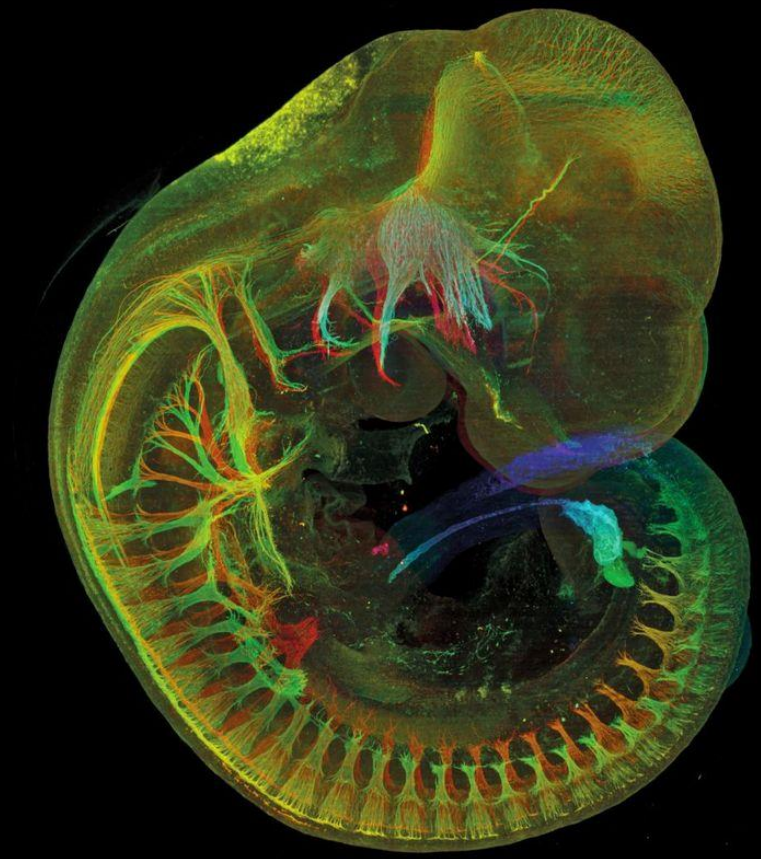
MUNI MED
Department of Histology and Embryology

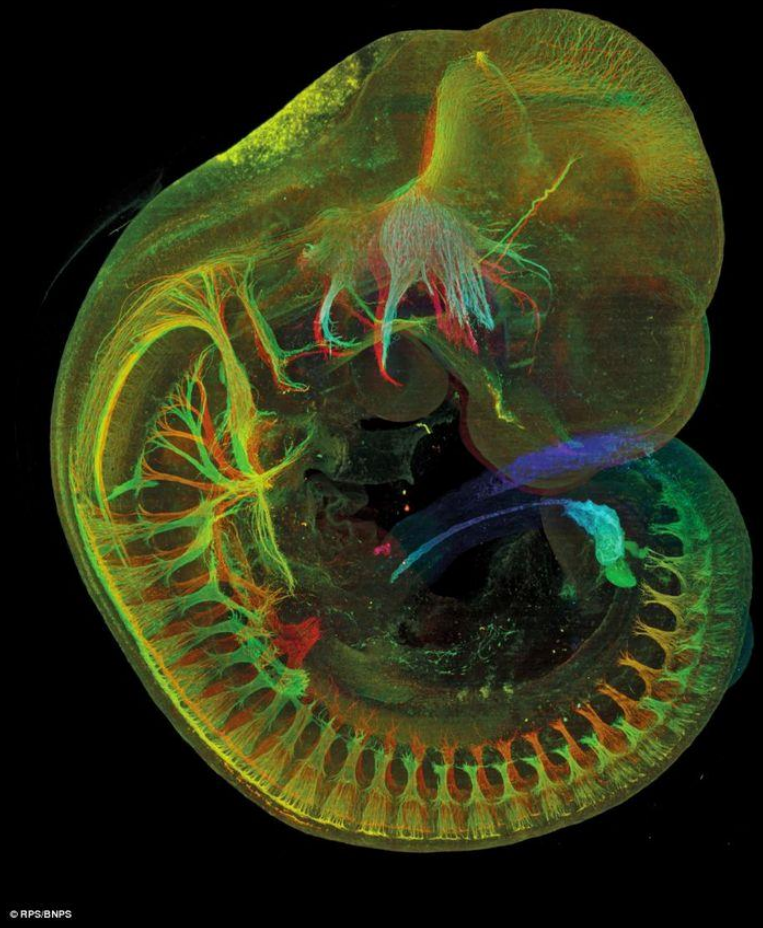


Introduction to embryology III

Petr Vaňhara

LECTURE CONTENT

MUNI MED
Department of Histology and Embryology



1. Revision of early embryogenesis
2. Trilaminar germ disc embryo
3. Folding of embryo
4. Pregnancy and fetal development
5. Prenatal diagnostics

FIRST EVENTS IN HUMAN LIFE

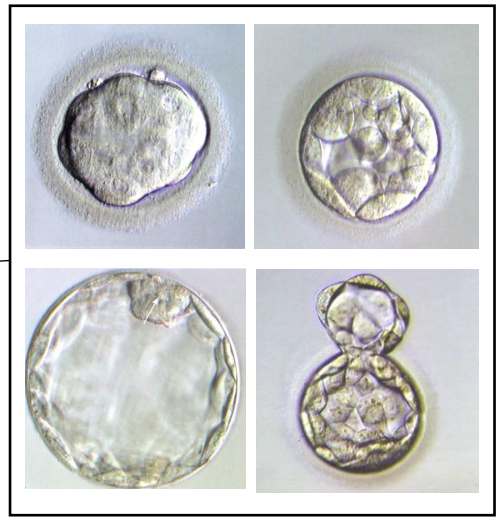
Fertilization

START!

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

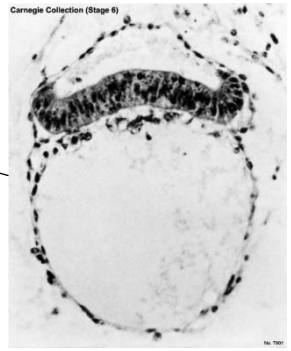
Cleavage

Blastogenesis



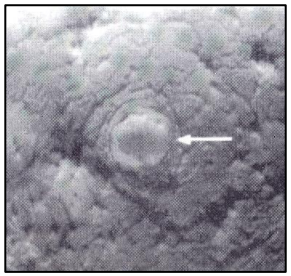
1st week

Embryogenesis



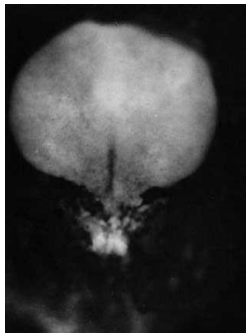
Implantation

- Adhesion of blastocyst
- Differentiation of trofoblast
- End of implantation



2nd week

- Differentiation of embryoblast
- **Bilaminar germ disc**
- Amniotic cavity
- Primary yolk sac
- Extraembryonic mesoderm

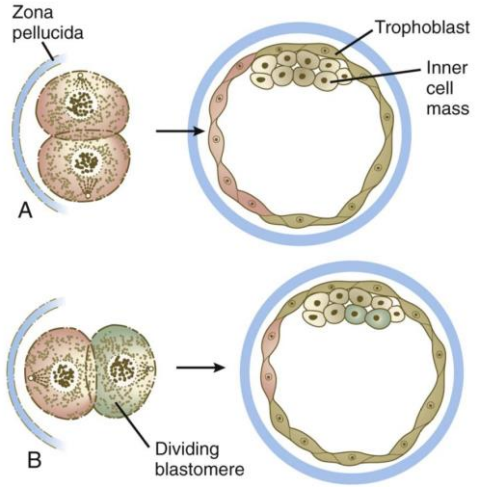


3rd week

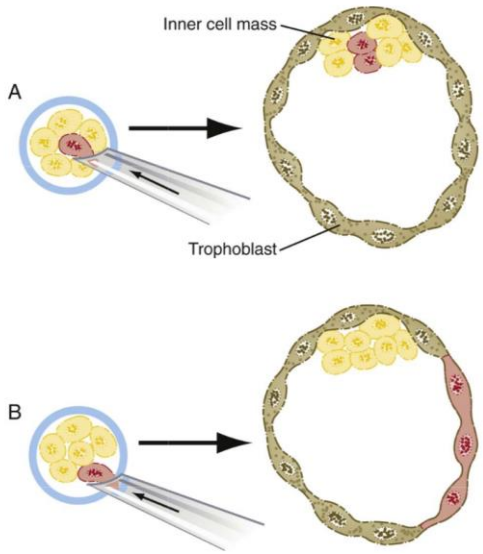
- **Trilaminar germ disc**
- Differentiation of epiblast
- Primitive node and primitive streak
- Differentiation of mesoderm
- Differentiation of ectoderm and neuroectoderm
- Somitogenesis

1st week

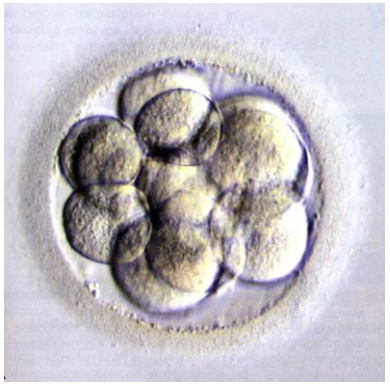
Mechanism of diferentiation

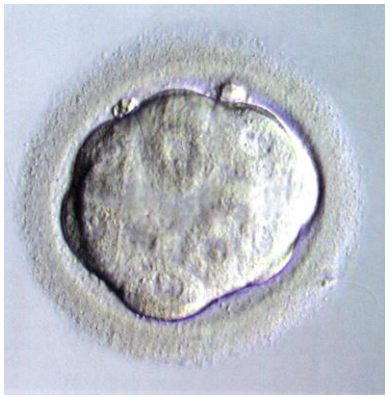


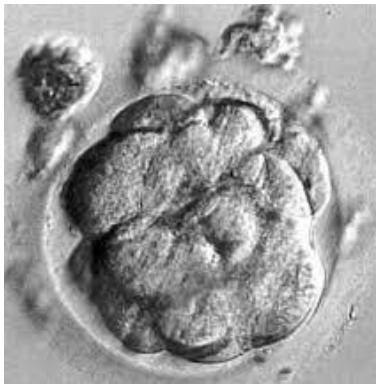
„cell polarity“

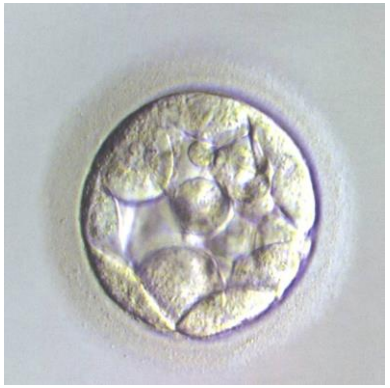


„inside-outside“



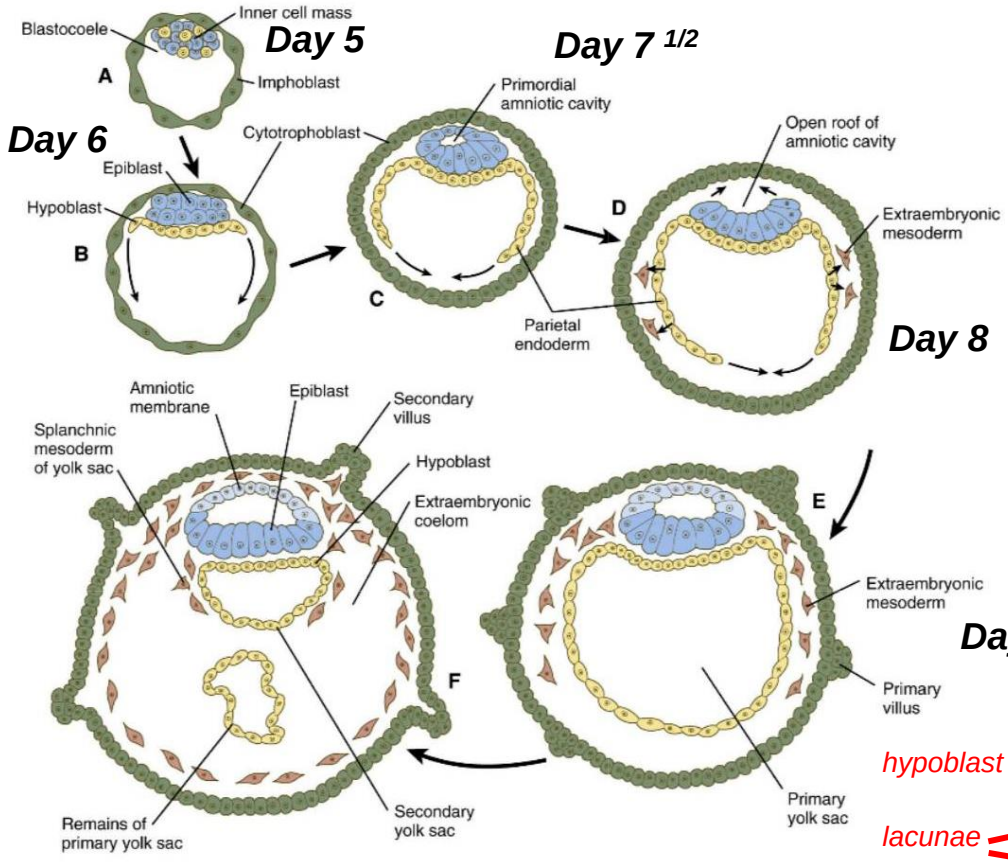




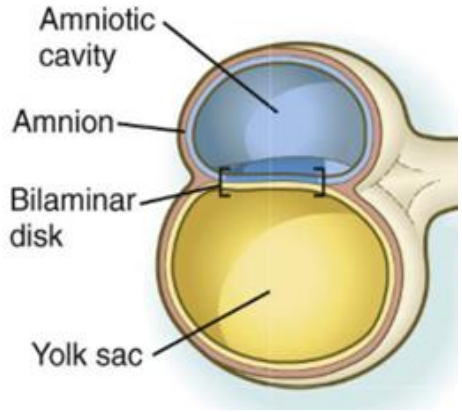


- 16-cell embryo is still totipotent – later (32-cell), it loses the full developmental potential → cell are **determined.**

