Glossary Animal Physiology Circulatory System (see also *Human Biology 1)*

Aneurism: Localized dilatation of the artery wall due to the rupture of collagen sheaths.

Arteriosclerosis: A disease marked by an increase in thickness and a reduction in elasticity of the arterial wall; SMC, smooth muscle cells can (due to an increase in Na-intake or permanent stress related factors) be stimulated to increase deposition of SMC in the media surrounding the artery resulting in a decreased lumen available for the blood to be transported, hence rising the blood pressure, which itself signalizes to the SMC that more cells to be deposited to resist the increase pressure until little lumen is left over, leading for example to heart attack.

Arterial System: The branching vessels that are thick, elastic, and muscular, with the following functions:

- act as a conduit for blood between the heart and capillaries
- act as pressure reservoir for forcing blood into small-diameter arterioles
- dampen heart -related oscillations of pressure and flow, results in an even flow of blood into capillaries
- control distribution of blood to different capillary networks via selective constriction of the terminal branches of the arterial tree.

Atria: A chamber that gives entrance to another structure or organ; usually used to refer to the atrium of the heart.

Baroreceptor: Sensory nerve ending, stimulated by changes in pressure, as those in the walls of blood vessels.

Blood: The fluid (composed of 45% solid compounds and 55% liquid) circulated by the heart in a vertebrate, carrying oxygen, nutrients, hormones, defensive proteins (albumins and globulins, fibronigen etc.), throughout the body and waste materials to excretory organs; it is functionally similar in invertebrates.

Erythrocyte: (Gk. eruthros, red + cutos, hollow vessel) A red blood cell whose main function is transporting oxygen to the tissues. Hemoglobin is the O_2 carrying pigment of the erythrocytes, formed by the developing erythrocate in bone marrow. A complex protein composed of four heme groups and four globin polypeptide chains plus several hundreds amino acids

Leukocyte: (Gk. leukos, white or colorless + cutos, hollow vessel) White blood cells; functions in the body's defense against invading microorganisms or other foreign matters; are divided in four classes: phagocytes (neutrophils and monocytes), eosinophiles, basophiles, and lymphocytes.

- Basophiles: Involved in inflammation that releases an anticlotting agent at the site of an injury and produces the chemical substance histamine, which delays the spread of invading microorganisms.
- Esinophiles: Enzyme carrying cells that break down foreign proteins and break up blood clots.
- Lymphocyte: (L. lympha, water + cutos, hollow vessel) A white blood cell formed in lymph tissue; active in the immune response that protect the body against infectious diseases - two main classes: B-lymphocytes, involved in the formation of antibody formation, and T-lymphocyte, involved in cell mediated immunity.
- Phagocytes: The type of cells attracted to damaged or infected tissue, where they take up food particles (bacteria, viruses and cell debris) by endocytosis.

Plasma: The liquid portion of blood or lymph.

Thrombocyte: (Platelete) A disc-shaped cell fragment important in blood clotting.

Capillary: The crucial part of the circulatory system where the transfer of substances between blood and tissues across the walls of the capillaries occurs;

Continous C.: The least permeable with few clefts (<4nm in width); located in muscle, nervous tissue, the lungs, connetcive tissue, and exocrine glands.

Fenestrated C.: Exhibit intermediate permeability posses pericapillary space in form of pores; are found in the renal glomerulus, intestines and endocrine glands.

Sinusoidal C.: The most permeable with paracellular gaps; are present in the liver, bone marrow, spleen, lymph nodes, and adrenal cortex.

Electrolytic Exchange in C.:

Filtration: At the arterial end of the capillary, a net fluid flow across the capillary walls resulting from the difference between blood pressure (hydrostatic pressure p_h) and colloid osmotic pressure (p_c)of the extracellular fluid ($p_h > p_h$).

Uptake (resorbtion): At the venous end of the capillary the fluid is drawn back to the plasma from the extracellular space ($p_h < p_h$); uptake is slightly smaller than filtration (90%), unless the remaining 10% are not drained away by the lymphatic system, an edema will form.

Circulatory System: An organ system, generally consisting of a heart, blood vessels, and blood, that transports substances around the body of an animal - see also lymph. Factors like cholesterol, stress, nicotine and lack of physical exercise strongly influence the capabilities of the CS.

Open CS.: A system in which blood pumped by the heart empties via an artery into an open fluid space, the hemocoel, lying between the ecto- and endoderm; the fluid is referred to as hemolymph; low O_2 diffusion through tissue; percentage of blood- to body volume rather high (20-30%); low blood pressure, therefore excretion via nephridia; insects use trachea for direct gas exchange instead, e.g.: arthropods mollusks.

Closed CS.: Blood flows in a continuos circuit of tubes from arteries to veins through capillaries (specific areas can be shunted off/on, with different pressures in different systems, i.e.: lung- and systemic system), allowing system of high blood pressure and ultrafiltration of blood in kidneys; high pressurized system requires lymphatic system; transport of nutrients and respiratory gasses to target tissues; maintains homeostasis (constant body temperature); ratio of blood to body volume rather low (5-10%);e.g.: mammals, vertebrates.

- **Micro-** CS.: The capillary section of the circulatory system, in which the exchange of gases and metabolic products take place - see capillary.
- **Pulmonary** CS.: The blood vessel system that carries oxygen-poor blood from the heart to the lungs, where gas exchange occurs, and carries oxygen-rich blood back to the heart.
- **Systemic** CS.: The blood vessel system that carries oxygen-rich blood from the heart too the body and returns oxygen -poor blood to the heart.

Diffusion: (L. diffundere, to pour out) Dispersion of atoms, molecules, or ions as a result of random thermal motion (Brownian motion); the net movement of suspended or dissolved particles from a more concentrated region to a less concentrated region as a result of random movement (Brownian motion) of individual molecules resulting in a uniform distribution within the medium:

$D = d^2/t$ $[m^2/s]$

Fick's D. EQ.: Defines the rate of solute diffusing through a solvent; (due to Brownian motion) of the dissolved substance within the medium; the rate of diffusion is:

$M = D_s \cdot A \cdot (\Delta c/\Delta s)$ $[1/(m^2 \cdot s)]$

e.g.: ink dropped into a water filled jar will slowly diffuse throughout the solute.

d, distance	[m]
t, time	[s]
D_s, coef. of diffusion	$[m^2/s]$
c, concentration	$[1/m^3]$
s, distance	[m]
N, number of units	[-]
V, volume	$[m^3]$
A, cross sectional area	$[m^2]$

Edema: Retention of interstitial fluid in organs or tissues, when excess fluid is not carried away by the lymphatic system; the balance between hydrostatic and colloidal-osmotic pressure in the capillary bed is upset.

Efferent: Centrifugal; a neuron that carries information from higher brain centers toward structures in the periphery.

E. **Control**: The coordinated control of reception of peripheral nerve tissue by the CNS; e.g.: efferent control of sound-sensitivity in a loud environment, selectively filtering out the someone's voice.

Fibroblast: A type of connective tissue cells, found in almost all vertebrate organs, that secretes collagen and other components of the extracellular matrix; it migrates and proliferates during wound healing and in tissue culture.

-genesis: (Gk. genesis, the beginning, origin) Referring to the development and sprouting of vascular tissue (capillary sprouts) and is divided into the migrating-, dividing-, and maturing stage.

Angiogenesis: (secondary angiogenesis) Budding of endothelial cells, fibroblasts (cells which secrete basic units of fibers which then polymerize) and SMC metamorphosing into new vascular tissue; i.e.: wound healing within capillary bed; endometrial lining of the uterus - menstrual cycle; or development of tumors.

Vasculargenesis: (primary angiogenesis) Mesenchym -cells, deriving from the mesoderm, evolve into angioblasts (early stage of vascular tissue) to differentiate into erythroblasts, plasma, and endothelium cells.

Heart: In humans, the heart consists of two separate pumps. The right half pumps the blood through the lungs, and a left half pumps the blood to the peripheral organs. Each of these two separate hearts is a pulsatile two-chambered pump composed of an atrium and a ventricle.

Atrium: (L. hallway) A chamber of the heart that receives blood from the veins, and serve as a blood reservoir; the right receiving deoxygenated blood from the body an the left receiving oxygenated blood from the lungs.

Node: Two groups of specialized cardiac fibers (nodal fibers) stimulate and integrate the heart beat.

- AV - **Atrioventricular** N.: Specialized conducting tissue in the heart, which, along with Purkinje tissue (ramification of AV-fibers) forms a bridge for electrical conduction of the impulse from atria to ventricle.
- SA - **Sinoatrial** N.: A mass of specialized cardiac tissue that lies at the junction of the superior vena cava with the right atrium; it acts as the pacemaker of the heart in initiating each cardiac contraction.

Ventricle: The ventricle supplies the main force that propels the blood through either the pulmonary or the periphery muscular organ that pumps blood through vessels.

Dual Circuit H.: A heart that pumps two separate circuits, specifically the pulmonary and systemic circuits.

Dual Pressure H.: A dual circuit heart in which each circuit receives blood at different pressures.

Endocard: The internal lining of the heart chamber; equivalent to *tunica interna* of vessels.

Myocard: The heart muscle; equivalent to *tunica media* of vessels.

Epicard: External covering of the heart wall, (inner layer of pericardium), eqvlt. to *tunica externa* of vessels.

Pericardium: The serous membrane that envelops the heart and secretes fluids that lubricate the surface that touches surrounding structures to prevent damage; i.e.: the connective tissue sacs that encloses the heart.

Cardiac Cycle: The two most important components of the left ventricle diagram are the ***diastolic*** and ***systolic*** pressure. These two curves are volume-pressure curves.

- Phase 1-Period of filling: This phase begins at a ventricular volume of about 45ml and diastolic pressure near to 0mm Hg. As pulmonary venous blood flows into the ventricle from the atrium, the volume normally increases to about 115ml (end-diastolic volume).
- Phase 2-Period of isovolumic contraction: Volume of the ventricle does not change. However, pressure inside the ventricle rises to equal the pressure in the aorta of about 80mm Hg.
- Phase 3-Period of ejection: Systolic pressure rises even higher because still more contraction of the heart. Simultaneously the volume of the ventricle decreases since blood flows out of the ventricle into the aorta.
- Phase 4-Period of isovolumic relaxation: At the end of ejection, the semilunar valves of the ventricles close, and the ventricular pressure falls back to the diastolic pressure level. Thus the ventricle returns to its starting point, with about 45ml of blood left in the ventricle at an arterial pressure close to 0mm Hg.

Diastole: The diastolic pressure curve is determined by filling the heart with progressively greater quantities of blood and then measuring the diastolic pressure immediately before ventricular contraction occurs, which is the end-diastolic pressure of the ventricle (relaxed myocardium);

Systole: The systolic pressure curve is determined by preventing any outflow of blood from the heart and measuring the maximum systolic pressure that is achieved during ventricular contraction at each volume of filling.

Cardiac Control: Increase or decrease of heartbeat is regulated by two essential nerves; for endocrine related effects see hormones-endocrine .

- Sympaticus: Managed by the sympatethic NS, resulting in an increased heartbeat.
- Vagus: Managed by the parasympatethic NS, resulting in a lowered heartbeat.

Cardiac Output: The volume of blood per unit time from the ventricle

heart-minute volume = HMV = $f_H \cdot V_S$ [l]

f_H, heart rate [1/min]

V_S, stroke volume of 1 beat [l]

Stroke volume is the difference between the volume of the ventricle just before (end diastolic volume) and the volume of the ventricle at the end of contraction (end systolic volume). The average volume the heart pumps through the body of an adult oscillates around 5[l] at 70[beats/min]; it can be increased up to 20[l] under certain conditions by increasing the filling phase.

Hematocrit: The percentage of blood volume occupied by red blood cells; 40-50% in humans, i.e.: 55% plasma (liquid phase) and 45% cells and cell fragments (solid phase).

Hemoglobin: see blood.

Hydrodynamics (Hemo-): The circulatory system itself is a hydrodynamic system, using laminar flow for the steady transport of fluid (blood), avoiding turbulent conditions (deposits in the vessels) which would sharply disrupt efficiency; the velocity of flow is related to the total cross-sectional area of a certain part of circulation and can be described with the Hagen-Poiseuille's law, La Place's, and Bernoulli's EQ.

Bernoulli's EQ: The pressure in a fluid decreases as fluid velocity increases. Over-all-pressure = hydrostatic + hydrodynamic pressure:
$p_0 = p_1 + ½·ρ·v_1^2 = p_2 + ½·ρ·v_2^2$ [Pa].
A fluid that undergoes a pressure change undergoes an energy change:
$ΔW = ΔKE\ (½·m·v^2) + PE\ (m·g·y)$

ρ, density of liquid		[kg/m³]
v, velocity of liquid		[m/s]
g, grav. accelerat. 9.81		[m/s²]
m, mass		[kg]
y, height		[m]

Hagen-Poiseuill's Law: In laminar flow, the flow is directly proportional to the driving pressure, and resistance is independent of flow; the rate of flow is (simplified) $Q ≈ r^4$:

$$\frac{V}{Δt} = \frac{π·(p_2-p_1)·r^4}{8·η·l} = [m^3/s] \qquad \text{simplified: } V/t ≈ r^4$$

a doubled radius result in a 16-fold increase of the rate of flow.
the viscosity index η is highly dependent on the percentage of solid particles suspended in the fluid.

V, volume		[m³]
t, time		[s]
V, volume		[ml]
p, pressure [N/m²]		[Pa]
π, 3.14		[-]
η, viscosity index		[kg/(s·m)]
l, length of tube		[m]

La Place's Eq: The wall tension in a thin-walled tube is proportional to the transmural pressure and the to the radius of curvature; in spherical tubes is:
$T_w = r·p$ [m/s]

p, pressure [N/m²]		[Pa]
r, radius		[m]

Reynold's Number: The tendency of a flowing gas or liquid to become turbulent is proportional to its velocity and density and inversely proportional to its viscosity; it indicates the change from laminar to turbulent flow; with an increase of speed, a laminar flow sooner or later will change into turbulent one:
$R_N = ρ·v_{av}·d/η$ [-]

v_{av}, average velocity		[m/s]
η, viscosity index		[kg/(s·m)]
d, diameter		[m]
l, length		[m]

Hypertension (high blood pressure) Arterial pressure is greater than the upper range of accepted normality (> 110mm Hg resting condition, diastole > 90 mmHg, systole > 135-140 mmHg) due to following reasons:

- Nervous (central) regulation: Baroreceptors of the arterial wall near the heart detect changes in blood pressure; signals to the vasomotor center. By a combination of excitation and inhibition of appropriate motor neurons. Heart rate decreases if pressure is too high or increases when pressure is too low.
- Periphere (local) regulation: nerval, myogen, hormonal, local metabolisch and hemodynamic (stretching)

ANP (atrial natriurethic peptide): One of a family of peptide hormones, cleaved from a single precursor peptide and produced in the cardiac atria, the physiological effects of which includes increased urine output, increases Na^+-excretion, and a receptor mediated vasodialtion, resulting in lower blood pressure.

- High salt intake, there is excess H_2O that causes the total volume of blood in the circulatory system to increase, this increase in volume causes blood pressure to go up.
- Atherosclerosis (hardening of the arteries) due to the build up of fatty deposits (plaque) inside the arteries, therefore, narrowing the artery cavity and causing blood pressure to rise
- other types of steroids or excess aldosterone causes primary aldosteronism in which aldosterone increases the rate of reabsorbtion of salt and water by the tubules of the kidneys, thereby reducing the loss of these in the urine while causing an increase in the extracellular fluid volume, as a result, hypertension occurs.
- Renin is a small protein enzyme released by the kidneys, in the juxtaglomerular apparatus, when the arterial pressure falls too low, in turn, it raises the arterial pressure in several different ways, thus helping to correct the initial fall in pressure.
- Excess amounts of angiotensin circulating in the blood, the entire long-term renal-body fluid mechanism for arterial pressure control automatically becomes set to a higher than normal arterial pressure level. Angiotensin causes the kidneys to retain salt and water, and adrenal glands to secrete aldosterone which increases salt and water reabsorption by the kidney tubules.
- Excess mineralcorticoid production causes blood pressure to rise
- Capillary fluid shift - increased lymphatic fluid
- Stress,

Ischemia: The absence of blood flow (to an organ or tissue) caused by a sudden drop in blood pressure, due to loss of blood, shock etc., leading to collapse of the artery by the resting- tension of the media (WTRP); causing a so called “no-reflow“ status, known in transplant surgery.

