Chapter 12: DNA and RNA

Section 1: DNA

Do You Remember…

- What organelle is known as the “control center” of the cell?
- What is DNA?
- What do you call visible DNA?
- What are chromosomes composed of?
- What are located on chromosomes?
- How do genes control the activity of the cell?*

Frederick Griffith

Oswald Avery

Griffith and Avery

- Griffith curious how bacteria kills.
- Finds disease-causing bacteria kills.
- Finds non-disease causing bacteria doesn’t.
- Heat kills disease causing bacteria and then it doesn’t kill NO MORE!
- Mixes heat killed and non-disease and kills.
- Discovered transformation, the traits of one organism passed on to another. Example is the ability of non-disease causing bacteria to inherit the ability to kill.
- Avery extracted “juice” from bacteria and repeated experiment. Carefully destroyed different molecules, such as proteins, until he found DNA caused transformation.*

Figure 12–2 Griffith's Experiment

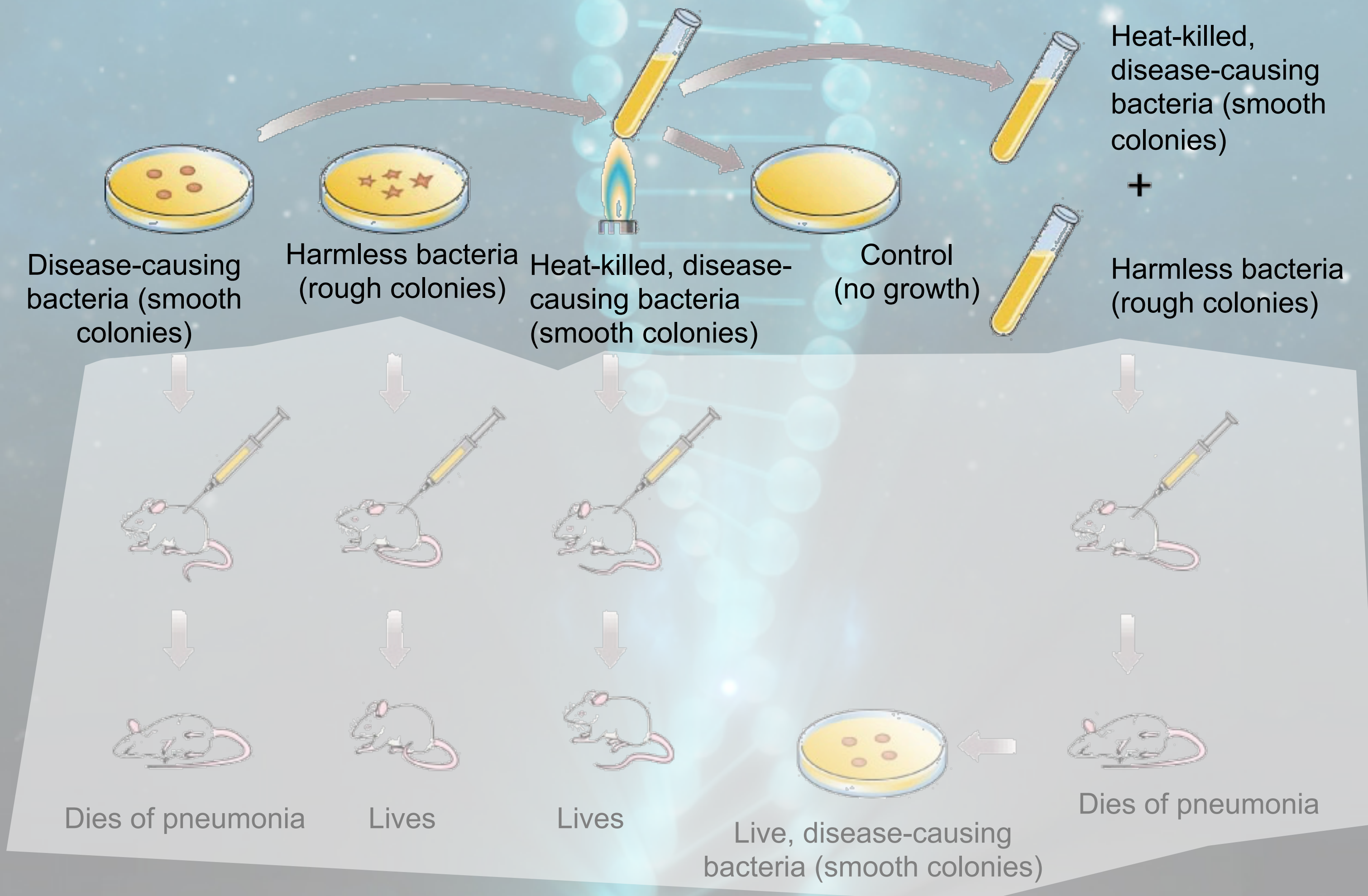
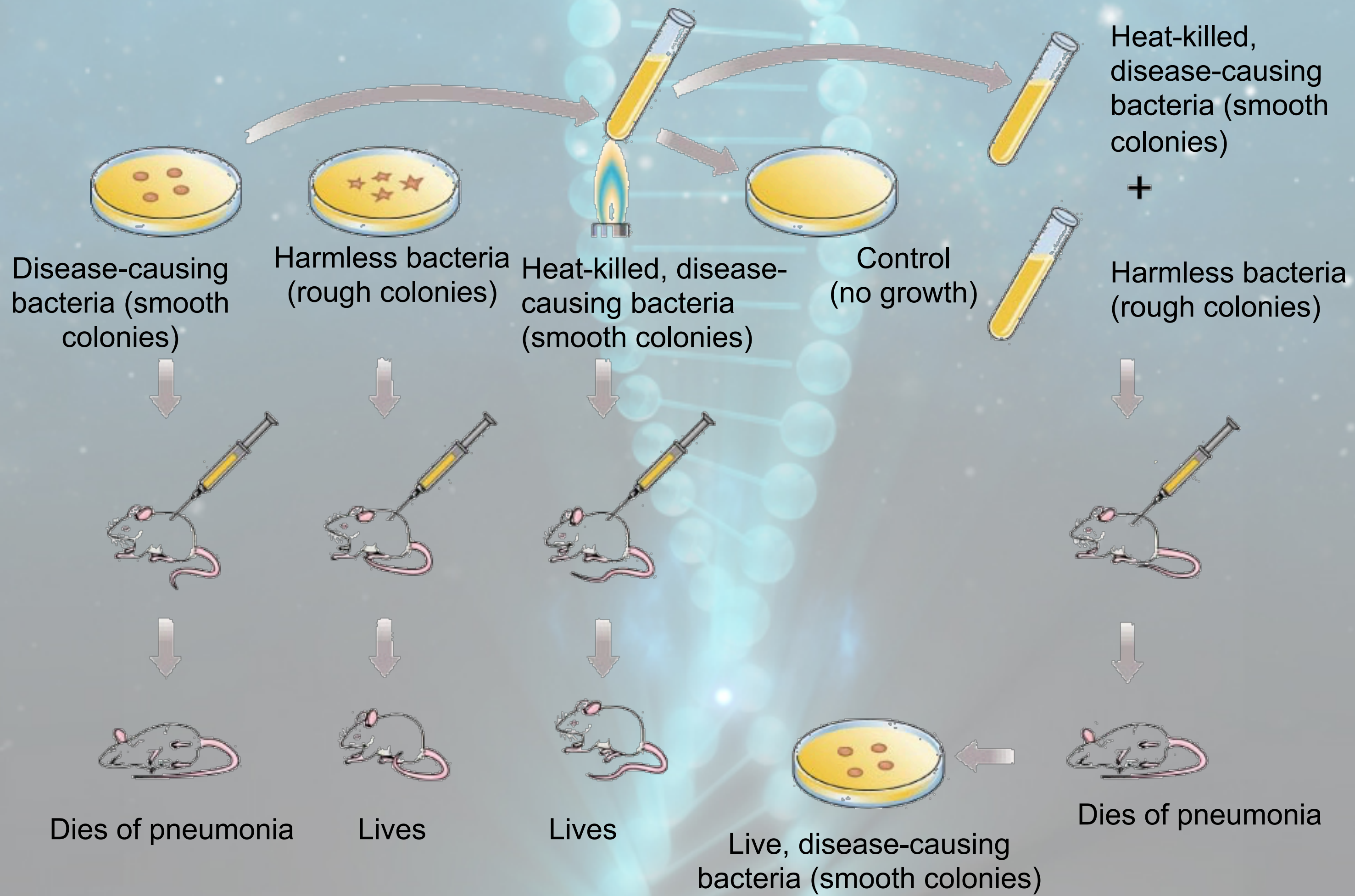


Figure 12–2 Griffith’s Experiment



- Avery and other scientists discovered that DNA is the nucleic acid that stores and transmits the genetic information from one generation of an organism to the next.
- What was the Hershey-Chase experiment to prove Avery’ s ideas?
- Followed a bacteriophage with radioactive markers as it infected a bacteria.
- What were the results?
- Hershey and Chase concluded that the genetic material of the bacteriophage was DNA not proteins.*

Figure 12–4 Hershey-Chase Experiment

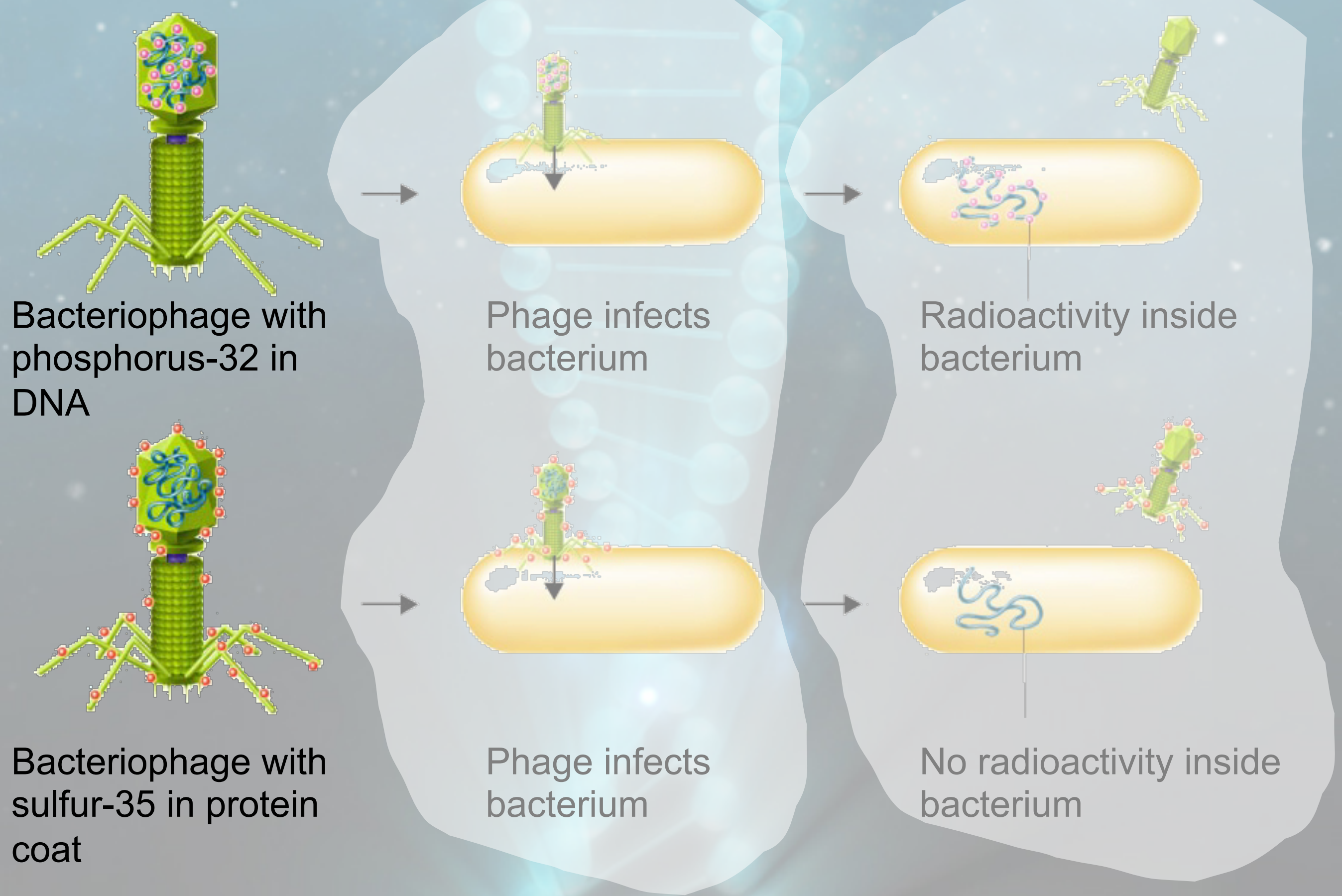
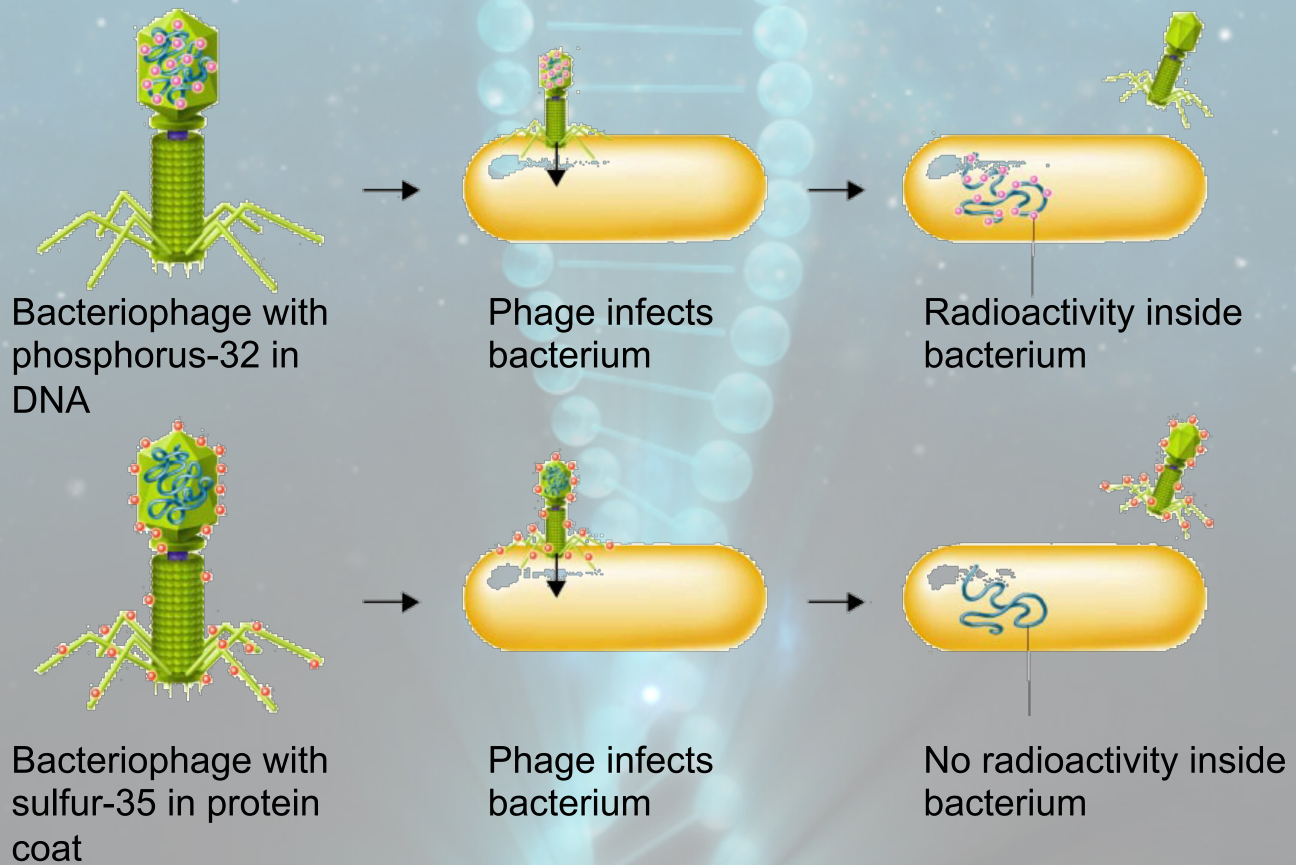


