Chapter 10. Cardiovascular System

Part 1 | Heart Anatomy & Function

1 Learning Objectives

After completing this part you should be able to …

1. **Identify the external and internal anatomical landmarks** of the heart, including all four chambers, valves, and the course of the great vessels.
2. **Trace the flow of blood through the heart during a single cardiac cycle**, correlating valve movements with the phases of systole and diastole.
3. **Explain the mechanical and electrical events** that create the normal heart sounds (S_1, S_2) and the waveforms of the Wiggers diagram.
4. **Relate basic cardiac anatomy and physiology to physiotherapy practice**, such as monitoring heart sounds, pulse, and responses to exercise.

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2 Gross Structure of the Heart

Aspect	Details	Clinical / PT Note
Position	Oblique in mediastinum; ⅔ left of midline; apex at 5^{th} left intercostal space, mid-clavicular line	Apex beat palpation during vitals
Layers	*Fibrous pericardium* → *parietal serous* → *pericardial cavity* (15 mL fluid) → *visceral serous (epicardium)* → *myocardium* → *endocardium*	Pericarditis pain ↑ with supine; pericardial effusion → muted heart sounds
Chambers	• **Right Atrium (RA)** – receives venous blood via SVC, IVC, coronary sinus • **Right Ventricle (RV)** – pumps to pulmonary trunk • **Left Atrium (LA)** – receives oxygenated blood via 4 pulmonary veins • **Left Ventricle (LV)** – pumps to aorta; thickest wall	LV hypertrophy palpable as laterally displaced apex in CHF
Valves	**Atrioventricular (AV):** – *Tricuspid* (RA→RV) – *Mitral/Bicuspid* (LA→LV) **Semilunar (SL):** – *Pulmonary* (RV→pulmonary trunk) – *Aortic* (LV→aorta)	Auscultation sites: "APe To Man" (Aortic, Pulmonary, Tricuspid, Mitral)
Great Vessels	Aorta, Pulmonary trunk & arteries, Pulmonary veins, SVC, IVC	Pulse sites: carotid, radial, dorsalis pedis correspond to arterial branches

Valve Support Apparatus

- **Chordae tendineae** anchor cusps to **papillary muscles** → prevent prolapse during ventricular systole.
- Dysfunction = murmur / regurgitation; PT screens for exercise intolerance.

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3 Cardiac Cycle & Blood Flow

Phase	Mechanical Event	Valve Status	Pressure Changes	Heart Sounds
Atrial Systole (≈ 0.1 s)	Atria contract, topping-up ventricles (≈ 20 % fill)	AV open; SL closed	Atrial P ↑ slightly	—
Isovolumetric Ventricular Systole	Ventricles begin to contract – all valves closed	AV snap shut → $\mathbf{S_1}$	Ventricular P rises sharply	**S_1 ("lub")**
Ventricular Ejection (Rapid + Reduced)	SL open; blood expelled	AV closed; SL open	LV P peaks at 120 mm Hg; RV ~ 25 mm Hg	—

Phase	Mechanical Event	Valve Status	Pressure Changes	Heart Sounds
Isovolumetric Ventricular Diastole	Ventricles relax – all valves closed	SL close → **S_2**	Ventricular P falls below atrial	**S_2 ("dub")**
Passive Ventricular Filling (Rapid + Diastasis)	AV open; ventricles fill 80 %	AV open; SL closed	Ventricular P low; atrial P just higher	Possible S_3 in youth / HF

Blood-Flow Path

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SVC/IVC → RA → Tricuspid → RV → Pulmonary valve → Pulmonary arteries → Lungs → Pulmonary veins → LA → Mitral → LV → Aortic valve → Aorta → Systemic circulation
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- **Right heart = pulmonary pump** • **Left heart = systemic pump**
- Flow is **series** (pulmonary → systemic) but **pressure** differs: LV wall ~ 3× RV; vital for exercise prescription.

