Respiration Module

Session 4 – Oxygen in blood

Blood gas carriage

- blood carries oxygen to tissues
- carbon dioxide away from tissues

Oxygen transport

- oxygen is not very soluble in water
- at pO_2 of 13.3 kPa it dissolves 0.13 $mmol.l^{-1}$
- at rest we need 12 mmol oxygen per minute
- which is contained in 92l

Oxygen transport

- even if all the oxygen could be extracted
- cardiac output would have to be impossibly high
- need a chemical reaction to transport more per litre of blood

Oxygen binding

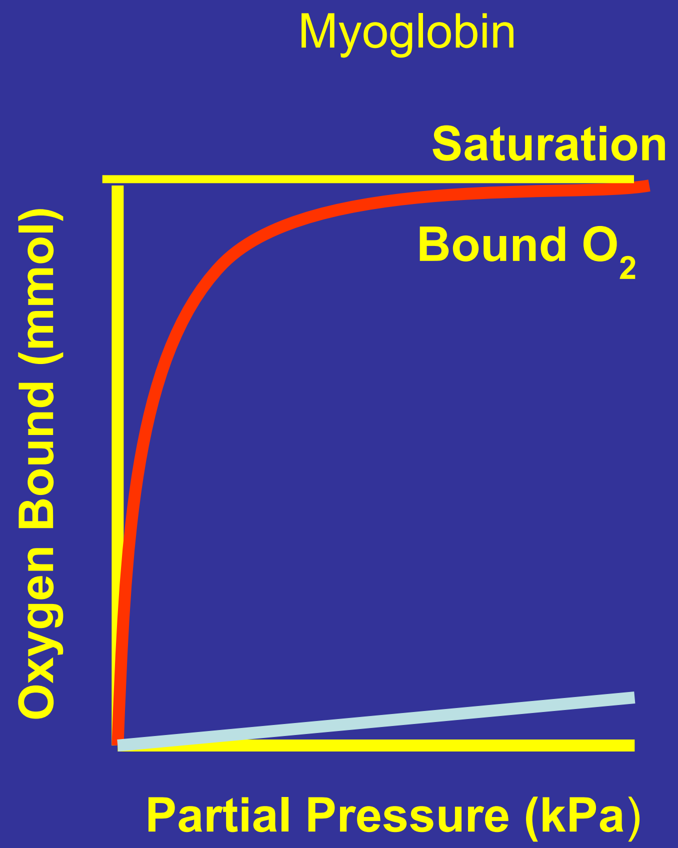
- many substances will react chemically with oxygen
- so getting it into the blood is not a problem
- getting it out again is the trouble
- need a very reversible reaction

Respiratory pigments

- a number of pigments bind oxygen reversibly
- oxygen combines reversibly with Haem
- oxygenation not oxidation

Dissociation curves

- the reversibility of oxygen binding is represented by a dissociation curve
- plot of amount O_2 bound vs pO_2
- total content then bound + dissolved

