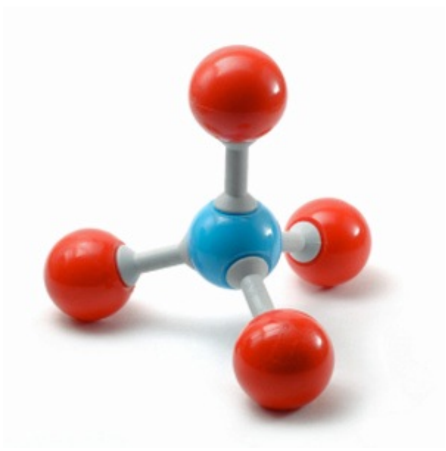
Ch17

Genetic Code

Protein synthesis.

Reading and using the data stored in DNA.

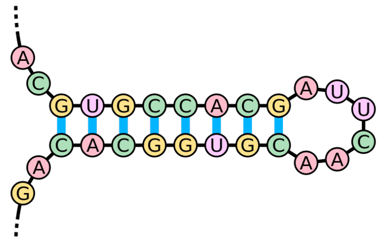


version 1.0

Ch17

Genetic Code

- RNA
  - Differences from DNA
  - Function & Structure
    - Stems & Loops
  - Types of RNA
    - Messenger (mRNA)
    - Transfer (tRNA)
    - Ribosomal (rRNA)



- Protein Synthesis
  - Genes are stored in DNA
  - Transcription
    - Code is written on mRNA
    - Codons / Genetic Code
      - START & STOP signals
      - Amino Acid Codes
  - tRNA
    - Anticodons
    - Structure & Activation
  - Chain Elongation
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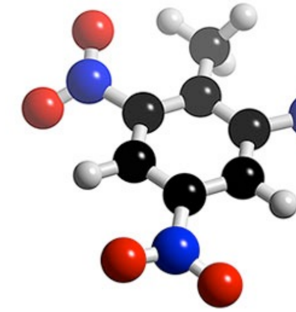
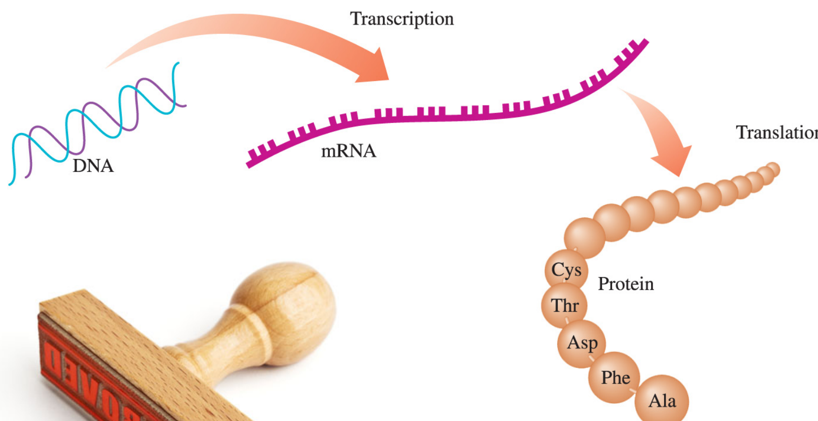
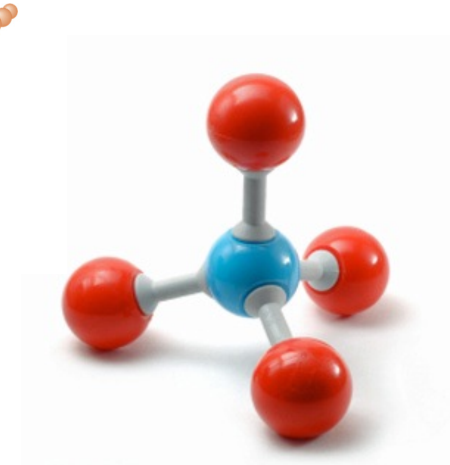


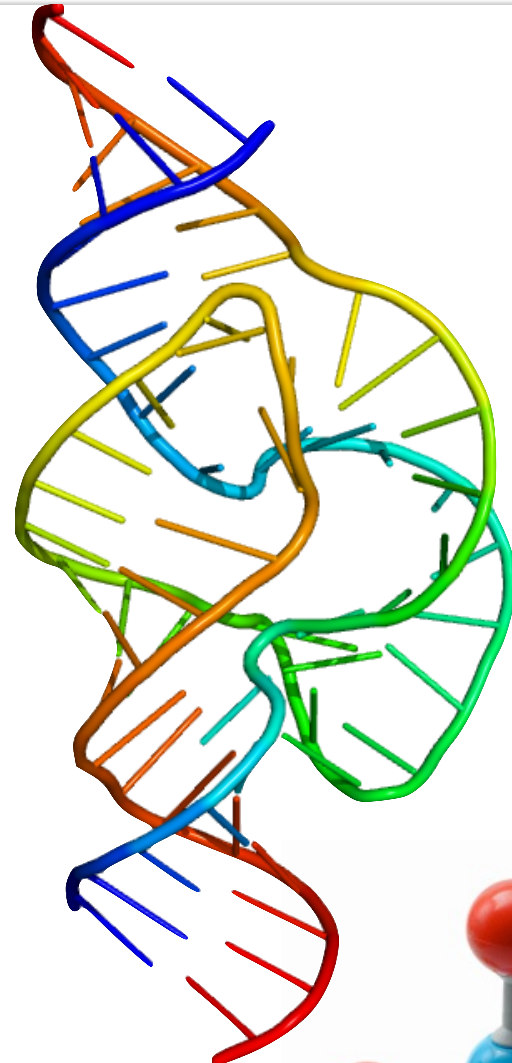




RNA

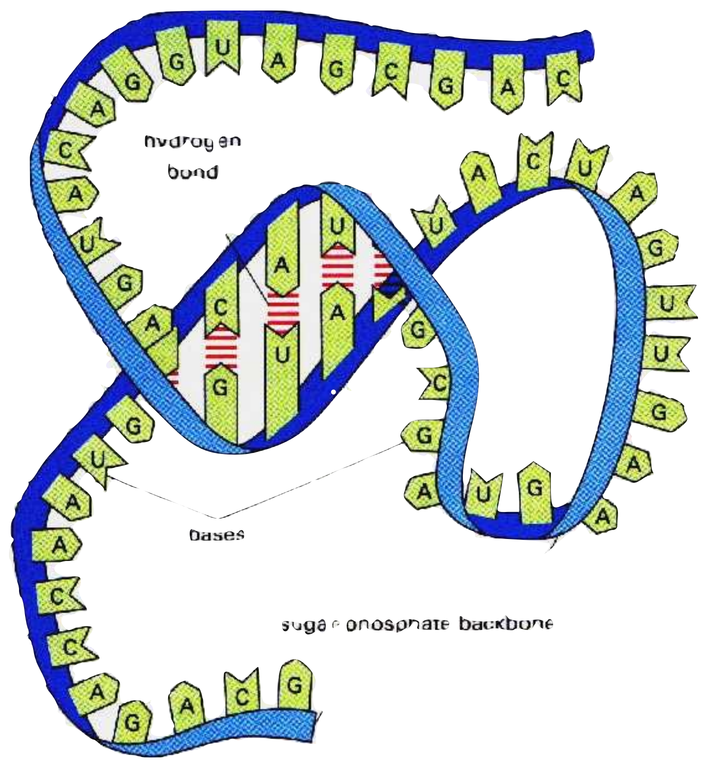
- RNA makes up most of the nucleic acid found in the cell.
- It moves the genetic information needed for cell operation from where it's stored to where it's used.
- RNA molecules are polymers of nucleotides and differ from DNA molecules in four important ways:

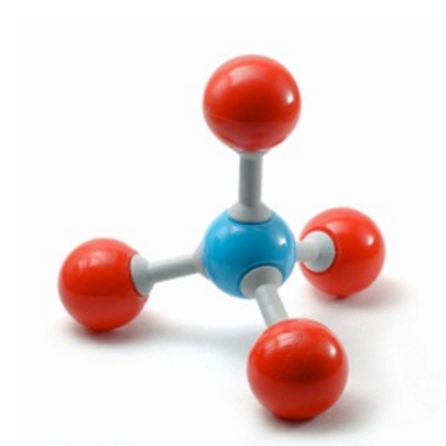
  1. The sugar in RNA is ribose rather than the deoxyribose found in DNA.
  2. The base uracil replaces thymine.
  3. RNA molecules are single stranded; DNA is double stranded.
  4. RNA molecules are much smaller than DNA molecules.



RNA Structure

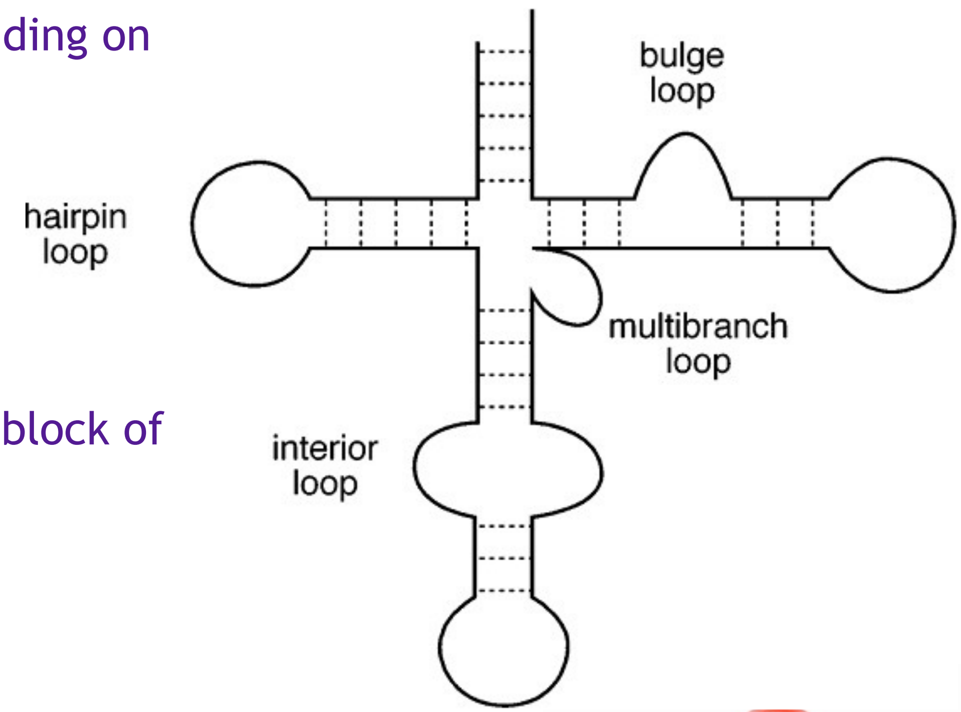
- RNA is a smaller molecule than DNA.
- But it’s still a big molecule, which can fold over on itself.
- Because it is composed of a single strand it’s bases are unpaired.
- The bases can pair with bases elsewhere in the same chain.
- These strong intramolecular interactions between base pairs produce tertiary structures.
- Common tertiary structures include:
  - Stems (intramolecular double helix)
  - Loops

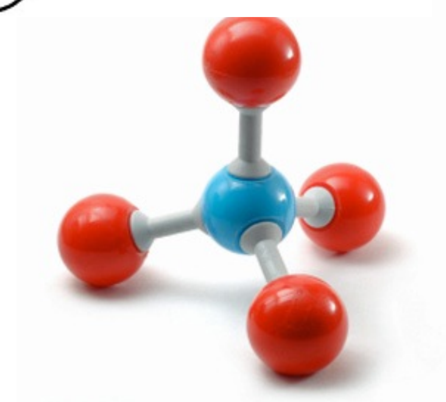


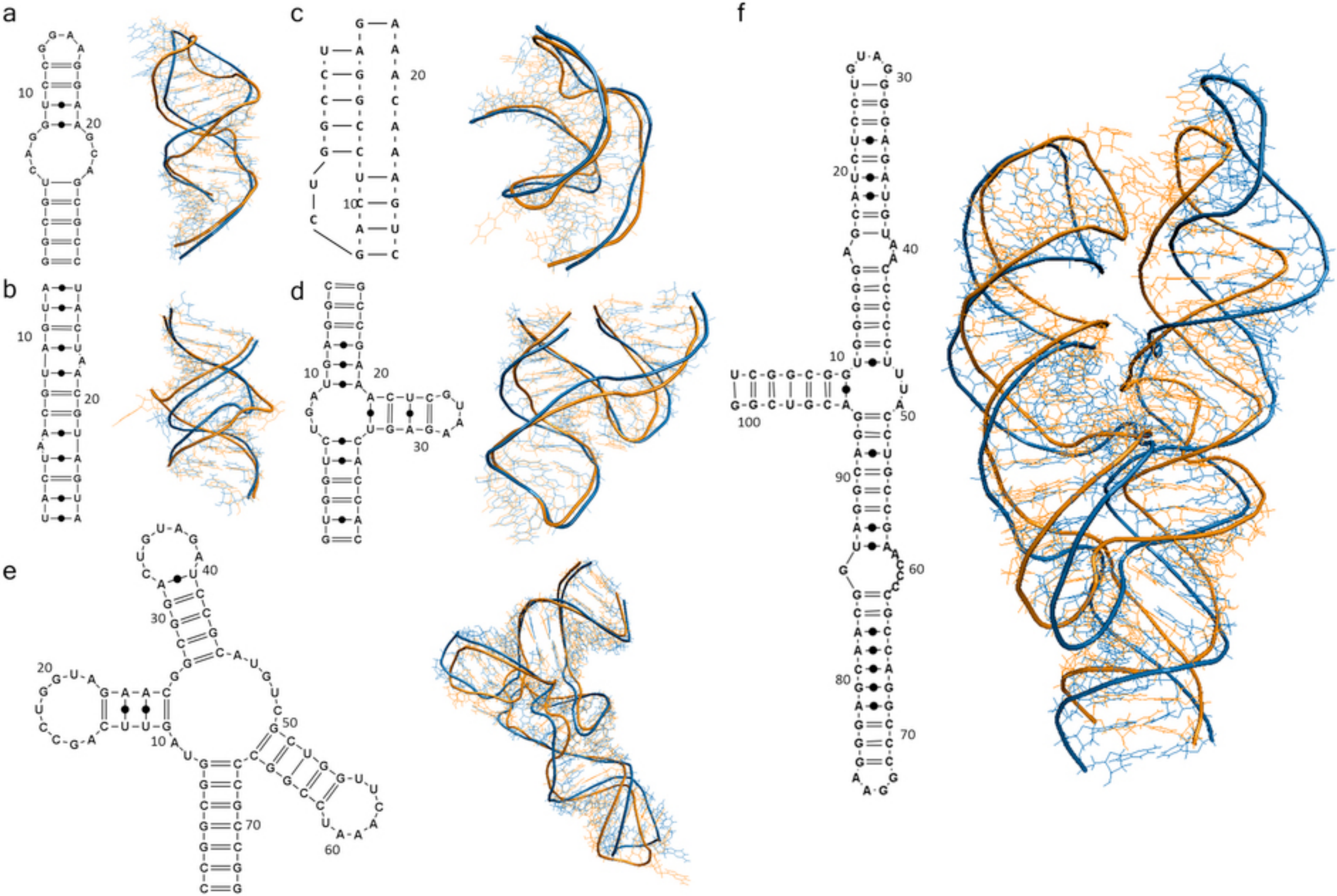


RNA Structure

- Loops occur in RNA when the base pairs on either side of the loop form intramolecular bonds
- There are different kinds of loops depending on their location:
  - Bulge loops
  - Interior loops
  - Multibranch loops
  - Stem loops (or hairpin loops)
- The resulting structure is a key building block of many larger RNA secondary structures.

