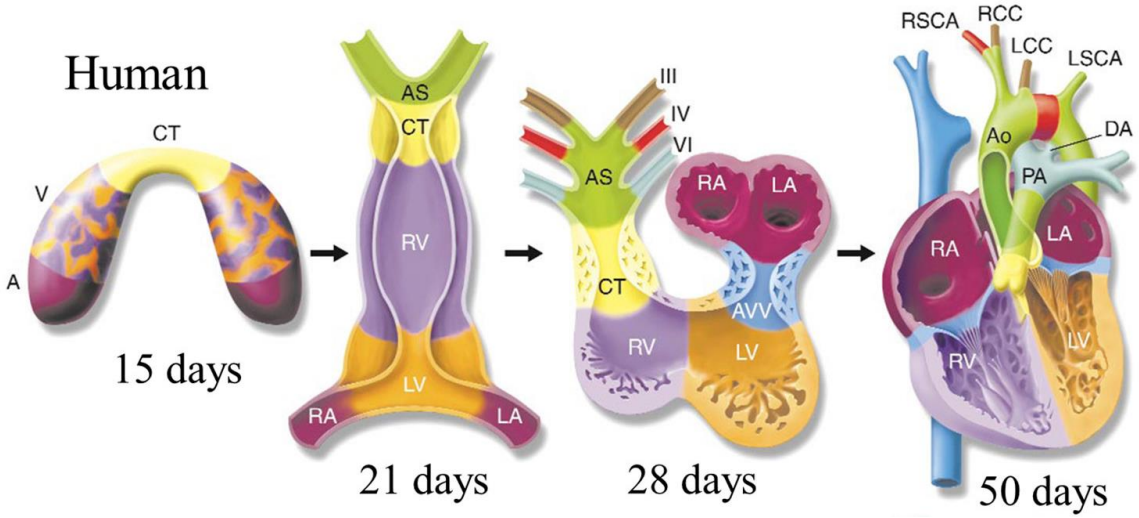
MUNI MED
Ústav histologie a embryologie

# DEVELOPMENT OF CARDIOVASCULAR SYSTEM




## 2024

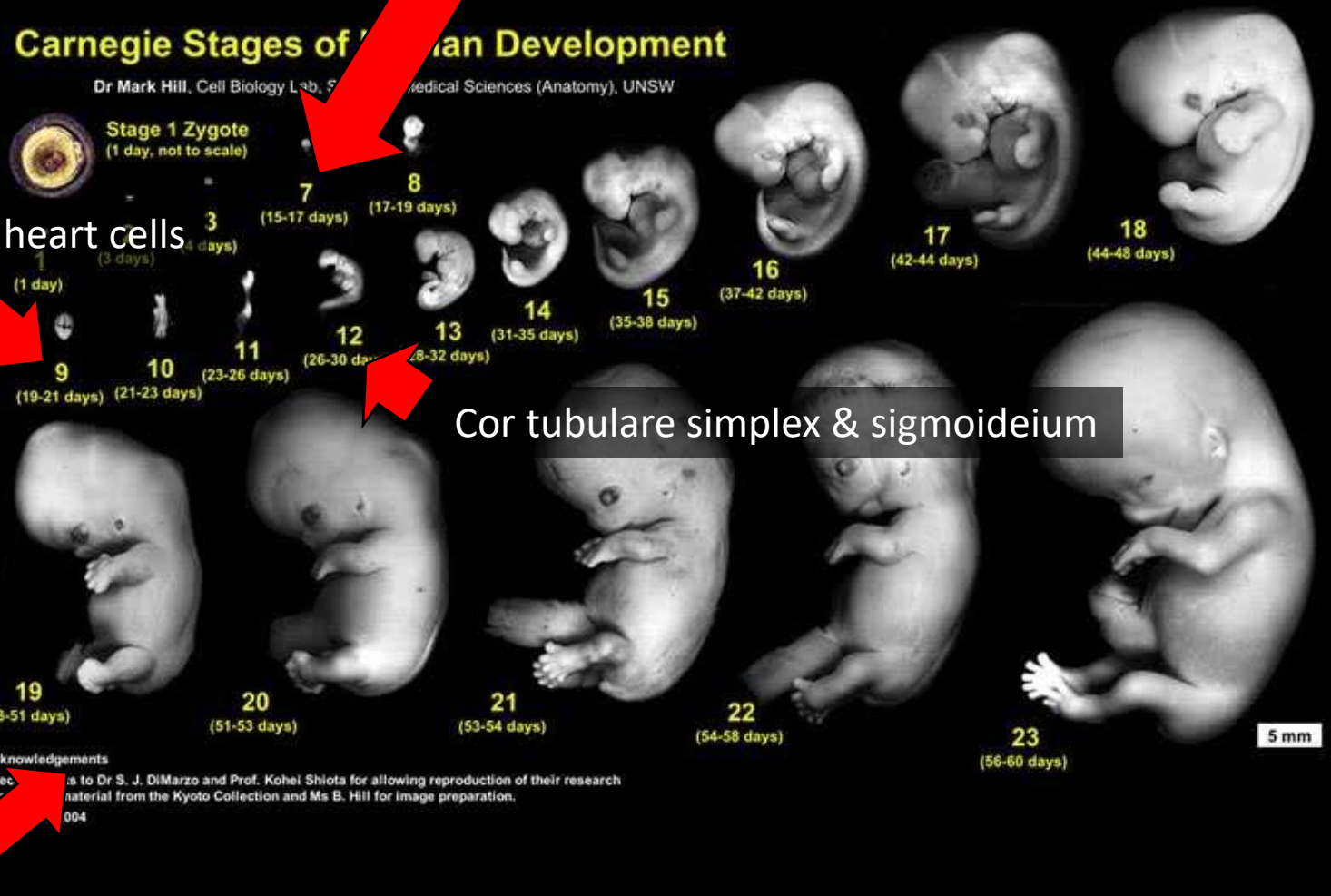
Petr Vaňhara

# DEVELOPMENT OF CARDIOVASCULAR SYSTEM

Fitst morphological hallmarks of developing heart

First activity of heart cells

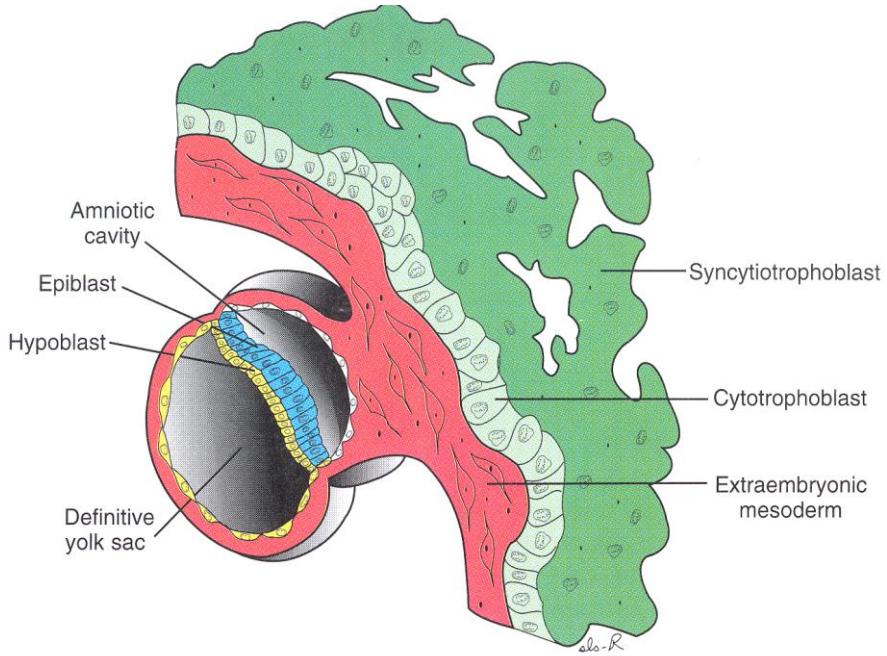
Cor tubulare simplex & sigmoideum

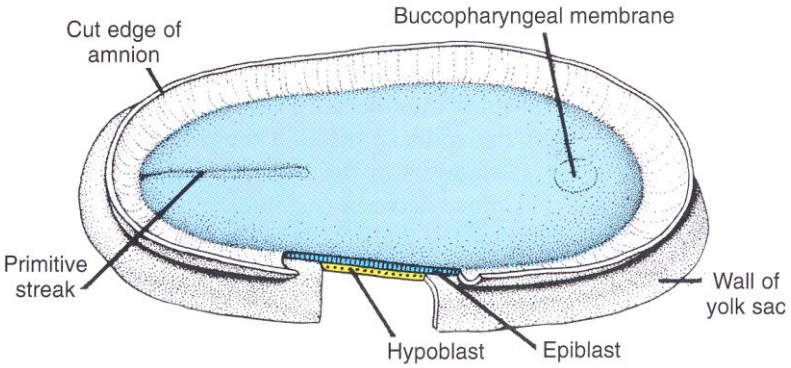



Fully functional, four-chamber heart

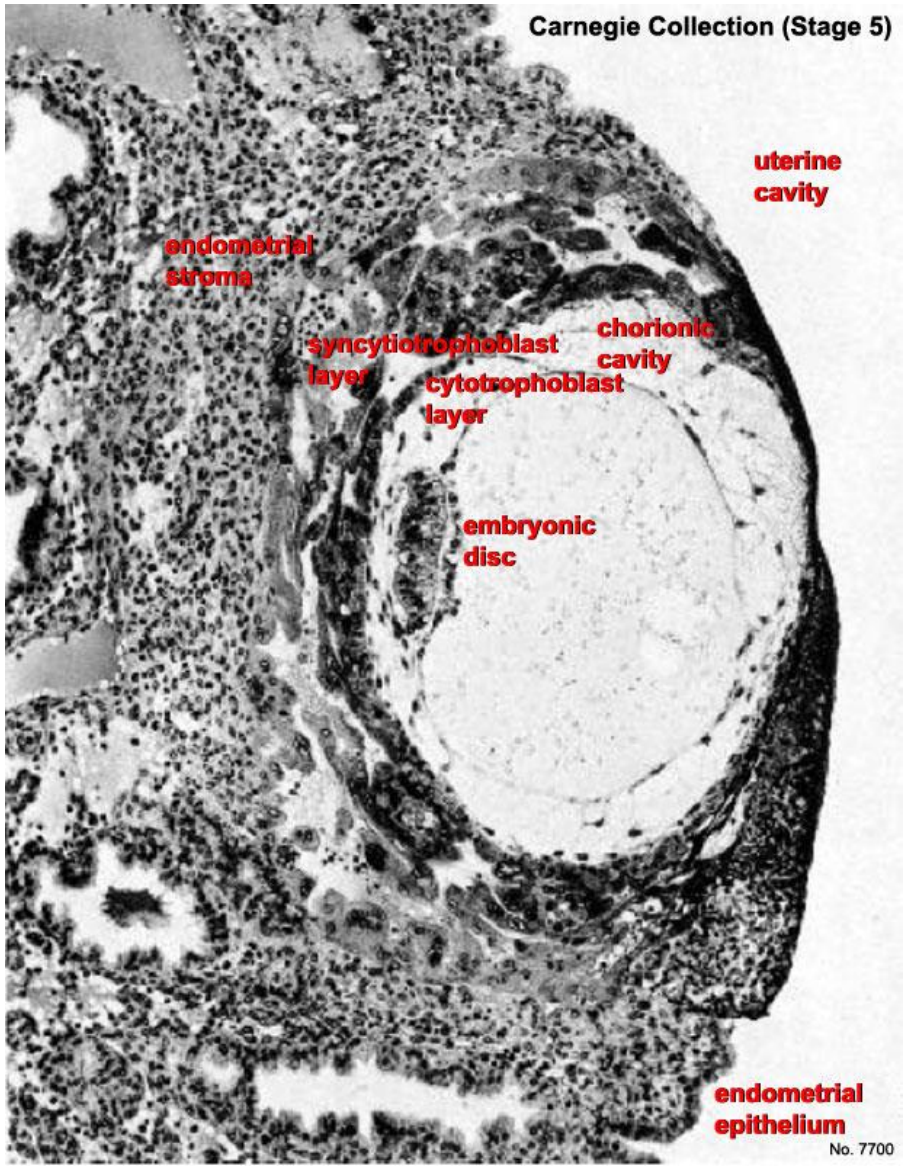
**Week 2-3**


Carnegie Collection
(Stage 5)
No. 7700


Amniotic cavity
Epiblast
Hypoblast
Definitive yolk sac
Syncytiotrophoblast
Cytotrophoblast
Extraembryonic mesoderm

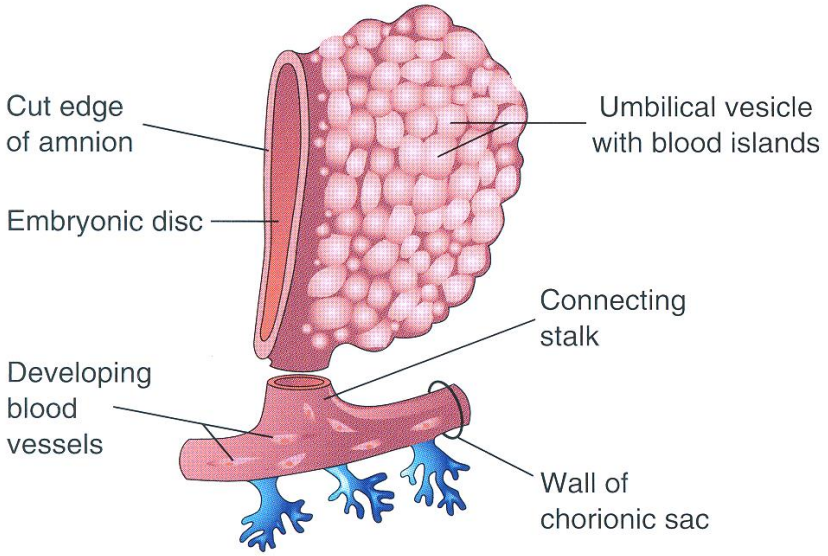

Cut edge of amnion
Buccopharyngeal membrane
Primitive streak
Wall of yolk sac
Hypoblast
Epiblast

# DEVELOPMENT OF CARDIOVASCULAR SYSTEM



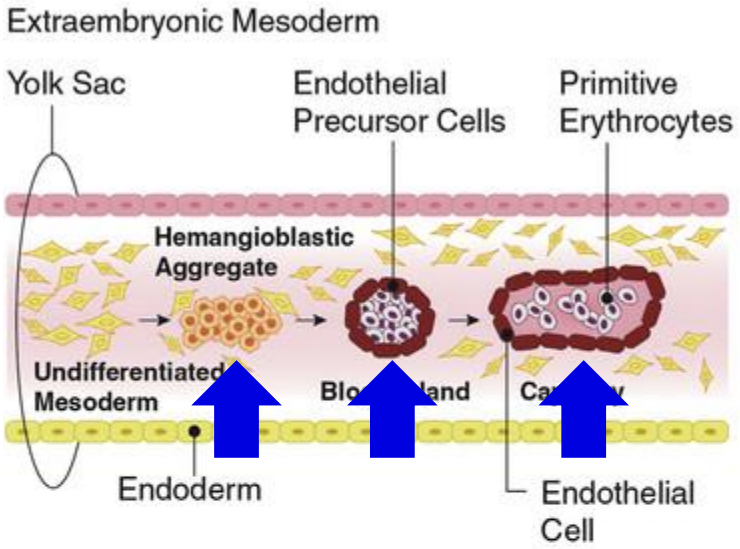

**Week 2-3**

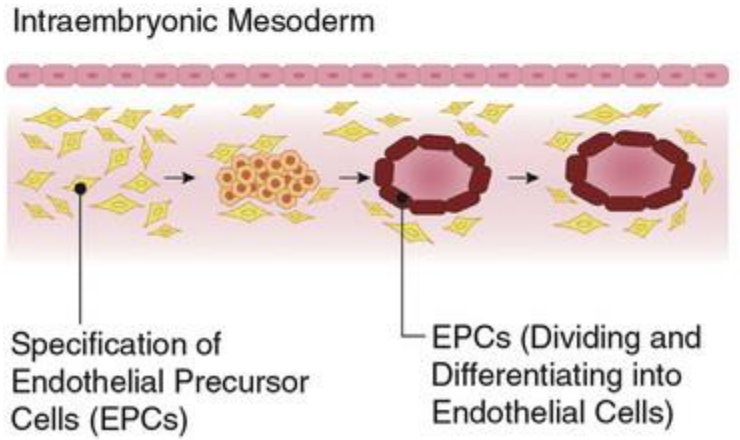
- rapid growth of embryo
- insuffcient supply by diffusion
- first vascularisation develops **outside** embryo – yolk sac, chorion and connecting stalk
- bipotential (hem)angioblasts in blood islands
- vasculogenesis and angiogenesis
- blood cells formation



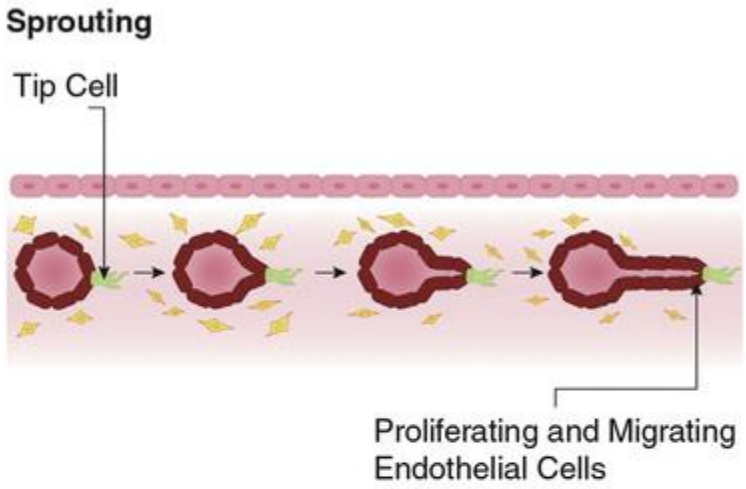
# VASCULOGENESIS AND ANGIOGENESIS

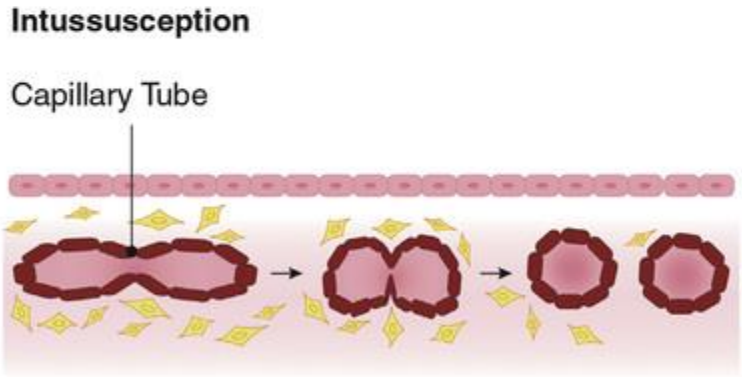
## VASCULOGENESIS
**= in situ differentiation**



