Ventilation

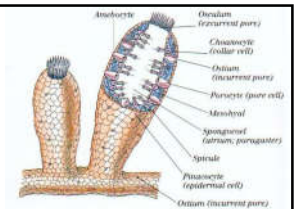
- Increase exchange rate by moving medium over respiratory surface
- Water – ~800x heavier than air, potentially expensive ventilation
  - Oxygen per unit mass
    - Air: 1.3 g contains 210 ml O_2
    - Water: 1000 g contains 5-10 ml O_2
- Air – diffusion can only occur once gasses dissolved, all respiratory surfaces must be wet
  - Respiratory flux

Systems

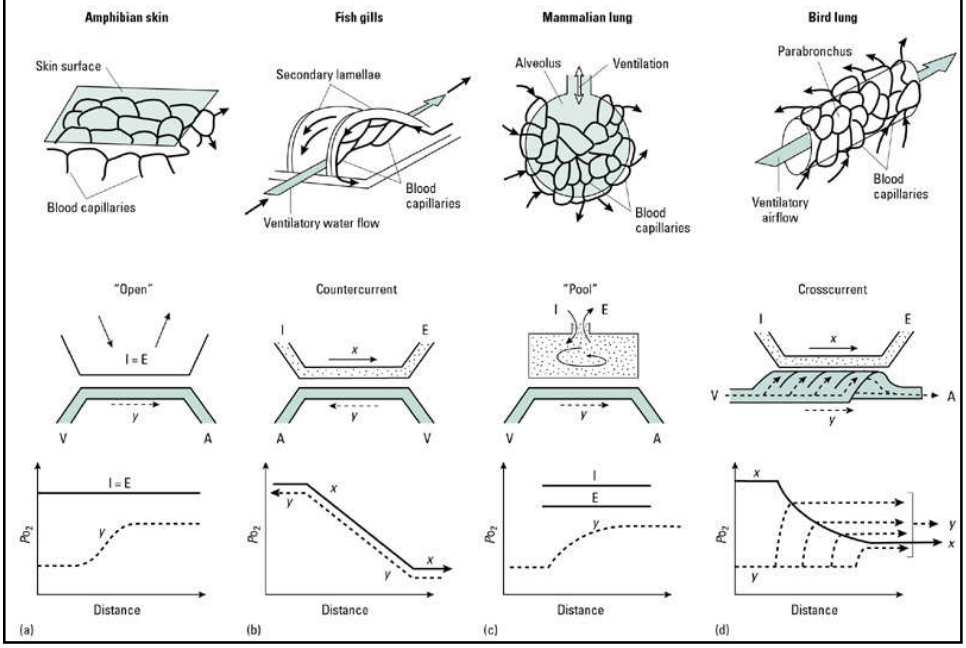
- **Ventilation system** - devote resources to anatomical structures or behaviors aimed at increasing ventilation and thus potential gas exchange
- **Circulatory system** – devote resources to anatomical structures to more efficiently move gasses (and other things) around the body
  - More efficient control and delivery

Types of Ventilation Systems

- Cilliary action
- Muscle pumps
  - Buccal pumps
  - Body wall
- Body positioning
- Ram ventilation
- Negative pressure diaphragms

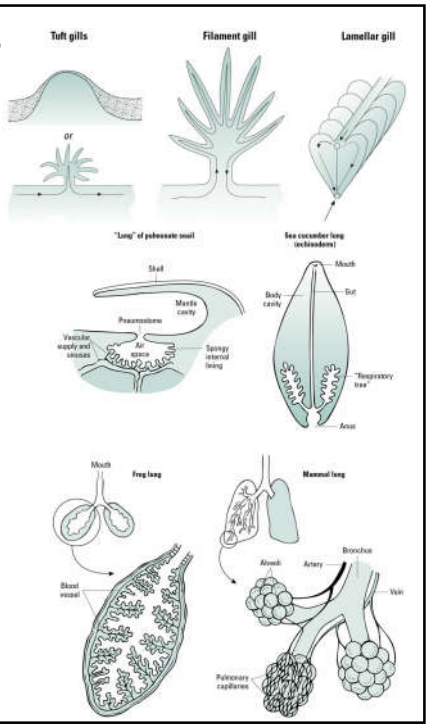


Air/Water Interaction with Surface



Types of respiratory structures

- **Skin (cutaneous)**
- **Gills** – protruding structure, increases surface area
  - Tuft
  - Filament
  - Lamellar
- **Trachea** – internalized but not centralized
- **Lung** – internalized and centralized structure

