

Respiratory System

Chapter 13

- **External Respiration**
 - exchange of O₂ and CO₂ between vascular system and external environment
- **Internal Respiration**
 - exchange of O₂ and CO₂ between vascular system and tissues of the body

External Respiration

- Involves skin (cutaneous respiration), gills and/or lungs
- Mechanism = passive diffusion
 - In order for gases to diffuse across a membrane, the membrane must be moist
 - Although most vertebrates have some type of hemoglobin, oxygen movement is still passive

GILLS

- Specialized respiratory organs - highly variable
- Primitive anatomy:
 - Gill slits (internal & external)
 - Gill bar
 - Supported by visceral arch
 - Supplied with blood by afferent branchial artery
 - Covered on one or both sides by gill lamellae
 - Holobranch, demibranch & pseudobranch

- Variation in gill structures:

- Agnatha
 - have "marsipobranchs" supported by branchial basket cartilage
 - Lampreys - 7 pairs of gill pouches
 - Hagfish - 6-14 pairs of gill pouches
 - utilize buccal force pump
- Chondrichthyes
 - have "naked" gill slits
 - gill formula = spiracle + demibranch + 4 holobranchs

- Variation in gill structures:

- Actinopterygians & Crossopterygians
 - operculate gills
 - spiracle variable - becomes involved with ear structures
 - typically 4 holobranchs
 - gill rakers in two rows
- Dipnoi
 - also operculate but gill lamellae greatly reduced
 - Australian lungfish - similar to other bony fish
 - African & S. American lungfish - obligate lung breathers
 - » no lamellae on gill bars 1 or 2

- External Gills:

- seen in some fish and amphibians
- typical pattern in amphibians is 3 pairs

- Amniotes:
 - neither internal nor external gill ever develop
 - gills are functionally replaced by lungs
- Where did lungs come from?
 - **Swim bladder**
- Two types of swim bladders:
 - **Physostomous**
 - connected by pneumatic duct to digestive system

- **Physoclistous**
 - loss of pneumatic duct
 - contain a **Red Gland** (rete mirabile)
 - may contain an **Oval**
- Swim bladder structure:
 - dorsally positioned (mostly), elongated sac
 - arise from pharyngeal pouches - component of digestive system
 - smooth walled (mostly) with little vascularization

- Function:
 - hydrostatic organ
 - may be used as accessory respiratory organ
 - **Trabeculae** present in the swim bladders (lungs) of lungfish

LUNGS

- Functionally replace gills in tetrapods as the major site of gaseous exchange.
- Pharyngeal derivative; endoderm with some mesodermal tissue
- Basic Anatomy:
 - Glottis
 - median ventral opening to air tract
 - Larynx
 - enlarged chamber just posterior to glottis
 - Trachea
 - ventral air tube
 - Primary bronchi
 - initial bifurcation of trachea leading to each lung
 - Paired lungs
 - highly vascularized, subdivided elastic sacs

LUNGS

- Fish
 - lung is relatively simple in structure
 - smooth interior surface, little vascularization
- Dipnoi
 - first sign of subdivision of interior surface
 - trabeculae specialized to maximize gas exchange
 - mechanism of air movement is via buccal force pump

- Tetrapods
 - major trend towards increased efficiency by:
 1. increasing structural complexity to increase surface area
 2. anatomical changes related to respiratory mechanics

Amphibian Lungs

- Lung structure little changed over that of a fish
- Some internal folding seen in some species
- No internal tube system
- Size of the lung related to importance of the lung in individual species
 - (combined with gills, skin, and buccal mucosa)
- Mechanism still buccal force pump

Reptile Lungs

- Lung is the only organ of respiratory exchange
- Lung development dependent upon size and metabolic needs
- First appearance of **alveoli**
- Development of bronchiole subdivision
- Mechanism includes buccal force pump plus:
 - intercostal & trunk musculature for expansion of body cavity
 - relaxation of this musculature for exhalation

Reptile Lungs

- Special reptile respiratory mechanisms
 1. turtles utilize special muscles associated with limb and head opening
 2. crocodilians require additional mechanisms due to size
 - lung attached to anterior margin of liver
 - inhalation aided by **diaphragmatic** muscle
 - exhalation aided by **transversal** muscles

Bird Respiration

- flight and homeothermy result in high oxygen demand
 - has led to the most highly developed respiratory system of all vertebrates
 - the bird lung:
 - small and compact
 - tightly adhered to the ribs & thoracic vertebrae
 - highly vascularized
 - inelastic
 - are connected to a series of non-vascular air sacs extending throughout the body (8 to 14)
 - » cervical sacs - neck region
 - » interclavicular sac - beneath furcula
 - » thoracic sacs - both anterior and posterior
 - » abdominal sacs
 - no alveoli but instead tiny air tubules called **parabronchi**
 - parabronchi = functional respiratory unit

Bird Respiration

- **Parabronchi** = "air capillaries"
 - arranged in a highly branched network throughout the lungs
 - represent 50% of the volume of the lungs
 - each is surrounded by capillaries
 - air and blood move in opposite directions = countercurrent flow

Bird Respiration

- **Mechanics of Bird Respiration**
 - inhalation via contraction of sternal and rib musculature
 - inflates air sacs
 - exhalation via compression of ribs and abdominal musculature
 - forces air out of air sacs into the lungs
- Avian breathing also tied to wing beats:
 - upstroke = inhalation
 - downstroke = exhalation

Mammalian Respiration

- Lungs - occupy most of the thoracic cavity
 - each lung enclosed in pleural membrane within its own pleural cavity
 - alveoli system maximized compared to other vertebrates
 - # and size of alveoli directly related to metabolic needs of the organism
 - internal bronchiole system highly divided

Mammalian Respiration

- Respiratory Mechanics
 - inherited typical muscular system of reptiles (intercostal & trunk musculature)
 - **diaphragm** added to improve inhalation efficiency
 - Inhalation
 - active process involving diaphragm, intercostal and trunk musculature
 - Exhalation
 - passive process of relaxation - aided by elasticity of lung tissue
 - Forced exhalation
 - involves contraction of abdominal musculature
