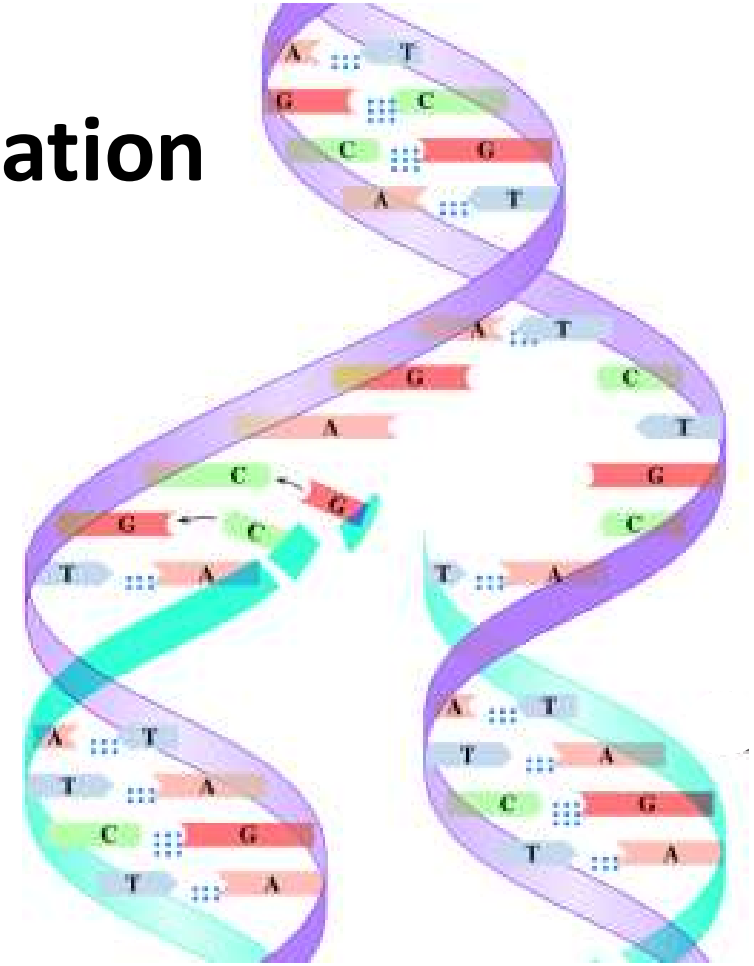
Central DOGMA of LIFE: DNA ….RNA…..PROTEIN

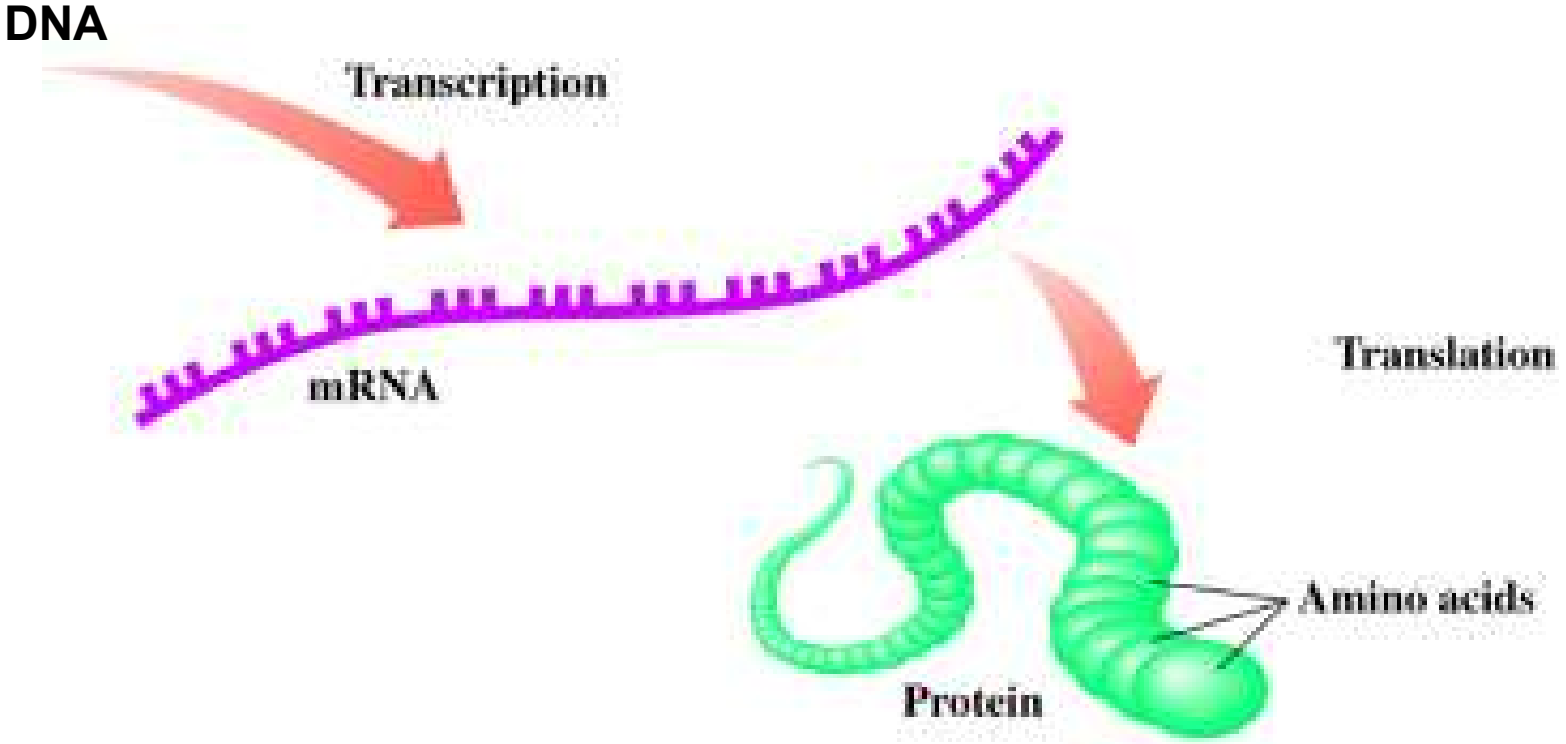
DNA Replication



In **DNA replication**

- genetic information is maintained each time a cell divides.
- the DNA strands unwind.
- each parent strand bonds with new complementary bases.
- two new DNA strands form that are exact copies of the original DNA.

RNA and the Genetic Code



RNA

RNA

- transmits information from DNA to make proteins.
- has several types

Messenger RNA (mRNA) carries genetic information from DNA to the ribosomes.

Transfer RNA (tRNA) brings amino acids to the ribosome to make the protein.

Ribosomal RNA (rRNA) makes up 2/3 of ribosomes where protein synthesis takes place.

Types of RNA

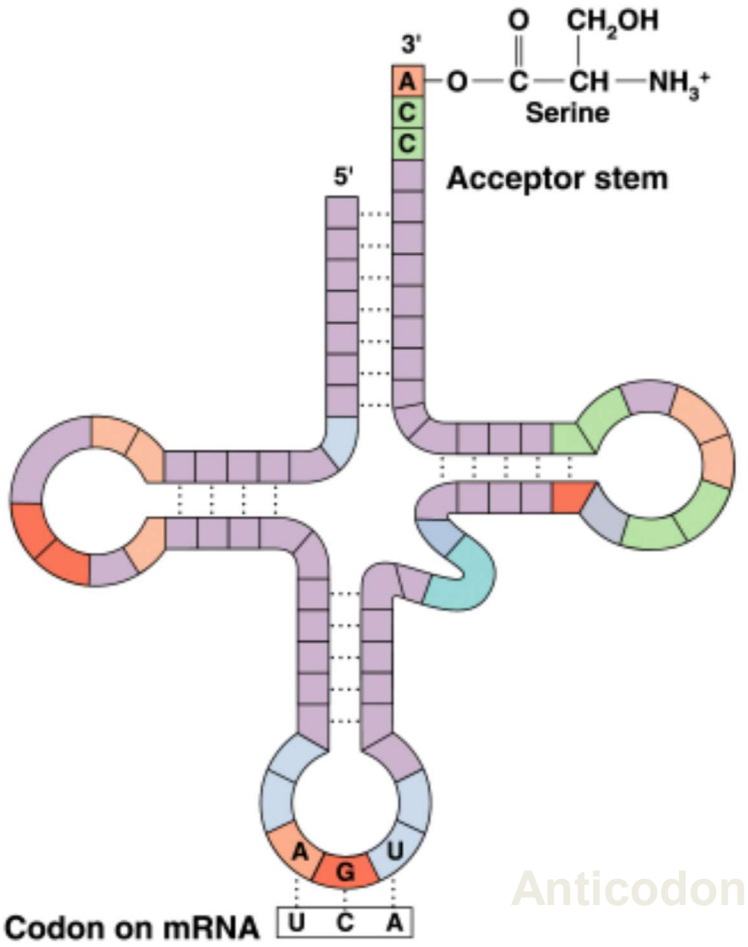
Types of RNA Molecules

Type	Abbreviation	Percentage of Total RNA	Function in the Cell
Ribosomal RNA	rRNA	75	Major component of the ribosomes
Messenger RNA	mRNA	5–10	Carries information for protein synthesis from the DNA in the nucleus to the ribosomes
Transfer RNA	tRNA	10–15	Brings amino acids to the ribosomes for protein synthesis

tRNA

Each **tRNA**

- has a triplet called an anticodon that complements a codon on mRNA.
- bonds to a specific amino acid at the acceptor stem.



Protein Synthesis

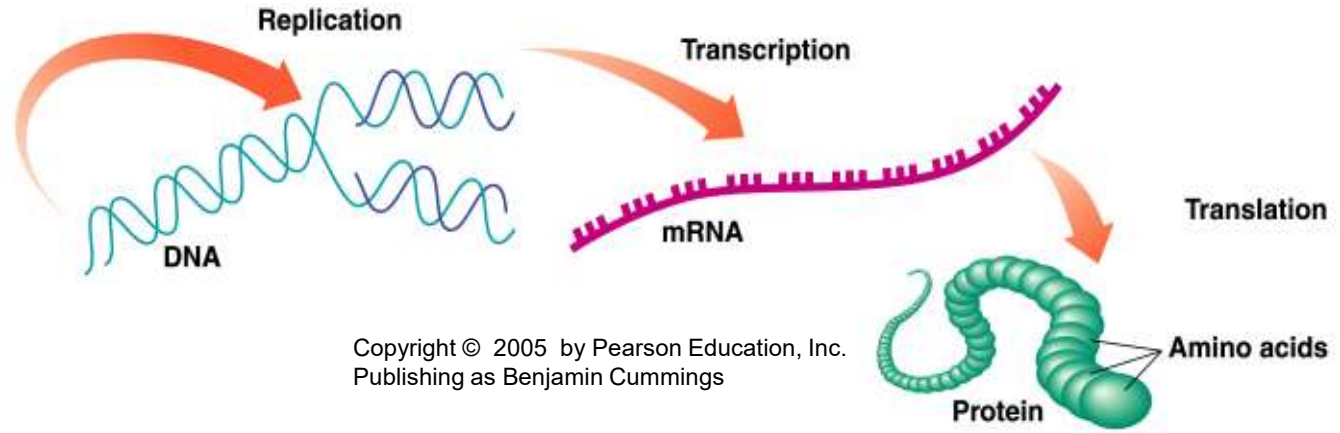
Protein synthesis involves

- **transcription**

  mRNA is formed from a gene on a DNA strand.

