# An Introduction to Animal Diversity

Tuesday, January 04, 2011
11:30 AM

**Timeline:**

- 4.5 billion years ago earth formed
- 4 billion years ago oceans formed
- 3.5 billion years ago fossils formed
- 2.5 billion years ago oxygen formed in air
- 2 billion years ago fossil eukaryotes
- 1.5 billion years ago fossil multicellular
- 600-700 million years ago fossil animals

Earth was very different then -> no plants, fungi or animals
There were bacteria, water and multicellular organisms

**Choanoflagellates** are closely related to animals but are not animals

Studying protists that are closely related to us can help us learn what our common ancestor may have been like:

- They have: cell body, flagella, microvilli
- Algae get stuck in microvilli -> feed by endocytosis
- Some are anchored to a surface\they wave flagella and cause a current which traps algae
- Can form colonies with hundreds of cell usually embedded in a gel -> similar to current living sponges
- Compare to sponges which are all multicellular
- Figure 32.3

**Sponges:** Have amoeboid cells in gel to hold them together. There are other biochemical similarities
**Hydra:** Has a simple body plan with flagella. They use muscle to trap other organisms
**Planaria** (flatworms): can move around. Same plan as hydra to digestive system
**Nematoda** (roundworm): has a more complex digestive system

**Evolution can be traced through embryology**

1. Single cell (zygote) -> cleavage
2. Eight-cell stage (same size) -> cleavage
3. Blastula (hollow ball) -> gastrulation
4. Gastrula
5. Figure 32.2

**Evolution of Multicellularity**

- Ancestral colonial flagellate
  - Multicellularity
- Metazoa
  - "true tissues" diploblastic
- Eumetazoa
  - Bilateral symmetry & triploblastic
- Bilateria
- Figure 32.10

**Diploblastic Animals**

- Two true tissues that specialize: endoderm and ectoderm
- **Endoderm:** forms the lining of digestive tract
- **Ectoderm:** forms outer covering
- Ex: jellies are diploblastic animals, have gastrovascular cavities

**Triploblastic Animals**

- **Ectoderm:** becomes surface tissue, integumentary system, central nervous system
- **Endoderm:** becomes the lining of the digestive tract
- **Mesoderm:** cells form endoderm break away and specialize into mesoderm. Becomes muscles and organs
- Most posses a body cavity or coelom

**Body Cavities:** cushions/suspends internal organs and helps prevent injury

- **Coelomates:** triploblastic animals that has a "true coelom" -> a body cavity completely lines by tissue derived from mesoderm
- **Pseudocoelomates:** triploblastic animals with body cavity formed from mesoderm and endoderm -> not suspended
- **Acoelomates:** triploblastic animals lacking a body cavity
- Figure 32.8

**Fate of the Blastopore**

- Blastopore formed by gastrulation
- Develops into incomplete digestive system
- Keeps dividing and form into complete digestive system

**Protostome vs. deuterostome**

- Cleavage is spiral and determinate in protostome development and radial and indeterminate in deuterostome development
- Variation in coelom formation -> both mesoderm form from endoderm
- Fate of blastopore: blastopore forms into mouth in protostome development. Blastopore forms into anus in deuterostome development

**Clade:** an ancestral species and all of its descendants
Ex: Animalia is a clade but sponges are not, they are a grade
Figure 32.11

**Animalia**

- Multicellular organisms
- Don’t have a cell wall -> supported by structural proteins, collagen (important/abundant)

**Most animals have:**

- Tissues -> organs->systems
- Sexual reproduction/gastrulation
- Nerve cell and muscle cell
- Most are chemoheterophs: ingestion via digestive system
- Oxidation of organic molecules to generate provided by outside sources
- Ex: fungi don't have a digestive system

# Animal Form & Function

Thursday, January 06, 2011
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There are approximately 1.7 million species of plants and animals
Animals are diverse, both in their morphology and physiology and in the niches they occupy
In spite of this diversity, they share many features

**Unity and Diversity:** Natural selection has driven the evolution of animals that are well suited to their environment
**Structure and Function:** Structure determines function
Ex: Hemoglobin structure allows it to pick up oxygen and serve its function

**Structural and Function have limits**

- Evolution is constrained by chemistry and physics
- Ex: convergent evolution in fast swimmers and flight -> constrained by the physical properties of water and air
- Figure 40.2

**Size in constrained too**

- Ants are remarkably strong for their small size
- Strength of muscle in animals depends on the cross-sectional area
- Size matters -> smaller - stronger (relative)
- Ex: ant size in proportion to weight lifted

**Contact with the Environment**

- In single celled organisms, such as amoeba, the entire surface is in contact with the environment -> gas is exchanged through diffusion
- As you increase size (animals) cells need to specialize into organs to exchange material with the surrounding environment -> more complex
- Figure 40.3, 40.4

**Tissue Structure and Function**

1. **Epithelilal Cellls**

- Characterized by how many layers of cells in a tissue
- Ex: lungs are single layer of flat cells whereas skin has many layers
- Cuboidal epithelium: kidney tubules, thyroid & salivary glands
- Simple columnar epithelium: intestine lining
- Pseudostratified ciliated columnar epithelium: nasal passage, cilia move mucus along surface
- Stratified squamous epithelium: outer skin, esophagus, anus, vagina
- Simple squamous: blood vessels and lungs. Leaky -> allows for diffusion

2. **Connective cells:**

- Bind and support other tissues
- Loose connective tissues: collagenous, elastic and reticular fibers holds organs in place. cells are very scattered
- fibrous connective tissue: dense with collagenous fibers
- Parallel bundles -> tendons and ligaments
- Bone: mineralized connective tissue
- Cartilage: collagenous fibers embedded in rubbery matrix
- Strong yet flexible -> vertebrae disks
- Adipose tissue: loose connective tissue that stores fat for fuel
- Blood: has liquid extracellular matrix
- Erthrocytes, leucytes platelets

3. **Muscle cells:**

- Responsible for all body movements
- Skeletal muscle: voluntary movement. Bundles of long muscle fibers
- Contractile units called sacromere -> striated muscle
- Cardicac muscles: contractile wall of heart is striated
- Carries out unconscious tasks
- Smooth muscle: lacks striation
- Lines digestive tract and arteries

4. **Nervous cell:**

- Neurons consist of axon and dendrites
- Figure 40.5

**Lumen of stomach**
**Mucosa:** epithelial layer lining lumen
**Submucosa:** matrix of connective tissue containing blood vessels and nerves
**Muscularis:** smooth muscle lining
**Serosa:** outermost layer of stomach

**Organ Systems**
All systems contribute to homeostasis

**Homeostasis:** a steady-state physiological condition of the body

- The body maintains the internal environment within narrow limits required for life
- Temperature, acidity, osmotic potential (solute concentration), concentration of oxygen, food, waste, carbon dioxide

**Interstitial fluid:** fluid that fills the space between cells in an animal. Temperature, pressure, acidity must be maintained so cells can live

- It is the immediate environment that determines the fate of every cell
- Animals do not all maintain every aspect of their internal environment at all times
- River otter is a regulator, bass maintains homeostasis- just not body temperature
- Figure 40.7

**Thermoregulation:** maintenance of body temperature between tolerable range because some proteins only function at certain temperature ranges