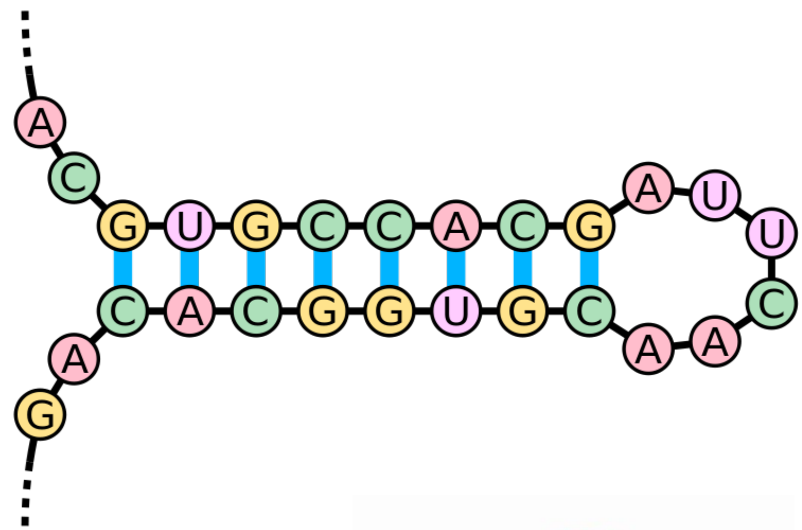


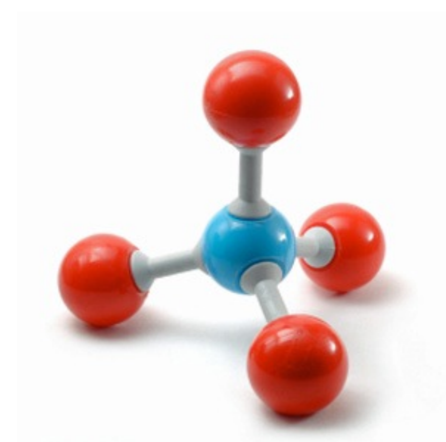



a
b
c
d
e
f

RNA Structure

- Loops can occur in single strand DNA but are much more common in RNA.
- Loops that are less than three bases long have too much ring strain and do not form.
- Large loops with no stem are also unstable.
- Optimal loop length is 4-8 bases long.
- One common loop with the sequence UNCG (N= U, A, C, G) is known as a "tetraloop" and is particularly stable due to the base-stacking interactions of its component nucleotides.
- The three most common loops contain the sequences GNRA, UNCG or CUYG.

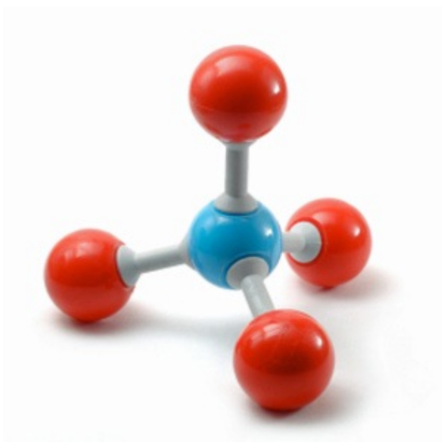




Three types of RNA

- RNA transmits information from DNA to make proteins and has several types:
- Messenger RNA (mRNA) carries genetic information from DNA in the nucleus to the ribosomes in the cytoplasm.
- Transfer RNA (tRNA) interprets the genetic information in mRNA and brings specific amino acids to the ribosome for protein synthesis.
- Ribosomal RNA (rRNA), the most abundant type of RNA, is combined with proteins to form ribosomes.

Type	Abbreviation	Function in the Cell	Percentage of Total RNA
Ribosomal RNA	rRNA	Synthesizes protein; major component of the ribosomes	80
Messenger RNA	mRNA	Carries information for protein synthesis from the DNA in the nucleus to the ribosomes	5
Transfer RNA	tRNA	Brings amino acids to the ribosomes for protein synthesis	15



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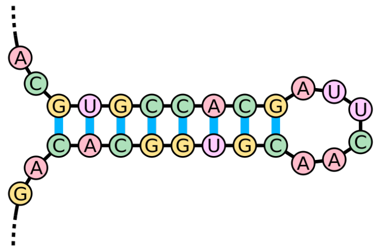

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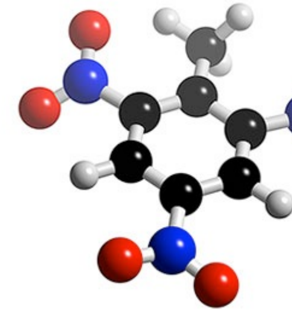
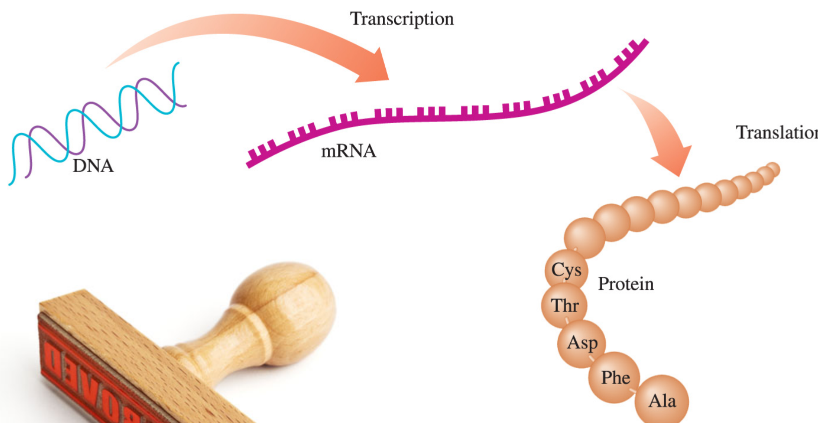
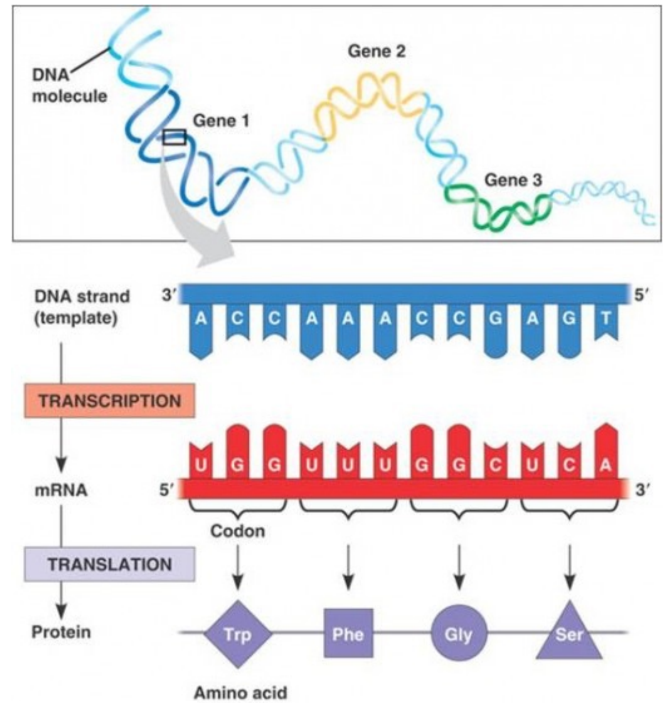
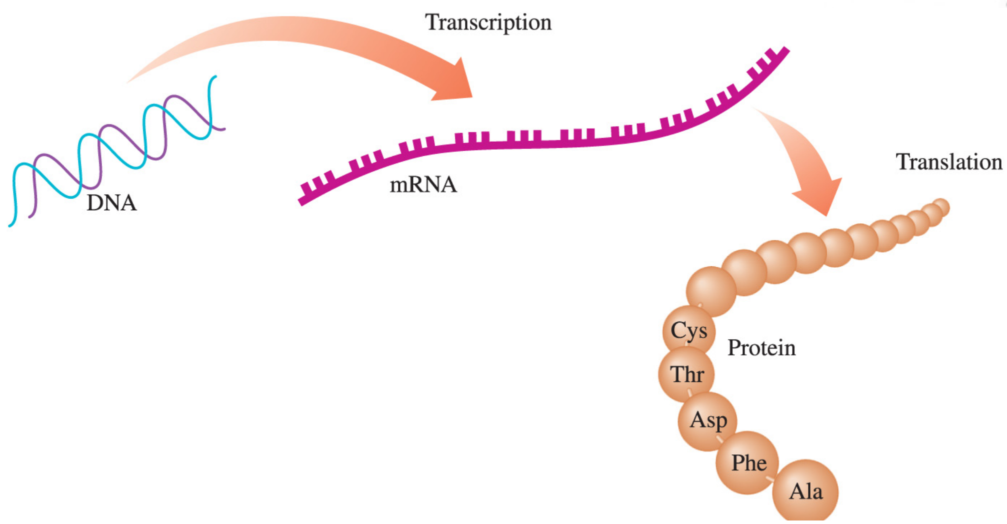


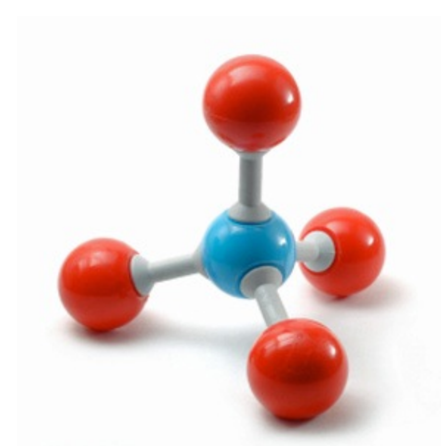


Protein Synthesis

- A gene is a section of one strand of DNA that has the sequence needed to build a specific peptide.
- That sequence get's copied into messenger RNA (mRNA) by the process of transcription.
- The messenger RNA brings that information to the ribosomes.
- The ribosomes build the amino acid from the sequence by the process of translation.
- We'll look at those two processes one at a time.

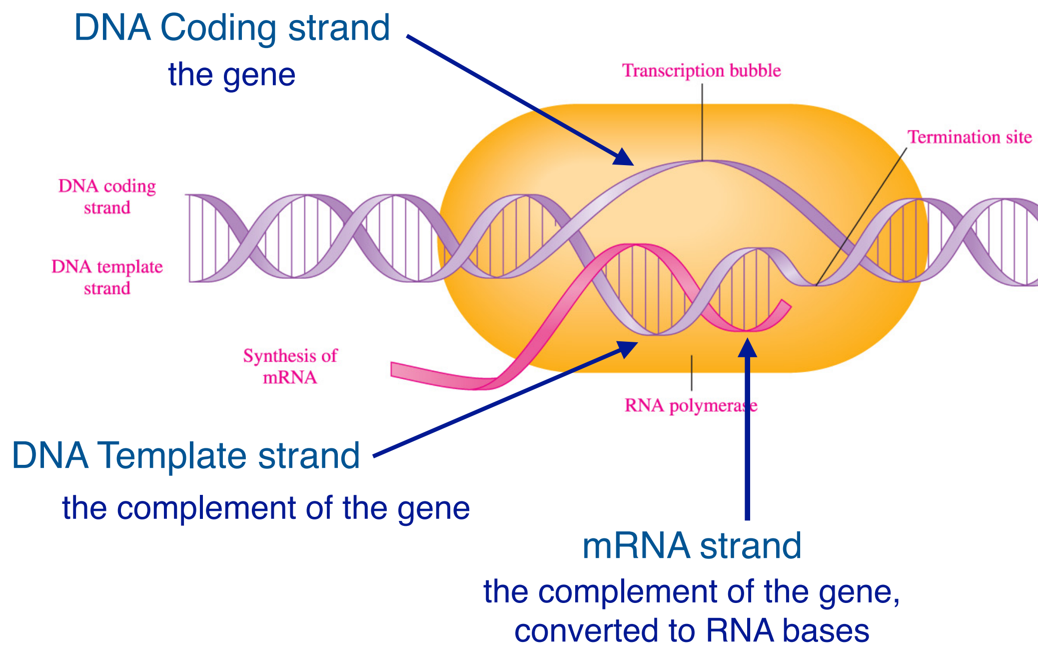




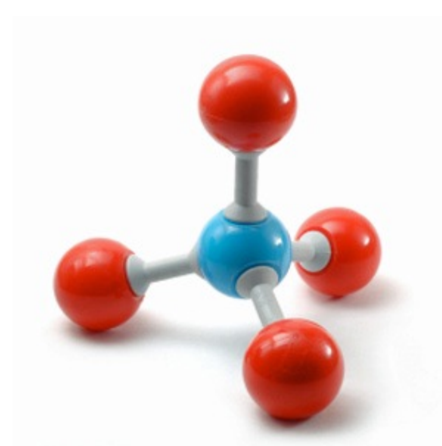


Protein Synthesis

- Transcription involves building a new mRNA molecule based on the gene information in DNA.
- The mRNA is built by the enzyme mRNA polymerize.
- mRNA is synthesized using complementary base pairing
  - Cytosine (C) and guanine (G) pair to each other in DNA and RNA.
  - DNA adenine (A) pairs with RNA uridine (U)
  - DNA thymine (T) paris with RNA adenine (A)

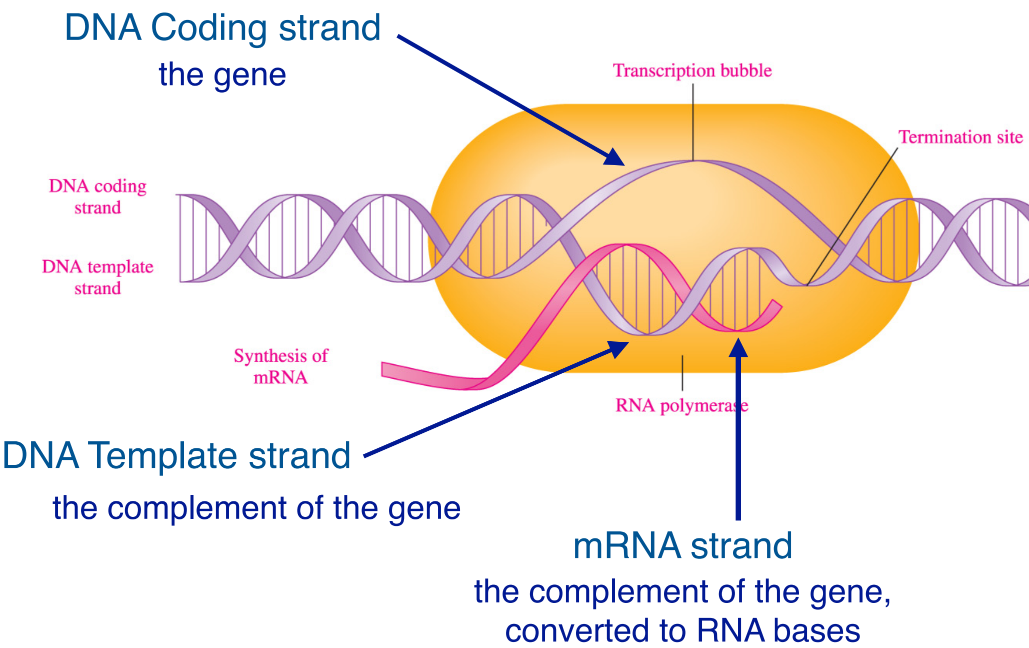


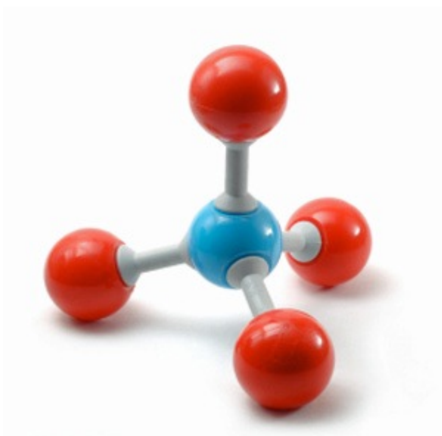
DNA side		RNA side
C	→	G
G	→	C
A	→	U
T	→	A



Protein Synthesis

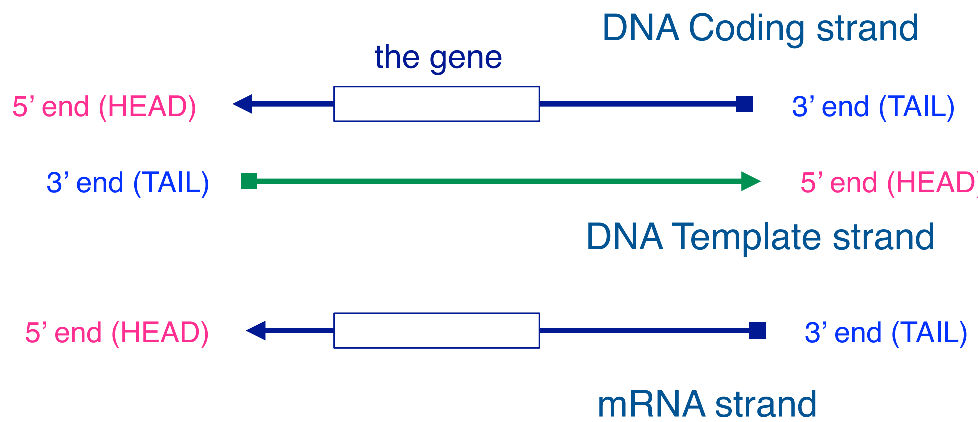
- Transcription involves three strands of nucleic acid.
  - The DNA coding strand.
    - This is the strand which contains the sequence defined as the gene.
  - The DNA template strand.
    - This is the complementary sequence to the gene.
    - mRNA reads from this strand, the one opposite the gene.
  - The mRNA strand.
    - The mRNA strand is built with bases that complement the template strand.

