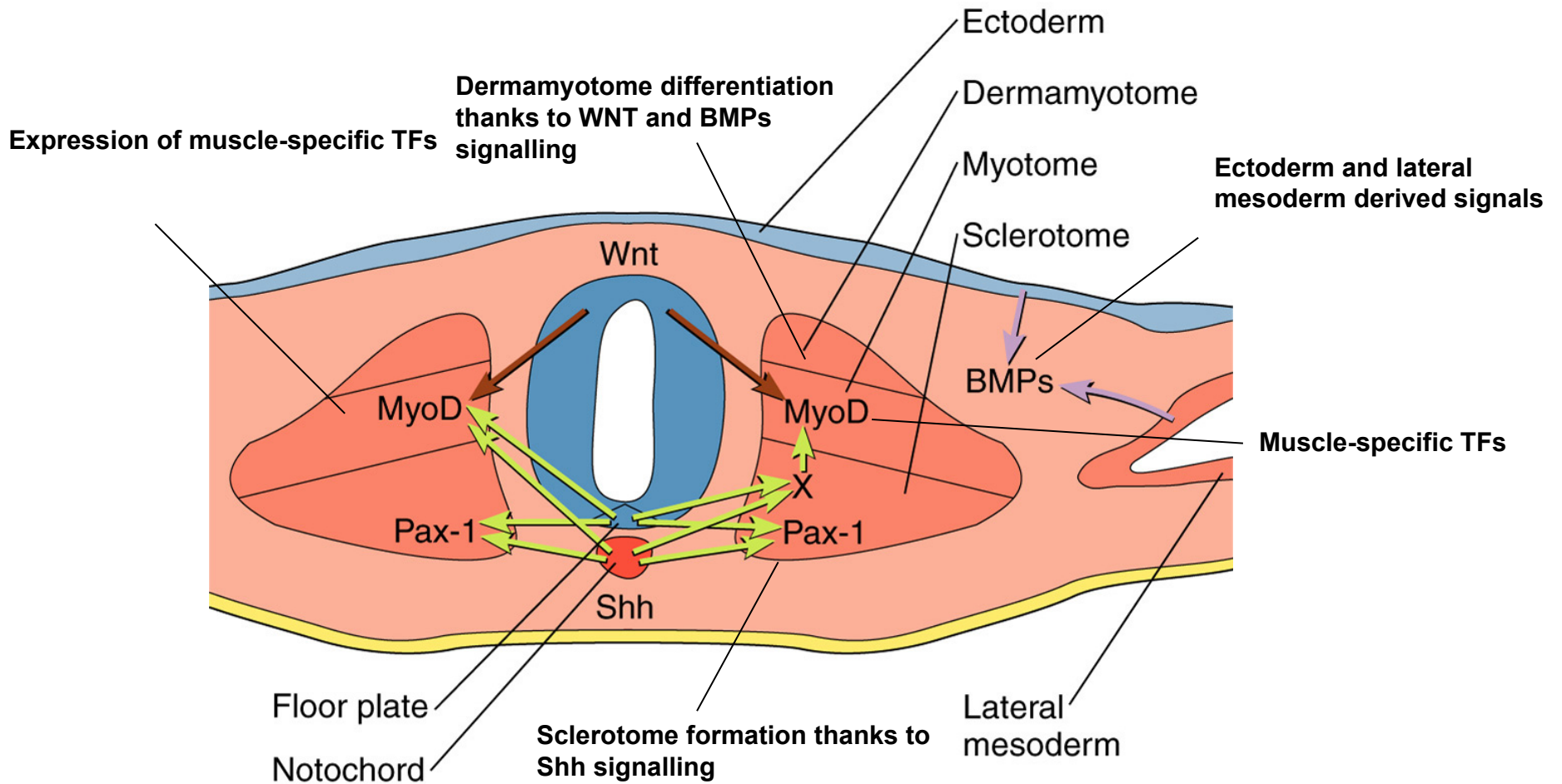


- **MYOD, MYF5**
  - Muscle cells specific TFs
- **Mouse DELTA homologue**
  - Somites segmentation signalling

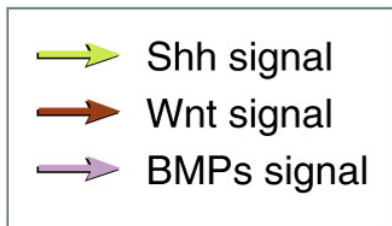


KEY





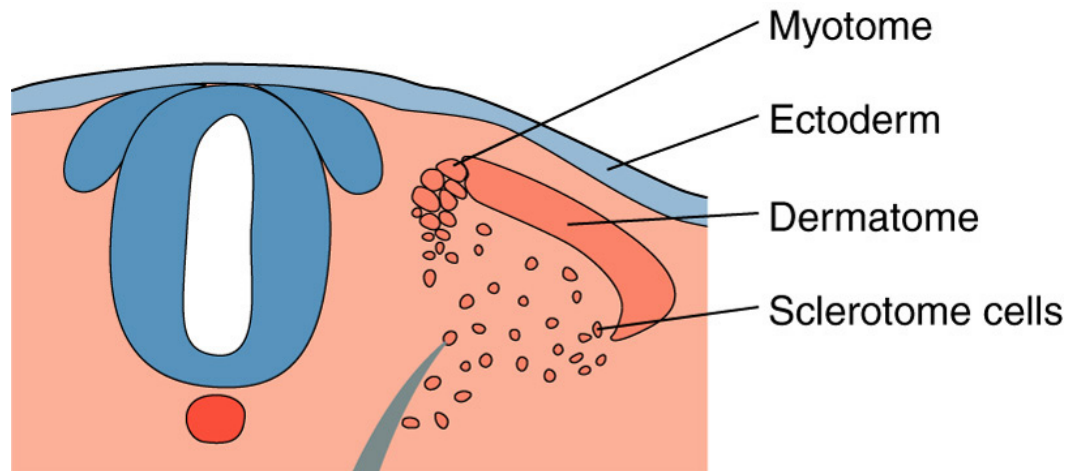
**KEY**



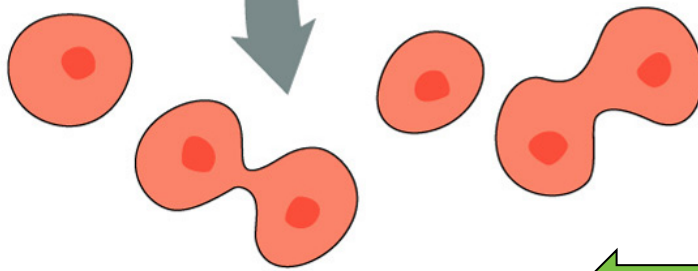
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- Mesoderm derivatives development
  - somites formation and signalling
  - formation of muscles



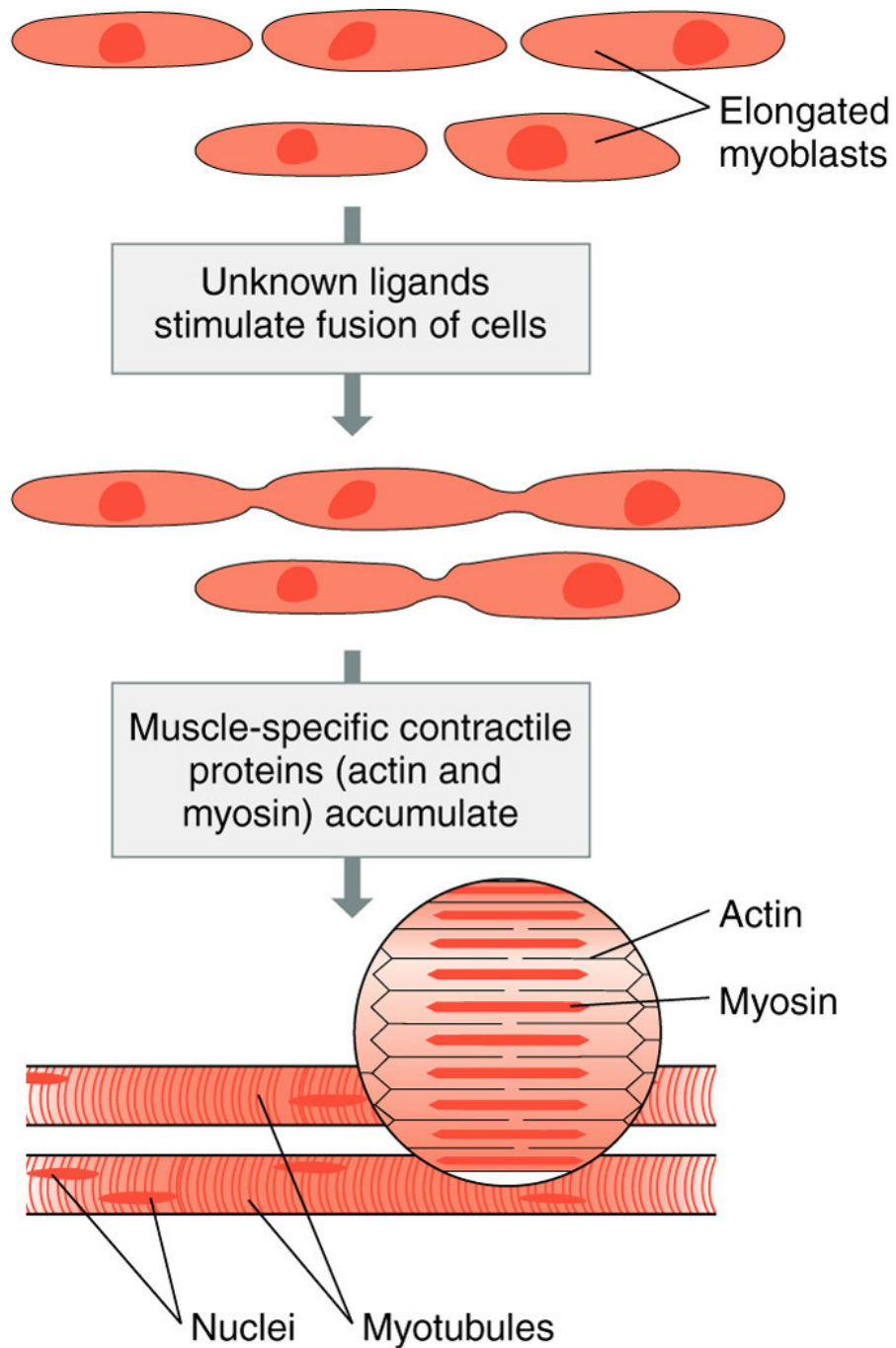
Myoblasts within myotome region proliferate



Cell division ceases

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



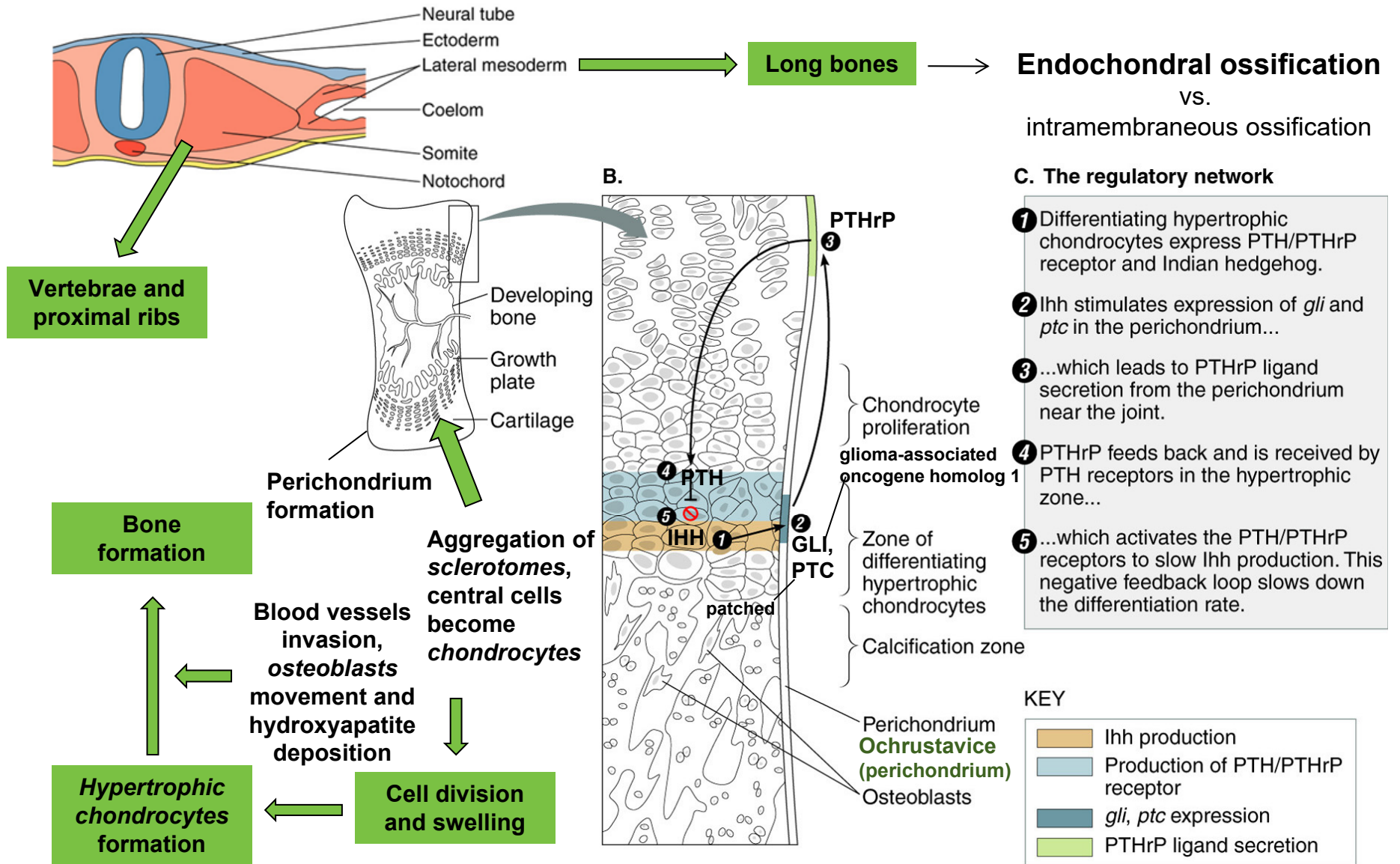


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## Organogenesis in Vertebrates: Endo- and Mesodermal Derivatives

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  - endochordal ossification and signalling

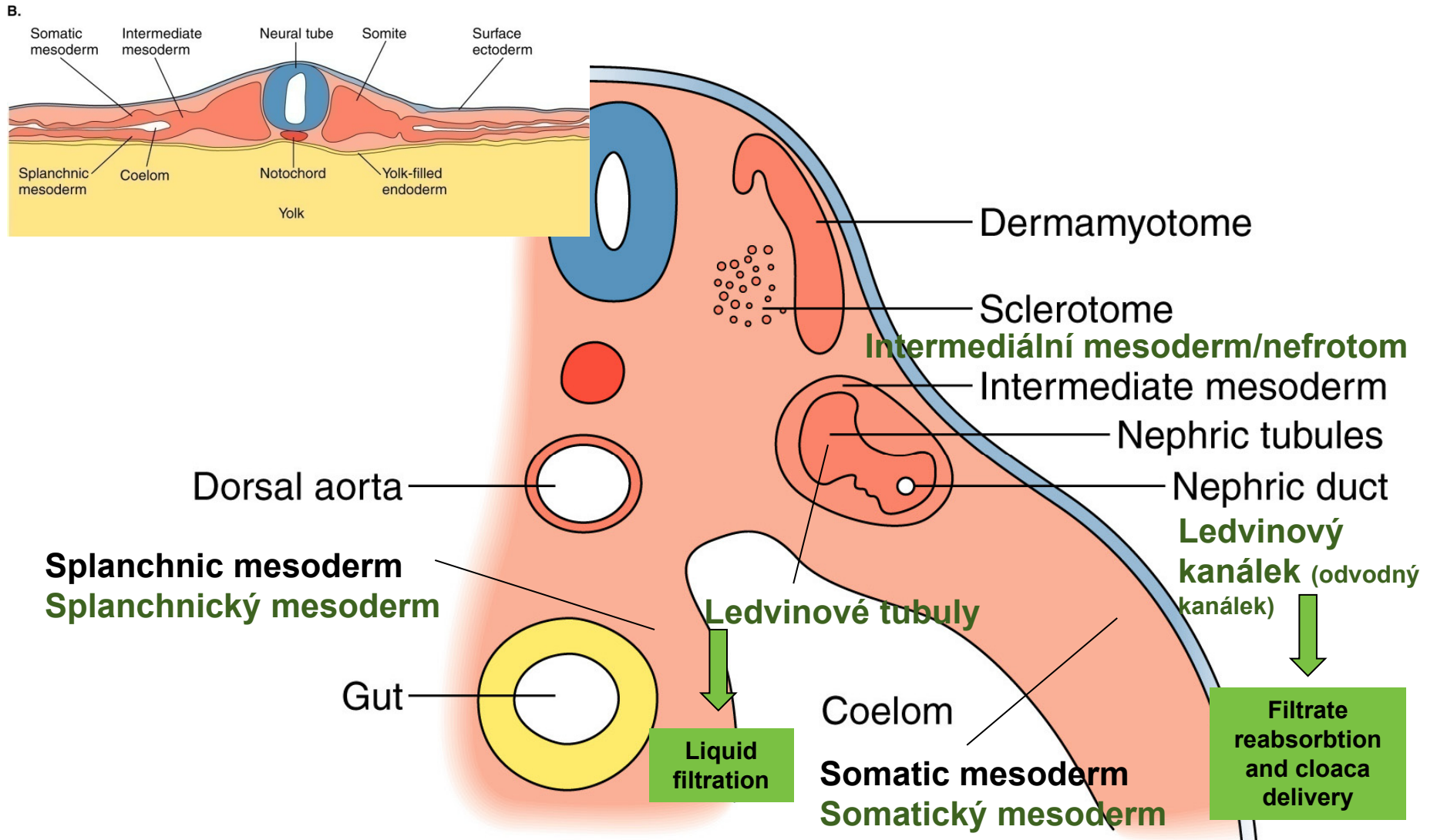




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  - nephrogenesis



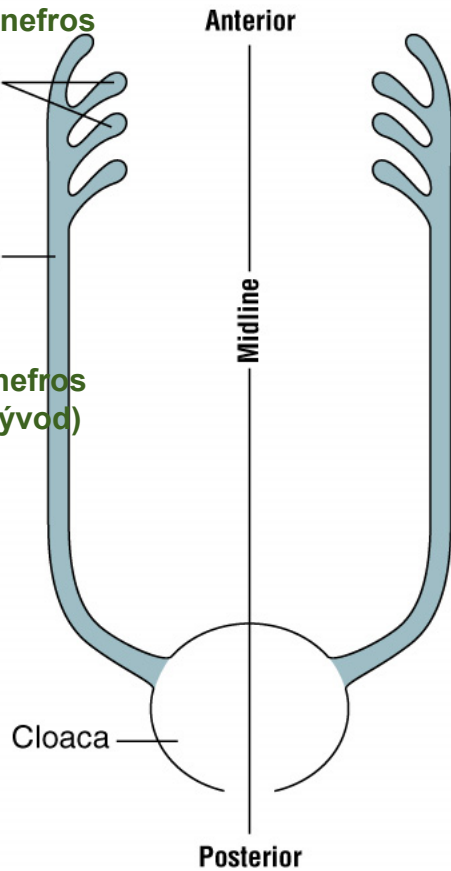
### A. Pronephros

#### Tubuly pronefros

Pronephric tubules

Pronephric (Wolffian) duct

#### Vývod pronefros (Wolffiiho vývod)



sliznatky (bezčelistnatí)  
hagfishes (Agnatha)

