Cardio-Respiratory Exercise Physiology

STARTER – Group Activity

- Write a definition for the following term

HOMEOSTASIS

Can you give examples of where this takes place in the body?

Learning Objectives

- **List** the principal structures of the ventilatory system

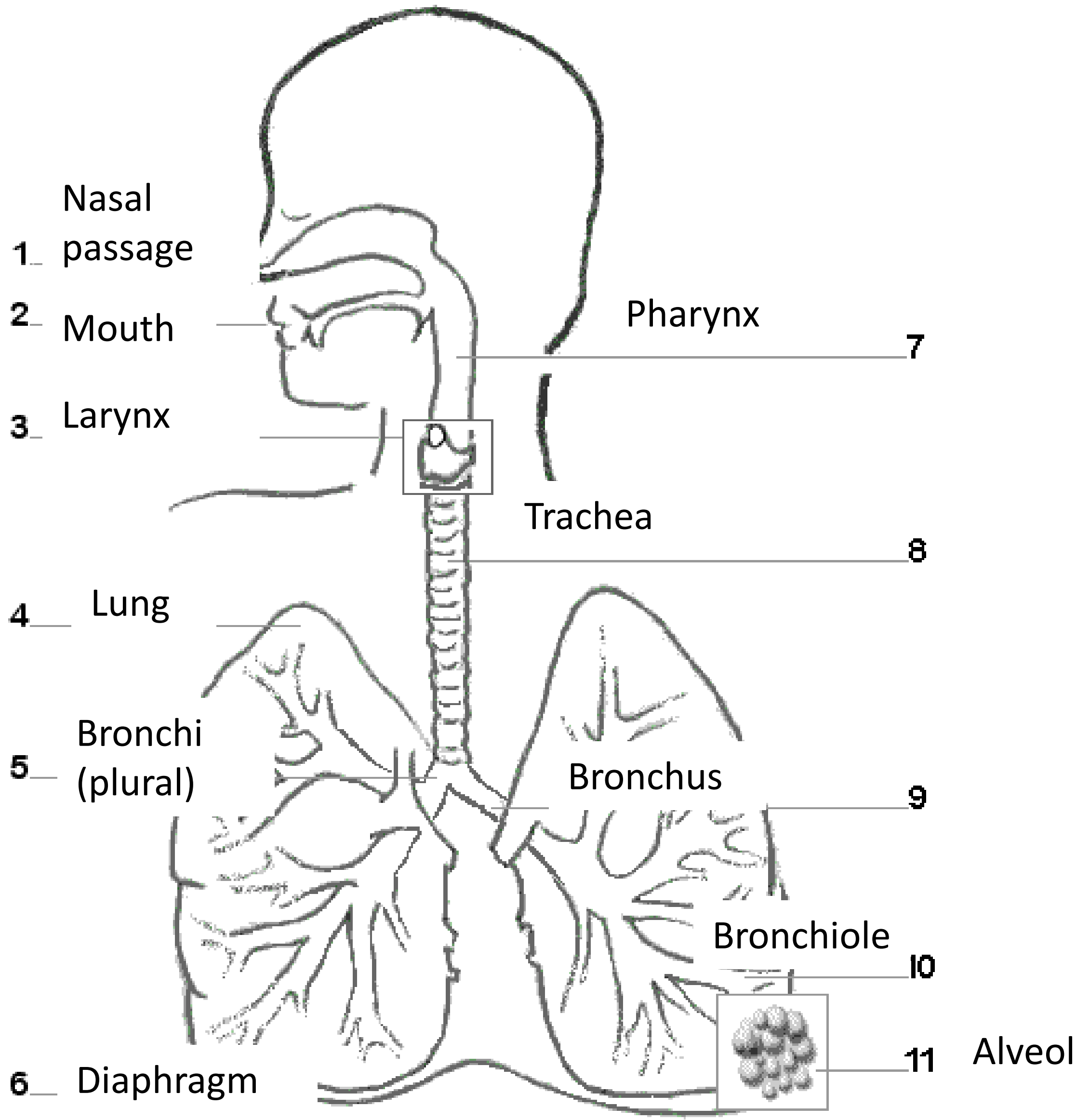
- **Outline** the functions of the conducting airways.

Watch this video on the respiratory system!

Can you label the diagram in your workbook?

- bronchioles
- trachea
- diaphragm
- inhale
- bronchi
- blood capillary
- exhale
- cough
- pharynx
- nose
- alveoli

Label the Respiratory System!



Structural components of the respiratory system

Trachea	
Smooth muscle	Contracts and relax to allow diameter of airways to be controlled. During exercise the muscle relaxes – making the airways wider – reduces resistance to air flow – aids ventilation Muscles contracts to narrow the airways when challenged with foreign material (e.g. pollen) to protect airways and alveoli
Elastic fibres	Stretch to allow expansion during inhalation and recoil during exhalation; prevent over expansion
C-shaped rings of cartilage	Provide structural support Prevent collapse of airway during inhalation Allows flexibility during movement without narrowing of airways Allows oesophagus to expand during swallowing

Smooth muscle and elastic fibres in the trachea

Smooth muscle is found in the walls of the trachea, bronchi and bronchioles

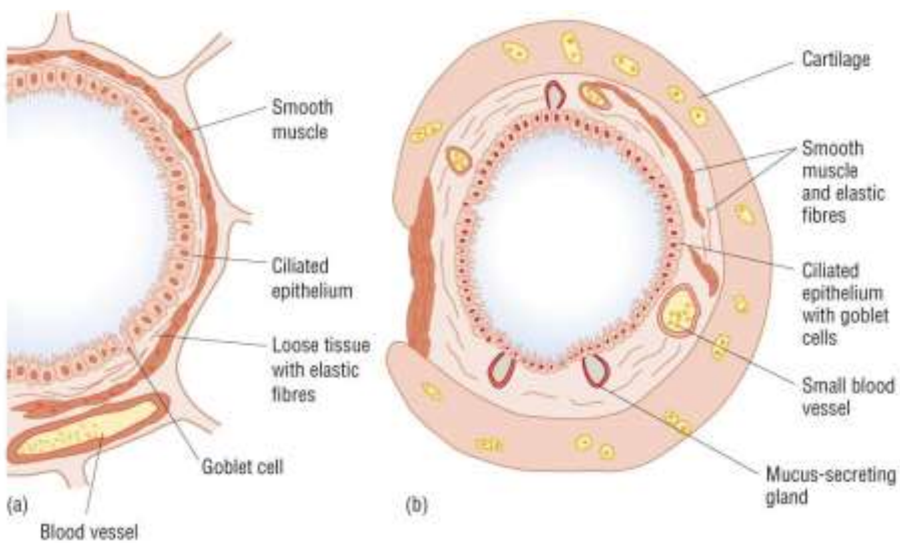
Smooth muscle relaxes during exercise, widening the lumen

Results in less resistance to airflow

Elastic fibres stretch on inspiration and recoil to help push air out when exhaling

Describe and explain the distribution and functions of the different tissues found in the lungs.

Structure	Function/Characteristics
Cartilage	**Supports trachea and bronchi. Prevents it from collapsing when air pressure is low. Some flexibility to move neck. Allows oesophagus to expand during swallowing.**



Structural components of the respiratory system

Inside surface of trachea – epithelial lining	
Goblet (mucus) cells	Secrete mucus – traps particles (e.g. dust, pollen, bacteria) – reduce risk of infection & inflammation
Ciliated epithelium	Cilia beat in a synchronised pattern to move (waft) mucus (with particles) towards throat – to be swallowed (stomach acid kills bacteria) or expectorated; prevents infection Cells contain numerous mitochondria (energy for ciliary movement)
Loose tissue	Inside surface of cartilage – glandular tissue, connective tissue, elastic fibres, smooth muscle and blood vessels

Ciliated epithelium

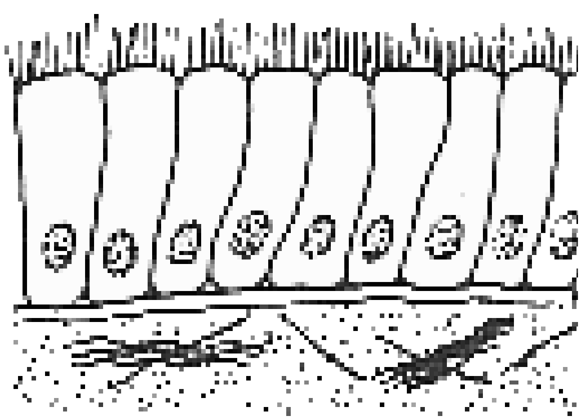
Simple columnar epithelial cells

Fine hair-like outgrowths

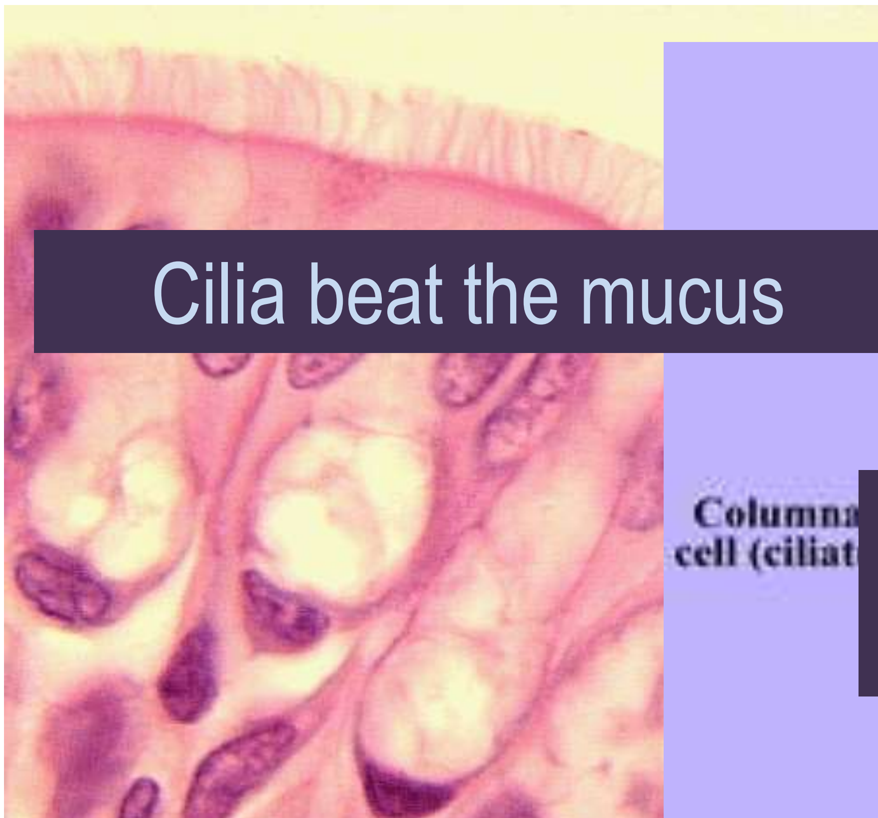
Rapid, rhythmic, wavelike beatings

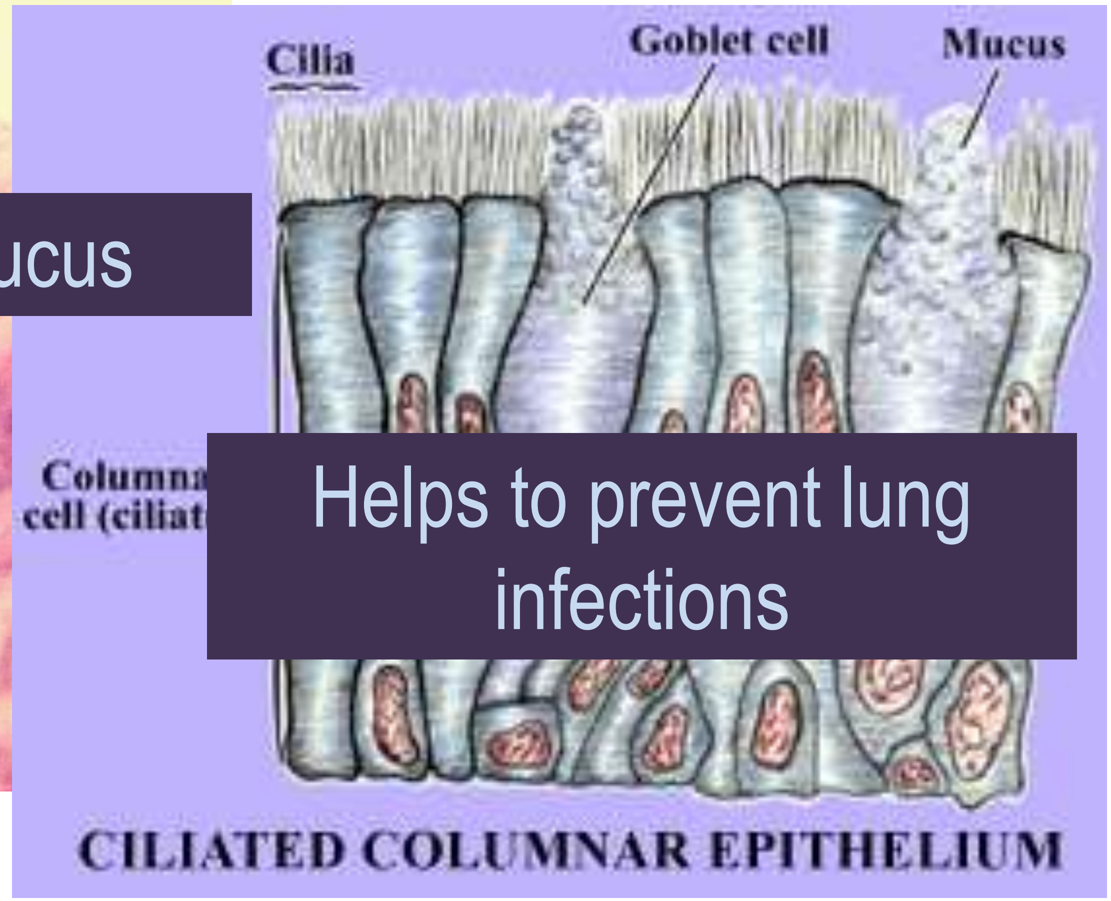
Movement of mucus

Usually found in the air passages like the nose, uterus and fallopian tubes



Ciliated epithelium





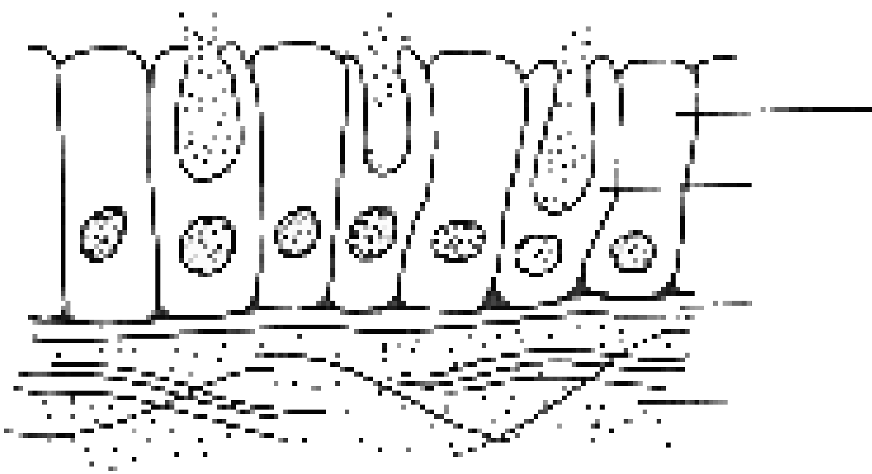
Cilia beat the mucus

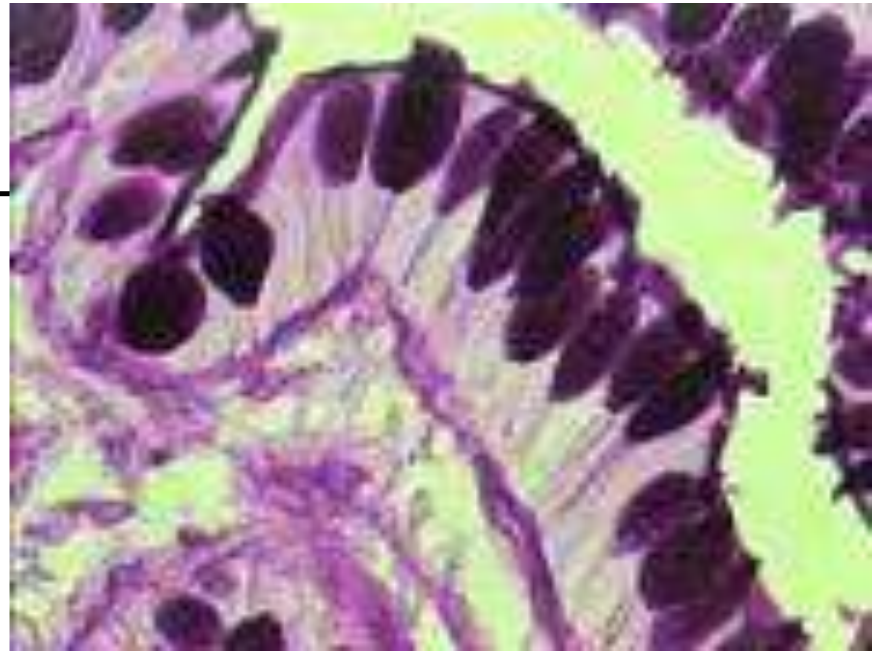
Helps to prevent lung infections

Goblet cells

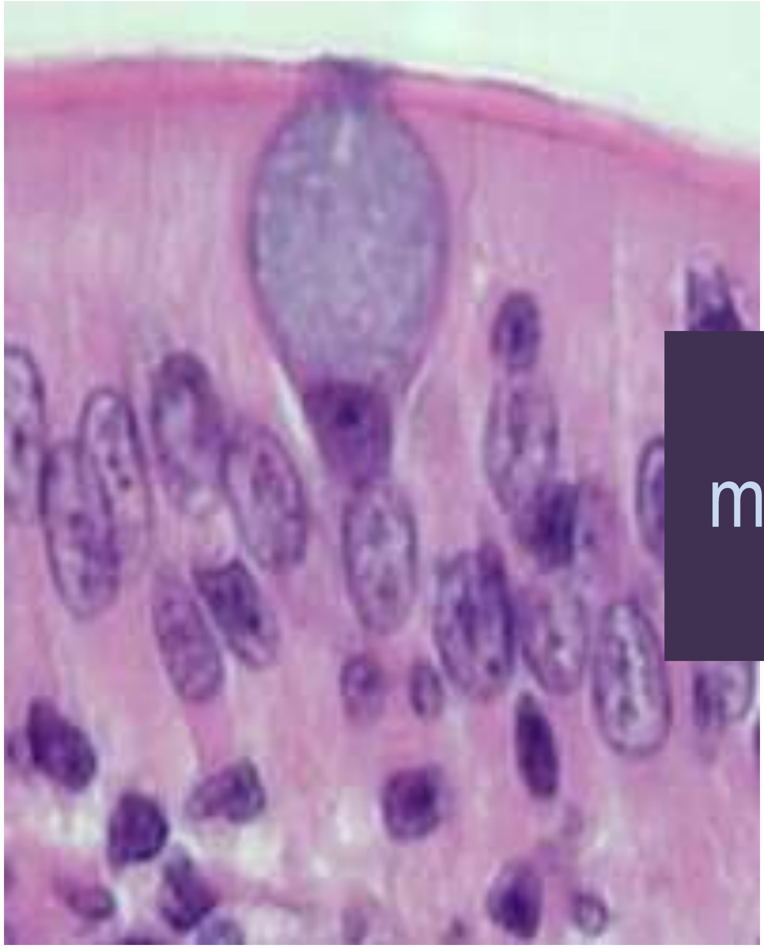
Specialised as gland cells

Synthesising and secreting mucus





Goblet cells



Secrete mucus

Mucus traps microorganisms and dust particles in inhaled air

Pairs Activity – Breathing rate and exercise

Speed is key for pulling off snowboarding's death-defying tricks. are pulled down by gravity, and are pushed against the side of the halfpipe by g-forces.

Competitors pump their legs against these forces to build speed, which allows them to jump higher.

Slopestyle is a new event at the Sochi Winter Olympics 2014. Snowboarders travel down a slope dotted with obstacles, including quarterpipes, rails and progressively higher jumps.

On the way, they perform feats of aerial acrobatics, with tricks like the backside triple cork 1440 — three head-over-heels flips and four full revolutions.

STARTER – Mechanics of ventilation

What happens to pressure in the lungs during
-inspiration?
-expiration?

How much air can be inhaled during vigourous exercise?

Where is the respiratory centre?

What gas is responsible for changing breathing rate?

Learning Objectives

- **Explain** the mechanics of ventilation in the human lungs.

Group Acitivity – Can you make a model lung?

- Folow the instructions and use the material in the kit given

- **Challenge** – you only have 10 minutes!

Ventilation

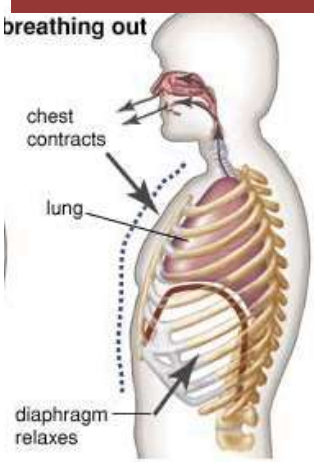
The **ribcage, intercostal muscles** and **diaphragm** all work together to move air into and out of the lungs, where gas exchange occurs across the thin (single-celled) walls of the alveoli

Ventilation is a physical process, relying on the principle of Boyle's Law – which state

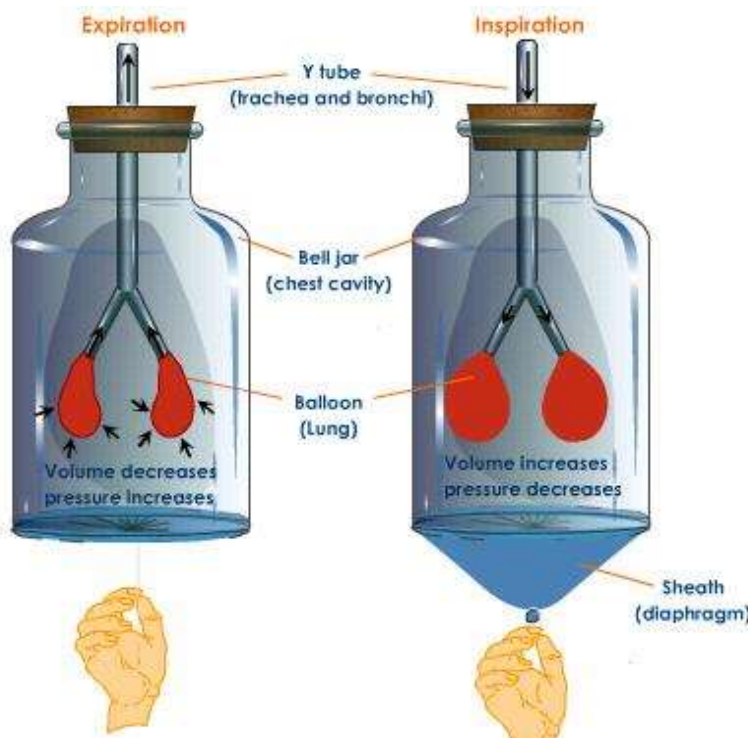
"*Pressure is inversely proportional to volume*"

The mechanism can be illustrated using a bell jar model of the respiratory system – however, the model does not illustrate involvement of the rib cage and the intercostal muscles in ventilation

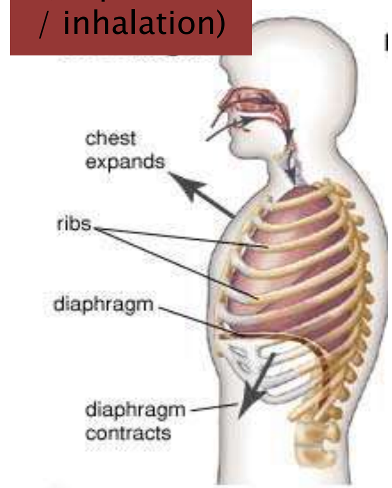
Breathing out (expiration / exhalation)



Internal intecostals contract in forced expiration

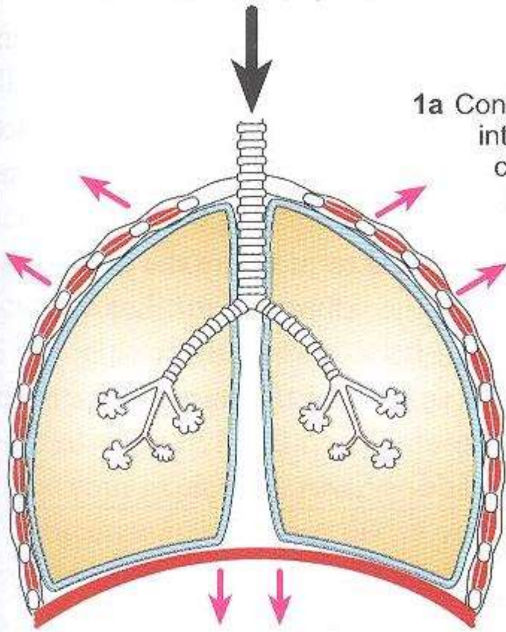


Breathing in (inspiration / inhalation)



Breathing in

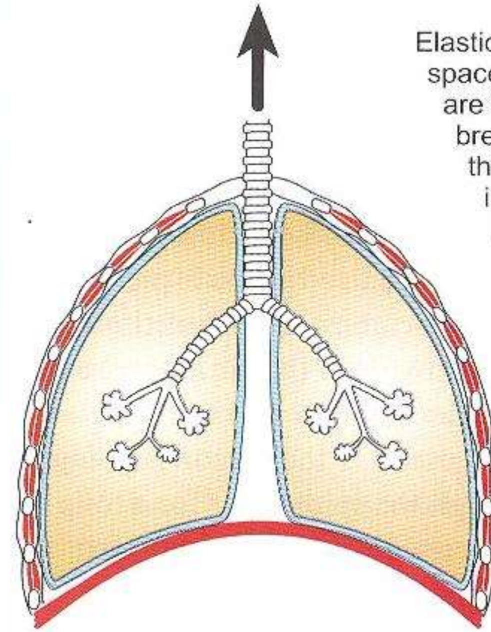
2 Pressure in the thorax falls with the increase in volume caused by rib and diaphragm movements. Air flows in down a pressure gradient.



1a Contraction of external intercostal muscles causes the rib cage to move upwards and outwards – increasing the volume of the thorax.

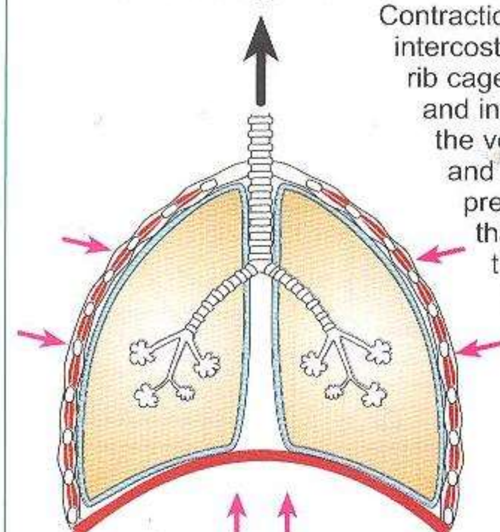
1b Contraction of muscle in the diaphragm pulls the diaphragm lower – increasing the volume of the thorax.

Relaxed breathing out

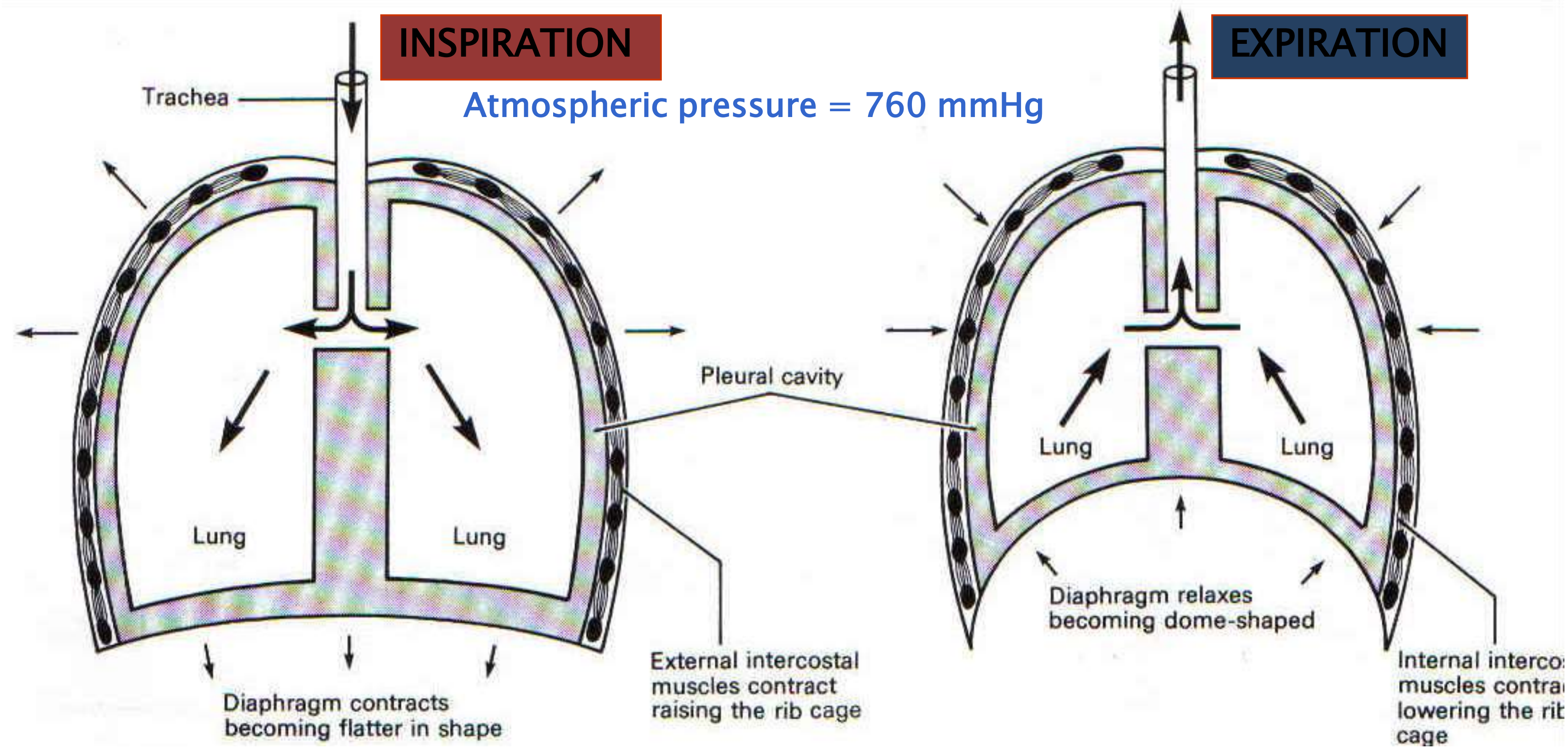


Elastic fibres in the spaces between alveoli are stretched when breathing in. When the diaphragm and intercostal muscles relax, the elastic fibres recoil causing the pressure in the thorax to rise. Air flows out of the lungs.

