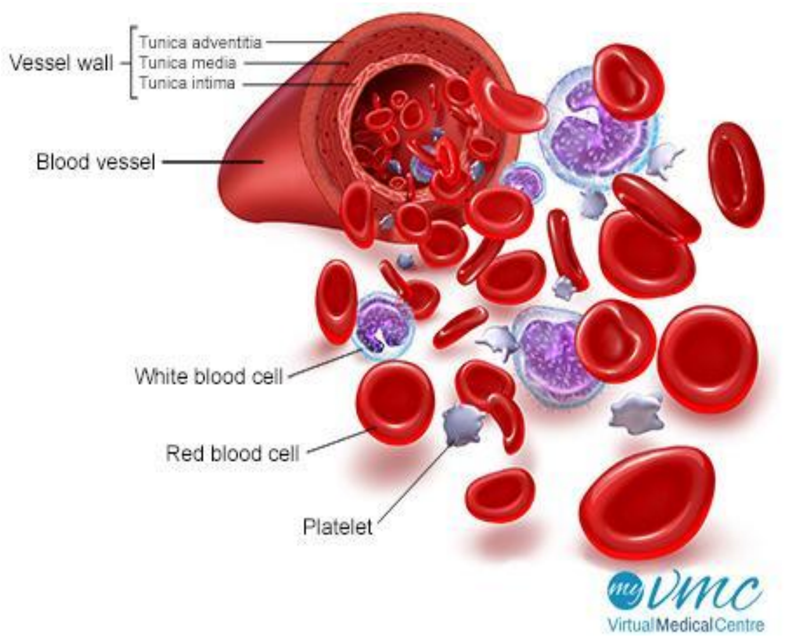
Structure & Function of the Cardiovascular System

2.2.1 State the composition of blood

- It is heavier and more viscous than water and accounts for about 8% of our total body weight.
- Healthy adult males have around 5-6 liters of blood and females about 4-5 liters.
- Its color varies, depending upon the amount of oxygen it is carrying, from dark red (oxygen poor) to bright red (oxygen rich).



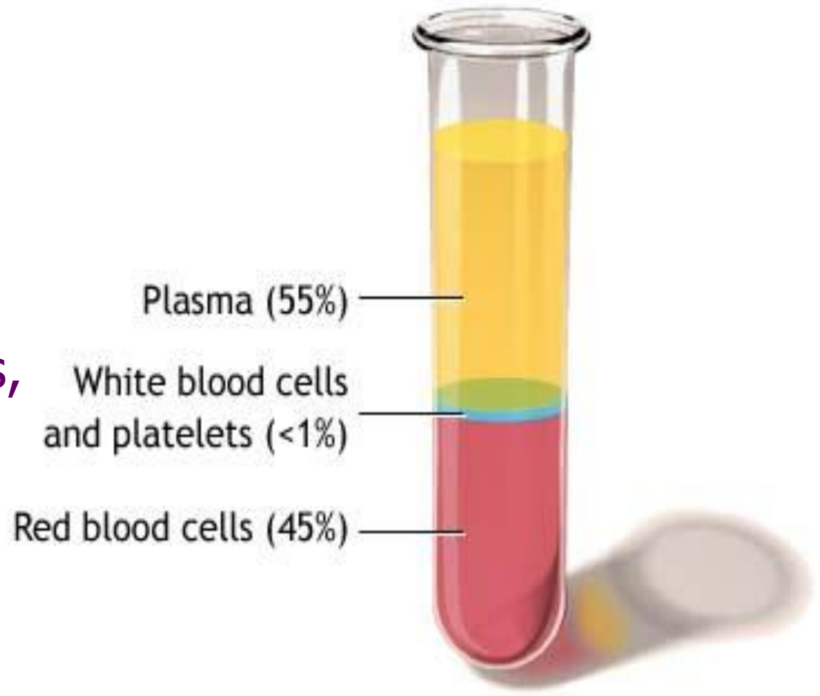
Exercise Physiology

2.2.1 State the composition of blood

- **Erythrocytes** (Red Blood Cells RBC's):
- **Leukocytes** (White Blood Cells)
- **Platelets** (Thrombocytes)

The total volume of erythrocytes is known at the **hematocrit**!

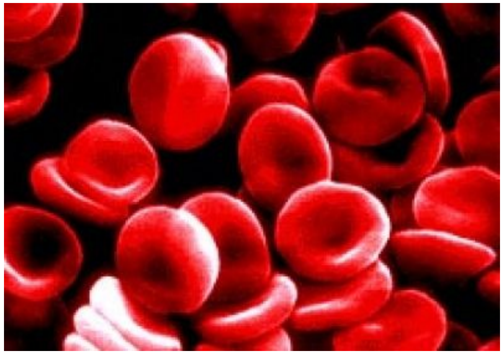
- **Plasma**: liquid portion of blood and responsible for the transport of electrolytes, proteins, gases, nutrients, waste products and hormones.

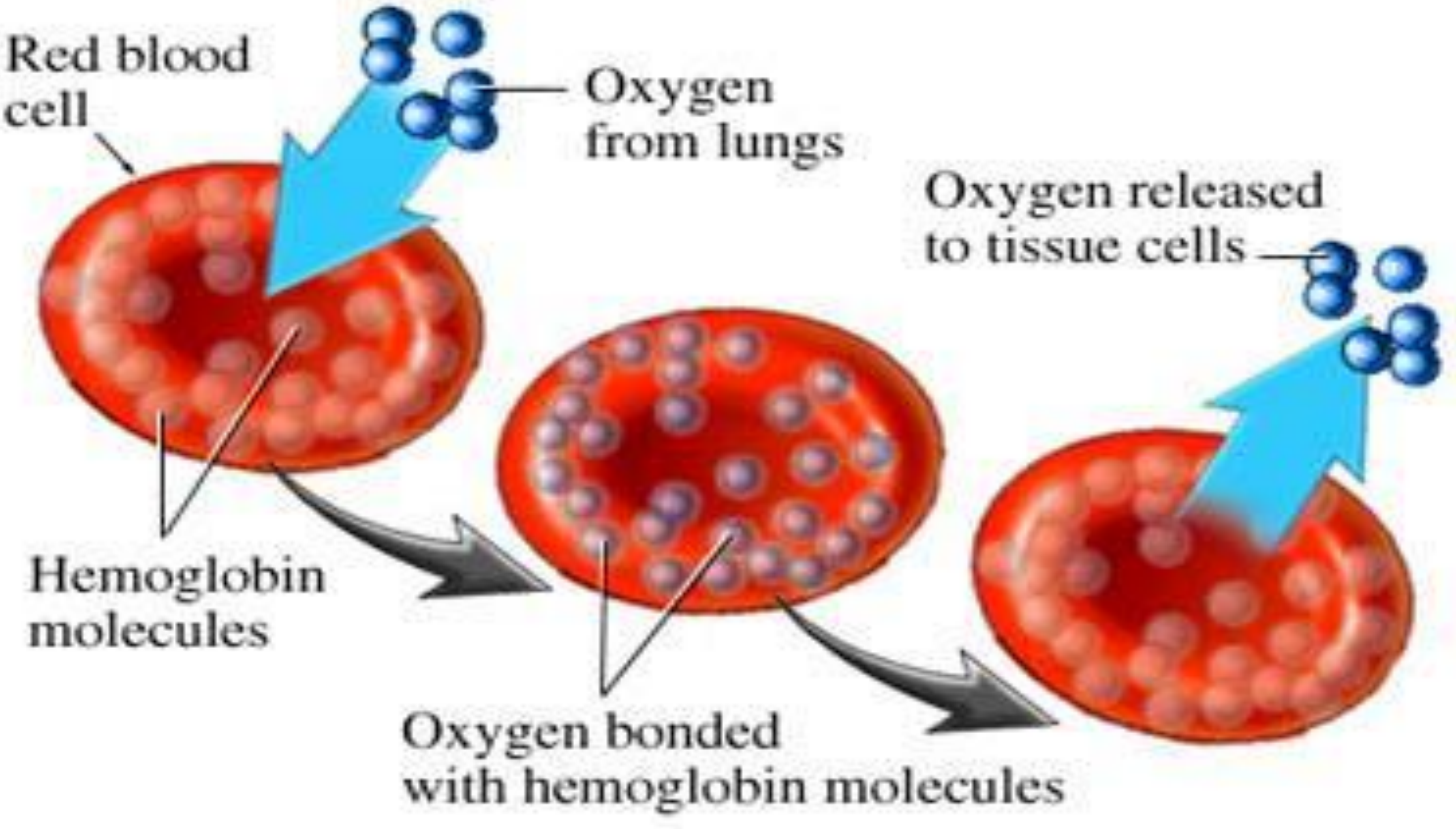


Exercise Physiology

2.2.2 Distinguish between the functions erythrocytes, leucocytes and platelets

- **Erythrocytes (Red Blood Cells)**: contain an oxygen-carrying pigment called hemoglobin, which carries oxygen gives blood its red color.
- They live for around 120 days, and are replaced at the at the astonishing rate of 2 million cells per second.




Red blood
cell
Oxygen
from lungs
Oxygen released
to tissue cells
Hemoglobin
molecules
Oxygen bonded
with hemoglobin molecules

Sub-topics

1. Structure & function of the ventilatory system
2. Structure & function of the cardiovascular system

2.2.2 Distinguish between the functions erythrocytes, leucocytes and platelets

- **Leukocytes (White Blood Cells):** exist in our bodies to combat infection and inflammation.
- They do this by ingesting foreign microbes in a process called phagocytosis.


neutrophil

IB

Sports, exercise and health science

Topic 2

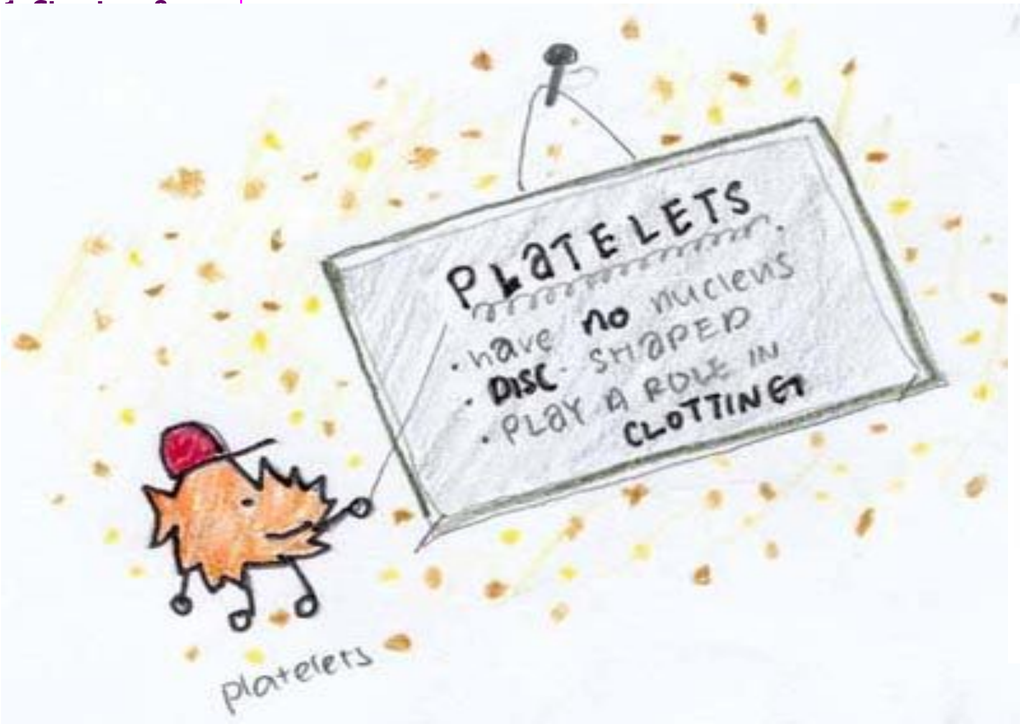
Exercise physiology

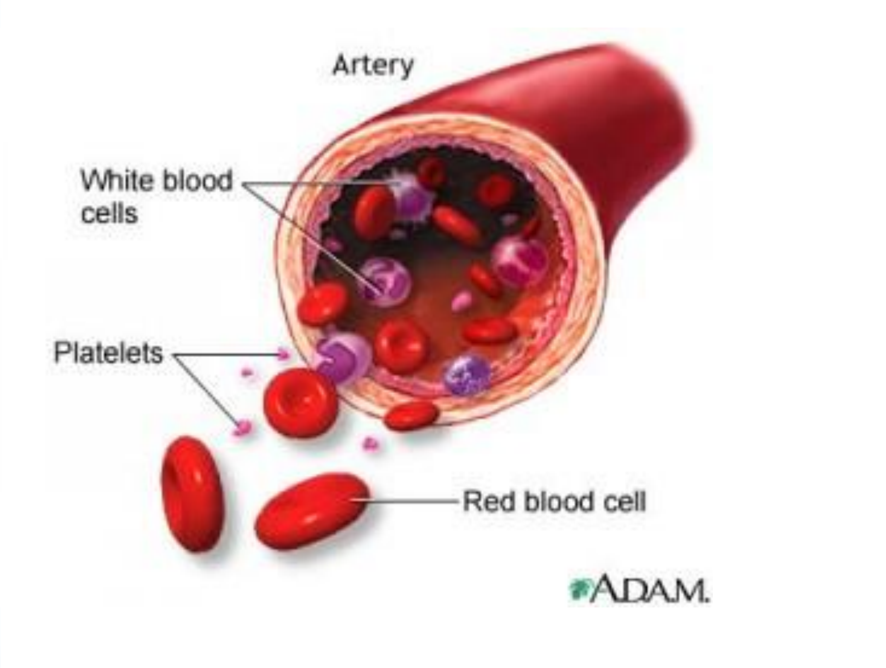
Sub-topics

Exercise Physiology

2.2.2 Distinguish between the functions erythrocytes, leucocytes and platelets

- **Platelets (Thrombocytes)**: involved in the process of clotting and help repair slightly damaged blood vessels.





Exercise Physiology

2.2.1 State the composition of blood

Blood performs a number of specialized functions:

- Transports nutrients, oxygen, carbon dioxide, waste products and hormones to cells and organs around the body.
- Protects us from bleeding to death - via clotting, from disease, by destroying invasive micro organisms and toxic substances.
- Acts as a regulator of temperature, the water content in cells, and body pH. (remember that narrow window we like!!)

Browne et al 2001

2.2.1 State the composition of blood

Blood performs a number of specialised functions:

- Small % of oxygen dissolves in plasma, most of it attaches to iron-rich hemoglobin
  - Lungs have high partial pressure of O2 so O2 easily binds to hemoglobin
  - Active muscles have a low partial pressure so O2 detaches from hemoglobin easily and diffuses in.
- CO2 is produced during exercise and is transported to the lungs via the veins, partly dissolved in blood but mostly in the temporary form of bicarbonate

Browne et al 2001

Exercise Physiology

2.2.1 State the composition of blood

Blood performs a number of specialised functions:

- Hemoglobin concentrations are controlled by the hormone **erythropoietin** (EPO)
  - Stimulates red blood cell production
  - More RBC's = more oxygen = increased aerobic performance
  - This is why endurance athletes live at high altitudes
    - Less oxygen in air stimulates EPO to produce more RBC's and thus hemoglobin
    - They return to sea level and perform better

Browne et al 2001

2.2.1 State the composition of blood

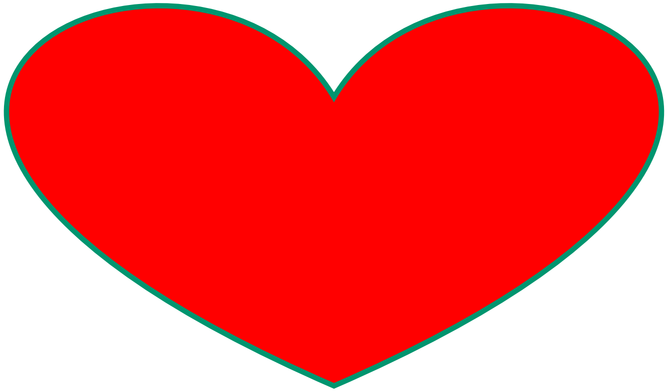
Blood performs a number of specialised functions:

- There are illegal methods to increasing RBC's in athletes
  - **Blood doping** - removing some blood from an athlete after training at altitude which stimulates EPO to increase RBC's
  - This blood is reintroduced to the athlete just before competition to increase athletic performance
- Athletes can be injected with **synthetic EPO** so skip the above process.
- Detection of synthetic EPO and blood doping is hard
- When you travel to high elevations (even without training) your EPO increases you RBC's

Exercise Physiology

2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

- Your heart is about the same size as your fist.
- An average adult body contains about five liters of blood.
- All the blood vessels in the body joined end to end would stretch 62,000 miles **or** two and a half times around the earth.
- The heart circulates the body's ENTIRE blood supply about 1,000 times each day.
- The heart pumps the equivalent of 5,000 to 6,000 liters of blood each day.



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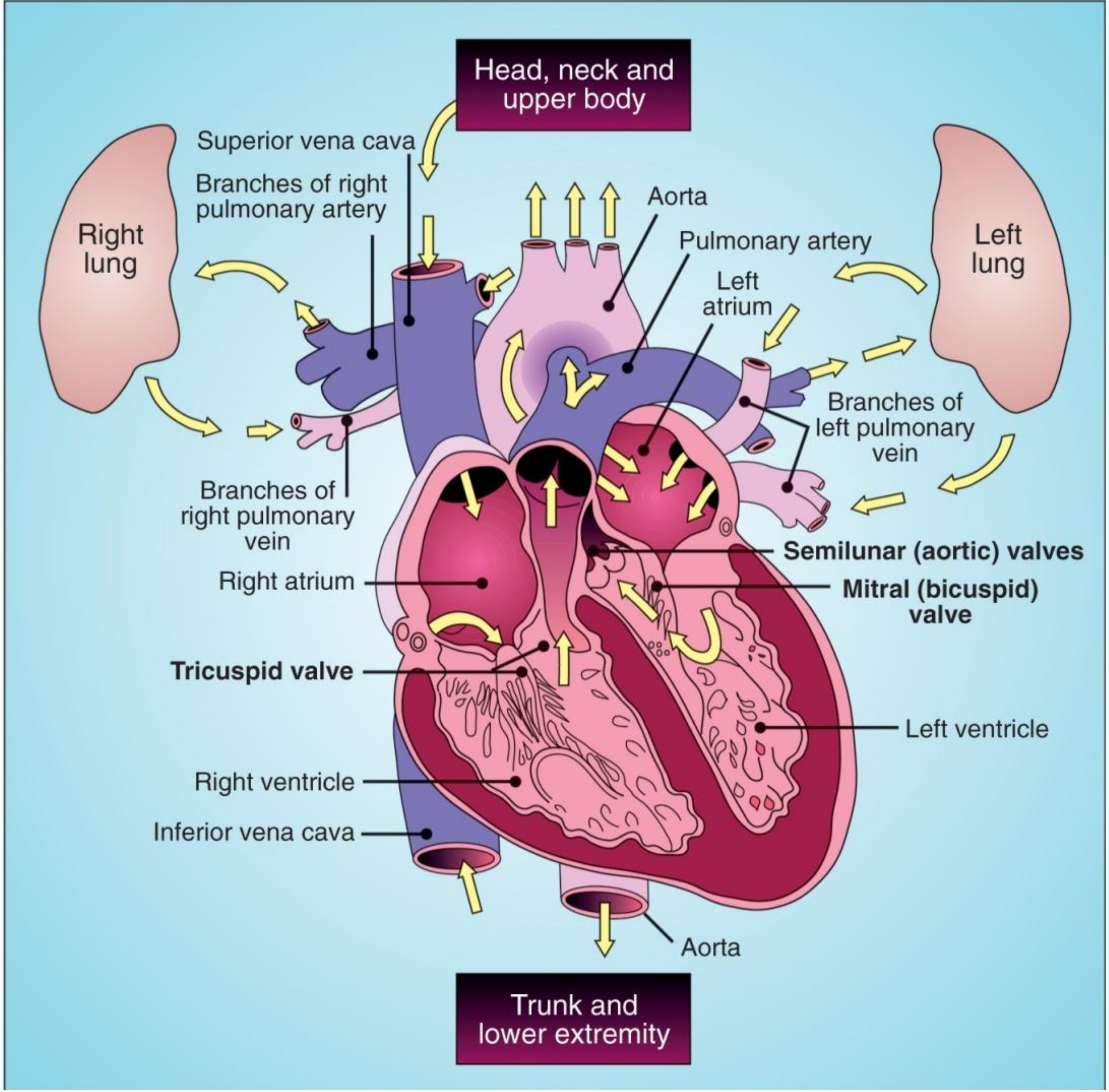
Sports, exercise and health science

