

## Topic 2 Molecular Biology

### Topic 2.7 DNA Replication, Transcription and Translation

**Essential idea:** Genetic information in DNA can be accurately copied and can be translated to make the proteins needed by the cell.

### Understandings:

- 2.7.U4 Transcription is the synthesis of mRNA copied from the DNA base sequences by RNA polymerase.
- 2.7.U5 Translation is the synthesis of polypeptides on ribosomes.
- 2.7.U6 The amino acid sequence of polypeptides is determined by mRNA according to the genetic code.
- 2.7.U7 Codons of three bases on mRNA correspond to one amino acid in a polypeptide.
- 2.7.U8 Translation depends on complementary base pairing between codons on mRNA and anticodons on tRNA.

### Applications and Skills:

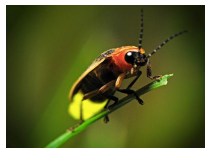
- 2.7.S1 Use a table of the genetic code to deduce which codon(s) corresponds to which amino acid.
- 2.7.S3 Use a table of mRNA codons and their corresponding amino acids to deduce the sequence of amino acids coded by a short mRNA strand of known base sequence.
- 2.7.S4 Deducing the DNA base sequence for the mRNA strand.

## I. Transcription and Translation

Q - What is the purpose of transcription and translation?

A - These processes work together to create a polypeptide which in turns folds to become a protein. Proteins carry many essential functions in cells. For more detail review 2.4.U7 *Living organisms synthesize many different proteins with a wide range of functions.*

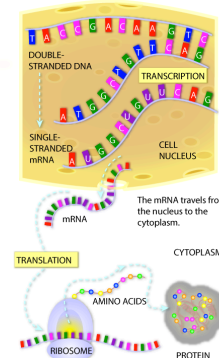
Catalysis	Tensile strengthening	Transport of nutrients and gases	Cell adhesion
Muscle contraction			Hormones
Cytoskeletons			Receptors
Blood clotting			Packing of DNA
Membrane transport			Immunity



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## I. Transcription and Translation

**TRANSCRIPTION:** In the nucleus, the cell's machinery copies the gene sequence into messenger RNA (mRNA), a molecule that is similar to DNA. Like DNA, mRNA has four nucleotide bases - but in mRNA, the base uracil (U) replaces thymine (T).



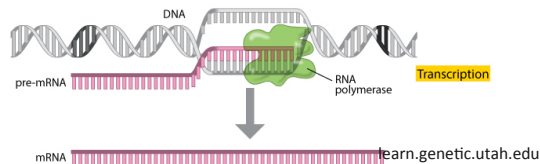
**TRANSLATION:** The protein-making machinery, called the ribosome, reads the mRNA sequence and translates it into the amino acid sequence of the protein. The ribosome starts at the sequence AUG, then reads three nucleotides at a time. Each three-nucleotide codon specifies a particular amino acid. The "stop" codons (UAA, UAG and UGA) tell the ribosome that the protein is complete.

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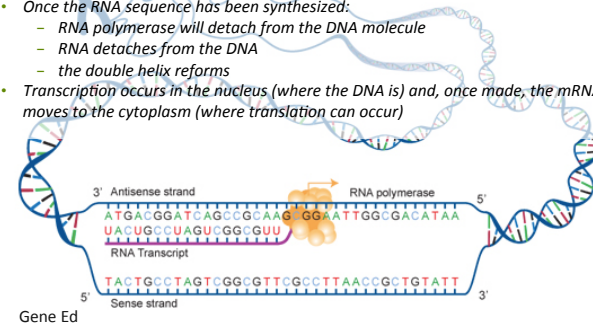
## I. Transcription and Translation

### A. Transcription is the synthesis of mRNA copied from the DNA base sequences by RNA polymerase-

1. Transcription is the process by which an RNA sequence is produced from a DNA template:
2. Three main types of RNA are predominantly synthesized:
  - a. Messenger RNA (mRNA): A transcript copy of a gene used to encode a polypeptide
  - b. Transfer RNA (tRNA): A clover leaf shaped sequence that carries an amino acid
  - c. Ribosomal RNA (rRNA): A primary component of ribosomes



