Delft, University of Technology

Programming Life 1

Introduction to molecular biology: The Nucleic Acid World

Programming Life – Group 2
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Chemical Structure

Deoxyribonucleic acid (DNA) contains **genetic information**. All DNA in an organism is called the **genome**. DNA encodes for all **proteins** needed to live. DNA molecules are linear polymers where each monomer is comprised of a phosphate group, a **nucleotide**, bound by sugar. The monomers only differ in their nucleotide, which is called the **base**. In DNA the sugar is **deoxyribose** and the bases ***guanine*** (G), ***adenosine*** (A), ***cytosine*** (C) and ***thymine*** (T). In RNA the sugar is **Ribose** and the base T is replaced by ***uracil*** (U).

The structure of the monomers yields a **double-helix form**. Through hydrogen bonding, *T and A* are paired, *G and C* are paired. The opposite sides of DNA are therefore **complements**. The non-covalent hydrogen bonds can be broken, resulting into two DNA strands, which is necessary for DNA **replication**. DNA strands can be paired with RNA strands. This is called **hybridization**.

RNA, Transcription and Translation

RNA is usually single stranded and is therefore more flexible, making interactions with itself possible. Some parts of DNA encode for RNA, instead of proteins. A **gene** consists of the region encoding for the protein plus all surrounding *control regions*. To go from DNA to protein, a polymer, the **genetic information** in one of the two strands of DNA is copied[1] through **transcription** to ***messenger RNA*** (mRNA); the gene is **expressed**. That strand is called **noncoding strand**[2]. Its complement is the **sense strand**. Genes may overlap, which commonly occurs in **viruses** as a way of packing as much information as possible. RNA encodes for 20 different **amino acids**. Three consecutive bases are called **codons** and encode for one acid. There are multiple encodings for a single acid. Three codons infer a stop signal – or **terminator signal**, which ends of the protein polymer.

transfer RNA (tRNA) has a three-base **anticodon** and mediates the addition of amino acids to a protein chain. The enzymatic activity that joins amino acids is due to ***ribosomal RNA*** (rRNA). The process of mRNA - with the aid of tRNA and rRNA - to proteins is called **translation**.

Gene control

Some regions of DNA are **regulatory elements**: control sequences. The control regions where RNA *polymerase*[3] binds to start transcription are called **promotors**. Other controls are **activators** which improve binding of RNA polymerase and **repressors** which do the opposite. Sequential parts of noncoding DNA are called **introns**, protein-coding sequences are called **exons**. **RNA splicing** removes the introns and mends the exons**. Gene regulation**[4] is mainly the cell types within which genes are activated, their timing and magnitude. These are necessary to regulate **gene expression**. Over- and under expression can have devastating effects. In bacteria gene organization allows for **operons**: sequential encoding for proteins without a stop signal, meaning only one control region for several proteins, that are transcribed to a single piece of mRNA. Operons are rarely found in eukaryotes.

Evolution and mutation

Genes may be changed, added, or destroyed because of **mutations**. Change causes **evolution**. Molecular biologist can *transfer* individual genes between organisms to produce proteins that some humans are missing because of defects.

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[1] From the ‘3 end to the ‘5 end. The mRNA is then translated from the ‘5 to the ‘3 end. Read: only one direction encodes for the correct codons, thus amino acids, thus actual proteins. You can name the ends, so you can infer the transcription and translation directions.
[2] Also **anticoding** or **antisense** strand
[3] Enzyme that unbinds DNA so mRNA can be created from DNA
[4] By **antisense RNA** (aRNA), **small interfering RNA** (siRNA) and **small nuclear RNA** (snRNA), the latter also to edit mRNA and maintain chromosome tips (telomeres).