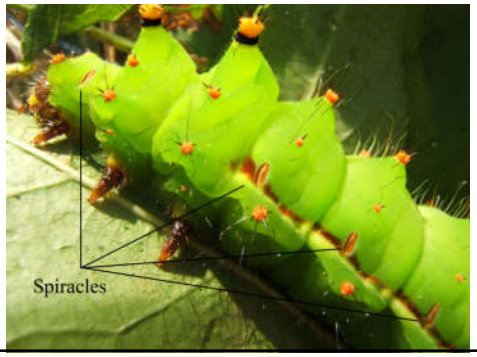


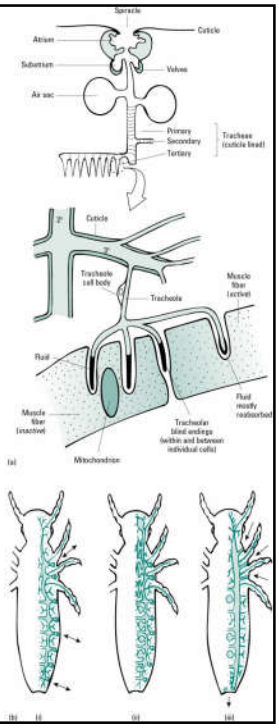
Cutaneous exchange

- Most animals get some oxygen this way
- Requires thin, moist skin
- Flow of deoxygenated body fluids near skin surface
- Ontogenetic trends – most larval fish do not use gills
- Some secondary loss of lungs (Plethodontidae)
- Ventilation (Lake Titicaca frog)

Trachea systems

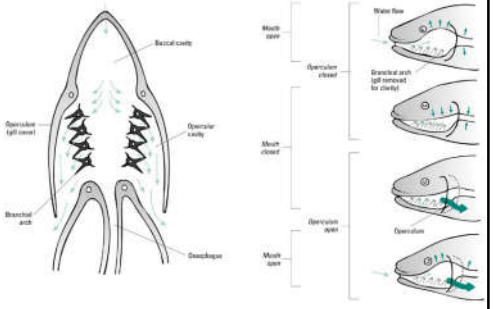
- Multiple independent tubes
- Spriacles for ventilation
- Branches supply tissues directly
- Some connected to “gills”
- Body movement for ventilation



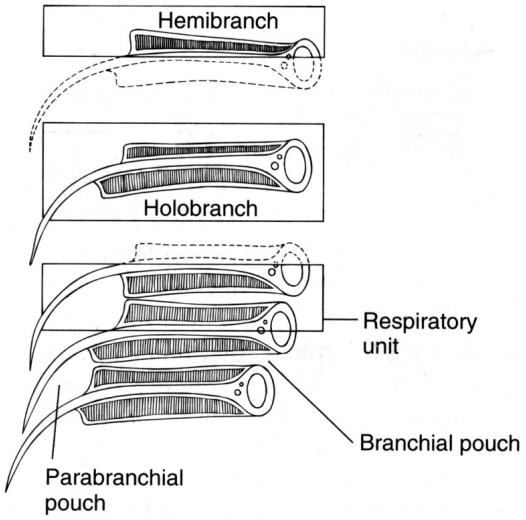


Fish Gills

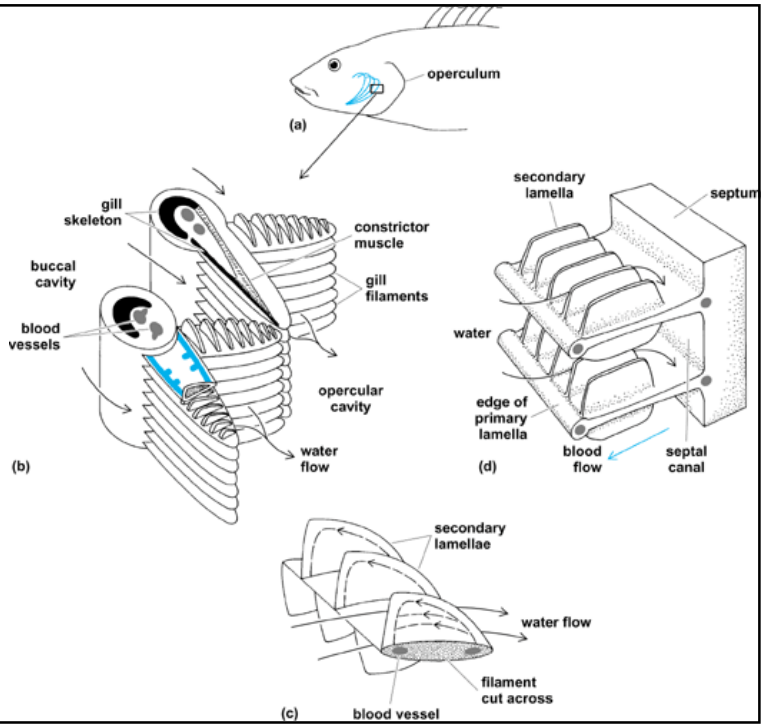
- Ventilation
  - One way flow
  - pumps: buccal, opercular, stomach, esophageal
  - ram ventilation
- **Ventilation to profusion ratio** = volume pumped to volume in contact with gills
  - Higher value requires more gill surface area



