

Translation Study Guide

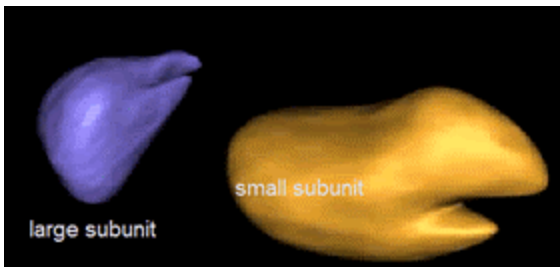
This study guide is a written version of the material you have seen presented in the replication unit.

In translation, the cell uses the genetic information contained in mRNA to make the proteins that carry out the cell's work. The cell translates the code contained in the mRNA into a new language, the language of proteins, based on amino acids. Other types of RNA, such as transfer RNA (tRNA) also assist in the protein-assembly process.

Components

In this section, you will be introduced to the components involved in the process of protein synthesis, called translation. This process requires a protein/RNA complex called the ribosome and several other components to read the mRNA and produce a new protein.

Ribosome

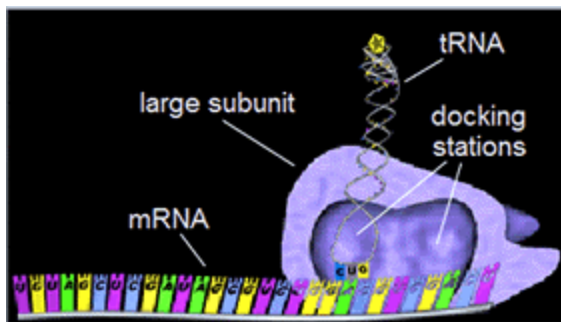


What is a ribosome?

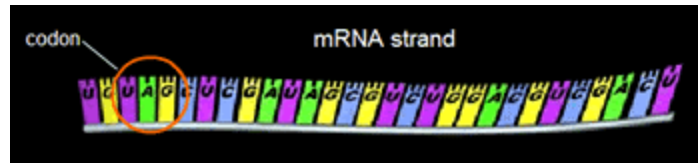
- A ribosome is a molecular machine that coordinates protein assembly.
- Ribosomes are composed of several proteins with tightly coiled RNA (called ribosomal RNA or rRNA) wrapped around them.
- Ribosomes consist of two parts, the large and small subunits, which clamp around the mRNA that needs to be translated.

What is a ribosome's role in translation?

- A ribosome brings together correctly the mRNA, which needs to be translated, and the tRNA, which assists in the translation process, to come together correctly.
- During translation, tRNA molecules carrying amino acids are positioned in the ribosome's two docking sites.
- Afterwards, this machinery can disassemble and be reused many times.
- In the upcoming animation, you will see a ribosome assembling a polypeptide chain, a future protein.



Codons



What is a codon?

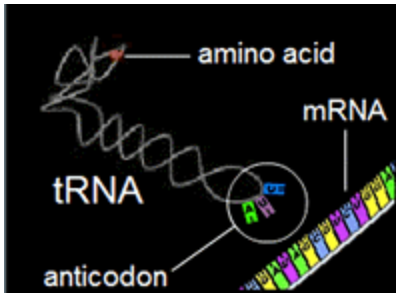
- A codon is a sequence of three nucleotides on an mRNA strand that encodes a specific amino acid.
- The mRNA sequence, in turn, is derived from the cell's DNA.

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

Which codons correspond to which amino acids?

- This chart shows the correspondence between codons and amino acids.
- This code has been deciphered. By knowing a DNA sequence, it is possible to determine the sequence of amino acids in the polypeptide chain for which the DNA codes.
- Sixty-four different three nucleotide combinations (codons) can be made using the four nucleotides in mRNA ($4^3 = 64$ combinations).
- Three codons are called stop codons, which tell the cell to stop translating the mRNA and do not encode an amino acid.
- The code is redundant. For most amino acids, multiple codons exist, each of which could code for that amino acid.

Transfer RNA (tRNA)



What is tRNA?