Topic 2
Exercise physiology

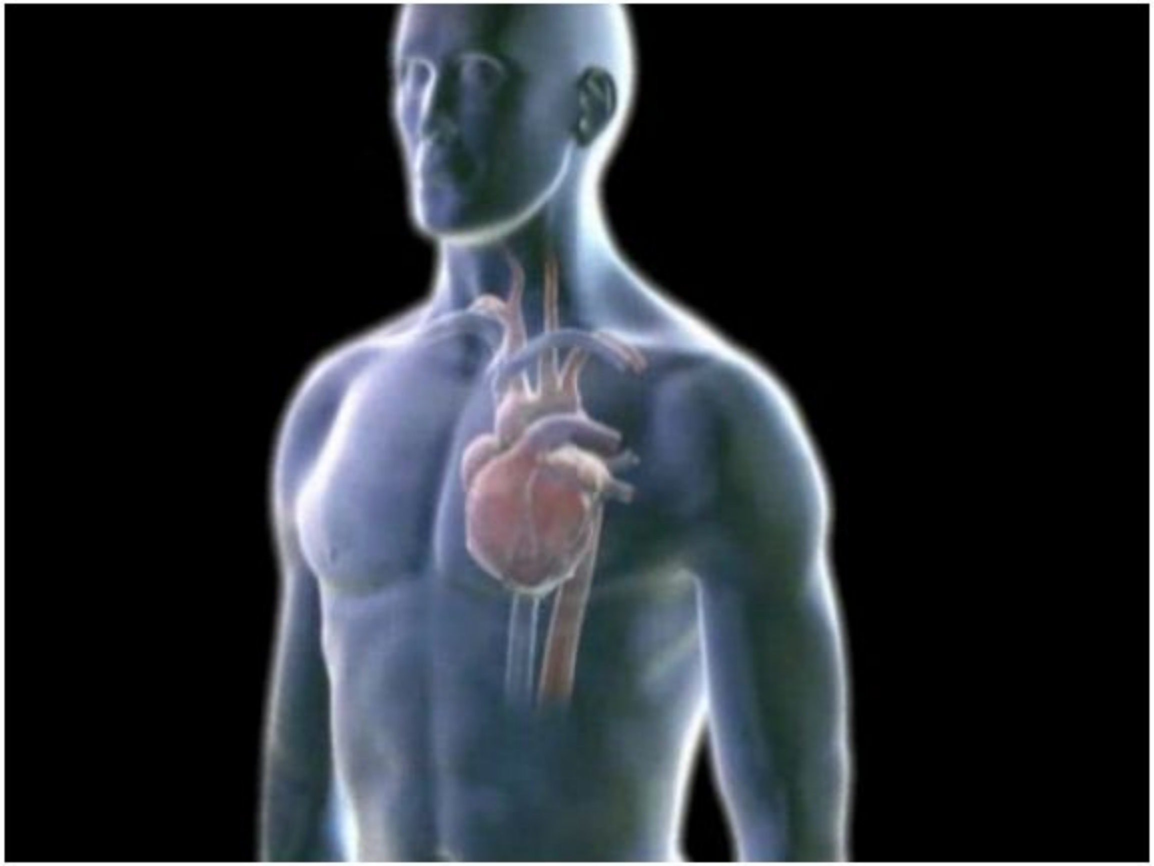
Sub-topics

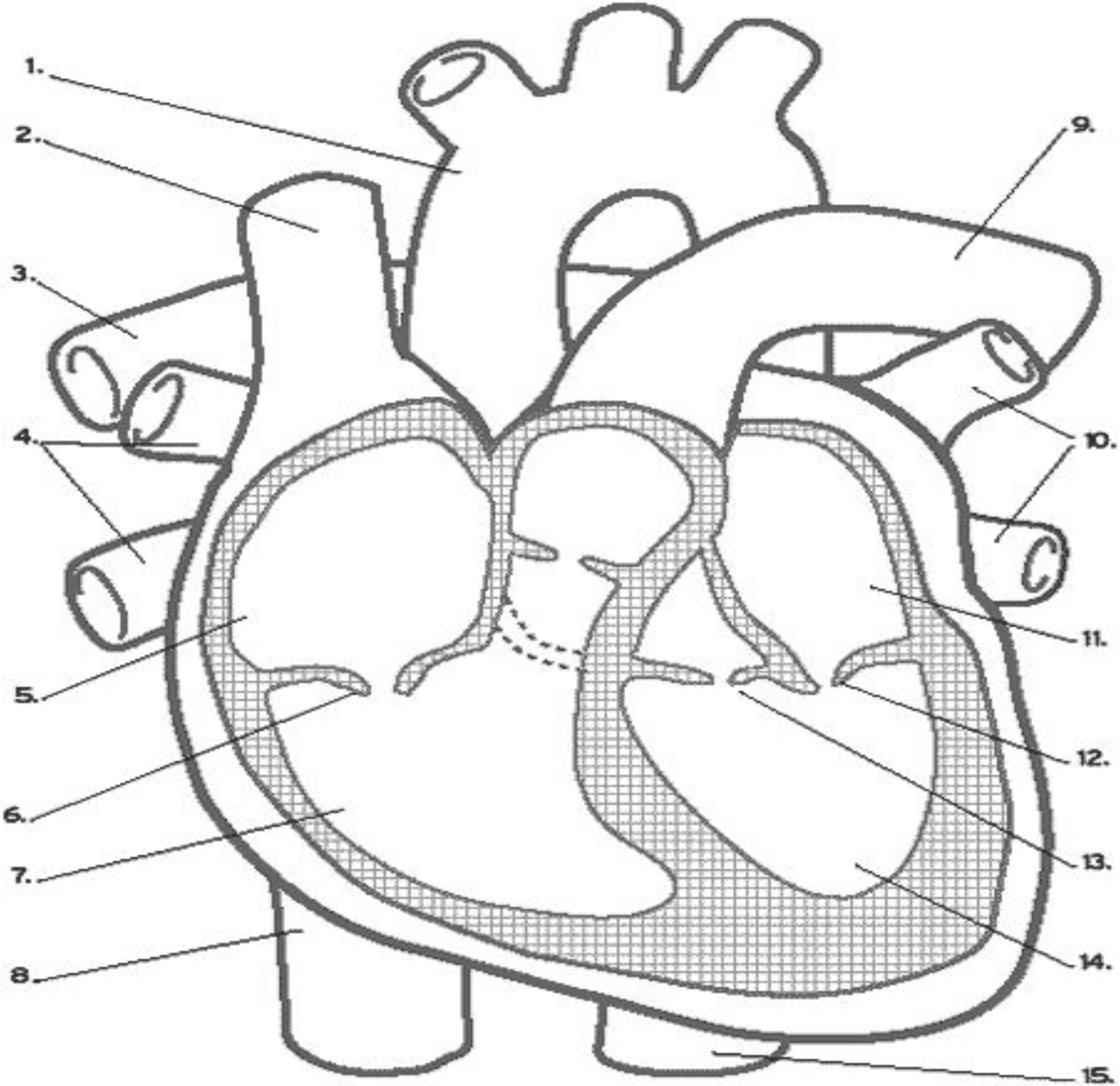
1. Structure & function of the ventilatory system
2. Structure & function of the cardiovascular system



Exercise Physiology

2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels



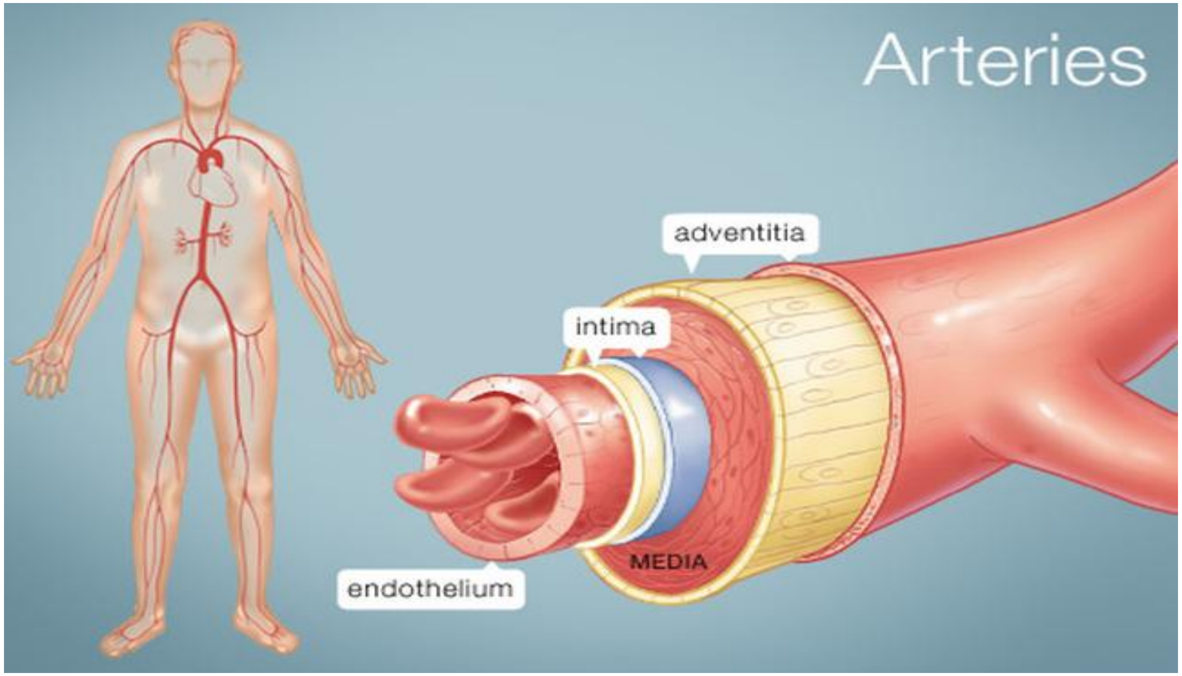


1. Aorta
2. Superior Vena Cava
3. Right Pulmonary artery
4. Right Pulmonary Vein
5. Right Atrium
6. Tricuspid valve
7. Right Ventricle
8. Inferior vena cava
9. Left Pulmonary Artery
10. Pulmonary vein
11. Left Atrium
12. Bicuspid valve
13. Aortic Valve
14. Left Ventricle
15. Aorta

2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

….First we must discuss circulation….

- **Arteries**
  - Relatively large blood vessels in diameter
  - Thick muscular walls with considerable pressure exerted by the oxygen-rich blood within
  - Responsible for blood transport away from the heart
  - Arteries branch into narrower arterioles



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Sports, exercise and health science

Topic 2
Exercise physiology

Sub-topics

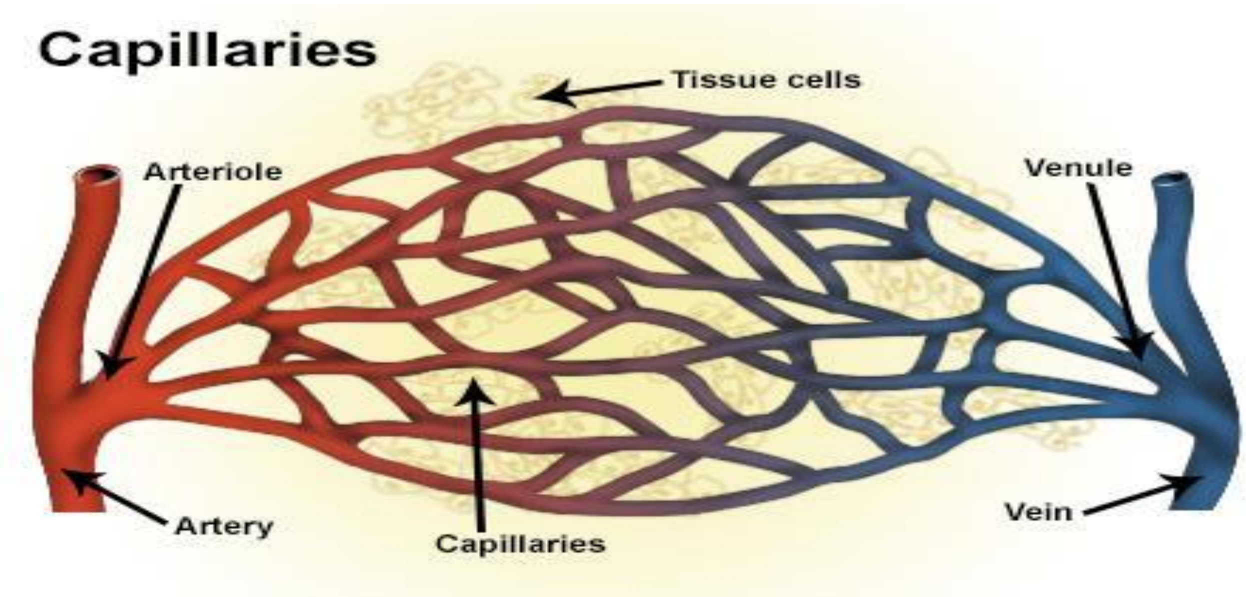
1. Structure & function of the ventilatory system

2. Structure & function of the cardiovascular system

2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

....First we must discuss circulation....

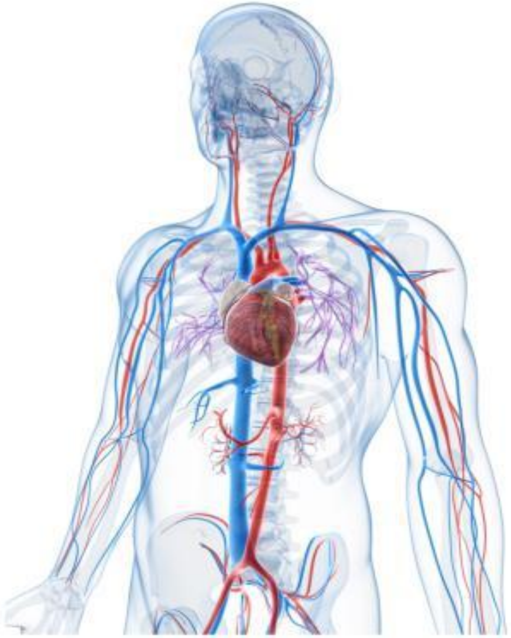
- **Capillaries**
  - Blood supplied by the arterioles
  - Narrow blood vessels with extremely thin walls
  - Form extensive branching network through tissues
  - Sites of gas exchange between blood and tissues



2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

....First we must discuss circulation....

- **Veins**
  - Capillaries link to larger vessels called venules and then to larger veins
  - Delivers deoxygenated (low oxygen content) back towards the heart
  - Significantly less muscular and fibrous than arteries due to lower internal pressure
  - Contains series of valves in order to prevent backflow



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Sports, exercise and health science

Topic 2

Exercise physiology

Sub-topics

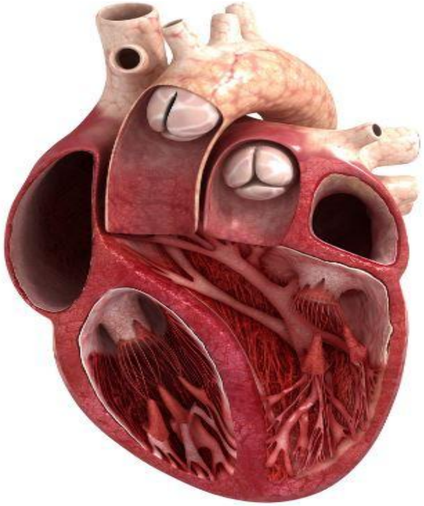
1. Structure & function of the ventilatory system

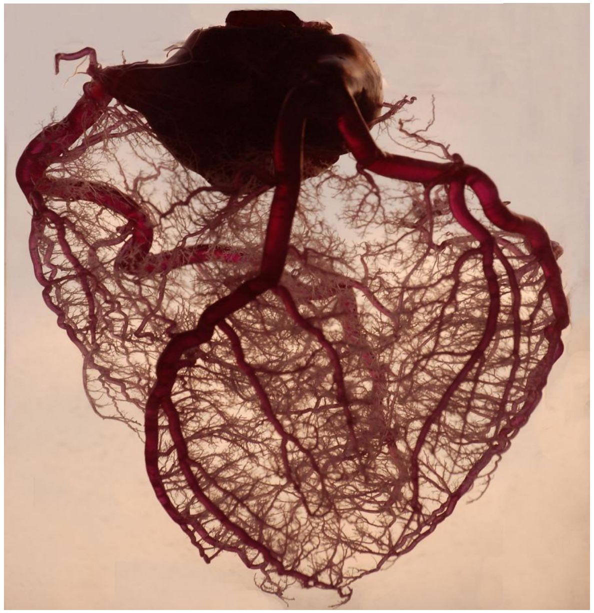
2. Structure & function of the cardiovascular system

2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

....First we must discuss circulation....

- **The heart**
  - The involuntary pump (muscle) at the center of the cardiovascular system
  - It is a sequence of chambers that are enclosed by walls of specialized muscle fibers (cardiac muscle cells!!)
    - Smooth, striated, involuntary
- The heart is the link between two distinct loops of circulation in our bodies.

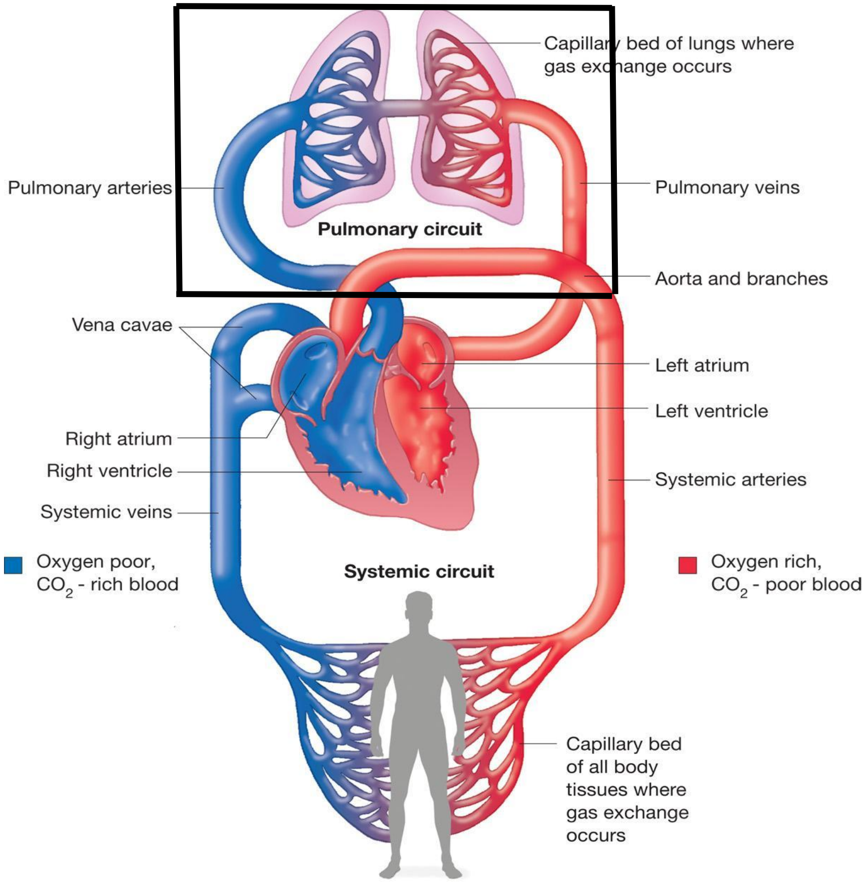




Exercise Physiology

2.2.5 Outline the relationship between the pulmonary and systemic circulation

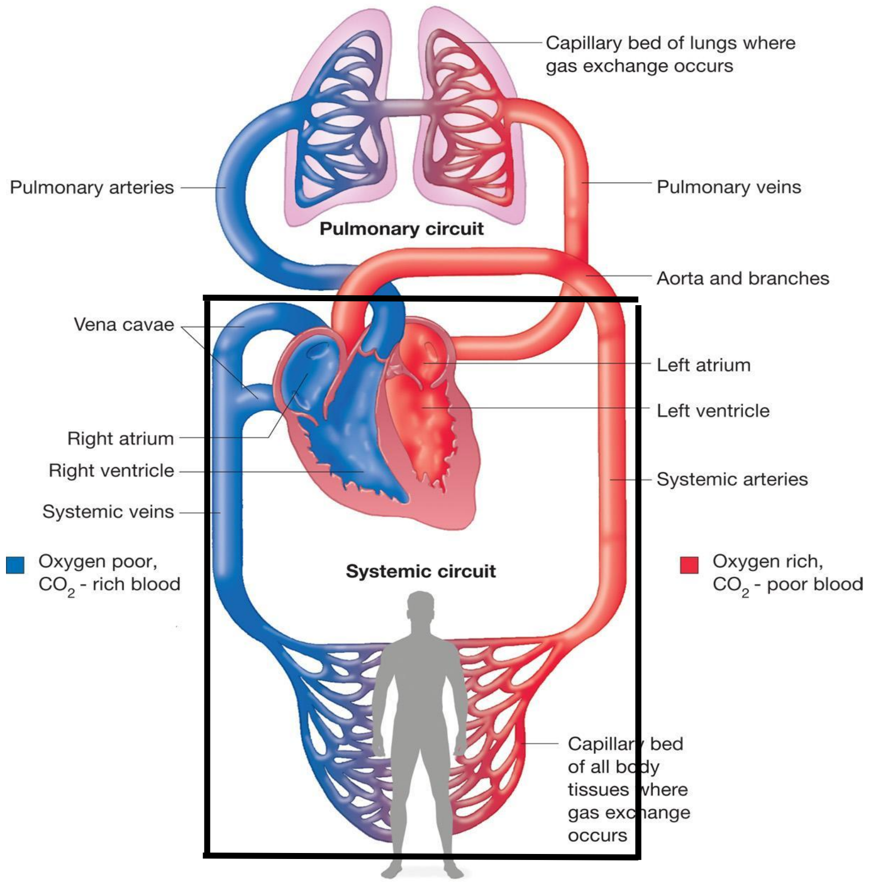
- **Pulmonary circulation** is the portion of the cardiovascular system which carries oxygen-depleted blood away from the heart, to the lungs, and returns oxygenated blood back to the heart.
- The term is contrasted with systemic circulation.



