Tutorial 26: Replication, Transcription and Translation

Goals:

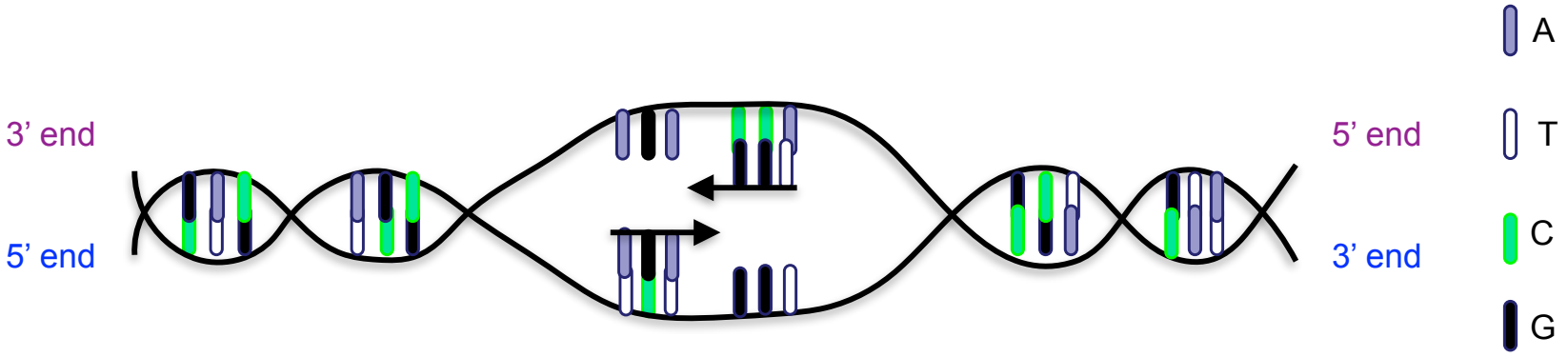
- ✓ To look at a brief overview of the flow of genetic information in replication, transcription and translation.
- ✓ To be able to describe how DNA replicates.
- ✓ To be able to describe how RNA is synthesized from DNA (transcription).
- ✓ To be able to describe the process of protein synthesis (translation).
- ✓ To understand the roles of mRNA, rRNA and tRNA in protein synthesis.
- ✓ To be able to read the genetic code.
- ✓ To understand how mutations in DNA can lead to genetic diseases.

Replication

"It has not escaped out notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material."

-Watson and Crick, Nature 1953

- **Replication** is the process in which the entire genetic code of a DNA double helix is copied into two new DNA double helices.
  (1) The two complementary strands of DNA are separated via helicase enzymes.
  (2) The two separated strands each provide a template from which the other strand can be synthesized.
  (3) Free nucleotides form hydrogen bonds to the separated strands (A to T and C to G), and the DNA polymerase enzymes catalyze the reaction between the 5'-phosphate of the free nucleotide and the 3'- hydroxyl of the growing DNA strand.
  (4) Each strand is read in the 3' to 5' direction, and each new strand is replicated anti-parallel in the 5' to 3' direction via DNA polymerase enzymes.
  (5) The result is two new DNA double helices that will go into the nuclei of two new cells.