### B. Mesonephros

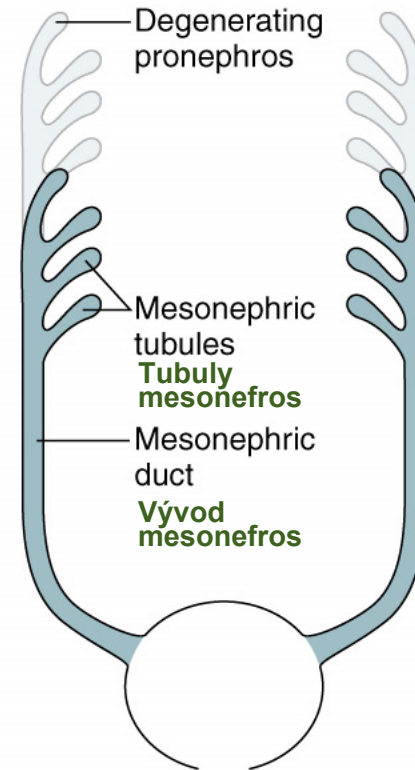
Degenerating pronephros

Mesonephric tubules

#### Tubuly mesonefros

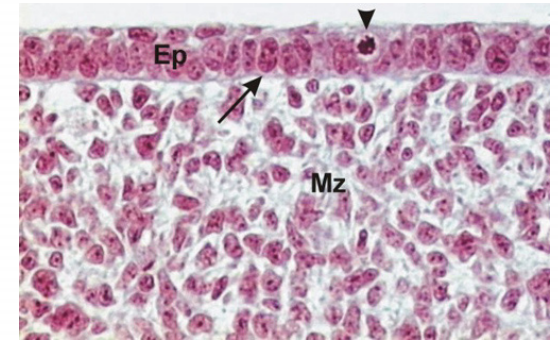
Mesonephric duct

#### Vývod mesonefros

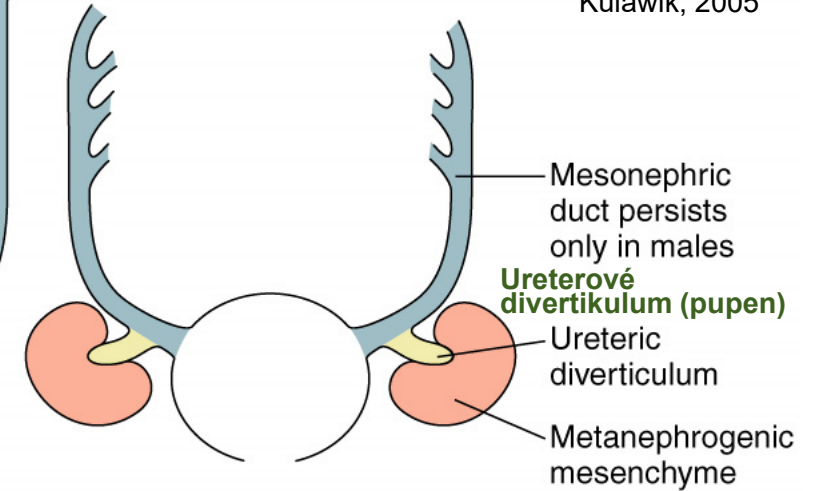


amphibians, fishes

### C. Metanephros

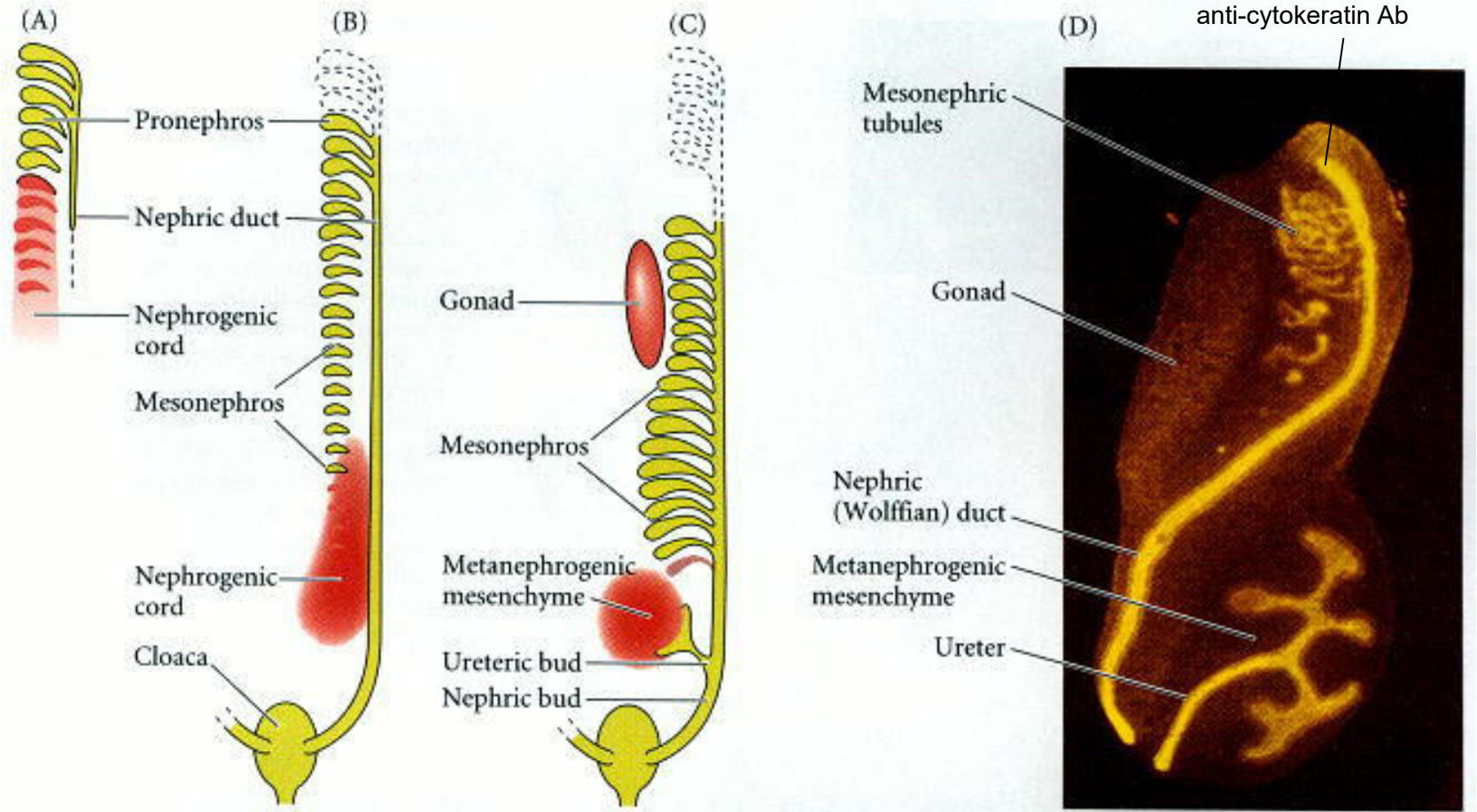


Kulawik, 2005



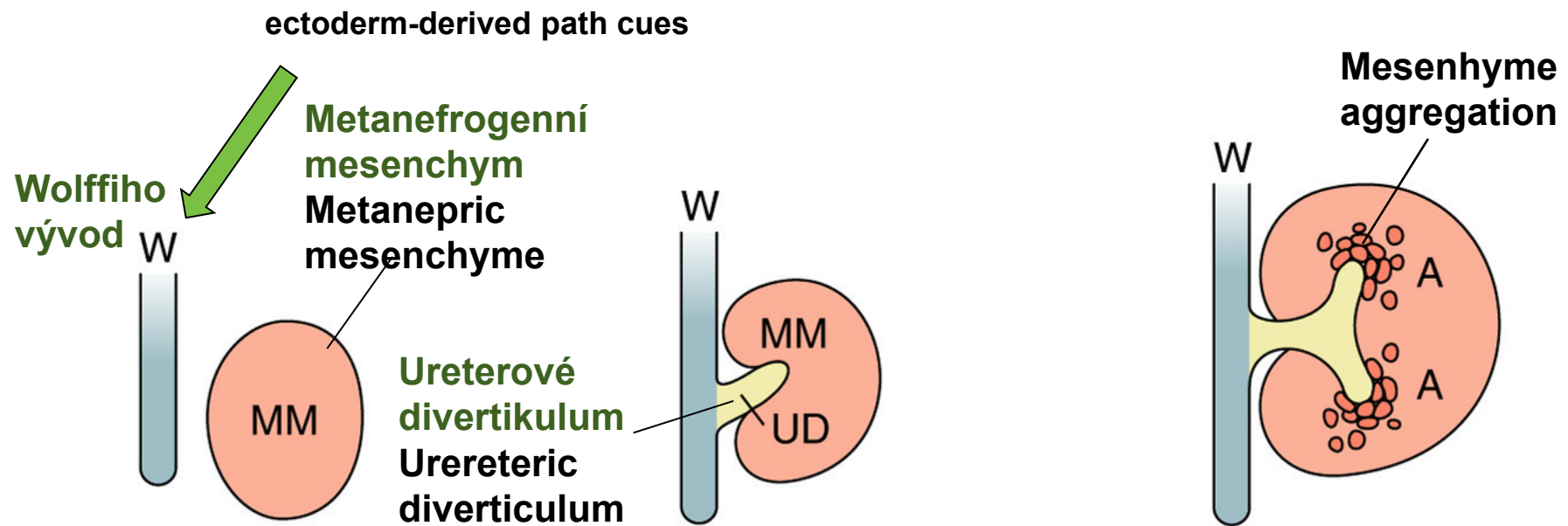
amniotes





Gilbert, SF, Developmental biology

## Intermediate mesoderm of a 13-day mouse embryo



1

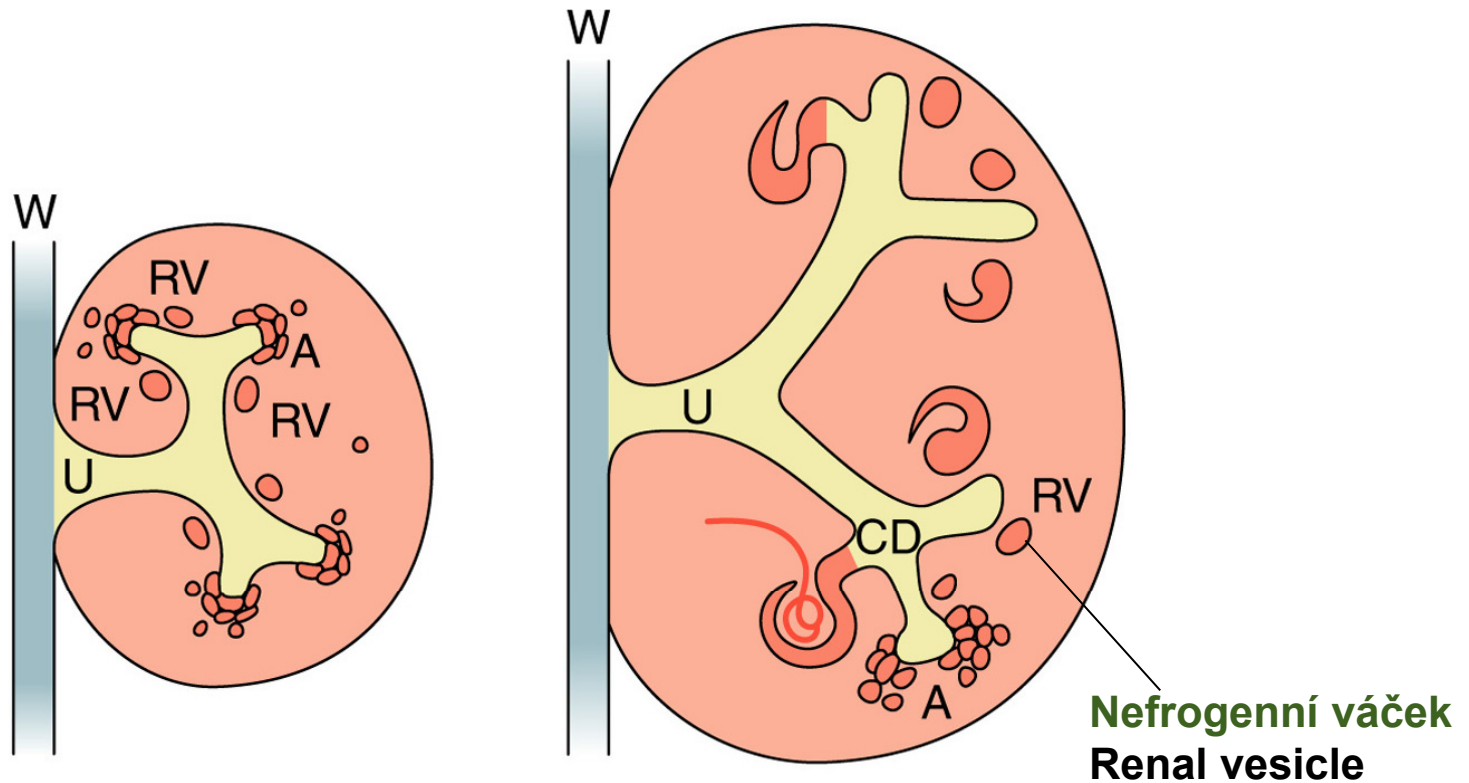
The Wolffian duct elongates. Metanephric mesenchyme is specified.

2

The ureteric bud evaginates. Mesenchymal cells respond.

3

The ureteric bud branches. Mesenchymal cells aggregate.



**4**

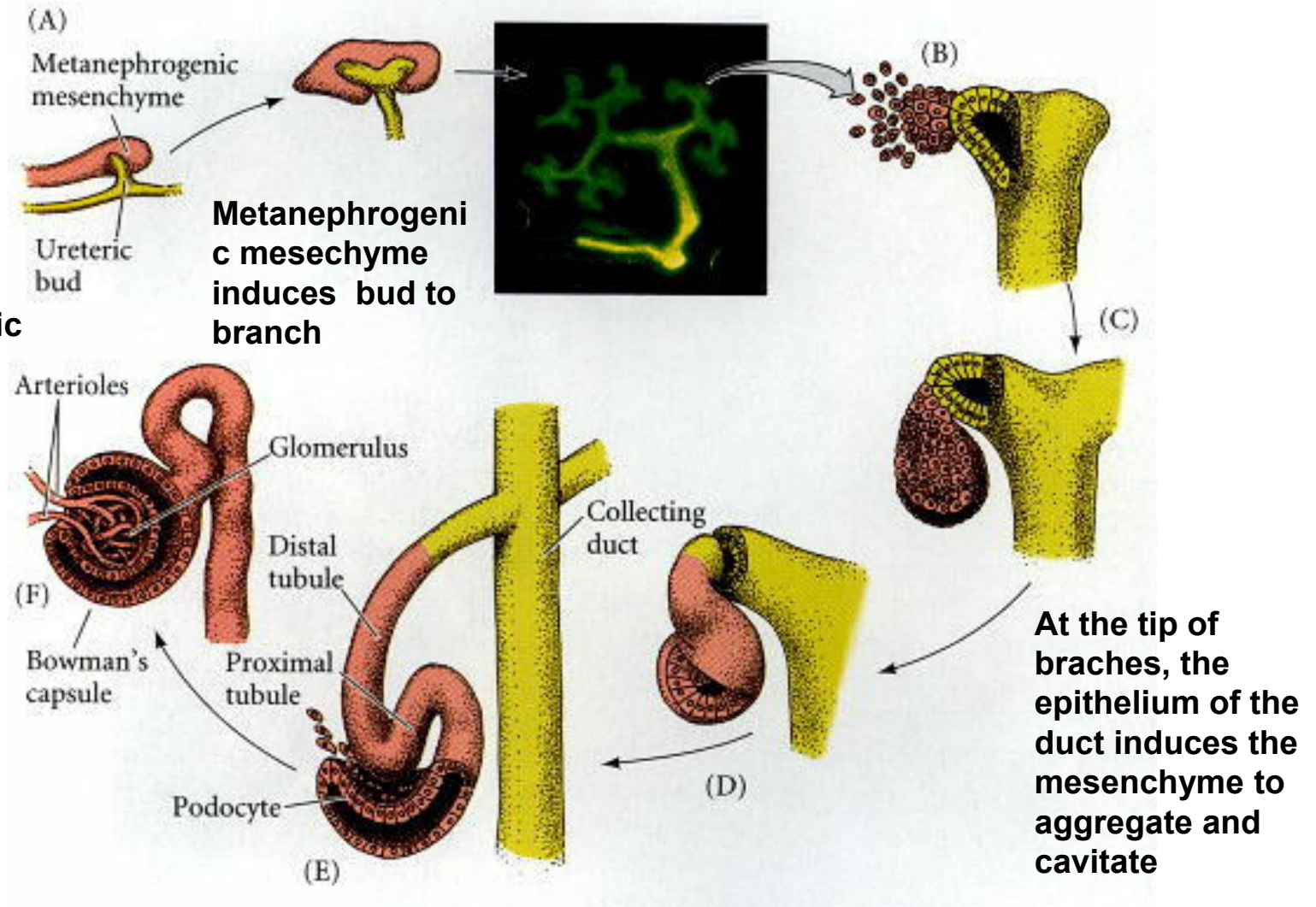
Renal vesicles form.  
Branching and  
aggregation continues.

