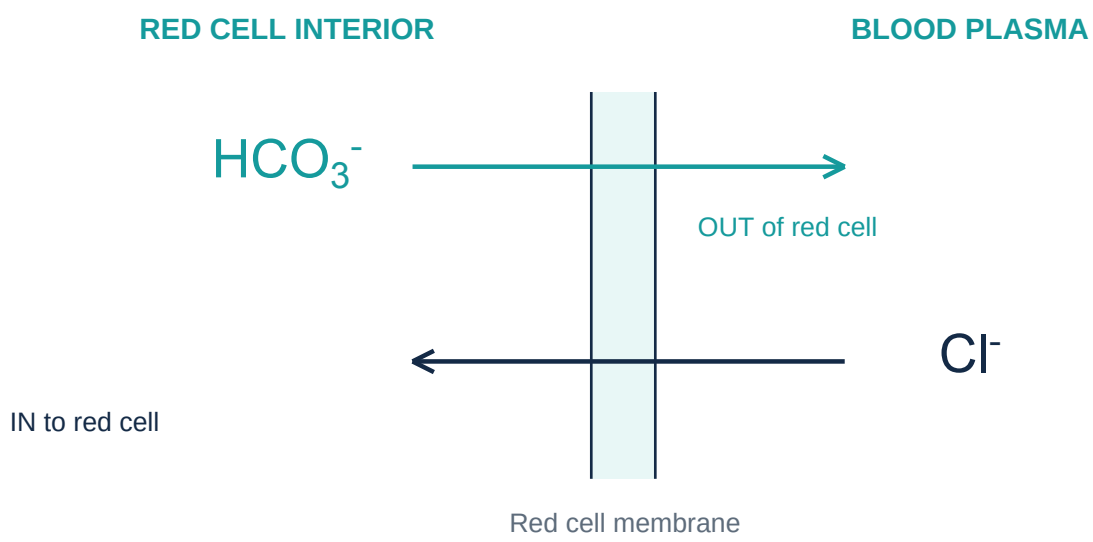
At tissues: chloride enters

The chloride shift links carbon dioxide processing inside red blood cells with transport in the surrounding plasma. Always state the direction relative to the red cell.

1. ION MOVEMENT AT RESPIRING TISSUES



A membrane exchange protein couples these opposite movements. Diagram shows net directions, not a pore through which ions freely mix.

2. MAKE HYDROGENCARBONATE INSIDE THE CELL

Carbon dioxide from tissues enters red cells. Carbonic anhydrase catalyses its reaction with water to form carbonic acid, which dissociates into hydrogen and hydrogencarbonate ions. Haemoglobin buffers many of the hydrogen ions.

3. EXPORT ONE ANION; IMPORT ANOTHER

Hydrogencarbonate ions move out into plasma while chloride ions move into the red cell. Both ions carry one negative charge. This exchange maintains electrical balance while allowing carbon dioxide to be carried away mainly in hydrogencarbonate form.

Tissues: HCO_3^- out, Cl^- in.

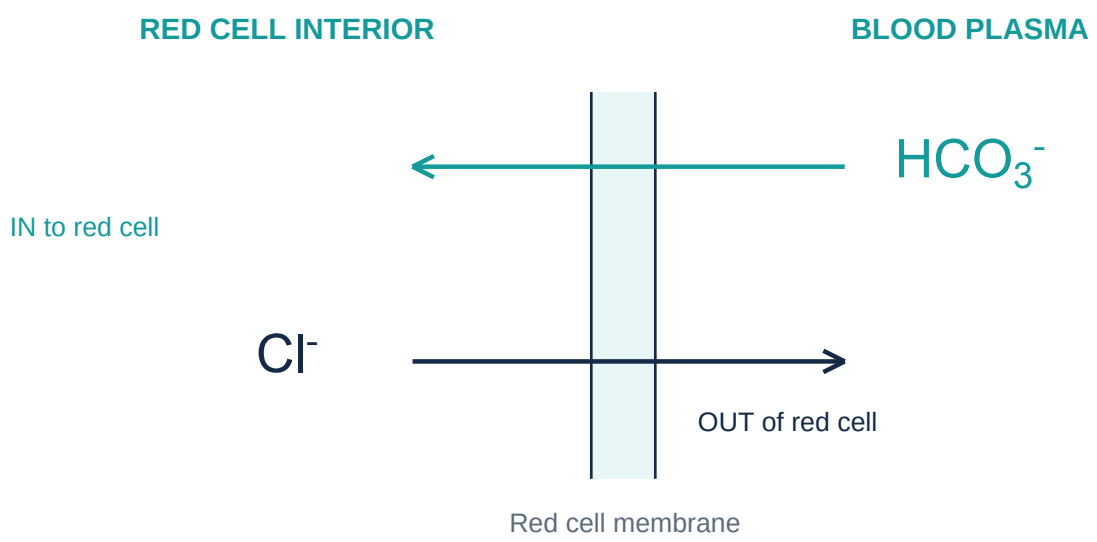
Carbon dioxide conversion and export: OpenStax Biology 2e, section 39.4.
Electroneutral exchange: NCBI MeSH, Anion Exchange Protein 1, Erythrocyte.

