

C8545 Developmental Biology

Lesson 2

Early Development of *Drosophila*

Jan Hejátko

Functional Genomics and Proteomics of Plants

CEITEC

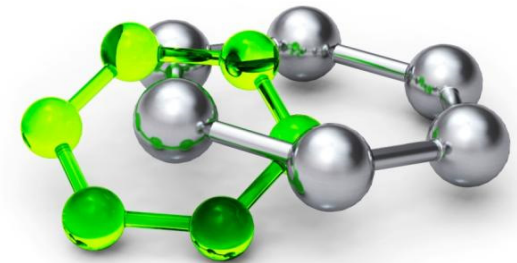
and

National Centre for the Biomolecular Research,

Faculty of Science

M U N I
S C I

Masaryk University, Brno
hejatko@sci.muni.cz, www.ceitec.eu



Outline of Lesson 2

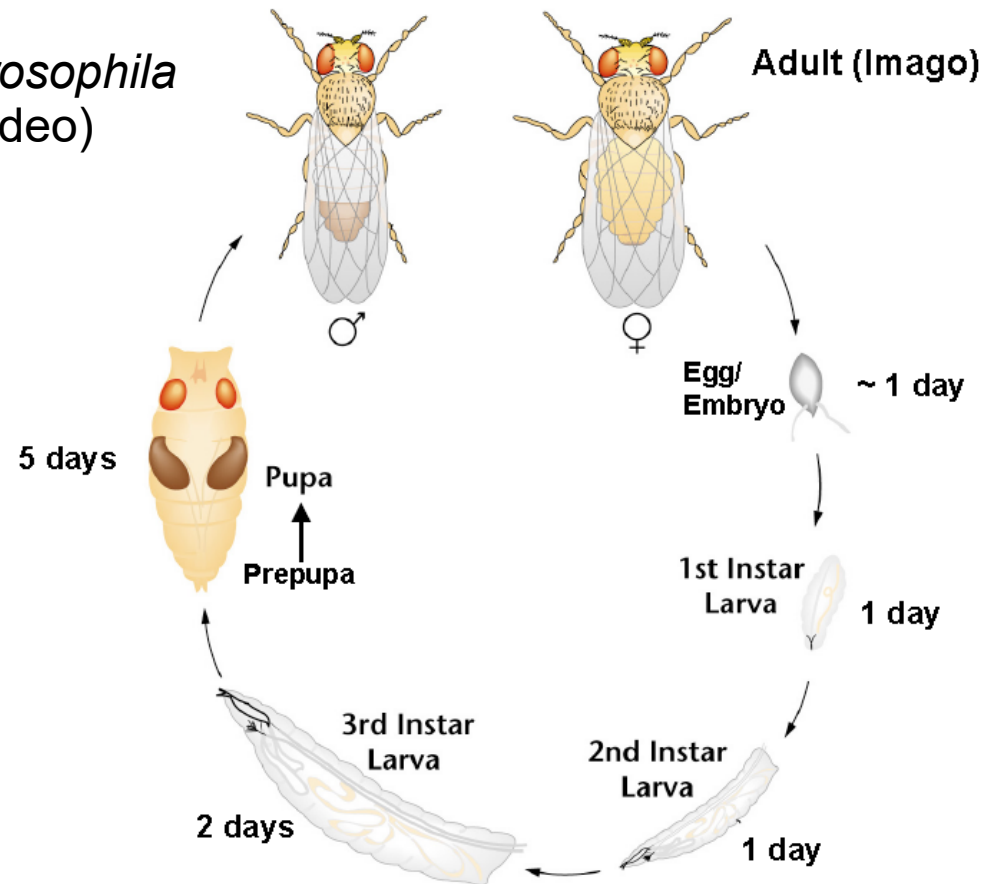
Early Development of *Drosophila*

- 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*

Outline of Lesson 2

Early Development of *Drosophila*

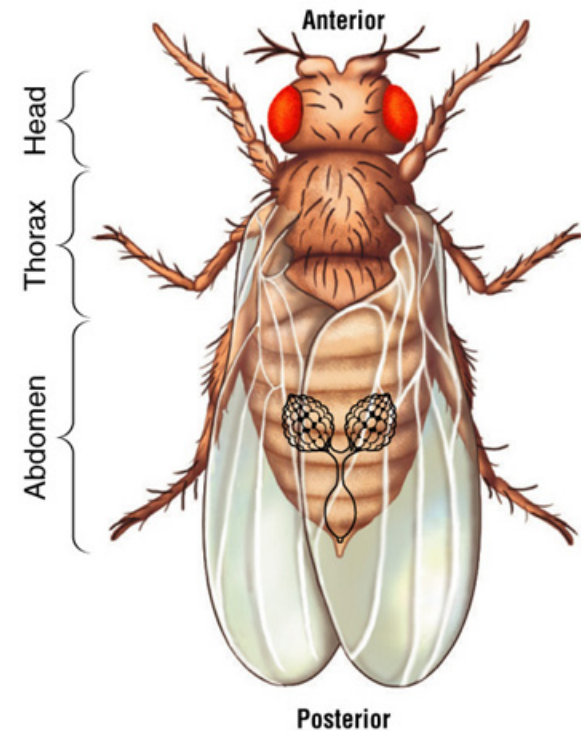
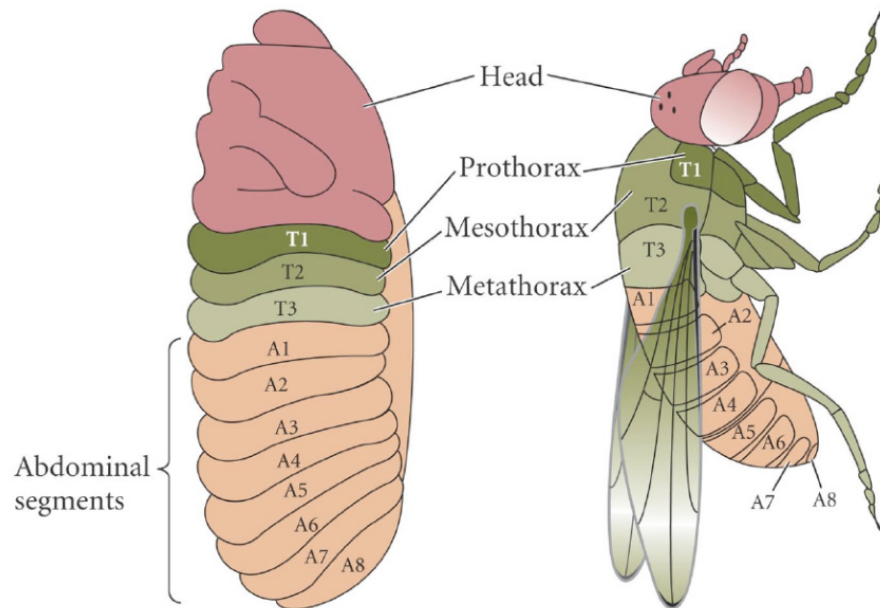
- Introduction into *Drosophila*
 - Life cycle (video)



Outline of Lesson 2

Early Development of *Drosophila*

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



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Early Development of *Drosophila*

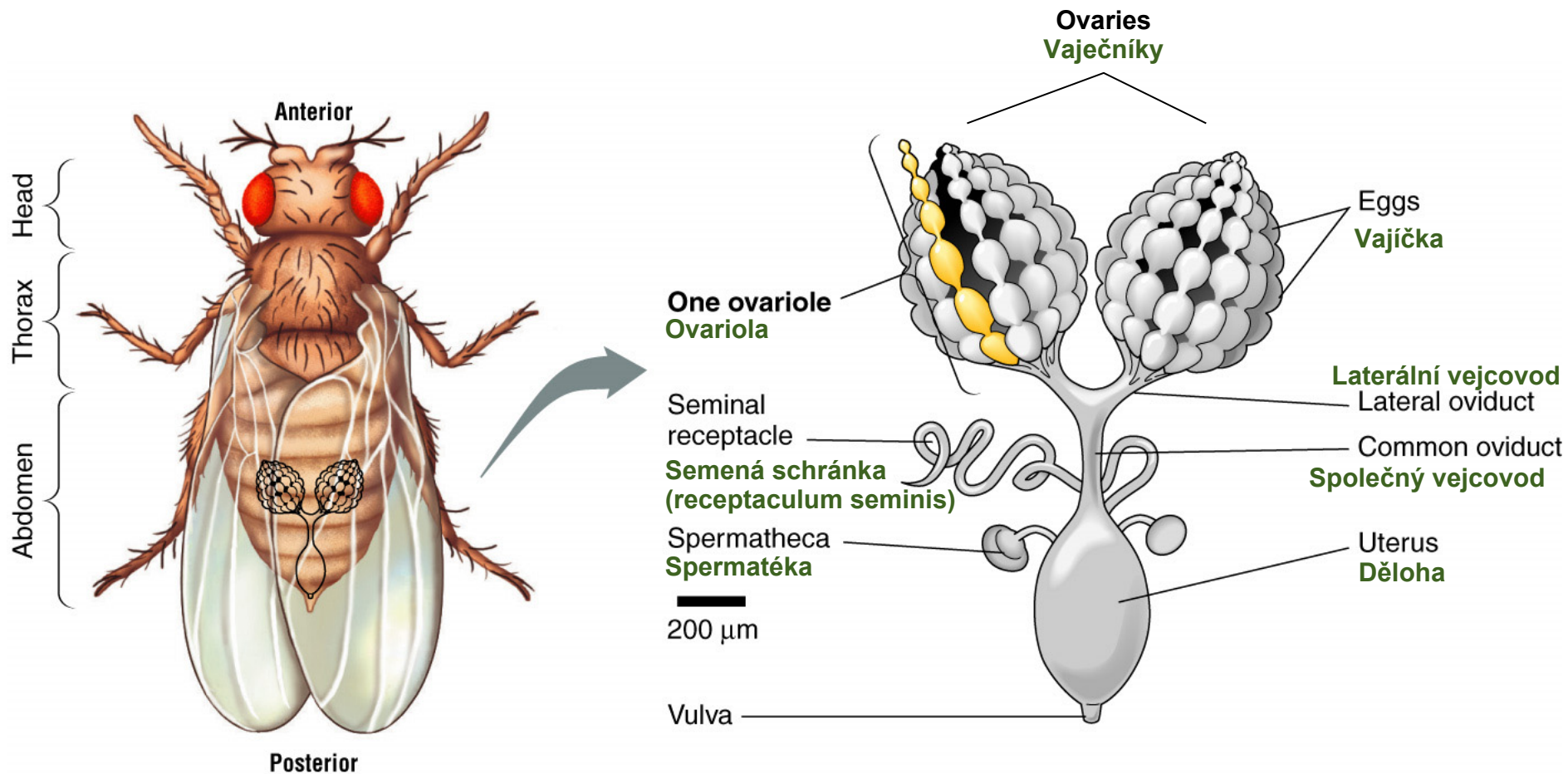
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 - Mating (video)



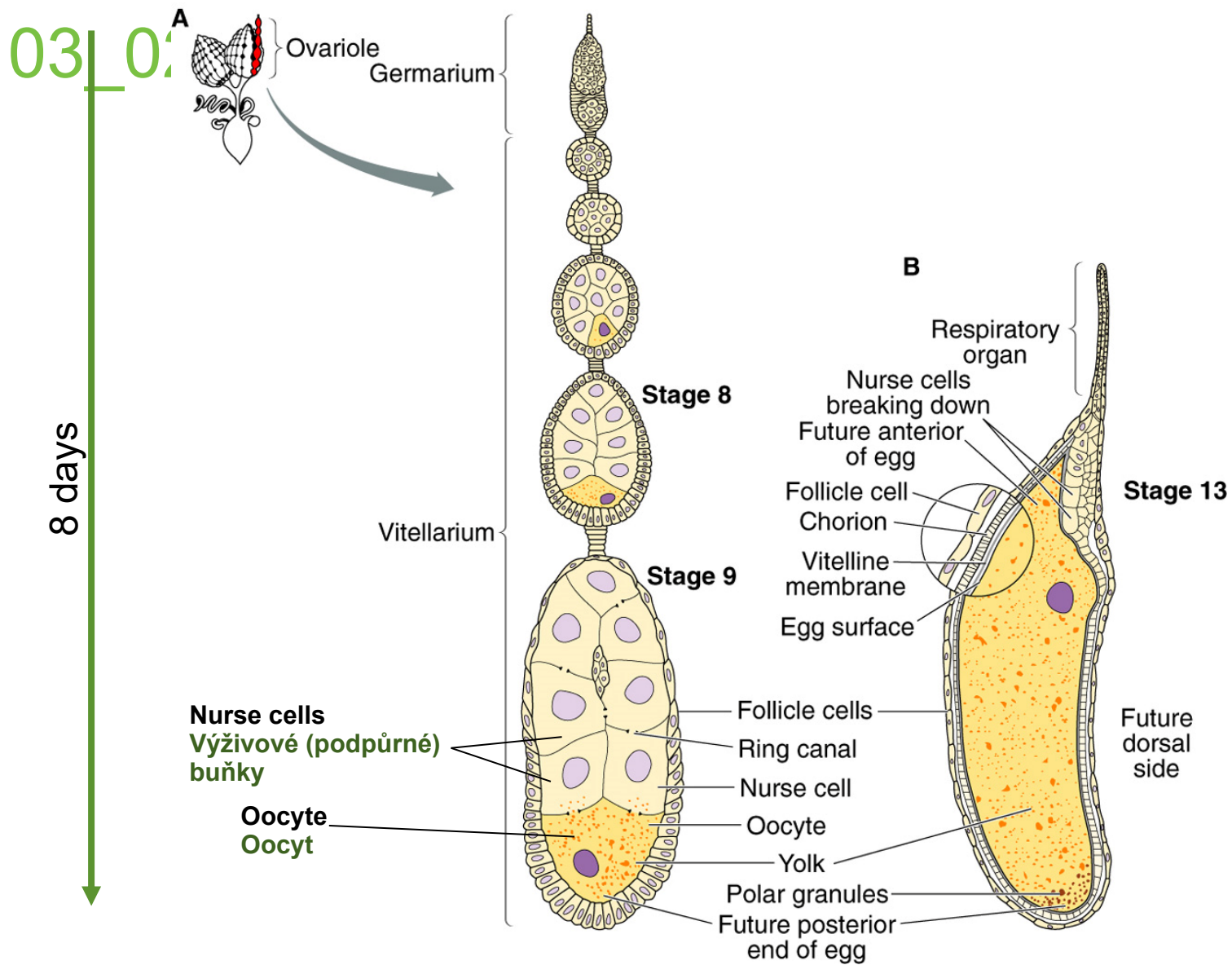
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Early Development of *Drosophila*

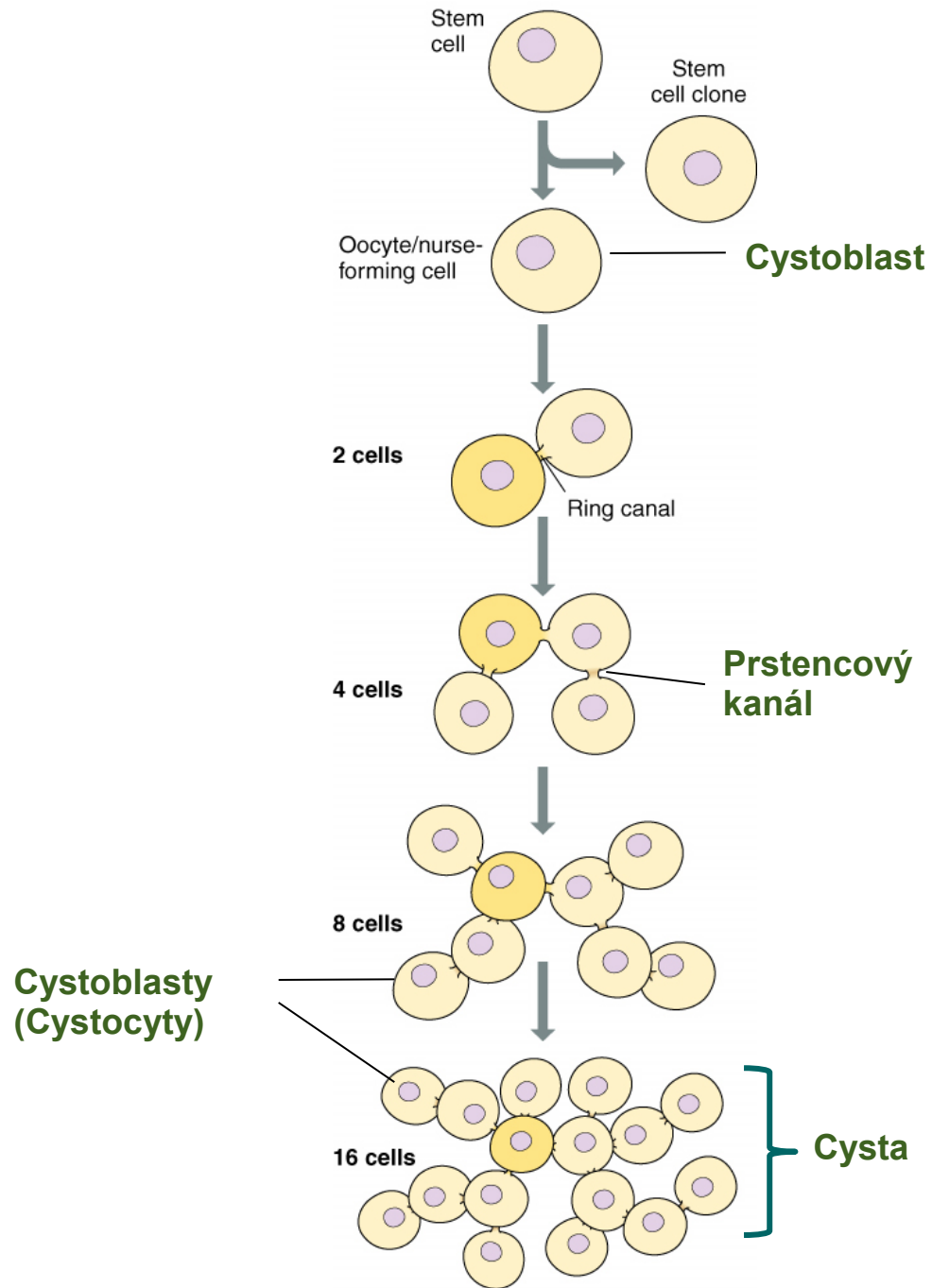
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 - Anatomy (video)
 - Mating (video)
- Oogenesis



- Video of sperm size and behavior









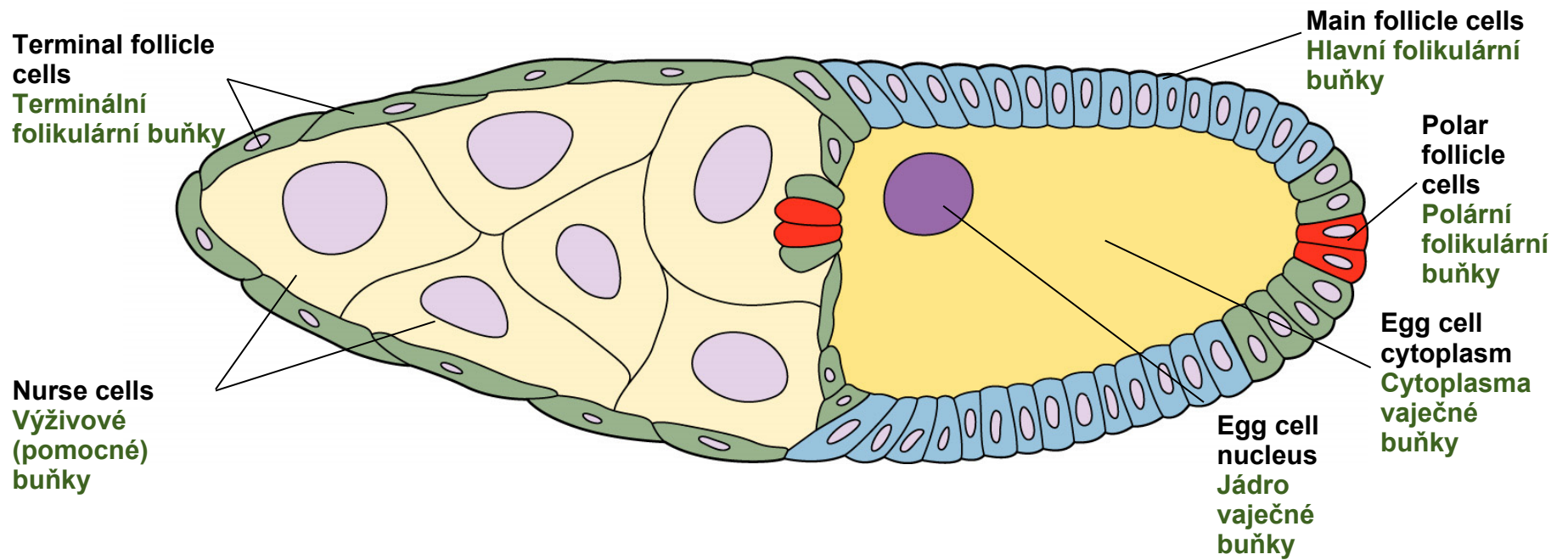
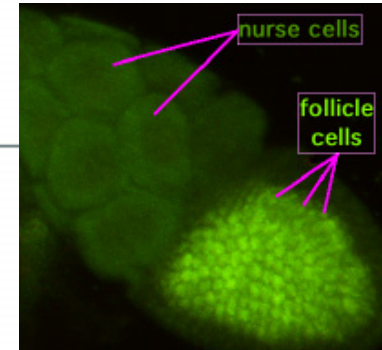
Oogonium/stem cell division



A.

