Cardiovascular System

SCRUBS

STUDENT COLLABORATIVE RESOURCES FOR UNDERSTANDING AND BRODY SUCCESS

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School of Medicine 2025

Resources Used
BSOM Coursepack
The Developing Human

Mission Statement

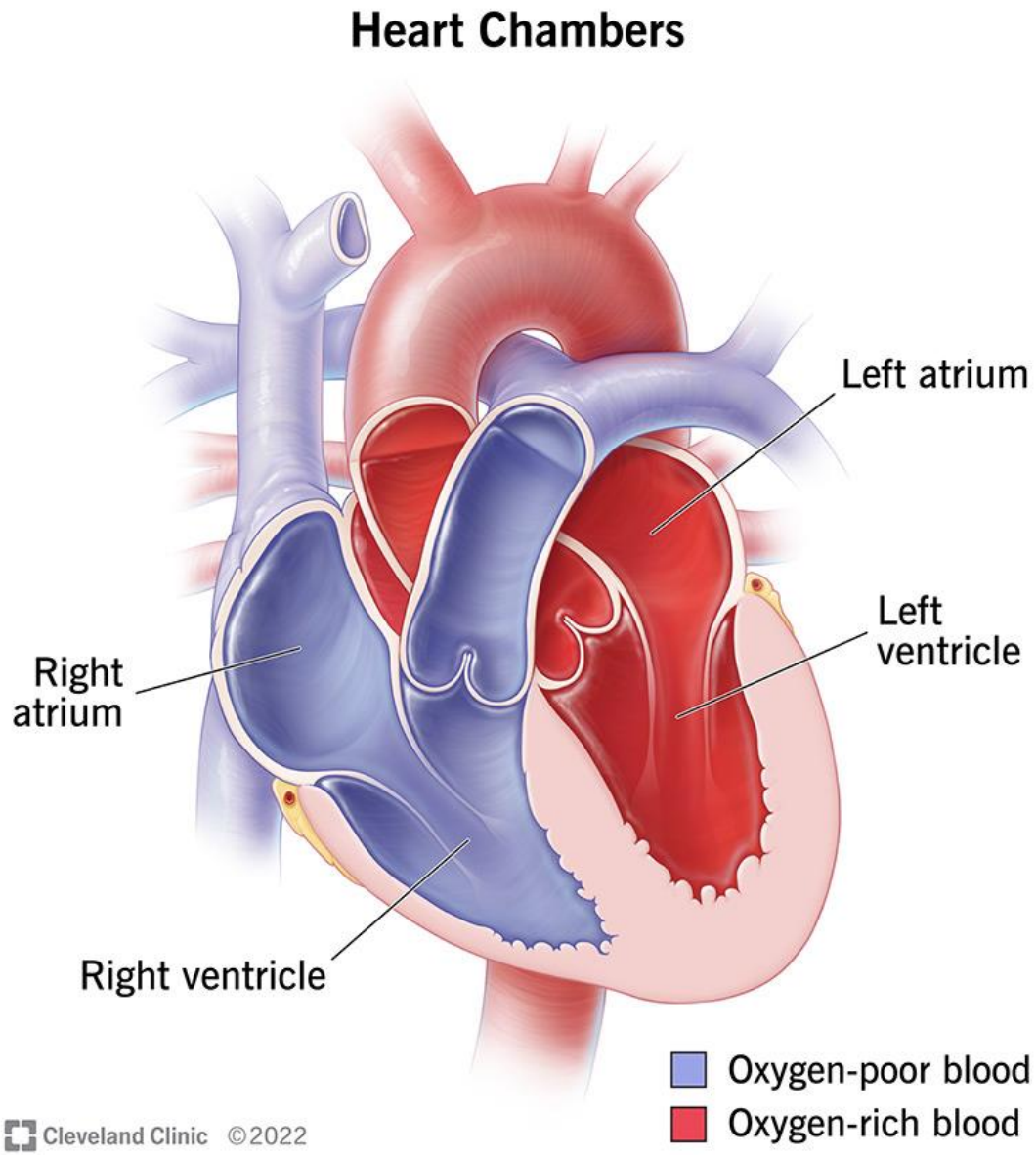
SCRUBS is a student-driven initiative that aims to develop supplemental recourses for current and future cohorts that will pass through Brody. Members of **SCRUBS** participate in a variety of sub-committees working to create resources for students, by students. These resources aim to offer unique perspectives from students that have walked in the same shoes, developing resources that we wish we had been exposed to during our time in the course.

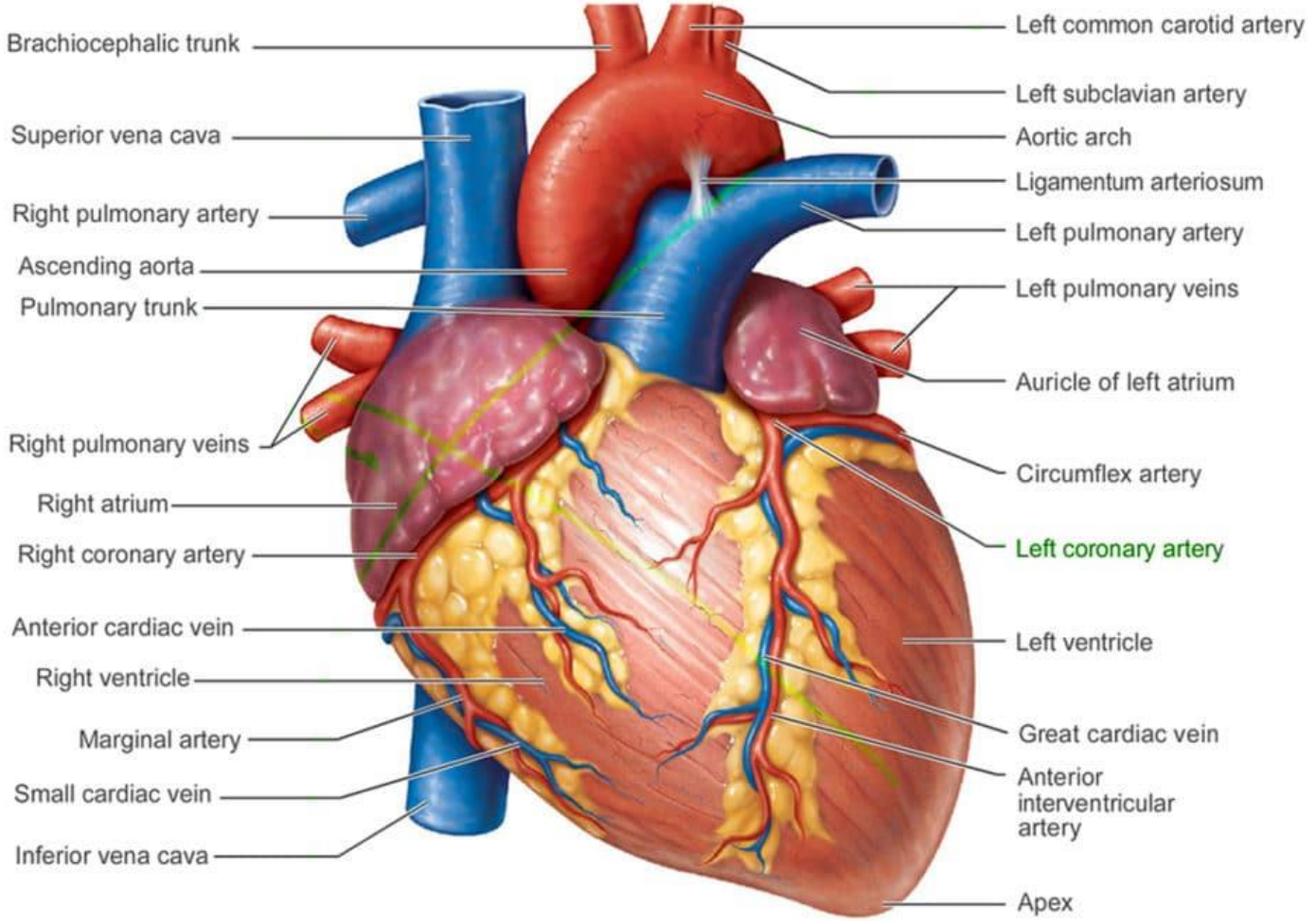
The hope is this organization will become a staple of the Brody student body, exemplifying the unique collaborative community that Brody offers. If this is a mission that aligns with your goals and you have the desire to help those that will come behind you, as well as a goal to leave your mark on Brody as a whole, we invite you to join the team!

Disclaimer

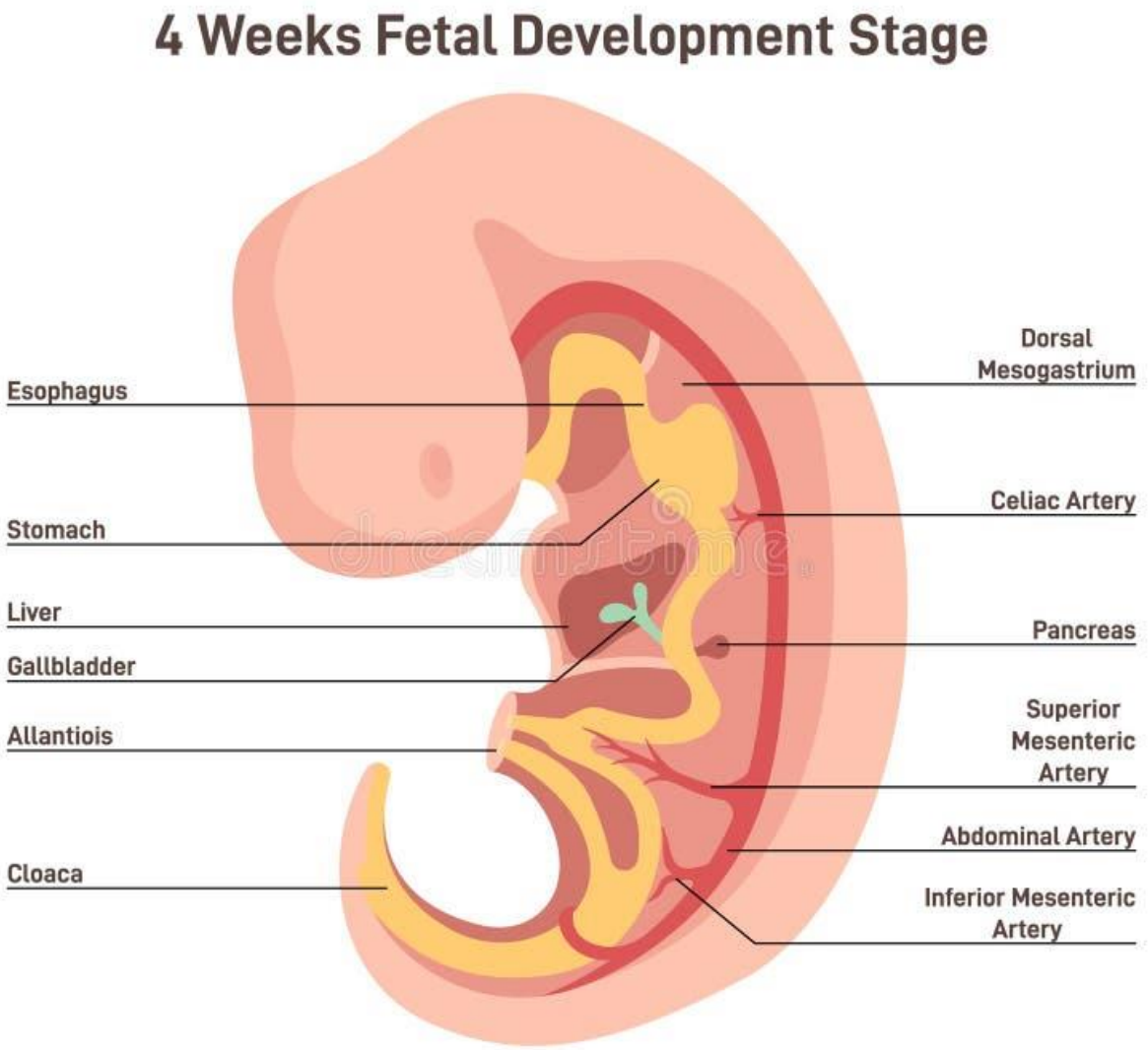
The resources that are included in this document are made by students and not the faculty. As such, there is the possibility for errors in our development, although this is mitigated via a team approach to development with multiple stages of vetting. If there is a contradiction with the coursework presented within your course, please go by the course documents. Additionally, **SCRUBS** aims to supply ***supplemental recourses***, however these are in no way replacements to the instruction of the Brody faculty. Use these recourses as a supplement, but not as your primary source for course material.

