Fundamentals of Biology 1A - Notes

---ALWAYS PRINT THE EXCLAMATION SLIDES---

9.10.2016

Chapters prior to chapter 4 (from Campbell)

Acidification process of the ocean:
$CO2 + H2O \rightarrow H2CO3$
$H2CO3 \rightarrow H^+ + HCO_3^-$
$H^+ + CO3^{2-} \rightarrow HCO3^-$
$CO3^{2-} + Ca^{2+} \rightarrow CaCO3$

Four emergent properties of water contribute to Earth's suitability for life:
H-bonds keep water molecules clpse to each other and this cohesion helps pull water upward water-conducting cells of plants. Also, surface tension.
Water has a high specific heat.
Ice floats on water, which is why life can exist under frozen surfaces.
Water is a versatile solvent.

29.9.2016

Chapter 4 - Carbon and the diversity of life

There are different isomers:

-structural isomers
-cis-trans isomers: cis = X is on the same side; trans = X is on the opposite site
-enantiomers: chirality different; one cannot rotate the molecule such that it is congruent (like hands) - molecule has to be mirrored

Enantiomers: important in pharmaceutical industry; two enantiomers of a drug may have completely different effects. (can be active, ineffective, disastrous etc.)

How does the body differentiate between them? Schlüssel-Schloss Prinzip + enzymes and the principle are chiral too.

Most important functional groups in chemistry of life (see p113 - learn by heart):

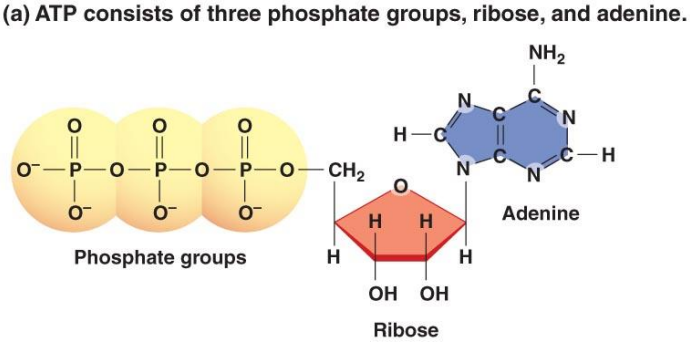
hydroxyl, carbonyl, carboxyl, amino, sulfhydryl, phosphate and methyl groups
(learn them by heart and how they look like, chemical characteristics...)

There are about 20 amino acids. They differ from one another in the position of their 3rd central C-atom.

ATP:
A phosphate molecule - adenosine is attached to a string of three phosphate groups. It is the primary energy-transferring molecule. One can interconnect the hydrolysis of ATP to catalyse other chemical

reactions. (learn its chemical struction - see exlam slide.)

Hydrolyse: Chemical molecule is broken down in water like ATP
=> ATP -> P + ADP, this catalyses/favours other chemical reactions.



Chapter 5: The structure and function of large biological molecules

All living beings consist of 4 classes: proteins, lipids, nucleic acids, carbohydrate
Macromolecules are built from polymers.

Polymers: long molecule consisting of many similar building blocks =>
monomers are the small building blocks ->
3 of 4 classes of life's organics molecules are polymers: proteins, nucleic acids and carbohydrates.

A polymer is created by a condensation reaction (dehydration removes H-molecule, forming a new bond with a monomer)
Hydrolysis is the reverse process: polymer is broken down - water is added to it, separating the polymer in a smaller one and in a monomer.
(Which polymers do humans break down? Carbohydrates in the digestion system. Which carbohydrates? Starch (glucose is a component of starch.)

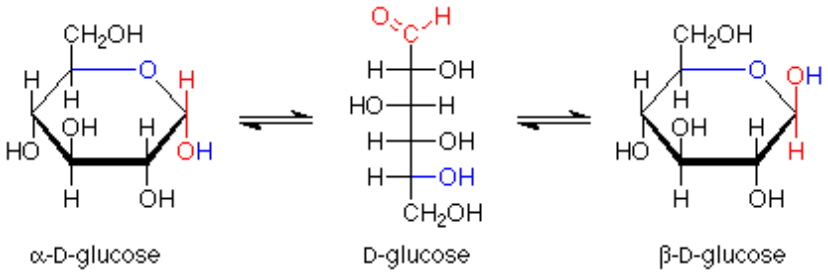
Def. Hydrolysis: Breaking down a polymer by inserting water molecule in a chain.

Carbohydrates: include sugars and polymers of sugars - simplest carbohydrate is a monosaccharide (single sugar).
Molecular formula of a monosaccharide is a multiple of CH_2O. (**general: $C_nH_{2n}O_n$**)
Ex. Glucose: n=6.

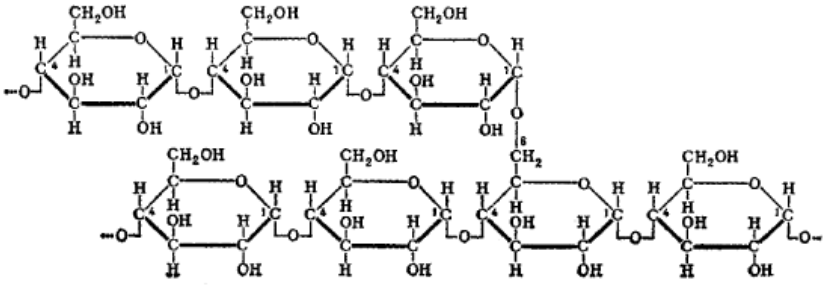
Hydroxyl groups are an important feature of carbohydrates - they are soluble in water because of hydroxyl groups (normally), because they can create H-bonds/bridges with water.
Trioses: 3-carbon-sugars ($C_3H_6O_3$). There are 2 different glyceryl aldehydes because of chirality.

Monosaccharides serve as fuel for cells and as raw material for building molecules.

Polymer of alpha-glucose: starch
Polymer of beta-glucose: cellulose
alpha-glucose has its OH group facing downwards, beta-glucose upwards. Cellulose is mostly straight allowing it to also form



h-bonds with the hydroxyl groups of other monomers lying parallel to it. In humans and other beings, there is an enzyme, which is used to hydrolize the alpha linkages, but is useless for the beta linkages.



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Two monosaccharides can make a glycosidic linkage (by dehydration) creating a disaccharide.

Glycogen is being regulated by insulin and glucagon by feedback mechanism depending on the glucose levels in the systems, especially in the blood.

H-bonds keep the cellulose fibrils together which make the system incredibly stable. Fungi and bacteria have found a way to invade those crystalline structures and to dissolve these H-bonds by hydrolysis. (Herbivores have a symbiotic relationship with them.)

Lipids: Most important are fats, steroids, phospholipids. They are **hydrophobic**, since they consist mostly of hydrocarbons, which form non-polar covalent bonds.
Lipids are no real polymers. Lipids are not the direct product of genetic information (e.g. nucleic acids are the direct product of genetic information, while carbohydrates are not.)

In a fat, three fatty acids are joined to glycerol by an ester linkage, creating a triaglycerol.
Fatty acids vary in length and in the number of the location of double bonds.
-Saturated: only single bonds; at room temperature, molecules are closely together -> solid-
-Unsaturated: there are double bonds; is more space-filling -> liquid.

Functions of fats: Energy storage (fats are stored in adipose cells), regulate temperature, insulate the body.

Phospholipids: major component of membranes -> the hydrophobic tail will point towards the interior while the hydrophilic head will point towards the exterior in water. That way, membranes are created. The membrane breaks down without the presence of water.

Proteins: page 126. There are different types with different functions: Enzymatic, defensive, storage, transport, hormonal, receptor, structural, contractile and motor proteins.

Levels of protein structure:
Primary structure: linear chain of amino acids.
Secondary structure: regions stabilized by hydrogen bonds between atoms of the polypeptide backbone.
Tertiary structure: three-dimensional shape stabilized by interactions between side chains.
Quaternary structure: association of two or more polypeptides (some proteins only.)

Denaturation: Protein is made into its primary structure thus losing its functionality. This can occur through high temperature, change of the solvent it is in (only in water can it work properly) or other chemical treatments.
Renaturation: Reverse of denaturation by restoring the physical and chemical environment to normal.

6.10.2016

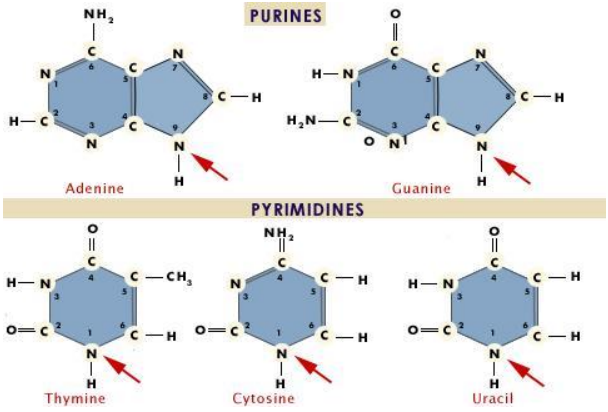
The role of nucleic acids
There is DNA and RNA:
DNA provides directions for its own replication.
DNA directs synthesis of mRNA and though mRNA controls protein synthesis which occurs on ribosomes.

