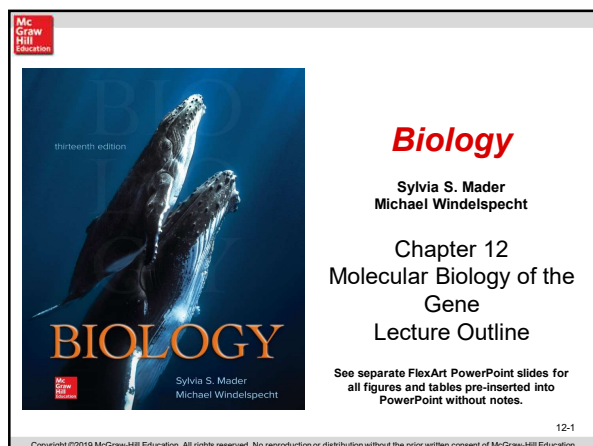


DNA Structure & Function



Outline

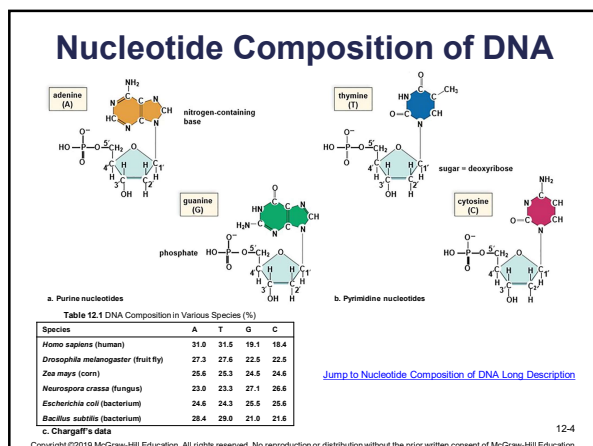
- 12.1 The Genetic Material
- 12.2 Replication of DNA
- 12.3 Gene Expression: RNA and the Genetic Code
- 12.4 Gene Expression: Transcription
- 12.5 Gene Expression: Translation

The Genetic Material (7)

DNA contains:

- Two nucleotides with purine bases
 - **Adenine (A)**
 - **Guanine (G)**
- Two nucleotides with pyrimidine bases
 - **Thymine (T)**
 - **Cytosine (C)**

DNA Structure & Function



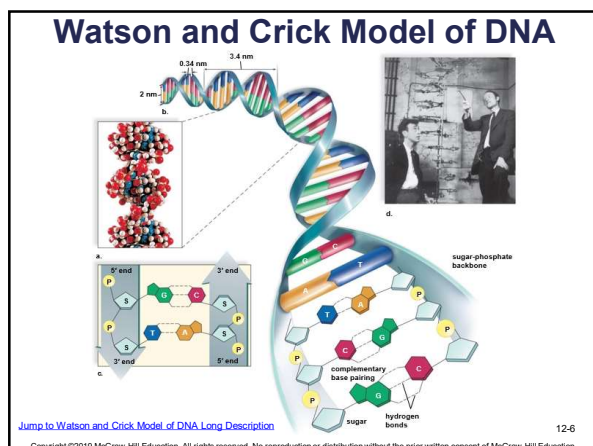
The Genetic Material (10)

The Watson and Crick Model (1953)

- **Double helix** model is similar to a twisted ladder.
 - Sugar-phosphate backbones make up the sides.
 - Hydrogen-bonded bases make up the rungs.
 - The two DNA strands are antiparallel.
 - Information stored in DNA must be read in the 5 prime to 3 prime direction so DNA is replicated in a 5 prime to 3 prime direction.
- Complementary base pairing ensures that a purine is always bonded to a pyrimidine (A with T, G with C).
- They received a Nobel Prize in 1962.

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DNA Structure & Function

12.2 Replication of DNA

DNA replication is the process of copying a DNA molecule.

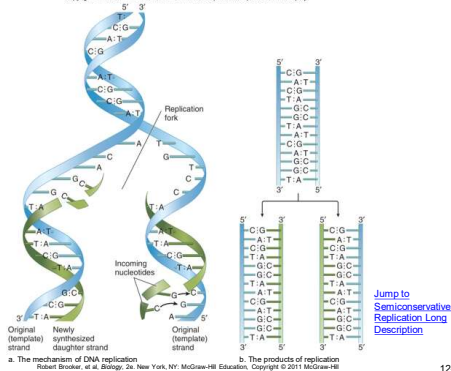
Semiconservative replication: Each strand of the original double helix (*parental* molecule) serves as a **template** (mold or model) for a new strand in a daughter molecule.