- tRNA is a type of RNA that is folded into a specific three-dimensional structure. It carries and transfers an amino acid to the polypeptide chain that the ribosome is assembling.
- One end of the tRNA contains an anticodon, a sequence of three nucleotides that is complementary to the three nucleotides in the corresponding codon on the mRNA. Each anticodon is specific to one and only one codon.
- By binding its anticodon to the complementary mRNA codon, the tRNA acts as an adapter, bringing into position the correct amino acid that is needed for the polypeptide chain.
- Each cell makes 61 different tRNAs, one for each functional codon in the genetic code.

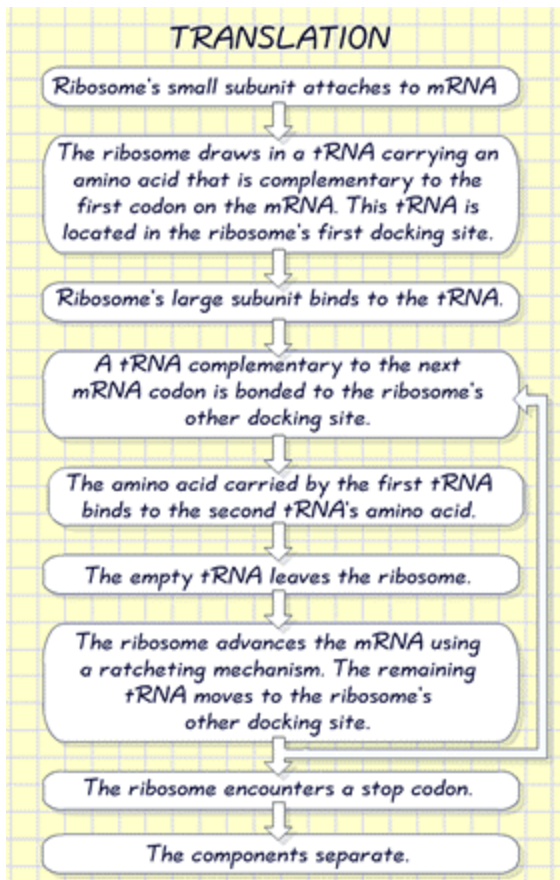
How does tRNA bind to codons in the mRNA?

- The complementary bases on the codon and anticodon are held together by hydrogen bonds, the same type of bonds that hold together the nucleotides in DNA.
- The ribosome only allows the tRNA to bind to the mRNA if it is carrying an amino acid. Once the amino acid is added to the polypeptide chain, the binding is no longer favored.

How does the code in DNA get converted into a specific amino acid sequence in the polypeptide?

- Nucleotides in the DNA specify the nucleotides in the mRNA.
- Nucleotides in the mRNA are read 3 at a time (as codons) by the ribosome.
- Each codon specifies a particular amino acid in the growing polypeptide chain.
- That codon matches only the anticodon of the tRNA carrying the particular amino acid specified by the codon.
- The ribosome facilitates the binding of the tRNA to the codon. The tRNA carries the correct amino acid, which is added to the polypeptide chain in the correct position.
- In the animation for this unit, you will see tRNA carrying and transferring amino acids to assemble a polypeptide chain.

