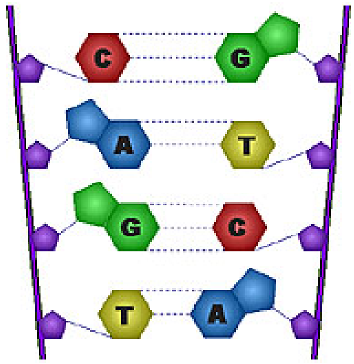
DNA, RNA & protein synthesis

DNA (DNA = deoxyribonucleic acid)

- DNA is the genetic material of all living cells and of many viruses.
- DNA is: an alpha double helix of two polynucleotide strands.
- The genetic code is the sequence of bases on **one** of the strands.
- A gene is a specific sequence of bases which has the information for a particular protein.
- DNA is self-replicating - it can make an identical copy of itself.
- Replication allows the genetic information to pass faithfully to the next generation.
- Replication occurs during the 'S' (= synthesis) stage of interphase just before nuclear division.
- The chromosomes contain 90% of the cell's DNA.
- 10% is present in mitochondria and chloroplasts.
- **Adenine** (A) and **Guanine** (G) are **purine** bases
- **Thymine** (T) and **Cytosine** (C) are **pyrimidine** bases
- Hydrogen bonds link the complementary base pairs:
    - Two between A and T (A = T)
    - Three between G and C (G ≡ C)
- A single unit in the chain is a **nucleotide**.
    - This consists of a **phosphate group,**
    - **a pentose sugar** *(D = DNA; R = RNA)* and
    - an **organic base (ATGC = DNA; AUGC = RNA)**



RNA (RNA = ribonucleic acid)

- Three different types of RNA, (messenger (mRNA), transfer (tRNA) ribosomal (rRNA))
- All are made in the nucleus (**transcription)**
    - ribosomes are synthesised in the nucleolus;
    - mRNA prepared there too – introns removed
- All types of RNA are involved in protein synthesis:
    - mRNA: copies the information from the DNA.
    - tRNA: carries the **specific** amino acid to the mRNA in contact with the ribosome.
    - rRNA: makes up 55% of ribosomes (the other 45% = protein).

NB. Some RNA molecules can function as enzymes.

Differences between DNA and RNA

- DNA is double stranded; RNA is a single stranded
- N.B. ATP is **also** a nucleotide, with ribose as the pentose sugar.
- DNA contains the pentose sugar **deoxyribose**; RNA contains the pentose sugar **ribose**.
- DNA has the base **Thymine (T)** but not **Uracil (U)**; RNA has **U** but not **T**.
- DNA is very long (billions of bases); RNA is smaller (hundreds to thousands of bases)
- DNA is self-replicating, RNA is copied from the DNA so it is not self-replicating

The genetic information is held within the base sequence along a DNA strand.

A **codon** is a sequence of **three nucleotides**, coding for **one amino-acid.**
The genetic code is **universal**, thus all life must have had a **common ancestor (i.e. evolution)**

Coding structures (Exons)

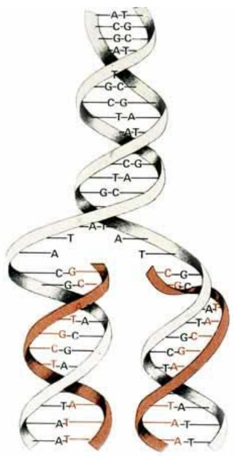
- These are the parts of the DNA that contain the code for the synthesis of protein or RNA.
- These coding sequences are present within genes.

Non-coding Structures.

- This is DNA that does **not** contain information for the synthesis of protein or RNA.
- The non-coding sequences are found both **between** genes and **within** genes (= **introns**).
- These non-coding sequences have been termed 'junk DNA' but they:
    - do play a role in gene expression (i.e. whether a gene is switched 'on' or 'off')
    - act as spacer material,
    - permit the synthesis of many new proteins and
    - play an important role in evolution.
- Non-coding DNA makes up 95% of human DNA.
- Non-coding DNA segments within genes are called introns.

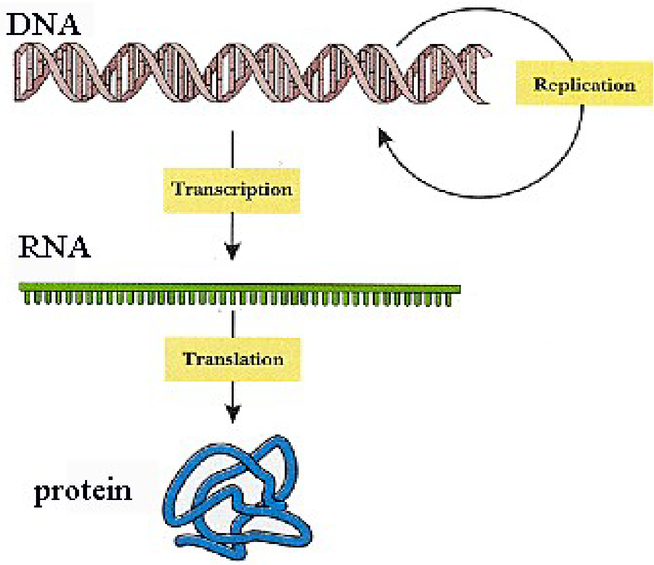
DNA Replication

This takes place during the **S stage of interphase**



- Nucleotides are synthesised in huge quantities in the cytoplasm.
- An enzyme unzips the two complementary strands of DNA.
- New complementary nucleotides link to the exposed bases on the separated strands.
- The general name for this group of enzymes is **DNA polymerase**.
- A new complementary strand is built along each 'old' strand.
- Two DNAs, identical to the original and each other, are now present.
- Each new DNA molecule is thus 'half old' and 'half new'
    - **'semi-conservative replication'.**

Protein Synthesis



Gene - A section of DNA containing a particular sequence of bases that codes for a specific protein.

