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生科館 **Rm730**

Chapter 10

Molecular Biology of the Gene

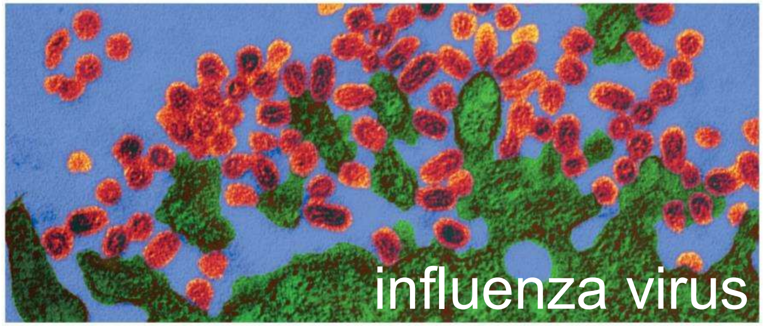
PowerPoint Lectures

Campbell Biology: Concepts & Connections, 8th Edition, Global Edition

REECE • TAYLOR • SIMON • DICKEY • HOGAN

Lecture by Edward J. Zalisko

Introduction



- The 2009 H1N1 influenza virus
  - spread so quickly that it was declared a pandemic,
  - reached 207 countries,
  - infected more than 600,000 people
  - killed an estimated 20,000 people.

2002-2003 SARS, 10%, 744
2014 Ebola, >50%, >10,000
2015-2016 Zika, 0.1%
(致死率)

- Viruses share some of the characteristics of living organisms, but are generally not considered alive because they are not cellular and cannot reproduce on their own.
- Combating any virus requires a detailed understanding of
  - molecular biology,
  - the study of DNA, and
  - how DNA serves as the basis of heredity.

Where do deadly viruses come from?
2013.10 10 polio cases in Syria
2014.4 36 Syrian and 2 Iraqi (mostly under 2)
2014.6 Emergency vaccination
2017.6 2nd outbreak
Polio virus: simple RNA virus

非洲豬瘟病毒 African Swine Fever Virus, dsDNA virus
(general swine fever viruses are ssRNA viruses)

Mongolia, Vietnam, China, Japan, Cambodia and parts of Europe.

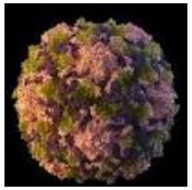
US braces for African swine fever
American Veterinary Medical Association - 15 小時前
Pigs with African swine fever can have cutaneous hemorrhage and necrosis. Hemorrhagic lesions may be dark red in the center. (Courtesy of ...

China, US to attend global forum on African Swine Fever, says Canada
iPolitics.ca - 8 小時前
Canada will host the inaugural African Swine Fever Forum starting April 30 in Ottawa as hog producers and animal health experts grapple with ...

A Vicious, Untreatable Killer Leaves China Guessing
深入報導 - The New York Times - 2019年4月22日
查看全部

Reports: All of China affected by African swine fever
WATTAgNet Industry News & Trends (blog) - 10 小時前
The last region in China to be affected by African swine fever (ASF) has reported its first cases, while new outbreaks have been confirmed in ...

China's pork industry under threat as African swine fever spreads to al…
South China Morning Post - 2019年4月21日
African swine fever, which is deadly to pigs but not harmful to humans, has now



Polio, Pakistan, the progress and difficulties with WHO spokesperson ...
Outbreak News Today - 2019年4月4日
Thanks to vaccinations, cases of wild poliovirus globally have dropped dramatically. In the 1980s the estimated global number of paralytic ...

Pakistan polio worker killed, WHO condemnation
Outbreak News Today - 2019年4月10日
It was recently reported that a polio worker in Pakistan was shot and killed while he was supporting polio eradication and immunization efforts ...

「暴民陰謀論」殺死了防疫醫療團：伊波拉疫情前線的絕望罷工
「全心對抗致命病毒傳染的人，卻得遭受陰謀論的『醫療暴力』？」非洲中部、國內戰亂頻仍的「剛果民主共和國」（DRC），正遭遇人類史上第二嚴重的「伊波拉疫情大爆發」。但當前線病況已進入「全境擴散」的崩潰邊緣時，冒著生命危險深入疫區的跨國防疫醫療團，卻不斷遭遇「疫情陰謀論」的暴力威脅——大批受到假新聞煽動的暴民，不斷對防疫據點發動攻擊；在上周五，甚至殺害了WHO派遣的防疫專家。於是在內憂外患的包夾之下，灰心心死的伊波拉防疫團隊，24日也在疫情前線發動了示威抗爭：他們要求國際社會與剛果政府「擔保醫療工作者最基本的安全」，否則將自5月1日起全面罷工，任憑防疫工作隨謠言陰謀論一併毀滅。https://global.udn.com/global_vision/story/8662/3776066

Armed Groups Are Attacking Health Workers Responding To Ebola ...
https://www.npr.org/.../armed-groups-are-attacking-health-workers-resp... - 翻譯這個網頁
2 天前 - There's been a deadly escalation of the workers trying to curb the Ebola outbreak in the Congo.

Democratic Republic of Congo Sees A Recent
https://www.npr.org/.../democratic-republic-of-congo-sees-a-r
2019年4月5日 - The World Health Organization marked increase in new cases of Ebola in the D Congo. More than ...

Why Does Ebola Keep Spreading In Congo? H
https://www.npr.org/.../why-does-ebola-keep-spreading-in-congo-heres-... - 翻譯這個網頁
2019年2月25日 - Responders are zeroing in on an important source of new infections in the towns of Katwa and Butembo.

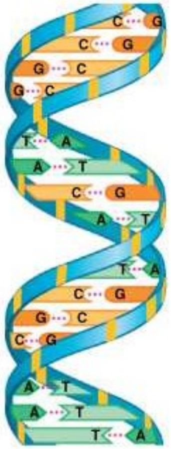
Ebola outbreak in Congo still not an international crisis, WHO decides

By **Jon Cohen** | Apr. 12, 2019 , 6:20 PM

No need to sound the world's loudest public health alarm bell about the lingering Ebola outbreak in the Democratic Republic of the Congo (DRC), an expert panel convened by the World Health Organization (WHO) in Geneva, Switzerland, **decided today**. The controversial decision not to declare what is known as a Public Health Emergency of International Concern (PHEIC) comes as the outbreak has sickened at least 1206 people, killing 63% of them.

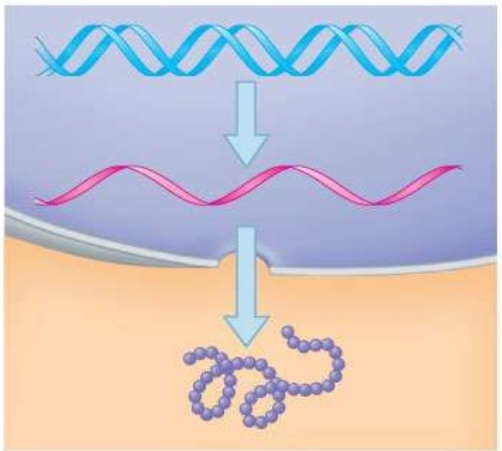
Figure 10.0_1

Chapter 10: Big Ideas

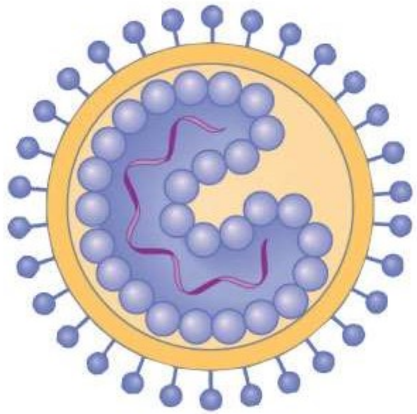


The Structure of the Genetic Material (10.1-10.3)

DNA Replication (10.4-10.5)



The Flow of Genetic Information from DNA to RNA to Protein (10.6-10.16)



The Genetics of Viruses and Bacteria (10.17-10.23)

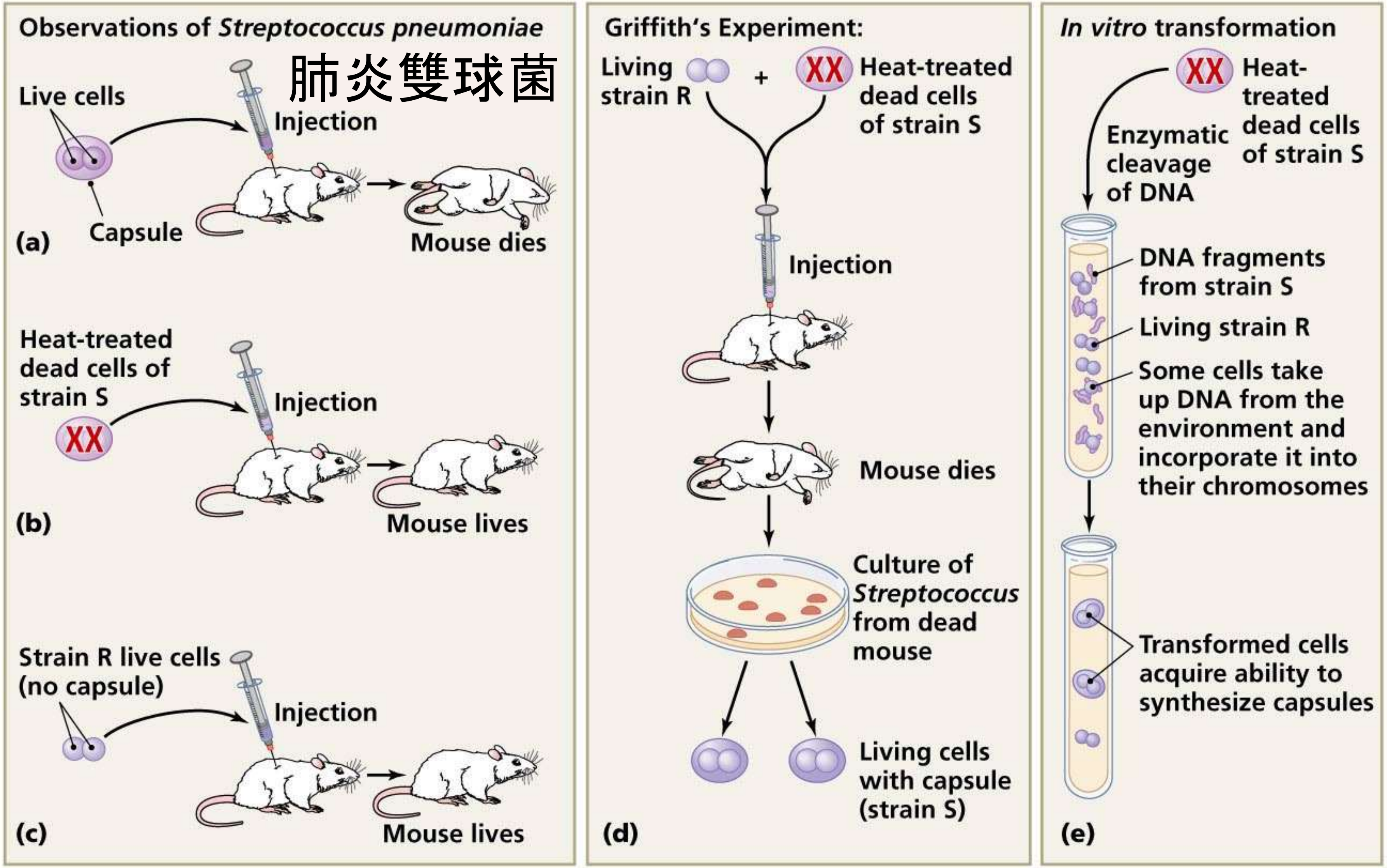
THE STRUCTURE OF THE GENETIC MATERIAL

10.1 Experiments showed that DNA is the genetic material

- Early in the 20th century, the molecular basis for inheritance was a mystery.
- Biologists did know that genes were located on chromosomes. But it was unknown if the genetic material was **DNA or Protein**?
- Until the 1940s, the case for proteins serving as the genetic material was stronger than the case for DNA.
  - Proteins are made from 20 different amino acids.
  - DNA was known to be made from just four kinds of nucleotides.
- Studies of bacteria and viruses
  - ushered in the field of **molecular biology**, the study of heredity at the molecular level, and
  - revealed the role of DNA in heredity.

10.1 Experiments showed that DNA is the genetic material

- In 1928, Frederick Griffith discovered that a "transforming factor" could be transferred into a bacterial cell. He found that
  - when he exposed heat-killed pathogenic bacteria to harmless bacteria, some harmless bacteria were converted to disease-causing bacteria and
  - the disease-causing characteristic was inherited by descendants of the transformed cells.



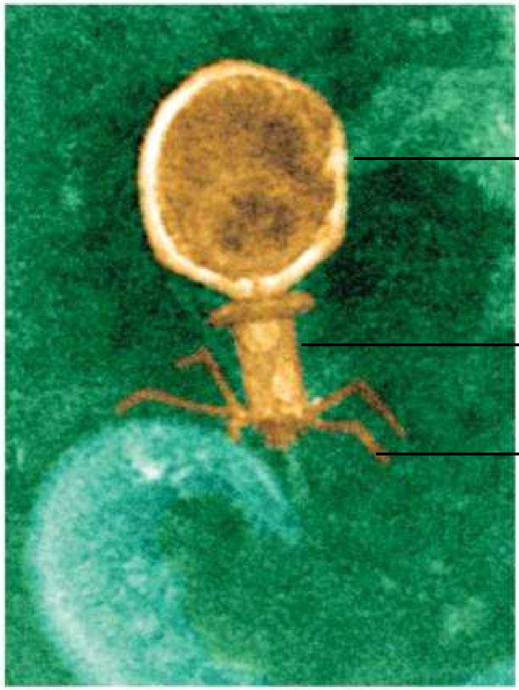
http://academic.pgcc.edu/~kroberts/Lecture/Chapter%207/horizontal.html

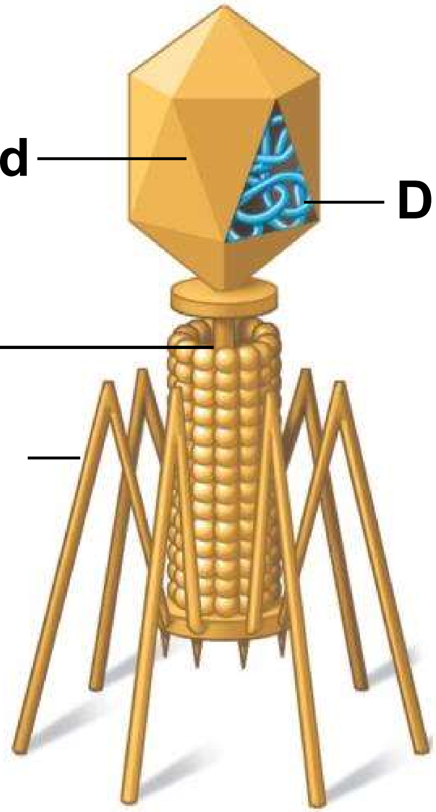
10.1 Experiments showed that DNA is the genetic material

- In 1952, Alfred Hershey and Martha Chase used bacteriophages to show that DNA is the genetic material of T2, a virus that infects the bacterium *Escherichia coli* (*E. coli*).
  - **Bacteriophages** (or **phages** for short) are viruses that infect bacterial cells. 嗜菌體
  - 硫
  - **Phages** were labeled with radioactive sulfur to detect proteins or radioactive phosphorus to detect DNA. 磷
  - Bacteria were infected with either type of labeled phage to determine which substance was injected into cells and which remained outside the infected cell.

10.1 Experiments showed that DNA is the genetic material

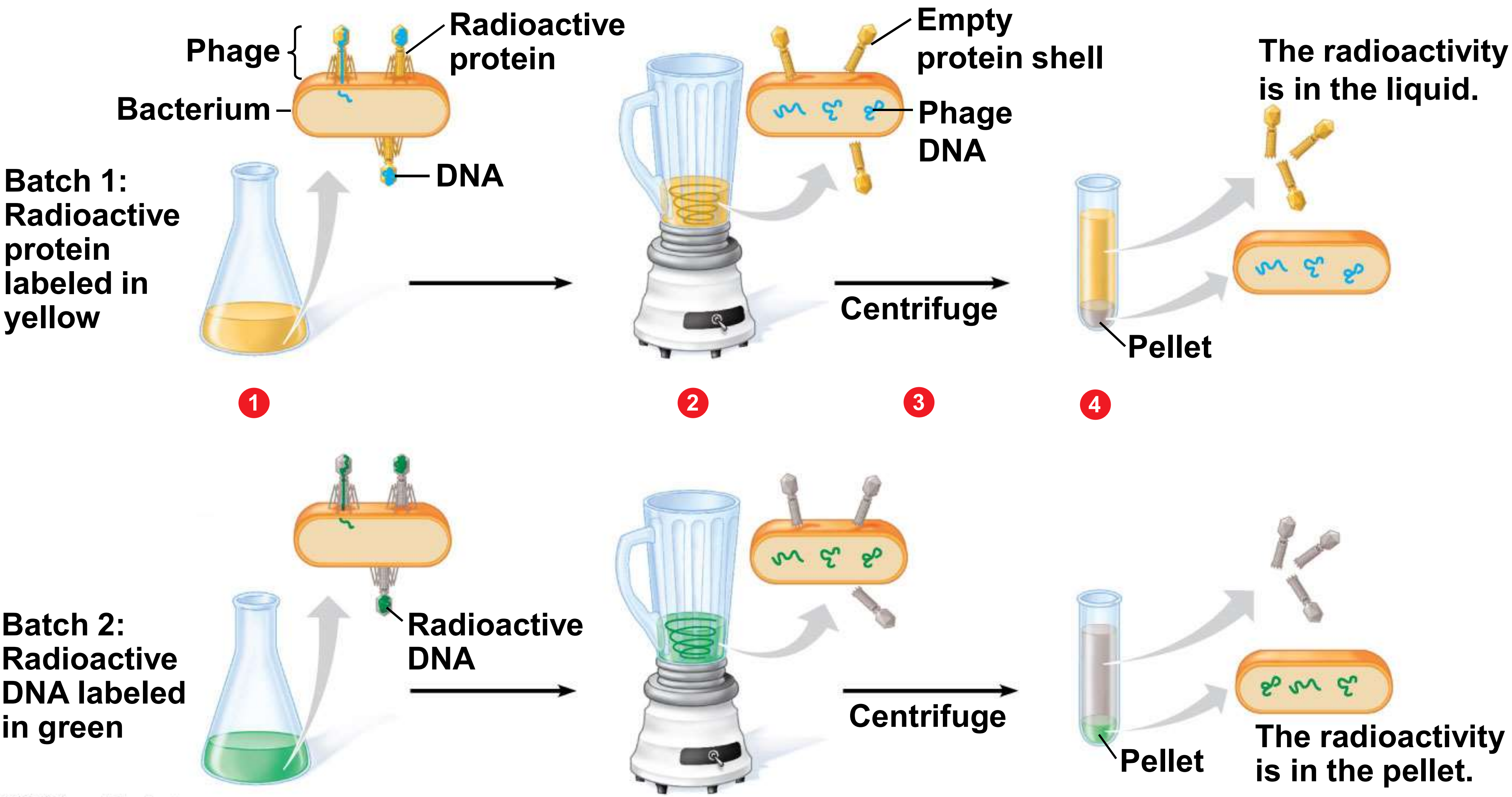
- The sulfur-labeled protein stayed with the phages outside the bacterial cell, while the phosphorus-labeled DNA was detected inside cells.





- Cells with phosphorus-labeled DNA produced new bacteriophages with radioactivity in DNA but not in protein.

Figure 10.1B


Phage
Radioactive protein
Bacterium
DNA
Batch 1: Radioactive protein labeled in yellow
Empty protein shell
Phage DNA
Centrifuge
The radioactivity is in the liquid.
Pellet
1
2
3
4
Batch 2: Radioactive DNA labeled in green
Radioactive DNA
Centrifuge
Pellet
The radioactivity is in the pellet.

A Phage Replication Cycle

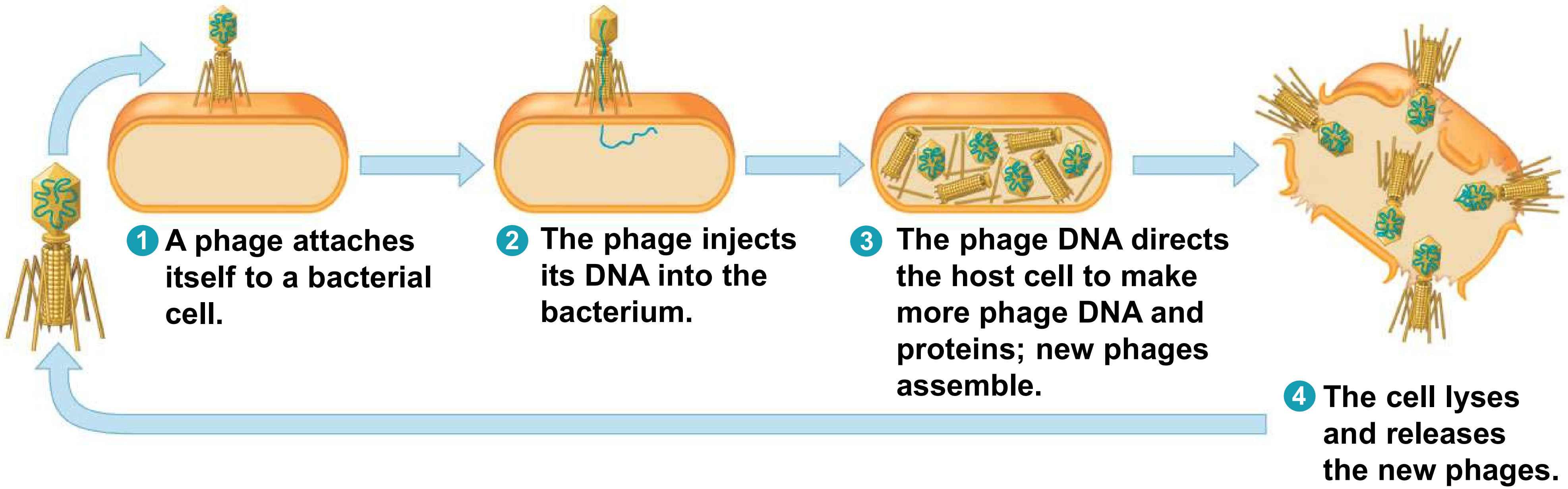
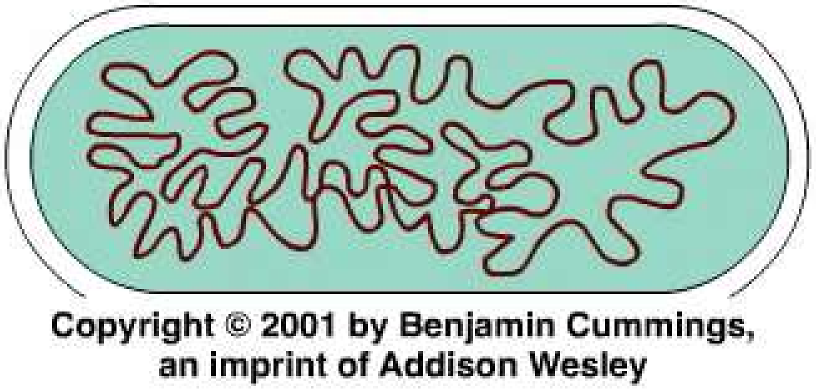


Figure 10.1C outlines our current understanding—as originally formulated by Hershey and Chase—of the replication cycle of phage T2.