Recall – Adult Cardiac Anatomy

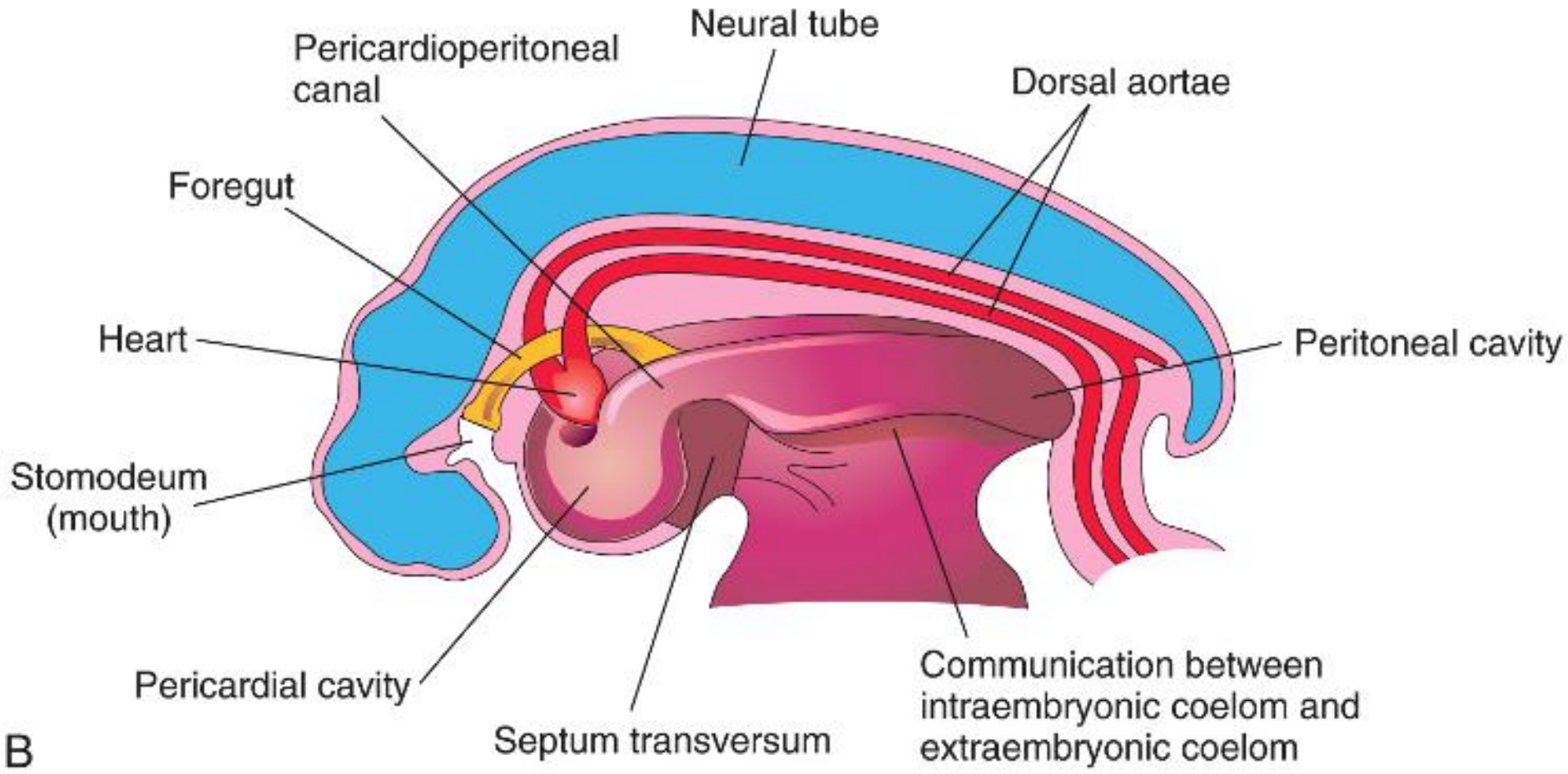




Snapshot – Development During the 4th -5th Weeks



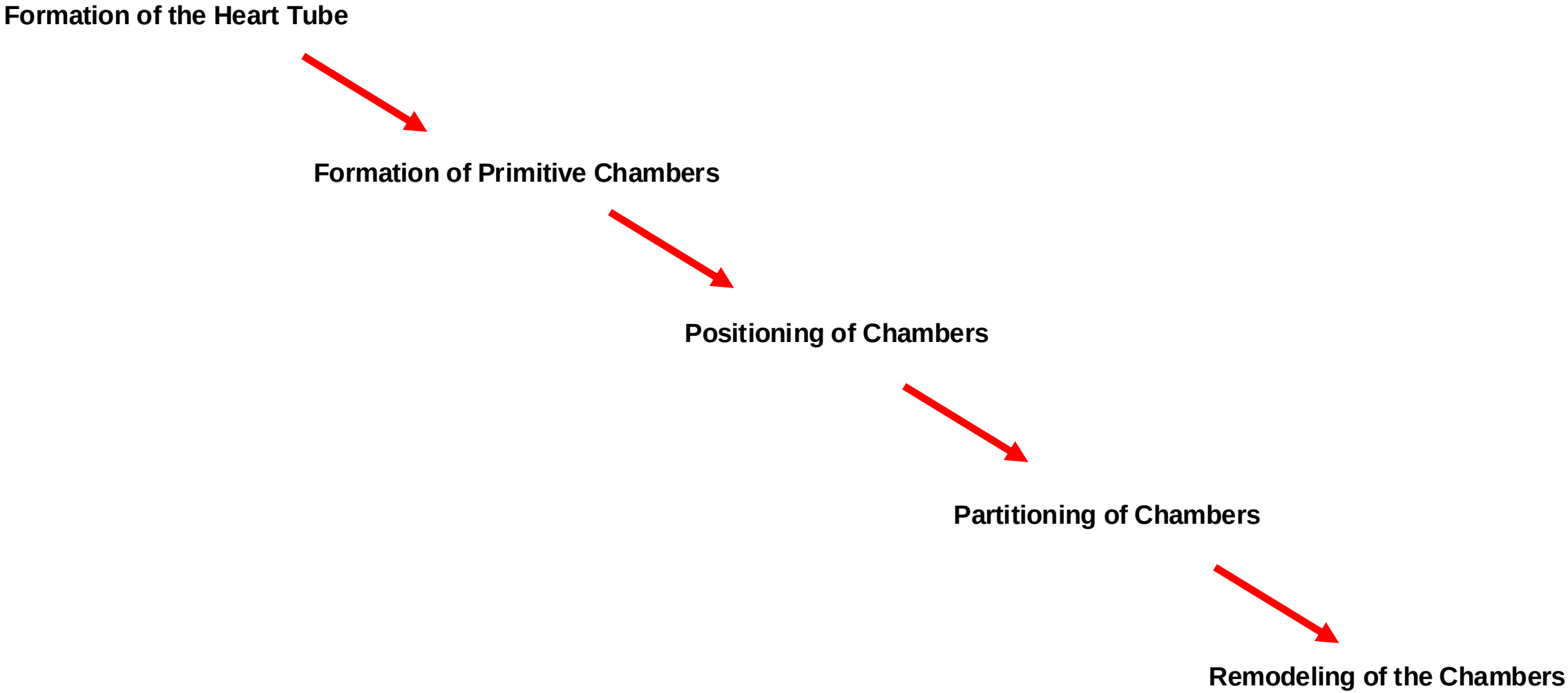
Formation of Body Cavities and Head Fold



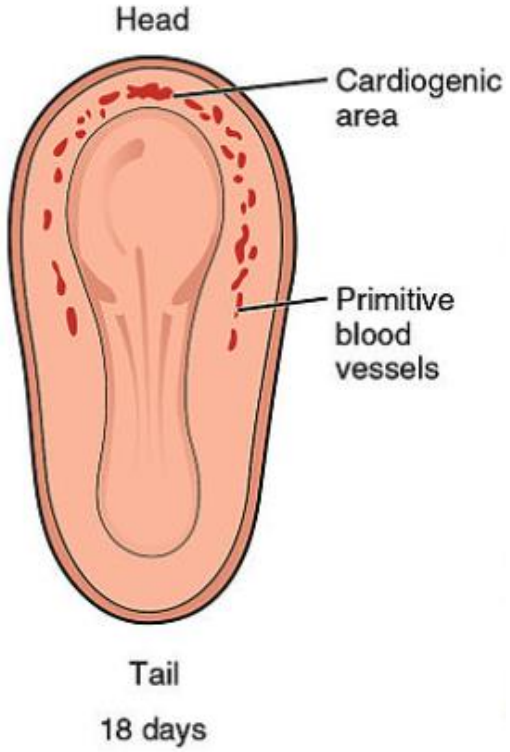
Intraembryonic Coelom Differentiates into Regions

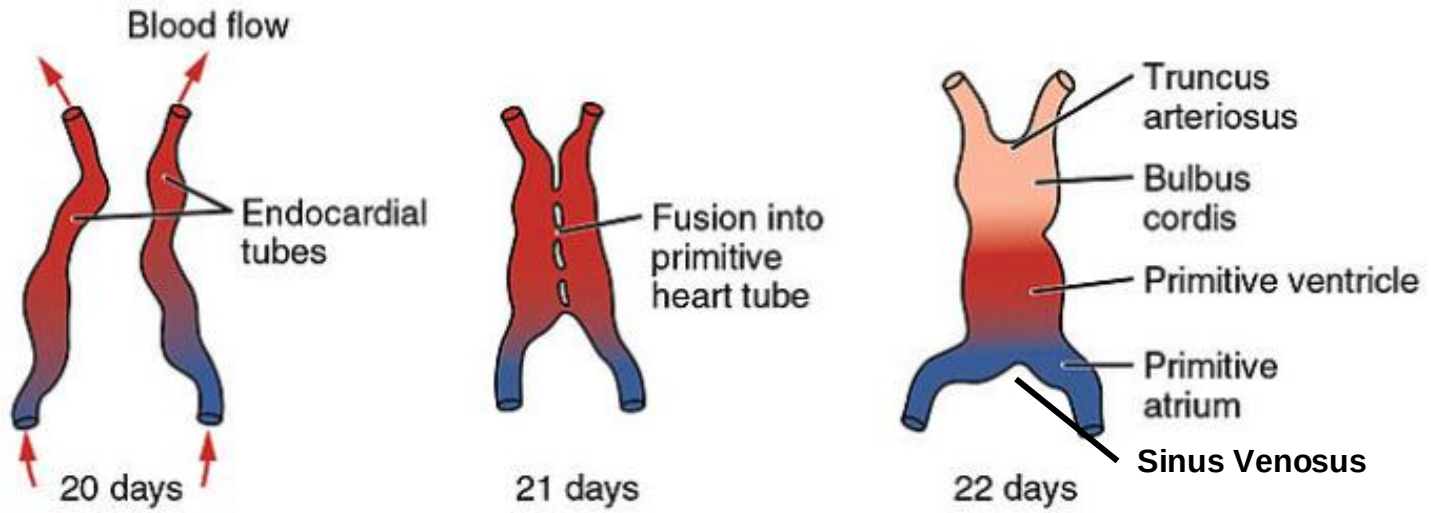
- Pericardial Cavity
- Pericardioperitoneal Canal
- Peritoneal Cavity

Development of the Heart: A Preview



Formation of the Heart Tube





1) Mesoderm in the **cardiogenic area** gives rise to **angioblastic cords**
   - Angio= vessel
   - Blastic = "germ" or "sprout"
   - Aka → Formation of blood vessels

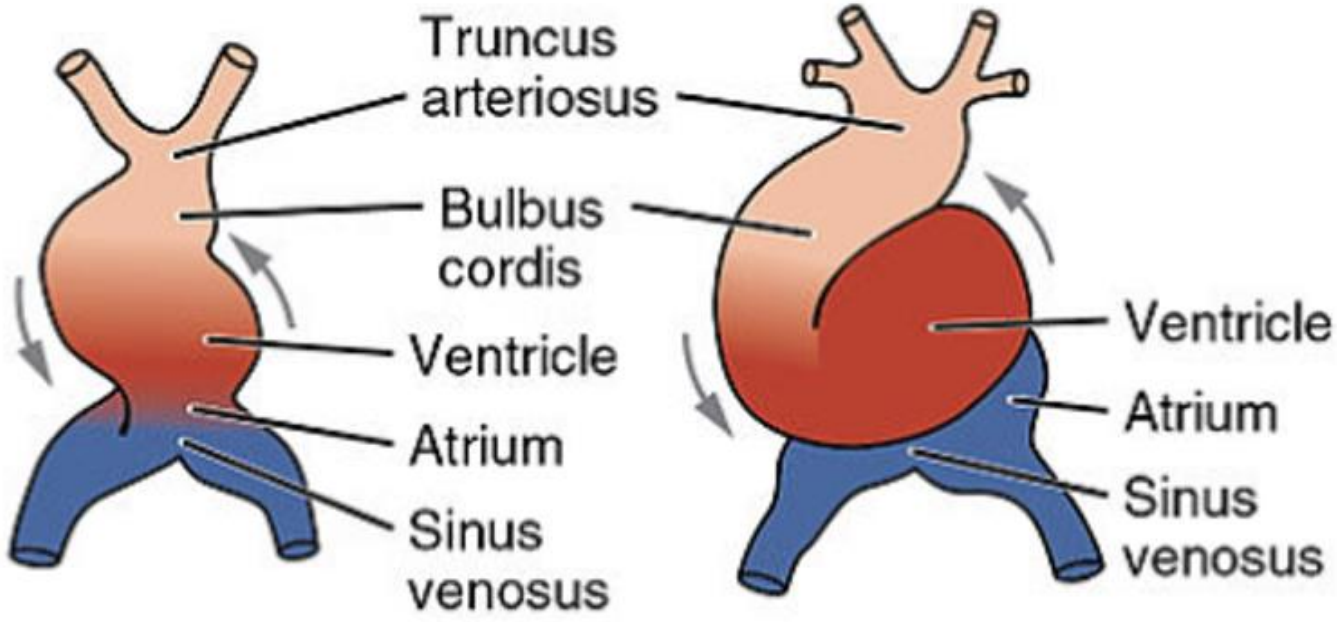
2) Antiblastic cords canalize to from **endocardial heart tubes**
   - Forms the **ENDO**cardum specifically
   - The myocardium and epicardium will form from splanchnic mesoderm

3) Endocardial heart tubes fuse and dilations form
   - Truncus Arteriosus → Outflow track
   - Sinus Venosus → Inflow track

Bulboventricular Loop and Positioning of Chambers

Initial Growth

- Locked positioning of the TA and SV
  - TA locked with pharyngeal arches
  - SV locked with septum transversum
- Differential Growth of Ventricle and Bulbus Cordis

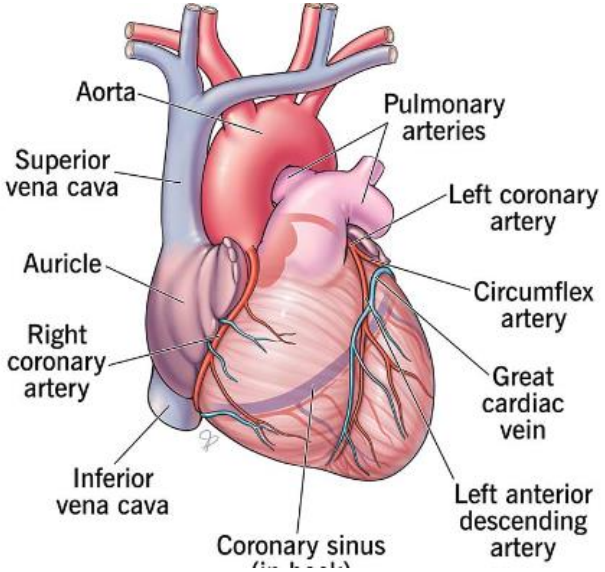


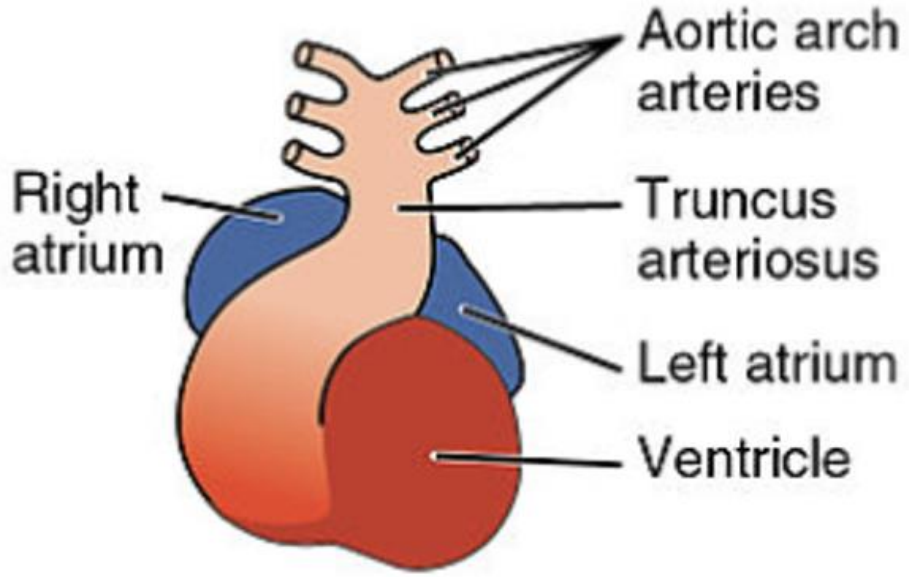
Rotation of Chambers

- The bulbus cordis moves to the right, while the ventricle moves to the left
- The atrium/sinus venosus are moved to the posterior aspect of the developing heart

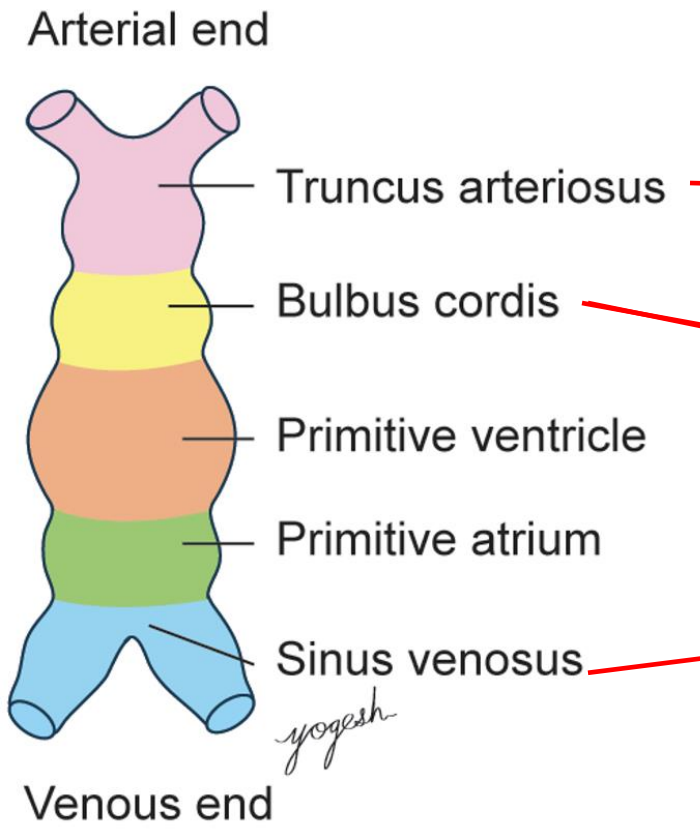
Result

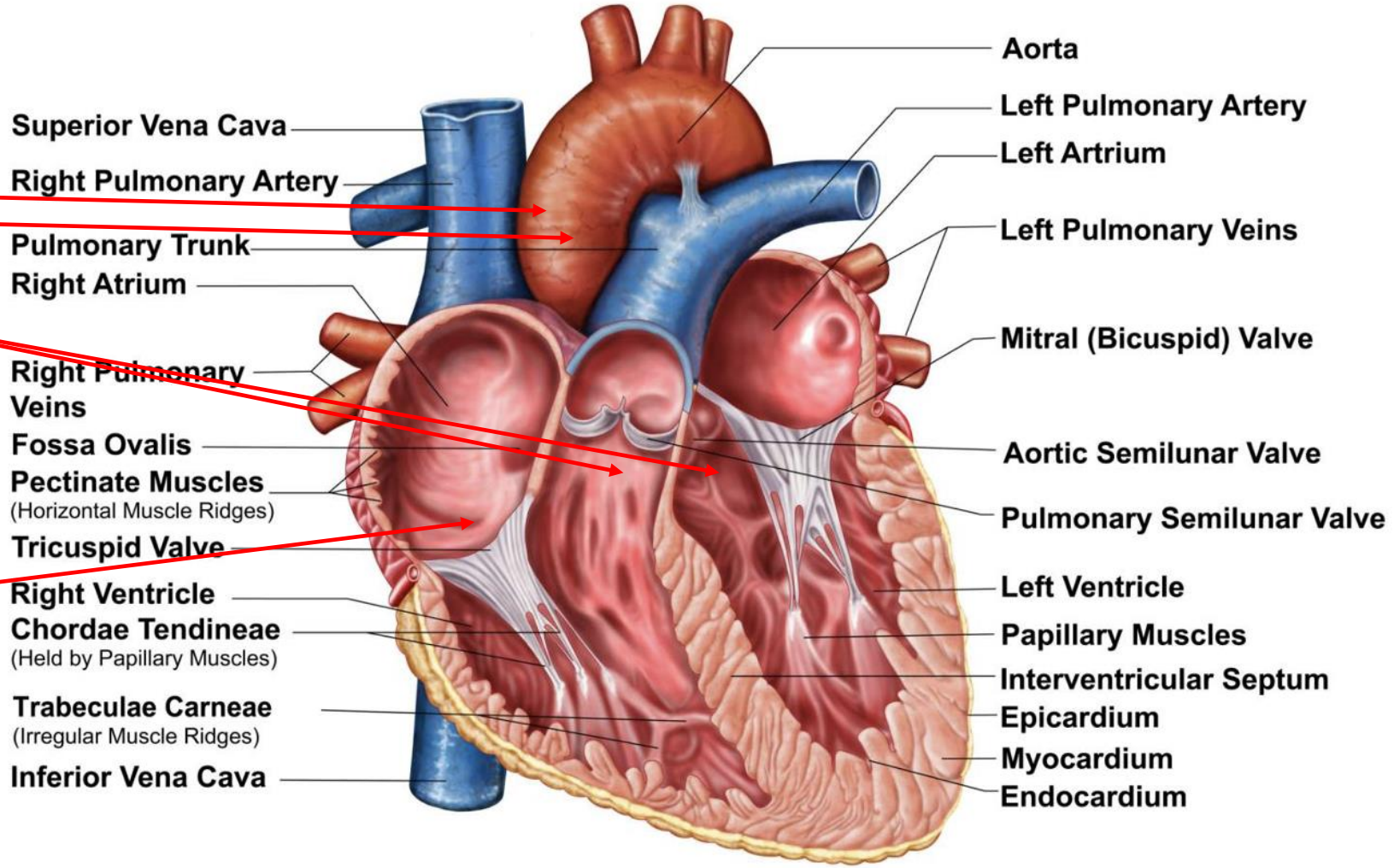
Relative position of heart chambers established