Protein Synthesis - The **transcription** of a specific DNA base sequence into mRNA and its **translation**, by a ribosome, into a particular amino acid sequence forming a protein.

Genetic Code

- The universal code that determines the function of all possible triplets of DNA / mRNA.
- Most triplets specify a particular amino acid (= a codon).
- Some triplets function as a start or stop signal for protein synthesis.
- It is a **degenerate code** as a particular amino acid may be coded for by more than one codon.

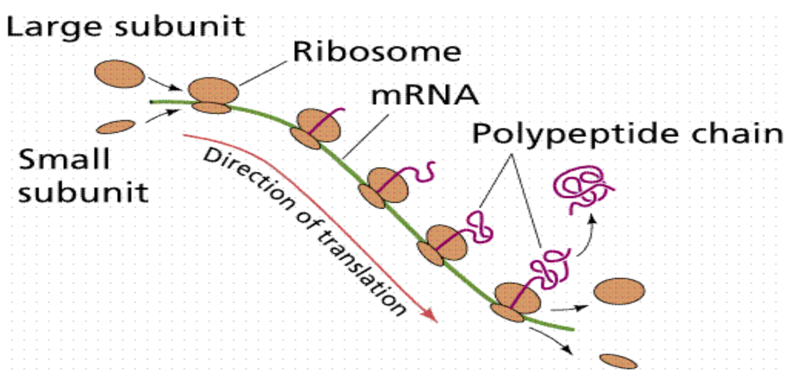
Process of Protein Synthesis – transcription and translation

Transcription – DNA base sequence to mRNA base sequence

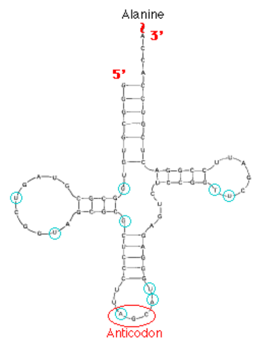
- The 'code' for the protein is carried by one of the DNA strands in the gene.
- An enzyme separates the two DNA strands at the gene locus exposing the gene sequence.
- A **complementary** copy - mRNA - is made of the gene sequence –
  - new nucleotides form a complementary RNA strand
  - using the DNA gene sequence strand as a 'master'
  - the enzyme RNA polymerase links the new nucleotides forming **mRNA**.
- **Uracil** (U) is the complementary base to adenine in RNA, **thymine** (T) is not found in RNA.
- The complementary RNA copy is called **messenger RNA** (mRNA).
- The mRNA separates from the DNA strand and passes from the nucleus to the cytoplasm.

Translation – mRNA base sequence to amino acid sequence.

- A ribosome binds to the start point of the mRNA.
- The ribosome will 'decode' the mRNA in sets of three bases (a **codon**).
- Each codon specifies **a particular amino acid**.
- **The sequence of bases on the mRNA determines the sequence of amino acids in the protein** – any change = a mutation
- Two codons of the mRNA are exposed in turn.
- Two complementary tRNA molecules attach to these two mRNA triplets.
- The amino acids of the tRNA bond together (**peptide bond – condensation reaction)**
- The leading tRNA detaches from its amino acid and from the mRNA.
- The ribosome 'moves' to the next codon and another complementary tRNA attaches.
- The newly arrived complementary tRNA then adds a new amino acid.
- The process repeats, codon by codon, to the end of the mRNA (until a stop codon is reached).
- The amino acid sequence is now complete.
- The polypeptide (amino acid chain) folds giving the protein its normal functional shape.
- **Primary structure = amino-acid sequence** (determined by DNA sequence)
- **Secondary structure = many H- bonds** making
  - **Alpha helix** (very common) or
  - **Beta-pleated sheet** (rare – butterfly wings and silk)
  - **Thus affected by pH, temperature**
- **Tertiary structure** = disulphide bridges and further H-bonds – forms **active sites**
- **Quaternary structure (rare) – only haemoglobin (**Van der Waal's forces)



Ribosomal RNA (rRNA)
A ribosome is roughly 50% protein and 50% RNA (known as rRNA).



Transfer RNA (tRNA)

- tRNA is found in large amounts in the cytoplasm.
- Single stranded but folded back on itself with three exposed bases (**'anticodon'**) at one end and a particular amino acid at the opposite end.
- tRNAs are 'adapters' linking amino acids to nucleic acids in protein synthesis.
- There are 64 (4 x 4 x 4) **possible** triplets;
- there are 61 tRNAs - the other 3 are 'stop' signals
- There are only 20 different amino-acids, so
    - each amino-acid is coded for by more than one codon (tRNA);
    - thus the code is **degenerate** (or 'semi-redundant')

Note: transcription occurs in the nucleus; **translation** occurs in the cytoplasm.