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4 Electrical Events & Mechanical Correlates (Wiggers Diagram Snapshot)

ECG	Mechanical Phase	PT Significance
P wave	Atrial depolarisation → Atrial systole	Atrial kick important in elderly; atrial fibrillation loses this
QRS complex	Ventricular depolarisation → Isovolumetric systole & ejection	Monitor for arrhythmia during graded exercise test
T wave	Ventricular repolarisation → Isovolumetric relaxation	Tall, peaked T in hyper-kalaemia – exercise contraindication

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5 Structure–Function–Clinical Correlations

Anatomy Feature	Functional Benefit	PT Application
Helical myocardial fibre orientation	Torsional LV contraction ↑ ejection efficiency	In MI, fibre loss ↓ stroke volume → adjust aerobic intensity
Mitral valve bicuspid design	Withstands high LV pressure	Post-valve replacement: avoid sustained Valsalva (↑ afterload)
Coronary artery perfusion in diastole	Aortic recoil drives flow	HR > 140 bpm shortens diastole – limit in CAD clients
Right ventricular thin wall	Low-pressure pump to lungs, compliant to preload	Fluid overload in HFpEF manifests as peripheral oedema →

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6 Self-Check Quiz (Answers below)

1. **Which heart valves close at the onset of ventricular systole, and what heart sound is produced?**
2. **Trace the pathway of a red blood cell from the right atrium to the left subclavian artery.**
3. **Why is the left ventricular wall thicker than the right?**
4. **At what point in the cardiac cycle are all four valves closed, and what is the functional purpose of this phase?**
5. **Name the primary pacemaker of the heart and its normal intrinsic rate.**

1. The **tricuspid and mitral (AV) valves** close, producing the **first heart sound (S_1).**
2. RA → Tricuspid → RV → Pulmonary valve → Pulmonary arteries → Lungs → Pulmonary veins → LA → Mitral → LV → Aortic valve → Ascending aorta → Aortic arch → Left subclavian artery.
3. The LV must generate higher pressure (≈ 120 mm Hg) to propel blood through systemic circulation, requiring a thicker muscular wall.
4. **Isovolumetric contraction (early systole) and isovolumetric relaxation (early diastole)** – these phases allow ventricular pressure to rise or fall rapidly without changing volume, ensuring unidirectional flow.

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5. **Sino-atrial (SA) node** – intrinsic rate ≈ 60–100 beats min^{-1}.

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7 Suggested Lab Activities

Activity	Skill Gained
Heart-sound Auscultation Circuit	Identify S_1-S_2 timing with radial pulse; recognise split S_2, S_3, murmurs
3-D Heart Model Dissection	Trace chambers, valves, coronary arteries; simulate valve opening
Pulse & Blood-Pressure Lab	Correlate systolic/diastolic BP with cardiac cycle phases during posture changes
ECG & Wiggers Integration Workshop	Map ECG to mechanical events using animated diagram

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8 Key Take-Home Points

- The heart's **four-chamber, two-pump design** ensures continuous pulmonary and systemic circulation.
- **Valve timing** governs unidirectional flow; auscultation detects dysfunction early.
- The cardiac cycle links **electrical depolarisation → mechanical contraction → pressure changes → blood flow** – a foundation for exercise physiology.
- Physiotherapists integrate heart anatomy & function when prescribing activity, monitoring vitals, and recognising red-flag cardiac signs.

Part 2 | Blood Vessels & Circulation

1 Learning Objectives

At the end of this part you will be able to …

1. **Differentiate the three principal blood-vessel types**—arteries, capillaries, veins—by wall structure, diameter, and functional role.
2. **Describe the hierarchical branching** from elastic artery → arteriole → capillary → venule → large vein, and explain how each segment regulates pressure and flow.
3. **Trace the complete systemic and pulmonary circuits**, noting pressure ranges, oxygenation changes, and major organ-specific "portal" deviations.
4. **Relate vascular physiology to physiotherapy practice**, such as orthostatic hypotension management, compression therapy for venous insufficiency, and warm-up effects on arterial compliance.

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2 Histological & Functional Spectrum of Blood Vessels

Level	Typical Diameter	Tunica Media Features	Key Function	Clinical / PT Relevance
Elastic arteries (conducting) e.g., Aorta, Pulm. trunk	10–25 mm	40–70 elastic lamellae interlaced with smooth muscle	Damp pressure oscillation ("Windkessel")	Aortic stiffness ↑ with age → higher systolic BP; aerobic exercise preserves compliance
Muscular arteries (distributing) e.g., Radial, Femoral	1–10 mm	Thick smooth-muscle layers; external elastic lamina prominent	Direct regional blood flow via vasomotor tone	Palpation sites for pulse & BP; spasm in PVD limits walking distance
Arterioles (resistance)	10–100 µm	1–2 layers smooth muscle	Major determinant of systemic vascular resistance (SVR)	Warm-up induces vasodilation ↓ after-load; cold increases tone—contra in Raynaud's

