Nucleic Acids

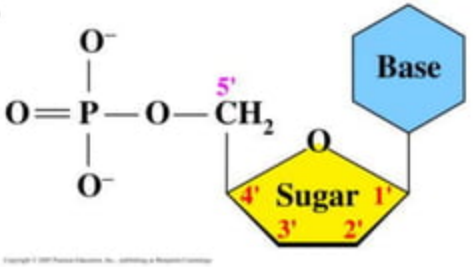
Nucleic acids are:

- molecules that store information for cellular growth and reproduction.
- deoxyribonucleic acid (DNA) and ribonucleic acid (RNA).
- large molecules consisting of long chains of monomers called nucleotides.

Nucleic Acids

The nucleic acids DNA and RNA
consist of monomers called nucleotides that consist of a

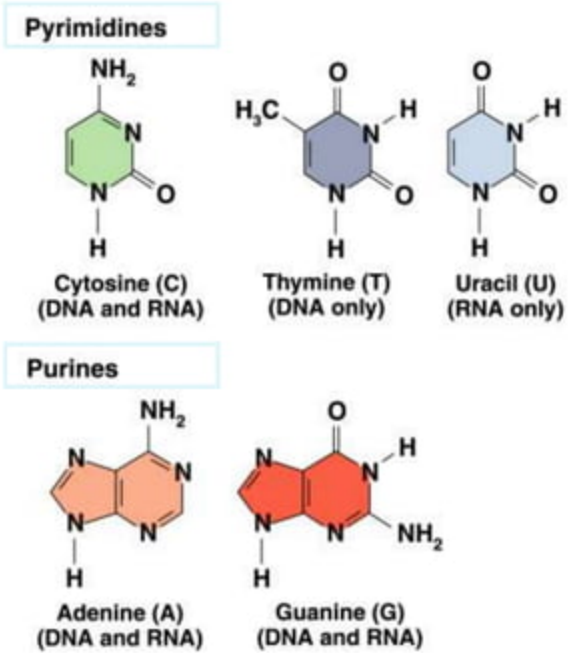
- pentose sugar.
- nitrogen-containing base.
- phosphate.



Nitrogen Bases

The nitrogen bases in DNA and RNA are

- pyrimidines C, T, and U.
- purines A and G.



Nitrogen-Containing Bases in DNA and RNA

DNA contains the nitrogen bases

- Cytosine (C)
- Guanine (G) — *same in both DNA and RNA*
- Adenine (A)
- Thymine (T) — *different in DNA than RNA*

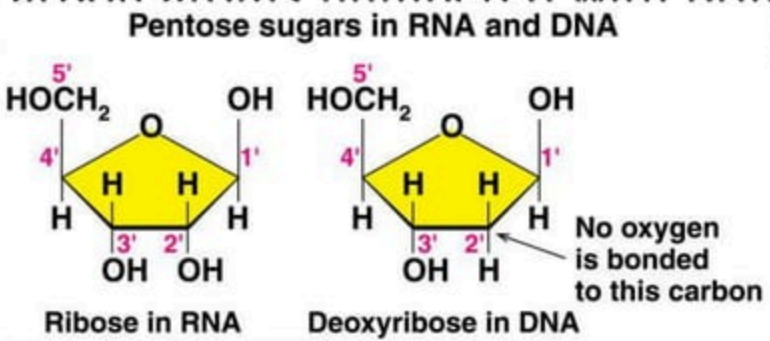
RNA contains the nitrogen bases

- Cytosine (C)
- Guanine (G) — *same in both DNA and RNA*
- Adenine (A)
- Uracil (U) — *different in DNA than RNA*

Pentose Sugars

The pentose (five-carbon) sugar

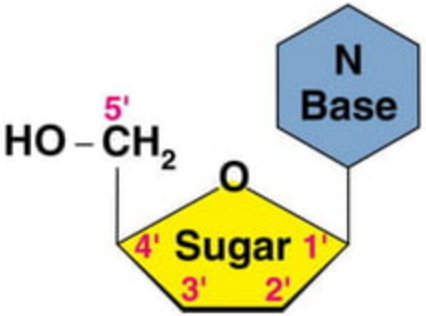
- in RNA is ribose.
- in DNA is deoxyribose with no O atom on carbon 2'.
- has carbon atoms numbered with primes to distinguish them from the numbers assigned to the nitrogen bases.



Nucleosides

A **nucleoside**

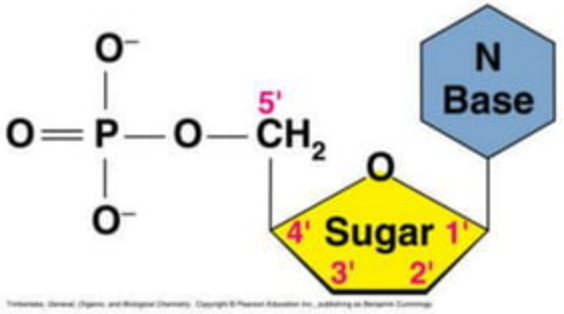
- has a nitrogen base linked by a glycosidic bond to C1' of a sugar (ribose or deoxyribose).
- is named by changing the the nitrogen base ending to -osine for purines and -idine for pyrimidines.