- Types of gills
  - **Holobranch**: lamellae on both sides of the fillament
  - **Hemibranch**: lamellae on one side
  - **Pseudobranch**: no true lamellae



Gills



Gill area

- Greater in marine than freshwater
- Greater for more metabolically active fish (e.g. tuna)
- Generally comparable to mammal lung surface area

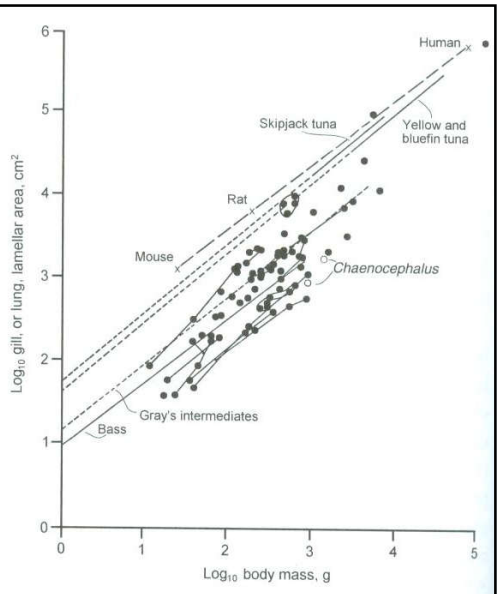


Figure 8.5 Log_{10} gill lamellar area in skipjack tuna (*Katsuomus pelamis*), yellowfin tuna (*Thunnus albacares*), bluefin tuna (*Th. thynnus*), and other fishes and log_{10} lung area in mammals as a function of log_{10} body mass. Sources: Modified from Muir (1969) and Hughes (1972a).

Fish bimodal breathers

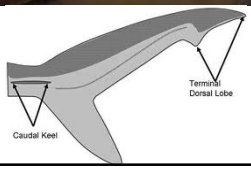
- Scales typically reduce cutaneous exchange
- Gape at water surface for boundary layer water
- Some will use air bladders
  - Get oxygen from air bladder
  - Release CO_2 and ammonia from gills
- **Obligate** vs. **facultative** air breathers

Evolution of lungs

- Air bladders initially for gas exchange, modified for buoyancy

- Required volume for neutral buoyancy
  - Weight (specific gravity) of tissues
    - Bone > cartilage
    - Proteins > fats
  - Specific gravity of water (1.0 for fresh, 1.025 for marine)
    - Freshwater fish ~ 5.5-8.3% of fish volume
    - Marine fish ~ 3.1-5.7% of fish volume

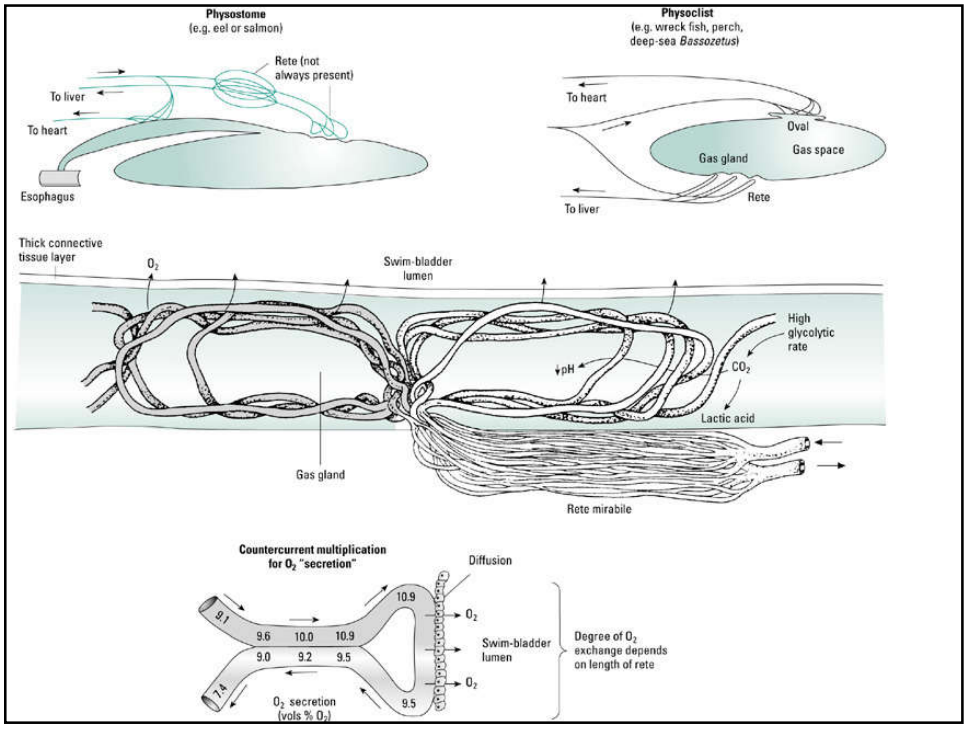
- Elasmobranchs - no air bladder
  - Specific gravity of lipids in liver
    - **Diacyl glyceryl ehters** – 0.908
    - **Triglycerides** – 0.922
  - Heterocercal tail