Lymph: Plasmalike fluid collected from interstitial fluid and returned to the bloodstream via the thoracic duct; contains white (but not red) blood cells; see also blood.

Lymphatic System: A collection of blind-ending tubes which drain filtered extracellular fluid from tissues and return it to the blood circulation.

Hemolymph: The blood of invertebrates with open circulatory systems.

Myogenic: Capable of producing an intrinsic cycle of activity.

M. **Pacemaker**: A pacemaker that is a specialized muscle cell.

Myoglobin: An iron-based, hemoglobinlike pigment of certain muscle fibers;

p - **Pressure**: The ratio of force to the area over which it is distributed: F, force [$kg \cdot m/s^2$] [N]

$p = F/A$ [N/m^2] = [Pa] ($F \perp A$); A, area [m^2]

Blood P. (BP): BP can be regulated in various ways; i.e.: increased heart pumping capacity, increase pumping frequency, increased contraction; specialized baroceptors (p-sensors in the arterial wall) measure the BP; BP decreases rapidly once it reaches the arteriol section; it coincidences with a sharp fall in velocity as well; BP remains down once past the capillary bed, whereas velocity increases again the closer (larger venules) to the heart - see hydrodynamics and vessel. BP-Regulation:

- **Hormonal** BPR.: Wall-tension receptors within the endothelial cell detect excess stretching, which release a hormonal substance causing the SMC to increase WTRP, causing contraction, e.g. stress hormones or dilatation by generating nitrogen oxide (NO).
- **Innervation**: Allows the brain to actively control BP by increasing or lowering the wall tension of arteries.
- **Metabolic** BPR.: Local dilatation of artery to increase blood flow to the demanding area, along with simultaneous constriction in other areas guaranties that BP can be maintained at a constant level.

Absorbtion P.: The taking up of substance by diffusion; at the venous end of the capillary bed, COP normally exceeds HP so that there is a net force that draws water into the capillaries.

Colloid Osmotic P. (COP): A system in which fine solid particles are suspended in a liquid; together with osmosis create a pressure necessary to prevent osmotic flow between two solutions separated by a semipermeable membrane (capillaries), draws water into the capillaries.

Filtration P.: The passage of a liquid through a filter following a pressure gradient; at the arterial end of the capillary bed, HP normally exceeds COP, resulting in a net force that moves water out of the capillaries.

Hydrostatic P. (HP): Force excreted over an area due to pressure in a fluid (blood pressure), opposed to COP.

Transmural P.: The difference in pressure across the wall of a blood vessel - see capillary.

Wall Tension Resting Potential (WTRP): A constant wall pressure is exerted by the SMC (innervated by the para-/sympathetic NS) to enable the arteries to adjust to take part in blood pressure control, by dilatation or compression; older people generally suffer from higher blood pressure than younger due to loss of elasticity, or the occurrence of stenosis (little or no flow through the artery) or ischemia (no-reflow status after collapse of an arterial wall).

Vaso- (L. vaso,) Pertaining to the blood pressure in arteries. *Serotonin* can have either a vasodilator or a vasoconstrictor effect, depending on the condition or the area of the circulation.

Vasoconstriction (L. constringere, to contract) Contraction of circular muscles of arterioles, decreasing their volume and increasing the vascular resistance and blood pressure (BP). Some vasoconstrictors:

- *Angiotensin* constricts very powerfully the small arterioles.
- Ca^+-ion concentration causes vasoconstriction; calcium stimulates smooth muscle contraction.
- *Epinephrine* occasionally dilates the coronary arteries during increased heart activity.
- *Norepinephrine* is a powerful vasoconstrictor hormone
- *Vasopressin* (ADH) is formed in the hypothalamus, it is the body's most potent constrictor substance, it also has an all-important function in controlling water reabsorption.

Vasodilatation: (L. dilatare, to enlarge) A widening of the lumen of the blood vessels, increasing blood flow, but decreasing blood pressure BP. Some vasodilators:

- *Acetate* and *citrate* both causes mild degrees of vasodilatation.
- *ANP*: (atrial natriurethic peptide): Produced in the cardiac atria, causes increased urine output by increasing Na^+-excretion, and a receptor mediated vasodialtion.
- *Bradykinin*: substances like kinin are frequently formed in the blood and tissue fluids.
- Elevated CO_2 concentration causes moderate vasodilatation in most tissues.
- H^+ *ion* above normal concentration (decrease pH) causes dilatation of the arterioles.
- *Histamine* released at injuries is a powerful vasodilator effect on the arterioles and has the ability to greatly increase capillary porosity, allowing leakage of both fluid and plasma protein into the tissues.
- Heavy K^+-ion concentration inhibits of smooth muscle contraction.
- *Lactic Acid*: Muscle related answer during excessive exercise.
- Mg^+ -ion concentration beyond normal inhibit smooth muscle contraction.
- Na^+ ion concentration causes mild arteriolar dilatation, mainly due to an increase of osmolality of the fluids rather than from a specific effect of sodium ion itself. Increased quantities of glucose or other nonvasoactive substances also causes arteriolar dilatation as well.
- *Prostaglandins* causes vasoconstriction, but the important ones are vasodilatation agents.

Ventricle: A small cavity; also the chamber of the vertebrate heart.

Vessel: Conducting organs of blood; consist of the following structures:

Endothelium: Single cell layer forming the internal lining of blood vessels.

Smooth Muscle Cell (SMC): Spindle shaped, unstriated muscle cells; an involuntary muscle.

Tunica Adventitia: Fibrous outer layer of arterial blood vessel walls.

Tunica Intima: Inner lining of arterial blood vessel walls.

Tunica Media: Middle layer of arterial blood vessel walls consisting of SMC and elastic tissue.

Types of:

Artery: A vessel through which the blood passes away from the heart to the various parts of the body; typically has thick, multilayered, muscular elastic walls; acts as a pressure reservoir (similar to a bike-tire) to force blood into the capillaries and dampen oscillations of the heart; generally, elasticity decreases with increasing distance from the heart (becomes stiffer).

- **Aorta**: In vertebrates, the main artery of the body leaving the heart.
- **Arteriole**: A minute arterial branch nearest (proximal) to capillary.

Capillary: Microscopic (8μm thick) thin-walled vessel located in the tissues connecting an artery and vein; rarely more than 1mm from any body cell, in which blood velocity is very low. Capillaries are fenestrated with small pores up to 100[nm] in diameter, allowing diffusion of substances.

- C. **Bed**: Very permeable network of endothelial cells, allowing the plasma to connect to the lymphatic system; Ions, gases, and organic molecules pass to the interstitial fluid through to the capillary walls, and waste products back from tissue into the capillary - see diffusion.

Vein: Vessel through which blood passes from the tissues (capillary beds) toward the heart, typically has thin walls and valves that prevent a reverse flow of blood; acts as a large volume-low pressure blood reservoir with dilating walls (p doesn't increase when blood volume increases); almost 65% of the circulating blood resides in veins.

- **Venule**: A small vessel that arises from a capillary bed connecting a vein.
- ***Vena Cava***: In vertebrates, the main vein of the body entering the heart.
- ***Vena portae***: The main vein leaving from the liver.

Viscosity: A measure of a fluid's resistance to flow.

Glossary Animal Physiology – Digestion (see also Human Biology 1)

Absorption: The taking up of a substance by diffusion or active transport through the lining of the digestive tract, tubule, walls, or other surfaces.

Active Transport: Energy requiring translocation of a substance across a membrane, usually against a concentration gradient; see AP-nerve.

Bile: see liver.

Carrier Mediated Transport: Trans-membrane transport of solutes achieved by membrane embedded carriers.

Chyme: The semi-fluid contents of the stomach consisting of partially digested food and gastric secretions.

Diffusion: (L. diffundere, to pour out) Dispersion of atoms, molecules, or ions as a result of random thermal motion (Brownian motion); the net movement of suspended or dissolved particles from a more concentrated region to a less concentrated region as a result of random movement (Brownian motion) of individual molecules resulting in a uniform distribution within the medium:

$D = d^2/t$ $[m^2/s]$

Fick's D. EQ.: Defines the rate of solute diffusing through a solvent; (due to Brownian motion) of the dissolved substance within the medium; the rate of diffusion is:

$M = D_s \cdot A \cdot (\Delta c/\Delta s)$ $[1/(m^2 \cdot s)]$

e.g.: ink dropped into a water filled jar will slowly diffuse throughout the solute.

d, distance	[m]
t, time	[s]
c, concentration	$[1/m^3]$
s, distance	[m]
N, number of units	[-]
V, volume	$[m^3]$
A, cross sectional area	$[m^2]$

Digestion: The reverse of synthesis; large organic compounds are digested by hydrolysis (a reaction in which water molecules are reintroduced between building blocks, which then separate).

Intracellular D.: The (chemical) enzymatic breakdown of microscopic nutrient molecules occurring within cells; e.g.: protists, etc.

Extracellular D.: Enzymatic digestion of macroscopic food particles occurring outside of the cell in alimentary systems; e.g.: intestinal digestion etc.

D. **Enzymes**: Enzymes (hydrolase) secreted by alimentary canal to aid in chemical digestion.

D. **Gland**: An aggregation of specialized cells that secrete or excrete digestive substances, such as pancreas and liver (exocrine glands).

D. **Tube**: Buccal cavity (teeth, radula etc.) pharynx (swallow), esophagus (gullet), gaster (stomach), pancreas, gall bladder, duodenum (small intestine), jejunum (area between small intestine and ileum), ileum (posterior section of the small intestine), cecum (the blind pouch in the alimentary canal), colon

Steps in D. in complex animals: Food enters one end of the digestive tract (mouth) and moves in a single direction through the gut tube; wastes exit at the other end of the tube (anus); between the two ends, a variety of specialized regions and structures perform special digestive roles, with the overall result being an absorption of nutrients into the circulatory system, needed by each cell of the body.

Mechanical D.: Ingestion an mastication, the mechanical breakdown of food into small pieces by teeth or gizzards.

Chemical D.: The chemical breakdown of macromolecules (proteins, carbohydrates, fats, and nucleic acids) into small subunits (amino acids, simple sugars, fatty acids, and nucleotides) by HCl and enzymes in the stomach and the small intestine (different digestive enzymes attack different types of food).

Absorption: The uptake of the molecular subunits (monomers) and other nutrients from the gastrointestinal tract into the bloodstream. Absorption depends upon the length of small intestine and shape of circular folds and villi; absorption is carried out by endocytosis, active transport, and carrier mediated transport.

Elimination: The removal of indigestible wastes.

Endocytosis: Bulk uptake of materiel into a cell by membrane in-pocketing to form an internal vesicle.

Food: Organic compounds used in the synthesis of new bio-molecules and as fuel in the production of cellular energy; i.e. carbohydrates (monosaccharides, such as glucose, disaccharide such as sucrose, polysaccharides such as starch i.e.: amylose, amylopectin), lipids (fatty acids), proteins (essential amino acids i.e.: lysine, leucine, phenylalanine, isoleucine, tryptophan, valine, threonine, and methionine), vitamins (simple organic compounds not manufactured by the body i.e.: A, E, D, K etc.), minerals (inorganic chemical elements, i.e.: Fe, I, Ca, P, S, etc.) - see gastrointestinal secretions and tables below.

According the organism involved, food can be taken up as sucking, raptorial feeding, parasitism, suspension feeding, deposit feeding or by active food intake as seen in complex animals.

Gallbladder: The sac beneath the right lobe of the liver that stores bile - see there.

Gastrointestinal Secretions: Aqueous mixtures of substances of salivary glands, secretory cells in the stomach, intestinal epithelium, secretory cells of the liver and pancreas by means of primary secretion of acinar cells which are altered before excreted in the secondary modifying duct.

Digestive Enzyme: Necessary to catalyze hydrolysis of large foodstuff molecules into simpler compounds that are small enough to cross cell membranes of the intestinal barrier - see table below.

1. **Carbohydrase**: A group of polysaccharides and glycosidases; polysaccharides hydrolyze the glycosidic bonds of long chained carbohydrates (cellulose, glycogen, starch).
2. **Lipase**: A pancreatic enzyme which accounts for the emulsification (fats are rendered water soluble) achieved with lecithin cleaves the ester bonds of the fatty building blocks; formation of micelles is aided by bile salts.
3. **Protease**: A pancreatic, protolytic enzymes, which attack peptide bonds of proteins and polypeptides; e.g.: typsin attacks only those peptide bonds of carboxyl groups provided by arginine or lysine; chymotrypsin those of carboxyl groups provided by tryosine, phenylalaline, tryptophan, leucine, and methiodine; pepsin accounts for the gastric protease (at low pH); proteolytic enzymes hydrolize polypeptides into oligopeptides.
4. **Other Digestive Enzymes - Cholecystokinin** CKK: A hormone secreted by the small intestine that triggers the pancreas to release protein-digesting enzymes; serves also as a brain messenger to indicate the sensation of being full.
   - **Gastrin**: A digestive hormone secreted in the stomach that regulates the secretion of other digestive juices (actively controlling the level of pH in the stomach) - see stomach.
   - GI.-**Hormone**: Peptide hormones that regulate the basic electric rhythm (peristalsis) of smooth muscle in the alimentary canal.
   - **Proenzyme** (Pespinogen): Digestive enzymes (trypsinogen, chymotrypsinogen), activated by hydrochloric acid - precursors to pepsin - see pancreas.
   - **Secretin**: A digestive hormone secreted in the small intestine that triggers the pancreas to secrete bicarbonate HCO_3^-, which neutralizes stomach acid.

Gut: The alimentary canal or any of its parts, especially the stomach or intestines.

Head-G.: Anterior (cranial) region of the alimentary canal providing an external opening for food reception.

Fore-G.: The upper region of the alimentary canal involved in food conduction, storage and digestion (esophagus which transports the broken food particles via peristalsis towards the stomach).

Mid-G.: Major alimentary canal site for the chemical digestion of protein, fat, and carbohydrates.

Hind-G.: The terminal region of the alimentary canal, responsible for absorption of ions and water, storing and eventually eliminating the remnants of digested food.

Intestine: Long, tube-like section of the digestive tract between the stomach and anus of vertebrates; protected by a mucus lining; most food digestion and absorption takes place via villi, themselves covered with microvilli.

Duodenum: small intestine; with the help of excretions from the pancreas and the liver cleaves the greasy components of food (peptidase cleaves proteins, sucrase cleaves sugars, amylase cleaves starch and glycogen, lipase cleaves lipids, nuclease cleaves nucleic acids) - see table below.

Jejunum: area between small intestine and ileum

Ileum: Posterior section of the small intestine

Cecum: The blind pouch; no known digestive function; contains cells of immune system.

Colon: The last portion of the large intestine, the wide part of the alimentary canal that leads to the rectum; absorbs water, ion and vitamin from the chyme, stores and solidifying feces.

Rectum: The portion of the intestine between colon and anus; expels solid wastes by defecation.

Anus: The opening of the alimentary canal; waste elimination.

Major Intestinal secretions: for pancreatic and bile secretions, see there.

CCK (cholecystokenin): Stimulates pancreatic secretion and induces contraction of the gallbladder, liberating the fat-emulsifying bile into the small intestine; CCK is released in response to the presence of amino and fatty acids in the duodenum.

GIP (Gastric inhibitory peptide) liberated from the small intestine in response of high levels of fatty acids, suppresses gastric secretion of HCL and pepsin.

Secretin: Stimulates pancreatic secretion, but inhibits gastric activity by lowering gastrin release.

Liver: The large, lobed gland that destroys blood cells, stores glycogen, vitamins and iron, detoxifies poisons, disperses glucose to the bloodstream (induced by insulin), disperses glucose to the bloodstream, and produces bile (derivative from the breakdown of red blood cells = color of feces, i.e.: modified cholesterol molecules which act like a detergent).

Blood is transportet to the liver by both an artery and a vein, whereas only one vein drains the blood from it (*Vena portae*). The liver is the main glucose-binding organ which converts the sugar-rich blood (400mg/0.1L **B**lood **G**lucose **L**evel) originating from the intestine, into glycogen (lowering the BGL to approx. 100mg/0.1L, hence reducing the osmotic properties of blood), an otherwise elevated BGL would have damaging effects to peripheral tissue and organs.