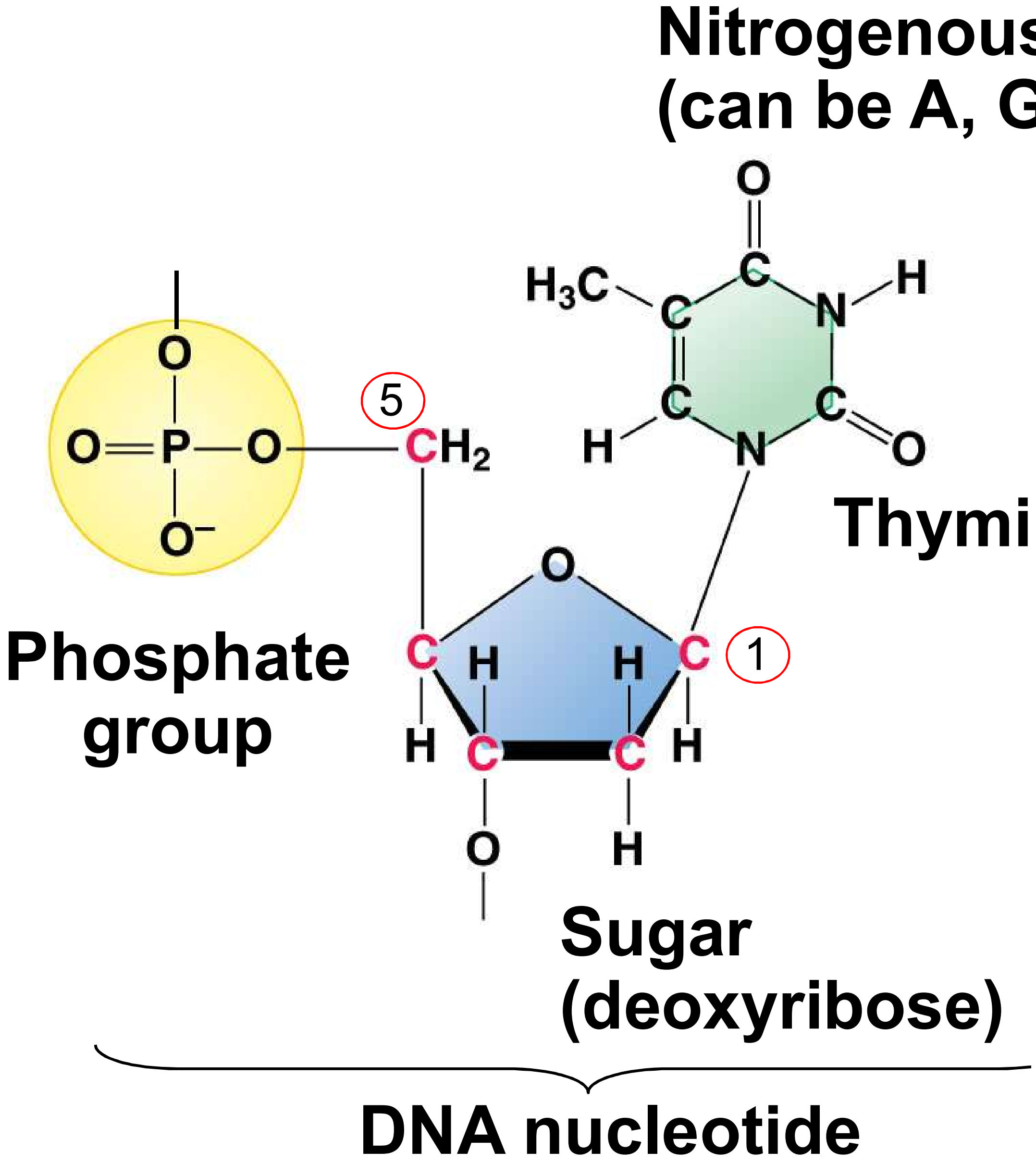
Animation: Phage T2 Reproductive Cycle
Right click on animation / Click play

Animation: Hershey-Chase Experiment
Right click on animation / Click play

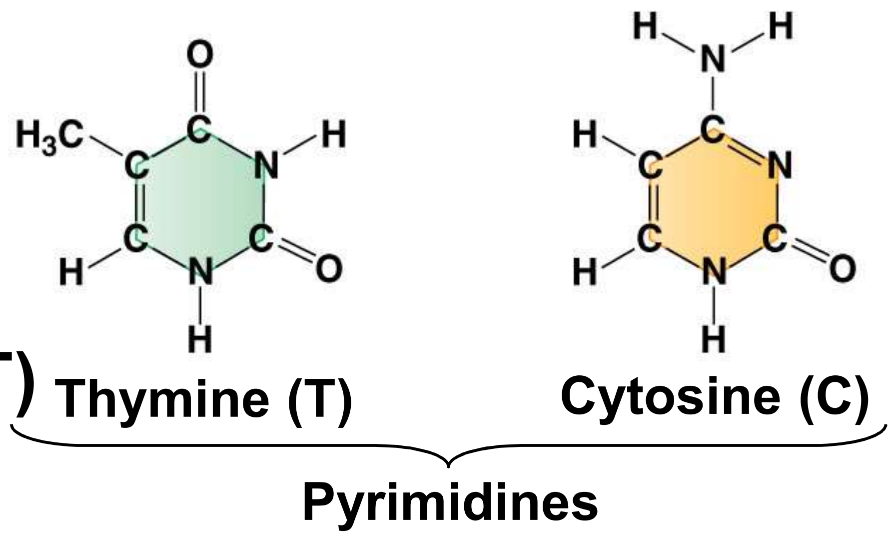
Radioactivity appears in the new phages when DNA is labeled

10.2 DNA and RNA are polymers of nucleotides

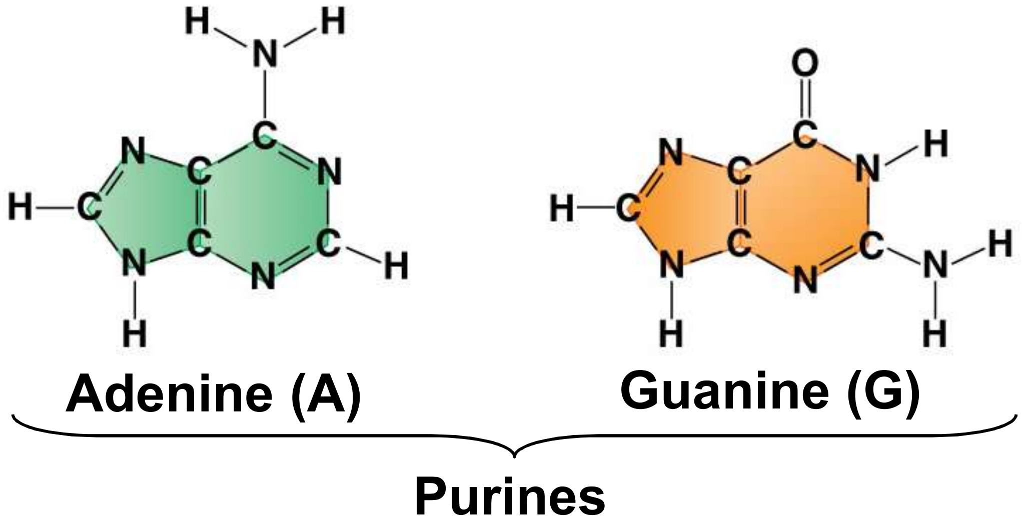
- DNA and RNA are nucleic acids consisting of long chains (polymers) of chemical units (monomers) called **nucleotides**.
- One of the two strands of DNA is a DNA **polynucleotide**, a nucleotide polymer (chain).
- A **nucleotide** is composed of a 核苷酸
  - nitrogenous base, 氮基
  - five-carbon sugar, and
  - phosphate group. 磷酸根
- The nucleotides are joined to one another by a **sugar-phosphate backbone**.
- Each type of DNA nucleotide has a different nitrogen-containing base: adenine (A), cytosine (C), thymine (T), and guanine (G).



Nitrogenous base
(can be A, G, C, or T)
Thymine (T)
Phosphate group
Sugar (deoxyribose)
DNA nucleotide
5
1

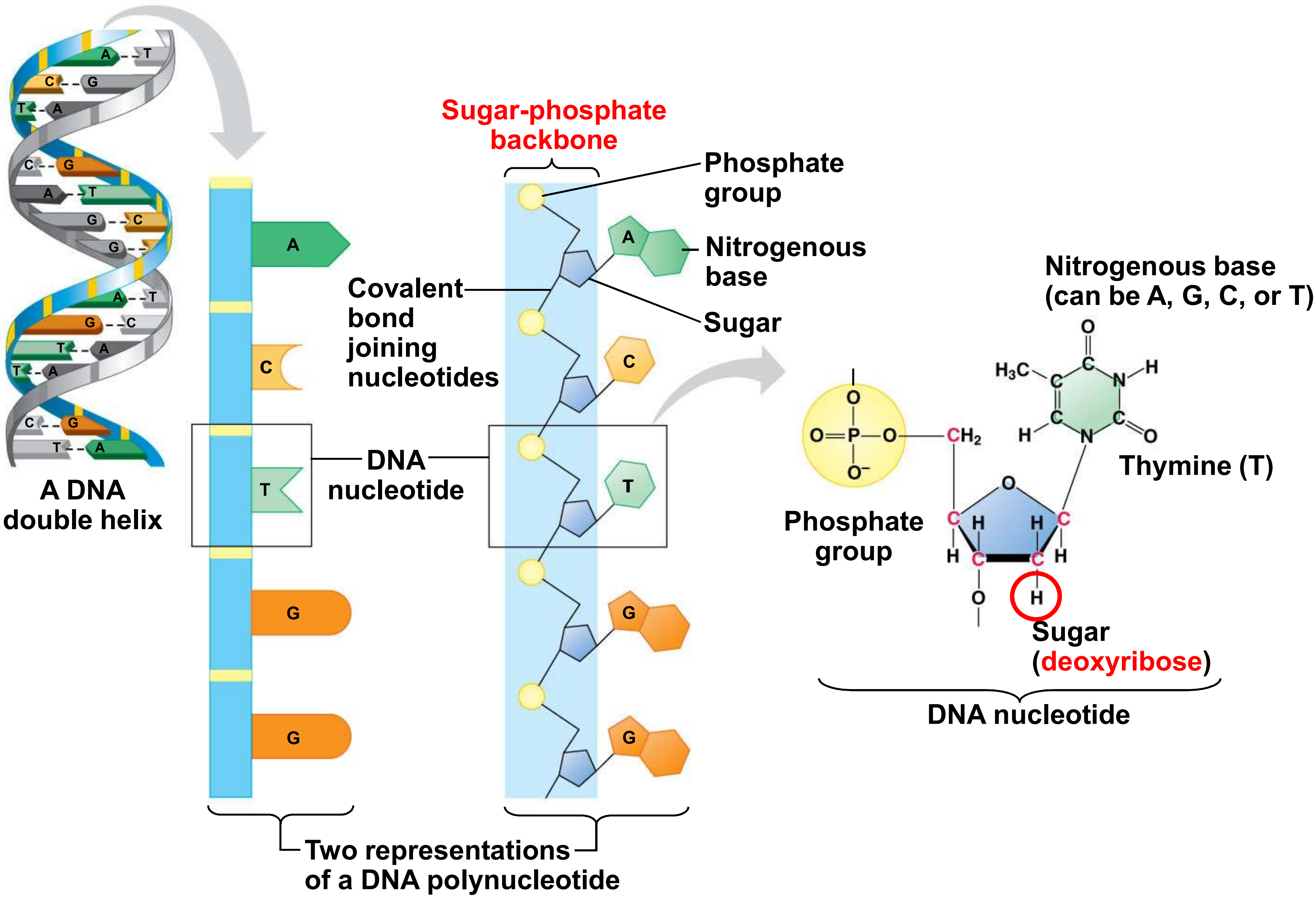


Thymine (T)
Cytosine (C)
Pyrimidines

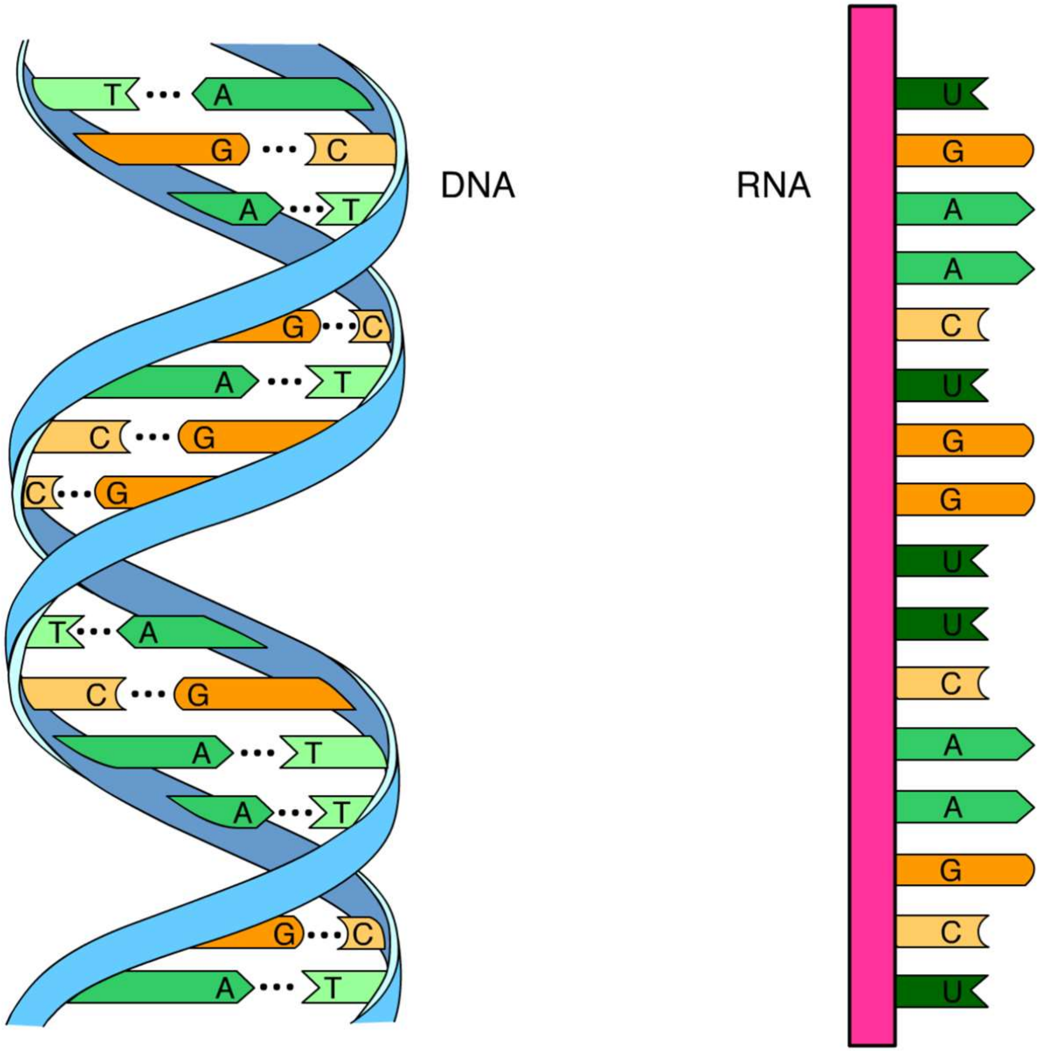


Adenine (A)
Guanine (G)
Purines

Figure 10.2A



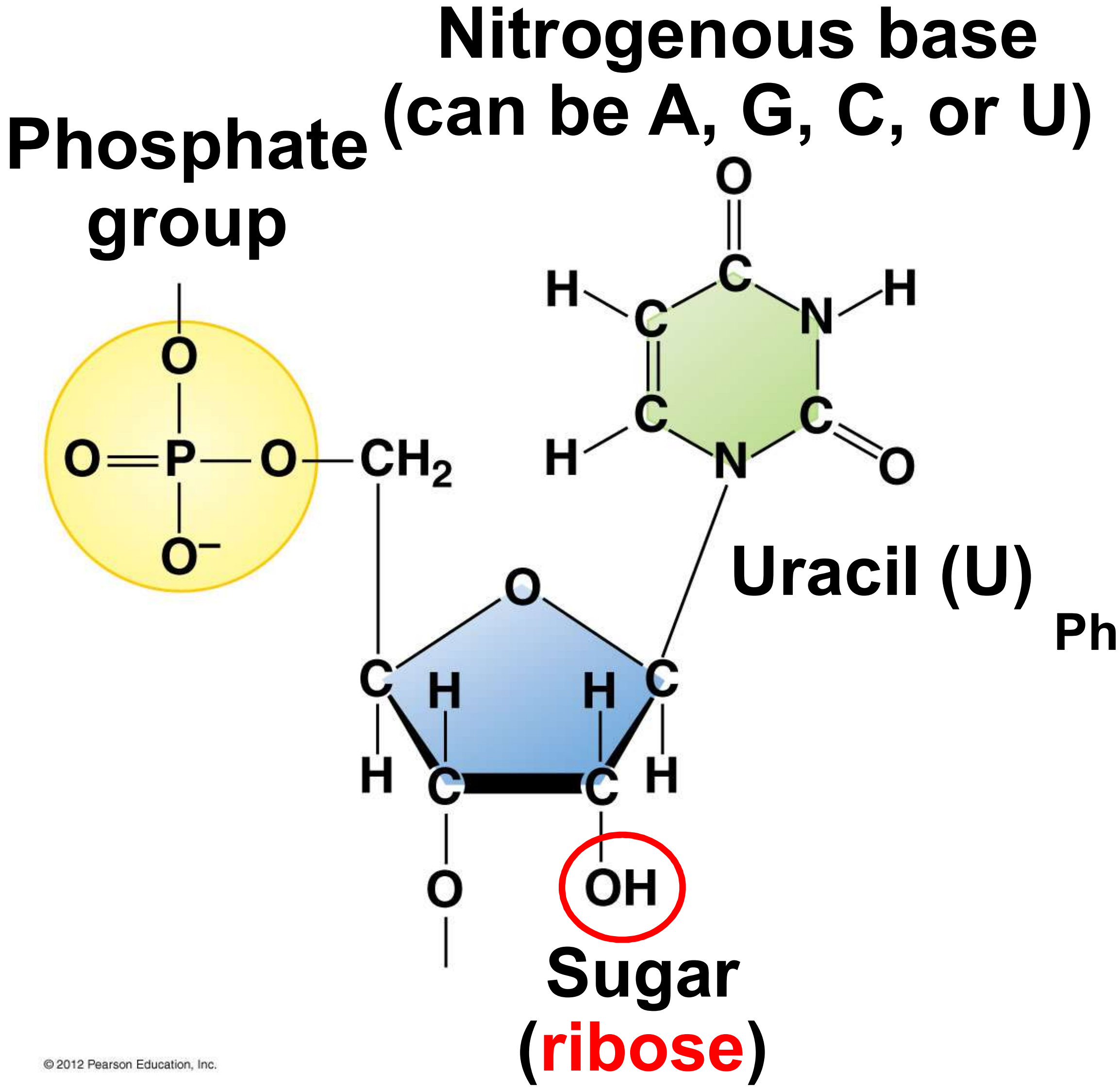
A DNA double helix
Sugar-phosphate backbone
Phosphate group
Nitrogenous base
Sugar
Covalent bond joining nucleotides
DNA nucleotide
Nitrogenous base (can be A, G, C, or T)
Thymine (T)
Phosphate group
Sugar (deoxyribose)
DNA nucleotide
Two representations of a DNA polynucleotide

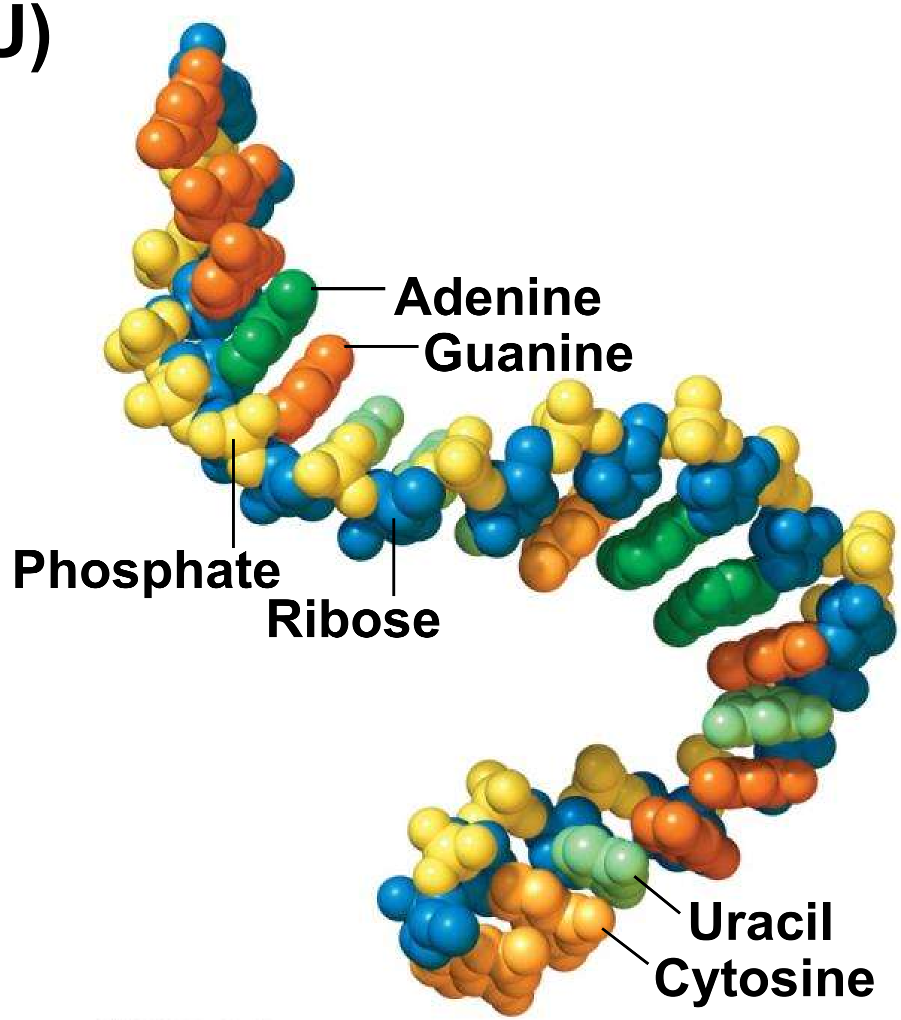


Animation: DNA and RNA Structure
Right click on animation / Click play

10.2 DNA and RNA are Polymers of Nucleotides

- RNA (ribonucleic acid) is unlike DNA in that it
  - uses the sugar ribose (instead of deoxyribose in DNA) and
  - RNA has the nitrogenous base **uracil** (U) instead of thymine.



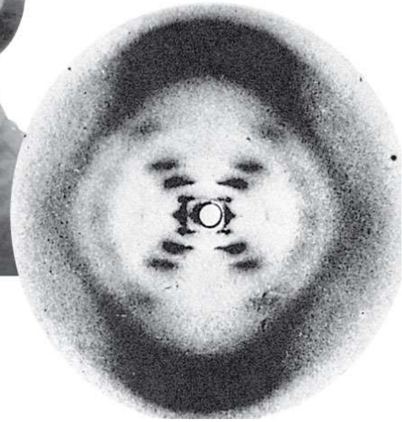


10.3 DNA is a double-stranded helix

- After the 1952 Hershey-Chase experiment convinced most biologists that DNA was the material that stored genetic information, a race was on to determine how the structure of this molecule could account for its role in heredity.
- Researchers focused on discovering the three-dimensional shape of DNA.
- American James D. Watson journeyed to Cambridge University in England, where the more senior Francis Crick was studying protein structure with a technique called X-ray crystallography.
- While visiting the laboratory of Maurice Wilkins at King's College in London, Watson saw an X-ray image of DNA produced by Wilkins's colleague, Rosalind Franklin.

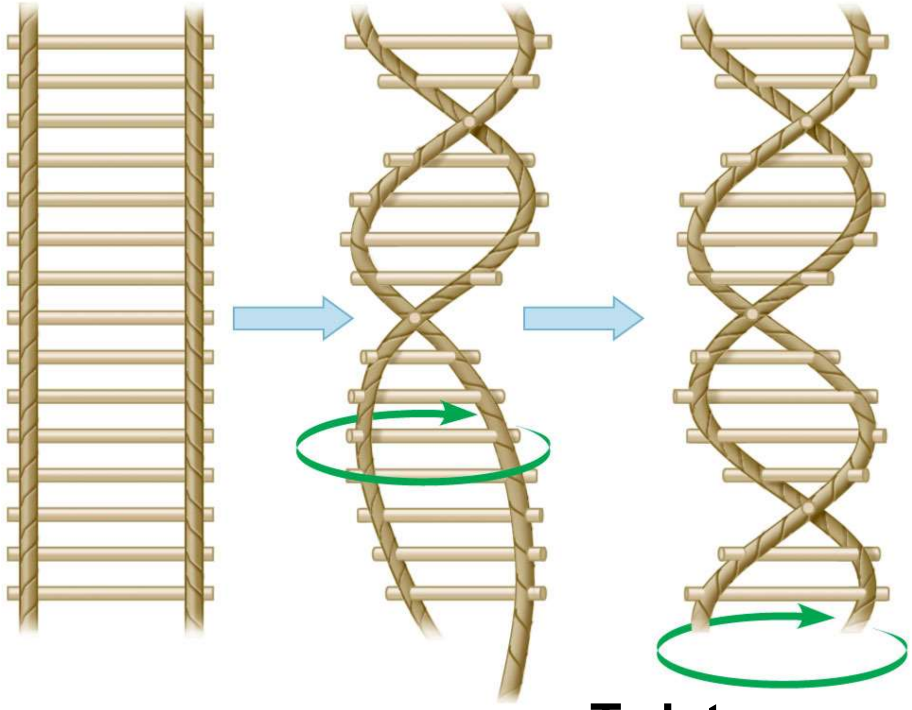
10.3 DNA is a double-stranded helix

Rosalind Franklin



- Watson deduced the basic shape of DNA to be a helix (spiral) with a uniform diameter and the nitrogenous bases located above one another like a stack of dinner plates.
- The thickness of the helix suggested that it was made up of two polynucleotide strands.
- Watson and Crick reported that DNA consisted of two polynucleotide strands wrapped into a **double helix**.
  - The sugar-phosphate backbone is on the outside.
  - The nitrogenous bases are perpendicular to the backbone in the interior.
  - Specific pairs of bases give the helix a uniform shape.
    - A pairs with T, forming two hydrogen bonds, and
    - G pairs with C, forming three hydrogen bonds.

