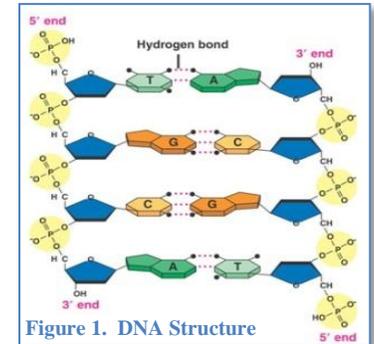


SAT Biology Review: Central Dogma

DNA and RNA Structure

Nucleic acids are large polymers composed of nucleotide monomers. Nucleotides themselves are composed of a phosphate group, a five carbon sugar (ribose in RNA and deoxyribose in DNA), and one of five different nitrogenous bases (adenine, guanine, cytosine, and thymine in DNA and uracil in RNA). Carbons of the sugar are numbered 1' through 5'. The nitrogenous base is attached to the 1' carbon and two nucleotides are linked together via their 3' and 5' carbons.

DNA molecules are double helices composed of two strands of nucleotides across from each other with the nitrogenous bases inward (like rungs of a ladder) and the phosphate and deoxyribose on the outside. The two strands are **antiparallel** (one is 3'→5', the other 5'→3') and are held together by hydrogen bonds between the bases (two hydrogen bonds between A and T and three hydrogen bonds between C and G).



RNA molecules are single-stranded, and often contort and twist back on themselves forming complex 3-D shapes similar to proteins. RNA serves many roles in the cell such as **ribozymes** (RNA catalysts, similar to enzymes), tRNA, rRNA, and mRNA (all discussed later).

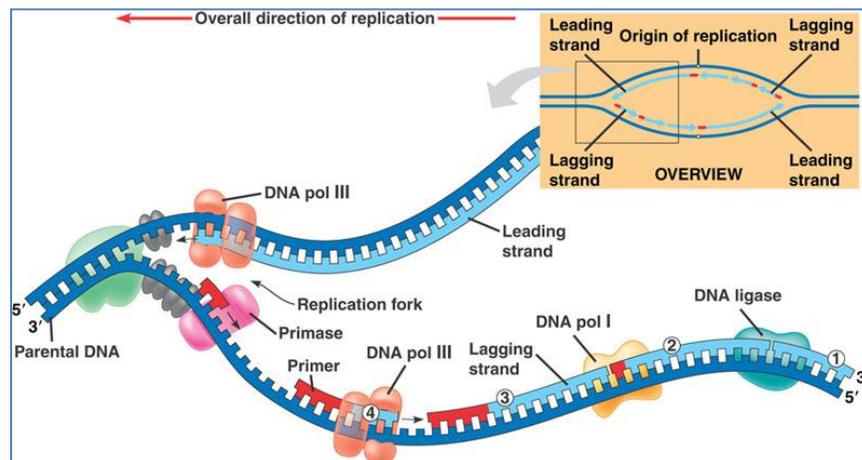
DNA Replication

DNA is replicated in order to create an identical daughter molecule for cell reproduction. Replication occurs during S phase of the cell cycle. DNA replication is semi-conservative: two new daughter molecules will be composed of one original strand of DNA hydrogen bound to a newly synthesized strand.

Replication begins at precise points on chromosomes (the *ori*, *origin* of replication), where the enzyme helicase unwinds and opens the double helix by breaking the hydrogen bonds between each facing base. The open helix is maintained by SSB proteins (single-strand binding protein), and DNA synthesis begins with the creation of a **primer** (a short 5-10 base pair RNA) by primase.

DNA polymerase synthesizes a new strand, using the RNA primer as a starting point. Complementary bases bind to their counterpart on the old, or template, strand. DNA polymerase then covalently bonds these new bases. Because of the specificity of enzyme active sites, the DNA can only fit in DNA polymerase in one direction; thus, the new DNA strand is always built 5'→3' while the template strand can only be read 3'→5'.

Because of this directionality, DNA replicates in different directions and at different efficiencies on each strand. The template (original) strand running 3'→5' can be used to create one continuous daughter strand of DNA, and is called the **leading strand**. DNA built from the opposite strand (5'→3') can only be built in short segments called **Okazaki fragments**, which must be sealed into one continuous piece by ligase. This is the **lagging strand**.



Transcription and Translation

DNA encodes the information needed to synthesize the tens of thousands of different proteins and nucleic acids in a living organism. The information to build one unique product is called a **gene**. Not all genes are needed in every cell or in every situation; **gene or transcriptional regulation** is the ability to enhance access to a required gene and restrict or prevent access to an unneeded gene.