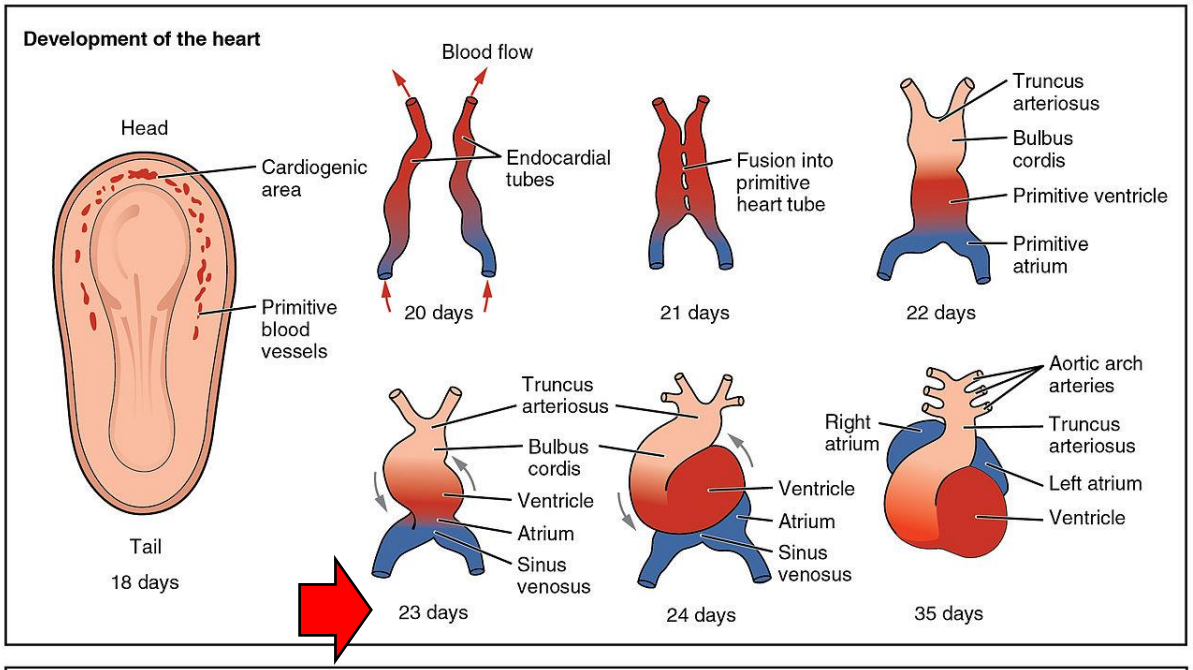




## ANGIOGENESIS
**= remodelling and expansion**



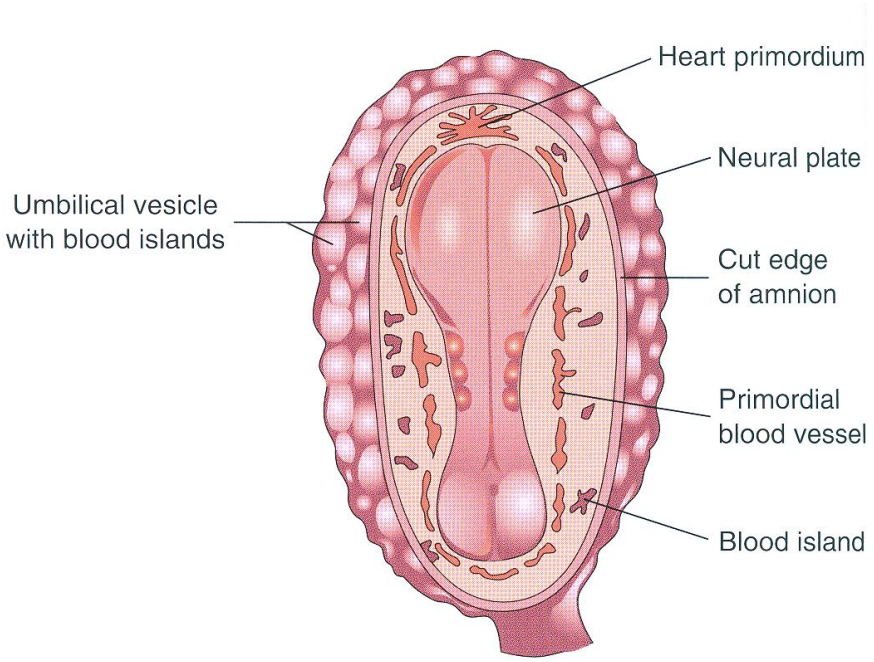



# Development of heart and the first vasculature

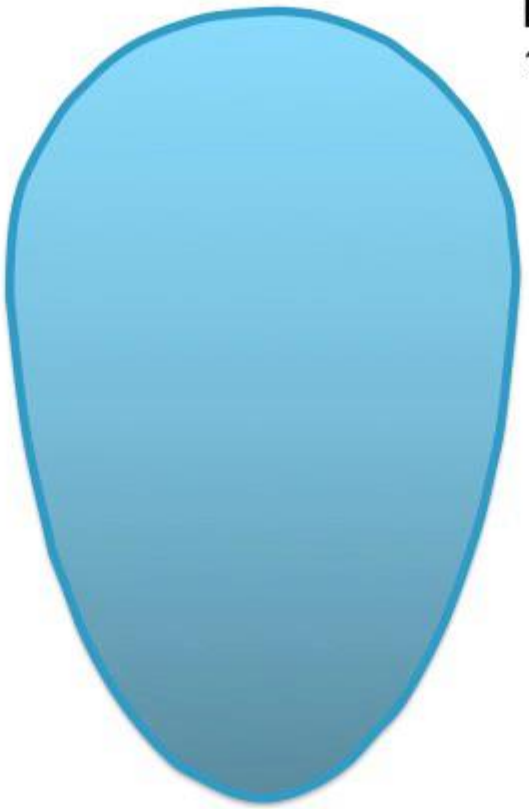


**End of week 3**

- **embryonic vasculogenesis** approx. 2 days later after establishment of extra-embryonic vessels
- primordial blood vessels
- **heart primordium** in cardiogenic area → **endocardial tubes**
- embryonic hematopoiesis from para-aortic clusters in AGM



## Week 3



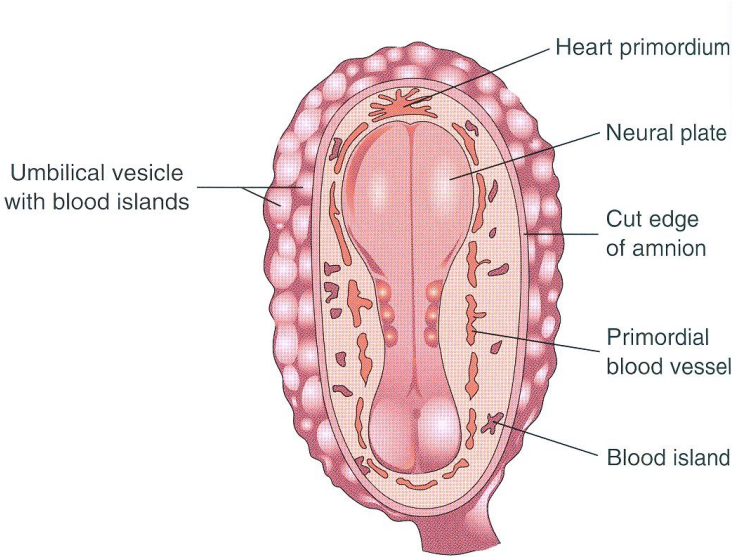
**Epiblast**

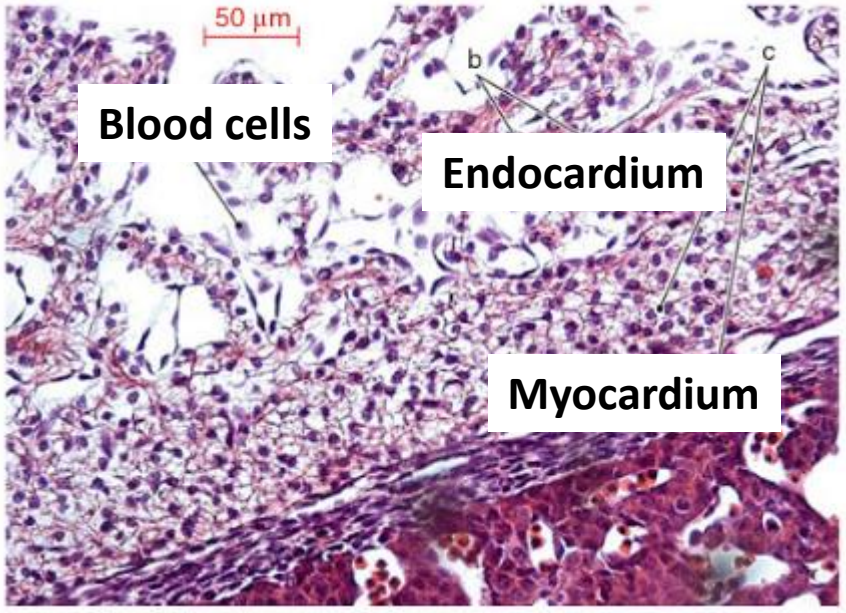
***18 days, dorsal surface***

## Development of primitive heart

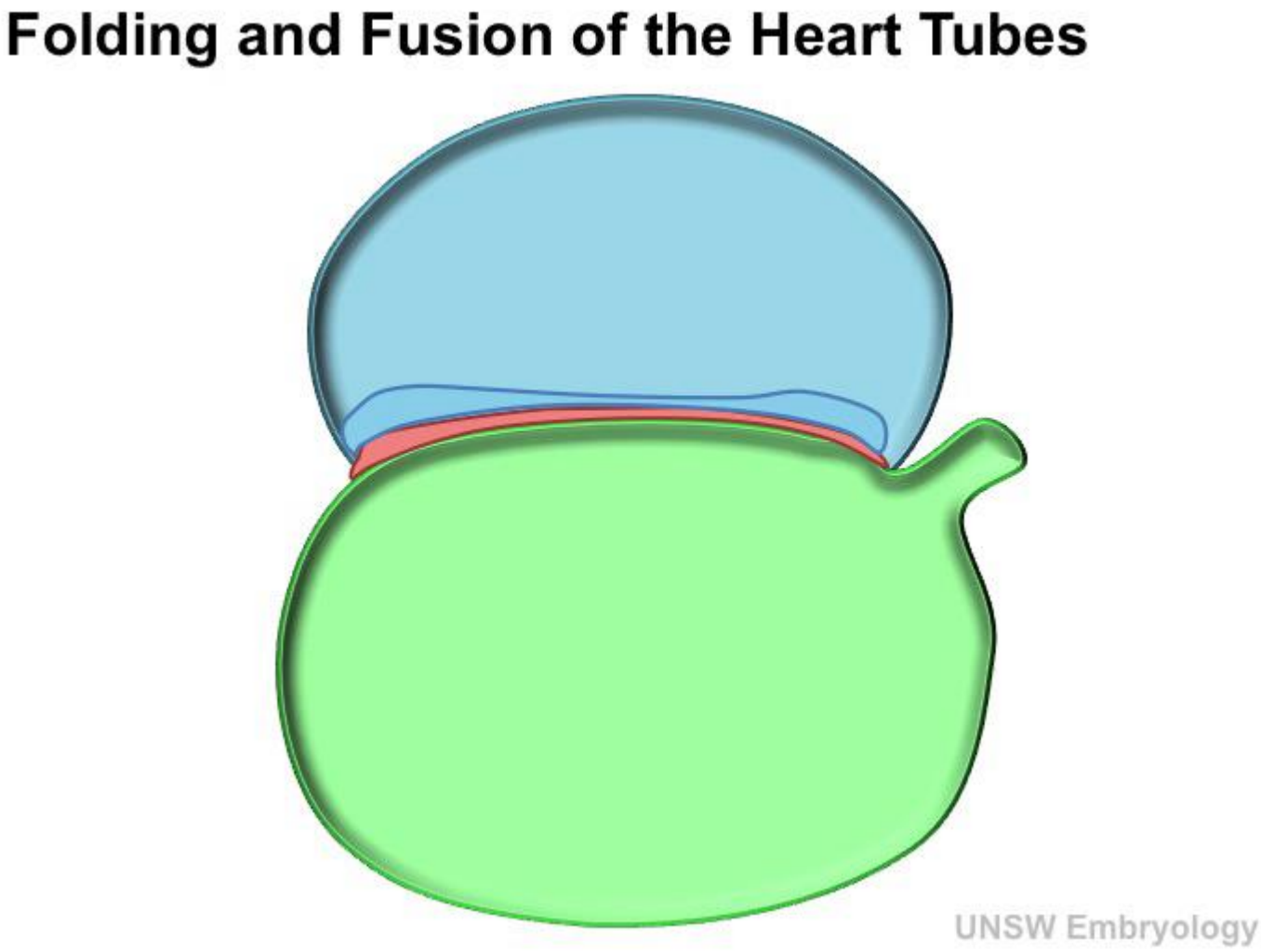
**Week 3**

- paired endocardial **heart tubes** (**cor tubulare duplex**) derived from embryonic splanchnopleura in cardiogenic area
- flexion of the embryo → medial fusion of paired tubes into **simple-tubular heart** (**cor tubulare simplex**)
- visceral mesoderm constitutes **myoepicardial layer**: **myocardium** and **epicardium**
- **cardiac jelly** → subendocardial connective tissue
- heart starts beating day 21-22
- blood starts flow ~week 4th



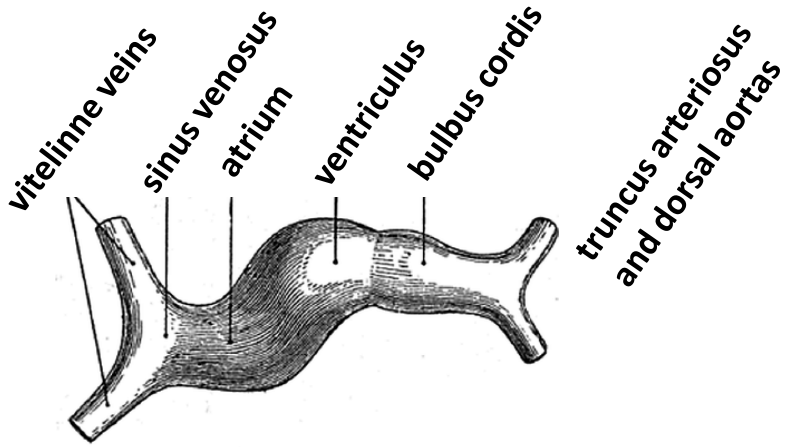
**Week 3-4**



## Week 4

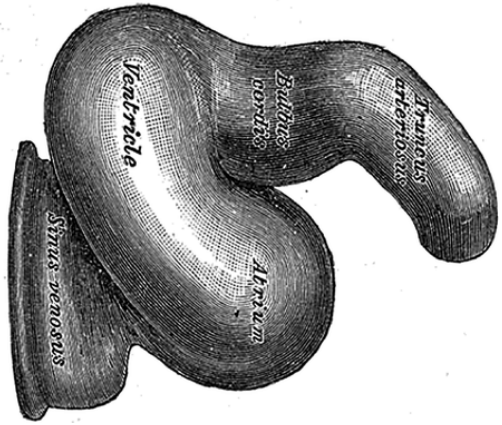
- **simple-tubular heart** (cor tubulare simplex and cor tubulare sigmoideum )
- **sinus venosus → atrium → ventriculus → bulbus cordis→ truncus arteriosus**

