# 1.2 The heart, lungs and homeostasis

Name: _____ Class: _____ Date: _____ **Total: 30 marks**

**KEY WORDS** sinoatrial node • stroke volume • cardiac output • tidal volume • partial pressure • negative feedback

## Objective

Build the skills to answer exam questions on the **heart** and **lungs**, **cardiac output**, ventilation and gas exchange, and **homeostasis** during exercise.

**You must be able to:**

- describe the conduction of the heartbeat and calculate cardiac output
- describe breathing, lung volumes and minute ventilation
- explain gas exchange using partial pressure
- explain temperature and blood glucose regulation as negative feedback
- explain the effects of heat and altitude, and acclimatization

## 1 Key knowledge and worked examples

### ■ Heart, lungs and homeostasis

**Heart:** four chambers; **double circulation** (right side → lungs; left side → body). The heartbeat starts in the **sinoatrial (SA) node** (pacemaker) → atria contract → **atrioventricular (AV) node** (short delay) → **bundle of His** → **Purkinje fibres** → ventricles contract.

$$\text{cardiac output } Q = \text{heart rate (HR)} \times \text{stroke volume (SV)}$$

e.g. HR 70 beats $\text{min}^{-1}$ × SV 70 ml = 4900 ml $\text{min}^{-1}$ ≈ 4.9 L $\text{min}^{-1}$.

**Venous return** rises in exercise by the **muscle pump** (contracting muscles squeeze veins; valves stop backflow), the **respiratory pump** and **venoconstriction**.



exercises.lol exercises.com.cn

**Breathing in (rest):** the **diaphragm** contracts and flattens; the external **intercostal** muscles lift the ribs; chest volume rises, pressure falls, air flows in. In exercise, extra muscles help, and breathing out becomes active.

| volume | meaning |
|---|---|
| **tidal volume** (TV) | air in or out per breath (about 0.5 L at rest) |
| **vital capacity** | most air you can breathe out after the deepest breath in |
| **residual volume** | air left in the lungs after the hardest breath out |

$$\text{minute ventilation } V_E = \text{TV} \times \text{breathing rate}$$

**Gas exchange:** $O_2$ and $CO_2$ move by **diffusion** from high to low **partial pressure**. Alveoli have a huge surface area, walls one cell thick and a rich capillary supply. **Chemoreceptors** detect rising $CO_2$ (lower pH) and increase breathing.

**Homeostasis** keeps the internal environment stable by **negative feedback**: a change is detected and the response reverses it.

- **Temperature:** sweating (evaporation removes heat) and **vasodilation** of skin vessels.
- **Blood glucose:** if it falls, the pancreas releases **glucagon**, so the liver breaks glycogen into glucose; if it rises, **insulin** helps cells take it up.

**AHL – environment:** in heat and humidity, sweat evaporates poorly; **heat acclimatization** (about 1–2 weeks) brings earlier, more dilute sweating and a larger plasma volume. At altitude the air is still 20.9% oxygen, but **barometric pressure is lower**, so the **partial pressure** of $O_2$ is lower and less $O_2$ diffuses into the blood. Over weeks, more **EPO** is released, so red blood cells and haemoglobin rise.

**Answer shapes:** for a calculation, write the formula, the numbers with units, and the answer with units.

## 2 Practice

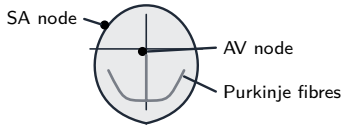
**2.1** An athlete has a heart rate of 150 beats $\text{min}^{-1}$ and a stroke volume of 120 ml. Calculate the cardiac output in L $\text{min}^{-1}$. [2]



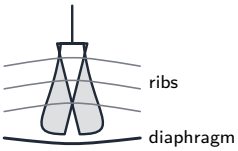
HR 150 beats $\text{min}^{-1}$

SV 120 ml

**2.2** Describe how the electrical impulse that starts each heartbeat spreads through the heart. [3]



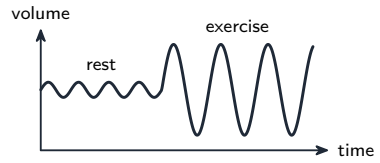

**2.3** Describe the mechanics of breathing in at rest. [3]




**2.4** The table shows breathing data for a student.

| | **tidal volume (L)** | **breaths min$^{-1}$** |
|---|---|---|
| rest | 0.5 | 12 |
| hard exercise | 2.5 | 40 |

(a) Calculate the minute ventilation at rest and in exercise. [2]




(b) Calculate how many times larger it is in exercise. [1]

(c) Name the receptors that detect the rise in blood $CO_2$. [1]

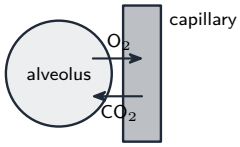


exercises.lol exercises.com.cn

## 3 Exam-style questions

**3.1** The diagram shows an alveolus and a capillary.

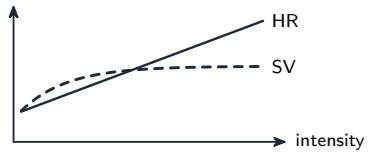
(a) Explain how oxygen moves from the alveolus into the blood. [2]




(b) Explain **two** features of the alveoli that make gas exchange fast. [2]

**3.2** The graph shows stroke volume and heart rate as exercise intensity rises.

(a) Describe how stroke volume changes as intensity rises. [2]




(b) Explain why heart rate rises just before exercise starts. [2]

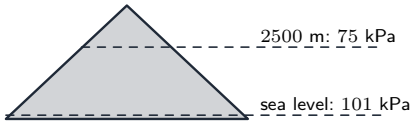
(c) Explain how venous return increases during exercise. [2]



exercises.lol exercises.com.cn

**3.3** A team trains at 2500 m, where air pressure is about 75 kPa (sea level: 101 kPa). Air is 20.9% oxygen at both heights.

(a) Calculate the partial pressure of oxygen at sea level and at 2500 m. [2]




(b) Explain why less oxygen enters the blood at altitude. [2]

(c) Describe **two** adaptations after several weeks at altitude. [2]

(d) Explain how heat acclimatization helps an athlete compete in a hot climate. [2]



exercises.lol exercises.com.cn