- Too cold: for every 10 degrees the rates of most enzymes-mediated reactions decrease by twice or three times
- Too hot: increasing temperature generally increases reaction rates. But many have decreased activity of proteins. At high temperature proteins may denature -> lose secondary and tertiary structures. Membrane may change properties, becoming more fluid
- "warn-blooded" and "cold-blooded" are the wrong terms -> warm most of the time and cold most of the time, warm sometimes

**Endothermic**: organisms for which internal sources provide most of the heat for temperature regulation, while some heat from external.
Ex: humans

**Ectothermic:** organisms for which external sources provide most of the heat for temperature regulation, while some heat from internal
Ex: snakes

**Homeothermic:** organisms that maintain a relative stable and constant body temperature (otter)

**Poikilothermic:** organisms whose body temperature varies with its environment (bass)

How does thermoregulation work? Balancing heat loss and heat gain

1. Conduction: the direct transfer of thermal motion (heat) between molecules of objects in direct contact with each other
2. Convection: transfer of heat by the movement of air or liquid past a surface of body
3. Evaporation: process by which a liquid changes into gas -> removal of heat form surface
4. Radiation: emission of electromagnetic waves by all objects warmer that absolute zero -> all objects

Heat tends to go form a hotter object to a colder one
    Ex: figure 40.10
Metabolic activity can also be a source of heat
    Ex: Figure 40.17

Thermoregulation: controls the exchange and generation of heat

1. Insulation: reduced heat exchange -> fur and feathers
2. Circulatory Adaptations: control the distribution of blood within the body

- Warm: vessels open up and send more blood to skin
- Cold: vessels close up and keep blood away form surface and towards organs
- Counter-current exchange: vessels that run near each other can warm and cool each other.
    - Ex: goose legs

3. Cooing by evaporative heat loss: sweat
4. Behavioral responses: ex: stand I breeze, lizard in sun
5. Adjusting metabolic heat production : figure 40.15

# Animal Nutrition

Tuesday, January 11, 2011
11:30 AM

Animals are chemoheyerotrophs: they must consume organic molecules for energy (chemical energy) and carbon (build)

**Chemical Energy (form food):**
- Required for muscle contraction, nerve resting potentials, protein production, DNA replication
- Comes form carbohydrates, lipid and proteins
- Generate chemical energy through cellular respiration

**Organic Molecules:**
- Organic carbon and nitrogen
- Required for the synthesis of organic molecules such as carbohydrates, lipids and proteins
- We build carbohydrates, lipids and proteins

Animals also require essential nutrients

**Essential nutrients:** substances an organism requires but cannot synthesize
- Essential amino acids
- Essential fatty acids
- Vitamins
- Minerals

1. **Essential Amino Acids**
- Animals requires 20 amino acids to make proteins
- Most animals can synthesize about half of these organic molecules that have nitrogen
- Other must be acquired from food
- Humans require 8 essential amino acids from their diet
- Ex: Figure 41.2

2. **Essential Fatty Acids**
- Animals require fatty acids to make lipids and related molecules (phospholipids)
- Animals can typically synthesize from organic molecules
- Others acquired from diet

3. **Vitamins**
- Organic molecules required from diet in very small amounts
- Typically required for certain enzymes to function -> cofactors
- Ex: vitamin C (ascorbic acid) acts as a cofactor for many enzymes including those that synthesize collagen
- Most animals can produce their own Vitamin C - not humans though

4. **Minerals**
- Inorganic nutrients required in diet in small amounts
- Animals diet must provide mineral

**Summary:**
- Chemical energy
- Organic molecules -> used to build its own
- Essential nutrients -> cant produce their own

**Main stages of food processing**
1. **Ingestion**
   a. Suspension Feeding: -> Ex. Whale Baleen
   b. Substrate Feeders live in the food they eat -> Ex. Earth Worms
   c. Fluid Feeders -> Ex. Mosquito, hummingbird
   d. Bulk Feeders -> Ex. Snakes
- Chemically breaking down food
- Hydrolysis adds a water molecule, breaking bonds
- Into smaller units that individual cells can pick up
- Carbohydrates, disaccharides, poly saccharine -> monosaccharide's
- Sucrose, lactose, maltose -> glucose, fructose
- Proteins, polypeptides -> amino acids
- Collagen, insulin -> valine, serine, lysine
- Lipids, fats, oils -> glycerol, fatty acids
- Nucleic acids, DNA, RNA -> nitrogenous bases, monosaccharide's, phosphates

2. **Digestion**
3. **Absorption**
4. **Elimination**

**Intracellular vs. Extracellular**
- Intracellular: food brought onto cell by endocytosis (by vesicles)

- Extracellular: food digested outside of cell and then transported in-absorption
- Figure 6.14

**Porifera**
- Covered by epidermis
- Underneath is a gel layer -> mesophyl
- Spicules -> like sponge skeleton
- Inside are choanocytes
- Figure 33.4

**Hydra Digestive System**
- Has incomplete digestive system -> food enters and waste exits through the same opening
- Intracellular and extracellular digestion
- Figure 41.8

**Nematoda**
- Has complete digestive system
- All bilateria (not including platyhelminthes) have complete digestive systems and rely in extracellular digestion

**Human Digestive System**
- Figure 41.10

- **Oral Cavity:** teeth, tongue, salivary glands
- Figure 41.11
  - **Teeth:** cut, smash, grind food
    - Breaks off pieces of food to be ingested
    - Increase surface area available for digestion
  - **Tongue:** manipulates food and forms into bolus
  - **Saliva**
    - Amylase: enzyme that hydrolyzes starch and glycogen into small polysaccharides and the disaccharides maltose
    - Mucin: slippery glycol-protein (carbohydrate-protein complex) lubricates bolus and pushes it to pharynx
      - NB. Pharynx opens into nasal cavity and glottis
    - Peristalsis: muscles that relax and contract -> passes food down
- **Stomach:**
  - Figure 41.12
  - Sphincter at either end
  - Folds of epithelial tissue
  - Can hold up to 2L
  - Gastric glands release gastric juice

- **Three kinds of stomach cells:**

1. **Chief Cells:** produce and release pepsin (a digestive enzyme) which hydrolyzes proteins into smaller polypeptides
2. **Parietal Cell:** release HCl, disrupts extracellular matrix and cell walls, activates pepsin
3. **Mucus cells:** produce mucus, protects stomach lining from HCl and pepsin -> peptic ulcer

- **Gastric Glands Produce:**
  - Pepsin (gastric juices)
  - HCl (gastric juices)
  - Mucus

- **Stomach summary**
  - Break up tissue
  - Start protein digestion
  - Kills bacteria
  - Stores food because rest of digestive system can't handle large amounts of food

- **After the stomach**
  - Muscle churn stomach contents -> chyme: watery mixture
  - Chyme goes to first part of small intestine -> duodenum
  - Chyme is very acidic and duodenum lining is not very protected, therefore, pancreas come in

- **Pancreas:** releases pancreatic juice into duodenum

- **Pancreatic Juice:**
  - Has bicarbonate that neutralizes the acidity of chyme
  - Trypsin and chymotrypsin -> are the enzymes that continue further digestion of proteins
  - Nucleases: hydrolyzes nucleic acids into nucleotides
  - Lipase: hydrolyzes lipids into glycerol, fatty acids and monoglycerides

- **Liver:** produces bile (nit an enzyme)
  - Extra bile is stores in the gall bladder
  - Bile: emulsifies lipids -> acts like a soap and breaks up lipids
  - Big lipid droplets are broken apart

