OCR (B) Biology A-level

4.1.2 - Metabolism and exercise

Flashcards

Define aerobic fitness and list some factors that influence it.

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Measures the ability to use atmospheric oxygen in aerobic respiration to release energy for muscle cells. Affects a person’s heart rate, breathing rate & recovery time.

- age
- gender
- participation in exercise

Outline the immediate and long-term effects of exercise on the respiratory system.

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immediate: breathing rate & tidal volume increase

long-term: increased maximum breathing rate; vital capacity increases; intercostal muscles & diaphragm become stronger so thoracic cavity can expand more; increased capillary network surrounding alveoli ∴ faster gas exchange

Outline the immediate and long-term effects of exercise on the cardiovascular system.

Outline the immediate and long-term effects of exercise on the cardiovascular system.

immediate: cardioacceleratory centre causes heart rate to rise ∴ cardiac output increases; blood pressure rises; increased blood flow to muscles, less to digestive organs

long-term: heart muscle more efficient ∴ higher resting stroke volume, lower resting heart rate, lower blood pressure; more capillaries; capillaries widen; greater blood volume

Outline the immediate and long-term effects of exercise on the skeletal system.

Outline the immediate and long-term effects of exercise on the skeletal system.

immediate: rate of contraction increases, so rate of aerobic respiration increases & anaerobic respiration may begin

long-term: muscle mass increases; more mitochondria in cells; more glycogen & myoglobin stored

What are F.I.T.T. factors?

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Factors that need to be considered when designing an effective training program to improve aerobic fitness.

	Cardio	***Muscle strength***	***Muscle endurance***	***Flexibility***
Frequency	3 – 5 times weekly	3 times weekly	3 – 5 times weekly	As a warm-up/ cool-down for every exercise session
Intensity	60 – 90% of heart rate reserve	3 – 7 repetitions	8 – 12 repetitions	To the point of tension but without pain
Time	At least 20 mins	Time needed for given number of reps		10 – 40 secs per stretch
Type	Running, rowing swimming…	Weights, resistance machines, push-ups…		Stretching

List some methods that may be used to supplement exercise in order to improve athletic performance.

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- carbohydrate loading diets
- recombinant erythropoietin (RhEPO)
- blood doping
- steroids

Describe and evaluate the use of carbohydrate loading diets.

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Increases glycogen level in muscle cells by increasing carbohydrate intake & reducing exercise for up to 6 days.

Up to 3% improvement in endurance events. No benefit if event is less than 90 mins.

Important to choose foods with low fat content to avoid weight gain/lethargy.

Describe and evaluate the use of recombinant erythropoietin (RhEPO).

Describe and evaluate the use of recombinant erythropoietin (RhEPO).

Injecting RhEPO hormone stimulates bone marrow to produce red blood cells.

More oxygen supplied to tissues. Delays anaerobic respiration in endurance events. Improvements after 4 weeks equivalent to expected progress over several years.

Thickens blood. Blood clots, heart attack & stroke more likely.

Describe and evaluate the use of blood doping.

Describe and evaluate the use of blood doping.

Blood transfusion increases number of red blood cells. Uses the athlete's own blood which was collected & stored or blood from a compatible donor.

More oxygen supplied to tissues. Delays anaerobic respiration in endurance events.

Thickens blood. Blood clots, heart attack & stroke more likely.

Homologous transfusion always carries risk of rejection.

Describe and evaluate the use of steroids.

Describe and evaluate the use of steroids.

Anabolic steroids e.g. testosterone build muscle mass.

Improves strength & endurance. May enhance muscle repair.

May cause high blood pressure, increased LDL level, higher risk of tendonitis, liver damage. May affect sexual characteristics e.g. shrunken testicles, irregular periods.

What is VO_2 max?

What is VO_2 max?

A measure of aerobic fitness.

Represents the maximum rate at which oxygen can be taken in, transported & used by cells.

Describe the role of haemoglobin.

Describe the role of haemoglobin.

Present in red blood cells. Oxygen molecules bind to haem groups & are carried around the body via the circulatory system. Hb has variable affinity for oxygen depending on partial pressure of oxygen, $p(O_2)$.