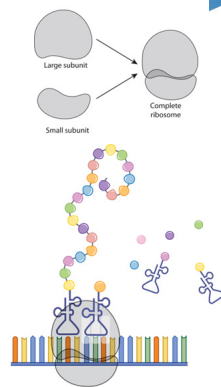
- The enzyme RNA polymerase binds to a site on the DNA at the start of a gene (The sequence of DNA that is transcribed into RNA is called a gene).
- RNA polymerase separates the DNA strands and synthesizes a complementary RNA copy from the antisense DNA strand
- It does this by covalently bonding ribonucleoside triphosphates that align opposite their exposed complementary partner (using the energy from the cleavage of the additional phosphate groups to join them together)
- Once the RNA sequence has been synthesized:
  - RNA polymerase will detach from the DNA molecule
  - RNA detaches from the DNA
  - the double helix reforms
- Transcription occurs in the nucleus (where the DNA is) and, once made, the mRNA moves to the cytoplasm (where translation can occur)



## I. Transcription and Translation

### B. Translation is the synthesis of polypeptides on ribosome-

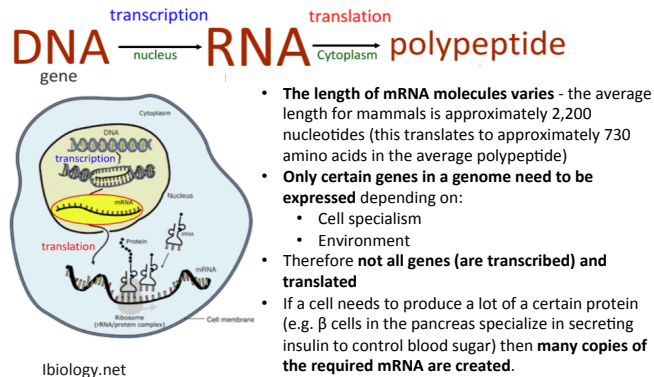
1. Translation is the process of protein synthesis in which the genetic information encoded in mRNA is translated into a sequence of amino acids in a polypeptide chain
  - a. A ribosome is composed of two halves, a large and a small subunit. During translation, ribosomal subunits assemble together like a sandwich on the strand of mRNA:
    1. Each subunit is composed of RNA molecules and proteins
    2. The small subunit binds to the mRNA
    3. The large subunit has binding sites for tRNAs and also catalyzes peptide bonds between amino acids



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## II. Messenger RNA and the Genetic Code-

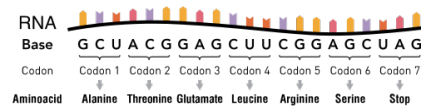
**Messenger RNA (mRNA):** A transcript copy of a gene used to encode a polypeptide



## III. Codons

A. Codons of three bases on mRNA correspond to one amino acid in a polypeptide-

- The genetic code is the set of rules by which information encoded in mRNA sequences is converted into proteins (amino acid sequences) by living cells
  - Codons are a triplet of bases which encodes a particular amino acid
  - As there are four bases, there are 64 different codon combinations ( $4 \times 4 \times 4 = 64$ )
  - The codons can translate for 20 amino acids



		Second letter			
First letter	U	C	A	G	
	UUU Phe UUC Phe UUA Leu UUG Leu	UCU Ser UCC Ser UCA Ser UCG Ser	UAU Tyr UAC Tyr UAA STOP UAG STOP	UGU Cys UGC Cys UGA STOP UGG Trp	
C	CUU Leu CUC Leu CUA Leu CUG Leu	CCU Pro CCC Pro CCA Pro CCG Pro	CAU His CAC His CAA His CAG His	CGU Arg CGC Arg CGA Arg CGG Arg	
A	AUU Ile AUC Ile AUA Ile AUG Met	ACU Thr ACC Thr ACA Thr ACG Thr	AAU Asn AAC Asn AAA Lys AAG Lys	AAG Lys AAA Lys AAA Lys AAA Lys	
G	GUU Val GUC Val GUA Val GUG Val	GCU Ala GCC Ala GCA Ala GCG Ala	GAA Glu GAG Glu GAA Glu GAG Glu	GAU Asp GAC Asp GAA Asp GAG Asp	

