C8545 Developmental Biology

Lesson 3

Early Development of Amphibians and Amniotes

Jan Hejátko

Functional Genomics and Proteomics of Plants
CEITEC
and
National Centre for the Biomolecular Research,
Faculty of Science

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

Outline of Lesson 3

Early Development of Amphibians and Amniotes

- Oogenesis in amphibians
- Blastula formation and dorsoventral axis fomation in amphibians
  - cleavage of *Xenopus* zygote (video)
- Gastrulation
  - gastrulation of amphibians (video)
- Neurulation
  - neurulation in *Xenopus* (video)
- Oogenesis in amniotes - chicken
- Gastrulation in amniotes – chicken
  - early and late gastrulation in chicken (video)

Outline of Lesson 3

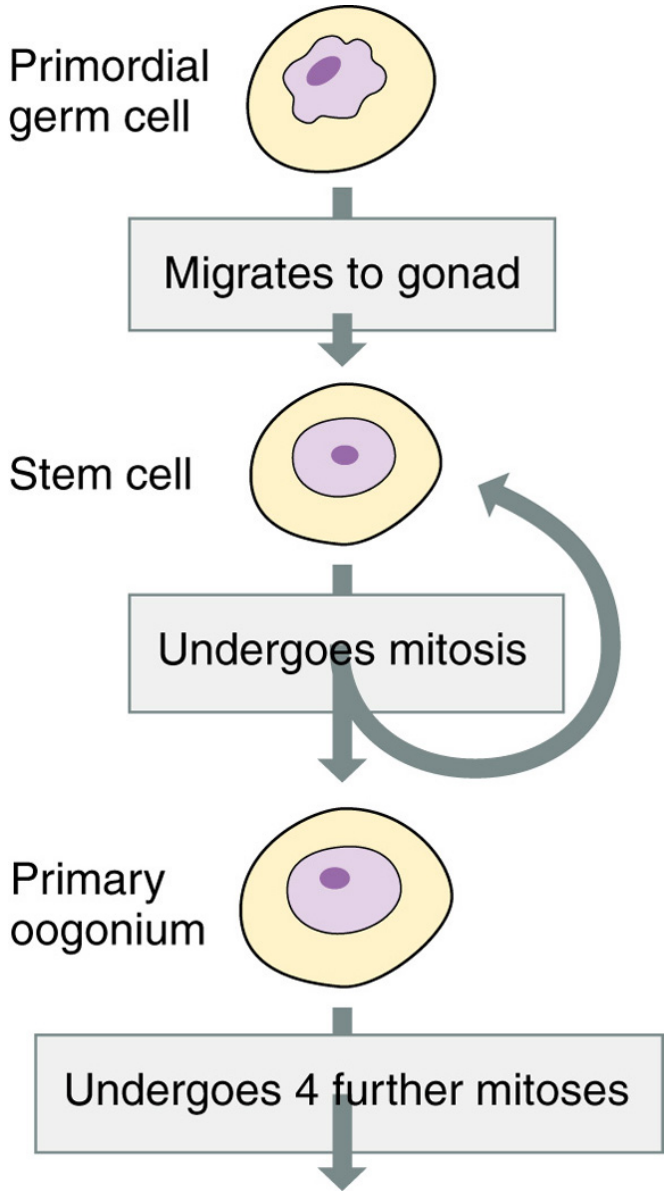
Early Development of Amphibians and Amniotes

- Gastrulation in amniotes – chicken
  - early and late gastrulation in chicken (video)
- Formation of extraembryonic tissues in amniotes – chicken

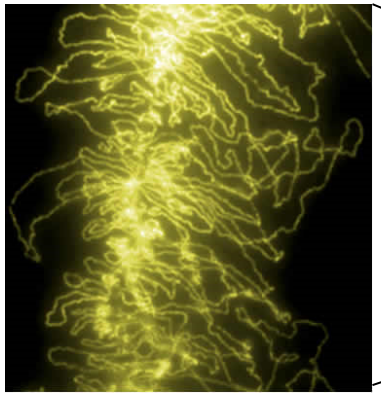
Outline of Lesson 3

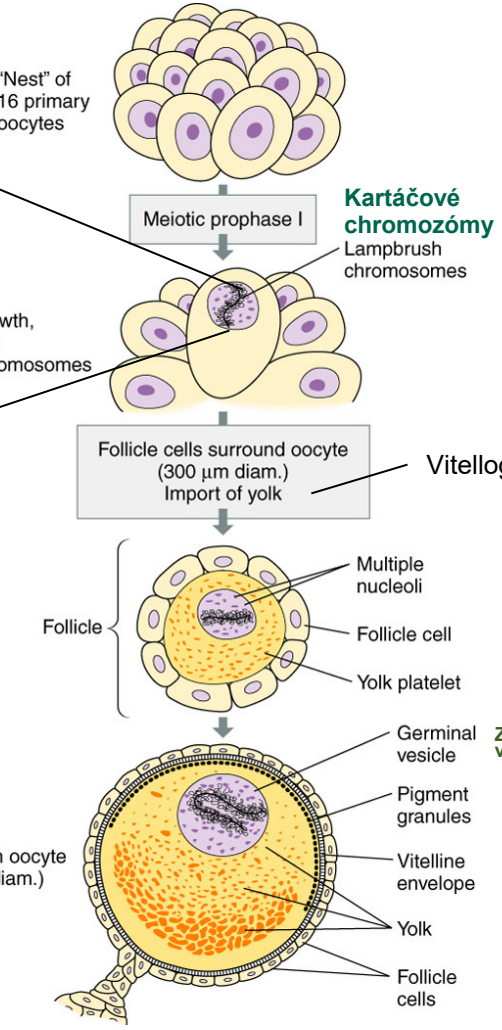
Early Development of Amphibians and Amniotes

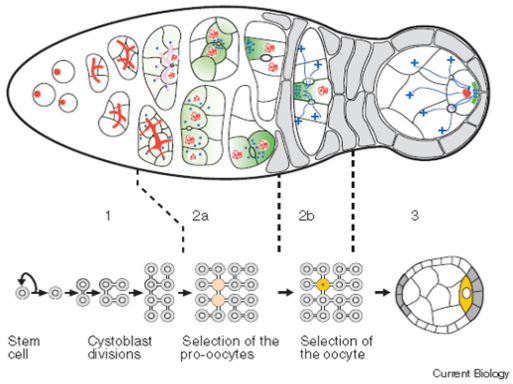
- Oogenesis in amphibians


Primordial germ cell
Migrates to gonad
Stem cell
Undergoes mitosis
Primary oogonium
Undergoes 4 further mitoses

Oogenesis in *Xenopus* vs. oogenesis in *Drosophila*

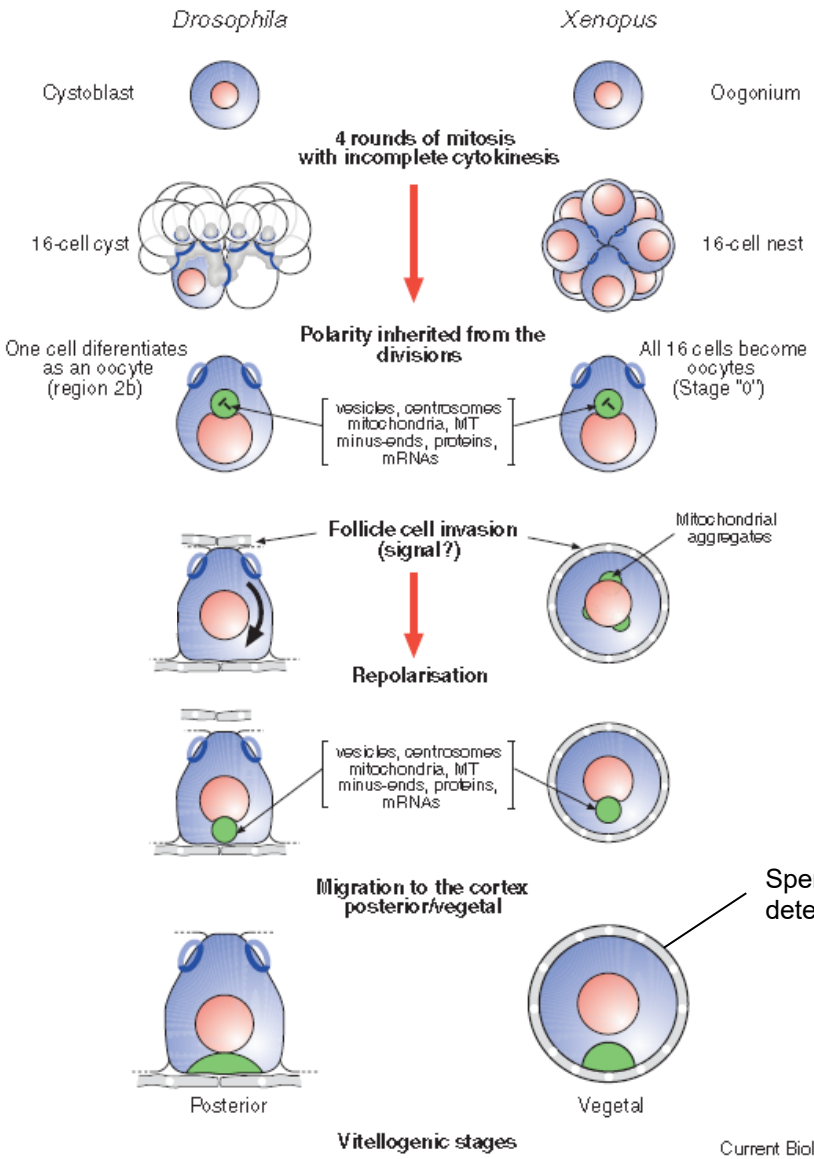






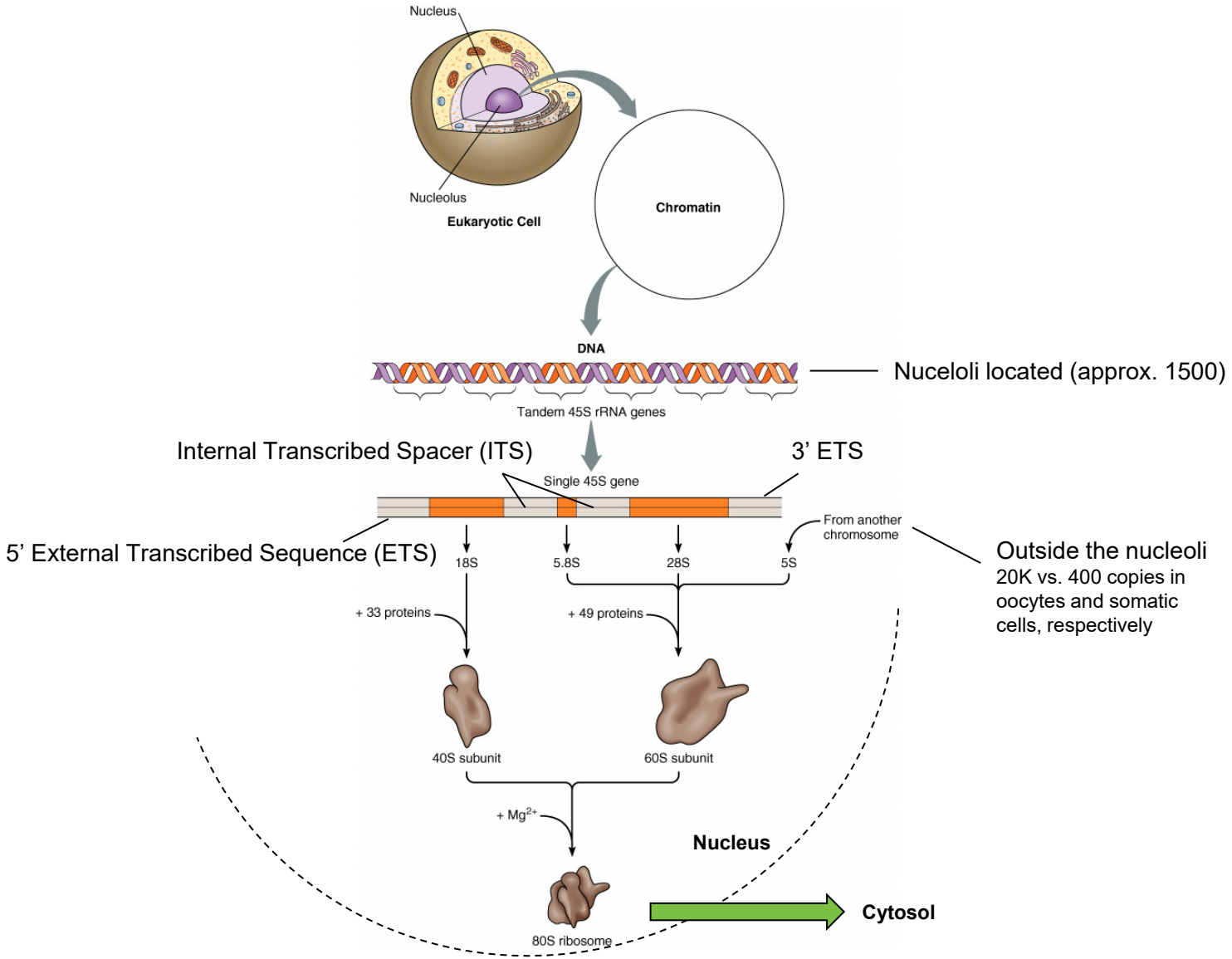
Huynh and Johnston., *Curr Biol* (2004)

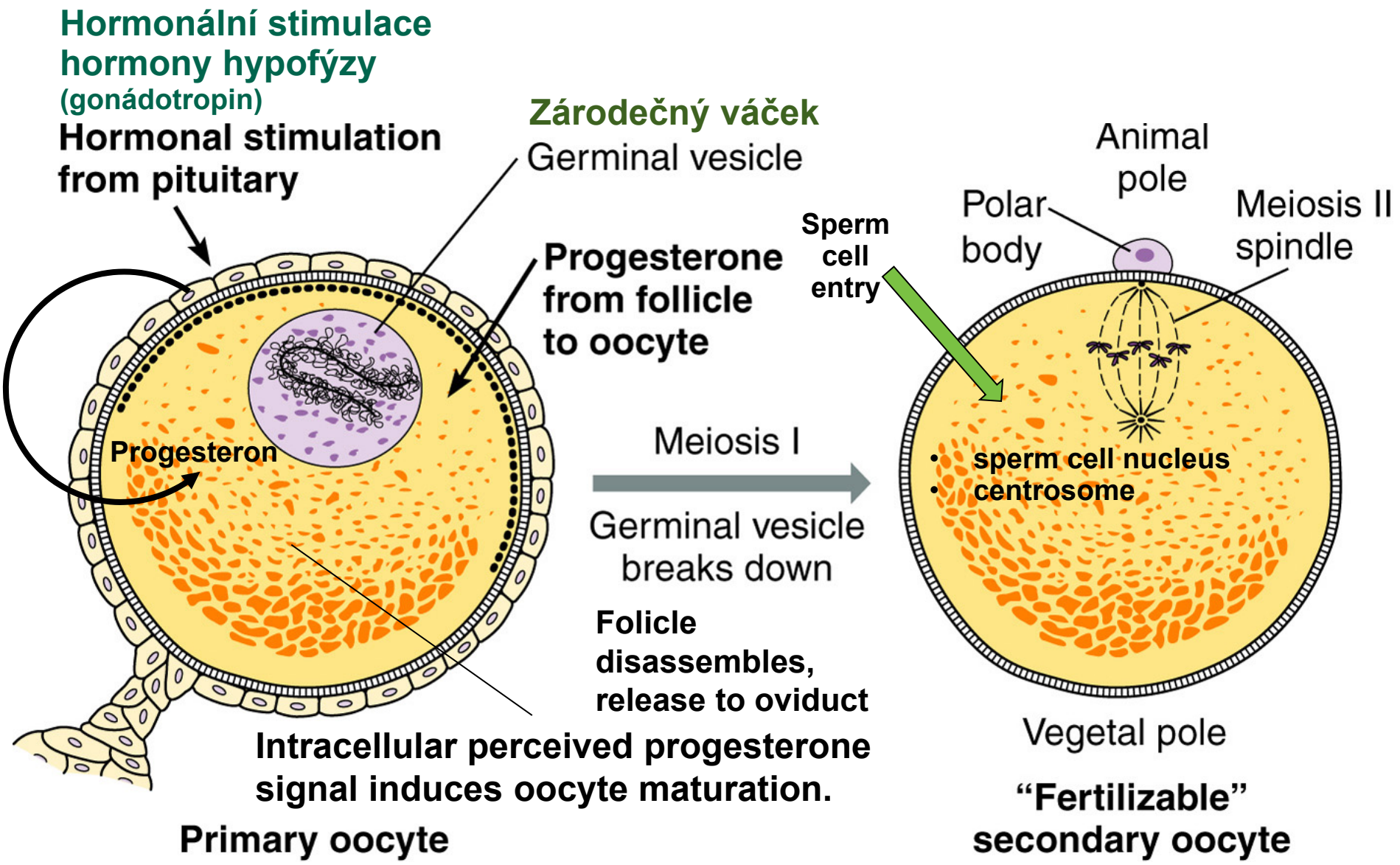
CEITEC



Sperm entry in the animal hemisphere determines the future dorsoanterior position

