Bio Factsheet

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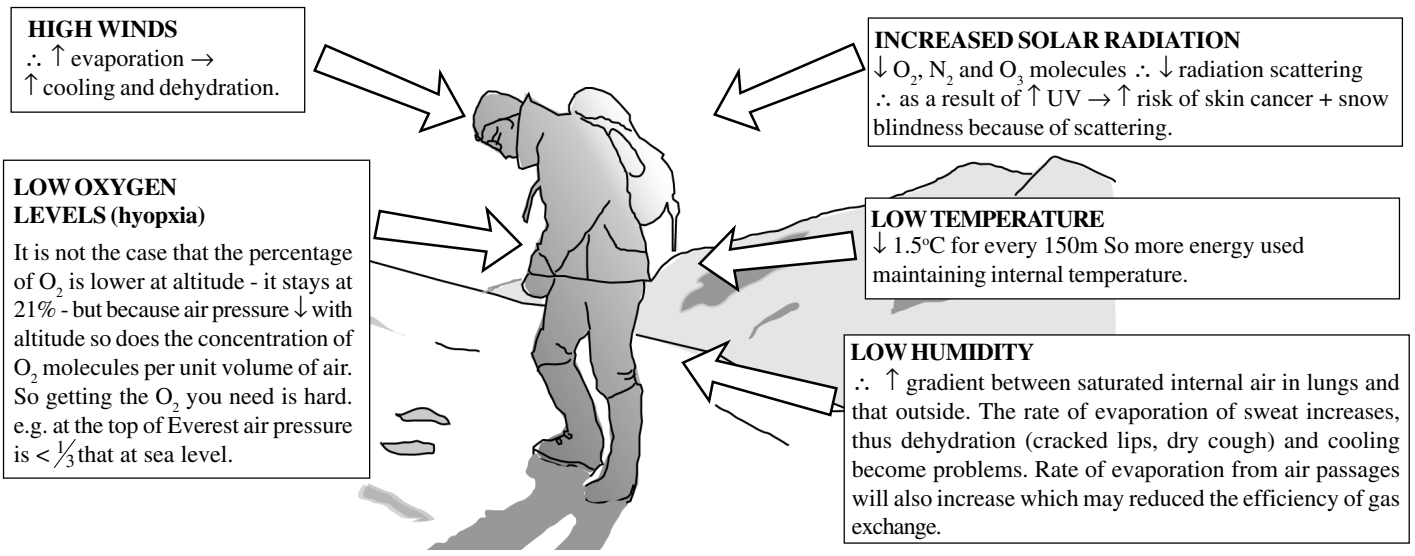
High Altitude Biology

This Factsheet will:
1. Summarise the human physiological responses to high altitude.
2. Give examples of the type of application and synoptic question that have appeared recently on this topic

Life at high altitude comes with its problems (Fig 1)

***Exam Hint**: this topic is only explicitly mentioned on xbut can appear as an Application question on any specification. Because the physiological responses involve the heart, lungs, brain and general circulatory system, the question is an obvious candidate for a synoptic question.*

Fig 1 High altitude problems



Hypoxia (low oxygen partial pressure) means that the diffusion gradient between the external environment and the internal cells is reduced. Thus, it becomes harder to get sufficient oxygen to the cells. The body has three **responses**:
1. Hyperventilation (to get more oxygen to the alveoli)
2. Increased rates of diffusion between the alveoli and the blood in the pulmonary capillaries
3. Increased transport of oxygen in the blood.

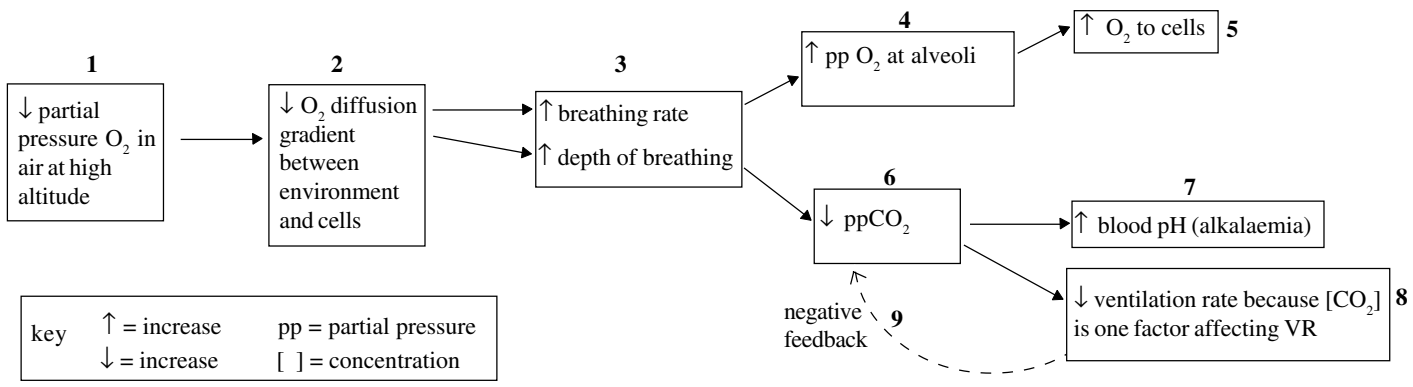
Typical Exam Question
Why may stage 9 be considered an example of negative feedback? *(4 marks)*