KEY

Follicle cells:		Germline cells:	
	Main body		Nurse
	Polar		Oocyte cytoplasm
	Terminal		Oocyte nucleus

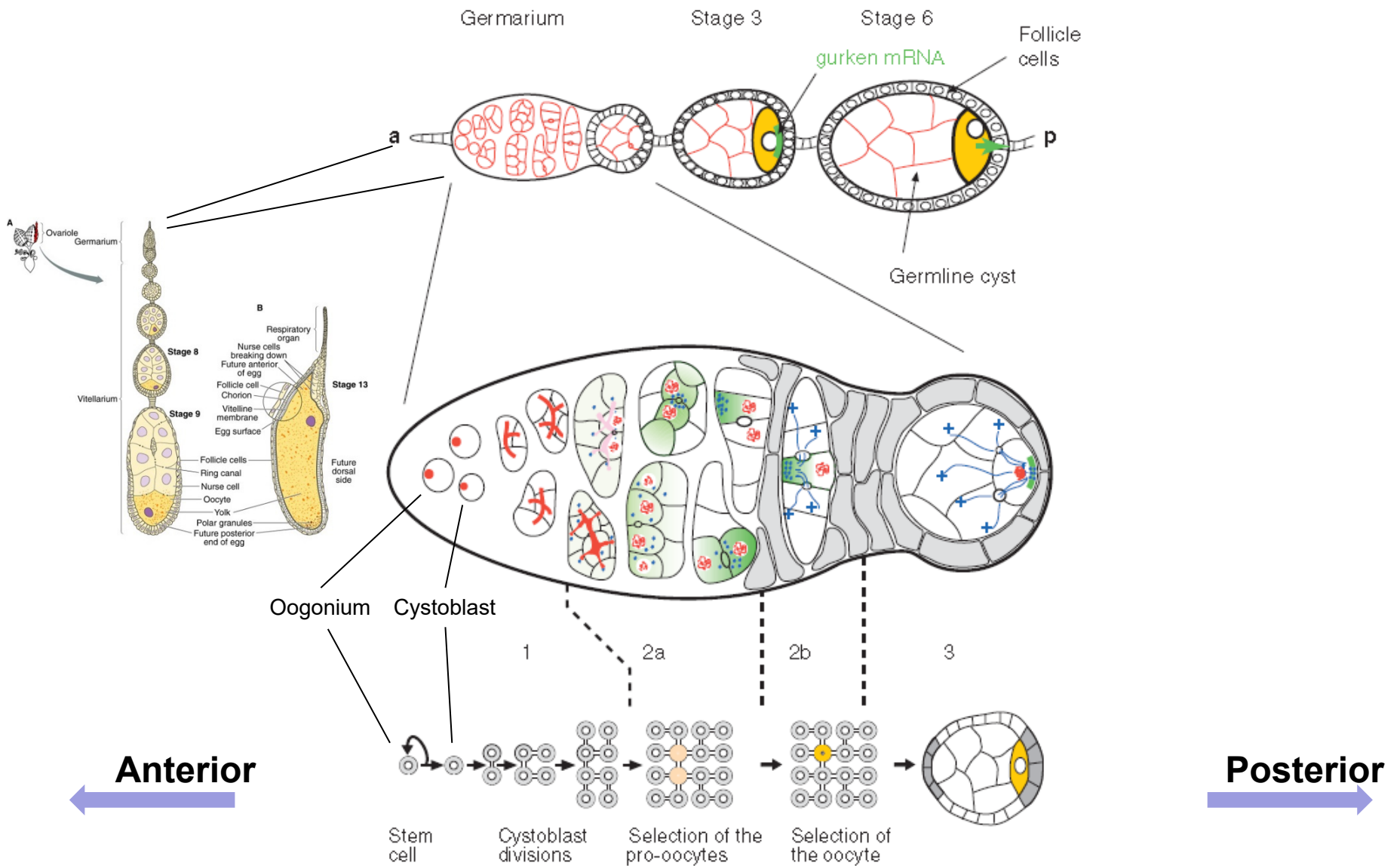


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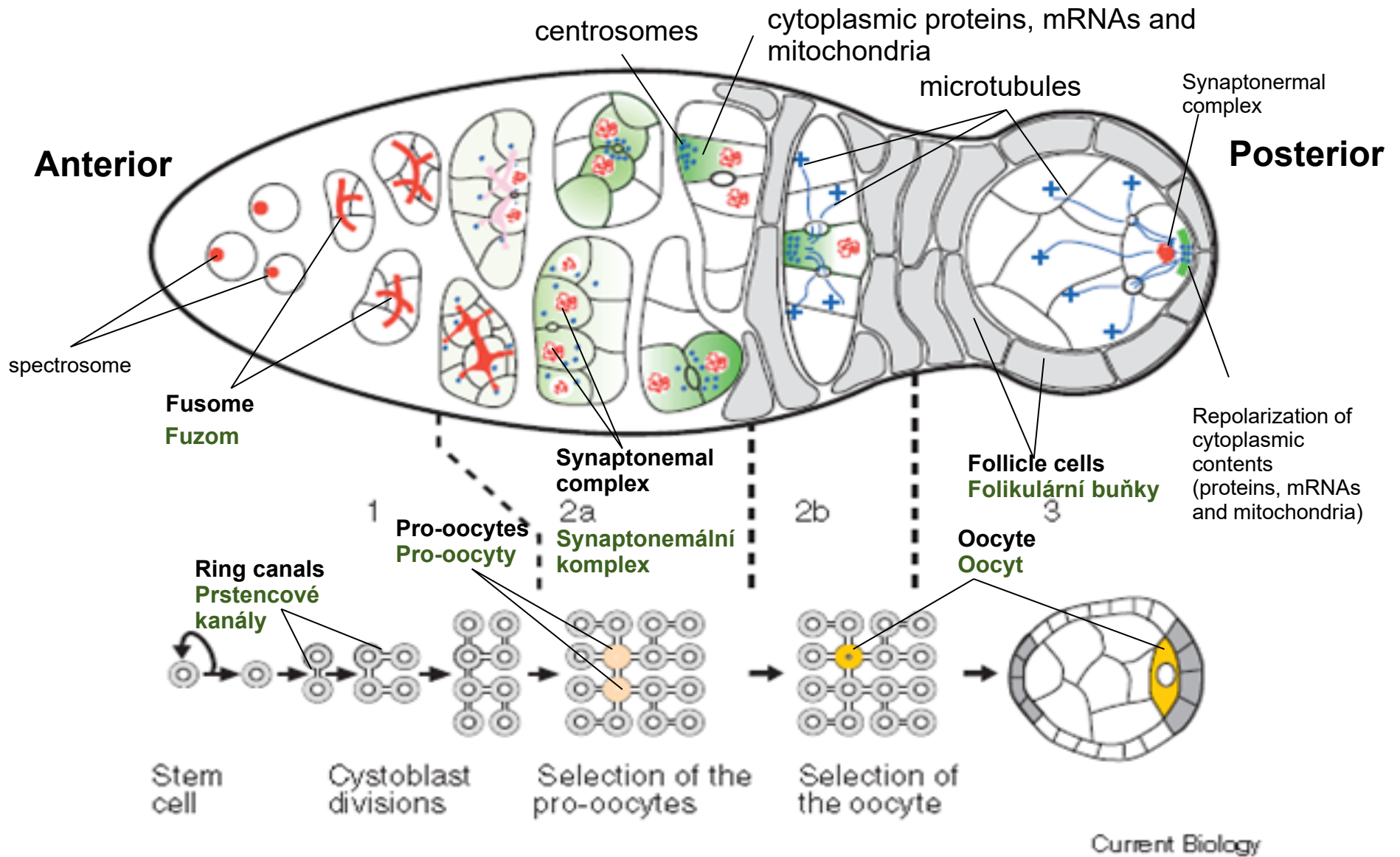
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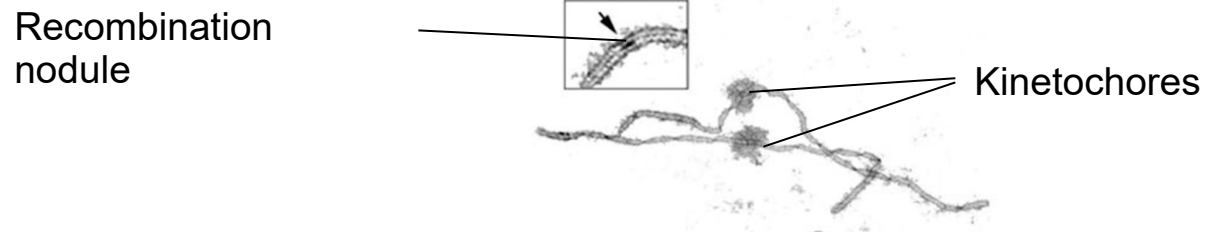
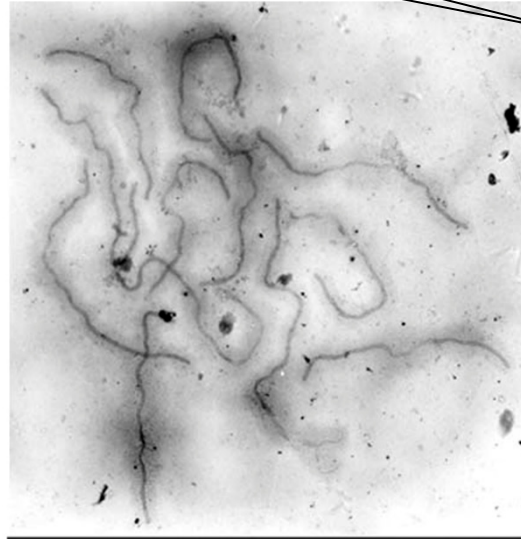
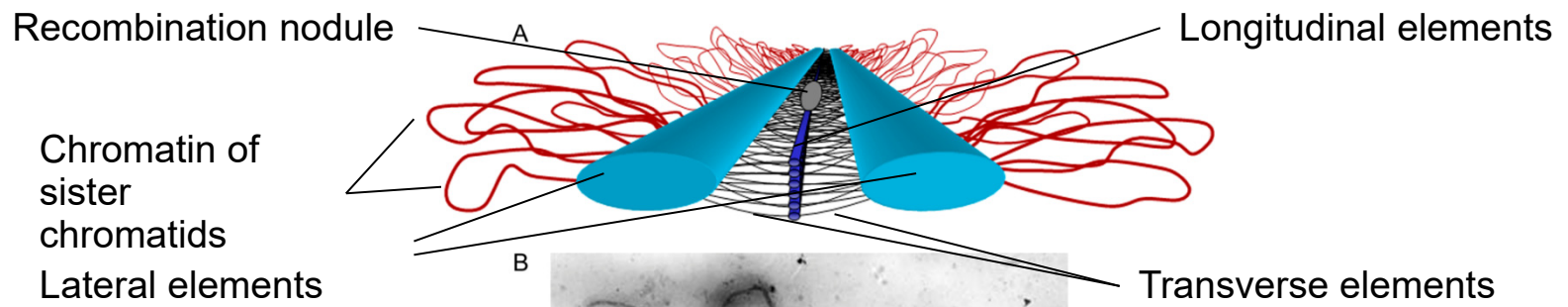


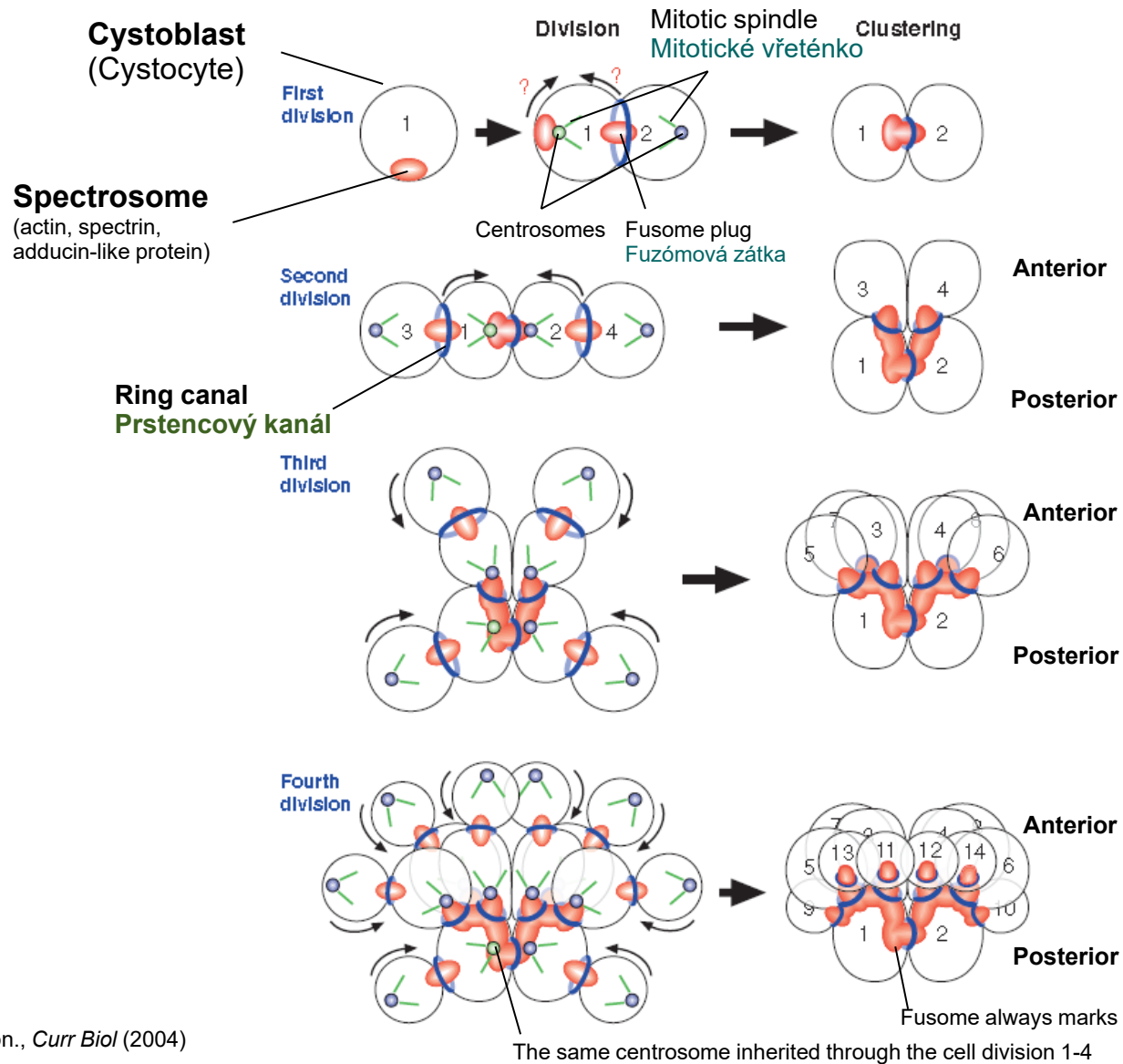
Huynh and Johnston., *Curr Biol* (2004)

Current Biology

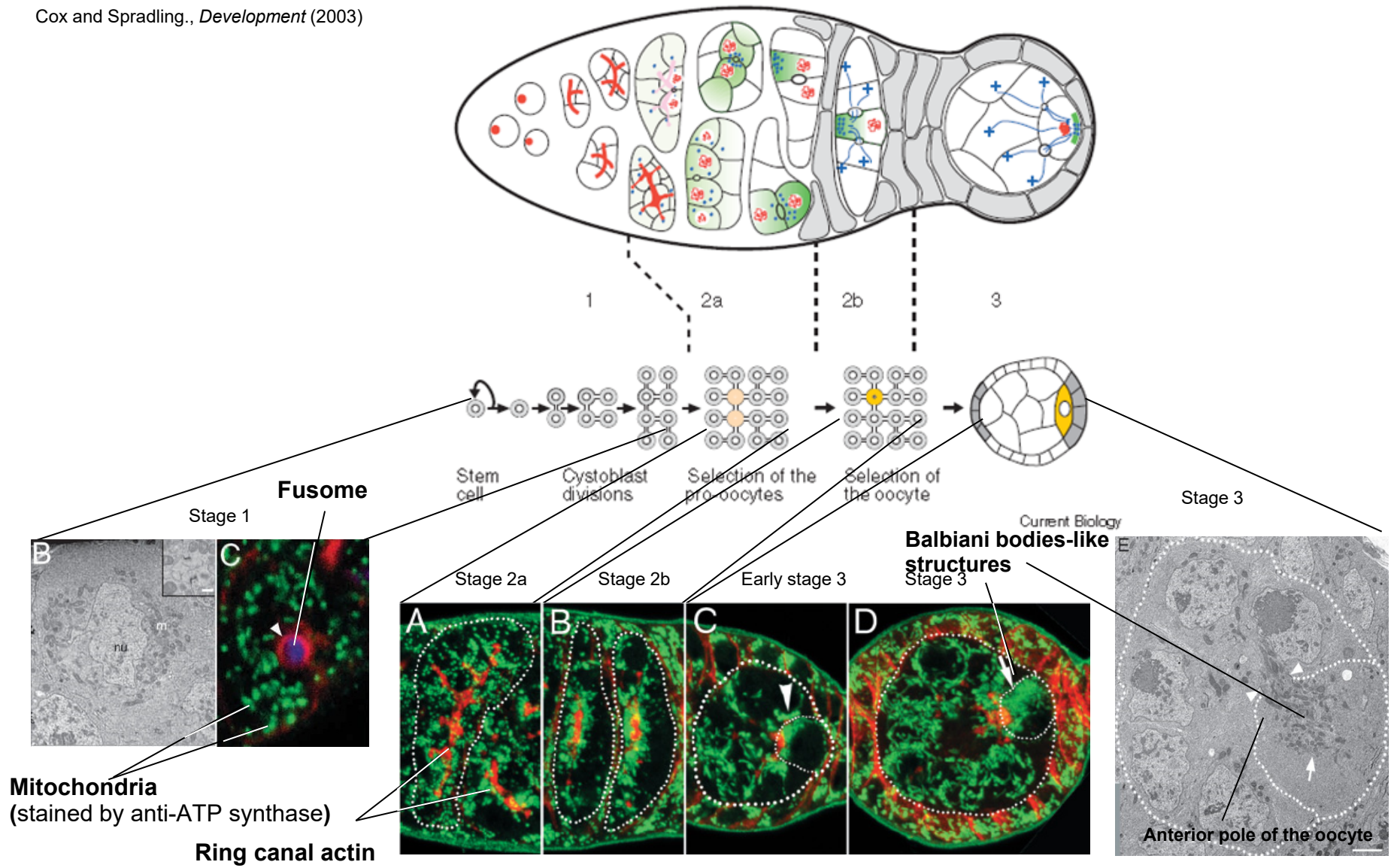


Huynh and Johnston., *Curr Biol* (2004)





