11.1.1 Ventilation, air composition, exercise and keeping the airways clean

Name: _____ Class: _____ Date: _____ **Total: 35 marks**

KEY WORDS gas exchange 气体交换 • diaphragm 膈 • thorax 胸腔 • trachea 气管 • carbon dioxide 二氧化碳

Objective

Sheet 11.1 covered the alveoli and one breathing question. This sheet is the rest of 11.1, and it is nearly all of the unit's exam marks: naming the parts of the breathing system, the **cartilage** 软骨 in the trachea, how the ribs, **intercostal muscles** 肋间肌 and **diaphragm** 膈 change the volume and pressure of the **thorax** 胸腔, what makes **expired air** 呼出气体 different from inspired air, why exercise changes your breathing, and how **goblet cells** 杯状细胞 and **ciliated cells** 纤毛细胞 keep the lungs clean. This sheet covers syllabus 11.1.

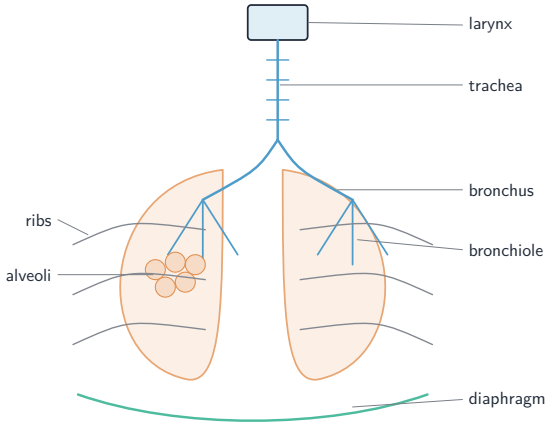
You must be able to:

- describe the features of a gas exchange surface: large surface area, thin, good blood supply, good **ventilation** 通气
- identify the lungs, diaphragm, ribs, intercostal muscles, **larynx** 喉, **trachea** 气管, **bronchi** 支气管, **bronchioles** 细支气管, **alveoli** 肺泡 and their capillaries, including the internal and external intercostal muscles
- state the function of the cartilage in the trachea
- explain how the ribs, the internal and external intercostal muscles and the diaphragm produce the volume and pressure changes that ventilate the lungs
- investigate and describe the differences between inspired and expired air, using **lime-water** 石灰水 as a test for carbon dioxide, and explain those differences
- investigate, describe and explain the effect of physical activity on the rate and depth of breathing
- explain the role of goblet cells, **mucus** 黏液 and ciliated cells in protecting the breathing system

1 Worked examples

Study these first. Each one shows a **method** that a question later on this sheet needs.

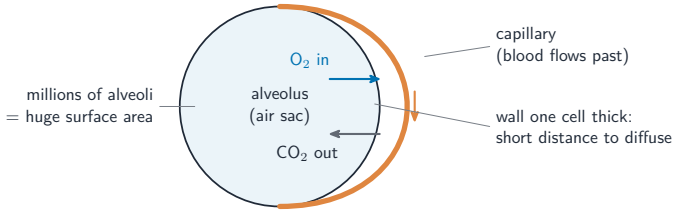
■ The parts, and the one function you are asked for



Air travels: **larynx** → **trachea** → **bronchi** → **bronchioles** → **alveoli**, where the exchange happens.

- The **cartilage** in the trachea wall is the only part whose *function* is examined: it holds the trachea **open**, so that air can always pass even when the pressure inside drops.
- The **intercostal muscles** lie between the ribs. The **external** ones pull the ribs **up and out**; the **internal** ones pull them **down and in**.

■ Why an alveolus is a good gas exchange surface

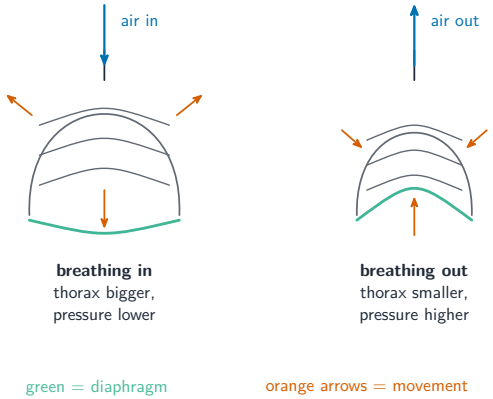


Four features, and each one must be paired with **what it does**:

feature	why it helps
large surface area – millions of alveoli	more gas can diffuse at the same time
thin – the wall is one cell thick	a **short diffusion distance** 扩散距离
good blood supply – a network of capillaries	keeps a steep **concentration gradient** 浓度梯度
good ventilation – air is replaced with every breath	also keeps the gradient steep

- Naming a feature alone is half a mark's work. "Large surface area **so more diffusion can happen at once**" is the full answer.