Nucleotides

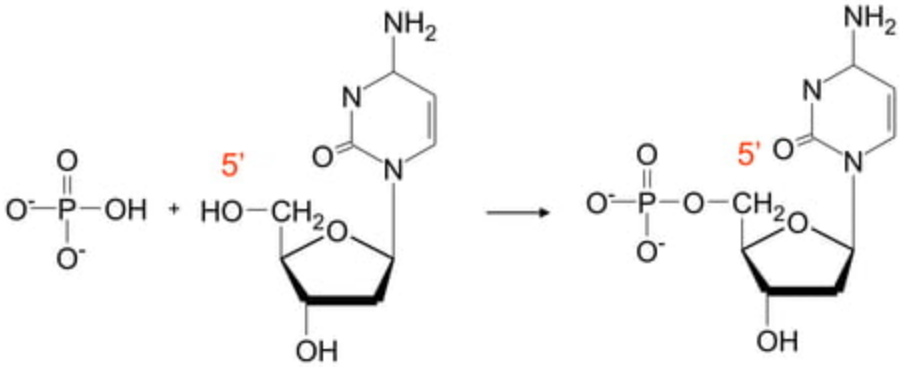
A nucleotide

- is a nucleoside that forms a phosphate ester with the C5' –OH group of a sugar (ribose or deoxyribose).
- is named using the name of the nucleoside followed by 5'-monophosphate.



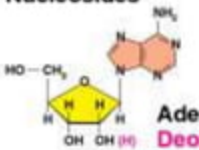
Formation of a Nucleotide

A nucleotide forms when the −OH on C5' of a sugar bonds to phosphoric acid.

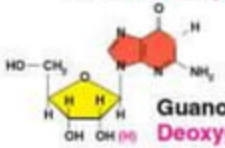


Nucleosides and Nucleotides with Purines

Nucleosides

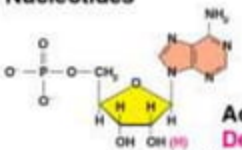


Adenosine
Deoxyadenosine

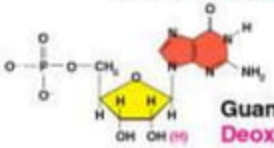


Guanosine
Deoxyguanosine

Nucleotides



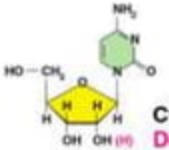
Adenosine 5'-monophosphate (AMP)
Deoxyadenosine 5'-monophosphate (dAMP)



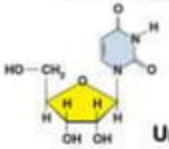
Guanosine 5'-monophosphate (GMP)
Deoxyguanosine 5'-monophosphate (dGMP)

Nucleosides and Nucleotides with Pyrimidines

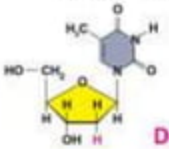
Nucleosides



Cytidine
Deoxycytidine

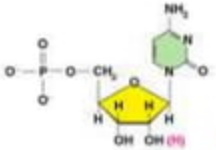


Uridine

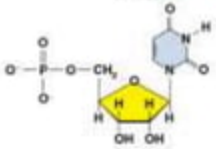


Deoxythymidine

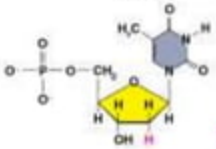
Nucleotides



Cytidine 5'-monophosphate (CMP)
Deoxycytidine 5'-monophosphate (dCMP)



Uridine 5'-monophosphate (UMP)



Deoxythymidine 5'-monophosphate (dTMP)

