Response to exercise

4.4.2.2 · Bioenergetics · revision notes

How your body meets the extra energy demand of exercise: heart rate, breathing rate and breath volume increase, and if the muscles run short of oxygen they respire anaerobically, causing lactic acid to build up, muscle fatigue and an oxygen debt. Higher tier adds what happens to lactic acid in the liver and the full definition of oxygen debt. Expect data on heart rate or breathing, often with a calculation.

Key facts

- Exercise → heart rate, breathing rate and breath volume increase
- Not enough oxygen → anaerobic respiration: glucose → lactic acid
- Long vigorous exercise → muscles fatigue and stop contracting efficiently
- Grade 7+ only Oxygen debt = the extra oxygen needed after exercise to react with the accumulated lactic acid and remove it from the cells
- Purpose: more oxygenated blood to the muscles for respiration
- Lactic acid builds up → oxygen debt
- Grade 7+ only Blood carries lactic acid to the liver, where it is converted back into glucose
- Percentage change = (new − original) ÷ original × 100

Notes

Changes during exercise

- During exercise your muscles contract more, so they need more energy from respiration.
- Your **heart rate**, **breathing rate** and **breath volume** (how much air each breath moves) all increase.
- This supplies the muscles with more **oxygenated blood**, bringing more oxygen and glucose for aerobic respiration and removing the extra carbon dioxide.

When oxygen runs short

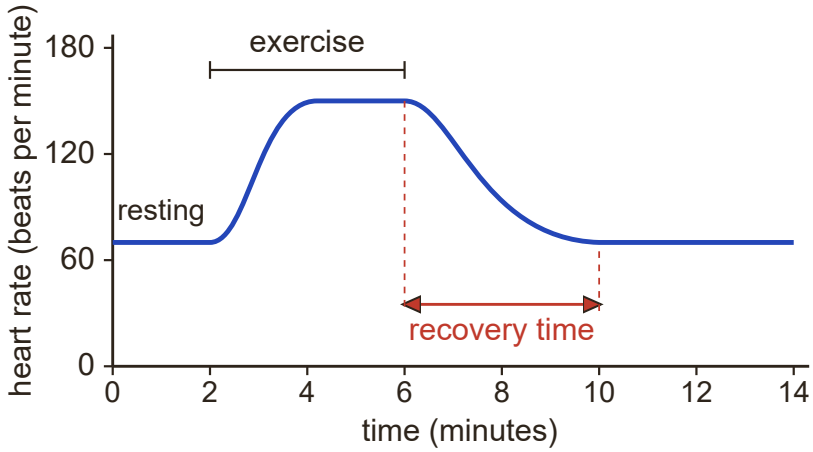
- In vigorous exercise the heart and lungs cannot supply oxygen fast enough, so muscle cells also respire **anaerobically**: glucose → lactic acid.
- The oxidation of glucose is incomplete, so **lactic acid** builds up in the muscles and an **oxygen debt** is created.
- During long periods of vigorous activity, muscles become **fatigued** and stop contracting efficiently.
- Anaerobic respiration adds to aerobic respiration; it does not replace it.

Repaying the oxygen debt Grade 7+ only

- Blood flowing through the muscles carries the lactic acid to the **liver**, where it is converted back into glucose.
- **Oxygen debt** is the amount of extra oxygen the body needs after exercise to react with the accumulated lactic acid and remove it from the cells.
- This is why your breathing rate and heart rate stay high for a while after you stop exercising.

Investigating exercise and working with data

- Investigation: measure each person's resting heart rate, have them do a set exercise for a set time, then measure the heart rate straight away and every minute until it returns to resting.
- Keep the same exercise, time and intensity; use people of similar age, sex and fitness; repeat or use several people and calculate means.
- Heart rate is measured in beats per minute: count your pulse for 15 seconds and multiply by 4.
- Breathing rate is measured in breaths per minute.
- Percentage increase = (value during exercise − resting value) ÷ resting value × 100.
- Recovery time is how long the rate takes to return to its resting value after exercise. A fitter person usually has a lower resting heart rate and recovers more quickly.



Heart rate stays high for a while after exercise stops. A fitter person recovers sooner.

How to answer each type of question

Explain why heart rate and breathing rate increase

2 to 3 marks | Grade 5

1. Start with the muscles: they contract more, so they need more energy.
2. Say that more respiration is needed.
3. Link the changes to supplying more oxygen (and glucose) in the blood, and removing carbon dioxide.

Example. During a race a runner's heart rate and breathing rate increase.
Explain why.

Model answer. The muscles are contracting more, so they need more energy (1). This energy comes from more (aerobic) respiration (1). So more oxygenated blood must be pumped to the muscles, to supply more oxygen (and glucose) (1).

Calculate a percentage change from exercise data

2 marks | Grade 5

1. Find the change: new value − original (resting) value.
2. Divide by the original value, not the new one.
3. Multiply by 100 and add the % sign.

