

Heart A-Z

Pericardium and Heart — Introduction and Pericardium (Fibrous & Serous Layers, Dissection, Clinical Anatomy)

Introduction

- The **pericardium** is a **fibro-serous sac** that encloses the **heart** and the **roots of the great vessels**, situated within the **middle mediastinum**.
- It consists of two layers — the **fibrous pericardium** (outer) and the **serous pericardium** (inner)

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- The heart lies within both fibrous and serous pericardial sacs; during development, it **invaginates into the serous sac** without rupturing it.
- The visceral layer (epicardium) covers the heart, while the parietal layer fuses with the fibrous pericardium

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- Functionally, the pericardium **anchors the heart**, **prevents overdistension**, and allows frictionless movement during cardiac contraction.

Fibrous Pericardium

- **Structure:** A **conical fibrous sac**, tough and inelastic, enclosing the heart and great vessels.
- **Apex:** Blunt; fused with the **roots of great vessels** and **pretracheal fascia** at the level of the **sternal angle**.
- **Base:** Broad; inseparably fused with the **central tendon of the diaphragm**.
- **Anterior attachment:** Connected to the sternum by **superior and inferior sternopericardial ligaments**.
- **Posterior relations:** Principal bronchi, esophagus with surrounding nerve plexus, and descending thoracic aorta
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- **Lateral relations:** Mediastinal pleura, phrenic nerve, and pericardiophrenic vessels
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- **Functions:**
 - Keeps the heart in position within the mediastinum.
 - Prevents sudden overfilling and overexpansion during cardiac cycles.

Serous Pericardium

- **Structure:** Thin, double-layered membrane lined by **mesothelium**.
 - **Parietal layer:** Fused to the fibrous pericardium.

- **Visceral layer (epicardium):** Closely adherent to the heart except along grooves where vessels intervene.
 - The two layers are continuous around the **roots of the great vessels** — aorta, pulmonary trunk, venae cavae, and pulmonary veins.
 - **Pericardial cavity:** Potential space between parietal and visceral layers containing **serous fluid** for lubrication.
 - **Functions:**
 - Minimizes friction between the heart and surrounding structures.
 - Ensures smooth cardiac movement during systole and diastole
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Sinuses of Pericardium

1. Transverse Sinus

- A horizontal passage between arterial and venous ends of the heart tube.
- **Anterior boundary:** Ascending aorta and pulmonary trunk.
- **Posterior boundary:** Superior vena cava.
- **Inferior boundary:** Left atrium.
- Opens laterally into the general pericardial cavity.
- **Development:** Formed by degeneration of the **dorsal mesocardium**.

- **Clinical importance:** Used during cardiac surgery to clamp great vessels for cardiopulmonary bypass

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2. Oblique Sinus

- A narrow cul-de-sac behind the left atrium.
- **Anteriorly:** Left atrium
- **Posteriorly:** Parietal pericardium and esophagus
- **Laterally:** Reflections of pericardium around pulmonary veins
- Permits **free pulsation of left atrium** and develops as veins of the heart separate during embryogenesis

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Dissection of Pericardium

- Incise the pericardium vertically and transversely to expose the **heart and great vessels**.
- Identify the **transverse sinus** between aorta and SVC and the **oblique sinus** behind the left atrium.
- Note relations of fibrous pericardium with **diaphragm**, **sternum**, and **pleura** during dissection.

Clinical Anatomy

- **Pericarditis:** Inflammation causing chest pain due to friction between pericardial layers; pain radiates to **shoulder tip (C4 dermatome)** through **phrenic nerve**.
- **Pericardial effusion:** Accumulation of fluid within pericardial cavity leading to **cardiac tamponade** (compression of heart).
- **Pericardiocentesis:** Drainage of pericardial fluid by needle insertion through **left 5th intercostal space near sternum** to avoid coronary vessels.
- **Constrictive pericarditis:** Chronic fibrosis and thickening of pericardium leading to **restricted cardiac filling** and venous congestion.
- **Developmental origin:** Fibrous pericardium arises from **septum transversum**, while serous layers arise from **coelomic epithelium**

Heart — External Features and Clinical Anatomy

Heart — Introduction

- The **heart** is a **conical hollow muscular organ** located in the **middle mediastinum** within the **pericardium**.
- Its function is to **pump blood throughout the body**, maintaining systemic and pulmonary circulation.
- The term *cardia* (Greek) gives rise to “cardiac,” while *cor* (Latin) gives rise to “coronary.”
- It lies **obliquely behind the sternum**, with **one-third to the right** and **two-thirds to the left** of the midline.

- The **apex** points downwards, forwards, and to the left; blood flow through the heart is **downwards, forwards, and leftwards**.
- Dimensions: approximately **12 × 9 cm**; weight about **300 g in males** and **250 g in females**

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External Features

- The heart has **four chambers**: right and left atria (upper chambers) and right and left ventricles (lower chambers).
- Atria are separated by the **interatrial groove**; ventricles by the **interventricular groove** (anterior and posterior parts).
- The **atrioventricular groove (coronary sulcus)** separates atria from ventricles externally

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External Characteristics:

1. Apex

- Formed by the **left ventricle**.
- Directed downwards, forwards, and to the left.
- Lies at the level of the **left 5th intercostal space**, about **9 cm from the midsternal line**.

- Its beat felt as the **apex beat (point of maximal impulse)**.

2. **Base (Posterior Surface)**

- Formed mainly by the **left atrium**, partly by the **right atrium**.
- Lies opposite the apex and faces posteriorly towards the vertebral column.
- Receives **four pulmonary veins** and **superior and inferior venae cavae**.

3. **Surfaces of the Heart**

- **Sternocostal (anterior) surface:** Formed mainly by the right atrium and right ventricle; related to sternum and costal cartilages.
- **Diaphragmatic (inferior) surface:** Formed mainly by the left ventricle and partly by the right ventricle; rests on the diaphragm.
- **Left pulmonary surface:** Formed by the left ventricle; related to the left lung and pleura.
- **Right pulmonary surface:** Formed by the right atrium; related to the right lung and pleura.