- **translation**

mR



Transcription: Synthesis of mRNA

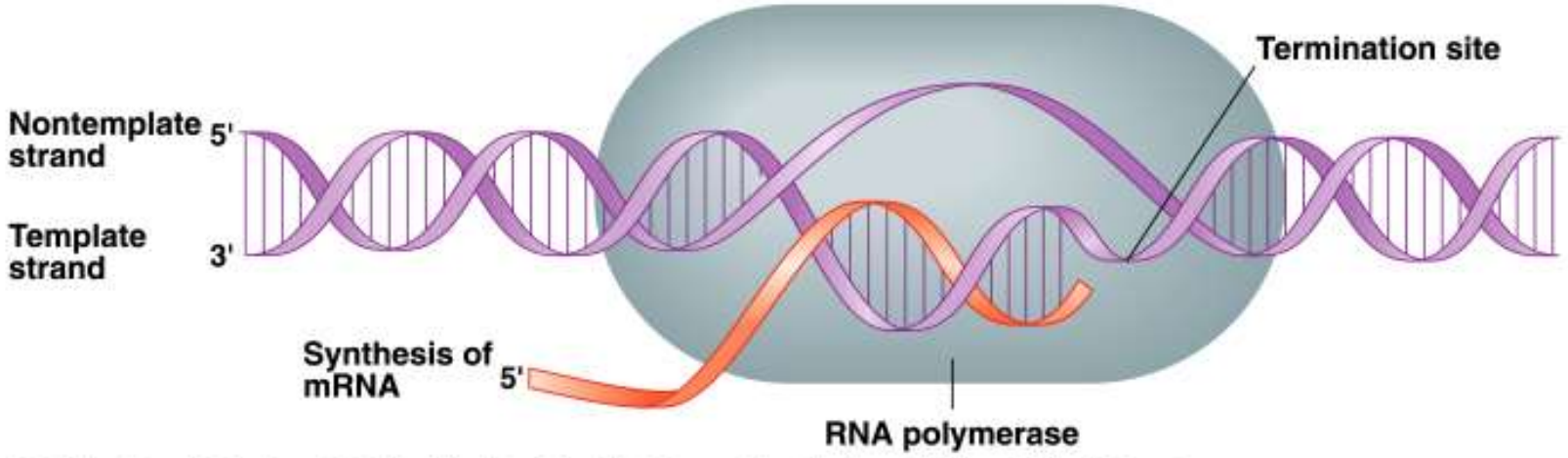
During **transcription**

- a section of DNA containing the gene unwinds.
- one strand of DNA bases is used as a template.
- **mRNA** is synthesized using complementary base pairing with uracil (U) replacing thymine (T).
- the newly formed mRNA moves out of the nucleus to ribosomes in the cytoplasm.

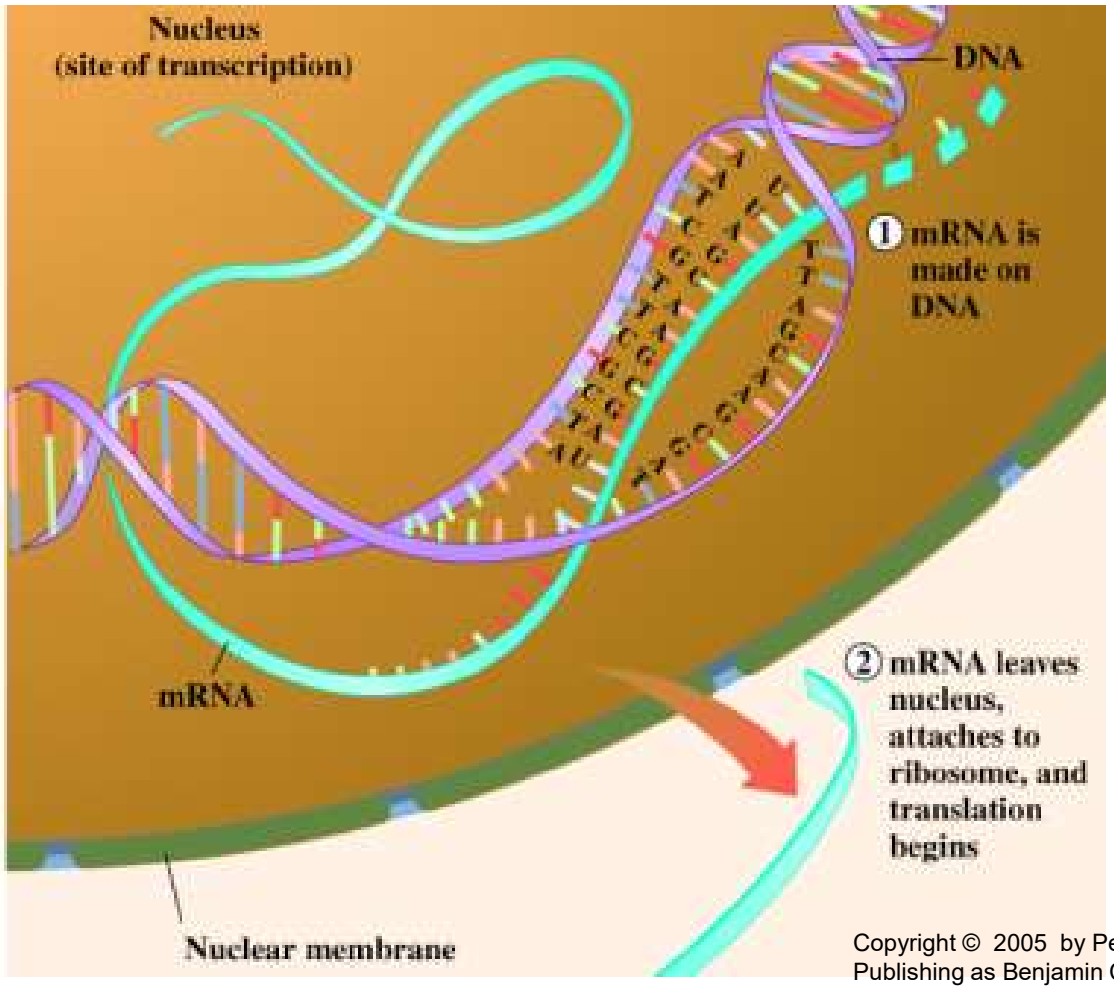
RNA Polymerase

During transcription,

- **RNA *polymerase*** moves along the DNA template to synthesize the corresponding mRNA

- 

Protein Synthesis: Transcription



Genetic Code

The genetic code

- **is a sequence of amino acids in a mRNA that determine the amino acid order for the protein.**
- **consists of sets of three bases (triplet) along the mRNA called codons.**
- **has a different codon for all 20 amino acids needed to build a protein.**
- **contains certain codons that signal the “start” and “end” of a polypeptide chain.**

The Genetic Code: mRNA Codons

Table 22.4 mRNA Codons: The Genetic Code for Amino Acids

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

[a] Codon that signals the start of a peptide chain. STOP codons signal the end of a peptide chain.

Codons and Amino Acids

Determine the amino acids from the following codons in a section of mRNA.

—CCU —AGC—GGA—CUU—

According to the genetic code, the amino acids for these codons are

CCU = proline AGC = serine

GGA = glycine CUU = leucine

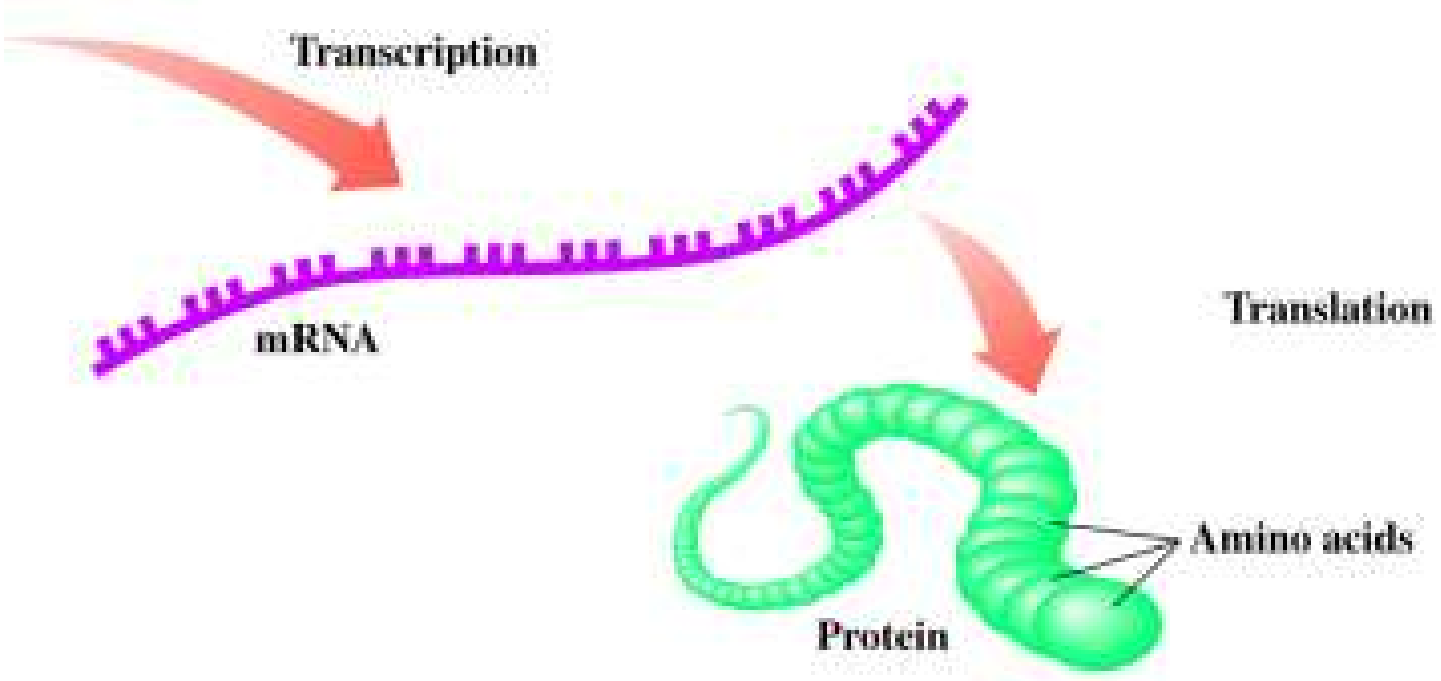
This mRNA section codes for an amino acid sequence of —