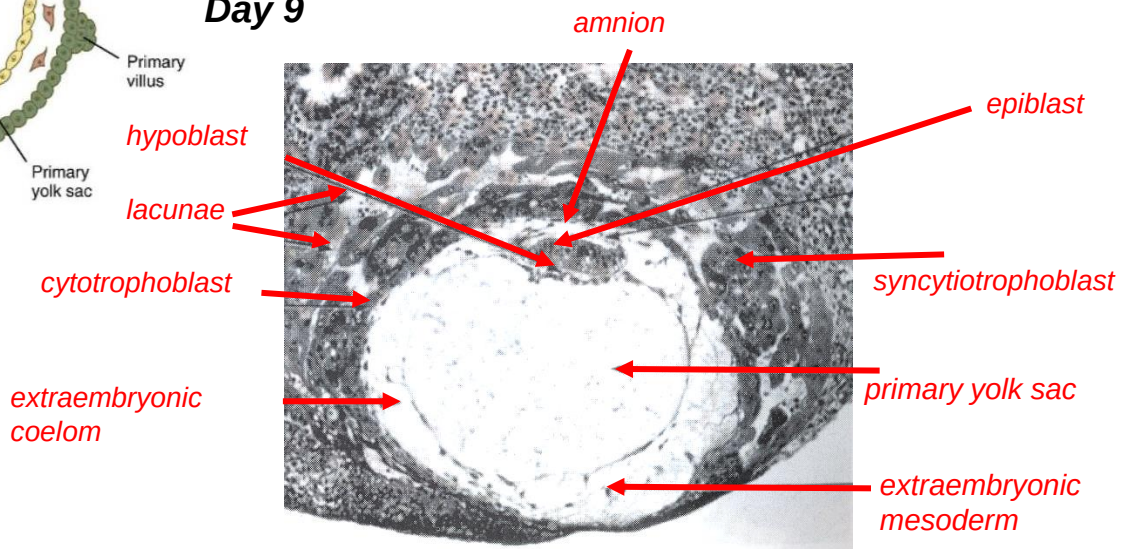
1st-2nd week BILAMINAR GERM DISC



end of 2nd week



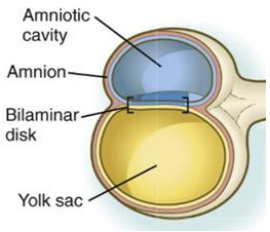
Day 9

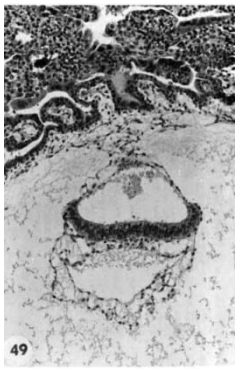


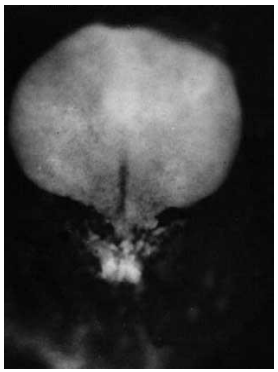
TRILAMINAR GERM DISC

PRIMITIVE STREAK AND PRIMITIVE NODE

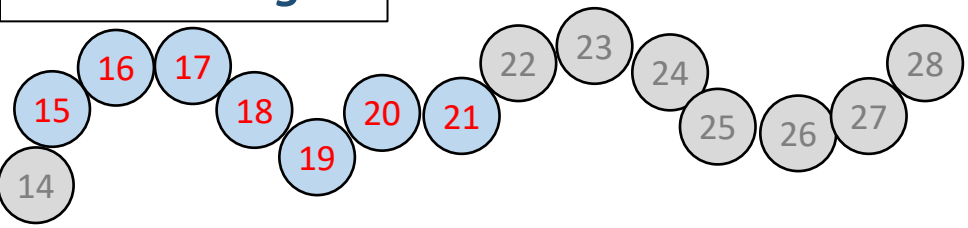
2nd week *ends*

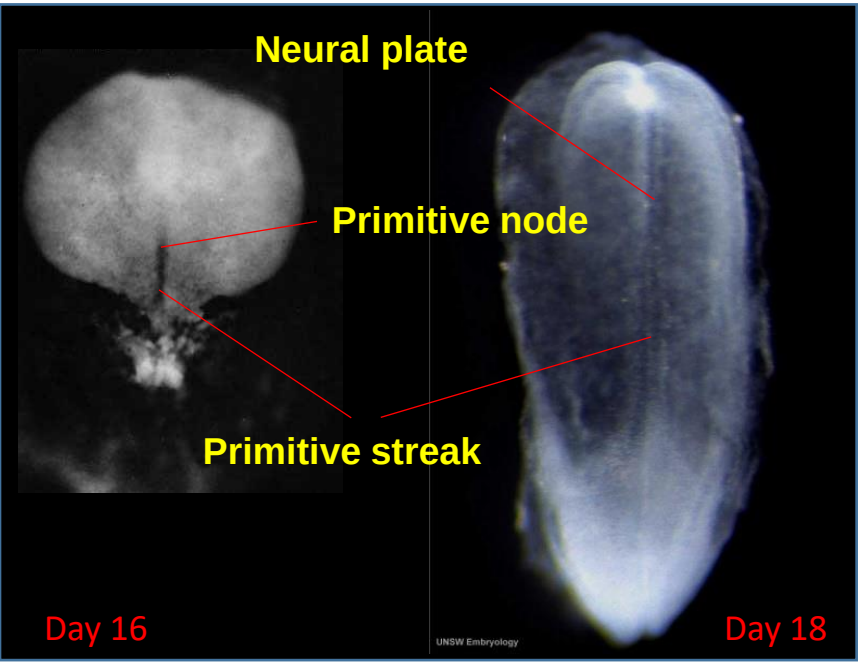




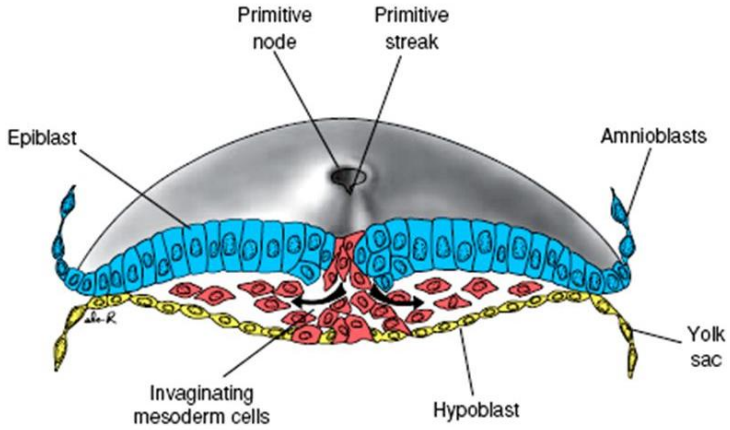


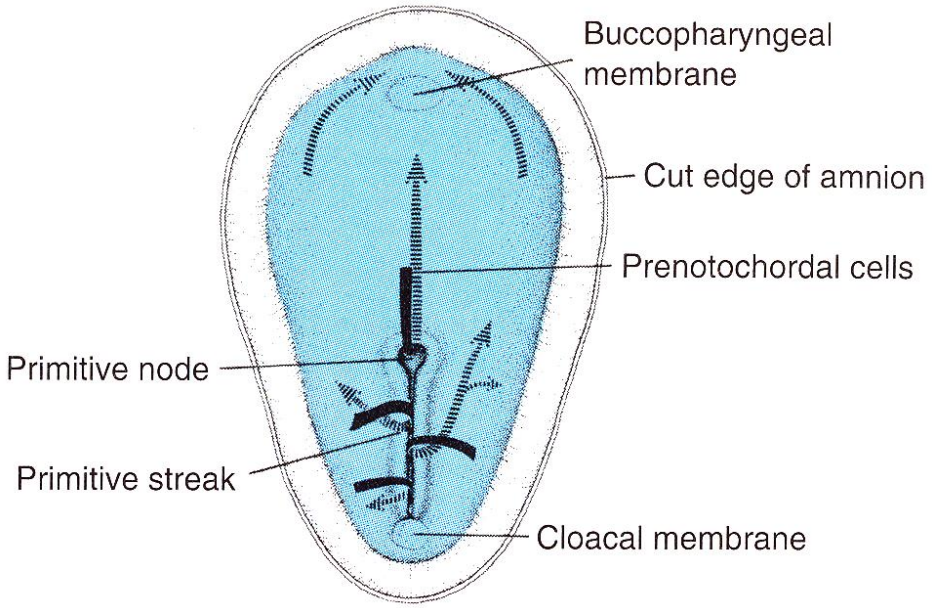
3rd week *begins*





NEW STRUCTURES

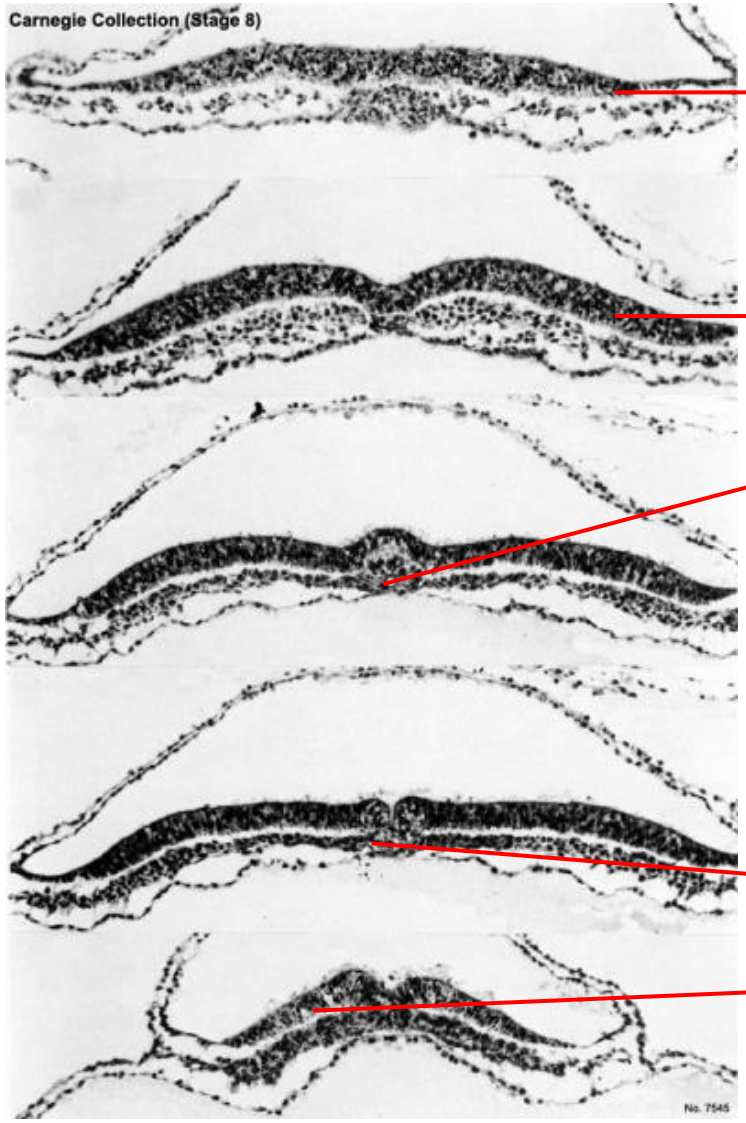




TRILAMINAR GERM DISC

PRIMITIVE STREAK AND PRIMITIVE NODE

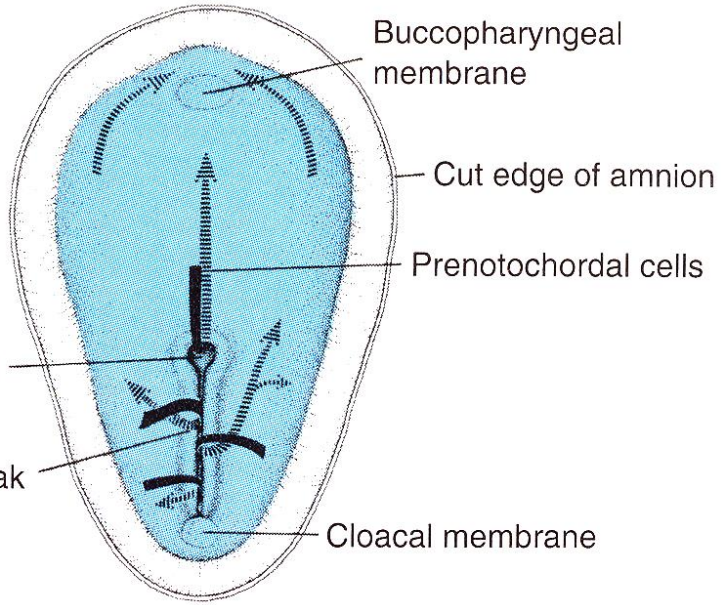
3rd week



Prechordal plate

Neural plate

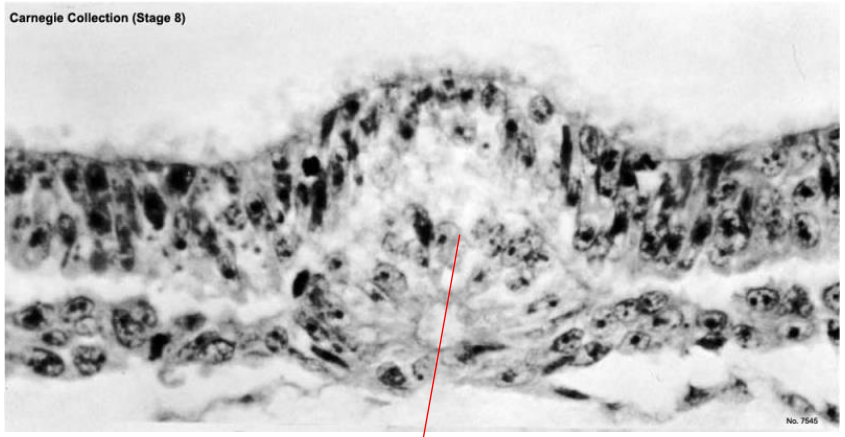
Notochordal process

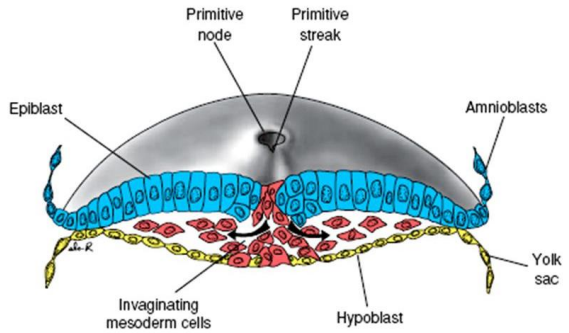


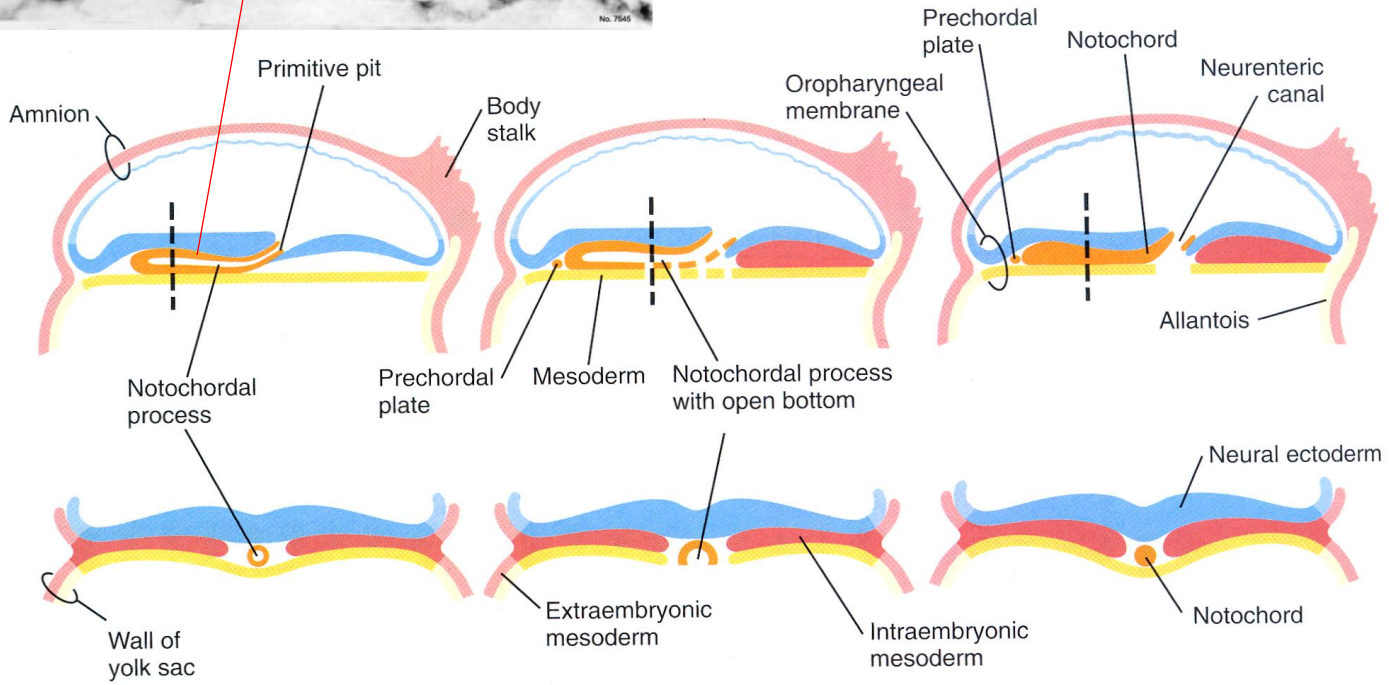
TRILAMINAR GERM DISC

PRIMITIVE STREAK AND PRIMITIVE NODE

3rd week





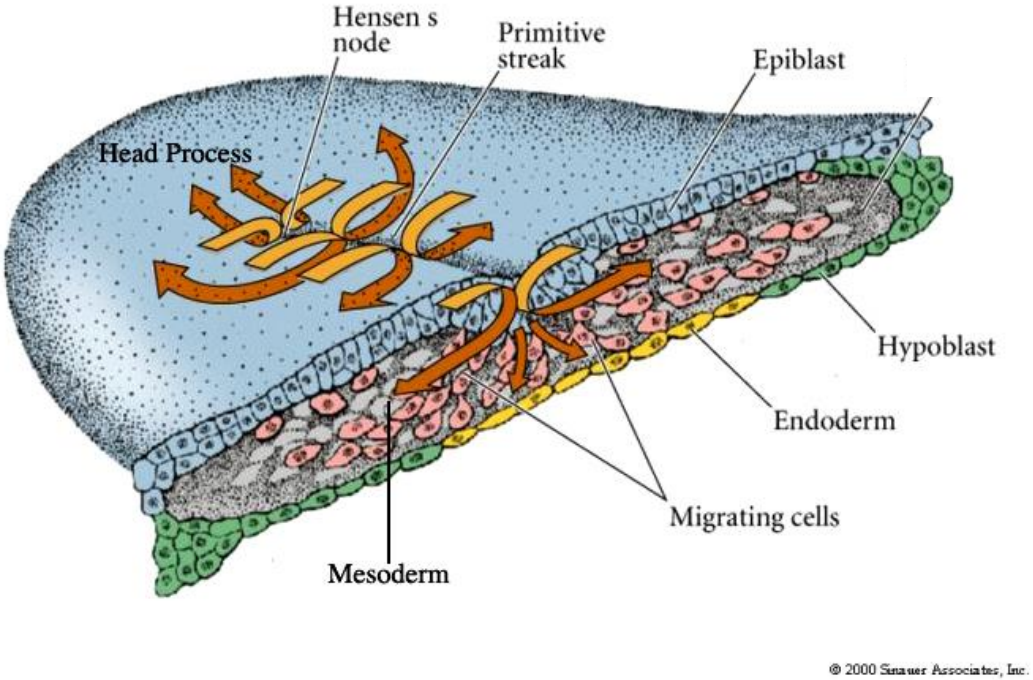


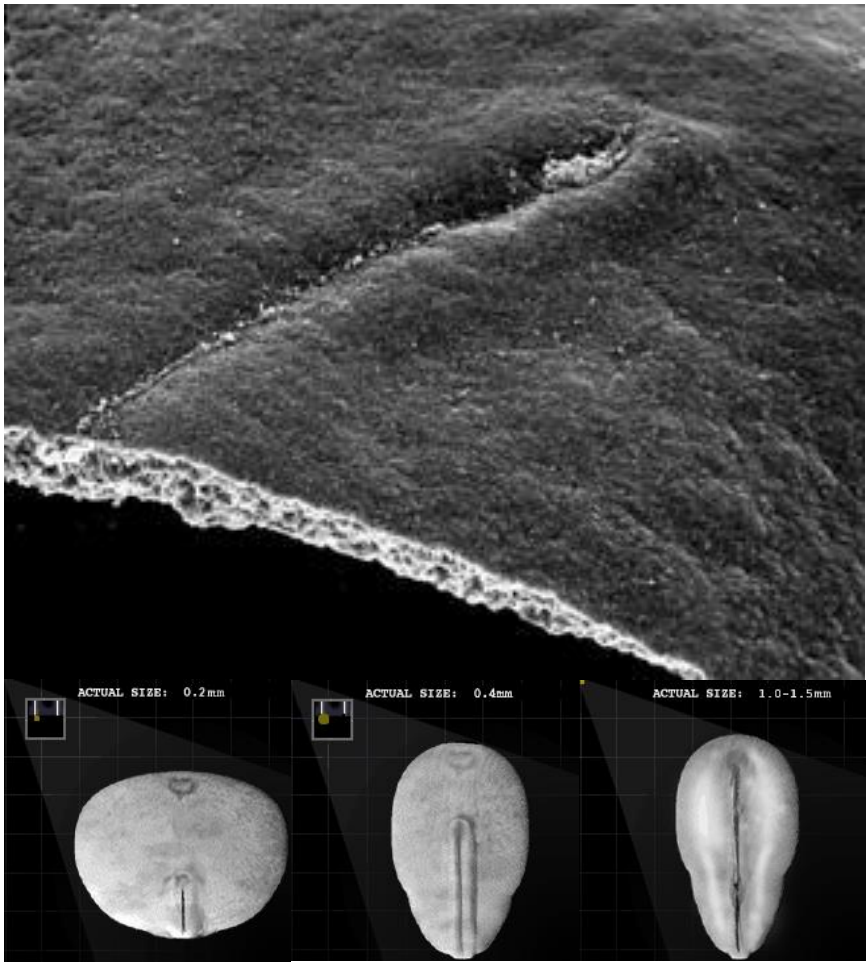
Day 17 Day 18 Day 19

TRILAMINAR GERM DISC

PRIMITIVE STREAK AND PRIMITIVE NODE

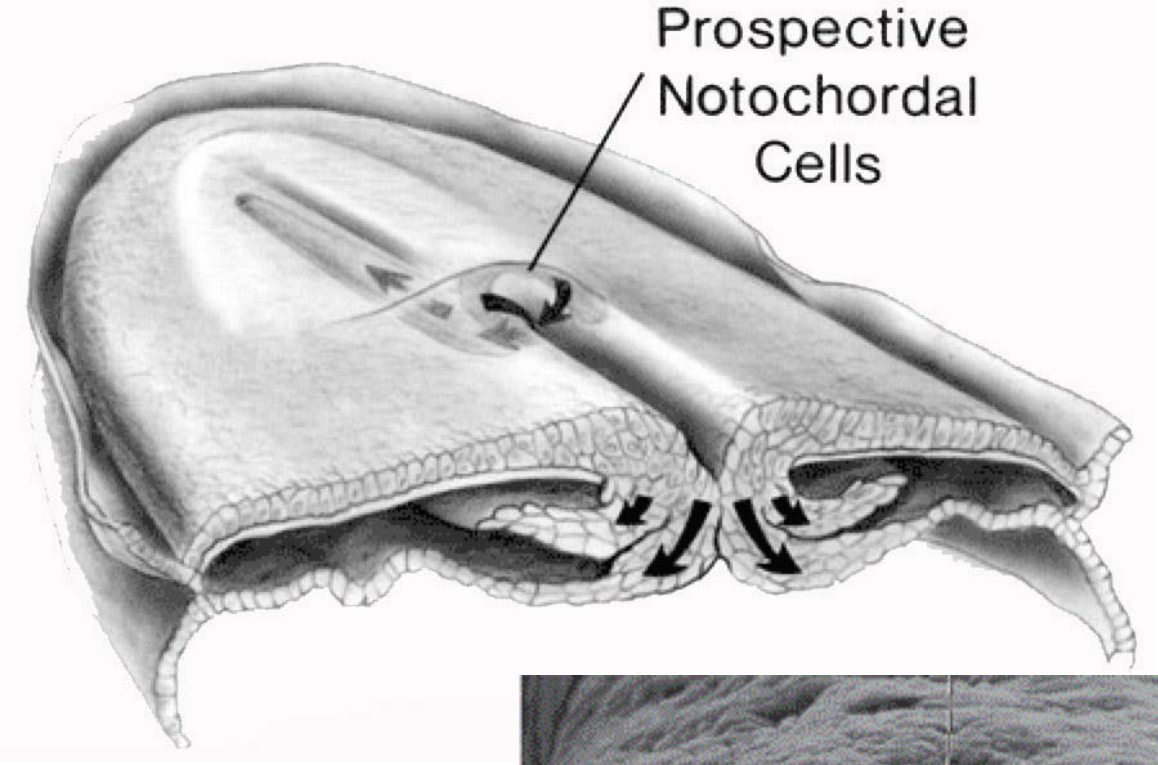
3rd week





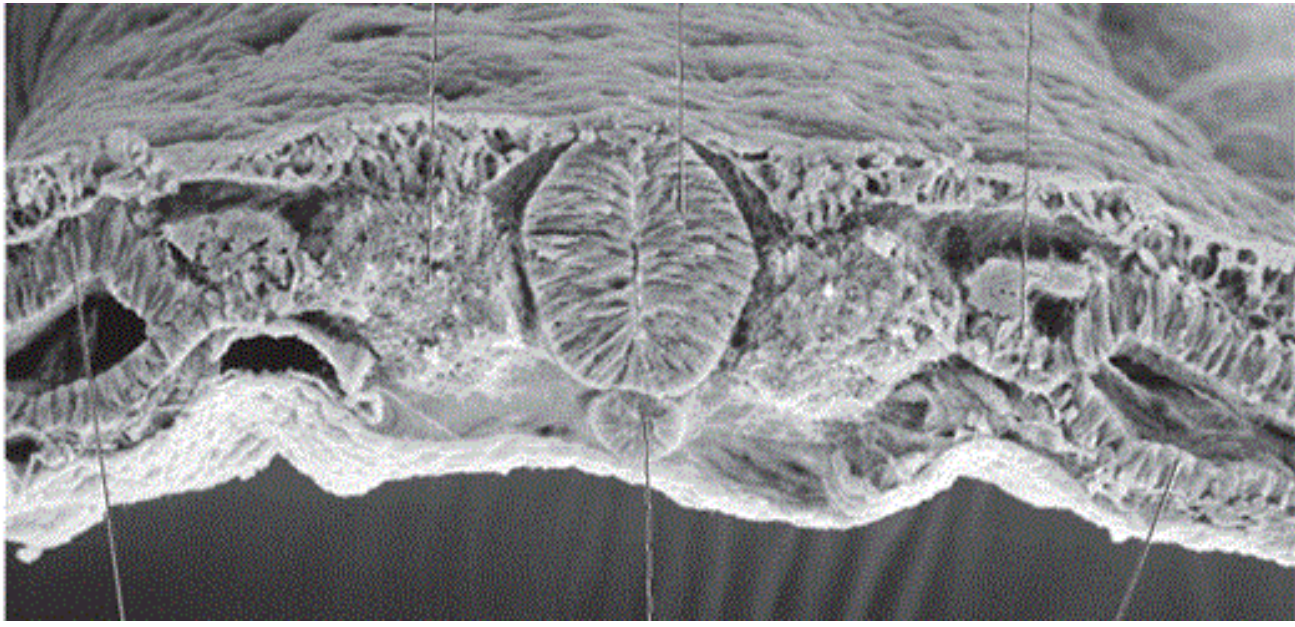
A new cell population appears - MESODERM