Fish Air Bladders

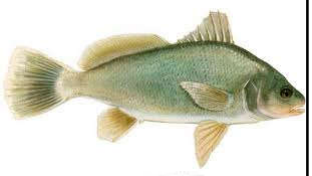
- Typically not paired

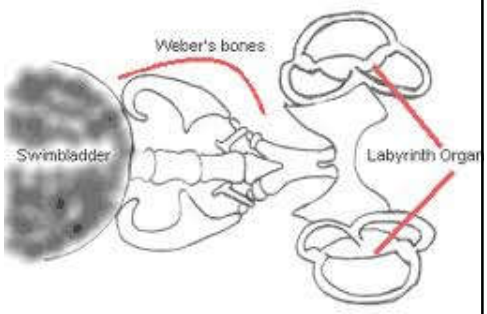
- Dorsal location
- **Physoclistous** – air bladder not open to GI tract
  - **Gas gland** and **rete mirabile**
- **Physostomous** – air bladder opens into GI tract



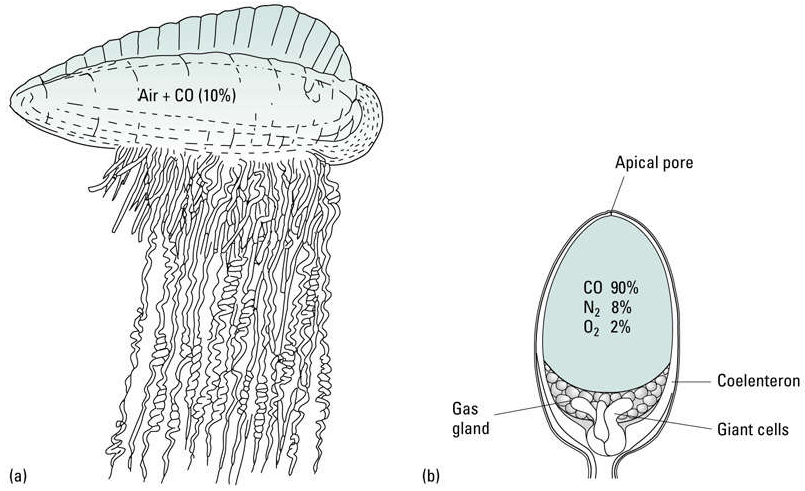
Secondary use of air bladders

- Sound production
- Sound detection
  - Weberian aparatus
- Adipose storage
- Light organs
- Secondary loss of air bladders