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Semiconservative Replication

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Replication of DNA (1)

Replication requires the following steps:

- Unwinding, or separation, of the two strands of the parental DNA molecule by the DNA helicase enzyme
- Single-stranded binding proteins (SSB) attach to newly separated DNA and prevent helix from re-forming.
- Complementary base pairing between a new nucleotide and a nucleotide on the template strand
 - DNA primase places short primers on the strands to be replicated.
 - Polymerase recognizes RNA and begins DNA synthesis.
 - The two strands are replicated differently: leading and lagging strands.
 - Joining of nucleotides in the lagging strand by DNA ligase form the new strand.
 - Each daughter DNA molecule contains one old and one new strand.

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DNA Structure & Function

Replication of DNA (3)

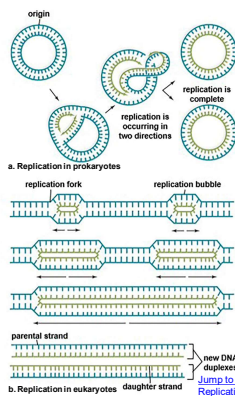
Eukaryotic Replication

- DNA replication begins at numerous points along each linear chromosome.
- DNA unwinds and unzips into two strands.
- Each old strand of DNA serves as a template for a new strand.
- Complementary base pairing forms a new strand paired with each old strand.
- Requires enzyme **DNA polymerase**

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Prokaryotic versus Eukaryotic Replication



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Replication of DNA (5)

Accuracy of Replication

- DNA polymerase is very accurate, yet makes a mistake about once per 100,000 base pairs.
 - Capable of identifying and correcting errors

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DNA Structure & Function

12.3 Gene Expression: RNA and the Genetic Code

Genes Specify Enzymes

- Archibald Garrod described inborn errors of metabolism.
- Beadle and Tatum:
 - Experiments on the fungus *Neurospora crassa*
 - Proposed that each gene specifies the synthesis of one enzyme
 - One gene, one enzyme hypothesis

The flow of genetic information is from DNA to RNA to protein to an observed trait.

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Gene Expression: RNA and the Genetic Code (1)

The mechanism of gene expression

- DNA in genes specify information, but information is not structure and function.
- Genetic information is expressed into structure and function through protein synthesis.

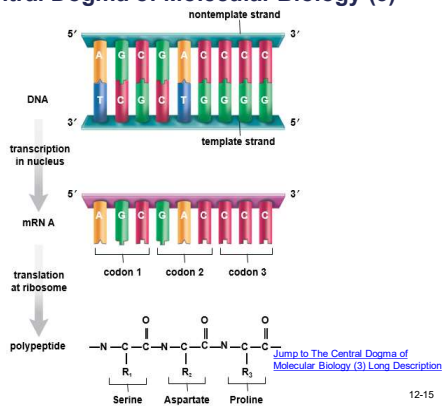
The expression of genetic information into structure and function:

- DNA in a gene determines the sequence of nucleotides in an RNA molecule.
- RNA controls the primary structure of a protein.

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The Central Dogma of Molecular Biology (3)



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Gene Expression: RNA and the Genetic Code (2)

RNA is a polymer of RNA nucleotides.

- RNA nucleotides contain the sugar ribose instead of deoxyribose.
- RNA nucleotides are of four types: **uracil (U)**, **adenine (A)**, **cytosine (C)**, and **guanine (G)**.
- Uracil (U) replaces thymine (T) of DNA.

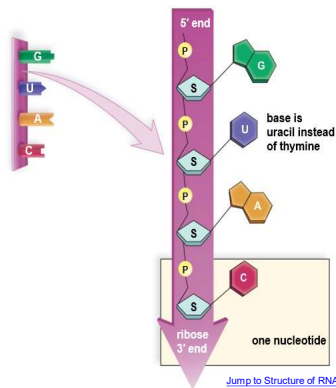
Types of RNA

- **Messenger (mRNA)** takes a message from DNA in the nucleus to ribosomes in the cytoplasm.
- **Ribosomal (rRNA)**, along with ribosomal proteins, make up ribosomes, where polypeptides are synthesized.
- **Transfer (tRNA)** transfers the appropriate amino acid to the ribosomes.