Exercise Physiology

2.2.5 Outline the relationship between the pulmonary and systemic circulation

- **Systemic circulation** is the portion of the cardiovascular system which **carries oxygenated blood** away from the heart, to the body, and **returns deoxygenated blood** back to the heart.
- This term is contrasted with pulmonary circulation.



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Sports, exercise and health science

Topic 2
Exercise physiology

Sub-topics

1. Structure & function of the ventilatory system

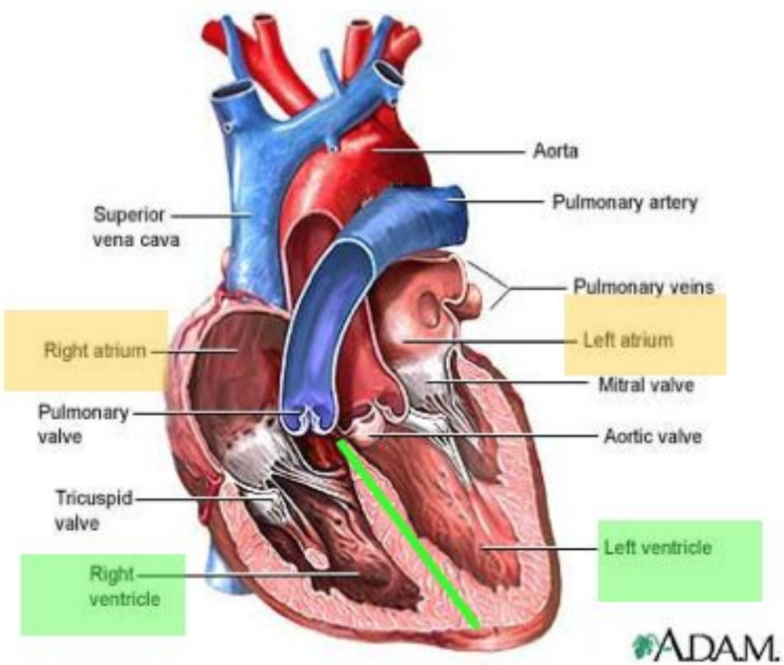
2. Structure & function of the cardiovascular system

2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

- The heart is a highly efficient four-chambered double-pump system. It is split into left and right sides which works synchronously.

- The right side of the heart receives deoxygenated blood and sends blood to the lungs (pulmonary circuit)

- The left side of the heart receives oxygenate
- d blood from the lungs and sends it to the body (systemic circuit)



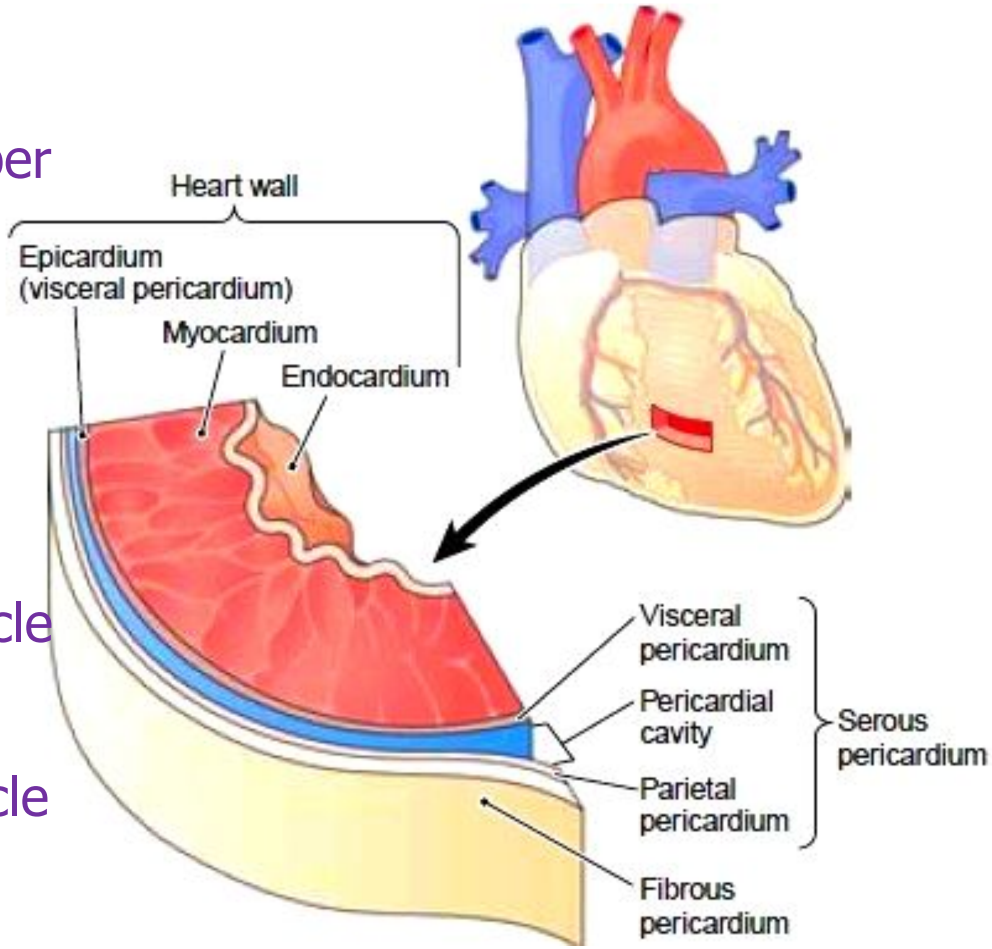
2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

Pericardium – a double-walled sac around the heart composed
- The Function of the Pericardium:
  - Protects and anchors the heart
  - Prevents overfilling of the heart with blood
  - Allows for the heart to work in a relatively friction-free environment

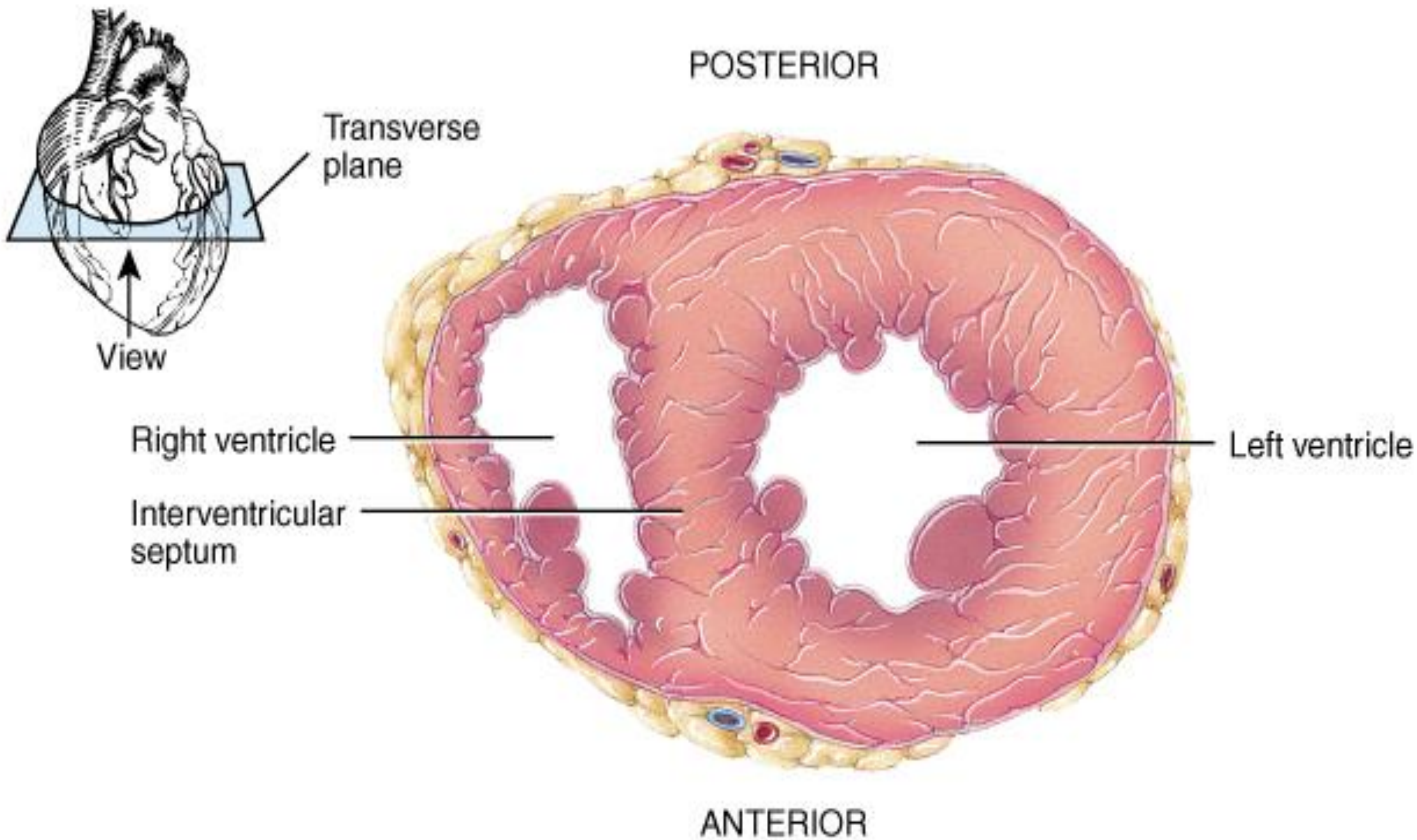
Epicardium – a membrane that forms the innermost layer of the pericardium and the outer surface of the heart.
Myocardium – cardiac muscle layer forming the bulk of the heart
Fibrous skeleton of the heart – crisscrossing, interlacing layer of connective tissue
Endocardium – layer of the inner myocardial surface

2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

- Thickness of myocardium varies according to the function of the chamber
- Atria are thin walled, deliver blood to adjacent ventricles
- Ventricle walls are much thicker and stronger. Right ventricle supplies blood to the lungs (little flow resistance) left ventricle wall is the thickest to supply systemic circulation (high flow resistance)

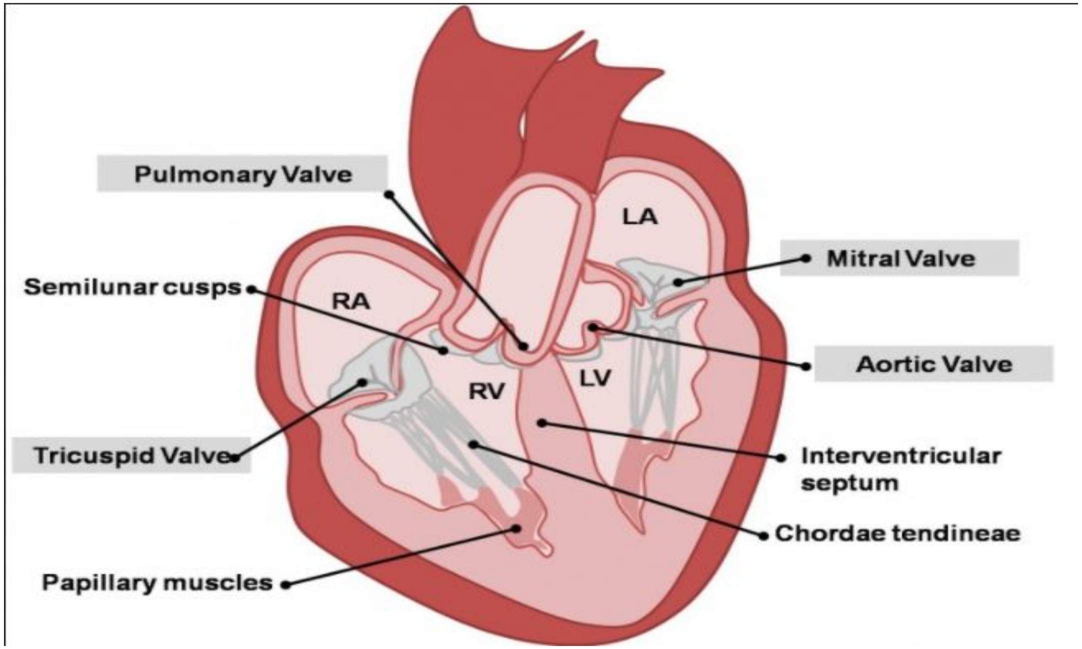


2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels



2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

- There are a series of valves between chambers that close and open by force based on a coordinated sequence of heart muscle contractions
- The valves promote blood flow through the heart in one direction
- The valves also ensures that heart muscle contractions increase pressure in the heart chambers to properly eject blood



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Sports, exercise and health science

Topic 2
Exercise physiology

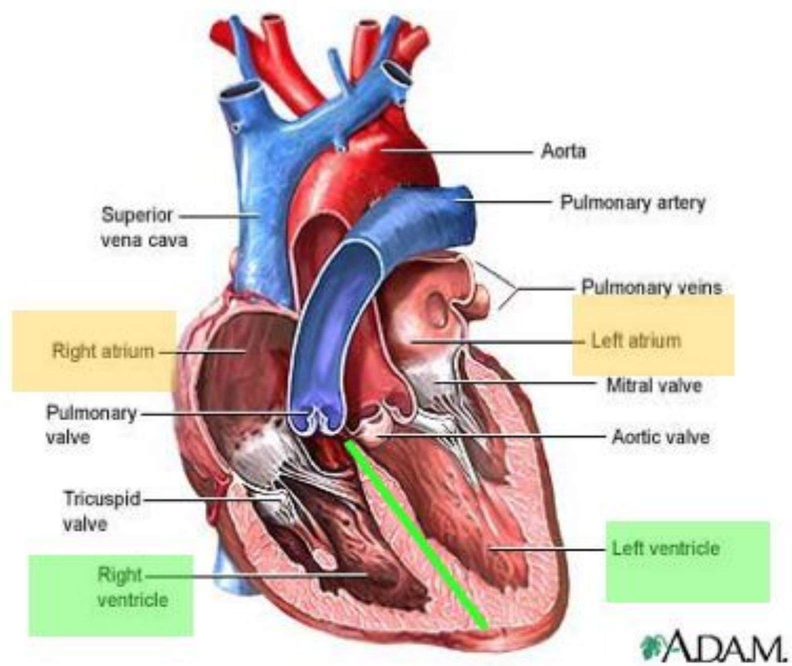
Sub-topics

1. Structure & function of the ventilatory system

2. Structure & function of the cardiovascular system

2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

- The heart is a highly efficient four-chambered double-pump system. It is split into left and right sides which works synchronously.



- **Atria are the blood receiving chambers of the heart**

- Each side of the heart has an <u>atrium</u> (each counts as one of the four chambers) which receives blood from a vein

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Sports, exercise and health science

Topic 2
Exercise physiology

Sub-topics

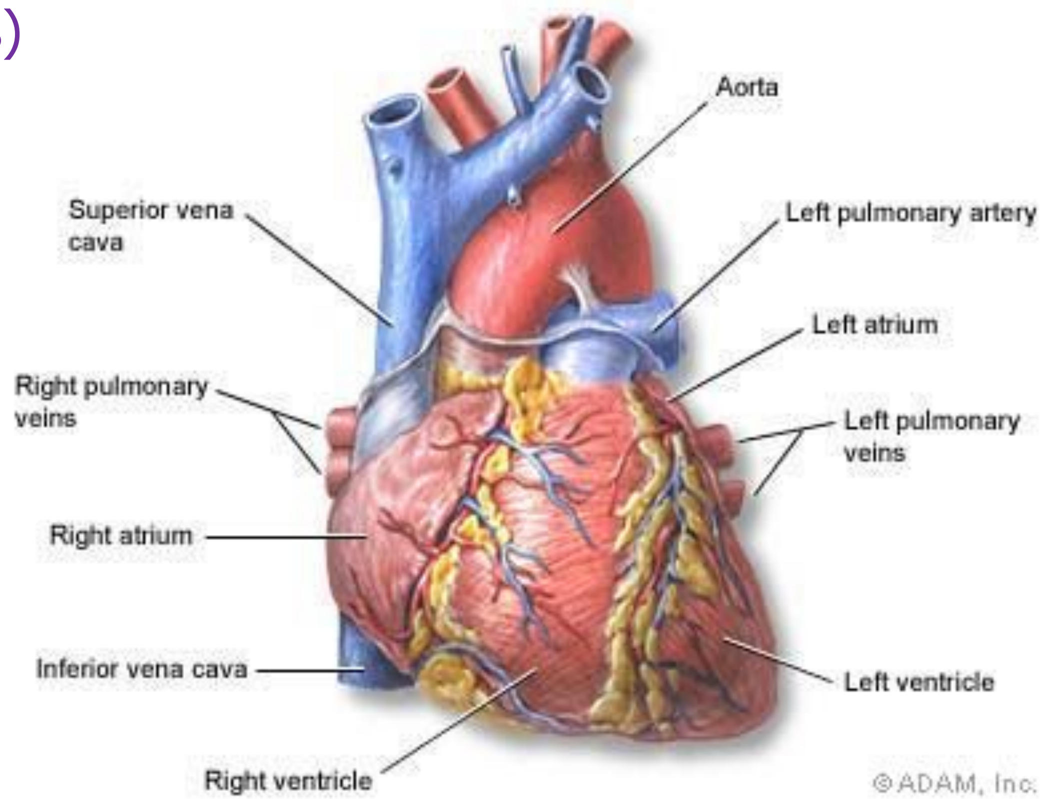
1. Structure & function of the ventilatory system

2. Structure & function of the cardiovascular system

2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

- Blood enters **right atria** from superior and inferior vena cava and coronary sinus (deoxygenated blood)
- - Coronary sinus = carries blood used by heart
- Blood enters **left atria** from pulmonary veins (oxygenated blood from lungs)

- As the atria fill with blood, the pressure increases. Once it matches the pressure of the valve, the valve opens and the blood flows to the ventricles



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Sports, exercise and health science

Topic 2
Exercise physiology

Sub-topics

1. Structure & function of the ventilatory system

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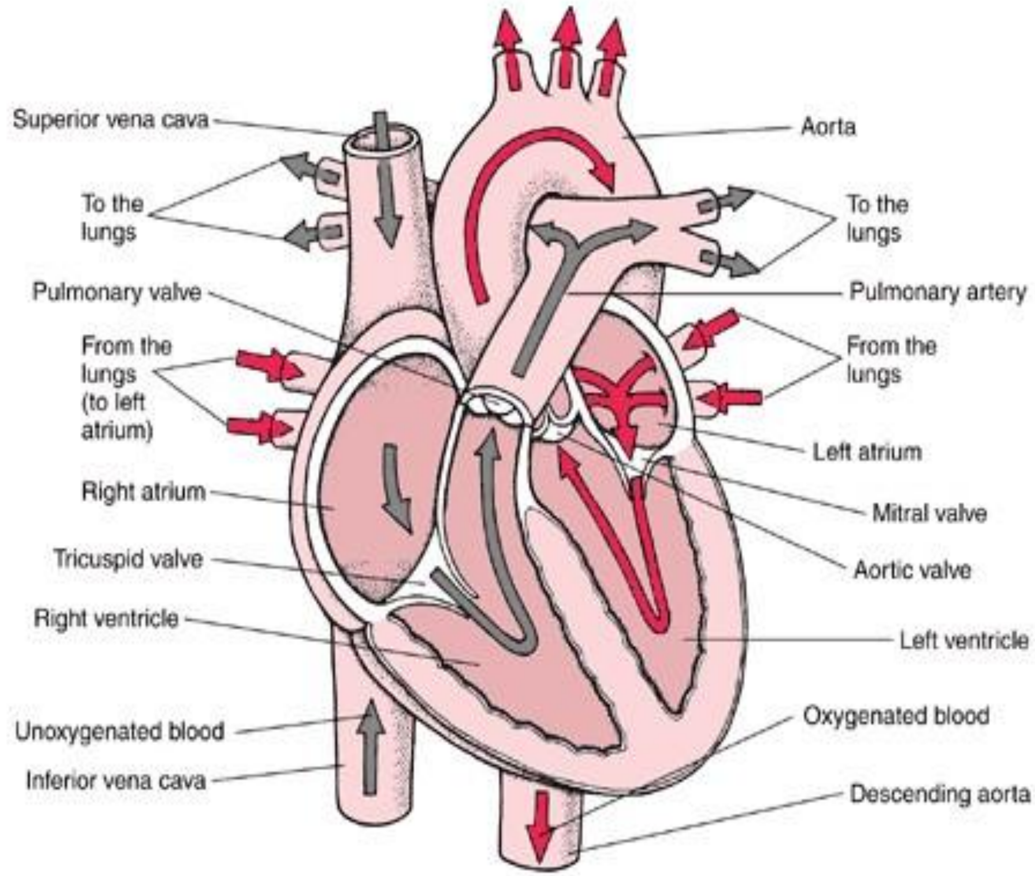
2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

