BIOL1007 Lecture and Practical Summary Notes

BIOL1007 // Module 1: Information Transfer Notes

[redacted]

L1 - Information in cells

Introduction to information management

- We have known that information transfer happens for thousands of years.
- Information must be able to be:
    - Stored; somewhere where it is:
        - Stable
        - Corruption-free
        - Protected
        - Backed up
    - Accessed;
        - Easily
    - Retrieved;
        - Quickly
    - Read;
        - (Decoded) easily
        - Selectively
    - And used.
        - Appropriately.
- The above principles apply to genetic information.
- Genetic information must be:
    - Stable - resistant to attack by compounds inside the cell.
    - Corruption-free - the information carrying part can't be modified.
    - Protected - against unwarranted access
    - Backed-up - can be repaired if needed.
- DNA is the sole molecule that can claim all of the above principles.
- Our bodies, like computers, specialise in information management:
    - The brain is responsible for long-term memory (stable) and short-term memory (transient). There is always a stable and an unstable copy of information.
    - Our organs are responsible for everyday function, and are controlled by the brain.
- Information is the opposite of entropy: order vs. chaos.
- According to the 2nd Law of Thermodynamics, opposing entropy requires energy input.

Carbon-based information technology (IT)

- In our bodies, there is:
    - DNA (stable copy)
    - RNA, a copy of some of the DNA to form a transient molecule.
    - Proteins, transient molecules translated from RNA by ribosomes.
- Transcription - DNA to RNA! Translation - RNA to protein! You have to transcribe before you can translate.
- Some terminology:
    - Genome: all the DNA inside a cell
    - Transcriptome: all the RNA inside a cell
    - Proteome: all the protein inside a cell
- There are several types of RNA:
    - Messenger RNA - mRNA - 1-2% - used to make proteins as a polypeptide chain.
    - Transfer RNA - tRNA - 15-16% - assists decode mRNA during translation.
    - Ribosomal RNA - rRNA - 80% - catalyses assembly of amino acids during translation.
    - Other types include small nuclear RNA and micro RNA.
- Most of the genome doesn't code for proteins (~98%)
- The other parts are thought to regulate the speed of transcription.
- The parts of a protein include:
    Ion channels

    - Ion channels
    - Receptors
    - Antibodies

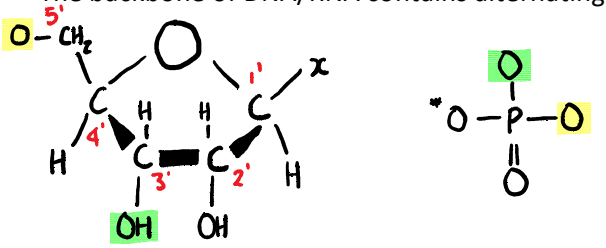
    - Enzymes
    - Transcription factors
- The central dogma is the direction of flow of genetic information of the genome.
- Reverse transcription copies RNA back to DNA. This is how HIV is so deadly.
- Reverse translation does not exist!
- Every cell in our body contains the same genetic information, except red blood cells and reproductive cells (which only have one copy instead of two).
- Localised function theory means that some sequences of the genome may not be represented at all!
- The big four types of organic cells are:
    - Fats;
    - Carbohydrates;
    - Proteins; and
    - Nucleic acids.
- Proteins and nucleic contain information through their (different) compositions of monomers.

Biopolymers

- Linear biopolymers always have a defined beginning and end.
- Biopolymer synthesis is anabolic, and occurs in one direction only!
- Some of the monomer may be lost in (addition) polymerisation, only leaving the residue in the chain.
- In DNA and RNA, synthesis occurs over a common sugar/phosphate backbone in the 5' phosphate to 3' hydroxyl direction.
- Why isn't silicon the basic of life? It has a large atomic radii, only allowing for weak covalent bonds. Silicon would rather bond with oxygen than itself, and so it is forms glass and sand, not organic compounds.
- Carbon forms strong covalent bonds, and is under kinetic control (activation energy for reaction is too high), and so it is perfect for our bodies. Sometimes, enzymes help with kinetic control in our bodies.