- **Small Intestine:**
  - Main function is to absorb nutrients from chyme
  - Is lined with the same cells that line the stomach
  - Peristalsis is at work here like in esophagus
  - Has many folds and villi covered with epithelium
  - Microvilli are in contact with the chyme -> maximizes surface area -> ~300m2
  - Transport across epithelial cells through active transport or facilitated diffusion in blood depending on the nutrient
  - Lipids are passed to the lymphatic system
  - Small intestine is ~6m in length
  - Duodenum: 25cm (where rest of digestion takes place)
  - Jejunum: absorption
  - Ileum: absorption
  - Figure 41.15

- **Duodenum:**

1. Produces saccharides which hydrolyze polysaccharides and disaccharides into monosaccharide's
2. Peptidase: hydrolyzes polypeptides and dipeptides into amino acids
3. Other enzymes: hydrolyzes nucleotides into nucleotide bases, sugars and phosphates
4. Figure 41.13

- **Large Intestine:**
  - Made up of: colon, cecum, appendix, rectum
  - Peristalsis continues

1. **Colon:** absorbs water from chyme, ~ 7L of water in secreted into chime
2. **Cecum:** reservoir of bacteria
3. **Appendix:** little function
4. **Rectum:** stores wastes called feces, undigested material like cellulose fiber, bacteria

# Circulation

Thursday, January 13, 2011
11:30 AM

**Homeostatsis**: each cell must exchange material with its immediate environment. Recall: thin double layer of cells in amoeba vs. complex animals with systems

**Contact with the Environment:**

- Porifera don't have and internal environment to worry about
- Don't have circulatory system
- Nematoda, Cnidaria, corals, hydra, jellies don't have circulatory systems
- They do have gastrovascular cavities
- Branches into hydra tentacles and jellies and platyhelminthes
- Allows for easier exchange with external environment (maximizes surface area) -> still not circulatory system

**A more efficient system**

- Open circulatory system: pump interstitial fluid in one direction, like a pipe (recall: animation)
- Closed circulatory system: or use separate fluids -> blood composition is different form that of the interstitial fluid while the interstitial fluid between cells stays in place
- Figure 42.3

**Open Circulatory System**

- Fluid is not so specialized
- Hemolymph: circulatory fluid found in open circulatory systems. It is also the interstitial fluid. Animal like arthropods and mollusks have open circulatory systems in which their organs are bathes (hemolymph)

**Closed Circulatory System**

- The main mover of blood is peristalsis
- Annelida, humans, and cephalopods have closed circulatory systems

**Circulatory System Plumbing 101**

**Heart:** pumps blood

- Atrium recieves blood
- Ventricle pumps blood out of heart

**Blood Vessels:** conducts blood through the body

- **Artery:** carries blood from the heart. Typically carries oxygenated blood
- **Vein:** carries blood to the heart
- Capillaries allows exchange between blood and surrounding tissues
- **Artery:** arteriole (smallest) carries blood from an artert to capillaries
- **Vein:** venule (smallest) carries blood from capillaries to a vein
- **Portal:** carry blood from capillaries to capillaries
- Ex. Hepatic portal vein

**Direction of Blood Flow**

- Heart -> Arteries -> Arterioles -> Capillaries -> Venules -> Veins -> Heart
- Figure 42.4, 42.5

**Organization of Circulatory System**

- Ex. Figure 42.4

**Single Circulation in Fish**

- Bony fish, rays and sharks have a two chamber heart
- Blood passes through heart one a circuit
- Two chambered heart: an atrium and a ventricle
- Oxygen and carbon dioxide exchanged through gills ->systemic circulation
- Drop in blood pressure when passing through capillaries -> limits rate of blood flow

**Double Circulation in Vertebrates**

- Has two distinct circuits: pulmonary and systemic circuits
- Provides more efficient flow of blood to brain, muscles, organs because heart repressurizes the blood after passing through capillaries
- Figure 42.5

**Amphibians:** three chambered heart

- Two atria and one ventricle
- Is advantageous to them, but there is still some mixing of blood
- They are still able to exchange with environment through their skin when under water and blood continues to flow

**Reptiles:** Three "and a half" chambered heart

- Reply exclusively on their lunges
- Have a bypass system - right systemic aorta - when under water blood continues to flow -> skips pulmonary circuit
- Dividing septum that separates ventricles

**Mammals and birds:**

- Four chambers: two atria and two ventricles
- Left side receives blood and pumps only oxygenated blood
- Right side receives and pumps only deoxygenated blood
- Supports the endothermic way of life of mammals and birds (ie fish lose mush less heat than mammals do. They need efficient system to be able to move quickly)

**Mammalian Circulation:** The two circuits function simultaneously

1. Right ventricle contracts and pumps blood to lung via
2. Pulmonary arteries
3. Blood flows through capillary beds in lungs and loads up with oxygen
4. Blood returns via pulmonary veins and flows to left atrium
5. Blood flows into left ventricle
6. Blood leaves heart through aorta which branches and leads to arteries throughout body a) forelimbs/head b) organs legs
7. Then capillary beds where diffusion of oxygen into tissues and carbon dioxide is produced by cellular respiration
8. Capillaries -> venules -> veins -> inferior and superior vena cava
9. Blood flows to right atrium then into right ventricle -> lungs
10. Figure 42.6

**Mammalian Heart**

- Atrioventricular valves prevent blood from flowing from the ventricle to atrium
- Semilunar valves prevent blood from flowing from artery to ventricle
- Figure 42.7
- The heart is self-activating
- Figure 42.8 and 42.9

**Blood Vessel Structure and Function**

- Capillary: one layer of squamous cells
- Has precapillary sphincters that regulate blood passage
- Blood flows slowly through capillaries which allows more time for diffusion
- Figure 42.12, 42.11 & 42.15
- Arteries: blood flows freely (pump from heart)
- Veins: have valves along them to force blood back to heart
- Figure 42.14
- The concentration of blood is higher than that of the interstitial fluid
- The pressure in blood is higher than that of the interstitial fluid
- There is a tendency for water to diffuse from high concentration to low concentration -> net movement of water form blood into interstitial fluid
- Figure 42.15 & 42.16

Osmosis -> <- Pressure

- While blood pressure tends to drive fluid out of capillaries, the presence of blood proteins tends to pull fluid back into capillaries
- These proteins are too large to pass through the membrane

**Blood Composition**

**Plasma**

- 55% of blood -> thicker than water
- Contributes to blood's viscosity
- Water: surrounds cells in blood - they are suspended in plasma
- Ions: maintain osmotic balance, pH buffering, regulation of membrane permeability
- Plasma proteins: albumin, fibrinogen, immunoglobulin
- Involved in: osmotic balance, pH buffering, clotting, defense, (albumins involved in transport)
- Substances transported by blood: nutrients, waste, respiratory gases, hormones
- Figure 42.17

**Cellular Elements**

- 45% of blood
- Erythrocytes (RBC) -> majority of blood cell composition
- They transport oxygen and carbon dioxide
- Their form is related to their function -> maximizes surface area
- Leukocytes (WBC): defense and immunity
- There are five major types of white blood cells
- They are also found outside the circulatory system, in the interstitial fluid

- Platelets (throbmocytes): blood clotting
- Cells produced in bone marrow
- Figure 42.19

**Platelets**

- Specialized cells are derived from the stem cells
- Serve both a structural and molecular function in blood clotting
- Vessels are lines with endothelium tissue
- Platelets can be very sticky -> stick to damaged blood vessels