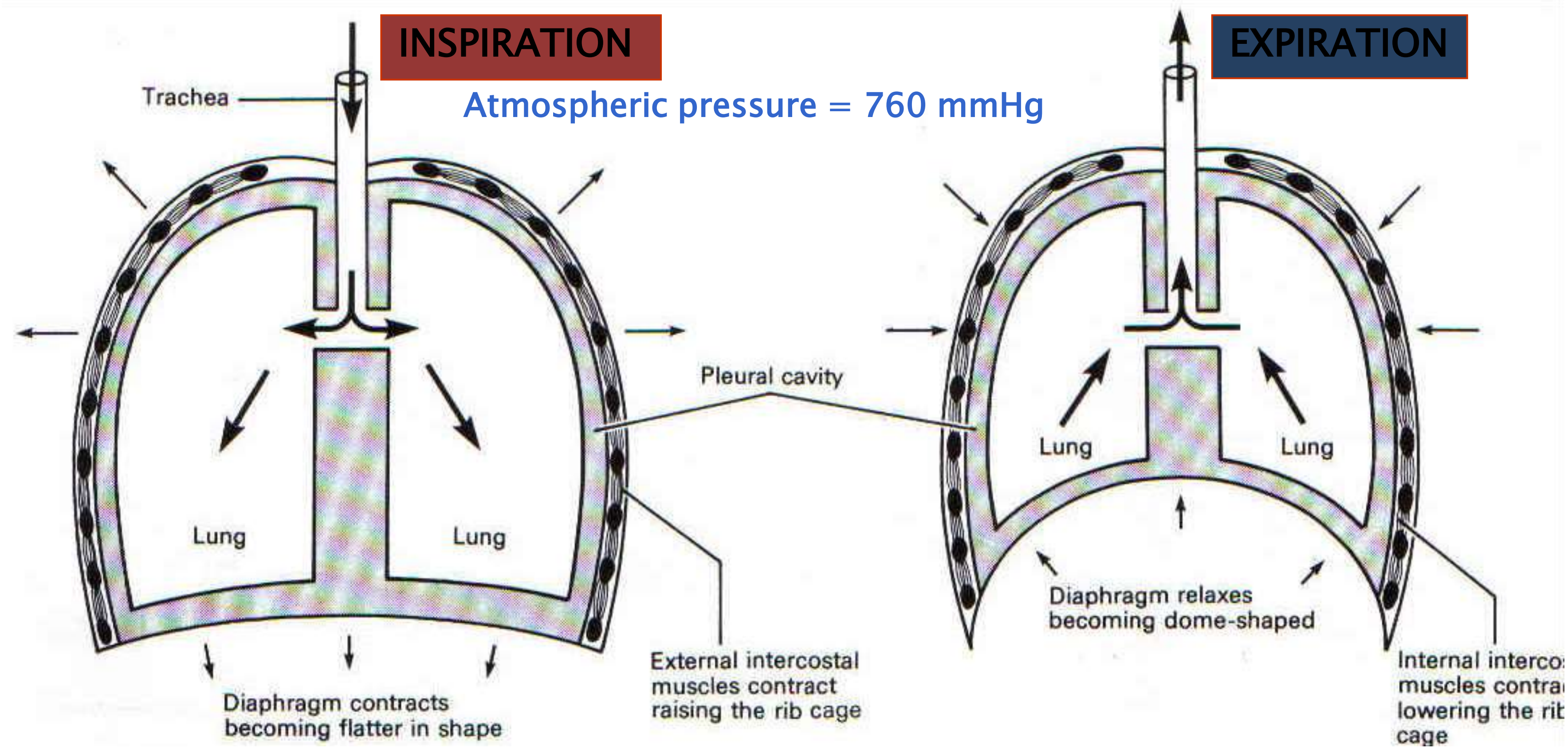
Forced breathing out



Contraction of the internal intercostal muscles causes the rib cage to move downwards and inwards. This decreases the volume of the thorax and increases the pressure of air inside so that it now flows out of the lungs. Diaphragm muscle relaxes. Contraction of the abdominal wall raises pressure in the abdomen and raises the diaphragm.



Group Activity – Can you sort the statements into inspiration and expiration?



- Diaphragm & external intercostals contract
- Rib cage raised (upwards and outwards)
- Diaphragm lowered (becomes flatter)
- Volume of chest cavity increases
- Pressure in chest cavity drops to below atmospheric pressure to 758 mmHg
- Air moves into lungs from atmosphere
- Active process

- Diaphragm & external intercostals relax
- Rib cage lowered
- Diaphragm raised (dome shape) due to push from abdominal organs
- Volume of chest cavity decreases
- Pressure in chest cavity increases to above atmospheric pressure to763 mmHg
- Air forced out of lungs into atmosphere
- Aided by elastic recoil and abdominal organs
- Passive process

Answers

Part of model	Part of real body	How model is the same as the body	How the model is different from the body
plastic bottle	ribcage	approximate shape – with shoulder and straighter section	has no muscles attached to 'ribs' and so is rigid and cannot move up and down/ in and out
balloon	lung	inflates and deflates will deflate almost completely due to elastic recoil	single bag, not a series of tubes with terminal alveoli; balloon does not fill the space, or stick to the inside of the ribcage
plastic sheet	diaphragm	domed up position matches position when air is exhaled	pulls down further than flat; is not elastic like a muscle – has to be pushed in and out by us
tube into balloon	trachea/ bronchus	the windpipe is a relatively wide tube conducting air into the lungs	does not divide. Is not held open by horseshoe shaped stiffening rings

How does changing the diameter of the tube affect how easy it is to move air in and out of the balloon?

Use this observation to explain how asthma affects someone's breathing.

- Changing the diameter of the tube makes it significantly harder to push air out of the lungs.
- An asthmatic will not be able so easily to push the high CO_2 /low O_2 air out of the lungs and so will not be able to draw in enough 'fresh' air.
- The physical effort of breathing out can become exhausting.
- The narrowed tubes produce a 'wheezing' sound as air is pushed in and out.

Evaluate how well this system models the working of your lungs.

- filling the balloon with porous sponge
- using a balloon that more nearly fills the space
- sticking the balloon to the ribcage with a film of water
- using a branching tube and two balloons etc

STARTER– Can you complete this table?

	Inhaling (Inspiration)	Exhaling (Expiration)
Volume of thorax		
Diaphragm muscle		
Movement of diaphragm		Relaxes and resumes to dome shape
External intercostal muscles		
Rib cage movement		
Pressure in chest cavity	Decreases below atmospheric pressure	
Movement of air		

	Inhaling (Inspiration)	Exhaling (Expiration)
Volume of thorax	Increases	Decreases
Diaphragm muscle	Contracts	Relaxes
Diaphragm	Flattens and pushes digestive organs down	Relaxes and resumes to dome shape
External intercostal muscles	Contracts/expands	Relaxes
Rib cage	Upward and outward	Inward and downward
Pressure in chest cavity	Decreases below atmospheric pressure	Increases below atmospheric pressure
Movement of air	Into the lungs down pressure gradient	Air forced out of lungs

Learning Objectives

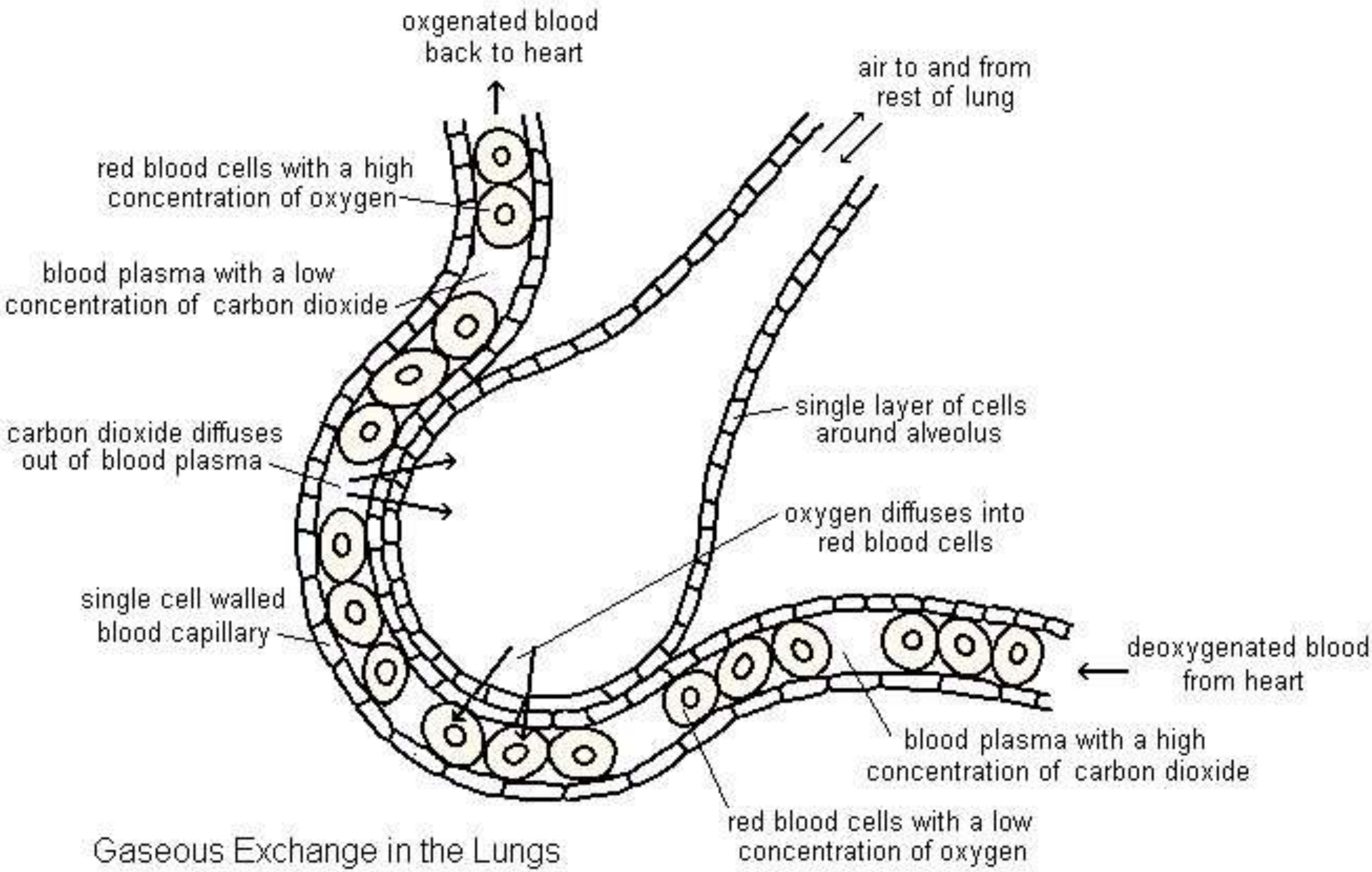
- **Outline** the role of hemoglobin in oxygen transportation.
- **Explain** the process of gaseous exchange at the alveoli.
- **Describe** nervous and chemical control of ventilation during exercise.

STARTER: Gas exchange

- Can you define partial pressure?
- Why is partial pressure important for diffusion of oxygen?

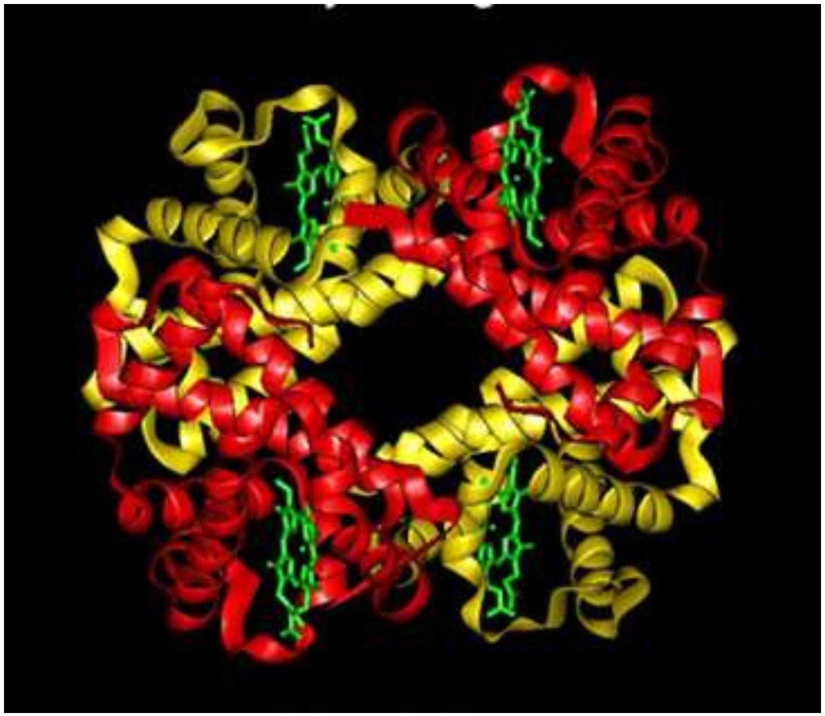
Group Activity – Annotate your diagram with the correct statements

- Single-cell walled blood capillary
- Deoxygenated blood from heart
- Air to and from rest of lung
- Carbon dioxide diffuses out of blood plasma
- Single layer of cells around alveolus
- Blood plasma with a low concentration of carbon dioxide
- Red blood cells with a low concentration of oxygen
- Oygenated blood back to the heart
- Red blood cells with a high concentration of oxygen
- Oxygen diffuses into red blood cells
- Blood plasma with a high concentration of carbon dioxide



Gaseous Exchange in the Lungs

Haemoglobin

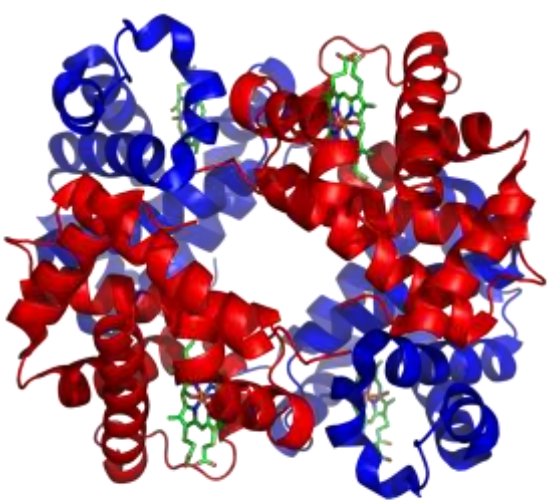


- gives red blood cells their colour
- can carry up to 4 molecules of O_2
- associates and dissociates with O_2
- contains iron

Role of Haemoglobin

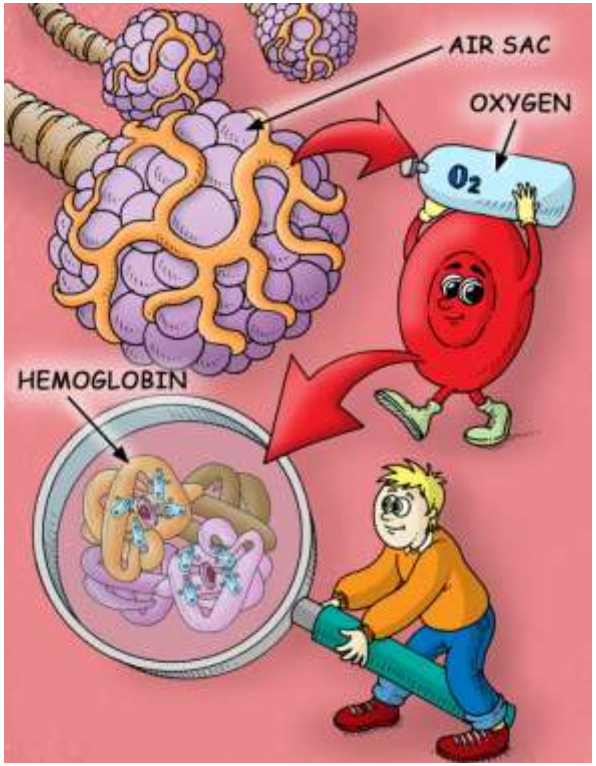
Haemoglobin is a protein found in **red blood cells**

Haemoglobin + Oxygen $\rightleftharpoons$ Oxyhaemogobin

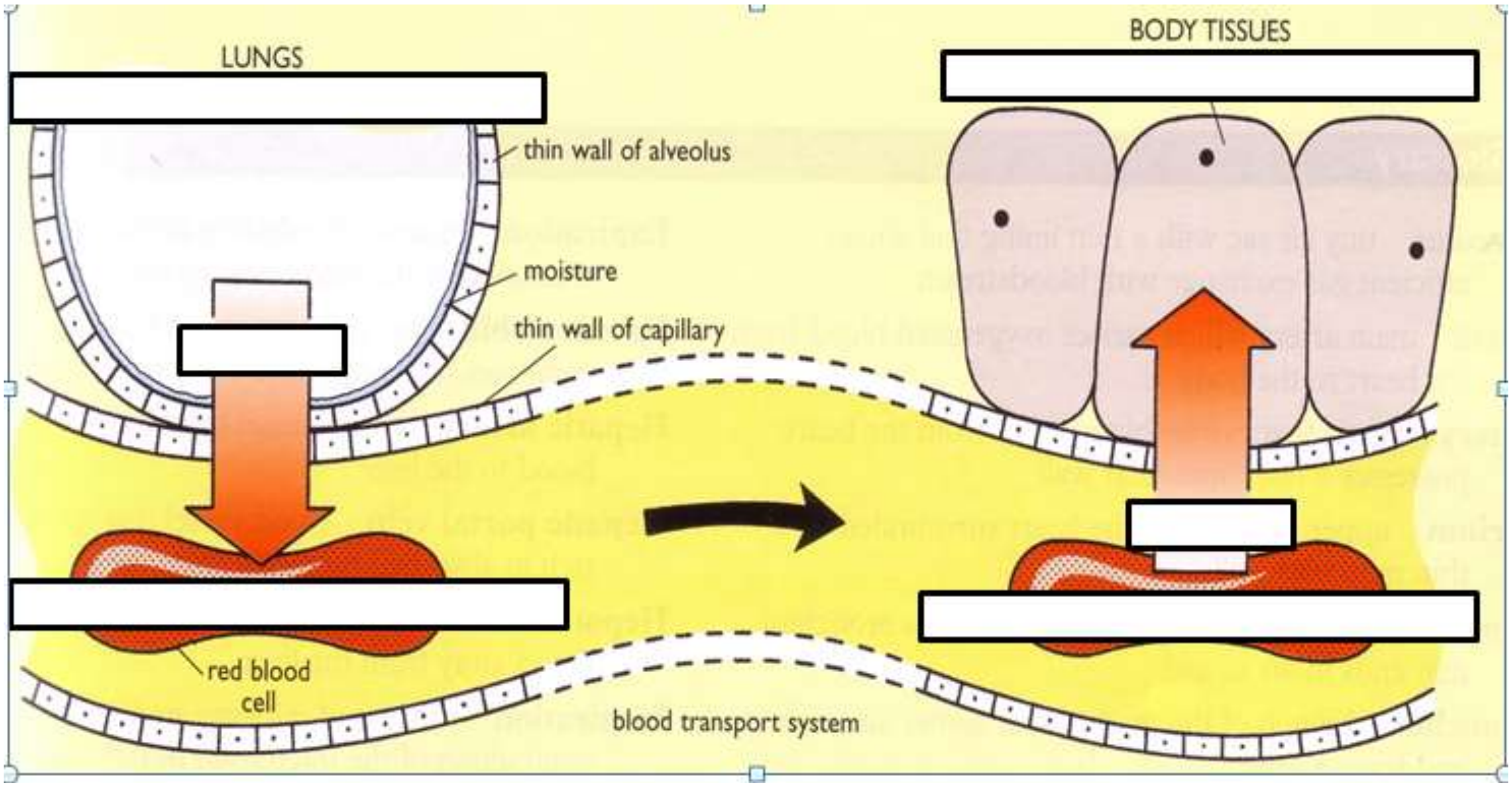


Class activity -Roleplay time!

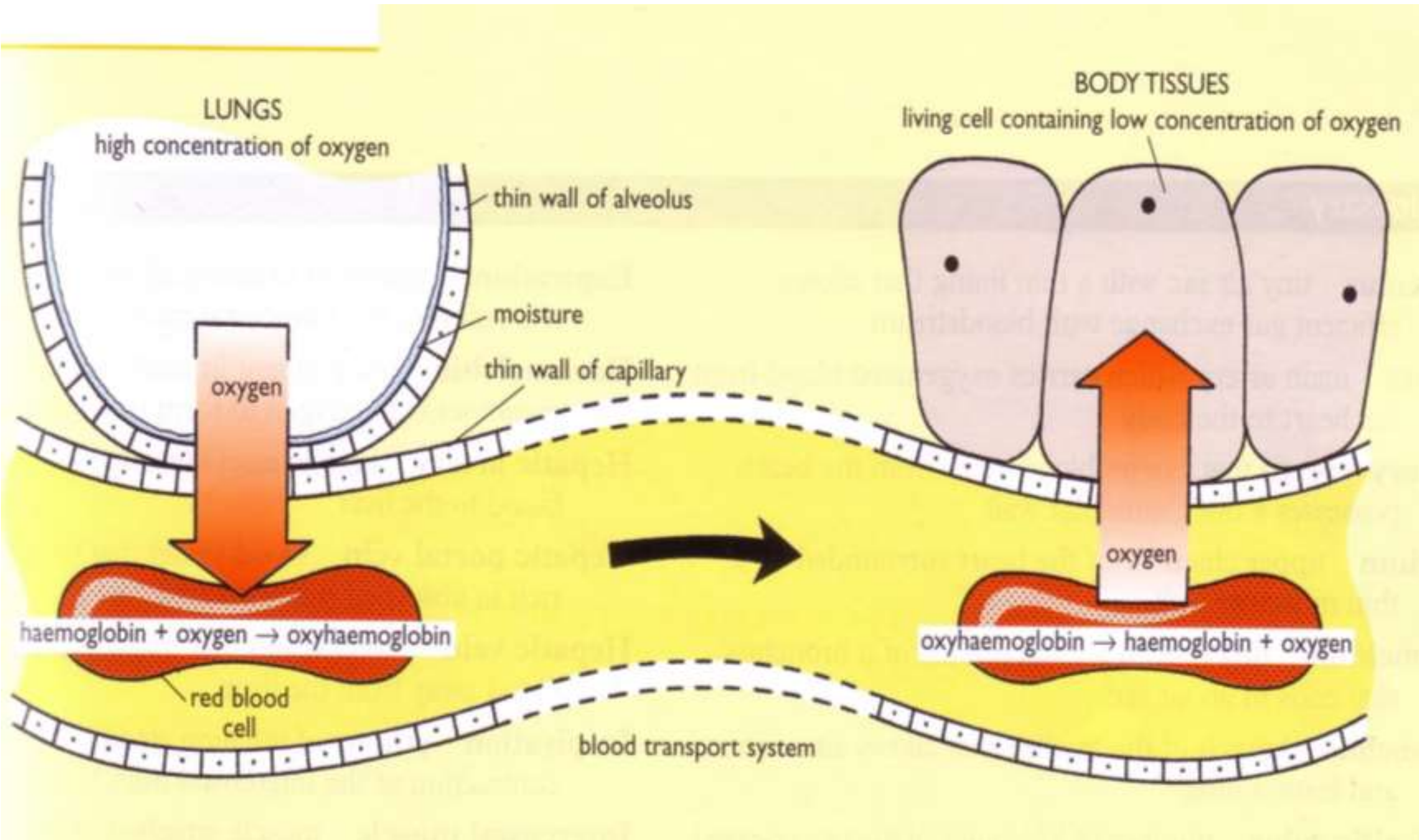
- How does the blood transport oxygen around the body?



Individual activity – Annotate the diagram in your workbook



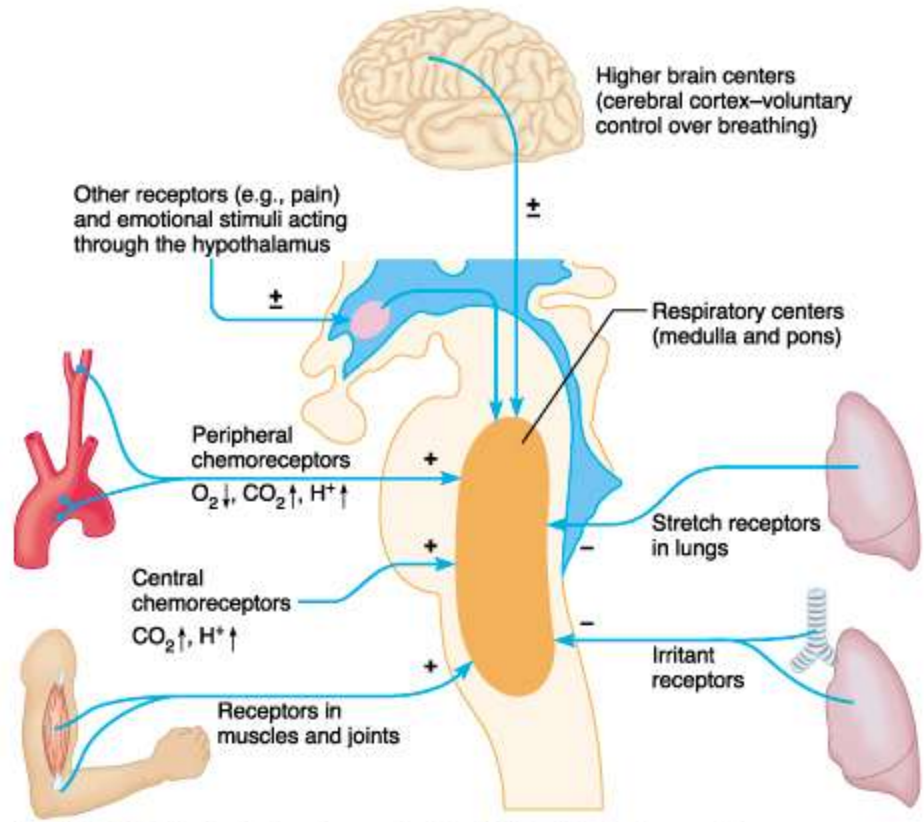
Carrying oxygen



Group thought- Why do you breathe faster and deeper when exercising?

Now answer the question in your workbook

- Neural control of ventilation requires the information collected by lung stretch receptors, muscle proprioreceptors and chemoreceptors.
- ventilation increases as a direct result of increases in blood acidity levels (low pH)
- this is due to increased carbon dioxide content of the blood detected by the respiratory centre in the brain .
- This results in an increase in the rate and depth of ventilation.



STARTER: Exercise induced asthma

- What are some causes of exercise-induced asthma?
- Give some examples of sypmtoms associated with exercise-induced asthma
- What tests are used to help diagnose exercise-induced asthma

Learning Objective

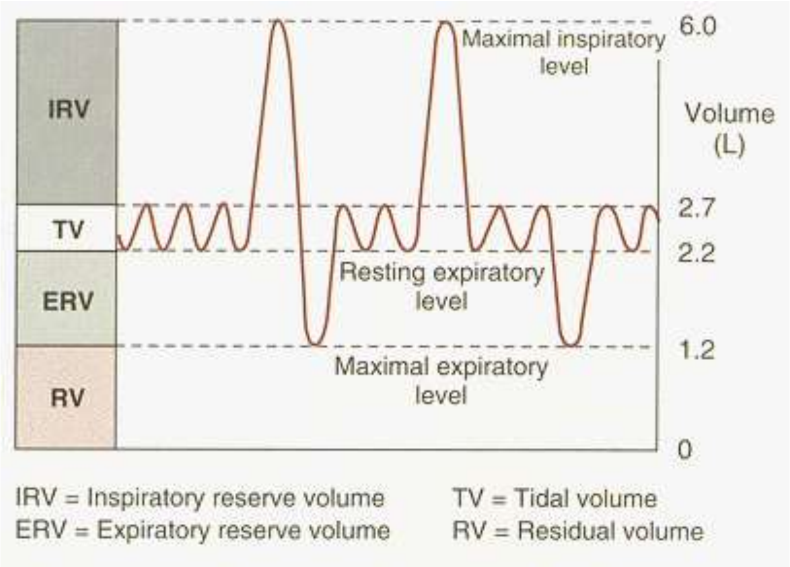
Define the terms:

- *pulmonary ventilation*
- *total lung capacity (TLC)*
- *vital capacity (VC)*
- *tidal volume (TV)*
- *expiratory reserve volume (ERV)*
- *inspiratory reserve volume (IRV)*
- *residual volume (RV)*

Pulmonary Ventilation

Can you copy the definitions into your workbook as we go through the next few slides?