Ventilation: what moves, what happens to volume, what happens to pressure

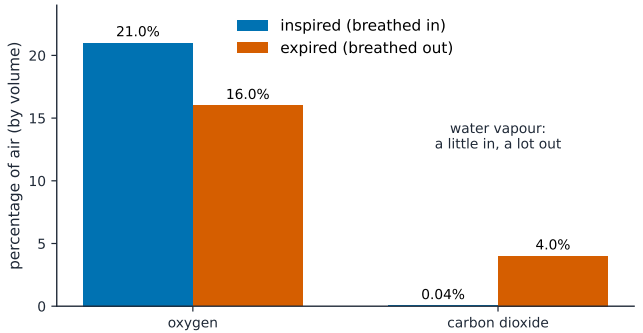


Answer in this order every time: **muscles → ribs and diaphragm → volume → pressure → air moves**.

	breathing in	breathing out
external intercostal muscles	contract	relax
internal intercostal muscles	relax	contract
ribs	move **up and out**	move **down and in**
diaphragm	**contracts** and flattens	**relaxes** and domes up
volume of the thorax	**increases**	**decreases**
pressure in the thorax	**decreases**	**increases**
air	moves **in**	moves **out**

- Air always moves from **higher** pressure to **lower** pressure. Writing "the lungs suck the air in" earns nothing.
- The diaphragm **contracts to flatten**. Saying it "relaxes downwards" is the commonest error on this unit.

Inspired and expired air

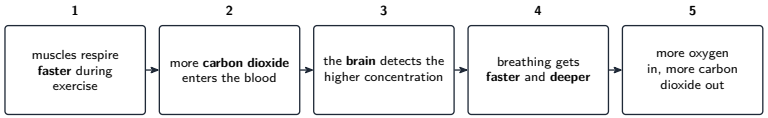


expired air: ↓ O_2, ↑ CO_2, ↑ water vapour (vs inspired)

gas	inspired	expired	why
oxygen	about 21%	about 16%	some diffused into the blood, to be used in **respiration** 呼吸作用
carbon dioxide	about 0.04%	about 4%	made by respiration in the body cells, and diffused out of the blood
water vapour	little	a lot	the alveoli and airways are **moist**, and water evaporates from them

The limewater test. Bubble each sample of air through limewater. **Expired air turns the limewater milky much faster**, because it contains far more carbon dioxide. The inspired-air tube is the **control**: it goes milky only slowly, which shows the difference is real.

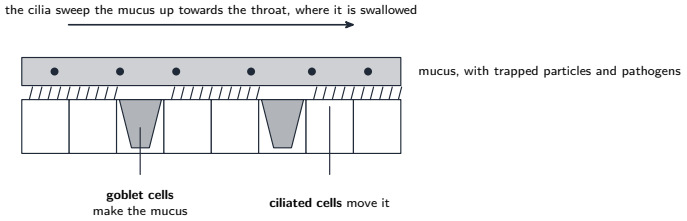
Exercise and breathing



The brain responds to the **carbon dioxide** concentration, not to a shortage of oxygen. Every step here is a separate marking point.

- Both the **rate** (breaths per minute) and the **depth** (volume of each breath) increase.
- The trigger the exam wants is the **carbon dioxide concentration in the blood**, detected by the **brain**. Answers built on "the body needs more oxygen" miss the marking point.

Keeping the airways clean



Two cell types, two jobs. A question that asks about *protection* wants both: the mucus traps the particles, and the cilia carry them away from the lungs.

- **Goblet cells** make the sticky **mucus**, which **traps** particles and pathogens in the air you breathe in.
- **Ciliated cells** carry hair-like **cilia** that beat and **sweep the mucus up** the trachea to the throat, where it is swallowed.
- Two cell types, two jobs. A question about protection wants both.

2 Practice

Now use the methods above.