Names of Nucleosides and Nucleotides

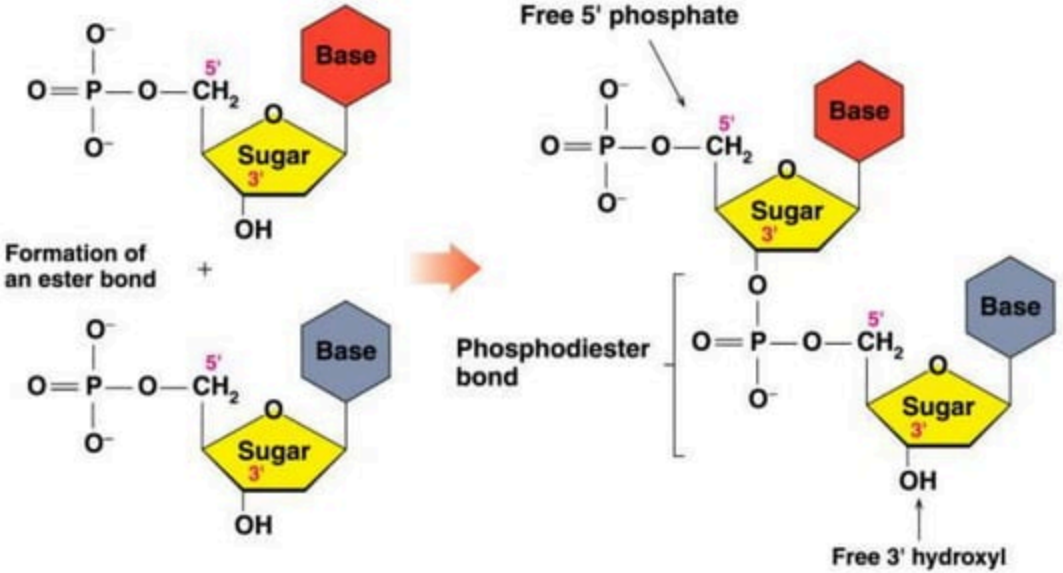
Base	Nucleosides	Nucleotides
RNA		
Adenine (A)	Adenosine (A)	Adenosine 5'-monophosphate (AMP)
Guanine (G)	Guanosine (G)	Guanosine 5'-monophosphate (GMP)
Cytosine (C)	Cytidine (C)	Cytidine 5'-monophosphate (CMP)
Uracil (U)	Uridine (U)	Uridine 5'-monophosphate (UMP)
DNA		
Adenine (A)	Deoxyadenosine (A)	Deoxyadenosine 5'-monophosphate (dAMP)
Guanine (G)	Deoxyguanosine (G)	Deoxyguanosine 5'-monophosphate (dGMP)
Cytosine (C)	Deoxycytidine (C)	Deoxycytidine 5'-monophosphate (dCMP)
Thymine (T)	Deoxythymidine (T)	Deoxythymidine 5'-monophosphate (dTMP)

Primary Structure of Nucleic Acids

In the primary structure of nucleic acids

- nucleotides are joined by phosphodiester bonds.
- the 3'-OH group of the sugar in one nucleotide forms an ester bond to the phosphate group on the 5'-carbon of the sugar of the next nucleotide.

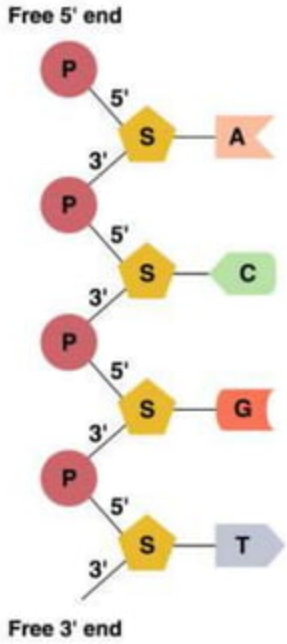
Primary Structure of Nucleic Acids



Structure of Nucleic Acids

A nucleic acid

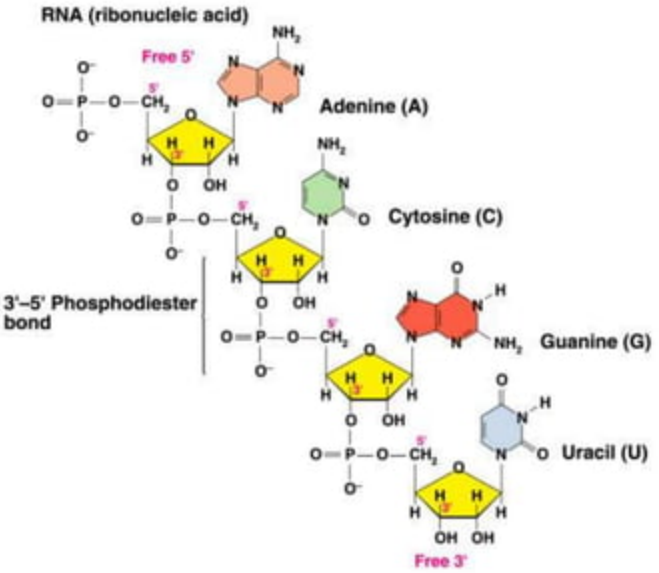
- has a free 5'-phosphate group at one end and a free 3'-OH group at the other end.
- is read from the free 5'-end using the letters of the bases.
- This example reads —A—C—G—T—.



Example of RNA Structure

The primary structure of RNA,

- is a single strand of nucleotides with bases A, C, G, and U.
- is linked by phosophodieste r bonds between ribose and phosphate.

