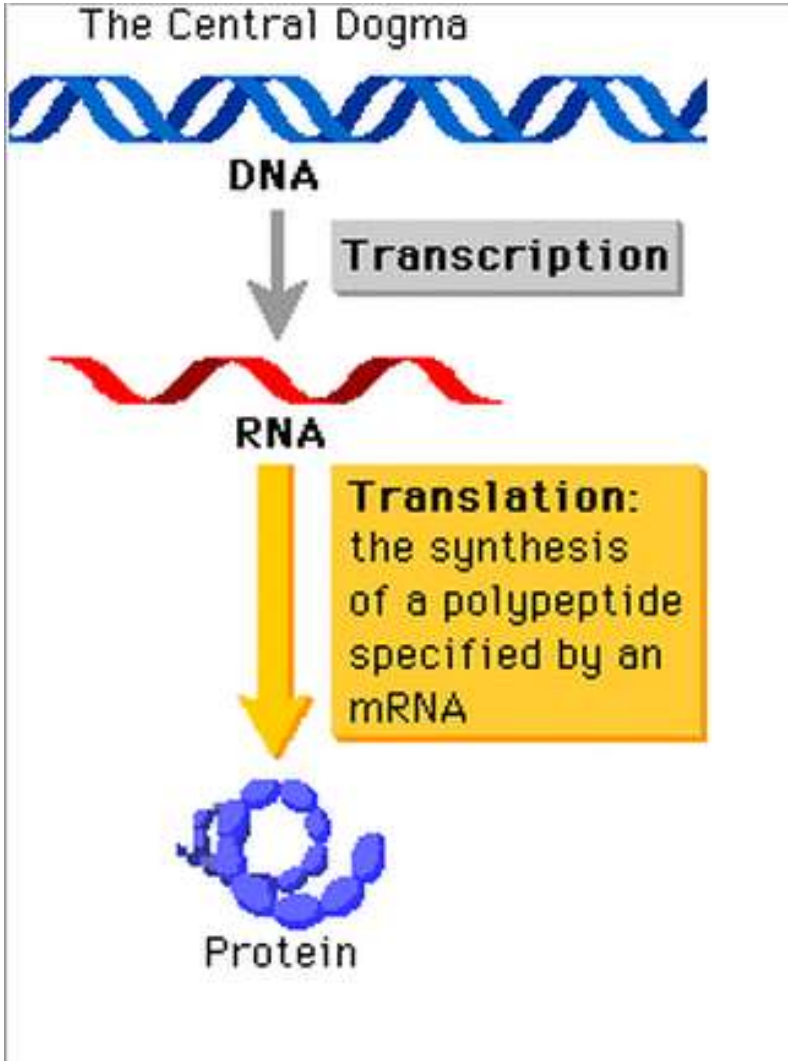
The Central Dogma of Biology



10.2 DNA, not protein, is the genetic material

- **Hershey and Chase Experiment**
  - In their experiment, Hershey and Chase relied on a chemical difference between DNA and protein to solve whether DNA or protein was the genetic material

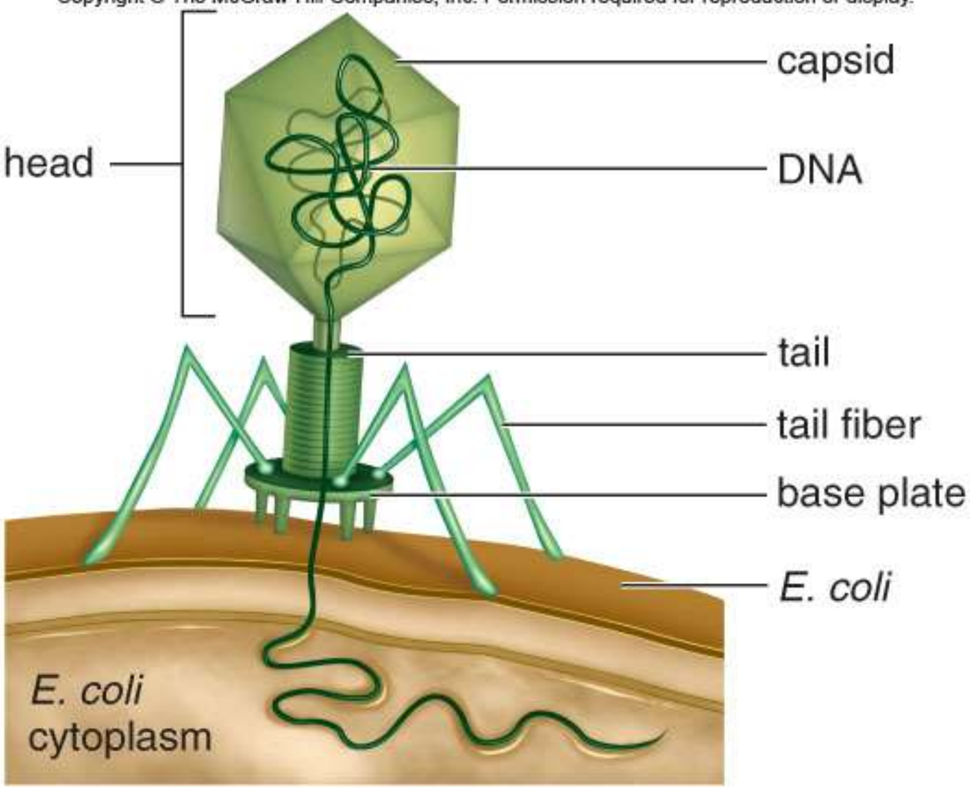
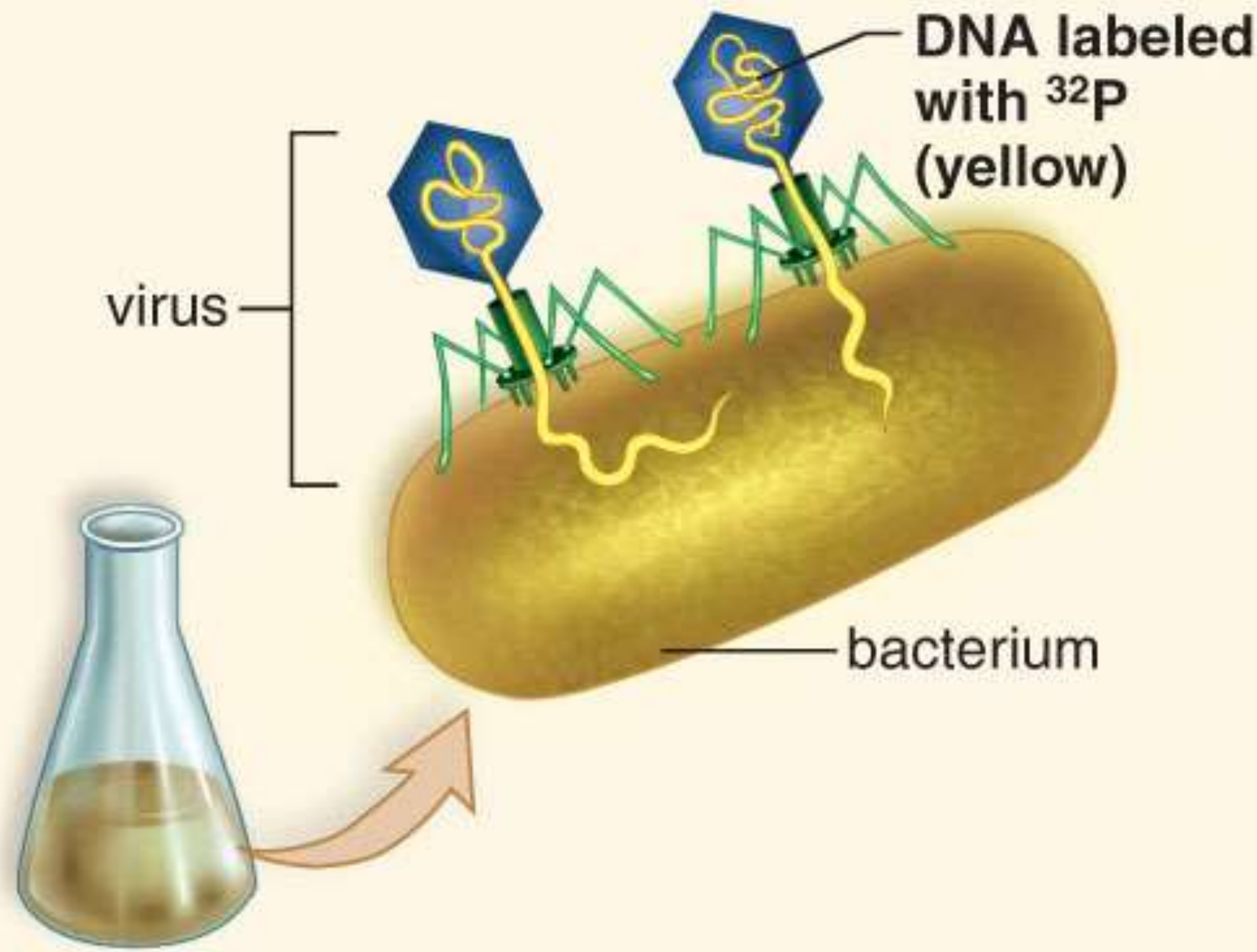


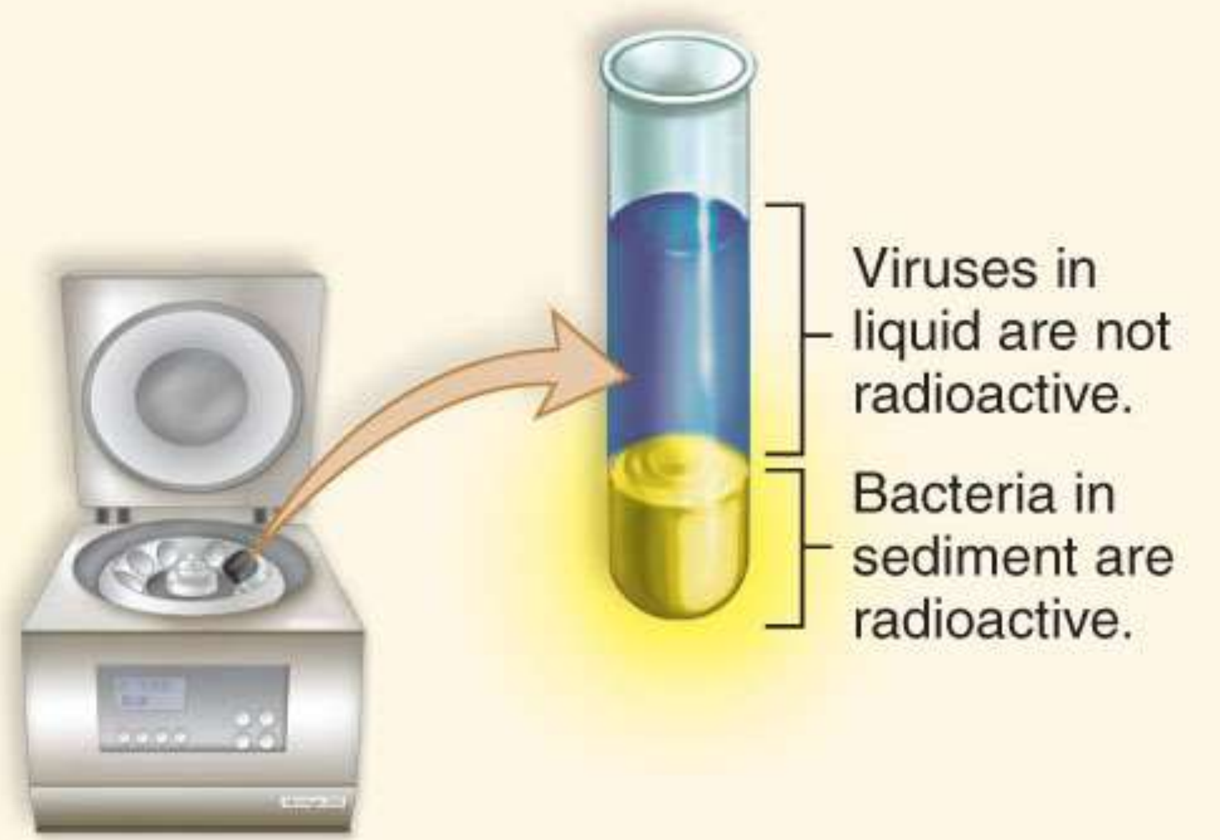
Figure 10.2A Structure of the virus (T2 bacteriophage) used by Hershey and Chase

Figure 10.2B Hershey and Chase experiment I



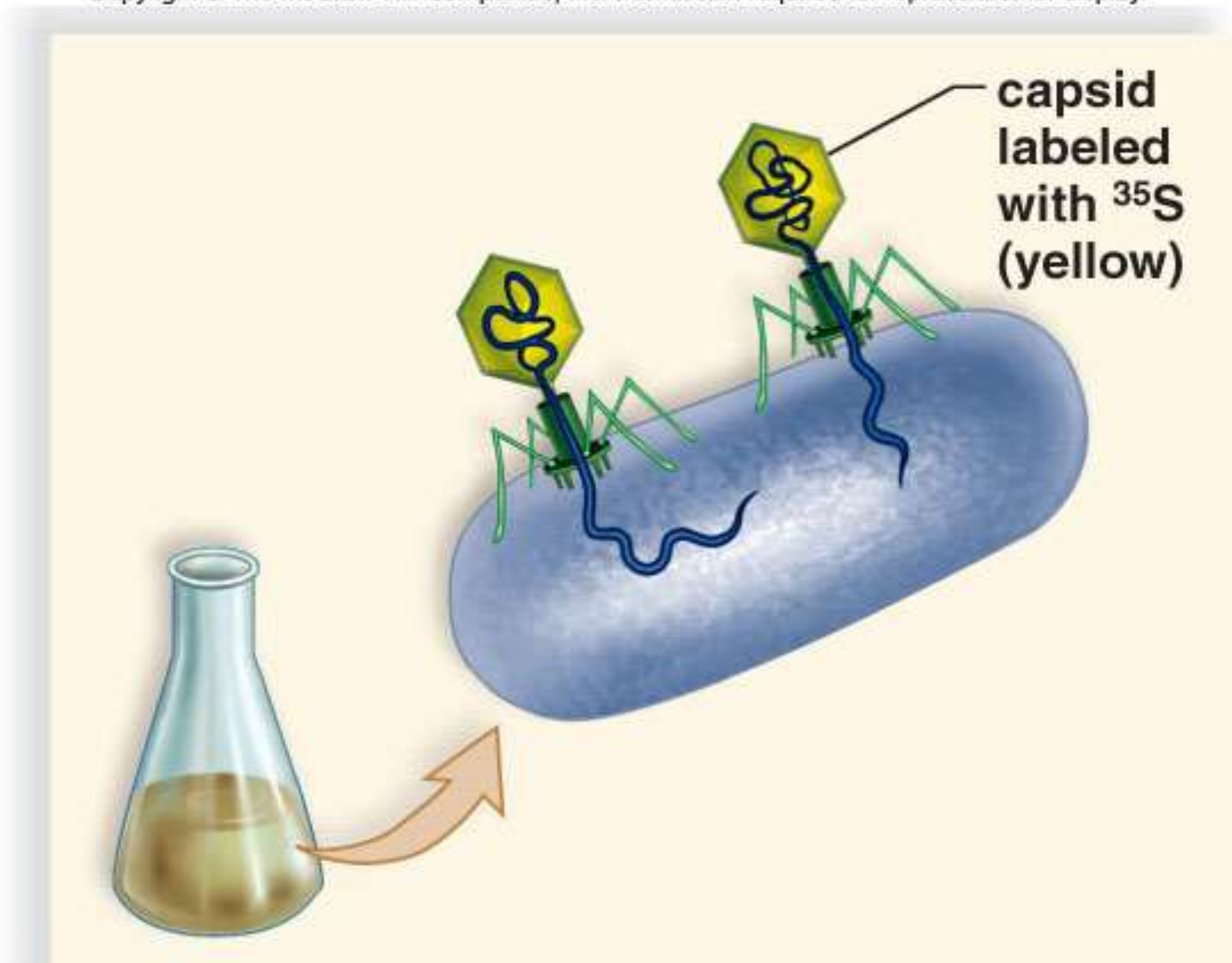
1 When bacteria and viruses are cultured together, radioactive viral DNA enters bacterium.

Figure 10.2B Hershey and Chase experiment I (Cont.)



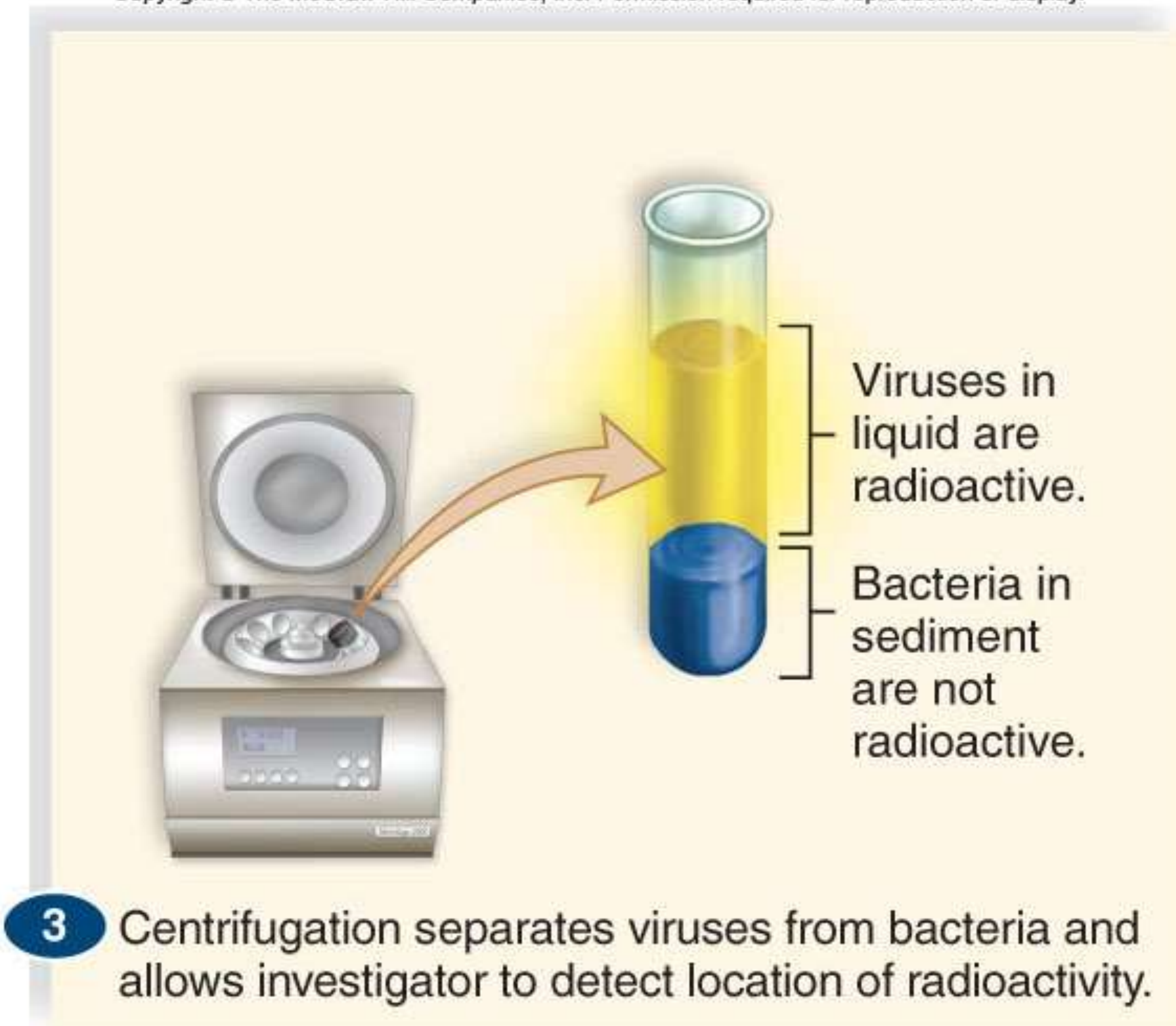
3 Centrifugation separates viruses from bacteria and allows investigator to detect location of radioactivity.

Figure 10.2C Hershey and Chase experiment II



1 When bacteria and viruses are cultured together, radioactive viral capsids stay outside bacteria.

Figure 10.2C Hershey and Chase experiment II (Cont.)



Hershey and Chase take-home

- The results from Hershey and Chase experiments suggested that the DNA of the virus entered the hosts (and not the protein), where viral reproduction takes place.
- Therefore, DNA is the genetic material and not proteins.

10.3 DNA and RNA are polymers of nucleotides

- **Nucleic acids** contain only **nucleotides**, molecules that are composed of a nitrogen-containing base, a phosphate, and a pentose (5-carbon sugar)
- **DNA (deoxyribonucleic acid)** contains the 5-carbon sugar deoxyribose
- DNA contains four nucleotides with different bases
  - **Adenine, Guanine, Thymine, and Cytosine**

Figure 10.3A DNA is a polynucleotide—contains many nucleotides

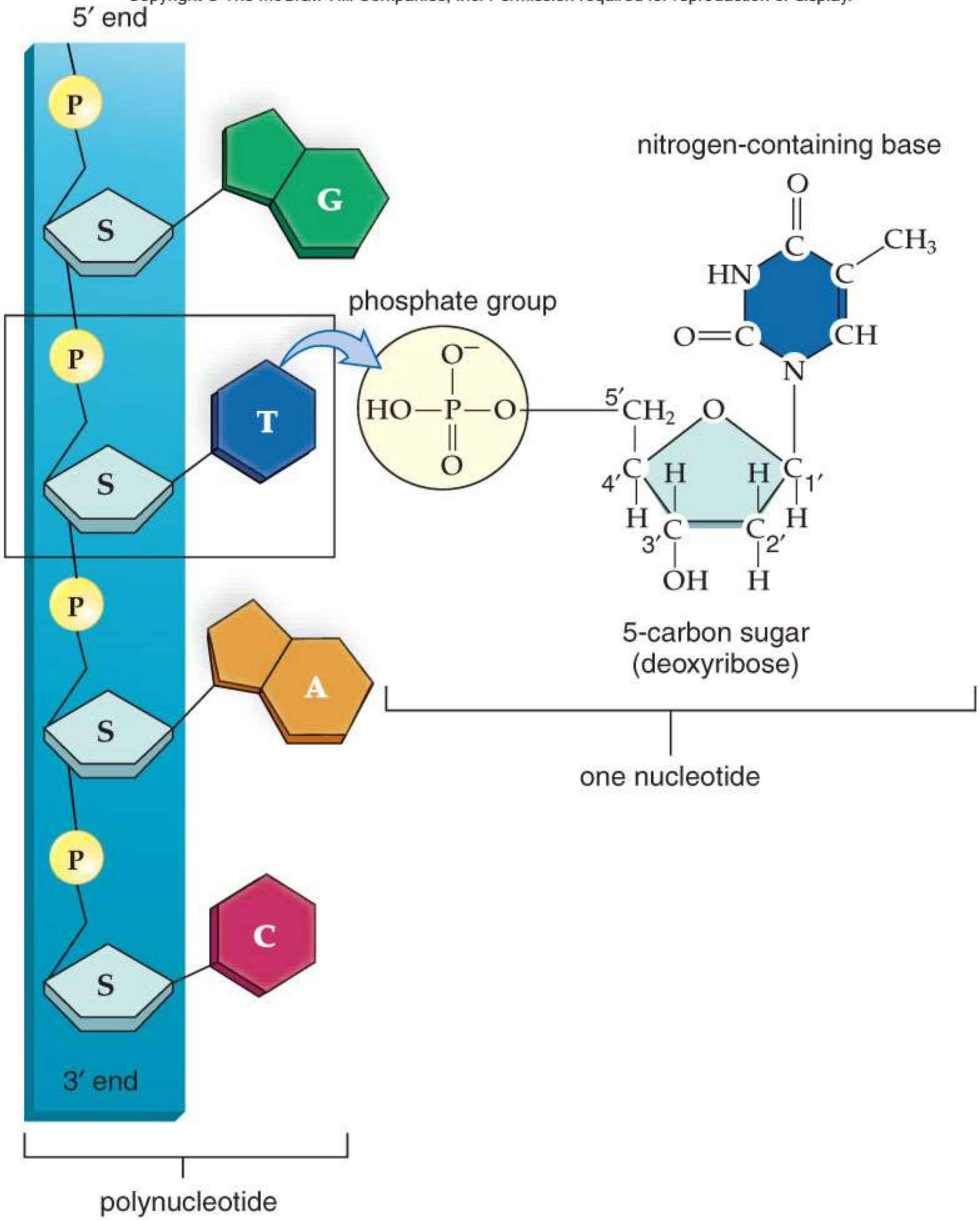
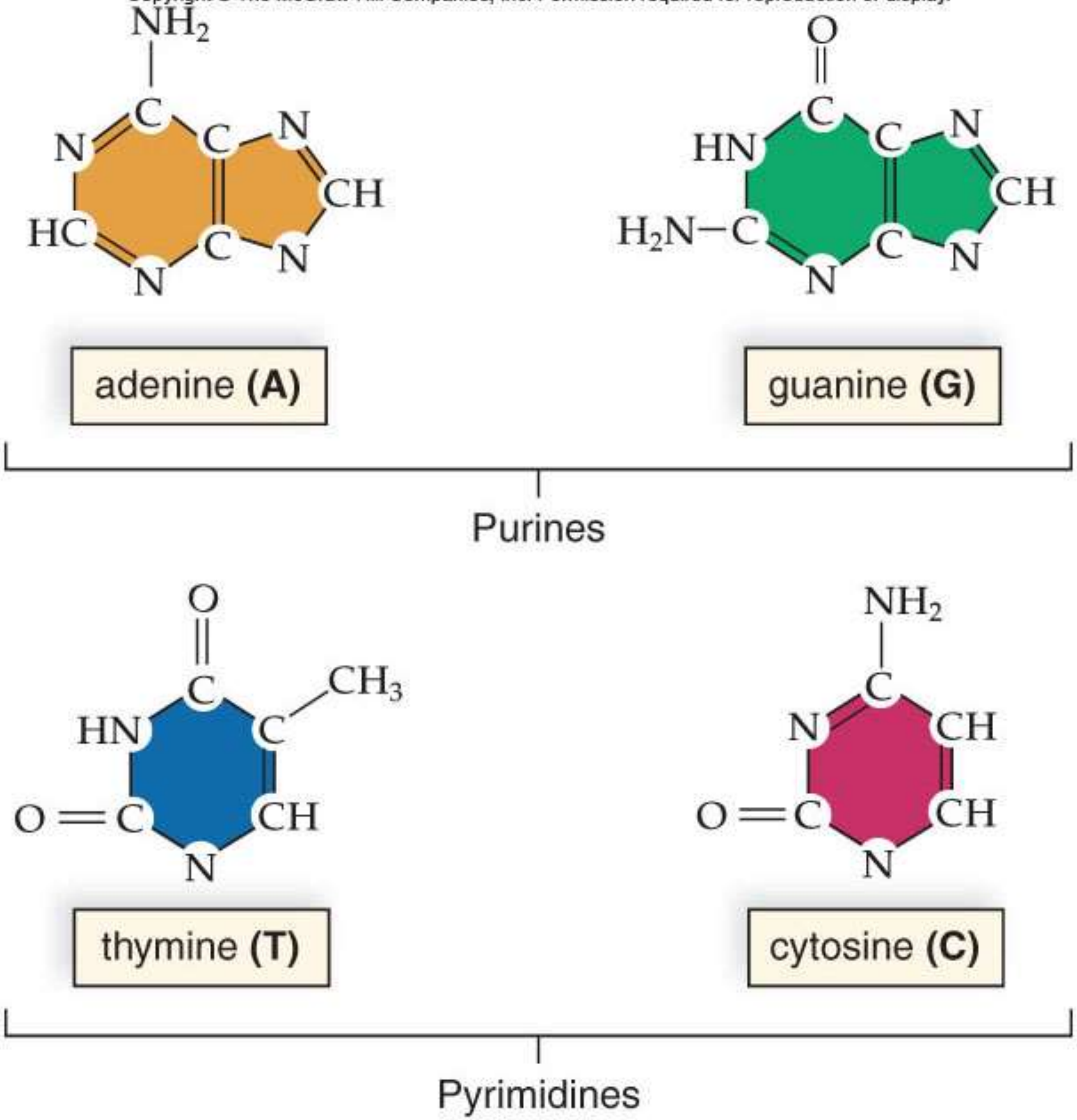


Figure 10.3B The four bases in DNA nucleotides



RNA

- **RNA (ribonucleic acid)** another polymer of nucleotides
- RNA differs from DNA
  - Has ribose as a sugar, not deoxyribose
  - Has uracil in place of thymine

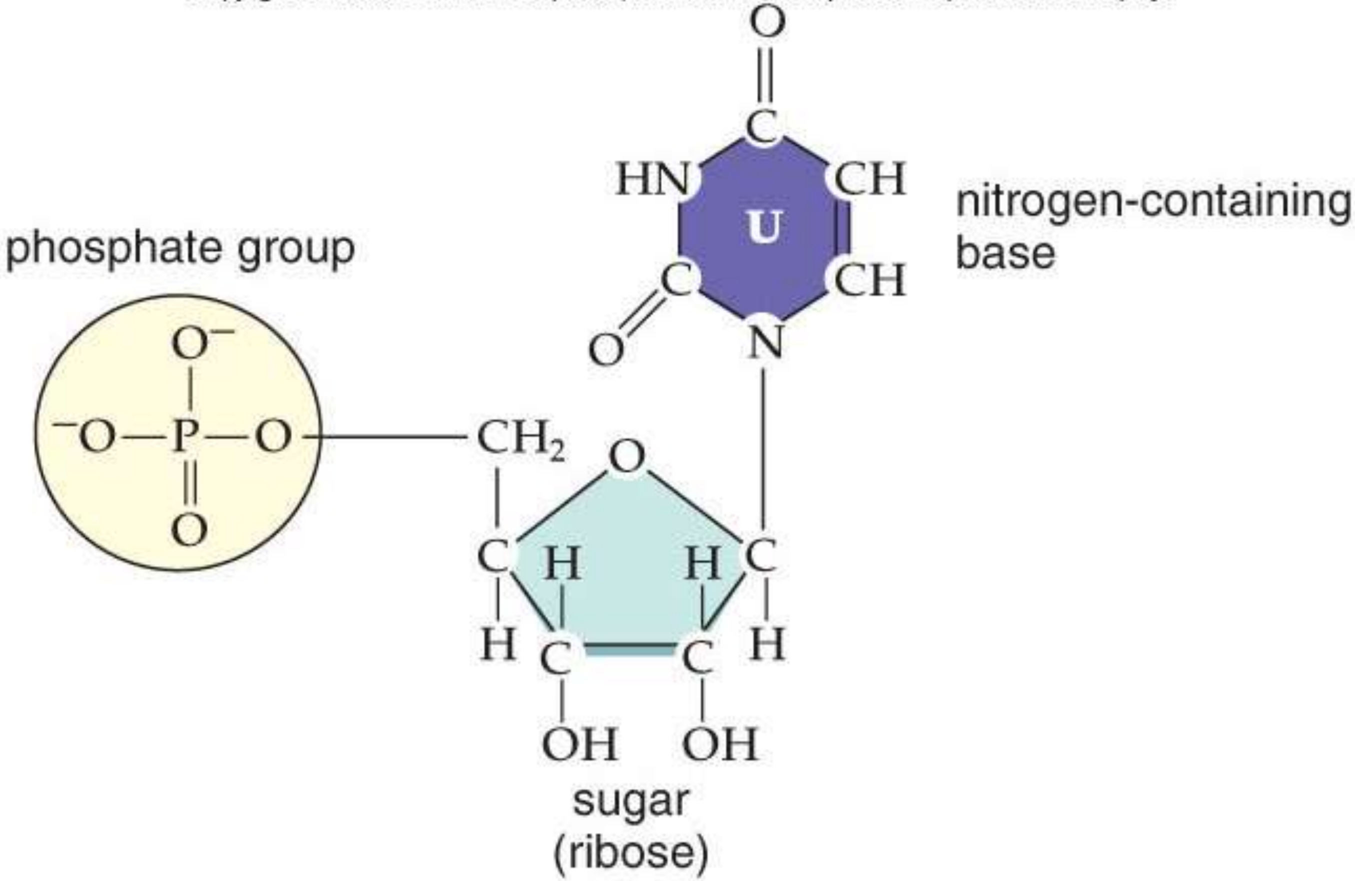


Figure 10.3C The uracil nucleotide in RNA replaces thymine in DNA

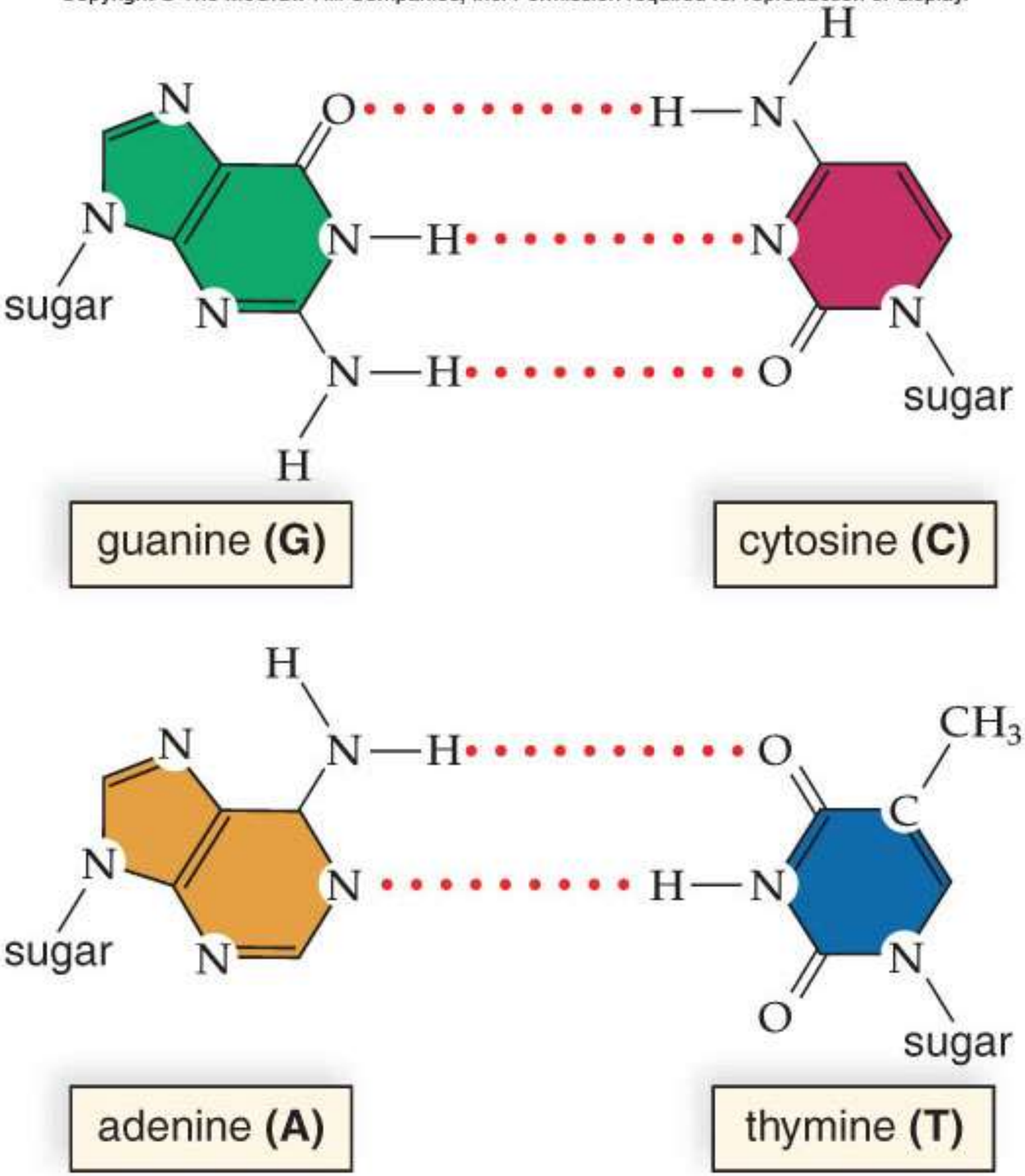


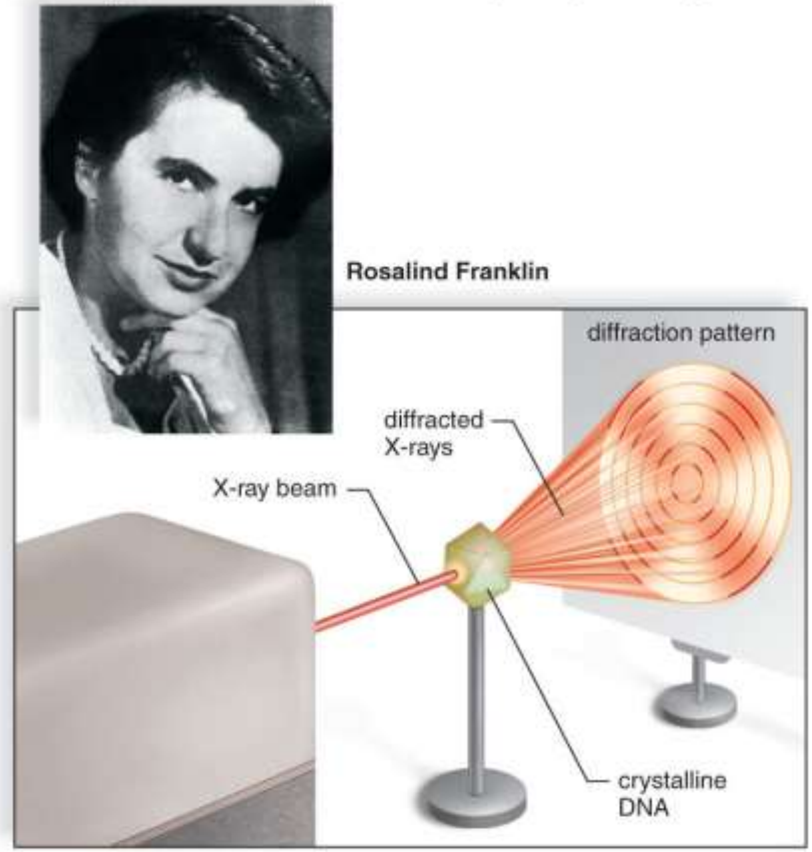
Figure 10.4 Complementary base pairing

Chargaff's rules:

1. **Amount of A,T,C,G vary from species to species**
2. **In each species, amt. of A=T and C=G**

10.5 DNA is a double helix

- The double helix suggests that the stability and variability of the molecule is in the sequence of bases

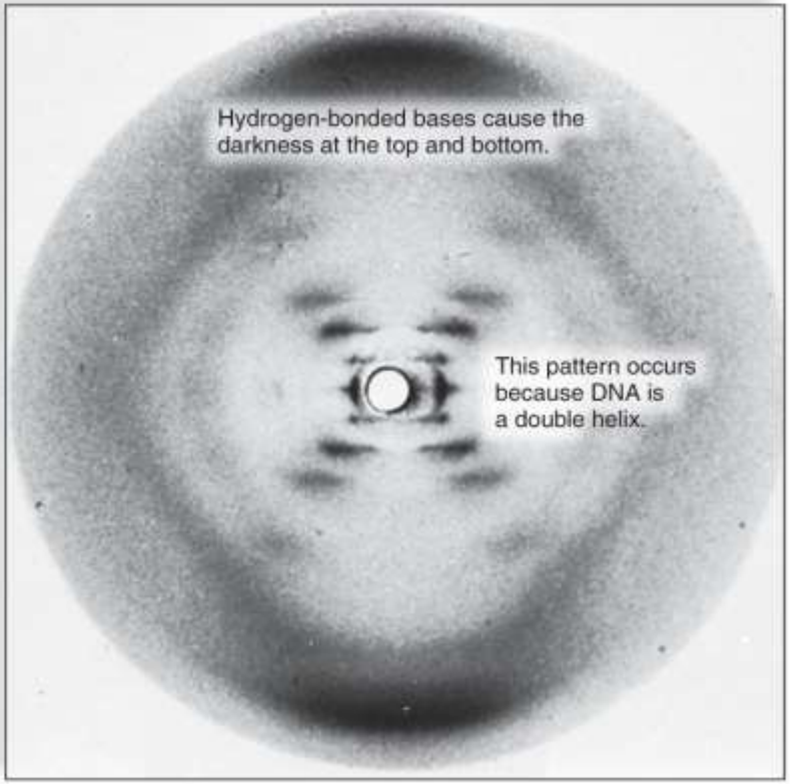


Procedure to obtain X-ray diffraction pattern of DNA

Figure 10.5A X-ray diffraction of DNA

10.5 DNA is a double helix

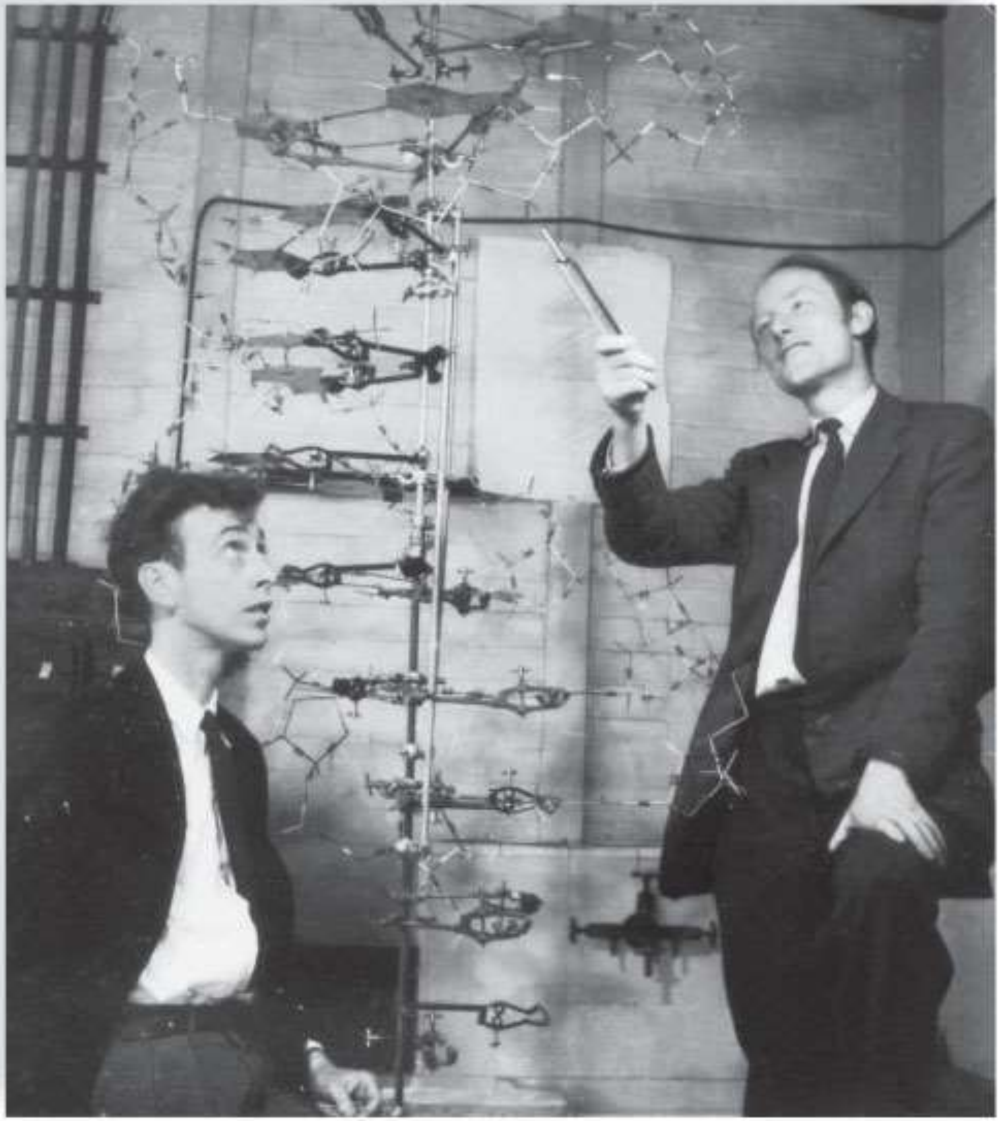
- The double helix suggests that the stability and variability of the molecule is in the sequence of bases



Photograph of diffraction pattern

Figure 10.5A X-ray diffraction of DNA (Cont.)