Figure 12–4 Hershey-Chase Experiment

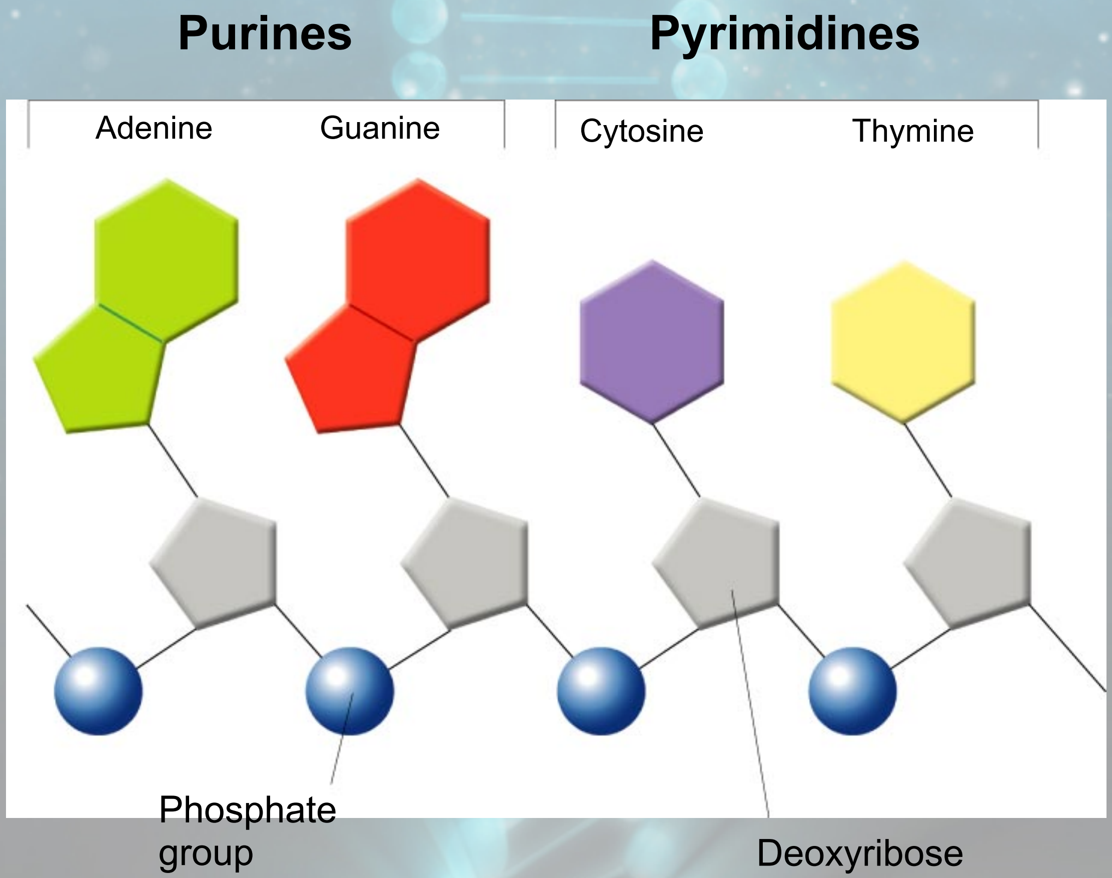


Structure of DNA

- It wasn’t good enough to know DNA was the genetic carrier now they wanted to know how it worked.
- What were the three critical things genes could do?
- Carry information from one generation to another, put that information to work via characteristics, and had to be easily copied.*

- What are the sub-units of DNA called?
- Nucleotides.
- What are the three units of each nucleotide?
- 5 carbon sugar called deoxyribose, a phosphate group, and a nitrogenous base.
- What are the names of the 4 different bases of DNA?
- Adenine and guanine, the purines, and cytosine and thymine, the pyrimidines.
- What forms the backbone of the DNA chain?
- The sugar and phosphate molecules.*

Figure 12–5 DNA Nucleotides



- What were Chargaff's rules?
- He discovered that the amount of adenine almost always matched the amount of thymine and the amount of cytosine almost always matched the amount of guanine.

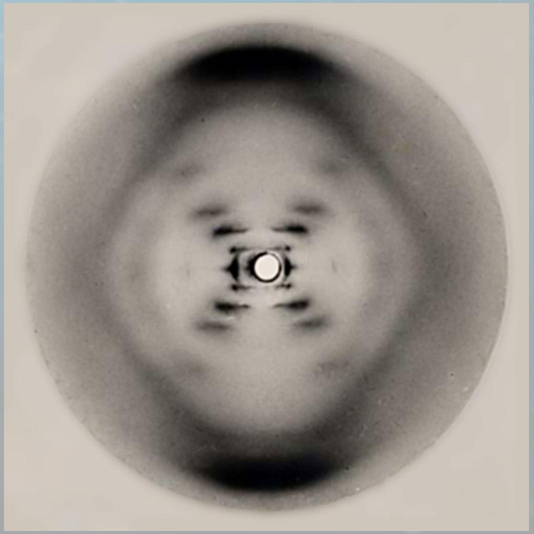
Source	Mol % of Bases					Ratios	
	Adenine (A)	Guanine (G)	Cytosine[a] (C)	Thymine (T)	(G + C)	A/T	G/C
Bacteriophage ϕX174	24.0	23.3	21.5	31.2	44.8	0.77[b]	1.08[b]
Bacteriophage T7	26.0	23.8	23.6	26.6	47.4	0.98	1.01
Escherichia coli B	23.8	26.8	26.3	23.1	53.2	1.03	1.02
Neurospora	23.0	27.1	26.6	23.3	53.8	0.99	1.02
Corn (maize)	26.8	22.8	23.2	27.2	46.1	0.99	0.98
Tetrahymena	35.4	14.5	14.7	35.4	29.2	1.00	0.99
Octopus	33.2	17.6	17.6	31.6	35.2	1.05	1.00
Drosophila	30.7	19.6	20.2	29.5	39.8	1.03	0.97
Starfish	29.8	20.7	20.7	28.8	41.3	1.03	1.00
Salmon	28.0	22.0	21.8	27.8	44.1	1.01	1.01
Frog	26.3	23.5	23.8	26.8	47.4	1.00	0.99
Chicken	28.0	22.0	21.6	28.4	43.7	0.99	1.02
Rat	28.6	21.4	21.6	28.4	42.9	1.01	1.00
Calf	27.3	22.5	22.5	27.7	45.0	0.99	1.00
Human	29.3	20.7	20.0	30.0	40.7	0.98	1.04

Source: Data taken from H. E. Sober (ed.), *Handbook of Biochemistry,* 2nd ed. (Chemical Rubber Publishing Co., 1970). Values for higher organisms vary slightly from one tissue to another, probably as a result of experimental error.

[a] Amount includes, for some organisms, a few percent of a modified base, 5-methylcytosine.

[b] This bacteriophage has a single-strand DNA, which need not follow Chargaff's rule.

- What was Rosalind Franklin's contribution to our understanding of DNA?
- She provided evidence, using x-ray diffraction techniques, which showed DNA had a Helix shape.*



- What were Watson and Crick’s contributions to DNA?
- They were able to make three-dimensional models which showed how DNA could replicate.
- Watson and Cricks model of DNA was a double helix, in which two strands of DNA wound around each other.*