Bile: Viscous yellow or greenish alkaline fluid produced by the liver and stored in the gallbladder; containing bile salts, bile pigments (such as bilirubin and billiverdin, from the breakdown of red blood cells), certain lipids, and glycine. It emulsifies, and splits fat globules into micelles.

Bile Salts: Bile acid such as cholic acid conjugated with glycine or taurine, promoting emulsification and solubilization of intestinal fats (Na^+, K^+, Ca^{2+}, Cl^-, HCO_3^-).

Gallbladder: An sac lined with smooth muscle cells, that concentrates (withdrawal of water), regulates ionic concentration, and stores bile for eventual discharge into the intestine. Discharge of bile is stimulated by CCK (cholecystokinin).

Pancreas: A exocrine gland located behind the stomach. Secretes digestive enzymes into the small intestine (trypsin and chymotrypsin cleave proteins; carbopeptidase cleaves peptides; amylase cleaves starch and glycogen, lipase cleaves lipids, nucleases cleave nucleic acids - see table below), neutralizes stomach acid (bicarbonate), and the hormones insulin (take up of sugars) and glucagon (release of sugars) into the blood, by regulating blood glucose levels.

Peristalsis: A traveling wave of constriction in tubular tissue produced by contraction of circular muscle.

Saliva: A water-like fluid secretes in the upper alimentary canal (headgut); aids in mechanical and chemical digestion. α-amylase is contained in the saliva to facilitate digestion of carbohydrates ($pH \approx 6.5$ required for amylase to work). Saliva also serves as lubrication (muco-polysaccharide = mucin) of the chewed substances.

Stomach: An expandable, elastic-walled sac of the gut that receives food from the esophagus ($pH \approx 1.5$ caused by the hydrochloric secretions causing amylase to denaturize, acts also as a bacterio- and fungicide); stores and churns food, initiates protein digestion, forms of chyme; the stomach is the major site of hydrolisation (pepsin cleaves proteins , trypsin).

Monogastric S.: A single muscular tube or sac.

Digastric S.: The multi-chambered stomach of ruminants. Microrganisms in the first division of the stomach carry out fermentation; partially digested food is carried back to the mouth for remastication to be swallowed again to reach the second section of the stomach where hydrolysis takes place.

HCl is catalyzed by carbonic anhydrase by the reaction of: $CO_2 + H_2O \leftrightarrow H_2CO_3$

Major gastric secretions:

HCl (hydrochloric acid): Excreted by parietal cells (oxyntic) located in the gastric mucosa; HCl is secreted when the vagal motor discharges,

Gastrin, a gastric hormone (deriving from polyric cells of the lower stomach), triggers secretion of HCl and pepsin which under acidic influence cleaves to pepsinogen ; secretion is enhanced with foods such as caffeine, alcohol, and active ingredients in spices;

Mucin: Special mucus secreting cells protect gastric lining from auto-digestion.

Vorous: (L. voreare, to devour) Eating or feeding on.

Carniv.: (L. carnum, meat) An animal that eats the flesh of other animals.

Detriv.: (L. detritus, decay) An organism that takes energy from dead or waste organic matter.

Herbiv.: (L. herbum, plant) An animal that consumes plants as food.

Omniv.: (L. omni, all) An animal that consumes both plant and animal matter as food.

Major digestive enzymes

Enzyme	Substrate	Product	Formation
Carbohydrate Digestion - Carbohydrase - Polysaccharides			
Amylase	starch, glycogen	maltose	salivary glands, pancreas
Cellulase	cellulose	cellobiose	bacteria in part of gut
Carbohydrate Digestion - Carbohydrase - Disaccharidase			
Maltase	maltose	glucose	small intestine
Lactase	lactose	glucose, galactose	small intestine
Sucrase	sucrose	glucose, fructose	small intestine
Lipid Digestion			
Lipase	triaglycerol	di- + monoglycerol, fatty acids, glycerol	pancreas
Protein Digestion - Proteases - Endopeptidases			
Pepsinogen to Pepsin	polypeptide bonds adjacent to phenylalanine or tryosine	large peptides	stomach
Trypsinogen to Trypsin	polypeptide bonds adjacent to arginine or lysine	large peptides	stomach
Chymotrypsinogen to Chymotrypsin	many other polypeptide bonds	large peptides	stomach
Protein Digestion - Proteases - Exopeptidases			
Carboxypeptidase	CO_2H end of large peptides	small peptides, amino acids	pancreas
Aminopeptidase	NH_2 end of large peptides	small peptides, amino acids	pancreas
Tripeptidase	small peptides	amino acids	intestine
Dipeptidase	small peptides	amino acids	intestine
Enterokinase	trypsinogen	trypsin	intestine
Nucleic Acid Digestion			
Nuclease	nucleic acid	nucleo-tides, -sides	pancreas

Important Minerals

Macrominerals and their functions	
Calcium (Ca)	Component of shells, bones and teeth, muscle contraction, blood clotting, hormone secretion
Phosphorus (P)	Component of bones and teeth, energy metabolism; component of nucleic acid and lipids
Chlorine (Cl)	Principal extracellular negative ion; water balance; acid-base balance; formation of gastric HCl
Sulfur (S)	Component of many proteins
Potassium (K)	Main intracellular positive ion; transmission of impulses in nerve +muscle (effects membrane permeability); acid-base balance; protein synthesis
Sodium (Na)	Main intracellular positive ion; transmission of impulses in nerve + muscle; acid-base balance; water balance
Magnesium (Mg)	Appropriate balance between Mg and Ca needed for nerve and muscle function; lack of Mg leads to cramps); activates enzymes
Microminerals and their functions	
Chromium (Cr)	Required in the glucose metabolism; lack of Cr reduced glucose uptake
Cobalt (Co)	Component of cobalamin (vitamin B_{12}); synthesis of red blood cells
Copper (Cu)	Enzyme activation (thyrosinase); synthesis of hemoglobin; lack of Cu interferes with pigmentation and *anemia*;
Iodine (I)	Component of thyroid hormone, boosts metabolism; lack of I leads to goiter in adults and cretinism in infants; *anemia* due to inhibited synthesis of B_{12}
Flour (F)	Incorporated into the enamel of teeth; too much of it stains teeth grayish
Iron (Fe)	Component of hemoglobin, myoglobin, and cytochromes; deficiency first leads to *Regads* (torn angles of the mouth), tiredness, and in sever cases to *anemia* (deficiency in red blood cells)
Manganese (Mn)	Enzyme activation (pyruvat-decarboxylase); lack of Mn leads to sterility and *Chondro-dystrophy* (malformations of the bones);
Molybdenum (Mo)	Enzyme activation (aldehyd-oxidase)
Selenium (Se)	Enzyme activation (glutathion-peroxidase); antioxidant; lack of Se could lead to *muscular atrophy*; liver-, muscle-, and heart disturbances; depression of the immune system; decreased pathogenic resistance;
Zinc (Zn)	Enzyme activation (carbohydrase, alcohol- and lactat-dehydrogenase); lack of Zn can be a cause of *Anorexia*, altered sense of taste (gustin relies upon Zn), loss of hair, *Alopecia*, retarded wound healing

Common Vitamins

Vitamin	Common Sources	Function	Symptoms of Deficiency
Water soluble (hardly any overdose possible)			
B_1,Thiamine	Yeast, meat, whole grains, eggs, milk, green veggies	B_1 pyrophosphate coenzyme in decarboxy-lation reactions during carbohydrate meta-bolism (enzyme activator – decarboxlase); heat sensitive; alcoholics have an increased demand of B_1	*Beriberi*: spasms or rigidity of legs, nerve & muscle degeneration; deficiency of heart activity, depression, forgetfulness;
B_2,Riboflavin	same as B_1; colon bacteria	Flavin mononucleotide and flavin dinucleotide (FMN, FAD) are coenzymes for dehydro-genase reactions - electron transport in mitochondria and certain oxidations in the ER	Similar to PP deficiency, cracking finger nails and lips; *Rhagaden*, depression, malforma-tion of the unborn
B_6,Pyridoxine	same as B_1	Pyridoxol-phosphate is a coenzyme for many reactions involving amino acid metabolism: transamination, decarboxylation, etc.; essential for brain-, heart-,and liver activities	Dermatitis, gastro-intestinal disturbances, *Anemia*, skin disorders, depressions, cramps
B_{12},Cobalami n	Synthesized by intestinal bacteria, in animal foods only	Intrinsic factor; Co-containing coenzymes involved in amino acid conversion and for DNA synthesis; cell division; synthesis inhibited in alcoholics;	Decreased RNA activity resulting in *Anemia*; inflam-mation of nervous tissue
C, Ascorbic Acid	Citrus fruits and fresh veggies	Maintenance of intercellular substances: collagen fibers of connective tissue, capillary walls, helps in the absorption of Fe; involved in the buildup of teeth, bones, and the formation of blood and stress hormones	*Scurvy*: bleeding gums, loosening of teeth (*Gingivitis* – smoking), slow wound healing;
H, Biotin	Bacteria, Plants (readily available) and animals, yeast (bound to proteins)	Involved in skin formation; decomposition of carbohydrates and as a building factor of certain proteins; has anti-oxidative properties	Inflamed and scaly skin, pallid tongue, *conjunctivitis* sensitive eyes
PP, Niacin, Nicotinic acid	same as B_1	**P**ellagra **P**reventive (*pelle agra*); Nicotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP)are coenzymes for many dehydrogenase reactions in cellular oxidation	*Pellagra*: cracked, scaly skin, dark-red tongue & mouth irritated mucous membr. (*diarrhea*), nervous disorders (*shaker*), insanity
Folic Acid	same as B_1	Coenzyme tetrahydrofolic acid converts glycine to serine; required in DNA synthesis; cell division	Similar to B_{12} deficiency, *Anemia*, disturbed growth of hair and bone; inflamma-tions of mucus membrane
Pantothene Pantothenic acid	coenzyme A in every living cell, as in yeast, whole grain, liver, kidney, egg, veggies	part of coenzyme A and essential in the bodies metabolism; hair, tissue and mucus membrane formation require panthotene as well as synthesis of antibodies	Likelihood of infections in the gastrointestinal tract, growth retarding, *Burning feet* syndrome
Fat soluble			
A, Retinol	Butter, eggs, fish liver oils, plants; carotene in plants can be con-verted to vitamin A	Component of the light-sensitive pigment, visual purple, in the retina; maintenance and growth of epithelial cells (skin); functioning sexual organs;	Night blindness, inflammation of eyes, dry and scaly skin, increased susceptibility to infection
D_2, Ergo- D_3, Chole- -calciferol	Butter, eggs, fish oils, liver; formed in skin w/ UV light	Absorption and utilization of Ca and P; required in muscle activity and blood clothing, signal transmission of nerves, cell permeability	*Rickets*: weak bones and defective teeth, *osteoporosis*,
E, α-Tocopherol	Veggie-+-oil, , egg yolk, milk fat, liver, widely distributed	Not completely known, antioxidant (protects cell membranes – lipids), maintains muscle	Ruptured red blood cells, anemia, sterility, neg. effects on muscle and nervous tissue
K, Phyto-menadion	Green veggies, colon bacteria	Quinone compounds - generated by intestinal bacteria for the synthesis of blood-clotting proteins in the liver	Bleeding, especially in newborns, who lack bacteria

Glossary Animal Physiology - Metabolism

Bowmans Capsule: see kidney.
Excretion: The elimination of metabolic waste products from the body; the nitrogen-containing amino acid (NH_2) can't be oxidized, hence being transferred to ammonia (NH_3); ammonia is highly toxic to cells; in vertebrates, the main excretory organs are the kidneys.
Ammonotelic E.: Excretion of nitrogen in the form of diluted ammonia (expels one N/ molecule of ammonia).
Ureotelic E.: Excretion of nitrogen (ammonia), converted into less toxic in the form of urea (expels two N/molecule of urea).
Uricotelic E.: Excretion of nitrogen, converted into a combination of ammonia and CO_2 in form of toxic uric acid (expels four N/molecule of uric acid).
Glomerulus: A coiled mass of capillaries; as found in the Bowman's capsule - see kidney.
Homeostasis: The process associated with the maintenance of a constant state.
Kidney: The main excretory organ of the vertebrate body; filters nitrogenous wastes from blood, and regulates the balance of the water solutes in blood plasma by reabsorbing water, salts and nutrients:
Distal Tubulus: Salts, water, and nutrients are reabsorbed from the loop back to the blood leading to a very conentrated urine.
Loop of Henel: A U-shaped bend in the portion of a renal tubule that lies in the renal medula, responsible for the reabsorbtion of most of the water from the primary urine.
Proximal Tubulus: .
Nephron: Anatomical and functional unit of the vertebrate kidney, and consists of:

- **Bowmans Capsule** (Glomerular Capsule): A globular expansion at the beginning of a renal tubule and surrounding the glomerulus.
- **Glomerulus**: (L. glomerulo, little ball) A collection of tightly coiled capillaries enclosed in the Bowmans capsule, where primary urine is formed.

Renal Arteries: Nitrogen-collection of primary urine formation, where water, salts, sugars, urea filtered out from the N-rich blood enter the kidney via the arteries.
Renal Cortex: The outer part of the kidney where blood filtration takes place.
Renal Medulla: The central part of the kidney housing the loop of Henle.
Renal Pelvis: The central cavity of the kidney which collects urine before it passes to the ureter.
Renal Vein: Nitrogen-cleansed blood leaves the kidney via the veins.
Urethra: The tube that carries urine from the kidney to the bladder.
Osmoregulation: The effective osmotic pressure, regulated actively by the transport of ions in- and out of the cells maintaining osmolarity with respect to the environment.
O. **Pressure**: The relative osmotic pressure of a solution under given conditions; i.e. its osmotic effects on a cell relative to the osmotic effect of plasma on the cell.

- **Isososmotic**: Pertaining to a solution of equal osmotic concentration to that of another solution.
- **Hyperosmotic**: Higher osmotic concentration of solutes than that of another solution, compared with.
- **Hypoosmotic**: Lower osmotic concentration of solutes than that of another solution, compared with.

Salt gland: Osmoregulatory organ of many birds and reptiles that live in desert or marine environments. A hypertonic aqueous exudate is formed by active salt secretion into small tubules situated above the eyes and is excreted via the nostrils.

Glossary Animal Physiology - (Hormone)

Gland: A group of cells organized into a discrete secretory organ.

Adrenal Gland: (L. ad, to; renes, kidney) Secretes hormones mainly involved in the body's response to stress, such as epiphrine (adrenaline) and norepiphrine (noradrenaline). Neural stimuli induce release of corticoid-releasing hormone (CRH) from hypothalamic neurosecretory cells. Subsequent release of ACTH from the anterior pituitary gland stimulates secretion of glucocorticoids by the adrenal cortex. These steroids produce an increase in blood glucose and liver glycogen by stimulating conversion of amino acids (predominantly from muscles) and fats (fat cells) to glucose. The presence of glucocorticoids prevents further release of CRH and ACTH in a negative feedback loop at both pituitary and hypothalamus.

Gonads: Progesterone, a steroid derivative of cholesterol, is converted into androgens in males and trigger the development of their primary sex characteristics. Androgens are the precursors to estrogens in females, and stimulate later development of primary sexual characteristics in female. (see *HB-1 reproduction* for scans).

- **Females**: Neural input trigger the release of gonadotropin-releasing hormone (GnRH) by the hypothalamus, which stimulates the anterior pituitary gland to secrete FSH and LH.
  Follicular Phase: FSH promotes growth of the primordial follicle in one ovary - usually only one follicle per month. The maturing follicle grows rapidly by secreting increasing amounts of estrogen, which causes the uterine lining to become thicker and more heavily supplied with blood. Stronger estrogen levels eventually cause a rise in LH from the pituitary gland (essential for ovulation) which peaks on about the 14^{th} day, triggering the oocyte to break its meiotic arrest and complete its first meiotic division. The developing follicle ruptures and releases the ovum (ovulation).
  Luteal Phase: The ovary begins its journey down the fallopian tube; the follicle cells left behind in the ovary enlarge and form a new gland, the corpus luteum (yellow body). Corpus luteum cells start to secrete estrogen plus large quantities of progesterone, which promote further buildup of endometrium. High levels of estrogen and progesterone inhibit the hypothalamus from making releasing factors and the pituitary gland from releasing LH and FSH. If the egg is not fertilized, the inner lining of the uterus is shed, a process known as menstruation, and the cycle starts again. If the egg is fertilized, the implanting egg signals the placenta to generate hCG, which rescues the corpus luteum, until the placenta itself can produce LH and FSH (usually after two to three months)
- **Males**: Neural stimuli and low testosterone blood levels trigger the release of gonadotropin-releasing hormone (GnRH) by the hypothalamus. GnRH stimulates the release of LH and FSH from the anterior pituitary gland. Seminiferous tubules of the mammalian testes are lined with germ and Sertoli cells. Binding of FSH to receptors on Sertoli cells stimulates spermatogenesis in the germ cells after sexual maturity (continuously or seasonally). Sertoli cells also are responsible for synthesis of androgen-binding protein (ABP) and inhibin. The Leydig cells produce and secrete testosterone. Both testosterone and inhibin suppress GnRH production in the hypothalamus, hence, itself diminishing the release of FSH and LH from the anterior pituitary gland (adeno-hypophysis).