Figure 10.3C



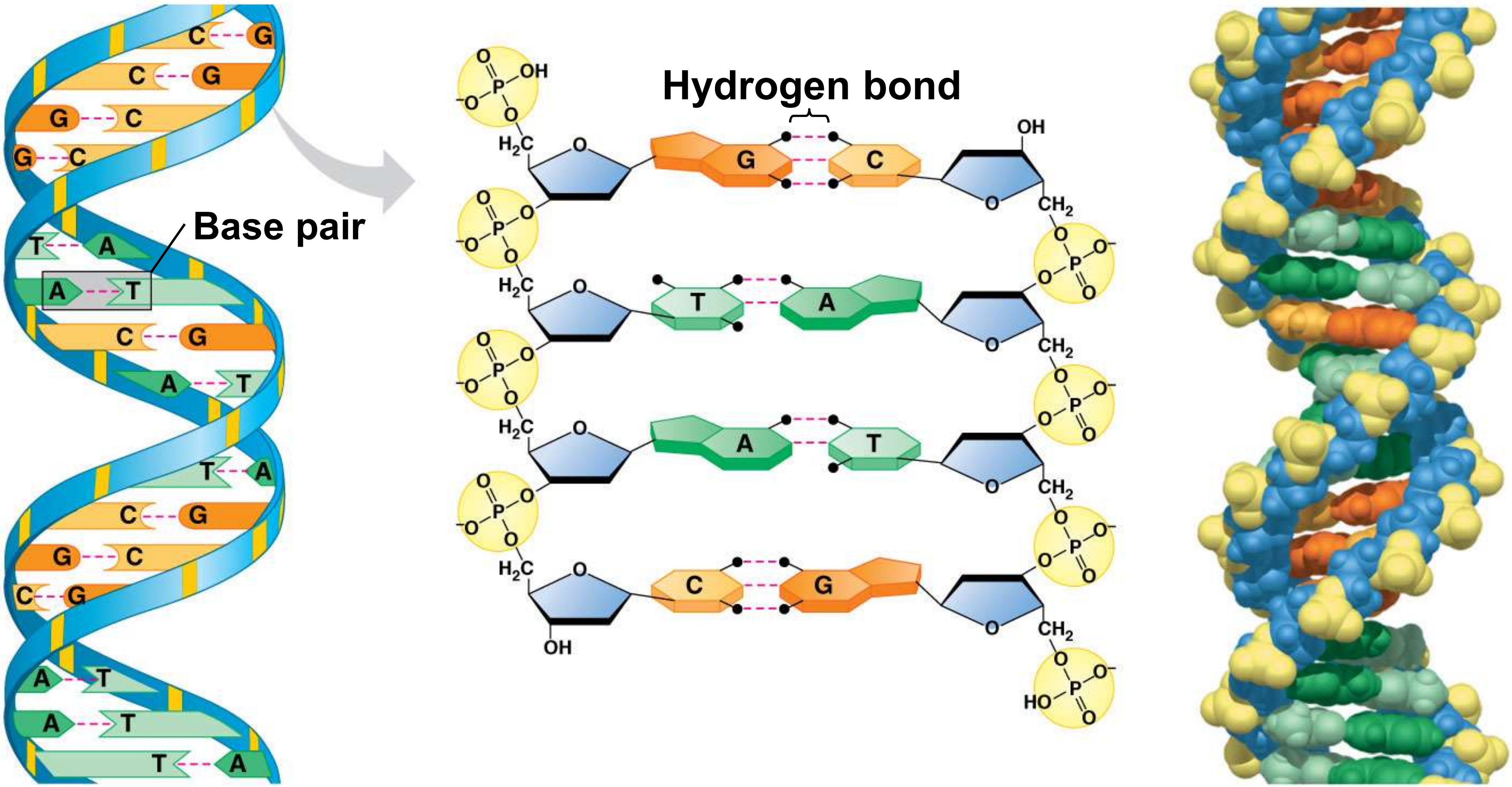
Animation: DNA Double Helix

DNA之父沃森：「科學種族主義」陰影下的雙螺旋人生
臺灣新浪網 - 2019年4月10日
他是一位科學家，發現DNA雙螺旋結構；卻因頻頻發表涉嫌種族歧視言論 ... 譽為DNA之父、曾獲諾貝爾獎的美國科學家詹姆斯·沃森（James Watson） ...

稱智商跟種族有關DNA之父榮銜全被撤
自由時報電子報 - 2019年1月14日
稱智商跟種族有關DNA之父榮銜全被撤 ... 美國科學家詹姆斯·華生（James Watson），因發表「應受譴責」的歧視黑人言論，聲稱種族與智商息息相關， ...

DNA之父因種族歧視被剝奪榮譽頭銜
supermedia.hk (新聞發布) - 2019年1月14日

Figure 10.3D



Ribbon model

Partial chemical structure

Computer model

http://www.youtube.com/watch?v=NvtvqGdMJbo

10.3 DNA is a double-stranded helix

- In 1962, the Nobel Prize was awarded to
  - James D. Watson, Francis Crick, and Maurice Wilkins.
  - Rosalind Franklin probably would have received the prize as well but for her death from cancer in 1958. Nobel Prizes are never awarded posthumously.

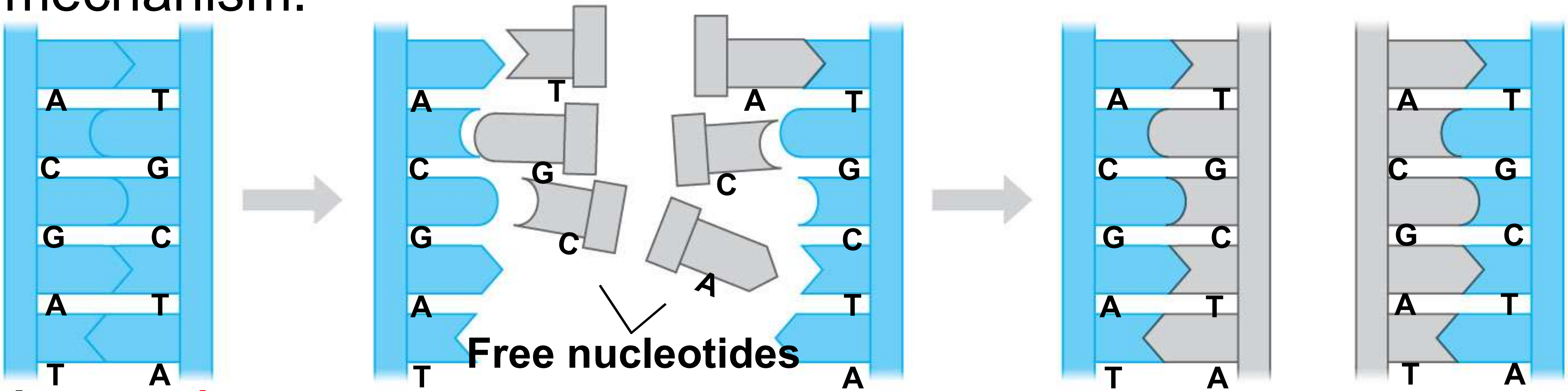
X-ray diffraction

- The Watson-Crick model gave new meaning to the words *genes* and *chromosomes*. The genetic information in a chromosome is encoded in the nucleotide sequence of DNA.

DNA REPLICATION

10.4 DNA replication depends on specific base pairing

- In their description of the structure of DNA, Watson and Crick noted that the structure of DNA suggests a possible copying mechanism.



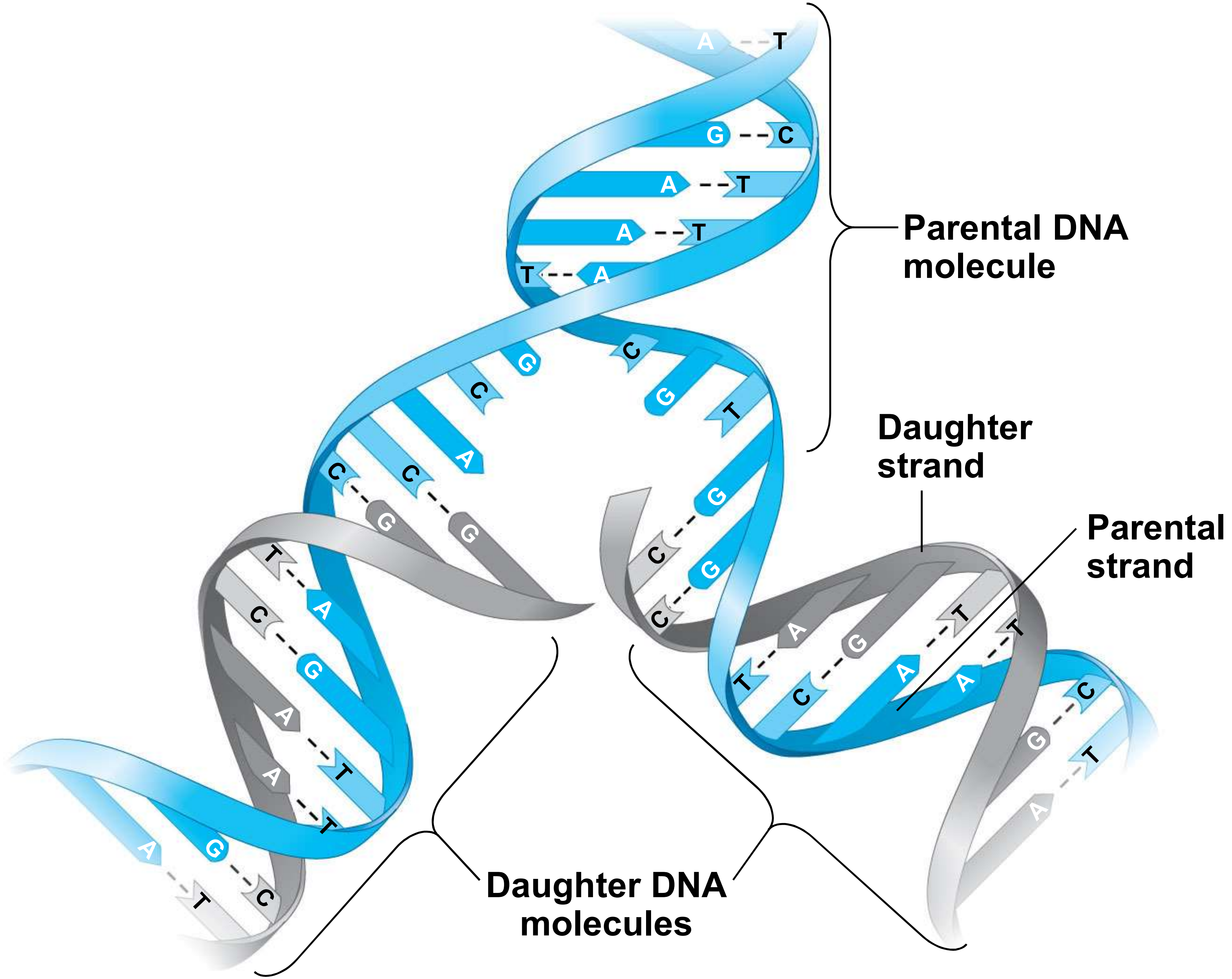
A parental molecule of DNA

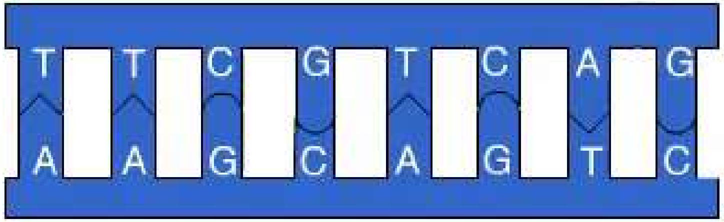
The parental strands separate and serve as templates

Two identical daughter molecules of DNA are formed

- DNA replication follows a **semiconservative model**.
  - The two DNA strands separate.
  - Each strand is used as a pattern to produce a complementary strand, using specific base pairing.
  - Each new DNA helix has one old strand with one new strand.

Figure 10.4B


Parental DNA molecule
Daughter strand
Parental strand
Daughter DNA molecules



Animation: DNA Replication Overview
Right click on animation / Click play

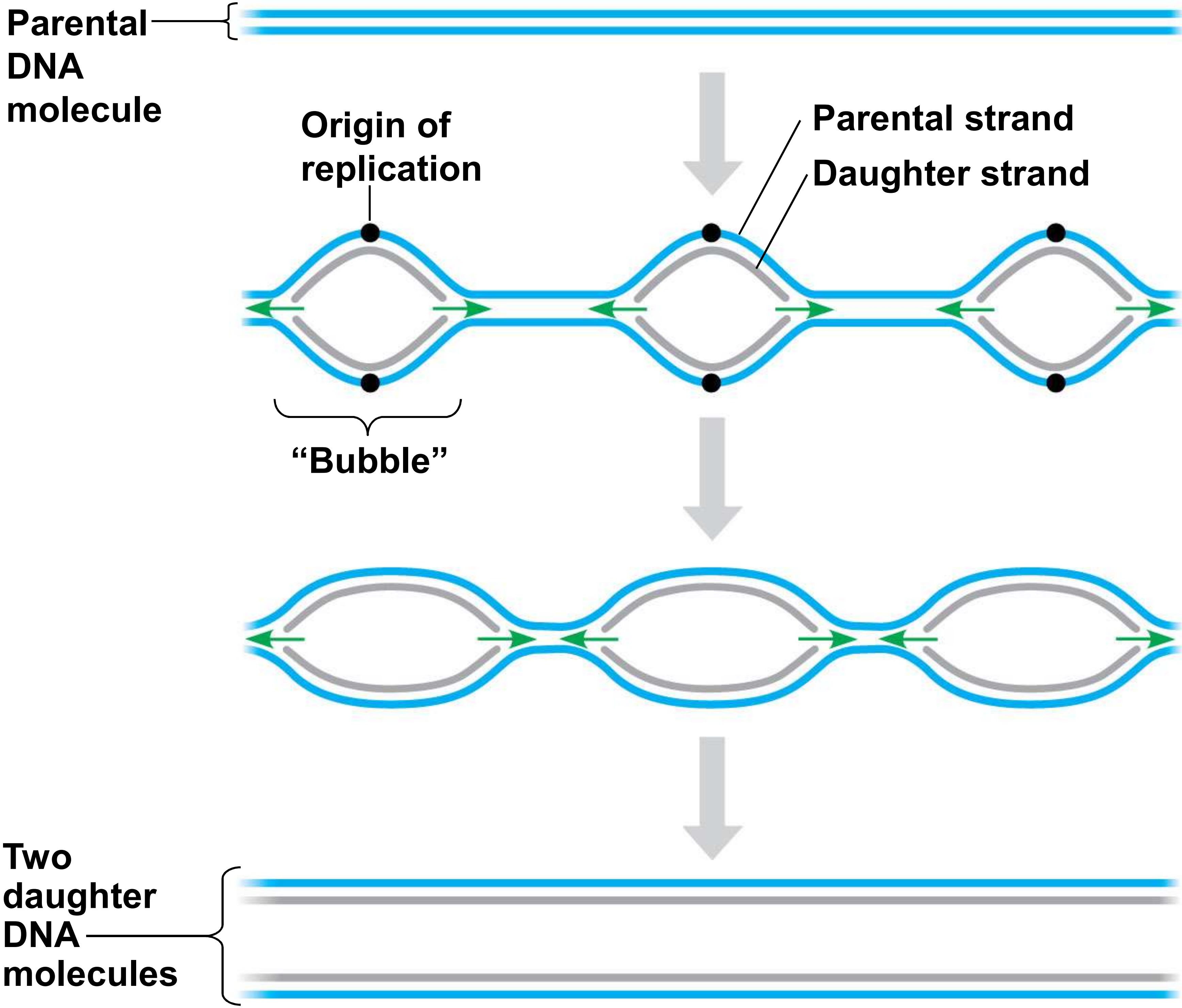
10.5 DNA replication proceeds in two directions at many sites simultaneously

- Replication of a DNA molecule begins at particular sites called origins of replication, short stretches of DNA having a specific sequence of nucleotides.
- Proteins that initiate DNA replication
  - attach to the DNA at the origin of replication and
  - separate the two strands of the double helix.
- Replication then proceeds in both directions, creating replication “bubbles.”
- DNA replication occurs in the 5′ to 3′ direction.
  - Replication is continuous on the 3′ to 5′ template.
  - Replication is discontinuous on the 5′ to 3′ template, forming short segments called Okazaki fragments.

10.5 DNA replication proceeds in two directions at many sites simultaneously

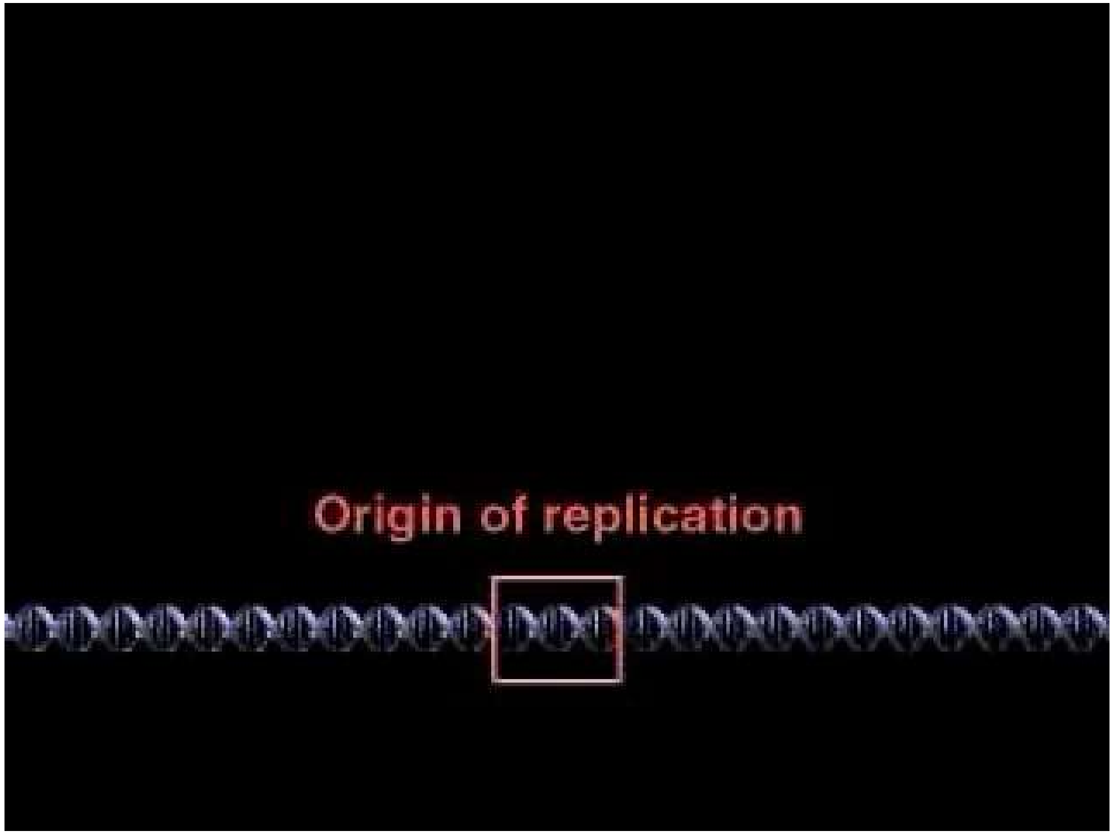
- Two key proteins are involved in DNA replication.
  1. **DNA ligase** joins small fragments into a continuous chain.
  2. **DNA polymerase**
     - adds nucleotides to a growing chain and
     - proofreads and corrects improper base pairings.
- DNA polymerases and DNA ligase also repair DNA damaged by harmful radiation and toxic chemicals.
- DNA replication ensures that all the somatic cells in a multicellular organism carry the same genetic information.

Figure 10.5A



Parental DNA molecule
Origin of replication
Parental strand
Daughter strand
"Bubble"
Two daughter DNA molecules

Figure 10.5B



Animation: Origins of Replication

Multiple origins

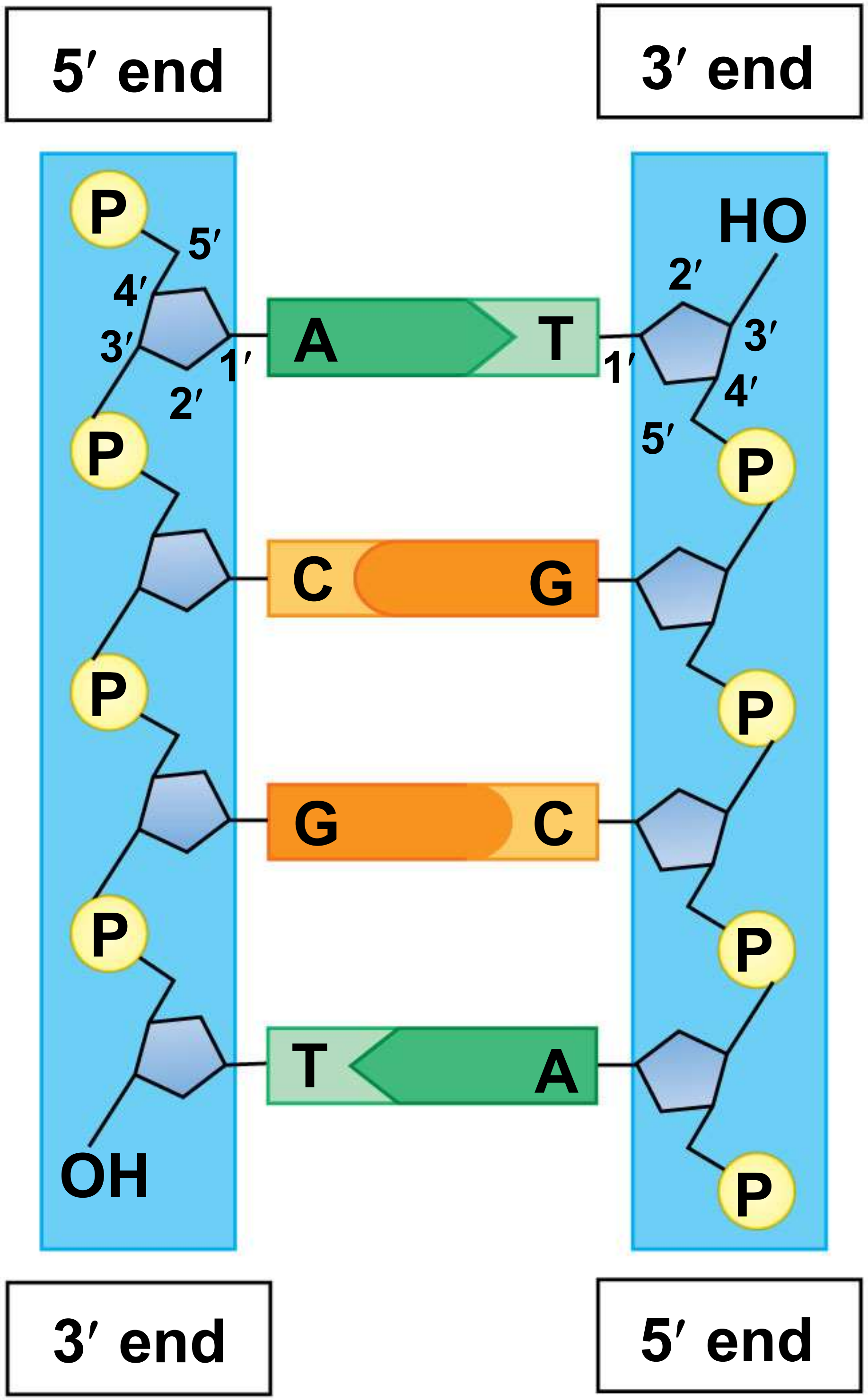
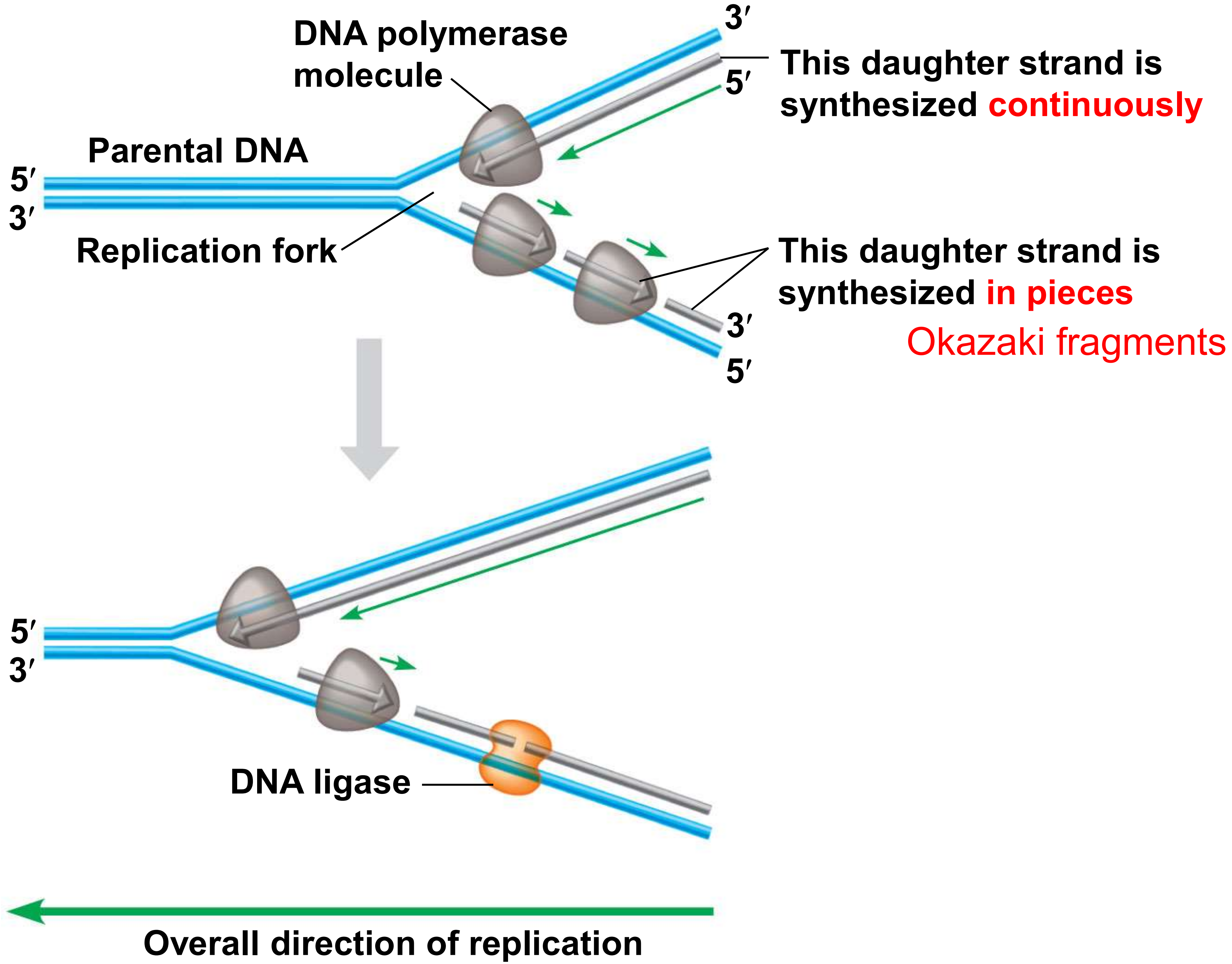
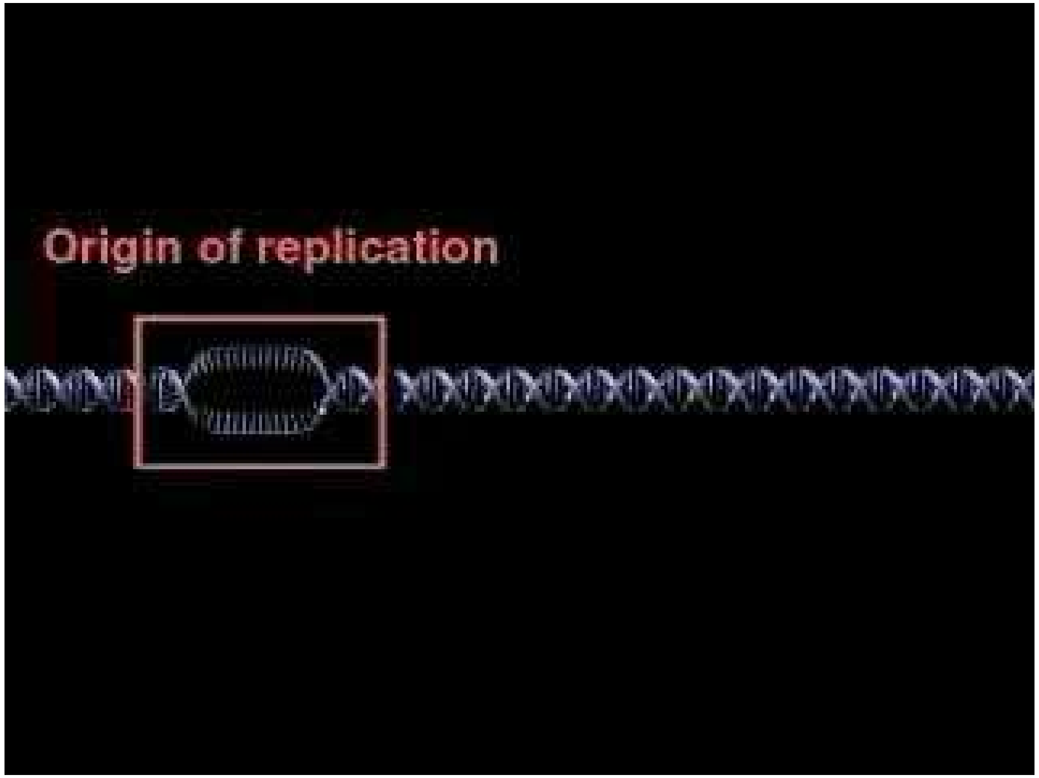