Example. A student's resting heart rate was 64 beats per minute. After 3 minutes of running it was 112 beats per minute.
Calculate the percentage increase in heart rate.

Model answer.

112 − 64 = 48 (1)

48 ÷ 64 × 100 = 75% (1)

Explain muscle fatigue

3 marks | Grade 6

1. Say that not enough oxygen reaches the muscles.
2. So the muscle cells respire anaerobically.
3. Lactic acid builds up, and the muscles stop contracting efficiently.

Example. At the end of a 400 m sprint, an athlete's leg muscles are fatigued.
Explain why.

Model answer. Oxygen could not be supplied to the leg muscles fast enough (1), so the muscle cells respired anaerobically (1). Lactic acid built up in the muscles, so they could not contract efficiently (1).

Interpret recovery data

3 marks | Grade 5

1. Pick out the resting values, the maximum values and the recovery times.
2. Compare the two people using numbers from the data.
3. Make a conclusion that the data support, using 'suggests' if you cannot be certain.

Example. Two people did the same exercise. The table shows their results.

Person	Resting heart rate (beats per minute)	Maximum heart rate (beats per minute)	Time to
A	60	140	
B	75	170	

Suggest which person is fitter. Use the data to support your answer.

Model answer. Person A (1). Person A has a lower resting heart rate, 60 compared with 75 beats per minute (1). Person A's heart rate returns to resting sooner, after 4 minutes compared with 9 minutes / rises by less, 80 compared with 95 beats per minute (1).

Explain why breathing stays fast after exercise

3 marks | Grade 7

1. Say that lactic acid built up during anaerobic respiration, creating an oxygen debt.
2. Say that extra oxygen is needed to react with the lactic acid and remove it from the cells.
3. Add that the blood carries lactic acid to the liver, where it is converted back into glucose.

Example. After a sprint, an athlete keeps breathing deeply and quickly for several minutes, even though they are resting.
Explain why.

Model answer. Lactic acid built up in the muscles during anaerobic respiration, creating an oxygen debt (1). Extra oxygen is needed to react with the lactic acid and remove it from the cells (1). The blood carries the lactic acid to the liver, where it is converted back into glucose (1).

Don’t lose marks

- Saying you breathe faster 'to get more energy'. Breathing supplies oxygen; respiration transfers the energy.
- Saying 'the heart pumps oxygen to the muscles'. The heart pumps oxygenated blood.
- Saying muscles switch from aerobic to anaerobic respiration. In hard exercise they respire aerobically and anaerobically at the same time.
- Higher tier: saying lactic acid is turned into glucose in the muscles. This happens in the liver.
- Higher tier: defining oxygen debt as 'a lack of oxygen during exercise'. It is the extra oxygen needed after exercise to react with the lactic acid.
- In percentage change questions, dividing by the value during exercise instead of the resting value.

More tips

Memory tricks

- Three things go up: heart rate, breathing rate and breath volume.
- Fatigue chain: not enough oxygen → anaerobic respiration → lactic acid builds up → fatigue and oxygen debt.
- Higher tier: a debt is paid back later. After exercise you keep breathing hard to pay back the oxygen.
- Higher tier: Lactic acid goes to the Liver (L for L), where it becomes glucose again.

Exam technique

- Link every change to its purpose: heart rate increases → more oxygenated blood to the muscles → more aerobic respiration.
- When you describe data, quote figures with units, for example 'rose from 70 to 150 beats per minute'.
- Treat breathing rate and breath volume as two separate changes; each can be a separate mark.
- Higher tier: in an oxygen debt definition, include 'extra oxygen', 'after exercise', 'react with lactic acid' and 'remove it from the cells'.
- In a 6-mark 'design an investigation' answer, give in order: resting measurement, the exercise and its duration, measurements after it, control variables, repeats and means.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **State how exercise changes heart and breathing**
Heart rate, breathing rate and breath volume all increase.

Grade 4 — **Explain why heart and breathing rates increase**
To supply the muscles with more oxygenated blood for the extra respiration needed to contract.

Grade 5 — **Explain when muscles respire anaerobically**
When oxygen cannot be supplied fast enough for aerobic respiration alone, as in vigorous exercise.

Grade 5 — **Calculate changes from exercise data**
Work out increases, percentage changes and recovery times from tables and graphs of heart rate or breathing rate.

Grade 6 — **Explain muscle fatigue in long exercise**
Lactic acid builds up from anaerobic respiration, and over long vigorous exercise muscles stop contracting efficiently.

Grade 7 — **Describe how lactic acid is removed**
Blood carries lactic acid from the muscles to the liver, where it is converted back into glucose.

Grade 7 — **Define oxygen debt**
The extra oxygen the body needs after exercise to react with the accumulated lactic acid and remove it from the cells.

Grade 8 — **Explain fast breathing after exercise**
Breathing and heart rate stay high to supply the extra oxygen needed to repay the oxygen debt.

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