

Bi8940 Developmental biology

Lesson 1

Introduction into the Study of Development

Jan Hejátko

Laboratory of Molecular Plant Physiology,
Department of Functional Genomics and Proteomics,
and

Functional Genomics and Proteomics of Plants

CEITEC

Masaryk University,
Brno, Czech Republic

hejatko@sci.muni.cz, www.ceitec.eu



INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

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



Outline of Lesson 1

- The course at a glance and literature
- Repetitorium of basic terms
 - Major body directions
 - Mitosis vs. Meiosis
- Overview of development
 - Asymmetrical cell division as a major force of the development
 - Genetic integrity of the differentiated cells
 - Concept of stem cells
- Gametogenesis, fertilization and lineage tracing



The Course at a Glance

- **Lesson 1**

- Introduction into the Study of Development
 - Repetitorium of Basic Terms
 - Overview of Development
 - Gametogenesis, Fertilization and Lineage Tracing

- **Lesson 2**

- Oogenesis and Early Development of *Drosophila*

- **Lesson 3**

- Early Development of Amphibians and Amniotes

- **Lesson 4**

- Vertebrate Organogenesis
 - Development of Ectodermal Derivatives



The Course at a Glance

- **Lesson 5**
 - Vertebrate Organogenesis
 - Development of Mesodermal and Endodermal Derivatives
- **Lesson 6**
 - Plant Reproduction
- **Lesson 7**
 - Plant Embryogenesis
- **Lesson 8**
 - Postembryonic Plant Development



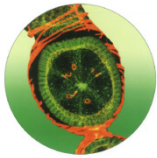
The Course at a Glance

- **Lesson 9**
 - Morphogenesis in Animals and in Plants

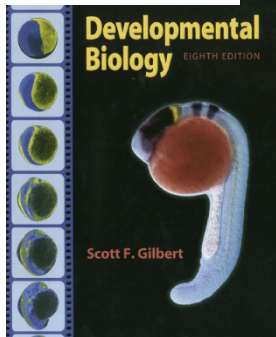
- **Lesson 10**
 - Regulation of Gene Expression in the Development

Literature

PRINCIPLES OF
DEVELOPMENTAL
BIOLOGY



Fred H. Wilt & Sarah C. Hake

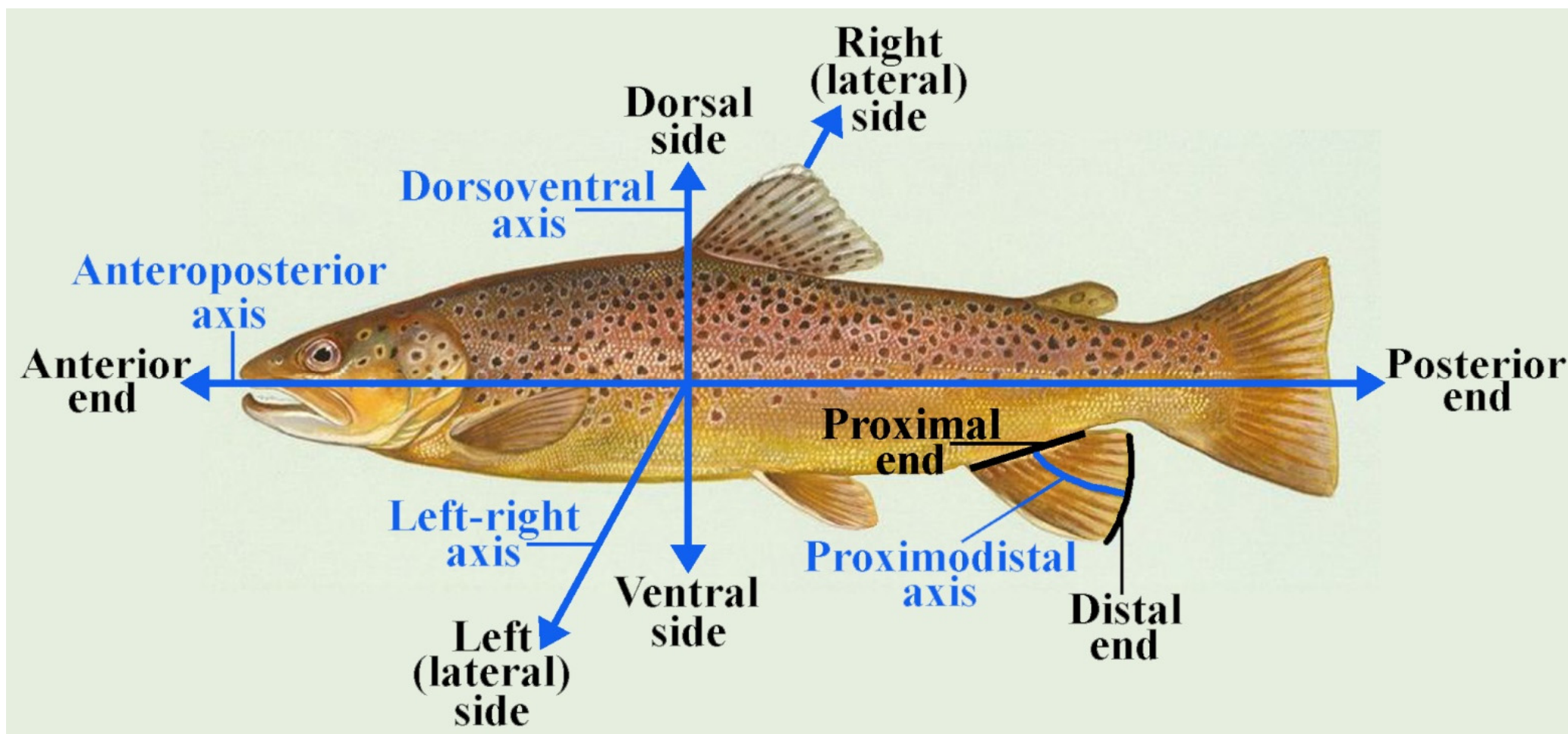


- **Fred H. Wilt and Sarah Hake, Principles of Developmental Biology** (W.W. Norton & Company, New York, London, 2004)
- **Scott F. Gilbert, Developmental Biology**, eighth edition (Sinauer Associates, Inc., Publishers Sunderland, Massachusetts, USA, 2006)
- Zdeněk Vacek, Embryologie (Grada Publishing, 2006)
- Dubová J., Hejátko J., Friml J. (2005) Reproduction of Plants, in Encyclopedia of Molecular Cell Biology and Molecular Medicine (ed, R. A. Meyers), pp. 249 – 295. Wiley-VCH, Weinheim, Germany
- Selected original papers in scientific journals

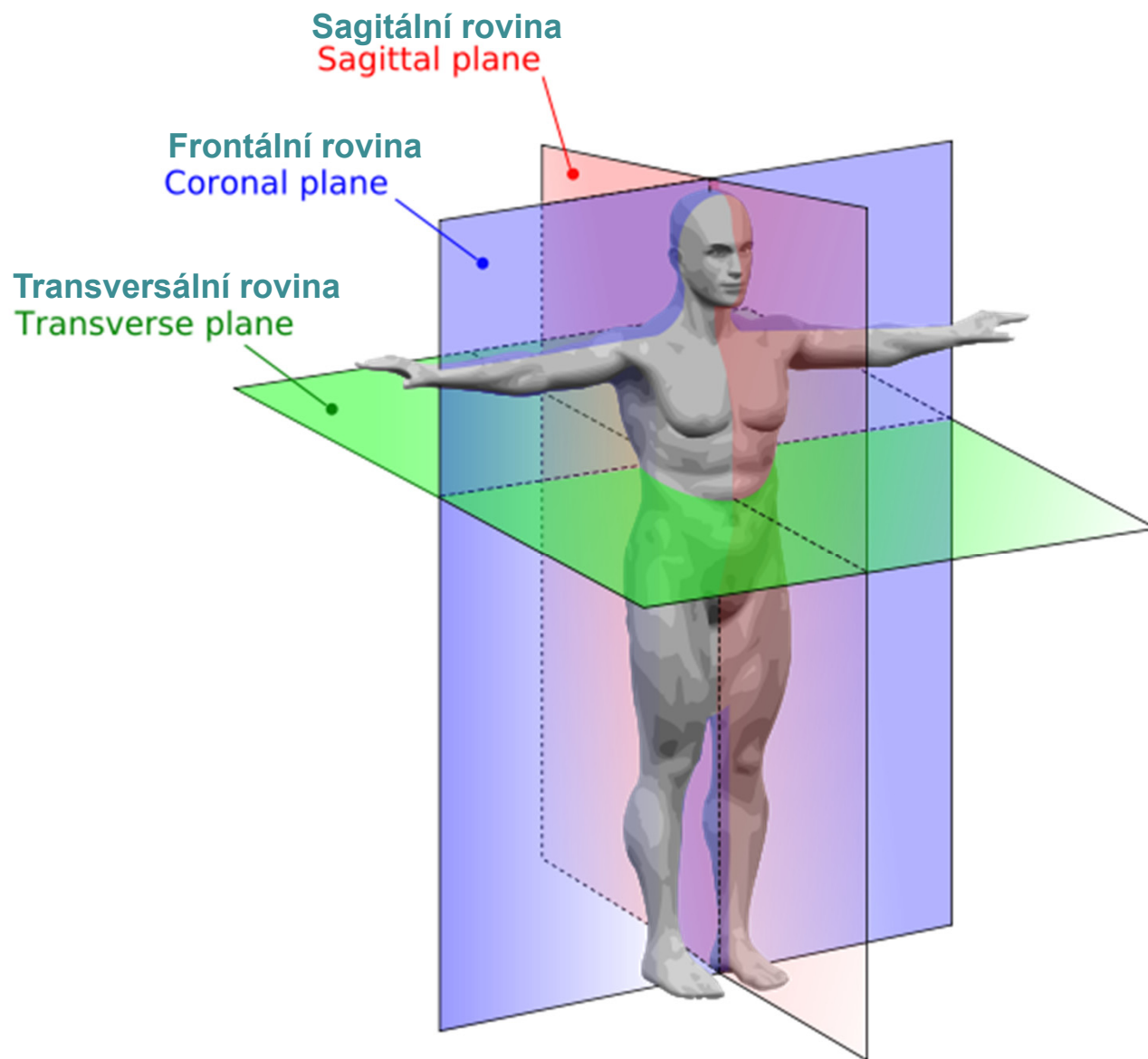


Outline of Lesson 1

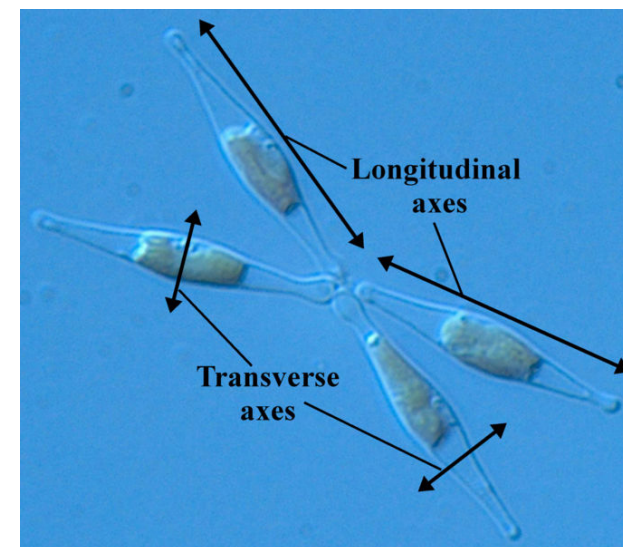
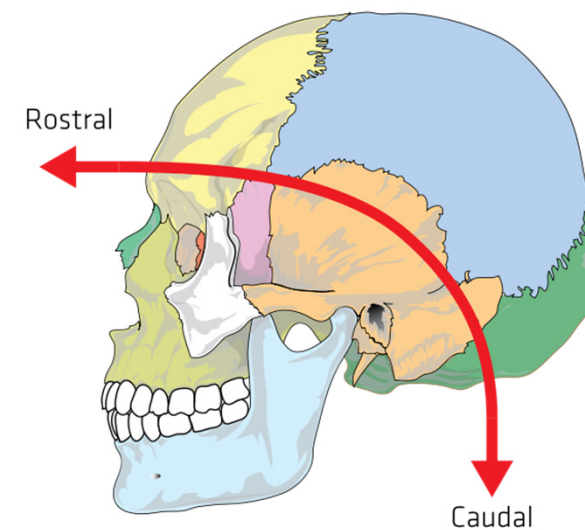
- The course at a glance
- Repetitorium of basic terms
 - Major body directions

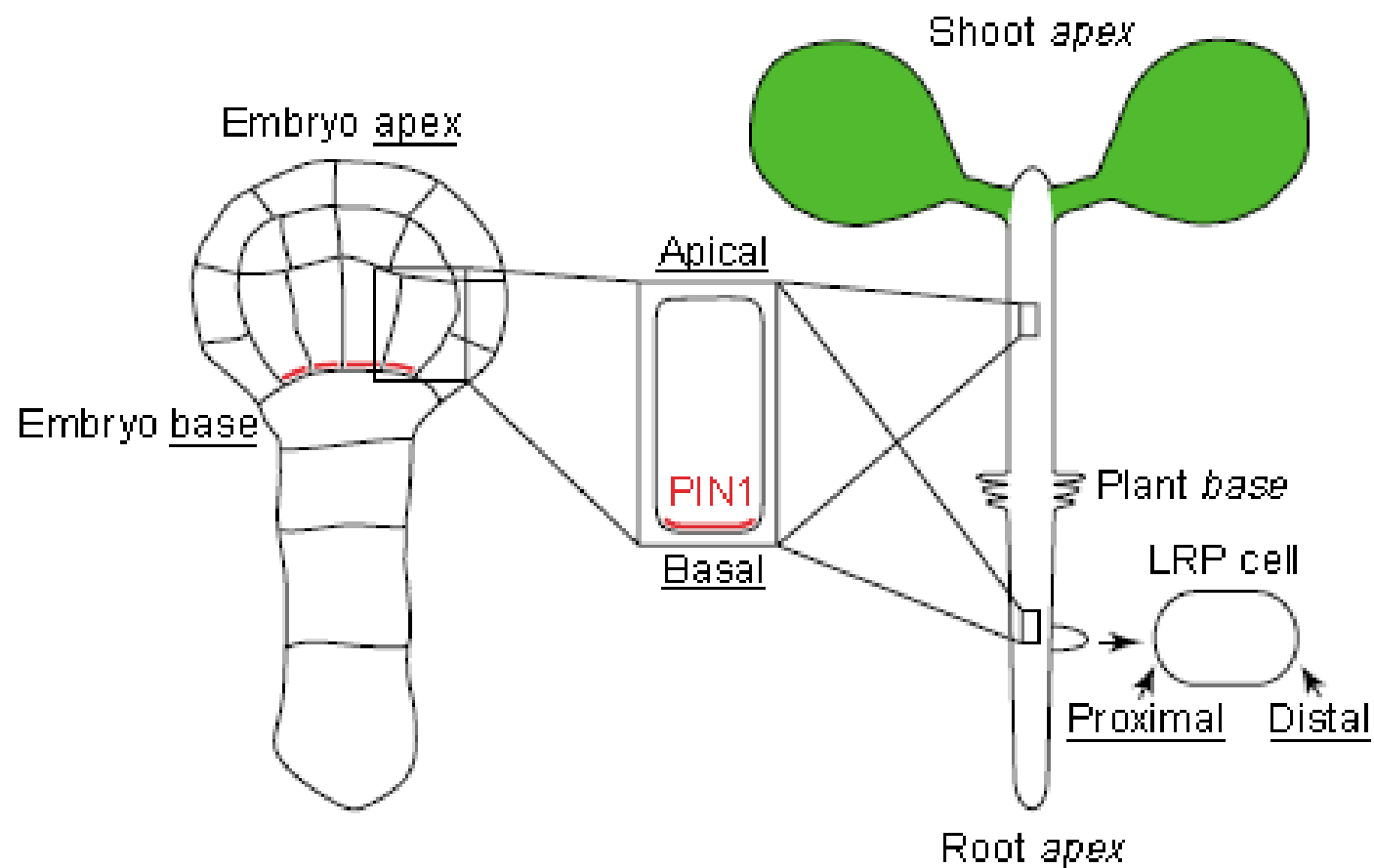


http://en.wikipedia.org/wiki/Anatomical_terms_of_location



http://en.wikipedia.org/wiki/Anatomical_terms_of_location

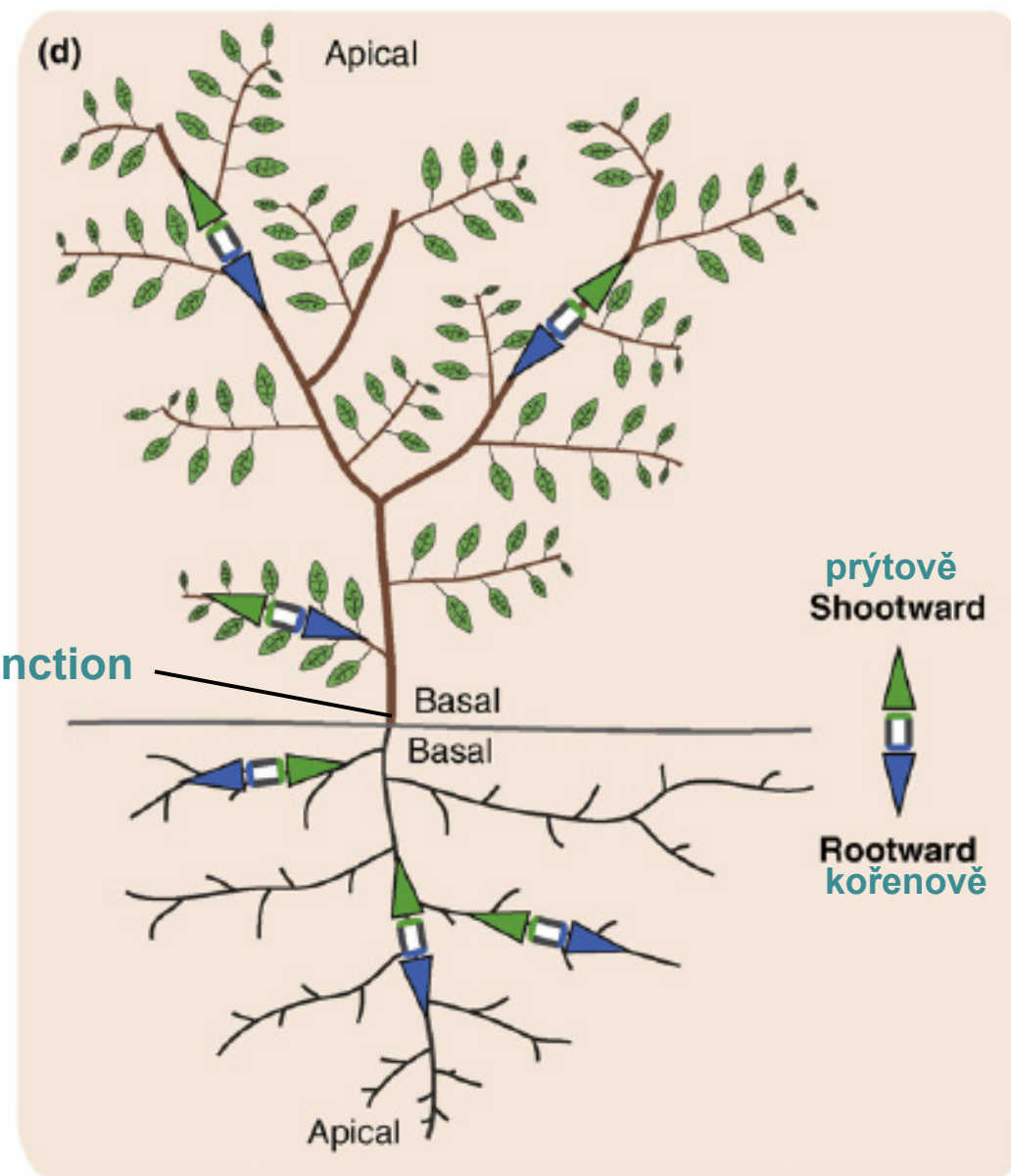




Friml et al., *Trends Plant Sci* (2006)

