CELLS & MICROSCOPES

Transmission Electron Microscope: Can observe very thin sections cut by an ultramicrotome.
Scanning Electron Microscope: Can observe only the surface.

Centimeter * 10 = Millimeter, Millimeter * 1000 = Micrometer, Micrometer * 1000 = Nanometer
e.g. 5 Nanometers = 0.005 Micrometers = 0.000005 Millimeters
e.g. 1 Millimeter = 1000 Micrometers = 1000000 Nanometers

Real = Image / Magnification.
Image = Real * Magnification
Magnification = Image / Real

Hypotonic: High H_2O concentration (low substrate concentration)

Cells in a hypotonic solution will burst (after being first turgid) due to the excess amount of water entering it via osmosis. (The bursting is called haemolysis).

Isotonic: Same concentration.

Cells in an isotonic solution will have no net movement of water.

Hypertonic: Low H_2O concentration (high substrate concentration)

Cells in a hypertonic solution will lose water as the concentration of water is higher in the cell than in the exterior environment. The cell will shrivel, called crenation. The cell is likely to become first flaccid, then plasmolysed.

Phospholipid Bilayer Membrane:
Steroids, O_2, CO_2, ethanol etc. can pass through while glucose, proteins and lipids cannot. Substances that pass through must be small and uncharged (covalent bonds, as opposed to ionic bonds).

Nucleus:
Largest organelle. Roughly spherical, surrounded by membrane called the nuclear envelope, which has openings called nuclear pores. Outer membrane joins to endoplasmic reticulum.
Contains most of a cell's genetic material, instructions for making proteins and controls protein synthesis. Makes mRNA.

Nucleolus: Not surrounded by membrane. Makes RNA and ribosomes. These pass into the cytoplasm and exit the nucleus via the nuclear pores.

Ribosomes:
Two variations: 80s (60s and 40s subunits) and 70s (30s and 50s subunits). Made of RNA+Protein.
Subunits hook and join to mRNA to start protein synthesis. These assemble and make proteins (e.g. antibodies, insulin, digestive enzymes).

RER (Rough Endoplasmic Reticulum):
Contains tubules, vesicles and cisternae (stacks of membrane-bound structures) within cells. Has sacs. “Rough” because ribosomes fixed on the exterior (ribosomes made of RNA and protein).
Fixed ribosomes synthesize proteins and prepare newly-made ones to send to Golgi Apparatus.

SER (Smooth Endoplasmic Reticulum):
Contains branched tubules and few/no ribosomes. Contains enzymes that break down harmful substances. Synthesizes lipids and neutralizes toxins. (e.g. lots of SER to neutralize toxins in the human liver).

Golgi Apparatus:
Made of stacks of membrane-bound structures called cisternae. Each cisterna is a flat, membrane-bound disc with special Golgi enzymes.
Receives newly-made lipids and proteins, and modifies+sorts them for cell secretion or for use within the cell. It also makes lysosomes from proteins received from the RER.

Mitochondria:
Has two phospholipid membranes. Inner membrane has lots of folds to increase surface area

and heighten ATP production.
Makes ATP (adenosine triphosphate), which is a cell's “rechargeable battery” and energy source. It also is in charge of signaling, cell differentiation, cell death and cell growth. Makes ATP by respiration, and ATP molecules are sent out to be used in various parts of the cell.

Chloroplasts:
Flat discs of 2-10 micrometers diameter and 1 micrometer thickness. Has two (inner+outer) phospholipid membranes. The material inside the chloroplasts are called stroma. Contains chlorophyll, is therefore green.
Captures light energy and performs photosynthesis. Produces food for plants. Sunshine required for ATP in chloroplasts, the energy from ATP is used to make sugars.
Not existent in animal cells.

Lysosomes:
Contains acid hydrolase, and has a membrane. Is a bag of enzymes, secreted by the Golgi.
Breaks down waste and cellular debris. Digests food. Also plays a role in autolysis (when the lysosome pops, releasing enzymes and eating the entire cell, causing cell death).