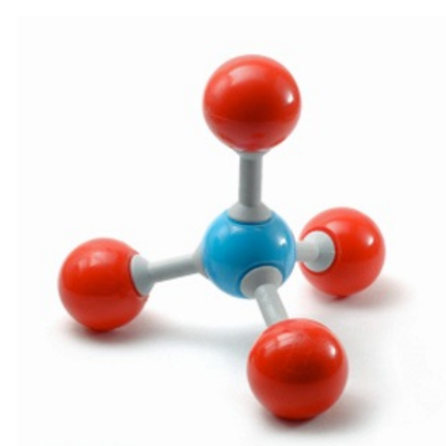




Protein Synthesis

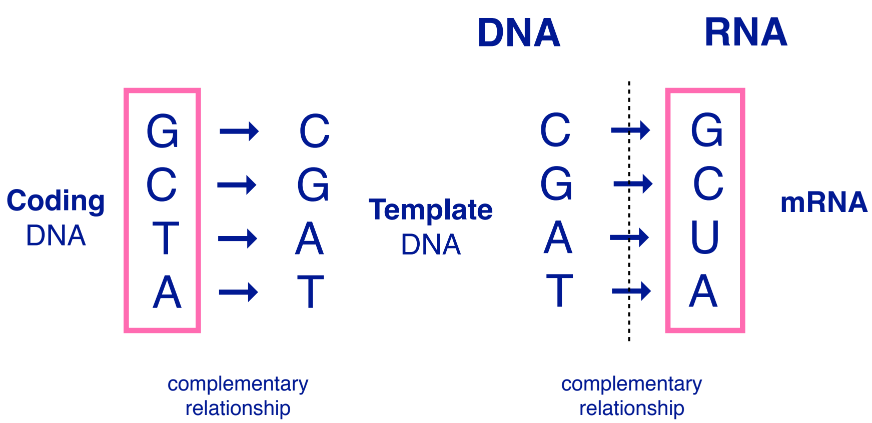
- Each pair of interacting strands run in opposite directions.
  - The DNA coding strand and DNA template strand run head to tail.
    - The 5’ end of one matches to the 3’ of the other.
  - The DNA template strand and mRNA strand run head to tail.
    - The 5’ end of one matches to the 3’ of the other.
- That means going from the gene to the mRNA strand, the directions are reversed *twice*.
- The sequence in the gene and in the mRNA strand run in the same direction.

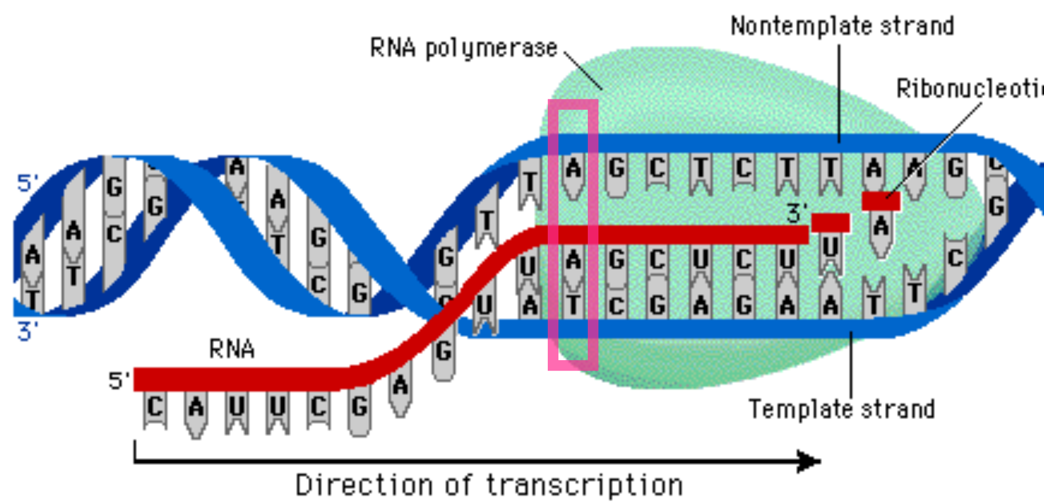


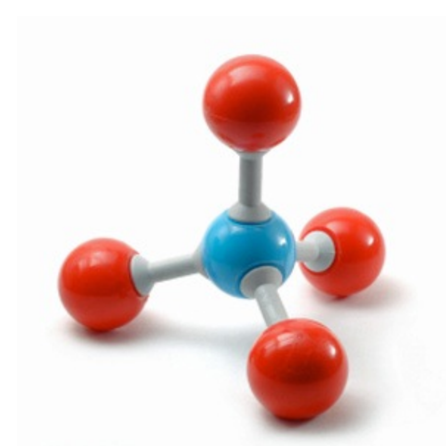


Protein Synthesis

- Because base pairs are complimentary in both processes, the gene expressed in the mRNA is the same as the gene expressed in the coding DNA.
  - EXCEPT: <u>T in DNA becomes U in RNA</u>







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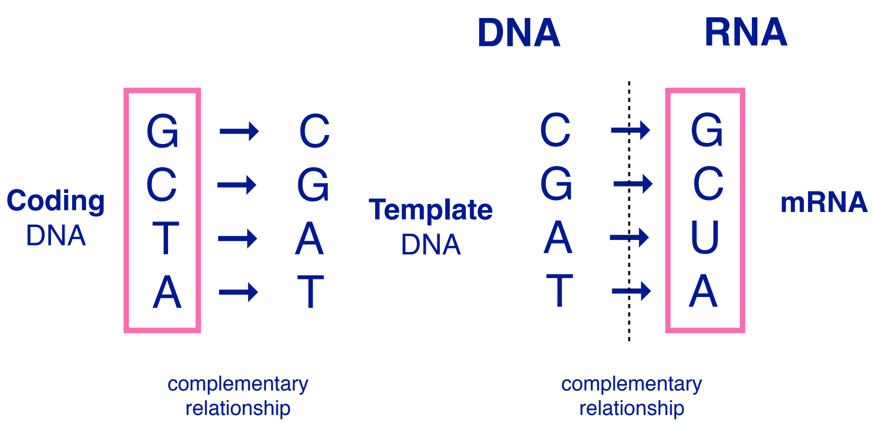


DNA Coding strand

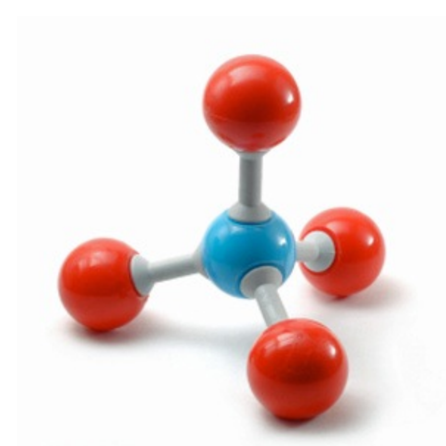
5' — A — G — C — T — C — 3'

DNA Template strand

3' — T — C — G — A — G — 5'

mRNA strand

5' — A — G — C — U — C — 3'



Try it.

- Given this section of template DNA what sequence of mRNA is produced?

DNA
side

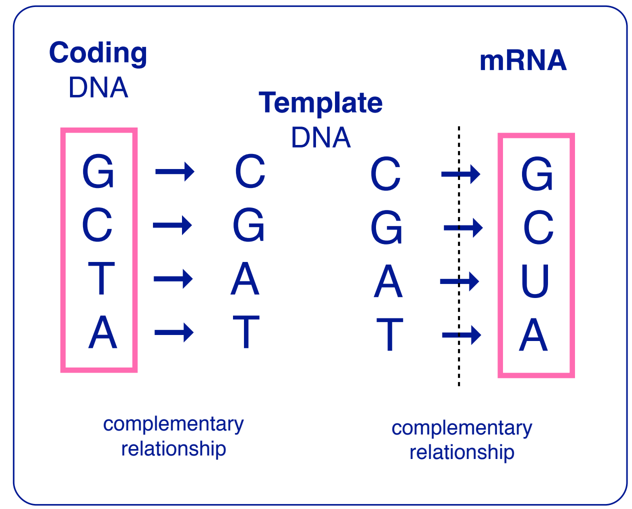
— C — T — A — A — G — G —

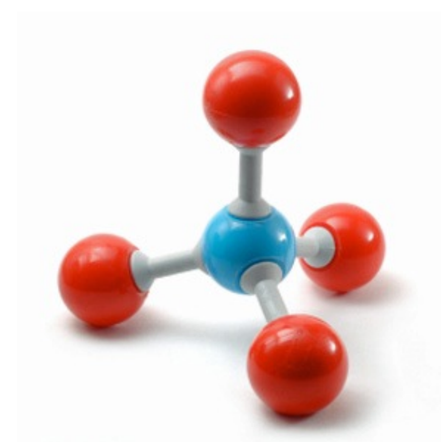
A. — G — A — T — T — C — C —

B. — G — A — U — U — C — C —

C. — C — U — A — A — G — G —

RNA
side





Try it.

- Given this Gene what sequence of mRNA is produced?
  (the gene is in the coding DNA)

DNA
side

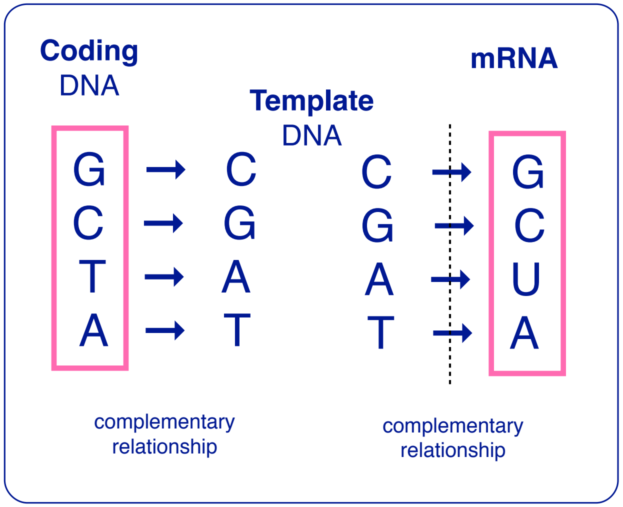
— C — T — A — A — G — G —

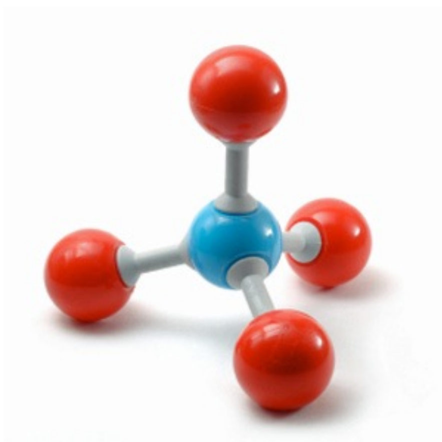
A. — G — A — T — T — C — C —

B. — G — A — U — U — C — C —

C. — C — U — A — A — G — G —

RNA
side





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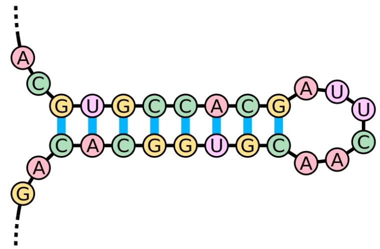

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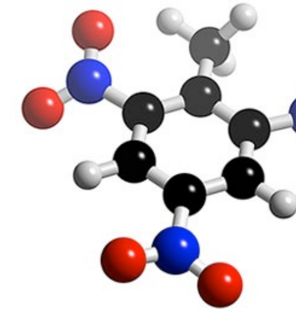
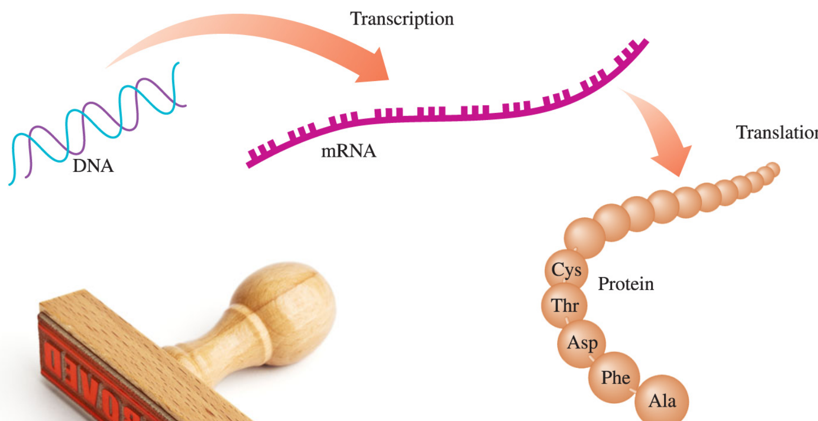




Reading Genetic Code

- Three nucleotides in a row is a triplet.
- Some combinations of nucleotides in a triplet specify an amino acid or instruction.
  - Codons are combinations that mean specific actions or amino acids.
- Codons of genetic code are like bytes of computer code.

a computer says “01001000” → this means “H”