DNA contains genetic information which is physically realized in its sequences (one DNA contains many genes). The double helix structure is only realized in aqueous surroundings.
The genetic information is saved twice (double helix structure.)

In prokaryotes, the DNA is not spatially separated, since they have no nucleus.

A nucleic acid is composed of: a nitrogenous base, a pentose sugar and one or more phosphate groups; it is called a nucleotide -> many nucleotides (=: NT) make a polynucleotide by forming covalent bonds between the -OH group on the 3' carbon and on the phosphate on the 5' carbon of the other NT. Nucleic acids are polymers called polynucleotides (=: PNT).

Nitrogenous bases:
Pyrimidines: Cytosine (C), Thymine (T) in DNA <=> Uracil (U) in RNA
=> they have a single six-membered ring.
Purines: Adenine (A), Guanine (G)
=> they have six-membered ring fused to a 5-membered ring.



In DNA, the nitrogenous bases form h-bonds as A-T and G-C.
See page 127 for the 20 amino acids.

tRNA can form intramolecular h-bonds (with itself). The 3-D structure is defined by the sequence of the bases.

For enzymes, it is not important that they are created by amino proteins, it can also be an RNA enzyme. Crucial is the 3-D structure of the surface.
Ribosomes are RNA enzymes that catalyse/fuse peptide bonds.

Chapter 6 - Energy and Life

Catabolic pathways release energy by breaking down complex molecules into simpler compounds. E.g. Cellular respiration (breakdown of glucose in the presence of oxygen.)

Anabolic pathways consume energy to build larger, complex molecules from simpler ones. E.g. amino acids to proteins.
This has to remain in a flowing equilibrium.

Biological order and disorder:
Cells create order from unordered material Energy is required. Organism replace ordered forms of matter and energy with less ordered forms. Energy input of an ecosystem is light and exits it as heat.

The "free-energy change" (dG) of a reaction tells us whether it occurs spontaneously.
It is: dG high -> more free energy; less stable; greater work capacity.
dG small -> less free energy; more stable; less work capacity.
dG negative <=> reaction occurs spontaneously.

Exergonic reactions proceed with a net release of free energy and they do not require external energy inputs. They are spontaneous.

Endogenic reactions absorb free energy from their surroundings and they are nonspontaneous. They require external energy inputs. dG positive.

7.10.2016

Def: dG = dH + T*dS (interpretet d as delta)

Thermodynamically spoken, an organism is in equilibrium when it is dead.

ATP powers cellular work by coupling exergonic reactions to endergonic ones.
A cell does three main kinds of work: chemical, transport, mechanical.
ATP is composed of ribose, adenine and three phosphate groups.
ATP's second function is the synthesis of RNA (functioning as substrate).

ATP to ADP has dG negative (process is called hydrolysis, so water is needed).

ATP hydrolysis leads to a change in protein shape and binding ability.

13.10.2016

Competitive inhibitors bind to the active site of an enzyme, competing with the substrate.

Non-competitive inhibitors bind to another part of an enzyme, causing the enzyme to change shape and making the active site less effective.
Inhibitors can be toxins etc.

Evolution of enzymes:
Enzymes are proteins. Different environmental circumstances might favour other enzymes (to evolve).

Cells can regulate their metabolism by switching on or off the genes for the enzyme production or by regulating the activity of enzymes otherwise.
-> Allosteric regulation occurs when a regulatory molecule binds to a protein at one site and affects the protein's function at another site.

Feedback Inhibition:
The end product of a metabolic pathway stops the production of more than is needed, such that the cell does not need to waste chemical resources.
E.g. Threonine to Isoleucine (uses 5 enzymes; Isoleucine binds to the allosteric site when it is produced, but unbinds when it is used up by the cell. That way, there will mostly be the same amount of isoleucine in the cell.)
Another way to regulate it is by regulating the enzyme itself by regulating the transcription of the genes, such that less enzymes are available.

Enzymes are localised in the cell and physically separated by membranes typically. Therefore, certain processes can only take place in certain places of the cell, since the necessary enzymes are only available there.

APPENDIX:
ATP typically transfers energy from exergonic to endergonic reactions by phosphorylating other molecules (adding phosphate groups). ADP to ATP is an exergonic process.

Chapter 7: Cell Structure and Function

There is a correlation between cell structure and function (biochemistry and cytology).
Technique: Differential centrifugation. It is centrifuged for some time. Depending on how long, one will get different things on the pellet.

Eukaryotic cells have internal membranes that compartmentalize their functions. Prokaryotes do not have internal membranes.

All cells have an extracellular matrix.

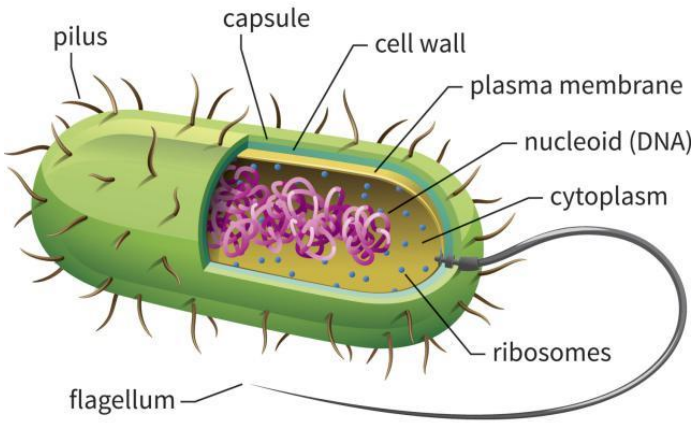
It is vital that when you draw a eukaryotic cell that the nucleus has a double membrane (not one membrane).

The plasma membrane allows certain things to pass, like oxygen, chemical waste etc.

Prokaryotes have a big surface-volume ratio.
Cell with the biggest surface: intestine cells.

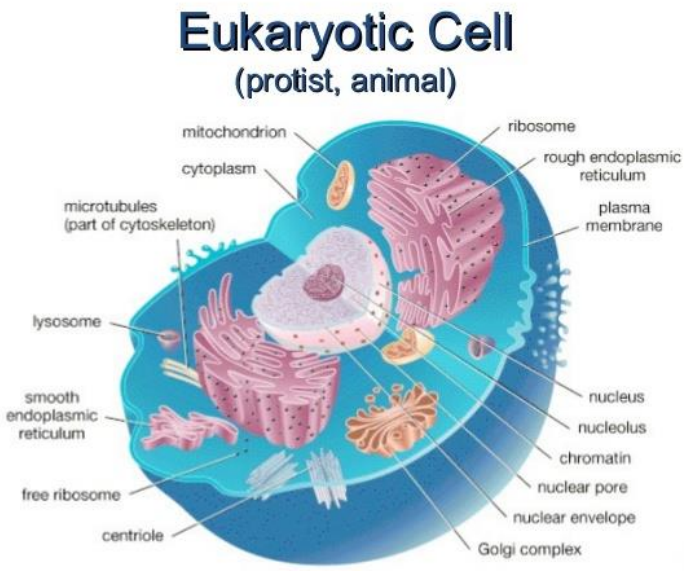
The membranes within the cell define reaction spaces.

In prokaryotes, the DNA is concentrated in an open region which is called nucleoid (it is not separated physically from the cytosol, it is simply a bunch of DNA in the cytosol concentrated at that spot.)



The Nucleolus is the place of synthesis of the ribosomes.
Ribosomes carry out protein synthesis either in the cytosol (free ribosomes) or in the rough ER (bound ribosomes).

Components of the endomembrane system: nuclear envelope, ER, golgi apparatus, lysosomes, vacuoles, plasma membrane.
These components are either continuous or connected via transfer by vesicles.
It regulates protein traffic and performs metabolic functions in the cell.



Smooth ER is responsible for the synthesis or membranes; it lacks ribosomes. Synthesis of phospholipids takes place there; stores calcium ions; detoxifies drugs and poisons; metabolizes carbohydrates.
Rough ER is responsible for the synthesis of membranes.; surface is studded with ribosomes; secretes glycoproteins; distributes transport vesicles, proteins surrounded by membranes. The synthesis occurs directly in the lumen of the rough ER.

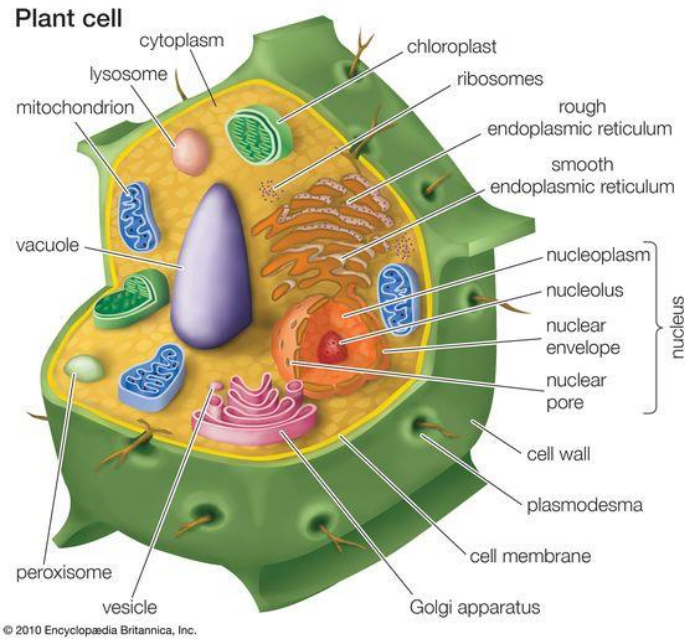
14.10.2016

Golgi apparatus:
Functions of the golgi apparatus: Modifies products of the ER; manufactures certain macromolecules; sorts and packages materials into transport vesicles.
It is like a distribution centre. The vesicles are like postmen, the proteins have the information where they need to be delivered to.
The cis face is the receiving side of the golgi apparatus while the trans face is the "shipping" side of it.