**Process:**

1. Endothelium is damaged and connective tissue in vessel wall is exposed. Stick to collagen fibers in connective tissue when it is exposed via injury -> triggered clot
2. Platelets for a plug that provided emergency protection against blood loss
3. seal is reinforced by a clot of fibrin

- **Clotting** factors form, which then forms the cascade
    1. Platelets
    2. Damaged Cells
    3. Plasma

- **Cascade:** factors produce more and more thrombin -> which converts fibrinogen into fibrin (active form) -> fibrin clot (network)
- Cascade starts as platelet plug is forming
- Hemophilia -> disease characterized by excessive bleeding
- Figure 42.18

# Gas Exchange

Thursday, February 10, 2011
1:31 PM

- Organisms exchange gases with the environment
- Not necessary in simple organisms like Porifera, Nematoda, Cnidaria, platyhelminthes
- Ex: Annelida (marine worm) has a large surface area. Folds or body segments which function as gills, increase contact with water, and serve in crawling and swimming

**Gills:**

- Greatly increase surface area
- Ex: Arthropods: lobster/crayfish use water flow through feathery gills under exoskeleton -> appendages drive water over the gill surfaces under shell
- Sea stars have tubular projections that act as gills -> use tube feet as well
- Molluska (snail has internal gills like lungs)
- Figure 42.21

**Insects don't have gills**

- Arthropods -> deliver air to tissues through a tracheal system
- Use openings called spiracle to send air to the tubes and then to the rest of body
- Their circulatory system delivers just nutrients, not gases
- Figure 42.23

**Chordate have a respiratory system**

- Have gills on either side suspended in water -> increases surface area in contact with water
- Ex: Fish open and close mouth to pass water through gills using the operculum (gill cover) -> this forces the water through the gills when mouth is closed
- Use countercurrent exchange as blood flows through gill filaments
- Exchange a fluid
- Get a lot of oxygen form water transferred to blood -> maximize efficiency
- Oxygen diffuses into blood that runs through gill filaments
- Figure 42.22

**Human Respiratory System**

Terms: Figure 42.24

- Nostrils
- Nasal Cavity
- Pharynx
- Oral Cavity
- Esophagus
- Glottis
- Larynx
- Epiglottis (closes off the glottis)
- Trachea (surrounded by cartilage rings for support)
- Bronchus
- Lungs
- Bronchial Tree
- Bronchioles (soft walled surrounded by muscle tissue)
- Alveolus

**Functions:** conduct air, filter, warm, humidify

- Bacteria can get stuck in the mucus of nasal cavity
- Warms so that the heart can function properly
- Humidify because surfaces of alveolus are moist for efficient gas exchange
- Bronchioles adjust air flow to alveolus where gas exchange occurs

**Fick's Equation of Diffusion:**

$$Q = \frac{DA \times (P_1 - P_2)}{L}$$

- Q is the rate of diffusion -> maximize
- D is the diffusion coefficient -> moist surface
    - (depends in the medium, molecules involved -> how readily substance occur)
- A is the surface are diffusing across -> many small alveoli
- P's are partial pressure of the substance -> breathing
- L is the length across which diffusion must occur -> simple squamous epithelium

**Partial Pressure:** the pressure exerted by a particular gas in a mixture of gases

Ex: air pressure 760mm Hg

21% oxygen

$P(O_2) = 21\% \times 760mm\ Hg = 160mm\ Hg$

- Inhaled air 160 units of oxygen partial pressure
- Exhaled air 120 units of oxygen partial pressure
- Concentration of $O_2$ 104 units in alveolus
- Oxygen leaves alveolus and diffuse into blood 104 units
- Blood entering tissues 100 units
- Low concentration in these tissues (40) -> concentration of oxygen delivered back to lungs
- In alveolar capillaries: $O_2$ 40, $CO_2$ 45
- Concentration $CO_2$ is around 40 in alveoli

- About 97% of the oxygen carried in blood is bound to hemoglobin
- About 23% of the $CO_2$ carried in blood is bound to hemoglobin
- About 70% of $CO_2$ transported by blood has reacted with water to form carbonic acid

- The concentration of $CO_2$ in the blood affects acidity (more $CO_2$ = more acidity) which affects the amount of $O_2$ carried by hemoglobin
- Shifting in acidity helps release or pick up oxygen
- Figure 42.29, 42.27

**Control Mechanism:** monitors the level of $CO_2$ in blood which monitors $O_2$ levels

- Medulla Oblongata
- Pons
- Aorta, Carotid arteries -> nerve impulses relay changes in $CO_2$ and $O_2$ concentrations
- Breathing control centers -> nerve impulses trigger muscle contractions

**Diaphragm**

- Diaphragm contracts and relaxes
- Increase volume of chest cavity -> more room for lungs to expand and pressure in lungs is less than exterior pressure and air flows in
  - Ex: collapsed lung interferes with pressure in lung
- Figure 42.25
- Diaphragm and muscles between ribs help respiration

**Typical Volume of Air in Lungs**

- Typical inspiration 2.7 L air in respiratory system
- Typical expiration 2.2 L air in respiratory system
- Forced expiration 1.2 L air in respiratory system
- Tidal volume is the amount of air inhaled/exhaled in each breath
- It is approximately 500mL -> this mixes with the 2.2 L that is already in the lungs. This is why the concentration of $O_2$ in alveoli is so low compared to the $O_2$ concentration in the air we breathe

**Bird Respiratory System**

- Doesn't draw air into lungs -> they are rigid (air tubes)
- They inhale air into a set of sacs towards the rear of the animal completely replaces the air in lungs - unlike us
- They maintain a much higher partial pressure $O_2$ in their lungs because rate of diffusion is directly proportional to difference in partial pressure -> efficient
- Figure 42.26

# The Immune System

Thursday, January 20, 2011
11:30 AM

**Innate Immunity:** rapid (constant) response to a broad range of microbes -> almost anything that tries to invade body

1. **External Defenses (Barrier Defenses):** Skin, Mucous membranes, secretions
2. **Internal Defenses:** Phagocytic cells, antimicrobial proteins, inflammatory responses, natural kill cells

**Acquired Immunity:** slower response to specific microbes (not enforced all then time)

- Restricted to chordates and vertebrates
- Humoral response (antibodies)
- Cell-mediated response

**Innate Immunity:** found in all animals

**External Defenses:**

- Physical barriers like skin lining of trachea
- Chemical barriers like lysozymes in tears, mucous, saliva, HCl in gastric juices
- Produces a small preset group of receptor proteins
  - Pathogens recognition
  - Detect broad range

**Internal Defenses:**

- Immune cells respond to molecules on fungi and bacteria that are not found in the cell
- Important to distinguish self from non-self by detecting molecules (proteins) that are unique to theses invaders -> Ex: cell walls of bacteria
- Phagocytic cells: hemocytes in hemolymph of insects -> Figure
- Antimicrobial proteins: circulate through body
- Inactivates of kills bacteria, fungi, etc

**Innate immunity of vertebrates**

- Physical barriers
- Chemical barriers
- Phagocytic barriers
- Antimicrobial proteins

**Internal Defenses**

**Phagocytic cells:**

- **Leukocytes:**
  - **Neutrophils:** most common 60%-70% of leukocytes
  - **Monocytes:** 3%-8% of leukocytes
    - Develop into macrophages -> some take up residence in various tissues
  - **Eosinophils:** 2%-4% of leukocytes
    - Enter parasitic worms and release destructive enzymes
- **Dendritic Cells:** involved in acquired immunity