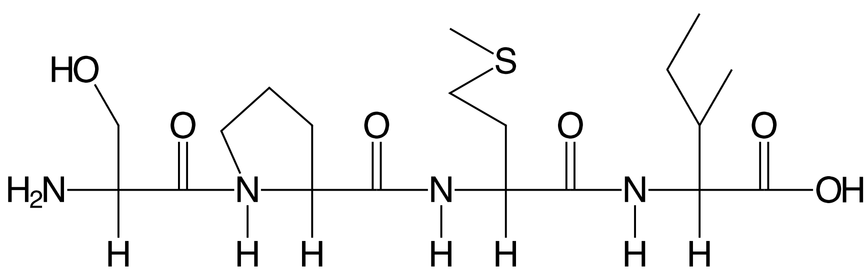
a computer says “01100101” → this means “e”

“0100100001100101011011000110110001101111” is “Hello”

mRNA says “UCA” → this means Serine

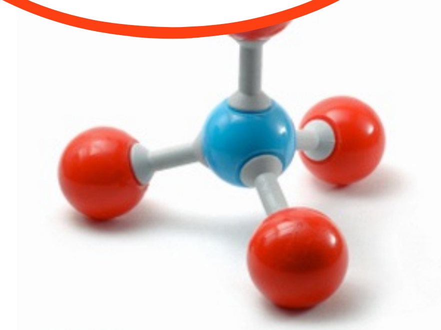
mRNA says “CCG” → this means Proline

“UCACCGAUGAUA” is “Serine Proline Methionine Isoleucine ”



Binary Bits	Character
01001000	H
01100101	e
01101100	l
01101100	l
01101111	o
00100000	space
01001010	J
01101111	o
01110011	s
01101000	h
[illegible]	[illegible]
[illegible]	[illegible]

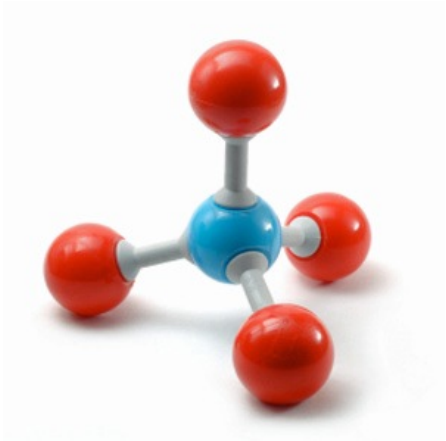
An amino acid can have more than one codon:
UCA means Serine
UCC also means Serine



Reading Genetic Code

- Three nucleotides in a row is a triplet.
- Some combinations of nucleotides in a triplet specify an amino acid or instruction.
    - Codons are combinations that mean specific actions or amino acids.
- Other codons are instructions on how to use those amino acids.
    - The beginning of a mRNA sequence is called the 5' UTR (untranslated region).
    - The UTR has some information specific to different kinds of cell processes.
    - At some point a AUG byte is introduced. AUG means Methionine.
    - The first methionine encountered tells the ribosomes to start building with the next codon.
        - This is the START codon.
    - What follows is the blue print, the sequence or primary structure, for a specific protein.
    - When that's complete the file is ended with either UAA, UAG, or UGA.
        - This is the STOP codon.

Binary Bits	Character
01001000	H
01100101	e
01101100	l
01101100	l
01101111	o
00100000	space
01001010	J
01101111	o
01110011	s
01101000	h
01110101	u
01100001	a



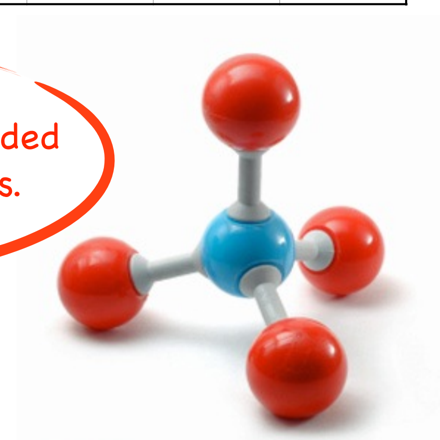
Reading Genetic Code

- A total of 64 codons are possible from the triplet combinations of A, G, C, and U.
- Codons have been determined for all 20 amino acids needed to build a protein.
- At the beginning of mRNA, the codon AUG signals the start of protein synthesis.
- A codon stop signal of UGA, UAA, and UAG in mRNA signals for the termination of protein synthesis.

mRNA Codon to Amino Acid Translation

	U		C		A		G	
U	UUU	PHE (F)	UCU	SER (S)	UAU	TYR (Y)	UGU	CYS (C)
	UUC		UCC		UAC		UGC	
	UUA	LEU (L)	UCA		UAA	STOP	UGA	STOP
	UUG		UCG		UAG		UGG	TRP (W)
C	CUU	LEU (L)	CCU	PRO (P)	CAU	HIS (H)	CGU	ARG (R)
	CUC		CCC		CAC		CGC	
	CUA		CCA		CAA	GLN (Q)	CGA	
	CUG		CCG		CAG		CGG	
A	AUU	ILE (I)	ACU	THR (T)	AAU	ASN (N)	AGU	SER (S)
	AUC		ACC		AAC		AGC	
	AUA		ACA		AAA	LYS (K)	AGA	ARG (R)
	AUG	MET (M)	ACG		AAG		AGG	
G	GUU	VAL (V)	GCU	ALA (A)	GAU	ASP (D)	GGU	GLY (G)
	GUC		GCC		GAC		GGC	
	GUA		GCA		GAA	GLU (E)	GGA	
	GUG		GCG		GAG		GGG	

This table will be provided on exams and quizzes.



Try it.

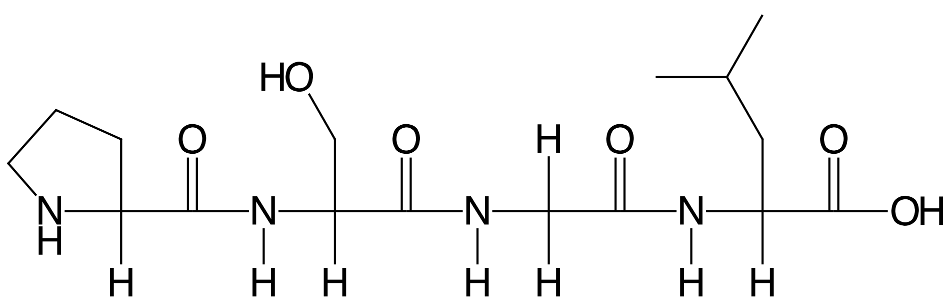
- Determine the amino acids from the following codons in a section of mRNA.

— CCUAGCGGACUU —

— CCU — AGC — GGA — CUU —

Pro Ser Gly Leu

— Pro — Ser — Gly — Leu —



mRNA Codon to Amino Acid Translation

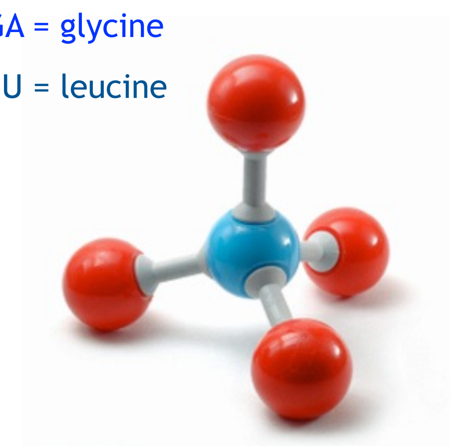
	U		C		A		G	
U	UUU	PHE (F)	UCU	SER (S)	UAU	TYR (Y)	UGU	CYS (C)
	UUC		UCC		UAC		UGC	
	UUA	LEU (L)	UCA		UAA	STOP	UGA	STOP
	UUG		UCG		UAG		UGG	TRP (W)
C	CUU	LEU (L)	CCU	PRO (P)	CAU	HIS (H)	CGU	ARG (R)
	CUC		CCC		CAC		CGC	
	CUA		CCA		CAA	GLN (Q)	CGA	
	CUG		CCG		CAG		CGG	
A	AUU	ILE (I)	ACU	THR (T)	AAU	ASN (N)	AGU	SER (S)
	AUC		ACC		AAC		AGC	
	AUA		ACA		AAA	LYS (K)	AGA	ARG (R)
	AUG	MET (M)	ACG		AAG		AGG	
G	GUU	VAL (V)	GCU	ALA (A)	GAU	ASP (D)	GGU	GLY (G)
	GUC		GCC		GAC		GGC	
	GUA		GCA		GAA	GLU (E)	GGA	
	GUG		GCG		GAG		GGG	

CCU = proline

AGC = serine

GGA = glycine

CUU = leucine



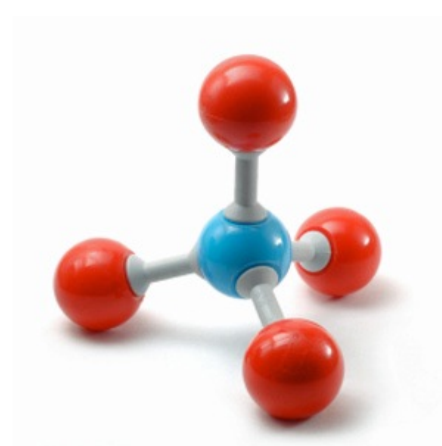
Try it.

- Given the following DNA sequence, what is the first amino acid in the gene?

GGGACAGAATGTGTTGCAGGAACTTC
TTCTGGAAGACCTTCTCCTCCTGCAA
ATAAAACCTCACCCATGAATGCTCACG
CAAGTTTAATTACAGACCTGAA

mRNA Codon to Amino Acid Translation

	U		C		A		G	
U	UUU	PHE (F)	UCU	SER (S)	UAU	TYR (Y)	UGU	CYS (C)
	UUC		UCC		UAC		UGC	
	UUA	LEU (L)	UCA		UAA	STOP	UGA	STOP
	UUG		UCG		UAG		UGG	TRP (W)
C	CUU	LEU (L)	CCU	PRO (P)	CAU	HIS (H)	CGU	ARG (R)
	CUC		CCC		CAC		CGC	
	CUA		CCA		CAA	GLN (Q)	CGA	
	CUG		CCG		CAG		CGG	
A	AUU	ILE (I)	ACU	THR (T)	AAU	ASN (N)	AGU	SER (S)
	AUC		ACC		AAC		AGC	
	AUA		ACA		AAA	LYS (K)	AGA	ARG (R)
	AUG	MET (M)	ACG		AAG		AGG	
G	GUU	VAL (V)	GCU	ALA (A)	GAU	ASP (D)	GGU	GLY (G)
	GUC		GCC		GAC		GGC	
	GUA		GCA		GAA	GLU (E)	GGA	
	GUG		GCG		GAG		GGG	



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GGGACAGAATGTGTTGCAGGAACTTC
TTCTGGAAGACCTTCTCCTCCTGCAA
ATAAAACCTCACCCATGAATGCTCACG
CAAGTTTAATTACAGACCTGAA

start code in RNA is 'AUG'

start code in the coding strand of DNA is 'ATG'

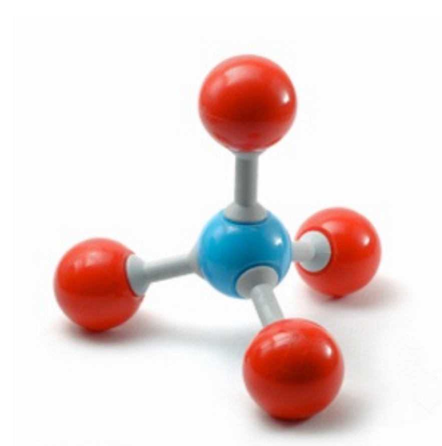
the first codon in DNA after that is 'TGT'

this corresponds to the RNA codon 'UGU'

this is the codon for Cysteine.

mRNA Codon to Amino Acid Translation

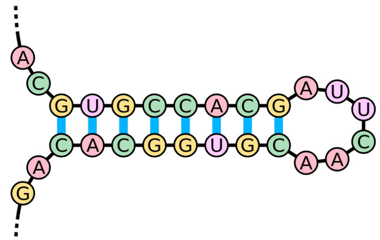
	U		C		A		G	
U	UUU	PHE (F)	UCU	SER (S)	UAU	TYR (Y)	UGU	CYS (C)
	UUC		UCC		UAC		UGC	
	UUA	LEU (L)	UCA		UAA	STOP	UGA	STOP
	UUG		UCG		UAG		UGG	TRP (W)
C	CUU	LEU (L)	CCU	PRO (P)	CAU	HIS (H)	CGU	ARG (R)
	CUC		CCC		CAC		CGC	
	CUA		CCA		CAA	GLN (Q)	CGA	
	CUG		CCG		CAG		CGG	
A	AUU	ILE (I)	ACU	THR (T)	AAU	ASN (N)	AGU	SER (S)
	AUC		ACC		AAC		AGC	
	AUA		ACA		AAA	LYS (K)	AGA	ARG (R)
	AUG	MET (M)	ACG		AAG		AGG	
G	GUU	VAL (V)	GCU	ALA (A)	GAU	ASP (D)	GGU	GLY (G)
	GUC		GCC		GAC		GGC	
	GUA		GCA		GAA	GLU (E)	GGA	
	GUG		GCG		GAG		GGG	



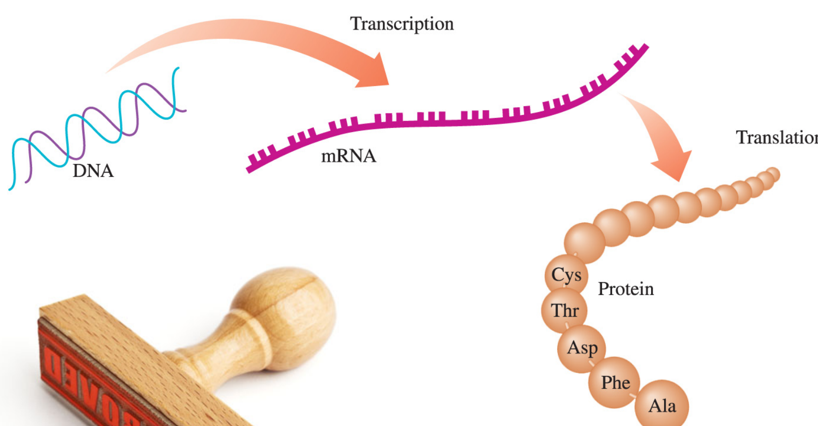
Ch17

Genetic Code

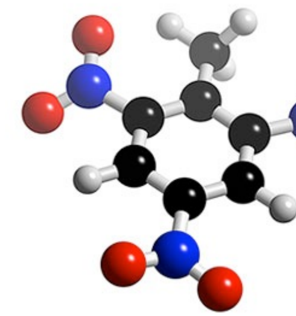
- RNA
  - Differences from DNA
  - Function & Structure
    - Stems & Loops
  - Types of RNA
    - Messenger (mRNA)
    - Transfer (tRNA)
    - Ribosomal (rRNA)



- Protein Synthesis
  - Genes are stored in DNA
  - Transcription
    - Code is written on mRNA
    - Codons / Genetic Code
      - START & STOP signals
      - Amino Acid Codes
  - tRNA
    - Anticodons
    - Structure & Activation

