

Breathing, carbon dioxide and exercise

investigate breathing in humans, including the release of carbon dioxide and the effect of exercise

For Pearson Edexcel International GCSE Biology 4BI1 and Science (Double Award) 4SD0. Teacher answers start on a new page.

Name

Date

Aim

To show that exhaled air contains more carbon dioxide than inhaled air, and to investigate the effect of exercise on breathing rate.

Background

Body cells release energy by respiration and make carbon dioxide as a waste product. The carbon dioxide diffuses into the blood, is carried to the lungs and is breathed out. Air breathed out therefore contains much more carbon dioxide (about 4%) than air breathed in (about 0.04%).

Limewater turns cloudy (milky) when carbon dioxide is bubbled through it. **Hydrogen-carbonate indicator** can also be used: it turns from red/orange to yellow when carbon dioxide is added.

During exercise, muscles respire faster to release more energy, so they make more carbon dioxide and use more oxygen. The **breathing rate** (breaths per minute) and the depth of each breath increase, to remove the extra carbon dioxide and supply more oxygen. After exercise the rate stays high for a while and then falls gradually back to the resting rate.

Hypothesis

Exhaled air contains more carbon dioxide than inhaled air, and breathing rate increases after exercise because the muscles respire faster and produce more carbon dioxide.

Variables

Independent	Part 1: inhaled or exhaled air. Part 2: rest or exercise (and the time since exercise)
Dependent	Part 1: the time taken for the limewater to turn cloudy. Part 2: the breathing rate (breaths per minute)
Control	• Volume of limewater in each tube • Same person breathing, at the same speed and depth • The same type and length of exercise for each person • Same person counting breaths, or the same method of counting • Same time of day and same room temperature

Equipment

- 2 boiling tubes with 2-holed bungs, each fitted with a long and a short glass tube
- Limewater (or hydrogen-carbonate indicator), about 20 cm³ per tube
- Rubber or plastic tubing, a clean mouthpiece (one per student, or sterilised between users)
- Boiling tube rack and measuring cylinder, 25 cm³
- Stopclock or stopwatch
- A step or a space for running on the spot
- Partner to count breaths
- Eye protection

Risk assessment

Hazard	Risk	Precaution
Limewater (calcium hydroxide solution)	Irritates the eyes and skin.	Wear eye protection and wash splashes off straight away. Do not allow the liquid into the mouth.
Sucking limewater into the mouth	Swallowing the irritant liquid.	Set up the tubes so that you breathe in through the tube with the short glass tube and out through the one with the long tube, so liquid cannot reach your mouth. Do not suck on the long tube. Use only a clean mouthpiece.
Sharing mouthpieces	Spread of infection.	Use one mouthpiece per person or sterilise them between users.
Exercise	Dizziness, asthma attack, falling, muscle strain.	Anyone with asthma, heart conditions or an injury should not exercise (they can be the counter instead). Stop if you feel dizzy or unwell. Clear the space and do not exercise for longer than agreed.
Glass tubes	Cuts and breakage.	Handle with care and put into bungs gently with a cloth.

Method

1. Put on eye protection. Put the same volume of limewater (about 20 cm³) into two boiling tubes, labelled A (inhaled air) and B (exhaled air).
2. Fit each tube with a 2-holed bung carrying a long and a short glass tube. Join the short tube of A and the long tube of B to the two sides of a clean mouthpiece with tubing (as in the diagram), so that air is breathed in through A and out through B.
3. Breathe in and out slowly and steadily through the mouthpiece. Air breathed in is drawn through the limewater in tube A and air breathed out bubbles through the limewater in tube B. Time how long it takes for the limewater to turn cloudy in each tube.
4. Record your observations. Stop after 5 minutes if a tube has not changed.
5. Replace the limewater with fresh limewater and repeat step 3 straight after 2 minutes of exercise, to see if the time to turn cloudy changes.
6. To measure breathing rate: sit still for 2 minutes. Your partner counts the number of breaths you take in one minute. Repeat twice more and calculate the mean resting breathing rate.
7. Exercise for 2 minutes, for example stepping on and off a step or running on the spot.
8. Immediately after exercise, sit down and have your partner count the number of breaths in the first minute. Record this as the breathing rate for minute 1 after exercise.
9. Continue to count breaths each minute, recording the rate for minutes 2, 3, 4 and 5 after exercise, until the rate has returned to the resting rate.
10. Calculate each breathing rate using: breathing rate (breaths per minute) = number of breaths ÷ time in minutes, then work out the mean resting rate.
11. Plot a graph of breathing rate against time after exercise.