Lysosome:
Lysosomes are membraneous sacs of hydrolytic enzymes that can digest macromolecules. These lysosomal enzymes can hydrolyze proteins, fats, polysaccharides and nucleic acids. These enzymes work best inside the acidic environment within the lysosome. The enzymes are very dangerous. They are kept inside the lysosome, if they spread throughout the cell, the cell would be destroyed. Another control mechanism is the pH-value. pH-value of cytoplasma is a bit higher than 7. If they were to enter the cytoplasma they'd be rendered inactive.
Lysosomes also use enzymes to recycle the cell's own organelles and macromolecules. This is called **autophagy**. A lysosome can also fuse with a food vacuole and digest the molecules inside of it. When it fuses with a food vacuole it is called **phagocytosis**.

Plant cells can generate a turgor, since the cells are stiff.

Mitochondria and chloroplasts have a different origin and thus also completely different tasks (Generating forms of energy basically.)



Mitochondria and chloroplasts have similarities with bacteria and they contain their own DNA. They are enveloped by a double membrane; contain free own ribosomes and circular DNA moleclues. They can grow and reproduce somewhat independently from the rest of the cell.

The theory behind this is called **the endosymbiont theory**. It is assumed that a eukaryotic cell engulfed a non-photosynthetic prokaryotic cell, which then formed an endosymbiont relationship with its host. They then later on merged into a single organism. (At least one of these cells may have taken up a photosynthetic cell, becoming the ancestor of the chloroplast.)

Peroxisomes: Oxidation.

Plant cells have cell walls while animal cells possess an extracellular matrix (ECM). It is mostly made up of glycoproteins and other carbohydrates. Most abundant glycoprotein is **collagen**.

20.10.2016

Plasma membranes are selectively permeable. Nonpolar molecules can pass the plasma membranes rapidly, since they are hydrophobic. Polar molecules cannot.

The main ingredient of membranes are lipids and proteins although carbohydrates are also important.

Def. Amphipathic: a molecule has both a hydrophilic and hydrophobic ending, e.g. phospholipids.

Fluid Mosaic Model: Model of membranes; the hydrophilic phospholipids are the fluid part while the carbohydrates and proteins in between are the mosaic part.

There are different types of membranes which have adapted to their environment (very hot, very cold, fluctuating temperature). Logically, their structure is somewhat different.

Factors that influence membrane fluidity:

Fluid: Unsaturated hydrocarbon tails; since these have double bonds, they are sort of kinked preventing packing which leads to enhanced membrane fluidity.

Viscous: Saturated carbon tails; no double bonds, only single bonds leading to packing together of the phospholipids. Membrane viscosity increased.

Cholesterol in animal membranes reduces the membrane fluidity at moderate temperature and hinders the solidification of them at low temperatures.

Why does diffusion exist?
In Diffusion, after some time, there will be an equilibrium of molecules in the available space, which occurs on its own. One can also control diffusion by, for example, removing molecules from the cell. Therefore, molecules from the outside space will enter the cell due to diffusion.

Osmosis is the diffusion of water through a selectively permeable membrane specifically.

Through osmosis, a cell can regulate or optimize its turgor.

Tonicity: ability of a surrounding solution to cause a cell to gain or lose water.
Isotonic sol.: no net movement of water across the plasma membrane and the outside.
Hypertonic sol.: cell loses water. Solute concentration greater than in the cell.
Hypotonic sol.: cell gains water.

Osmoregulation: Ability of a cell to actively regulate the osmotic pressure.
Def. Osmotic pressure: Measure of the tendency of water to move from one solution to another by osmosis.
Osmoregulation takes care off the cell's electrolytes concentration by maintaining a healthy equilibrium of water. Therefore, the concentration of salts / ions does not become too concentrated nor too diluted. Turgor is also regulated. Removing water from the cell would decrease the pressure within the cell; adding water to the cell would increase its pressure.

Facilitated diffusion: transport proteins speed up the passing of molecules through the membranes. Channel proteins enable only certain molecules such as water or ions to pass through them, probably because these molecules are important and it is vital for the cell to have access to these fast enough. Aquaporins are channels only for water. Ion channels are channels only for ions (see brain).

A channel has a specific surface structure. It can be polar and hydrophilic or charged (in case of ions.) In

case of proteins, the surface also has to be charged respectively, such that the charged part of the amino acid is attracted to it. The protein can pass the channel that way.
These processes require no energy, since they are considered to be passive transport mechanisms.

An active transport requires energy. It is performed by specific proteins embedded on the membrane. It requires energy since it is carried out against the concentration gradient of the molecule.

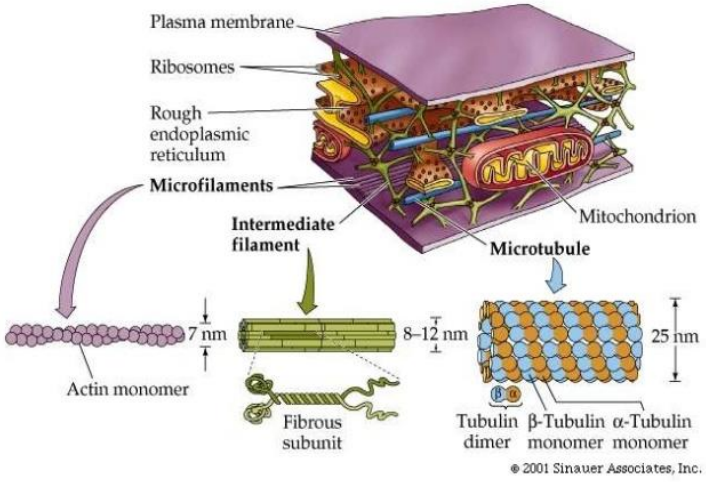
Membrane potential is the voltage difference across a membrane.

Proton pump: transports H+, protons, from the cytoplasm to the extracellular fluid even if the concentration in the extracellular fluid is higher than in the cytoplasm.

Endocytosis: Cell requires energy to perform exocytosis (engulfing molecules and transporting it into the cell). Large polar molecules cannot pass through the hydrophobic plasma or cell membrane by passive means.

Exocytosis: Cell requires energy to perform exocytosis (transporting large molecules out of the cell). E.g. ion channels.

APPENDIX: Cell skeletons:



Dimensions: Microtubules: around 20nm; Mcrofilaments: 7nm; intermediate filaments: 8-12nm

Extracellular matrix (ECM): It is outside of the cell membrane and has the following functions: support, adhesion, movement, regulation.

Chapter 9: Cell communication

Cells normally communicate via chemical signals. There is also cell-cell interaction. Different mechanisms give rise to different signals. In all these mechanisms, information is being conveyed from one cell to another cell.

21.10.2016

E.g. yeast cells. A and alpha cells exist. There needs to be some sort of intercellular communication in order to convey the information that one y east cell is A-type and the other alpha-type. The use chemicals signals and receptors (on the surface of the cells). This induces a reaction in the inner cell, thus communication succeeded.

Animal and plant cells also have cell junctions that directly connect to adjacent cells.
Those are called gap junctions. A cell in a certain surrounding will do a different program. For this, cell-cell recognition is required.

Long-distance signalling is done by chemical called hormones.

Cells need a receptor specific to the chemical in order to respond to it accordingly.

Secretory vesicles mainly secrete proteins. This has an influence on the targeted cell in the environment.

Def. Protein Kinase: Enzyme that transfers phosphates from ATP to a protein.

Def. Protein phosphatase: Enzyme that removes phosphates from a protein. Also called dephosphorylation.

These two processes act as a molecular on/off switch.

There are 3 main stages in cell signaling:
Reception, Transduction, Response

Signaling molecule, normally soluble, has to be caught on the surface of the cell. A certain protein on the surface is needed, called receptor protein (transmembraneprotein). Signaling molecule can bind to it. It has to go through the membrane, so it is connected to the inner cell in some way.
The signal is transducted by relay molecules. The original signal is translated into a biochemical process within the cell.
This cascade leads to an activation response of the cell. This can lead to an enzymatic response, production of a specific set of genes and so on. The whole behaviour of a cell is influenced that way.

Reception: Signal molecules are called ligand. They are specific to the transmembrane protein (receptor). The change of shape of the receptor is often the initial transduction of the cells. The only thing proteins actually do is changing their shape.

