Nora Henry
James Napier
Emma Dougan

CCEA AS

LIFE & HEALTH SCIENCES

Updated

COLOURPOINT EDUCATIONAL

© 2022 Nora Henry, James Napier, Emma Dougan and Colourpoint Creative Ltd

Print ISBN: 978-1-78073-337-1
eBook ISBN: 978-1-78073-338-8

Updated Edition
First Impression

Layout and design: April Sky Design
Printed by: GPS Colour Graphics Ltd, Belfast

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, scanning, recording or otherwise, without the prior written permission of the copyright owners and publisher of this book.

Copyright

Copyright has been acknowledged to the best of our ability. If there are any inadvertent errors or omissions, we shall be happy to correct them in any future editions.

Front cover: iStockphoto

Images that are copyright to other sources are acknowledged adjacent to the relevant image. All other images are copyright ©Colourpoint Creative Limited.

Colourpoint Educational
An imprint of Colourpoint Creative Ltd
Colourpoint House
Jubilee Business Park
Jubilee Road
Newtownards
County Down
Northern Ireland
BT23 4YH

Tel: 028 9182 6339
E-mail: sales@colourpoint.co.uk
Website: www.colourpoint.co.uk

The Authors

NORA HENRY is a teacher at a Belfast grammar school and a part-time tutor for a university education department. She works for an examining body as Principal Examiner for GCSE Chemistry, Reviser for A level Chemistry and Reviser for A Level Life and Health Sciences. In addition to this text, she has written around 30 textbooks, workbooks and study guides for GCSE and A Level.

JAMES NAPIER is a former teacher at a Northern Ireland grammar school. He has written and co-written a number of Biology and Science textbooks supporting the work of students and teachers. He works for an examining body as Chief Examiner for A Level Biology. He has also published a range of Popular Science books in the areas of Genetics and Evolution. His 'non-science' charity books have raised significant amounts of money for cancer and mental health charities.

EMMA DOUGAN is a tutor for a Life Sciences pathway Foundation Degree in Applied Industrial Sciences. She works for an examining body as Principal Examiner for A Level Life and Health Sciences and GCSE Double Award Biology.

Publisher's Note: This book has been through a rigorous quality assurance process by an independent person experienced in the CCEA specification prior to publication. It has been written to help students preparing for the AS Life and Health Sciences specification from CCEA. While Colourpoint Educational, the authors and the quality assurance person have taken every care in its production, we are not able to guarantee that the book is completely error-free. Additionally, while the book has been written to address the CCEA specification, it is the responsibility of each candidate to satisfy themselves that they have fully met the requirements of the CCEA specification prior to sitting an exam set by that body. For this reason, and because specifications and CCEA advice change with time, we strongly advise every candidate to avail of a qualified teacher and to check the contents of the most recent specification for themselves prior to the exam. Colourpoint Creative Ltd therefore cannot be held responsible for any errors or omissions in this book or any consequences thereof.

CONTENTS

Note: In line with feedback from teachers, this edition has been written for a proposed revised version of the specification that had not yet been approved at the time of publication in 2022. For completeness, it also includes the material on semiconductors (chapter 16) that are present in the original specification but not the proposed revised specification. Teachers and students are strongly encouraged to refer to the version of the CCEA specification that is in use at the time of teaching, and to always give precedence to the wording on the CCEA specification where there are any discrepancies.

Unit AS 2:
Human Body Systems

1: CARDIOVASCULAR SYSTEM

Students should be able to:

2.1.1 describe the components and functions of the cardiovascular system;

2.1.2 demonstrate an understanding of the histological structure and function of arteries, veins and capillaries;

2.1.3 demonstrate an understanding of the structure and functioning of the heart, including the phases of the cardiac cycle as well as pressure and volume changes in the heart chambers and major arteries;

2.1.4 demonstrate an understanding of heart sounds and the representation of the excitation wave in an electrocardiogram (ECG), including identifying a normal ECG trace and ECG traces for tachycardia, ventricular fibrillation and bradycardia heartbeats and how these relate to physiological status; and

2.1.5 demonstrate how to measure pulse rate (the typical resting pulse rate range for adults is 60–100 beats per minute) and blood pressure (using a sphygmomanometer), and know normal values for blood pressure for both genders for ages 18-40 years and how changes in these may relate to physiological status.