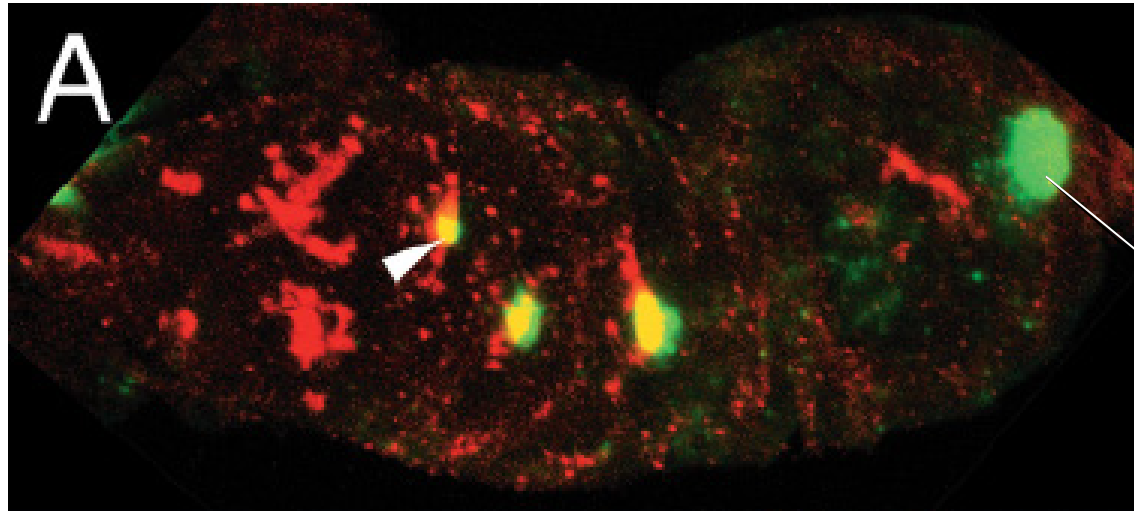
Huynh and Johnston., *Curr Biol* (2004)



OSK

- mRNA stability,
- Oocyte microtubule cytoskeleton polarization
- Oogenesis

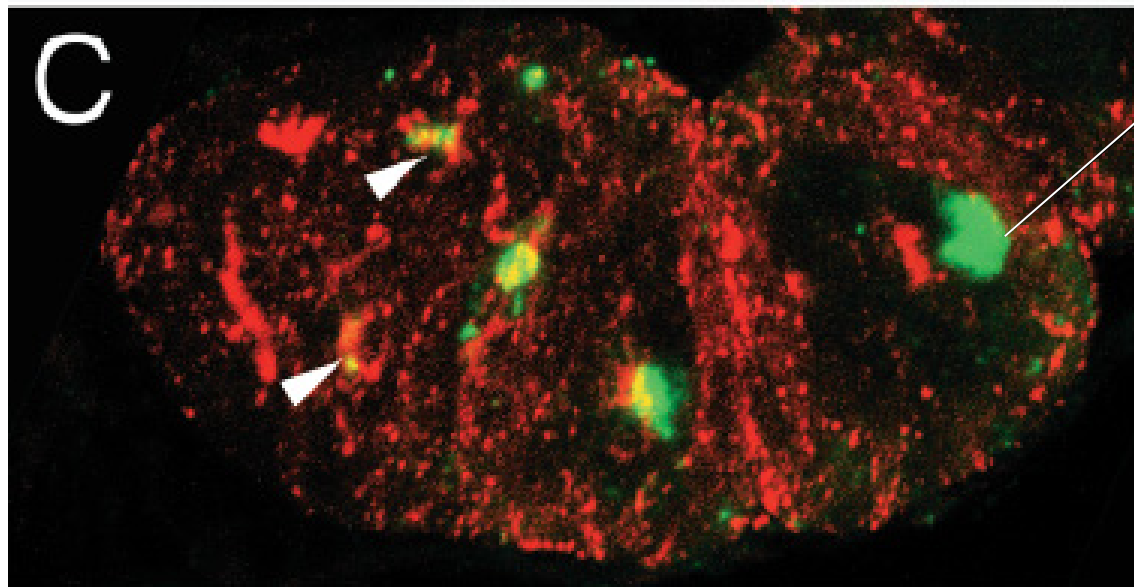
ANTERIOR



ORB

- mRNA translation,
- mRNA polyadenylation

C



POSTERIOR

Repolarization in stage 3

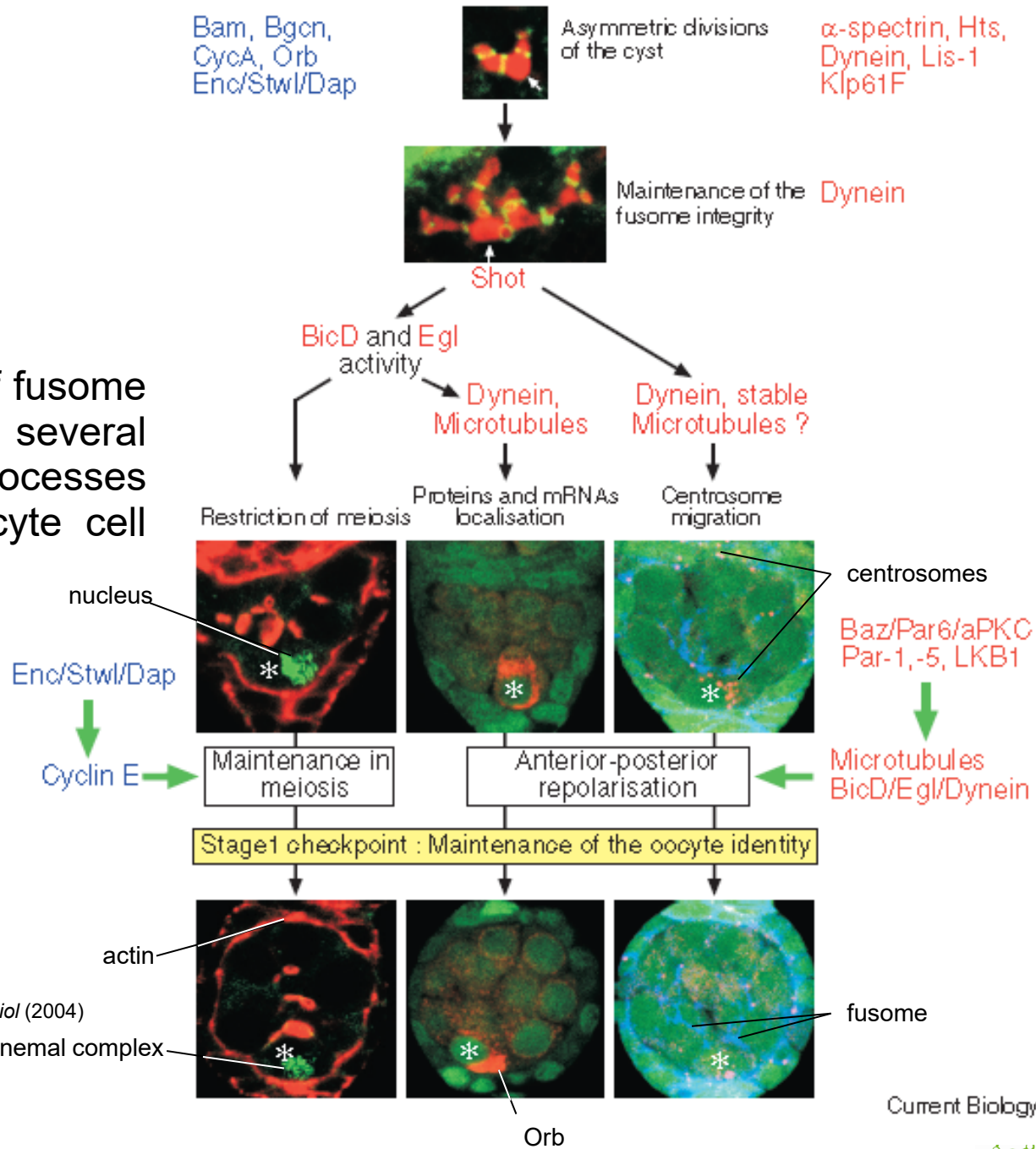
Cox and Spradling, *Development* (2003)

Stage 2a

Stage 2b

Stage 3

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

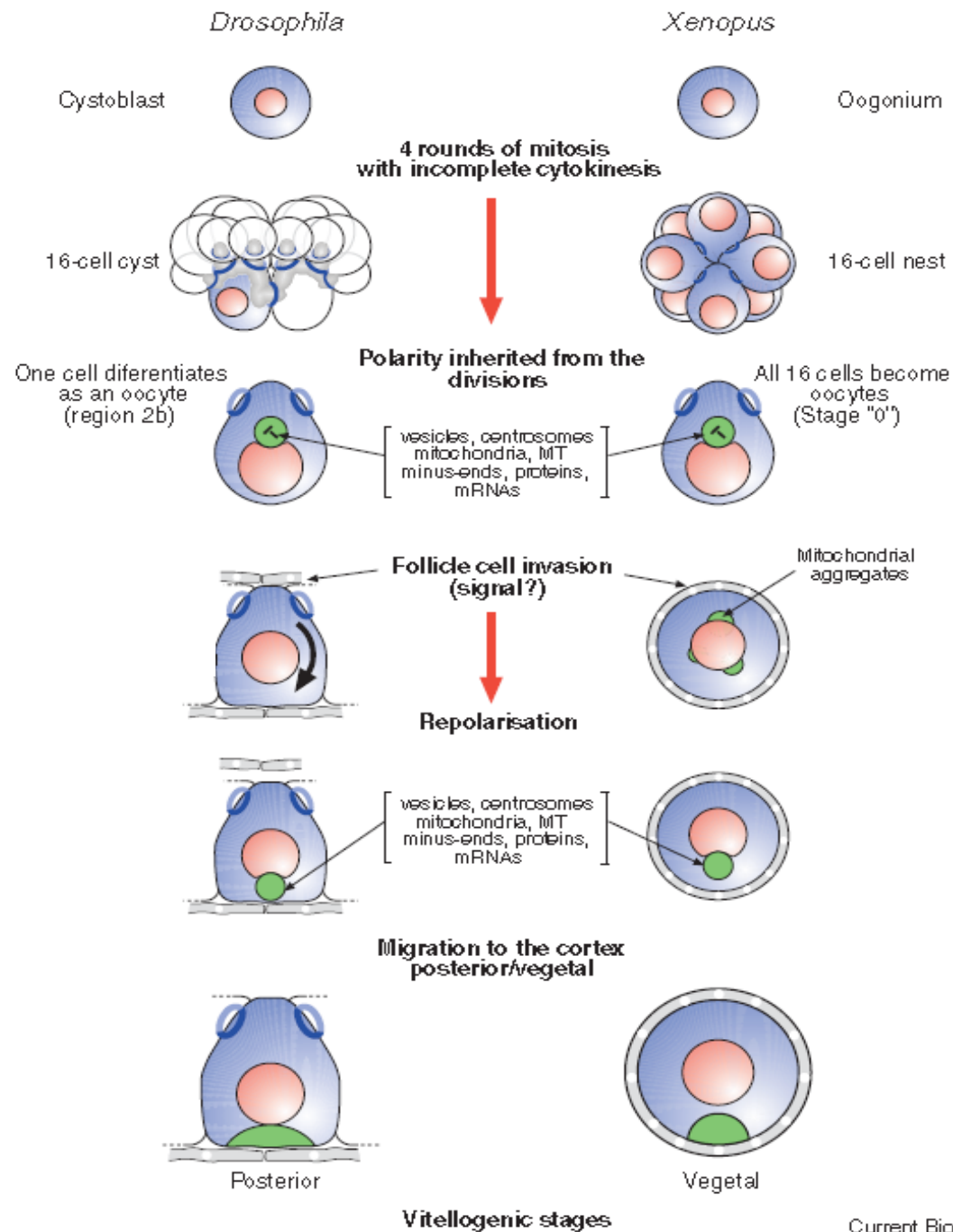


Huynh and Johnston., *Curr Biol* (2004)

Synaptonemal complex

Current Biology

LEITEC



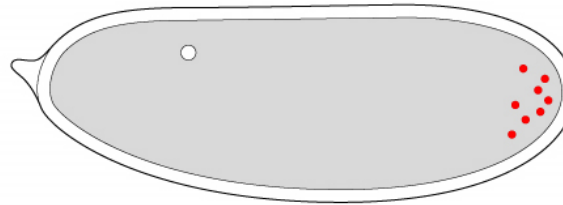
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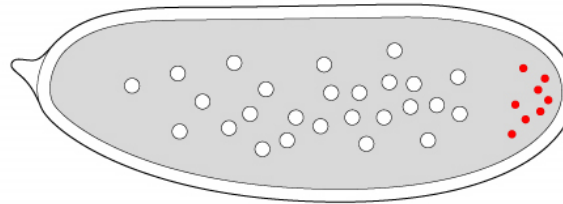
Anterior ↔ Posterior

