

## Gas exchange:

All (larger) organisms need to exchange oxygen and carbon dioxide.

To do this, most need to have some type of special respiratory organ.

Respiratory organs:

Essentially a system that provides O<sub>2</sub> (and gets rid of CO<sub>2</sub>) to the organism.

Often, a circulatory system (if present) will support the respiratory system by moving oxygen and carbon dioxide around the body.

But first we need to get gases in and out of the body.

There are many different kinds of respiratory systems:

Skin, gills, trachea, lungs, others (e.g, book lungs).

All of these must be moist on the surface where gas exchange actually takes place.

Gases are absorbed and released through diffusion, and this must take place across a moist surface.

Skin [**Fig. 22.2A, p. 455**]:

If this is the only method of gas exchange, it usually only works for smaller organisms.

The surface area provided by skin is not very large.

Some examples are earthworms, and some amphibians. Their skin is always moist.

A group of salamanders is known as lungless salamanders, and is actually found on campus!

[As an aside, reptiles are not “slimy”, but many amphibians are.]

Gills [**FIG. 22.2B, p. 455**]:

Used by many aquatic organisms, and just a few terrestrial ones.

The idea is to produce a structure with a very folded outer surface.

This increases surface area dramatically.

Blood is then pumped through the gills, where oxygen and carbon dioxide are exchanged.

Gills are made more efficient with a counter current system [**Fig. 22.3, and not in book**].

Counter current system:

In a nutshell, things never reach equilibrium, as they would in “same”, or “con” current flow.

In a same current system, once you reach equilibrium, substances or temperature can no longer be exchanged.

In a counter current system, you never reach equilibrium so substances or temperature can be exchanged the entire length of the system.

See overhead.

Counter current systems are much more efficient are also used in commercial heating and cooling!

Many organisms have a mechanism for moving water over the gills (ventilation):

Current passing through the mouth of fish (gills flapping, mouth opening and closing).

Appendages in crayfish, lobster and other crustaceans that move water over gills.

A very few terrestrial organisms have modified gills, for example isopods.

They do manage to keep the gills moist.

But generally, gills collapse outside of water, so fish and other animals with gills suffocate (they can't move air across the gills anymore)

Trachea [FIG. 22.2C, p. 455]:

Notice that this refers to a type of structure - humans have a “trachea”, but in our case this is a tube going from the throat to the lungs.

*Trachea* as a respiratory organ is found primarily in insects.

Essentially, this is a tree like structure, with the trunk opening to the outside of the body, and the branches going off to the inside in ever finer divisions.

Larger insects are helped by “body contractions - like a bellows”, which helps move air in and out of the body.

The openings (spiracles) are easily visible along the abdomen of larger insects.

Lungs [Fig. 22.2D, p. 455]:

Found mostly in vertebrates.

Lungs are a complex folded structure that greatly increases the surface area available for respiration.

Oxygen and carbon dioxide are exchanged across the surface of this structure, and then transported around the body by the circulatory system.

Note: the statement about turtles in older editions is almost complete nonsense:

Turtles breathe through lungs just like any other reptile.

They use muscles around their hind legs to expand the lung cavity inside their shell.

It is true that a very few species supplement oxygen / carbon dioxide exchange by moving water through their anus, but this generally happens only when they're hibernating.

Mammalian lungs - details [Fig. 22.6, p. 459]:

Structure:

Air travels from the nose or mouth into the larynx (= voice box) and then into the trachea.

The larynx and trachea are supported by cartilage - [why?].

The trachea then branches into bronchi (two in humans, but animals (e.g., pigs), may have more).

The bronchi divide into finer and finer tubes (bronchioles).

The epithelial surfaces of all these ducts/tubes are covered with cilia and mucus.

This removes foreign particles, etc.

Particles are trapped by the mucus, the cilia then push the mucus to the back of the throat where it is swallowed.

At the ends of the bronchioles, they dead end into a cluster of air-sacs called alveoli.

Alveoli look like a bunch of grapes [Fig. 22.6, p. 459], and are surrounded with very fine capillaries.

These capillaries release carbon dioxide and pick up oxygen.

Ventilation:

Humans have negative pressure breathing:

The diaphragm contracts, increasing volume of chest (thoracic) cavity.

The rib muscles also contract, further increasing volume of chest.

Both working together cause air to move into lungs [OVERHEAD, fig. 22.8A, p.460]

Creates a negative pressure in the thoracic cavity, so air rushes in.

When these muscles relax, air is pushed back out of the lungs.

Other vertebrates (e.g. frogs) do use positive pressure breathing:

In this case air is pushed into the lungs, usually by muscles in the throat.

Ventilation in birds:

This is actually more efficient than in mammals:

Birds have evolved a “one-way” system of moving air through the lungs  
**[Fig., not in text (it used to be!)]**.

We have a two way system, and there is always a little bit of “residual” volume left in our lungs that we can't exchange with every breath.

Control of breathing (what triggers breathing?):

We sense small changes in blood pH (or cerebrospinal fluid).

As it turns out, we actually monitor CO<sub>2</sub> concentration.

As CO<sub>2</sub> increases, it reacts with water and creates carbonic acid.

This causes changes in blood pH, which we sense.

Oxygen concentration usually does not impact breathing:

But very low blood pressure or volume (usually caused by massive bleeding) can cause a breathing impulse caused by low oxygen.

Transport of oxygen and carbon dioxide by blood:

Hemoglobin transports oxygen in vertebrates.

(A similar compound, hemocyanin (uses copper instead of iron) transports blood in arthropods and many mollusks).

Hemoglobin in red blood cells (RBC's) picks up oxygen in lungs, and then releases this at the appropriate place in the body.

In the presence of high oxygen, RBC's absorb oxygen (using hemoglobin).

In areas of low oxygen concentration (e.g. in active tissues) , RBC's release oxygen (from hemoglobin).

Carbon dioxide, however, is a bit more complicated.

**[Fig., not in text; for some silly reason they got rid of this figure starting with the 5<sup>th</sup> edition, although this is described (not very well) on top of p. 463)]**.

RBC's pick up  $\text{CO}_2$ , and convert this into carbonic acid.

Carbonic acid forms bicarbonate and hydrogen ions.

The hydrogen ions are then bound to the hemoglobin, preventing the release of Carbon dioxide from the RBC (and preventing large pH changes).

The bicarbonate is released into the blood plasma and further prevents large pH changes.

In the lungs, this process is reversed:

The hydrogen ion is released, and recombined with bicarbonate to make carbonic acid.

Carbonic acid is turned back into  $\text{CO}_2$ , the  $\text{CO}_2$  attached to the hemoglobin is also released.

$\text{CO}_2$  is then released across the alveoli and removed.