Centrioles:
Barrel-shaped, walls of nine triplets of microtubules at right angles.
Controls movement of materials in and out of the cell. Organizes mitotic spindles and performs cytokinesis. Used in mitosis and meiosis.

Plasma membrane:
Phospholipid bilayer, a fluid mosaic model. Hydrophobic lipid (water-soluble) tails are kept inwards and hydrophilic (phosphate) heads point outwards. Contains transmembrane proteins (membrane stability etc.), cholesterol (for fluidity), carrier proteins (allows large water-soluble materials to pass by facilitated diffusion), channel proteins (enable polar, water-soluble materials to pass by facilitated diffusion) etc.
Controls what goes in/out of the cell. Plays part in cell adhesion and signaling, etc.

Cellulose cell wall:
Tough and thick, but flexible. Is a pressure vessel. Does filtering, and offers support and protection to plant cells. Nonexistent in animal cells.

Vacuole:
Enclosed and filled with water. No set size or shape.
Isolates harmful things, and contains waste+water+small molecules (e.g. minerals and soluble sugars). Maintains acidic pH. Exports unwanted things. Maintains cell pressure.

Vesicles:
Blob of proteins/enzymes received from RER.
Stores+transports+digests cellular products and waste. Can release contents outside of the cell by merging with plasma membrane.

Peroxisomes:
Less than 1 micrometer in diameter.
Catalyses enzymes, and is used to break down H2O2. H2O2 is a highly toxic metabolic waste product.

Plasmodesmata:
Connects one plant cell to another. In animal cells: “gap junctions”.

Centrifugation: Spins cell parts at very high speed. Densest/heaviest parts sink to the bottom while lightest/smallest parts float to the top.Useful for separating cell parts.

BIOCHEMISTRY

Carbon: 4 bonds
Nitrogen: 3 bonds
Oxygen: 2 bonds
Hydrogen: 1 bond
Sulfur: 2 bonds

Carbohydrates:
Provides energy. Made up of carbon, hydrogen and oxygen, therefore is an organic compound. There are 3 types: Monosaccharides, disaccharides and polysaccharides.

Monosaccharides:
Building blocks (single units), small molecules. Soluble (e.g. glucose in blood). Is used by all living things as an energy supply. General formula: (CH2O)n, when “n” is between 3 and 7). These are white crystalline solids, dissolves in water to form sweet-tasting solutions.

Subdivisions:

1. Hexose monosaccharides (6 carbon molecules, e.g. fructose [fruit sugar], alpha and beta glucose [C6H12O6]).
2. Pentose monosaccharides (5 carbon, e.g. ribose, deoxyribose)
3. Triose monosaccharides (3 carbon, e.g. pyruvic acid in respiration)

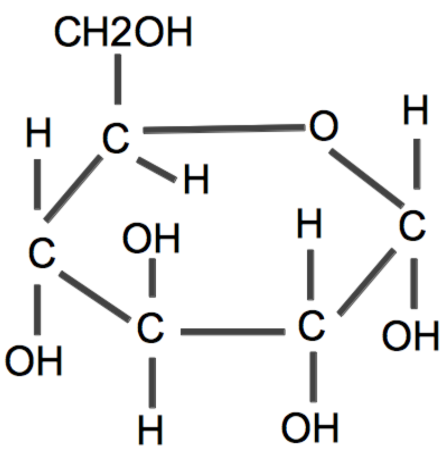
Disaccharides:
2 monosaccharides joined together (loses 1 H2O molecule in the joining process). General formula: (CH2O)n-H2O. These are less soluble than monosaccharides and sometimes used as a store (e.g. plants store starch). They can cause osmosis.

e.g. Sucrose (made of glucose+fructose, is the sugar in plants' phloem), lactose (the sugar in milk, made of glucose+galactose), maltose (in plants, beer, bread, malt, made of 2 alpha glucose molecules).