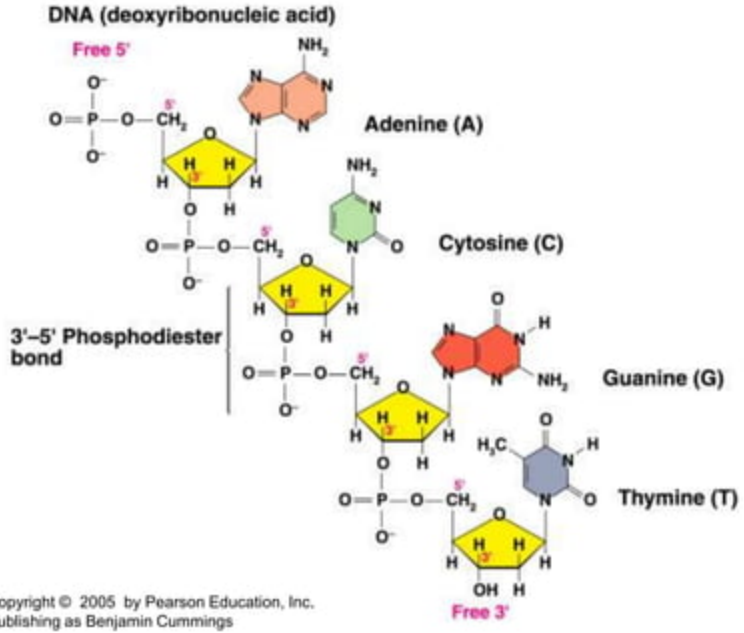


DNA Double Helix

Example of DNA

In DNA,

- nucleotides containing bases A, C, G, and T are linked by ester bonds between deoxyribose sugars and phosphate groups.



DNA Double Helix

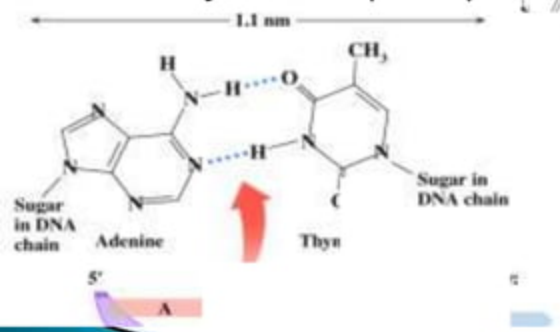
A double helix

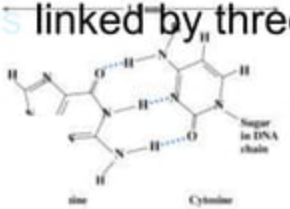
- is the structure of DNA.
- has two strands of nucleotides that wind together.
- is held in place by of two hydrogen bonds that form between the base pairs A–T.
- is held in place by three hydrogen bonds that form between the base pairs G–C.

Complementary Base Pairs

DNA contains complementary base pairs in which

- Adenine is always linked by two hydrogen bonds with thymine (A−T).
- Guanine is always linked by three hydrogen with Cytosine (G−C).

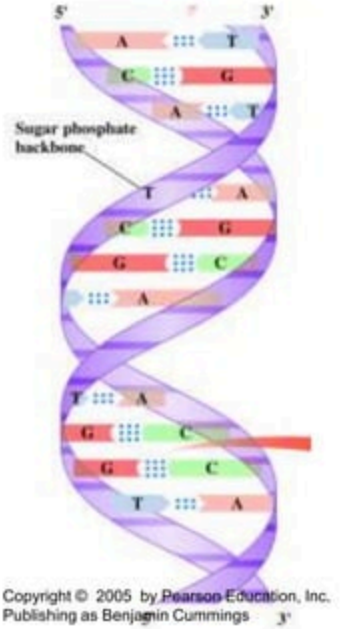




Double Helix of DNA

In the double helix of DNA

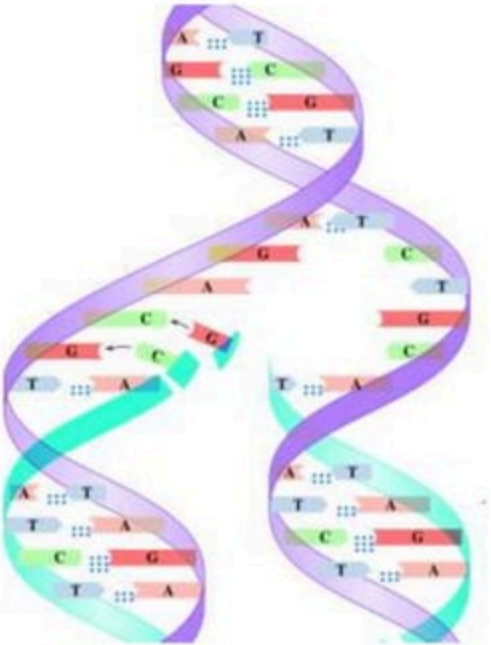
- two strands of nucleotides form a double helix structure like a spiral stair case.
- hydrogen bonds link bases A–T and G–C.
- the bases along one strand complement the bases along the other.