4. **Borders of the Heart**

- **Right border:** Right atrium (from SVC to IVC).
- **Left border:** Left ventricle and left auricle.
- **Inferior border:** Right ventricle.
- **Superior border:** Both atria with the great vessels (aorta, pulmonary trunk, SVC).

5. Grooves or Sulci

- **Coronary sulcus:** Encircles the heart, separating atria and ventricles; contains coronary vessels.
- **Anterior interventricular groove:** Between right and left ventricles on sternocostal surface; contains anterior interventricular artery and great cardiac vein.
- **Posterior interventricular groove:** Between ventricles on diaphragmatic surface; contains posterior interventricular artery and middle cardiac vein.
- **Crux of the heart:** The meeting point of interatrial, atrioventricular, and posterior interventricular grooves

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Types of Circulation

- **Systemic circulation:** Left ventricle → body → right atrium.
- **Pulmonary circulation:** Right ventricle → lungs → left atrium.
- These systems ensure oxygenation and nutrient transport throughout the body

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Clinical Anatomy

- The **precordium** is the area of the chest wall overlying the heart.

- **Tachycardia:** Abnormally rapid heartbeat.
- **Bradycardia:** Abnormally slow heartbeat.
- **Arrhythmia:** Irregular heartbeat.
- **Palpitation:** Awareness of one's heartbeat.
- **Inflammations of heart layers:**
 - *Pericarditis* — inflammation of pericardium.
 - *Myocarditis* — inflammation of myocardium.
 - *Endocarditis* — inflammation of endocardium.
- **Apex beat:** Normally felt in the left 5th intercostal space, 9 cm from the midsternal line.
- **Dextrocardia:** Congenital condition where the heart lies on the right side, with the apex beat on the right.
- **Situs inversus:** Complete mirror-image arrangement of thoracic and abdominal viscera

Right Atrium — Structure and Dissection

Position

- The **right atrium** forms the **right upper chamber** of the heart.
- It receives **venous blood** from the entire body and delivers it to the **right ventricle** through the **tricuspid orifice**.

- It constitutes the **right border**, part of the **upper border**, a portion of the **sternocostal surface**, and part of the **base** of the heart

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External Features

1. Shape and Orientation:

- Vertically elongated chamber extending between **SVC (above)** and **IVC (below)**.
- Prolonged leftwards to form the **right auricle**, a small ear-like muscular pouch covering the root of the aorta and overlapping the right ventricle.

2. Sulcus Terminalis:

- A shallow vertical groove on the **right border**, extending from the **SVC** to the **IVC**.
- Internally represented by the **crista terminalis** — a muscular ridge.
- The **upper part** of this sulcus houses the **sinoatrial (SA) node**, the heart's natural pacemaker

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3. Right Atrioventricular Groove:

- Separates the right atrium from the right ventricle.
- Lodges the **right coronary artery** and **small cardiac vein**

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Dissection

- Make an incision along the **upper edge of the right auricle** from the anterior end of the **SVC opening** to the **anterior end of IVC opening**.
 - Cut the **anterior wall near its left margin** and reflect the flap rightwards to expose the interior.
 - Identify:
 - **Crista terminalis** — a vertical ridge.
 - **Pectinate muscles** — horizontal muscular ridges.
 - **Fossa ovalis** on interatrial septum.
 - **Opening of coronary sinus** (to left of IVC).
 - **Tricuspid valve cusps** near the atrioventricular orifice
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Tributaries / Inlets

1. **Superior vena cava**
2. **Inferior vena cava** (guarded by **Eustachian valve**)
3. **Coronary sinus** (guarded by **Thebesian valve**)

4. **Anterior cardiac veins**
5. **Venae cordis minimae (Thebesian veins)**
6. Occasionally, **right marginal vein**

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Internal Features

1. **Smooth Posterior Part (Sinus Venarum):**

- Derived embryologically from the **right horn of the sinus venosus**.
- Receives SVC, IVC, and coronary sinus.
- Contains **intervenous tubercle of Lower**, a small projection that directs venous flow during fetal life

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2. **Rough Anterior Part (Pectinate Part):**

- Derived from **primitive atrium**.
- Contains **musculi pectinati**, giving comb-like ridges (especially in the auricle).
- The **crista terminalis** separates this part from the sinus venarum

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3. **Interatrial Septum:**

- Features the **fossa ovalis** — a depression in the lower part representing the **site of foramen ovale** of the fetus.
- The raised margin is called the **annulus ovalis (limbus fossae ovalis)**.
- The foramen ovale normally closes after birth; if it persists, it can cause a **right-to-left shunt**

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Right Ventricle — Structure and Dissection

Position and Extent

- The **right ventricle** forms:
 - The **inferior border** of the heart.
 - **Two-thirds of the anterior (sternocostal) surface.**
 - **One-third of the diaphragmatic (inferior) surface.**
- It receives blood from the right atrium and pumps it into the **pulmonary trunk**

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External Features

1. **Anterior (Sternocostal) Surface:** Lies behind the sternum and costal cartilages.

2. **Inferior (Diaphragmatic) Surface:** Rests on the diaphragm, sharing this area with the left ventricle.
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Internal Features

1. **Two Functional Parts:**

- **Inflowing Part:**

- Rough with muscular ridges called **trabeculae carneae** (from proximal bulbus cordis).

- **Outflowing Part (Infundibulum/Conus Arteriosus):**

- Smooth conical region leading to **pulmonary trunk** (from mid bulbus cordis).

- The two parts are separated by **supraventricular crest (infundibulovenricular crest)**

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2. **Orifices:**

- **Right atrioventricular (tricuspid) orifice** with tricuspid valve.

- **Pulmonary orifice** with pulmonary valve.