- After the blood moves through the atrium, it is directed into a larger and thicker-walled ventricle.
- The ventricles then pushes blood our of the heart into an artery for transport away from the heart



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Sports, exercise and health science

Topic 2
Exercise physiology

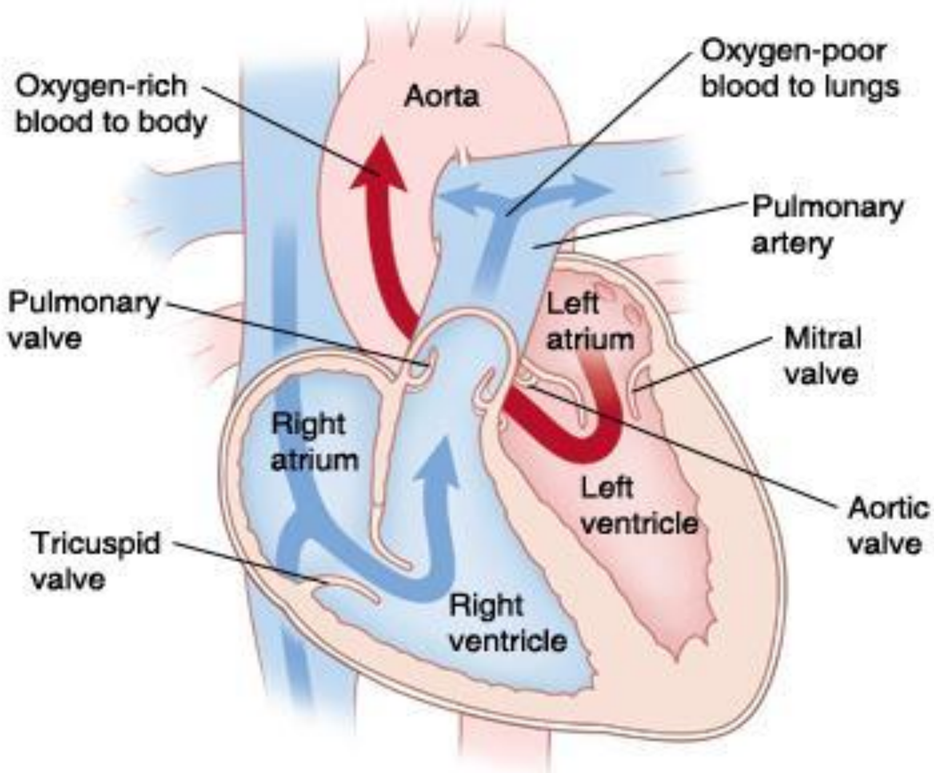
Sub-topics

1. Structure & function of the ventilatory system

2. Structure & function of the cardiovascular system

2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

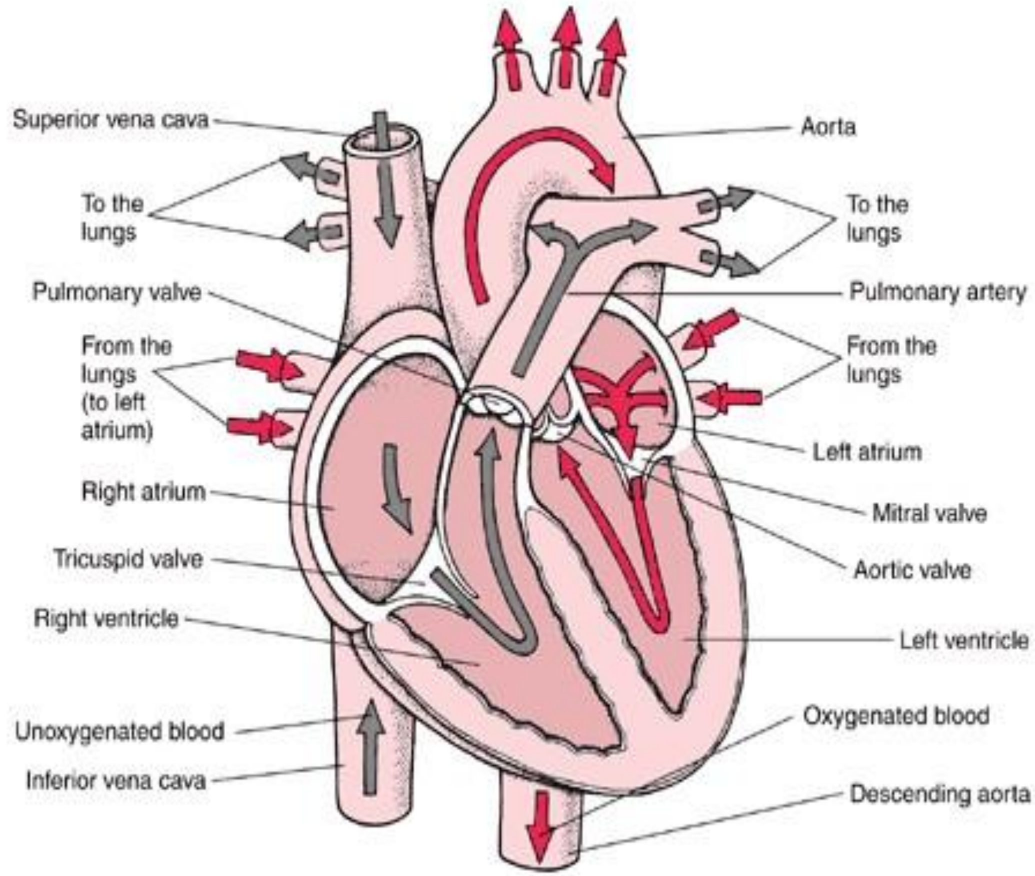
- Ventricles are the discharging chambers of the heart
- **Right ventricle** pumps blood into the pulmonary system (to the lungs)
- **Left ventricle** pumps blood into the aorta (to the body`



2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

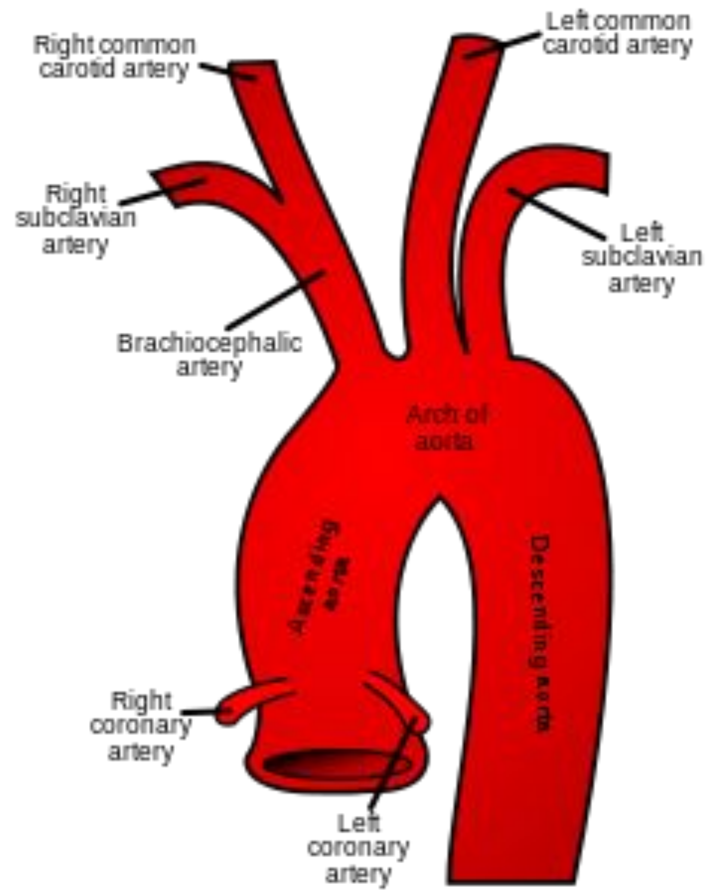
Vessels **returning blood to the heart** include:

1. Right and left pulmonary veins
2. Superior and inferior vena cava



2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

- Vessels moving **blood away from the heart** include:
  1. Pulmonary trunk, which splits into right and left pulmonary arteries
  2. Ascending aorta (three branches)
     a. Brachiocephalic
     b. Left common carotid
     c. Subclavian arteries

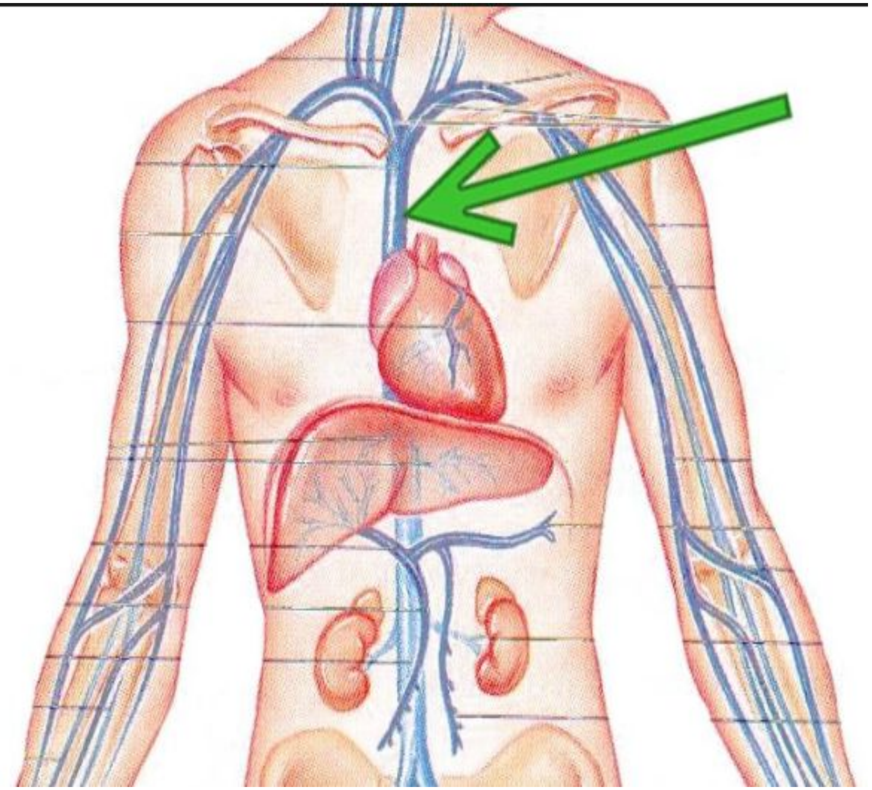


2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

Vessels **returning blood to the heart** include:

Superior vena cava - A large vein that receives blood from the head, neck, upper extremities, and thorax and delivers it to the right atrium of the heart.

Inferior vena cava - returns deoxygenated blood to the heart from parts of the body below the diaphragm (kidneys to toes)



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Sports, exercise and health science

Topic 2

Exercise physiology

Sub-topics

1. Structure & function of the ventilatory system

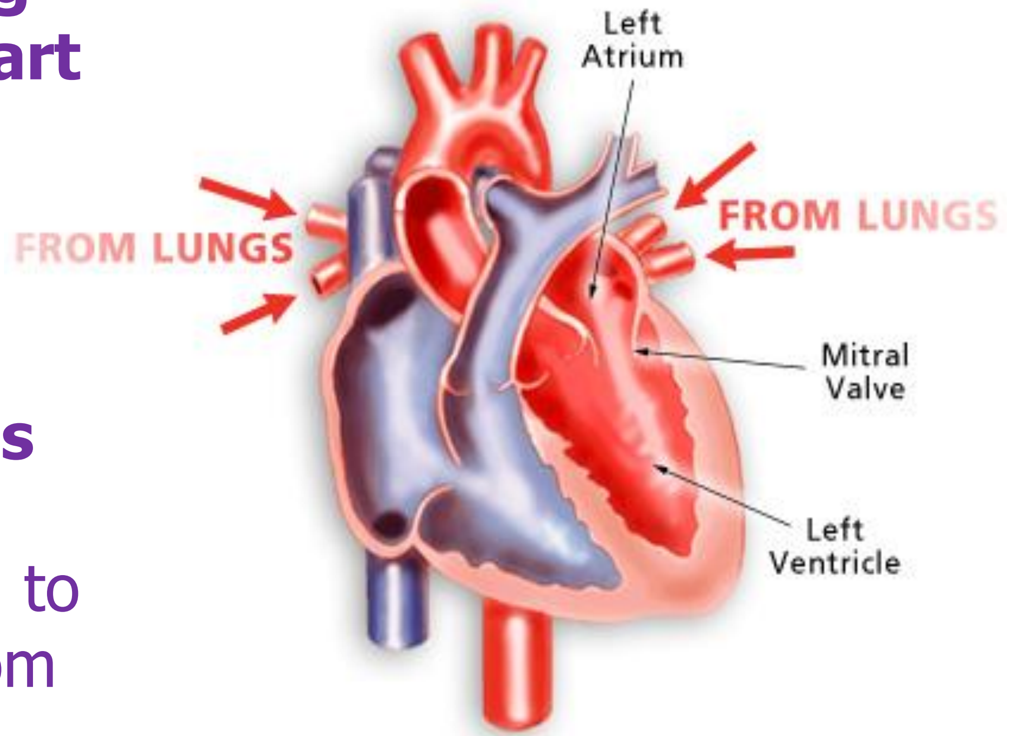
2. Structure & function of the cardiovascular system

2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

Vessels **returning blood to the heart** include:

Right and left pulmonary veins

- They return oxygenated blood to the left atrium from the lungs



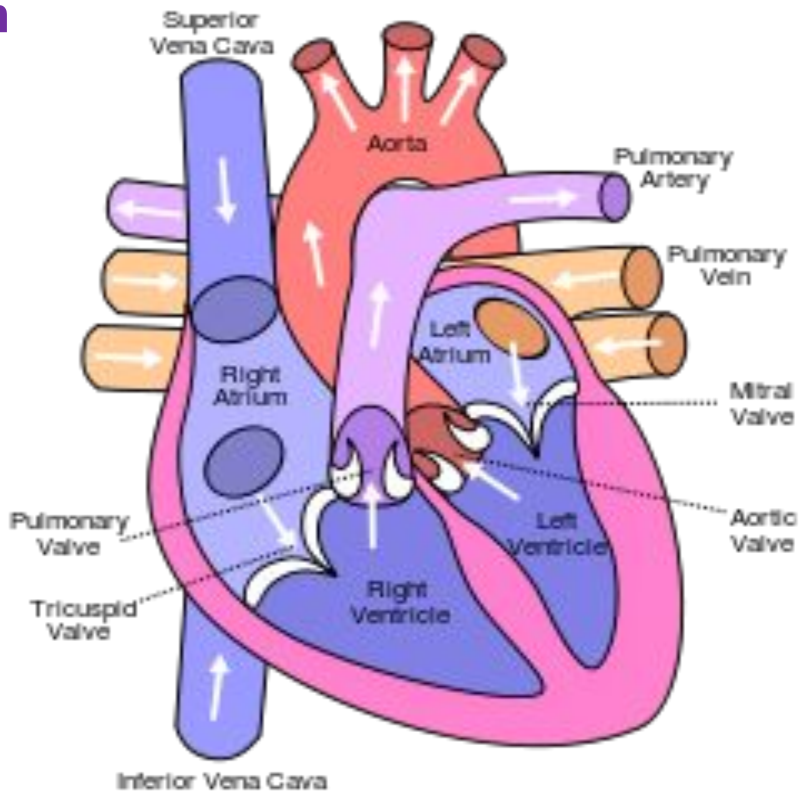
2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

Vessels moving **blood away from the heart** include:

Right & Left Pulmonary Artery

- responsible for transporting oxygen-depleted blood away from the heart and back toward the lungs.

- The main **artery** splits into the **left pulmonary artery** and the **right pulmonary artery**, each of which directs the blood to the corresponding lung.



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Sports, exercise and health science

Topic 2 Exercise physiology

Sub-topics

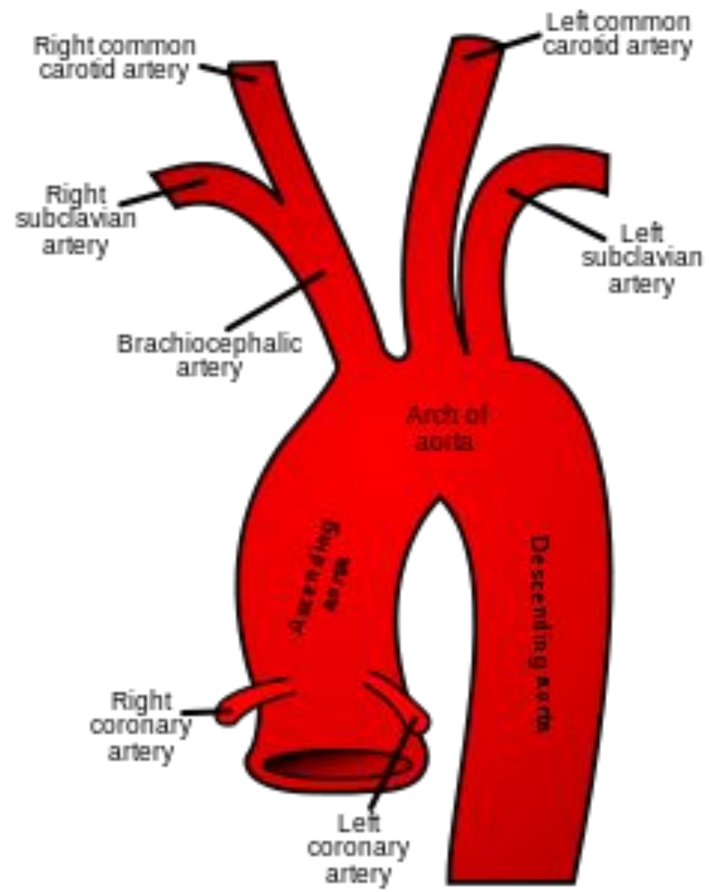
1. Structure & function of the ventilatory system
2. Structure & function of the cardiovascular system

2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

Vessels moving **blood away from the heart** include:

Of the AORTA

- **Brachiocephalic artery** – supplies blood to the right arm, head and neck (includes the right common carotid artery
- **Left common carotid artery** – supplies blood to the head, neck and left arm
- **Left subclavian artery** – supplies blood to the upper body and left arm



2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

The heart has 4 valves:

- The mitral valve and tricuspid valve, which control blood flow from the atria to the ventricles
- The aortic valve and pulmonary valve, which control blood flow out of the ventricles

Essentials for properly working valves:

- The valve is properly formed and flexible.
- The valve should open all the way so that the right amount of blood can pass through
- The valve closes tightly so that no blood leaks back into the chamber.

Human heart valves are remarkable structures. These tissue-paper thin membranes attached to the heart wall constantly open and close to regulate blood flow (causing the sound of a heartbeat). This flexing of the tissue occurs day after day, year after year. In fact, the tissue withstands about 80 million beats a year, or 5 to 6 billion beats in an average lifetime. Each beat is an amazing display of strength and flexibility.

2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

How the valves on the RIGHT SIDE of the heart work:

1. The veins of the body all eventually drain into the right atrium, which is the receiving chamber of the right side of the heart.
2. Once the right atrium is full, the tricuspid valve opens, allowing the oxygenated blood to flow into the right ventricle.
3. As the pressures begin to change in the right atrium and right ventricle, the tricuspid valve closes.
4. The right ventricle then contracts and pumps the deoxygenated blood through the pulmonary valve, and into the lungs.
5. After the right ventricle empties, the pulmonary valve closes and everything starts again

2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

How the valves on the LEFT SIDE of the heart work:

1. The newly oxygenated blood flows from the lungs to the left atrium
2. As the left atrium fills with oxygenated blood, the mitral valve remains closed.
3. As the pressure changes within the left atrium and left ventricle, the mitral valve opens, allowing the oxygenated blood to flow into the left ventricle.
4. As the left ventricle fills, the pressures in the left atrium and left ventricle changes. Once the left ventricle is filled, the mitral valve closes as the left ventricle begins to contract. (By closing at this time, the mitral valve prevents the oxygenated blood in the left ventricle from flowing back to the lungs.)
5. As the left ventricle contracts, the oxygenated blood leaves the heart and crosses the aortic valve.
6. The oxygenated blood leaves the left ventricle and crosses the aortic valve which enters the aorta and distributes blood to the body.