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

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

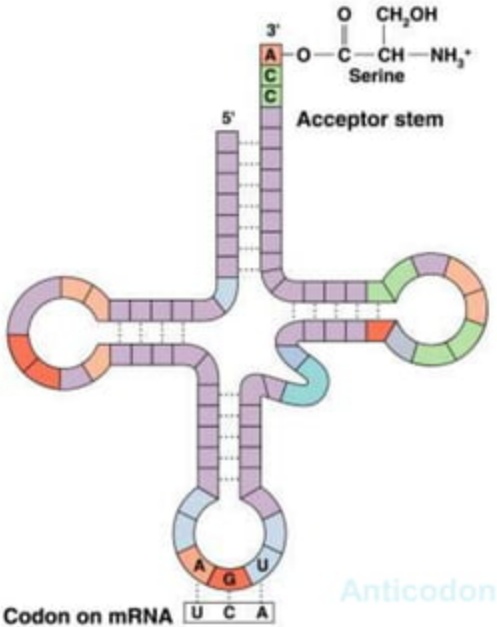
Types of RNA Molecules

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

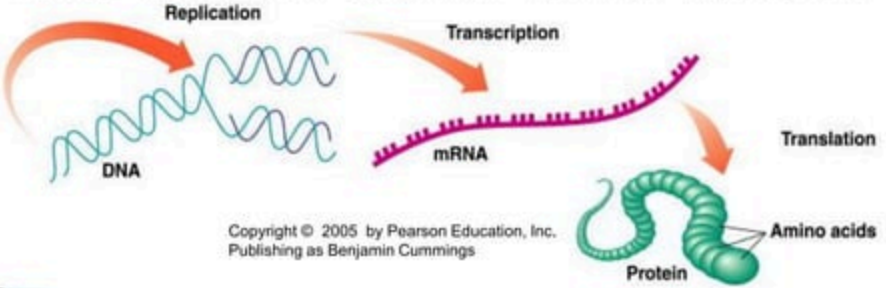
Protein synthesis involves

- transcription

  mRNA is formed from a gene on a DNA strand.

- translation

  tRNA molecules bring amino acids to mR



Transcription: Synthesis of mRNA

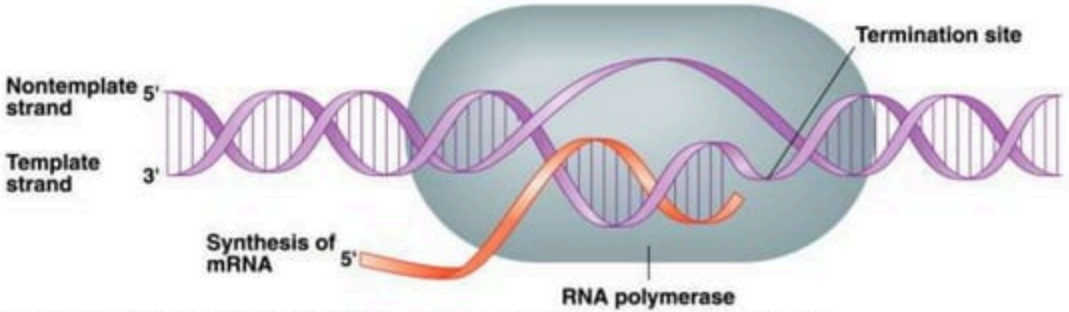
During transcription

- 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.



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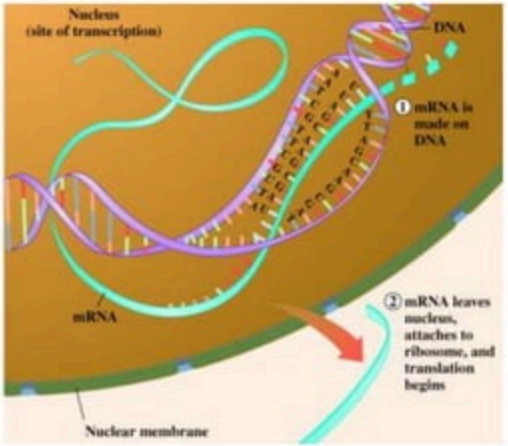
Protein Synthesis: Transcription



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

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
	*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