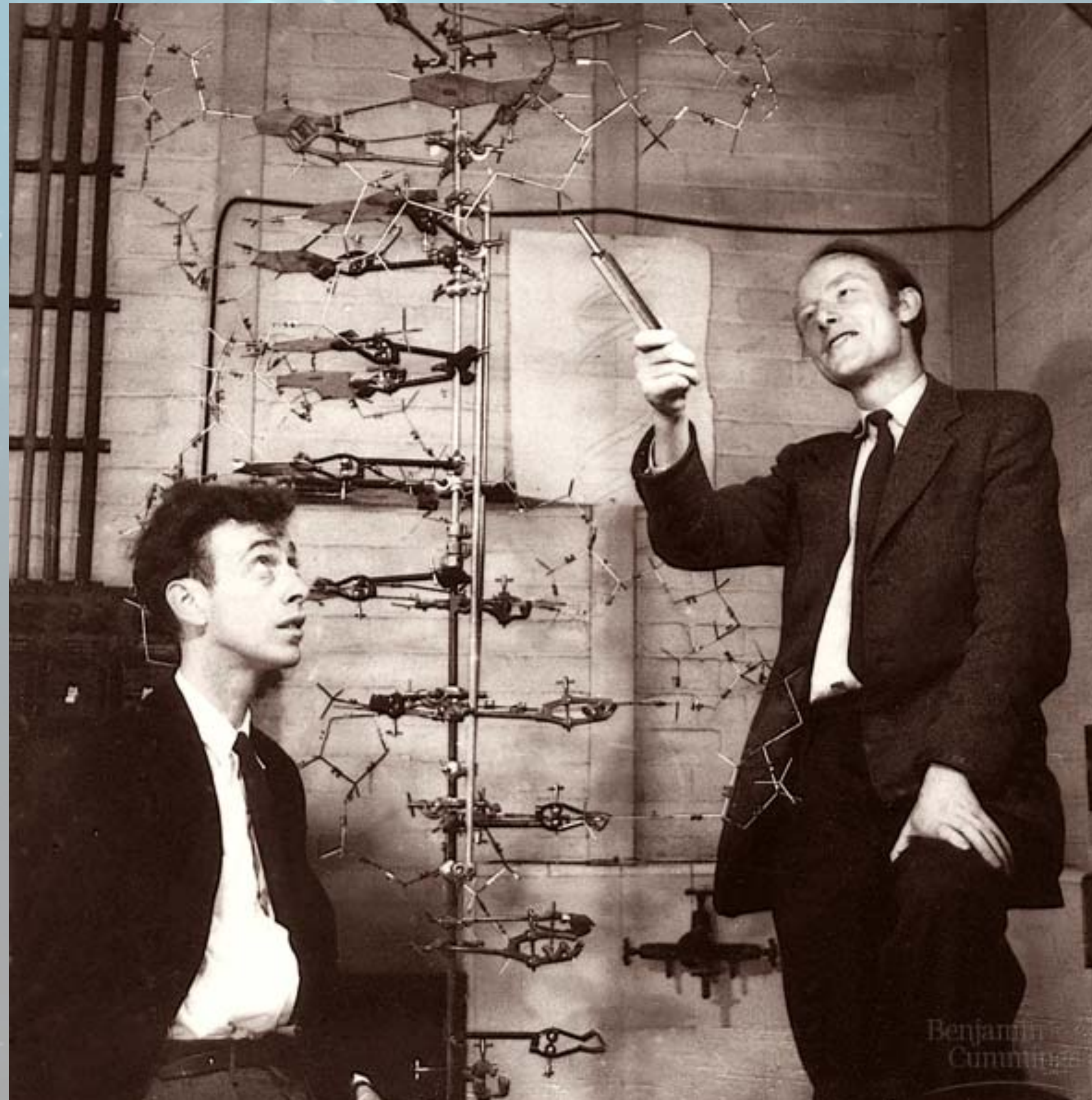
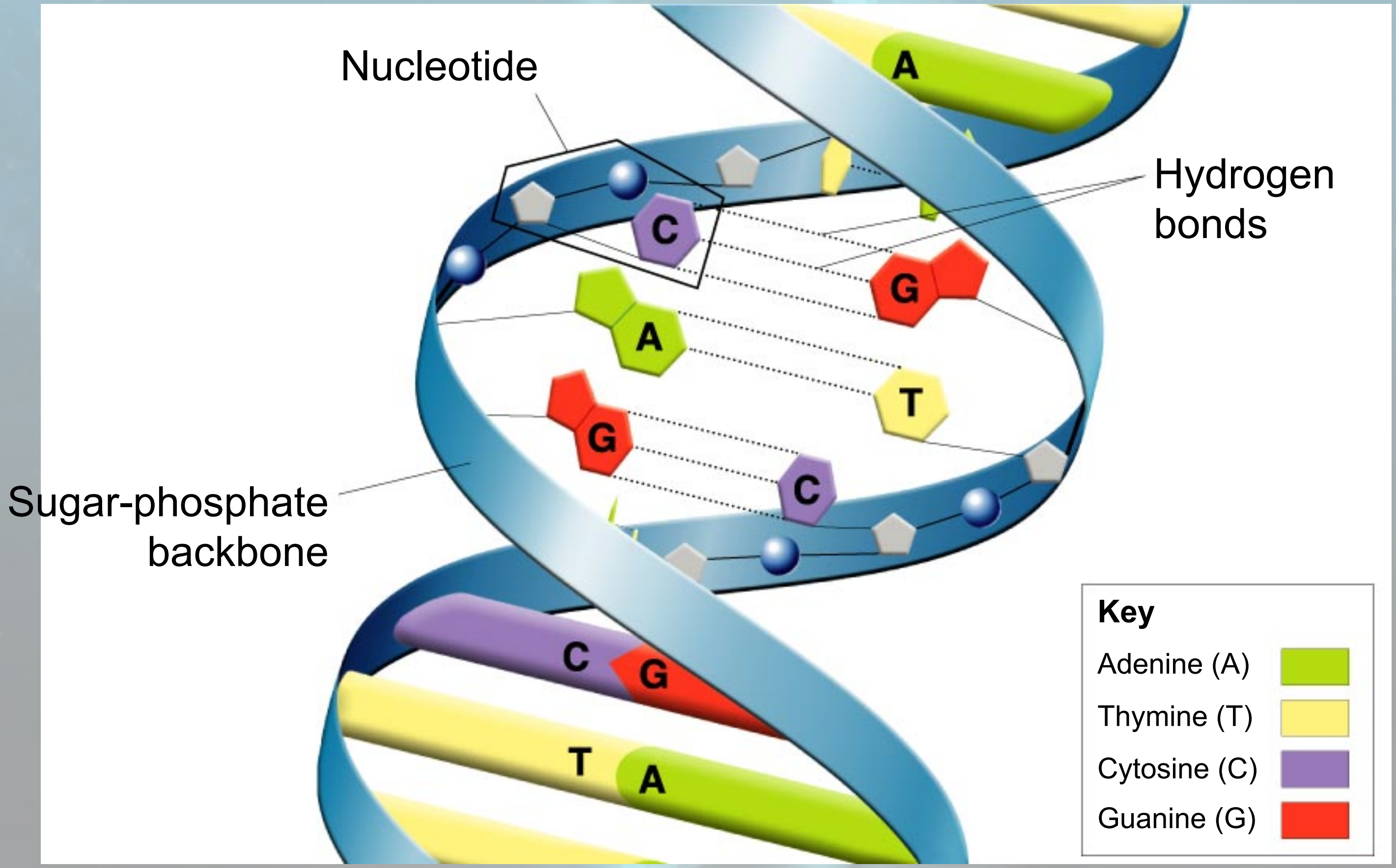


Figure 12–7 Structure of DNA



12-1 Section Review

- List the conclusions Griffith, Avery, Hershey, and Chase drew from their experiments.
- Describe Watson and Crick's model of the DNA molecule.
- What are the four kinds of bases found in DNA?
- How did Watson and Crick's model explain why there are equal amounts of thymine and adenine in DNA?*

Chapter 12: DNA and RNA

Section 2: Chromosomes and DNA Replication

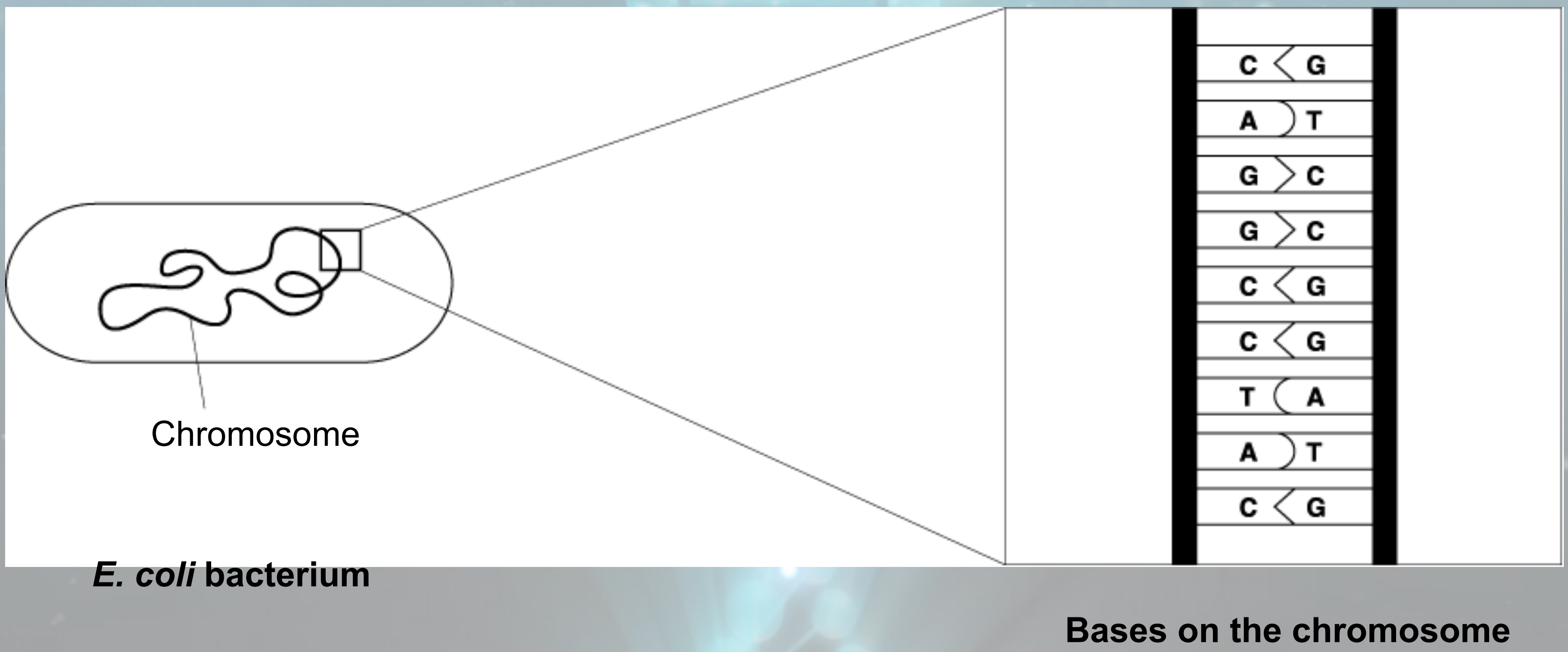
Intro

- DNA Polymerase.
- Based on the root word and the suffix what does this word mean?*

DNA and Chromosomes

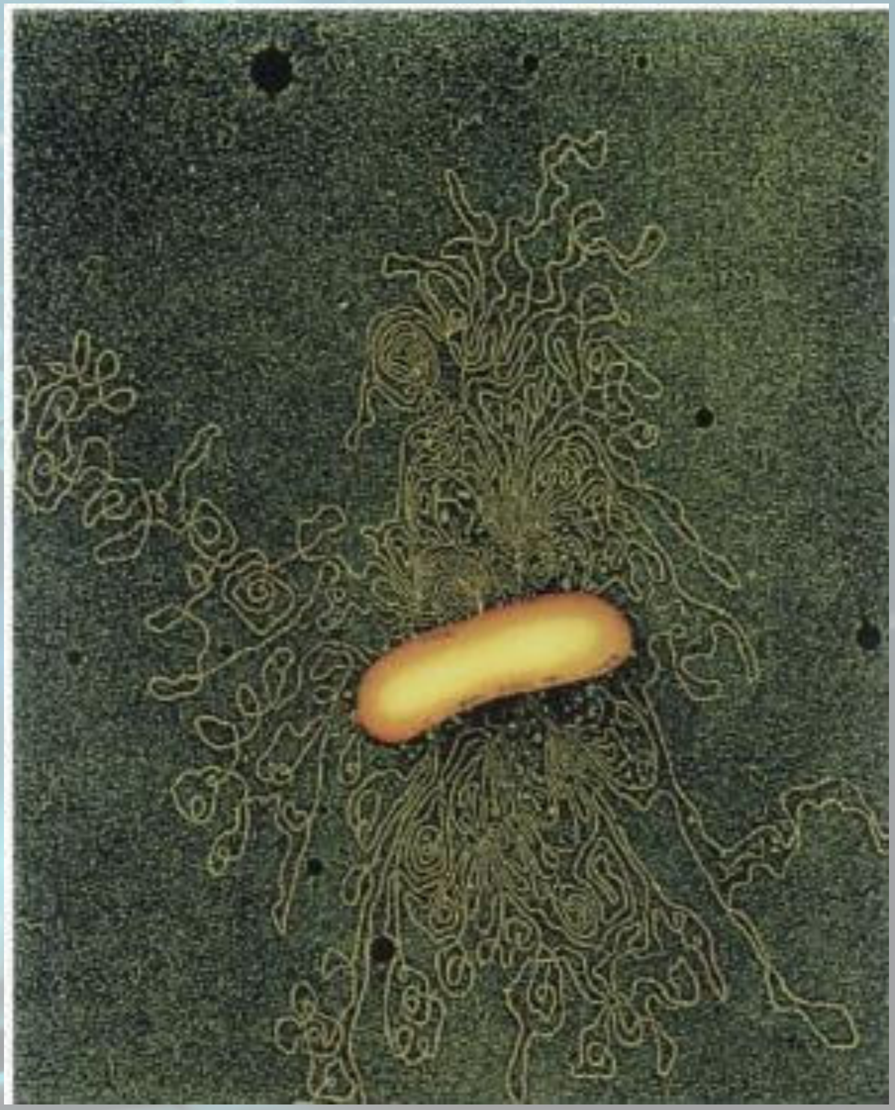
- What are prokaryotic and eukaryotic cells again?
- How are their DNA different?
- Prokaryotic cells have one circular ring of DNA.
- Eukaryotic cells have linear DNA.
- Where is the DNA found in prokaryotic and eukaryotic cells?
- Prokaryotic in the cytoplasm and eukaryotic in the nucleus.*