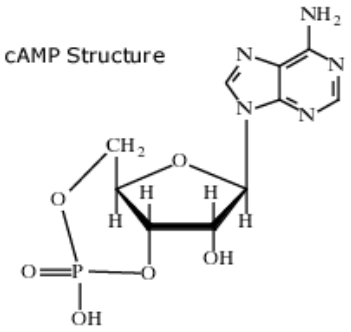
Three main types of receptors:
G protein coupled receptors: G protein coupled receptors are transmembranes. G protein containing GDP is nearby (under the membrane). When the ligand binds to the receptor, the 3-D structure of the receptor changes, thus the G protein can bind to the receptor and the G protein gains GTP. This G protein with GTP is excited and goes to an enzyme which activates it, thus an enzymatic response occurred.
One can also control this process externally with medicaments.

Receptor tyrosine kinases: they attach phosphate to tyrosine. It can trigger several signal transduction pathways at once. The phosphate is covalently bonded to the HO-group of tyrosine. Helper proteins can bind to the modified parts.

Ion channel receptors: The receptors become a gateway when the ligand binds to it, thus the receptor changes its surface structure. Ions can enter the cell.
There needs an ion pump in order to recover the gradient.

Intracellular receptors: Those are specialized receptors. Its signals can pass the cell membrane since they are hydrophobic. It binds to the intracellular receptor and then can enter the nucleus through its openings, activating the protein synthesis. Effectively, it can activate and regulate genes.

APPENDIX: cyclic AMP (adenosine monophosphate) is one of the most widely used second messenger. Adenylyl cyclase converts ATP to cAMP in response to an extracellular signal.
cAMP usually activates protein kinase A which phosphorylates other proteins.



Def. Apoptosis: Controlled cell suicide. It is induced by an extracellular death signalling molecule, damages in DNA or misfolding of proteins in the endoplasmatic reticulum.

27.10.2016

Chapter 10: Cell Respiration

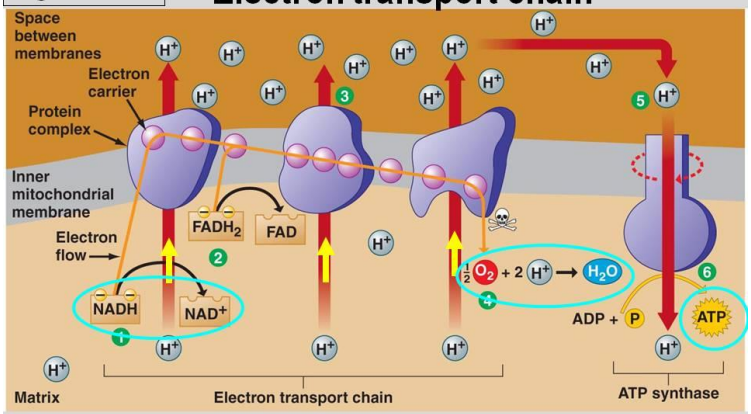
Aerobic cellular respiration: Glucose + O2 -> Water + CO2 + ATP and heat

Stepwise energy harvest via NAD+ and the electron transport chain:

Def. Dehydrogenase: Enzyme; it oxidizes its substrate by splitting of a hydrogen anion (formally: H-).

Def. Kinase: An enzyme that catalyses the transfer of a phosphate group from a high energy, phosphate molecule to its substrate (often the hydroxy group, -OH, of the substrate is replaced by the phosphate group). This process is also known as phosphorylation. A kinase can also induce the inverse process, also known as dephosphorylation.

Figure 6.11 **Electron transport chain**

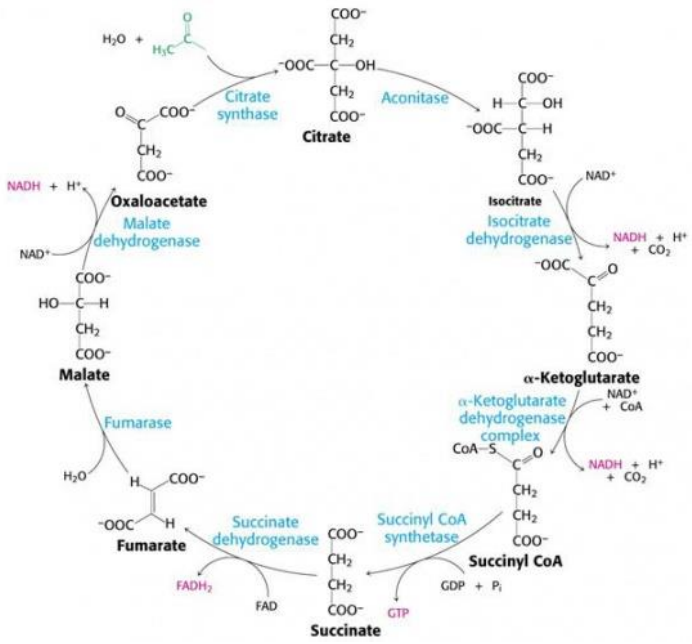


4-5 is sometimes called chemi-osmosis, kinetic energy of H^+ flowing back through ATP synthase powers the synthesis of ATP from ADP (also called oxidative phosphorylation in your book)

3 states of harvesting energy from glucose:

Glycolysis (sugar splitting): glucose to two pyruvates; occurs in the cytoplasm and has two major phases: energy investment phase and energy payoff phases; it occurs whether or not O2 is present.
Energy investment: Glucose + 2 ATP yields 2 ADP and 2 P
Energy Payoff: 4 ADP + 4 P yields 4 ATP formed.
and: 2 NAD+ + 4 e- + 4 H+ yield 2 NADH + 2 H+
Those processes yield 2 pyruvate and 2 water molecules.
(see slide "GLYCOLYSIS: Energy Investment Phase" for the chemical steps - you must know it all by heart.)

Citric acid cycle (also called Krebs cycle): occurs within the mitochondria; is transported through 2 membranes, the inner and outer membrane of the mitochondria; with the presence of O2 where the oxidation of glucose is completed.
Before the citric acid cycle can take place, the pyruvate is oxidized to Acetyl CoA (pyruvate dehydrogenase) using CO2, NAD+ and Coenzyme A. Pyruvate is broken down to CO2.
Cycle oxidizes organic fuel from pyruvate, generating 1 ATP, 3 NADH, 1 FADH2 per turn.
This process is responsible for creating NADH as much as possible. In the next process, NADH is used for ATP synthesis.



oxidative phosphorylation: occurs on the inner mitochondria membrane - that's where the enzymes are located; this process produces the most ATP as it is powered by redox reactions (90% of all the ATP).

The electron transport chain is the inner membrane if the mitochondria. Most of the chain's components are proteins, existing in multiprotein complexes. The carriers alternate reduced and oxidized states as they accept and donate electrons. They drop in free energy as they do down the chain and are finally passed to O2 and water.

Electrons are transferred from NADH or FADH2 to the electron transport chain.

For each molecule of glucose degraded to CO2 and water, the cell makes 32 molecules ATP.

Chemiosmosis: The Energy Coupling Mechanism:
Electron transfer in the electron transfer chain causes protein to pump the H+ from the mitochondrial matrix to the intermembrane space.
H+ moves back across the membrane passing through protein complex, ATP synthase.

ATP synthase uses the exergonic flow of H+ to drive phosphorylation of ATP.

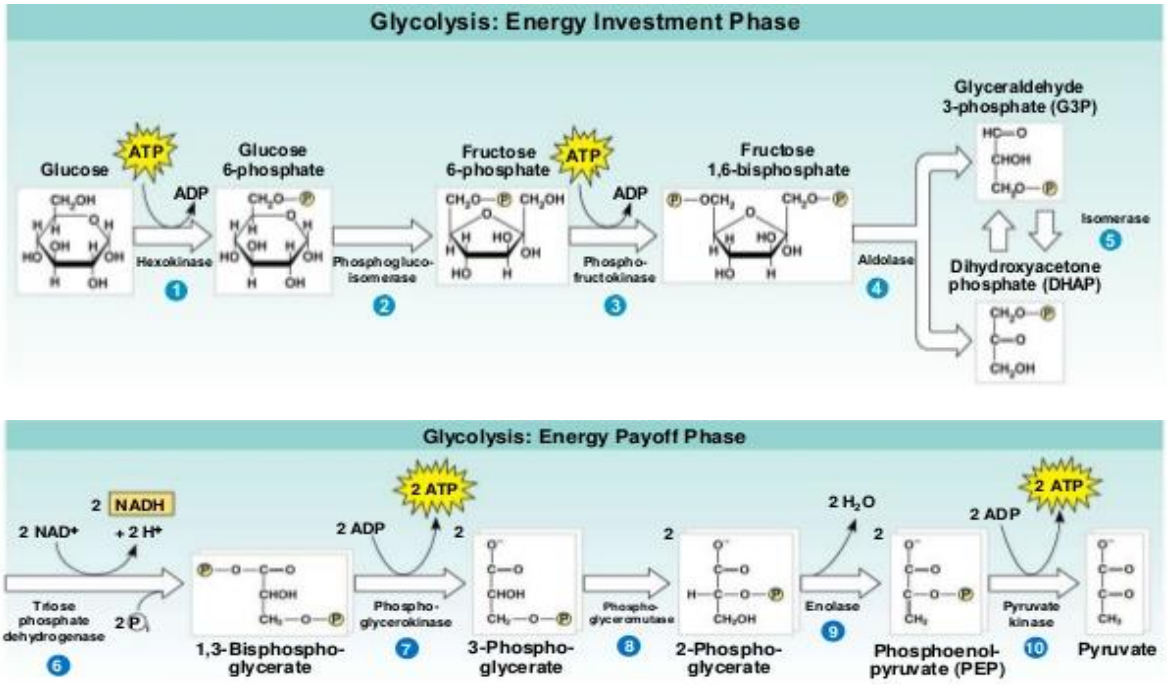
The H+ gradient is referred to as a proton-motive force, emphasizing its capacity to do work.