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Structure of RNA



[Jump to Structure of RNA Long Description](#)

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RNA Structure Compared to DNA Structure

Table 12.3 RNA Structure Compared to DNA Structure

	RNA	DNA
Sugar	Ribose	Deoxyribose
Bases	Adenine, guanine, uracil, cytosine	Adenine, guanine, thymine, cytosine
Strands	Single-stranded	Double-stranded with base pairing
Helix	No	Yes

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DNA Structure & Function

The Genetic Code (1)

The unit of the **genetic code** consists of **codons**, each of which is a unique arrangement of symbols.

Each of the 20 amino acids found in proteins is uniquely specified by one or more codons.

- The symbols used by the genetic code are the mRNA bases.
- Function as "letters" of the genetic alphabet
- The genetic alphabet has only four "letters" (U, A, C, G).
- Codons in the genetic code are all three bases (symbols) long.
- They function as "words" of genetic information.
- Permutations:
 - There are 64 possible arrangements of four symbols taken three at a time.
 - They are often referred to as triplets.
- Genetic language only has 64 "words."

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Messenger RNA Codons

	Second Base U	Second Base C	Second Base A	Second Base G	
First base U	UUU phenylalanine	UCU serine	UAU tyrosine	UGU cysteine	Third Base U
First base U	UUC phenylalanine	UCC serine	UAC tyrosine	UGC cysteine	Third Base C
First base U	UUA leucine	UCA serine	UUA stop	UGA stop	Third Base A
First base U	UUG leucine	UCG serine	UAG stop	UGG tryptophan	Third Base G
First base C	CUU leucine	CCU proline	CAU histidine	CGU arginine	Third Base U
First base C	CUC leucine	CCC proline	CAC histidine	CGC arginine	Third Base C
First base C	CUA leucine	CCA proline	CAA glutamine	CGA arginine	Third Base A
First base C	CUG leucine	CCG proline	CAG glutamine	CGG arginine	Third Base G
First base A	AUU isoleucine	ACU threonine	AUU asparagine	AGU serine	Third Base U
First base A	AUC isoleucine	ACC threonine	AAC asparagine	AGC serine	Third Base C
First base A	AUA isoleucine	ACA threonine	AAA lysine	AGA arginine	Third Base A
First base A	AUG (start) methionine	ACG threonine	AAG lysine	AGG arginine	Third Base G
First base G	GUU valine	GCU alanine	GAU aspartate	GGU glycine	Third Base U
First base G	GUC valine	GCC alanine	GAC aspartate	GGC glycine	Third Base C
First base G	GUA valine	GCA alanine	GAA glutamate	GGA glycine	Third Base A
First base G	GUG valine	GCG alanine	GAG glutamate	GGG glycine	Third Base G

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12.4 Gene Expression: Transcription

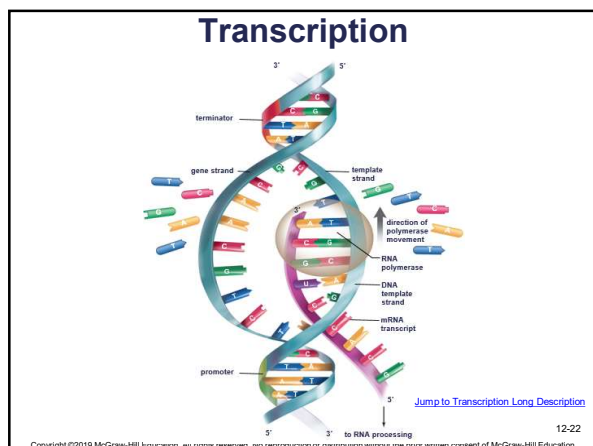
Transcription

- A segment of DNA serves as a template for the production of an RNA molecule.
- The gene unzips and exposes unpaired bases.
- It serves as a template for mRNA formation.
- Loose RNA nucleotides bind to exposed DNA bases using the C = G and A = U rule.
- When the entire gene is transcribed into mRNA, the result is a **pre-mRNA transcript** of the gene.
- The base sequence in the pre-mRNA is complementary to the base sequence in DNA.

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DNA Structure & Function



First Step: Transcription (1)

Pre-mRNA is modified (or processed) before leaving the eukaryotic nucleus.