Hypophysis: (Gk. hypo, under; physis, growth) See pituitary gland.

Pancreas: A gland located behind the stomach that secrets digestive hormones into the small intestine and the hormones insulin and glucagon (islets of Langerhans) into the bloodstream (see scan below);

- **Blood sugar**: High levels of blood glucose and glucagon and/or gastrointestinal hormones (GIP) signaling food ingestion, stimulate the pancreatic β-cells to secrete **insulin**, which enforces glucose uptake in all tissues (liver, muscles, kidneys - glucose reabsorbtion from filtrate) - hyperglycemia, a process known as glycogenesis (polymerization of glucose to glycogen) and lipogenesis. **Glucagon**, secreted by pancreatic α-cells, exert an action that is antagonistic to that of insulin, stimulating glycogenolysis, lipolysis (gluconeogenesis), to prevent hypoglycemia in which glucose is released into the bloodstream to maintain vital body functions.
- **Growth**: Growth releasing hormone (GRH) from the hypothalamus trigger the release of growth hormone (GH) from the anterior pituitary gland, usually several hours after a meal or after prolonged exercise, in response to insulin-induced hypoglycemia (low levels of blood sugar). GH causes lipolysis, fatty acid uptake by muscle tissue and inhibits glucose uptake in most tissues. This GH-induced inhibition leads to a rise in plasma glucose, which stimulates insulin secretion. The insulin stimulates glucose uptake into cells and thus counteracts GH-induced hyperglycemia.

Pineal G.: An endocrine gland located in the vertebrate midbrain that produces the hormone melatonin; probably involved in body rhythms.

Pituitary G.: (or hypophysis) A complex endocrine organ situated at the base of the brain and connected to the hypothalamus by a stalk. The anterior lobe secrets growth hormones, prolactin, LH, FSH, ACTH, TSH, and MSH; the posterior lobe stores and releases oxytocin and ADH. Much of the functioning of the pituitary is under the control of the hypothalamus (1^{st} order), and pituitary hormones (2^{nd} order) control most of the other endocrine glands (target) - see negative feedback loop.

Thymus G.: A gland in the neck or thorax of many vertebrates; makes and stores lymphocytes in addition to secreting hormones.

Thyroid G.: A large endocrine gland in the neck of vertebrates regulating the body's growth and use of energy by secreting thyroxine (T_4) and triiodothyronine (T_3); see scan below;

Neural stimuli (low skin temperature and stress) trigger the release of TSH-releasing hormone (TRH) from the hypothalamic neurosecretory cells; TRH itself stimulates secretion TSH from the anterior pituitary gland. In response to TSH, the thyroid secrets the thyroid hormones, which increase metabolism in skeletal, cardiac muscle, liver, and kidney, hence lead to the metabolic generation of heat. The negative feedback of thyroid hormones cause both the anterior pituitary gland and the hypothalamus to suppress the emission of their mediating substances TRH and TSH.

- <u>Hyperthyroidism</u> (excess production of TSH) of the gland.
  Symptoms: intolerance to heat, increased sweating, mild to extreme weight loss and diarrhea, muscular weakness, nervousness, extreme fatigue, sleeplessness, tremor in the hands. Toxic Goiter, the entire gland is increased to 2 to 3 times normal size. Thyroid adenoma or tumor that develops in the thyroid tissue and secretes large quantities of TH.
- <u>Hypothyroidism</u>. The effects are just opposite to those of hyperthyroidism. Probably results from autoinmunity against the thyroid gland, thus destroying it; resulting in thyroiditis (immflamation), decrease secretion of TH, enlargement of gland-thyroid goiter. Also it results from the lack of iodine during early stages of development in fish, birds; cretinism in humans (somatic, neural and sexual retardation, reduction in metabolic rate to ½ of normal rate, and resistance to infection). Myxedema in adults, i.e.: arteriosclerosis occurs because the lack of TH, increases cholesterol in blood which diminishes liver excretion of cholesterol in the bile.
- **Parathyroid**: One of a set of four small endocrine glands located on the thyroid gland. It secretes parathyroid hormone (PTH), which controls blood calcium levels. Calcitonin and PTH have opposite effects on plasma Ca^{2+} levels in mammals. Low levels of plasma Ca^{2+} stimulate the cells of the parathyroid gland to release PTH (Ca^{2+} mobilization from bones and forming urine in kidneys). High concentrations of Ca^{2+} in the blood stimulates parafollicilar cells in the thyroid gland to release calcitonin, which suppresses release of Ca^{2+} from bones. Calcitonin, the active hormonal form of vitamin D, also increases intestinal absorption of Ca^{2+}. Both hormones exerts negative feedback on its own (see scan below);

Endocrine: A hormonal pathway characterized by the production of a biologically active substance by a ductless gland; the substance then is carries through the bloodstream to initiate a cellular response in a distal target cell or tissue.

E. **Gland**: Ductless organs or tissues that secrete a hormone into the blood circulation; e.g.: pituitary-, thyroid gland, etc. (see gland).

E. **Response**: Hormones trigger a signal cascade, gene activation and/or alter permeability of cell membranes.

Exocrine: Of or relating to organs or structures that secrete substances via a duct.

E. **Gland**: A gland that secretes a fluid via a duct; e.g.: salivery-, milk-, silken thread glands etc.

Feedback Loop: A control system in which the result of a process influences the functioning of the process.

Negative FL.: The hypothalamus produces a releasing or inhibiting factor that causes the anterior pituitary to secrete or not secrete a peptide hormone; if secreted travels in the blood, eventually reaching the target gland, causing it to secrete a third hormone, generally of steroid or amine origin; as the level of this hormone builds, it feeds back to the hypothalamus and/or pituitary and blocks additional hormone release.

Heart: Granula within the atrium of the heart (hormone storing tissue) contain ANP, which has an immediate impact to the function of the heart; i.e.: lowering blood pressure.

Hormone: A chemical compound synthesized by specific tissues or glands and secreted by an endocrine tissue into the bloodstream, stored in vesicles or granules; influences the activity of a target tissue via a signal cascade, gene activation and/or alter permeability of cell membranes (in comparison to nerve-conducted signals is far slower in response but having a prolonged effect).

Neuro- H.: A substance that exists within the neurons of the nervous system and exerts hormonal effects outside the nervous system.

Neurotransmitters: A chemical that transmits a nerve impulse across a synapse.

Paracrine H.: A primitive hormone that acts on cells immediately adjacent to the ones that secrete it.

Pheromone: A compound produced by one individual that affects another individual at a distance.

True H.: A chemical produced by non-neural cells in one part of the body that has an effect on another part of the body.

Chemical Classes of H. based on four molecular groupings:

Amine H.: Derivatives of amino acids in which at least one H-atom is replaced by an acyl group; e.g.: thyroid hormones etc.

Fatty Acid H.: Such as prostaglandins, are derived from straight-chain fatty acids

Steroid H.: Cyclic hydrocarbon derivatives synthesized from cholesterol; e.g.: estrogen, testosterone, ecdysone, etc. trigger their activity by switching on/off certain genes.

Peptide and Protein H.: The largest and most complex group of hormones; it includes growth hormones and oxytocin; their activity is based on a second messenger cascade.

Types and effects of H.: See also table below.

ACTH - **A**dreno**C**ortico**T**ropic H.: A hormone released by cells in the adenohypophysis that acts mainly on the adrenal cortex, stimulating growth and corticosteroid production and secretion in that organ.

ADH: **A**nti**D**iuretic H.: a hormone made in the hypothalamus and liberated from storage in the neurohypophysis; acts on the epithelium of the renal collecting duct by stimulating osmotic reabsorbtion of water, thereby producing a more concentrated urine; it also acts as vasopressor; but interferes with the brain, by decreasing its capabilities.

AGT: **A**n**G**io**T**ensin: A protein in the blood, converted from angiotensinogen by the action of renin; it first exists as a decapeptide (AGT-I) that is acted upon by a peptidase, which cleaves if into an octapeptide (AGT-II), a potent vasopressor and stimulator of aldosterone secretion.

Androgens: Male hormones that have musculinizing activity; important for growth, development, morphologic differentiation, development and regulation of sexual and reproductive behaviors and cycles (e.g. facial hair in men) at the time of puberty.

Contribute to general growth and protein synthesis-of myofibrillar proteins in muscle (muscularity).

ANP: **A**triale **N**atri-uretic **P**eptide, a peptide hormone cleaved from a single precursor peptide and produced in the cardiac atria, the physiological effects of which include increased urine output, increased sodium excretion, and a receptor-mediated vasodilatation, the net result of which is lowered blood pressure. Interferes with vasopressin (ADH) and renin.

AS - Aldo**S**terone: Released by the adrenal cortex causing the kidneys to conserve sodium and water and to excrete potassium.

BE - **B**eta**E**ndorphin: A hormone acting on pain receptors in the brain by decreasing the amount of pain experienced of a stressed individual. It is released by the interior pituitary glands by the breakdown of ACTH.

Calcitonin: Influences the Ca^{2+} levels in the blood. It deposites Ca^{2+} in the bones, and lowers of Ca^{2+} excretion in renal tubes.

CCK - **C**hole**C**ysto**K**inin: A hormone liberated by the upper intestinal mucosa that induces gallbladder contraction and releas of pancreatic enzymes.

HC - **H**ydro**C**ortisone: A hormone released by the adrenal cortex of the adrenal gland, speeding up the metabolism of sugars, proteins, and fats when under stress.

Ecdysone: A steroid hormone which triggers molting (high concentrations) and metamorphosis (low concentrations) in insects.

Estrogen: A female sex hormone produced by the ovary; prepares the uterus to receive an embryo in mammals, and causes secondary sex characteristics to develop in mammalian females. It stimulates somatic tissue growth (hips) development of mammary gland and to maintain uterine lining.

FSH - Follicle **S**timulating **H**.: An anterior pituitary gonadotropin that stimulates the development of ovarian follicles in the female and testicular spermatogenesis in the male.

Glucagon: A hormone released by the pancreas causing blood sugar levels to rise. IT induces glycogenolysis and release of glucose into the blood.

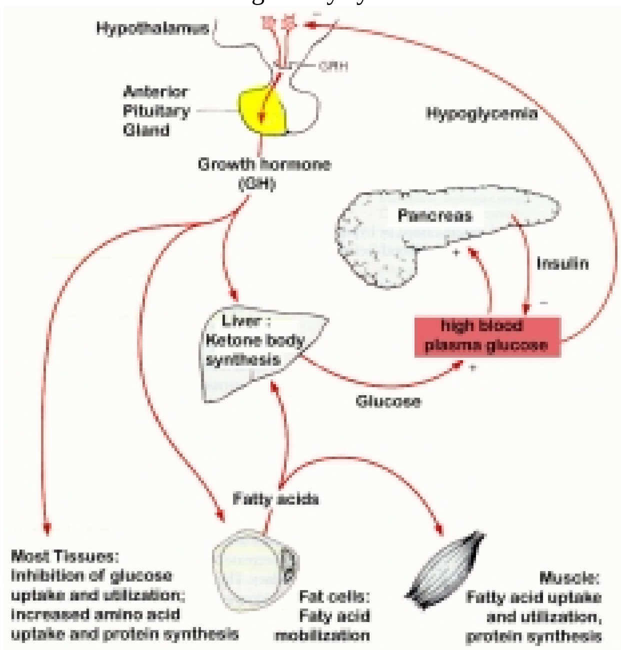
Gluco-Corticoids: Steroids synthesized in the adrenal cortex with wide-ranging metabolic activity; includes cortisone, cortisol, corticosterone, and 11-deoxycorticosterone. It effects muscles by inducing a net loss of amino acids, frees fatty acid mobilization, triggers deamination of amino acids (gluconeogenesis) in the liver.
GH - **G**rowth **H**.: A protein hormone that is secreted by the anterior pituitary and stimulates growth; directly influences protein, fat, and carbohydrate metabolism and regulates growth rate.
GnRH - Gon**adoprin **R**eleasing **H**.: Hormones that influence the activity of gonads; in particular, those secreted by the anterior pituitary.
hCG - **H**uman **C**horionic **G**onadotropin: This hormone prevents the onset of a new menstruation cycle, which would otherwise flush a fertilized and implanted egg from the uterus.
Inhibin: See müllerian inhibiting hormone.
Insulin: A protein hormone of the pancreas that causes cells to remove the sugar glucose from the blood. It suppresses glycogenolysis in the liver, induces glycogen synthesis in muscles, increases absorption of glucose from urine filtrate in kidneys, increases transport of glucose and amino acids into cells.
LH - **L**uteinizing **H**.: A gonatropin that is secreted by the adenohypohpysis and that acts with FSH to induce ovulation of the ripe ovum and liberation of estrogen from the ovary; also influences formation of the corpus luteum and stimulates growth in and secretion from the male testicular Leydig cells.
Melatonin: An amine hormone released during the dark cycle of the day, promoting sleep and inhibiting gonadal activity and is one cause of seasonal affective disorder.
PTH - Para**T**hyroid **H**.: Influences the Ca^{2+} levels in the blood. It mobilizes Ca^{2+} from the bones, resorbtion of Ca^{2+} in renal tubes, and increases absorption of Ca^{2+} from intestine mediated by clacitriol.
Progesterone: A female sex hormone secreted by the corpus luteum in the ovary the stimulates uterine wall thickening and mammary duct growth.
PRL - **PR**o**L**actin: An adenohypophyseal hormone that stimulates milk production and lactation after parturition in mammals.
Testosterone stimulates spermatognesis, somatic tissue stimulation growth, primary and secondary male sex characteristics, and behavioral brain changes.
TSH - **T**hyroid **S**timulating **H**.: An adenohypophyseal hormone that precursors to thyroxine stimulating the secretory activity of the thyroid gland.
Thyroxine: The most abundant thyroid hormone, which governs metabolic and growth rates and stimulates nervous system function. It effects muscle tissue, the heart, liver and kidneys.
Vasopressin: see ADH

Hypophysis: see glands, pituitary gland.

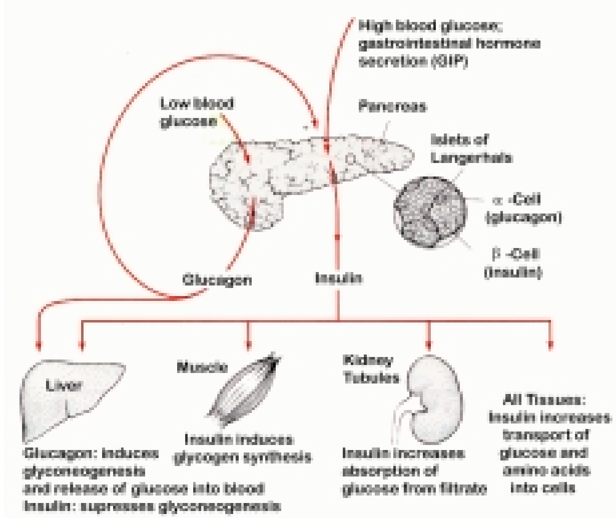
Hypothalamus: The part of the diencephalon that forms the floor of the median ventricle of the brain (base of the brain); a collection of nerve cells responsible for regulating body temperature, many functions of the autonomic nervous system and many endocrine functions.

Renin: A proteolytic enzyme produced by specialized cells in renal arterioles; converts angiotensinogen to angiotensin, which shows its effect by forcing the main artery of the kidney to contract.

