Module 3F – Protein Synthesis

- So far in this unit, we have examined:
  - How genes are transmitted from one generation to the next
  - Where genes are located
  - What genes are made of
  - How genes are replicated
  - How damaged genes are repaired

1

Protein Synthesis

- In this, the final module of the unit, we will examine how genes work to control the genetic traits of organisms.

2

Objective # 32

Describe the central dogma of molecular biology.

3

Objective 32

- According to the central dogma of molecular biology, the flow of information in cells is from DNA, to RNA, to proteins.
- Basically, genes control the traits of organisms by controlling which proteins are made.
- Although there are exceptions, in general, each gene codes for the production of one polypeptide.

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Objective 32

The process of protein synthesis can be divided into 2 stages: transcription and translation.

1) During transcription, DNA is used as a template to make 3 types of RNA:
   a) messenger-RNA (mRNA)
   b) ribosomal-RNA (rRNA)
   c) transfer-RNA (tRNA)

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Objective 32

2) During translation, the 3 types of RNA (mRNA, rRNA, and tRNA) are used to link amino acids together in the correct sequence in order to produce the desired protein.

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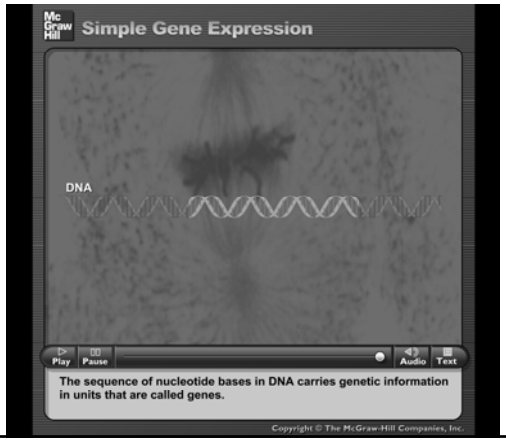

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Objective # 33

Name the 3 types of RNA involved in protein synthesis and briefly describe the structure and function of each.

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Objective 33

- Messenger RNA (mRNA) is a single, long, unbranched, and uncoiled chain of RNA nucleotides.
- The sequence of bases on the mRNA molecule is a code which specifies the sequence for joining amino acids together in order to form a specific polypeptide.

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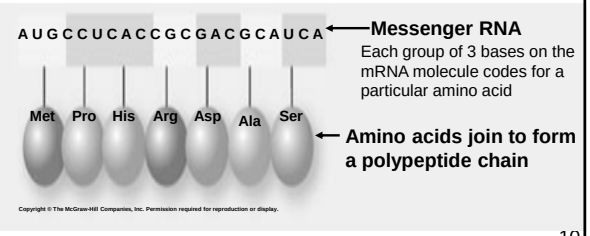
The sequence of bases on the mRNA is a code that determines the sequence of amino acids in the polypeptide being synthesized:



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Objective 33

- Ribosomal RNA (rRNA) also consists of a long, unbranched chain of RNA nucleotides. It joins with proteins to form the ribosomal subunits.
- Each ribosome is composed of 2 subunits – a large subunit and a small subunit.
- Eukaryotic ribosomal subunits are larger than those found in prokaryotes.

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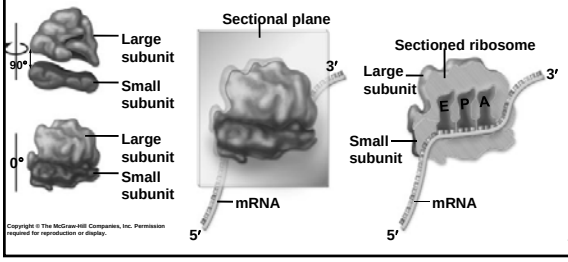
During protein synthesis, the 2 ribosomal subunits join with a molecule of mRNA and then read the code on the mRNA in order to form a polypeptide:



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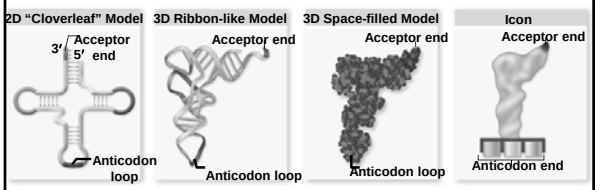
Objective 33

- Transfer RNA (tRNA) is composed of a long unbranced chain of RNA nucleotides that is coiled into a specific 3-dimensional shape:



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Objective 33

- Special enzymes called aminoacyl-tRNA synthetases attach an amino acids to the acceptor end of each tRNA molecule.
- A tRNA with an amino acid attached is called a "charged" tRNA
- The tRNA then brings the amino acid to the ribosome where it is linked with other amino acids according to the sequence specified by the mRNA.

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Objective # 34

In detail, describe the process of transcription in prokaryotic cells including initiation, elongation, and termination.