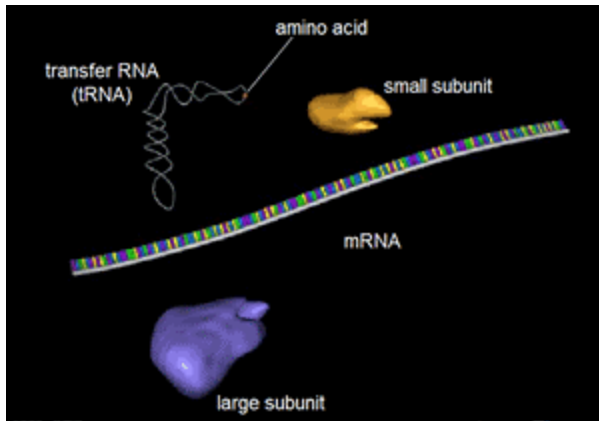
Process Flow Chart



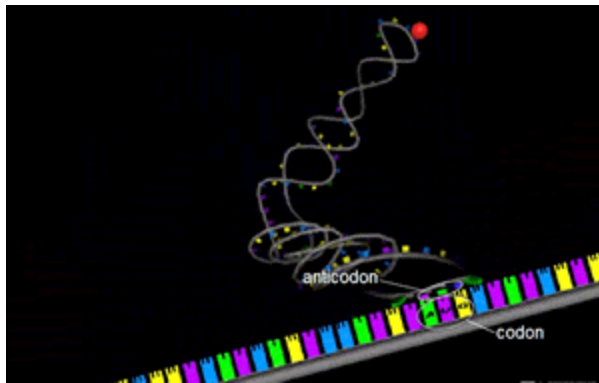
Animation script

In translation, the cell uses an mRNA strand that it has just transcribed from its genetic code as a template to assemble proteins. The cell has just transcribed this mRNA strand from its DNA, and it now translates the mRNA's nucleotide sequence into a chain of amino acids. This chain, called a polypeptide, forms the basic structure of a protein.

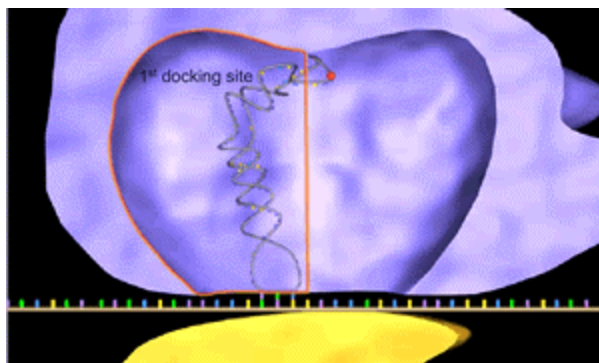
A cellular component called a ribosome coordinates the translation process. A ribosome is a molecular machine that synthesizes proteins in the cell. It consists of two main parts, a large and small subunit.



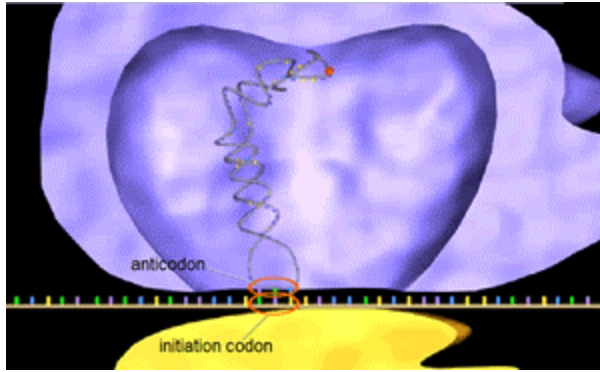
The ribosome brings together the mRNA to be translated and a set of molecules called transfer RNAs, or tRNAs, which are floating in the cell. tRNAs are adapter molecules that coordinate between the mRNA and the polypeptide chain that the cell needs to build. Each tRNA is designed to carry a specific amino acid that it can add to a polypeptide chain.



tRNAs bring their amino acids to the mRNA in a specific order. This order is determined by the attraction between a codon, a sequence of three nucleotides on the mRNA, and a complementary nucleotide triplet on the tRNA, called an anticodon. This anticodon also specifies the particular amino acid that the tRNA carries. Only the tRNA carrying the next amino acid in the polypeptide chain has the anticodon that binds to the appropriate location on the mRNA. This system ensures that amino acids are added to the chain in the correct order.

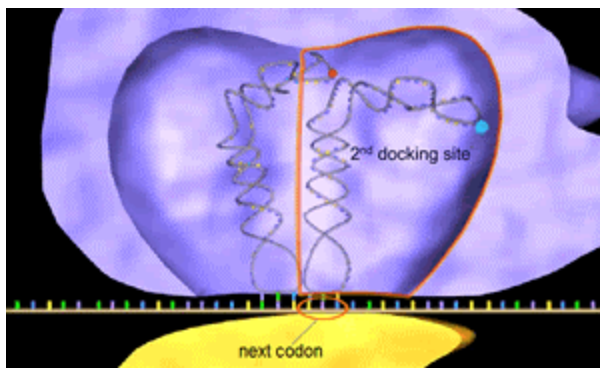


At the beginning of translation, the ribosome and a tRNA attach to the mRNA. The tRNA is located in the ribosome's first docking site.