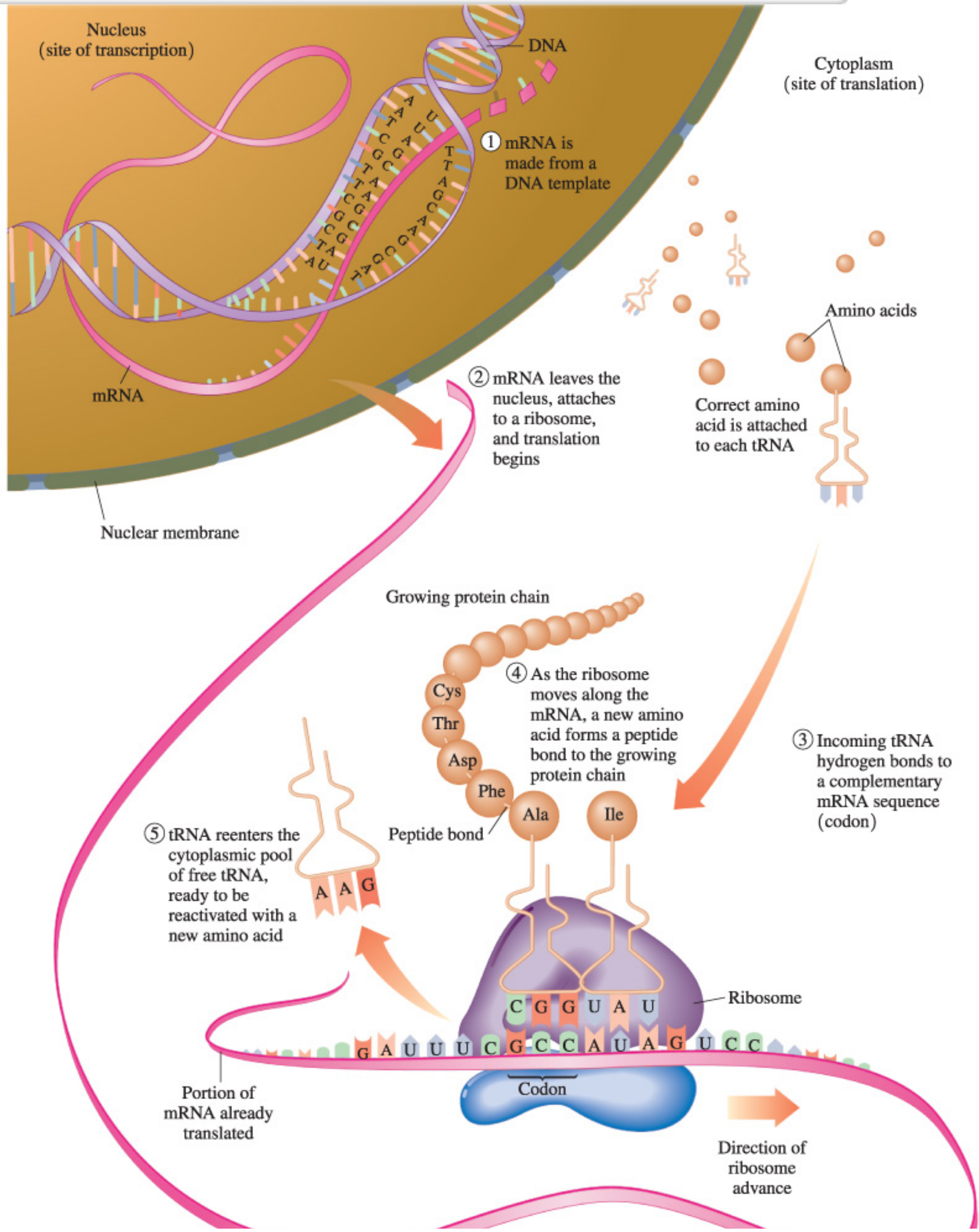


- Chain Elongation
  - Termination
- Mutation
  - Mistakes happen
- Viruses
  - Taking over the factory



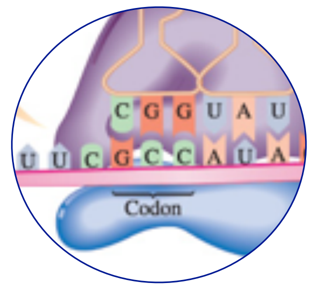
tRNA Translates and Transfers

- Translation is the second coding.
- In translation ribosomes make peptide bonds to build the protein.
- tRNA are RNA strands that translate between genetic code amino acids.
- tRNA collects the correct amino acid and delivers it for linking into the protein.



tRNA Translates and Transfers

- Ribosomes use tRNA to collect the correct amino acid and deliver it for linking into the protein.
- Each tRNA courier is encoded with a mirror image of one codon.
- Anticodons are a triplet of bases that pair with the codon corresponding to the needed amino acid.



thing that transfers message

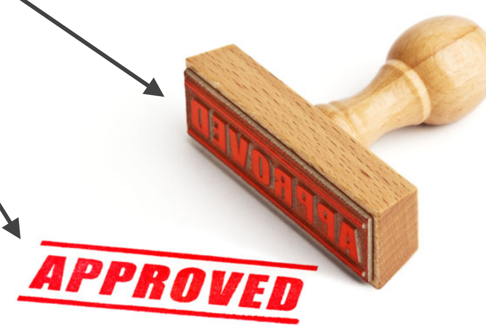
message

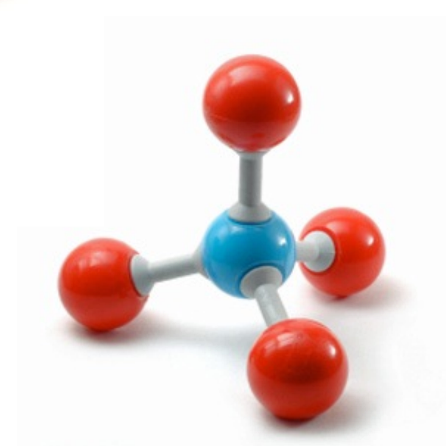
mRNA Codon		tRNA Anticodon
G	→	C
C	→	G
U	→	A
A	→	U

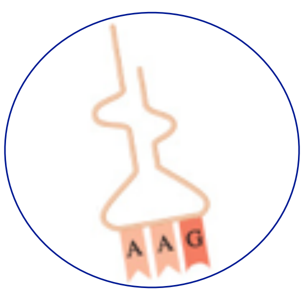
complementary relationship

thing that transfers message

message



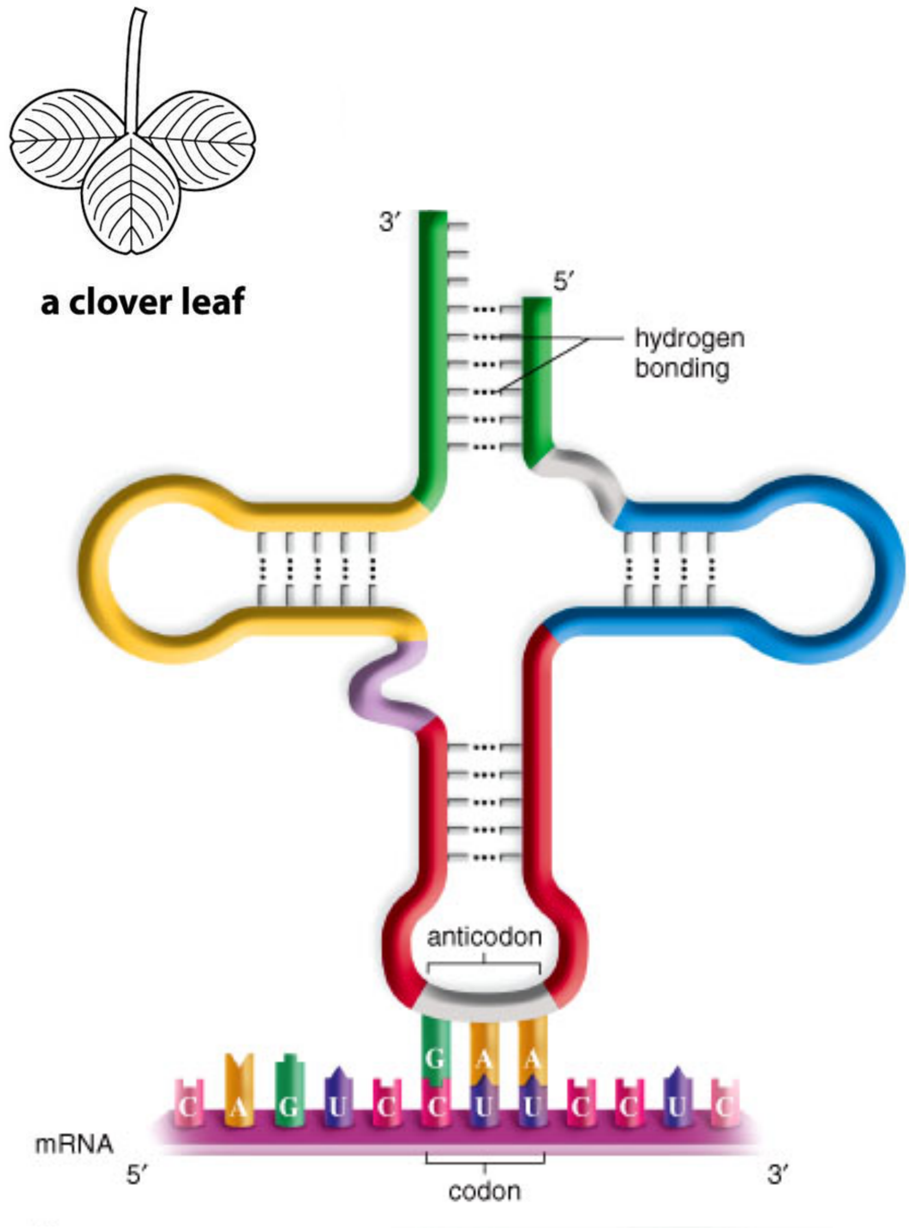




anticodon

tRNA Translates and Transfers

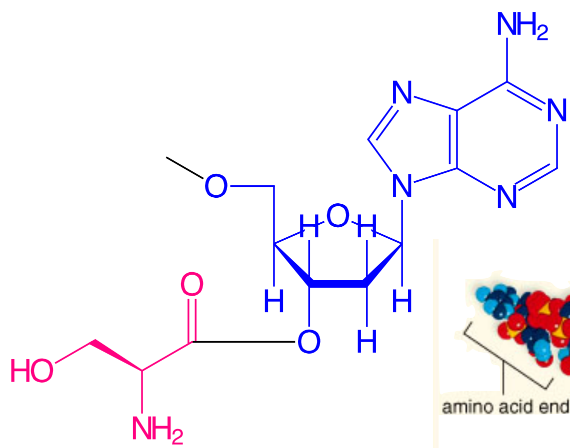
- tRNA Molecules
  - Are of uniform size, 70 to 90 nucleotides.
  - Have a 3′-end that starts with the nucleotide sequence ACC.
    - ACC is known as the acceptor stem.
  - Have an anticodon on a loop opposite the acceptor stem.
  - Have three loops, a clover leaf shape.

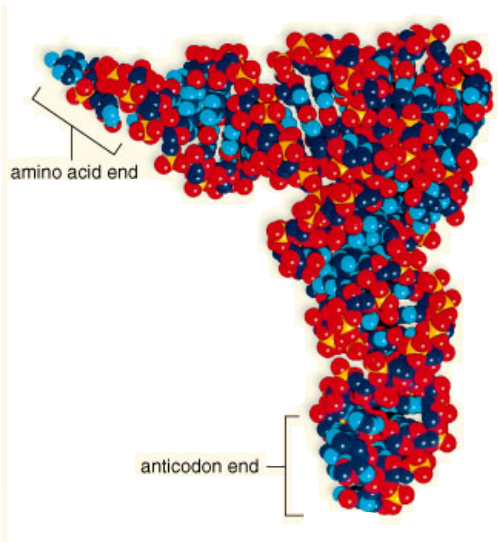


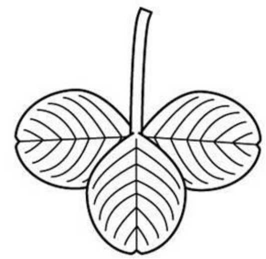
Activation of tRNA

tRNA are activated when they bond with an amino acid.

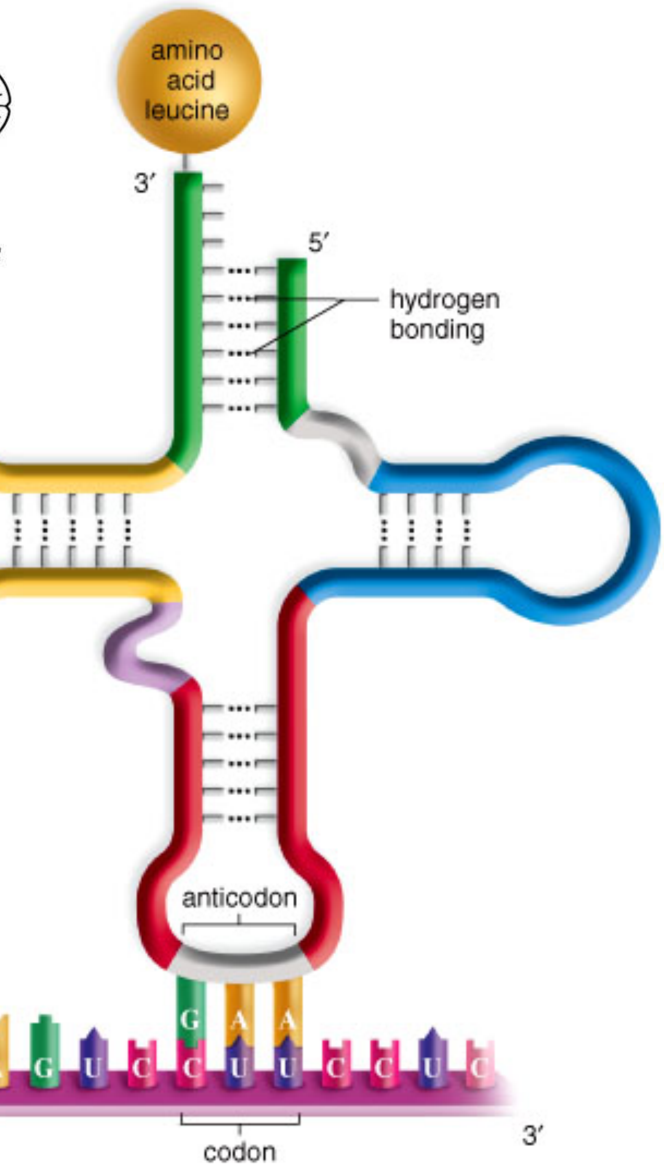
tRNA forms an ester bond between the carboxylate group of the amino acid and the hydroxyl group of the nucleic acid on the acceptor stem.







a clover leaf



Try it.

- What amino acid does the anticodon GUA identify?