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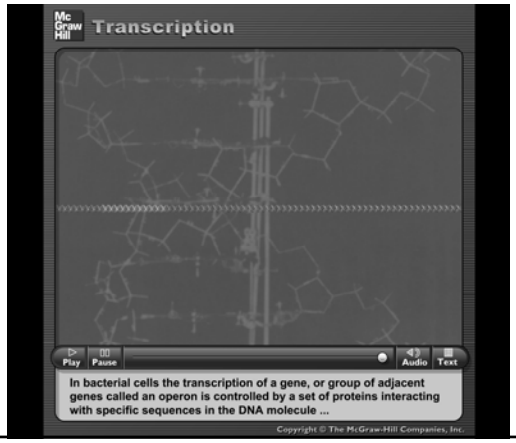

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Objective # 35

In detail, describe the process of translation in prokaryotic cells including initiation, elongation, and termination.

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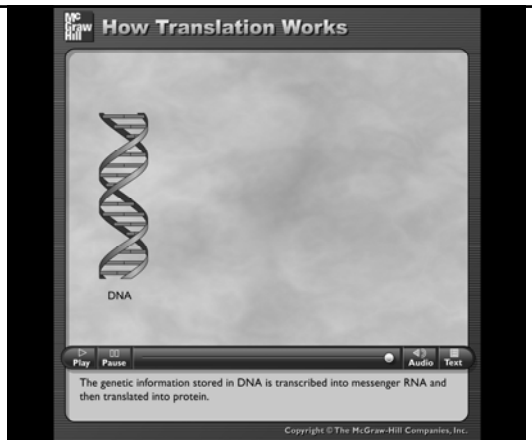

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Objective 35

- The next 3 slides provide a more detailed look at the 3 stages of translation in prokaryotic cells:

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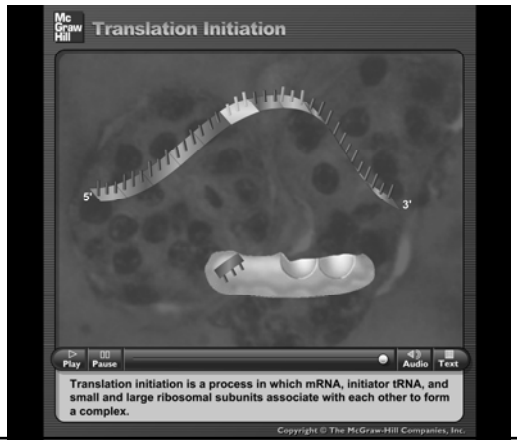

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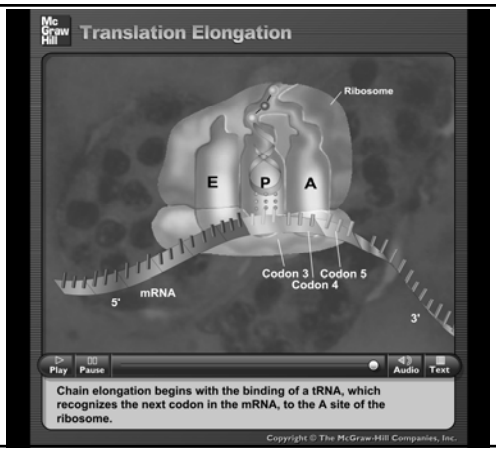

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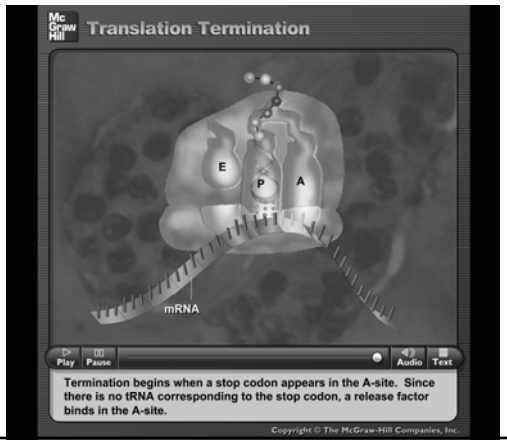

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Objective # 36

Explain how protein synthesis in eukaryotes differs from protein synthesis in prokaryotes.