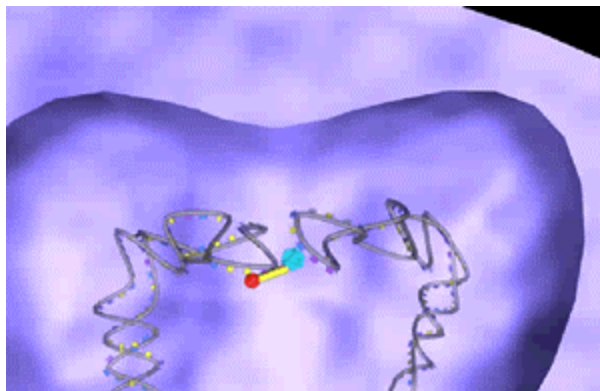


This tRNA's anticodon is complementary to the mRNA's initiation codon, where translation starts.

The tRNA carries the amino acid that corresponds to that codon.

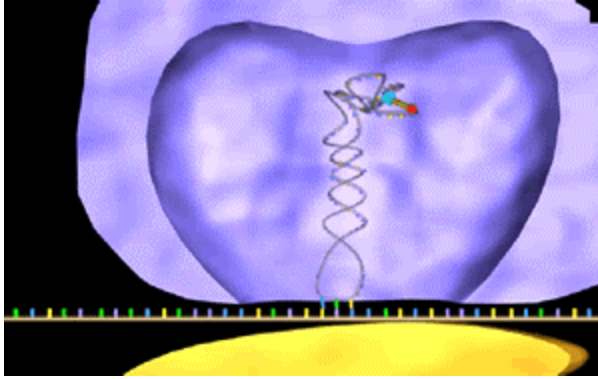


The next mRNA codon is now exposed in the ribosome's other docking site. A tRNA with the complementary anticodon is attracted to the ribosome and binds to this codon. The tRNA carries the next amino acid in the polypeptide chain.

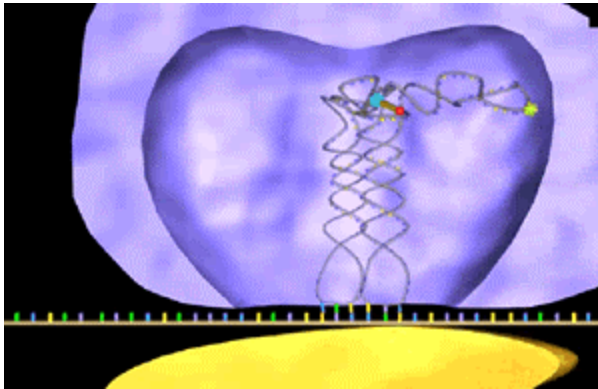


The first tRNA transfers its amino acid to the amino acid on the newly arrived tRNA, and a chemical bond is made between the two amino acids.

The tRNA that has given up its amino acid is released. It can then bind to another molecule of the amino acid and be used again later in the protein-making process.

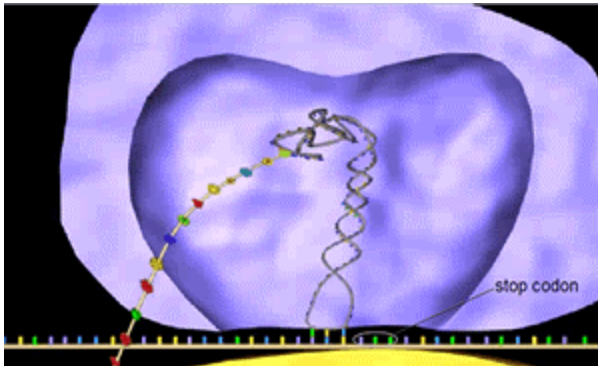


Using a ratcheting mechanism, the ribosome advances the mRNA, three nucleotides at a time. The ribosome also shifts the tRNA carrying the polypeptide chain into its recently vacated docking site.

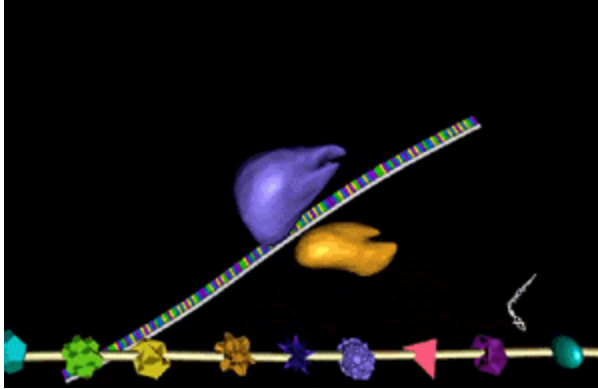


A tRNA whose anticodon is complementary to this next mRNA codon is attracted to the ribosome and the mRNA.