Prokaryotic Chromosome Structure



DNA Length

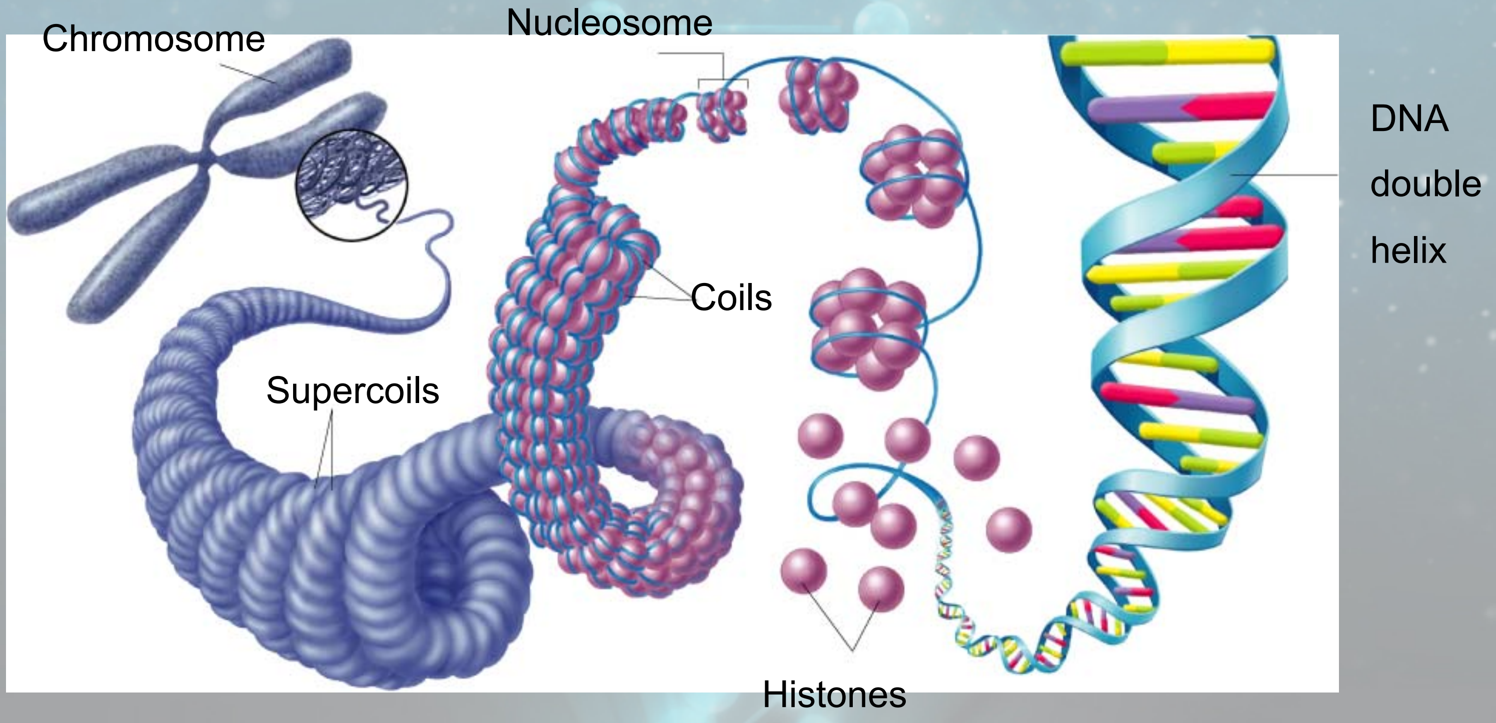
- DNA can be roughly 1000 times as long as the cell that contains it.
- Analogy of backing a 300 meter rope into a backpack.*



Chromosome Structure

- What are base pairs again?
- Connected pairs of bases (A-T, G-C) holding the two strands of DNA together.
- What is chromatin?
- Tightly packed DNA around proteins called histones.
- What is a Nucleosome?
- A bead-like structure formed as DNA folds around itself.
- What is it’s job?
- To fold enormous lengths of DNA into the tiny space available in the nucleus.*

Chromosome Structure of Eukaryotes

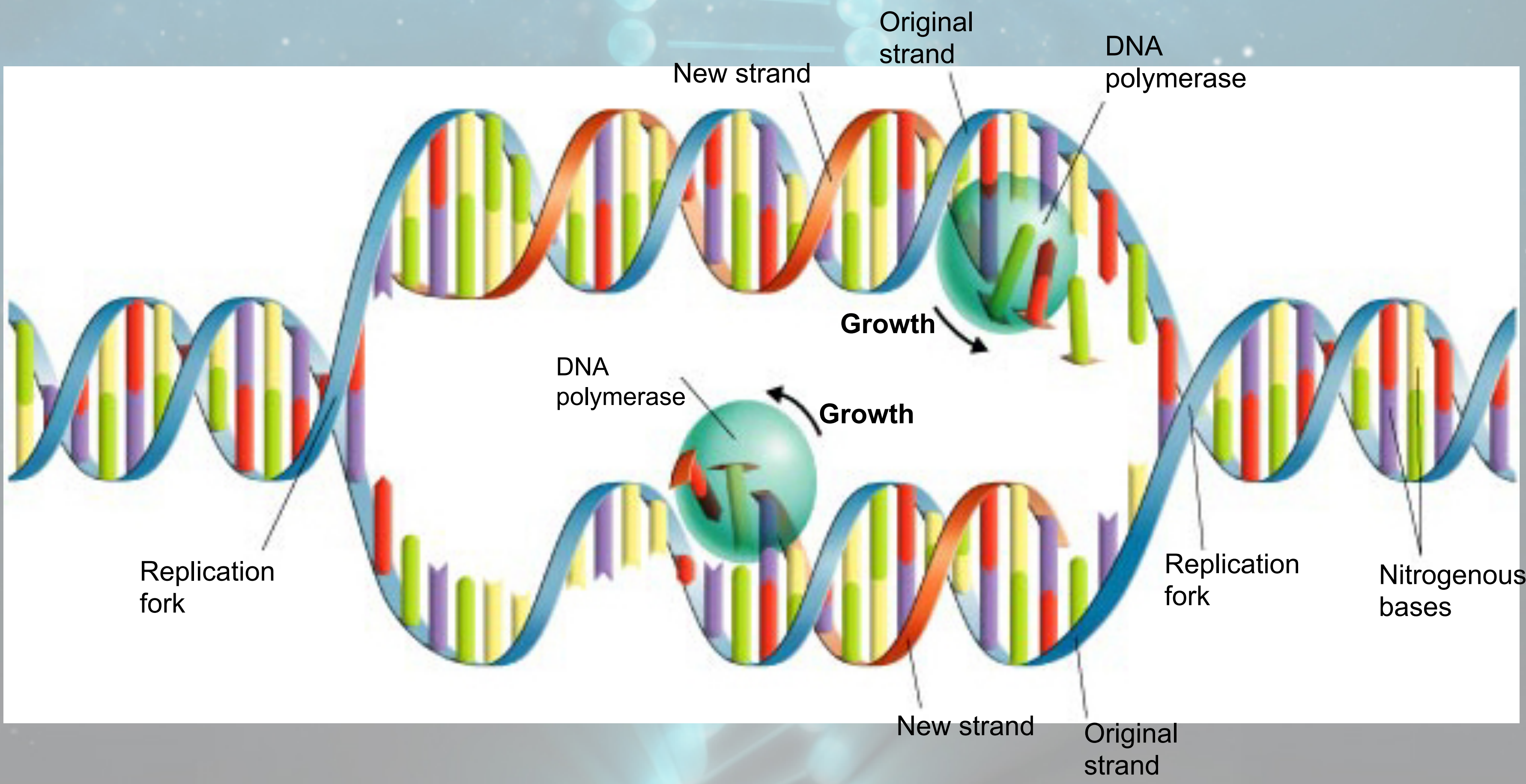


DNA Replication

- What function may nucleosomes provide while the DNA is being “read”?
- Rearrangement of the nucleosomes opens up hidden areas of the DNA to allow different genes to be read.
- Define replication.
- The copying process a cell uses to make a copy of it’s DNA.
- How does the shape of DNA lend itself to be replicated?
- When the DNA molecule is split and following the base-pair rules, each half can be used as a template to recreate the entire molecule.*

- How does replication differ in prokaryotic and eukaryotic cells?
- Prokaryotic cells begin to replicate a one spot and then continue around the circle in both directions.
- Eukaryotic DNA replication begins at many spots, and replication continues in both direction till completed.
- What do you call the site where separation and replication occur?
- Replication forks.*

DNA Replication



Replication Process

- What are the steps of DNA replication?
- Enzymes “unzip” the DNA molecule.
- Each side of the molecule serves as a template for the other.
- DNA polymerase, an enzyme, catalyzes the reactions to form new bonds on the new nucleotides and also acts as a “proof-reader” to make sure the new strand is correct.

During DNA reproduction the DNA molecule separates into two strands, then produces two new complementary strands following the rules of base-pairing. Each strand of the double helix of DNA serves as a template, or model, for the other half.*

12-2 Section Review

- Explain how DNA is replicated.
- Where and in what form is eukaryotic DNA found?
- How are the long DNA molecules found in eukaryotes packed into short chromosomes?
- How are histones related to nucleosomes?
- What is the role of DNA polymerase in DNA reproduction?

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- Mystery Message Procedure.
- By overlapping the segments of DNA you'll be able to put the entire sequence in correct order.

Chapter 12

Section 3: RNA and Protein Synthesis

Structure of RNA

- What does it mean to transcribe something?
- To write a copy of it.
- What does it mean to translate something?
- To express something in another language.
- What is RNA?
- Ribonucleic Acid.
- How is RNA and DNA similar?
- Both consist of a long chain of nucleotides made from a 5 carbon sugar, a phosphate group, and a nitrogenous base.
- How is RNA and DNA different?
- RNA's sugar is ribose, is generally a single strand, and replaces thymine with uracil.
- RNA can be thought of as a working copy of DNA.*

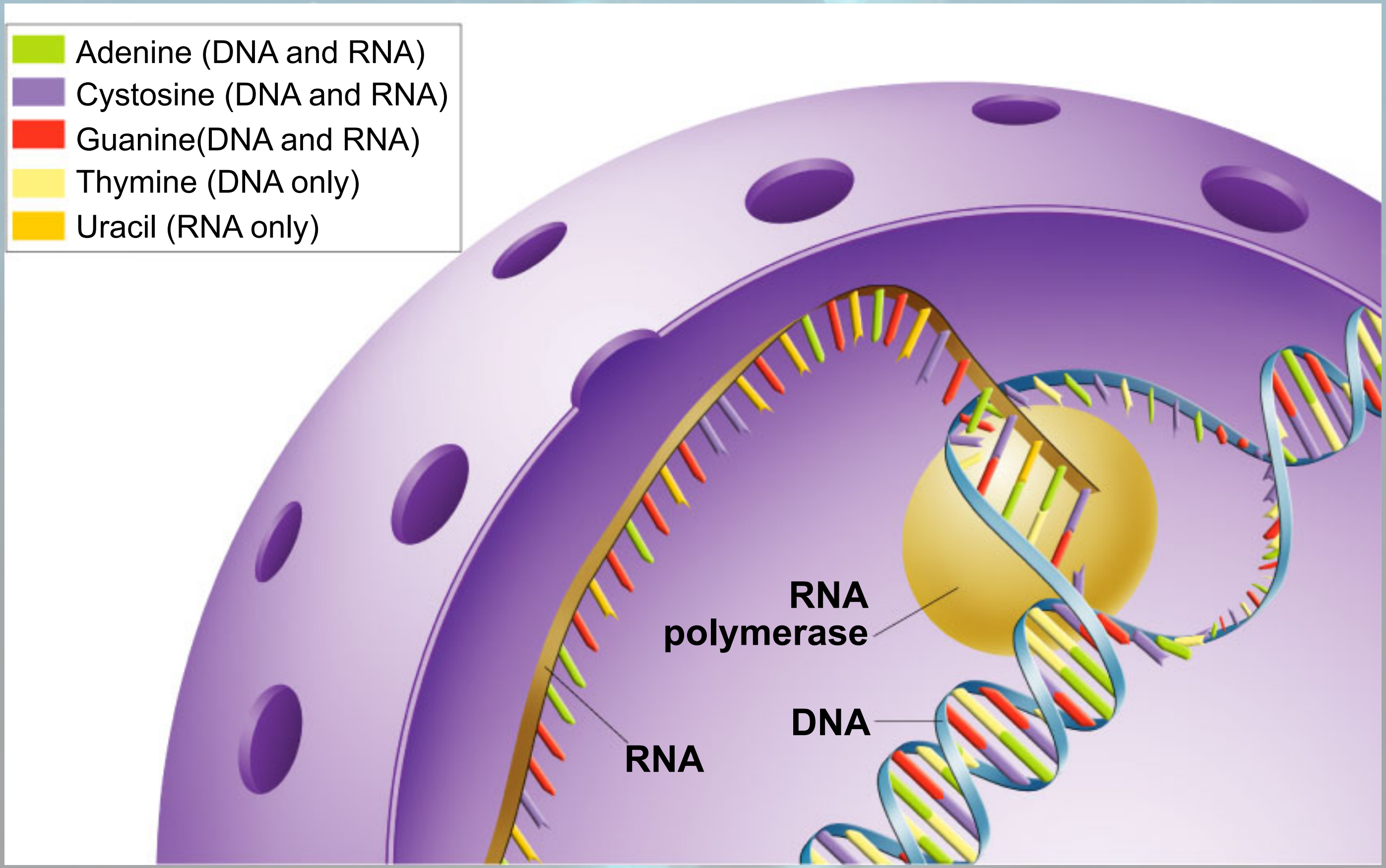
Types of RNA

- What are the three main types of RNA?
- The three main types of RNA are messenger RNA, ribosomal RNA, and transfer RNA.
- What is the function of messenger RNA (mRNA)?
- To carry copies of instruction for assembling amino acids into proteins from the nucleus to the rest of the cell.
- What is the function of ribosomal RNA (rRNA)?
- rRNA is in ribosomes an serves to assist transcription of mRNA.
- What is the function of transfer RNA?
- Transfers each amino acid to the ribosome as the protein is being assembled.*

