ACE SERIES

Essentials of Anatomy
A Concise Textbook

Volume 1

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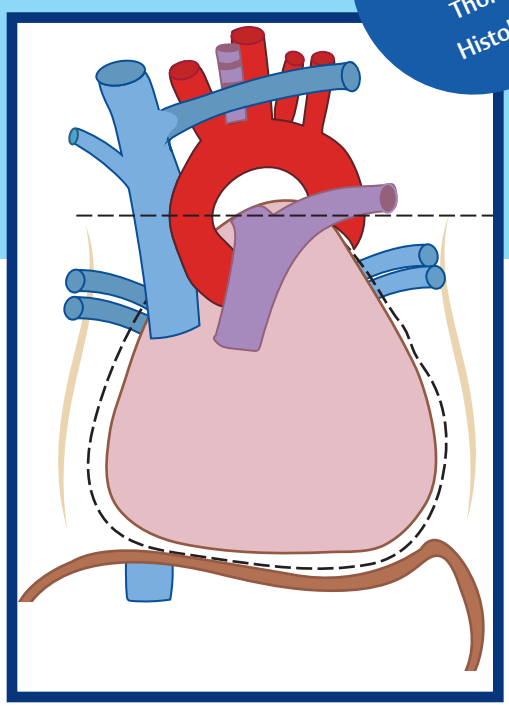
Second Edition

General Anatomy
Upper Limb
Thorax
Histology



Online at MedOne Q&A

Thieme

Contents

Repositioning Note

From Thieme Test Prep Series to Ace Series

For years, Q&A-format books have been synonymous with last-minute exam preparation, designed primarily to help students navigate university examinations with efficiency and precision. Although this approach has served its purpose, the evolving needs of medical education demand a more integrated, concept-driven learning resource, one that supports not just recall, but also enhanced understanding of the core concepts.

This shift marks a deliberate repositioning of our **Thieme Test Prep Series** from **exam-oriented aids** to **academically aligned, institution-relevant learning tools**, now called **Ace Series**, that complement teaching, curriculum alignment, and structured learning. **Ace** literally means to do very well.

At the core of this transformation lies a simple but powerful principle: student-centric learning anchored in conceptual clarity.

What's Changing?

- **From Test Prep to Concise Learning Resources:** These books are no longer limited to serving as revision guides. They have been carefully restructured to function as **concise textbooks**, covering all **essential and high-yield topics required for MBBS curricula**. Each answer is designed not only to help students reproduce information in exams but also to build foundational understanding.
- **From Reactive Studying to Proactive Learning:** Earlier, the content was optimized primarily around anticipated exam questions. The revised approach expands this scope, ensuring that students can rely on these books throughout their academic cycle, from first exposure to final revision.
- **From Fragmented Knowledge to Structured Clarity:** Topics are curated and organized to provide logical flow, clinical relevance, and conceptual continuity, enabling students to connect ideas rather than memorize isolated answers.
- **From Concept Building to Exam Readiness:** These books now bridge the crucial gap between building concepts and preparing the students well for not only their university exams but PGME as well. This is achieved by integration of MCQs (clinical, conceptual, and case-based) with these resources.

What Remains Constant?

Despite this evolution, the strengths that make these books indispensable remain intact:

- Exam alignment: All content continues to be mapped to university requirements and frequently tested areas
- Q&A format: Retained for its clarity, accessibility, and efficiency in learning
- High-yield focus: Emphasis on what truly matters—clinically and academically

Why This Matters?

Medical education today requires resources that do more than help students pass exams—it requires tools that help them understand various aspects of medicine.

By bridging the gap between concise textbooks and exam-oriented preparation, these books now serve multiple stakeholders:

- Students: who gain a reliable, structured, and easy-to-navigate learning companion
- Faculty and institutions: who can integrate these books into teaching frameworks as standardized, curriculum-aligned resources

The Outcome

The result is a resource that is:

- Comprehensive yet concise
- Exam-relevant yet concept-driven
- Student-friendly yet institution-ready

This repositioning reflects our commitment to evolving with the needs of modern medical education, ensuring that students are not only prepared to clear university examinations, but also equipped to build strong clinical foundations.

In essence, these are no longer just books to help students pass exams; they are books designed to help students understand, retain, and apply medicine with confidence.

Key Highlights

Competencies

AN2.1	Describe the parts, types, peculiarities of each type, and the blood and nerve supply of bones
AN2.2	Describe the laws of ossification, epiphysis, and various types of epiphyses and their importance
AN2.3	Describe the special features of a sesamoid bone

A comprehensive content mapping has been done to align with the revised NMC 2024 curriculum, ensuring integration of newly introduced topics for enhanced learning outcomes.

Q1. Name the components of the skeletal system and their functions. (AN2.1)

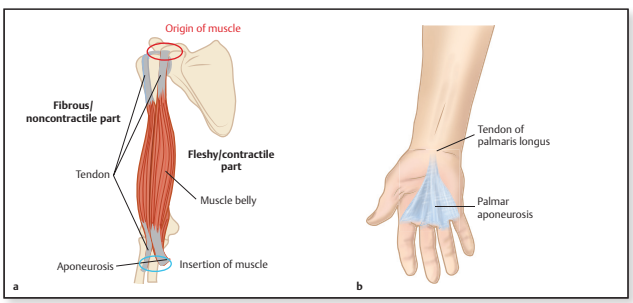
Components of the Skeletal System

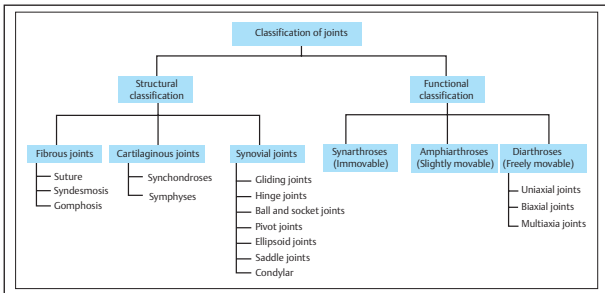
The following are the components of the skeletal system:

- Rigid structures: *Bones* that contribute to the skeleton.
- Flexible connective tissue: *Cartilage* that reduces friction and absorbs shock at joints.
- Tough bands of dense connective tissue: *Ligaments* that connect bones to each other.

The updated CBME-aligned content structured in concise Q&A format which enhances clarity, boosts engagement and strengthens retention.

High quality illustrations are provided for better clarity and enhanced visual impact.





Pulmonary circulation (lesser circulation)	Systemic circulation (greater circulation)
Supplies oxygen and removes carbon dioxide from the heart	Moves blood from the heart to various tissues of the body and vice versa
Components are the pulmonary veins	Components are the aorta and the superior and inferior venae cavae
Carries deoxygenated blood from the right ventricle via the pulmonary trunk and pulmonary arteries to the lungs	Carries oxygenated blood and nutrients from the left ventricle via the aorta to the tissues of the body
Transport of oxygenated blood via pulmonary veins from the lungs to the left atrium	Transport of deoxygenated blood via the superior and inferior venae cavae from the body to the right atrium
The chambers used are the right ventricle and the left atrium	The chambers used are the left ventricle and the right atrium
Blood flow is from right to left	Blood flow is from left to right

The content incorporates numerous flowcharts and tables to simplify complex topics, support easy retention, and ensure reproducibility in exams.

Clinical Importance

- Deep vein thrombosis (DVT): Clots in deep veins (especially legs).
- Varicose veins: Superficial venous incompetence (e.g., great saphenous vein).
- Central venous access: Jugular, subclavian, or femoral veins are used for intravenous (IV) lines.
- Superficial limb veins: Used for grafts (e.g., great saphenous vein in coronary bypass).

Each volume covers a variety of clinical conditions pertaining to the topic for understanding the anatomical basis of the clinical condition.

Regarding testing of muscles choose the odd one

A. Clavicular fibers of Pectoralis major – asking to abduct the arm to 90 degrees and then moving anteriorly against resistance
B. Trapezius – shrugging the shoulders
C. Serratus anterior = asking the person to stretch both upper limbs and push the wall
D. Latissimus dorsi – abducting the arm to 60 degrees and then adducting against resistance

Integrated online MCQs makes content more interactive, strengthens self-assessment, enhances knowledge retention, and prepares students for their exams.

Nerves of brachial plexus with root value C5,6 – 4S's A

1. Supra scapular nerve
2. subscapular nerve(upper)
3. subscapular nerve (lower)
4. Subclavius nerve
5. Axillary nerve

'Numerology in anatomy' helps students remember anatomy more easily, makes learning quicker, supports exam preparation, and reduces mental effort.

Clinical case scenario

Problem: A young adult comes to Orthopedic OP with a history of falling on outstretched hand with pain and weakness of right wrist of 15 days duration.
On examination: Patient complained about pain along the lateral side of wrist when asked to dorsiflex and abduct the hand. There is tenderness over anatomical snuffbox.
X-ray examination confirmed fracture of scaphoid.
Question:

- Give anatomical explanation for the condition
- Why is this condition clinically important?

Clinical case scenarios have been integrated to enable students to apply anatomy and develop clinical reasoning.

Numerology in Anatomy

Number Mnemonics: List of Three

1. Three types of joints
   a. Fibrous joints
   b. Cartilaginous joints
   c. Synovial joints
2. Three types of fibrous joints
   a. Sutures
   b. Syndesmosis
   c. Gomphosis
3. Three types of bone cells
   a. Osteoblast
   b. Osteocyte
   c. Osteoclast
4. Three basic types of muscles
   a. Skeletal muscle
   b. Cardiac muscle
   c. Smooth muscle
5. Three synovial joints with fibrocartilage-covered articular cartilage
   a. Temporomandibular joint
   b. Sternoclavicular joint
   c. Acromioclavicular joint
6. Three axes of movement in a synovial joint
   a. Anteroposterior axis—abduction and adduction
   b. Transverse axis—flexion and extension
   c. Vertical axis—medial and lateral rotation
7. Three principal planes of the body
   a. Sagittal plane
   b. Coronal plane
   c. Transverse plane
8. Nerves closely related to humerus
   a. Axillary
   b. Radial
   c. Ulnar
9. Nerves supplying hand
   a. Ulnar
   b. Median
   c. Radial
10. Muscles supplied by radial nerve in the anterior compartment of arm
    a. Brachioradialis
    b. Extensor carpi radialis
    c. Lateral part of brachialis
11. Contents of quadrangular space—**VAN**
    a. Posterior circumflex humeral vein
    b. Posterior circumflex humeral artery
    c. Axillary nerve
12. Structures in suprascapular notch—**VAN**
    a. Suprascapular vein
    b. Suprascapular artery
    c. Suprascapular nerve
13. Structures piercing clavipectoral fascia—**VAN**
    a. Cephalic vein
    b. Thoraco-acromial artery
    c. Lateral pectoral nerve
14. Muscles of flexor compartment of arm—**BBC**
    a. Biceps
    b. Brachialis
    c. Coracobrachialis
15. Muscles inserted on the greater tubercle of humerus—**SIT**
    a. Supraspinatus
    b. Infraspinatus
    c. Teres minor
16. Muscles inserted into the parts of bicipital groove—lady between two majors
    a. Teres major (medial lip)
    b. Pectoralis major (lateral lip)
    c. Latissimus dorsi (floor)
17. Trunks of brachial plexus
    a. Upper
    b. Middle
    c. Lower
18. Nerves supplying trapezius muscle
    a. Accessory
    b. Anterior ramus of C3
    c. Anterior ramus of C4
19. Branches of lateral cord of brachial plexus
    a. Lateral pectoral nerve
    b. Lateral root of median nerve
    c. Musculocutaneous nerve
20. Cords of brachial plexus
    a. Lateral
    b. Medial
    c. Posterior
21. Muscles in the superficial layer of posterior compartment of forearm supplied by posterior interosseous nerve
    a. Extensor digitorum

b. Extensor digiti minimi
c. Extensor carpi ulnaris

22. Muscles in the superficial layer of posterior compartment of forearm that are supplied by radial nerve
    a. Brachioradialis
    b. Anconeus
    c. Extensor carpi radialis longus

23. Hypothenar muscles/muscles supplied by deep branch of ulnar nerve
    a. Abductor digiti minimi
    b. Flexor digiti minimi
    c. Opponens digiti minimi

24. Veins at elbow
    a. Cephalic
    b. Basilic
    c. Median cubital

25. Structures forming delto-pectoral triangle
    a. Pectoralis major muscle
    b. Deltoid muscle
    c. Clavicle

26. Major bursae in relation to gleno-humeral joint
    a. Subscapular
    b. Subacromial
    c. Infraspinatus

27. Synovial bursae in palm
    a. Radial
    b. Ulnar
    c. Digital (three in number)

28. Origins of deltoid muscle
    a. Crest of spine of scapula (inferior border)
    b. Acromion (lateral margin)
    c. Clavicle (lateral one-third of anterior border)

29. Actions of deltoid
    a. Abduction of arm
    b. Flexion of arm (clavicular fibers)
    c. Extension of arm (posterior fibers)

30. Muscles producing elevation of scapula
    a. Levator scapulae
    b. Rhomboideus major
    c. Rhomboideus minor

31. Modifications of deep fascia of palm
    a. Flexor retinaculum
    b. Palmar aponeurosis
    c. Fibrous flexor sheaths

32. Three major openings in diaphragm
    a. Inferior vena cava
    b. Esophagus
    c. Aorta

33. Three parts of aorta
    a. Ascending
    b. Arch
    c. Descending

34. Three parts of sternum
    a. Manubrium
    b. Body
    c. Xiphoid

35. Three structures running in costal groove from above downwards—**VAN**
    a. Intercostal vein
    b. Intercostal artery
    c. Intercostal nerve

36. Three subdivisions of inferior mediastinum
    a. Anterior
    b. Middle
    c. Posterior

37. Three splanchnic nerves
    a. Greater
    b. Lesser
    c. Least

38. Three anteroposterior structures at hilum of lung—**VAB**
    a. Vein
    b. Artery
    c. Bronchus

39. Three muscles in intercostal space
    a. External intercostals
    b. Internal intercostals
    c. Transversus thoracis

40. Three arteries originating from arch of aorta
    a. Brachiocephalic
    b. Left common carotid
    c. Left subclavian

41. Three veins opening into right atrium—**SIC**
    a. Superior vena cava
    b. Inferior vena cava
    c. Coronary sinus

42. Three tubular structures in superior mediastinum—**TOT**
    a. Trachea
    b. Esophagus
    c. Thoracic duct

43. Three important nerves of superior mediastinum—**PVC**
    a. Phrenic
    b. Vagus
    c. Cardiac

44. Three arteries in typical intercostal space
    a & b. Anterior intercostal arteries
    c. Posterior intercostal artery

21B. Heart and Development

Competencies

AN22.2	Describe and demonstrate the external and internal features of each chamber of the heart
AN22.3	Describe and demonstrate the origin, course, and branches of the coronary arteries
AN22.4	Describe the anatomical basis of ischemic heart disease
AN22.5	Describe and demonstrate the formation, course, tributaries, and termination of the coronary sinus
AN22.6	Describe the fibrous skeleton of the heart
AN22.7	Mention the parts, position, and arterial supply of the conducting system of the heart
AN25.2	Describe the development of the pleura, lung, and heart
AN25.3	Describe fetal circulation and changes occurring at birth
AN25.4	Describe the embryological basis for (1) atrial septal defect, (2) ventricular septal defect, (3) Fallot's tetralogy, and (4) tracheoesophageal fistula
AN25.5	Describe the developmental basis of congenital anomalies, transposition of great vessels, dextrocardia, patent ductus arteriosus, and coarctation of the aorta
AN25.6	Mention the development of the aortic arch arteries, superior vena cava, inferior vena cava, and coronary sinus
AN25.7	Identify the structures seen on a plain X-ray of the chest (posteroanterior view)
AN25.9	Demonstrate the surface marking of lines of pleural reflection, lung borders and fissures, trachea, heart borders, apex beat, and surface projection of the valves of the heart

Q1. Describe the external features of the heart. Add a note on the surface marking of the heart. How will you interpret the cardiac shadow in an X-ray of the chest? (AN22.2, AN25.7, AN25.9)

External Features of the Heart Including Surface Marking

The heart is a hollow, conical, muscular pump that keeps blood circulation going, and its size is approximately that of the closed fist of the same person (**Fig. 21b.1**).