**cor tubulare simplex**



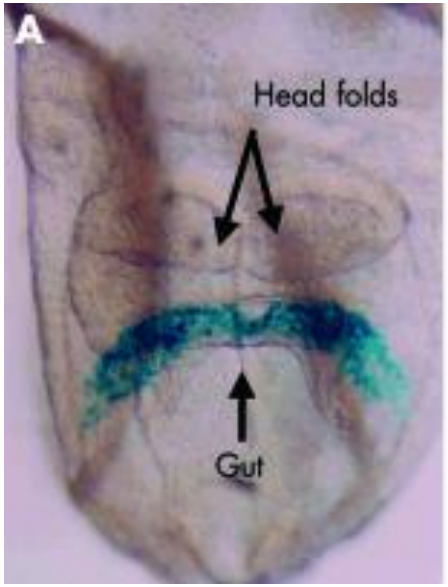

**venous end** **arterial end**

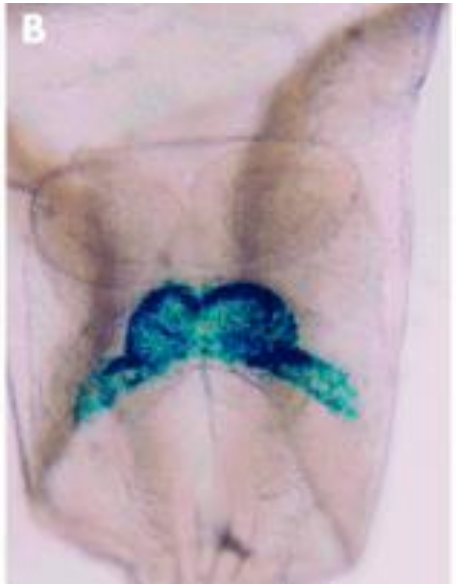
**cor tubulare sigmoideum**

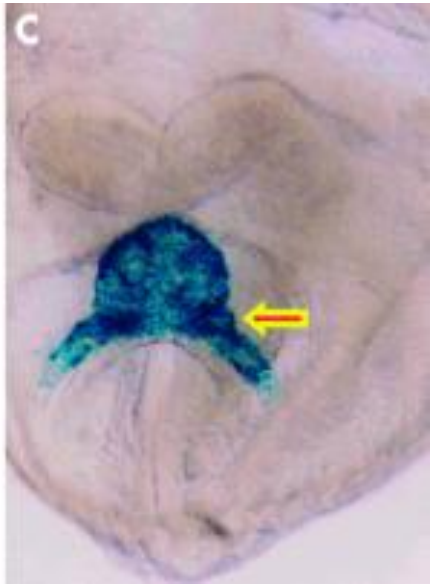


# DEVELOPMENT OF HEART

**fusion of endocardial tubes** and development of simple tubular heart

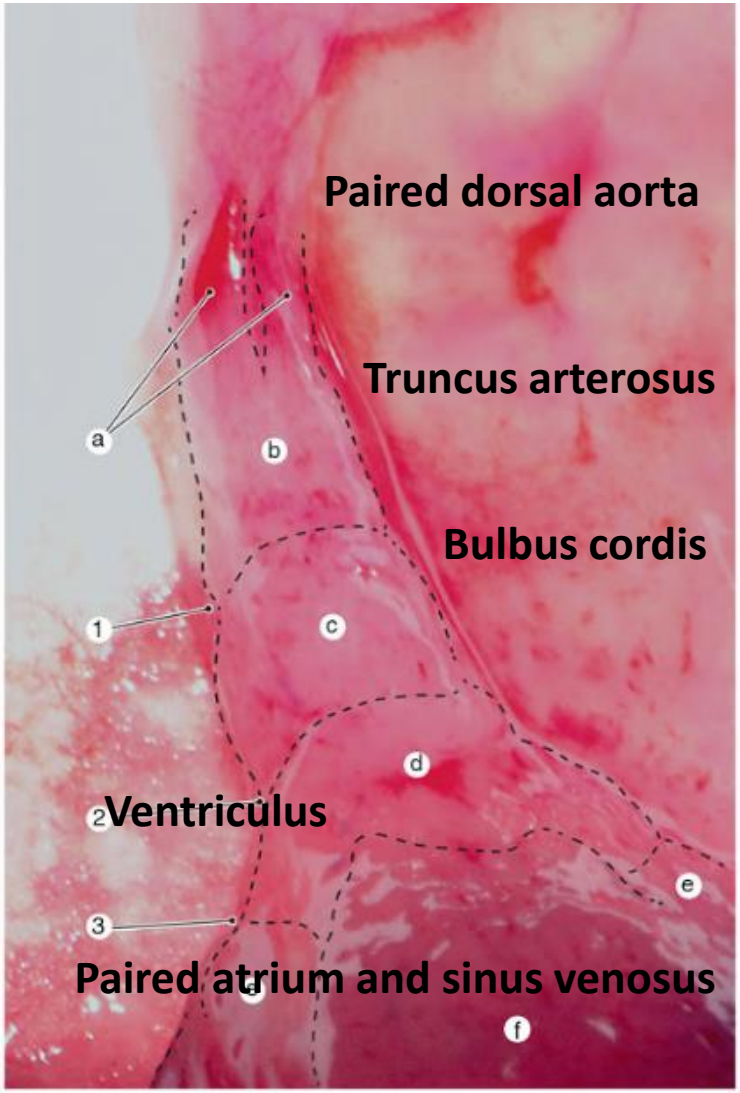


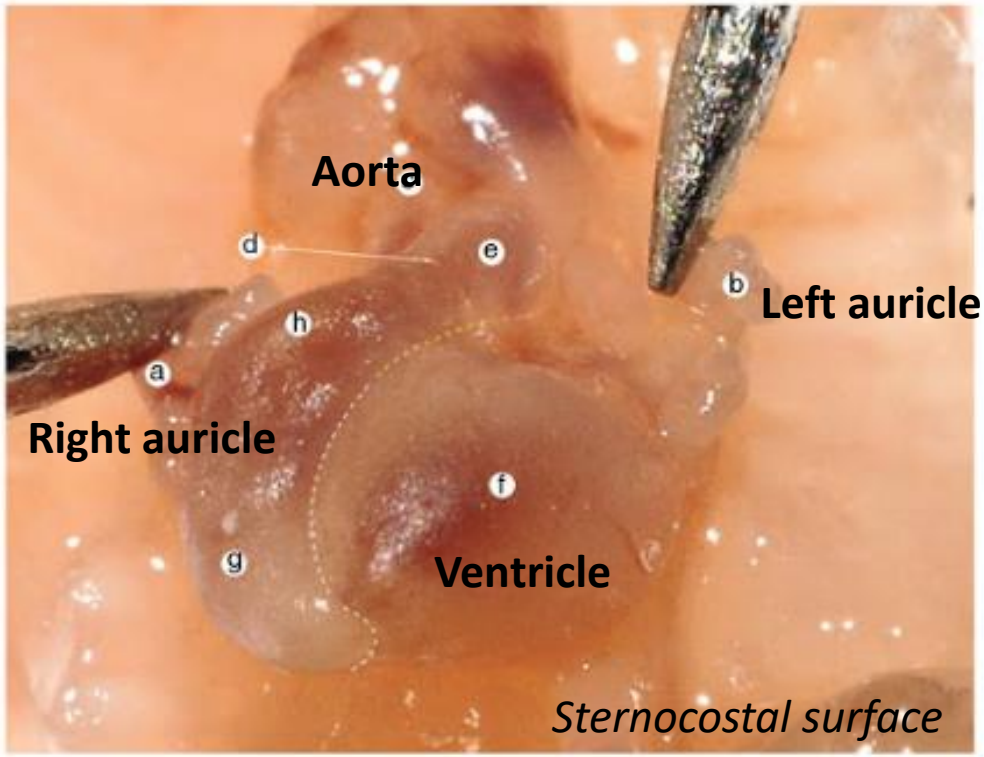

## Week 4

### Cor tubulare simplex

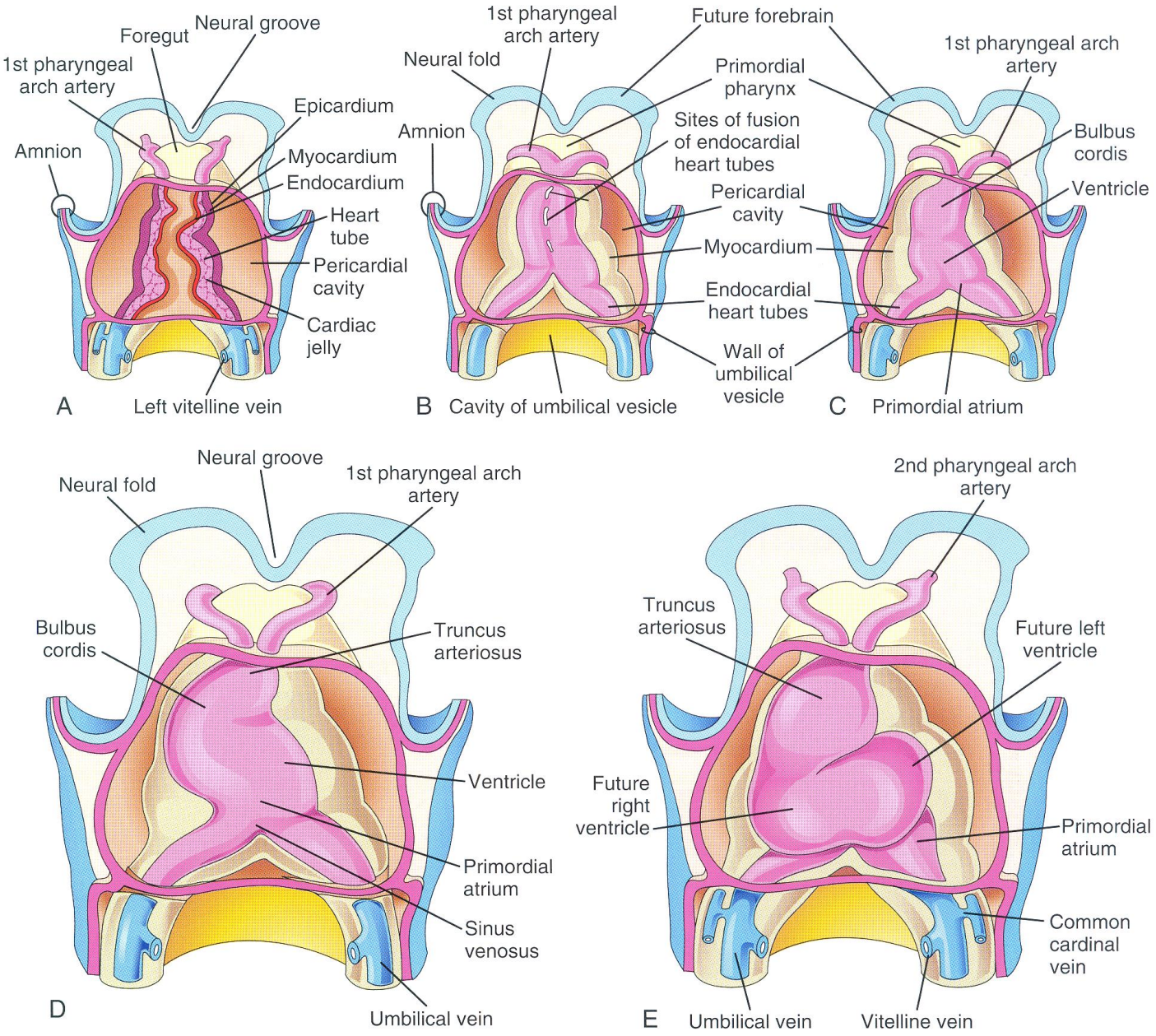



**tubular heart is a genuine anatomical structure**

### Cor tubulare sigmoideum

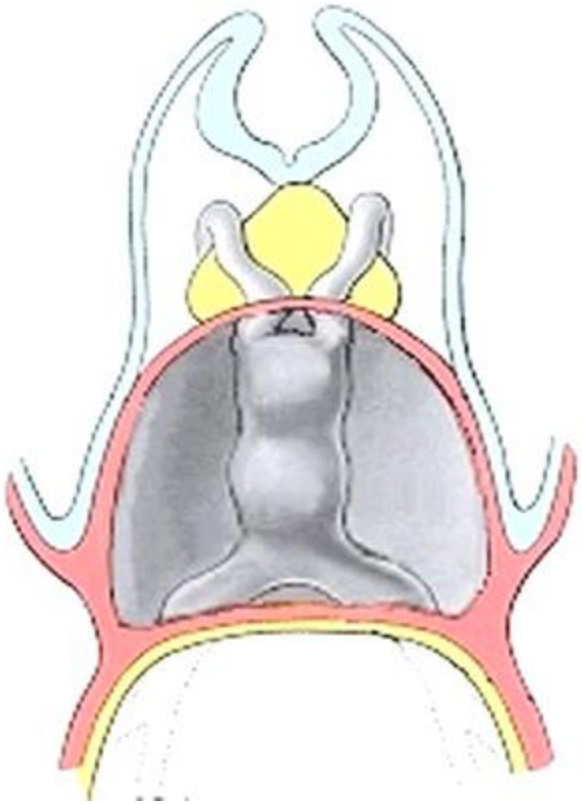


# DEVELOPMENT OF HEART



# DEVELOPMENT OF HEART

**Week 4**

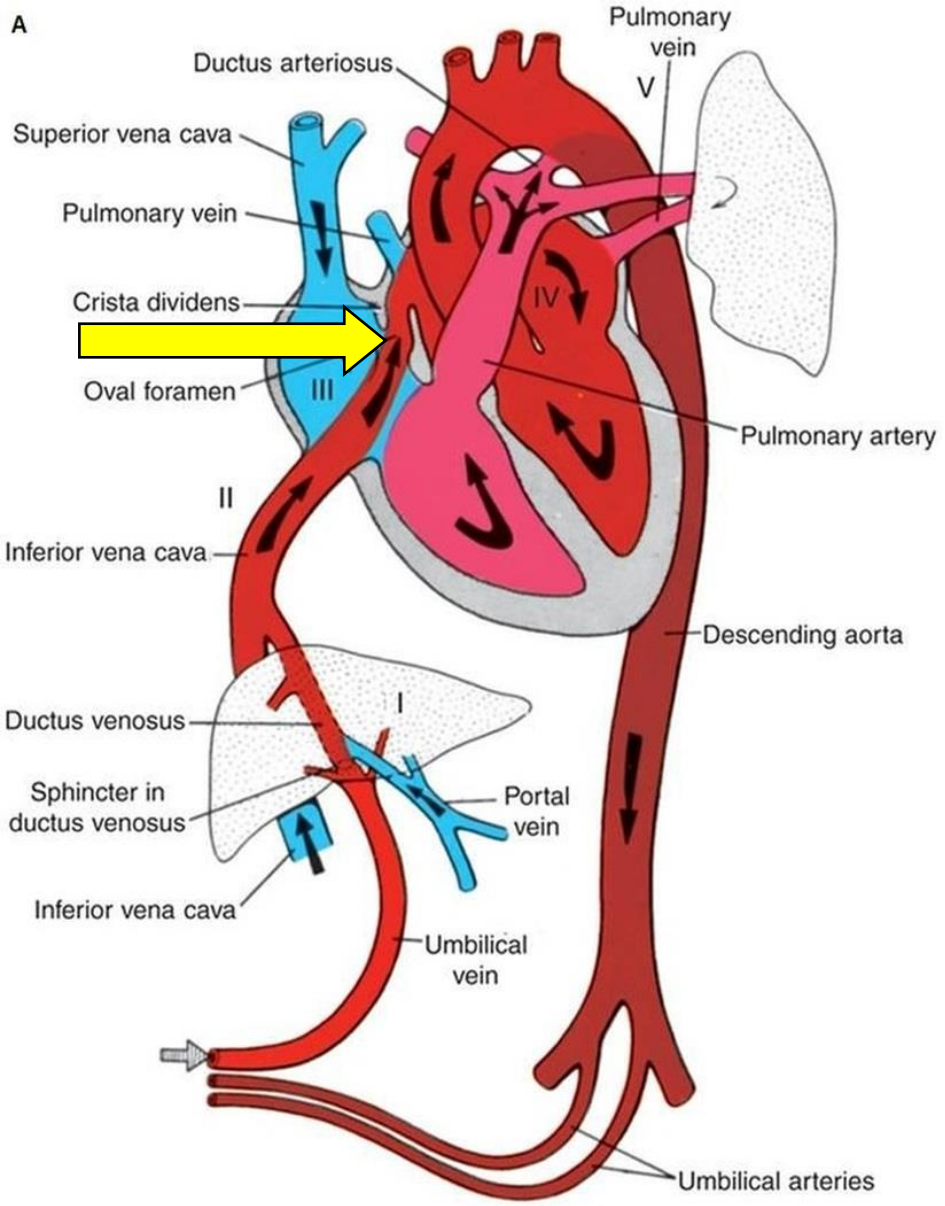


## Partitioning of atrium commune

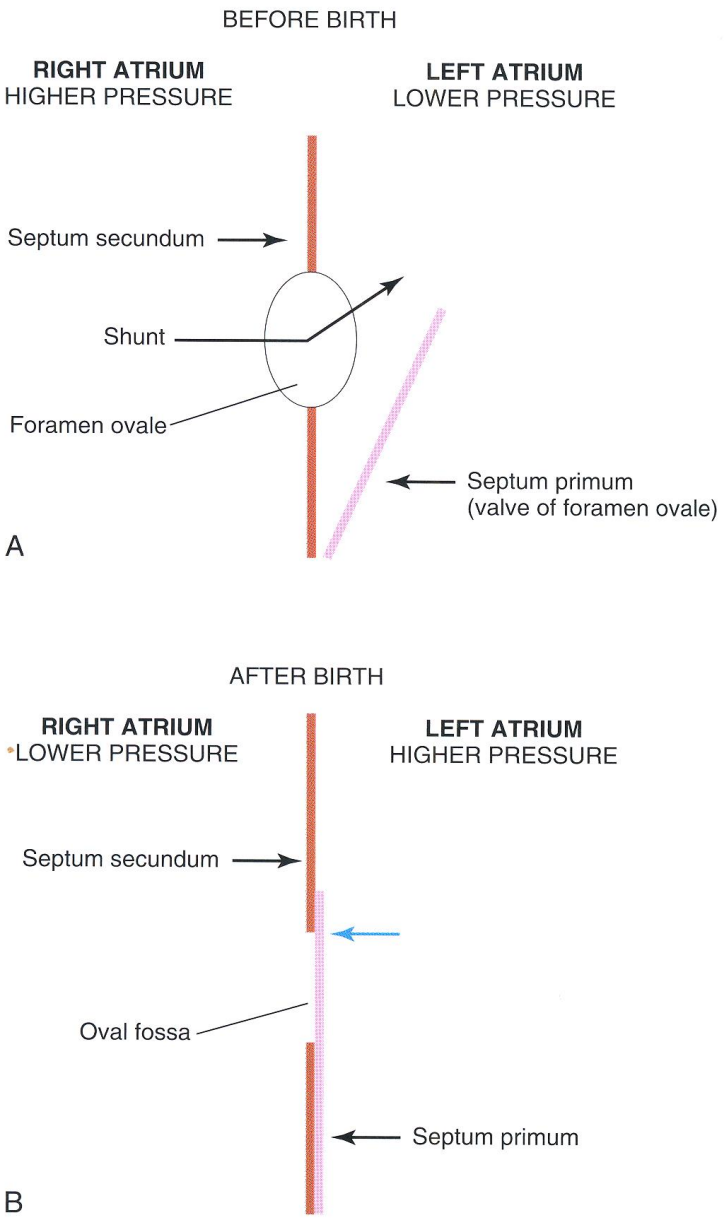
- septum primum grows from dorso-cranial wall towards endocardial cushions
- incoplete closure → **foramen** (ostium) **primum**
- by apoptosis → **foramen secundum**
- **septum secundum** → surrounds **foramen ovale**
- valvula foraminis ovalis from septum primum

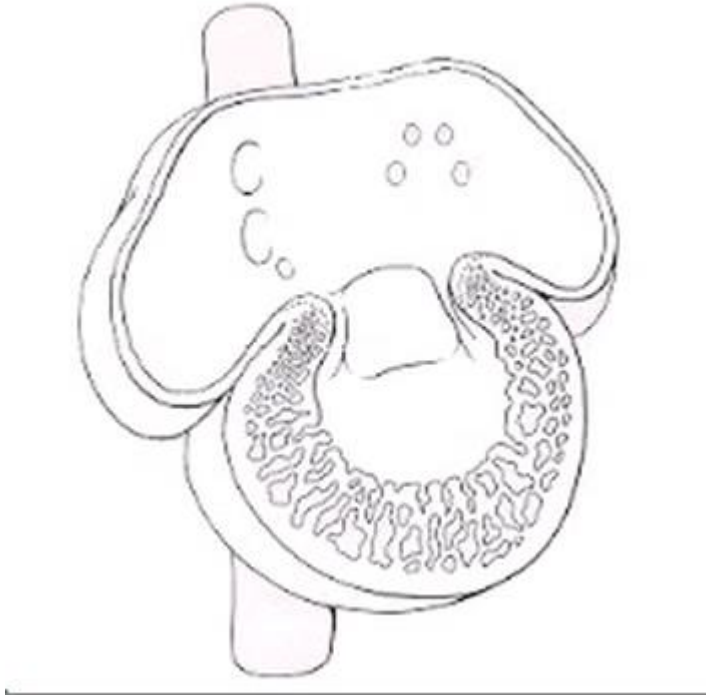
- foramen ovale: crucial embryonic shunt
- foramen ovale patens

- after atrial septation:
- opening of sinus venosus shifts to the right
- rest of sinus venosus → sinus coronarius

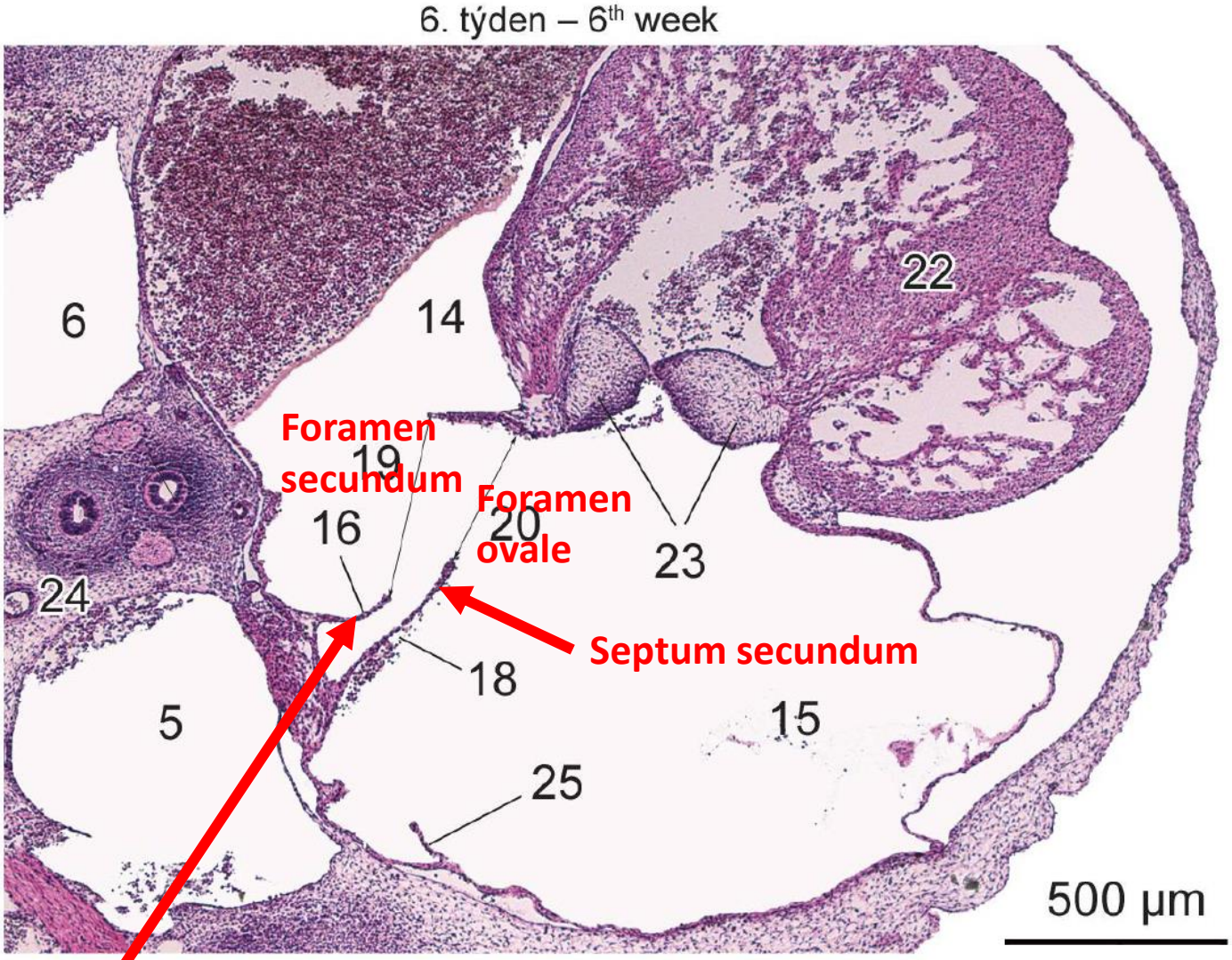


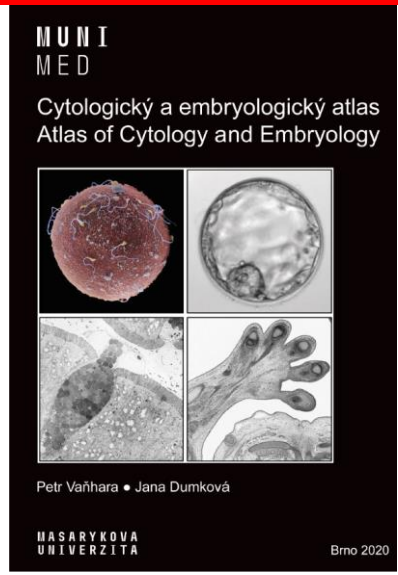
# DEVELOPMENT OF HEART



# DEVELOPMENT OF HEART



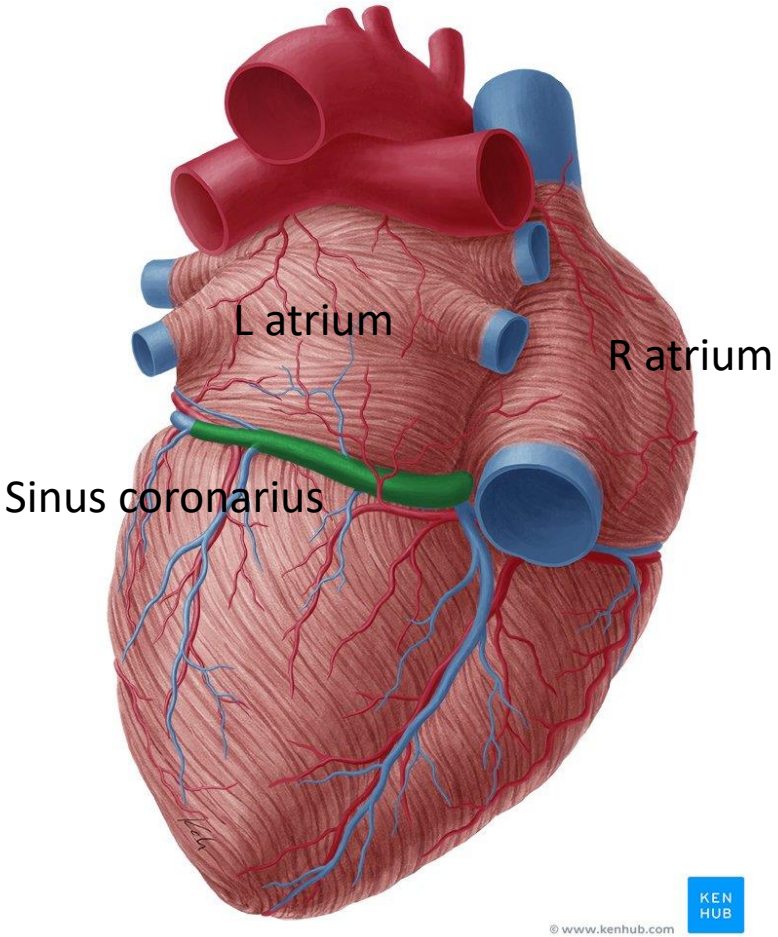


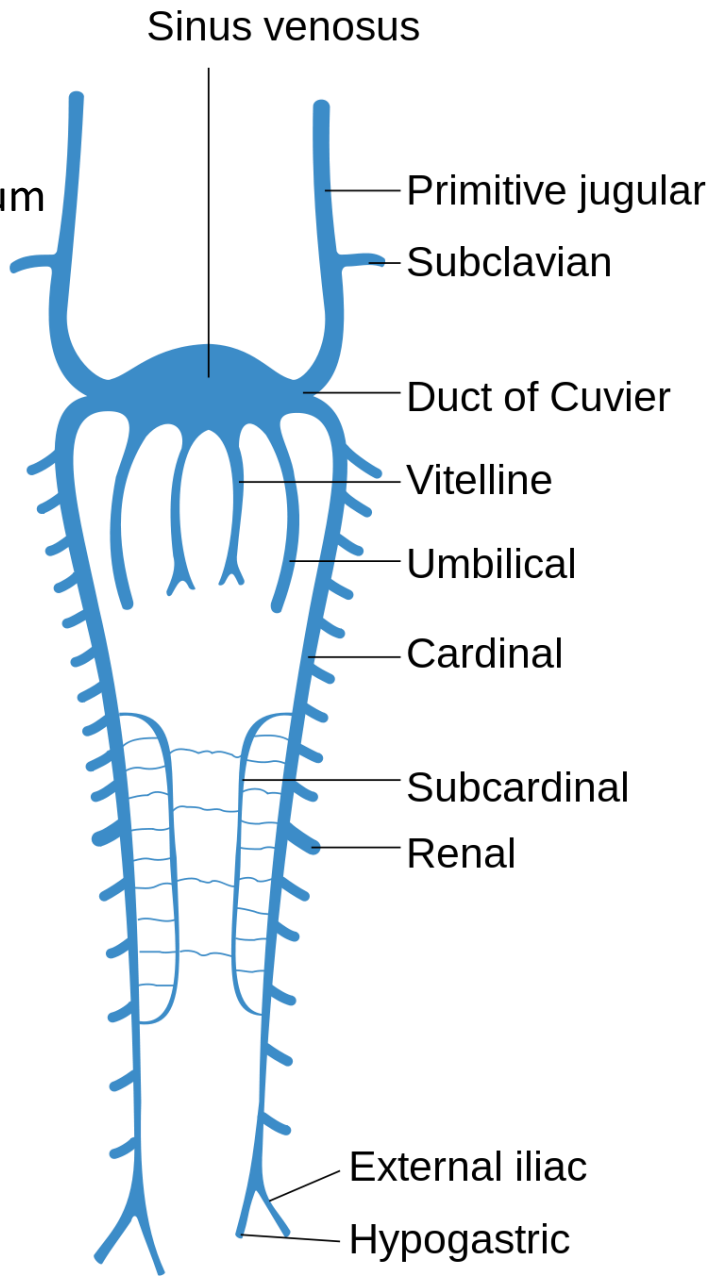

**Vývoj srdce – development of heart.** (1) perikardová dutina – pericardial cavity, (2) *bulbus cordis*, (3) *ventriculus primitivus*, (4) *atrium commune*, (5) *cornu dx. sinus venosus*, (6) *cornu sin. sinus venosus*, (7) dorsal aortae, (8) *truncus arteriosus*, (9) *conus cordis*, (10) základ pravé komory – developing right ventricle, (11) budoucí 1. faryngová arterie (aortální oblouk) – developing 1st pharyngeal artery (aortic arch), (12) *sulcus bulboventricularis*, (13) základ levé komory – developing left ventricle (14) *atrium sin.*, (15) *atrium dx.*, (16) *septum primum*, (17) *foramen* (*ostium*) *primum*, (18) *septum secundum*, (19) *foramen* (*ostium*) *secundum*, (20) *foramen ovale*, (21) *foramen interventriculare*, (22) *septum interventriculare*, (23) endokardové polštářky (návalky) – endocardial cushions, (24) *mediastinum*, (25) venózní chlopeň – venous valve.