Transcription

- Define transcription.
- The production of RNA molecules by copying part of the nucleotide sequence of DNA into a complementary sequence in RNA.
- Which enzyme is needed for transcription?
- RNA polymerase.
- During transcription, RNA polymerase binds to DNA and separates the DNA strands. RNA polymerase then uses one strand of DNA as a template from which nucleotides are assembled into a strand of RNA.
- What are promoters?
- Specific base sequences which allow RNA polymerase to bind and start or stop transcription.*

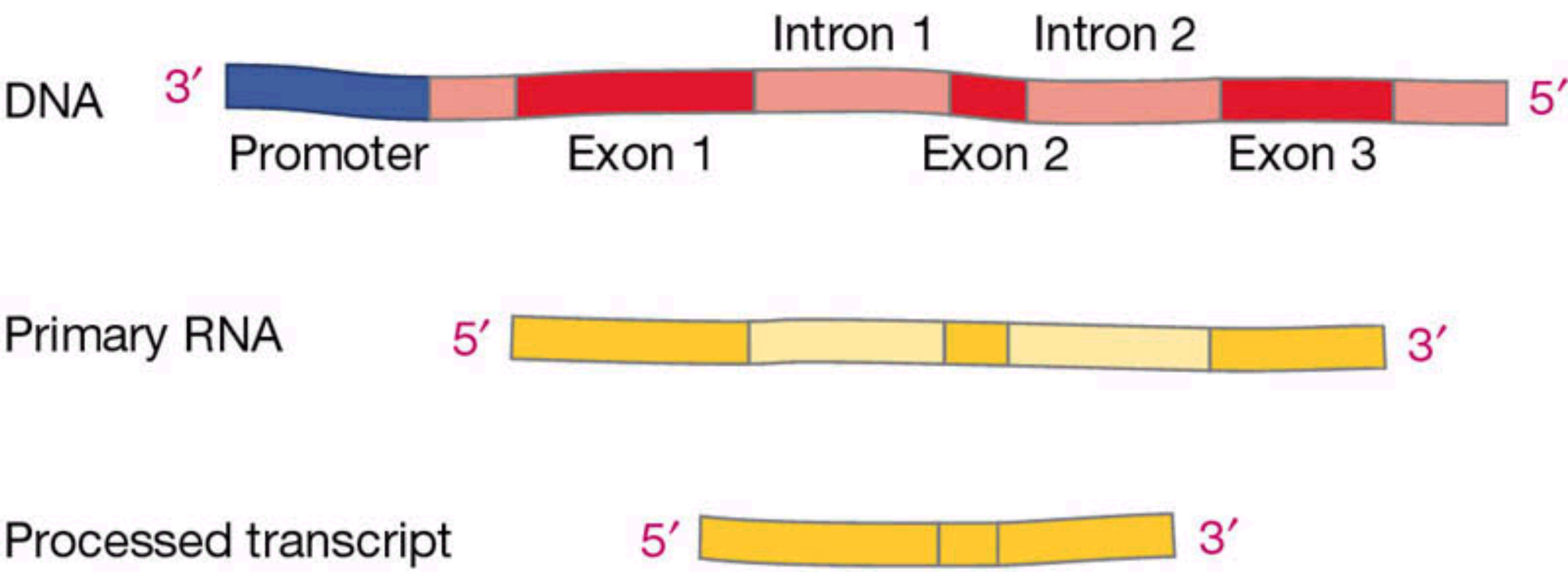
Figure 12–14 Transcription



RNA Editing

- Before protein synthesis, the mRNA copy is edited, or sections are removed.
- When the RNA is edited, what do you call the sequences removed while the RNA is still in the nucleus?
- Introns.
- What do you call the remaining portions of RNA when they are spliced back together?
- Exons.
- Why does the cell waste all this energy?
- We don't really know. Some suggest that splicing allows the same gene to produce different proteins in different tissue. Others suggest a role in evolution.*

(a) Noncoding regions must be edited out of RNA transcripts.



The Genetic Code

- What do we call the long chains of amino acids?
- Polypeptides.
- How many different amino acids are there?
- 20.
- How do only 4 different bases code for 20 amino acids?
- The genetic code is read in 3 letter blocks.
- UCGCACGGU
- UCG-CAC-GGU
- Serine-Histidine-Glycine
- Some sequences code for the same amino acid, some code for stop only and no amino acid.*

The Genetic Codon Wheel

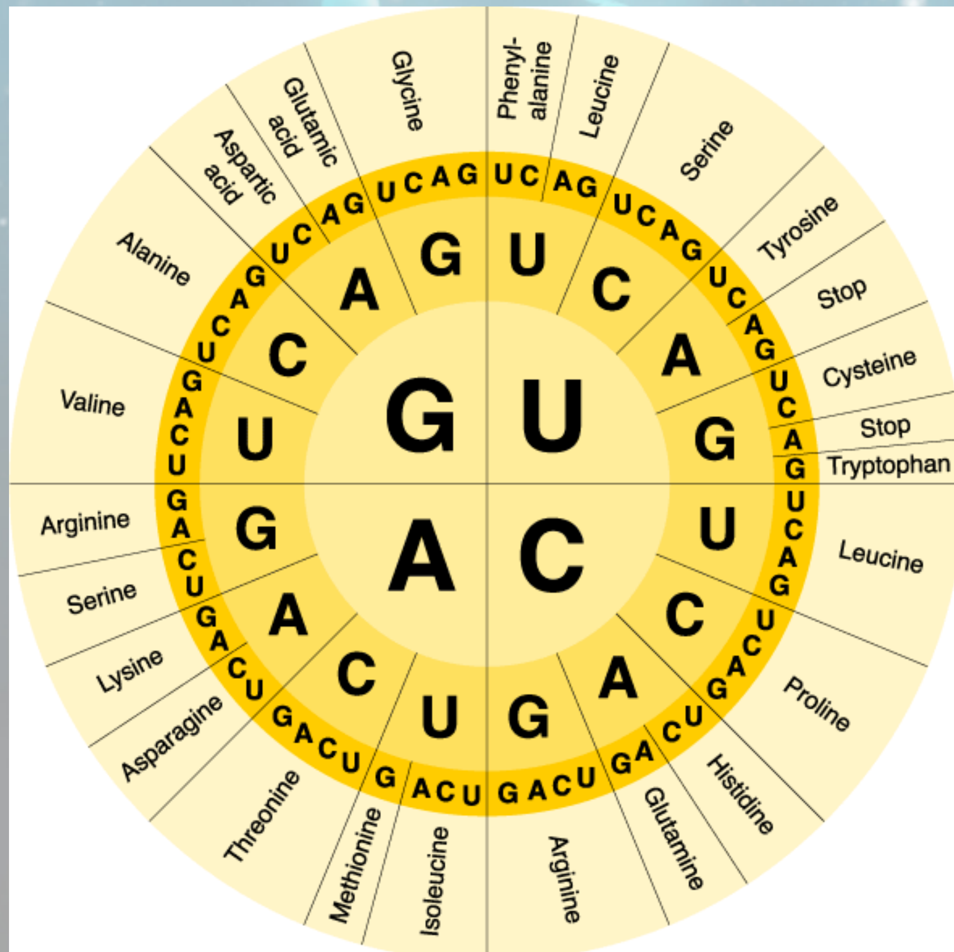
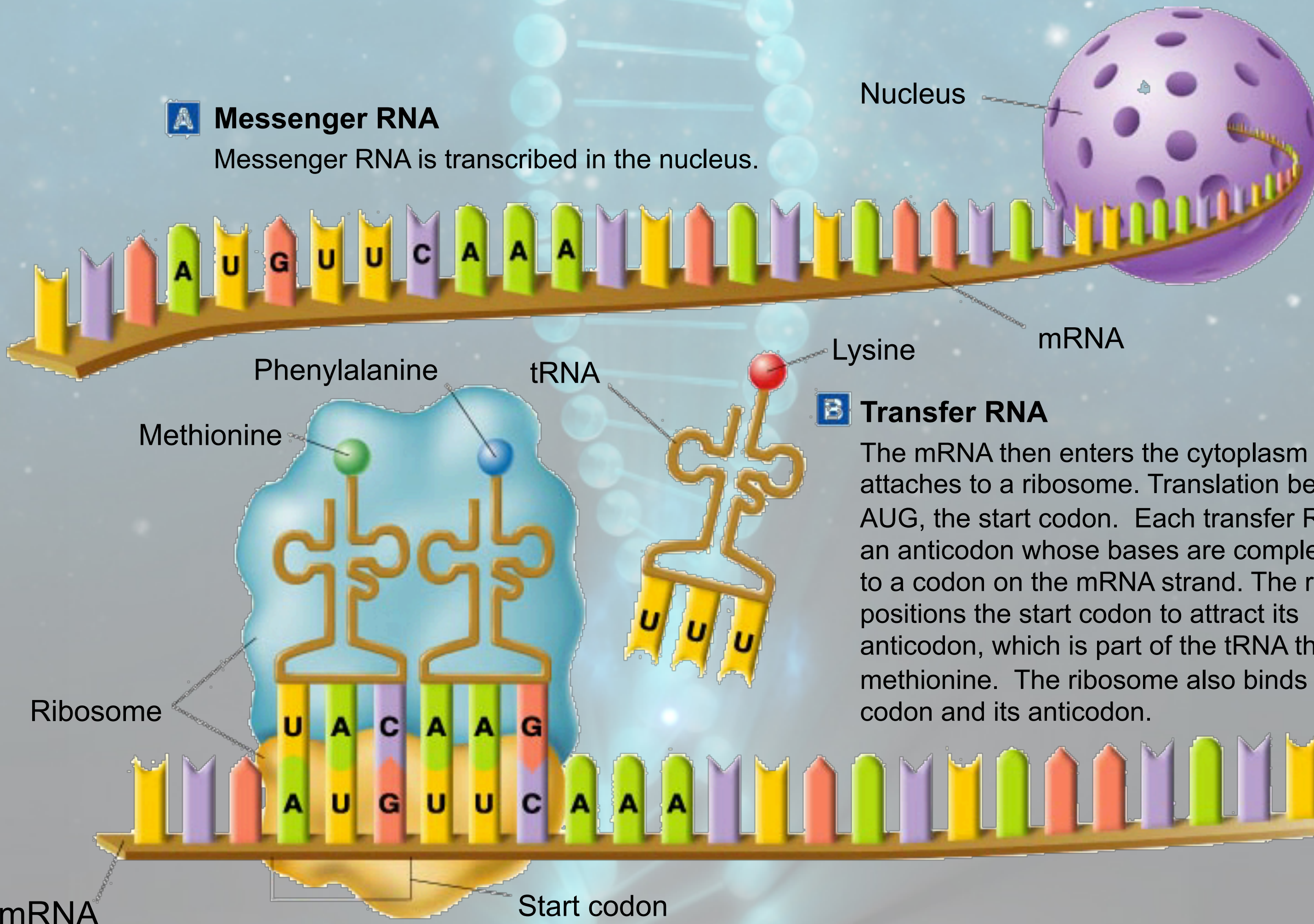


Figure 12–18 Translation

A Messenger RNA

Messenger RNA is transcribed in the nucleus.

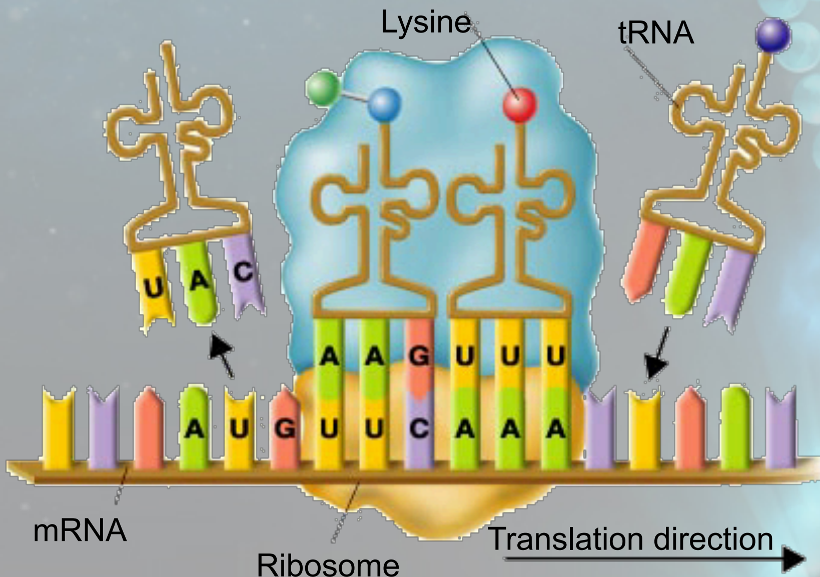


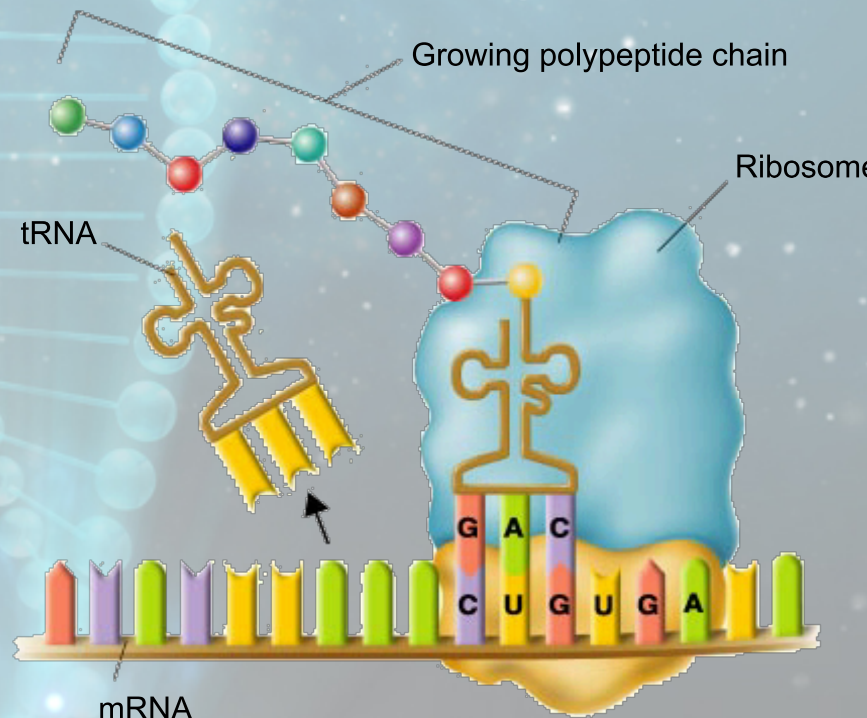
B Transfer RNA

The mRNA then enters the cytoplasm and attaches to a ribosome. Translation begins at AUG, the start codon. Each transfer RNA has an anticodon whose bases are complementary to a codon on the mRNA strand. The ribosome positions the start codon to attract its anticodon, which is part of the tRNA that binds methionine. The ribosome also binds the next codon and its anticodon.