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

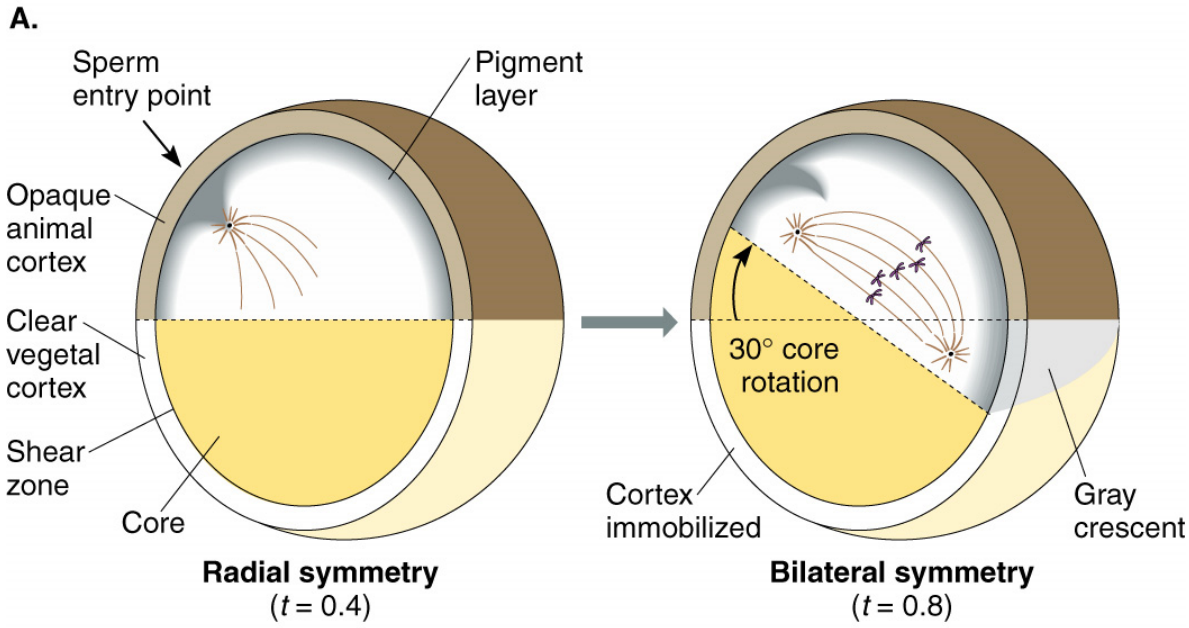

Nucleus
Nucleolus
Eukaryotic Cell
Chromatin
DNA
Tandem 45S rRNA genes
Nuceloli located (approx. 1500)
Internal Transcribed Spacer (ITS)
3' ETS
Single 45S gene
5' External Transcribed Sequence (ETS)
From another chromosome
18S
5.8S
28S
5S
Outside the nucleoli
20K vs. 400 copies in oocytes and somatic cells, respectively
+ 33 proteins
+ 49 proteins
40S subunit
60S subunit
+ Mg2+
Nucleus
80S ribosome
Cytosol


Hormonální stimulace
hormony hypofýzy
(gonádotropin)
Hormonal stimulation
from pituitary
Zárodečný váček
Germinal vesicle
Progesterone
from follicle
to oocyte
Progesteron
Meiosis I
Germinal vesicle
breaks down
Folicle
disassembles,
release to oviduct
Intracellular perceived progesterone
signal induces oocyte maturation.
Primary oocyte
Sperm
cell
entry
Animal
pole
Polar
body
Meiosis II
spindle
sperm cell nucleus
centrosome
Vegetal pole
“Fertilizable”
secondary oocyte

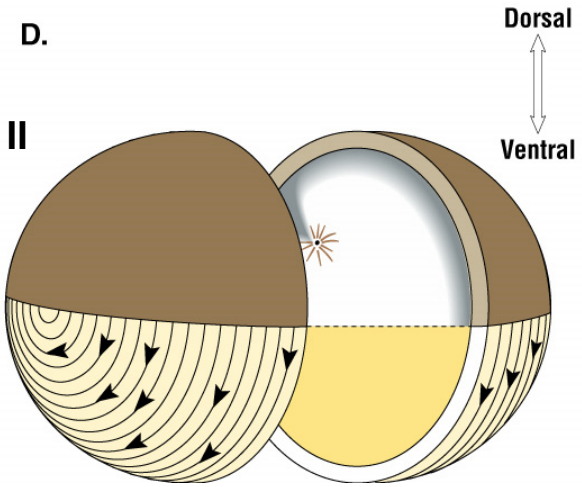
Outline of Lesson 3

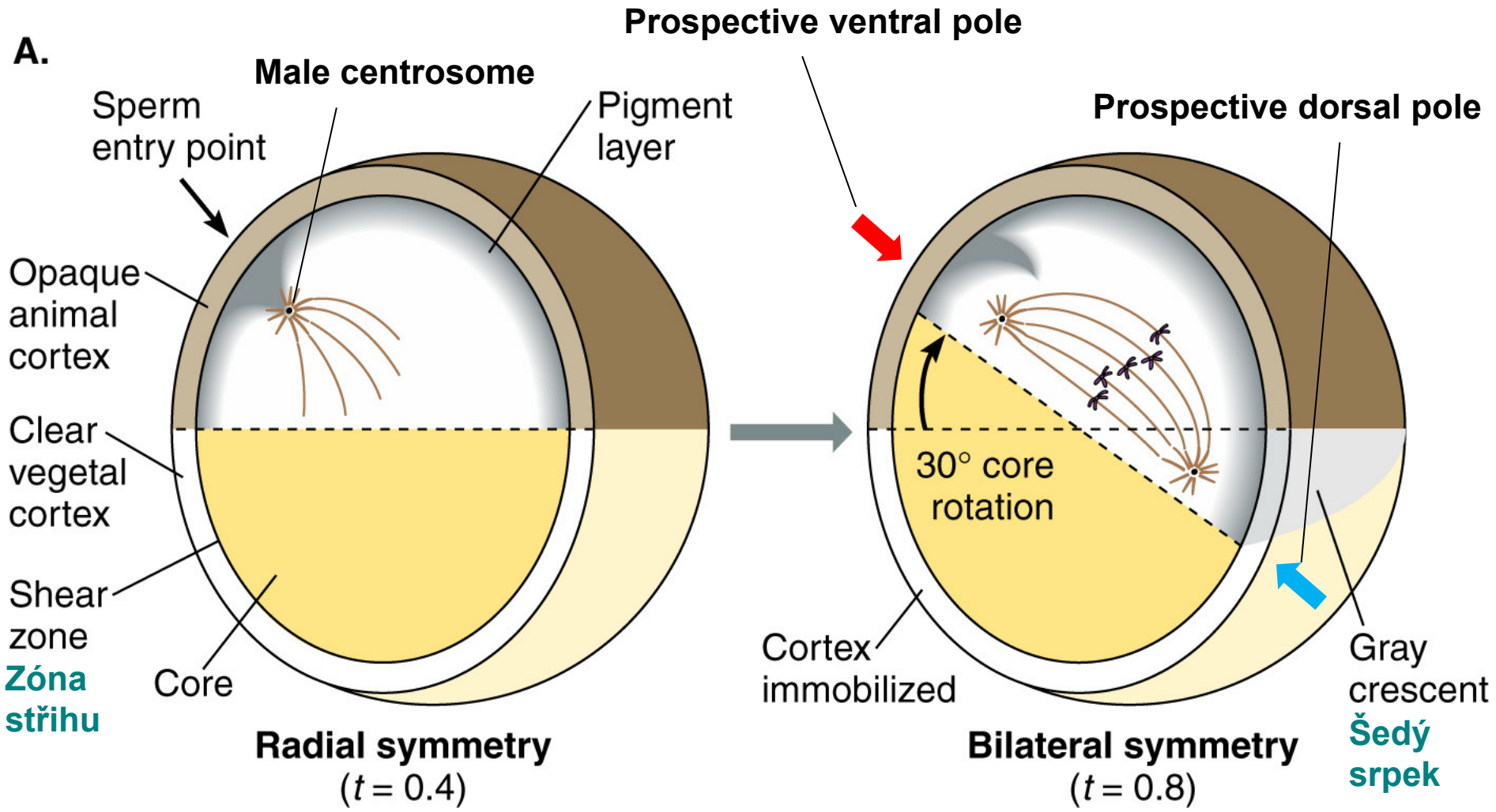
Early Development of Amphibians and Amniotes

- Oogenesis in amphibians
- Blastula formation and dorsoventral axis formation in amphibians

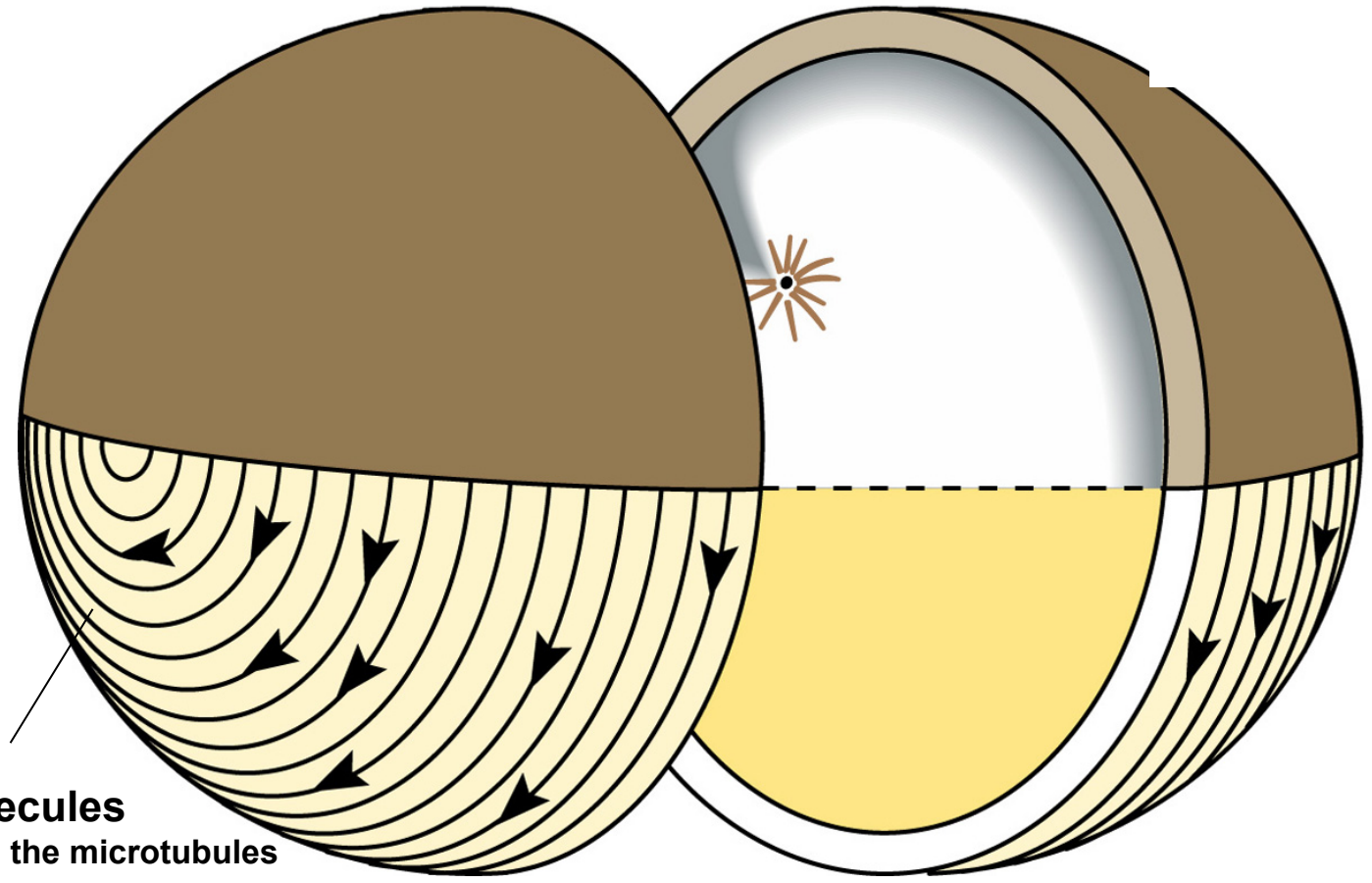


- **Completion of meiosis II**
- **Syngamy**

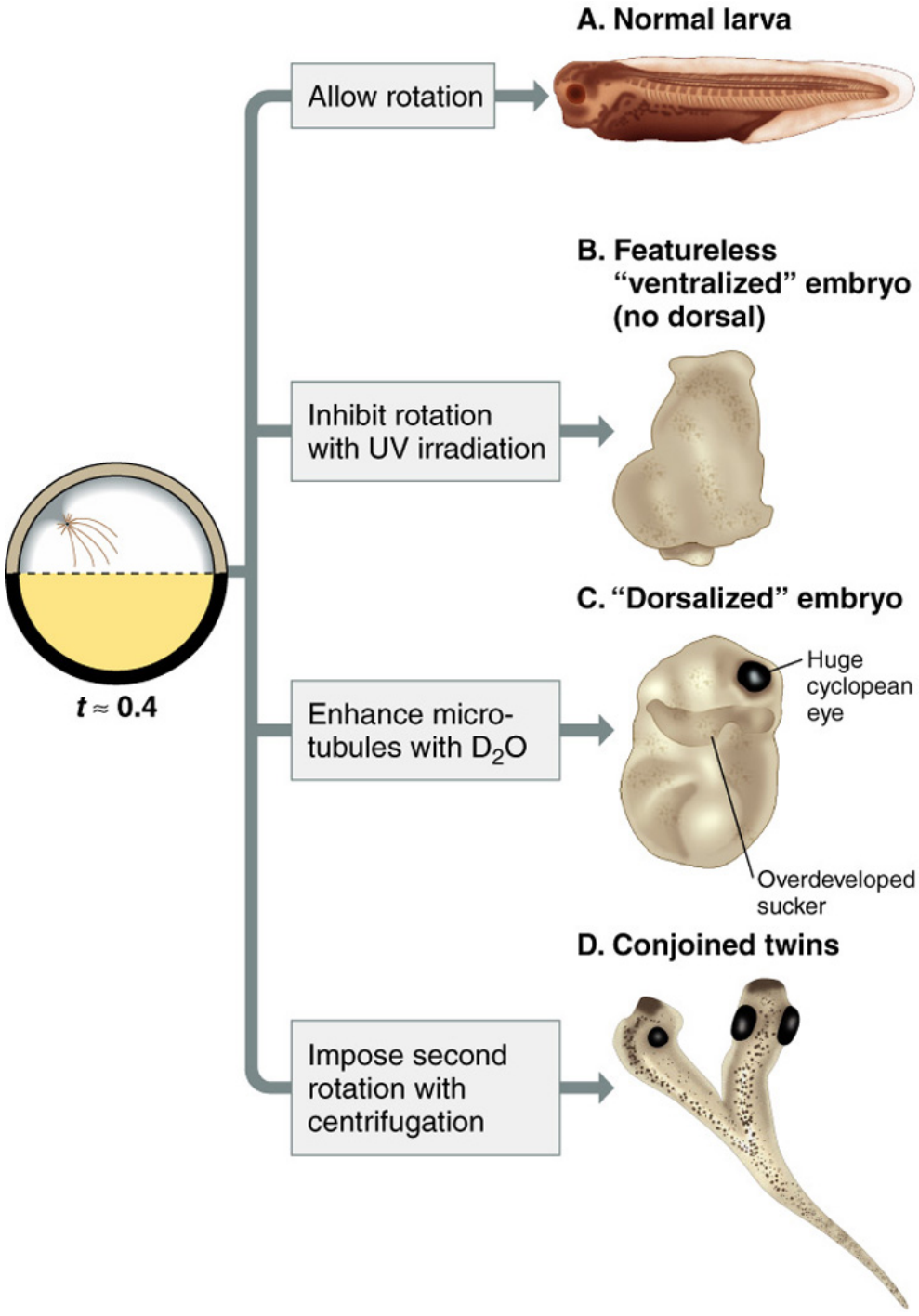



A.
Male centrosome
Prospective ventral pole
Sperm entry point
Pigment layer
Prospective dorsal pole
Opaque animal cortex
Clear vegetal cortex
Shear zone
Zóna střihu
Core
30° core rotation
Cortex immobilized
Gray crescent
Šedý srpek
Radial symmetry
(t = 0.4)
Bilateral symmetry
(t = 0.8)

D.



