Mammalian Breathing

A Level

In vertebrates, the organ responsible for gas exchange between the blood and the environment (lungs or gills) is actively ventilated. The mechanisms of ventilation ("breathing") are different among vertebrates. The questions below relate specifically to mammalian breathing.

Part A Inhalation

During inhalation, the lungs expand. This is caused by the following processes:

- The diaphragm [ ], changing from a [ ] to a [ ]. This causes the thorax to expand downwards.
- The external intercostal muscles [ ]. This causes the ribcage to move upwards and outwards, causing the thorax to expand in these directions.

The increase in the volume of the thorax causes thoracic pressure to [ ]. This causes air to move into the lungs through the nose/mouth.

Items:

contracts **relaxes** **flatter shape** **more domed shape** **contract** **relax** **increase** **decrease**

Part B Exhalation

During exhalation, the lungs return to their resting size. This is caused by the following processes:

- The diaphragm [ ] from a [ ] to a [ ]. This causes the thorax to reduce in volume.
- The external intercostal muscles [ ]. This causes the ribcage to move down and inwards, causing the thorax to reduce in volume.

The decrease in the volume of the thorax causes thoracic pressure to [ ]. This causes air to move out of the lungs through the nose/mouth.

Normal exhalation is a passive process, caused by muscle relaxation and elastic recoil of the alveoli. However, other muscles (e.g. the abdominal muscles and internal intercostal muscles) can actively contract to increase exhalation rate if necessary (e.g. during exercise).

Items:

contracts **relaxes** **flatter shape** **more domed shape** **contract** **relax** **increase** **decrease**

Part C Breathing statements

Which of the following is/are correct when a healthy human **breathes in**? Select all that apply.

- [ ] The ribcage moves up and out because air enters the lungs.
- [ ] The volume of the thorax decreases and the thoracic pressure increases.
- [ ] Energy is required to contract the intercostal muscles but not the diaphragm.
- [ ] The alveoli expand and the elastic fibres surrounding them are stretched.
- [ ] none of the above

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Intrapleural Pressure Changes

A Level

C C C

Figure 1 shows the changes in intrapleural pressure during one complete breathing cycle of an individual.

