

# Bi8940 Developmental Biology

## Lesson 2

Early Development of *Drosophila*

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Department of Functional Genomics and Proteomics,  
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CEITEC

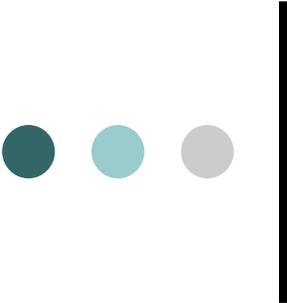
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Brno, Czech Republic

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INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

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



# Outline of Lesson 2

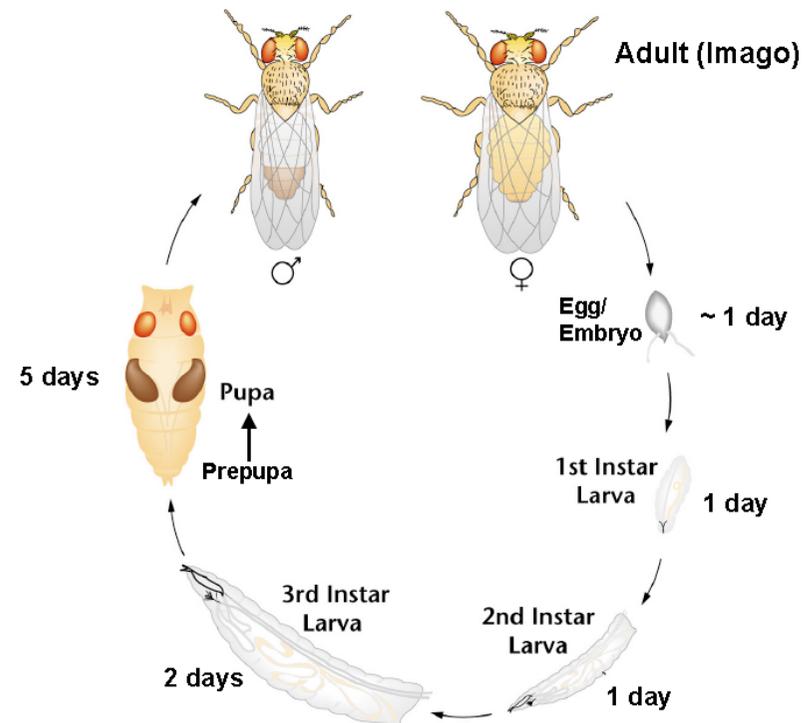
## Early Development of *Drosophila*

- Introduction into *Drosophila*
  - Life cycle (video)
  - Anatomy (video)
  - Mating (video)
- Oogenesis
  - molecular mechanisms of the early axis formation
- Early embryogenesis
- Gastrulation
  - Video of gastrulation in *Drosophila*
- Overview of metamorphosis
- Introduction into genetic and molecular mechanisms of the early embryogenesis in *Drosophila*

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## Early Development of *Drosophila*

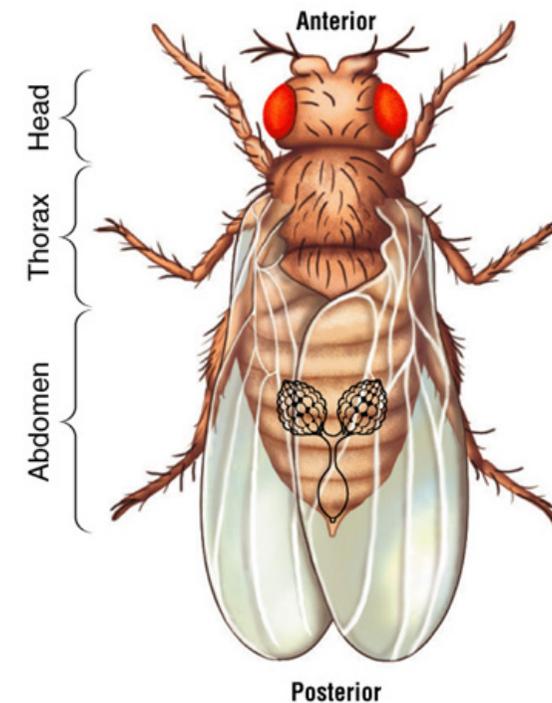
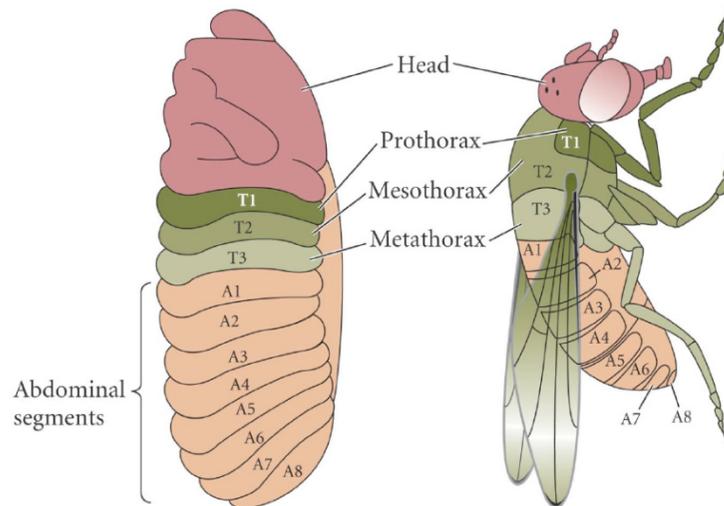
- Introduction into *Drosophila*
  - Life cycle (video)



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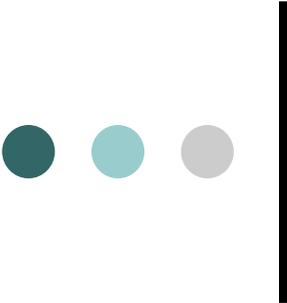


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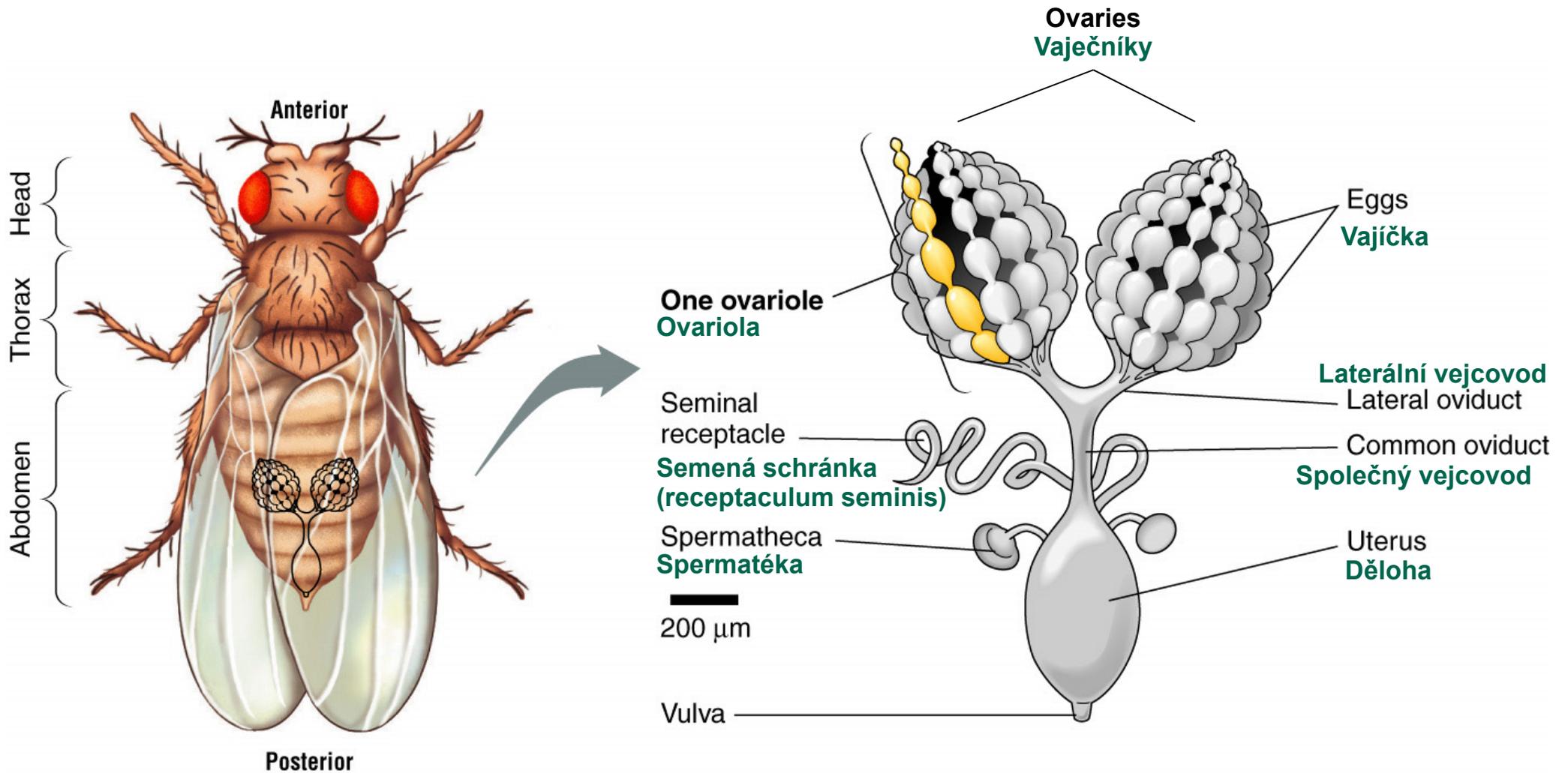




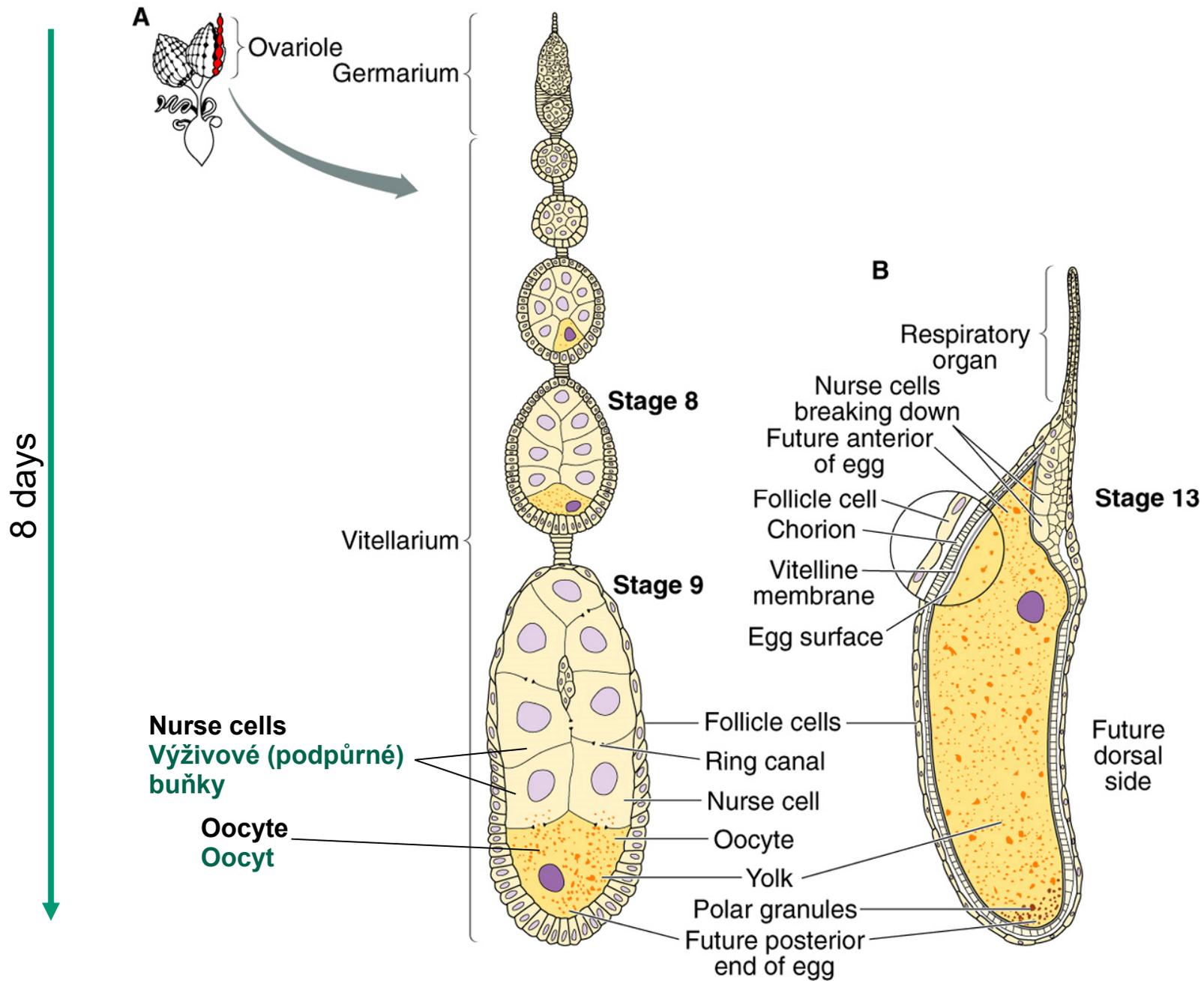
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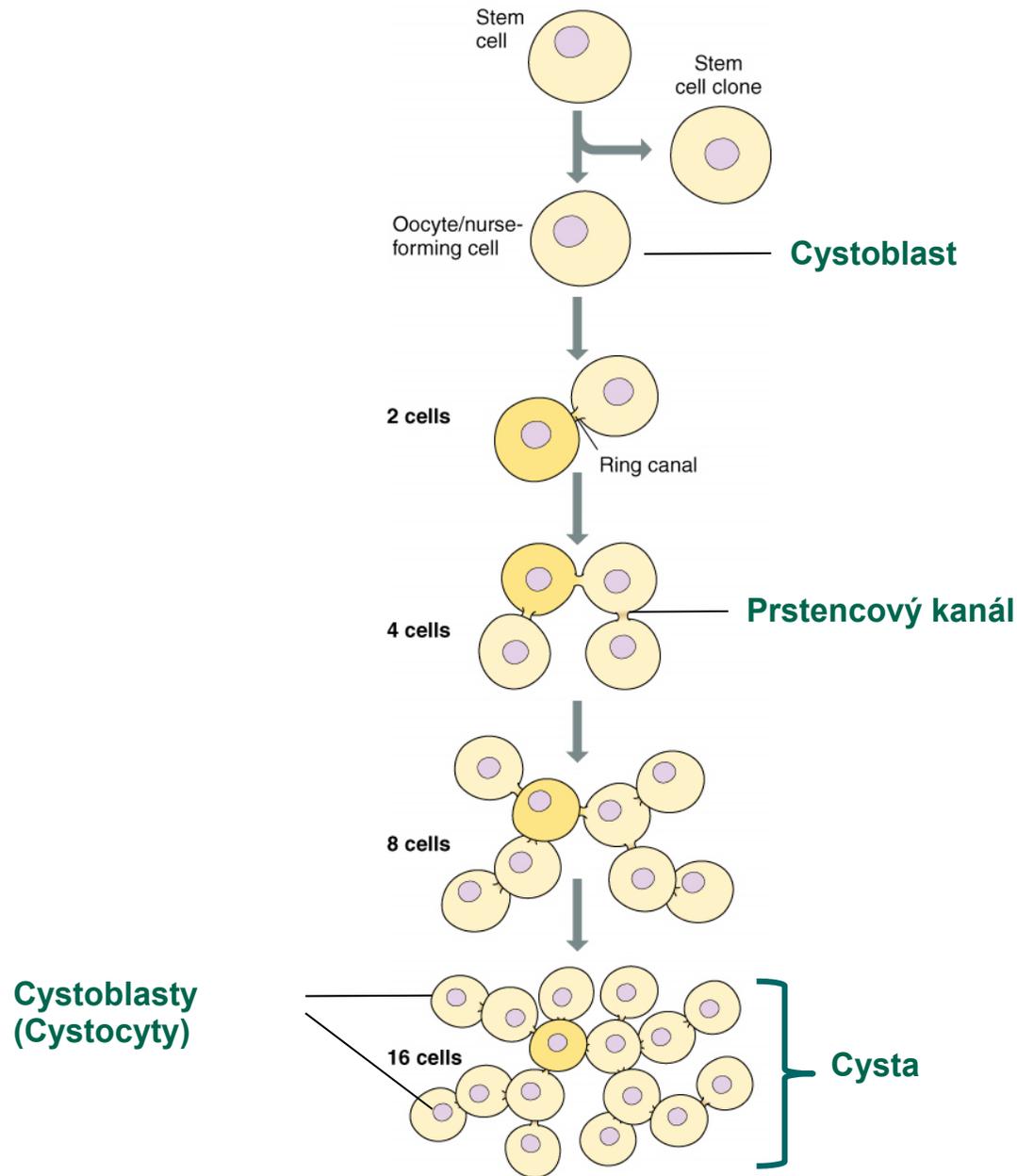
- 
- Introduction into *Drosophila*
    - Life cycle (video)
    - Anatomy (video)
    - Mating (video)
  - Oogenesis



- Video of sperm size and behavior



### Oogonium/stem cell division



A.

