Protein Synthesis

CK-12 Study Guides
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Biology

Big Picture

DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) are the molecules that provide genetic directions to the cells of all organisms. Almost all organisms use DNA as their principle genetic material with the exception of certain RNA viruses. DNA contains instructions for making proteins, which determine the structure and function of the cells. RNA carries that information from DNA to the ribosomes where proteins are made. Transcription is the process of transferring genetic information from DNA to RNA, and translation is the process of using the information from RNA to create proteins.

Key Terms

Central Dogma of Molecular Biology: Doctrine that genetic instructions in DNA are copied by RNA, which carries them to a ribosome where they are used to synthesize a protein.

Protein Synthesis: Process in which cells make proteins that includes transcription of DNA and translation of mRNA.

Genetic Code: Universal code of three-base codons that encodes the genetic instructions for the amino acid sequence of proteins.

Codon: Group of three nitrogen bases in nucleic acids that makes up a code "word" of the genetic code and stands for an amino acid, start, or stop.

Transcription: Process in which genetic instructions in DNA are copied to form a complementary strand of mRNA.

RNA Polymerase: An enzyme that helps produce RNA during transcription.

Promoter Site: Region of a gene where a RNA polymerase binds to initiate transcription of the gene.

Introns: Non-coding regions of mRNA that are removed by splicing.

Extrons: Coding regions.

Translation: Process in which genetic instructions in mRNA are "read" to synthesize a protein.

Types of RNA

Messenger RNA (mRNA): Type of RNA that copies genetic instructions from DNA in the nucleus and carries them to ribosomes in the cytoplasm.

Ribosomal RNA (rRNA): Type of RNA that helps form ribosomes and assemble proteins.

Transfer RNA (tRNA): Type of RNA that brings amino acids to ribosomes where they are joined together to form proteins.

Protein Synthesis

Protein molecules play a huge role in the body, as many of our structures are made of protein. The genetic instructions in DNA is carried by RNA to the ribosomes where the proteins are made. The relationship DNA → RNA → protein is known as the **central dogma of molecular biology.**

The Genetic Code

During **protein synthesis**, the protein is built up one amino acid at a time. DNA contains the information that determines which amino acid comes next.

DNA is made up of four different nitrogen bases: adenosine (A), thymine (T), cytosine (C), and guanine (G).

These bases make up the **genetic code**. All living things have the same genetic code. Groups of three of these bases form a **codon** that stands for an amino acid or codes for a start or stop signal.

Role of RNA

DNA always stays in the nucleus, yet the actual process of protein synthesis occurs in the ribosomes of the rough endoplasmic reticulum. Instructions coding for a specific protein from the DNA are transferred to the ribosomes in the form of RNA, a small molecule that can leave the nucleus. The codons in RNA are complementary to the codons in DNA, so the thymine (T) in DNA is replaced with uracil (U) in RNA.

There are three main types of RNA:

- **messenger RNA** (mRNA): copies the genetic instructions from DNA in the nucleus and carries them to ribosomes in the cytoplasm
- **ribosomal RNA** (rRNA): helps form ribosomes
- **transfer RNA** (tRNA): brings amino acids to ribosomes

While DNA can make protein, protein cannot make DNA.

Notes

This guide was created by Cindy Lam and Jin Yu. To learn more about the student authors, http://www.ck12.org/about/ck-12-interns/.

Protein Synthesis cont.

Protein Synthesis (cont.)

Reading the Genetic Code

To figure out the amino acids that make up protein, search for the start codon (AUG).

- There is only one start codon - protein synthesis must always start from AUG.

From AUG, group three letters at a time. Use a table to find what amino acid each codon codes for.

- Continue until you reach a stop codon (UAG, UGA, and UAA).
- The start and stop codons do not code for any amino acids - they only signal for protein synthesis to begin or to stop.