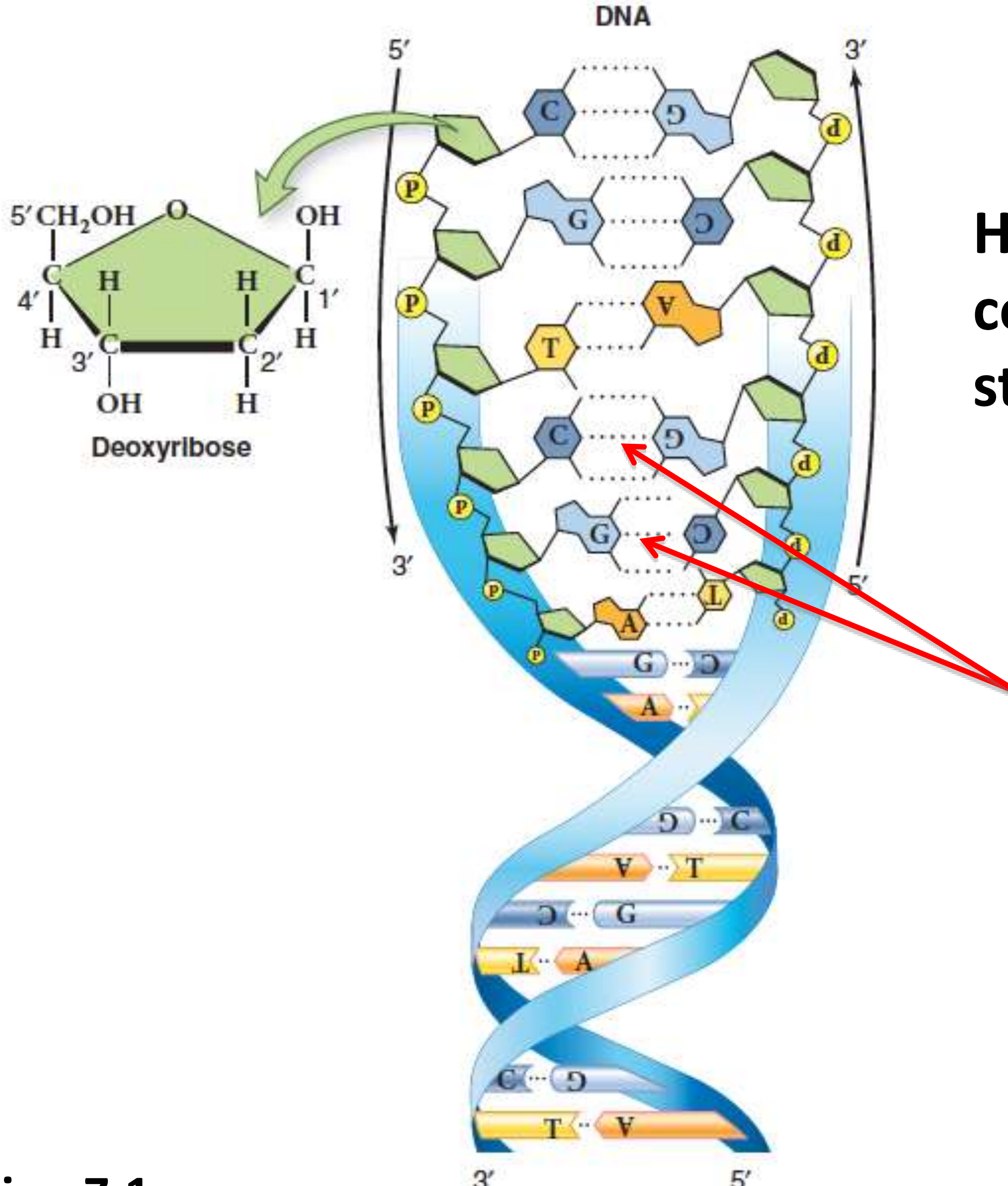
Figure 10.5B The Watson and Crick model of DNA



Watson and Crick with the DNA model they built.

(Watson, Crick): © A. Barrington Brown/Photo Researchers, Inc.

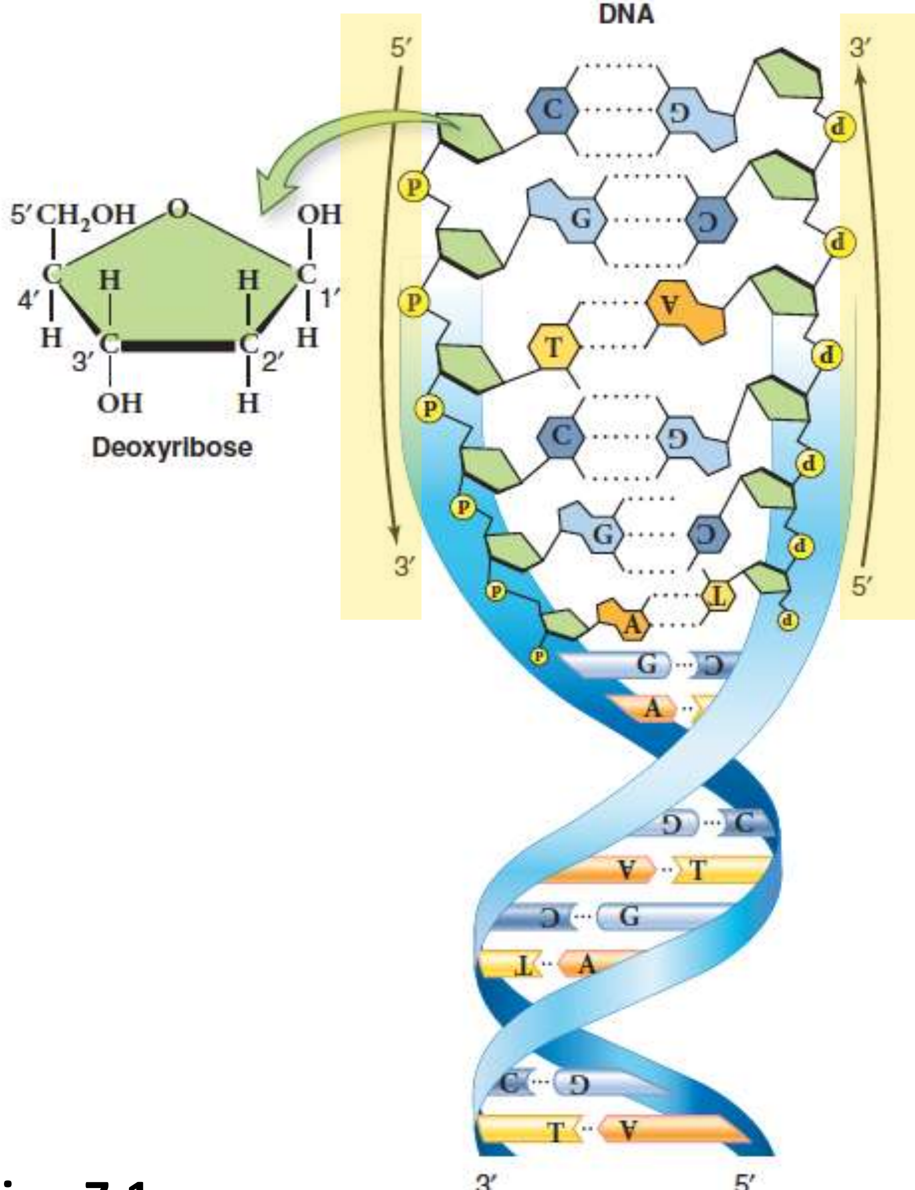
DNA Is a Double Helix



Hydrogen bonds connect complementary DNA strands.

Hydrogen bonds

DNA Is a Double Helix



Opposite ends of the strand are designated 5' and 3'. Note that the strands are oriented in different directions.

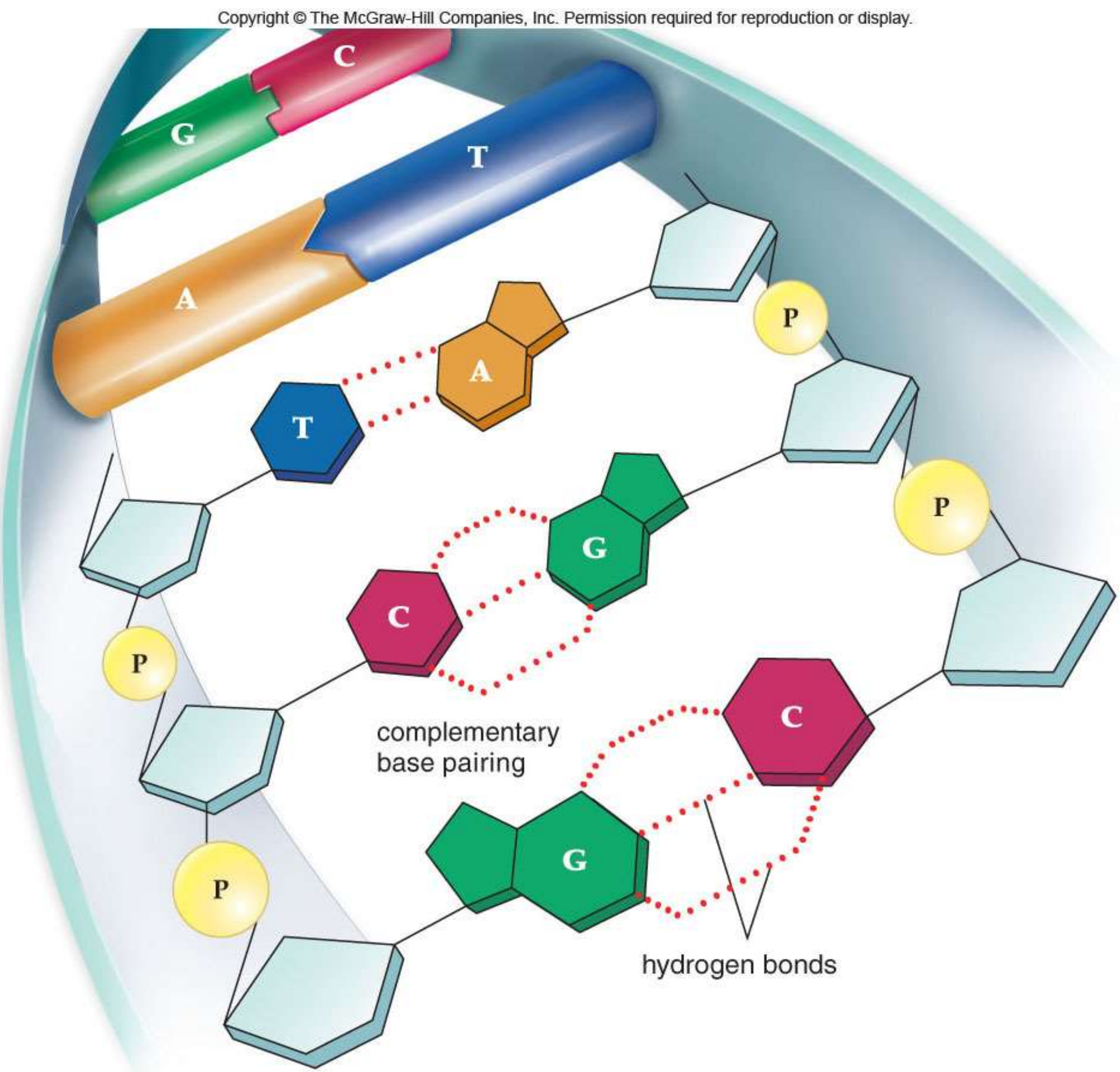
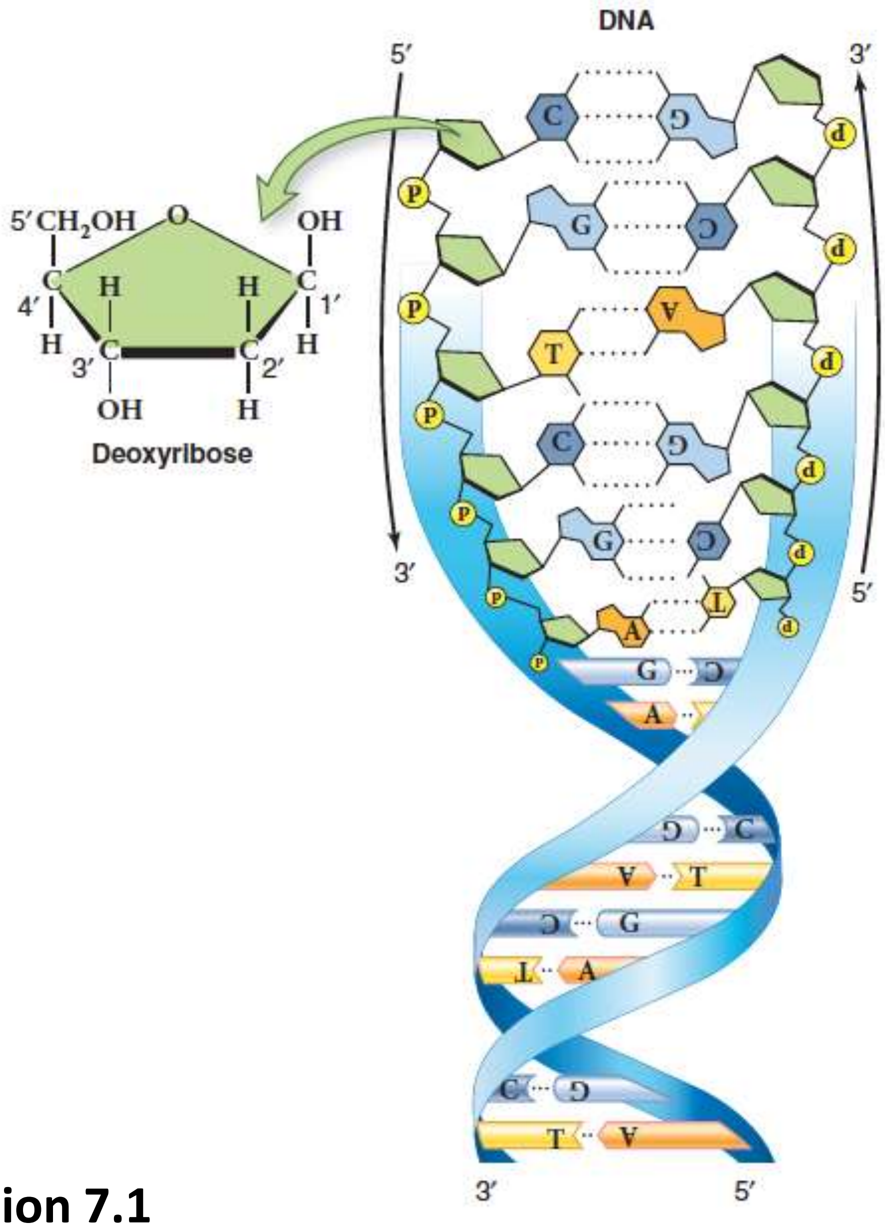


Figure 10.5B The Watson and Crick model of DNA (Cont.)

DNA Is a Double Helix



The nucleotide sequence in one strand therefore determines the sequence in the other strand. The two strands are complementary.

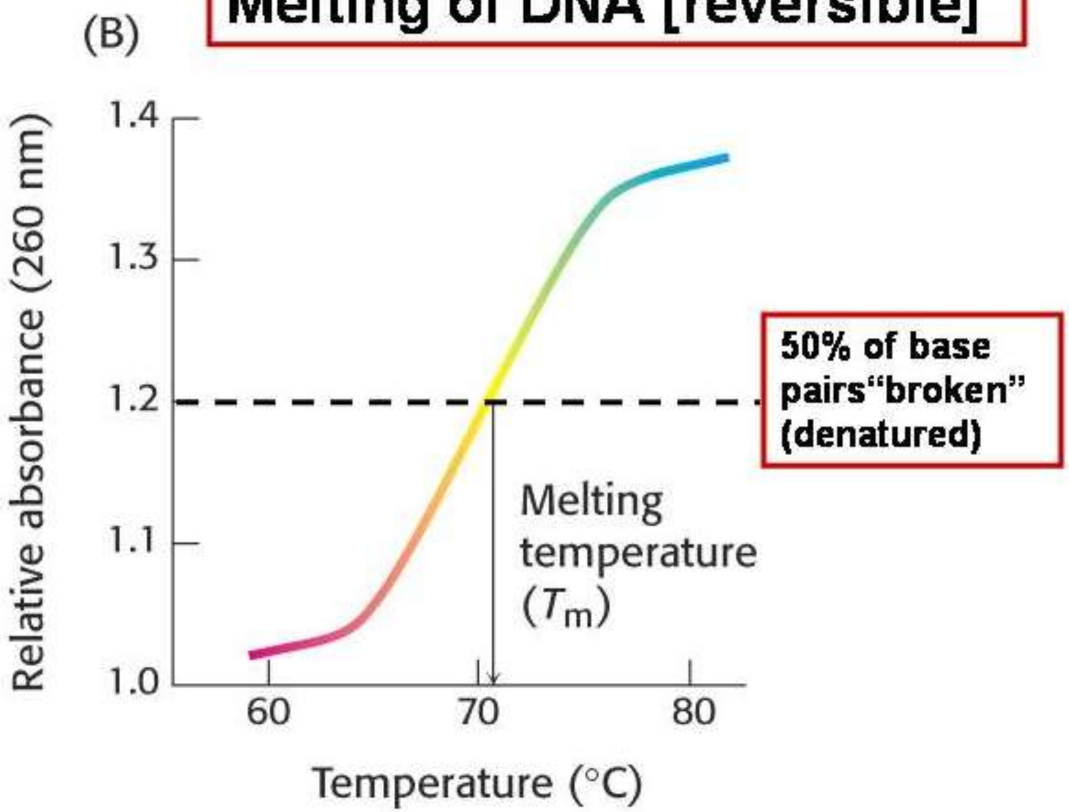
What forces make DNA a double helix?

- Attractiveness of bases
- Repulsion forces of oxygen in phosphate backbone
- Hydrophobic interactions of bases with water

What type of bonds cause DNA to wind into a double helix?

- Hydrophobic- keep H_2O out of DNA helix from negatively charged phosphates
- Hydrogen bonding between A-T and C-G
- Van der waals- optimize space in electron cloud by **base stacking** (i.e. certain molecular combinations are more stable and ergo better at stacking energy
- Covalent- DNA polymer itself

Melting of DNA [reversible]



DNA Can Be Duplicated

Objectives

- Know the order, steps, location and enzymes responsible for the replication of DNA
- ** Will be an essay question on your exam**

Amazing DNA facts

- Humans share 50% of their DNA with bananas.
- Cells can contain 6-9 feet of DNA. If all the DNA in your body was put end to end, it would reach to the sun and back over 600 times.
- DNA in all humans is 99.9 percent identical. It is about one tenth of one percent that makes us all unique, or about 3 million nucleotides difference.

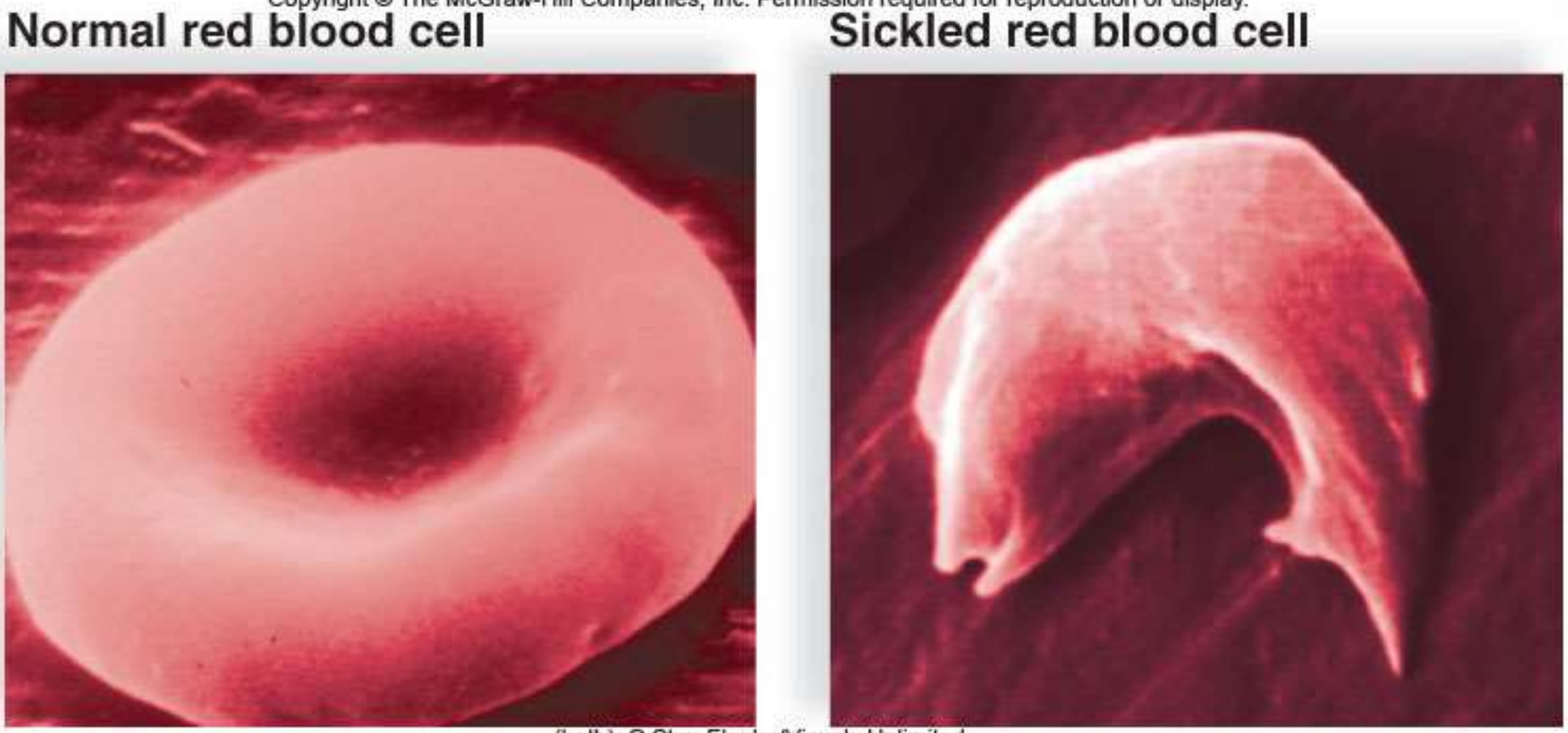
Amazing facts cont.

- DNA can store **25** gigabytes of information per inch and is the most efficient storage system known to human. So, humans are better than computers!!
- In an average meal, you eat approximately **55,000,000** cells or between **63,000 to 93,000** miles of DNA.
- It would take a person typing 60 words per minute, eight hours a day, around **50** years to type the human genome.

Central Dogma of Biology

10.8 Genes are linked to proteins

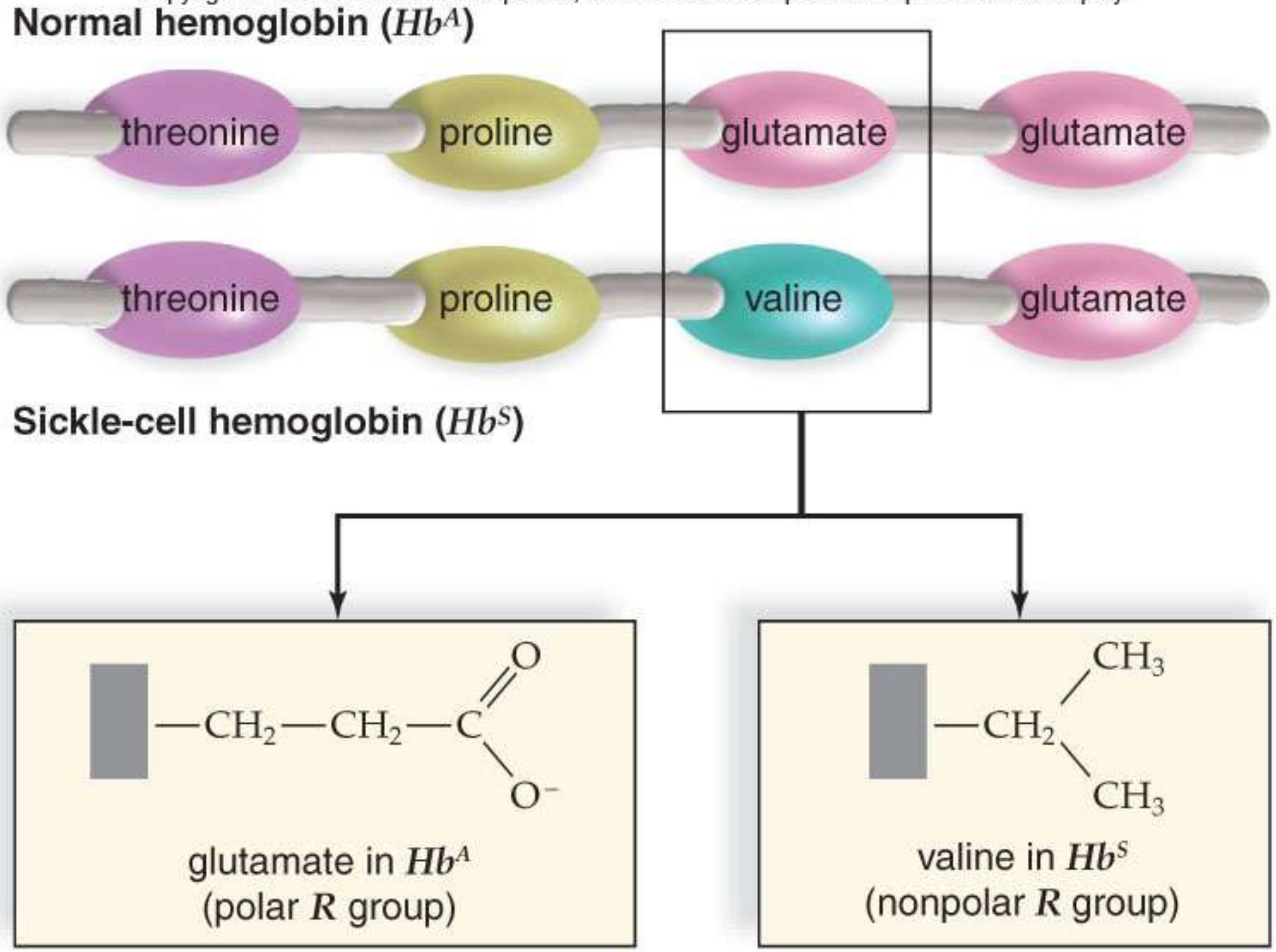
Figure 10.8 Chemical basis of sickle-cell disease in humans



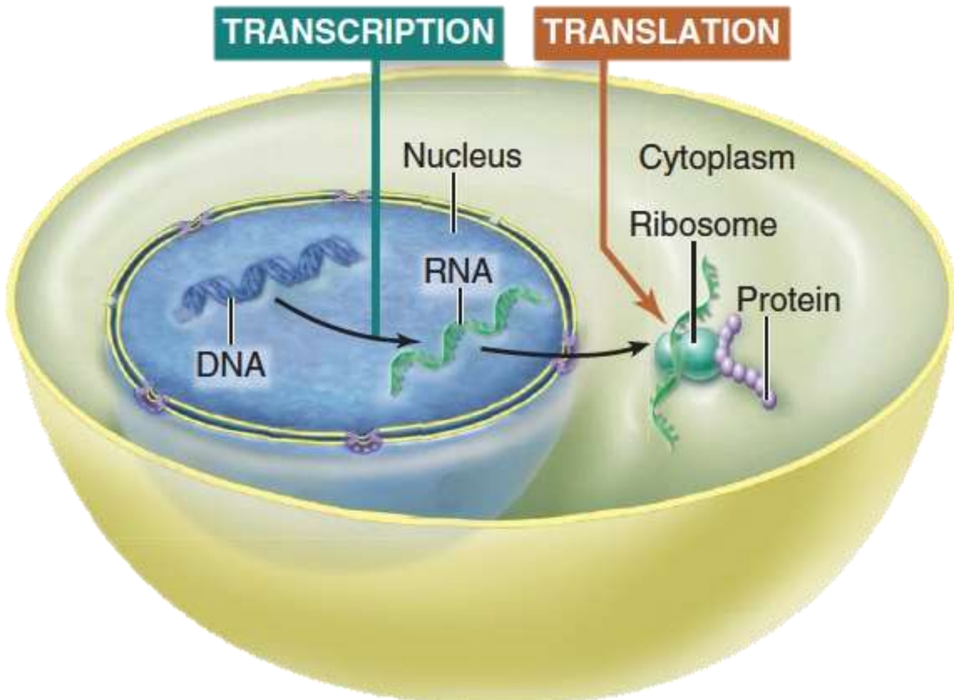
(both): © Stan Flegler/Visuals Unlimited

10.8 Genes are linked to proteins

Figure 10.8 Chemical basis of sickle-cell disease in humans (Cont.)



Protein Production Starts with DNA



Transcription produces an RNA molecule that's complementary to DNA.

In translation, the information in RNA is used to make a protein.

- What is RNA?

Figure 7.8

Protein Production Starts with DNA

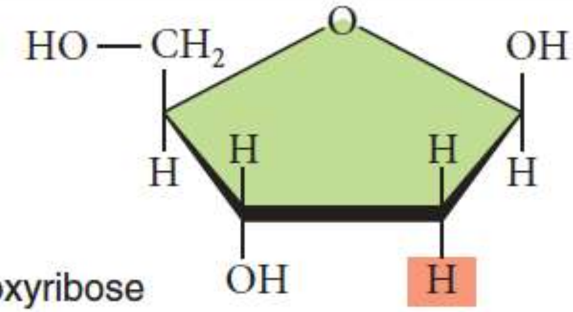
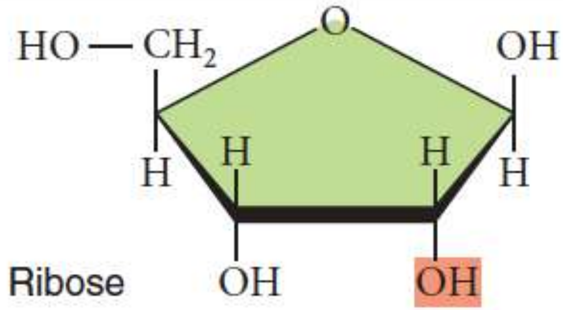
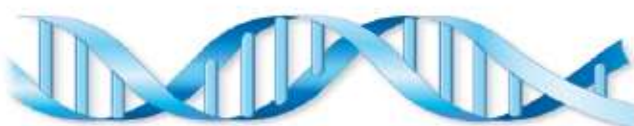
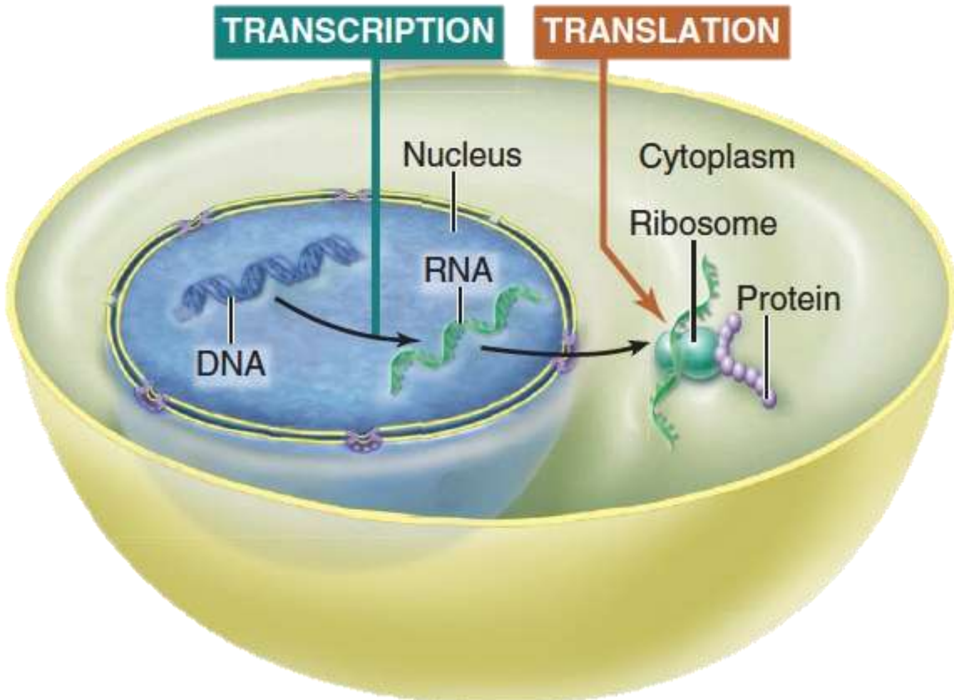
a.	DNA	RNA
Sugar	 Deoxyribose	 Ribose
Nucleotide bases	Adenine (A) Guanine (G) Cytosine (C) Thymine (T)	Adenine (A) Guanine (G) Cytosine (C) Uracil (U)
Form	 Double-stranded	 Generally single-stranded
Functions	Stores RNA- and protein-encoding information; transfers information to next generation of cells	Carries protein-encoding information; helps to make proteins; catalyzes some reactions

Figure 7.9

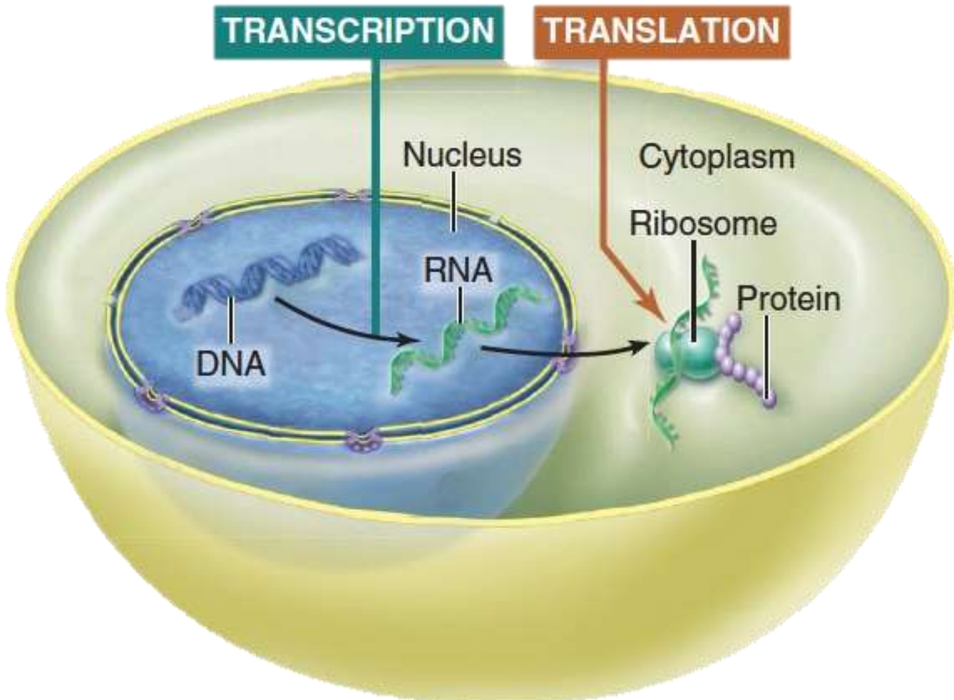
Protein Production Starts with DNA



RNA plays an important role in protein production.