Polysaccharides:
Many monosaccharides/disaccharides joined together. Insoluble and doesn't cause osmosis.

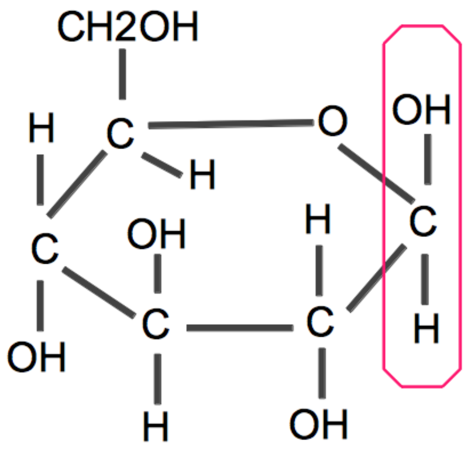
e.g. starch (plants' carbohydrate store), cellulose (β-glucoses joined together), glycogen (animals' carbohydrate store), lignin (xylem vessels) (structural carbohydrate).

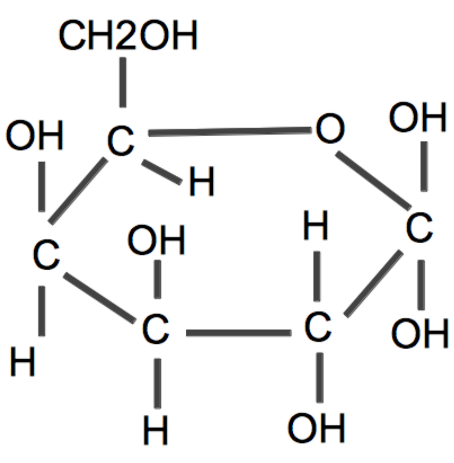
Starch: Hundreds of α-glucose molecules joined together.



Left: α-glucose

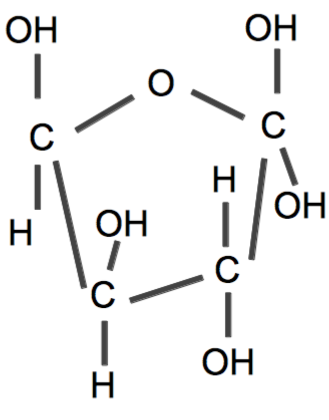
Right: β-glucose

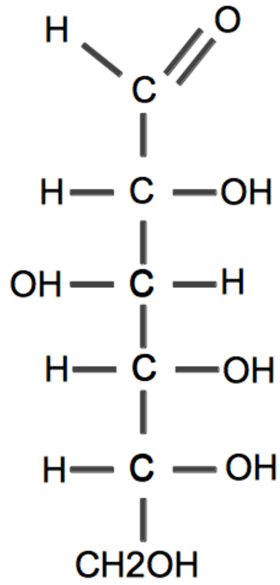




Left: Galactose

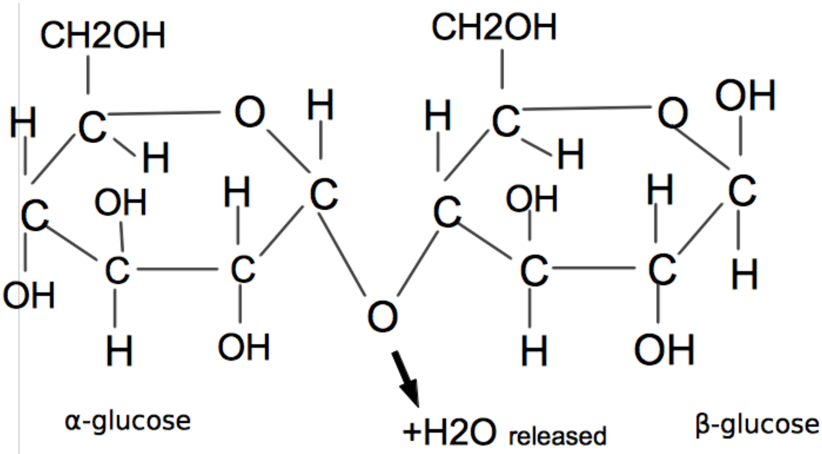
Right: Fructose





All these molecules can exist in ring (as shown) or in straight form.
Right: straight-form α-glucose. The O creates a double bond with the C.