1st base	2nd base: U	2nd base: C	2nd base: A	2nd base: G
U	UUU (Phe/F) Phenylalanine	UCU (Ser/S) Serine	UAU (Tyr/Y) Tyrosine	UGU (Cys/C) Cysteine
U	UUC (Phe/F) Phenylalanine	UCC (Ser/S) Serine	UAC (Tyr/Y) Tyrosine	UGC (Cys/C) Cysteine
U	UUA (Leu/L) Leucine	UCA (Ser/S) Serine	UAA Ochre (*Stop*)	UGA Opal (*Stop*)
U	UUG (Leu/L) Leucine	UCG (Ser/S) Serine	UAG Amber (*Stop*)	UGG (Trp/W) Tryptophan
C	CUU (Leu/L) Leucine	CCU (Pro/P) Proline	CAU (His/H) Histidine	CGU (Arg/R) Arginine
C	CUC (Leu/L) Leucine	CCC (Pro/P) Proline	CAC (His/H) Histidine	CGC (Arg/R) Arginine
C	CUA (Leu/L) Leucine	CCA (Pro/P) Proline	CAA (Gln/Q) Glutamine	CGA (Arg/R) Arginine
C	CUG (Leu/L) Leucine	CCG (Pro/P) Proline	CAG (Gln/Q) Glutamine	CGG (Arg/R) Arginine
A	AUU (Ile/I) Isoleucine	ACU (Thr/T) Threonine	AAU (Asn/N) Asparagine	AGU (Ser/S) Serine
A	AUC (Ile/I) Isoleucine	ACC (Thr/T) Threonine	AAC (Asn/N) Asparagine	AGC (Ser/S) Serine
A	AUA (Ile/I) Isoleucine	ACA (Thr/T) Threonine	AAA (Lys/K) Lysine	AGA (Arg/R) Arginine
A	AUG[A] (Met/M) Methionine	ACG (Thr/T) Threonine	AAG (Lys/K) Lysine	AGG (Arg/R) Arginine
G	GUU (Val/V) Valine	GCU (Ala/A) Alanine	GAU (Asp/D) Aspartic acid	GGU (Gly/G) Glycine
G	GUC (Val/V) Valine	GCC (Ala/A) Alanine	GAC (Asp/D) Aspartic acid	GGC (Gly/G) Glycine
G	GUA (Val/V) Valine	GCA (Ala/A) Alanine	GAA (Glu/E) Glutamic acid	GGA (Gly/G) Glycine
G	GUG (Val/V) Valine	GCG (Ala/A) Alanine	GAG (Glu/E) Glutamic acid	GGG (Gly/G) Glycine

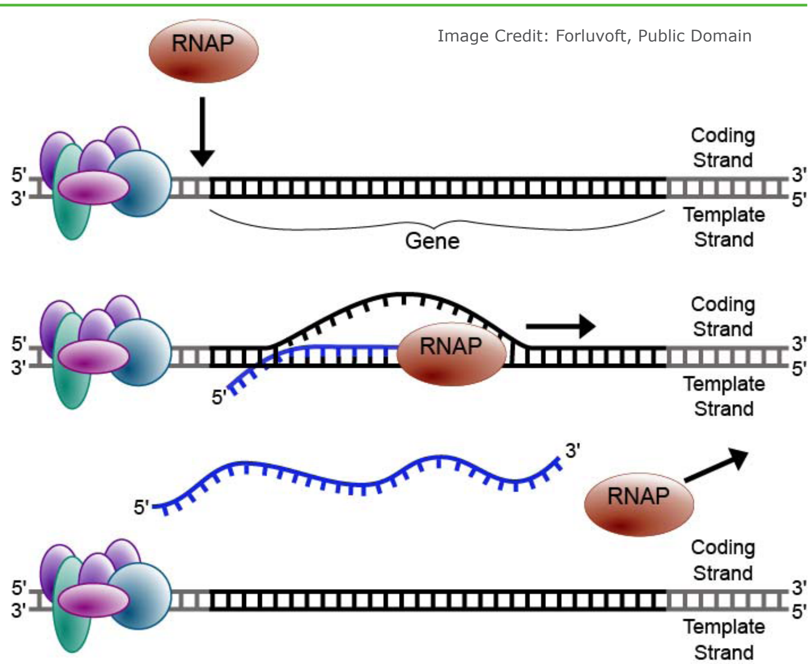
nonpolar	polar	basic	acidic	(stop codon)

You can see in the table that the genetic code is redundant. There are 64 possible codons, yet proteins contain only 20 amino acids.

Transcription

Transcription, the processing of making mRNA complementary to the DNA template, is broken down into 3 steps:

1. Initiation: An enzyme called **RNA polymerase** binds to the end of a coding region called the **promoter**. The DNA unwinds its double helix structure.
2. Elongation: After unwinding, RNA polymerase adds the complementary nucleotides to the new, budding mRNA strand.
3. Termination: The completed pre-mRNA strand detaches from the DNA strand.