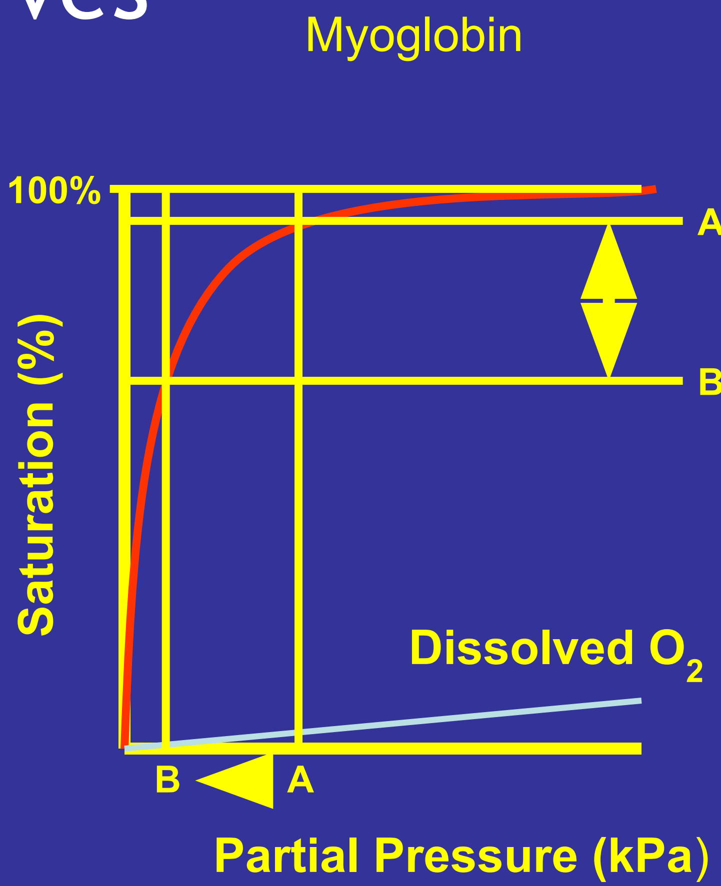


Dissociation curves

- chemical binding saturates above a given pO_2
- the amount of oxygen bound then depends on how much pigment
- so dissociation curves normally expressed as percentage of amount of oxygen bound at saturation
- and are independent of pigment concentration

Using dissociation curves

- tells you how much oxygen will be bound or given up
- when blood is moved from one pO_2 to another



Using dissociation curves

- work out the difference in fractional saturations
- between the two pO_2's
- and multiply it by the amount bound at full saturation
- to tell you how much oxygen is taken or given up

Haemoglobin

- a tetramer - 2 alpha & 2 beta subunits
- each subunit has one haem + globin
- overall molecule has variable quaternary structure

The moods of Haemoglobin

- the molecule may be tense
- or relaxed

The moods of Haemoglobin

- relaxed haemoglobin
- is laid back and
- loves to bind oxygen

The moods of Haemoglobin

- tense haemoglobin
- is uptight
- and does not bind oxygen well

The moods of Haemoglobin

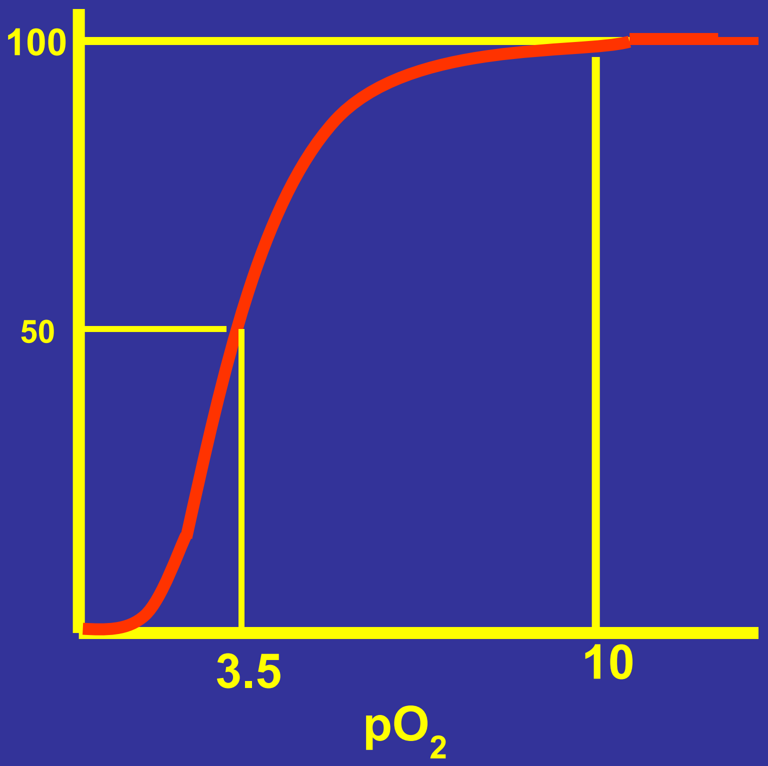
- haemoglobin gets anxious
- when pO_2 is low
- so it is hard to bind the first oxygen
- as most molecules are in the tense form

The moods of Haemoglobin

- as oxygen binds haemoglobin
- feels better and relaxes
- so binding the next oxygen is much easier
- as many more molecules relax

Haemoglobin dissociation curve

- initially the relationship between pO_2 and binding is shallow
- but binding facilitates further binding
- so the curve steepens rapidly as pO_2 rises
- until saturation
- a sigmoid curve