3. **Muscular Ridges (Trabeculae Carneae):**

- **Ridges (fixed elevations)**

- **Bridges**
 - **Pillars or papillary muscles** — three in number:
 - **Anterior (largest)**
 - **Posterior (small)**
 - **Septal (multiple small heads)**
 - Each gives rise to **chordae tendineae** attached to valve cusps
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4. **Septomarginal Trabecula (Moderator Band):**

- Muscular band from interventricular septum to base of anterior papillary muscle.
 - Contains the **right branch of the AV bundle**, facilitating conduction
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5. **Interventricular Septum:**

- Oblique; consists of:
 - **Upper membranous part** — separates right atrium from left ventricle.
 - **Lower muscular part** — separates two ventricles.
 - Its external position corresponds to the **interventricular grooves**
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Dissection of Right Ventricle

- Make an incision along the **ventricular aspect of the right atrioventricular groove** extending to the **inferior border**.
- Continue along the **inferior border** up to the **anterior interventricular groove**.
- Cut along the **infundibulum** and reflect the wall leftwards to expose:
 - **Trabeculae carneae**
 - **Papillary muscles with chordae tendineae**
 - **Moderator band**
 - **Tricuspid and pulmonary valves**

Left Atrium — Structure and Dissection

Position

- The **left atrium** is a **quadrangular chamber** situated **posteriorly** in the heart.
 - It forms the **left two-thirds of the base**, the **greater part of the upper border**, parts of the **sternocostal** and **left surfaces**, and the **left border**.
 - It receives **oxygenated blood** from the **four pulmonary veins** (two from each lung) and pumps it into the **left ventricle** through the **left atrioventricular (mitral) orifice**
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Features

- **Posterior wall:** Smooth and receives the pulmonary veins.
- **Anterior wall:** Formed by the **interatrial septum**.
- **Interior:** Mostly smooth due to incorporation of pulmonary veins during development.
- **Auricle:** Muscular pouch projecting forward, containing **pectinate muscles** forming a reticular pattern — the only rough part.
- **Fossa lunata:** Seen on septal wall, corresponding to the **fossa ovalis** of the right atrium.
- **Tributaries:** Four pulmonary veins and a few **venae cordis minimae**

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Dissection

- Cut off the **pulmonary trunk** and **ascending aorta** immediately above their valves.
- Remove the **upper part of the left atrium** to visualize its interior.
- Observe:
 - Openings of four pulmonary veins on the posterior wall.
 - Smooth atrial surface and thin **auricular appendage**.

- Upper surface of **mitral valve cusps** projecting into the left ventricle.
- Note that the **anterior wall of the oblique sinus** of the pericardium is formed by the **posterior surface** of the left atrium

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Left Ventricle — Structure and Dissection

Position

- The **left ventricle** receives **oxygenated blood** from the left atrium and pumps it into the **aorta**.
- It forms the **apex of the heart**, part of the **sternocostal surface**, most of the **left border and left surface**, and **two-thirds of the diaphragmatic surface**

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Features

1. External Surfaces:

- **Anterior (sternocostal)**
- **Inferior (diaphragmatic)**
- **Left surface**

2. Interior Parts:

- **Lower rough part:** Contains **trabeculae carneae** — developed from the primitive ventricle.
- **Upper smooth part (aortic vestibule):** Leads to the **aortic orifice**; derived from the **mid-portion of the bulbus cordis**.

3. Orifices:

- **Mitral orifice:** Guarded by the **bicuspid (mitral) valve**.
- **Aortic orifice:** Guarded by the **aortic valve**.

4. Papillary Muscles:

- **Two in number** — anterior and posterior.
- **Chordae tendineae** from both attach to both valve cusps.

5. Shape and Wall Thickness:

- Cavity is **circular in cross-section**.
- Wall is **three times thicker** than that of the right ventricle due to higher systemic pressure

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Dissection

- Open the ventricle by cutting along its **left border** from the apex towards the **aortic vestibule**.
 - Observe:
 - **Papillary muscles and chordae tendineae**.
 - **Mitral valve cusps** guarding the atrioventricular orifice.
 - **Aortic valve cusps** (three semilunar cusps) at the outflow tract.
 - Note the **thick muscular wall** and **smooth aortic vestibule**.
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Clinical Anatomy of Atria and Ventricles

- **Mitral Stenosis:**
 - Causes **left atrial enlargement**, leading to compression of the **esophagus** and **dysphagia** (difficulty in swallowing).
 - Often produces a **diastolic murmur**.
- **Tricuspid Stenosis:**
 - Leads to **right atrial enlargement** and venous congestion.
- **Mitral Incompetence:**
 - Backflow from the left ventricle to the left atrium during systole ? **pansystolic murmur**.
- **Aortic Stenosis:**

- Causes **left ventricular hypertrophy** due to increased resistance to outflow.
- **Aortic Regurgitation:**
 - Backflow into left ventricle during diastole ? **dilated, hypertrophied left ventricle**.
- **Pulmonary Stenosis / Regurgitation:**
 - Affects the right ventricle; may lead to **right ventricular hypertrophy** and **cyanosis**.
- **Ventricular Septal Defect (VSD):**
 - Congenital opening between ventricles ? **left-to-right shunt** and pulmonary hypertension.
- **Atrial Septal Defect (ASD):**
 - Persistence of **foramen ovale** ? left-to-right shunt; often asymptomatic in adults.
- **Congestive Heart Failure:**
 - Weak ventricular pumping ? systemic or pulmonary congestion.
- **Myocardial Infarction:**
 - Common in left ventricle due to blockage of **left anterior descending artery**.
- **Cardiac Tamponade:**
 - Fluid accumulation compresses all four chambers, particularly **thin-walled atria**, leading to **reduced venous return**

Structure of the Heart

- The **heart** is a **four-chambered muscular organ** made of specialized cardiac muscle called **myocardium**.
- It consists of **two atria** (right and left) and **two ventricles** (right and left), separated by **interatrial** and **interventricular septa**.
- The atria act as **receiving chambers**, while the ventricles serve as **pumping chambers**.
- The **interatrial septum** is thin, whereas the **interventricular septum** has a **thick muscular part** and a **thin membranous part**.
- The heart wall is composed of three layers:
 - **Endocardium**: Inner endothelial lining covering valves and chambers.
 - **Myocardium**: Middle muscular layer responsible for contraction.
 - **Epicardium**: Outer serous covering (visceral layer of serous pericardium).
- The **fibrous skeleton of the heart** consists of dense connective tissue forming **four fibrous rings (annuli fibrosi)** around the orifices of the heart valves and provides attachment for cardiac muscle and valves.
- The **cardiac skeleton** electrically insulates the atria from the ventricles except through the **AV bundle**, ensuring proper sequential contraction

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Valves of the Heart

The heart valves ensure **unidirectional flow** of blood and prevent regurgitation during the cardiac cycle. They are of two main types:

1. Atrioventricular (AV) Valves

(a) Tricuspid Valve (Right AV Valve)

- Situated between **right atrium and right ventricle**.
- Has **three cusps** – anterior, posterior, and septal.
- Attached to **fibrous ring** and connected to **papillary muscles** via **chordae tendineae**.
- Opens during **diastole** (blood flows into the right ventricle) and closes during **systole** to prevent regurgitation.

