# Cardiac physiology and vascular efficiency – the body's transport system

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## Stuff you all need to know!

- Cardiac cycle, role of heart valves and sounds
- Heart rate, pulse
- Stroke volume, cardiac output
- Change in heart rate – neural, hormonal, intrinsic
- Circulatory systems
- Blood vessels – features and function
- Venous return.
- Blood distribution – vascular shunt, role of vasomotor centre.
- Blood flow, pressures, velocities.

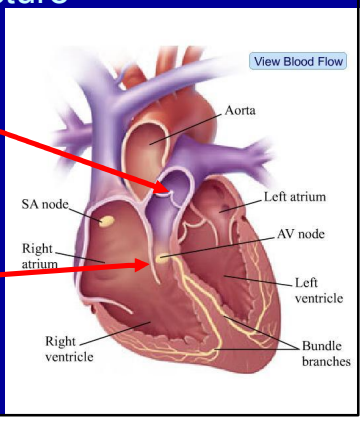
## OCR/Edexcel

- Conduction system of the heart
- Sinoatrial node
- Atrioventricular node
- Bundle of His and Purkinje fibres

## Heart Structure

Semi-lunar valves separates ventricles from arteries

Atrio-ventricular (a-v) valve separates atria from ventricles



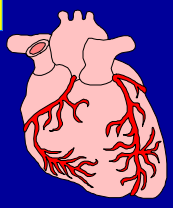

## Heart - blood flow

- Blood flows through heart
- From veins to atria
- Atria through atrio-ventricular valves to ventricles
- Ventricles through semi-lunar valves to arteries
- Heartbeat = contraction and relaxation

## Cardiac cycle

Contraction = systole

Relaxation = diastole



The order of contraction

Diastole

Atrial systole

Ventricular systole

High pressure (systole) in chambers forces valves open

Valves close when pressure drops again (diastole)

## Conduction system of the heart

Sinoatrial node

↓

Atrioventricular node

↓

Bundle of His

↓

Purkinje fibres

## Cardiac Output

Cardiac Output = Heart Rate x Stroke Volume

Q. = HR X SV

Stroke Volume - Volume of blood ejected each contraction (*systole*) c...

Units!

Rest

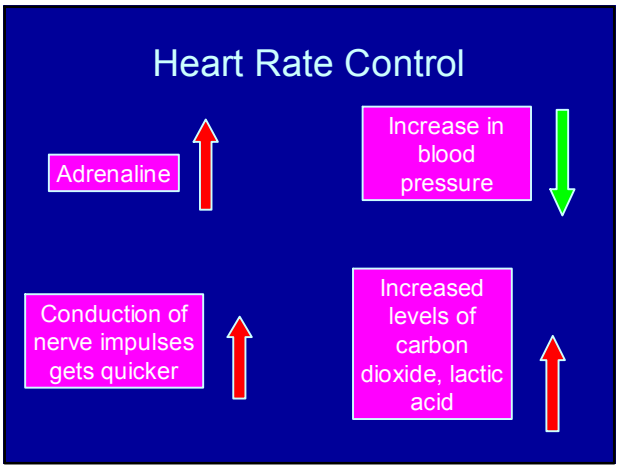
60bpm x 83ml = 5000ml$^{-1}$ (5 litres)

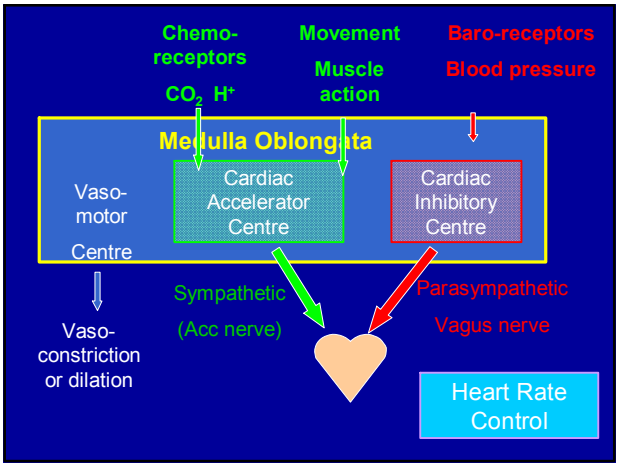
Max work (trained)