Figure 10.5C

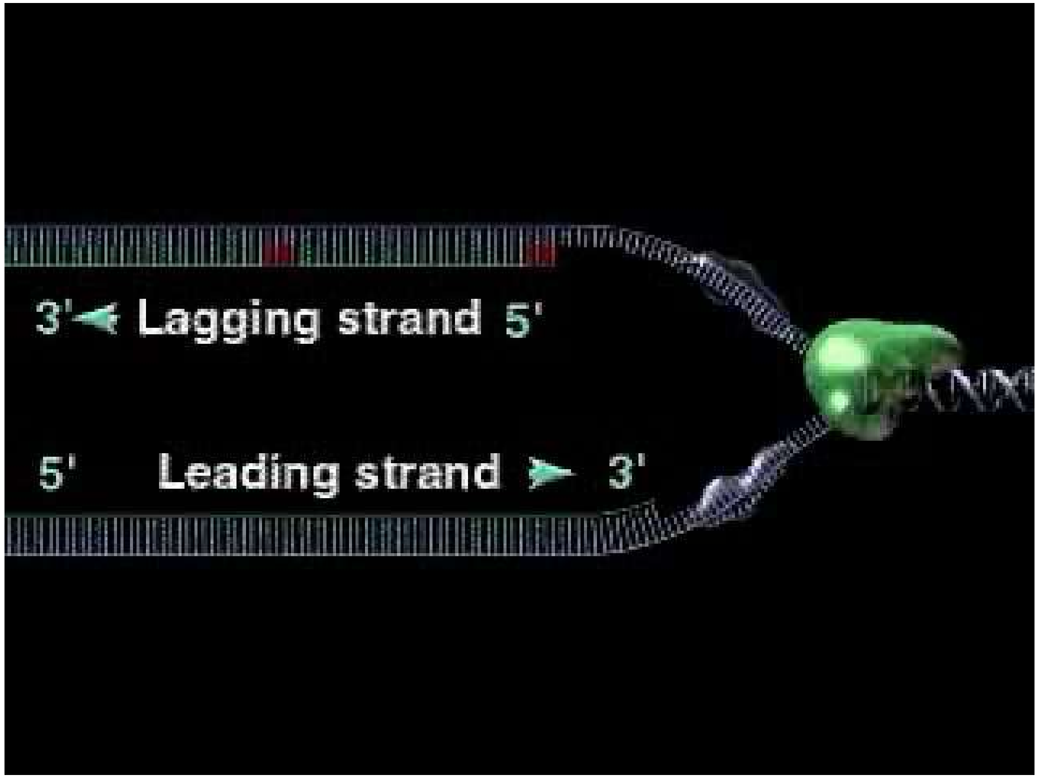


DNA polymerase molecule
Parental DNA
5′
3′
Replication fork
3′
5′
This daughter strand is synthesized continuously
This daughter strand is synthesized in pieces
3′
5′
Okazaki fragments
5′
3′
DNA ligase
Overall direction of replication

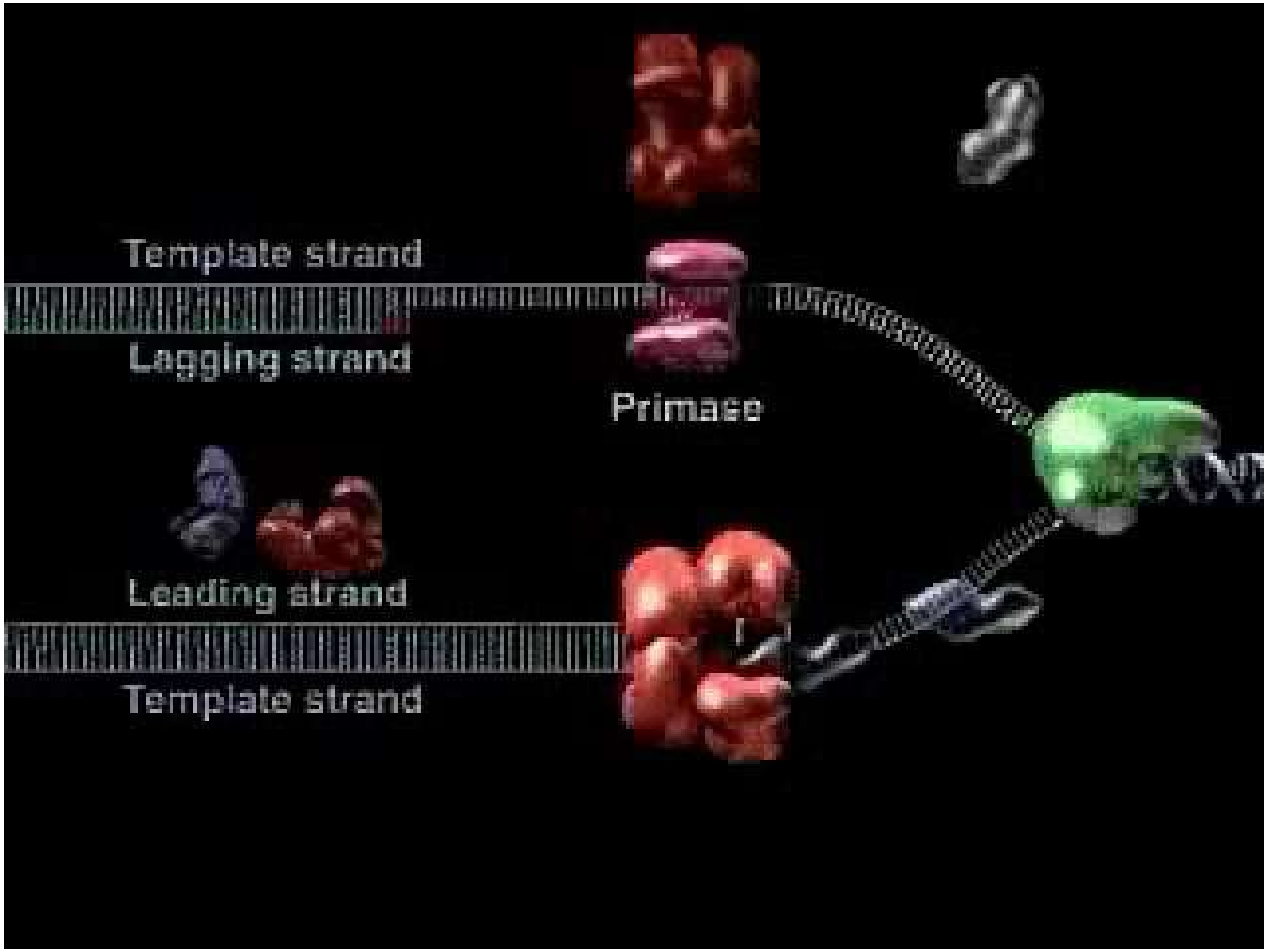
Animation: Leading Strand



Animation: Lagging Strand



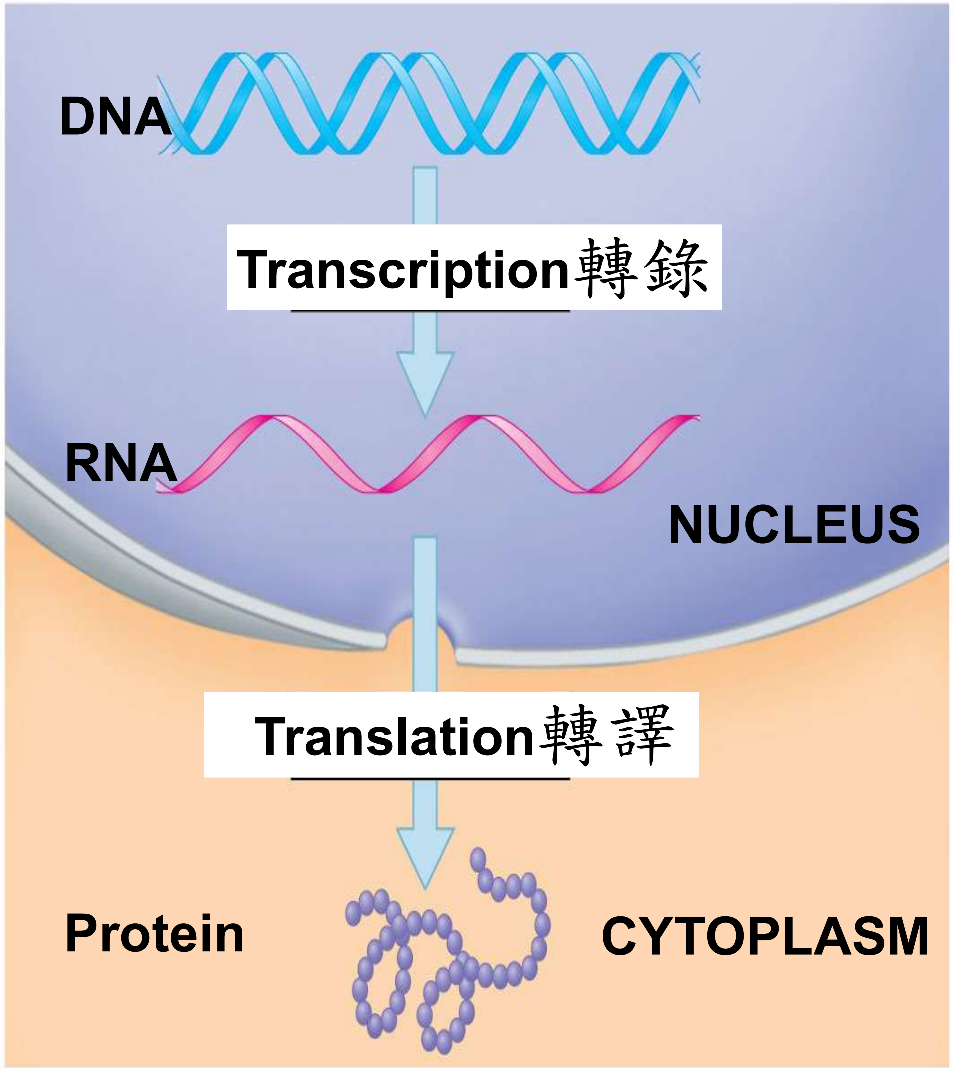
Animation: DNA Replication Review



THE FLOW OF GENETIC INFORMATION FROM DNA TO RNA TO PROTEIN

10.6 Genes control phenotypic traits through the expression of proteins

- DNA specifies traits by dictating protein synthesis.
- Proteins are the links between genotype and phenotype.
- The molecular chain of command is from DNA in the nucleus to RNA and RNA in the cytoplasm to protein.
- **Transcription** is the synthesis of RNA under the direction of DNA.
- **Translation** is the synthesis of proteins under the direction of RNA.



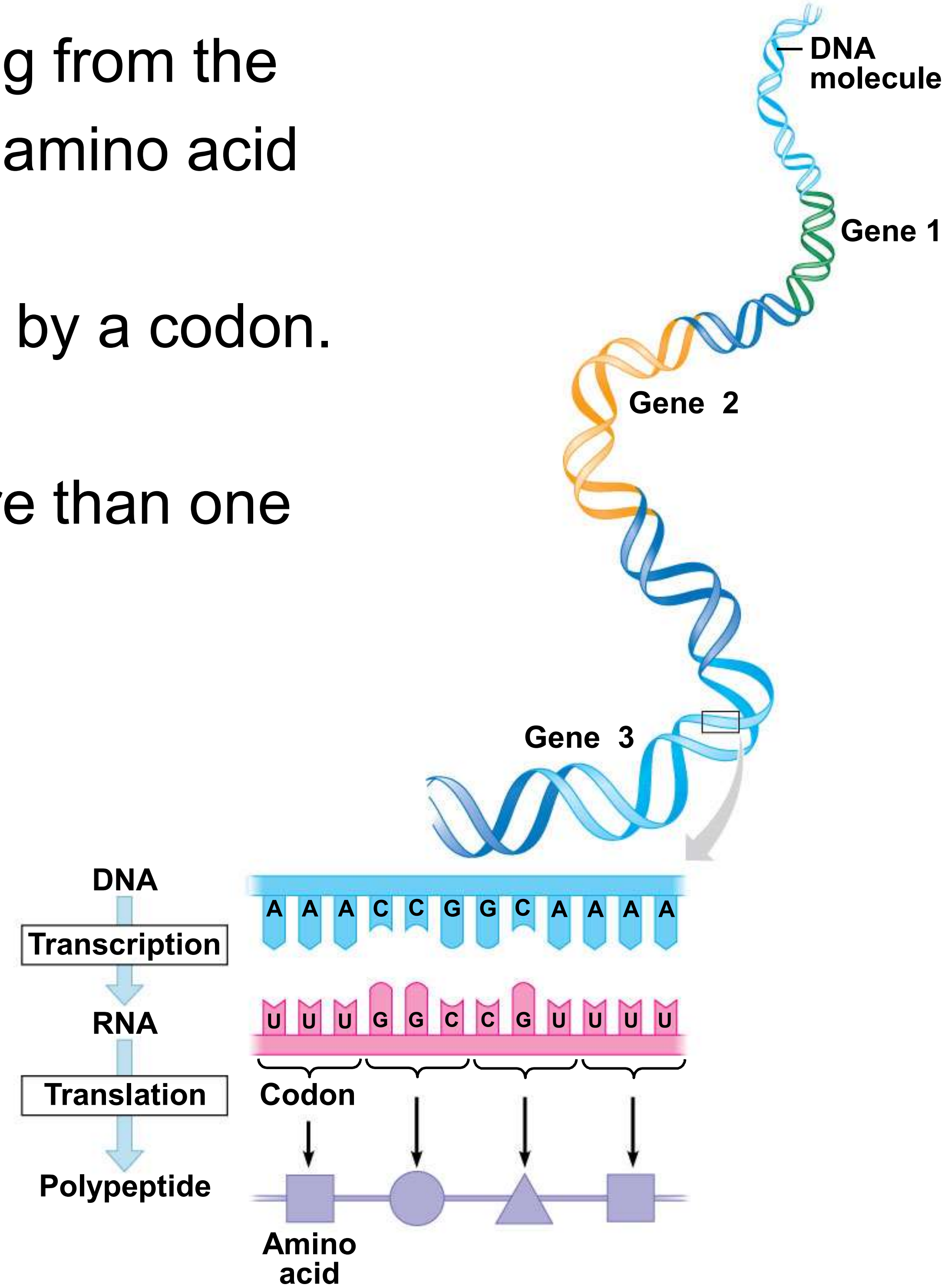
10.6 Genes control phenotypic traits through the expression of proteins

- Genes provide the instructions for making specific proteins.
  - The initial one gene–one enzyme hypothesis was based on studies of inherited metabolic diseases.
  - The one gene–one enzyme hypothesis was expanded to include all proteins.
  - Most recently, the one gene–one polypeptide hypothesis recognizes that some proteins are composed of multiple polypeptides.
- But RNA transcribed from some genes is not translated but nonetheless has important functions.
- Many eukaryotic genes code for a set of polypeptides (rather than just one) by a process called alternative splicing.

10.7 Genetic information written in codons is translated into amino acid sequences

- The sequence of nucleotides in DNA provides a code for constructing a protein.
  - Protein construction requires a conversion of a nucleotide sequence to an amino acid sequence.
  - Transcription rewrites the DNA code into RNA, using the same nucleotide “language.”
  - The flow of information from gene to protein is based on a **triplet code**: the genetic instructions for the amino acid sequence of a polypeptide chain are written in DNA and RNA as a series of nonoverlapping three-base “words” called **codons**.

- Translation involves switching from the nucleotide “language” to the amino acid “language.”
- Each amino acid is specified by a codon.
- 64 codons are possible.
- Some amino acids have more than one possible codon.



10.8 The genetic code dictates how codons are translated into amino acids

- The **genetic code** is the amino acid translations of each of the nucleotide triplets.
  - Three nucleotides specify one amino acid.
    - 61 codons correspond to amino acids.
    - AUG codes for methionine and signals the start of transcription.
    - 3 "stop" codons signal the end of translation.
- The **genetic code** is
  - *redundant*, with more than one codon for some amino acids,
  - *unambiguous* in that any codon for one amino acid does not code for any other amino acid,
  - *nearly universal*—the genetic code is shared by organisms from the simplest bacteria to the most complex plants and animals (evolutionary kinship that connects all life)

Second base

First base	U	C	A	G	Third base
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
U	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
U	UUA Leu	UCA Ser	UAA Stop	UGA Stop	A
U	UUG Leu	UCG Ser	UAG Stop	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
C	CUC Leu	CCC Pro	CAC His	CGC Arg	C
C	CUA Leu	CCA Pro	CAA Gln	CGA Arg	A
C	CUG Leu	CCG Pro	CAG Gln	CGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
A	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
A	AUA Ile	ACA Thr	AAA Lys	AGA Arg	A
A	AUG Met or start	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
G	GUC Val	GCC Ala	GAC Asp	GGC Gly	C
G	GUA Val	GCA Ala	GAA Glu	GGA Gly	A
G	GUG Val	GCG Ala	GAG Glu	GGG Gly	G

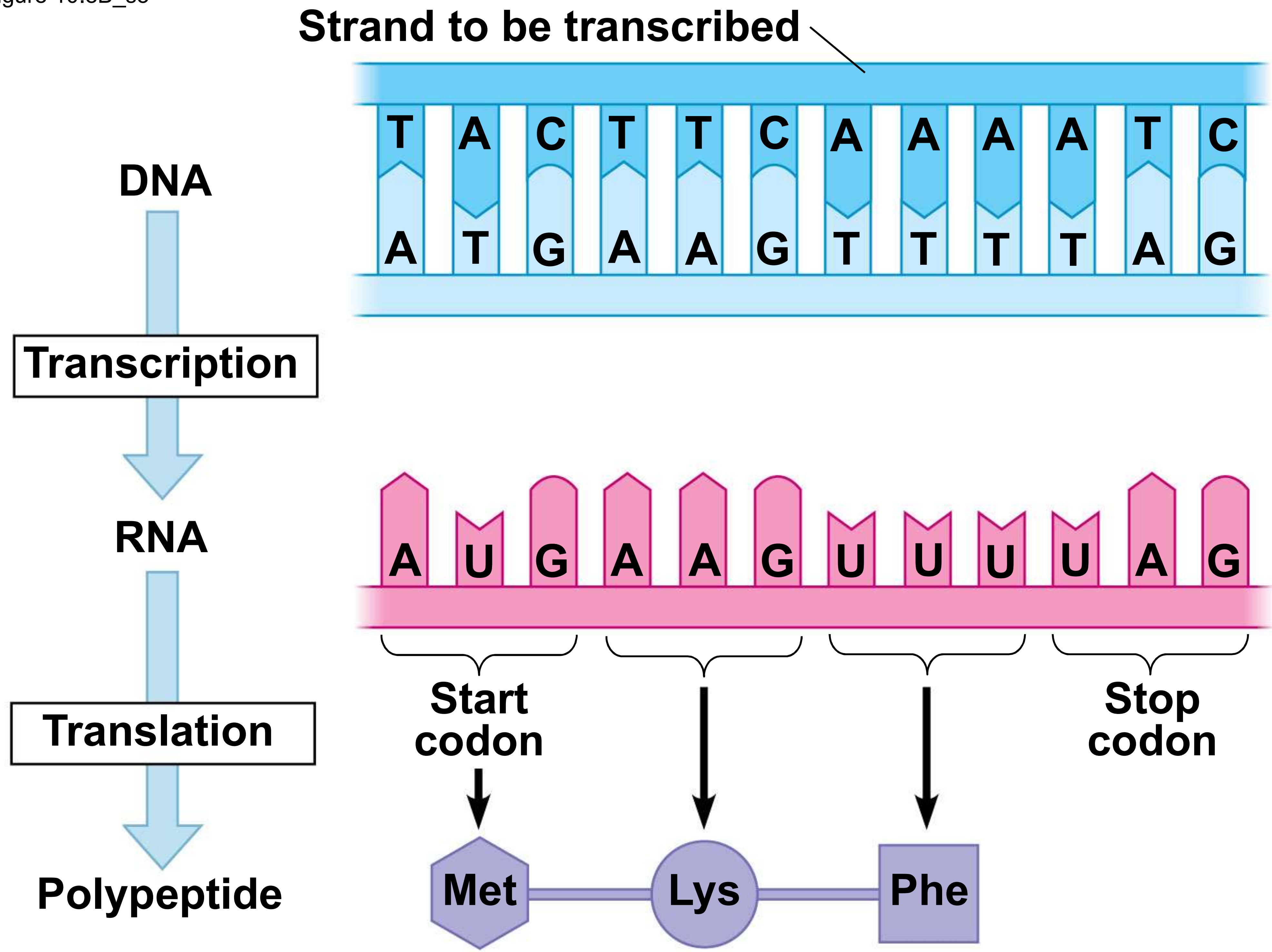
Left: engineered to express a red fluorescent protein

redundant

unambiguous

nearly universal

Figure 10.8B_s3

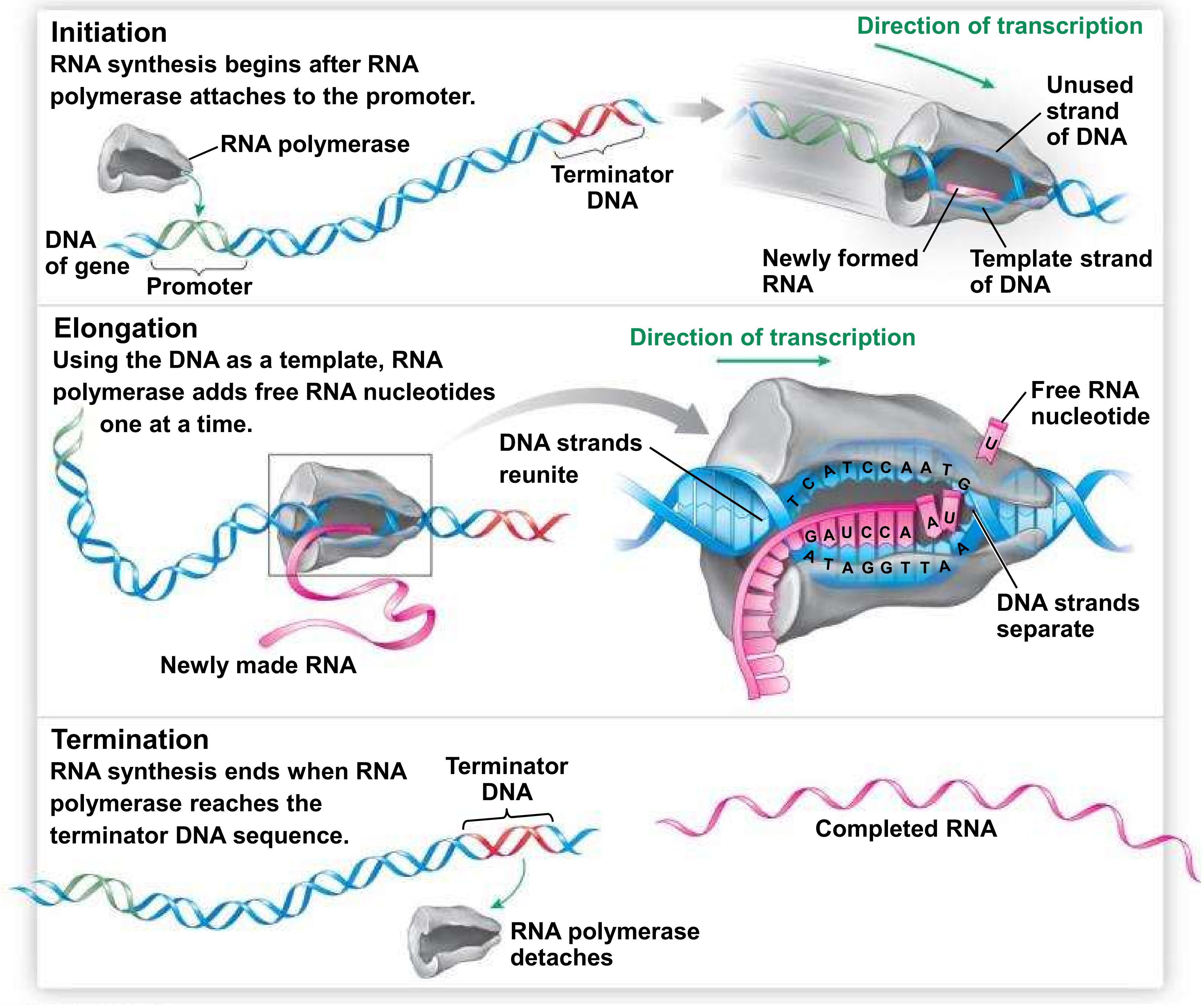


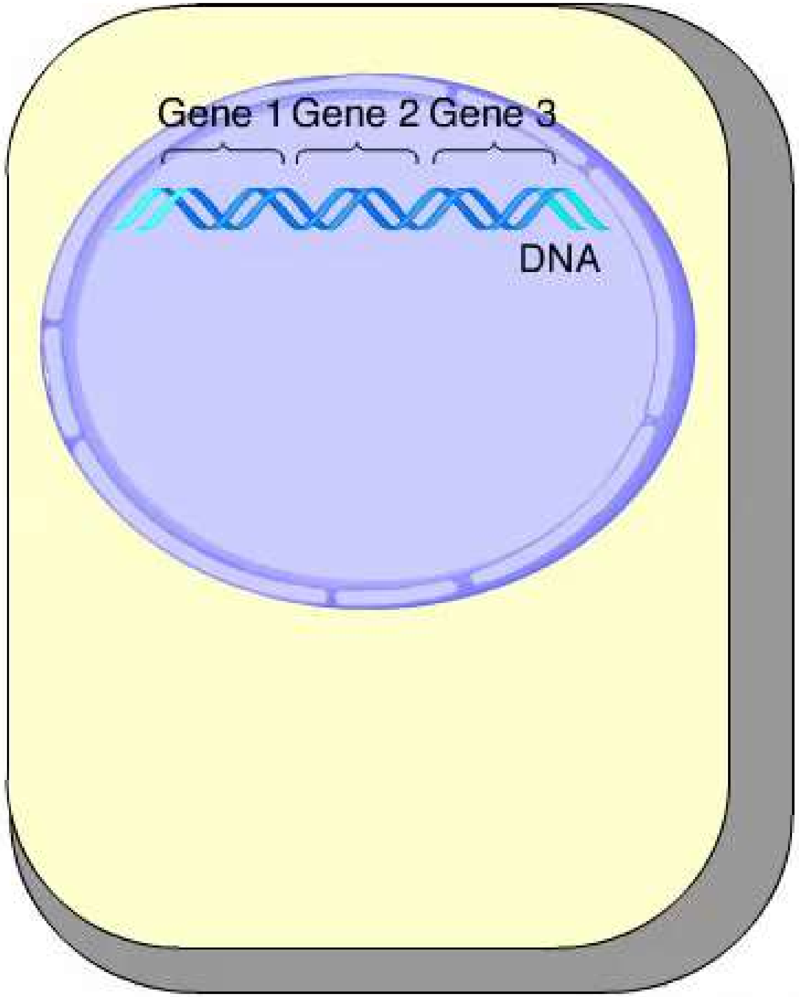
10.9 Transcription produces genetic messages in the form of RNA