Plants generate O2 from water. Aerobic organisms generate water from O2. All O2 is of biogenic origin.

Fermentation and anaerobic respiration allows organisms to produce ATP without O2. The electron transport chain ceases to exist. Therefore, glycolysis couples with fermentation or anaerobic respiration to produce ATP.

Fermentation: Glycolysis + reactions that regenerate NAD+ which can be reused by glycolysis.
(Two common types are alcohol fermentation and lactic acid fermentation.)

APPENDIX: Glycolysis energy investment and payoff phase:



02.11.2016

Chapter 11: Photosynthesis

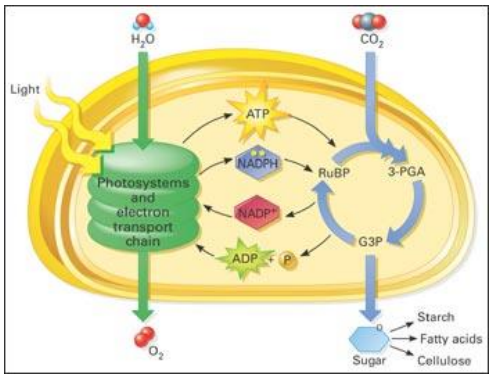
Def. Autotroph: Organism sustains itself without eating anything derived from another organism. They are the producers of the biosphere; they can produce organic molecules from CO2 and other inorganic molecules.

Def. Heterotroph: An organism that requires organic compounds as its source of energy.

Comparison between mitochondria and chloroplasts: They are quite similar; chloroplasts have thylakoids and thylakoid space (and of course they also possess DNA).

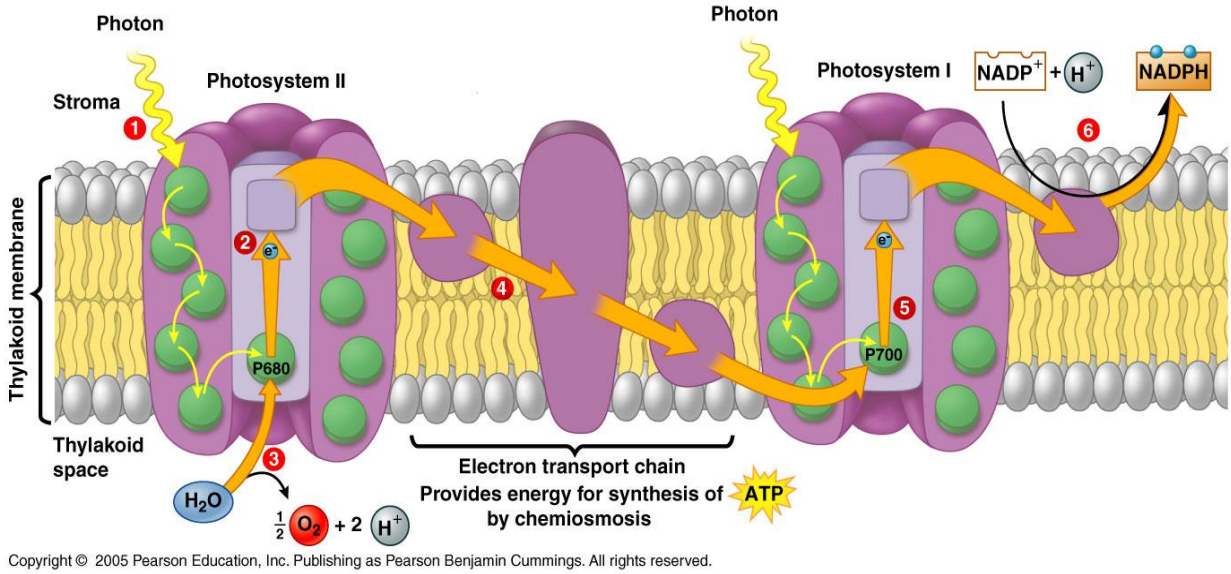
The oxygen atoms of CO2 and up as sugar and water in the process of photosynthesis.

In the thylakoid happens the light reactions (with water). This produces ATP and NADPH which is used for the calvin cycle. Calvin cycle produces ADP and NADP+ and it also produces sugar with the addition of CO2.



In the membrane of the thylakoid, there are so called pigments that can absorb certain wavelengths of light. Different kinds of pigments do absorb different wavelengths. Not absorbed light is either reflected or transmitted, so the cell is protected. Otherwise, it would become to reactive and destroy itself.

Reflexion and Fluorescence by light: How a photosystem harvests light:
...
(look at slide. There are 8 steps. Use 1 sentence per step). There are 2 photosystems (=: PS) in the thylakoid. Both contain pigments and they interact with one another.
Pigments are called chlorophyll a and b (and carotenoids). They have a porphyrin ring which is the light absorbing head of the whole molecule (it also has a hydrocarbon tail, which interacts with hydrophobic regions of proteins inside thylakoid membranes of the chloroplast). In chlorophyll a and b, only 1 functional group of the porphyrin ring differs, which causes these pigments to absorb slightly different wavelengths.



The cyclic electron flow: Only the PS1 is involved in the production of cythochrome complex (?). No NADPH and O2 is produced, but ATP still is. There are some bacteria that only have PS1. They can grow under weak light very well, though they struggle with intense light (they stop growing).
8 steps in linear electron flow:

1) A photon hits a pigment and its energy is passed until it excites the P680 molecule.
2) An excited electron is transferred to the primary acceptor. We now call it P680+.
3) Water is split by enzymes, thus reducing P680+ to P680 with the electrons. P680+ is the strongest known oxidizing biological agent. O2 is produced as a by-product.
4) Each electron falls down an electron chain from the primary electron acceptor in PS2 to PS1.
5) Energy released drives the creation of a proton gradient across the thylakoid membrane. Diffusion across the membrane dives ATP synthesis.
6) Likewise, P700 loses an electron through light exciting the pigments in PS1. The new electron from the PS2 reduces P700+ to P700 again.
7) Each electron falls down an electron chain from PS1 to the protein ferredoxin (Fd).
8) The electron is transferred to NADP+ reducing it to NADPH.

In cyclic electron flow, the electron cycles back from Fd to PS1. It does not create NADPH and no O2 either. It still produces ATP. It is believed that it has evolved before the linear electron flow. It might protect the cell from light induced damage.

The calvin cycle uses ATP and NADPH to reduce CO2 to sugar (it is the 2nd part of photosynthesis):
Phase 1: Carbon fixation
Use enzyme **Rubisco**, the most common enzyme in the world. 3 CO2 per cycle are needed. 3 CO2 + RuBP decays to 3-phosphoglycerate.

Phase 2: Reduction
They use 6 ATP to get 1,3-Biphosphoglycerate and 6 ADP. This outcome is used for the next phase.
The upper molecule together with NADPH create G3P and 6 NADP+ and 6 P (glucose and other organic compounds.)

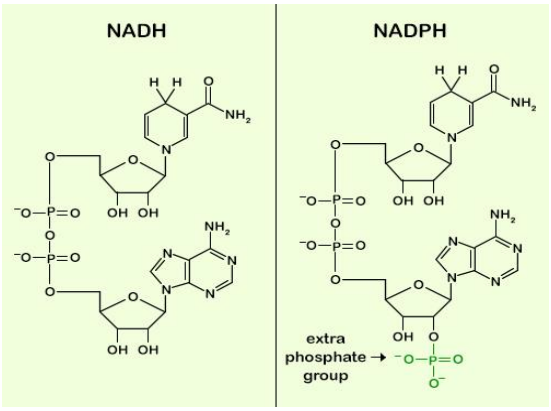
Phase 3: Regeneration of RuBP
3 ATP needed to regenerate RuBP from G3P.
For the cycle, 18 ATP and 6 CO2 are needed.

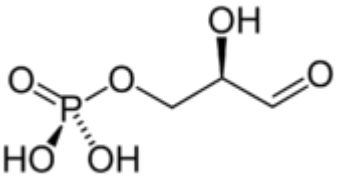
Excess sugars are stored by the plant as starch in the roots, stem etc.

Summary:
Light reactions: Are carried out by the molecules and the thylakoid membranes. Convert light energy to chemical energyy of ATP. Split water and relase oxygen to the atmospere-
Calvin cycle reactions: Take place in the stroma. Use ATP and NADPH to convert CO2 to the sugar G3P. Return ADP, inorganic phosphate and NADP+ to the light reactions.

If the thylakoid is punctured so that the interoir of the thylakoid is no longer seperated from the stroma. This would affect the synthesis of ATP most directly.