Stage 1
10 min
1 nucleus



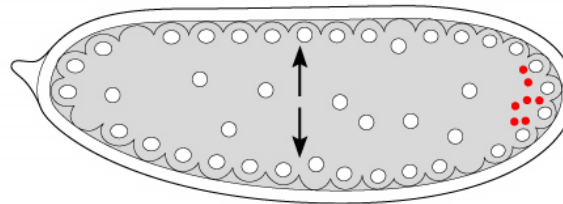
Formation of polar granules

Stage 7
72 min
64 nuclei



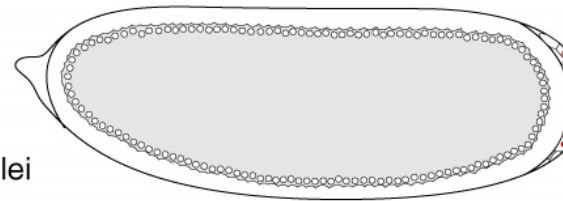
Buildup of nuclei

Stage 8
90 min
128 nuclei



Migration of nuclei

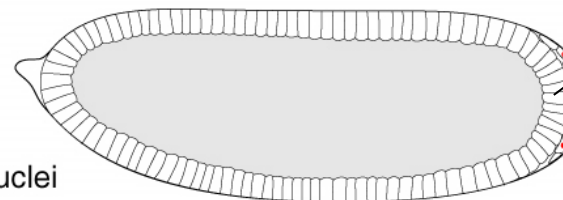
Stage 10
150 min
about 750 nuclei



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

Formation of pole cells

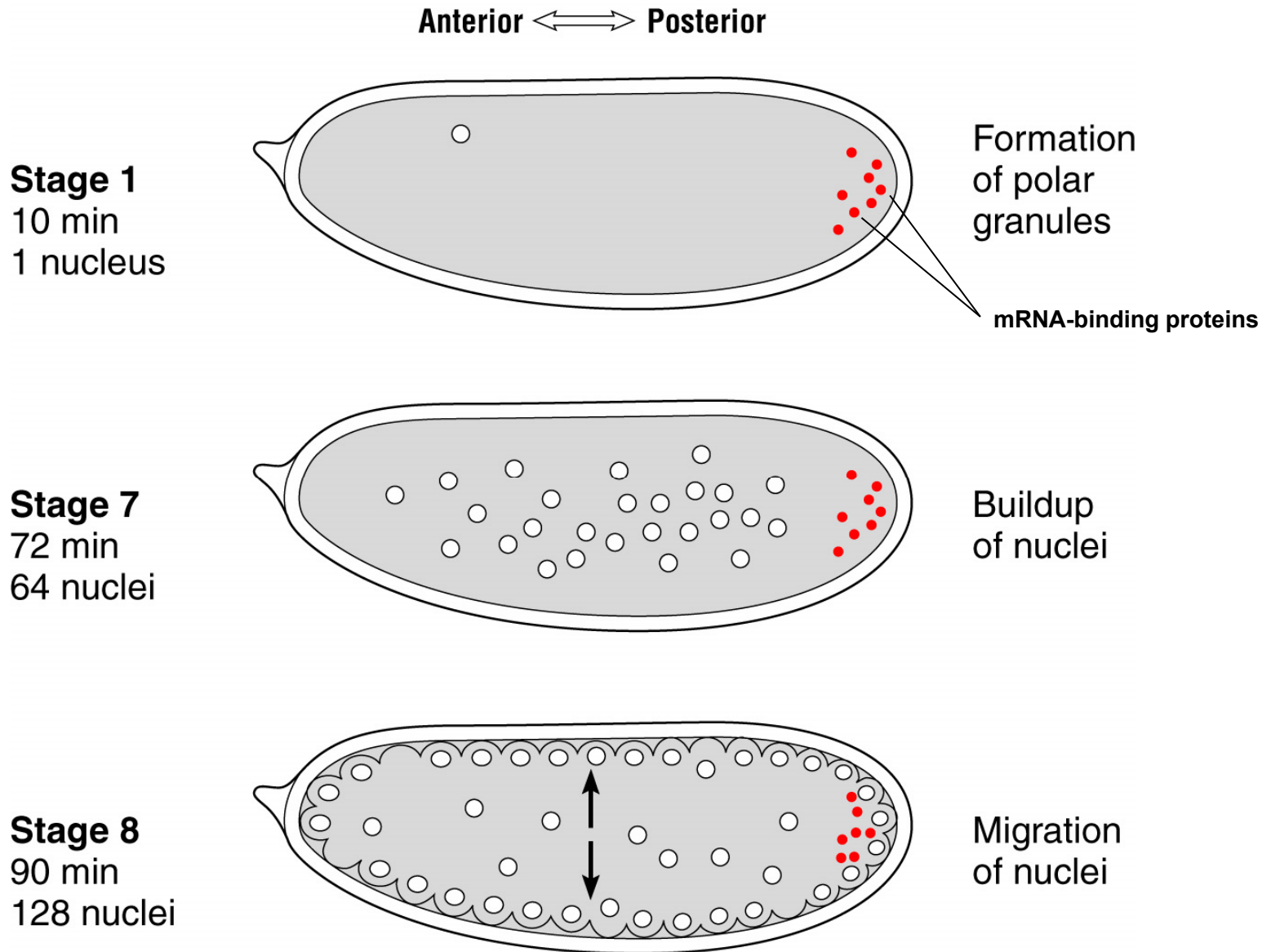
Stage 14
about 4 h
about 2,048 nuclei

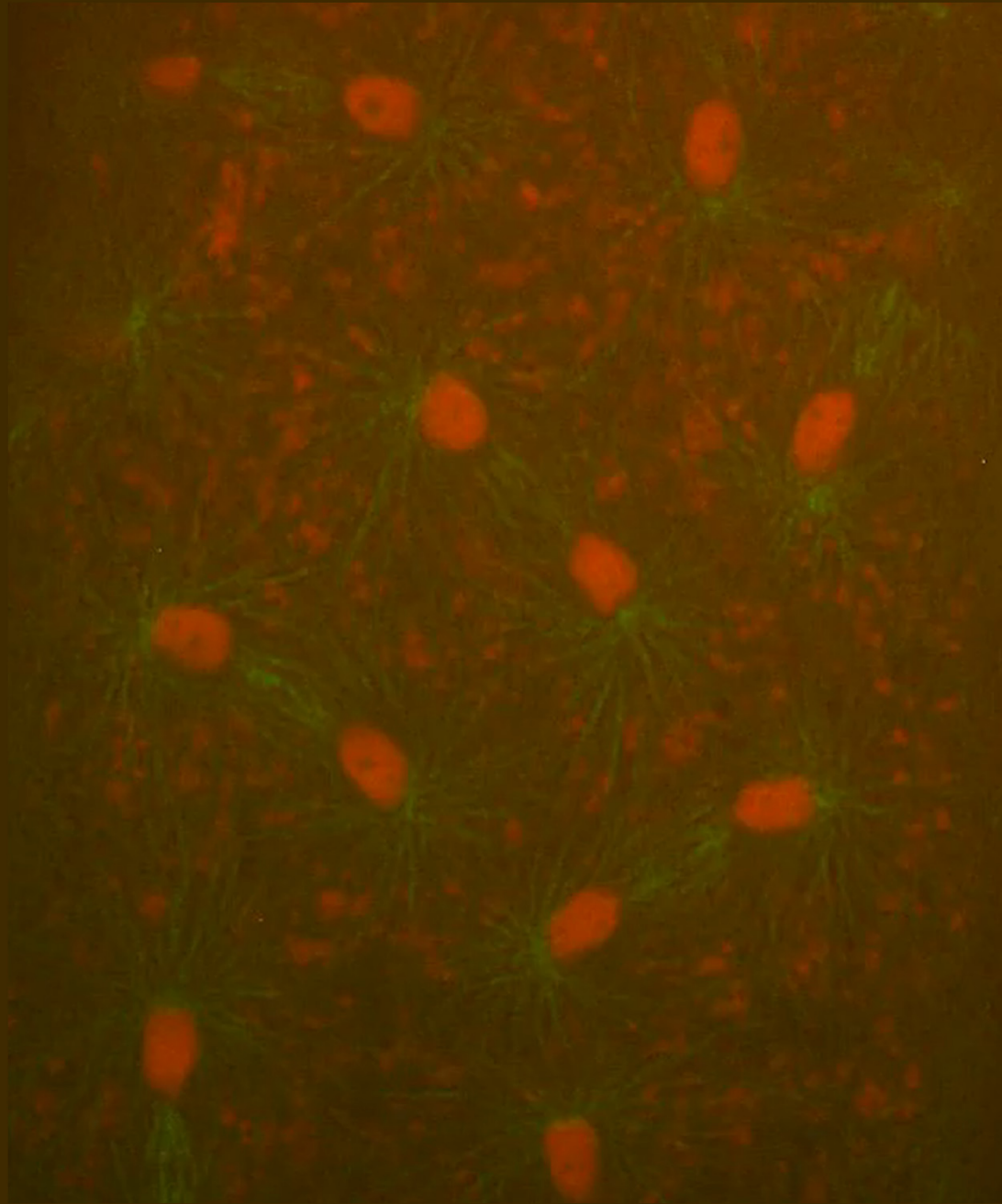


Cellular blastoderm
Buněčný blastoderm

Formation of true cells

Blastula formation

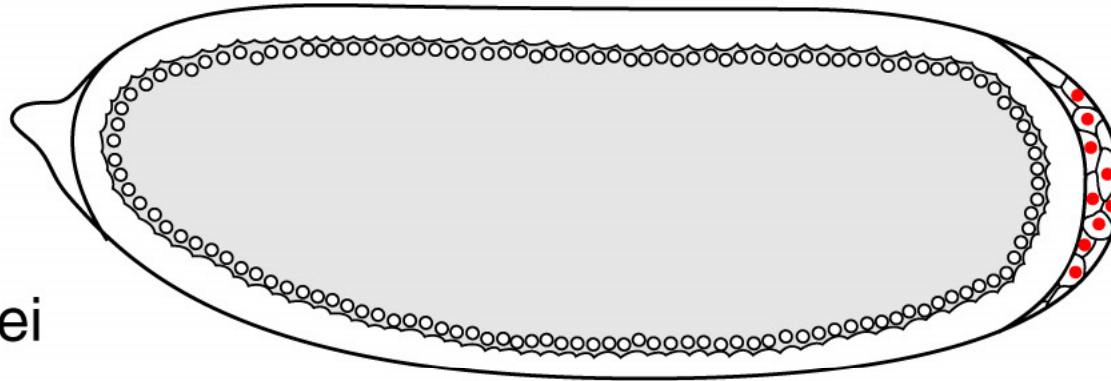




Synchronized nuclear divisions in the early *Drosophila* embryo

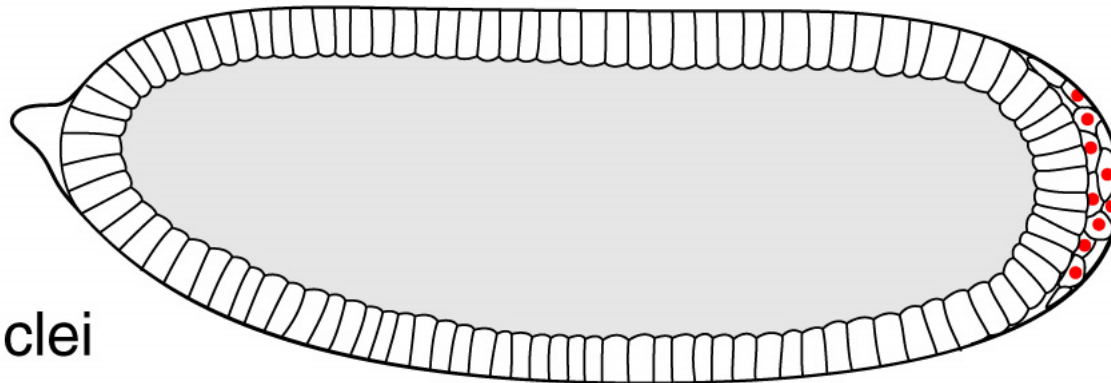
Anterior ↔ Posterior

Stage 10
150 min
about 750 nuclei



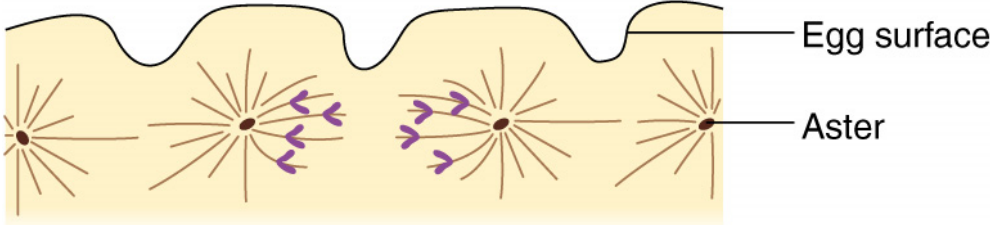
Formation
of pole
cells

Stage 14
about 4 h
about 2,048 nuclei

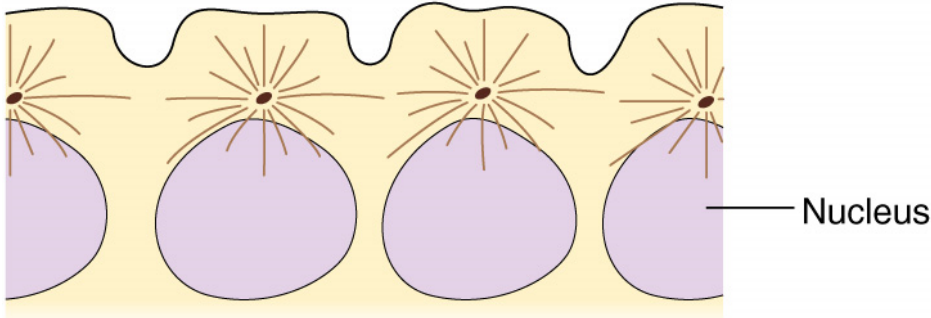


Formation
of true
cells

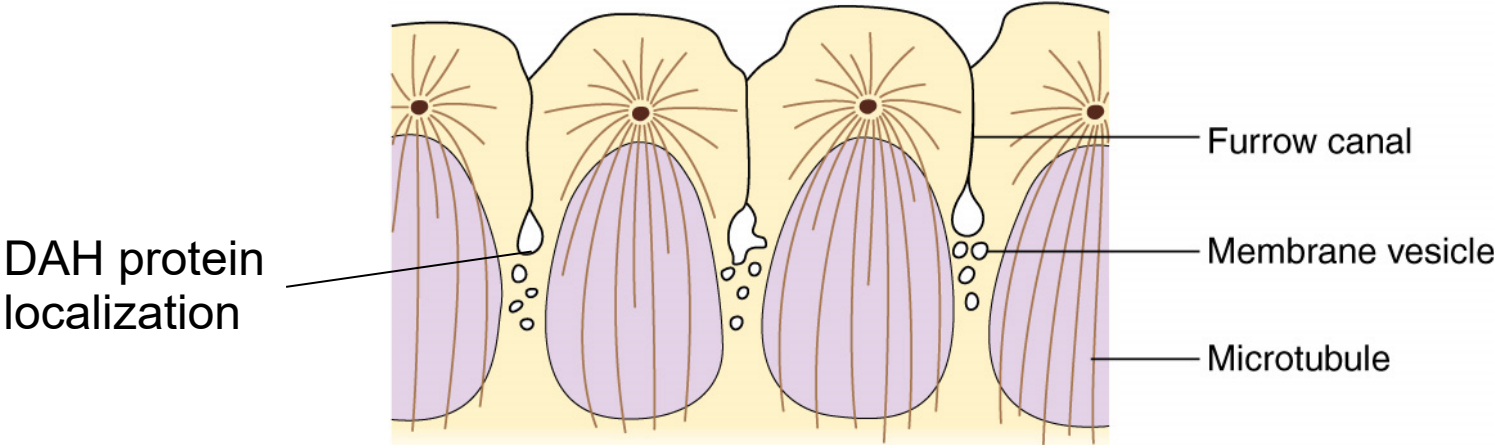
A. Chromosomes separate on the mitotic spindle.



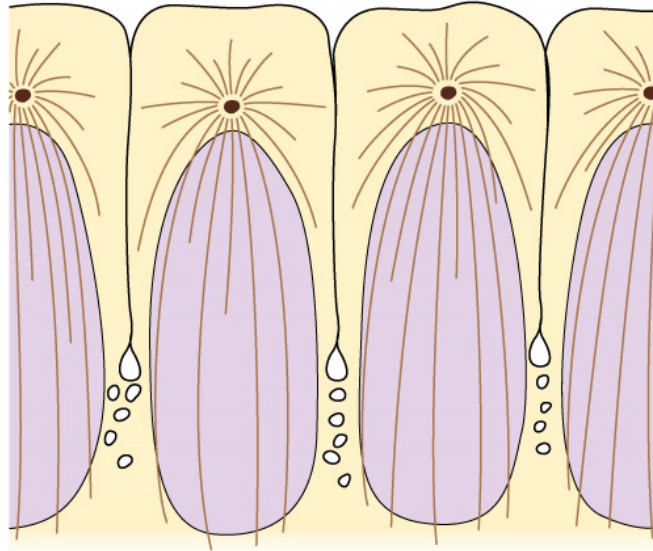
B. Nuclei reform.



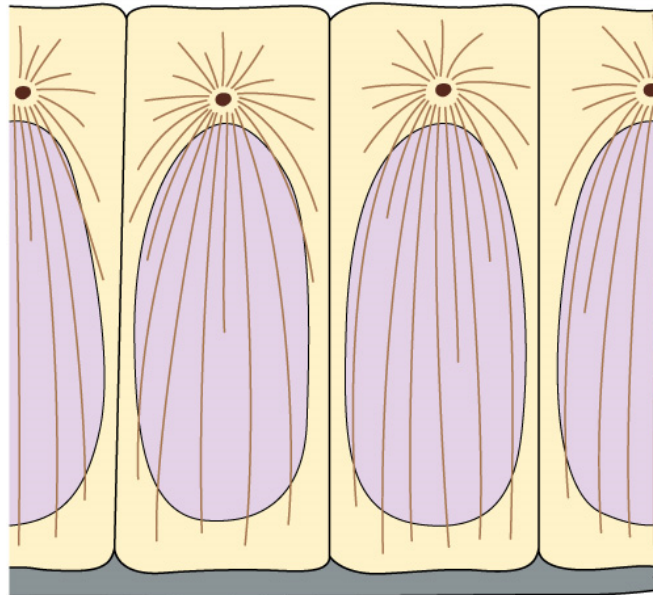
C. Nuclei enlarge. Furrow canals form, added at the tips by membrane vesicles.