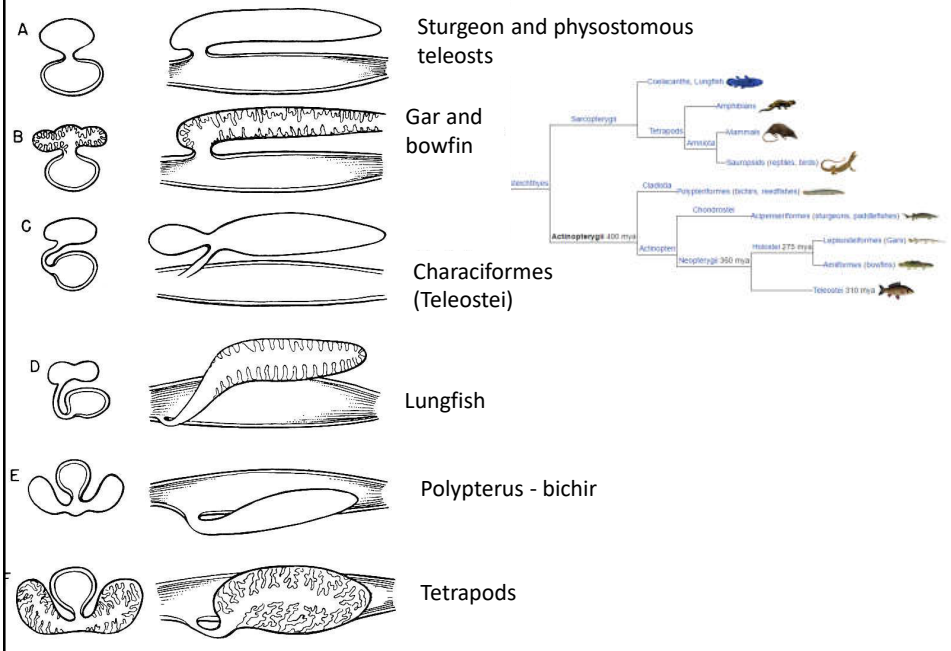




Other air bladders

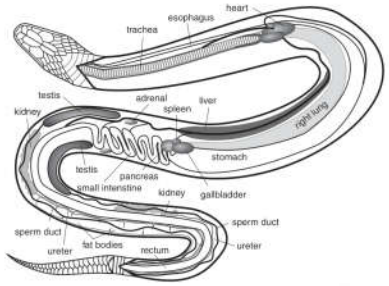


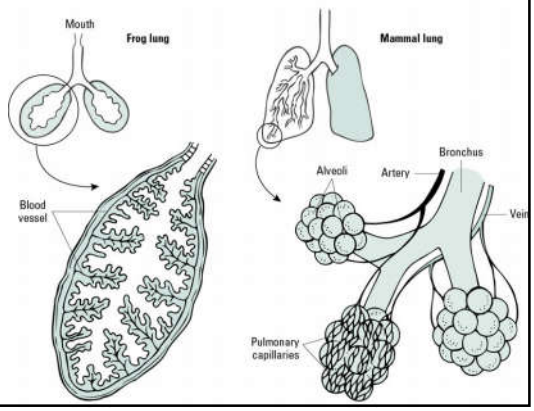
Evolution of lungs



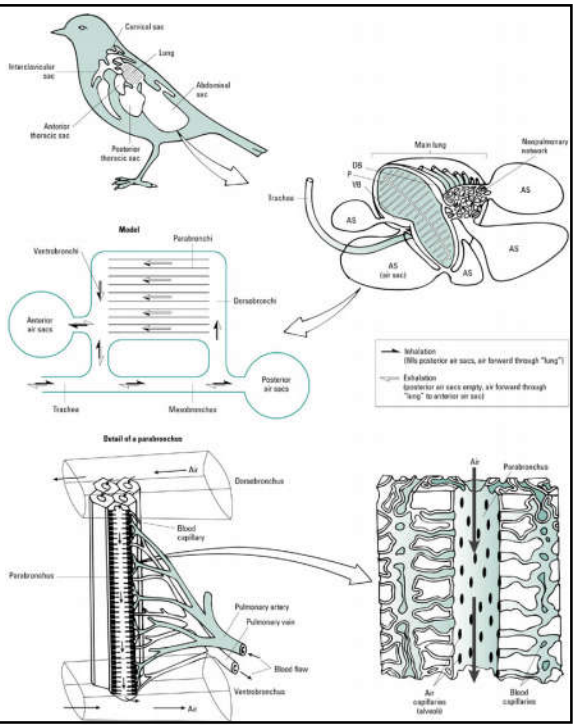
Evolution of lungs

- Derived from teleost air bladders, modified pockets on the GI tract
- Typically paired (most snakes 2nd loss of left lung)
- Amphibians, reptiles and mammals – bidirectional pool system
- Birds – unidirectional
- Invertebrate lungs (e.g. terrestrial crabs, pulmonate snails) independently derived.





Bird Lungs



Ventilating lungs

- Internal surface wet, why don't surfaces stick?
  - **Lung compliance**
  - **Surfactants**
- Tidal volume
- Dead space
- Alveolar dead space
- Positive pressure pump (e.g. amphibians)
- Negative pressure pump (e.g. mammals)
  - Collapsed lung
- Bird lungs – fill in rhythm with wing beats