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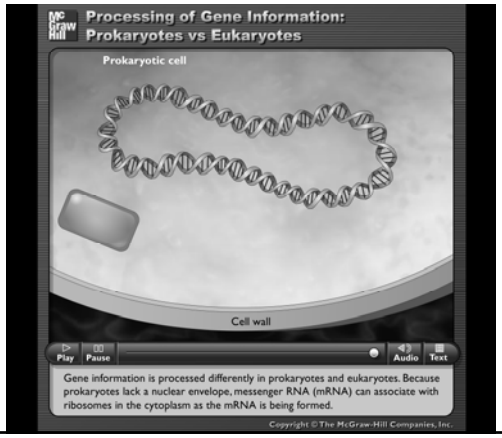

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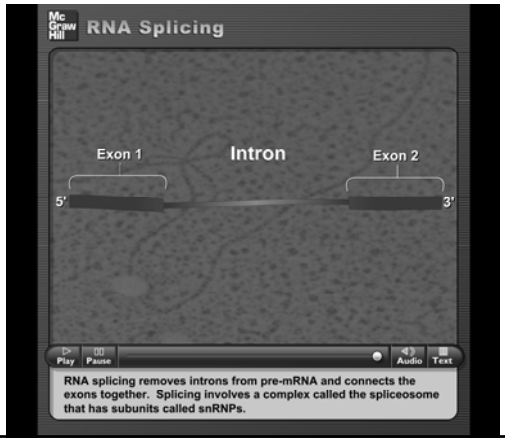

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Objective 36

TABLE 15.2 Differences Between Prokaryotic and Eukaryotic Gene Expression

Characteristic	Prokaryotes	Eukaryotes
Introns	No introns, although some archaeal genes possess them.	Most genes contain introns.
Number of genes in mRNA	Several genes may be transcribed into a single mRNA molecule. Often these have related functions and form an operon. This coordinates regulation of biochemical pathways.	Only one gene per mRNA molecule; regulation of pathways accomplished in other ways.
Site of transcription and translation	No membrane-bounded nucleus; transcription and translation are coupled.	Transcription in nucleus; mRNA moves out of nucleus for translation.
Initiation of translation	Begins at AUG codon preceded by special sequence that binds the ribosome.	Begins at AUG codon preceded by the 5′ cap (methylated GTP) that binds the ribosome.
Modification of mRNA after transcription	None; translation begins before transcription is completed.	A number of modifications while the mRNA is in the nucleus. Introns are removed and exons are spliced together; a 5′ cap is added, a poly-A tail is added.

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Objective # 37

Describe and be able to use the base pairing rules for DNA to DNA, DNA to RNA, and RNA to RNA. Also be able to use the codon/amino acid dictionary to translate a segment of mRNA.

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Objective 37

DNA	A	T	G	C
DNA	T	A	C	G

DNA	A	T	G	C
RNA	U	A	C	G

RNA	A	U	G	C
RNA	U	A	C	G

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Objective 37

- The codon/amino acid dictionary shows us which amino acid each codon codes for:

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The Genetic Code

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

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Objective # 38

- Explain and give examples of the following types of mutations:

a) Point mutations

b) Chromosomal mutations

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Objective 38 a

- Point mutations involve alterations in the structure or location of a single gene. Generally, only one or a few base pairs are involved.
- Point mutations may be caused by physical damage to the DNA from radiation or chemicals, or may occur spontaneously.

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Objective 38 a

Types of point mutations include:

- Substitutions – the replacement of one or more base pairs with different pairs.

Original DNA	Substitution
TACAGCTTA ATGTCGAAT	TACAGTTTA ATGTCAAAT

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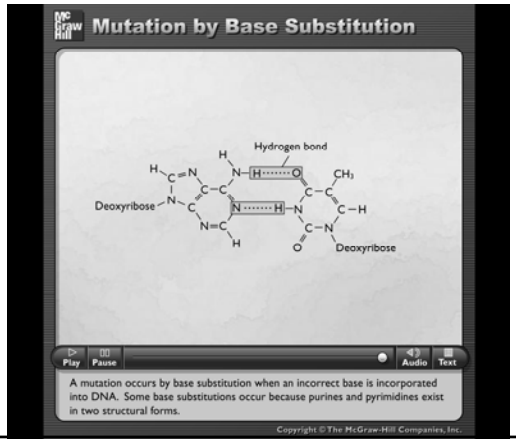

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Objective 38 a

- Additions or insertions – the addition of one or more base pairs to a gene.

Original DNA	Insertion
TACAGCTTA ATGTCGAAT	TACAGCTTTA ATGTCGAAAT

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Objective 38 a

- Deletions – the removal of one or more base pairs from a gene.

Original DNA	Deletion
TACAGCTTA ATGTCGAAT	TACGCTTA ATGCGAAT

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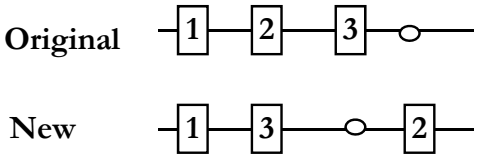
Objective 38 a

- Transpositions – the movement of a gene from one location to another within the genome.



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Objective 38 a

- Transposons are small segments of DNA capable of moving at random from one location to another within the genome of a single cell.
- When a transposon is inserted into a gene at a new location, this often destroys the disrupted gene's function. This is called insertional inactivation.

