AS/A Levels Biology:

Transport in Mammals

Lesson 8.04

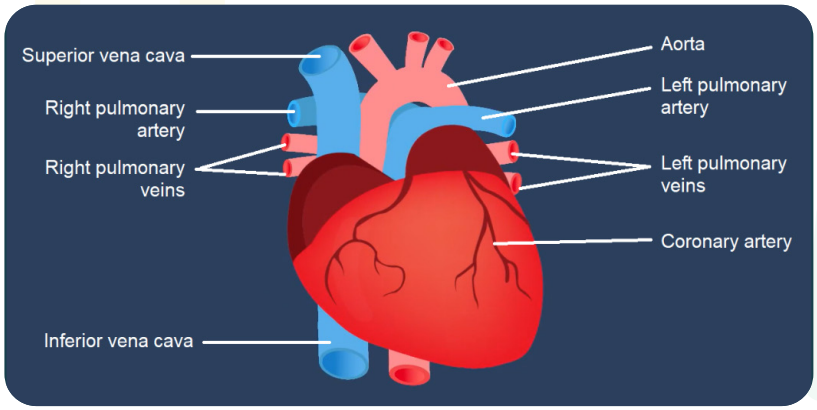
The Heart

Revision Notes

Candidates should have an understanding of:

- Describe the external and internal structure of the mammalian heart
- Explain the differences in the thickness of the walls of the:
  - Atria and ventricles
  - Left ventricle and right ventricle
- Describe the cardiac cycle, with reference to the relationship between blood pressure changes during systole and diastole and the opening and closing of valves
- Explain the roles of the sinoatrial node, the atrioventricular node and the Purkyne tissue in the cardiac cycle (knowledge of nervous and hormonal control is not expected)

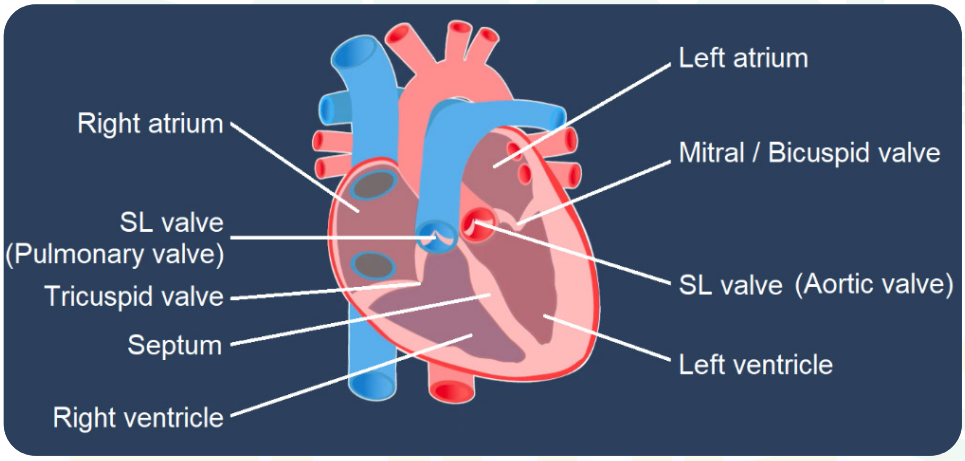
- **External structure of the mammalian heart:**



  - **Aorta:**
    - The **aorta** is a **large arching blood vessel** with branches supplying blood **upwards** to the **head,** and **downwards** to the **rest of the body.**

- **Pulmonary arteries:**
  - The other blood vessels leaving the heart are the **pulmonary arteries.** After leaving the heart, they branch very quickly into the **left and right pulmonary arteries**, taking **deoxygenated blood** to the **left** and **right lungs** respectively.
- **Pulmonary veins:**
  - The **left pulmonary vein** and the **right pulmonary vein** bring blood back to the heart from the **left** and **right lungs** respectively. They are the **only veins** that carry **oxygenated blood.**
- **Venae cavae:**
  - On the right-hand side of the heart, there are **two large veins**, one runs **vertically downwards** and other **vertically upwards.**
  - The vein which **brings blood from the head** is called the **superior vena cava,** while the one that brings **blood from the rest of the body** is called the **inferior vena cava**.
- **Coronary arteries:**
  - The **coronary arteries** are present on the **surface** of the **heart.** These arteries branch from the **aorta**, and **deliver oxygenated blood** to the **walls** of the **heart** itself.

- **Internal structure of the mammalian heart:**
  - If the heart is vertically cut open, **four chambers** can be seen.