CCU —AGC—GGA—CUU—

—Pro — Ser — Gly — Leu —

Nucleic Acids and Protein Synthesis

Protein Synthesis: Translation



Initiation of Protein Synthesis

For the **initiation** of protein synthesis

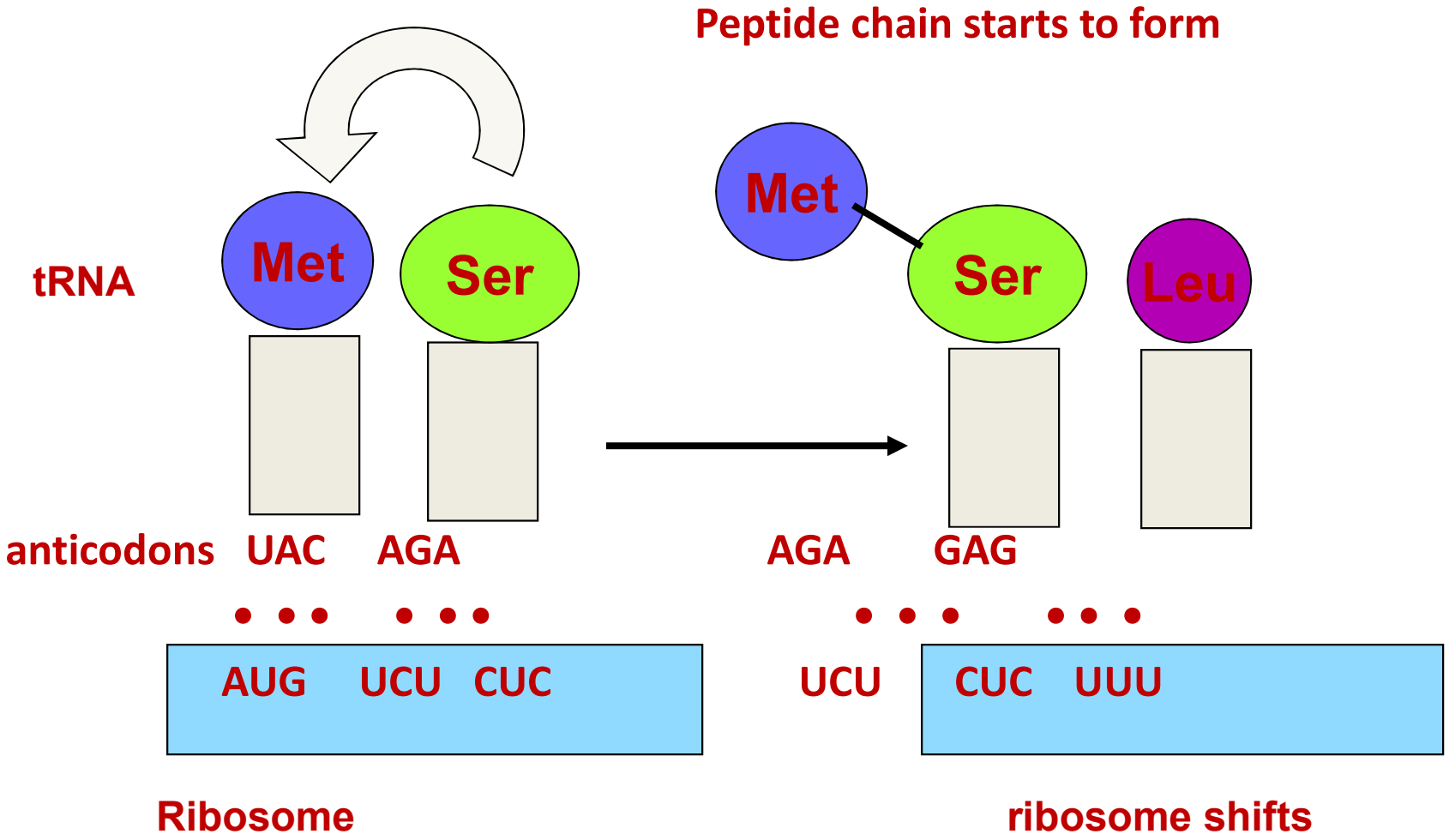
- a mRNA attaches to a ribosome.
- the start codon (AUG) binds to a tRNA with methionine.
- the second codon attaches to a tRNA with the next amino acid.
- a peptide bond forms between the adjacent amino acids at the first and second codons.

Translocation

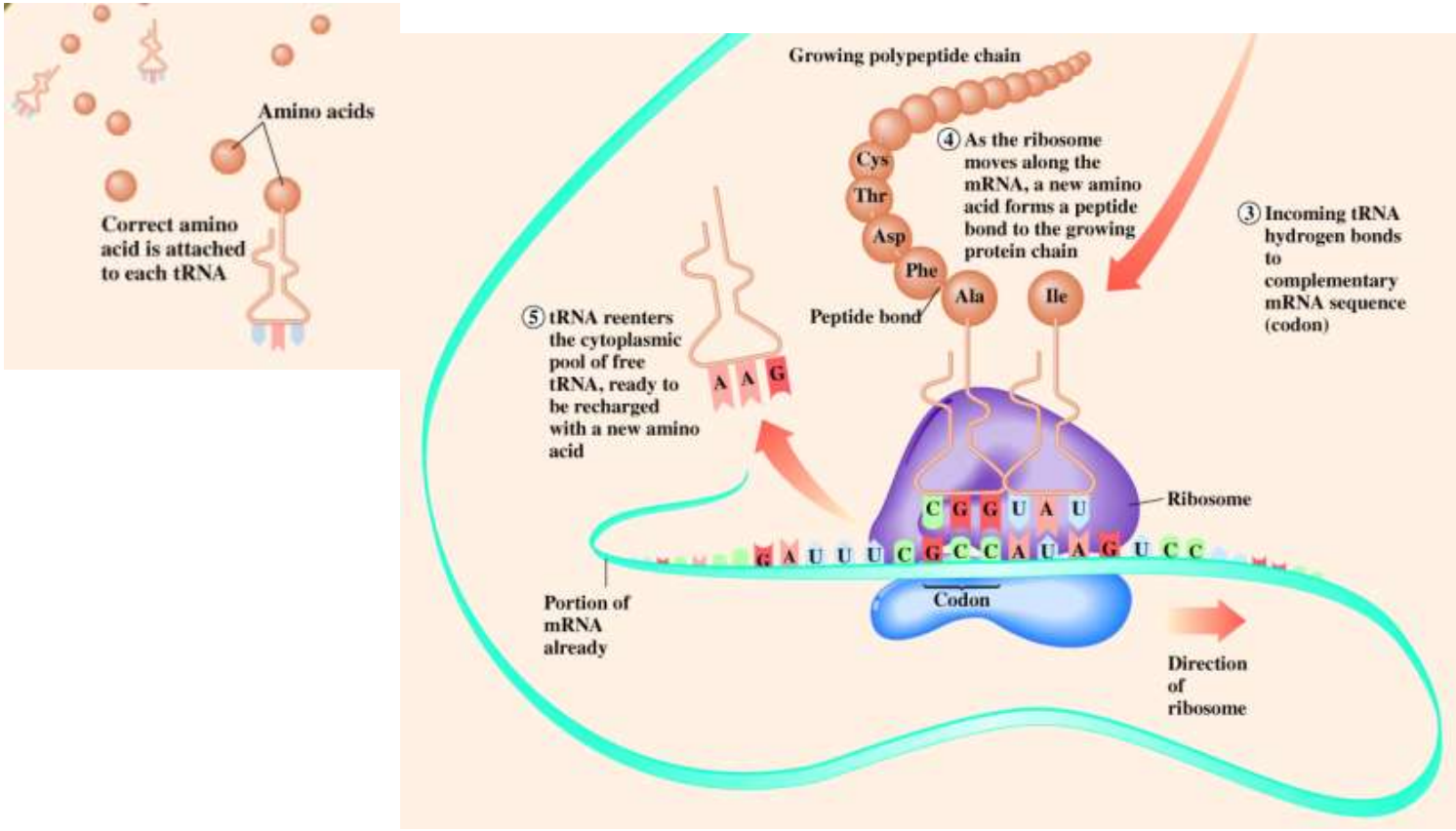
During **translocation**

- the first tRNA detaches from the ribosome.
- the ribosome shifts to the adjacent codon on the mRNA.
- a new tRNA/amino acid attaches to the open binding site.
- a peptide bond forms and that tRNA detaches.
- the ribosome shifts down the mRNA to read next codon.

Peptide Formation



Protein Synthesis



translation

Termination

In the **termination** step

- all the amino acids are linked.
- the ribosome reaches a “stop” codon: UGA, UAA, or UAG.
- there is no tRNA with an anticodon for the “stop” codons.
- the polypeptide detaches from the ribosome.

Summary of Protein Synthesis

To summarize protein synthesis:

- A mRNA attaches to a ribosome.
- tRNA molecules bonded to specific amino acids attach to the codons on mRNA.
- Peptide bonds form between an amino acid and the peptide chain.
- The ribosome shifts to each codon on the mRNA until it reach the STOP codon.
- The polypeptide chain detaches to function as an active protein.

Mutations

A **mutation** can

- alter the nucleotide sequence in DNA.
- result from mutagens such as radiation and chemicals.
- produce one or more incorrect codons in mRNA.
- produce a protein containing one or more incorrect amino acids.
- produce defective proteins and enzymes.
- cause genetic diseases.