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Sports, exercise and health science

Topic 2

Exercise physiology

Sub-topics

1. Structure & function of the ventilatory system

2. Structure & function of the cardiovascular system

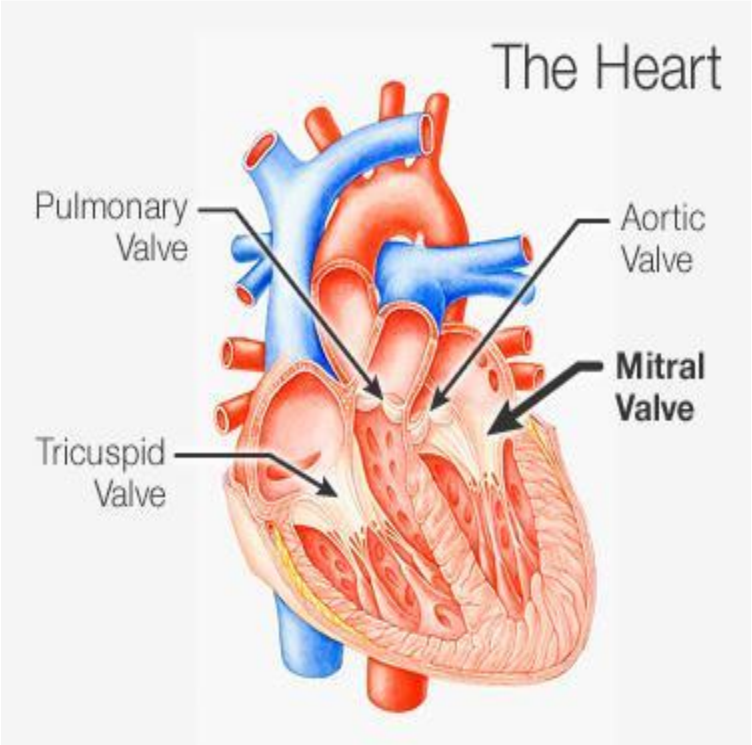
2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

MITRAL VALVE (aka Bicuspid valve, aka right Atrioventricular valve)

- Closes off the left atrium, collecting the oxygen-rich blood coming in from the lungs.
- Opens to allow blood to pass from the left atrium to the left ventricle.

AORTIC VALVE

- Closes off the left ventricle that holds the oxygen-rich blood before it is pumped out to the body.
- Opens to allow blood to leave the heart (from the left ventricle to the aorta and on to the body).



IB

Sports, exercise and health science

Topic 2

Exercise physiology

Sub-topics

1. Structure & function of the ventilatory system

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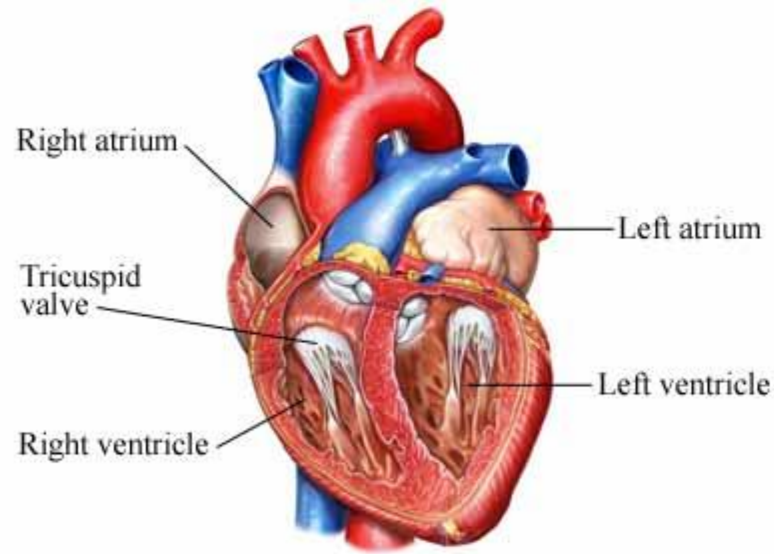
2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels

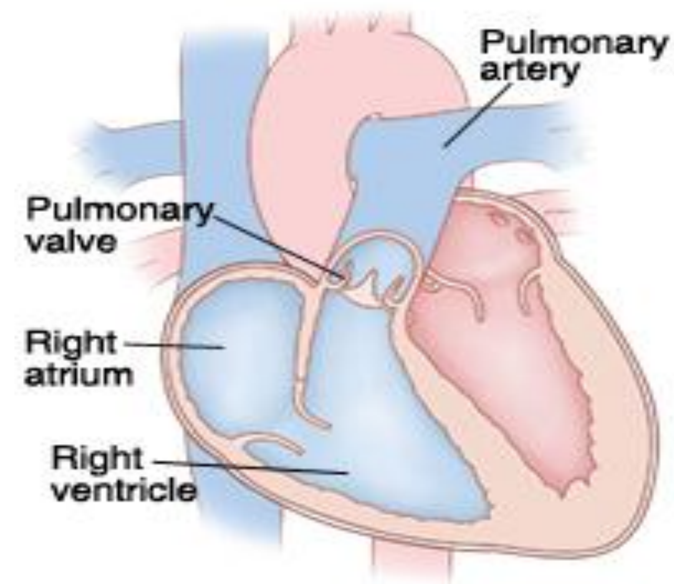
TRICUSPID VALVE (aka Right Atrioventricular Valve)

- Closes off the right atrium that holds blood coming in from the body.
- Opens to allow blood to flow from the right atrium to the right ventricle.
- Prevents the back flow of blood from the ventricle to the atrium when blood is pumped out of the ventricle.



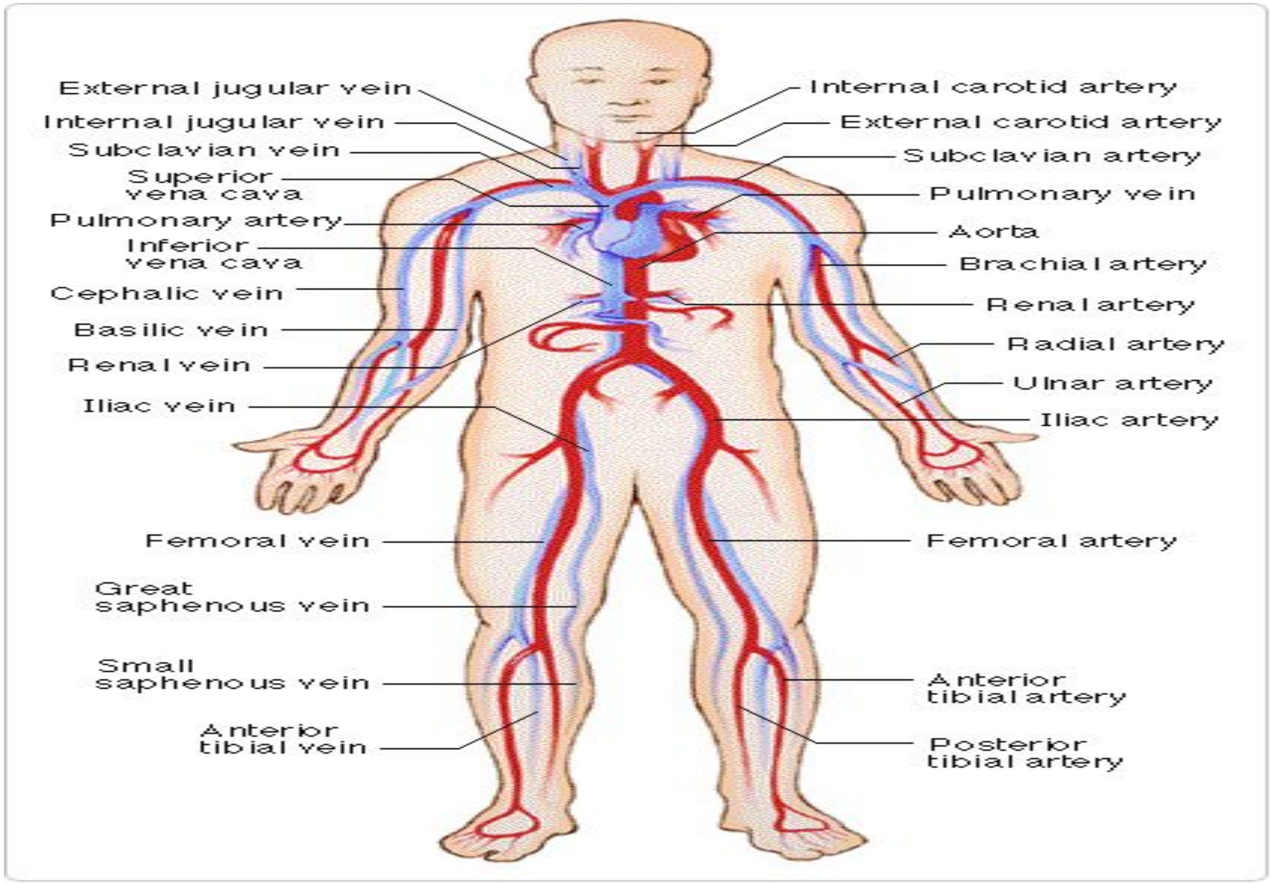
PULMONARY VALVE (or Pulmonic Valve)

- Closes off the right ventricle.
- Opens to allow blood to be pumped from the heart to the lungs (through the pulmonary artery) where it will receive oxygen.



Exercise Physiology

2.2.3 Describe the anatomy of the heart with reference to the heart chambers, valves and major blood vessels



Exercise Physiology

2.2.4 Describe the intrinsic and extrinsic regulation of heart rate and the sequence of excitation in the heart muscle

- The heart is able to beat after being separated from the body of it's owner (as seen in horror films/etc) is not totally a product of overactive imaginations.
- The heart can actually continue to beat for a number of hours if supplied with appropriate nutrients and salts.
- This is because the heart has it's own specialized conduction system and can beat independently of it's nerve supply.

Solomon & Davis

The hearts blood supply

2.2.4 Describe the intrinsic and extrinsic regulation of heart rate and the sequence of excitation in the heart muscle

- **Coronary circulation**
  - **Right coronary artery:** Supplies predominantly the right atrium and ventricle
  - **Left coronary artery:** Supplies the left atrium and ventricle, and a small portion of the right ventricle

IB

Sports, exercise and health science

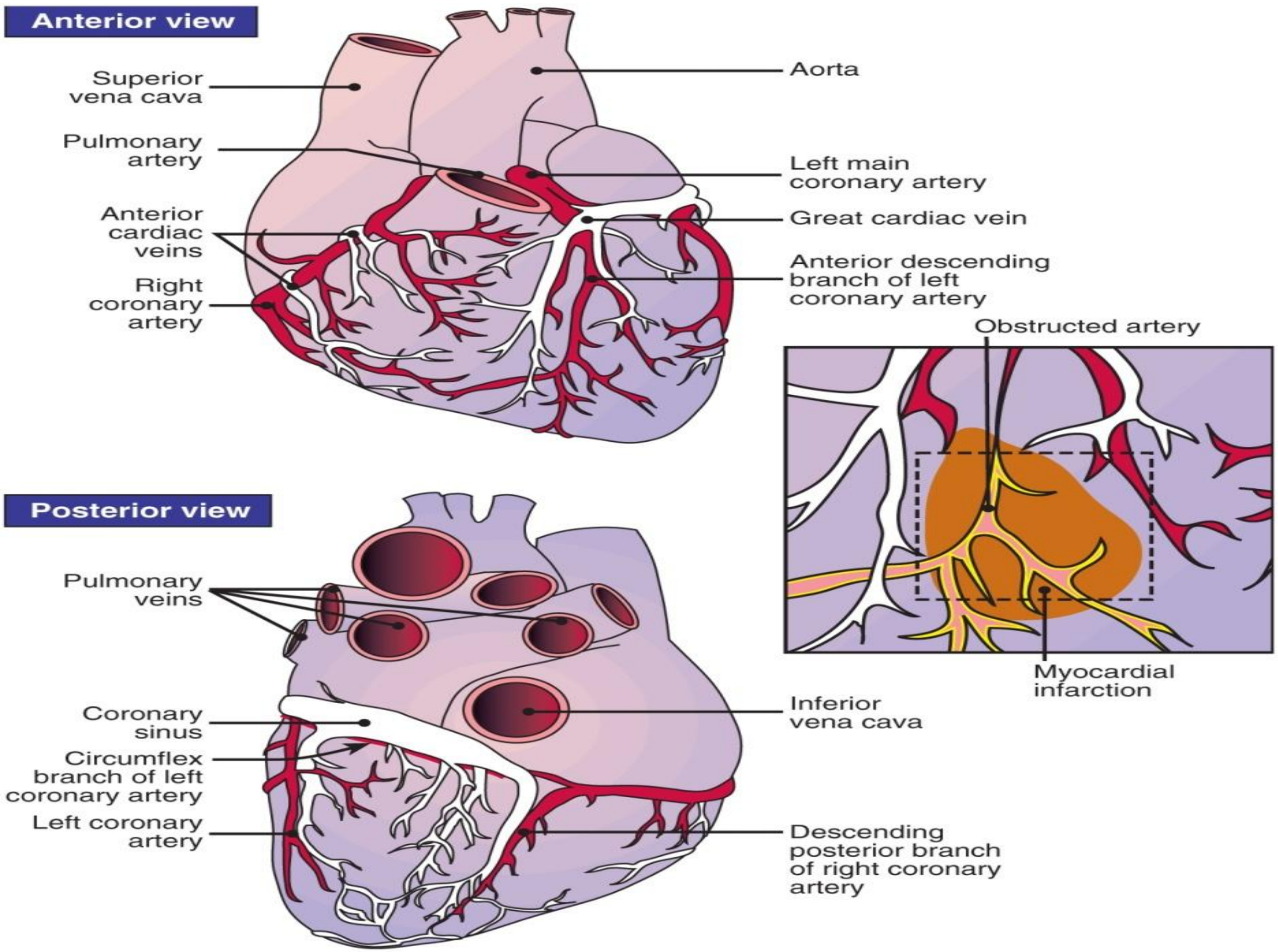
The hearts blood supply

Topic 2

Exercise physiology

Sub-topics

1. Structure & function of the ventilatory system
2. Structure & function of the cardiovascular system



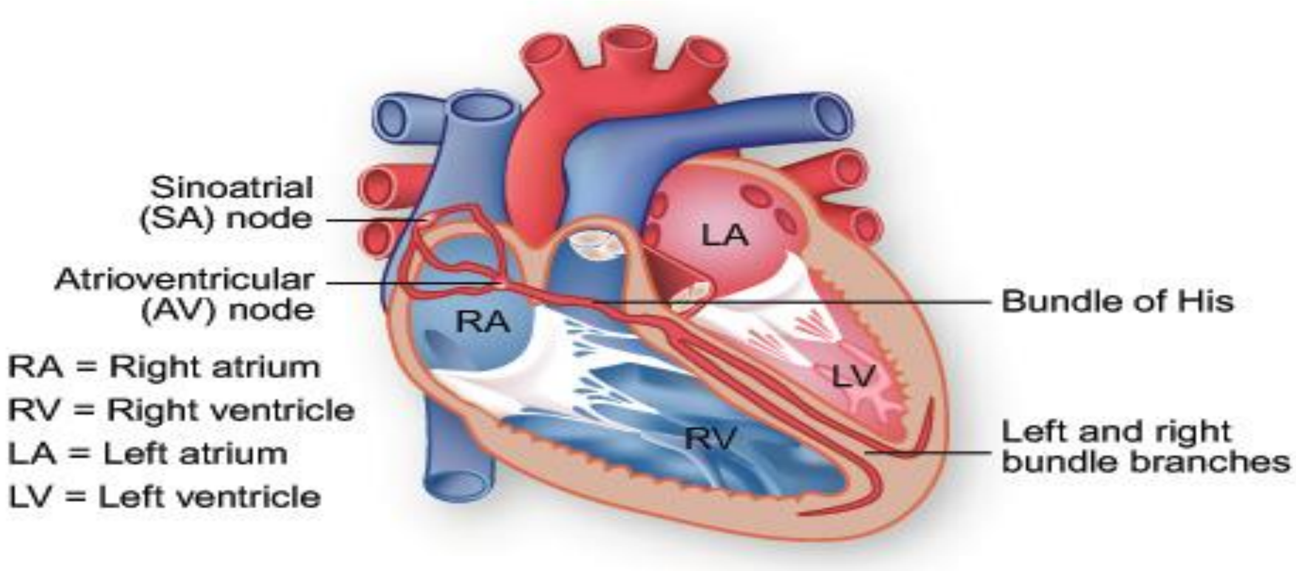
Exercise Physiology

2.2.4 Describe the intrinsic and extrinsic regulation of heart rate and the sequence of excitation in the heart muscle

- The sinoatrial (SA) node is a small mass of specialized muscle in the posterior wall of the right atrium.
- Because automatic self-excitation of the SA node initiates each heart beat, setting the basic pace for the heart rate, the SA node is known as the pace maker.
- The end of the fibers of the SA node fuse with surrounding atrial muscle fibers so that the contraction spreads, producing atrial contraction.

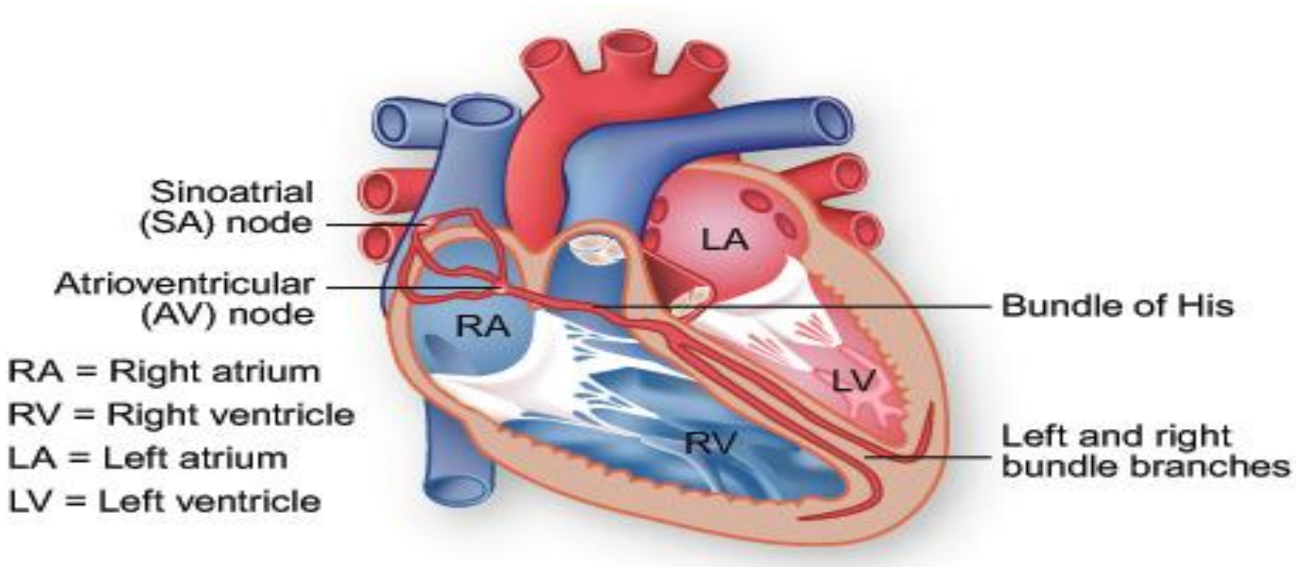
Exercise Physiology

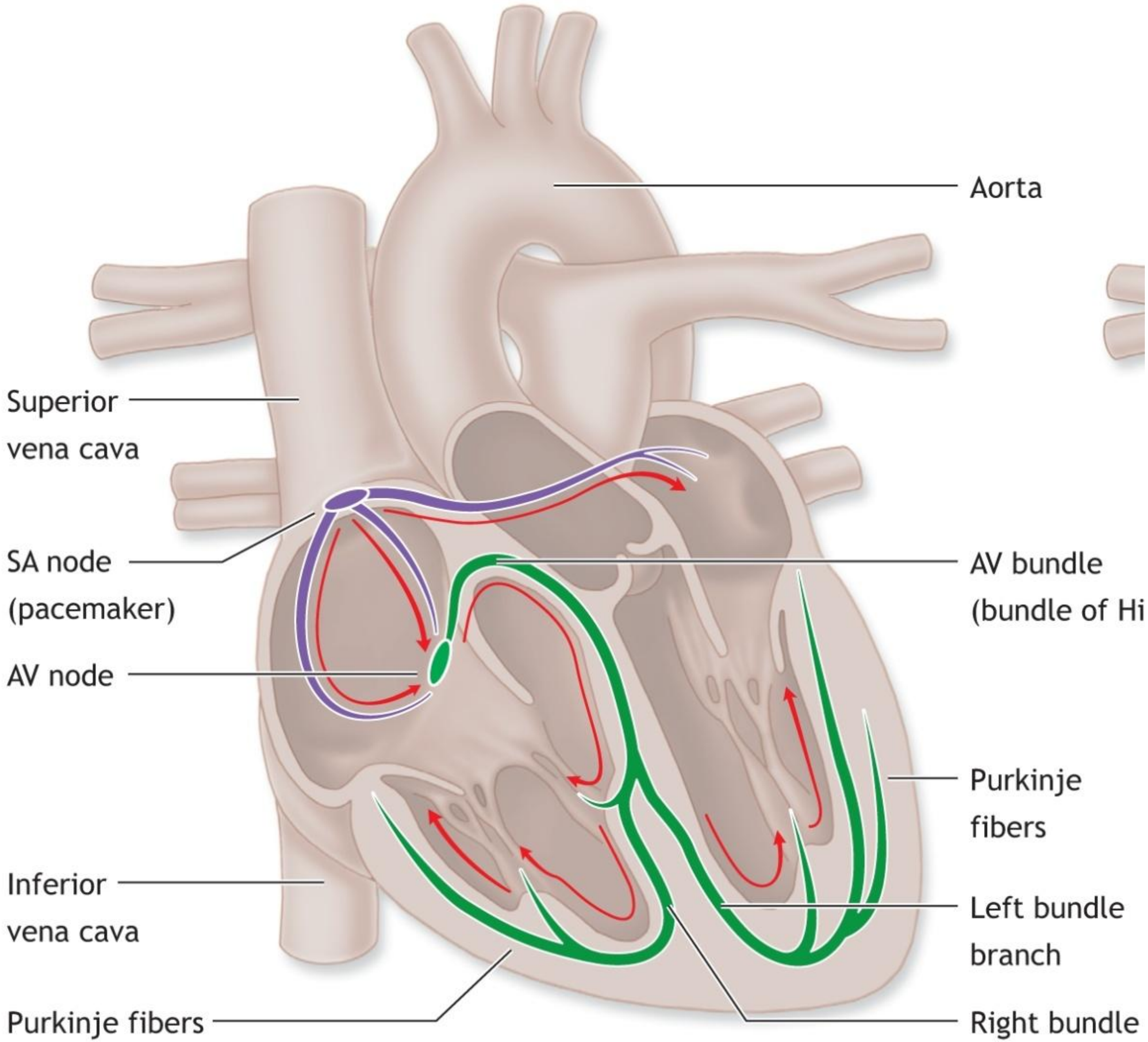
- Several groups of atrial muscle fibers conduct the contraction to the atrioventricular (AV) node, which spreads action potential (impulse) throughout the rest of the heart via specialized muscle fibers called Purkinje fibers.
    - These form the atrioventricular (AV) bundle OR bundle of his.