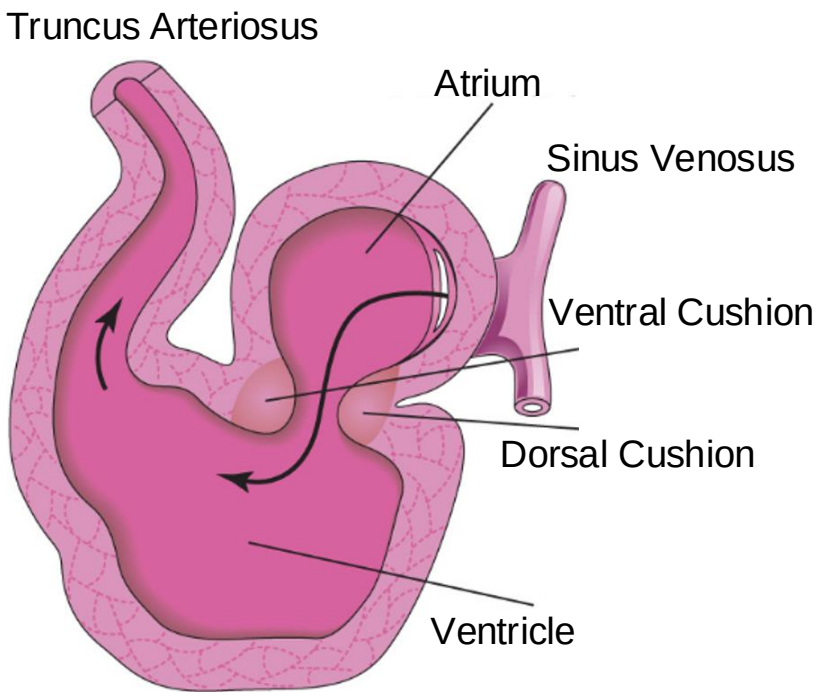
A preview, what is the end goal?

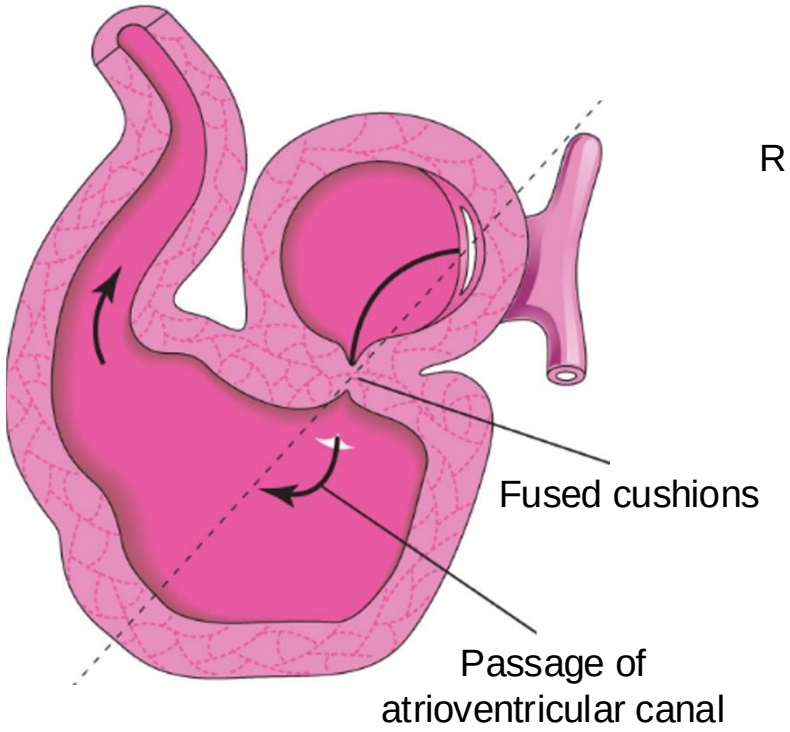


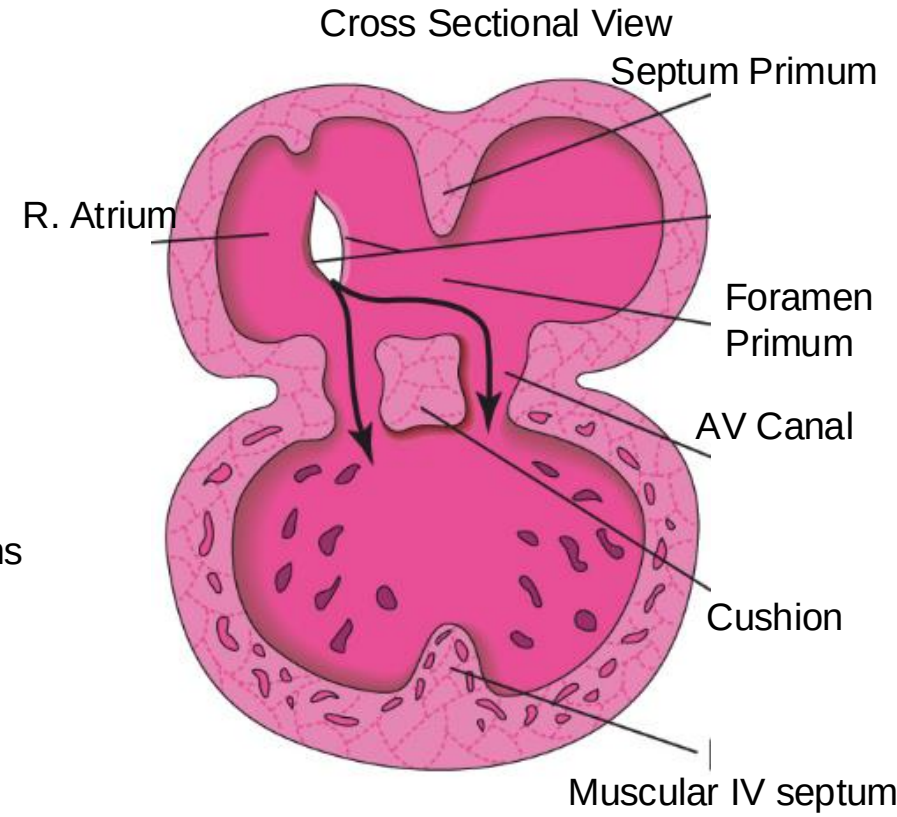


Dilation	Sinus Venosus	Atrium	Ventricle	Bulbus Cordis	Truncus Arteriosus
Derivative	Sinus venarum, coronary sinus	Trabeculated R/L atria	Trabeculated R/L ventricles	Conus arteriosus, aortic vestibule	Proximal aorta, pulmonary trunk

Partitioning of the AV Canal – Endocardial Cushions







1. **Cardiac Jelly** gives rise to **endocardial cushions**
2. Anterior and posterior cushions come together
3. Fusion separates the R. and L. **atrioventricular canals**

Separating the Right and Left Atrium

Septum Primum Forms

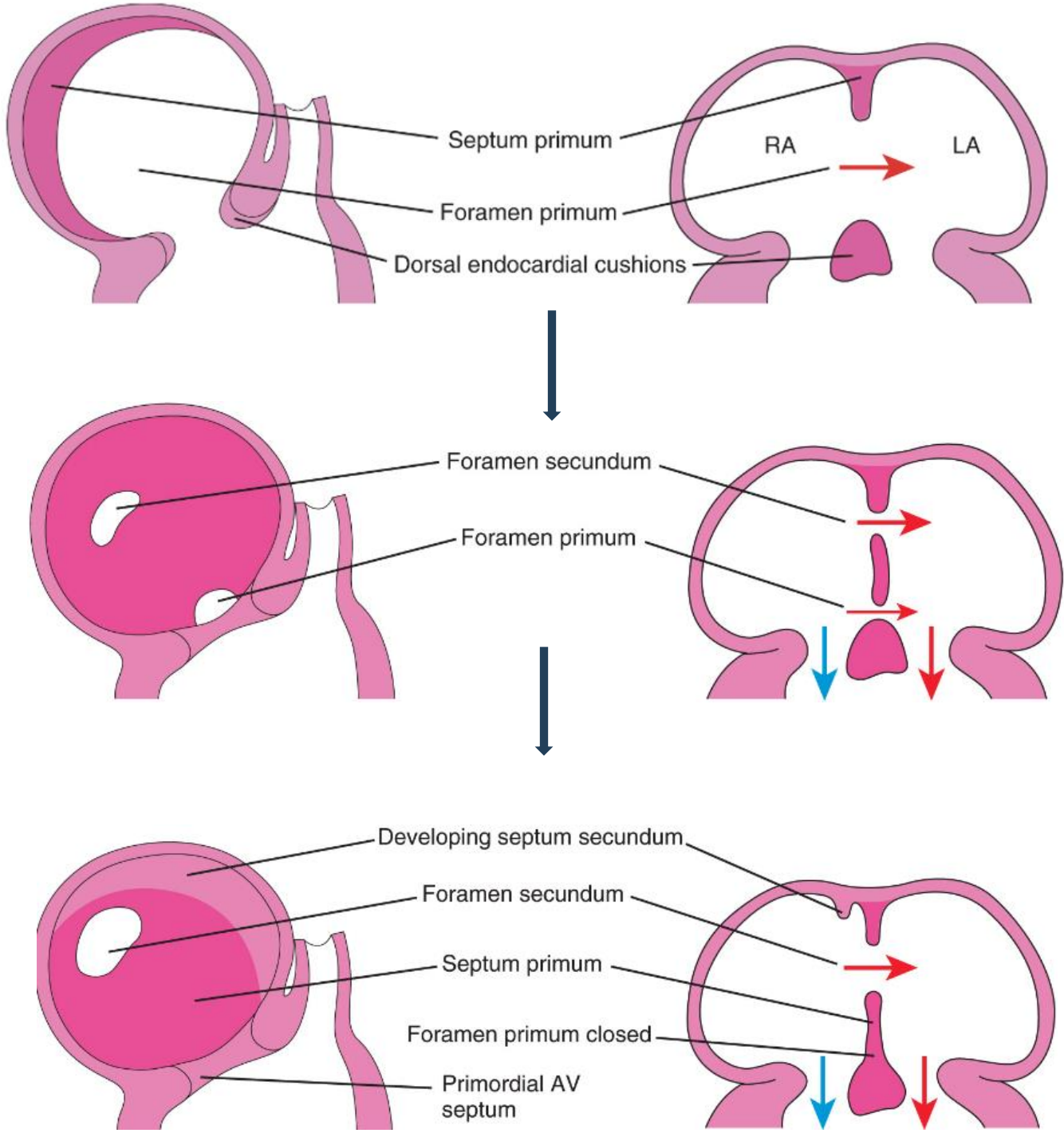
- Extends from <u>posterior superior</u> wall of atrium
- Grows towards the cushion
- Space between cushion and septum = **foramen primum**

Foramen Secundum Forms in Septum Primum

- Superior pole of septum primum degrades
- The new hole that is formed is called **the foramen secundum**
- Eventually the septum joins the cushion and the foramen primum is obliterated

Septum Secundum Begins Development

- Stronger and more muscular than the primum (forms just to the right of the primum)
- Grows from <u>anterior superior</u> wall downward



Continued

Foramen Ovale Forms

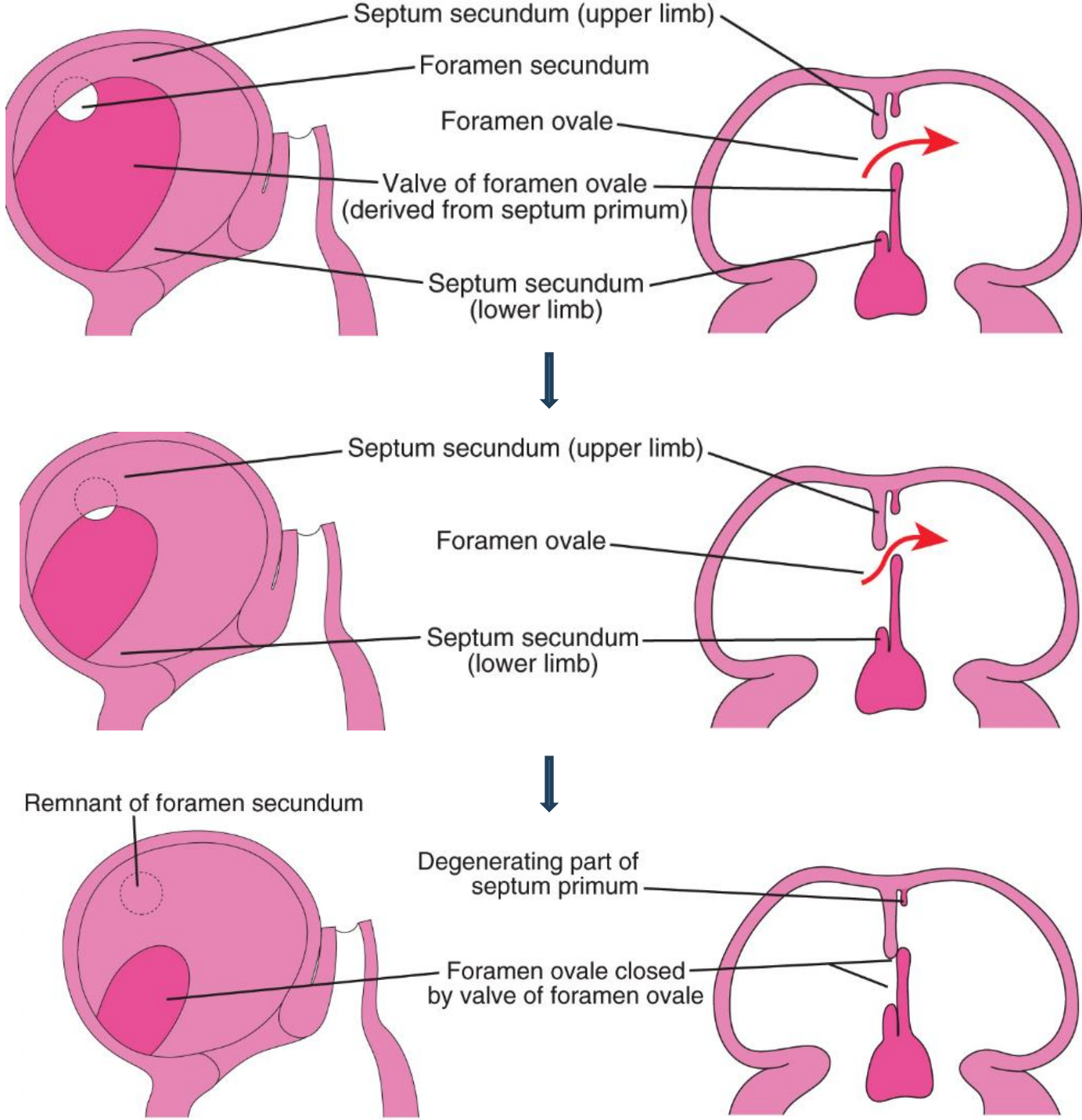
- The foramen ovale is the space between the superior and inferior limbs of the septum secundum