KEY

**Follicle cells:**

 Main body

 Polar

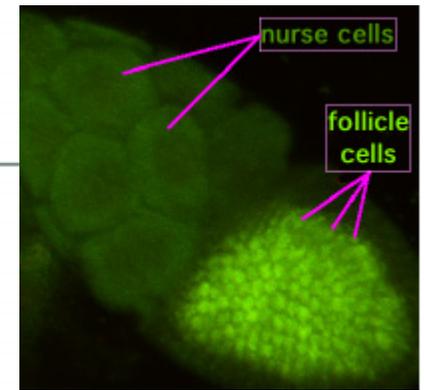
 Terminal

**Germline cells:**

 Nurse

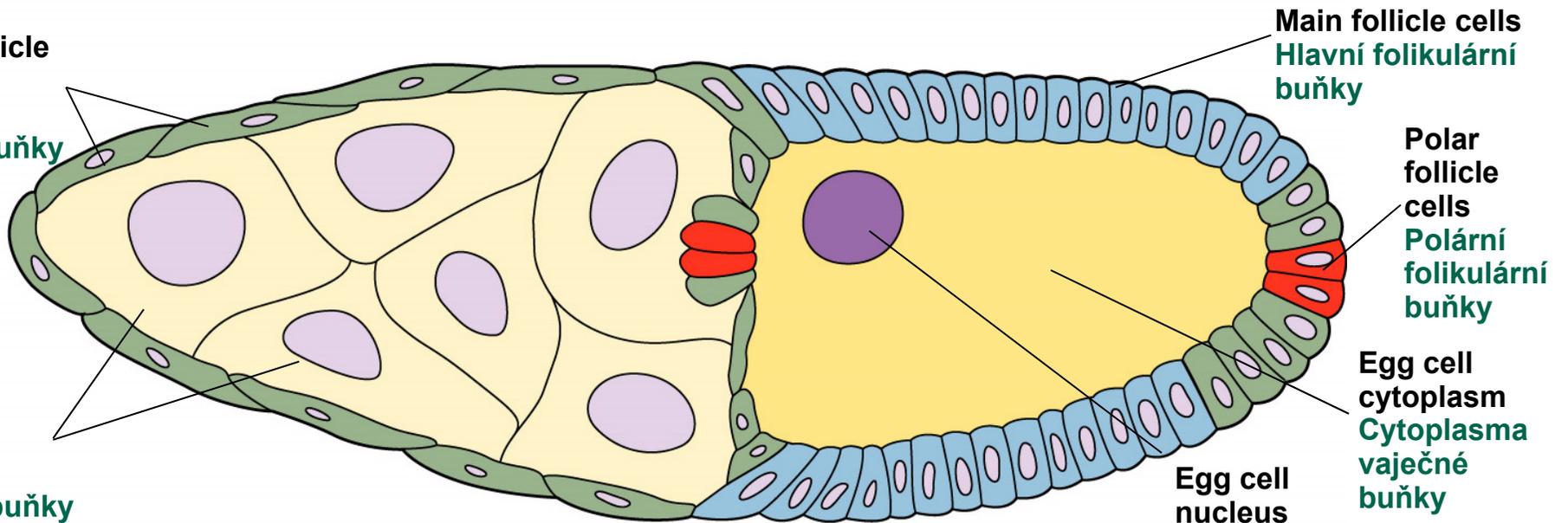
 Oocyte cytoplasm

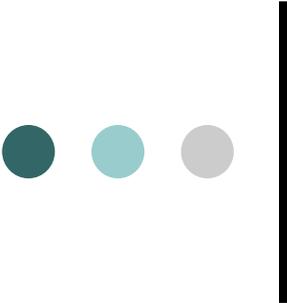
 Oocyte nucleus



Terminal follicle cells  
Terminální folikulární buňky

Nurse cells  
Výživové (pomocné) buňky

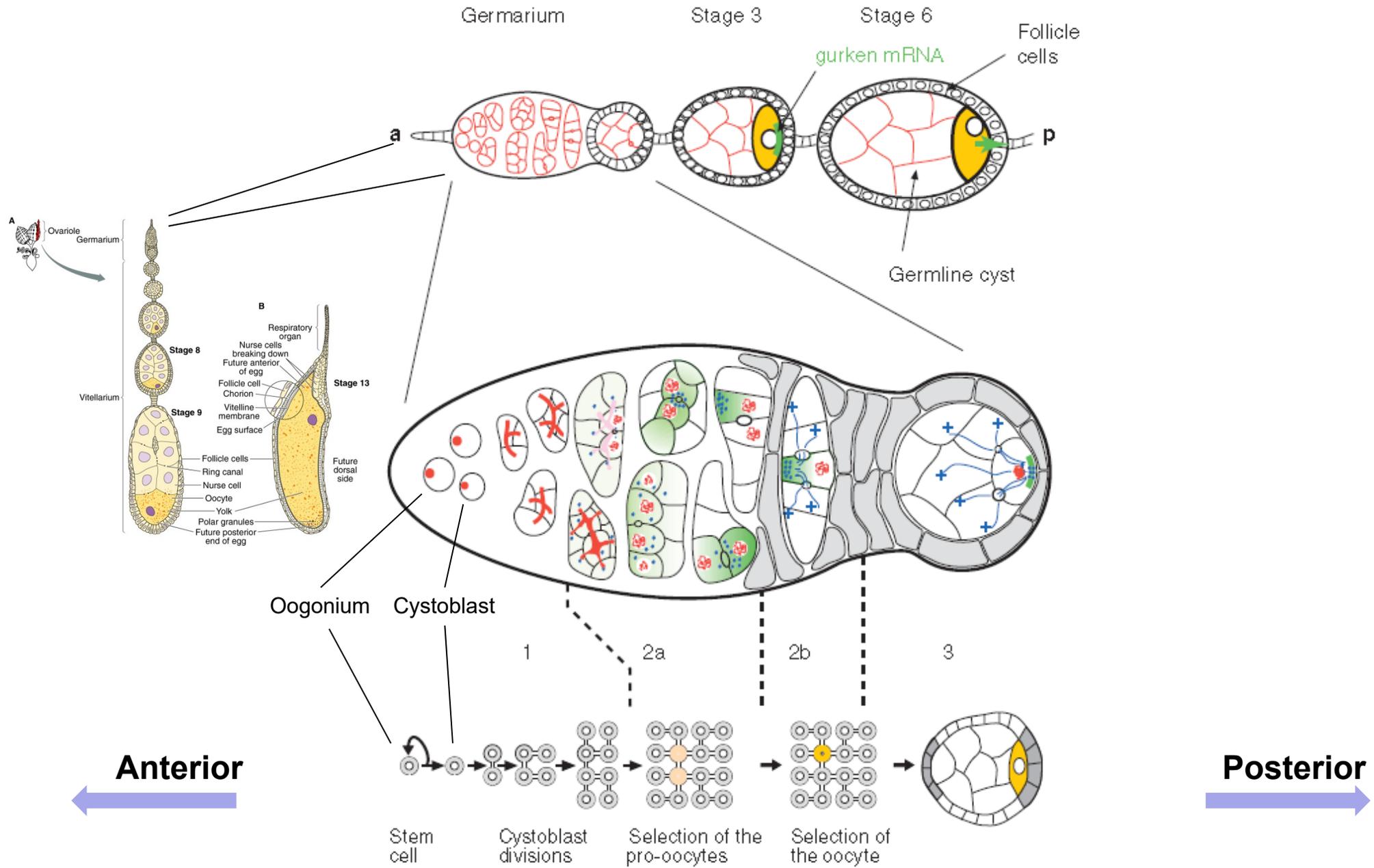




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  - molecular mechanisms of the early axis formation



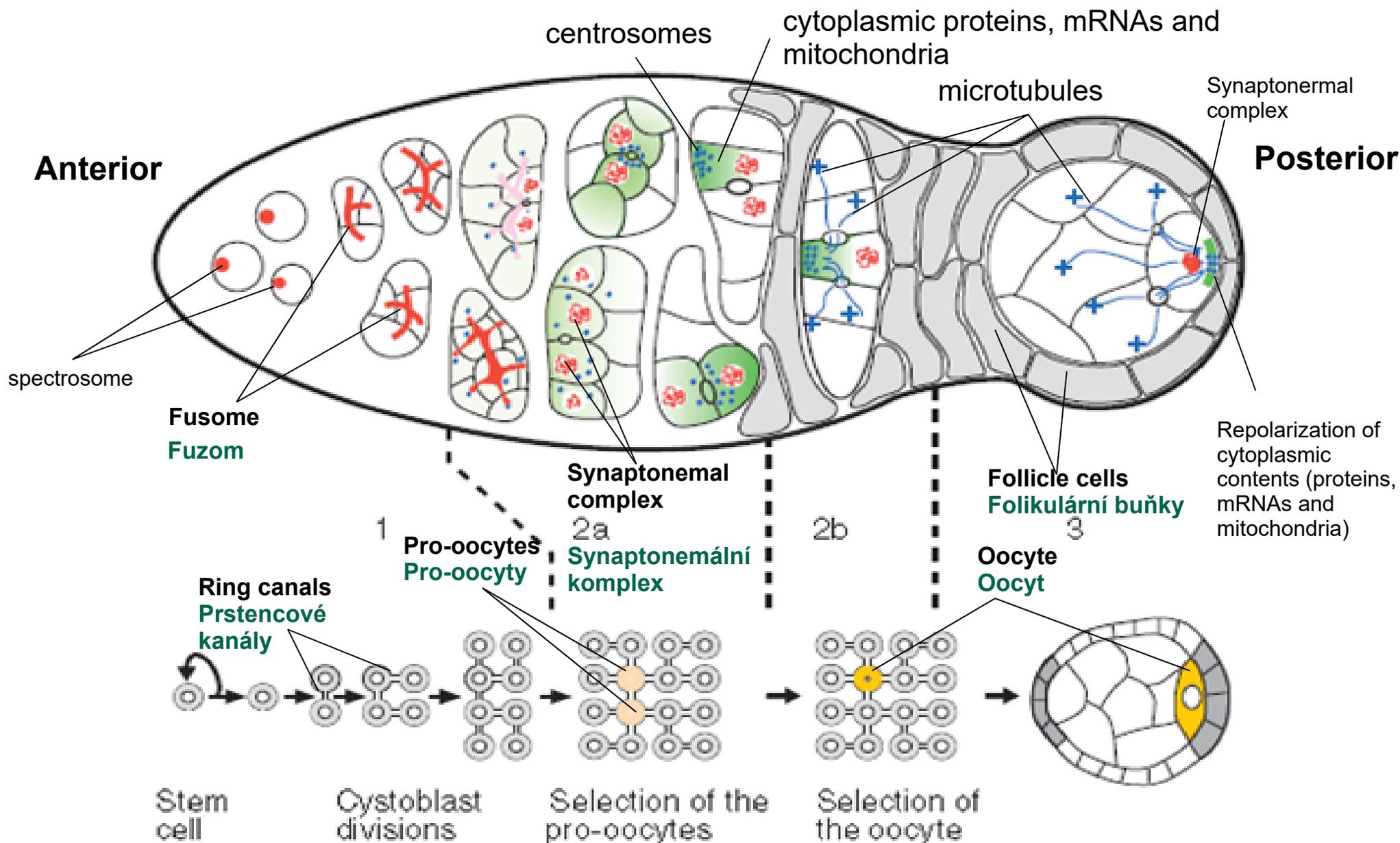
Huynh and Johnston., *Curr Biol* (2004)

Current Biology



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



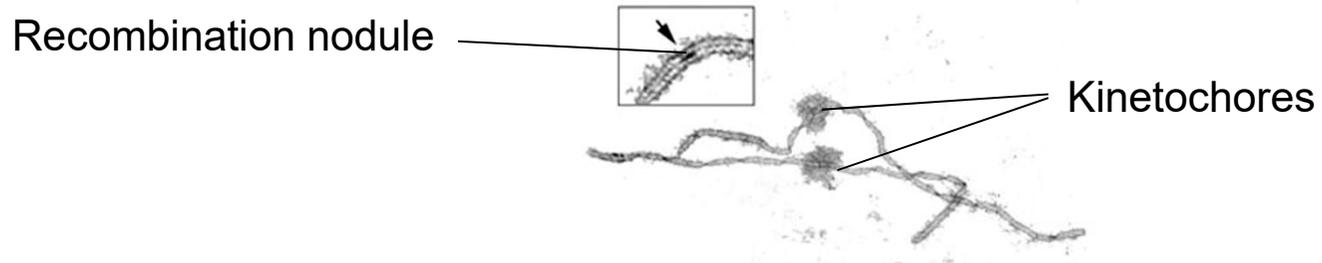
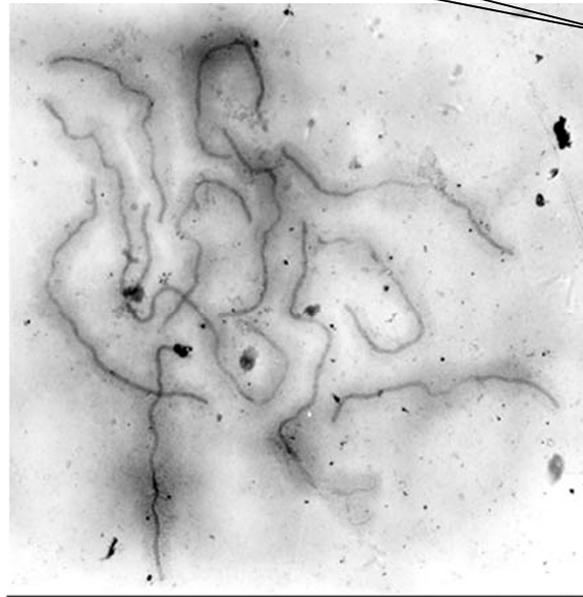
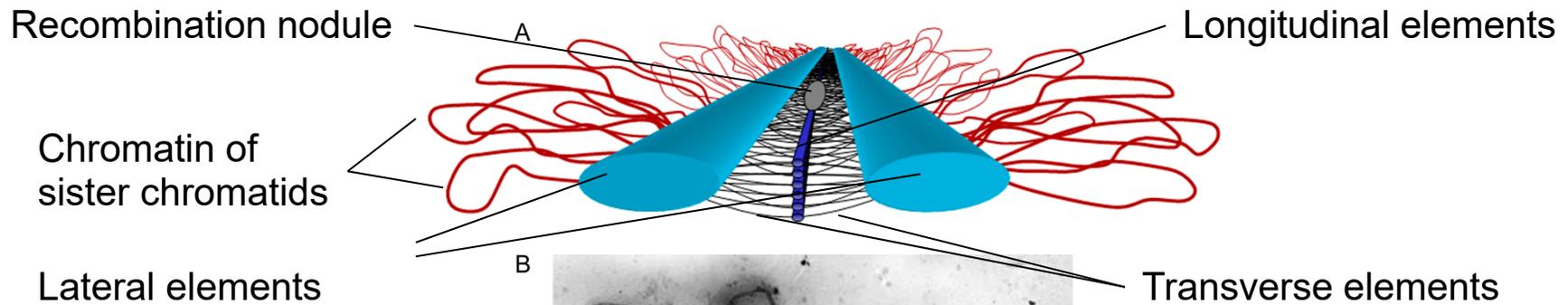
Current Biology

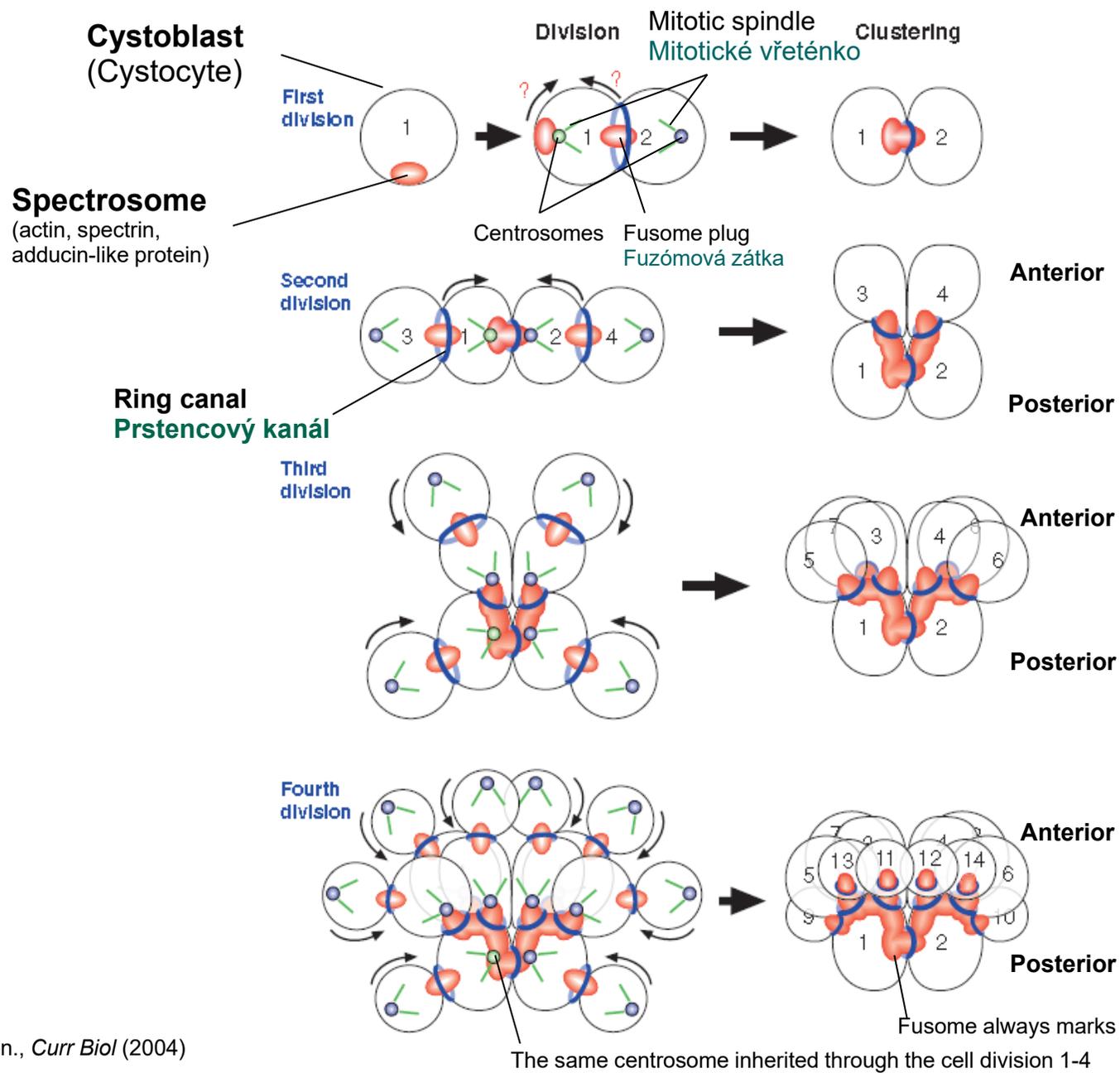
Huynh and Johnston., *Curr Biol* (2004)



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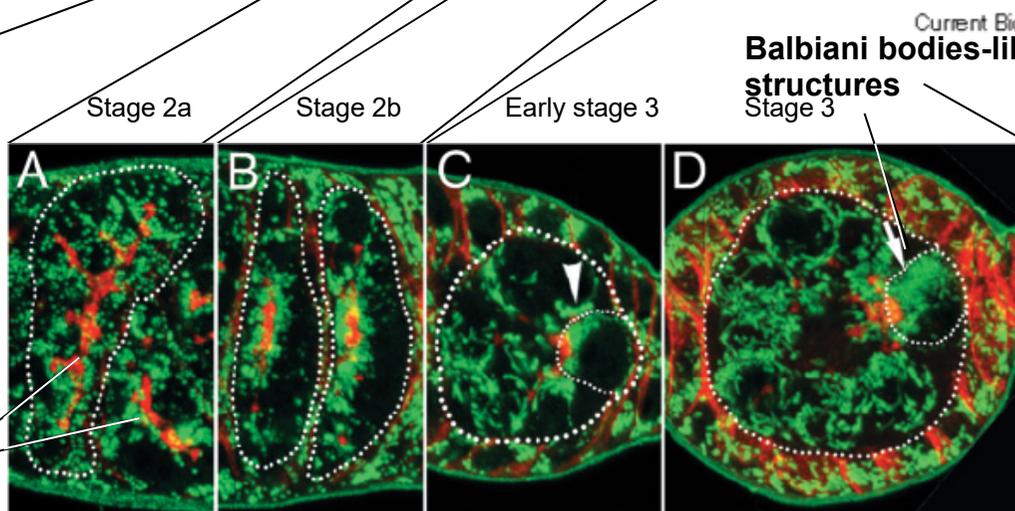
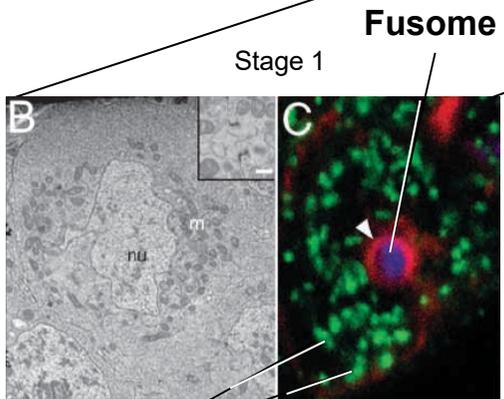
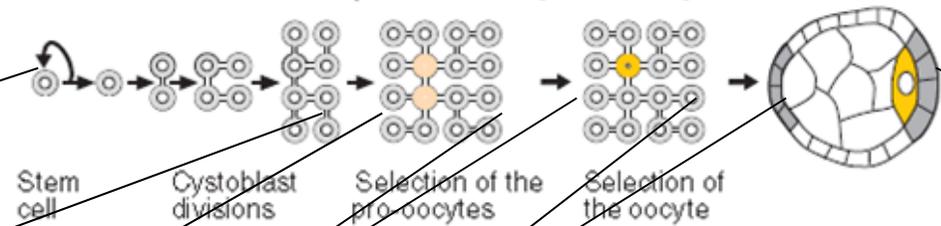
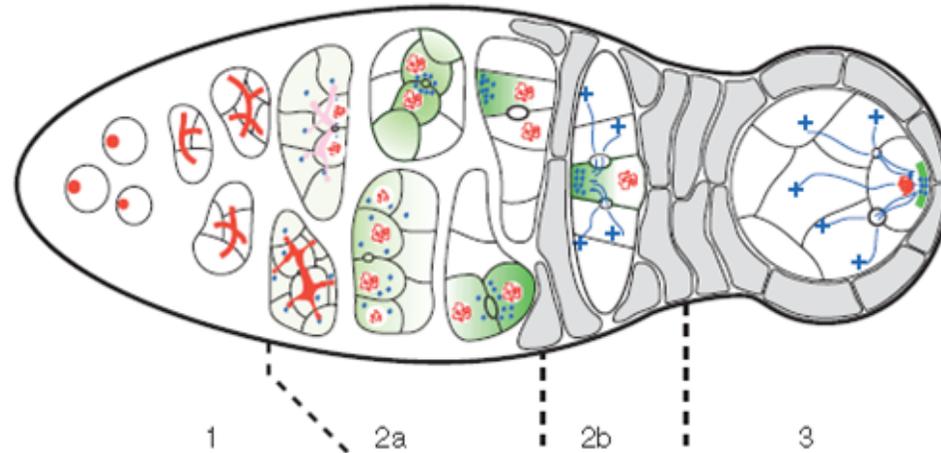