*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 —

Initiation of Protein Synthesis

For the initiation of protein synthesis

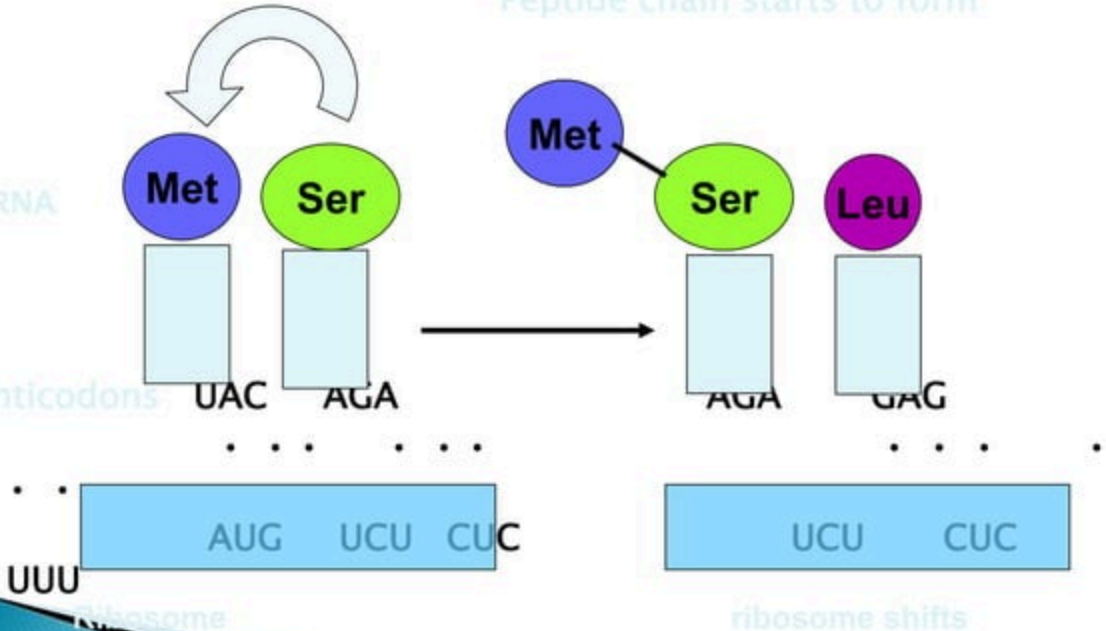
- a mRNA attaches to a ribosome.
- the start codon (AUG) binds to a tRNA with methionine.
- the second codon attaches to a tRNA with the next amino acid.
- a peptide bond forms between the adjacent amino acids at the first and second codons.

Translocation

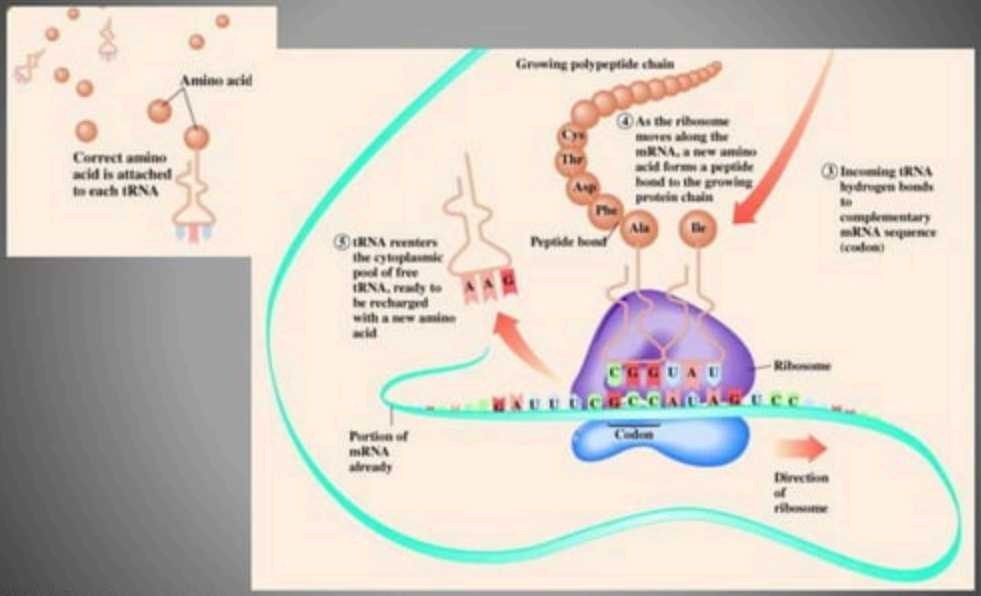
During translocation

- 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

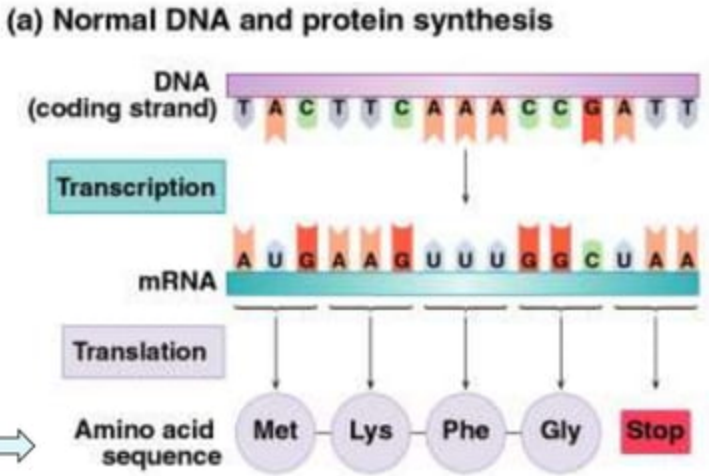
- alter the nucleotide sequence in DNA.
- result from mutagens such as radiation and chemicals.
- produce one or more incorrect codons in mRNA.
- produce a protein containing one or more incorrect amino acids.
- produce defective proteins and enzymes.
- cause genetic diseases.