Examples of Genetic Diseases

Galactosemia

Cystic fibrosis

Downs syndrome

Muscular dystrophy

Huntington's disease

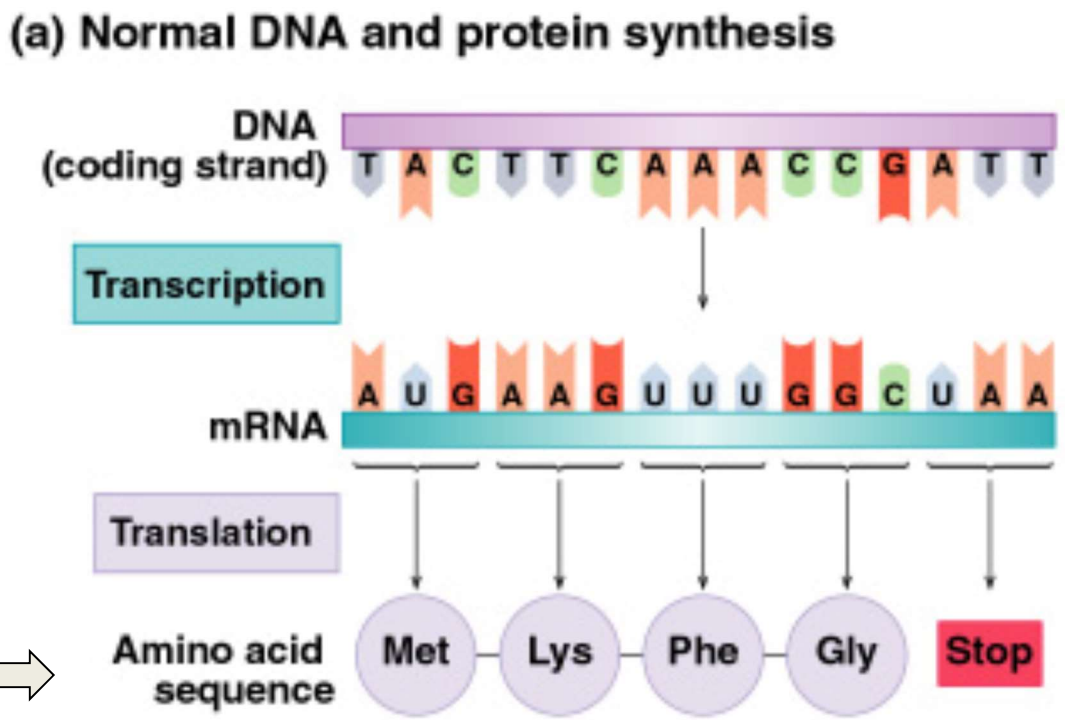
Sickle-cell anemia

Hemophilia

Tay-Sachs disease

Normal DNA Sequence

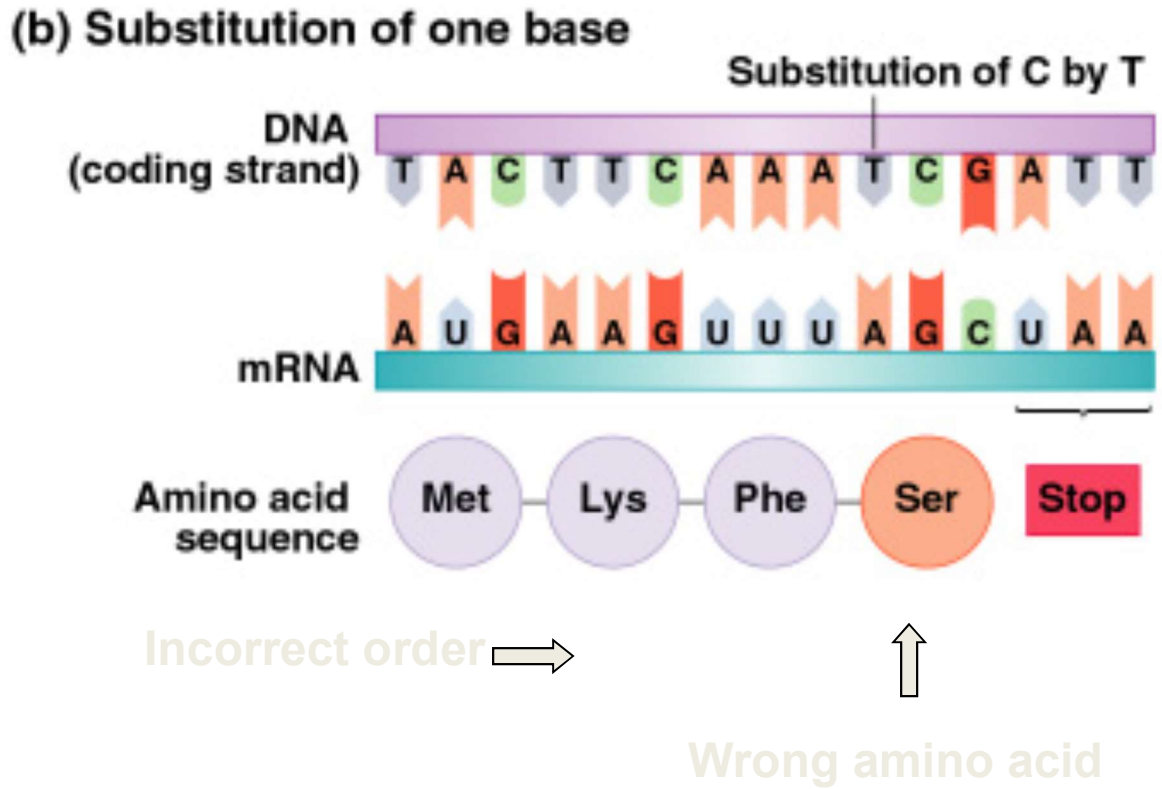
The normal DNA sequence produces a mRNA that provides instructions for the correct series of amino acids in a protein.



Mutation: Substitution

Substitution

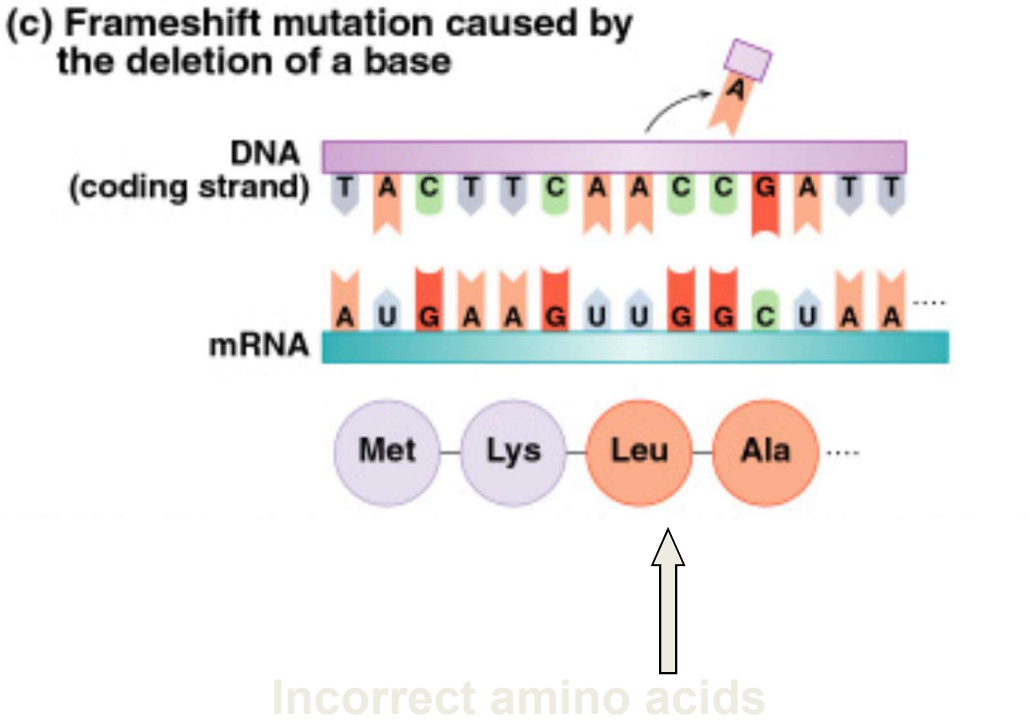
- of a base in DNA changes a codon in the mRNA.
- of a different codon leads to the placement of an incorrect amino acid in the polypeptide.



Frame Shift Mutation

In **frame shift mutation**,

- an extra base adds to or is deleted from the normal DNA sequence.
- all the codons in mRNA and amino acids are incorrect from the base change.



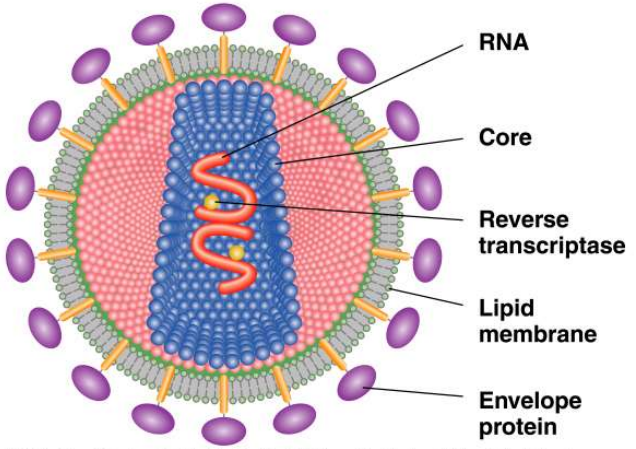
Failure to Stop at Cell Cycle Checkpoints

Mutation in a gene that usually slows the cell cycle	Rate of cell division is accelerated.
Failure to pause for DNA repair	Faulty DNA leads to unregulated cell growth.
Loss of control over telomere length	Cancer cells have telomerase, an enzyme that elongates telomeres. Cells continue to divide after 50 mitoses.

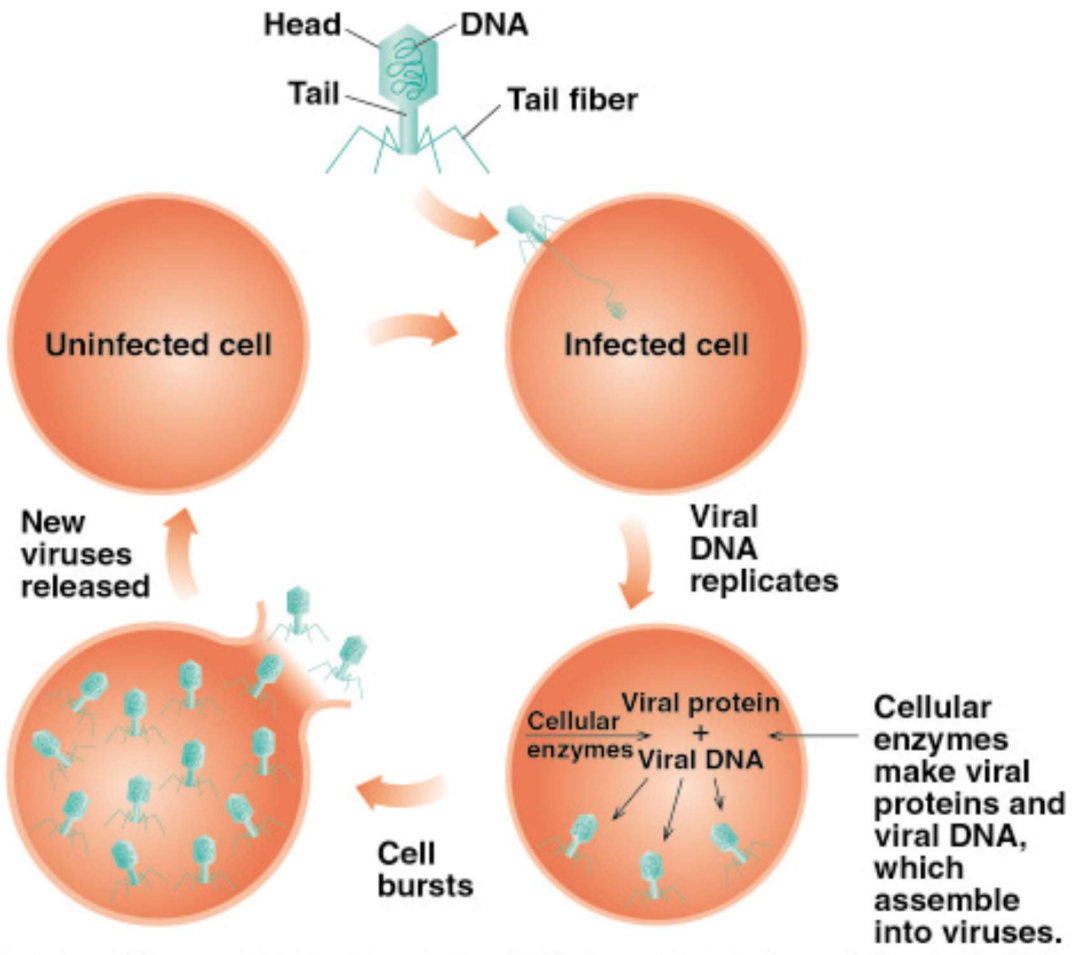
Viruses

Viruses

- are small particles of DNA or RNA that require a host cell to replicate.
- cause a viral infection when the DNA or RNA enters a host cell.
- are synthesized in the host c
  RNA produced by viral DNA.