Figure 7.8

Protein Production Starts with DNA



Three types of RNA interact to produce proteins:

- **Messenger RNA (mRNA)**
- **Ribosomal RNA (rRNA)**
- **Transfer RNA (tRNA)**

Figure 7.8

Clicker Question #1

What is the main function of DNA?

A. encode proteins
B. produce ATP
C. speed up cell reactions
D. provide structural support to the cell
E. All of the choices are correct.

Clicker Question #1

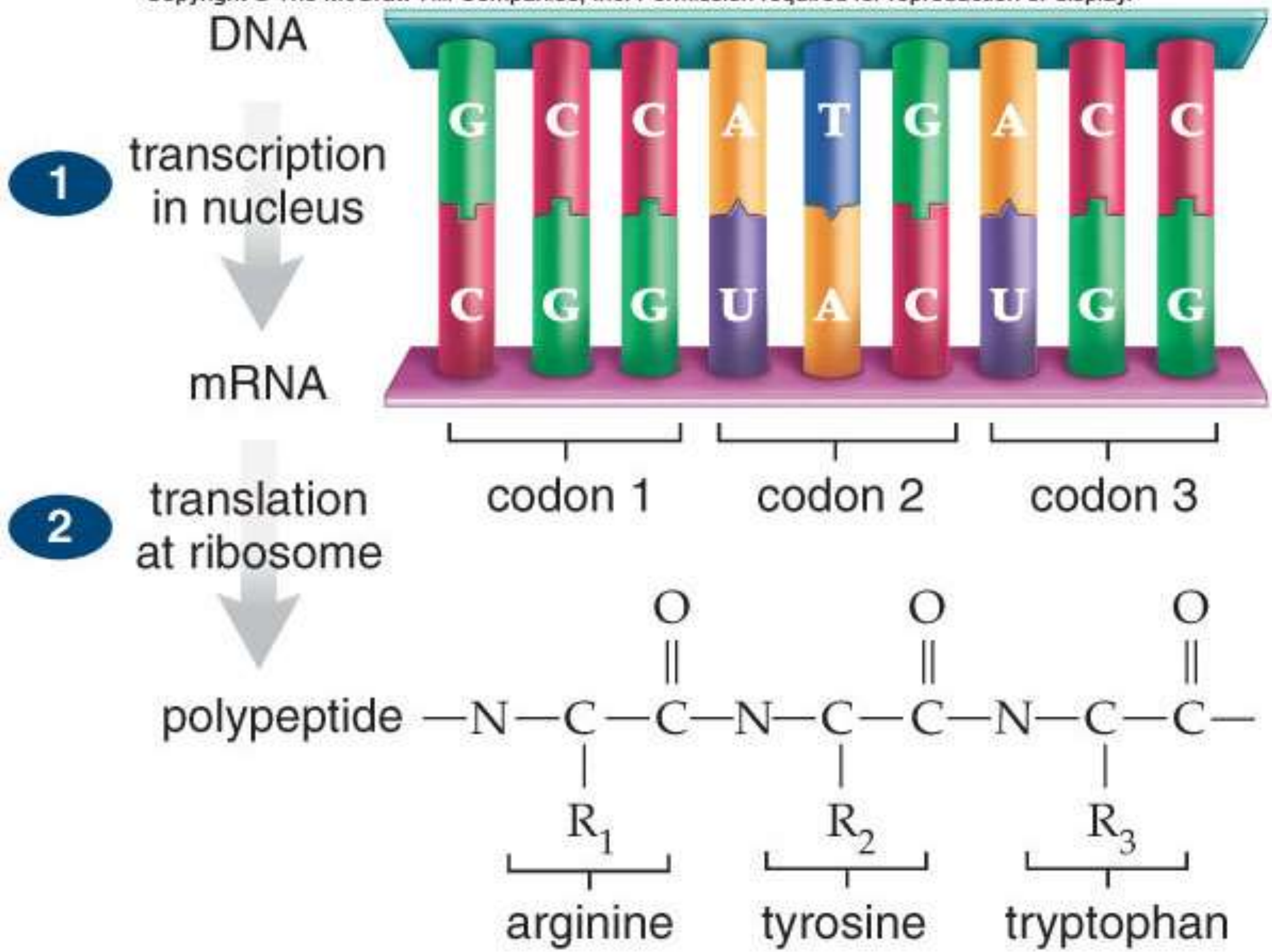
What is the main function of DNA?

A. encode proteins
B. produce ATP
C. speed up cell reactions
D. provide structural support to the cell
E. All of the choices are correct.

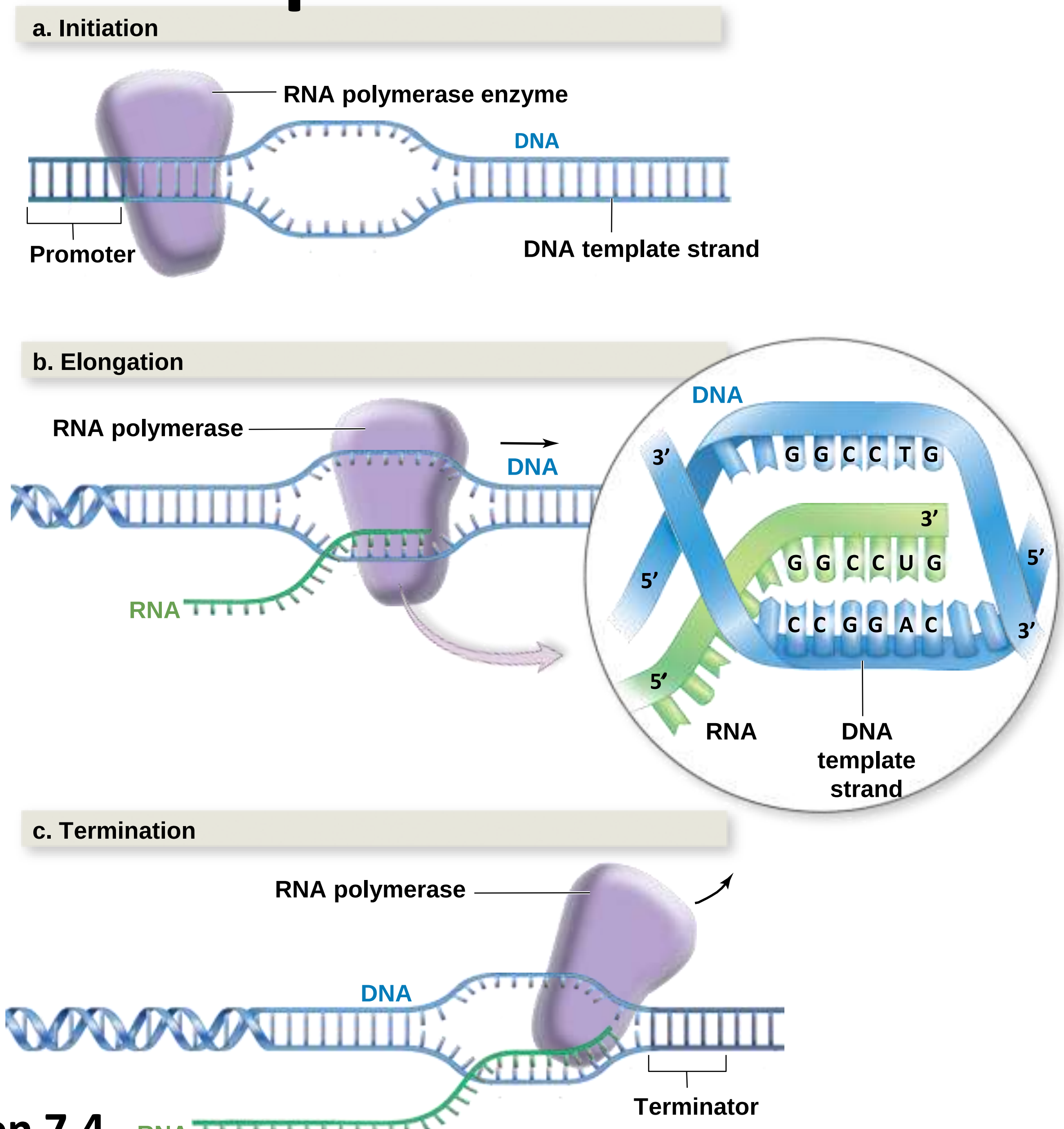
The making of a protein requires transcription and translation

- **Gene -** segment of DNA that specifies the amino acid sequence of a protein
- During **transcription** DNA serves as a template for RNA formation
  - DNA is transcribed, monomer by monomer, into RNA
- During **translation** an RNA transcript directs the sequence of amino acids in a polypeptide

Overview of gene expression



Transcription Uses DNA to Create RNA



Transcription has three steps:

- Initiation
- Elongation
- Termination

We will look at these steps one at a time.

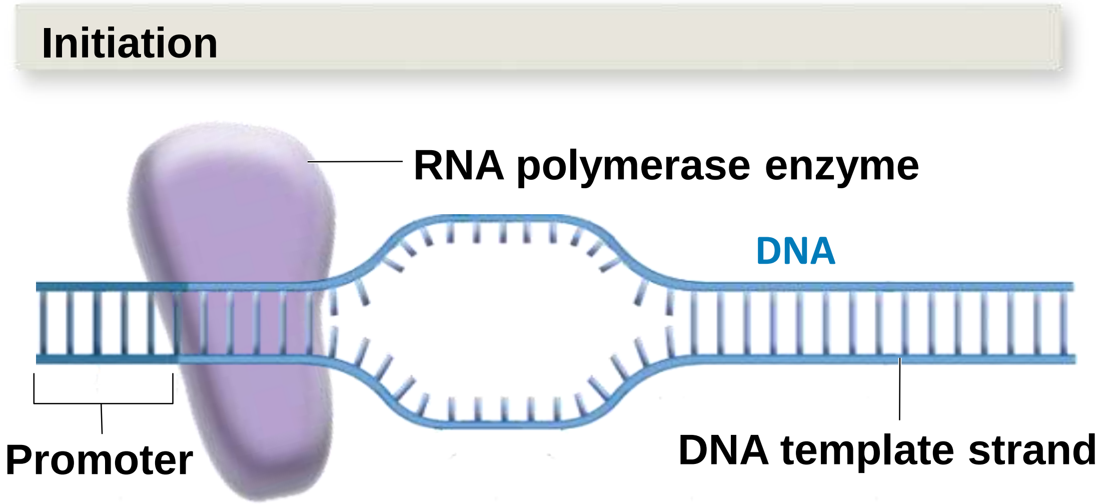
Figure 7.10

During transcription, a gene passes its coded information to an mRNA

- **messenger RNA (mRNA) -** takes instructions from DNA in the nucleus to the ribosomes in the cytoplasm
- **RNA polymerase** joins the nucleotides together
  - **Promoter** defines the start of a gene, the direction of transcription, and the strand to be transcribed
- Stop sequence causes RNA polymerase to stop transcribing the DNA and to release the mRNA molecule, called an **mRNA transcript**

Transcription Uses DNA to Create RNA

Initiation

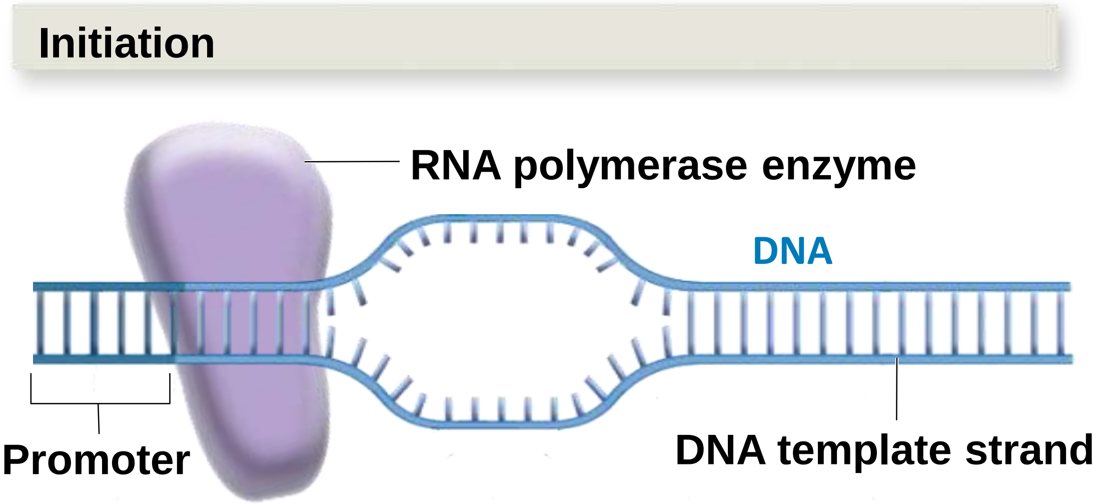


RNA polymerase binds to the promoter (TATA box), which is the beginning of the gene.

Figure 7.10

Transcription Uses DNA to Create RNA

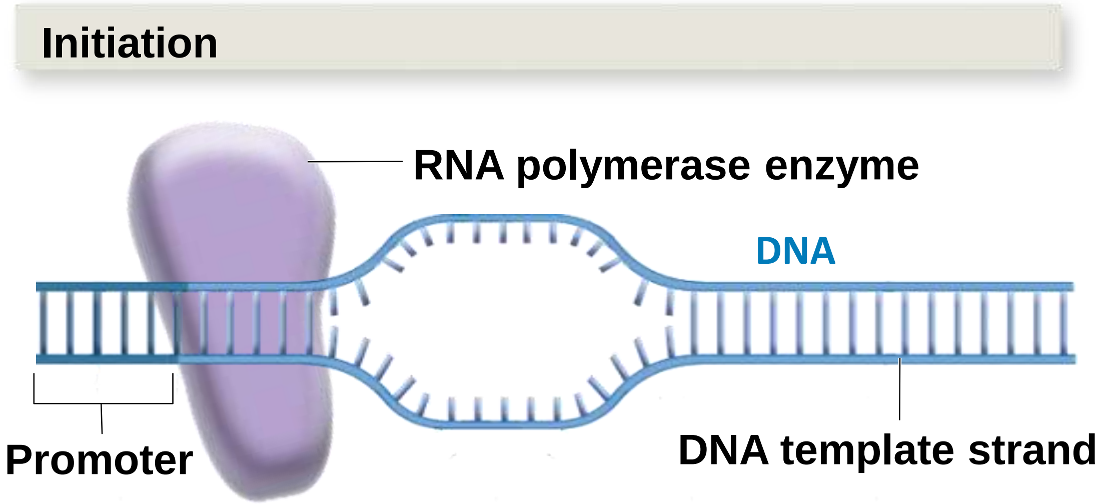
Initiation



Enzymes (not shown) unzip the DNA.

Transcription Uses DNA to Create RNA

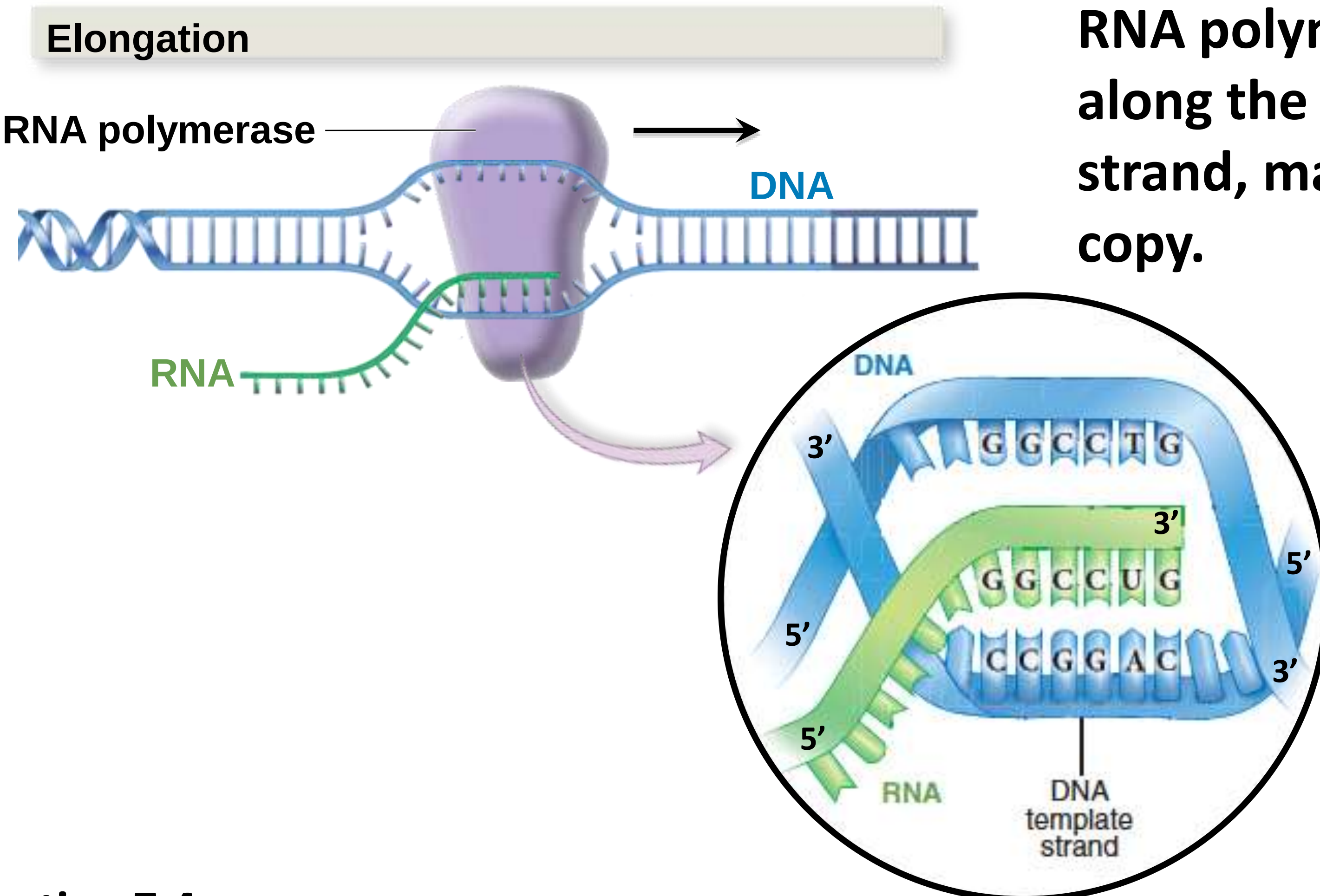
Initiation



The DNA template strand encodes the RNA molecule.

Transcription Uses DNA to Create RNA

Elongation

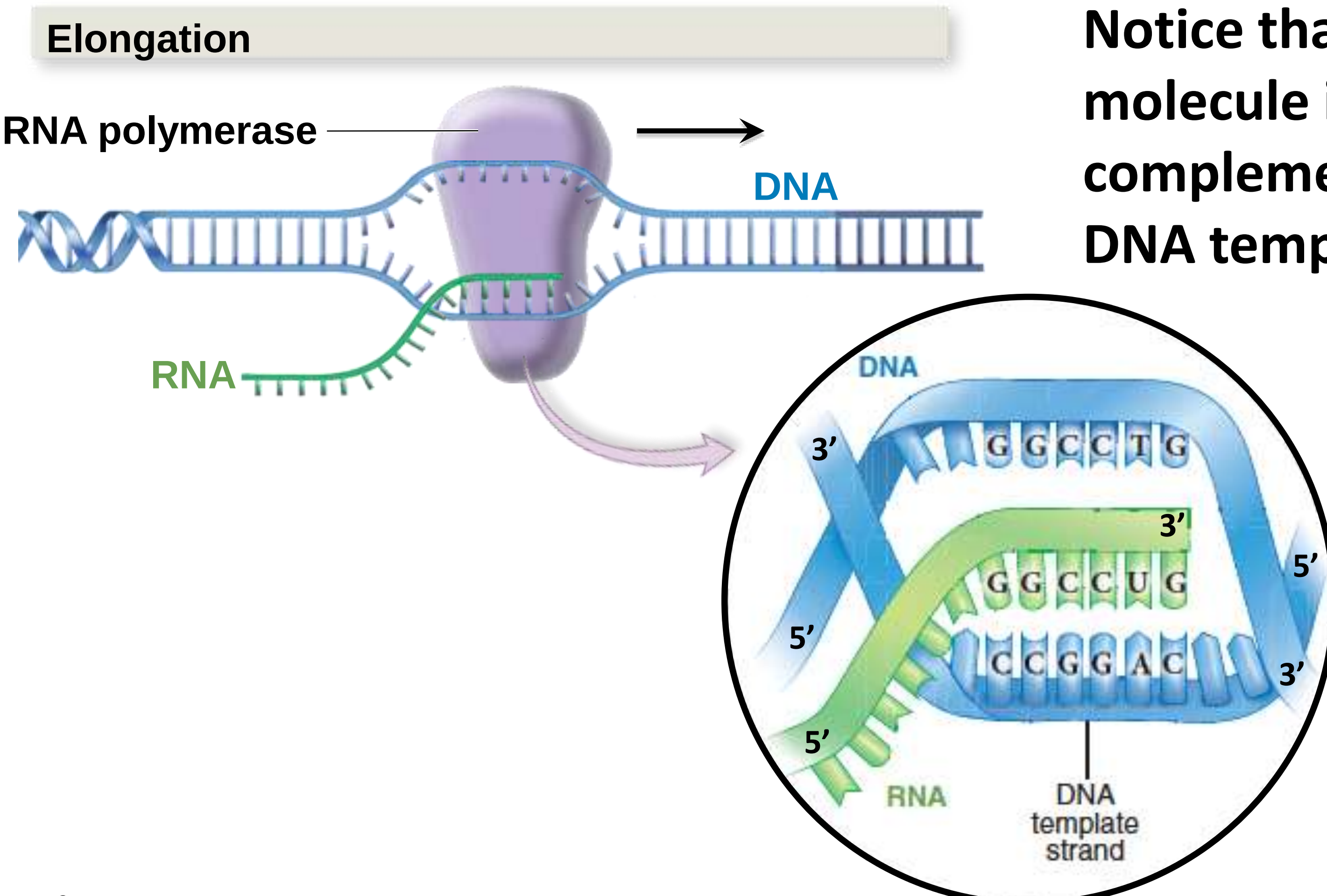


RNA polymerase moves along the template strand, making an RNA copy.

Figure 7.10

Transcription Uses DNA to Create RNA

Elongation

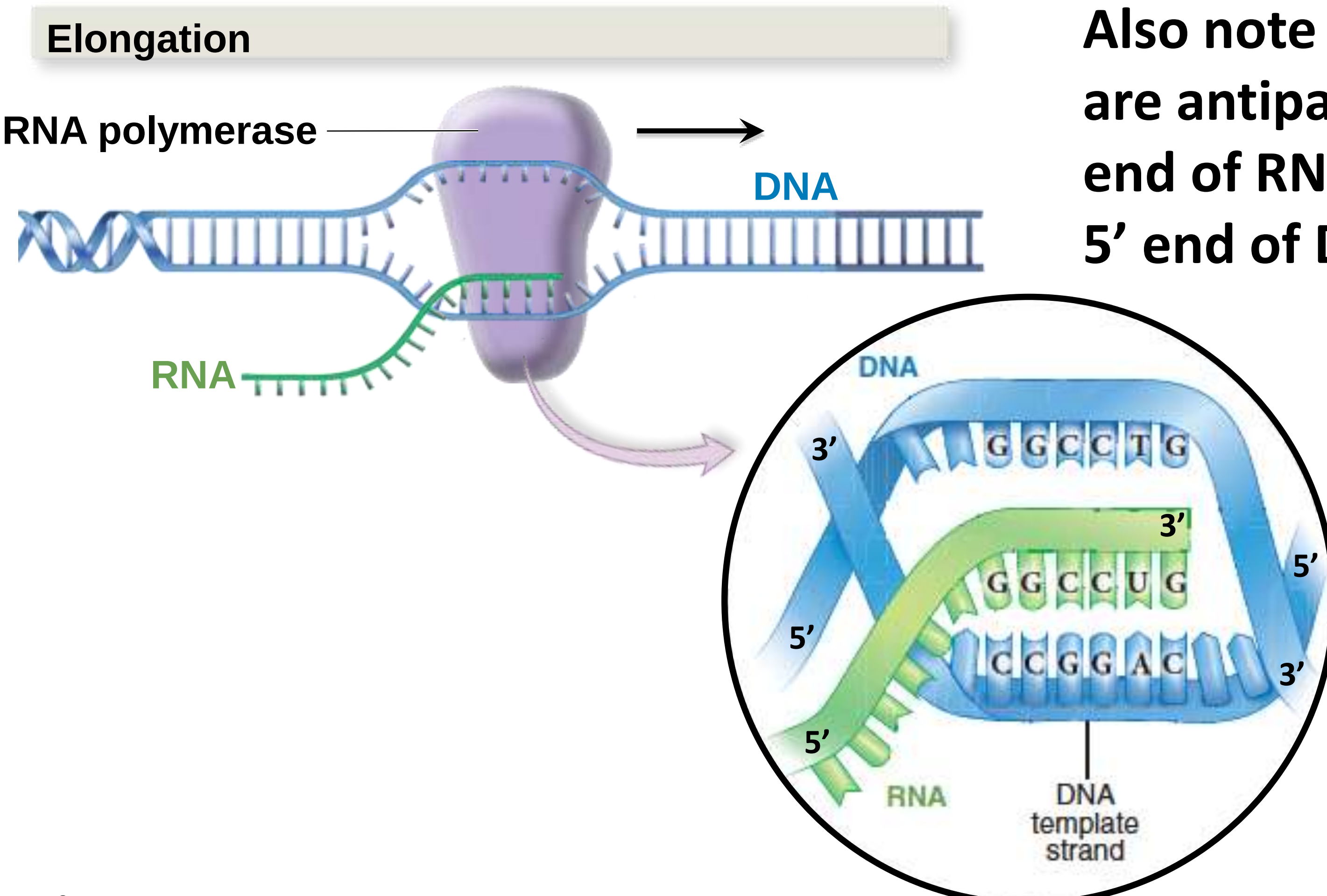


Notice that the RNA molecule is complementary to the DNA template strand.

Figure 7.10

Transcription Uses DNA to Create RNA

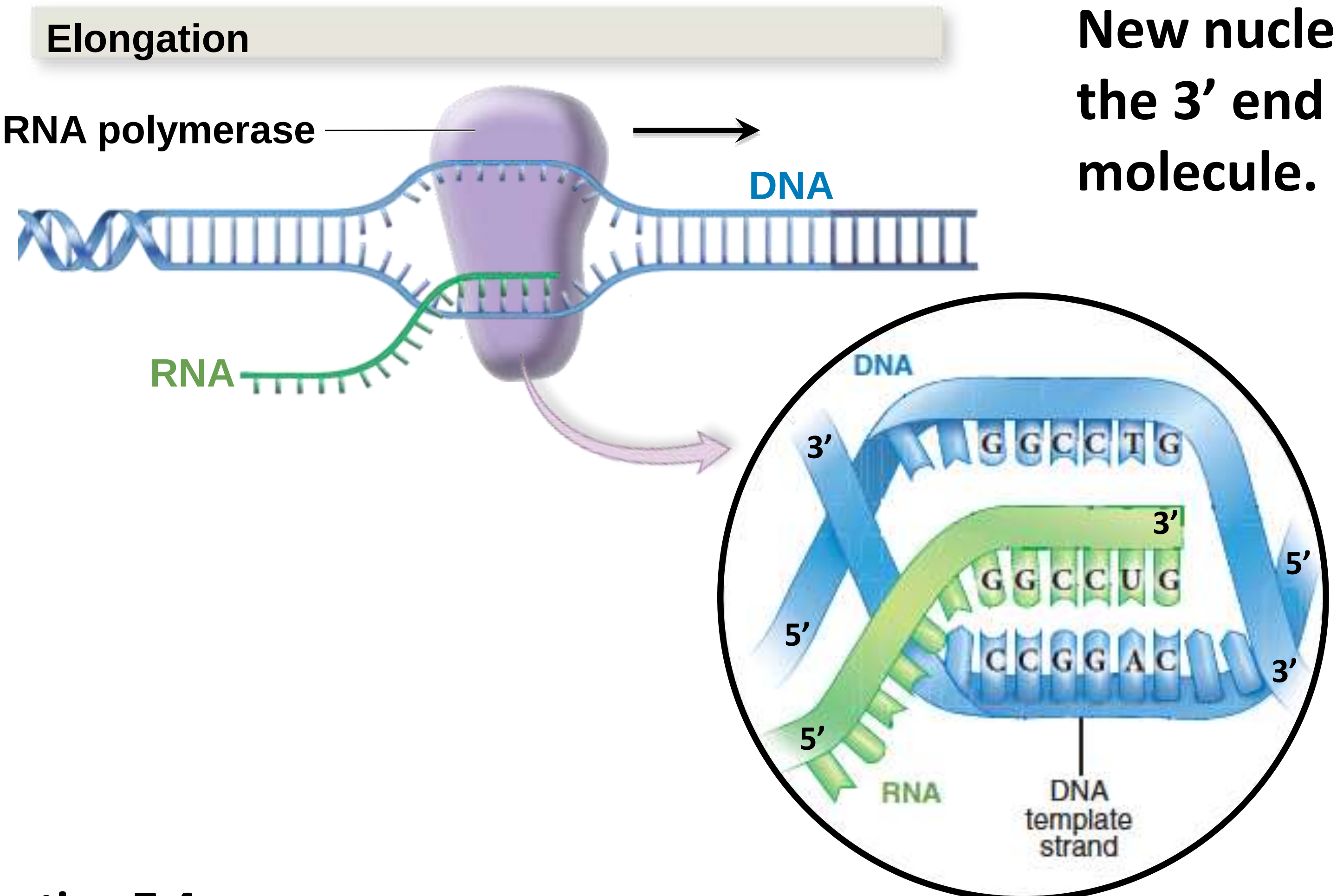
Elongation



Also note that the strands are antiparallel: the 3’ end of RNA matches the 5’ end of DNA.

Transcription Uses DNA to Create RNA

Elongation

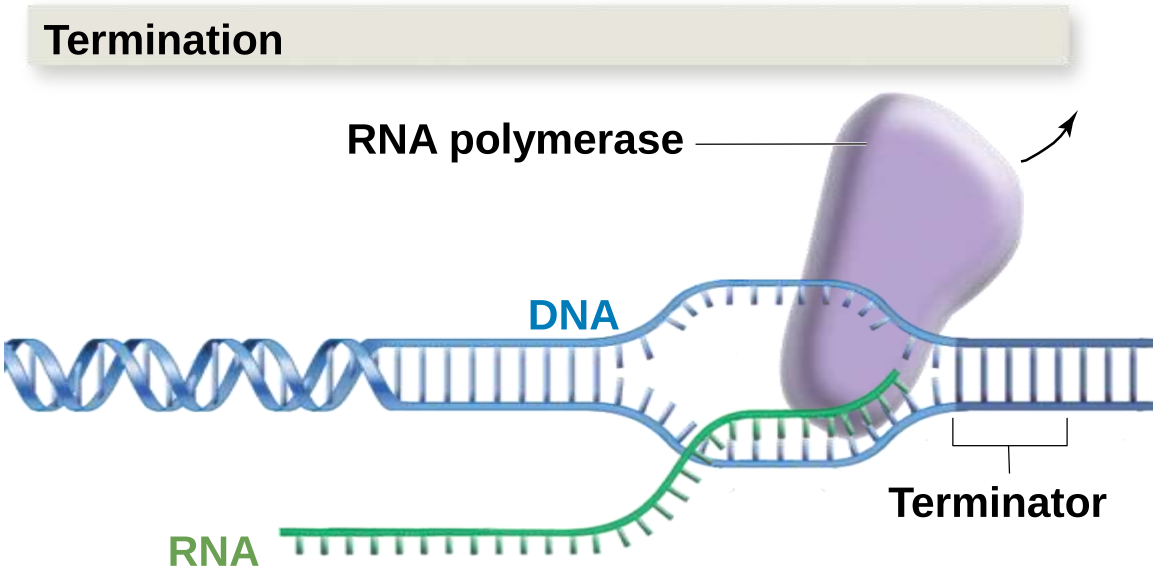


New nucleotides add to the 3′ end of the RNA molecule.

Figure 7.10

Transcription Uses DNA to Create RNA

Termination

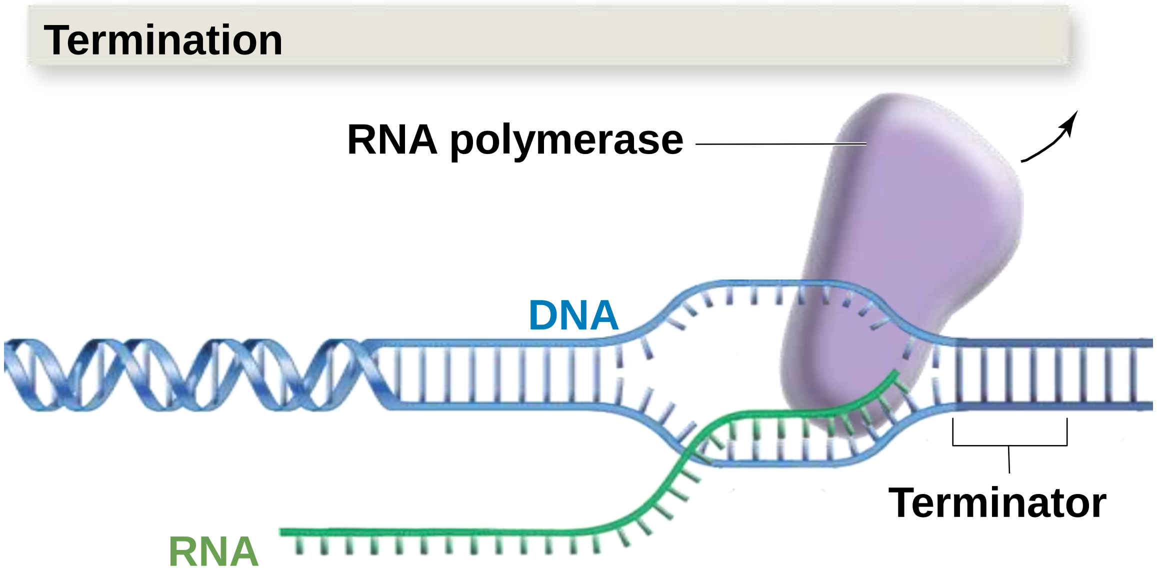


RNA polymerase reaches the terminator, which is the end of the gene.

Figure 7.10

Transcription Uses DNA to Create RNA

Termination



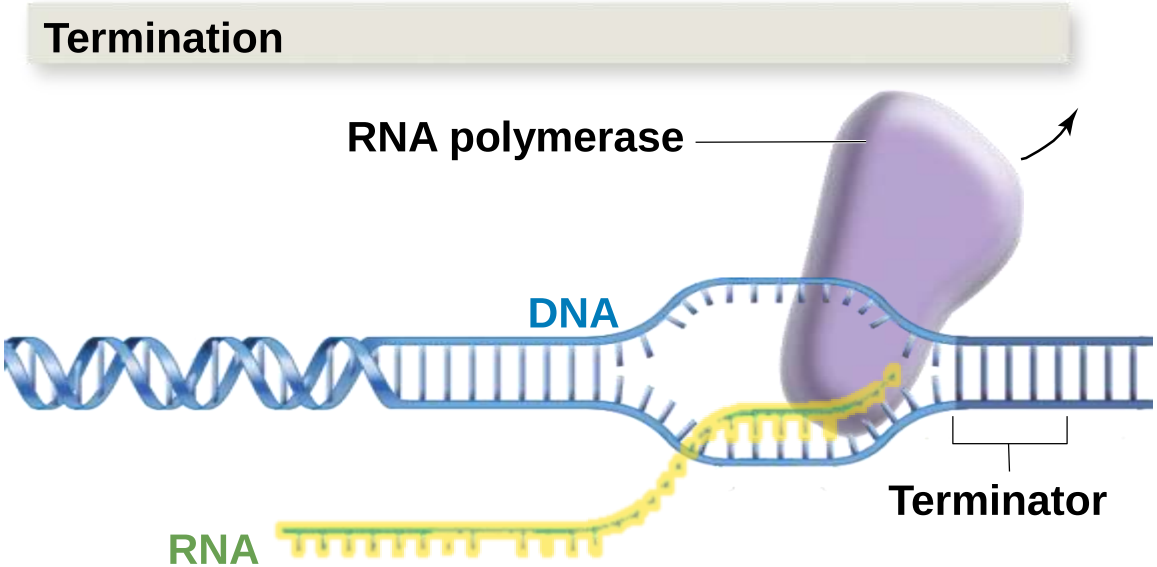
RNA, DNA, and RNA polymerase separate.

DNA becomes a double helix again.