The cardiovascular system

The key components of the cardiovascular system are:

- blood
- the blood vessels (arteries, veins and capillaries)
- the heart

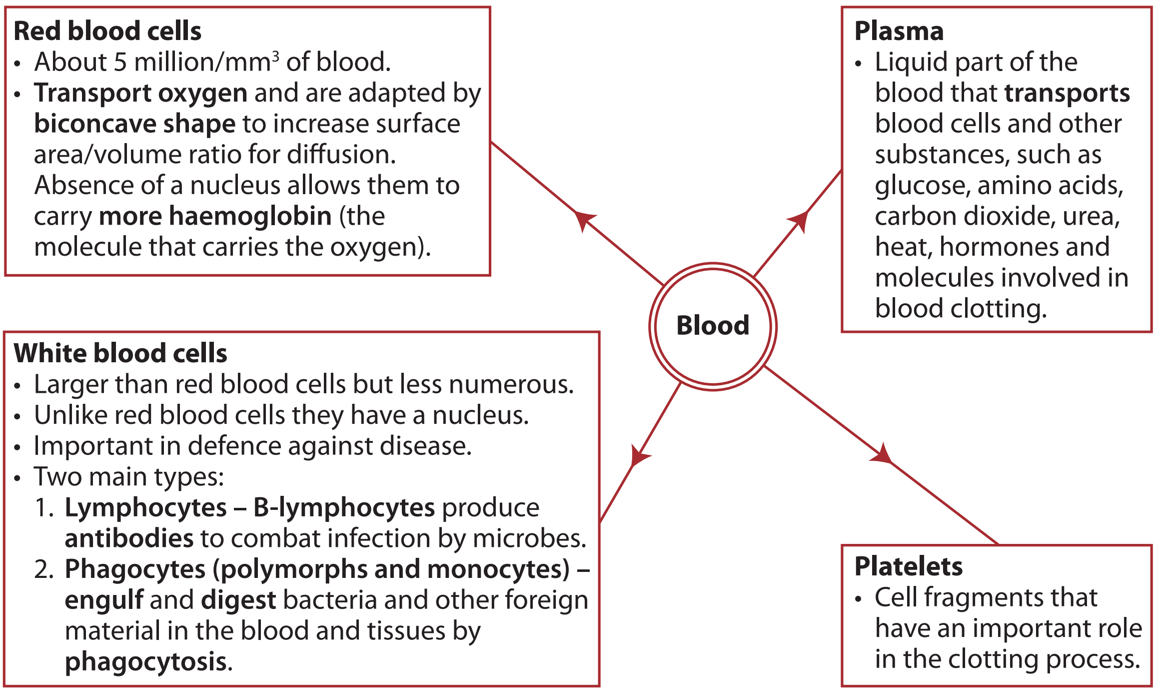
Blood

The main blood components are the blood cells, platelets and the plasma. The components of the blood have two main functions, these being **transport** and **defence against disease**. The diagram below summarises the key features and roles of the main blood components.

The blood vessels

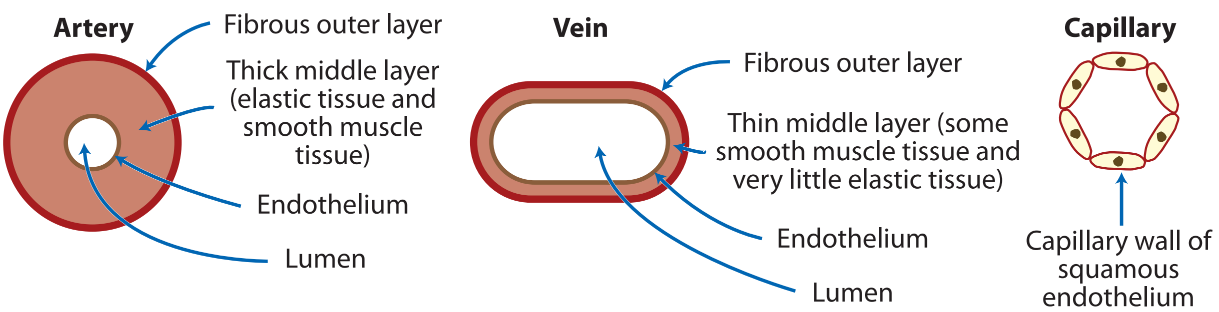
The three main types of blood vessels are the arteries, veins and capillaries.