(b) Mitral Valve (Left AV Valve / Bicuspid Valve)

- Between **left atrium and left ventricle**.
 - Has **two cusps** – anterior (aortic) and posterior (mural).
 - Stronger and thicker than the tricuspid valve due to higher left ventricular pressure.
 - Guarded by **chordae tendineae** from **anterior and posterior papillary muscles**.
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2. Semilunar Valves

(a) Pulmonary Valve

- At the junction of **right ventricle and pulmonary trunk**.

- Formed by **three semilunar cusps** – right, left, and anterior.
- Each cusp has a **nodule at its center** (nodule of Morgagni) and **lunule** on its free margin.
- During **ventricular systole**, the valve opens; during **diastole**, backflow fills the sinuses, causing closure.

(b) Aortic Valve

- Situated between **left ventricle and aorta**.
 - Has **three semilunar cusps** – right, left, and posterior.
 - Above each cusp is an **aortic sinus**:
 - The **right and left coronary arteries** arise from right and left aortic sinuses.
 - Mechanism of closure is similar to the pulmonary valve.
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Functional Notes

- **Valves are passive structures** – they open and close due to **pressure differences** between chambers.
 - **Chordae tendineae and papillary muscles** prevent cusp eversion during systole.
 - The **sound of valve closure** produces the **heart sounds**:
 - **First sound (S1)**: Closure of AV valves.
 - **Second sound (S2)**: Closure of semilunar valves.
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Clinical Anatomy of the Valves and Heart Structure

1. Valve Pathologies

- **Mitral Stenosis:**

- Narrowing of mitral orifice ? obstruction of left atrial emptying ? **left atrial hypertrophy** and **pulmonary congestion**.
- Produces a **diastolic murmur**.

- **Mitral Regurgitation (Incompetence):**

- Incomplete closure of valve ? backflow into left atrium ? **pansystolic murmur**.

- **Tricuspid Stenosis:**

- Causes **systemic venous congestion, enlarged liver, and edema**.

- **Tricuspid Regurgitation:**

- Leads to **systolic pulsation in jugular veins**.

- **Aortic Stenosis:**

- Obstruction to outflow ? **left ventricular hypertrophy**.
- Produces **systolic murmur** radiating to neck.

- **Aortic Regurgitation:**

- Backflow during diastole ? **volume overload, LV dilation, and “water hammer” pulse**.

- **Pulmonary Stenosis / Regurgitation:**

- Affects right ventricle; often congenital; associated with **cyanosis** in severe cases.
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2. Other Clinical Conditions

- **Heart Murmurs:** Abnormal sounds due to turbulent flow across diseased valves.
 - **Endocarditis:** Inflammation of endocardium and valves (often bacterial).
 - **Rheumatic Heart Disease:** Immune-mediated damage to valves (usually mitral).
 - **Prolapse of Mitral Valve:** Bulging of valve leaflets into atrium during systole.
 - **Artificial (prosthetic) valves:** Replacements used in severe stenosis or incompetence.
 - **Calcific Aortic Stenosis:** Degenerative change common in elderly, causing thickened, immobile cusps.
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3. Clinical Investigations

- **Auscultation:** Detects valve murmurs; each valve has specific areas for listening:
 - **Mitral area:** 5th left intercostal space (midclavicular line).
 - **Tricuspid area:** 5th right intercostal space near sternum.
 - **Pulmonary area:** 2nd left intercostal space.
 - **Aortic area:** 2nd right intercostal space.
 - **Echocardiography:** Visualizes valves and chamber movements.
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- **Electrocardiography (ECG):** Detects conduction and chamber enlargement.

Fibrous Skeleton, Musculature, and Conducting System of the Heart — with Clinical Anatomy

Fibrous Skeleton of the Heart

- The **fibrous skeleton** is a dense network of **fibrocartilaginous connective tissue** that forms the framework of the heart.
 - It provides **structural support** for valves, **anchors cardiac muscle fibers**, and **electrically insulates** the atria from the ventricles except through the **AV bundle (Bundle of His)**.
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Main Components:

1. Four Fibrous Rings (Annuli Fibrosi):

- Surround the **right and left atrioventricular orifices**, **aortic orifice**, and **pulmonary orifice**.
- These maintain the shape and patency of valve openings.

2. Right and Left Fibrous Trigones:

- Connect adjacent rings, forming the **central fibrous body**.
- The **right fibrous trigone** is strong and lies between the aortic and right AV rings, transmitting the **Bundle of His**.

3. Membranous Part of Interventricular Septum:

- Derived from the fibrous skeleton; contributes to separation of atria and ventricles.
-

Functions of Fibrous Skeleton:

- Maintains integrity of valve openings.
 - Provides attachment for **cusps of valves** and **myocardial fibers**.
 - Electrically insulates atria from ventricles, ensuring **sequential contraction**.
 - Prevents overstretching of valve orifices during contraction.
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Musculature of the Heart

The heart consists of **specialized cardiac muscle fibers (myocardium)** arranged in spiral and circular patterns.

Atrial Musculature:

- Two layers:
 1. **Superficial layer:** Common to both atria; encircles both chambers.
 2. **Deep layer:** Separate for each atrium.
 - The right atrial musculature continues into the **superior vena cava** and **coronary sinus**, forming sphincter-like arrangements.
 - The left atrial musculature extends around **pulmonary veins**.
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Ventricular Musculature:

- Composed of three layers:
 1. **Superficial (spiral) layer:** Common to both ventricles; fibers cross the apex and form a **vortex**.
 2. **Middle circular layer:** Present mainly in the left ventricle.
 3. **Deep longitudinal layer:** Lines the cavity and forms **papillary muscles** and **trabeculae carneae**.