Answer
Negative feedback returns a system that has moved away from equilibrium back towards equilibrium;
Falling carbon dioxide partial pressure has lead to a reduction in the ventilation rate (VR);
The fall in VR has allowed the [CO_2] to increase again;
Thus [CO_2] has returned to its normal equilibrium level;
= negative feedback;

1. Hyperventilation

Hyperventilation – breathing faster and deeper –helps us to get the oxygen we need but it has several other effects (Fig 2).

Fig 2. Hyperventilation



2. Accelerated diffusion at the alveoli

Compared to lowlanders, people who are native to high altitudes have:
(i) larger alveoli surface area, allowing faster diffusion of oxygen across them;
(ii) larger blood volume, allowing them to carry more oxygen

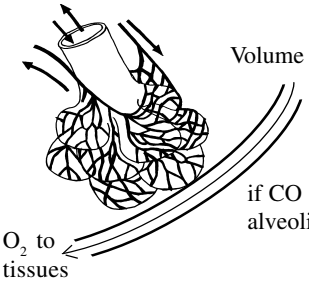
As might be expected, native highlanders also have :
(i) More red blood cells;
(ii) More haemoglobin in each red blood cell

3. Increased transport of oxygen in the blood

The three factors that affect the volume of oxygen that can be carried in the blood are summarised in Fig 3.

Fig 3. Factors affecting O_2 carried in blood

1. Cardiac Output (CO) (volume of blood pumped out per minute) = **Heart Rate** (beats/minute) × **Stroke Volume** (volume of blood pumped at each beat)



Volume = Cardiac output

if CO ↑ then any O_2 supplied to the alveoli can be carried away quickly

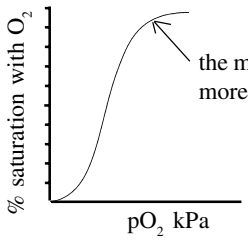
O_2 to tissues

2. Haemoglobin concentration

As concentration of haemoglobin↑ the volume of O_2 that can be carried ↑

Typical Exam Question
This is the commonest exam question topic!

3. Haemoglobin saturation



the more saturated the haemoglobin the more it is carrying

Besides all of these changes to the pulmonary and cardiac systems, high altitude also lead to conservation and redistribution of body fluids

Changes to body fluids

In mild hypoxia:

ADH secretion↓ → ↓ water reabsorbed in collecting duct → ↑ urine produced

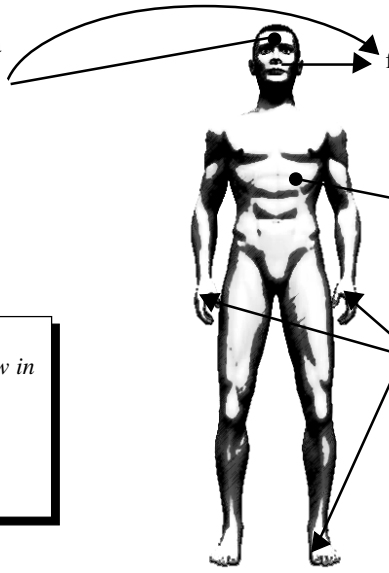
But in severe hypoxia;

ADH secretion↑ → ↑ water reabsorbed in collecting duct → ↓ urine → ↓ dehydration

Fluids are distributed away from the extremities and this contributes to an accumulation of fluid, particularly in the brain and lungs (Fig 4)

Fig 4. Redistribution of fluids

↑ fluid in vessels in brain → cerebral oedema pushing the brain against the cranium → severe headaches → death



facial swelling

↑ accmulation of fluid outside blood vessels of lungs
→ pulmonary oedema
→ breathlessness and frothing at mouth

↓ flow to extremities

Typical Exam Question
What is the significance of the reduced flow in fluids to the body's extremities?

Answer
Fluids are warm;
Vasoconstriction will reduce heat loss;

Mental reaction
The main effects are;
1. decreased mental activity
2. decreased concentration and ability to make decisions. These are symptoms of mountain sickness which has often been blamed for the deaths of mountaineers who become unable to think clearly and make logical decisions. These symptoms disappear when the individual returns to low altitude.