- Overview of transcription
  - An RNA molecule is transcribed from a DNA template by a process that resembles the synthesis of a DNA strand during DNA replication.
  - RNA nucleotides are linked by the transcription enzyme **RNA polymerase**.
  - Specific sequences of nucleotides along the DNA mark where transcription begins and ends.
  - The “start transcribing” signal is a nucleotide sequence called a **promoter**.

10.9 Transcription produces genetic messages in the form of RNA

1. **Initiation**, involving the attachment of RNA polymerase to the promoter and the start of RNA synthesis,
2. **Elongation**, as the newly formed RNA strand grows, and
3. **Termination**, when RNA polymerase reaches the terminator DNA and the polymerase molecule detaches from the newly made RNA strand and the gene.
   - The polymerase molecule now detaches from the RNA molecule and the gene.


Initiation
RNA synthesis begins after RNA polymerase attaches to the promoter.
RNA polymerase
DNA of gene
Promoter
Terminator DNA
Direction of transcription
Unused strand of DNA
Newly formed RNA
Template strand of DNA
Elongation
Using the DNA as a template, RNA polymerase adds free RNA nucleotides one at a time.
Direction of transcription
Free RNA nucleotide
DNA strands reunite
Newly made RNA
DNA strands separate
Termination
RNA synthesis ends when RNA polymerase reaches the terminator DNA sequence.
Terminator DNA
Completed RNA
RNA polymerase detaches



Animation: Transcription
Right click on animation / Click play

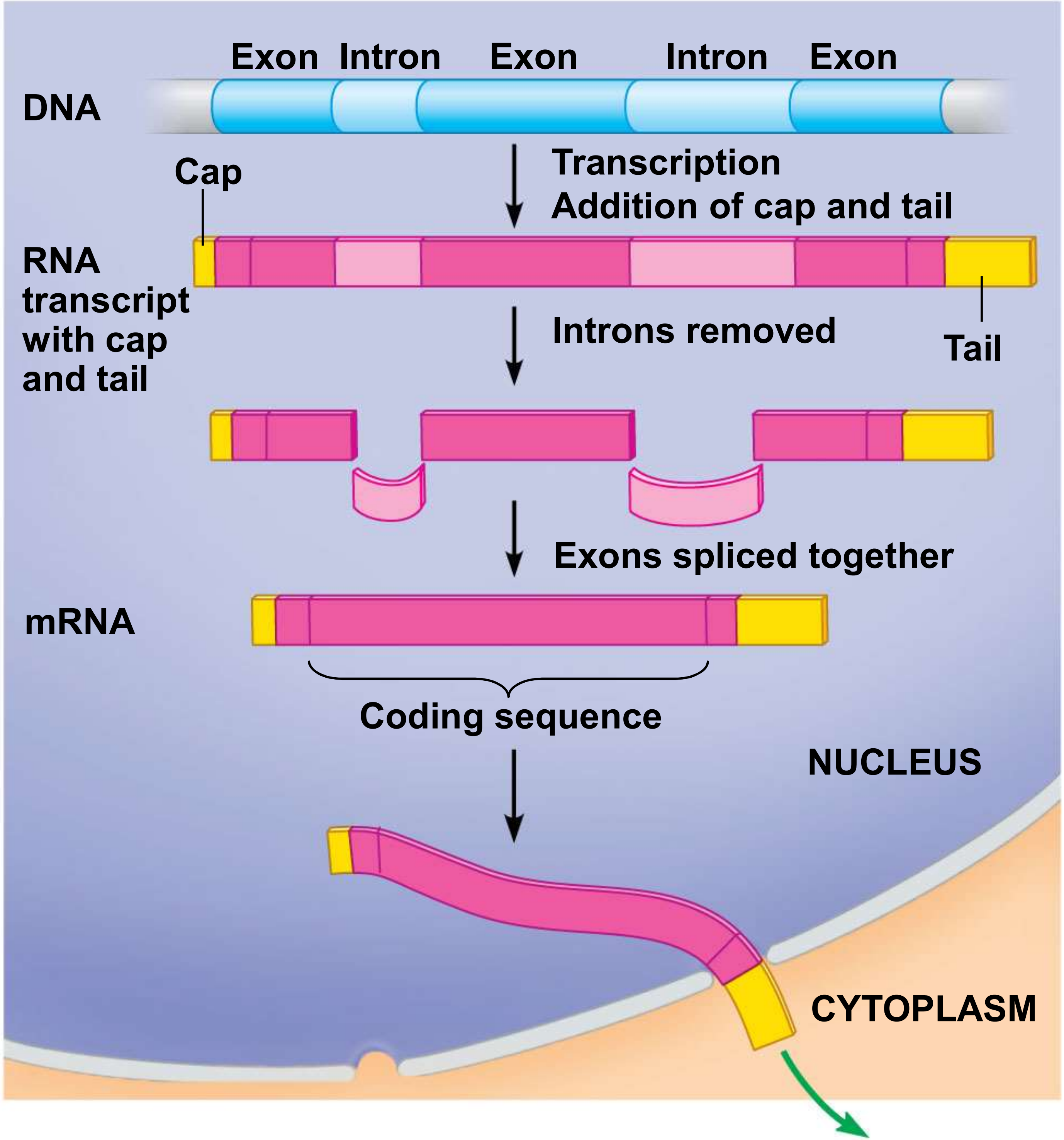
10.10 Eukaryotic RNA is processed before leaving the nucleus as mRNA

- **Messenger RNA (mRNA)**
  - encodes amino acid sequences and
  - conveys genetic messages from DNA to the translation machinery of the cell, which in
    - prokaryotes, occurs in the same place that mRNA is made, but in
    - eukaryotes, mRNA must exit the nucleus via nuclear pores to enter the cytoplasm.
- Eukaryotic mRNA has **introns**, interrupting sequences that separate **exons**, the coding regions.

10.10 Eukaryotic RNA is processed before leaving the nucleus as mRNA

- Eukaryotic mRNA undergoes processing before leaving the nucleus.
  - **RNA splicing** removes introns and joins exons to produce a continuous coding sequence.
  - A cap and tail of extra nucleotides are added to the ends of the mRNA to
    - facilitate the export of the mRNA from the nucleus,
    - protect the mRNA from attack by cellular enzymes, and
    - help ribosomes bind to the mRNA.
    - The cap and tail themselves are not translated into protein.

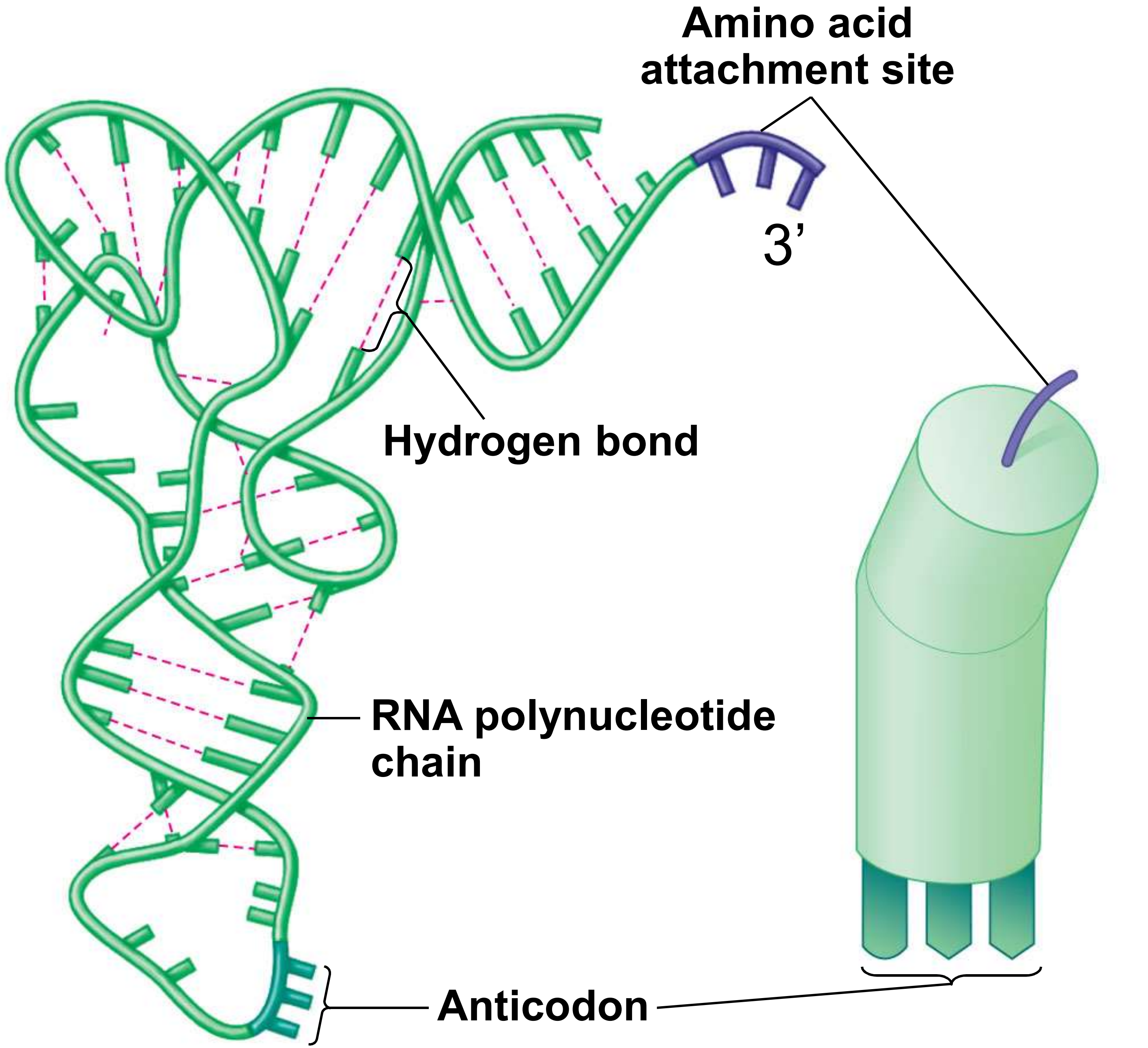
Figure 10.10


Exon
Intron
Exon
Intron
Exon
DNA
Cap
Transcription
Addition of cap and tail
RNA transcript with cap and tail
Introns removed
Tail
Exons spliced together
mRNA
Coding sequence
NUCLEUS
CYTOPLASM

10.11 Transfer RNA molecules serve as interpreters during translation

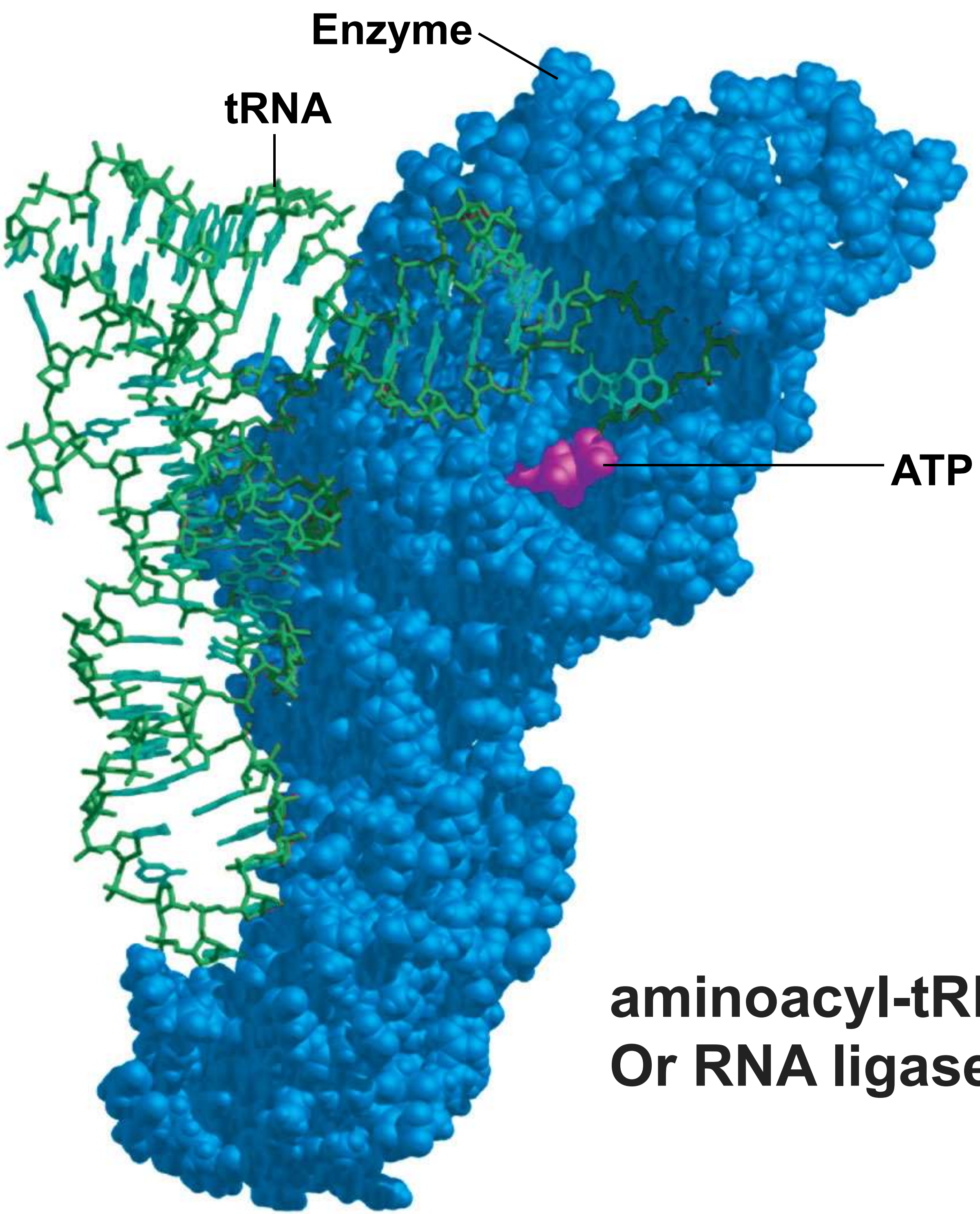
- **Transfer RNA** (**tRNA**) molecules function as an interpreter, converting the genetic message of mRNA into the language of proteins.
- Transfer RNA molecules perform this interpreter task by
  - picking up the appropriate amino acid and
  - using a special triplet of bases, called an **anticodon**, to recognize the appropriate codons in the mRNA.

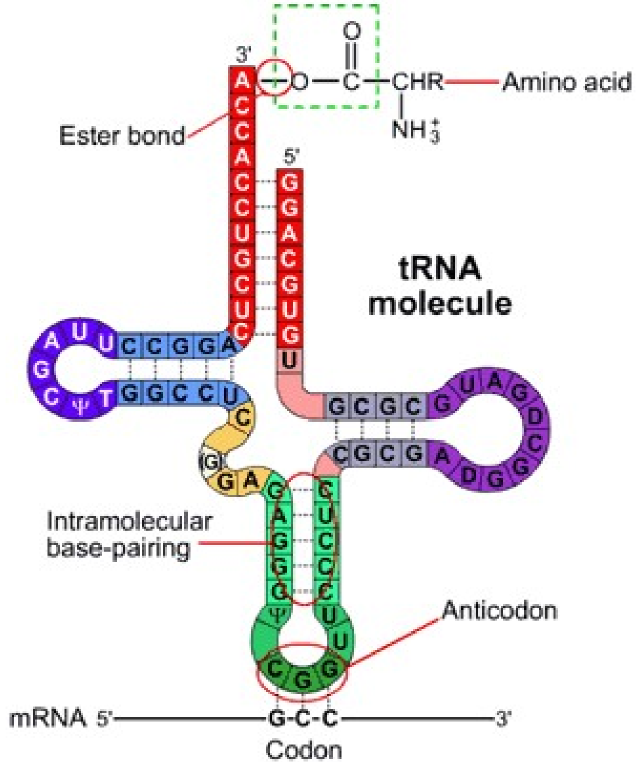
Figure 10.11A



A tRNA molecule, showing its polynucleotide strand and hydrogen bonding

A simplified schematic of a tRNA



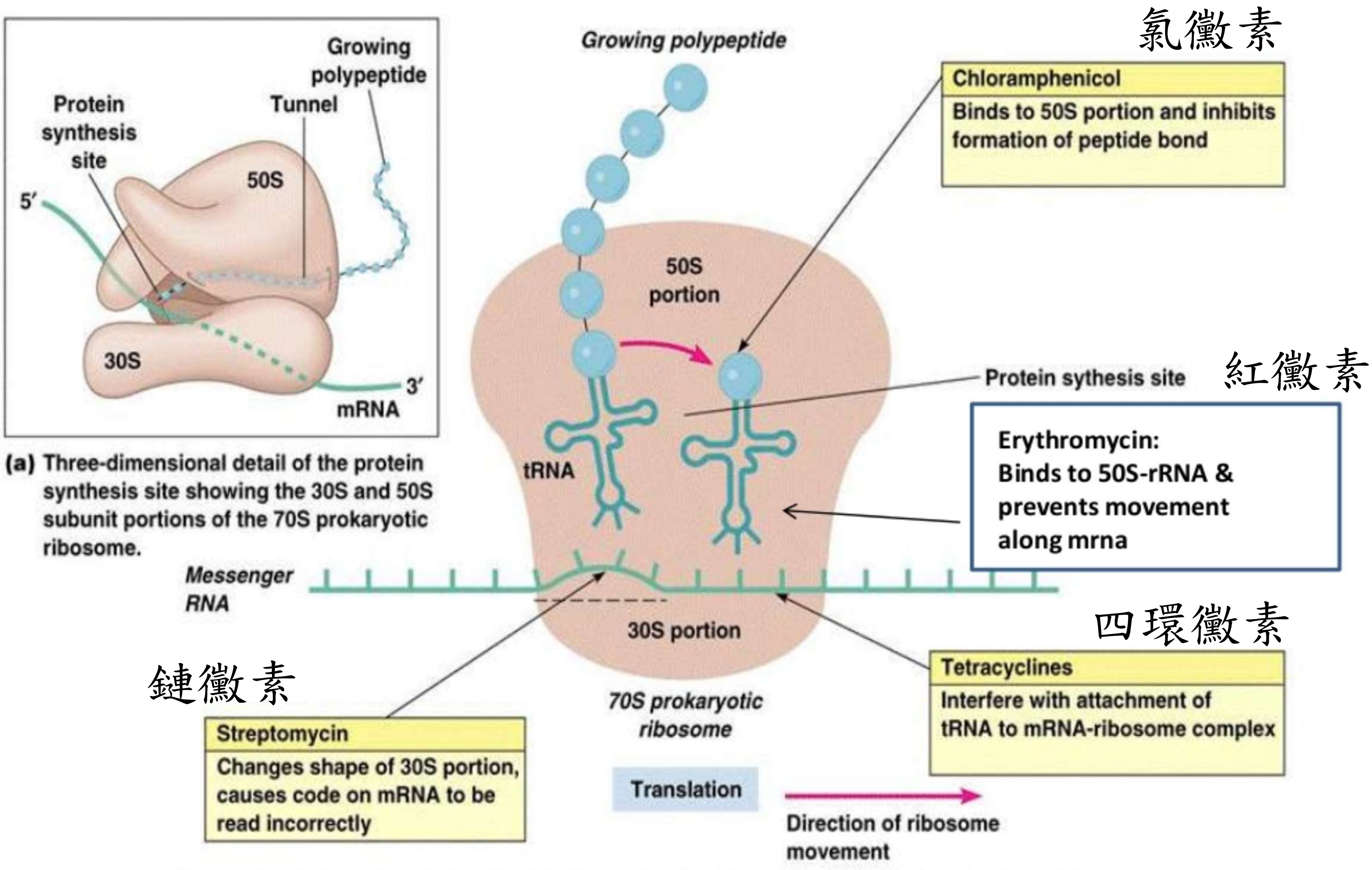


DNA from the Beginning
http://www.dnaftb.org/

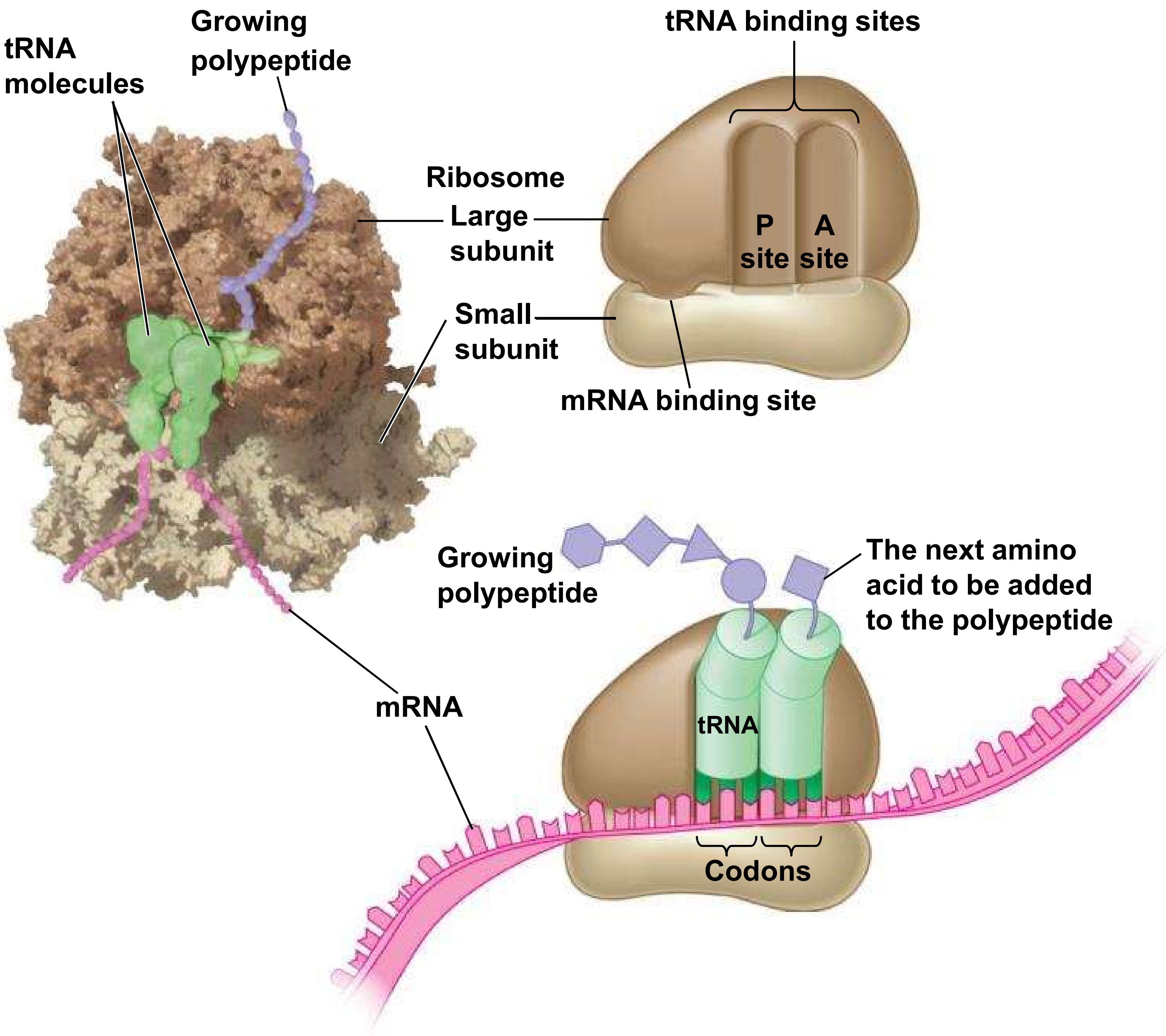
aminoacyl-tRNA synthetase
Or RNA ligase

10.12 Ribosomes build polypeptides

- Translation occurs on the surface of the **ribosome**.
  - Ribosomes coordinate the functioning of mRNA and tRNA and, ultimately, the synthesis of polypeptides.
  - Ribosomes have two subunits: small and large.
  - Each subunit is composed of ribosomal RNAs and proteins.
  - Ribosomal subunits come together during translation.
  - Ribosomes have binding sites for mRNA and tRNAs.
- The ribosomes of bacteria and eukaryotes are very similar
- Those of eukaryotes are slightly larger and different in composition.
- The differences are medically significant.
  - Certain antibiotic drugs can inactivate bacterial ribosomes while leaving eukaryotic ribosomes unaffected.
  - These drugs, such as tetracycline and streptomycin, are used to combat bacterial infections.