Motor molecules
located along the microtubules

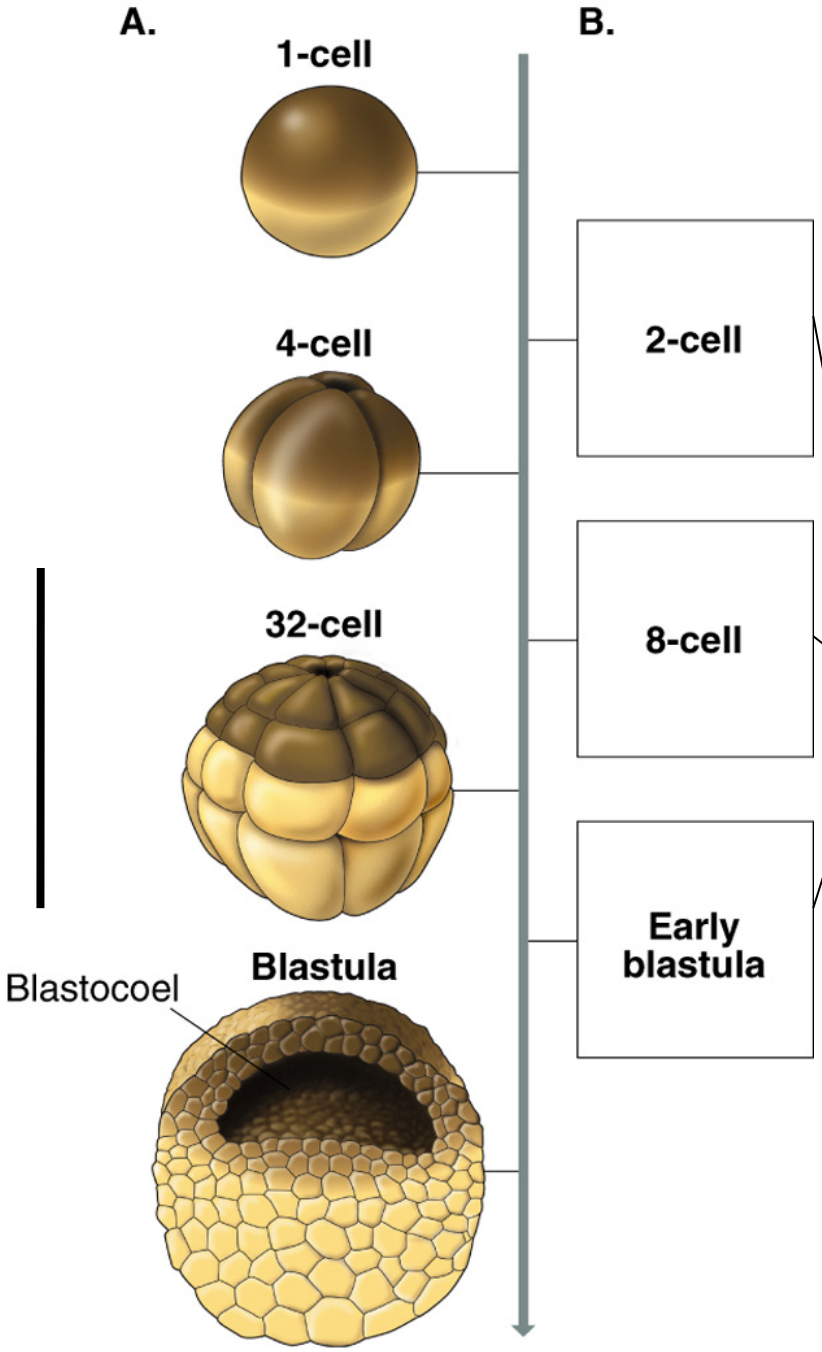


Zbytnělá cementová žláza (adhezivní orgán)

Morus nigra (mulberry)

16-64 cells: morula

128 cells: blastula



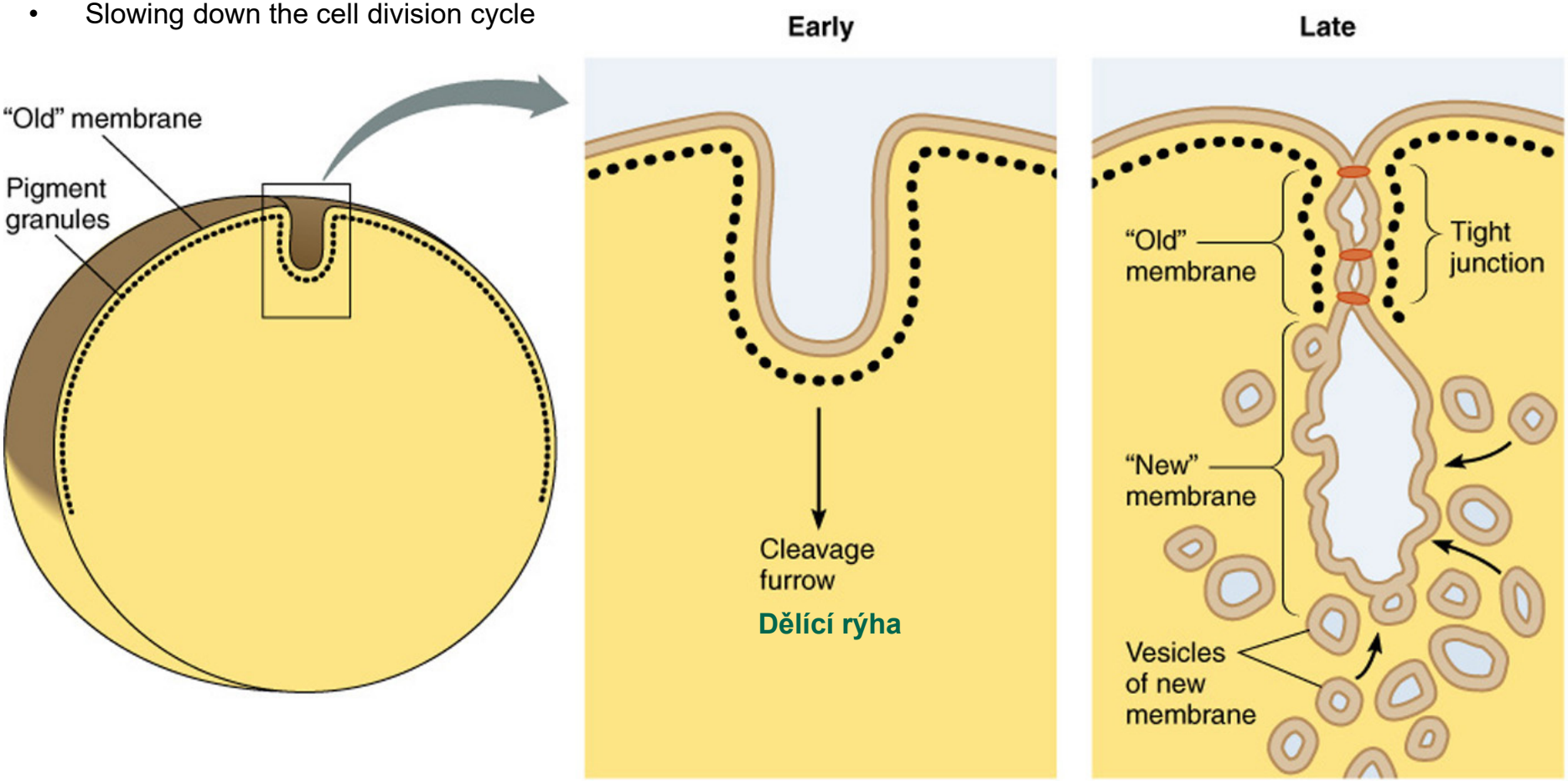
Complete cell divisions
(including cytokinesis)

First 12 rounds of cell divisions at high peace
(every 15 min. each)

2^{12} (approx. 4000) cells

Important molecular events precede further development at the midblastula transition (MBT)

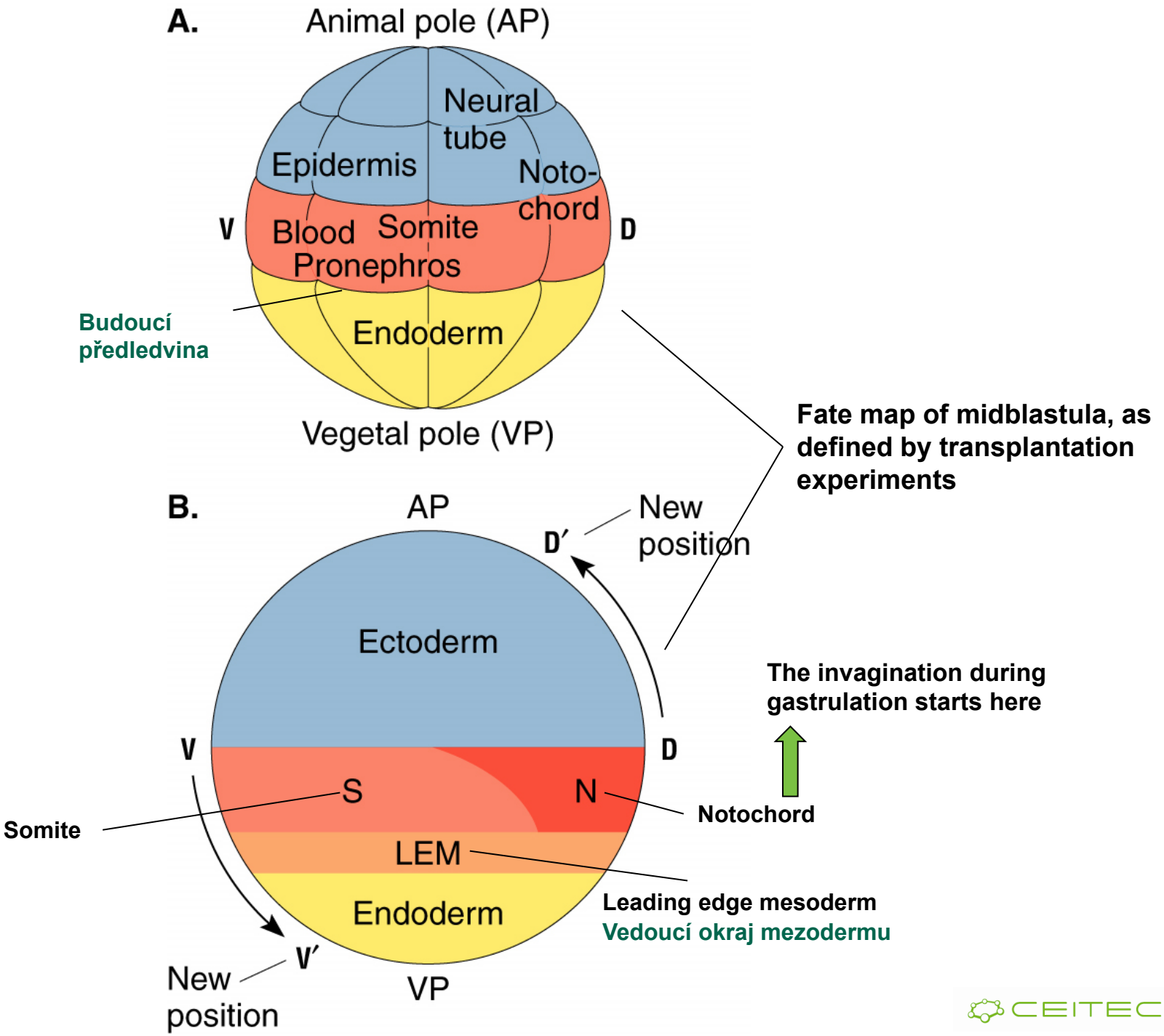
- Induction of transcription
- Acquiring potential of cell motility
- Slowing down the cell division cycle

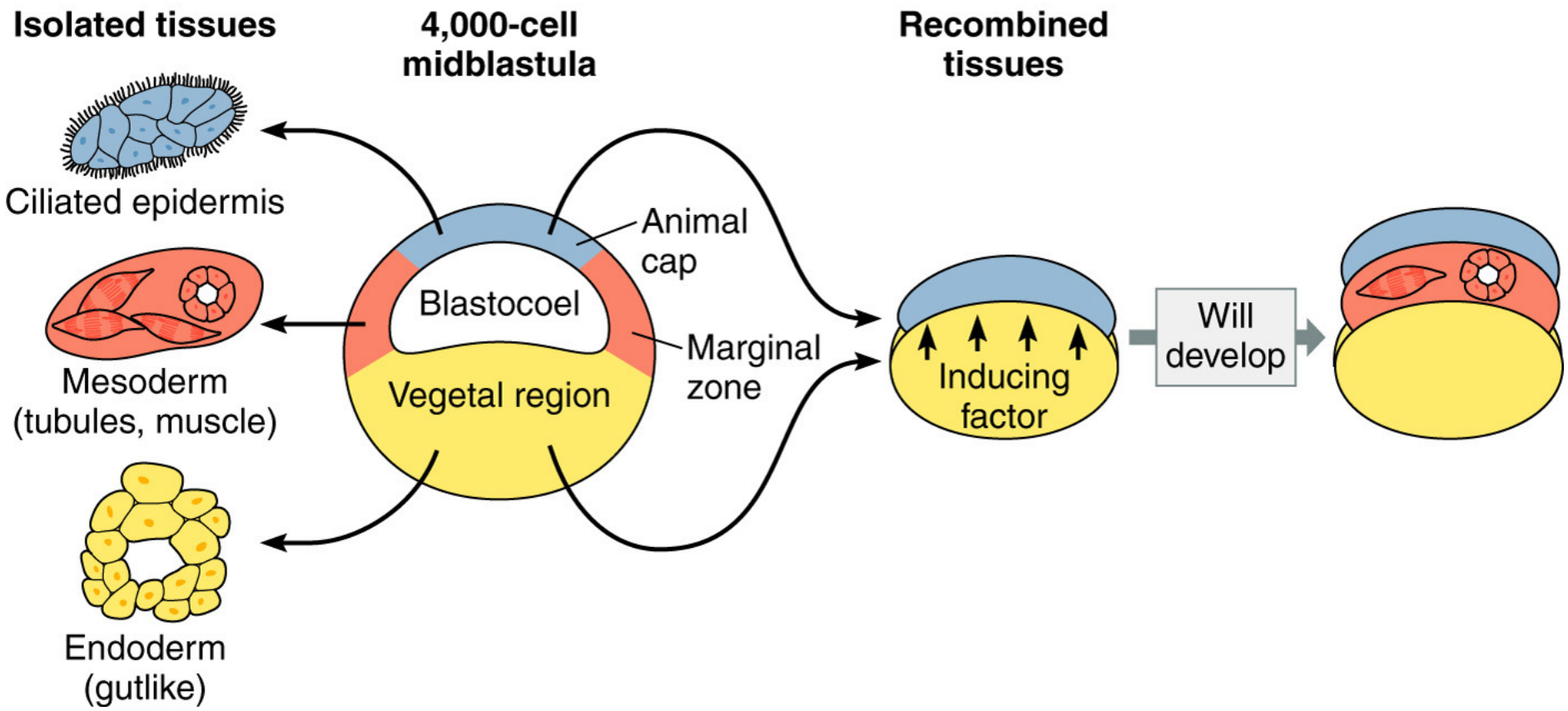


Outline of Lesson 3

Early Development of Amphibians and Amniotes

- Oogenesis in amphibians
- Blastula formation and dorsoventral axis fomation in amphibians
  - cleavage of *Xenopus* zygote (video)

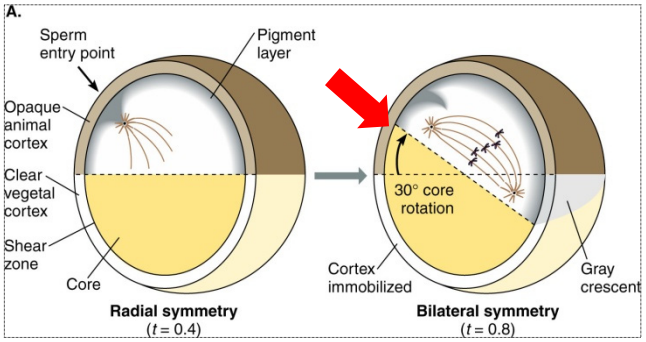

A.
Animal pole (AP)
Neural tube
Epidermis
Noto-chord
V
Blood
Somite
Pronephros
D
Budoucí předledvina
Endoderm
Vegetal pole (VP)
Fate map of midblastula, as defined by transplantation experiments
B.
AP
D′
New position
Ectoderm
The invagination during gastrulation starts here
V
D
S
N
Somite
Notochord
LEM
Leading edge mesoderm
Vedoucí okraj mezodermu
Endoderm
V′
New position
VP


Isolated tissues
4,000-cell midblastula
Recombined tissues
Ciliated epidermis
Mesoderm (tubules, muscle)
Endoderm (gutlike)
Animal cap
Blastocoel
Marginal zone
Vegetal region
Inducing factor
Will develop

Outline of Lesson 3

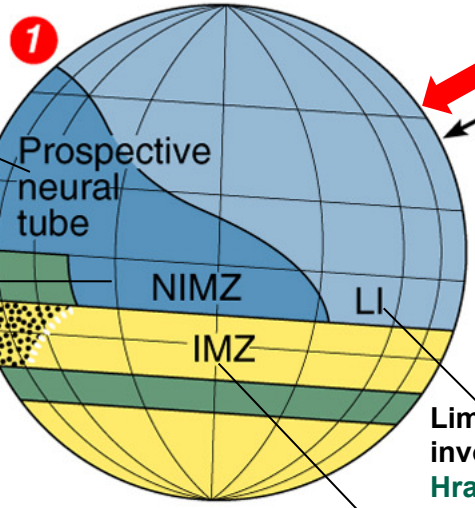
Early Development of Amphibians and Amniotes

- Oogenesis in amphibians
- Blastula formation and dorsoventral axis fomation in amphibians
  - cleavage of *Xenopus* zygote (video)
- Gastrulation in amphibians



Stage
A. Late Blastula

Surface Views
Animal pole



Vegetal pole

Budoucí nervová trubice

Non-involuting marginal zone
Neinvolující marginální zóna (NIMZ)