Terminology	(a) <u>Anatomical</u>	(b) <u>Cellular</u>	(c) <u>Proposed</u>
Shoot	Apical Basal	Apical Basal	Shootward Rootward
Root	Basal [★] Apical [★]	Apical [★] Basal [★]	Shootward Rootward

Root/shoot junction

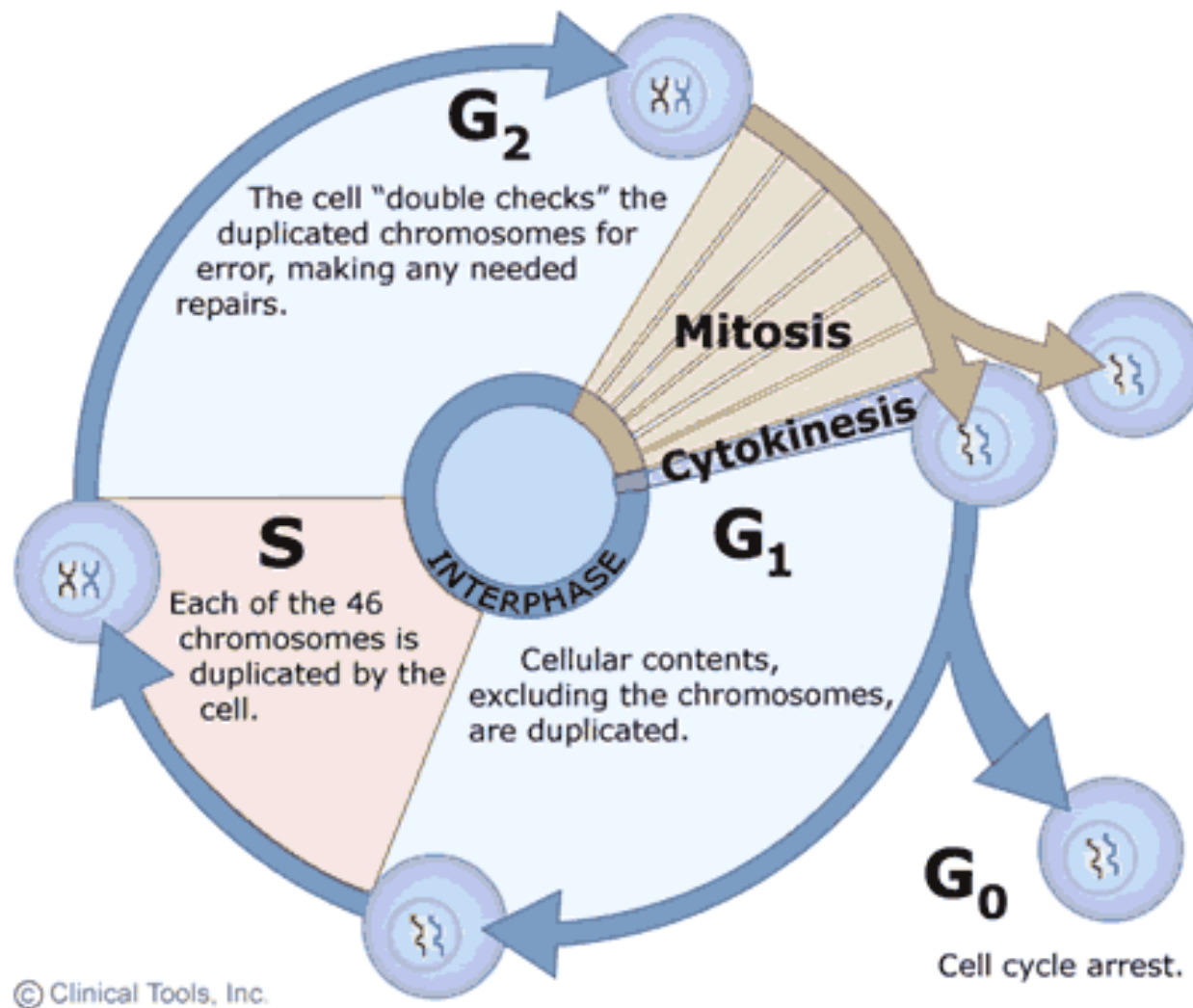


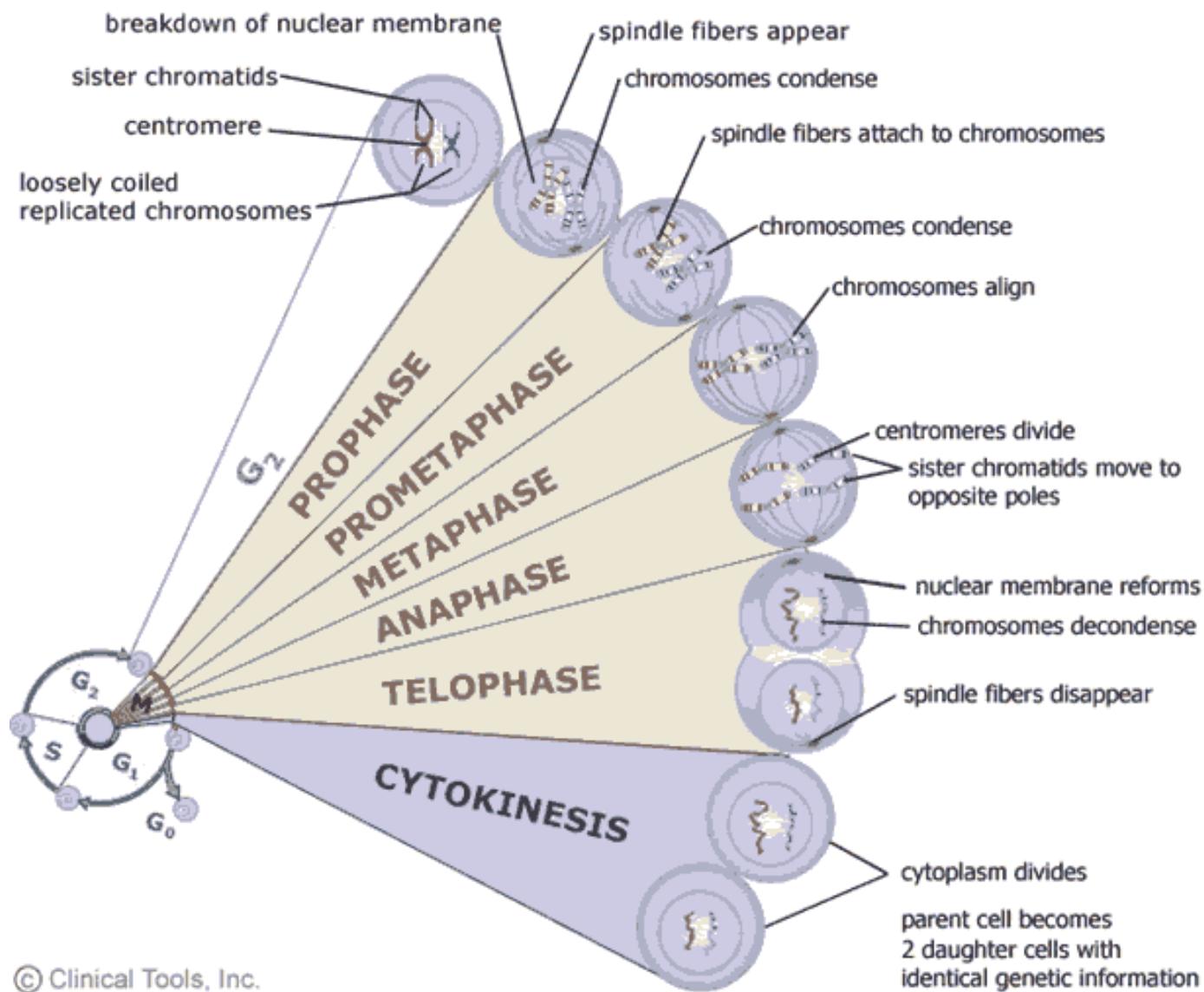
Baskin et al., *Trends Plant Sci* (2010)

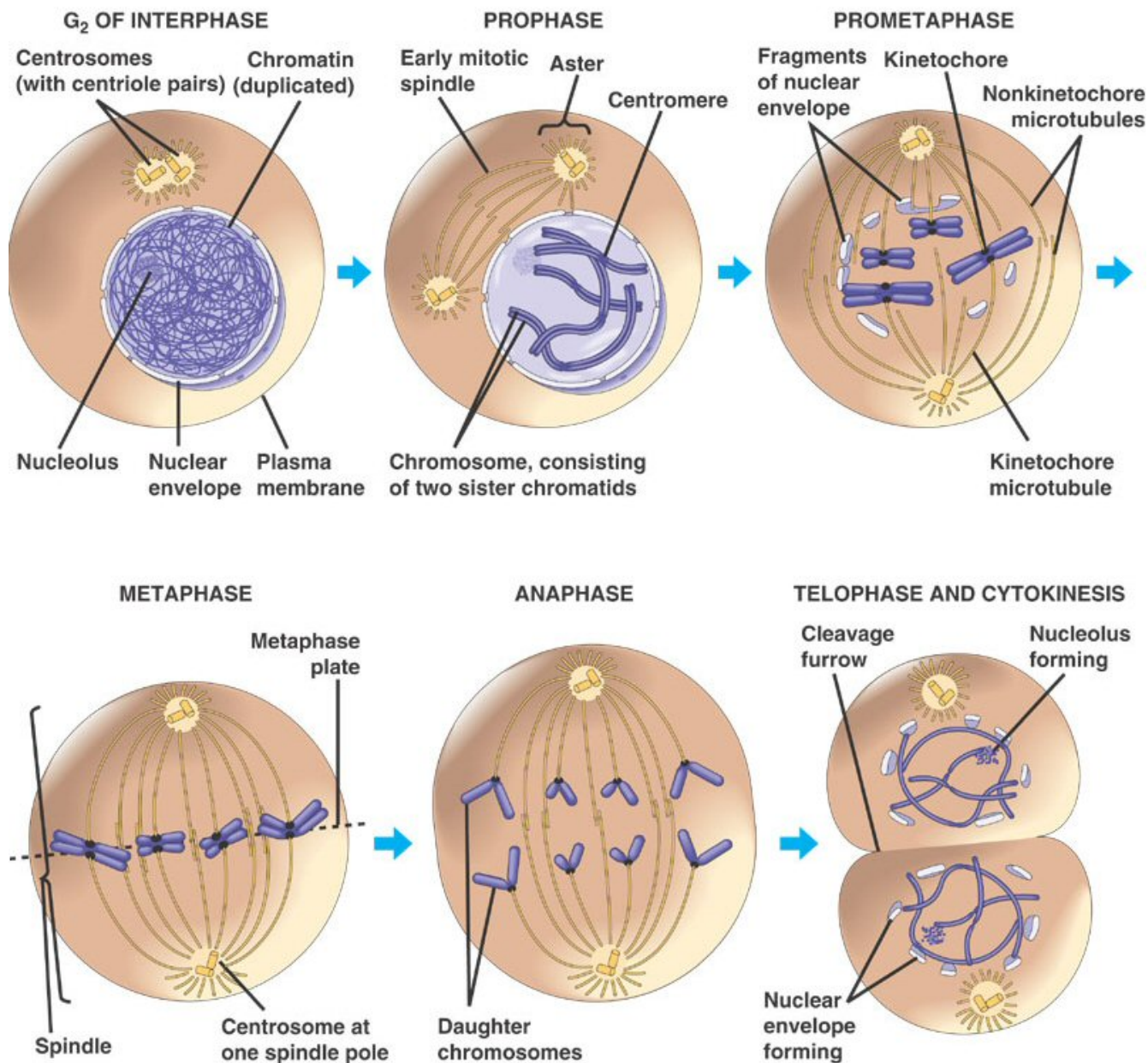


Outline of Lesson 1

- The course at a glance
- Repetitorium of basic terms
 - Major body directions
 - Mitosis vs. meiosis









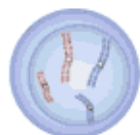
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

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

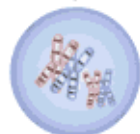
Meiosis I in Males

Prophase I

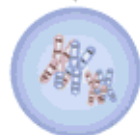
chromosomes begin to condense



homologous chromosomes pair
crossing over occurs

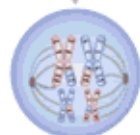


recombinant chromosomes



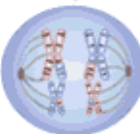
Metaphase I

spindle fibers attach to chromosomes
chromosomes line up in center of cell



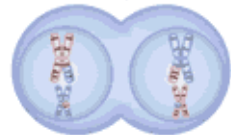
Anaphase I

chromosomes start to move to opposite
ends of cell as spindle fibers shorten



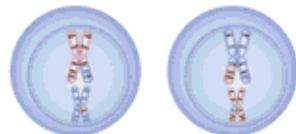
Telophase I

chromosomes reach opposite ends
nuclear membrane forms



Cytokinesis

cell division occurs



sperm cell precursor sperm cell precursor

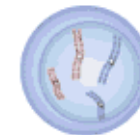
- Leptotene
- Zygotene
- Pachytene
- Diplotene
- Diakinesis

© Clinical Tools, Inc.

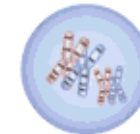
Meiosis I in Females

Prophase I

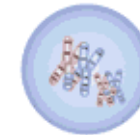
chromosomes begin to condense



homologous chromosomes pair
crossing over occurs

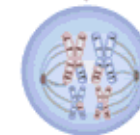


recombinant chromosomes



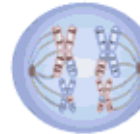
Metaphase I

spindle fibers attach to chromosomes
chromosomes line up in center of cell



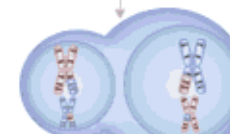
Anaphase I

chromosomes start to move to opposite
ends of cell as spindle fibers shorten



Telophase I

chromosomes reach opposite ends
nuclear membrane forms



polar body egg cell precursor

Cytokinesis

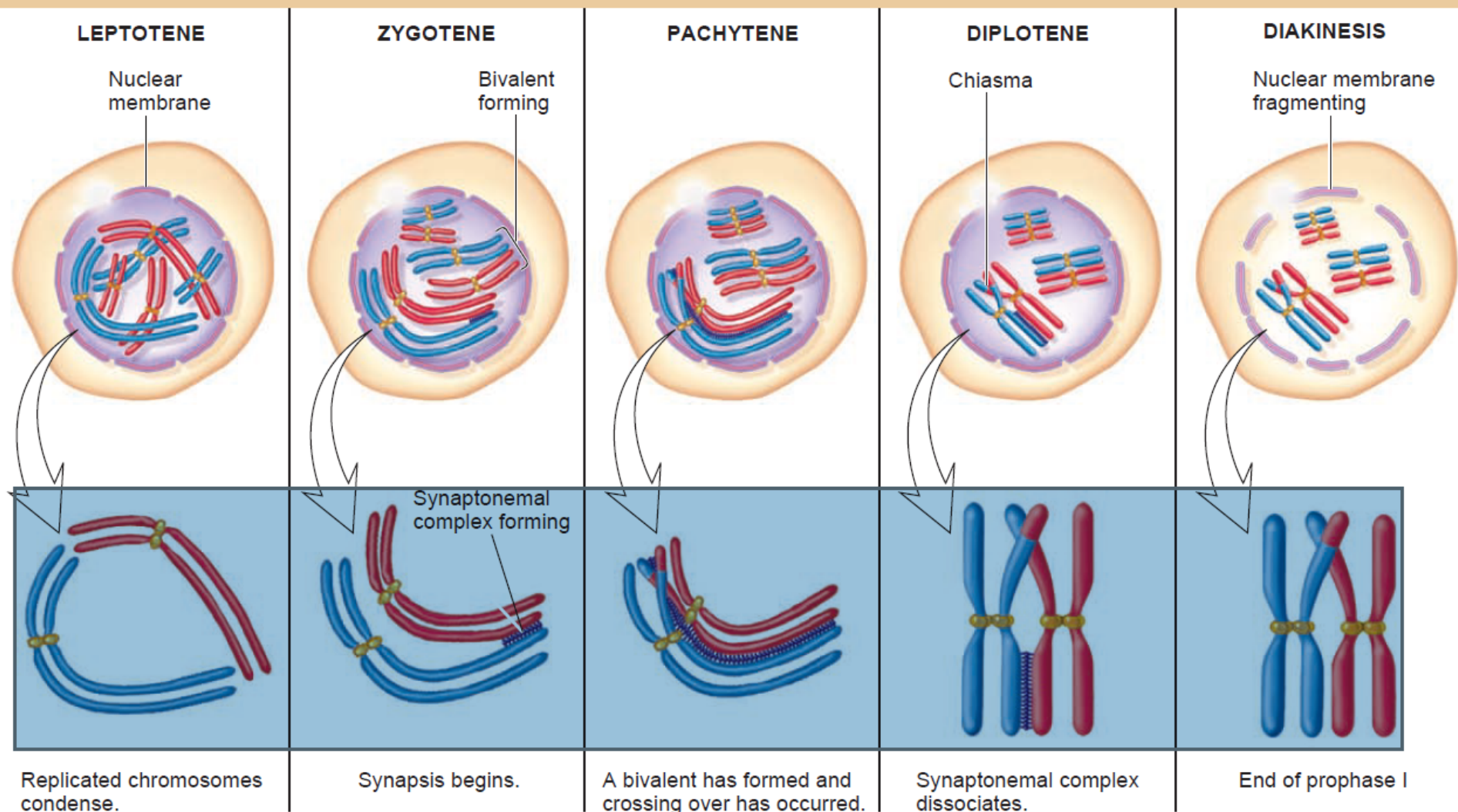
cell division occurs



polar body egg cell precursor

© Clinical Tools, Inc.