Exercise Physiology

- The heart rate that is produced solely by the SA node, with no neural control or hormonal control, is known as **intrinsic heart rate regulation**.





Aorta
Superior vena cava
SA node (pacemaker)
AV node
Inferior vena cava
Purkinje fibers
AV bundle (bundle of Hi
Purkinje fibers
Left bundle branch
Right bundle

A little gruesome
You can close your eyes if it makes you uncomfortable.

Exercise Physiology

2.2.4 Describe the intrinsic and extrinsic regulation of heart rate and the sequence of excitation in the heart muscle

- Although the heart is capable of beating independently of body control systems, in order to adapt its rate to the changing needs of the body it is carefully regulated by the nervous system.
- A number of other factors, including hormones, blood chemistry and change in body temperature can influence heart rate.

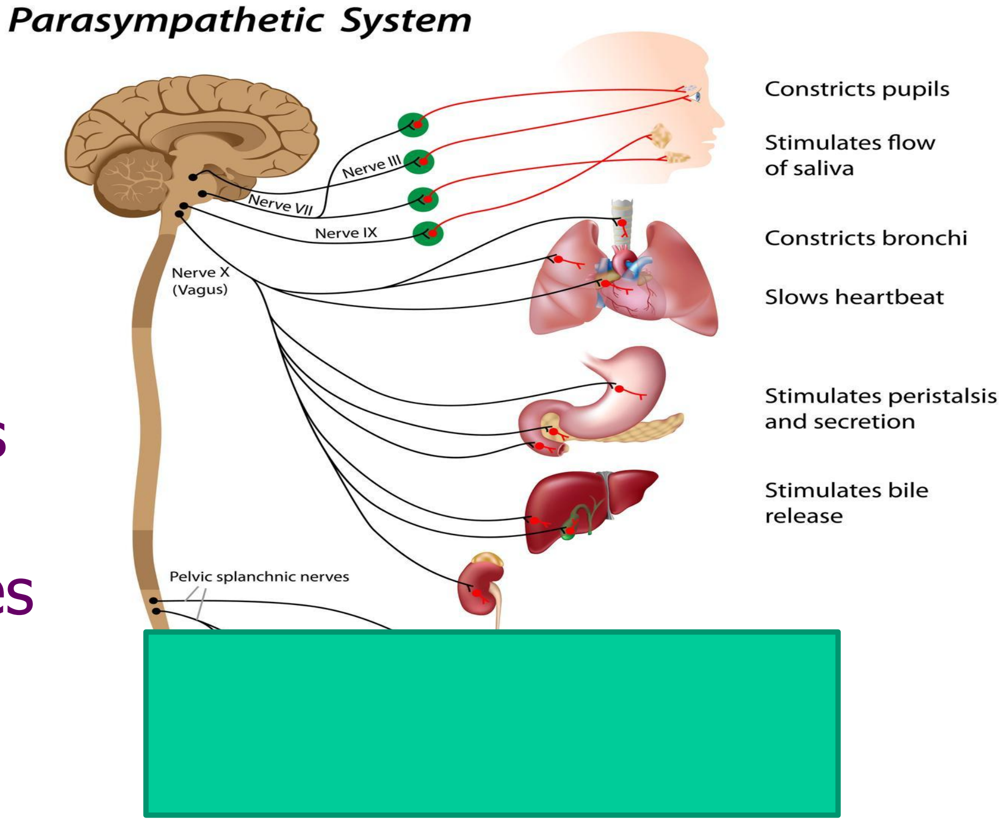
Exercise Physiology

2.2.4 Describe the intrinsic and extrinsic regulation of heart rate and the sequence of excitation in the heart muscle

- The heart is innervated (supplied with nerves) by:

- parasympathetic nerves that slow it's rate, and

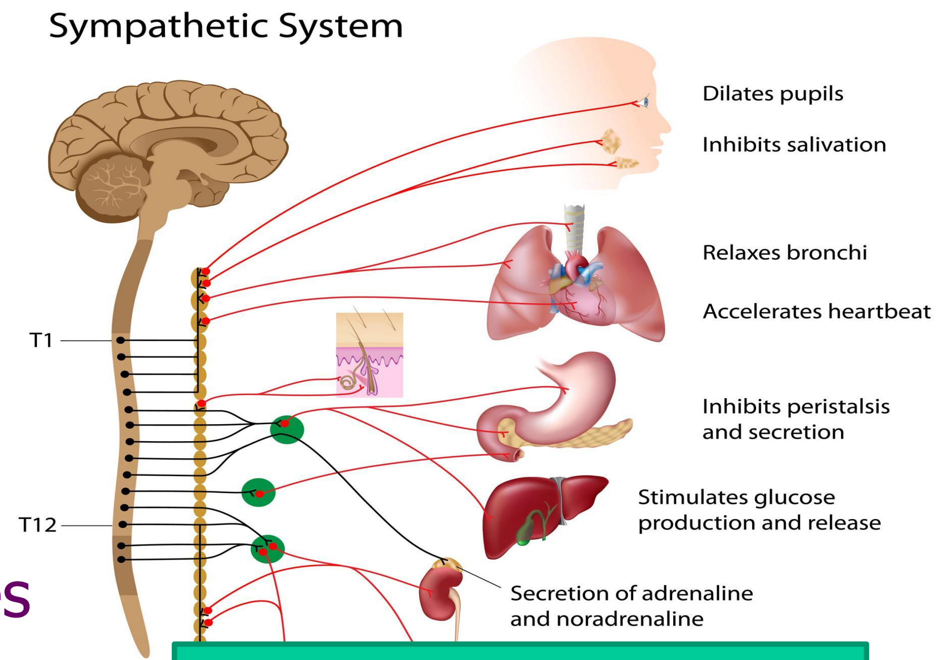
- sympathetic nerves that speed it up.



Exercise Physiology

2.2.4 Describe the intrinsic and extrinsic regulation of heart rate and the sequence of excitation in the heart muscle

- The heart is innervated (supplied with nerves) by <u>parasympathetic</u> nerves that slow it's rate, and by <u>sympathetic</u> nerves that speed it up.



Exercise Physiology

2.2.4 Describe the intrinsic and extrinsic regulation of heart rate and the sequence of excitation in the heart muscle

- The change of heart rate the sympathetic and parasympathetic nerves/nervous systems can produce is an example of **extrinsic heart rate regulation.**

IB
Sports, exercise and health science

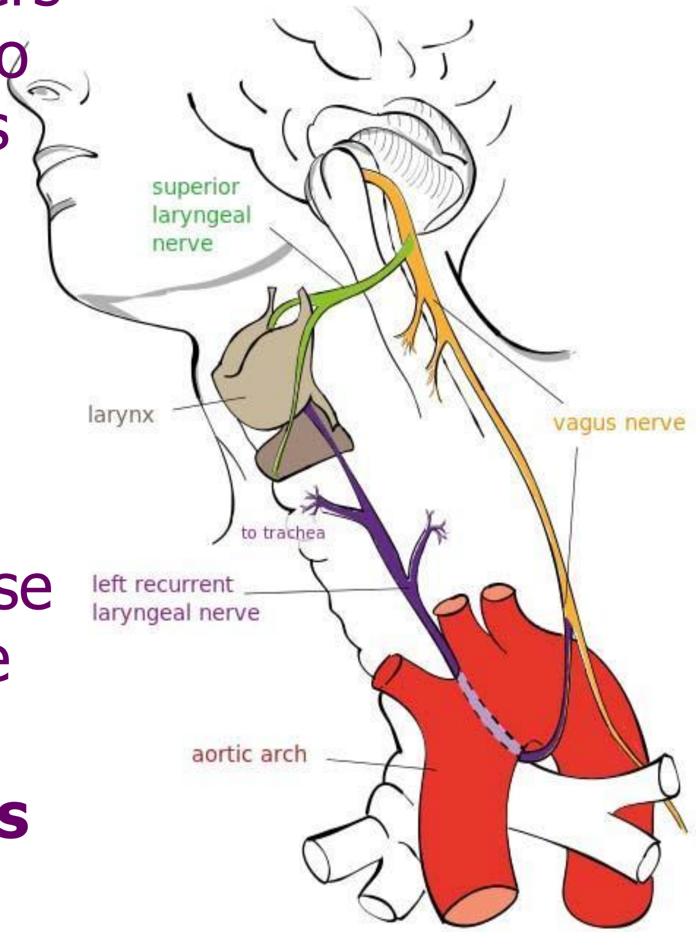
Exercise Physiology

Topic 2
Exercise physiology

Sub-topics

1. Structure & function of the ventilatory system
2. Structure & function of the cardiovascular system

- Parasympathetic innervation originates in the cardiac centers **in the medulla** and passes to the heart by way of the vagus nerves.
- Vagus nerve fibers supply the SA (sinoatrial) and AV (atrioventricular) nodes.
- When stimulated, these parasympathetic nerves release acetylcholine, which slows the heart.
- **This slowing of the heart is called Bradycardia**



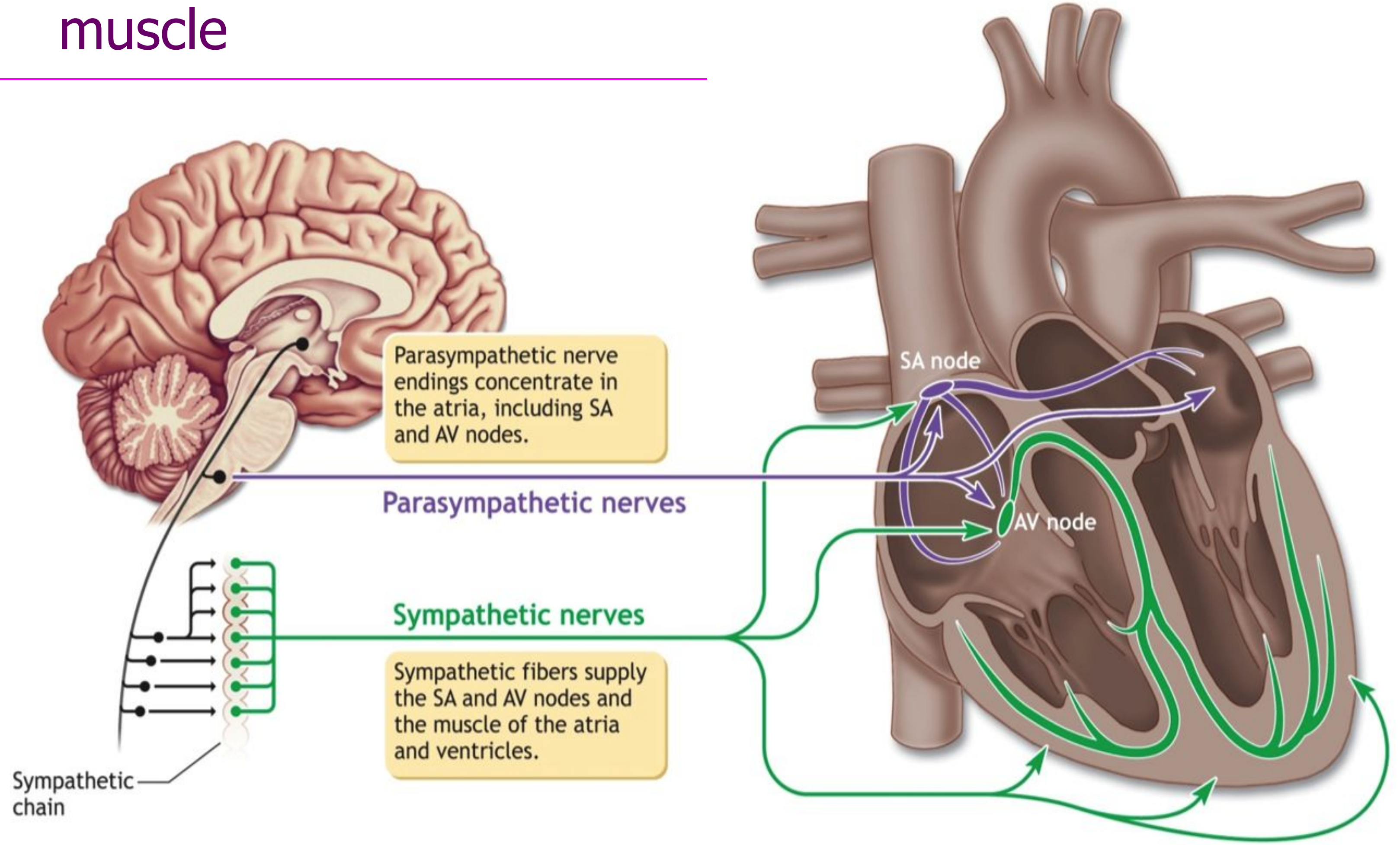
Exercise Physiology

2.2.4 Describe the intrinsic and extrinsic regulation of heart rate and the sequence of excitation in the heart muscle

- Sympathetic nerves that serve the heart originate in the **upper thoracic spinal cord** and reach the myocardium by way of several nerves sometimes called accelerator nerves.
- These nerves supply the nodes and also the muscle fibers themselves.

Exercise Physiology

2.2.4 Describe the intrinsic and extrinsic regulation of heart rate and the sequence of excitation in the heart muscle



Exercise Physiology

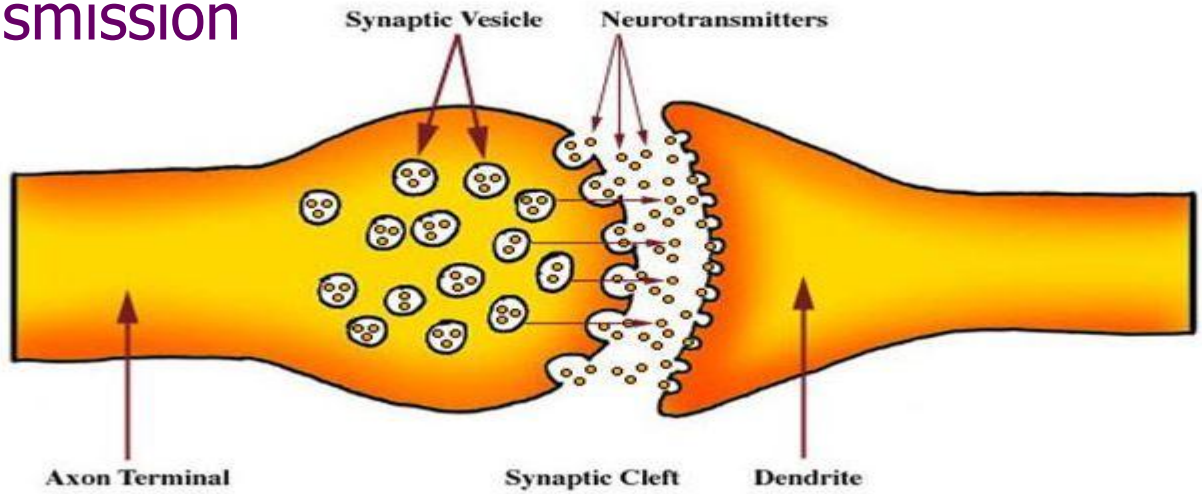
2.2.4 Describe the intrinsic and extrinsic regulation of heart rate and the sequence of excitation in the heart muscle

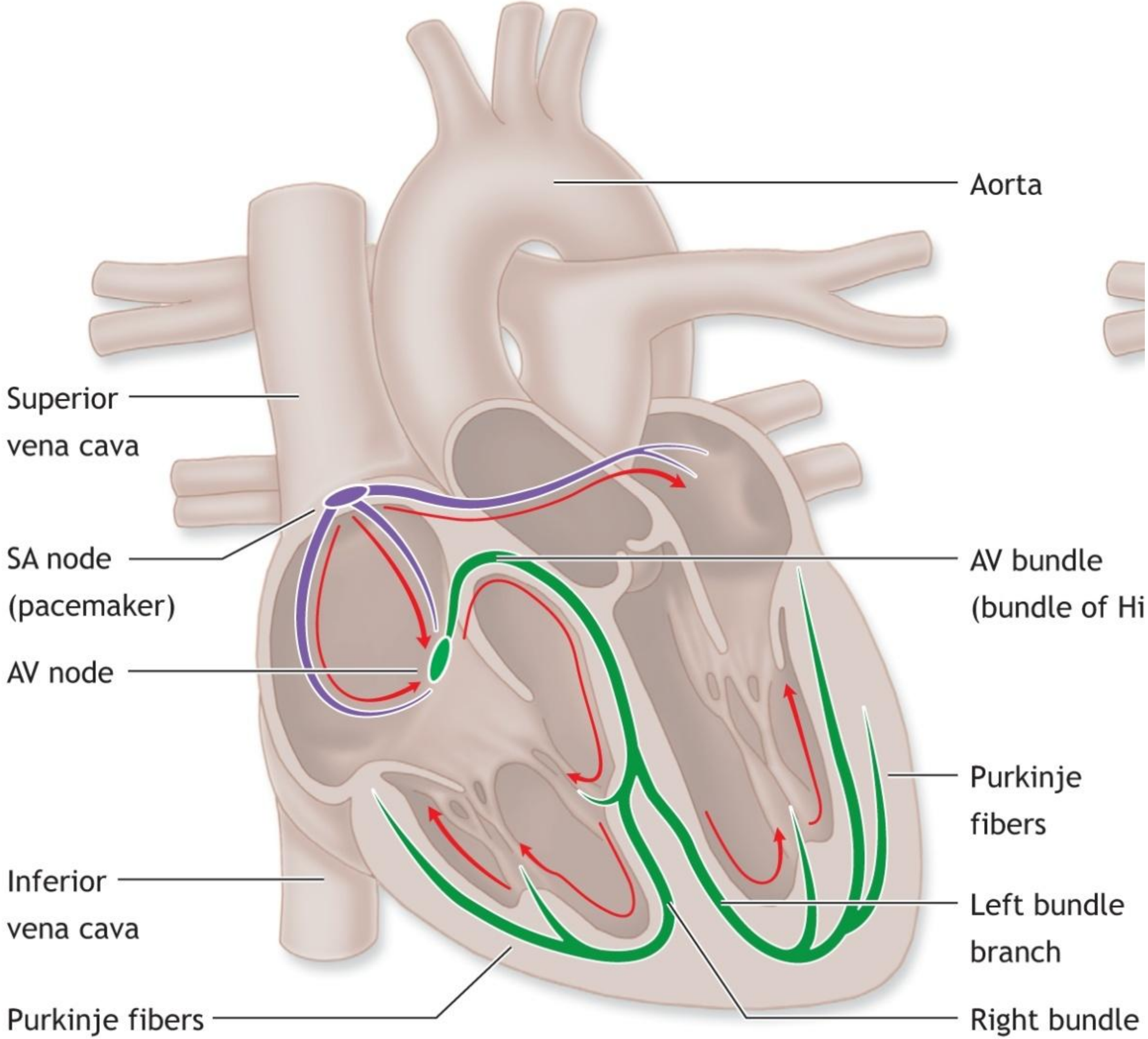
- When Sympathetic nerves are stimulated, they release norepinephrine or noradrenaline, which increases the heart rate as well as the strength of ventricular contraction (heart beat) .
- This speeding up of the heart rate is called Tachycardia