Location

- Middle mediastinum.
- Within the pericardial sac.
- Above the diaphragm.

Orientation

- Oblique.
- Behind the sternum and costal cartilages.
- Two-thirds of its breadth is to the left of the median plane.
- One-third is to the right of the median plane.
- Great vessels of the heart look upward.
- The diaphragmatic surface is downward.

Measurements

- Apex to base: 12 cm.
- Transverse diameter: 9 cm.
- Anteroposterior: 6 cm.
- Weight: 250 to 300 g.

Presenting Parts

- Apex (**Fig. 21b.1** and **Fig. 21b.2**).
- Base/posterior surface.
- Surfaces:
  - Sternocostal/anterior.
  - Diaphragmatic/inferior: Faces downward.
  - Left pulmonary surface.
  - Right pulmonary surface.
- Borders:
  - Right.
  - Left.

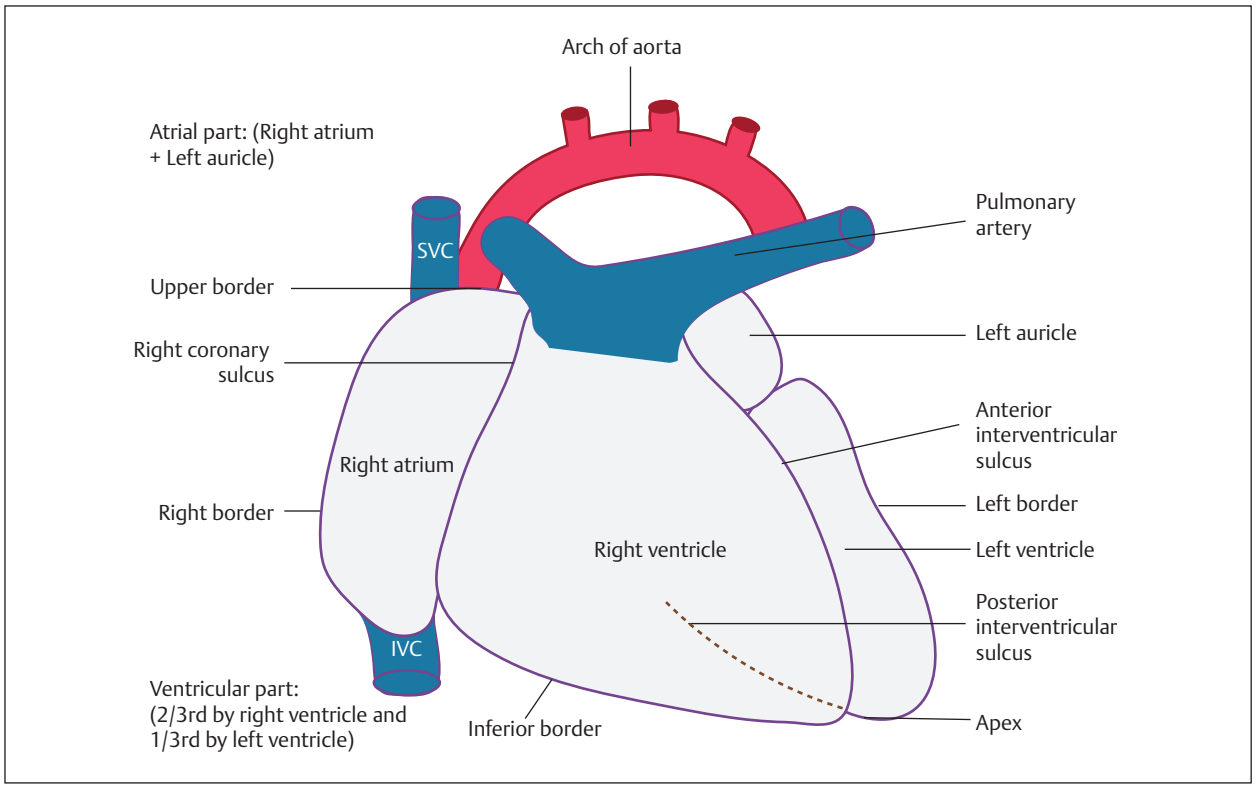


Fig. 21b.1 Heart: external features—sternocostal surface. IVC, inferior vena cava; SVC, superior vena cava.

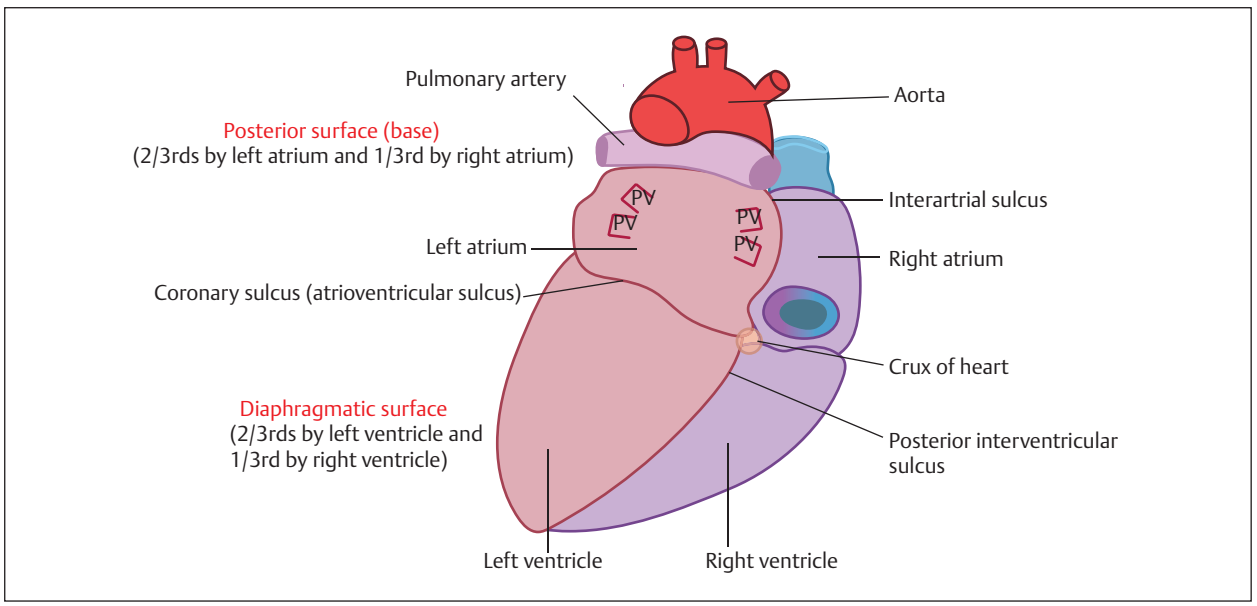


Fig. 21b.2 Heart: external features—posterior and diaphragmatic surfaces. PV, pulmonary vein.

- Superior.
- Inferior.

- Chambers:
  - Right heart: Pulmonary circulation—atrium and ventricle.
  - Left heart: Systemic circulation—atrium and ventricle.

Apex

- Shape: Conical.
- Direction: Downward, forward, and to the left.
- Location: Left fifth intercostal space; 3.5 inches (9 cm) from the median plane. *This is the point where the inferior border meets the left margin.*
- Contributing chambers: Only the left ventricle.
- The pericardium and diaphragm separate the apex from the fundus of the stomach.

Clinical Importance

- Apex:
  - The apex beat is the impulse (thrust of cardiac contraction during ventricular systole) felt as a light tap in:
    - In adults, at the left fifth intercostal space in the midclavicular line just medial to the apex, as the heart is positioned obliquely.
    - In infants (up to the 7th year), at the left third or fourth intercostal space just lateral to the midclavicular line as the heart is positioned more horizontally.
- Dextrocardia: Malpositioning of the heart with the apex on the right side.

Base/Posterior Surface

- Shape: Quadrilateral.
- Direction: Backward and slightly to the right.
- Extent: From the bifurcation of the pulmonary trunk superiorly to the coronary sinus inferiorly.
- Position: Lies opposite to the middle four (T5–T8) thoracic vertebrae.
- Chambers contributes to the posterior surfaces of the right and left atria, but mainly the left atrium.
  - Left atrium: Two-thirds and receives four pulmonary veins.
  - Right atrium: One-third and receives the superior vena cava and the inferior vena cava (IVC).
- Boundaries:
  - Above: Bifurcation of the pulmonary trunk.
  - Below: Posterior to the atrioventricular (AV) groove lodging.
    - Coronary sinus.
    - Anastomosis between the right coronary and the circumflex branch of the left coronary arteries.
  - Right: Right border of the heart.
  - Left: Left border of the heart.
  - Behind: Oblique sinus of the pericardium, esophagus, and aorta, and these separate it from the vertebral column.

Clinical Importance

Clinical base: It is the upper border of the heart.

Surfaces

- Sternocostal surface:
  - Most anterior.
  - Lies behind the body of the sternum and the third to sixth costal cartilages.
  - Formation: Divided by the coronary groove into the following:
    - Atrial part: Formed by the right atrium and partly the left auricle.
    - Ventricular part: Formed by the two ventricles, mainly the right ventricle (two-thirds) and left ventricle (one-third).
  - The two ventricles are separated by the anterior interventricular groove that lodges the anterior interventricular or the left anterior descending (LAD) artery and the great cardiac vein.
- Diaphragmatic surface:
  - Flat.
  - Rests on the central tendon of the diaphragm.
  - Formation:
    - Left two-thirds: Left ventricle.
    - Right one-third: Right ventricle.
  - Two ventricles are separated by the posterior interventricular groove: Lodges the posterior interventricular artery and the middle cardiac vein.
- Left pulmonary surface:
  - Formation:
    - Left ventricle: Mainly.
    - Left atrium and auricle: Partly.
  - Forms cardiac impression on the left lung.
- Right pulmonary surface:
  - Formation:
    - Right atrium.
  - Forms indentation on the right lung.

Borders of the Heart

The borders of the heart are listed in **Table 21b.1**.

Table 21b.1 Borders of the heart

Features	Upper border	Lower border	Right border	Left border
Direction	Oblique	Straight	Convex	Convex
Chambers forming	Two atria, mainly the left	Right ventricle and the small apical part of the left ventricle	Right atrium	Left auricle and left ventricle
Extent	Outer margin of the aorta to the pulmonary trunk	Opening of the inferior vena cava to the apex	Opening of the superior vena cava to the inferior vena cava	Base to the apex
Surfaces separated	–	Sternocostal and diaphragmatic	Base and sternocostal surface	Sternocostal and left
Other features	Concealed by the aorta and the pulmonary trunk	The marginal branch of the right coronary runs along this border	Faces the right lung	Faces the left lung The marginal branch of the left coronary runs along this border

Grooves and Sulci

These demarcate the chambers of the heart:

- External boundary between the two chambers of the heart.
- Contents: Blood vessels and a variable amount of fat.
- Classification:
  - AV groove/coronary sulcus.
  - Interventricular grooves: Anterior and posterior.

Coronary Sulcus or Atrioventricular Groove

- It encircles most of the heart and is the external boundary between the superior atria and inferior ventricles.
- It is anteriorly deficient because of the presence of the root of the pulmonary trunk.
- It is divided into an anterior and a posterior part. The anterior part is divided into right and left parts.
- The right half of the anterior part is between the right atrium and the right ventricle. It runs downward and to the right and lodges in the right coronary artery.
- The left half of the anterior AV groove separates the left auricle and the left ventricle. It lodges the circumflex branch of the left coronary artery.
- The posterior part of the AV groove separates the base from the diaphragmatic surface. It lodges in the coronary sinus.

Anterior and Posterior Interventricular Sulci/ Grooves

- Anterior (interventricular sulcus): It is a shallow groove on the anterior/sternocostal surface of the heart. This is the external boundary between the right and left ventricles. It lodges the interventricular branch of the left coronary/LAD artery and the great cardiac vein.
- Posterior interventricular sulcus: This is located on the posterior surface of the heart and forms the external boundary between ventricles and lodges the posterior interventricular branch of the right coronary artery and the middle cardiac vein.

Clinical Importance

- Area of superficial cardiac dullness:
  - Area of the right ventricle not covered by the lung.
  - Cause: Cardiac notch along the anterior border of the left lung.
  - Boundaries:
    - Left: Cardiac notch of the anterior border of the left lung.
    - Right: Anterior border of the right lung.
  - Significance: This area is chosen for drawing pericardial fluid by passing a needle through this area to avoid injury to the lung.

Surface Marking of the Heart

The heart can be marked on the surface by marking the following four points (**Fig. 21b.3**):

A. The upper border of the right third costal cartilage 1.0 cm from the lateral margin of the sternum.
B. The right sixth costal cartilage 0.5 cm from the lateral margin of the sternum.
C. The lower border of the left second costal cartilage 1.0 cm from the lateral margin of the sternum.