Arteries carry blood away from the heart. As these are the blood vessels leaving the heart they carry blood under high pressure and their structure reflects this. The main arteries subdivide to form smaller arteries and arterioles, which in turn subdivide to form capillaries. **Capillaries** have permeable one cell



thick walls allowing exchange of materials between the blood and tissues. The capillaries eventually merge to form venules, which in turn merge to form small **veins**, which themselves merge to form larger veins that empty their blood into the venae cavae. The structure and function of the main types of blood vessel are summarised in the table below.

Feature	Artery	Vein	Capillary
Structure	• **Thick wall** (an outer thin layer of fibrous tissue, with a thick middle layer of **smooth muscle** and **elastic tissue**, with a thin inner endothelial layer of very thin squamous epithelial cells). • A **narrow lumen**. • Usually an overall **rounded shape**.	• **Thin wall** (an outer thin layer of fibrous tissue, with a thin middle layer containing some muscle and very little elastic tissue, with an inner endothelial layer of squamous cells). • A **large lumen** • **Valves** at intervals along its length. • Much **less regular in shape than an artery**.	• Microscopic vessel with a **one cell thick wall** (consisting of squamous endothelium).
Blood pressure	High (in pulses)	Low	Low
Adaptations	• The **elastic tissue** in the thick middle layer allows the artery to **stretch** as the blood **pulses** out of the heart and through the arteries. • As the **elastic tissue recoils** between heartbeats it helps push blood along the arteries and smooths blood flow. • The **muscle tissue** in the middle layer is essentially a **supporting** layer – it provides strength.	• The **large lumen** offers **little resistance** to blood flow (essential due to low blood pressure in veins). • **Valves** prevent the backflow of blood. There is much **less muscle tissue and elastic tissue** in the walls (again due to the low pressure and the absence of a pulse in veins). • However, as in an artery, a vein has a thin outer protective fibrous layer and an internal endothelial layer of squamous cells.	• Its small size allows an **extensive network** of capillaries, providing a **large surface area** for the diffusion of material. • A capillary has a **very thin wall** (one cell thick) which allows exchange between the blood and the tissues. • The capillary wall is **permeable** to respiratory gases, nutrients such as glucose, and waste including urea, but it is not permeable to large proteins and red blood cells.



Artery, vein and capillary (not to scale)

Tip: The structure of the blood vessels is closely related to the pressure at which they will carry blood. Arteries are adapted for carrying blood at high pressure and veins are adapted for carrying blood at low pressure.

Tip: Note that each of the three types of blood vessel has a thin layer of squamous endothelial cells lining the lumen.

The heart

The heart is the organ that pumps blood through the body. Humans (and other mammals) have a **double circulation**, meaning that the blood travels through the heart twice in each complete circuit of the body. Effectively, this means that there are two distinct circulatory systems – the pulmonary (lung) and systemic (body) systems – with each beat of the heart pumping blood into each system. The right side of the heart pumps blood to the lungs and the left side pumps blood around the body.

The two sides of the heart are separated by a thick muscular wall (the septum) which runs through the centre of the heart.

Heart chambers

Each side has an upper chamber (atrium) and a lower chamber (ventricle). The muscular walls of these chambers are adapted to reflect their respective roles.

- **Atria** – these upper chambers have relatively thin walls, as they receive blood from the lungs (**left atrium**) or the body (**right atrium**) and pump blood into the ventricles that lie directly below them.
- **Ventricles** – these lower chambers have much thicker walls, as they pump blood to the lungs (**right ventricle**) or around the body (**left ventricle**). As the lungs are only a short distance from the heart, the right ventricle does not have to pump blood with the force that the left ventricle does in order to pump blood around the body. Consequently, the right ventricle has less muscular (thinner) walls than the left ventricle.

Tip: You should be able to explain why the walls of the ventricles are thicker than the atria, and why the left ventricle has thicker walls than the right ventricle.