Level	Typical Diameter	Tunica Media Features	Key Function	Clinical / PT Relevance
Capillaries	5–10 µm	Single endothelial layer + basal lamina	Exchange of gases, nutrients, waste	Massage & active muscle pump ↑ capillary perfusion & lymph return
Venules (post-capillary → muscular)	10 µm–1 mm	Sparse muscle; pericytes	Leukocyte migration; capacitance	Inflammation ↑ permeability → oedema; elevation and muscle activity assist clearance
Medium & large veins e.g., Great saphenous, Venae cavae	1–30 mm	Thin media, thick tunica externa; **valves** in limbs	Low-pressure return, volume reservoir (> 60 % blood)	Calf-muscle pump; compression stockings; orthostatic intolerance post-bedrest

PT Pearl: Elastic arteries recoil during diastole, sustaining coronary perfusion; failure (arteriosclerosis) means care when prescribing high-intensity intervals in older clients.

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3 Specialised Capillary Types

Type	Structure	Location	Functional Note
Continuous	Tight junctions; intact basal lamina	Muscle, skin, CNS (BBB)	Transcytosis & pinocytosis limited; manual therapy cannot directly alter BBB permeability
Fenestrated	Pores with diaphragms	Endocrine glands, intestines, kidneys (glomeruli)	Facilitates filtration; hemodialysis PT accounts for fluid shifts
Sinusoidal	Large gaps, discontinuous basal lamina	Liver, spleen, bone marrow	Allows cell passage; post-leukaemia mobilisation protocols monitor marrow perfusion

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4 Circulatory Circuits

4.1 Pulmonary Circulation (Low-Pressure, Oxygenation Circuit)

1. **RV → Pulmonary trunk** (25/8 mm Hg)
2. Pulmonary arteries → arterioles → **Pulmonary capillaries** (gas exchange)
3. Venules → **Pulmonary veins (×4)** → **LA**

Mean pressure ≈ 15 mm Hg; thin vascular walls allow recruitment during exercise.
PT Context: Supine cycle ergometry increases venous return; right-HF patients require upright positioning to avoid overload.

4.2 Systemic Circulation (High-Pressure Delivery Circuit)

`LV (120/8 mm Hg)` → Aorta → Elastic ↓ Muscular arteries ↓ Arterioles **(major pressure drop)** ↓ Capillaries (exchange) ↓ Venules ↓ Veins ↓ Venae cavae → RA

Special sub-circuits

Circuit	Route	Why it Matters
Hepatic Portal	Gut → Portal vein → Liver sinusoids → Hepatic vein	First-pass detox; cirrhosis ↑ portal pressure, exercise must prevent Valsalva
Coronary	LV → Coronary arteries → Cardiac capillaries → Cardiac veins → Coronary sinus → RA	Perfusion occurs in diastole; HR control crucial in CAD

Circuit	Route	Why it Matters
Cerebral (Circle of Willis)	Carotid + Vertebral systems	Redundant flow; cervical mobilisation precautions for vertebral arteries

5 Haemodynamics in a Nutshell

- **Flow (Q) = ΔP / R** (Ohm's law) – arterioles alter **R** via vasomotion.
- **Compliance (C) = ΔV / ΔP** – veins ≫ arteries; prolonged standing pools blood → fainting; ankle pumps restore venous return.
- **Poiseuille's law:** radius⁴ effect → small change in arteriole diameter dramatically alters flow; warms-ups leverage this.
- **Muscle pump + respiratory pump** augment venous return—basis for active recovery and diaphragmatic breathing cues.

6 Structure–Function–Clinical Correlation

Scenario	Anatomical Basis	Physiotherapy Strategy
Varicose veins	Valve incompetence, vein wall dilation	Graduated compression, calf strengthening, avoid prolonged static standing
Deep Vein Thrombosis (DVT)	Slow flow in deep veins, hyper-coagulability	Early ambulation post-surgery, ankle pumps, educate on red flags (Homan sign unreliable)
Orthostatic hypotension post-bedrest	↓ Venous tone & plasma volume	Tilt-table progression, hydration, compression garments
Peripheral Arterial Disease (PAD)	Atherosclerotic narrowing of muscular arteries	Graded walking to near-claudication pain (collateral recruitment), foot-skin checks
Edema post-mastectomy	Lymphatic + venous overload in arm	Manual lymph drainage, kinesiotape, UE elevation during exercises