At high $p(O_2)$ e.g. lungs, O_2 **associates** to form oxyhaemoglobin. At low $p(O_2)$ e.g. respiring tissues, O_2 **dissociates** to form deoxyhaemoglobin.

Write an equation for the formation of oxyhaemoglobin.

Write an equation for the formation of oxyhaemoglobin.

$Hb + 4O_2 \rightleftharpoons Hb.4O_2$

Note that full saturation is rare. Oxyhaemoglobin dissociation curves never show 100% saturation because they represent an average of all blood cells in the body.

What do oxyhaemoglobin dissociation curves show?

What do oxyhaemoglobin dissociation curves show?

Saturation of haemoglobin with oxygen (%), plotted against partial pressure of oxygen (kPa). Curves further to the left show that the haemoglobin has a higher affinity for oxygen.

Explain the shape of oxyhaemoglobin dissociation curves.

Explain the shape of oxyhaemoglobin dissociation curves.

Sigmoid (S-shaped) due to cooperative binding:

When 1st O_2 molecule binds, it changes tertiary structure of haemoglobin so that it is easier for the 2nd & 3rd molecules to bind.

3rd changes tertiary structure of haemoglobin so that it is more difficult for the 4th molecule to bind.

What is a respiratory pigment?

What is a respiratory pigment?

A conjugated protein with a prosthetic group that enables the binding of oxygen.

Name 3 common respiratory pigments.

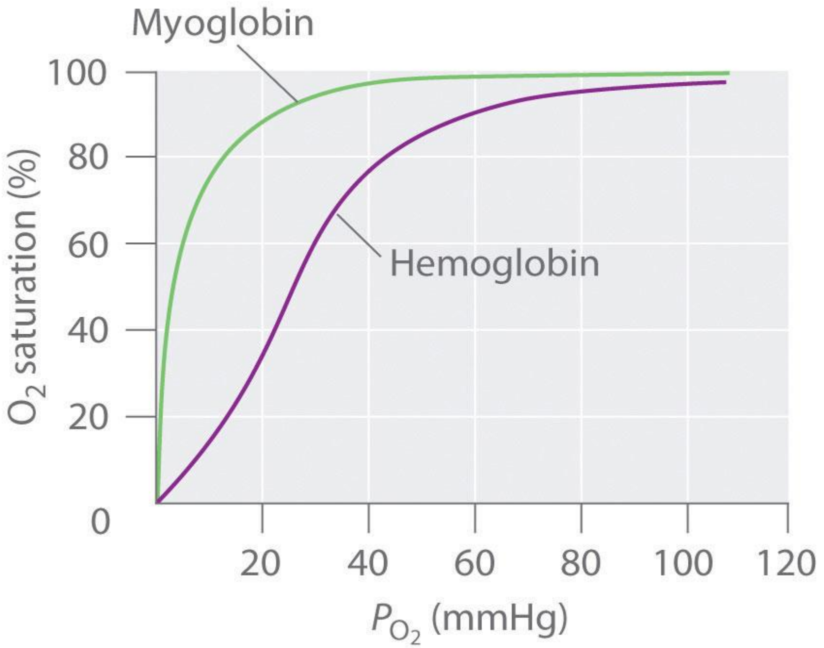
Name 3 common respiratory pigments.

- adult haemoglobin
- fetal haemoglobin
- myoglobin

How does myoglobin differ from haemoglobin?

How does myoglobin differ from haemoglobin?

- Only has one haem group.
- Has a very high affinity for oxygen even at low partial pressures.
- Is found in muscle cells of mammals with high metabolic demands.



