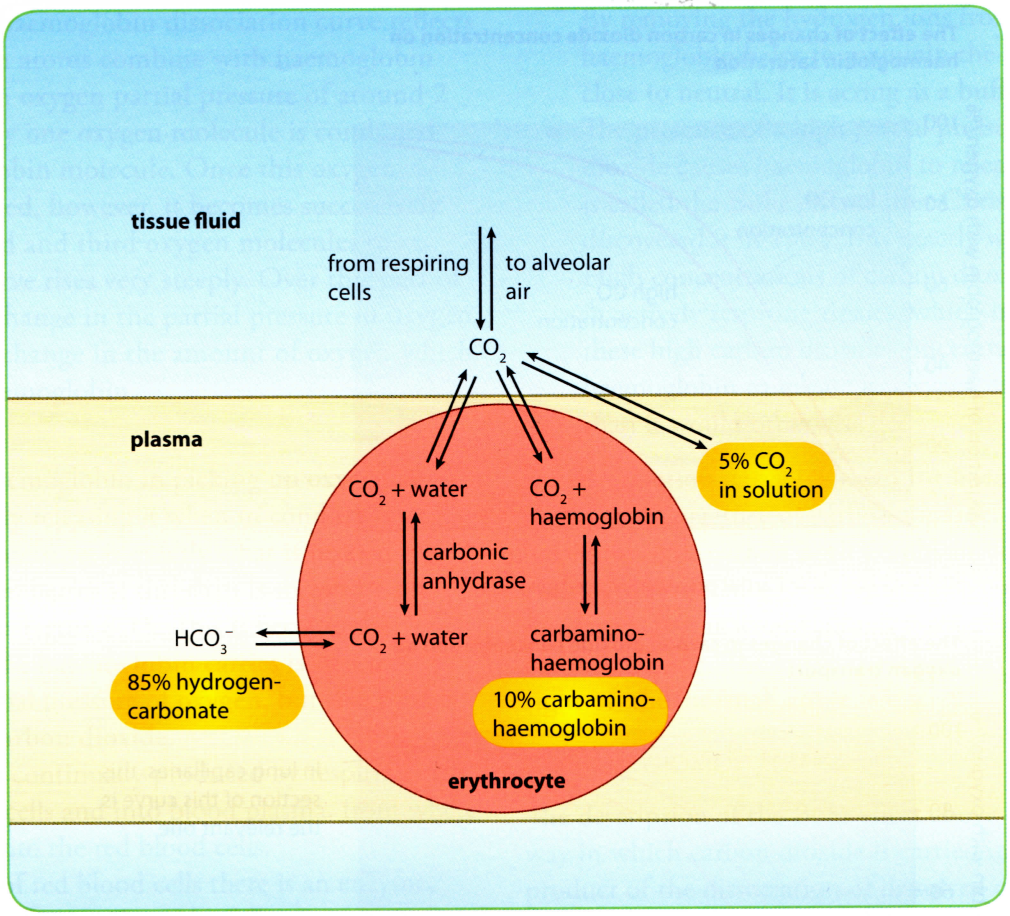


Figure 8.17 Carbon dioxide transport in the blood. The blood carries carbon dioxide partly as undissociated carbon dioxide in solution in the plasma, partly as hydrogencarbonate ions in solution in the plasma, and partly combined with haemoglobin in the red blood cells.

Carbon monoxide, CO, is formed when a carbon-containing compound burns incompletely. Exhaust fumes from cars contain significant amounts of carbon monoxide, as does cigarette smoke. When such fumes are inhaled, the carbon monoxide readily diffuses across the walls of the alveoli, into blood, and into red blood cells. Here it combines with the haem groups in the haemoglobin molecules, forming **carboxyhaemoglobin**.

Haemoglobin combines with carbon monoxide 250 times more readily than it does with oxygen. Thus, even if the concentration of carbon monoxide in air is much lower than the concentration of oxygen, a high proportion of haemoglobin will combine with carbon monoxide. Moreover, carboxyhaemoglobin is a very stable compound; the carbon monoxide remains combined with the haemoglobin for a long time.

The result of this is that even relatively low concentrations of carbon monoxide, as low as 0.1% of the air, can cause death by asphyxiation. Treatment of carbon monoxide poisoning involves administration of a mixture of pure oxygen and carbon dioxide: high concentrations of oxygen to favour the combination of haemoglobin with oxygen rather than carbon monoxide, and carbon dioxide to stimulate an increase in the breathing rate.

Cigarette smoke contains up to 5% carbon monoxide (see pages 157–158). If you breathed in 'pure' cigarette smoke for any length of time, you would die of asphyxiation. As it is, even smokers who inhale also breathe in some normal air, diluting the carbon monoxide levels in their lungs. Nevertheless, around 5% of the haemoglobin in a regular smoker's blood is permanently combined with carbon monoxide. This considerably reduces its oxygen-carrying capacity.

