Transport of gases by blood.

Reading - Chapter 13 in “Animal Physiology”, pages 525-538.

Dalton’s law of Partial Pressure -

Partial pressure of each gas in a mixture is independent of the other gases, so the total pressure equals the sum of the partial pressures.

At sea level, atmospheric pressure is 760 mmHg.
- O₂ is 20.95% or 159 mmHg
- CO₂ is 0.03% or 0.2 mmHg
- N₂ is 78.09% or 600.6 mmHg
Solubility of gases in water

The amount of dissolved gas depends on:
1. nature of gas (size, polarity)
2. pressure of gas in gas phase
3. temperature
4. presence of solutes in water

At 15° C, 1 atm., pure gas
O₂ - 34.1 ml/L
N₂ - 16.9 ml/L
CO₂ - 1019 ml/L

Respiratory Pigments

Hemoglobin

Four globin protein subunits, each containing one heme molecule.
Antarctic Ice Fish

30° seawater - 4.46 ml O₂/liter
0° seawater - 7.97 ml O₂/liter

### TABLE 2.2 Common respiratory pigments and examples of their occurrence in animals.

<table>
<thead>
<tr>
<th>Pigment</th>
<th>Description</th>
<th>Molecular weight</th>
<th>Occurrence in animals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemocyanin</td>
<td>Copper-containing protein, carried in solution</td>
<td>300 000–9 000 000</td>
<td>Molluscs: chitons, cephalopods, prosobranch and pulmonate gastropods, not lamellibranchs</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Arthropods, crabs, lobsters, Arachnomorphs: Limulus, Euscorpius</td>
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<tr>
<td>Hemerythrin</td>
<td>Iron-containing protein, always in cells, nonporphyrin structure</td>
<td>108 000</td>
<td>Sipunculids: all species examined</td>
</tr>
<tr>
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<td></td>
<td>Polychaetes: Magelona, Priapulids: Halicryptus, Priapulus</td>
</tr>
<tr>
<td>Chlorocruorin</td>
<td>Iron-porphyrin protein, carried in solution</td>
<td>2 750 000</td>
<td>Brachiopods: Lingula</td>
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<td></td>
<td></td>
<td></td>
<td>Restricted to four families of Polychaetes: Sabellidae, Serpulidae, Chlorhahmidae, Ampharetidae, prosthetic group alone found in starfish (Luidia, Astopecten)</td>
</tr>
<tr>
<td>Hemoglobin</td>
<td>Iron-porphyrin protein, carried in solution or in cells; most extensively distributed pigment</td>
<td>17 000–3 000 000</td>
<td>Vertebrates: almost all, except leptocephalus larvae and some Antarctic fish (Chaenichthys)</td>
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<td>Echinoderms: sea cucumbers</td>
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<td>Molluscs: Planorbis, Pismo clam (Tivela)</td>
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<td>Arthropods: insects (Chironomus, Gastrophilus); crustacea (Daphnia, Artemia)</td>
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<td></td>
<td>Annelids: Lumbricus, Tubilex, Arenicola, Spirorbis</td>
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<td></td>
<td></td>
<td>Some species have hemoglobin, some chlorocruorin, others no blood pigment; Serpula (both hemoglobin and chlorocruorin)</td>
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<td></td>
<td></td>
<td></td>
<td>Nematodes: Ascaris</td>
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<td></td>
<td></td>
<td>Flatworms: parasitic trematodes</td>
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<td>Protozoa: Paramecium, Tetrahymena</td>
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<td></td>
<td>Plants: yeasts, Neurospora, root nodules of leguminous plants (clover, alfalfa)</td>
</tr>
</tbody>
</table>
Oxygen-hemoglobin dissociation curve of a pigeon.

The important property of respiratory pigments is that they combine reversibly with oxygen over the range of partial pressures encountered by the animal.

Bohr shift - Dumping of oxygen at the tissues is enhanced by reduced pH.

Bohr shift in hemocyanin from a crab
Fetal versus maternal blood

Some sipunculid worms have hemerythrin in both their blood and coelomic fluid.
Tadpole hemoglobin

Dissociation curves and body size in mammals

Problem - small animals have higher rates of oxygen consumption per unit body mass.

Solution:

1. Unloading pressure is higher in smaller animals.
Capillary density and body size

**Solution:**
1. Unloading pressure is higher in smaller animals.
2. Capillary density is higher in smaller animals.

Effect of body size on Bohr shift in mammals

**Solution:**
1. Unloading pressure is higher in smaller animals.
2. Capillary density is higher in smaller animals.
3. Bohr shift is greater in smaller mammals.
Transport of oxygen during strenuous exercise

Three-fold increase in oxygen delivery.

The mechanism of CO$_2$ transport is fundamentally different from O$_2$ transport.

CO$_2$ is 30 times more soluble than O$_2$.

CO$_2$ can be eliminated without a giant specialized respiratory surface.
Total CO₂ content of blood

- Deoxygenated blood, total CO₂
- Oxygenated blood, total CO₂
- Bicarbonate + carbamino CO₂
- Molecular CO₂
- Dissolved
- Haldane effect
- Chemically combined

Arterial-venous change in CO₂
57%
27%

Bohr effect
Haldane effect
The combination of \( \text{O}_2 \) with Hb in the lung causes Hb to become a stronger acid. This displaces CO\(_2\) from the blood.

1. Reduces tendency of CO\(_2\) to combine with -NH\(_2\) groups

2. Drives HCO\(_3^-\) to CO\(_2\) + H\(_2\)O