Heart valves

The blood leaves the heart in 'pulses' that coincide with each heartbeat and the heart functions as a one-way pump. Heart valves prevent the blood from flowing back into the atria, as the ventricles contract, and from flowing back into the ventricles from the arteries. There are two types of valves:

- **The atrioventricular (AV)** valves – lie between the atria and the ventricles and prevent the backflow of blood into the atria when the ventricles contract. The valve between the right atrium and right ventricle is sometimes referred to as the **tricuspid** valve and the valve between the left atrium and left ventricle as the **bicuspid** valve.
- **The semilunar (arterial)** valves – lie at the base of the aorta and pulmonary artery and prevent the backflow of blood from the arteries into the ventricles.

The **atrioventricular valves** are anchored by the **papillary muscles** that are embedded in the ventricle wall. **Chordae tendinae** (valve tendons) link the muscles and the valves. These tendons anchor the valves and prevent the valves turning 'inside out' as pressure in the ventricles builds up during contraction.

The **semilunar (arterial)** valves at the base of the arteries close only when the pressure in the arteries exceeds that in the ventricles. When blood is being pumped out of the ventricles they are pushed flat against the artery walls and do not impede flow.

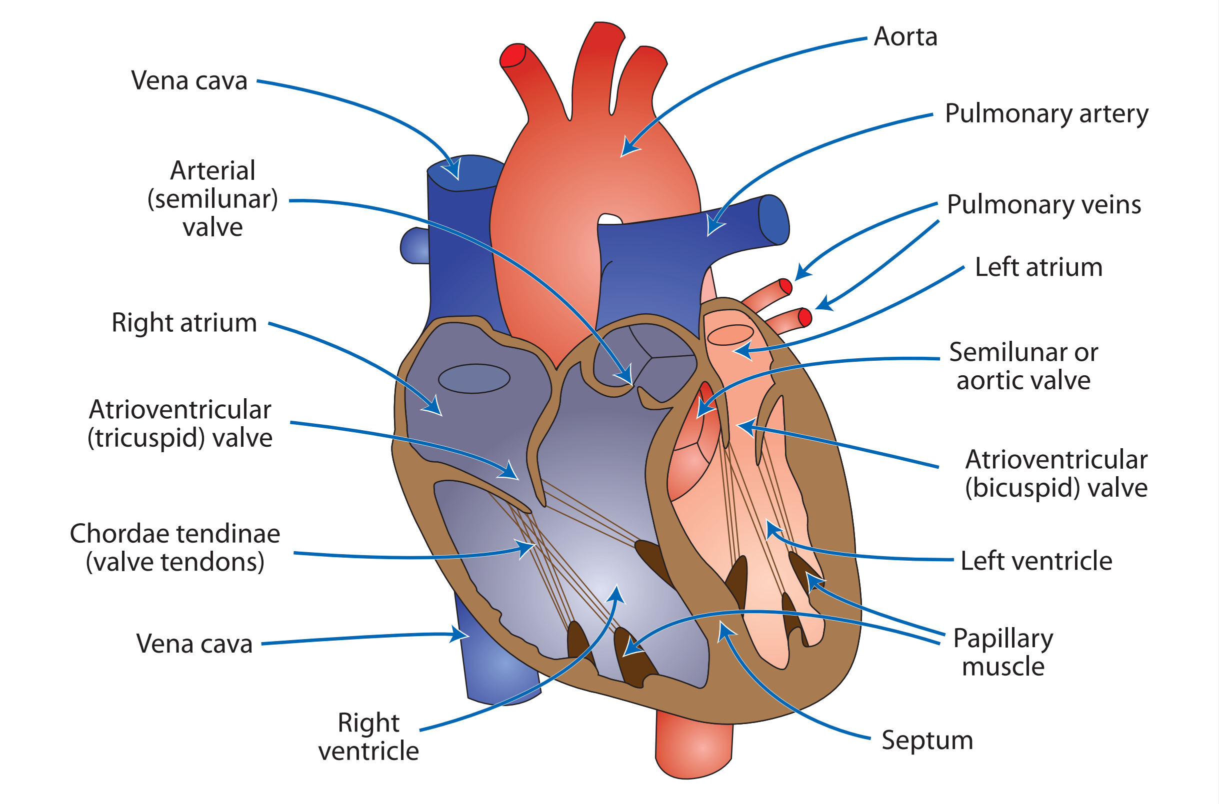
Blood vessels entering and leaving the heart