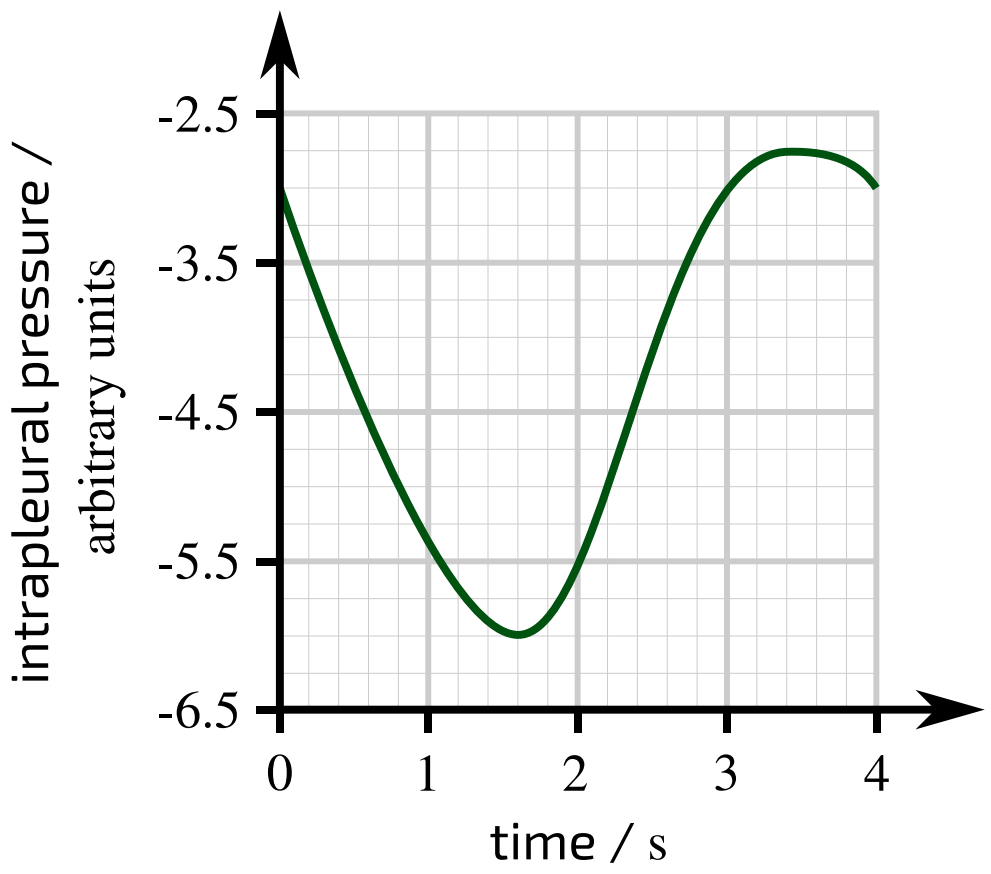

Figure 1: Intrapleural pressure over time during one complete breathing cycle of an individual.

Part A Breathing statements

Which of the following statements are correct? Select all that apply.

- [ ] The diaphragm is **contracting** between 2 and 3 seconds
- [ ] The individual is breathing **in** between 0 and 1 seconds.
- [ ] The diaphragm is **relaxing** between 2 and 3 seconds
- [ ] The individual is breathing **out** between 0 and 1 seconds.
- [ ] The external intercostal muscles are **relaxing** between 3.5 and 4 seconds
- [ ] The external intercostal muscles are **contracting** between 3.5 and 4 seconds

Part B Percentage increase

Calculate the total percentage increase in intrapleural pressure during exhalation.

Give your answer to 2 sf.

Part C Breathing rate

Calculate the breathing rate of this individual.

Assume that the individual continues breathing at the same rate.

Adapted with permission from NSAA 2023 Section 1 Q78

Gameboard:
STEM SMART Biology Week 18 - Respiratory Systems 2

Pulmonary Ventilation Rate

A Level

C C C

Pulmonary Ventilation Rate (PVR) is a measure of the volume of air that moves in and out of the lungs per minute. It is measured using a spirometer, and can be used to assess fitness levels and diagnose respiratory diseases.

Part A Formula

The formula for calculating pulmonary ventilation rate is as follows:

$$\text{Pulmonary ventilation rate (PVR)} = \square \ \square \ \square$$

Items:

tidal volume | vital capacity | breathing rate | $\times$ | $\div$ | $+$ | $-$

Part B Pulmonary ventilation rate calculation

Using a spirometer, an individual's tidal volume and breathing rate were measured.

Tidal volume $= 500\,\text{cm}^3$

Breathing rate $= 12$ breaths per minute

Calculate this individual's pulmonary ventilation rate.

Part C Breathing rate calculation

Using a spirometer, an individual's pulmonary ventilation rate and tidal volume were measured.

Pulmonary ventilation rate $= 6.4\,\mathrm{dm}^3\ \mathrm{min}^{-1}$

Tidal volume $= 400\,\mathrm{cm}^3$

Calculate this individual's breathing rate.

Part D Tidal volume calculation

Using a spirometer, an individual's pulmonary ventilation rate and breathing rate were measured.

Pulmonary ventilation rate $= 8.1\,\mathrm{dm}^3\ \mathrm{min}^{-1}$

Breathing rate $= 18$ breaths per minute

Calculate this individual's tidal volume.

Created for isaacphysics.org by Lewis Thomson

Gameboard:

STEM SMART Biology Week 18 - Respiratory Systems 2

Spirometry Analysis

A Level

C C C

In a test to compare the function of the human respiratory system in different individuals, individuals were asked to breathe out as hard as possible for as long as possible. The volume exhaled was recorded using a spirometer.

The graph shows the results obtained after carrying out this test on two males with the same height and body mass.

The investigators were particularly interested in two measurements:

- Forced Vital Capacity (FVC): the maximum total volume of air an individual can forcefully breathe out after breathing in as deeply as possible
- Forced Expiratory Volume (FEV1): the maximum volume of air an individual can forcefully breathe out in 1 second