Examples of Genetic Diseases

Galactosemia
Cystic fibrosis
Downs syndrome
Muscular dystrophy
Huntington's disease
Sickle-cell anemia
Hemophilia
Tay-Sachs disease

Normal DNA Sequence

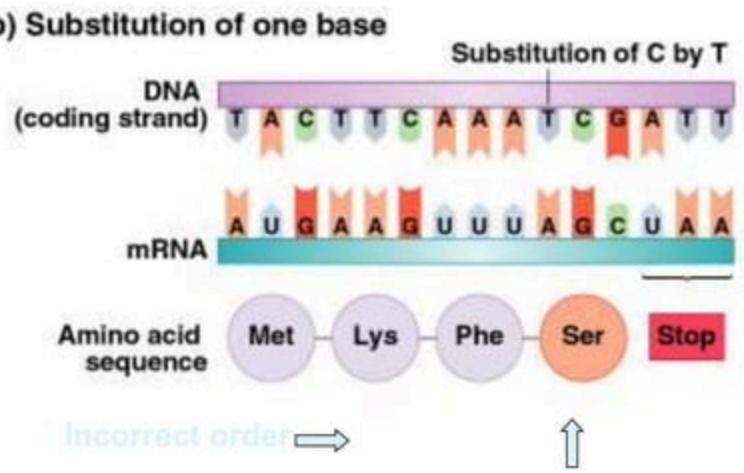
The normal DNA sequence produces a mRNA that provides instructions for the correct series of amino acids in a protein.



Mutation: Substitution

Substitution

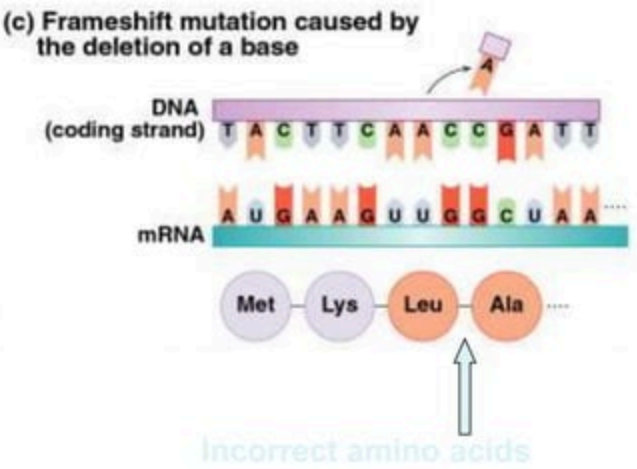
- of a base in DNA changes a codon in the mRNA.
- of a different codon leads to the placement of an incorrect amino acid in the polypeptide.



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.

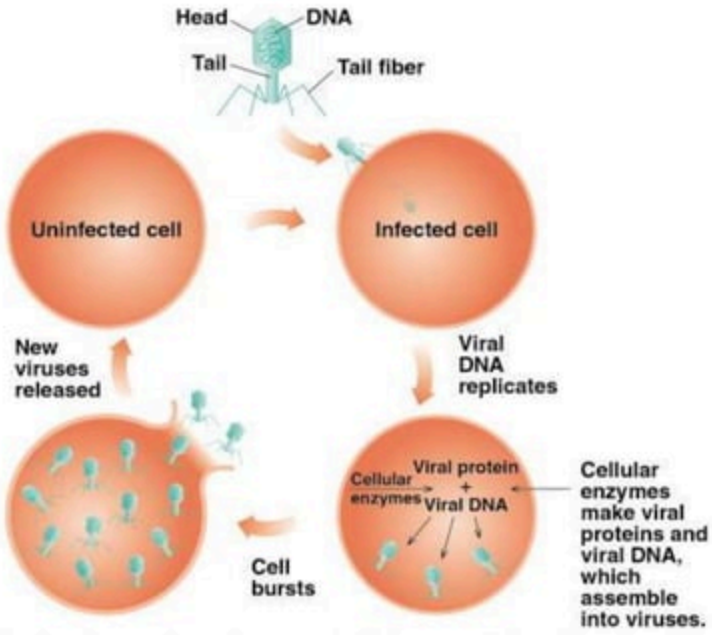


Viruses

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 cell from the viral RNA produced by viral DNA.