There are four major blood vessels that enter or leave the heart:

- **The aorta** – is the major **artery** that carries **oxygenated** blood from the **left ventricle**. Arterial branches leading from the aorta carry blood to all the major organs of the body except the lungs.
- **The pulmonary artery** – carries **deoxygenated** blood from the **right ventricle** to the lungs.
- **The venae cavae** – bring **deoxygenated** blood back from the body, returning blood to the **right atrium**.
- **The pulmonary vein** – transports **oxygenated** blood from the lungs to the **left atrium**.

Tip: The pulmonary artery and the pulmonary vein are unusual because the artery carries deoxygenated blood and the vein carries oxygenated blood. They are typical in that they carry blood away from and to the heart respectively, and are histologically (structurally) similar to other arteries and veins.

The diagram below shows the main features of the heart.

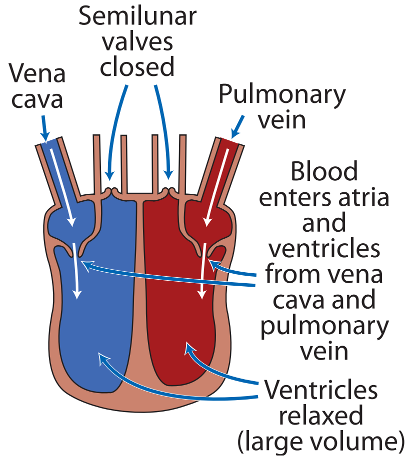
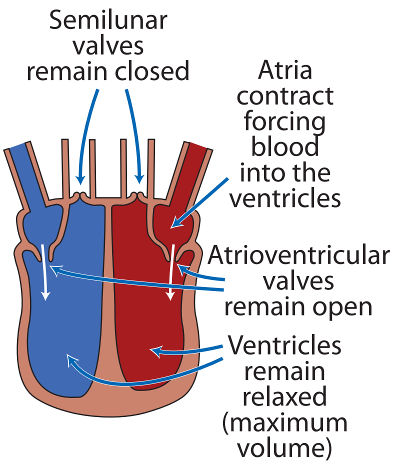
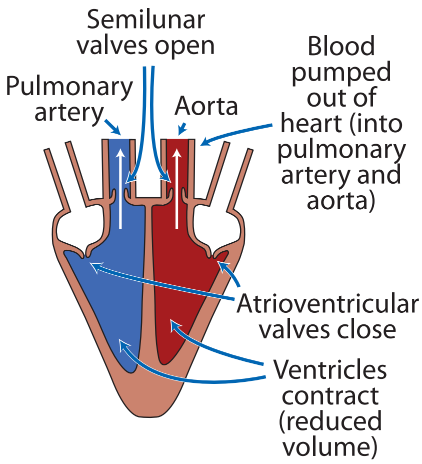


Section through the heart

The **coronary arteries** are arteries that branch off the aorta to supply blood to the heart muscle itself. These can normally be seen running along the outside of the heart surface.

The cardiac cycle

The **cardiac cycle** describes the sequence of events that occur during one heartbeat. This sequence normally occurs between 60–80 times per minute in a human heart. **Diastole** describes a phase when the heart muscle is relaxed and **systole** indicates contraction is taking place. The cardiac cycle has three main stages as described in the table opposite.