**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



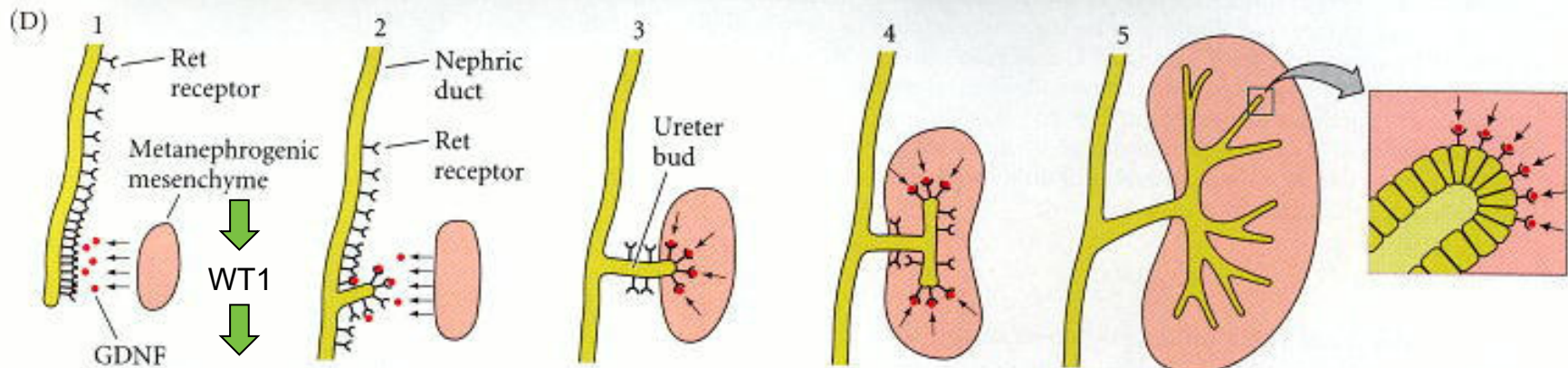
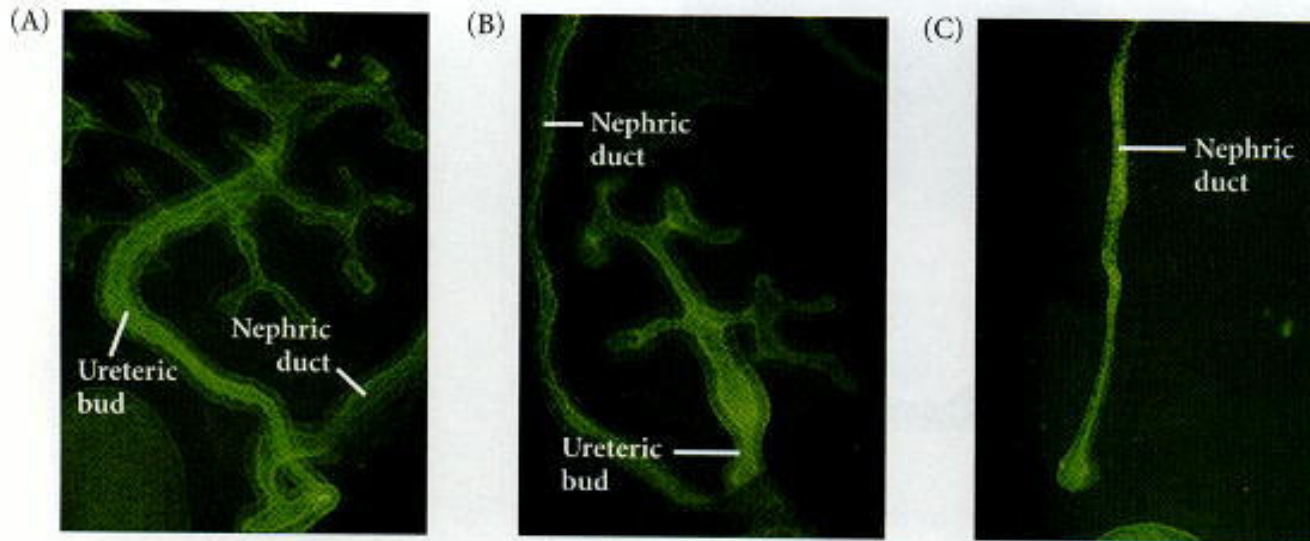
# Reciprocal induction in kidney development

The role of glial-derived neurotrophic factor (GDNF)

*GDNF/GDNF*

*GDNF/gdnf*

*gdnf/gdnf*



Metanephrogenic mesenchyme ability to respond to ureteric bud

Gilbert, SF, Developmental biology

Metanefrogenní mesenchym

Primární sběrací kanálek  
(vzniká větvením ureterického  
divertikula)

Nefrogenní váček

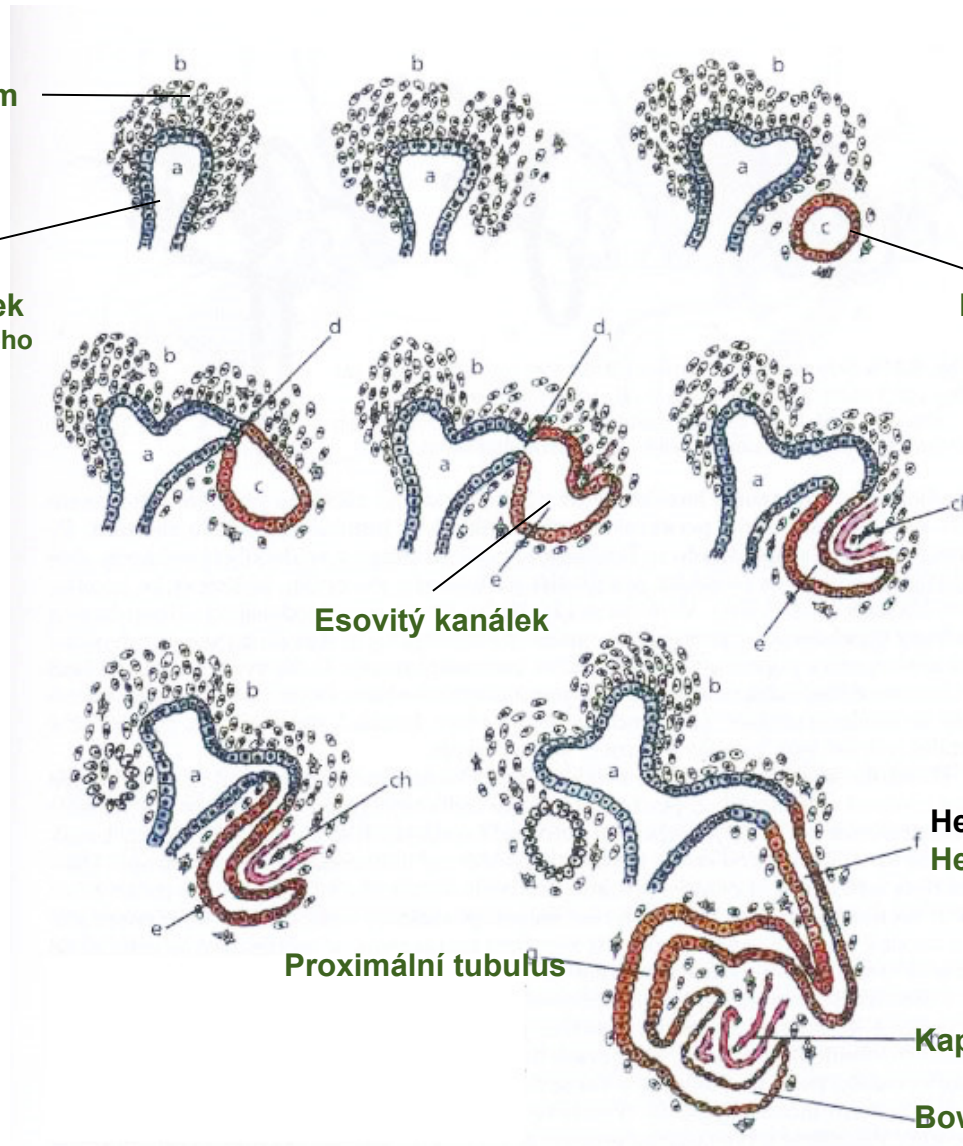
Esovitý kanálek

Henle loop  
Henleyova klička

Proximální tubulus

Kapiláry glomerulu

Bowmanův váček



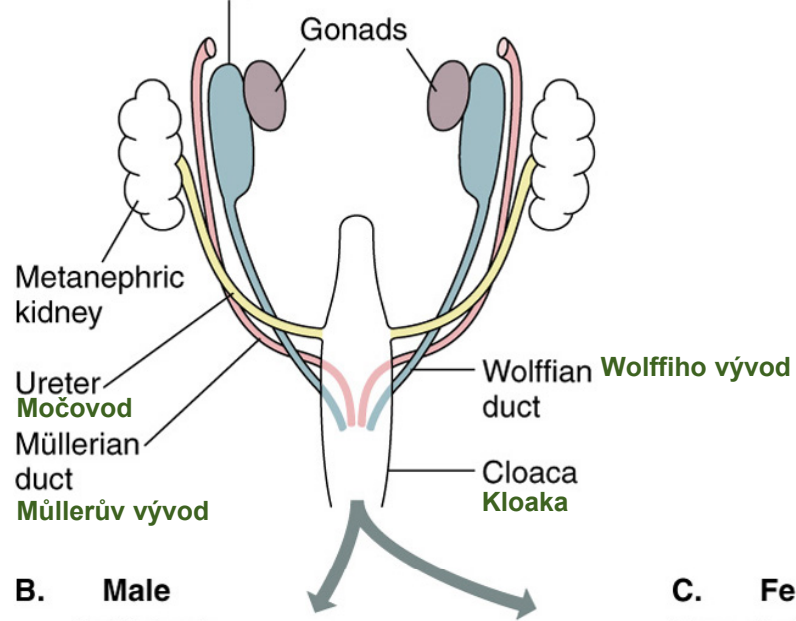
Vacek, Embryologie (2006)

# Outline of Lesson 5

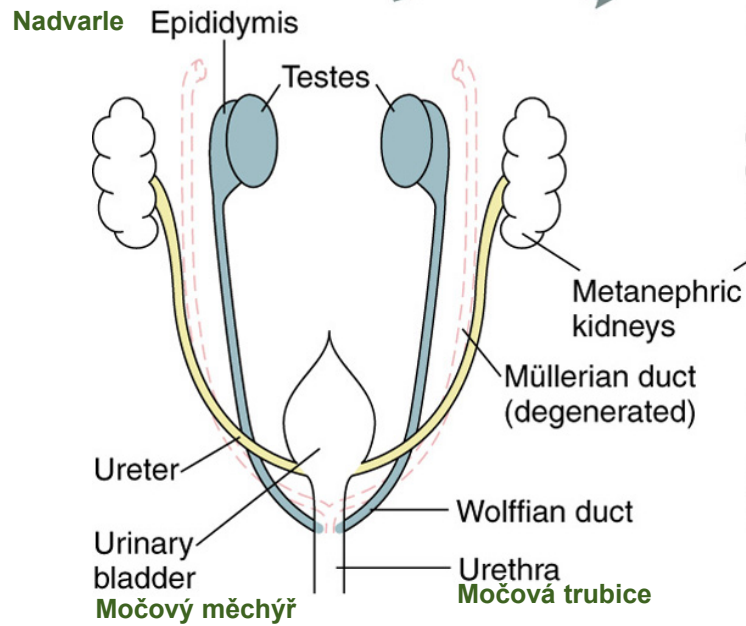
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  - formation of gonads

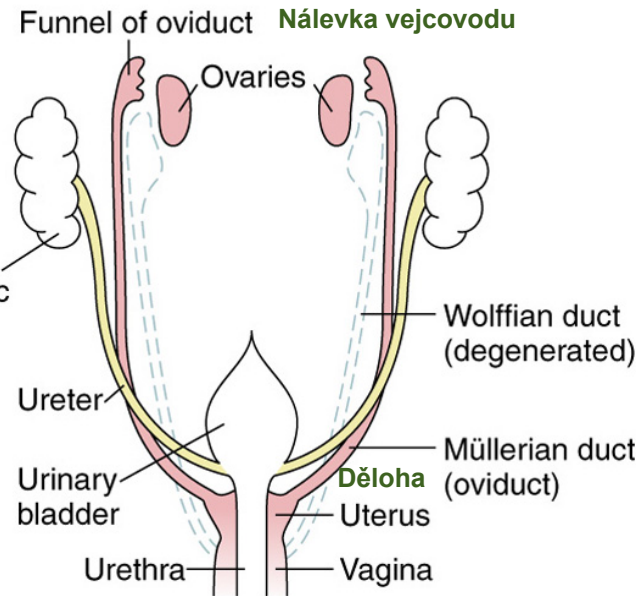
**A. Undifferentiated**  
Mesonephros



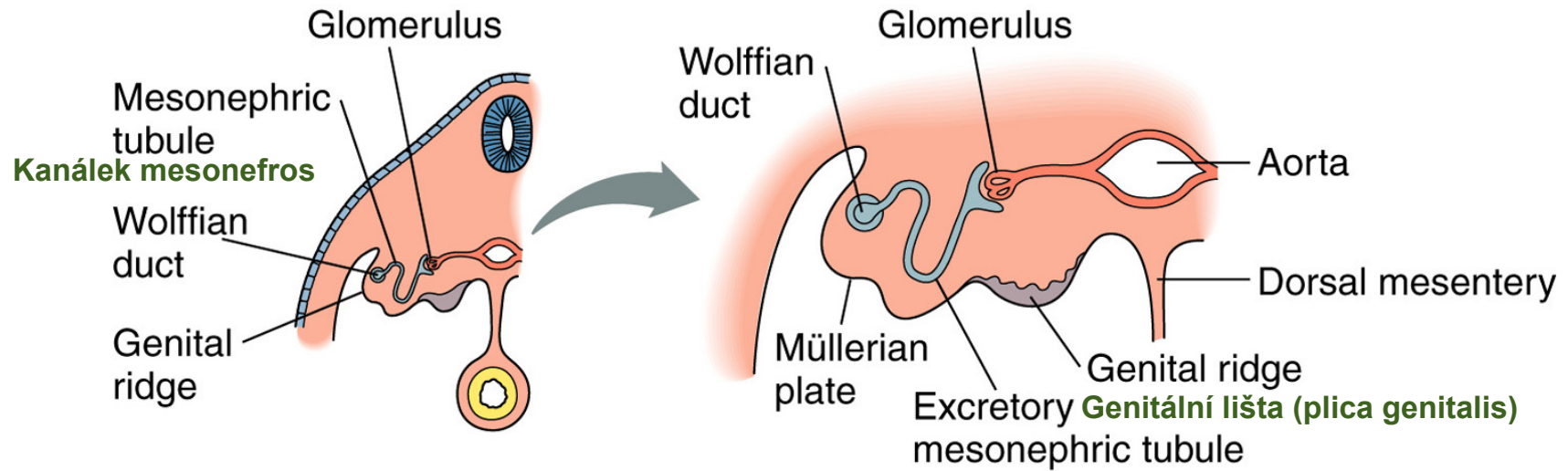
**B. Male**



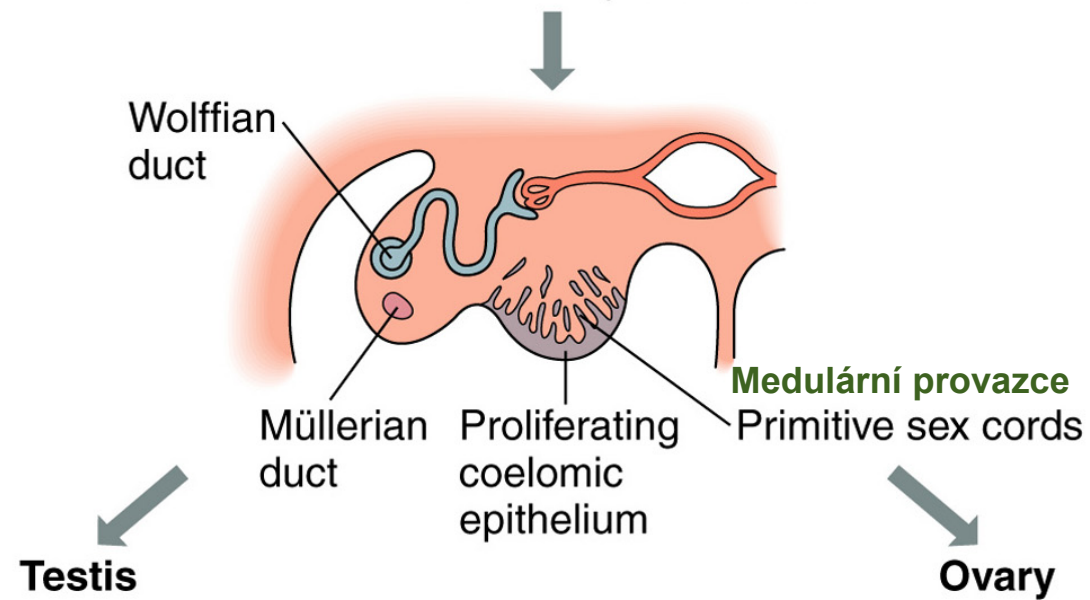
**C. Female**



### A. 4 Weeks



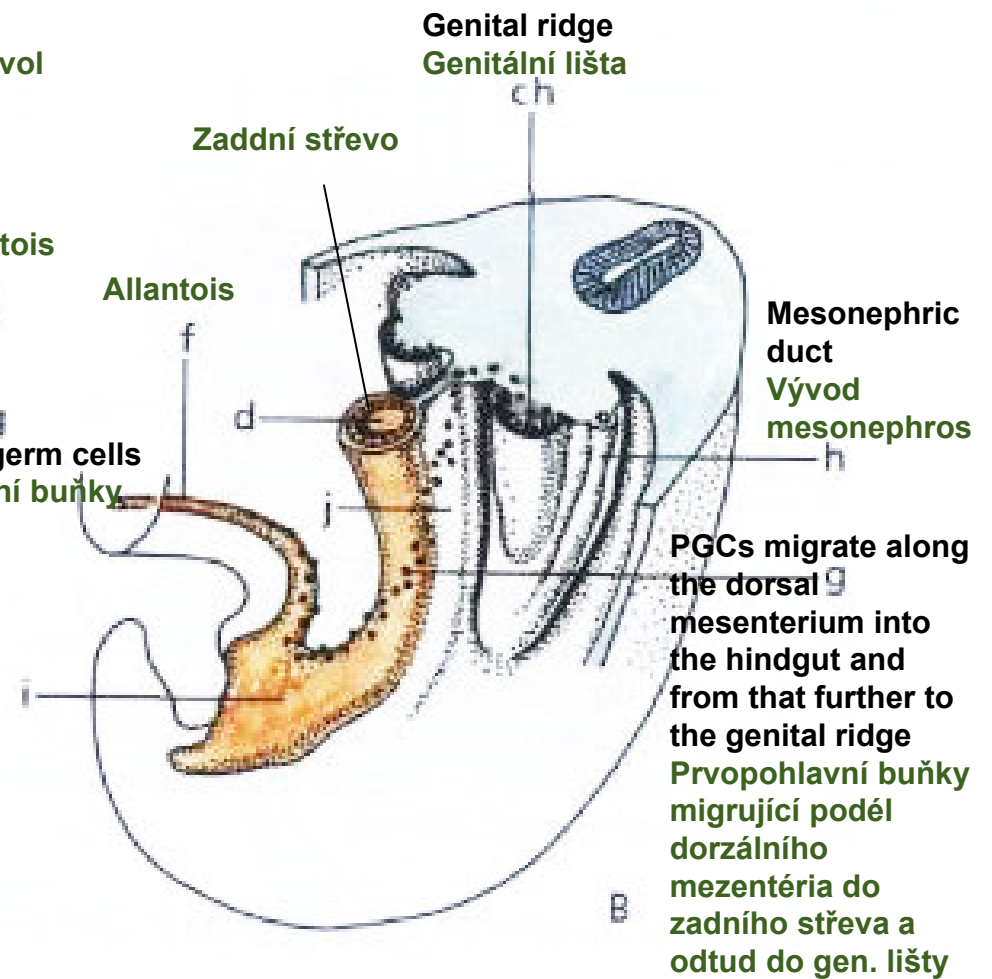
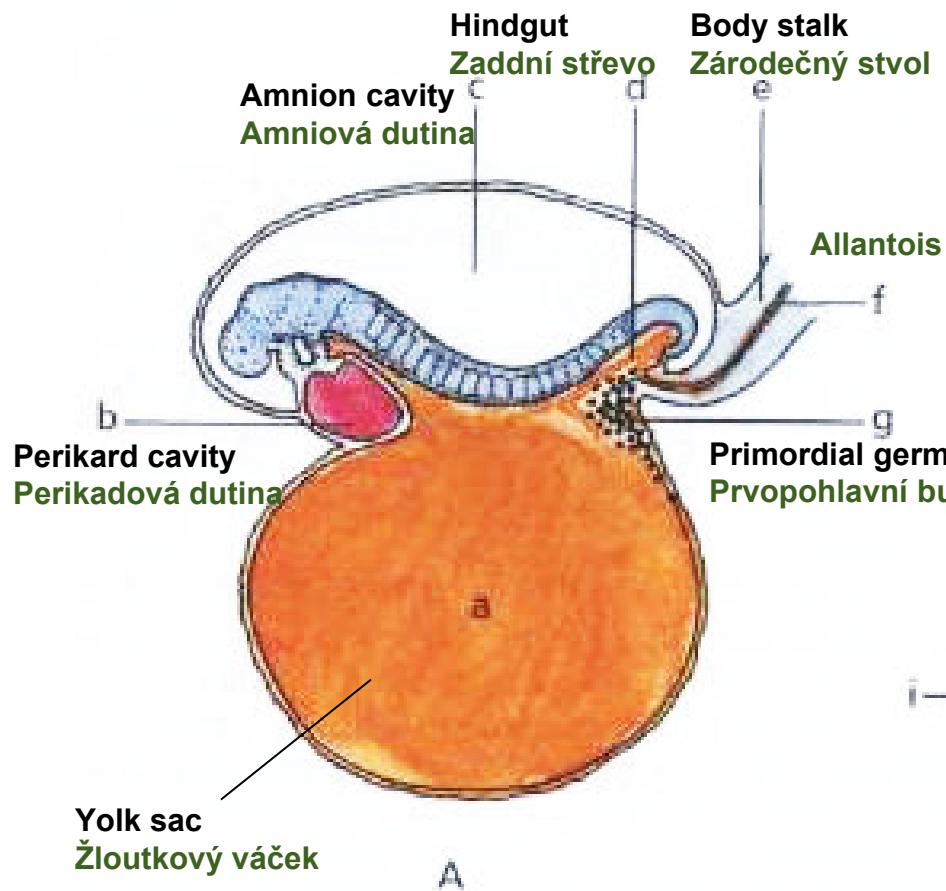
### B. 6 Weeks