Figure 7.10

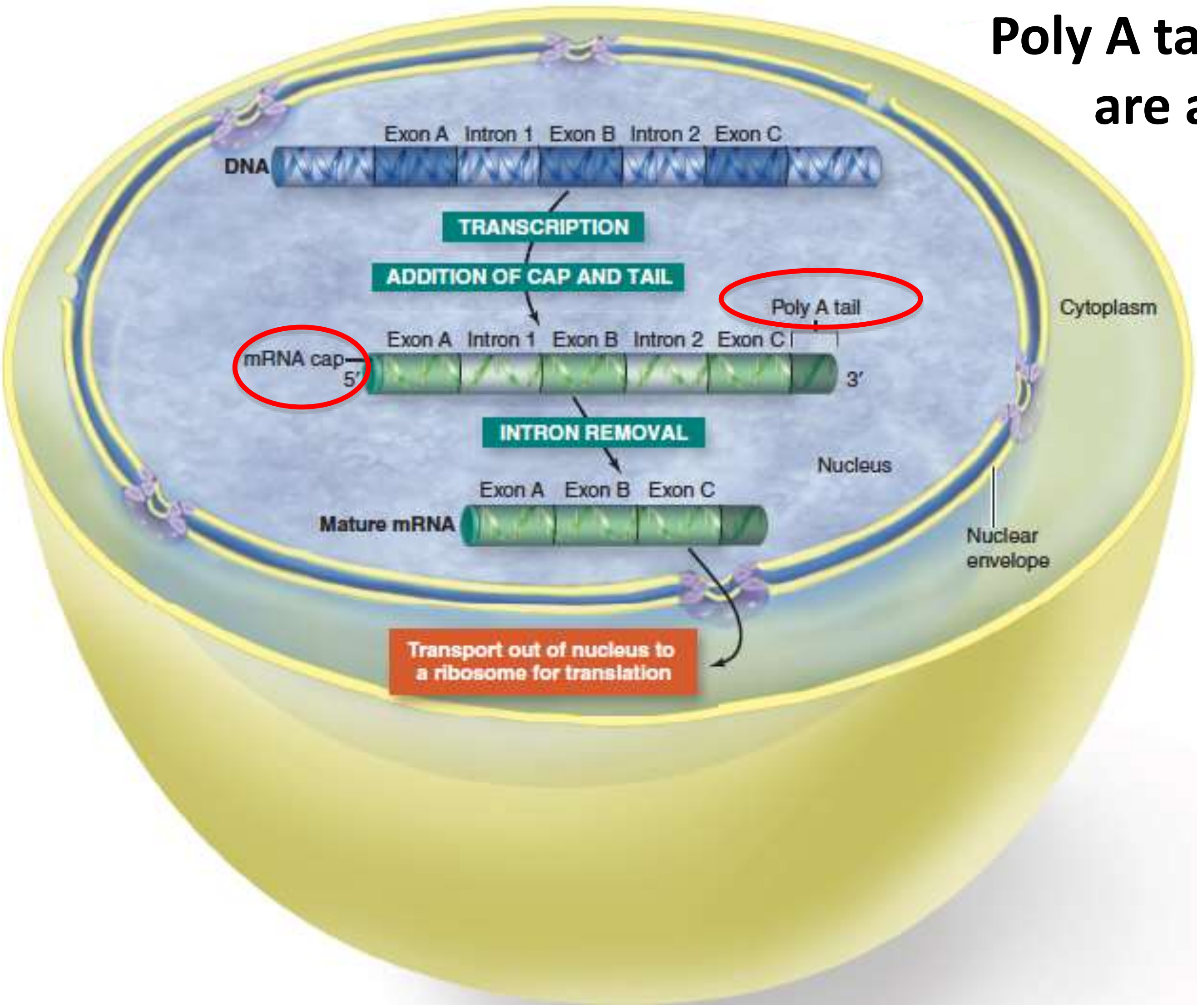
Transcription Uses DNA to Create RNA

Termination



The cell produced an RNA copy of a gene!

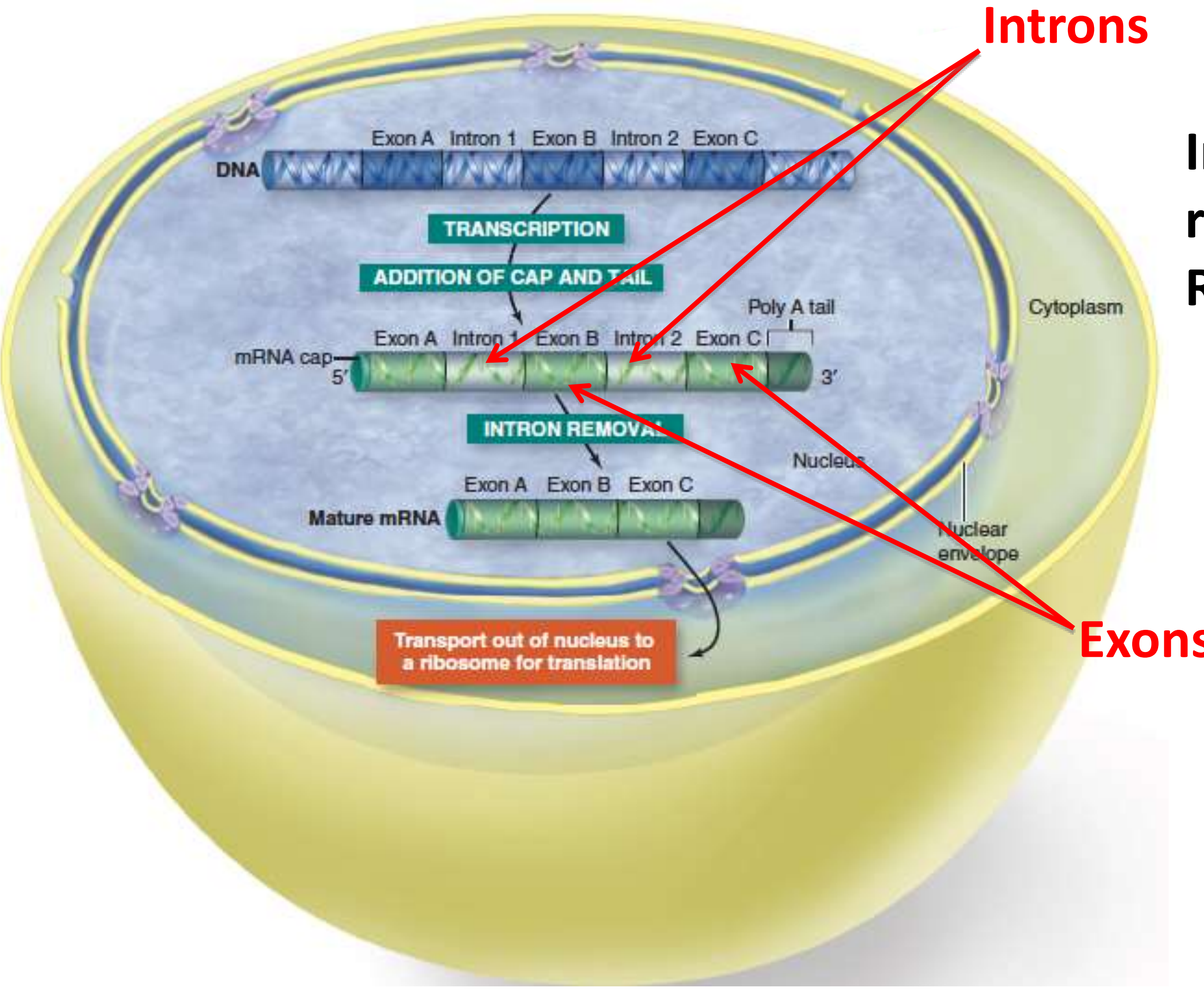
RNA Is Processed in the Nucleus



Poly A tail and mRNA cap are added to the RNA.

Figure 7.11

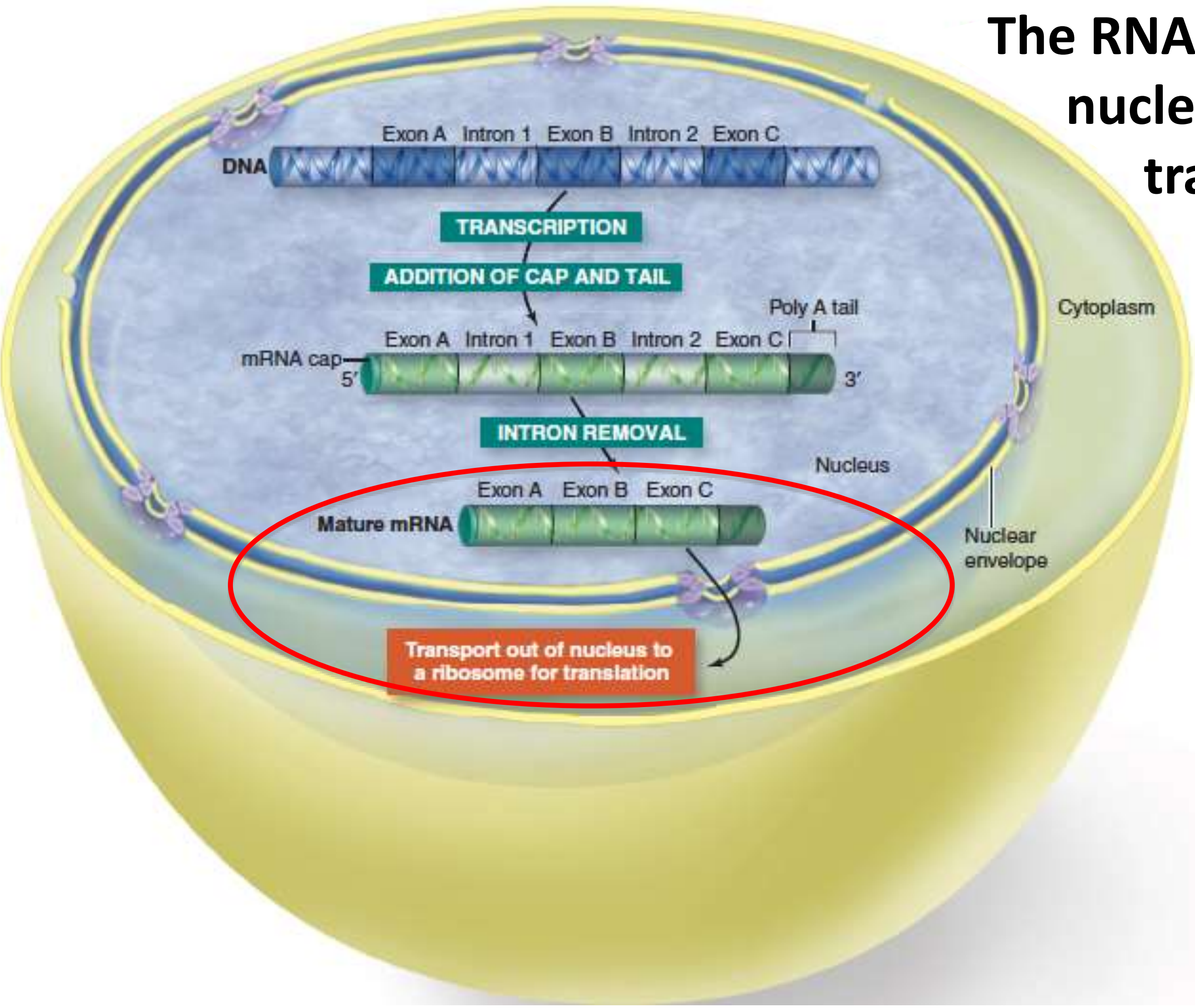
RNA Is Processed in the Nucleus



Introns are removed from the RNA molecule.

Figure 7.11

RNA Is Processed in the Nucleus



The RNA then leaves the nucleus. Onward to translation!

Section 7.4

Figure 7.11

In eukaryotes, an mRNA is processed before leaving the nucleus

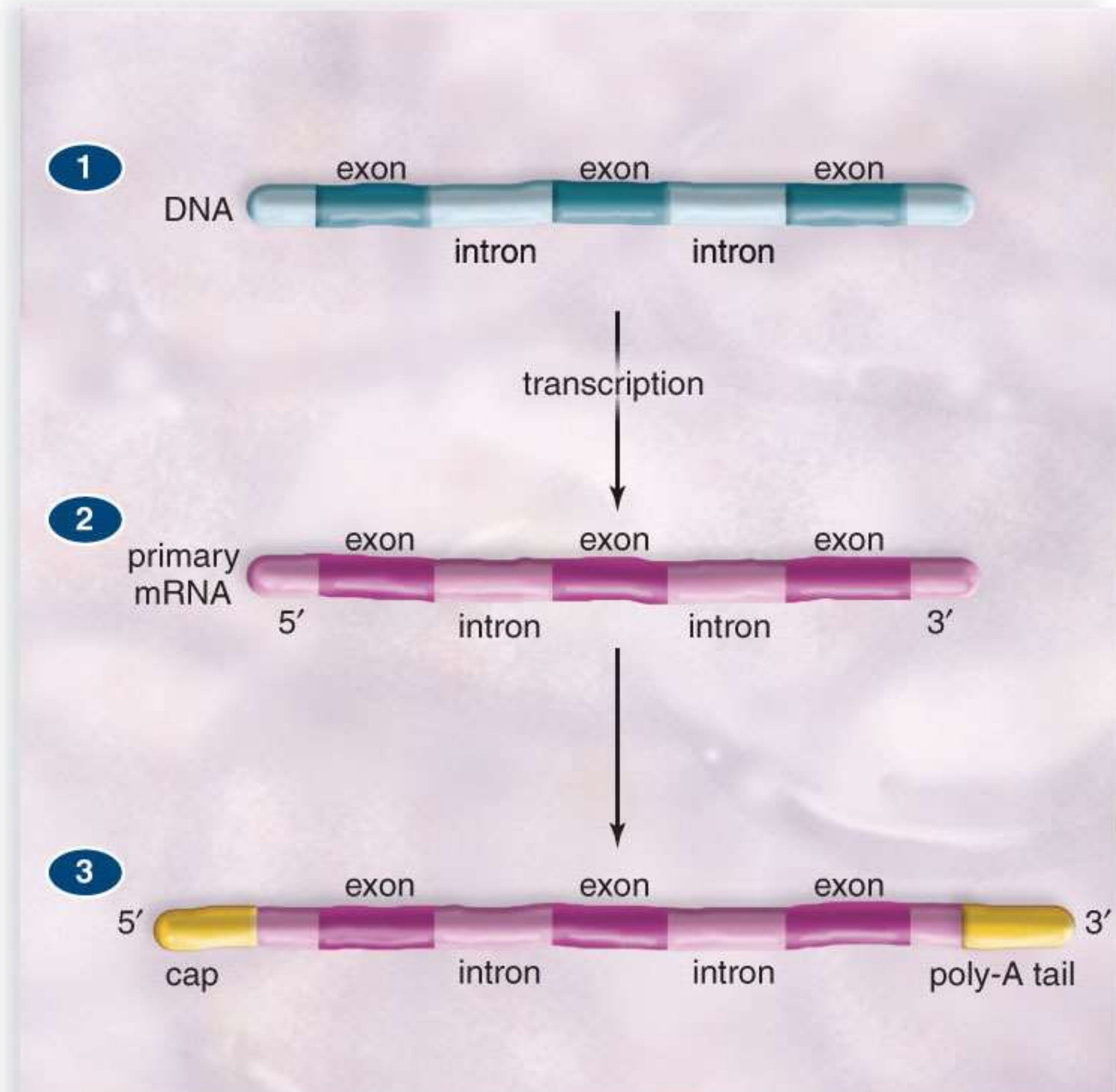
- Primary mRNA is composed of exons and introns
  - The exons of mRNA will be expressed, but the **introns** will not
- **Function of Introns**
  - Might allow exons to be put together in different sequences so that various mRNAs and proteins can result from a single gene
  - Some introns might regulate gene expression by feeding back to determine which coding genes are to be expressed and how they should be spliced

Maturation of mRNA processing in eukaryotes

1. RNA Polymerase makes a transcript of DNA using RNA bases

2. A pre-mRNA from DNA is made that has both introns and exons

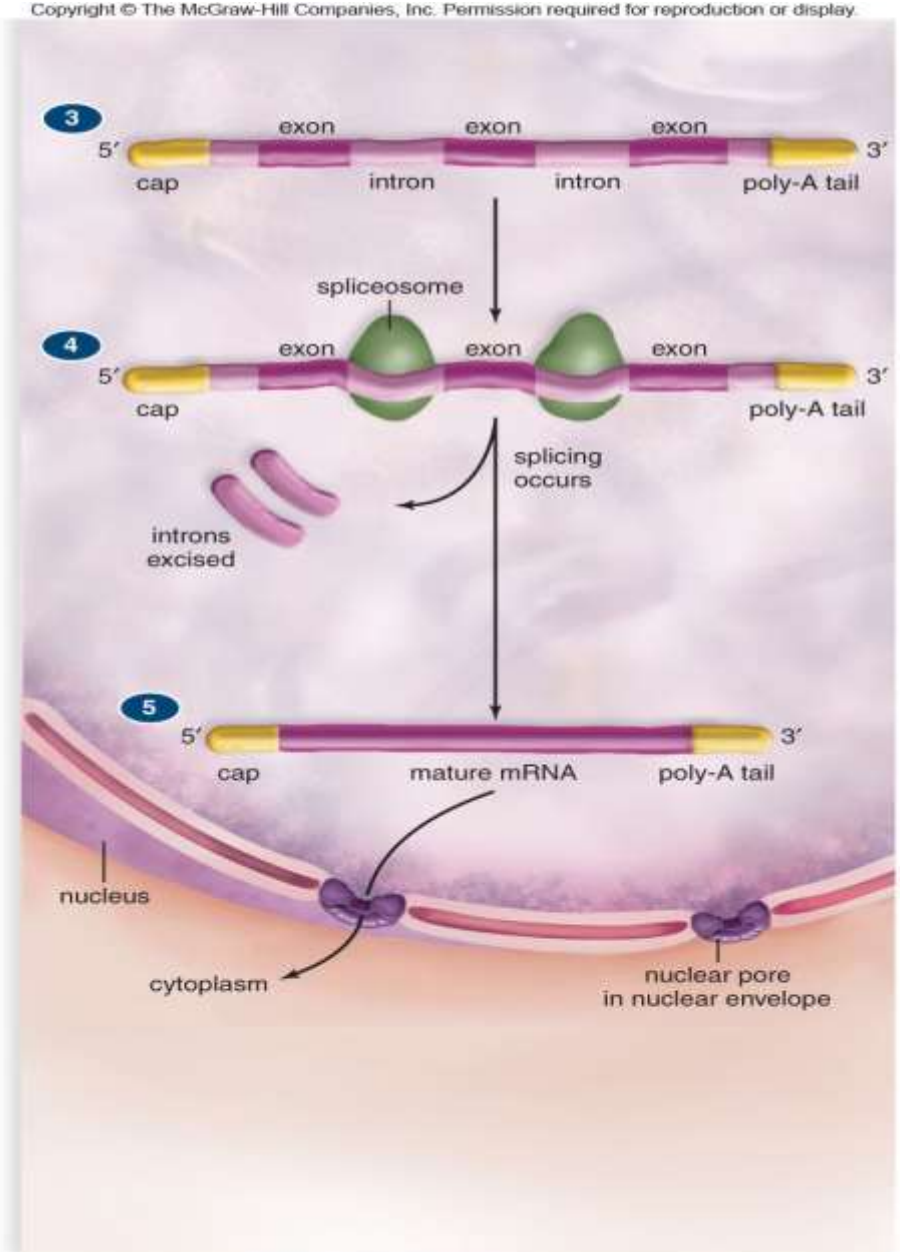
3. A 5’ cap and 3’ poly-A tail are put onto pre-mRNA



Maturation of mRNA processing in eukaryotes

4. Spliceosomes spice the noncoding regions (aka introns)

5. A mautre mRNA is now made with a 5' cap, only exons, and 3' poly-A tail



Clicker Question #2

If the DNA template strand has the following sequence, what would be the nucleotide sequence of the complementary RNA molecule produced in transcription?

Template strand: AGTCTT

A. AGTCTT
B. AGUCUU
C. TCAGAA
D. TCUGUU
E. UCAGAA

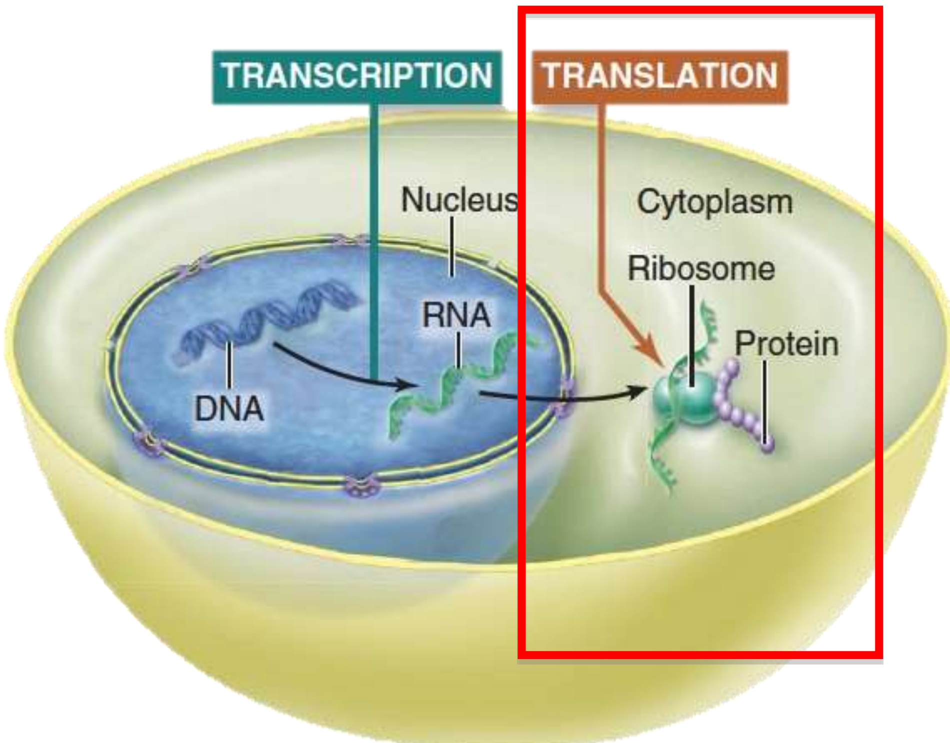
Clicker Question #2

If the DNA template strand has the following sequence, what would be the nucleotide sequence of the complementary RNA molecule produced in transcription?

Template strand: AGTCTT

A. AGTCTT
B. AGUCUU
C. TCAGAA
D. TCUGUU
$\boxed{\text{E. UCAGAA}}$

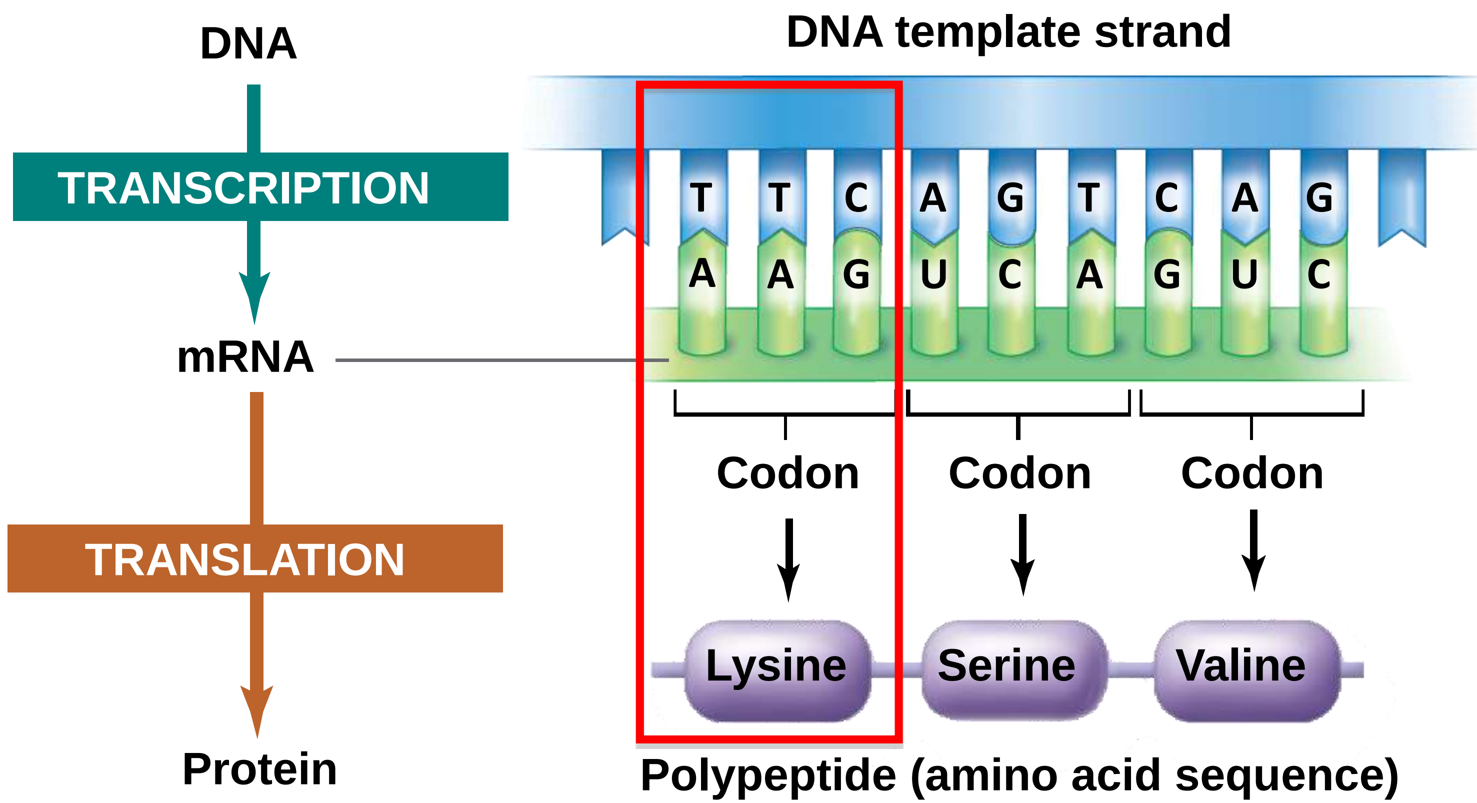
Translation Builds the Protein



Now let's look at how a ribosome uses RNA to produce a protein.

Figure 7.8

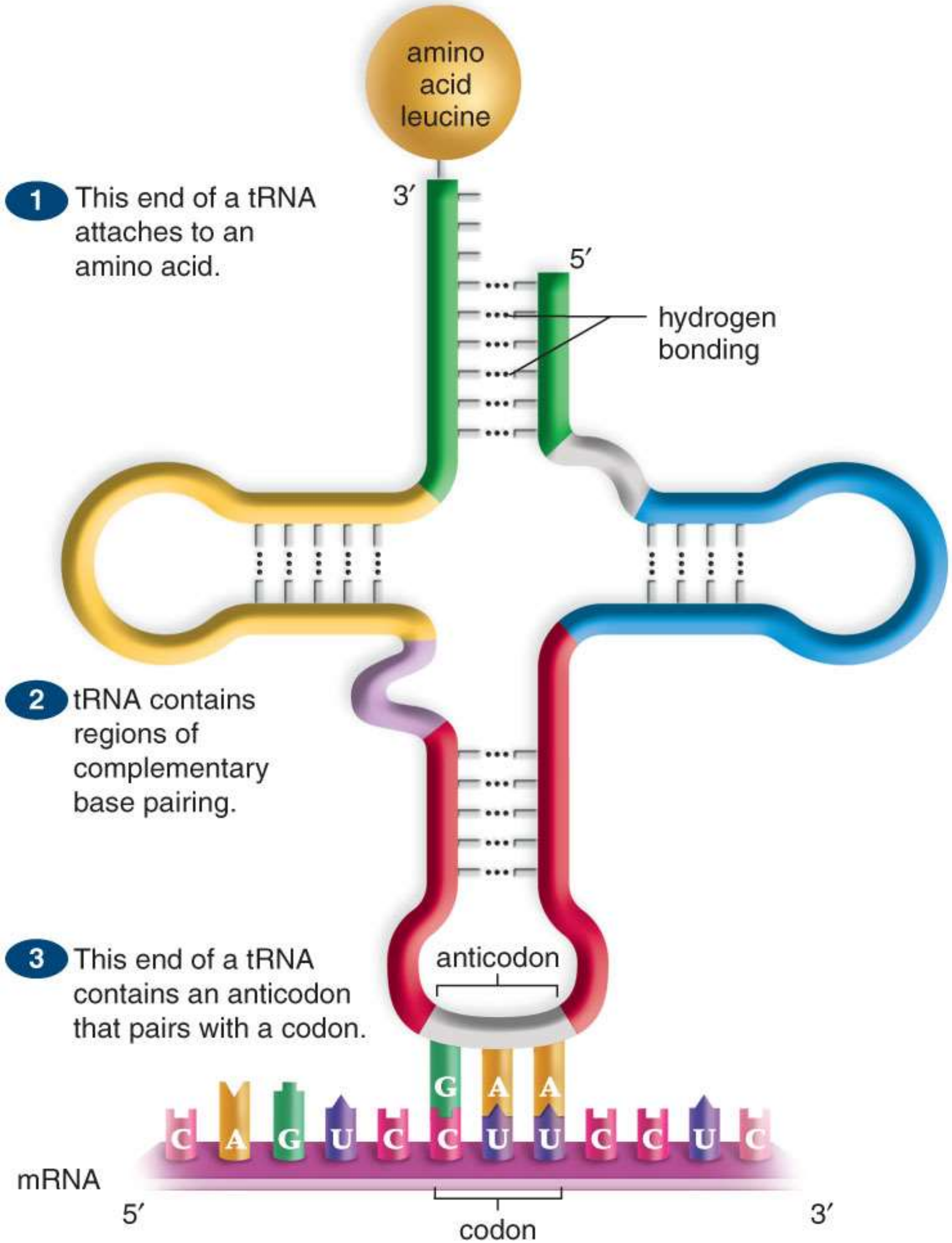
Translation Builds the Protein



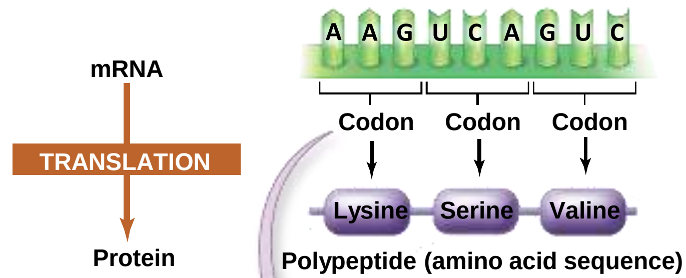
A codon is a three-nucleotide sequence that encodes one amino acid.

Figure 7.12

Cloverleaf model of tRNA



Translation Builds the Protein



The genetic code shows which mRNA codons correspond to which amino acids.

The Genetic Code

Second letter of codon

First letter of codon	U	C	A	G	Third letter of codon
U	UUU Phenylalanine (Phe; F)	UCU Serine (Ser; S)	UAU Tyrosine (Tyr; Y)	UGU Cysteine (Cys; C)	U
	UUC	UCC	UAC	UGC	C
	UUA Leucine (Leu; L)	UCA	UAA Stop	UGA Stop	A
	UUG	UCG	UAG Stop	UGG Tryptophan (Trp; W)	G
C	CUU Leucine (Leu; L)	CCU Proline (Pro; P)	CAU Histidine (His; H)	CGU Arginine (Arg; R)	U
	CUC	CCC	CAC	CGC	C
	CUA	CCA	CAA Glutamine (Gln; Q)	CGA	A
	CUG	CCG	CAG	CGG	G
A	AUU Isoleucine (Ile; I)	ACU Proline (Pro; P)	AAU Asparagine (Asn; N)	AGU Serine (Ser; S)	U
	AUC	ACC	AAC	AGC	C
	AUA	ACA	AAA Lysine (Lys; K)	AGA Arginine (Arg; R)	A
	AUG Start Methionine (Met; M)	ACG	AAG	AGG	G
G	GUU Valine (Val; V)	GCU Proline (Pro; P)	GAU Aspartic acid (Asp; D)	GGU Glysine (Gly; G)	U
	GUC	GCC	GAC	GGC	C
	GUA	GCA	GAA Glutamic acid (Glu; E)	GGA	A
	GUG	GCG	GAG	GGG	G

Figure 7.12

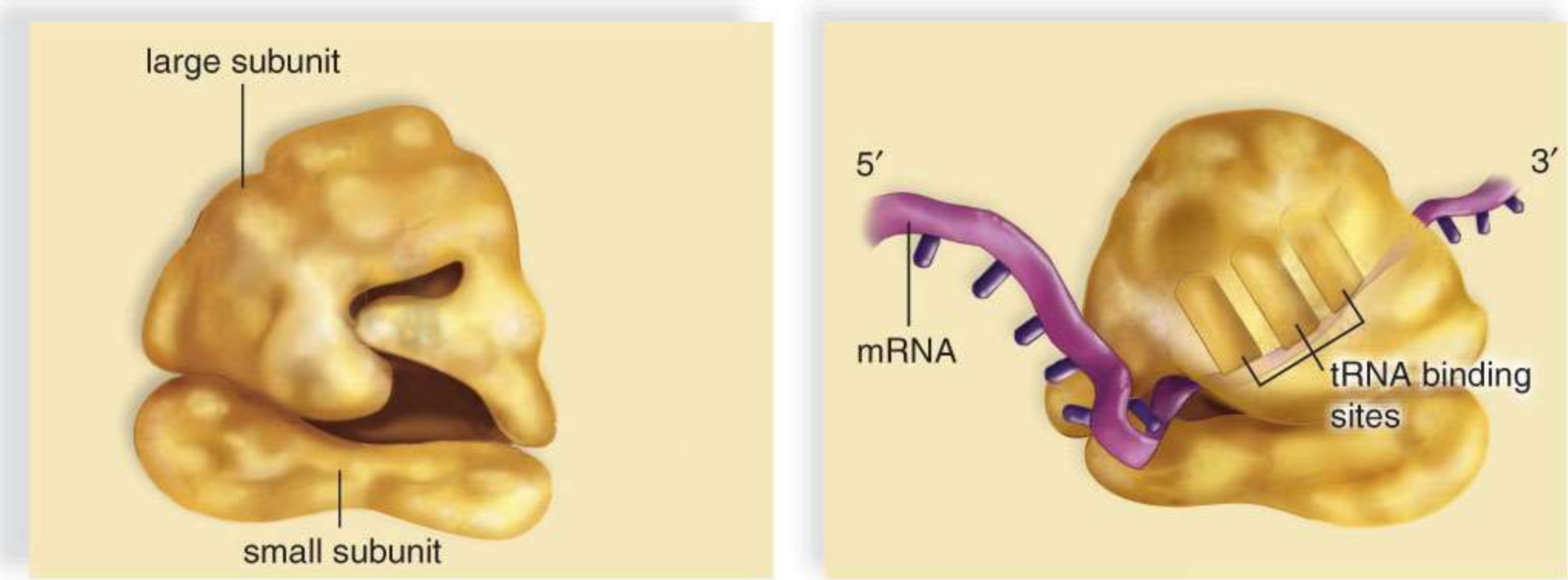
The genetic code for amino acids is a triplet code

- **Genetic code -** sequence of nucleotides in DNA specifies the order of amino acids in a polypeptide
- **Important properties of the genetic code:**
  - The genetic code is degenerate
  - The genetic code is unambiguous
  - The code has start and stop signals

RNA codons

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

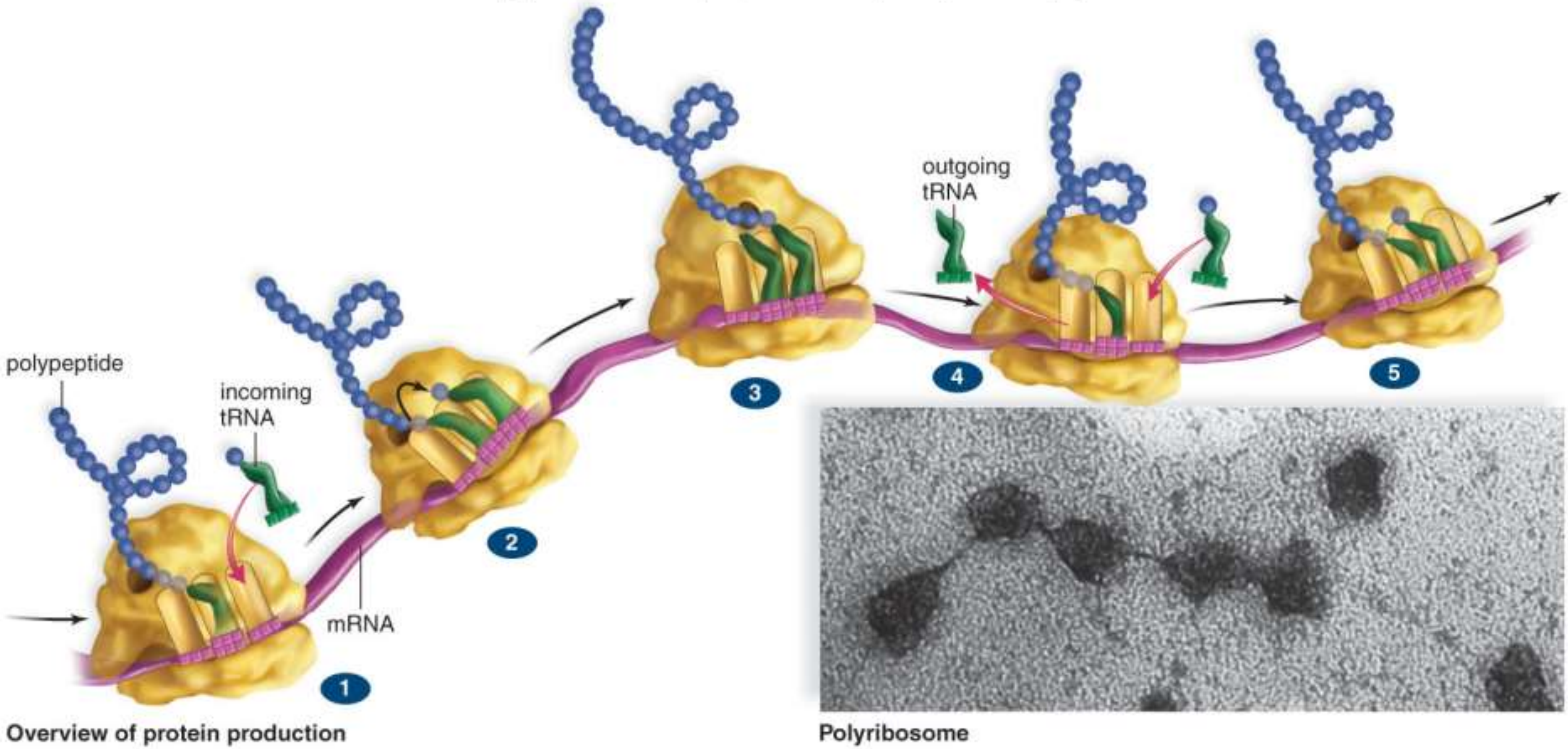
Ribosome structure and function



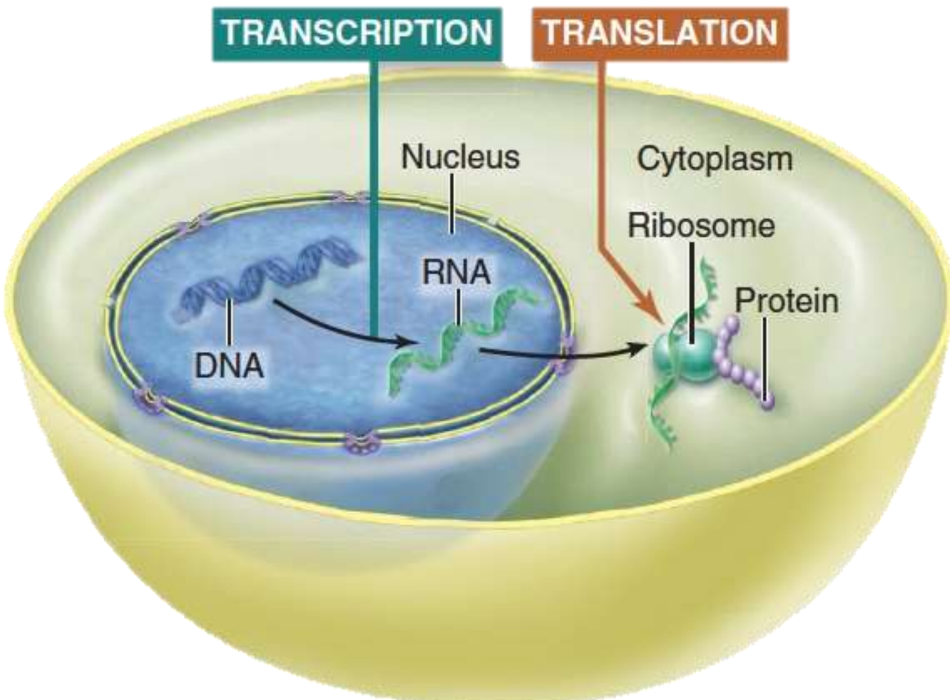
Structure of a ribosome

Binding sites of ribosome

Ribosome structure and function (Cont.)