# DEVELOPMENT OF HEART

- **sinus venosus** during atrial septation:

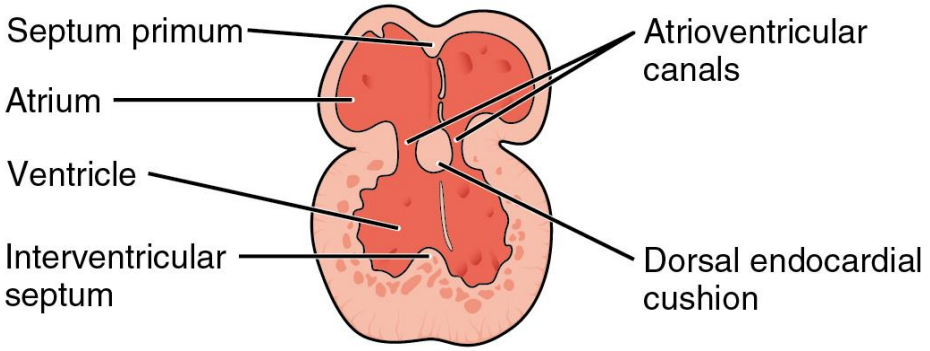
- shift of sinus venosus opening to the right → right atrium
- left part sinus venosus is separated → sinus coronarius



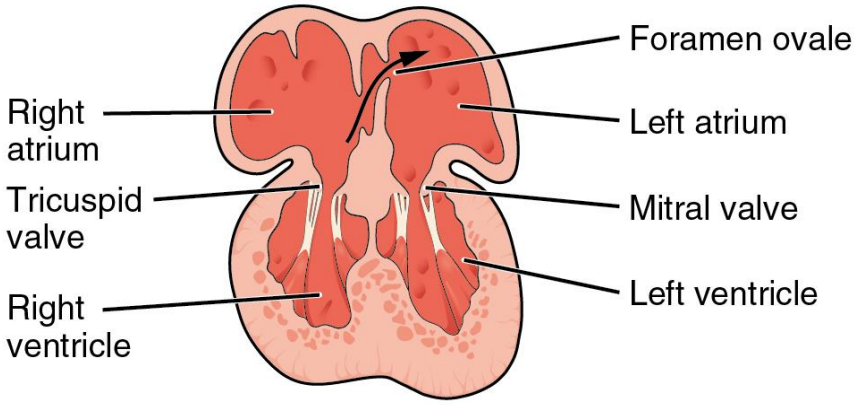



## Partitioning of ventriculus communis

- septum interventriculorum primitivum – temporary
- septum interventriculare at the end of week 4 – grows cranially
- foramen interventricualre – closure linked to development of aortico-pulmonary septum
- pars membranacea (septi interventricularis)
- pars muscularis (septi interventricularis) - medial walls of both ventricles




28 days

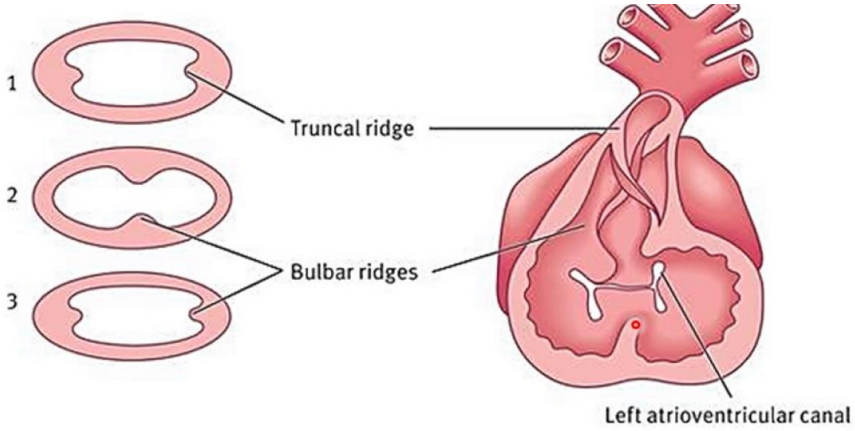


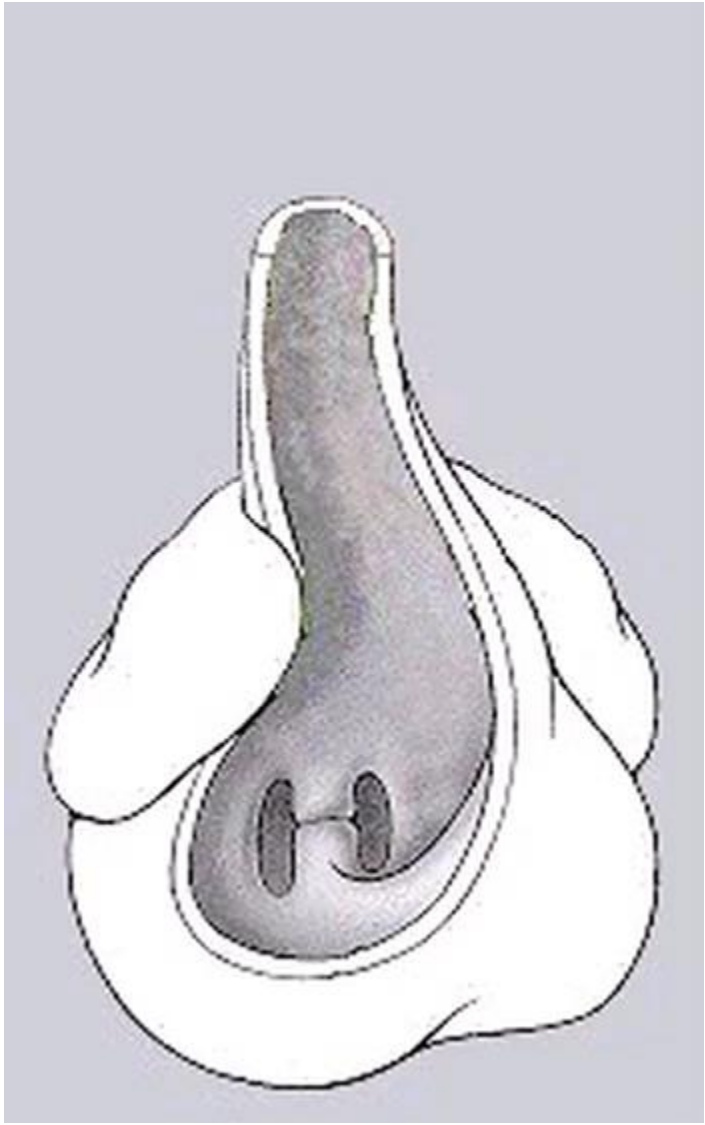

8 weeks

# DEVELOPMENT OF HEART

- **Partitioning of bulbus cordis and truncus arteriosus**
- 5th week – ridges in bulbus and truncus from neural-crest mesenchyme
- 180° spiraling – spiral aortico-pulmonary septum
- pulmonary trunk twists around aorta

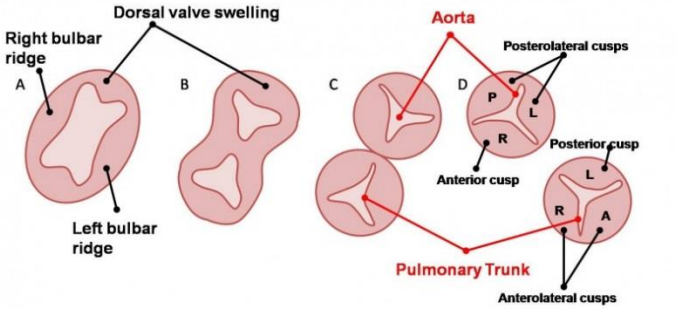
- bulbus cordis is embedded into the definitive ventricles:
- right ventricle: conus arterious (infundibulum) → pulmonary trunk
- left ventricle: aortic vestibule

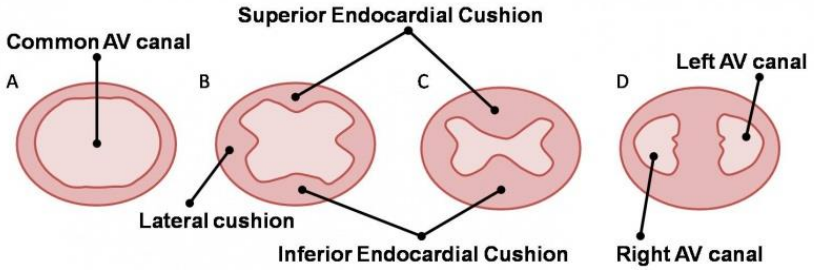


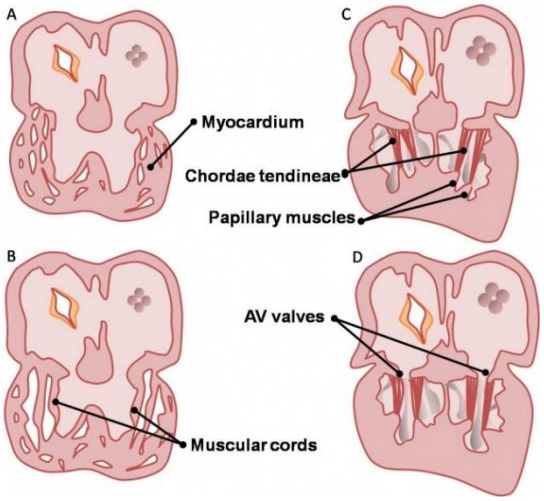



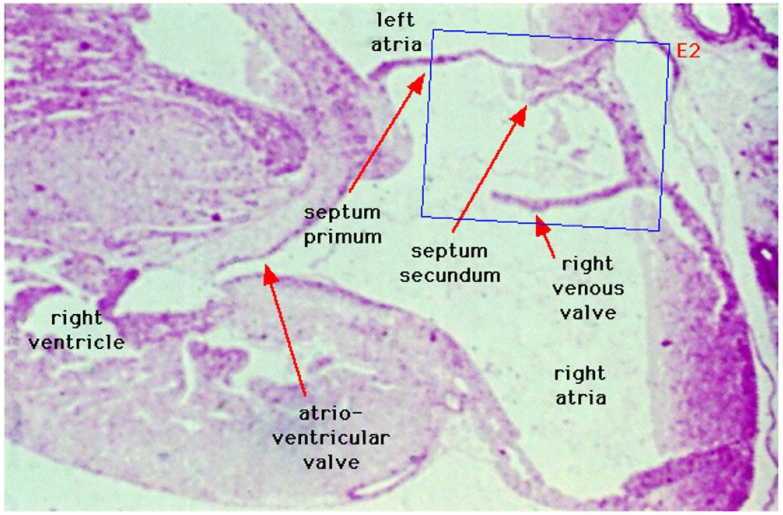
- **Development of cardiac valves**

- **semilunar valves** develop by the partitioning of truncus arteriosus from three swellings of endocardial tissue
- neural crest origin
- **AV valves** (tricuspid and mitral) develop similarly at AV canals

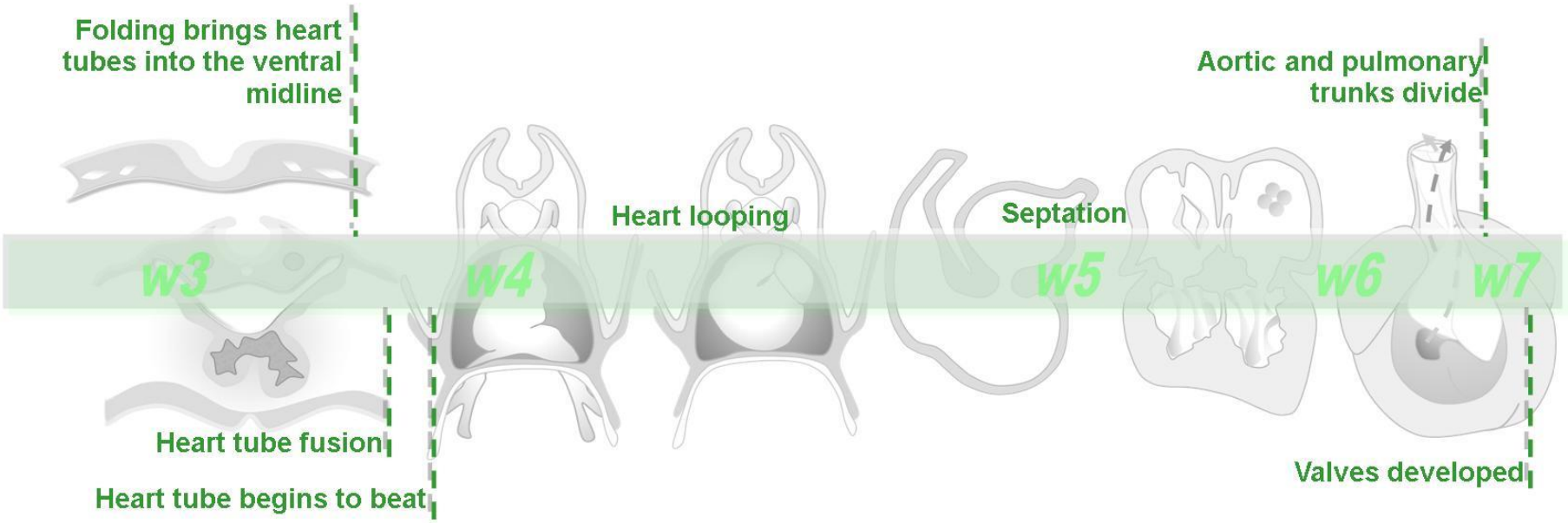


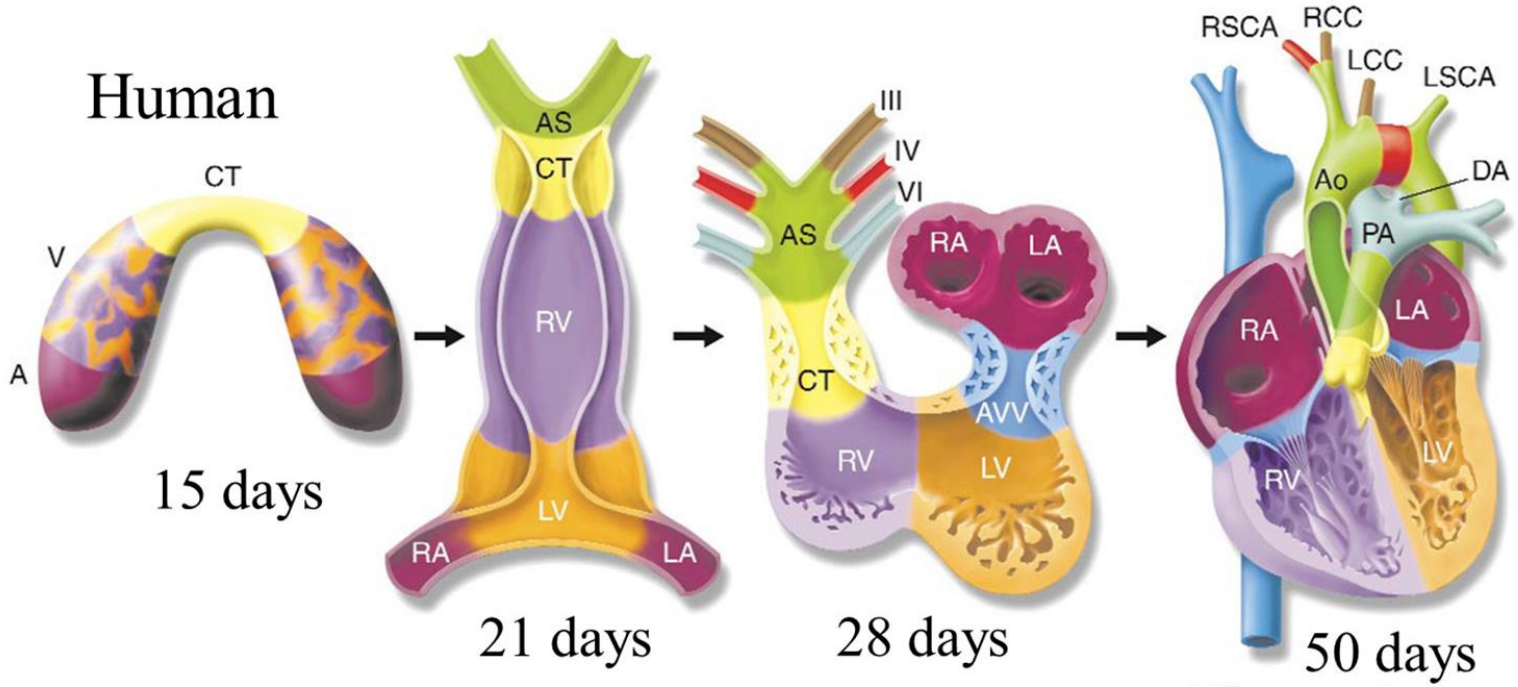



# DEVELOPMENT OF CARDIOVASCULAR SYSTEM

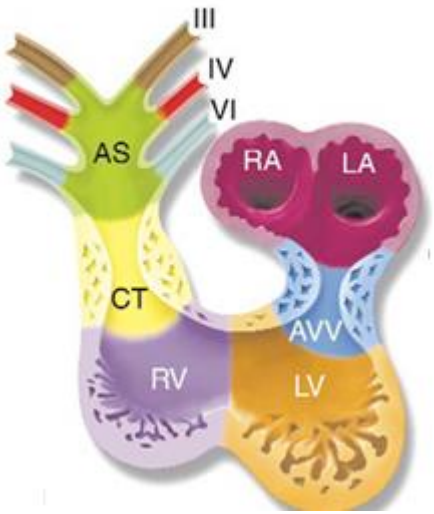


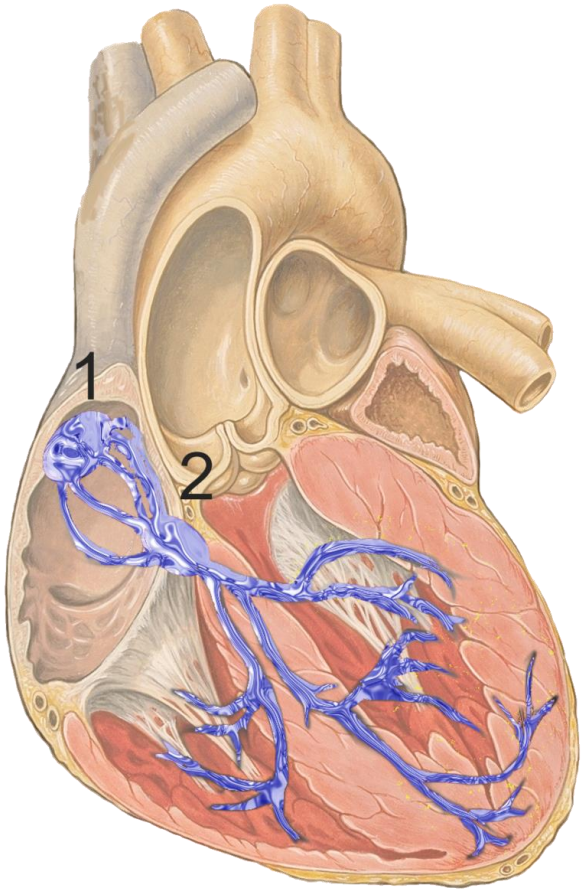



## Development of conductive heart system

Definitive conductive heart system provides the electrical conduction between atria and ventricles