http://www.slideshare.net/minhazahmed21/min-antibac (slide19)

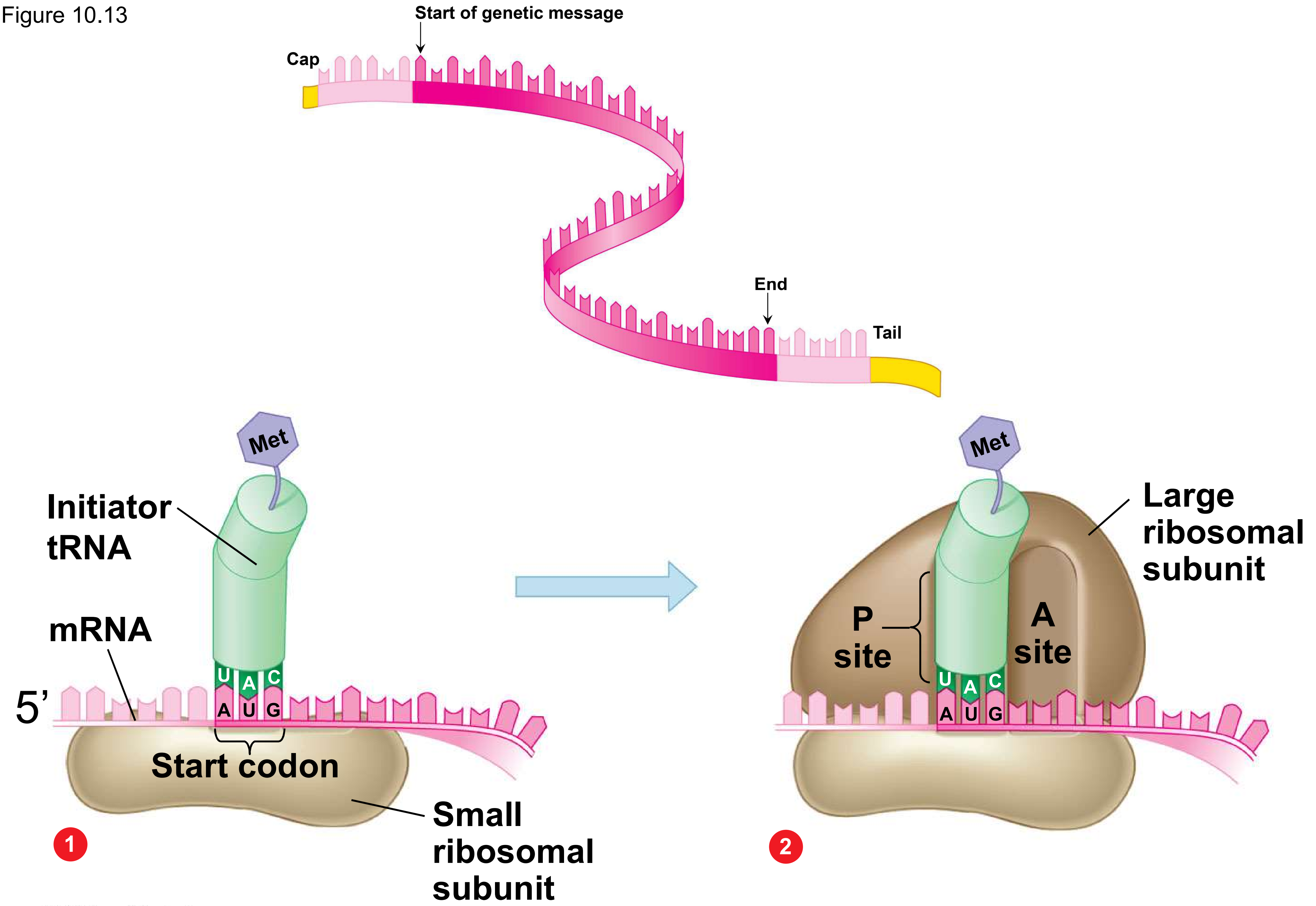

tRNA molecules
Growing polypeptide
tRNA binding sites
Ribosome
Large subunit
P site
A site
Small subunit
mRNA binding site
Growing polypeptide
The next amino acid to be added to the polypeptide
mRNA
tRNA
Codons

10.13 An initiation codon marks the start of an mRNA message

- Translation can be divided into the same three phases as transcription: 1. initiation, 2. elongation, and 3. termination.
- Initiation brings together
  - mRNA, a tRNA bearing the first amino acid, and the two subunits of a ribosome.
- Initiation establishes where translation will begin.
- Initiation occurs in two steps.

1. An mRNA molecule binds to a small ribosomal subunit and the first tRNA binds to mRNA at the **start codon.**
   - The start codon reads AUG and codes for methionine.
   - The first tRNA has the anticodon UAC.
2. A large ribosomal subunit joins the small subunit, allowing the ribosome to function.
   - The first tRNA occupies the **P site**, which will hold the growing peptide chain.
   - The **A site** is available to receive the next tRNA.

Figure 10.13



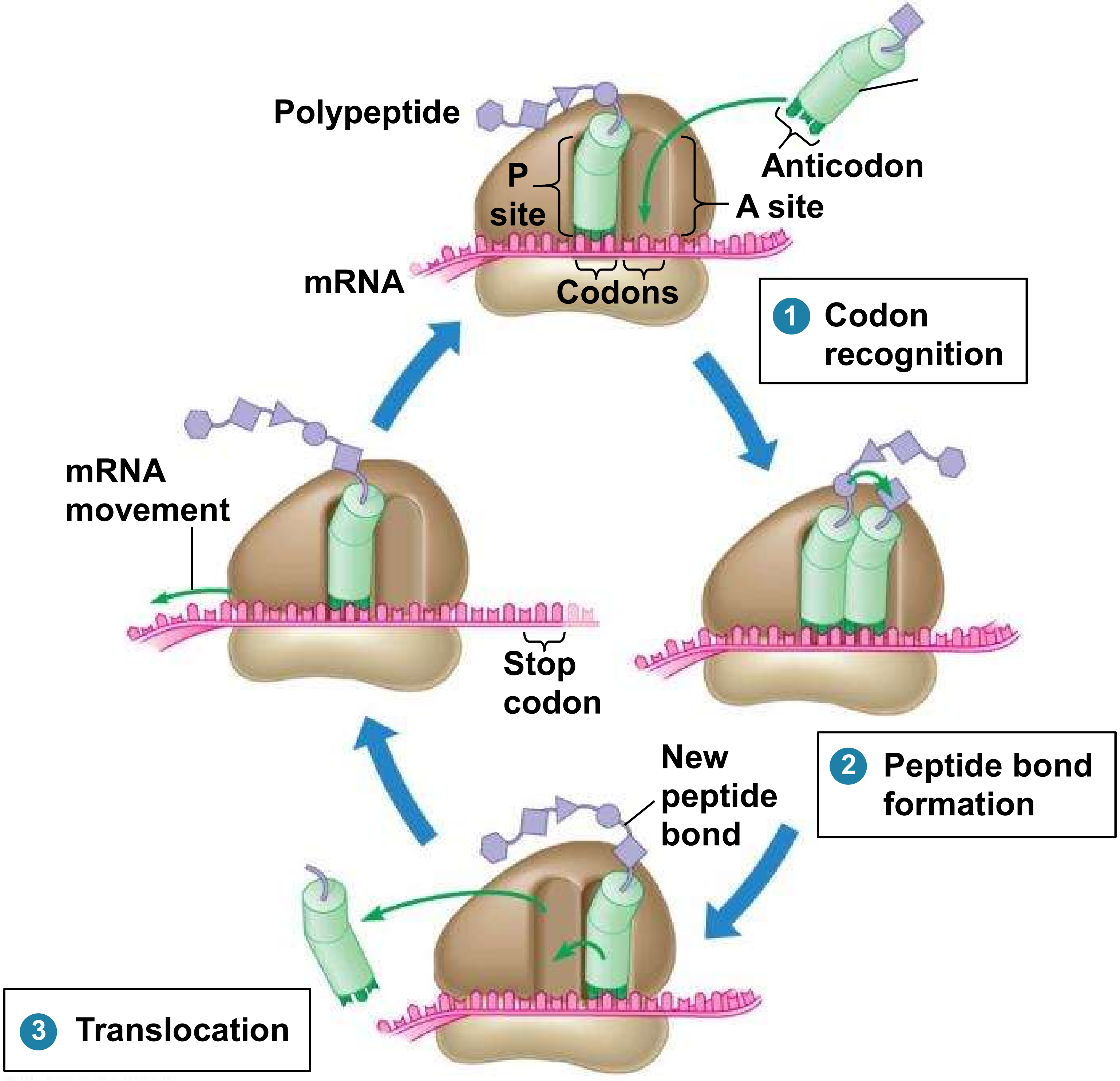
Start of genetic message
Cap
End
Tail
Met
Initiator tRNA
mRNA
5'
U A C
A U G
Start codon
Small ribosomal subunit
1
Met
Large ribosomal subunit
P site
A site
U A C
A U G
2

10.14 Elongation adds amino acids to the polypeptide chain until a stop codon terminates translation

- Once initiation is complete, amino acids are added one by one to the first amino acid.
- Each addition occurs in a three-step elongation process.
- Each cycle of elongation has three steps.

1. **Codon recognition**: The anticodon of an incoming tRNA molecule, carrying its amino acid, pairs with the mRNA codon in the A site of the ribosome.
2. **Peptide bond formation**: The polypeptide separates from the tRNA in the P site and attaches by a new peptide bond to the amino acid carried by the tRNA in the A site.
3. **Translocation**: The P site tRNA (now lacking an amino acid) leaves the ribosome, and the ribosome translocates (moves) the remaining tRNA (which has the growing polypeptide) from the A site to the P site.

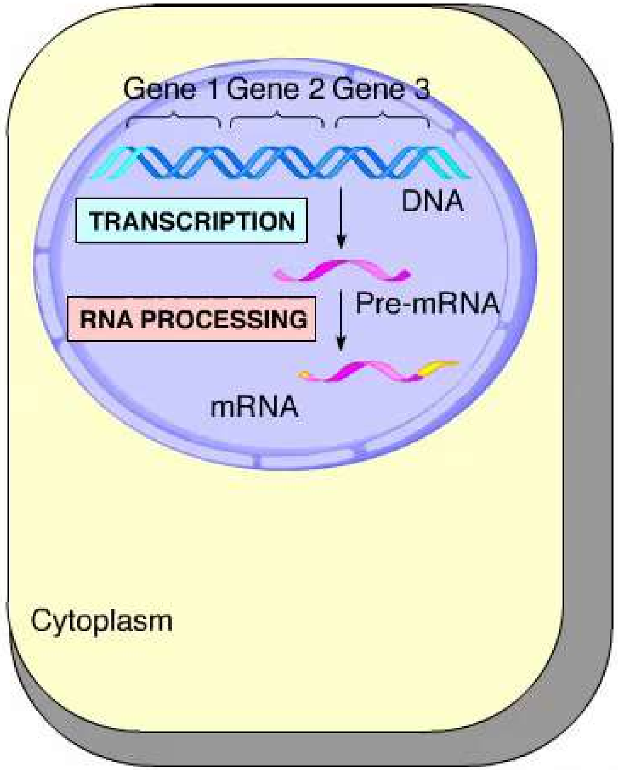
Figure 10.14_s4



10.14 Elongation adds amino acids to the polypeptide chain until a stop codon terminates translation

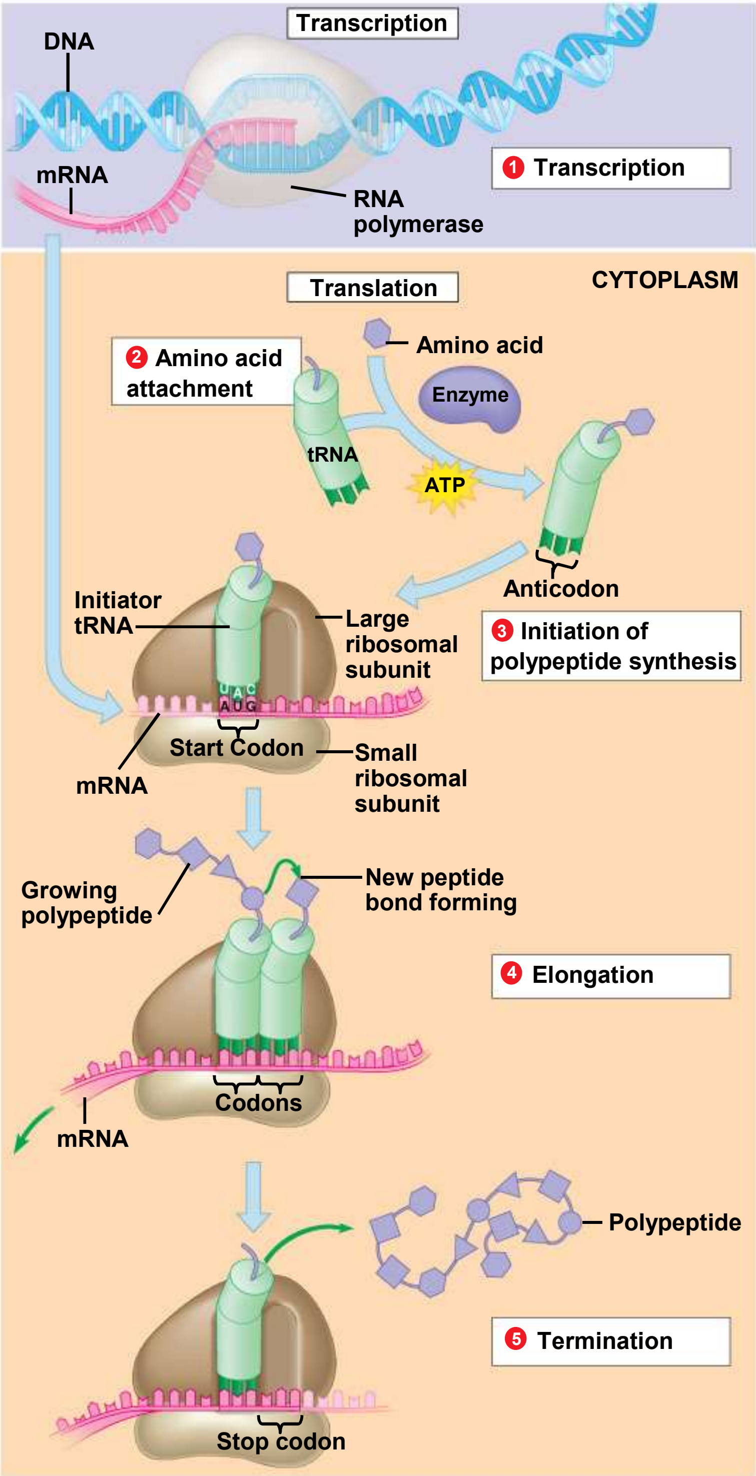
- Elongation continues until the termination stage of translation, when
  - the ribosome reaches a stop codon,
  - the completed polypeptide is freed from the last tRNA, and
  - the ribosome splits back into its separate subunits.

Animation: Translation



10.15 Review: The flow of genetic information in the cell is DNA → RNA → protein

- The flow of genetic information is from DNA to RNA to protein.
  - In transcription (DNA → RNA), the mRNA is synthesized on a DNA template.
  - In eukaryotic cells, transcription occurs in the nucleus, and the messenger RNA is processed before it travels to the cytoplasm.
  - In prokaryotes, transcription occurs in the cytoplasm.
- Translation can be divided into four steps, all of which occur in the cytoplasm:
  1. amino acid attachment,
  2. initiation of polypeptide synthesis,
  3. elongation, and
  4. Termination.



Virtual Cell Animations Project

North Dakota State University

http://vcell.ndsu.edu/animations/

http://vcell.ndsu.edu/animations/flyt
hrough/movie-flash.htm

Replication: 50 nt./s in human
(1000 in bacteria)

Transcription: 30~40 nt./s
(50 in bacteria)

Translation: 15 a.a./sec

https://www.youtube.com/user/ndsuvirtualcell

10.16 Mutations can change the meaning of genes

- A **mutation** is any change in the nucleotide sequence of DNA.
- Mutations can involve
  - large chromosomal regions or
  - just a single nucleotide pair.
- Mutations within a gene can be divided into two general categories.

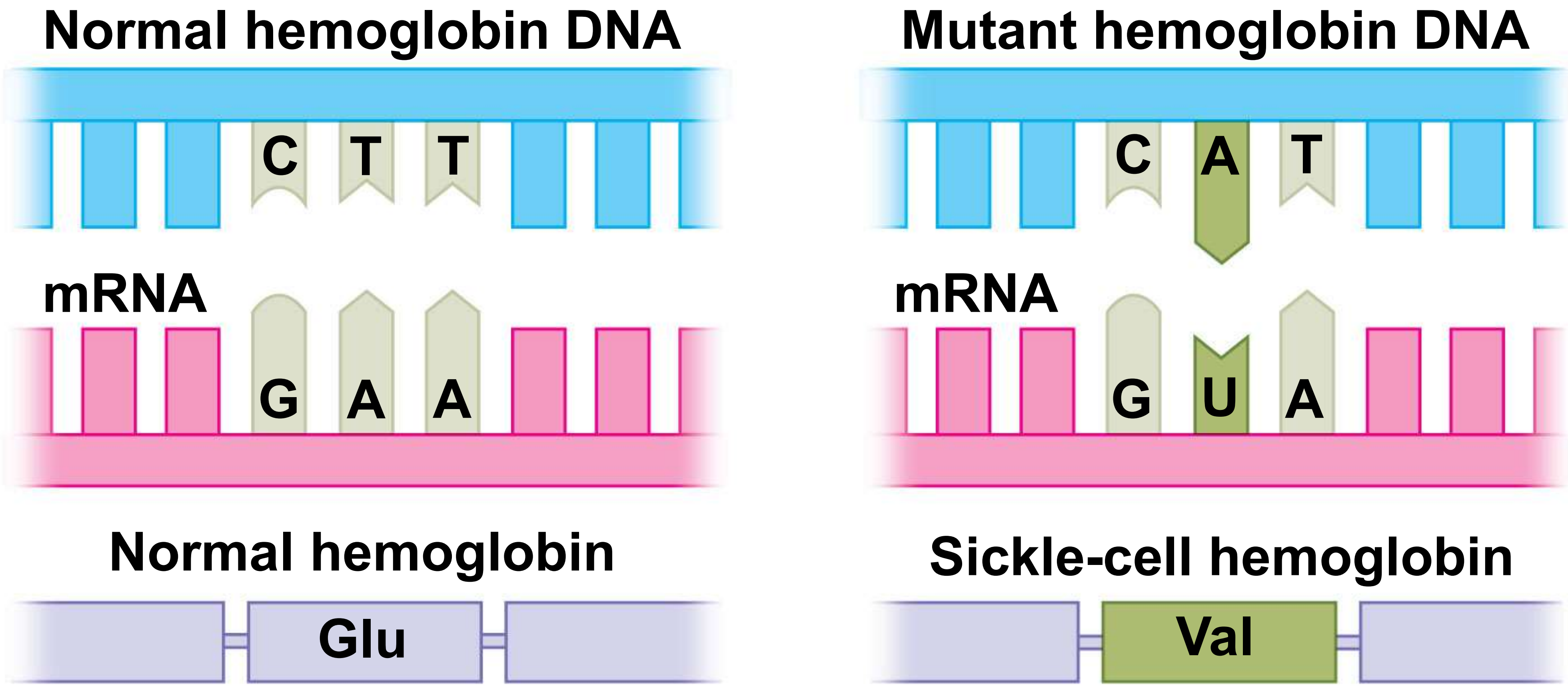
1. Nucleotide substitutions involve the replacement of one nucleotide and its base-pairing partner with another pair of nucleotides.
   - **silent mutation**: have no effect at all
   - **missense mutation**: produces a different amino acid,
   - **substitution**: produces an improved protein that enhances the success of the mutant organism and its descendant, or
   - **nonsense mutation:** change an amino acid into a stop codon

10.16 Mutations can change the meaning of genes

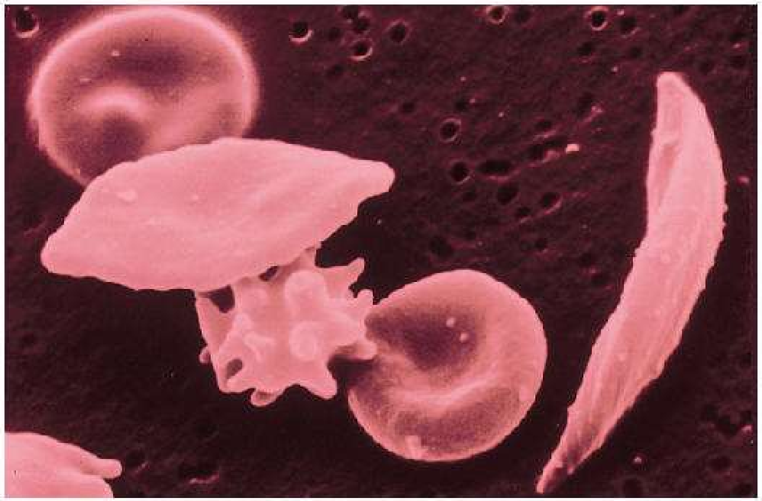
2. Nucleotide insertions or deletions of one or more nucleotides in a gene may
   - cause a **frameshift mutation**, which alters the reading frame (triplet grouping) of the genetic message,
   - lead to significant changes in amino acid sequence downstream of the mutation, and
   - produce a nonfunctional polypeptide.

- Mutagenesis is the production of mutations.
- Mutations can be caused by
  - spontaneous errors that occur during DNA replication or recombination or
  - mutagens, which include high-energy radiation such as X-rays and ultraviolet light and Chemicals.