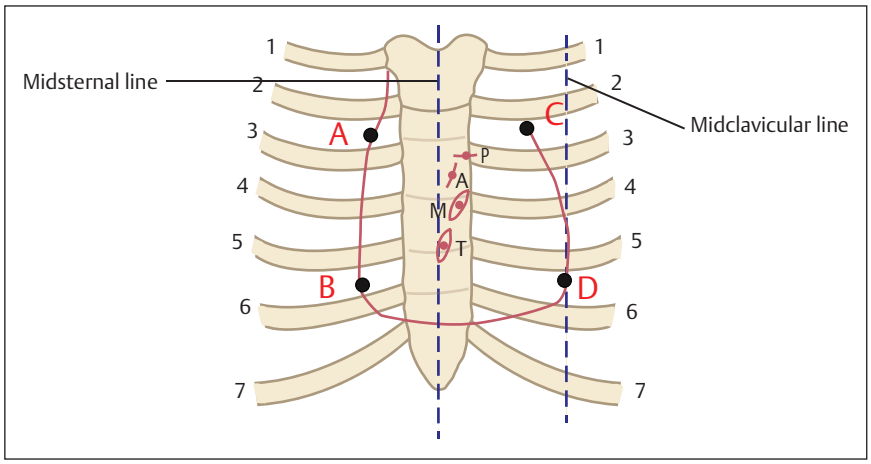


Fig. 21b.3 Surface marking of the heart and valves of the heart. A, aortic; M, mitral (bicuspid); P, pulmonary; T, tricuspid.

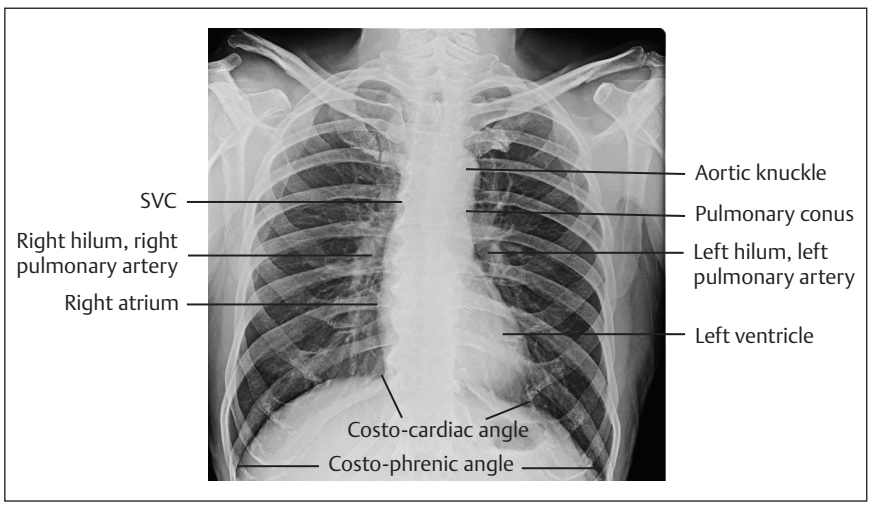


Fig. 21b.4 Cardiac shadow in chest radiograph. SVC, superior vena cava.

D. The left fifth intercostal space medial to the midclavicular line (location of the apex beat).

Borders of the Heart

- Right border: Joining points A and B by a line convex to the right with maximum convexity in the fourth intercostal space.
- Left border: Joining points C and D by a line convex to the left.
- Upper border: Joining points A and C.
- Lower border: Joining points B and D by a line convex downward at its right and left ends with concavity downward in the middle. It passes through the xiphisternal joint.

Apex of the Heart

- Marking a point on the left fifth intercostal space just medial to the midclavicular line.

Cardiac Shadow in Chest Radiograph

- Plain X-ray of the chest in the posteroanterior (PA) view presents shadows of the heart and other structures that are seen as individual prominences (**Fig. 21b.4**).
- The heart shadow (sternocostal surface) is studied with reference to the ribs and costal cartilages. If the shadow is greater than normal limits, it indicates cardiomegaly.
- Along the left border, from above to below, are the aortic arch, pulmonary artery, left auricle, and left ventricle.
- Along the right border, the shadows, from above to below, are the superior vena cava and the right atrium.
- The shadow of the inferior border is formed mainly by the right ventricle.

The two-thirds and one-third formula for the position and external features of the heart for quick reference:

- **Position in the thorax:** Two-thirds of the heart lies to the left and one-third to the right of the median plane.
- **Anterior (sternocostal surface):** The ventricular part is formed two-thirds by the right ventricle and one-third by the left ventricle.
- **Inferior (diaphragmatic surface):** Formed two-thirds by the left ventricle and one-third by the right ventricle, resting on the diaphragm.

Q2. Describe the right atrium in detail and add a note on its development. (AN22.2, AN25.2)

Right Atrium

It can be described under three components: external features, internal features, and interatrial septum.

External Features

Shape: Quadrilateral chamber.
Situation: Behind and to the right side of the right ventricle.

Surfaces and Borders Contributed

It forms the following:

- A part of the sternocostal surface.
- The entire right border.
- One-third of the base of the heart.

Extent: It extends from the orifice of the superior vena cava (behind the third right costal cartilage) to the orifice of the IVC (behind the sixth right costal cartilage).

Other Features

- Right auricle:
  - A small, hollow, wrinkled, conical muscular pouch.
  - Projects toward the left and arises from the anterosuperior part of the atrium.
  - Overlaps the right side of the ascending aorta.
  - Increases the capacity of the atrium to hold a greater volume of blood.
- Sulcus terminalis:
  - Shallow vertical groove.
  - Runs along the right border of the heart.
  - Corresponds with the crista terminalis in the interior of the right atrium.

Internal Features

The right atrium is divided into two parts—smooth posterior and rough anterior—by a smooth muscular ridge, crista terminalis, that extends from the orifice of the superior vena cava to the orifice of the IVC (**Fig. 21b.5**).

Sinus Venarum

- Posterior smooth-walled part of the right atrium.
- Development: Sinus venosus.

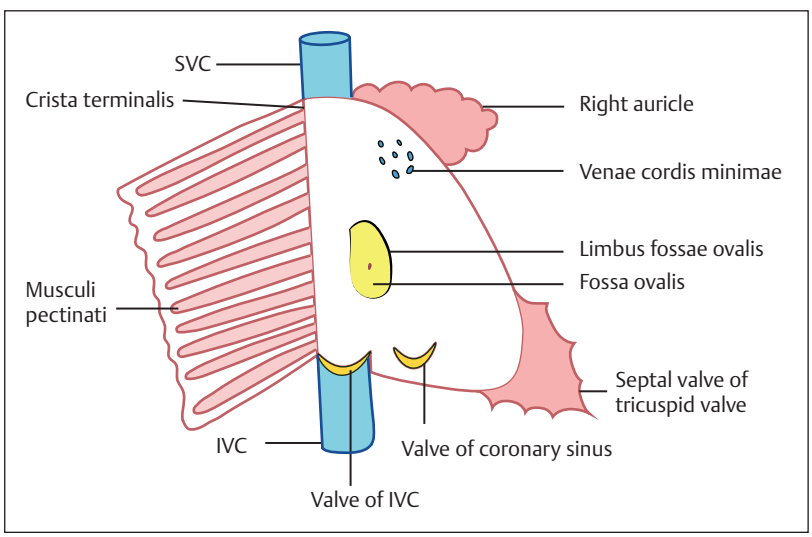


Fig. 21b.5 Right atrium: internal features. IVC, inferior vena cava; SVC, superior vena cava.

- Openings: All large veins entering the right atrium:
  - Superior vena cava: In the upper and posterior part.
  - IVC: In the lower part, close to the interatrial septum. A semilunar fold of the endocardium, the valve of the IVC (eustachian valve), guards the opening. During fetal life, it directs the oxygen-rich blood from the right atrium to the left atrium.
  - Coronary sinus: Lies between the orifice of the IVC and the right AV orifice. The valve of the coronary sinus guards the opening of the coronary sinus.
  - Venae cordis minimae: Open in the numerous small apertures located in the septal wall.
  - Right AV orifice: Largest opening. The right atrium opens into the right ventricle through the right AV orifice, which is guarded by the tricuspid valve.

Atrium Proper

It is the anterior rough part.

- Its walls appear like the teeth of a comb.
- Auricle:
  - An appendage that arises from the upper and anterior part of the atrium proper.
  - It is to the right of the ascending aorta.

Crista Terminalis and Sulcus Terminalis

- A smooth muscular ridge/line of meeting of the sinus venarum and atrium proper on the internal surface of the atrial wall is called the crista terminalis.
- The position of the crista terminalis corresponds to the sulcus terminalis, a groove present on the external surface of the atrium.
- The crista terminalis is a **C**-shaped ridge. It starts on the interatrial septum, passes anterior to the opening of the superior vena cava, and runs along the lateral wall of the atrium to reach the opening of the IVC, where it becomes continuous with the valve of the IVC.
- Development: From the upper part of the right venous valve.

Musculi Pectinati

- Several transversely running muscular ridges in the wall of the right atrium.
- They start from the crista terminalis and run forward toward the auricle.

Development of the Right Atrium

The right atrium develops from the following:

- The rough trabeculated part (atrium proper) in front of the crista terminalis, including the right auricle, develops from the right half of the common (primitive) atrium.
- The smooth part (sinus venarum) behind the crista terminalis develops from absorption of the right horn of the sinus venosus and the right half of the AV canal into the right atrium because of enlargement of the sinoatrial (SA) orifice.

Q3. Write in detail about the interatrial septum: anatomy, development, and atrial septal defect. (AN25.4)

Interatrial Septum

The septum separating the right atrium from the left atrium (**Fig. 21b.5**).
Orientation: It is oblique so that the right atrium lies in front of the left atrium.

Presenting Features

The presenting features of the interatrial septum when viewed from within the right atrium are the following:

- Fossa ovalis: It is an oval depression on the interatrial septum to the left of the IVC opening. The wall of the fossa ovalis is thin and represents the embryonic septum primum.
- Limbus fossa ovalis (annulus ovalis): It is a sickle-shaped, sharp margin surrounding the upper, anterior, and posterior margins of the fossa ovalis. It is deficient inferiorly. It represents the lower curved edge of the embryonic septum secundum.
- Triangle of Koch: It is a triangular area with the following boundaries:
  - Front: The base of the septal leaflet of the tricuspid valve.
  - Behind: The anteromedial margin of the opening of the coronary sinus.
  - Above: The tendon of Todaro (subendocardial ridge extending dorsally from the central fibrous body to the left horn of the valve of the IVC).
- Torus aorticus: This is an elevation in the anterosuperior part of the septum caused by bulging of the right posterior aortic (noncoronary) sinus and cusp of the aortic valve. It is superior to the coronary sinus and anterior to the fossa ovalis.

Development of the Interatrial Septum

- The common atrial chamber communicates posteriorly with the sinus venosus and anteroinferiorly with the ventricle (**Fig. 21b.6**).
- It is divided into right and left halves by two septa that later fuse.
- Septum primum: It is a sickle-shaped septum that arises from the roof and dorsal wall of the primitive atrium to the left of the septum spurium. It grows downward toward the septum intermedium and the AV canal. The blood from the right atrium must reach the left atrium during fetal life, and this necessitates the development of a communication between the right and left atria.
- Ostium primum: The foramen at the caudal end of the septum primum for communication between atria.
- Ostium secundum: As the septum primum is coming down to meet the septum intermedium, a second foramen appears at the upper part of the septum primum called the ostium secundum. The ostium primum gets closed as the septum primum fuses with the septum intermedium.
- Septum secundum: It appears between the septum primum and the septum spurium, grows down, and overlaps the free edge of the septum primum, forming the opening known as the foramen ovale between the two chambers. The lower edge of the septum secundum is thick. The upper edge of the septum primum forms the lower edge of the ostium secundum and is thin and flap-like.
- Foramen ovale: Blood flows from the right atrium to the left atrium through this oblique valvular passage during the fetal period. When blood flows from left to right, the thin flap-like septum primum meets the thick septum secundum and closes the foramen ovale. After birth, due to increased pressure in the left atrium when compared with the right, the foramen ovale is closed permanently.
- Remnants of septa in adults:
  - Fossa ovalis: Septum primum.
  - Limbus fossa ovalis: Septum secundum.

Clinical Importance

Defects in the formation of the interatrial septum:

- Septum primum defect: The septum primum fails to join the septum intermedium.
- Septum secundum defect: Failure of development of the septum secundum and the foramen secundum remains widely open, leading to an ostium secundum defect.
- Patent foramen ovale: The septum primum and secundum develop normally. The oblique passage remains patent after birth.
- Premature closure of the foramen ovale before birth leads to hypertrophy of the right atrium and ventricle and underdevelopment of the left side of the heart.

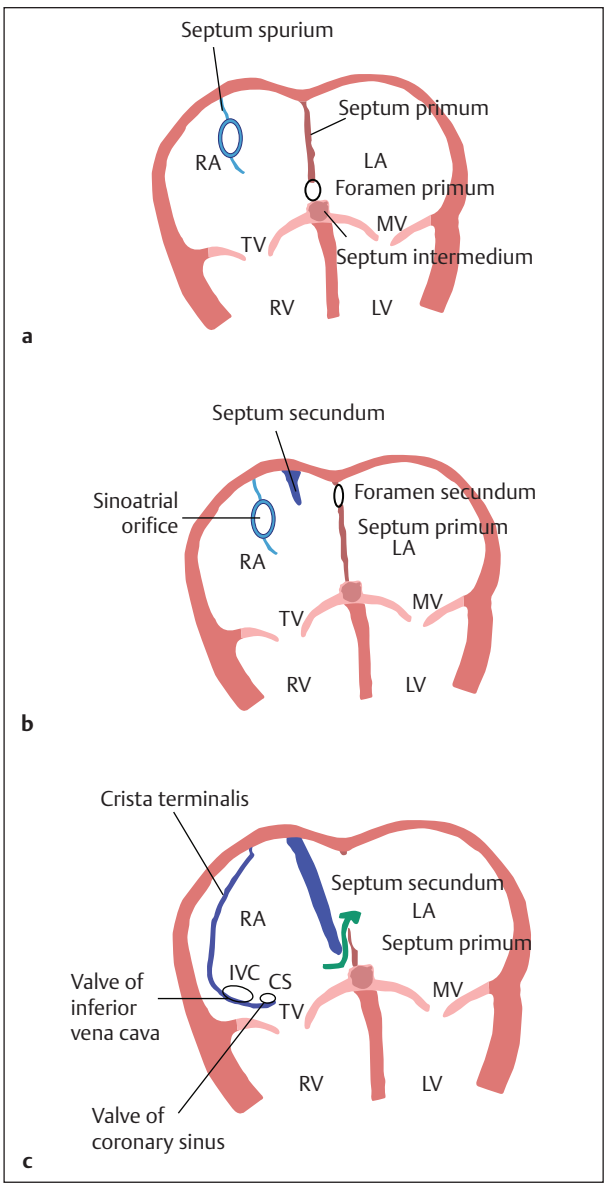


Fig. 21b.6 Development of the interatrial septum. **(a)** Formation of the septum primum and foramen primum. **(b)** Formation of the septum secundum and fusion of the septum primum with the septum intermedium. **(c)** Formation of the valvular (oblique) passage: foramen ovale. CS, coronary sinus; IVC; inferior vena cava; LA, left atrium; ventricle; LV, left ventricle; MV, mitral valve; RA, right atrium; RV, right ventricle; TV, tricuspid valve.