L2 . Wash your hands and clear away the apparatus.

Results

Breathing rate before and after exercise		
Time	Number of breaths in 1 minute	Breathing rate (breaths per minute)
At rest, test 1		
At rest, test 2		
At rest, test 3		
At rest, mean		
Minute 1 after exercise		
Minute 2 after exercise		
Minute 3 after exercise		
Minute 4 after exercise		
Minute 5 after exercise		

Graph

Line graph with time after exercise (minutes, 0 to 5) on the x-axis and breathing rate (breaths per minute) on the y-axis. Plot the rate for each minute after exercise and join the points with straight lines. Draw a dashed horizontal line at the mean resting breathing rate to show when the rate has recovered.



Exam questions 10 questions · 29 marks

1 Describe how the apparatus is arranged so that a student can compare inhaled and exhaled air using limewater. [2 marks]

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2 State what you would observe in each tube and explain the difference. [2 marks]

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3 Explain where the extra carbon dioxide in exhaled air comes from. [2 marks]

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4 The table shows the number of breaths in one minute for a student at rest. Calculate the mean resting breathing rate. [3 marks]

Breaths in 1 minute at rest	
Test	Number of breaths in 1 minute
1	14
2	16
3	15

Answer =

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- 5** After exercise the student's breathing rate was 28 breaths per minute. Calculate the percentage increase in breathing rate compared with the mean resting rate of 15 breaths per minute. **[3 marks]**

Answer =

- 6** Explain why breathing rate increases during exercise. **[3 marks]**

- 7** Suggest why the breathing rate stays high for a few minutes after the exercise has stopped. **[2 marks]**

- 8** Give three variables that should be controlled if two students compare the effect of exercise on breathing rate. **[3 marks]**

9 Describe how you would investigate the effect of exercise on breathing rate and explain the results you would expect. **[6 marks]**

[illegible]

10 A student suggests that exhaled air could be tested with hydrogen-carbonate indicator instead of limewater. Describe the colour change expected and explain how the result would differ after exercise. **[3 marks]**

[illegible]

Teacher answers

Practical 9: Breathing, carbon dioxide and exercise. The example results are practice data, not real measurements.

Example results

Example results (practice data): breathing rate of one student		
Time	Number of breaths in 1 minute	Breathing rate (breaths per minute)
At rest, test 1	14	14
At rest, test 2	16	16
At rest, test 3	15	15
At rest, mean	15	15
Minute 1 after exercise	28	28
Minute 2 after exercise	24	24
Minute 3 after exercise	20	20
Minute 4 after exercise	17	17
Minute 5 after exercise	15	15

Conclusion

The limewater in tube B (exhaled air) turned cloudy quickly, but the limewater in tube A (inhaled air) stayed clear or turned cloudy only slowly. This shows that exhaled air contains much more carbon dioxide than inhaled air, because carbon dioxide is made by respiration in body cells and removed in the lungs. After exercise the breathing rate rose from a resting mean of 15 breaths per minute to 28 breaths per minute, then fell back to 15 by minute 5. The exercising muscles respired faster, producing more carbon dioxide and needing more oxygen. A higher, deeper breathing rate removes the carbon dioxide faster and takes in more oxygen. If the exhaled air was tested after exercise, the limewater would turn cloudy faster than at rest.