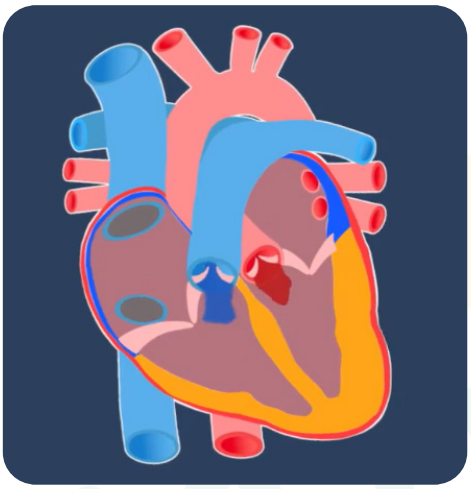


- **Septum:**
  - Septum is a muscular **wall** that **separates** the **two chambers** on the **left side** of the heart from the **two chambers** on the **right.**
  - **Blood cannot pass** through the **septum.**

- ### Atria:
    - The **upper chamber** on each side of the heart is called an **atrium** or **auricle**.
    - The two atria **receive blood** from the **veins.**
    - The **blood** from the **venae cavae** flows into the **right atrium.**
    - The **blood** from the **pulmonary veins** flows into the **left atrium.**
- ### Ventricles:
    - The **lower chambers** are called the **ventricles.**
    - **Blood** flows from the **left atrium** into the **left ventricle**, and from the **right atrium** to the **right ventricle**.
    - The blood is then pumped from the **right ventricle** to the **pulmonary arteries** and from the **left ventricle** to the **aorta.**
- ### Valves:
    - They **prevent backflow** of **blood.**
    - The valves present between the **ventricles** and **arteries** are called **semilunar (SL) valves.**
    - The valves present between the **atria** and **ventricles** are called **atrioventricular (AV) valves.**
    - The **AV valve** on the **left** is the **mitral or bicuspid valve,** and the **AV valve** on the **right** is the **tricuspid valve.**

• Differences in the thickness of the walls of different chambers of the mammalian heart:

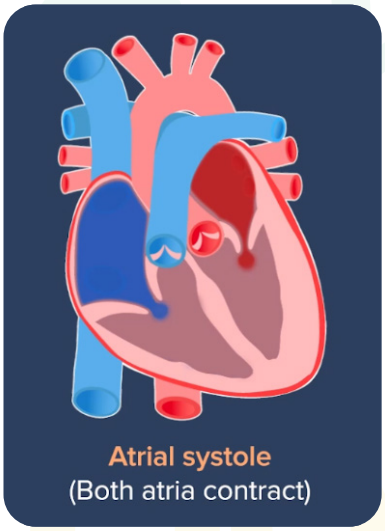
- ### Atria and ventricles:
    - **Ventricles** have much **thicker walls** than **atria.**
    - **Atria** only needs to push blood to the **ventricles.**
    - **Ventricles** need to develop much more force when they contract, to push blood **out of the heart** and **around the body.**



- **Left ventricle and right ventricle:**
  - **The right ventricle** has a **thinner wall** than the left ventricle. This is because the force produced by the right ventricle is relatively small for the blood to get to the **lungs**, which is **very close to the heart.**
  - On the other hand, the **left ventricle** has to develop **sufficient force** to supply blood to the **rest of the body organs.**

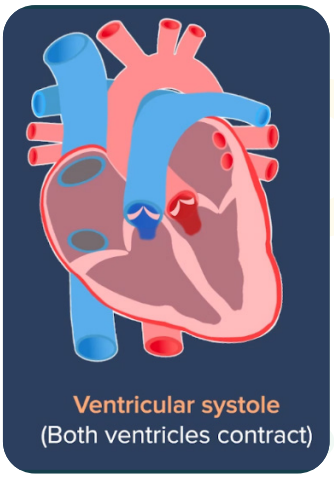
- **Cardiac cycle:**
  - Our heart **beats** around **70 times per minute.**
  - The sequence of events leading to **one heartbeat** is called a **cardiac cycle.**
  - **Cardiac cycle** comprises mainly **three stages: atrial systole, ventricular systole,** and **ventricular diastole.**

- **Atrial systole, ventricular systole, and ventricular diastole:**
  - **Atrial systole:**
    - When **blood** from pulmonary veins and venae cavae **enters atria,** both atria **contract.** This condition is called **atrial systole.**
    - During atrial systole, blood **pressure** is **higher** in the **atrium** than in the ventricle, which forces the **AV valve** to **open**, pushing the blood into **ventricles.**