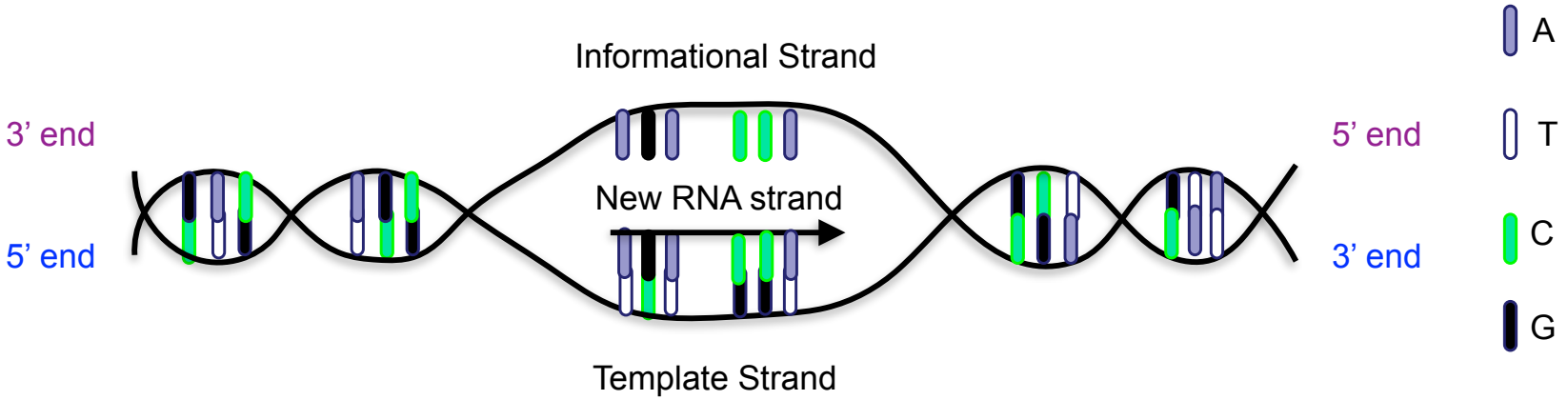


Transcription

- **Transcription** refers to the process in which RNA is synthesized from DNA.

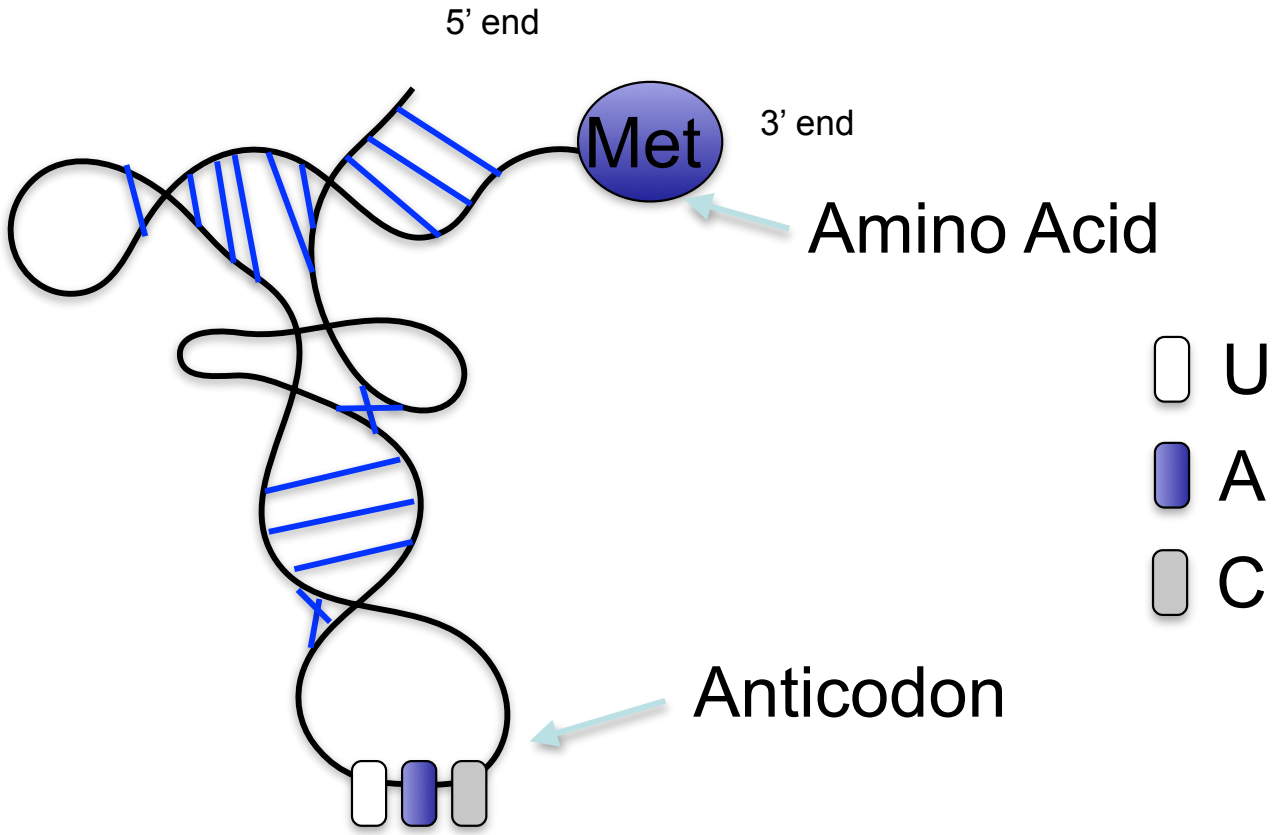
- The process of transcription is very similar to replication, except that only a single strand of RNA is synthesized, so transcription is on a much smaller scale.
  (1) Short segments of DNA unwind to expose the bases for a single gene.
  (2) One of the exposed DNA strands (the template strand) forms hydrogen bonds to free nucleotides, and RNA polymerase enzymes catalyze the reaction between the 5'-phosphate of the free nucleotide and the 3'- hydroxyl of the growing RNA strand.
  (3) The strand that does not participate in hydrogen bonding is called the informational strand. Note that the RNA strand formed is almost identical to the informational strand, except that all T are replaced with U and the sugars in RNA are ribose rather than deoxyribose.
  (4) Once the RNA has been synthesized, the DNA reforms the double helix.