Viruses

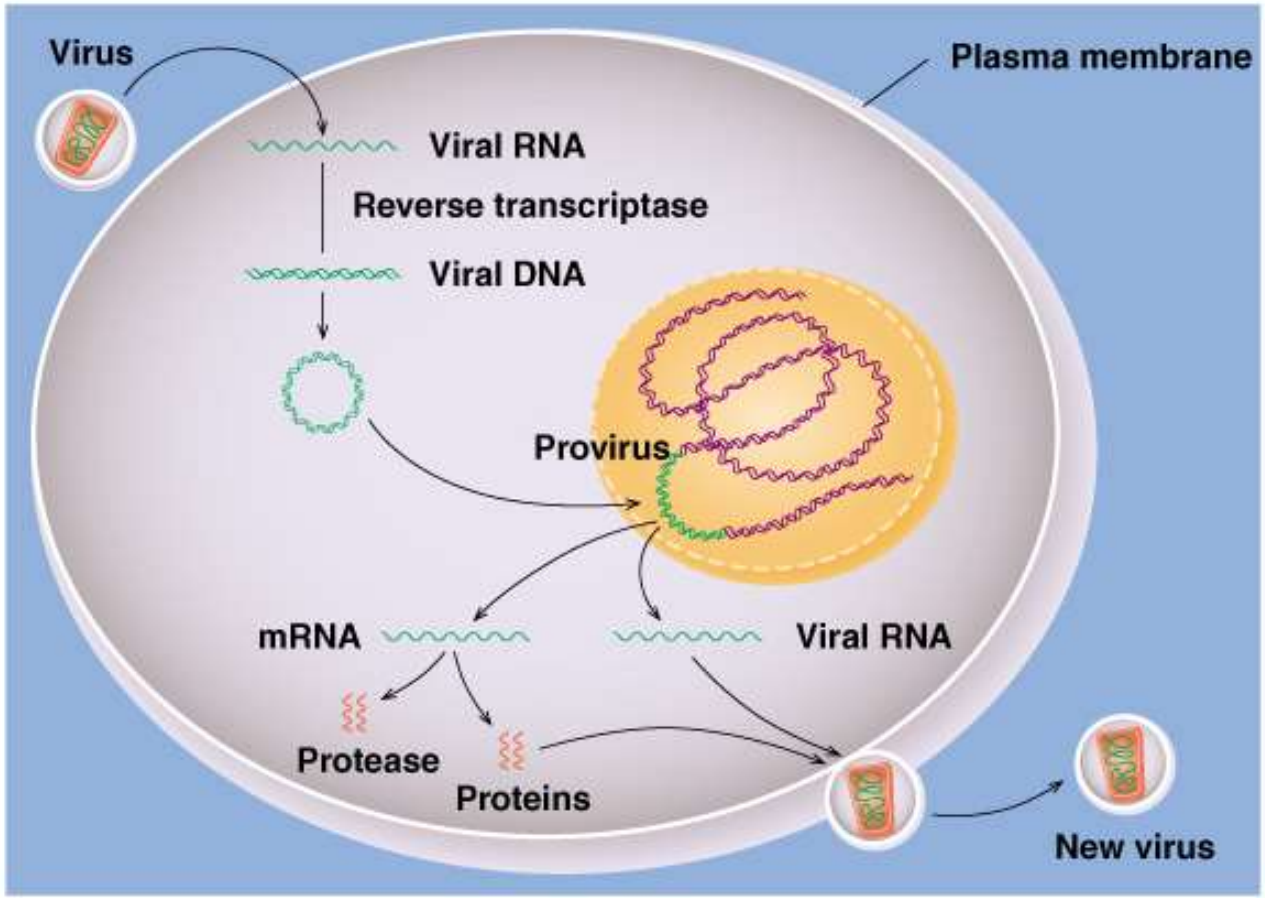

Head
DNA
Tail
Tail fiber
Uninfected cell
Infected cell
New viruses released
Viral DNA replicates
Cellular enzymes
Viral protein
+
Viral DNA
Cellular enzymes make viral proteins and viral DNA, which assemble into viruses.
Cell bursts

Reverse Transcription

In **reverse transcription**

- a retrovirus, which contains viral RNA, but no viral DNA, enters a cell.
- the viral RNA uses *reverse transcriptase* to produce a viral DNA strand.
- the viral DNA strand forms a complementary DNA strand.
- the new DNA uses the nucleotides and enzymes in the host cell to synthesize new virus particles.

Reverse Transcription

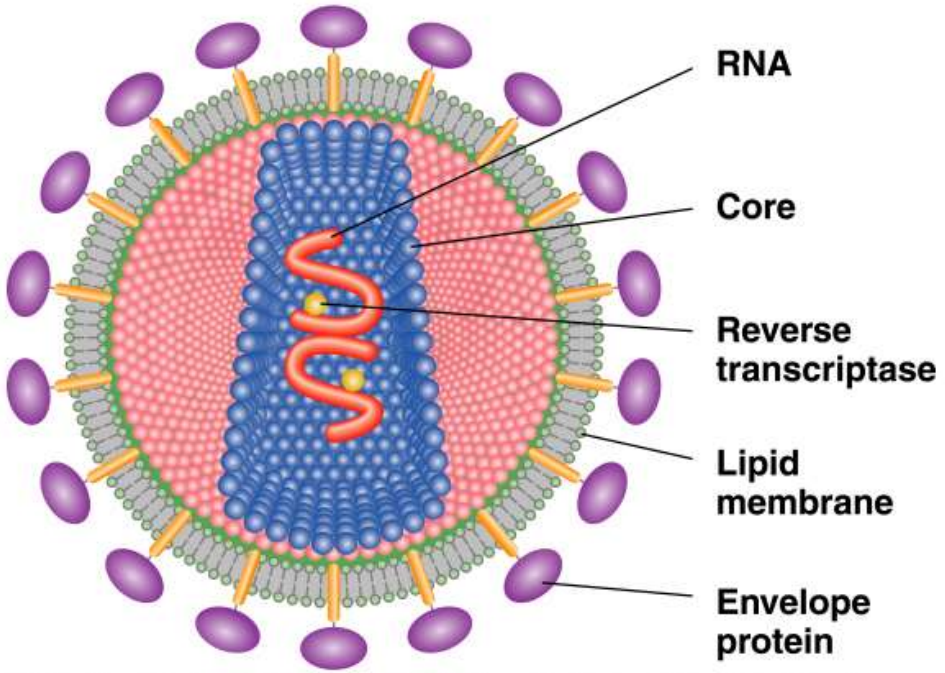


Timberlake, *General, Organic, and Biological Chemistry*. Copyright © Pearson Education Inc., publishing as Benjamin Cummings

HIV Virus and AIDS

The **HIV-1 virus**

- is a retrovirus that infects T4 lymphocyte cells.
- decreases the T4 level and the immune system fails to destroy harmful organisms.
- causes pneumonia and skin cancer associated with AIDS.



Timberlake, *General, Organic, and Biological Chemistry.* Copyright © Pearson Education Inc., publishing as Benjamin Cummings

HIV virus

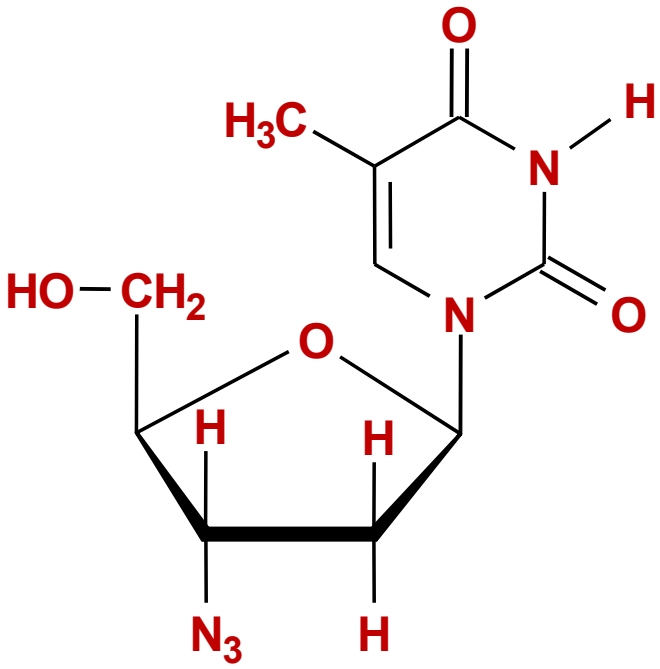
AIDS Treatment

- One type of AIDS treatment prevents reverse transcription of the viral DNA.

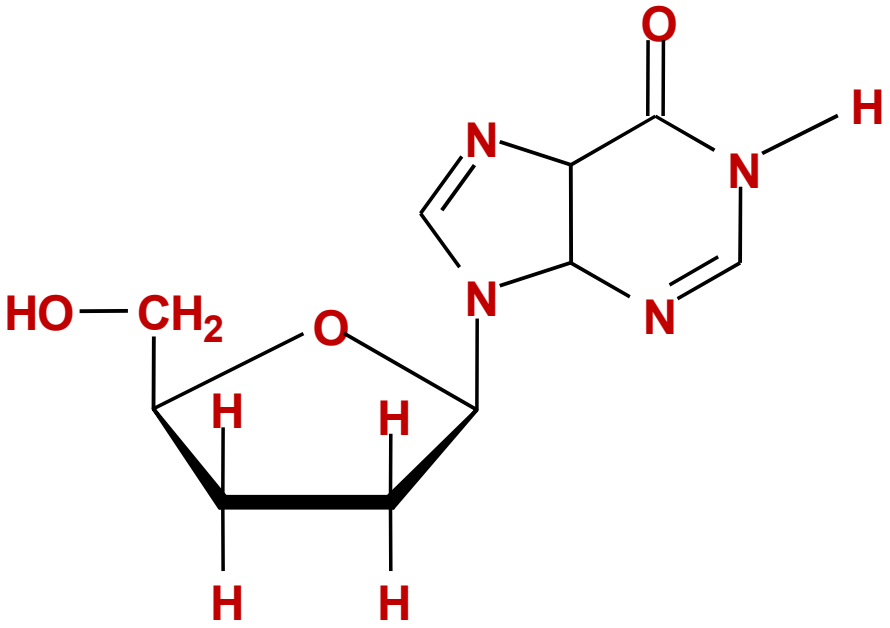
- When altered nucleosides such as AZT and ddI are incorporated into viral DNA, the virus is unable to replicate.

AIDS Treatment

Azidothymine (AZT)



Dideoxyinosine (ddI)



AIDS Treatment

- Another type of AIDS treatment involves protease inhibitors such as saquinavir, indinavir, and ritonavir.
- Protease inhibitors modify the active site of the protease enzyme, which prevents the synthesis of viral proteins.

Inhibited by AZT, ddI

reverse transcriptase

Inhibited by protease inhibitors

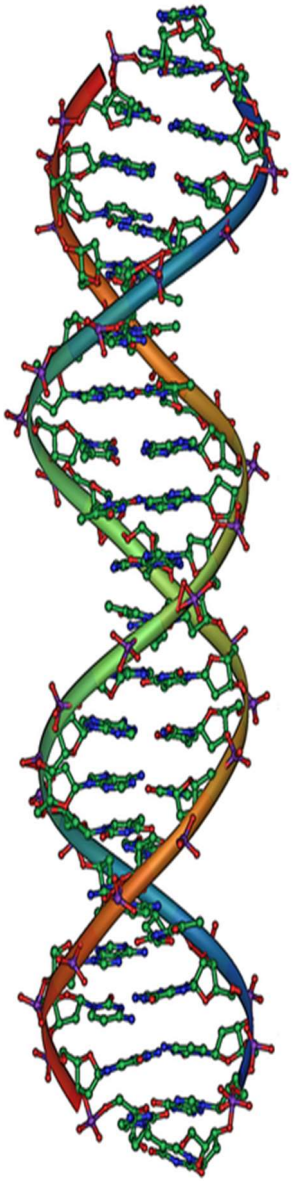
protease

Viral RNA → Viral DNA → Viral proteins

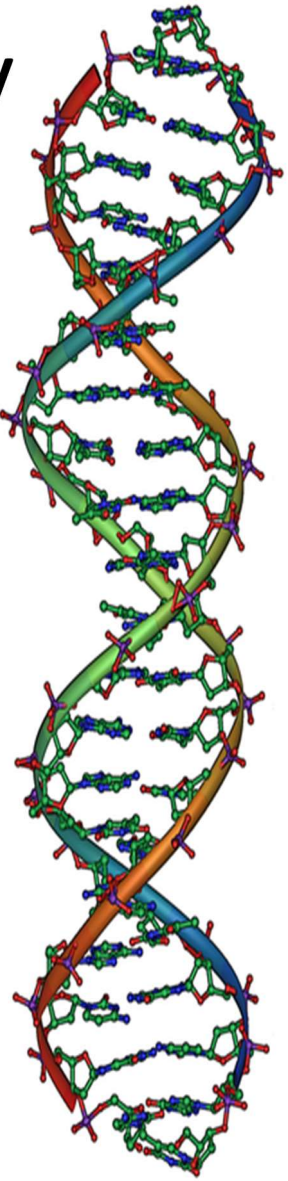
Genetics and Evolution

Genetics

- is the science of heredity and variation in living organisms.
- Heredity is the transmission of genes from one generation to another.
- Variations are the differences in living organisms of their own kind.