L2 - Information in biopolymers 1

- DNA and RNA are the most important biopolymers in our bodies.
- The backbone of DNA/RNA contains alternating sugar and phosphate molecules.



- Left - ribose (sugar); Right - phosphate
- Ribose:
    - The base (ACGU) connects to the 1' carbon denoted by x. This bond is called the N-glycosidic bond, where the N refers to the nitrogen in the base.
    - 2'-carbon has a hydroxyl group attached, which is not present in DNA.
    - 3'-carbon has a hydroxyl group attached, where the phosphate will attach (green).
    - 5'-carbon has an oxygen atom, which will be removed when the ribose is attached to the previous phosphate on the backbone (yellow).
- Phosphate:
    - Has an overall negative charge, and is therefore hydrophilic.
    - Has a number of applications, including electrophoresis and ethanol precipitation.
- The bond between the ribose and the phosphate is called the phosphodiester bond.

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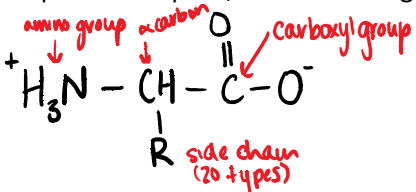
- The bases connected to the backbone are either:
    - Purines - adenine and guanine.
    - Pyrimidines - cytosine and thymine/uracil.

- What is the difference between DNA and RNA?
    - Deoxyribonucleic acid instead of ribonucleic acid.
    - Thymine in DNA is similar to uracil in RNA except it has a methyl group on the 5'-carbon of the base. However, the orientation of the group doesn't affect processing.
    - DNA doesn't have a hydroxyl group on the 2'-carbon of the ribose.
- How does DNA meet the information storage criteria?
    - Stable; resistant to attack? The missing hydroxyl on DNA makes the DNA more stable, and hence chemically protected. If "a rogue hydroxyl comes floating by", it will try to take a proton from the 2'-carbon hydroxyl. The remaining oxygen will then look to react with the nearby phosphate, which will snap the backbone! If the 2'-carbon is not present, this cannot happen.
    - Corruption-free? Having thymine instead of uracil solves this problem. Cytosine is an unstable base, and spontaneously oxidatively deamidates to uracil (about 100 times per day for each DNA polymer). If uracil was a normal part of DNA, then it could not be excised and removed, leading to corruption.
    - Protected from unwarranted access? DNA is not a spiral staircase! It actually has a major and minor groove, with access only possible through the major groove.

- Forces in DNA molecules:
    - Strong forces - nucleotides are joined by the phosphodiester bond.
    - Weak forces - hydrophobic interactions (pH must be right), electronic interactions (about pi-bonds), hydrogen bonding, hydrogen bonding, ionic interactions, Van der Waals forces.
- Experimental techniques:
    - To promote base pairing:
        - Lower the temperature
        - Increase the ionic strength - two strands of DNA oppose each other, but adding sodium ions will act as a shield and bring the strands together.
        - Keep the pH around 7 (neutral)
    - To disrupt base pairing, do the opposite (up the pH)
- Melting temperature will increase with more cytosine-guanine base pairings, as these strong bonds increase the energy required to melt the molecule.

L3 - Information in biopolymers 2

- The amino acid structures coded by RNA determine the structure of the protein translated, which then determines the function of the protein.
- Proteins are diverse: some are embedded in a membrane, some are hydrophobic, some are positive at pH 7, others are negative etc.



- Above is the alpha amino acid, the basic structure of all 20 amino acids.
- Two amino acids would usually bond via condensation polymerisation, however this would give off water. Ribosomes allow for hydrolysis in a water-free environment.
- There are basic types of side chains:
    - Hydrophilic aliphatic - chains of CH_2
        - Only have C-C and C-H bonds.
    - Aromatic - chains carbon rings with double bonds
    - Polar non-ionic - chains with hydroxyl, SH or amides
        - Have a dipole, but no proton exchange