Haemoglobin dissociation curve

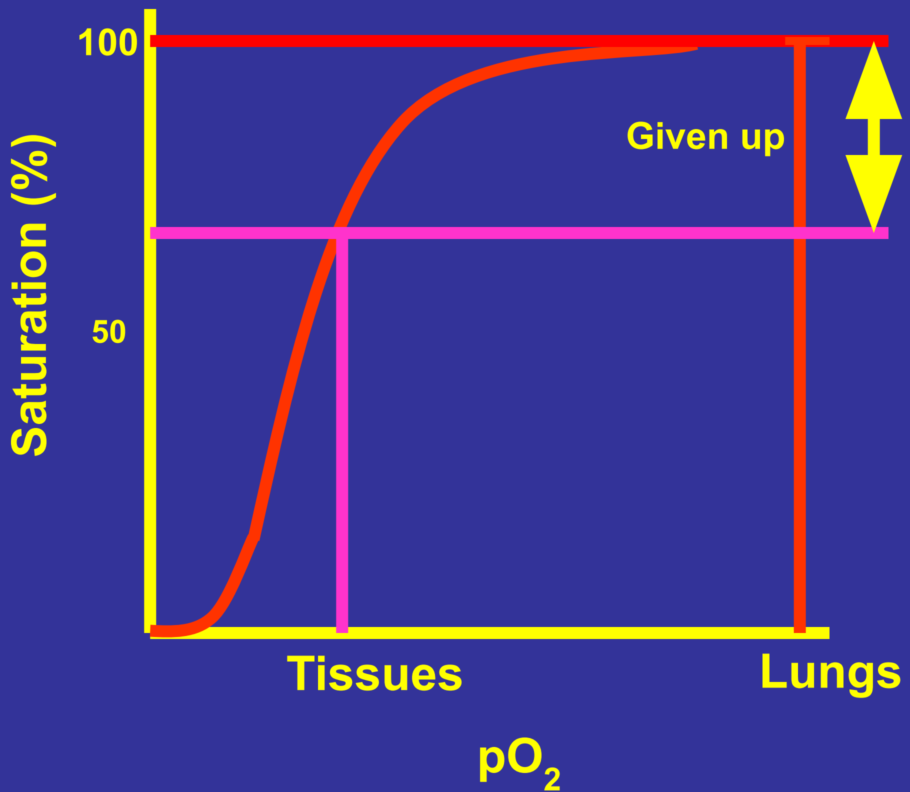
- haemoglobin saturated above 8.5 kPa
- virtually unsaturated below 1 kPa
- half saturated at 3.5-4 kPa
- so saturation changes greatly over narrow range of pO_2
- highly reversible reaction

Haemoglobin in the lungs

- alveolar pO_2 13.3 kPa
- so Hb well saturated
- Hb in normal blood 2.2 $mmol.l^{-1}$
- each molecule binds 4 oxygen
- so oxygen content 8.8 $mmol.l^{-1}$

Haemoglobin in the tissues

- tissue pO_2 varies, but typically 5 Kpa
- haemoglobin now about 65% saturated
- change in binding = 100 - 65%
- oxygen given up 8.8 x 0.35 $mmol.l^{-1}$
- c 3 $mmol.l^{-1}$



Haemoglobin in venous blood

- still has over half its oxygen bound
- so tissues could remove more
- how?

Tissue pO_2

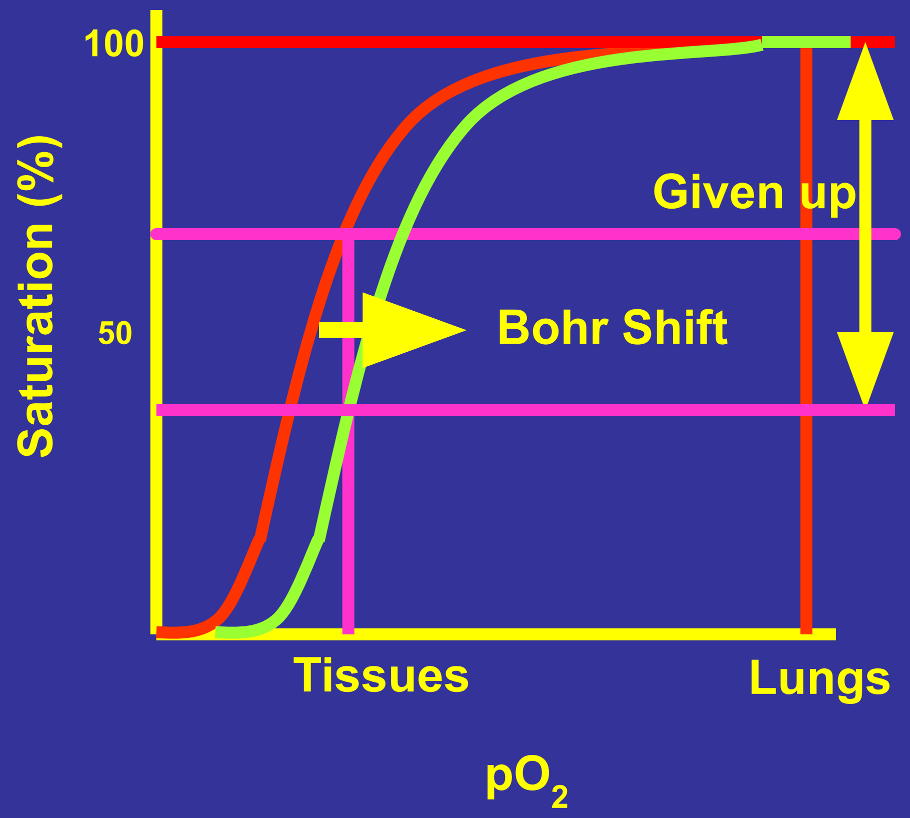
- if lower more oxygen will be given up
- how low can it get?