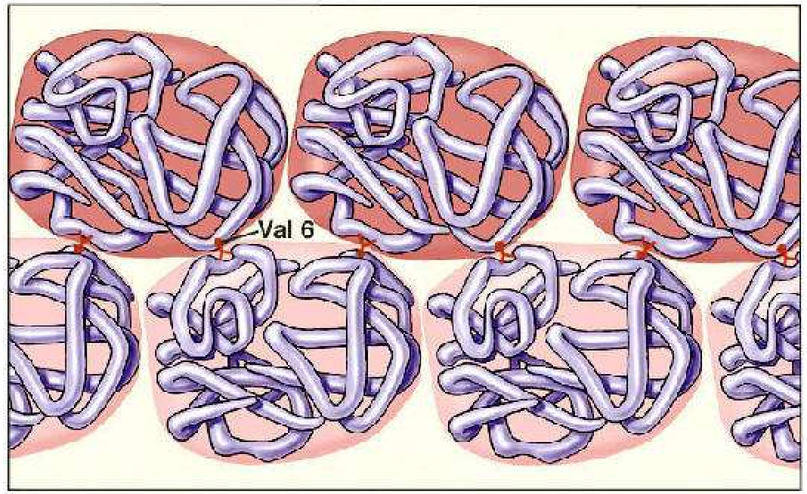
Figure 10.16A



Sickle Cell Anemia

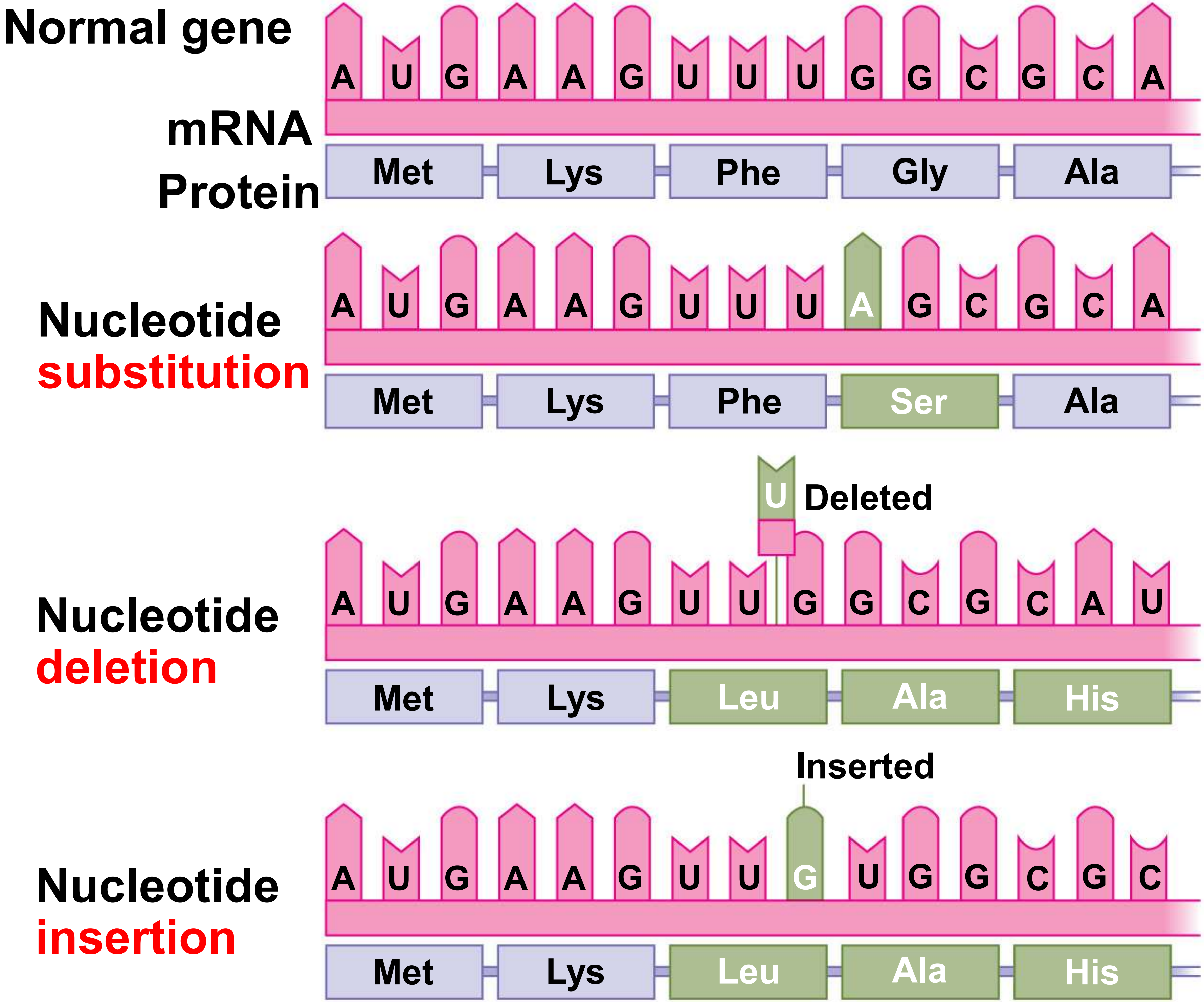


Sickle Cell Anemia



http://faculty.southwest.tn.edu/rburkett/GB%20Genetics.htm

Figure 10.16B



THE GENETICS OF VIRUSES AND BACTERIA

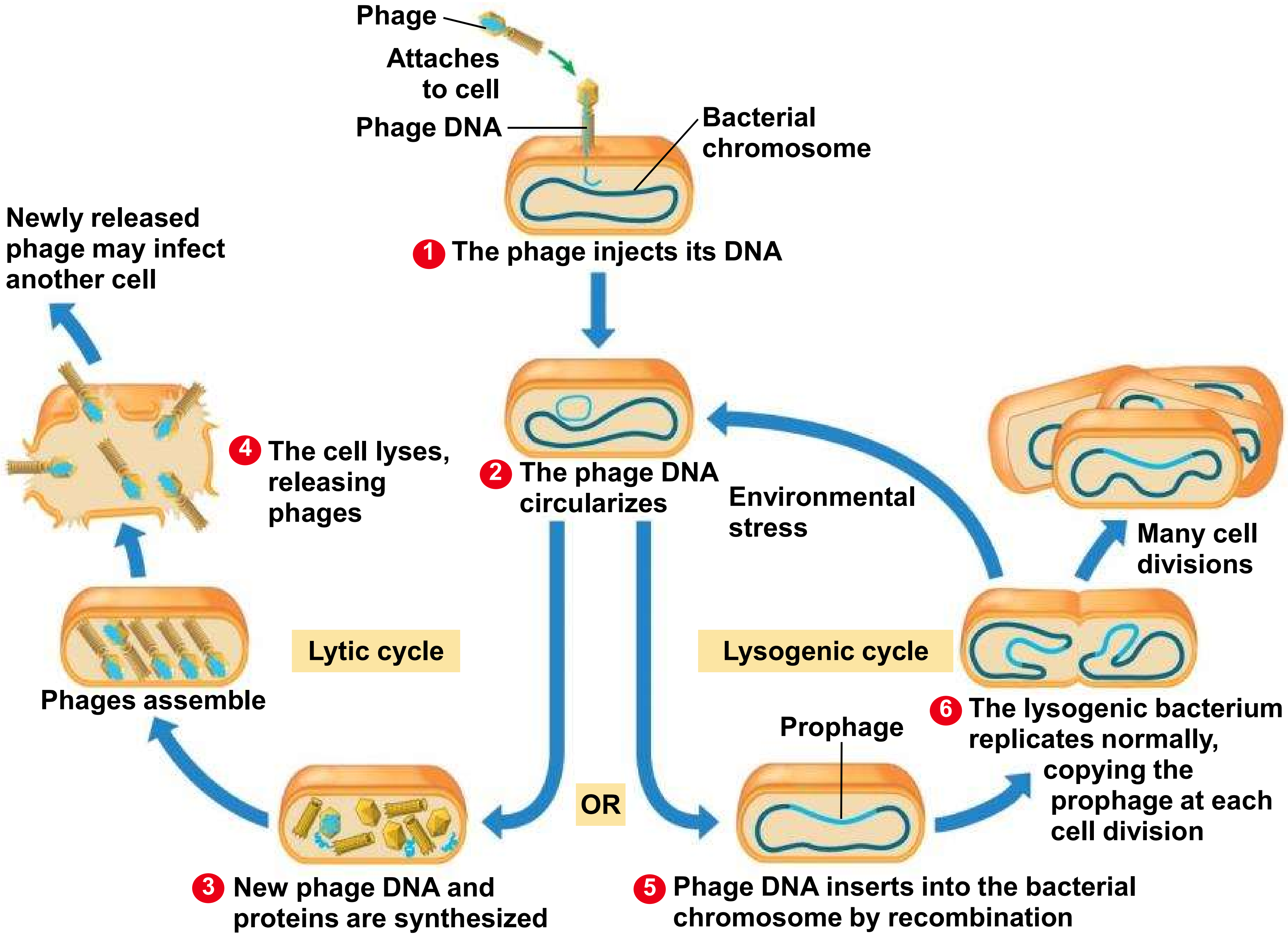
10.17 Viral DNA may become part of the host chromosome

- A **virus** is an infectious particle consisting of little more than "genes in a box," a bit of nucleic acid, wrapped in a protein coat called a **capsid**, and in some cases, a membrane envelope.
- Viruses have two types of reproductive cycles. 殼體
  1. In the lytic cycle,
     - viral particles are produced using host cell components,
     - the host cell lyses, and
     - viruses are released.

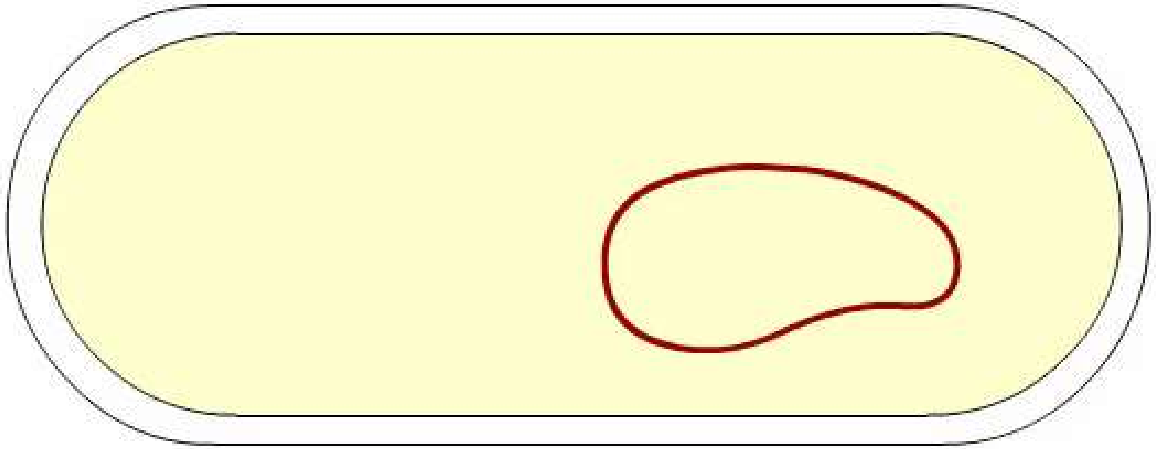
10.17 Viral DNA may become part of the host chromosome

2. In the Lysogenic cycle
   - Viral DNA is inserted into the host chromosome by recombination.
   - Viral DNA is duplicated along with the host chromosome during each cell division.
   - The inserted phage DNA is called a prophage.
   - Most prophage genes are inactive.
   - Environmental signals can cause a switch to the lytic cycle, causing the viral DNA to be excised from the bacterial chromosome and leading to the death of the host cell.

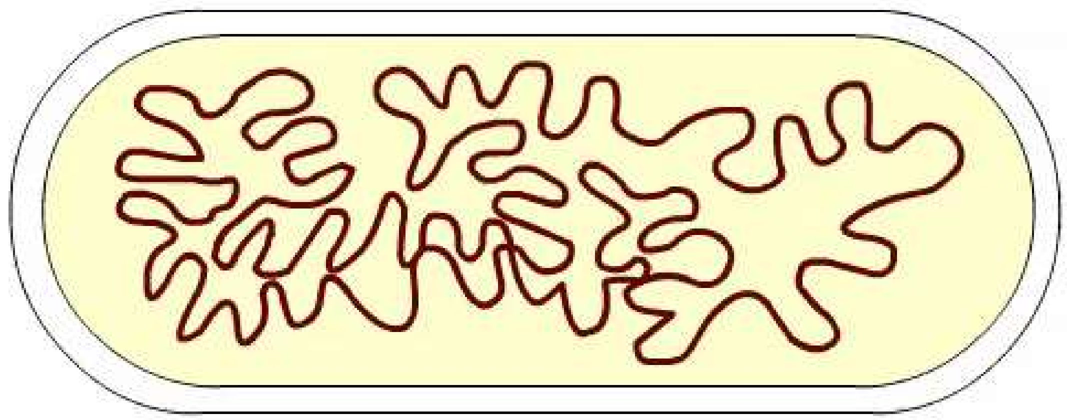
Figure 10.17-0



Animation: Phage λ Lysogenic and Lytic Cycles



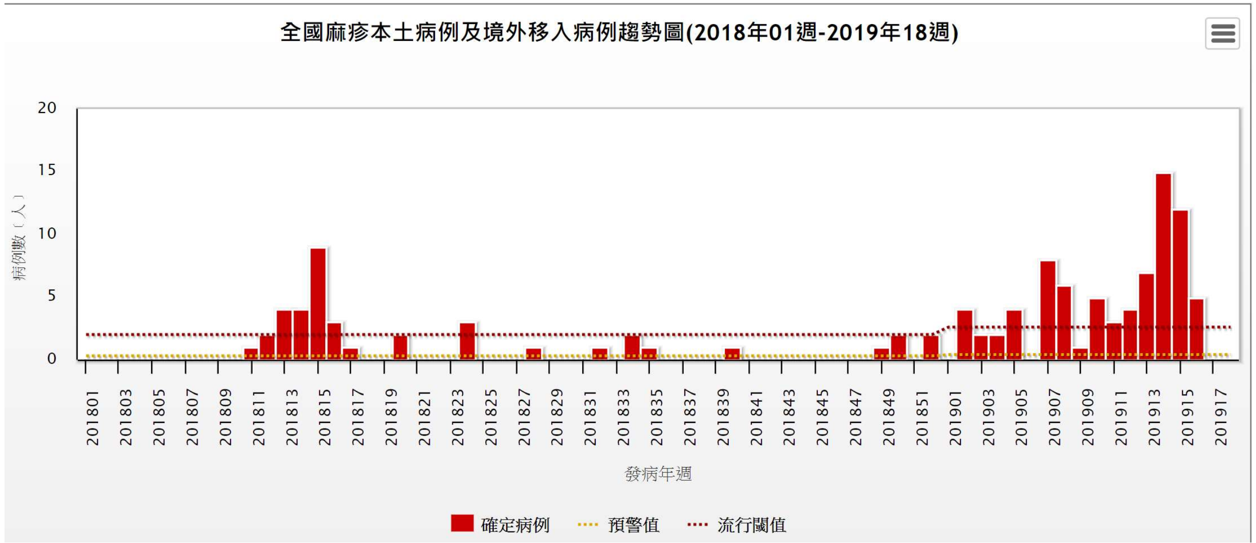
Animation: Phage T2 Lytic Cycle



10.18 Many viruses cause disease in animals and plants

- Viruses can cause disease in animals and plants.
- DNA viruses and RNA viruses cause disease in animals.
- A typical animal virus has a **membranous outer envelope** and projecting spikes of glycoprotein.
- The envelope helps the virus enter and leave the host cell.
- Many animal viruses have RNA rather than DNA as their genetic material. These include viruses that cause the common cold, measles, mumps, polio, and AIDS.

麻疹 腮腺炎 小兒麻痺



全球麻疹大爆發！

疫苗猶豫

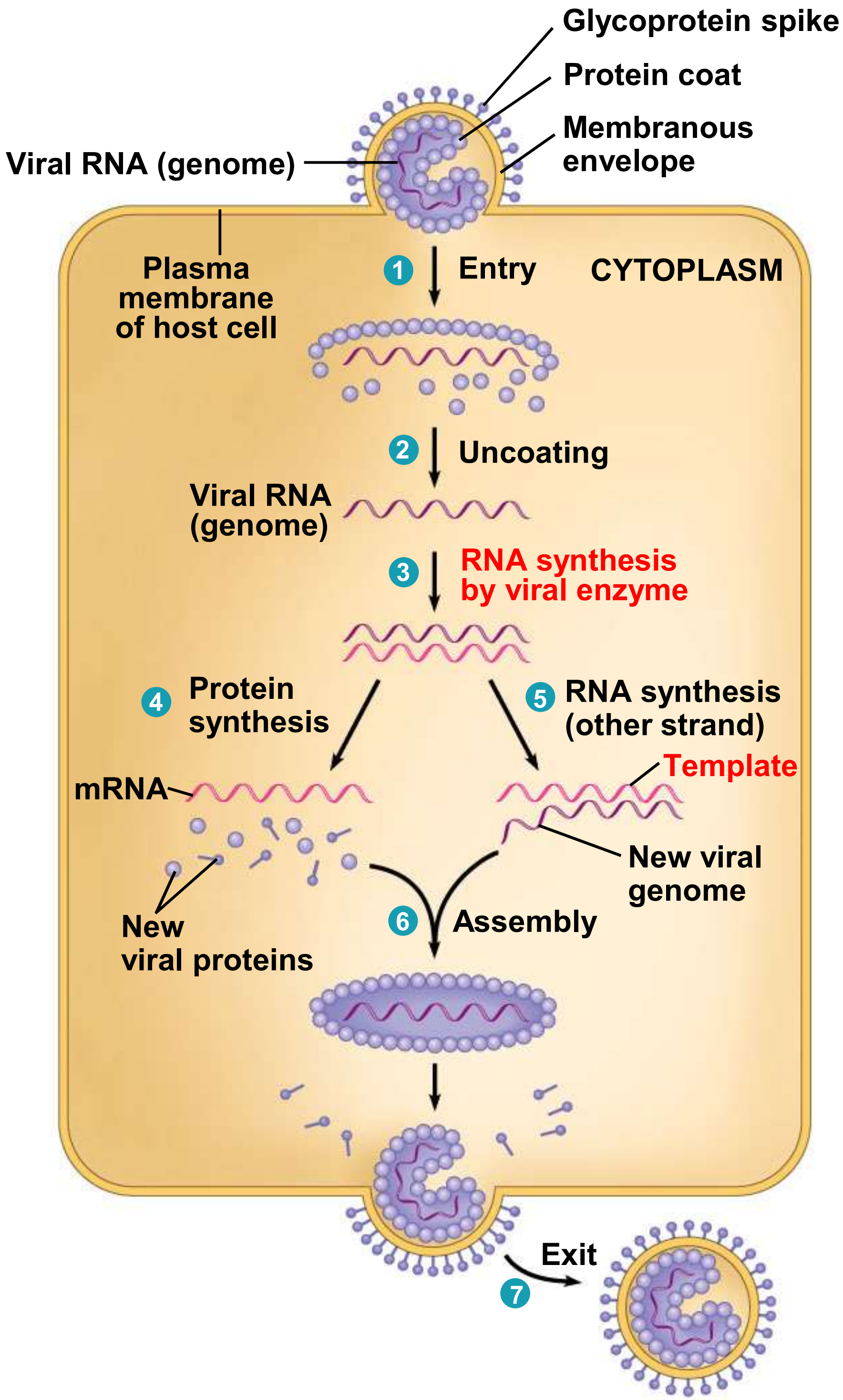
傳染病統計資料查詢系統
https://nidss.cdc.gov.tw/ch/SingleDisease.aspx?dc=1&dt=2&disease=055

10.18 Many viruses cause disease in animals and plants

- The reproductive cycle of the mumps virus, a typical enveloped RNA virus, has seven major steps:
  1. entry of the protein-coated RNA into the cell,
  2. uncoating—the removal of the protein coat,
  3. RNA synthesis—mRNA synthesis using a viral enzyme,
  4. protein synthesis—mRNA is used to make viral proteins,
  5. new viral genome production—mRNA is used as a template to synthesize new viral genomes,
  6. assembly—the new coat proteins assemble around the new viral RNA, and
  7. exit—the viruses leave the cell by cloaking themselves in the host cell's plasma membrane.

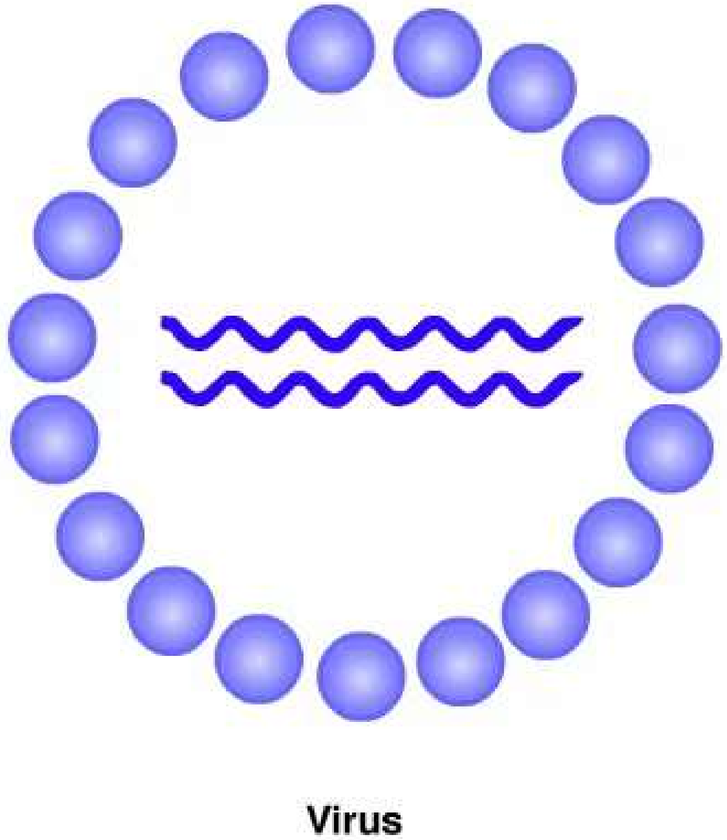
Figure 10.18

Mumps virus
腮腺炎病毒



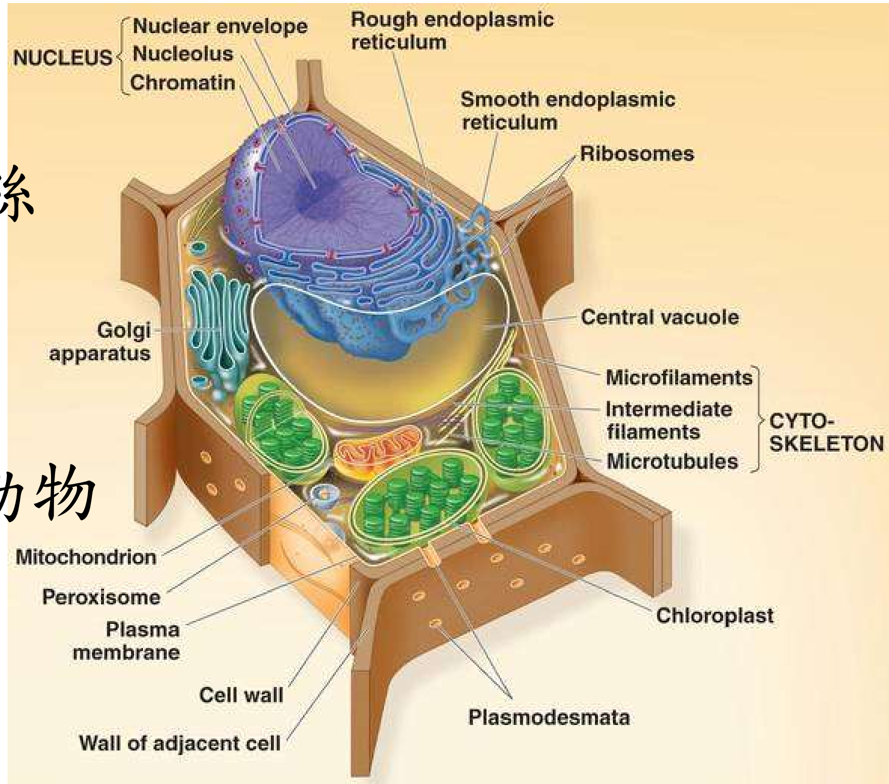
Membrane from host

Animation: Simplified Viral Reproductive Cycle

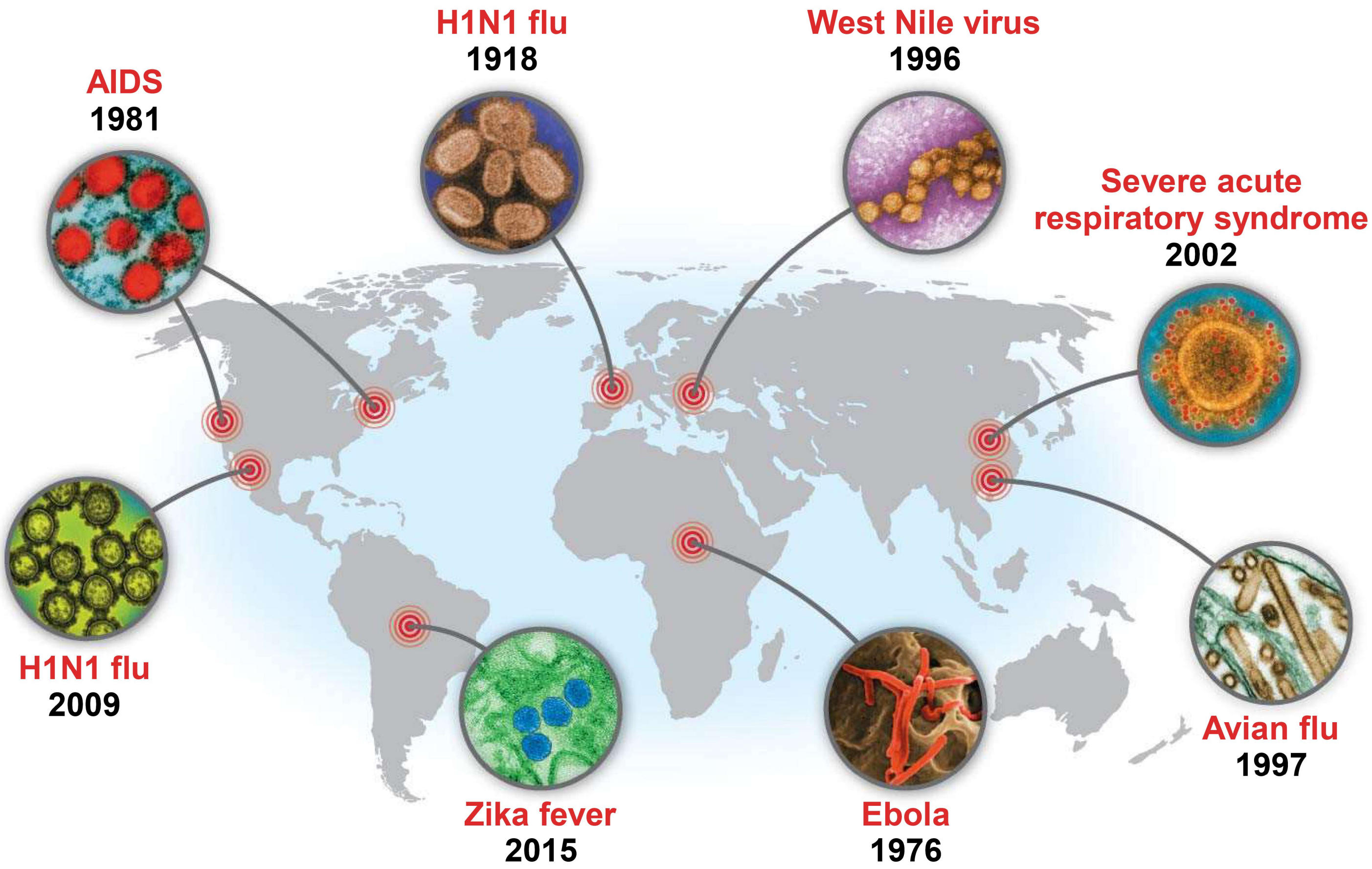


10.18 Many viruses cause disease in animals and plants

- Some animal viruses, such as herpesviruses, reproduce in the cell nucleus. 疱疹病毒
- Most plant viruses are RNA viruses.
  - To infect a plant, they must get past the outer protective layer of the plant.
  - Viruses spread from cell to cell through plasmodesmata. 原生質絲
  - Infection can spread to other plants by insects, herbivores, humans, or farming tools. 草食動物
- There are no cures for most viral diseases of plants or animals.



