

Exercise walk-through

8.2

Transport of oxygen and carbon dioxide

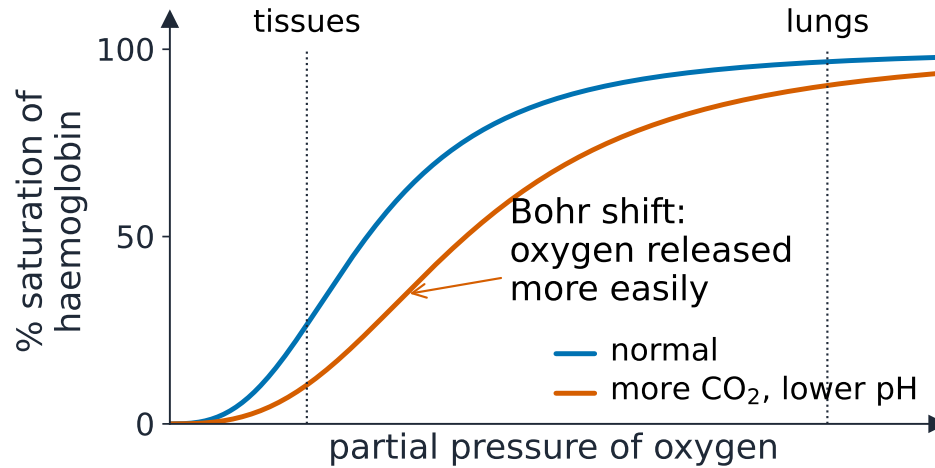
A-Level Biology

Oxygen transport and the Bohr shift

Haemoglobin loads oxygen in the lungs (high **partial pressure**) and unloads it in the tissues.

The **Bohr shift** : more CO_2 (lower pH) moves the curve **right**, so oxygen is released where it is most needed.

Oxygen transport and the Bohr shift, in detail



Bohr shift (right): $\uparrow \text{CO}_2 / \downarrow \text{pH} \rightarrow$ lower O_2 affinity $\rightarrow$ unload at tissues

Haemoglobin loads oxygen in the lungs and unloads it in the tissues; the Bohr shift moves the curve right so more is released

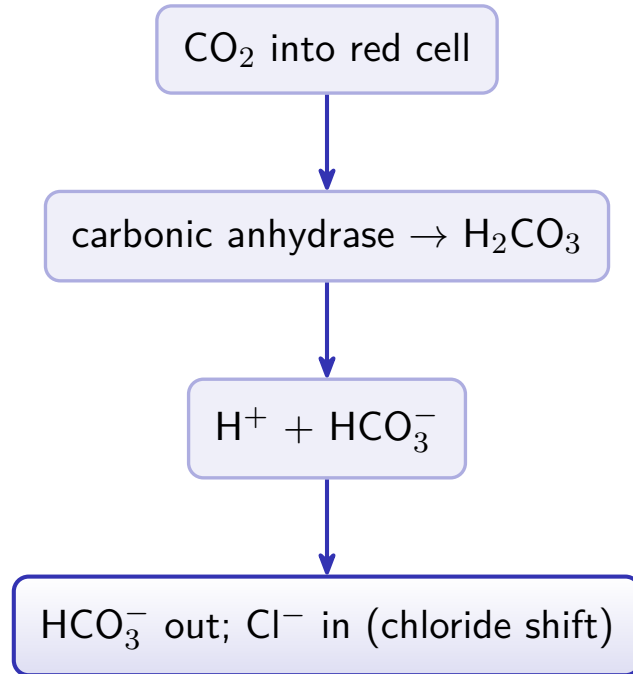
Carbon dioxide transport

Most CO_2 travels as
hydrogencarbonate
ions :

- **carbonic anhydrase** speeds $\text{CO}_2 + \text{water}$
- the **chloride shift** keeps charge balanced
- haemoglobin mops up the H^+

Carbon dioxide transport, continued

Most CO_2 travels as **hydrogencarbonate** ions in the plasma.