Once again, the polypeptide chain is transferred to the new tRNA, the empty tRNA is released, and the ribosome ratchets through the mRNA another three nucleotides, simultaneously shifting the tRNA as well. As this process continues, the polypeptide chain grows longer.



Translation continues until the ribosome encounters a stop codon in the mRNA. This nucleotide triplet signals that the polypeptide chain is complete.



The stop codon causes all the components of translation to separate. The ribosome can disassemble and be used again. The mRNA is discarded by being degraded back into its building blocks, the nucleotides. New mRNA can be synthesized via transcription when more of that protein is needed.

The cell has now successfully translated one of its genes into a polypeptide chain, the raw material of a protein. This chain will be further processed and folded into a protein. Every protein-encoding gene in the cell is transcribed and translated in this manner so that the cell can create the thousands of proteins that it needs to carry out all of its essential functions.



Translation, then, is one stage in the process in which the cell's genetic information is used to create proteins. The cell's DNA is first transcribed in a temporary copy (mRNA), which is then translated into the amino acid sequence of a protein.

Glossary of terms

amino acids – twenty molecules that are the building blocks of proteins. String of amino acids make up protein's primary structure.

anticodon – a sequence of three nucleotides on a tRNA molecule that bond to a complementary sequence on an mRNA molecule. The anticodon sequence determines the amino acid that the tRNA carries.

codon – a sequence of three nucleotides on a mRNA molecule that encode a specific amino acid

complementary - matching, such as between pairs of nucleotides in a DNA molecule

DNA - the molecule that stores and encodes an organism's genetic information. DNA is a double helix molecule made up of two twisted strands that are held together by hydrogen bonds between paired nucleotides. The two strands are chemically oriented in opposite directions.

enzyme - a type of protein that performs cellular activities

hydrogen bond - a weak bond that holds together complementary base pairs in a DNA molecule

messenger RNA (mRNA) – a type of RNA that conveys genetic instructions on how to assemble proteins from the cell's DNA to its protein-making machinery. mRNA contains a copy of one or a few genes from a cell's chromosome.

nucleotides - the building blocks of DNA and RNA molecules that contain the cell's genetic code. Adenosine, cytidine, guanosine, thymidine, and uridine are all nucleotides.

polypeptide chain – the long chain of amino acids that is created during translation. A polypeptide chain becomes a protein when it folds into its final functional shape.

protein - a molecular machine that carries out vital tasks in the cell, such as providing structural support, processing nutrients, copying a cell's DNA, and regulating other cellular functions. Proteins are made of long chains of amino acids that fold into complex three-dimensional shapes. Each type protein has a unique amino acid sequence and a specific function in the cell.

replication – the process in which a cell's DNA is copied prior to cellular reproduction

ribosomal RNA (rRNA) – a type of RNA that assists in the protein-making process. rRNA is found in the cell's ribosomes.

ribosome – a molecular machine that coordinates protein assembly. A ribosome consists of two parts, a large and small subunit, which clamp around an mRNA molecule that needs to be translated. A ribosome is composed of several proteins with tightly coiled rRNA wrapped around them.

RNA – a polymer made of a single strand of nucleotides. RNA contains the same nucleotides as DNA, with the substitution of uridine for thymidine.

stop codon – a three-nucleotide sequence that signals the cell to end protein synthesis during translation

transcription – the process in which a cell's DNA is copied into messenger RNA, which is then read by the cell's protein-making machinery. Transcription is a major step in the transfer of information in biology. **Transcribe** is the verb associated with transcription.

transfer RNA (tRNA) – a type of RNA that is folded into a three-dimensional structure. tRNA carries and transfers an amino acid to the polypeptide chain being assembled during translation.

translation – the process in which a cell converts genetic information carried in an mRNA molecule into a protein. Translation is a major step in the transfer of information in biology. In this case, **translate** is the verb associated with translation.