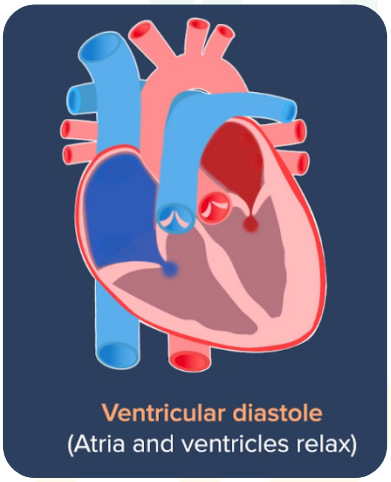


  - **Ventricular systole:**
    - About **0.1 seconds after** the atria **contract,** the thick, muscular **walls** of the **ventricles squeeze inwards** and **increase** the **blood pressure**. This is called **ventricular systole.**
    - As the **pressure** in the **ventricles** becomes **greater** than the pressure in the atria, the **AV valves shut, preventing** the **backflow** of **blood** into the **atria.**
    - Instead, the **blood** rushes **upwards** into the **aorta** and the **pulmonary arteries,** pushing **open** the **SL valves** in these vessels, letting the **blood out of the heart.**

- The **ventricular systole** lasts for about **0.3 seconds.**

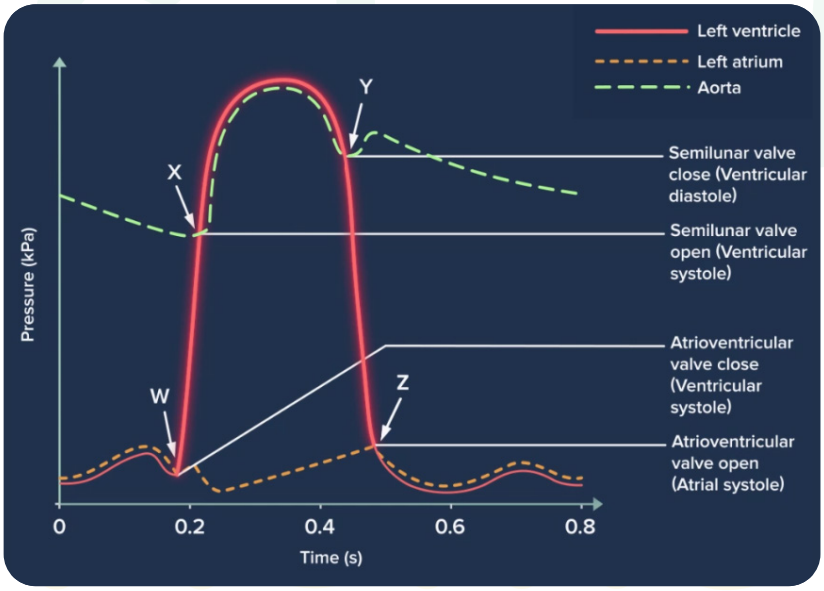


- **Ventricular diastole:**
  - Finally, the **ventricles relax,** and this stage is called **ventricular diastole.**
  - In this stage, the **pressure** in the **ventricles drops.**
  - The **SL valves close** instantly after their **cusps** are **filled** with **high-pressure blood** to **prevent** the **backflow** of the **blood** into the **ventricles.**
  - As the entire **heart muscles relax,** the **blood** from the veins **flows** into the **two atria.**
  - In the **atria, blood pressure** is **very low.** Even so, the **thin walls** of the atria get **swollen,** providing **very little resistance** to the blood flow.
  - Some of the **blood** even **trickles downwards** into the **ventricles**, through the **AV valves.**
  - This leads to the **contraction of atrial muscle**, which **forcefully pushes** the **blood down** into the **ventricles,** and the entire **cycle repeats.**



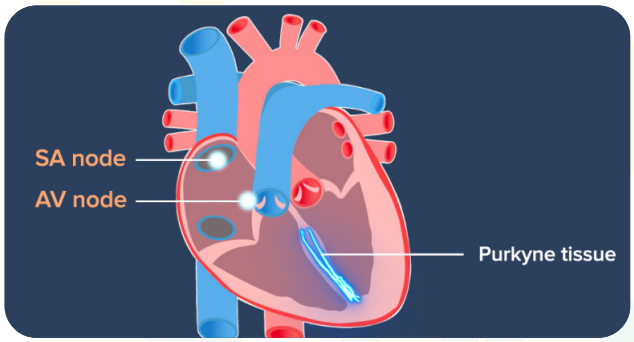
- **Opening and closing of valves during a cardiac cycle:**
  - **Valves** play a **major role** in the **coordination** of the **heart** and **maintain** a **unidirectional flow of blood.**
  - **Contraction increases** pressure and **relaxation lowers** pressure.