7 Self-Check Quiz (answers below)

1. **Which vessel type constitutes the major resistance component of systemic circulation and why?**
2. **State two structural differences between a muscular artery and a medium-sized vein.**
3. **Trace a drop of blood from the left ventricle to the right atrium, passing through the hepatic portal system.**
4. **What physiologic mechanisms assist venous return during rhythmic diaphragmatic breathing?**
5. **Why is systolic pressure lower in the pulmonary artery than in the aorta?**

Answers

1. **Arterioles**—their narrow lumen and circular smooth-muscle coat allow large, rapid changes in radius, and resistance is inversely proportional to radius⁴.
2. Artery has **thicker tunica media** with more smooth muscle & elastic laminae; vein has **larger lumen, valves, and thicker tunica externa**.
3. LV → Aorta → Celiac/SMA/IMA branches → Capillaries of GI tract → **Hepatic portal vein** → Liver sinusoids → Hepatic veins → IVC → RA.
4. Descent of diaphragm ↓ thoracic pressure & ↑ abdominal pressure, creating a gradient that **sucks blood into thorax**; simultaneously diaphragm movement massages IVC.
5. Pulmonary circuit is short and vessels are highly compliant; RV wall generates only ~25 mm Hg to protect delicate alveolar capillaries from high pressure.

8 Suggested Practical / Lab Activities

Activity	Focus
Elastic vs Muscular Artery Histology Slides	Identify internal/external elastic laminae; discuss compliance implications
Segmental BP & Doppler Workshop	Detect PAD, calculate ankle-brachial index
Venous-Return Challenge	Measure HR/BP lying → standing with and without ankle pumps or diaphragmatic breathing
Portal Circulation Flow Map	Build a physical string model on torso to visualise portal vs systemic routes

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9 Key Take-Home Points

- **Arteries distribute, arterioles regulate, capillaries exchange, veins return**—each segment's wall composition matches its role.
- **Pulmonary vs systemic circuits** differ chiefly in pressure and oxygenation, but are in series; any left-heart failure backs into pulmonary circulation first.
- **Physiotherapists manipulate body position, muscle activity, external compression, and breathing** to optimise vascular return and tissue perfusion.
- Understanding vessel structure illuminates precautions for modalities like cryotherapy (vasoconstriction) and heat (vasodilation).

Part 3 | Common Cardiovascular Disorders

1 Learning Objectives

By the end of this part you should be able to …

1. **Define and classify major cardiovascular disorders** that a physiotherapist commonly encounters: essential hypertension, ischaemic heart disease, heart failure, valvular disease, peripheral arterial disease, venous and lymphatic disorders.
2. **Explain the underlying pathophysiology, risk factors, hallmark signs & symptoms, and typical investigations** for each disorder.
3. **Summarise evidence-based physiotherapy goals and precautions** across acute, sub-acute, and chronic phases.
4. **Screen for red-flag presentations** that mandate immediate medical referral.

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2 Essential (Primary) Hypertension

Item	Key Points	PT Implications
Definition	Resting BP ≥ 130/80 mm Hg (per ACC/AHA) on ≥ 2 separate occasions	Baseline vitals at every initial visit
Pathophysiology	↑ Systemic vascular resistance (SNS over-activity, RAAS up-regulation) ± ↑ cardiac output	Aerobic conditioning ↓ SVR via endothelial NO
Risk Factors	Age > 50, obesity, sedentary lifestyle, high Na^+ diet, alcohol excess, stress, genetics	Lifestyle counselling integral part of PT
Clinical Signs	Often asymptomatic; headaches, exertional SOB, retinal changes	Monitor for exaggerated pressor response during exercise
Complications	LV hypertrophy, stroke, CKD, retinopathy	Use RPE rather than target HR early in programme

Item	Key Points	PT Implications
Physiotherapy Focus	Moderate-intensity continuous or interval training ≥ 30 min most days (target 50-70 % VO_2max); resisted exercise at 40-60 % 1RM with breath control; relaxation & breathing techniques	

3 Ischaemic Heart Disease (IHD)

Aspect	Stable Angina	Acute Coronary Syndrome (ACS)	PT Take-aways
Cause	Fixed atherosclerotic narrowing	Plaque rupture → thrombus, ↓ coronary flow	Recognise chest pain pattern & risk stratify
Classic Symptom	Predictable chest pressure with exertion, relieved by rest or GTN	Unremitting pain, radiates to jaw/arm, diaphoresis, nausea	Stop exercise immediately; activate emergency protocol
Investigations	ECG ± stress test, coronary CT	12-lead ECG, troponin, angiography	PT post-MI starts ≤ 48-72 h if haemodynamically stable
Rehab Phases	Phase I (in-patient), Phase II (supervised OP), Phase III (maintenance)	Monitor HR, BP, RPE; terminate if ≥ 2 mm ST-depression	