The remnants of the septum primum form the valve or the foramen ovale

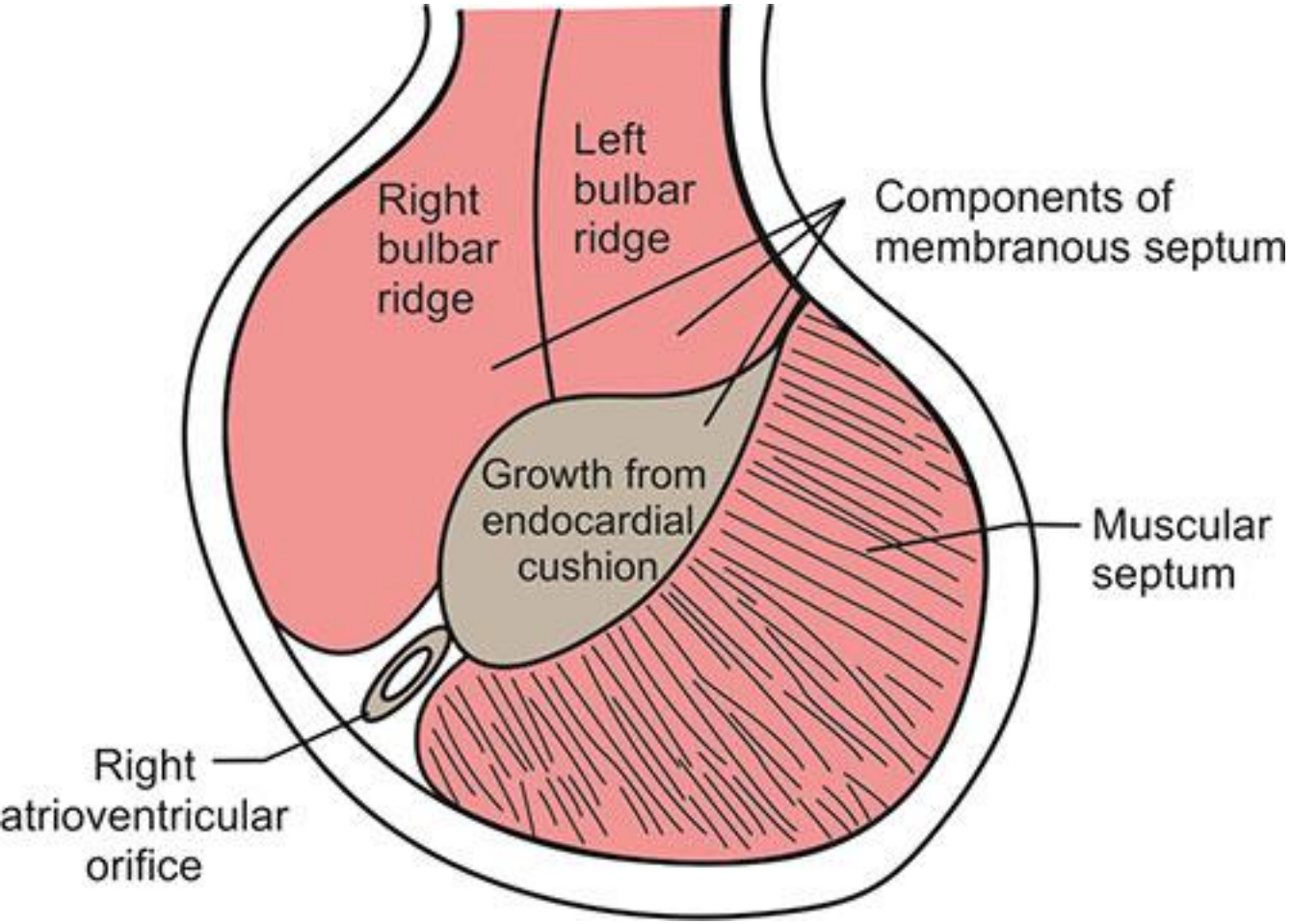
- The superior pole degrades, leaving the inferior segment
- This segment becomes a valve, redirecting blood flow

At birth → Valve fuses with septum secundum to stop Right to Left shunting

- This is secondary to pressure changes
- The remnant is called the fossa ovalis



Interventricular Septum Formation



Muscular interventricular septum develops

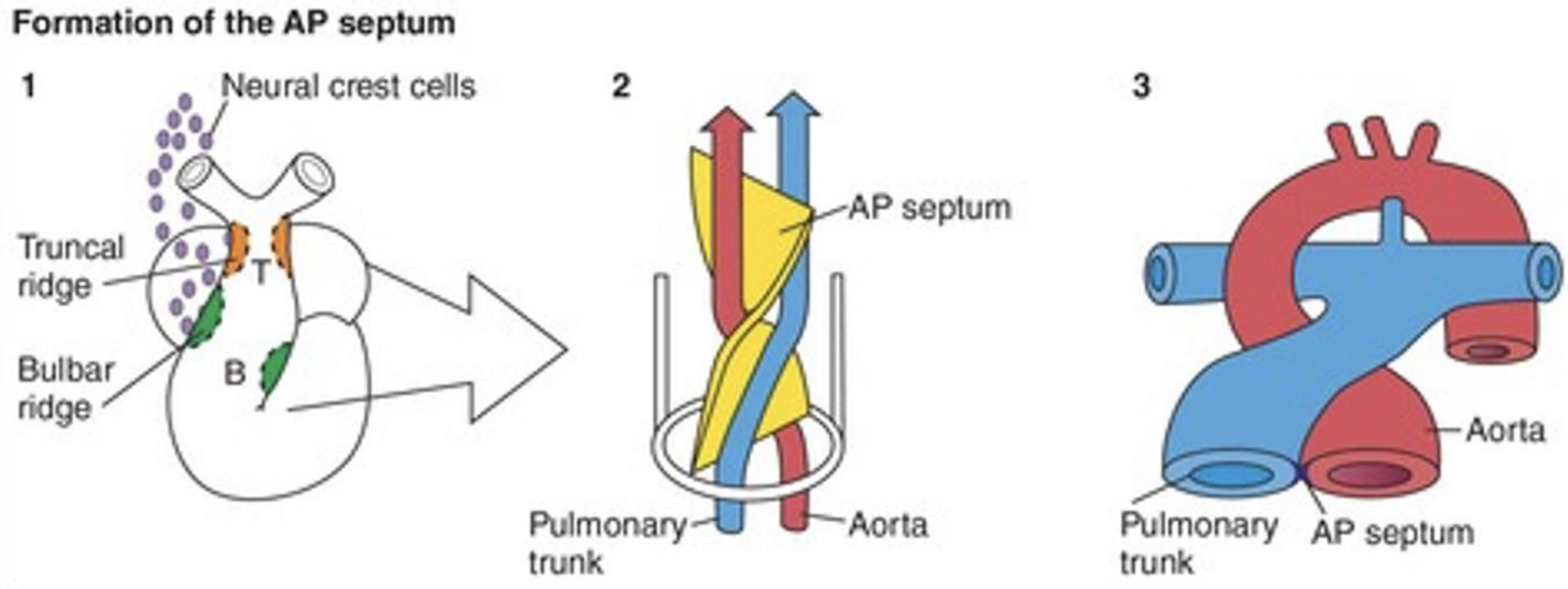
Develops from the anterior inferior aspect of developing ventricles and grows towards the endocardial cushions

Resulting space prior to fusion is called the interventricular foramen

Membranous interventricular septum fuses with muscular interventricular septum and aorticopulmonary septum

Membranous intermuscular septum forms from the endocardial cushions. Aorticopulmonary septum will separate the outflow tracts (more in a moment)

Partitioning of the Outflow Tracts



Bulbar and Truncal Ridges Form

Invasion of **neural crest cells** into the TA and BC form midline ridges that will eventually fuse to form the **aorticopulmonary septum**

This aorticopulmonary septum will separate the outflow tracts of the pulmonary trunk and the aorta

180 degree spiral results in adult orientation of the outflow tracts

Rotation results in the aorta coming off the right side of the heart and the pulmonary trunk coming off the left side of the heart

Structure	Bulbus Cordis (R)	Bulbus cordis (L)	Truncus Arteriosus (R)	Truncus Arteriosus (L)
Derivative	Conus Arteriosus	Aortic Vestibule	Pulmonary Trunk	Proximal Aorta

Development of the Heart: Summary

1) Angioblastic cords form
- Mesoderm in the cardiogenic area
- Will canalize to form **endocardial heart tubes**

2) Fusion of heart tubes
- Fusion forms the primitive heart tube
- *Endocardium specifically*
- Myocardium/Epicardium = splanchnic mesoderm

3) Primitive dilations/chambers
- **Truncus arteriosus (TA)**
- **Bulbus cordis**
- **Ventricle, Atrium**
- **Sinus Venosus (SV)**

4) Bulboventricular loop forms
- Locked orientation of TA and SV
- Bulbus cordis and TA grow quickly
- Bulbus cordis moves to the right, ventricle to the left, and atrium/SV moves posterior

5) **Relative relationship of heart chambers formed (atrium, ventricles, inflow, outflow)**
- Venous return = SV/atrium
- Arterial outflow = TA/Ventricles

6) **Partitioning of left/right sides of heart begins**
- Before this there is only one tube
- Result will be R and L heart circulation

7) **Atrial Partitioning**
- **Cardiac jelly** induces **endocardial cushions**
- Cushions from on anterior/posterior walls
- **Septum primum** grows from superior-postirior wall
- **Foramen primum** present
- Apoptosis of superior portion of septum primum forms the **foramen secundum**
- **Septum secundum** forms, but does not fuse with cushions → Leaving the **foramen ovale**
- Blood is able to pass from right heart to left heart via the foramen ovale/foramen secundum

8) **Ventricular Partitioning**
- **Muscular interventricular septum** arises from the floor towards endocardial cushions
- Is met by the **membranous interventricular septum**, which arises from the endocardial cushions

9) **Partitioning of outflow tracts**
- **Bulbar and truncal ridges** from due to neural crest migration
- These ridges give rise to the **aorticopulmonary septum**
- Bulbis cordis → conus arteriosus and aortic vestibule
- TA → pulmonary trunk + Proximal aorta
- 180 spiral → places aorta on right as it exits the heart and pulm. trunk on the left

Forming the Peripheral Vasculature

Remodeling of the Sinus Venosus and Atria (Inflow tracts)

Sinus Venosus Receives Venous Return

- Left and Right Horn – Initially same size
  - Cardinal veins = From embryo
  - Vitelline veins = From umbilical vesicle
  - Umbilical veins = From placenta

Shift towards R. sided return

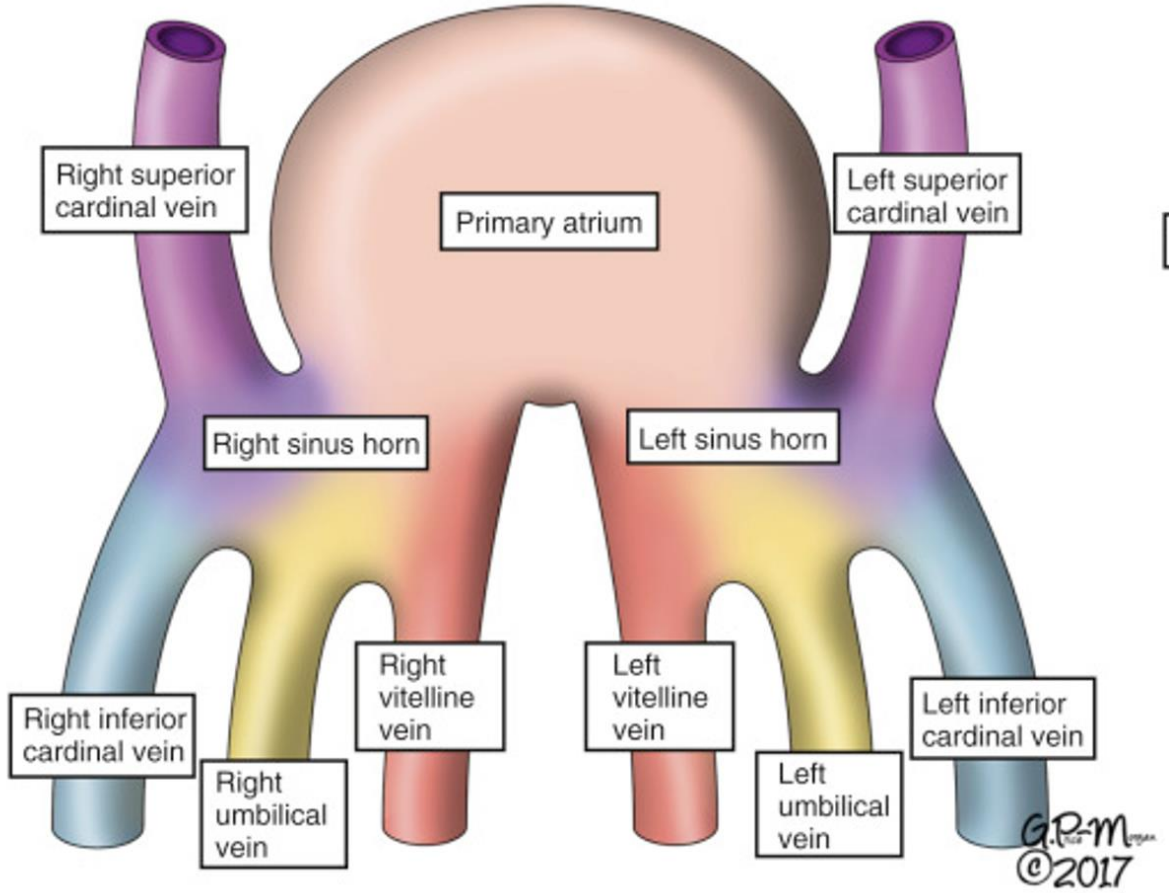
- Degrade left sided umbilical and vitelline veins
- Left cardinal vein anastomosis with right cardinal vein

Left horn → Coronary sinus

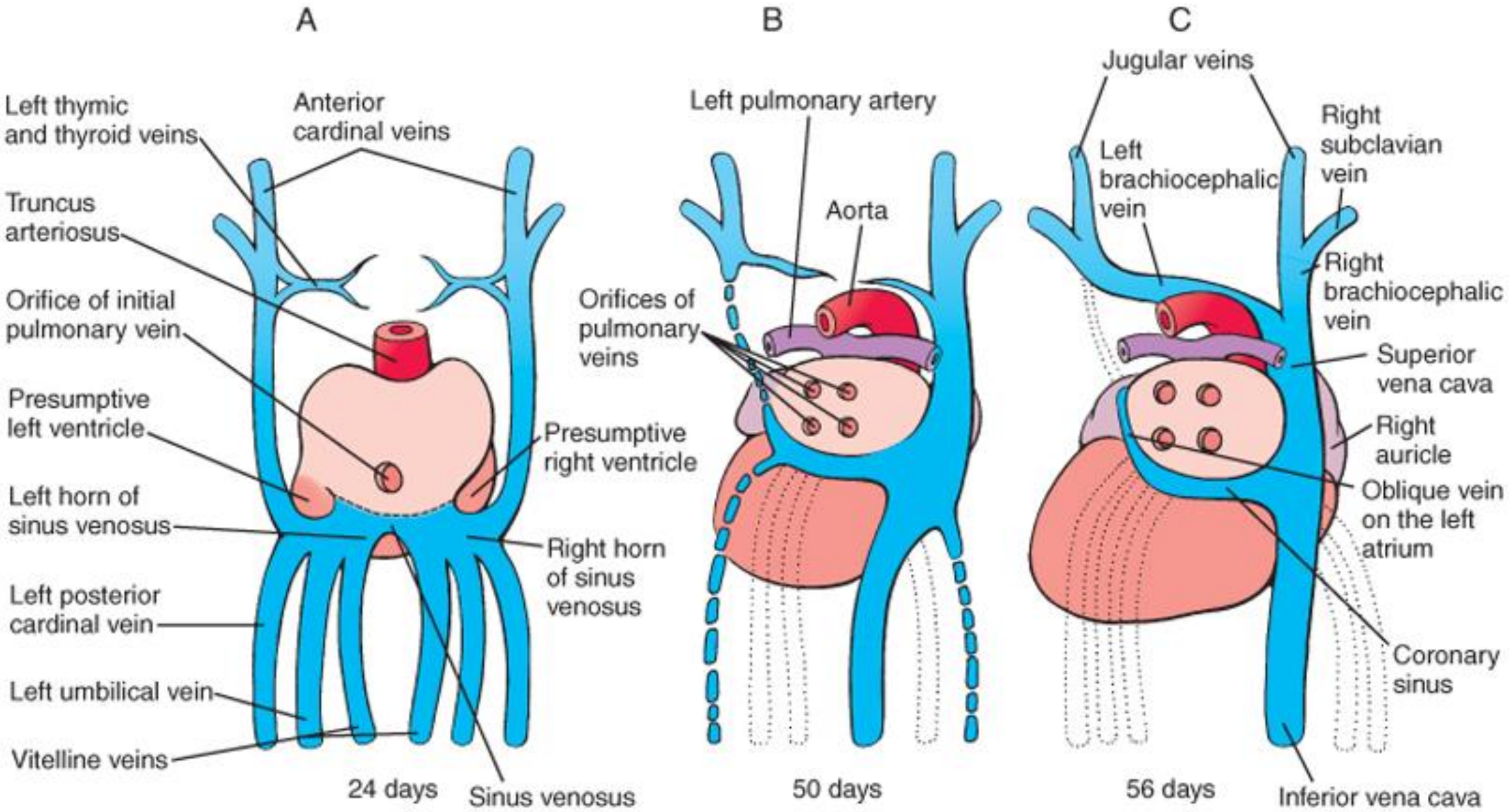
Right horn → Incorporated into R. Atrium