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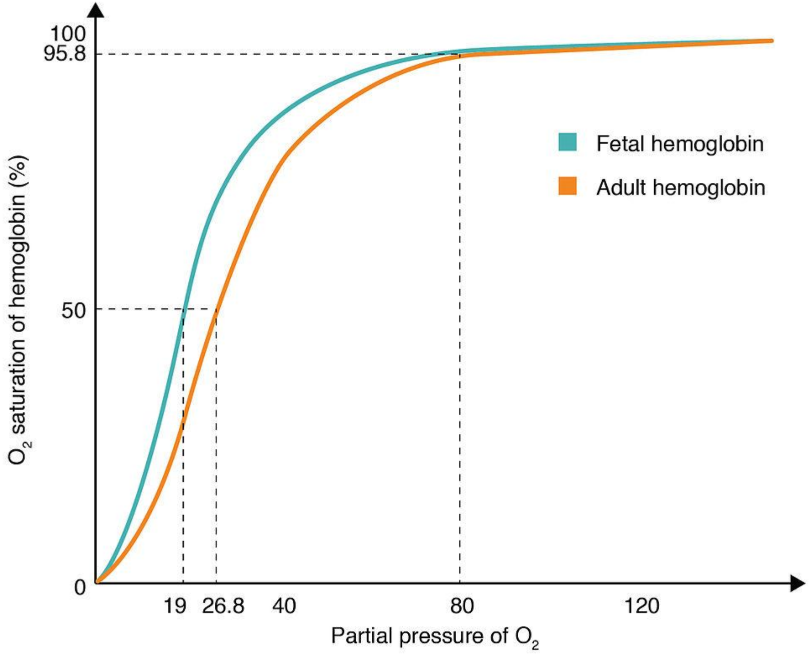
How does fetal haemoglobin differ from adult haemoglobin?

How does fetal haemoglobin differ from adult haemoglobin?

$p(O_2)$ is low by the time it reaches the fetus, therefore fetal haemoglobin has higher oxygen affinity than adult. Allows both mother & child’s oxygen needs to be met.



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How do temperature and pH affect oxygen dissociation?

How do temperature and pH affect oxygen dissociation?

As temperature increases, bond between oxygen & haem group weakens due to an increase in kinetic energy. Dissociation curve shifts right.

H^+ ions change tertiary structure of haemoglobin so that it has a lower oxygen affinity. More acidic pH, curve shifts right. More alkaline pH, curve shifts left.

Explain the function of carbonic anhydrase.

Explain the function of carbonic anhydrase.

CO_2 from respiration diffuses into red blood cells (& plasma).

Carbonic anhydrase enzyme catalyses:

$CO_2 + H_2O \rightleftharpoons H_2CO_3$ (carbonic acid).

Carbonic acid dissociates:

$H_2CO_3 \rightleftharpoons HCO_3^-$ (hydrogencarbonate) $+ H^+$

H^+ ions bind to oxyhaemoglobin in buffering action:

$Hb.4O_2 + H^+ \rightleftharpoons Hb.H + 4O_2$

Define oxygen debt and oxygen deficit.

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Oxygen debt (also referred to as Excess Post-Exercise Oxygen Consumption or EPOC): amount of additional O_2 needed after exercise to return body systems to their previous state

Oxygen deficit: volume of O_2 required during exercise minus volume of O_2 obtained

Describe the gross structure of skeletal muscle.

Describe the gross structure of skeletal muscle.

Muscle cells are fused together to form bundles of parallel muscle fibres (**myofibrils**).

Arrangement ensures there is no point of weakness between cells.

Each bundle is surrounded by **endomysium**: loose connective tissue with many capillaries.

Describe the microscopic structure of skeletal muscle.

Describe the microscopic structure of skeletal muscle.

myofibrils: site of contraction

sarcoplasm: shared nuclei and cytoplasm with lots of mitochondria & endoplasmic reticulum

sarcolemma: folds inwards towards sarcoplasm to form transverse (T) tubules

Draw a diagram to show the ultrastructure of a myofibril.

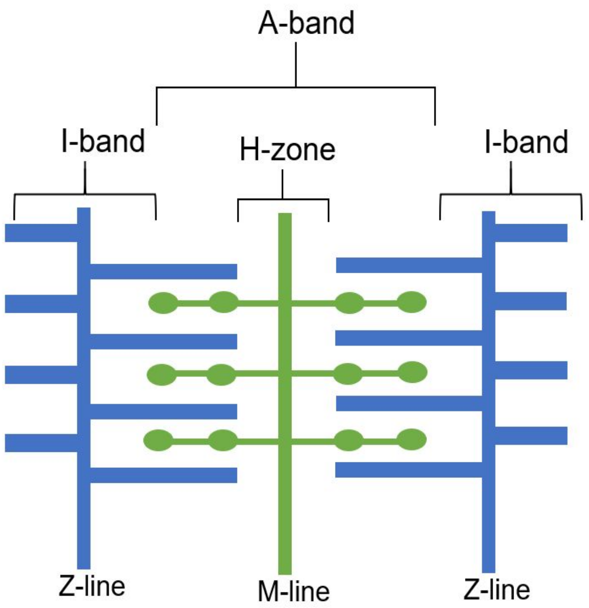
Draw a diagram to show the ultrastructure of a myofibril.