NOTOCHORD

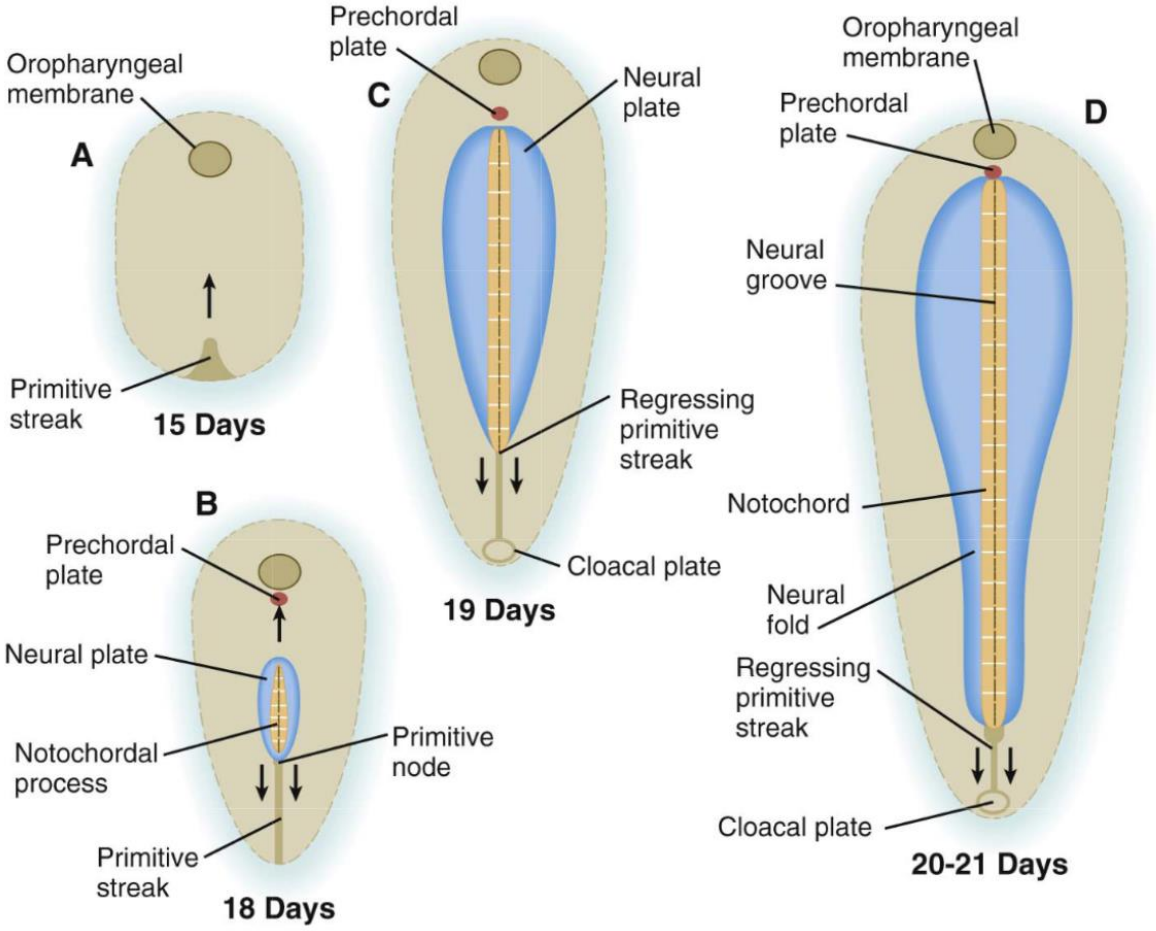


End of 2nd week

End of 3rd week

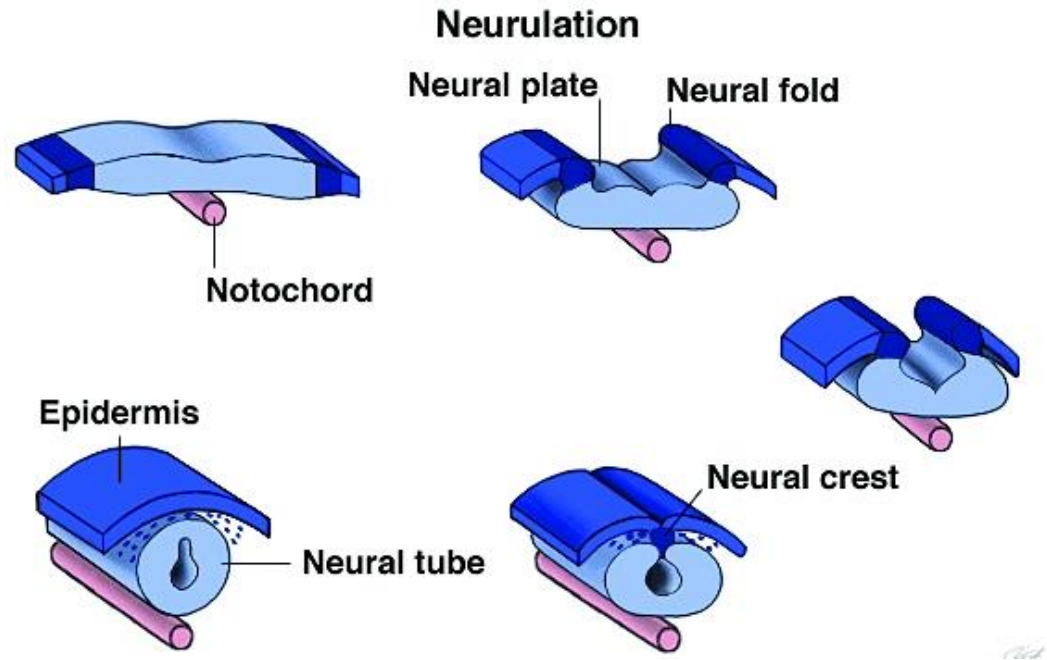


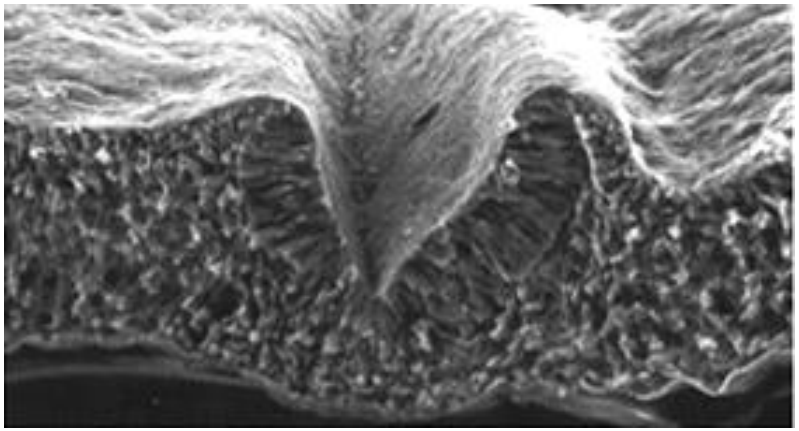
3rd week

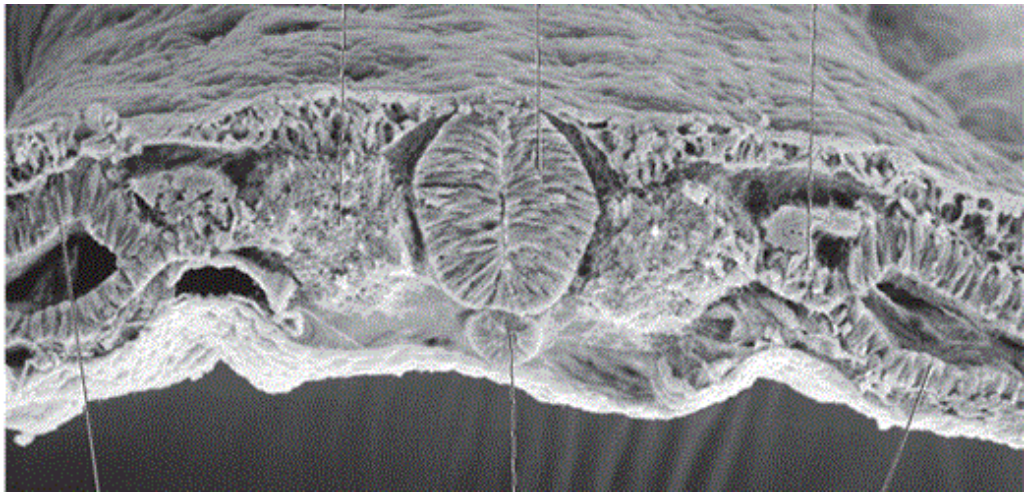


Notochord induces differentiation of ectoderm – cellular basis of nerve system is established – **NEUROECTODERM**

3rd week



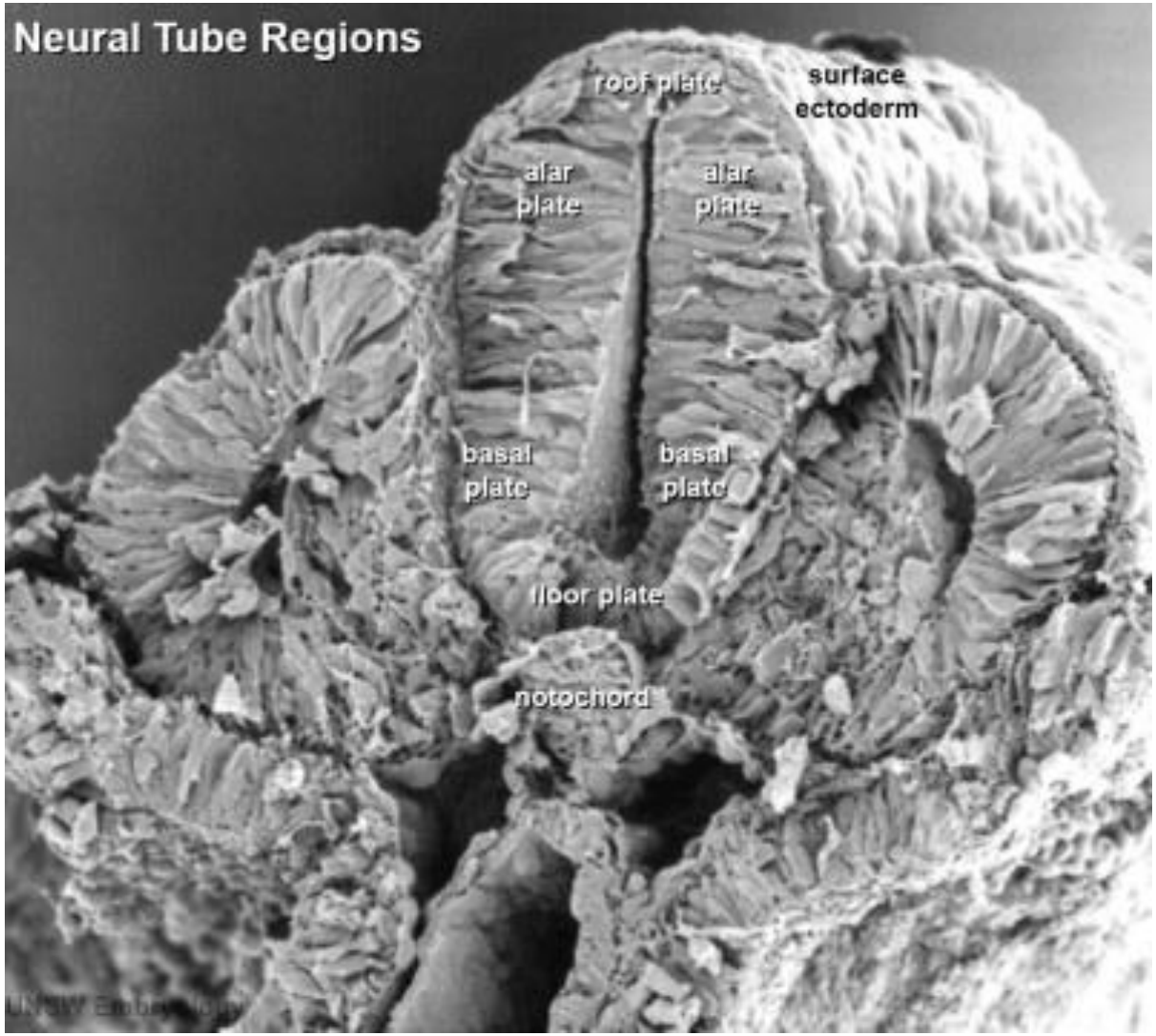


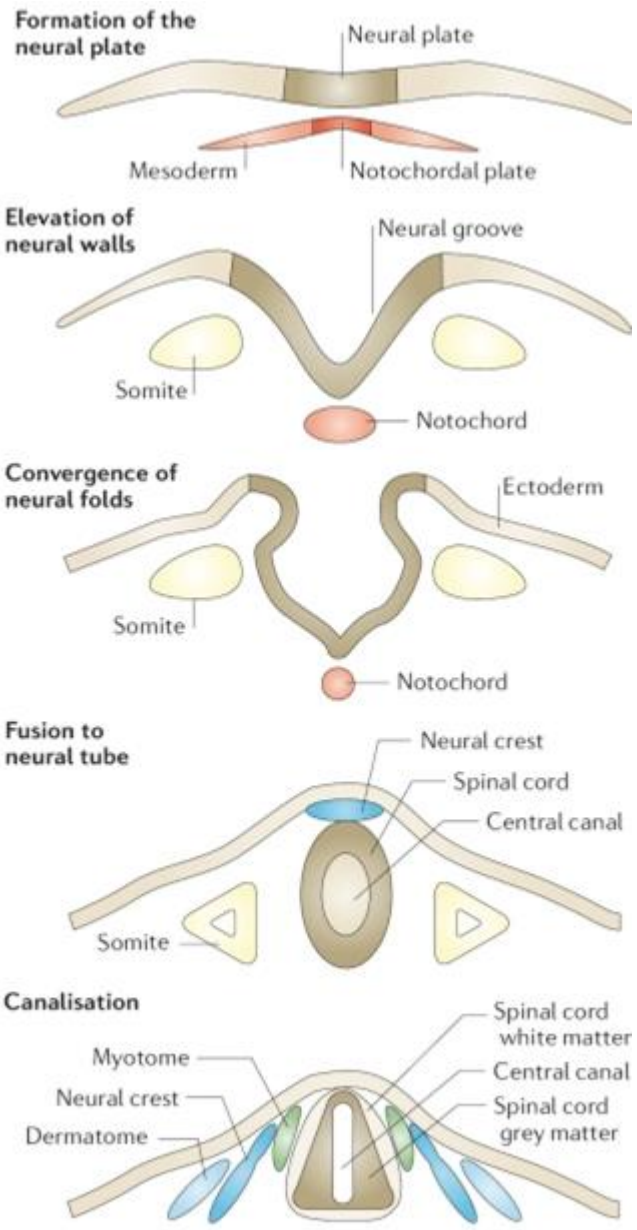


- **Neural plate**
- **Neural folds**
- **Neural tube**

- **Neural crest**

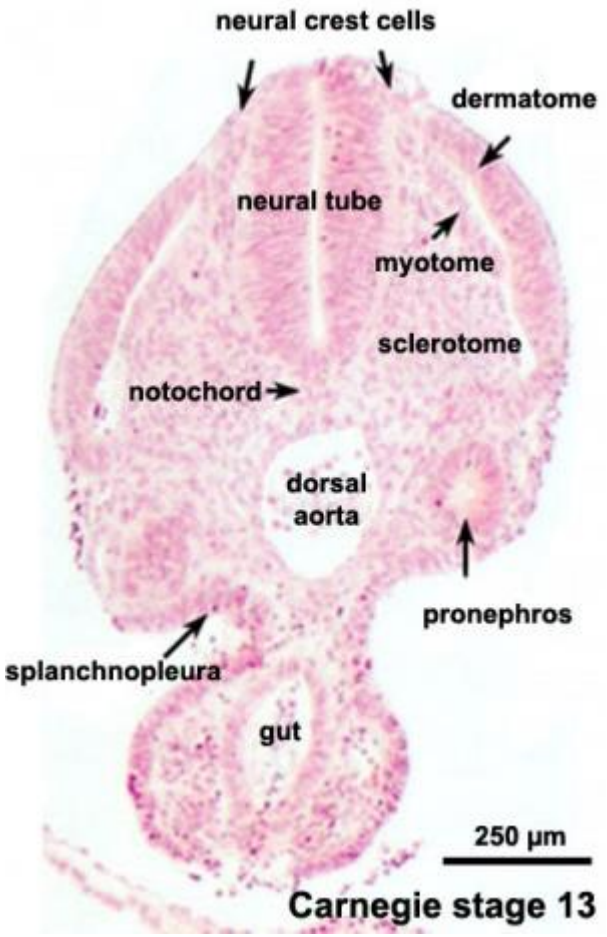
3rd – 4th week

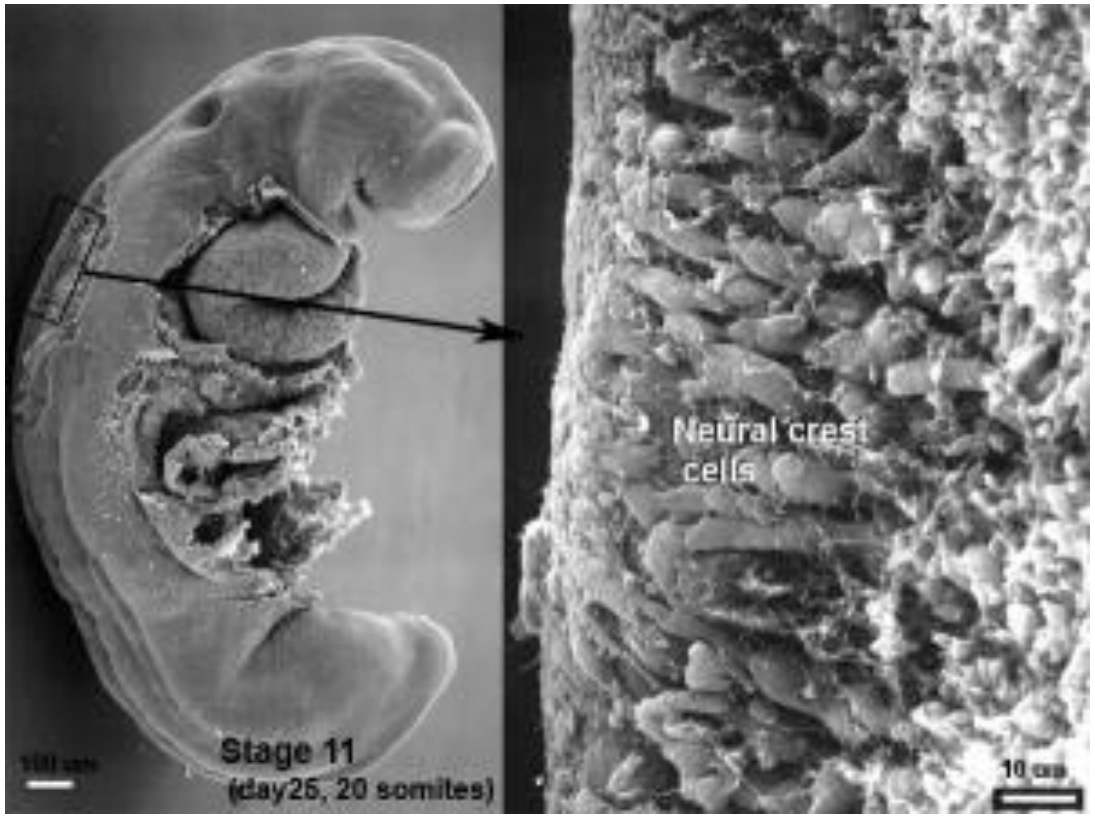

Neural Tube Regions
roof plate
surface ectoderm
alar plate
alar plate
basal plate
basal plate
floor plate
notochord