2.1 Name the tube that carries air from the larynx to the bronchi, and state the function of the cartilage in its wall. [2]

2.2 State **two** features of a gas exchange surface, and explain how each one helps gas exchange. [4]

2.3 Describe what the external intercostal muscles and the diaphragm do when a person breathes in. [3]

2.4 Explain how the volume and the pressure inside the thorax change when a person breathes in, and why this makes air enter the lungs. [3]

2.5 Describe what you would see when expired air is bubbled through limewater, and state what the control should be. [2]

2.6 State the function of goblet cells and the function of ciliated cells. [2]

3 Exam-style questions

3.1 Which row describes the thorax when a person breathes **in**? [1]

	external intercostal muscles	diaphragm	volume of thorax	pressure in thorax
A	contract	contracts and flattens	increases	decreases
B	contract	relaxes and domes up	increases	decreases
C	relax	contracts and flattens	decreases	increases
D	relax	relaxes and domes up	decreases	increases

3.2 The table shows the composition of inspired and expired air.

gas	inspired air / %	expired air / %
oxygen	21	16
carbon dioxide	0.04	4

(a) Explain why expired air contains less oxygen than inspired air. [2]

(b) Expired air also contains much more water vapour. Explain why. [2]

(c) Expired air still contains 16% oxygen. Explain why this makes mouth-to-mouth resuscitation useful. [2]

3.3 A student measured her breathing rate and the volume of each breath before, during and after five minutes of exercise.

when	breathing rate / breaths per minute	volume of each breath / dm^3
at rest	14	0.5
during exercise	30	1.8
5 minutes after exercise	18	0.8

(a) Calculate the volume of air she breathed in one minute at rest, and in one minute during exercise. [2]

(b) Describe the effect of exercise on her breathing. [2]

(c) Explain, in terms of carbon dioxide, why her breathing changed during exercise. [4]

(d) Five minutes after the exercise stopped, her breathing rate was still above its resting value. Explain why. [2]

(e) State **two** variables she should keep the same if she repeats the investigation with a friend. [2]

Solutions

Each answer shows the steps, then the **result**.

2.1

- the **trachea**
- the cartilage holds the trachea **open**, so air can always pass through it

2.2

- any **two** features, each with its reason:
- **large surface area** – so more gas can diffuse at the same time
- **thin, one cell thick** – so the diffusion distance is short
- other acceptable pairs: a **good blood supply**, or **good ventilation**, each because it keeps a steep concentration gradient

2.3

- the **external intercostal muscles contract**
- so the ribs move **up and out**
- the **diaphragm contracts** and **flattens**, moving down

2.4

- the volume of the thorax **increases**
- so the pressure inside it **decreases**, and becomes lower than the air pressure outside
- air therefore moves **from the higher pressure outside to the lower pressure inside**, and enters the lungs

2.5

- the limewater turns **milky** (cloudy white) quickly
- the control is a second tube of limewater through which **inspired air** is drawn; it goes milky only slowly, showing the difference is caused by the expired air

2.6

- goblet cells make **mucus**, which traps particles and pathogens
- ciliated cells have **cilia** that sweep the mucus up to the throat, where it is swallowed

3.1 A

- breathing in: the external intercostals contract and the diaphragm contracts and flattens, so the thorax gets **bigger** and the pressure inside gets **lower**
- **B** has the diaphragm doing the opposite; **C** and **D** describe breathing out

3.2

(a)

- oxygen **diffuses** from the air in the alveoli into the blood

- because it is used by the body cells in **respiration**, which keeps its concentration in the blood low

(b)

- the alveoli and the airways have **moist** surfaces
- water **evaporates** from them into the air, so the air breathed out carries much more water vapour

(c)

- 16% is still a high enough concentration of oxygen for it to **diffuse into the casualty's blood** in the alveoli
- so their cells can still respire, which keeps them alive until help arrives

3.3

(a)

- multiply the rate by the volume of each breath

at rest: $14 \times 0.5 = \mathbf{7}$ $\mathrm{dm}^{\mathbf{3}}$ per minute during: $30 \times 1.8 = \mathbf{54}$ $\mathrm{dm}^{\mathbf{3}}$ per minute

(b)

- the breathing **rate** rose, from 14 to 30 breaths per minute
- the **depth** of each breath rose too, from 0.5 to 1.8 dm^3

(c)

- her muscles **respired faster** during the exercise, to release more energy
- so they produced more **carbon dioxide**, which entered the blood
- the **brain** detected the increased carbon dioxide concentration in the blood
- and increased the **rate and depth** of breathing, so that more carbon dioxide is removed and more oxygen taken in

(d)

- the carbon dioxide concentration in her blood has **not yet returned** to its resting level
- so the brain is still stimulating faster, deeper breathing until the extra carbon dioxide has been removed

(e)

- any **two** of: the **type** of exercise; how **long** the exercise lasts; how **hard** the exercise is; the time after exercise at which the measurements are taken