Scope: Cambridge Biology 9700 syllabus, section 8.2, outcome 2, p. 28.

At lungs: reverse the exchange

Blood arriving at the lungs must regenerate carbon dioxide so it can diffuse into the alveoli and be exhaled. The net chloride shift reverses here.

1. ION MOVEMENT AT THE LUNGS



A membrane exchange protein couples these opposite movements. Diagram shows net directions, not a pore through which ions freely mix.

2. REGENERATE CARBON DIOXIDE INSIDE THE RED CELL

$$H^+ + HCO_3^- \rightleftharpoons H_2CO_3 \rightleftharpoons CO_2 + H_2O$$

3. FROM HYDROGENCARBONATE TO EXHALED GAS

Hydrogencarbonate returning from plasma combines with hydrogen ions released by haemoglobin. Carbonic anhydrase catalyses conversion of carbonic acid to carbon dioxide and water. CO_2 diffuses from blood into alveoli; ventilation removes it.

In the displayed reaction, net conversion at the lungs is towards the right. The enzyme catalyses the carbonic acid / carbon dioxide step, not the membrane exchange of ions.

Reverse chloride shift and lung reactions: OpenStax Anatomy & Physiology 2e, 22.5.
Gas release: OpenStax Biology 2e, section 39.4.

Scope: Cambridge Biology 9700 syllabus, section 8.2, outcome 2, p. 28.

Why the chloride shift matters

Two processes work together: chemical reactions change the form of carbon dioxide, while membrane transport exchanges hydrogencarbonate for chloride.

1. A ONE-FOR-ONE EXCHANGE OF NEGATIVE IONS

HCO_3^-

One negative charge leaves

Cl^-

One negative charge enters

AT TISSUES

The coupled exchange transfers no net electrical charge across the membrane. It avoids charge separation that would oppose continued hydrogencarbonate export. Chloride does not chemically neutralise or become hydrogencarbonate.

2. SUPPORT EFFICIENT CARBON DIOXIDE TRANSPORT

Export limits accumulation of hydrogencarbonate in the red cell and makes plasma available to carry it. Together with carbonic anhydrase and haemoglobin buffering, this supports continued uptake of tissue CO_2. At the lungs, exchange supplies hydrogencarbonate for CO_2 release.

3. DISTINGUISH TRANSPORTER FROM ENZYME

Supporting detail: the exchanger is AE1, also called band 3. It exchanges one chloride ion for one hydrogencarbonate ion; it is not an ATP-driven pump. Carbonic anhydrase is a different protein, catalysing a chemical reaction inside the cell.

Do not reverse just one arrow: at tissues, hydrogencarbonate leaves and chloride enters; at lungs, hydrogencarbonate enters and chloride leaves. Haemoglobin buffers H^+, whereas chloride exchange preserves electrical balance. These are related but different roles.

Anion exchange and transport capacity: AE1 exchange-kinetics study (2013).
Exchanger identity and role: NCBI MeSH, Anion Exchange Protein 1, Erythrocyte.

Scope: Cambridge Biology 9700 syllabus, section 8.2, outcome 2, p. 28.