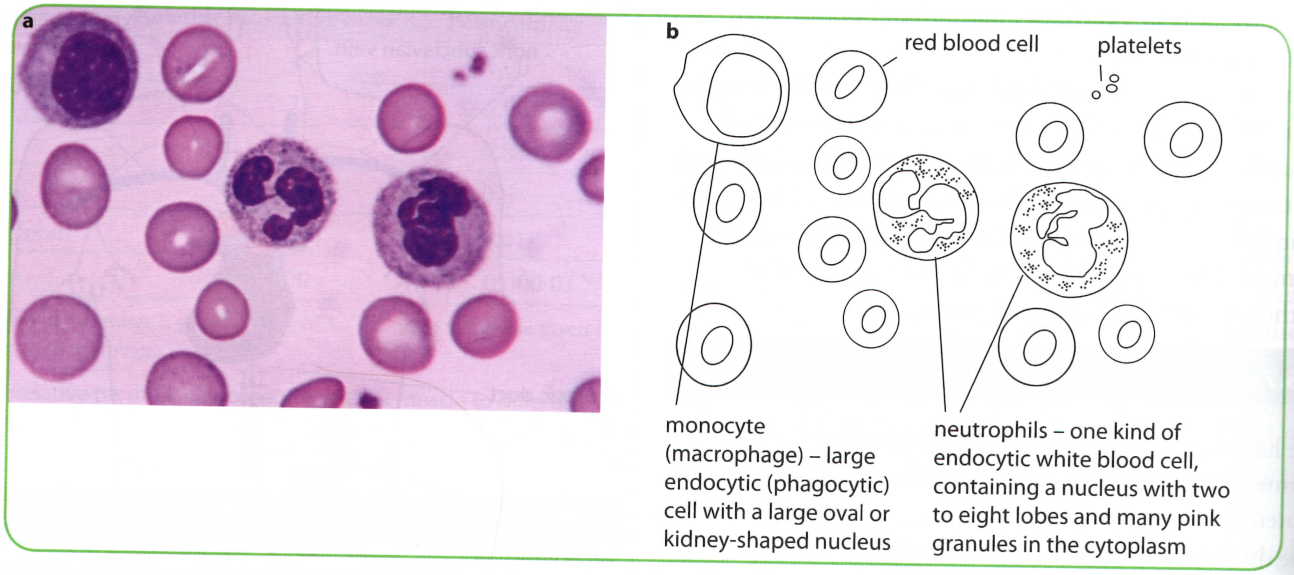

Figure 8.11 **a** Photomicrograph of human blood. It has been stained so that the nuclei of the cells are dark purple (× 1500). **b** Diagram some of the cells shown in the micrograph.

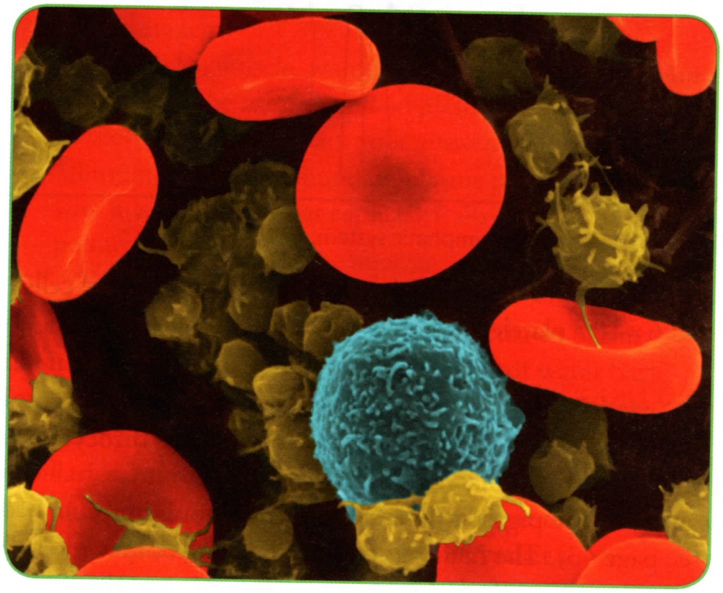

Figure 8.12 False-colour SEM of human blood. Red blood cells are coloured red. The blue sphere is a white blood cell. Platelets are coloured yellow (× 4000).