In front of a gene is a **promoter** (a region of DNA that identifies and locates specific families of genes), and behind it is a **terminator** (signifies the end). Transcription occurs at all times in the cell cycle except during mitosis. **RNA polymerase** binds to the promoter, and opens the double helix. Reading the 3'→5' template strand, it synthesizes a complementary strand of **mRNA** (a RNA copy of a DNA segment; it encodes the instructions to build a protein). RNA polymerase stops transcribing the DNA and falls off when it reaches the terminator.

After the mRNA is made, it must be modified by: (1) the addition of a **methyl-G cap** added to the 5' beginning (to protect against destruction), (2) the addition of a **poly-A tail** of about 250 adenines added to the 3' end (serves as a timer regulating the lifespan of the message), and (3) **splicing**, which cuts out **introns** (interrupting sequences of DNA), leaving the **exons** (coding regions).

mRNA encodes proteins through unique combinations of the four bases in three-base groups called **codons**. There are 64 possible codons encoding 20 amino acids and 3 stops, so there is usually more than one codon per amino acid. Codons are recognized by **tRNA** molecules, which are inverted L-shaped RNA molecules that have an **anticodon** (a three-base sequence that is complementary to one of the 64 codons) at the bottom, and the corresponding amino acid bound at the top.

Translation is the process of building a protein from the mRNA; it requires the mRNA, tRNAs, ribosomes, and energy (in the form of the energy molecule GTP, which is related to ATP). Ribosomes are huge complexes that coordinate the building of the new proteins, aligning the tRNAs with the mRNA, and catalyzing the formation of peptide bonds between the different amino acids that make up the new protein. Ribosomes are composed of a protein framework draped with rRNA (ribosomal RNA); some of that rRNA serves as ribozymes that catalyze the peptide bond. Ribosomes have three grooved active sites, called the **E, P and A sites**. The mRNA binds under the three sites. The P and A sites align the growing protein with the next amino acid, delivered by a tRNA (the anticodon of the tRNA bonds with the codon in the mRNA), and catalyze the formation of the peptide bond between the last amino acid of the growing protein and the next amino acid. GTP powers the movement of the ribosome down the mRNA, moving over by one codon. The empty tRNA is now in the E site, and is ejected. The appropriate tRNA now moves into the A site, and is bound to the growing protein. This occurs until the stop codon is reached, which causes the ribosome to fall away from the mRNA. The ribosome is now available to translate other mRNAs; the original mRNA is available to be translated again; and the empty tRNAs will be recharged by enzymes.

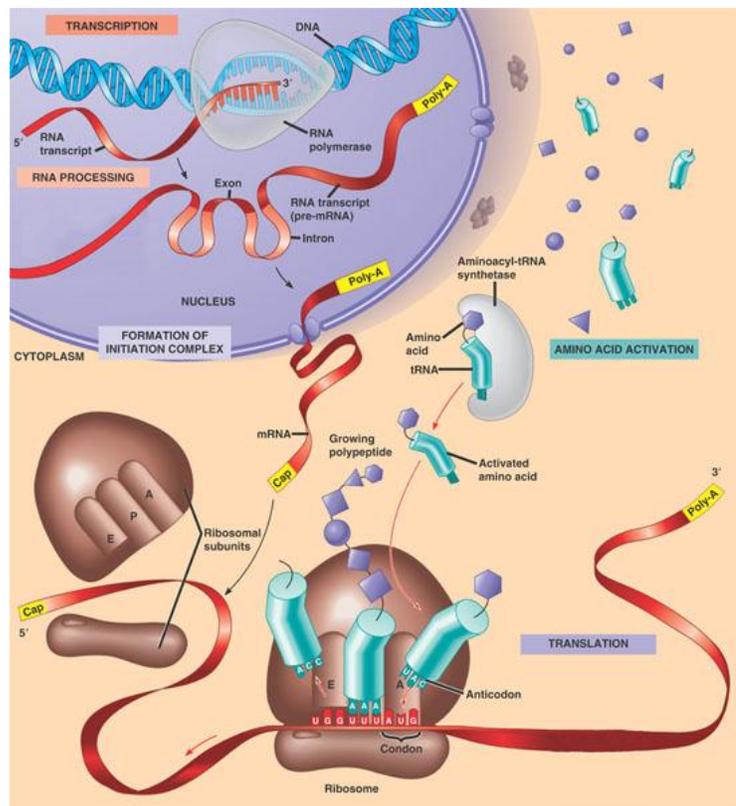


Figure 3. Overview of transcription and translation.