Huynh and Johnston., *Curr Biol* (2004)



INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

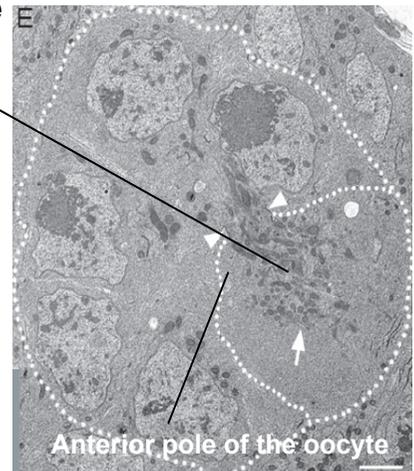
Tato prezentace je spolufinancována  
Evropským sociálním fondem  
a státním rozpočtem České republiky



Mitochondria (stained by anti-ATP synthase)

Ring canal actin

Current Biology  
Balbiani bodies-like structures  
Stage 3



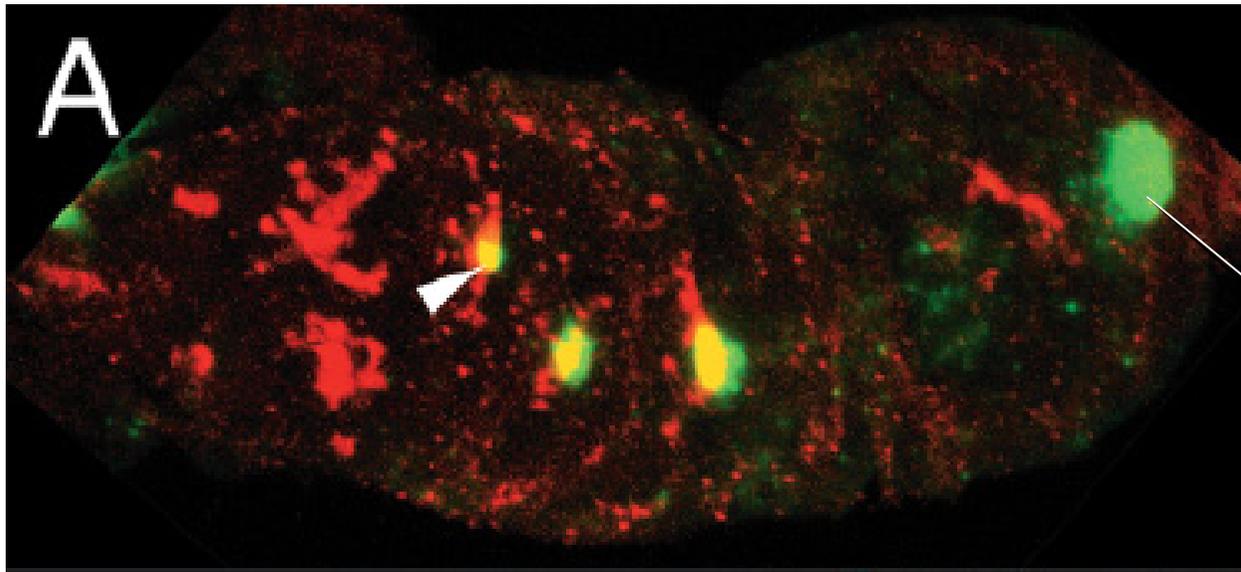
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

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

## OSK

- mRNA stability,
- Oocyte microtubule cytoskeleton polarization
- Oogenesis

ANTERIOR

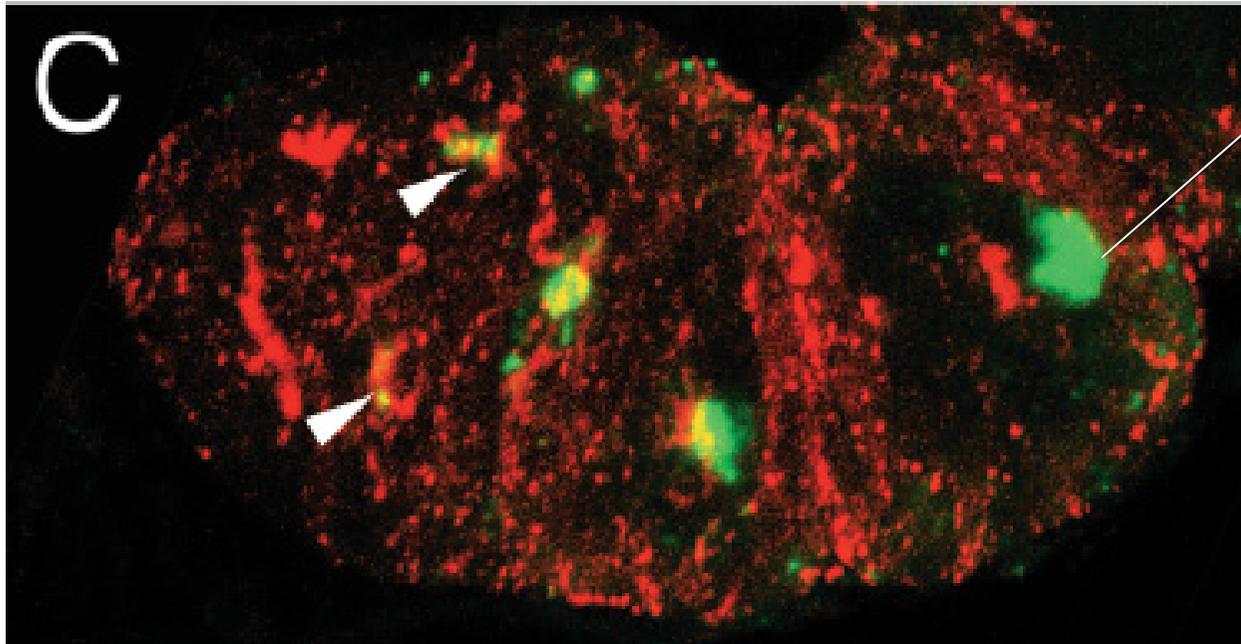


Repolarization in stage 3

POSTERIOR

## ORB

- mRNA translation,
- mRNA polyadenylation



Cox and Spradling, *Development* (2003)

Stage 2a

Stage 2b

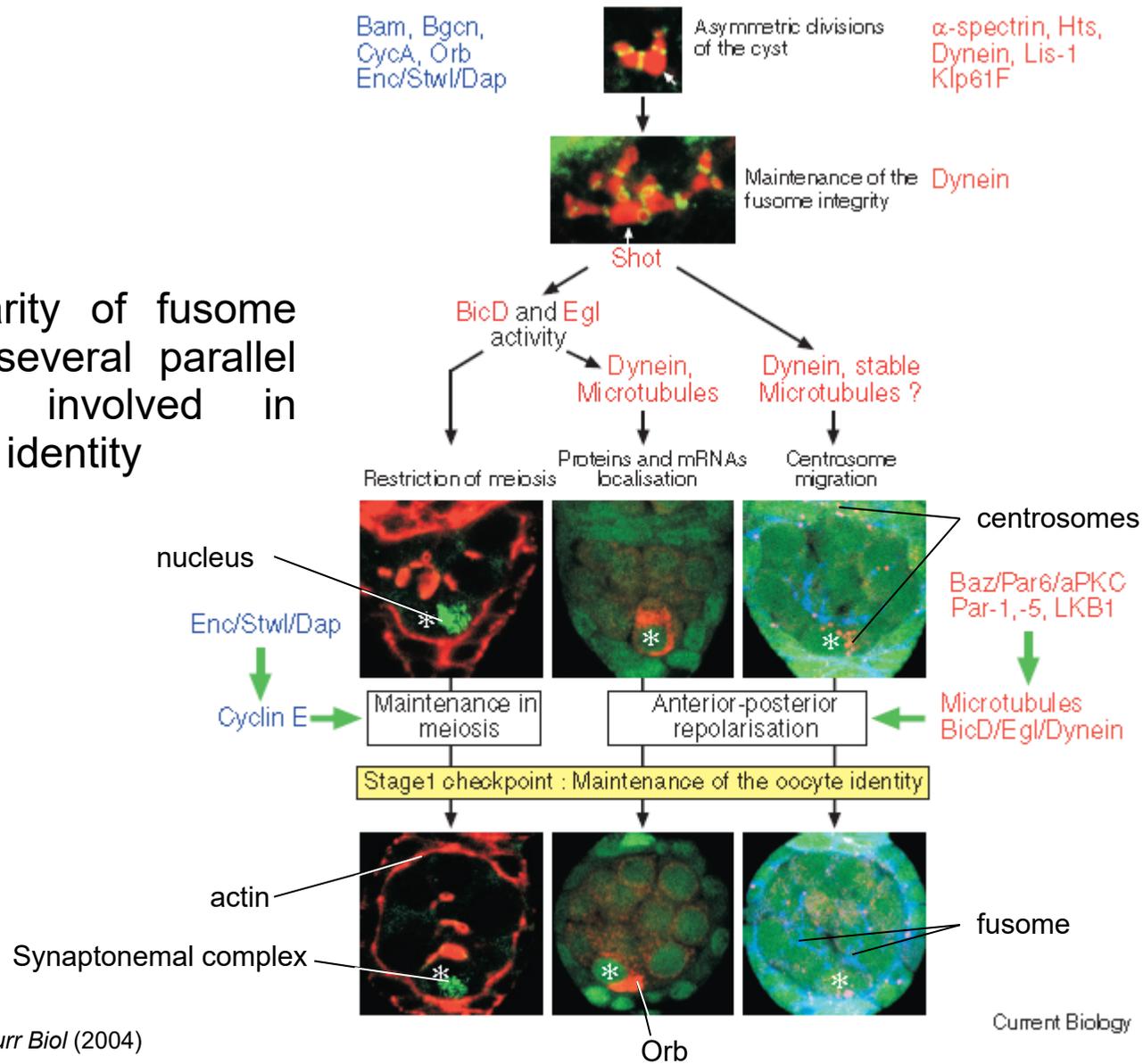
Stage 3



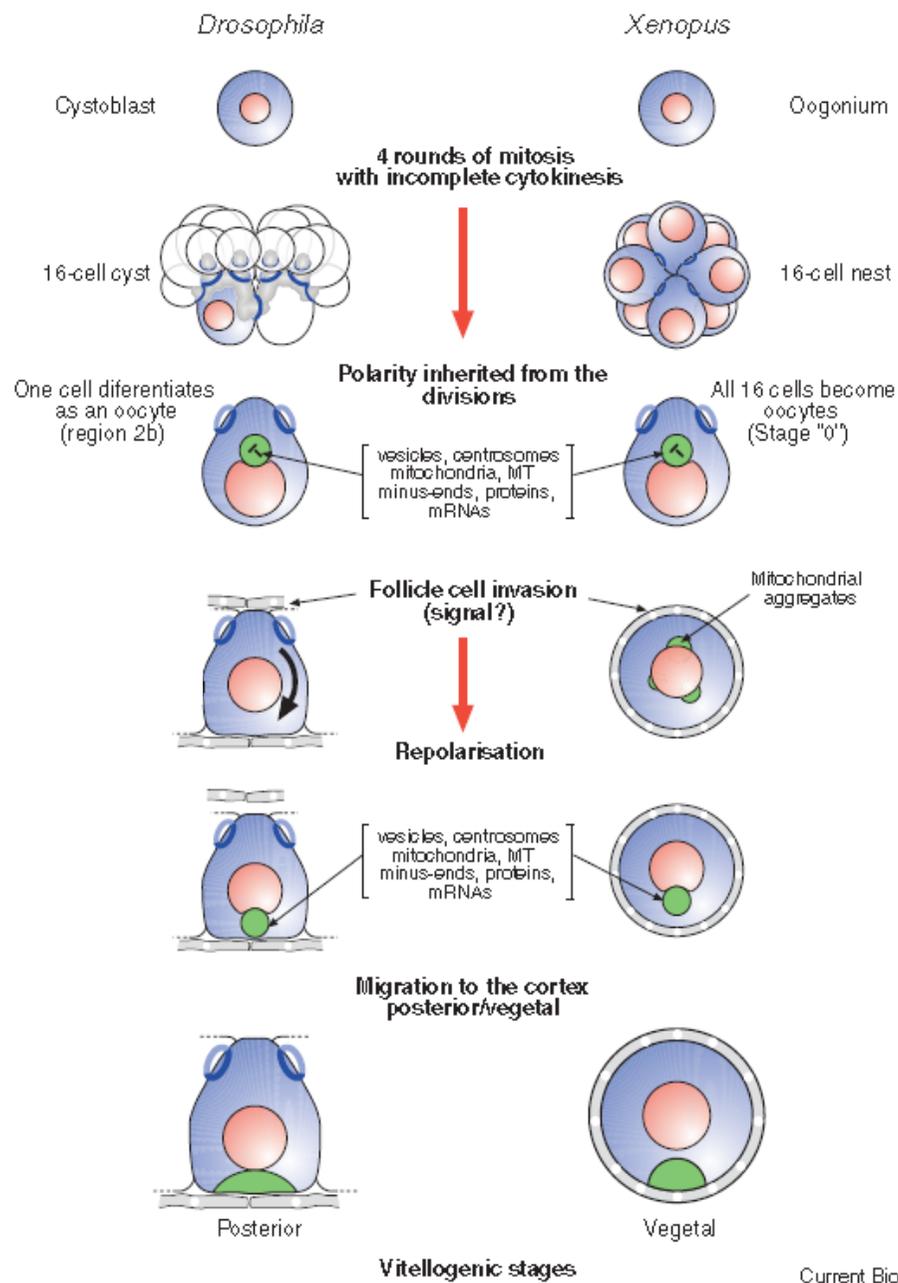
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Evropským sociálním fondem  
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Initial polarity of fusome regulates several parallel processes involved in oocyte cell identity



Huynh and Johnston., *Curr Biol* (2004)



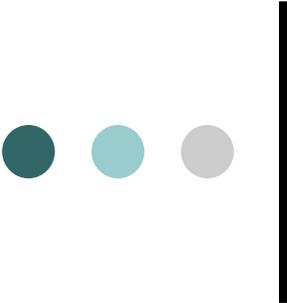
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Current Biology



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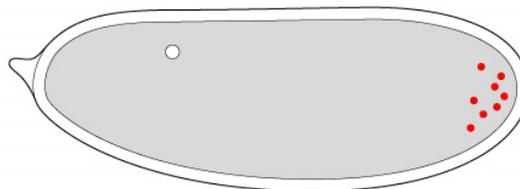
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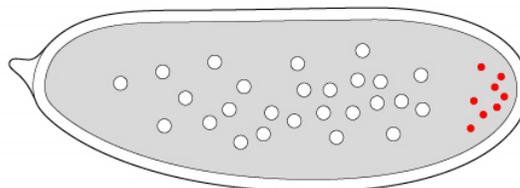
Anterior ↔ Posterior

**Stage 1**  
10 min  
1 nucleus



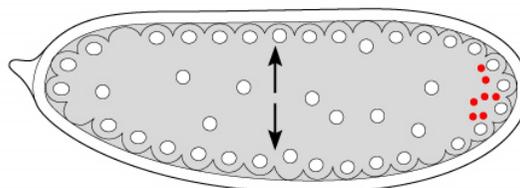
Formation of polar granules

**Stage 7**  
72 min  
64 nuclei



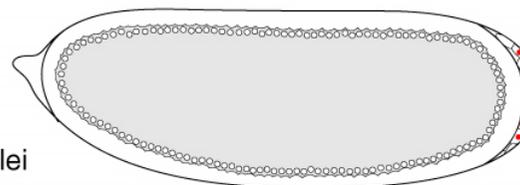
Buildup of nuclei

**Stage 8**  
90 min  
128 nuclei



Migration of nuclei

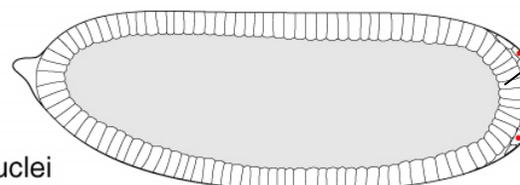
**Stage 10**  
150 min  
about 750 nuclei