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## III. Codons

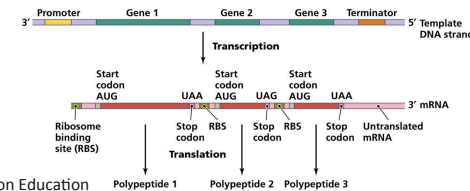
		Second letter				Third letter
First letter	U	C	A	G		
	UUU Phe UUC Phe UUA Leu UUG Leu	UCU Ser UCC Ser UCA Ser UCG Ser	UAU Tyr UAC Tyr UAA STOP UAG STOP	UGU Cys UGC Cys UGA STOP UGG Trp		U C A G
C	CUU Leu CUC Leu CUA Leu CUG Leu	CCU Pro CCC Pro CCA Pro CCG Pro	CAU His CAC His CAA His CAG His	CGU Arg CGC Arg CGA Arg CGG Arg		U C A G
A	AUU Ile AUC Ile AUA Ile AUG Met	ACU Thr ACC Thr ACA Thr ACG Thr	AAU Asn AAC Asn AAA Lys AAG Lys	AGU Ser AGC Ser AGA Ser AGG Ser		U C A G
G	GUU Val GUC Val GUA Val GUG Val	GCU Ala GCC Ala GCA Ala GCG Ala	GAU Asp GAC Asp GAA Glu GAG Glu	GGT Gly GGC Gly GGA Gly GGG Gly		U C A G

**Key:**

Ala = Alanine (A)  
Arg = Arginine (R)  
Asn = Asparagine (N)  
Asp = Aspartate (D)  
Cys = Cysteine (C)  
Gln = Glutamine (Q)  
Glu = Glutamate (E)  
Gly = Glycine (G)  
His = Histidine (H)  
Ile = Isoleucine (I)  
Leu = Leucine (L)  
Lys = Lysine (K)  
Met = Methionine (M)  
Phe = Phenylalanine (F)  
Pro = Proline (P)  
Ser = Serine (S)  
Thr = Threonine (T)  
Trp = Tryptophan (W)  
Tyr = Tyrosine (Y)  
Val = Valine (V)

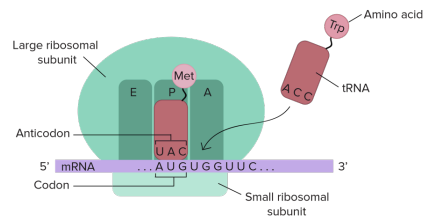
## III. Codons

- Different codons can translate for the same amino acid (e.g. GAU and GAC both translate for Aspartate) therefore the genetic code is said to be degenerate
- The order of the codons determines the amino acid sequence for a protein
- The coding region always starts with a **START codon (AUG)** therefore the first amino acid in all polypeptides is Methionine
- The coding region of mRNA terminates with a **STOP codon** - the STOP codon does not add an amino acid - instead it causes the release of the polypeptide



## IV. Codons and Anticodons

- A. Translation depends on complementary base pairing between codons on mRNA and anticodons on tRNA-
1. Amino acids are carried by **transfer RNA (tRNA)**
  2. The anti-codons on tRNA are complementary to the codons on mRNA



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## IV. Codons and Anticodons

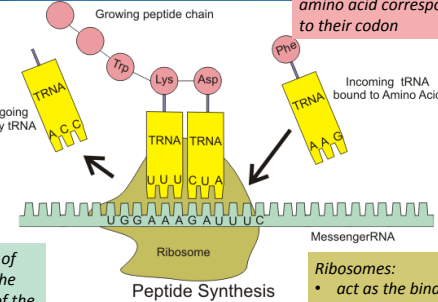
tRNA molecules have an anticodon of three bases that binds to a complementary codon on mRNA

tRNA molecules carry the amino acid corresponding to their codon

Key components of translation that enable genetic code to synthesize polypeptides

mRNA has a sequence of codons that specifies the amino acid sequence of the polypeptide

Ribosomes:  
• act as the binding site for mRNA and tRNA  
• catalyze the peptide bonds of the polypeptide



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## IV. Codons and Anticodons

The large subunit binds to the small subunit of the ribosome. There are three binding sites on the large subunit of the ribosome, but only two can contain tRNA molecules at a time

Growing peptide chain

Phe

Trp

Lys

Asp

4

TRNA

TRNA

U U U

C U A

U G G A A A G A U U C

Ribosome

MessengerRNA

Peptide Synthesis

The mRNA contains a series of codons (3 bases) each of which codes for an amino acid.

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An outline of translation and polypeptide synthesis

mRNA binds to the small subunit of the ribosome.

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## IV. Codons and Anticodons

A peptide bond is formed between the two amino acids (carried by the tRNAs)

tRNAs with anticodons complementary to the codons bind (the bases are linked by the formation of hydrogen bonds)

Growing peptide chain

Phe

Trp

Lys

Asp

7

TRNA

TRNA

U U U

C U A

U G G A A A G A U U C

Ribosome

MessengerRNA

Peptide Synthesis

The ribosome moves along the mRNA and presents codons in the first two binding sites

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