

Protein Synthesis

The body requires many complicated proteins that are used as the structures of all cells, as well making up many of the body's organelles. Some of the most important proteins the body must make are **ENZYMES**. Enzymes are catalysts for all reactions - without them, none of the thousands of chemical reactions that body must perform could be carried out.

The DNA acts as a giant recipe book for all these proteins. The DNA molecules are too big to leave the nucleus, but all the assembling of proteins is all done in the cytoplasm, outside the nucleus.

How can DNA direct the making of protein? WITH THE HELP OF RNA!

RNA versus DNA

RNA is similar to DNA chemically, but with three important differences:

1. The five carbon sugar that forms the backbone is **ribose**, not deoxyribose.
2. There is no thymine (T) in RNA - it is replaced with uracil (U)
3. RNA is a **single** helix, not a double

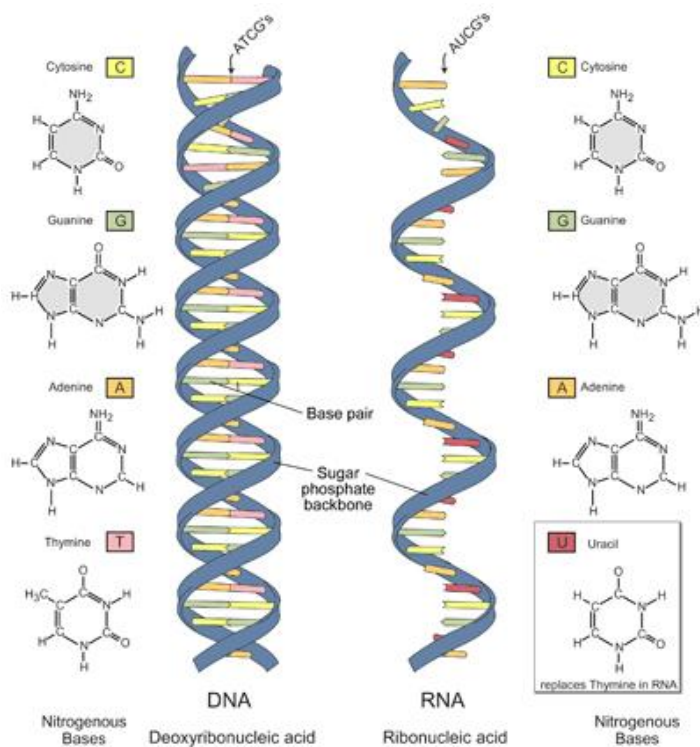


Image adapted from: National Human Genome Research Institute.

There are three different types of RNA, and each is involved in a different part of protein synthesis:

1. Messenger RNA (mRNA)

- made up of thousands of nucleotides
- transcribes the complement of DNA

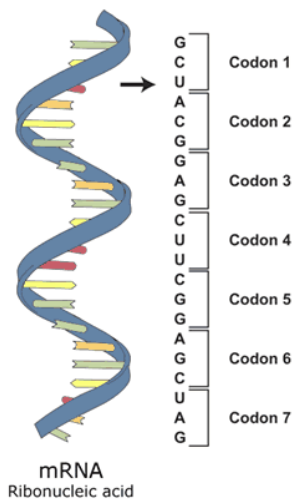
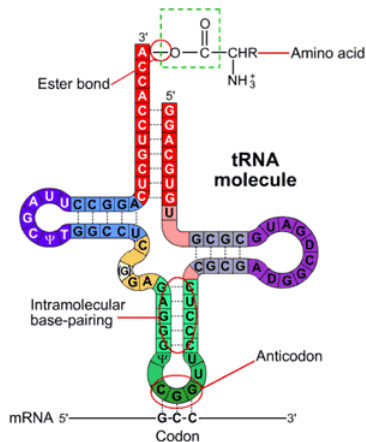


Image adapted from: National Human Genome Research Institute. Talking Glossary of Genetic Terms. Available at: www.genome.gov/Pages/Hyperion/DIR/VIP/Glossary/Illustration/codon.shtml.