Formation of pole cells

**Pole cells** – the first true cells  
**Pólové buňky**-první pravé buňky

**Stage 14**  
about 4 h  
about 2,048 nuclei



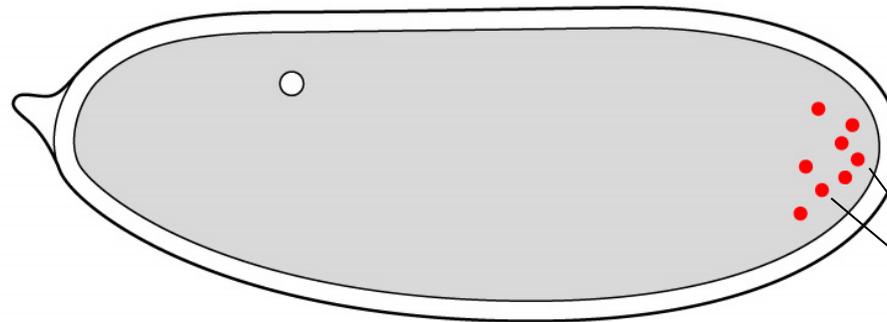
Formation of true cells

**Cellular blastoderm**  
**Buněčný blastoderm**

## Blastula formation

Anterior ↔ Posterior

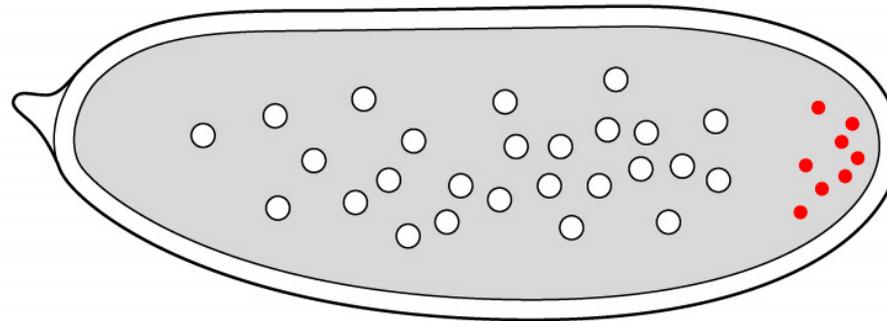
**Stage 1**  
10 min  
1 nucleus



Formation  
of polar  
granules

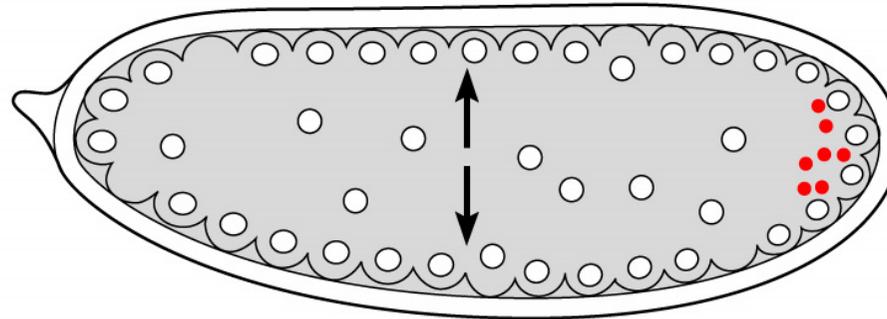
mRNA-binding proteins

**Stage 7**  
72 min  
64 nuclei

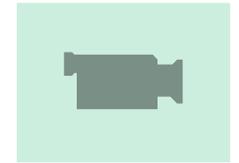
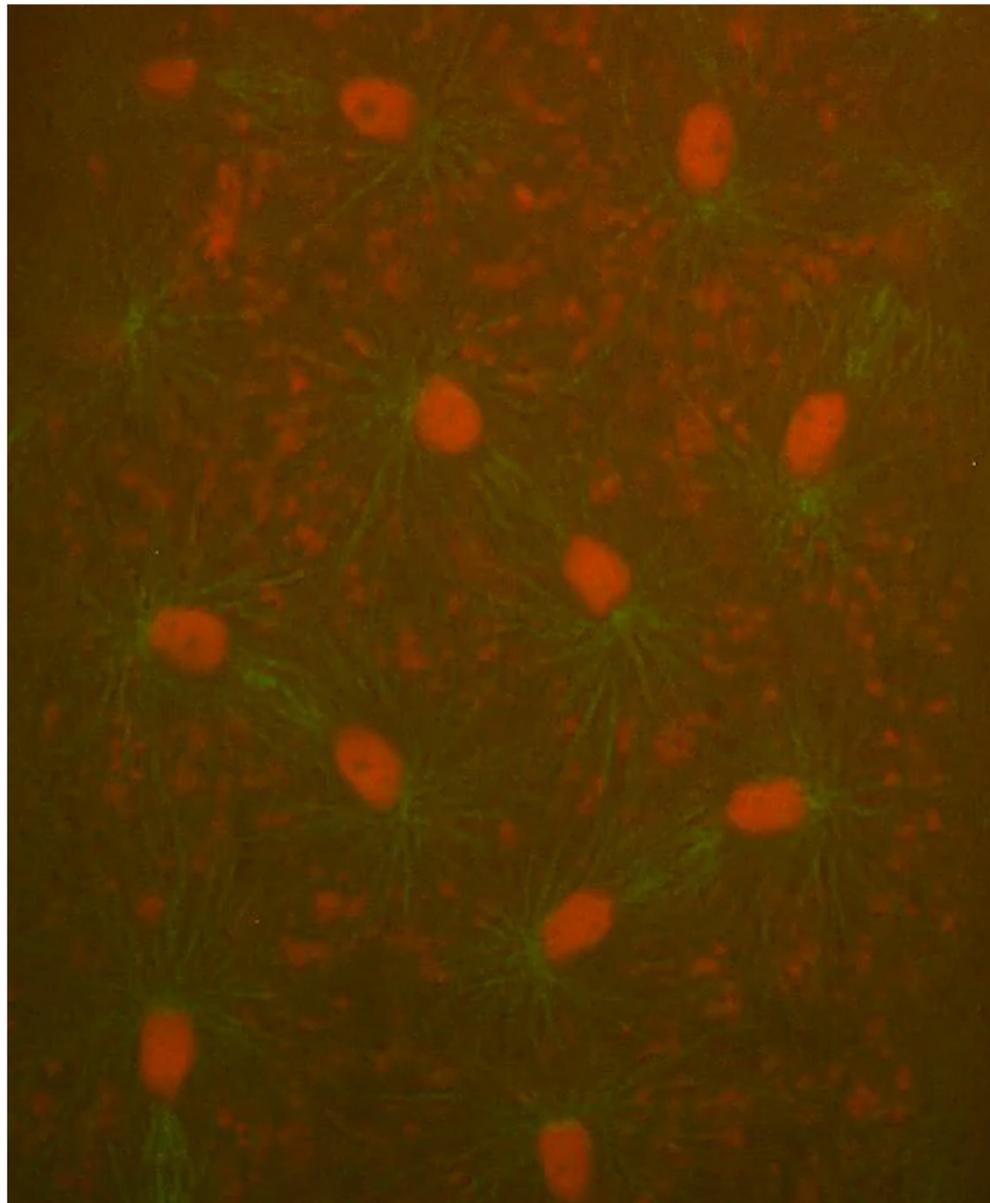


Buildup  
of nuclei

**Stage 8**  
90 min  
128 nuclei



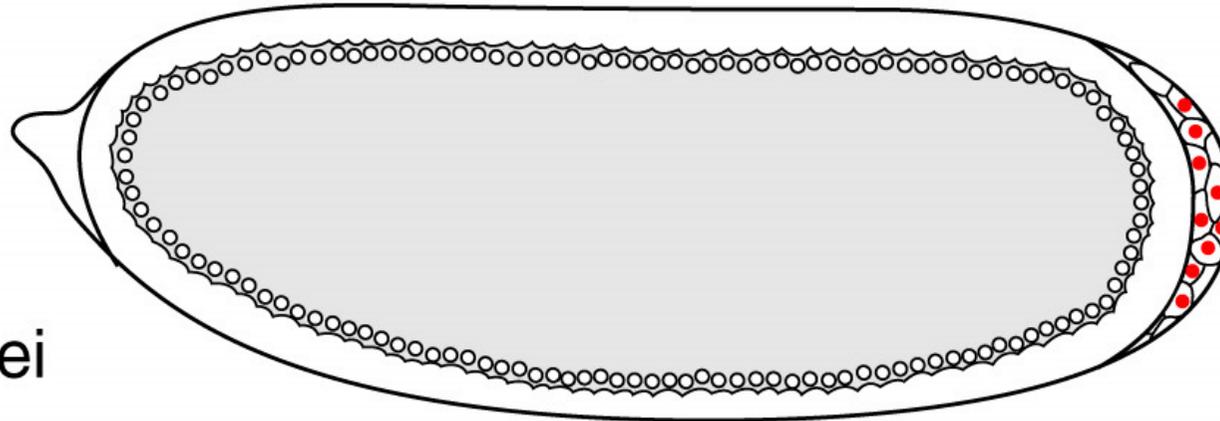
Migration  
of nuclei



Synchronized nuclear divisions in the early *Drosophila* embryo

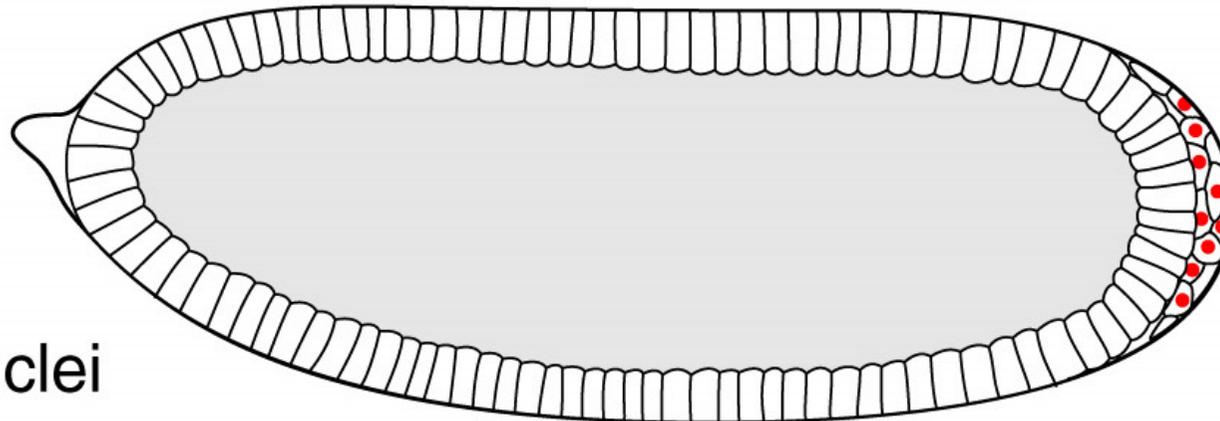
Anterior ↔ Posterior

**Stage 10**  
150 min  
about 750 nuclei



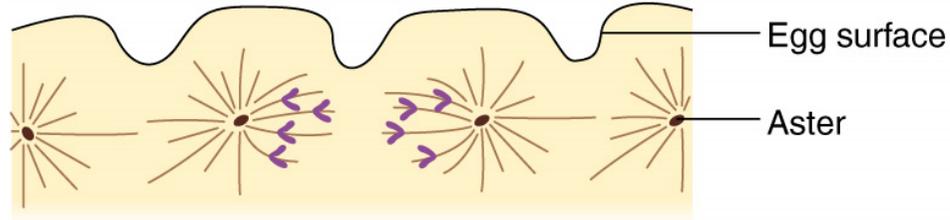
Formation  
of pole  
cells

**Stage 14**  
about 4 h  
about 2,048 nuclei

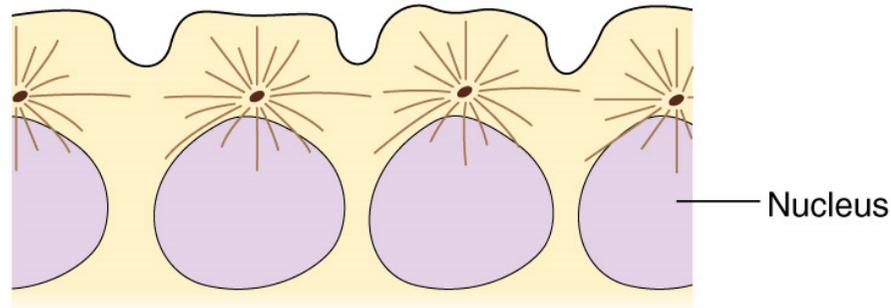


Formation  
of true  
cells

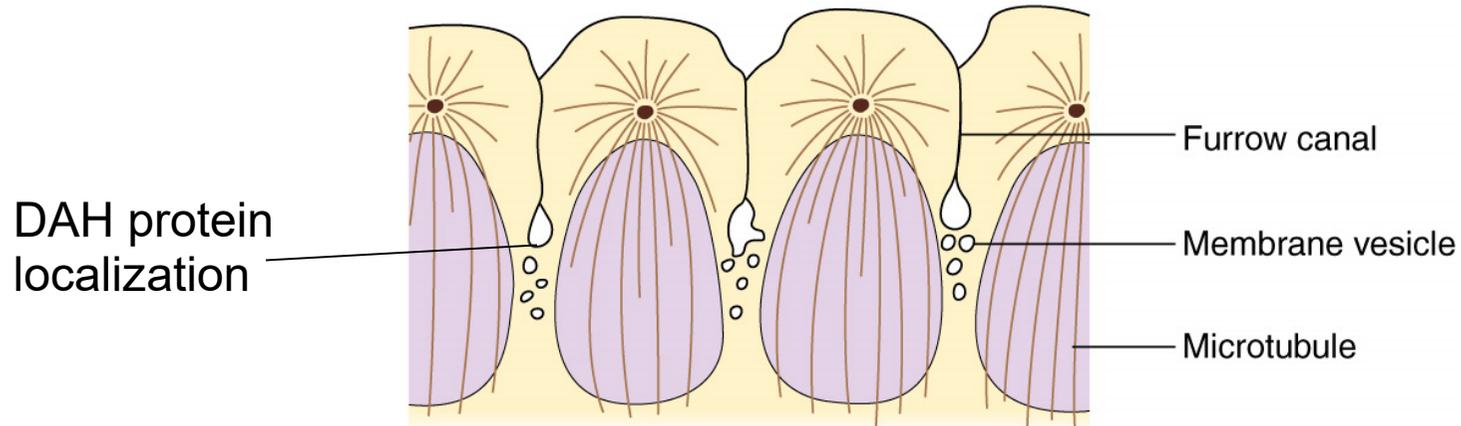
**A. Chromosomes separate on the mitotic spindle.**



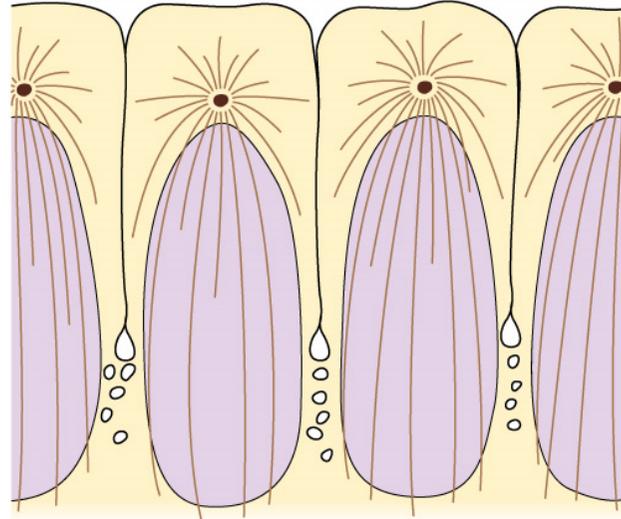
**B. Nuclei reform.**



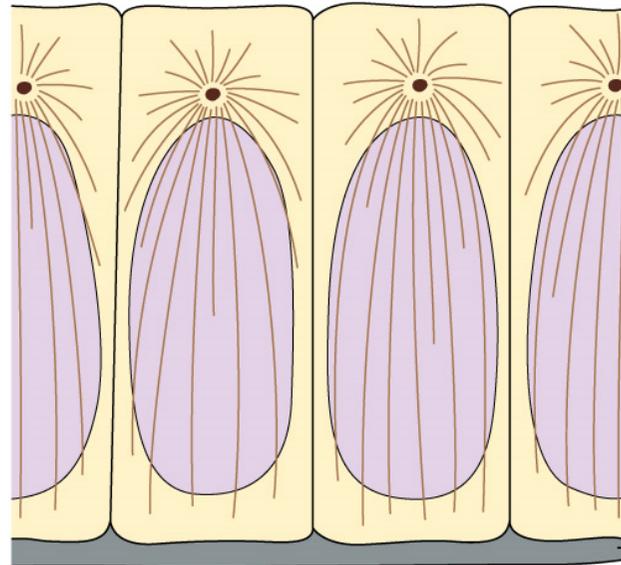
**C. Nuclei enlarge. Furrow canals form, added at the tips by membrane vesicles.**