<table>
<tr><th>Stage</th><th>Atria</th><th>Ventricle</th><th>Diagram</th></tr>
<tr><td>Diastole</td><td>Atrial walls relax.
Blood enters the atria from the vena cava and the pulmonary vein.</td><td>Ventricle walls also relax.
Semilunar valves close as arterial pressure exceeds the ventricular pressure (due to there being little blood in the ventricles and the ventricles having a larger volume, as the walls are not contracting).
As the AV valves are open, blood enters the ventricles from the atria.</td><td>
</td></tr>
<tr><td>Atrial systole</td><td>Walls of the atria contract forcing more blood into the ventricles.
AV valves remain open as the pressure in the atria still exceeds the pressure in the ventricles.
Blood continues to enter the atria from the vena cava and the pulmonary vein.</td><td>Ventricle walls remain relaxed.
Ventricle volume continues to increase as they fill with blood.
Semilunar valves remain closed.</td><td>
</td></tr>
<tr><td>Ventricular systole</td><td>Walls of atria relax.</td><td>Ventricle walls contract.
AV valves close as the pressure in the ventricles now exceed the pressure in the atria.
The chordae tendinae prevent the AV valves blowing 'inside out'.
As ventricle pressure reaches its peak, the semilunar valves are forced open, forcing blood into the arteries.
By the end of ventricular systole, the ventricles will be at their smallest volume.</td><td>
</td></tr>
</table>

Pressure changes in the cardiac cycle
The diagram below shows the pressure changes during the cardiac cycle. Stages A–F are summarised below.

A Atrial walls contract (atrial systole), increasing atrial pressure, AV values are open (as atrial pressure > ventricular pressure) and semilunar valves remain closed (as aortic pressure > ventricular pressure).

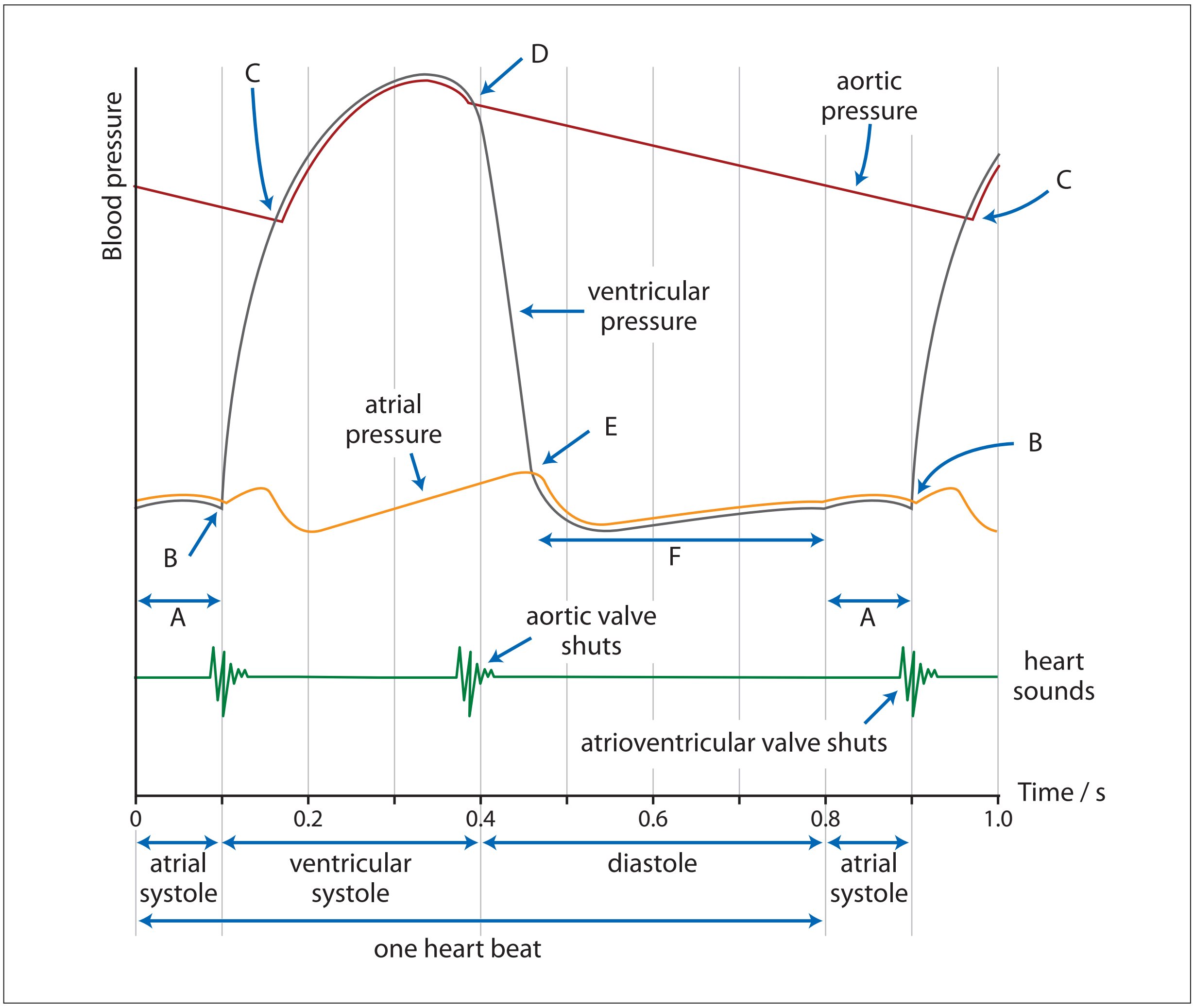
B Atrial contraction is complete (atria are empty of blood) and ventricles begin to contract (start of ventricular systole). Ventricular pressure > atrial pressure, which leads to AV valves closing **(first heart sounds)**.