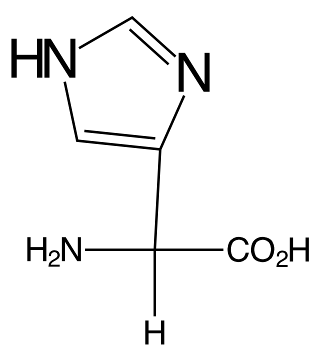
tRNA — GUA —

↓

mRNA — CAU —

↓

HIS (histidine)



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	U		C		A		G	
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	UUC		UCC		UAC		UGC	
	UUA	LEU (L)	UCA		UAA	STOP	UGA	STOP
	UUG		UCG		UAG		UGG	TRP (W)
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	CUC		CCC		CAC		CGC	
	CUA		CCA		CAA	GLN (Q)	CGA	
	CUG		CCG		CAG		CGG	
A	AUU	ILE (I)	ACU	THR (T)	AAU	ASN (N)	AGU	SER (S)
	AUC		ACC		AAC		AGC	
	AUA		ACA		AAA	LYS (K)	AGA	ARG (R)
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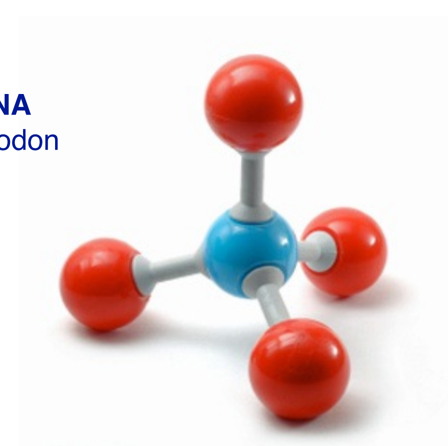
G	GUU	VAL (V)	GCU	ALA (A)	GAU	ASP (D)	GGU	GLY (G)
	GUC		GCC		GAC		GGC	
	GUA		GCA		GAA	GLU (E)	GGA	
	GUG		GCG		GAG		GGG	

mRNA Codon

G → C
C → G
U → A
A → U

tRNA Anticodon

complementary relationship



Ch17

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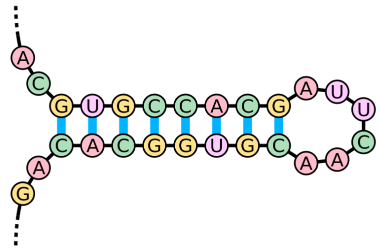

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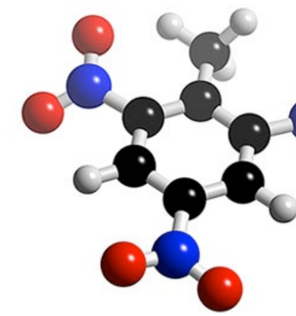
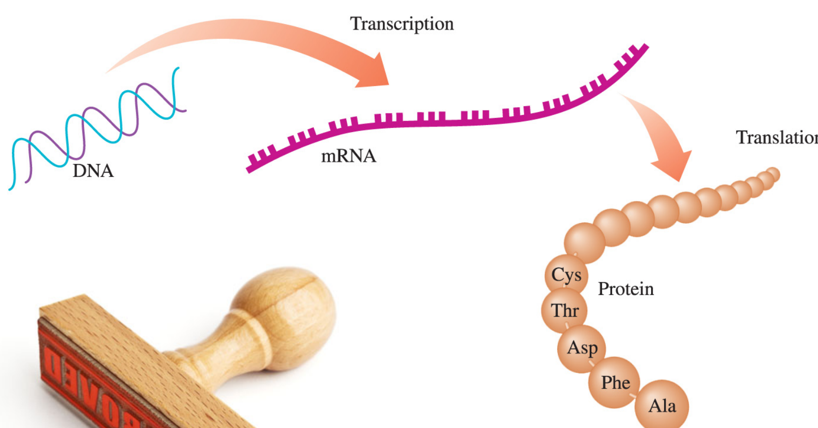
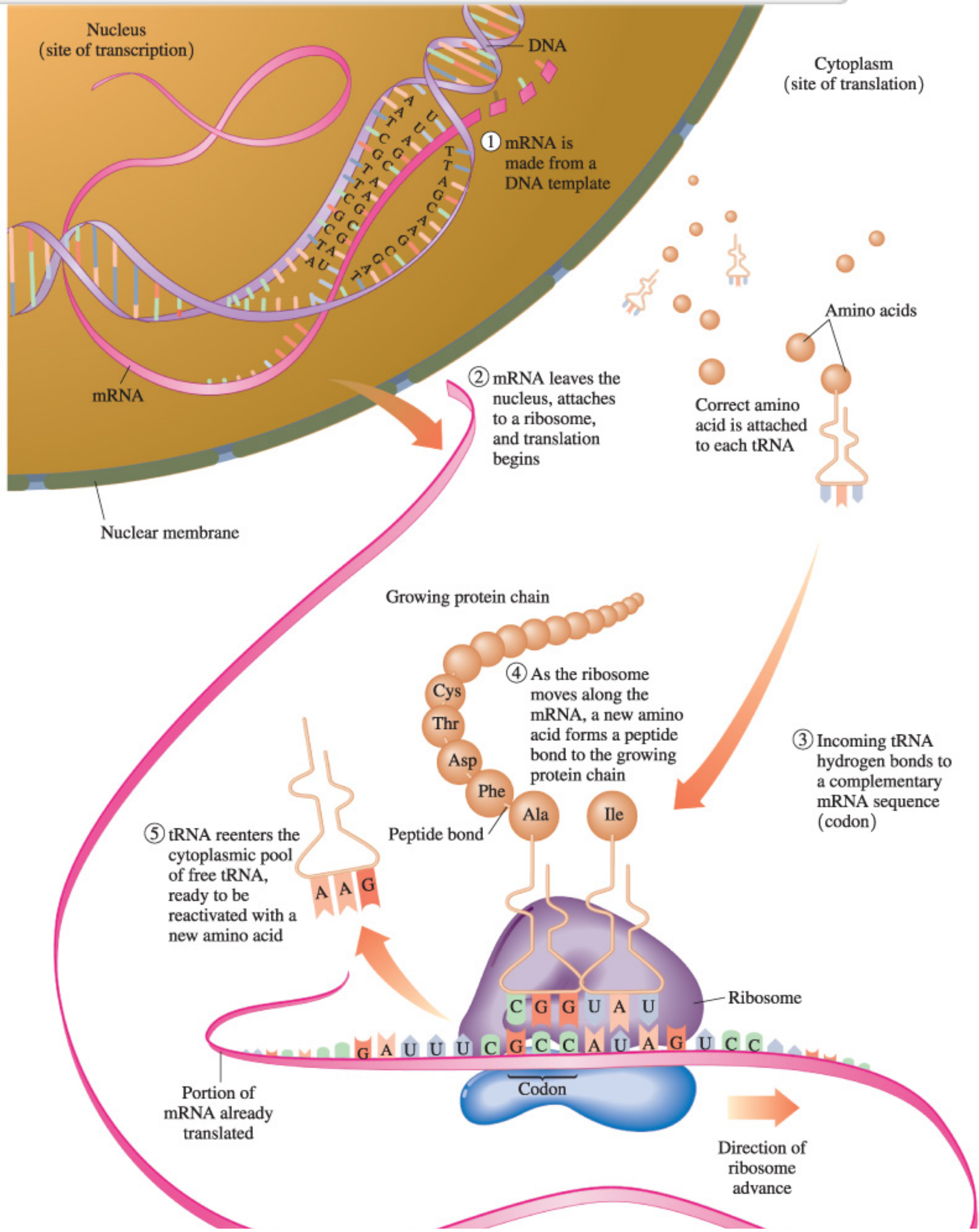




Protein Synthesis: Translation

- Translation is the second stage.
- In translation ribosomes make peptide bonds to build the protein.
- tRNA are RNA strands that translate between genetic code amino acids.

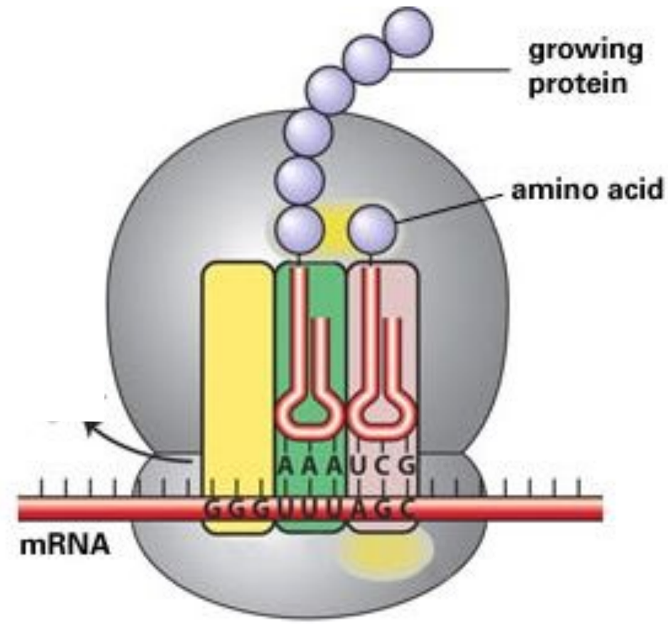
Step
1. DNA transcription
2. Activation of tRNA
3. Initiation and chain elongation
4. Chain termination

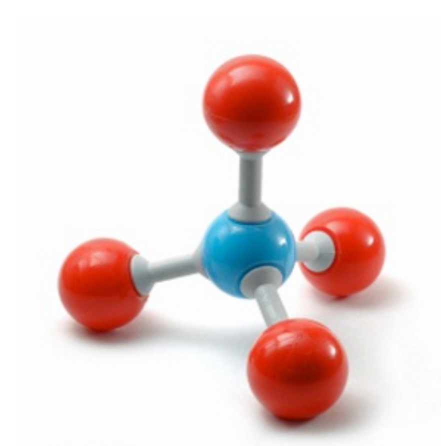


Initiation and Chain Elongation

Protein synthesis begins when mRNA binds to a ribosome.

- The first codon in mRNA is a start codon, AUG, which forms hydrogen bonds to methionine−tRNA.
- Another tRNA hydrogen bonds to the next codon, placing a second amino acid adjacent to methionine.
- A peptide bond forms between the C-terminal of methionine and the N-terminal of the second amino acid.

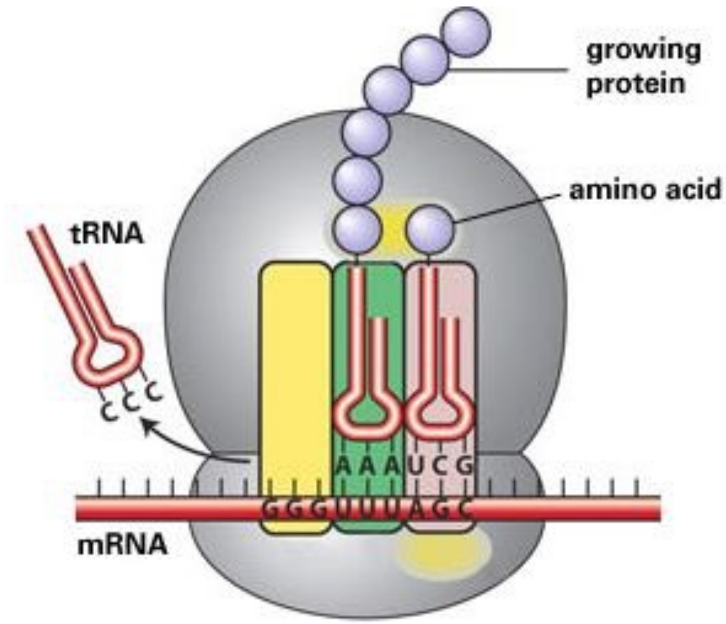


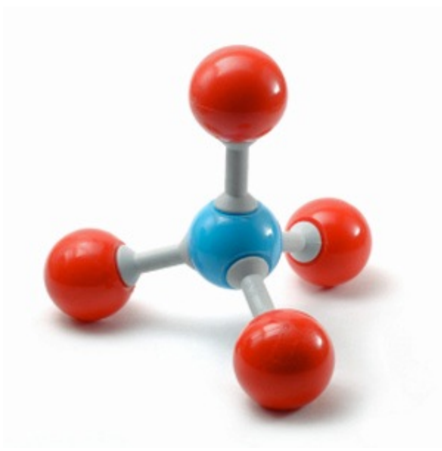


Translocation and Chain Elongation

- The initial tRNA detaches from the ribosome, which shifts to the next available codon, a process called translocation.

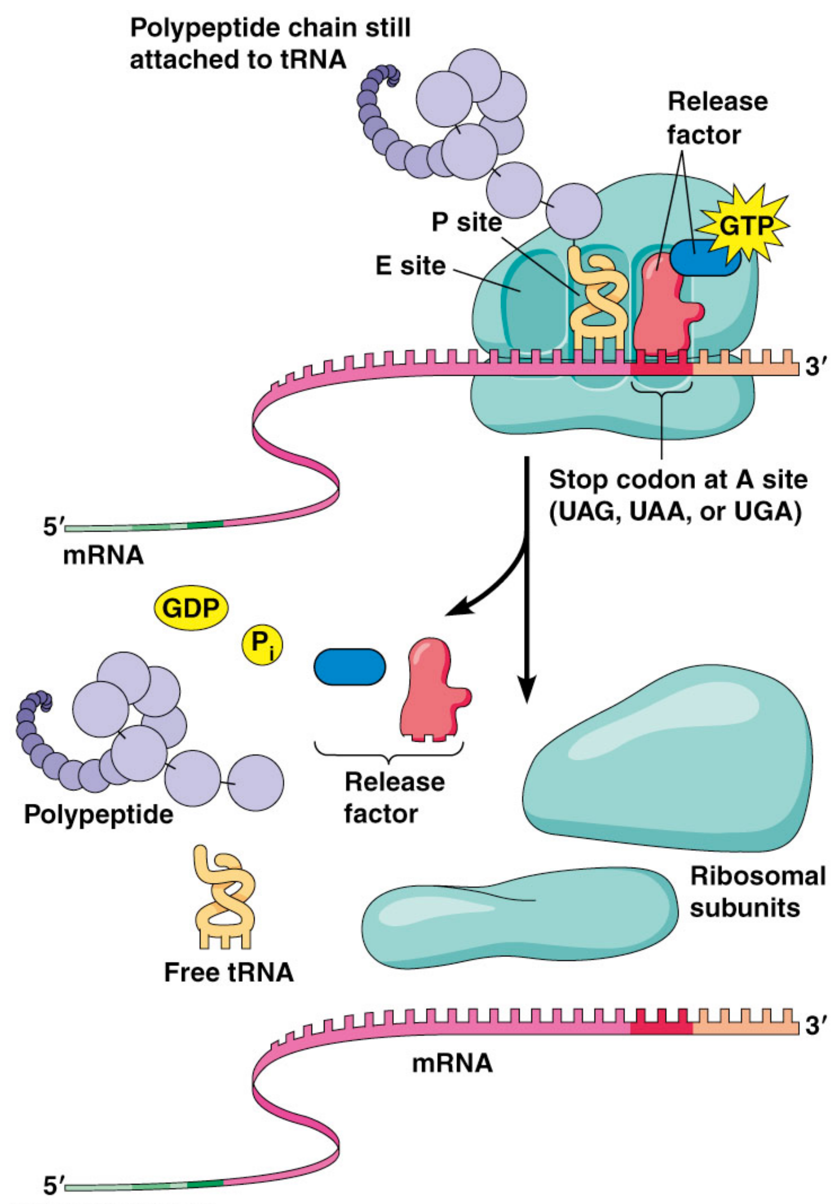
- During chain elongation, the ribosome moves along the mRNA from codon to codon, so that the tRNAs can attach new amino acids to the growing protein chain.