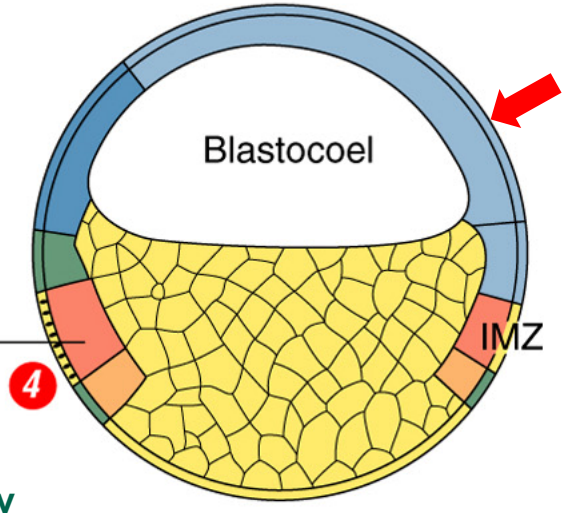
Prospective bottle cells (blastopore begins here)
Blastopor (prvoústa)

Sperm would probably have entered near here at time of fertilization

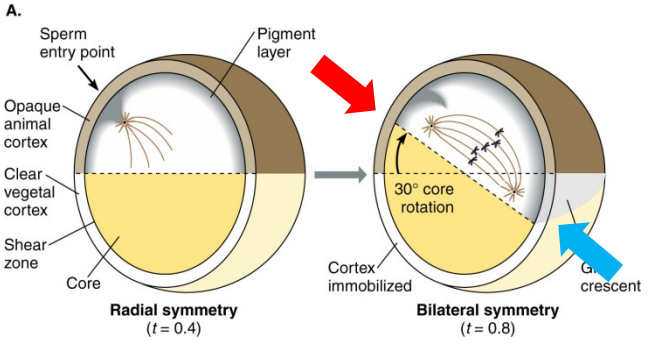
Limit of involution
Hranice involuce

Involuting marginal zone
Involující marginální zóna (IMZ)

Cutaway Views
AP

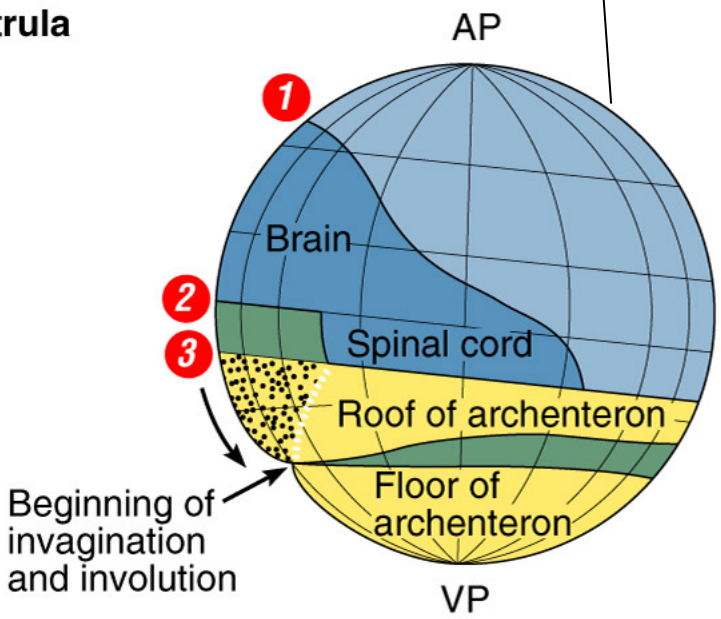


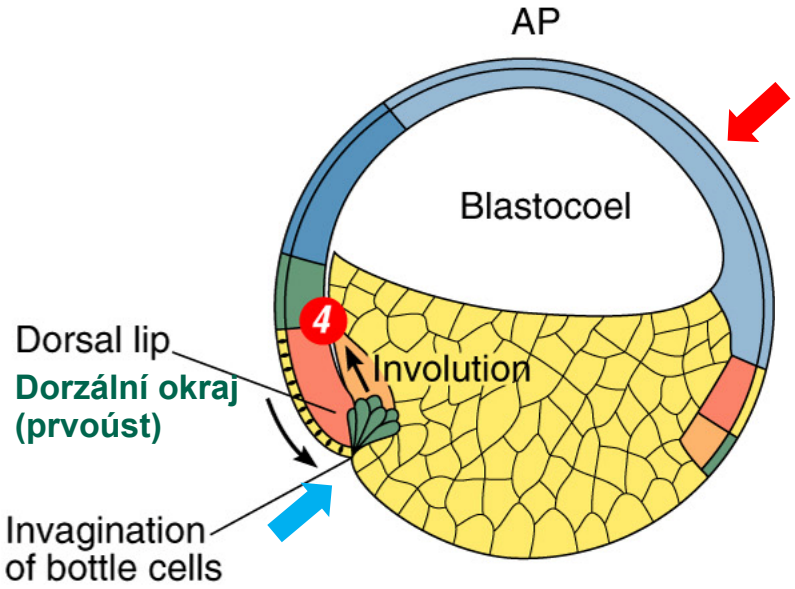
Dorsal IMZ (Spemann organizer)
Dorzální IMZ(Spémanův organizátor)



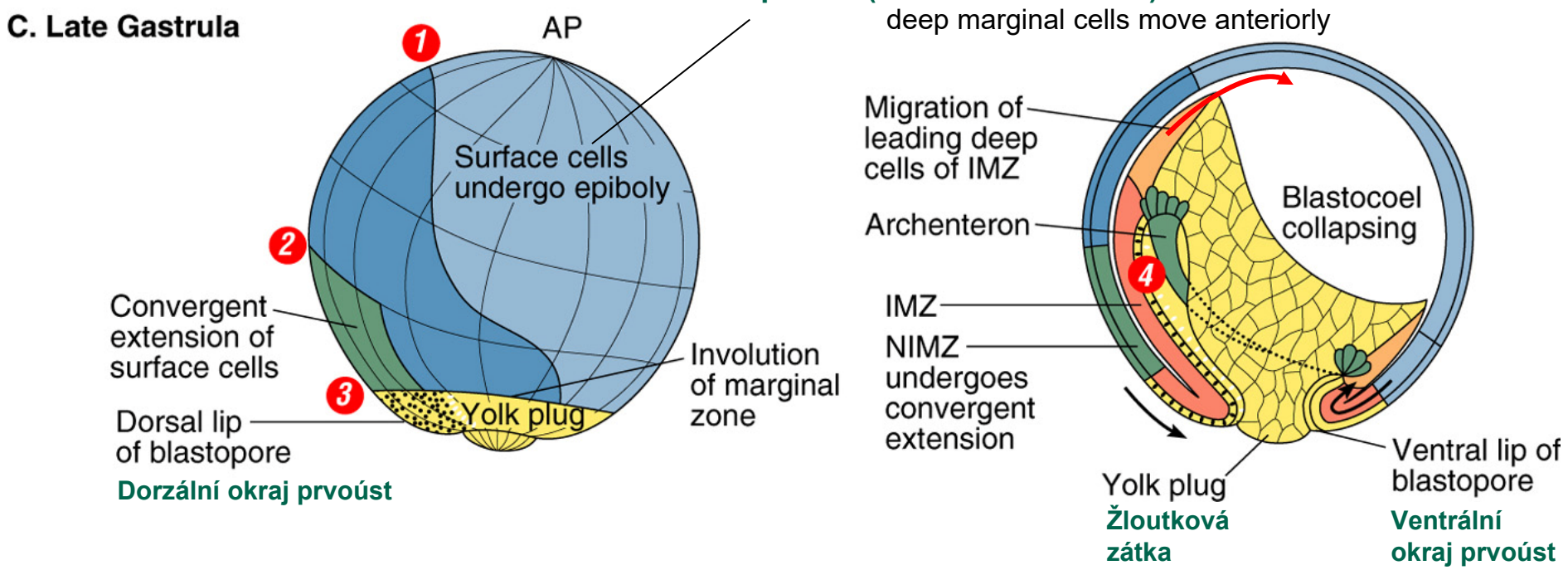
Entry of sperm cell

B. Early Gastrula

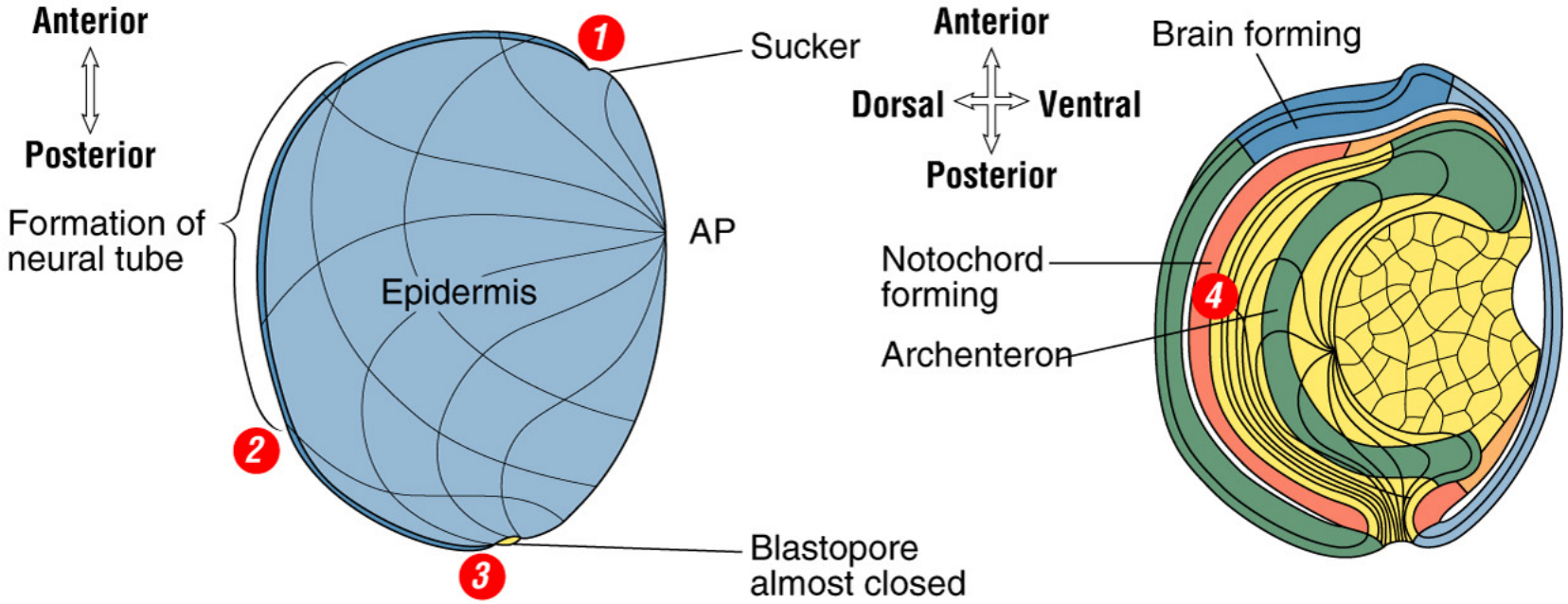




Oblast epibolie (radiální interkalace)



D. Neurulation Finished



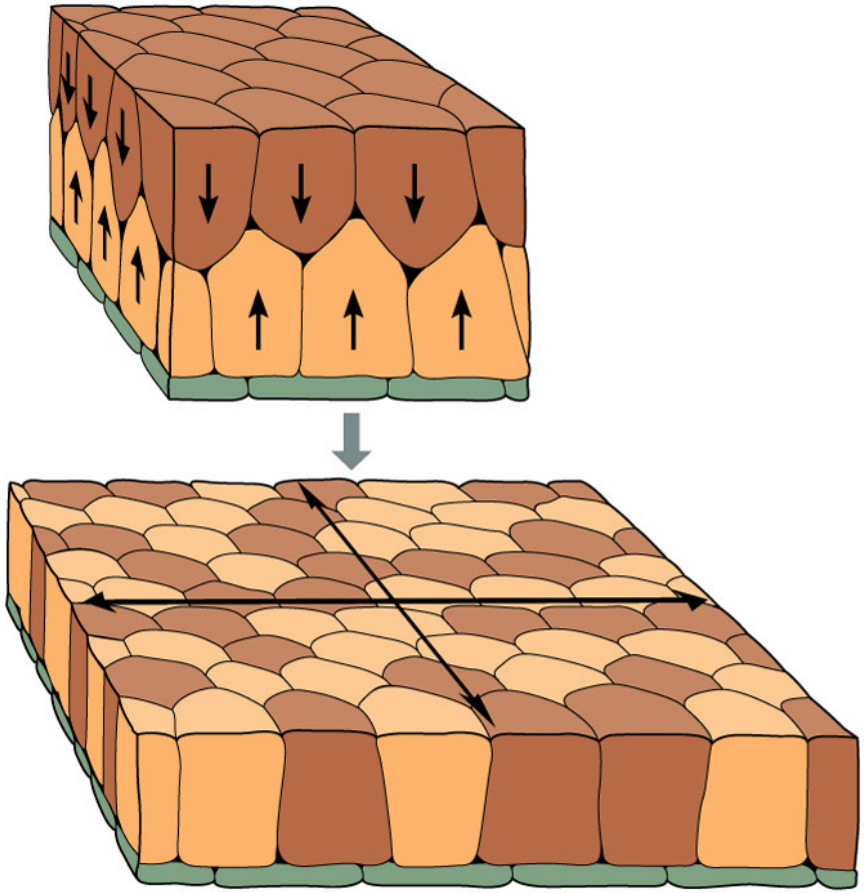
Outline of Lesson 3

Early Development of Amphibians and Amniotes

- Oogenesis in amphibians
- Blastula formation and dorsoventral axis fomation in amphibians
  - cleavage of *Xenopus* zygote (video)
- Gastrulation in amphibians
  - gastrulation of amphibians (video)