Translation Builds the Protein



Translation also occurs in three steps:

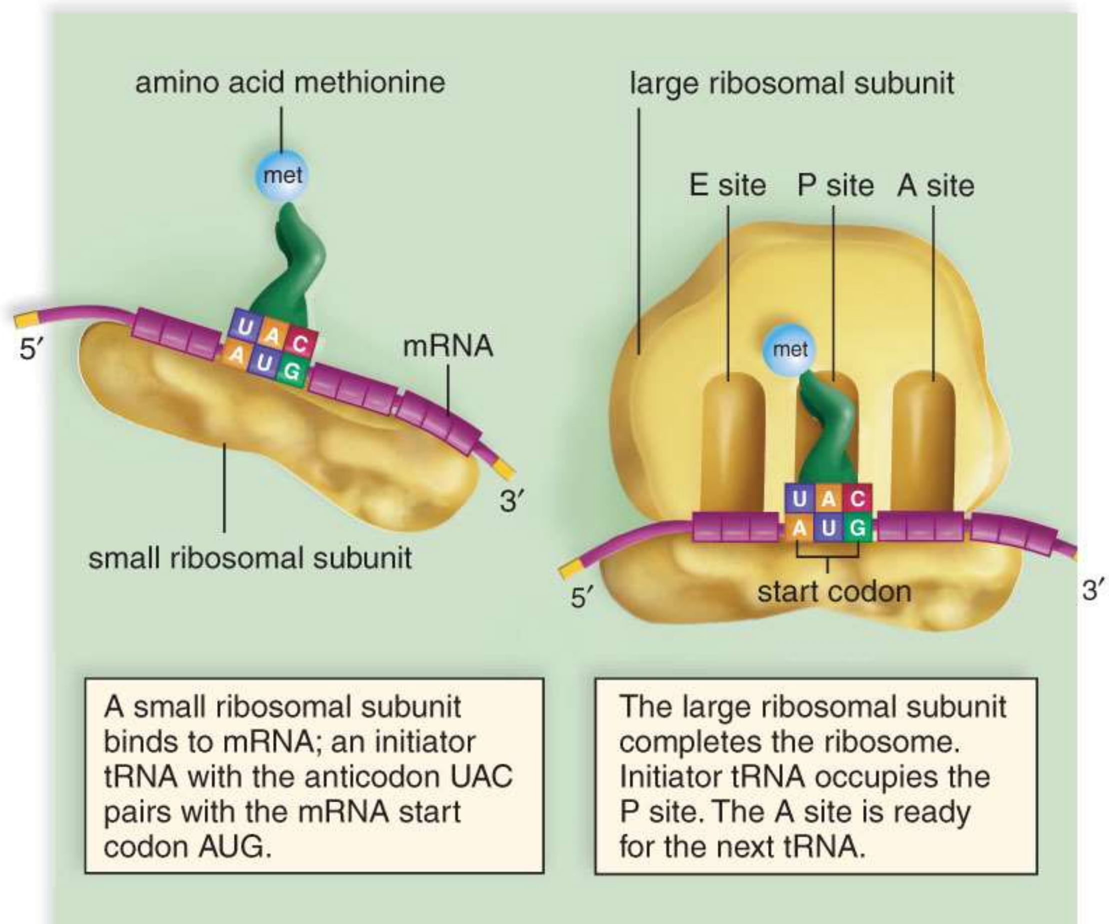
- **-Initiation**
- **-Elongation**
- **-Termination**

All of these steps happen at ribosomes.

Figure 7.8

Initiation begins the process of polypeptide production

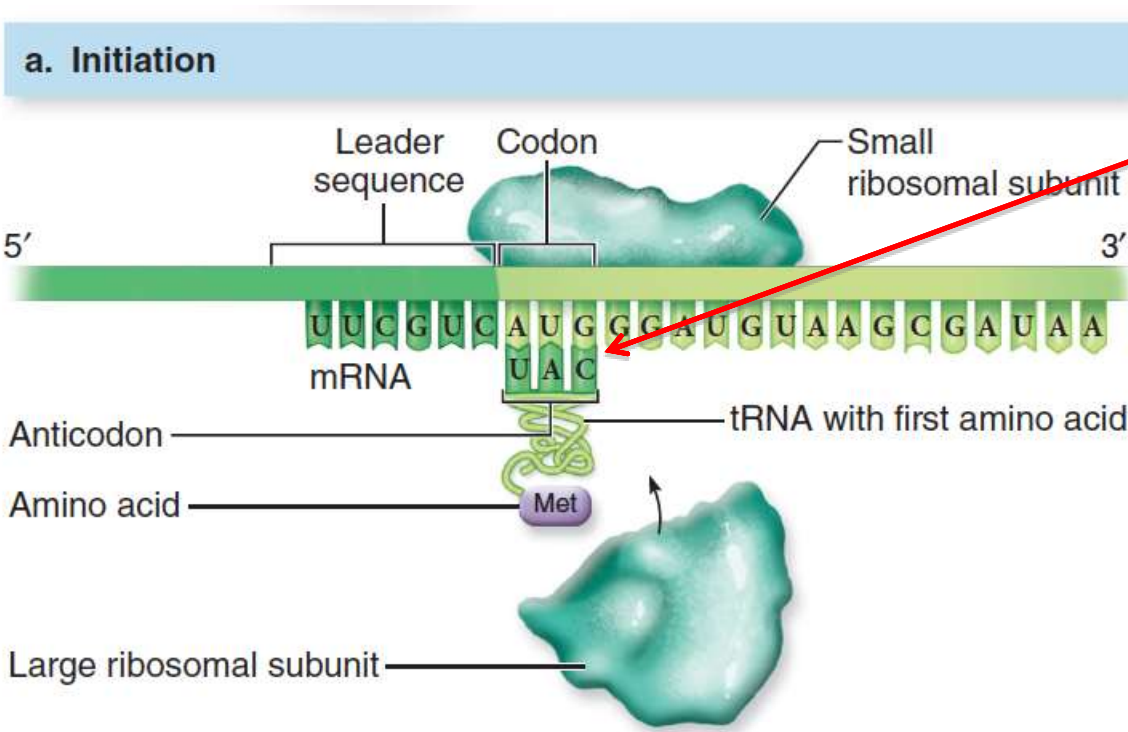
- **Initiation -** the step that brings all the translation components together



Initiation

Translation Builds the Protein

Initiation



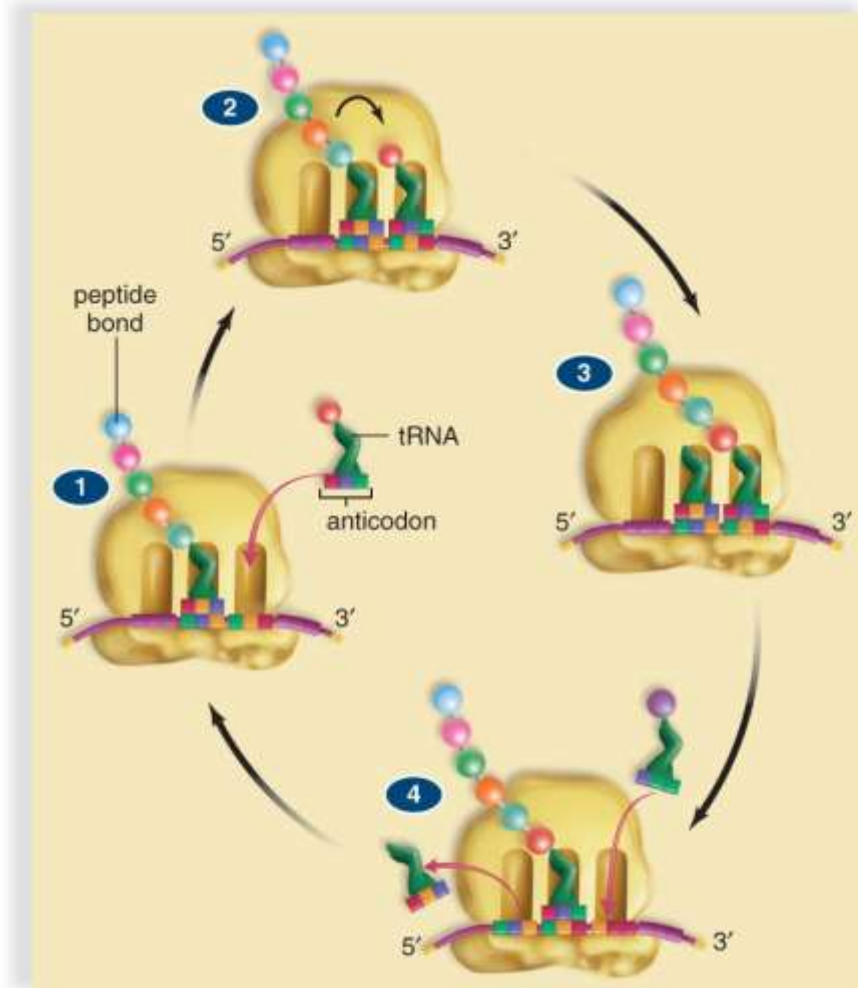
- tRNA complementary base pairs to mRNA
- tRNA already carries an amino acid (Met)

Figure 7.15

Elongation builds a polypeptide one amino acid at a time

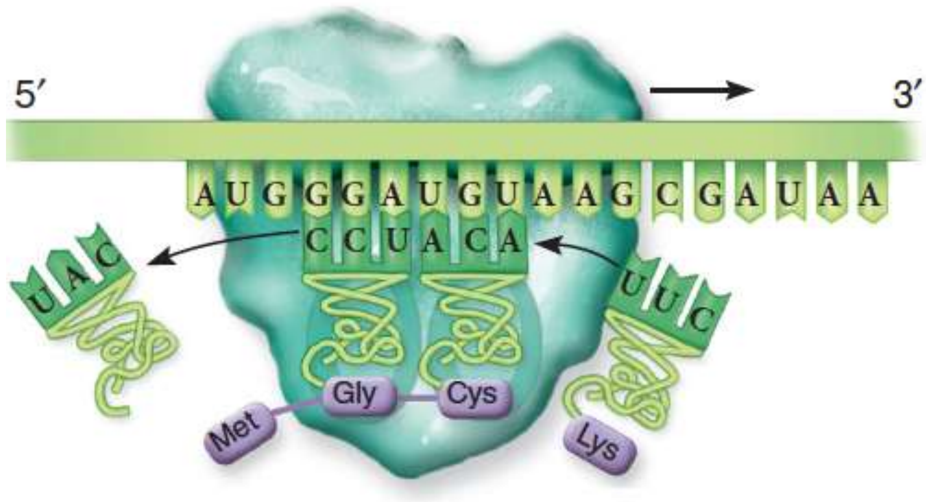
- **Elongation -** a polypeptide increases in length one amino acid at a time

Elongation cycle



Translation Builds the Protein

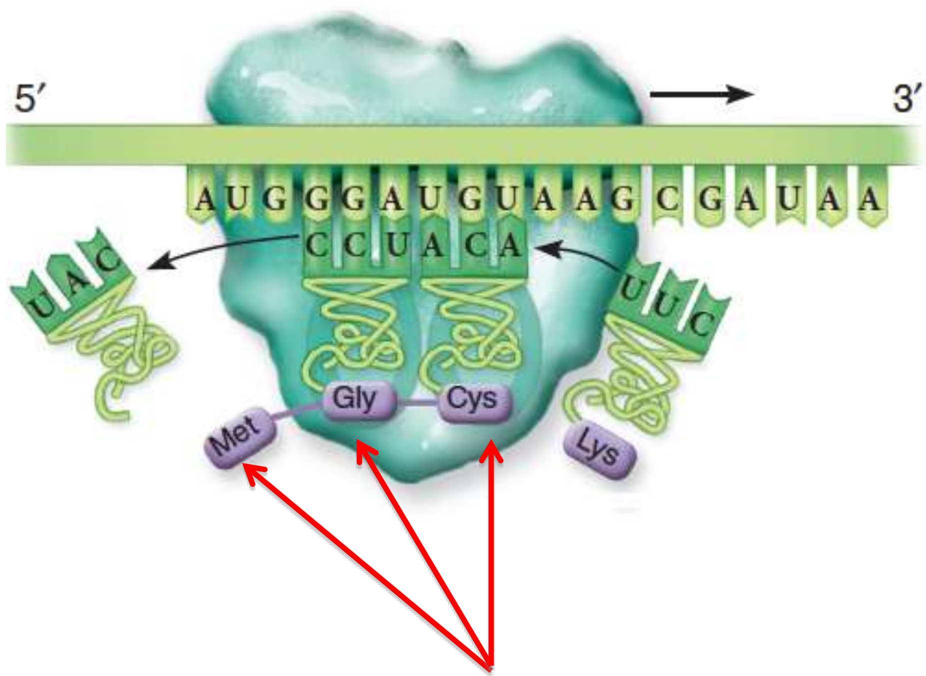
Elongation



- **The first tRNA leaves**
- **The ribosome moves to the right, and a third tRNA comes in**

Translation Builds the Protein

Elongation



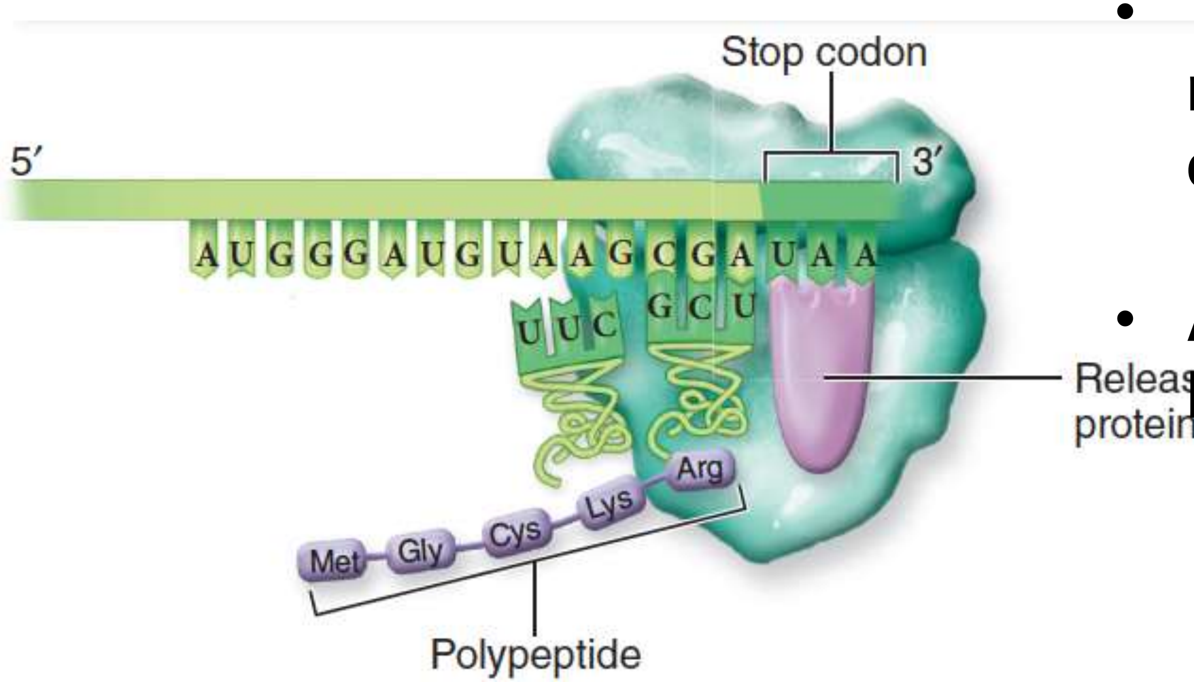
Linked amino acids

- **But, notice that the amino acids remain bonded together!**
- **This process continues and the protein grows**

Figure 7.15

Translation Builds the Protein

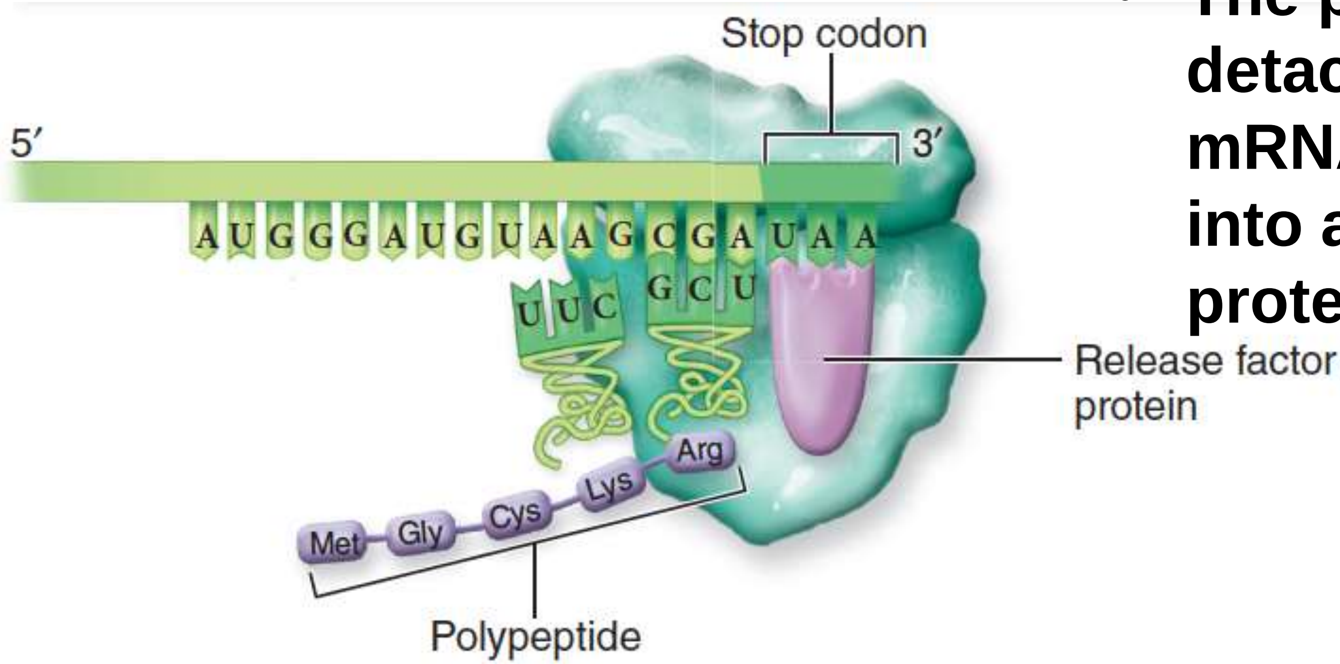
Termination



- **The ribosome reaches the stop codon**
- **A release factor binds**

Translation Builds the Protein

Termination



- **The polypeptide detaches from the mRNA and folds into a functional protein**

Translation Builds the Protein

Translation is efficient when multiple ribosomes attach to an mRNA molecule simultaneously.

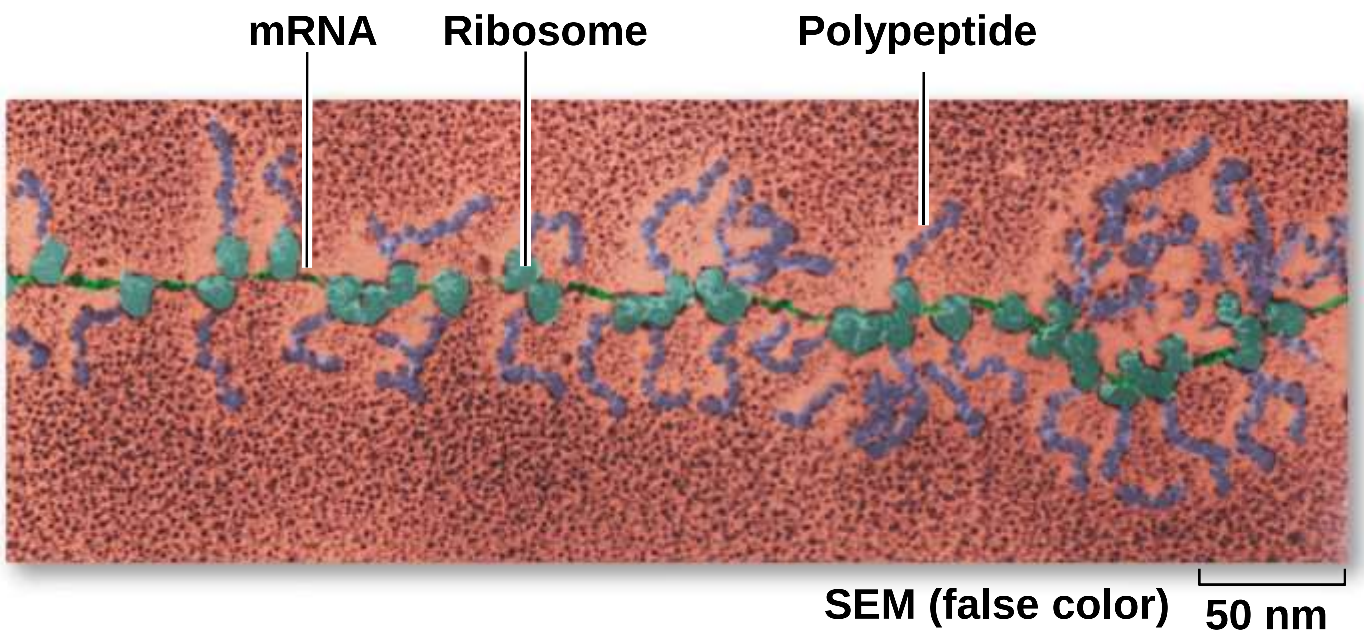


Figure 7.16

Let's review gene expression

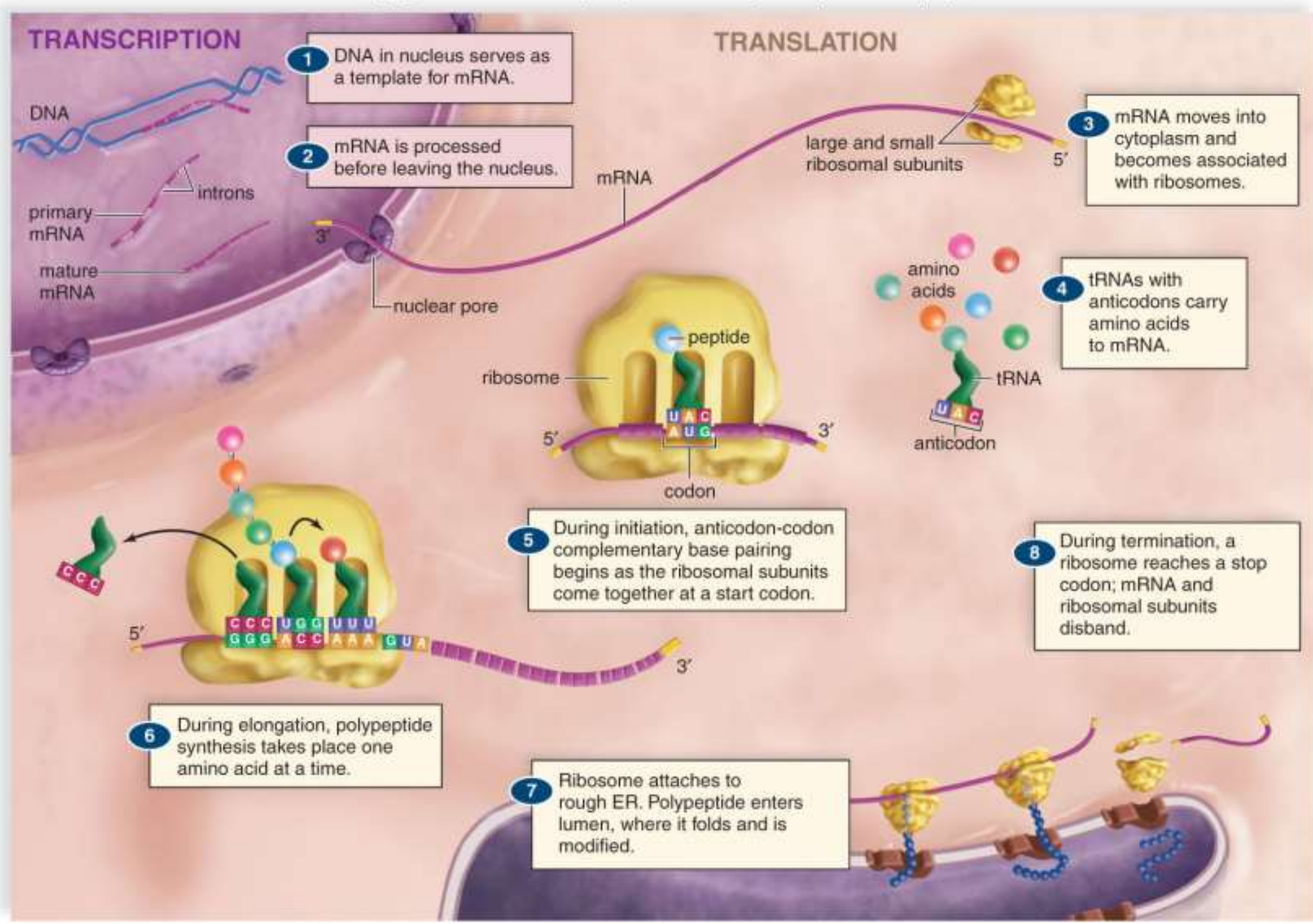


TABLE 10.17 Participants in Gene Expression

Name of Molecule	Special Significance	Definition
DNA	Genetic information	Sequence of DNA bases
mRNA	Has codons	Sequence of three RNA bases complementary to DNA
tRNA	Has an anticodon	Sequence of three RNA bases complementary to codon
rRNA	Located in ribosomes	Site of protein synthesis
Amino acid	Monomer of a polypeptide	Transported to ribosome by tRNA
Polypeptide	Enzyme, structural, or secretory product	Amino acids joined in a predetermined order

Connecting the Concepts:

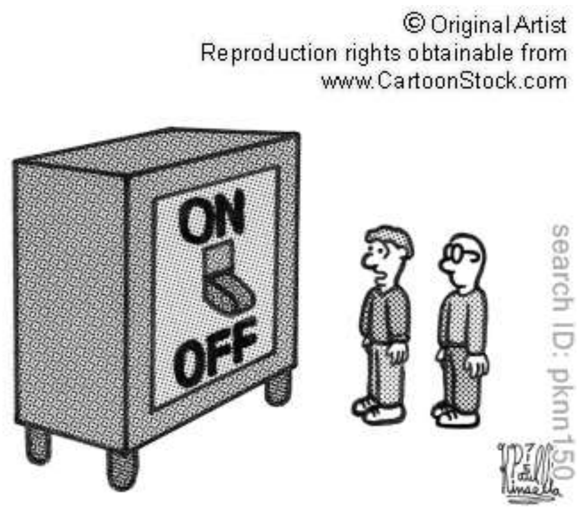
- Using all previously collected data concerning DNA structure, Watson and Crick were able to arrive at the legendary design of DNA—a double helix
- Complementary base pairing explains the replication of DNA, how RNA molecules are made
- Geneticists have confirmed that proteins are the link between the genotype (DNA combination) and the phenotype (physical appearance)

Food for thought?

- How would you design an intelligent being to react to the environment?

Consider that....

- Every cell of the body contains ALL the DNA for the organism.
- Would you want to turn on all 25,000 genes in our body at the same time? Why or why not?
- Not all genes are necessary all the ti
- Cells must then have the ability to tu
-



"How do you work this thing?"

Francois Jacob and Jacques Monod

- Experiments with E. Coli showed that it is capable of regulating the expression of its genes
- An operon consists of the following elements
- 1. Promoter - where RNA polymerase attaches, signaling the start of the gene

2. Operator - where a repressor binds, stopping the transcription of that gene

3. Structural Genes - genes coding for the enzyme, they are transcribed as a unit

The *lac* Operon: The inducible operon

- The first well-understood example of how gene expression is controlled
- *Prokaryotic* gene expression

Logic of Lac operon

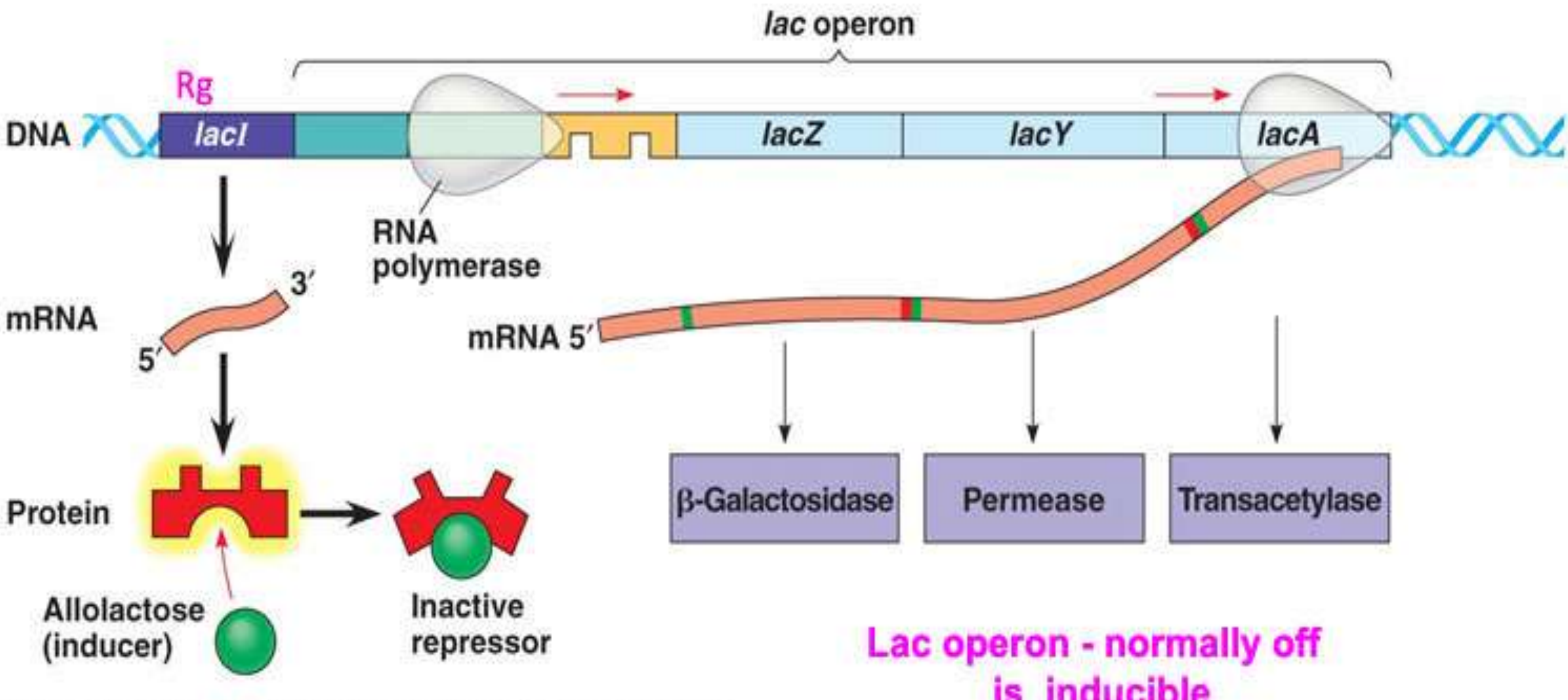
1. Lactose is an energy source but it is not always present

- 2. Genes encoding enzymes that metabolize lactose are **only needed** **(efficiency!!!)** when lactose is present

- 3. If lactose and glucose are both present, glucose is the preferred energy source **(efficiency!!!)**

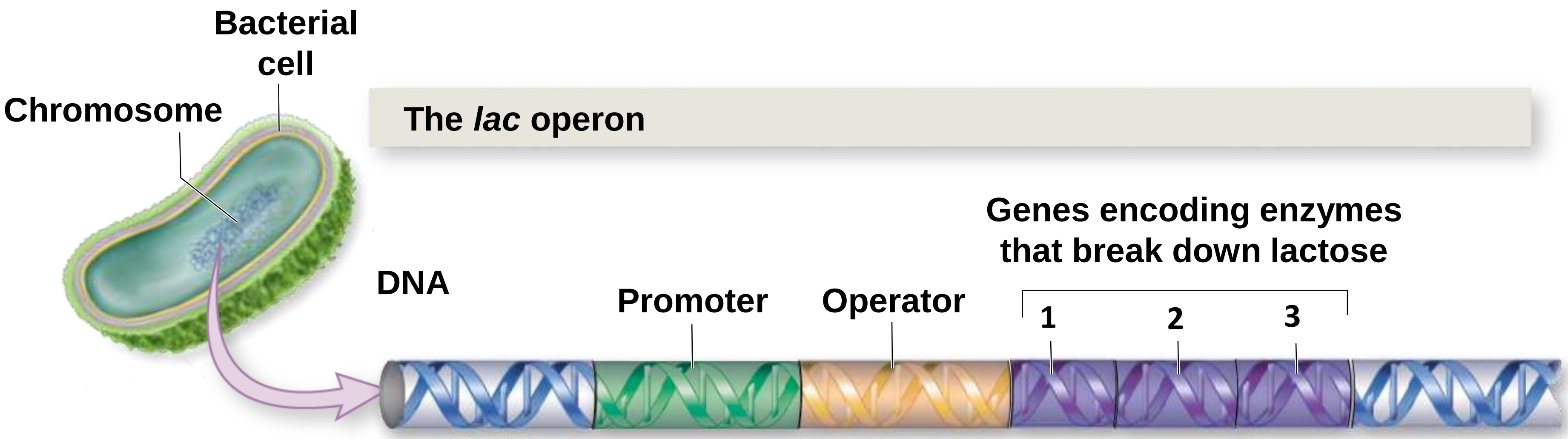
The *lac* Operon: The inducible operon

This region is normally in the "off" position, it turns on when lactose is present



(b) Lactose present, repressor inactive, operon on

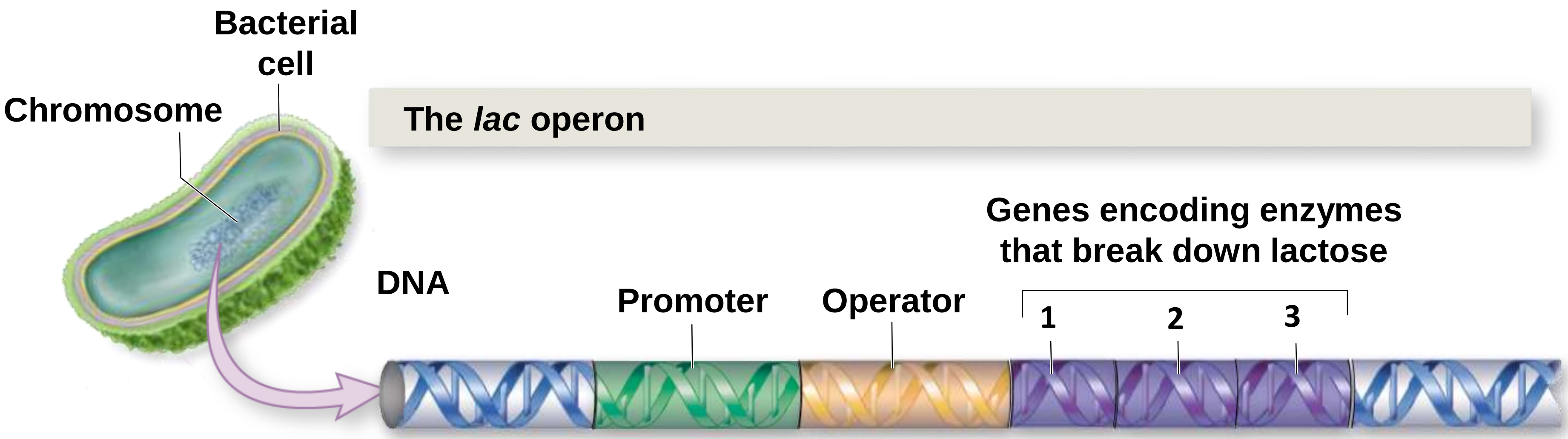
Protein Synthesis Is Highly Regulated



Genes in prokaryotes are organized into operons, groups of genes that are always transcribed together.

Figure 7.17

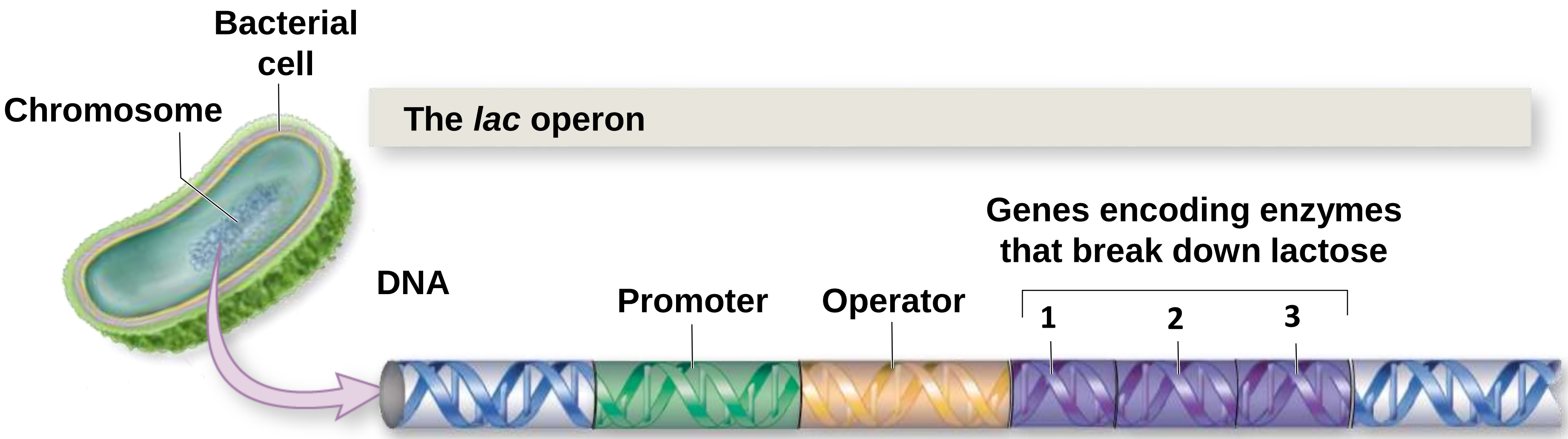
Protein Synthesis Is Highly Regulated



The *lac* operon includes three genes that encode lactose-digesting enzymes.