Formation of the neural plate
Neural plate
Mesoderm
Notochordal plate
Elevation of neural walls
Neural groove
Somite
Notochord
Convergence of neural folds
Ectoderm
Somite
Notochord
Fusion to neural tube
Neural crest
Spinal cord
Central canal
Somite
Canalisation
Spinal cord white matter
Myotome
Central canal
Neural crest
Spinal cord grey matter
Dermatome

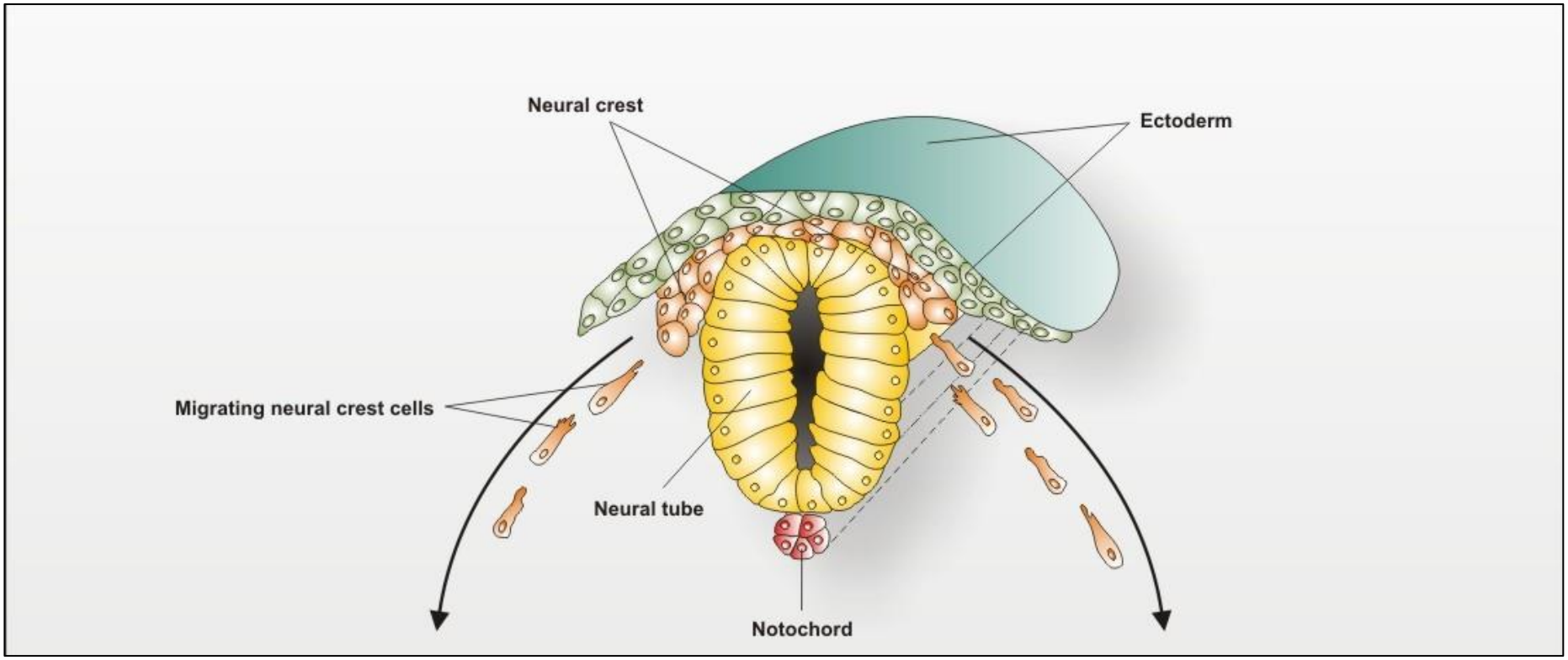
NEURULATION

NEURAL TUBE AND NEURAL CREST



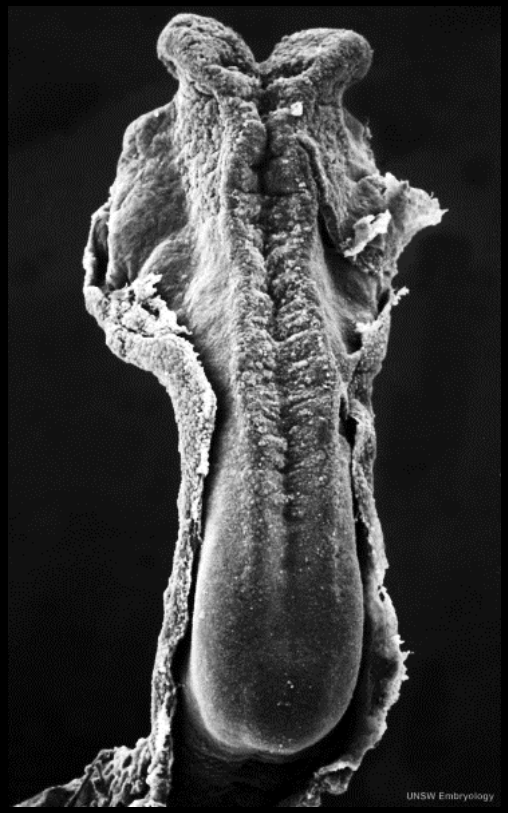


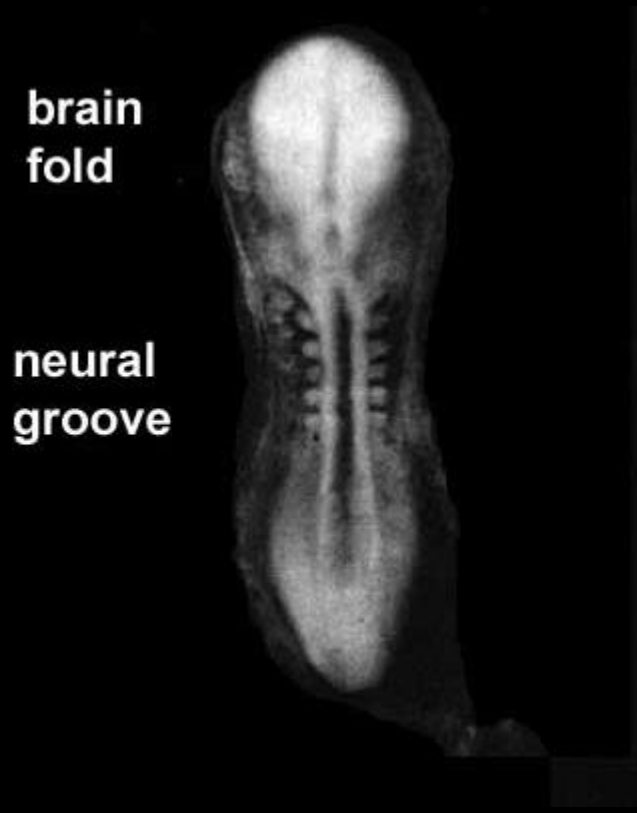
NEURAL CREST AND ITS DERIVATIVES

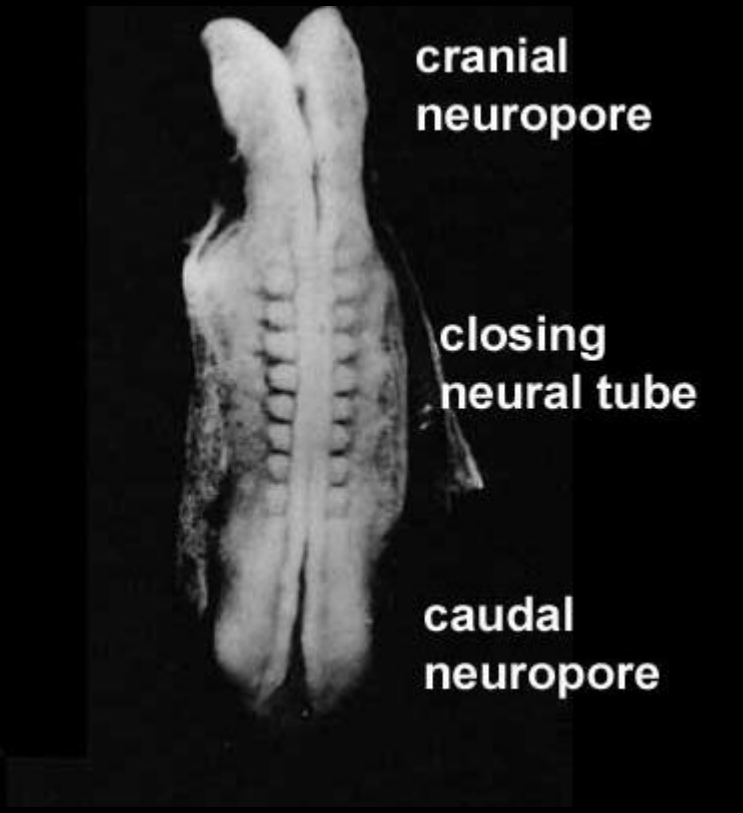


- Peripheral nerve system including glia
- Enterochromaffin cells
- Melanocytes
- Craniofacial connective tissue
- Odontoblasts
- Adrenal medulla
- ...

NEURAL TUBE

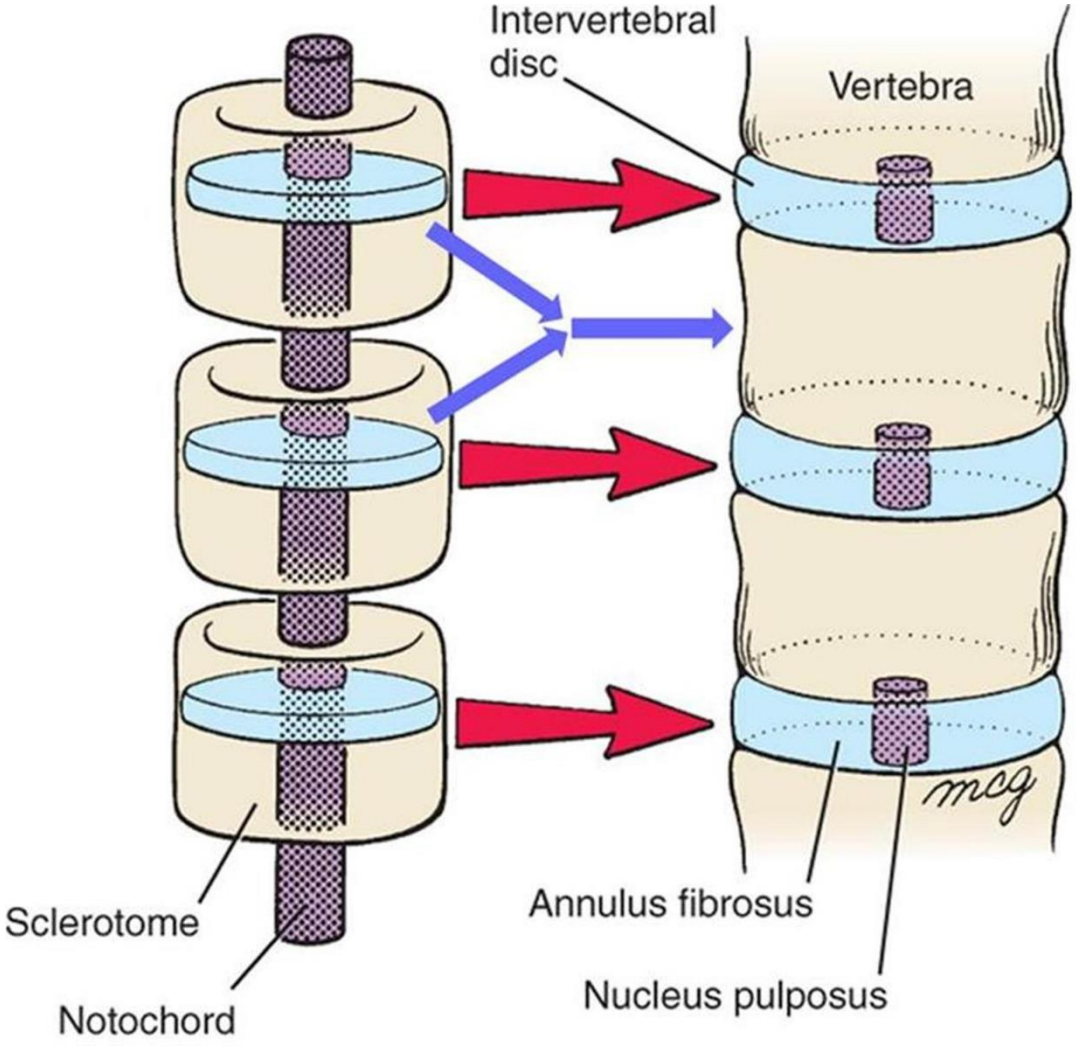

UNSW Embryology

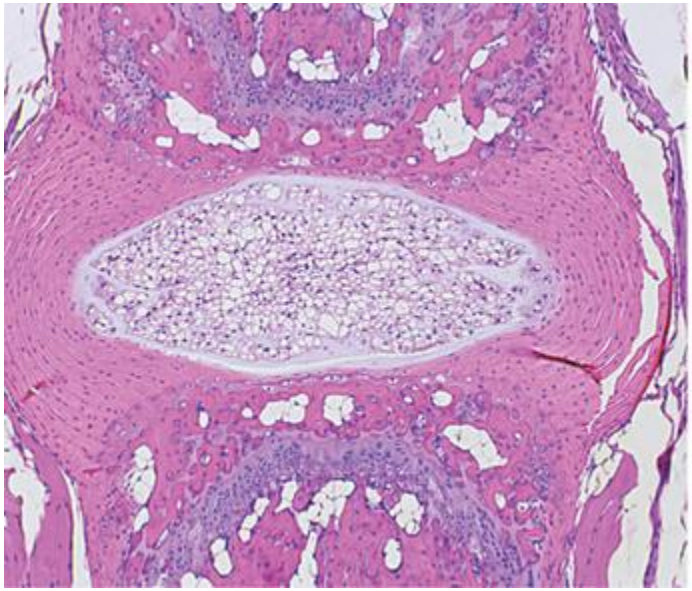

brain fold
neural groove


cranial neuropore
closing neural tube
caudal neuropore

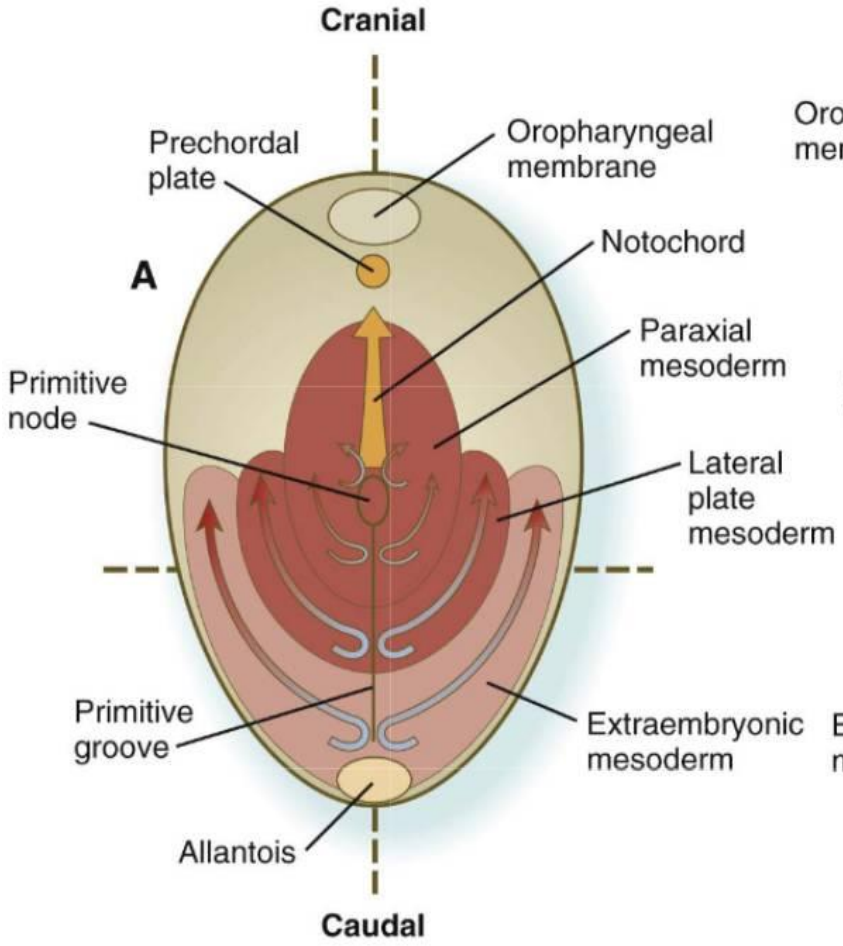
NOTOCHORD IN ADULT BODY

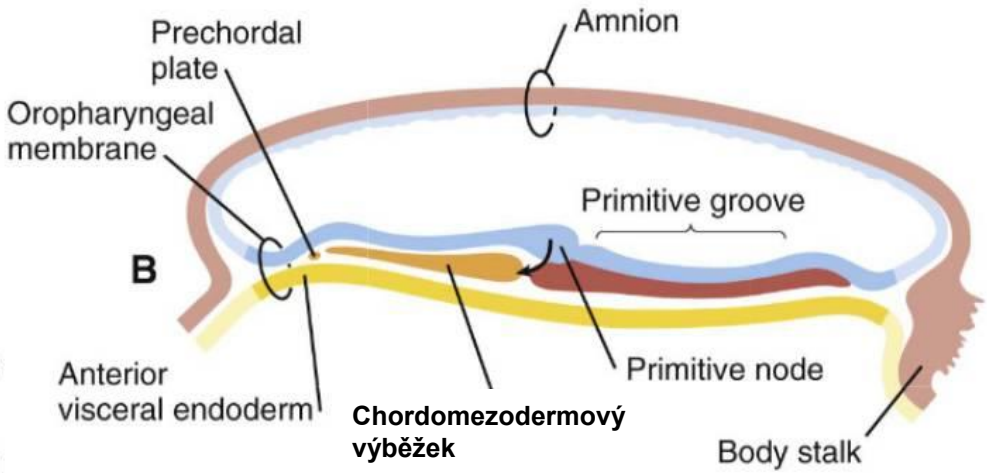
INTERVERTEBRAL DISC

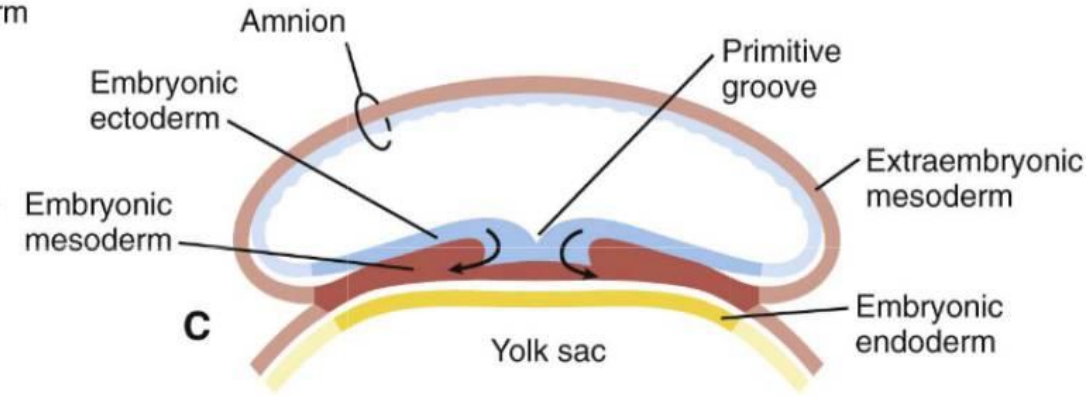




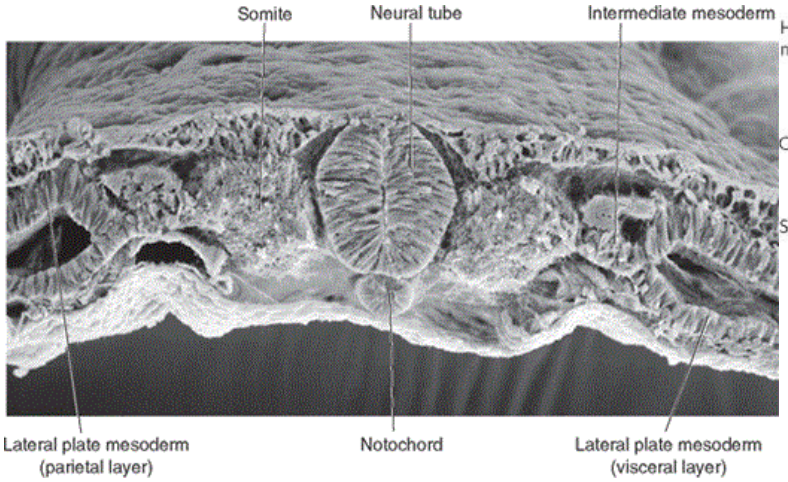
3rd week

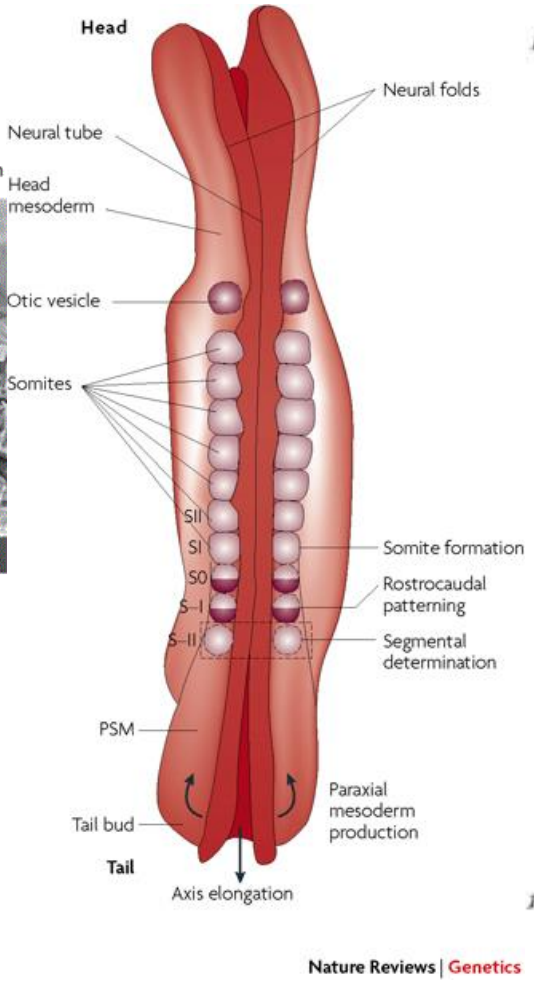

Cranial
Prechordal plate
Oropharyngeal membrane
Notochord
A
Paraxial mesoderm
Primitive node
Lateral plate mesoderm
Primitive groove
Extraembryonic mesoderm
Allantois
Caudal