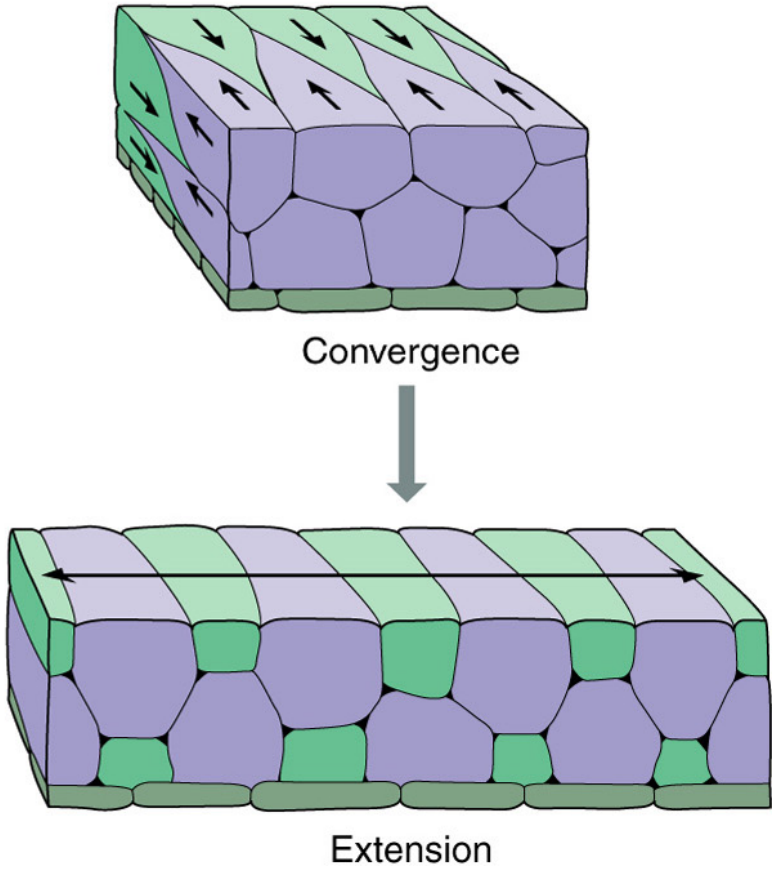
Radiální interkalace

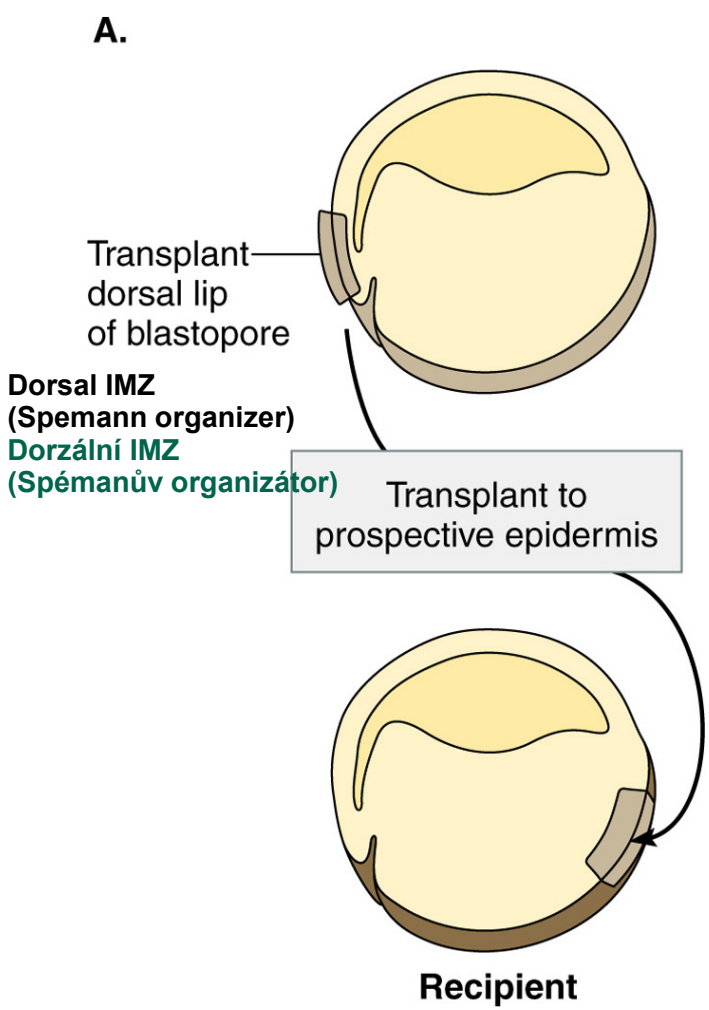
A. Radial intercalation

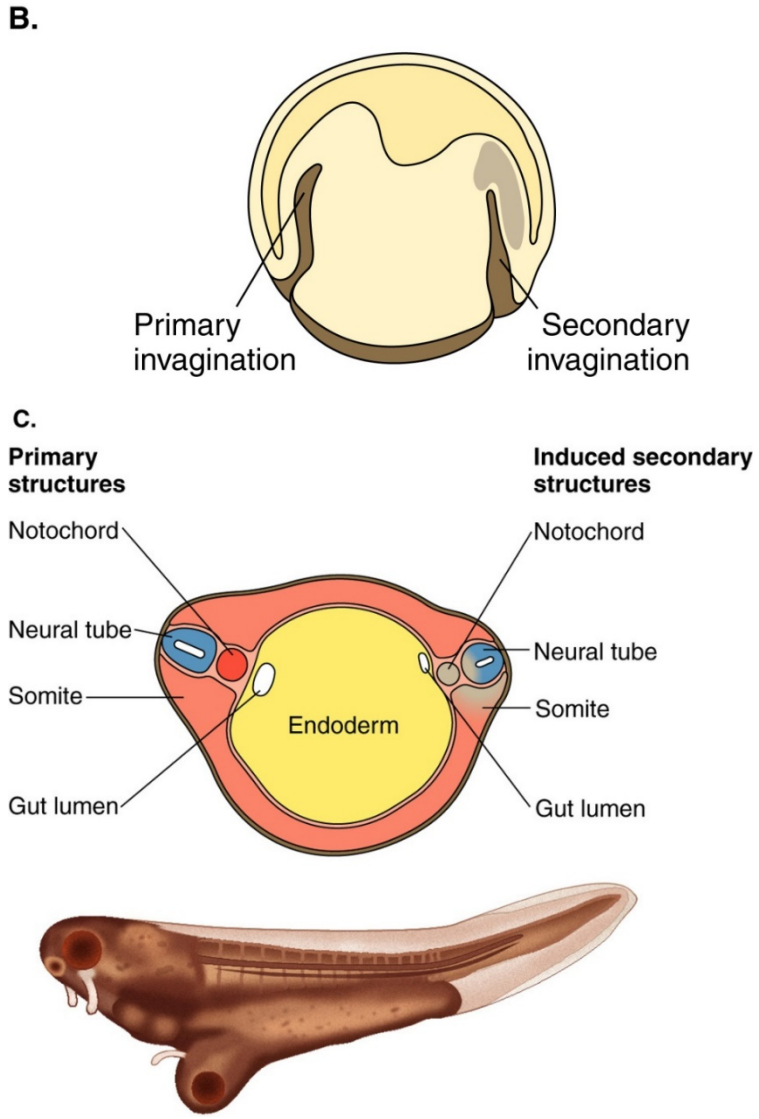


Mediolaterální interkalace

B. Mediolateral intercalation



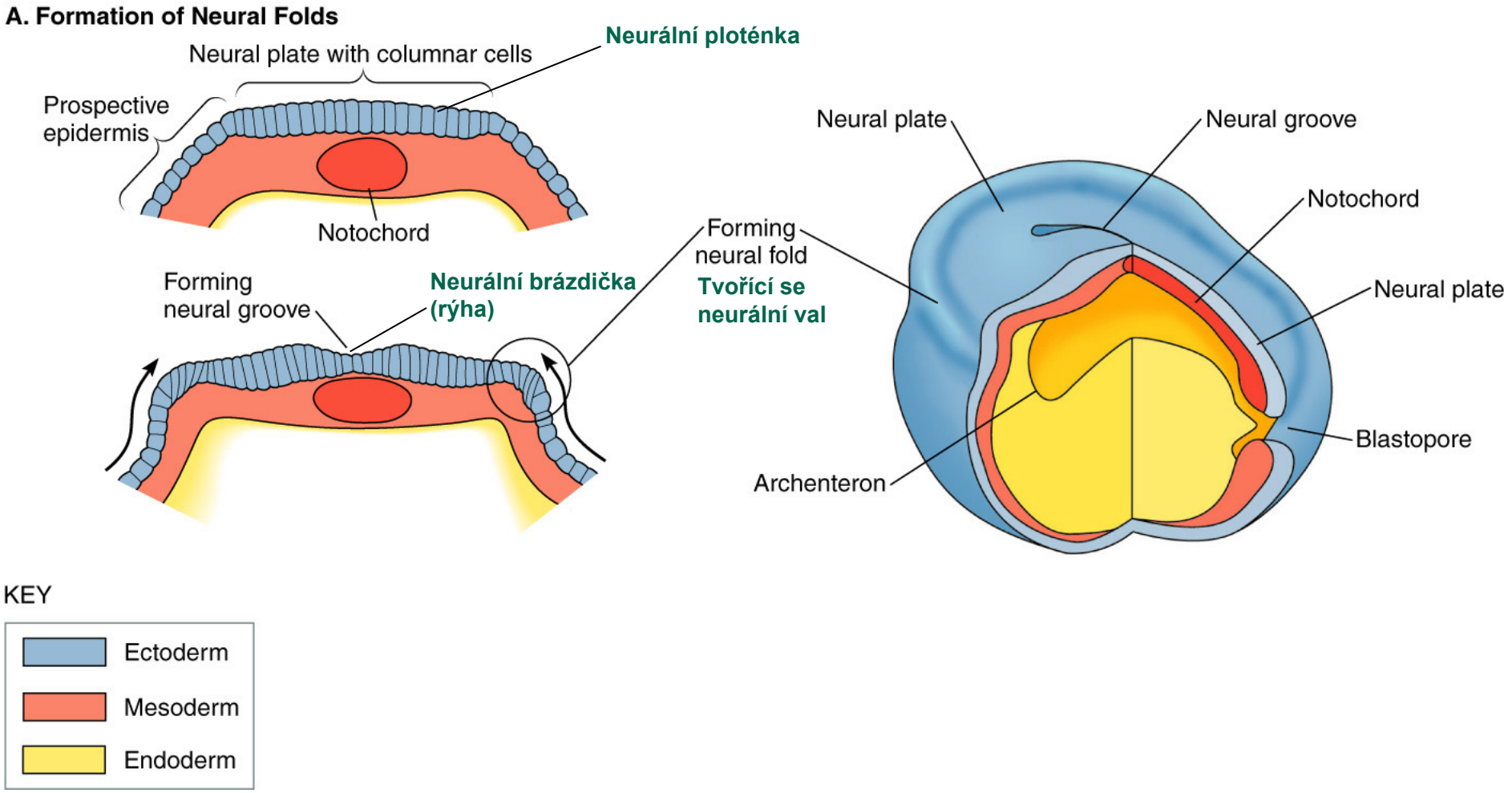

A.
Transplant
dorsal lip
of blastopore
Dorsal IMZ
(Spemann organizer)
Dorzální IMZ
(Spémanův organizátor)
Transplant to
prospective epidermis
Recipient


B.
Primary
invagination
Secondary
invagination
C.
Primary
structures
Induced secondary
structures
Notochord
Neural tube
Somite
Gut lumen
Endoderm
Notochord
Neural tube
Somite
Gut lumen

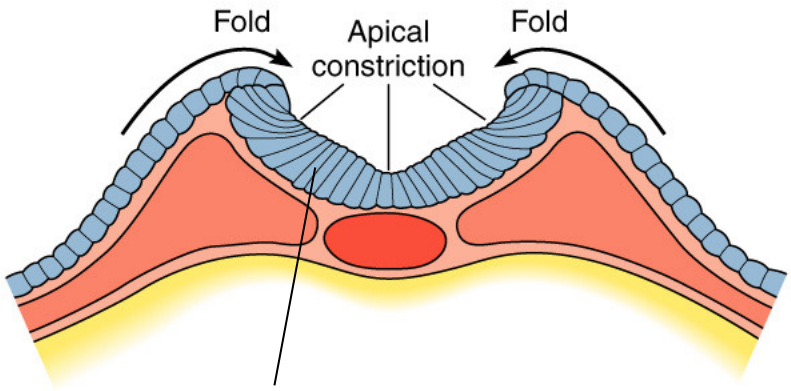
Outline of Lesson 3

Early Development of Amphibians and Amniotes

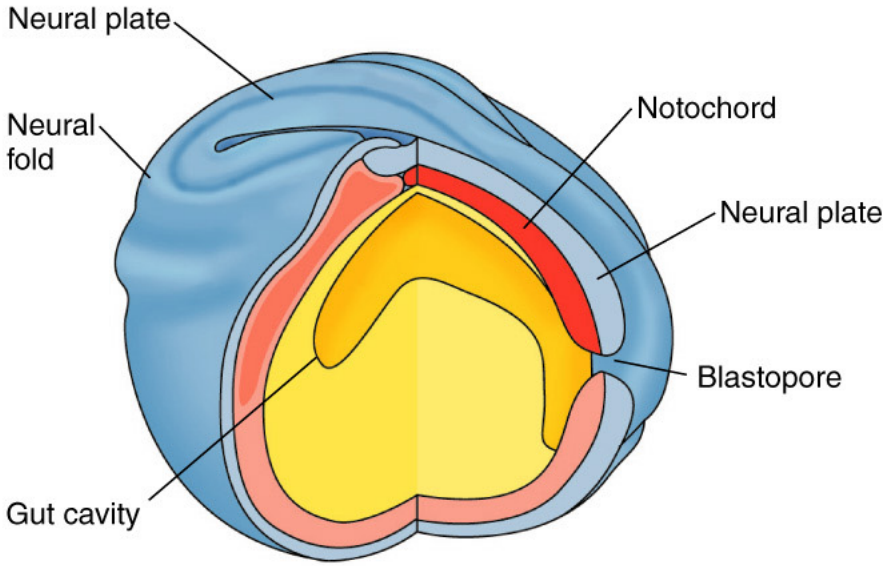
- Oogenesis in amphibians
- Blastula formation and dorsoventral axis fomation in amphibians
  - cleavage of *Xenopus* zygote (video)
- Gastrulation
  - gastrulation of amphibians (video)
- Neurulation


A. Formation of Neural Folds
Neural plate with columnar cells
Neurální ploténka
Prospective epidermis
Notochord
Forming neural groove
Neurální brázdička (rýha)
Forming neural fold
Tvořící se neurální val
Neural plate
Neural groove
Notochord
Neural plate
Blastopore
Archenteron
KEY
Ectoderm
Mesoderm
Endoderm

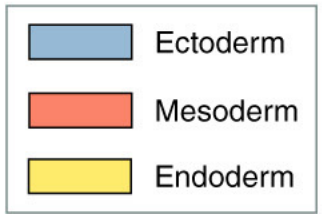
B. Elevation of Neural Folds

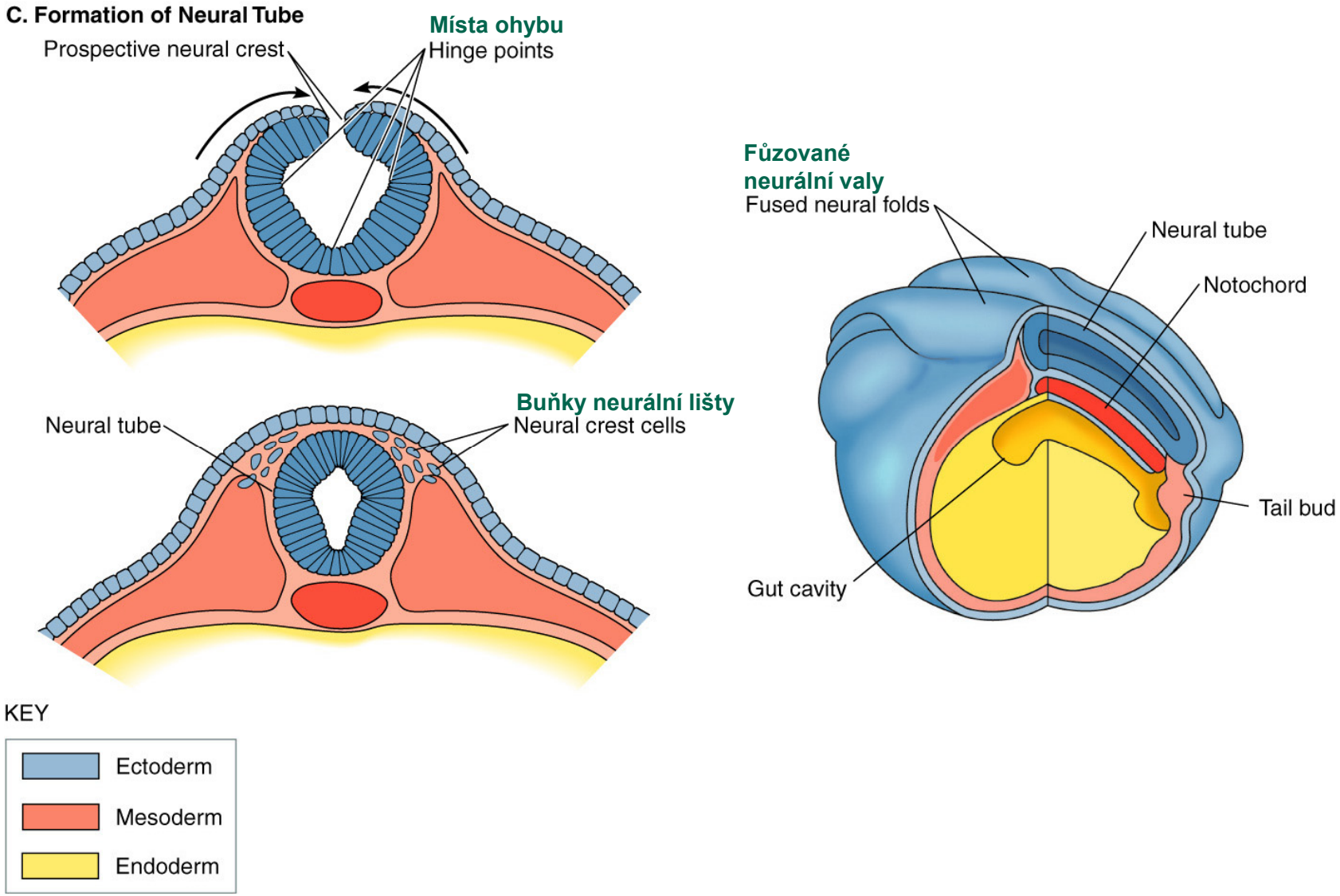


Change of the cell shape due to microfilament action



KEY

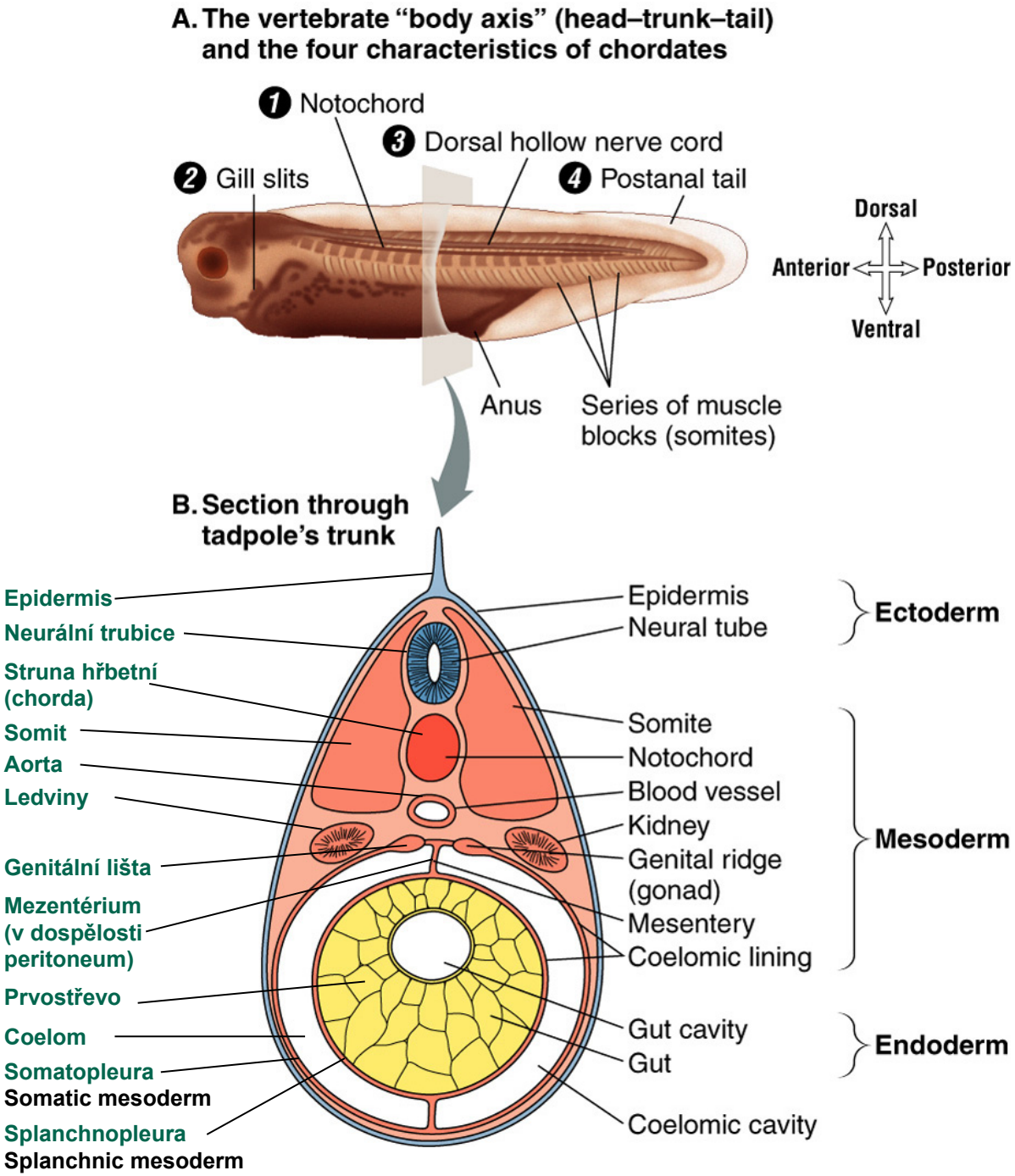



C. Formation of Neural Tube
Prospective neural crest
Místa ohybu
Hinge points
Neural tube
Buňky neurální lišty
Neural crest cells
KEY
Ectoderm
Mesoderm
Endoderm
Fůzované
neurální valy
Fused neural folds
Neural tube
Notochord
Tail bud
Gut cavity