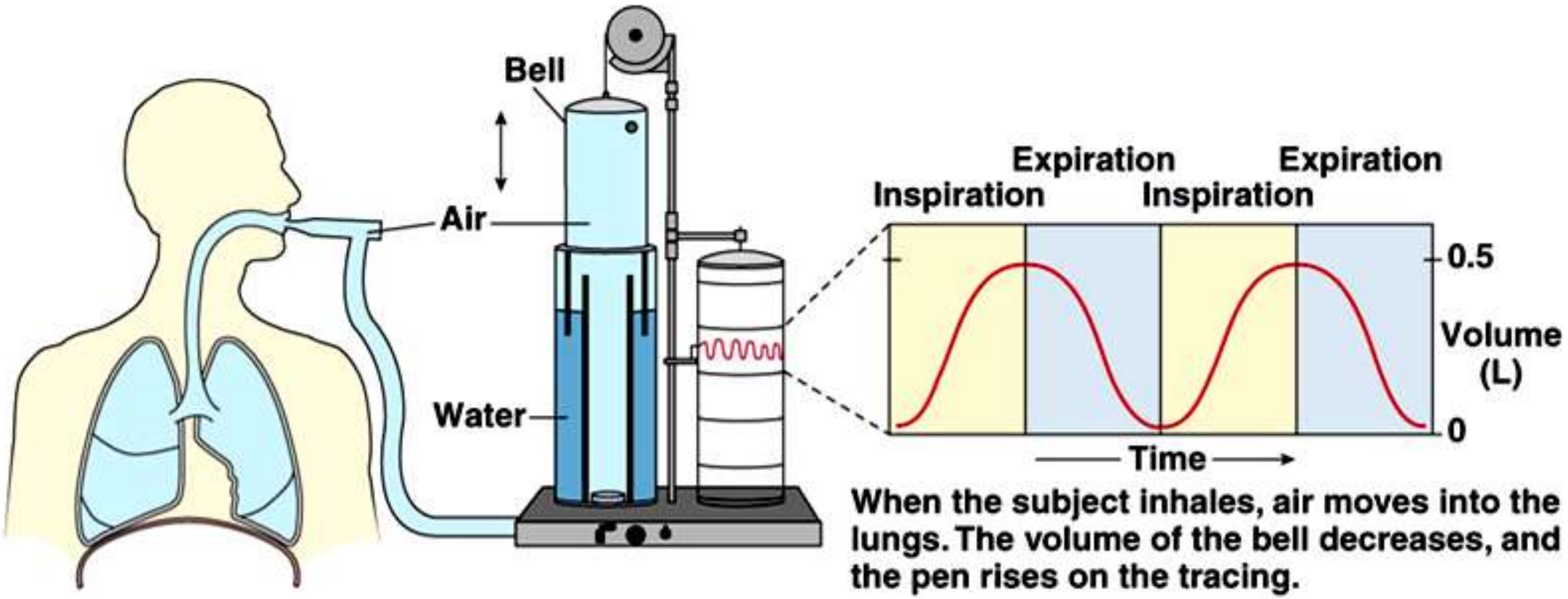
The total volume of gas per minute inspired or expired expressed in liters per minute



or

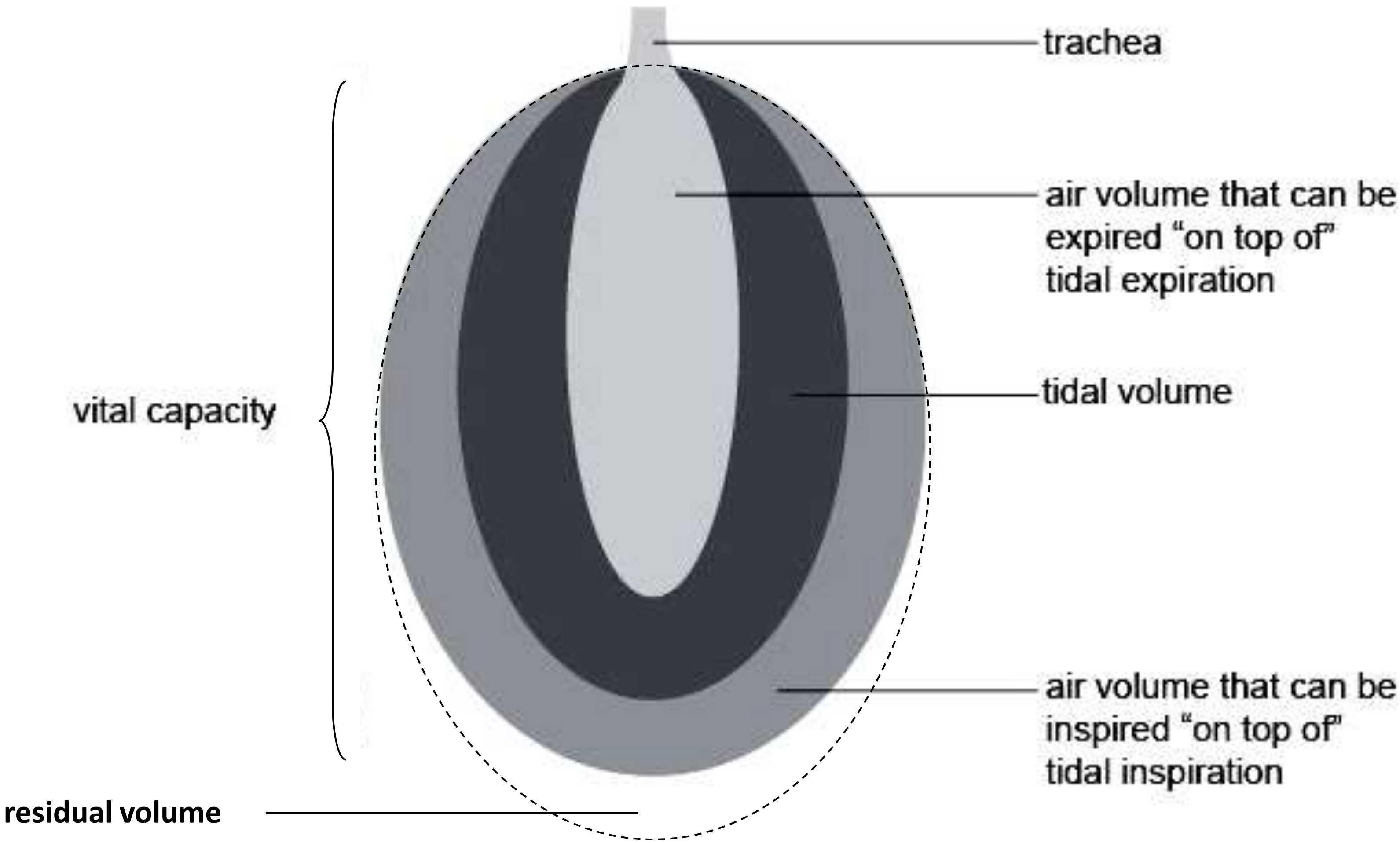
tidal volume x breathing rate

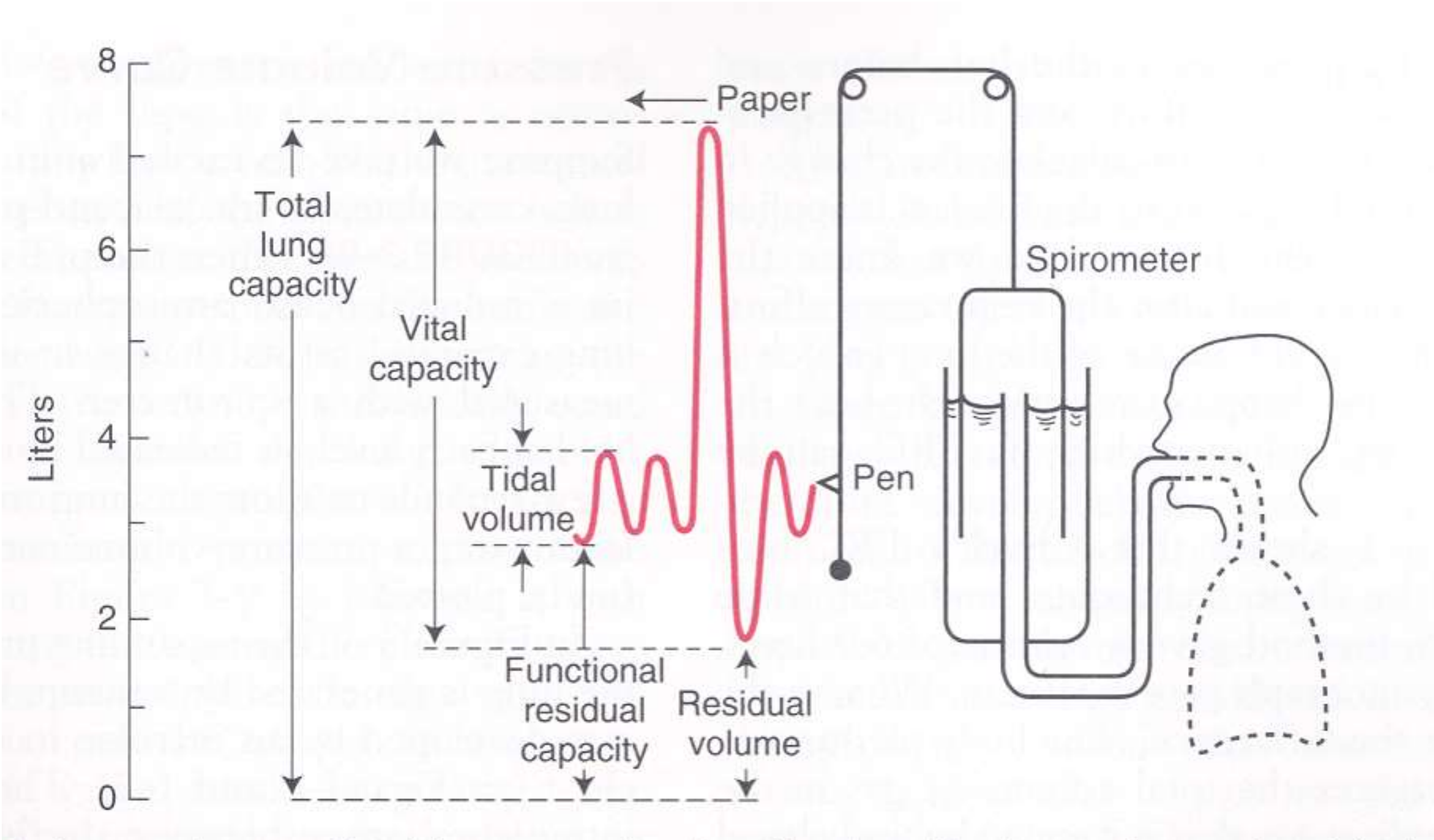
Spirometer



- A device that measures the ***volume*** of gas entering or leaving the mouth
- A spirometer measures changes in ***lung volume***
- A spirometer measures subdivisions of **vital capacity**
- A spirometer does NOT measure ***residual volume***

Lung volumes





Vt Tidal volume

VC Vital Capacity

ERV/IRV Expiratory/Inspiratory reserve volume

These are all measured easily with spirometers

FRC Functional residual capacity

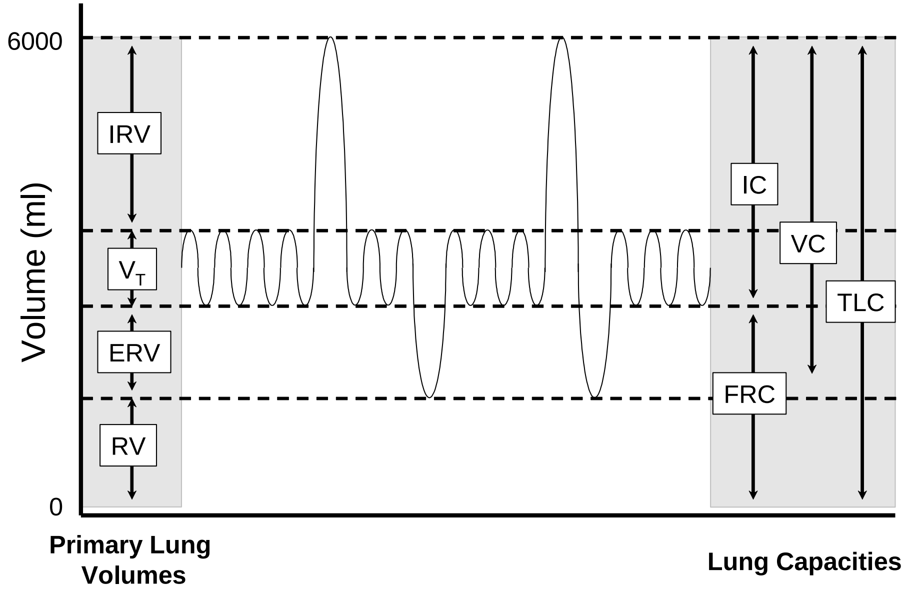
RV residual volume

TLC Total lung capacity (RV + VC)

Measuring these requires more specialized equipment

Tidal Volume (TV)

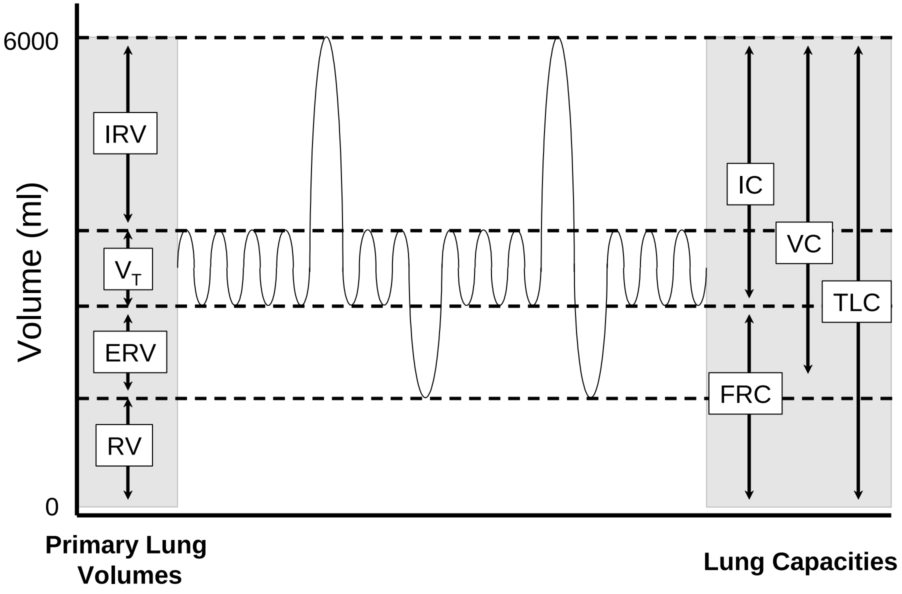
- amount of air entering/leaving lungs in a single, “normal” breath
- ca. 500 ml at rest, ↑ w/ ↑ activity



Inspiratory Reserve Volume (IRV)

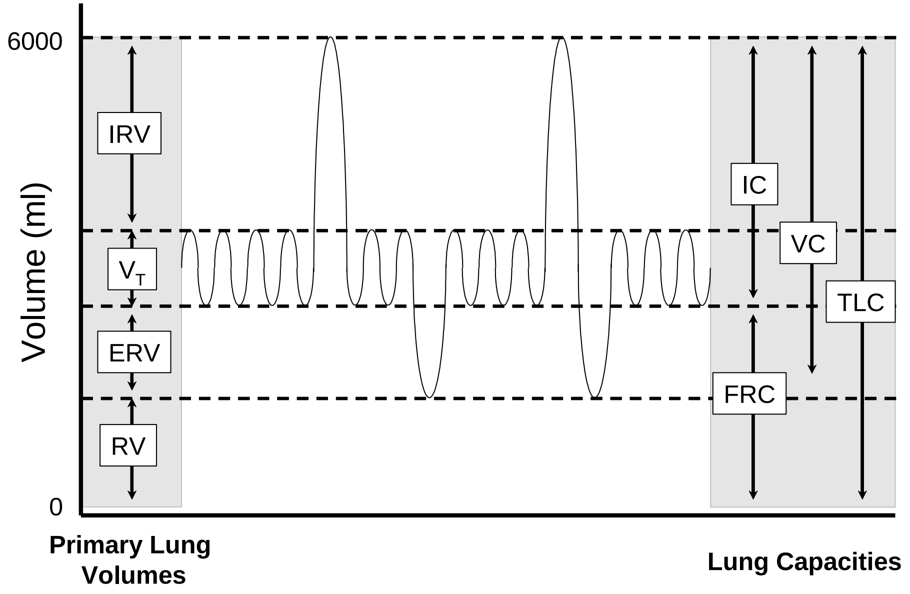
- additional volume of air that can be maximally inspired beyond V_T by forced inspiration

- ca. 3100 ml. at rest



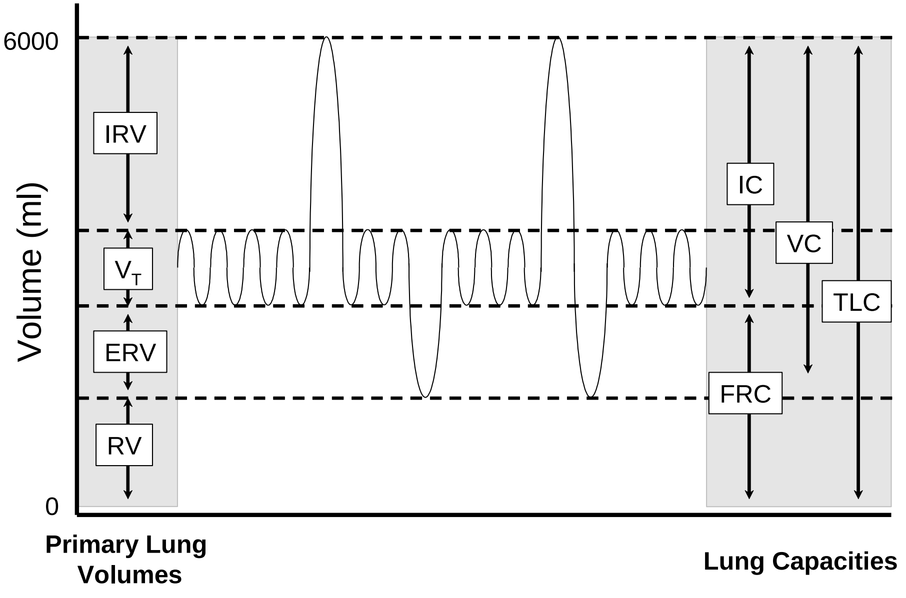
Expiratory Reserve Volume (ERV)

- additional volume of air that can be maximally expired beyond V_T by forced expiration
- ca. 1200 ml. at rest



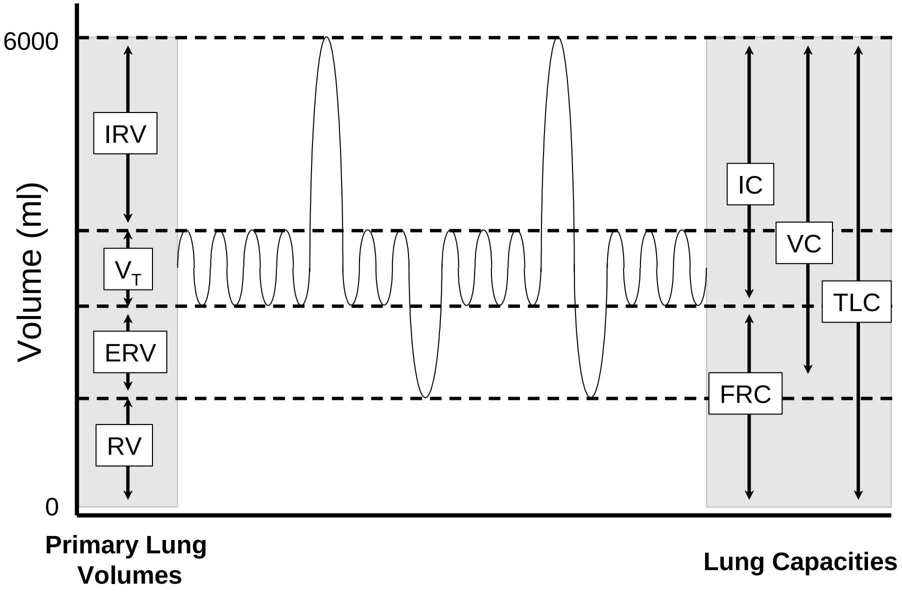
Residual Volume (RV)

- volume of air still in lungs following forced max. expiration
- ca. 1200 ml. at rest



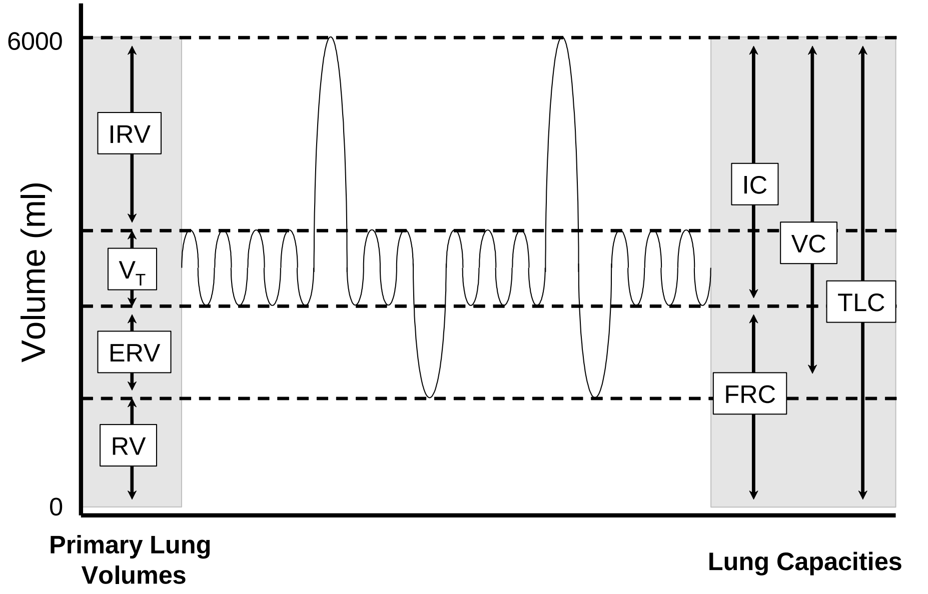
Total Lung Capacity (TLC)

- total amount of air that the lungs can hold
- volume of air in lungs at the end a maximal inspiration
- VT + IRV + ERV + RV

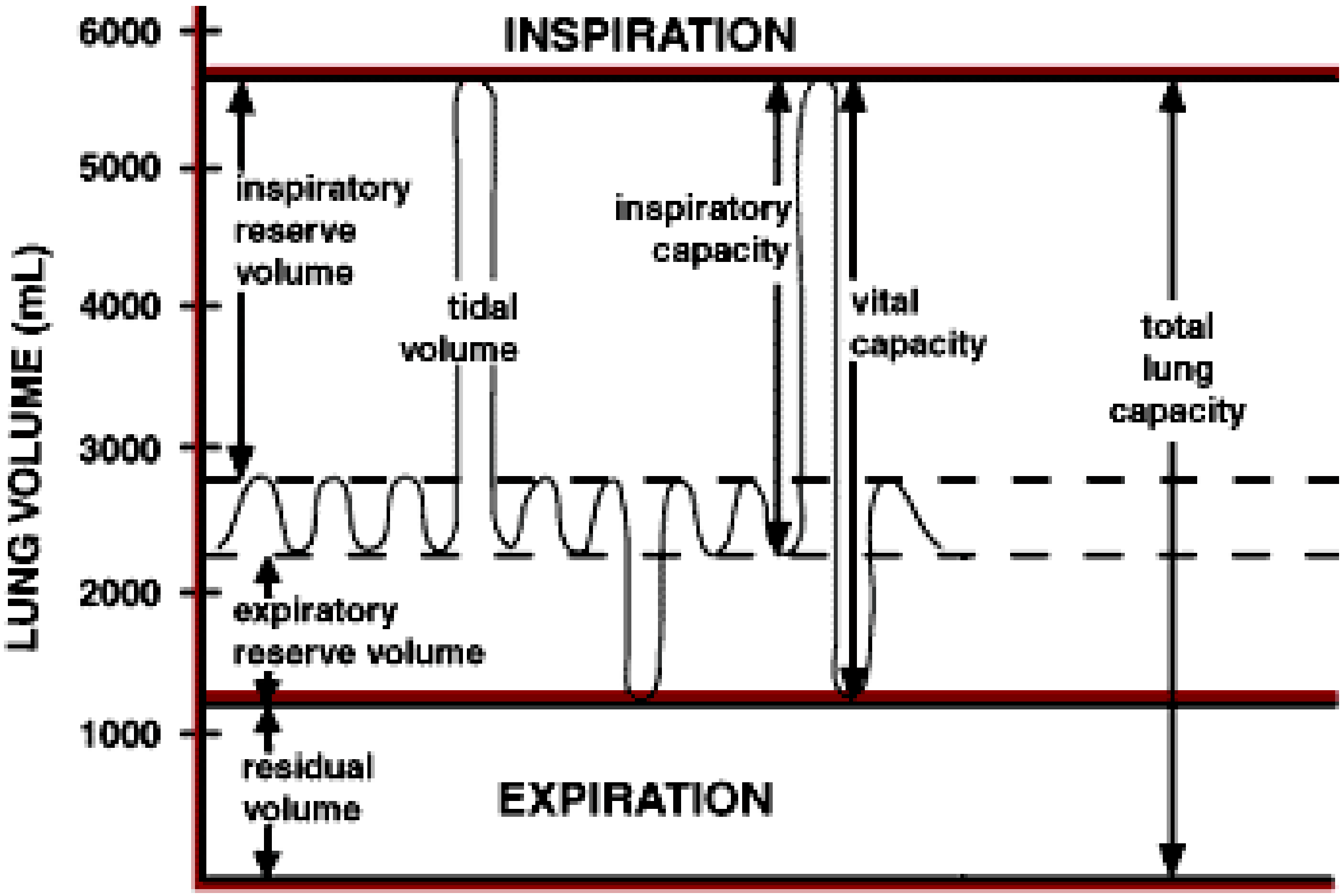


Vital Capacity (VC)

- max. amt. air that can move out of lungs after a person inhales as deeply as possible
- VT + IRV + ERV

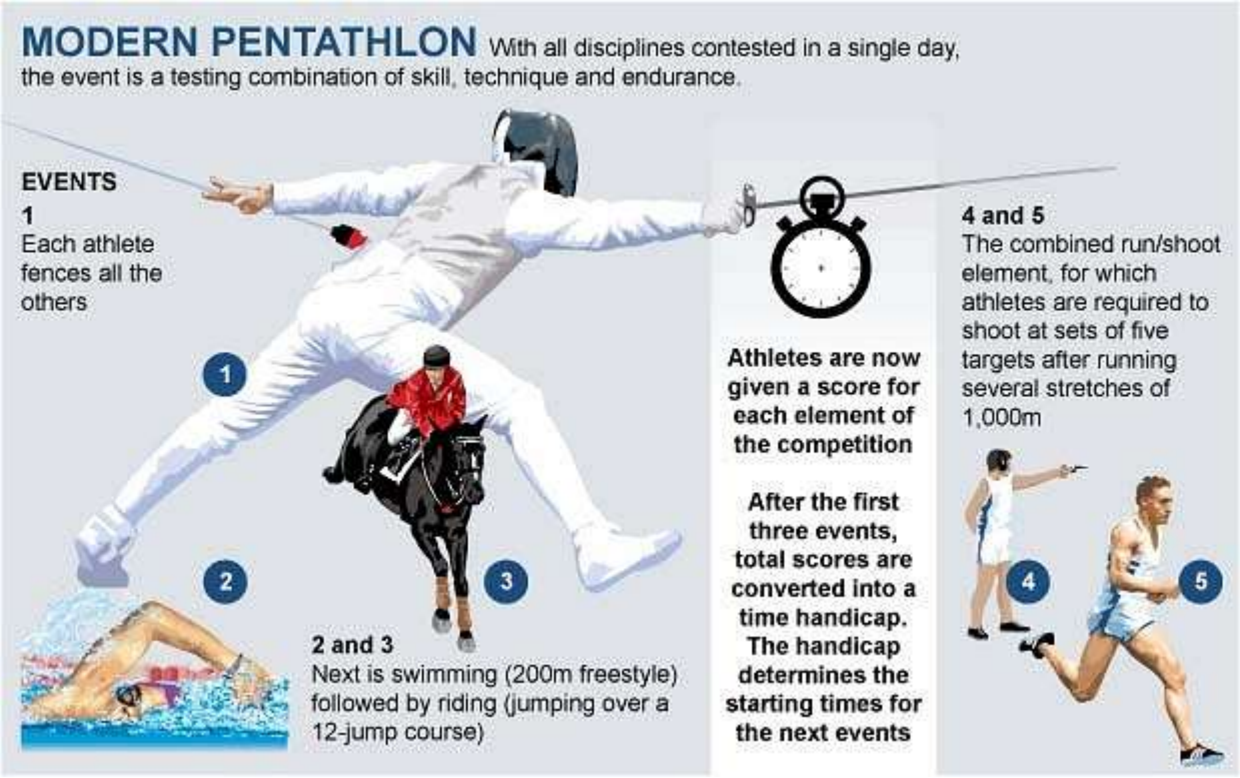


Lung volumes



Practical Activty – Measuring Lung Capacity

- Working in **pairs** – carry out the practical in your workbook



Starter – Spirometer trace PPQ

You have 8 min to complete the ppq in your workbook

Question	Marking guidance	Mark	Comments
(a)(i)	(Lung volume) increases / reaches a maximum (at B);	1	Do not negate mark for ‘breathing out’ if qualified e.g. when (lung volume) decreases
(a)(ii)	Flattens / lowers / moves down; (Diaphragm / muscle) contracts;	2	Reject: second mark only if intercostal muscles cause the diaphragm to flatten
(b)	Pulmonary ventilation = tidal volume × breathing rate; Breathing rate increases / more breaths per min (between C and D) / peaks get closer; Tidal volume / volume of air (inhaled) per breath increases (between C and D) / deeper breaths; (Tidal volume increase) qualified by data from graph e.g. approximate three-fold increase / appropriate calculation;	3 max	Accept: ventilation rate instead of breathing rate Neutral: breathing increases Accept: breathe quicker Neutral: volume in lungs increases Accept: distance from bottom to top of peak increases for ‘tidal volume increases’ Neutral: higher peaks for ‘tidal volume increases’

Learning Objectives

- **State** the composition of blood
- **Distinguish** between the functions of erythrocytes, leukocytes, and platelets.
- **Describe** the anatomy of the heart with reference to the heart chambers, valves and major blood vessels.

Group Activity – Heart and Blood poster

Your group has this period to make a poster showing the following information

1. Label a diagram for the heart showing the following
- Four chambers of the heart
- Valves of the heart
- Main blood vessels of the heart

2. Complete a flow chart of the path that blood takes through the heart.

3. Identify the function of erythrocytes, leukocytes, and platelets.

4. Use information from the poster to complete the relevant sections in your workbook

YOUR POSTER WILL BE GRADED USING A RUBRIC

THE GRADE WILL BE USED FOR A CLASSWORK GRADE

CATEGORY	Full Pts.		Partial Pts.		No Pts.	Grade
Use of Class Time (10 points)	Used time well during each class period. Consistently focused on getting the project done. Never distracted others. (10)	Used time well during each class period. Usually focused on getting the project done and rarely distracted others. (8)	Used some of the time well during class period. Some focus on getting the project done but occasionally distracted others. (6)	Did not use class time to focus on the project and/or often distracted others. (4)	Did not use class time to work on project at all. Disengaged and/or total distraction (2)	/10
Labels (15 points)	All items of importance on the poster are clearly labeled with identifiers that can be read at least 3 ft. away. (15)	Almost all items of importance on the poster are clearly labeled and can be read from at least 3 ft. away. (12)	Several items of importance on the poster are clearly labeled. Labels can be read from at least 3 ft. away. (9)	Labels are too small to view and/or many important items were not labeled. (6)	Required items were not labeled at all. (3)	/15
Content (25 points)	The poster includes all required elements as well as additional information. (25)	All required elements are included on the poster. (20)	All but 1 of the required elements are included on the poster. (15)	Several required elements are missing. (10)	Most of the required elements are missing. (5)	/25

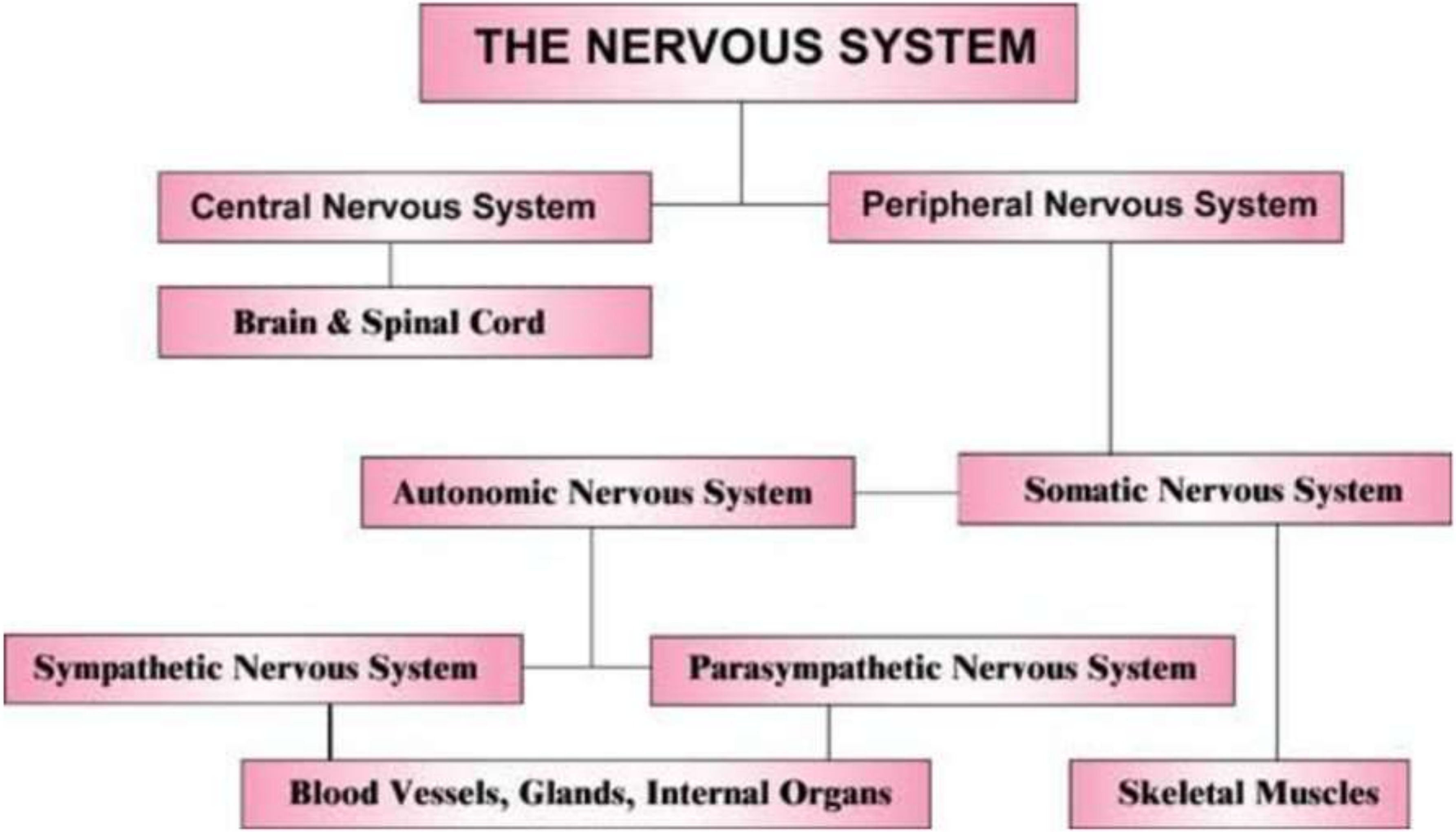
CATEGORY	Full Pts.		Partial Pts.		No Pts.	Grade
Content Accuracy (15 points)	All facts on the poster are accurate. (15)	Mostly accurate facts are displayed, and there are 10 or more facts present. (12)	50% of the facts on the poster are accurate. (9)	Few of the facts are accurate and/or are not displayed on the poster. (6)	Little to no accuracy recorded on poster. (3)	/15
Attractivenes s (5 points)	The poster is exceptionally attractive in terms of design, layout, and neatness. (5)	The poster is attractive in terms of design, layout and neatness. (4)	The poster is acceptably attractive though it appears a bit messy. (3)	The poster is distractingly messy or very poorly designed. It is not attractive. (2)	The poster appears as if little to no time was invested. (1)	/5
Creativity (5 points)	The poster is exceptionally creative, with several added components and/or decorations. (5)	The poster is creative, with a few added components and/or decorations. (4)	The poster is somewhat creative with at least one added component and/or decoration. (3)	The poster has a few creative elements. (2)	The poster has no creative elements. (1)	/5

Starter – The Cardiac Cycle Song!