Condensation Reaction (applies to all lipids, proteins and DNA):
Breaks bonds, creating hydrolysis reactions.



This is a 4-1 glycosidic bond, because it connects Carbon 1 of α-glucose to Carbon 4 of β-glucose. If two α-glucose molecules bond (like above), it creates maltose, a disaccharide.

Different bonds have different names:
Between carbohydrates: glycosidic bond
Between lipids: ester bond
Between proteins: peptide bond
Between nucleic acids: phosphodiester linkage

A bond between α-glucose and fructose, creating sucrose, is a 1-2 bond (Carbon 1 bonds with Carbon 2). This also releases a H2O molecule.

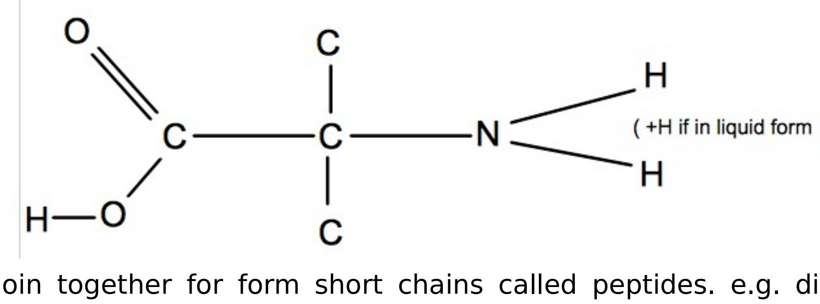
Polysaccharides:
Many monosaccharides joined together with glycosidic bonds.
e.g. Starch: Amylose & Amylopectin

1) Amylose: Made using α-glucose joined with 1-4 glycosidic bonds. Its shape causes it to spiral 360 degrees every 6 α-glucoses. To hold the amylose spiral together, Hydrogen bonds between H and OH groups are found on the α-glucoses in the spiral.
2) Amylopectin: Mostly 1-4 glycosidic bonds, but a few 1-6 glycosidic bonds between α-glucose molecules. Causes it to take a zigzag shape.

Animal equivalent to starch (food store): glycogen, which is similar to Amylopectin and has lots of branches. These food stores are mostly found in the liver and muscles.

Amino acids + Proteins:

Basic Structure: see right



Amino acids: monomers, join together for form short chains called peptides. e.g. dipeptide (made of two amino acids). They join via a condensation reaction (like carbohydrates).
Polypeptides: longer chains of amino acids, are polymers.
Proteins: the finished, functional molecule made from one polypeptide chain or more.

Lipids: Fats & oils. Stores energy, is waterproof, provides insulation. The most common lipid is triglyceride, and it is made up of three glycerol molecules arranged in an E shape. Saturated fatty acids are straight (in C – C bonds), and unsaturated ones are bendy (C = C bonds). The longer lipid chains are, the more solid they are. Unsaturated lipids take up more space but are also easier to digest. Cholesterol affects liquidity in plasma membranes.

Breaking polymers (catabolising): add water (hydrolyzing).
Joining monomers: remove water (condensation reaction).

Proteins are made of: Hydrogen, Oxygen, Nitrogen and some Sulfur (CHONS).

Diffusion:
Movement of substances from high to low concentrations by kinetic movement. Can be across a membrane or in a space. Osmosis is diffusion of water. Diffusion is faster if difference between concentrations is larger, or if temperature is higher, or if the membrane (if crossing one) is thinner. Special situation: in relatively impermeable membranes. Then, substances may travel in and out through channel/carrier/transmembrane proteins (facilitated diffusion).