Viruses

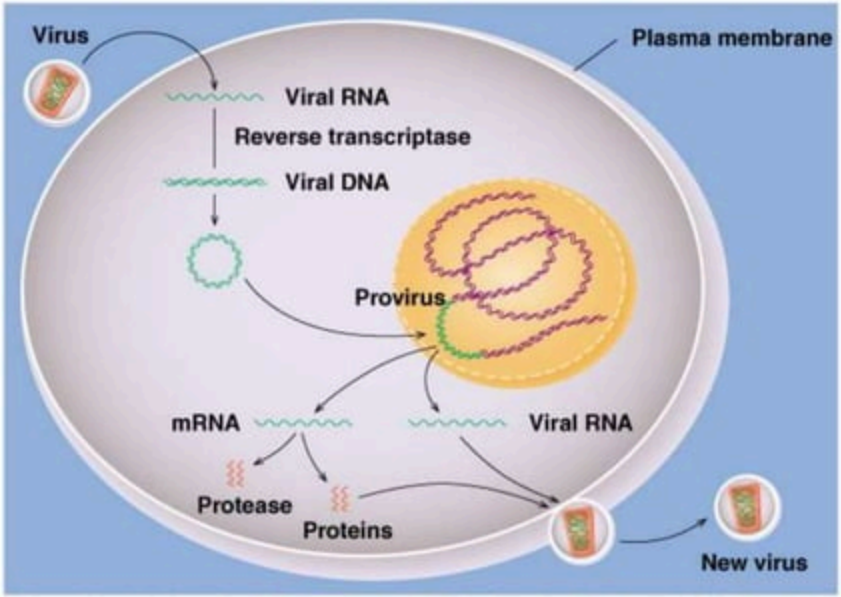

Head
DNA
Tail
Tail fiber
Uninfected cell
Infected cell
New viruses released
Viral DNA replicates
Cellular enzymes
Viral protein
+
Viral DNA
Cellular enzymes make viral proteins and viral DNA, which assemble into viruses.
Cell bursts

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



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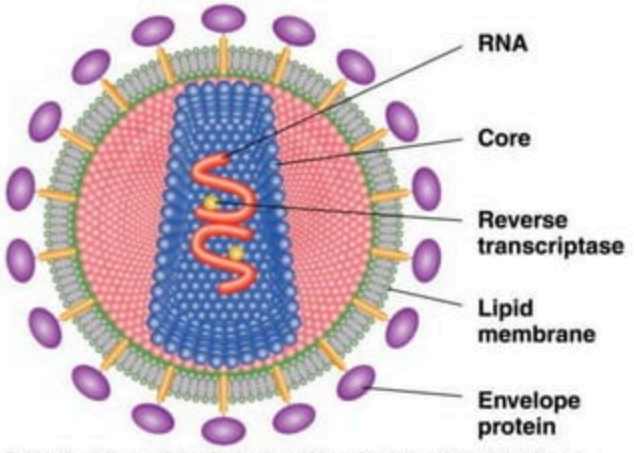
HIV Virus and AIDS

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



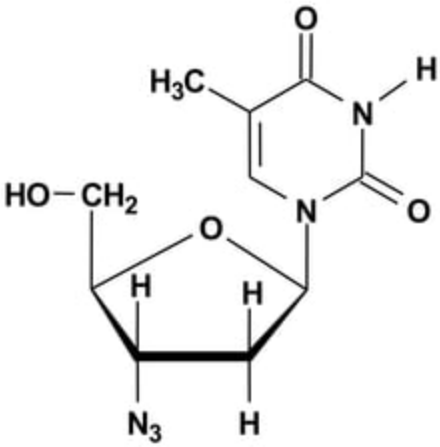
HIV virus

AIDS Treatment

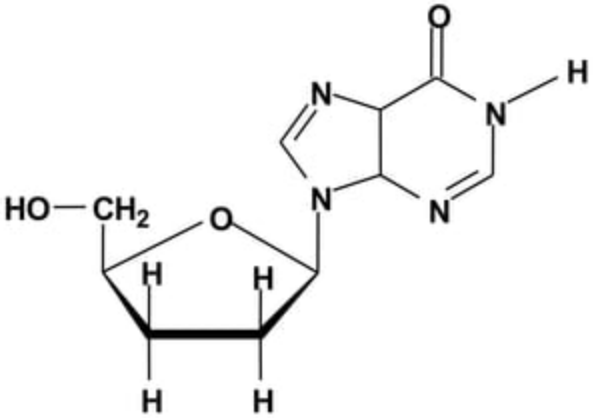
- One type of AIDS treatment prevents reverse transcription of the viral DNA.
- When altered nucleosides such as AZT and ddI are incorporated into viral DNA, the virus is unable to replicate.

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.