Figure 7.17

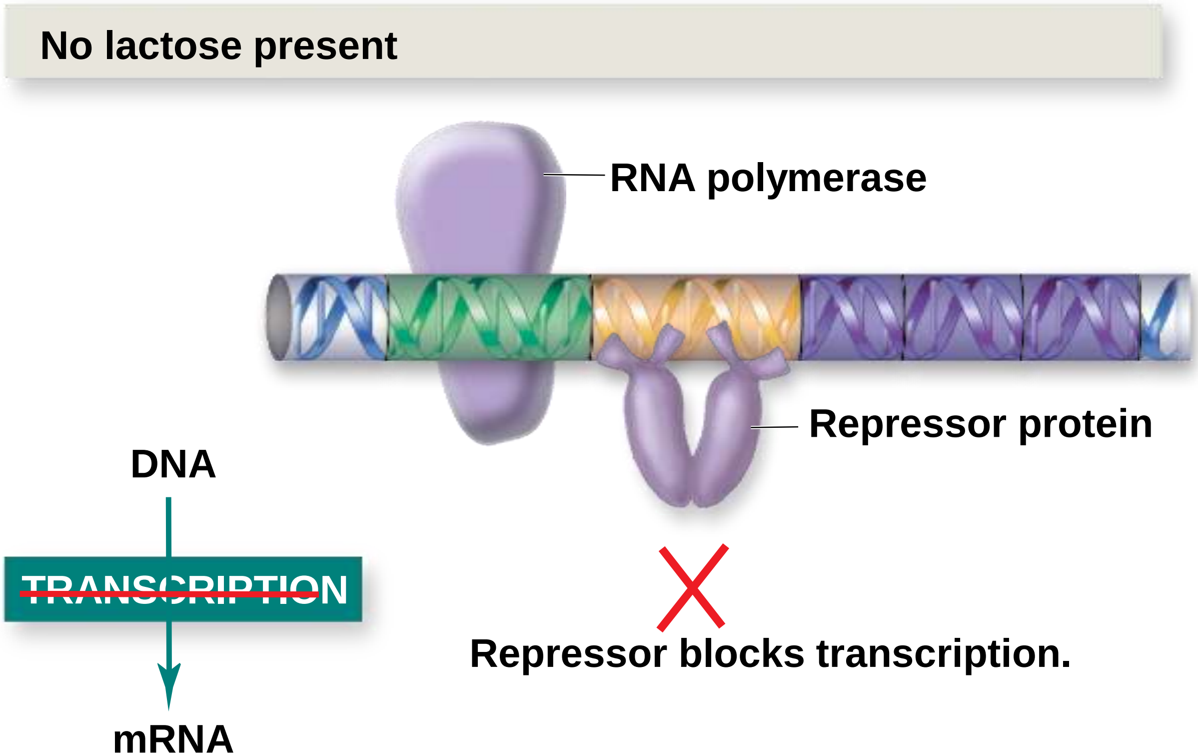
Protein Synthesis Is Highly Regulated



The promoter and operator control gene expression.

Figure 7.17

Protein Synthesis Is Highly Regulated

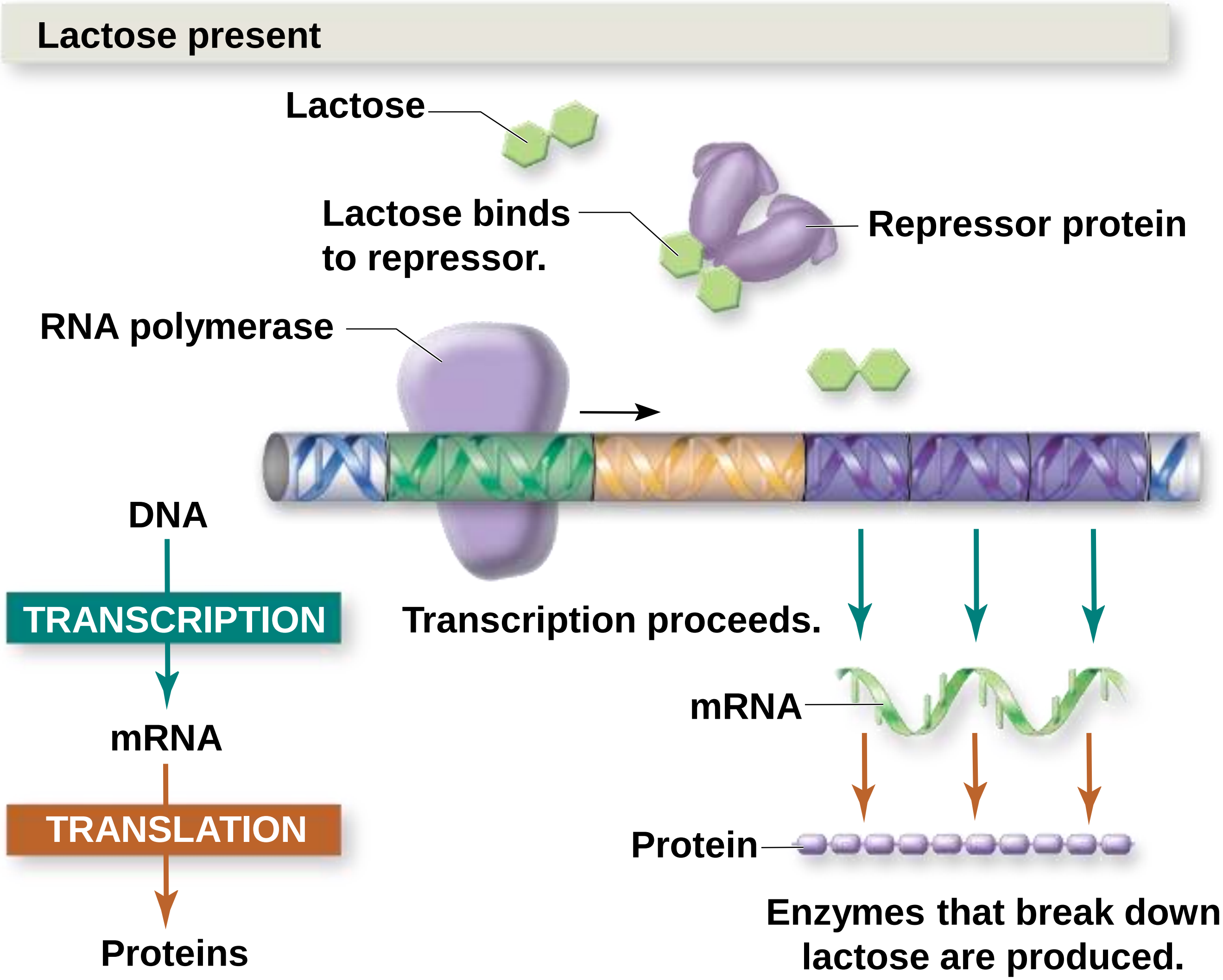


Lactose absent: lactose-digesting enzymes not needed

A repressor protein blocks transcription

Figure 7.17

Protein Synthesis Is Highly Regulated



Lactose present: repressor binds to lactose, changes shape, and releases the operator

Protein synthesis of lactose-digesting enzymes occurs

Figure 7.17

Protein Synthesis Is Highly Regulated

Protein synthesis requires lots of energy!

Cells save energy by only producing needed proteins.

Both prokaryotes and eukaryotes regulate protein synthesis, but in different ways.

Now let's look at eukaryotes.

Section 7.5

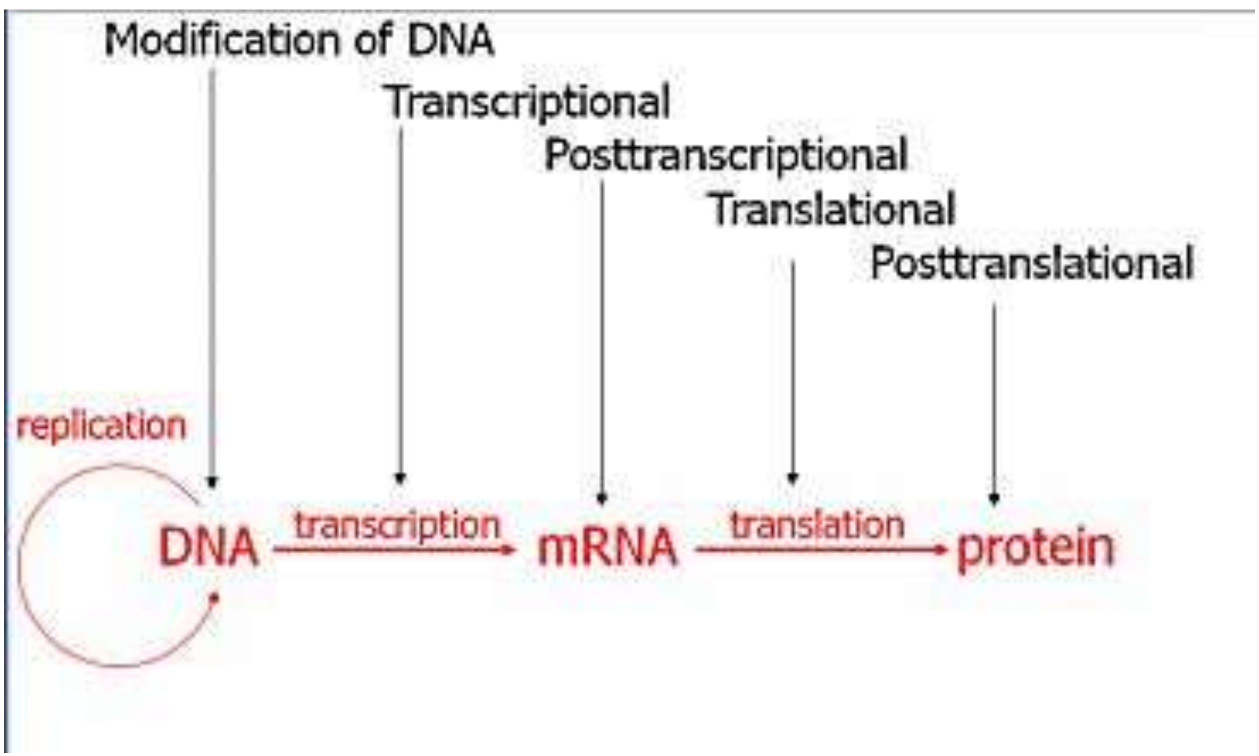
Transcriptional control in Eukaryotes

- You may expect transcriptional control in eukaryotes to

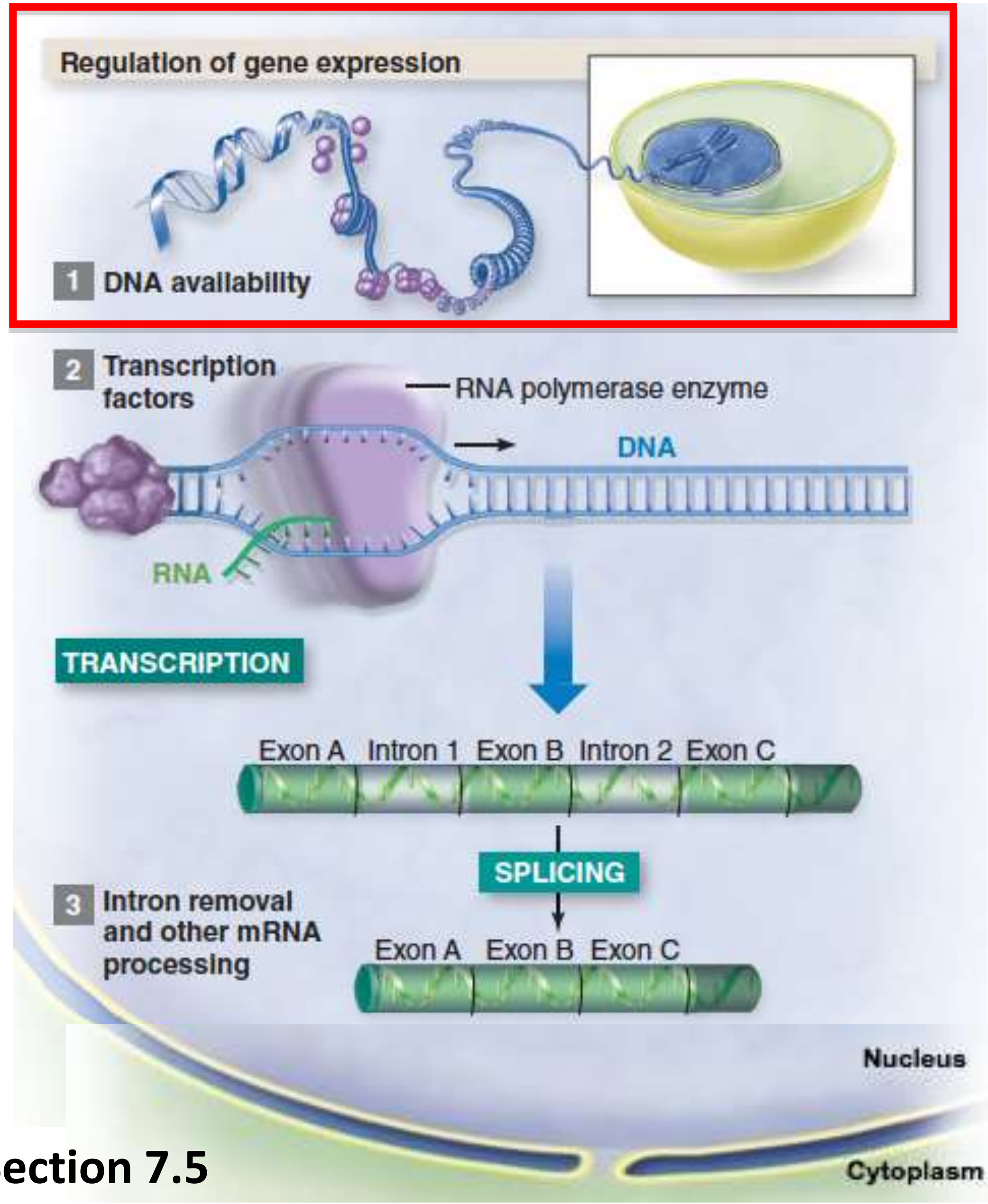
1. Involve the organization of chromatin
2. Include regulatory proteins such as the repressor proteins from the lac operon.

In eukaryotes, a variety of mechanisms regulate gene expression

- 1. chromatin structure
- 2. transcriptional control
  3. post transcriptional control
- 4. translational control
- 5. post translational control



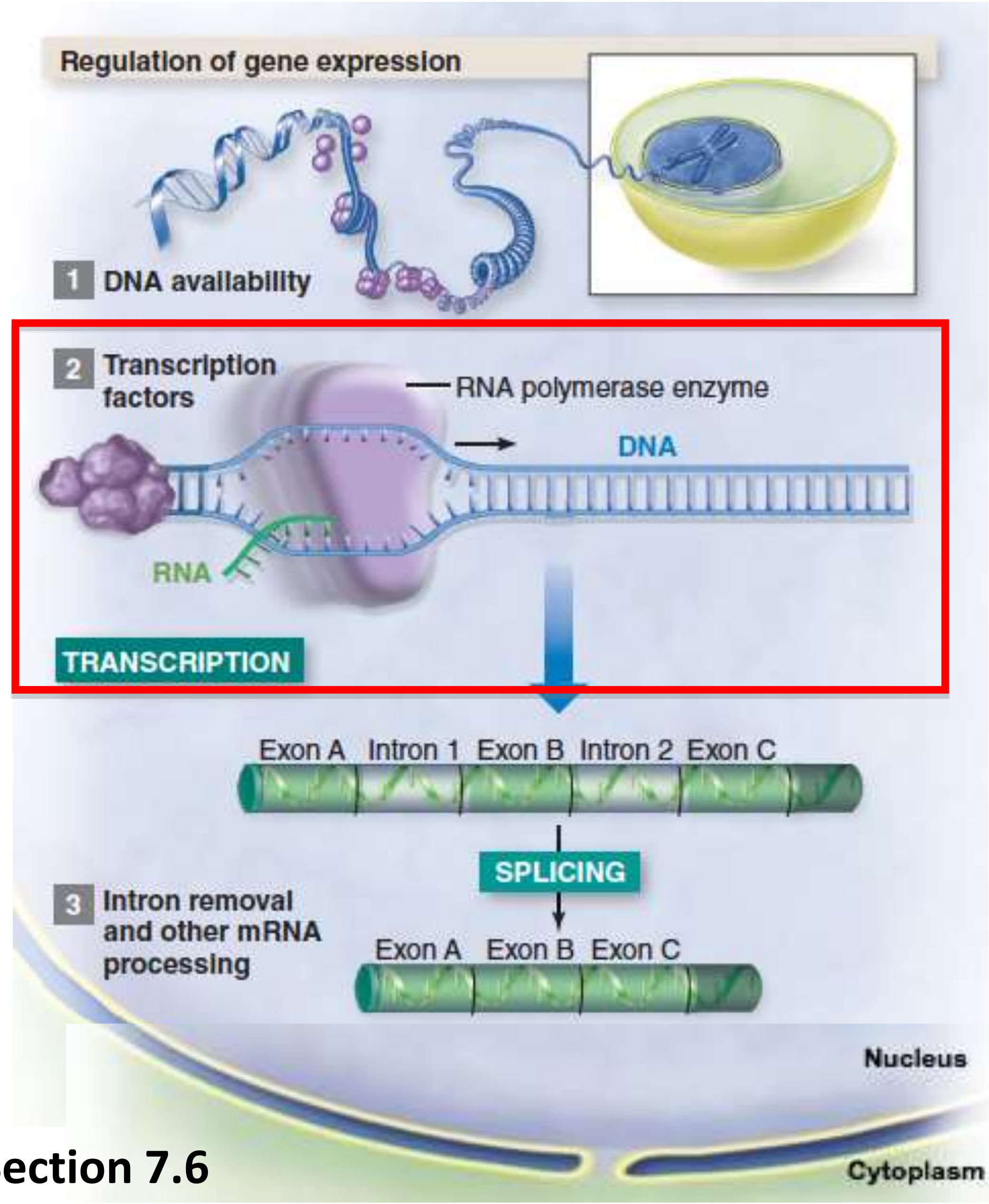
Protein Synthesis Is Highly Regulated



Gene regulation starts in the nucleus.

Figure 7.19

Protein Synthesis Is Highly Regulated

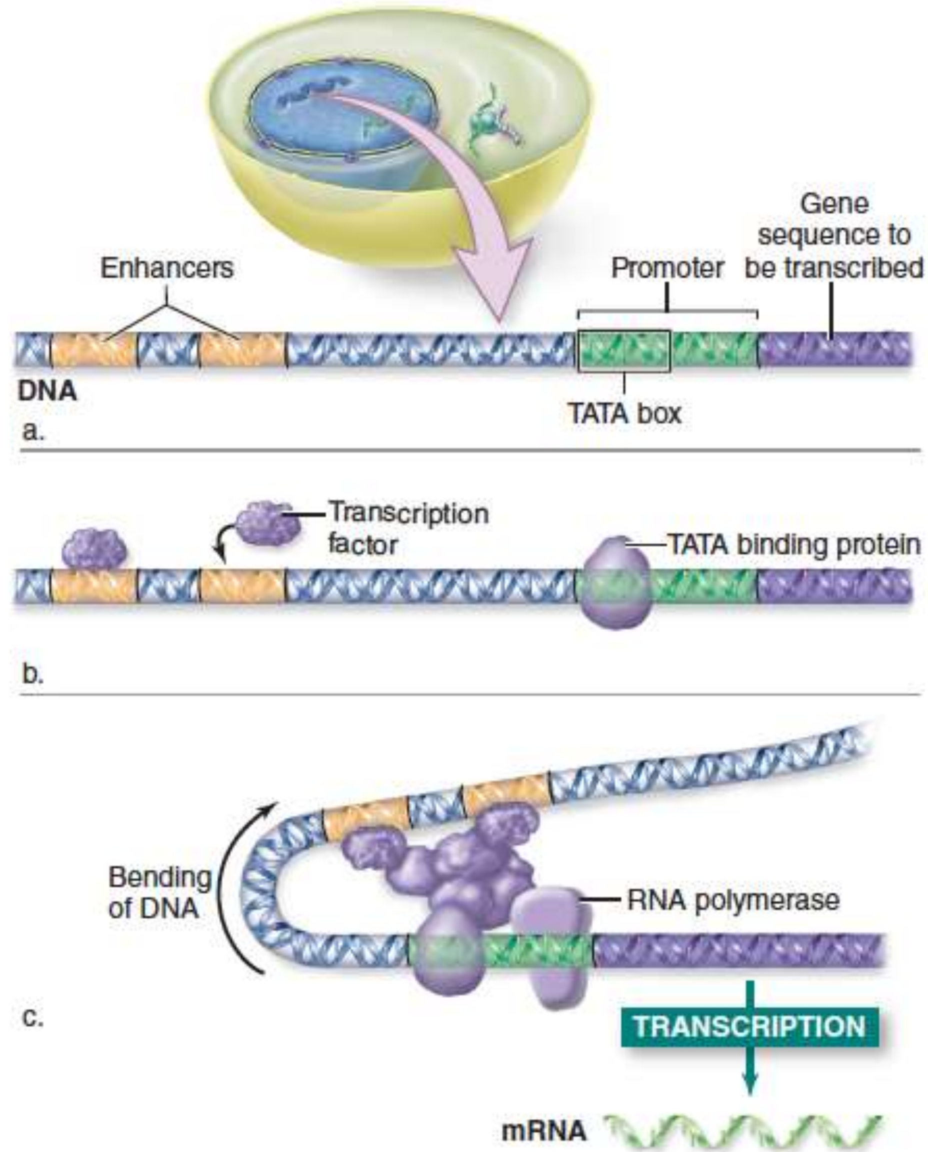


Transcription can only occur if the correct transcription factors are present.

Figure 7.19

Protein Synthesis Is Highly Regulated

Proteins called transcription factors bind to nucleotide sequences called enhancers. A TATA binding protein binds to the promoter.

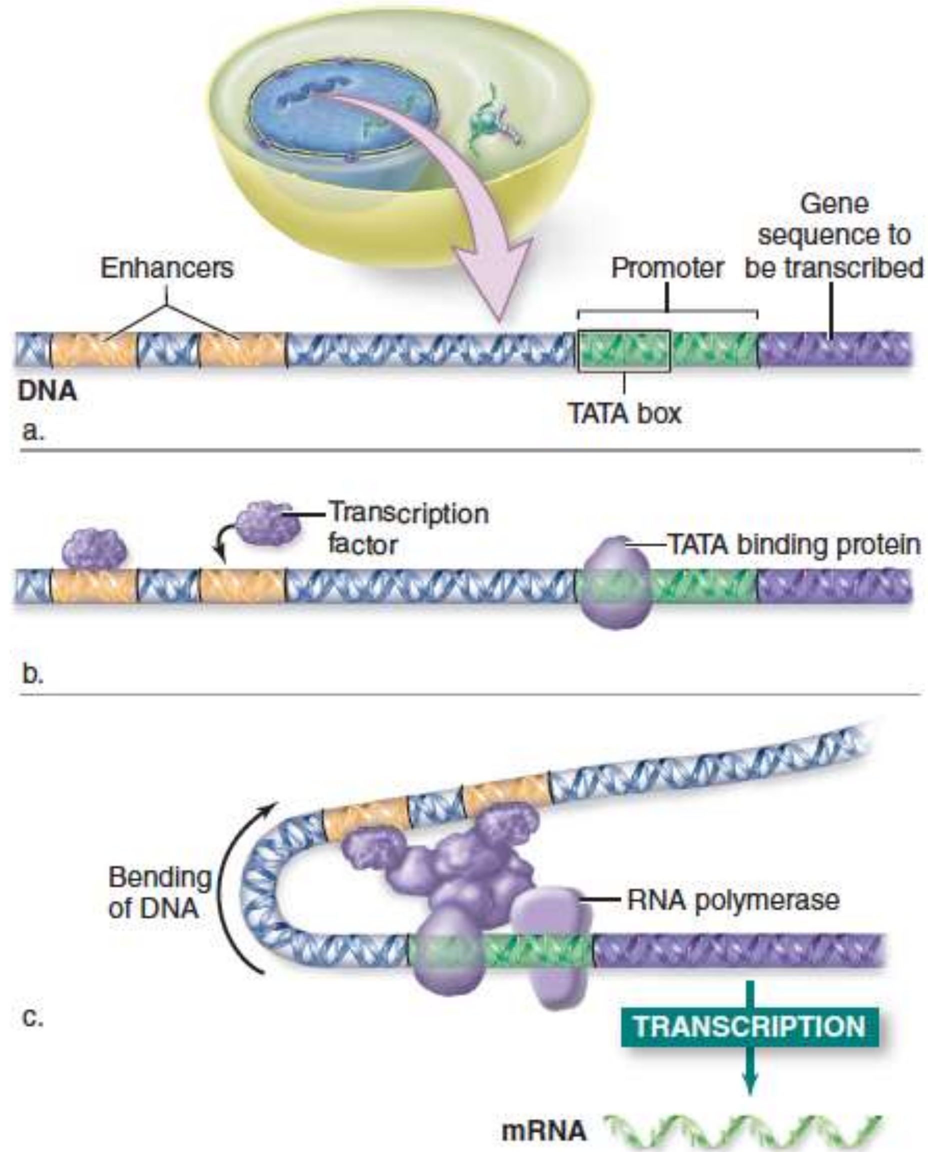


Section 7.5

Figure 7.18

Protein Synthesis Is Highly Regulated

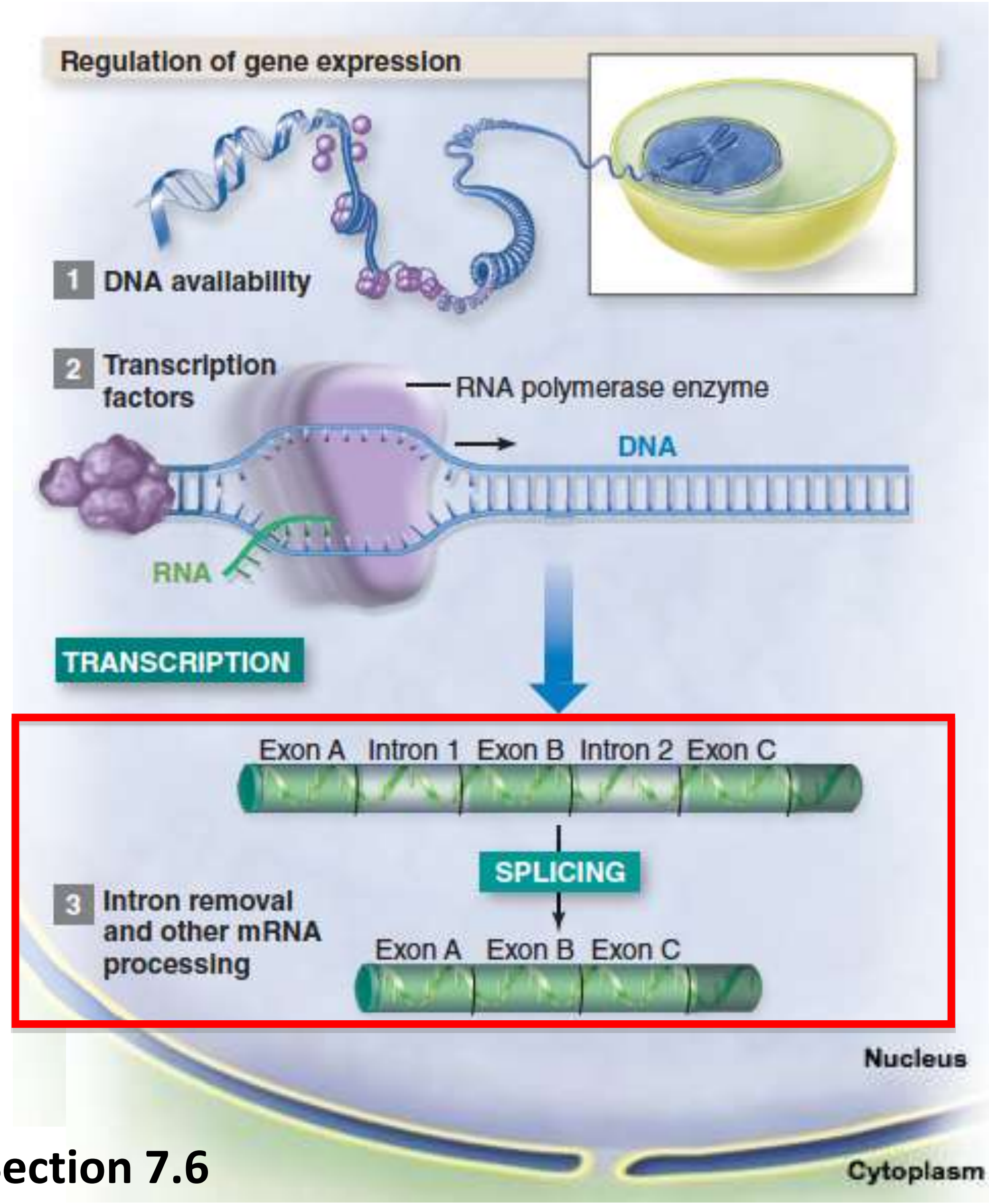
Transcription factors, the TATA binding protein, and RNA polymerase form a complex of proteins that initiates translation.



Section 7.5

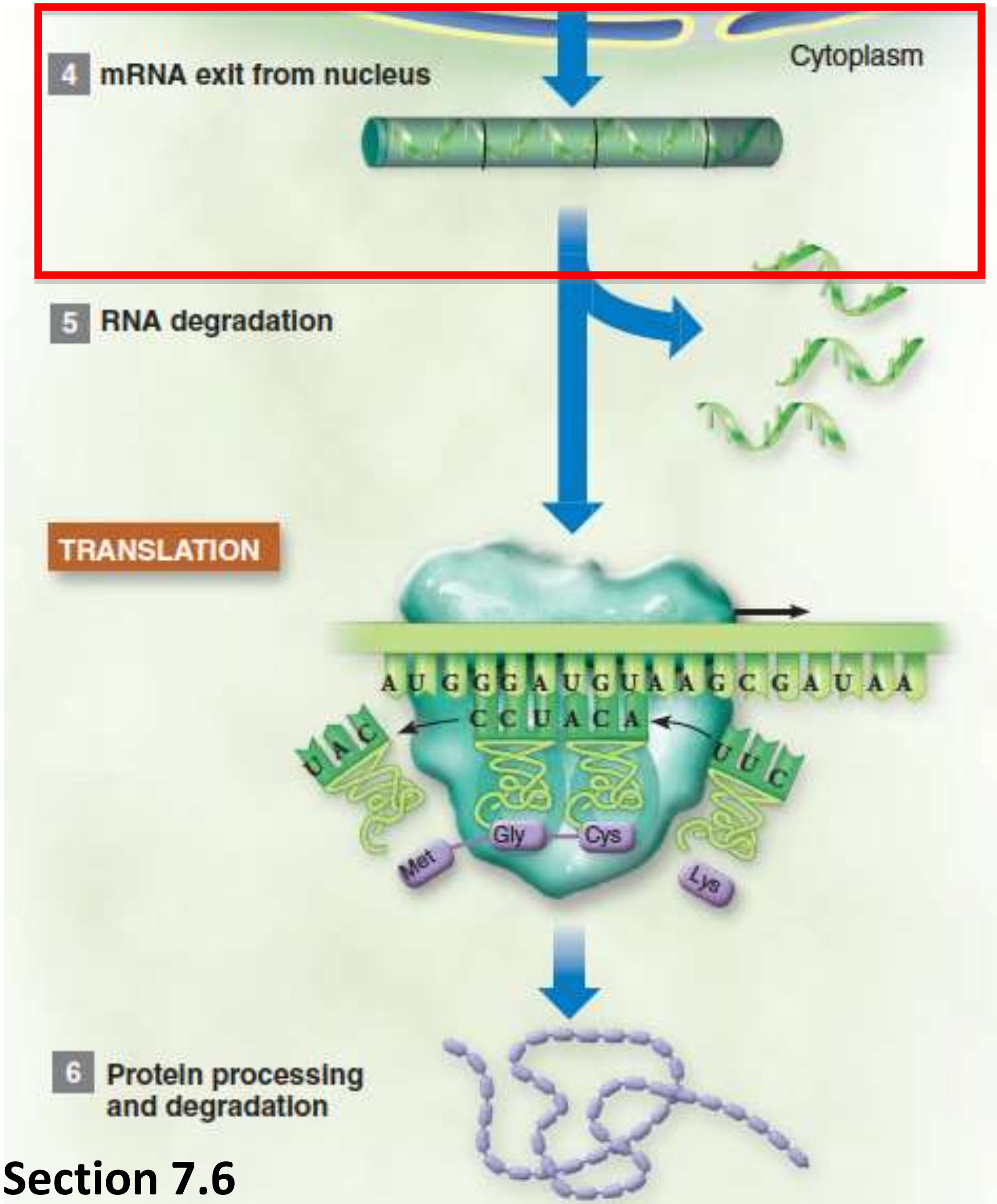
Figure 7.18

Protein Synthesis Is Highly Regulated



One gene can encode multiple proteins if different introns are removed.

Protein Synthesis Is Highly Regulated

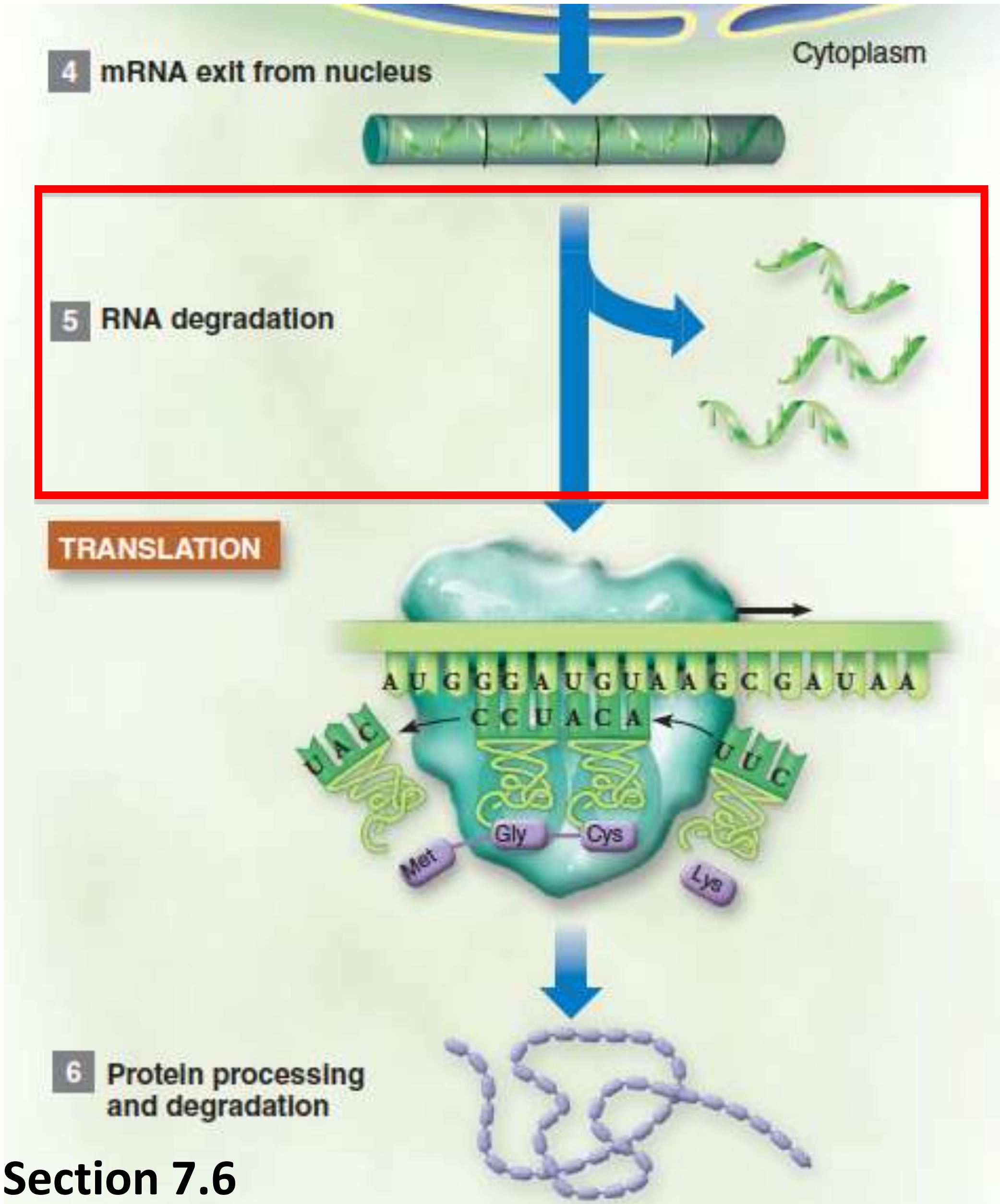


Gene regulation continues in the cytoplasm.