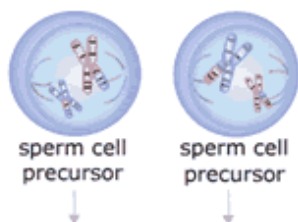
STAGES OF PROPHASE OF MEIOSIS I



Meiosis II in Males

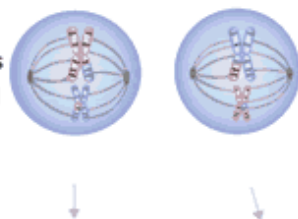
Prophase II

chromosomes begin to condense
nuclear membrane dissolves
spindle fibers form



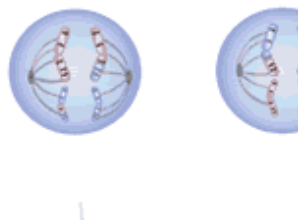
Metaphase II

spindle fibers attach to chromosomes
chromosomes line up in center of cell



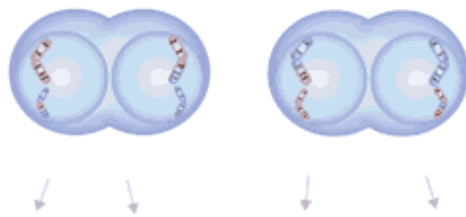
Anaphase II

centromeres divide and sister chromatids move to opposite ends of cell as spindle fibers shorten



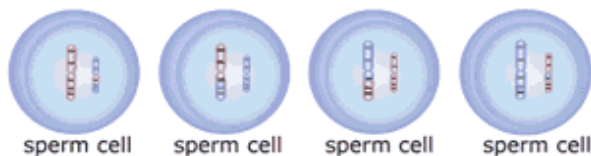
Telophase II

chromosomes reach opposite ends
nuclear membrane forms



Cytokinesis

cell division occurs

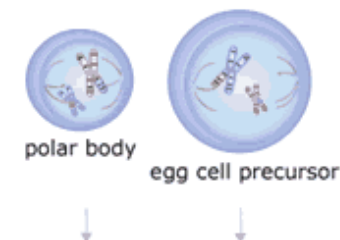


© Clinical Tools, Inc.

Meiosis II in Females

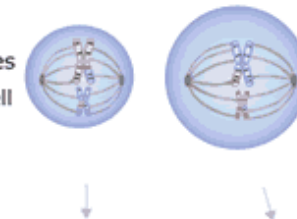
Prophase II

chromosomes begin to condense
nuclear membrane dissolves
spindle fibers form



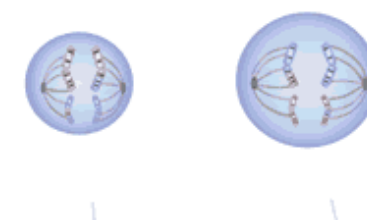
Metaphase II

spindle fibers attach to chromosomes
chromosomes line up in center of cell



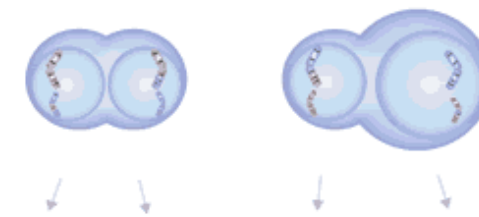
Anaphase II

centromeres divide and sister chromatids move to opposite ends of cell as spindle fibers shorten



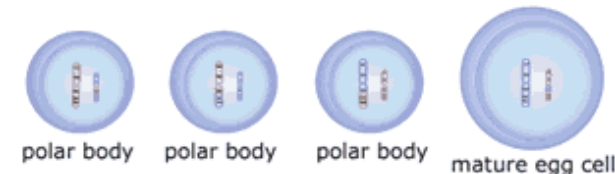
Telophase II

chromosomes reach opposite ends
nuclear membrane forms



Cytokinesis

cell division occurs

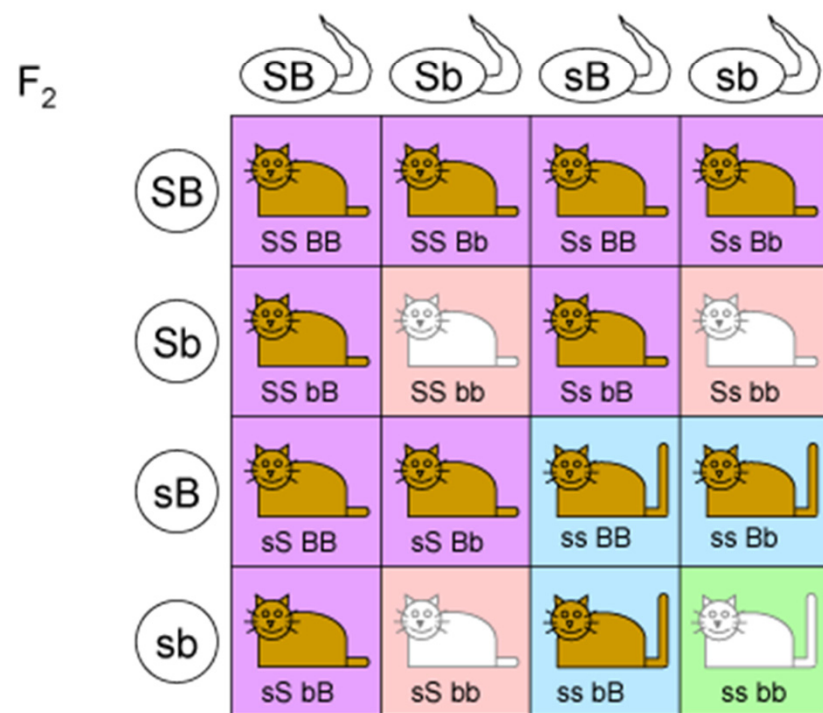
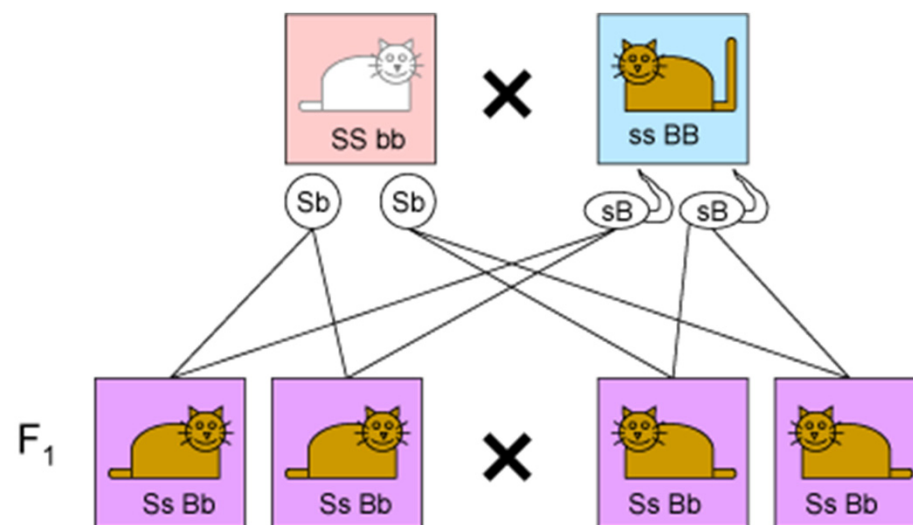


© Clinical Tools, Inc.



INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

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

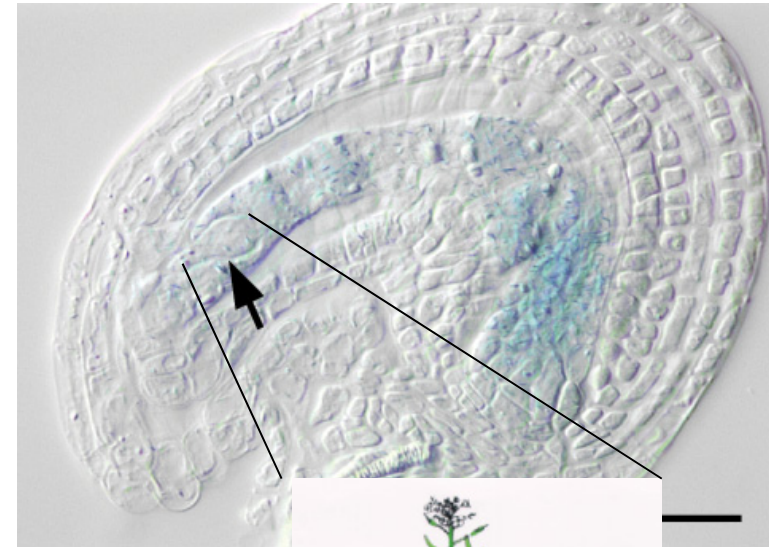


Wikipedia



Outline of Lesson 1

- The course at a glance
- Repetitorium of basic terms
 - Major body directions
 - Mitosis vs. Meiosis
- Overview of development
 - Asymmetrical cell division as a major force of the development

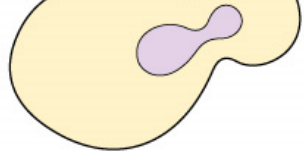


Wikipedia and Bio-Image

A. Yeast Mitosis (Budding)

This mother cell will change its mating type

This daughter cell can only be the same mating type as mother



Scale: Mature yeast cell $\approx 10 \mu\text{m}$

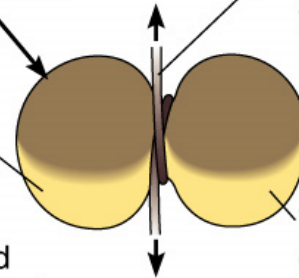
B. Amphibian Embryo (2-Cell Stage)

Sperm entered original oocyte here

Pulling ligature tight separates two cells

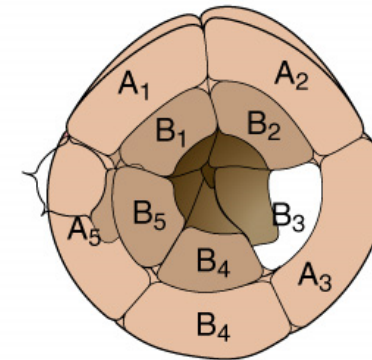
This one produces monster composed mainly of gut

This one can produce tadpole



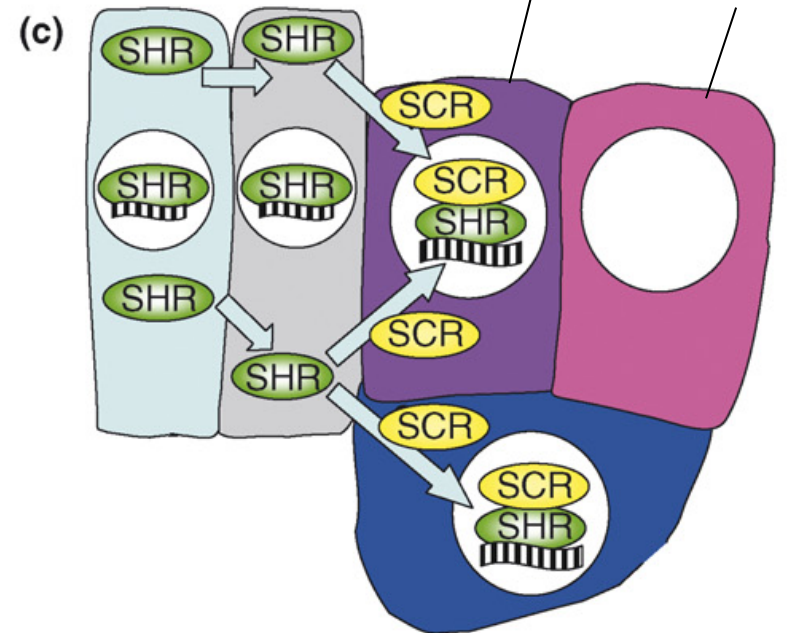
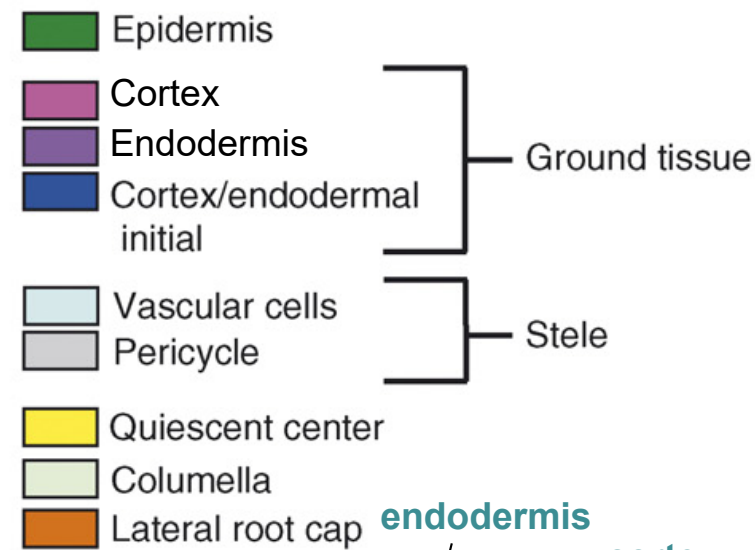
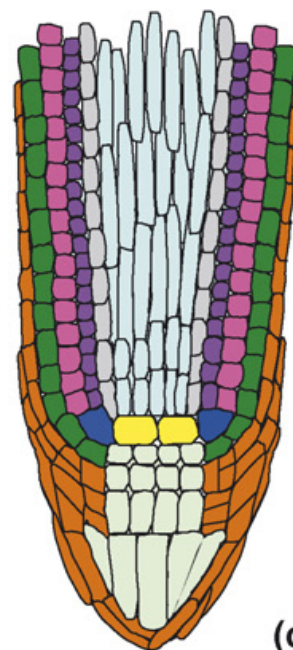
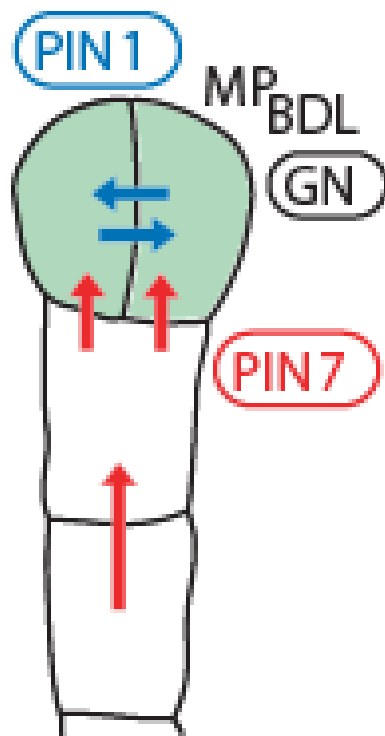
Scale: Entire egg $\approx 1 \text{ mm}$

C. Mouse Embryo (16-Cell Stage)



Each AB pair (A_1B_1 , A_2B_2 , etc.) arose from one mother cell. A cells can only form extra-embryonic tissues like placenta. B cell descendants may form the embryo proper.

Scale: Entire embryo $\approx 100 \mu\text{m}$



Dubova, Hejatko, Friml (2005)

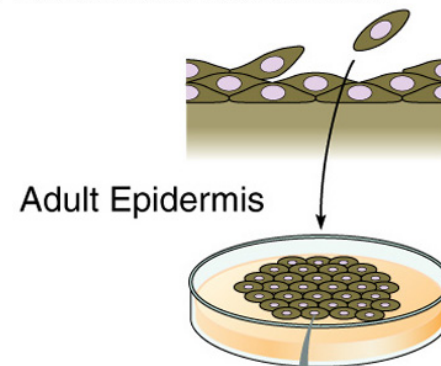
Petricka & Benfey, *Curr Opin Genet Dev* (2008)



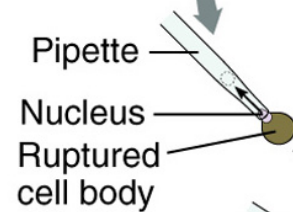
Outline of Lesson 1

- The course at a glance
- Repetitorium of basic terms
 - Major body directions
 - Mitosis vs. Meiosis
- Overview of development
 - Asymmetrical cell division as a major force of the development
 - Genetic integrity of the differentiated cells

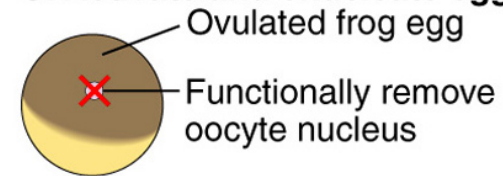
A. Dissociate and culture



B. Obtain nucleus



C. Activate and enucleate egg



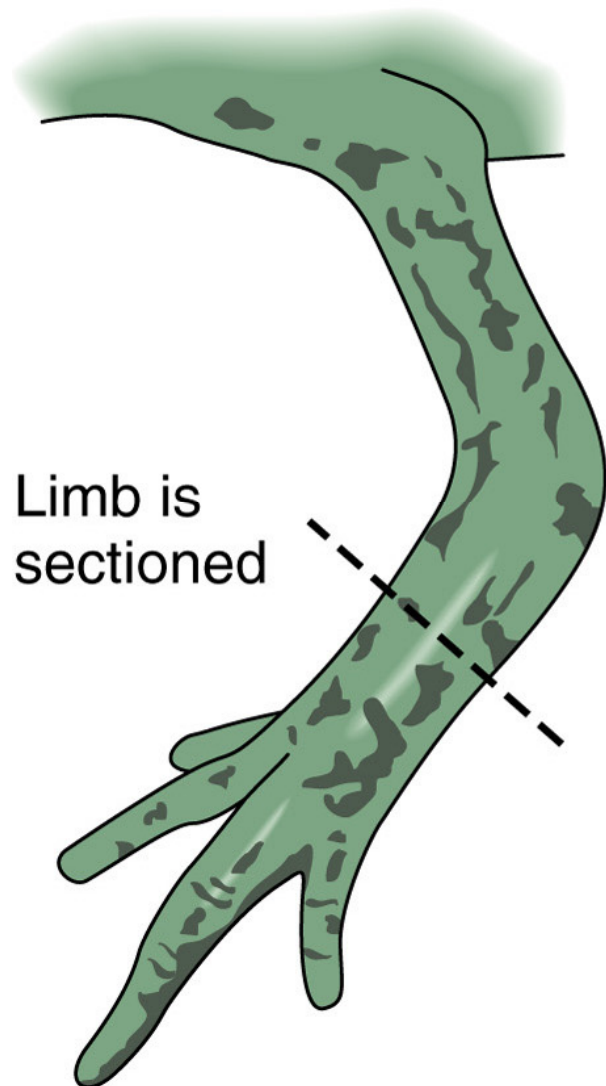
D. Cleavage



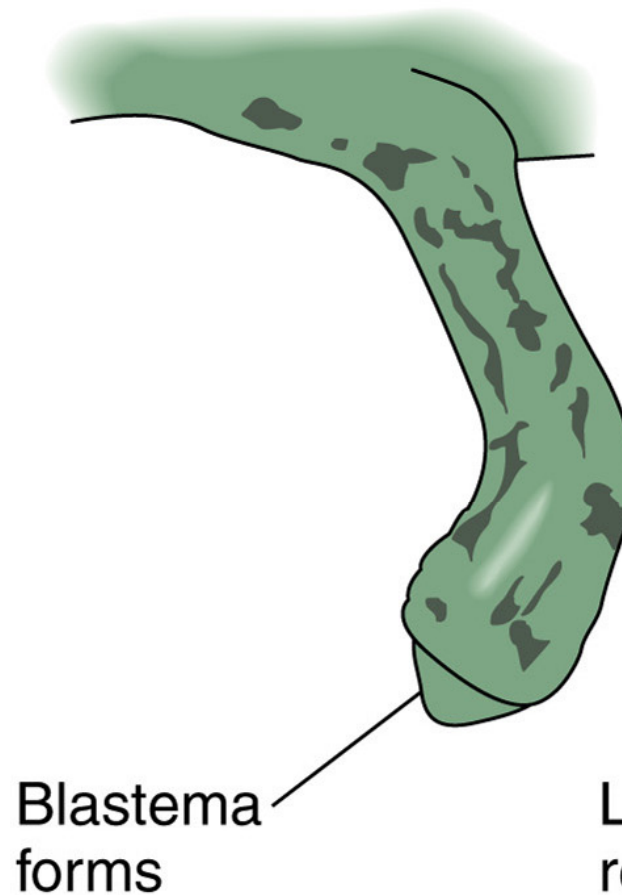
E. Complete tadpole



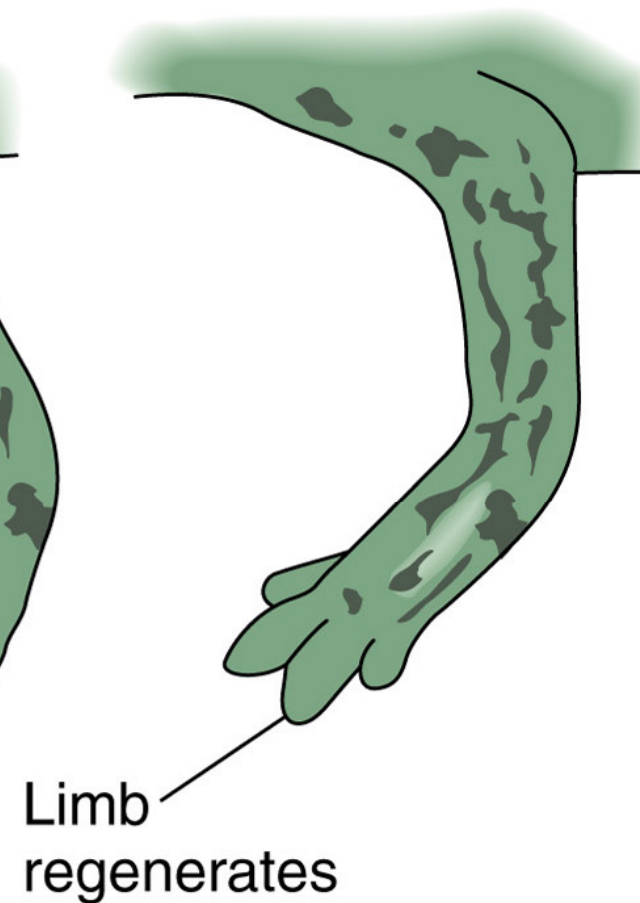
A.