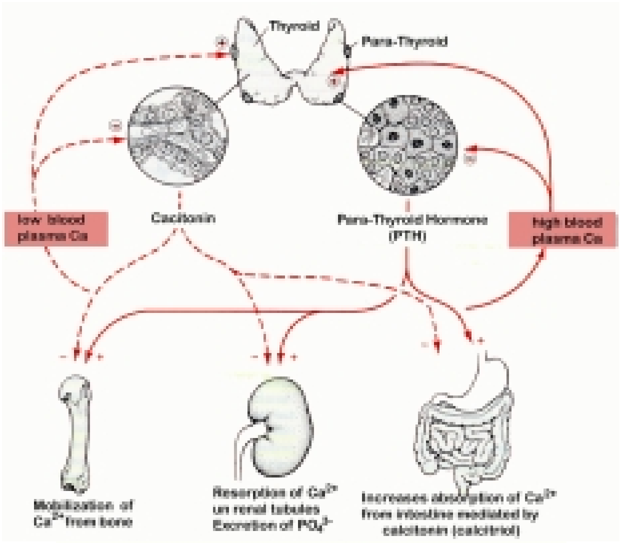
Four basic hormonal regulatory systems



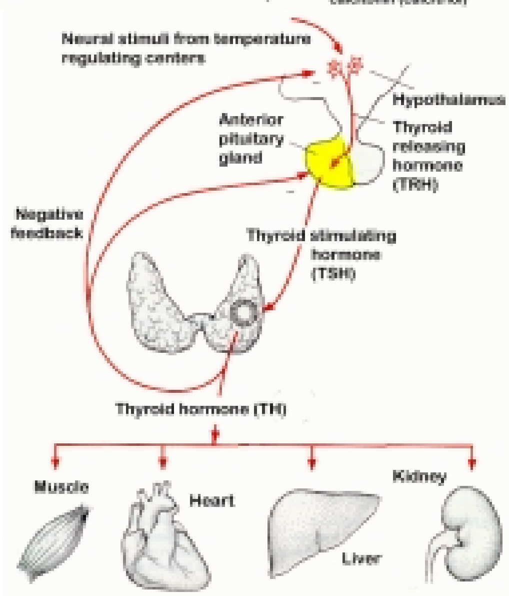
Many of the actions of GH ate antagonistic to those of insulin. Output of insulin from pancreatic β-cells occurs in response to high blood glucose, as after a meal. GH is released, usually several hours after a meal or after prolonged exercise, in response to insulin-induced hypoglycemia. GH causes lipolysis and fatty acid uptake by muscle tissue for energy and by the liver for ketone body synthesis. The GH-induced general depression of glucose uptake (except CNS) leads to a rise in plasma glucose, which then stimulates insulin secretion. The insulin stimulates glucose uptake into cells and thus counteracts GH-induced hyperglycemia.



The pancreatic hormones insulin and glucagon play a major role in regulating blood glucose levels. High levels of blood glucose and glucagon and/or gastrointestinal hormones signaling food ingestion (e.g. GIP) stimulate the pancreatic β-cells to secrete insulin, which stimulates glucose uptake in all tissues. Glucagon, secreted by pancreatic α-cells, exerts an action that is antagonistic to that of insulin in the liver, where it stimulates glycogenolysis and glucose release, besides other effects



Calcitonin and PTH have opposite effects on plasma Ca^{2+} levels in mammals. Low levels of Ca^{2+} stimulate the cells of the parathyroid glands to release PTH, which has several actions all tending to increase plasma Ca^{2+}. High concentrations of Ca^{2+} in the blood stimulate para-follicular cells in the thyroid gland to release calcitonin, which acts to increase plasma Ca^{2+}. Calcitriol, the active hormonal form of vitamin D, also increases intestinal absorption of Ca^{2+}.



The thyroid hormones, which regulate metabolism in various tissues, are regulated by neural stimuli and negative feedback. A low skin temperature and stress stimulates TRH release from the hypothalamic neuro-secretory cell; TRH then stimulates secretion of TSH from the anterior pituitary gland. The thyroid responds by secreting the thyroid hormones, which cause increased metabolism in skeletal and cardiac muscle, liver, and kidney and hence lead to the metabolic generation of heat. Feedback inhibition by thyroid hormones apparently occurs at the levels of both the anterior pituitary gland and the hypothalamus. The follicle shown superimposed in the thyroid gland is drawn at a disproportionately large scale.

Major vertebrate endocrine tissues and hormones

Tissue	Hormone	Class*	Target	Major Actions
Adrenal Cortex	sex steroids		unknown	stimulate growth of body hair in women
	androgen	**S**	many cells	muscular development, pubic hair growth, libido
	mineralocorti-coids	**S**	kidney	increase Na conservation e.g.: aldosterone
	glucocorticoids	**S**	many cells	stimulate carbohydrate metabolism and decrease inflammation e.g.: cortisol
Adrenal medulla	epinephrine (= adrenaline)	**AAd**	circulatory system	increases heart rate, blood pressure, and blood sugar
	nor-epinephrine	**AAd**	circulatory system	generally same as epinephrine
Gastro-intestinal tract	gastrin	**Pep**	gut cells	stimulates HCL secretion
	CCK	**Pep**	pancreas	stimulates digestive enzyme secretion
Hypothalamus	releasing and inhibiting h.	**Pep**	anterior pituitary	stimulate of inhibit release of pituitary hormones
Kidney	erythropoietin	**P**	blood cell precursors	stimulates red blood cell production
Liver	somatomedins	**Pep**	many cells	synthesis of DNA of protein, cell growth
Parathyroid	parathormone	**Pep**	bones	stimulates Ca^{2+} release into blood
			digestive tract	stimulates Ca^{2+} uptake into blood
Pancreas	insulin	**P**	many cells	stimulates glucose uptake from blood
	glucagon	**P**	many cells	stimulates glucose release from cells into blood
Pineal	melatonin	**AAd**	hypothalamus	blocks secretion of LH- and FSH releasing factors
			brain	promotes sleep
Pituitary (anterior) = adeno- -hypohysis	TSH	**GP**	thyroid	stimulates synthesis and secretion of thyroxine
	PRL	**Pep**	mammary gland	stimulates milk synthesis
	ACTH	**Pep**	adrenal cortex	stimulates synthesis of sex steroids, mineralocorticoids, glucocorticoids
	endorphines		brain	decrease pain
	GH	**P**	many cells	stimulates general body growth
	LH	**GP**	ovary	stimulates ovulation and synthesis of estrogen and progesterone
	FSH	**GP**	ovary	stimulates growth of ovarian follicle
Pituitary (post.) =neurohyp.	oxytocin	**Pep**	mammary gland	milk ejection, uterus contractions during birth
	ADH	**Pep**	kidney	increases water absorption
Placenta	hCG	**GP**	corpus luteum in ovary	stimulates progesterone synthesis
	plac. lactogen	**Pep**	mammary gland	stimulates mammary gland development
Ovary	estrogen = estradiol	**S**	many cells	stimulates female development and behavior
	progesterone	**S**	uterus	stimulates growth of uterine lining
Skin	cholecalciferol = Vitamin D	**S**	many cells	promotes absorption of mineral ions from gut, release of Ca^{2+} from bones
Thyroid	thyroxine	**AAd**	most cells	increases metabolic rate and growth, causes metamorphosis in amphibians
	calcitonin	**Pep**	bones	stimulates Ca^{2+} uptake
Testis	testosterone	**S**	many cells	stimulates male development and behavior
	müllerian inhibiting h.		pre-oviduct cells	kills pre-oviduct cells
Thymus	thymosin	**Pep**	white blood c.	stimulates differentiation

*) Chemical classification: **AAd** amino-acid derivative, **Pep** peptide, **P** protein, **GP** glycoprotein, **S** steroid,

Glossary Animal Physiology - (Heart and Muscle)

Muscle Fiber: A skeletal muscle cell; a giant cell with many nuclei and numerous myofibrils, capable of contraction when stimulated. It consists of myofibrils, sacromeres, actin and myosin filaments. ATP is a crucial factor, since it binds to the myosin head, causing it to release the actin, which itself cleaves the ATP to ADP+P as the head swings forward and binds actin again for another stroke.

Actin: (Gk. actos, a ray) A ubiquitous protein, connected to the sacromere that participates in muscle contraction and other forms of cellular motility. G-actin is the globulas monomer that polymerizes to form F-actin, the backbone of the thin filaments of the sacromere of muscle.

Actoyosin: A complex of muscle proteins formed when myosin cross-bridges bind to actin in thin filaments.

Electromechanic coupling:

Myofibril: A longitudinal unit of muscle fiber made up of sacromeres and surrounded by the sacoplasmic reticulum, containing actin- and myosin-filaments

Myosin: The protein that makes up the thick filaments and cross bridges in muscle fibers; it is also found in many other cell types and is associated with cellular motility.

Sarcolemma: The surface (plasma) membrane of a muscle fiber.

Sacromere: (Gk.sacros, flesh; meros, part of) The contractile unit of myofibrils bounded by transverse tubules.

Sarcoplasmatic Reticulum (SR): A smooth membrane-limited network surrounding each myofibril (equivalent of endoplasmatic reticulum in cells). Ca is stored in the SR and released as free Ca^{2+} during muscle excitation-contraction coupling.

Transverse Tubules: Branching membrane-bounded, intercommunicating tubules that are continuos with the surface membrane and are closely opposed to the terminal cisternae of the sarcoplasmic reticulum.

M. **Contraction**: A trigger from an nACh receptor initiates the process by releasing Ca^{2+}; the ions attach to troponin (part of the actin protein) and trigger contraction; a sliding filament mechanism of muscle contraction shortens the sarcomere; the filaments past each other because myosin heads bind to actin, and as each head binds, it pushes the actin filament past like an oar and then swings forward for another stroke.

Isometric MC.: Contraction during which a muscle does not shorten significantly.

Isotonic MC.: Contraction in which the force generated remains constant while the muscle shortens.

Tetanus: An uninterrupted muscular contraction caused by high frequency motor impulses.

Types of M.:

Cardiac M.: A self-contracting muscle where the contracting waves (with the self-generated AP's) propagate along the entire tissue (staring from the sinus node down to the apex); the CNS implies a modulating task only; see also circulatory system - heart:

- Sympaticus stimulation: Managed by the sympatethic NS, resulting in an increased heartbeat.
- Vagus stimulation: Managed by the parasympatethic NS, resulting in a lowered heartbeat.

Smooth M.: A muscle without sarcomeres, hence without striations myofilaments are non-uniformly distributed within small, mononucleated, spindle-shaped cells; the type of muscle found in the intestinal tract, because of their extended rate of response; smooth muscle cells communicate electrically through gap junctions and tend to contract in sequential waves.

- neuronal stimulation
- hormonal stimulation
- local metabolic stimulation
- endothelial cells (see circulatory system)

Striated M.: Characterized by sacromeres aligned in register, the type skeletal muscles are made of; the more motorneurons stimulate the muscle, the stronger is the contraction .

Rigor Mortis: Rigidity that develops in dying muscle as ATP becomes depleted and cross bridges remain attached.

Sphincter: A ring-shaped band of muscle fibers capable of constricting an opening or a passageway.

Tendon: A band of tough fibrous connective tissue that anchors a skeletal muscle to the skeleton, allowing contraction of the muscle to move the body of an animal.

Tetanus: see Muscle contraction.

Tonus: Sustained resting contraction of muscle, produced by basal neuromotor activity.

Glossary Animal Physiology - (Respiration)

Alveolus: see lung.
Bohr Effect: The phenomenon in which hemoglobin releases O_2 more easily in acidic environment (as blood pH falls to 7.2 = venous blood), as when muscles are working hard: $CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$.
Carbon Dioxide Affinity: CO_2 is transported away from the tissues to the lungs in distinct manners:

- Some of the CO_2 gas enters the blood by forming a weak acid: $CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$.
- Carbonic anhydrase facilitates absorption of CO_2 gas in water (blood).
- The remaining CO_2 gas is attached to the amino groups of the hemoglobin.

Convection: The mass transfer of heat due to mass movement of a gas or liquid.
Counter-current Flow: A mechanism in which two different fluids flow in opposite directions and can exchange substances at points of contact along a concentration gradient - as in gills, see respiratory organ.
Diffusion: (L. diffundere, to pour out) Dispersion of atoms, molecules, or ions as a result of random thermal motion (Brownian motion); the net movement of suspended or dissolved particles from a more concentrated region to a less concentrated region as a result of random movement (Brownian motion) of individual molecules resulting in a uniform distribution within the medium:
$D = d^2/t$ [m^2/s]

d, distance	[m]
t, time	[s]

Gas Diffusion: O_2 diffusion and CO_2 diffusion in humans

O_2 diffusion	CO_2 diffusion in humans
• Air passes from the mouth or nose	• In an exchange, CO_2 diffuses out of the cells and into the blood,
• then to the trachea to the lungs (high O_2 concentration)	• Diffusing out of the capillary (as long as colloid osmotic pressure is intact)
• O_2 diffuses from tiny sacs (alveoli) in the lungs, then into blood capillaries (low O_2 concentration) + Bohr effect.	• Entering the alveolus (by principle of cdiffusion);
• Enters red blood cells and binds to the iron-containing protein hemoglobin (structure is like an O_2 sponge).	• Carried to the lungs $CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$ and binding at HB to become carbamino hemoglobin
• In each systemic capillary, O_2 leaves hemoglobin (intermediate O_2 concentration), and diffuses into tissue cells (low O_2 concentration).	• Diffusing from the alveolar capillaries (concentration gradient) to the alveolar sac, to be expelled from the body in the next exhalation.

Gas Laws: Basic physical principles form the framework for respiration in biologic systems - see chemistry-gas.

Avogadro's Law: Equal volumes of different gases at the same temperate and pressure contain equal numbers of molecules. 1 [mol] ($6.022 \cdot 10^{23}$ molecules) of gas at 0[°C] and 1[bar] occupies **22.414** [l] = mole-volume.

Charles and Gay Lussac's Law: Either the pressure or the volume of a gas is directly proportional to absolute temperature if the other is held constant;
$V_1/T_1 = \text{constant} = V_2/T_2$
$p \cdot V = n \cdot R \cdot T$ [$m^3 \cdot N/m^2$]

V, volume [m^3] or	[l]
T, temperature	[K]
R, gas constant 8,314	[J/(K·mol)]
n, molar amount	[mol]

Dalton's Law of Partial Pressure: The partial pressure of a gas in a mixture is independent of other gases present; the total pressure is the sum of the partial pressure of all gasses present: e.g.:
p_{O2} in air: 101[kPa]·0.2094 = 21.15[kPa]
$p_A = x_A \cdot p_T$ [Pa]

x_A, mole fraction	[-]

Henry's Law: The solubility of a gas in a liquid is proportional to the pressure of the gas over the solution; see chemistry liquids.

Gill: see respiratory organ.
Hemoglobin: see respiratory pigment.

Lung: The principal air-breathing organ of most land vertebrates; see also respiration organ.
These soft, elastic sacs are suspended in the thoracic cavity, enclosed by the fluid filled pleural sac: Ventilation of the lungs is possible because of the activity of the diaphragm and the expandable rib cage, which draws fresh air in and allows stale air to rush back out.
Alveoli: (L. small cavity) A thin-walled, saclike, microscopic structure, surrounded by blood capillaries, in the vertebrate lung where gas exchange takes place. Each lung contains millions of alveoli.
L. **Capacity**: In mammalians, split into the following sectors:

- **Inspiratory Capacity** = the tidal volume + inspiratory reserve volume; the amount of air (3.5l) that a person can breath beginning at the normal expiratory level and distending the lungs to the maximum.
- **Functional Residual Capacity** = expiratory reserve volume + residual volume; the amount of air remaining in the lungs at the end of normal expiration (2.3l).
- **Vital Capacity** = inspiratory reserve volume + tidal volume + expiratory reserve volume. It is the maximum amount of air that a person ccan expell form the lungs after first filling the lungs to the maximum extent and then expiring to the maximum extent (4.6l).
- **Total lung capacity** = vital capacity + residual volume. Maximum volume to which the lungs can be expanded with the greatest possible inspiratory effort (5.l)

Neural Regulation of Breathing: Pattern generator determining the depth and amplitude of each breath, and the rhythm generator, controlling breathing frequencies, besides sensory information of pH, CO_2, and O_2 content are processed in the medullary respiratory centers of the brain.