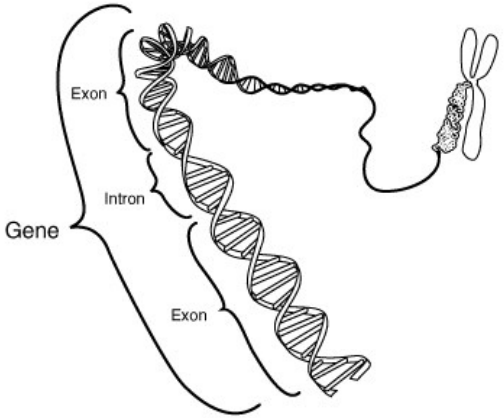
Important Terms in the Study of Genetics



- Gene

  -is the basic unit of heredity in a living organism

  -is a segment of a DNA that, that determines a trait.



Definition of Some Genetic Terms

- Genotype

  - genetic makeup or composition for a particular trait. (TT or Tt or tt)

- Phenotype

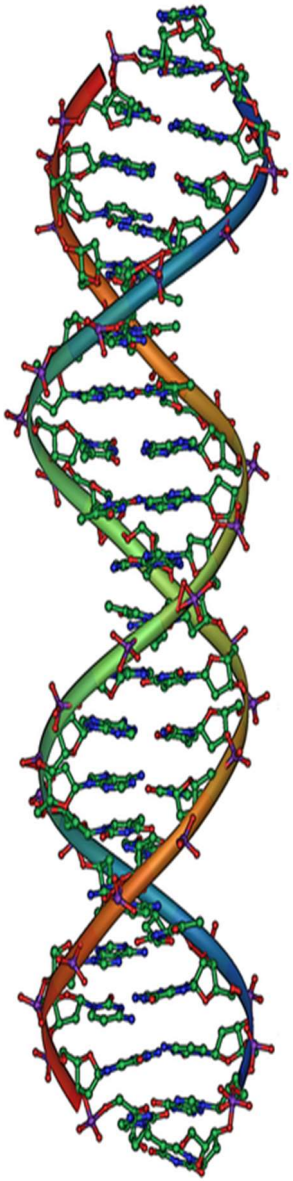
  - the visible trait or characteristic of an organism determined by a specific genotype. (tall- TT or Tt or short (tt)

- Genome

  - Sum total of all the genotypes for all the traits of an individual organism.

- Gene Pool

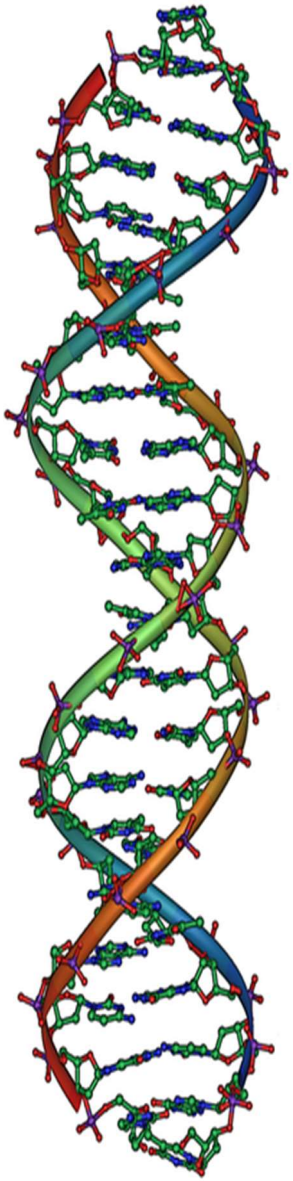
  - the total of all genes carried by all individuals in an interbreeding population



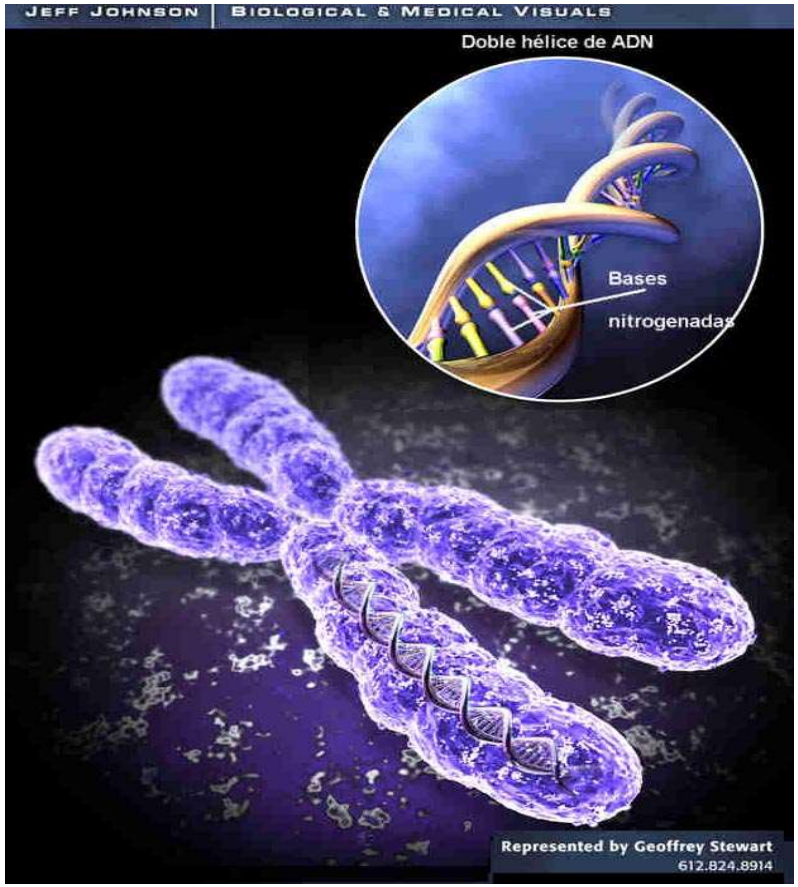
What is a Chromosome?

- is an organized structure of DNA and protein that is found in cells

- A threadlike linear strand of DNA and associated proteins in the nucleus of eukaryotic cells that carries the genes and functions in the transmission of hereditary information.



Illustrations of a Chromosome



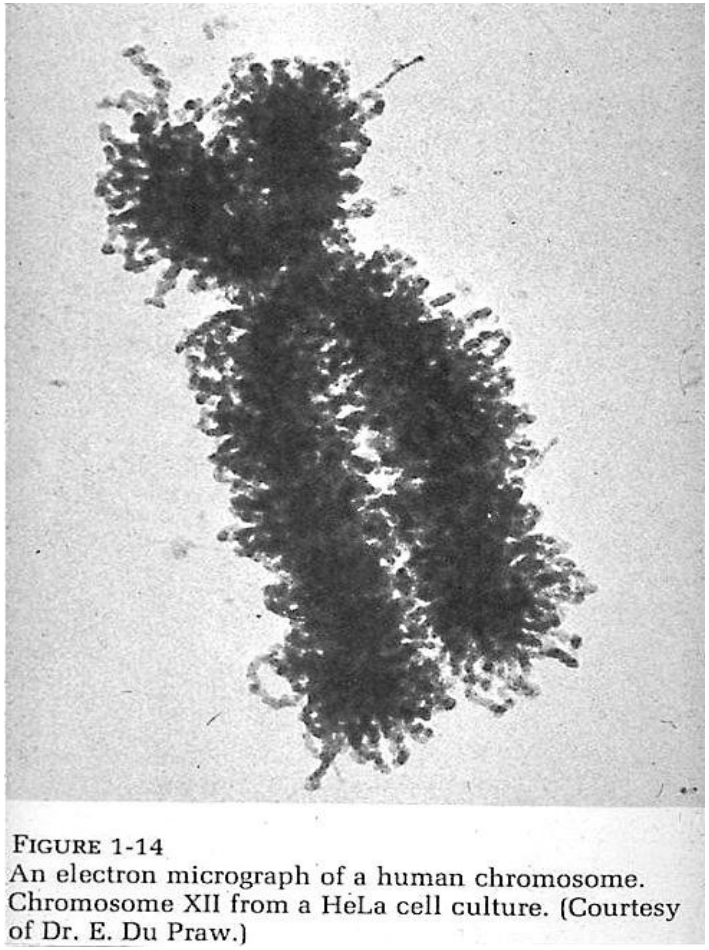
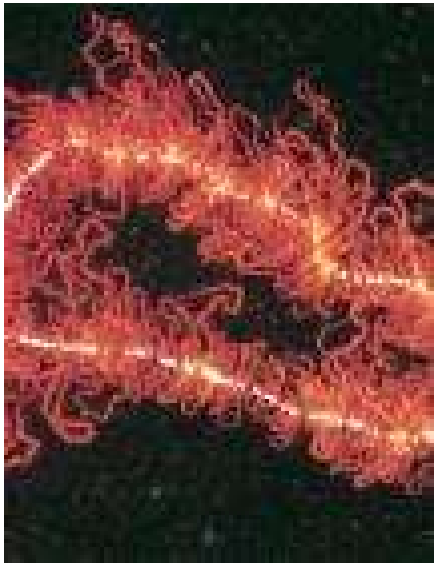


FIGURE 1-14
An electron micrograph of a human chromosome. Chromosome XII from a HeLa cell culture. (Courtesy of Dr. E. Du Praw.)