- Significant differences between replication and transcription:
  (1) In replication the entire genetic code is copied. In transcription only a short segment (a gene) is copied.
  (2) In replication two new DNA double helices form for two new daughter cells. In transcription a single strand of RNA is formed.



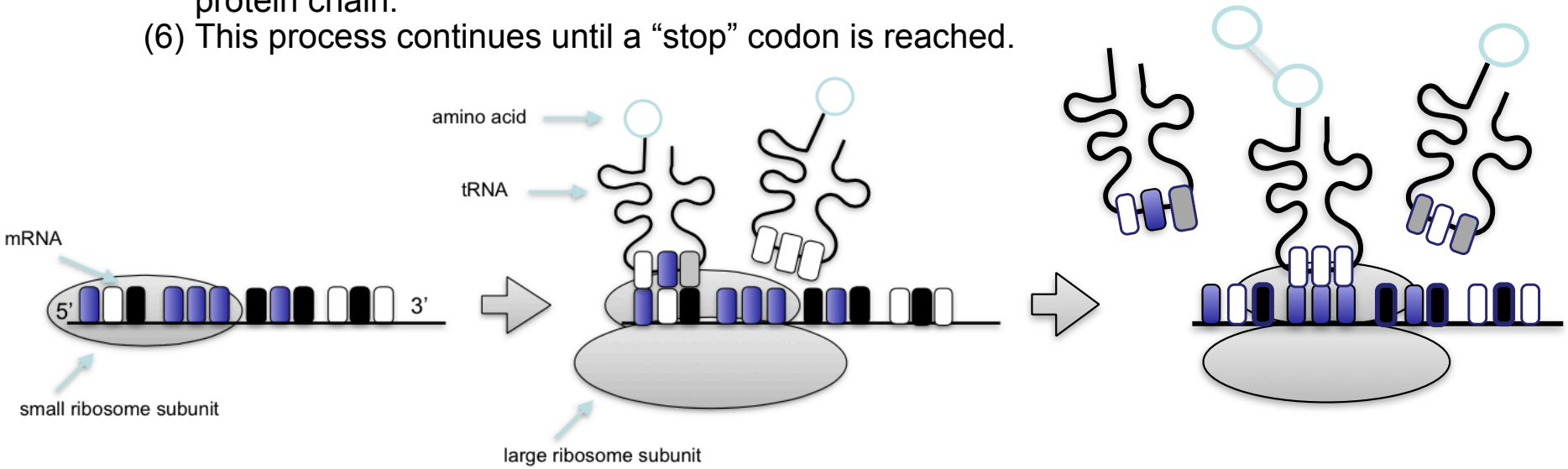
Translation

- **Translation** is the process in which the genetic message carried by RNA is decoded and used for protein synthesis. Translation involves three different types of RNA:
  - **Messenger RNA (mRNA)** carries the genetic information from the cell nucleus (after transcription) to the site of protein synthesis in the cytoplasm. mRNA contains the necessary genetic information in triplet codes called **codon**.
  - **Ribosomal RNA (rRNA)** is contained in the ribosomes within the cell cytoplasm. This is the site at which protein synthesis occurs.
  - **Transfer RNA (tRNA)** carries the correct amino acid to the site of protein synthesis. tRNA have an **anticodon** that will complementary base pair to the correct codon of mRNA, thus ensuring delivery of the correct amino acid. See the cartoon depiction of a tRNA molecule below.



Translation Continued

- An overview of the process of translation is given below:
  (1) mRNA passes from the nucleus of a cell and into the cytoplasm where is meets up and binds with rRNA. The first codon on mRNA is always 5' AUG 3', which acts as the "start" codon.
  (2) The first tRNA carries the appropriate amino acid to the rRNA. Complementary base pairing occurs between the codon of the mRNA and the anticodon of the tRNA. The "start" codon always codes for the amino acid methionine.
  (3) The second tRNA carries the second amino acid to the rRNA, and complementary base pairs to the mRNA.
  (4) Enzymes within the ribosome catalyze the formation of the new peptide bond between the two amino acids.
  (5) The first tRNA breaks free, and the next tRNA brings in the third amino acid for the growing protein chain.
  (6) This process continues until a "stop" codon is reached.



The Genetic Code

- The codon of the mRNA codes for a particular amino acid, start or stop in the process of translation.

First Base (5' end)	*Second Base*	*Third Base* U	C	A	G
U	*U*	*Phe*	*Phe*	*Leu*	*Leu*
	C	*Ser*	*Ser*	*Ser*	*Ser*
	A	*Tyr*	*Tyr*	*Stop*	*Stop*
	G	*Cys*	*Cys*	*Stop*	*Trp*
C	*U*	*Leu*	*Leu*	*Leu*	*Leu*
	C	*Pro*	*Pro*	*Pro*	*Pro*
	A	*His*	*His*	*Gln*	*Gln*
	G	*Arg*	*Arg*	*Arg*	*Arg*
A	*U*	*Ile*	*Ile*	*Ile*	*Met*
	C	*Thr*	*Thr*	*Thr*	*Thr*
	A	*Asn*	*Asn*	*Lys*	*Lys*
	G	*Ser*	*Ser*	*Arg*	*Arg*
G	*U*	*Val*	*Val*	*Val*	*Val*
	C	*Ala*	*Ala*	*Ala*	*Ala*
	A	*Asp*	*Asp*	*Glu*	*Glu*
	G	*Gly*	*Gly*	*Gly*	*Gly*

Mutations and Genetic Diseases

- Errors that are carried along during DNA replication are called mutations.

DNA	***mRNA***	***AA***	***Properties of AA***	***Affect***
CTC	GAG	Glu	Hydrophilic/Acidic	Normal
CTT	GAA	Glu	Hydrophilic/Acidic	None
CTA	GAU	Asp	Hydrophilic/Acidic	None
CAC	GUG	Val	Hydophobic/Neutral	Less water soluble
ATC	UAG	Stop Codon	Not Applicable	No protein made or shortened protein