Q4. Describe the right ventricle in detail and add a note on its development. (AN22.2, AN25.2)

Right Ventricle

External Features

- Shape: Triangular.
- Location: In front and to the left of the right atrium.
- Surfaces and borders of the heart contributed:
  - Two-thirds of the anterior/sternocostal surface.
  - One-third of the diaphragmatic surface.
  - Inferior border.
- Groove:
  - The AV groove (vertical part) separates the right atrium and the right ventricle.

Internal Features

The right ventricle is divided into two parts by a muscular ridge called the *supraventricular crest* (**Fig. 21b.7**).

Inflow Part (Rough Part)

- Large, lower, rough part.
- Contains muscular ridges: Trabeculae carneae.
- Develops from the primitive ventricle.

Outflow Part (Smooth Part)

- Small, upper part.
- Forms the infundibulum.
- Develops from the conus part of the bulbus cordis.

Cavity

It is flat and crescent shaped in the transverse section due to a bulging interventricular septum.

Wall

It is thinner than the left ventricle, approximately 4 to 5 mm:

- Muscular projections: A series of muscular projections/ridges gives a spongelike appearance. These are formed by raised bundles of cardiac muscle fibers.
  - Trabeculae carneae: Irregular muscular ridges. Types:
    - Ridges: Fixed projections.
    - Bridges: Ends fixed and the central part free.
    - Pillars: Base fixed and apex free.
  - Papillary muscles:
    - Pillars of the trabeculae carneae and cone shaped.
    - Project into the cavity.
    - Base: Attached to the ventricular wall.
    - Apex: Connected to the cusps of the tricuspid valve by fibrous cords, the chordae tendineae.
    - Three in number and are connected to the cusps of the tricuspid valve through the trabecular carneae and chordae tendineae:
      - Anterior.
      - Posterior.
      - Septal.
  - Moderator band (septomarginal trabeculae): Part of the conducting system of the heart:
    - Thick muscular ridge.

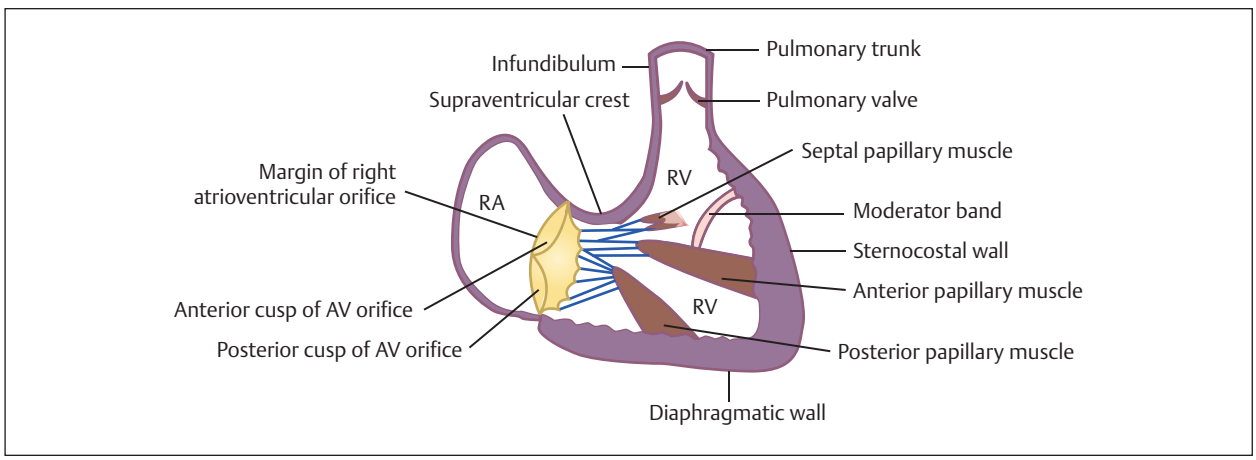


Fig. 21b.7 Right ventricle (RV): internal features. AV, atrioventricular; RA, right atrium.

- Extent: From the interventricular septum to the anterior papillary muscle, passing across the ventricular cavity.
- Conveys the right branch of the AV bundle of His (part of the conducting system).
- Prevents overdistension of the right ventricle.

Orifices and Communications

- Right AV orifice: Right atrium.
- Pulmonary orifice: Pulmonary trunk.

Development of the Right Ventricle

- Inflow (rough) part from the proximal one-third of the bulbus cordis and the right part of the primitive ventricle.
- Outflow (smooth) part from the middle one-third (conus part) of the bulbus cordis.

Q5. Describe the left atrium in detail and add a note on its development. (AN22.2, AN25.2)

Left Atrium

External Features

- Shape: Quadrangular.
- Situation:
  - Posterior: Behind and to the left of the right atrium.
- Contribution:
  - To the heart surfaces: Forms two-thirds of the base of the heart.
  - Left auricle: Anterior projection of the upper end that overlaps the infundibulum of the right ventricle.
  - The anterior wall of the oblique sinus of the pericardium.

Internal Features

- Posterior wall: Smooth (**Fig. 21b.8**):
  - Receives blood from the lungs through four pulmonary veins.
  - Pulmonary veins were absorbed into the heart during development.
- Anterior wall: It is rough because the ridged pectinate muscles are confined to the auricle of the left atrium. But the anterior wall of the left atrium is smooth and presents the lunate fossa that corresponds to the fossa ovalis of the right atrium.

Openings in the Left Atrium

- Pulmonary veins: There are four pulmonary veins in the posterior wall, and they have no valves.
- Left AV orifice: Also called the mitral valve. Blood passes from the left atrium into the left ventricle through the bicuspid (mitral) valve. It has two cusps.
- Small opening of the venae cordis minimae.

Development

It develops from three components:

- Left half of the primitive atrial chamber.
- Left half of the AV canal.
- Absorbed proximal parts of the pulmonary veins.

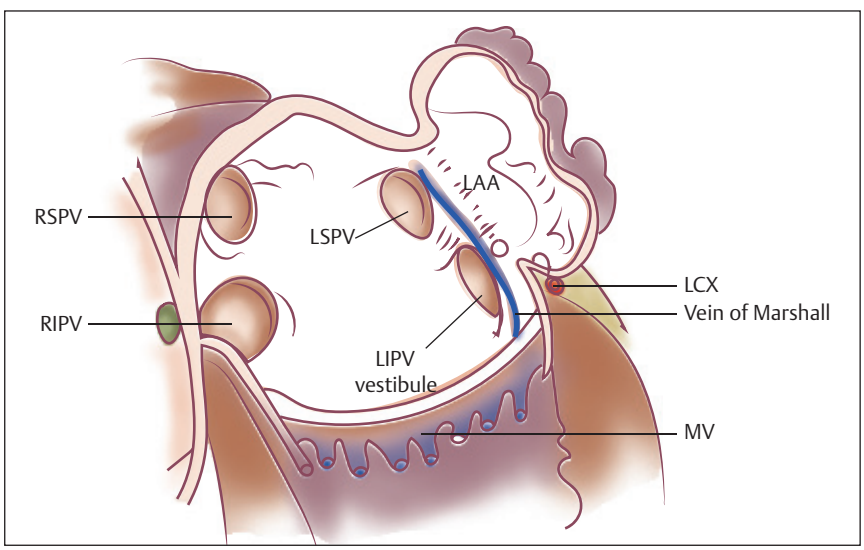


Fig. 21b.8 Left atrium: internal features. LAA, left auricular appendage; LCX, left circumflex artery; LIPV, left inferior pulmonary vein; LSPV, left superior pulmonary vein; MV, mitral valve; RIPV, right inferior pulmonary vein; RSPV, right superior pulmonary vein.

Q6. Describe the left ventricle in detail and add a note on its development. (AN22.2, AN25.2)

Left Ventricle

External Features

- Thickness: Thickest part of the heart (10–15 mm).
- Shape: Triangular.
- Contribution of the left ventricle to the heart surfaces and borders:
  - Sternocostal surface: Small part.
  - Diaphragmatic surface: Two-thirds.
  - Left border: Most of it.
  - Apex of the heart.

Internal Features

It is divided into two parts (**Fig. 21b.9**):

- Inflow part:
  - Large, rough lower part.
  - Contains the trabeculae carneae.
  - Lies below the aortic vestibule.
  - Develops from the primitive ventricle.
- Outflow part:
  - Small, smooth, upper part—aortic vestibule.
  - Ascending aorta starts here.
  - Lies between the interventricular septum and the anterior cusp of the mitral valve.
  - Develops from the conus part of the bulbus cordis.
- Wall:
  - The trabeculae carneae and chordae tendineae anchor the cusps of the bicuspid valve to the papillary muscles.
  - Papillary muscles: There are two papillary muscles (anterior and posterior) attached to the cusps of the mitral valve.
  - No moderator band.
- Openings:
  - Left AV orifice: Communicates with the left atrium.
  - Aortic orifice: Communicates with the ascending aorta.

Q7. Write in detail about the Interventricular septum: anatomy, development and ventricular septal defect. (AN25.4)

Interventricular Septum

Location and Parts

- It is the thick wall that separates the right and left ventricles (**Fig. 21b.10**).

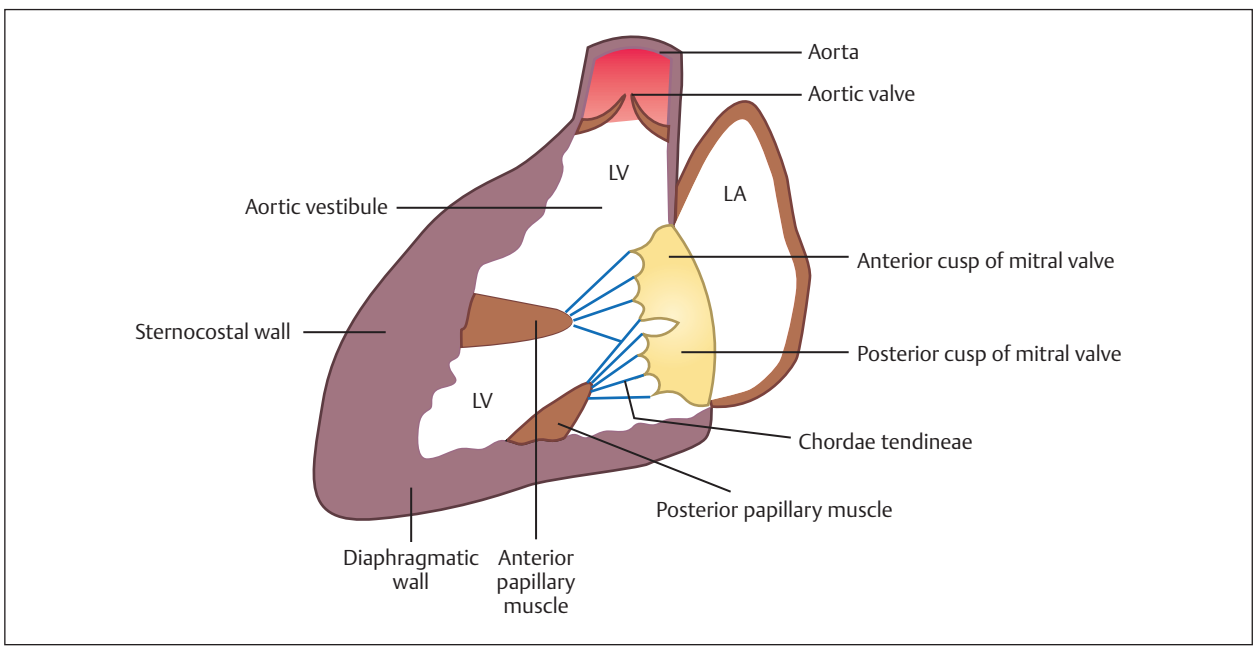


Fig. 21b.9 Left ventricle (LV): internal features. LA, left atrium.

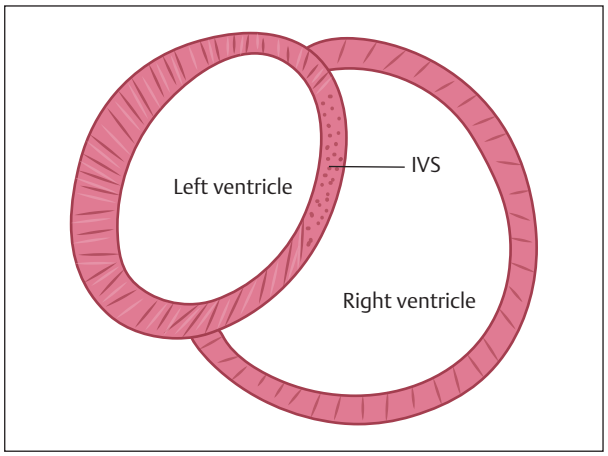


Fig. 21b.10 Interventricular septum (IVS).

- Direction of the septum: Oblique and directed backward and to the right.
- The septum is made up of two parts: a muscular part and a membranous part.
- The muscular part is the major part and is thick. The upper part of the septum is thin and membranous.
- The position of the left ventricle is posterior to the right ventricle. The anterior wall and part of the right wall of the left ventricle are provided by the muscular part of the interventricular septum. The muscular part of the septum bulges into the right ventricle.
- The upper part of the septum nearer to the aortic orifice is thin and fibrous. It is called the membranous part or pars membranacea septi.
- The muscular and membranous parts differ in their development. The membranous part of the septum is the frequent site for ventricular septal defects.