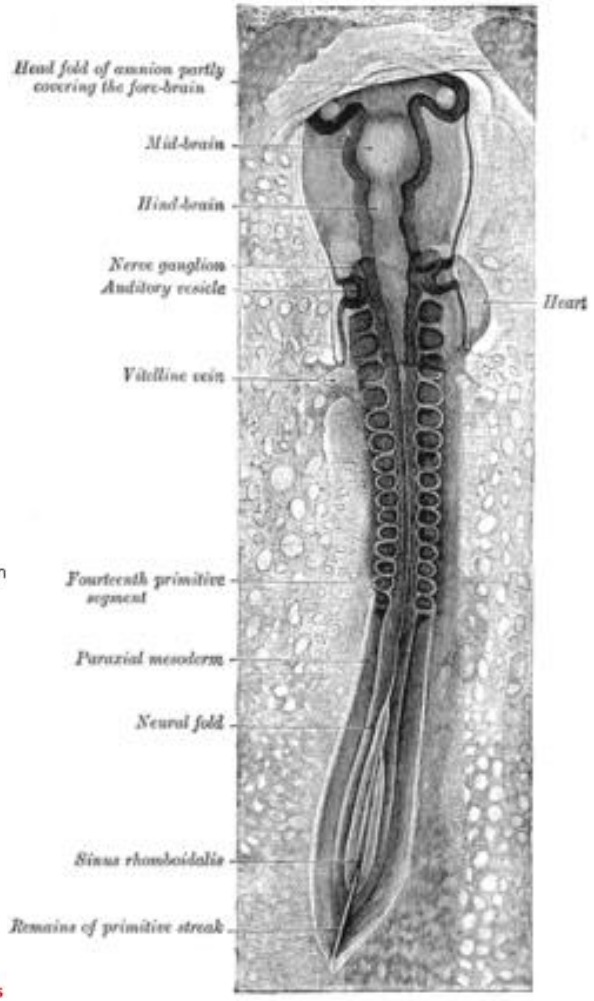

Prechordal plate
Amnion
Oropharyngeal membrane
Primitive groove
B
Anterior visceral endoderm
Primitive node
Chordomezodermový výběžek
Body stalk


Amnion
Primitive groove
Embryonic ectoderm
Extraembryonic mesoderm
Embryonic mesoderm
C
Embryonic endoderm
Yolk sac

3rd – 4th week

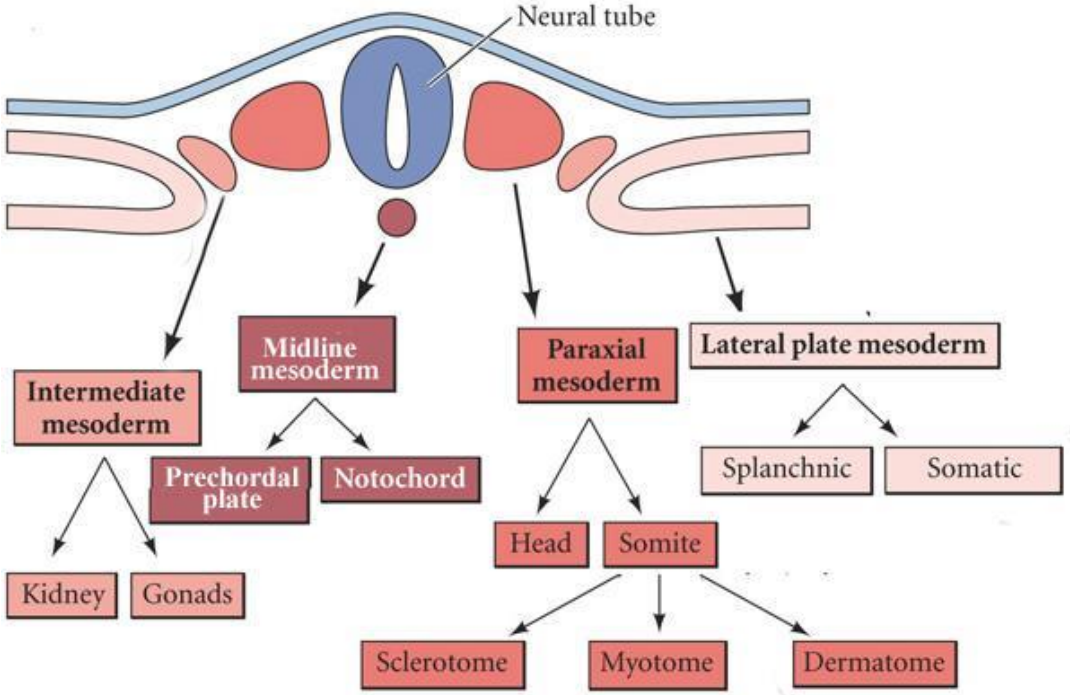

Somite
Neural tube
Intermediate mesoderm
Lateral plate mesoderm (parietal layer)
Notochord
Lateral plate mesoderm (visceral layer)

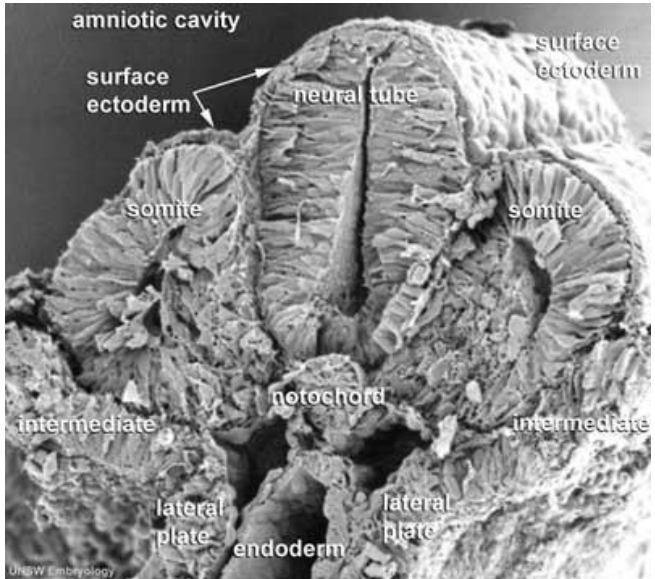

Head
Neural folds
Neural tube
Head mesoderm
Otic vesicle
Somites
SII
SI
S0
S–I
S–II
Somite formation
Rostrocaudal patterning
Segmental determination
PSM
Tail bud
Tail
Paraxial mesoderm production
Axis elongation
Nature Reviews | Genetics

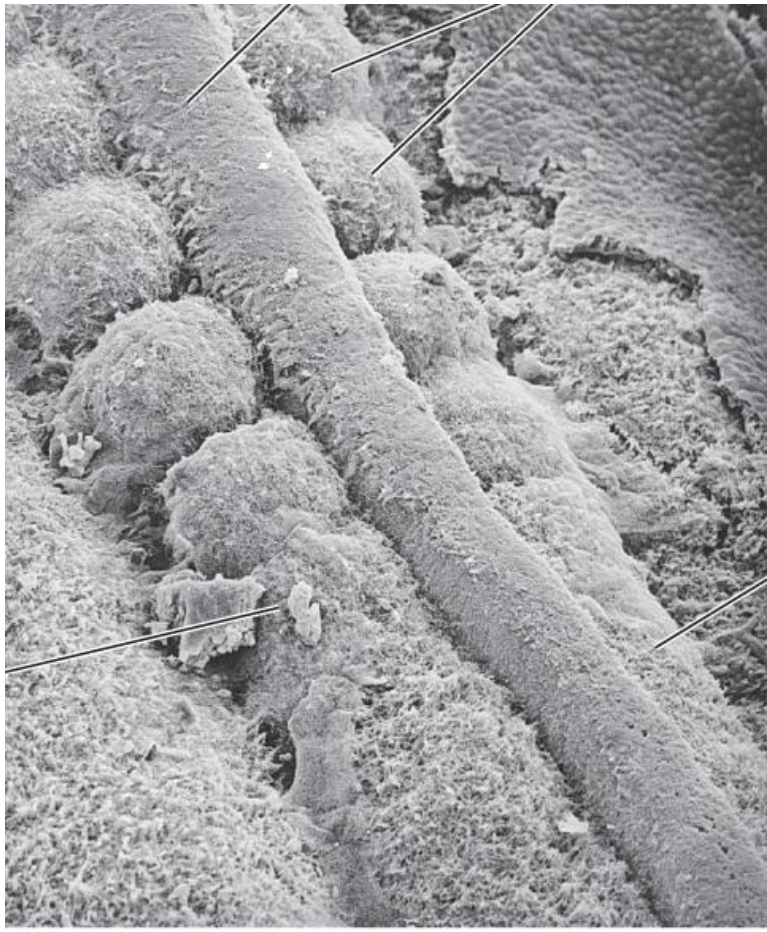

Head fold of amnion partly covering the fore-brain
Mid-brain
Hind-brain
Nerve ganglion
Auditory vesicle
Heart
Vitelline vein
Fourteenth primitive segment
Paraxial mesoderm
Neural fold
Sinus rhomboidalis
Remains of primitive streak

DERIVATIVES OF MESODERM

SOMITES

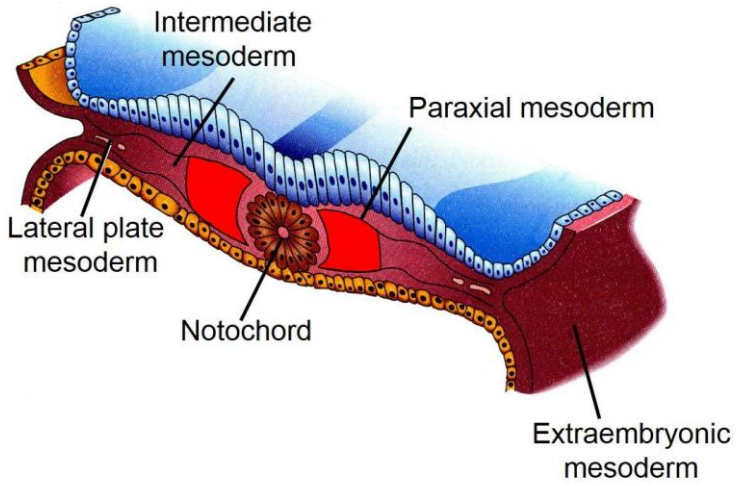


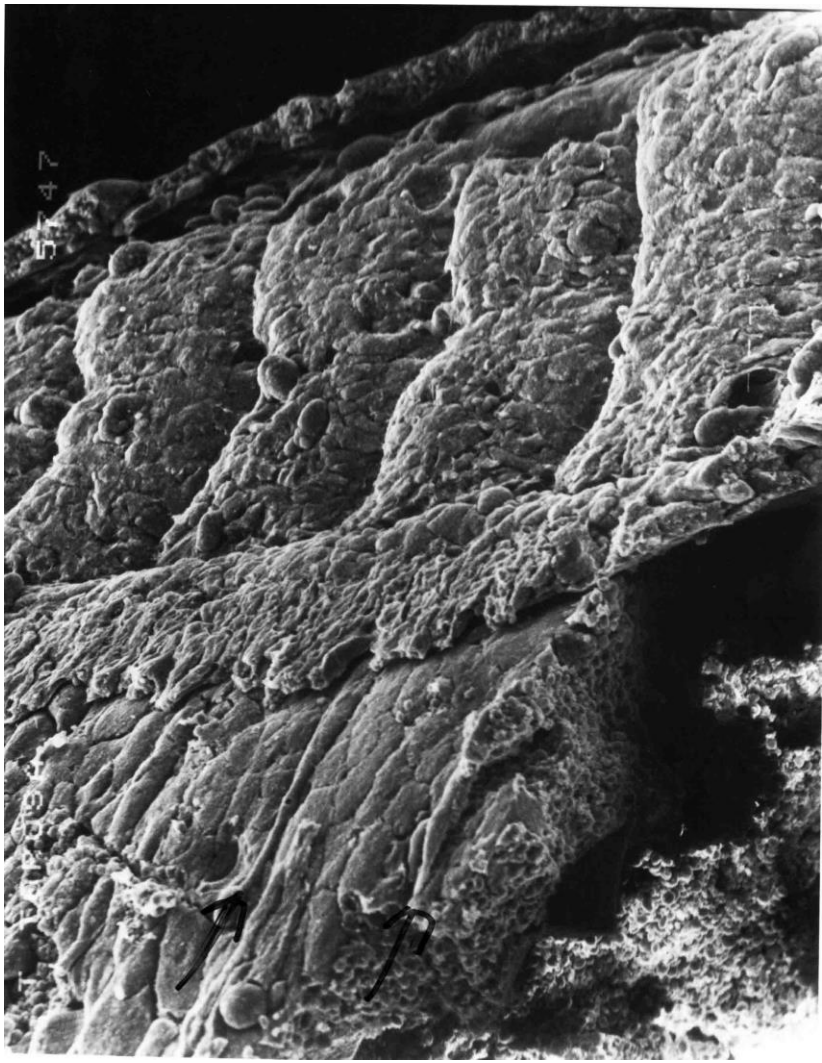




OTHER DERIVATIVES OF MESODERM

3rd – 4th week

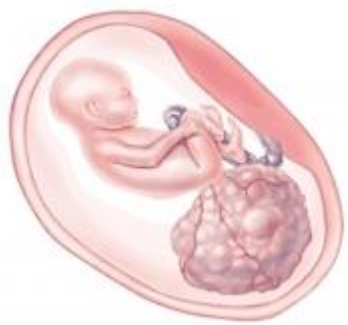


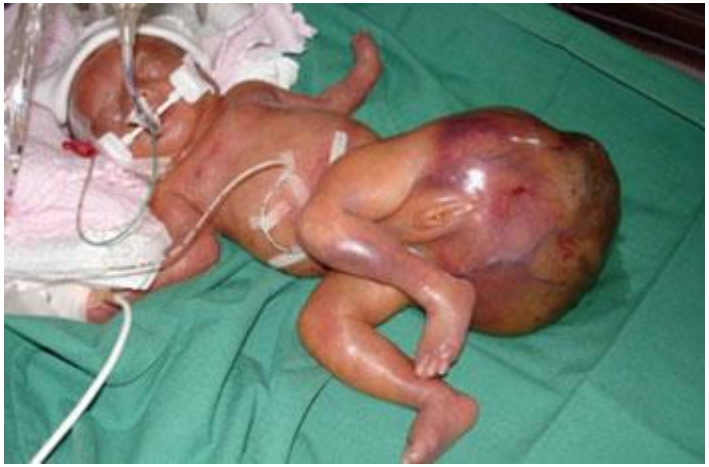


- heart, cardiovascular system
- urogenital system
- muscle and skeletal system
- hematopoietic and lymphatic systems
- connective tissue, dermis
- mesothelium

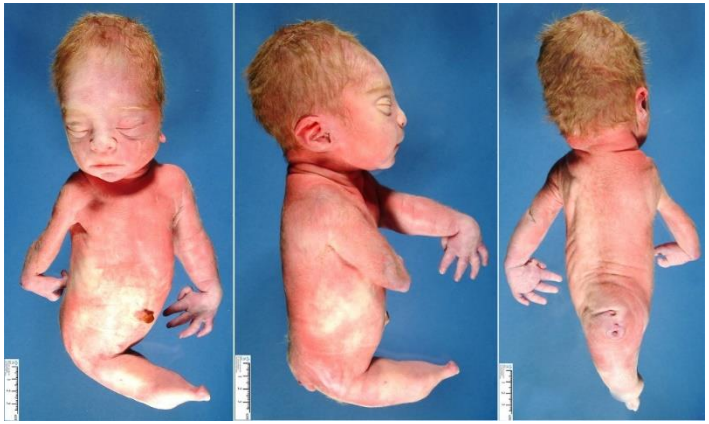
DEVELOPMENTAL DISORDERS DURING GASTRULATION

- Primitive streak is a temporary embryonic structure. Persistent primitive streak causes **sacrococcgyeal teratoma**.