Errors and improvements

Error	Effect on the results	Improvement
The student counting breaths changes their own breathing by thinking about it.	The resting rate may be higher or lower than normal.	Have a partner count the breaths without telling the student when the counting starts, or count while the student is distracted by reading.
The exercise is different in length or intensity for different trials.	Breathing rate changes cannot be compared fairly.	Use the same exercise, for the same time and at the same pace (for example 30 steps in one minute), timed with a stopclock.
Breaths are counted in whole numbers over one minute only.	Results are less precise and one miscount has a large effect.	Count for 2 minutes and halve the total, or use a breath sensor; repeat and calculate a mean.
The student does not breathe at a steady speed through the limewater apparatus.	The times to cloud differ for reasons other than carbon dioxide concentration.	Breathe at a steady rate, and use the same volume of limewater and the same tubes each time.
Only one student is tested.	Their results may not be typical of other people, so the conclusion is less reliable.	Test several students and compare the mean breathing rates.

Mark scheme

One mark for each point unless a maximum is given. Words in brackets are not needed for the mark.

1. [2]

- air is breathed in through one tube of limewater / tube A and out through the other / tube B (1)
- tubes arranged so that limewater cannot be sucked into the mouth / the long tube dips into the limewater in the tube for exhaled air (1)

2. [2]

- inhaled air tube stays clear (or takes much longer to turn cloudy); exhaled air tube turns cloudy (1)
- exhaled air contains more carbon dioxide (1)

3. [2]

- it is made by respiration in body cells (1)
- it diffuses into the blood and is carried to the lungs where it diffuses into the alveoli and is breathed out (1)

4. [3]

- $14 + 16 + 15 = 45$ (1)
- $45 \div 3$ (1)
- 15 breaths per minute (1) unit required

5. [3]

- $28 - 15 = 13$ (1)
- $13 \div 15 \times 100$ (1)
- 87% (1) allow 86.7

6. [3]

- muscles respire faster / need more energy (1)
- so they produce more carbon dioxide and need more oxygen (1)
- breathing faster (and deeper) removes carbon dioxide / supplies more oxygen (1)

7. [2]

- carbon dioxide is still in the blood / muscles are still respiring faster (1)
- it takes time to remove the carbon dioxide / the rate gradually falls to resting (1) allow oxygen debt

8. [3]

- same type of exercise (1)
- same duration / intensity of exercise (1)
- same time since exercise when counting (1)
- same method of counting / same fitness / same age (1)
- Max 3

9. [6]

Level 3 5-6	A full method with resting measurements, a standard exercise, readings after exercise and at intervals, controls and repeats. The explanation links muscle respiration, carbon dioxide and oxygen to the rise in breathing rate and the recovery.
Level 2 3-4	A method with resting and exercise measurements and some control or repeat; the explanation is incomplete.
Level 1 1-2	A few relevant points, for example counting breaths before and after exercise, with little detail or explanation.

Indicative content

- sit still and count breaths in one minute at rest; repeat and calculate a mean
- exercise for a set time (for example 2 minutes) at a steady pace
- count breaths in the first minute after exercise, and each minute until the rate returns to resting
- control: same exercise, same person, same method of counting; use a partner to count
- expected: breathing rate is higher after exercise and then falls gradually
- reason: muscles respire faster, so they produce more carbon dioxide and use more oxygen
- faster, deeper breaths remove the carbon dioxide and supply the oxygen

10. [3]

- red/orange to yellow (1)
- after exercise the colour change would be faster (1)
- because exhaled air contains more carbon dioxide after exercise / muscles respire faster (1)

Exam tips

- Limewater goes cloudy (milky) with carbon dioxide. Do not say it 'goes white' or 'changes colour' without saying cloudy.
- Give the unit for breathing rate: breaths per minute. Show the working for means and percentage changes.
- In explanations, link exercise to faster respiration in the muscles, then to more carbon dioxide and oxygen use, and then to a higher breathing rate.
- State both parts of the idea: exhaled air has more carbon dioxide than inhaled air because of respiration in cells.

- Describe the safe arrangement of tubes: you must not be able to suck limewater into your mouth.