Visitors and natives
Many textbooks describe visitors to high altitudes becoming *acclimatised* whilst natives of high altitudes are said to be *adapted* (Table 1)

Table 1. Native and visitor

Visitors	Natives
Gradually becomes used to lower oxygen partial pressures with increase in vital capacity	Adapted to low oxygen partial pressures
Hyperventilate	Hyperventilate (but for less time)
No increase in alveolar surface area	Raised alveolar surface area and blood volume
Increased Heart Rate and Cardiac Output(CO) for a few days but then stroke volume decreases so CO returns to normal	Increased Heart Rate
Increased haemoglobin concentration and increased number of red cells – as a result of greater secretion of erythropoietin from kidney – and increased blood volume	Increased haemoglobin concentration and number of red cells and these remain higher than the in the visitor
Oxygen dissociation curve shifts to right	Oxygen dissociation curve remains to the right of the visitor
Increased chance of oedema and mental difficulties	
Increased chance of dehydration	

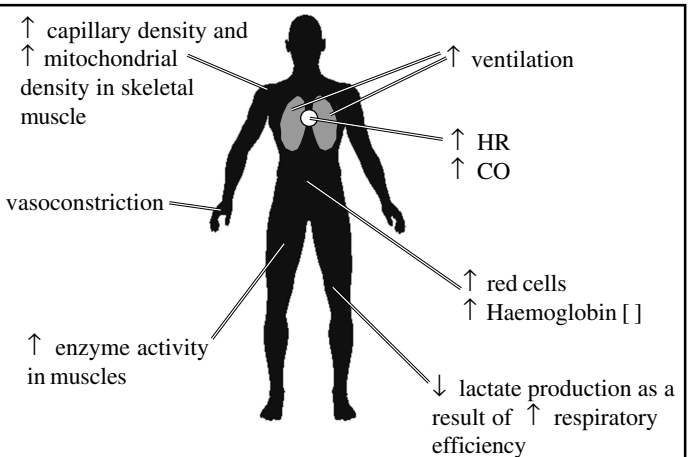
Typical Exam Question
What is the significance of the oxygen dissociation curve of a highlander being to the right of a lowlander's oxygen dissociation curve?

Answer
It makes the release of oxygen to the tissues more efficient. At any pp O_2 the percentage saturation of a highlander's haemoglobin is ***less than*** *that of a lowlanders – in other words, the oxygen isn't in the haemoglobin anymore, it's been released to the tissues, where it is needed.*

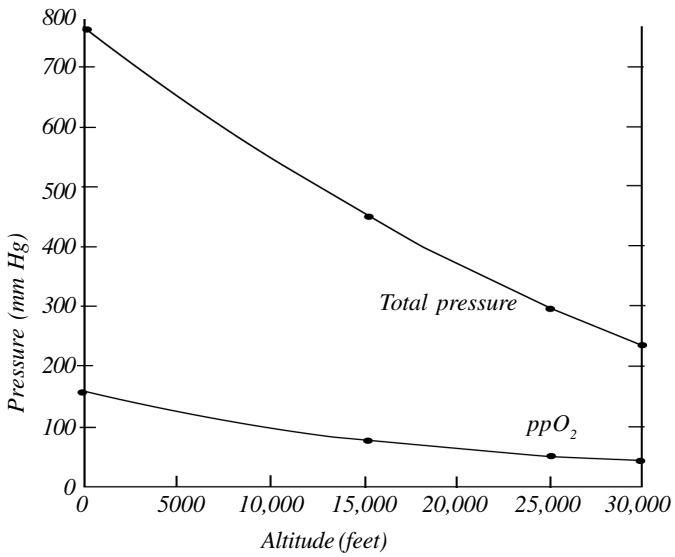
There is however evidence to suggest that there is no genetic basis to these adaptations. When highlanders return to lower altitudes, they lose many of these features including hyperventilation, high haemoglobin concentrations and high cardiac output. Thus, it may be better to consider visitors and natives as merely being acclimatised to different degrees.

Fig 5 summarises the most important physiological responses to high altitude. Make sure that you understand the significance of each of the responses. Hint: think oxygen and temperature

Fig 5 Important physiological responses



Typical Exam Question
The graph shows the effect of altitude on the total pressure and the partial pressure of oxygen.



(a) (i) Describe the trends shown [1]
(ii) Describe the physiological effects of this trend [2]

Answer
(a) (i) Both total pressure and partial pressure O_2 fall with altitude
(ii) Increasingly difficult to obtain O_2; hyperventilation;

Acknowledgements:
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