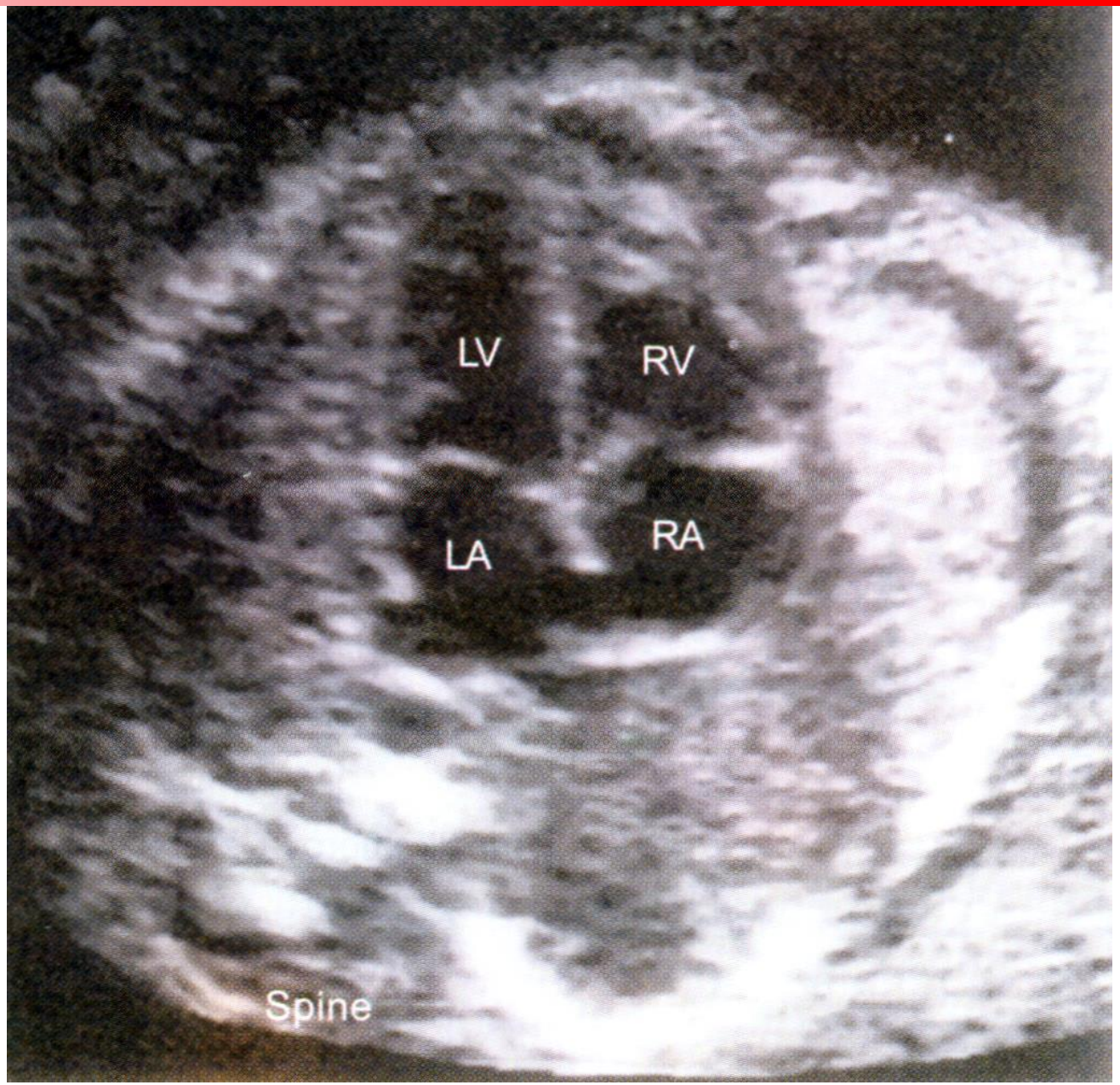
- First are all muscle layers are connected
- Primitive atrium – primary pacemaker
- SA node in 5th weeks from tissues of sinus venosus
- Cells of interatrial and atrioventricular septa contribute to formation of AV node and fasciculus atrioventricualris → bundle branches → ventricular myocardium



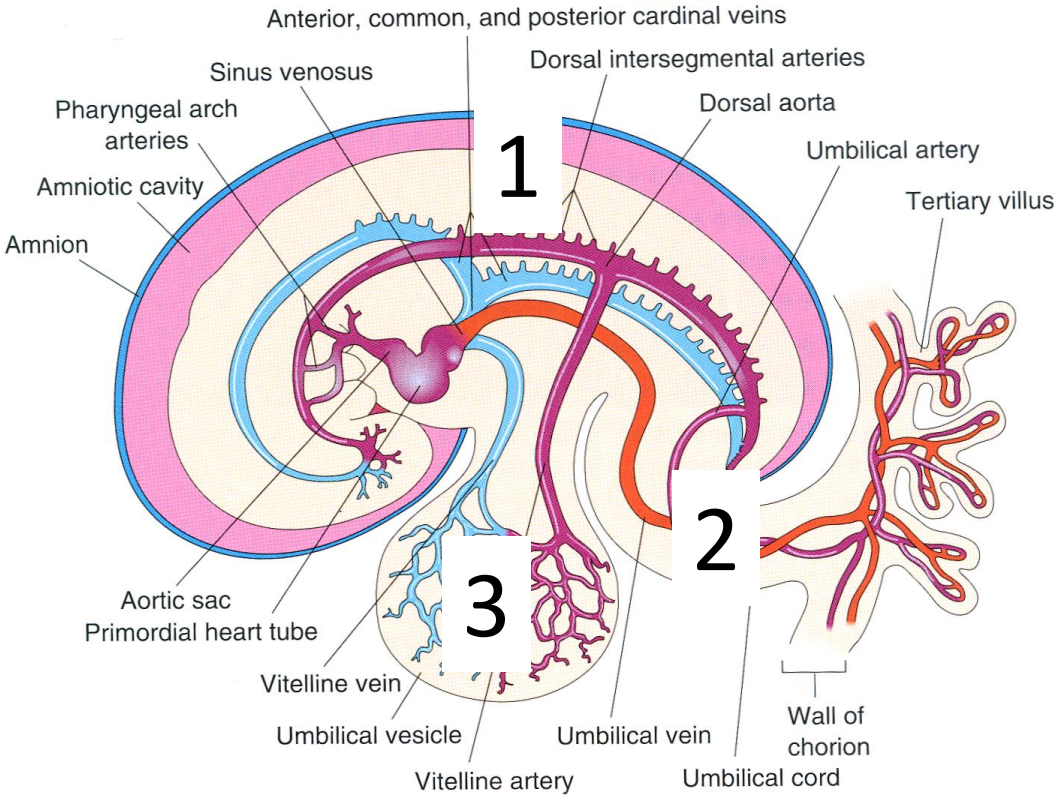
# DEVELOPMENT OF HEART

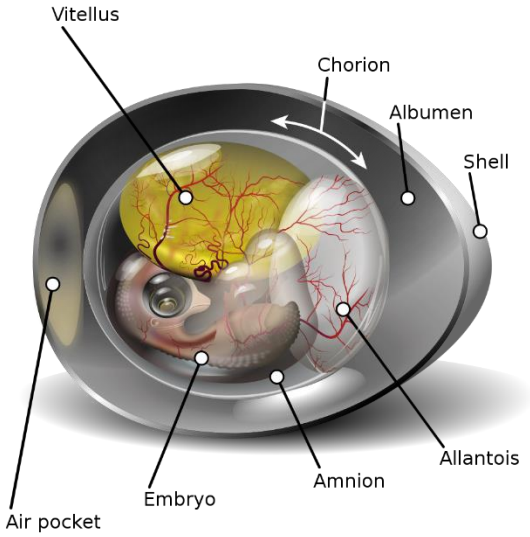
**Week 20**

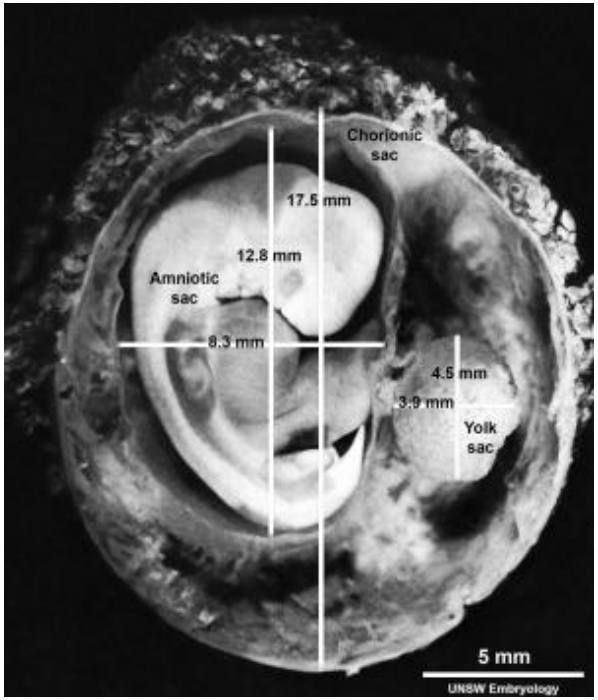


# DEVELOPMENT OF CARDIOVASCULAR SYSTEM

## Week 4

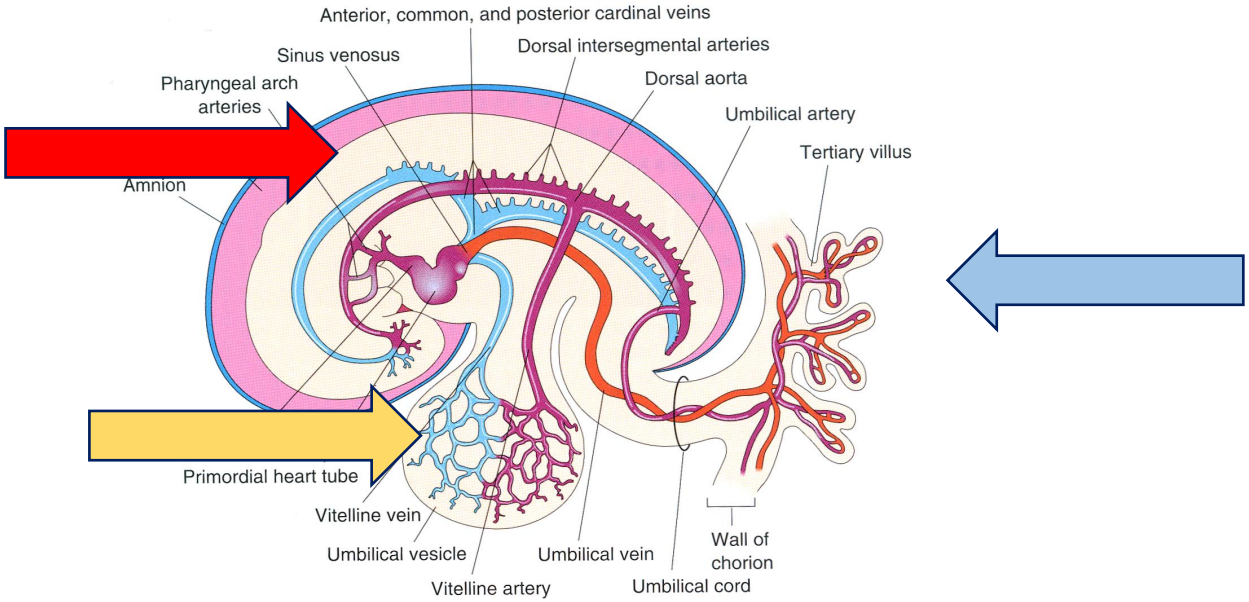


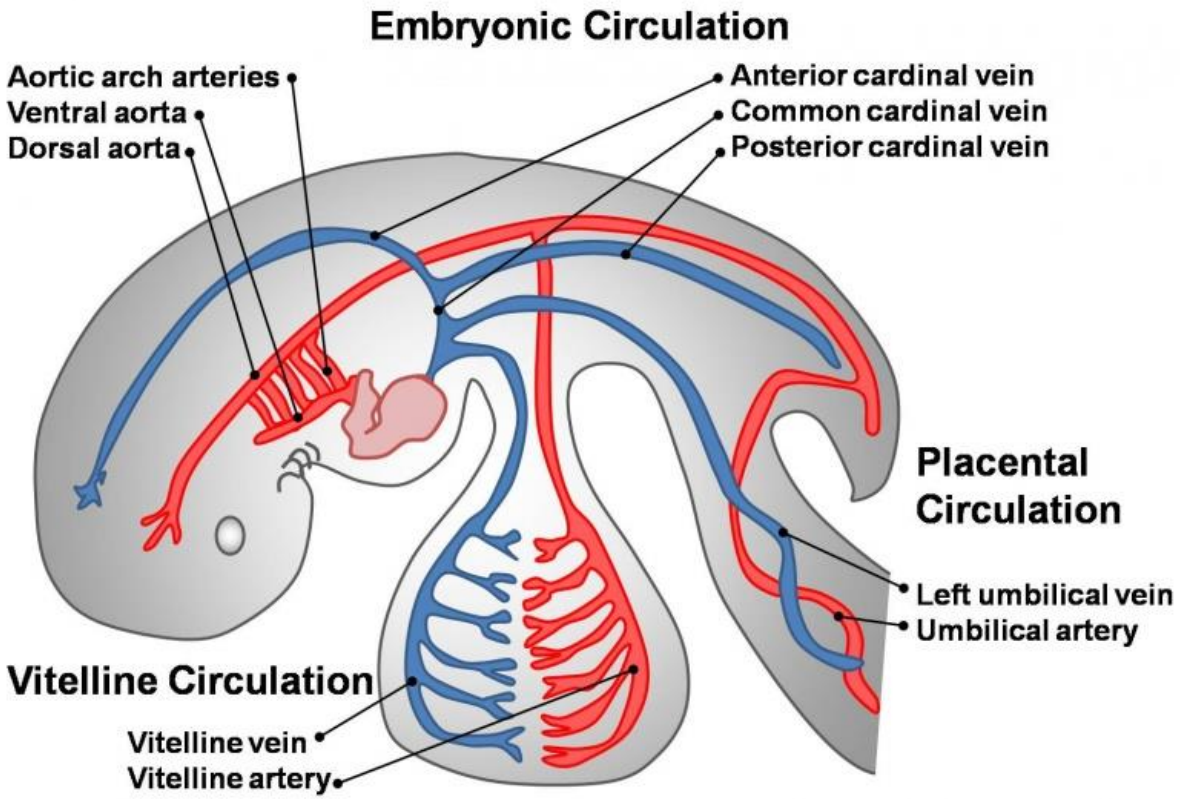



## Week 4

- **embryonic circulation**: heart tube → *truncus arteriosus* → aortal arches → paired dorsal aorta → caudally fuse into single aorta dorsalis → capillary beds → paired cardinal veins (drain pre- and postcardinal veins) → *ductus Cuvieri* → *sinus venosus*
- **vitelline circulation**: dorsal aorta → *aa. omphalomesentericae* → fuse into single *a. omphalomesenterica* → *vv. omphalomesentericae + vv. umbilicales* → paired *truncus vitelloumbilicalis* → *sinus venosus*
- **umbilical circulation**: dorsal aorta → *aa. umbilicales* → chorion → *vv. umbilicales* + *vv. omphalomesentericae* → paired *truncus vitelloumbilicalis* → *sinus venosus*



# Arteries


Embryonic Circulation
Aortic arch arteries
Ventral aorta
Dorsal aorta
Anterior cardinal vein
Common cardinal vein
Posterior cardinal vein
Placental Circulation
Left umbilical vein
Umbilical artery
Vitelline Circulation
Vitelline vein
Vitelline artery

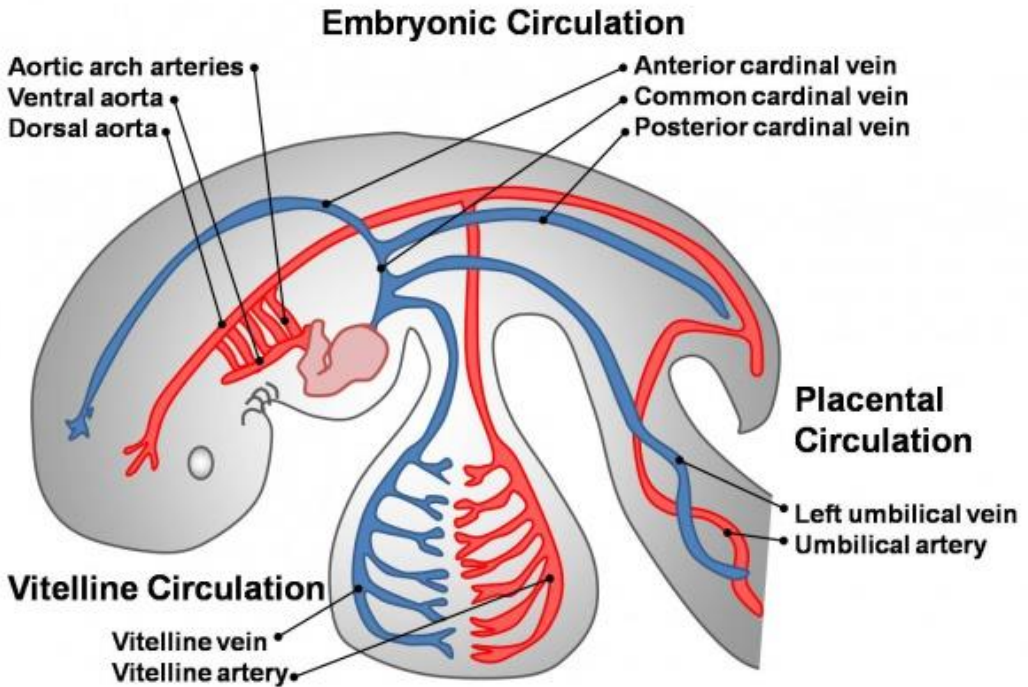
# DEVELOPMENT OF ARTERIES

## Dorsal aorta

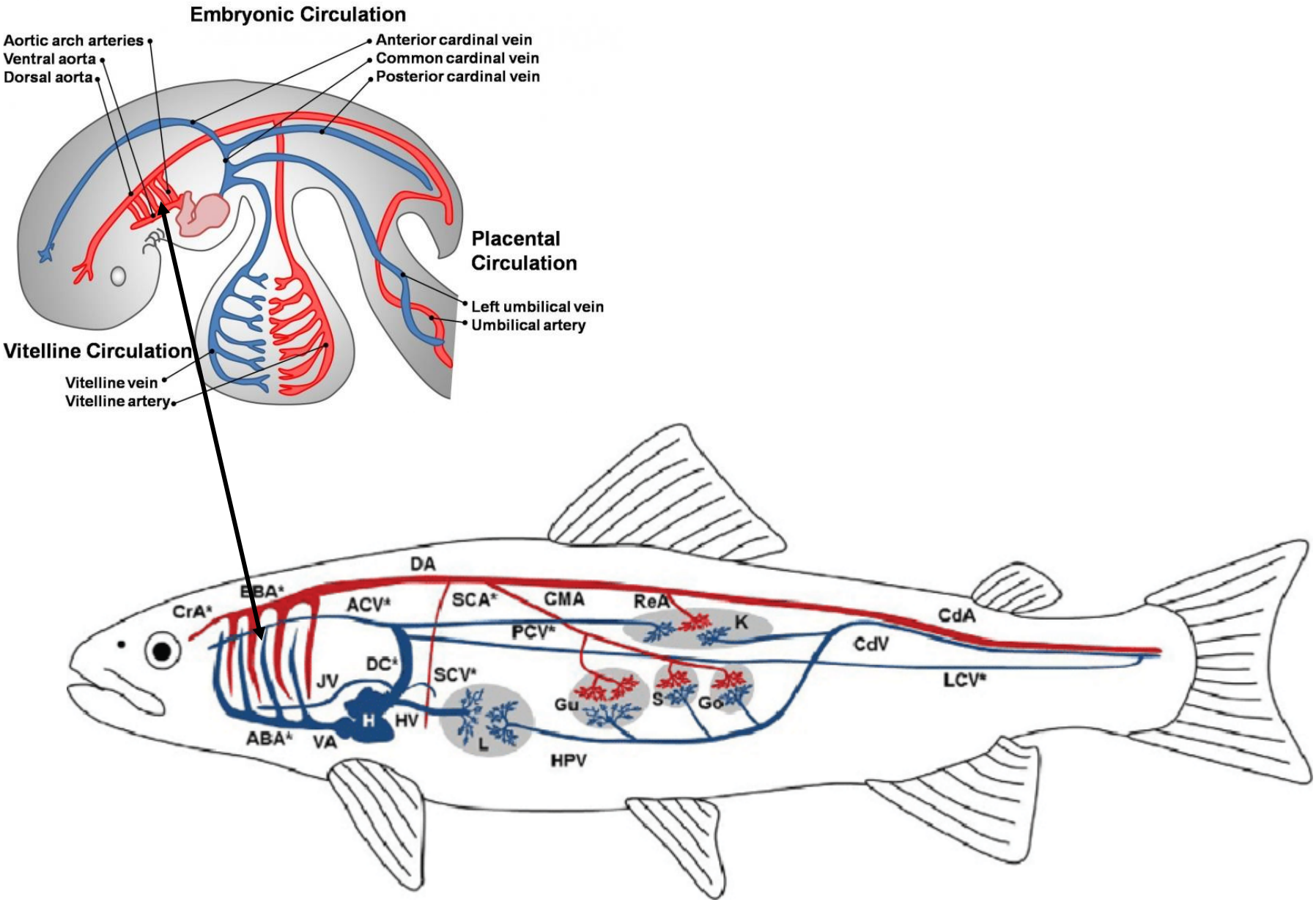
- originally a paired structure - fusion into a single dorsal aorta → a. descendens
- aortal arches