Functional Importance:

- The spiral arrangement produces a **wringing or twisting motion** during systole, ensuring efficient ejection of blood.
 - The contraction begins at the **apex** and moves upwards, aiding in ventricular emptying.
-

Conducting System of the Heart

This system ensures that electrical impulses are generated and transmitted in an orderly sequence for coordinated contraction.

Components:

1. Sinoatrial (SA) Node

- *Location:* Upper end of **crista terminalis**, near SVC opening in right atrium.
 - *Function:* Natural pacemaker of the heart; initiates impulse (70–80/min).
 - *Blood Supply:* Right coronary artery (in 60% cases).
 - *Action:* Causes atrial contraction.
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2. Atrioventricular (AV) Node

- *Location:* Lower part of interatrial septum, near the **coronary sinus opening**.
- *Function:* Receives impulse from SA node via atrial musculature and transmits to AV bundle.
- *Delay:* Allows completion of atrial contraction before ventricular systole.

3. Atrioventricular (AV) Bundle of His

- *Origin:* From AV node.
- *Course:* Passes through the **fibrous skeleton**, runs along **membranous interventricular septum**, then divides.
- *Branches:*
 - **Right bundle branch:** Runs along **interventricular septum**, enters **moderator band**, and ends in **anterior papillary muscle** of right ventricle.
 - **Left bundle branch:** Descends on left side of septum and spreads in **Purkinje fibers**.

4. Purkinje Fibers

- *Structure:* Specialized large fibers located beneath the endocardium.
- *Function:* Rapid conduction to all parts of ventricular musculature, ensuring synchronous contraction.

Sequence of Impulse Conduction

SA Node ? Atrial Muscles ? AV Node ? AV Bundle ? Right & Left Bundle Branches ? Purkinje Fibers ? Ventricular Myocardium

This sequence ensures that **atria contract first**, followed by **ventricles**, for effective pumping.

Clinical Anatomy

1. Heart Block:

- Failure of conduction through the AV node or bundle.
- *First-degree*: Delayed conduction.
- *Second-degree*: Intermittent block.
- *Third-degree (complete block)*: No conduction; atria and ventricles beat independently.
- *Treatment*: Pacemaker implantation.

2. Arrhythmias:

- Abnormal rhythm from faulty conduction.
- *Examples*: Atrial fibrillation, ventricular fibrillation, premature beats.

3. Artificial Pacemaker:

- Device implanted to regulate heart rhythm when SA node fails.

4. Bundle Branch Block:

- Damage to right or left branch ? asynchronous ventricular contraction.

- *Right bundle block*: Delay in right ventricular activation.
- *Left bundle block*: Delay in left ventricular activation, seen on ECG as broad QRS.

5. Ischemia of Conducting Tissue:

- Often due to **coronary artery disease** (especially right coronary).
- Leads to **SA or AV nodal dysfunction** and rhythm disturbances.

6. Atrial Flutter & Fibrillation:

- Rapid uncoordinated atrial contractions; ECG shows absence of P waves.

7. Ventricular Fibrillation:

- Chaotic ventricular activity ? no effective pumping; fatal if untreated.
- Immediate **defibrillation** required.

8. Ectopic Pacemaker Activity:

- When another region (e.g., AV node or Purkinje fibers) assumes pacemaking due to SA node failure.

9. Tachycardia / Bradycardia:

- *Tachycardia*: >100 bpm
- *Bradycardia*: <60 bpm — may occur due to SA node dysfunction.

10. Electrocardiography (ECG):

- Diagnostic tool reflecting electrical activity of the heart.
- *P wave*: Atrial depolarization.
- *QRS complex*: Ventricular depolarization.
- *T wave*: Ventricular repolarization.

Right Coronary Artery (RCA) and Left Coronary Artery (LCA) — Anatomy and Dissection

Right Coronary Artery (RCA)

Origin and Course

- The **right coronary artery** arises from the **anterior (right) aortic sinus** of the ascending aorta, just above the **aortic valve**.
 - It passes **forward and to the right**, between the **right auricle** and **pulmonary trunk**, running in the **right atrioventricular (coronary) groove** toward the **posterior surface** of the heart.
 - Near the **crux of the heart**, it gives off its terminal branch — the **posterior interventricular artery** (in most hearts).
-

Branches and Areas Supplied

1. Conus Artery (Infundibular Branch):

- Supplies the **conus arteriosus (infundibulum)** of the right ventricle.

2. **Right Atrial Branch:**

- Supplies the **right atrium**.
- One branch ascends near the SVC and is often the **SA nodal artery** (in ~60% of people).

3. **Right Marginal Artery:**

- Runs along the **acute margin** of the heart.
- Supplies the **right ventricle**.

4. **Posterior Interventricular (Descending) Artery:**

- Runs in the **posterior interventricular groove** up to the apex.
- Supplies:
 - Posterior one-third of interventricular septum
 - Adjacent parts of both ventricles
 - AV node (in ~80% of cases)

5. **Small Ventricular Branches:**

- Supply the **diaphragmatic surface** of right ventricle.

6. **Terminal Branches:**

- Anastomose with branches of **left coronary artery** near the apex and posterior surface.

Areas Supplied by RCA

- **Right atrium and most of right ventricle**
 - **Posterior part of left ventricle (diaphragmatic surface)**
 - **Posterior one-third of interventricular septum**
 - **SA node (60%) and AV node (80%)**
-

Dissection of Right Coronary Artery

- Remove fat and pericardium over the **right atrioventricular groove**.
 - Trace the RCA from its origin at the aortic sinus around the right border.
 - Identify its **right marginal branch** along the inferior border.
 - Continue tracing posteriorly to the **crux of the heart**, where it gives off the **posterior interventricular branch**.
 - Observe anastomoses with the **circumflex branch** of LCA at the crux.
-

Left Coronary Artery (LCA)

Origin and Course

- The **left coronary artery** arises from the **left posterior (left) aortic sinus** of the ascending aorta.

- It lies between the **left auricle** and the **pulmonary trunk** and is usually about **1–1.5 cm long** before dividing into its main branches.