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Objective 38 b

- Chromosomal mutations involve large scale changes in the structure of a chromosome (affecting many genes), or changes in the number of chromosomes present (extra or missing chromosomes).

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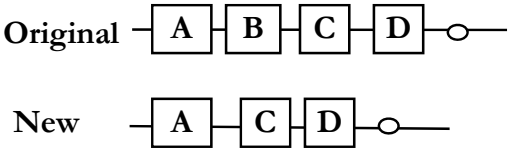
Objective 38 b

- Chromosomal mutations include:
- Deletions – a piece of a chromosome is lost entirely:



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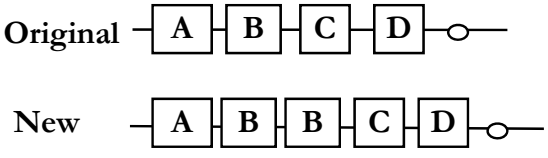
Objective 38 b

- Duplications – a piece of a chromosome duplicates itself so that two or more copies are present:



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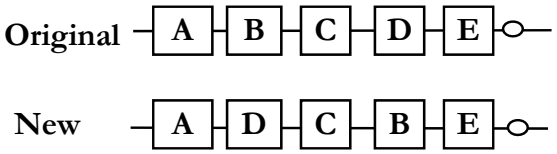
Objective 38 b

- Inversions – the gene order in a segment of the chromosome is reversed:



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Objective 38 b

- Translocations – a piece of a chromosome breaks off and attaches to a different chromosome.
- Aneuploidy – the presence of one or more extra chromosomes.
- Polyploidy - the presence of one or more extra sets of chromosomes.

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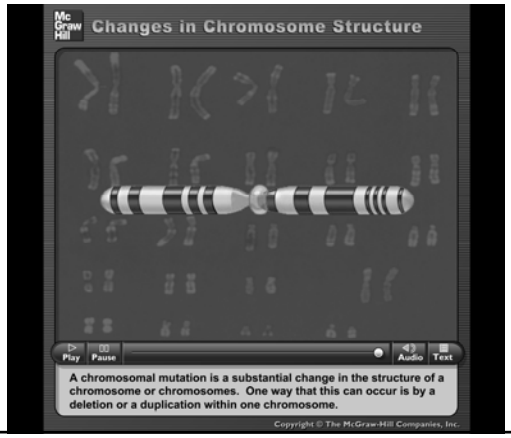

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Objective # 39

Explain how the following types of point mutations can alter the structure of a polypeptide chain:

substitution

insertion

deletion.

46

Objective 39

- Substitutions that change a codon for one amino acid into a different codon for the same amino acid are called silent mutations:

	Original	Substitution
DNA	TACAGCTTA	TACAGTTTA
mRNA	AUGUCGAAU	AUGUCAAAU
AAs	Met-Ser-Asp	Met-Ser-Asp

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Objective 39

- Substitutions that change a codon for one amino acid into a codon for a different amino acid are called missense mutations:

	Original	Substitution
DNA	TACAGCTTA	TACACCTTA
mRNA	AUGUCGAAU	AUGUGGAAU
AAs	Met-Ser-Asp	Met-Try-Asp

48

Objective 39

- Substitutions that change a codon for one amino acid into a stop codon are called nonsense mutations:

	Original	Substitution
DNA	TACAGCTTA	TACATCTTA
mRNA	AUGUCGAAU	AUGUAGAAU
AAs	Met-Ser-Asp	Met-Stop

49

Objective 39

- The genetic code does not contain any punctuation marks to show where one codon ends and another begins.
- Therefore, insertions or deletions that do not involve multiples of 3 base pairs will change the reading frame of the gene, and alter all codons downstream from the mutation. These are called frameshift mutations:

50

Objective 39

	Original	Insertion
DNA	TACAGCTTA	TACTAGCTTA
mRNA	AUGUCGAAU	AUGAUCGAAU
AAs	Met-Ser-Asp	Met-Iso-Glu

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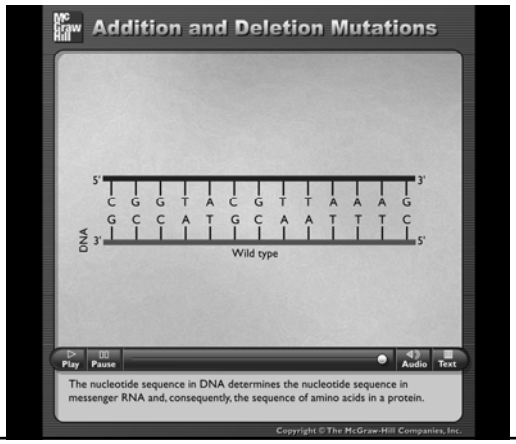

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