Chain Termination

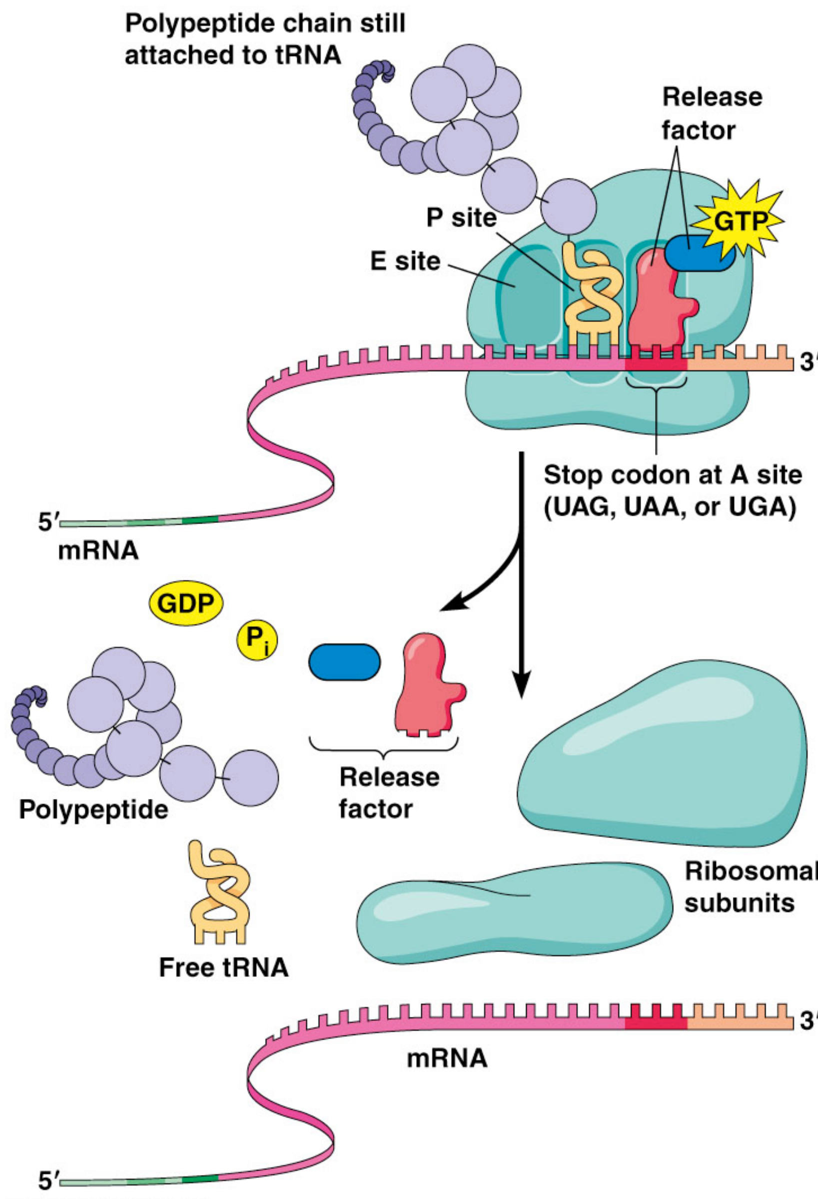
- In the termination step,
  - all the amino acids are linked
  - the ribosome reaches a “stop” codon: UGA, UAA, or UAG
  - there is no tRNA with an anticodon for the “stop” codons
  - the polypeptide detaches from the ribosome
  - the initial amino acid, methionine, is usually removed from the beginning of the protein chain



Termination

Once the polypeptide is released,

- the R groups of the amino acids in the new polypeptide can form hydrogen bonds to give the secondary structures of α helices, β-pleated sheets, or triple helices
- chains form cross-links such as salt bridges and disulfide bonds to produce tertiary and quaternary structures, making it a biologically active protein

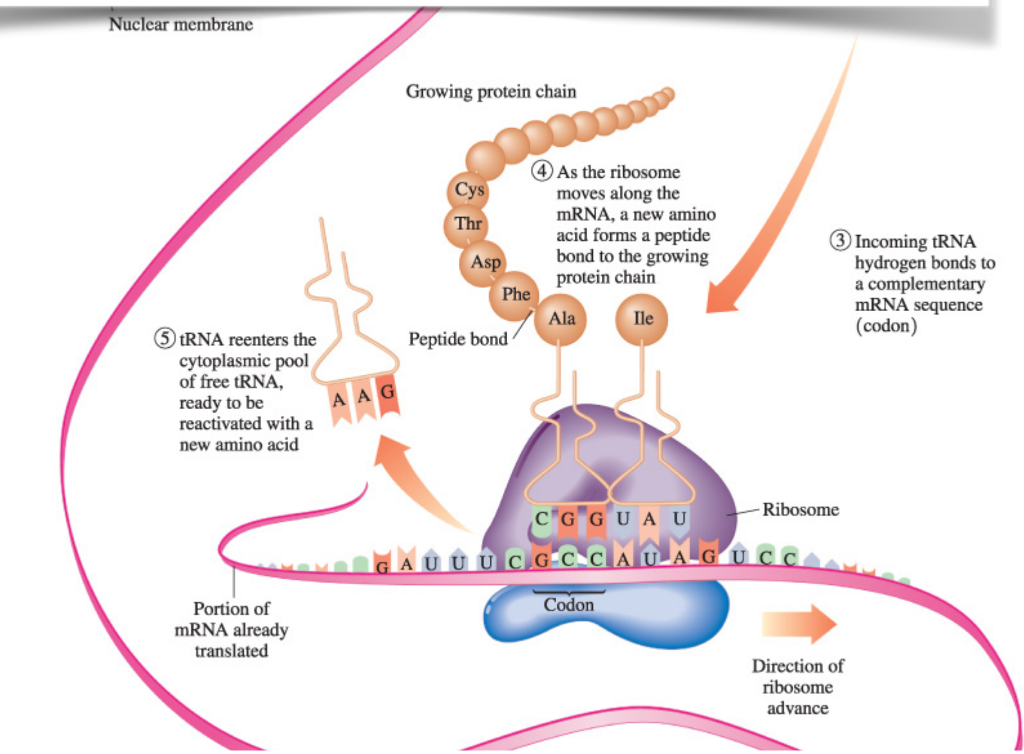


Protein Synthesis Overview

- The DNA strand opens.
  1. The template strand gets transcribed to mRNA.
  2. tRNA is activated, it picks up the necessary amino acids.

     Anticodons on the tRNA translate the mRNA into amino acids.
  3. Ribosome makes the peptide bonds from amino acids tRNA provides.
  4. The system finishes and releases the new peptide.

Step	Site: Materials	Process
1. DNA transcription	Nucleus: nucleotides, RNA polymerase	A DNA template is used to produce mRNA.
2. Activation of tRNA	Cytoplasm: amino acids, tRNAs, aminoacyl–tRNA synthetase	Molecules of tRNA pick up specific amino acids according to their anticodons.
3. Initiation and chain elongation	Ribosome: Met–tRNA, mRNA, amino acyl–tRNAs	A start codon binds the first tRNA carrying amino acid methionine to the mRNA. Successive tRNAs bind to and detach from the ribosome as each amino acid adds to the protein.
4. Chain termination	Ribosome: stop codon on mRNA	The protein is released from ribosome.



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C → G
G → C
A → U
T → A

First Letter	Second Letter: U	Second Letter: C	Second Letter: A	Second Letter: 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[b]	UGA STOP[b]	A
	UUG Leu	UCG Ser	UAG STOP[b]	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 START[a]/Met	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

START[a] codon signals the initiation of a peptide chain.
STOP[b] codons signal the end of a peptide chain.

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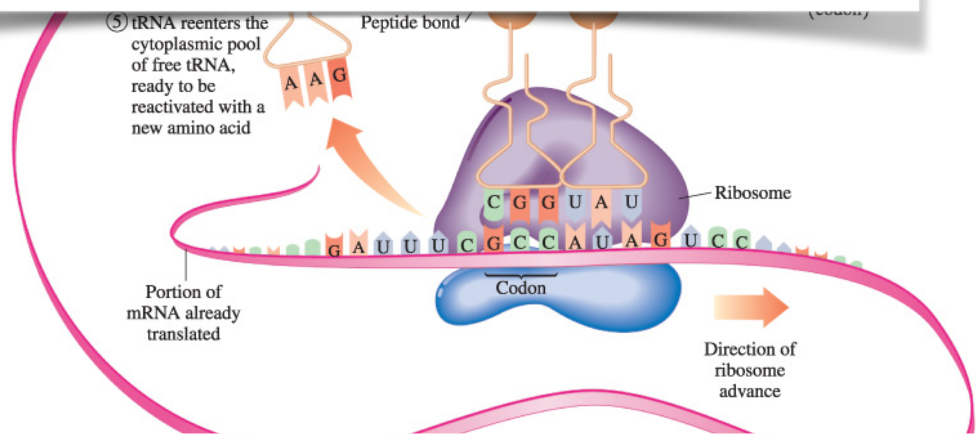
Nucleus	
DNA coding strand	—GCG AGT GGA TAC—
DNA template strand	—CGC TCA CCT ATG—
Ribosome (cytoplasm)	
mRNA	—GCG AGU GGA UAC—
tRNA anticodons	CGC UCA CCU AUG
Protein amino acids	—Ala—Ser—Gly—Tyr—



Try it.

The following section of DNA is used to build mRNA for a protein:

– GAA – CCC – TTT –

C → G
G → C
A → U
T → A

A. What is the corresponding mRNA sequence?

— CUU — GGG — AAA —

B. What are the anticodons on the tRNAs?

GAA for CUU

CCC for GGG

UUU for AAA

C. What is the amino acid order in the peptide?

— CUU — GGG — AAA —

Leu — Gly — Lys

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

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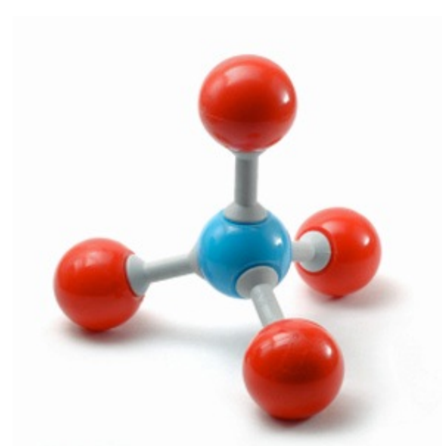

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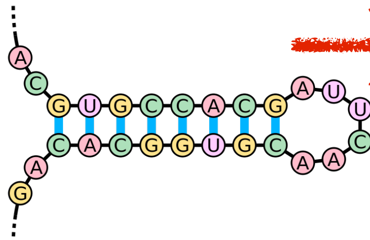

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  - Termination
- Mutation
  - Mistakes happen
- Viruses
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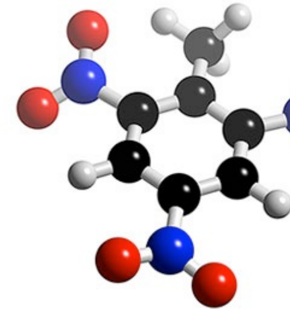
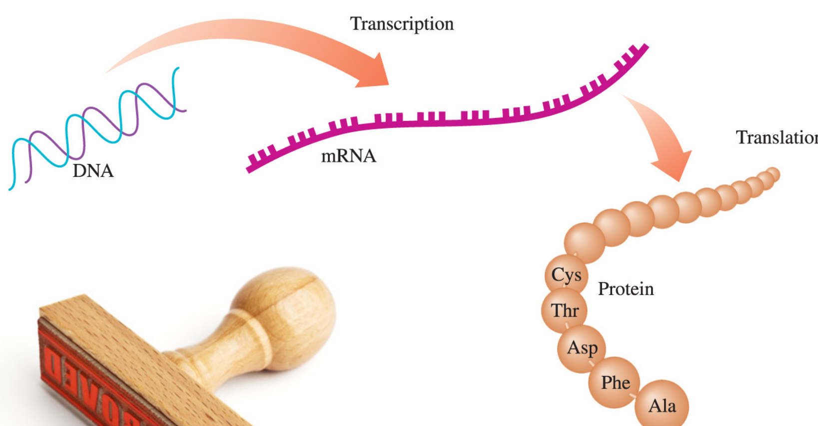




Genetic Mutations

- If the enzyme that converts tyrosine to melanin is defective, no melanin is produced and a genetic disease known as albinism results.
- A peacock with albinism does not produce the melanin needed to make the bright colors of its feathers.

Mutations

A mutation, or change in the nucleotide sequence of DNA, may

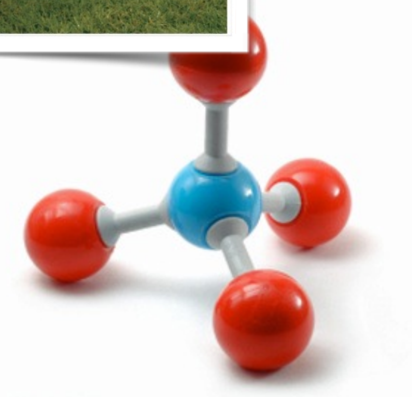
- alter the sequence of amino acids
- affect the structure and function of a protein in a cell

Mutations may result from

- X-rays
- overexposure to sun (ultraviolet, or UV, light)
- chemicals called mutagens
- some viruses

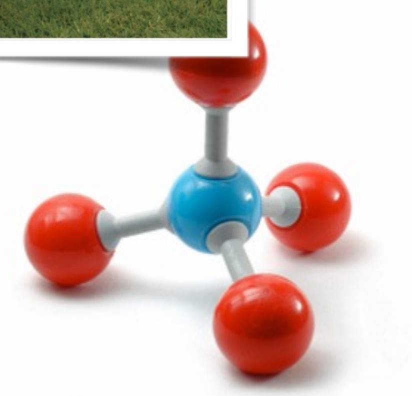
Mutations

- If a mutation occurs in a somatic cell, a cell other than a reproductive cell, the altered DNA will be limited to that cell and its daughter cells.
- If the mutation causes uncontrolled growth, cancer could result.
- If a mutation occurs in a germ cell (egg or sperm), then all the DNA produced in a new individual will contain the same genetic change.



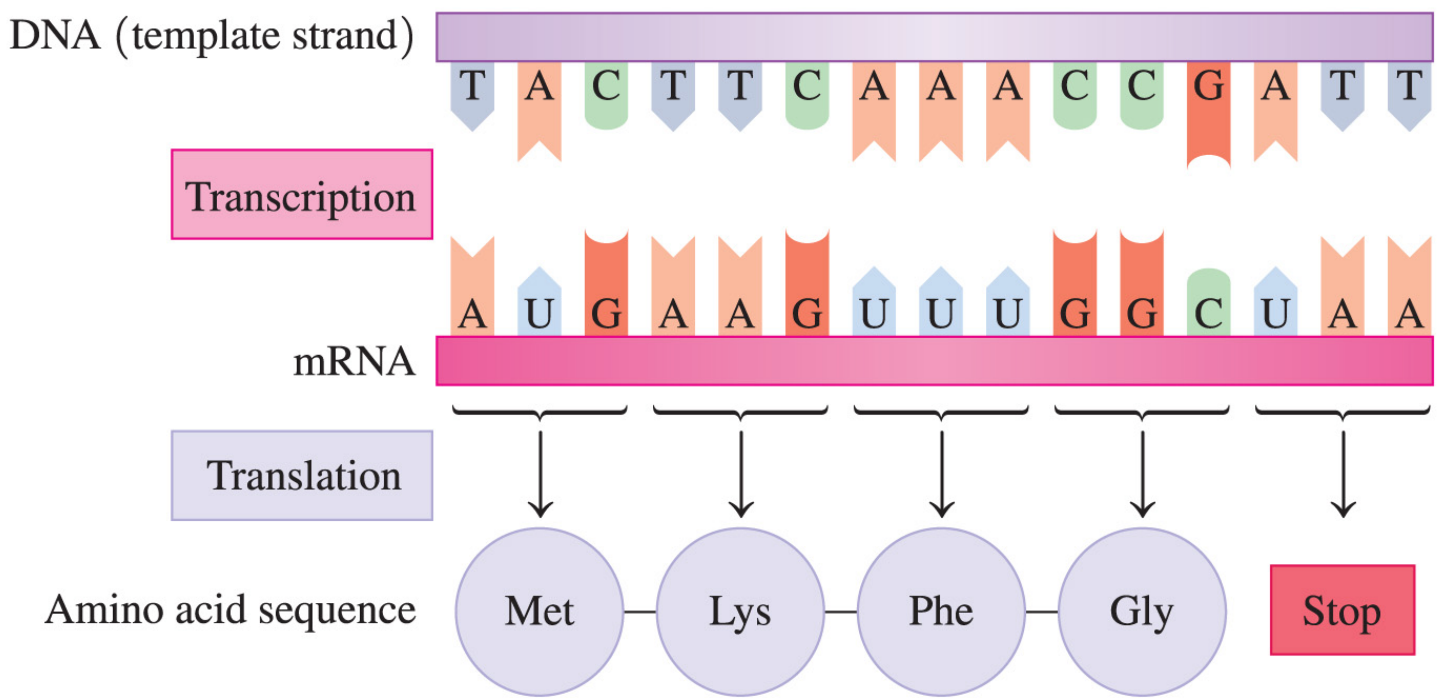
Types of Mutations

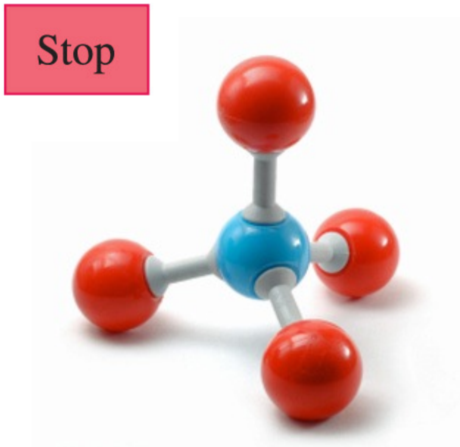
- A substitution or point mutation is the replacement of one base in the template strand of DNA with another.
- If a substitution or point mutation changes the nucleotide, a different amino acid may be inserted into the polypeptide.
- If this produces no change in the amino acid sequence, it is called a silent mutation.
- A frameshift mutation is the insertion or deletion of a single nucleotide into the sequence resulting in a change to all subsequent codons, leading to a new amino acid sequence.