High altitude

We obtain our oxygen from the air around us. At sea level, the partial pressure of oxygen in the atmosphere is just over 20 kPa, and the partial pressure of oxygen in an alveolus in the lungs is about 13 kPa. If you look at the oxygen dissociation curve for haemoglobin in Figure **8.15** (page 155), you can see that at this partial pressure of oxygen, haemoglobin is almost completely saturated with oxygen.

If, however, a person climbs up a mountain to a height of 6500 metres, then the air pressure is much less (Figure **8.18**). The partial pressure of oxygen in the air is only about 10 kPa, and in the lungs about 5.3 kPa. You can see from Figure **8.15** that this will mean that the haemoglobin will become only about 70% saturated in the lungs. Less oxygen will be carried around the body, and the person may begin to feel breathless and ill.

SAQ 8.12

Mount Everest is nearly 9000 m high. The partial pressure of oxygen in the alveoli at this height is only about 2.5 kPa. Explain what effect this would have on the supply of oxygen to body cells if a person climbed to the top of Mount Everest without a supplementary oxygen supply.

If someone travels quickly, over a period of just a few days, from sea level to a very high altitude, the body does not have enough time to adjust to this drop in oxygen availability, and the person may suffer from **altitude sickness**.

The symptoms of altitude sickness frequently begin with an increase in the rate and depth of breathing, and a general feeling of dizziness and weakness. These symptoms can be easily reversed by going down to a lower altitude.

Some people, however, can quickly become very ill indeed. The arterioles in their brain dilate, increasing the amount of blood flowing into the capillaries, so that fluid begins to leak from the capillaries into the brain tissues. This can cause disorientation. Fluid may also leak into the lungs, preventing them from functioning properly. Acute altitude sickness can be fatal, and a person suffering from it must be brought down to low altitude immediately, or given oxygen.

However, if the body is given plenty of time to adapt, then most people can cope well at altitudes up to at least 5000 metres. In 1979, two mountaineers climbed Mount Everest without oxygen, returning safely despite experiencing hallucinations and feelings of euphoria at the summit.

As the body gradually acclimatises to high altitude, a number of changes take place. Perhaps the most significant of these is that the number of red blood cells increases. Whereas red blood cells normally make up about 40–50% of the blood, after a few months at high altitude this rises to as much as 50–70%. However, this does take a long time to happen, and there is almost no change in the number of red blood cells for at least two or three weeks at high altitude.

SAQ 8.13

Explain how an increase in the number of red blood cells can help to compensate for the lack of oxygen in the air at high altitude.

SAQ 8.14

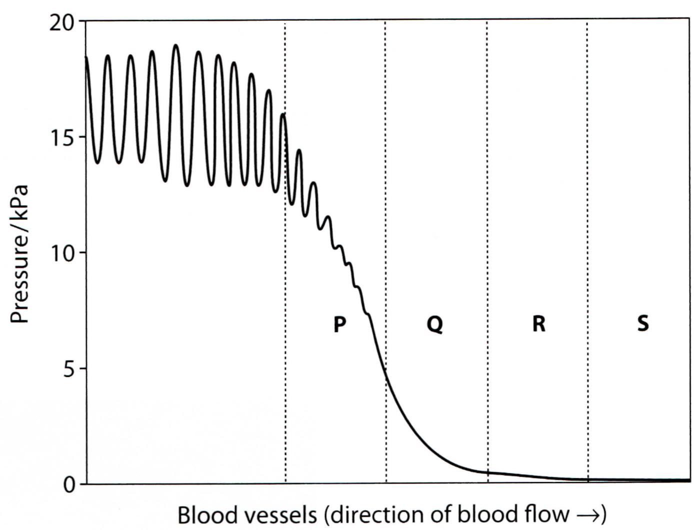
Athletes often prepare themselves for important competitions by spending several months training at high altitude. Explain how this could improve their performance.

Figure 8.18 A climber rests on the summit of Mount Everest. He is breathing oxygen through a mask.

People who live permanently at high altitude, such as in the Andes or Himalayas, show a number of adaptations to their low-oxygen environment. It seems that they are not genetically different from people who live at low altitudes, but rather that their exposure to low oxygen partial pressures from birth encourages the development of these adaptations from an early age. They often have especially broad chests, providing larger lung capacities than normal. The heart is often larger than in a person who lives at low altitude, especially the right side, which pumps blood to the lungs. They also have more haemoglobin in their blood than usual, so increasing the efficiency of oxygen transport from lungs to tissues.

End-of-chapter questions

1 The diagram shows the changes in blood pressure as blood flows through the blood vessels in the human systemic circulatory system.



Which correctly identifies the vessels labelled **P** to **S**?

	P	Q	R	S
A	artery	capillary	arteriole	venule
B	arteriole	artery	venule	capillary
C	artery	arteriole	capillary	venule
D	venule	capillary	arteriole	artery