**D. Nuclei continue to grow and the furrow canals progress.**

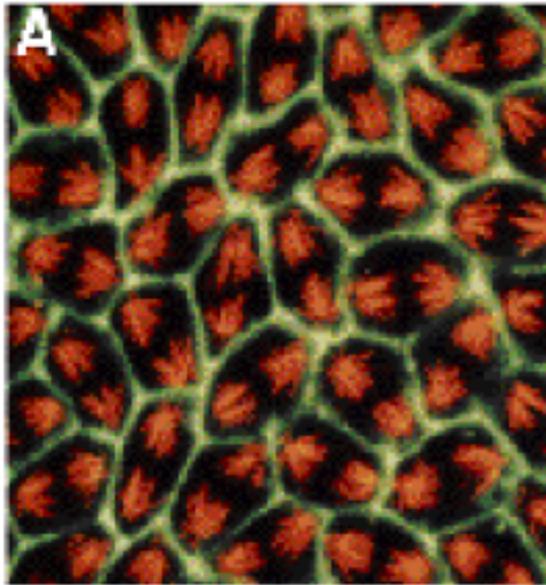


**E. Cellularization is completed and yolk membrane is in place.**

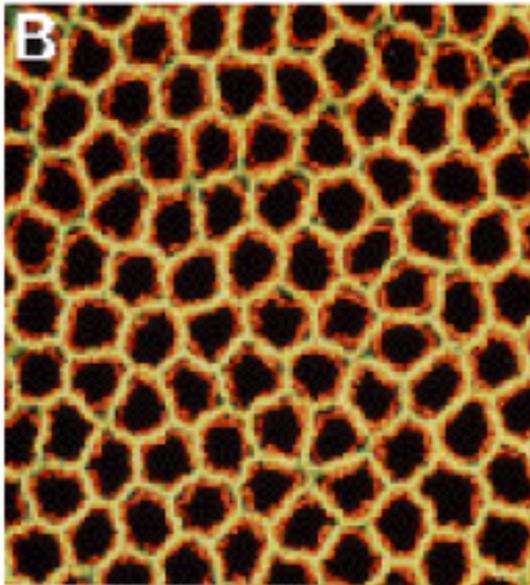


Yolk membrane

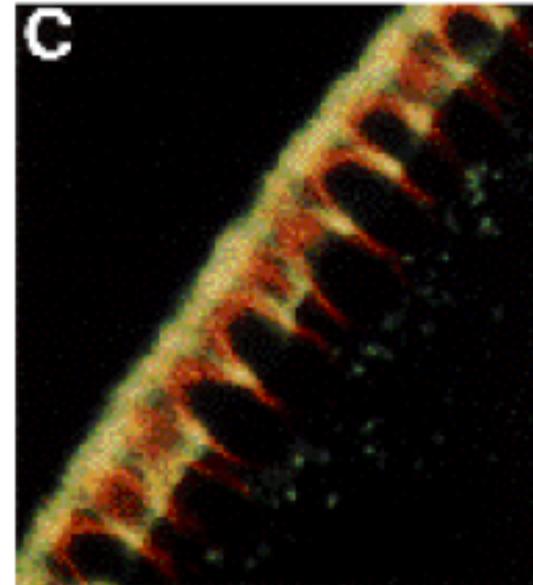
**syncytial mitosis**



**cellularization  
(grazing section)**



**cellularization  
(cross section)**

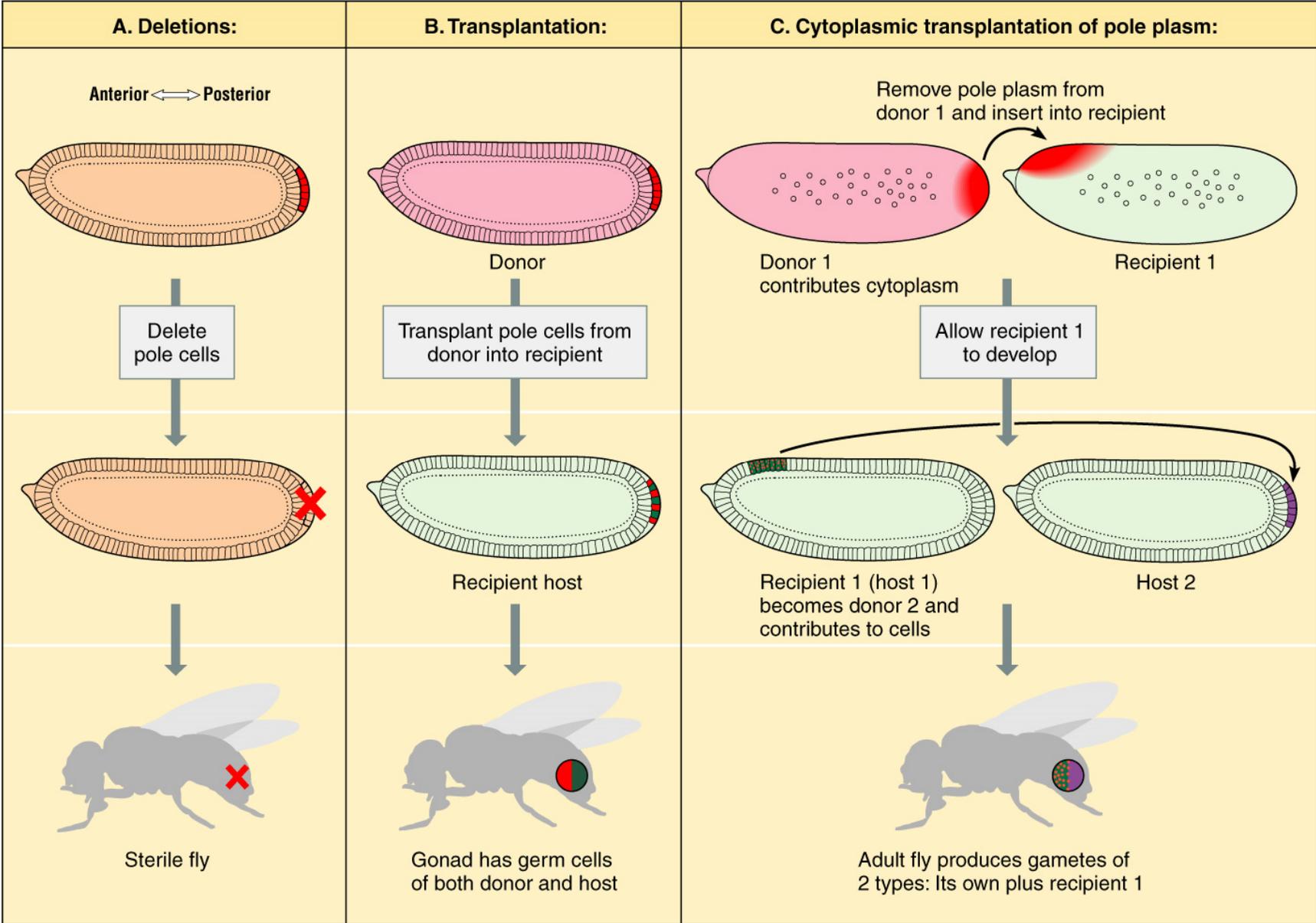


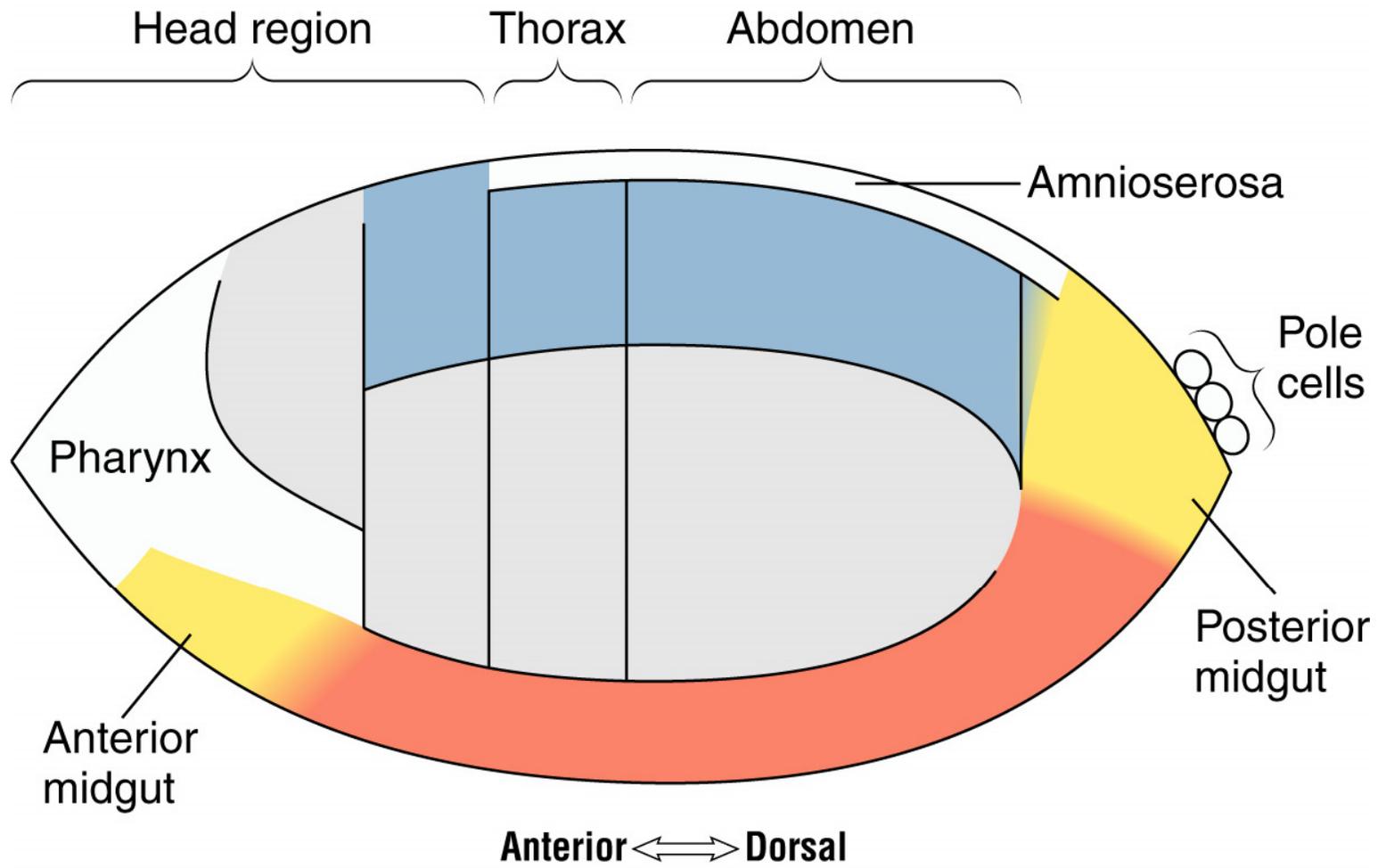
Sullivan et al., *Development* (1993)



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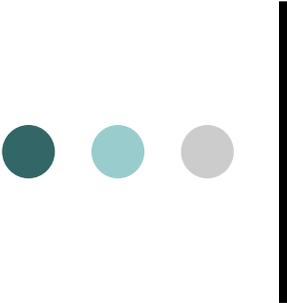
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KEY

	Neural tissues		Dorsal epidermis
	Endoderm		Mesoderm



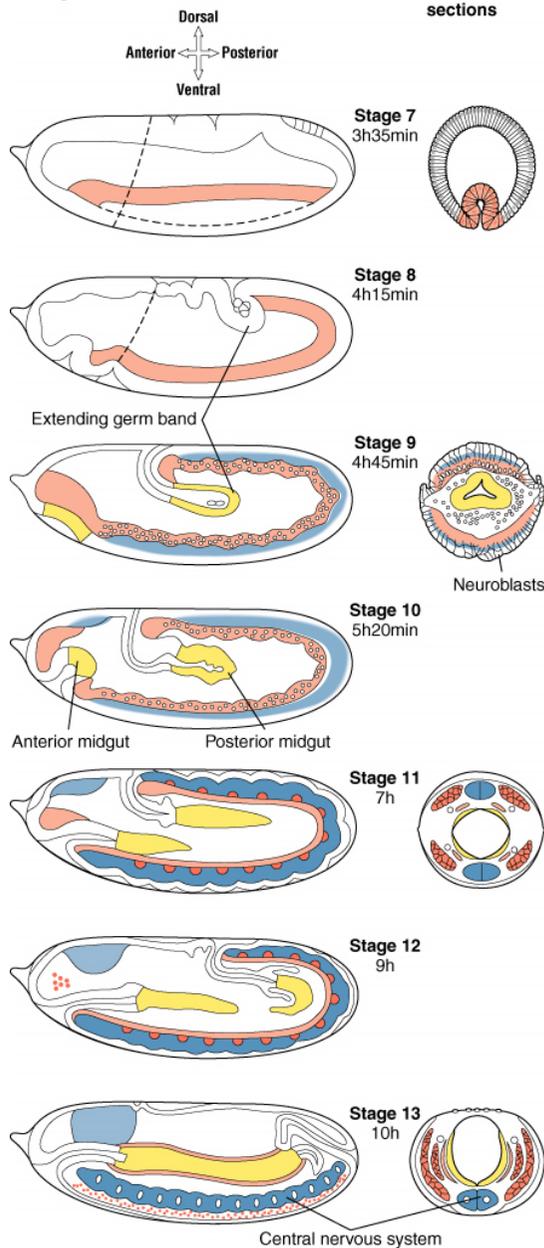
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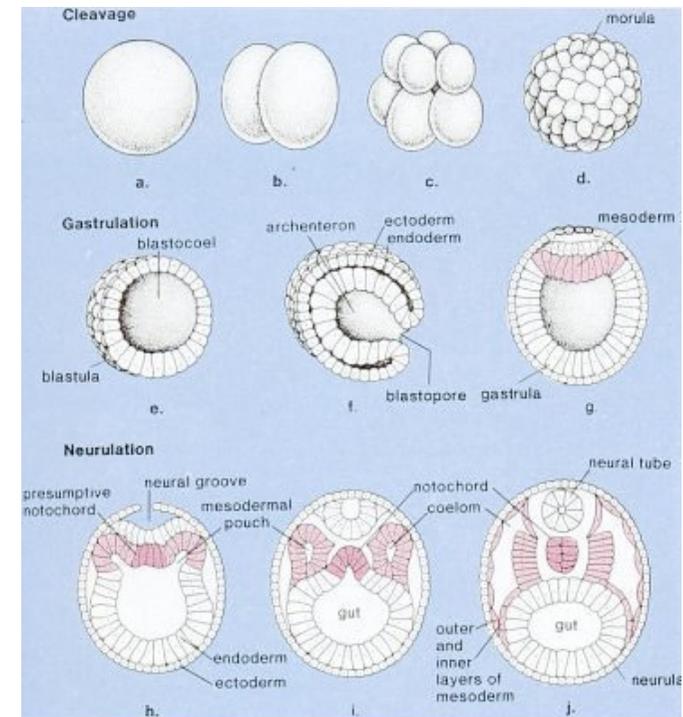
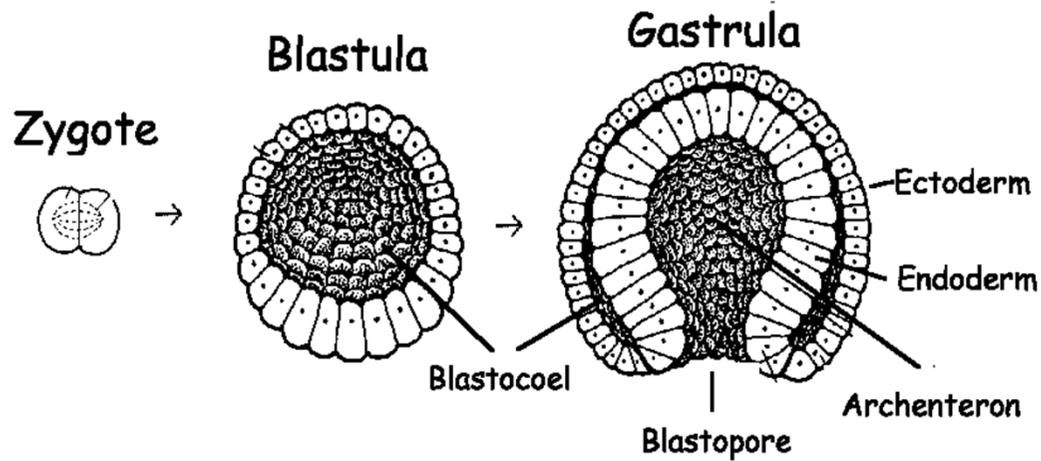
A. Sagittal sections

B. Cross sections



Change in position

Cell differentiation



**Embryonic Development of Lancelet :**

**Cleavage produces the morula**

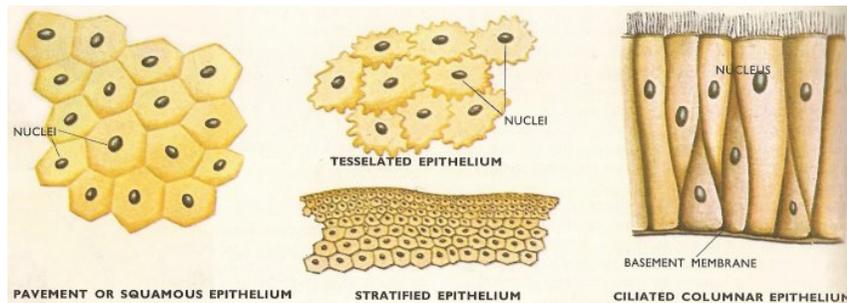
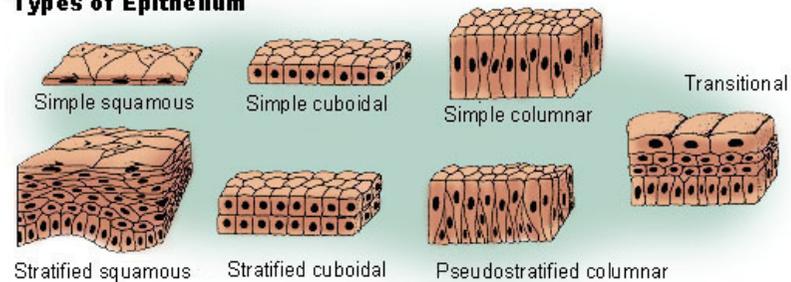
**Gastrulation by invagination produces the three germ layers**

**Neurulation produces the neural tube called the neurula**

Embryonální vývoj kopinatce

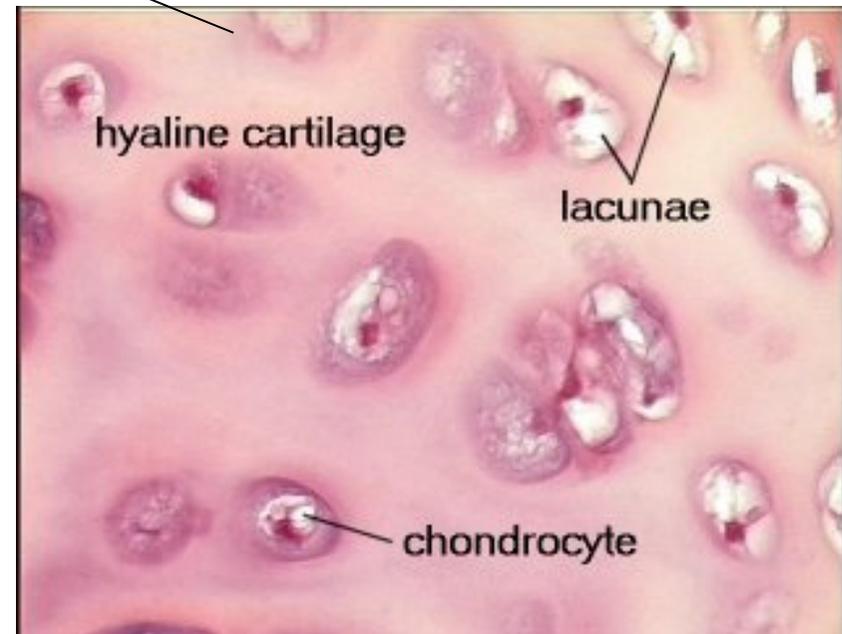
# Epithelium Epitel

## Types of Epithelium

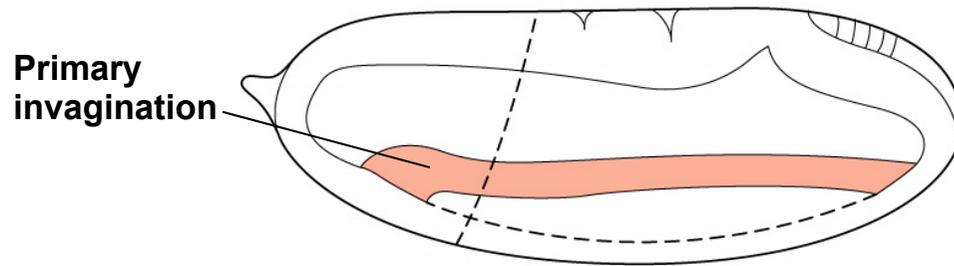
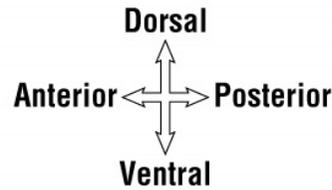


# Mesenchyme Mesenchym

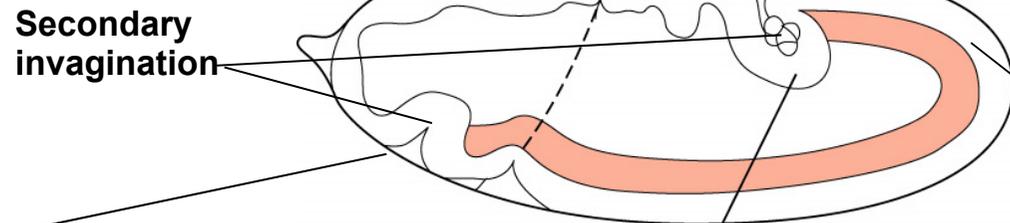
Hyalinní (sklovitá,  
kloubní) chrupavka



## A. Sagittal sections



Primary invagination

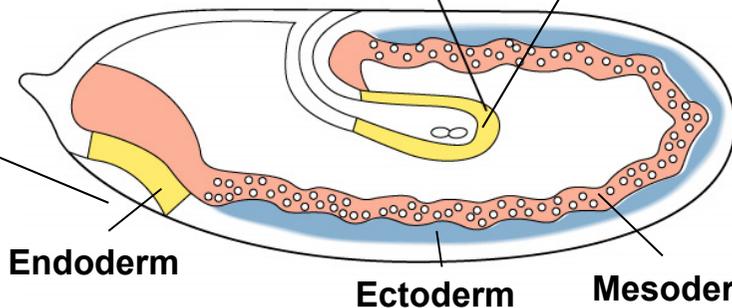


Secondary invagination

Extending germ band (via *convergent extension*)...and progression of hindgut invagination

Stomodeum formation and invagination

Tvorba a invaginace předního střeva (stomodea – primitivní ústní jamky)



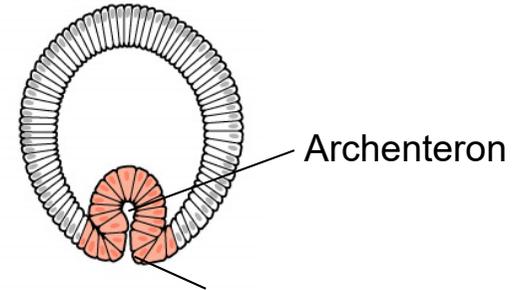
Endoderm

Ectoderm

Mesoderm

## B. Cross sections

Stage 7  
3h35min



Archenteron

Ventral furrow/Ventrální rýha

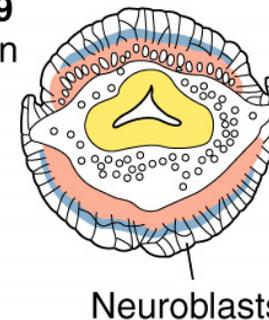
Mesoderm

Somatic/somatický

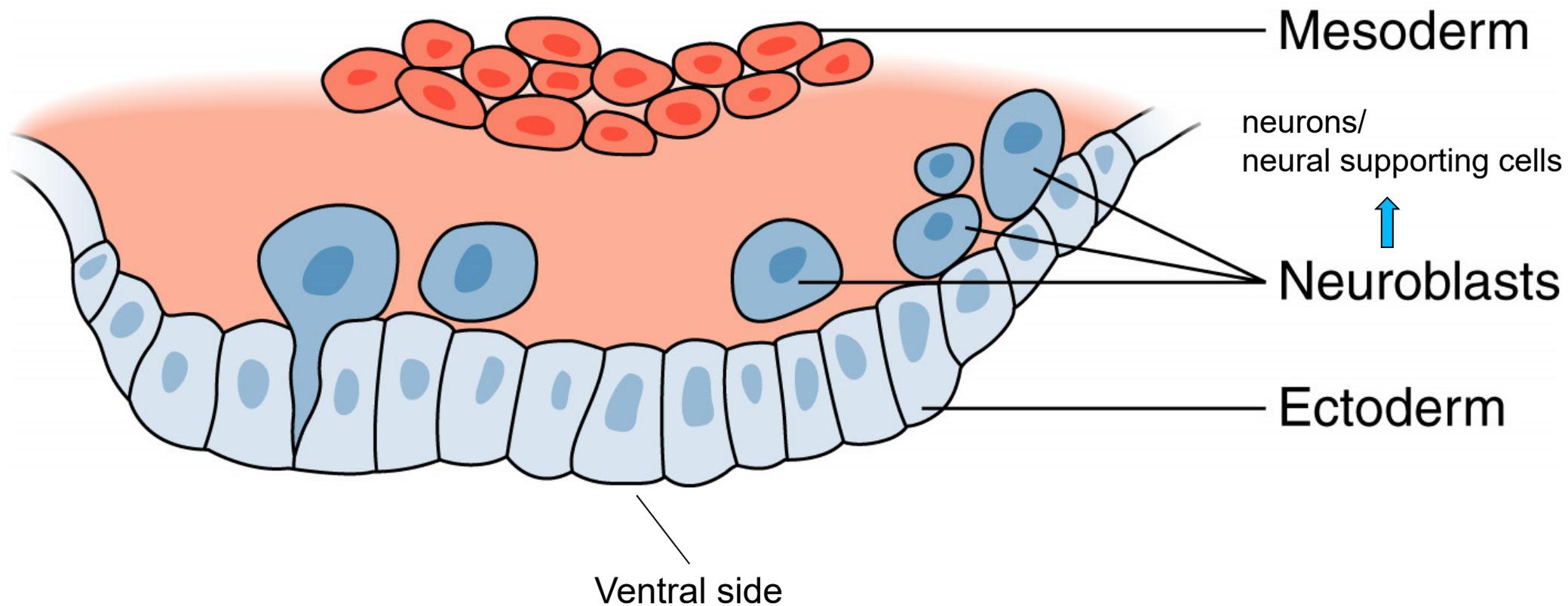
Visceral/viscerální

Zárodečný proužek a jeho *konvergentní extenze* umožňující další invaginaci zadního střeva