- Modifications to the ends of the primary transcript:
 - Cap on the 5 prime end
 - The *cap* is a modified guanine (G) nucleotide.
 - It helps a ribosome determine where to attach when translation begins.
 - Poly-A tail of 150 to 200 adenines on the 3 prime end
 - It facilitates the transport of mRNA out of the nucleus.
 - It inhibits degradation of mRNA by hydrolytic enzymes.

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First Step: Transcription (2)

Pre-mRNA is composed of **exons** and **introns**.

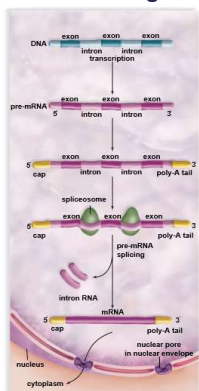
- The exons will be expressed.
- The introns occur *in* between the exons.
 - The exons are "expressed" and the introns are "in the way."
 - It allows a cell to pick and choose which exons go into a particular mRNA.
- RNA splicing:
 - Primary transcript consists of:
 - Some segments that will not be expressed (introns)
 - Segments that will be expressed (exons)

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DNA Structure & Function

Messenger RNA Processing in Eukaryotes (4)



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12.5 Second Step: Translation

Translation

- The sequence of codons in the mRNA at a ribosome directs the sequence of amino acids into a polypeptide.
- A nucleic acid sequence is translated into a protein sequence.

Transfer RNA (or tRNA) molecules have two binding sites:

- One associates with the mRNA transcript.
- The other associates with a specific amino acid.
- Each of the 20 amino acids in proteins associates with one or more of 64 types of tRNA.
- The "wobble" hypothesis predicts that the third position in the tRNA anticodon doesn't obey the A-U/G-C configuration rule and can be variable.

Translation

- An mRNA transcript associates with the rRNA of a ribosome in the cytoplasm or a ribosome associated with the rough endoplasmic reticulum.
- The ribosome "reads" the information in the transcript.
- The ribosome directs various types of tRNA to bring in their specific amino acid "fares."
- The tRNA specified is determined by the code being translated in the mRNA transcript.

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Second Step: Translation (1)

tRNA molecules come in 64 different kinds.

All are very similar except that

- One end bears a specific triplet (of the 64 possible) called the **anticodon**.
- The other end binds with a specific amino acid type.
- tRNA synthetases attach the correct amino acid to the correct tRNA molecule.

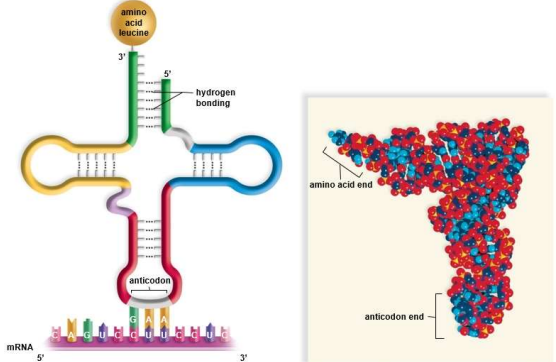
All tRNA molecules with a specific anticodon will always bind with the same amino acid.

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DNA Structure & Function

Structure of a tRNA Molecule (4)



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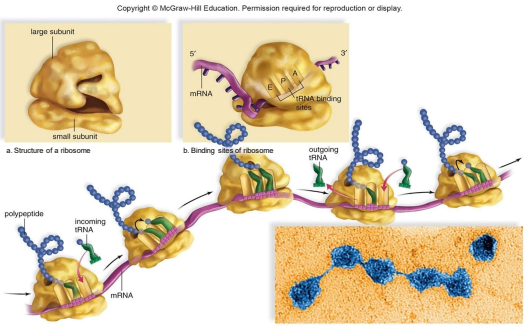
Second Step: Translation (2)

Structure and function of ribosomes

- Ribosomal RNA (rRNA):
 - Produced from a DNA template in the nucleolus of a nucleus
 - Packaged with proteins into large and small ribosomal subunits
- A completed ribosome has three binding sites to facilitate pairing between tRNA and mRNA.
 - The E (for exit) site
 - The P (for peptide) site, and
 - The A (for amino acid) site
- The large ribosomal subunit has enzyme activity that creates a peptide bond between adjacent amino acids.
 - The peptide bond is created many times to produce a polypeptide which folds into its three-dimensional shape and becomes a protein.

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Ribosome Structure and Function



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DNA Structure & Function