Figure 12–18 Translation (continued)

C The Polypeptide "Assembly Line"
The ribosome joins the two amino acids—methionine and phenylalanine—and breaks the bond between methionine and its tRNA. The tRNA floats away, allowing the ribosome to bind to another tRNA. The ribosome moves along the mRNA, binding new tRNA molecules and amino acids.





D Completing the Polypeptide
The process continues until the ribosome reaches one of the three stop codons. The result is a growing polypeptide chain.

The Roles of DNA and RNA

- What is the advantage of making copies RNA, and copy of DNA, and sending it out to make proteins.
- The master plan of DNA is kept protected in the nucleus while the RNA is sent out to the cytoplasm to make proteins.
- Why are proteins so important?
- Proteins are keys to everything that living things do.*

Quick Lab Page: 303.

- GACAAGTCCACAATC
- Left to right decode the above sequence.
- CUGUUCAGGUGUUAG
- Now from right to left.
- GAUUGUGGACUUGUC
- Are they the same?
- Do you think that nucleotides are decoded in only one direction?
- Define translation.
- Now translate the first decode into amino acids.
- The decoding of an mRNA message into a polypeptide chain (protein).*

12-3 Section Review

- List the three main types of RNA.
- What happens during transcription?
- What happens during translation?
- Describe the three main differences between RNA and DNA.
- Use the genetic code, identify the amino acids that have the following messenger RNA strand codes. UGGCAGUGC.
- Tryptophan-glutamine-cysteine

Chapter 12

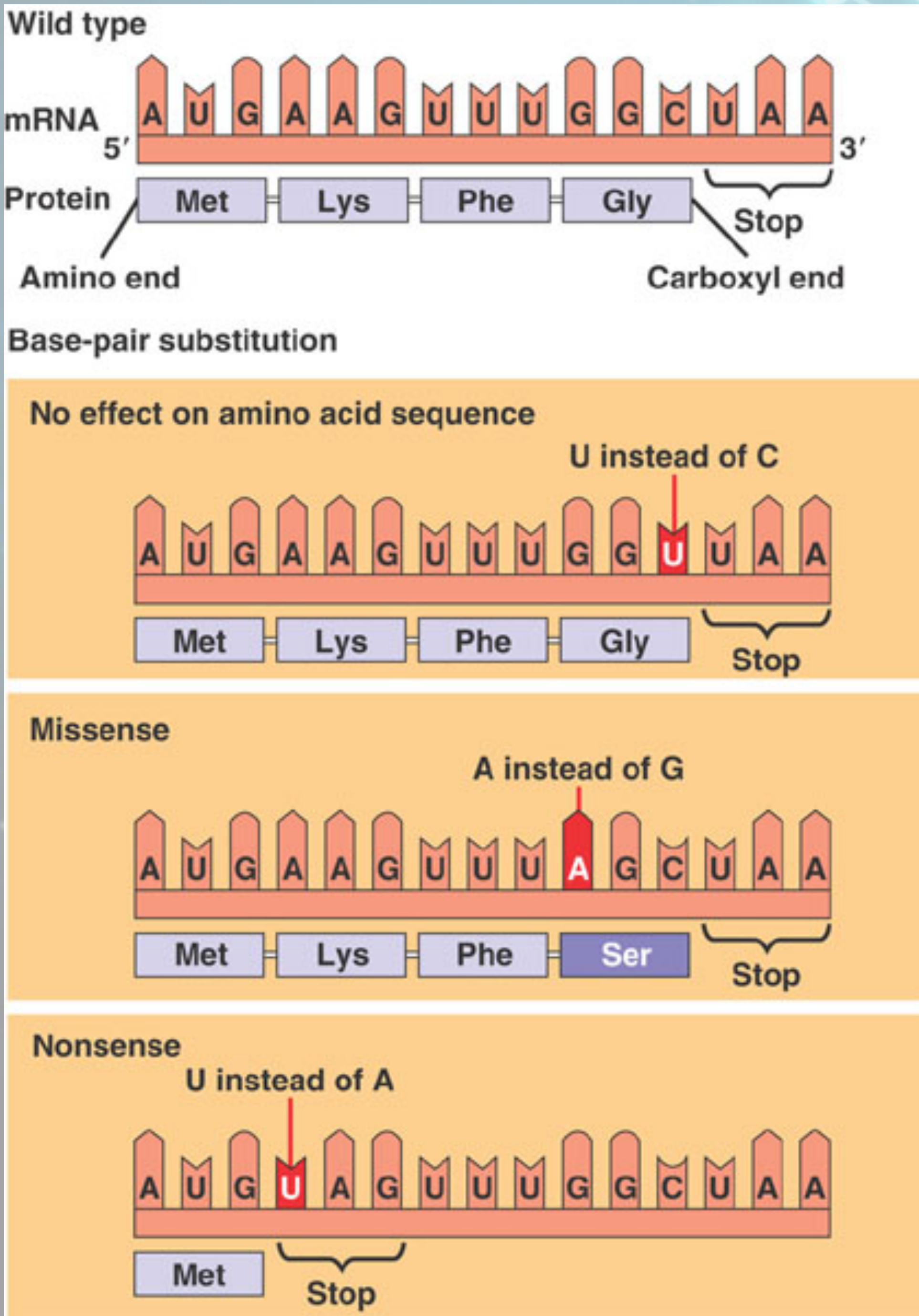
Section 4: Mutations

Gene Mutations

- No matter how precise replication is sometimes in the 3 billion base pairs there are mistakes.
- What do we call these mistakes in our DNA?
- Mutations, from the Latin word mutare, meaning "to change".
- Gene mutations result from changes in a single gene. Chromosomal mutations involve changes in whole chromosomes.*

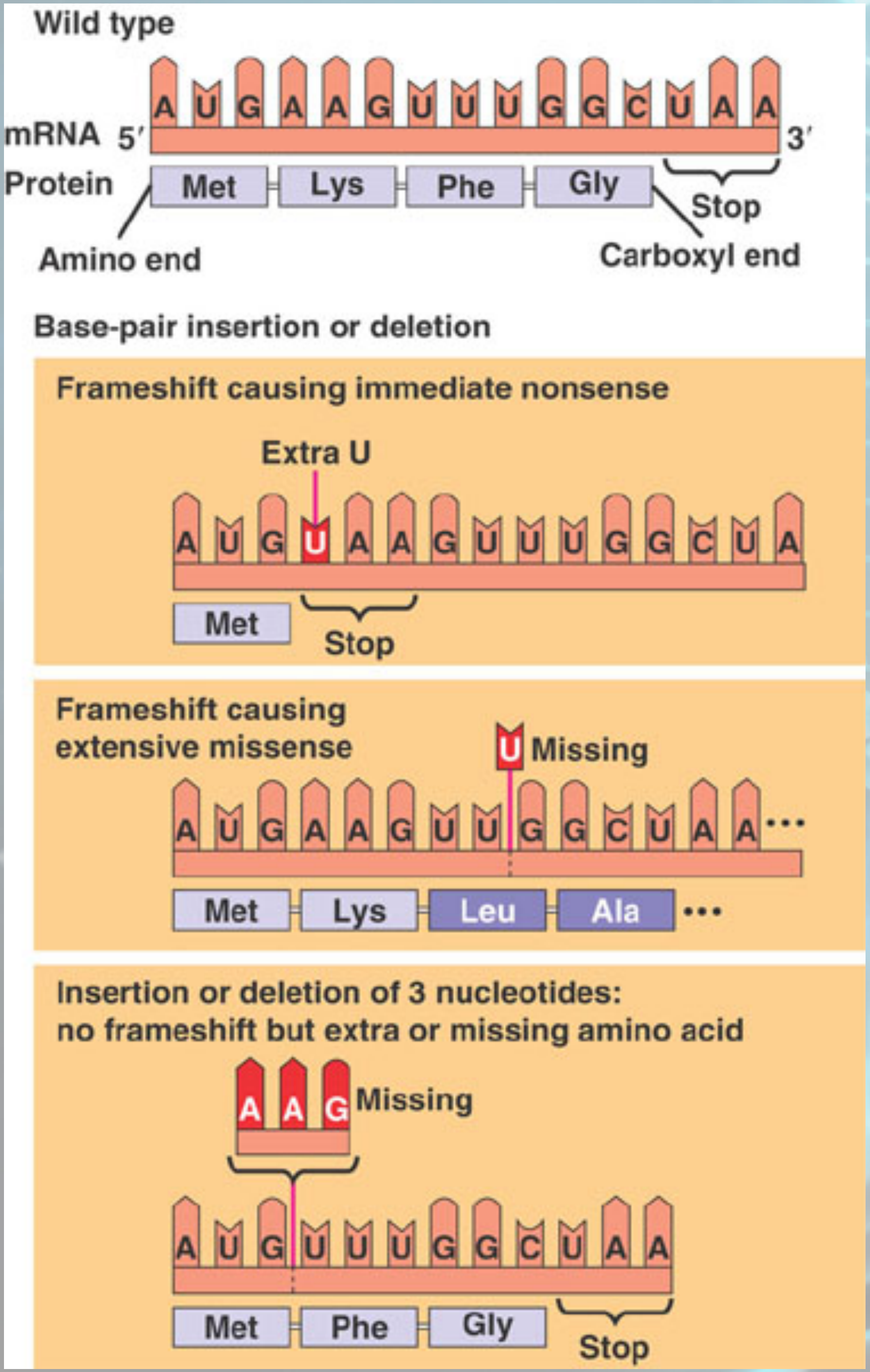
- What do we call mutations that affect only one nucleotide?
- Point mutations.
- Why point mutations?
- Because they occur at a single point in the DNA sequence.
- What is a substitution mutation?
- One nucleotide is substituted with another in the DNA sequence.
- Does the resulting protein made from this gene always change the amino acid called for by the gene?
- Normally but not always.
- How many amino acids may be affected?
- Only one.*

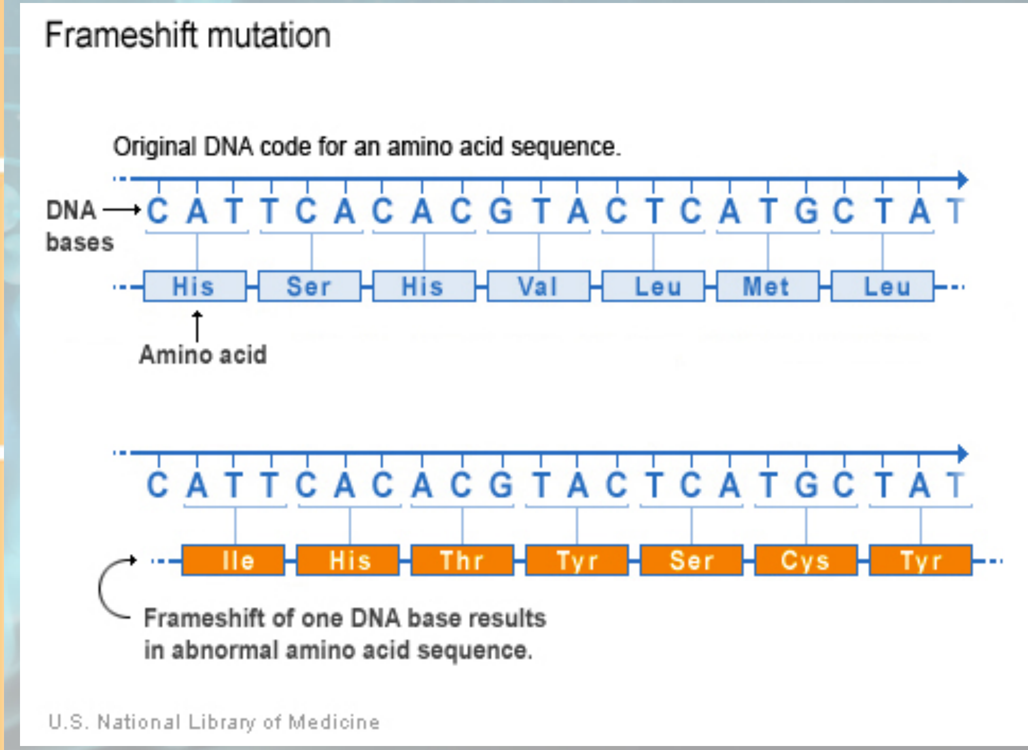
Substitution Mutations



- What is an insertion or deletion mutation?
- An extra nucleotide is either inserted into the DNA sequence or is deleted from the sequence.
- Why do we call these mutations "Frameshift mutations?
- Because they shift the "reading frame" of the gene code. Every codon after the mutation will be affected.
- Frameshift mutations can alter the protein enough that it may be unable to perform it's functions.*