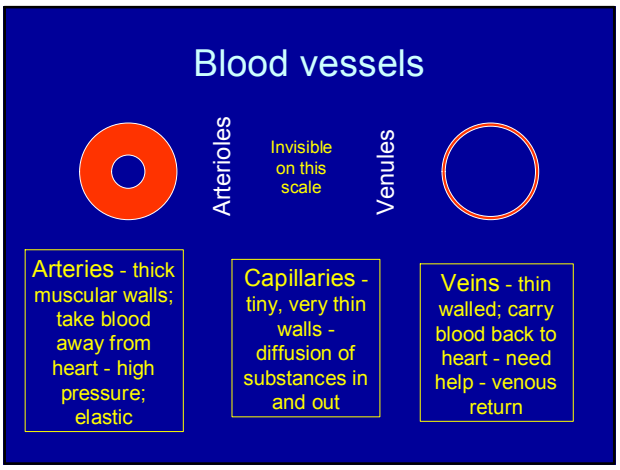
200bpm x 170ml = 34000ml$^{-1}$(34 litres)

## Effects of exercise

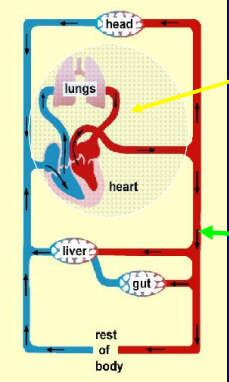
| | |
|---|---|
| Heart rate increases | Action of parasympathetic vagus nerve and sympathetic nerves on SAN |
| Stroke volume increases | Stronger contraction - more of contents ejected |
| Cardiac output increases | Supplying more oxygen-rich blood to exercising muscles |


Heart Rate Control
Adrenaline
Increase in blood pressure
Conduction of nerve impulses gets quicker
Increased levels of carbon dioxide, lactic acid


Chemo-receptors
$CO_2$ $H^+$
Movement
Muscle action
Baro-receptors
Blood pressure
Medulla Oblongata
Vaso-motor Centre
Cardiac Accelerator Centre
Cardiac Inhibitory Centre
Sympathetic
(Acc nerve)
Parasympathetic
Vagus nerve
Vaso-constriction or dilation
Heart Rate Control


Blood vessels
Arterioles
Invisible on this scale
Venules
Arteries - thick muscular walls; take blood away from heart - high pressure; elastic
Capillaries - tiny, very thin walls - diffusion of substances in and out
Veins - thin walled; carry blood back to heart - need help - venous return