- It divides into:

1. **Anterior Interventricular Artery (Left Anterior Descending / LAD)**
2. **Circumflex Artery (LCX)**

A small **left conus branch** may arise near its origin.

Branches and Areas Supplied

1. Anterior Interventricular Artery (LAD):

- Runs in the **anterior interventricular groove** toward the apex.
- Gives **diagonal branches** to the left ventricle and **septal branches** to the anterior two-thirds of the interventricular septum.
- *Supplies:*
 - Both ventricles (anterior surface)
 - Anterior two-thirds of interventricular septum
 - Apex of heart

2. Circumflex Artery (LCX):

- Passes to the left in the **coronary sulcus** and reaches the **posterior surface**.
- Gives the **left marginal artery** and several **atrial and ventricular branches**.

- *Supplies:*

- Left atrium
- Lateral and posterior parts of left ventricle
- SA node (in 40% of people)

3. Left Conus Artery (if present):

- Supplies the upper part of left ventricle near pulmonary trunk.
-

Areas Supplied by LCA

- Left atrium and ventricle (major part)
 - Right ventricle (anterior part)
 - Anterior two-thirds of interventricular septum
 - Apex of the heart
 - SA node (40%)
-

Dissection of Left Coronary Artery

- Remove pericardium between **left auricle** and **pulmonary trunk**.
- Identify the short **trunk of LCA** and trace its bifurcation:
 - Follow **LAD** down the anterior interventricular groove to the apex.

- Observe its **diagonal** and **septal branches**.
- Trace **circumflex branch** in the coronary sulcus posteriorly to note the **left marginal artery**.
- Observe anastomoses between LAD and **posterior interventricular artery** at the apex.

Summary of Coronary Artery Distribution

ARTERY	MAIN AREAS SUPPLIED
Right Coronary Artery (RCA)	Right atrium, most of right ventricle, posterior part of left ventricle, posterior 1/3 of septum, SA & AV nodes (majority).
Left Coronary Artery (LCA)	Left atrium, left ventricle (anterior, lateral, posterior), anterior 2/3 of septum, apex, SA node (in 40%).

Clinical Relevance

- **Coronary Artery Disease (CAD):**
 - Narrowing due to **atherosclerosis** leads to **ischemic heart disease** and **angina pectoris**.
 - Commonly affected artery: **LAD (widow-maker artery)**.
- **Myocardial Infarction (MI):**
 - Complete occlusion of a coronary artery ? necrosis of myocardium.
 - Common sites (in order):

1. LAD
2. RCA
3. LCX

- **Collateral Circulation:**

- Limited anastomosis between terminal branches of RCA and LCA.
- In gradual obstruction, these enlarge; in sudden occlusion, infarction occurs.

- **Coronary Dominance:**

- Determined by which artery gives rise to **posterior interventricular branch**.
- **Right dominance:** 70% (from RCA).
- **Left dominance:** 10% (from LCX).
- **Co-dominant:** 20% (both contribute).

- **Coronary Angiography:**

- Visualizes coronary circulation; used to locate occlusions or stenoses.

- **Coronary Artery Bypass Graft (CABG):**

- Surgical revascularization using grafts (e.g., **internal thoracic** or **great saphenous vein**) to bypass blocked segments.

Cardiac Dominance and Clinical Anatomy

Cardiac Dominance

Definition:

Cardiac dominance refers to the **artery that supplies the posterior one-third of the interventricular septum** and gives rise to the **posterior interventricular (descending) artery (PDA)**.

This artery also supplies the **AV node** and parts of the diaphragmatic surface of the ventricles.

Types of Cardiac Dominance:

1. Right Dominance (?70% of people)

- **Posterior interventricular artery** arises from the **right coronary artery (RCA)**.
- The RCA thus supplies:
 - Posterior part of interventricular septum
 - Inferior wall of both ventricles
 - AV node and most of conduction system
- This is the **most common pattern**.

2. Left Dominance (?10% of people)

- **Posterior interventricular artery** arises from the **circumflex branch of the left coronary artery (LCA)**.
- The LCA supplies both the **anterior and posterior septum** and nearly the **entire left ventricle**, making infarction more extensive when it's blocked.

3. Co-Dominance (?20% of people)

- Both the RCA and LCA contribute to the **posterior interventricular supply** — RCA gives off a small branch, and LCA (via LCX) gives off another.
 - This provides a **better collateral network**.
-

Functional Importance:

- Dominance determines which coronary artery supplies the **AV node** and **posterior septum**, areas critical for cardiac conduction.
 - Hence, the site of occlusion and its dominance pattern strongly influence the **extent of myocardial infarction** and **type of conduction defect** observed clinically.
-

Clinical Anatomy of Coronary Circulation and Dominance

1. Coronary Artery Disease (CAD):

- **Atherosclerosis** of coronary arteries leads to **ischemia** (insufficient blood supply) of the myocardium.
 - Commonly affected arteries:
 1. **Left Anterior Descending (LAD)** — most common ("*widow-maker*").
 2. **Right Coronary Artery (RCA)**.
 3. **Circumflex Artery (LCX)**.
 - Narrowing of >70% of lumen produces **angina pectoris**, while total occlusion causes **myocardial infarction (MI)**.
-

2. Myocardial Infarction (MI):

- **Definition:** Death of myocardial tissue due to loss of blood supply.
 - **Common sites:**
 - *Anterior wall infarction* ? LAD occlusion.
 - *Inferior wall infarction* ? RCA occlusion (in right-dominant hearts).
 - *Posterior wall infarction* ? LCX occlusion (in left-dominant hearts).
 - **Clinical signs:** Severe chest pain radiating to left arm, sweating, hypotension, arrhythmia.
-

3. Collateral Circulation:

- Small anastomoses exist between terminal branches of RCA and LCA (especially at the apex and posterior surface).
 - In **gradual obstruction**, these enlarge to maintain perfusion.
 - In **sudden occlusion**, they are inadequate ? infarction occurs.
-

4. Coronary Artery Bypass Graft (CABG):

- Used in severe CAD to restore blood flow.
- Common grafts:
 - **Internal thoracic (mammary) artery.**
 - **Great saphenous vein.**