Frameshift Mutations

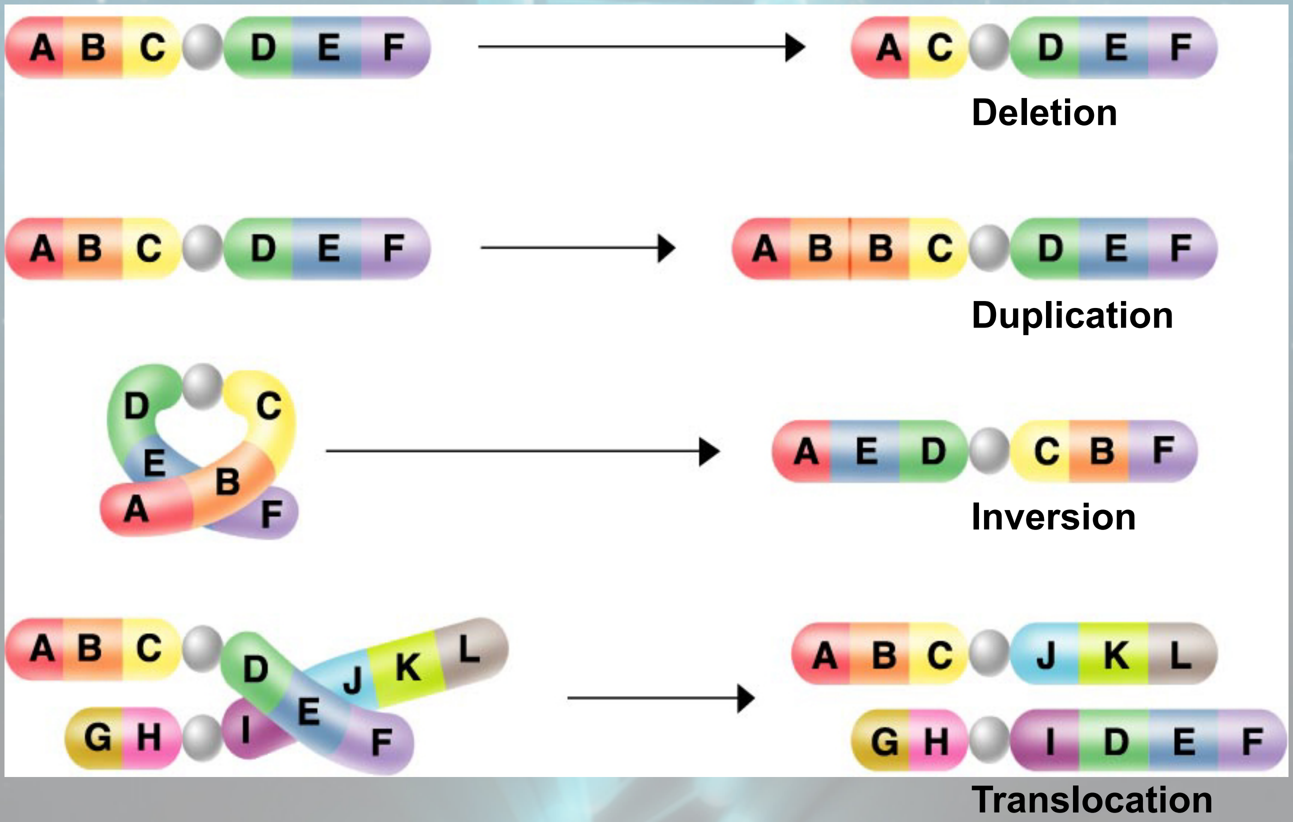




Chromosomal Mutations

- What is a chromosomal mutation?
- A mutation that involves changes in the number or structure of chromosomes. Locations and number of copies of genes can be effected.
- What are some types of chromosomal mutations?
- Deletion: loss of all or part of a chromosome.
- Duplication: a segment of chromosome is duplicated.
- Inversion: part of a chromosome is oriented in the reverse of its usual direction.
- Translocation: part of one chromosome breaks off and attaches to another, nonhomologous, chromosome.*

Chromosomal Mutations



Section 12-4 Review

- What is a gene mutation? What is a chromosomal mutation?
- What is a point mutation?
- What are two kinds of frameshift mutations?
- What are four kinds of chromosomal mutations?
- The effects of mutations aren’t always visible. How might a biologist determine whether a mutation has taken place and which type of mutation it is?

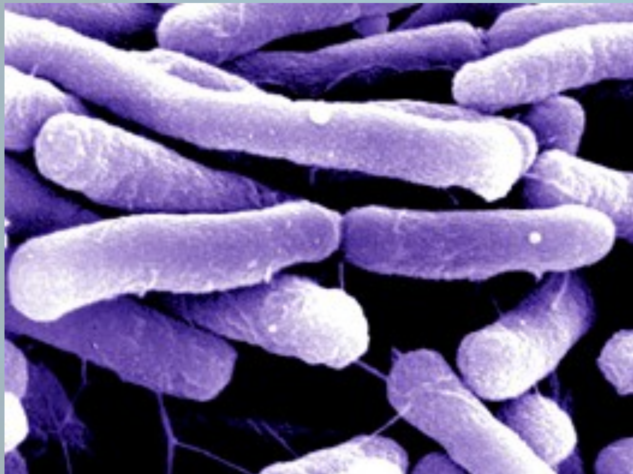
Chapter 12

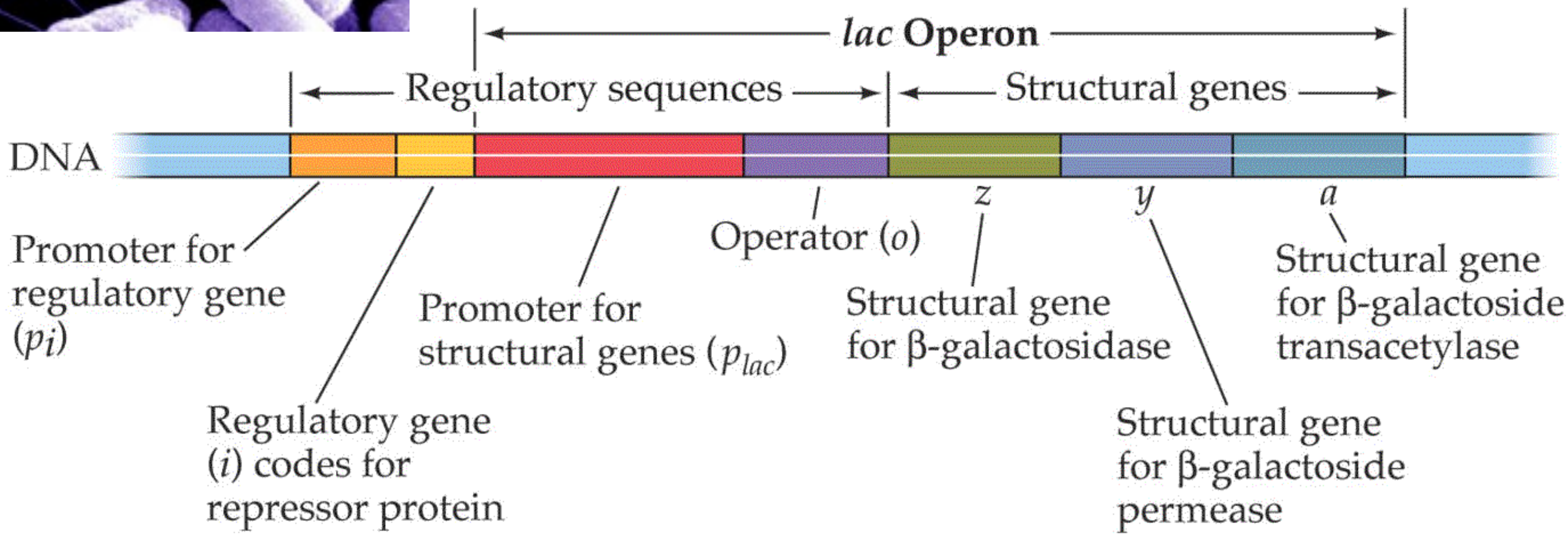
Section 5: Gene Regulation

Example of Gene Regulation

- What do you think of when you hear the words regulatory and express?
- What function would a regulatory site on a gene perform?
- Places where other proteins, binding directly to the DNA sequences at those sites, can regulate transcription.
- What do you call a group of genes that operate together?
- An operon.
- In *E. coli* what is the *lac* operon?
- A group of genes that allow the *E. coli* bacterium to be able to use the sugar lactose as a food.*