- The **AV valves open** when **atrial pressure** is **higher** than the ventricular pressure and the **SL valves open** when the **ventricular pressure is higher** than the aortic pressure.
- And conversely, the **AV valves close** when **ventricular pressure is higher** than the atrial pressure and the **SL valves close** when the aortic **pressure is higher** than ventricular pressure.
- **Graph showing opening and closing of valves during a cardiac cycle:**



- Initially, **atria contract, increasing** the atrial **pressure,** which leads to the **opening** of the **AV valve.**
- Then **blood** passes through the **AV valve** to the **ventricles,** which **lowers** the **atrial pressure** and **increases ventricle pressure** causing the **AV valves** to **close** as shown in point **W.**
- The **contraction** of the **ventricles** further **increases** the **ventricular pressure** and causes the **SL valves** to **open** as shown in point **X**.
- At this point, the **ventricular pressure** is **higher** than in the **aorta** and in the **pulmonary artery,** which allows the **blood** to pass through them **emptying the ventricles.**
- Then, the **ventricular pressure decreases**, which leads to the **closing** of the **SL valve** as shown in point **Y.**
- The **further decrease** in **ventricular pressure** leads to the **opening of the AV valves** as shown in point **Z** and the **process repeats.**
- From point **W to X**, even though the ventricular **pressure increases**, the **volume** of **blood stays the same.**
- Similarly, from point **Y to Z,** the **ventricular pressure is decreasing** but the **volume** of **blood stays constant.**

- **Roles of sinoatrial node, atrioventricular node and Purkyne tissue:**



  - **Sinoatrial node:**
    - The **cardiac cycle** is **initiated** in a **specialised patch of muscle** in the **right atrium wall,** called the **sinoatrial node (SAN).**
    - The **muscle cells** of the **SAN generate** the **impulse** and **set** the **rhythm** for all the other cardiac muscle cells.
    - Its **rate** can be **adjusted** by the **nerves connecting** it with the brain.
    - As the **muscle** in the **SAN contracts,** it produces an **electrical excitation wave**, which **sweeps** through all the muscle in the **whole atria** of the heart.
  - **Atrioventricular node:**
    - The **excitation wave** generated by the SAN makes the muscle in the **atrial walls contract simultaneously,** and the **electrical wave sweeps onwards** and reaches **another patch of cells** called the **atrioventricular node (AVN).**
    - The **AVN situated** in the **septum** is the **only route** through which the **excitation wave** is **conducted** from the **atria** to the **ventricles.**
    - This is because **a band of fibres** is present **between** the **atria** and the **ventricles which does not transmit electrical impulses** to the ventricle walls.
    - So, since the **AVN** is the **only route**, the **conduction of impulse** is **delayed** for **almost 0.1 seconds** before it actually travels down to the ventricles.
  - **Purkyne tissue:**
    - From the AVN, the **excitation wave** moves **down** swiftly through the **septum** of the heart, **along the fibres** known as **Purkyne tissue.**
    - Once the **excitation wave arrives** at the **base** of the **septum**, it **spreads outwards** and **upwards** through the **ventricular walls.**
    - These **waves** in **ventricles** cause the **cardiac muscle** in ventricular walls to **contract** from the **bottom** towards the **top,** squeezing the blood **upwards** and into the **arteries.**
    - The **ventricles** then **relax**. After this, the **SAN contracts again**, and the **whole cycle repeats.**

Here's an example of an examination question on this topic:

1) Which sequence of letters correctly identifies the order of events during the cardiac cycle?

T atrial walls contract

U impulse is delayed a fraction of a second

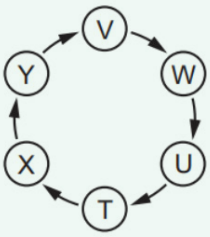
V wave of excitation enters the atrioventricular node

W wave of excitation passes down the Purkyne tissue

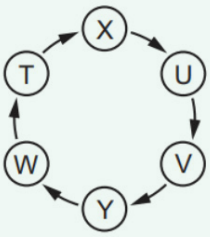
X wave of excitation spreads from the sinoatrial node

Y ventricles contract

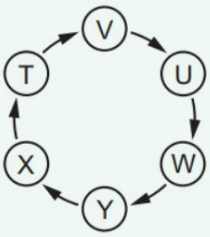
A



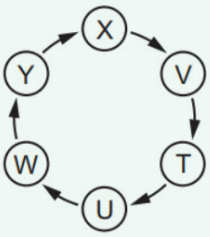
B



C



D



Answer: C

The cardiac cycle initiates at the SAN. So the starting point is **X**, which denotes the wave of excitation spreads from the sinoatrial node.
After the wave of excitation spreads, the atrial walls contract, denoted by **T**.
Then, the wave of excitation enters the AVN, which is denoted by **V**.
After this, the impulse is delayed a fraction of a second, denoted by **U**.
Then, the wave of excitation passes down the Purkyne tissue, denoted by **W**.
Finally, the ventricles contract, denoted by **Y**.

This correct sequence of events is given by option C.

Thus, option C is the correct answer.