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

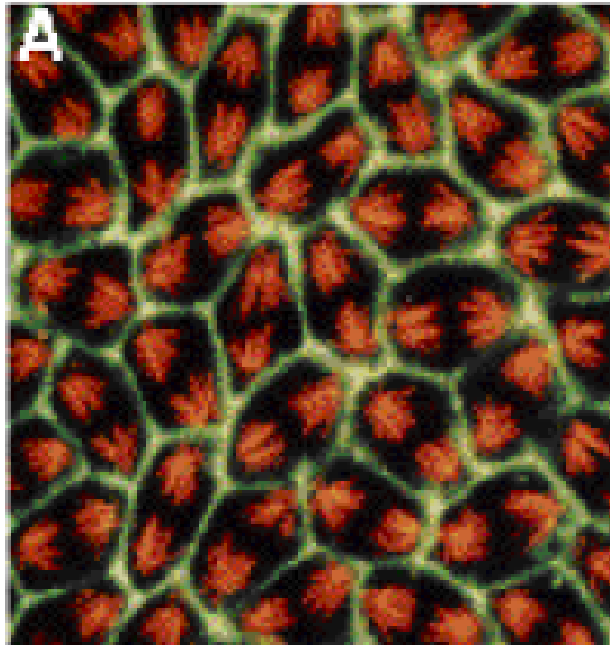


E. Cellularization is completed and yolk membrane is in place.

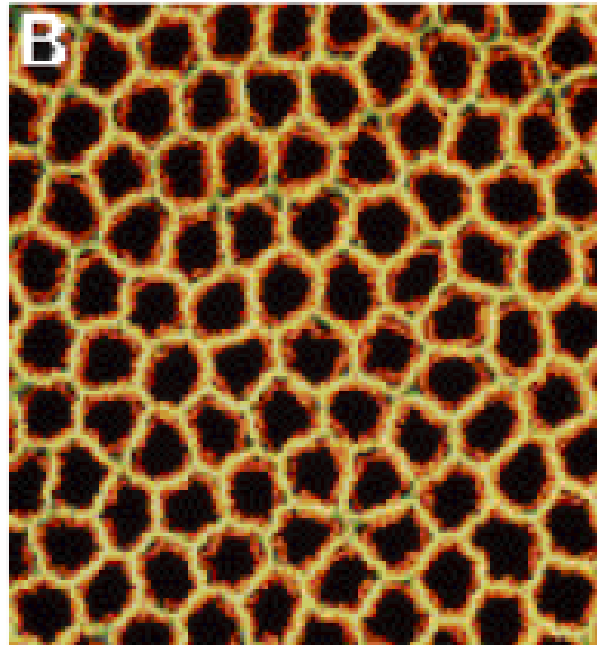


Yolk membrane  CEITEC

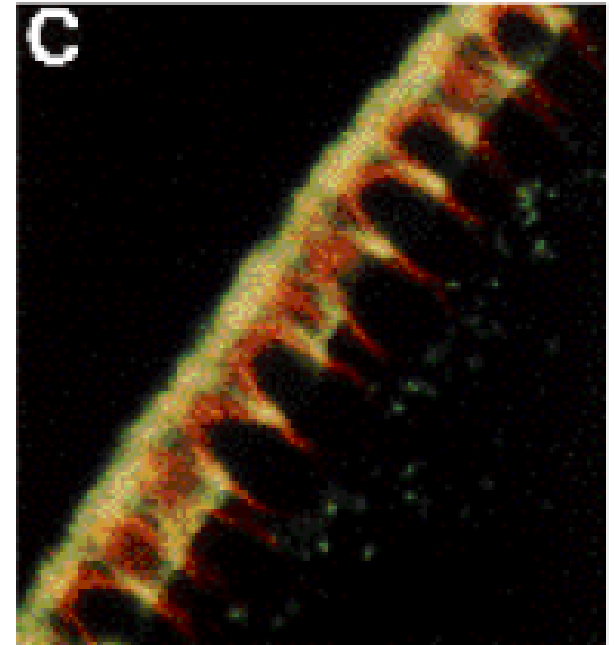
syncytial mitosis



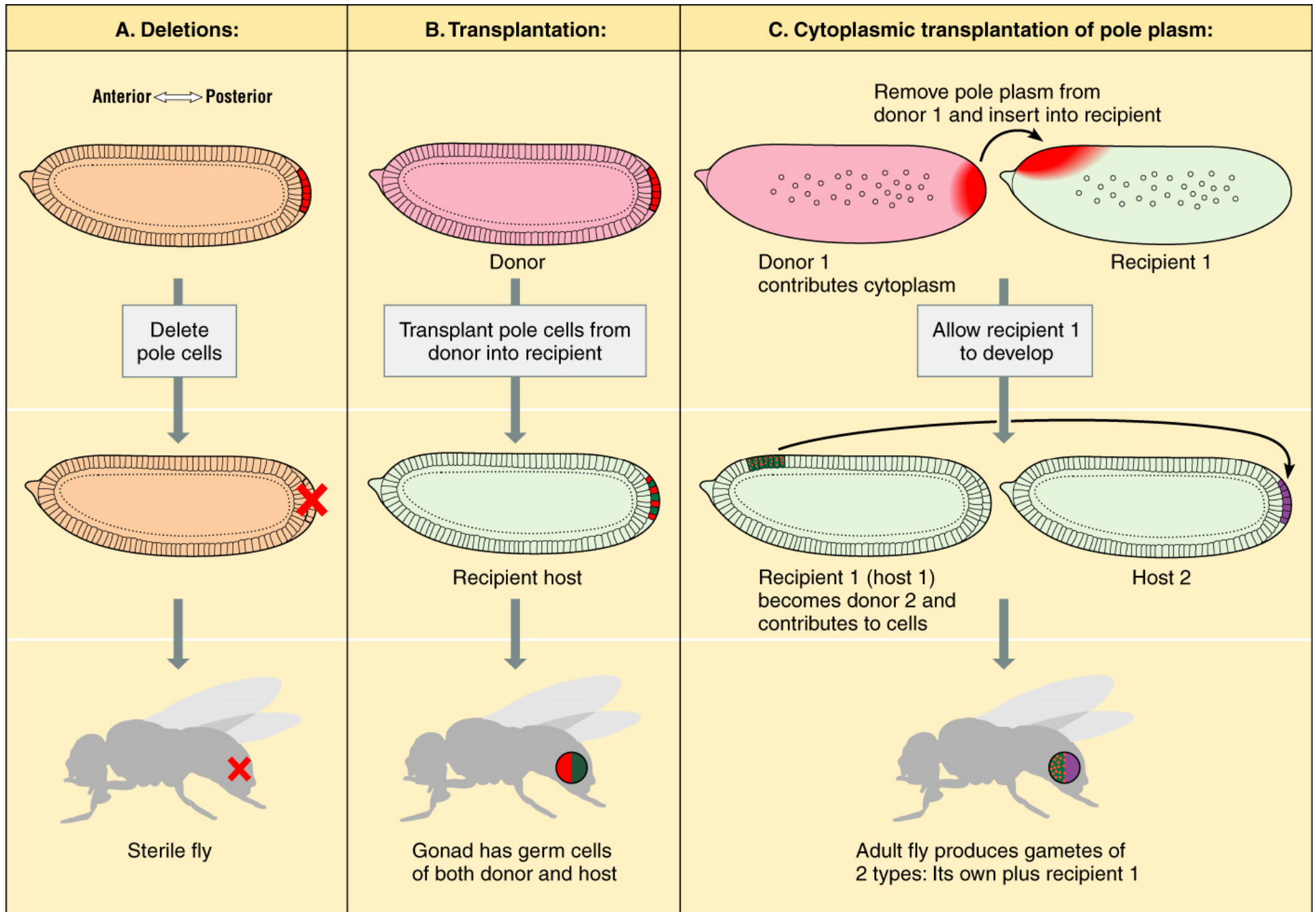
**cellularization
(grazing section)**

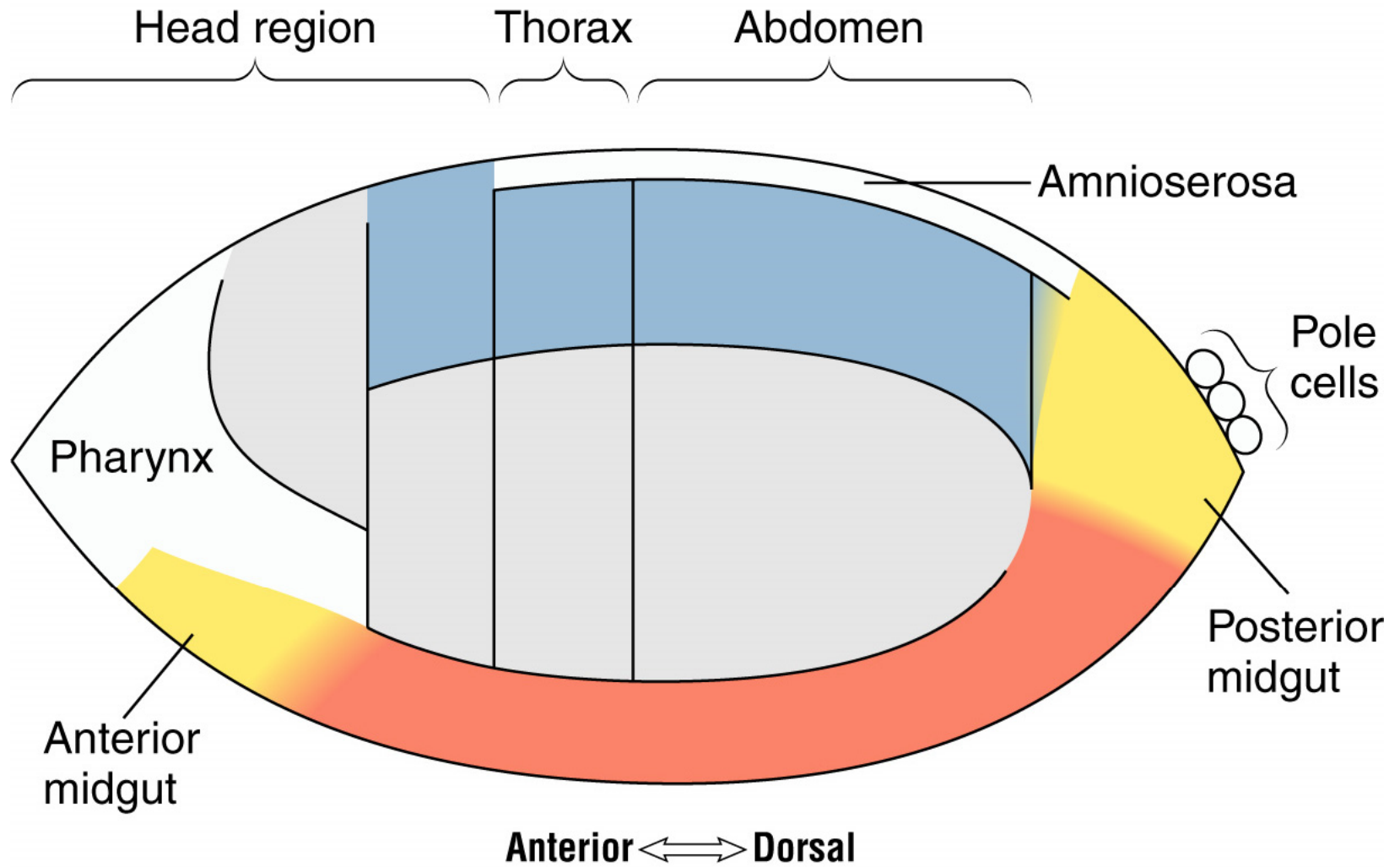


**cellularization
(cross section)**



Sullivan et al., *Development* (1993)





KEY

	Neural tissues		Dorsal epidermis
	Endoderm		Mesoderm

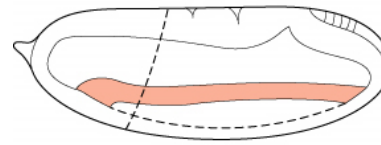
Outline of Lesson 2

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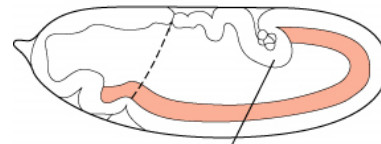
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A. Sagittal sections

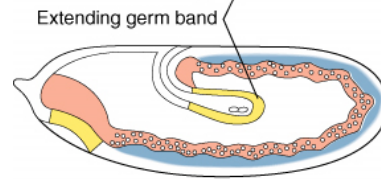
Dorsal
Anterior ↔ Posterior
Ventral



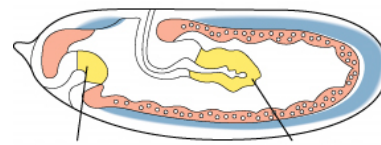
Stage 7
3h35min



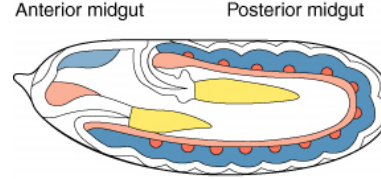
Stage 8
4h15min



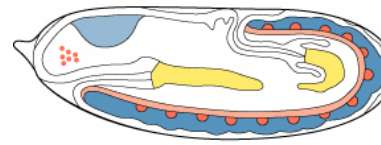
Stage 9
4h45min



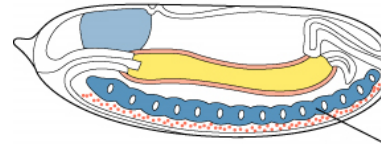
Stage 10
5h20min



Stage 11
7h



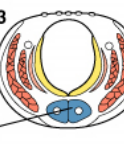
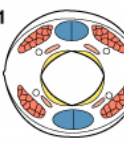
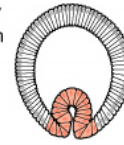
Stage 12
9h



Stage 13
10h

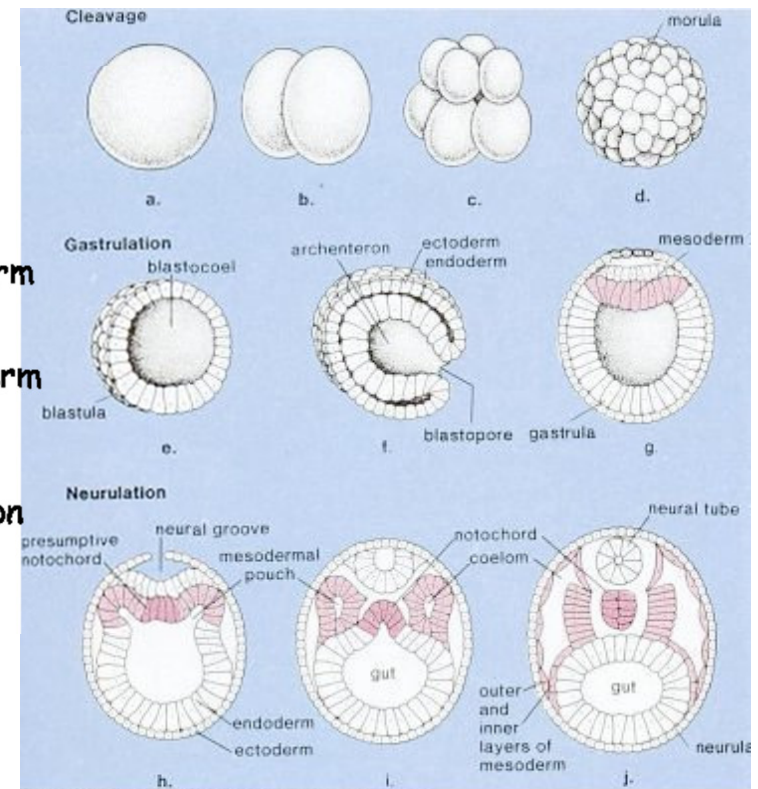
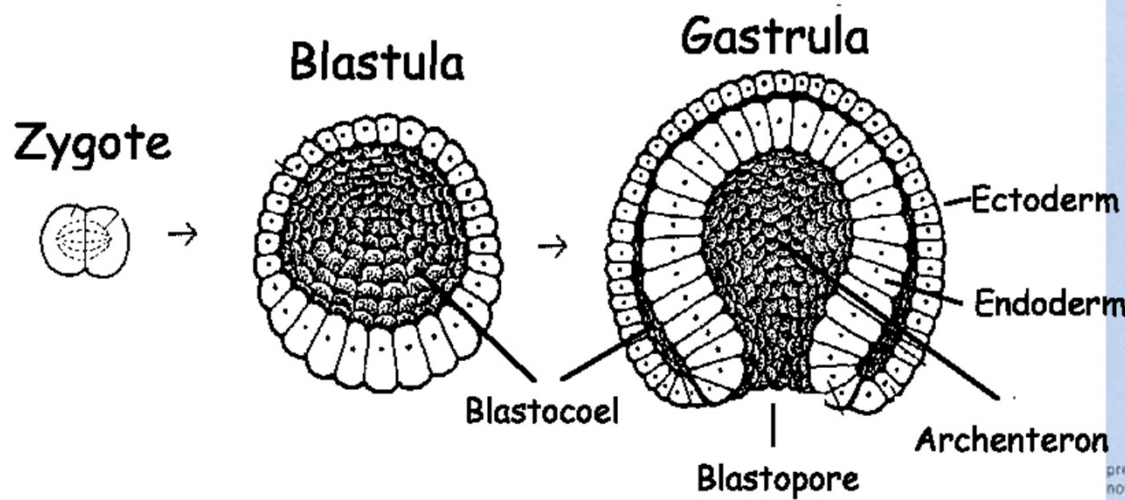
Central nervous system

B. Cross sections



Change in position

Cell differentiation



Embryonic Development of Lancelet :

Cleavage produces the morula

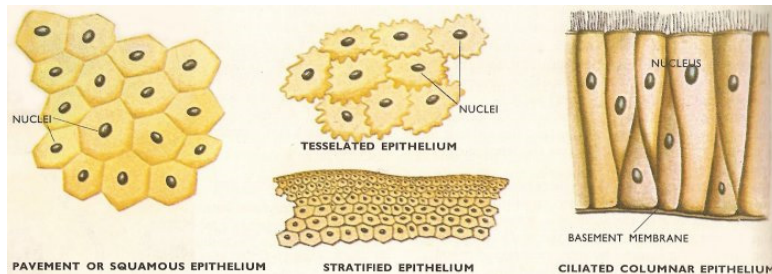
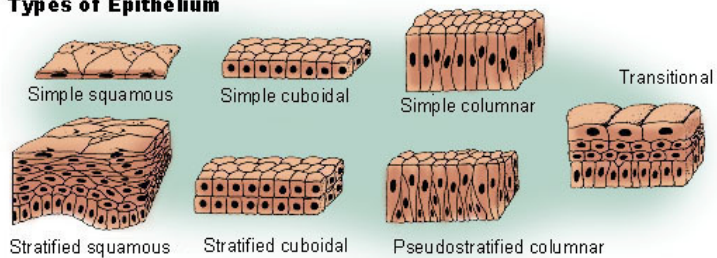
Gastrulation by invagination produces the three germ layers

Neurulation produces the neural tube called the neurula

Embryonální vývoj kopinatce

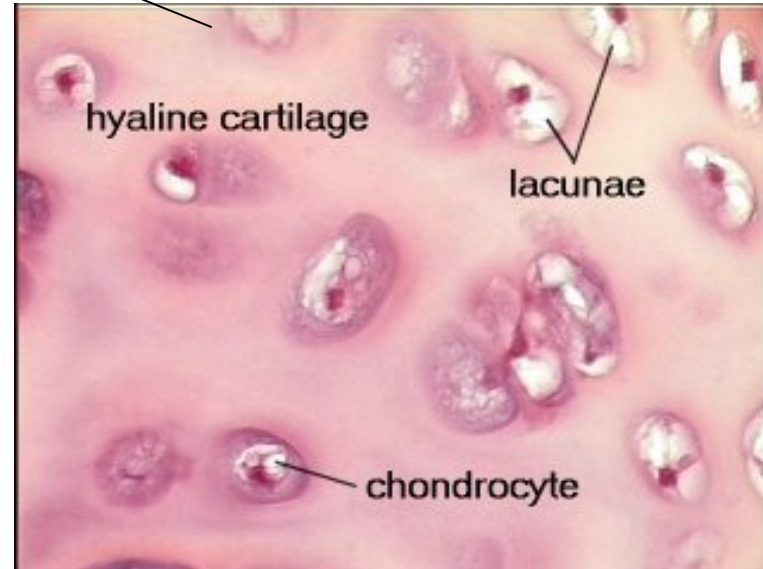
Epithelium Epitel

Types of Epithelium

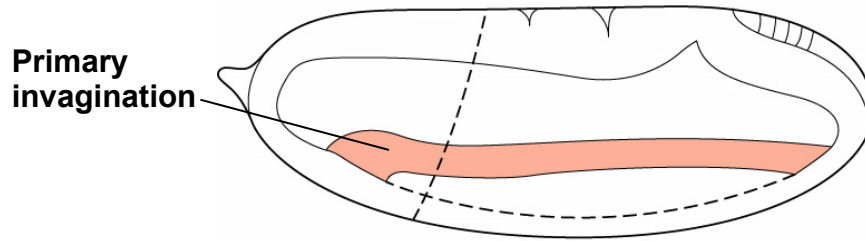
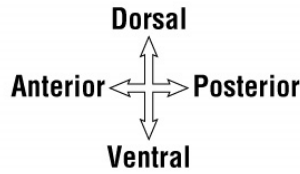