Chromatin

Illustration of a Chromatin



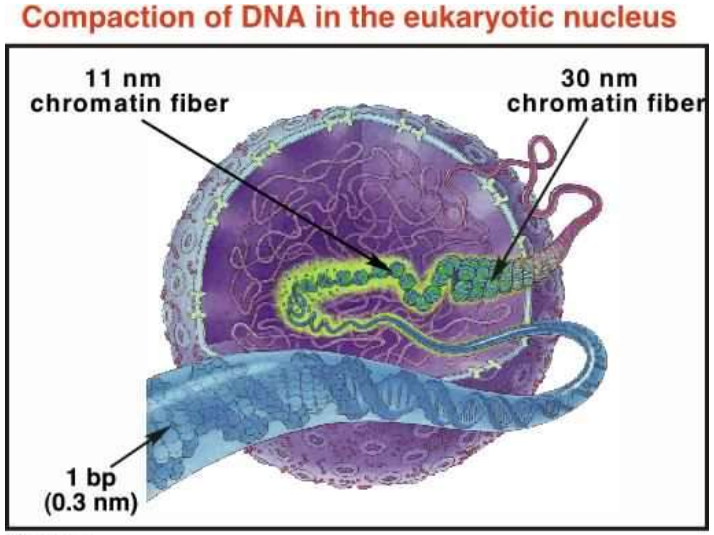
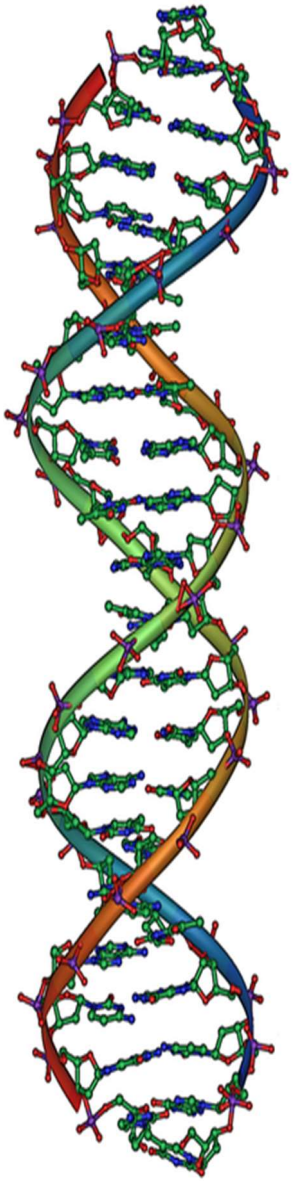


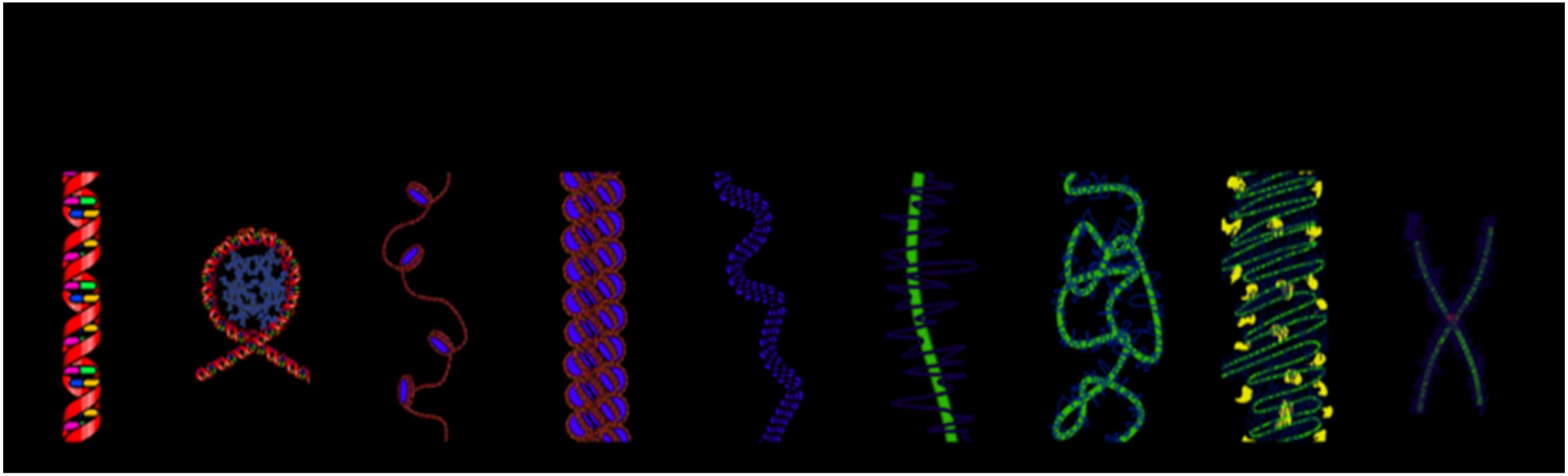
Figure 1

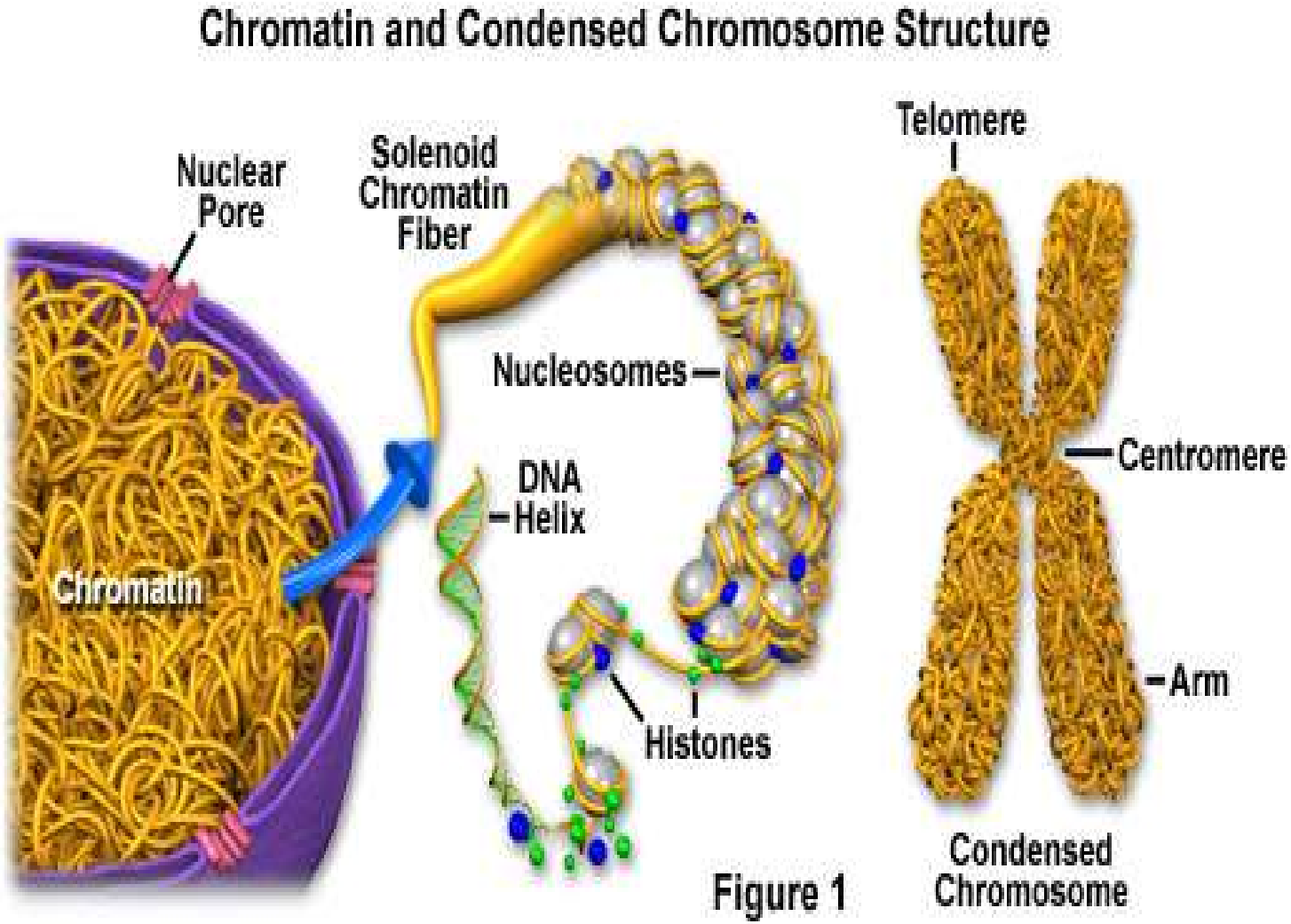
Chromatin

- is the complex combination of DNA, RNA, and protein that makes up chromosomes. It is found inside the nuclei of eukaryotic cells, and within the nucleoid in prokaryotic cells.
- The supercoiling of eukaryotic DNAs results primarily from the folding of the DNA about histone proteins to form chromatin.

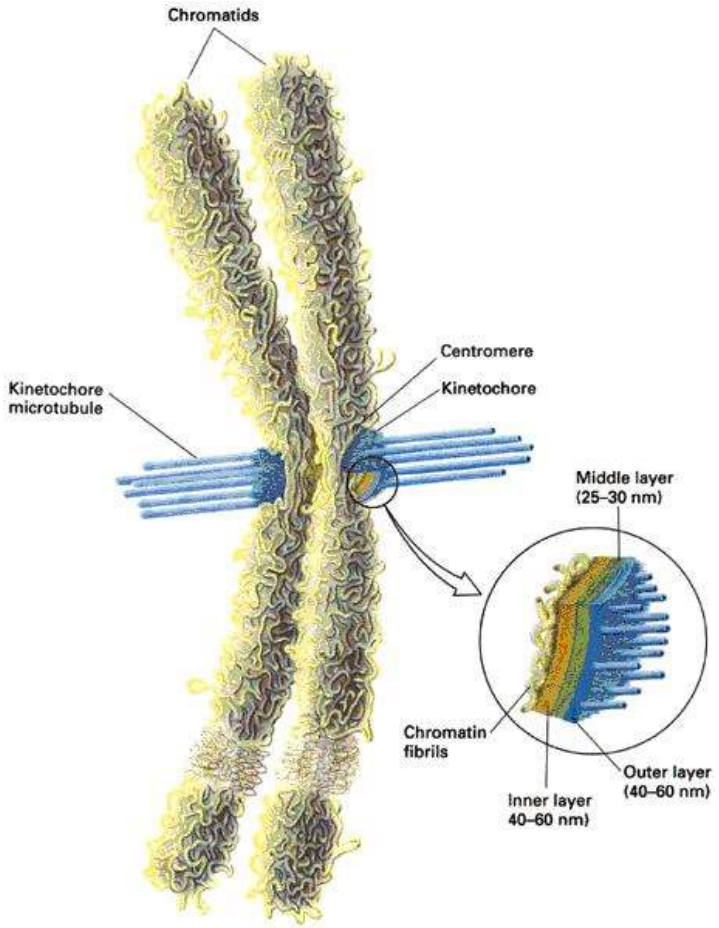


How a Chromosome is formed




Chromatin and Condensed Chromosome Structure
Nuclear Pore
Solenoid Chromatin Fiber
Telomere
Nucleosomes
Centromere
DNA Helix
Chromatin
Histones
Arm
Condensed Chromosome
Figure 1

