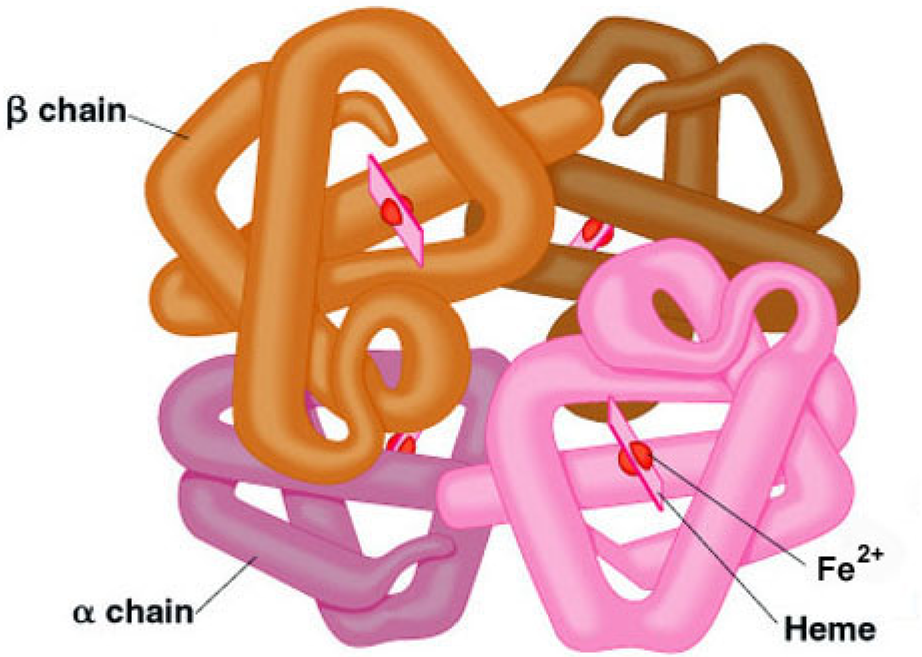
1. A QUICK RECAP ON HEMOGLOBIN

- A **protein** with a **quaternary structure, consisting** of **four polypeptides.**
- Found in **red blood cells**.
- **Each polypeptide** contains one **heme group**, containing **iron (Fe^{2+})**.
- **One O_2** can bind to each **heme group.**
- When a **hemoglobin molecule** contains the **maximum** amount of **oxygen**, it is **HbO_8** (called **oxyhemoglobin**).



2. OXYGEN DISSOCIATION CURVES

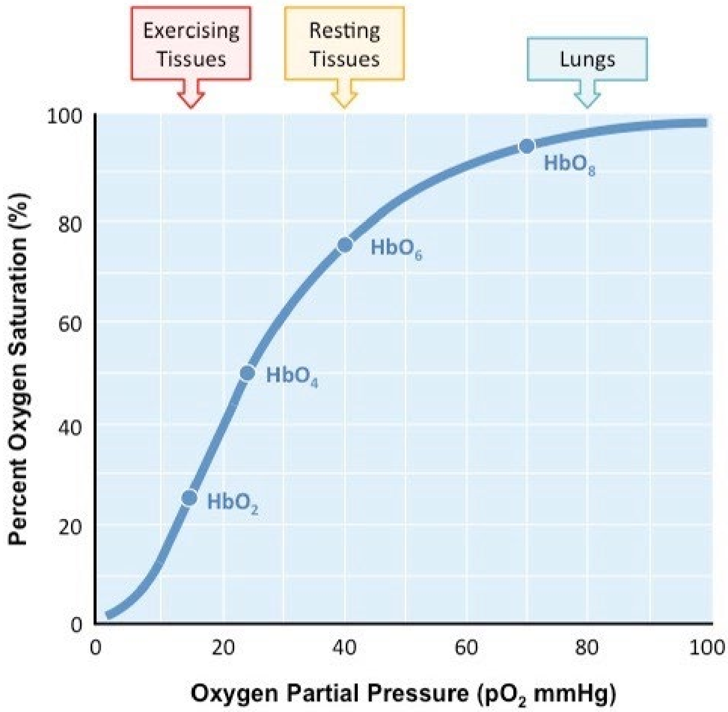
- The **percentage saturation** of haemoglobin is **100** if **all** the hemoglobin molecules in blood are carrying **four** oxygen molecules.