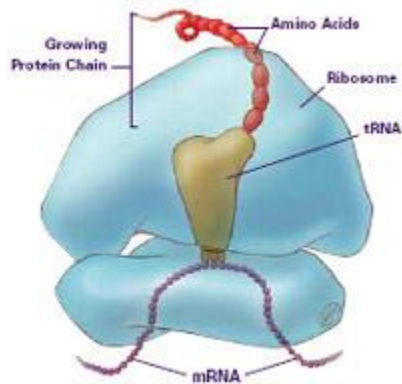
2. Transfer RNA (tRNA)

- about 80 nucleotides long
- Has an anticodon of three bases on bottom part
- has a shape to carry a specific amino acid on top
- a particular anticodon matches up with a codon on the mRNA



3. Ribosomal RNA (rRNA)

- formed in the nucleolus
- makes ribosomes
- ribosomes are the location of protein synthesis in the cytoplasm



THE STEPS OF PROTEIN SYNTHESIS

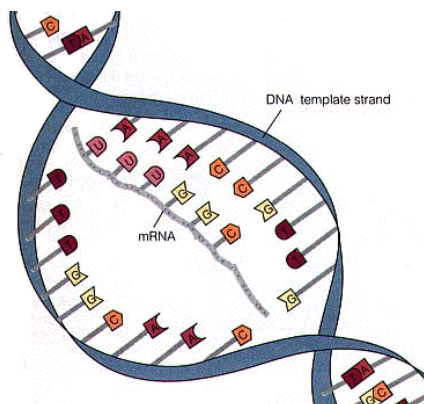
Protein synthesis involves two major processes :

1. **TRANSCRIPTION** - the copying of the DNA strand's genetic message (recipe) onto a molecule of mRNA
2. **TRANSLATION** - taking the code now on the mRNA, feeding it through a ribosome and assembling a protein molecule with the help of the tRNA

TRANSCRIPTION STEPS

The purpose of transcription is to copy down the 'recipe' because you can't take the 'cookbook' (DNA) out of the nucleus. All of **transcription happens in the nucleus.**

- ▶ DNA strands separate briefly
- ▶ complementary RNA nucleotides match up with the correct bases on the DNA - this part is like replication only with RNA nucleotides instead of DNA nucleotides
- ▶ this keeps going until it hits a STOP code on the DNA, enzymes join it together and it leaves the DNA strand
- ▶ DNA goes back to double helix



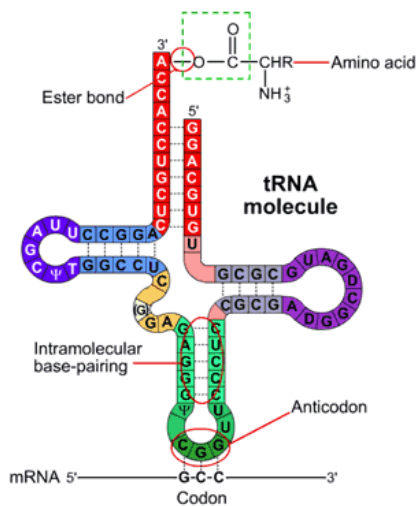
Now the mRNA has the message - BUT IN OPPOSITE BASES. Each group of **three bases is called a codon**. Each codon specifies a particular amino acid. The correct amino acids are linked together in the correct order, according to the 'recipe' by next process – TRANSLATION. All of these amino acids that will become linked to form a protein, are found in the cytoplasm, along with the ribosomes needed to link them together, so **translation happens in the cytoplasm**.

TRANSLATION STEPS

The next step is to take the recipe, which is written in mirror image, and use the tRNA to assemble the correct protein in the ribosomes.

tRNA has an odd shape

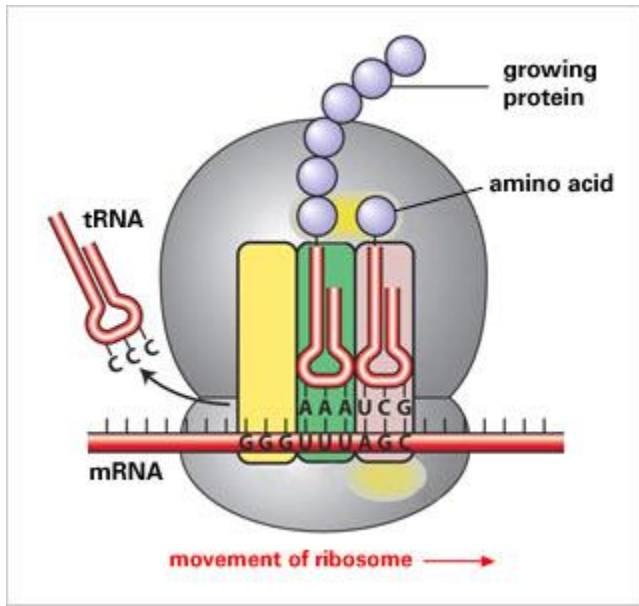
- At one end is a tail that can pick up a specific amino acid and carry it along to the ribosome
- At the other end of the tRNA is an anticodon that is the opposite 3 bases to a section of mRNA