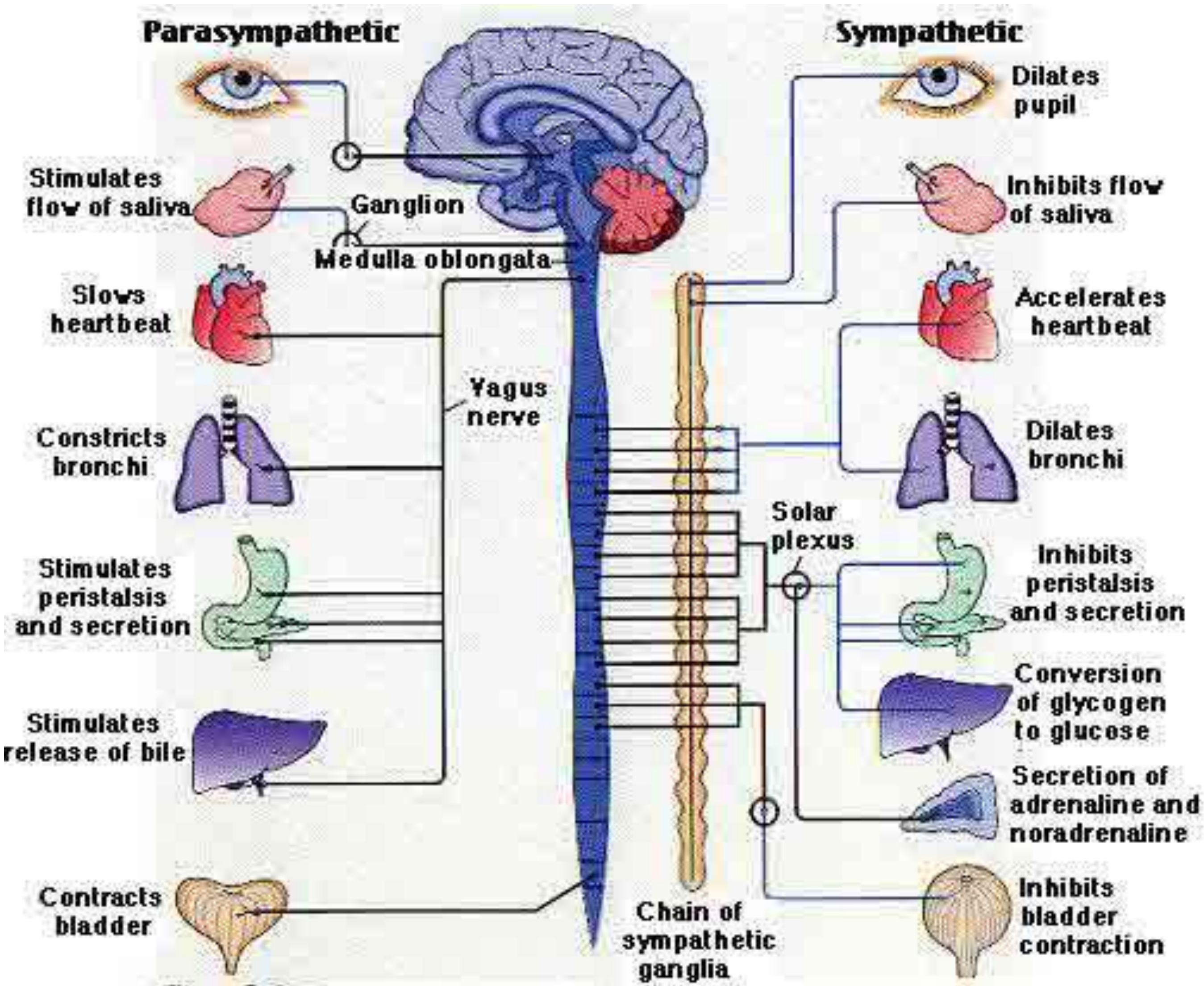
Learning Objective

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

DIVISIONS OF NERVOUS SYSTEM

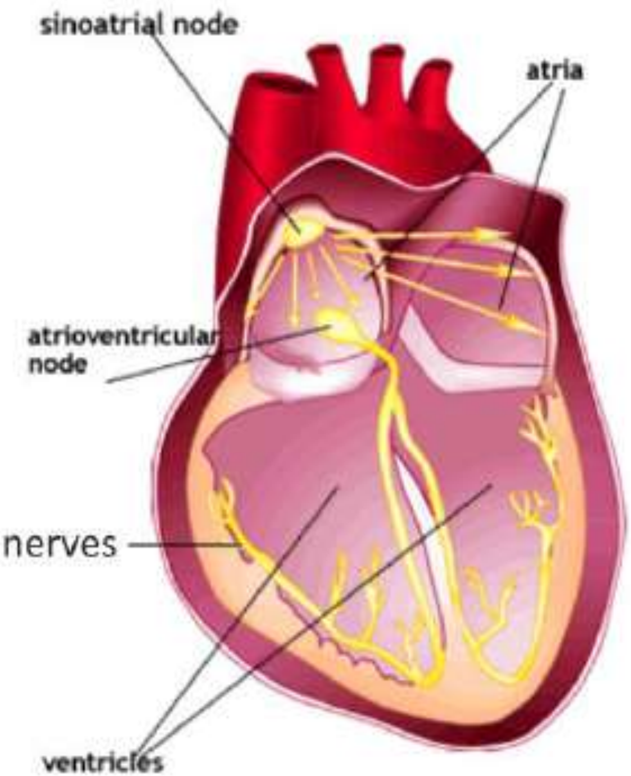


The autonomic nervous system



Control of the Heart Beat

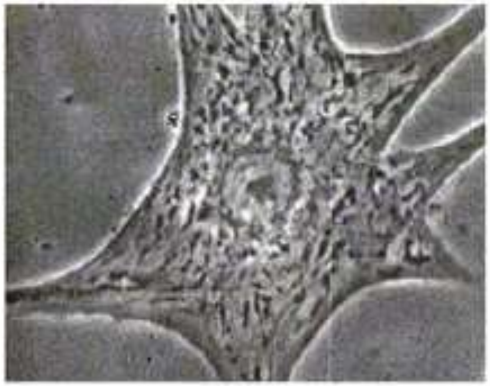
Beating of the heart is due to myogenic muscle contraction.



http://www.mda.org/publications/Quest/q106resup.html

This means the myocyte (muscle cell) itself is the origin of the contraction and is not controlled externally.

Cardiac cell contracting:



http://www.emc.maricopa.edu/faculty/farabee/BIOBK/heartbeat.gif

A region of myocytes called the sinoatrial node (pacemaker) controls the rate of the heartbeat.

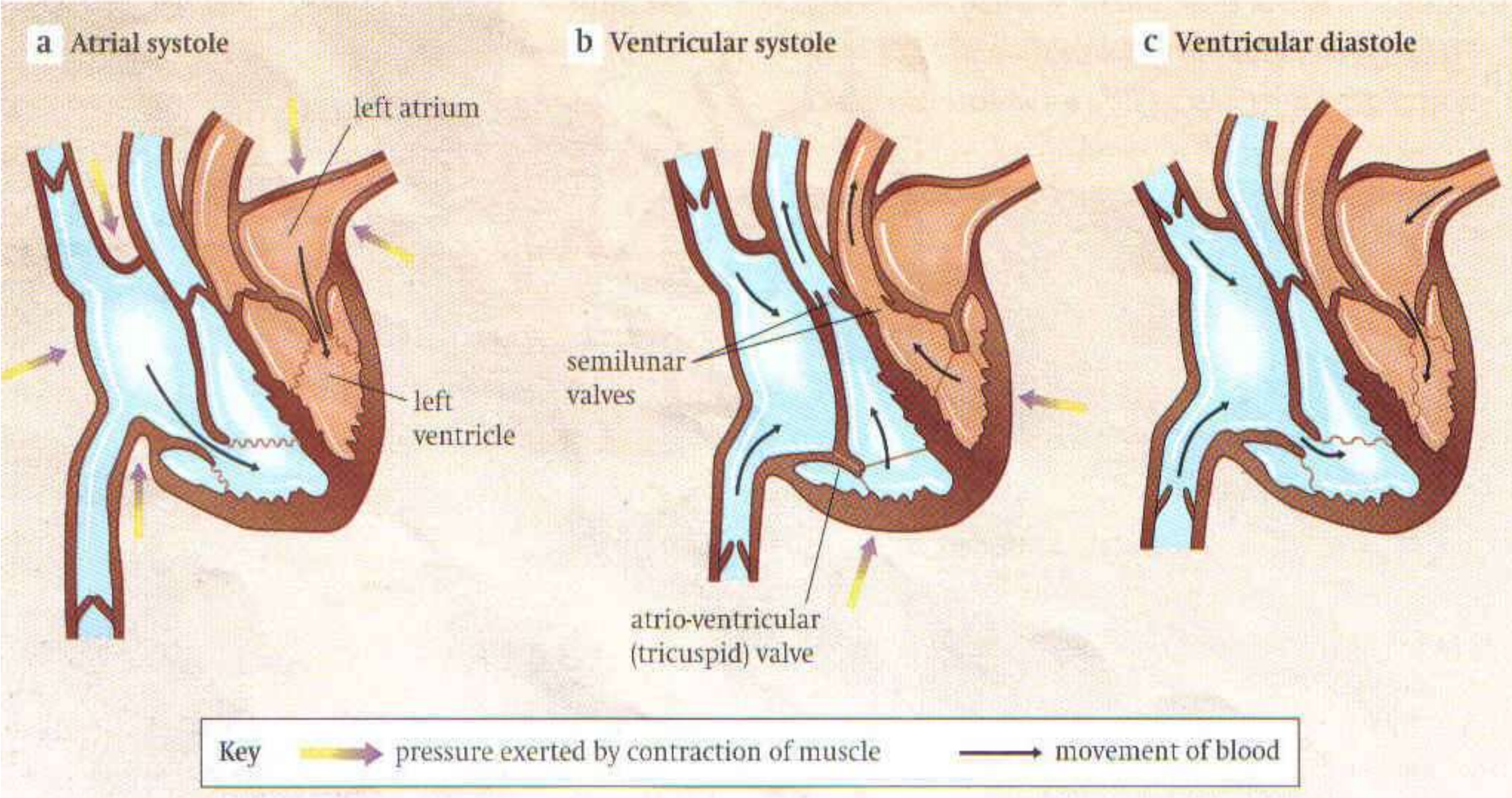
Now DEFINE the key terms on your handout!

A wave of excitations is sent from the sinoatrial node, causing the atria to contract. This excitation is conducted to the atrioventricular node, where it is passed through nerves to the muscles of the ventricles, causing them to contract.

Myogenic initiation of the contraction means that the heart does n stop beating - it is not a conscious process.

GROUP THOUGHT

Cardiac muscle is indefatigable - what does this mean and how would you expect the histology of it to differ from regular muscle tissue?



The cardiac cycle. Only three stages in this continuous process are shown.
a Atrial systole Both atria contract. Blood flows from the atria into the ventricles. Backflow of blood into the veins is prevented by closure of valves in the veins.
b Ventricular systole Both ventricles contract. The atrio-ventricular valves close. The semilunar valves in the aorta and pulmonary artery open. Blood flows from the ventricles into the arteries.
c Ventricular diastole Atria and ventricles relax. Blood flows from the veins through the atria and into the ventricles.

The pathway followed by the wave of excitation

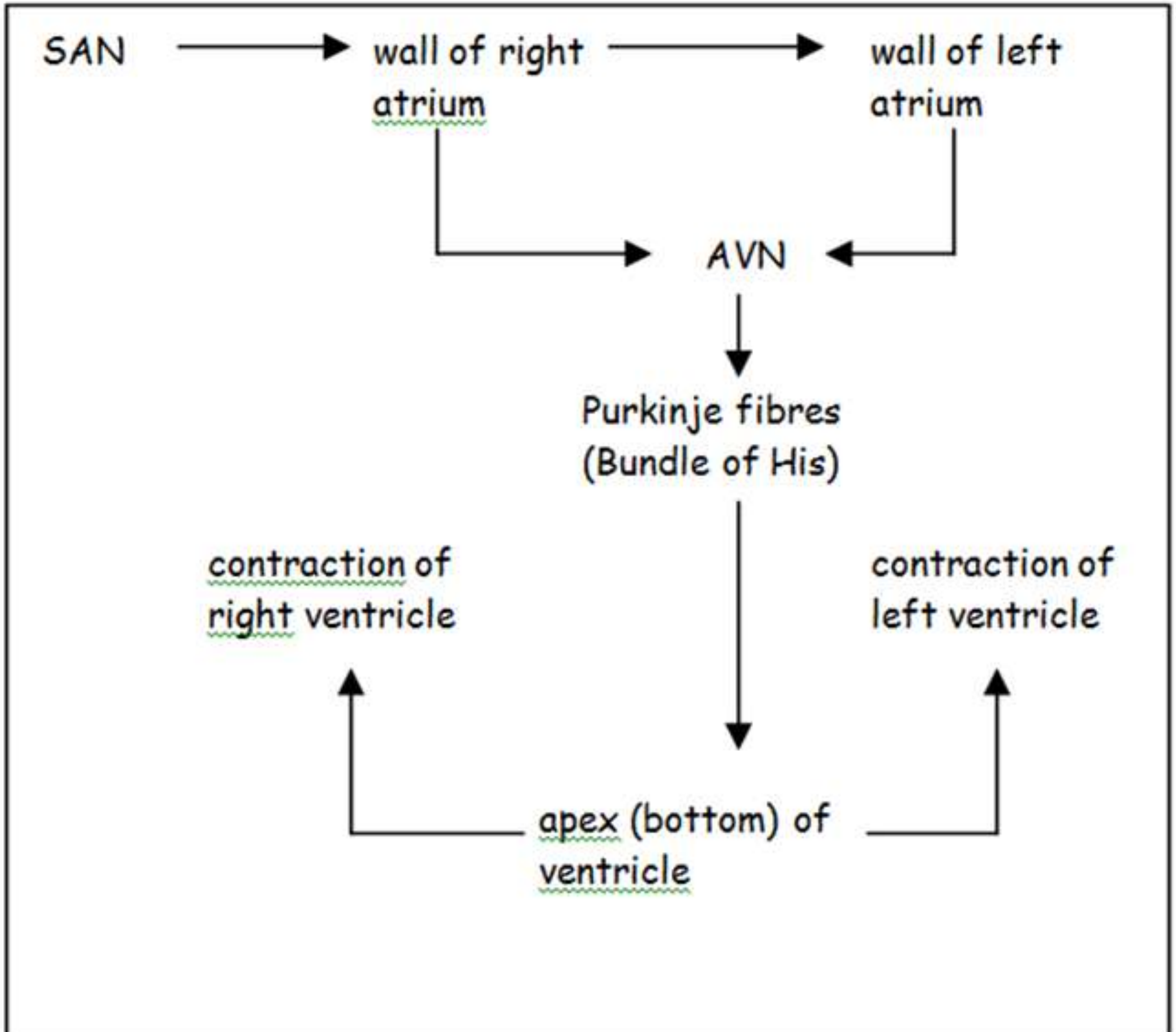
Sinoat

Excitat
spreac
atria

Atriov
node

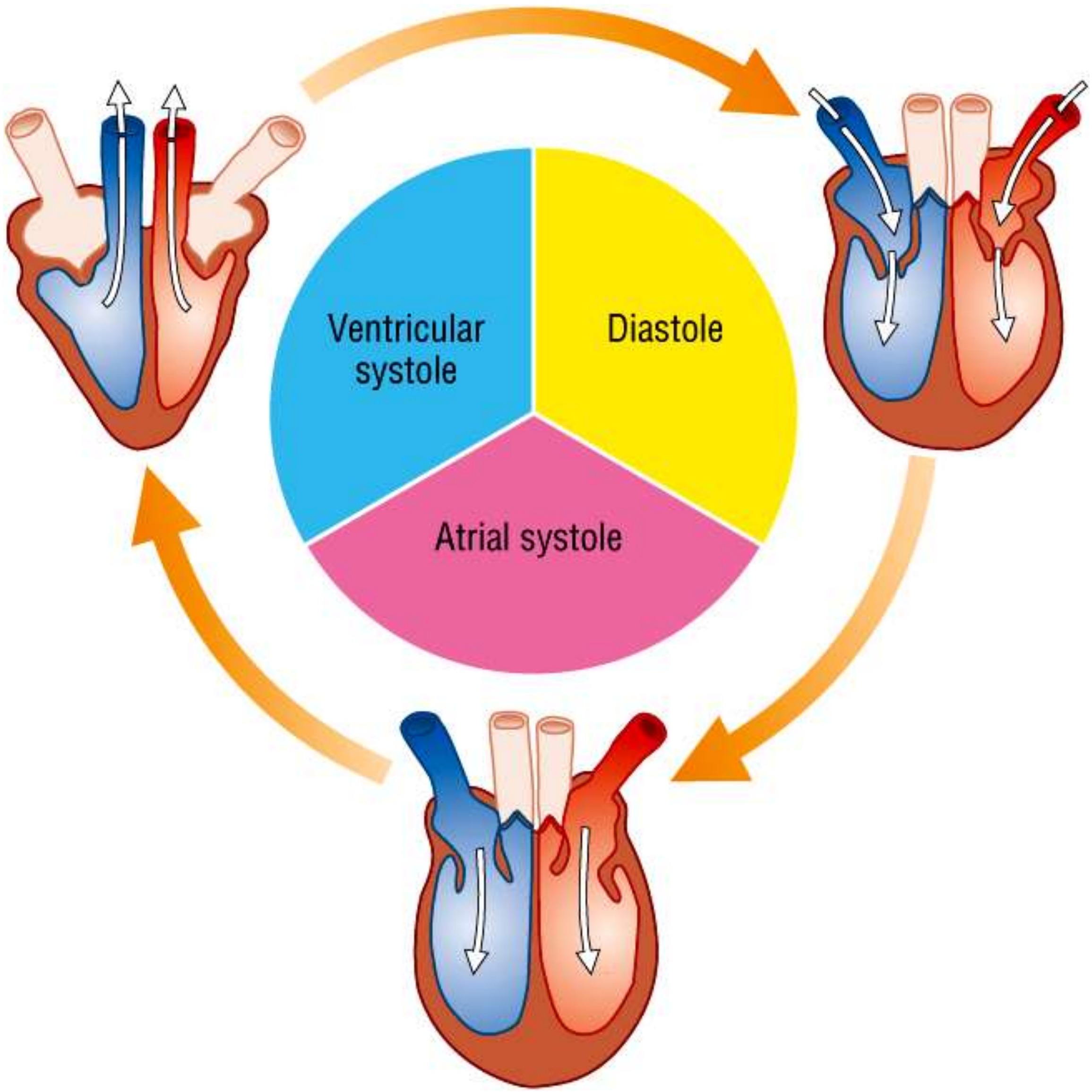
Purky
carries
down

Excitat
up wal



xercise on
ALLY!

INDIVIDUAL ACTIVITY: *Can you complete the ANNOTATE and EXLPAIN exercise on your handout?*



You MUST include the following:

- **Details of the 3 stages of the cardiac cycle**
- **The key terms from your handout**

You SHOULD try and include

- **The pathway followed by the wave of excitation**

You MIGHT

- **Want to try WITHOUT notes!**

STARTER – Past Paper Question

How is breathing rate regulated by the body to meet the increasing demands of exercise during a game of netball?

....

....

....

....

....

....

....

....

(4 marks)

1. Increased carbon dioxide/lactic acid/acidity
2. Detected by chemoreceptors/baroreceptors/mechanoreceptors/proprioceptors/
thermoreceptors
3. In carotid arteries/aortic arch
4. Nerve impulses to respiratory centre/medulla
5. Nerve impulses to breathing muscles/diaphragm/intercostal muscles
6. Deeper and faster breathing 4 marks

Learning Objectives

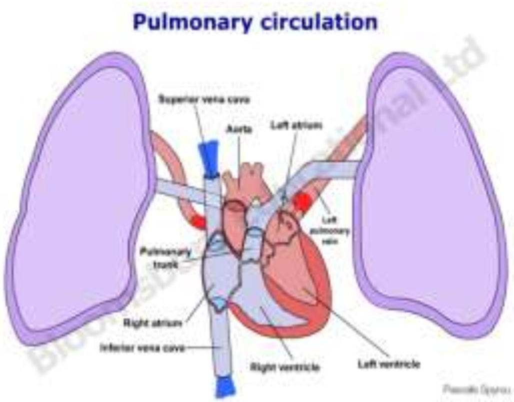
Describe the relationship between heart rate, cardiac output and stroke volume at rest and during exercise.

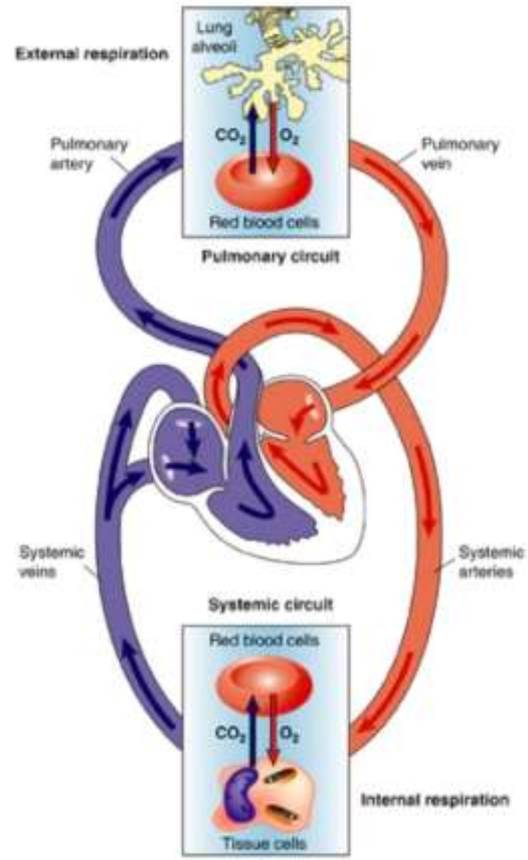
Analyze cardiac output, stroke volume, and heart rata data for different populations at rest and during exercise.

Can you copy the definitions into your workbook as we go through the next few slides?

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.





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. The term is contrasted with pulmonary circulation

Cardiac Output & Stroke Volume

- **Cardiac Output L/m (Q)** = Blood pumped per minute
- **Stroke Volume L (SV)** = Blood pumped per beat

Equation: Q= HR x SV

Ok so if Cardiac Output is calculated by…

Q=HR x SV then…

How is Stroke Volume Calculated?

$$\text{Stroke Volume (L/SV)} = \frac{\text{Cardiac Output (Q)}}{\text{Heart Rate}}$$

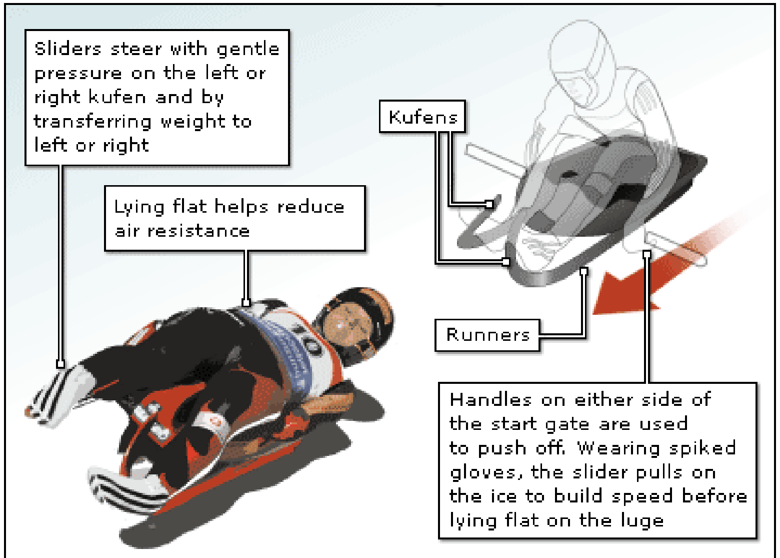
Individual activity

1. Take your resting heart rate at rest now. (count the number of beats in 15 s and multiply by 4)

2. Work out your cardiac output if you assume your stroke volume is 80 millilitres.

3. Use the data to fill in the relevant space in your workbook

Your answer should be between 4-6 litres

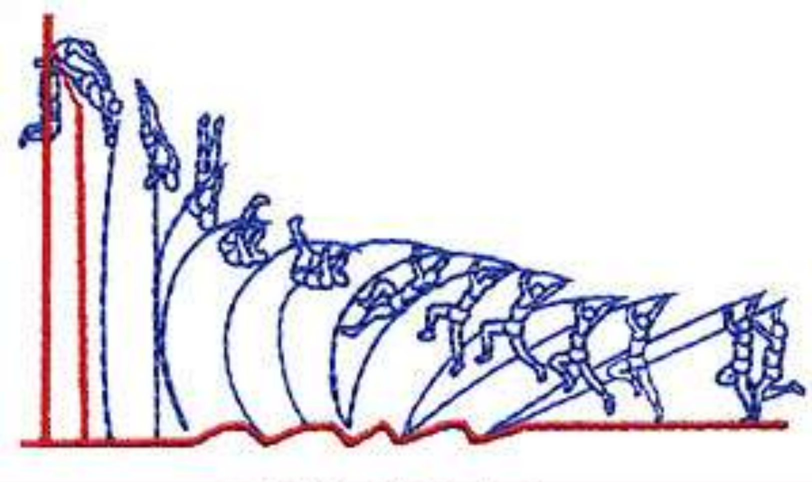


The following table below shows some typical values for cardiac output at varying levels of activity:

Activity Level	Heart rate (**HR**) (beats/min)	Stroke Vol (**SV**) (ml)	Cardiac output (l/min) (**HR*SV**)
Rest	72	70	5
Mild	100	110	11
Moderate	120	112	13.4
Heavy (highly trained athletes)	200	130	30

STARTER – GROUP THOUGHT– What is the effect of exercise on cardiac output?

Group thought – What is the effect of exercise on cardiac output



Pole Vault Technique

Cardiac output is increased by increasing both the heart rate and stroke volume, both which increase in proportion to the intensity of exercise.

Learning Objectives

- **Analyze** cardiac output, stroke volume, and heart rata data for different populations at rest and during exercise.

Individual Activity - Types of Exercise

Sub-maximal exercise is the average method of working out; you are not working at your physiological .... Heart rate is measured in .... and relates to sub-maximal exercise in that when you are exercising, your measured heart rate is not as .... as it could be.

When you reach your maximum amount of work that you are physiologically capable of performing, your heart rate will .... Heart rate should respond in a .... fashion to physical activity; however, other factors such as your medical history and level of fitness may play a role. .... exercise should .... the heart rate, but not bring it to its maximum.

Maximum beats per minute fast plateau

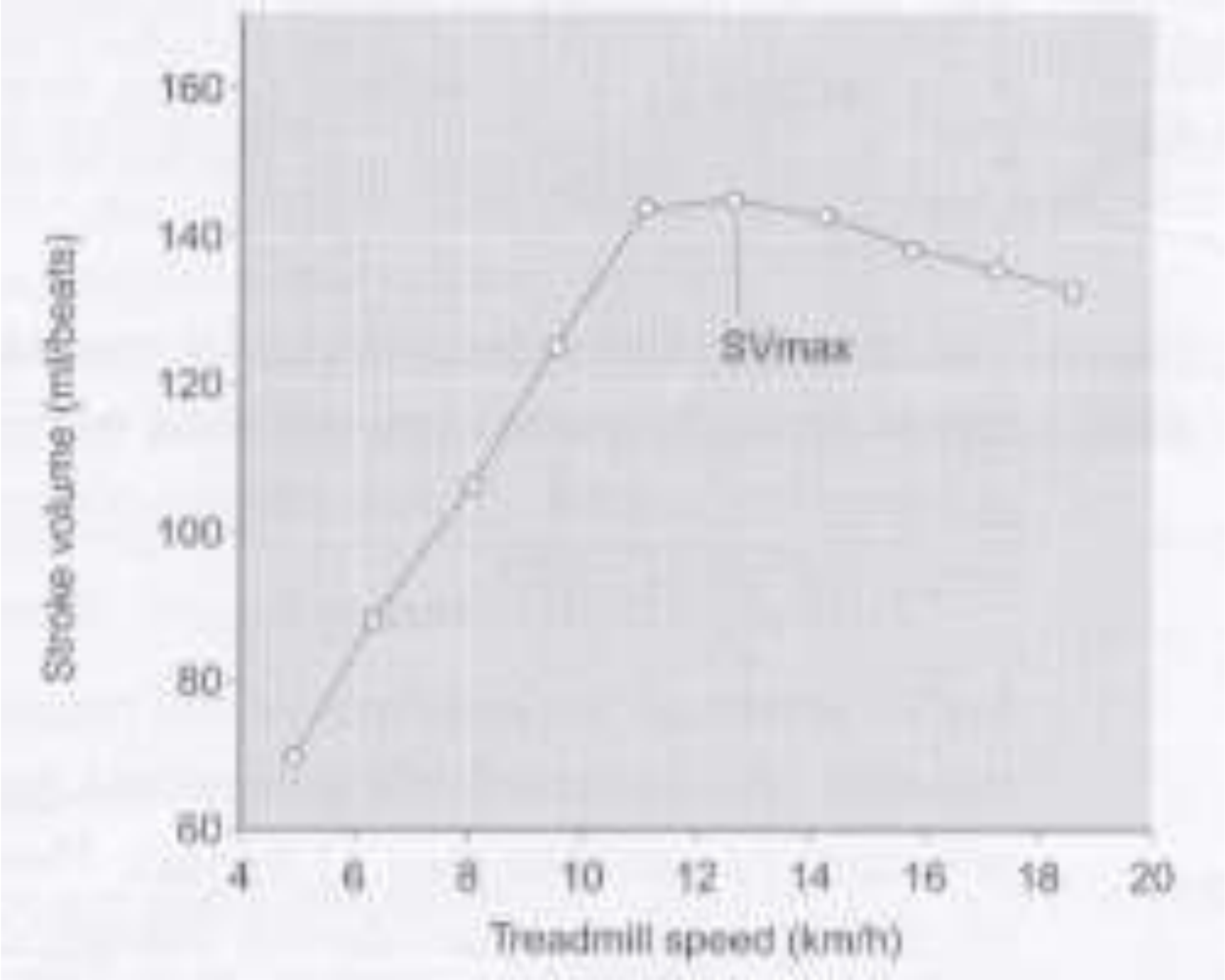
Linear sub-maximal increase slow decrease

Individual Activity - Types of Exercise

Sub-maximal exercise is the average method of working out; you are not working at your physiological maximum. Heart rate is measured in beats per minute and relates to sub-maximal exercise in that when you are exercising, your measured heart rate is not as fast as it could be.