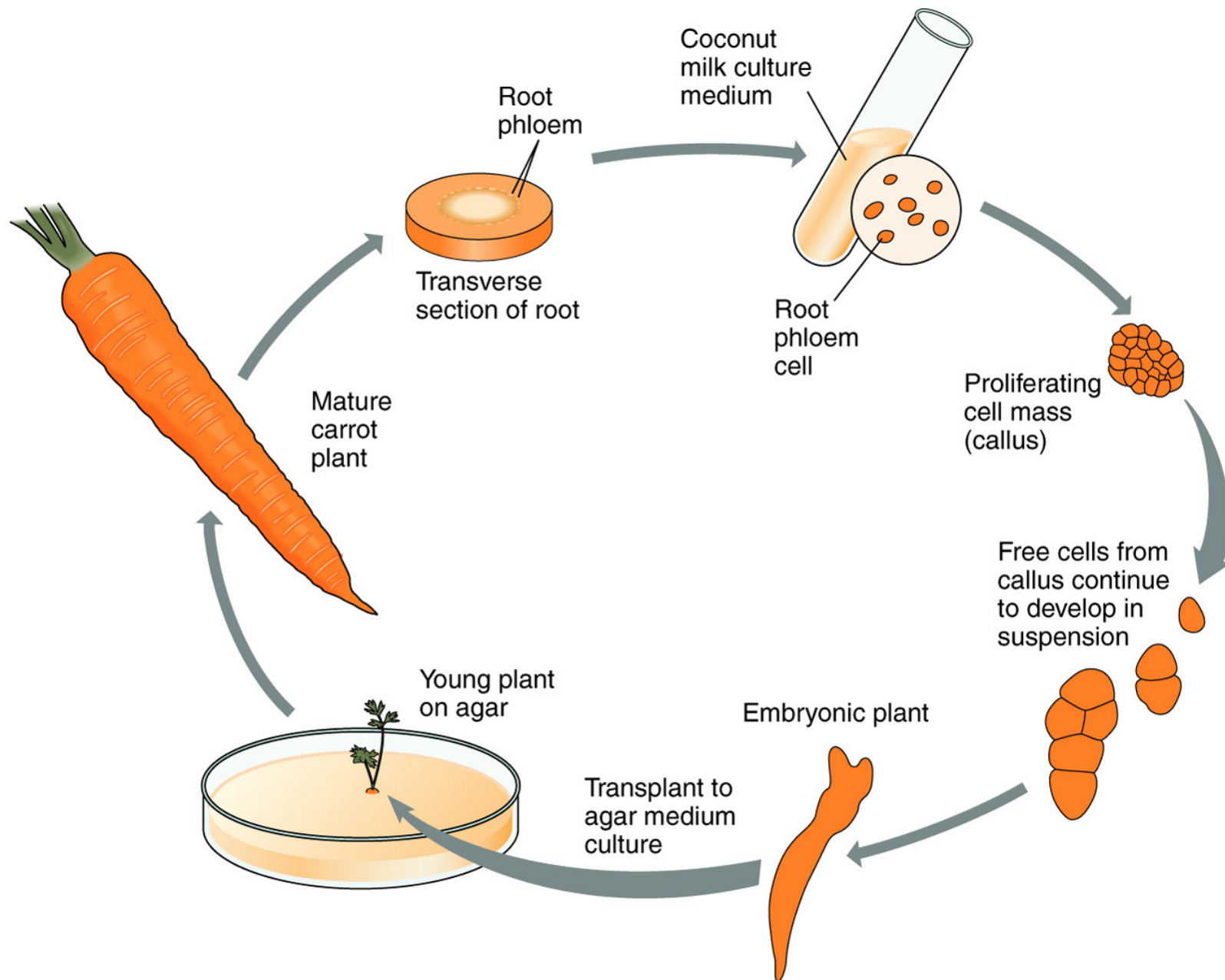
B.



C.



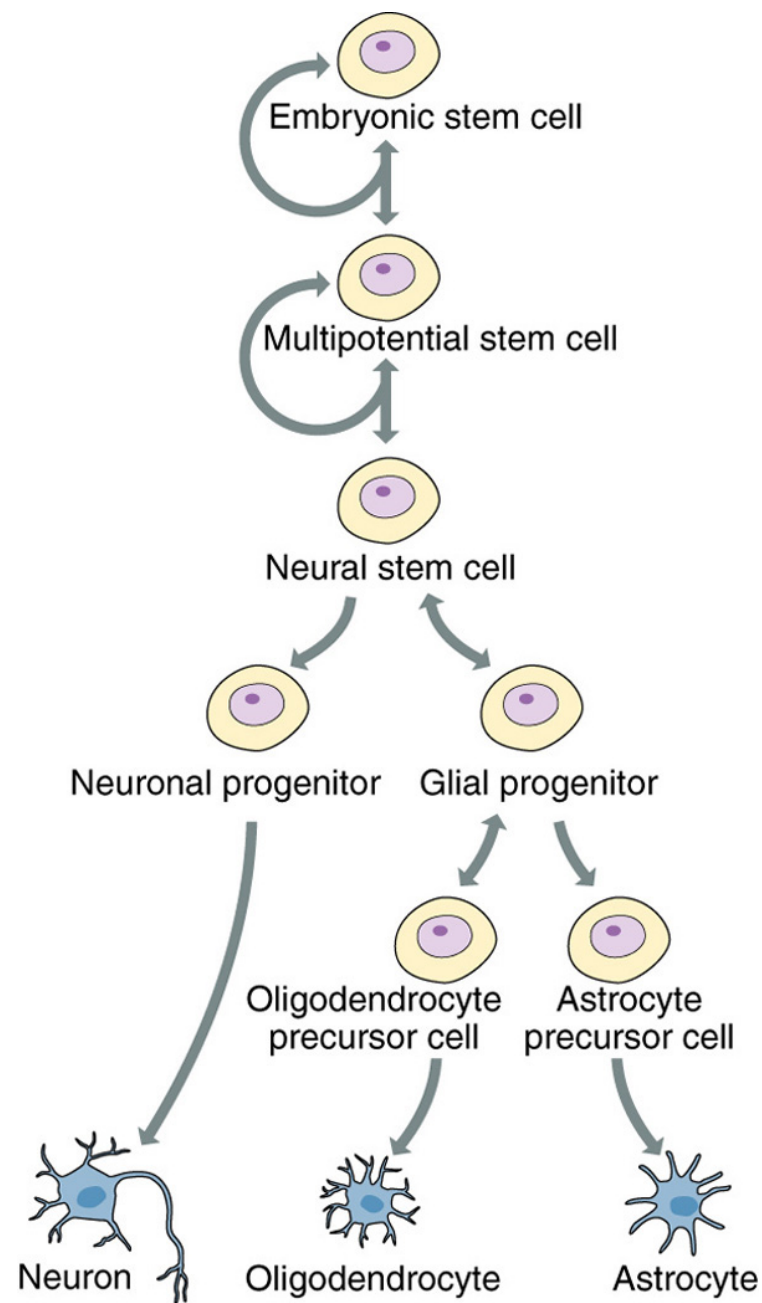
Limbs regeneration in salamander





Outline of Lesson 1

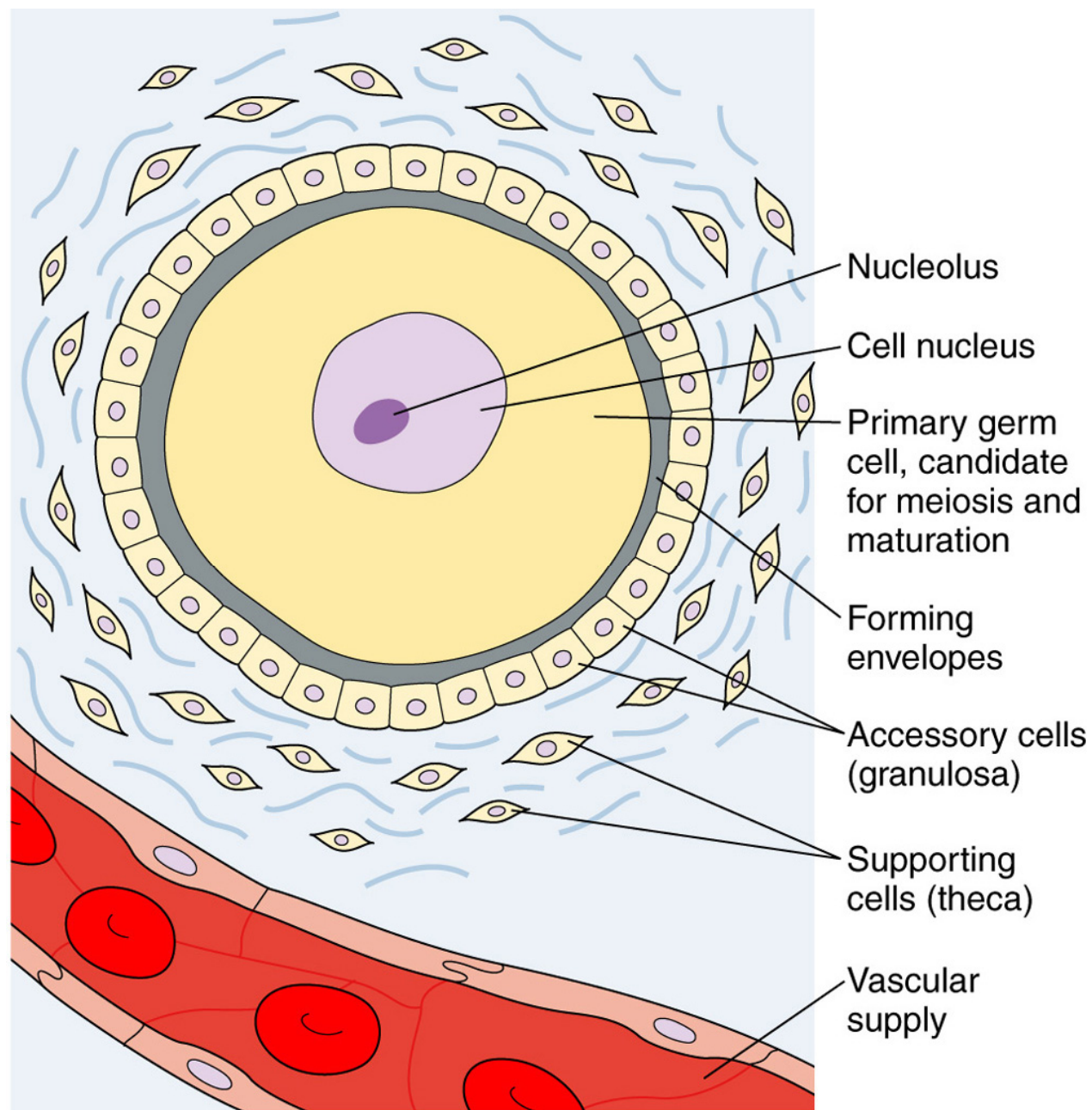
- The course at a glance
- Repetitorium of basic terms
 - Major body directions
 - Mitosis vs. Meiosis
- Overview of development
 - Asymmetrical cell division as a major force of the development
 - Genetic integrity of the differentiated cells
 - Concept of stem cells





Outline of Lesson 1

- The course at a glance
- Repetitorium of basic terms
 - Major body directions
 - Mitosis vs. Meiosis
- Overview of development
 - Asymmetrical cell division as a major force of the development
 - Genetic integrity of the differentiated cells
 - Concept of stem cells
- Gametogenesis, fertilization and lineage tracing

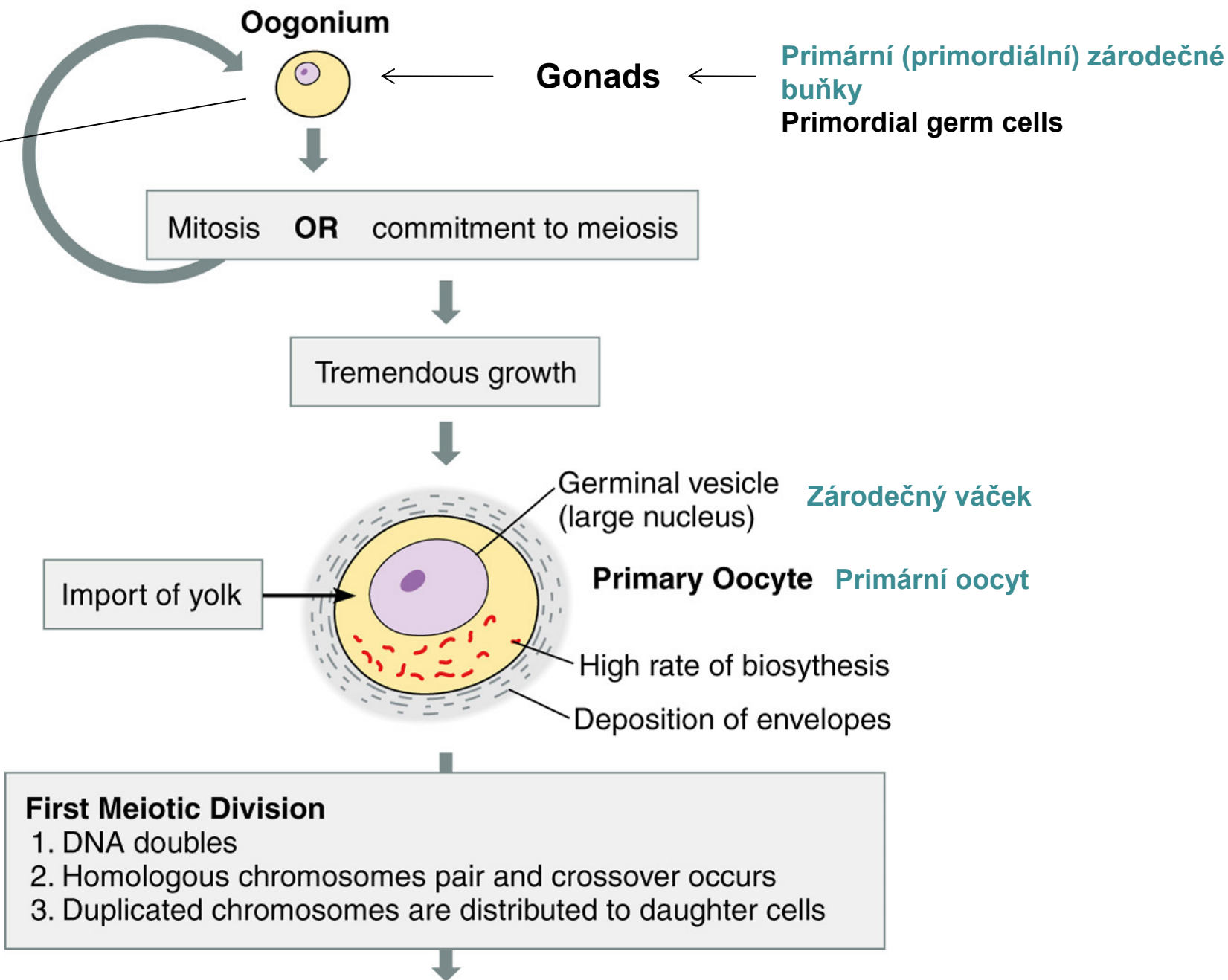


**Primární
zárodečná buňka**

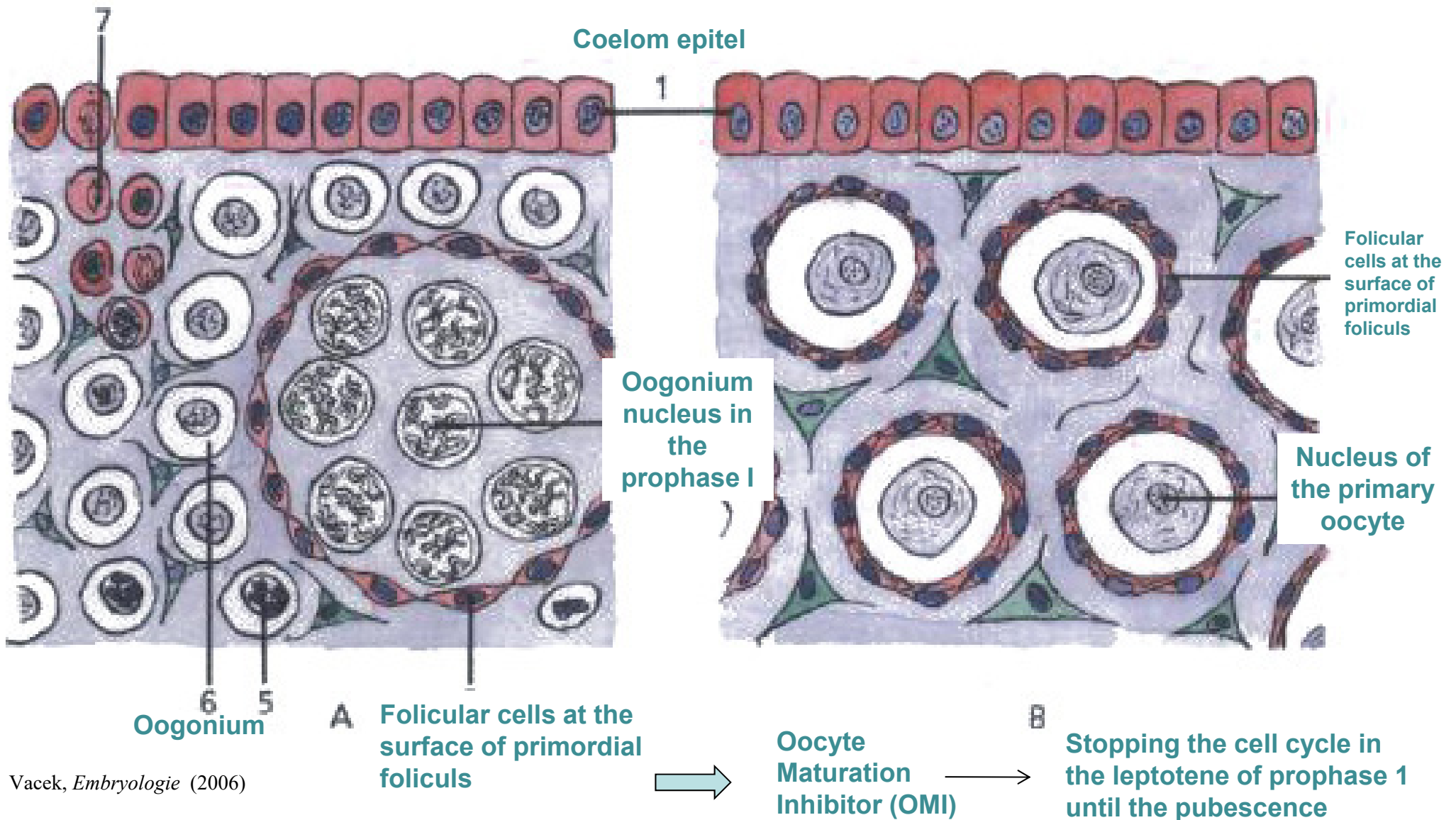
**Folikulární buňky na
povrchu vyvíjejících
se primordiálních
folikulů**