Development

- The arterial end of the primitive heart tube is the bulbus cordis. It is divided into three parts: proximal, middle, and distal (**Fig. 21b.11**).
- The proximal part and middle part (conus cordis) merge with the primitive ventricle to form the bulboventricular cavity. This cavity is divided into right and left parts in such a way that each half communicates with the corresponding atrium. The conus cordis forms the outflow part of both ventricles.
- Two septa (the proximal and distal bulbar septa) develop in relation to the walls of the conus cordis. The distal bulbar septum divides the conus into the aortic vestibule and infundibulum. The proximal bulbar septum contributes to the interventricular septum.
- There are three parts of the interventricular septum:
  - Muscular part: It grows upward from the floor of the bulboventricular cavity in its middle and divides the lower part of this cavity into right and left parts. This muscular part meets the septum intermedium (fused AV cushions). The cephalic part of the septum presents two horns: a dorsal horn and a ventral horn. The dorsal horn fuses with the right edge of the dorsal AV cushion at the AV orifice. The ventral horn fuses with the left edge of the ventral AV cushion. At this stage, a gap appears at the upper margin of the muscular septum between the two ventricles. This gap is closed by the septum intermedium and the proximal bulbar septum.
  - Bulbar part: It is contributed by the proximal bulbar septum, which is formed by fusion of the right and left bulbar ridges that originate from the walls of the conus part of the bulboventricular cavity. The right and left ridges of the proximal bulbar septum grow downward and join the dorsal and ventral horns of the muscular part of the interventricular septum, respectively.
  - Membranous part: After the fusion of the muscular and bulbar parts of the septum, there exists a gap between the two parts. This gap is filled by the proliferation of tissue from the right side of the AV endocardial cushions (right edge of the septum intermedium).

Interventricular Septal Defects

- This is one of the most common congenital heart defects (**Fig. 21b.12**).
- Seventy percent are in the membranous part, as it is the place where several embryonic structures merge.
- Increased blood flow to the right ventricle causes right ventricular hypertrophy and can cause pulmonary hypertension.

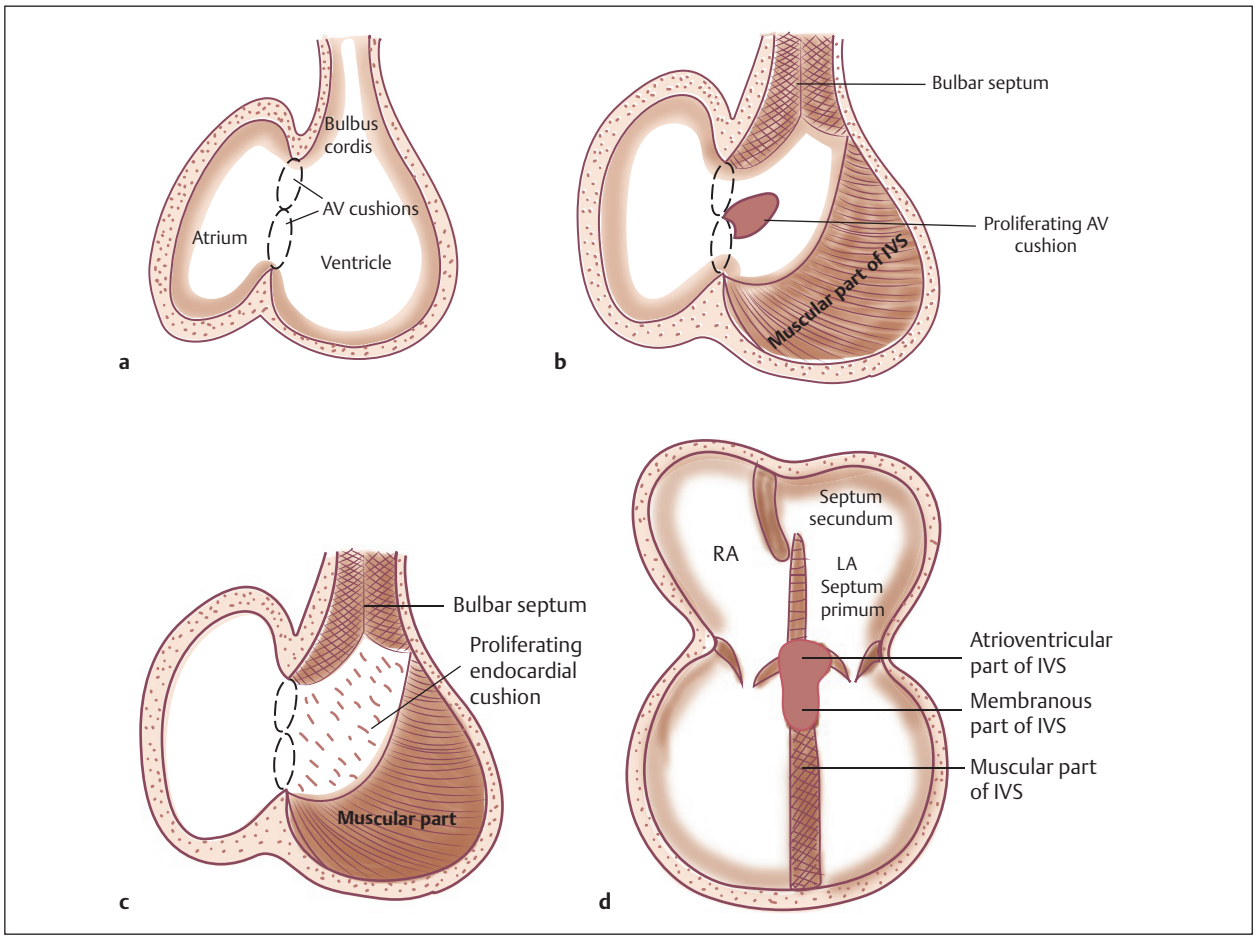


Fig. 21b.11 **(a–d)** Development of the interventricular septum (IVS). AV, atrioventricular; LA, left atrium; RA, right atrium.

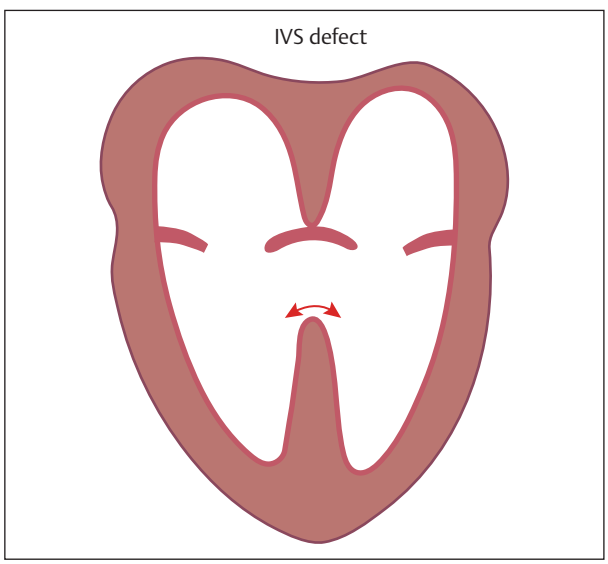


Fig. 21b.12 Ventricular septal defect. IVS, interventricular septum).

Q8. Write short notes on the atrioventricular and semilunar valves of the heart and their surface marking. (AN22.2, AN25.9)

Atrioventricular and Semilunar Valves of the Heart

There are two pairs of heart valves:

- The AV valves are located between the atria and the ventricles (**Table 21b.2**; **Fig. 21b.3** and **Fig. 21b.13**):
  - Right AV or tricuspid valve.
  - Left AV or bicuspid/mitral valve.
- Semilunar valves (**Table 21b.3**; **Fig. 21b.3** and **Fig. 21b.13**):
  - Aortic valve.
  - Pulmonary valve.

Table 21b.2 Description of atrioventricular valves

Feature	Tricuspid valve	Bicuspid valve
Situation	Between the right atrium and the right ventricle	Between the left atrium and left ventricle
Shape	Oval, admits three fingers	Oval, admits two fingers
Structure	▪ A fibrous ring surrounding each atrioventricular orifice ▪ Cusps formed by duplication of the endocardium of the heart	
Cusps	3 cusps: anterior, posterior, and septal	2 cusps: anterior and posterior
Attachment of cusps	Each cusp has the following: ▪ Base attached to the fibrous ring of the orifice and apex, and a free margin that receives attachment of the chordae tendineae ▪ Smooth atrial and rough ventricular surface	
Attachment of chordae tendineae	One end to the apex of the papillary muscle and the other end to the adjoining parts of two cusps to the apices and free margin	
Papillary muscle: number	3 numbers: large anterior and posterior, and small septal	2 numbers: anterior and posterior
Papillary muscle attachment at the base	▪ The anterior muscle is attached to the sternocostal wall ▪ The posterior muscle is attached to the diaphragmatic wall and the interventricular septum ▪ The septal muscle is attached to the interventricular septum	▪ The anterior muscle is attached to the sternocostal wall ▪ The posterior muscle is attached to the diaphragmatic wall
Surface marking	▪ 4.0 cm broad ▪ Placed vertically behind the sternum ▪ The upper end is at the level of the fourth costal cartilage in the midline ▪ The lower end is slightly inclined to the right and reaches the level of the fifth costal cartilage	▪ 3.0 cm broad ▪ Obliquely placed deep to the left half of the sternum at the level of the fourth costal cartilage
Auscultatory area	Lower end of the sternum (right half)	Left fifth intercostal space 3.5 inches from the midline: site of the apex beat
Heart sound	First heart sound (LUB) due to closure of atrioventricular valves	
Clinical importance	Tricuspid stenosis: Narrowing can lead to right heart failure	Mitral stenosis: Narrowing can cause enlargement of the left atrium
Development	Right lateral and ventral endocardial cushions in relation to the atrioventricular canal	Left lateral and dorsal endocardial cushions in relation to the atrioventricular canal

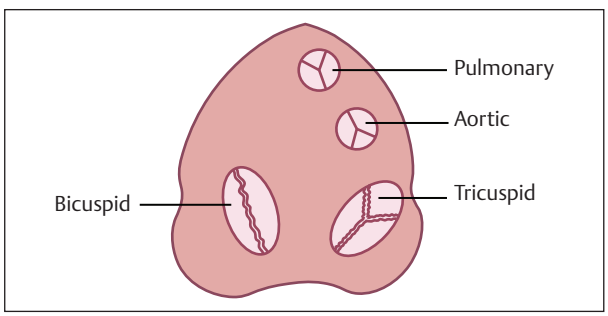


Fig. 21b.13 Valves of the heart.

Q9. Write short notes on the fibrous skeleton of the heart. (AN22.6)

Fibrous Skeleton of the Heart

- Definition: A complex framework of four interconnected dense collagen fibrous rings that surround the ostia of the valves of the heart.
- Location: At the bases of both ventricles (junction of the atria and ventricles) around the right and left AV, pulmonary, and aortic orifices.

Table 21b.3 Description of the semilunar valves

Feature	Pulmonary valve	Aortic valve
Situation	Between the infundibulum of the right ventricle and the pulmonary trunk	Between the aortic vestibule of the left ventricle and the ascending aorta
Shape and size	Circular, 3 cm	Circular, 2.5 cm
Cusps in adult	3 cusps: anterior, right, and left	3 cusps: right, left, and posterior
Changes in the vessel wall	The wall of the pulmonary trunk dilated above the cusps, forming three sinuses (two anterior and one posterior)	▪ The wall of the aorta is slightly dilated above the three cusps, forming three sinuses (one anterior and two posterior) ▪ The right coronary artery originates from the anterior aortic sinus ▪ The left coronary artery arises from the left posterior sinus. The right posterior sinus is a noncoronary sinus
Structure	▪ The mouths of the cusps are directed upward ▪ Each has a fibrous nodule at the midpoint of the free edge ▪ On either side of the nodule is the thickened crescentic edge called the lunule, extending to the base	
Surface marking	▪ 2.5 cm broad ▪ Lies partly behind the left third costal cartilage and partly behind the sternum	▪ 2.5 cm broad ▪ Lies obliquely behind the left half of the sternum at the level of the third intercostal space
Auscultatory area	The second left intercostal space near the sternum	The second right intercostal space near the sternum
Heart sound	The second heart sound (DUB) due to closure of the semilunar valves	
Clinical importance	Pulmonary stenosis: It is congenital and part of Fallot's tetralogy. It can cause right ventricular hypertrophy	Aortic stenosis can cause left ventricular hypertrophy
Development	Endocardial cushions (right, left, and anterior cusps) at the conus–truncus junction	Endocardial cushions (right, left, and posterior cusps) at the conus–truncus junction

Constituents

Fibrous Rings: Surrounding the Valves

- AV rings: There are two AV rings in relation to the tricuspid and bicuspid valves (**Fig. 21b.14**). The two rings fuse in the form of "8."
- Aortic ring: In relation to the aortic valve.
- Pulmonary ring: In relation to the pulmonary valve.

Interconnection of Rings

- Trigonum fibrosum dextrum (TFD)/right fibrous trigone: Between the AV and aortic rings.
- Trigonum fibrosum sinistrum (TFS)/left fibrous trigone: Between the mitral and aortic rings.
- Tendon of the infundibulum: Between the pulmonary and aortic rings.

Purpose

- Provide rigidity to the AV orifices and the roots of the aorta and pulmonary trunk.
- Provide attachment sites for the cusps of valves and prevent over-dilatation and valve incompetence.
- The fibrous skeleton, along with the membranous part of the interventricular septum, provides attachment for cardiac muscle fibers.
- Acts as an electrical insulator: Does not allow the spread of an electrical impulse from the atria to the ventricle. Impulse will pass only through the bundle of His.

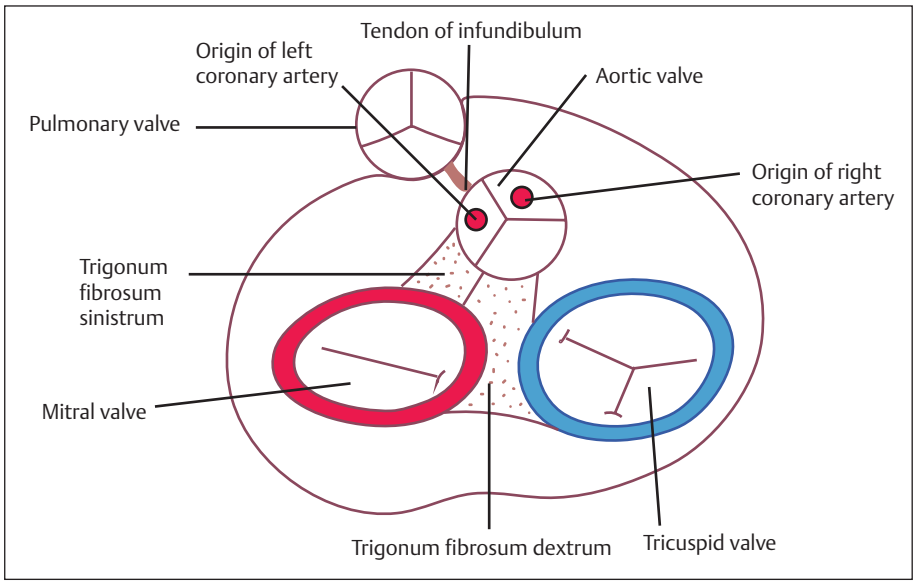


Fig. 21b.14 Fibrous skeleton of the heart.