- Incorporated into posterior wall, becomes smooth region of R atrium (sinus venarum)
- The crista terminalis separates the smooth and rough region of the R atrium (houses SA node)

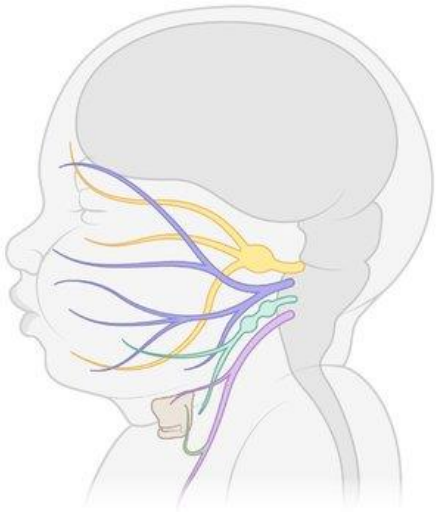
Primordial Pulmonary Vein forms from L atrium



Structure	Derivative
L. Horn	Coronary sinus
R. Horn	SVC, IVC, Smooth part of the R. Atrium



Recall, the Pharyngeal Apparatus

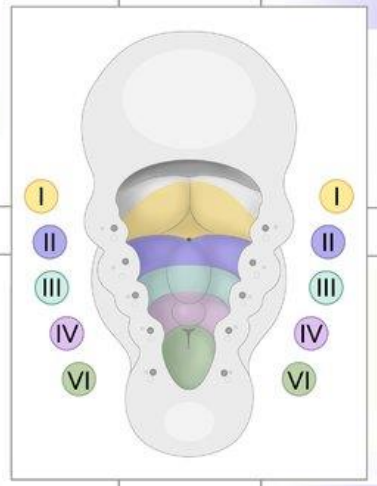


Trigeminal nerve (V)

Facial nerve (VII)

Glossopharyngeal nerve (IX)

Vagus nerve (X)
(superior laryngeal nerve)
(recurrent laryngeal nerve)

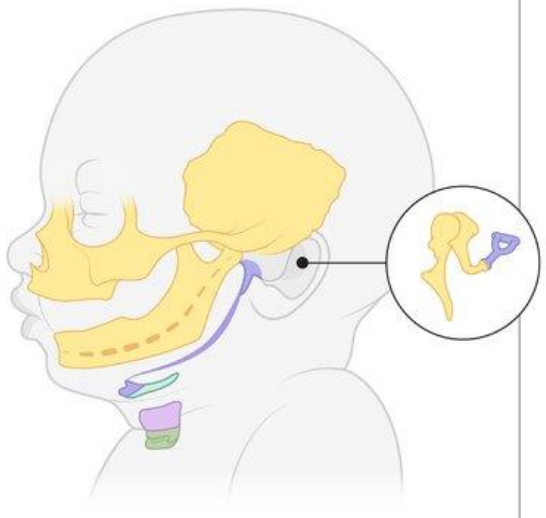


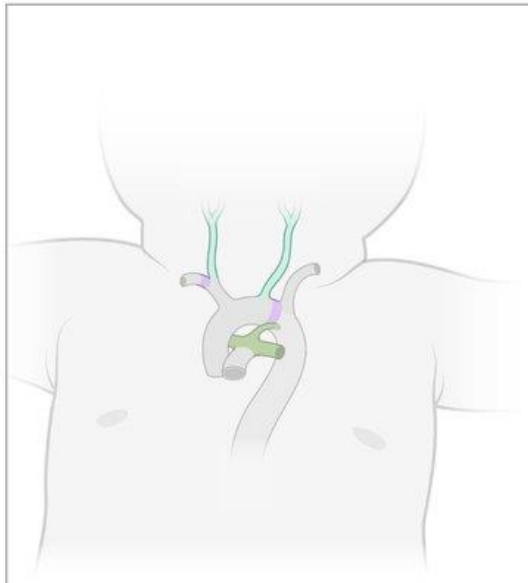
Meckel cartilage
Malleus, incus
Mandible
Maxilla
Several other bones of the skull
(e.g., part of temporal bone)

Reichert cartilage
Stapes
Styloid process
Stylohyoid ligament

Hyoid bone

Laryngeal cartilages





Common carotid arteries
External carotid arteries
(sprout)
Internal carotid arteries
(proximal)

Right subclavian artery
(small portion)
Aortic arch
(small portion)

Pulmonary arteries
Ductus arteriosus

Muscles of mastication
Mylohyoid muscle
Tensor tympani muscle
Tensor veli palatini muscle

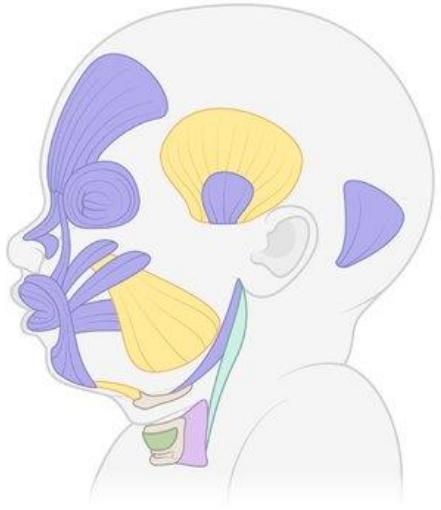
Digastric muscle

Muscles of facial expression
Stylohyoid muscle
Stapedius muscle

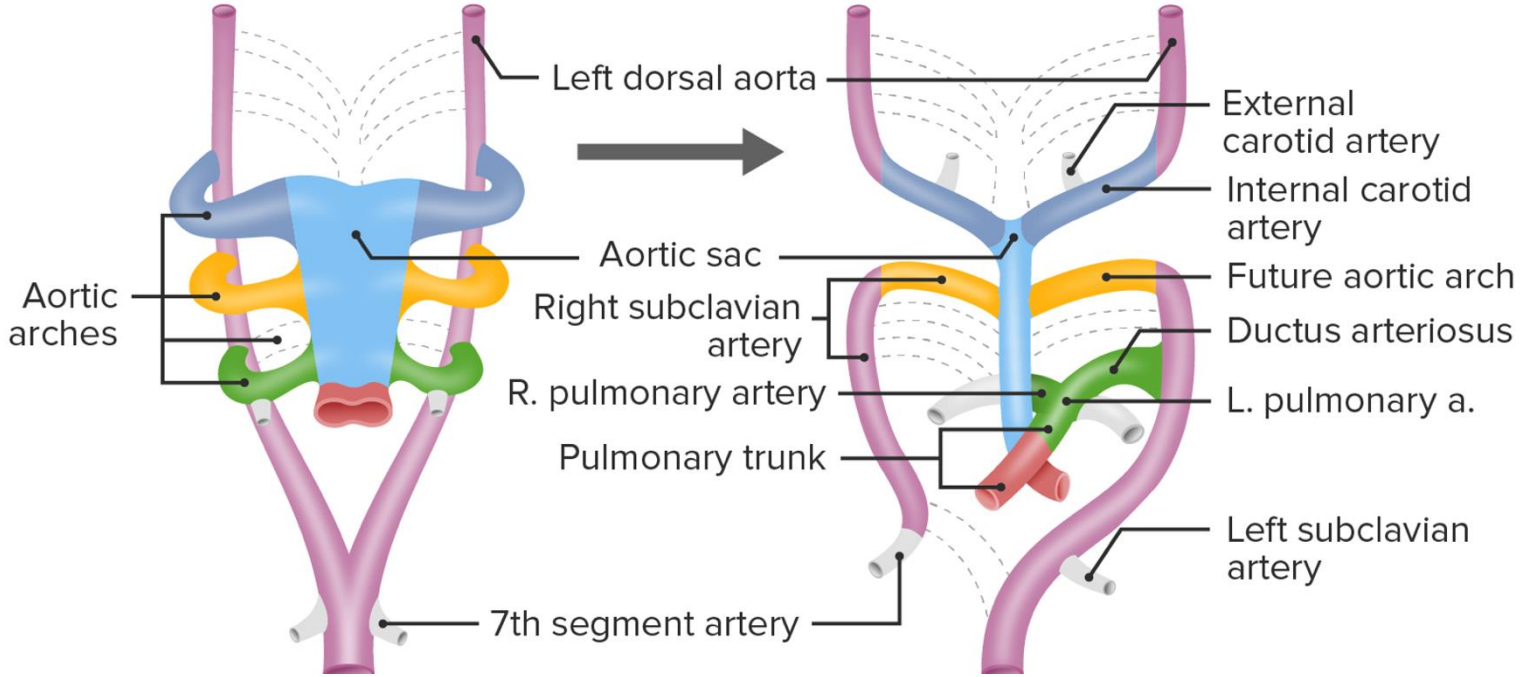
Stylopharyngeus muscle

Pharyngeal constrictor muscles
Cricothyroid muscle
Palatopharyngeus muscle

Intrinsic muscles of the larynx



Pharyngeal Arch Artery Derivatives



3rd pharyngeal arch arteries

4th pharyngeal arch arteries

6th pharyngeal arch arteries

Truncus arteriosus

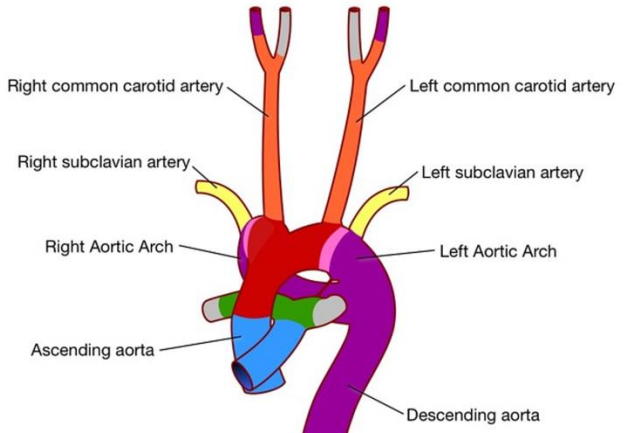
Aortic sac

Pharyngeal arch arteries grow from the aortic sac

Six pairs in total: 1,2 have small contributions to adult anatomy, 5 degrades completely

Pharyngeal Arch	Derivatives
1	Part of Maxillary Artery
2	Stapedial Artery
3	Common Carotid, Proximal Internal Carotid
4	**L.** = Arch between L. common and subclavian **R**. = Proximal R. Subclavian
6	L. = Proximal L pulmonary artery + Ductus arteriosus R. = Proximal R. pulmonary artery

There is differential growth of the R. and L. sides resulting in different adult anatomical structures



Development of Dorsal Aortic Branches

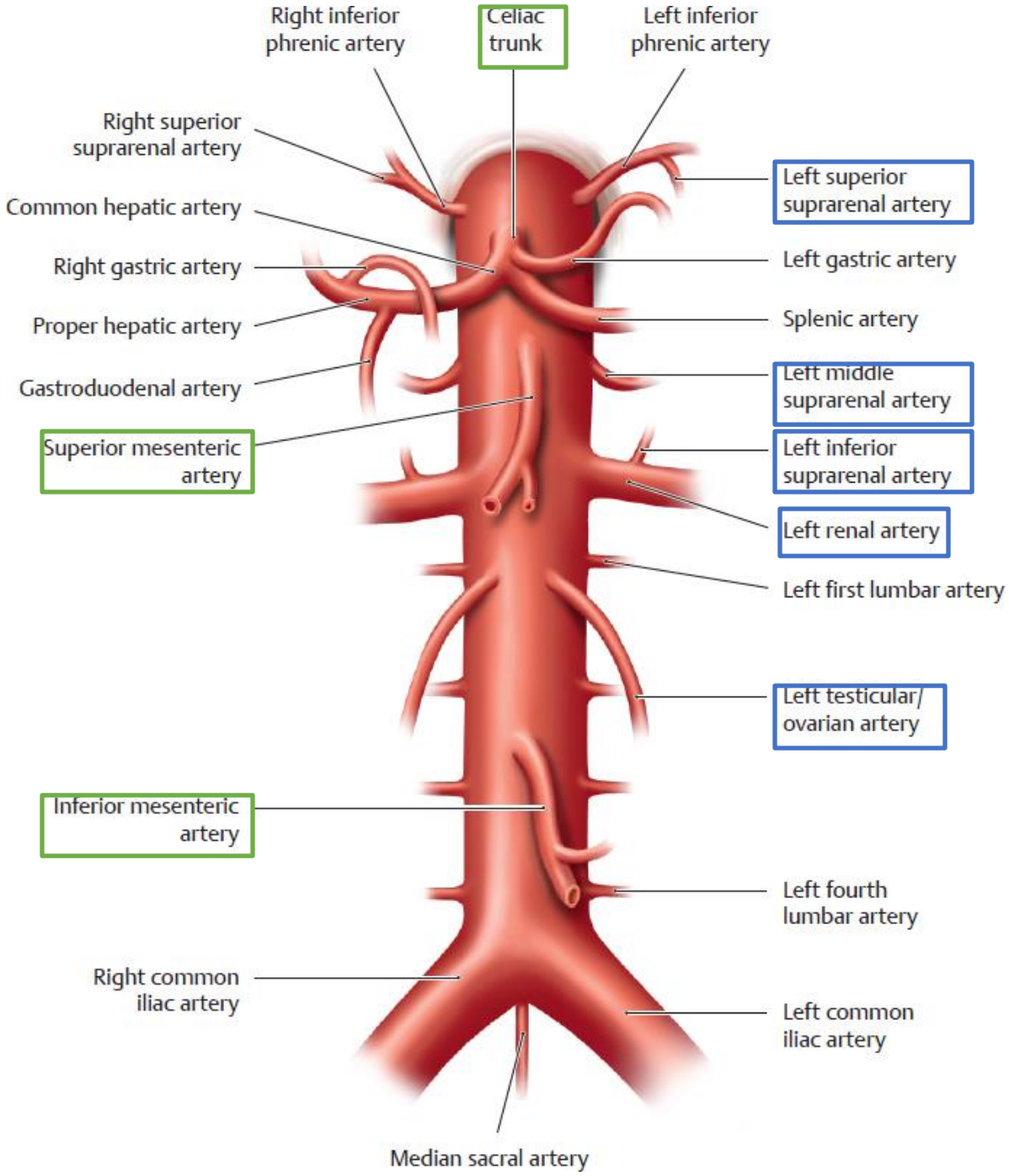
Three Major Components

Ventral Branches: Vitelline, Proximal Umbilical, Distal Umbilical

Lateral Branches

Dorsal Branches

Branches of Dorsal Aorta	Derivatives
Vitelline	Esophageal, Celiac, SMA, IMA
Proximal Umbilical	Superior vesicular, umbilical, internal iliac
Distal Umbilical	Medial umbilical ligaments
Lateral	Renal, suprarenal, gonadal arteries
Dorsal	All other branches (ex. Thoracic, Lumbar, Sacral)