## Ventral aorta

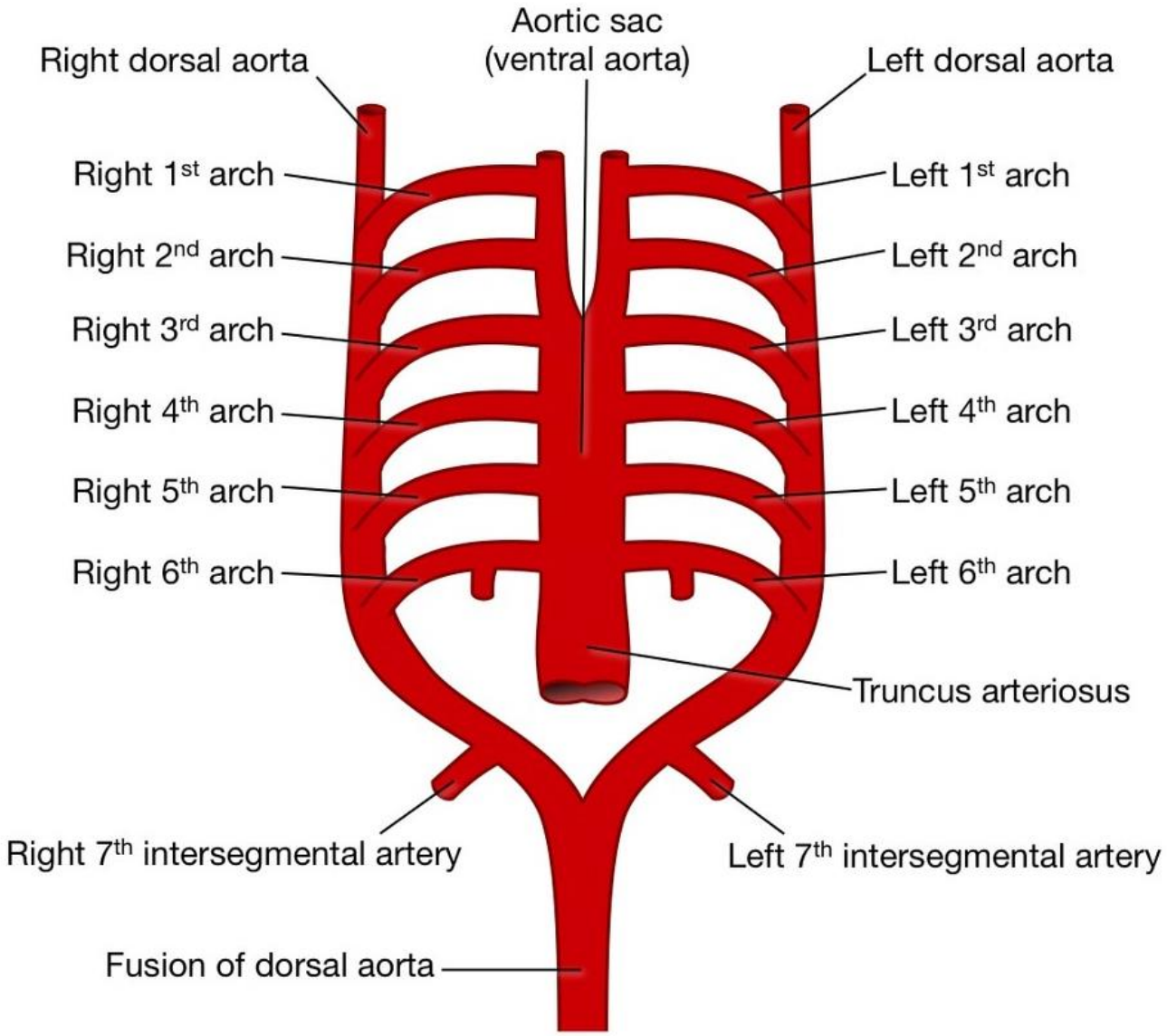
- originally a paired structure
- fusion into the aortic cas when embryo folds



# DEVELOPMENT OF ARTERIES

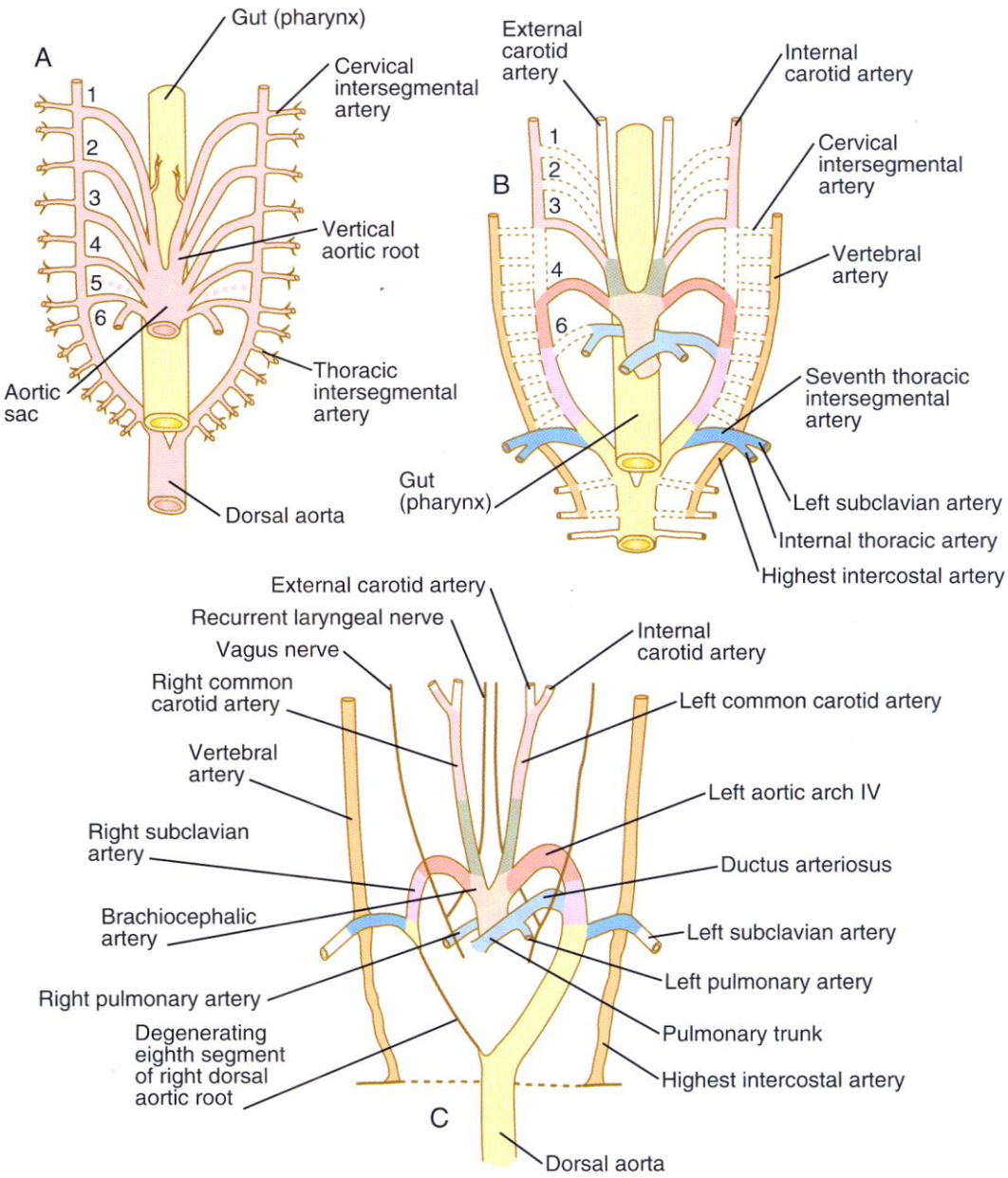


## Development of large arteries – aortic arches



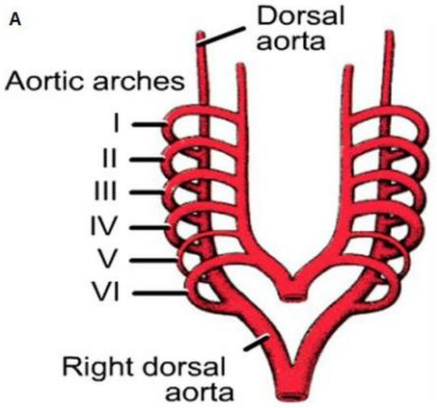
# DEVELOPMENT OF ARTERIES

## Aortic arches



# DEVELOPMENT OF ARTERIES

## Aortic arches




1 mostly disappears, **a. maxillaris**

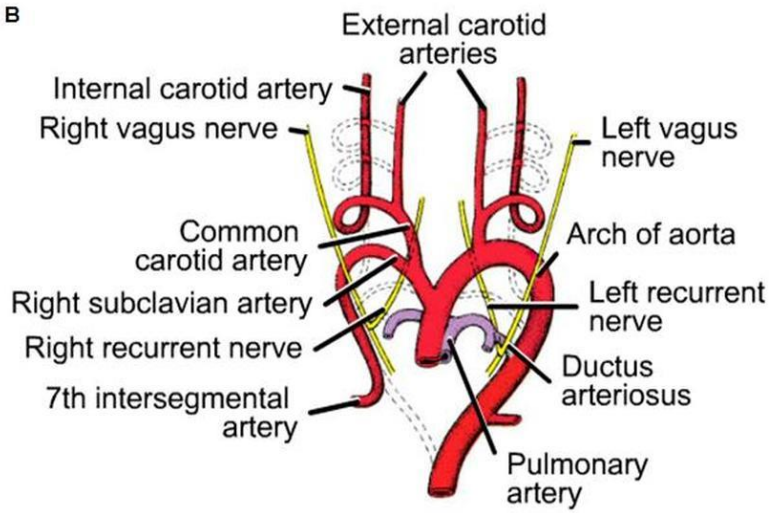
2 mostly disappears, **a. stapedia** and **a. hyoidea**

3 proximal parts **aa. carotides communes**, distal parts of **aa. carotides internae**

4 right: proximal part of **a. subclavia dextra** (distal part from dorsal aorta and 7th intersegmental artery);
left: **arcus aortae** (aorta develops from aortic sac and left dorsal aorta)

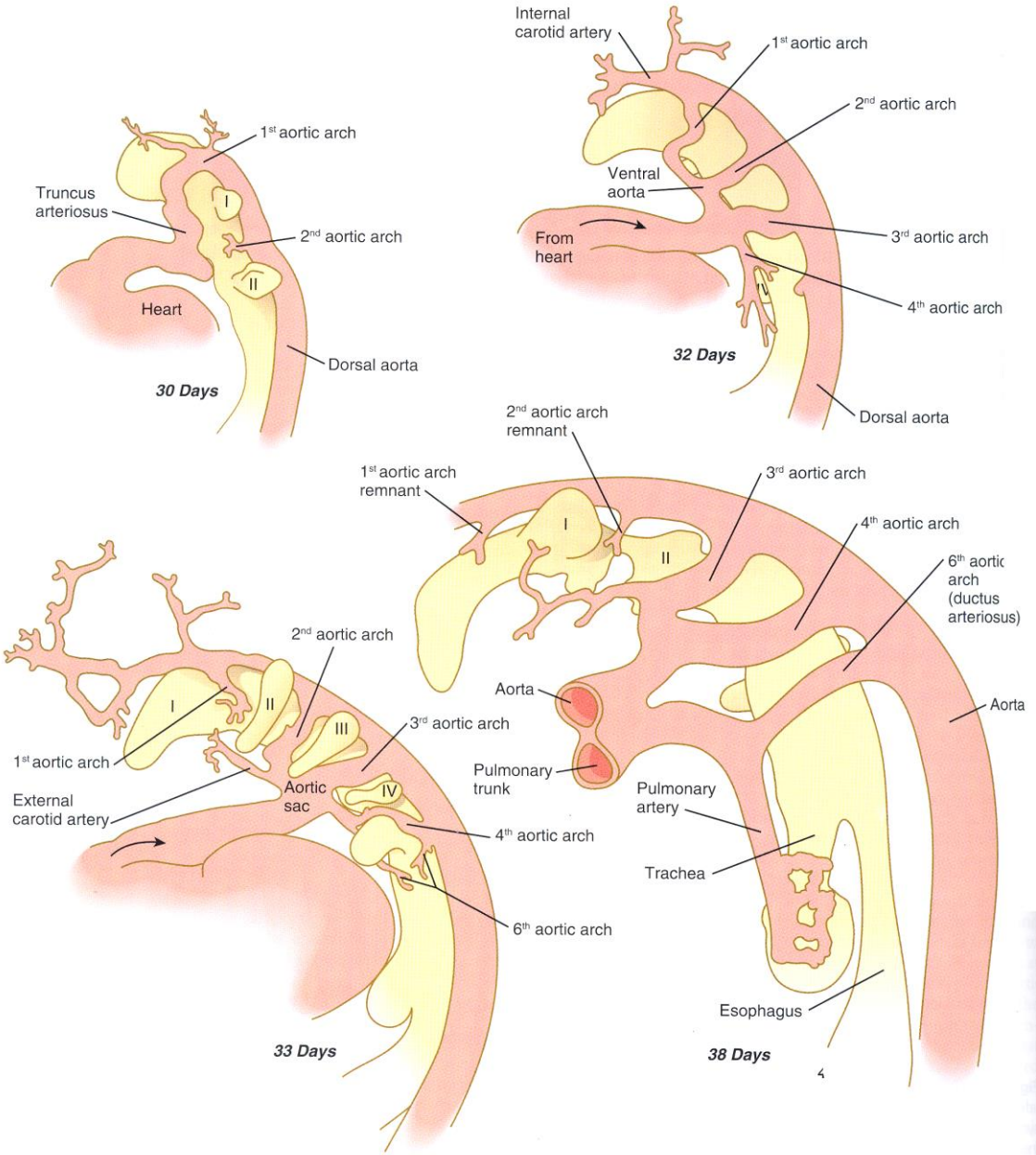
5 does not develop or quickly degenerates

6 right: from proximal part: **a. pulmonalis dextra**, distal part disappears
left: from proximal part: **a. pulmonalis sinistra**, from distal part: **ductus arteriosus**.



# DEVELOPMENT OF ARTERIES

## Aortic arches



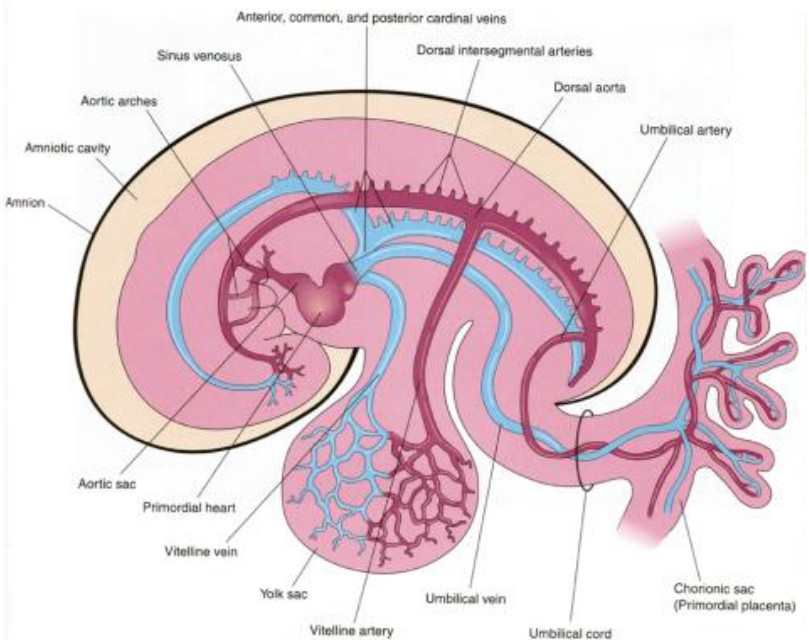
# DEVELOPMENT OF ARTERIES

## Branches of dorsal aorta

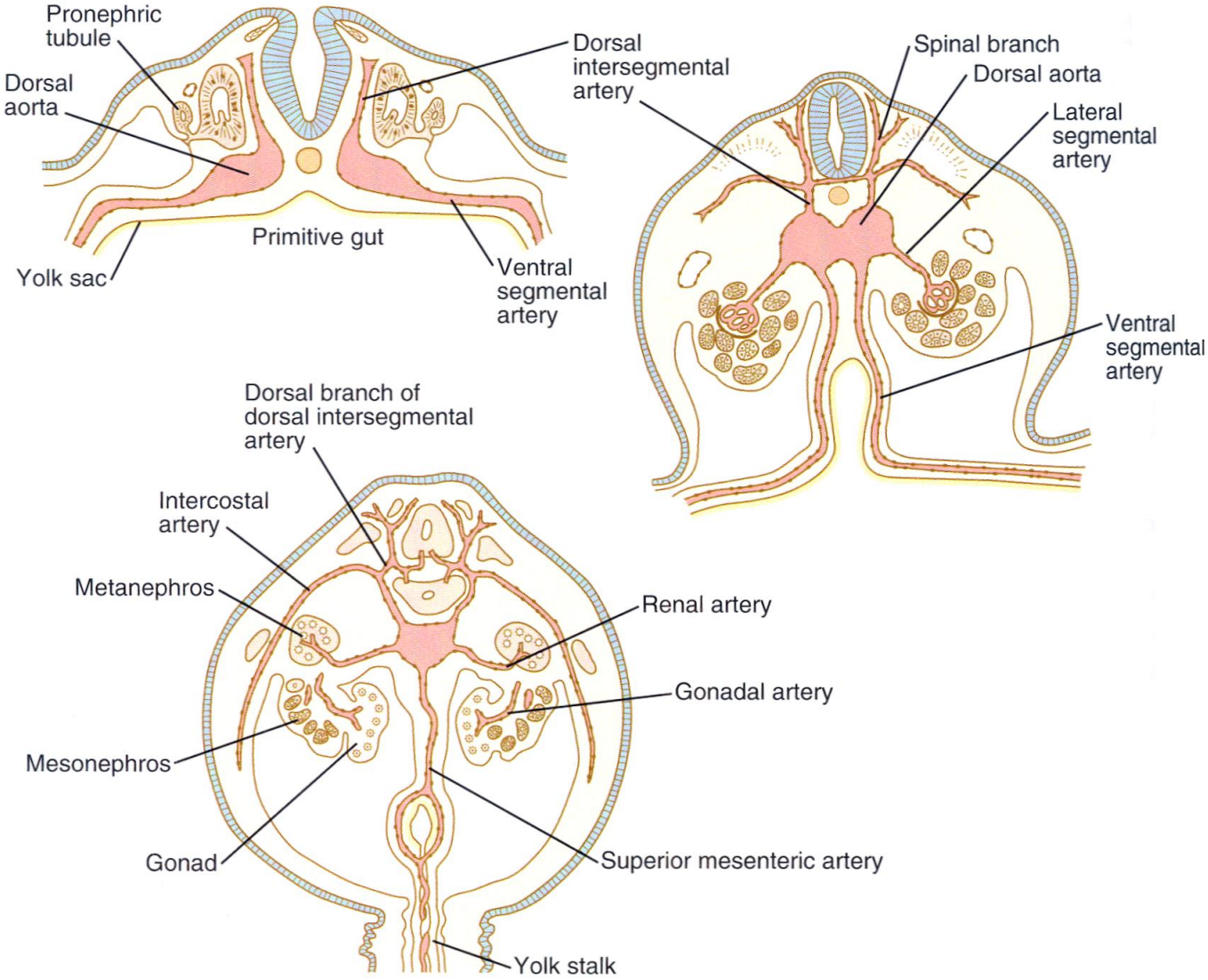
- **intersegmental arteries** (parietal, dorsal) a **visceral** (ventral, towards primitive gut)

- arteries between somites
- vascularisation of somites and their derivatives
- intersegmental arteries are precursors for:
  - neck → **a. vertebralis**
  - chest → **aa. intercostales**
  - abdomen → **aa. lumbales**
  - sacral → **aa. sacrales laterales**
- part of 7th intersegmental artery → **a. subclavia dx**.
- caudal end of dorsal aorta → **a. sacralis media**

- **truncus coeliacus**
- **a. mesenterica superior**
- **a. mesenterica inferior**