When you reach your maximum amount of work that you are physiologically capable of performing, your heart rate will plateau Heart rate should respond in a linear fashion to physical activity; however, other factors such as your medical history and level of fitness may play a role. slow exercise should increase the heart rate, but not bring it to its maximum.

Changes in stroke volume in response to increasing exercise intensity;



Can you complete the sentences in your workbook as we go through the next few slides?

Stroke Volume

- **Increases** during exercise – why?

- At a **linear** rate to the speed/intensity of the exercise (up to about **40-60%** of maximum intensity exercise)

- Once 40-60% of maximum intensity is reached stroke volume **plateaus**.

- Therefore stroke volume reaches its **maximum** during **sub-maximal** exercise

What causes stroke volume (and therefore Q) to increase?

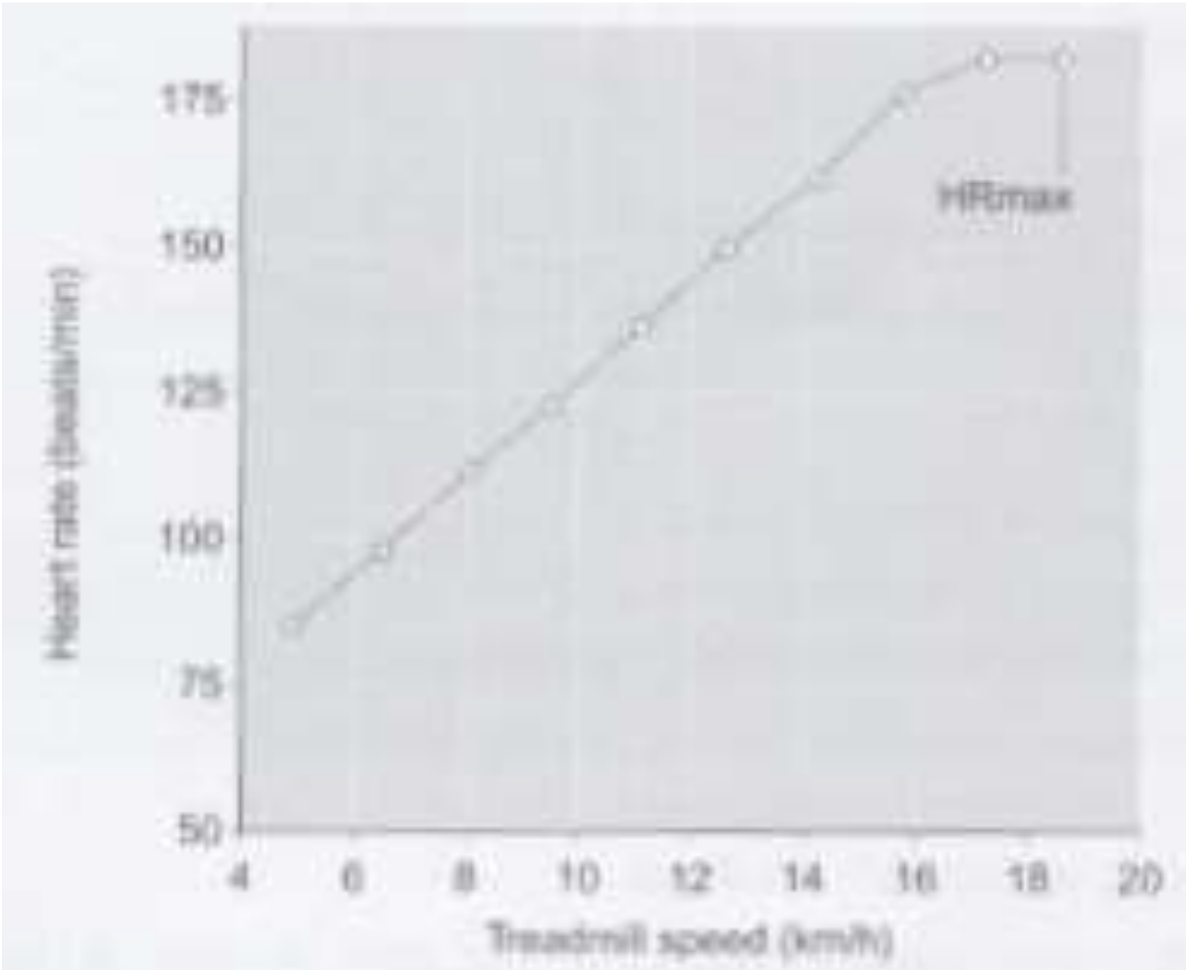
- More blood is being returned to the heart – this is called **venous return**
- Less blood left in heart (**End Systolic Volume**)
- Increased **diastolic filling** occurs, this increases the pressure and stretches the walls of the ventricles, which means that a more forceful contraction is produced
- This is known as **Starling's Law** (more stretch = more forceful contraction)

- During maximal exercise the cardiac output will need to be increased, however stroke volume has already reached its maximum – ***what happens to allow Q to increase?***

- Heart rate **increases**

- As a result of this stroke volume starts to **decrease** – the increase in HR means that there is not as much time for the ventricles to fill up with blood, so there is less to eject (causes the HR to increase even more)

Changes in heart rate in response to increasing exercise intensity



Heart Rate

Before Exercise

- Increases above resting HR before exercise has begun – known as **Anticipatory Rise**, is as a result of the release of adrenalin which stimulates SA node

Maximal Exercise

- **Increases** dramatically once exercise starts, continues to increase as **intensity** increases
- **Decreases** as exercise intensity decreases

Heart Rate and Sub-Maximal Exercise

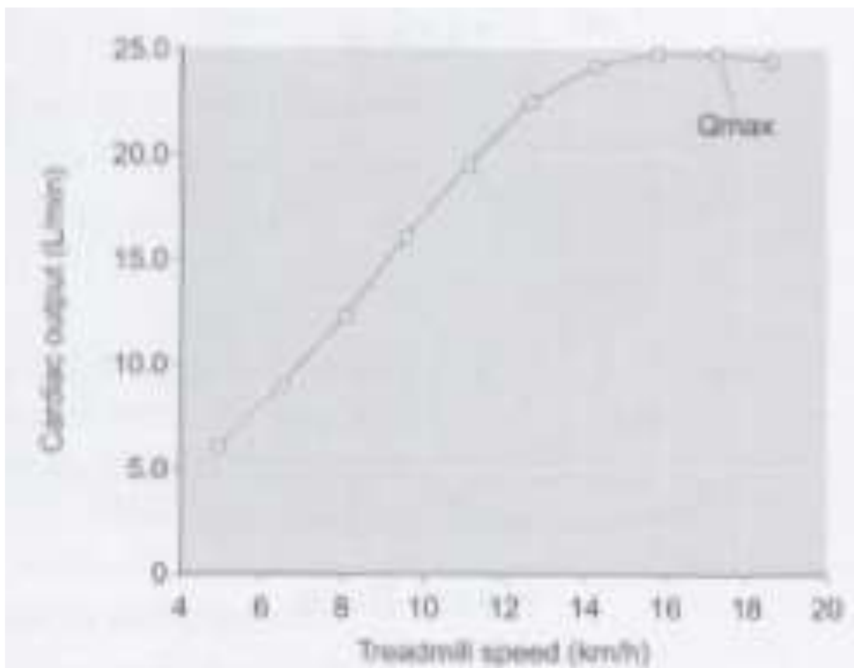
- Plateaus during sub-maximal exercise, called **Steady State** – this means that the oxygen demand is being meet

After Exercise

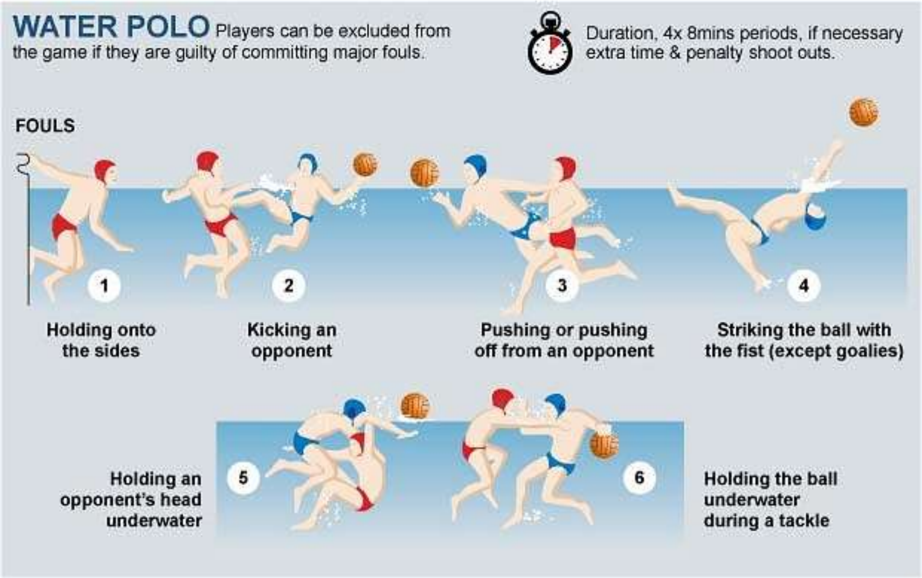
- After exercise – decreases **dramatically**
- Then **gradually** decreases

Cardiac Output

- **Increases** directly in line with intensity from resting up to maximum
- **Plateaus** during sub-maximal exercise



Individual Activity – Data Analysis Questions



Starter – Group thought

How does the heart change as a result of training?

Learning Objectives

- **Discuss** the effect of exercise on the physiology of the heart

- **Explain** cardiovascular drift

la·crosse \lə'krȯs *also* -räs\ *n* -s *often attrib* [CanF *la crosse*, lit., the crosier, the hooked stick] : a game originating among the No. American Indians that is played on a turfed field by 2 teams of 10 players each of whom uses a long-handled stick with which the ball is caught, carried, and thrown with the object being to throw the ball into the opponents' goal — compare CROSSE

lacrosse stick *n* : CROSSE

Pic. 5

lacrosse stick

from Websters

Stroke Volume

- Heart muscle increases in size, known as . .
- **Cardiac Hypertrophy** AND
- **Athlete's heart**
- The left ventricle increases in size

- **Individual thought - why this ventricle?**

- Thicker walls of the heart allow a more **forceful contractions**, there more blood can be pumped per beat, resulting in an increase in. . .
- **Stroke Volume**

Heart Rate

- Due to an increase in SV the heart will not have to pump as many times (both at rest and during exercise), resulting in a decrease in. . .

- **Heart rate** (at rest and during exercise)

- When an athlete’s resting heart rate falls below 60bpm it is known as . . .
- **Bradycardia**

- During sub-maximal exercise, a trained athlete’s heart rate would not rise as much
- It would reach **steady state sooner**
- And recover faster

- **Greater heart rate range** – resting heart rate is lower so there is more room for an increase when exercising
- Maximum heart rate stays the same (220-age)

Cardiac Output

- The volume of cardiac output at rest. . .
- Stays the same (lower resting heart rate but increase in stroke volume)
- The **maximum cardiac output** of an individual. . .
- **Increases**, so a trained athlete can deliver oxygen to the muscles for a longer period of time)

Other Factors

- The percentage of blood that the heart pumps out per beat is known as **ejection fraction**

- A trained athlete experiences an **increase in ejection fraction** because their heart will pump more forcefully each beat

- Even though **resistance training** (strength) does not work the CV system, an athlete will still will experience an increase in the size of their heart muscle (myocardium) and therefore their stroke volume will increase (more forceful contraction)

- The heart itself will experience **capillarisation** – this will increase the blood supply to the heart and ensure it continues to work for longer

Individual Activity

Write the statements below into the correct place in the summary table in your workbook

Increases as heart muscle is stronger – can contract more forcefully (as does ejection fraction)

Stays the same during sub-maximal exercise
Maximum cardiac output increases (athlete can last longer)

Increases as heart muscle is stronger – can contract more forcefully (as does ejection fraction)

Stays the same

Lower during sub-maximal exercise
Greater heart rate range (starts lower so has more room for increase)
Maximum stays same (220-age)

Decreases (below 60bpm = bradycardia)

Summary of Changes

	Heart Rate	Stroke Volume	Cardiac Output
Rest	Decreases (below 60bpm = bradycardia)	Increases -can contract more forcefully (as does ejection fraction)	Stays the same
Exercise	Lowers during sub-maximal exercise Greater heart rate range (starts lower so has more room for increase) Maximum stays same (220-age)	Increases as heart muscle is stronger – can contract more forcefully (as does ejection fraction)	Stays the same during sub-maximal exercise Maximum cardiac output increases (athlete can last longer)

Individual Activity – Past Paper Question

Briefly explain the terms 'cardiac output' and 'stroke volume', and the relationship between them. **(3)**

A. Cardiac output – 'the volume of blood pumped from heart/ventricle in one minute;

B. Stroke volume – 'the volume of blood pumped from the heart/ ventricle in one beat;

C. Cardiac output = stroke volume x heart rate/Q = SV x HR

Explain how it is possible for a trained performer and an untrained performer to have the same cardiac output for a given workload. **(4)**

A. Different sized hearts/hypertrophy –trained bigger;

B. Different stroke volumes – trained bigger;

C. Different heart rates – untrained higher;

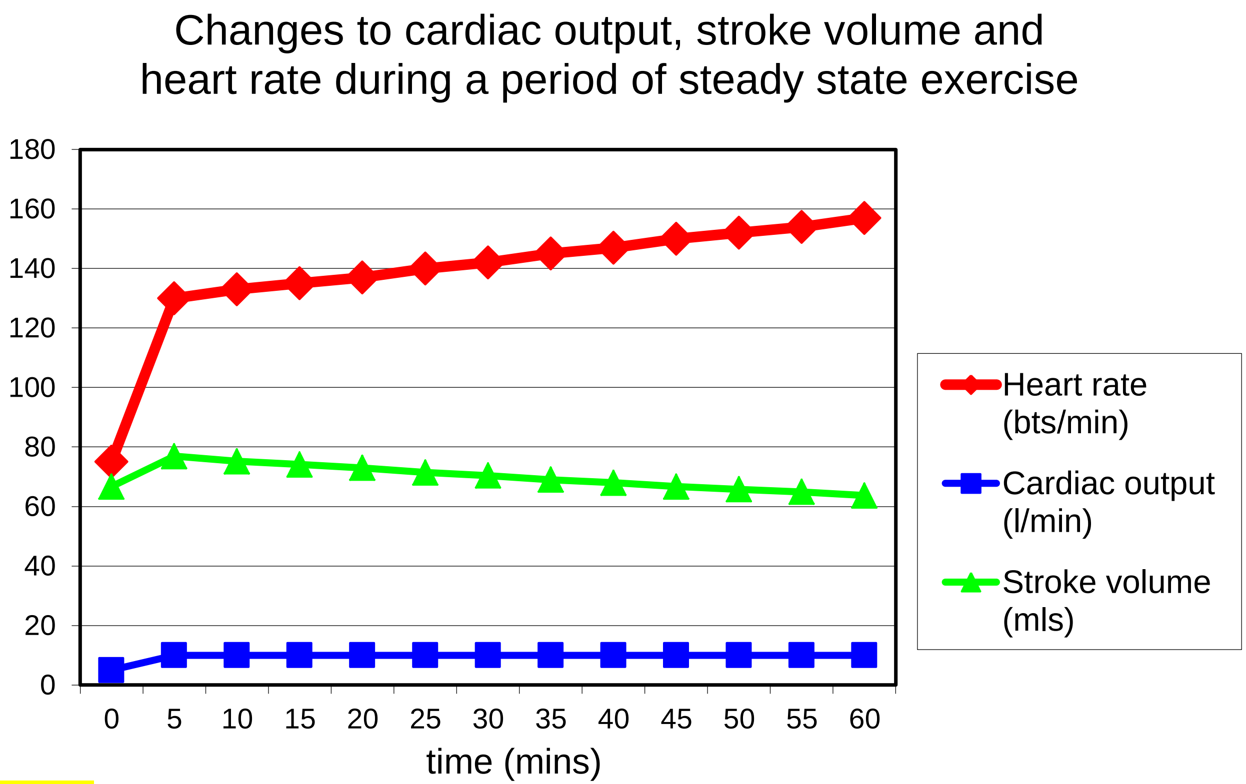
D. Can only occur at sub maximal workloads;

E. At higher workloads untrained will not be able to increase their heart rate sufficiently;

F. Different physiques/size/mass –untrained bigger.

Practical Activity – Calculating your maximal heart rate for exercise

Starter – Complete the statements



- Steady state exercise lasting 60 minutes
- Cardiac output stays same
- Stroke volume decreases
- Heart rate increases

Learning Objective

- **Explain** cardiovascular drift
- **Compare** the distribution of blood at rest and the redistribution of blood during exercise

Explanation of cardiovascular drift

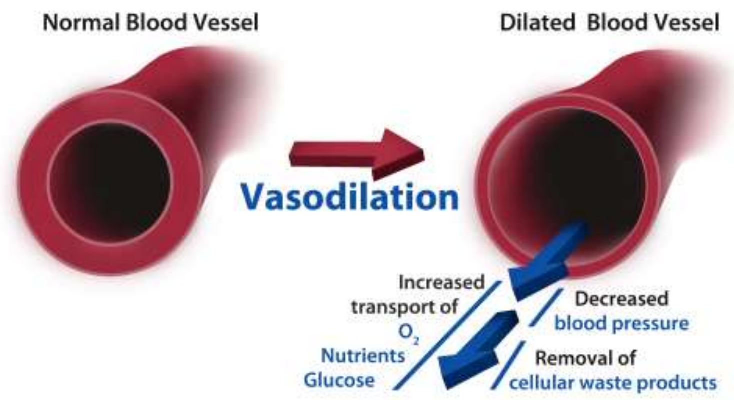
- Continuous exercise – decrease in volume of blood plasma
  - Fluid seeps into surrounding tissues and cells
  - Fluid lost to sweating
  - If athletes fail to re-hydrate, can further reduce the volume of blood returning to heart

- Reduces blood volume and hence reduces stroke volume

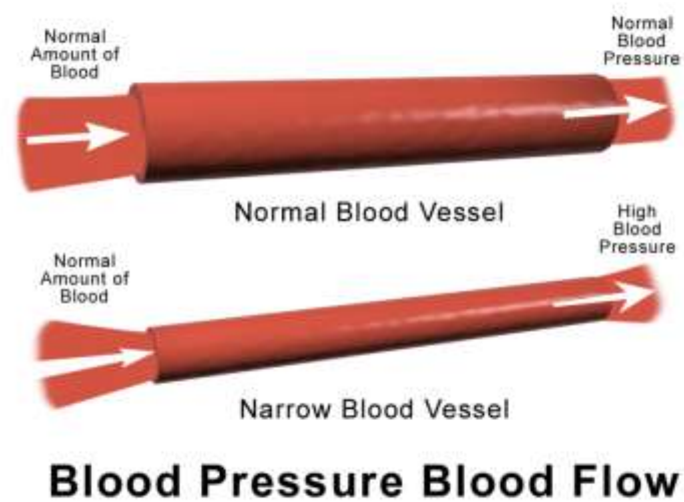
- Hence reduced venous return -
  (Starling's Law)
- Cardiac output (Q) needs to be kept constant
- Q = SV x HR - if SV ↓, then Q must ↑
- Hence need for increase in heart rate during steady state exercise to maintain

Group thought – can you remember the meaning of the following terms?

VASODILATION



VASOCONTRICTION



Can you write the defintions into your workbook using your own words?

Blood flow changes during exercise

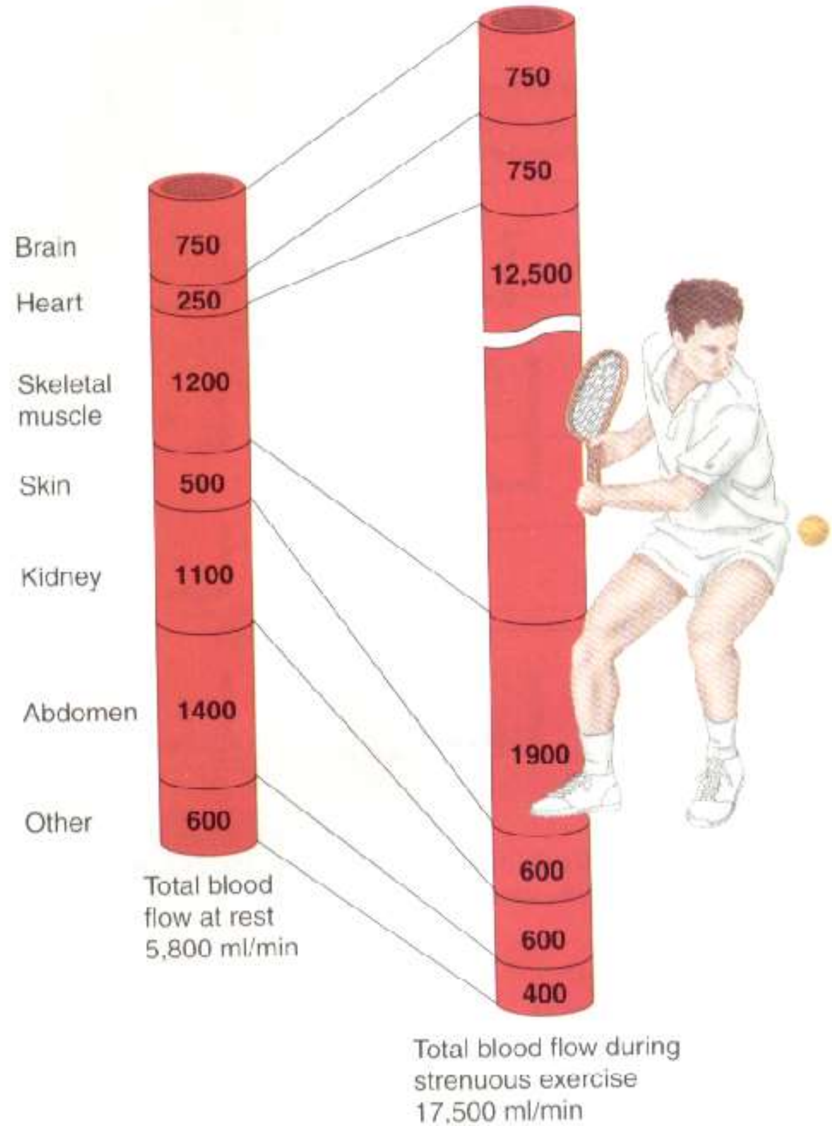


FIGURE 20.12 ***Distribution of blood flow to selected body organs at rest and during strenuous exercise.***

Individual Activity

- Read the passage in your workbook
- Complete the table using the statements below

Temperature regulation. Vasodilation of arterioles increases flow rate to the skin. We go red and lose some heat through evaporation of sweat.

The brain needs a constant supply of oxygen to function properly. Exercise makes no change to this demand.

As a working muscle, the heart needs its share of oxygen. When the heart rate increases, it needs more oxygen to make energy and to remove CO_2.

Non-essential function during exercise.

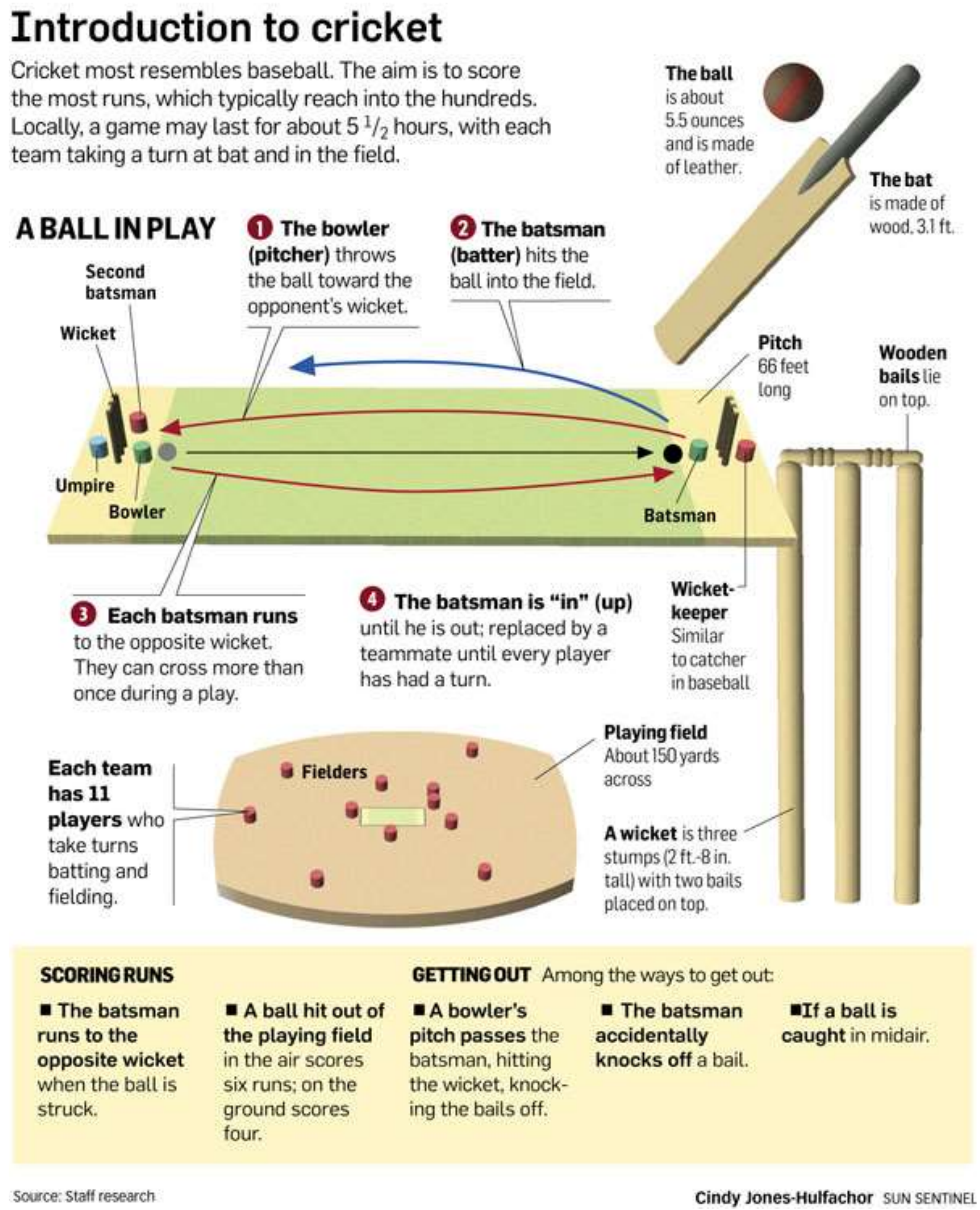
Non-essential function during exercise.

Increased cardiac output is a response to increased work rate and the associated demand for energy. Cardiac output is raised by increasing heart rate and stroke volume

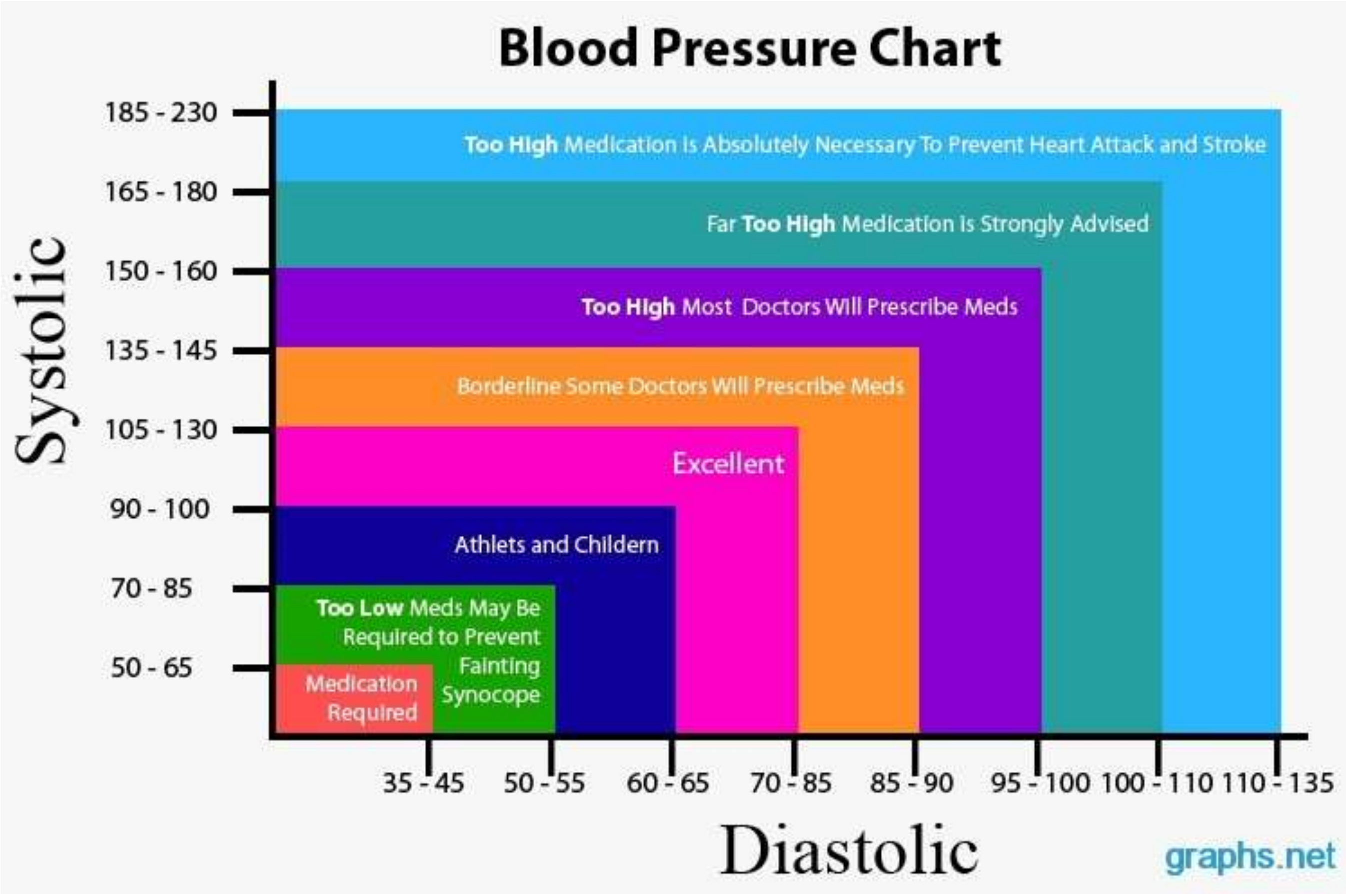
Energy is made where it is needed – in this case working muscle. Increased blood flow brings oxygen and removes waste products ie CO_2 and lactic acid away. The redirection of blood flow is achieved by "**shunting**".

Describe	Explain
Skeletal muscle – massive increase in blood flow (26 fold) to working muscle. At maximum effort muscle takes 88% of blood flow	Energy is made where it is needed – in this case working muscle. Increased blood flow brings oxygen and removes waste products ie CO_2 and lactic acid away. The redirection of blood flow is achieved by "shunting".
Coronary vessels – blood vessels that serve cardiac muscle (which needs oxygen and respiratory substrates). Nearly a 5 fold increase in blood flow during exercise.	As a working muscle, the heart needs its share of oxygen. When the heart rate increases, it needs more oxygen to make energy and to remove CO_2.
Skin – small increase in blood flow to the skin during exercise.	Temperature regulation. Vasodilation of arterioles increases flow rate to the skin. We go red and lose some heat through evaporation of sweat.
Kidneys – significant reduction in blood flow during exercise.	Non-essential function during exercise.
Liver & gut - significant reduction in blood flow during exercise.	Non-essential function during exercise.
Brain – blood flow is maintained at the same level during exercise.	The brain needs a constant supply of oxygen to function properly. Exercise makes no change to this demand.
Whole body – the volume of blood pumped per minute is the same measure as cardiac output.	Increased cardiac output is a response to increased work rate and the associated demand for energy. Cardiac output is raised by increasing heart rate and stroke volume.

Now try the past paper question!