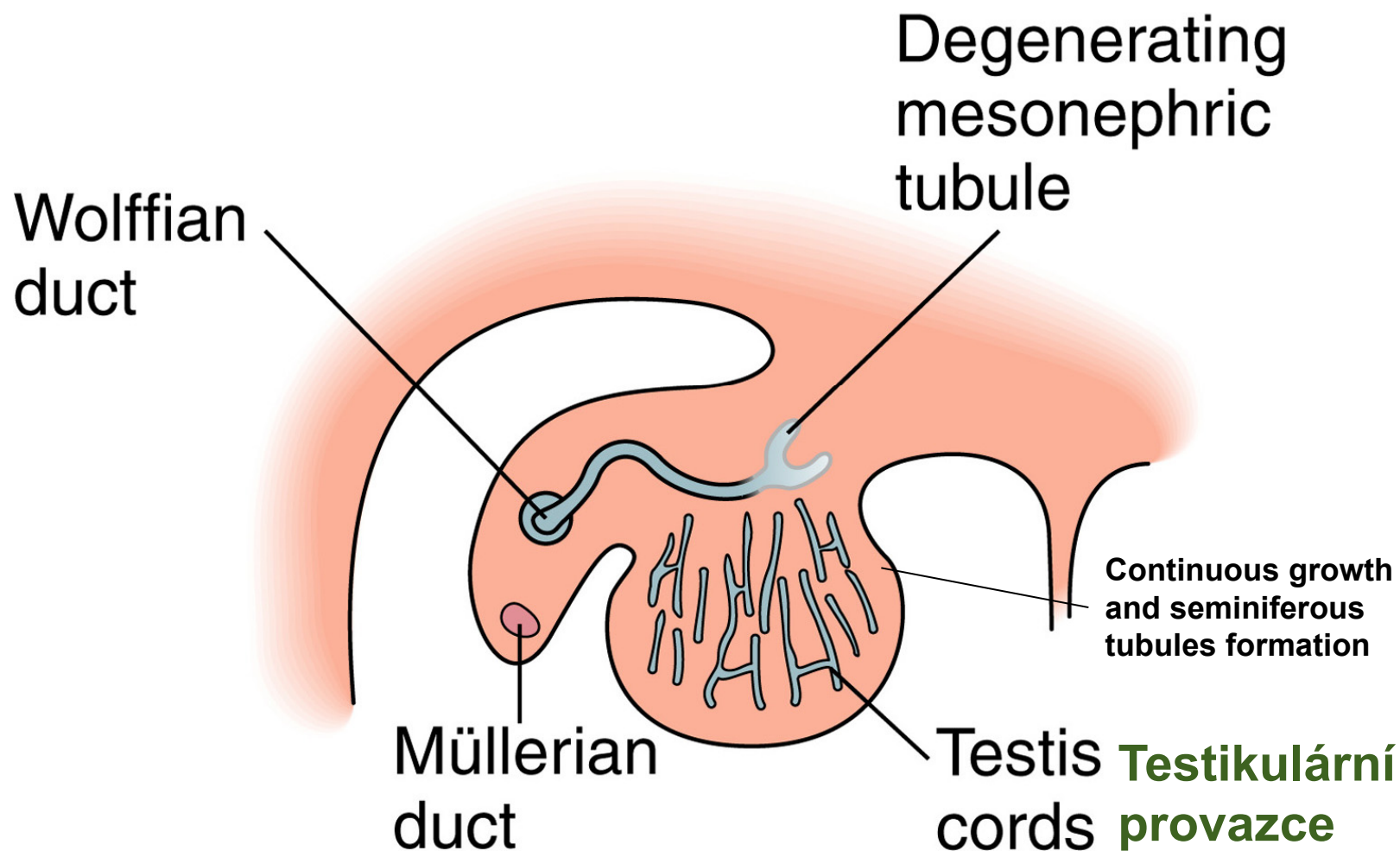
20-days-old human embryo

26-days-old human embryo

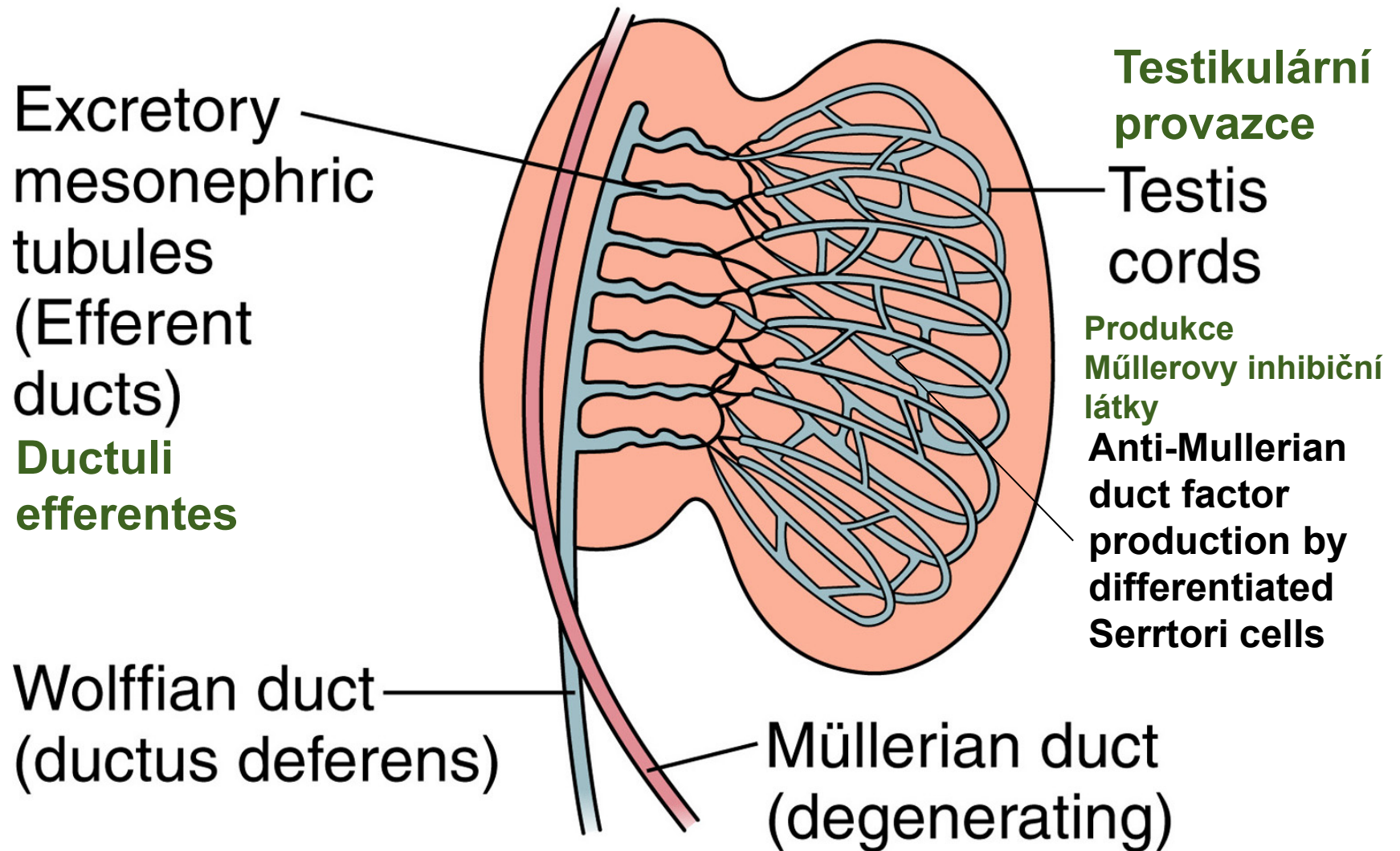


Vacek, Embryologie (2006)