Clinical Importance

Defects of the fibrous skeleton cause improper closure of valves, leading to regurgitation (leaking heart valve) and valve incompetence.

Q10. Describe the blood supply of the heart. (AN22.3)

a. Describe the coronary arteries. Write briefly on coronary dominance and its clinical importance. (AN22.3, AN22.4, AN22.5, AN25.6)
b. Anatomical basis of ischemic heart disease. (AN22.4)
c. Anatomical basis of coronary bypass surgery. (AN22.3)
d. Anatomical basis of coronary angioplasty. (AN22.3)
e. Venous drainage of the heart and coronary sinus. (AN22.5, AN25.6)

a. Arterial Supply: Coronary Arteries and Coronary Dominance

- The heart is supplied by two coronary arteries (right and left) that arise from the ascending aorta.
- The coronary arteries and their branches form a circle and loop around the heart like a crown.
- The right coronary artery arises from the anterior aortic sinus, whereas the left coronary artery arises from the left posterior aortic sinus.
- The main arteries and major branches are usually subepicardial.
- Those in the AV and interventricular grooves are deeply situated.
- Caliber: 1.5 to 5.5 mm.

The description of the coronary arteries can be found in **Table 21b.4** and **Fig. 21b.15**.

Coronary Dominance

- Variations in the coronary arterial distribution mainly affect the diaphragmatic aspect of the ventricles, and it reflects the relative "dominance" of supply by the left or right coronary artery. The artery that gives the posterior interventricular branch is the dominant artery.
- There are three types:
  - Right dominance: It is typical and common. The posterior interventricular branch arises from the right coronary artery in 70% of cases.
  - Left dominance: The posterior interventricular branch arises from the circumflex branch of the left coronary artery in 20% of cases.
  - Balanced: The posterior interventricular branch is contributed to by both coronary arteries in 10% of cases.

Clinical Importance

- In left dominance, a block in the left coronary artery affects the entire left ventricle and interventricular septum.
- In right or balanced dominance, a block in the right coronary artery spares two-thirds of the septum and the left ventricle.

Table 21b.4 Coronary arteries: origin, course, branches, and distribution

Feature	Right coronary artery	Left coronary artery
Origin	Anterior aortic sinus	Left posterior aortic sinus
Course	First segment: From the origin, it runs between the pulmonary trunk and the right auricle to the coronary sulcus	Courses between the pulmonary trunk and the left atrial appendage to the left part of the atrioventricular groove on the sternocostal surface
	Second segment: It runs on the sternocostal surface in the anterior part of the atrioventricular groove (coronary sulcus) up to the junction of the right border and the inferior border of the heart	▪ It bifurcates into the circumflex and the anterior interventricular (left anterior descending [LAD]) branches ▪ Circumflex branch: It runs to the left in the anterior part of the atrioventricular groove, then curves around the left border of the heart and runs downward and right in the posterior part of the atrioventricular groove to anastomose with the terminal branch of the right coronary artery ▪ Anterior interventricular branch: It runs downward and to the left in the anterior interventricular groove. Near the apex of the heart, it runs a short course on the posterior interventricular groove and anastomoses with the posterior interventricular branch of the right coronary artery
	▪ Third segment: It curves around the inferior cardiac border to run along the right portion of the posterior atrioventricular groove ▪ It finally reaches the crux of the heart: meeting point of the posterior atrioventricular, interatrial, and interventricular grooves	
Branches	First segment: ▪ Right conus artery: pulmonary trunk and infundibulum ▪ Artery of the sinoatrial (SA) node: 60% cases Second segment: ▪ Right anterior atrial rami ▪ Right anterior ventricular rami ▪ Right marginal artery Third segment: ▪ Atrial branches: right atrium ▪ Ventricular branches: diaphragmatic surface of the right ventricle ▪ Posterior interventricular branch: 70% cases ▪ Artery of the atrioventricular node	Circumflex branch: ▪ Atrial branches: left atrium ▪ Anterior ventricular branches: left ventricle ▪ Left marginal artery: along the left margin of the heart ▪ Artery of the SA node: 40% cases ▪ Posterior interventricular branch: 20% cases Anterior interventricular branch (LAD): ▪ Anterior ventricular ▪ Diagonal branch ▪ Left conus artery ▪ Anterior septal branches ▪ Posterior septal branches
Chambers supplied	▪ Right atrium ▪ Left atrium (small part) ▪ Most of the right ventricle ▪ Small part of the left ventricle (diaphragmatic surface) ▪ Posterior two-thirds of the interventricular septum ▪ Conducting system of the heart: SA node, atrioventricular node, bundle of His and its branches	▪ Left atrium (most of it) ▪ Left ventricle (most of it) ▪ Right ventricle (small part) ▪ Anterior two-thirds of the interventricular septum ▪ Right and left bundle branches

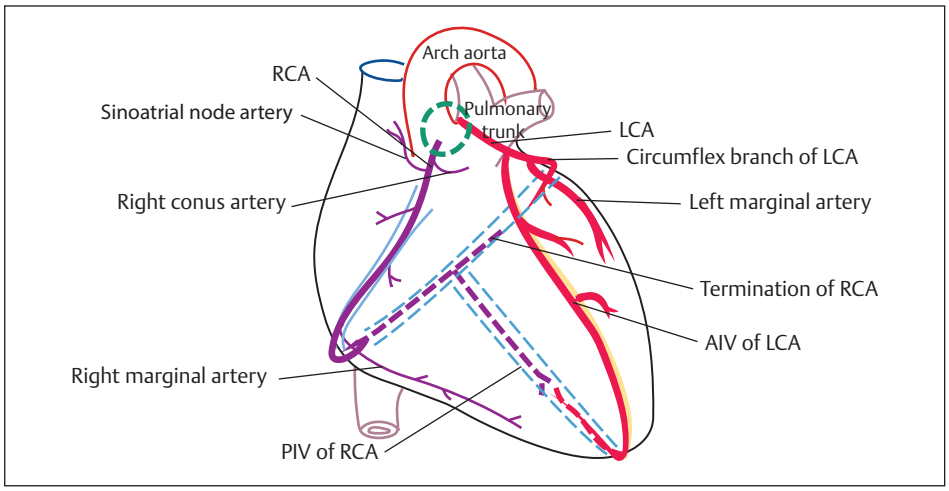


Fig. 21b.15 Coronary arteries. AIV, anterior interventricular; LCA, left coronary artery; PIV, posterior interventricular; RCA, right coronary artery.

b. Anatomical Basis of Ischemic Heart Disease

Clinical Importance

Ischemic Heart Disease

- Synonym: Coronary artery disease (CAD)/coronary heart disease (CHD).
- Definition: It is a heart disease due to inadequate blood supply to the myocardium because of narrowing of the coronary arteries or their partial or complete blockage by atheromatous plaques (atherosclerosis).
- Types:
  - Anginal pectoris:
    - Narrowing of the coronary arteries leads to reduced blood supply to the cardiac myocardium.
    - This causes myocardial ischemia (inadequate supply of oxygenated blood), and the patient complains of pain in the chest and radiation on the left shoulder and the medial side of the arm and forearm.
    - The pain occurs on exertion and is relieved by rest.
  - Myocardial infarction:
    - Sudden blockage of the stem of the coronary artery or one of its major branches causes myocardial ischemia, followed by myocardial infarction (formation of thrombus), leading to complete loss of blood supply to a part of the myocardium.
    - This causes the sensation of pain in the chest, difficulty in breathing, and tachycardia.
    - Pain radiates to the medial side of the left arm, forearm, and hand. Sometimes, it is referred to the jaw.
    - Common sites of myocardial infarction are the following:
      - Occlusion of the LAD coronary artery: Most commonly occluded artery. Occlusion leads to infarction of the anterior wall of the left ventricle, apex of the heart, and anterior two-thirds of the ventricular septum. Because of its extensive area of blood supply, occlusion can cause sudden death.
      - Occlusion of the right coronary artery or its branch, the posterior interventricular artery: This results in infarction of the inferior wall of the left and right ventricles, and the posterior one-third of the ventricular septum. If occlusion is proximal, it affects the blood supply of the right ventricle, and this is less common.
      - Occlusion of the circumflex artery: Infarction of the lateral wall of the left ventricle, except the apex. Its occlusion is less common.

c. Coronary Artery Bypass Surgery

Clinical Importance

- Synonym: Coronary artery bypass graft (CABG).
- Definition: It is a procedure to improve blood supply to the heart in patients with coronary artery blocks.
- A graft of either an artery or a vein is connected to the coronary artery proximal and distal to the block. The great saphenous vein is commonly used for CABG because it is easily accessible for dissection and has a diameter close to that of the coronary artery. It can be used for multiple grafts. The commonly used artery is the left internal thoracic artery and is used if one graft is required.

- This graft shunts blood from the aorta to the coronary artery distal to the block, thus improving the circulation to the heart.

d. Coronary Angioplasty

Clinical Importance

- This procedure is performed to relieve obstruction to the blood flow in the coronary arteries.
- A catheter with a small balloon attached to its tip is passed into the coronary artery to the site of obstruction. Then, the balloon is inflated.
- If there is a clot, it gets flattened, and the patency of the vessel will be restored.
- Drugs to dissolve the clot (thrombokinase) can be injected at the site of the clot.
- To maintain the dilatation, intravascular stents are placed.

e. Venous Drainage of Heart/Coronary Sinus

Venous drainage of the heart is through the following veins (**Fig. 21b.16** and **Fig. 21b.17**):

- Coronary sinus.
- Anterior cardiac veins are on the anterior surface of the right ventricle and open directly into the right atrium.
- Venae cordis minimae (thebesian veins): Tiny vessels of myocardium that open directly into the chambers of the heart.

Coronary Sinus

- Largest vein of the heart.
- Most of the venous drainage of the heart is through the coronary sinus into the right atrium.
- Location: Posterior part of the AV groove (coronary sulcus).
- Length: 3.0 cm.
- Origin, course, and termination: It is a continuation of the great cardiac vein and begins at the left end of the coronary sulcus. It runs from left to right in the posterior part of the AV groove between the left atrium and the left ventricle. It ends in the right atrium between the openings of the IVC and the right AV orifice.
- Valve of the coronary sinus: It is a semilunar valve that guards the opening of the coronary sinus into the right atrium. Developmentally, it is the lower part of the right venous valve.
- Its tributaries are listed in **Table 21b.5** and **Fig. 21b.17**.
- **Development:** The coronary sinus develops from the left horn of the sinus venosus and a part of the left common cardinal vein. The oblique vein of the left atrium is a remnant of the part of the left duct of Cuvier (left common cardinal vein).

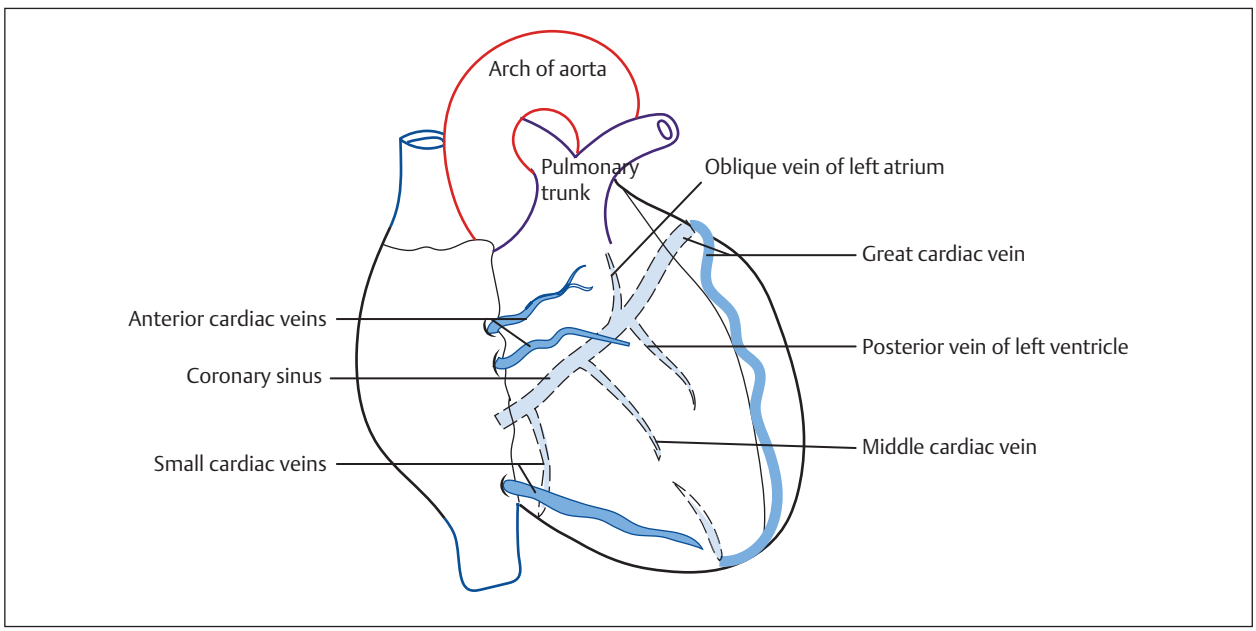


Fig. 21b.16 Venous drainage of the heart.