STARTER: How to use a sphygmomanometer



1 to 12 months	75 / 50	90 / 60	100 / 75
1 to 5 years	80 / 55	95 / 65	110 / 79
6 to 13 years	90 / 60	105 / 70	115 / 80
14 to 19 years	105 / 73	117 / 77	120 / 81

Learning Objectives

Define the terms SYSTOLIC and DIASTOLIC blood pressure.

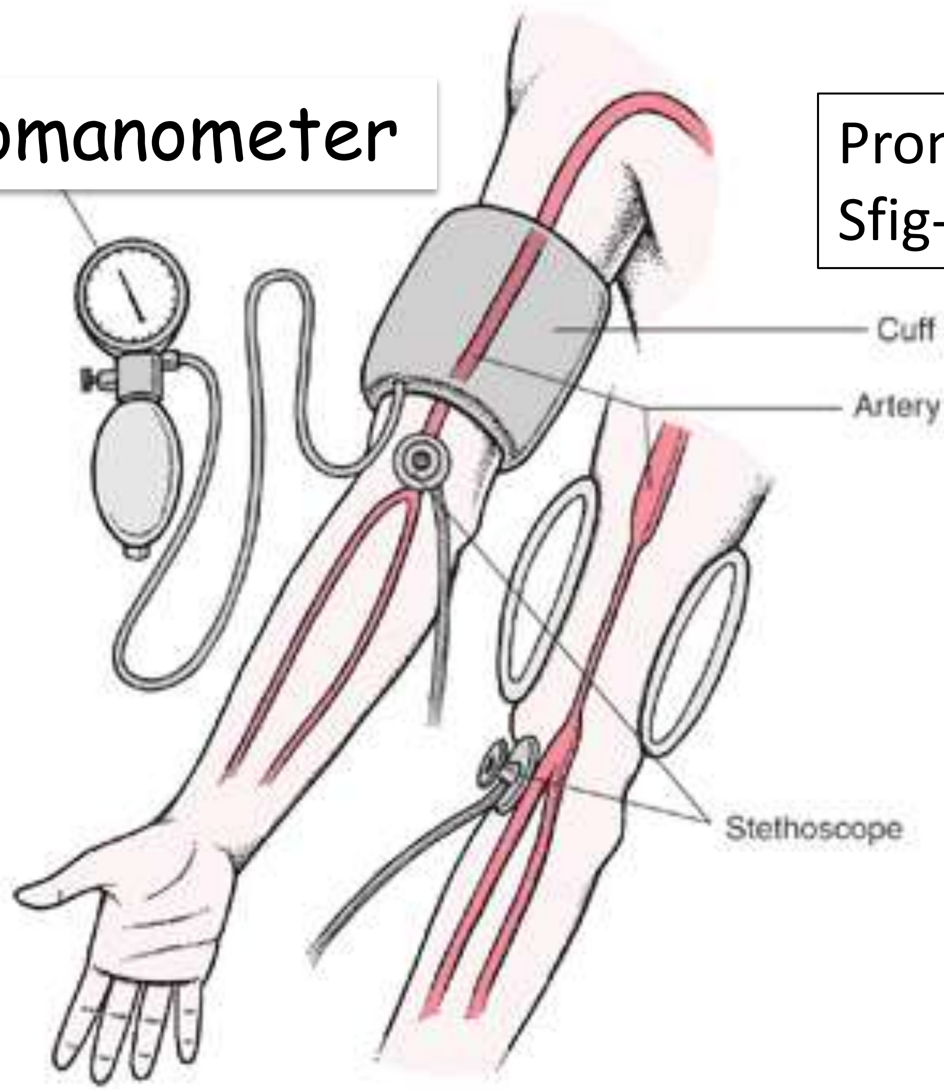
Discuss how systolic and diastolic blood pressures respond to dynamic and static exercise.

Analyze systolic and diastolic blood pressure respond to dynamic and static exercise.

Measuring blood pressure

Sphygmomanometer

Pronunciation:
Sfig-mo-man-o-meter



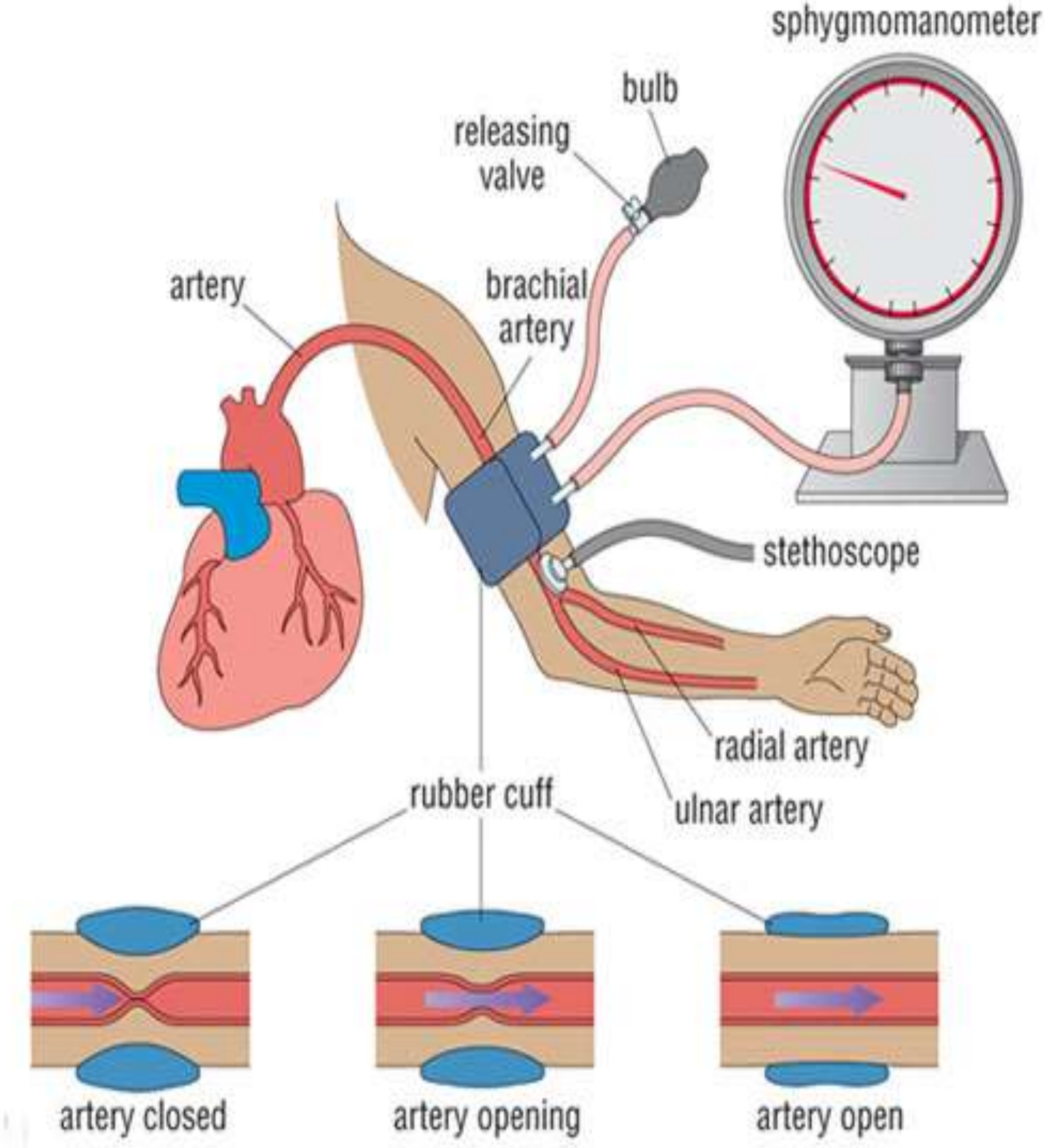
Group Activity – Pop quiz!

1. Where is the cardiovascular centre?
2. What does the sympathetic nerve do to the heart rate?
3. What is the name of the parasympathetic nerve?
4. What are chemoreceptors detecting? Give an example.
5. How does adrenaline increase heart rate?

Blood Pressure

- Measured in blood vessels (**artery**)
- Determined by **cardiac output** and **resistance to flow** of blood in vessels
- Resistance to flow affected by **diameter** of blood vessels
- Narrower vessels (**vasoconstriction**)
- Wider vessels (**vasodilation**)

Now complete the notes in your workbook



The pressure in the cuff is increased until the blood flow stops, and then the flow gradually returns as the cuff is slowly deflated.

This enables you to measure the blood pressure when the artery is closed by pressure from the cuff, and when the artery is fully open.

Recording blood pressure

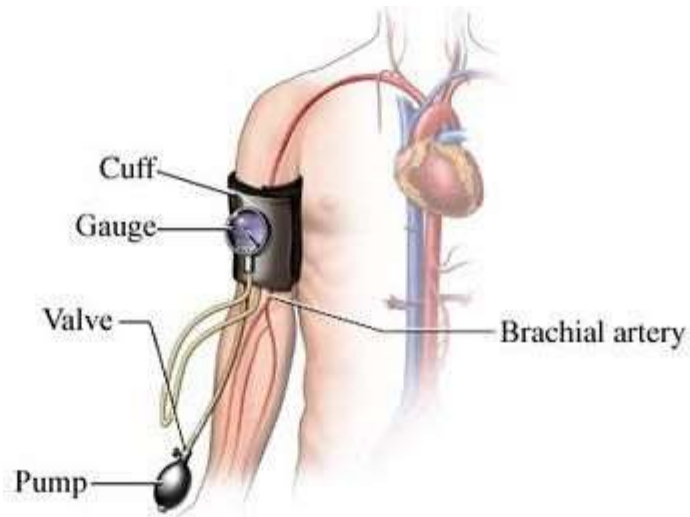
- Systolic blood pressure:
  - Maximum blood pressure
  - Occurs when ventricles are contracting (at the end of the cardiac cycle)

- Diastolic blood pressure:
  - Minimum blood pressure
  - Occurs when ventricles are relaxed and filled with blood (at the beginning of the cardiac cycle)

- We record blood pressure as: Systolic BP/Diastolic BP

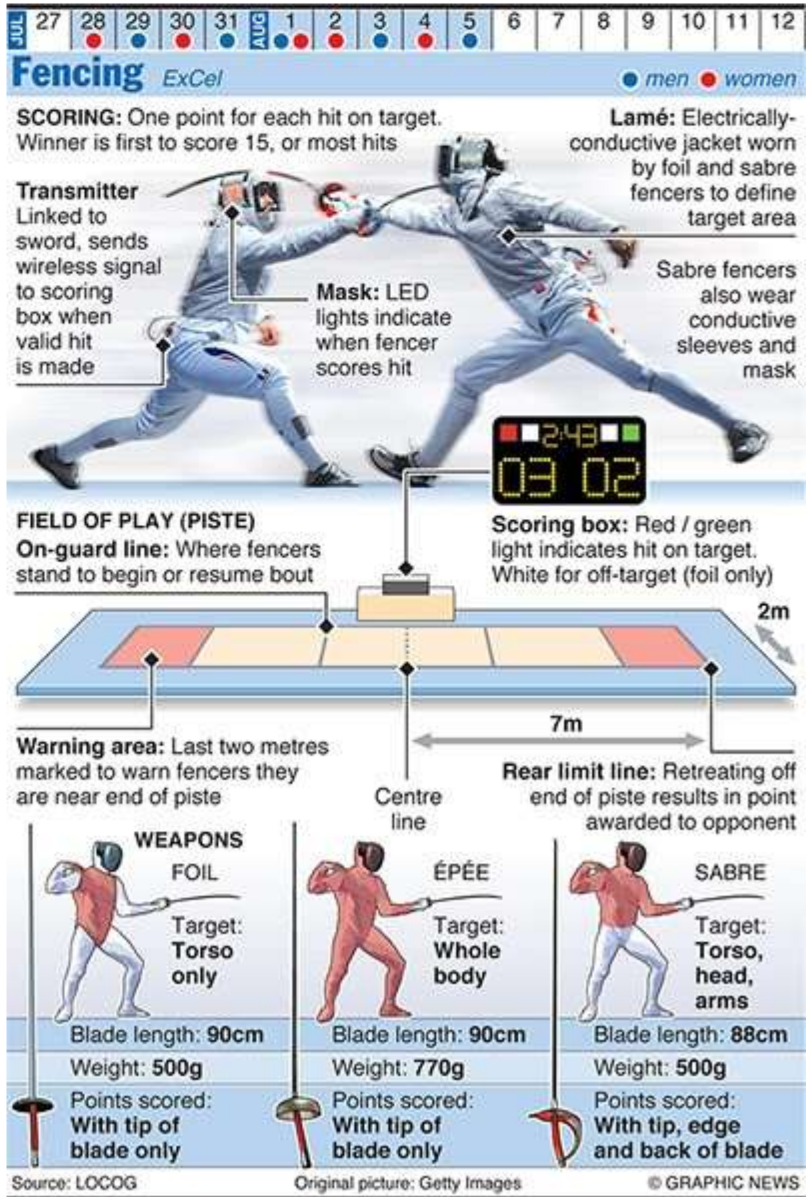
- Diastolic pressure gives clearest indication of resistance to flow in blood vessels

Measuring Your Blood Pressure

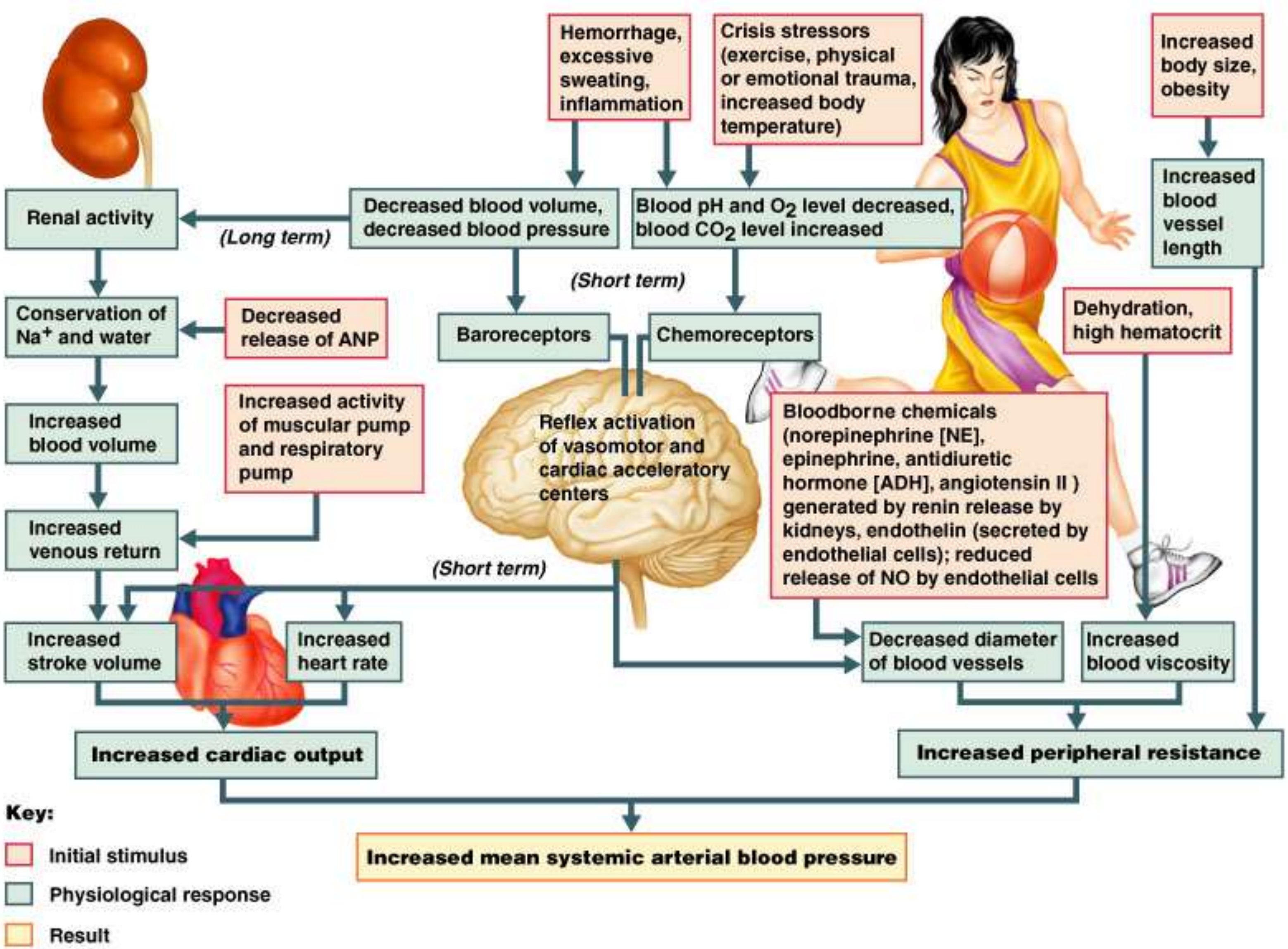


- The average blood pressure reading should be 120/80 mmHg
- mmHg millimetres of mercury. A unit of measuring force per unit area.

Individual Activity – Cloze Exercise



Group thought – what factors affect



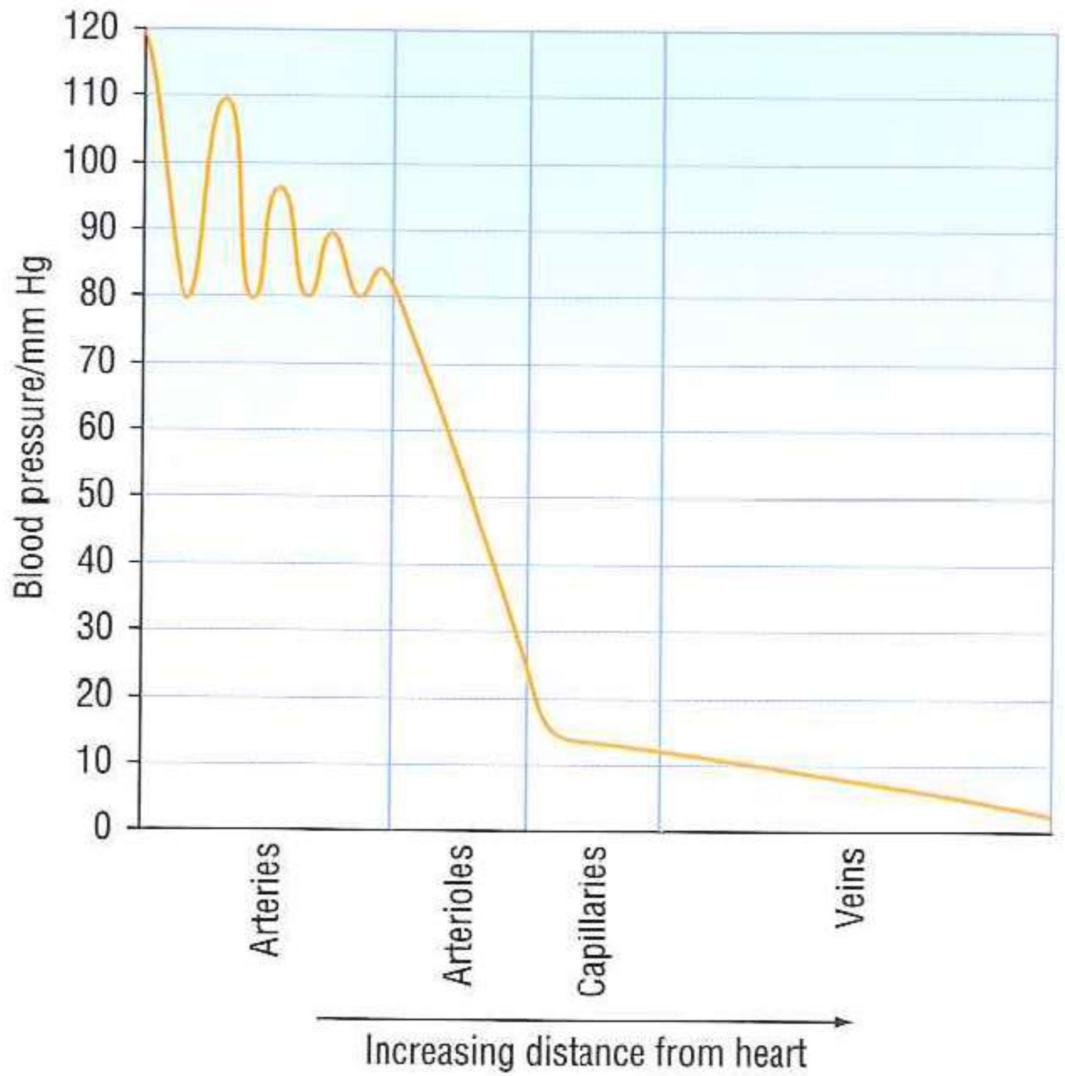
Factors affecting blood pressure

- Cardiovascular centre
  – Diameter of blood vessels controlled by stimulation of sympathetic and parasympathetic nerves
- Smoking

Now complete the table in your workbook

  – Nicotine causes vasoconstriction
  – Build up of fatty deposits in vessels
- Diet
  – High fat diet leads to build up of fatty deposits in blood vessels
- Adrenaline
  – Causes selective vasoconstriction & vasodilation
- Increase in blood viscosity
  – Excess water loss (sweating/excessive urination)

Pairs Activity: **Describe** the blood pressure trend



Individual Activity – Data Analysis Question

Starter: **ToK in SEHS**

Why do you think Jonathan collapsed?

Do you agree with the decision of the race organisers?

Learning Objectives

Explain maximal oxygen consumption.

Discuss the variability of maximal oxygen consumption in selected groups.

Maximal oxygen uptake

ALSO CALLED:

- VO_2 max
- Peak aerobic power
- Maximal aerobic power
- Maximum voluntary oxygen consumption
- Cardio-respiratory aerobic capacity
- Maximal cardio-respiratory fitness
- Maximal functional aerobic capacity

VO_2 max

- A maximum rate at which an individual can consume O2 during maximal exertion.
- Expressed as the maximum volume of oxygen consumed/min
- **Absolute: litres per min (L/min)**
- **Relative: milliliters per kilogram per minute (ml/kg/min)**

Now define this term in your workbook

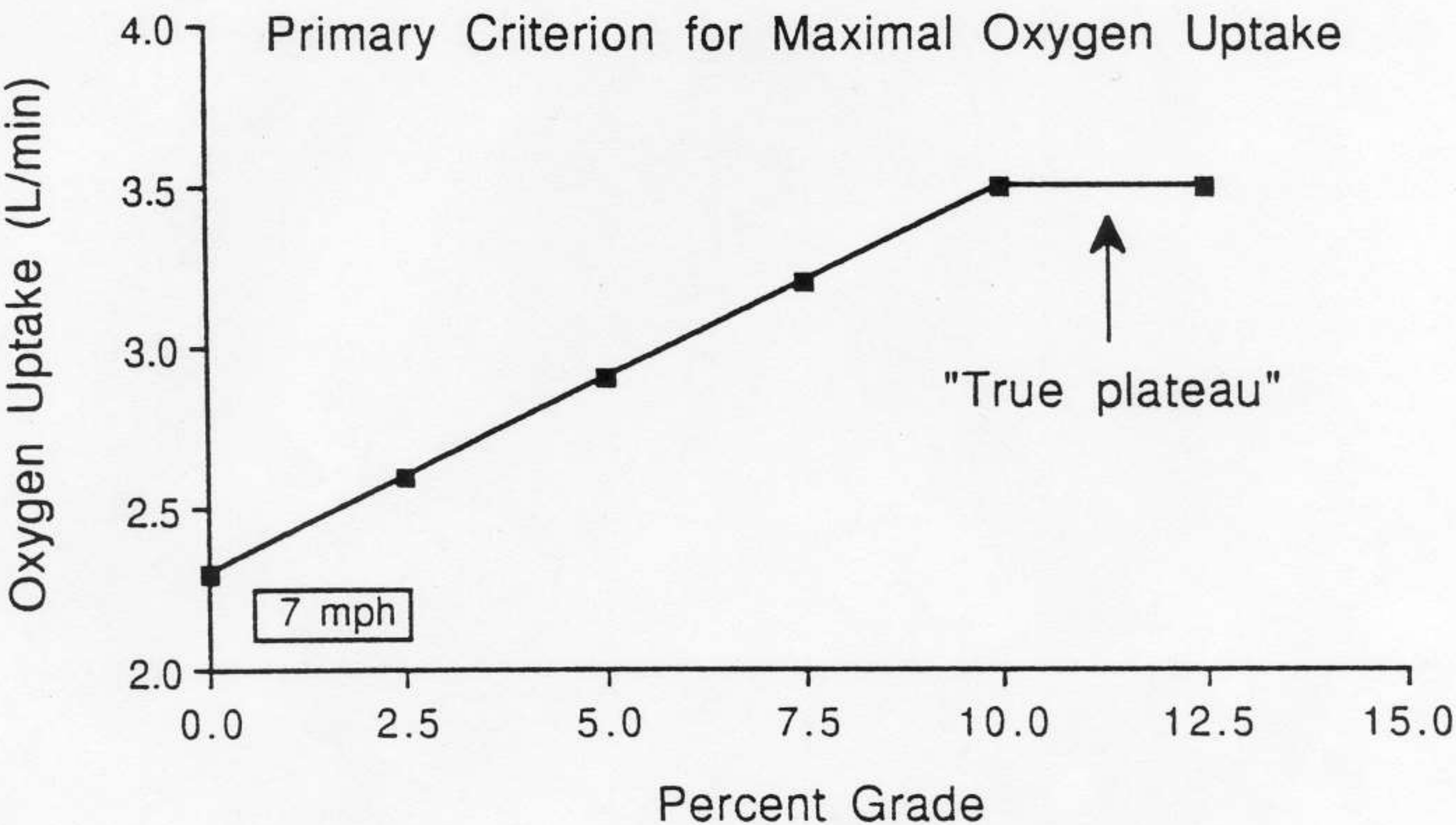
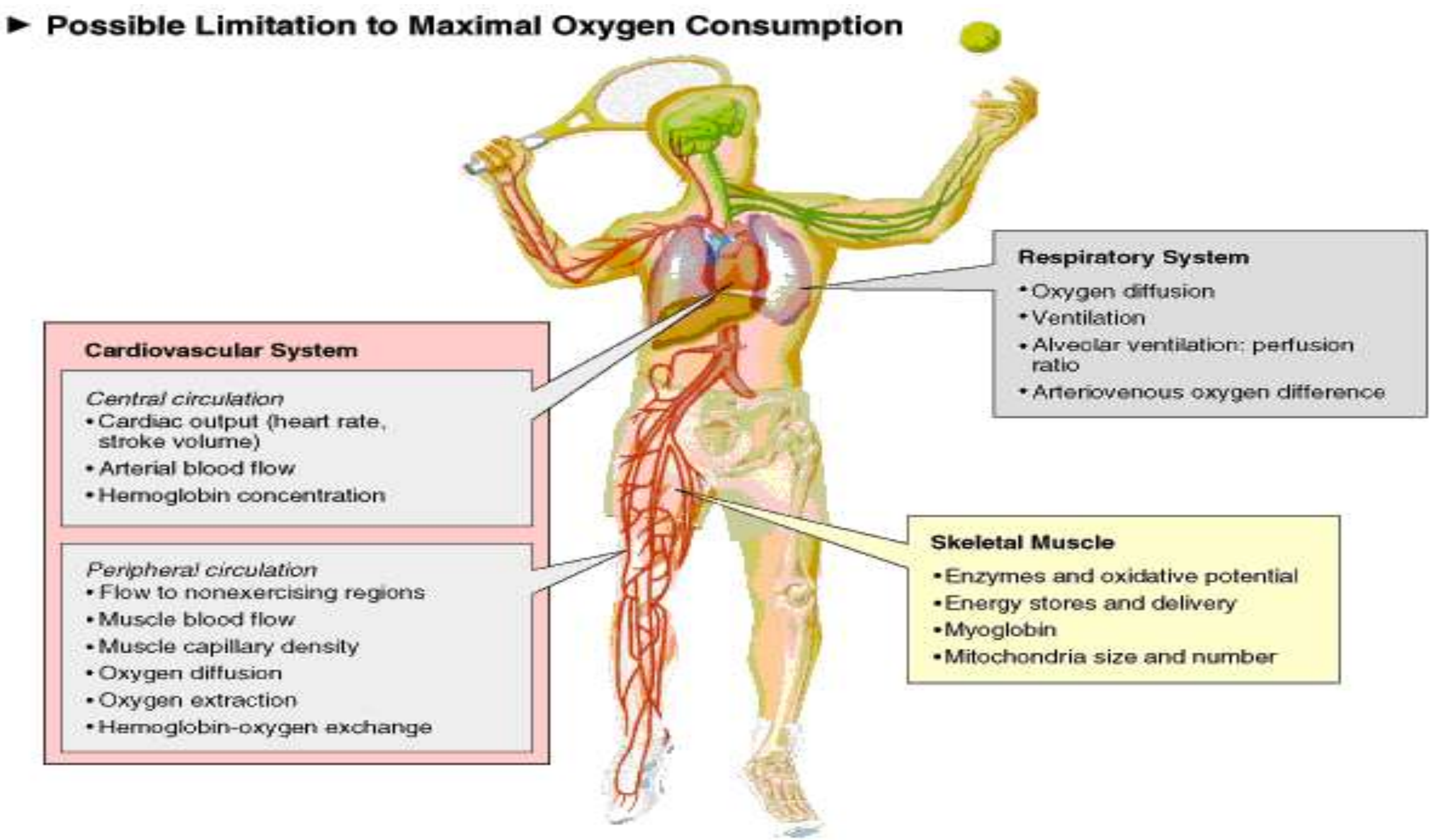


Figure 1—Plot of oxygen uptake versus percent grade showing a "true plateau" in oxygen uptake, signifying that maximal oxygen uptake ($\dot{V}O_{2max}$) has been achieved.

VO₂ max depends on



Individual thought – can you define cardiac output?

Fick equation

VO_2 **max =**

max. cardiac output X max. arterio-venous oxygen difference

($L.min^{-1}$) (ml per 100ml)

Group Activity

Complete the table in your workbooks

	Cardiac output $L.min^{-1}$		$(A\text{-}V)O_2$ ml per 100ml		VO_2 max $L.min^{-1}$	
	Child	*Adult*	*Child*	*Adult*	*Child*	*Adult*
Cycle 60W	9.4	12.4	11.1	8.9		
Run 3mph	6.7	12.3	8.7	8.4		

Groupt thought – Which factors affect VO_2 max?

Factors affecting VO_2 max

- Heredity
- Age
- Sex
- Body size and composition
- Training status
- Types of muscle fibers used during the exercise
- Altitude
- Temperature

Fill in the table in your workbook as we go through the next few slides

Factors affecting VO_2 max

Heredity

- It is well established that the limits for developing fitness capacity are linked to genetic endowment.
- Genetic effect is currently estimated at approximately 20-30% for VO_2 max, 50% for maximum heart rate, and 70% for physical working capacity.