## C. 8 Weeks

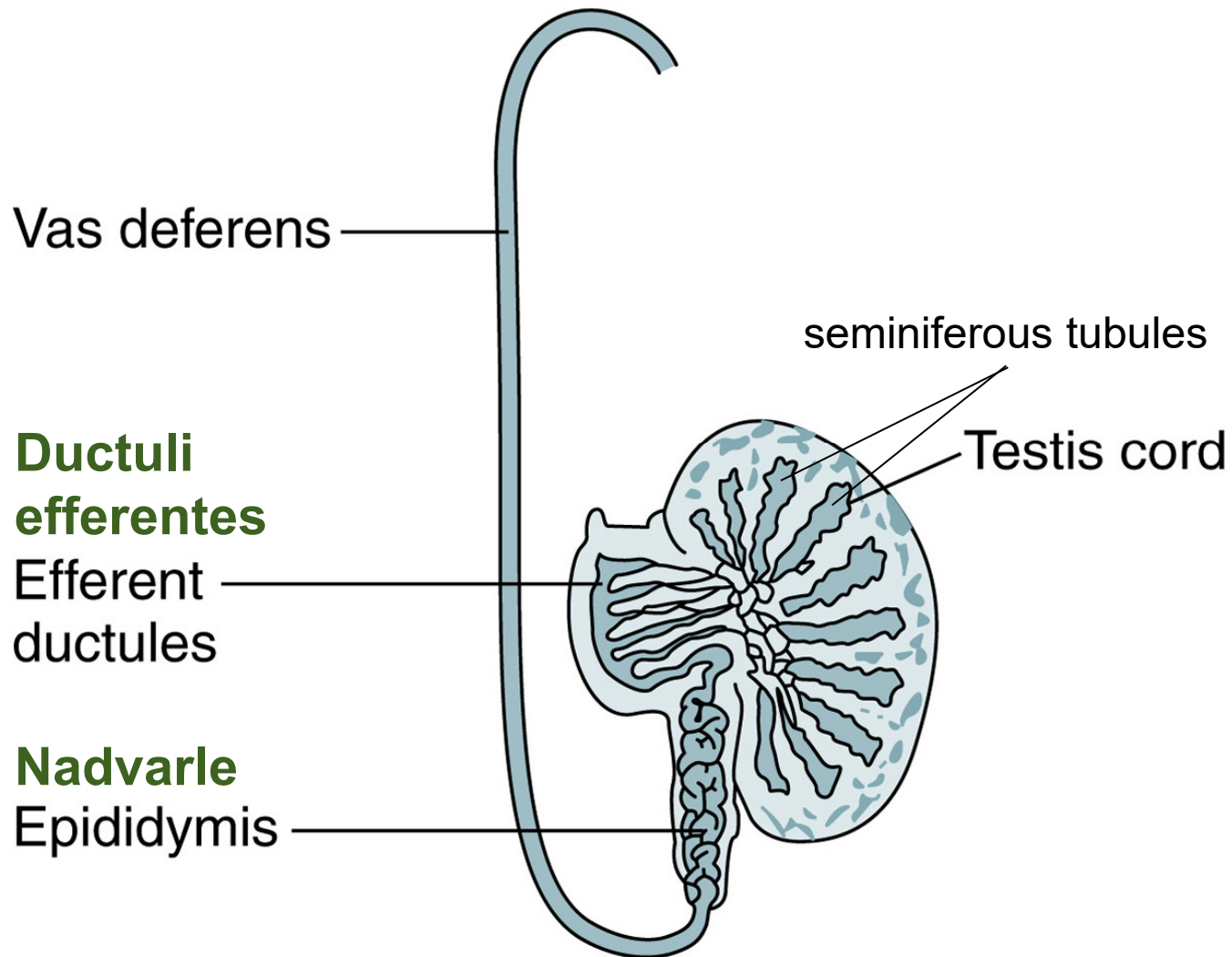


## D. 16 Weeks





## E. Adult



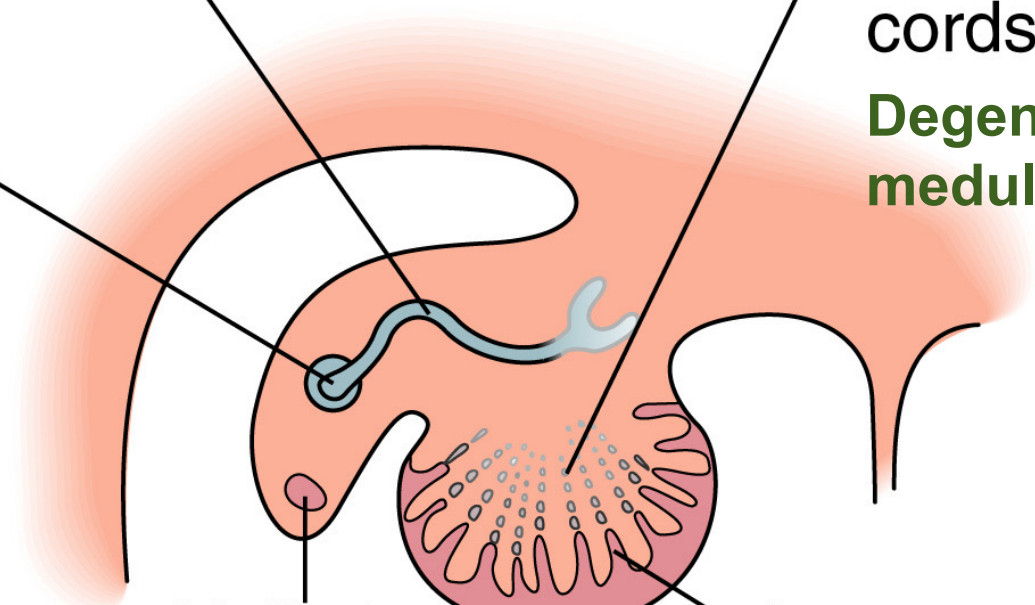
## F. 7 Weeks

Degenerating  
mesonephric  
tubule

Wolffian  
duct

Degenerating  
medullary  
cords

Degenerující  
medulární provazce



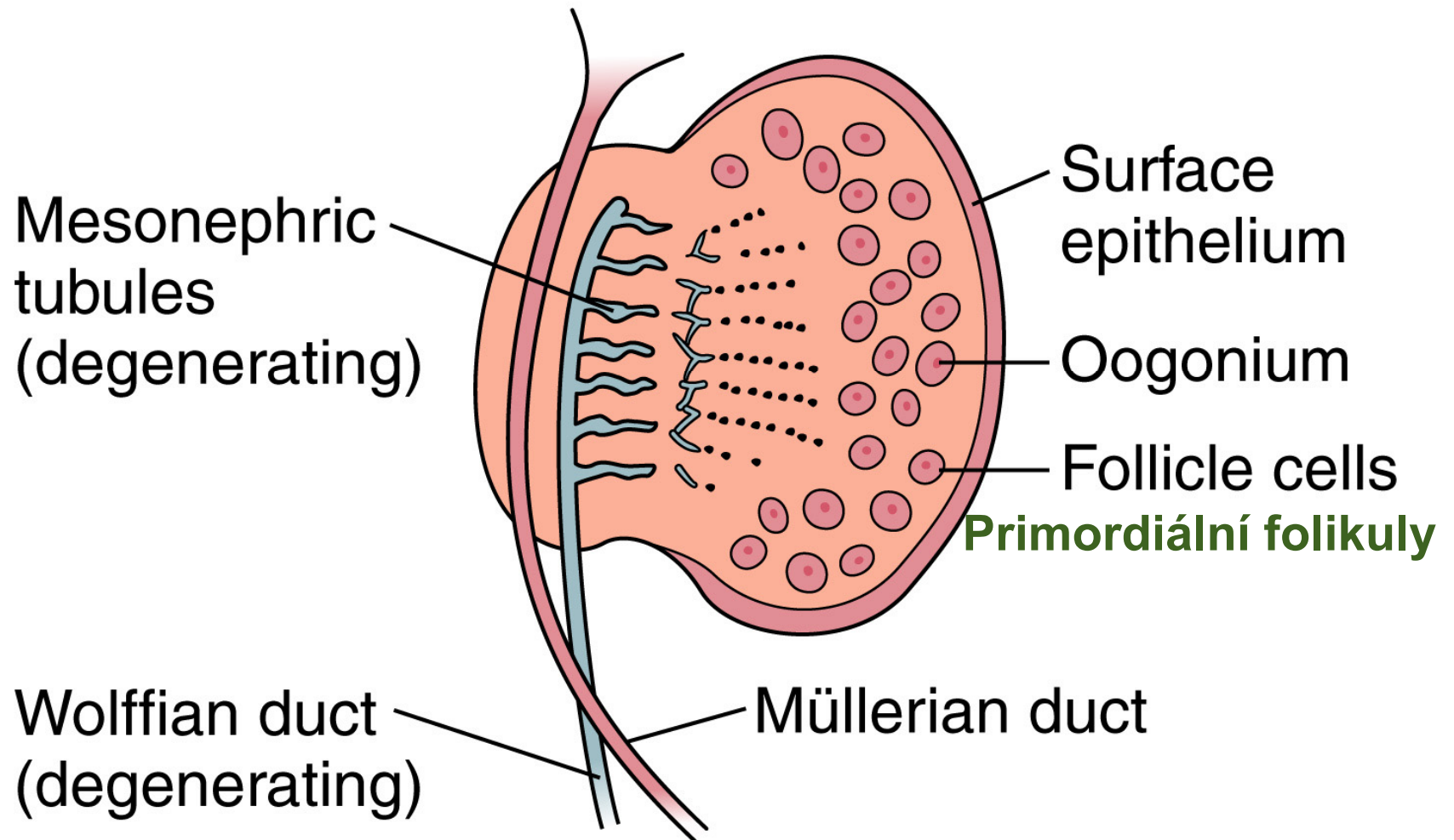
Müllerian  
duct

Epithelium

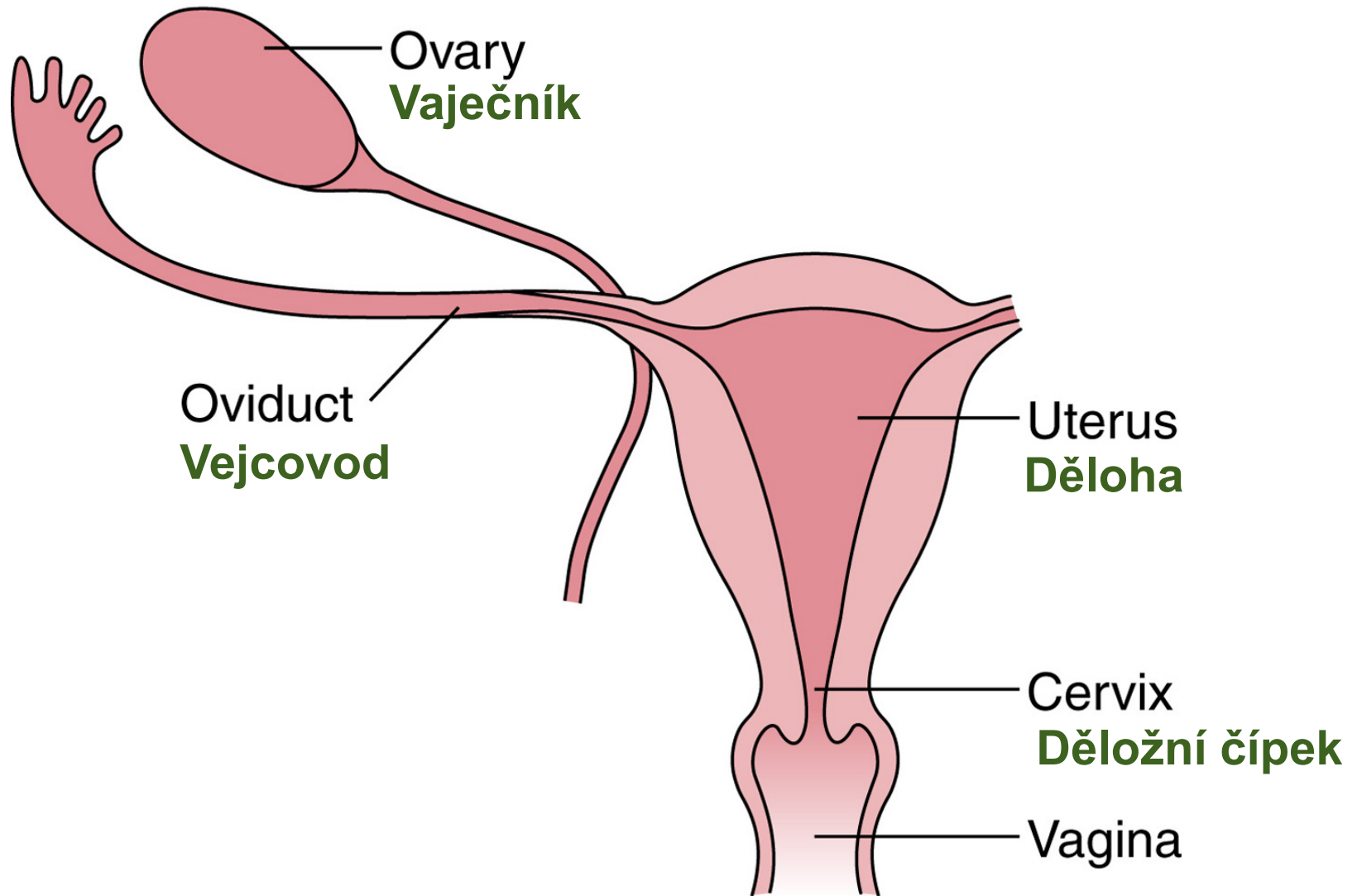
Cortical  
cords

Kortikální provazce

## G. 21 Weeks



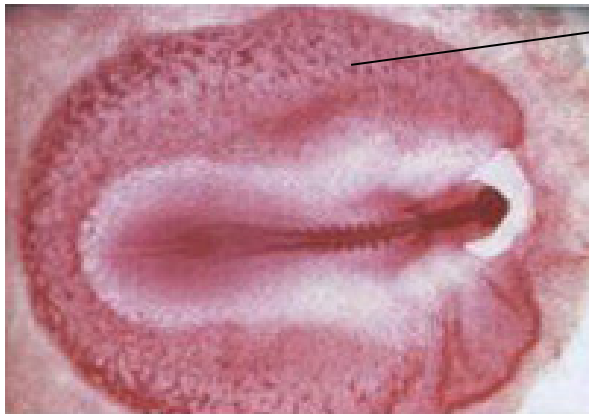
## H. Adult



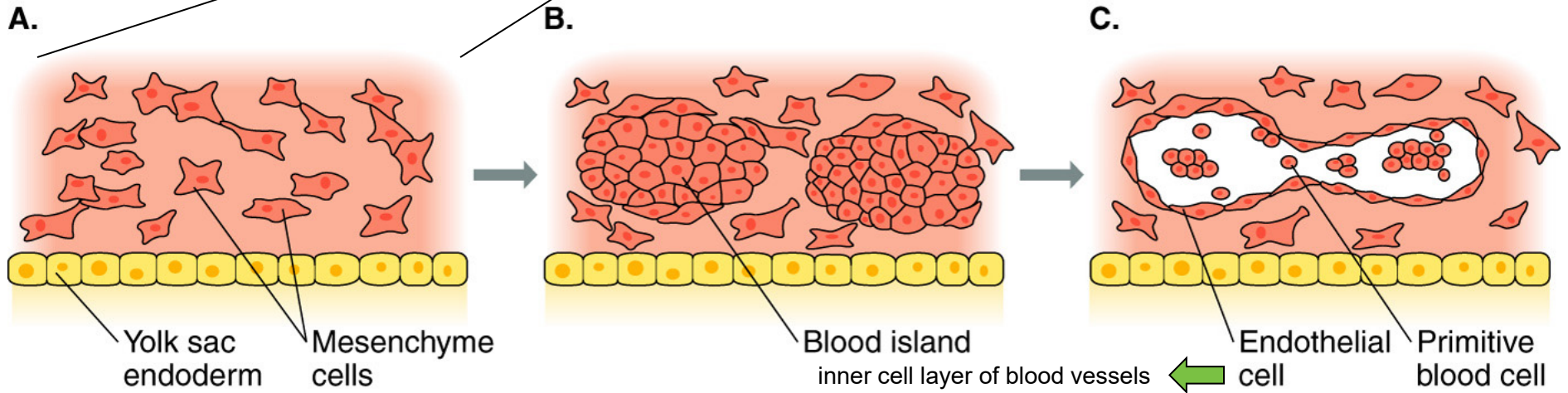
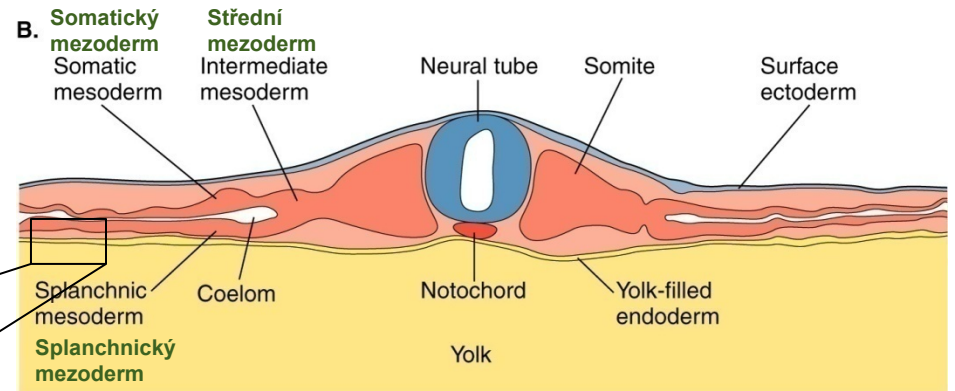
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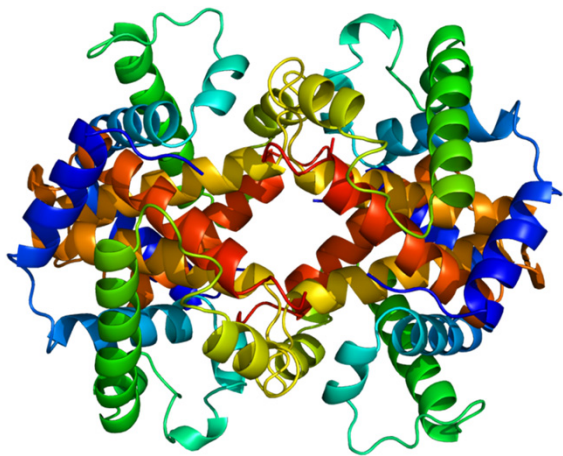
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  - formation of gonads
  - hematopoiesis and circular system development



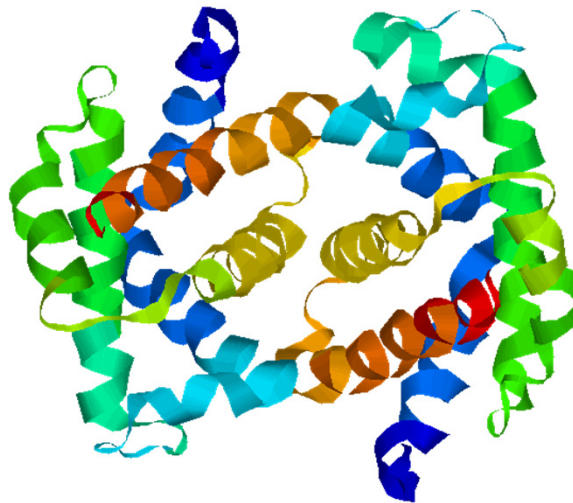
**Krevní ostrůvky**  
**Blood islands**



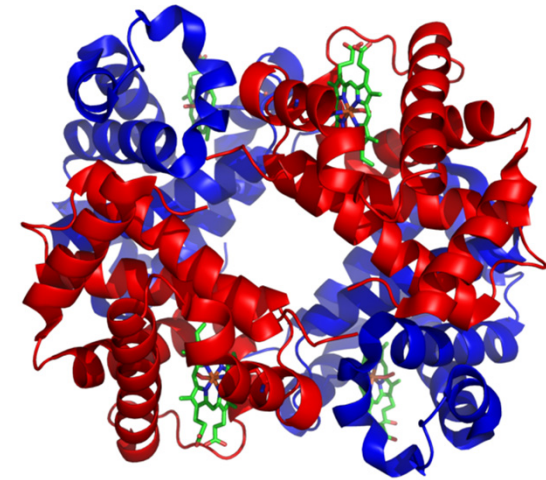




**Embryonic hemoglobin  $\epsilon\zeta\zeta\zeta$**   
yolk sac



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

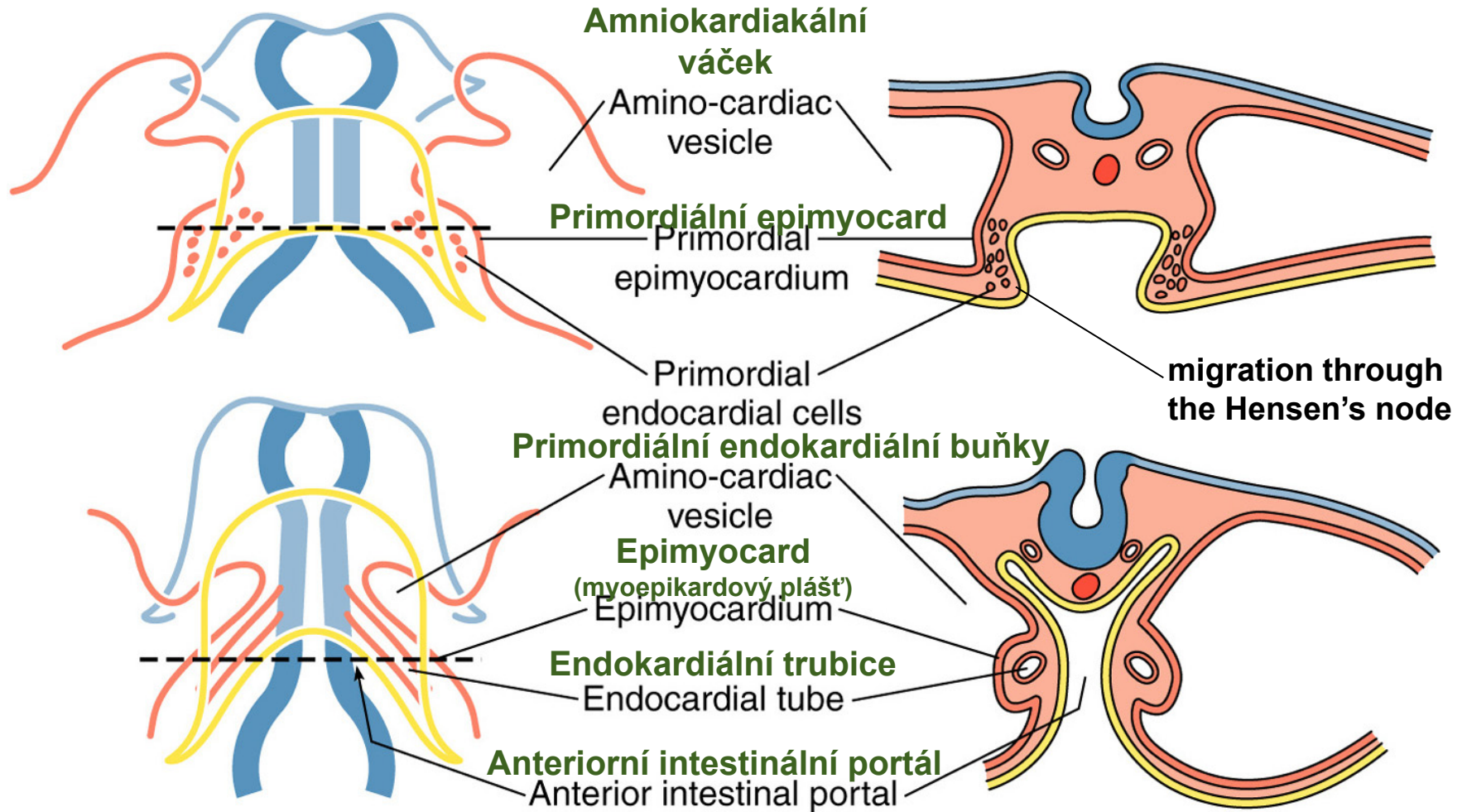


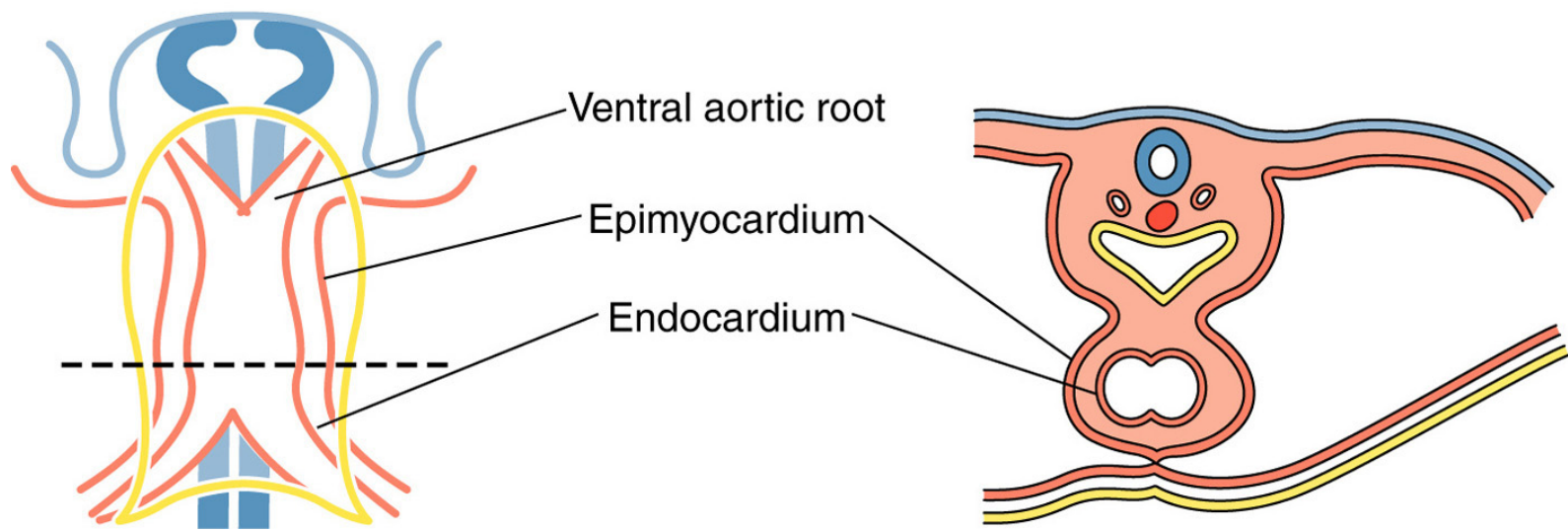
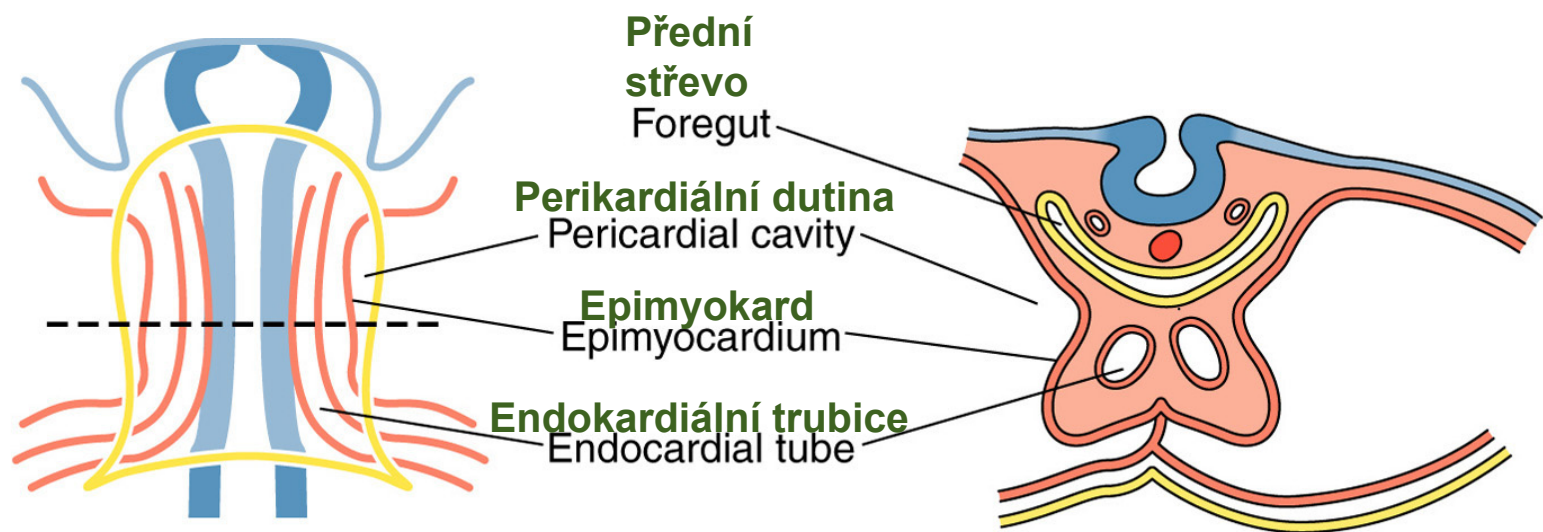
**Adult hemoglobin  $\alpha\beta\beta$**   
bone marrow