Podpůrné buňky

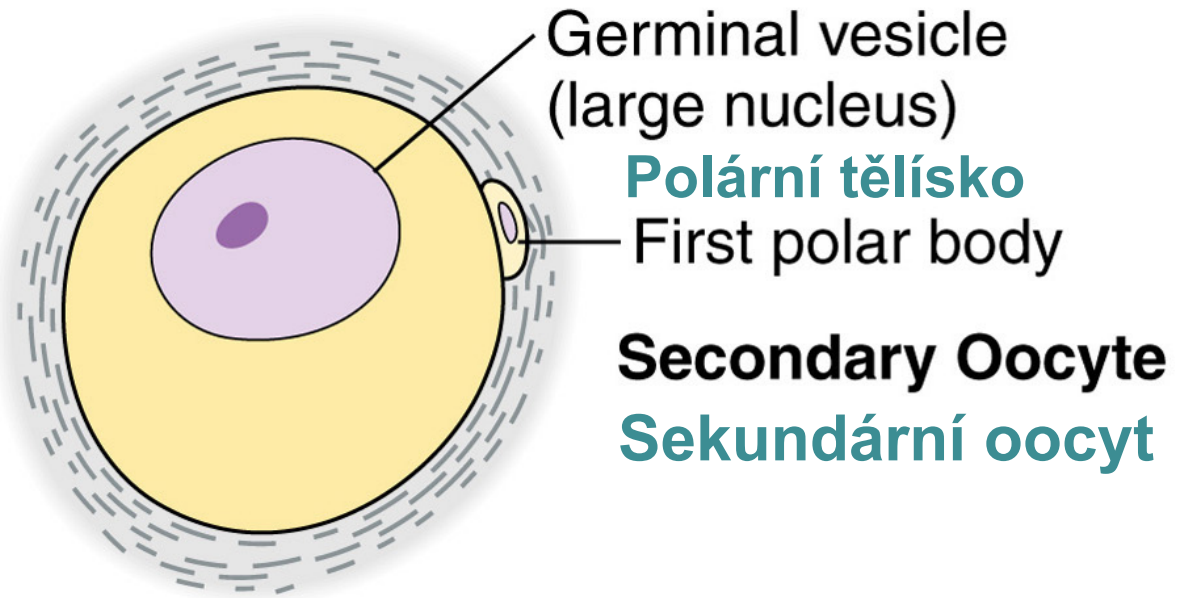
Genuine stem cells in amphibians, but NOT in humans



Section through the ovary of 2-months- (A) and 7-months-old (B) human foetus



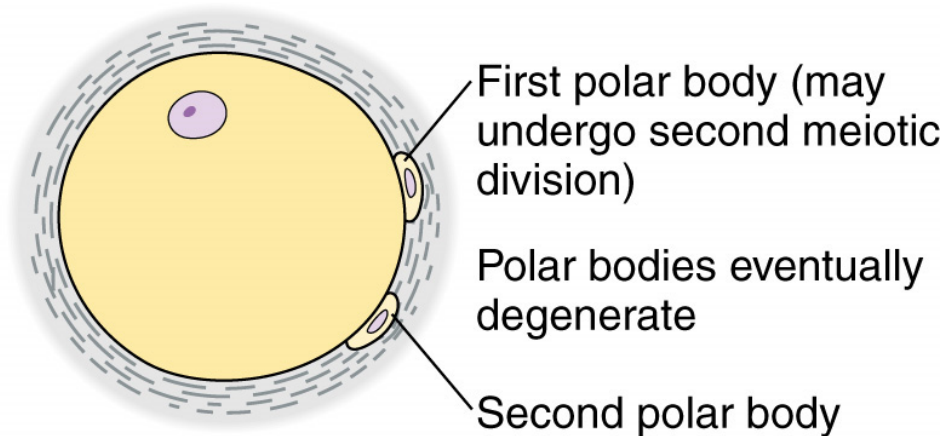
Vacek, *Embryologie* (2006)



Second Meiotic Division

1. No DNA synthesis
2. Duplicated chromatids separate and are distributed to daughter cells (which are haploid)

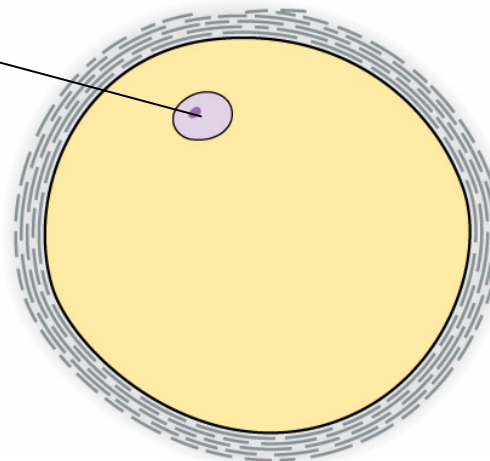




Ootid (haploid) **Ootida** (mateřská vaječná buňka)

May undergo further physiological maturation

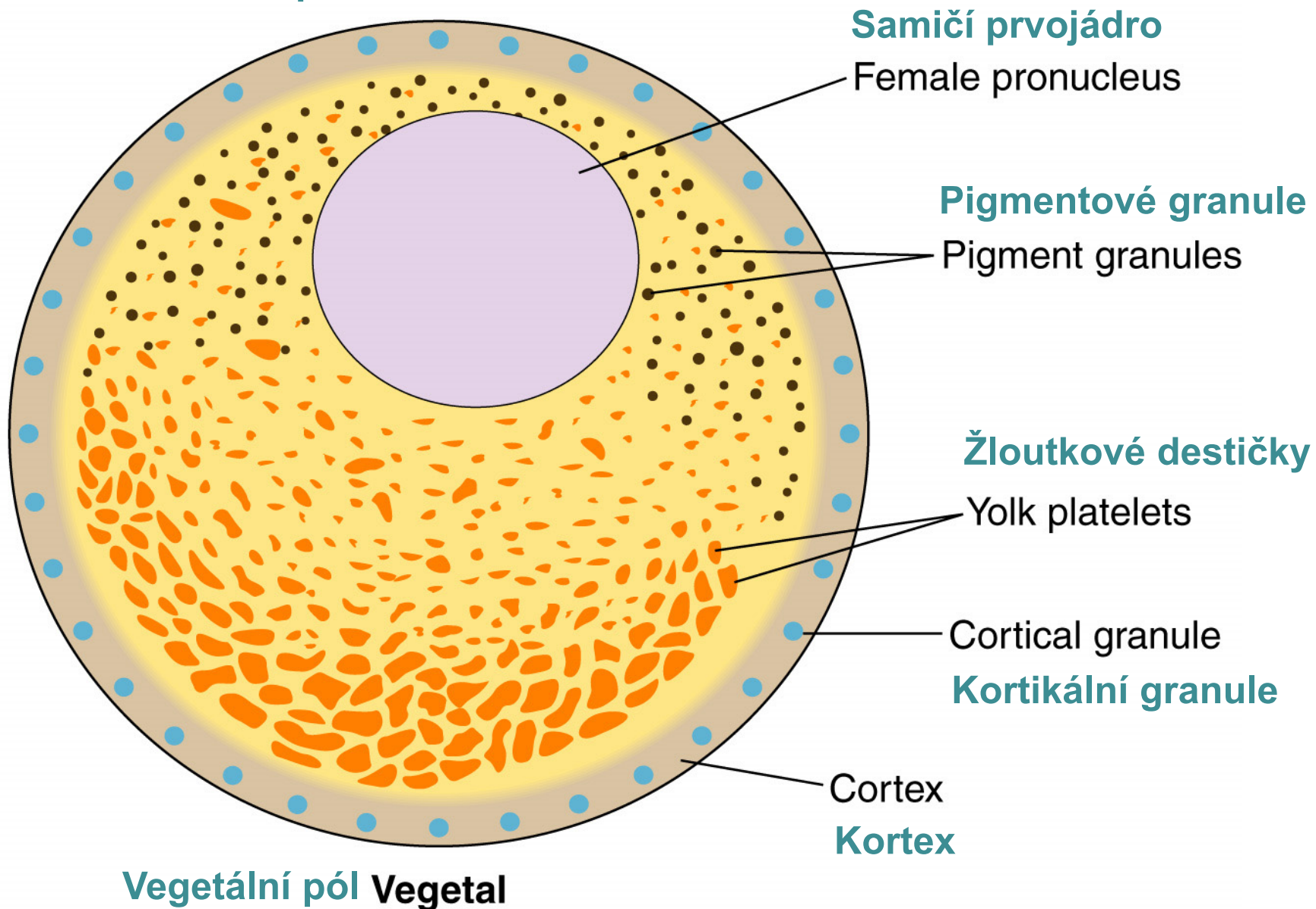
Pronucleus



Mature Egg

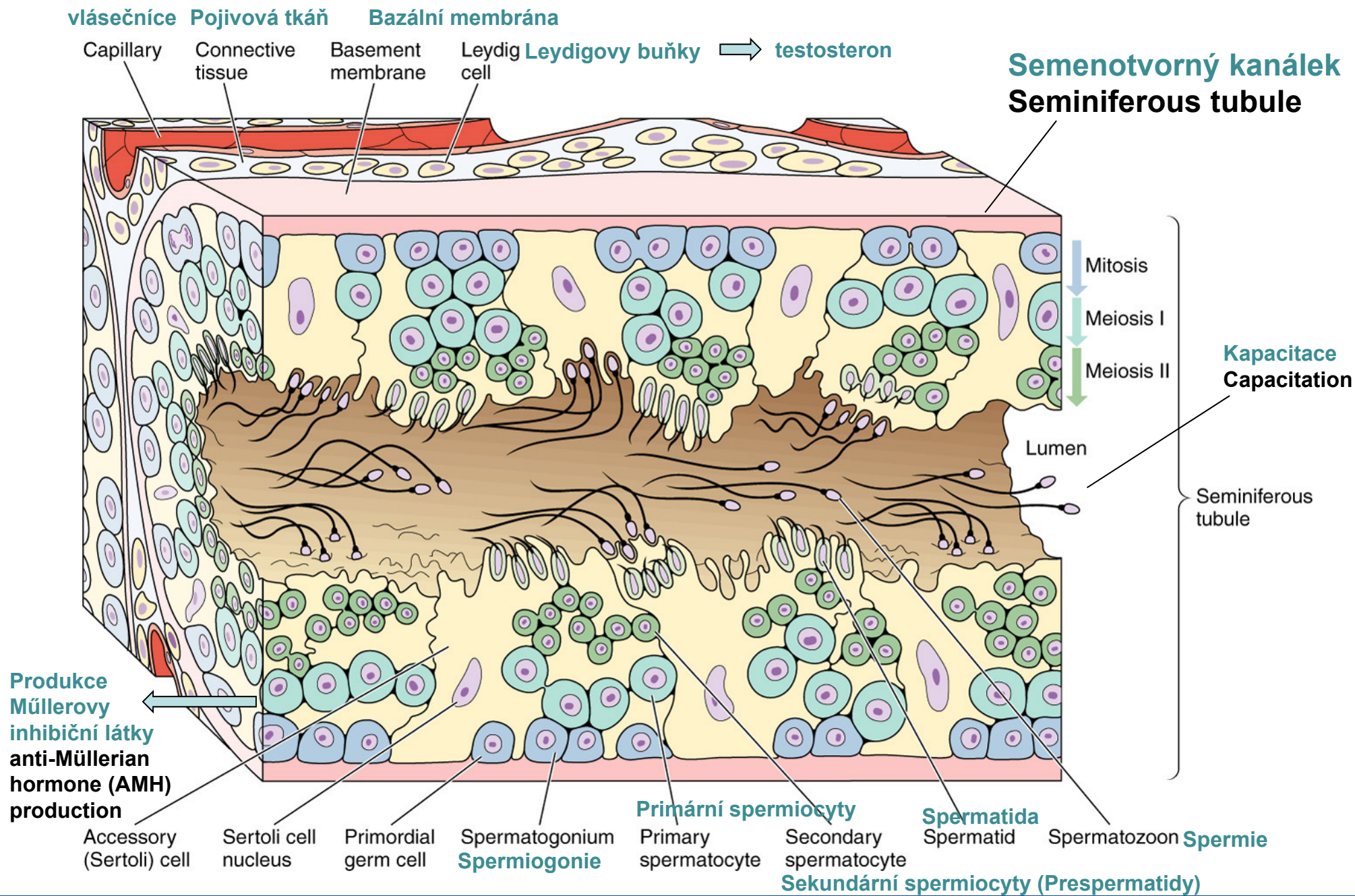
A.

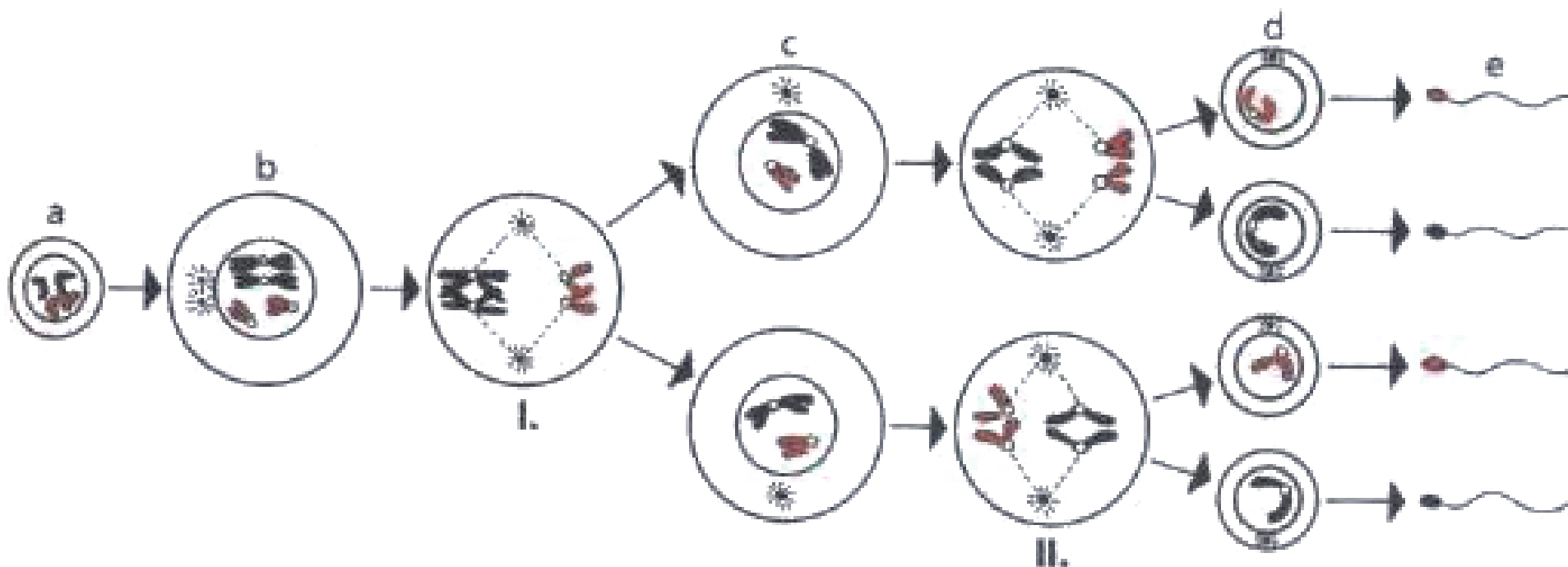
Animální pól Animal





Ostrich's egg...the largest cell in the world 😊.