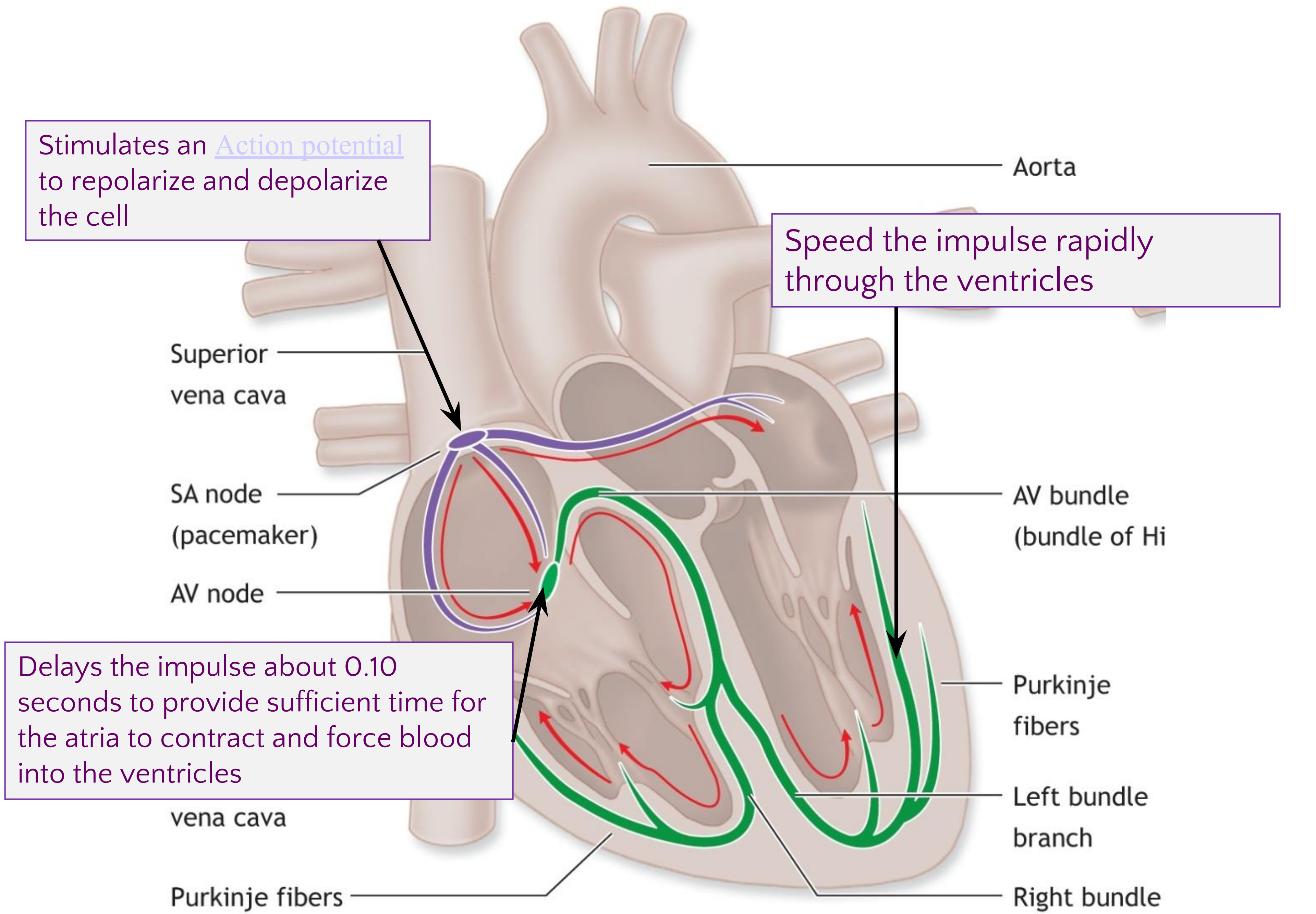
Exercise Physiology

2.2.4 Describe the intrinsic and extrinsic regulation of heart rate and the sequence of excitation in the heart muscle

- Noradrenaline is released from the adrenal medulla of the adrenal glands as a hormone into the blood
- It is also a neurotransmitter in the central nervous system and sympathetic nervous system where it is released from noradrenergic neurons during synaptic transmission

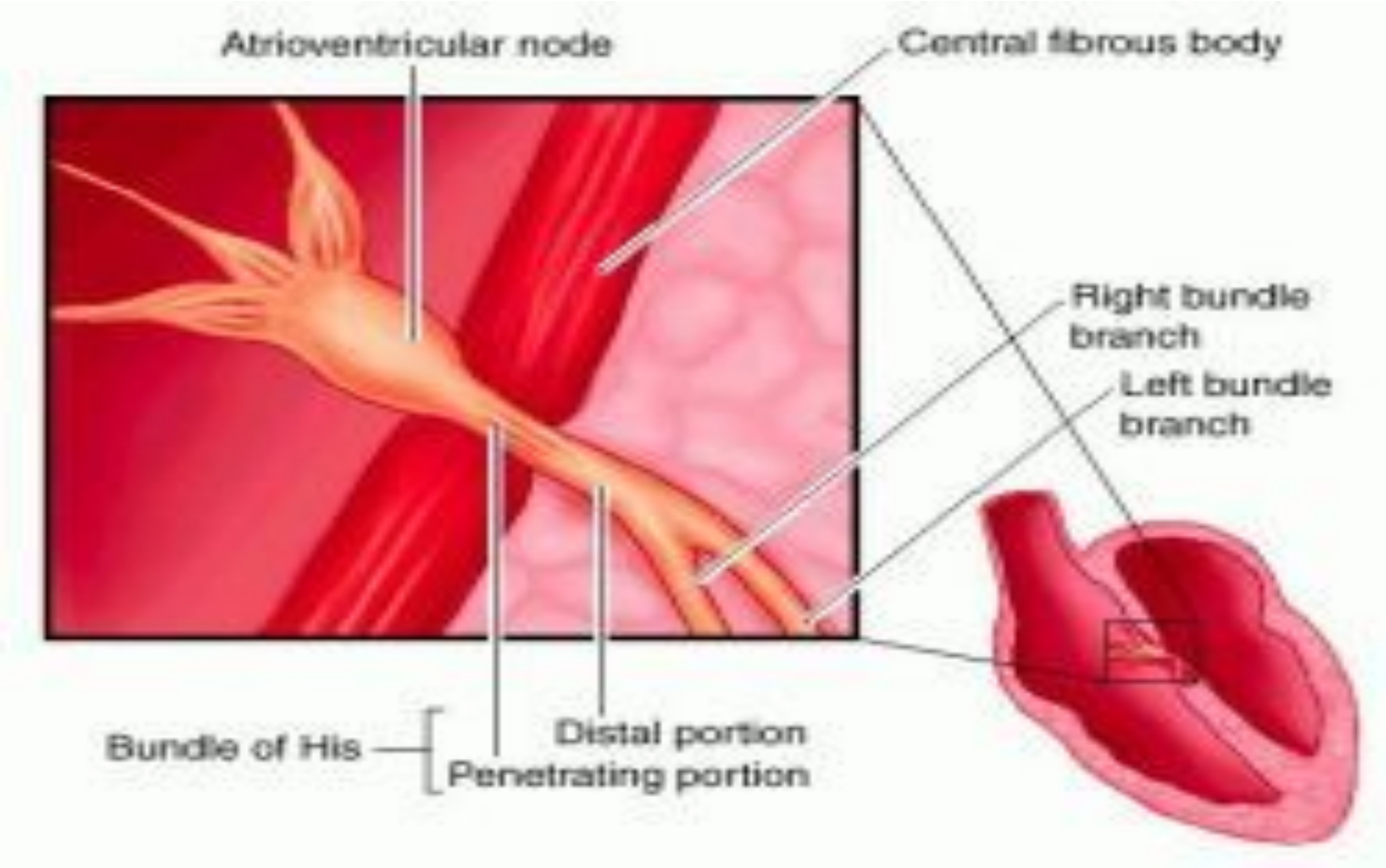


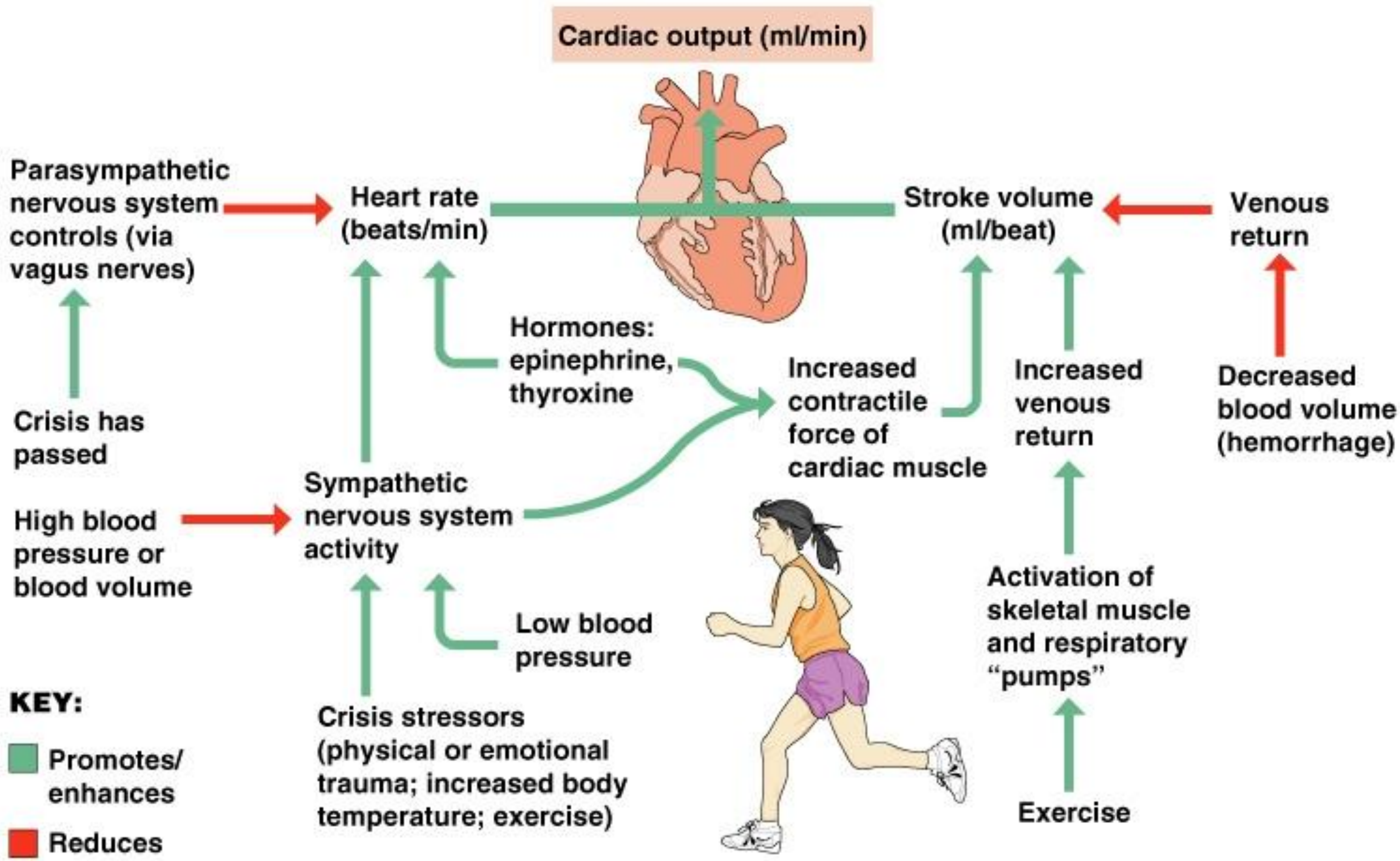

Aorta
Superior vena cava
SA node (pacemaker)
AV node
Inferior vena cava
Purkinje fibers
AV bundle (bundle of Hi
Purkinje fibers
Left bundle branch
Right bundle

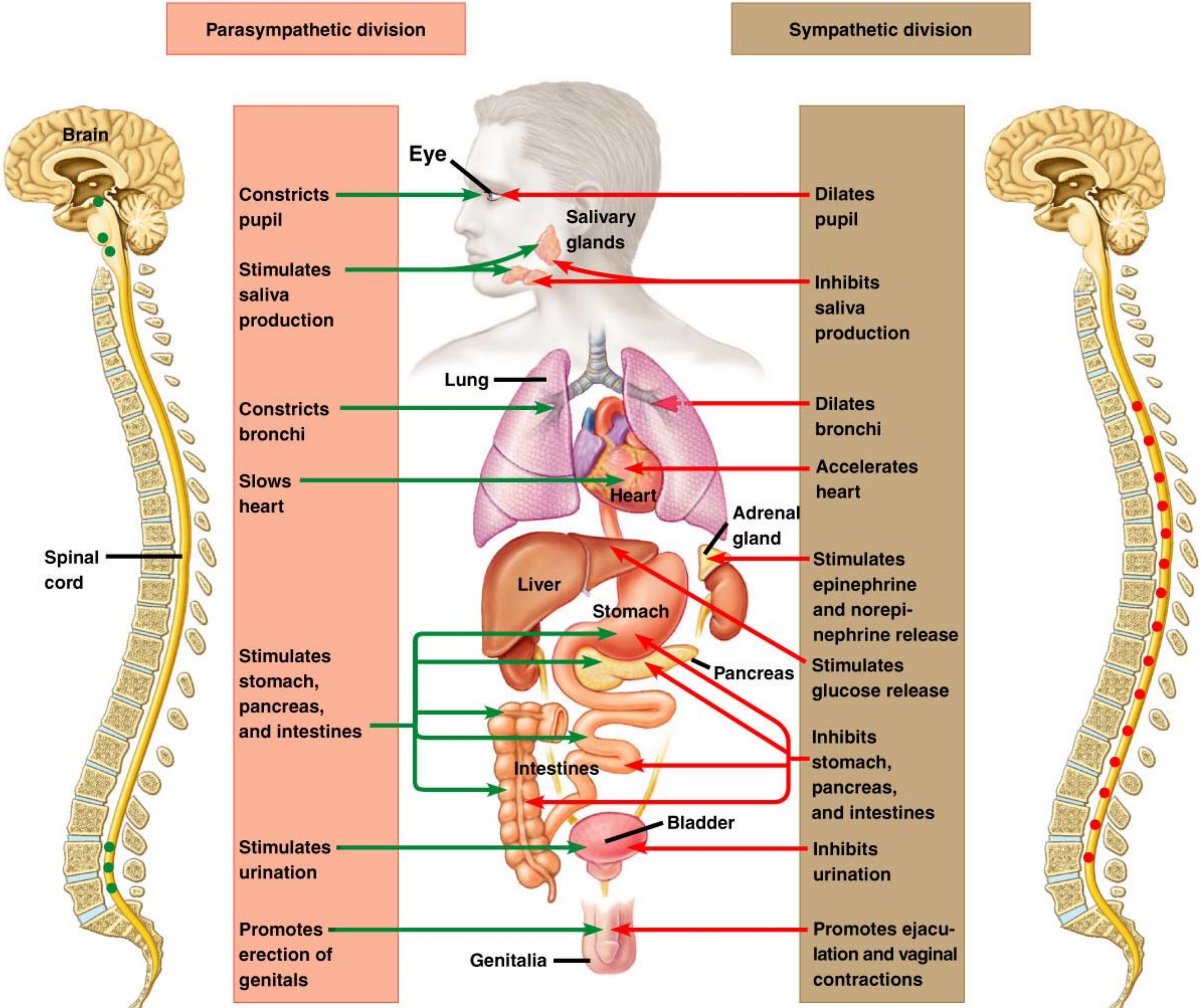

Stimulates an Action potential to repolarize and depolarize the cell
Speed the impulse rapidly through the ventricles
Delays the impulse about 0.10 seconds to provide sufficient time for the atria to contract and force blood into the ventricles
Aorta
Superior vena cava
SA node (pacemaker)
AV node
AV bundle (bundle of Hi
Purkinje fibers
Left bundle branch
vena cava
Purkinje fibers
Right bundle

Exercise Physiology

2.2.4 Describe the intrinsic and extrinsic regulation of heart rate and the sequence of excitation in the heart muscle




Cardiac output (ml/min)
Parasympathetic nervous system controls (via vagus nerves)
Heart rate (beats/min)
Stroke volume (ml/beat)
Venous return
Hormones: epinephrine, thyroxine
Increased contractile force of cardiac muscle
Increased venous return
Decreased blood volume (hemorrhage)
Crisis has passed
Sympathetic nervous system activity
High blood pressure or blood volume
Low blood pressure
Activation of skeletal muscle and respiratory "pumps"
Crisis stressors (physical or emotional trauma; increased body temperature; exercise)
Exercise
KEY:
Promotes/ enhances
Reduces


Parasympathetic division
Sympathetic division
Brain
Spinal
cord
Eye
Constricts
pupil
Dilates
pupil
Salivary
glands
Stimulates
saliva
production
Inhibits
saliva
production
Lung
Constricts
bronchi
Dilates
bronchi
Slows
heart
Accelerates
heart
Heart
Adrenal
gland
Stimulates
epinephrine
and norepi-
nephrine release
Liver
Stomach
Stimulates
glucose release
Pancreas
Stimulates
stomach,
pancreas,
and intestines
Inhibits
stomach,
pancreas,
and intestines
Intestines
Bladder
Stimulates
urination
Inhibits
urination
Promotes
erection of
genitals
Promotes ejacu-
lation and vaginal
contractions
Genitalia

Exercise Physiology

2.2.6 Describe the relationship between heart rate, cardiac output and stroke volume at rest and during exercise

- Heart Rate = the speed of the heartbeat measured by the number of contractions of the heart per minute (bpm)
- Cardiac Output = the amount of blood pumped from the heart in one minute. This measured in liters per minute.
- Stroke Volume = the amount of blood pumped by each ventricle in each contraction. The average volume is about 0.07 liters of blood per beat.

Exercise Physiology

2.2.7 Analyse cardiac output, stroke volume and heart rate data for different populations at rest and during exercise.

- All of the previous increase as a result of exercise

- One response to exercise of the cardiovascular system is the increase in cardiac output from around 5 liters at rest to between 20 and 30 liters during maximal exercise.
- The response is due to an increase in stroke volume in the rest to exercise transition, and an increase in heart rate.

Exercise Physiology

2.2.7 Analyse cardiac output, stroke volume and heart rate data for different populations at rest and during exercise.

- Heart rate can reach 200bpm or more in some individuals. Maximal cardiac output differs between people primarily due to differences in body size and the extent to which they might be endurance trained.

Sewell et.al 2005

Exercise Physiology

2.2.7 Analyse cardiac output, stroke volume and heart rate data for different populations at rest and during exercise.

- An improvement in cardiac performance brought about by endurance training occurs as a result of changes in:
  - Stroke volume (increased)
  - Heart rate (decreased for a set workload)
  - Ventricular mass and volume (increased)

Sewell et.al 2005

Exercise Physiology

2.2.8 Explain cardiovascular drift

- If you begin a 90 minute steady state ride on your bicycle trainer at a controlled intensity, your heart rate may be 145 after 10 minutes. However, as you ride and check your heart rate every 10 minutes, you will notice a slight upward "drift".

Exercise Physiology

2.2.8 Explain cardiovascular drift

- By 90 minutes, your heart rate may be 160.

- Why is this happening if intensity is held constant?
- There are two explanations.

1) As you exercise, you sweat. A portion of this lost fluid volume comes from the plasma volume. This decrease in plasma volume will diminish venous return and stroke volume. Heart rate again increases to compensate and maintain constant cardiac output. Maintaining high fluid consumption before and during the ride will help to minimize this cardiovascular drift, by replacing fluid volume.

Exercise Physiology

2.2.8 Explain cardiovascular drift

2) Your heart rate is controlled in large part by the "Relative" intensity of work by the muscles.

So in a long hard ride, some of your motor units fatigue due to glycogen (sugar) depletion. Your brain compensates by recruiting more motor units to perform the same absolute workload.

There is a parallel increase in heart rate. Consequently, a ride that began at heart rate 150, can end up with you exhausted and at a heart rate of 175, 2 hours later, even if speed never changed!

