

Gas exchange:

Respiratory organs:

- essentially a system that provides oxygen to the organism. Usually, the circulatory system (if present) then delivers this to the cells, but oxygen needs to be put into the circulatory system to begin with. Thus, respiratory organs have developed.

- Many different kinds:

- skin
- gills
- trachea
- lungs
- others (e.g. book lungs)

- All share the characteristic that the surface where gas exchange takes place is moist. Diffusion must take place across a moist surface.

1) skin [Fig. 22.2A, p. 455]:

- if this is used exclusively, then it only works for smaller organisms, since the surface area provided by skin is not very large. Earthworms, and some amphibians (some amphibians do not have lungs) are a good example (note that their skin is always moist). [Reptiles are not “slimy”, but many amphibians are.]

2) gills [FIG. 22.2B, p. 455]:

- used by many aquatic organisms, and just a few terrestrial ones. Idea is to produce a structure with a very folded outer surface. This increases surface area dramatically. Blood is then pumped through the gills, and picks up oxygen/gives up carbon dioxide. This is made more efficient with a counter current system [Fig. 22.3, and not in book].

- counter current - in a nutshell, things never reach equilibrium, as they would in “same”, or “con” current flow. See overhead. Gases (or heat) can be exchanged along the entire length of the exchange.

- counter current ideas also help preserve heat (illustrate)

- problem - oxygen concentration in water is low, so gills must be very efficient. But at least the surface is always moist.

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

- current passing through mouth of fish (gills flapping).
- appendages in crayfish and lobsters that move water over gills.
- terrestrial organisms with modified gills: isopods (gills do remain moist), more terrestrial species have lung-like invaginations that assist in respiration.
- difficult to support gills out of water.

3) trachea [FIG. 22.2C, p. 455]:

- found primarily in insects. Essentially 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. Thus all parts of the body get oxygen.
- larger insects are helped by “body contractions - like a bellows”, which helps move air.

4) lungs [Fig. 22.2D, p. 455]:

- found mostly in vertebrates. Essentially a complex folded structure that greatly increases the surface area available for respiration. Oxygen and Carbon dioxide must be transported from/to lungs to/from rest of body by the circulatory system.
- Note: statement about turtles on p. 456 (left side) is mostly nonsense. With very few exceptions, turtles breathe through lungs just like any other reptile. They use muscles around their hind legs to expand the lung cavity inside their shell. A few species do supplement oxygen uptake by breathing through the anus/mouth, but generally only when hibernating.

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

- air travels from nose or mouth into larynx and then into trachea.
- larynx and trachea are supported by cartilage - [why?]
- the trachea branches into bronchi (two in humans, but pigs, for example, have three)
- bronchi divide into finer and finer tubes (bronchioles).
- the epithelial surfaces of ducts are covered with cilia and mucus. This removes foreign particles, etc.
- at the ends of the bronchioles, these dead end into a cluster of air-sacs called alveoli.

- Alveoli look like a bunch of grapes [Fig. 22.6B, p. 459], and are surrounded with very fine capillaries. These capillaries release carbon dioxide and pick up oxygen.

Ventilation - negative pressure breathing:

- diaphragm contracts, increasing volume of chest (thoracic) cavity.
- rib muscles contract, also increasing volume of chest.
- both working together cause air to move into lungs.
- [OVERHEAD, fig. 22.8A, p.460]

- Comment: other vertebrates (e.g. frogs) use positive pressure breathing).

Ventilation in birds:

- more efficient than in mammals - have evolved a “one-way” system of moving air through the lungs [Fig., not in text (used to be!)].
(Lab comment - no residual volume to worry about)

Control of breathing:

- by sensing small changes in blood pH (or cerebrospinal fluid) CO₂ concentration is monitored. As CO₂ increases this stimulates increased respiration rate.

- Oxygen concentration usually does not impact breathing rate directly, unless this becomes severely depressed.

Transport 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 RBC's picks up oxygen in lungs, and then releases this at the appropriate place in the body.
 - Essentially, in the presence of high oxygen, RBC's don't release oxygen, but instead become saturated.
 - As oxygen concentration drops, RBC's become more prone to releasing oxygen.

- Carbon dioxide, however, is picked up by RBC's and then converted into carbonic acid by reacting with water.

- Carbonic acid forms bicarbonate and hydrogen ions. Hydrogen ions are then bound to the hemoglobin, preventing the release of Carbon dioxide (and preventing large pH changes) until the RBC gets to the lungs.

- In lungs, hydrogen is released, and this process is reversed, eventually allowing RBC to release Carbon dioxide [**Fig., not in text; note:** for some silly reason they got rid of this figure in the 5th & 6th edition (see equation on top of the right hand side of p. 463)].