Exercises 2.1-2.2

2.1 State where on the dissociation curve haemoglobin (a) loads oxygen and (b) unloads oxygen. [2]

2.2 Name the enzyme that catalyses the reaction of carbon dioxide with water. [1]

Exercises 2.1·2.2

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2.1

(a)

- at high partial pressure of oxygen (in the lungs)

(b)

- at low partial pressure of oxygen (in respiring tissues)

2.2 Name the enzyme that catalyses the reaction of carbon dioxide with water. [1]

2.2

- carbonic anhydrase

Exercises 3.1-3.2

3.1 In which form is **most** carbon dioxide carried in the blood?

[1]

☐

A dissolved in plasma

B as hydrogencarbonate ions

C as carbaminohaemoglobin

D as carbonic anhydrase

3.2 The Bohr shift moves the oxygen dissociation curve to the right. This means that, at a given partial pressure of oxygen, haemoglobin:

[1]

☐

A is more saturated with oxygen

B releases oxygen more readily

C carries more carbon dioxide directly

D has a higher affinity for oxygen

Exercises 3.1-3.2

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[1]

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- A dissolved in plasma
- B as hydrogencarbonate ions
- C as carbaminohaemoglobin
- D as carbonic anhydrase

3.1 B

- Most CO_2 is carried as hydrogencarbonate ions

3.2 The Bohr shift moves the oxygen dissociation curve to the right. This means that, at a given partial pressure of oxygen, haemoglobin:

[1]

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- A is more saturated with oxygen
- B releases oxygen more readily
- C carries more carbon dioxide directly
- D has a higher affinity for oxygen

3.2 B

- Shifting right means lower affinity, so haemoglobin releases oxygen more readily

Exercise 3.3 (a)

3.3 Use the dissociation curve idea: in the lungs haemoglobin is 98% saturated; in an exercising muscle it falls to 25%.

(a) Calculate the percentage of oxygen unloaded to the muscle.

[1]

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(a)

- $98 - 25 = 73\%$

Exercise 3.3 (b)

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(b) Explain how the Bohr shift increases the oxygen delivered to exercising muscle. [3]

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(b)

- exercising muscle releases more CO_2 , lowering pH; this shifts the curve right, so at the same pO_2 haemoglobin is less saturated and releases more oxygen; so more oxygen is delivered exactly where respiration is fastest

Exercise 3.4

3.4 Explain the importance of the chloride shift.

[2]

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[2]

3.4

- as HCO_3^- leaves the red cell, chloride ions move in to keep the charge balanced inside the cell

Exercise 3.5 (a)

3.5 The graph described below shows two oxygen dissociation curves for human haemoglobin: curve **P** at a carbon dioxide partial pressure of 5 kPa, and curve **Q** at 9 kPa, which lies to the right of **P**.

(a) Explain the shape of curve **P**, referring to the effect of binding the first oxygen molecule. [3]

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(a)

- The curve is **S-shaped** (sigmoid). At low partial pressures it is hard for the first oxygen to bind, so the curve rises slowly; binding it changes the shape of the haemoglobin so that the remaining sites are more accessible, and the next molecules bind much more readily – the steep middle section – until the molecule saturates and the curve levels off

Exercise 3.5 (b)

3.5 The graph described below shows two oxygen dissociation curves for human haemoglobin: curve **P** at a carbon dioxide partial pressure of 5 kPa, and curve **Q** at 9 kPa, which lies to the right of **P**.

(b) Name the shift from **P** to **Q**, and explain how carbon dioxide causes it. [3]

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(b)

- The **Bohr shift**. Dissolved carbon dioxide forms carbonic acid, which dissociates and lowers the pH; the extra hydrogen ions bind to haemoglobin and change its shape, lowering its affinity for oxygen, so at any given oxygen partial pressure less oxygen is held

Exercise 3.5 (c)

3.5 The graph described below shows two oxygen dissociation curves for human haemoglobin: curve **P** at a carbon dioxide partial pressure of 5 kPa, and curve **Q** at 9 kPa, which lies to the right of **P**.

(c) Explain the benefit of this shift to a person during vigorous exercise.

[3]

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(c) Explain the benefit of this shift to a person during vigorous exercise. [3]

(c)

- Exercising muscle respires faster and releases more carbon dioxide; the curve shifts right in exactly those tissues; so haemoglobin unloads more oxygen precisely where the demand is greatest, while the lungs – with low carbon dioxide – still load it fully

Exercise 3.5 (d)

3.5 The graph described below shows two oxygen dissociation curves for human haemoglobin: curve **P** at a carbon dioxide partial pressure of 5 kPa, and curve **Q** at 9 kPa, which lies to the right of **P**.

(d) Describe **two** ways, other than as carbamino-haemoglobin, in which carbon dioxide is carried in the blood, and give the equation for the main one. [3]

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(d)

- About 5% dissolves directly in the plasma; most, about 85%, is carried as **hydrogencarbonate ions** in the plasma; $\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$, catalysed inside the red cell by carbonic anhydrase