Tissue pO_2

- must be high enough to drive oxygen out to cells
- cannot fall below 3 kPa in most tissues
- the higher the capillary density the lower it can fall (cf heart muscle)

Getting more oxygen off Hb

- the mood of haemoglobin also depends on pH
- the molecule is more relaxed in alkaline conditions
- and more tense in acid

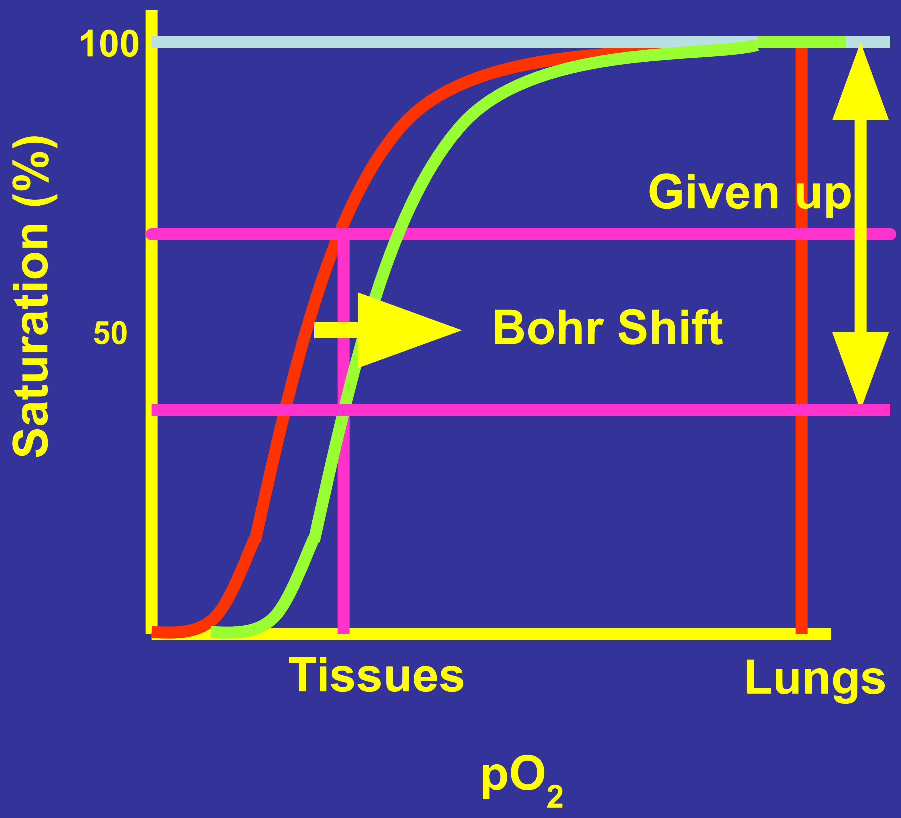


The Bohr shift

- in acid conditions the dissociation curve shifts along the pO_2 axis
- so that at any pO_2 Hb binds less oxygen

In the tissues

- pH is lower
- so extra oxygen given up
- higher temperature has similar effect



Maximum unloading

- in tissues where pO_2 can fall low
- conditions are acid and warm
- about 70% of bound oxygen is given up

Over the whole body

- about 27% of the oxygen in arterial blood is given up to the tissues
- much more given up in exercise
- an ‘oxygen reserve’