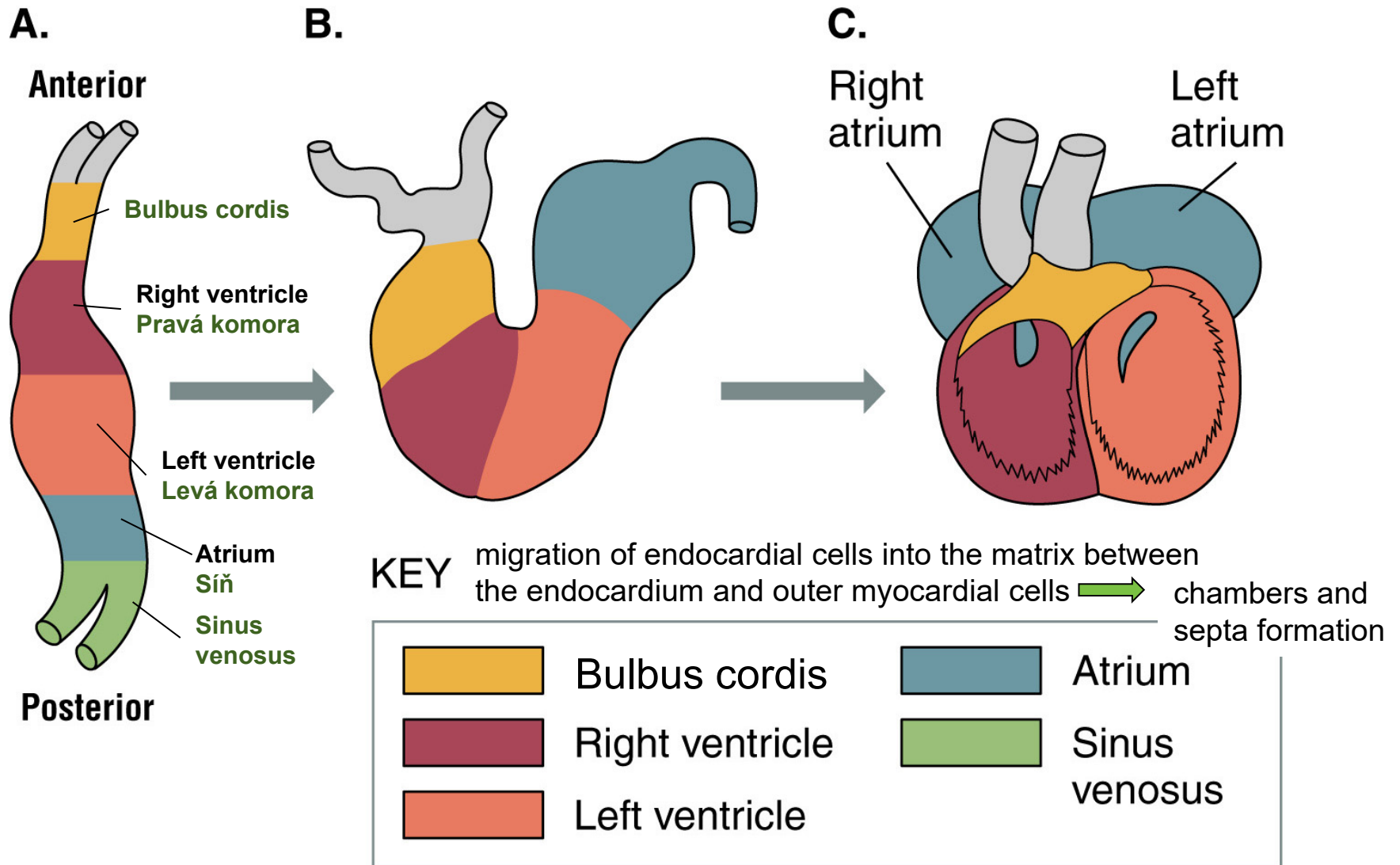


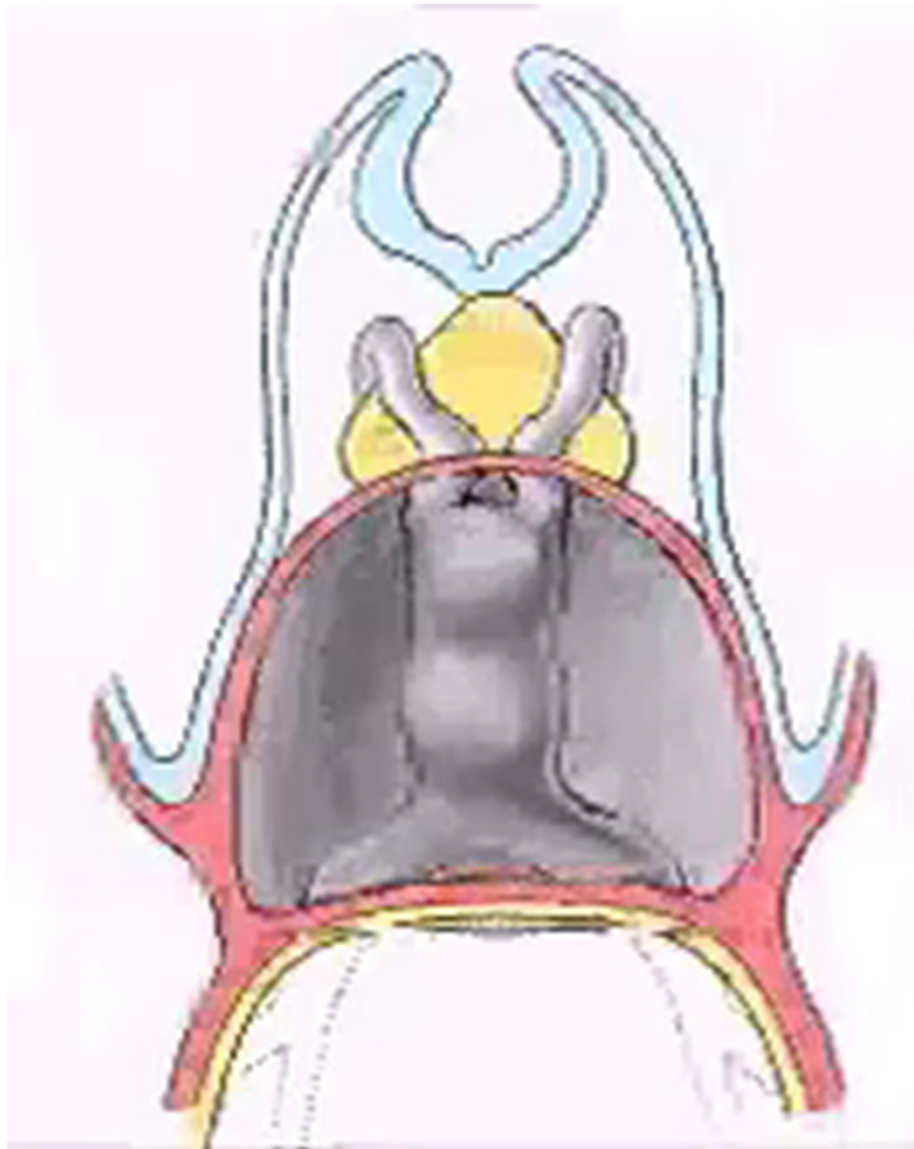
**A. Ventral views**

**B. Transverse views**



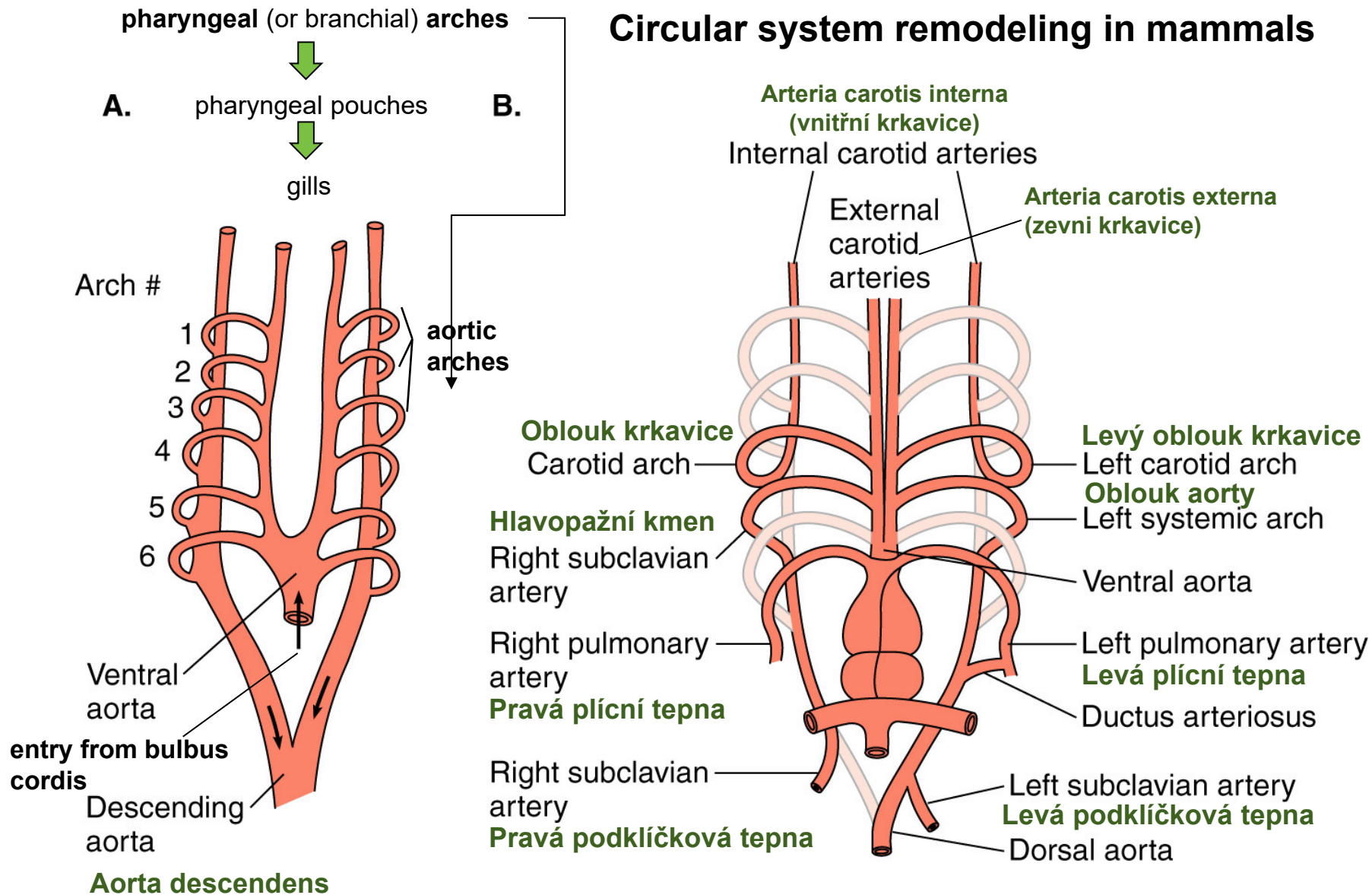






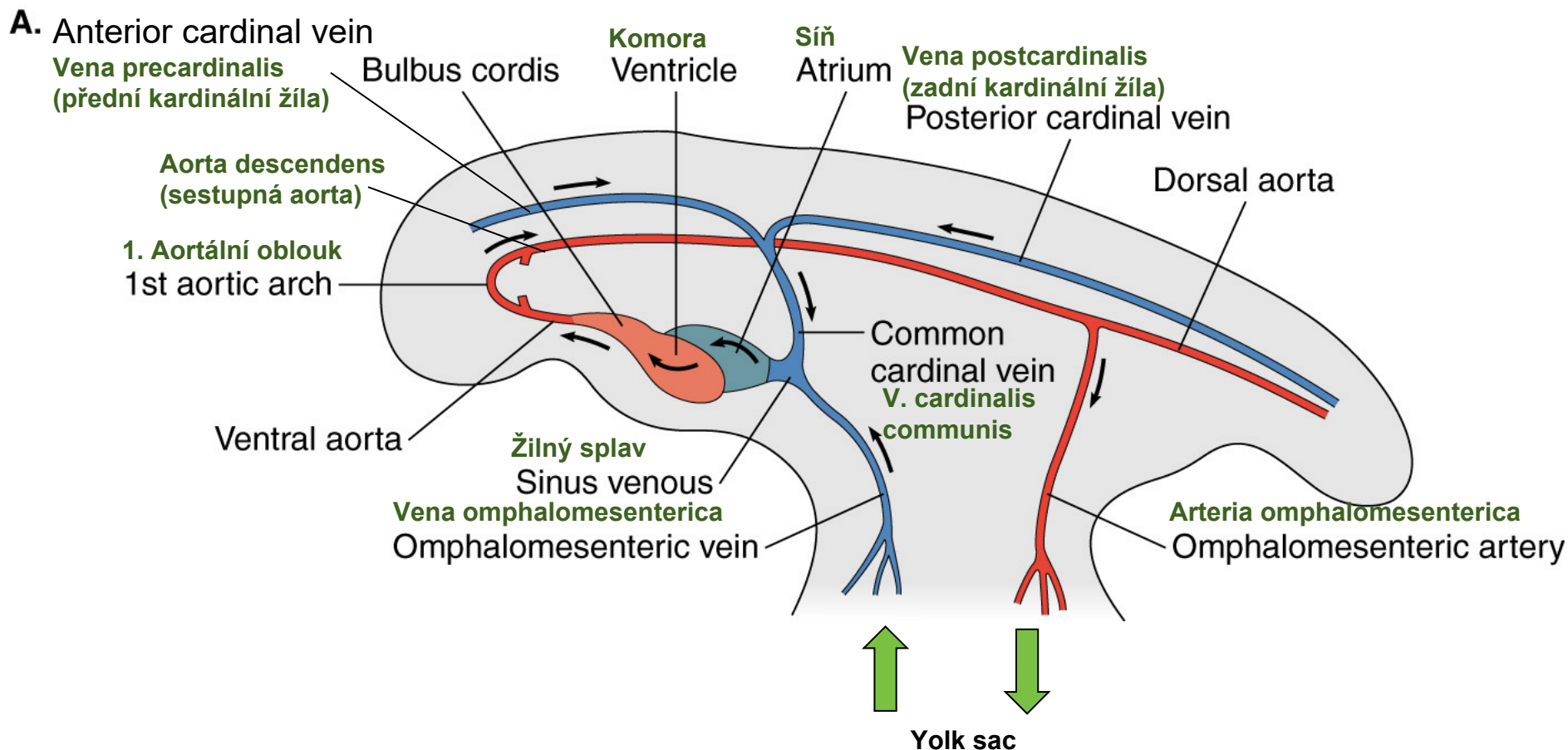


## Circular system remodeling in mammals



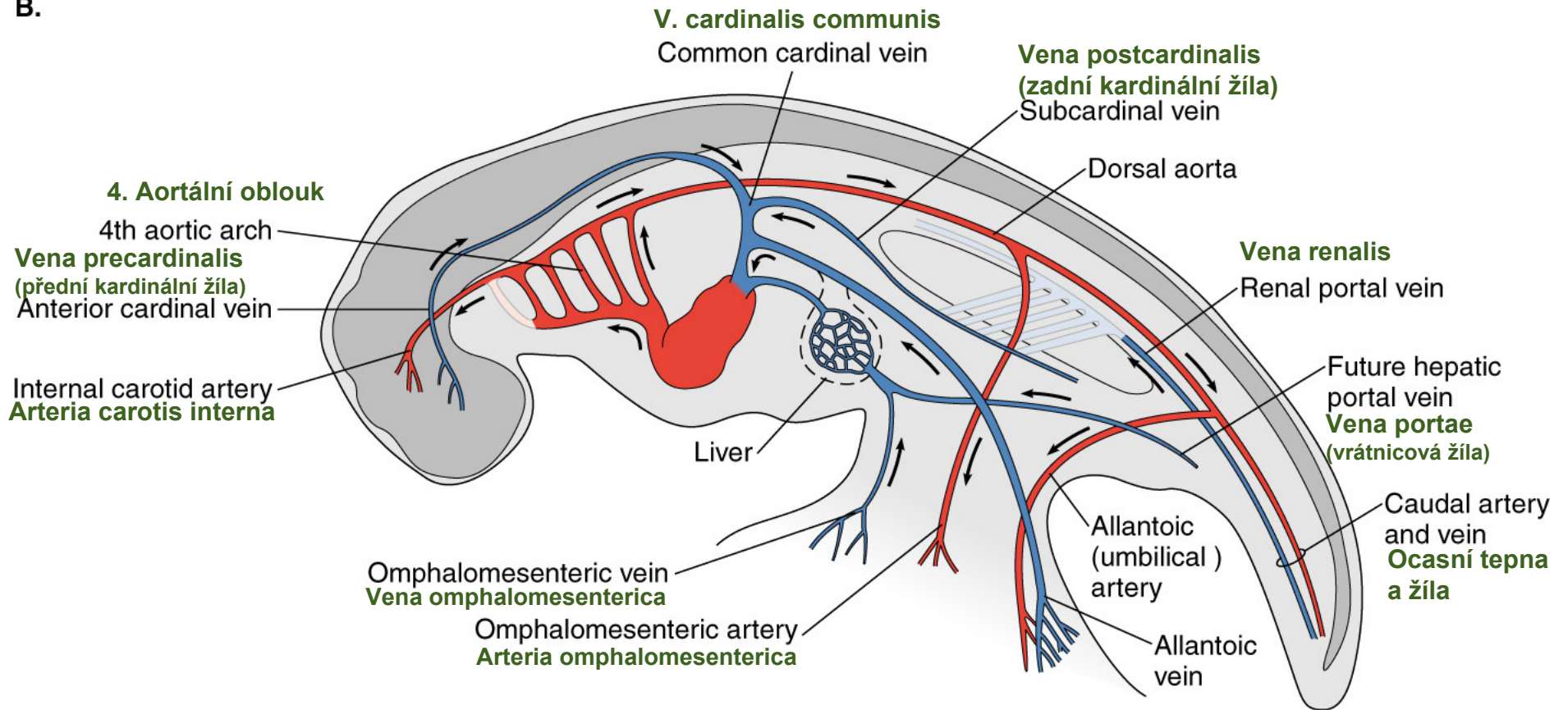


# Blood streaming in the initial circular system in amniote embryo



# Blood streaming in the remodeled circular system in amniote embryo

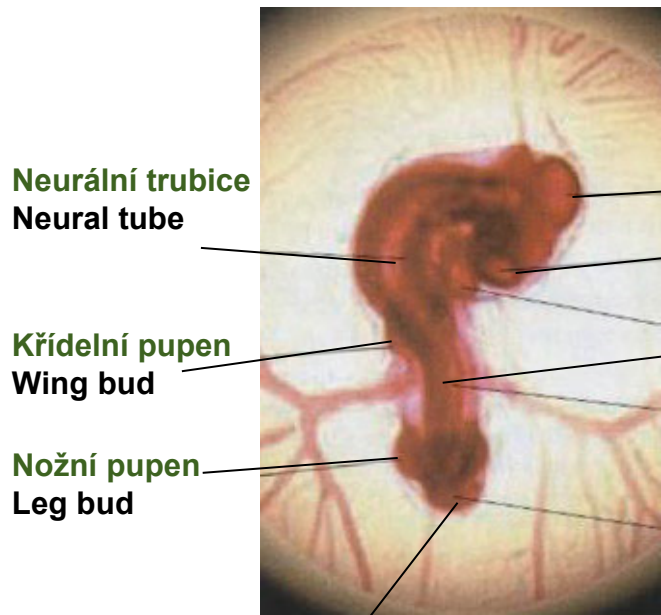
B.