Spermatogonium
Spermiogonie

Primary spermatocyte
Primární spermiocyty

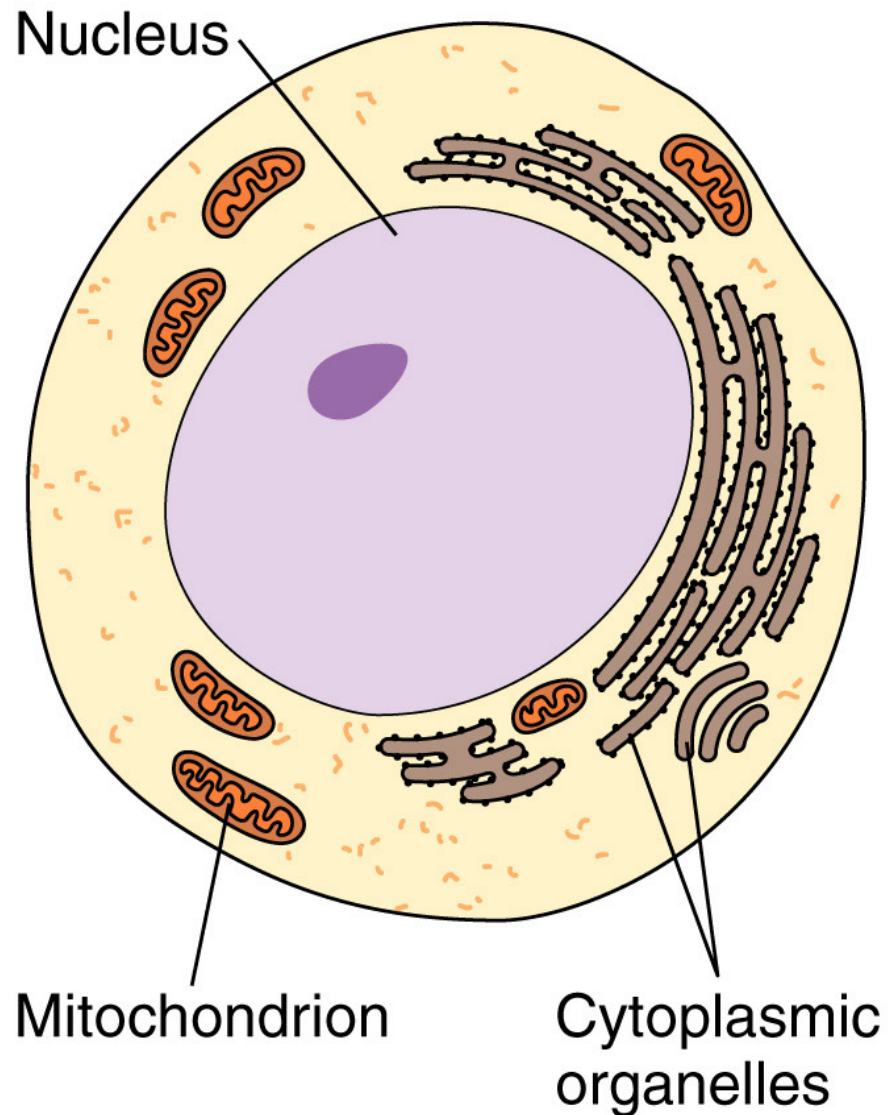
Secondary spermatocyte
Sekundární spermiocyty (Prespermatidy)

Spermatid
Spermatidy

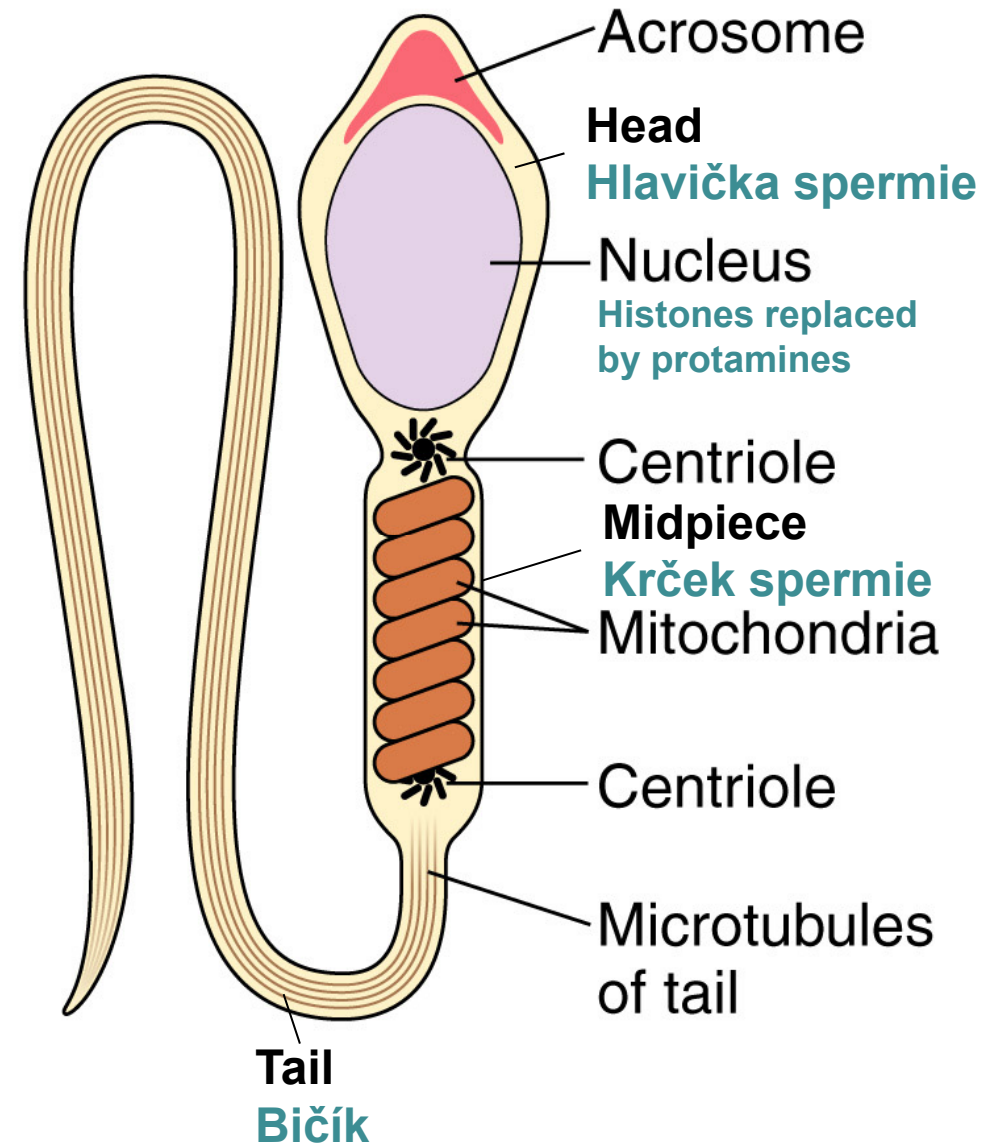
Spermatozoon
Spermie

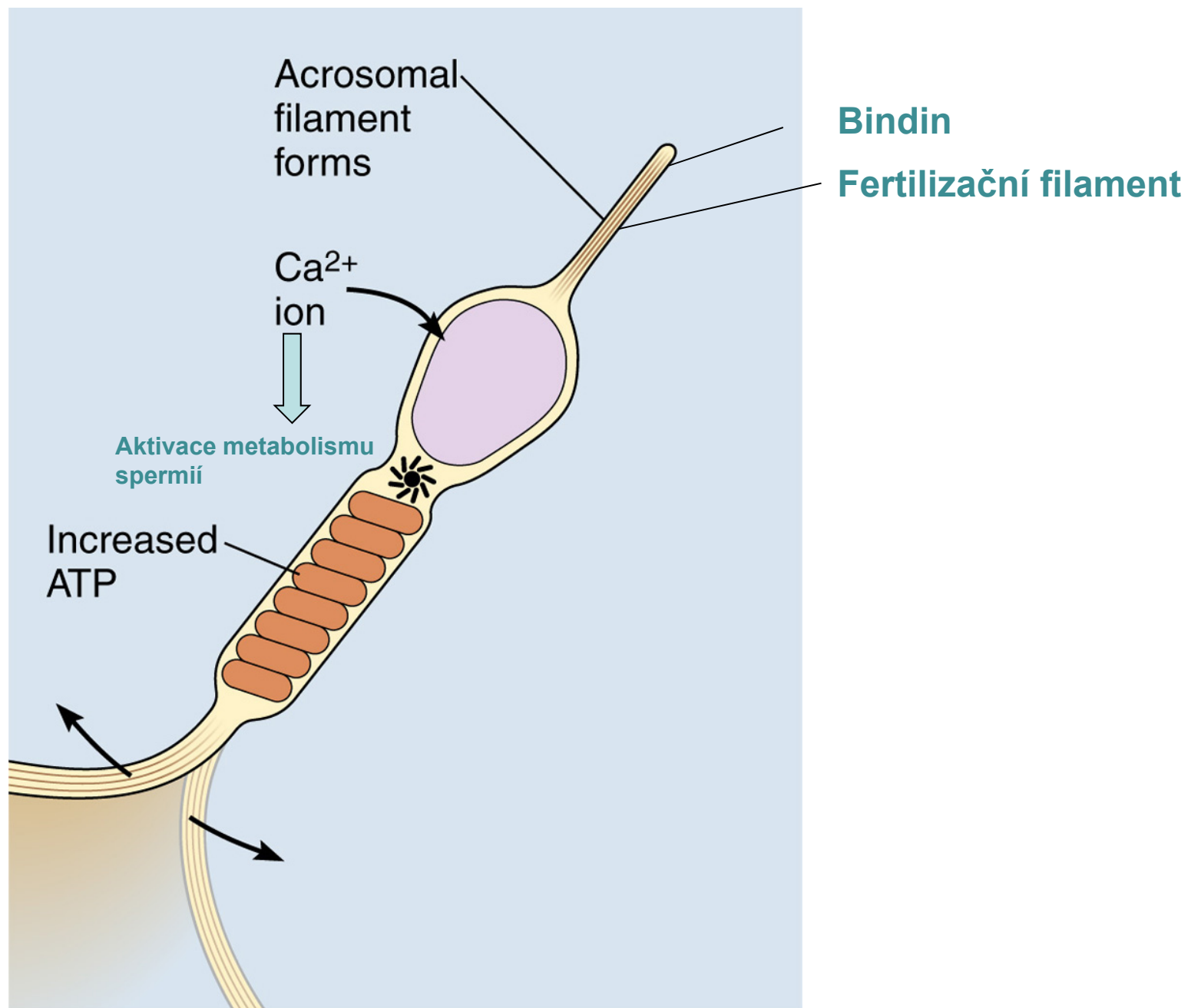
Vacek, *Embryologie* (2006)

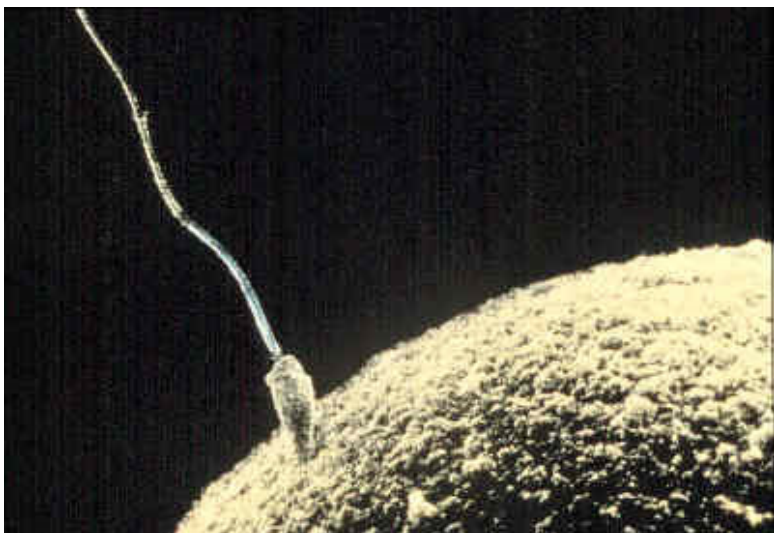
A. Spermatogonium



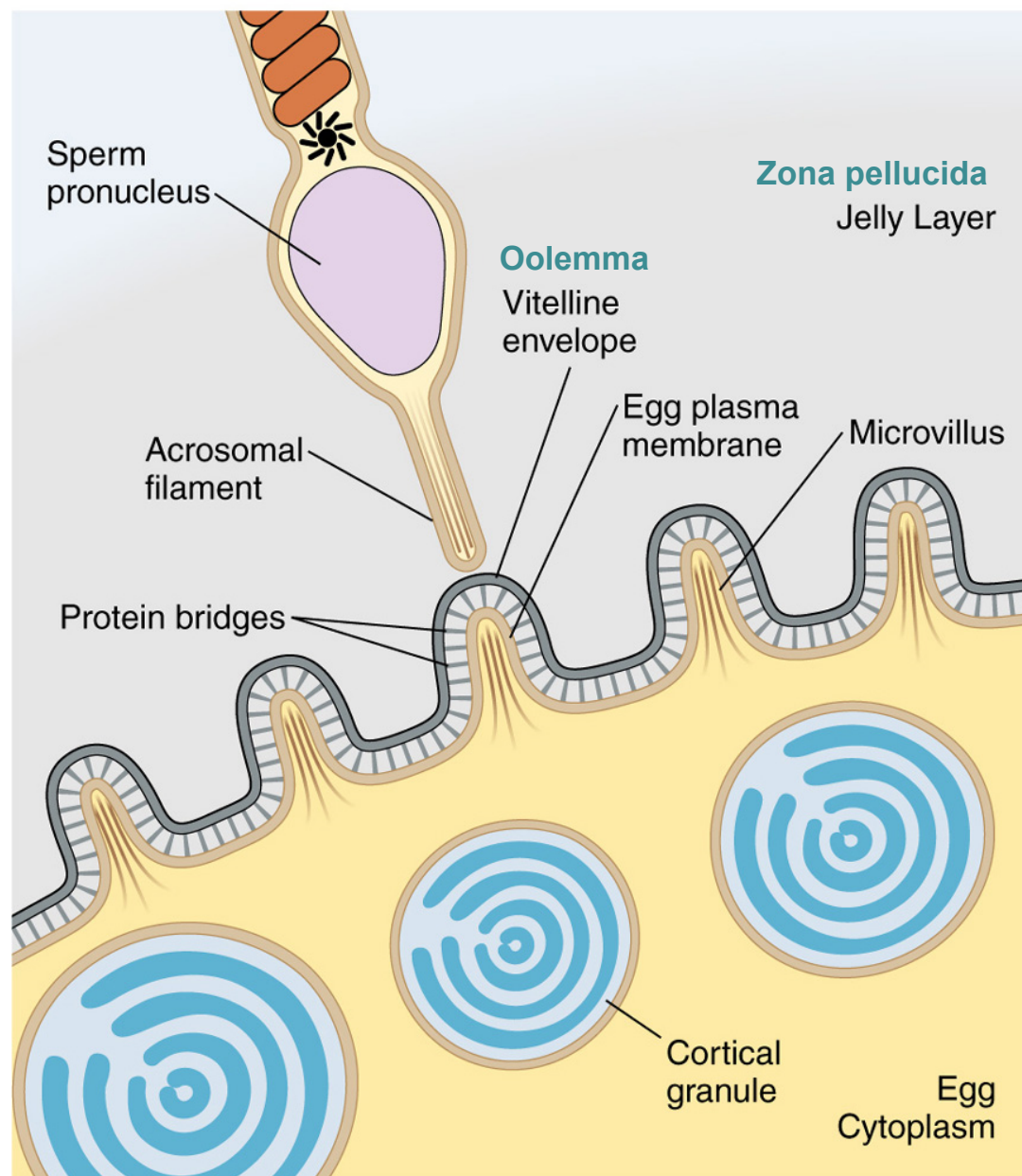
B. Spermatozoon





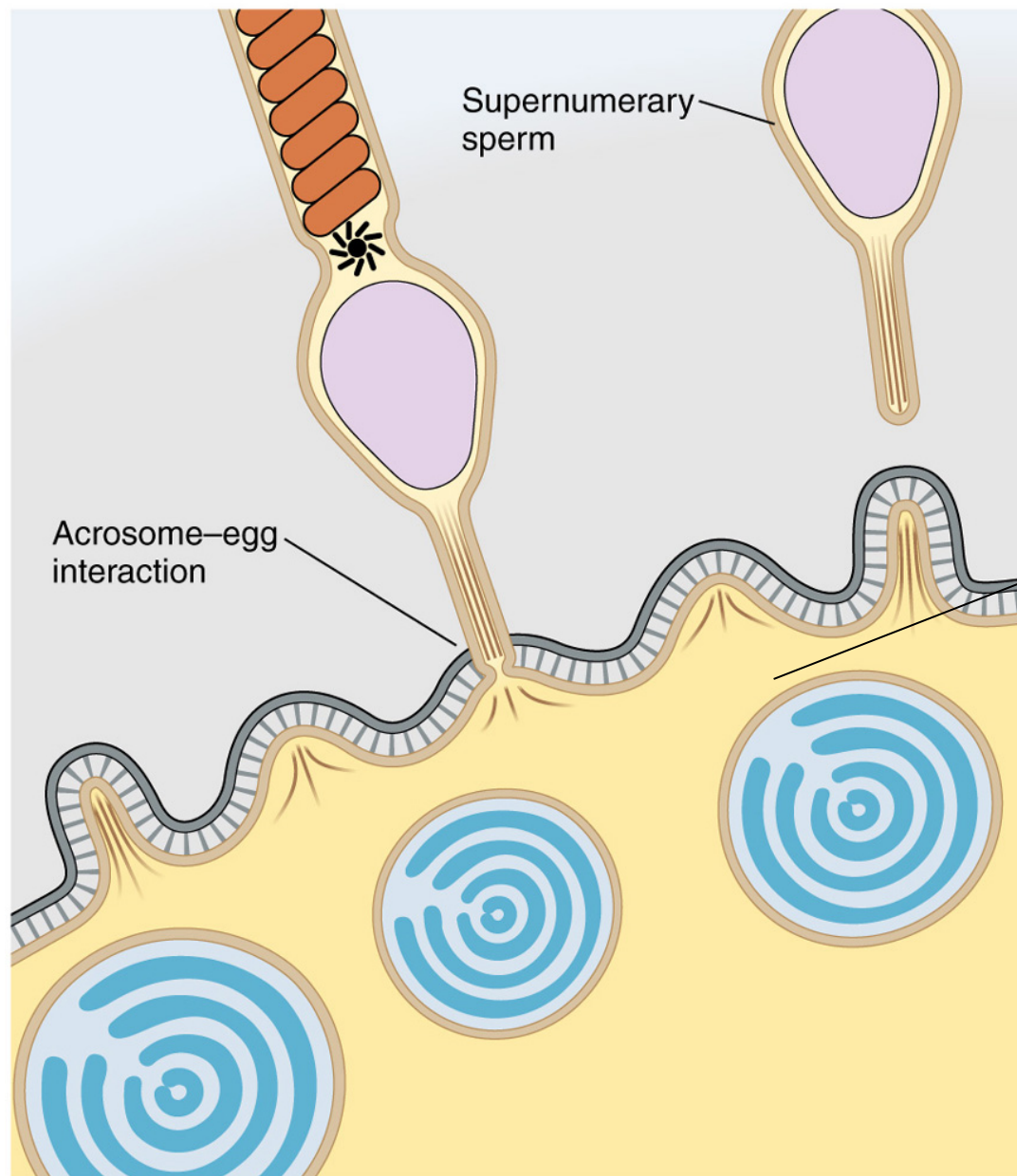


A.



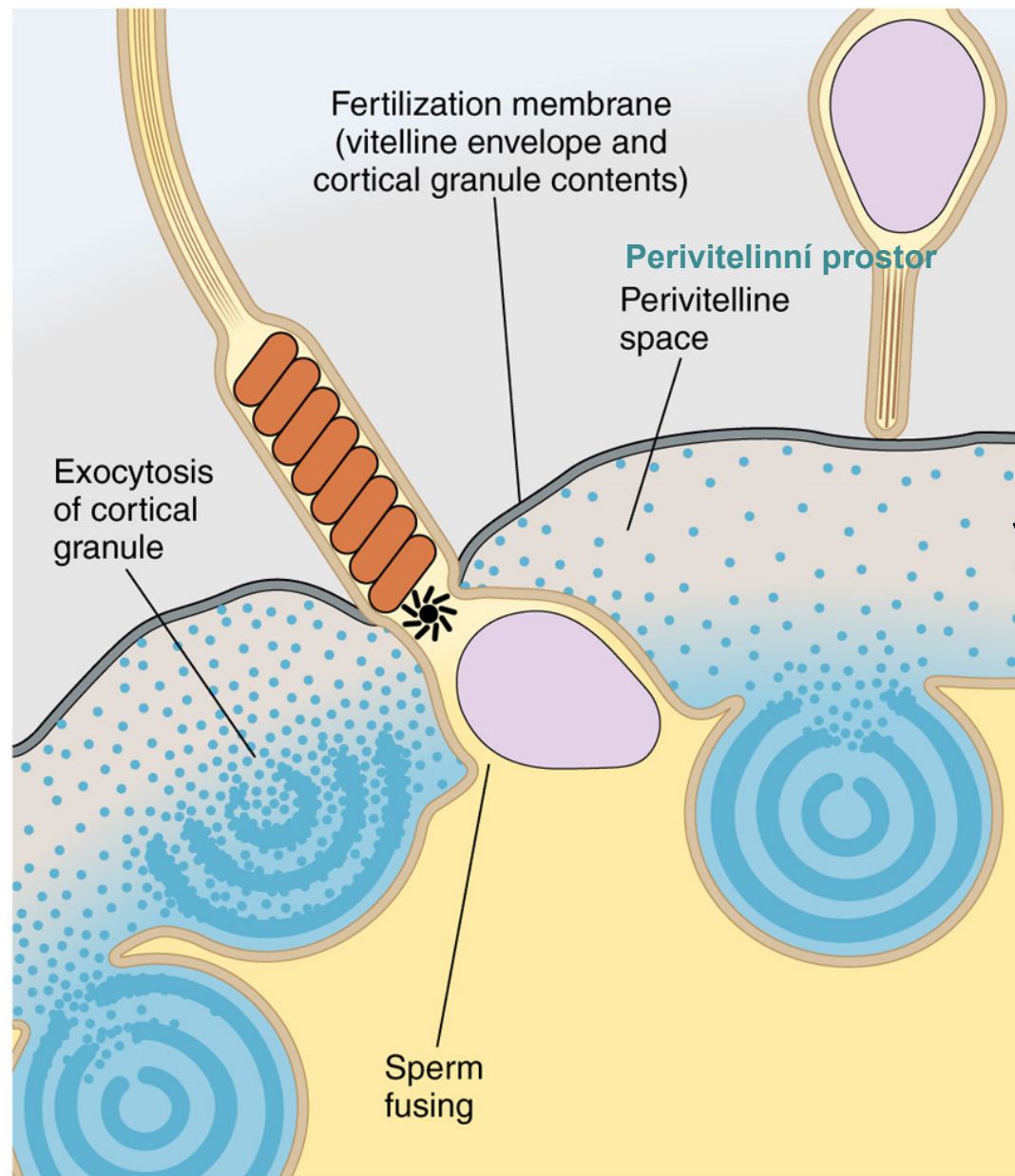
Wikipedia

B.