Active transport:
Requires energy provided by ATP, involves transmembrane protein pumps. Moves ions or molecules across the cell membrane against: 1) a concentration gradient, 2) ionic gradient.

E.g. in freshwater protists, their cytoplasm has a far lower water concentration than the freshwater, so they have to actively expel the water from their bodies.

Endo/Exocytosis: requires energy. Phagocytosis: regarding solids. Pinocytosis: regarding liquids.

Enzymes:
Controls reactions in living cells, and are biochemical catalysts (speeds up reactions that would otherwise be too slow). A series of steps occur, called a metabolic pathway. One specific enzyme controls each step. Enzymes control cell metabolism by knowing when to stop or start a metabolic pathway.

e.g. A → Enzyme 1 → B → Enzyme 2→ C → Enzyme 3→ D (end product).

If D is the chemical needed by the organism, 3 enzymes are needed to produce it from A. If too much of D has been made or if D is no longer needed, D temporarily inhibits Enzyme 1.

→ THIS APPEARED IN PAPER 1, NOV. 2003

Enzymes are globular (like a ball), unchanged by reactions, specific, with reversible reactions possible with some enzymes.

Energy of Activation: the energy required to start a reaction.

Inhibitors:
Enzymes have an active site where substrates attach. If charged, similar forces will repel (+/+ or -/-). Inhibitors reduce rate of enzyme-controlled reactions and happens naturally to control metabolic pathways. They can be substrates, drugs or poisons. There are three kinds:

1) Competitive: has structure similar to that of substrate – competes for active site.
2) Non-competitive: binds anywhere, but alters enzyme shape and therefore the active site, causing the active site to be useless to the substrate. Two kinds:
    a) reversible, b) non-reversible (e.g. heavy metals, nerve gas. Fatal).

DNA

DNA:
Copies 5' → 3', but DNA polymerase reads it 3' → 5'. Replicates by “unzipping” and then putting the corresponding letter to the ends, making two “zips”. Oekisaki fragments means that the DNA copies in small bits, and that the DNA ligase joins the bits together and removes primers.
DNA is acidic and human DNA is around 2m long. Histone proteins, in octomers, wrap DNA up and they control protein synthesis as well as hold the DNA in place. Wrapped-up DNA is called a chromosome. One = chromosome, Two = chromatids.

DNA:
A polymer, made of monomers (nucleotides). Nucleotides are made of: 1) sugar, 2) a nitrogenous base, 3) a phosphate group.
The nitrogenous bases in DNA are: Adenine, Guanine, Cytosine and Thymine. (ATGC)
In RNA, Thymine is replaced by Uracil. (AUGC)

Histones:
Usually in clumps of 8, called octomers/nucleosomes. Octomers hold both sides of a DNA strand to keep it in place. Making a DNA strand into a chromosome using octomers is called supercoiling. This makes the DNA smaller and fatter, to prepare for mitosis/meiosis. Octomers also help regulate transcription and gene expression within the cell.

RNA:
Single-stranded, believed to have evolved before DNA. They reside in the cytoplasm and help in protein synthesis etc.
mRNA: encodes info for making a polypeptide
Ribosomal RNA: used directly to make new ribosomes
tRNA: used to make new polypeptide molecules.

Protein Synthesis:
DNA in nucleus → (via transcription) → mRNA → (via translation) → Polypeptide

Transcription:
Initiation → Elongation → Termination.
The DNA strand copied is the anti-sense strand, outer strand is sense strand. The RNA polymerase binds at the promoter, the DNA unwinds (helicase “unzips” it), enzymes begin RNA synthesis, copying it 5' → 3'. Free RNA nucleoside triphosphate floating around attaches to the 3' end of the growing mRNA transcript as they are needed. The DNA is thereby translated into mRNA, which exits into the cytoplasm once finished (via nuclear pores). A terminator at the end of the DNA strand tells the RNA polymerase to stop. The polymerase falls off and may rejoin at the beginning.