- The **percentage saturation** of haemoglobin is **0** if **all** the hemoglobin molecules in blood are **not carrying any** oxygen molecules.

- Percentage saturation depends on the **surrounding oxygen concentration**, which is usually measured as a **partial pressure**.

- **Partial pressure** is the pressure **exerted** by a **gas** in a **mixture** of gases. For these curves, "think" of **partial pressure** as meaning "**concentration**".

- **Affinity** is hemoglobin's **attractiveness** (willingness to bind) to **oxygen**.



- The **oxygen-dissociation** curve for **hemoglobin** is **S-shaped** (sigmoidal).

- It is **not linear** because **binding potential** changes with each **additional O_2** molecule.

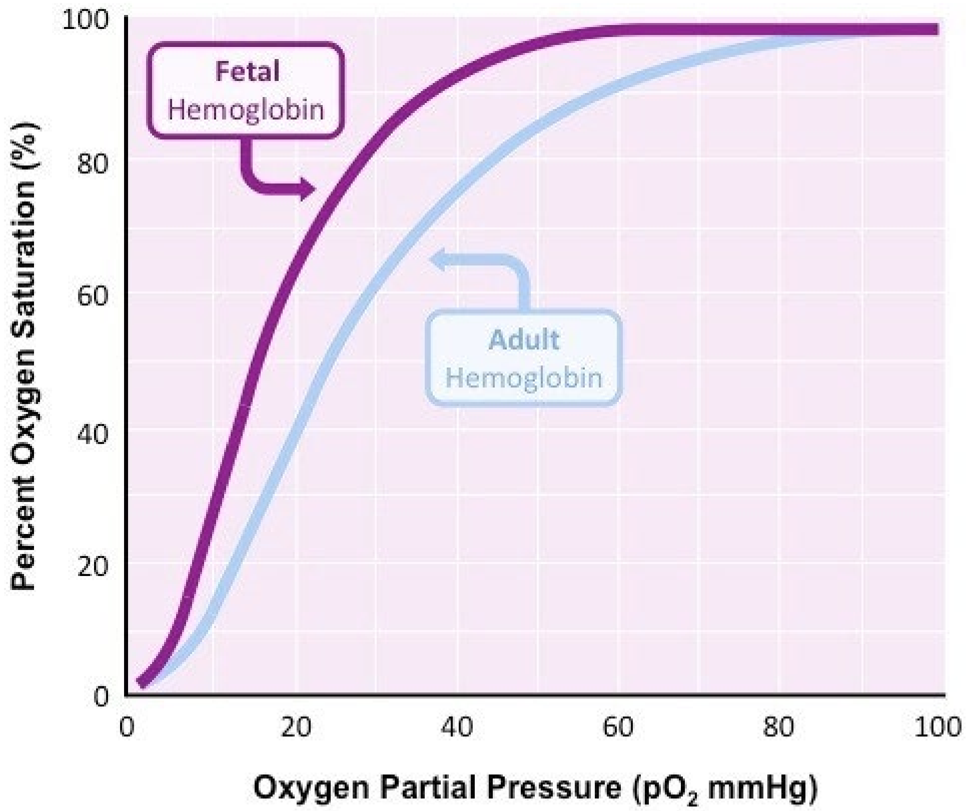
  - Binding of the **first O_2** causes a **shape change** that allows the **second** and **third molecules** to bind **easier**

  - It is **more difficult** for the **fourth O_2** to bind.

- At **respiring tissues**, where **pO_2** is **low**, hemoglobin has **lower affinity** for oxygen, so it **releases** oxygen **more readily**, for **faster respiration** = **more energy** released.

- At the **lungs**, where **pO_2** is **high**, hemoglobin has **higher affinity** for oxygen, so it **attaches** to oxygen **more readily**, rather than releases it.