Outline of Lesson 3

Early Development of Amphibians and Amniotes

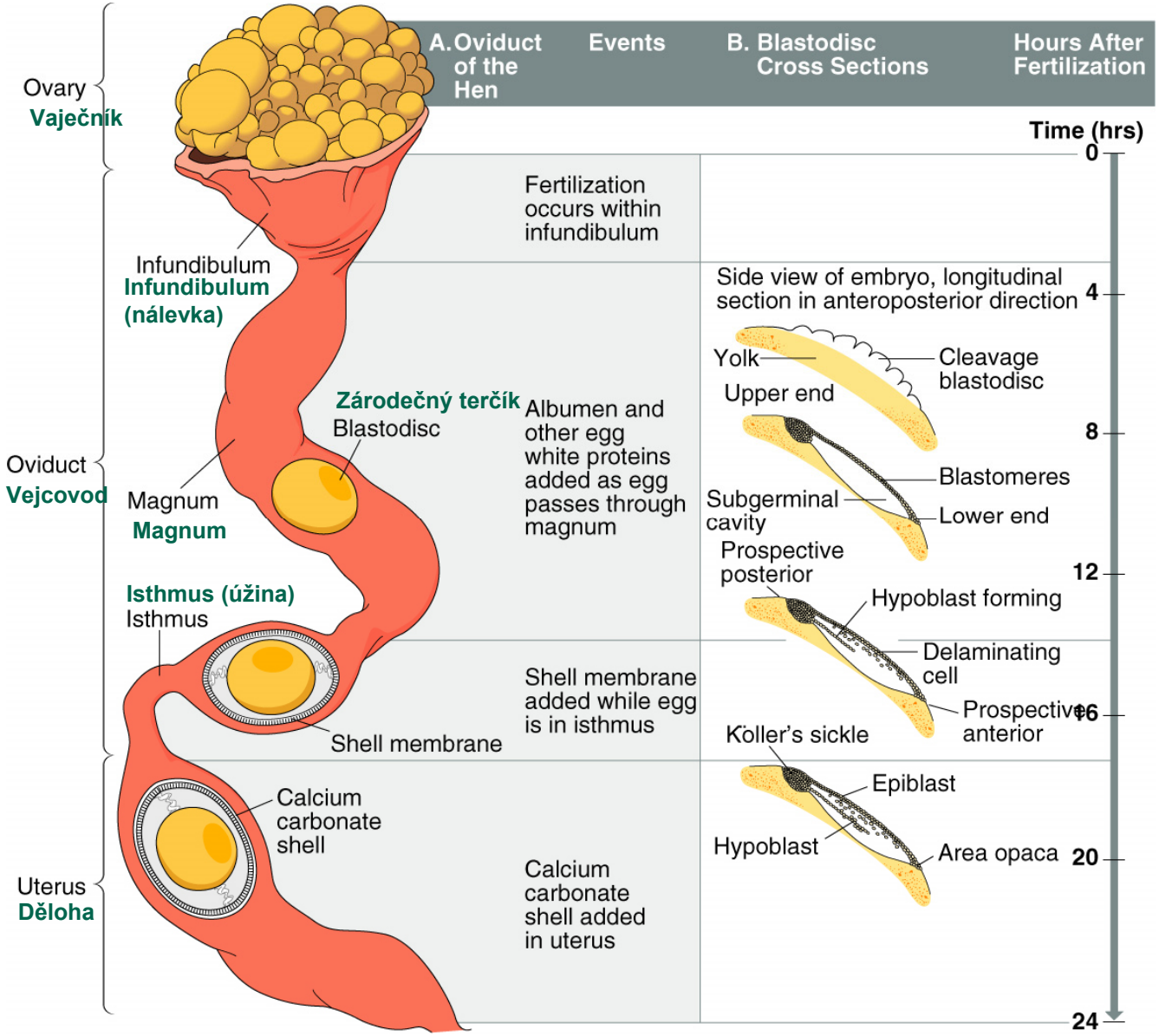
- Oogenesis in amphibians
- Blastula formation and dorsoventral axis fomation in amphibians
  - cleavage of *Xenopus* zygote (video)
- Gastrulation
  - gastrulation of amphibians (video)
- Neurulation
  - neurulation in *Xenopus* (video)


A. The vertebrate "body axis" (head–trunk–tail) and the four characteristics of chordates
1 Notochord
2 Gill slits
3 Dorsal hollow nerve cord
4 Postanal tail
Dorsal
Anterior
Posterior
Ventral
Anus
Series of muscle blocks (somites)
B. Section through tadpole's trunk
Epidermis
Neurální trubice
Struna hřbetní (chorda)
Somit
Aorta
Ledviny
Genitální lišta
Mezentérium (v dospělosti peritoneum)
Prvostřevo
Coelom
Somatopleura
Somatic mesoderm
Splanchnopleura
Splanchnic mesoderm
Epidermis
Neural tube
Ectoderm
Somite
Notochord
Blood vessel
Kidney
Genital ridge (gonad)
Mesentery
Coelomic lining
Mesoderm
Gut cavity
Gut
Endoderm
Coelomic cavity

Outline of Lesson 3

Early Development of Amphibians and Amniotes

- Oogenesis in amphibians
- Blastula formation and dorsoventral axis fomation in amphibians
  - cleavage of *Xenopus* zygote (video)
- Gastrulation in amphibians
  - gastrulation of amphibians (video)
- Neurulation
  - neurulation in *Xenopus* (video)
- Oogenesis in amniotes - chicken

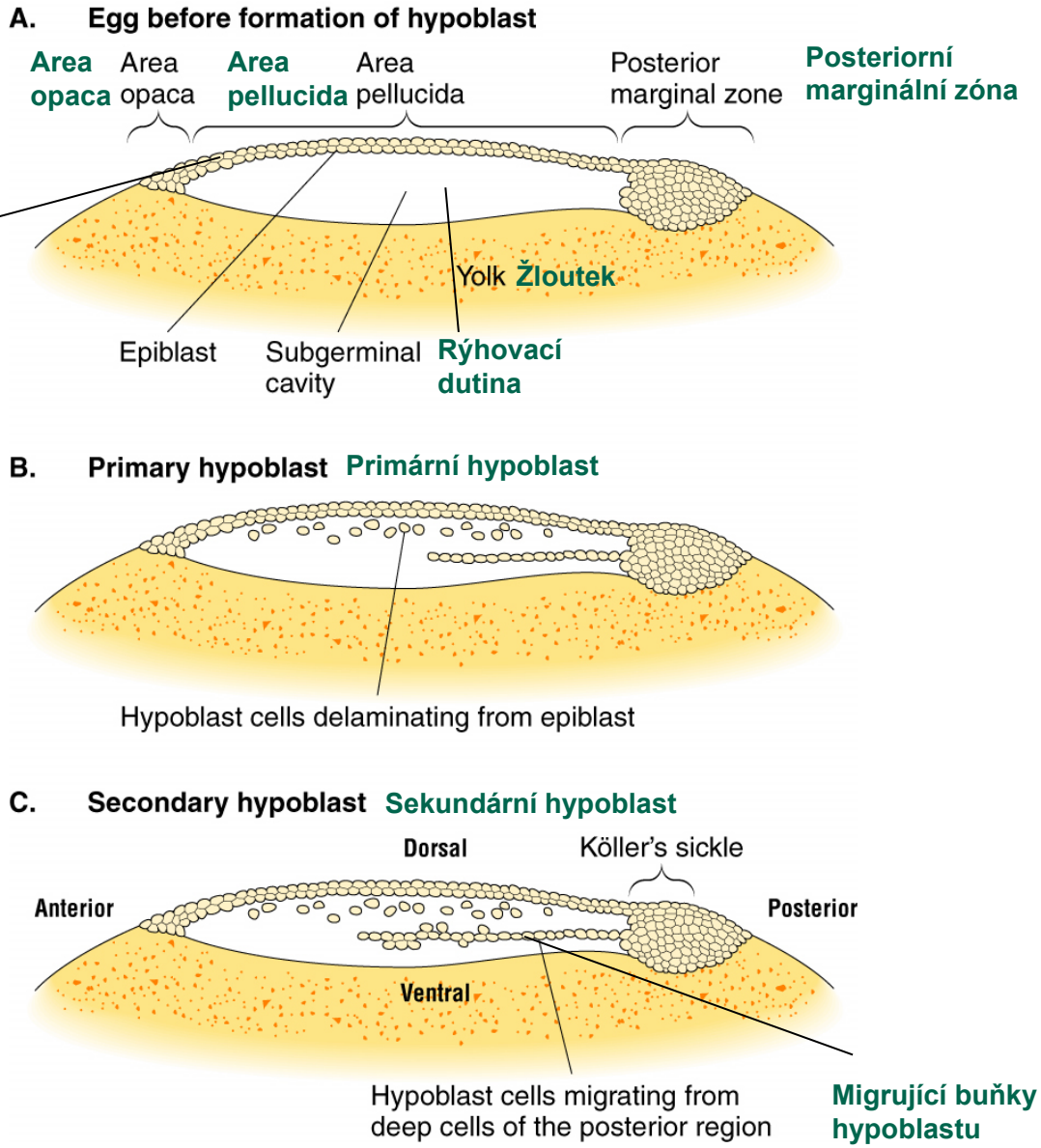

A. Oviduct of the Hen
Events
B. Blastodisc Cross Sections
Hours After Fertilization
Time (hrs)
0
4
8
12
16
20
24
Ovary
Vaječník
Oviduct
Vejcovod
Uterus
Děloha
Infundibulum
Infundibulum (nálevka)
Magnum
Magnum
Isthmus (úžina)
Isthmus
Shell membrane
Calcium carbonate shell
Zárodečný terčík
Blastodisc
Fertilization occurs within infundibulum
Albumen and other egg white proteins added as egg passes through magnum
Shell membrane added while egg is in isthmus
Calcium carbonate shell added in uterus
Side view of embryo, longitudinal section in anteroposterior direction
Yolk
Cleavage blastodisc
Upper end
Blastomeres
Subgerminal cavity
Lower end
Prospective posterior
Hypoblast forming
Delaminating cell
Prospective anterior
Koller's sickle
Epiblast
Hypoblast
Area opaca

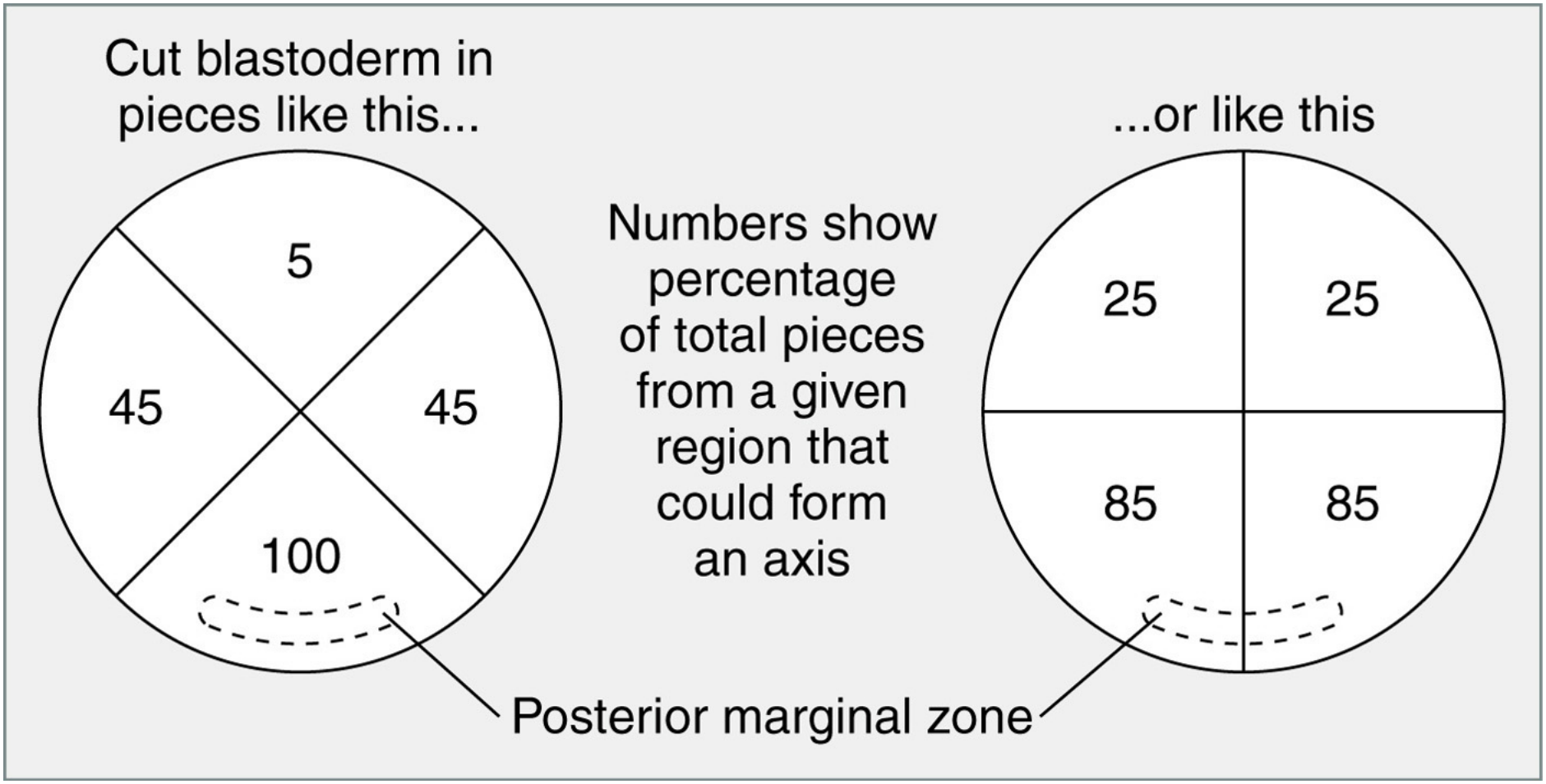
Outline of Lesson 3

Early Development of Amphibians and Amniotes

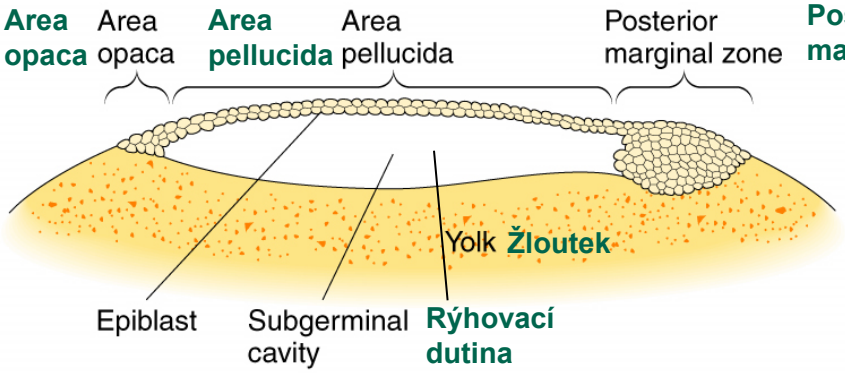
- Oogenesis in amphibians
- Blastula formation and dorsoventral axis fomation in amphibians
  - cleavage of *Xenopus* zygote (video)
- Gastrulation
  - gastrulation of amphibians (video)
- Neurulation
  - neurulation in *Xenopus* (video)
- Oogenesis in amniotes – chicken
- Blastula formation in amniotes - chicken