Oxygen Affinity: The hemoglobin-O_2 affinity is liable and dependent on the conditions within the red blood cell; affinity is reduced by the following:

- elevated temperature
- binding of organic phosphate ligands including 2,3-diphosphoglycerate (DPG), ATP, or GTP.
- Decrease in pH (increase in H^+ concentration); arterial blood pH = 7.6; venous pH = 7.2.
- Increase in CO_2: $CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$

Oxygen Dissociation: Saturated human arterial blood holds 20[ml] of oxygen per 100[ml] of blood, when the partial pressure of oxygen reaches about 13.3[kPa], as in the lungs; in thin-walled tissue capillaries, the partial pressure is about 5.33[kPa]; equals a 75% saturation, hence 5[ml] of oxygen per 100[ml] are given off; as CO_2 enters, rendering blood more acid, oxygen affinity decreases, liberating an extra 3[ml] of O_2 (Bohr effect). During vigorous exercise, the partial pressure of O_2 falls nearly to 2[kPa], extracting further O_2 from hemoglobin. Under best conditions only 75% of the O_2 delivered will be used up by the surrounding tissue.

OD curves: Describe the relationship between percent saturation and the partial pressure of oxygen. The O_2 dissociation curve of myoglobin and lamprey hemoglobin are hyperbolic because they have a single heme group; whereas, the other vertebrate hemoglobins are sigmoid because they have 4 heme groups.

Parabronchi: Air-conducting pathways in the bird lung; a series of 10µm small tubes extending between large dorsobronchi and ventibronchi, both of which are connected to an even larger tube the mesobranchus which joins the trachea anteriorly.

Respiration: The exchange of O_2 and CO_2 between cells and the environment (cellular respiration); respiration at the organismal level is the way an animal exchanges gases with the atmosphere.
Respiratory Organs for wet and dry environments:
Gill: A specialized structure that exchanges gases in water-living animals. The principle of countercurrent flow guarantees that CO_2 is given off, and O_2 is taken up (to increase efficiency of O_2 take up). The quantity of gas in solution is affected not only by partial pressure but also by the solubility of the particular gas and by factors that affect solubility, such as <u>temperature</u>.

- Gills can be external (some amphibians) or internal (fishes); internal gills are covered by an operculum (works as a push-pull-pump); between the gills slits are gill bars or tissue that supports the surfaces across which gases are exchanged, each gill bar is subdivided into hundreds of flexible gill filaments, which are in turn composed of many thin, platelike structures or lamellae, each lamella is a lacy meshwork of capillaries lying just one cell layer away from the water that passes through the gill filament.
- This proximity of blood to oxygenated water means that O_2 readily diffuses across the cells into capillaries, while CO_2 diffuses outward just as easily, the pumping heart helps to circulate the O_2-rich blood throughout the body.
- There is a countercurrent flow in which water flow moves in the opposite direction to the blood flow within the capillaries inside the gill’s lamellae (afferent - venous; efferent - arterial blood).

- The animal can collect sufficient O_2 for aerobic cellular respiration and an active life-style even though water holds less O_2 than air; cold water has a higher O_2 content than warmer waters.

Lung: The principal air-breathing organ of most land vertebrates.

- Aves: Air sacs associated to the lungs, when squeezed, air is forced through the parabronchi. The system of air sacs penetrates into adjacent bones and between organs, reducing the density of the bird. Air flow is bidirectional in the mesobranchus but unidirectional in the parabranchi; allowing the bird to rebreath (turbo charger) its partly oxigenized air therefore increasing efficiency, enabling the bird to fly at high altitudes.
- Mammal: Multi-chambered, elastic bags, suspended in the liquid filled pleural cavity (diaphragm + thoracic cage) enable respiration; muscles attached to the ribs and diaphragm passively inflate / deflate alveoli.
- Reptile: Respiration is predominantly achieved by the strengthening and relaxation of muscles at the toracic cage; in turtles by a forward movement of the shoulders.

Tracheae: Branching networks of hollow air passages, that end in air capillaries; found in insects.

R. **Pigment**: A protein, which enables the blood to carry far more O_2 than could be transported in simple solution; $Hb + O_2 \leftrightarrow HbO_2$ (in a loose bond), whereas CO_2 binds on the amino acids of Hb with the help of carbonic anhydrase; or as bicarbonate (HCO_3^-).

The most common respiratory pigments are:

- Hemoglobin (Fe^{2+} tetramer), the O_2 carrying pigment of the erythrocytes, formed by the developing erythrocate in bone marrow. A complex, 4-chained protein composed of four heme groups and four globin polypeptide chains plus several hundreds amino acids - deep sea fishes lack hemoglobins, since solubility of respiratory gases increase with depth.
- Myoglobin (Fe^{2+} monomer), an iron-containing protoporphyrin-globin complex found in muscle; having a higher affinity to O_2, serves as a reservoir for oxygen and gives some muscles their red or pink color; it is also common in diving organisms.
- Hemerytrhin, an invertebrate respiratory pigment that is a protein but does not contain heme.
- Hemocyanin, an invertebrate respiratory pigment that is a protein, contains copper, and is found in mollusks (except for bivalves) and crustaceans.

Some typical respiratory patterns:

Eupnea: Normal, quiet breathing typical of an animal at rest.

Hyperventilation: Increase and decrease, respectively, in the amount of air moved in or out of the lungs by changes in the rate and / or depth of breathing, such that ventilation no longer matches CO_2 production and blood CO_2 levels change.

Hyperpnea: Increase lung ventilation during exercise deeper breaths in response to increased CO_2 production.

Apnea: Absence of breathing.

Dyspnea: Labored breathing associated with the unpleasant sensation of breathlessness.

Polypnea: Increase in breathing rate without an increase in the depth of breathing.

Surfactant: When water forms a surface with air, the water molecules from the surface of the water tend to attract each other; as a result, the water surface tends to contract along with the alveoli keeping away gases from penetrating. Therefore, the surfactant is a surface active agent which reduces the surface tension of water.

Glossary Animal Physiology (Nervous System)

ACh: see transmitter substances.
Agonist: A substance that can interact with receptor molecules and mimic an endogenous signaling molecule.
Antagonist: Agents that inhibit, block, or counteract an effect.
Axon: The elongated cylindrical process of a nerve cell along which action potentials are conducted; a nerve fiber.
A. **Hillock**: The transitional region between an axon and the nerve cell body.
Axoplasm: The cytoplasm within the axon.
Cell: The basic unit of life; the most important neural cell types are:
Glia C.: (Gk. glia, to glue) Also known as neuroglia; inexcitable supportive cells associated with neurons in nervous tissue, which :
i) mechanically and electrically shield the neuron's axon,
i) provide nutrients for the neurons,
i) maintain a constant (homeostatic) condition for important ions (K^+, Ca^{2+}), and
i) repair and substitute defective nerve cells,
all types of glia cells ensure that AP's are transmitted quickly through the axon of nerve cells:
- **Macro**- GC.: Gliacells of the CNS, also known as ascocyte used in signal transmission of neurons.
- **Micro**-GC.: Glia cells with tasks of immunity of the brain; eliminate mutated brain cells and microrganic intruders by phagocytosis.
- **Oligodendrocyte**: Glial cells of the CNS with few processes wrapped around axons, forming myelin sheaths.
- **Schwann** C.: A neuroglial cell of the PNS that wraps its membrane around axons.

Nerve C.: (Neuron) A bundle of axons held together as a unit by connective tissue; and consists of soma (cell body), axon (cell process for outgoing AP's), dendrite (process for incoming AP's) and synapse (contact-plates to other cells).
Central Nervous System: see Nervous System.
Channel: see ion channel.
I - **Current**: By convention the energy transport or the flow of a positive electric charge (cation) from anode to cathode. Measured in amperes, where 1[A] is the flow of 6.25×10^{18} electrons per second.
Delayed outward C. (late outward c.): Current carried by K^+ through channels that open with time lag after onset of depolarization; responsible for the depolarization of the action potential.
Early inward C.: Depolarizing current of excitable tissues, carried by Na^+ or Ca^{2+}; responsible for the upstroke of the action potential.
Local Circuit C.: The current that spreads electronically from the excited portion of an axon during conduction of the nerve impulse, flowing longitudinally along the axon, across the membrane, and back to the excited portion.
cAMP (cyclic AMP): A ubiquitous cyclic nucleotide (adenosine 3`5`-cyclic mono-phosphate) produced from ATP by the enzymatic action of adenylate cyclase; important cellular regulatory agent that acts as the second messenger for many hormones and transmitter as a signal amplificator (see synapse - chemical receptor).
cGMP (cyclic GMP): A cyclic nucleotide (guanosine 3`5`-cyclic mono-phosphate) similar to cAMP, but present in much lower concentration than cAMP; acts as the antagonist to cAMP (see synapse - chemical receptor).
Dendrite: (Gk. dendros, tree) Fine processes of a neuron; the main receptive area of the cell for synaptic contacts.
Dynamic Range: The range of energy over which a sensory system is responsive and can encode information about stimulus intensity - see also Weber-Fechner law.
Efferent: Centrifugal; a neuron that carries information from higher brain centers toward structures in the periphery.
E. **Control**: The coordinated control of reception of peripheral nerve tissue by the CNS; e.g.: efferent control of sound-sensitivity in a loud environment, selectively filtering out the someone's voice.
Electrochemical Equilibrium: The state at which the concentration gradient of an ion across a membrane is precisely balanced by the electric potential.

Electrode: An electrical circuit element used to make contact with a solution, a tissue, or a cell interior; used either to measure potential or to carry current.

- **Anode**: Positive electrode or pole to which negatively charges ions (anion) are attracted.
- **Cathode**: The negative electrode to which positively charged ions (cation) are attracted.

Glass-Capillary Pipette Micro-E.: The lumen of a hollow glass electrode is filled with an electrolyte solution connected by a Ag-wire to the input of an amplifier.

Patch-Clamp Method: A method of investigation ion current transfer on a single sodium channel, with a 2µm tip- microelectrode held onto by gentle suction.

Electromotive Force (EMF): The potential difference across the terminals of a battery or any other source of electric energy; the greater the difference, the stronger is the EMF.

Electrotonus: see potential - propagation of action potential.

Endplate: The traditional name of the vertebrate neuromuscular synapse, where the motor axon ramifies into fine terminal branches over a specialized system of folds in the postsynaptic membrane of the muscle cell.

EPSP: see potential-synaptic.

Excitability: The property of altered membrane conductance (and often membrane potential) in response to stimulation; also known as membrane excitation.

Excitatory: In neurophysiology, pertaining to the enhanced probability of producing an action potential

Feedback: see Neural Integration.

Firing Level: Potential threshold for the generation of an AP (see there).

Frequency Modulation (FM): Information is encoded by varying the frequency at which the strength of the signal changes - in spontaneous active nerve cells.

Ganglion: An anatomical distinct concentration of neuron cell bodies.

G. **Cell**: A nonspecific term applied to some verve cell bodies, especially those located in ganglia of invertebrates or outside the vertebrate central nervous system proper.

Gap Junctions: Specialization for electrical coupling between cells, where intercellular spacing is only about 2nm and tubular assemblies of particles connect the opposed membranes.

Goldman Equation: The equation describing the equilibrium potential for a system in which more than one species of diffusible ions are separated by a semi-permeable membrane; if only one species can diffuse across the membrane the equation reduces itself to the Nernst equation

$$E_{ions} = \frac{R \cdot T}{z \cdot F} \cdot \ln \frac{P_K[K^+]_{out} + P_{Na}[Na^+]_{out} + P_{Cl}[Cl^-]_{in}}{P_K[K^+]_{in} + P_{Na}[Na^+]_{in} + P_{Cl}[Cl^-]_{out}} \quad [V]$$

E_X, potential difference [V]
Na, K, Cl, ion concentration [mole]
P_X, permeability constant [-]

Habituation: The progressive loss of behavioral response probability with repetition of a stimulus.

Hodgkin cycle: The regenerative, or positive-feedback, loop responsible for the upstroke of the action potential; depolarization causes an increase in the sodium permeability, permitting an increased influx of Na^+, which further depolarizes the membrane.

Impulse-initiating region (spike-initiating zone) The proximal portion of the axon, which has a lower threshold for action potential generation than either the some or the dendrites.

Information Processing: see CNS.

Inhibitory: In neurophysiology, pertaining to a reduction in probability of generating an action potential.

Initial Segment: Hillock area of axon proximal to the first myelinated segment; generally the site of impulse initiation.

Impulse Initiating Region (IIR or spike initiating zone): The proximal portion of the axon, which has a lower threshold for AP generation than either the soma or the dentrites.

Integral Protein: Proteins spanning the cell membrane that form selective filters and active transport devices that forward nutrients into, and cellular products , as well as waste, out of the cell.

Internode: Space along a myelinated axon, covered by the myelinating cell (see cell - Schwann or oligodendrocyte).

Ion: An atom or molecule that has lost or gained one or more electrons, thus being positively or negatively charged.

Anion: Negatively charged ion; attracted to the anode or positive pole.

Cation: A positively charged ion; attracted to a negatively charged electrode.

Ion Battery: The electromotive force capable of driving an ionic current across a membrane; results from unequal concentrations of an ion species in two compartments separated by the membrane.

Ion-exchange site (ion-binding site): An electrostatically charged site that attracts ions of opposite charge.

Ion Transport: Transmigration of charges along the membrane-gradient.

- **Active** T.: Energy-requiring translocation of a substance across a membrane, usually against its concentration or electrochemical gradient.
- **Primary** T.: Transport of a substance directly related to hydrolysis of ATP or other phosphagen.
- **Secondary** T.: Uphill transport of one substance coupled to and energy-derived from the downhill transport of another substance.

Ion Channel: Transmembrane, protein-lined pore in the plasma membrane allowing controlled passage of ions.

IC. **Activator**: (see receptor).

IC. **Inactivation**: In chemoreceptors after an AP has crossed a chemical synapse by:

i) Diffusion out of the gap;

i) reabsorption by presynaptic terminal (endocytosis);

i) enzymatic hydrolisation (by Ache);

i) inactivation of synaptic channels;

IC. **Regulation** of:

- **Voltage** activated: Achieved by changing the membrane potential (depolarization).
- **Ligand** activated: A hormone or transmitter activates channel chemically, requiring a receptor site.
- **Mechanically** activated: Deformation of the membrane activate channels (support by cytoskeleton).

Calcium C.: (Ca^{2+}) In synapses of motorneurons converting AP's into mechanical contractions of muscles (incl. cardiac) by inducing exocytosis of ACh-vesicles - see synapsis.

Sodium C.: (Na^{+}) Channels responsible for depolarization of the nerve membrane (see potential AP, sodium).

Potassium C.: (K^{+}) Channels responsible for the repolarization of the membrane (see potential AP).

- Potassium **activation**: An increase in the conductance of a membrane to K^{+} in response to depolarization.

IPSP: see potential-synaptic.

λ - **Length Constant**: The distance along a cell over which a potential change decays in amplitude by 1-1/e or 63%:

$V_t = V_0 \cdot (1-e^{-t/(R \cdot C)})$ [V]

it is determined by its capacity of isolation towards the extracellular domain and amount of cross-section

λ, length constant	[m]
V_0, max. amplitude	[V]
t, time	[s]
e, Euler constant 2,718	[-]

Ligand Gated Ion Channel: An ion channel through the cell membrane that opens when a molecule binds to the extracellular domain of the protein, causing it to open or close (see receptor).

Lipid: Any of the fatty acids, neutral fats, waxes, steroids, and phospholipids; lipids are hydrophobic and feel greasy.

Lipophilic: Having any affinity for lipids.

Membrane: Biological envelope (bilayer) surrounding a cell, plastid, mitochondrion etc, involved in separating electric charges and actively transporting ions via membrane- or ion pumps. Electro-physical characteristics similar to a RC-circuit, i.e. it behaves like a low-EQ-filter (see length constant, potential-membrane).

Tasks of the M.:

i) Separation of electric charges generating an ionic concentration gradient (chemical and electrically - see Nernst EQ) via intrinsic proteins, and

i) active transport of certain ions via channels (intrinsic proteins) rendering the membrane semipermeable,

Units of M.:

- **Cholesterol**: Disclike inlays to maintain fluidity of membrane bilayer even at very low temperatures.
- **Intrinsic Protein**: Mostly used as membrane pumps - see there.
- **Peripheral Protein**: Mostly as receptors or parts of an amplificatory cascade.
- **Triglyceride**: A neutral molecule composed of three fatty acids residues esterified to glycerol.