Change of the osmotic pressure due to release of the cortical granules content (macromolecules) and lifting of the vitelline envelope.

c.



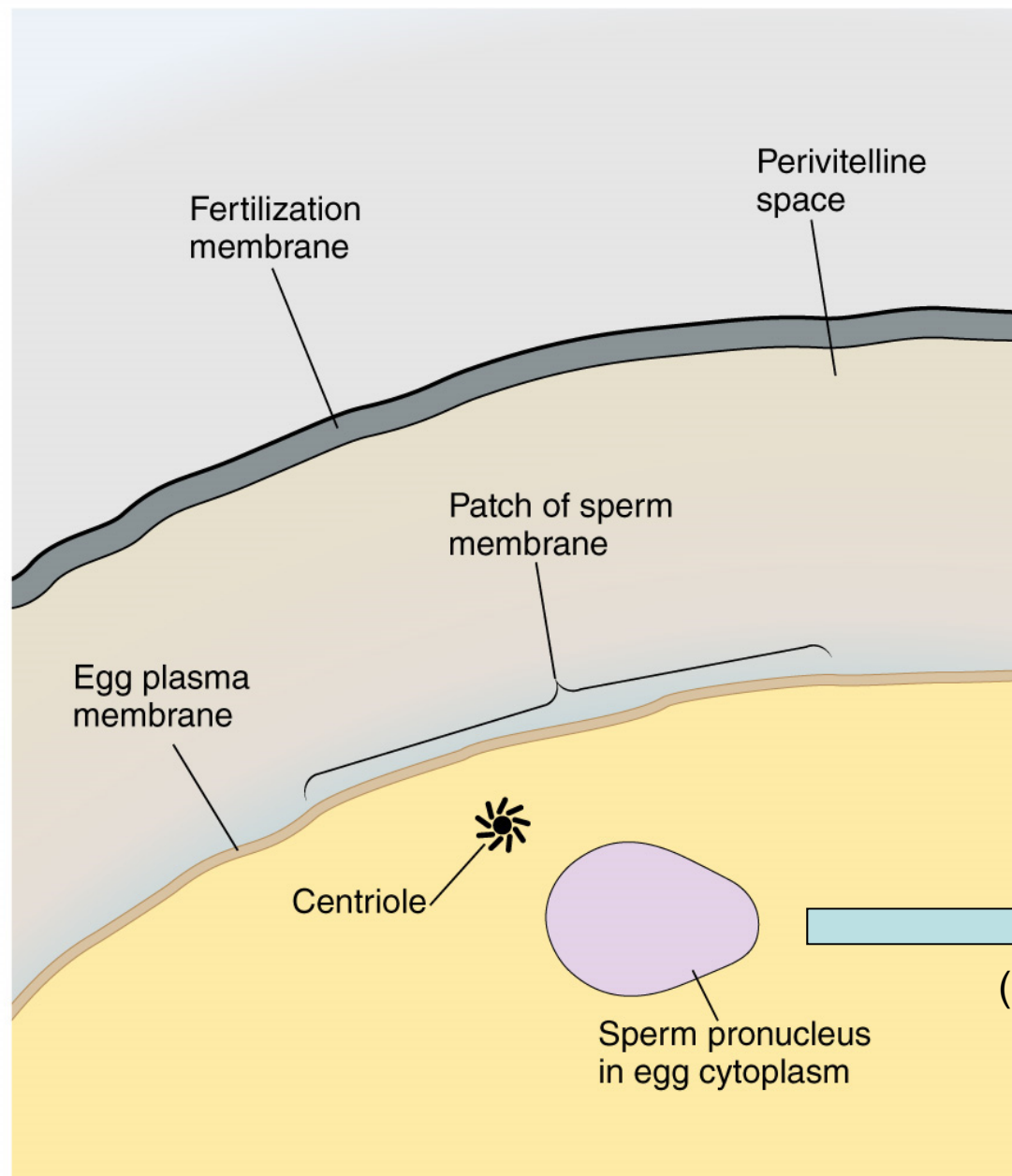
Cortical reaction

- proteolytic enzymes remove the sperm receptors
- Changes in the vitelline envelope mechanical properties
- Changes in the membrane potential

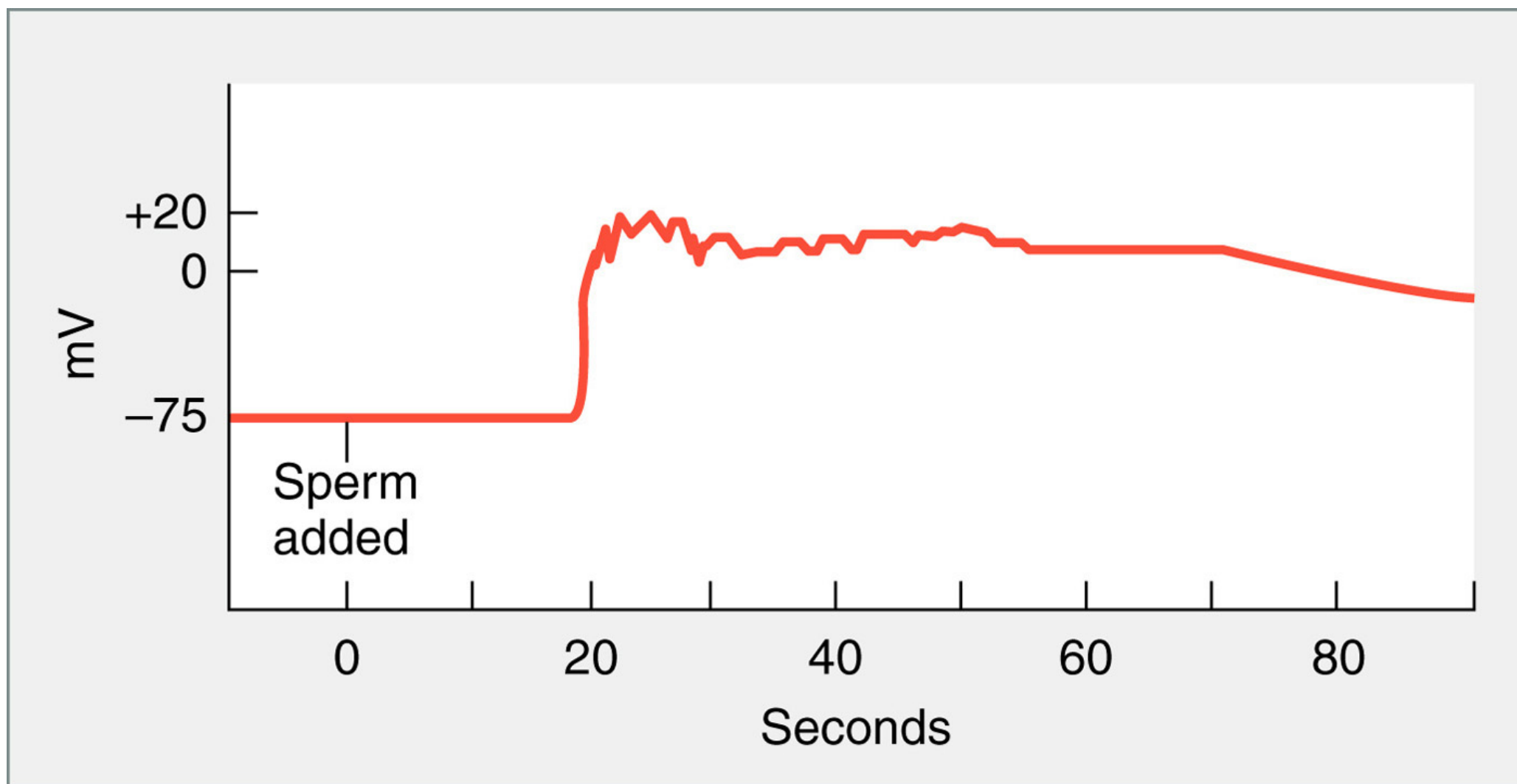


Avoiding of polyspermy

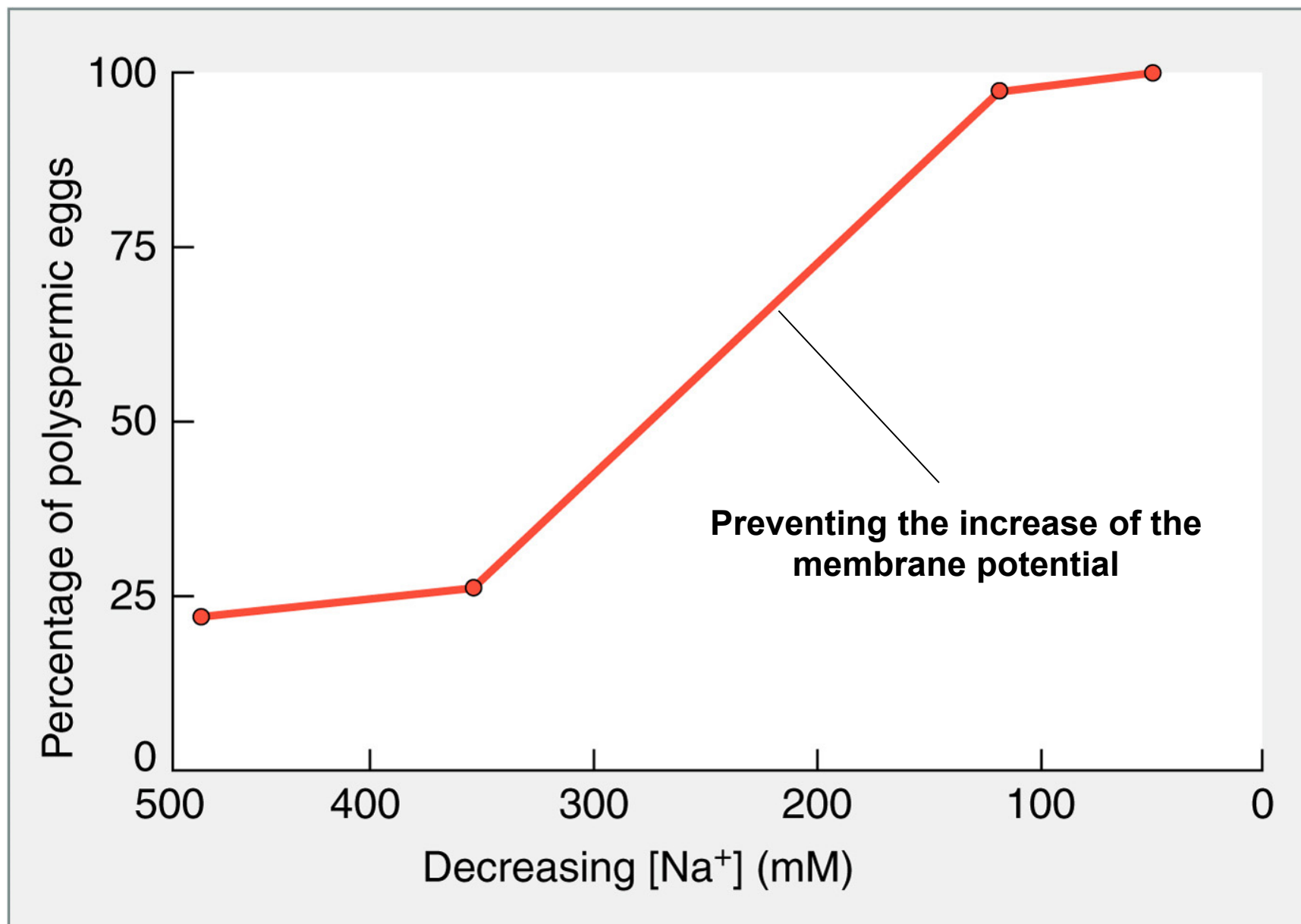
D.

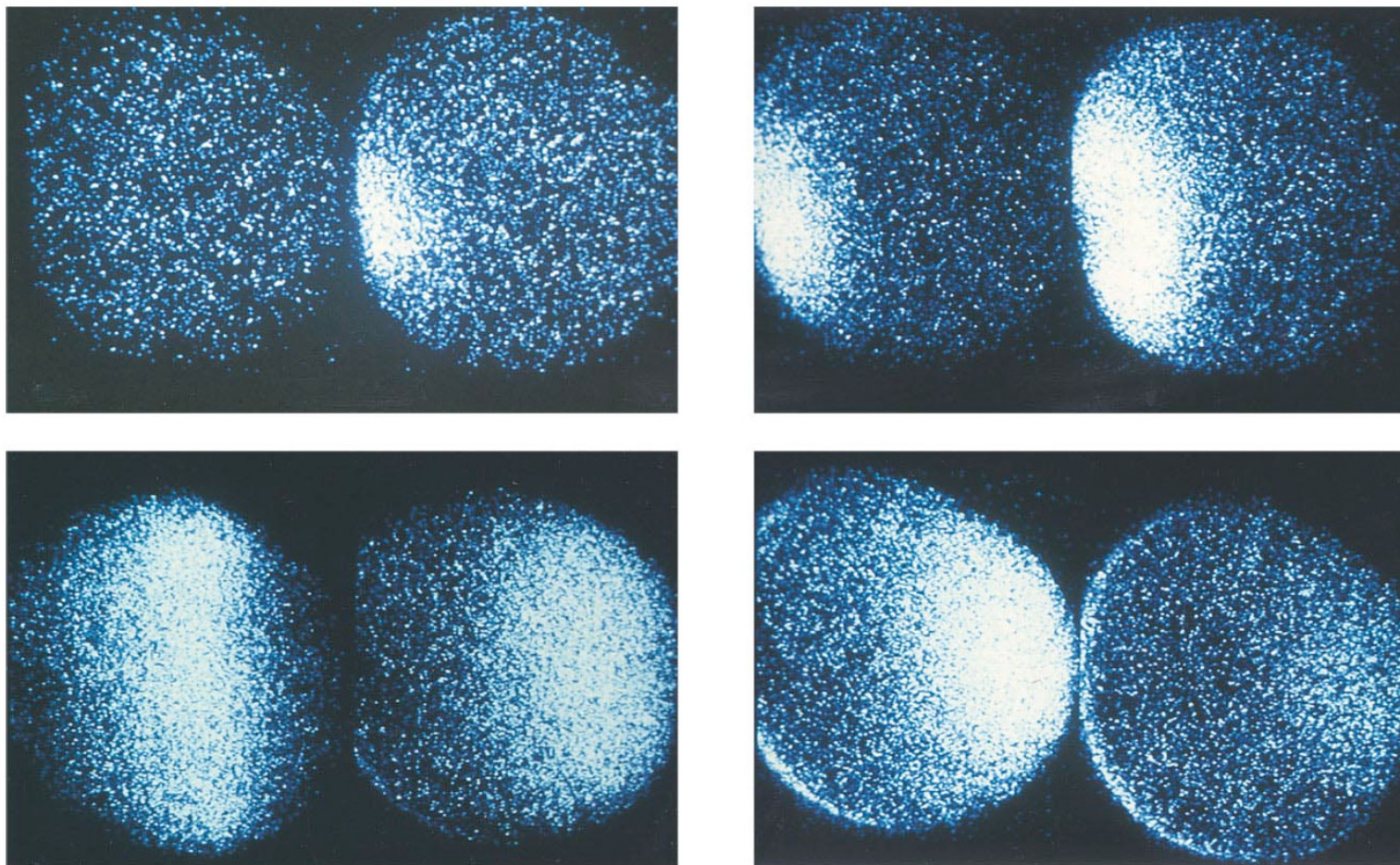


karyogamy
(in the S stage of mitosis 1)
karyogamie
(ve stádiu S fáze 1. mitózy)



C.





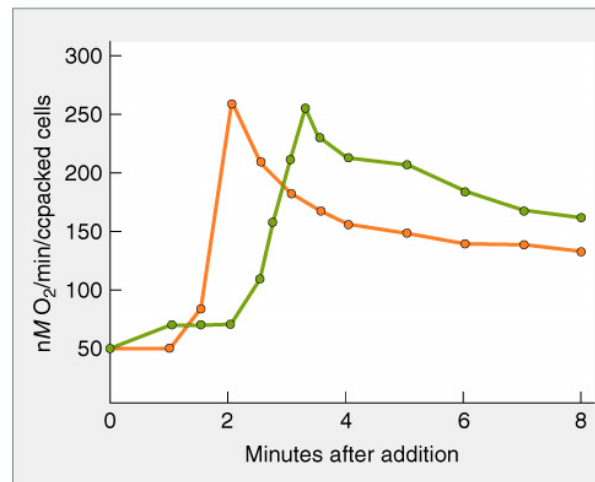
Lectures of Michael Lehmann, Ph.D., University of Arkansas, USA



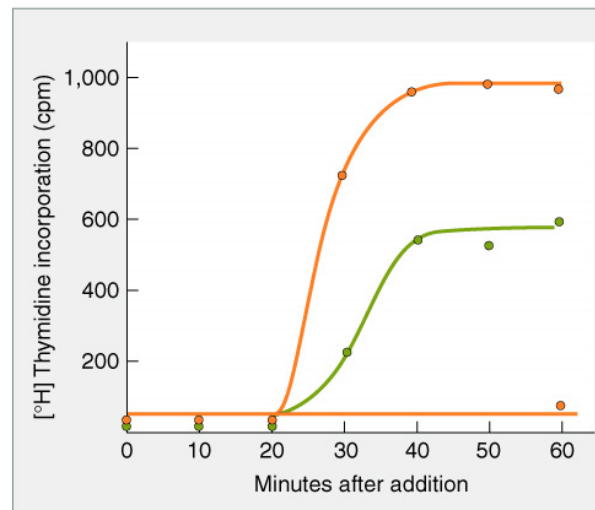
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

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

A.