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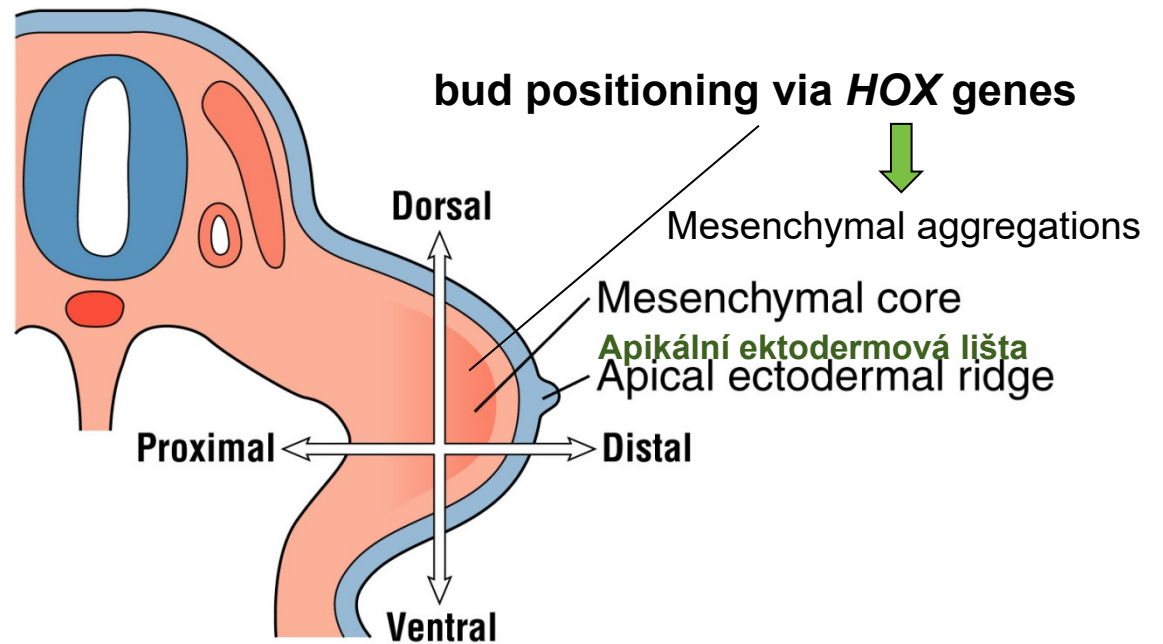
Střední mozek  
Midbrain

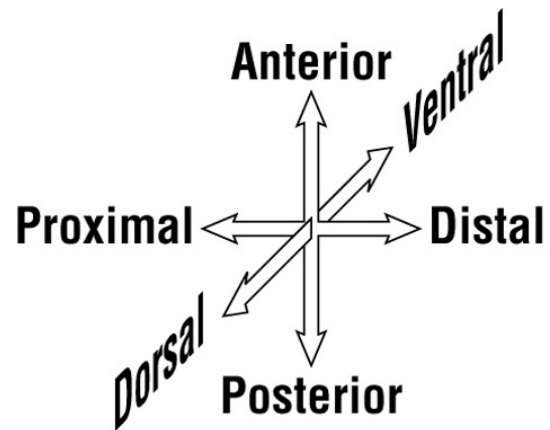
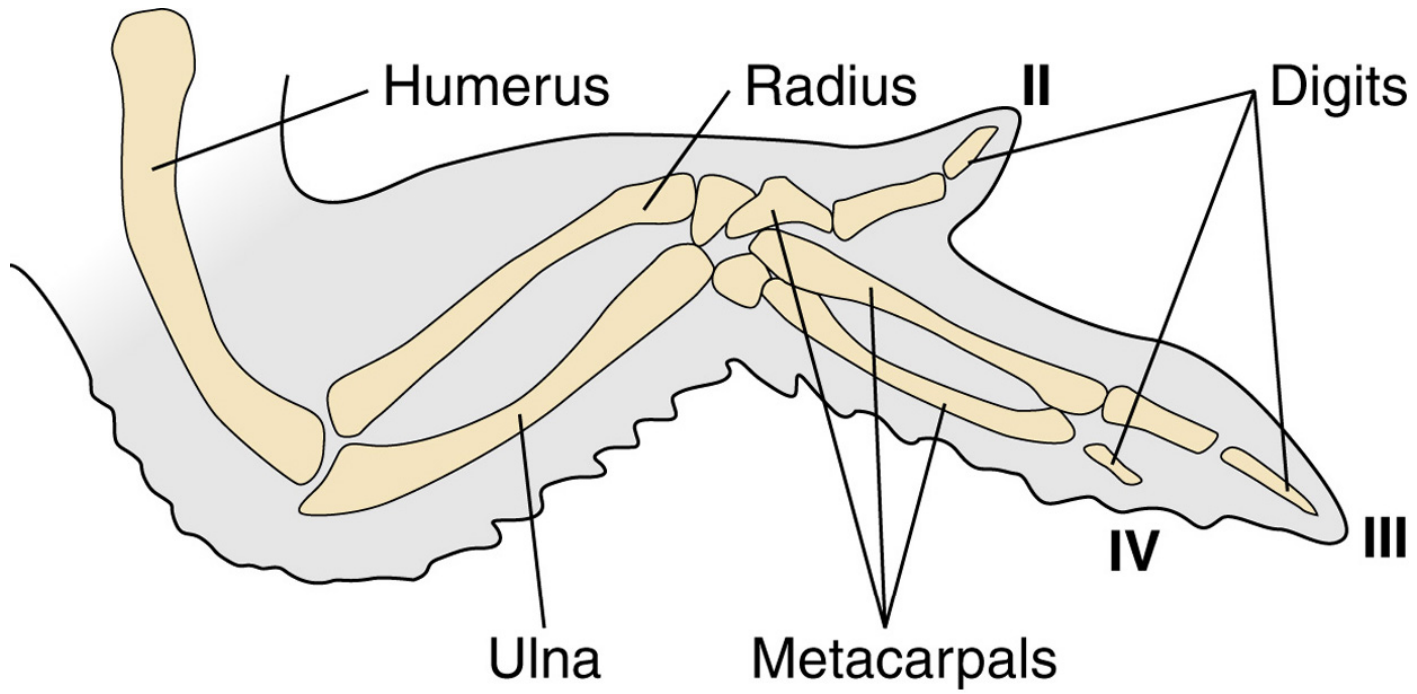
Oko  
Eye

Somity  
Somites

Ocas  
Tail

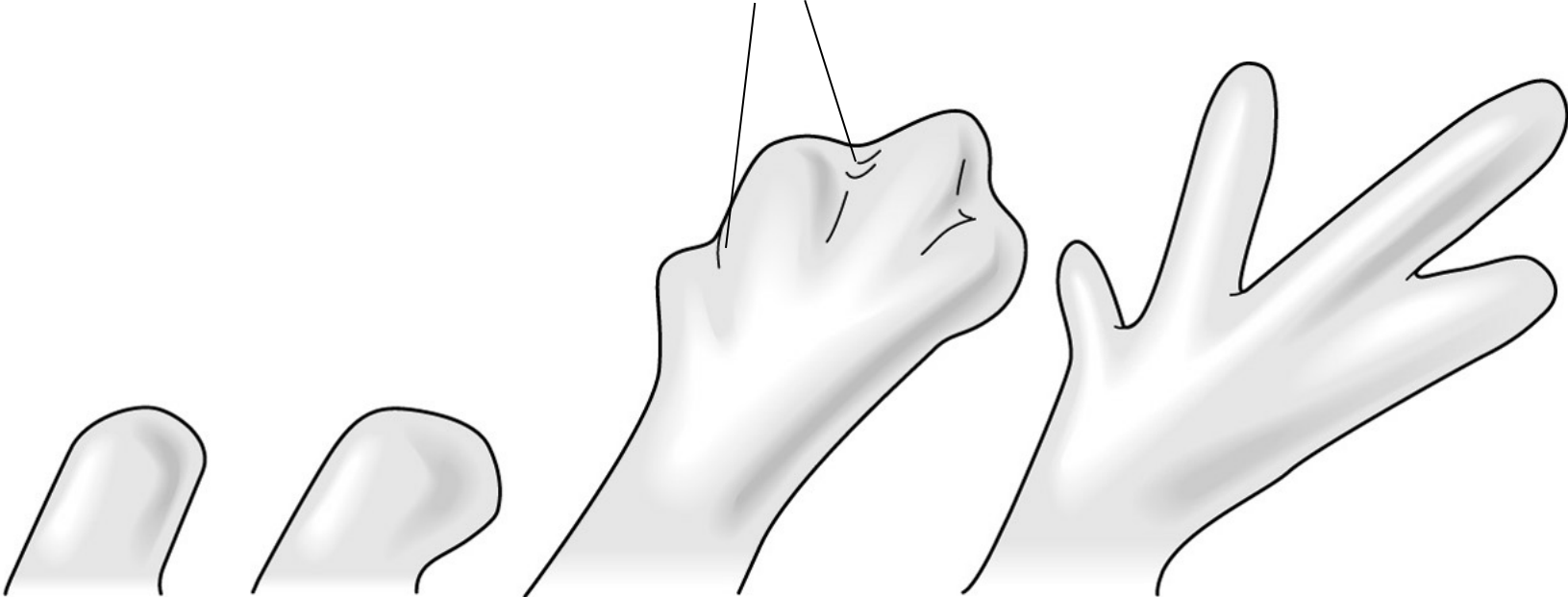
### B. Cross section of a chick wing bud







Apoptosis



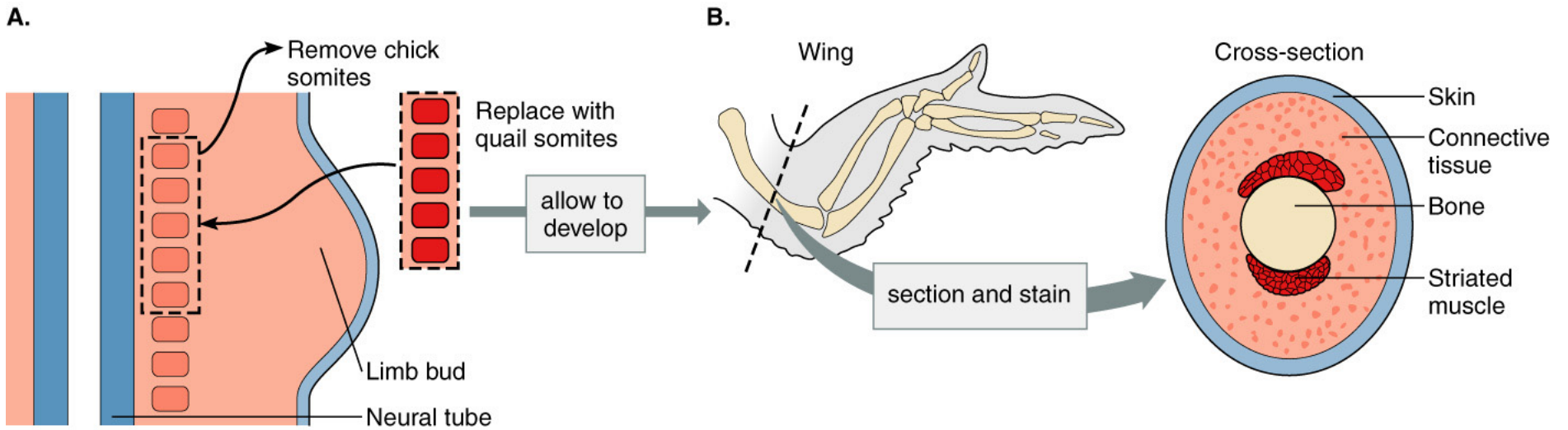
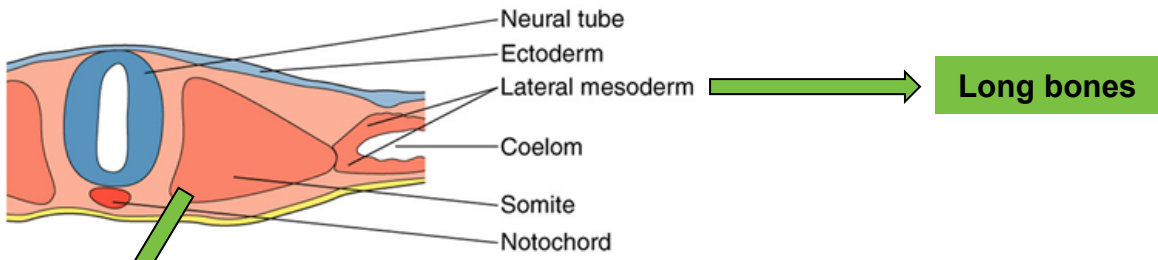
Stage:

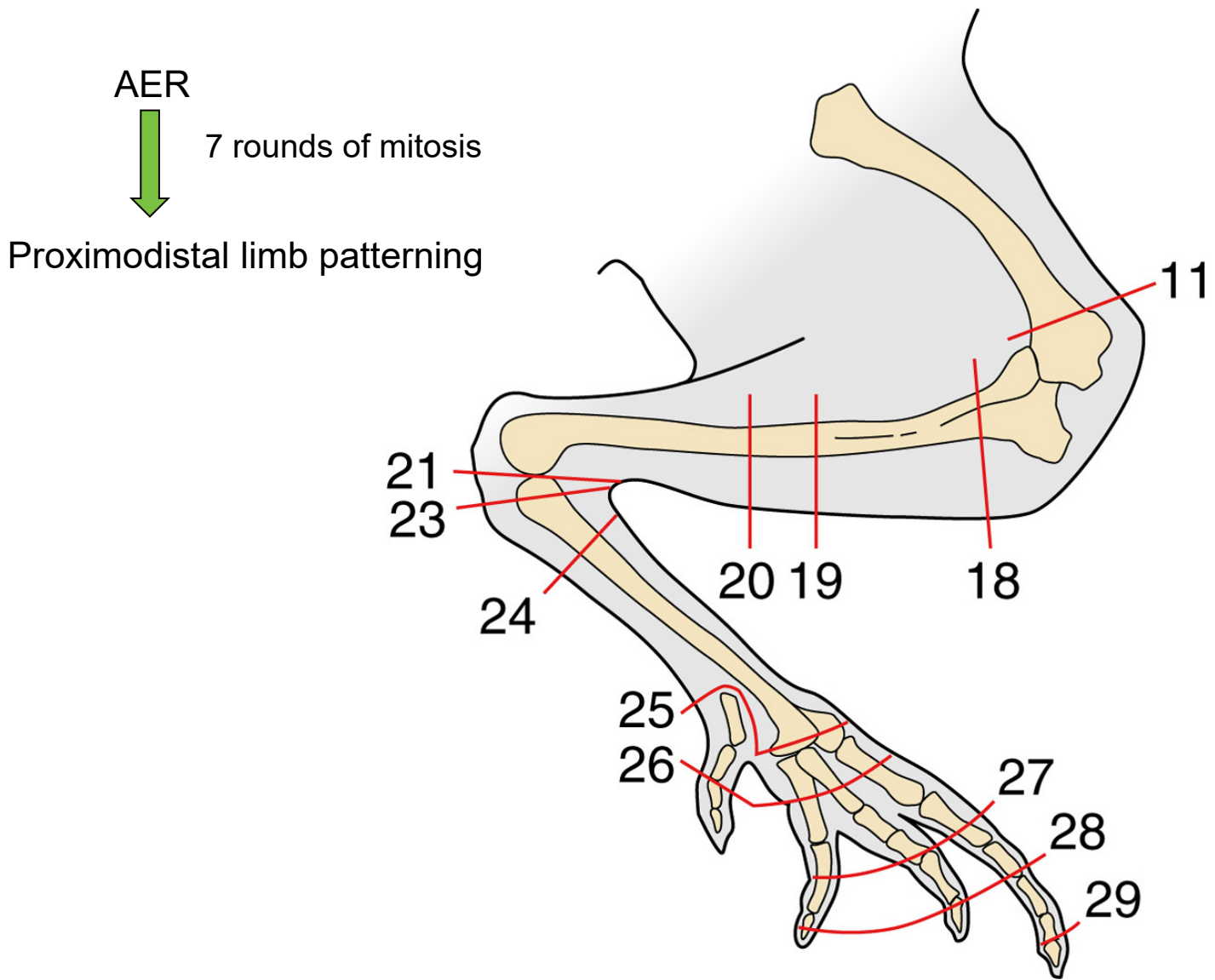
32

33

34

35





# Chicken embryo as a developmental model

Hamburger & Hamilton Stage 4 (15 hours)