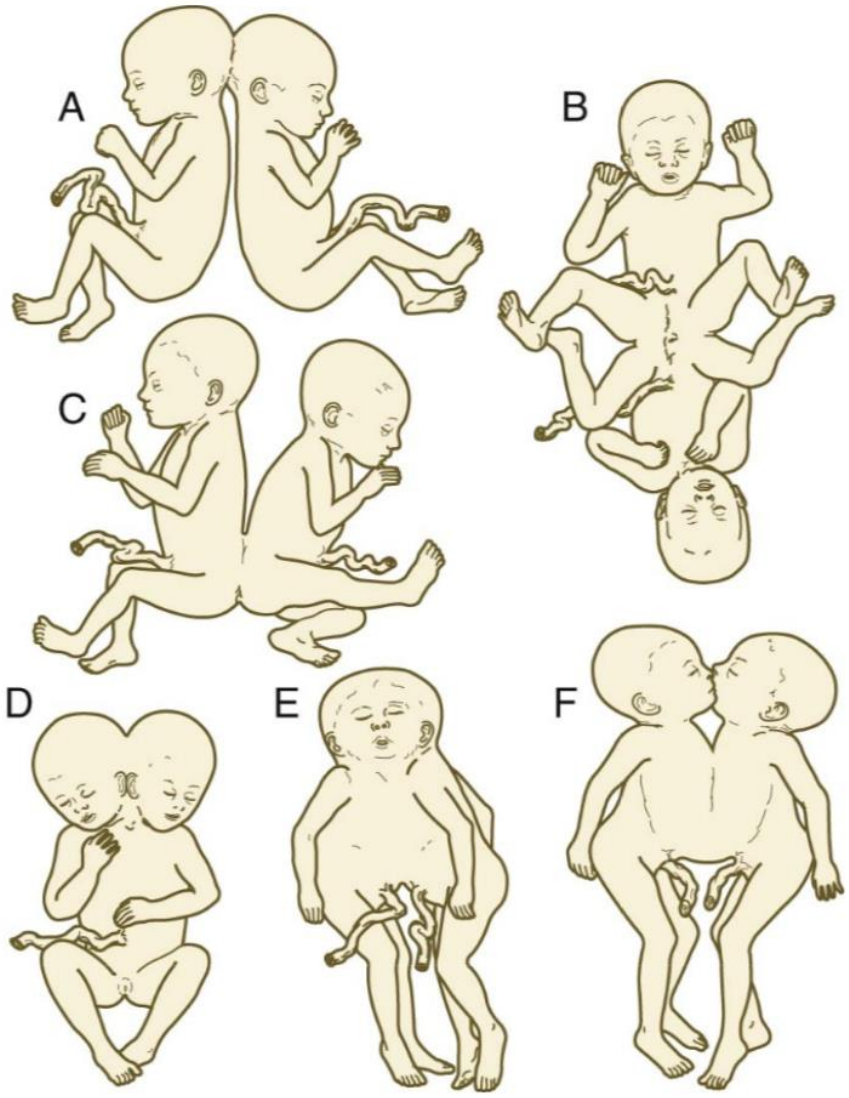
- Failure of primitive streak leads to absence of mesoderm in affected region - **sirenomelia**

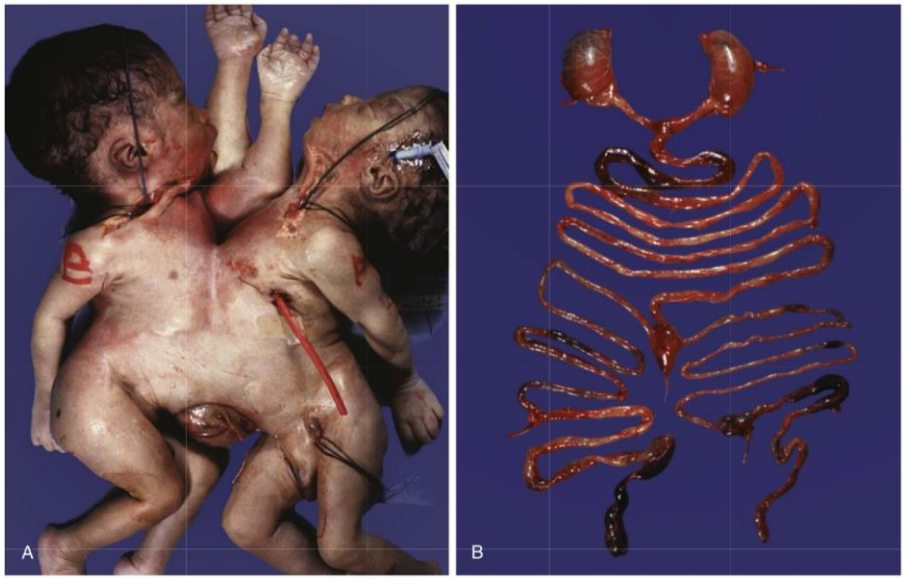


- limbs
- urogenital system
- GIT

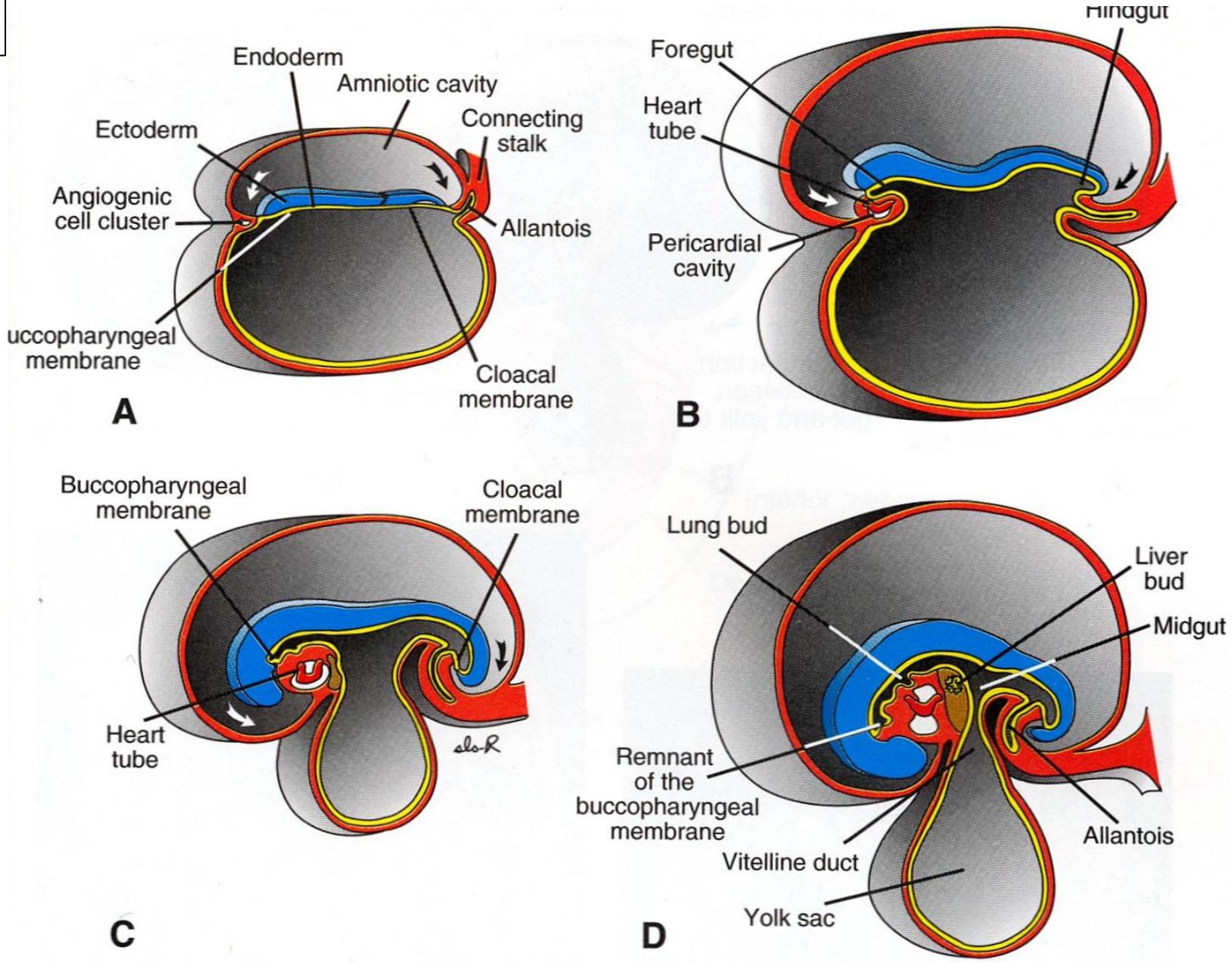
DEVELOPMENTAL DISORDERS DURING GASTRULATION

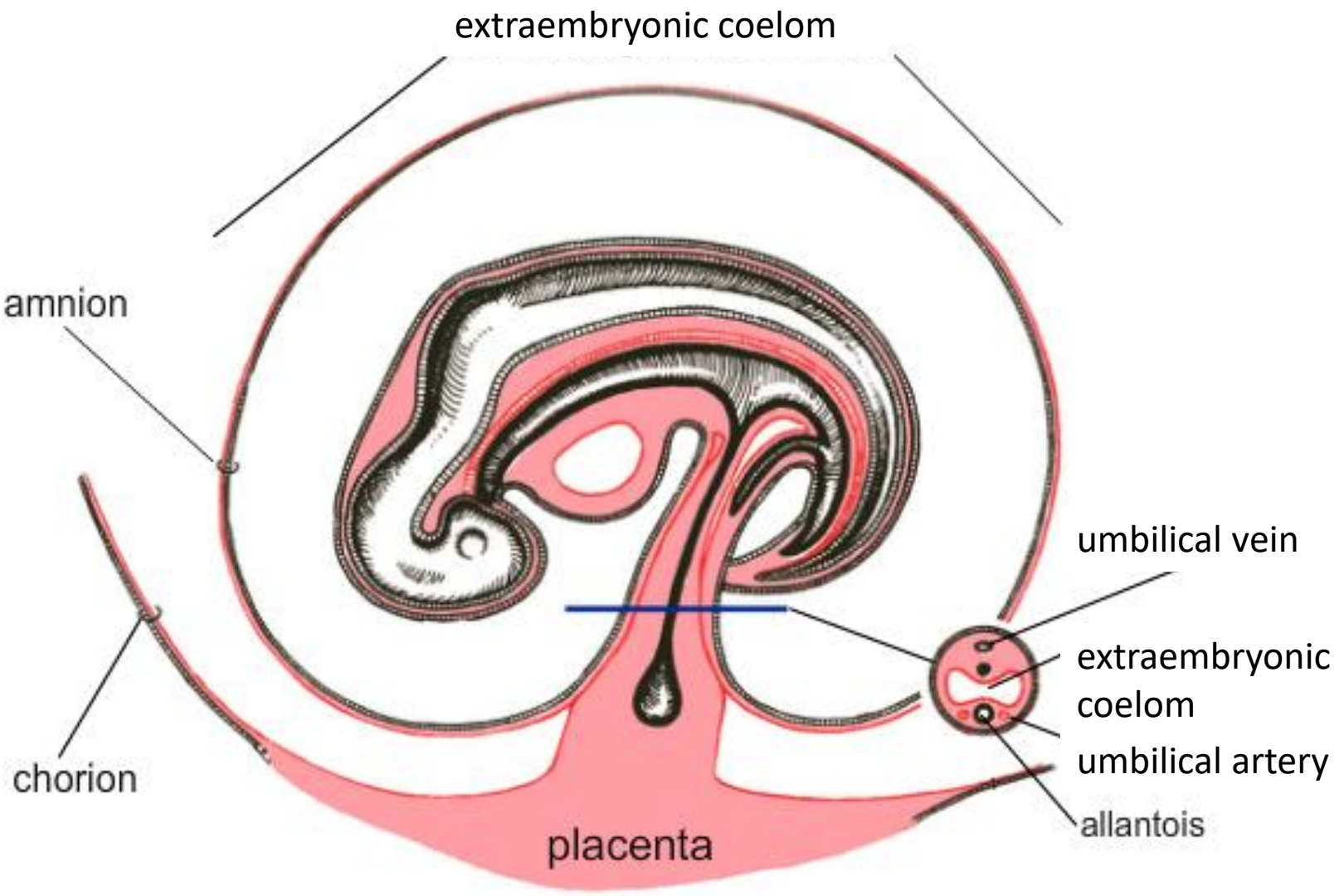
- If two primitive streaks form, conjoined twins may develop



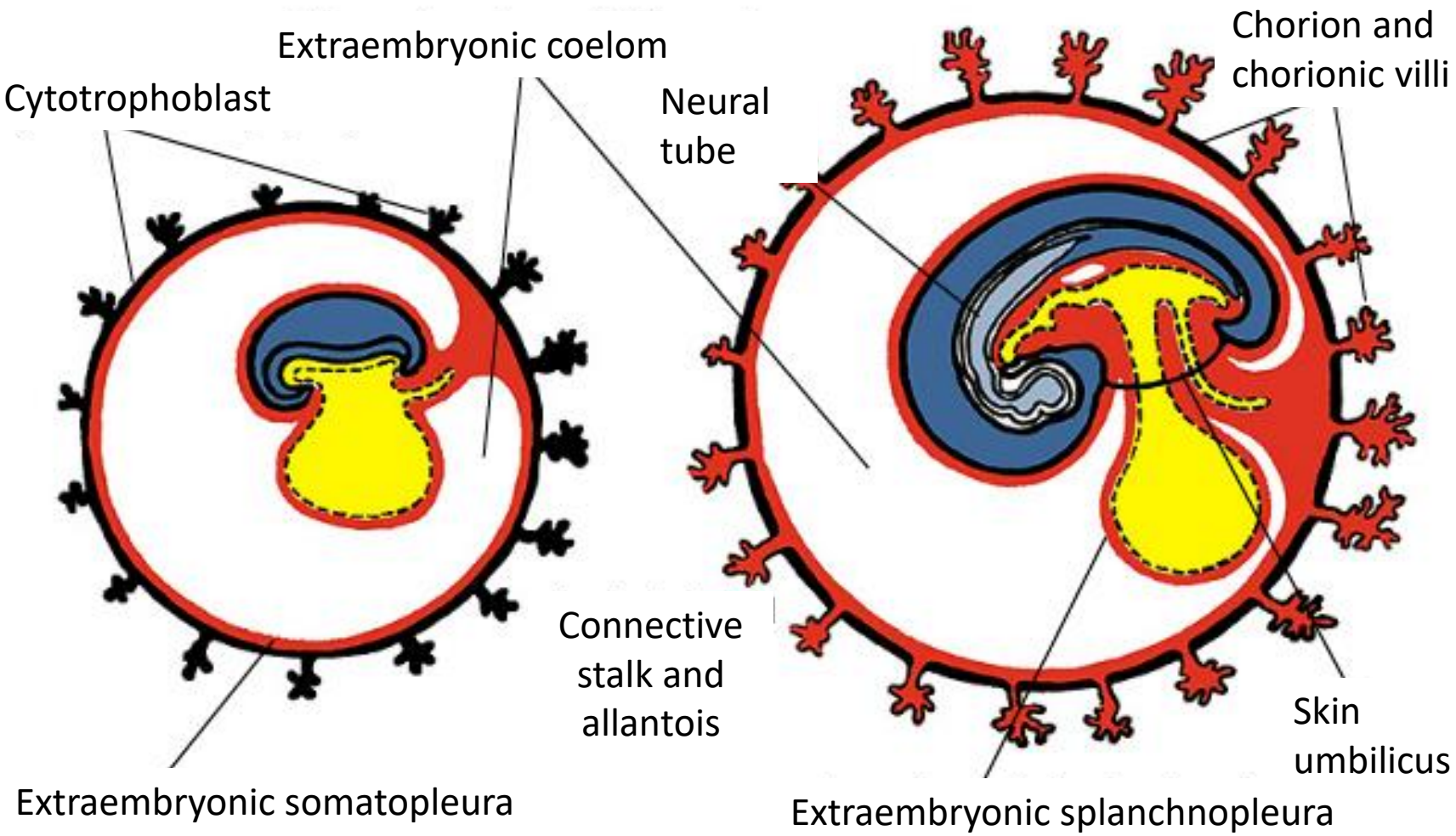


4th week


Endoderm
Amniotic cavity
Ectoderm
Connecting stalk
Angiogenic cell cluster
Allantois
uccopharyngeal membrane
Cloacal membrane
A
Hindgut
Foregut
Heart tube
Pericardial cavity
B
Buccopharyngeal membrane
Cloacal membrane
Heart tube
C
Lung bud
Liver bud
Midgut
Remnant of the buccopharyngeal membrane
Allantois
Vitelline duct
Yolk sac
D


extraembryonic coelom
amnion
umbilical vein
extraembryonic coelom
umbilical artery
allantois
chorion
placenta

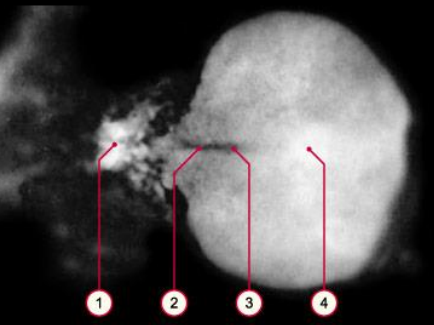
FOLDING OF EMBRYO



- bilaminar → trilaminar germ disc
- cephalocaudal and lateral flexion of embryo

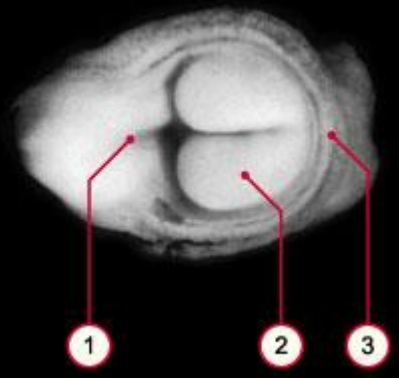
http://www.embryology.ch/anglais/iperiodembry/carnegie03.html#st710

Day 19
0.4 mm
Carnegie stage 7



1 Yolk sac
2 Primitive streak
3 Primitive node
4 Germ disc

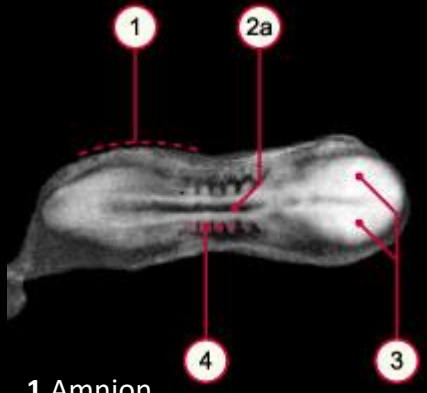
Day 25
1.5-2.5 mm
Carnegie stage 9



1 Primitive streak
2 Neural folds
3 Amnion

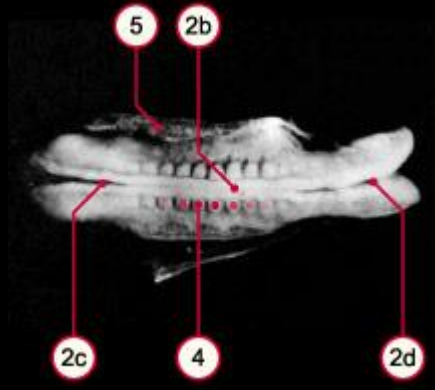
Day 28
2-3.5 mm
Carnegie stage 10

Dorsal



1 Amnion
2a Neural ridge
2b Neural tube
2c Caudal neuroporus
2d Rostral neuroporus

Ventral



3 Neural folds
4 Somites
5 Yolk sac

EMBRYONIC DEVELOPMENT

week 4-6

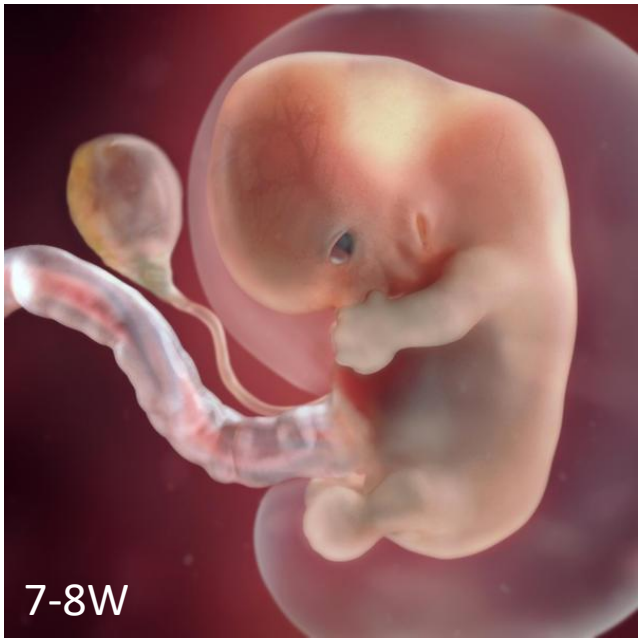
- Mesoderm segmentation
- Primitive gut
- Esophagotracheal diverticulum
- Heart (starts beating day 22-23)
- Limb buds
- Primary brain vesicles, closing of neuropores
- Differentiation of neural crest
- Origin of thyroid and anterior pituitary
- Ectodermal placodes, optic vesicle
- Liver diverticulum
- Septum transversum

- Segmentation of mesoderm continues
- Posterior pituitary
- Heart septation begins
- Lung buds branch - pseudoglandular stage of lung development
- Cochlea grows
- Lens vesicle, nasal placodes
- Fourth brain ventricle forms
- Pharyngeal arches, ridges and pouches
- Limb buds grow
- Hematopoiesis in liver
- Retinal pigment

- Derivatives of endodermal pharyngeal pouches (parathyroid, thymus)
- Adrenal gland
- Heart and lungs descended to thorax
- Innervation of limbs, differentiation of myoblasts
- Face development – maxillary and mandibulary processes, palatine, choans
- Telencephalon stratifies – archicortex, paleocortex and neocortex. Choroid plexus
- Rotation of stomach
- Pancreatic diverticula fuse

EMBRYONIC DEVELOPMENT

week 8



- Secretion from endocrine pancreas
- Growth of liver, growth and luminization of bile ducts
- Ossification of limbs begin
- Development of brain nuclei