C Continued contraction of the ventricles to the extent that ventricle pressure > arterial pressure, resulting in the semilunar valves opening.

D Arterial pressure increases so that arterial pressure > ventricular pressure. This leads to semilunar (arterial) valves closing due to the back pressure **(second heart sounds)**.

E Ventricular pressure falls (little blood present and walls begin to relax). Now, atrial pressure > ventricle pressure, resulting in the AV valves opening.

F Atrial pressure > ventricular pressure as blood is flowing into the atria. AV valves remain open and blood passively flows into the ventricles from the atria.



Pressure changes in the left side of the heart during the cardiac cycle (left atrium, left ventricle and aorta). The aortic valve is the semilunar valve at the base of the aorta.

The diagram shows that the atrial pressure rises, falls, then rises again between B and E. This can be explained by:

- the increased pressure of the contracting ventricles causing back pressure against the atria (B–C).
- the subsequent fall in pressure is caused by the relaxation (and increase in volume) of the atria.
- the increase in pressure between 0.2 seconds and E is caused by the atria filling with blood.

Tip: It is important to understand that the heart valves open and close in response to pressure changes either side of the valves (i.e. the AV valves open only if the pressure in the atria exceeds the pressure in the ventricles and close only if the ventricular pressure exceeds the atrial pressure). Valve action is a **response to pressure**; they **do not cause** the pressure changes.

Worked example

State the stages of the cardiac cycle during which the semilunar (arterial) valves open and close. Explain your answer.

Answer

Open during **ventricular systole**. The semilunar valves open when the pressure in the ventricles exceeds the pressure in the arteries (as occurs during ventricular systole) due to the ventricle walls contracting.

Close during **diastole**. Following ventricular systole, the ventricle muscle relaxes and springs out, increasing the volume of the ventricle. As the pressure in the ventricles falls, their pressure drops below the pressure in the arteries. The back pressure from blood in the arteries causes the semilunar valves to close. They remain closed during **atrial systole**.

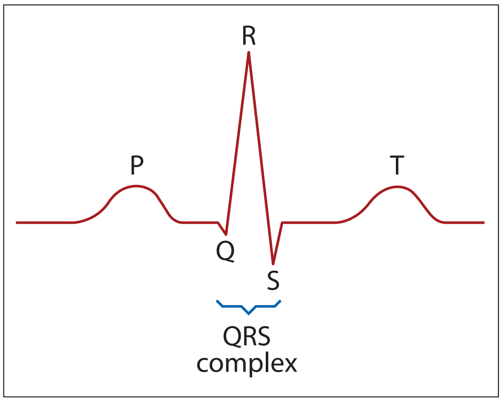
Coordination of the cardiac cycle and cardiovascular health

Interpreting ECGs

The sequences within the cardiac cycle are stimulated by a coordinated wave of **electrical excitation** through the heart. A small section in the wall of the right atrium acts as a **pacemaker (SA node – sinoatrial node)**, producing electrical signals that pass across the atria walls and then down into and across the ventricles. The **atrioventricular (AV) node** is an area of special tissue in the central wall of the heart (septum) at the junction of the atria and ventricles. It is this node that passes the electrical signal between the atria and the ventricles. Contraction of a particular part of the heart is a consequence of the wave of electrical excitation reaching that part.