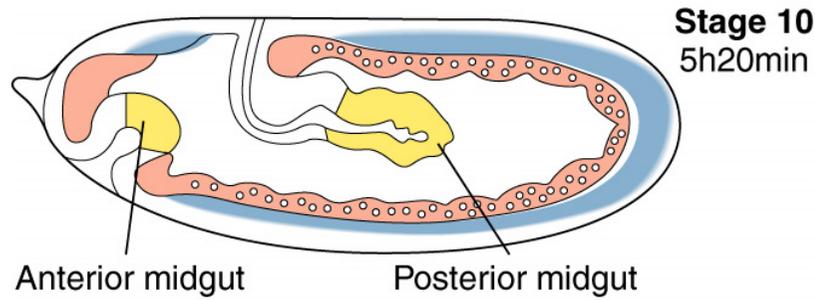
Stage 9  
4h45min



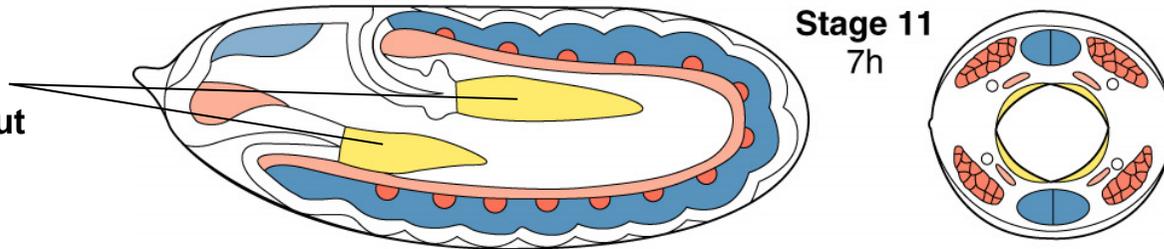
Neuroblasts



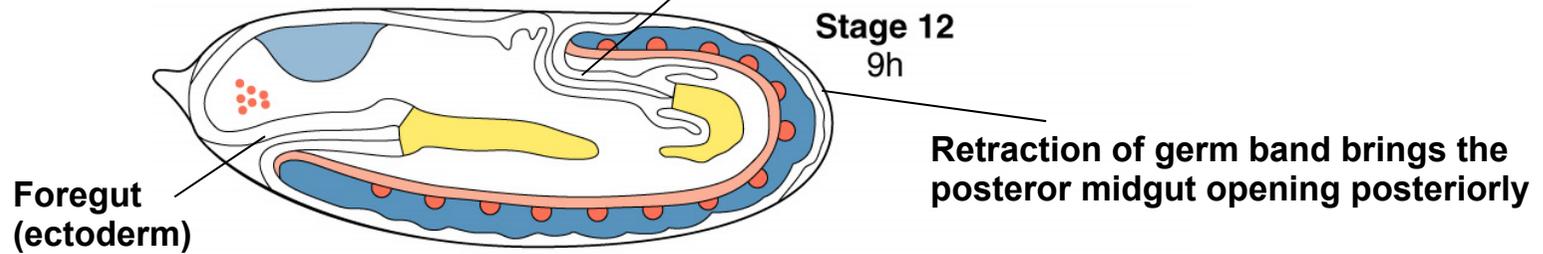
**Secondary invagination**



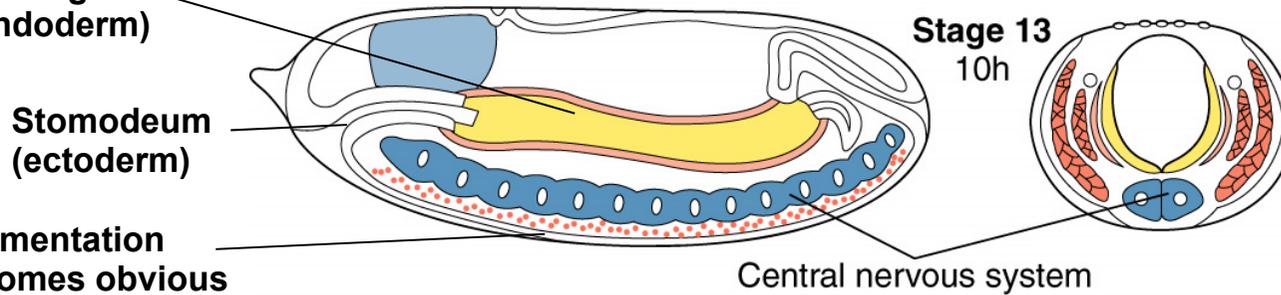
**Anterior and posterior midgut elongation**

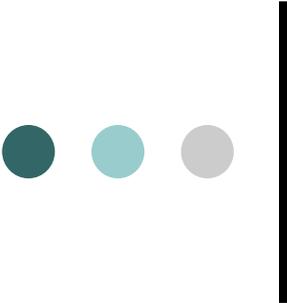


**Hindgut (ectoderm)**



**Anterior and posterior midgut fusion (endoderm)**

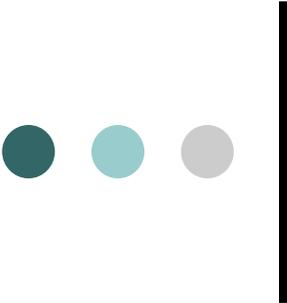




# Outline of Lesson 2

## Early Development of *Drosophila*

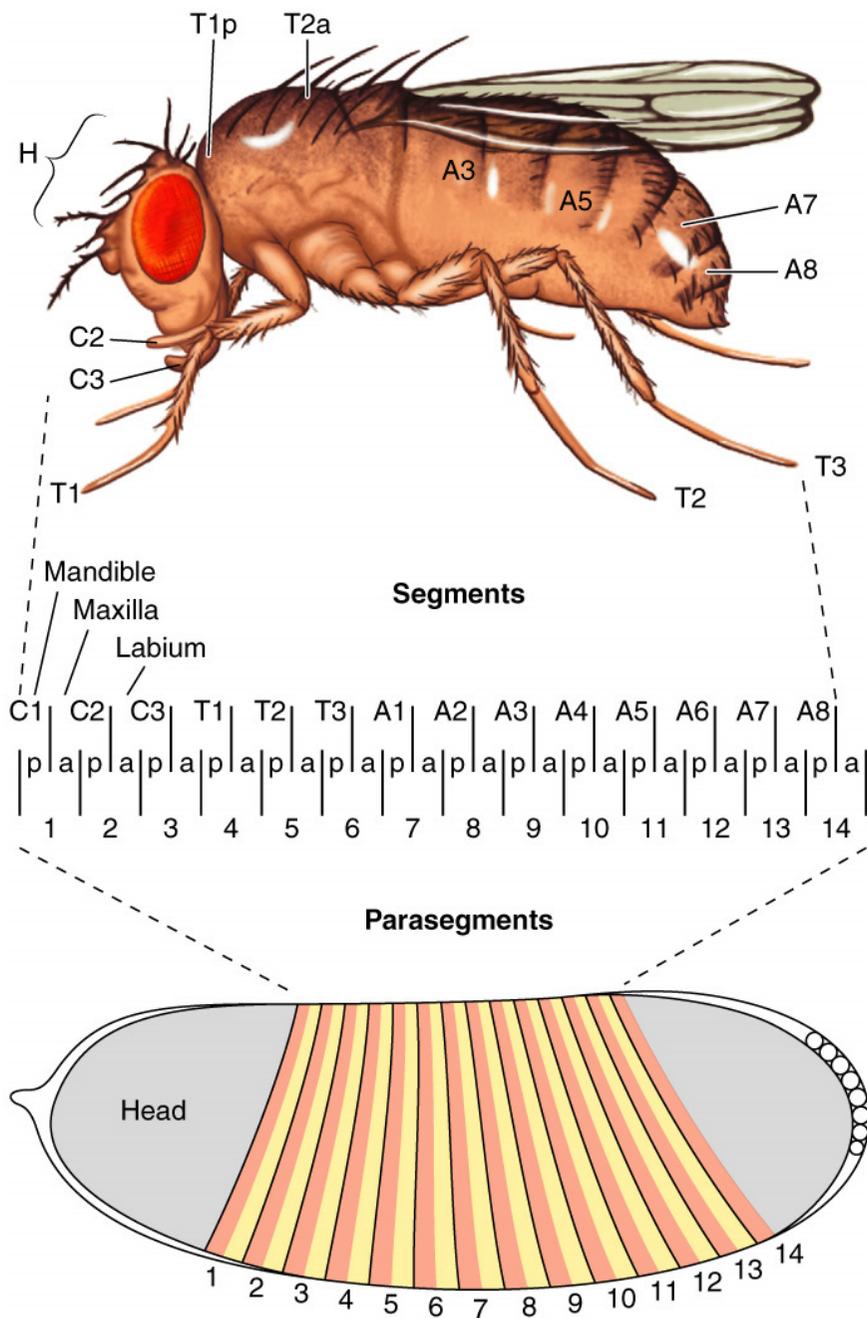
- Introduction into *Drosophila*
  - Life cycle (video)
  - Anatomy (video)
  - Mating (video)
- Oogenesis
  - molecular mechanisms of the early axis formation
- Early embryogenesis
- Gastrulation
  - Video of gastrulation in *Drosophila*



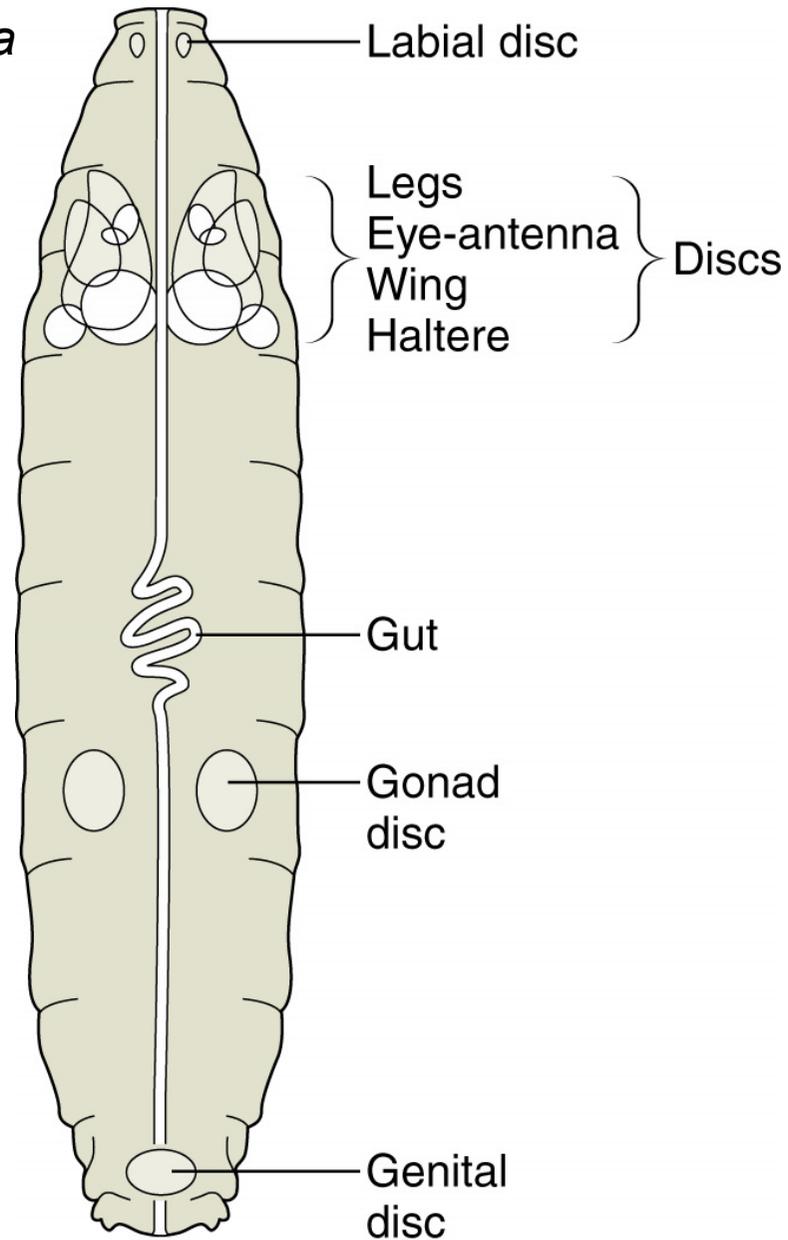
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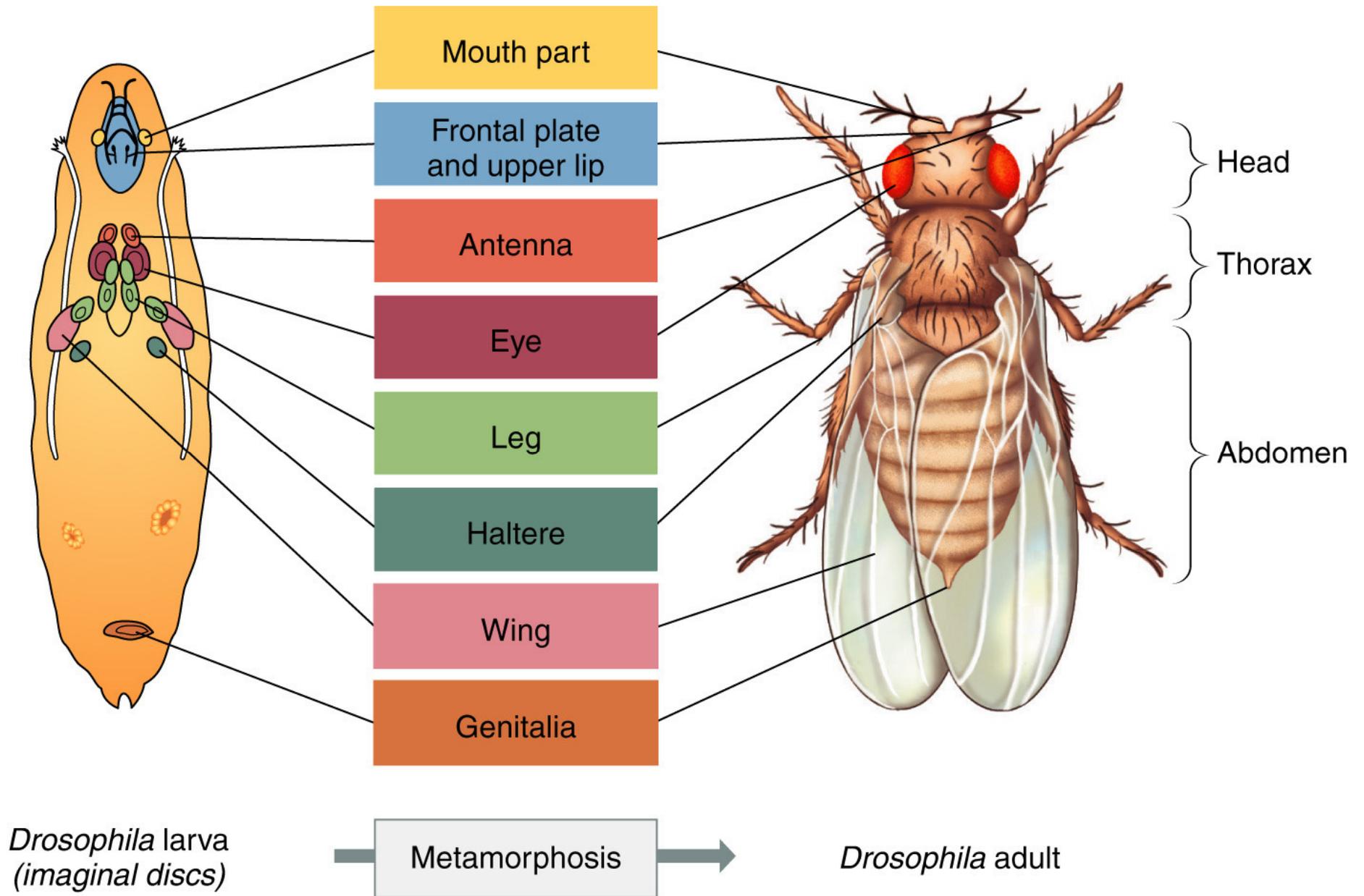
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  - Video of gastrulation in *Drosophila*
- Overview of metamorphosis



# Imaginal discs in *Drosophila* larva

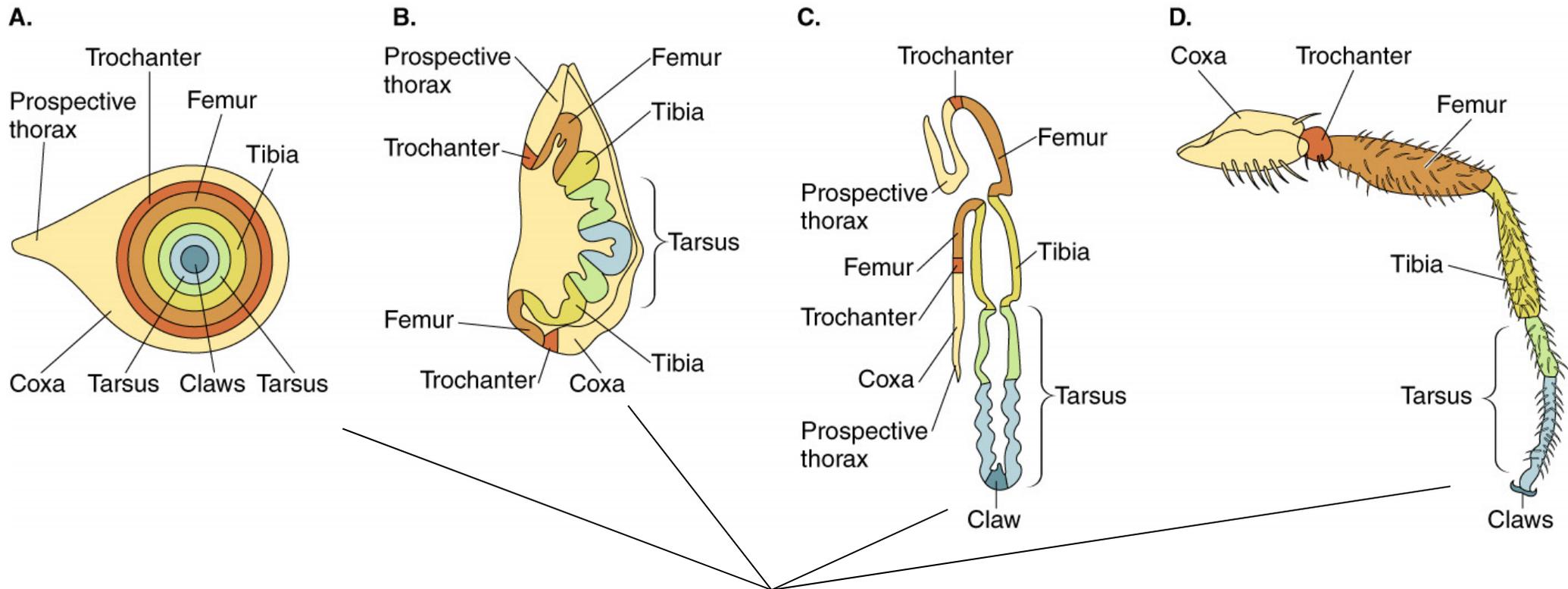




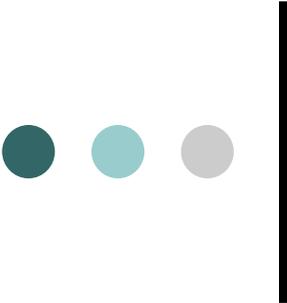
Predetermined cell fate

Adult structures

Morphogenetic movements during metamorphosis



Under control of **ecdyson** and **juvenile hormone**

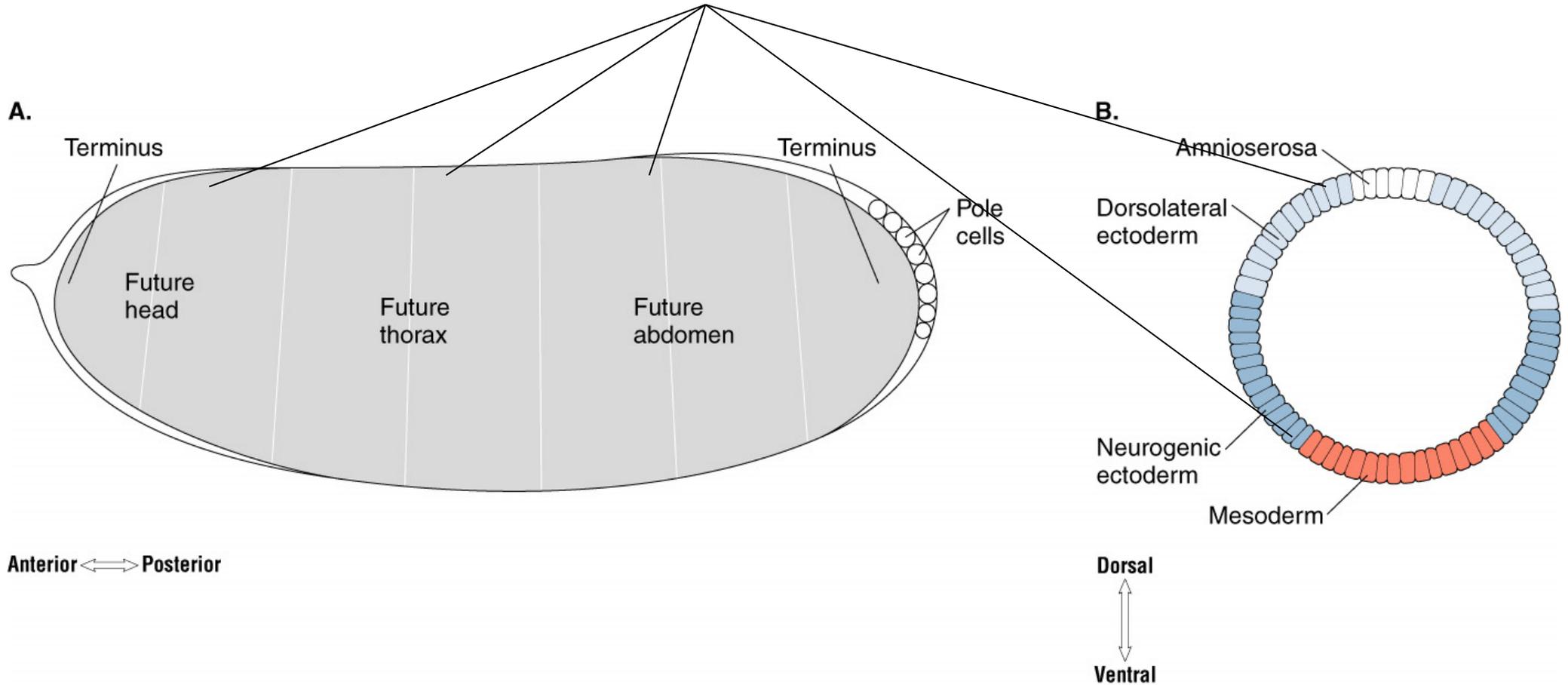


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## Early Development of *Drosophila*