Protein Synthesis cont.

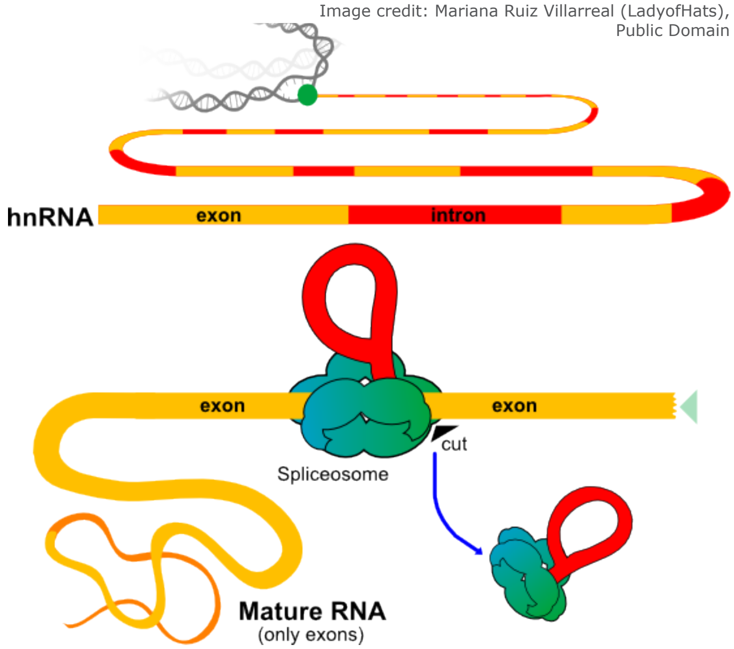
Processing mRNA

Before the pre-mRNA (also known as the hnRNA) strand can exit the nucleus, it must be modified.

These modifications include splicing, which removes **introns** from the pre-mRNA with spliceosomes.

The finished, mature mRNA then proceeds to translation.

Image credit: Mariana Ruiz Villarreal (LadyofHats), Public Domain

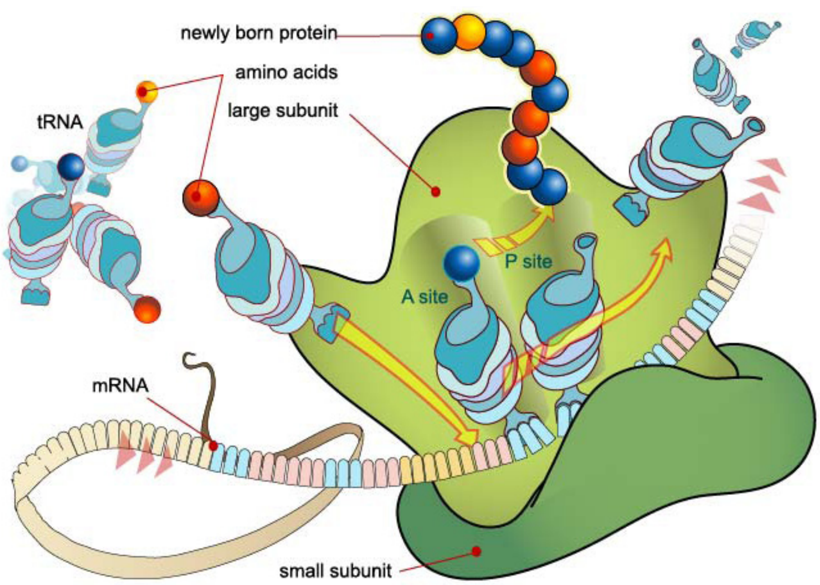


Translation

After leaving the nucleus, the strand of mRNA moves to a ribosome.

There, **translation** involves two different RNA molecules: mRNA (from transcription) and tRNA.

mRNA can be thought of as a guide or organizer, while the tRNA are the workers with the materials. tRNA carries anticodon complementary to the codon on mRNA. Whenever the anticodon on tRNA binds to the codon on mRNA, tRNA gives up its amino acid. The ribosome continues to build the protein until it reaches a stop codon.



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Common Misconceptions

- After transcription and before RNA processing, mRNA is called the pre-mRNA. This might be mislead you to think that RNA processing turns this pre-mRNA into mRNA. However, even before RNA processing, pre-mRNA is still a messenger RNA.
- RNA polymerase creates one RNA strand from only one of the two DNA strands at a time.