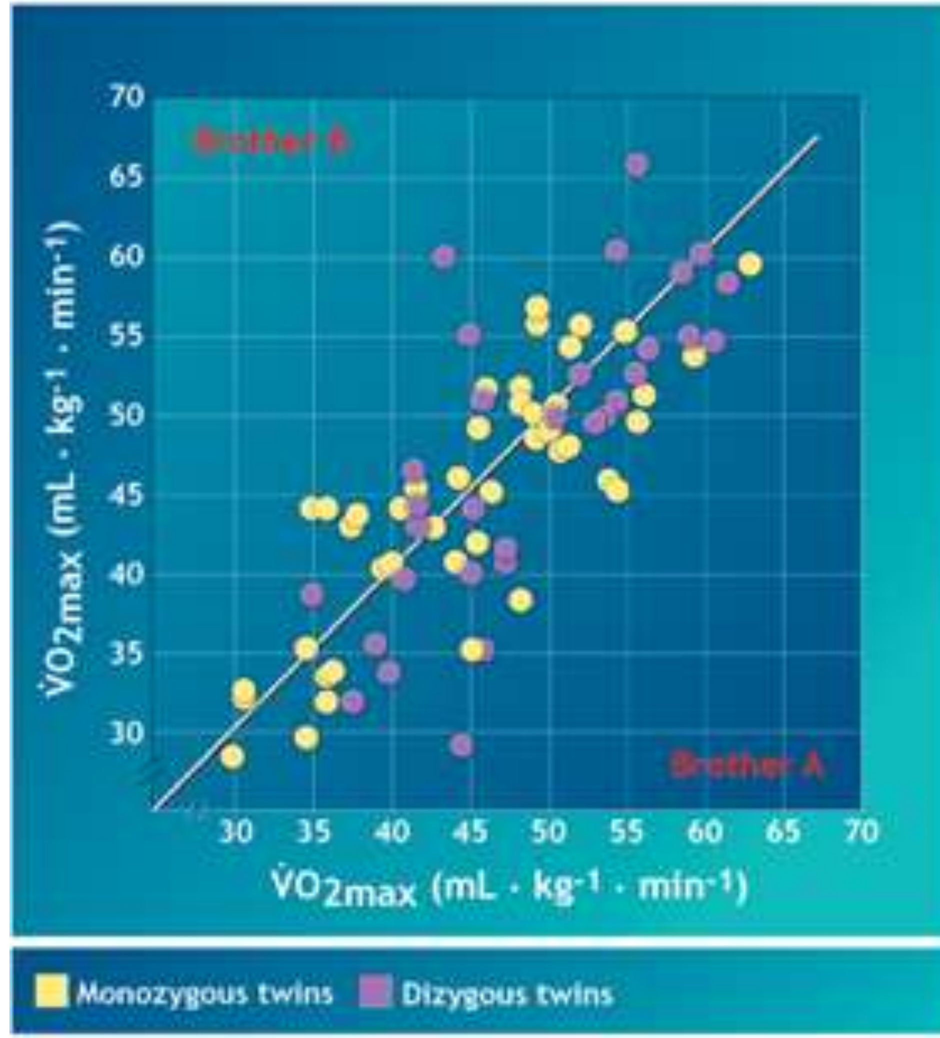


Figure 11.12. Maximal oxygen consumptions ($\dot{V}O_{2max}$) for pairs of monozygotic and dizygotic twin brothers. (From Bouchard C, et al. Aerobic performance in brothers, dizygotic and monozygotic twins. Med Sci Sports Exerc 1986;18:639.)

TABLE 11.4 ➤ ESTIMATED GENETIC CONTRIBUTION TO INDIVIDUAL DIFFERENCES IN IMPORTANT COMPONENTS OF HEALTH-RELATED PHYSICAL FITNESS

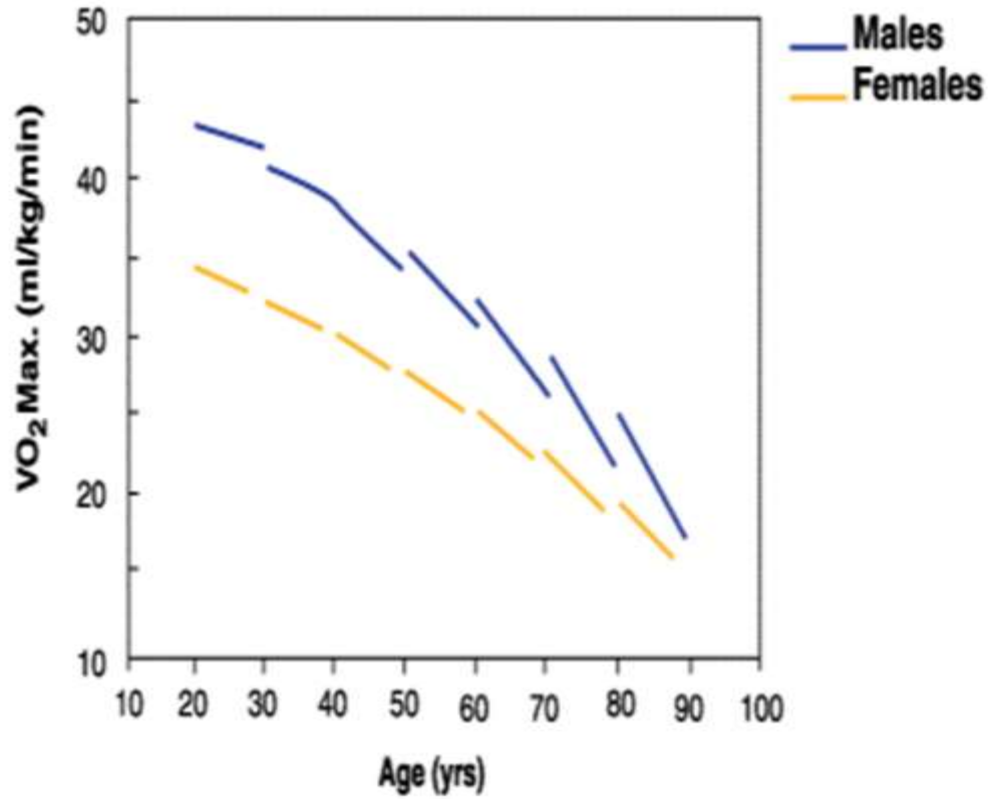
Fitness Component	Genetic Contribution
• $\dot{V}O_{2max}$	20–30%
• Submaximal exercise response	20–30%
• Muscular fitness	20–30%
• Blood lipid profile	30–50%
• Resting blood pressure	30%
• Total body fat	25%
• Regional fat distribution	30%
• Habitual activity level	30%

Modified from Bouchard C, Perusse L. Heredity, activity level, fitness, and health. in Physical activity, fitness, and health. Champaign, IL: Human Kinetics 1994.

Factors affecting VO_2 max

Age

- Children
- Absolute values for girls and boys are similar until age 12
- At age 14 VO_2 max value for boys 25% > girls and by age 16, the difference exceeds 50%.
- Relative values for boys VO_2 max remains level at about 52 ml/kg/min from age 6-16



http://jap.physiology.org/cgi/content/abstract/65/3/1147

Factors affecting VO_2 max

Adults

After age 25 its all down-hill (VO_2 max declines at a rate of 1% per year after age 25)

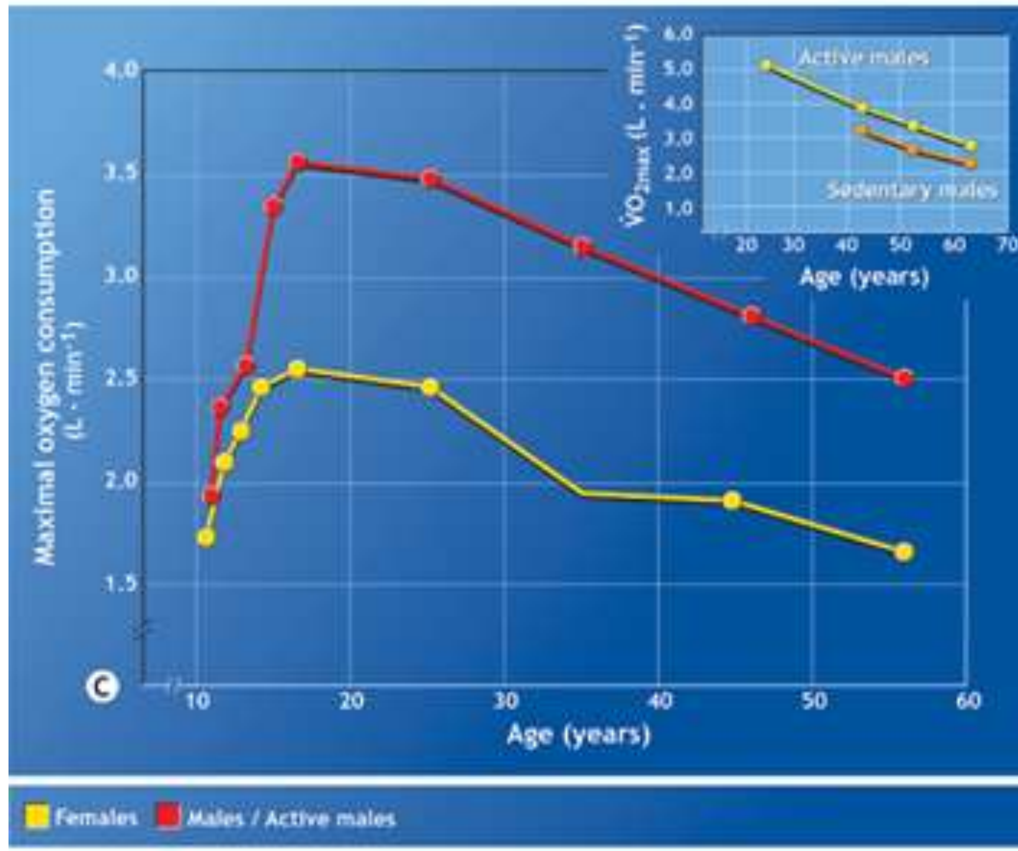
BUT one’s habitual level of physical activity has far more influence on aerobic capacity than age!

Factors affecting VO_2 max

Sex

- Even among trained endurance athletes, the sex difference for VO_2 max = 15-20% mainly due to differences in:

  - Differences in body composition
  - Hemoglobin (oxygen-carrying red pigment of the red blood corpuscles) concentration



Factors affecting VO_2 max

- **Body size and composition**

  An estimated 69% of the differences in VO_2 max scores among individuals can be explained by variations in body mass
- **Mode of exercise**

  Highest values are generally found during treadmill exercise, lowest on bicycle ergometer test; specificity is very important
- **Muscle fiber type**

  Slow oxidative fibers – highest oxygen consumption

Other factors affecting VO_2max

- **Altitude**

  Low partial pressure of O_2 in the atmosphere

  Lower partial pressure of O_2 in the arterial blood

  Lower hemoglobin saturation

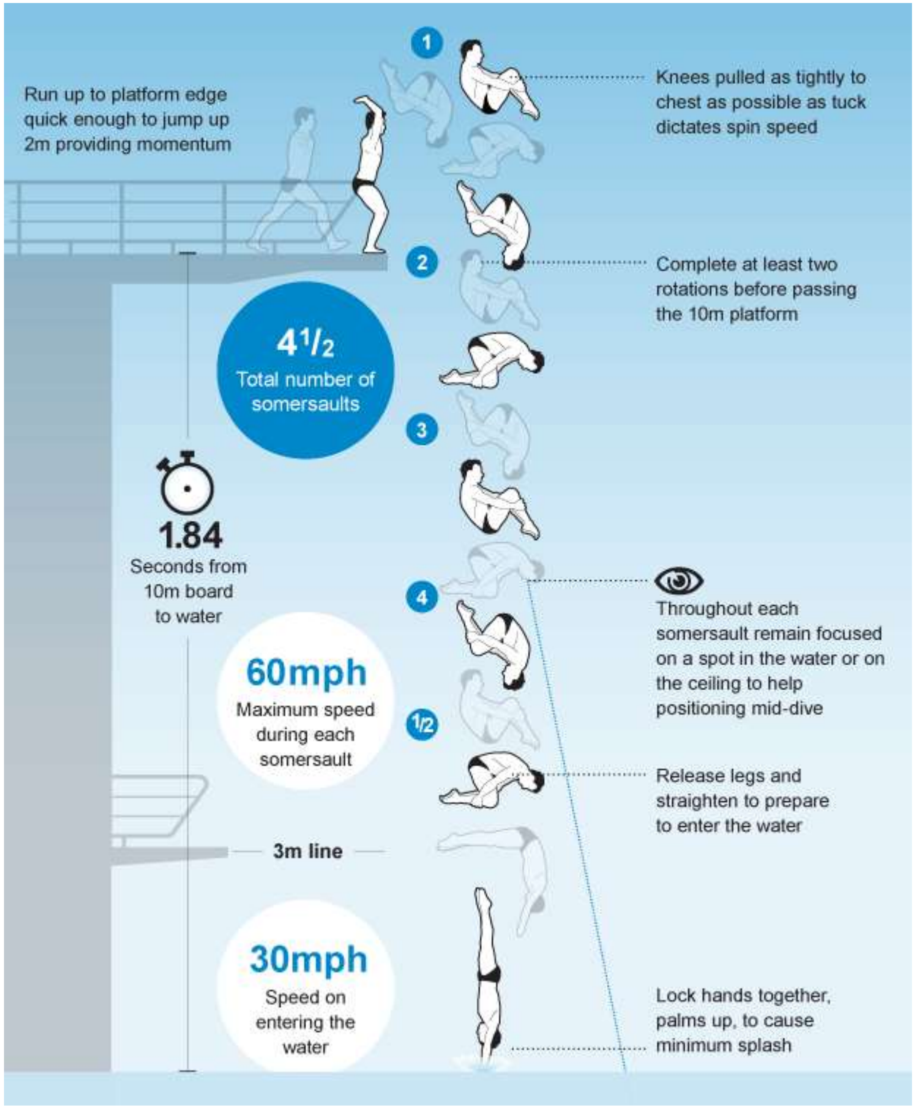
- **Temperature**

  Higher temperature – higher oxygen consumption

Why VO_2 testing?

- A measure of cardiorespiratory endurance gives us an indication of the individual's aerobic fitness.
- Endurance athletes generally have a larger capacity for aerobic energy transfer.
- VO_2 max is generally lower (10-20%) for females than males.

Practical Activity – Bleep Test to determine VO_2 max



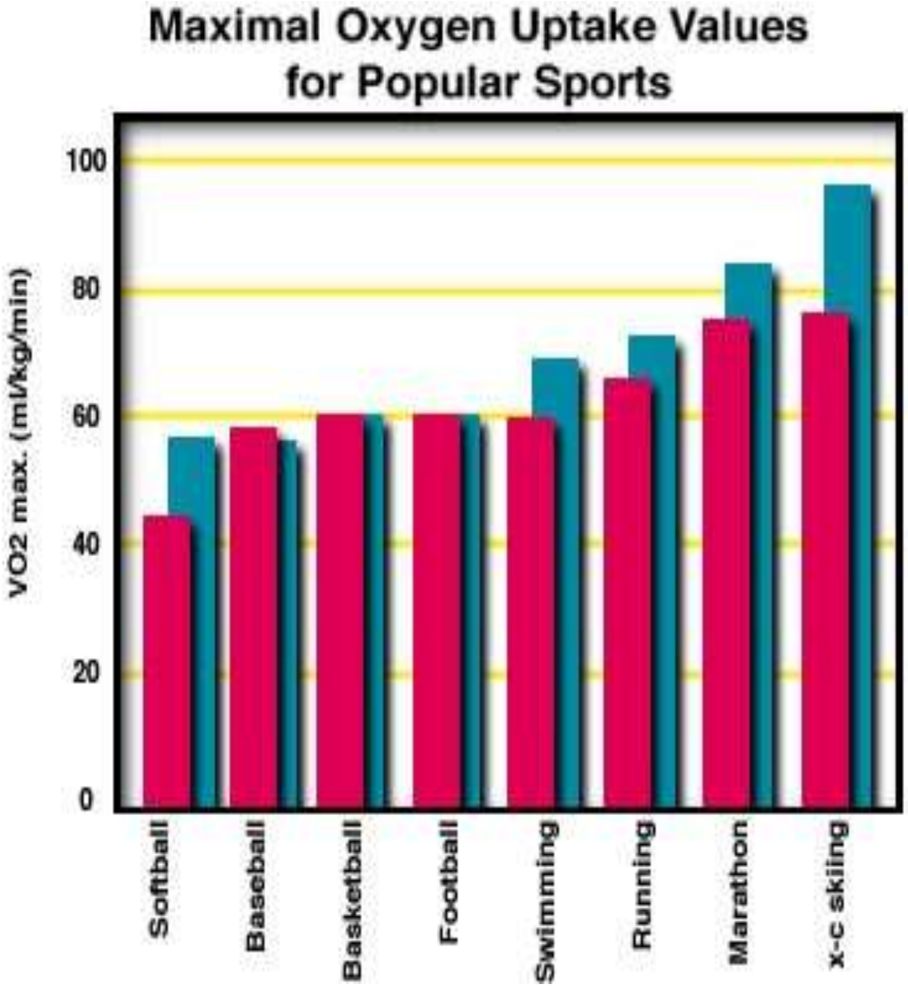
Learning Objective

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

Exercise and VO_2 max

- Moving from rest to exercise = energy requirements
- Metabolism increases in direct proportion to rate of work
- As demand for energy increases so does oxygen consumption (remember the role of produce ATP to do work)
- VO_2 eventually peaks = VO_2 max
- VO_2 may remain constant at max or drop slightly even through work intensity continues to increase.
- Increased O_2 consumption with increasing power output

Oxygen Uptake - Sports



Group thought:

Why so some sports have a higher VO_2 max than others?

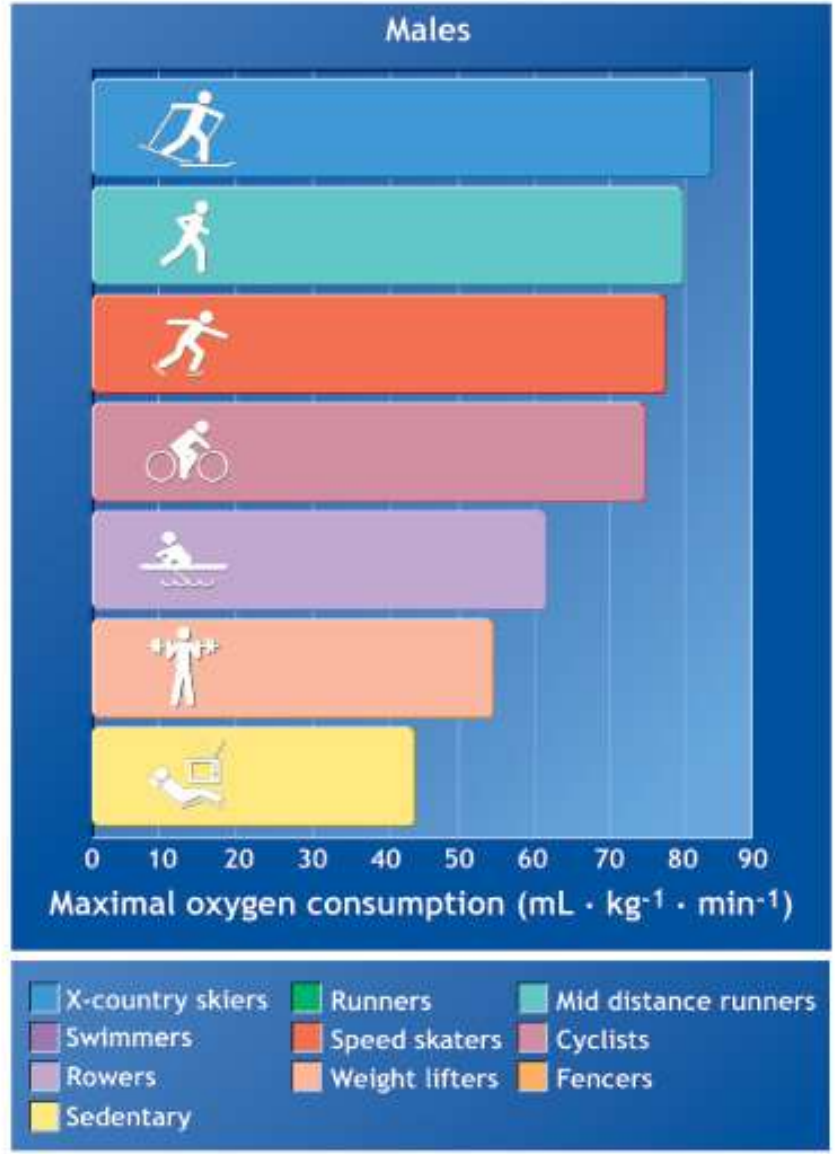
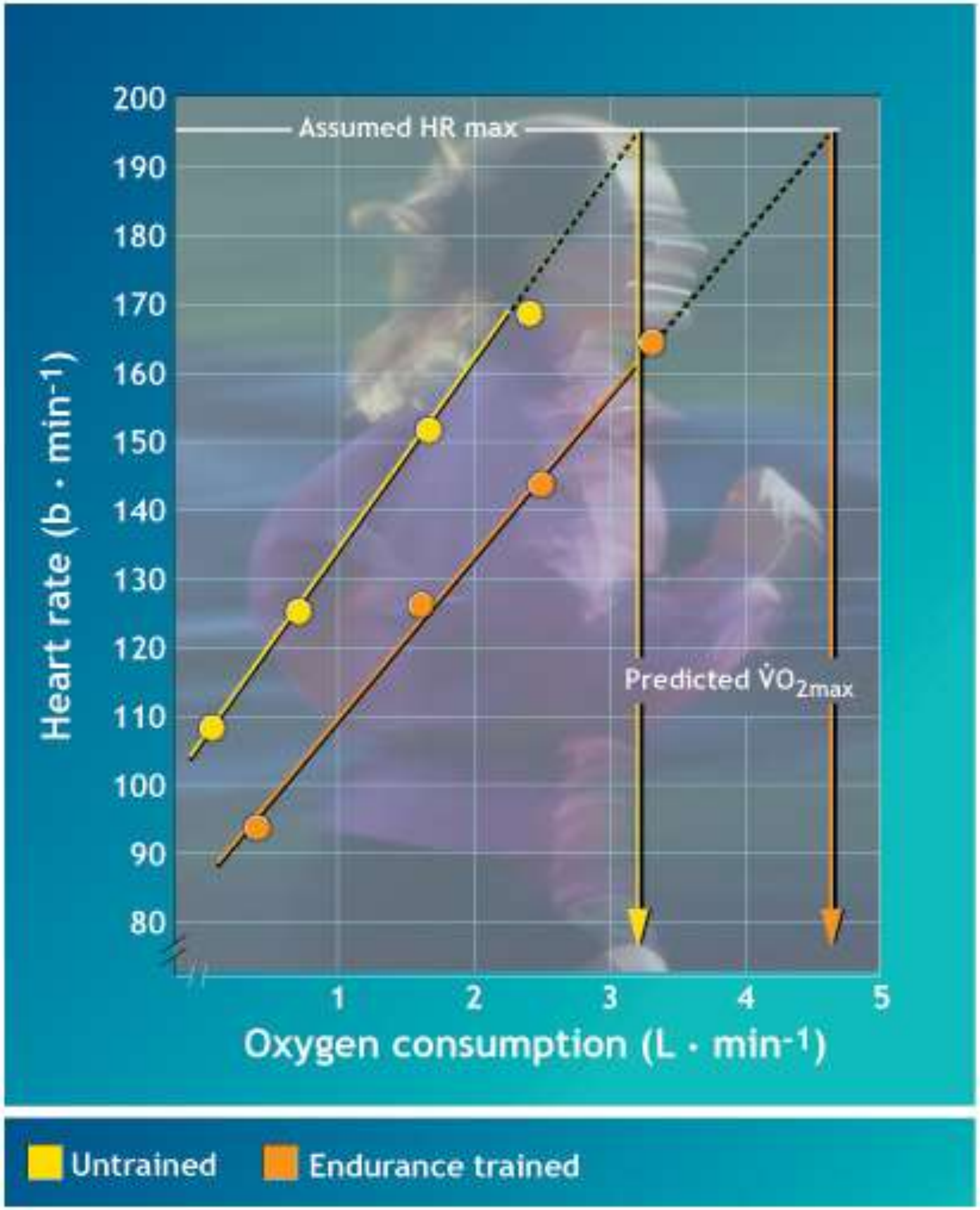


Figure 11.8B. Maximal oxygen consumption of male Olympic-caliber athletes in different sports categories compared with those of healthy sedentary subjects. (Adapted from Saltin B, Åstrand PO. Maximal oxygen consumption in athletes. J Appl Physiol 1967;23:353.)



Assumed HR max
Heart rate (b · min-1)
200
190
180
170
160
150
140
130
120
110
100
90
80
1
2
3
4
5
Oxygen consumption (L · min-1)
Predicted V̇O2max
Untrained
Endurance trained

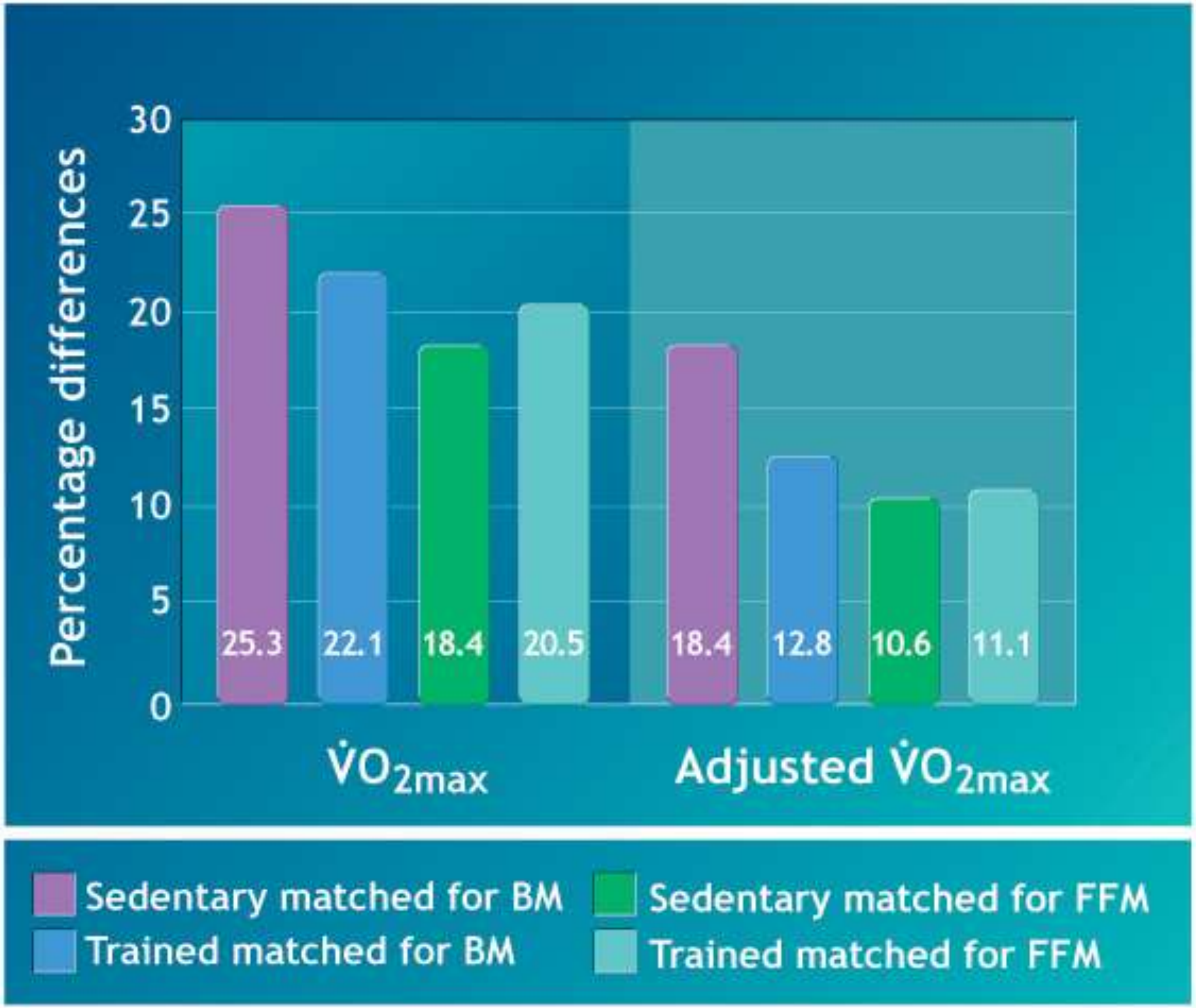


Figure 11.14. Percentage differences in $\dot{V}O_{2max}$, including the adjustment for hemoglobin *(adjusted $\dot{V}O_{2max}$)*, in sedentary and trained men and women matched for body mass (BM) and fat-free body mass (FFM). (From Keller BA, Katch FI. It is not valid to adjust gender differences in aerobic capacity and strength for body mass or lean body mass. Med Sci Sports Exerc 1991;23:S167.)

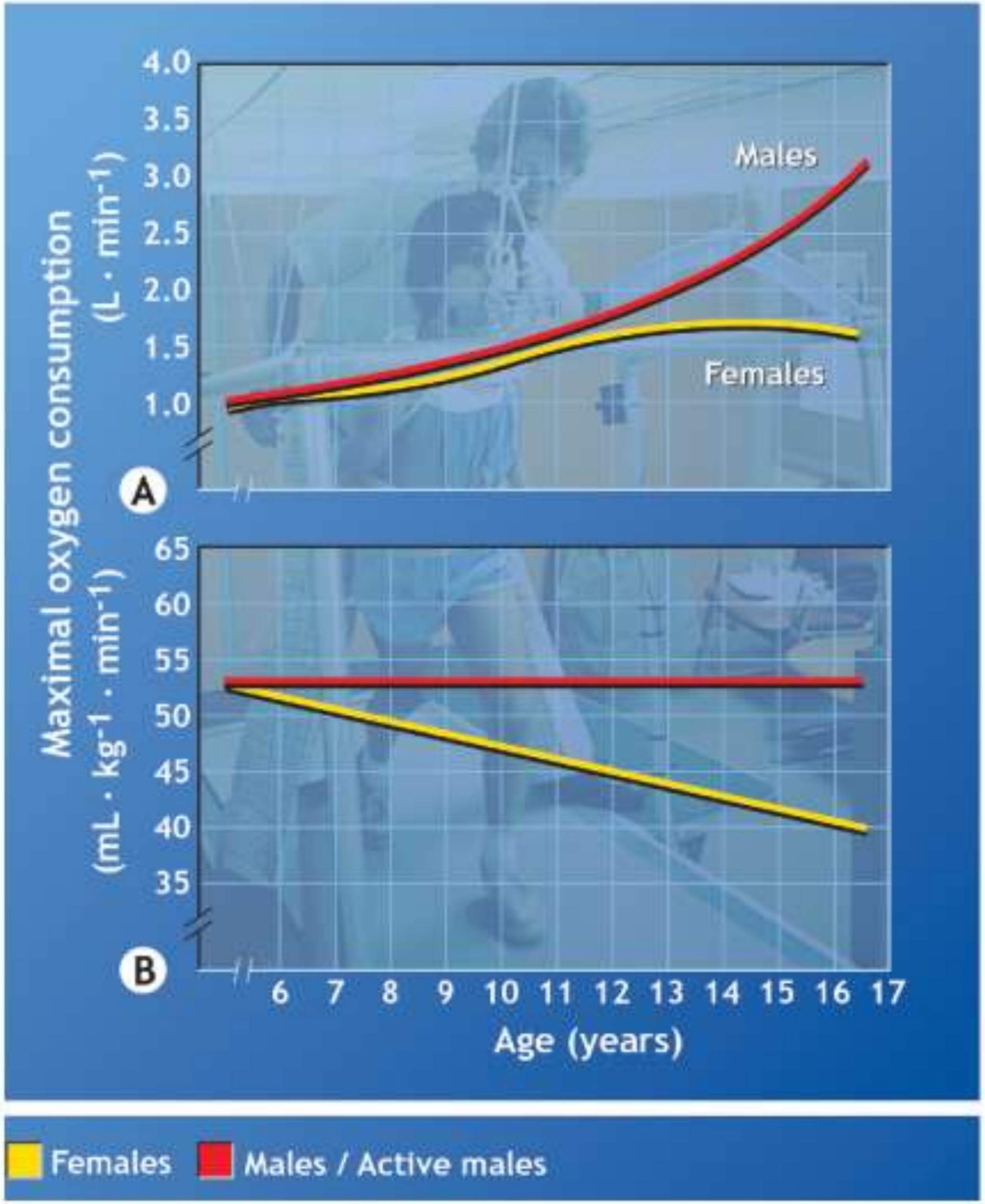


Figure 11.15 Maximal oxygen consumption in relation to age in boys and girls (A and B). (A and B from Krahenbuhl GS, et al. Developmental aspects of maximal aerobic power in children. Exerc Sport Sci Rev. Terjung RL, ed. vol 13, New York: Macmillan, 1985)

Individual Activity – Past Paper Question

(a) $63.2\,\text{ml}\,\text{min}^{-1}\,\text{kg}^{-1}$ *[1]*

(b) ventilation rate (increases more);
heart rate $\frac{(177-126)}{126}\times 100 = 40\%$ and ventilation rate $\frac{(42.9-26.0)}{26.0}\times 100 = 65\%$; *[2]*
To award the second mark both the heart rate and the ventilation rate are needed.