- **Radial artery.**

- Example: Left internal mammary artery anastomosed to LAD beyond the obstruction.
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5. Angina Pectoris:

- Transient chest pain caused by **temporary myocardial ischemia** without necrosis.
 - Triggered by exertion, stress, or cold exposure.
 - Relieved by **rest or nitroglycerin**, which dilates coronary vessels.
-

6. Coronary Artery Dominance and ECG Findings:

- In **right-dominant hearts**, RCA occlusion ? *inferior wall MI* (changes in leads II, III, aVF).
 - In **left-dominant hearts**, LCX occlusion ? *posterior-lateral wall MI* (changes in leads I, aVL, V5–V6).
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7. Coronary Artery Spasm (Prinzmetal Angina):

- Transient spasm of a coronary artery causing temporary ischemia even in absence of fixed obstruction.
 - Often affects the **LAD** or **RCA**; reversible with vasodilators.
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8. Arterial Supply of Conduction System:

- **SA Node:** RCA (in 60%), LCA (in 40%).
 - **AV Node:** RCA (in 80%), LCA (in 20%).
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- **AV Bundle (Bundle of His):** Anterior septal branches of LCA.
- Hence, right dominance ? conduction defects common after RCA occlusion.

9. Coronary Artery Variations:

- **High Origin:** Artery arises above the aortic sinus ? risk of compression.
- **Anomalous Origin:** LCA arising from right sinus — may pass between great arteries ? sudden death during exertion.
- **Myocardial Bridge:** A segment of coronary artery passes within myocardium — may compress during systole.

10. Investigations and Interventions:

- **Coronary Angiography:** Visualizes coronary lumen for stenosis.
- **Coronary CT Angiogram:** Non-invasive assessment.
- **Percutaneous Coronary Intervention (PCI):** Balloon angioplasty with or without stent placement.
- **Thrombolytic Therapy:** Dissolves clot in early MI (e.g., streptokinase).

Summary of Clinical Correlation:

CONDITION	INVOLVED ARTERY	CONSEQUENCE
Anterior wall MI	Left Anterior Descending (LAD)	Apex and anterior septal necrosis

CONDITION	INVOLVED ARTERY	CONSEQUENCE
Inferior wall MI	Right Coronary Artery (RCA)	Involves diaphragmatic surface
Posterior wall MI	Circumflex (LCX)	Posterior left ventricle necrosis
Conduction block	RCA (in right-dominant heart)	AV nodal ischemia
Severe heart failure	LAD + LCX lesions	Global LV dysfunction

Cardiac dominance is not merely an anatomical curiosity — it defines the **pattern of blood supply, the distribution of infarction, and the rhythm of survival**.

A heart's fate, quite literally, depends on which artery rules its back wall.

Veins and Nerve Supply of the Heart — with Clinical Anatomy

Veins of the Heart

1. Coronary Sinus

- The **largest vein of the heart**, about **3 cm long**, located in the **left posterior coronary sulcus**.
- Opens into the **posterior wall of the right atrium**.
- **Tributaries:**
 - **Great cardiac vein:** Follows the anterior interventricular and circumflex arteries; receives the **left marginal vein**.

- **Middle cardiac vein:** Runs with the posterior interventricular artery and drains into the mid-part of coronary sinus.
- **Small cardiac vein:** Follows the right coronary artery in the right posterior coronary sulcus; may receive the **right marginal vein**.
- **Posterior vein of left ventricle:** Lies on diaphragmatic surface; opens into coronary sinus.
- **Oblique vein of left atrium (vein of Marshall):** A remnant of the **left common cardinal vein**; opens into the left end of coronary sinus and may persist as a **left superior vena cava**.

2. Anterior Cardiac Veins

- 3–4 small veins from the **anterior wall of the right ventricle**, opening **directly into the right atrium**.

3. Venae Cordis Minimae (Thebesian Veins)

- Tiny valveless veins opening **directly into all four chambers** (especially right-sided).
- Contribute minor venous drainage but explain why **left-sided infarcts are more common** — since venous outflow is less on the left side

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Nerve Supply of the Heart

1. Sympathetic Supply

- Preganglionic neurons: **T1–T5 segments** of the spinal cord.

- Fibers synapse in the **sympathetic trunk ganglia** (including cervical ganglia).
- Postganglionic fibers form **cervical and thoracic cardiac nerves** ? contribute to **cardiac plexuses**.
- **Effects:**
 - Increase heart rate and contractility (**cardioaccelerator**).
 - Dilate coronary arteries (metabolic autoregulation).
 - Carry **pain fibers** — pain referred to dermatomes **T1–T5** (retrosternal and left arm/shoulder pain).

2. Parasympathetic Supply

- Derived from **vagus nerve (cranial nerve X)**.
- Preganglionic neurons: **dorsal nucleus of vagus**.
- Postganglionic fibers form **small cardiac branches** via **cardiac plexuses**.
- **Effects:**
 - Slow heart rate (**cardioinhibitory**).
 - Reduce contractility.
 - Cause mild **vasoconstriction** of coronary vessels.

3. Cardiac Plexuses

- Two interconnected plexuses convey both sympathetic and parasympathetic fibers:

- **Superficial Cardiac Plexus:**

- Lies **below the aortic arch**, in front of right pulmonary artery.
- Formed by **superior cervical cardiac branch of left sympathetic trunk** and **inferior cervical cardiac branch of left vagus**.

- **Deep Cardiac Plexus:**

- Lies **anterior to the tracheal bifurcation**.
- Receives fibers from both right and left sympathetic trunks and vagus nerves.
- Sends branches to **pulmonary and coronary plexuses**, distributing to atria and ventricles.
- **Left ventricle** has richer innervation due to its larger muscle mass

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Clinical Anatomy

1. Referred Cardiac Pain

- Pain from myocardial ischemia travels via **sympathetic afferents (T1–T5)** ? perceived in **left chest, shoulder, inner arm**, and occasionally **jaw**.
- This explains classical **angina pectoris** distribution.

2. Autonomic Effects

- **Sympathetic overactivity:** Tachycardia, hypertension, arrhythmia.
- **Parasympathetic stimulation (vagal):** Bradycardia or heart block.
- Sudden **vagal stimulation** may cause **syncope** or fainting due to transient cardiac inhibition.

