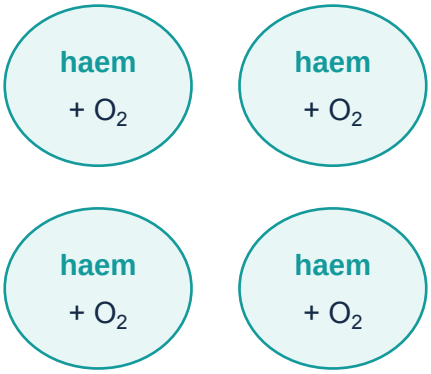
Carry oxygen reversibly

Red blood cells are erythrocytes. Haemoglobin inside them greatly increases the oxygen-carrying capacity of blood compared with oxygen dissolved in plasma alone.

1. HAEMOGLOBIN HAS FOUR OXYGEN-BINDING SITES



One fully loaded Hb molecule

Four globin subunits

Each subunit contains one haem group with iron that binds one oxygen molecule. A fully saturated haemoglobin molecule carries four O_2 molecules, not four oxygen atoms.

Circles represent subunits, not red cells. This is a binding-site schematic, not the protein's actual shape.

2. LOAD IN LUNGS; UNLOAD IN RESPIRING TISSUES

At the high oxygen partial pressure in lung capillaries, haemoglobin binds oxygen to form oxyhaemoglobin. At lower oxygen partial pressure in respiring tissues, it releases oxygen. Oxygen diffuses towards cells that use it in aerobic respiration.

$$\text{haemoglobin} + \text{oxygen} \rightleftharpoons \text{oxyhaemoglobin}$$

Reversible binding: the oxygen is carried, not used up by haemoglobin.

Structure supports function: the biconcave shape gives a large surface area relative to volume and a short diffusion distance. Mature mammalian red cells lack a nucleus, leaving room for haemoglobin; their flexibility lets them pass through narrow capillaries.

Oxygen binding: OpenStax Anatomy & Physiology 2e, section 22.5.
Red-cell adaptations: OpenStax, section 18.3.

Scope: Cambridge Biology 9700 syllabus, section 8.2, outcome 1, p. 28.

Convert carbon dioxide; buffer pH

Carbon dioxide from respiring tissues diffuses into the blood and then into red blood cells. Inside these cells, a fast reversible reaction makes transport as hydrogencarbonate possible.

1. FOLLOW THE REACTION INSIDE A RED BLOOD CELL

carbonic anhydrase

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

carbon dioxide + water — carbonic acid

dissociation

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

carbonic acid — hydrogen + hydrogencarbonate ions

The enzyme catalyses the first reaction in both directions; it is not a reactant. The second reaction releases a hydrogen ion and a hydrogencarbonate ion. All subscripts and ionic charges matter.

2. HAEMOGLOBIN BINDS HYDROGEN IONS

Free hydrogen ions would lower pH. Haemoglobin accepts many of these ions, forming haemoglobinic acid. This buffering reduces the change in pH; it does not mean that blood pH cannot change.

$$Hb^- + H^+ \rightleftharpoons HHb$$

Simplified acid-base notation: HHb represents haemoglobinic acid.

Keep the roles separate: carbonic anhydrase speeds up the reaction; haemoglobin buffers hydrogen ions. Hydrogencarbonate (bicarbonate) is HCO_3^-, not carbonic acid (H_2CO_3).

Carbon dioxide conversion and buffering: Doyle & Cooper, NCBI Bookshelf.
Reversible gas transport: Pittman, Regulation of Tissue Oxygenation, chapter 4.

Scope: Cambridge Biology 9700 syllabus, section 8.2, outcome 1, p. 28.

Three names, three different roles

Haemoglobin helps with both gases, but oxygen, carbon dioxide and hydrogen ions do not all bind in the same way. Name the substance attached before naming the haemoglobin form.

1. MATCH THE FORM TO WHAT IS BOUND

Oxyhaemoglobin O_2 at haem groups	Carries oxygen
Haemoglobinic acid H^+ accepted by haemoglobin	Buffers hydrogen ions
Carbaminohaemoglobin CO_2 on the globin protein	Carries some carbon dioxide

2. DIRECT CARBON DIOXIDE BINDING

Some carbon dioxide binds to amino groups on the globin part of haemoglobin, forming carbaminohaemoglobin. It does not bind to the iron site used by oxygen. This is distinct from carboxyhaemoglobin, which forms with carbon monoxide (CO), not carbon dioxide (CO_2).

3. RELEASE CARBON DIOXIDE IN THE LUNGS

Most carbon dioxide is transported as hydrogencarbonate, much of it in plasma after formation in red cells. In lung capillaries it returns to red cells and the reactions reverse, regenerating CO_2. Carbon dioxide also dissociates from carbaminohaemoglobin and diffuses into alveoli to be exhaled.

Whole-blood overview: carbon dioxide travels mainly as hydrogencarbonate, with smaller amounts bound to haemoglobin or dissolved as CO_2. Haemoglobinic acid carries hydrogen ions, not a bound CO_2 molecule. The membrane exchange called the chloride shift follows in Lesson 8.2.2.

Binding sites and transport forms: Pittman, Regulation of Tissue Oxygenation, chapter 4.
Lung reversal and CO_2 removal: Doyle & Cooper, NCBI Bookshelf.

Scope: Cambridge Biology 9700 syllabus, section 8.2, outcome 1, p. 28.