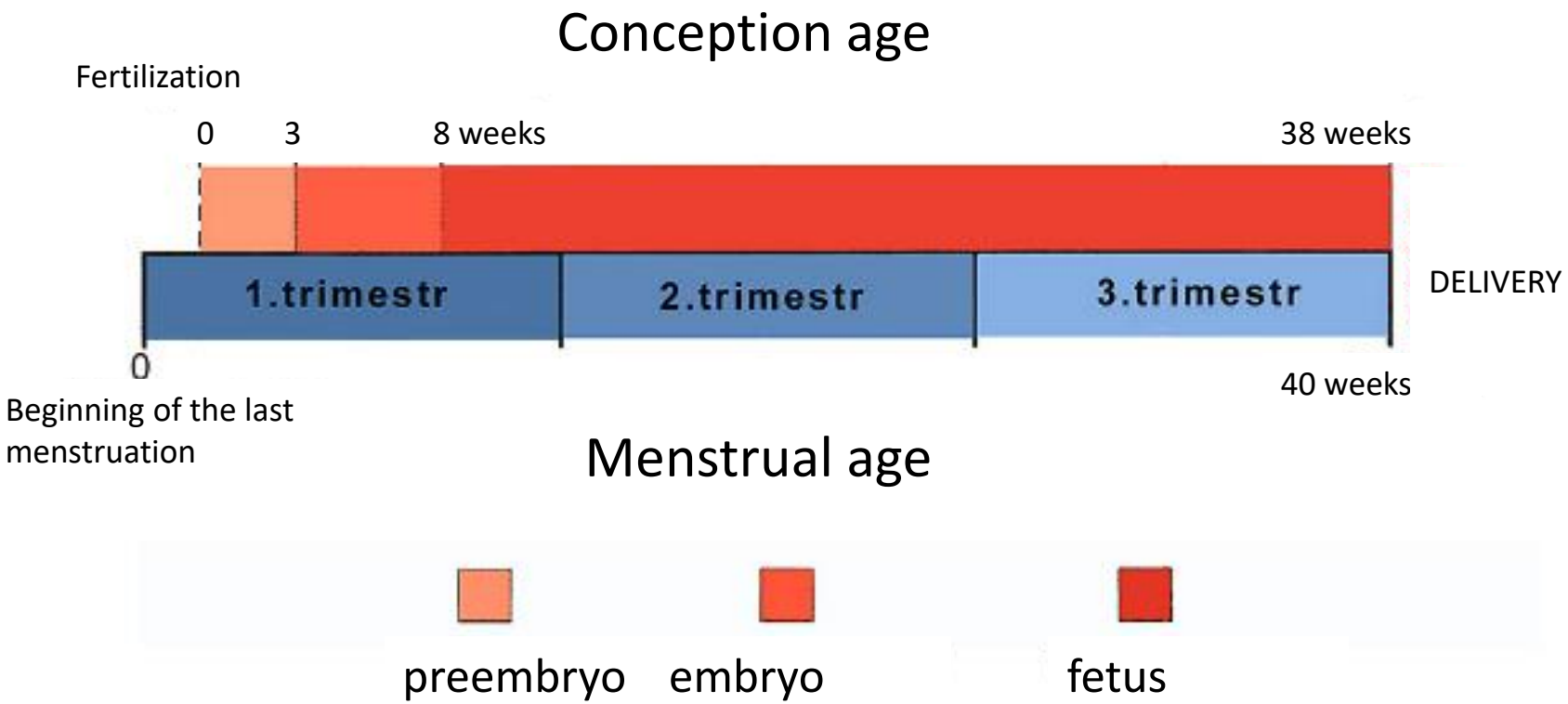
- Joints of upper and later lower limbs allow rotation
- Fingers grow
- Stratification of cerebellar cortex
- Perforation of anal membrane
- Herniation of intestinal loops
- Testes produce testosterone
- Nose, meatus, eyelids, developer, external ears start to grow
- Backbone - 33-34 cartilaginous vertebrae
- Embryonic tail diminished

LENGTH OF PREGNANCY

280 days (= 40 weeks = 10 lunar months) from the first day of the last **menstruation**

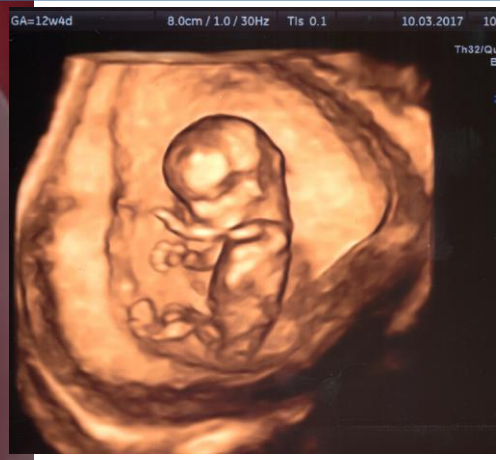
266 days (= 38 weeks) **from ovulation** (gestation age)

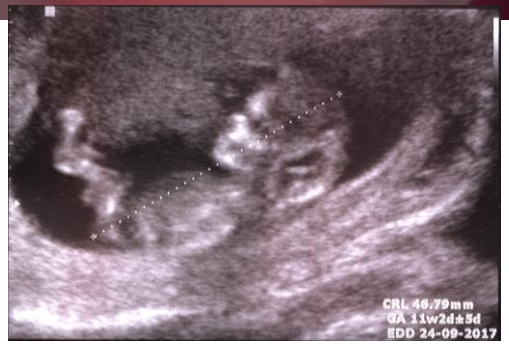
Calculation of term: First day of the last **menstruation + 1 year– 3 months + 7 days**



FETAL DEVELOPMENT

month 4-5





- Fetus swallows amniotic fluid – necessary for GIT development
- Rapid growth of head (non-proportional to rest of body)
- Eyelids fuse
- Ossification centers visible by ultrasound examination
- Development of external genitalia
- Kidneys produce urine, other organs start to work
- Skeletal muscles innervated
- Physiological umbilical hernia, in 12th weeks reposition of intestinal loops

- Rapid growth of fetus
- Ossification of skeleton
- Face growths, mandible visible
- Apparent external genitalia

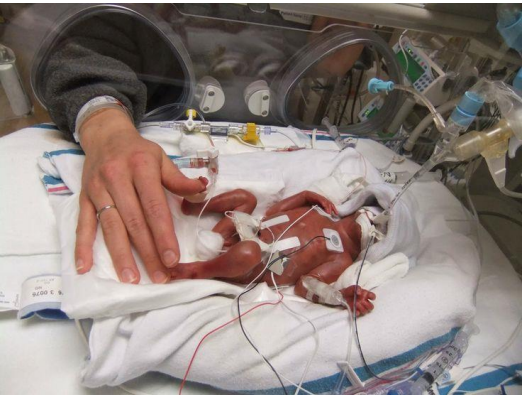
FETAL DEVELOPMENT

month 5-9

- Limbs growth
- Mother feels fetal movements
- Vernix caseosa, lanugo
- Short hairs and eyelashes
- Fetus reacts to sound and later to light
- Lungs start to produce surfactant
- Limit of viability

- Eyelids open
- Wrinkled skin with visible capillaries
- Subcutaneous fat
- Hairs grow
- Maturing of organ systems

- Subcutaneous fat accumulates in limbs
- Smooth, red skin
- Hallmarks of full term fetus



LENGTH OF PREGNANCY × FETAL MATURITY

Full term – related to length of pregnancy (menstrual age)

- preterm (<37 weeks)
- full term (38 – 40 weeks)
- after term (>42 weeks) (meconium in amniotic fluid)

Fetal maturity – development of fetus: **mature** X **immature**

HALLMARKS OF FETAL MATURITY

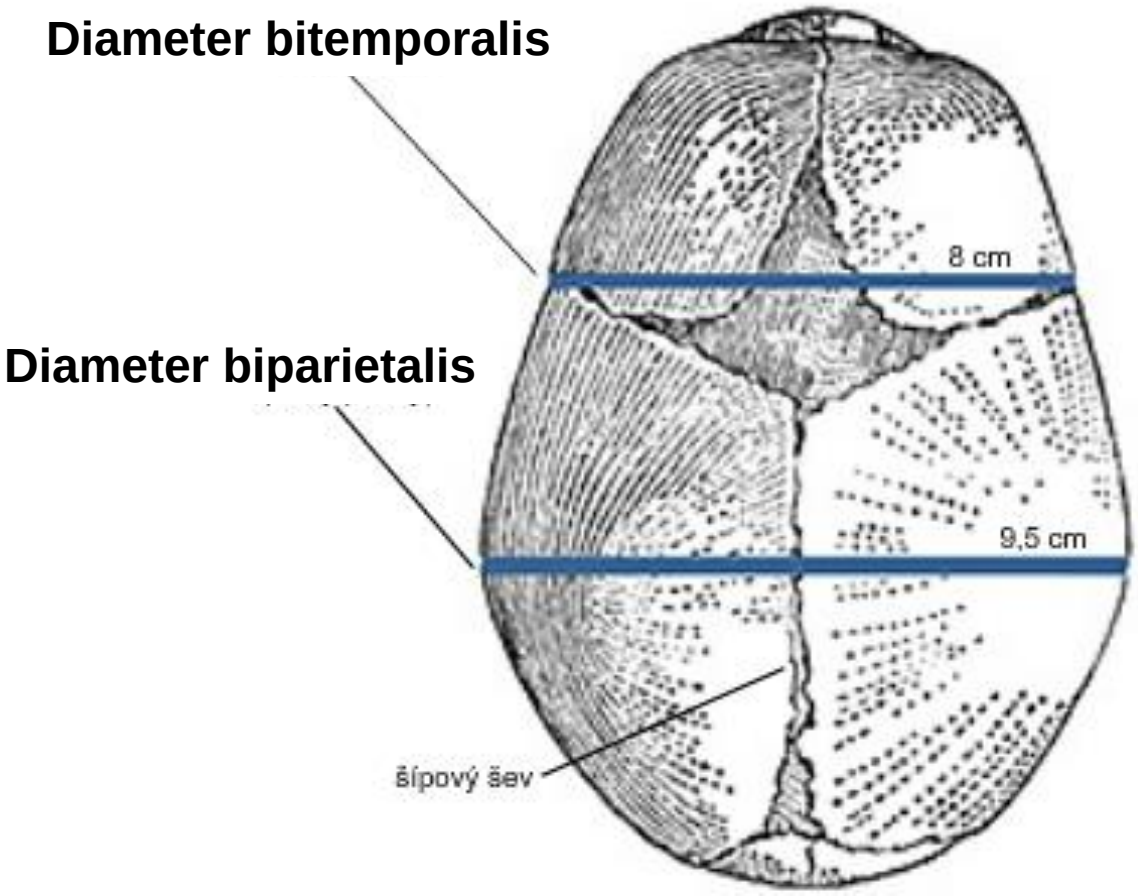
Major:

- **length (50 – 51 cm),**
- **weight** (around **3500 g**, physiological range 2500 - 4000g),
- head sizes
- boys - testes in scrotum, girls - labia majora over labia minora

Minor:

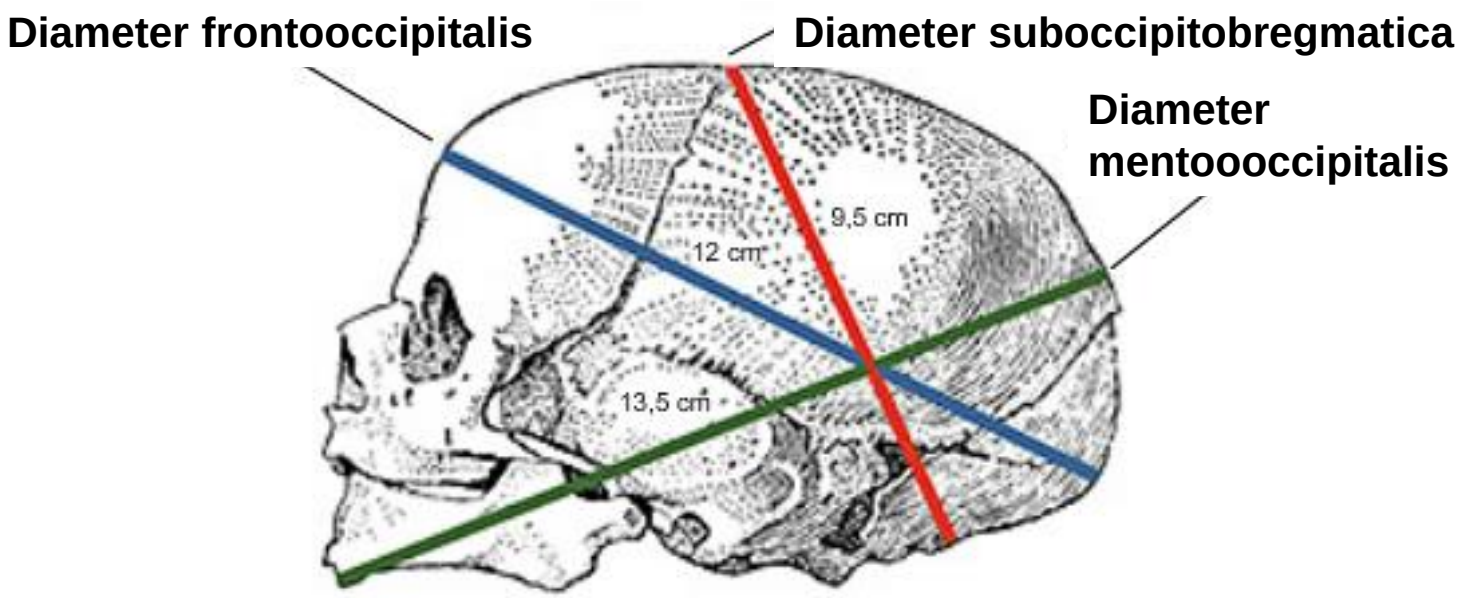
- eutrophic fetus, subcutaneous fat
- skin is not blue (no cyanosis), lanugo remains on shoulders and back,
- eyelashes, hairs several cm long, nails over fingertips
- cranial bones hard, anterior and posterior fontanelle are palpable, and separated
- newborn cries and moves (Apgar score)

Diameter bitemporalis – 8,00 cm
(join of the most distant points on sutura coronaria)
Diameter biparietalis – 9,5 cm
(join of midpoints of tubera parietalia)



Oblique sizes:

- **Diameter frontooccipitalis – 12.0 cm** (join of forehead midpoint and most distant point of occiput)
- **Circumferentia frontooccipitalis – 34.0 cm**
- **Diameter suboccipitobregmatica – 9.5 cm** (join of protuberantia occipitalis externa and midpoint of large fontanelle)
- **Circumferentia suboccipitobregmatica – 32.0 cm**
- **Diameter mentooccipitalis – 13.5 cm** (join of chin midpoint and most distant point of occiput)
- **circumferentia mentoocipitalis – 35 - 36 cm**
- **Diameter biacromialis – 12.0 cm, circumferentia biacromialis – 35 cm**
- (join of acromion – acromion)



RELATIONSHIP BETWEEN AGE AND LENGTH OF FETUS

RULE OF HASSE

- forensic medicne

3. – 5. lunar month: length in cm = square of month
6. – 10. lunar month: length in cm = months multiplied by 5

Lunar month	Length of fetus[cm]
3	9
4	16
5	25
6	30
7	35
8	40
9	45
10	50

FETUS IN UTERUS

1. **LIE (*SITUS*)** = relationship of the long axis of the fetus to that of the mother
- longitudinal: (99 %)
- transverse: (1 %) perpendicular axes
- oblique: unstable → longitudinal or transverse position

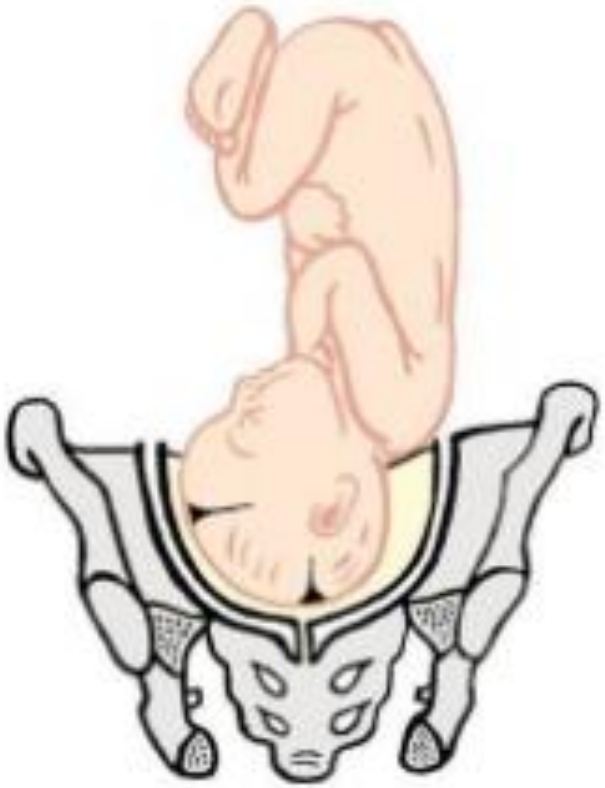
2. **POSITION (*POSITIO*)** = fetal backbone relative to uterus ridge
- **first**= left (back to the left)
- **second**= right (back to the right)
- first/second common/less common

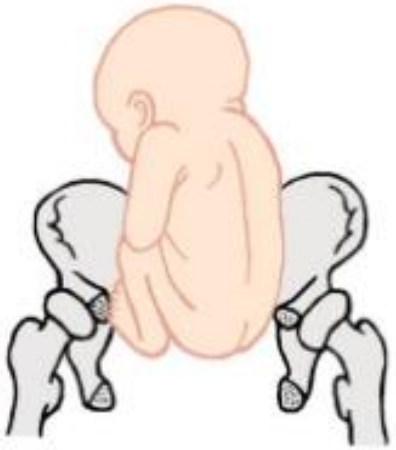
3. **FETAL HABITUS (*HABITUS*)** = relationship of one fetal part to another
- regular = head and limbs in flexion
- irregular = everything else

4. **PRESENTATION (*PRAESENTATIO*)** = that part of the fetus lying over the pelvic inlet; the presenting body part of the fetus.
- occiput (most common)
- vertex, forehead, face (1%)
- breech
- trunk, shoulder

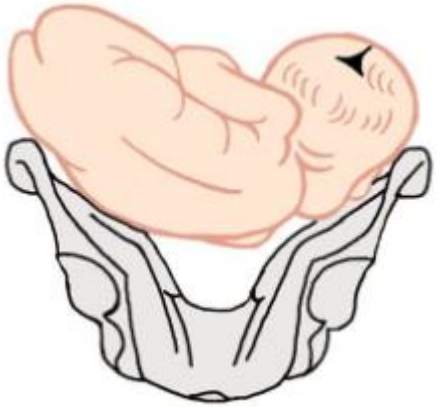
SITUS

longitudinal - occiput

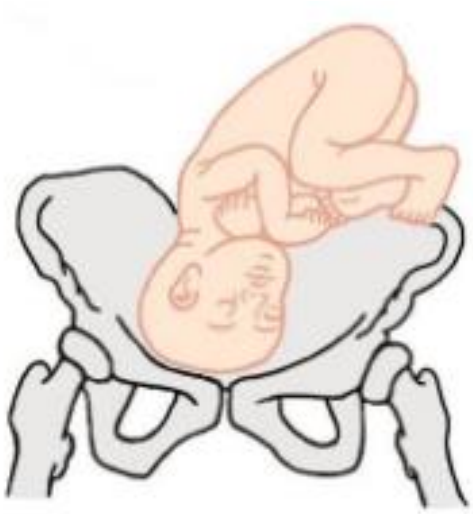




longitudinal - breech



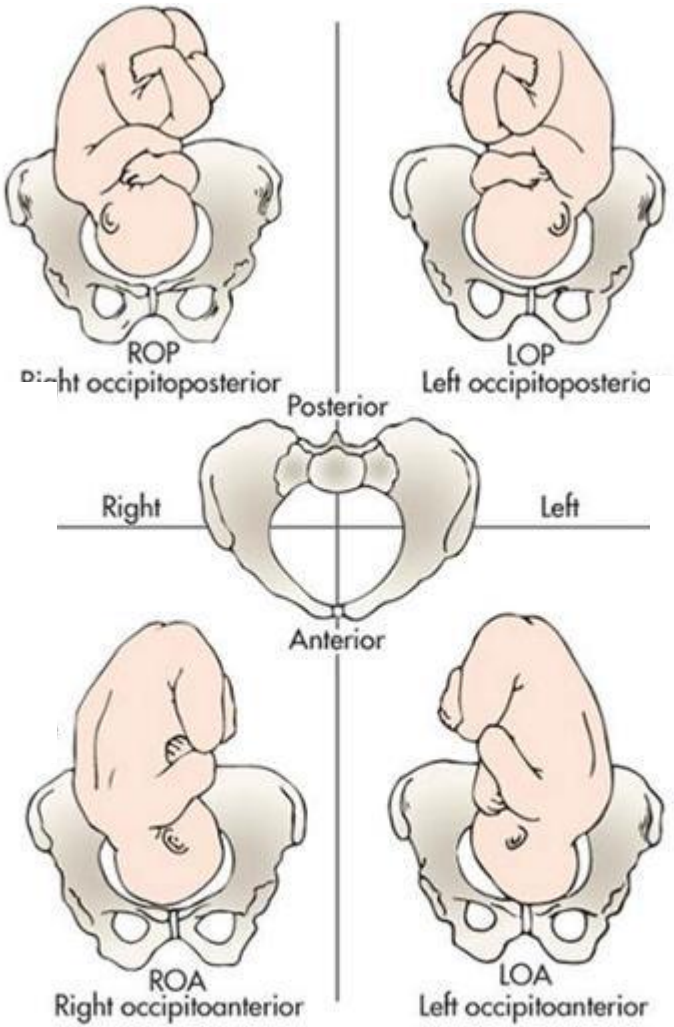
transverse



oblique

2. COMMON „RIGHT“

1. COMMON „LEFT“



2. LESS COMMON

1. LESS COMMON

Lie: Longitudinal or vertical
Presentation: Vertex
Reference point: Occiput
Attitude: General flexion