4 Heart Failure (HF)

Classification	Pathophysiology	Common Signs	PT Guidelines
HFrEF (EF < 40 %)	Systolic pump failure (MI, dilated cardiomyopathy)	Dyspnoea, peripheral oedema, S_3 gallop	Interval walking / cycling 40-60 % HR reserve; seated exercise if NYHA III
HFpEF (EF ≥ 50 %)	Diastolic stiffness (HTN, ageing)	Exertional dyspnoea, rapid BP rise	Longer warm-ups, cautious load progression
Acute decomp	Pulm. oedema, raised JVP	Pink frothy sputum	CONTRA-INDICATION to exercise; refer immediately

5 Valvular Heart Disease

Valve	Lesion	Murmur	Functional Effect	PT Note
Aortic	Stenosis	Systolic ejection (RSB)	Fixed CO → syncope on exertion	Avoid sudden position changes; monitor for dizziness
Mitral	Regurgitation	Pansystolic (apex)	Volume overload → LA dilation	Aerobic exercise beneficial; avoid heavy resistance if symptomatic

6 Peripheral Arterial Disease (PAD)

Key Facts	PT Management
Athero-occlusive disease mainly of femoral–popliteal and tibial arteries	**Supervised walking** to near-max claudication pain (30-50 min, 3–5 d·wk^{-1}) improves collateral flow
Ankle–Brachial Index < 0.9 diagnostic; ≤ 0.3 critical	Foot-care education; avoid heat packs over insensate skin

7 Venous & Lymphatic Disorders

Condition	Mechanism	PT Intervention
Chronic Venous Insufficiency	Valve failure & calf-pump weakness → oedema, ulcer	Graduated compression 20-40 mm Hg, calf strengthening, ankle ROM

Condition	Mechanism	PT Intervention
Deep Vein Thrombosis (DVT)	Virchow triad; highest risk post-surgery, immobility	Early ambulation; if diagnosed—follow anticoag. guidelines (avoid vigorous manual techniques over limb)
Secondary Lympho-edema (e.g., post-mastectomy)	Lymph-node removal / radiation	Manual lymph drainage, pneumatic compression, skin care, graded resistance without exacerbation

8 Integrated Red-Flag Screen for Physiotherapists

Symptom	Possible Cause	Action
Chest pain > 20 min not relieved by rest	ACS	Activate emergency response (chewable aspirin if protocol)
New-onset palpitations + dizziness	Arrhythmia	Stop exercise, record pulse, refer
Rapid weight gain > 2 kg in 24 h + ankle swelling	HF exacerbation	Refer GP/cardiologist promptly
Calf pain, warmth, swelling, + Homans sign	DVT (low sensitivity)	Urgent medical imaging

9 Self-Check Quiz (with Answers)

1. **List four modifiable risk factors for essential hypertension.**
   Answer: Obesity, high dietary sodium, sedentary lifestyle, excessive alcohol intake (others: stress, smoking, poor sleep).
2. **During an exercise test a patient develops chest pressure at 5 METs that resolves with rest. What is the likely diagnosis and next PT action?**
   Answer: Likely **stable angina**; stop test, document workload threshold, refer for medical optimisation before resuming training.
3. **Give two reasons why ankle-brachial index may be falsely elevated in diabetics.**
   Answer: Medial arterial calcification stiffens arteries; ABI overestimates flow. Toe-brachial index or Doppler waveform is preferred.
4. **Which heart sound indicates early diastolic filling and may signify heart failure in adults?**
   Answer: S_3 (ventricular gallop).
5. **Why are isometric holds at > 70 % MVC contraindicated in severe aortic stenosis?**
   Answer: They markedly ↑ after-load while a fixed valve limits cardiac output, precipitating syncope or arrhythmia.

10 Key Take-Home Messages

- Cardiovascular disorders range from **silent hypertension to life-threatening ACS and HF**—physios must screen, monitor, and adapt interventions.
- **Exercise is medicine** for most stable conditions; intensity, mode, and monitoring must align with pathology-specific guidelines.
- Recognise and act on **red-flag signs** rapidly; timely referral saves lives.
- Integrated lifestyle advice (weight, diet, stress, smoking cessation) is a core physiotherapy competency in cardiovascular health.