Structure and Localization of the Centromere and Kinetochore



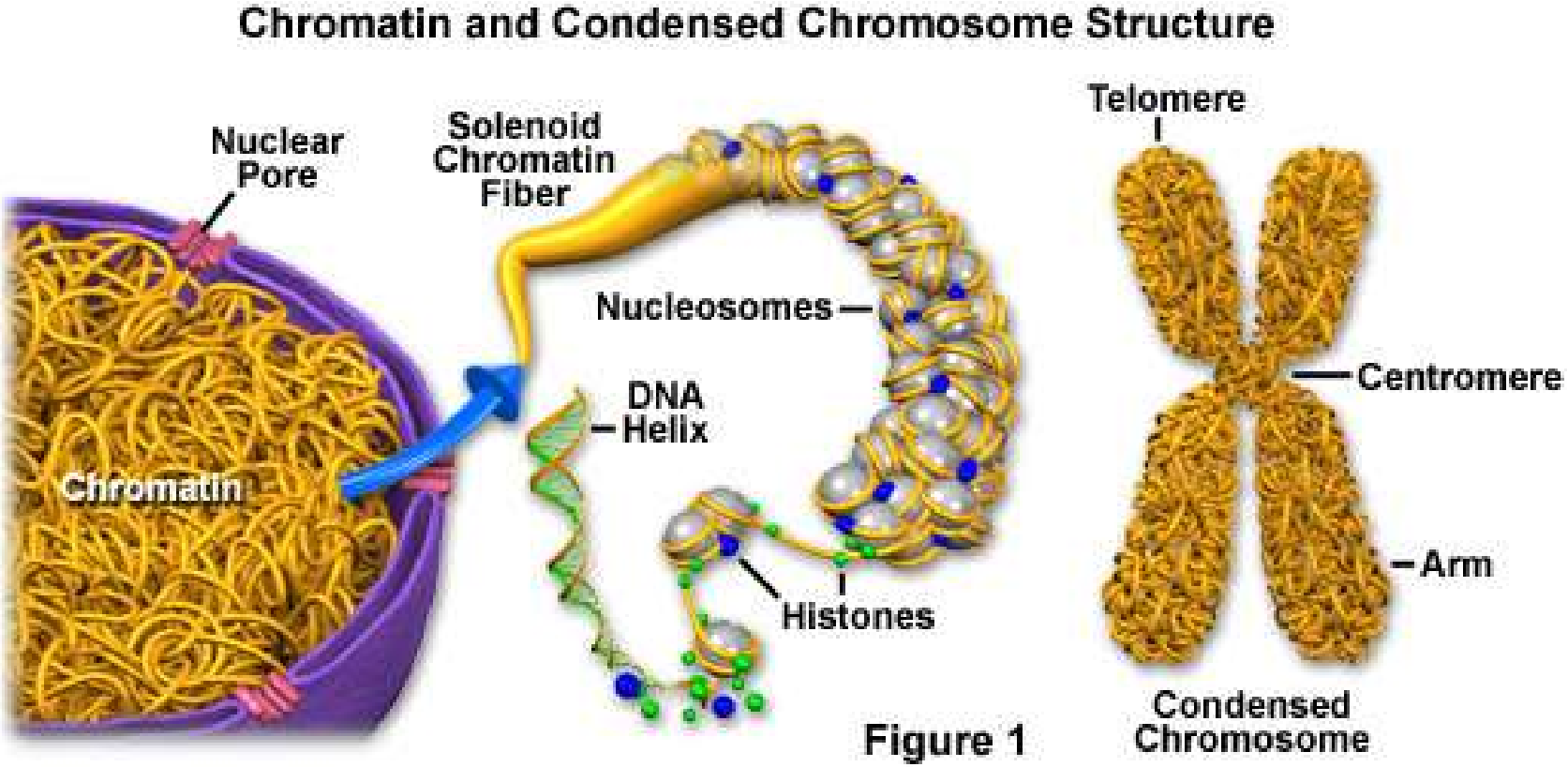
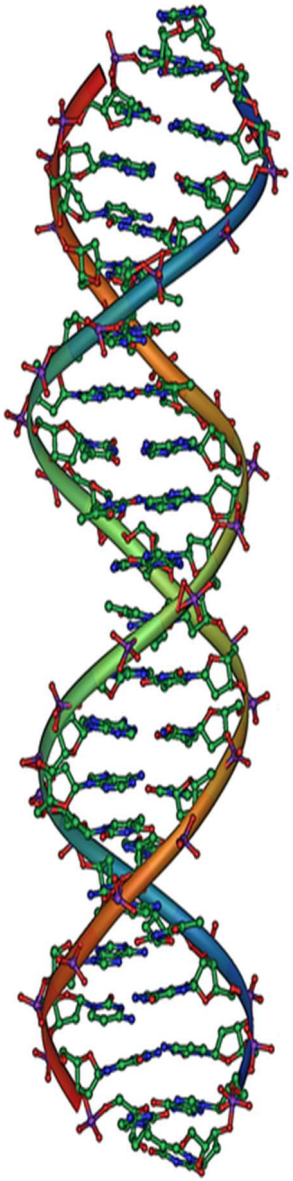

Chromatin and Condensed Chromosome Structure
Nuclear Pore
Solenoid Chromatin Fiber
Telomere
Nucleosomes
Centromere
DNA Helix
Chromatin
Histones
Arm
Condensed Chromosome

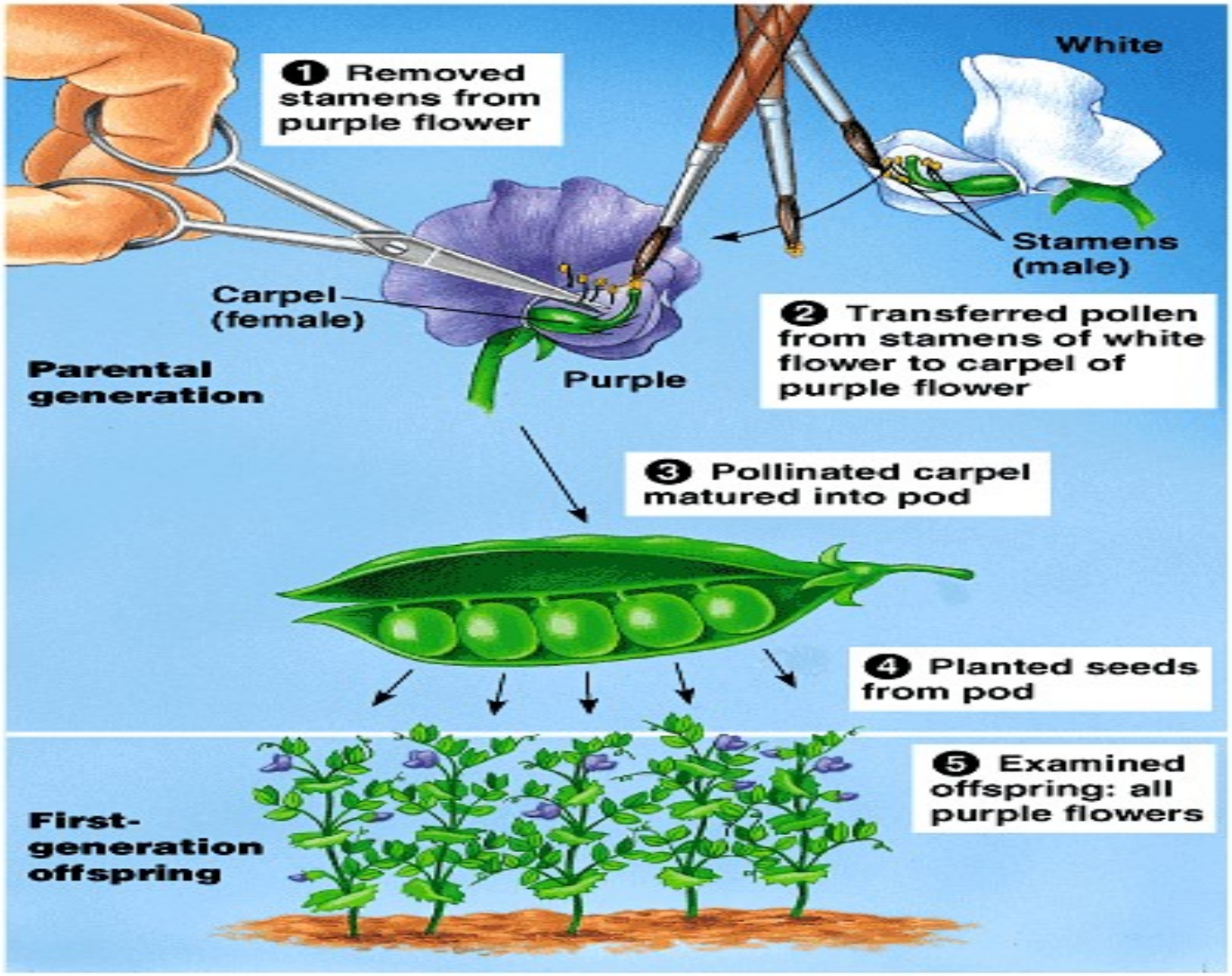
Figure 1

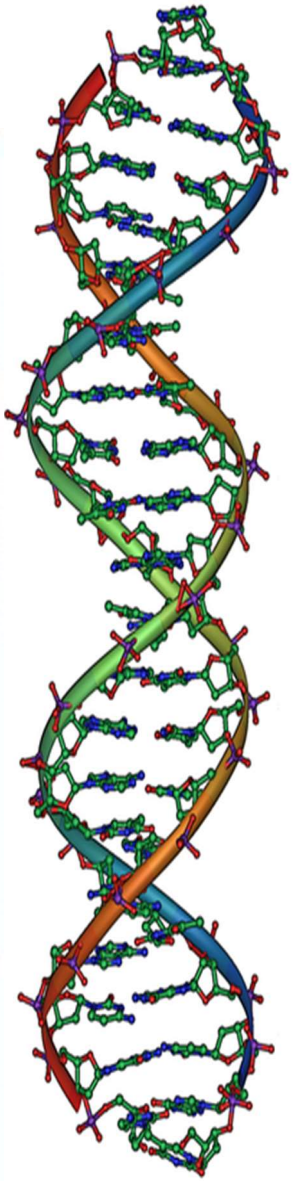
Gregor Johann Mendel

- **Gregor Johann Mendel** was an Augustinian priest and scientist, and is often called the father of genetics for his study of the inheritance of certain traits in pea plants.



Mendel's Experiment



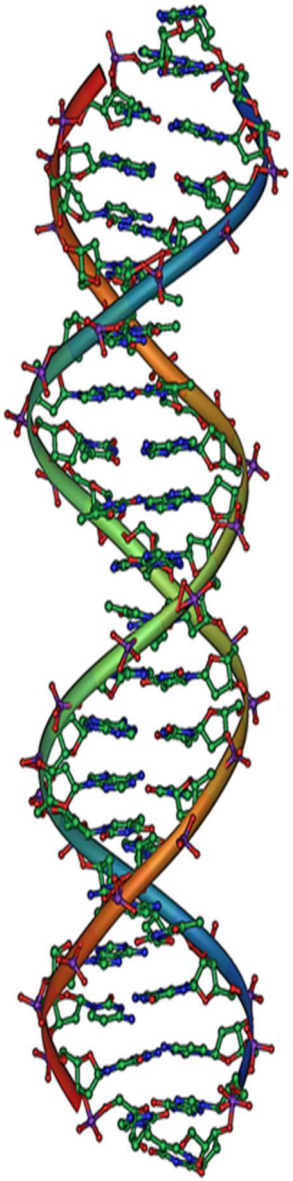


- *Homozygous genes* – genes that are morphologically alike.

  Ex. TT for tall ; tt for short

- *Heterozygous genes* –genes that are morphologically different

  Ex. Tt determines tall trait, one allele for tall trait (T) and another allele for short trait (t)



MENDELIAN LAWS

- **Law of segragation**

  This law states that all the genes for all the traits of an organism are equally divided and are equally distributed in all the resulting gametes after meiosis

- **Law of Independent Assortment**

  This law states that alleles of different genes are distributed randomly to the gametes and fertilization occurs at random

- **Law of complete dominance**

This principle states that a cross between homozygous dominant genes and homozygous recessive genes will result to a progeny of heterozygous genes determining all dominant traits

- **Law of co-dominance**

This principle states that a cross between homozygous dominant genes will result to a progeny of heterozygous genes determining a phenotype where both the dominant trait and recessive trait are expressed.

- **Law of incomplete dominance**

This principle states that a cross between homozygous dominant and recessive genes will result to a progeny of heterozygous genes determining an intermediate trait between the dominant trait and recessive trait. Both alleles exert an effect and jointly produce an intermediate phenotype.

EVOLUTION

- Gradual change in structure and function of an organism based on the changing environment.

Natural Selection- mechanism whereby the genes to be transmitted to the next generation is based on whether these genes determine traits that allow the organisms to cope or be adapted to the present environment

Sources of Changes in the Genes Leading to Evolution

- Positive mutation
- Sexual Reproduction

The result will always be appearance of variations in the next generation