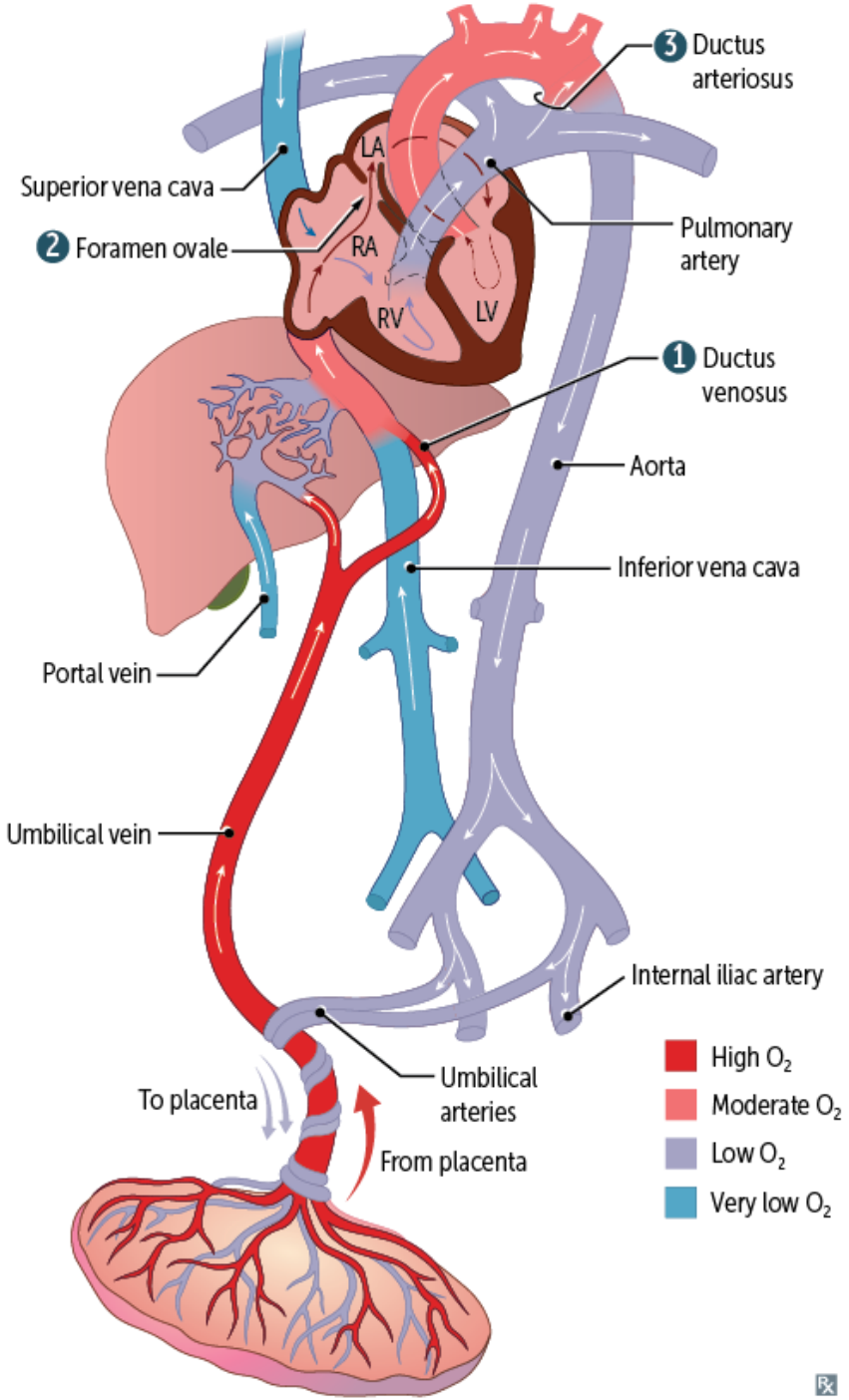
Fetal Circulation

Pathway – starting at placenta

1) Umbilical vein
2) Bypass liver with ductus venosus (straight to IVC)
3) IVC
4) Right atrium
5) L. Atrium via the foramen ovale
6) Left ventricle → Aorta
7) Back to placenta via umbilical arteries

Blood is shunted from the lungs via the ductus arteriosus (connects pulmonary vein and the aortic arch

Structure	Derivative
L. Umbilical Vein	Ligamentum teres hepatis
Ductus Venosus	Ligamentum venosum
Foramen ovale	Fossa ovalis
Ductus arteriosus	Ligamentum arteriosum
Umbilical arteries	Medial umbilical ligaments



Neonatal Circulation

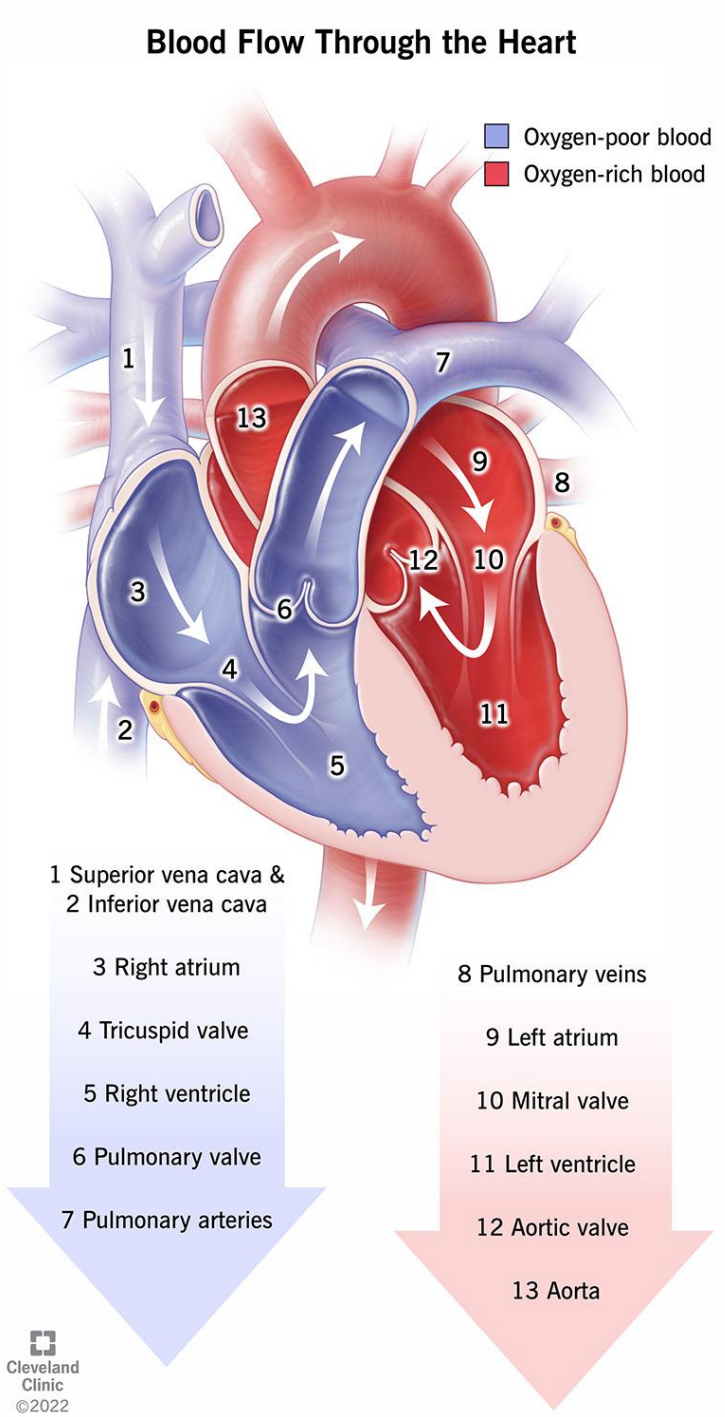
Once we begin to breath

Respiration begins → Increased pulmonary blood flow + L. atrial pressure

- Forces the Foramen ovale closed
- Now blood flows from R. atrium to R. ventricle to the lungs
- Pulmonary veins return oxygenated blood to the L. atrium

Ductus arteriosus begins to close, mediated by bradykinin

Structure	Derivative
L. Umbilical Vein	Ligamentum teres hepatis
Ductus Venosus	Ligamentum venosum
Foramen ovale	Fossa ovalis
Ductus arteriosus	Ligamentum arteriosum
Umbilical arteries	Medial umbilical ligaments



Clinical Anatomy

Alterations in Heart Formation Defining Terms

Left to Right Shunt = Blood from the left side of the heart (oxygenated) to the right side of the heart (deoxygenated)

Result = increased oxygenation in R. heart chambers

AKA – **Acyanotic** Heart Defect

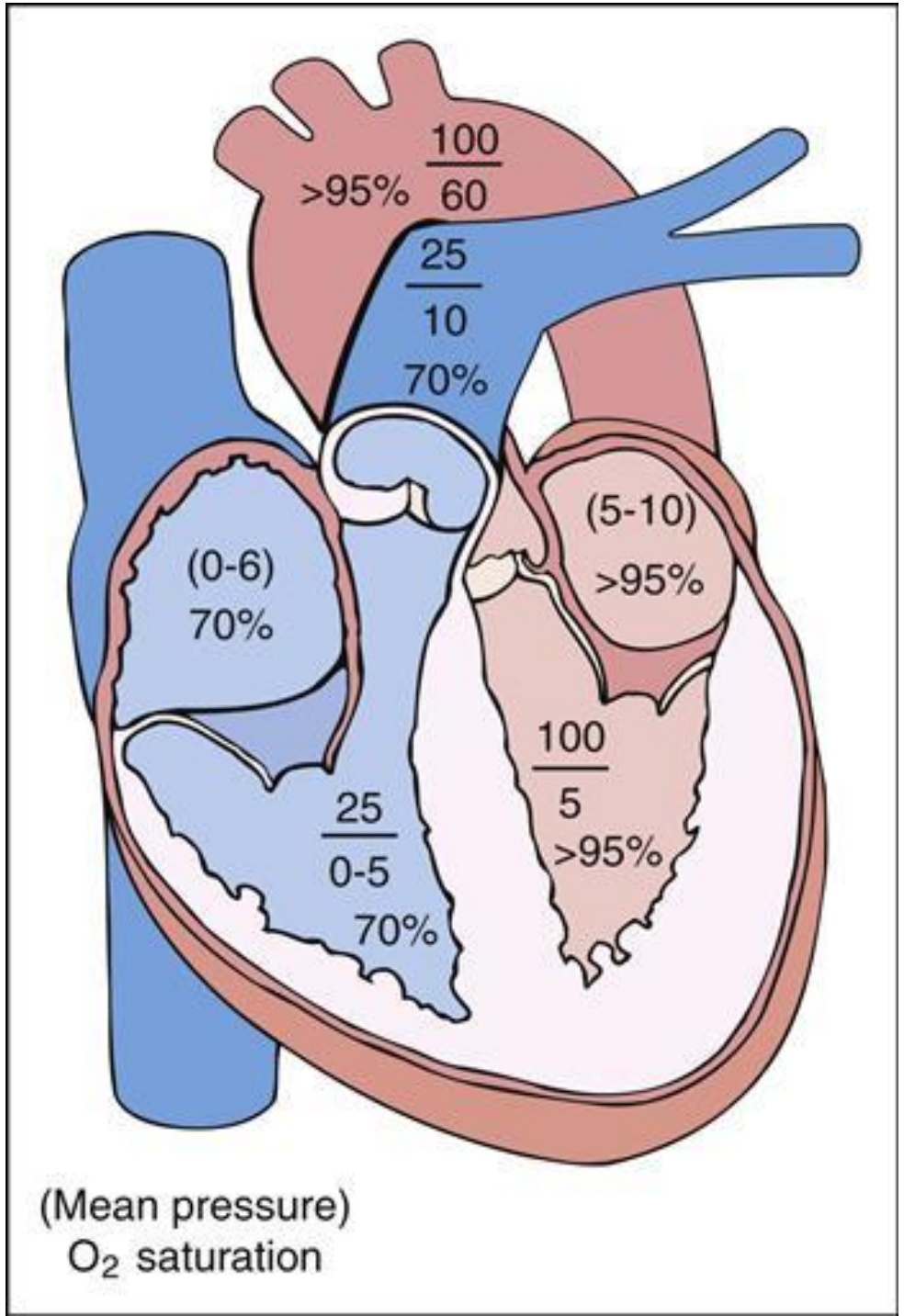
Right to Left Shunt = Blood from right side of the heart (deoxygenated) to the left side of the heart (oxygenated)

Result = Decreased oxygenation in

AKA – **Cyanotic** Heart Defect

Each chamber has an average pressure and oxygenation…. can you predict the changes based on defects?

General principle: Flow is from high pressure area to low pressure area



Acyanotic Defects

Atrial Septal Defects

ASDs = Defects in formation of septum primum or secundum

Probe Patent Foramen Ovale

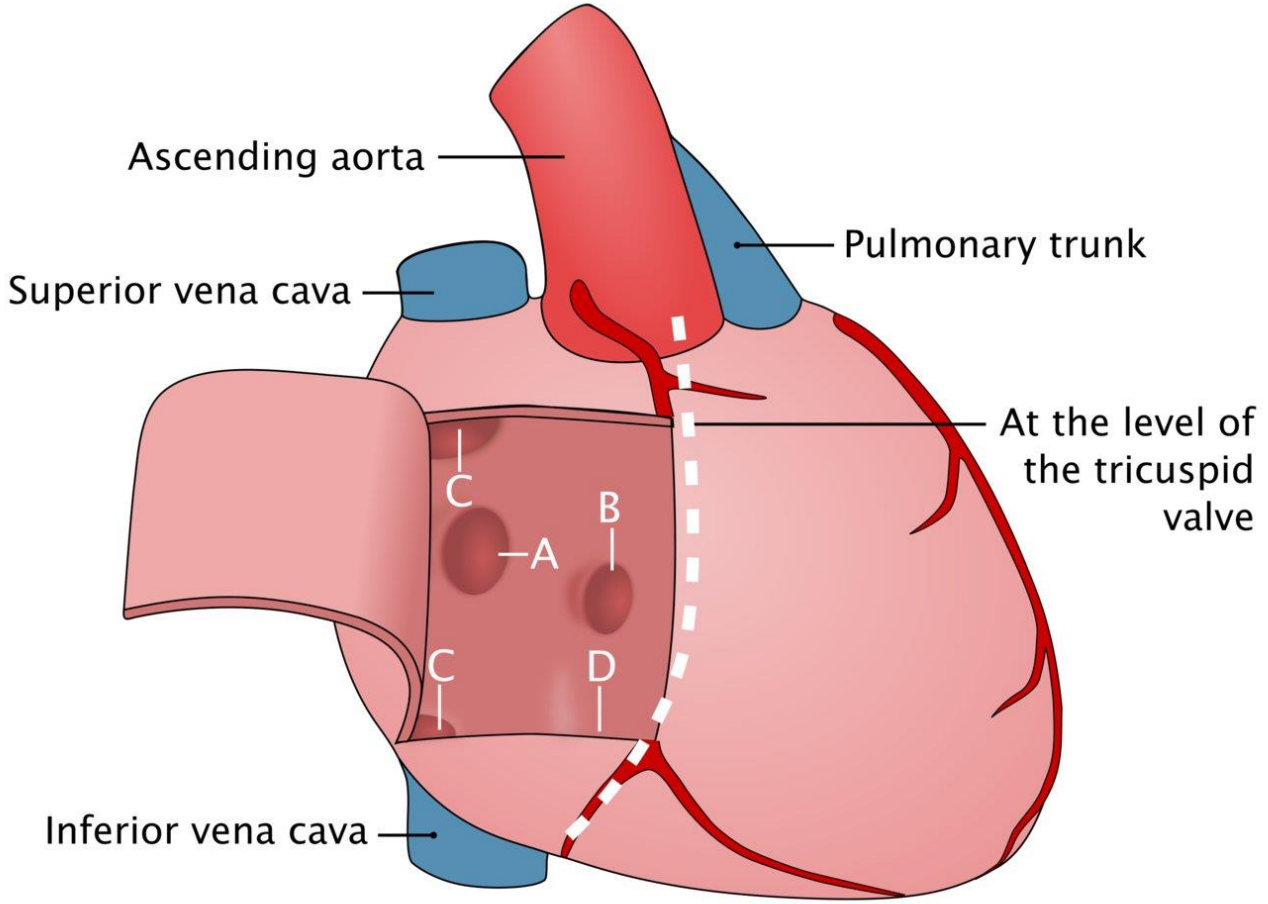
- Incomplete fusion of foramen ovale valve and septum secundum

Ostium Secundum Defects

- Abnormal reabsorption of primum or development of secundum, result in **patent foramen ovale**

Ostium Primum Defects

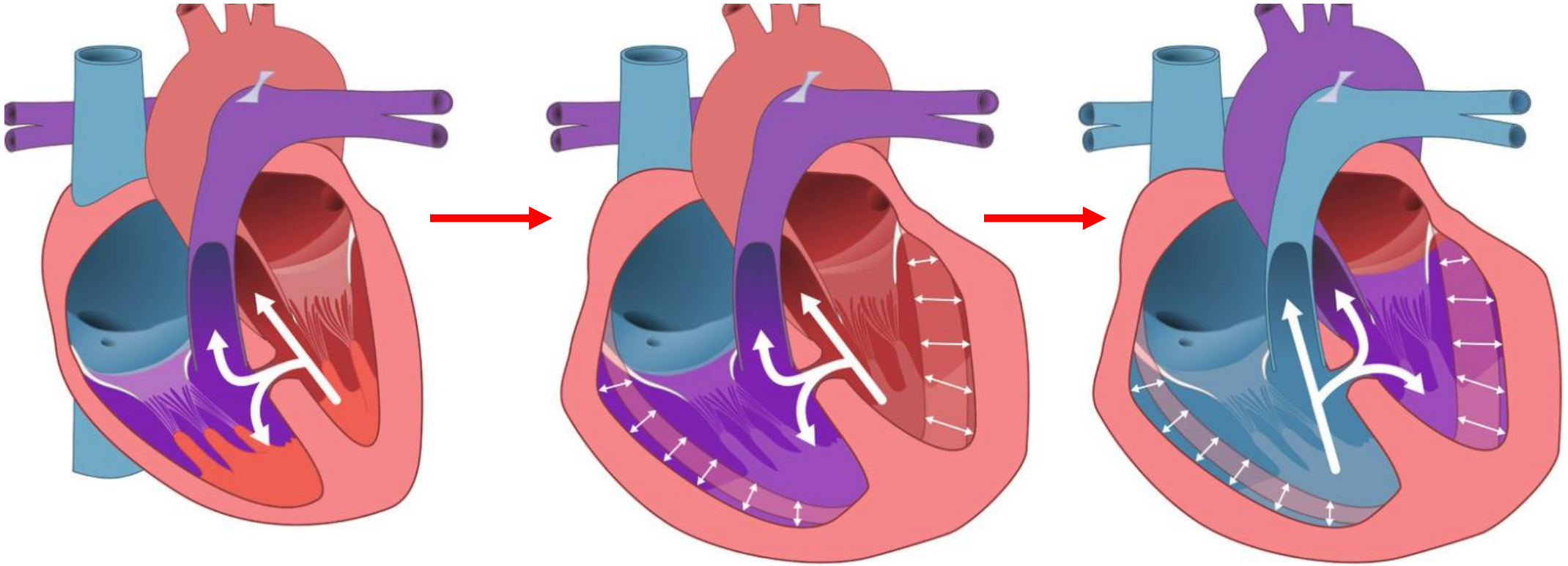
- Deficiency in endocardial cushions/atrioventricular septum
- Can lead to patent foramen primum (failure to fuse with cushions)