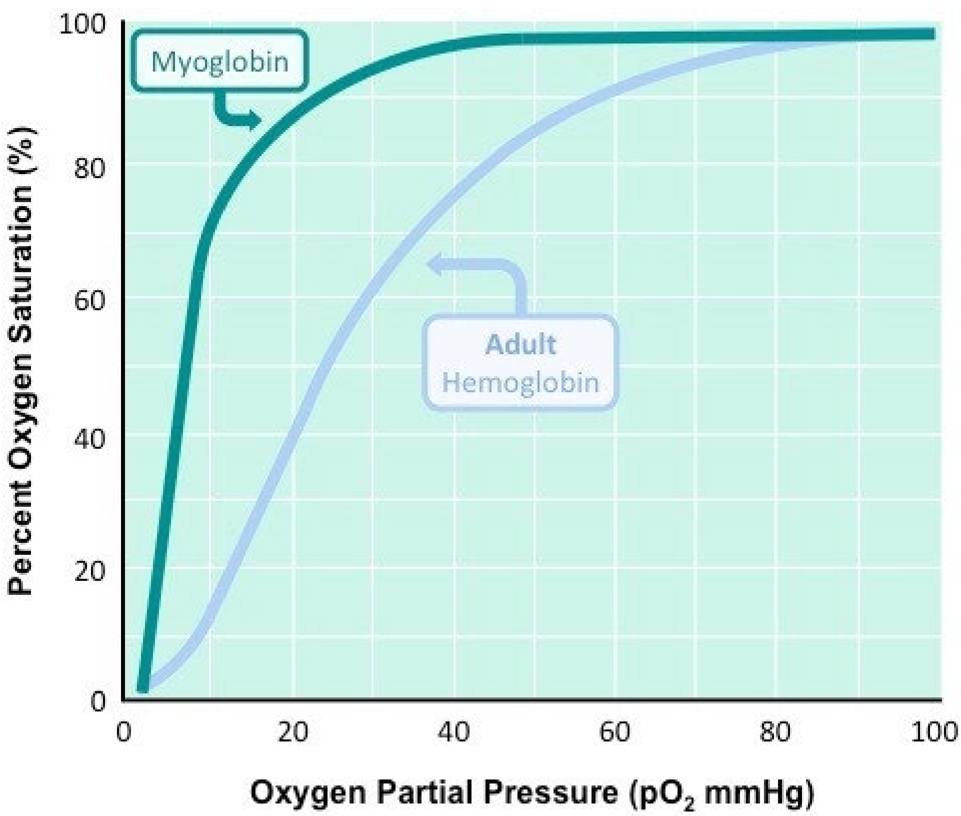
3. FETAL HEMOGLOBIN



- Oxyhemoglobin **forms** when the **pO_2 is high** and **dissociates** when **pO_2 is low**.
- Fetal hemoglobin has a slightly **different amino acid sequence** than adult hemoglobin.
- Fetal hemoglobin has a **higher affinity** for oxygen than adult haemoglobin (dissociation curve is shifted to the **left**)
- Fetal hemoglobin is **always more saturated** with **oxygen** than adult haemoglobin
- Fetal haemoglobin becomes **fully saturated** at a **lower pO_2**.
- Oxygen that **dissociates** from **adult** haemoglobin is therefore **picked up** by fetal haemoglobin (i.e. in the placenta).
- This oxygen will only be **released** by **fetal** haemoglobin once it enters the **respiring tissues**, where **pO_2 is low**.
- Following birth, **fetal** hemoglobin is **almost completely replaced** by **adult** hemoglobin (~ 6 months after birth)
- Fetal hemoglobin production can be **drug-induced** in **adults** to treat diseases such as **sickle cell anaemia**.