10.19 Emerging viruses threaten human health

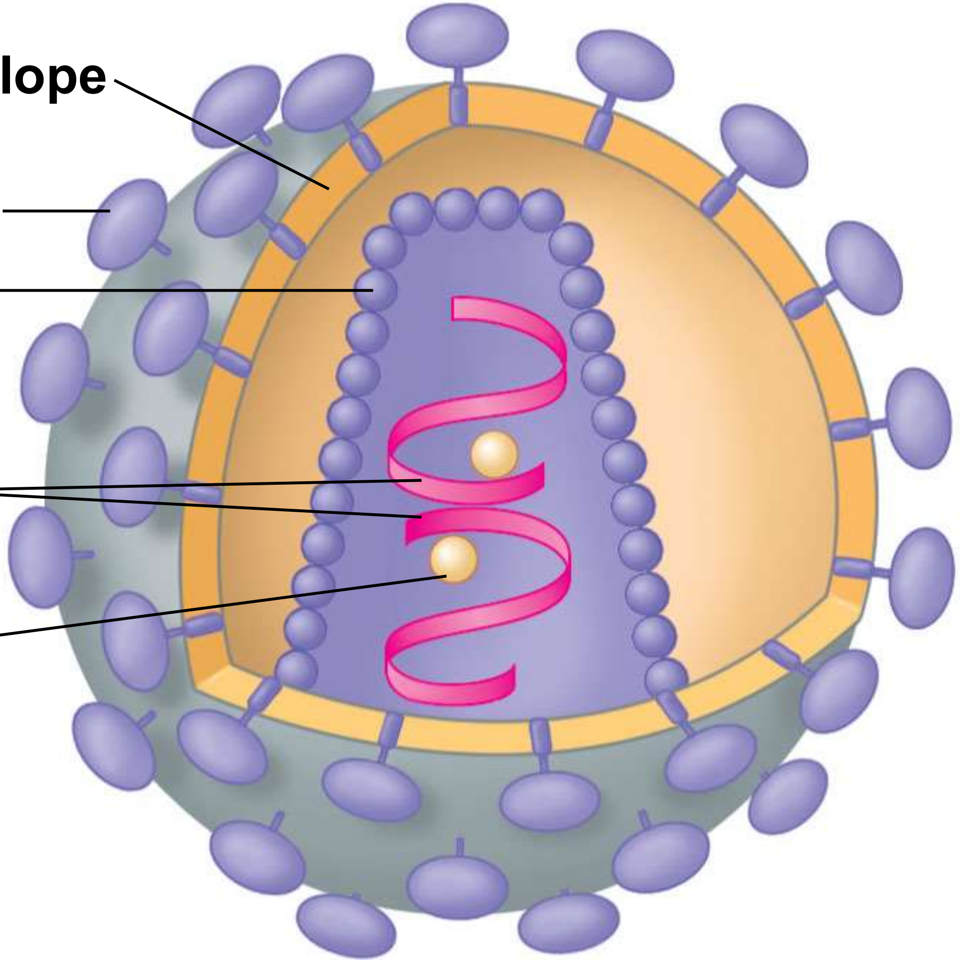


- Viruses that appear suddenly or are new to medical scientists are called **emerging viruses**. These include the
  - AIDS virus, Ebola virus, West Nile virus, and SARS virus.

- Three processes contribute to the emergence of viral diseases:
  1. **Mutation**—RNA viruses mutate rapidly; influenza virus, mutations creat new influenza virus strains to which previously vaccinated people have no immunity.
  2. **Contact** between species—viruses from other animals spread to humans. 2009 H1N1 flu, global epidemic, 207 countries & 600,000 people; ¾ of new human diseases originated in other animals
  3. **Spread** from isolated human populations to larger human populations, often over great distances; AIDS

10.20 The AIDS virus makes DNA on an RNA template

- **AIDS** (acquired immunodeficiency syndrome) is caused by **HIV** (human immunodeficiency virus).
- HIV
  - is an RNA virus,
  - has two copies of its RNA genome,



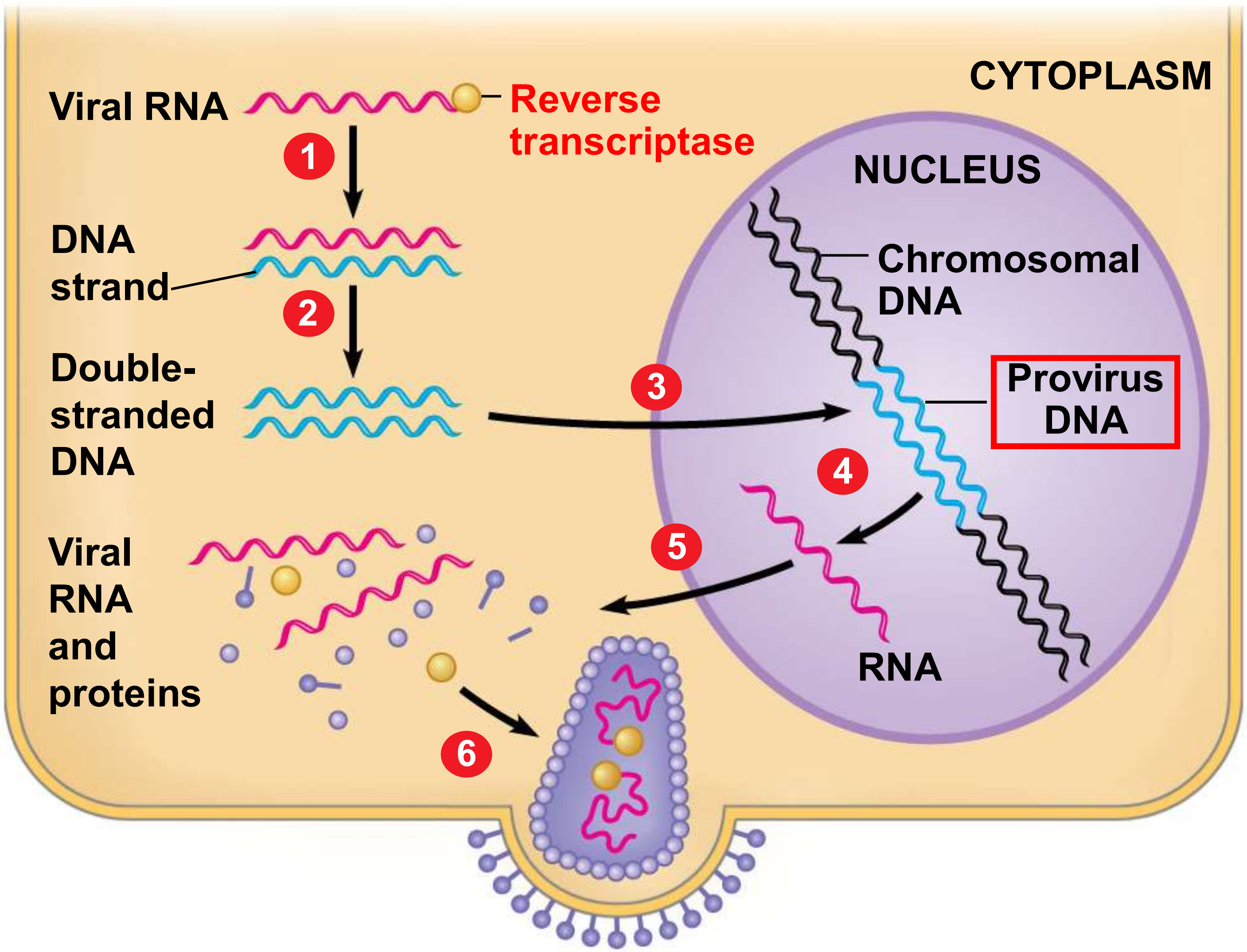
反轉錄酶

  - carries molecules of **reverse transcriptase**, which causes reverse transcription, producing DNA from an RNA template.

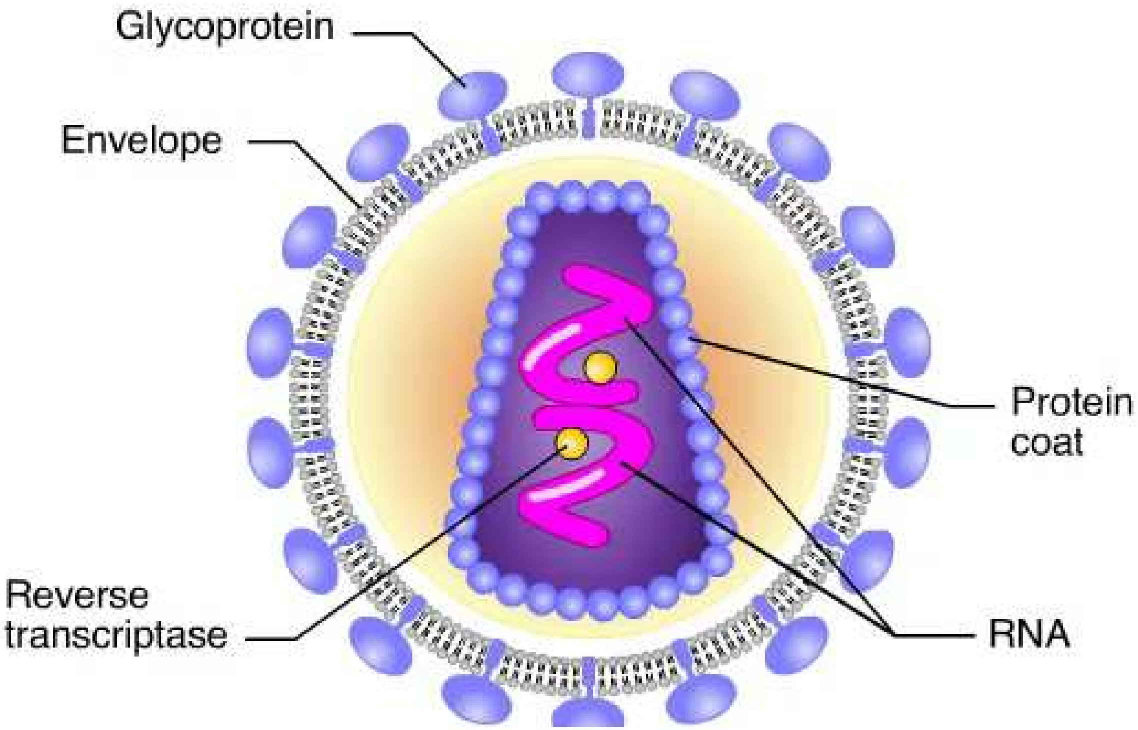
10.20 The AIDS virus makes DNA on an RNA template

- After HIV RNA is uncoated in the cytoplasm of the host cell,
  1. reverse transcriptase makes one DNA strand from RNA,
  2. reverse transcriptase adds a complementary DNA strand,
  3. double-stranded viral DNA enters the nucleus and integrates into the chromosome, becoming a provirus,
  4. the provirus DNA is used to produce mRNA,
  5. the viral mRNA is translated to produce viral proteins, and
  6. new viral particles are assembled, leave the host cell, and can then infect other cells.

Figure 10.20B



Animation: HIV Reproductive Cycle



Provirus may be dormant for years

10.21 Viroids and prions are formidable pathogens in plants and animals

- Some infectious agents are made only of RNA or protein.
  - **Viroids** are small, circular RNA molecules that infect plants.
  - Viroids replicate within host cells without producing proteins and interfere with plant growth. 類病毒
  - **Prions** are infectious proteins that cause degenerative brain diseases in animals. 209 a.a. (human) 狂牛症
  - Prions appear to be misfolded forms of normal brain proteins, which convert normal protein to misfolded prion versions.

Stanley B. Prusiner, 1997, The Nobel Prize in Physiology or Medicine; *"for his discovery of Prions - a new biological principle of infection"*

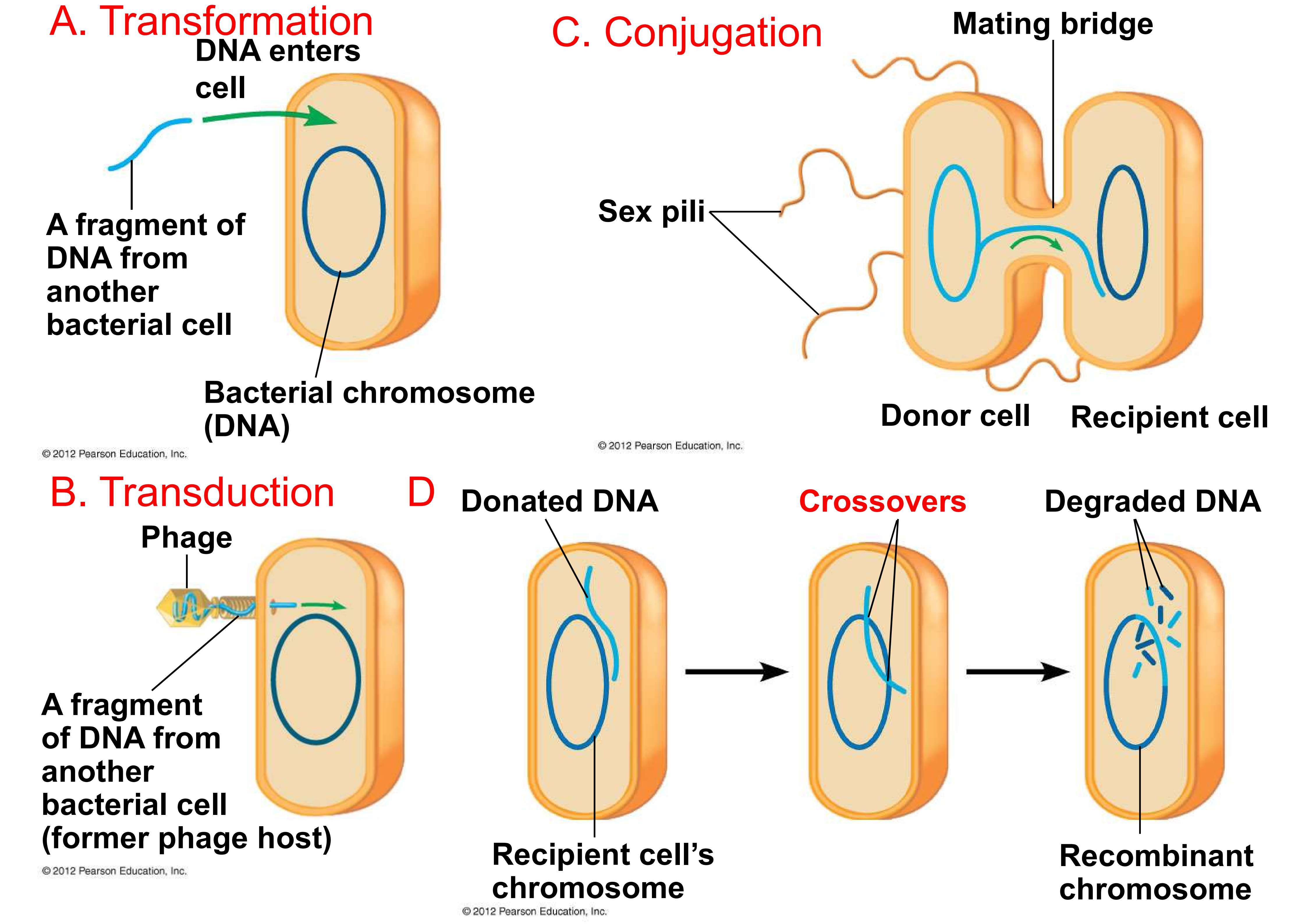
10.22 Bacteria can transfer DNA in three ways

- Viral reproduction allows researchers to learn more about the mechanisms that regulate DNA replication and gene expression in living cells.
- Bacteria are equally valuable as microbial models in genetics research.
  - Bacterial DNA is found in a single, closed loop, chromosome.
  - Bacterial cells divide by replication of the bacterial chromosome and then by binary fission.
  - Because binary fission is an asexual process, bacteria in a colony are genetically identical to the parent cell.

http://www.sciencebuddies.org/science-fair-projects/project_ideas/MicroBio_Interpreting_Plates.shtml

10.22 Bacteria can transfer DNA in three ways

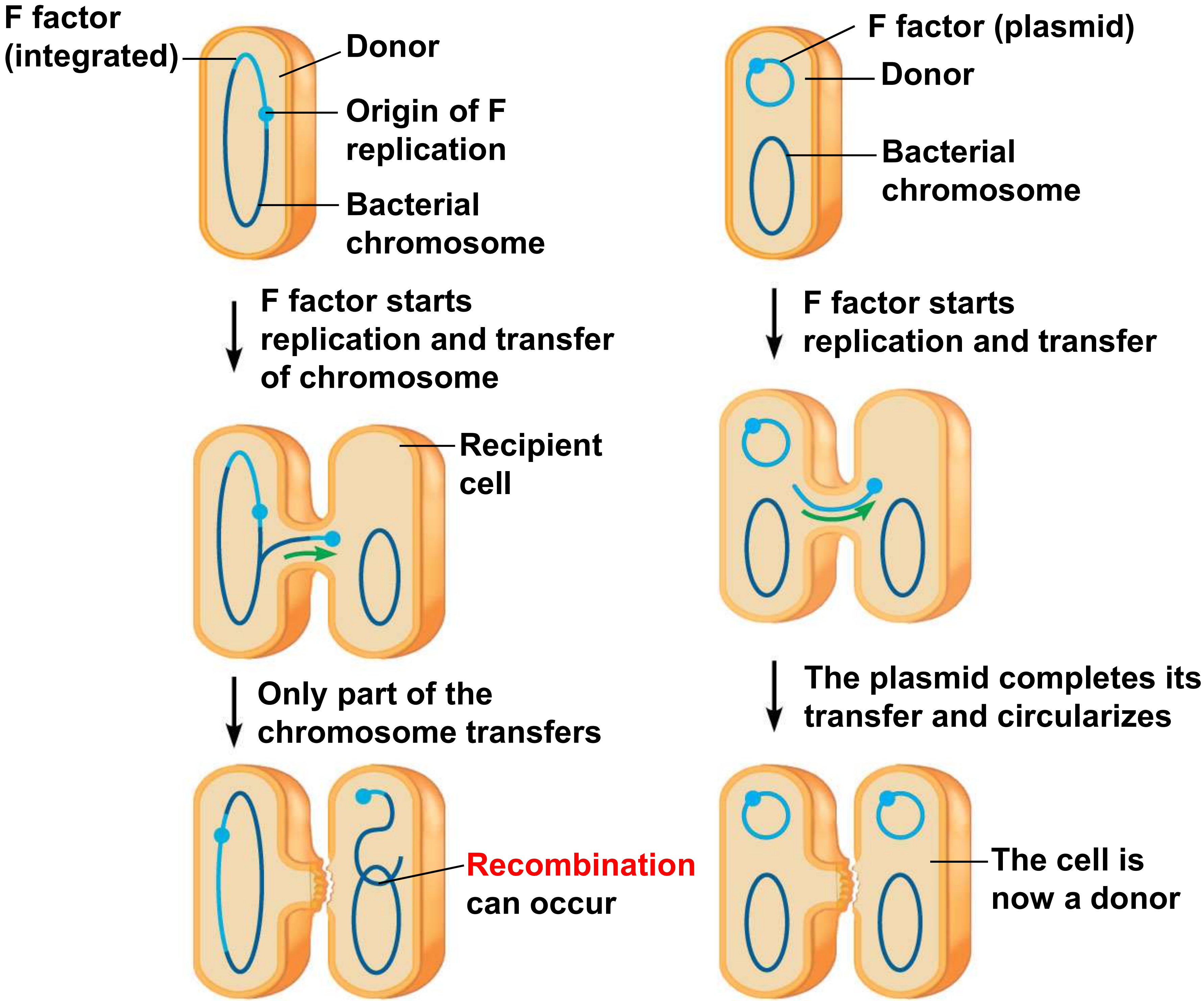
- Bacteria use three mechanisms to move genes from cell to cell.
  1. **Transformation** is the uptake of DNA from the surrounding environment.
  2. **Transduction** is gene transfer by phages.
  3. **Conjugation** is the transfer of DNA from a donor to a recipient bacterial cell through a cytoplasmic (mating) bridge.
- Once new DNA gets into a bacterial cell, part of it may then integrate into the recipient's chromosome.


A. Transformation
DNA enters cell
A fragment of DNA from another bacterial cell
Bacterial chromosome (DNA)
© 2012 Pearson Education, Inc.
C. Conjugation
Mating bridge
Sex pili
Donor cell
Recipient cell
© 2012 Pearson Education, Inc.
B. Transduction
Phage
A fragment of DNA from another bacterial cell (former phage host)
© 2012 Pearson Education, Inc.
D
Donated DNA
Crossovers
Degraded DNA
Recipient cell's chromosome
Recombinant chromosome
© 2012 Pearson Education, Inc.

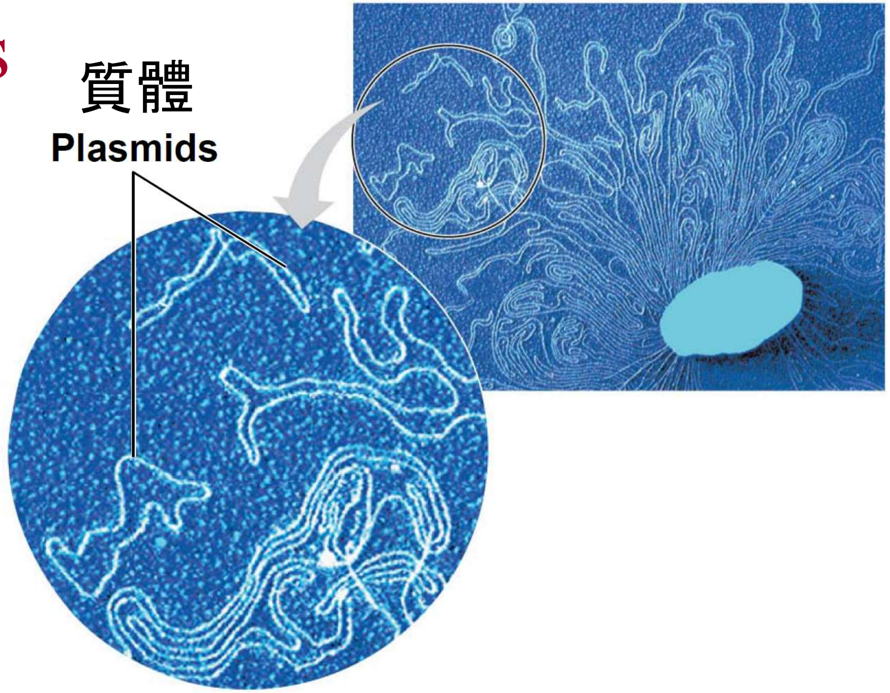
10.23 Bacterial plasmids can serve as carriers for gene transfer

- The ability of a donor *E. coli* cell to carry out conjugation is usually due to a specific piece of DNA called the **F factor**.
- During conjugation, the F factor is integrated into the bacterium's chromosome.
- The donor chromosome starts replicating at the F factor's origin of replication.
- The growing copy of the DNA peels off and heads into the recipient cell.
- Part of the F factor serves as the leading end of the transferred DNA.

Figure 10.23A-B



10.23 Bacterial plasmids can serve as carriers for gene transfer



- An F factor can also exist as a **plasmid**, a small circular DNA molecule separate from the bacterial chromosome.
  - Some plasmids, including the F factor, can bring about conjugation and move to another cell in linear form.
  - The transferred plasmid re-forms a circle in the recipient cell.
- **R plasmids** pose serious problems for human medicine by carrying genes for enzymes that destroy antibiotics.

ampicillin resistant

You should now be able to

1. Describe the experiments of Griffith, Hershey, and Chase, which supported the idea that DNA was life's genetic material.
2. Compare the structures of DNA and RNA.
3. Explain how the structure of DNA facilitates its replication.
4. Describe the process of DNA replication.
5. Describe the locations, reactants, and products of transcription and translation.
6. Explain how the "languages" of DNA and RNA are used to produce polypeptides.
7. Explain how mRNA is produced using DNA.
8. Explain how eukaryotic RNA is processed before leaving the nucleus.
9. Relate the structure of tRNA to its functions in the process of translation.
10. Describe the structure and function of ribosomes.

11. Describe the step-by-step process by which amino acids are added to a growing polypeptide chain.
12. Diagram the overall process of transcription and translation.
13. Describe the major types of mutations, causes of mutations, and potential consequences.
14. Compare the lytic and lysogenic reproductive cycles of a phage.
15. Compare the structures and reproductive cycles of the mumps virus and a herpesvirus.
16. Describe three processes that contribute to the emergence of viral disease.
17. Explain how the AIDS virus enters a host cell and reproduces.
18. Describe the structure of viroids and prions and explain how they cause disease.
19. Define and compare the processes of transformation, transduction, and conjugation.
20. Define a plasmid and explain why R plasmids pose serious human health problems.