Section 7.6

Figure 7.19

Protein Synthesis Is Highly Regulated

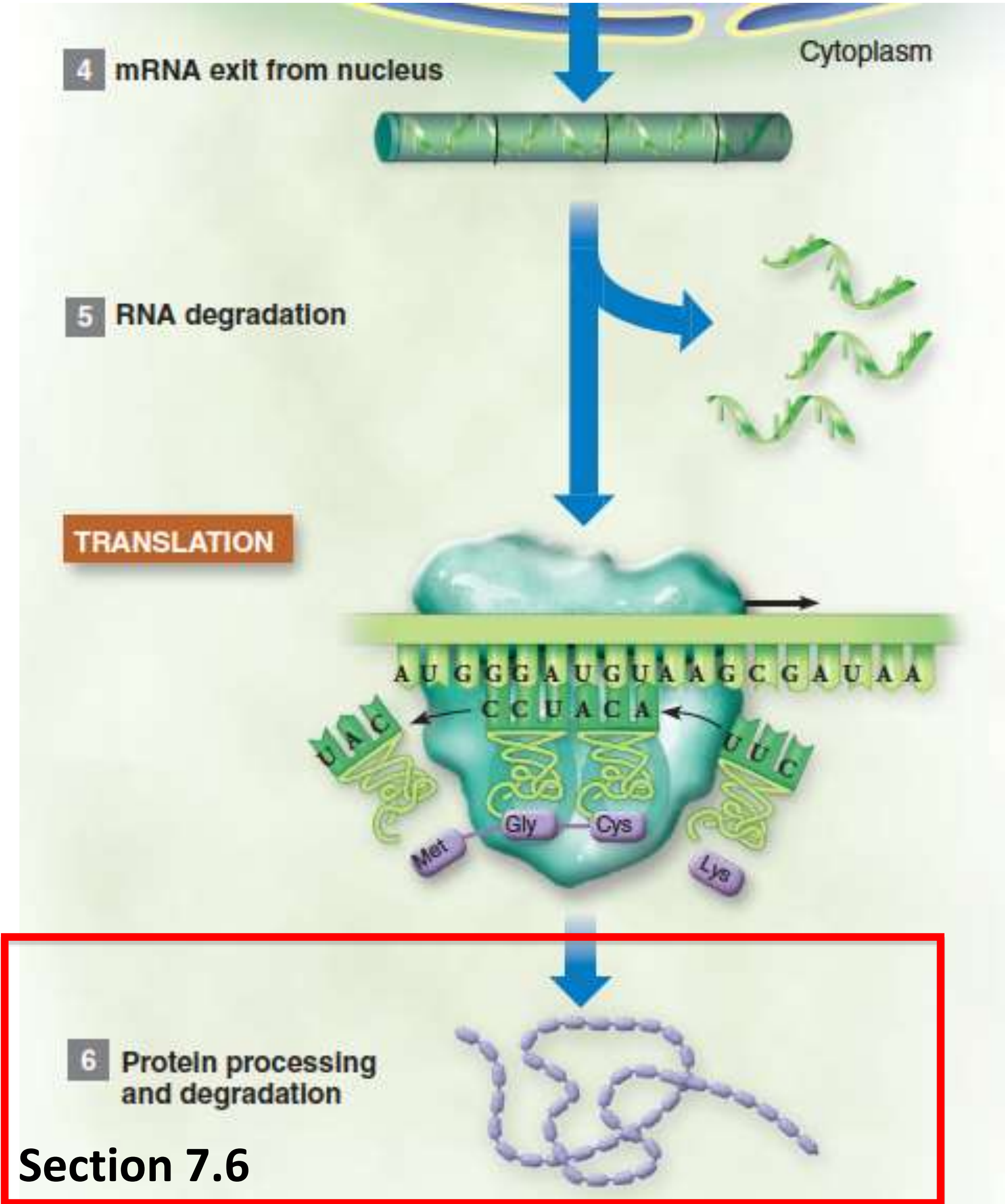


Some mRNA may be degraded before it is translated into protein. Other mRNA may be silenced by microRNA, short sequences of nucleotides that bind to the mRNA and prevent translation.

Section 7.6

Figure 7.19

Protein Synthesis Is Highly Regulated



Proteins must be properly folded before they are functional.

Section 7.6

Figure 7.19

7.6 Mastering Concepts

Why do cells regulate which genes are expressed at any given time?

DNA bursting from bacterial cell © Dr. Gopal Murti/Science Source

Mutations Are Changes in the Sequence of DNA Bases

DNA meets the criteria for the genetic material

- The genetic material must be:
  - Variable between species and *able to store information* that causes species to vary from one another
  - Constant within a species and *able to be replicated* with high fidelity during cell division
  - *Able to undergo rare changes*, called **mutations**, that provide the genetic variability that allows evolution to occur

Mutations Change DNA

A mutation in one gene causes a fly to develop legs where its antenna should be!

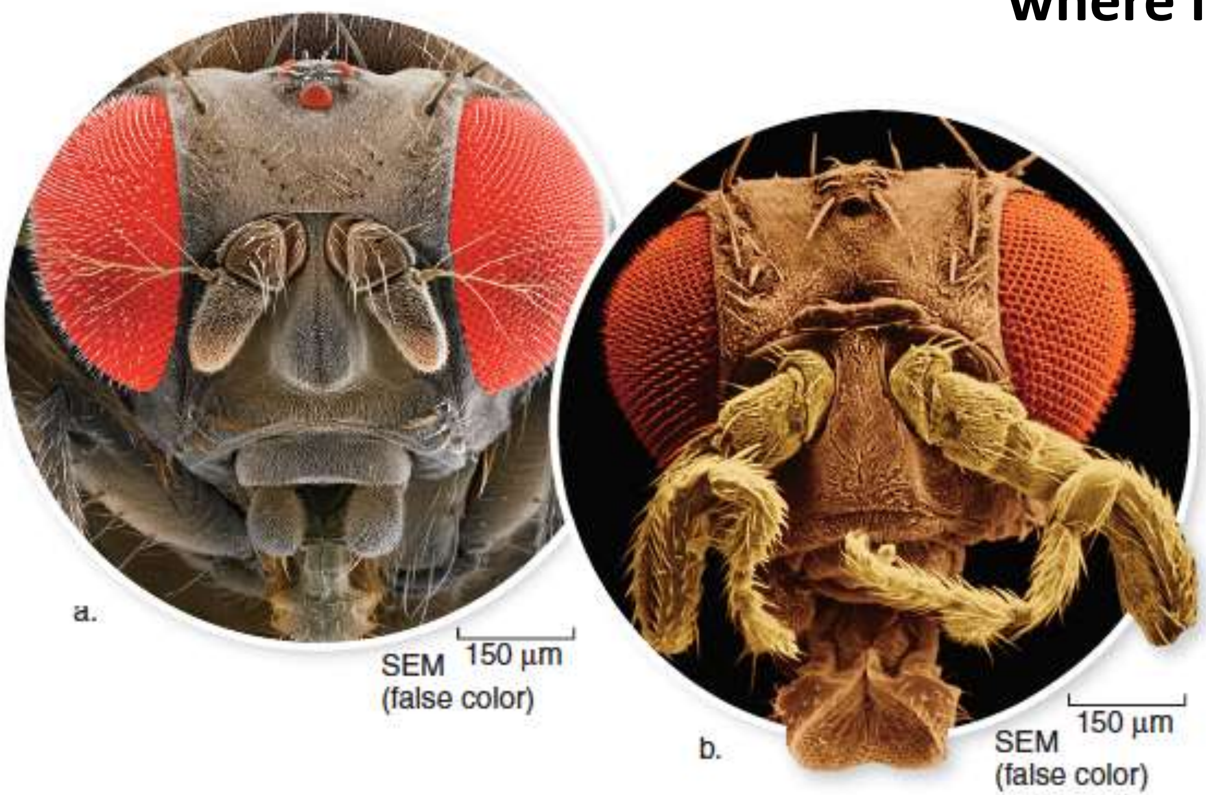
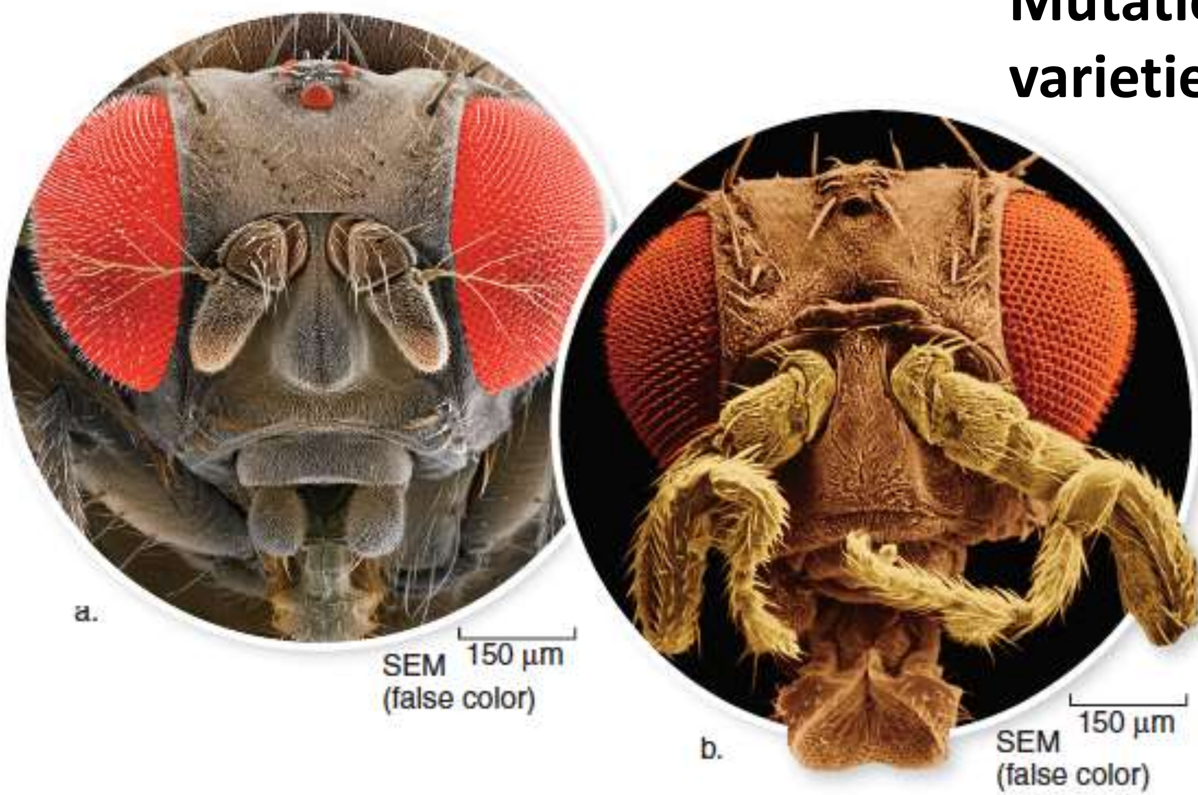


Figure 7.20

Mutations Change DNA

A mutation is a change in a cell's DNA sequence. Mutations come in several varieties.



Various Types of Mutations

- Mistake made from polymerase
- Mistake in DNA repair process
- Recombination
- Exogenous factors such as virus and transposons

Mutation categories

- Deleterious- mutation at splice junction or coding region
- Advantageous- any mutation that allows either an increased rate of survival, replication rate or ability to pass on genes
- Neutral- mutation at a non-coding region

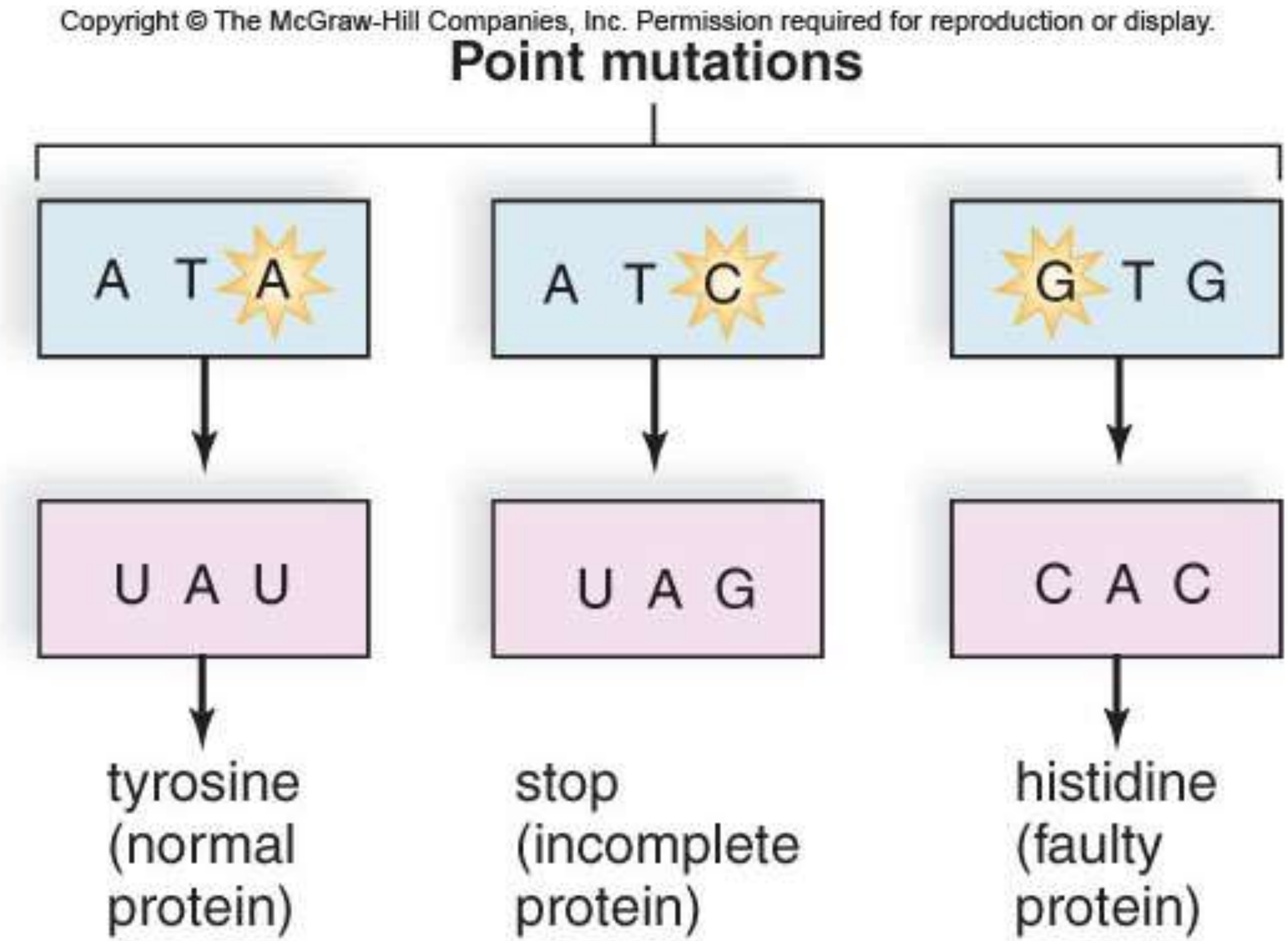
Definitions

- Synonymous substitution- mutation that does not change an amino acid (ex. Wobble base)
- Non-synonymous substitution- mutation that changes an amino acid
- Are all proteins the same in regards to fitness?

Mutations affect genetic information and expression

- **Genetic mutation -** a permanent change in the sequence of bases in DNA
  - **Point mutations -** a change in a single DNA nucleotide and, therefore, a change in a specific codon
  - **Frameshift mutations** occur when one or more nucleotides are either inserted or deleted from DNA

Types of point mutations



Mutations Change DNA

A point mutation changes one or a few base pairs in a gene.

Type	Illustration
Wild type	THE ONE BIG FLY HAD ONE RED EYE
Substitution	TH**Q** ONE BIG FLY HAD ONE RED EYE
Frameshift	THE ONE **Q**BI GFL YHA DON ERE DEY
Deletion of three nucleotides	THE ONE BIG HAD ONE RED EYE
Insertion of three nucleotides	THE ONE BIG **WET** FLY HAD ONE RED EYE

Mutations Change DNA

A point mutation changes one or a few base pairs in a gene.

Type	Illustration
Wild type	THE ONE BIG FLY HAD ONE RED EYE
Substitution	TH**Q** ONE BIG FLY HAD ONE RED EYE
Frameshift	THE ONE **Q**BI GFL YHA DON ERE DEY
Deletion of three nucleotides	THE ONE BIG HAD ONE RED EYE
Insertion of three nucleotides	THE ONE BIG **WET** FLY HAD ONE RED EYE

The table to the left uses sentences to show a few examples of point mutations.

Mutations Change DNA

A point mutation changes one or a few base pairs in a gene.

Type	Illustration
Wild type	THE ONE BIG FLY HAD ONE RED EYE
Substitution	TH**Q** ONE BIG FLY HAD ONE RED EYE
Frameshift	THE ONE **Q**BI GFL YHA DON ERE DEY
Deletion of three nucleotides	THE ONE BIG HAD ONE RED EYE
Insertion of three nucleotides	THE ONE BIG **WET** FLY HAD ONE RED EYE

The table to the left uses sentences to show a few examples of point mutations.

Remember that codons are sequences of three nucleotides. Each word in the sentences above represents one codon.

Table 7.2

Mutations Change DNA

Wildtype = original nucleotide sequence

Type	Illustration
Wild type	THE ONE BIG FLY HAD ONE RED EYE
Substitution	TH**Q** ONE BIG FLY HAD ONE RED EYE
Frameshift	THE ONE **Q**BI GFL YHA DON ERE DEY
Deletion of three nucleotides	THE ONE BIG HAD ONE RED EYE
Insertion of three nucleotides	THE ONE BIG **WET** FLY HAD ONE RED EYE

Table 7.2

Mutations Change DNA

Wildtype = original nucleotide sequence

Type	Illustration
Wild type	THE ONE BIG FLY HAD ONE RED EYE
Substitution	TH**Q** ONE BIG FLY HAD ONE RED EYE
Frameshift	THE ONE **Q**BI GFL YHA DON ERE DEY
Deletion of three nucleotides	THE ONE BIG HAD ONE RED EYE
Insertion of three nucleotides	THE ONE BIG **WET** FLY HAD ONE RED EYE

Substitution = changed nucleotide(s)

Table 7.2

Mutations Change DNA

Type	Illustration
Wild type	THE ONE BIG FLY HAD ONE RED EYE
Substitution	TH**Q** ONE BIG FLY HAD ONE RED EYE
Frameshift	THE ONE **Q**BI GFL YHA DON ERE DEY
Deletion of three nucleotides	THE ONE BIG HAD ONE RED EYE
Insertion of three nucleotides	THE ONE BIG **WET** FLY HAD ONE RED EYE

Wildtype = original nucleotide sequence

Substitution = changed nucleotide(s)

Deletion = nucleotide(s) deleted

Mutations Change DNA

Type	Illustration
Wild type	THE ONE BIG FLY HAD ONE RED EYE
Substitution	TH**Q** ONE BIG FLY HAD ONE RED EYE
Frameshift	THE ONE **Q**BI GFL YHA DON ERE DEY
Deletion of three nucleotides	THE ONE BIG HAD ONE RED EYE
Insertion of three nucleotides	THE ONE BIG **WET** FLY HAD ONE RED EYE

Wildtype = original nucleotide sequence

Substitution = changed nucleotide(s)

Deletion = nucleotide(s) deleted

Insertion = nucleotide(s) added

Table 7.2

Mutations Change DNA

Type	Illustration
Wild type	THE ONE BIG FLY HAD ONE RED EYE
Substitution	TH**Q** ONE BIG FLY HAD ONE RED EYE
Frameshift	THE ONE **Q**BI GFL YHA DON ERE DEY
Deletion of three nucleotides	THE ONE BIG HAD ONE RED EYE
Insertion of three nucleotides	THE ONE BIG **WET** FLY HAD ONE RED EYE

"Frameshift" mutations affect multiple codons.

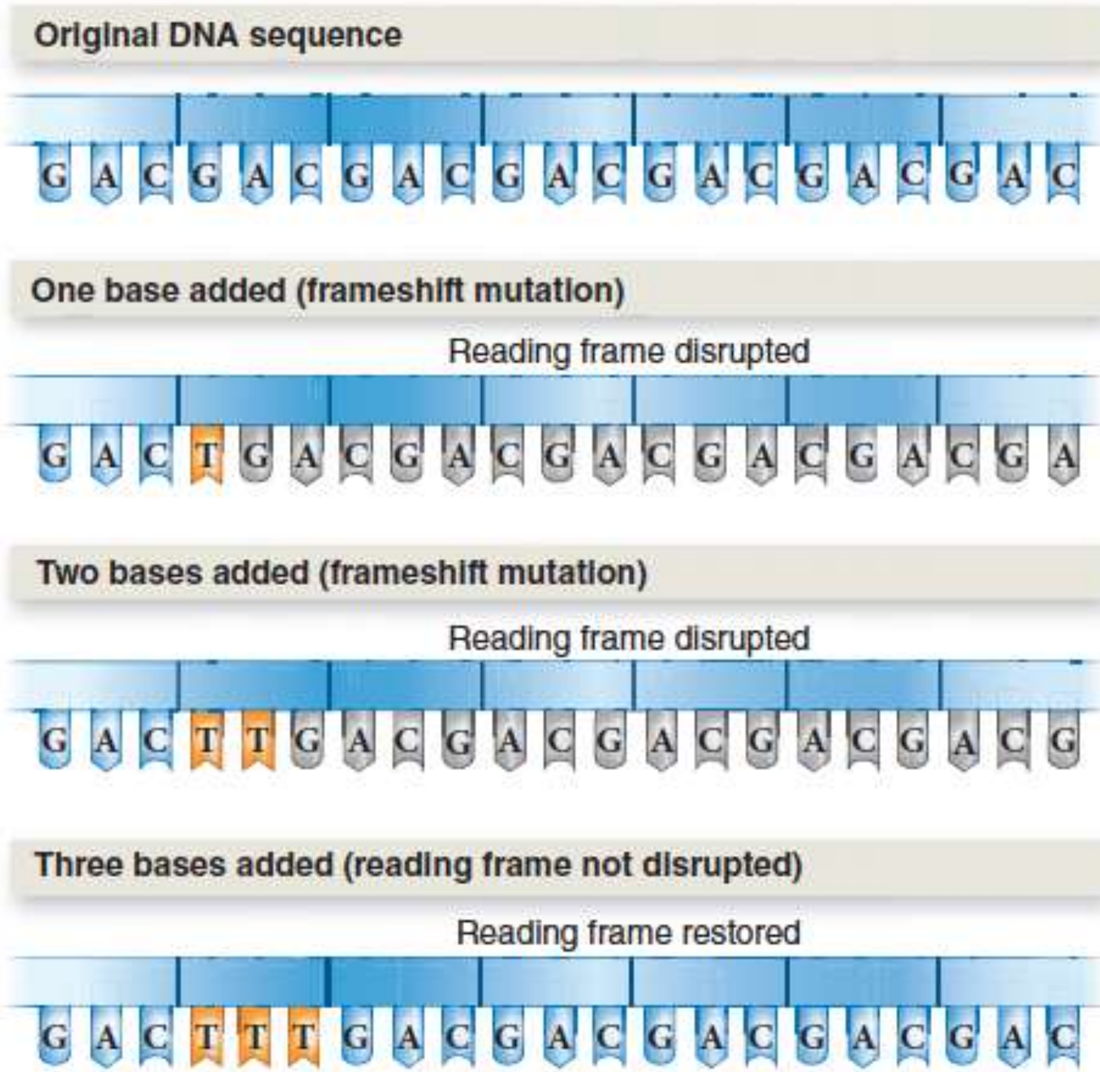
Insertion of one nucleotide changes every codon after the insertion.

Mutations Change DNA

Type	Illustration
Wild type	THE ONE BIG FLY HAD ONE RED EYE
Substitution	TH**Q** ONE BIG FLY HAD ONE RED EYE
Frameshift	THE ONE **Q**BI GFL YHA DON ERE DEY
Deletion of three nucleotides	THE ONE BIG HAD ONE RED EYE
Insertion of three nucleotides	THE ONE BIG **WET** FLY HAD ONE RED EYE

Deletions or insertions of three nucleotides add or delete entire codons, but do not affect other codons.

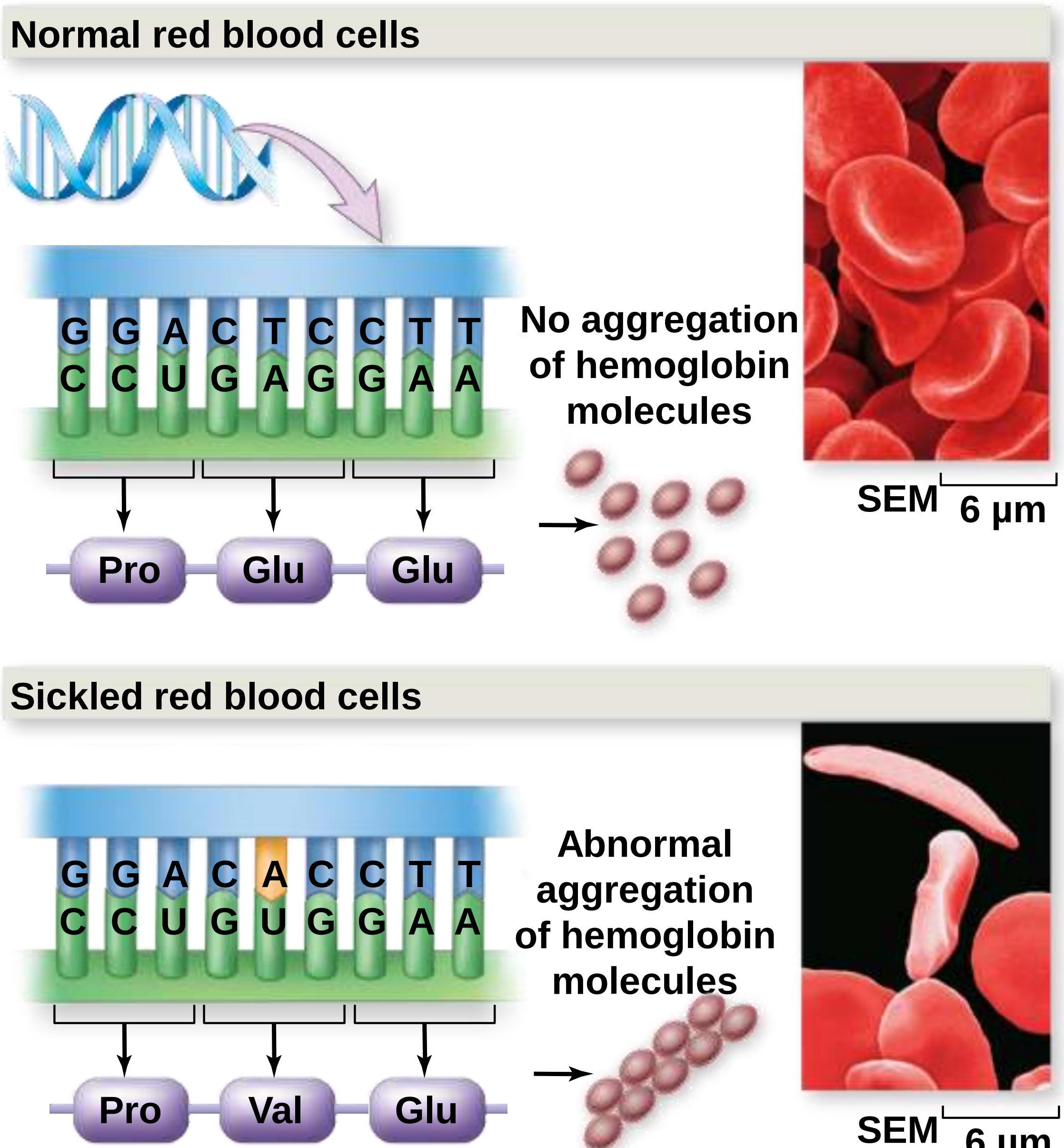
Mutations Change DNA



Section 7.7

Figure 7.22

Mutations Change DNA



A single base substitution in a hemoglobin gene causes blood cells to form abnormally, leading to sickle cell disease.

Figure 7.21

Mutations Change DNA

But mutations are not always harmful!

Figure 7.23

Mutations Change DNA

But mutations are not always harmful!

Mutations create different versions of alleles, which are alternative versions of the same gene.

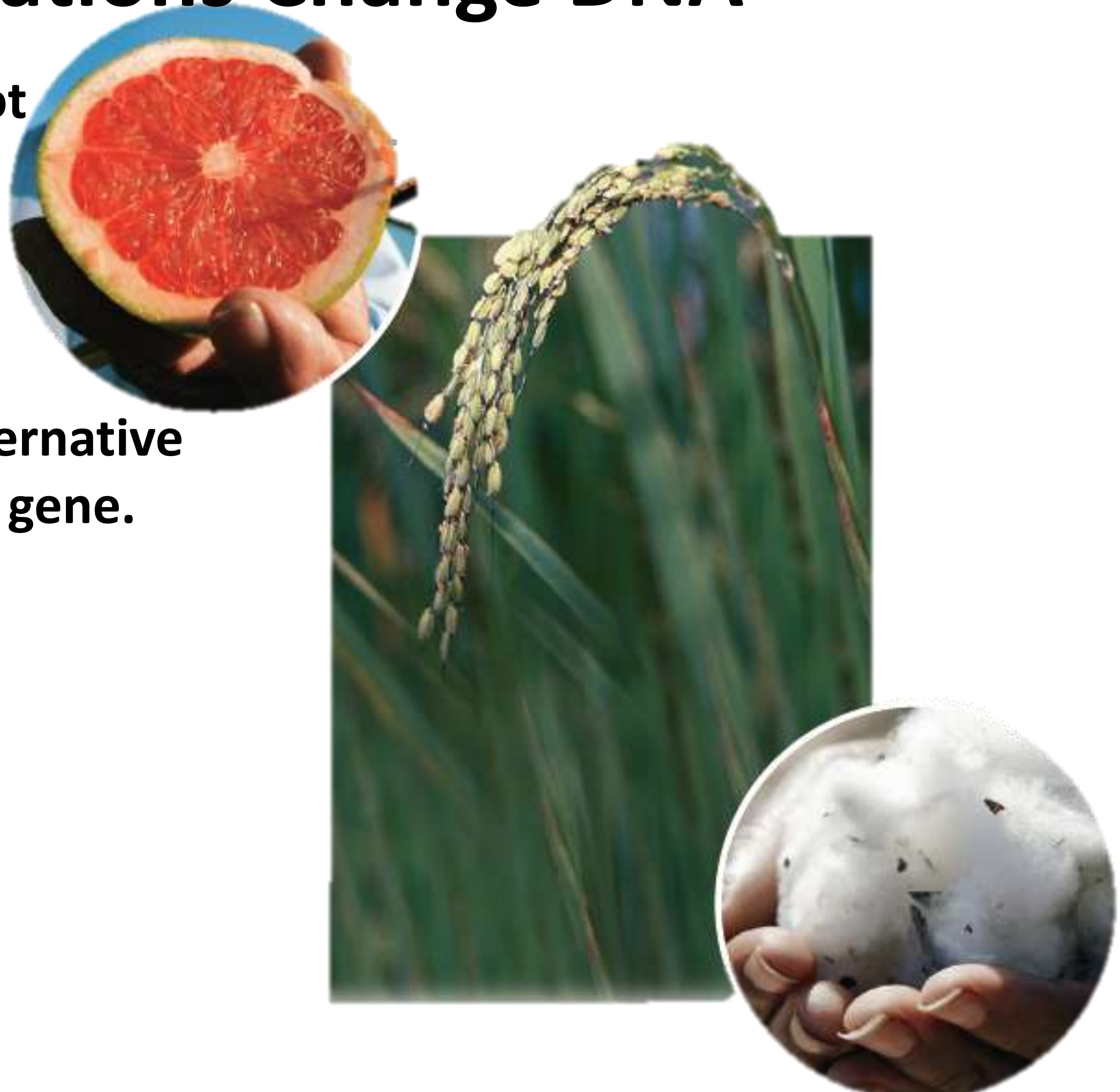


Figure 7.23

Mutations Change DNA

But mutations are not always harmful!

Mutations create different versions of alleles, which are alternative versions of the same gene.

Genetic variation is important for evolution.

Figure 7.23

Mutations Change DNA

But mutations are not always harmful!

Mutations create different versions of alleles, which are alternative versions of the same gene.

Genetic variation is important for evolution.

Plant breeders even induce mutations to create new varieties of plants.

Figure 7.23

Clicker Question #4

The DNA template strand sequence below mutates, as shown. What happens to the amino acids encoded by these two codons? (Hint: you will need to look at figure 7.7, the genetic code.)

Original sequence: AGT TCT
Mutated sequence: GGT TCC

A. Both amino acids change.
B. Only one amino acid changes.
C. Neither amino acid changes.

Clicker Question #4

The DNA template strand sequence below mutates, as shown. What happens to the amino acids encoded by these two codons? (Hint: you will need to look at figure 7.7, the genetic code.)

Original sequence: AGT TCT
Mutated sequence: GGT TCC

A. Both amino acids change.
B. Only one amino acid changes.
C. Neither amino acid changes.

Many agents can cause mutations

- Some mutations are spontaneous while others are due to environmental mutagens
- **Environmental Mutagens**
  - **Mutagen -** an environmental agent that increases the chances of a mutation
  - **Carcinogens -** cancer-causing agents
    - Tobacco smoke contains a number of organic chemicals that are known carcinogens

DNA Replication

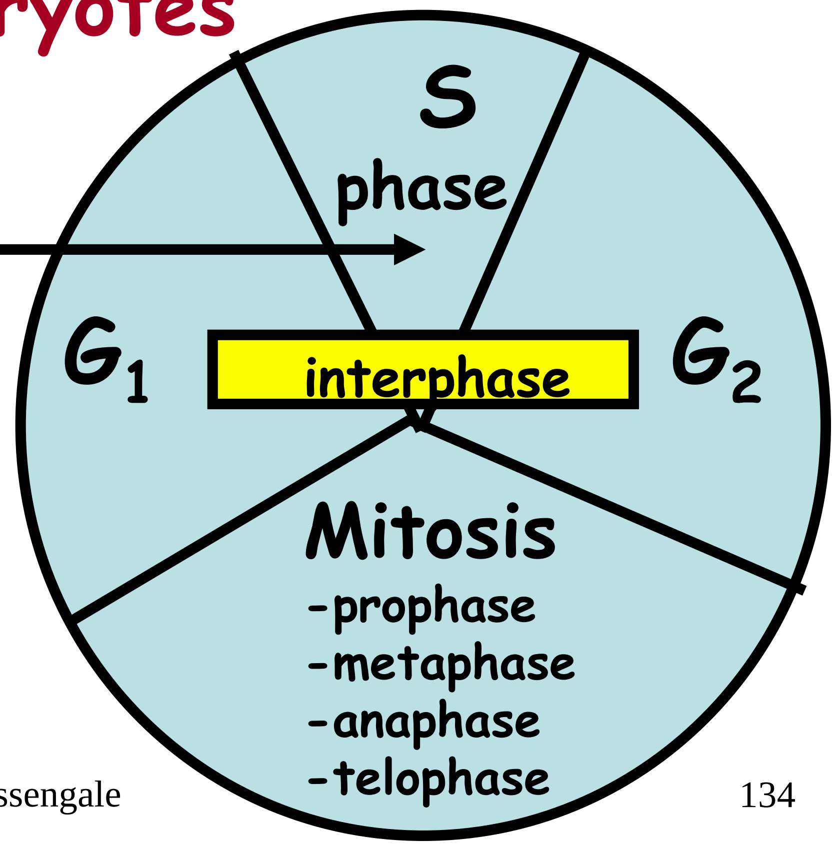
Replication Facts

- DNA has to be copied before a cell divides
- DNA is copied during the S or synthesis phase of interphase
- New cells will need identical DNA strands

Synthesis Phase (S phase)

- S phase during interphase of the cell cycle
- Nucleus of eukaryotes

DNA replication takes place in the S phase.