Mesenchyme Mesenchym

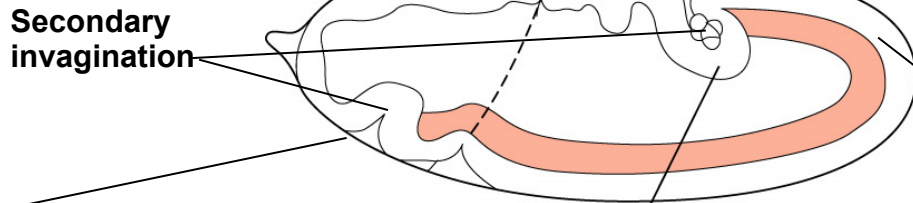
Hyalinní (sklovitá,
kloubní) chrupavka



A. Sagittal sections



Primary invagination

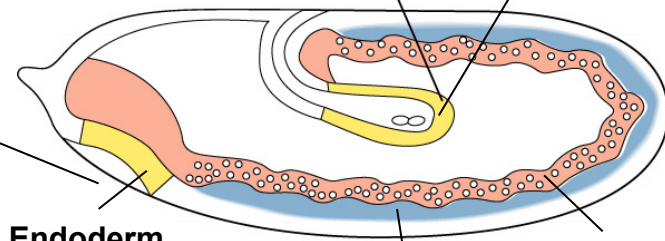


Secondary invagination

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

Stomodeum formation and invagination

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



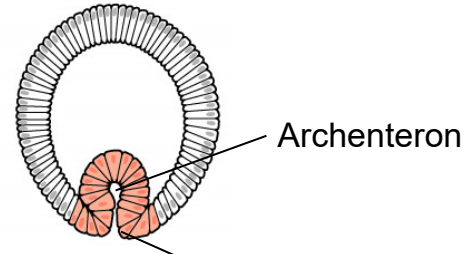
Endoderm

Ectoderm

Mesoderm

B. Cross sections

Stage 7
3h35min



Archenteron

Ventral furrow/Ventrální rýha



Mesoderm

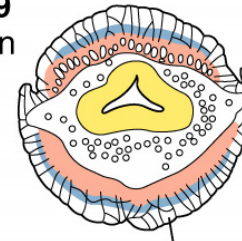
Somatic/somatický

Visceral/viscerální

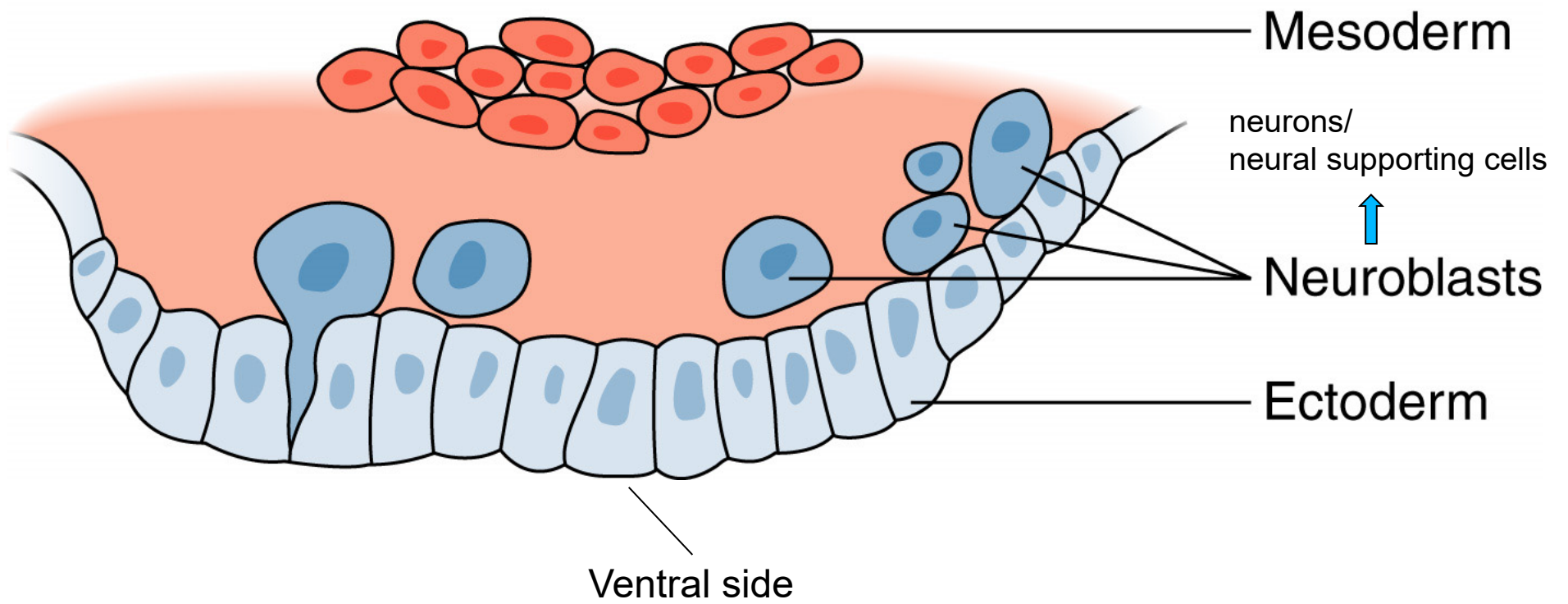
Stage 8
4h15min

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

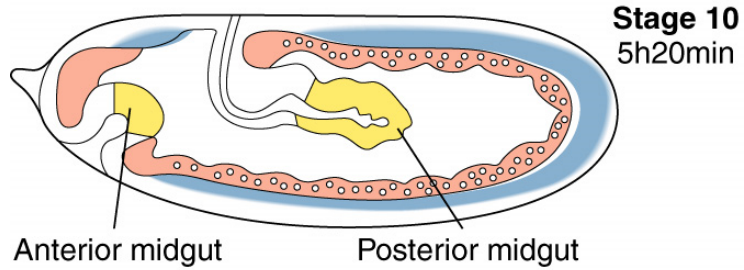
Stage 9
4h45min



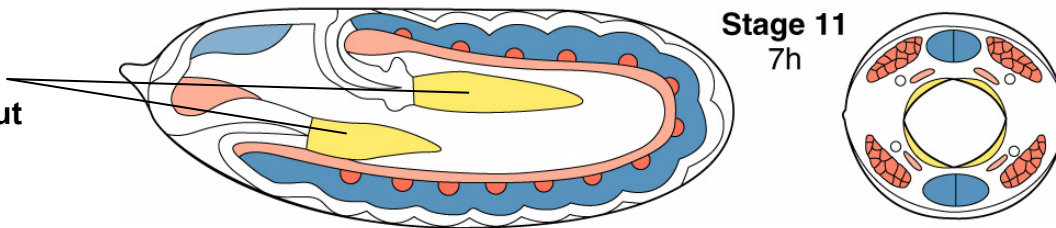
Neuroblasts



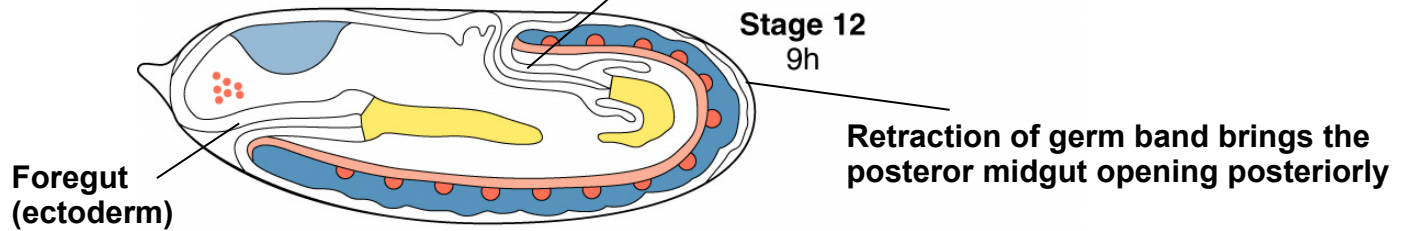
Secondary invagination



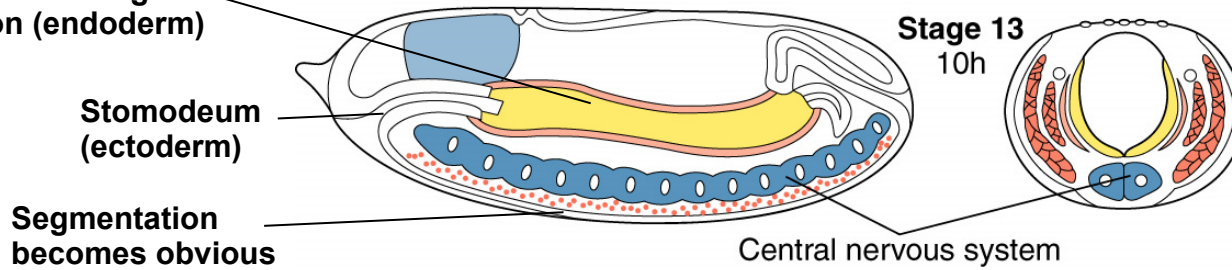
Anterior and posterior midgut elongation



Hindgut (ectoderm)



Anterior and posterior midgut fusion (endoderm)



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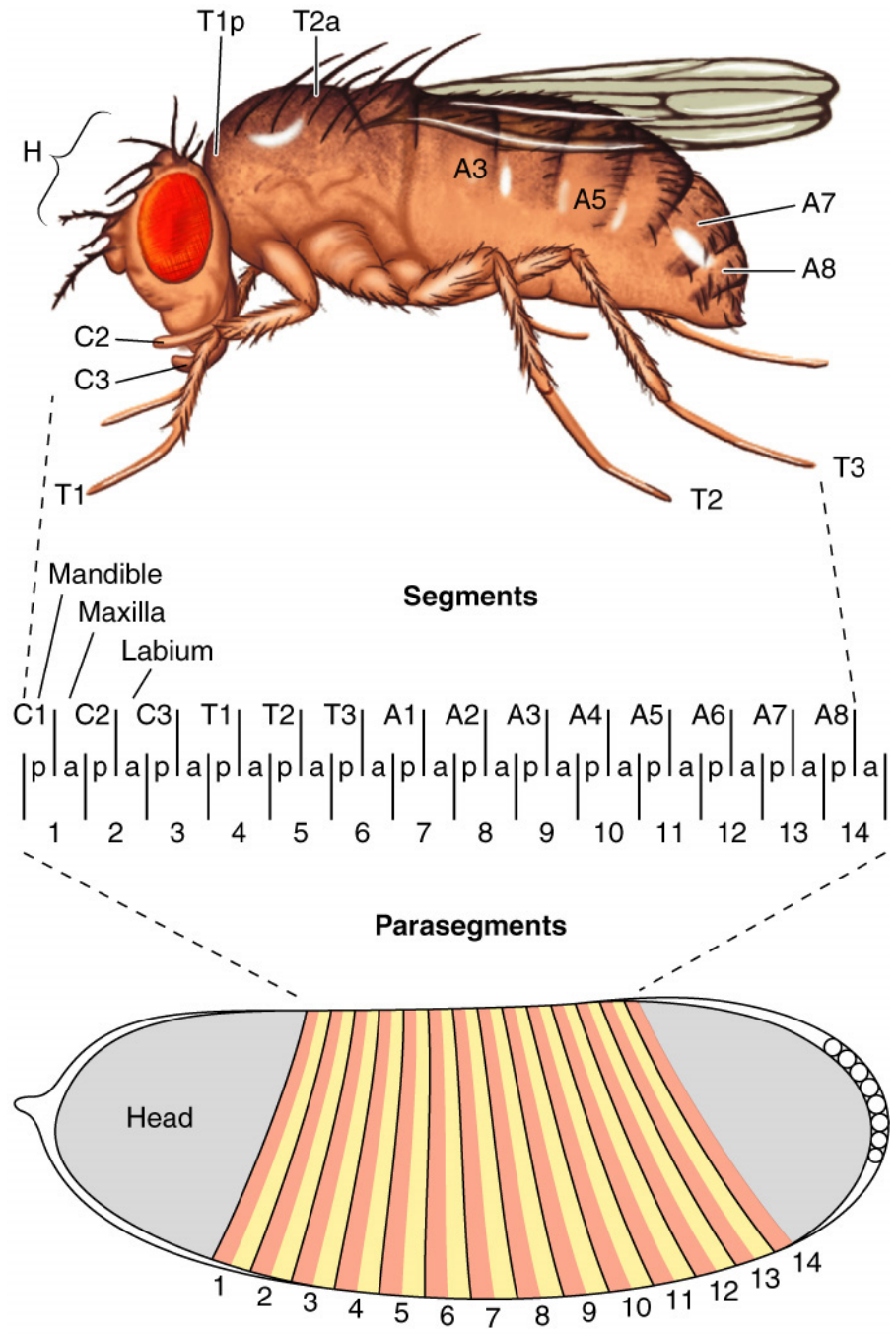
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- Early embryogenesis
- Gastrulation
 - Video of gastrulation in *Drosophila*

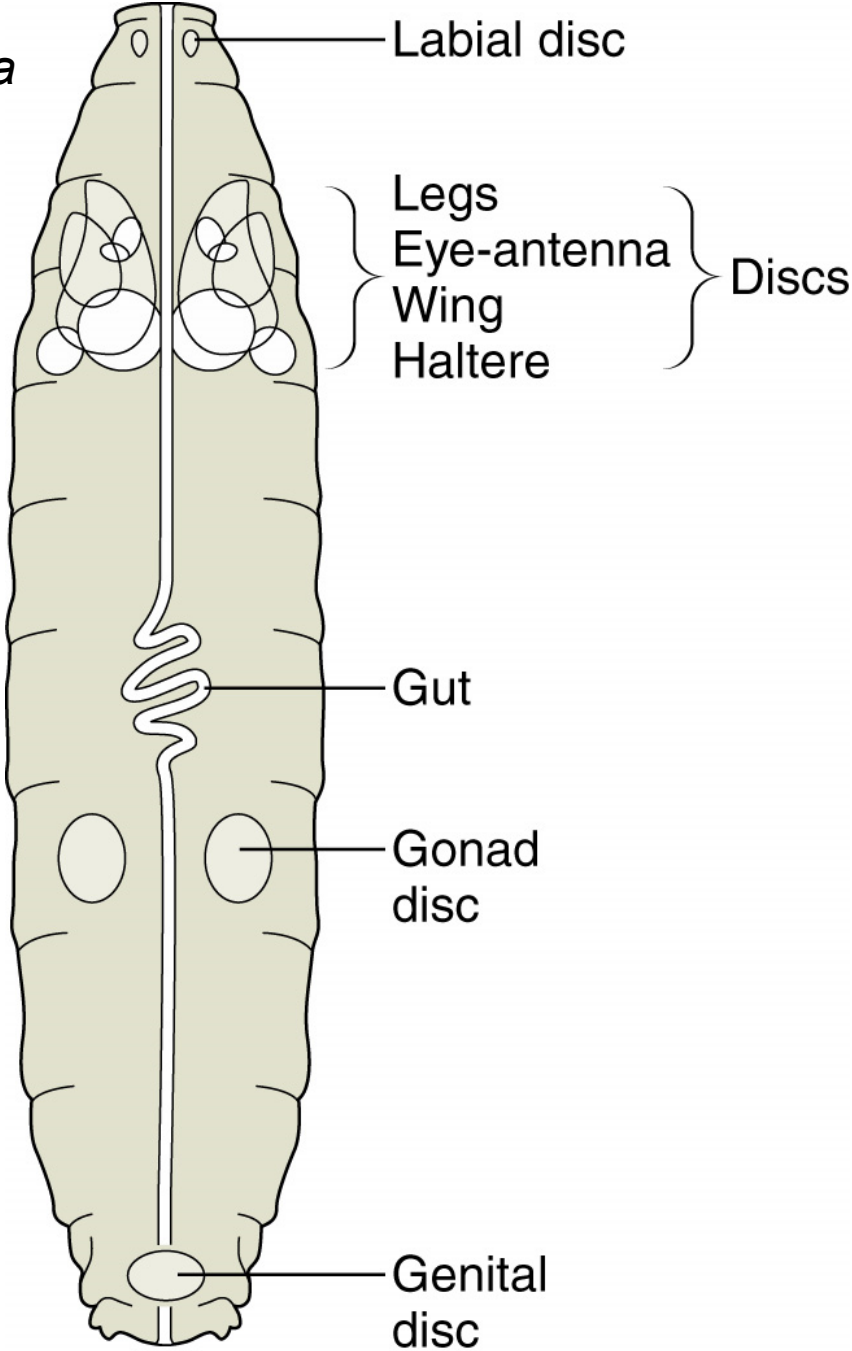
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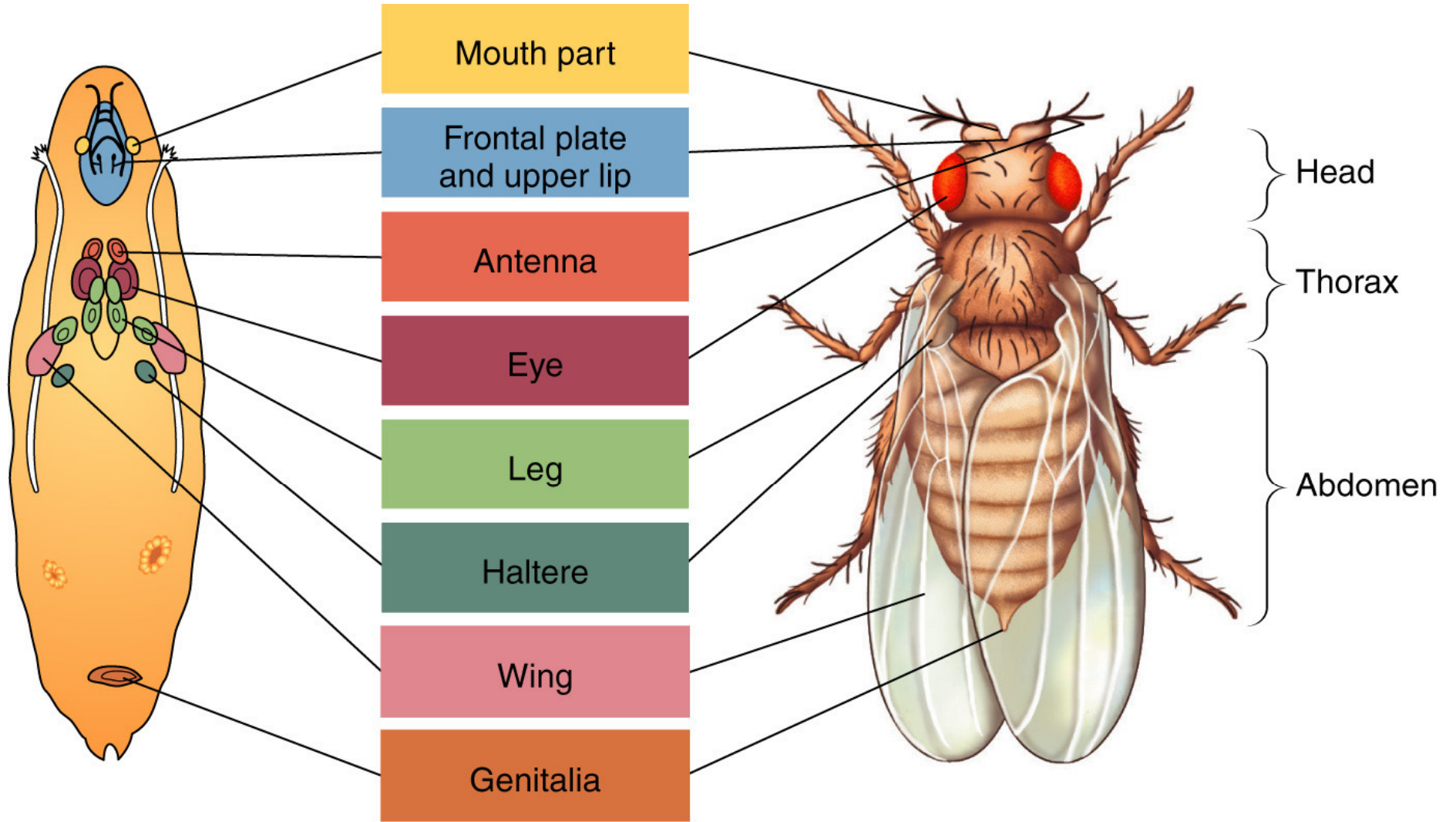
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- Overview of metamorphosis



Imaginal discs in *Drosophila* larva



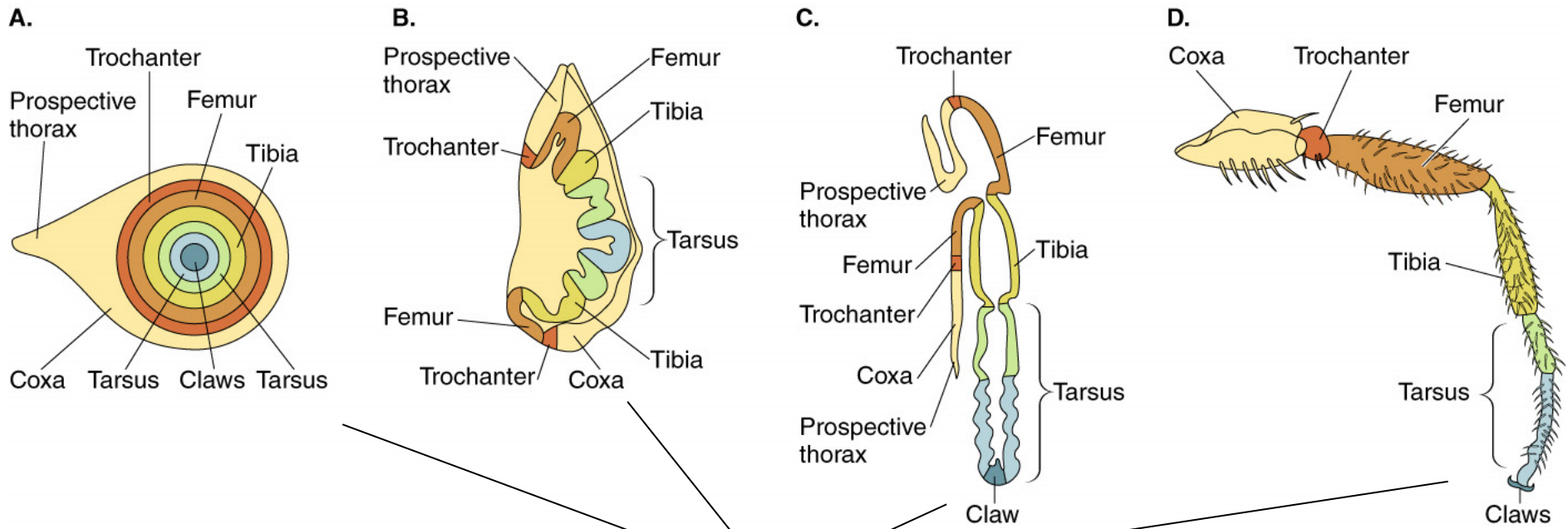


Predetermined cell fate

Adult structures



Morphogenic movements during metamorphosis



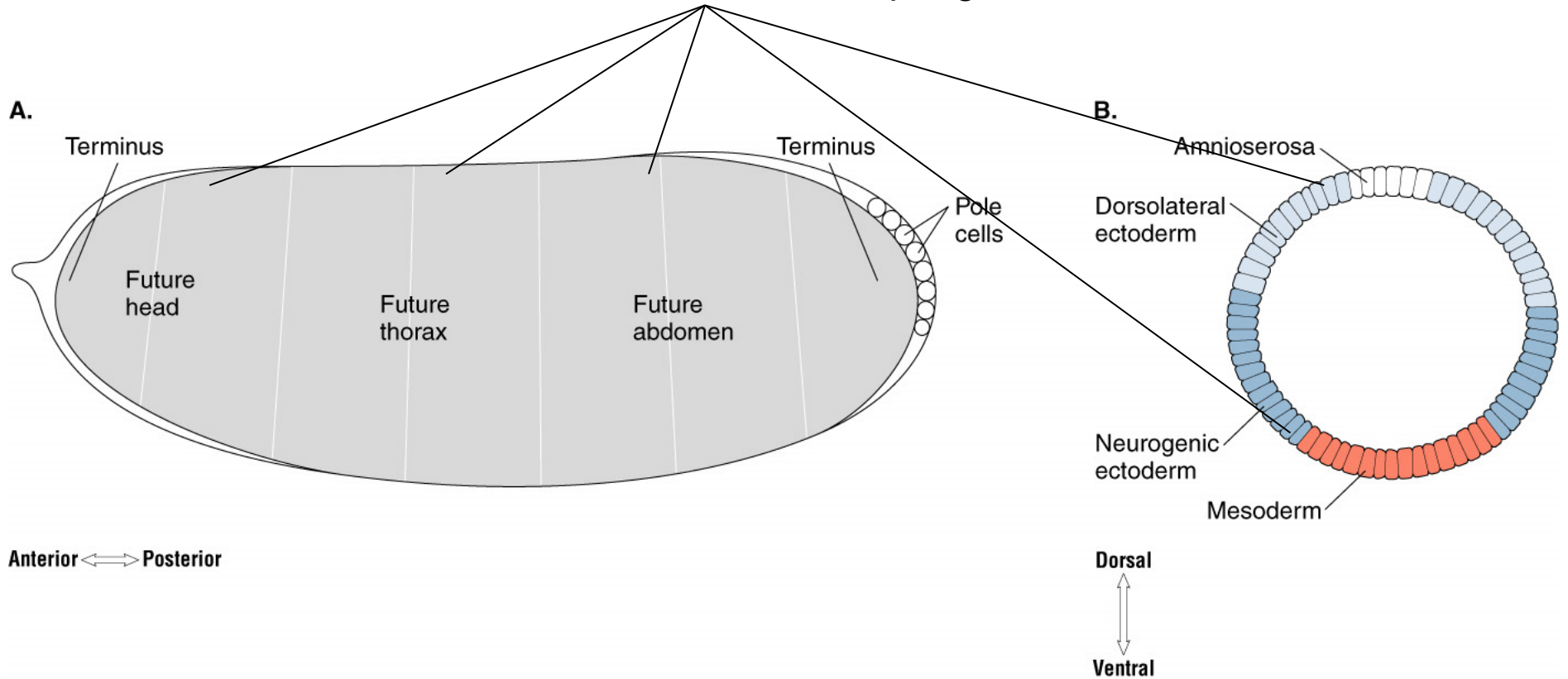
Under control of **ecdysone** and **juvenile hormone**