APPENDIX:
G3P (2-hydroxy-3-oxopropyl dihydrogen phosphate;



chemical formula: $C_3H_7O_6P$) 

3.11.2016

It is quite energetically ineffective to use water as a reactant (electrons-donor), since the oxygen really loves to keep the electrons to itself. It would be more practical to use H2S.
But water occurs in abundance, so one can do the process of photosynthesis everywhere even at the cost of using more energy.

All "conjugated systems" can absorb light.
E.g. Absorbing UV light provides too much energy for a cell which can lead to abnormal behaviour such as tumours.

In a PS, there are molecules that can absorb and pass the light energy to the next molecule. At some point, the light energy reaches a special pair of "chlorophyll a" molecules that gets such a high energy that it loses an electron. This electron is used to induce the next step.

The origin of photosynthesis lies within PS1. That's where the ATP is finally produced.

Chapter 12: The Mitotic Cell Cycle

The aim of mitosis is to produce genetically identical daughter cells. The exception is meiosis, which is a special type of cell division, that produces sperm and egg cells.

Eukaryotic cell division consists of mitosis (divisions of genetic material) and cytokinesis (division of cell plasm).

All the DNA in a cell constitutes the cell's genome. In eukaryotic cells, the genome is a bunch of DNA molecules. They are packaged into chromosomes.

Histones are proteins that are used to wind up the DNA. They are positively charged.
Why are histones positively charged? Since the DNA is negatively charged it allows for best interaction. Histones, just like any other protein, consists of amino acids. In this case, it is most commonly arginine, leucine and histidine, which are all positively charged amino acids (N-terminus is most often positive).

Def. Haploid: A cell contains only one set of chromosomes (in humans, it is the gametes (sperms and egg cells) which only have n=23 chromosomes).

Def. Diploid: A cell contains two sets of chromosomes (one of mother, the other of father). Most cells in humans are diploid. Plants can also be triploid or even polyploid.
Def. Somatic cells: nonreproductive cells; have two sets of chromosomes (diploid).
Def. Gametes: Reproductive cells; sperm and eggs; have half as many chromosomes as somatic cells. They are produced by meiosis.

A chromosome is winded, condensed DNA. 1 DNA replicates (transcripts), so there 2 identical DNAs. Those DNAs binds and are winded, so they are together. Those chromosomes are located in the cell nuclei.
All the chromosomes go to an imaginary plane in the middle of the cell.
That's when the spindle apparatus comes into play (consists of microtubuli). The tubulis are like fingers which attach to the centrosomes of the chromosomes.
The chromosome wanders on the microtubuli to the centromere of the spindle apparatus. Since there are 2 of them, they go to other sides respectively, which "tears" them apart. The chromosome becomes 2 sister chromatids.
Now the middle part of the cell divides into two smaller cell, each containing all the 46 sister chromatids. The DNA then unwinds again, so it can be used of course. This is mitosis in short.
The interphase cycle starts now.

Concept: The mitotic cycle alternates with interphase in the cell cycle.
Cell cycle consists of Mitotic (M) phase (mitosis and cytokinesis) and interphase.

Mitosis is divided into 5 subphases:
Prophase, prometaphase, metaphase, anaphase, telophase

Interphase is about 90% of the cell cycle. Subphases:
G1 phase (first gap): Main control checkpoint. It doubles all the cells contents but the DNA.
S phase (synthesis): DNA is doubled.
G2 phase (second gap): Double-checks if everything has been synthesized flawlessly.

The cell grows during all three phases but chromosomes are duplicated only during the S phase.

Centromeres make sure that the distribution of chromatids is equal.

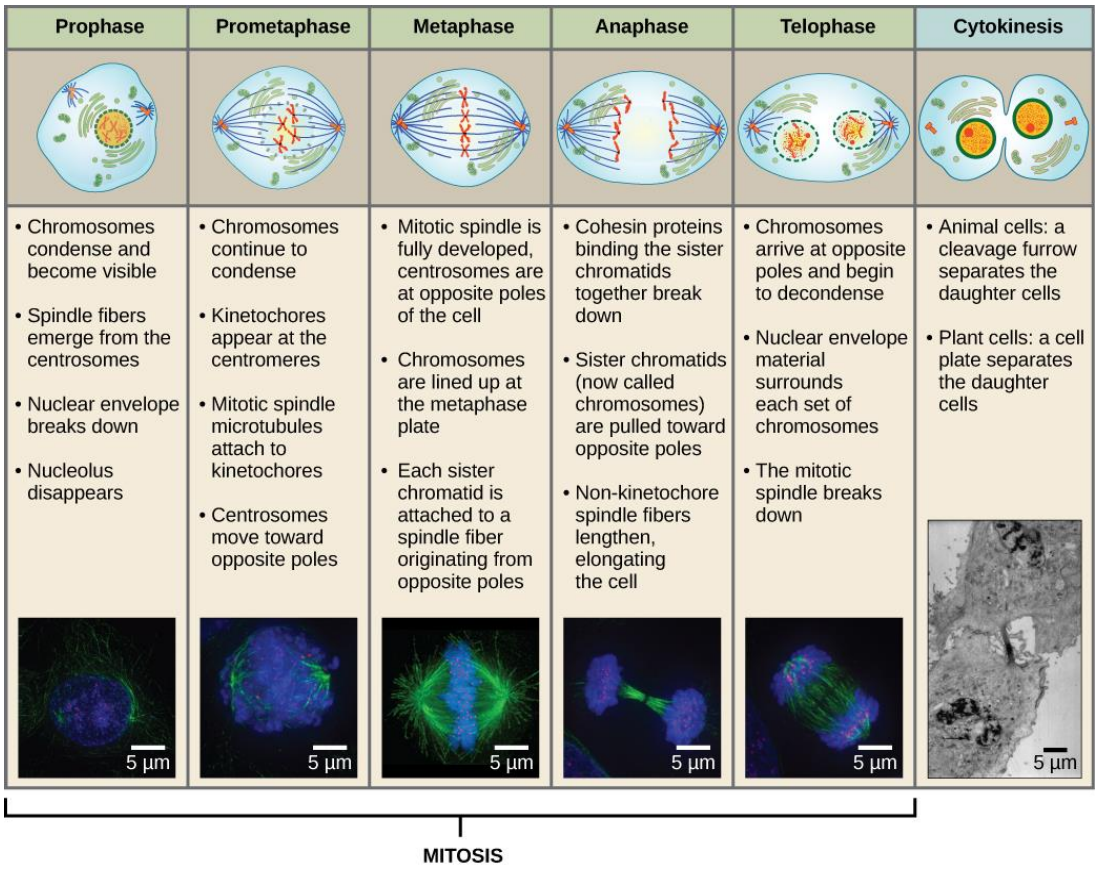
Mitotic spindle: a structure made of microtubules that control the movement during mitosis.

During the prometaphase, some spindle microtubules attach to the kinetochores of chromosomes and begin to move the chromosomes. The kinetochores are protein complexes associated with centromere.

Def. Kinetochore: Assembles on the centromere on specific parts of the DNA during cell division. The microtubule of the spindle apparatus can attach to it as well as the chromatids. Only in eukaryotes, since only eukaryotes undergo mitosis.

At the metaphase the chromosomes are all lined up at the metaphase plate which is an imaginary structure at the midway point between the spindle's two poles.
During the anaphase, the sister chromatids move along the kinetochore and microtubules and are

separated.



4.11.2016

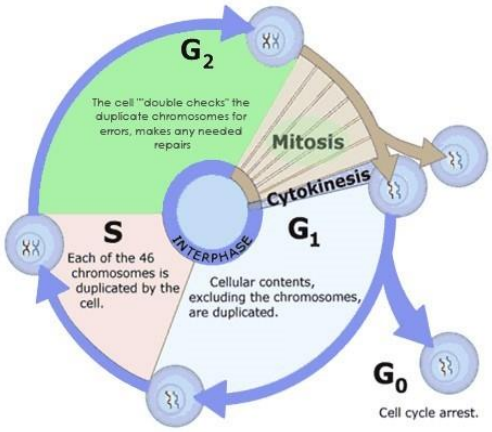
In plant cells, how is the cell wall built? The vesicles form a cell plate around the middle of the cell. Then, it becomes a cell wall floating in the middle of the parent cell. In the end, it fuses with the to and bottom. In each "chamber", there is a daughter cell.
The orientation of the spindle determines the geometry and direction of the growth of a cell.
In animals, it is the ability of the cell to move, which determines the direction and geometry of growth.

In prokaryotes, we do not talk about mitosis. Mitosis is characterized by cell nucleus division.
Prokaryotes do not possess one. We talk about binary fissure.
Chromosomes (DNA) are replicated and the daughter chromosomes move actively apart.
The cell divides in a similar way like plant cells. A secondary cell wall is created and then the cell divides.
There is no condensation of chromosomes in this process.

Concept: The eukaryotic cell cycles is regulated by a molecular control system.
The frequency of cell division varies with the type of cell. The differences result from regulation at the molecular level.
Cancer cells manage to escape these control processes.

It is theorized that there are internal cell signals in the cytoplasm that control the processes.