(c) $4.42\,\text{l}\,\text{min}^{-1}$ *or* $4.42\times 10^3\,\text{ml}\,\text{min}^{-1}$ *or* $4424\,\text{ml}\,\text{min}^{-1}$ *[1]*

(d) no data was collected while the subject was at rest;
intervals of data collection are not regular;
only one subject has been used / data is insufficient for generalizations;
data collection was not continued beyond 13:17 to verify that the final data reading is actually the VO_2 max / no plateau phase reached; *[2 max]*

(a) (i) the volume of blood pumped out of the heart with each contraction *[1]*

(ii) the volume of blood pumped from the heart per time/minute *[1]*

(b) stroke volume increases which reduces the number of beats required to maintain cardiac output *[1]*

(c) during exercise blood flow is different than at rest;
during exercise, blood flow to abdominal organs decreases;
during exercise, blood flow to skin/skeletal muscles/heart wall increases;
blood flow to the brain remains constant; *[3 max]*

STARTER – Video of the Terahumara

Learning Objective

Describe the cardiovascular adaptations resulting from endurance exercise training

GROUP THOUGHT

What changes have taken place in your body....

....when running a 5km race

...after training for 6 months for your 5km race?

ACUTE changes and CHRONIC adaptations!

Annotate the mind map in your workbook as we go through the next few slides

Acute physiological changes during exercise

Training effects are the physiological changes your body makes in response to the demands of the exercise you perform.

There are 2 kinds of responses to training:

- Acute (immediate) – last only for the duration of the exercise & the recovery period.

- Chronic – long-term adaptations & take about 6 weeks of training to develop.

Acute physiological changes during exercise

All cardio-respiratory (heart, blood, blood vessel & lung) responses to exercise are the body's way of trying to deliver more O_2, quickly & efficiently, to the working muscles in order to produce more ATP

Acute cardiovascular (circulatory system) responses to exercise

- ↑ heart rate
- ↑ stroke volume
- ↑ cardiac output
- ↑ blood pressure
- ↑ blood flow
- ↓ blood plasma volume

↑ Heart rate

When you begin to exercise, your HR increases to ↑ the supply of O_2 to the working muscles.

- If you exercise at a constant pace, your HR will level off & remain constant until you go faster or stop.
- This is ‘steady state’, and indicates that the muscles are receiving enough blood & O_2 to keep working at that pace. (O_2 supply = O_2 demand)
- HR ↑’s in direct proportion to the workload on the body. (linear relationship)

Oxygen Uptake During Steady State Exercise

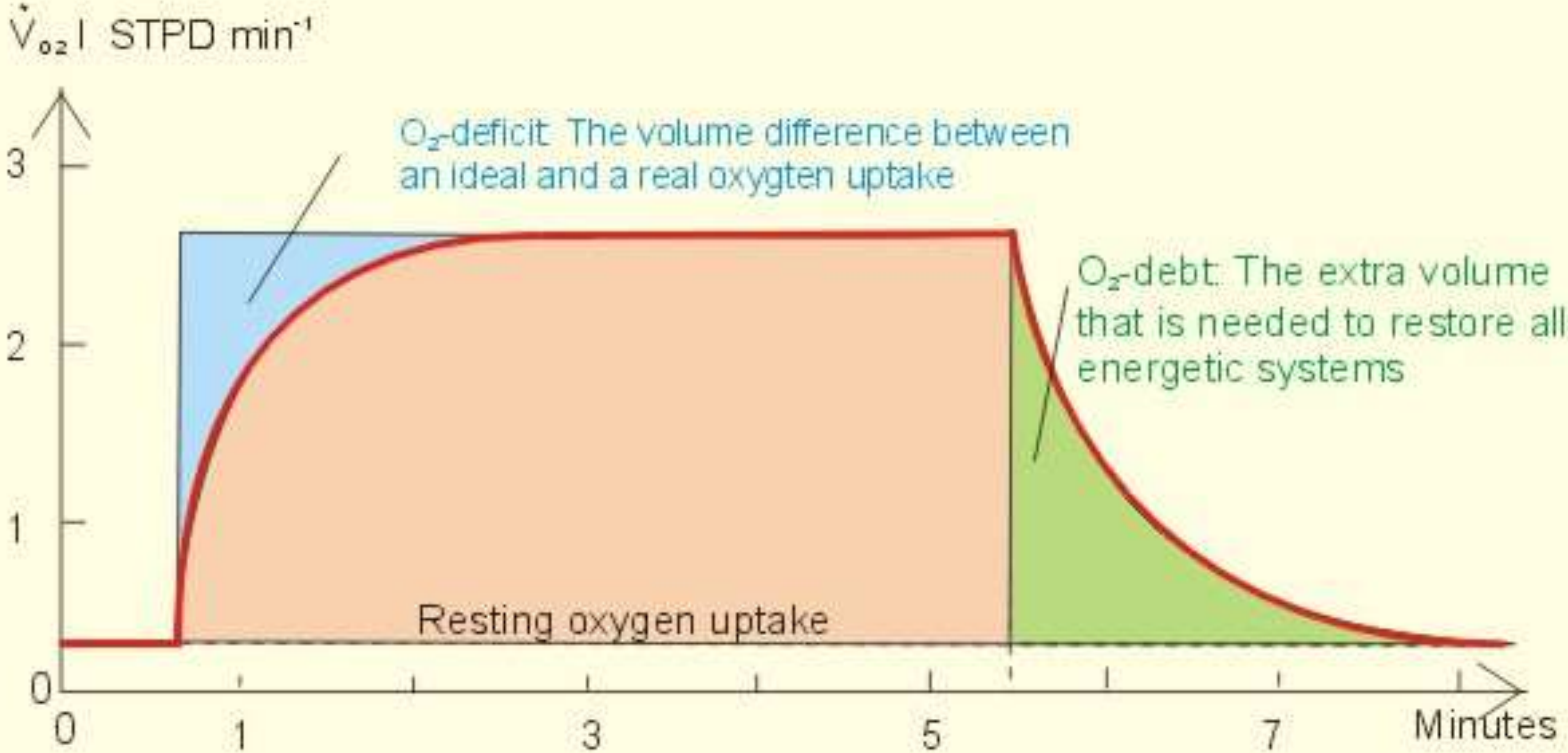


Fig. 18-7

KMc

↑ Stroke volume

- Stroke volume is the amount of blood pumped out of the L ventricle with each heart beat (contraction).
- Your SV depends on the size of your left ventricle, which is determined by a combination of genetics & training.
- **When you begin to exercise, your heart muscle contracts more forcefully to ↑ blood (& hence O_2) supply to your muscles. This causes a more complete emptying of your ventricles, so SV ↑'s.**

↑ Cardiac output

C.O. is the amount of blood pumped out of the heart's left ventricle in 1 minute.

CO = SV x HR

When you exercise, your CO ↑'s in an effort to ↑ the blood supply (& hence O2 delivery) to the working muscles.

During maximal exercise, the C.O. can on average reach 20-30L/min because of the doubling of the SV & tripling of the HR.

Rest:

60ml x 70 beats

= 4.2L/min

Maximal exercise:

120ml x 202

24.4L/min

↑ Blood pressure

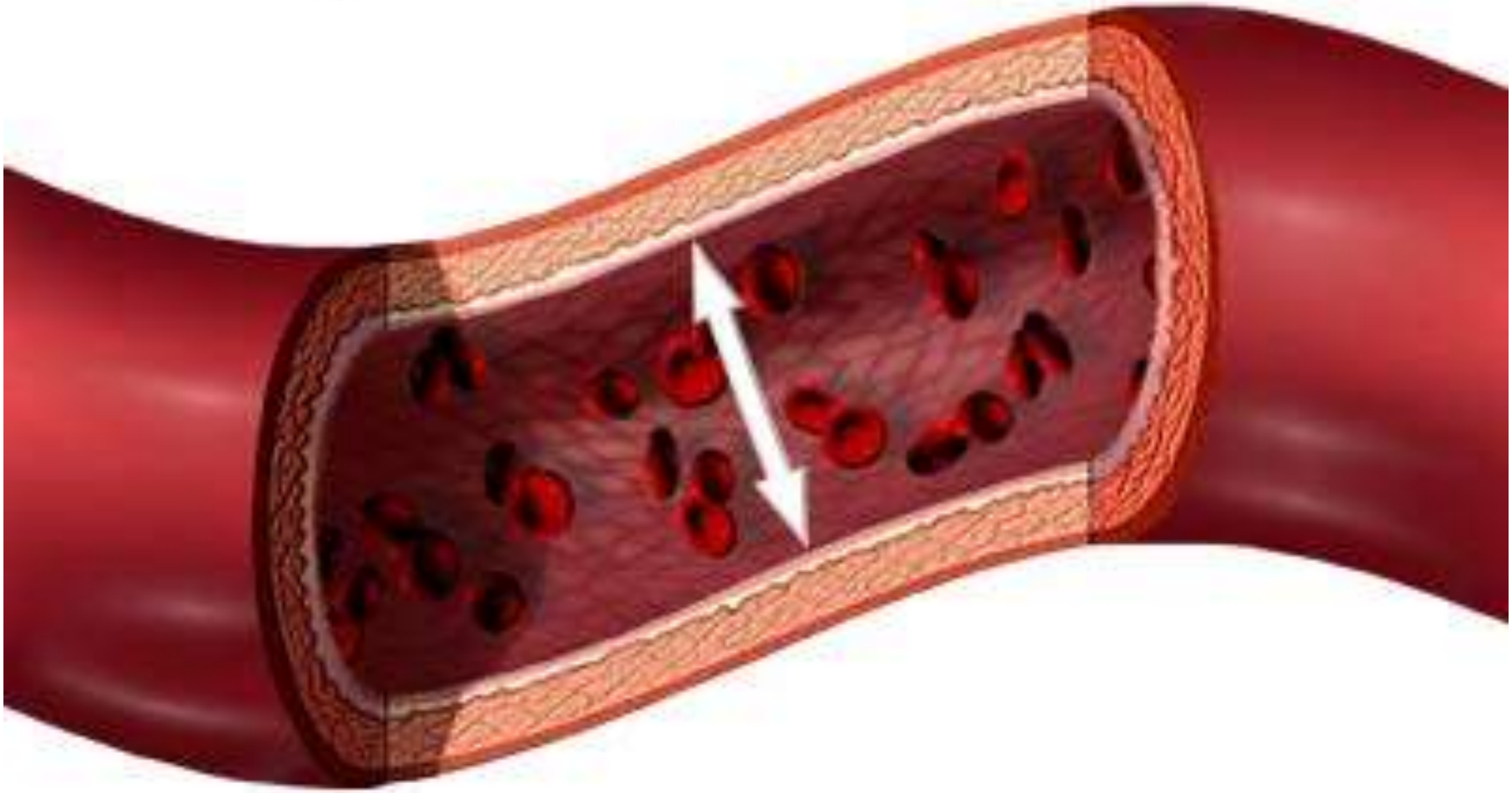
B.P. is a measure of the pressure produced by the blood being pumped into the arteries.

Systolic B.P. – pressure as the LV ejects the blood into the aorta during heart contraction

Diastolic B.P. – pressure in the arteries during relaxation of the heart.

B.P. ↑'s during exercise because SV, HR & CO all ↑, more blood is pumped into the arteries more quickly.

Blood pressure is the measurement of force applied to artery walls



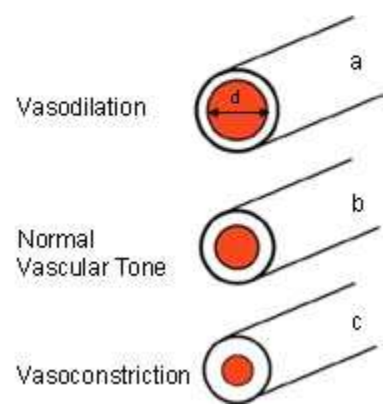
A.D.A.M.

↑ Blood flow

- During exercise, blood flow to the working muscles ↑'s because of ↑ CO & a greater distribution of blood away from non-working areas to active muscles.
- 80-85% of C.O. goes to working muscles, because muscle capillaries dilate to allow more blood flow to the muscles – called *vasodilation.*
- Blood flow to kidneys, stomach & intestines ↓ because the capillaries constrict – called *vasoconstriction.*

↑ Blood flow

- Blood flow to the lungs ↑'s, as the right ventricle ↑'s its activity during exercise.
- To allow for this ↑ blood flow to the muscles, there must be an accompanying ↑ in venous return (blood flow back to heart through the veins).



↓ Blood plasma volume

Due to an ↑ in sweating, the blood plasma volume ↓'s during strenuous exercise, especially in hot weather.

Acute Muscular Responses to Exercise

- ↑ contraction rate
- ↑ recruitment of muscle fibres & motor units to produce more force
- ↑ muscle temperature
- Depletion of fuel stores used to produce energy for contractions
- ↑ blood flow to muscles (blood vessels dilate)
- ↑ O_2 attraction at the muscle

Acute respiratory responses to exercise

During exercise & recovery, more O_2 must be delivered from the lungs to the working muscles, & excess O_2 must be removed from the working muscles.

- ↑ respiratory rate
- ↑ tidal volume
- ↑ ventilation
- ↑ lung diffusion
- ↑ O_2 uptake, or volume of O_2 consumed

↑ Respiratory rate

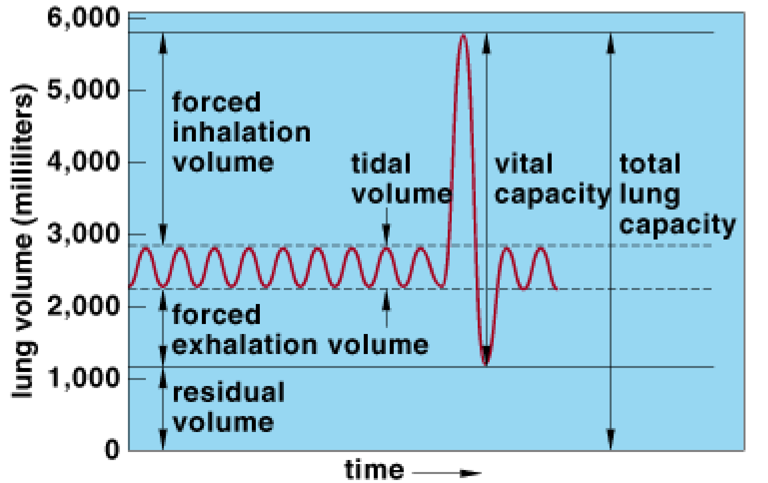
Respiratory rate is the number of breaths taken in 1 minute.

- At rest, you breathe about 12-15 times each minute.
- When you begin to exercise, the CO_2 level in the
- blood ↑'s, because CO_2 is a waste product of energy
- production.
- This triggers the respiratory centre in your brain & you
- breathe faster.

↑ Tidal volume

Tidal volume is the size of each breath taken.

- At rest, the average tidal volume is about 0.5L, which is enough to supply the body with O_2 .
- However, during heavy exercise, tidal volume can ↑ to 2.5L per breath as the body tried to ↑ the O_2 supply to the blood.



↑ ventilation

Ventilation is the amount of air breathed in 1 minute.

Therefore it depends on 2 factors:

- The number of breaths per minute (respiratory rate)
- The size of each breath (tidal volume)

Ventilation can be calculated using this formula:

Ventilation = tidal volume x respiratory rate

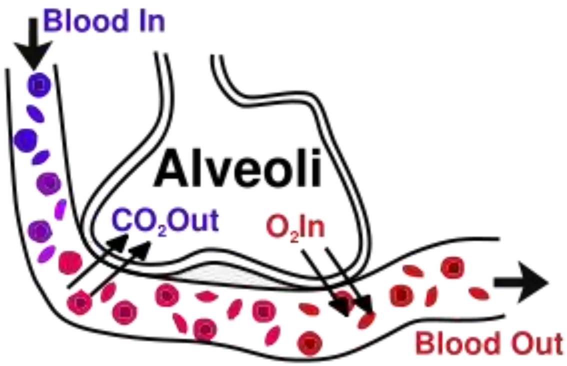
e.g V = 0.5L x 12 breaths/min.

= 6L/min

↑ Lung diffusion

- During strenuous exercise, there is a 3-fold ↑ in O_2 diffusion from the alveoli to the blood because of a massive ↑ in blood flow to the lungs & dilation of the capillaries surrounding the alveoli.

- Similarly, more O_2 diffuses from the blood into the alveoli, where it is breathed out.



↑ O2 uptake or volume of O_2 consumed (VO_2)

- Oxygen uptake (VO_2) is the amount of O_2 taken up & used by the body to produce energy.

- It reflects the total amount of work being done by the body.

- When you begin to exercise, your VO_2 ↑'s as your body absorbs more O_2 & uses it to produce more aerobic energy.

Chronic Training Adaptations

- When we discuss chronic adaptations to training we are asssuming that training has been occurring for a minimum of 6-8 weeks, training at least 3 sessions per week.
- **Why is this important? What if the athlete was training less than this?**
- Chronic adaptations can be seen either at rest, during submaximal work or during maximal work.

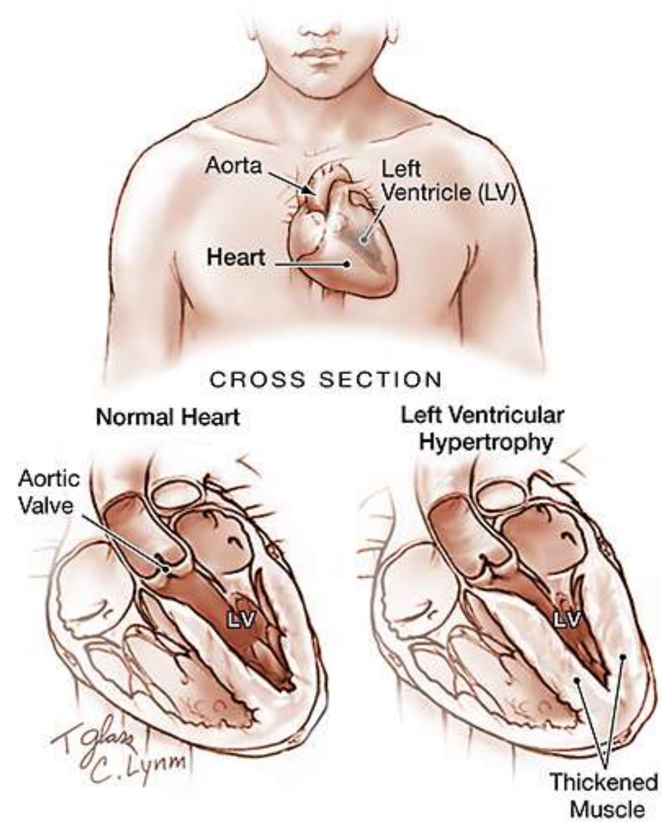
Chronic Adaptations vary depending on the following:

- Type and method of training – aerobic versus anaerobic.
- Frequency, duration and intensity of training.
- Individuals capacities – hereditary factors (your genetic make up)

Cardio respiratory adaptations from aerobic training

- Chronic cardio (heart) and respiratory (lungs) changes are easier to remember if you understand that the changes are occurring to improve the ability to carry oxygen around the body to the working muscles

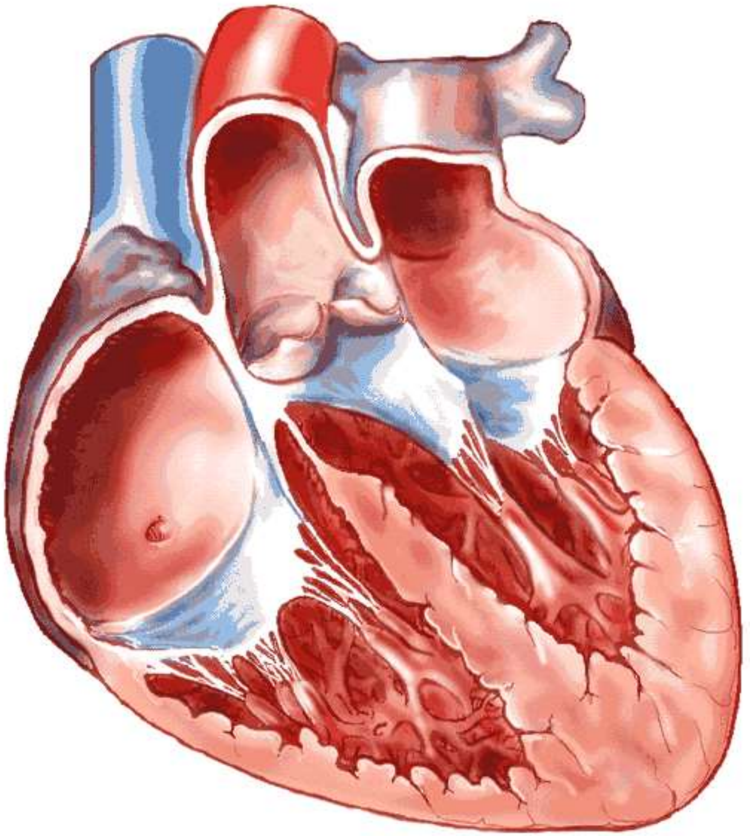
- These changes are important and decrease your chance of developing heart disease / problems.



CARDIOVASCULAR ADAPTATIONS

- **CARDIAC HYPERTROPHY**

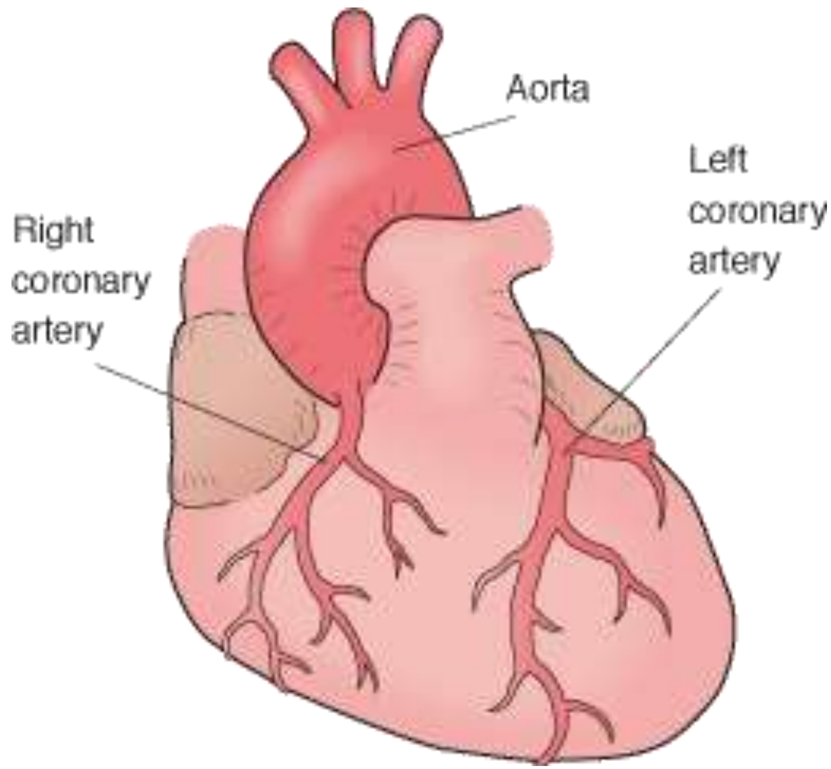
  Enlargement of the heart muscle itself. The heart chambers are enlarged, therefore increased ventricular volume – **most important is LV size – why?**



CARDIOVASCULAR ADAPTATIONS

- **INCREASED CAPILLARISATION OF THE HEART MUSCLE**
- Cardiac hypertrophy also leads to an increase in the capillary density and blood flow to the heart muscle itself.
- The increased supply of blood and O_2 allows the heart to beat more strongly and efficiently during both EXERCISE and REST.
- Also decreases chance of heart attack.

The Coronary arteries



CARDIOVASCULAR ADAPTATIONS

INCREASED STROKE VOLUME

- Stroke volume is the amount of blood pumped per beat.
- Through aerobic training SV increases at REST, during SUB MAX. workloads and MAX. workloads.

CARDIOVASCULAR ADAPTATIONS

LOWER RESTING HEART RATE

- Resting heart rate is very useful in determining aerobic fitness. Generally the lower the resting heart rate the greater the aerobic fitness level.

- Because the athlete has greater stroke volume the heart does not need to beat as often to pump the same amount of blood around the body

CARDIOVASCULAR ADAPTATION

LOWER HEART RATE DURING SUB MAX WORKLOADS

- Compared to untrained individuals, athletes have lower heart rates during sub max. workloads. Mainly due to increased SV.

- The heart works more efficiently

CARDIOVASCULAR ADAPTATIONS

IMPROVED HEART RATE RECOVERY

- The heart rate of an athlete will return to normal (pre exercise levels) quicker than an untrained person.

CARDIOVASCULAR ADAPTATIONS

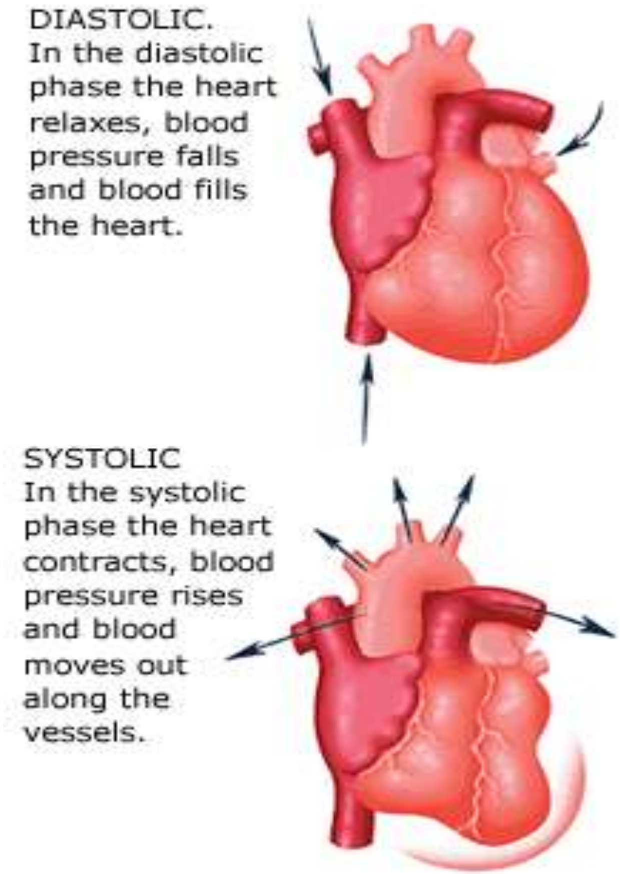
INCREASED CARDIAC OUTPUT (Q) AT MAXIMUM WORKLOADS

- Cardiac Output (Q) is the amount of blood pumped by the heart per minute
- Q remains unchanged at rest and even during sub max. work regardless of how hard you train.
- During max. exercise Q may increase up to 30 litres per minute for highly trained athletes

CARDIOVASCULAR ADAPTATIONS

LOWER BLOOD PRESSURE

- Both systolic and diastolic blood pressure levels may decrease during REST and EXERCISE.
- This helps by reducing resistance to blood flow and reduces strain on the heart.



CARDIOVASCULAR ADAPTATIONS

INCREASED ARTERIO-VENOUS OXYGEN DIFFERENCE (a-V O_2 diff)

- Due to increased myoglobin stores and an increase in size and number of mitochondria trained individuals are able to absorb more O_2 from their blood
- VO_2 diff is increased during SUB MAX and MAX exercise. A bigger V O_2 diff indicates greater uptake of O_2 by the muscle

CARDIOVASCULAR ADAPTATIONS

- **INCREASED BLOOD VOLUME AND HAEMOGLOBIN LEVELS**

- Aerobic training may lead to total blood volume increasing up to 25%, as a result RBC's may increase in number and therefore haemoglobin content increases thus O_2 carrying capacity increases also.

INCREASED CAPILLARISATION OF SKELETAL MUSCLE

- Long term aerobic training leads to increased capillarisation of the muscle, therefore more blood supply therefore more O_2 can be delivered to the muscle

Chronic adaptations to Aerobic training

RESPIRATORY ADAPTATIONS

INCREASED LUNG VENTILATION

- Aerobic training results in a more efficient and improved lung ventilation.

- At REST and during SUB MAX. work ventilation may be decreased due to improved oxygen extraction (pulmonary diffusion), however during MAX. work ventilation is increased because of increased tidal volume and respiratory frequency.

Chronic adaptations to Aerobic training

RESPIRATORY ADAPTATIONS

INCREASED MAXIMUM OXYGEN UPTAKE (VO2 MAX)

- VO2 max is improved as a result of aerobic training – it can be improved between 5 to 30 %.
- Improvements are a result of:

  -Increases in cardiac output

  -red blood cell numbers

  -a-VO2 diff

  - muscle capillarisation

  - greater oxygen extraction by muscles

Chronic adaptations to Aerobic training

RESPIRATORY ADAPTATIONS

INCREASED ANAEROBIC OR LACTATE THRESHOLD

- As a result of improved O2 delivery & utilisation a higher lactate threshold (the point where O2 supply cannot keep up with O2 demand) is developed.

- Much higher exercise intensities can therefore be reached and LA and H+ ion accumulation is delayed.

- The athlete can work harder for longer

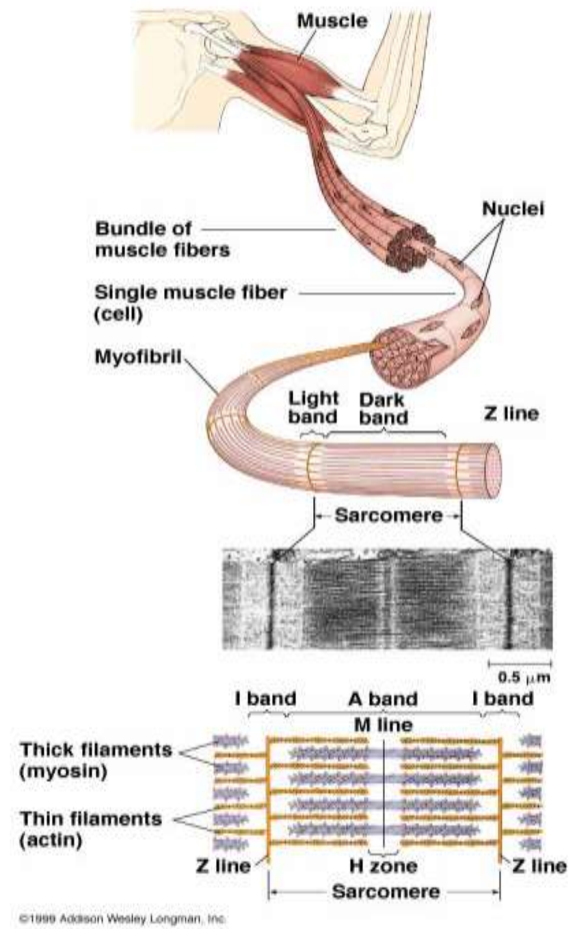
Chronic adaptations to Aerobic training

WITHIN THE MUSCLE TISSUE

- Chronic AEROBIC training adaptations within muscle tissue are best produced through:

- Continuous training

- High repetition resistance training



Chronic adaptations to Aerobic training

WITHIN THE MUSCLE TISSUE

- The following tissue changes occur:
- Increased O2 utilisation
  - increased size and number of mitochondria
  - Increased myoglobin stores
- Increased muscular fuel stores
- Increased oxidation of glucose and fats
- Decreased utilisation of the anaerobic glycolysis (LA) system
- Muscle fibre type adaptations