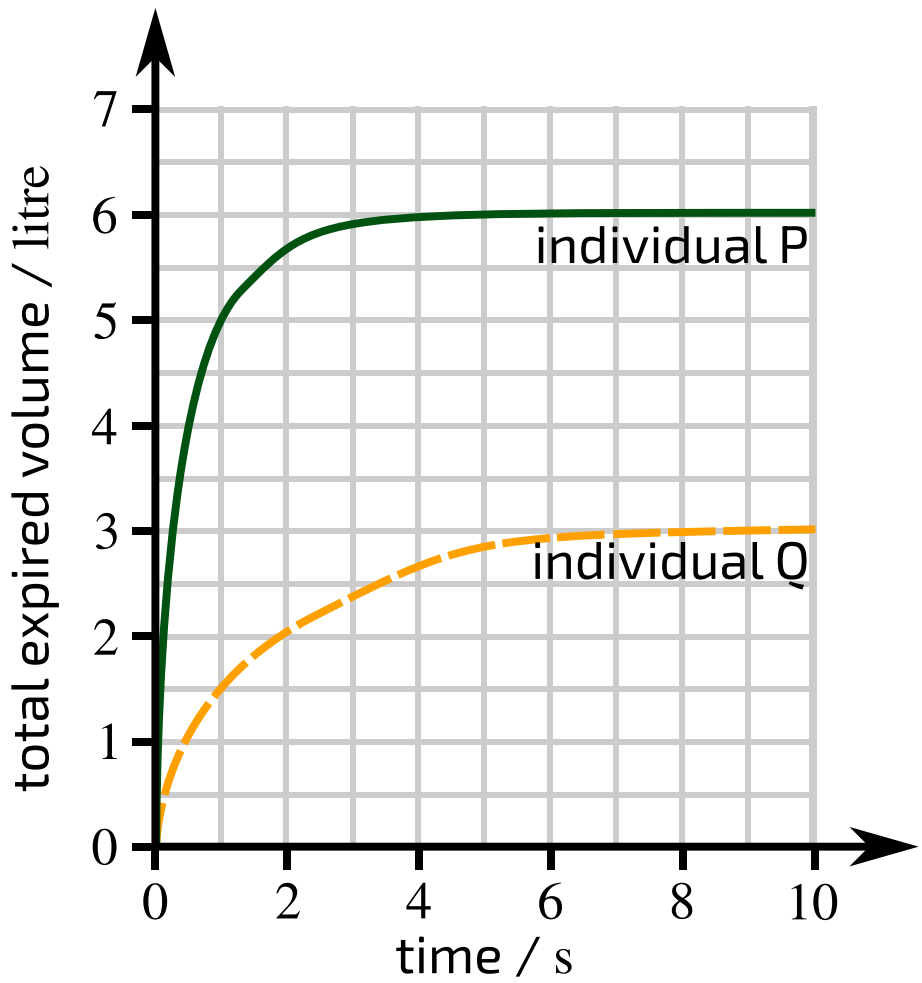

Figure 1: Spirometry results. The total expired volume of air is shown over time for two individuals.

Part A Forced Vital Capacities

How much greater is the forced vital capacity (FVC) of individual P than individual Q?

Give your answer as a percentage to the nearest percent.

Part B Forced Expiratory Volumes

How much greater is the forced expiratory volume (FEV1) of individual P than individual Q?

Give your answer as a percentage to the nearest percent.

Part C Breathing mechanisms

Which of the following statements are correct? Select all that apply.

- [ ] Individual Q's diaphragm was **more** domed at 7 seconds than at 2 seconds.
- [ ] Individual Q's diaphragm was **less** domed at 7 seconds than at 2 seconds.
- [ ] Between 0 and 1 seconds, the external intercostal muscles of both individuals are **contracting**.
- [ ] Between 0 and 1 seconds, the external intercostal muscles of both individuals are **relaxing**.
- [ ] The elastic fibres surrounding individual P's alveoli are **more** stretched at 2 seconds than at 0 seconds.
- [ ] The elastic fibres surrounding individual P's alveoli are **less** stretched at 2 seconds than at 0 seconds.

Adapted with permission from NSAA 2022 Section 2 Q45

Gameboard:
STEM SMART Biology Week 18 - Respiratory Systems 2

Peak Expiratory Flow

A Level

C C C

Peak expiratory flow (PEF) is a measure of the maximum rate at which a person can exhale.

The graph below shows the typical PEF values for men of different ages and heights.