**Other internal defenses that don't involve phagocytosis in vertebrates:**

- **Leukocytes**
  - **Basophils:** (inflammation)
  - **Lymphocytes:**
    - **T-Cells** -> acquired immunity
      **B-Cells** -> acquired immunity
  - **Natural Killer Cells:** destroy self cells (invaded cells (cancer))

**Antimicrobial Proteins:**

- Interferons are releases by infected cells -> trigger anti-virus defenses
- Complement system -> cascade of reactions that creates holes in the plasma membrane of invading cells

**Inflammatory Response:** when skin is damaged and bacteria enters, inflammatory response can be triggered

- Macrophage start phagocytosis
- Mast cells respond and release histamine -> increases blood flow to the area
- Increased permeability of capillaries -> redness, heat, swelling
- Blood clotting elements -> blood clot prevents further blood loss and infection
- Histamine attracts the monocytes and neutrophils to leave capillaries and engulf bacteria (help original macrophages)
- Figure

**Acquired Immunity**

- Unique among animals

- Integrated with innate immunity

**Lymphatic System:** functions in draining fluids

- As blood flows through capillaries, net movement of water out of vessel, and lymphatic capillaries accumulate fluid (now called lymph) and drains into lymphatic vessels
- Lymphatic vessels have valves, and lymph is forced through the lymphatic system

**Thoracic Duct:** dumps lymph into a major vein - vein because pressure is lower than in arteries

**Spleen** (separate from Lymphatic system): packed with lymphocytes and macrophages

- Stores lymphocytes, erythrocytes and throbmocytes (platelets)
- Removes warn out erythrocytes -> globins and iron from hemoglobin are recycled ; heme groups are converted into bilirubin is removed from the blood by the liver

**Bilirubin:** modified, excreted into biles

- Jaundice is excess bilirubin in the blood
- Is responsible for the yellow color in bruises
- Breakdown produce gives feces its brown color
- Bilirubin is also removed from the blood by kidneys and is responsible for the yellow color of urine
- Acts as a lymph node

**Lymphocytes:**

- B cells and T cells
- Both start in the bone -> Figure
- Lymphoid cells produced in bone marrow -> B cells
- Some lymphoid cells leave bone marrow and travel to thymus -> develop into T cells
- B cells and T cells have antigen receptors -> proteins embedded in protein membrane
- Antigen binding sites is very specific -> sticks to particular epitopes on antigen
- Each lymphocytes (B or T cell) has about 100 000 antigen receptors on its surface (all the same)
- Each human has about 1 000 000 different B cells and about 10 000 000 different T cells (each with a different antigen receptor with a different antigen binding site)
- Reason for variation
    - Figure
    - Deletion of DNA

**Antigen Binding Site**

- Is chemically sticky to specific molecules -> the right shapes must fit
- Functionally, T cells only bind to antigens that are presented by other cells to them
- MHC (major histocompatibility complex) produces a host cell protein that can present an antigen fragment to T cell receptors -> only way T cell will respond
- Figure 43.11

**Helper T Cell:** rapid division after contact with an antigen (presented in an MHC by phagoocytic cell). Helps to activate cytotoxic T cells and B cells

**Cyotoxic T cells:** a response to infected cell (virus)

- Cytotoxic T cells make CD4 (surface protein) that enhances binding
- Activated cytotoxic T cells secrete proteins that initiate destruction of target cells
- Attack host cells that are cancerous or infected by viruses
- Are activated by helper T cells and antigen presented by cancerous or infected cell
- Secret proteins that rupture the plasma membrane of self cells -> restricted to specific are
- Figure 43.14

**B Cells:** a response to extracellular pathogens

- B cell antigen receptors can bind to antigens that are free or on a pathogen
- Secretion of antibodies by B cells -> humoral response: an activated B cell gives rise to a clone of thousand of plasms cells which secret antibodies
- B cells that differ in antigen specificity divide -> five major antibody classes differ in their distributions and functions within the body
- Binding of antibodies to antigen on the surface of pathogens leads to elimination of microbes by phagocytosis and complement-mediated lysis
- After division some become memory cells and plasma cells -> antigen receptors are released into the lymph (plasma cells secrere a soluble form of antigen receptors) -> theses are called antibodies

**Antibodies:** anywhere in your body where antibodies comes into contact with that antigen they will stick to it and inactivate antigens by:

1. Viral neutralization
2. Agglutination of antigen-bearing particle, such as microbes
3. Precipitation of soluble antigens -> these enhance phagocytosis
4. Activation of compliment system and pore formation -> causes lysis

- Plasma cells -> function when needed and then disappear
- Antibodies circulate all the time
- When sick, you rpoduce more antibodies in your blood
- In exposed to same virus later on, memory cells increase the chance of B cells producing the exact right antigen -> virus is dealt with very quickly
- Different viruses require different antibodies to fight them

**Allergies**

- Antigens called allergens
- IgE take up residence on mast cells and stays there -> makes cell more sensitive to particular antigen -> antibodies triggered response
- Become hypersensitive and mast cell releases too much histamine which causes swelling

- Autoimmune disease -> immune reaction to your own body
- Vaccination -> memory cells
- Inject antigen from virus and gets into lymph notes and triggers memory cells -> can mount a really strong response if exposed to virus in future - booster shots to ensure that antigens last

# Osmoregulation and Excretion

Tuesday, January 25, 2011
11:30 AM

**Osmoregulation:** regulation of solute concentration and water balance by a cell or organism. Part of homeostasis -> cells can burst or lyse

**Excretion:** the disposal of nitrogen-containing metabolites and other waste products

**Osmoregulation:** is synonymous with tonicity - concentration of solute

- **Isoosmotic:** isotonic - same concentration
- **Hyperosmotic:** hypertonic - higher concentration of solute
- **Hypoosmotic:** hypotonic - lower concentration of solute

- **Osmoconformer:** animals that are isoosmotic with their environment - total solute concentration is the same as external environment
- Osmoregulator: animals that control their internal osmoregularity independently from their external environment -> takes a lot of energy to maintain
- Stenohaline: organisms that cannot tolerate substantial changes in external osmolarity
- Ex: goldfish in salt water would die
- Euryhaline: organisms that can tolerate changes in external osmolarity

- Most marine animals are osmoconformers -> sponges, chordates - body tissues are hypoosmotic to sea water

Salt water fish constantly loosing water via osmosis - water diffuses outside of fish

- Excretion of salt ions and small amounts of water in scanty urine from kidneys to
- Gain water and salt ions from food and by drinking sea water
- Excretion of salt ions from gills

Condrichthyes: slightly hyperosomotic in sea water

- High levels of urea in body fluids
- Must protect against toxic urea

**All freshwater animals are osmoregulators**
- Body tissues are hyperosmotic in fresh water
- Porifera have contractile vacuoles
- Cnidaria use gastrovascular cavity to excrete extra water (so water doesn't continue to diffuses into their cells)
- Chordates: body tissues are hyperosmotic to fresh water
- Osmotic water gain through gills
- Uptake water from environment and through eating -> excrete very dilute urine form kidneys
- Gills uptake salt ions via active transport into blood

**Terrestrial animals are osmoregulators**
- Arthropoda has an exoskeleton to prevent excess loss of water from body excretory system
- Mollusca: shell, mucus, excretory system
- Chordate: skin, excretory system, etc