Egg laying: 60,000 cells, about 1 mm in diameter



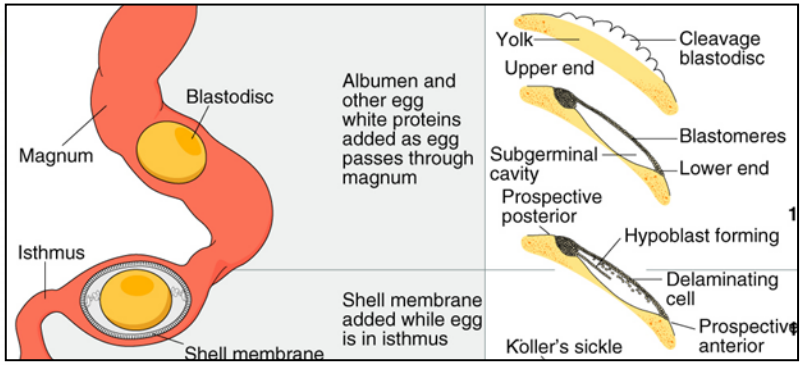

Cut blastoderm in pieces like this...
5
45
45
100
Posterior marginal zone
Numbers show percentage of total pieces from a given region that could form an axis
...or like this
25
25
85
85

A. Egg before formation of hypoblast

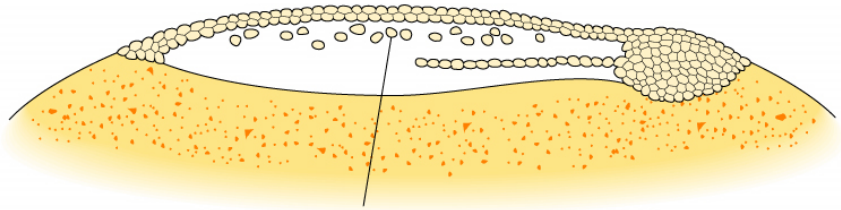


Posteriorní marginální zóna

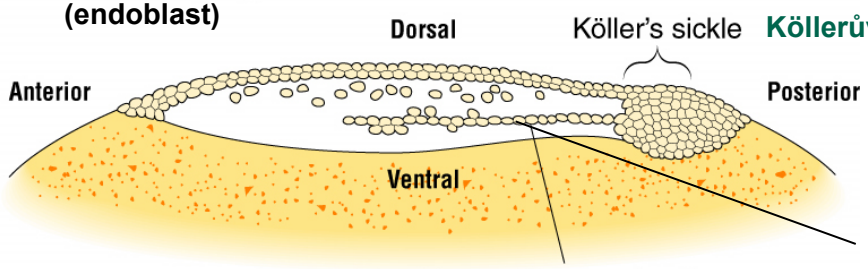
There is a role of graviotropism in the anteroposterior axis formation in birds



B. Primary hypoblast Primární hypoblast

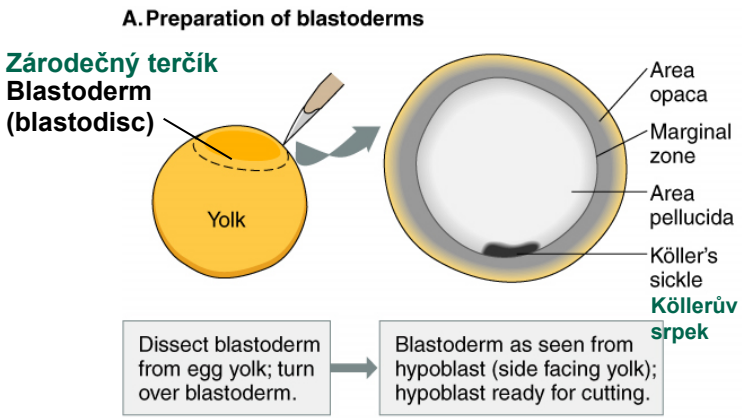


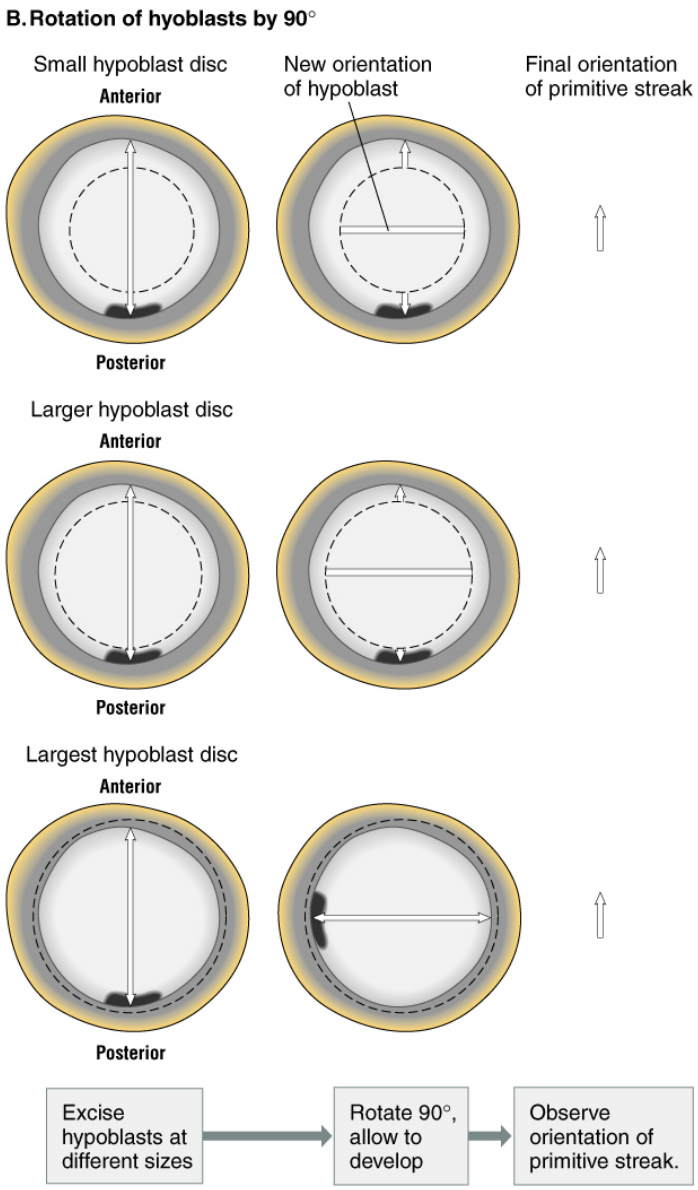
C. Secondary hypoblast (endoblast) Sekundární hypoblast



Köllerův srpek

Migrující buňky hypoblastu



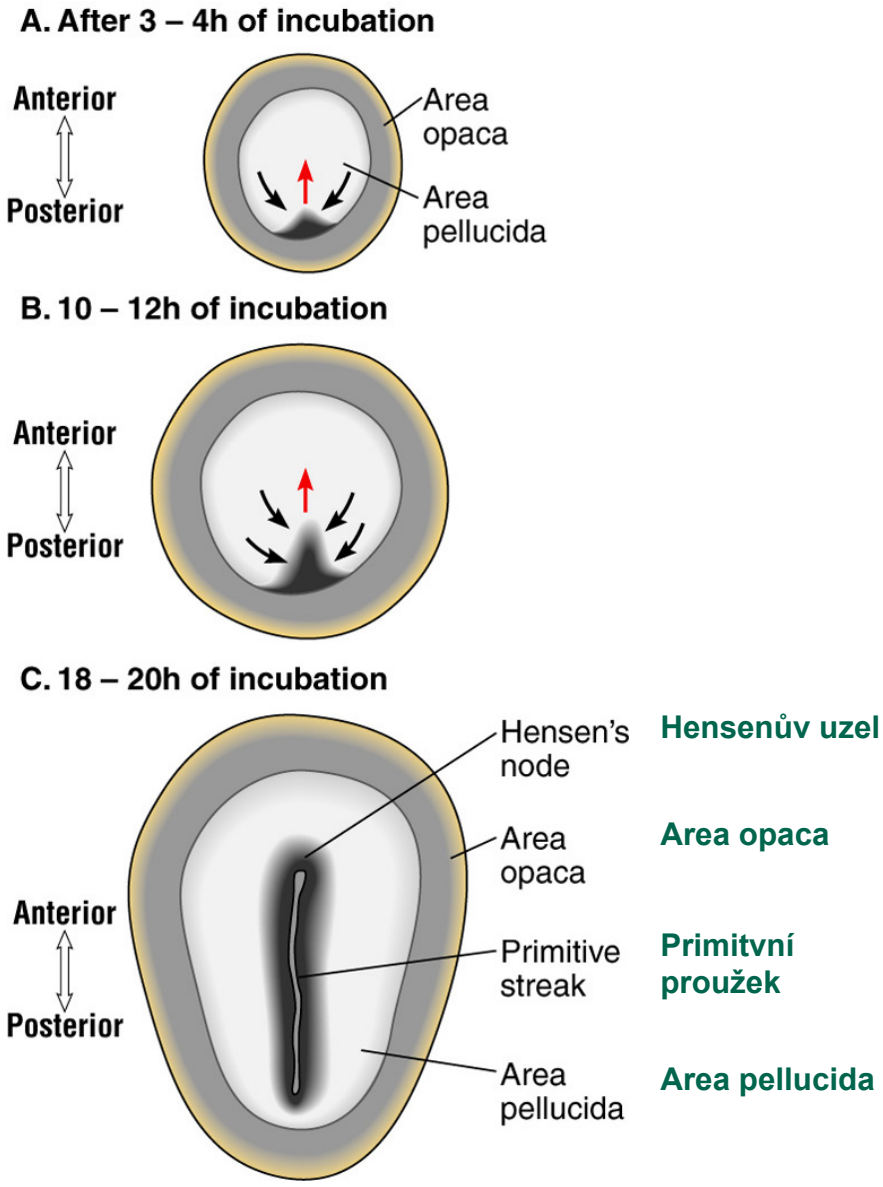


Does hypoblast determine the anteroposterior axis of epiblast?

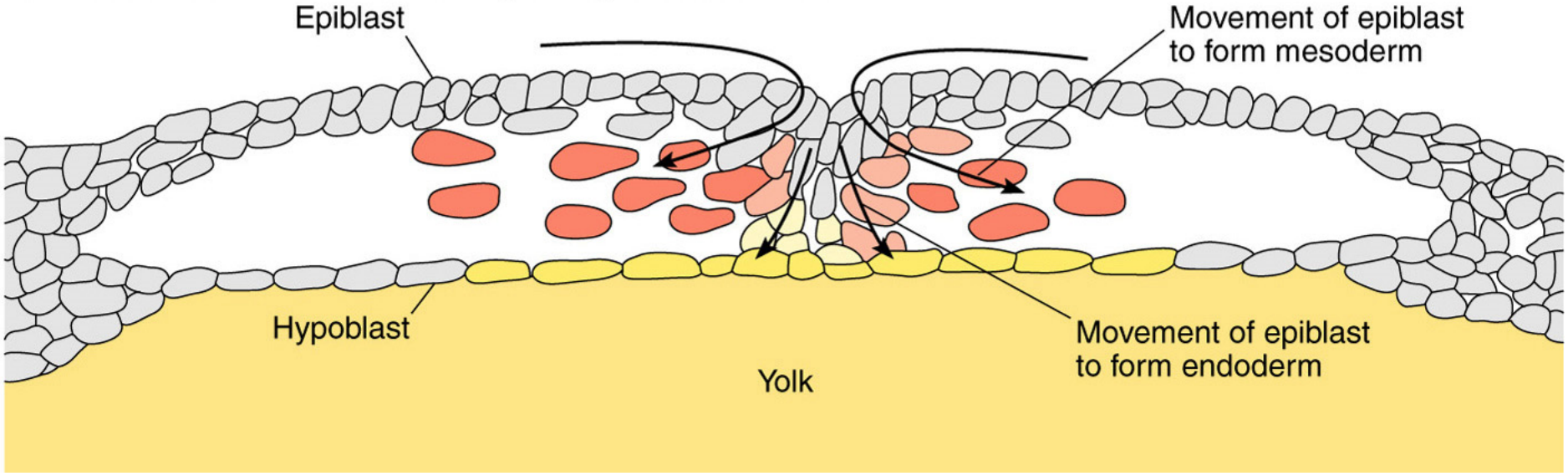
Outline of Lesson 3

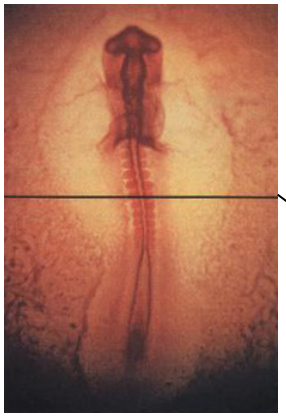
Early Development of Amphibians and Amniotes

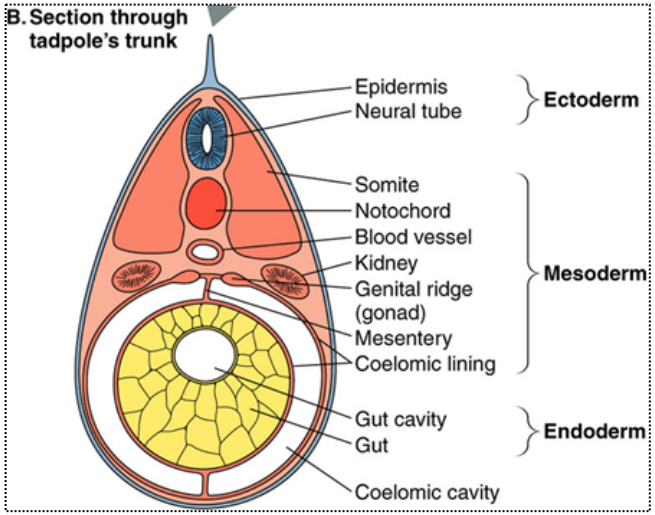
- Gastrulation in amniotes – chicken


A. After 3 – 4h of incubation
Anterior
Posterior
Area opaca
Area pellucida
B. 10 – 12h of incubation
Anterior
Posterior
C. 18 – 20h of incubation
Anterior
Posterior
Hensen's node
Area opaca
Primitive streak
Area pellucida
Hensenův uzel
Area opaca
Primitivní proužek
Area pellucida

D. Schematic of movements through the primitive streak







B.

Somatický mezoderm
Somatic mesoderm

Střední mezoderm
Intermediate mesoderm

Nervová trubice
Neural tube

Somity
Somite

Surface ectoderm

Splanchnic mesoderm
Splanchnický mezoderm

Coelom

Notochord

Yolk-filled endoderm

Yolk

Outline of Lesson 3

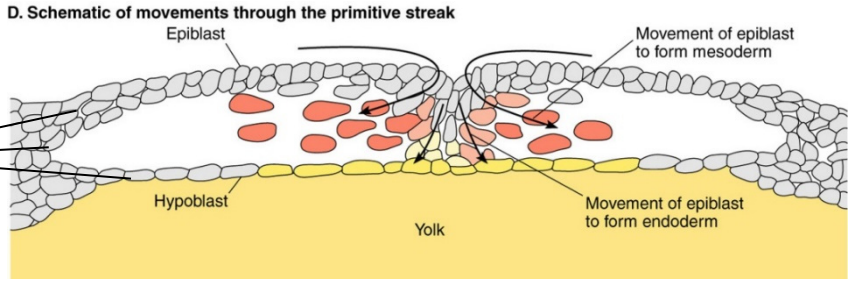
Early Development of Amphibians and Amniotes

- Gastrulation in amniotes – chicken
  - early and late gastrulation in chicken (video)

Outline of Lesson 3

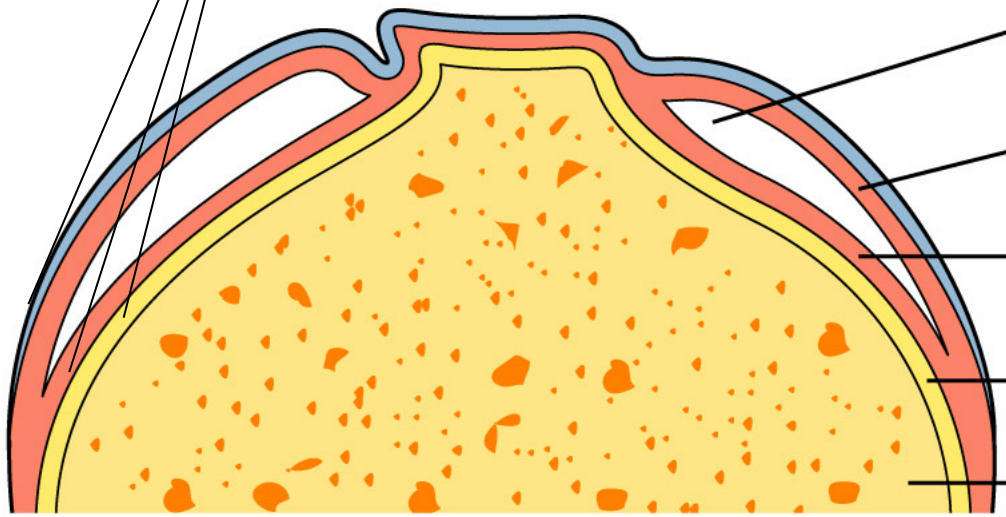
Early Development of Amphibians and Amniotes

- Gastrulation in amniotes – chicken
  - early and late gastrulation in chicken (video)
- Formation of extraembryonic tissues in amniotes - chicken



Origin of extraembryonic tissue

A.