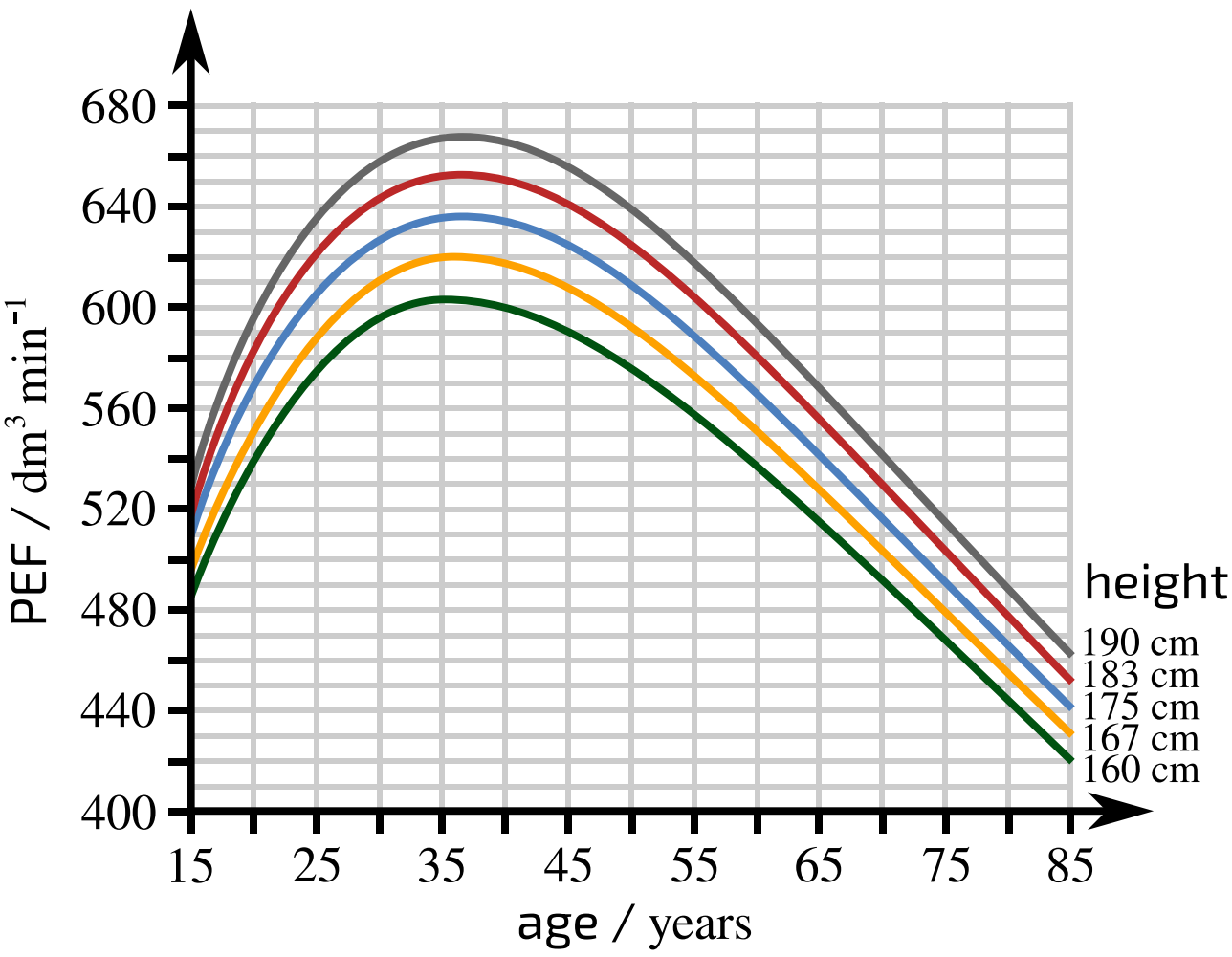

Figure 1: Typical peak expiratory flow (PEF) rates for men of different ages and heights.

Part A Percentage difference

How much higher is the PEF of a 45 year old man of $183\,\mathrm{cm}$ than the PEF of a 20 year old man of $175\,\mathrm{cm}$?

Give your answer as a percentage to the nearest percent.

Part B Percentage increase

For a man of $167\,\mathrm{cm}$, how much higher is their PEF at 35 years old than their PEF at 15 years old?

Give your answer as a percentage to the nearest percent.

Part C Percentage decrease

For a man of $167\,\mathrm{cm}$, how much lower is their minimum PEF than their maximum PEF?

Give your answer as a percentage to the nearest percent.

Adapted with permission from OCR A Level Biology A, June 2018, Biological Processes, Question 9

Gameboard:

STEM SMART Biology Week 18 - Respiratory Systems 2

Spirometry Measurements

A Level

C C C

A spirometer was used to measure an individual's lung function. The individual was asked to breathe normally for 30 seconds, then breathe in and out as deeply as possible, and then return to breathing normally. The results are shown in **Figure 1**.