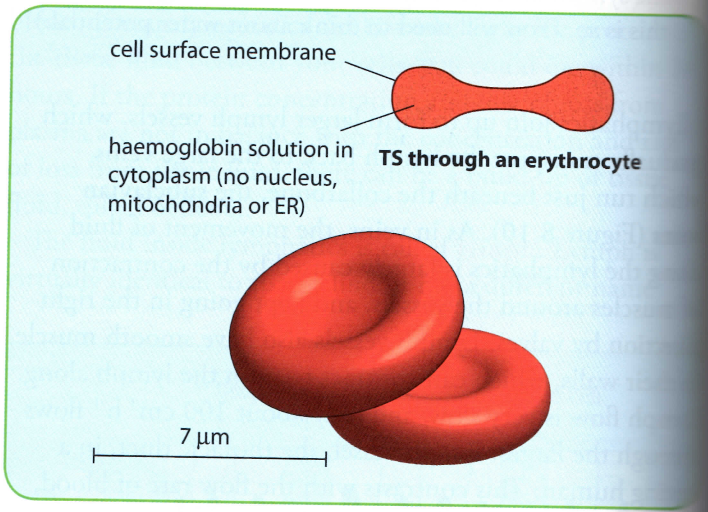

Figure 8.13 Red blood cells.

and eventually rupture within some 'tight spot' in the circulatory system, often inside the spleen.

The structure of a red blood cell is unusual in several ways.

- **Red blood cells are shaped like a biconcave disc.** The dent in each side of a red blood cell increases the amount of surface area in relation to the volume of the cell, giving it a large surface area to volume ratio. This large surface area means that oxygen can diffuse quickly into or out of the cell.

SAQ 8.8

Assuming that you have 2.5×10^{13} red blood cells in your body, that the average life of a red blood cell is 120 days, and that the total number of red blood cells remains constant, calculate how many new red blood cells must be made, on average, in your bone marrow each day.

- **Red blood cells are very small.** The diameter of a human red blood cell is about 7 μm, compared with the diameter of an average liver cell of 40 μm. This small size means that no haemoglobin molecule within the cell is very far from the cell surface membrane, and the haemoglobin molecule can therefore quickly exchange oxygen with the fluid outside the cell. It also means that capillaries can be only 7 μm wide and still allow red blood cells to squeeze through them, so bringing oxygen as close as possible to cells which require it.
- **Red blood cells are very flexible.** Some capillaries are even narrower than the diameter of a red blood cell. The cells are able to deform so that they can pass through these vessels. This is possible because they have a specialised cytoskeleton (page 73), made up of a mesh-like network of protein fibres that allows them to be squashed into different shapes, but then springs back to produce the normal biconcave shape.

- **Red blood cells have no nucleus, no mitochondria and no endoplasmic reticulum.** The lack of these organelles means that there is more room for haemoglobin, so maximising the amount of oxygen which can be carried by each red blood cell.

SAQ 8.9

Which of these functions could, or could not, be carried out by a red blood cell? In each case, briefly justify your answer.

a protein synthesis

b cell division

c lipid synthesis

d active transport

White blood cells

White blood cells are sometimes known as **leucocytes**, which just means 'white cells'. They, too, are made in the bone marrow, but are easy to distinguish from red blood cells in a blood sample because:

- white blood cells all have a nucleus, although the shape of this varies in different types of white cell
- most white blood cells are larger than red blood cells, although one type, lymphocytes, may be slightly smaller
- white blood cells are either spherical or irregular in shape, never looking like a biconcave disc (Figures **8.12** and **8.14**).

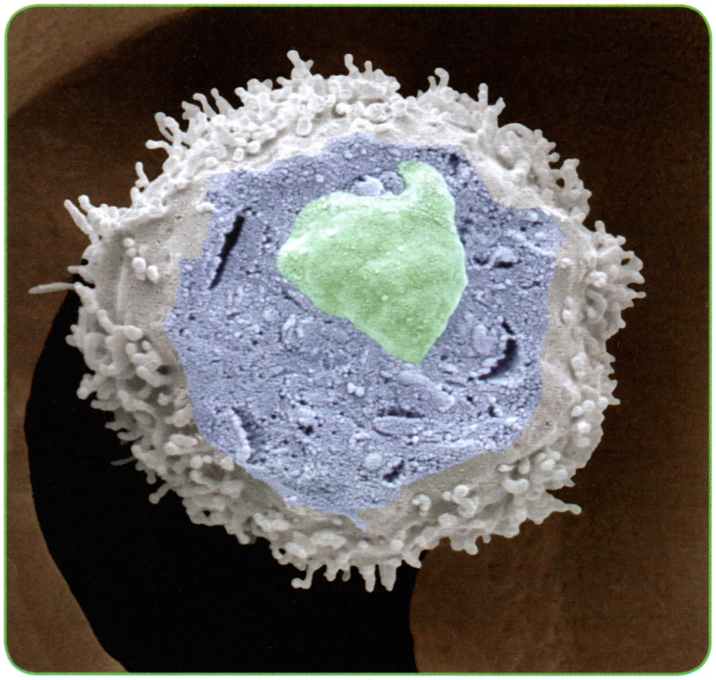

Figure 8.14 False-colour SEM of a section through a white blood cell (×6000). This is a lymphocyte.