Ventricular Septal Defects

VSDs = Defects in formation of membranous or muscular interventricular septum

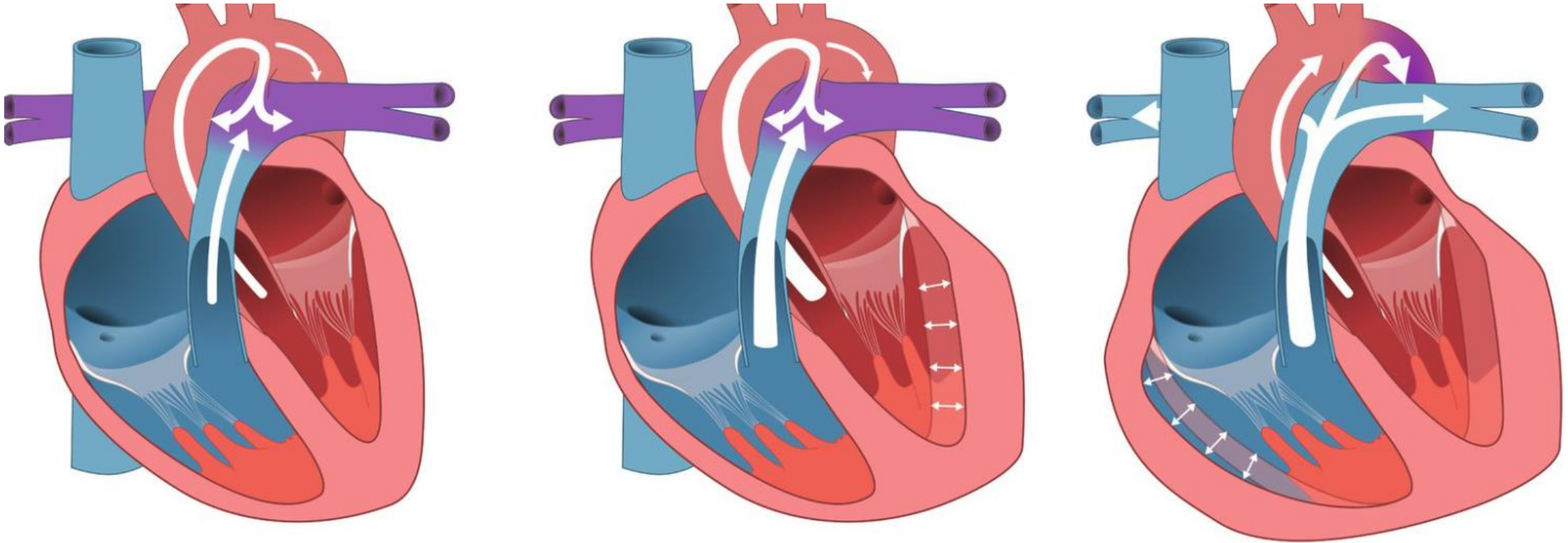
- Result in left to right shunting of blood
- Increases the pressures on the right side of the heart (can lead to heart failure and systemic backup)
- Increased in blood flow through the right side of the heart can also lead to pulmonary HTN
- Eventual right to left shift occurs (Eisenmenger syndrome)



Persistent Ductus Arteriosus (PDA)

PDAs = Failure of the ductus arteriosus to close under direction of Bradykinin

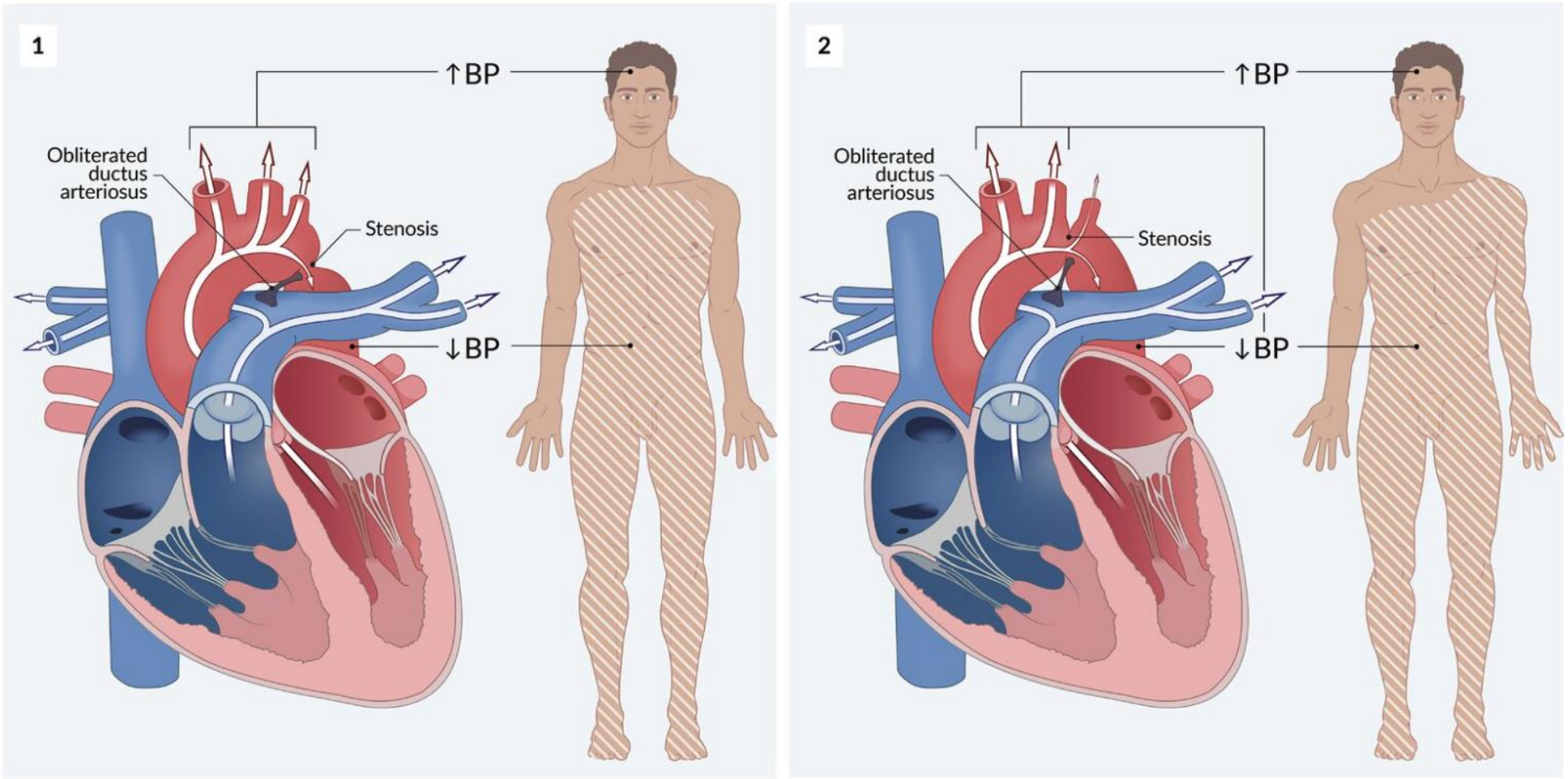
- Left to Right shunt: Aorta to the pulmonary trunk
- Can lead to increased pressure in pulmonary system
- Increased pressure to right heart can lead to heart failure
- Associated with maternal rubella infection



Coaction of the Aorta

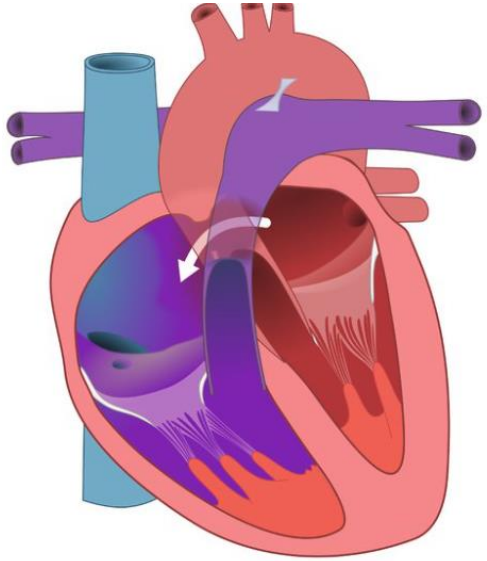
Coarctation = Narrowing of the Aorta, commonly occurs near junction of the ductus arteriosus (aka – pre or post L. subclavian artery)

- Pre L. Subclavian = High BP in right upper extremity, head with lower BP in L. upper extremity and bilateral lower extremities
- Post L. Subclavian = High BP in bilateral upper extremities, Low BP in bilateral lower extremities

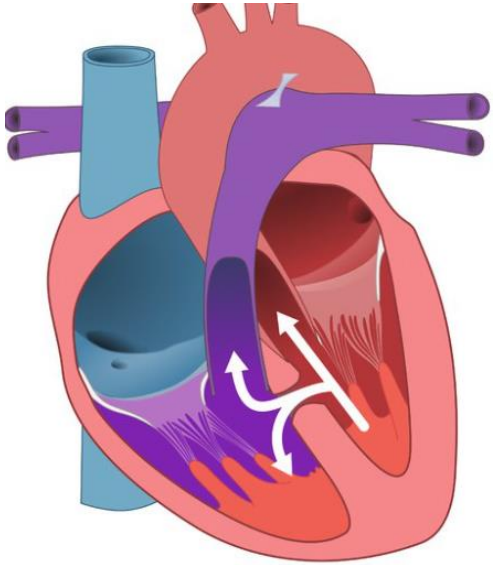


Acyanotic Heart Defects: Summary

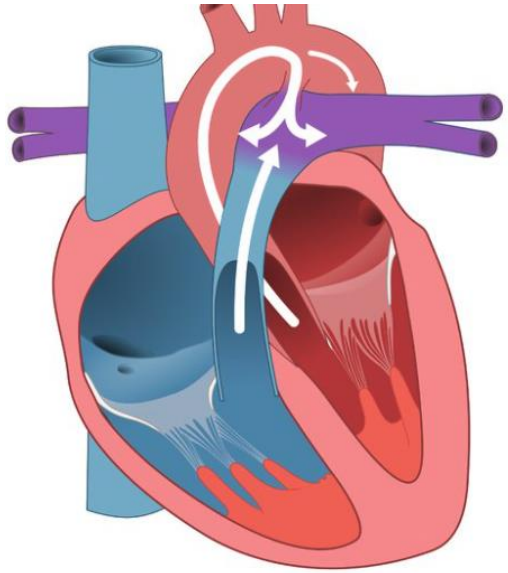
Condition	Key Features	Impact on Blood Flow	Associations
Atrial Septal Defect	Persistent hole between atria	Left to right shunting via the defect	Downs Syndrome, Maternal alcohol use
Ventricular Septal Defect	Persistent hole between ventricles	Left to right shunting via the defect	Downs Syndrome, Maternal alcohol use
Persistent Ductus Arteriosus	Ductus arteriosus remains open, connecting pulmonary trunk and aorta	Left to right shunting form the aorta (high pressure) to the pulmonary trunk (low pressure)	Maternal Rubella infection, Downs syndrome
Coarctation of Aorta	Narrowing of the aorta (usually distal to the left subclavian)	Impedes blood flow to lower body, increased upper body pressures	Turners syndrome



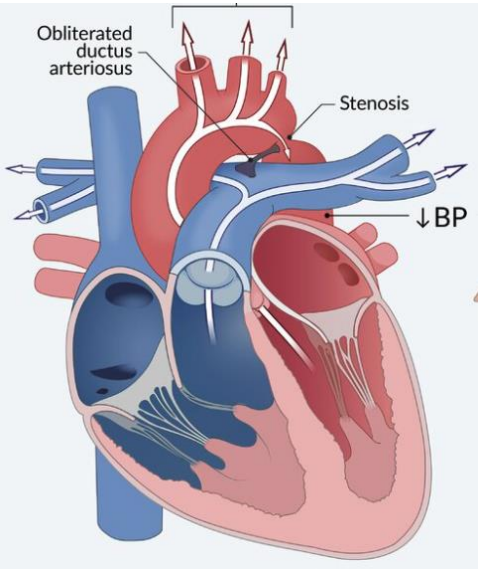
ASD



VSD



PDA



Coarctation

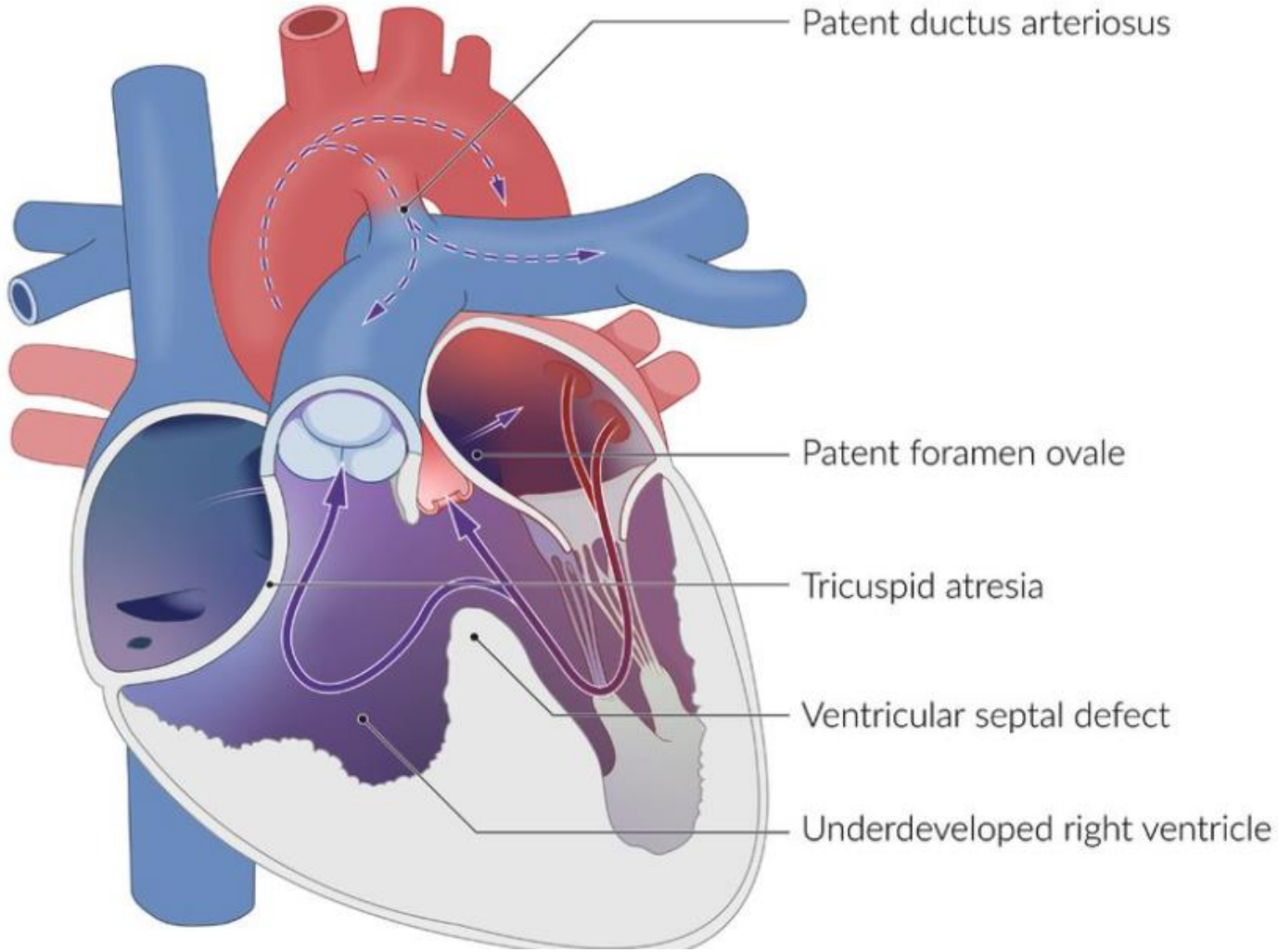
Cyanotic Defects

Tricuspid Atresia

Complete occlusion of R atrioventricular canal, underdeveloped R. ventricle, ASD, VSD