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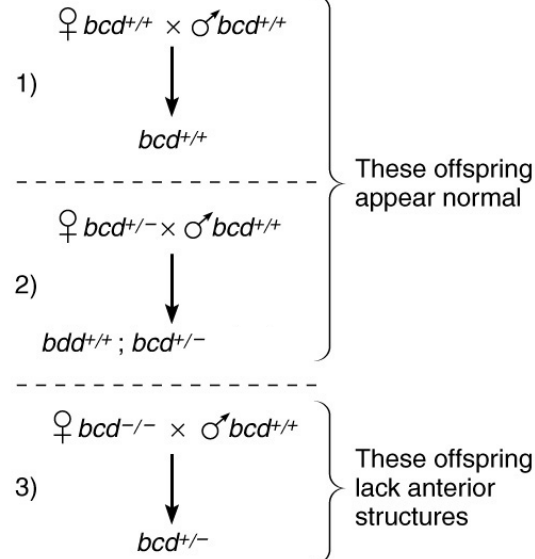
Different levels of morphogens



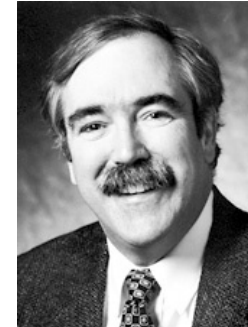
Klaus Sanders experiments in Germany, 1960's

	Genotype	Phenotype
A. Parents:	bcd^+/bcd^-	Both female and male normal
B. F₁:	1) $bcd^{+/+}$ 2) $bcd^{+/-}$ 3) $bcd^{-/-}$	All flies appear normal

C. Mate female F₁ to wild-type males:

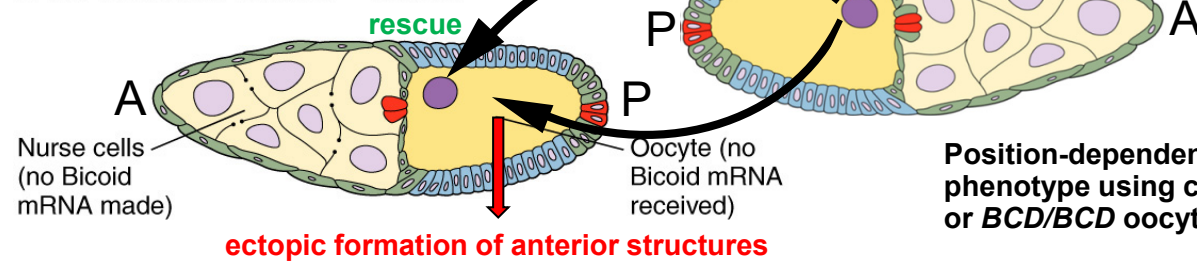


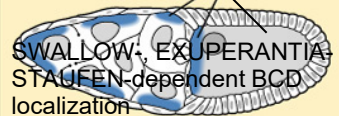
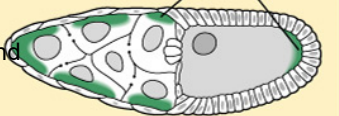
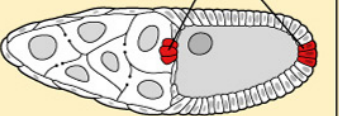
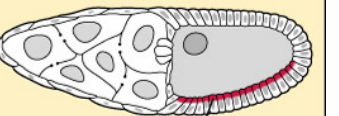
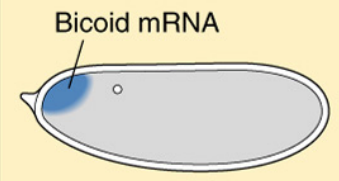
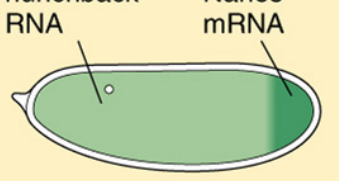
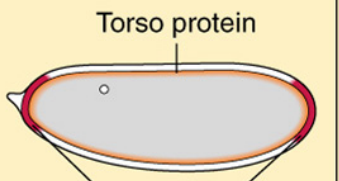
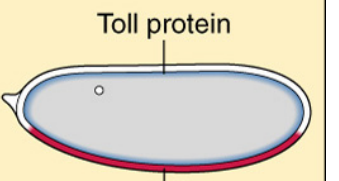
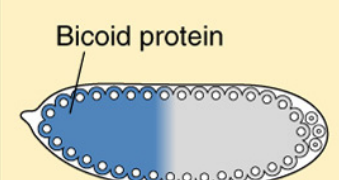
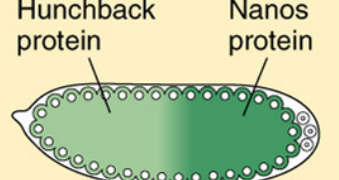
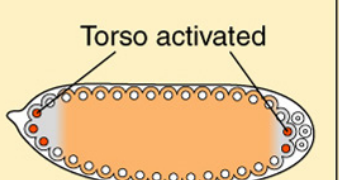
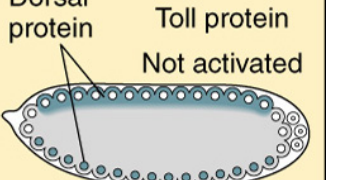
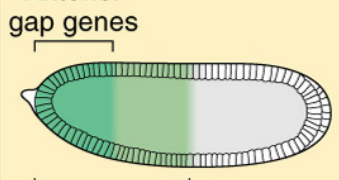
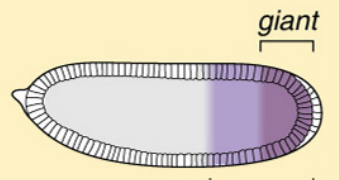
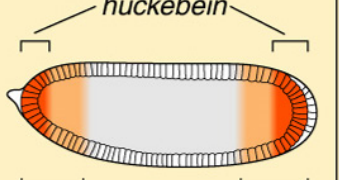
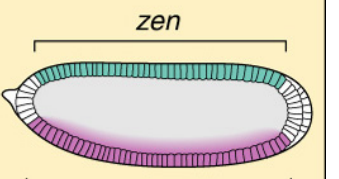
Christiane Nüsslein-Volhard
The Nobel Prize in Physiology or Medicine 1995



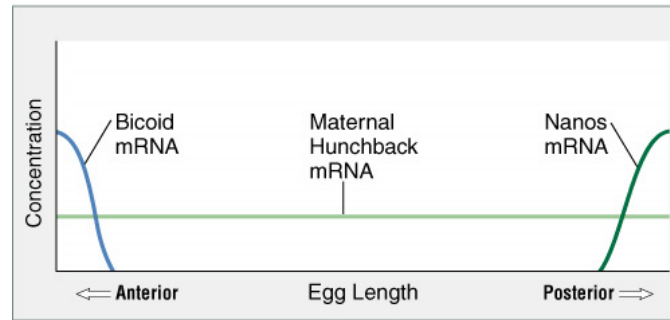
Eric F. Wieschaus
The Nobel Prize in Physiology or Medicine 1995

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

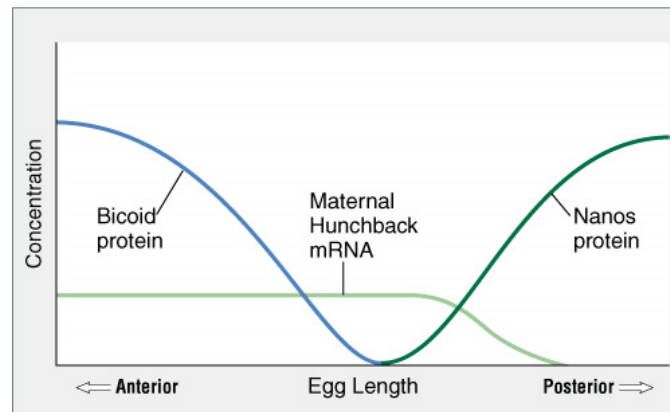


	Anterior:	Posterior:	Terminal:	Dorsoventral:
Oocyte/follicle	<p>Bicoid mRNA</p>  <p>SWALLOW, EXUPERANTIA and STAUFFEN-dependent BCD localization</p>	<p>Nanos mRNA</p> 	<p>Torsolike mRNA</p> 	<p>Pipe mRNA</p> 
Fertilized egg	<p>Bicoid mRNA</p> 	<p>Maternal hunchback RNA</p> <p>Nanos mRNA</p> 	<p>Torso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

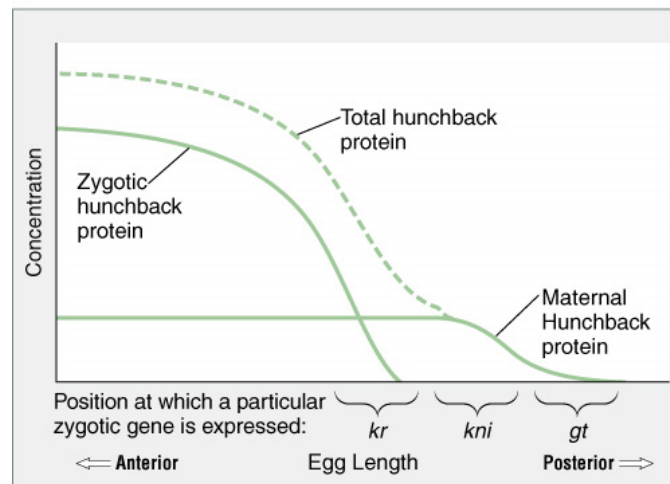
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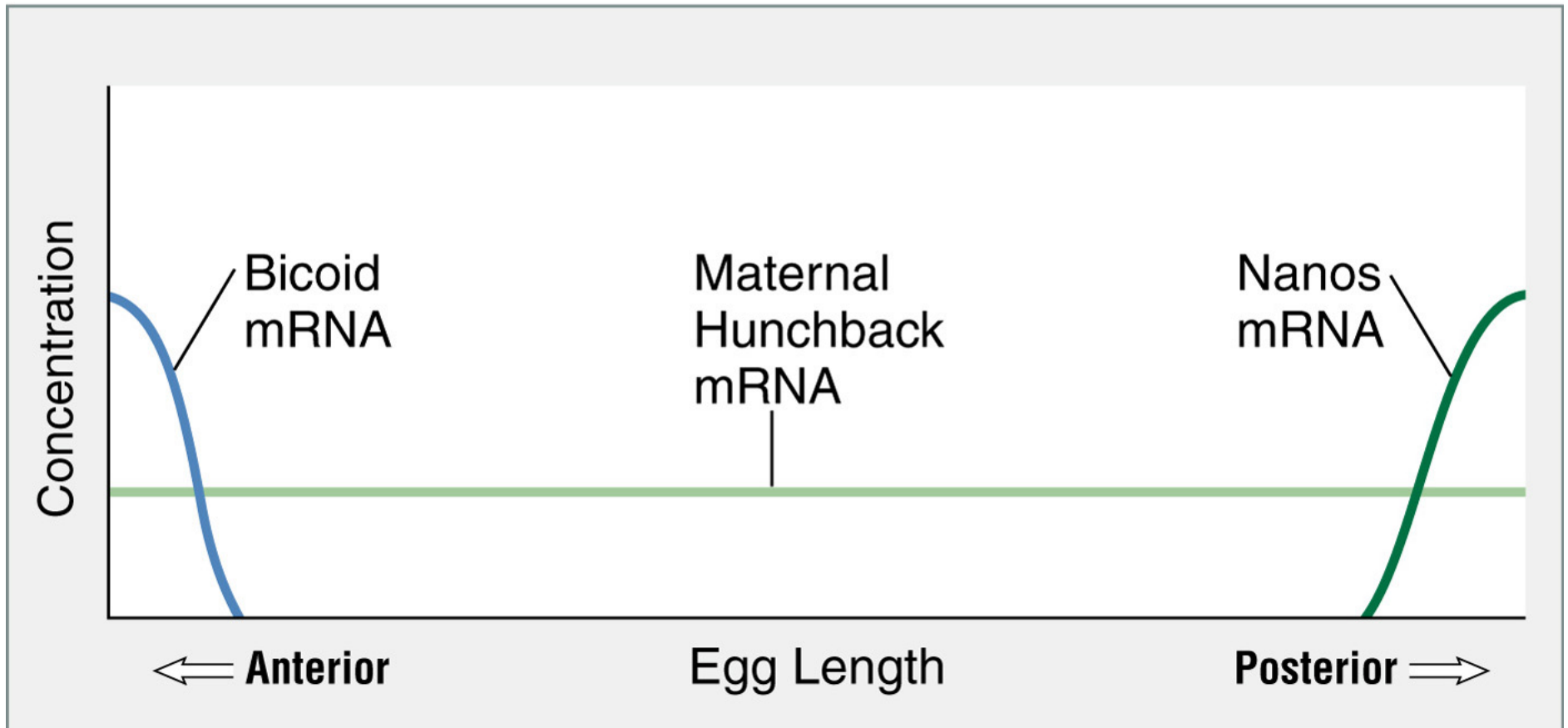
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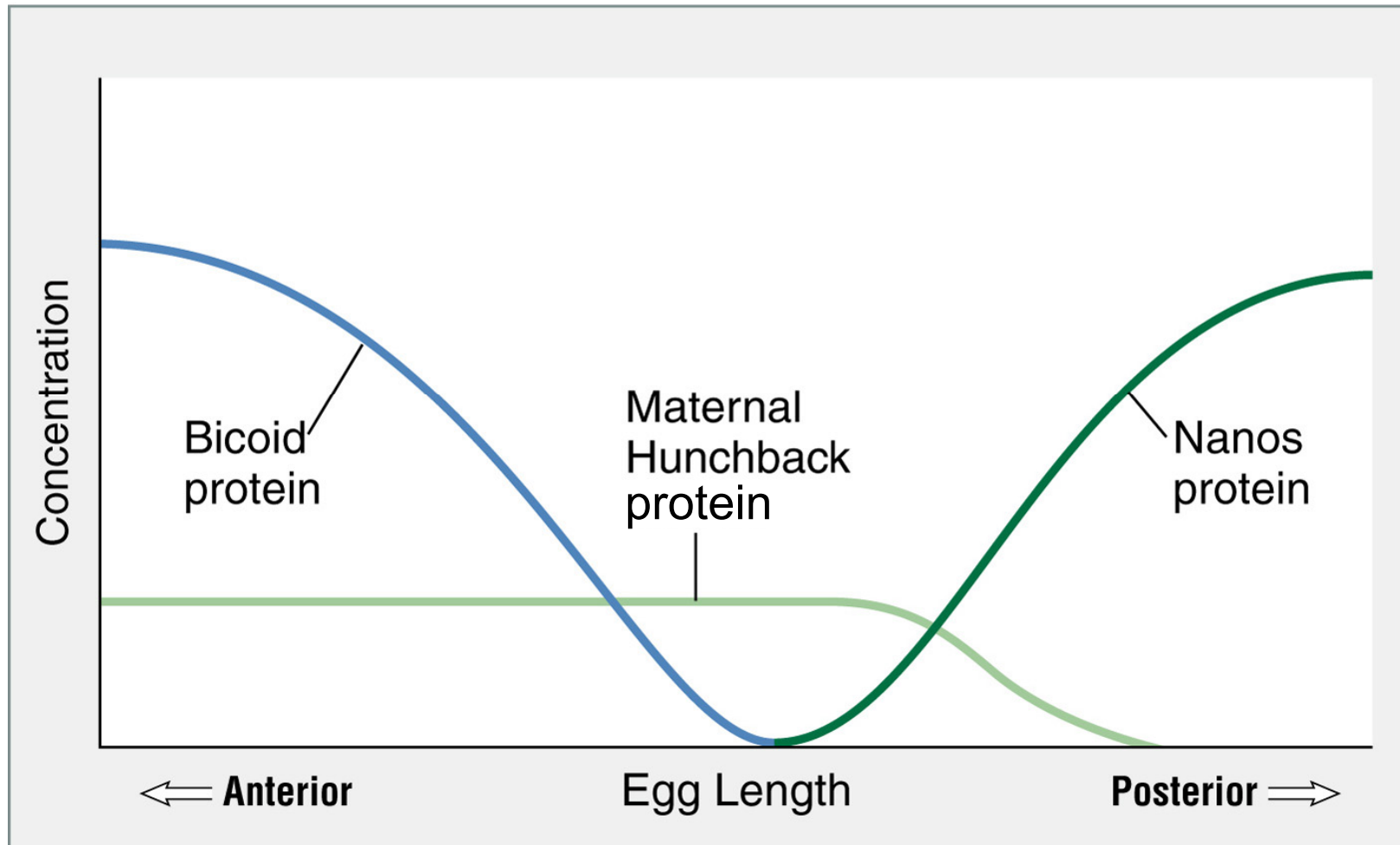
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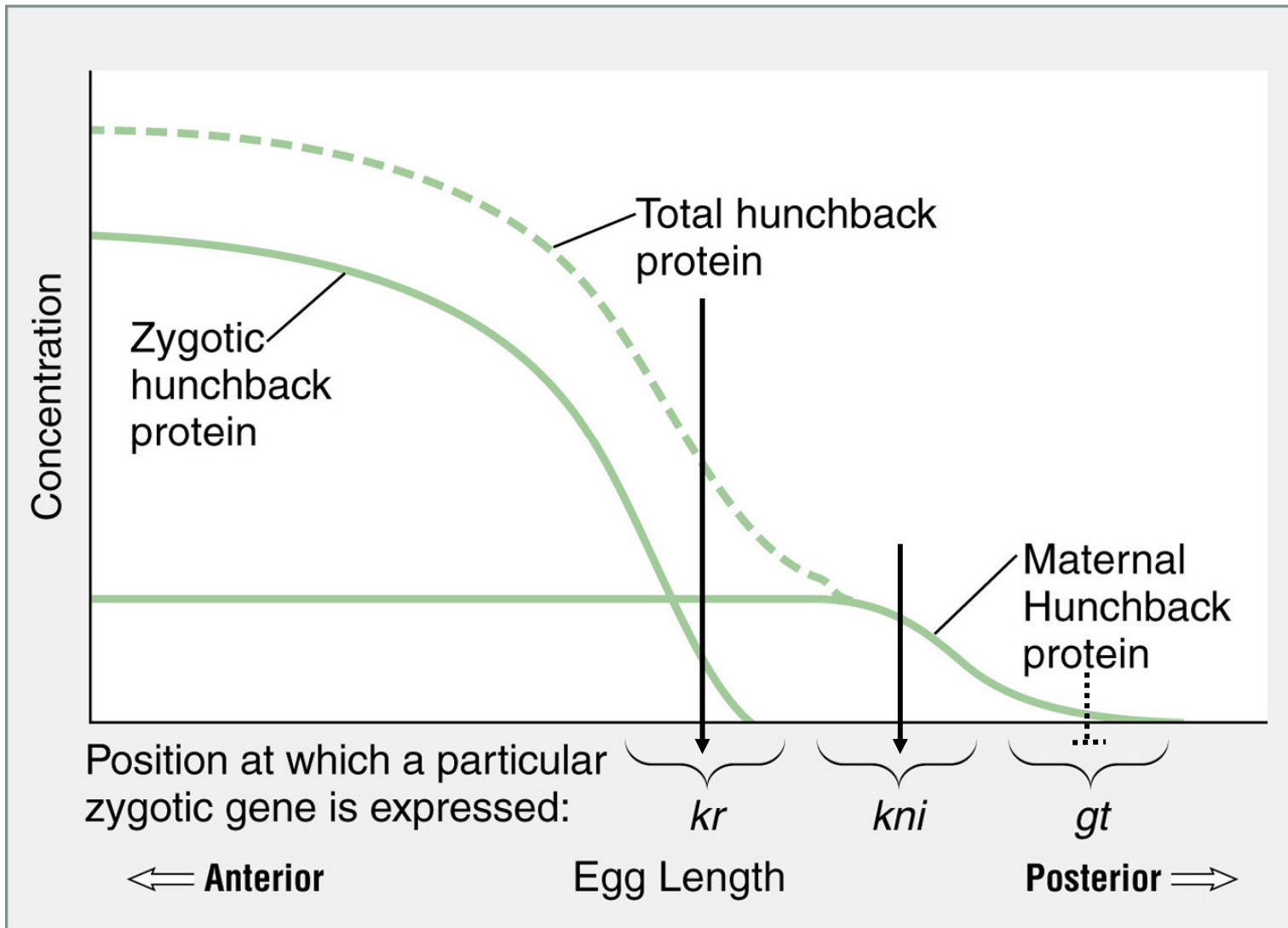
A.