DNA replication is semiconservative

- **DNA replication -** the process of copying a DNA molecule
- Replication requires the following steps:

  1. Unwinding: Old strands are unwound and “unzipped”

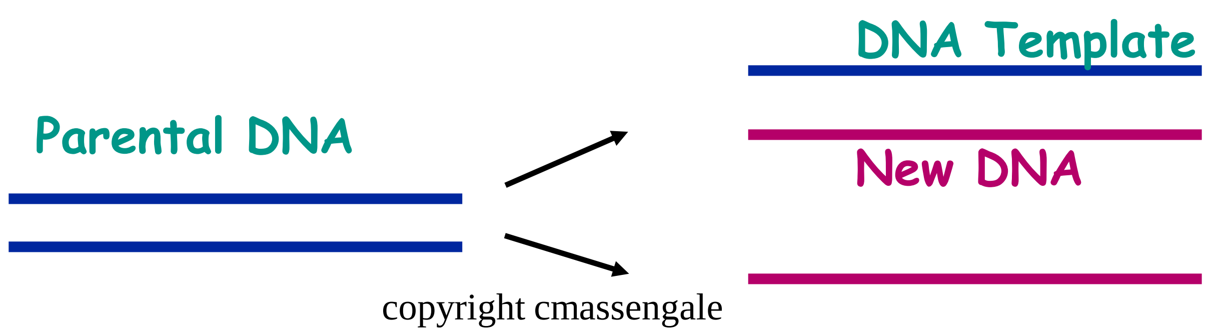
  2. Complementary base pairing or initiation: New complementary nucleotides are positioned by the process of base pairing

  3. Joining or elongation: Complementary nucleotides join to form new strands

    - Each daughter DNA molecule contains a template strand, or old strand, and a new strand
- Steps 2 and 3 are carried out by **DNA polymerase**

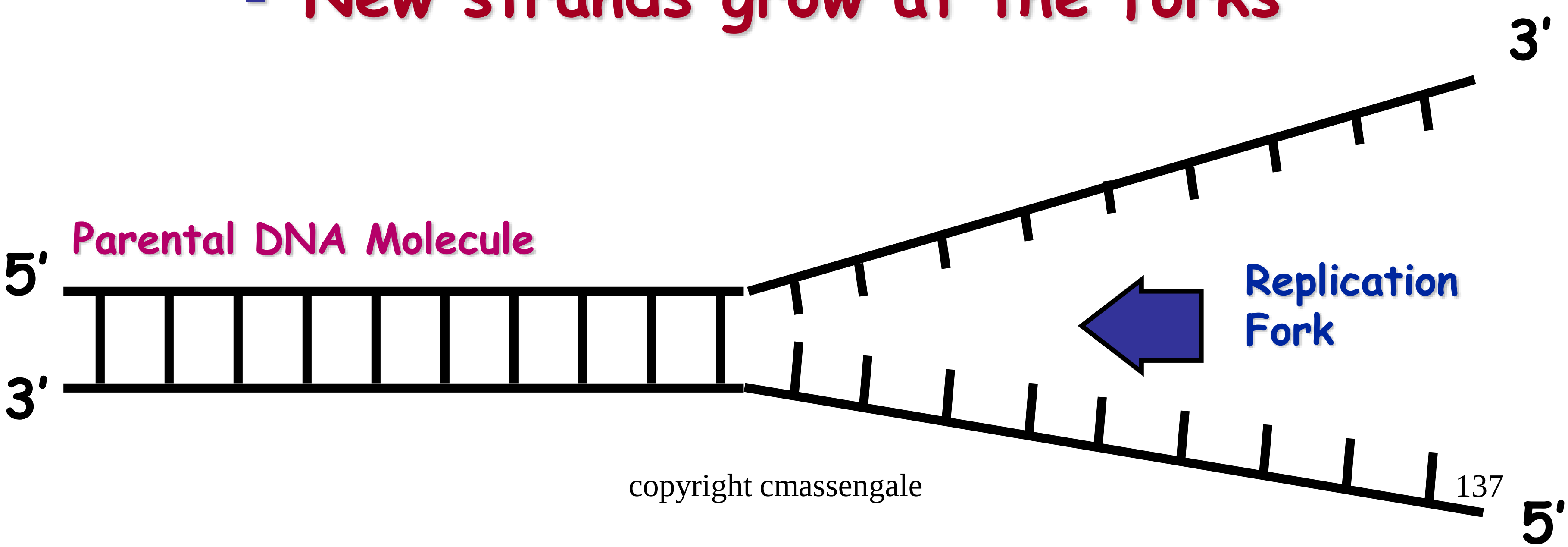
Semiconservative Model of Replication

- Idea presented by **Watson & Crick**
- The two strands of the parental molecule separate, and each acts as a **template** for a **new complementary strand**
- New DNA consists of 1 PARENTAL (original) and 1 NEW strand of DNA



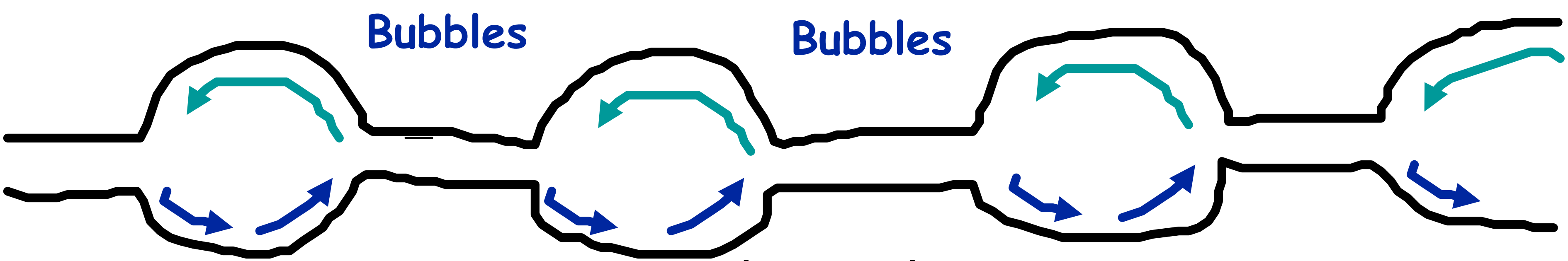
DNA Replication

- Begins at Origins of Replication
- Two strands open forming Replication Forks (Y-shaped region)
- New strands grow at the forks



DNA Replication

- As the 2 DNA strands open at the origin, Replication Bubbles form
- Prokaryotes (bacteria) have a single bubble
- Eukaryotic chromosomes have MANY bubbles

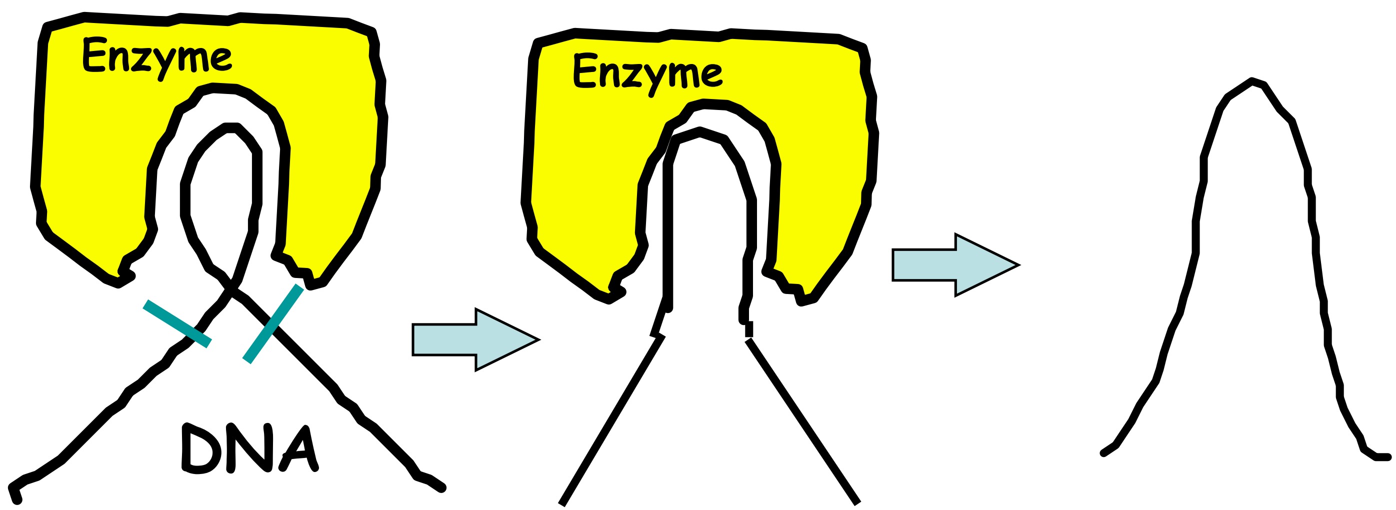


DNA Replication

- Enzyme Helicase unwinds and separates the 2 DNA strands by breaking the weak hydrogen bonds
- Single-Strand Binding Proteins attach and keep the 2 DNA strands separated and untwisted

DNA Replication

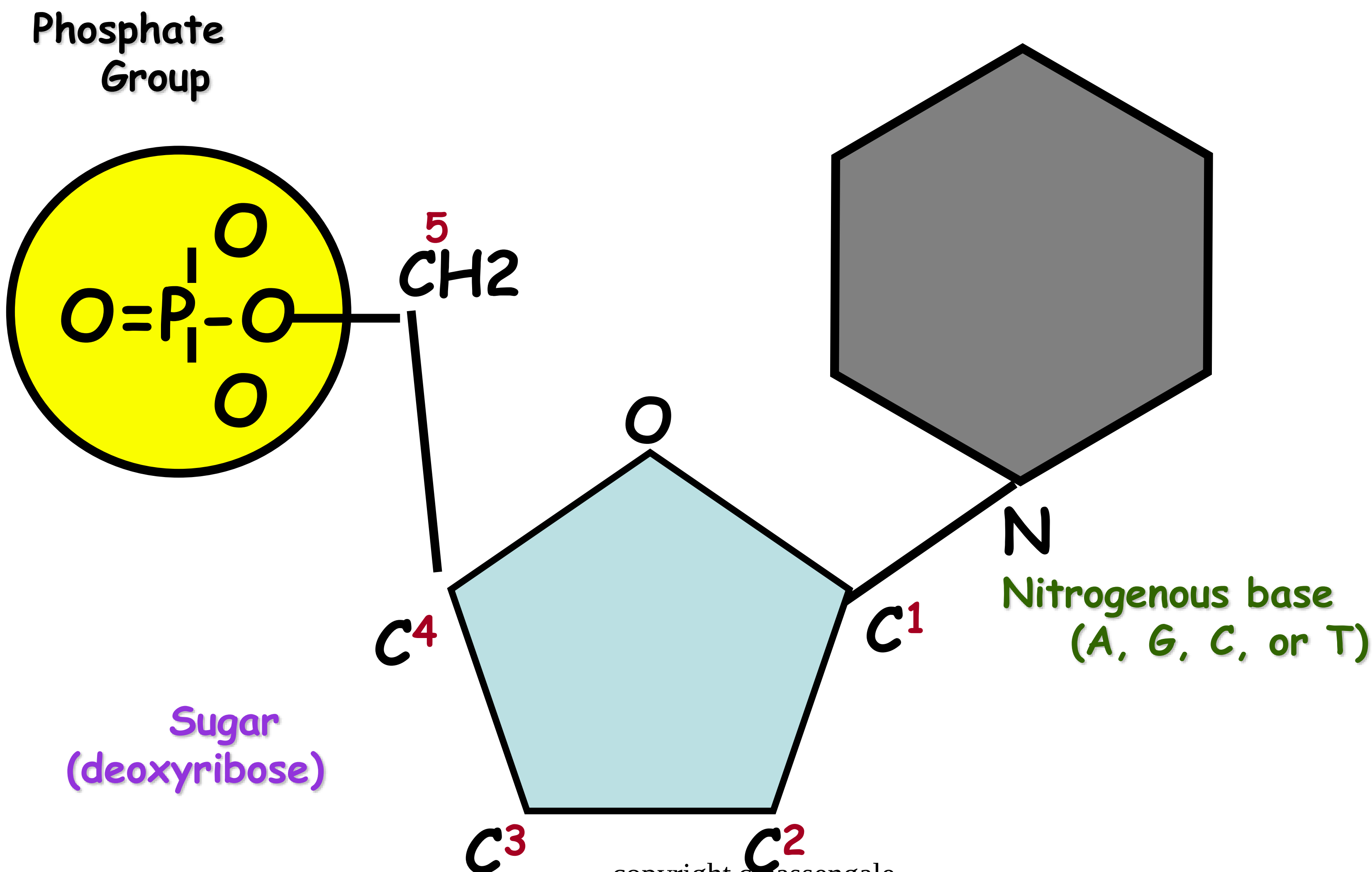
- Enzyme **Topoisomerase** attaches to the 2 forks of the bubble to **relieve stress** and **prevents supercoiling** of the DNA molecule as it separates



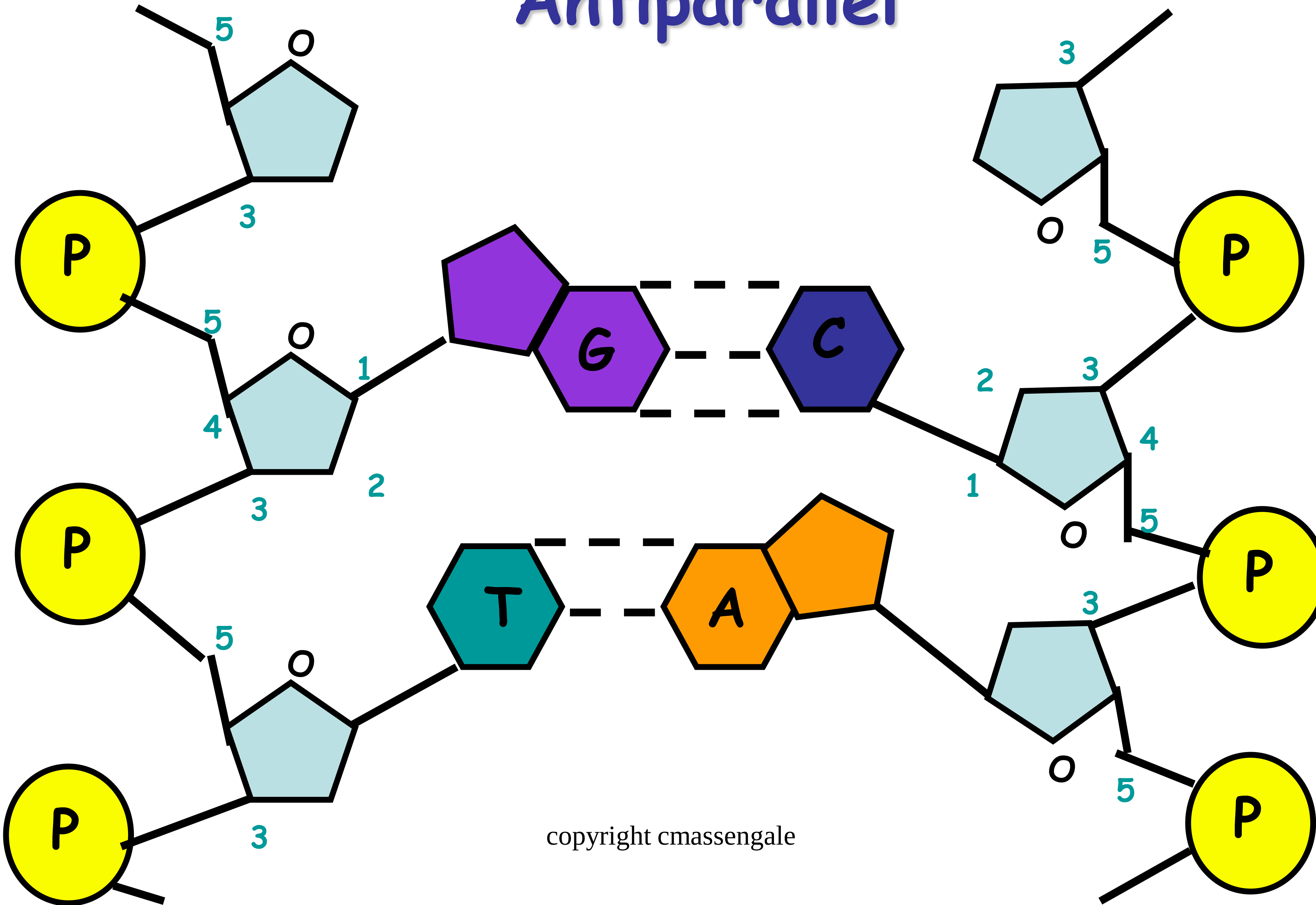
DNA Replication

- Before new DNA strands can form, there must be **RNA primers** present to start the addition of new nucleotides
- **Primase** is the enzyme that synthesizes the RNA Primer
- **DNA polymerase** can then add the new nucleotides

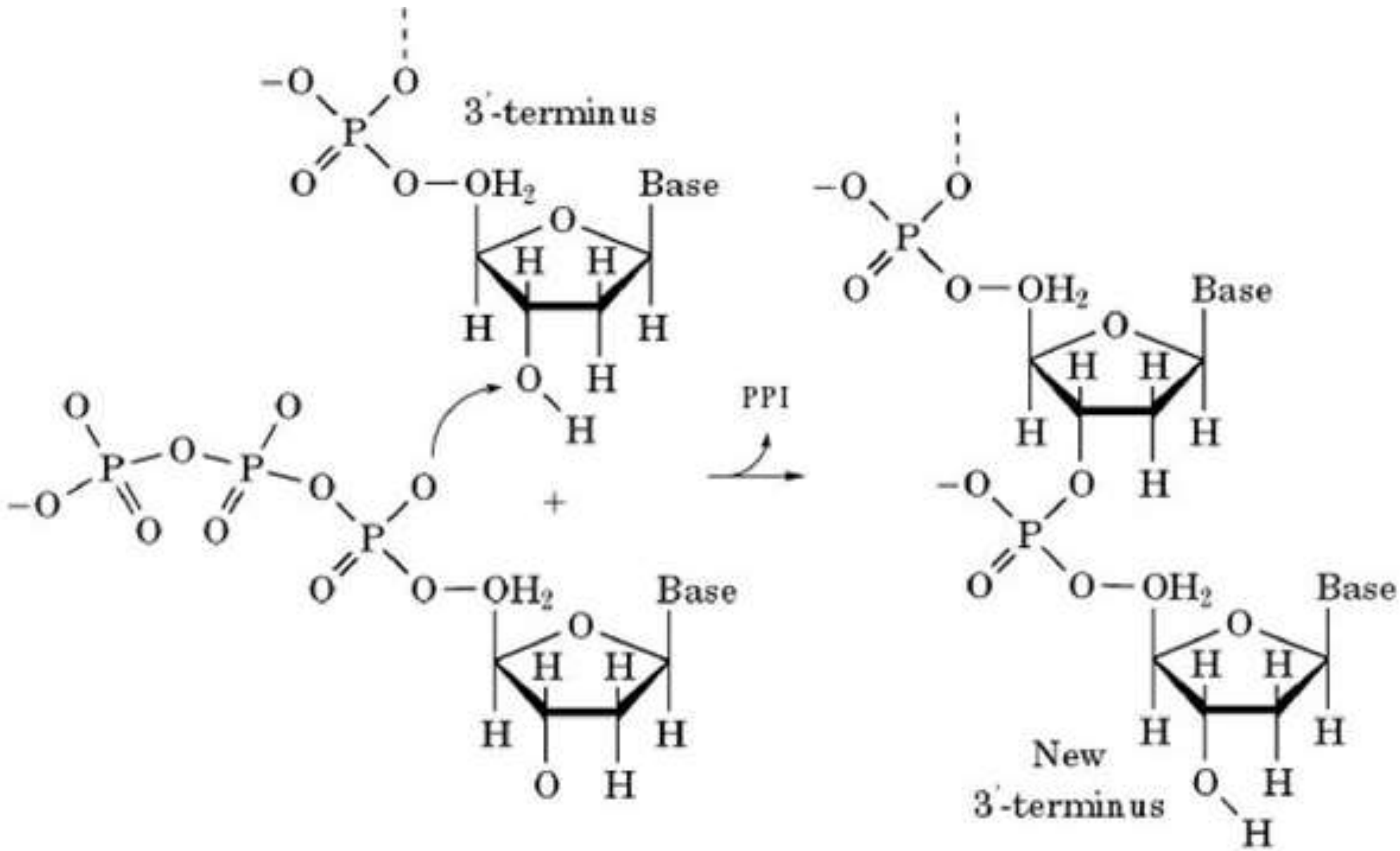
Remember HOW the Carbons Are Numbered!



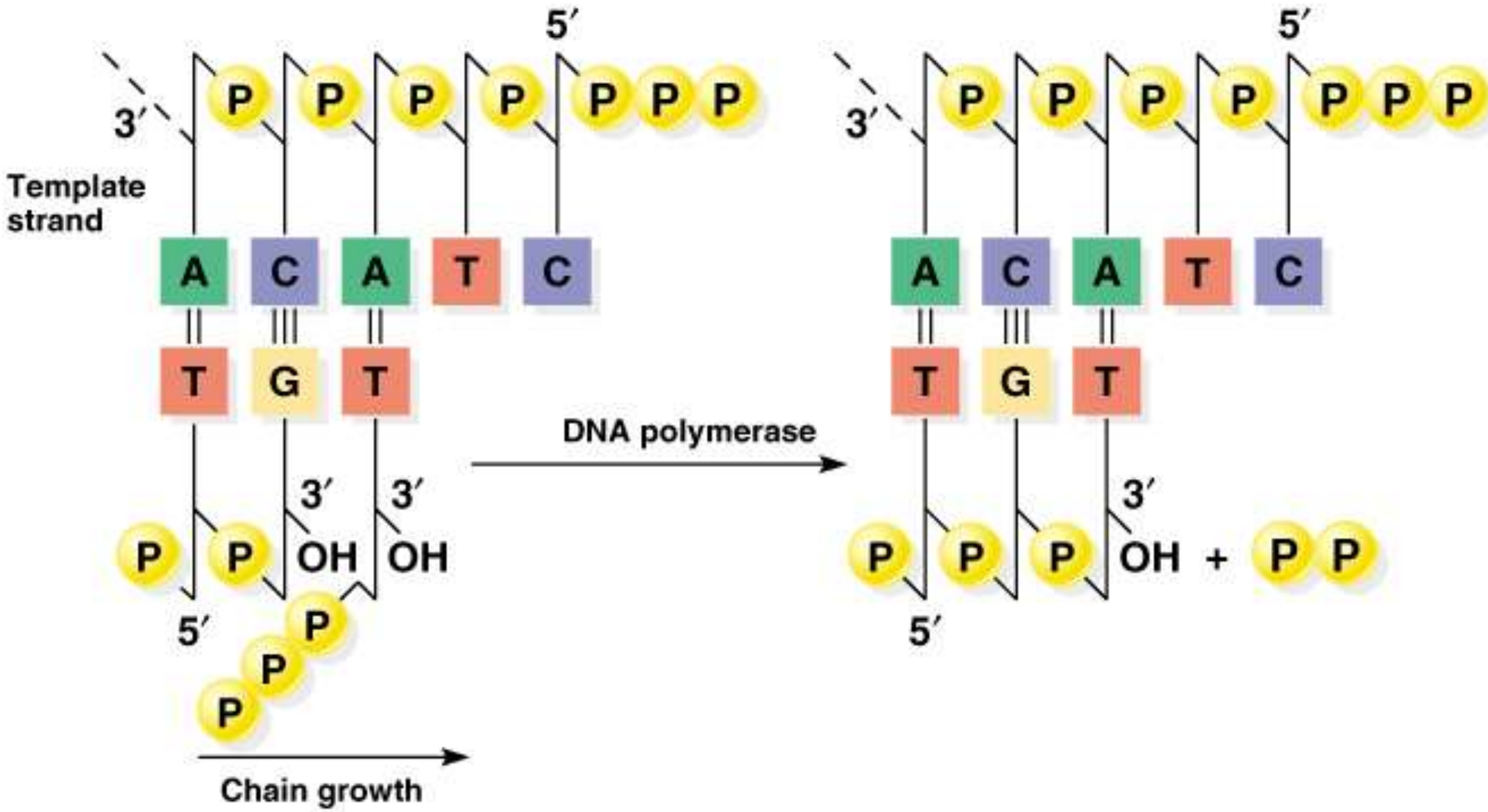
Remember the Strands are Antiparallel



Three main features of the DNA synthesis reaction:



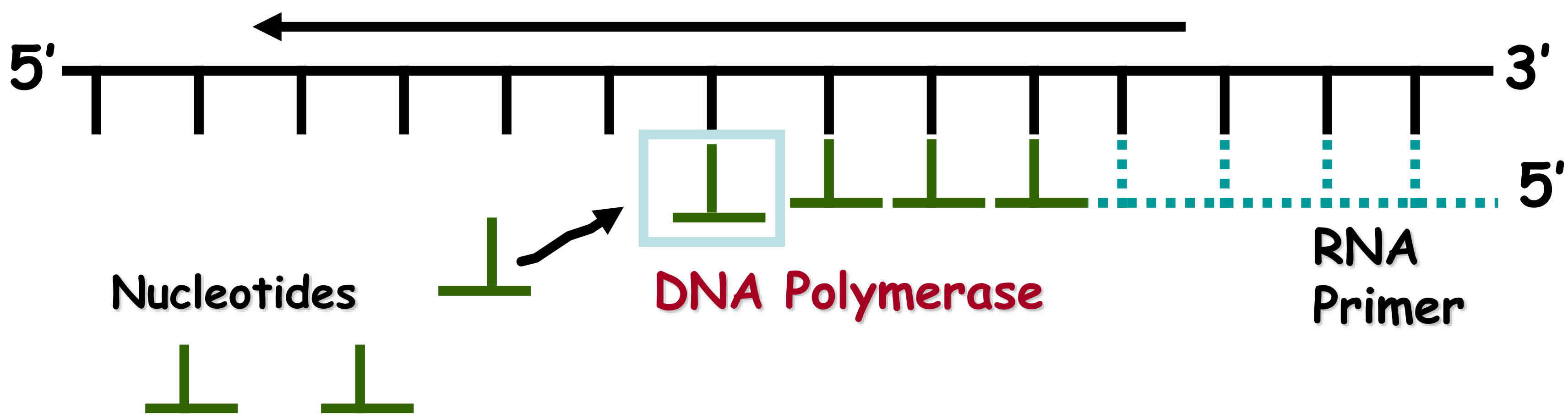
DNA elongation (Fig. 3.3b):



b) Shorthand notation

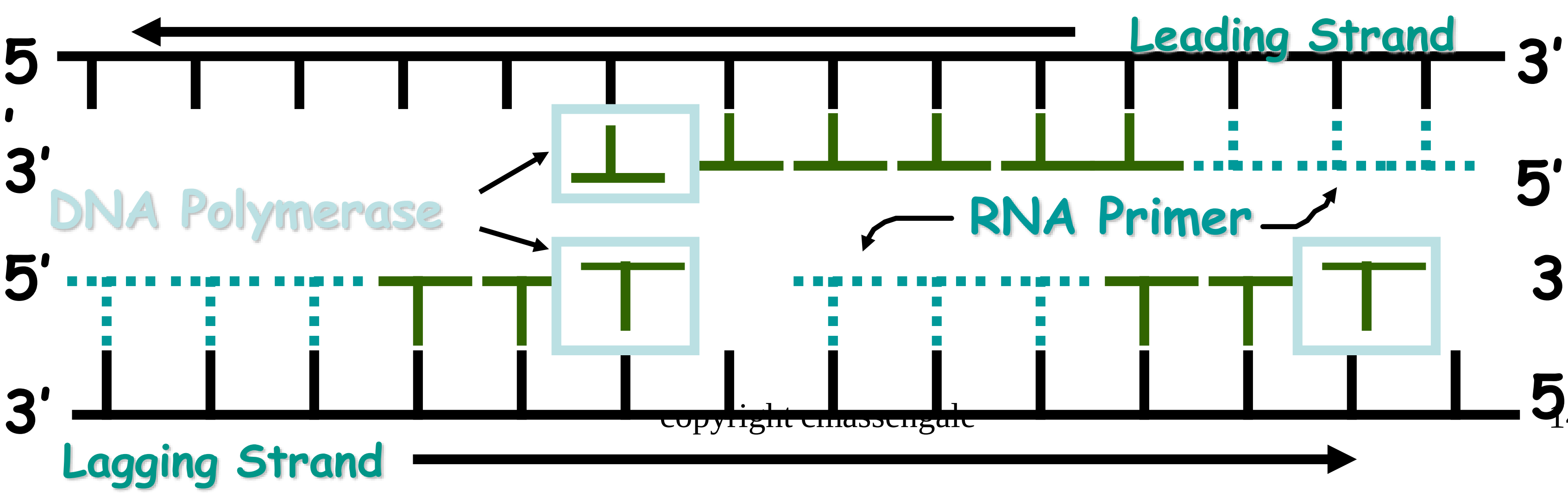
Synthesis of the New DNA Strands

- The **Leading Strand** is synthesized as a single strand from the **point of origin toward the opening replication fork**



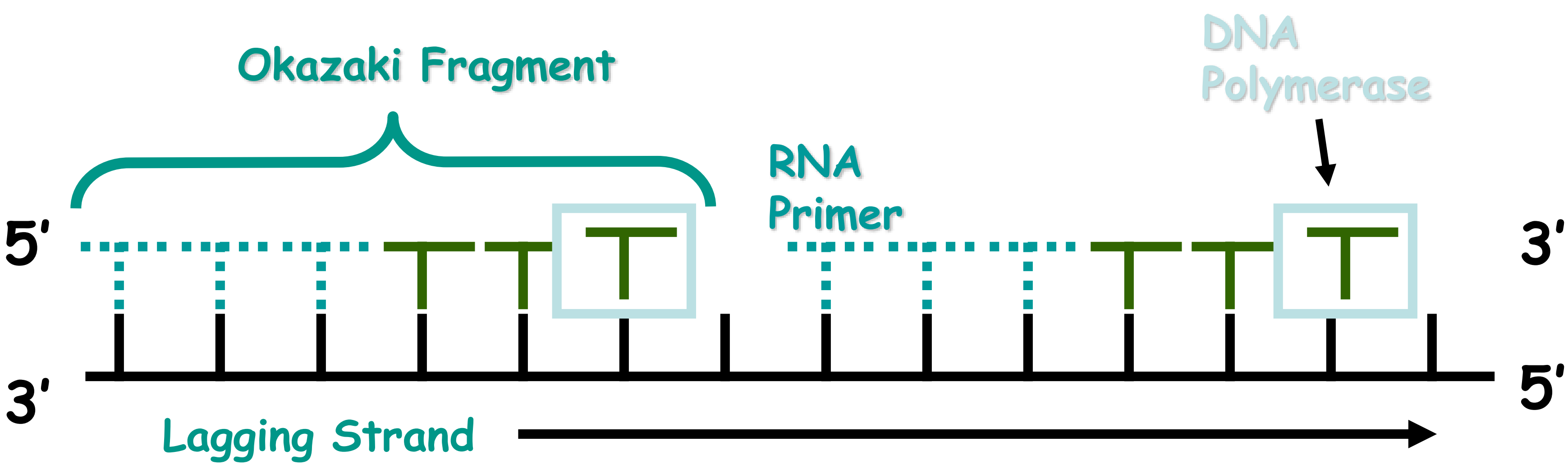
Synthesis of the New DNA Strands

- The Lagging Strand is synthesized discontinuously against overall direction of replication
- This strand is made in MANY short segments It is replicated from the replication fork toward the origin



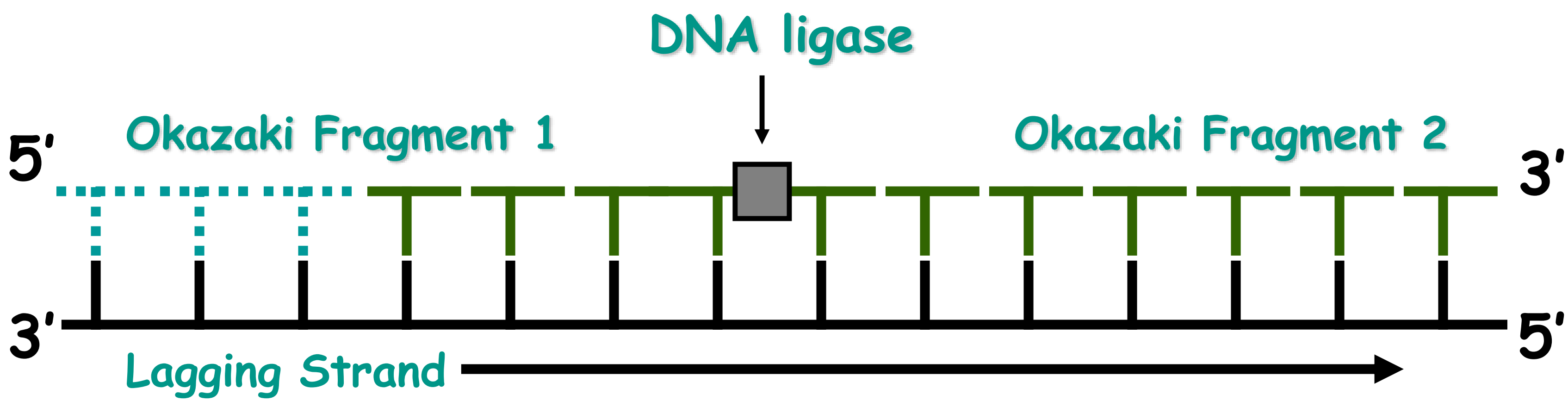
Lagging Strand Segments

- **Okazaki Fragments** - series of short segments on the **lagging strand**
- **Must be joined together by an enzyme ligase**

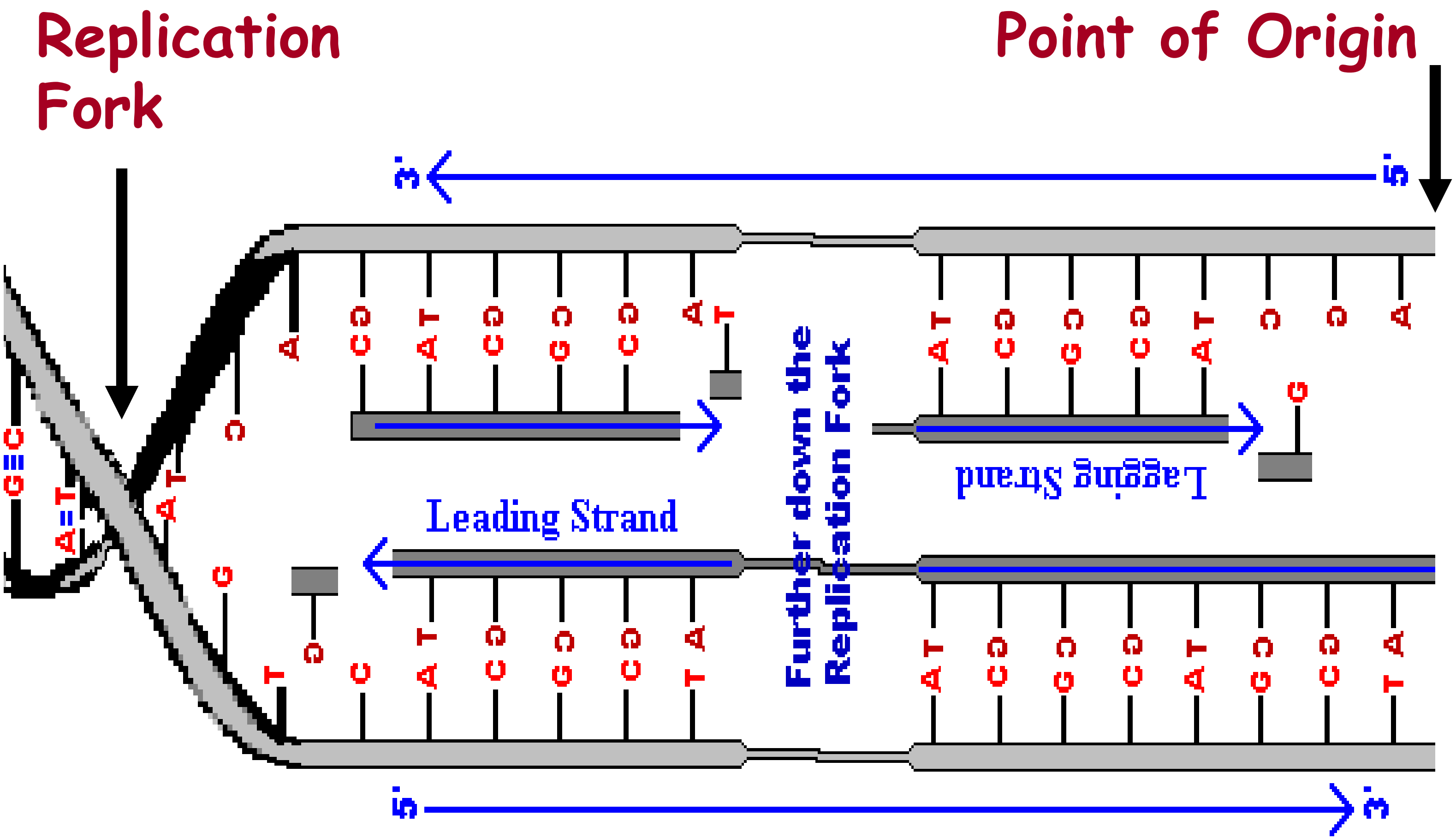


Joining of Okazaki Fragments

- The enzyme **Ligase** joins the Okazaki fragments together to make one strand



Replication of Strands



Putting it all together

- DNA Replication video
- Crash Course

1st step- Unwinding replication forks

What are the enzymes and proteins involved?

-Topiosomerase, Helicase, Gyrase, SSB proteins

2nd step- Initiation

What are the enzymes and proteins involved?

-Primase (RNA primer)

3rd step-Elongation

What are the enzymes and proteins involved?

-POL III, POL I, ligase

DNA Replication Errors

Proofreading New DNA

- DNA polymerase initially makes about **1 in 10,000** base pairing errors
- **Enzymes** proofread and correct these mistakes
- The new error rate for DNA that has been proofread is **1 in 1 billion** base pairing errors

Causes of damaged DNA can be damage

- Chemicals & ultraviolet radiation damage the DNA in our body cells
- Cells must continuously repair DAMAGED DNA
- Excision repair occurs when any of over 50 repair enzymes remove damaged parts of DNA
- DNA polymerase and DNA ligase replace and bond the new nucleotides together

Question:

- What would be the complementary DNA strand for the following DNA sequence?

DNA 5'-CGTATG-3'

Answer:

DNA 5'-CGTATG-3'

DNA 3'-GCATAC-5'

10.7 Many different proteins help DNA replicate

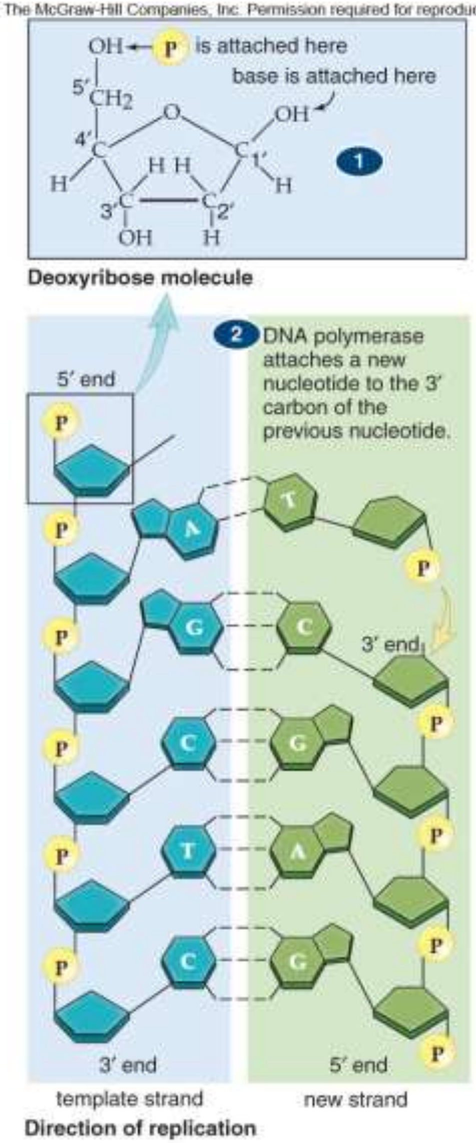
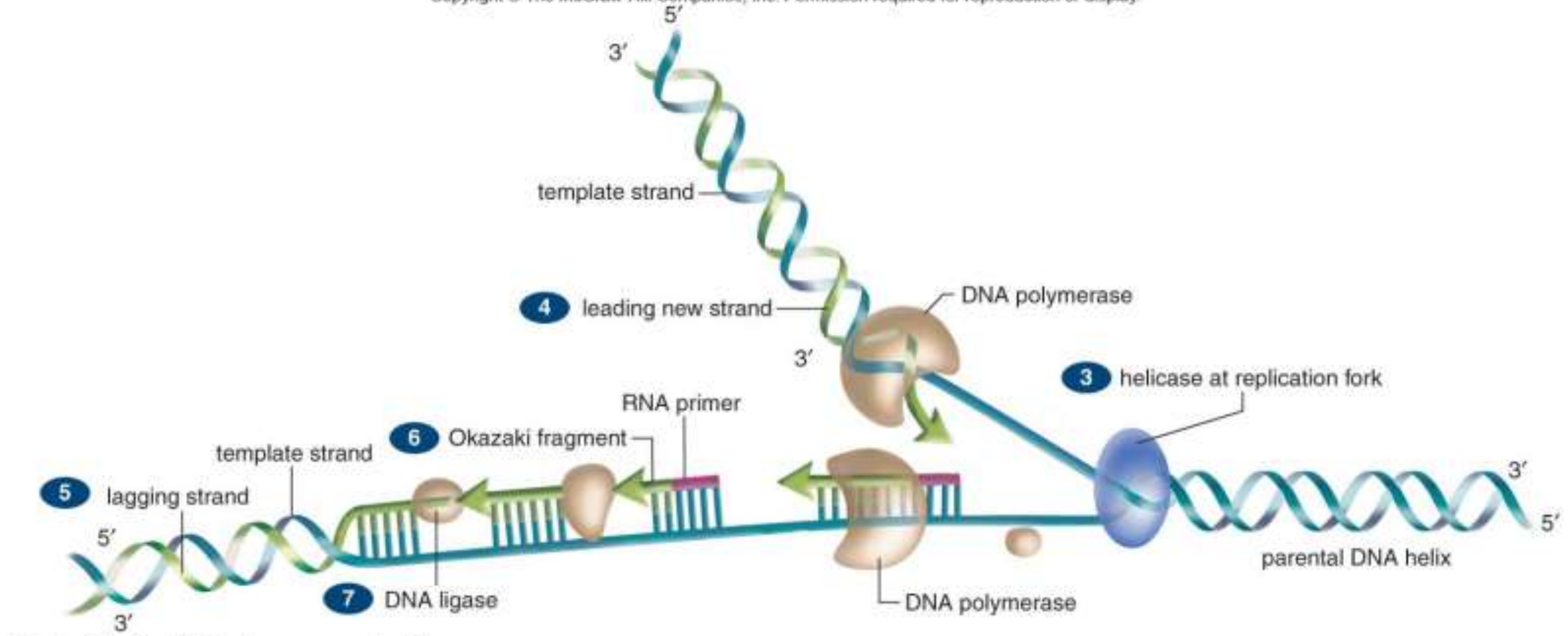


Figure 10.7 DNA replication (in depth)

10.7 Many different proteins help DNA replicate

Figure 10.7 DNA replication (in depth) (Cont.)



Replication fork introduces complications