- Introduction into *Drosophila*
  - Life cycle (video)
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- Overview of metamorphosis
- Introduction into genetic and molecular mechanisms of the early embryogenesis in *Drosophila*

## Different levels of morphogens

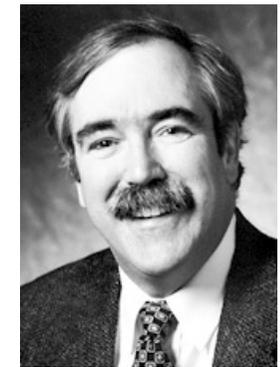


Klaus Sanders experiments in Germany, 1960's

	Genotype	Phenotype
<b>A. Parents:</b>	$bcd^+/bcd^-$	Both female and male normal
<b>B. F<sub>1</sub>:</b>	1) $bcd^{+/-}$ 2) $bcd^{+/-}$ 3) $bcd^{-/-}$	All flies appear normal
<b>C. Mate female F<sub>1</sub> to wild-type males:</b>	1) $\text{♀ } bcd^{+/+} \times \text{♂ } bcd^{+/+}$ ↓ $bcd^{+/+}$	These offspring appear normal
	2) $\text{♀ } bcd^{+/-} \times \text{♂ } bcd^{+/+}$ ↓ $bcd^{+/-}; bcd^{+/-}$	
	3) $\text{♀ } bcd^{-/-} \times \text{♂ } bcd^{+/+}$ ↓ $bcd^{+/-}$	These offspring lack anterior structures

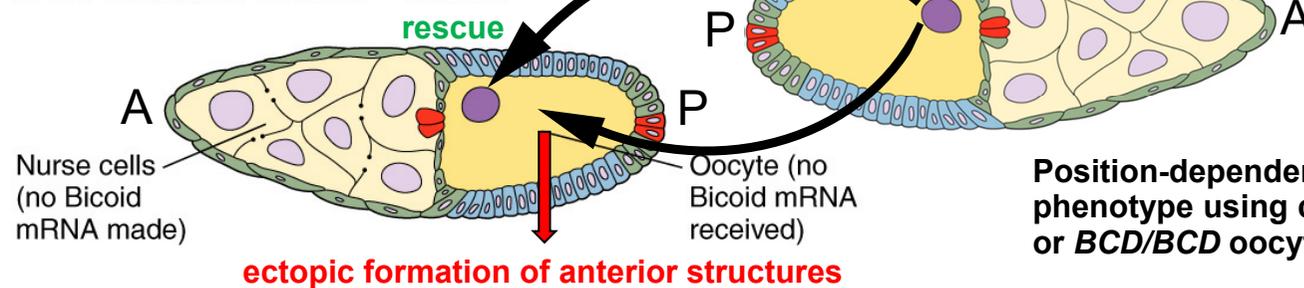


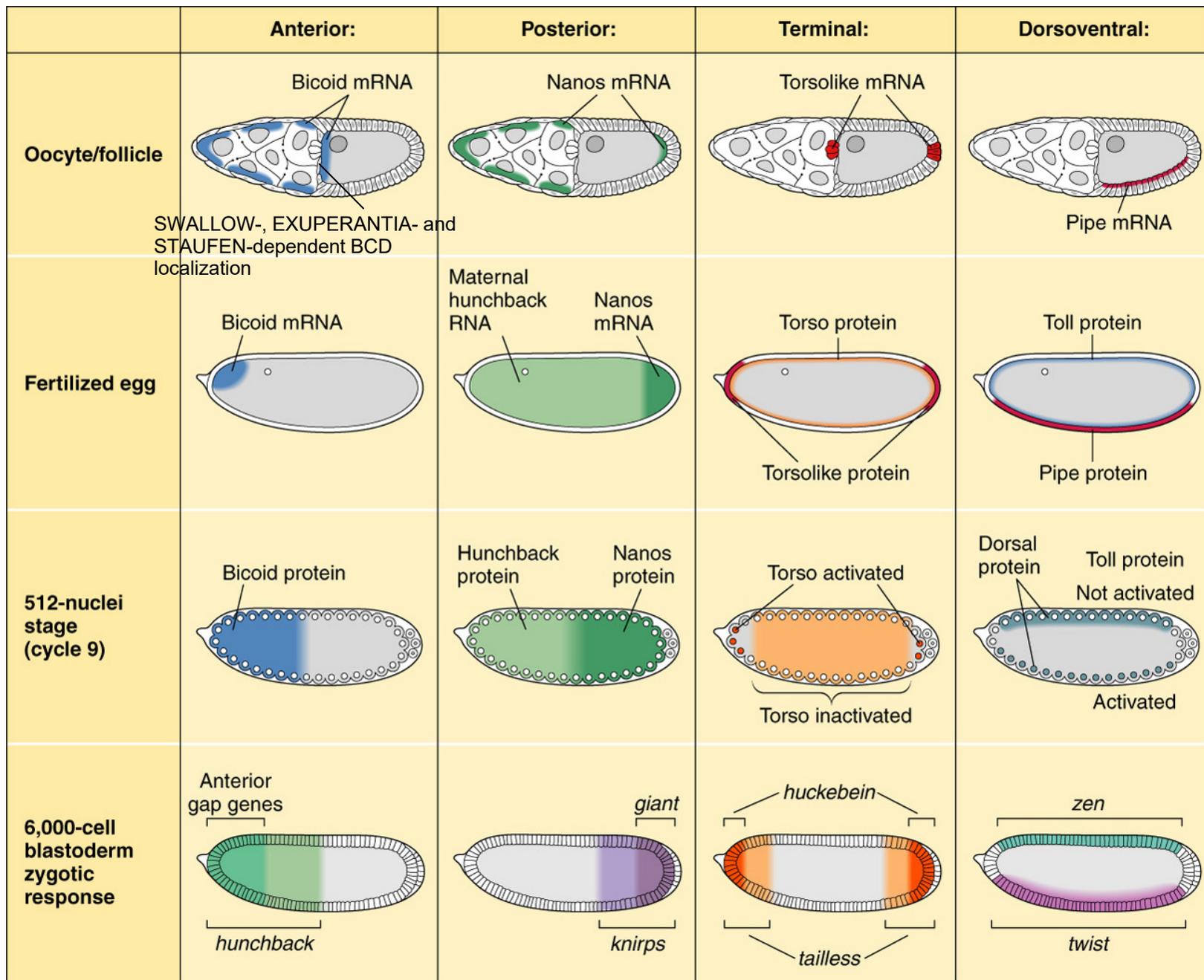
**Christiane Nüsslein-Volhard**  
The Nobel Prize in Physiology or Medicine 1995

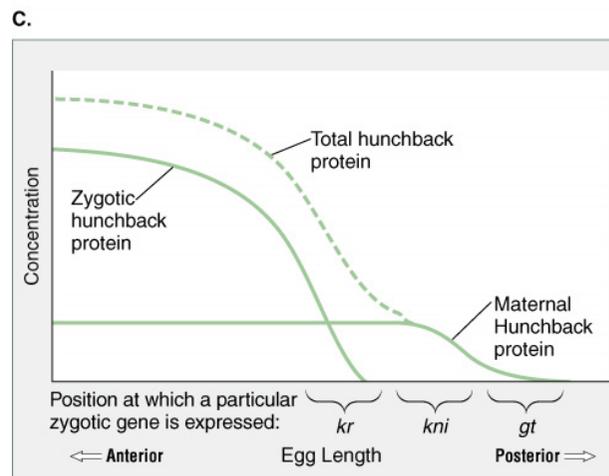
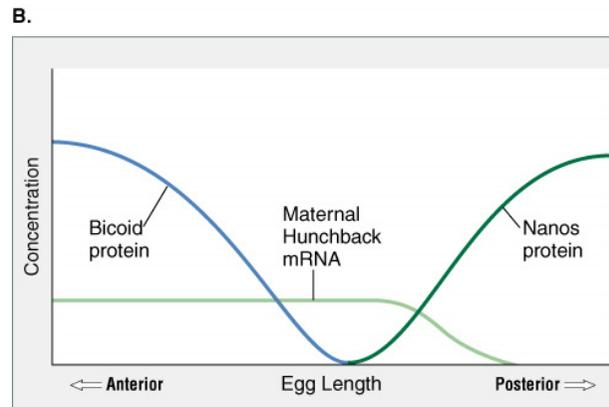
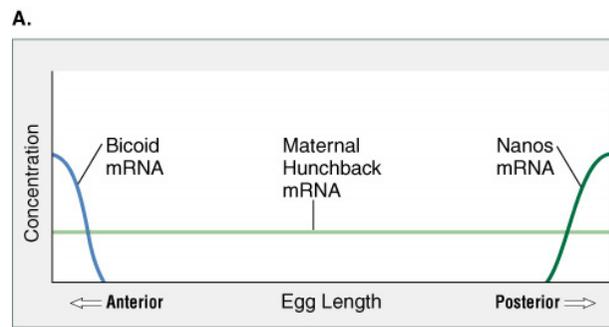


**Eric F. Wieschaus**  
The Nobel Prize in Physiology or Medicine 1995

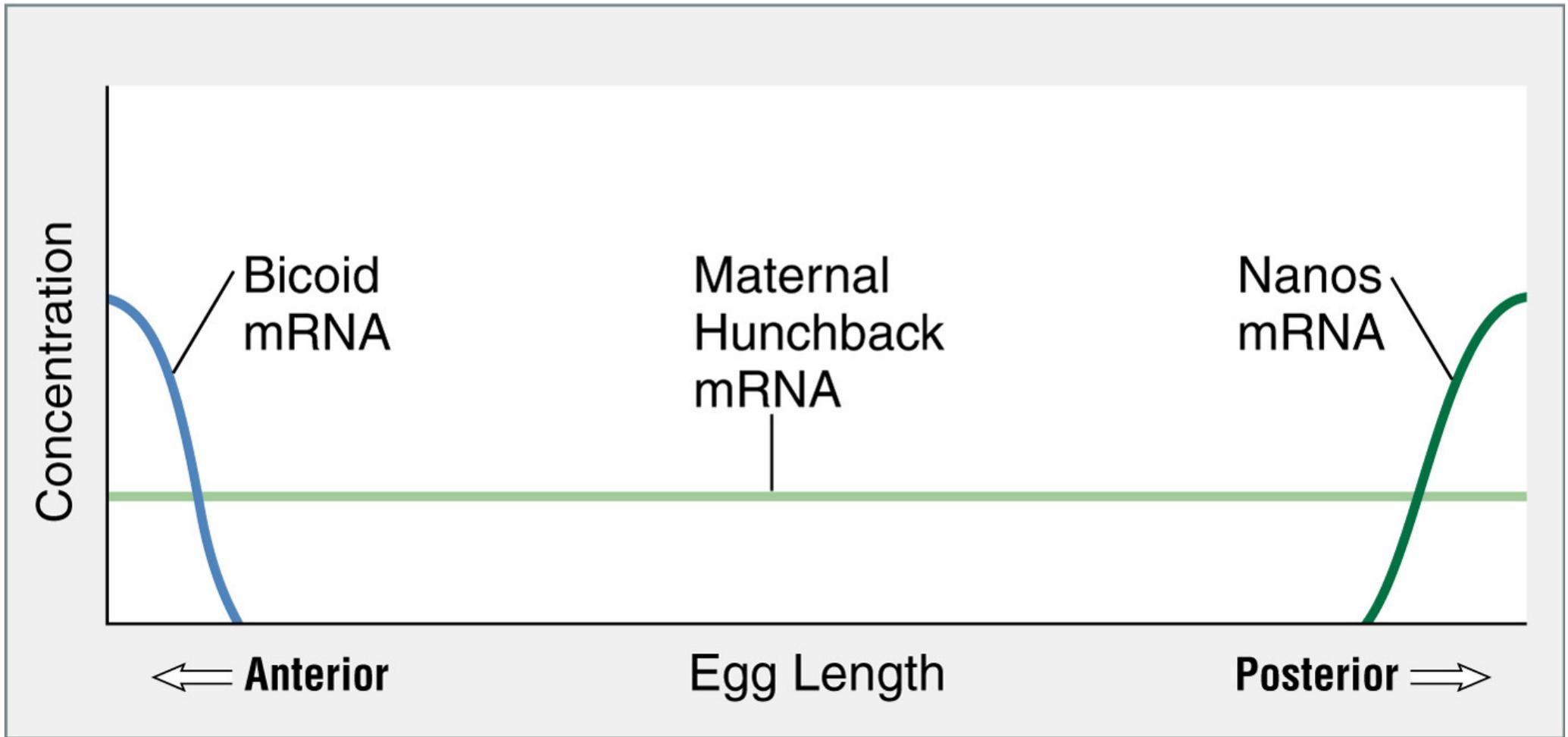
**D. The vitellarium of a  $bcd^{-/-}$  female:**



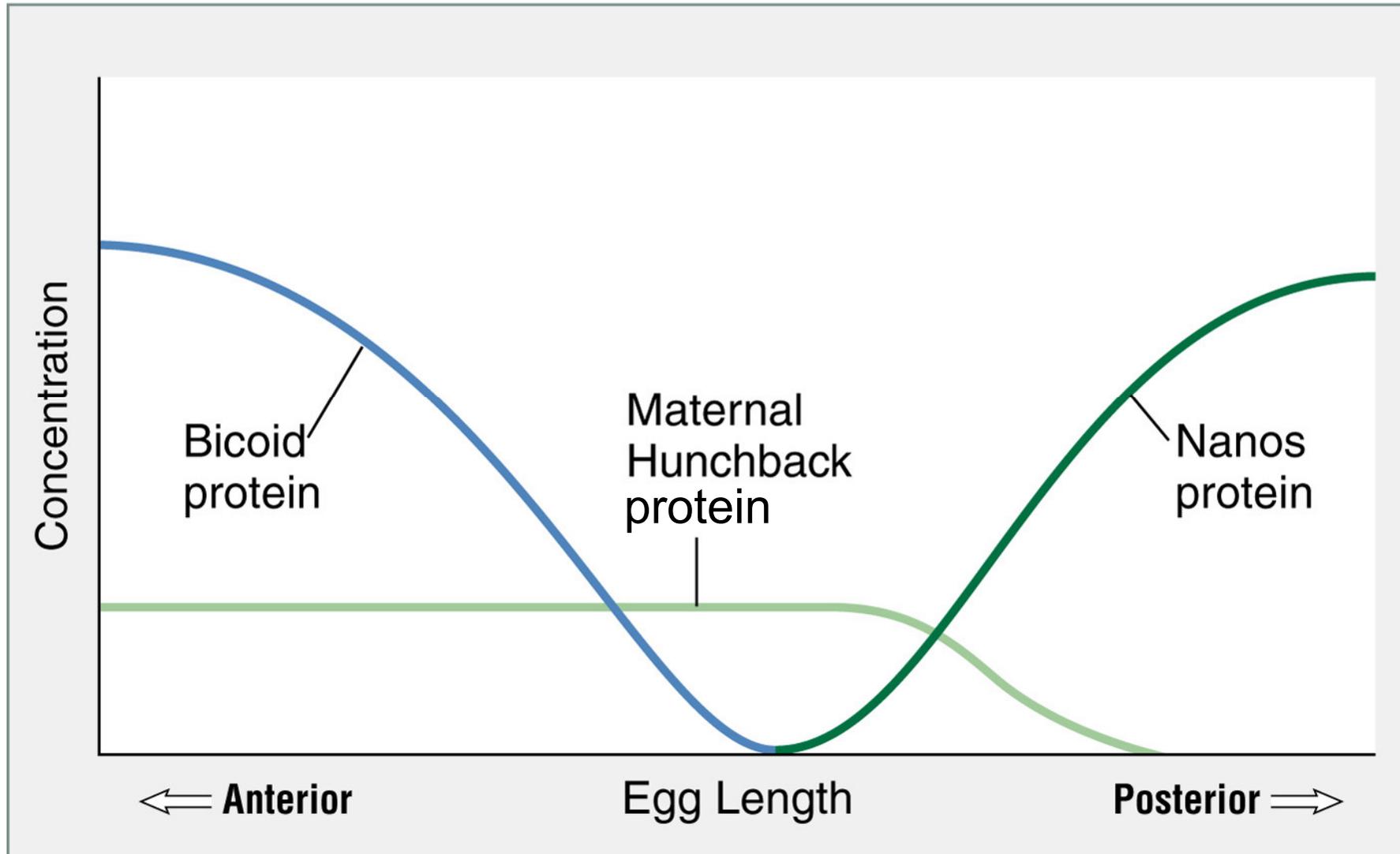




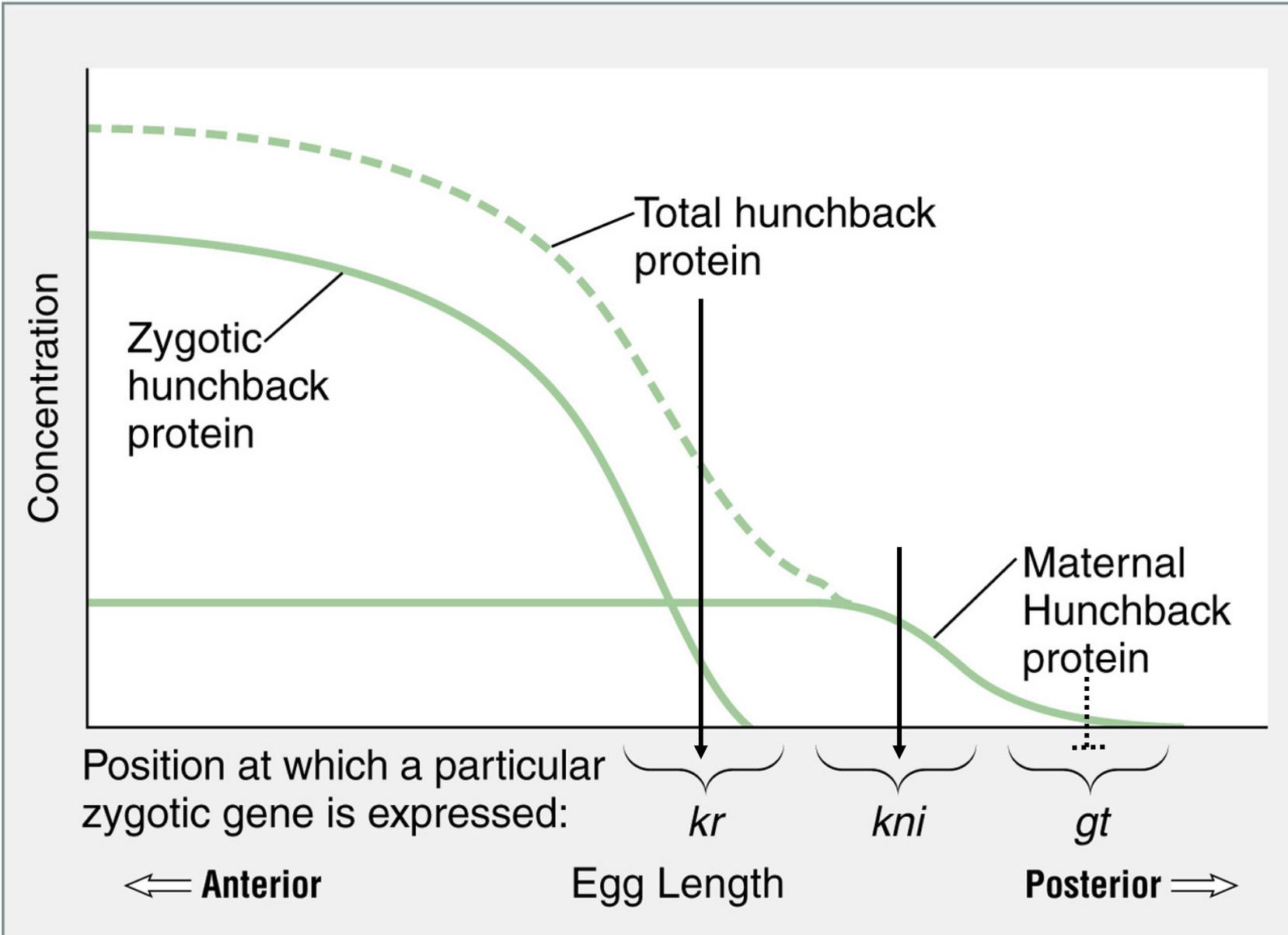
A.