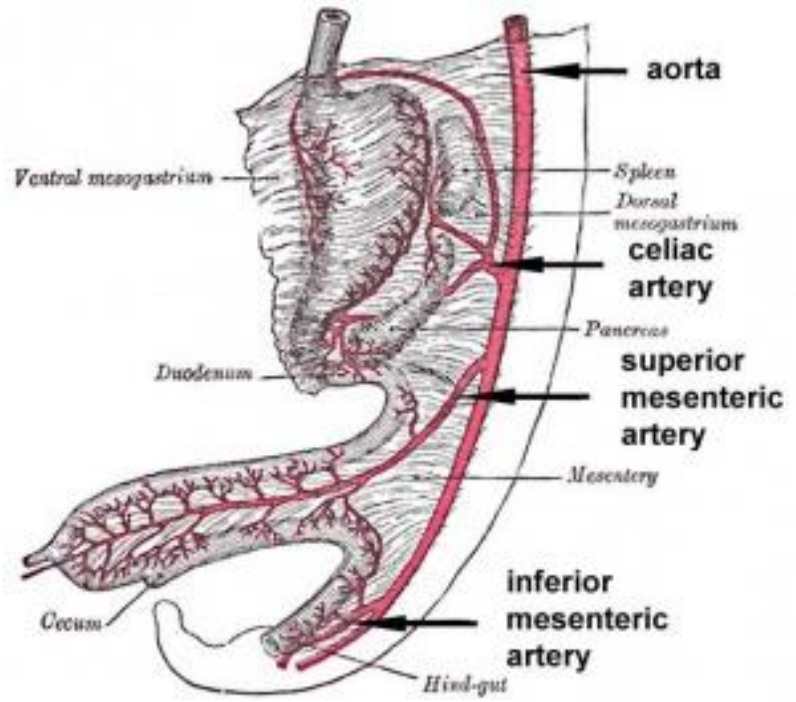


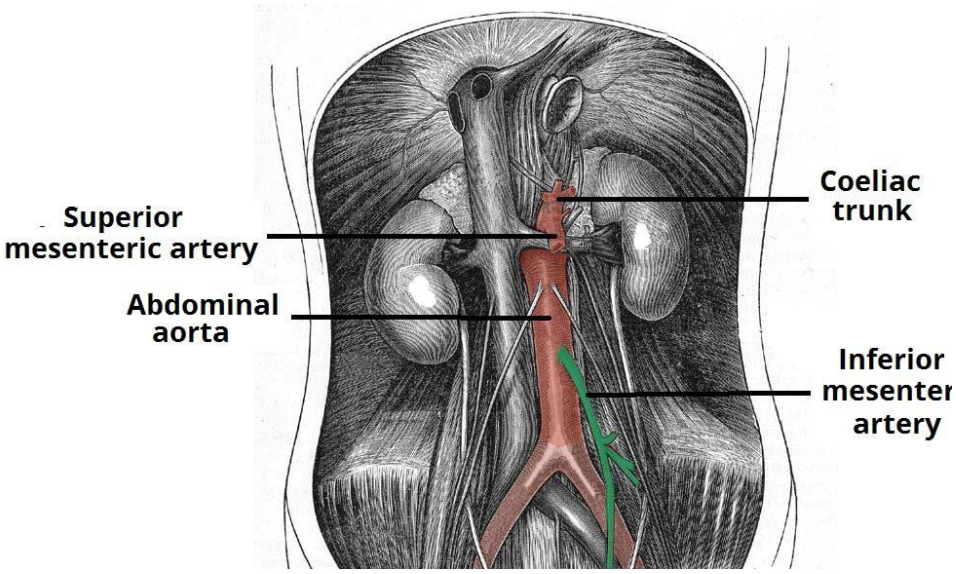
## Intersegmental arteries



## Vitelline arteries

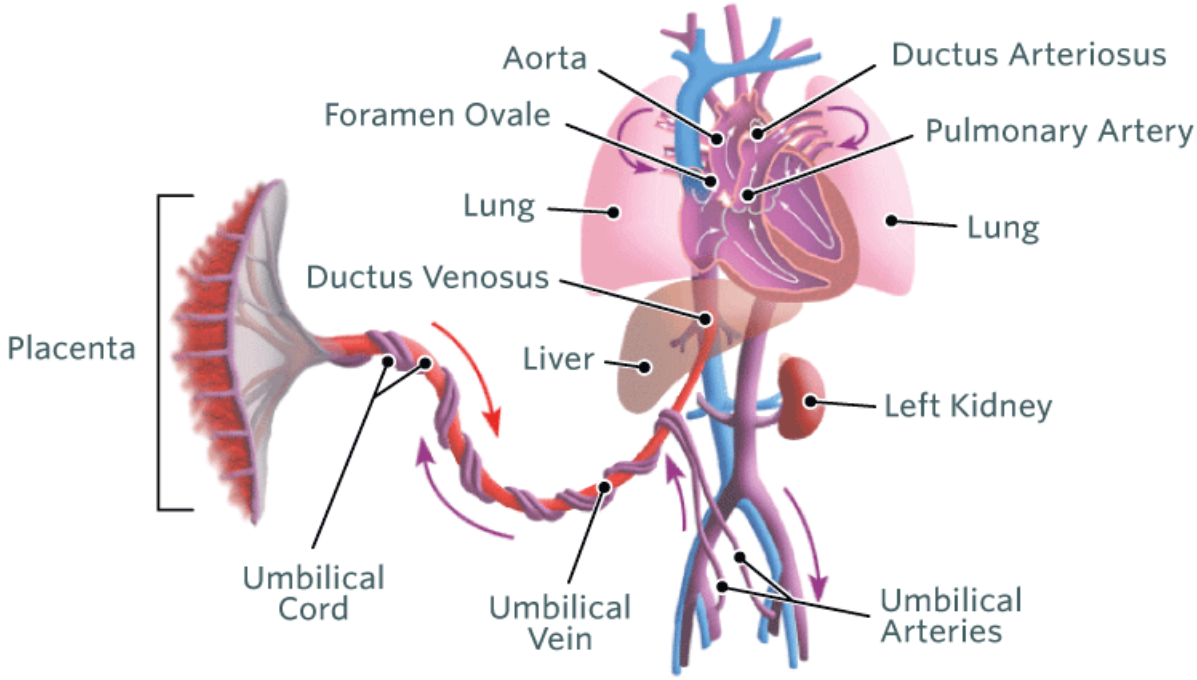
- ventral branches of dorsal aorta
- aa. vitellinae (aa. omphalomesentericae) reduced to three principal vessels:
  1. **truncus coeliacus**
  2. **a. mesenterica superior**
  3. **a. mesentrica inferior**



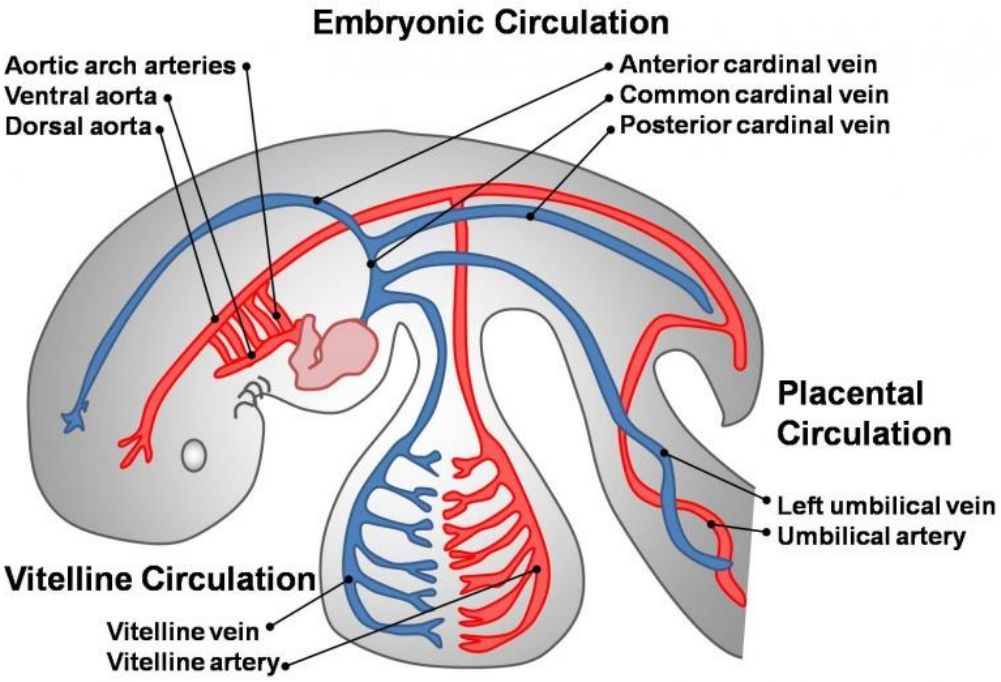



## Umbilical arteries

- First, **aa. umbilicales** are ventral branches of dorsal aorta
- Later, aa. umbilicales are continuations to **aa. iliacae communes** → **aa. iliacae internae**.
- Abnormally, a single a. umbilicalis develop (can result in growth retardation of fetus)
- After birth: proximal parts of aa. umbilicales form **aa. iliacae internae** and **aa. vesicales superiores**. Distal parts obliterate.



# Veins


Embryonic Circulation
Aortic arch arteries
Ventral aorta
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Anterior cardinal vein
Common cardinal vein
Posterior cardinal vein
Placental Circulation
Left umbilical vein
Umbilical artery
Vitelline Circulation
Vitelline vein
Vitelline artery

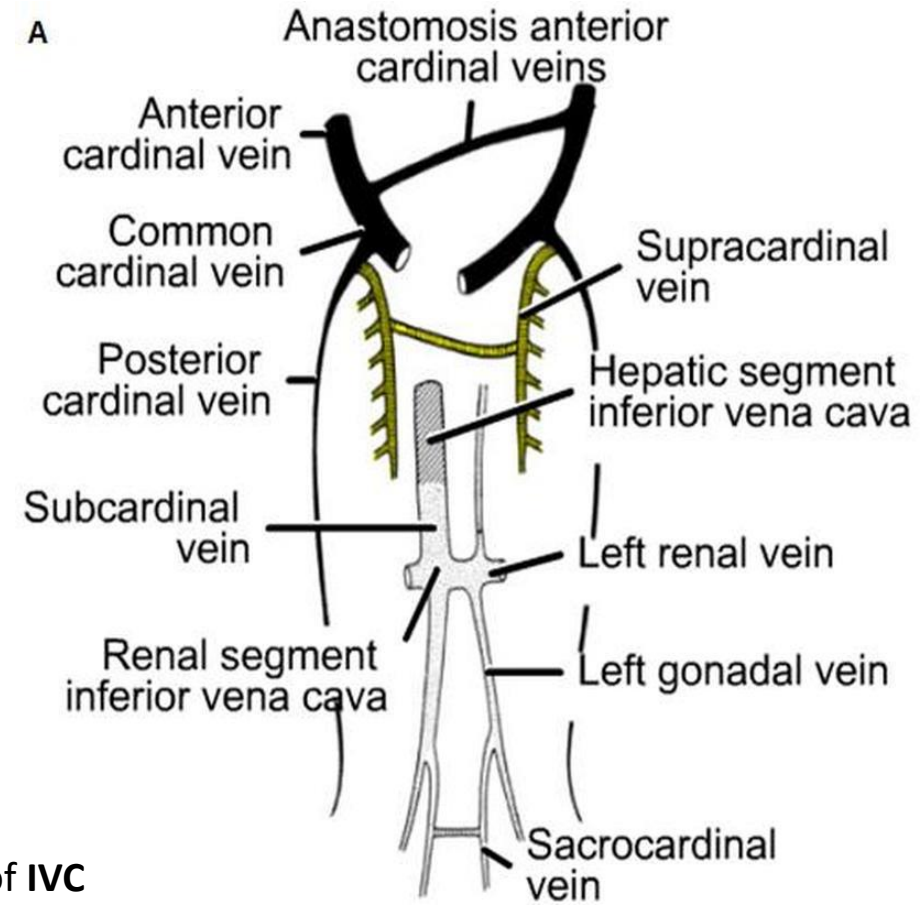
# DEVELOPMENT OF VEINS

## Cardinal veins

- main venous system of embryo
- **v. cardinales anteriores et posteriores**, → **v. cardinales communes**

- paired **v. cardinales anteriores**
- 8th week: anastomosis (L→R)
- → **v. brachiocephalica**
- caudal part of left v. card. ant. disappears
- right v. card. ant. + v. card. commun.: **SVC**

- paired **v. cardinales posteriores**
- primary vessels of mesonephros
- persist as **branches** of **v. hemiazygos** and **v. azygos**
- replaced by subcardinal and supracardinal veins




- paired v**. subcardinales**
- anastomoses also to v. cardinales posteriores
- left: **v. renalis**, v**. suprarenales**, **gonad veins**, part of **IVC**

- paired **v. supracardinales**
- cranial – anastomosis – **v. azygos** et **v. hemiazygos**
- caudal left v. supracardinalis disapears, right – lower part of **IVC** (anastomosis to v. subcardinalis)

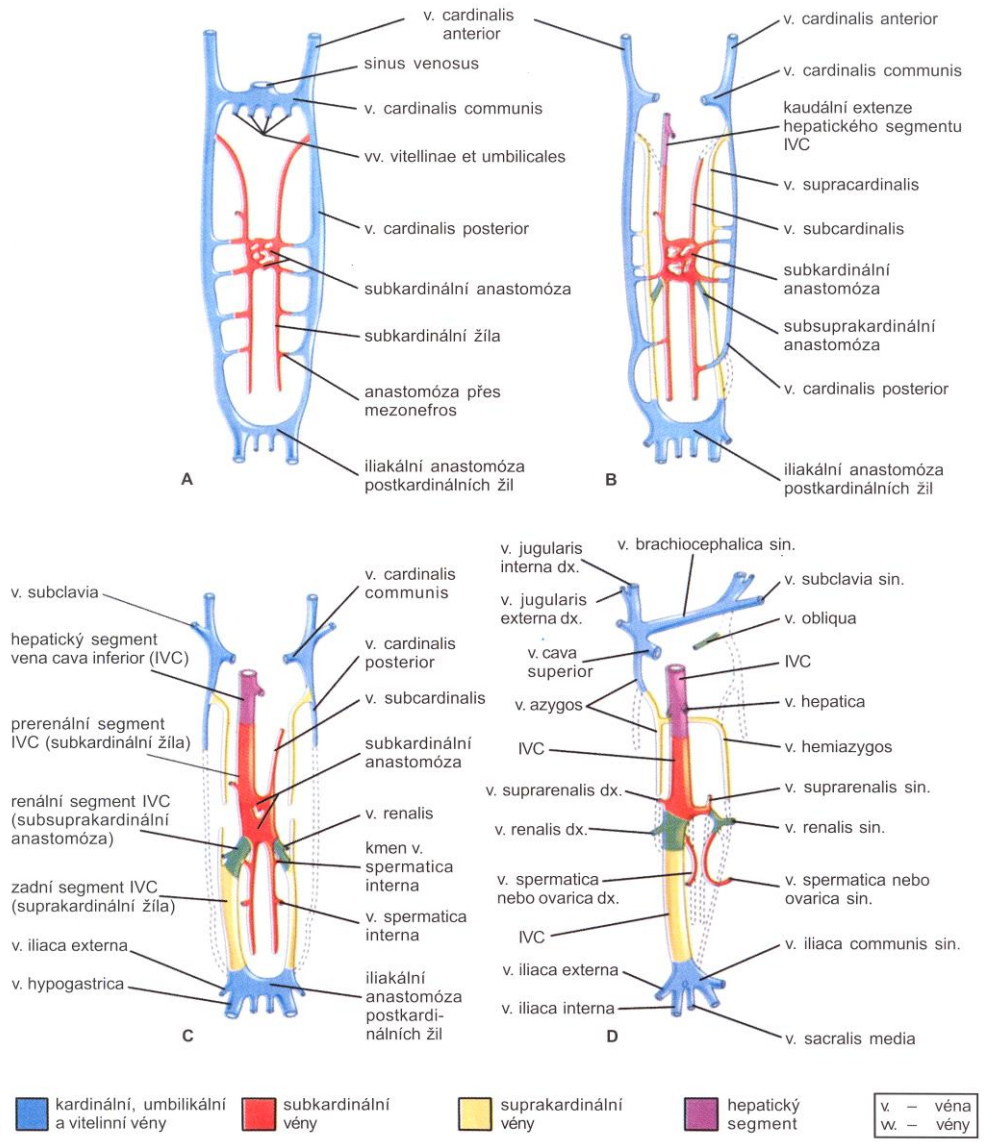
# DEVELOPMENT OF VEINS

## Cardinal veins and development of vena cava inferior

- four principal segments

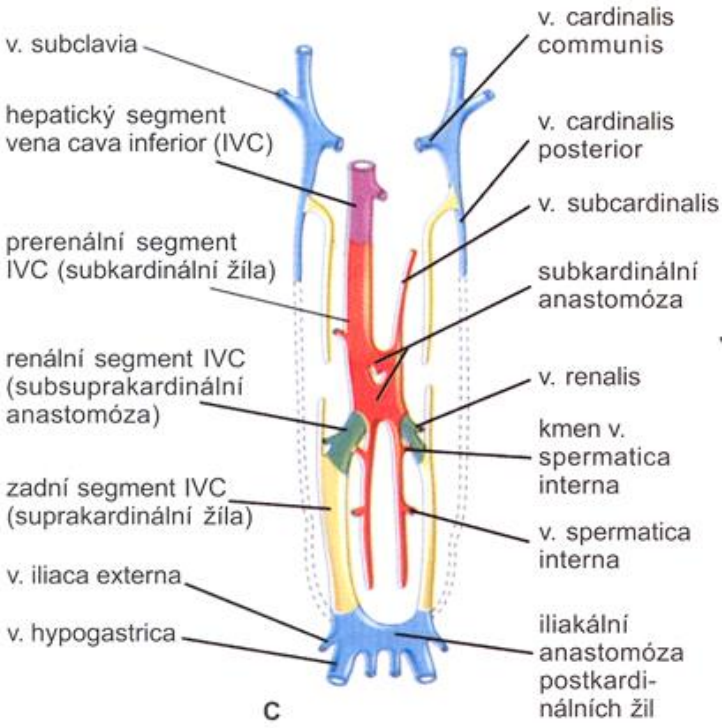
1 **hepatic segment** (proximal part of v. omphalomesenterica = v. hepatica)
2 **prerenal segment** (right v. subcardinalis)
3 **renal segment** (anastomosis between v. subcardinalis and v. supracardinalis
4 **postrenal segment** (right v. supracardinalis)

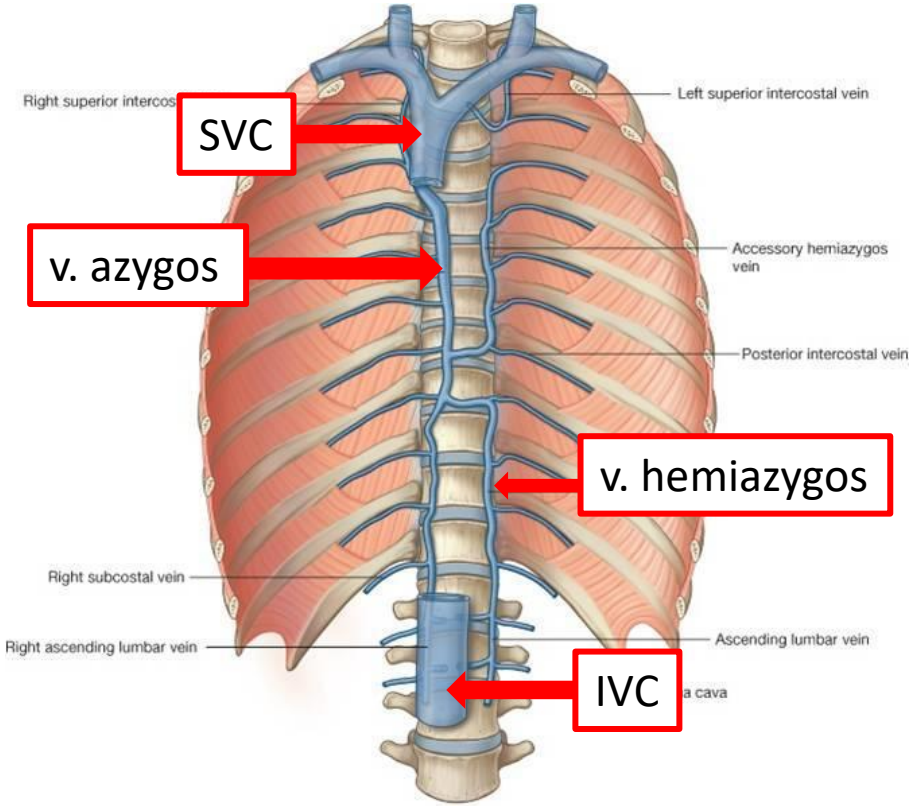
**Vena cava superior**: right v. cardinalis communis and v. cardinalis anterior



## Anomalies of venae cavae

- **Double SVC**: persistence of left anterior cardinal vein; Abnormal CVC opens to right atrium through sinus coronarius
- **Left SVC**: right anterior cardinal vein and v. cardinalis communis degenerate
- **Absence of hepatic segment** of IVC: blood drained through v. azygos and hemiazygos into right atrium. Vv. hepaticae opens to right atrium individually.
- **Double IVC**: absence of anastomoses between primitive caudal veins.