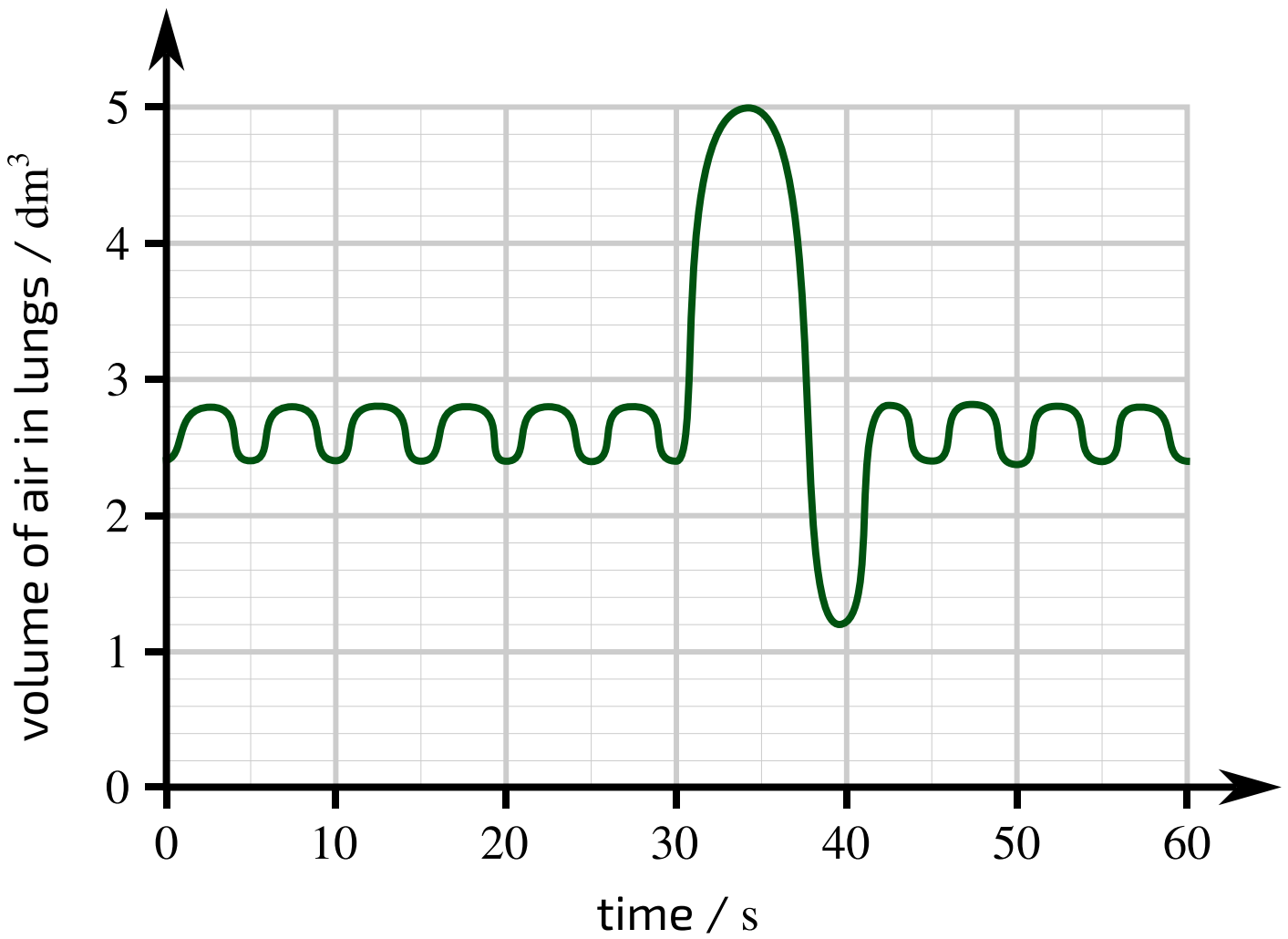

Figure 1: The results of a lung function test.

Part A Lung function values

Calculate each of the lung function values shown in the table below for the individual in **Figure 1**.

Tidal volume	
Vital capacity	
Residual volume	
Total lung capacity	

Part B Pulmonary ventilation rate (PVR)

Estimate the pulmonary ventilation rate (PVR) of the individual in **Figure 1**. Give your answer to 2 sf.