Tip: The table of the cardiac cycle (page 9) shows that atrial systole immediately precedes ventricular systole. While this is important in the functioning of the heart, it is controlled by the wave of electrical stimulation passing through the atrial walls before the ventricle walls.

An **electrocardiogram (ECG)** is a graphical representation of the electrical activity in the heart.



An ECG trace of a typical heartbeat

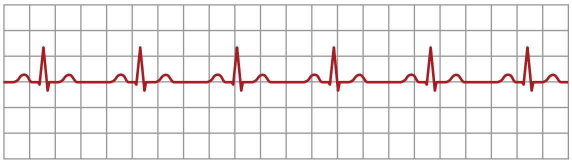
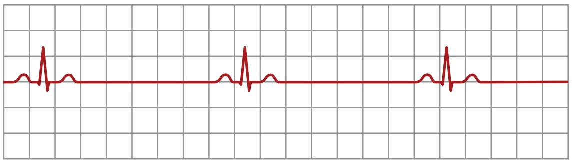
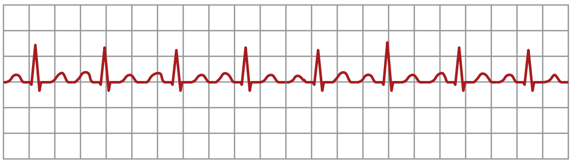
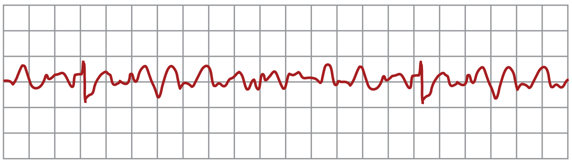
Key elements of the ECG are:

- the P wave represents the wave of electrical stimulation that triggers the contraction of the atria.
- the QRS complex represents the electrical activity that stimulates contraction of the ventricles.
- the T wave represents the relaxation of the ventricles.

Tip: The R peak has a much greater amplitude than P, as there is much greater electrical activity in the ventricles (reflecting their larger size and thicker muscle).

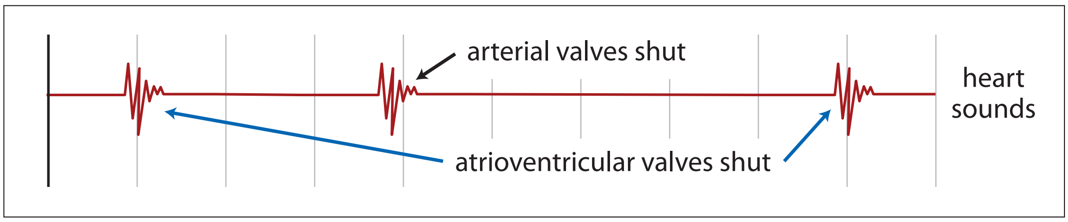
Tip: The short straight section between the P wave and the QRS complex represents the wave of excitation passing from the atria down into the ventricles.

The table below shows a range of heart traces, displaying normal and irregular heartbeats. The term **arrhythmia** is a general term for a heartbeat problem, meaning the heart is beating irregularly, too fast or too slow.

Heart condition	Trace	Effect
Normal heartbeat		
Bradycardia (heart beating too slowly – typically <60 bpm at rest)		Less blood reaches tissues, therefore there is less oxygen and glucose for respiration. Can cause fatigue, dizziness and fainting.
Tachycardia (heart beating too fast, typically >100 bpm at rest)		Results in rapid pulse rate, palpitations, chest pain, dizziness and fainting. Although the heart is pumping faster it is less efficient and pumps less blood per minute.
Ventricular fibrillation (abnormal rhythm and can indicate a heart attack is taking place)		Very irregular electrical stimulation and the heart contracts in a very uncontrolled and inefficient manner.

Heart sounds

Heart health can also be gauged by the sounds produced by a beating heart. During the cardiac cycle there are two main peaks of sound as identified in the diagram below. These sounds are produced by the atrioventricular and arterial valves closing, as explained earlier.



Heart sounds