M. **Pump**: Membrane-based cellular mechanism that actively transport substances against a gradient (converting KE into PE, which is used to propagate AP's along the axon) by splitting ATP into ADP - see sodium-potassium pump.

For every ion, there is a proper M.-pump: CA^{2+}, Cl^{-}, H^{+}, aminoacids, sugar, etc.

Motor Neuron: A nerve cell that innervates muscle fibers, usually via endplates.

Myelin Sheath: A sheath formed by many layers of Schwann cells membrane wrapped tightly around segments of axon in vertebrate nerve; serves as electrical insulation in saltatory conduction.

Nernst Equation: Equation for calculating the electrical potential difference across a membrane that will just balance the concentration gradient of an ion.

$$E_x = \frac{R \cdot T}{z \cdot F} \cdot \ln \frac{X_{ou}}{X_{in}} = 0.058 \cdot \log \frac{X_{ou}}{X_{in}} \quad [V]$$

E_X, potential difference [V]
X_{out}, X_{in}, int./ext. ion concentration [mole]

Nerve Toxin: A bundle of axons held together as a unit by connective tissue.

Atropin (belladonna): Plant derived alkaloid, blocking mACh-receptors inhibiting postsynaptic transmission.

Bungarotoxin (BuTX): A blocking agent composed of a group of neurotoxins isolated from the venom of snakes *Bungarus* (the krait) of the cobra family; binds selectively and irreversibly to nicotinic ACh receptors.

Conotoxin (CTX): A poison of *Conus striatus* (mulluscs) clogging Ca^{2+} channels.

Curare: see tubocurarine.

Eserine : (Fysostignin) Delays the work of AChe (enzymatic hydrolization of ACh) which causes prolonged stimulation of the postsynaptic receptors; e.g.: cramps in respiratory muscles.

Muscarine: Derived from mushrooms; opens the mACh receptors but leaves nACh receptors unaffected.

Nicotine: Plant alkaloid which opens the mACh receptors but leaves nACh-R unaffected.

Tetanus: Retrogradly neurotoxin (towards the cell body) transported in axons and that causes prolonged excitation of muscle fibers, causing tetanic contraction.

Tetraethylammonium: A synthetically generated mediator blocking the Ca^{2+} channels, causing prolonged muscular stimulus, resulting in cramps.

Tetracthylammonium (TEA): A quaternary ammonium agent, $(C_2H_5)_4N$, that can be used to block some potassium channels in membrane.

Tetrodotoxin (TTX): The pufferfish poison; selectively blocks Na^+ channels of excitable cells.

Tubocurarin: Plow-dart poison from Indians of the South American rainforest, blocking chemical endplate receptors by competitive inhibition of nACh receptors, hence halting postsynaptic transmission completely.

Nervous System: The collection of all neurons in an animals body. NS **Tasks** are:

- Control of mental and physical response reactions.
- Information uptake, -processing, and -memorization.
- Regulation of vital body functions.
- Signal processing: stimulus - reception - integration and neuronal response - motoric response

Autonomic or Vegetative NS: The efferent nerves that controls involuntary visceral functions; beyond conscious control of the brain; it regulates the vital functions like heart beat, respiration etc.:

- **Parasympatethic** NS: The craniosacral part of the autonomic NS; in general, increased activity of these neurons support vegetative functions such as digestion, relaxation, recovery, etc.
- **Sympatethic** NS: Thorocolumnar part of the autonomic NS; increased activity in the sympathetic neurons typically provides metabolic support for vigorous physical activity, fight or flight, stress-response, increased rate of heartbeat etc.

Central NS (CNS): A group of neurons and parts of neurons that are contained within the brain and spinal cord in vertebrates; or within the brain, ventral nerve cord, and major ganglia of invertebrates.

Information Processing in CNS:

- **Efferent Control**: An interplay of two mechanisms, one that enhances the responsiveness and the other that inhibits it , allows activity in the CNS either to increase or decrease the sensitivity of receptors.
- **Parallel** IP: A pattern of information processing in the NS in which multiple pathways simultaneously carry information about a particular input or output; the information carried in multiple channels is synthesized where pathways converge - allows fast and rapid responses; improved signal to noise ratio.
- **Serial** IP: A pattern of information processing in the NS in which a single pathway carries the information about a particular input or output; this way of IP is very slow and requires repeated use of the incoming/outgoing stimulus to obtain/achieve a result; is very slow and has a poor signal to noise ratio.
- **Transmitter-Receiver System**: Activation energy for extero-receptor originates from the sender (prey), i.e. noise generated by a mouse is located by the owl; or the other way round, when the energy is emitted by the hunter to capture its prey, as seen in bats (sonar).

Intrinsic NS.: Network of neurons in gastro-intestinal tract and -ducts responsible for digestive tasks.

Peripheral NS (PNS): The set of neurons and parts of neurons that lie outside of the CNS.

Neural Integration (Circuits): Summation of all synaptic input onto a postsynaptic cell, which may generate an AP; a system of interacting nerve cells - see synaptic integration.

Convergence: A pattern in which inputs from many different neurons impinge upon a single neuron.

Divergence: A pattern in which the axon of a single neuron branches, allowing it to synapse onto more than one synaptic target.

Lateral Inhibition: Reciprocal suppression of excitation by neighboring neurons in a sensory network; it produces enhanced contrast at boundaries an increase in dynamic range.

Negative Feedback: An inverted output signal being fed back to the input so as to stabilize the output.

Positive Feedback: The output is unstable because it is returned to the input without a sign inversion, and thus becomes self-reinforcing, or regenerative.

N. **Networks**: Various levels of neuronal circuits regarding their position within the body:

- **Local** NN.: Local neuronal circuit in the backbone, responsible for immediate reflexes.
- **Projection** NN.: One hemispheres of the brain controls the other body half and vice versa - crossover nerve fibers occurs in the medula.
- **Cortical** NN.: Foldings in the cortex, signing for a specific function (Broca-Wernicke areas) extending perpendicularly into the brain.

Summation of postsynaptic potentials:

- **Excitatory**-/Inhibitory S.: Stimulation of separate presynaptic pathways at one neuron, resulting in an increase (causing an AP) or decrease (local hyper-polarization) of the stimulus.
- **Facilitation**: An increase in the efficacy of a synapse as a result of a preceding activation of that synapse
- **Spatial** S.: Integration by a postsanyptic neuron of simultaneous synaptic currents that arise from the terminals of different presynaptic neurons.
- **Temporal** S.: Summation of sequential postsynaptic MP's (MP's occur not simultaneously).
- **LTP** (long term potentiation): An increase in synaptic efficacy that occurs due to sustained synaptic input lasting for a relatively long time - even days, weeks, or months (process of learning?)
- **PTP** (posttetanic potentiation): Increased efficacy of synaptic transmission following presynaptic stimulation at a high frequency; often followed by a posttetanic depression.

Neuronal Transport: Transport of substances within the axon of nerve cells:

Fast: Transport along the microtubulus of the axon via kinesin (antero) dynein (retro):

- **Anterograd** NT.: Nutritional transport within the cell from soma to axon (400mm/d) consumes ATP.
- **Retrograd** NT.: Nutritional transport from periphery to soma (200mm/d) through decomposition of cell material followed by the regeneration e.g.: tetanus virus, toxins etc.

Slow: **Axoplasmatic current** (1-10mm/d) via dis- and reassembly of micro-tubuli and -filaments.

Neurotransmitter: A chemical mediator released by presynaptic synaptic membrane. This process generally induces permeability increase to an ion or ions and thereby influences the electrical activity of the postsynaptic cell.

NT. **Substance**: see also synaptic transmitter-receptors.

- **Acetycholine** (Ach): An acetic acid ester of choline; important synaptic excitatory transmitter.
- **Catecholamine**: Transmitters synthesized from a single amino acid molecule. Most sympathetic nerves secrete the neurotransmitter epinephrin (adrenalin), speeding the heartbeat (agonist) while parasympathetic neurons secrete norepinephrine (noradrenalin), slowing it (protagonist).
- **Monoamines**:
- **Aminoacids**: Pyrine based molecules like ATP, glycin based molecules, and **GABA** (γ-aminobutyric acid) which is a transmitter with inhibitory effects upon the postsynaptic receptors.
- **Nemopeptide**: Phpsphorous containing molecules as found in endorfines and encepholins.
- **NO**: Chemical radical synthesized from arginin through NO-synthase, resulting in muscle relaxation.

Node of Ranvier: Regularly spaced interruption (about every millimeter) of the myelin sheath along the axon hosting clusters of Na^+ and K^+ channels..

Oligodendrocyte: see cell.

Patch-Clamp Method: A method of investigation ion current transfer (see electrodes).

Peripheral Nervous System: see Nervous System.

Permeability: The ease with which substances can pass through a membrane.

Parasympathetic Nervous System: see Nervous System.

Polarization: The membrane potential at rest (usually around -60mV) disturbed by an AP (see potential):

De-pol.: The reduction or reversal of the potential difference that exists across the cell membrane once excited, rendering to cell interior more positive e.g.: influx of Na^+ ions.

Hyper-pol.: Increase in MP, rendering the cell interior more negative than at rest e.g.: the excess influx of K^+,

Re-pol.: The return to MRP of a cell after depolarization, by closing the Na^+- and opening the K^+-channels.

Posttetanic Depression: Reduced postsynaptic response following prolonged presynaptic stimulation at a high frequency; believed to be due to presynaptic depletion of transmitter.

Posttetanic Potentiation (PTP): Increased efficacy of synaptic transmission following presynaptic stimulation at a high frequency; often follows posttetanic depression.

Potential: The potential above zero to the peak of the action potential.

Action P. (AP): Transient all-or-none reversal of a membrane potential produced by a regenerative inward current in excitable membranes originating from the hillock area; i.e.: nerve impulse, or spike; a typical AP starts with a depolarization, followed by an overshoot, and a final phase of repolarization (depends greatly upon Na^+/K^+ availability and the proper function of Na^+- and K^+-channels) and does not require ATP, instead used the PE generated by the membrane pumps. AP's are considered to be sent like a frequency modulated-signal i.e.: the more intense the stimulus, the denser the spikes are packed (FM-modulated)- AP's can't be added up.

- **All-Or-None Response** of AP: Pertaining to the independence of response magnitude from the strength of the stimulus; response is "all" if the stimulus achieves threshold and "none" if the stimulus fails to achieve threshold; (depolarization, overshooting, repolarization - see polarization and Hodgkin cycle).

Propagation of AP: Ca^{2+}-ions influx into a nerve cell will trigger an AP once threshold has been reached. At the site of AP, the membrane resting potential (-60mV) becomes more positive (+40mV) due to the opening of Na^+-channels. Depolarization spreads passively in both directions along the axon but the Na^+ channels proximal to the nerve cell are still inactivated (refractory period) and cannot be reopened again. Instead Na^+ channels distal to the AP site of the nerve cell have not yet experienced voltage change, hence *depolarization* will take place once the threshold-level is exceeded opening those Na^+-channels. The influx of Na^+-ions causes the axon-potential to *overshoot* until the repolarization-level is reached (+40mv). In this moment Na^+-channels close while K^+-channels open to allow K^+-ions to rush into the axon gradually *repolarizing* the potential until hyper-polarization is reached (-70mV). There K^+-channels close again to permit the potential to rise slightly to the resting potential (-60mV). Continuously operating Na^+/K^+-pumps transport Na^+-ions into the extracellular fluid, and K^+-ions into the axonal cytosol.

- **Active** P.: The membrane sustained propagation from one end to the other of the nerve of an AP which reached the threshold of response due to the stored potential energy built up by the membrane pumps.
- **Saltatory** P.: A series of discontinued AP's along myelin sheaths (passive conductance) and at each node of Ranvier (active conduction), enhancing transmission rapidly over internodial distances despite thin axons, and saving energy as well (see nodes of Ranvier, cell - Schwann).
- **Passive** P.: An AP not reaching the threshold will propagate as far as determined by the length constant of a particular nerve (determined by isolation and cross-section - see there).
- **Transmission of AP**: Transmission of AP from on to the other nerve is accomplished by either chemical or electrical synapses (see synapse-types of).

Electrochemical P.: Electr. potential developed across a membrane due to a chemical concentration gradient.

Electrotonic P.: Potential generated by local currents flowing across the membrane; i.e.: AP.

Endplate P. (EPP): A postsanyptic potential in the muscle at the neuromuscular junction (or motor endplate).

Equilibrium P.: (EP) Voltage difference across a membrane at which the ionic species in question is in electro-chemical equilibrium; it is dependent in the concentration gradient of the ions, as described by the Nernst EQ.

Membrane P. (MP): The electric potential measured from within the cell relative to the potential of the extracellular fluid, which is by convention at 0 potential i.e.: potential difference between opposite sides of the membrane; its a dynamic equilibrium of in- and outflowing ions;(see also MRP).

Receptor P.: A change in MP elicited in sensory receptor cells by sensory simulation, which changes the flow of ionic current across the cell membrane.

Resting P.: (MRP) The normal unstimulated membrane potential of a cell at rest; can be up to -100mV (average membrane potential at rest: -60mV for K^+-ions) resulting from an unbalanced Na^+/K^+ ratio, where for each 2 K^+-ions taken up, 3 Na^+-ions are transported out i.e.: dynamic balance of in/out-ward flowing ions (see Na/K pump).

Reversal P.: The MP at which no current flows through the membrane ion channels, even though the channels are open; it is equal to the EP for ions that are conducted through open channels - compare EPSP and IPSP.

Synaptic P.: Chemical agents that increase/decrease postsynaptic threshold for AP's:

- **EPSP** (excitatory postsynaptic potential): A change in the transmembrane potential of a postsynaptic cell that increases the probability of an AP in the cell; pushing the threshold level for AP's more towards the positive, e.g.: -10mV, with increased Na^+, Ca^{2+}, K^+ conductance.
- **IPSP** (inhibitory postsynaptic potential): A change in the transmembrane potential of a postsynaptic cell that reduces the probability of an AP in the cell; pushing the threshold level for AP's more into the negative, e.g.: -70mV, with increased K^+, Cl^- conductance.

Threshold P.: The potential just large enough to produce the response e.g., action potential, muscle twitch etc., by opening the sodium (Na^+) channels.

P. **Inhibition**: Neural inhibition resulting from the action of a terminal lending on the presynaptic terminal of an excitatory synapse, reducing the amount of transmitter released.

Quantal Synaptic Transmission: Neurotransmitter are release in multiples of discrete packets (via ACh vesicle).

Refractory period: The period of increased membrane threshold immediately following an action potential; it is highly frequency dependent due to the RC-characteristics of the membrane.

Absolute R.P.: The initial phase of the refractory period when no AP can be generated.

Relative R.P.: The later phase of the refractory period when the threshold is elevated.

Saltatory: Jumping; discontinuous (see propagation of AP).

Schwann Cell: see cell.

Second Messenger: A term applied to cAMP, cGMP, Ca2+, or any other intercellular regulatory agent that is itself under the control of an extracellular first messenger (ligand), such as a hormone.

Signal Processing: see CNS

Sodium: (see also ion channel).

S. **Activation**: An increased conductance of excitable membranes to sodium ions in response to membrane depolarization; believed to result from an opening of sodium gates associated with membrane channels.

S. **Hypothesis**: The upstroke of an action potential is due to an inward movement of Na^+ down its electrochemical gradient as a result of a transient increase in sodium permeability.

S. **Inactivation**: Loss of responsiveness of sodium gates to depolarization develops with time during a depolarization and persists for a short period after repolarization of the membrane.

S. **Pump** (Na-K Pump): Membrane mechanism responsible for active extrusion of Na^+ from the cell at the expense of metabolic energy (ATP $\rightarrow$ ADP + P). In some Na-pumps, there is a 3:2 exchange of intra- Na^+ for extracellular K^+.

Soma: The nerve cell body, or perikaryon; in general the body.

Spike initiating Zone (SIZ): Region of the nerve axon where an AP is initiated. In many neurons, the axon hillock.

Stimulus: A substance, action, or other influence that when applied with sufficient intensity causes a response.

Threshold S.: The minimum strength of stimulation necessary to produce a detectable response or AP.