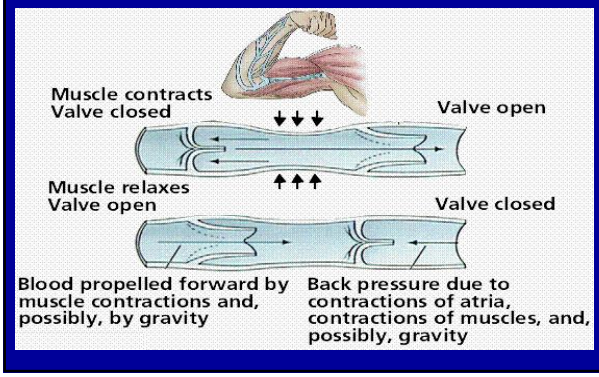
## Double Circulatory System



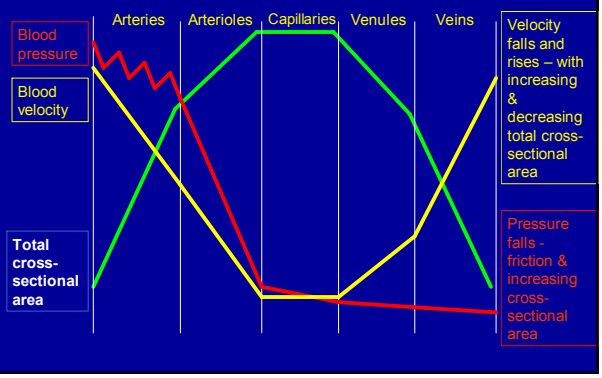

Pulmonary Circulation
Heart >Lungs > Heart

Systemic Circulation
Heart > Body > Heart

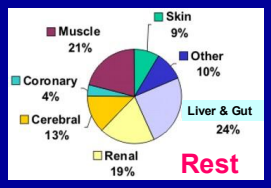
## Dynamics of Blood Flow

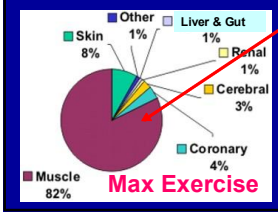



## Blood pressure and velocity



## Blood Flow Redistribution - % of Blood Flow




Blood is distributed to where it is required

Pre-capillary sphincters

During exercise blood is redistributed to the muscles

## Blood Flow Redistribution - Volume

Blood Flow in $cm^3$ per minute

| Area | Rest | Max Ex |
|---|---|---|
| Muscles | 1000 | 26000 |
| Heart | 250 | 1200 |
| Skin | 500 | 750 |
| Kidneys | 1000 | 300 |
| Liver & Gut | 1250 | 375 |
| Brain | 750 | 750 |
| Whole | 5000 | 30000 |

Increase to skeletal muscles & heart

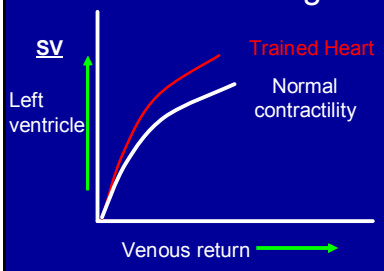
Decrease to liver, gut, kidneys

Brain stays same

Increase in total blood flow (Cardiac Output)

SV+ HR+

## Starlings Law




Trained heart will contract more powerfully

Increased venous return
Increased stroke volume
Increased filling of left ventricle

The information in Table 3 was obtained from a performer at rest and during a game of hockey.

| Organ system | Blood flow at rest $cm^3$ | Percentage of total blood flow $cm^3$ | Blood flow during the game $cm^3$ | Percentage of total blood flow $cm^3$ |
|---|---|---|---|---|
| Skeletal Muscle | 1 200 | 21 | 12 500 | 72 |
| Heart | 250 | 4 | 750 | 4 |
| Skin | 500 | 8.5 | 1 900 | 11 |
| Kidneys | 1 100 | 19 | 600 | 3.5 |
| Abdominal organs | 1 400 | 24 | 600 | 3.5 |
| Brain | 750 | 13 | 750 | 4 |
| Other | 600 | 10.5 | 400 | 2 |
| Total | 5 800 | 100 | 17 500 | 100 |

Table 3

(c) (i) Explain why the blood flow to the brain remains the same at rest and during the game. *(2 marks)*

(ii) Explain why there is a need for blood flow to increase to the skeletal muscles during the game and how this is achieved. *(4 marks)*

(iii) Blood supply is maintained by the venous return mechanisms. Explain how these mechanisms ensure the return of blood to the heart. *(3 marks)*

(c) (i) 1. Brain function needs to be maintained during exercise and at rest;
2. Brain requires nutrients/glucose/oxygen/O2;
3. Cognitive thought requires nutrients. *2 marks*
(ii) 1. Muscles need nutrients/oxygen to generate energy/work;
2. Stimulation by sympathetic nervous system;
3. Or adrenaline/noradrenaline is produced;
4. Controlled through arterioles;
5. By contraction of precapillary sphincters (control blood into capillaries);
6. Reduction of blood flow to the liver/kidneys/abdominal organs/gut;
7. Opening of vessels in the skeletal muscle/skin/coronary circulation;
8. Vasoconstriction/vasodilation.
9. This occurs due to drop in oxygen/rise in carbon dioxide levels/pH levels drop/increase in acidity/increase in temperature;
10. Detected by chemoreceptors. *4 marks*

(iii) 1. (Muscle pump) . skeletal muscles squeezing on veins;
2. Valves to prevent backflow;
3. (Respiratory pump) . changes that occur in the thoracic cavity during inspiration;
4. Cause compression of the veins, resulting in blood being forced towards the heart
5. Suction of blood into the heart, due to pressure changes;
6. Sympathetic nerve causes venous tone/veins contract to aid return of blood during exercise. *3 marks*