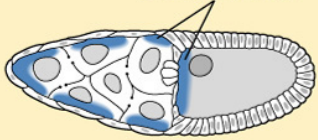
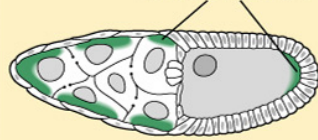
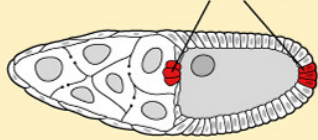
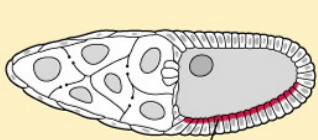

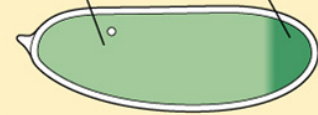
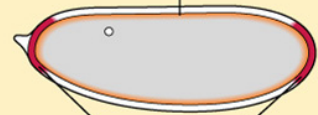
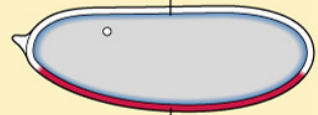
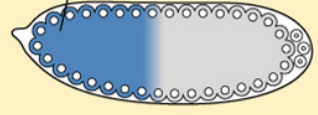
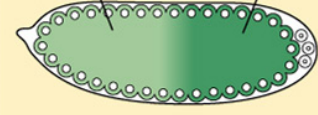
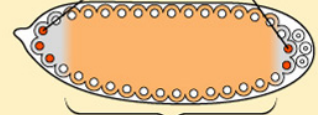
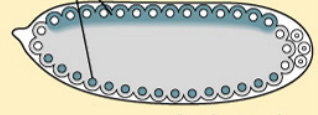
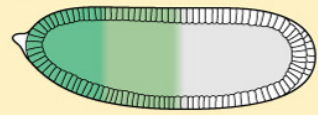
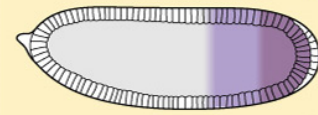
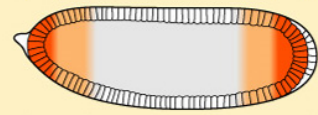
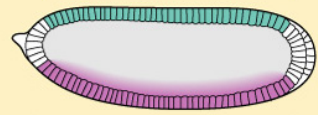


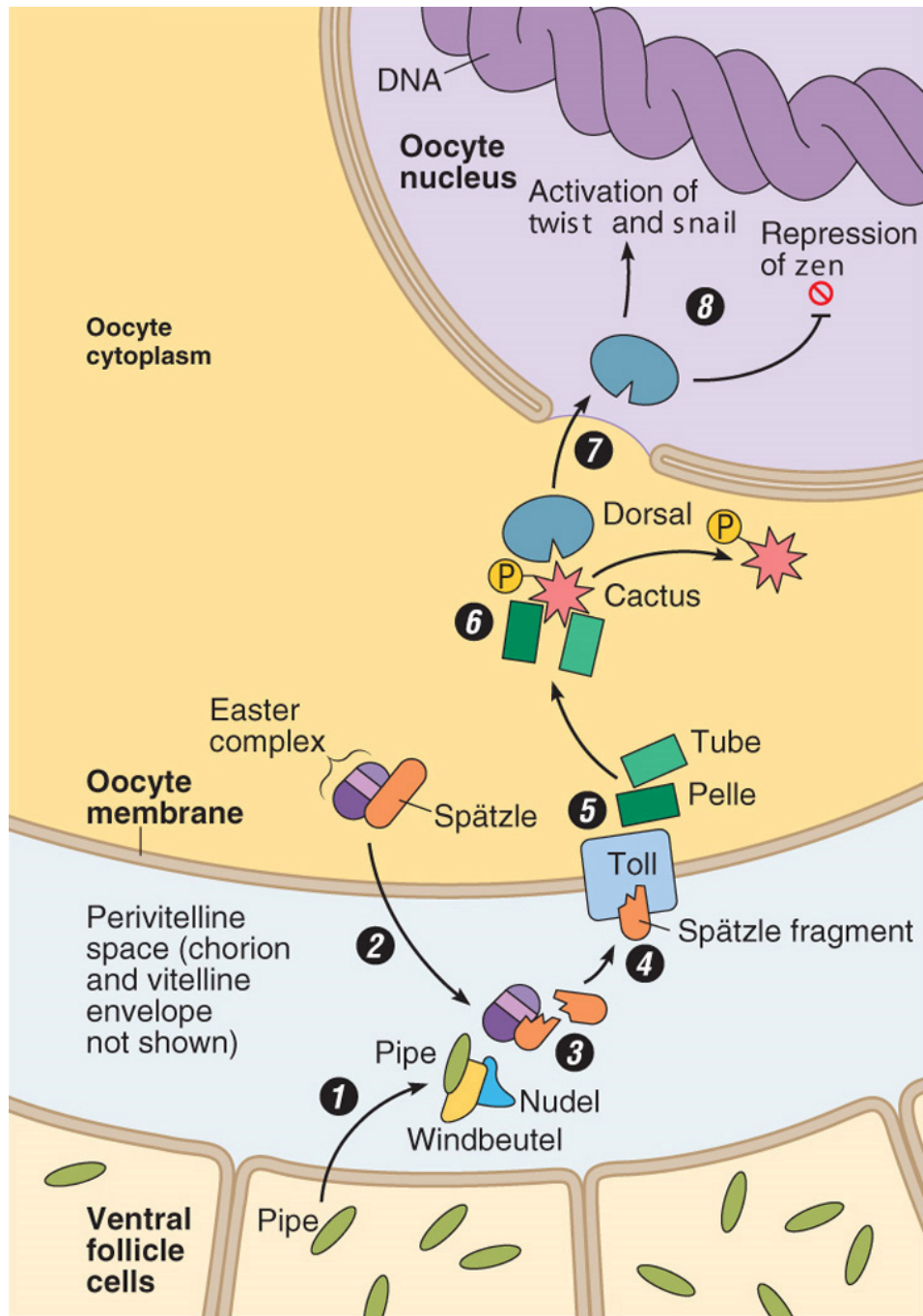
B.



C.

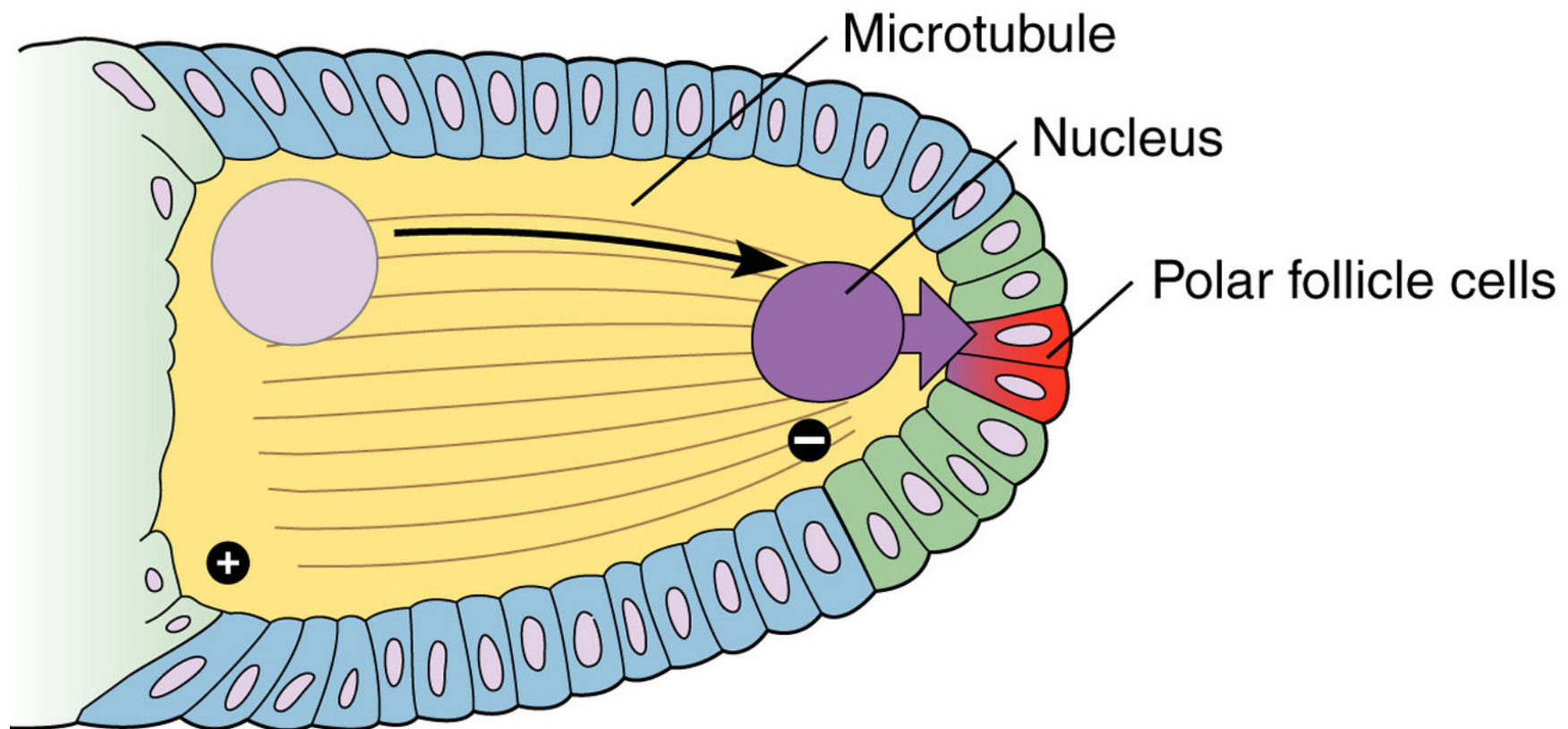


	Anterior:	Posterior:	Terminal:	Dorsoventral:
Oocyte/follicle	Bicoid mRNA 	Nanos mRNA 	Torsolike mRNA 	Pipe mRNA 
Fertilized egg	Bicoid mRNA 	Maternal hunchback RNA Nanos mRNA 	Torso protein Torsolike protein 	Toll protein Pipe protein 
512-nuclei stage (cycle 9)	Bicoid protein 	Hunchback protein Nanos 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 



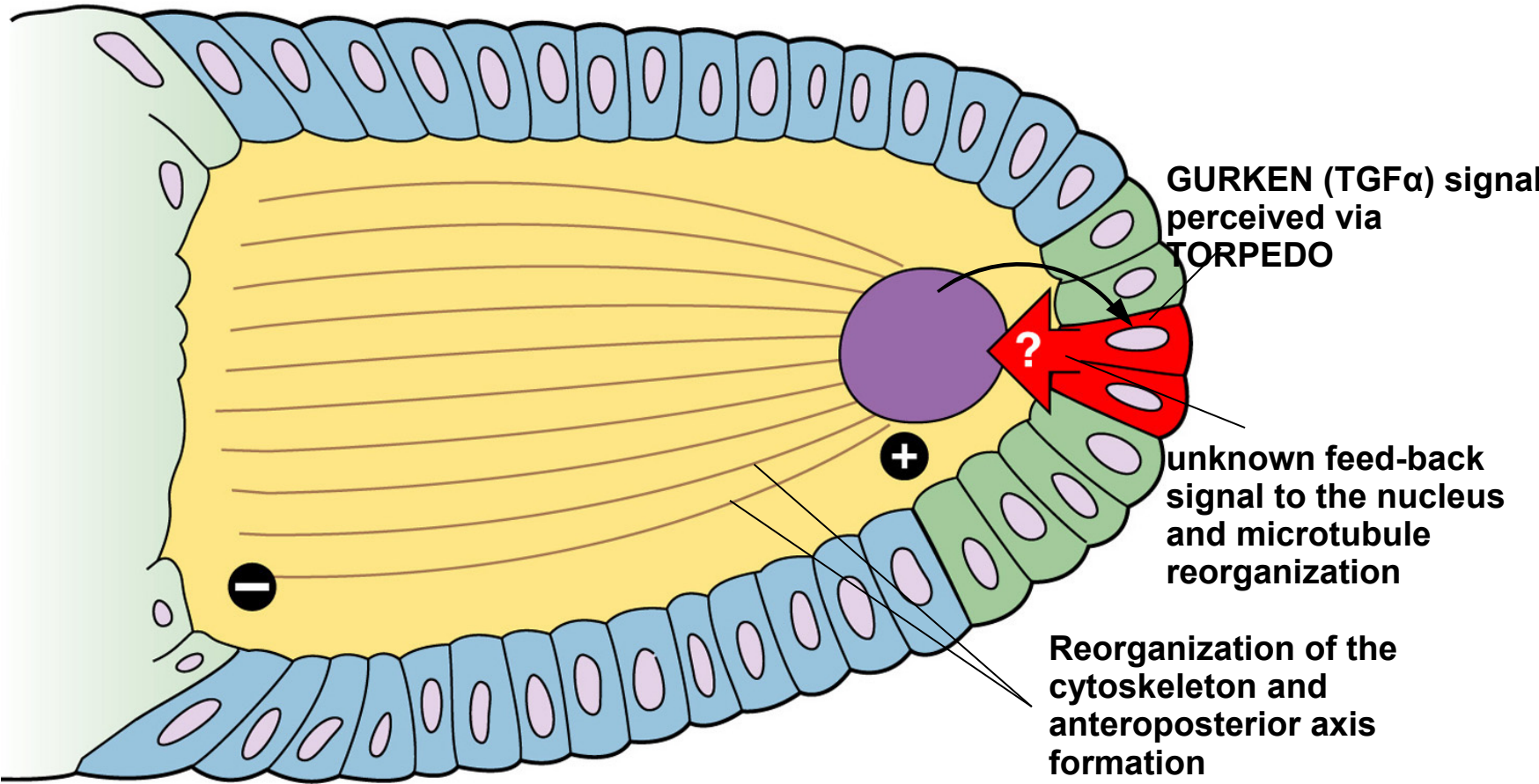
- 1 Only ventral follicle cells make Pipe. Complex of Pipe, Nudel, and Windbeutel proteins is secreted (only on ventral side). Pipe sulfates glycosaminoglycans (see Chapter 12) on the ventral side.
- 2 Nurse cells have deposited mRNA for Easter complex in the egg, and the Easter protein complex, which 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

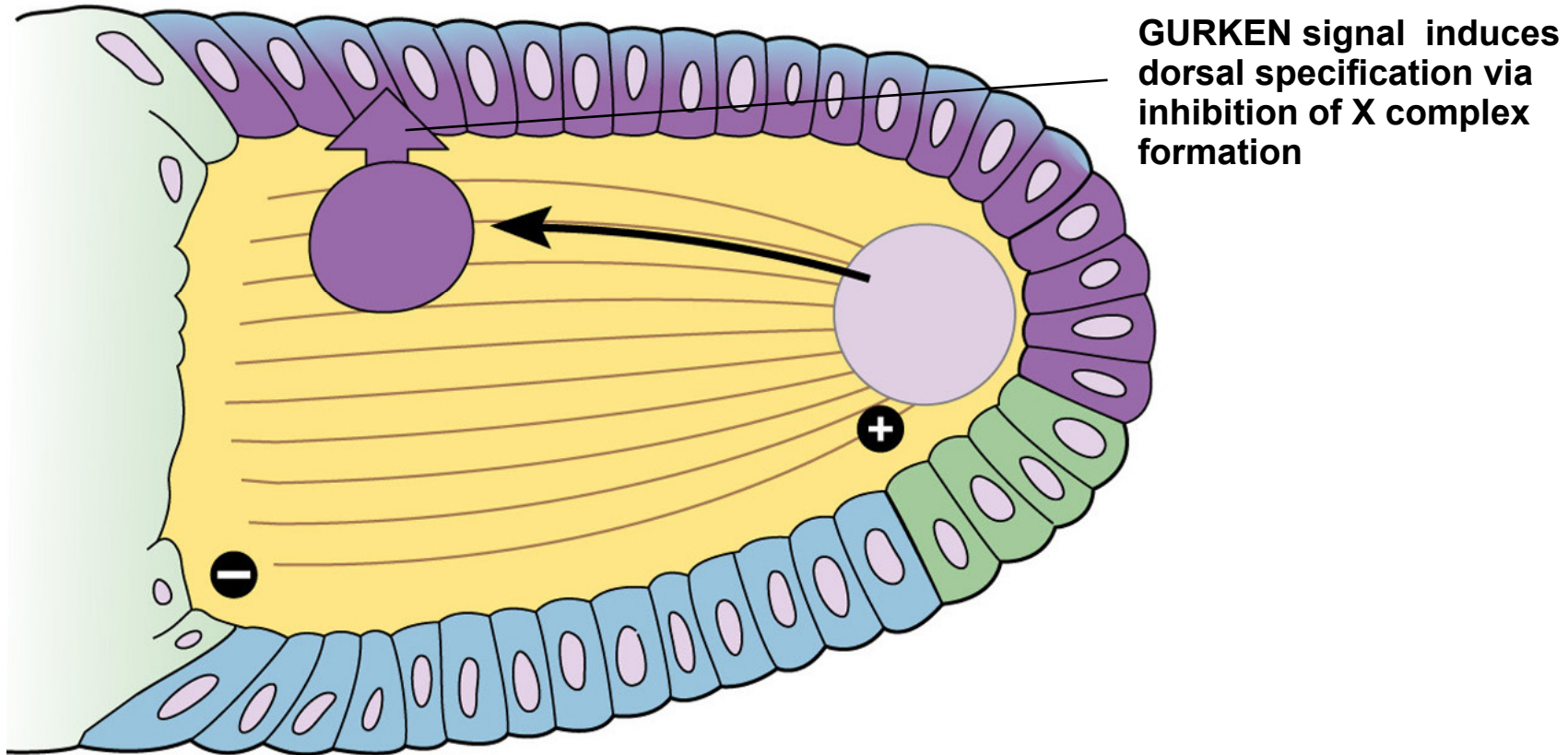


Maternal tissue as a **source of asymmetry** in the early *Drosophila* formation

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**.

Discussion