Z-line: boundary between sarcomeres

I-band: only actin (appears light under optical microscope)

A-band: overlap of actin & myosin (appears dark under optical microscope)

H-zone: only myosin



Describe the appearance of electron micrographs and photomicrographs of skeletal muscle tissue.

Describe the appearance of electron micrographs and photomicrographs of skeletal muscle tissue.

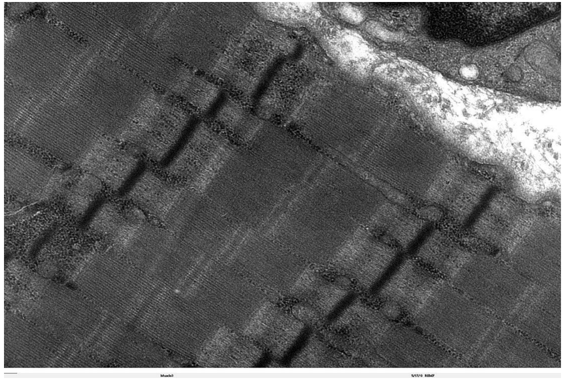
I-band:

light

A-band:

dark

electron micrograph



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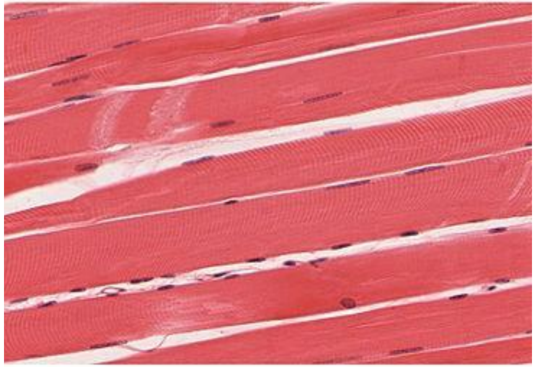
photomicrograph



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How is muscle contraction stimulated?

How is muscle contraction stimulated?

1. Neuromuscular junction: action potential = voltage-gated Ca^{2+} channels open
2. Vesicles move towards & fuse with presynaptic membrane
3. Exocytosis of acetylcholine (ACh) which diffuses across synaptic cleft
4. ACh binds to receptors on Na^+ channel proteins on skeletal muscle cell membrane
5. Influx of Na^+ = depolarisation

Explain the role of Ca^{2+} ions, troponin and tropomyosin in muscle contraction.

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1. Action potential moves through T-tubules in sarcoplasm = Ca^{2+} channels in sarcoplasmic reticulum open
2. Ca^{2+} binds to troponin, triggering conformational change in its shape; troponin displaces tropomyosin
3. Exposes binding sites on actin filaments so actinomyosin bridges can form

Outline the ‘sliding filament theory’.

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1. Myosin head with ADP attached forms cross-bridge with actin
2. Power stroke: myosin head changes shape & loses ADP, pulling actin over myosin
3. ATP attaches to myosin head, causing it to detach from actin
4. ATPase hydrolyses ATP→ADP(+Pi) so myosin head can return to original position
5. Myosin head re-attaches to actin further along filament
6. Continues until nerve impulse stops

How does sliding filament action cause a myofibril to shorten?

How does sliding filament action cause a myofibril to shorten?

Myosin heads flex in opposite directions = actin filaments are pulled towards each other. Distance between adjacent sarcomere Z lines shortens.

Sliding filament action occurs up to 100 times per second in multiple sarcomeres.

In ATP solution, tissue under microscope appears to shorten.