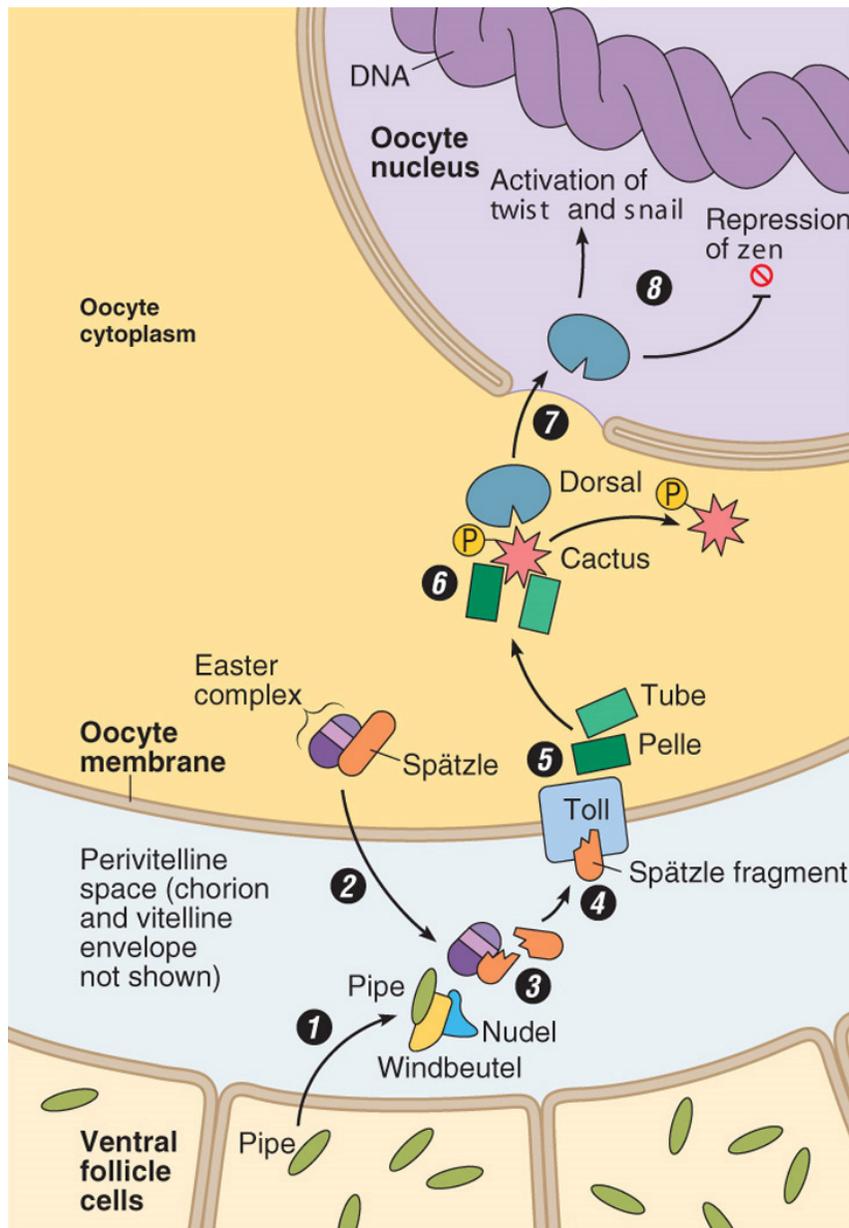
**B.**



C.

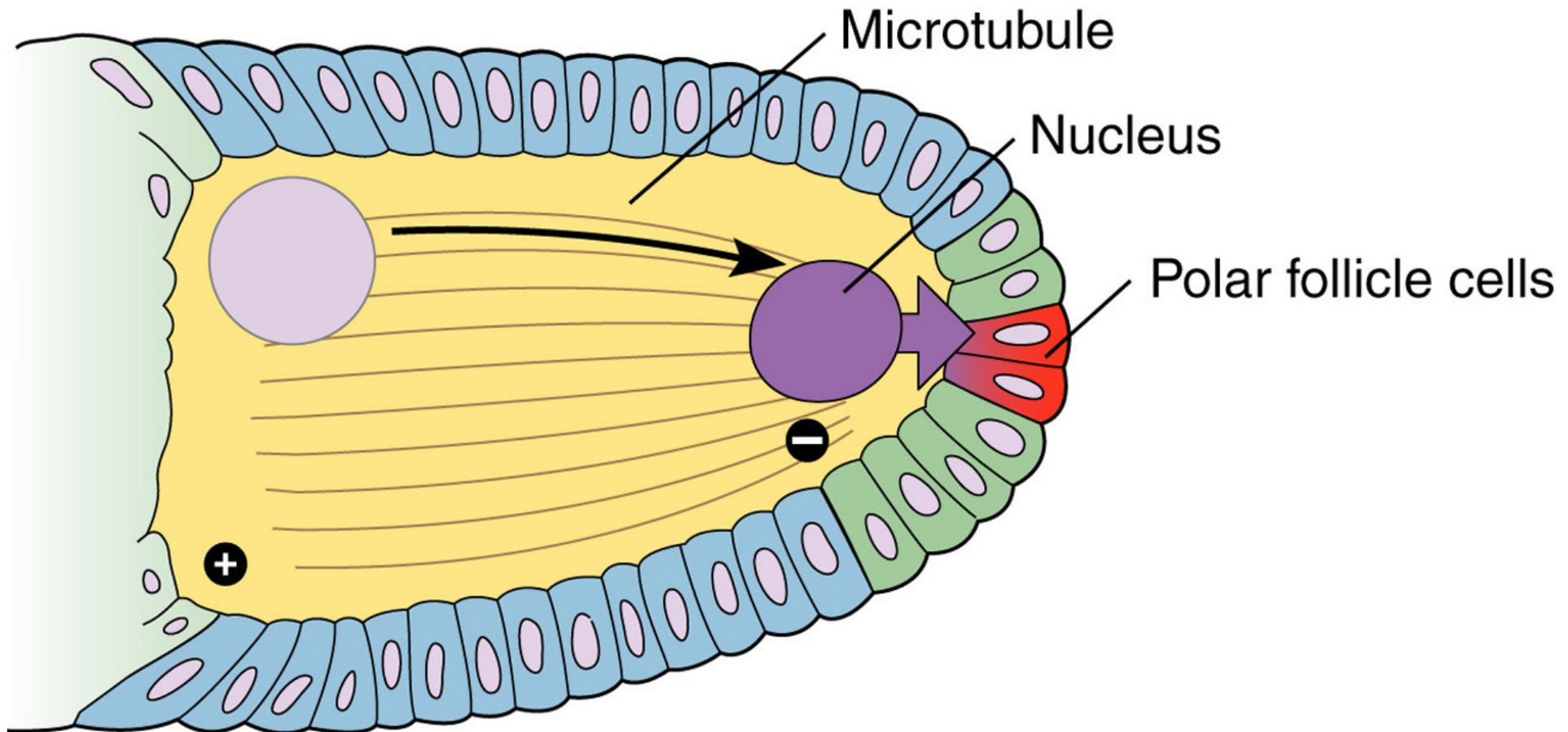


	Anterior:	Posterior:	Terminal:	Dorsoventral:
Oocyte/follicle	Bicoid mRNA 	Nanos mRNA 	Torsolike mRNA 	Pipe mRNA 
Fertilized egg	Bicoid mRNA 	Maternal hunchback RNA Nanos mRNA 	Torso protein Torsolike protein 	Toll protein Pipe protein 
512-nuclei stage (cycle 9)	Bicoid protein 	Hunchback protein Nanos protein 	Torso activated Torso inactivated 	Dorsal protein Toll protein Not activated Activated 
6,000-cell blastoderm zygotic response	Anterior gap genes hunchback 	giant knirps 	huckebein tailless 	zen twist 



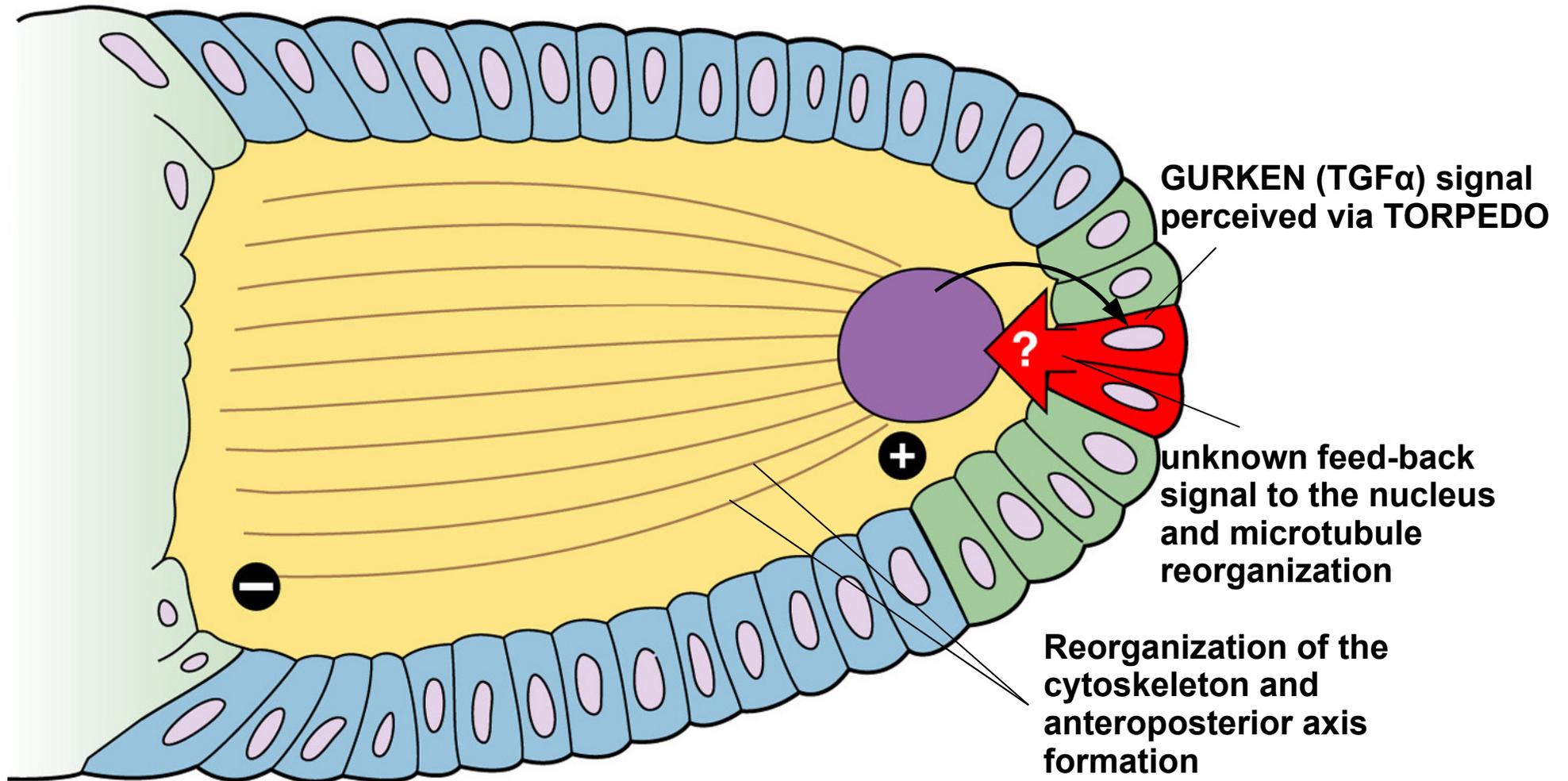
- 1 Only ventral follicle cells make Pipe. Complex of Pipe, Nudel, and Windbeutel proteins is secreted (only on ventral side). Pipe sulfates glycosaminoglycans (see Chapter 12) on the ventral side.
- 2 Nurse cells have deposited mRNA for Easter complex in the egg, and the Easter protein complex, which includes Snake and Gastrulation defective (Gdp), is secreted around the egg.
- 3 Easter complex and Pipe complex together cleave Spätzle.
- 4 Spätzle fragment activates the Toll receptor.
- 5 Toll activates Tube and Pelle.
- 6 Tube and Pelle phosphorylate Cactus so that it dissociates from Dorsal.
- 7 Free Dorsal enters the nucleus. It is a transcription factor.
- 8 Dorsal stimulates *twist* and *snail* (in mesoderm) and represses *zen* (in dorsal epithelium).

## A. Gurken induces polar follicle cells to adopt a posterior fate

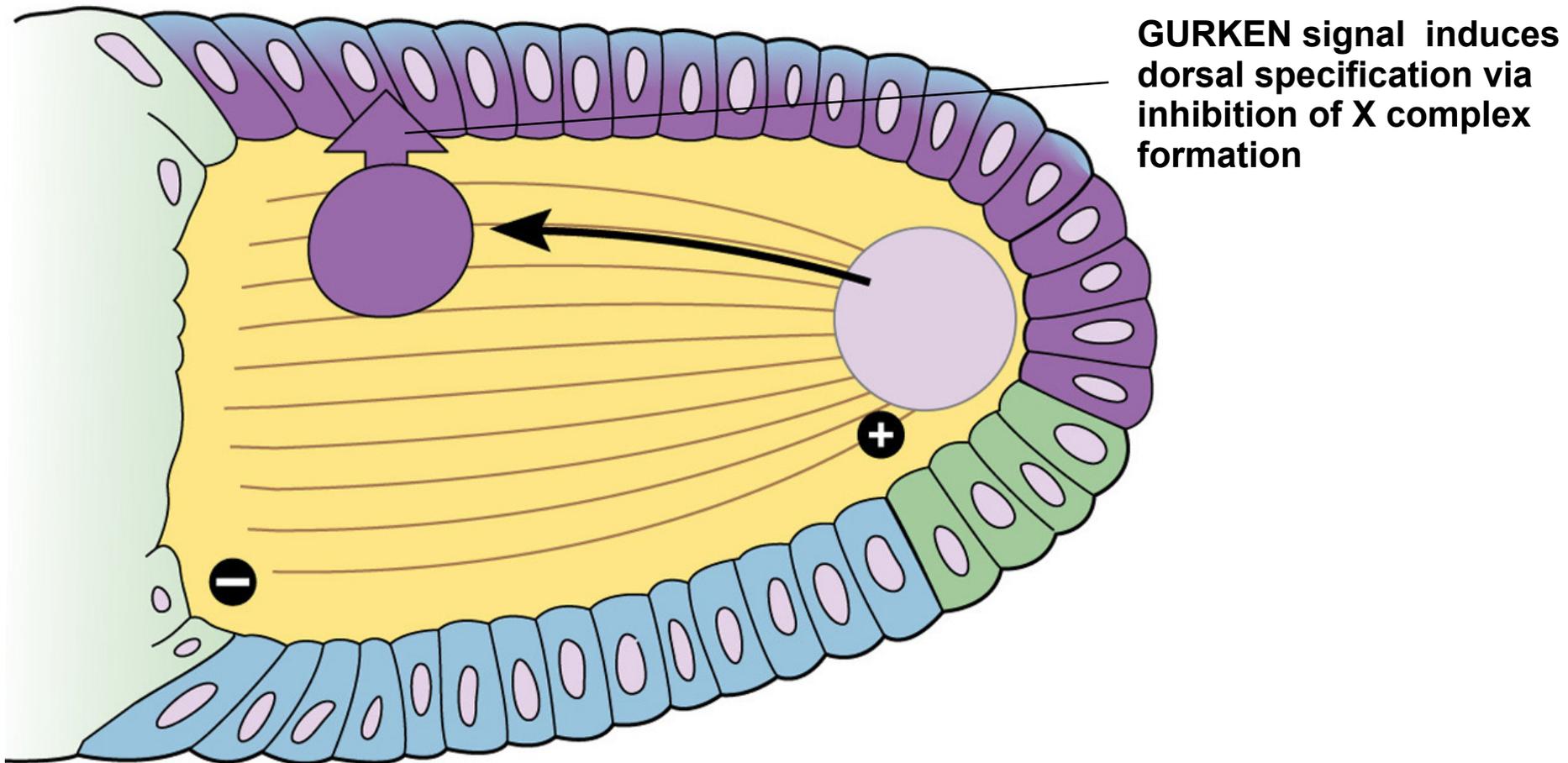


**Maternal tissue** as a **source of asymmetry** in the early *Drosophila* formation

## B. Unidentified signal induces repolarization of oocyte microtubules



## C. Nucleus moves up, to anterior pole, via microtubules where Gurken induces follicle cells to adopt dorsal fate



# Key Concepts

- **Axis formation** is based on the **asymmetrical distribution of molecular determinants**, mostly proteins and RNAs. Processes ensuring the asymmetrical distribution of those process occur **very early in the oogenesis**.
- The **cytoplasm may contain factors** (TFs) that regulate the expression of **target genes in the nucleus** as shown in pole plasm transplation experiments.
- During early development, the **developmental potential of cells** or group of cells **changes**.
- **Gastrulation** comprises a suite of **coordinated cell divisons and movements** that results into movement of specific cells from the surface to the interior.
- The **cytoplasm of embryo** in *Drosophila* and almost all other animal embryos **is heterogenic** in terms of the distribution of factors that regulate developmental fate of adjacent cells. The **origin of this heterogeneity is in the maternal tissue** and its **mutual interaction with the oocyte**.