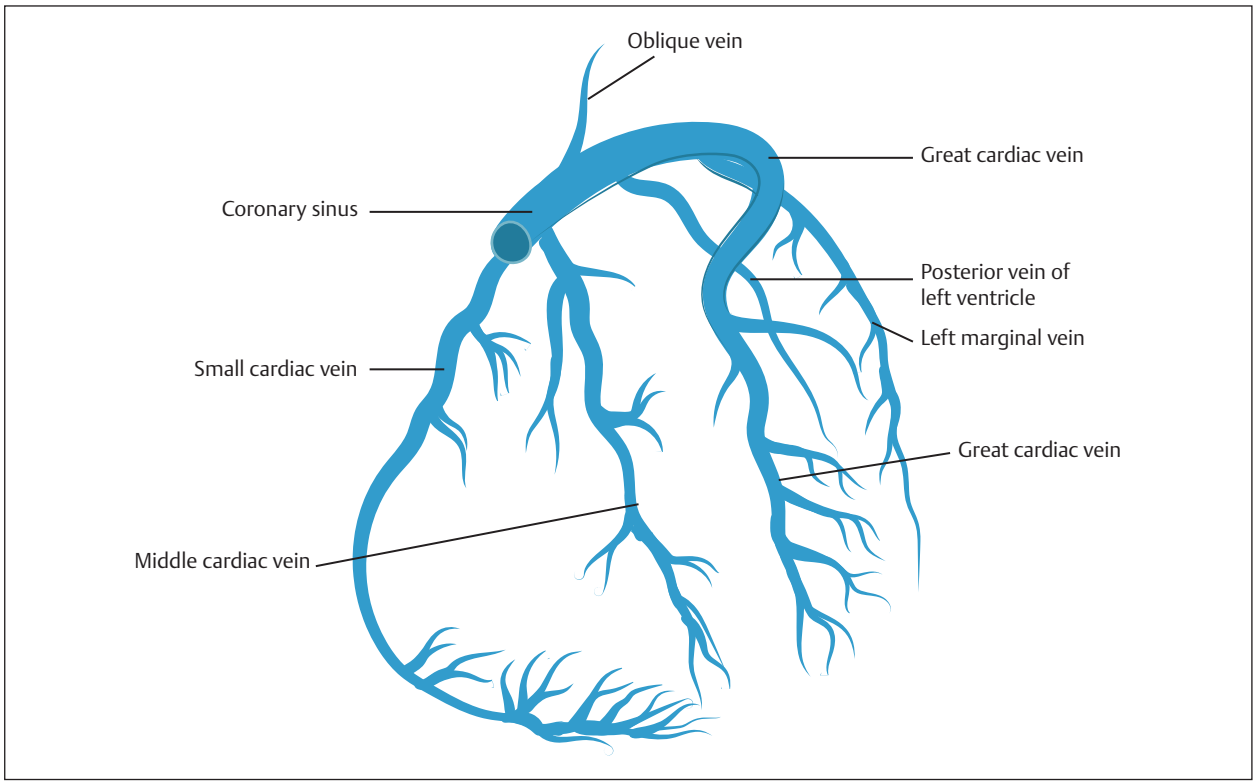


Fig. 21b.17 Coronary sinus.

Table 21b.5 Coronary sinus: tributaries

Vein	Location	Termination
Great cardiac vein (largest vein)	Anterior interventricular groove along with the anterior interventricular artery	Left end of the coronary sinus
Middle cardiac vein	Posterior interventricular groove along with the posterior interventricular artery	Right end of the coronary sinus
Small cardiac vein	Inferior border along with the right marginal artery	Right end of the coronary sinus
Posterior vein of the left ventricle	Diaphragmatic surface of the left ventricle, parallel to the middle cardiac vein	Coronary sinus to the left of the middle cardiac vein
Right marginal vein	Accompanies the marginal branch of the right coronary artery	Joins the small cardiac vein or opens directly into the right atrium
Left marginal vein	Accompanies the marginal branch of the left coronary artery	Drains into the coronary sinus
Oblique vein of the left atrium (vein of Marshall)	Small vein on the posterior surface of the left atrium	Joins the great cardiac vein to form the coronary sinus

Q11. Describe the conducting system of the heart. (AN22.7)

Conducting System of the Heart

Definition: A group of specialized cardiac muscle cells in the walls of the heart that send signals to the heart muscle, causing it to contract (**Fig. 21b.18**).

Components

- SA node of Keith and Flack.
- AV node of Tawara.
- AV bundle of His.
- Right and left bundle branches of His.
- Purkinje fibers.

Sinoatrial Node

- Situation: In the posterior wall of the right atrium, in the upper part of the sulcus terminalis, below the superior vena cava opening.
- Natural pacemaker of the heart: Generates impulses at the rate of 70/min.
- Measurement: 10 to 20 mm in length, 5 to 7 mm wide, and 1 mm deep.
- Blood supply: Nodal branch of the right coronary artery.
- Function: Initiates contraction of the cardiac muscle (heartbeat).
- Works under the influence of the autonomic nervous system (ANS):
  - Sympathetic stimulation: Increases the firing and heart rate.
  - Parasympathetic: Decreases the firing and heart rate.

Atrioventricular Node of Tawara

- Location: Right atrium near the interventricular septum above the opening of the coronary sinus in the triangle of Koch.
- Measurement: 8 mm anteroposteriorly.

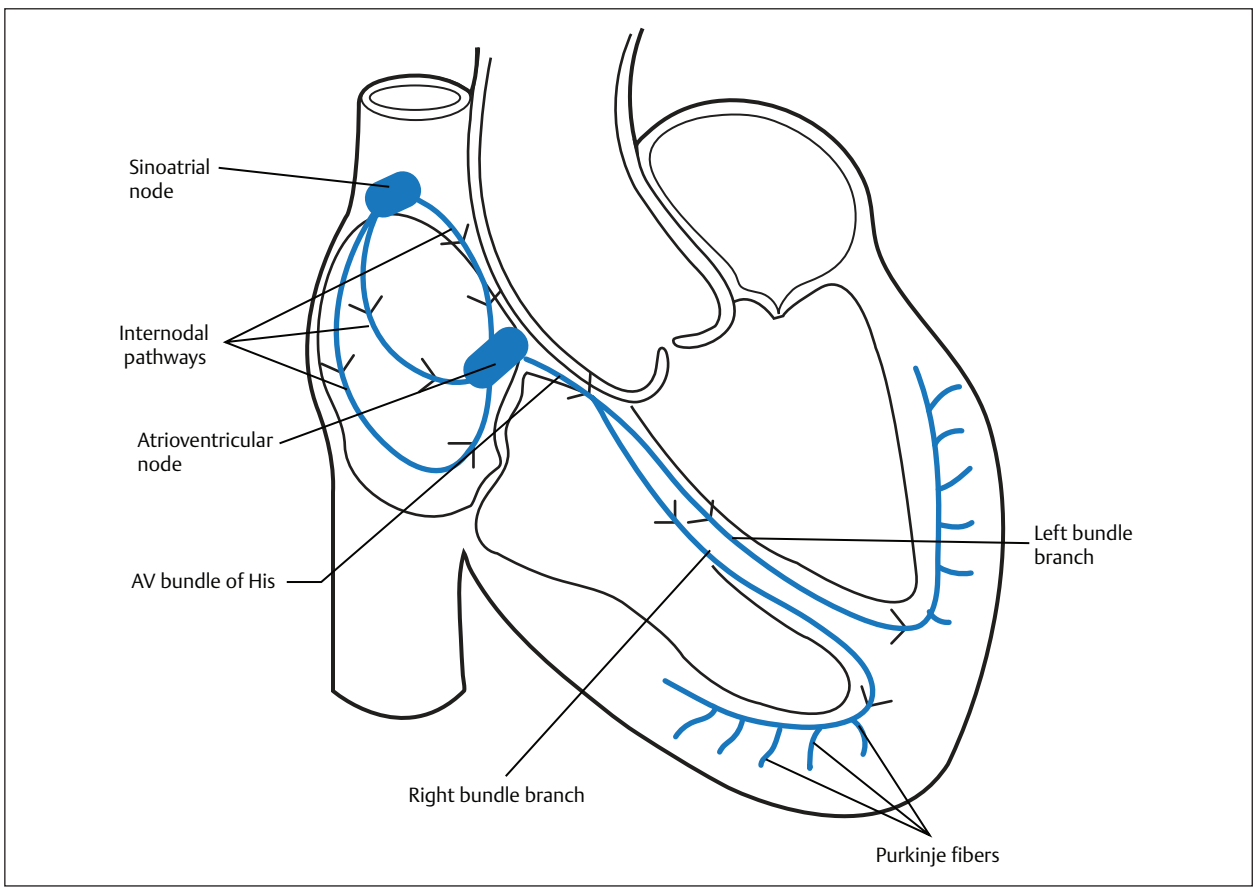


Fig. 21b.18 Conducting system of the heart.

- Conducts impulses to the ventricles via the AV bundle.
- Delays impulse by 120 milliseconds.

Atrioventricular Bundle of His

- It begins at the AV node.
- It runs along the inferior part of the membranous interventricular septum.
- It passes between the interventricular septum and the septal cusp of the tricuspid valve to enter the right ventricle.
- It divides into right and left branches.
- As the skeletal framework of the heart separates the muscles of the atria from the muscles of the ventricles for conducting impulses from the atria to the ventricles, the only way left is this bundle.

Right and Left Bundle Branches

The right and left bundle branches conduct impulses to the Purkinje fibers of the ventricles.

- The right bundle branch runs along the right side of the interventricular septum, and then through the moderator band. It reaches the base of the anterior papillary muscle and breaks into a network of Purkinje fibers.
- The left bundle branch passes along the left side of the ventricular septum and splits into anterior and posterior sheets to reach the base of the papillary muscles. Here they end in the Purkinje fibers.

Purkinje Fibers

These are the terminal branches of the right and left bundle branches. These ramify in the entire wall of the right and left ventricles underneath the endocardium.

Blood Supply

The whole conducting system is supplied by the right coronary artery, except the left branch of the AV bundle, which is supplied by the left coronary artery.

Clinical Importance of the Conducting System of the Heart

- Arrhythmias: Damage to the conducting system causes alteration in the rhythmic contraction of the ventricles. This is due to the failure of the AV bundle to conduct normal impulses, resulting in an irregular pulse.
  - Bradycardia: Slow pulse.
  - Tachycardia: Rapid pulse.
- A common cause of defective conduction is atherosclerosis of the coronary arteries, which causes decreased blood supply to the conducting system.

Q12. Describe the cardiac plexus briefly. (AN22.1)

- The cardiac plexus is the autonomic plexus of nerves at the base of the heart that innervates the heart.
- Components:
  - Sympathetic component: Derived from the cardiac nerves that arise from the sympathetic trunk.
  - Parasympathetic component: Derived from the cardiac branches of the vagus nerve.
- Subdivisions: It is divided into a superficial and a deep part, but both are closely connected (**Fig. 21b.19** and **Table 21b.6**).

Clinical Importance

- Damage to the vagus nerves (concerned with the function of decreasing the heart rate) leads to tachycardia.
- Damage to the sympathetic fibers (that can reduce the ability to increase heart rate) causes bradycardia.

Q13. Write a short note on Fallot's tetralogy giving the embryological basis. (AN25.4)

Fallot's Tetralogy

- Synonym: Tetralogy of Fallot.
- This is one of the most common congenital defects of the heart, accounting for 10% of congenital heart diseases.
- Embryological defect: AV endocardial cushions and bulbar septum fail to fuse with the muscular part. Usually, the membranous part is defective. Small defects close spontaneously. Large defects result in congestive heart failure.
- Components of the defect are the following (**Fig. 21b.20**):
  - Interventricular septal defect: This is a defect in the ventricular septum leading to communication between the two ventricles. This causes a mixture of oxygenated and deoxygenated blood.
  - Overriding of the aorta over the free upper edge of the interventricular septum: The aorta is shifted slightly to the right and lies above the ventricular septal defect. The enlarged aortic valve opens into both ventricles. The aorta receives blood from both ventricles (mixed

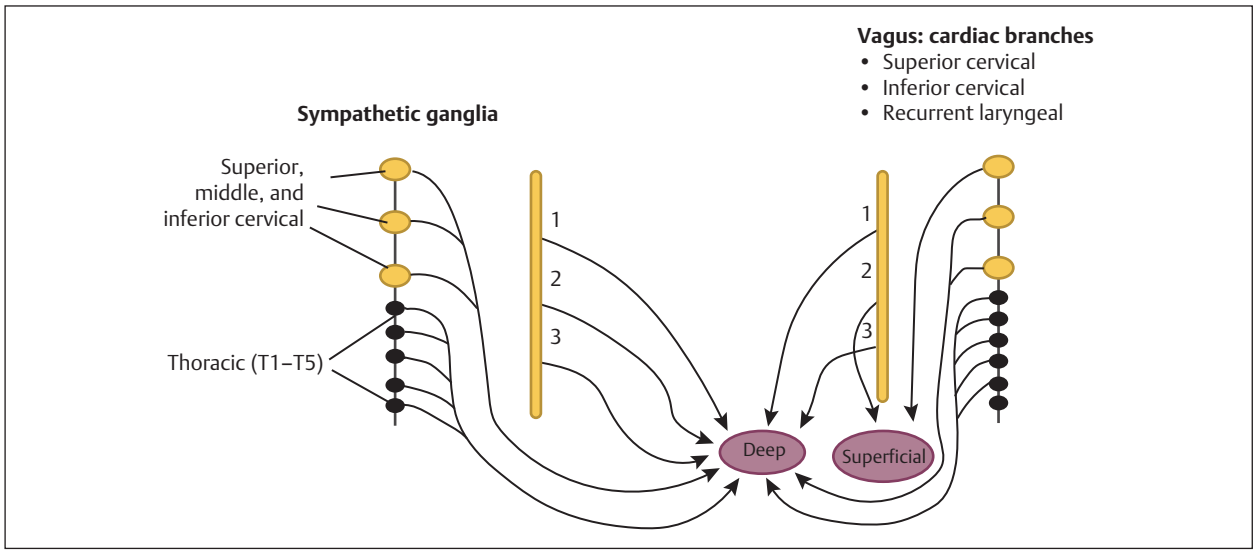


Fig. 21b.19 Cardiac plexus: formation.

Table 21b.6 Description of superficial and deep cardiac plexuses

Feature	Superficial cardiac plexus	Deep cardiac plexus
Location	Lies in the concavity of the aortic arch, close to the ligamentum arteriosum and in front of the right pulmonary artery	Lies between the aortic arch and the trachea
Formation	▪ Inferior cervical cardiac branch of the left vagus nerve ▪ Superior cervical cardiac branches from the superior cervical ganglia of the left sympathetic trunk	▪ Superior and inferior cervical cardiac branches of the right vagus nerve ▪ Superior cervical cardiac branch of the left vagus nerve ▪ Branches from both vagi arising in the thorax ▪ Branches from both recurrent laryngeal nerves ▪ Cardiac branches (numerous) derived from the cervical and upper thoracic parts of both sympathetic trunks, except the cardiac branches of the superior cervical sympathetic ganglia of the left sympathetic trunk
Branches	Branches to: ▪ Deep cardiac plexus ▪ Right coronary artery ▪ Left anterior pulmonary plexus	▪ The deep cardiac plexus is divided into right and left branches that supply the corresponding coronary and pulmonary plexuses ▪ Separate branches to the atria

blood). The less oxygenated blood circulates to the rest of the body.