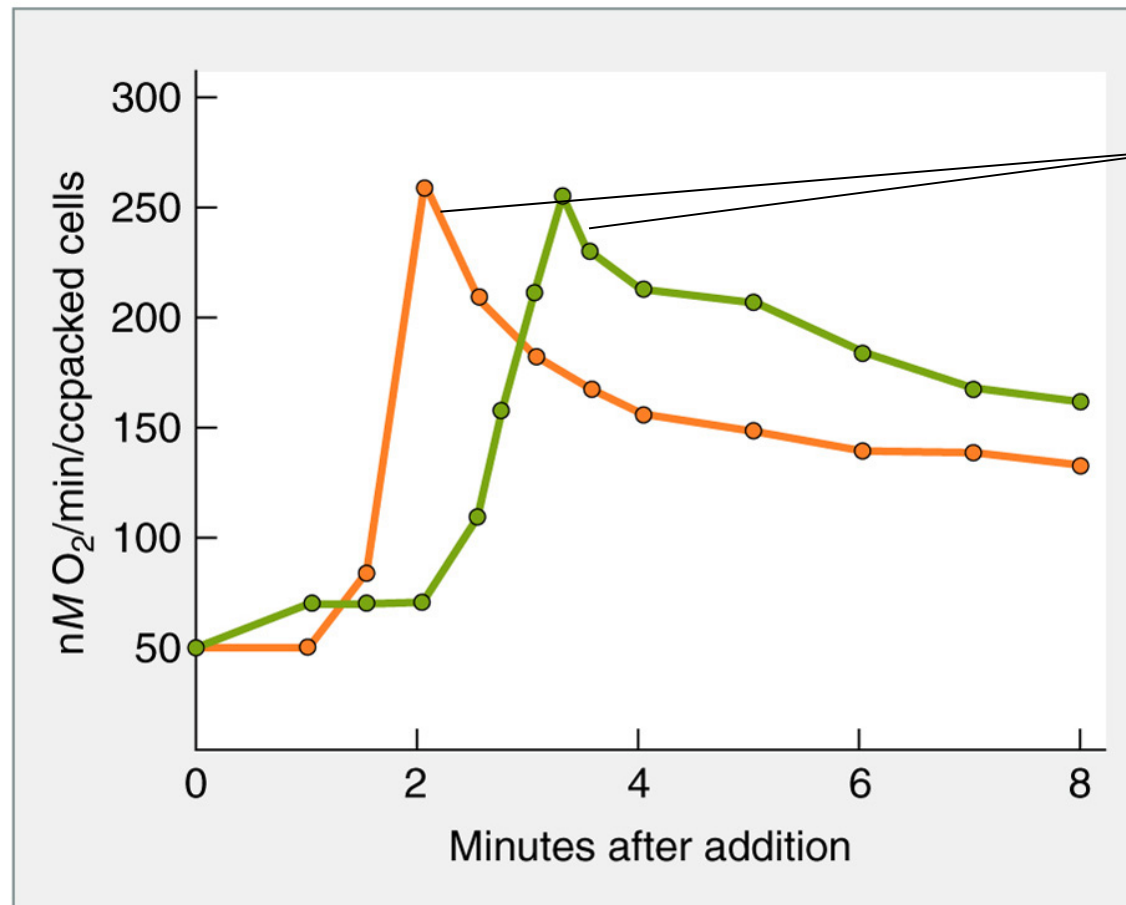
B.



KEY



A.

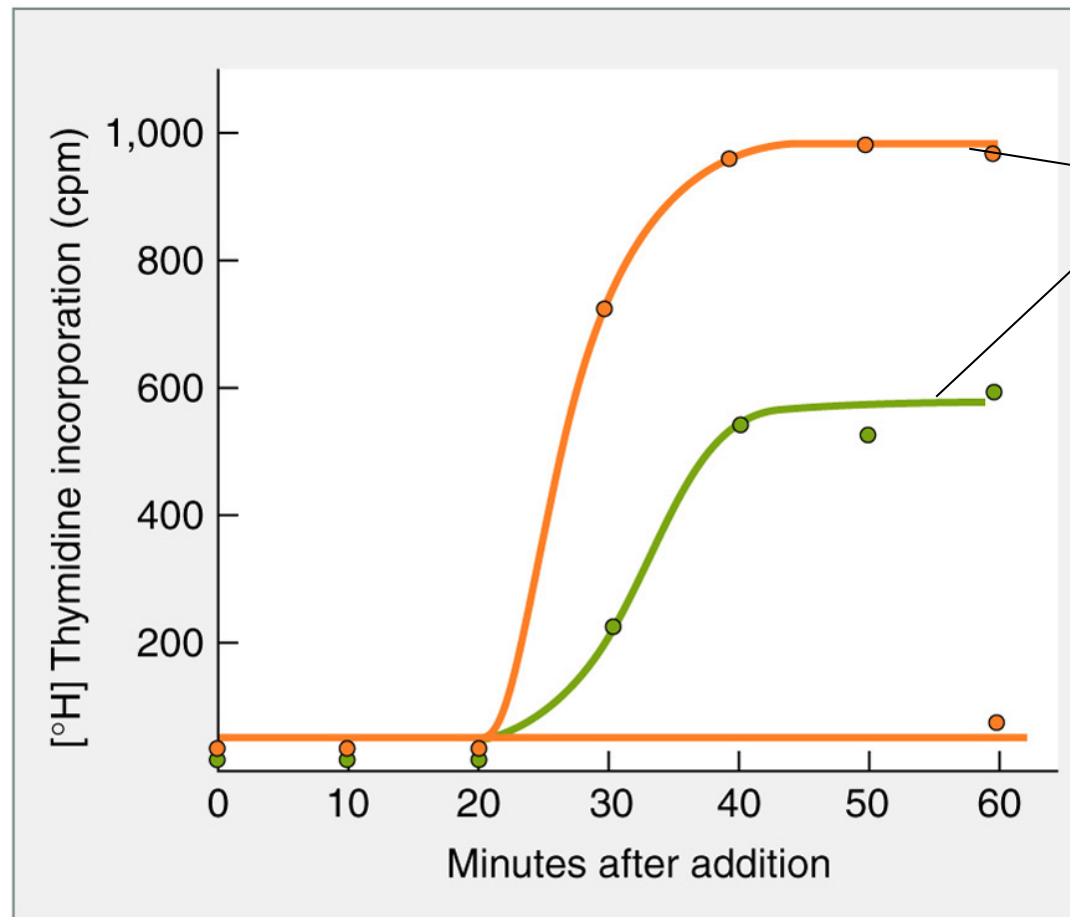


Activation of respiration

KEY

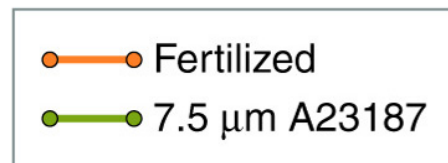


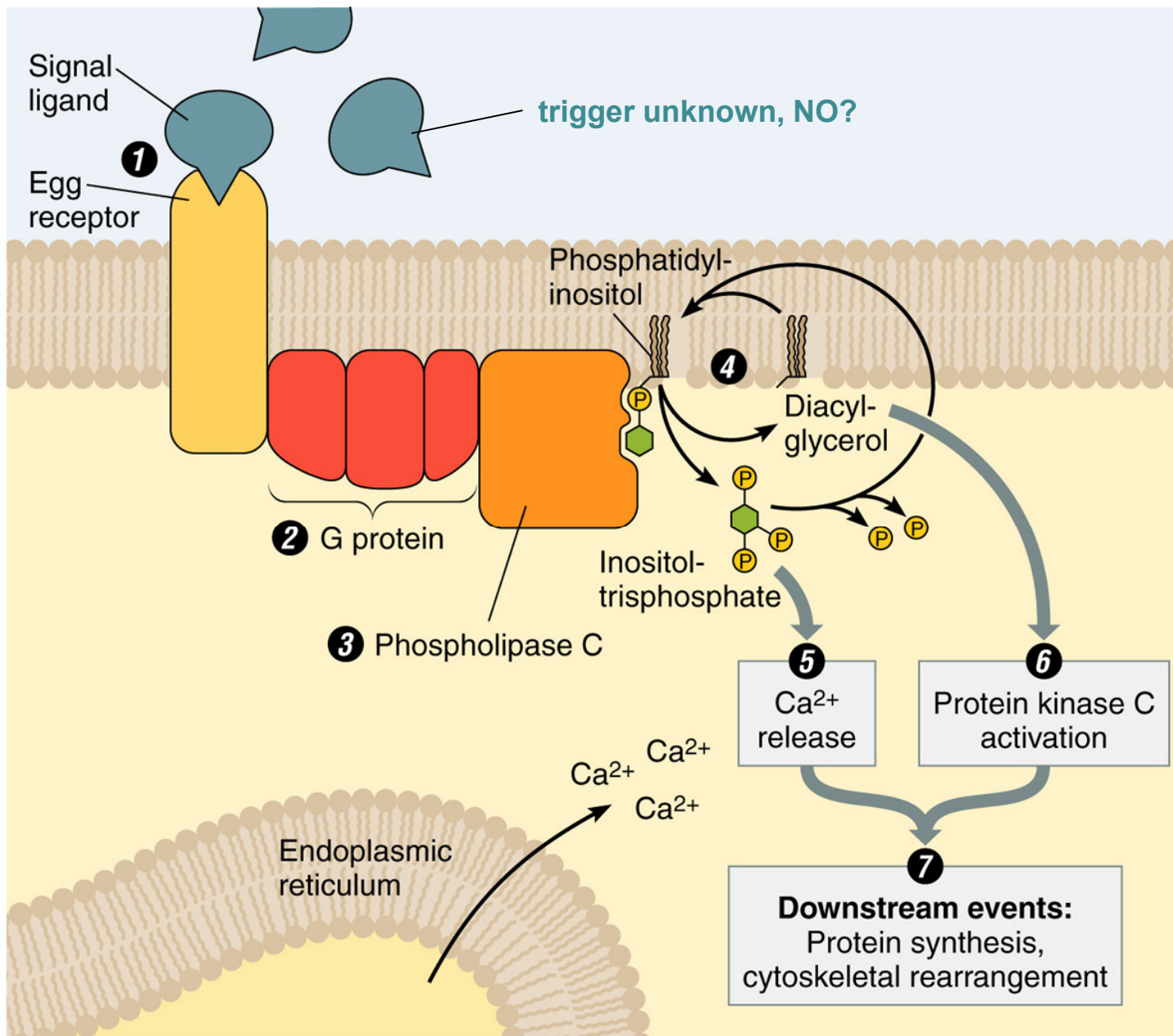
B.



Activation of
DNA
synthesis

KEY



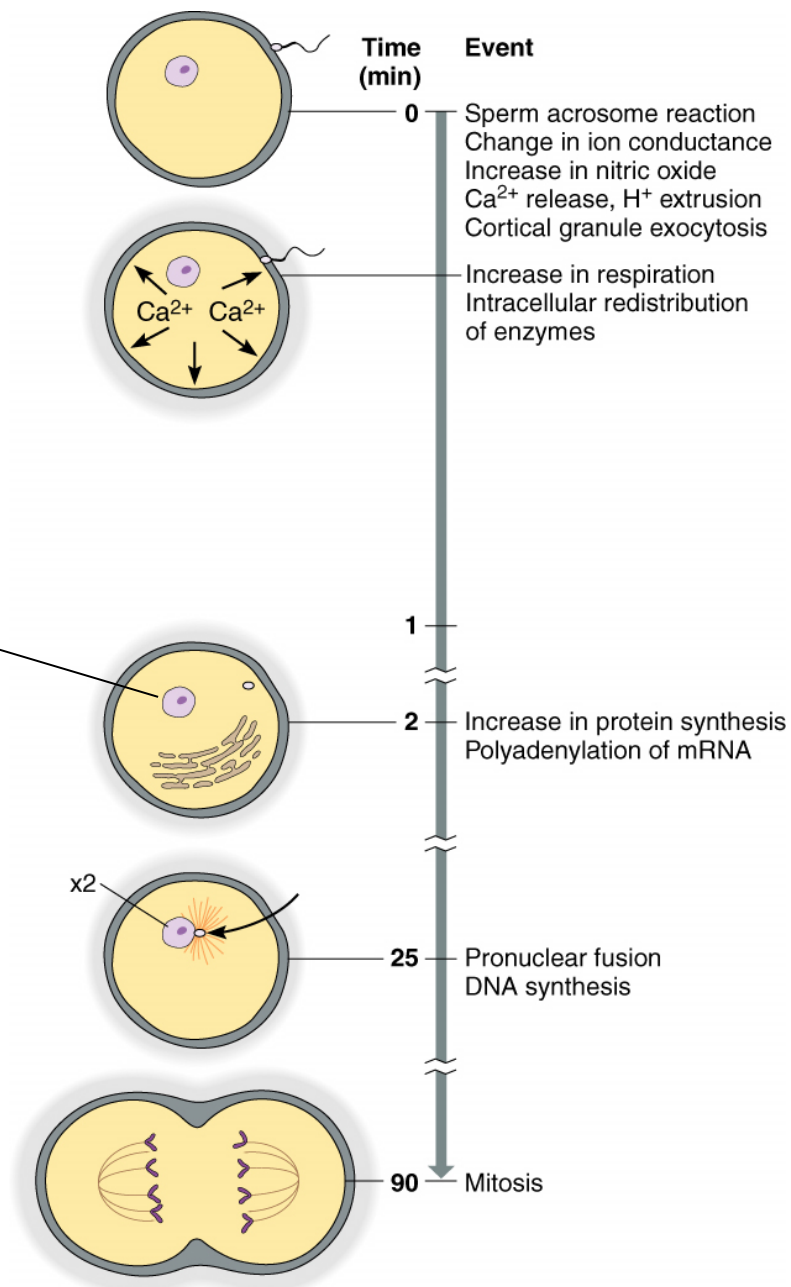




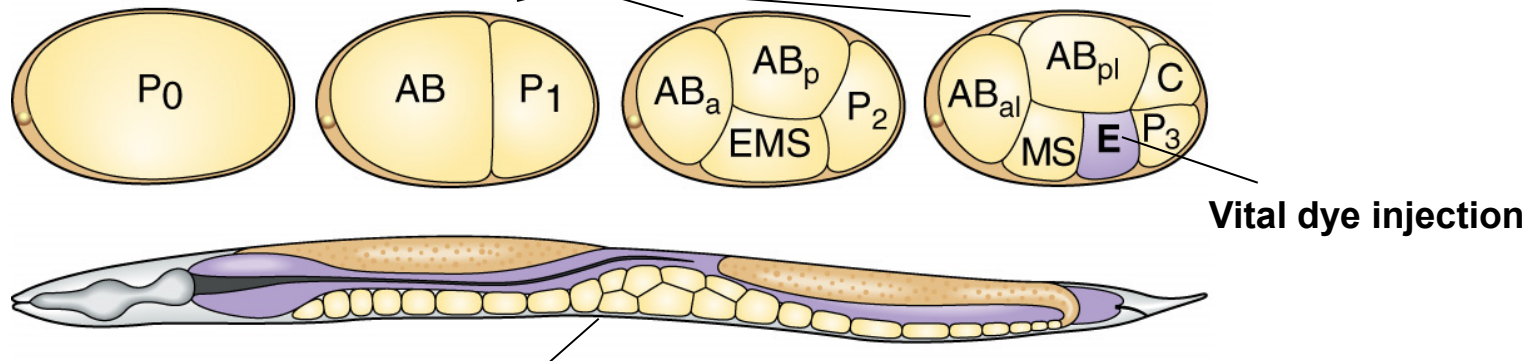
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

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

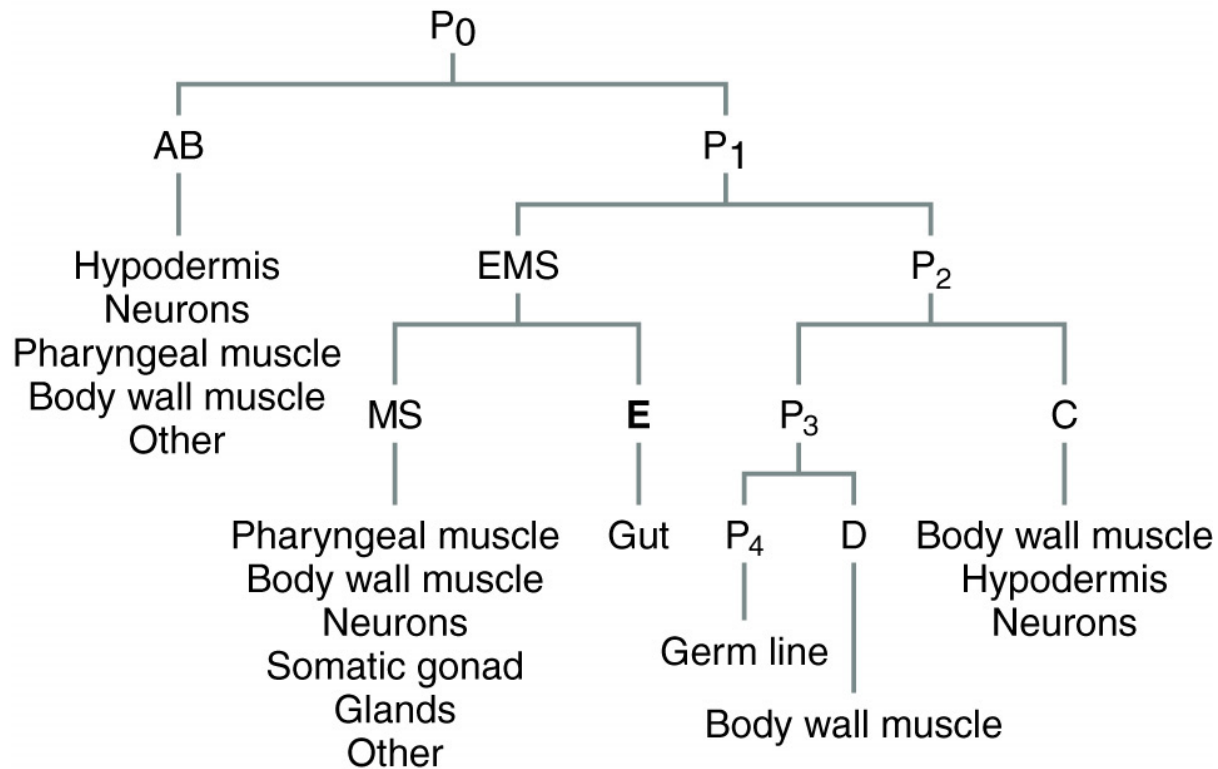
pH-dependent initiation of proteosynthesis from the egg-deposited mRNA



A. Fertilization-initiated cleavage/rýhování vajíčka



B. Regular and stereotypical cell pattern in *C. elegans* (558 embryonic and 9590 somatic cells)



Key Concepts

- *Asymmetric cell division* and underlying molecular mechanisms are the *core problem* of the developmental biology
- *Genetic integrity is maintained* during cell (de-)differentiation
- *Gametes* arise from a population of stem cells via *differentiation and reduction of the genome* to the haploid level
- *Formation of the oocyte* places a huge demands on the organism and *stocked material* allows the early development
- *Fertilization restores the chromosome number* and activates the egg. The activated gametes *reenter the cell cycle* and trigger the further development
- During animal development, *cell lineages* with *predetermined developmental fate* are *established in the early development*, which is not the case in the development of plants.