3. Clinical Tests and Lesions

- **Cardiac Plexus Damage:** Leads to altered rhythm or conduction block.
- **Stellate Ganglion Block:** Used therapeutically for refractory angina to reduce sympathetic tone.
- **Neurocardiogenic Syncope:** Excess vagal discharge ? hypotension, bradycardia, fainting.

4. Coronary Vein Involvement

- **Coronary Sinus Dilation:** Seen in increased right atrial pressure or **pulmonary hypertension**.
- **Coronary Sinus Catheterization:** Used for **retrograde cardioplegia** during open-heart surgery.
- **Persistent Left SVC:** Remnant of embryonic left common cardinal vein; drains into coronary sinus.

5. Thebesian Veins and Infarction

- Provide minor oxygenated blood return directly into chambers, but their small size means **no significant collateral flow** — hence infarcts are common in arterial occlusion.

Together, these vascular and neural systems regulate the **rhythm, tone, and perfusion** of the heart — a delicate equilibrium where **arterial drive, venous return, and autonomic command** maintain the heartbeat's eternal tempo.

Developmental Components, Molecular Regulation of Cardiac Development, and Foetal Circulation

Developmental Components of the Heart

- The heart develops from the **splanchnopleuric mesoderm** in front of the buccopharyngeal membrane during the **third week of intrauterine life**.
- Two **endocardial heart tubes** form and fuse in the midline to create the **primitive heart tube**, which differentiates into specific regions with distinct fates

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Main Components and Their Derivatives:

1. Right Atrium

- *Rough part*: Primitive atrial chamber proper.
- *Smooth part*: Derived from the **right horn of sinus venosus** and **interatrial septum**.
- *Demarcation*: **Crista terminalis** separates rough and smooth parts.

2. Left Atrium

- *Rough part*: Primitive atrial chamber proper.

- *Smooth part*: Formed by **absorption of pulmonary veins** and **interatrial septum**

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3. Right Ventricle

- *Rough part*: Derived from the **proximal portion of bulbus cordis**.
- *Smooth part*: From **conus cordis** (middle portion of bulbus cordis).

4. Left Ventricle

- *Rough part*: From the **primitive ventricle**.
- *Smooth part*: Also partly from **conus cordis**

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5. Interatrial Septum

- *Septum primum*: Forms **fossa ovalis**.
- *Septum secundum*: Forms **limbus fossae ovalis**.

6. Interventricular Septum

- *Muscular part*: Formed by the two ventricles.
- *Membranous part*: From **fusion of atrioventricular cushions** and **conal swellings** ; separates right atrium from left ventricle as well

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7. Truncus Arteriosus / Distal Bulbus Cordis

- Divides into **ascending aorta** and **pulmonary trunk**, separated by a **spiral septum**, explaining their intertwined relations

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- The **heart becomes fully functional by the end of the 2nd month** of intrauterine life.

Molecular Regulation of Cardiac Development

- **NKX-2.5 gene** (Nirenberg and Kim Homeobox 2.5):

The **master gene** regulating heart development, essential for early cardiac formation.

- **HAND-1 and HAND-2 genes:**

Govern **ventricular morphogenesis** and looping.

- **BMPs (Bone Morphogenetic Proteins 2 and 4):**

Secreted by **endoderm and lateral plate mesoderm**; induce the **cardiogenic field** in splanchnic mesoderm

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- **Crescent and Cerberus proteins:**

Inhibit **WNT proteins (3a and 8)** secreted by the neural tube — this inhibition **permits cardiac differentiation**.

- **Lefty-2:**

Regulates **cardiac looping** (left-right orientation).

- **TBX-5:**

Crucial for **septation of chambers** and **formation of atrioventricular canal**

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Foetal Circulation

- The **foetus is entirely dependent on the placenta** for oxygen and nutrients, as the **lungs are non-functional** in utero

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- Blood bypasses the pulmonary circuit through specific **foetal shunts**.

Sequence of Circulation:

1. **Oxygenated blood** ? from **placenta via single umbilical vein** ? **liver** ? bypasses it through **ductus venosus** ? joins **inferior vena cava**.
2. This blood enters the **right atrium**, then crosses the **foramen ovale** into the **left atrium**, bypassing lungs.
3. From **left atrium** ? **left ventricle** ? **aorta**, distributing to head and body.
4. Deoxygenated blood from the **SVC** enters the **right ventricle** ? **pulmonary trunk** ? **left pulmonary artery** ? **ductus arteriosus** ? **descending aorta**, where it mixes with oxygenated blood

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5. From the **descending aorta**, blood reaches **internal iliac arteries**, which give off **two umbilical arteries** returning to the **placenta** for reoxygenation.

Key Foetal Vascular Structures:

- **Umbilical vein** — brings oxygenated blood from placenta.
- **Ductus venosus** — bypasses the liver.
- **Foramen ovale** — connects right and left atria.
- **Ductus arteriosus** — connects pulmonary trunk and aorta.
- **Umbilical arteries (two)** — carry deoxygenated blood to placenta

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Changes at Birth

At birth, with **first breath**:

- **Lungs expand**, decreasing pulmonary resistance.
- **Foramen ovale** closes ? forms **fossa ovalis**.
- **Ductus arteriosus** closes ? becomes **ligamentum arteriosum**.
- **Umbilical vein** ? **ligamentum teres hepatis**.
- **Ductus venosus** ? **ligamentum venosum**.
- **Umbilical arteries** ? **medial umbilical ligaments**

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Clinical Correlations

1. **Atrial Septal Defect (ASD):** Incomplete fusion of septum primum and secundum ? persistent foramen ovale

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2. **Ventricular Septal Defect (VSD):** Failure of fusion of **endocardial cushion** and **bulbar ridges** forming membranous septum

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3. **Tetralogy of Fallot:**

- VSD
- Overriding aorta
- Pulmonary stenosis
- Right ventricular hypertrophy

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The heart's development elegantly mirrors its future function — a **sequence of folding, septation, and molecular choreography** that culminates in a four-chambered pump capable of sustaining life before and after birth.