Post-transcriptional modification:
Limited to eukaryotes. Methylguanosinecap added at the 5' end. Introns are removed from the sequence by spliceosomes. Exons remain.

Translation:
The base sequence of the mRNA is used to direct synthesis of the amino acid sequence of a polypeptide, using ribosomes. The anticodons decode the mRNA codons. There are at least 20 tRNA types, one per amino acid. (e.g. tRNA-gly → carries glycine). The amino acid is attached to the rRNA and forms a peptide bond with the next amino acid.
mRNA attaches to small subunit of ribosome at the 5' end, and exposes 2 mRNA codons which the ribosomal sub-unit can cover over. Inside the sub-unit are 2 compartments, and this will fill up with tRNA's that carry amino acids.
tRNA: Has an acceptor arm where amino acids attach at the top, and 3 bases forming the appropriate anticodon at the bottom. AUG is the start codon.
If translation happens in the cytoplasm, resulting proteins will stay inside the cell. If it happens in the RER, they will go to the Golgi → vesicle → exocytosis.

MEIOSIS & MITOSIS

Mitosis:
Produces 2 identical daughter cells. Asexual reproduction. Cells divide when there is limited food supply to decrease volume.
IPMAT:
Interphase: not dividing.
Prophase: Chromosomes become visible, centrioles migrate to opposite ends of the cell, produce microtubules which join the ends of the cell. Nucleolus disappears. Mitotic spindle formed.
Metaphase: Chromosomes line up along spindle equator, attached to fibres at the centromere. Spindle fibres pull chromatids slightly apart.
Anaphase: Spindle fibres shorten more, pulling chromatids apart. They migrate to opposite ends of the cell.
Telophase: (cytokinesis)
The cell divides into 2 (in animals). Each cell has a haploid copy of homologous chromosomes.

Meiosis:
Interphase: genetic material duplicated (46 * 2 = 92)
Prophase I: Duplicated chromatin condenses, and each chromosome consists of two sister chromatids. Crossing over may occur.
Metaphase I: Homologous chromosomes align at equatorial plate.
Anaphase I: Homologous pairs separate with sister chromatids remaining together.
Telophase I: Two daughter cells formed with each one containing only one chromosome of the homologous pair. (92 / 2 = 46, 46)
Prophase II: DNA does not replicate.
Metaphase II: Chromosomes align at the equatorial plate.
Anaphase II: Centromeres divide and sister chromatids move to opposite ends of cell.
Telophase II: Cell division complete, four haploid daughter cells resulted. (46/2=23, 46/2=23)

Nondisjunction: when a human gamete has too few or too many chromosomes, the zygote formed will be aneuploid. Nondisjunction occurs in Anaphase, when too few move to one end and too many move to another.

GENES & INHERITANCE

Mendel's laws:

1) Theory of Particulate Inheritance: characters are determined by discrete units that are inherited down through the generations. May skip generations.
2) Law of Segregation: pairs of alleles segregate unchanged.
3) Law of Independent Assortment: Genes are located on different chromosomes, so they will be inherited independently—i.e. The gametes may contain any combination of the parents' alleles.

Co-dominance: Both alleles contribute to phenotype, and independently and equally expressed. e.g. Red + White cows = Roan
Incomplete dominance: Neither one allele completely covers the other. e.g Red + White = Pink

9:3:3:1 ratio: For unlinked dihybrid hererozygous crosses.
1:1:1:1 ratio: e.g. cs,cs,cs,cs * CS,Cs,cS,cs = 4 groups

Dihybrid: e.g. SsFf x ssff = SF,Sf,sF,sf x sf,sf,sf,sf (1:1:1:1 result)