- There is no tricuspid valve to allow blood to flow from R. atria → R. ventricle
- ASD and VSD form to allow blood to fill the R. ventricle
- Once blood it in the R. ventricle it can be pumped into the lungs for oxygenation
- This blood returns to the L. atrium where it mixes with deoxygenated blood from the R. atrium (via ASD)

Result → Deoxygenated blood systemically

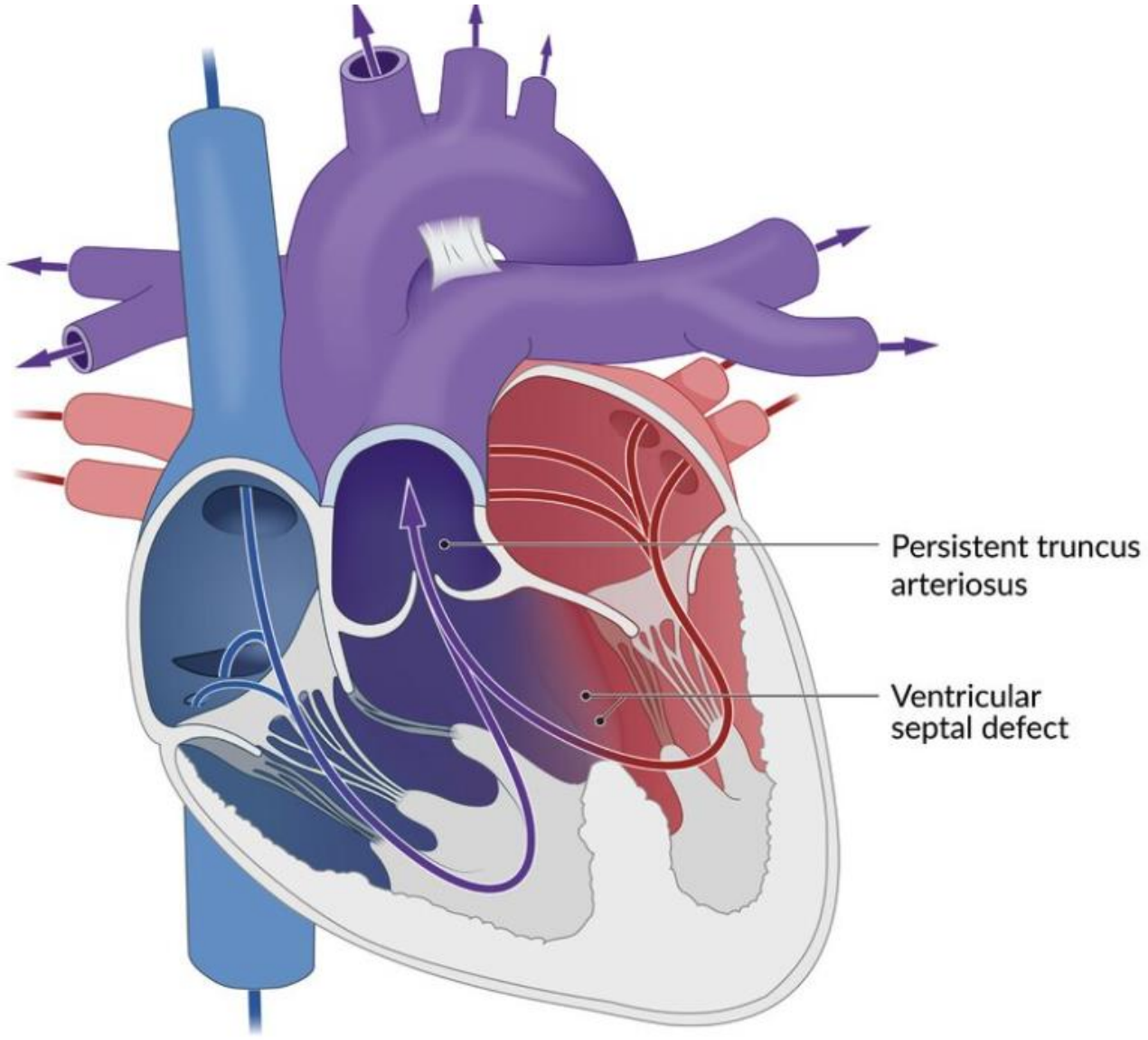


Persistent Truncus Arteriosus

Failed aorticopulmonary septum formation separating aorta and pulmonary trunk, associated with a VSD

- Blood from the L. atrium and R. atrium mix in the truncus arteriosus and then go to the lungs or the body

Result → Deoxygenated blood systemically

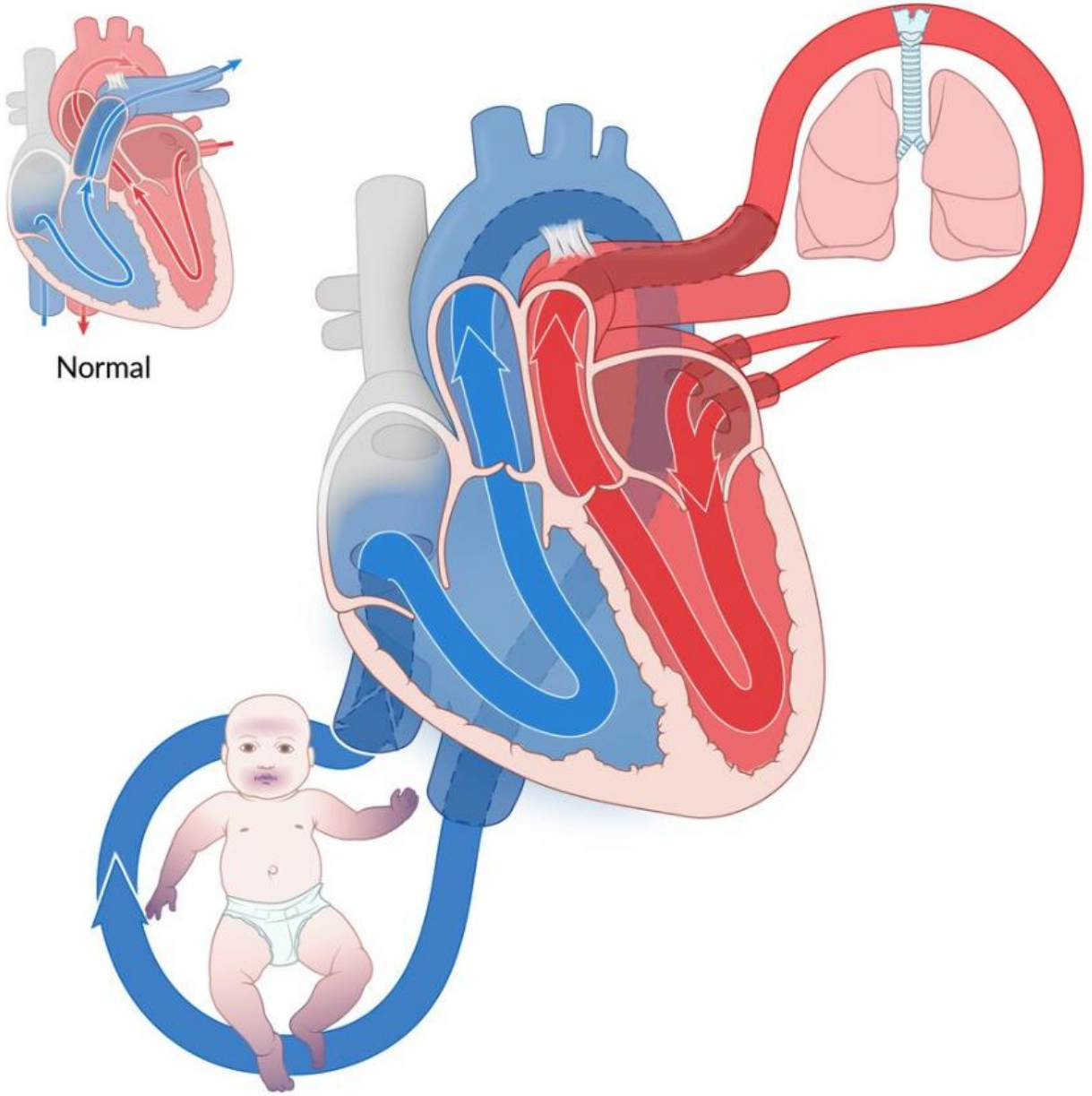


Transposition of the Great Vessels

Aorticopulmonary septum fails to spiral → R ventricle connects to aorta and L. ventricle connects to pulmonary trunk

- Blood from the R. ventricle goes directly to the body without being oxygenated by the lungs
- Blood from the L. ventricle goes directly to the lungs and back to the L. atrium in a circle, never getting to the rest of the body

Result → Deoxygenated blood systemically

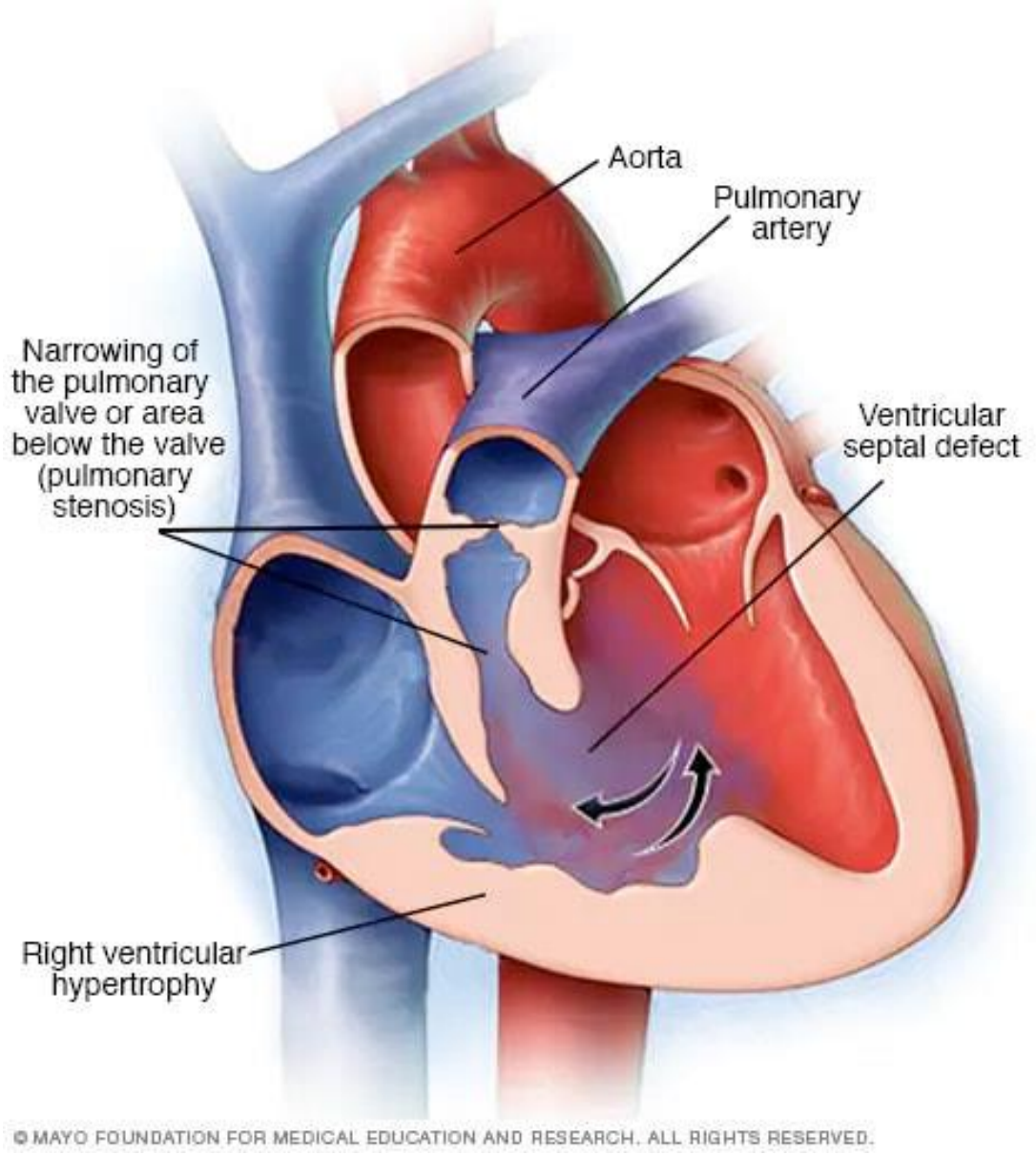


Tetralogy of Fallot

1. **Pulmonary stenosis**
2. **R Ventricular Hypertrophy**
3. **VSD**
4. **Overriding Aorta**

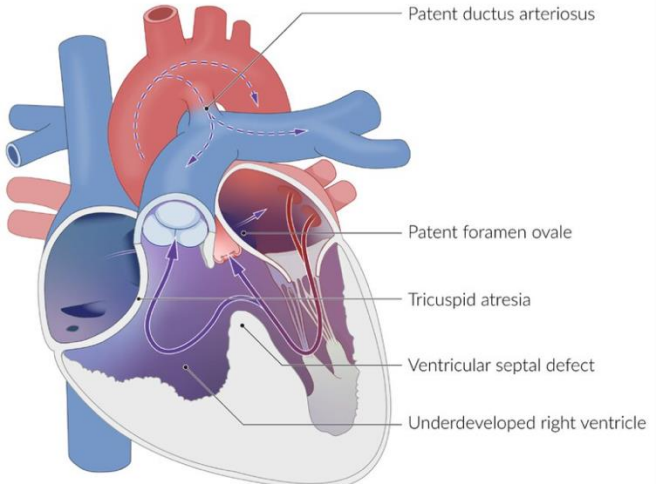
- Over time, as the R. ventricle hypertrophys and grows stronger, it forces blood to the left side of the heart
- This deoxygenated blood mixes with the oxygenated blood on the left side of the heart before being sent into the systemic system

Result → Deoxygenated blood systemically

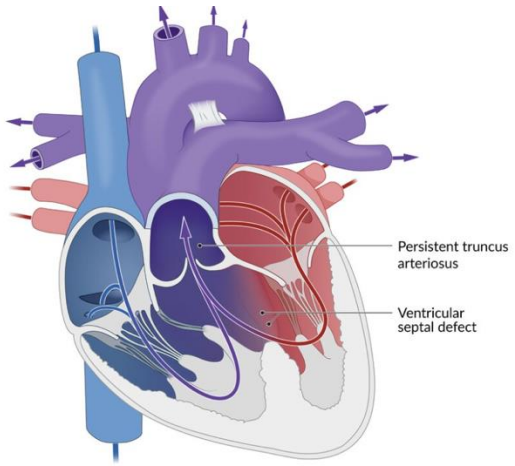


Cyanotic Heart Defects: Summary – The Terrible T's

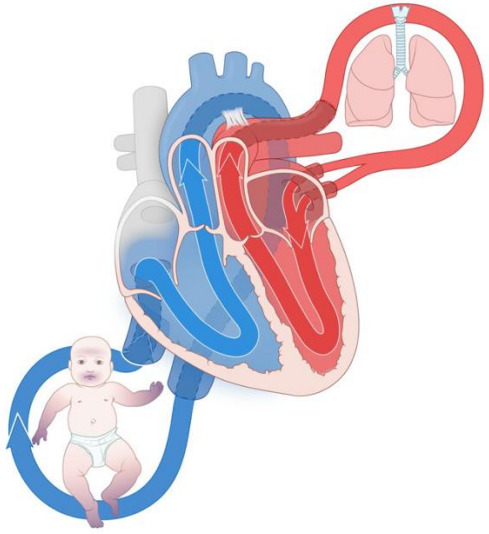
Condition	Key Features	Impact on Blood Flow
Tricuspid Atresia	Complete occlusion of R AV canal. Underdeveloped R. ventricle, ASD, VSD	Flow from R atrium → L atrium → L ventricle → VSD → Lungs for oxygenation
Persistent Truncus Arteriosus	Failed aorticopulmonary septum formation, VSD	Mixed blood to lungs and systemic circulation (Aorta and pulmonary trunk arise from the same region)
Transposition of the great arteries	Aorticopulmonary septum fails to spiral: R ventricle connects to aorta and L. ventricle connects to pulmonary trunk	Deoxygenated blood to systemic system (R atria → R ventricle → Aorta → Body → and back) *No way to oxygenate the blood*
Tetralogy of Fallot	Pulmonary stenosis, R. ventricular hypertrophy, VSD, overriding aorta	VSD, overriding aorta, and right ventricular hypertrophy allows for deoxygenated blood to reach the aorta → body



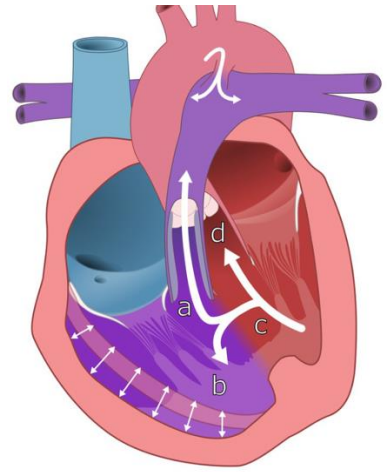
Tricuspid Atresia



Persistent Truncus



Transposition



TOF