Sympathetic Nervous System: see Nervous System.

Synapse: A junction between two directly interacting nerve cells, where impulses in the presynaptic cell influence the activity of the postsynaptic cell.

Electrical S.: Pre- and post-synaptic membrane are in close opposition and form gap junctions, allowing current to flow across the gap junctions; in one direction only; used for rapid response reactions (flight for fight); for synchronisation as in the heart; in certain glands, intestine, and liver.

Chemical S.: A junction between a neuron and another cell in which the signal from the presynaptic neuron is carried across the synaptic cleft by neurotransmitter molecules e.g.: ACh.

- **Inhibition**: Removal of synaptic transmitter by diffusion out of the gap, or quick reabsorption from the presynaptic terminal, or enzymatic decomposition (Ache), or by clogging postsynaptic receptors.
- **Stimulation**: An AP forces a take up of Ca^{2+} through appropriate channels which initiates exocytosis of vesicles containing the transmitter substances; since pre- and post synaptic membranes are separated by a tiny gap, these transmitter substances (ACh) diffuse through to bind onto postsynaptic receptors, producing a current within (AP). Then, transmitter substances in the gap are broken down, reabsorbed (endocytosis) or become diluted due to diffusion; used for delayed, extended (capacitive) response reactions achieved by the time-consuming process of hydrolisation of ACh by AChe.

The advantage of chemical S. over electric ones are signal amplification (see receptor - 2nd messenger cascade) and signal computation (see synaptic receptors).

S. **Cleft**: The space separating the nerve cells at a synapse.

S. **Delay**: The characteristic time lag encountered from the time an impulse reaches a presynaptic nerve terminal to the time a postsynaptic potential change occurs.

S. **Efficacy**: Effectiveness of a presynaptic impulse in producing a postsynaptic potential change.
S. **Inhibition**: A change in a postsynaptic cell that reduces the probability of its generating an action potential; produced by a transmitter substance that elicits a postsynaptic current having a reversal potential more negative than the threshold for the action potential
S. **Noise**: Irregular changes in postsynaptic MP produced by irregular sub-threshold synaptic input.
S. **Vesicle**: Membrane-bound vesicle that contain the synaptic transmitter substance.
S. **Receptor**: Molecules that are situated at a membrane and that interact specifically with messenger molecules, such as hormones and transmitters.
S. **Potential**: see potential.
Pre-S.: Located proximal to the synaptic cleft.
Post-S.: Located distal to the synaptic clefts.
EPSP: Excitatory postsynaptic potential - see potential-synaptic.
IPSP: Inhibitory postsynaptic potential - see potential-synaptic.
Endplates: The vertebrate neuromuscular synapse; the motor axon forms many fine terminal branches that end over a specialized system of folds in the postsynaptic membrane of muscle cells.

Synaptic Transmitter-**Receptor** (chemical):

Acethylcholinergic S. (ACh): CH_3-CO-O-CH_2-CH_2-N(CH_3)-OH see transmitter substances and synapses. The transmitter ACh is quickly released from the terminal (exocytosis triggered by the influx of Ca^{2+}-ions) to activate receptors at the postsanyptic end and in a simultaneous process which is slightly slower hydrolyzed to acetate and choline by the enzyme ACh-esterase. The liberated choline is taken up (endocytosis) by the presynaptic terminal and reacetylated to form new ACh-molecules.

- **Acetylcholinesterase** (AChe): An enzyme that hydrolyzes *ACh* and resides in the postsynaptic membrane surface.
- **mACh**-R: Muscarine, a toxin from certain mushrooms, activates other ACh-R found in the target cells of parasymphatic neurons in the vertebrate NS; it consists of seven protein subunits associated to form a trans-membrane channel (agonist: muscarin; antagon.: atropin).
- **nACh**-R.: Nicotine, an alkaloid from certain plants, mimics the action of ACh on the channels found at the vertebrate neuromuscular junctions and the PNS; it consists of five protein subunits associated to form a trans-membrane channel (agonist: nicotine; antagon.: curare).

Cascade R.: An intercellular regulatory agent triggered by receptor causes a chain-reaction of chemical substances released and captured by their proper proteins, resulting in an amplification of the original stimulus, since many of these transducers are activated just with one receptor.

- **cAMP**-R. (cyclic adenosine monophosphate): cAMP as the 2nd messenger has a stimulatory (Rs) and an inhibitory (Ri) receptor, which both communicate with the amplifying protein (adenylate cyclase) by way of transducer G-proteins(Gs, Gi) effecting cellular response.
- **Second Messenger Cascade**-R.: A cAMP, cGMP, Ca^{2+}, or any other intercellular regulatory agent that is itself under the control of an extracellular first messenger (triggered by a hormone) resulting in an intercellular reaction or e.g.: signal amplification.

Ligand Activated R.: A receptor type that generates a signal when a molecule binds to the extracellular domain of the protein.

- **Ionotrophic** R.: The transmitter substance binding to the receptor stimulates the receptor which itself activates the ion channel situated next to it (in direct contact).
- **Metabotrophic** R.: The transmitter substance binding to the receptor activates an internal signal cascade by releasing intercellular messenger substances which activate ion channels which are not necessarily next to the receptor.

Synaptic Integration: see neural integration - summation
Tight Junction: An area of membrane fusion between adjoining cells; prevents passage of extracellular material between the cells.
τ - **Time Constant**: A measure of the rate of accumulation or decay of an exponential process; the time required for an exponential process to reach 63% completion.
Train of Impulses: A rapid succession of action potentials (package of spikes) propagated down a nerve fiber.
Transduction: General term for the modulation of one form of energy by another one - see eye, nose, sensilla.
Transmitter: see neurotransmitter and synaptic transmitter receptor.

Vagus Nerve (Tenth cranial nerve): A major cranial nerve that sends sensory fibers to the tongue, pharynx, larynx, and ear; motor fibers to the esophagus, larynx, and pharynx; and parasympathetic and afferent fibers to the viscera of the thoracic and abdominal regions.

Voltage Clamping: An electronic method of imposing a selected membrane potential across a membrane by means of feedback control.

Weber-Fechner Law: Sensation increases arithmetically as a stimulus increases geometrically; the least perceptible change in stimulus intensity above any background bears a constant proportion to the intensity of the background - see dynamic range:

$I_E = k \cdot \log(I)$ [V]

I_E, experienced intensity	[var]
k, proportionality constant	[-]
I, intensity of stimulus	[var]

Glossary Animal Physiology - Senses

Cortex: External or surface layer of an organ; in this particular sense the outer areas of the brain associated to sensory capacities - the brain sees the picture, hears the music, feels the pain, not the receptors.

Auditory C.: Regions of the cerebral cortex that are associated with hearing.

Visual C.: The cerebral cortex in the optical region of the cerebrum, devoted to process visual information.

Ear: Frequency analyzing mechano-receptor, converting acoustical stimuli via a mechanical amplifier into electrical stimuli. This is done by the vibratory movement of the basilar membrane with respect to the tectorial membrane which produces shear on the stereocilia of the cochlea hair cells. For biophysical aspects of hearing, see biophysics).

Inner E.: Frequency analyzer; and transduction of vibratory liquid;

- **Cochlea**: A tapered tube wound into a spiral like the shell of a snail, containing hair cell receptors for detecting sound; high pitch near the oval window; low pitch versus helicotrema. Sound is captured as a wave travels through the endolymph, whereas the brain picks up the location of the stimulated hair cells not the frequency of the migrating wave! (hearing is a process of detecting locations rather than frequencies); every hair cell possesses a distinct mechanical resonance frequency in accordance with its frequency detecting location to increase stimulus response.
- **Helicotrema**: The opening that connects the upper, perilymph filled chochlear chamber with the lower one at the cochlear apex and is the area of low frequency detection.
- **Organ of Corti**: The tissue in the cochlea of the inner ear that contains the hair cells.
- Scala media: The cochlear duct, a membrane labyrinth containing the organ of Corti and the tectorial membrane; it is filled with endolymph (contains a high level of K^+-and Na^+-ions)
- Scala tympani: A cochlear chamber connected with the scala vestibuli through the helicotrema; filled with perilymph.
- Scala vestibule: A cochlear chamber connected with the scala tympani through the helicotrema; filled with perilymph.

Middle E.: Mechanical amplifier and pressure converter of 20:1 to avoid impedance mismatch.

- **Auditory Ossicle**: The bones of the middle ear (malleus, incus, and stape), connecting the thympatic membrane and the oval window.
- **Oval Window**: The connection between the inner ear and the cochlea; it is covered by the base of the stapes.

Outer E.: Sound capturing device. The entire outer ear acts as a resonance body with a tapered end facilitating the formation of a standing wave with a center frequency of approx. 3kHz; amplification x 4;

- **Tympanic Membrane**: The eardrum.

Eye: Organ of visual (photo-) reception that includes optical processing of light; e.g.: vertebrate eye:

Amacrin Cell: Neurons without axons, found in the inner plexiform layer of the vertebrate retina.

Cone: A vertebrate visual receptor cell that has a tapered outer segment in which the lamellar photosynthetic membranes remain continuos with the surface membrane; responds to one out of three particular colors (Red, Green, Blue); hue is calculated by differences of the RGB-values. Cones are only found in the fovea.

Cornea: The clear surface of the eye through which light passes as it enters the eye and is equipped with the corneal lens, which focuses light entering the ommatidium.

Fovea (area centralis): In the mammalian retina, the area with the highest visual resolution due to small divergence and convergence in the pathway linking photoreceptors to ganglia cells;

Horizontal Cell: A nerve cell whose fibers extends horizontally in the outer plexiform layer of the vertebrate retina; interconnecting adjacent photoreceptors, lowering resolution

Iris: The pigmented circular diaphragm located behind the cornea of the vertebrate eye.

Retina: The photosensitive inner surface of the vertebrate eye, made up of rods, cones, bipolar-, ganlia-, horizontal-, amacrin-, and gliacells plus pigmentation.

Rhodopsin: A purplish red, light-sensitive chromoprotein with 11-*cis* retinal as its prostethic group; found in the rods and cones of the retina.

Rod: One class of vertebrate visual receptor cells, next to cones; very sensitive to light, based on cellular physiology and on high degree of convergence onto second order cells; not sensitive to a particular frequency, rather to the full visible spectrum, hence cannot convey information about color.

Tasks of E.:

Receptive Field: The area of the retina by which stimulation by light causes a ganglia cell to activate or block - concentric on-off centers; fovea: 2.5um; peripheral retina: 2mm.

Signal Convergence: Fovea houses 1-20 cones/1bipolar cell (high resolution); retinal periphery connects 15-45 rods/1bipolar cell (increased sensitivity).

Transduction of light: A photon hitting the retina* causes the Na^+-channels (dark current) to decrease, consequently hyperpolarizing the receptor causing an AP. *) excited rhodopsin increases the activity of a G-protein on the discs (signal amplifying cascade), which then activate many PDE- (phosphodiesterase) molecules reducing the intracellular concentration of cCMP (see there). A low concentration of cGMP causes the NA^+ channels to close; the MRP becomes hyperpolarized (from -30mV to -55mV).

Other types of E.: Lens-EQ: $1/f = 1/b + 1/g$

Stigma: Eyespot of protista

Compound E.: The multifaceted arthropod eye; the functional unit is the ommatidium.

Hair Cell: A mechanosensory epithelial cell bearing stereocilia and in some cases a kinocilium.

Kinocilium: A true 9+2 cilium present in sensory hair cells; able to conduct certain movements.

Sensilla: Collections of sensory receptors in the periphery of an organism, usually an invertebrate; sensilla are typically very simple in structure, lacking 9+2 structures.

Stereocilium: Nonmotile filament-filled projections of hair cells; they lack the internal structure of motile 9+2 cilia.

Tip-Link: Tiny myosin-fibers connected to neighboring stereocilia or kinocilium (via myosinhead-actinfilament contact) adjusting the spontaneously active receptor to a fixed firing frequency considered as zero (no stimulus - see receptor cell, spontaneously active receptors).

Johnston Organ: An acoustical sense organ similar to a chordodontal organ, of most insects.

Jacobson Organ: Chemical receptor in reptiles and snakes, allowing them to locate prey via a chemical gradient triggered in the organ.

Lateral Line System: In fish to detect water current; water filled ramifying channels on the skin cause hair-cells (cupola) to be moved, triggering AP's.

Lyra Organ: Convex, membrane covered microscopically small gap w/ a dendrite at its center, allowing arthropods, like spiders who do not build nets to detect vibrations from ground substrate (usually monocots).

Nose: A typical chemical receptor housing the olfactory epithelium.

Olfactory Epithelium: Button sized patches in the nasal passages capable of detecting a vast amount of different smells and odors.

Olfactoric Transduction: Principle of signal amplification with a cascade receptor (D-R-G-AC-cAMP-INa); followed by an olfactoric projection in the brain; human = microsomat (10000 different odors).

Pacinian Corpuscles: Pressure receptors found in skin, muscle, joints, and connective tissue of vertebrates; they consist of a nerve ending surrounded by a laminated capsule of connective tissue.

Pappilla: Small conical pumps, taste buds capable of receiving flavor molecules like sweet, salty bitter and sour.

Range Fractionation: The pattern in which receptors within one sensory modality are tuned to receive information within relatively narrow, but not identical, intensity ranges, so the entire dynamic range of the modality is divided among different classes of receptors. For example, the human eye rods respond to dim light but are saturated in bright light; cones are less sensitive to dim light but remain responsive in bright light.

Receptor Cell: A neuronal cell that is specialized to respond to some particular sensory stimulation generally with logarithmic characteristics - see also cell, Weber-Fechner law and range fractionation. Tasks of RCs:

- **Selective Recognition of stimuli**: A low threshold-response to physical impact from the environment.
- **Transduction**: General term for the modulation of one kind of energy into another; sense organs transduce sensory stimuli (e.g. mechanical-, photonic-, chemical energy) into nerve impulses (AP).
- **Transformation**: Conversion of the transductive AP into a digital signal (frequency encoded).

RC.-**Response**: Extero-RC response caused by a stimuli arriving from the external environment:

Intensity Coding: see dynamic range.

Range Fractionation: see there.

Spontaneously Active: In the absence of any stimulus, the RC or 2nd sensory fiber fires spontaneously and covers the steep part of the curve relating the stimulus intensity to the frequency of APs, so even a very small stimulus will increase or decrease the rate of firing; consequently doesn't have a threshold e.g.: hair cells.

Phasic R.: A quickly adapting R, releasing many firing impulses but fading out as stimulus persist.

Phaso-Tonic R.: A compound R with both phasic- and tonic characteristics.

Tonic R.: Fires steadily during a maintained stimulus, although the firing frequency is highest at the beginning of the stimulation.

RC.-**Types**: (see also types of synapse).

Extero-RC.: Sensory organs that detect stimuli arriving at the surface of the body from a distance:

- **Chemo**-R.: A sensory receptor specifically sensitive to certain molecules (e.g. nose, taste, etc.).
- **Electro**-RC.: Sensory receptors that detect electrical signals (e.g. in electric fish).
- **Mechano**-RC.: A sensory receptor tuned to respond to mechanical deformation, distortion or pressure (e.g. fingertips-pacinian corpuscles, ear, etc.).
- **Photo**-RC.: A sensory cell that is tuned to receive light energy (e.g. eye).
- **Thermo**-RC.: Sensory nerve ending, responsive to temperature changes (e.g. in fingertips, etc.).

Interoceptive-RC.: Internal receptors responding to changes inside the body; connected to the vegetative NS.

Sensilla: see hair cell.

S. **Transduction**: Elongation of stereocilium activates mechano-receptive ionic K^+-channels, causing depolarization, forcing Ca^+ -channels to open which trigger an AP.

Sensor: A mechanical, electrical, or biological device that detects changes in its immediate environment.

S. **Adaptation**: Property of sensory systems to become less sensitive during prolonged or repeated stimulation.

Statocyst: Gravity sensing sensory organ made up of mechano-receptive hair cells and associated particles called statoliths (a small, dense, solid granule).

Taste: Gustatoric sense; enables humans to differ between, sour, salty, bitter, and sweet.

Tetanus: see Muscle contraction.

Tympanal Organ: Acoustic receptor of many invertebrates (insects) featuring a double membrane, allowing them to measure pressure gradients of sound waves, to locate prey or danger.