**Terrestrial animals must obtain water:**
- Metabolic water via cellular respiration generate water
- Drink it -> cannot drink salt water
- Exception: the albatross has salt glands and uses counter current system to drink salt water
- Figure hydrated Tardigrade

**Excretory System**
- Disposal if metabolic wastes is important in osmoregulation
- Nitrogenous wastes: typically come form breaking down proteins and amino acids
- Amino acids and nitrogenous bases -> mammals, many reptiles and sharks remove amino acid groups ($-NH_2$) to yields ammonia, urea and uric acid -> wastes that include nitrogenous wastes
- Figure 44.9
- Ammonia is toxic at low concentrations. It is flushed from body with copius water
- Urea requires energy to produce; it is less toxic -> tolerate higher concentration in body
- Requires less water to flush urea out
- Uric acid requires more chemical energy to produce (more than urea)
- It is insoluble in water
- Excreted as a paste without water (doesn't take any water with it)
- Sponges don't have excretory system -> use diffusion

**Most animals have excretory system**

- Filter process -> useful molecules are stripped from filtrate form blood - and waste stripped from blood into filtrate
- Flatworms use diffusion as well
- **Protonephridia:** pumps body fluid out, reclaim useful molecules, osmoregulation

**Annelida:** metanephridium pump body fluid out, reclaim useful molecules excretion and osmoregulation

- Take up water via osmosis from earth
- Have a coelom -> diffuse into tubular system

**Arthropoda:** Malpighian tubule takes up excreted nitrogenous wastes -> squeezed out into rectum

- Wastes and other ions pumped out
- Water follows by osmoregulation
- Most ions and water reclaims
- Excretion and osmoregulation

**Humans:** renal artery and vein supply blood to kidneys

- Kidney produces urine
- Ureter: empty into urinary bladder -> stores urine (has sphincters)
- Exit through urethra
- Kidney surround by renal capsule (protection) -> inside is renal cortex -> inside is renal medulla (has collecting ducts that empty into pelvis -> 1 000 000 nephrons attached to collecting ducts) -> center of kidney is renal pelvis (hollow space that empties out into ureter)

- **Nephrons figure:** Glomerulus, Bowman's Capsule, proximal tubule, loop of Henle (descending and ascending limb), distal tubule (empties into collecting duct)
- Filtrate (contains small molecules) is forced out of glomerulus and continues along

**Figure 44.14 & 44.15**

- Filtrate is blood plasma with salt, urea, amino acids, acid (everything but cellular components
- Interstitial fluid in medulla is hypertonic
- Tube is very permeanle to water -> diffuses into medulla
- It is impermeable to salt/ions
- Goes up ascending limb -> here membranes are permeable to salt (from filtrate to medulla) and impermeable to water -> NaCl pumped out -> use of energy
- Control mechanisms to maintian homestasis - reclaim useful molecules
- Left over makes its way to collecting duct -> urine
- Urea is in the filtrate (don't want to reclaim it) it becomes more concentration so diffuses into medulla
- Figure 44.16 (don't need to know concentrations)
- Descending -> concentrations increases progressively, as ascending, actively pump out solute to keep high concentration solute in medulla
- Goal: flush out urea with minimal water loss
- Figure 44.6

# Hormones and the Endocrine System

Thursday, January 27, 2011
11:30 AM

**Chemical Signal:** a molecule released by one cell that may influence the activity of another cell
**Local Regulator:** the molecule travels a short distance through the interstitial fluid, the cell influenced is nearby

**Neurotransmitter**
- **Paracrine Signal:** histamine, cytokines, growth factors, nitric oxide, prostogladins, interleukins, adenosine diphosphate (platelet activation)
- **Autocrine Signals:** cell release a chemical that affect the cell itself

**Hormone:** a molecule that travels through the circulatory system; the cell influenced may be far away
**Pheromone:** the molecule is released by the organism into the environment; the cell influenced is in another organism

**Hormone**
- Can be polar or nonpolar
- Steroid (modifications of cholesterol - are nonpolar) or anime/polypeptide/protein (can be polar)

**Receptor Proteins:**
- Required for a cell to respond to a chemical signal (hormones can't act on their own)
- Very specific Figure 45.6
- Different cells may respond differently to the same chemical siganl
- Ex: three different responses to epinephrine
- Found in plasma membrane or intracellular
- Figure 45.5
- Change achieved through signal transduction

**Signal transduction:** the linkage of a mechanical, chemical, or electromagnetic stimulus to a specifc cellular response

Figure

- Involves secondary messengers se Figure 45.6
- Ex: cAMP is a very common second messenger
- Triggers chemical cascade response glycogen -> glucose -> released into blood
- 1 molecule of epinephrine can trigger the release of about 100 million molecule of glucose
- $Ca^{++}$ is very common too

**Endocrine System**
- Is what uses these hormones - hormone system
- Endocrine glands: a ductless gland that secrete hormones directly into the interstitial fluid, form which they diffuse into the bloodstream
- Coordinating the activity of cells in different parts of your body Ex: Figure 45.13 -> hormones released by brain (brain hormones) involved in this process
  - Ecdysone is released when organism is ready to molt
  - Juvenile hormone

**Human Endocrine System**
- Pineal Gland
- Hypothalamus & Pituitary
- Thyroid Gland
- Parathyroid Glands
- Adrenal Glands
- Pancreas
- Reproductive System

**Hypothalamus and Pituitary** (master of endocrine gland) - extension of the brain
- Release many hormones
- Some influences other endocrine
- Figure 45.14 & 44.15

- They are integrated
- Some cells extend form hypothalamus to posterior pituitary
- Posterior and anterior pituitary -> hormones produced in hypothalamus
- Released hormones - two major important: ADH and Oxytocin Figure 45.15

ADH = antidiuretic hormone = vasopressin
- Polypeptide (9a.a.s)
- Released in response to increased osmolarity of plasma

- **Receptors:**
  - Distal tubules of nephridia -> increase permeability to water -> increased re-absorption of water from filtrate
  - Collecting duct of nephridia -> increased permeability to water and urea -> increased re-absorbance to water and urea
  - Thick ascending limb of loop of Henle or NaOH -> increased active transport or sodium form filtrate -> increased re-absorbance of salt
  - Figure -> ADH released by posterior pituitary -> hormonal control of excretion in humans NEGATIVE feedback
  - Osmoreceptors in hypothalamus -> stimulus
  - Drinking reduces blood osmolarity
- Hypothalamus (posterior pituitary) -> oxytocin -> muscles of uterus
- Contraction -> pressure on cervix -> mechanoreceptors send signal to hypothalamus. Cause pituitary to release more oxytocin POSITIVE feedback
- Releases hormones -> are carried to the anterior pituitary -> responds and releases other hormones under control of hypothalamus

**Hormones to Remember:**
**Antagonistic Hormones:**

- **Thyroid and Parathyroid Glands:**
  - Maintaining blood calcium levels -> solute part of solute concentration in blood Figure 45.20
  - Homeostatis: bones store calcium used to maintain Ca levels in the blood
  - Kidneys are also sensitive to PTH (hormone) -> invoved in controlling kidney activity
  - Low Ca levels -> kidney work extra hard to recover Ca (reduce loss)
  - Hihgh levels of Ca in blood -> thyroid released Calcitonin
  - Secretin and Gastrin
  - Table 45.1