There are many different kinds of white blood cell, with a wide variety of functions, although all are concerned with fighting disease. They can be divided into two main groups.

Phagocytes are cells that destroy invading microorganisms by phagocytosis (see page **80**). The commonest type of phagocytes can be recognised by their lobed nuclei and granular cytoplasm. The three white blood cells in Figure **8.11** are phagocytes.

Lymphocytes also destroy microorganisms, but not by phagocytosis. Some of them secrete chemicals called **antibodies**, which attach to and destroy the invading cells. There are different types of lymphocytes, which act in different ways, though they all look the same. Their activities are described in Chapter **13**. Lymphocytes are smaller than most phagocytes, and they have a large round nucleus and only a small amount of cytoplasm.

Haemoglobin

A major role of the cardiovascular system is to transport oxygen from the gas exchange surfaces of the alveoli in the lungs (see page **175**) to tissues all over the body. Body cells need a constant supply of oxygen in order to be able to carry out aerobic respiration. Oxygen is transported around the body inside red blood cells in combination with the protein **haemoglobin** (Figure **2.22**, page **44**).

As we saw in Chapter **2**, each haemoglobin molecule is made up of four polypeptides, each containing one haem group. Each haem group can combine with one oxygen molecule, O_2. Overall, then, each haemoglobin molecule can combine with four oxygen molecules (eight oxygen atoms).

$$\underset{\text{haemoglobin}}{\mathrm{Hb}} \quad + \quad \underset{\text{oxygen}}{4\mathrm{O_2}} \quad \rightleftharpoons \quad \underset{\text{oxyhaemoglobin}}{\mathrm{HbO_8}}$$

SAQ 8.10

In a healthy adult human, the amount of haemoglobin in 1 dm^3 of blood is about 150 g.

a Given that 1 g of pure haemoglobin can combine with 1.3 cm^3 of oxygen at body temperature, how much oxygen can be carried in 1 dm^3 of blood?

b At body temperature, the solubility of oxygen in water is approximately 0.025 cm^3 of oxygen per cm^3 of water. Assuming that blood plasma is mostly water, how much oxygen could be carried in 1 dm^3 of blood if there was no haemoglobin?

The haemoglobin dissociation curve

A molecule whose function is to transport oxygen from one part of the body to another must be able not only to **pick up** oxygen at the lungs, but also to **release** oxygen within respiring tissues. Haemoglobin performs this task superbly.

To investigate how haemoglobin behaves, samples are extracted from blood and exposed to different concentrations, or **partial pressures**, of oxygen. The amount of oxygen which combines with each sample of haemoglobin is then measured. The maximum amount of oxygen with which a sample can possibly combine is given a value of 100%. A sample of haemoglobin which has combined with this maximum amount of oxygen is said to be **saturated**. The amounts of oxygen with which identical samples of haemoglobin combine at lower oxygen partial pressures are then expressed as a percentage of this maximum value. Table **8.2** shows a series of results from such an investigation.

The percentage saturation of each sample can be plotted against the partial pressure of oxygen to obtain the curve shown in Figure **8.15**. This is known as a **dissociation curve**.

The curve shows that at low partial pressures of oxygen, the percentage saturation of haemoglobin is very low – that is, the haemoglobin is combined with only a very little oxygen. At high partial pressures of oxygen, the percentage saturation of haemoglobin is very high; it is combined with large amounts of oxygen.

Consider the haemoglobin within a red blood cell in a capillary in the lungs. Here, where the partial pressure of oxygen is high, this haemoglobin will be 95–97% saturated with oxygen – that is, almost every haemoglobin molecule will be combined with its full complement of eight oxygen atoms. In an actively respiring muscle, on the other hand, where the partial pressure of oxygen is low, the haemoglobin will be about 20–25% saturated with oxygen – that is, the haemoglobin is carrying only a quarter of the oxygen which it is capable of carrying. This means that

Partial pressure of oxygen / kPa	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Percentage saturation of haemoglobin	8.5	24.0	43.0	57.5	71.5	80.0	85.5	88.0	92.0	94.0	95.5	96.5	97.5	98.0

Table 8.2 The varying ability of haemoglobin to carry oxygen.