- Pulmonary stenosis: Narrowed pulmonary valve and pulmonary artery. This leads to inadequate blood flow to the lungs for saturation.
- Hypertrophy of the right ventricle: Thick right ventricular wall due to increased workload.

This defect causes inadequate blood flow from the heart to the lungs for saturation and reduces the supply of oxygenated blood to the body. Newborn babies present a bluish coloration of the skin called cyanosis. A baby born with this defect requires surgical procedures to correct the defect.

Q14. Write a note on fetal circulation. (AN25.3)

In fetal circulation, there are three types of blood, that is, highly oxygenated, deoxygenated, and mixed, whereas in adult circulation, there are only two types, namely, oxygenated and deoxygenated.

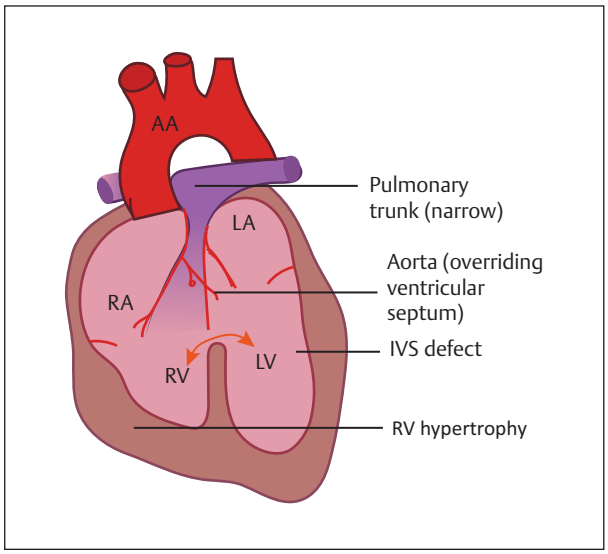


Fig. 21b.20 Tetralogy of Fallot: defects. AA, arch of aorta; IVS, interventricular septum; LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

Structural components of importance in fetal circulation are the following:

- Left umbilical vein.
- Umbilical arteries.
- Foramen ovale.
- Ductus venosus.
- Ductus arteriosus.

In fetal circulation, the blood is shunted three times at the following places:

- Ductus venosus.
- Ductus arteriosus.
- Foramen ovale.

The circulation of blood in the fetus can be described in the following sequence (**Fig. 21b.21**):

- The *placenta* is the organ of gaseous exchange in the fetus. Fetal blood is conveyed to the placenta through two *umbilical arteries* for oxygenation (lung function), addition of nutrients (like liver), and removal of wastes (as in kidneys).
- The oxygenated blood from the placenta reaches the fetus *via the left umbilical vein*, which joins the left branch of the portal vein.
- A small portion of this blood passes through the substance of the liver (hepatic sinusoids) to the IVC, termed *hepatic circulation*.
- The greater part of the oxygenated blood passes directly to the IVC through the *ductus venosus* that connects the left branch of the portal vein with the IVC. Thus, most of the oxygenated blood is shunted through the ductus venosus by passing the hepatic circulation. The ductus venosus has a sphincteric mechanism to control blood flow.
- The IVC pours its blood into the right atrium and also receives a small amount of deoxygenated blood from the lower half of the body, the hepatic veins.
- In the right atrium, most of the oxygen-rich blood is directed toward the left atrium (not the right ventricle) through the foramen ovale that connects the two atria.
- *The valve of the IVC* and *crista dividens* (lower edge of the septum secundum) facilitates passage through the foramen ovale into the left atrium.
- The rest of it gets mixed up with the blood returning to the right atrium through the superior vena cava and passes into the right ventricle.

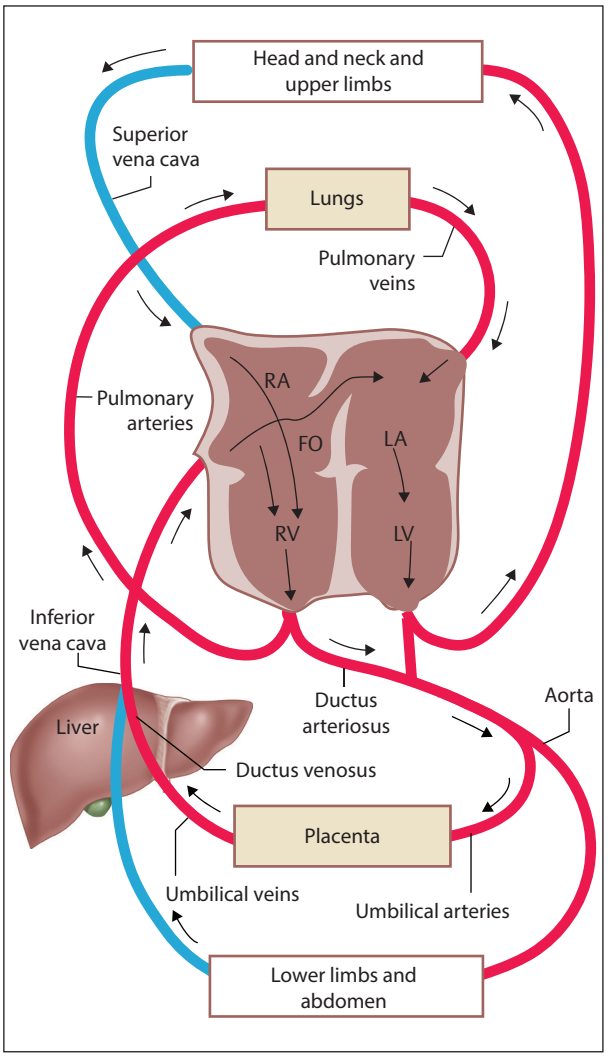


Fig. 21b.21 Fetal circulation. FO, foramen ovale; LA, left atrium; ventricle; LV, left ventricle; RA, right atrium; RV, right ventricle.

- The left atrium also receives a small amount of blood from the lungs via the *pulmonary veins* and sends it to the left ventricle.
- From the left ventricle, blood passes through the aorta that distributes the major share to the head and neck, upper limbs, and heart muscle.
- From the right ventricle, blood (mostly deoxygenated) passes through the pulmonary trunk. The major portion of it is conveyed to the descending aorta through the *ductus arteriosus*, where it gets mixed with the blood in the descending aorta.
- Only a small part of blood in the pulmonary trunk is conveyed through the *pulmonary arteries* to the lungs. This amount increases with the growth of the fetus as the lungs start maturing.
- The mixed blood in the descending aorta is transported to the placenta by a pair of umbilical arteries.
- A small part of the mixed blood provides nutrition to the thoracic and abdominal viscera, body wall, and lower limbs.

Q15. What are the changes in circulation occurring at birth? (AN25.3)

After the first breath of a newborn, the following changes take place in fetal circulation:

- To conserve blood in the fetus, the umbilical arteries contract immediately after birth. The proximal part of the umbilical artery becomes the *superior vesical artery*, and the distal part is fibrosed and forms the *medial umbilical ligaments*.
- The fetus receives a small amount of blood through the umbilical vein and ductus venosus. Delayed ligature of the umbilical cord provides an extra 50 mL of blood to the fetus. The obliterated left umbilical vein persists as the *ligamentum teres of the liver*, and the ductus venosus persists as the *ligamentum venosum*.
- After birth, the ductus arteriosus is closed due to the establishment of pulmonary circulation. The obliterated ductus arteriosus becomes the *ligamentum arteriosum*.
- Because of increased pulmonary venous return to the left atrium, the pressure in the left atrium is more than that of the right atrium. This closes the foramen ovale by apposition of the thin flap-like septum primum to the thick crista dividens of the septum secundum.
- Fetal structures and their adult remnants after birth because of obliteration are presented in **Table 21b.7**.

Table 21b.7 Changes in circulation after birth: fetal structures and adult remnants

Fetal structure	Adult remnant
Left umbilical vein	Round ligament of the liver
Proximal parts of the umbilical arteries	Superior vesical arteries
Terminal parts of the umbilical arteries	Medial umbilical ligaments
Ductus venosus	Ligamentum venosum
Ductus arteriosus	Ligamentum arteriosum
Foramen ovale	Gets closed

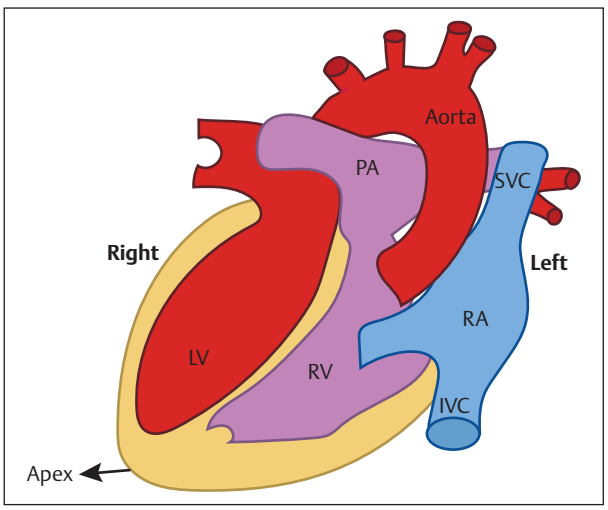


Fig. 21b.22 Dextrocardia. IVC, inferior vena cava; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle; SVC, superior vena cava.

Q16. Write a short note on dextrocardia. (AN25.5)

- This condition results from abnormal cardiac looping. The heart loops to the left instead of to the right (**Fig. 21b.22**).
- Total reversal of heart chambers and blood vessels occurs.
- The left ventricle and arch of the aorta will be on the right side. The superior vena cava, IVC, and pulmonary trunk will be on the left side.
- The apex of the heart is directed to the right.
- This condition can be part of the situs inversus totalis, where transposition of all thoracic and abdominal viscera occurs, or it can be an isolated anomaly.

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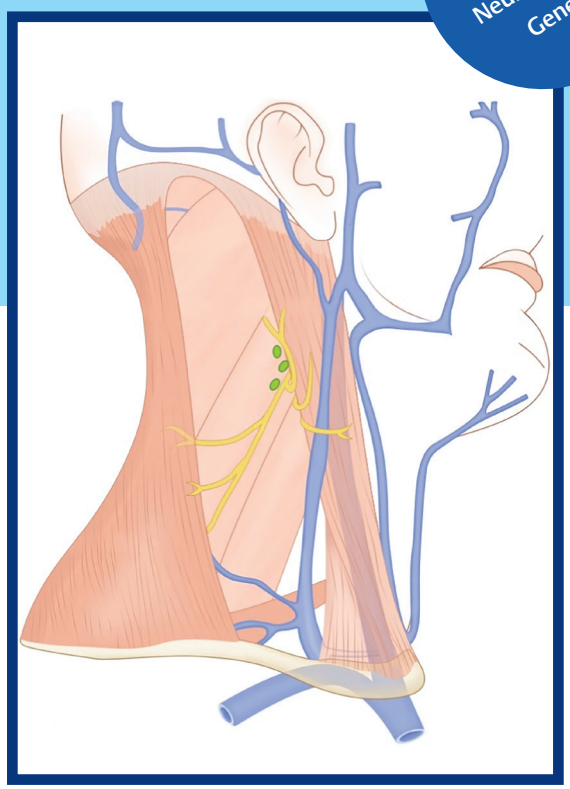

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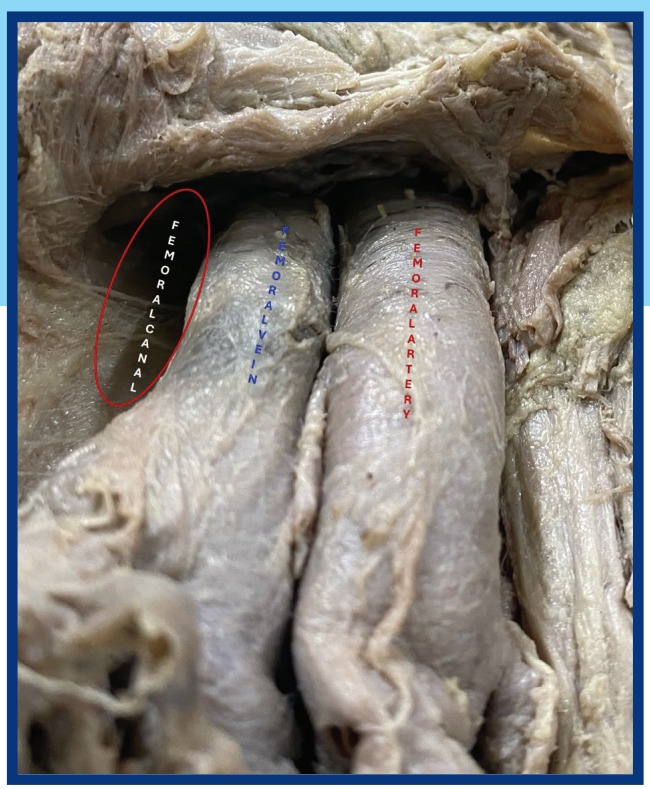

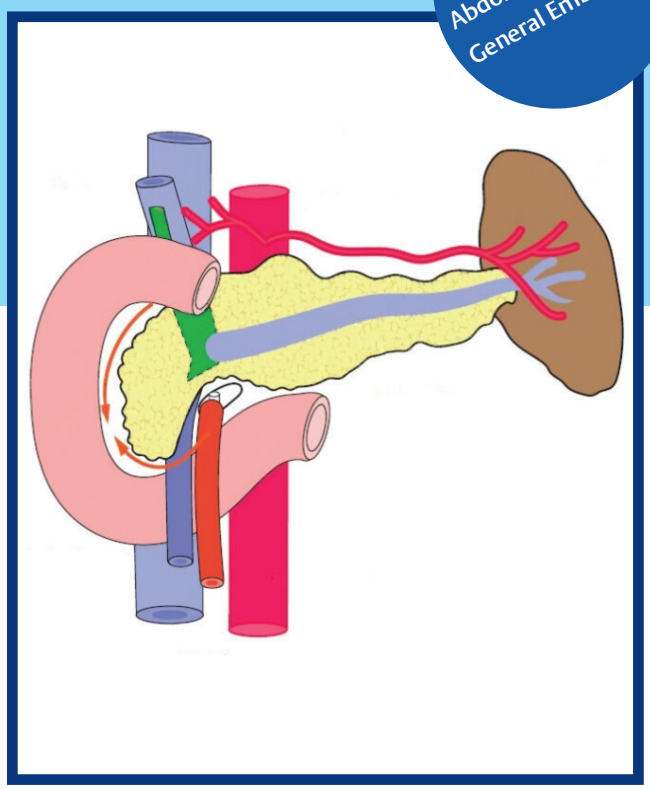

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