HABITUS AND PRESENTATION

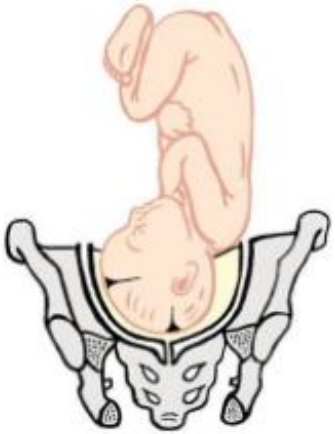
HABITUS

irregular (any other)

regular

PRESENTATION

occiput



vertex

forehead

face

PHYSIOLOGICAL IMPOSITION OF FETUS IN UTERUS

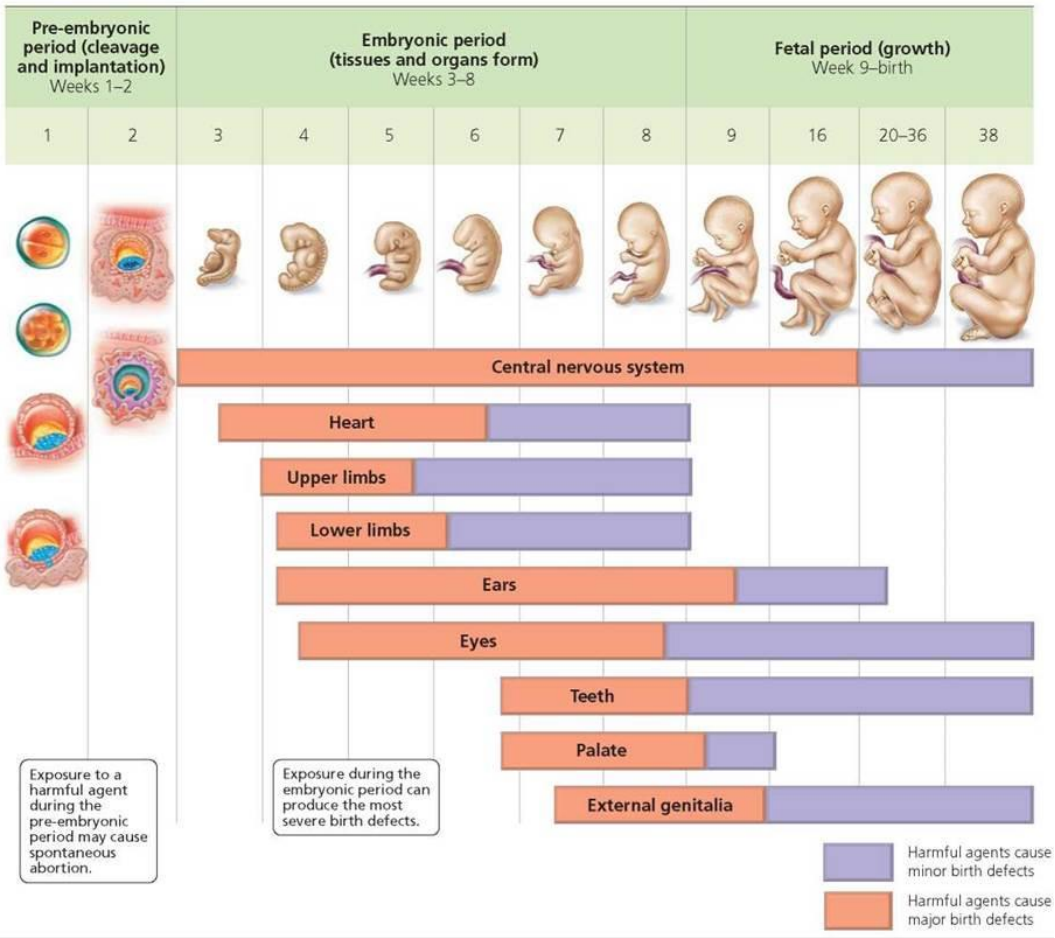
- **LIE LONGITUDINAL - HEAD FIRST**
- **POSITION FIRST COMMON**
- **HABITUS REGULAR**
- **PRESENTATION - OCCIPUT**

INTRODUCTION TO TERATOLOGY

- Congenital disorders – due to abnormal developmental events
- Genetic (inherited) or nongenetic (external) causes
- Teratogens

- Critical developmental periods

- Life style (alcohol, smoking, drugs)
- Infections (rubeola, HIV, toxoplasmosis)
- Lack or abundance of key substances (folic acid × retinoids)
- Chronic diseases (medical treatment)



INTRODUCTION TO PRENATAL DIAGNOSTICS

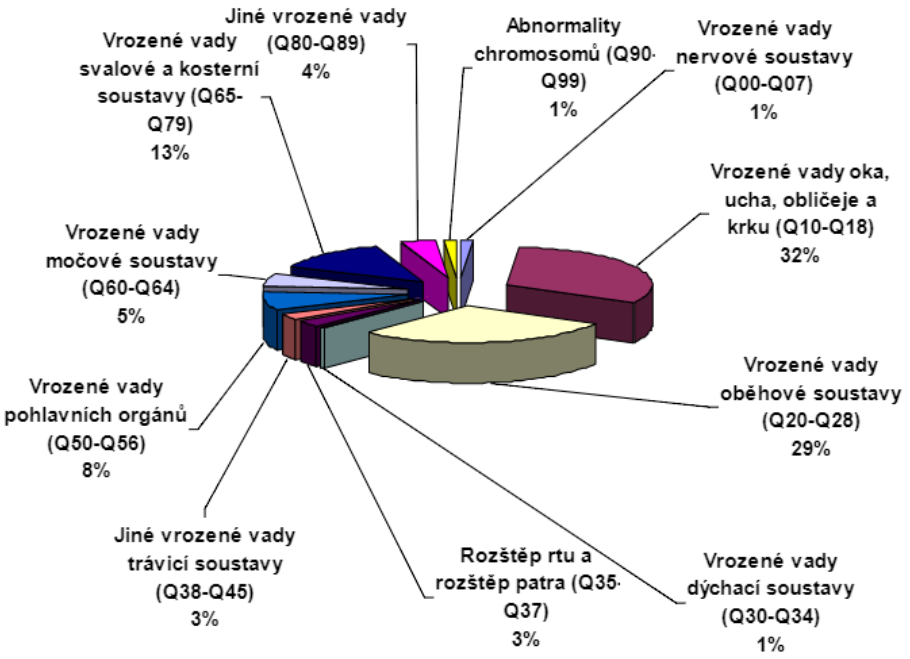
- Interdisciplinary care – biochemistry, genetics, gynecology and obstetrics, neonatology – parts of fetal medicine

- Revealing high risk pregnancies, access to preventive and therapeutic care

- Preventing delivery of fetuses with severe congenital malformations
- Support of delivery of genetically high-risk babies
- Planning and providing clinical care

- Genetic counselling
- Biochemical and ultrasound screening
- Karyotyping and DNA diagnostics
- Clinical diagnostics

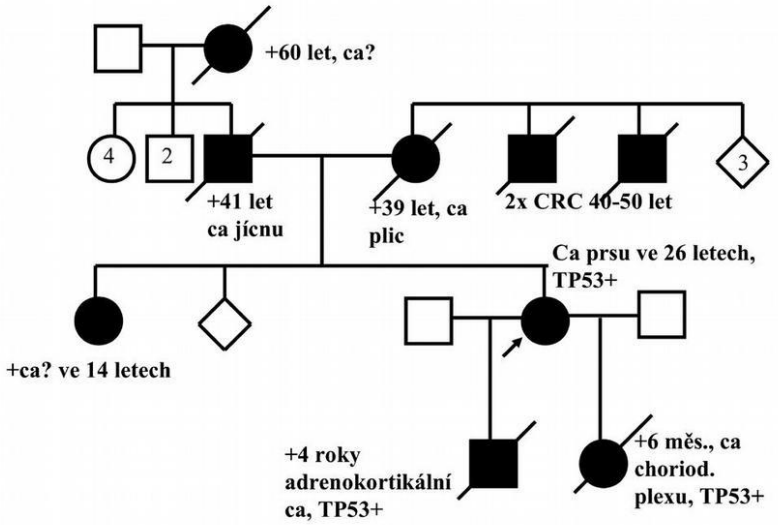
- Indication:
- congenital disorders in family
- positive screening in 1st or 2nd trimester
- abnormal finding by ultrasound
- maternal age (over 35 years)

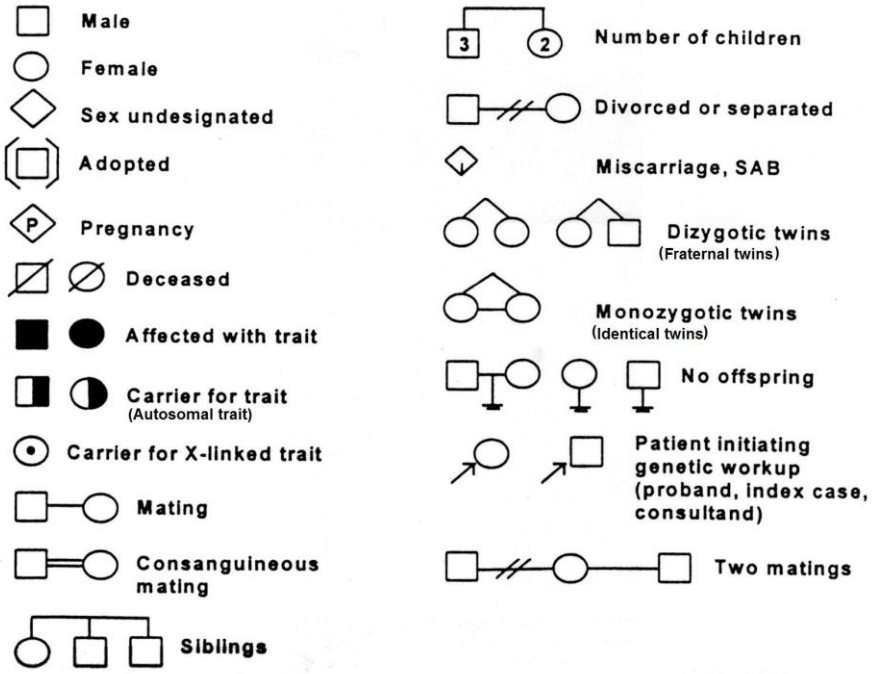


ČR 1994-2008

GENETIC COUNSELING

- Anamnesis (case history)
- Preconception counselling
- Explaining of examination results, causes, clinical symptoms, therapeutic options
- Minimization of risk of repeated disease
- Providing diagnosis and information for free choice
- Providing precise diagnosis and risk estimation
- Providing care during pregnancy and later





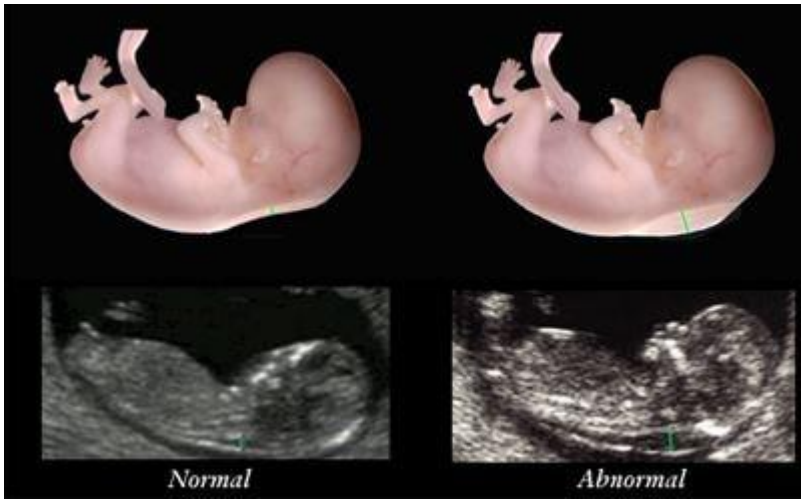
NONDIRECTIVE
ALL EXAMINATIONS AND
PROCEDURES ARE VOLUNTARY

BIOCHEMICAL SCREENING

- Non invasive
- Revealing high risk pregnancies – chromosomal aberrations and clefts
- **Screening is not a diagnostics** → further examinations (amniocentesis, karyotype, US)

- Tests between weeks 14-16 („TRIPLE test“)
- low sensitivity and specificity (50-60%), high false positivity (70%)
- AFP, E3, hCG
- chromosomal aberrations, abnormal closing of neural tube, defects of body walls

- Combined screening in week 11-13
- chromosomal aberrations – Down: 47,XY,+21, Edwards: 47,XY,+18, Patau 47,XY,+18
- US –nuchal translucence, NT
- PAPP-A, hCG (multiplies of median, MoM)
- age included in algorithm
- output: screening positive vs. negative (limit 1:100)



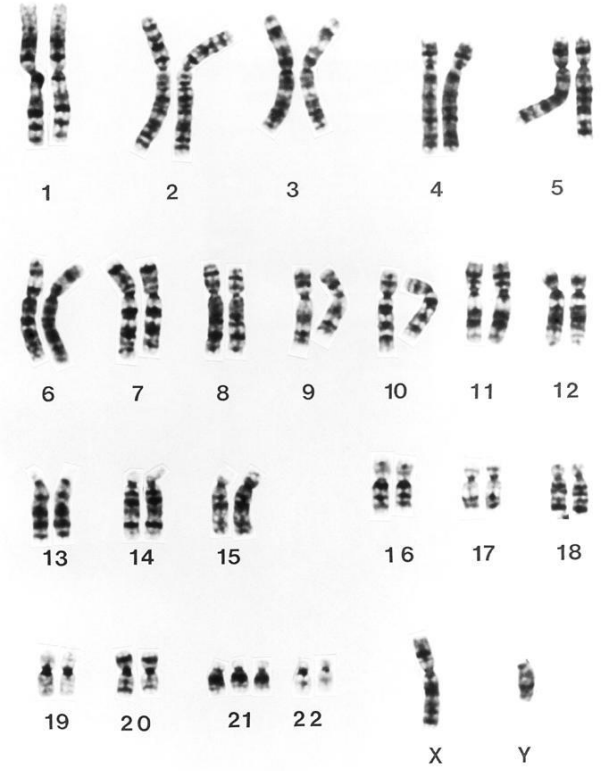
INVASIVE DIAGNOSTICS

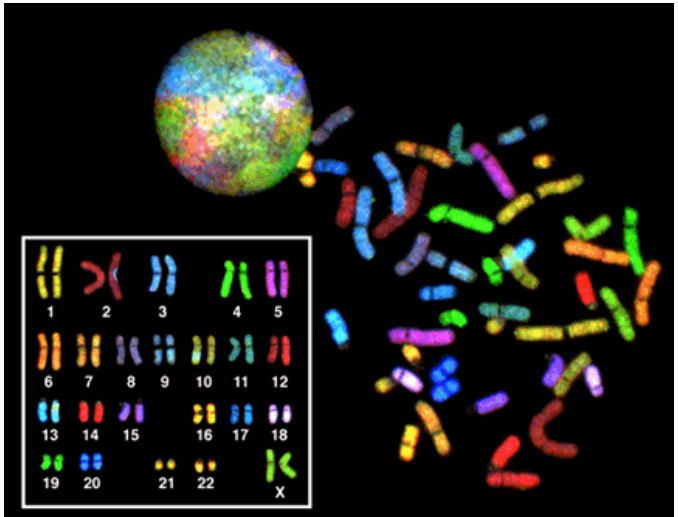
- Amniocentesis
- 16th-20th week
- US controlled amniotic fluid aspiration
- Cell culture, karyotype
- Risk of miscarriage 0.5-1%

- Chorion villus biopsy
- 10th-13th week
- Karyotype, molecular genetic examination
- Risk 0.5-1%

- Cordocentesis
- 22nd week
- Sampling of venous umbilical blood
- Now diagnostics and therapy of blood diseases (anemia, infections), or diagnostics in multiple pregnancies
- Risk 1%

- Fetoscopy
- Transabdominally (earlier transcervically)
- Visualization and fetal biopsy
- Risk 3-10%, done rarely





ULTRASOUND DIAGNOSTICS

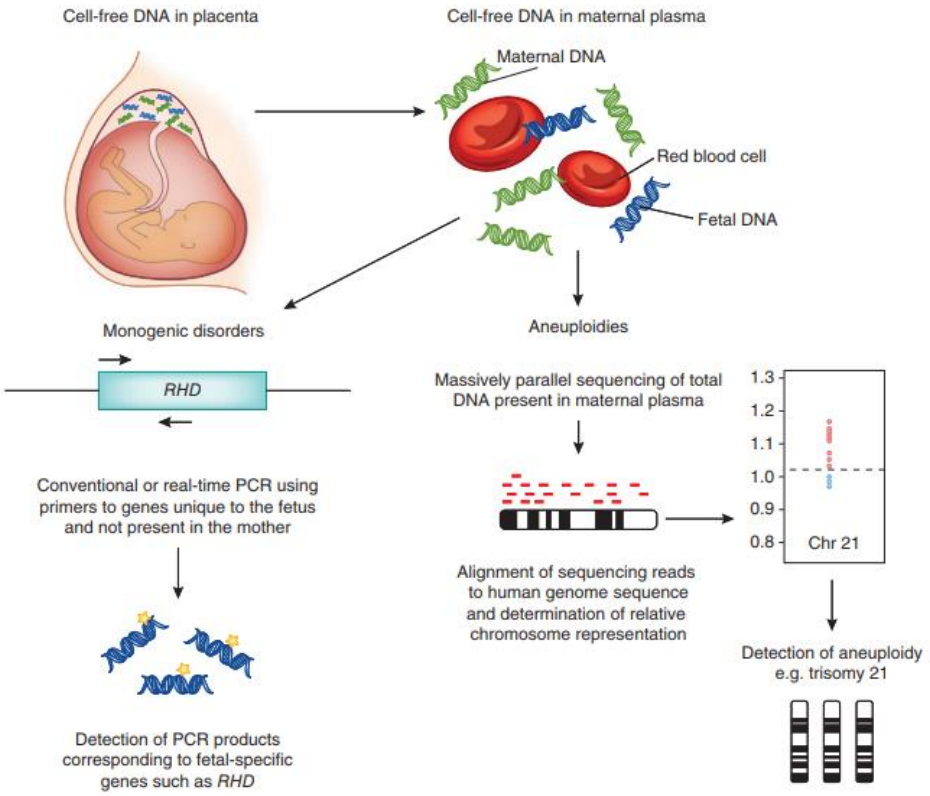
- 6-8th week
- confirmation of pregnancy, heart action
- number of fetuses

- 13-14th week
- nuchal translucence (risk > 3 mm)
- nasal bone (present × absent), **minor markers** (omphalocele, tricuspidal regurgitation, abnormality in ductus venosus flow, enlargement of urinary bladder-megavesica)
- fetal size

- 20-22nd week
- detailed screening
- fetal biometry (biparietal diameter, head circumference, length of femur)
- head and CNS (shape, cavity in septum pellucidum, ventricles, cerebellum, cisterna magna), face (lip, jaws, nose, orbits, profile), heart (action, size, axis, 4-chamber projection, outflow tracts, ...), thorax (pathological structures), abdominal cavity (stomach, intestine, kidneys, urinary bladder, umbilicus and umbilical vessels), backbone, limbs, palms, feet
- placenta, volume of amniotic fluid

- 30th week
- fetal size
- volume of amniotic fluid
- placenta (exclusion of *placenta praevia*)

ADVANCEMENTS IN MOLECULAR GENETICS



Analysis of cell-free fetal DNA in maternal blood
Since 12th week
Massive paralell sequencing (Next-Gen Sequencing)
Common aneuploidies (trisomy 21,13,18)
Monogeneous disorders

SOP-M8	NEINVAZIVNÍ DETEKCE ANEUPLOIDIÍ CHROMOZOMŮ 13, 18 A 21 POMOCÍ MULTIPLEX PCR A MASIVNÍHO PARALELNÍHO SEKVENOVÁNÍ (MPS)

Test Clarigo se značkou „CE", která je nezbytná pro provedení tohoto vyšetření v zemích EU, splňuje základní požadavky Směrnice Rady IVD 98/79/EC pro *in vitro* diagnostiku.

VÝSLEDEK VYŠETŘENÍ:

Chromozom	Stav	Fetální frakce	Předpokládané pohlaví plodu
13	normální	7,1 %	ženské
18	normální		
21	normální		

ZÁVĚR:

Analýzou volné fetální DNA cirkulující v krvi těhotné nebylo zjištěno zvýšené riziko aneuploidie chromozomů 13, 18 a 21.

Komentář: doporučujeme genetickou konzultaci.
Pozn: Při patologickém nálezu je výsledek nutné ověřit některým z invazivních postupů (např. odběr plodové vody, choriových klků, kordocentéza s následnou QF-PCR analýzou nebo stanovením klasického karyotypu apod.).

MUNI MED Department of Histology and Embryology

THANK YOU FOR ATTENTION

pvanhara@med.muni.cz
http://www.med.muni.cz/histology