A cell in the S phase was fused with a cell in G1 phase. The nucleus immediately entered the S phase - DNA was synthesized. So it seems that two cells in different phases can be fused together, resulting the fused cell to enter a new phase.
E.g. Cell 1 is in phase M, cell 2 in phase G1. When fused, the G1 nucleus entered mitosis even though chromosomes had not been duplicated.
Checkpoints from slide: M checkpoint; G1 checkpoint; G2 checkpoint. This has to be controlled and go in the direction (not the other way around). The cell can also measure, at which point it currently is.
G1 seems to be the most important checkpoint in many cells. G1 gives a go-ahead signal. If yes, then it will continue cell division. If not, it will go to G0 phase.



Def. G0 phase: A nondividing state in a cell. All metabolic processes are still active, but the cell will not divide.

There are two regulatory proteins involved in cell cycle control: Cyclins and cyclin-dependent kinases (cdks). Cdks phosphorylate the hydroxy groups of amino acids (such as serines, threonine, thyrosine).

Maturation promoting factor (mpf) is a cyclin-cdk complex that triggers a cell's passage past G2 checkpoint into M phase.

Cyclin accumulation: Start with mpf at G2 checkpoint. In M phase, mpf is degraded. In G1 it is broken down to cdk and degraded cyclins. S phase, nothing on slide. In G2 again, cdk and cyclin together go to G2 checkpoint and are combined to mpf (mpf is a complex consisting of cyclin and cdk). This is an internal regulation mechanism of a cell.

There are also external signals such as growth factors that stimulate a cell to grow (divide) - it activates an internal signal that induces mitosis. See example of platelet derived growth fatcors (PDGF) on the slides.
External factors can also be physical factors that, for example, induce the G0 phase.
E.g. density-depended inhibition, anchorage dependence (cells must be attached to a substrate to divide).
Def. Cancer cells (provisional): Cell does not respond normally to the body's control mechanisms.
Cell that is not influenced by density-dependent inhibition and anchorage dependence. It may not need growth factors to grow and divide for they make their own growth factors. It may convey a signal of a growth factor without it being present at all. Cell cycle control system may be abnormal.

A normal cell is converted to a cancerous cell by a process called transformation. If they are not eliminated by the immune system, they form masses of abnormal cells in healthy tissue called a tumour.
A benign tumour remains only at its original site. By this definition is it as a not metastasizing cell.
A malignant tumour will transform healthy cells in cancer cells. It may also penetrate tissues farther

away and produce even more tumours at other places of the body if it survives. It metastasizes (establishing tumours in other parts of the body).

APPENDIX:
Chromosomes: DNA of a eukaryotic cell is packaged in a structure called chromosomes. Each one is a long molecule of DNA, which carries hundreds to thousands of genes.
Chromatin: It is a DNA-complex with special proteins (such as histones) of which the chromosomes are made of.
Chromatid: After a chromosome has been doubled, the result is called a sister chromatid.

During cell division, only in G1-phase, anaphase and telophase do chromosomes exist as a single DNA molecule.

9.11.2016

Chapter 13: Meiosis – Sexual Reproductive Cycle

Genetics is the study of heredity and variation.
Heredity is the transmission of traits from one generation to the next.
Variation is demonstrated by the differences in appearance that offspring show from parents and siblings.

Children inherit the genes (chromosomes) not a particular physical trait.

Genes are made up of segments of DNA. They are passed to the next generation via gametes. Each gene has a specific location on a chromosome called locus.

Genetic variability is advantageous for a population against pathogens. Genetic variability in a given population is more stable to changing environments for they can adapt quicker to them.
Clones are offsprings from a parent which is already the best in example of its specie in its environment. So, it produces more of something that is already good. It makes a lot of sense in environments that are approximately constant in its physical and chemical parameters. They are very susceptible to pathogens though.

Def. Homologous chromosomes: The two chromosomes in each pair are called homologous chromosomes (one of the mother, the other of the father). They have the same length, shape and carry the same genes controlling the same inherited characters. The more chromosomes the higher the recombination. Other names: Homologs.

Def. Karyotype: An ordered display of pairs of the chromosomes of a cell.

Sex chromosomes determine the sex of the individual, they are called X and Y. Females have a homologous pair of XX, while males have XY (in humans). The remaining 22 pairs are called autosomes.

An unfertilized egg cell has the sex chromosome X by default.

Def. Zygote: Egg cell + sperm cell. A zygote has one set of chromosomes from each parent. It produces somatic cells by mitosis and develops into an adult.

The only haploid cells in animals are the gametes.

Meiosis to fertilization (1n) – fertilization to meiosis (2n). Mitosis cannot count, it does not care about haploid, diploid etc.

Plants and some algae exhibit **an alternation of generation**:
Def. Sporophyte: A diploid multicellular organism creates haploid spores by meiosis.
Def. Gametophyte: Each spore grows by mitosis. It makes haploid gametes by mitosis.
Fertilization by gametes results in a diploid sporophyte.
Therefore, in plants and some algae, mitosis occurs during both the haploid and diploid stage.

In most fungi and some protists, the only diploid stage is the zygote. Mitosis does not occur. The zygote creates the haploid cells by meiosis. The haploid stage is where mitosis occurs in fungi and some protists. The multicellular haploid organism produces gametes by mitosis.
So, mitosis occurs only during the haploid stage and the adult form creates gametes with this process (and not by meiosis, since it is haploid and would not be able to halve its set of chromosomes).

The only difference is where mitosis occurs exactly. Meiosis occurs only during the diploid stage though.

Example of the hydra:
When food is abundant, the hydra will reproduce asexually. It forms a bud on its surface and after 2 days ideally, the offspring will simply fall of the original hydra. When food is scarce, the swell up at produce gametes (meiosis occurs). They release free-swimming gametes which can fuse with an egg cell of another hydra. Some hydras are hermaphrodites.

Meiosis takes place in two sets of cell divisions called meiosis 1 and meiosis 2. The two cell divisions result in 4 daughter cells rather than two daughter cells like in mitosis. (2n -> 4 times 1n).

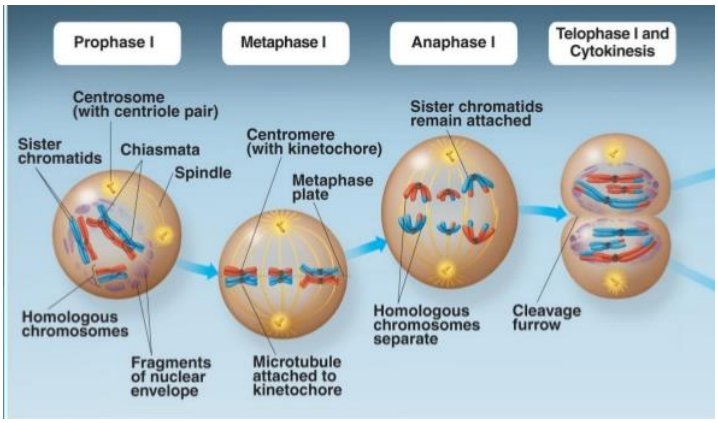
Every cell division starts with doubling the genetic information (S-phase, the synthesis phase, pretty much like in mitosis).

Interphase precedes meiosis 1. The DNA is duplicated, forming a paternal sister chromatid and a maternal sister chromatid. It's these two that will pair up in prophase 1 and undergo crossing-over.

After chromosomes are duplicated, it follows:
Meiosis 1: reductional division; homologs pair up and separate resulting in haploid cells with duplicated chromosomes.
It is divided in:
Prophase 1: Chromosomes pair up with their homologs (aligned gene by gene) and crossing-over occurs. DNA of non-sister chromatids are broken down and rearranged in the other chromosome at the exact same genlocus with help of proteins. Centrosome movement, spindle formation and break down of nuclear envelope (like in mitosis). Chiasma is an x-shaped region where crossover has occurred. Microtubules attach to the kinetochores at the centromere of each homolog.

Metaphase 1: The pairs are arranged at the metaphase plate.

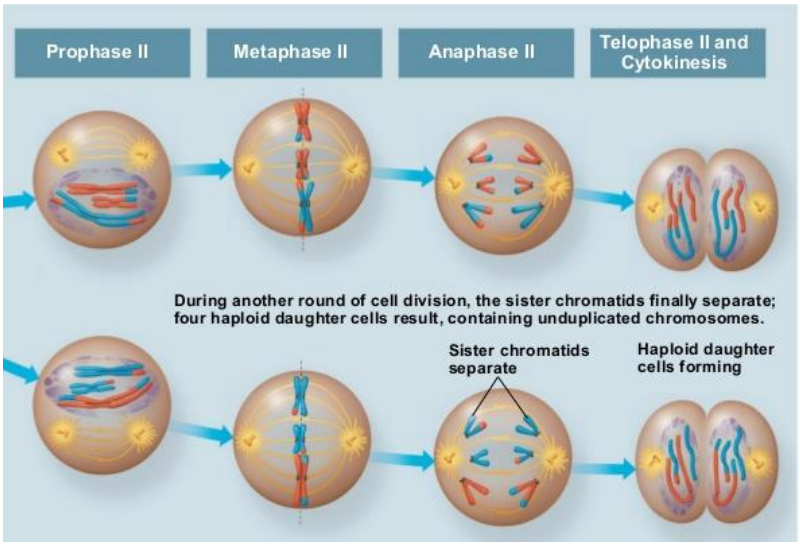
Anaphase 1: Proteins for sister chromatid cohesion are broken down. Homologs can separate and move toward opposite poles. The sister chromatid cohesion persists at the centromere, causing the chromatids to move together to a pole.