Note how the anticodon of the tRNA matches with the codon of mRNA!

Here's how it all works:

- Once the mRNA has the "reverse" recipe, it leaves the nucleus and goes into the cytoplasm
- Each tRNA picks up the specific amino acid it can carry
- Ribosomes attach to different points along the mRNA
- The tRNA with the correct anticodon and corresponding amino acid matches up with the mRNA inside a ribosome
- The tRNA moves off, picks up another amino acid to position in another part of the mRNA
- The ribosome moves to the next codon on the mRNA, another tRNA brings the correct amino acid in place
- The amino acid that was brought to that position is linked to the previous amino acid, forming a **peptide bond**
- This process continues until a STOP codon is detected and the new polypeptide or protein is made
- All these steps are carried out with the original instructions (recipe) in the nucleus within the DNA in the chromosomes.



Typical types of protein synthesis public exam questions:

Quite often the following chart is used. This chart shows what codons in the mRNA actually stand for. There are 19 different amino acids and START and STOP codons. Use the chart to answer questions like the ones that follow it. These are all taken from previous exams.

		Second letter				
		U	C	A	G	
First letter	U	UUU Phenyl-alanine UUC UUA Leucine UUG	UCU Serine UCC UCA UCG	UAU Tyrosine UAC UAA Stop codon UAG Stop codon	UGU Cysteine UGC UGA Stop codon UGG Tryptophan	U C A G
	C	CUU Leucine CUC CUA CUG	CCU Proline CCC CCA CCG	CAU Histidine CAC CAA Glutamine CAG	CGU Arginine CGC CGA CGG	U C A G
	A	AUU Isoleucine AUC AUA AUG Methionine; initiation codon	ACU Threonine ACC ACA ACG	AAU Asparagine AAC AAA Lysine AAG	AGU Serine AGC AGA Arginine AGG	U C A G
	G	GUU Valine GUC GUA GUG	GCU Alanine GCC GCA GCG	GAU Aspartic acid GAC GAA Glutamic acid GAG	GGU Glycine GGC GGA GGG	U C A G

Using the codon table above, which DNA sequence was used as a template to produce the polypeptide sequence glycine - isoleucine - phenylalanine?

- (A) CCC TAG AAC
- (B) CCG TAA AAG
- (C) GGA TAC AAT
- (D) GGC TAT AAA

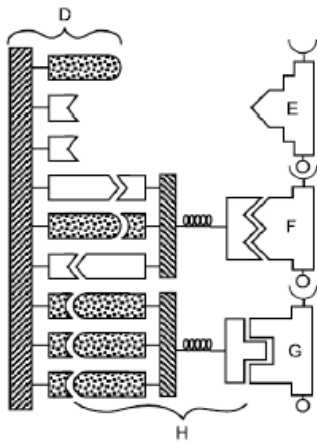
Using the mRNA codon table above, which is the amino acid sequence produced by tRNA molecules with anticodons 3' CAG UUC AUU 5' arriving in that order?

- (A) valine - asparagine - glycine
- (B) valine - asparagine - tyrosine
- (C) valine - lysine - stop
- (D) valine - lysine - tyrosine

Using the RNA codon table above, which new amino acid is produced when the original RNA strand, GUG ACU UCG, becomes the mutated RNA strand, GUG AUU UCG?

- (A) alanine
- (B) isoleucine
- (C) leucine
- (D) threonine

Other types of protein synthesis questions:



Which molecule acts as a template for the production of structure D?

- (A) amino acids
- (B) dipeptides
- (C) DNA
- (D) RNA

What type of structure would be partially formed by molecules E, F and G?

- (A) DNA
- (B) polypeptide
- (C) polysaccharide
- (D) RNA