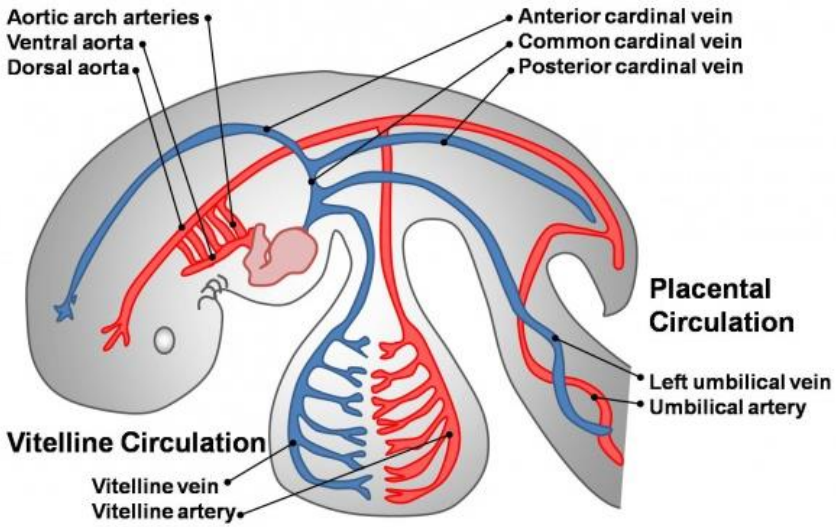
# DEVELOPMENT OF VEINS

## Vv. omphalomesentericae

- bring blood from yolk sac
- septum transversum
- sinus venosus (together with umbilical veins as trunci vitelloumbilicales)
- growth of liver – separation of omphalomesenteric veins to proximal (yolk sac-liver) and distal parts (liver-heart)
- distal parts form anastomoses and develop into v. portae
- proximal parts form posthepatic part of IVC

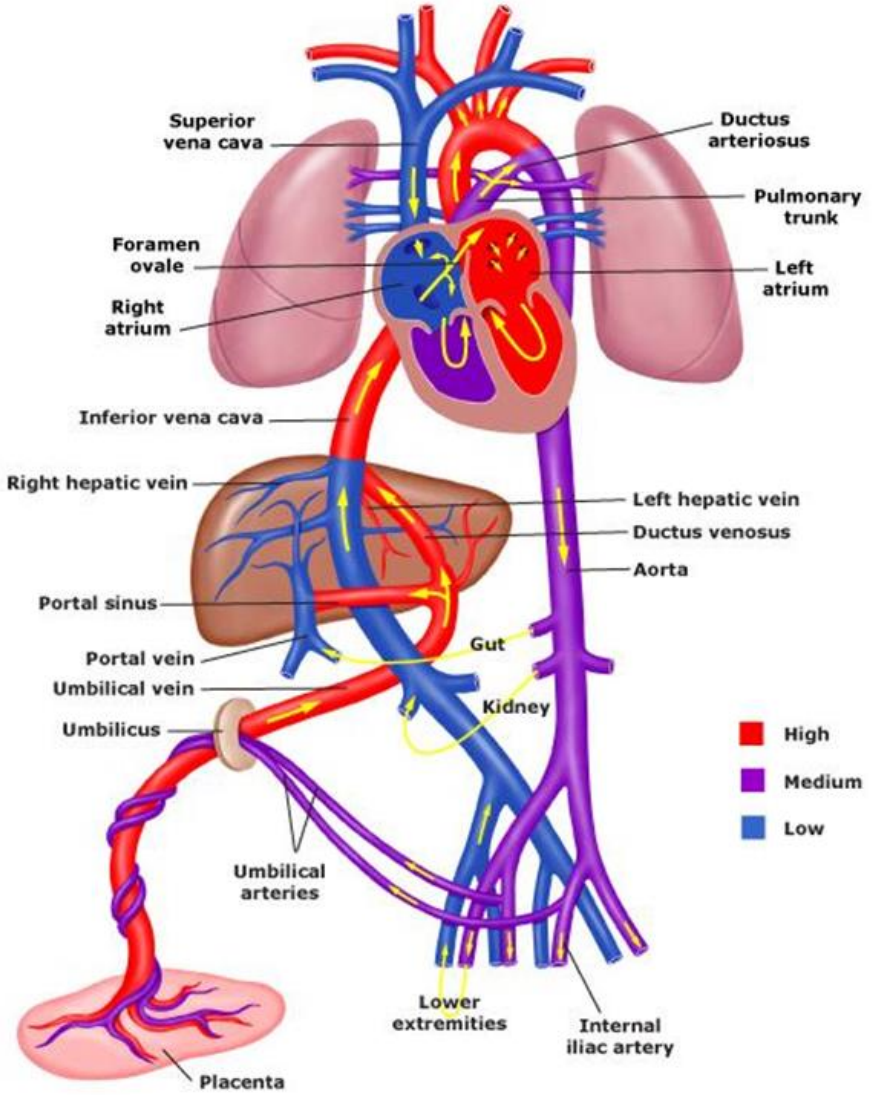
## Vv. umbilicales

- begin in chorionic villi
- due to liver growth lose connection with sinus venosus
- right v. umbilicalis disappears
- distal part of left v. umbilicalis forms ductus venosus (ligamentum venosum post natally)

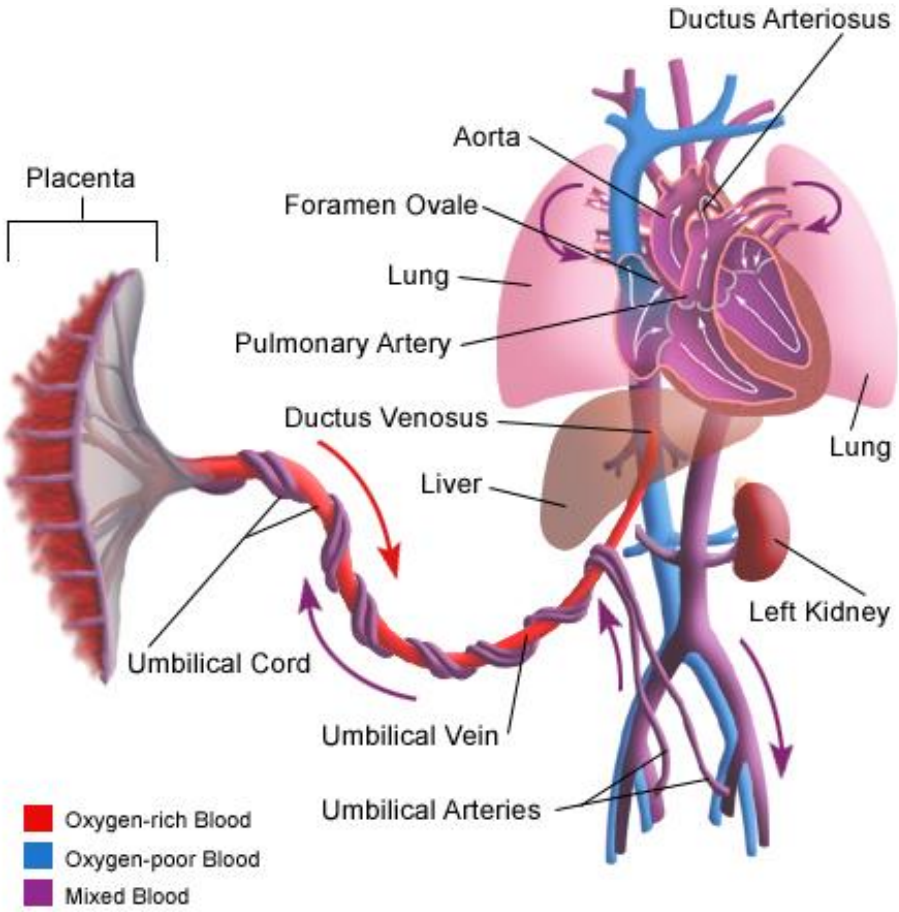


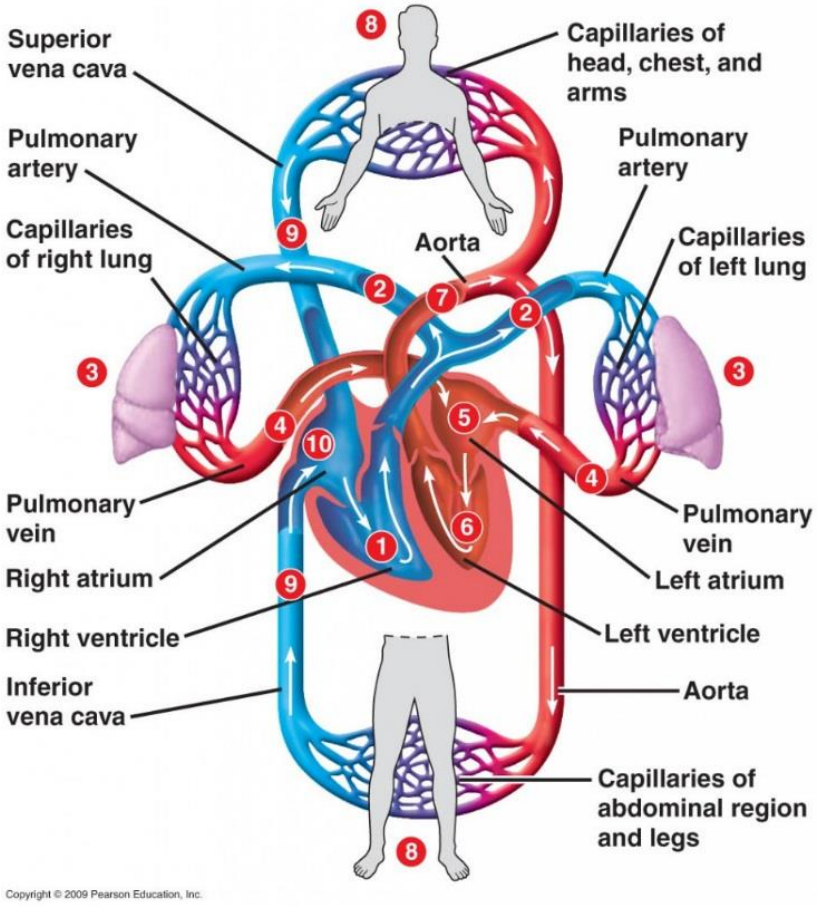

# Embryonic circulation

# Fetal circulation



# Fetal circulation

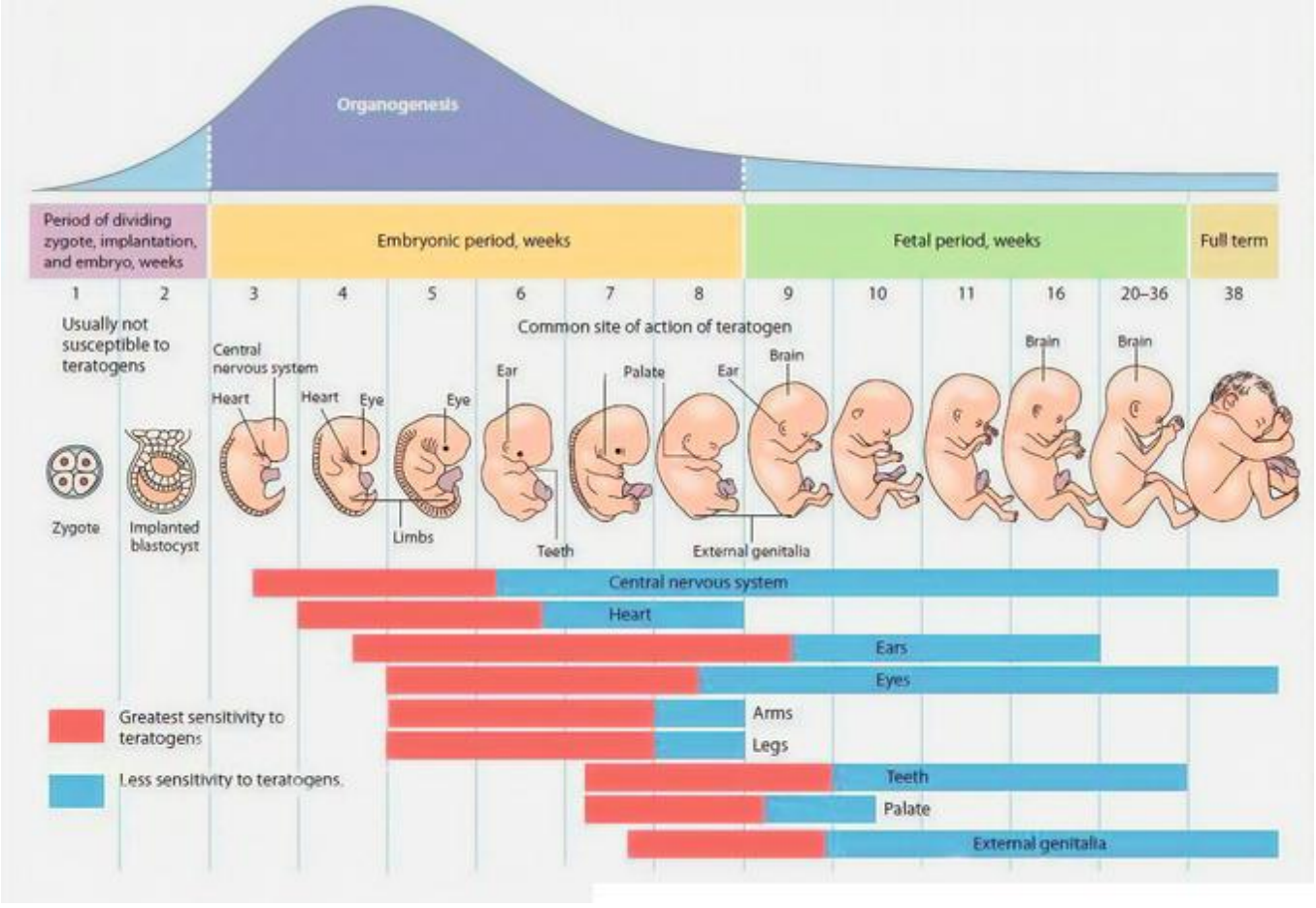



# Postnatal circulation

## Teratology

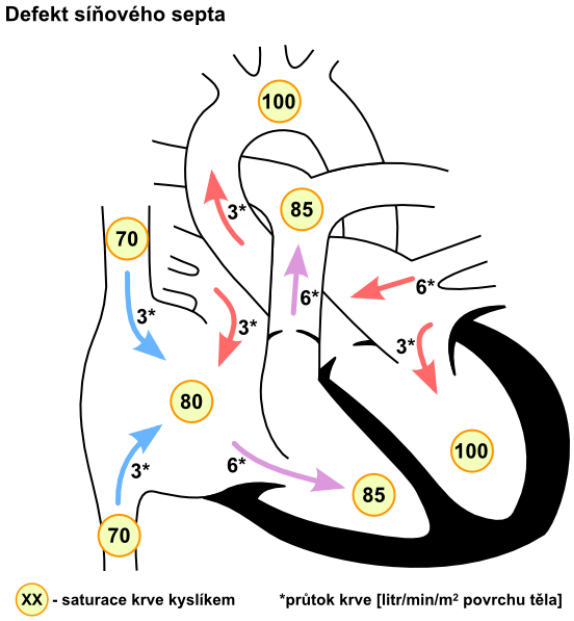
- Cyanotic vs. acyanotic
- Left-to-right shunt, right-to-left shunt, without shunt

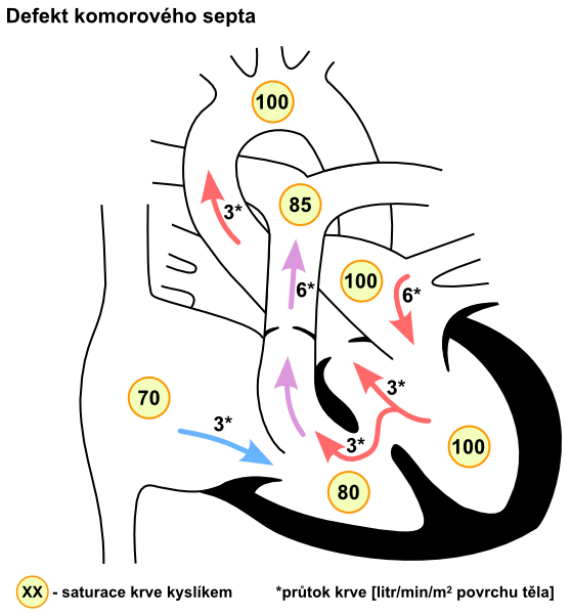


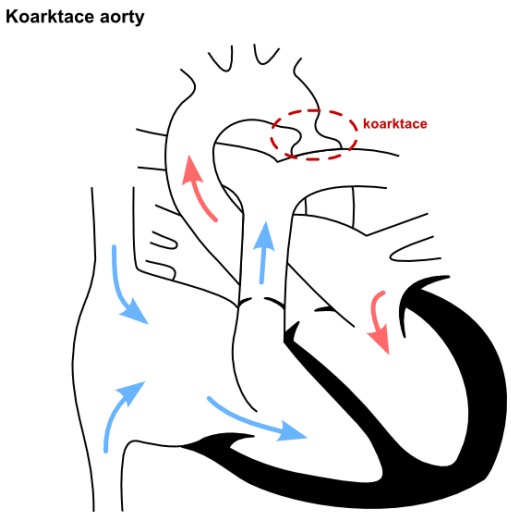
# DEVELOPMENT OF CARDIOVASCULAR SYSTEM

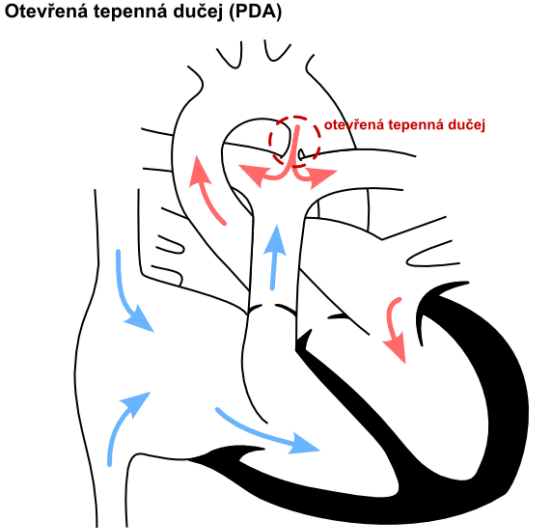
## Teratology

- Acardia
- Ectopia cordis
- Dextrocardia
- Atrial septal defects
- Ventricular septal defects
- Stenosis of truncus pulmonalis
- Atresia pulmonaris
- Tetra (penta)llogy of Fallot
- Coartaction of aorta
- Ductus arteriosus apertus



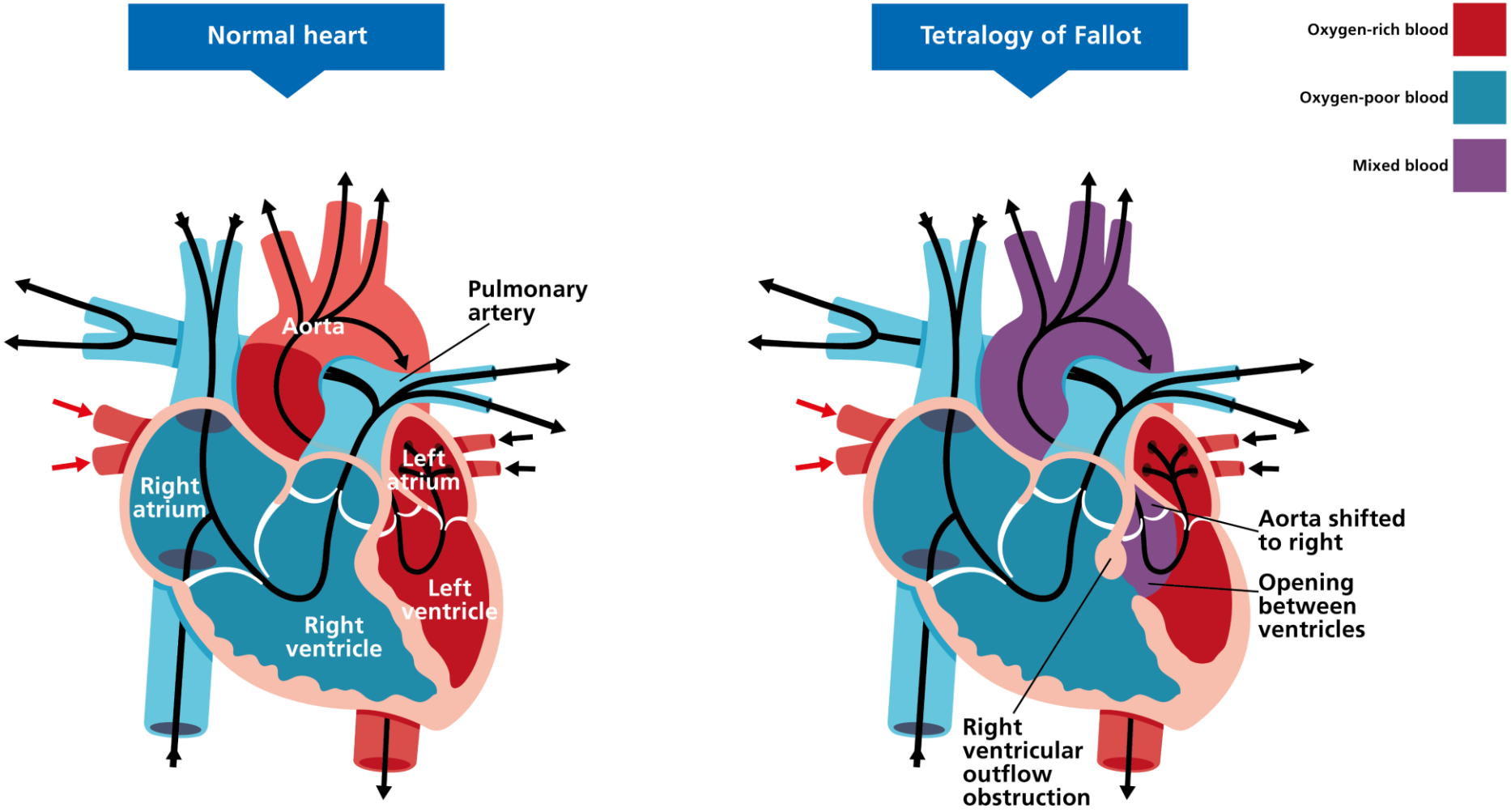



## Teratology

- Tetra (penta)llogy of Fallot



Thank you for attention