Telophase 1 and cytokinesis: Each cell has a haploid set of duplicated chromosomes. Two haploid daughter cells are formed. No chromosome duplication occurs between meiosis 1 and meiosis 2.

Meiosis 2: sister chromatids separate resulting in 4 haploid cells with unduplicated chromosomes.

Prophase 2: Spindle apparatus forms.



Metaphase 2: Chromosomes are positioned at the metaphase plate. The sister chromatids are not genetically identical because of meiosis 1. The kinetochores of sister chromatids are attached to the microtubules extending from opposite poles.

Anaphase 2: Breakdown of proteins holding the sister chromatids together. This allows them to move to opposing ends as single chromosomes.

Telophase 2 and cytokinesis: Nuclei form, chromosomes decondense. 4 cells with one set of chromosomes each (haploid) is produced from 1 mother cell. All 5 cells are genetically distinct from one another.

The crucial difference in meiosis and mitosis is: The sister chromatids are not separated in telophase 1. The chromosomes line up by homologous pairs. In mitosis, there are nor homologs lining up. Individual chromosomes line up at the metaphase plate.

10.11.2016

In mitosis, the number of chromosomes is conserved and the sister cells are genetically identical to the parent cell.

In meiosis, the number of chromosome sets is reduced from two to one. The sister cells are genetically different from one another and from the parent cell.
Both begin with duplication of chromosomes. In meiosis, the homologs also pair up. During metaphase 1, the genetic information of the homologs is recombined (depending on where which slice of the chromosome goes to which end).

Def. Mutation: Change in an organism's DNA. Original source of genetic information.

Def. Allele: Different versions of genes. The genes have the same locus on the chromosome, though the sequence of the nucleotides vary. The differences arise through mutation.

3 mechanisms contribute to genetic variation:
independent assortment of chromosomes: The number of combinations possible when chromosomes assort independently into gametes is 2^n, n is the haploid number.
crossing over: Occurs during prophase 1, when homologs pair up gene by gene. It produces recombinant chromosomes which combine DNA inherited from each parent. Homologous portions of two non-sister chromatids trade DNA portions (biomolecules such as proteins and DNA help the chemical reaction to take place). The DNA on the chromosome is cut with phosphodiesterase. The corresponding parts are brought to the other corresponding chromosomes, where the correct nucleotide sequence is. They are bound with DNA-ligase. 4 phosphodiesters have to be hydrolized. This process requires a very high precision, which is why it is catalysed by enzymes. It adds to increased genetic variability.
random fertilization: Any sperm can fuse with any ovum. There are more than 70 trillion diploid combinations.

Does genetic variability also occur in haploids reproduction cycles?

Natural selection results in the accumulation of genetic variations favoured by the environment.

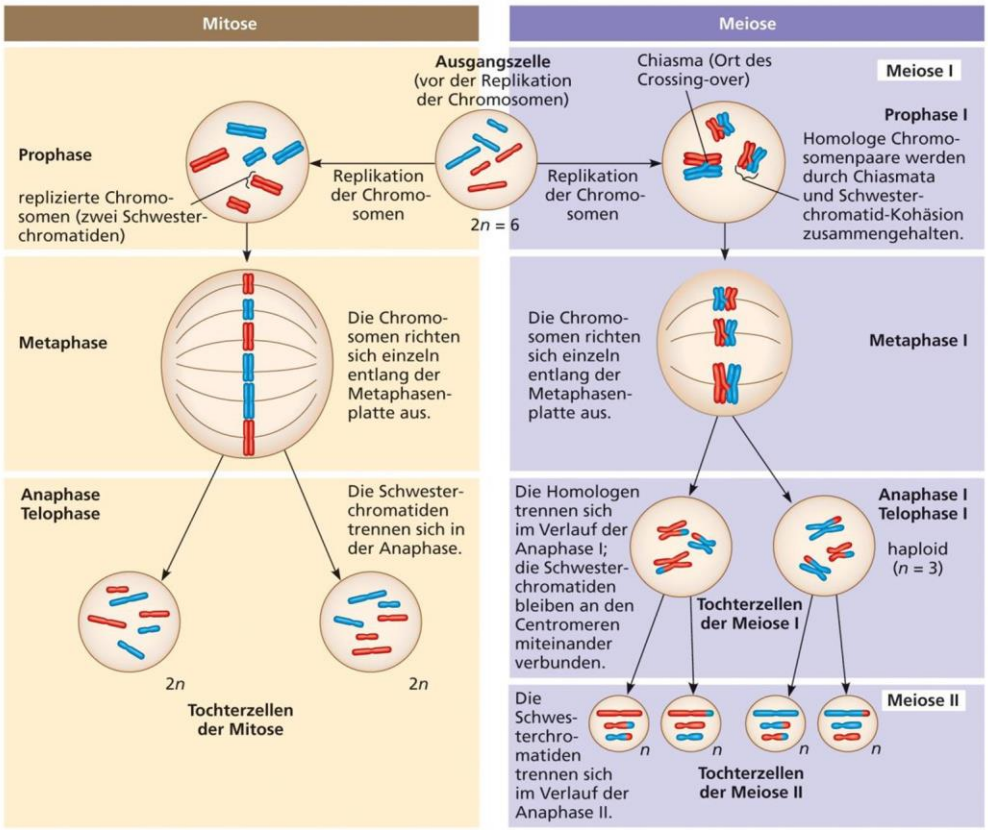
APPENDIX:

Difference in the reproduction cycle of plants and animals: Both produce gametes which are used for sexual reproduction. In animals, the haploid gametes do not undergo mitosis and they remain single-celled. In plants, the haploid gametes do undergo mitosis resulting in a multicellular haploid organism, called gametophyte (In plants, the gametophyte is often very small and not obvious at first, the sporophyte, which is diploid, is a tree for example).

Crossing over can only occur in meiosis 1, since after it, there are two cells now that cannot pair up with their homologs.
If crossing-over was not to occur in meiosis 1, there would be no association with the homologs. Thus, in metaphase, they would still go to opposite poles, but those without having paired up, would already be separated (this should only happen in meiosis 2). Thus, one will encounter abnormal chromosome distributions.

Comparison between mitosis and meiosis 2: In mitosis, the sister chromatids are genetically identical, while in meiosis 2, they are not due to crossing over in meiosis 1. Also, mitotically dividing cells can either have a haploid or diploid set of chromosomes (keep S-phase of the interphase in mind), but in

meiotically dividing cells, it is always a diploid set of chromosomes one is dealing with.



Zusammenfassung

Merkmal	Mitose	Meiose
DNA-Replikation	vollzieht sich während der Interphase vor Einsetzen der Mitose	vollzieht sich während der Interphase vor Einsetzen der Meiose I
Zahl der Teilungen	eine, umfasst Prophase, Metaphase, Anaphase und Telophase	zwei, jeweils Prophase, Metaphase, Anaphase und Telophase umfassend
Anlagerung (Synapsis) homologer Chromosomen	findet nicht statt	Vollzieht sich während der Prophase I, mit Crossing-over zwischen Nichtschwesterchromatiden; die resultierenden Chiasmata und die Schwesterchromatidkohäsion halten die Paare zusammen.
Zahl der Tochterzellen und genetische Ausstattung	Zwei, jede ist diploid (2*n*) und genetisch mit der Ausgangszelle identisch.	Vier, jede ist haploid (*n*) und enthält halb so viele Chromosomen wie die Ausgangszelle; genetisch von der Ausgangszelle und den anderen Meioseprodukten verschieden.
Rolle im Tierkörper	Entwicklung vielzelliger Organismen aus einer diploiden Zygote; Produktion von Zellen für das Wachstum, die Reparatur sowie – bei manchen Arten – für die ungeschlechtliche Vermehrung	Produktion der Gameten; Reduktion der Chromosomenzahl auf die Hälfte und Erzeugung genetischer Variabilität unter den Gameten

Abbildung 13.9: **Ein Vergleich von Mitose und Meiose in diploiden eukaryotischen Zellen.**

11.11.2016 (NP)

On lactose intolerance

(read Darwin's origin of species by means of natural selection if there's time)

Def. Evolution: Change of genetic make-up of a population through selection over a course of time.

Lactose is a combination of glucose and galactose. 2 hexoses are combined through glycosidic bond. The enzyme lactase with water breaks lactose in galactose and glucose. Those who do not possess lactase in the small intestine are intolerant to lactose- Their pH value becomes acidic resulting in diarrhea. The bacteria in the large intestine break down lactose without lactase and without oxygen which results into fermentation.

How do lactose-intolerant people survive their babyhood? Intolerance develops after the baby-age. After 1 year, babies become intolerant (normally) and when they try to drink milk, they will get sick and refuse drinking it in future. Lactase persistency is a mutation in the human population.

The most common tolerance is in middle-north Europe (and NA respectively). It was due to the Neolithic culture that made use of cows. They were dependent on cows.
Milk gives more kcal compared to meat. (milk: 500 kcal per day, meat: 160 kcal per day).
Lactose-tolerant people have more offspring which is a huge advantage in the long run.