# Animal Reproduction

Tuesday, February 01, 2011
11:30 AM

**Terms to Define:**

- **Zygote:** the diploid cell that results from the fusion of two gametes
- **Gamete:** a haploid (one allele at each locus) reproductive cell that fuses with another such cell to form a zygote
- **Egg:** a relatively large and non-motile gamete
- **Sperm:** a relatively small, generally motile gamete
- **Sexual Reproduction:** involves the fusion of two gametes to form a zygote
- **Asexual Reproduction:** doesn't involve the fusion of two gametes to form a zygote

**Asexual Reproduction:**

1. **Fission** (like in sea anemone)/ **Budding** (unequal splitting like in hydra)
    - Figure 46.2
2. **Fragmentation** (starfish get a limb cut off and grows new one from this single fragment)
3. **Gemmules** (the organism, not the process) are packages of cells spurted out by a sponge that settle and proliferate
4. **Parthenogenesis:** animal produces gametes, but they don't fuse with anything
    - Ex: Queen bees produce unfertilized eggs -> develop into a mature organism
    - The mature organism may be haploid -> haploid bees are always male and diploid are always female. Males can produce gamete via mitosis

**Sexual Reproduction**

**Hermaphrodite:** each individual is both male and female

1. **Sequential Hermaphrodite:** and individual is one sex at a time, but may change sexes
    - Ex: clown fish are all born males -> largest make in the group may turn female
2. **Simultaneous Hermaphrodite:** each individual is both sexs at the same time
    - Ex: like earth worms -> upon mating, both become pregnant

**Selfing:** an individual mating with itself
**External Fertilization:** the egg and sperm fuse outside of the body
**Internal Fertilization:** the egg and sperm fuse inside of the body

**Reproductive Organs:** present or absent
Ex: Sponges don't have sexual organs but can reproduce sexually

**Gonads:** gamete-producing organs
Ex: Figure 46.8

**Investment in reproduction:** two extremes (intermediates too)

1. **Low investment in each offspring** -> many offspring (Mortality tends to be high)
2. **High investment in each offspring** -> few offspring (Higher chance for success)

**Variable investments**

- **Gametes:** size, nutrients, protection
- **Embryos:** nutrients, environment, protection (Ex: Shell)
- **Young:** nutrients, environment, protection, culture

**Time Constraints**

- In most animals mating is restricted to certain times
- Timing may be controlled by: temperature, day light and rainfall

**Why Sex? Why have sexual reproduction evolved?**

**Disadvantages of Sexual Reproduction:**

- When sexes are separate, fewer offspring tend to be produced
- You reduce the rate of reproduction -> only half species can reproduce
- When sexes are separate, a mate must be found

**Advantages of Sexual Reproduction:**

- Alleles are mixed -> novel combinations of alleles are generated
- Deleterious alleles may be removed from useful alleles
- Useful alleles may be combined

**The Human Reproductive System:**
Figure 46.10

- Ovaries (gonands are the ovaries) -> where meiosis begins
- Oviduct (fallopian tube)
- Uterus (very small opening form oviduct to uterus)
- Uterine Wall -> relative;y thivk muscular wall

- Lined with endometrium
- Cervix (base of uterus)
- Vagina (also birth canal)
- Labia minora
- Labia majora
- Clitoris (prepuce, glans, shaft)
- Testes (gonads)
- Scrotum (contains testes)
- Epididymis (collects sperm form testes)
- Vas deferens
- Seminal vesicles
- Ejaculatory duct (delivers fluid/sperm to prostate)
- Prostate (urinary bladder sits on top of prostate, produced fluid which contributes to semen)
- Urinary duct (also goes into the prostate)
- Urethra
- Bulourethral gland
- Erectile tissues (network of blood vessels)
- Glans penis
- Prepuce (foreskin)

**Human Spermatogenesis**

Figure 46.12

- Controlled by hormone -> flows from hypothalamus to anterior pituitary and releases more hormones (FSH) -> encourages spermatogenesis
- And LH (a steroid hormone) -> signals cells to release testosterone

**Testosterone has 2 Effects:**

1. **Encourage Spermatogenesis:**
2. **Responsible for Primary** (growth of penis) and **secondary** (changes in puberty) **sexual characteristics** (particularly during growth and development) Levels are controlled by negative feedback -> pituitary and hypothalamus are both sensitive to testosterone

   Figure 46.13

Figure 46.14

- FSH and LH acts on ovary -> stimulates follicle dev. And Estradiol levels increase
- Estradiol is released and inhibits pituitary form released too much FSH and LH
- High levels of Estradiol = more FSH -> positive feedback

**Ovulation**

- Complex interplay of hormones
- If nor pregnancy results -> cycle restarts
- Ovulations -> pregnancy will result
  1. **Ovulation**
  2. **Fertilization**
  3. **Cleavage**
  4. **Blastula forms**
  5. **Implants into endometrium**
- From ovulation to implantation -> hormone released -> signals lining to no break down
- Embryo grows 3 trimesters of development
- During growth receives resources form mother
- Smooth muscle surrounds foetus
- Umbilical cord is part of the foetus -> attached to the placenta (embedded in endometrium)
- Placenta is made up of mother's tissue and foetus -> see Figure
- Blood doesn't mix but come into very close contact -> diffuses into foetus (nutrients and oxygen)

- Oxytocin plays a role: released by posterior pituitary
- Present before labor -> triggers contractions (receptors on uterus)
- Receptors become more sensitive towards end of pregnancy -> causes contractions (positive feedback loop)

**Human Birth:**

1. **Dilation of the cervix:** baby is pushed down by uterus and squeezes through cervix
2. **Expulsion:** delivery of the infant
3. **Delivery of the placenta:** umbilical cord is tied off and cut

# Animal Development

Thursday, February 03, 2011
11:47 AM

1. **Fertilization**

- **The sperm finds the egg**
  - Sperm is attracted by signal molecules (species-specific) released by egg
- **Acrosomal reaction**
  - Sperm contacts the egg
  - Sperm acrosome releases hydrolytic enzyme
  - Hydrolytic enzyme digest jelly coat of egg
  - Acrosomal process adheres to species-specific sperm-binding receptor protein in egg plasma membrane
  - sperm and egg plasma membrane fuse
  - Sperm nucleus enters egg
  - Depolarization of the membrane prevents other sperm from fusing with egg plasma
  - Fats-Block: quick but shore-termed
  - Figure 47.3
- **Cortical reaction**
  - Depolarization of the membrane releases calcium ions from the endoplasmic reticulum
  - Cortical granule fuse with plasma membrane and release contents by exocytosis
  - Vitelline layer splits form plasma membrane
  - Vitelline layer hardens, forms fertilization envelope
  - Sperm-bonding receptor proteins cut off
  - Slow Block: takes more time, but lasts longer
  - Figure
- **Activation of the egg**
  - Depolarization of the membrane releases calcium ions from the endoplasmic reticulum
  - Increased cellular respiration
  - Increased protein synthesis
- **Fusion of the nuclei**
  - The two haploid nuclei (from the sperm and egg) fuse to form a diploid nucleus
  - DNA syntheses begin

2. **Cleavage**

- **Establishing polarity**
  - The zygote is much larger than typical body cells
  - The cytoplasm of the zygote is not homogenous
    - Certain molecules (mRNA, proteins, yolk) are found at higher concentration in some parts of the cell
  - Cell division splits the cytoplasm among cells, and different cells end up with different concentrations of certain molecules
  - Different genes are "turned on" or "turned off" according to the concentration of the molecules
  - Autocrine and paracrine signals are released
- **Cell Division**
  - RNA from mother is in control
  - Zygote's own DNA takes over
  - A fluid-filled space develops in the center
  - Blastula