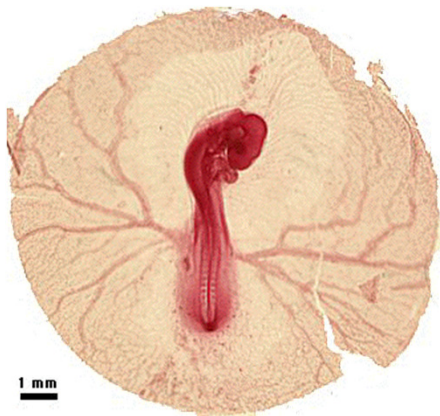
HH Stage 9 (31 hours 8 somite)



HH Stage 10 (33 hours)



HH Stage 16-17 (56 hours)



HH Stage 38 (12 days)



# In Vivo Imaging of Chick Development

Visualizing cell movements  
in living chick embryos

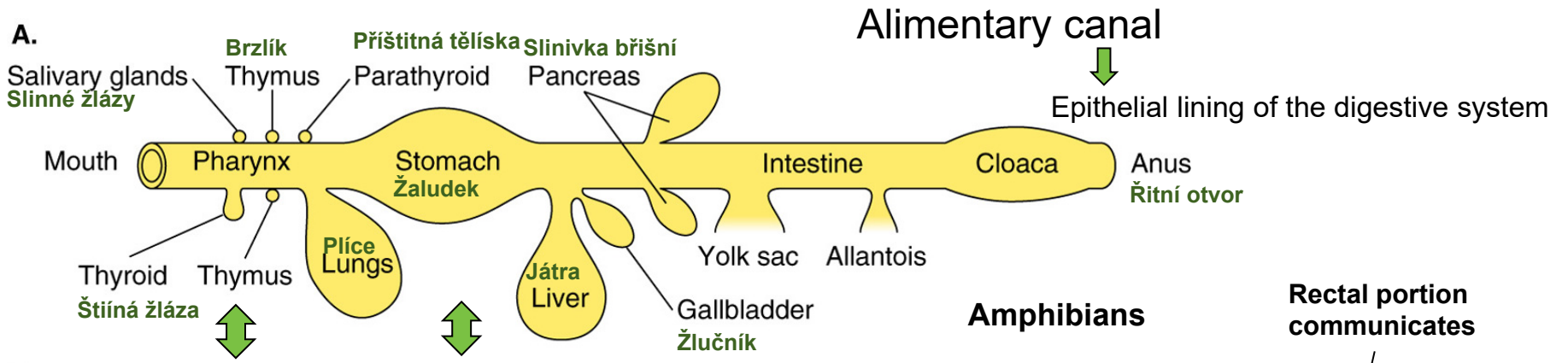
Paul Kulesa  
Scott Fraser Laboratory  
California Institute of Technology



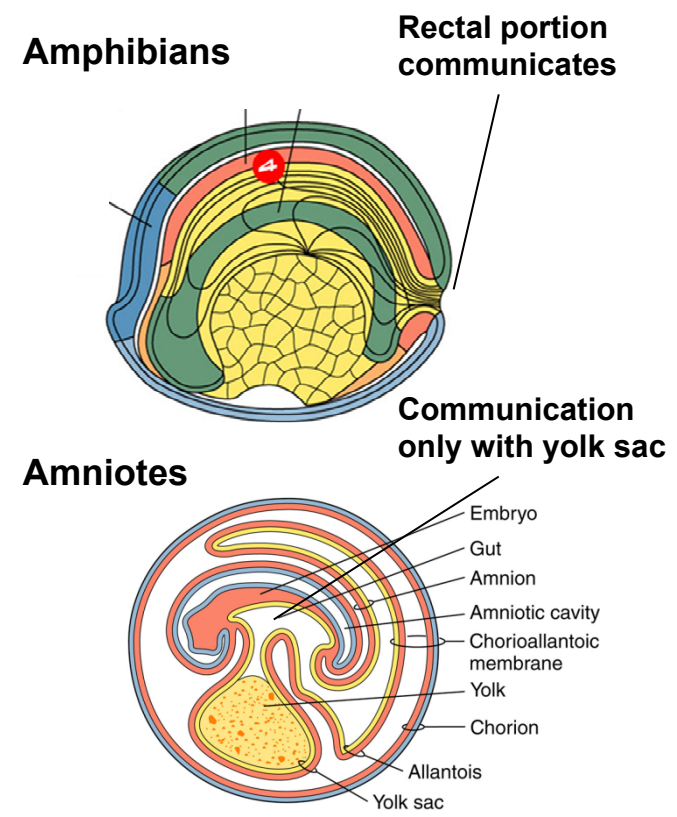
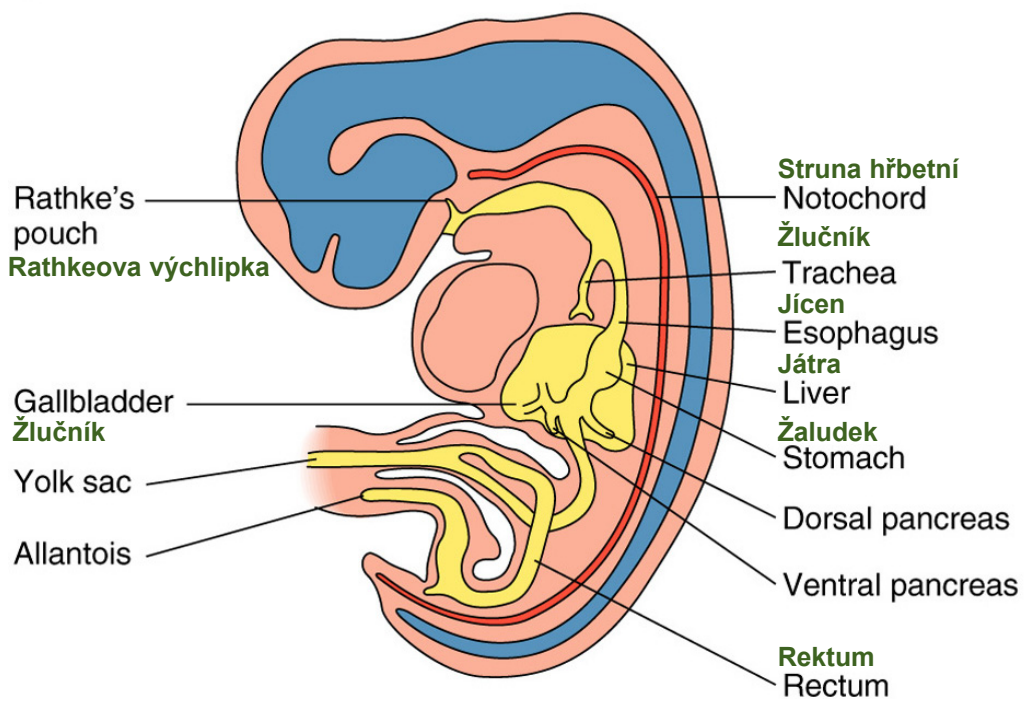
# Outline of Lesson 5

## Organogenesis in Vertebrates: Endo- and Mesodermal Derivatives

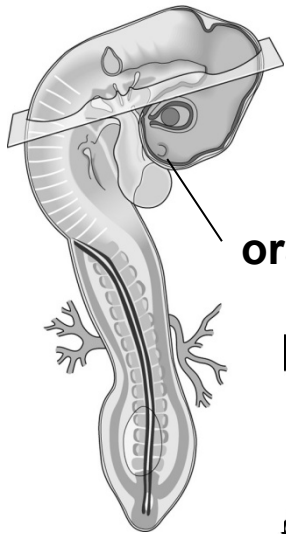
- Mesoderm derivatives development
  - somites formation and signalling
  - formation of muscles
  - endochordal ossification and signalling
  - nephrogenesis
  - formation of gonads
  - hematopoiesis and circular system development
  - limbs formation
  
- Endoderm derivatives development
  - alimentary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



**B.** Head mesoderm Splanchnic mesoderm



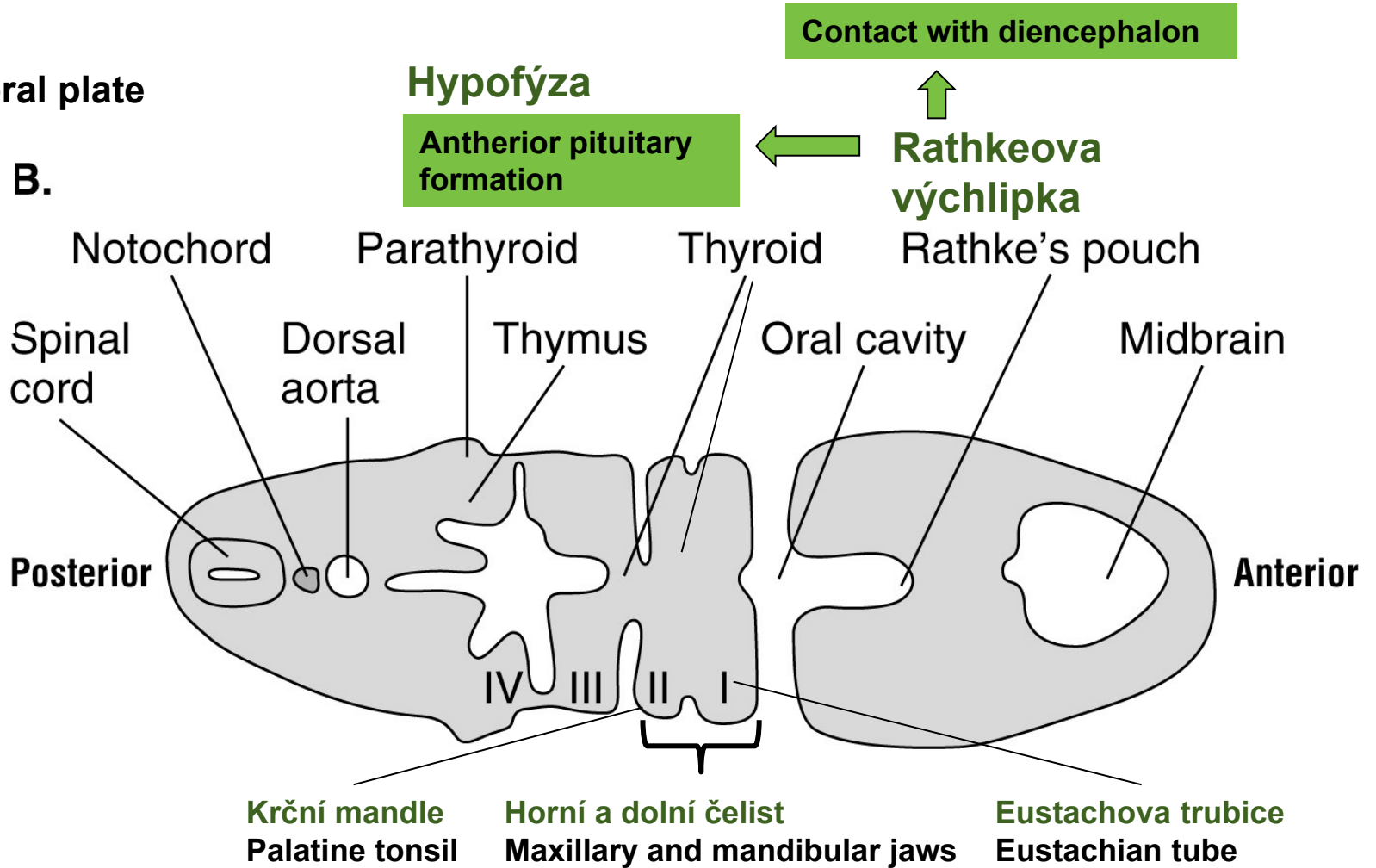
A.

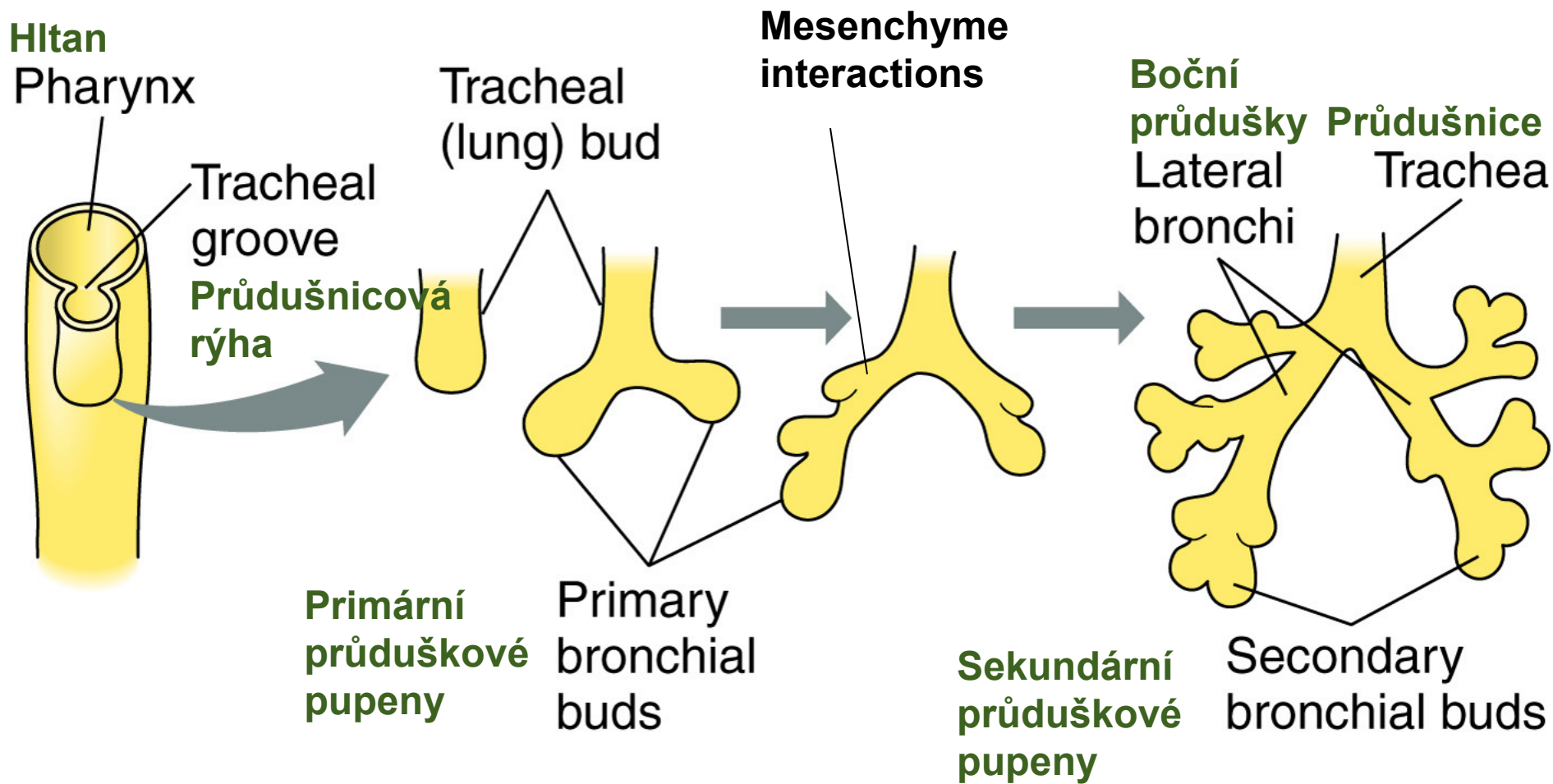


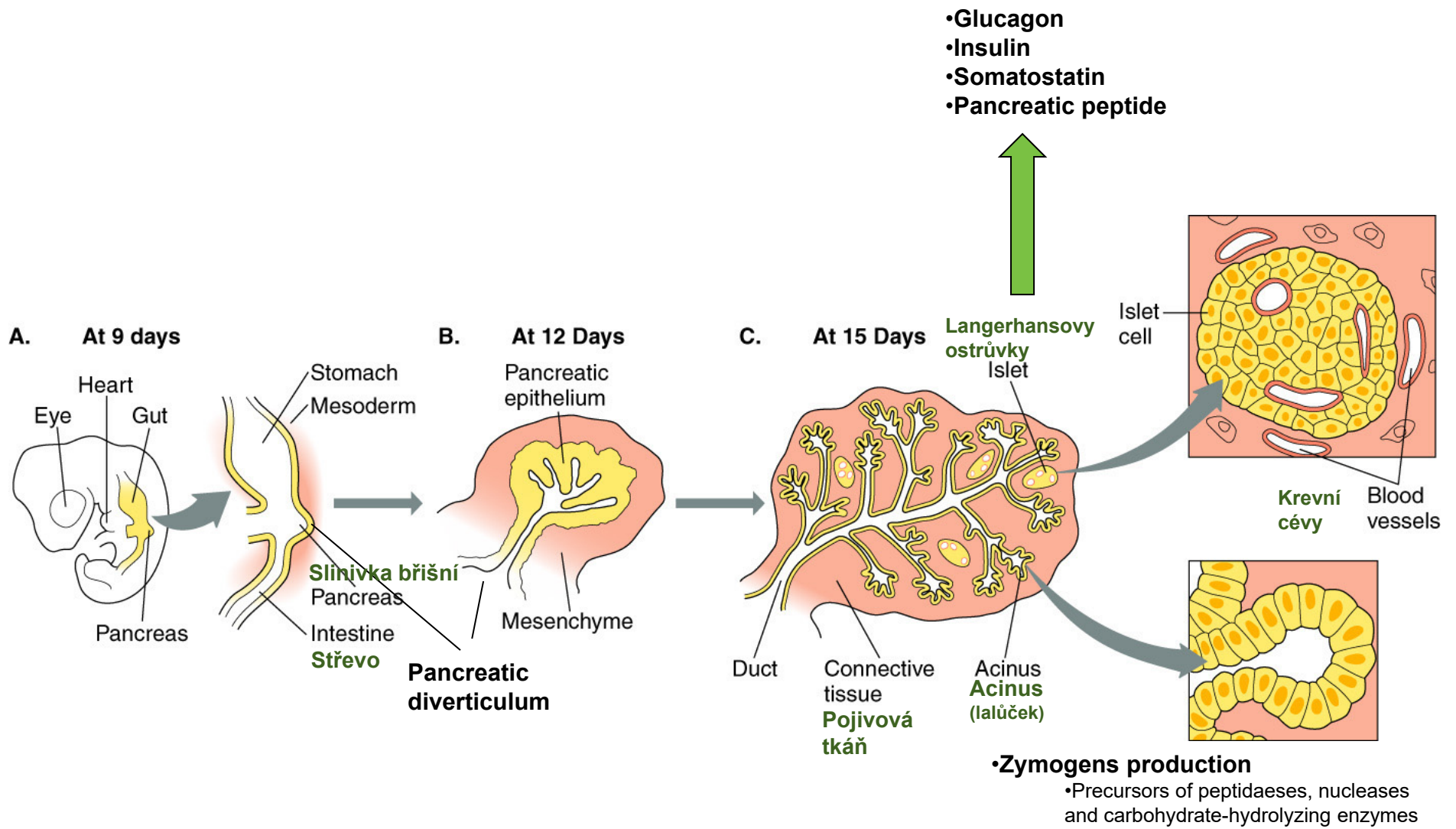
# Pharyngeal arch-specific endoderm derivatives development

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.

# Discussion