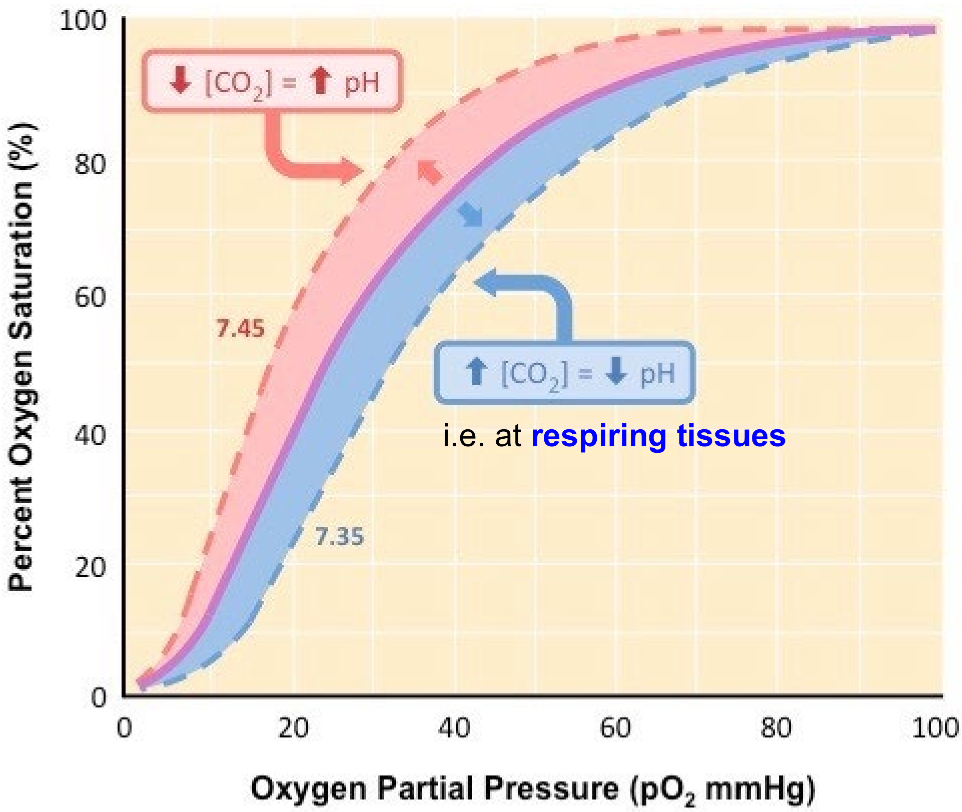
4. MYOGLOBIN

- Myoglobin is used to **store oxygen** in **muscles**.
- It consists of only **one heme** and **one globin** group.
- This explains why its **oxygen-dissociation curve** is **not** S-shaped (sigmoidal).



- The **oxygen-dissociation** curve for **myoglobin** is to the **left** of that for adult hemoglobin.
- Myoglobin has a **higher affinity** for oxygen than adult haemoglobin.
- Myoglobin becomes **saturated** at **lower pO_2**.
- Myoglobin will **hold onto** its **oxygen** supply until levels in the muscles are **<u>very</u> low** (e.g. during **intense** physical exercise)
- This **delayed release** of **oxygen** helps to **slow** the **onset** of **anaerobic respiration** and **lactic acid** formation during exercise.

5. THE BOHR SHIFT



- **Respiration decreases pO_2** and **increases pCO_2** at the **tissues.**
- **CO_2 decreases** the **blood pH** (dissolves to form **carbonic acid**).
- **H^+ binds** to hemoglobin and causes a **shape change**.
- This decreases **haemoglobin's affinity** for oxygen.
- So **more oxygen** is **released** at the **same pO_2**.
- This is known as the **Bohr shift** as it moves the **oxygen dissociation curve** to the **right**.
- The advantage of this is that **more oxygen** is **released** for **aerobic respiration**, so **more energy**/**ATP** is released.

6. GAS EXCHANGE AT HIGH ALTITUDE

The General Picture

- The **partial pressure** of **oxygen** at **high altitude** is **lower** than at sea level.
- Hemoglobin may **not** become **fully** saturated as it passes through the **lungs**.
- Body **tissues** may **not** be supplied with **enough oxygen**.
- A condition called **mountain (altitude) sickness** can develop, with **muscle weakness**, **rapid pulse**, **nausea** and **headaches**.
- This can be avoided by **acclimatization** to high altitude.

Acclimatization to high altitude	Natives living at high altitude
Red blood cell production increases	**Higher lung capacity**
Red blood cells contain more hemoglobin	**Greater lung surface area**
Muscles produce more myoglobin	**Higher tidal volume**
Muscles develop a denser capillary network	**Hemoglobin has a greater affinity for oxygen**
Ventilation rate increases	

High Altitude Training

ADVANTAGES
• **improved performance** at **lower oxygen levels** • (due to) **red blood cell production increasing** • (due to) **myoglobin production increasing in muscles** • (due to) **increased ventilation rate** • (due to) **more oxygen circulating**
RISKS
• **mountain (altitude) sickness** • **lower immunity** • **stroke** • **increased breakdown of muscle tissue** • **effects are not permanent – extended training needed at high altitude** • **unfair to competitors who do not train at high altitude**