Blood Pressure

2.2.9 Define the terms systolic and diastolic blood pressure

- **Systolic blood pressure**
  - Highest arterial pressure measured after left ventricular contraction
- **Diastolic blood pressure**
  - Lowest arterial pressure measured during left ventricular relaxation

- **Normal rest values = 120 mm Hg/80 mm Hg**
- **Hypertensive values = 300/120**

Blood pressure during exercise

2.2.10 Analyse systolic and diastolic blood pressure data at rest and during exercise

- **Rhythmic Exercise:** Increases systolic pressure in the first few minutes and then levels off; diastolic pressure remains relatively unchanged
- **Resistance (static) Exercise:** Can increase blood pressure dramatically – Muscular force/contraction compresses peripheral arteries increasing the resistance to blood flow

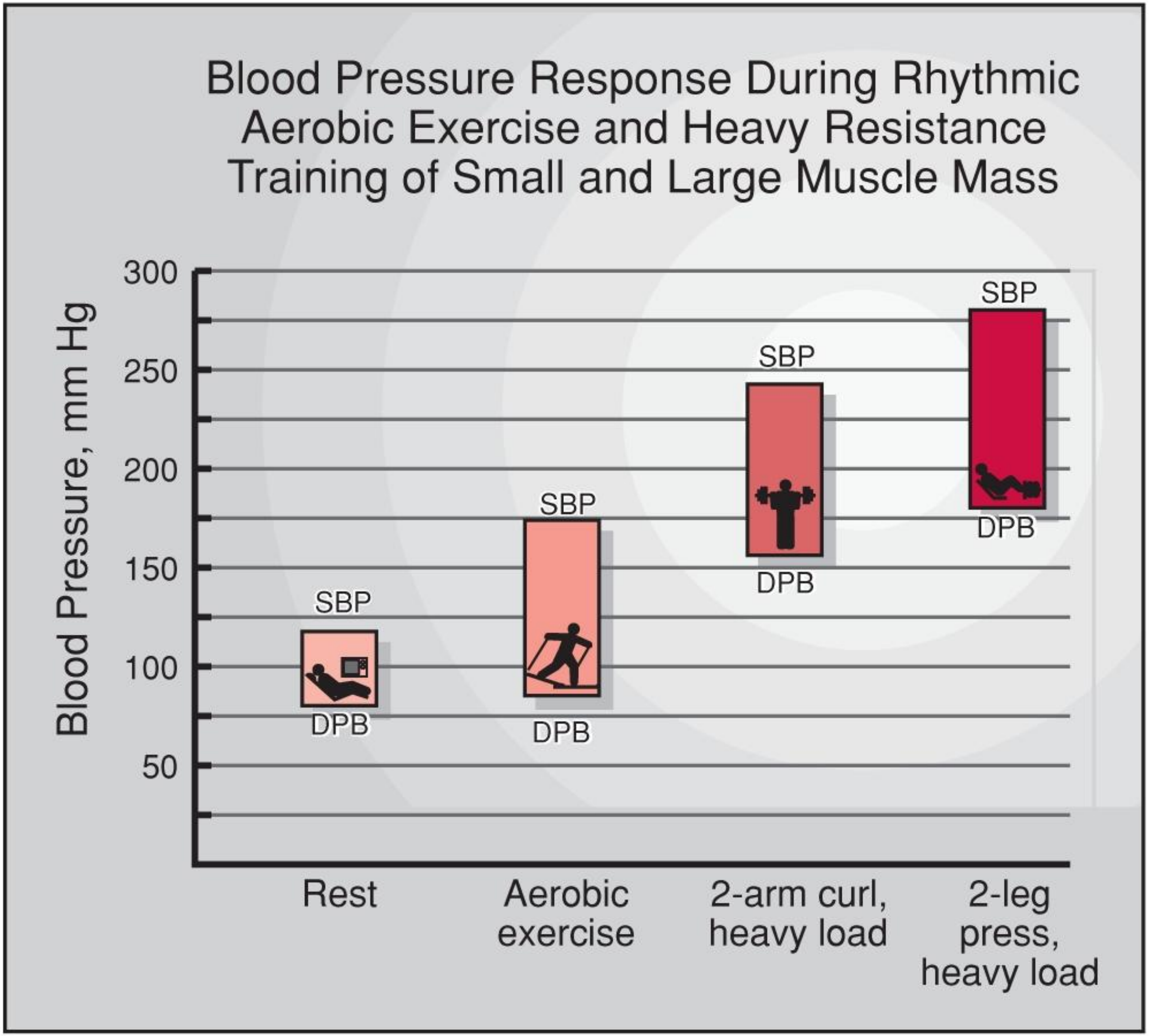
Blood pressure during exercise

2.2.10 Analyse systolic and diastolic blood pressure data at rest and during exercise

- **Upper-Body Exercise:** Exercise at a given percentage of $\dot{V}O_{2max}$ increases blood pressure substantially more in upper-body compared with lower-body exercise
- **In Recovery:** After a bout of sustained light- to moderate-intensity exercise, systolic blood pressure decreases below pre-exercise levels for up to 12 hours in normal and hypertensive subjects

Sub-topics

1. Structure & function of the ventilatory system
2. Structure & function of the cardiovascular system



BLOOD PRESSURE AND EXERCISE

For Your Information

LIFESTYLE CHOICES THAT LOWER BLOOD PRESSURE

Advice	Details	Decrease in Systolic Blood Pressure (mm Hg)
Lose excess weight	For every 20 lb you lose	5–20
Follow the DASH diet	Eat a lower fat diet rich in vegetables, fruits, and low-fat dairy foods	8–14
Exercise daily	Get 30 minutes a day of aerobic activity (e.g., brisk walking)	4–9
Limit sodium	Eat no more than 2400 mg a day (1500 mg is better)	2–8
Limit alcohol	Have no more than 2 drinks a day for men or 1 drink a day for women *(1 drink = 12 oz beer, 5 oz wine, or 1.5 oz 80-proof liquor)*	2–4

IB

Sports, exercise and health science

Exercise Physiology

Topic 2

Exercise physiology

2.2.12 Compare the distribution of blood at rest and the redistribution of blood during exercise

Sub-topics

1. Structure & function of the ventilatory system
2. Structure & function of the cardiovascular system

- During exercise, and at rest, the diameter of arteries, arterioles, and capillaries needs to be regulated to keep blood pressure at a sufficient level.
- Involuntary smooth muscle cells that lines the walls, and control blood in and out of capillaries contract or relax to change the diameter and blood pressure.
- Circulatory and nervous system work in sync to maintain blood flow and pressure.

Exercise Physiology

2.2.12 Compare the distribution of blood at rest and the redistribution of blood during exercise

- During exercise, muscles demand more oxygen and nutrients. They also produce more waste and CO_2

- Thus, more blood flow to where it's needed.
- The capillaries in the muscle where more blood is needed become dilated (opened) to a greater extent letting more blood come in.
- Unnecessary capillaries are constricted, reducing blood flow to noncritical organs and parts of the body.

Exercise Physiology

2.2.12 Compare the distribution of blood at rest and the redistribution of blood during exercise

- It takes little pressure to force the blood through veins because they offer little resistance to blood flow. There diameters are large and vein walls are so thin they can hold large volumes of blood.

Solomon & Davis

Exercise Physiology

2.2.12 Compare the distribution of blood at rest and the redistribution of blood during exercise

- On the other hand when one stands still for a long period of time blood pools in the veins.
- Within a few moments, pressure increases in the capillaries (veins are not accepting blood from them because they are dammed up with their own), and some plasma is lost to interstitial fluid (fluid in/around cells & organs).
- After a short time as much as 20% of the blood volume can be lost from circulation in this way.
- Arterial blood pressure falls and blood supply to the brain is diminished, sometimes resulting in fainting.

Exercise Physiology

2.2.12 Compare the distribution of blood at rest and the redistribution of blood during exercise

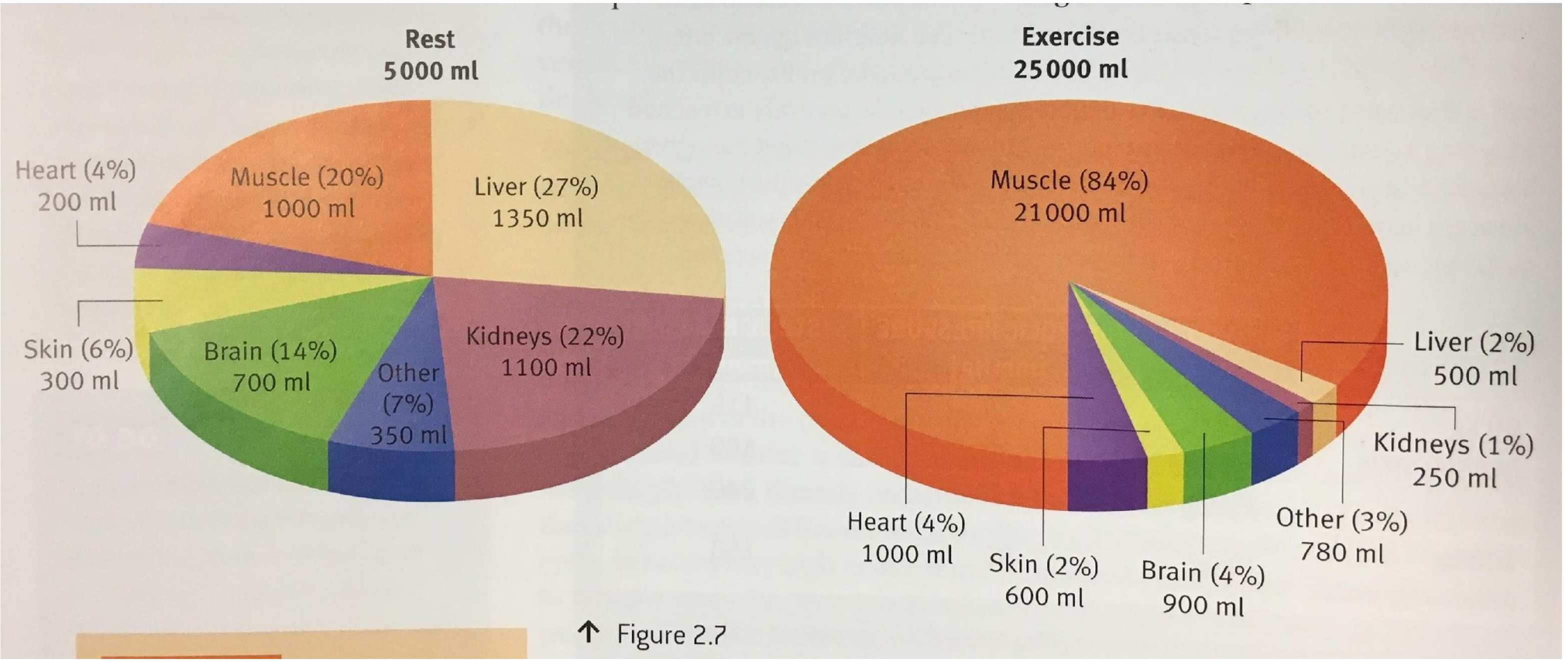
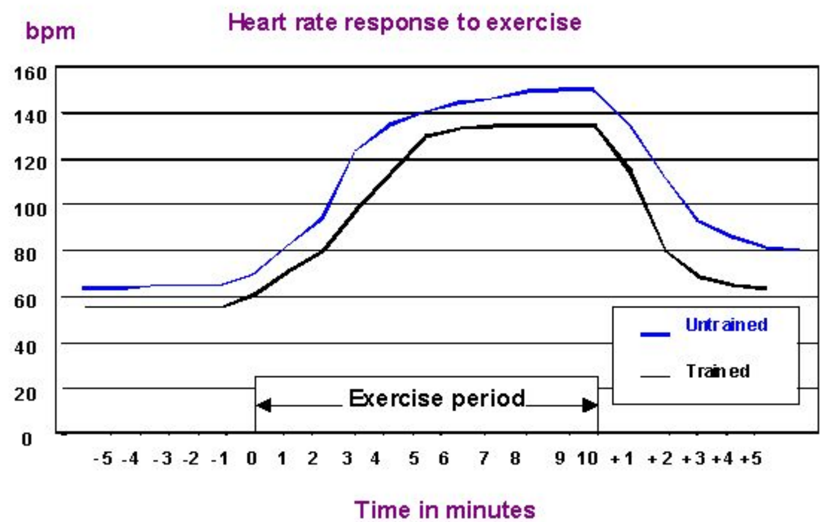


Figure 2.7

Exercise Physiology

2.2.13 Describe the cardiovascular adaptations resulting from endurance exercise training

- Resting heart rate decreases as a result of aerobic training. This is due largely to an increase in stroke volume.



Reference 1: Board of Studies NSW (1999). Personal development, health and physical education: Stage 6 syllabus.
Reference 2: Browne, S. (2001). HSC core 2 health priorities in Aust.: Summary quest. & sample HSC extended responses.
Reference 3: Browne, S., et. al. (2000). PDPHPE application and inquiry: HSC course. Oxford University Press: Melbourne.
Reference 4: Buchanan, D. & Nemec, M. (2003). HSC PDHPE. McMillan Education Australia: Melbourne.
Reference 5: Charles Sturt University. NSW HSC online. Available: http://hsc.csu.edu.au/pdhpe/

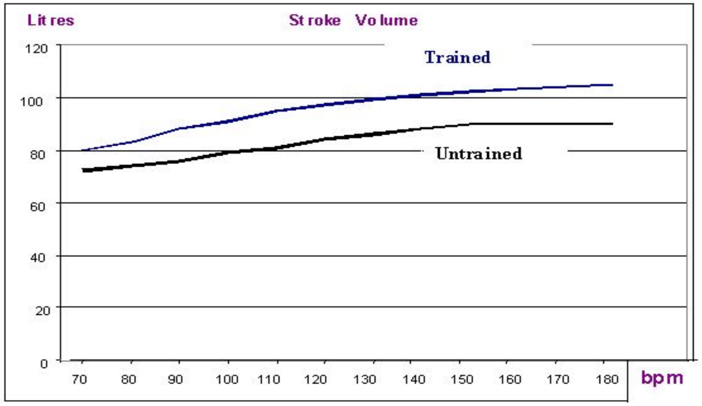
Exercise Physiology

2.2.13 Describe the cardiovascular adaptations resulting from endurance exercise training

Sub-topics

1. Structure & function of the ventilatory system
2. Structure & function of the cardiovascular system

- Stroke volume increases due to an increased cardiac hypertrophy (muscle size)/left ventricular volume from aerobic training. Therefore, for every heart beat, a trained athlete can pump more blood from the heart to the working muscles.



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Exercise Physiology

2.2.13 Describe the cardiovascular adaptations resulting from endurance exercise training

- Arterio-venous oxygen difference

The difference between the oxygen content of arterial blood and mixed venous blood. It may be expressed as millilitres of oxygen per 100 mL of blood. The value represents the extent to which oxygen is removed from the blood as it passes through the body.

http://www.answers.com/topic/arteriovenous-oxygen-difference?cat=health

Exercise Physiology

2.2.13 Describe the cardiovascular adaptations resulting from endurance exercise training

- Arterio-venous oxygen difference

Usually, the arterial oxygen concentration is measured in blood from the femoral, brachial, or radial artery, and the oxygen content of mixed venous blood is measured from blood withdrawn from the pulmonary artery.

http://www.answers.com/topic/arteriovenous-oxygen-difference?cat=health

IB

Sports, exercise and health science

Exercise Physiology

Topic 2

Exercise physiology

2.2.13 Describe the cardiovascular adaptations resulting from endurance exercise training

Sub-topics

1. Structure & function of the ventilatory system
2. Structure & function of the cardiovascular system

- Arterio-venous oxygen difference

At rest, the average arterial-venous oxygen difference is about 4-5 mL per 100 mL of blood, but it increases progressively during exercise reaching up to 16 mL per 100 mL of blood, indicating that more oxygen is extracted from the blood by active muscles.

http://www.answers.com/topic/arteriovenous-oxygen-difference?cat=health

Exercise Physiology

2.2.13 Describe the cardiovascular adaptations resulting from endurance exercise training

- Arterio-venous oxygen difference

The maximum arteriovenous oxygen difference of a trained athlete usually exceeds that of an untrained person. The training effect may be due to adaptations in the mitochondria, increased myoglobin (O_2 binding protein in muscle cells) content of muscles, or improved muscle capilarization.

http://www.answers.com/topic/arteriovenous-oxygen-difference?cat=health

Exercise Physiology

2.2.14 Explain maximal oxygen consumption

- Maximal oxygen consumption represents the functional capacity of the oxygen transport system and is sometimes referred to as maximal aerobic power or aerobic capacity.

Exercise Physiology

2.2.14 Explain maximal oxygen consumption (VO_2)

- Maximal oxygen consumption represents the functional capacity of the oxygen transport system and is sometimes referred to as maximal aerobic power or aerobic capacity.

- The VO_2 is directly assessed by measuring the gas concentration and the volume of air being breathed out at progressively increasing intensities of exercise.

Exercise Physiology

2.2.14 Explain maximal oxygen consumption

Exercise Physiology

2.2.15 Discuss the variability of maximal oxygen consumption in selected groups

When comparing $\dot{V}O_2max$ values between different populations it is crucial to recognise that the values can be expressed in two formats:

- **absolute** $\dot{V}O_2max$ is reported in $L.min^{-1}$
- **relative** $\dot{V}O_2max$ is the same value but normalised according to body mass in $ml.kg^{-1}.min^{-1}$.

Exercise Physiology

2.2.15 Discuss the variability of maximal oxygen consumption in selected groups

For activities that are considered weight-bearing it is more appropriate to use the relative $\dot{V}O_2max$ values as this makes an attempt to account for individual differences in size and mass. This is important as differences in size and mass explain the majority of the variability in absolute $\dot{V}O_2max$ values between individuals, due to factors such as active muscle mass, heart size, blood volume etc.

For example, an untrained healthy adult with a body mass of 70 kg may have an absolute $\dot{V}O_2max$ of 3.0 $L.min^{-1}$, which means a relative $\dot{V}O_2max$ of 42.9 $ml.kg^{-1}.min^{-1}$ (3.0×1000 to convert L to ml, then divide by 70kg). In contrast a 58 kg female hockey player may also have an absolute $\dot{V}O_2max$ of 3.0 $L.min^{-1}$, yet her relative $\dot{V}O_2max$ of 51.7 $ml.kg^{-1}.min^{-1}$ reflects her training adaptations that mean she will be able to run at faster speeds and for longer than the untrained male.

Exercise Physiology

2.2.15 Discuss the variability of maximal oxygen consumption in selected groups

- Young Vs Old

- Older people have a much lower VO_2 MAX.
- From adulthood, in males and females, relative VO_2 declines approx. 1% each year.
- - This is due to gradual decline of their max HR

A healthy 20yo male has a VO_2 max of 45 ml.kg
- Same person at 45 and 70yo would be 35 and 27.2 ml.kg

Exercise Physiology

2.2.15 Discuss the variability of maximal oxygen consumption in selected groups

- Trained Vs Untrained

  - A VO2 MAX exceeding 60ml is an indication of a trained athlete.
  - Highest values of VO2 max recorded was in cross-country skiers – 90ml.kg in males , 75ml.kg in females
  - Trained athletes are able to demonstrate their full cardio-respiratory potential, while untrained athletes yield fatigued muscles and are only able to reach sub-maximal levels.

Exercise Physiology

2.2.15 Discuss the variability of maximal oxygen consumption in selected groups

- Males Vs Females

-Absolute VO2 max values are lower for age-matched females.

-Heart size scales in proportion to lean body size, so therefore the male heart is usually bigger than the female heart. Stronger pump results in an increase in MAX VO2.

- Males also have a slightly higher hemoglobin concentration

Exercise Physiology

2.2.15 Discuss the variability of maximal oxygen consumption in selected groups

What limits $\dot{V}O_2$max?

Although we can see from Figure 2.1 that a limitation could occur anywhere in the oxygen transport system when $\dot{V}O_2$max is reached, it is widely believed that in the majority of healthy individuals the primary limitation is the capacity of the cardiovascular system to deliver oxygen. There are exceptions to this rule, including illness and extremely high aerobic fitness levels, but in most cases it is believed that the ventilation system and oxygen use at the muscle do not cause someone to reach $\dot{V}O_2$max.

2.2.15 Discuss the variability of maximal oxygen consumption in selected groups

How does training increase VO_2 max?

- Training induced changes to the heart and cardiovascular system (central adaptations) and changes within the muscle (peripheral adaptations)
- Main training response is increase in stroke volume and the time and effort it takes someone to reach their max heart rate (can work harder before reaching it)
- Stroke volume increases due to increases volume of left ventricle.

IB

Sports, exercise and health science

Exercise Physiology

Topic 2

Exercise physiology

2.2.16 Discuss the variability of maximal oxygen consumption with different modes of exercise

Sub-topics

1. Structure & function of the ventilatory system
2. Structure & function of the cardiovascular system

- Library Task: Consider cycling versus rowing.