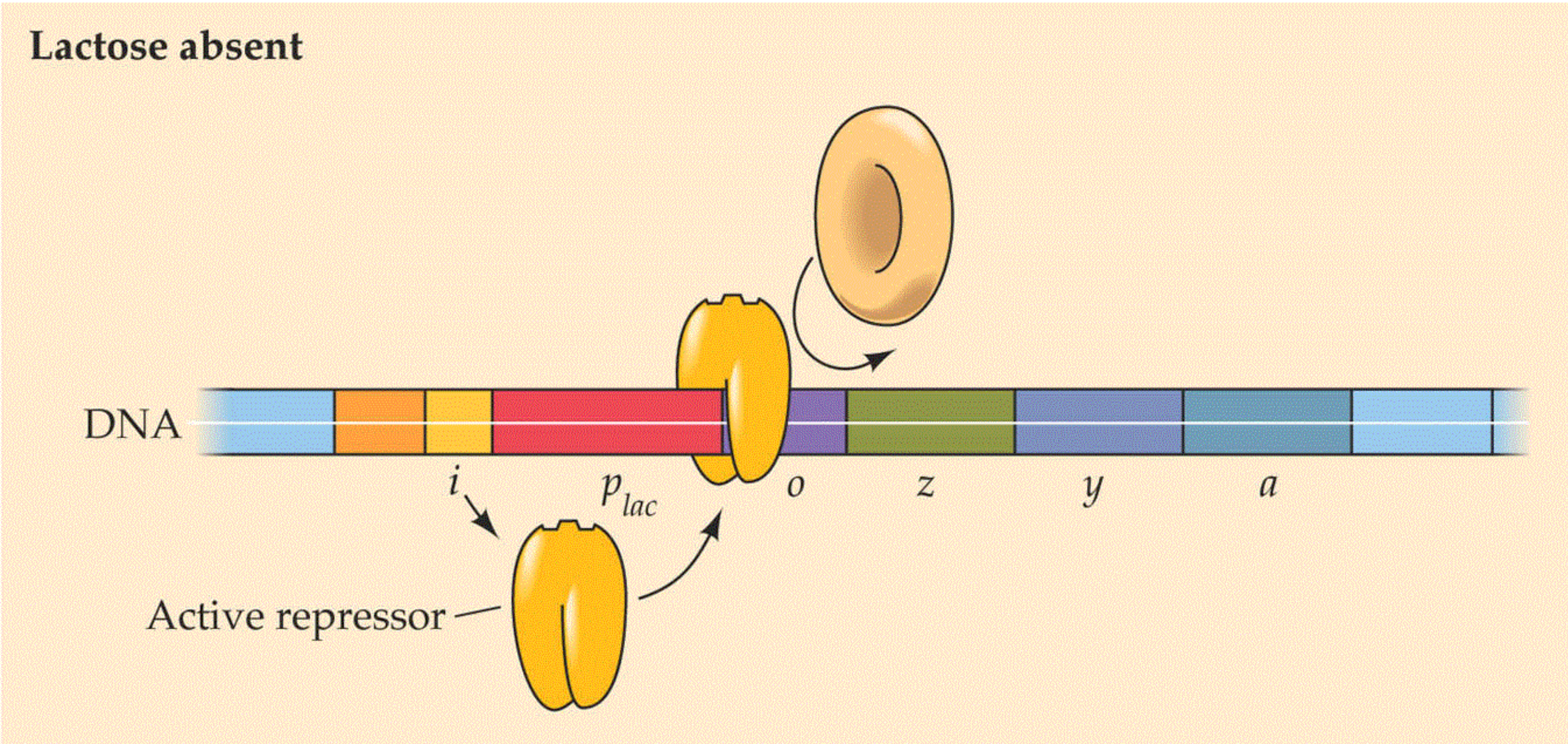
E. coli



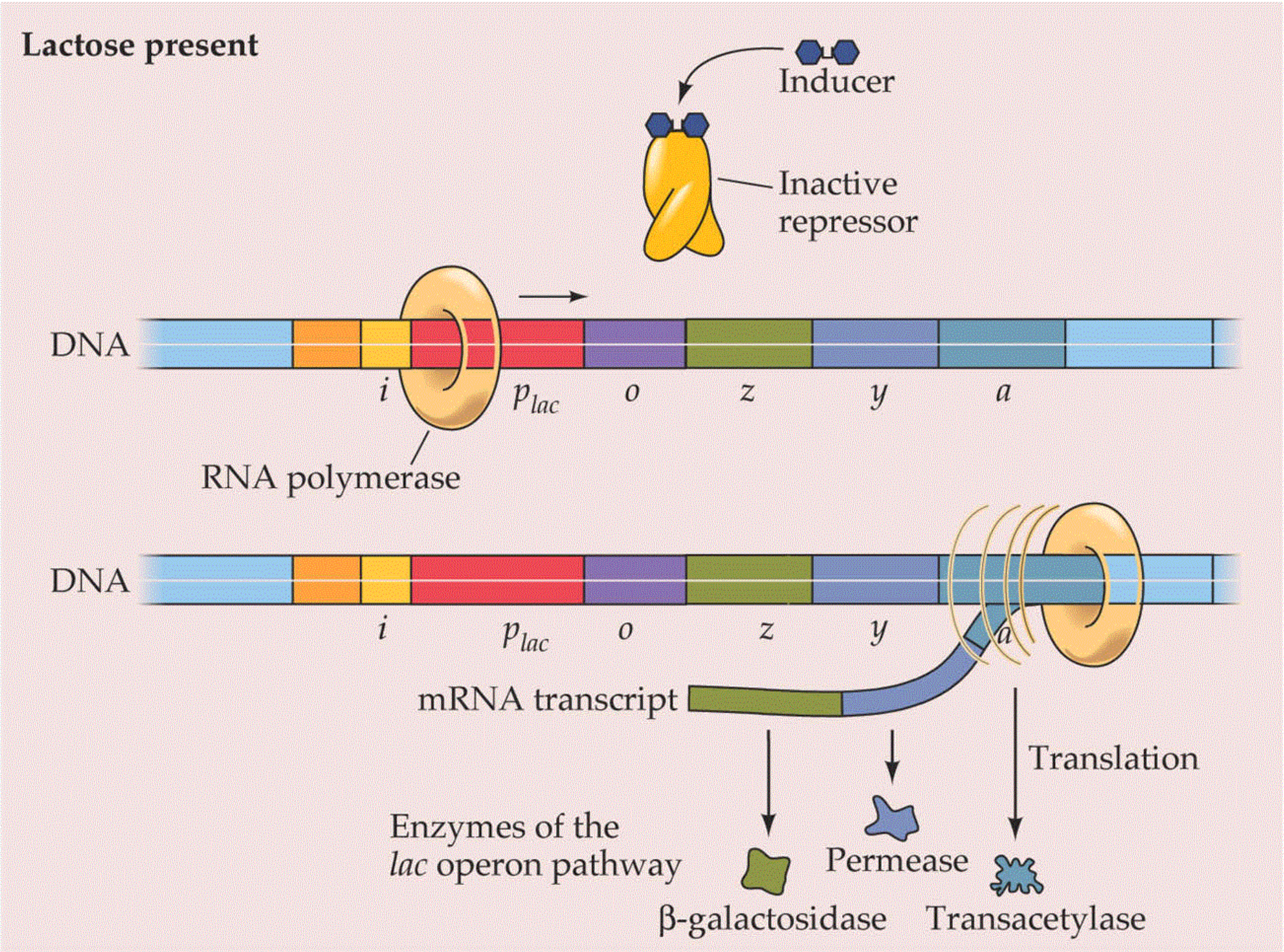


LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 13.16 The *lac* Operon of *E. coli*

- The lac genes are turned off by repressors and turned on by the presence of lactose.
- If E. coli grows in the presence of lactose then it must produce proteins to break-down lactose. If there is no lactose present then there is no need to produce these proteins.
- What is a repressor?
- A DNA-binding protein that stops transcription and “turns off” the gene.
- Define operator.
- An area in the gene where the repressor binds and stops transcription.*



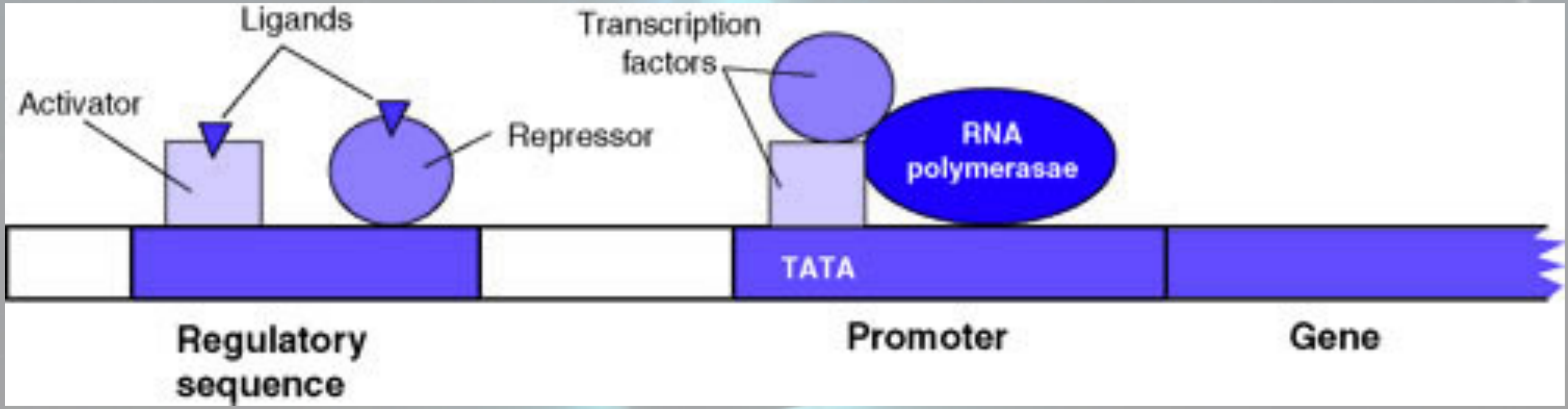
LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 13.17 The lac Operon: An Inducible System (Part 1)



LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, **Figure 13.17 The *lac* Operon: An Inducible System (Part 2)**

Eukaryotic Gene Regulation

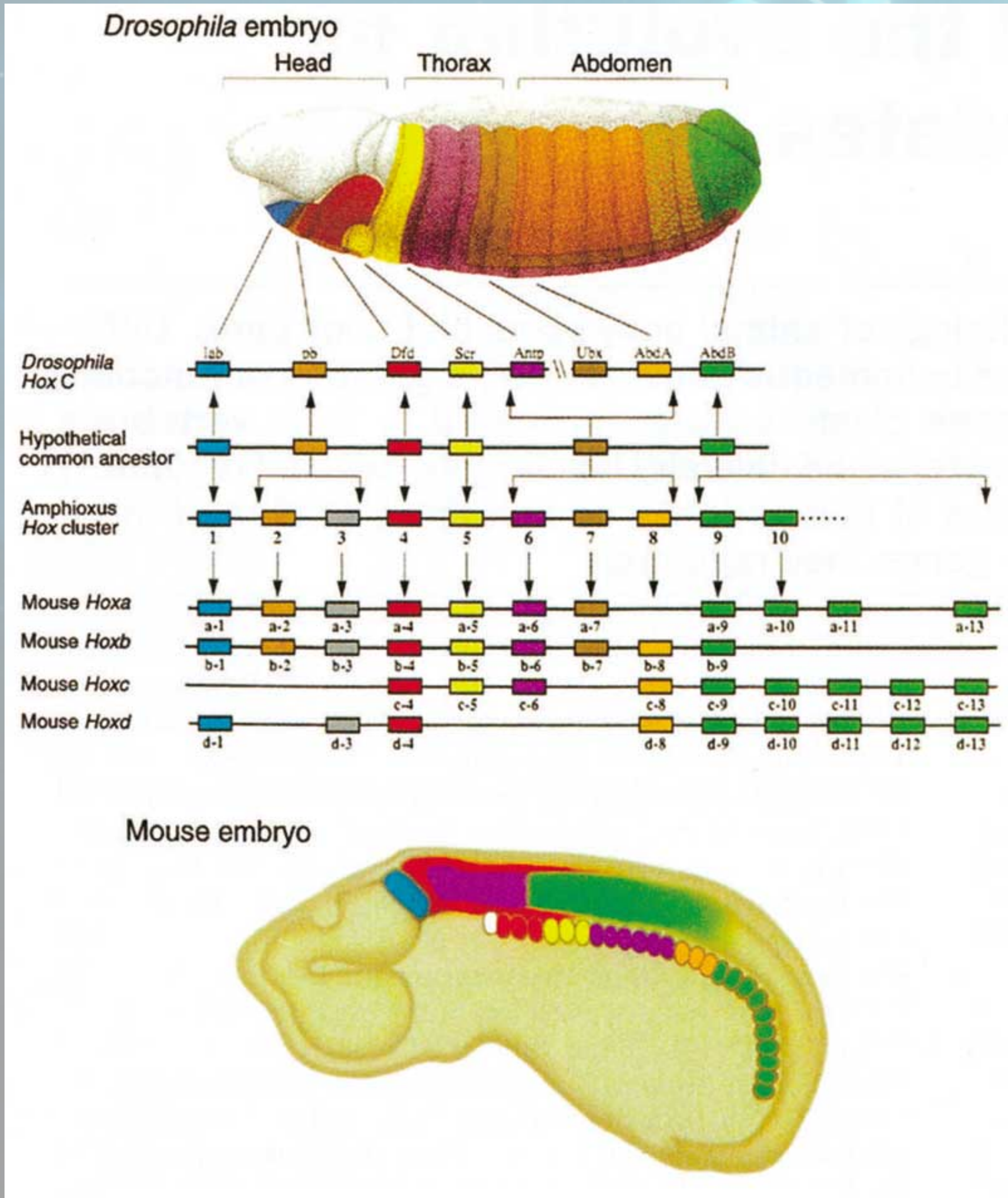
- Most eukaryotic genes are controlled individually and have regulatory sequences that are much more complex than those of the *lac* operon.
- What is the job of the "TATA Box"?
- To help position the RNA polymerase by marking the point at which transcription begins.



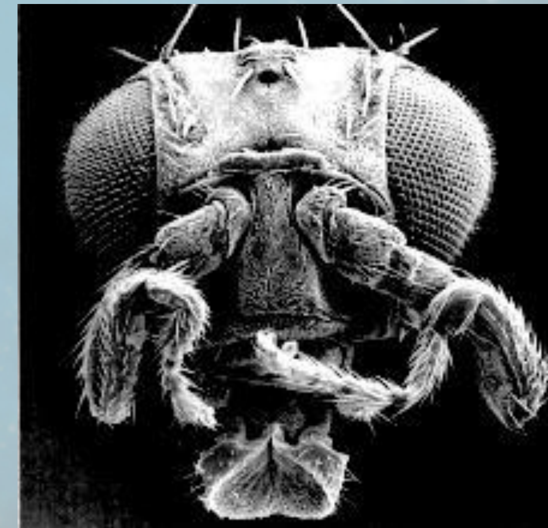
- Why is gene regulation so much more complex then in prokaryotes?
- There are so many different cell types in eukaryotes that not all genes need to be expressed all the time.*

Regulation and Development

- What is the function of hox genes?
- Genes which control the organs and tissues that develop in various parts of the embryo.
- Hox genes are considered "master control genes".
- How are most hox genes arranged?
- In almost the exact order they are expressed in the body.
- If hox genes are inserted into embryos they will grow body parts in the wrong area.
- Why might the hox genes be so similar?
- Patterns of genetic control have descended from common ancestors.*



Drosophila embryo
Head
Thorax
Abdomen
lab
pb
Dfd
Scr
Antp
Ubx
AbdA
AbdB
Drosophila Hox C
Hypothetical common ancestor
Amphioxus Hox cluster
1
2
3
4
5
6
7
8
9
10
Mouse Hoxa
a-1 a-2 a-3 a-4 a-5 a-6 a-7 a-9 a-10 a-11 a-13
Mouse Hoxb
b-1 b-2 b-3 b-4 b-5 b-6 b-7 b-8 b-9
Mouse Hoxc
c-4 c-5 c-6 c-8 c-9 c-10 c-11 c-12 c-13
Mouse Hoxd
d-1 d-3 d-4 d-8 d-9 d-10 d-11 d-12 d-13
Mouse embryo



Section 5 Review

- How is the lac operon regulated?
- Describe how most eukaryotic genes are controlled?
- What is a promoter?
- Why are only a limited number of genes expressed in each cell of a multicellular eukaryote?
- How is the way hox genes expressed in mice similar to the way they are expressed in fruit flies? How is it different?