3. **Gastrulation**

- Figure

4. **Organogenesis**

- Cells continue to exchange chemical signal
  - Based on these signals, cells begin to arrange themselves and specialize
  - Figure

# Neurons, Synapses and Signaling

Tuesday, February 08, 2011
11:45 AM

**Diffusion:** A substance tends to move from an area of high concentration to an area of low concentration

**Pressure:** A substance tends to move from an area of high pressure to an area of low pressure

**Electromagnetic Field:** A negative charged substance tends to move from an area of negative charge to an area of positive charge

**Cellular Respiration:**
The Electron Transport Chain (Chemiosmotic ATP Synthesis)

- All cells have voltages across their membranes
  - The cytoplasm is negative in charge relative to the outside
  - Due to the unequal distribution of ions
  - Electrochemical gradient (Figure)
  - $E_{ion}$ = 62mV (log $[ion]_{outside}/[ion]_{inside}$)
    - Note that the number of channels influences the rate at which equilibrium is achieved, but doesn't affect the equilibrium voltage.
  - Because positively-charged ions are diffusing both ways, diffusion is not constrained by the electromagnetic gradient
  - Not the rate of diffusion across the membrane becomes

**Resting Potential:**

- Figure 48.
- Must be maintained by active transport

**The Sodium-Potassium Pump**

- Figure
- 3 Sodium out, 2 Potassium in

**Neuron Plasma Membrane**

1. Phospholipid Bilayer
2. Sodium Channels
3. Potassium Channels
4. Sodium-Potassium Pump
5. Typical neuron resting potential -60 to -80 mV
6. Gated sodium channels
7. Gated potassium channels

- The sodium gates are sensitive to disturbance
- Disturbance Occurs
  - Sodium gates open for a moment
  - Some sodium diffuse into neuron
  - Movement of positively charged ions into the cell reduces the membrane potential
    - Depolarization -> quickly disappears -> graded depolarization
    - If the depolarization is great enough, nearby sodium gates open
    - More sodium diffuses into the cell
    - The depolarization increases

**Threshold**

- If the depolarization passes the threshold, all sodium gate open the inside of the neuron briefly become positively charged
  - Potassium gates then open (as the sodium gates close and become inactivated)
  - Potassium diffuses out, making the inside of the neuron negatively-charged again
  - The sodium potassium pump restores the resting potential
  - This is all called an **action potential**

- Action Potentials are "all or nothing"
- Frequency os action potentials may reflect strength of signal
- Last a few milliseconds
- It is followed by a short refractory period
  - The sodium gates remain inactive for a few milliseconds, preventing the initation of further graded or action potentials

**Graded Potential**

1. Some sodium gates open
2. Sodium diffuses into the neuron
3. Inside of the neuron becomes less negative (still negative)
4. Sodium gate close and lock
5. Sodium gates unlock (rate of potential)

**Action Potential**

1. Hyperpolarization
    a. All sodium gates open
    b. Sodium diffuese into the neuron
    c. Inside of the neuron becomes positive
2. Potassium gates open and sodium gates close and lock
3. Depolarization
    a. Potassium diffuses out of the neuron
    b. Inside of neuron beocmes negative again
4. Membrane returns to Resting State
    a. Potassium gates close
    b. Sodium gates unlock
    c. Figure 48.10

**Neuron**

- Figure 48.5
- Cell body
- Dendrites are narrow extensions of the cell body
- Axon -> long extension
- Axon hillock -> typically where an action potential originates
- The cell body and dendrites typically carry graded potentials to the axon hillock
- The axon typically carries action potentials away from the axon hillock
- Action potentials propagates along membranes
- Figure 48.11
- Small electric current (ions and electrons) cause action potential to propagate across membrane
- Refractory period ensures onw-way propagation

**Glial Cells (Glia)**

- Figure 48.12 & 48.13
- Nourishes neurons
- Regulate the extracellular fluid surrounding neurons
- Insulate axons
- Axon
- Schwann cell (has nucleus)
- Mylelin Sheath -> regularly spaced
- Layes of myelin
- Myelinated neuron: oligodendrocytes (Schwann Cells) in centeral nervous system
- Resting potential only maintained at the node of Ranvier
- Action potential jumps from node to node -> saltation (salatory) conduction
- Saves energy because faster signal propagation
- Schwann Cells and oligodendrocytes are glial cells

**Synapse**

- Connection between one neuron to the next
- Figure 48.15
- Calcium diffuse into cell and triggers exocytosis of the neurotransmitter -> released into synaptic cleft -> bumps into ion channels and can cause them to open -> triggers graded potential
- Can be re-used or broken down by enzymes
- Figure 48.16

1. Subthreshold, no summation
2. Temporal summation
3. Spatial summation (arrive from two different places)

- **Neurotransmitters:** acetylcholine, serotonin, glutamate, glycine, etc.
- Re-absorbed by the pre-synaptic neuron or broken down via endocytosis or active transport

- Some are inhibitory -> prevent action potential: triggers the opening of potassium channels of chlorine gates
- Increases movement of potassium out of the cell -> increase polarity
- Increased movement of chlorine into the cell -> increase negative charge inside cell
- Both result in hyperpolarization

- A few synapses have direct electrochemical connections
- Two neurons are connected by gap junctions
- Proteins channel connects the cytosol of two adjacent cells -> hydrophobic channel between
- Action potential can move form one neuron to the next -> neurons that don't require a lot of flexibility
- No neurotransmitter involved

# Nervous System

Tuesday, February 08, 2011
11:56 AM

- **Nervous System:** Coordination the activity of cells in different parts of the body

**Nerve Net**

- Network of neuron that connects stimuli with responses, without nerves, a brain, or ganglia
- **Nerve:** a bundle of neuron fibers surrounded by connective tissue
- **Brain:** organ of the central nervous system where information is processed and integrated
- **Ganglion:** a cluster of nerve cell bodies
- Figure

**The Human Nervous System**

- Figure
- Chordates have a dorsal hollow nerve cord (ectoderm)
    - Filled with cerbrospinal fluid down central canal
    - White Matter: myelinated axons
    - Grey matter: cell bodies, dendrites, unmylenated axons
    - Minges: with cerbrospinal fluid

**Afferent Neuron**

- Carries sensory information to the CNS

**Efferent Neuron**

- Carries instructions form the CNS to muscles and glands

**Interneuron**

- A neuron with in the CNS that is involved in detegradtion

**Brainstem**

- Homoeostasis
    - Breathing control centers
- Coordination of movement
- Conduction of information to and from higher brain centers

**Reticular Formation**

- Filters information going to cerebrum
    - Alertness

**Cerebellum**

- Coordination of movement and balance

**Diencephalon**

- **Epithalamus**
    - Produces CSF
        - Pineal gland
            - Produces melatonin (circadian rhythm)
- **Thalamus**
    - Directs signal from the senses to parts of the cerebrum
- **Hypothalamus**
    - Temperature, hunger, thirst, drives
    - Pituitary gland
- **Cerebrum**
    - Information processing
    - Perception, voluntary
    - Left side
        - Corpus callosum
- **Limbic System**
    - Emotion, motivation, olfaction, memory
- **Memory**
    - Changes in synaptic connections
        - Changes in presynaptic neuron

- Changes in postsynaptic neuron