Extraembryonální coelom
Extraembryonic coelom

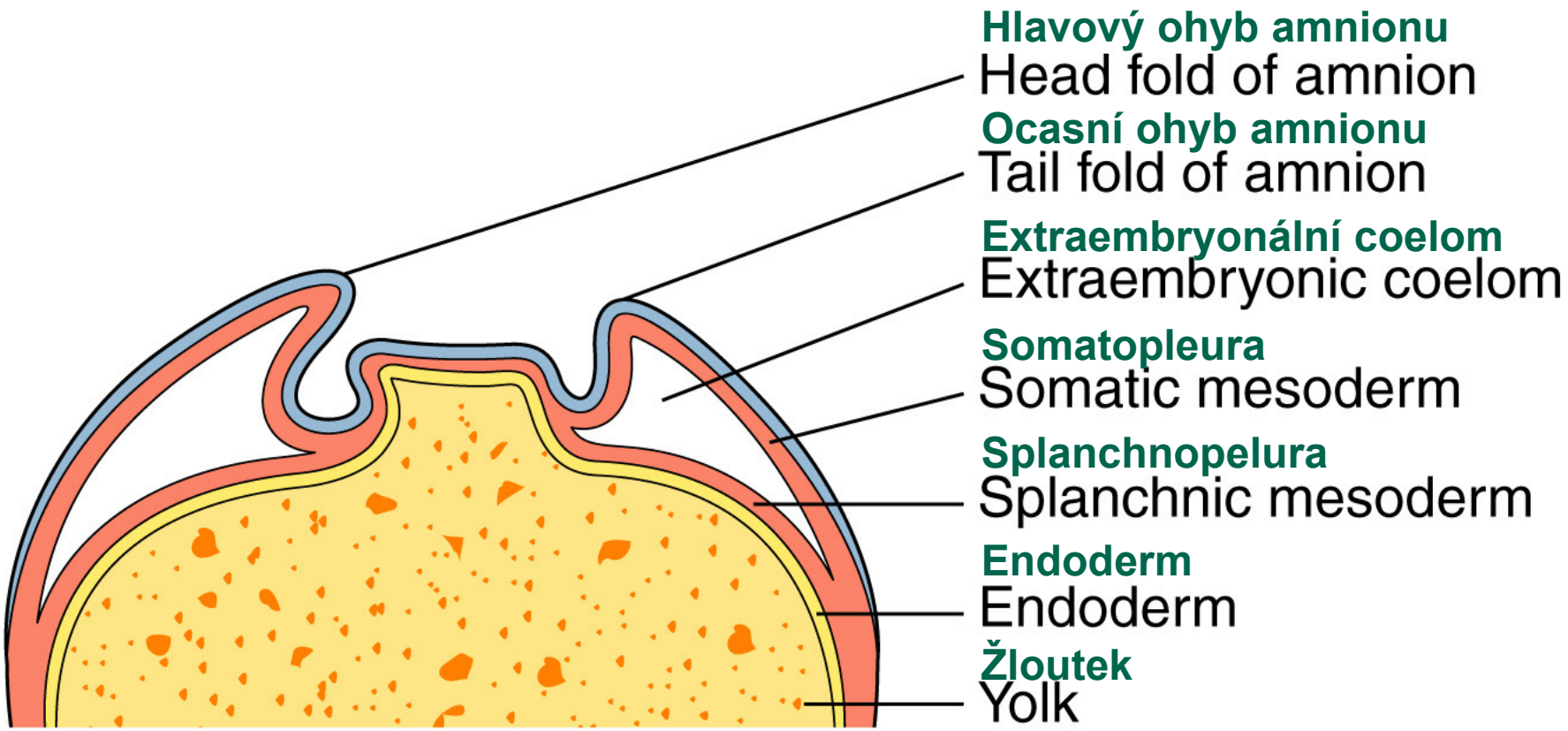
Somatopleura
Somatic mesoderm

Splanchnopleura
Splanchnic mesoderm

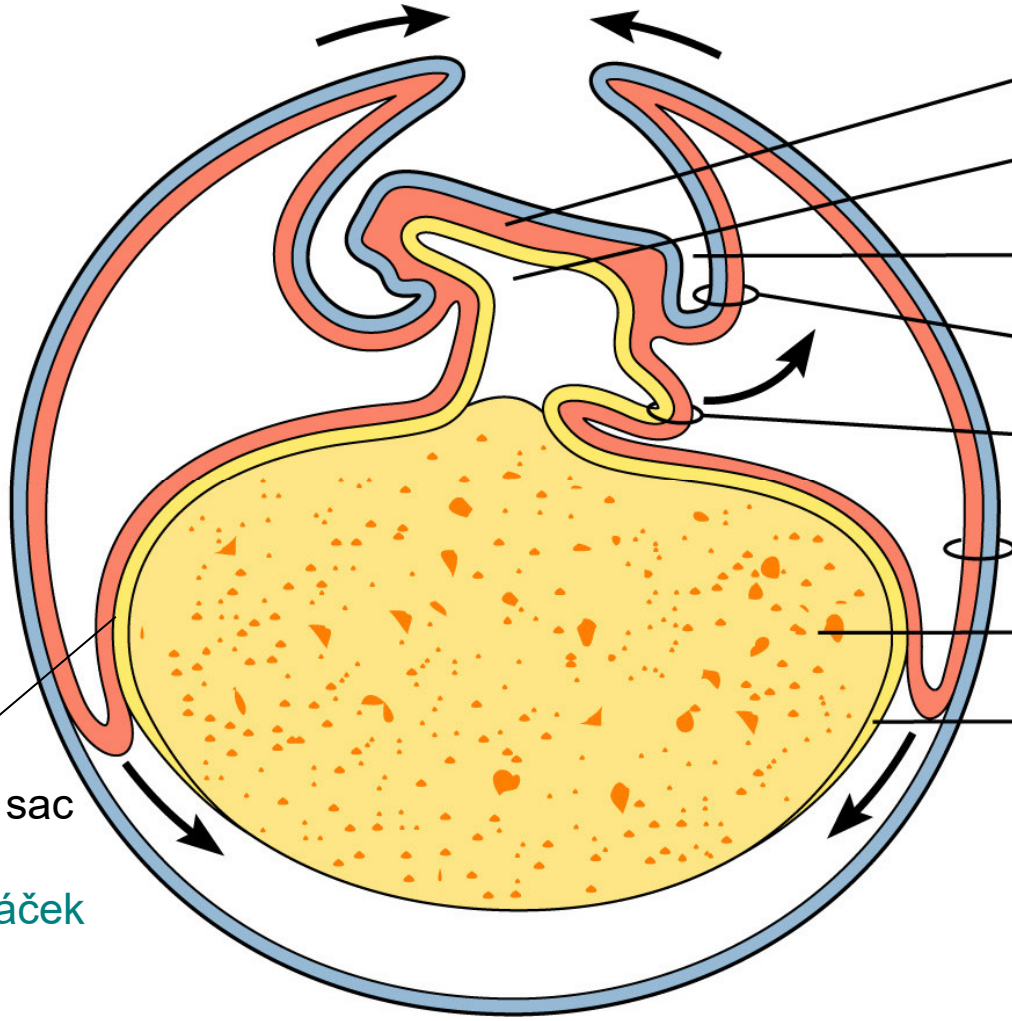
Endoderm
Endoderm

Žloutek
Yolk

B.

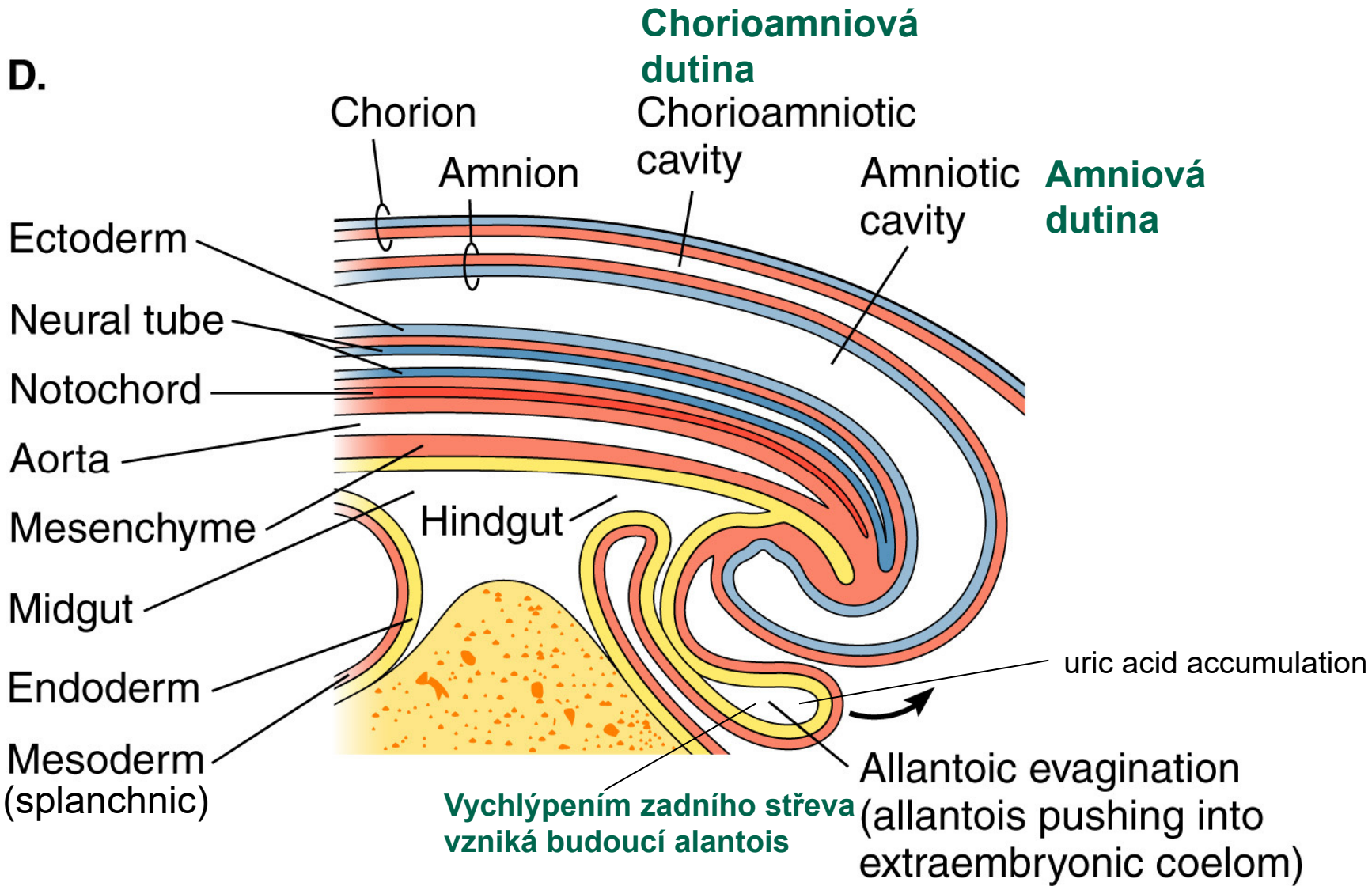

Hlavový ohyb amnionu
Head fold of amnion
Ocasní ohyb amnionu
Tail fold of amnion
Extraembryonální coelom
Extraembryonic coelom
Somatopleura
Somatic mesoderm
Splanchnopelura
Splanchnic mesoderm
Endoderm
Endoderm
Žloutek
Yolk

C.

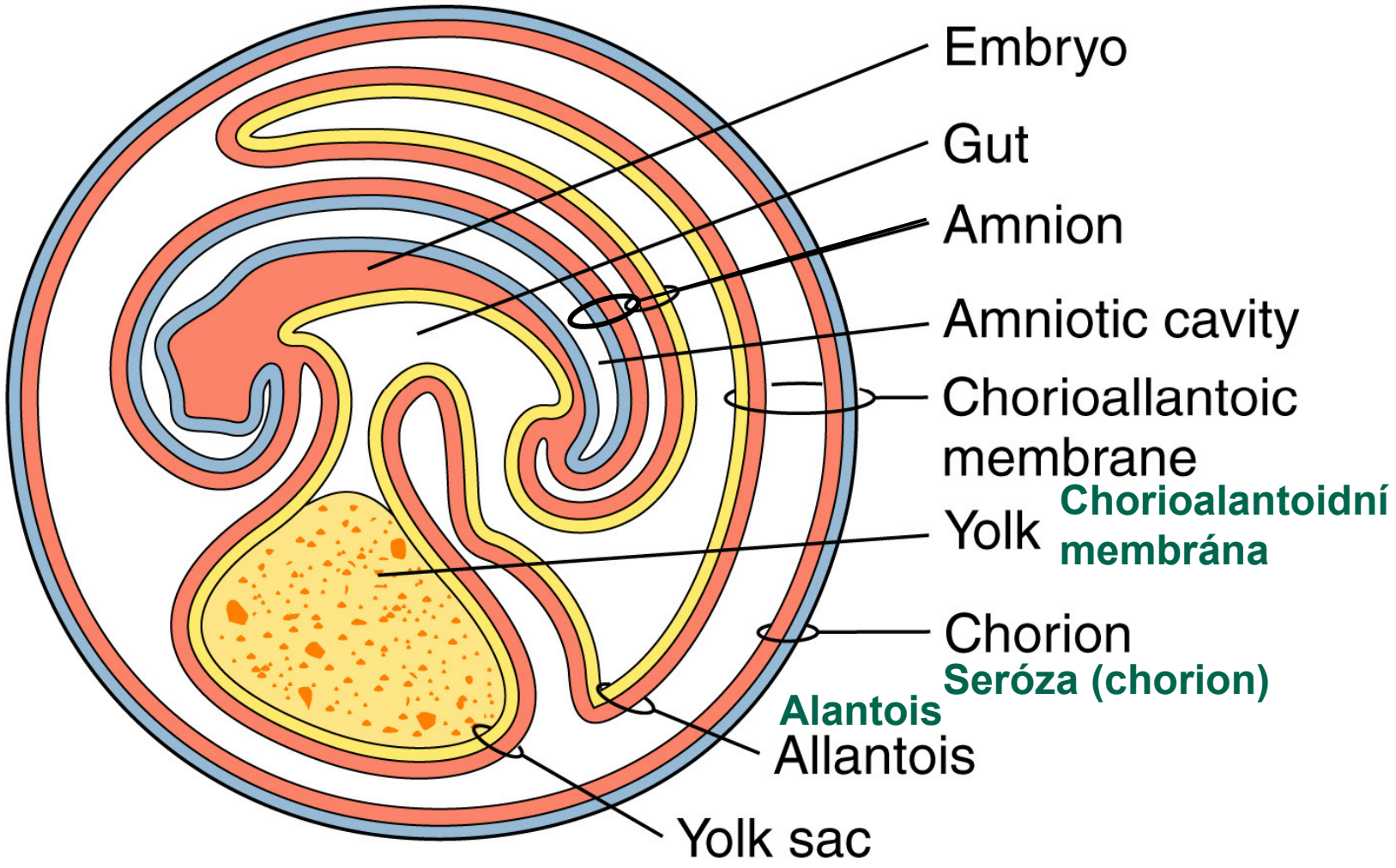


Embryo
Embryo
Střevo
Gut
Amniová dutina
Amniotic cavity
Amnion
Amnion
Alantois
Allantois
Seróza (chorion)
Chorion
Yolk
Extraembryonic endoderm
Extraembryonální endoderm

Future yolk sac
Budoucí žloutkový váček


D.
Chorioamniová dutina
Chorion
Chorioamniotic cavity
Amnion
Amniotic cavity
Amniová dutina
Ectoderm
Neural tube
Notochord
Aorta
Mesenchyme
Midgut
Endoderm
Mesoderm (splanchnic)
Hindgut
uric acid accumulation
Vychlýpením zadního střeva vzniká budoucí alantois
Allantoic evagination (allantois pushing into extraembryonic coelom)

E.


Embryo
Gut
Amnion
Amniotic cavity
Chorioallantoic membrane
Chorioalantoidní membrána
Yolk
Chorion
Seróza (chorion)
Alantois
Allantois
Yolk sac

Key Concepts

- First source of **asymmetry originates from the oogenesis** both in *Drosophila* and *Xenopus*.
- In *Xenopus*, another **important source of asymmetry** leading to breaking of the virtual radial symmetry of the egg and **dorsoventral axis specification** is the **sperm entry** that induces **cytoplasm rotation**.
- These processes result into **Speman organizer differentiation** and allow **specification of the cell fate** during **blastula formation**.
- **Gastrulation** allows **further delimitation of the developmental fate**.
- **Amniotes** developed **terrestrial adaptations** that are of **extraembryonic origin**.

Discussion