Normal DNA and Protein Synthesis

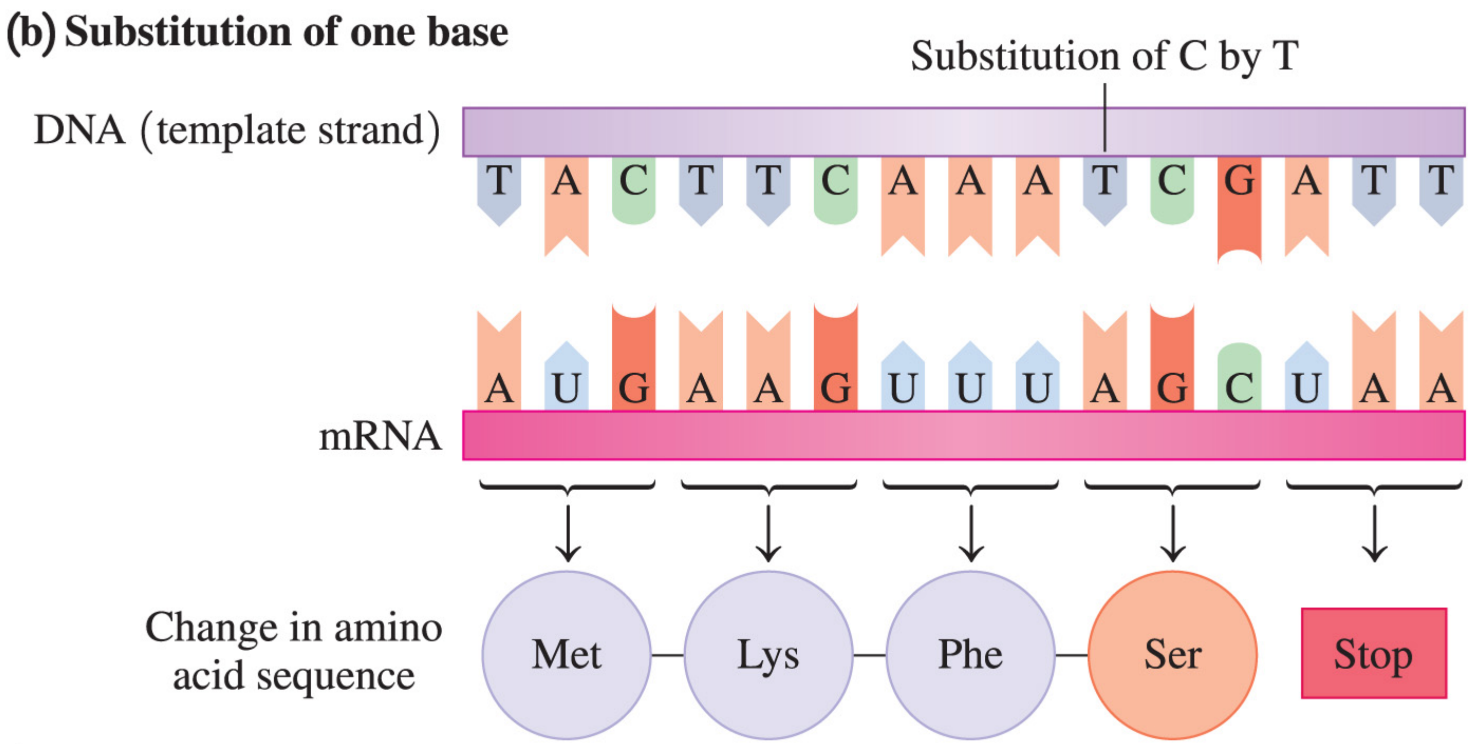
The normal DNA sequence produces an mRNA that provides instructions for the correct series of amino acids in a protein.





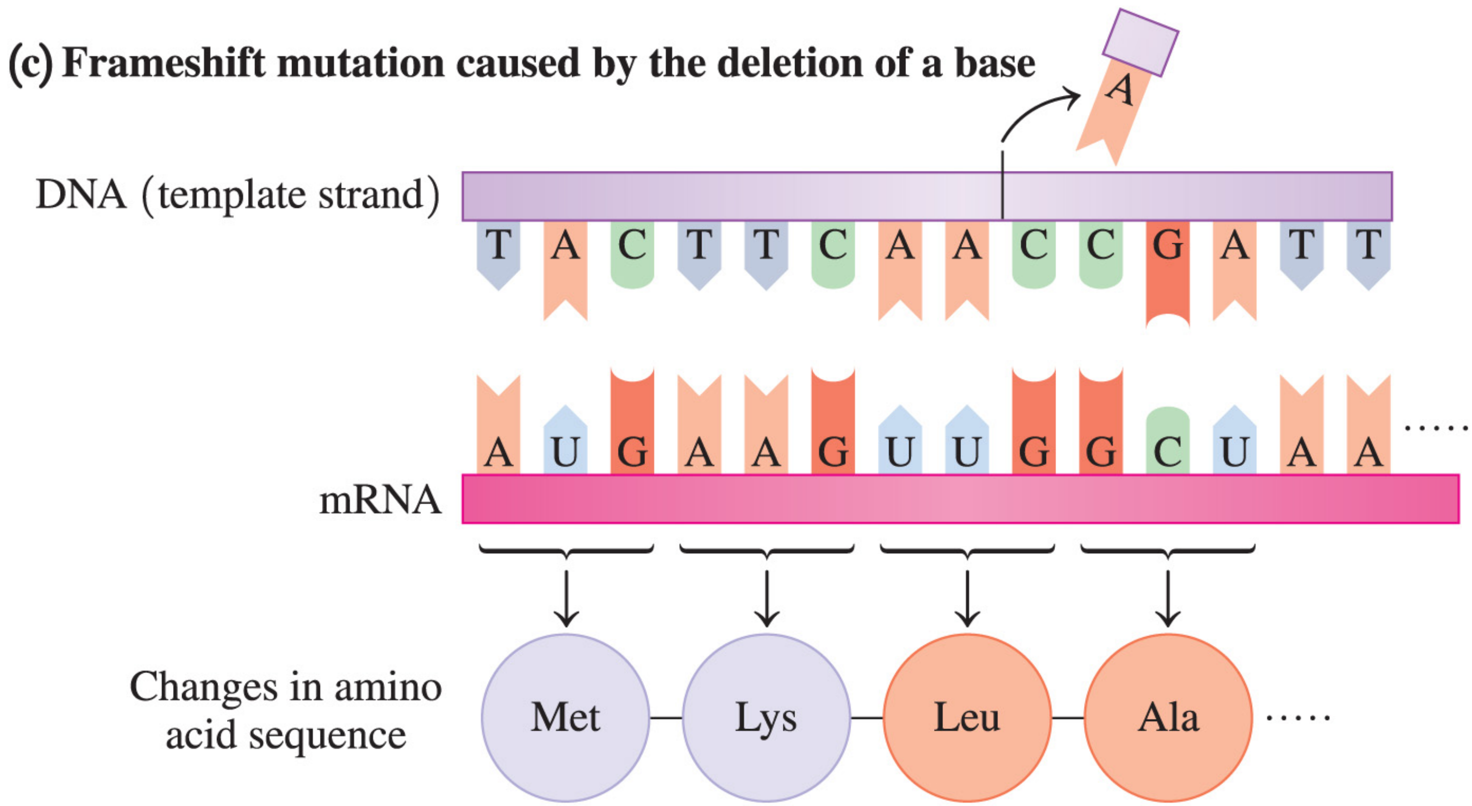
Mutation: Substitution

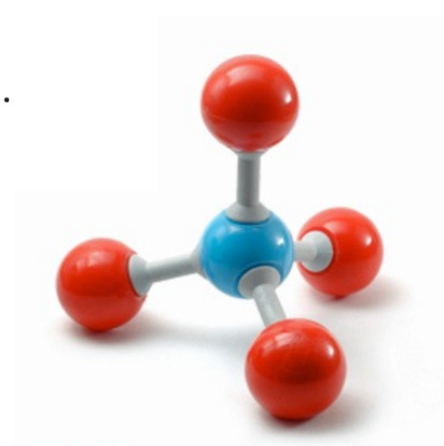
Substitution of a base in DNA changes a codon in the mRNA, leading to the placement of an incorrect amino acid in the polypeptide.



Frameshift Mutation

The deletion of a base causes a frameshift mutation, which changes the mRNA codons that follow the mutation and produces a different amino acid sequence.

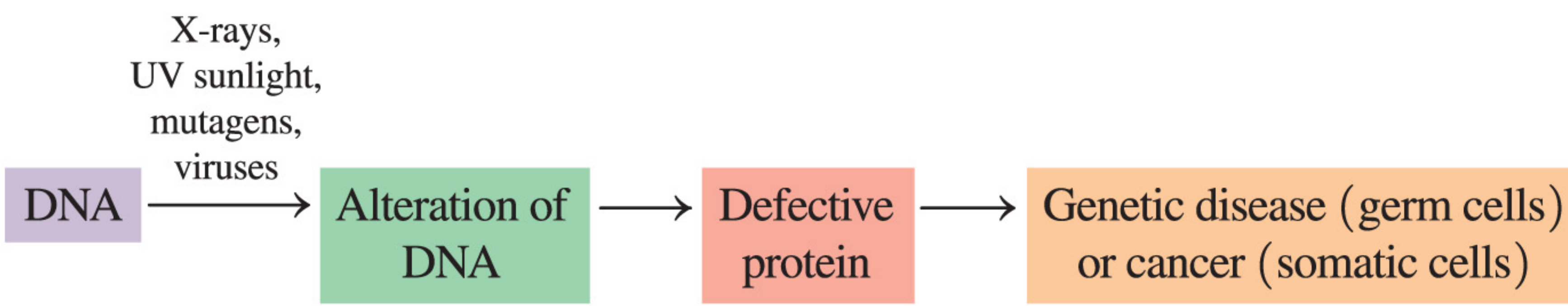


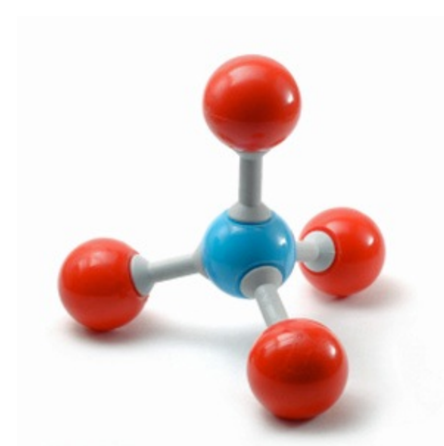


Effect of Mutations

When a mutation causes a change in the amino acid sequence, the structure of the resulting protein may be severely altered, causing loss of its biological activity.

When this condition is hereditary, it is called a genetic disease.

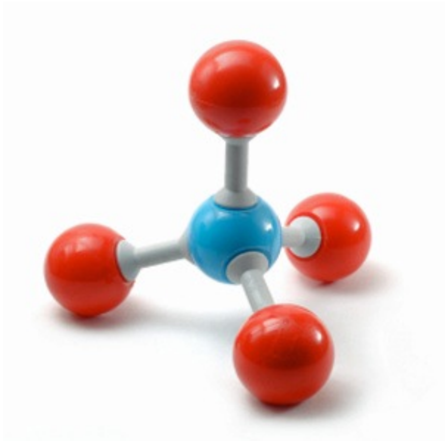




Genetic Diseases

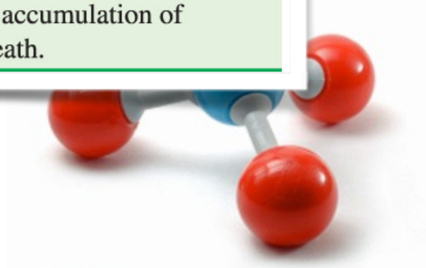
A genetic disease is the result of a defective enzyme caused by a mutation in its genetic code. For example,

- phenylketonuria (PKU) results when DNA cannot direct the synthesis of the enzyme phenylalanine hydroxylase, required for the conversion of phenylalanine to tyrosine
- albinism results when the enzyme that converts tyrosine to melanin is defective



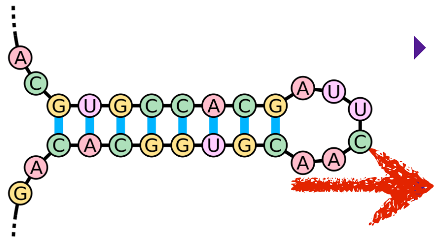
Genetic Diseases

Genetic Disease	Result
Galactosemia	In galactosemia, the transferase enzyme required for the metabolism of galactose-1-phosphate is absent, resulting in the accumulation of galactose-1-phosphate, which leads to cataracts and mental retardation. Galactosemia occurs in about 1 in every 50 000 births.
Cystic fibrosis (CF)	Cystic fibrosis is caused by a mutation in the gene for the protein that regulates the production of stomach fluids and mucus. CF is one of the most common inherited diseases in children, in which thick mucus secretions make breathing difficult and block pancreatic function.
Down syndrome	Down syndrome is the leading cause of mental retardation, occurring in about 1 of every 800 live births; the mother's age strongly influences its occurrence. Mental and physical problems, including heart and eye defects, are the result of the formation of three chromosomes (trisomy), usually number 21, instead of a pair.
Familial hypercholesterolemia	Familial hypercholesterolemia occurs when there is a mutation of a gene on chromosome 19, which produces high cholesterol levels that lead to early coronary heart disease in people 30 to 40 years old.
Muscular dystrophy (MD) (Duchenne)	Muscular dystrophy, Duchenne form, is caused by a mutation in the X chromosome. This muscle-destroying disease appears at about age 5, with death by age 20, and occurs in about 1 of 10 000 males.
Huntington's disease (HD)	Huntington's disease affects the nervous system, leading to total physical impairment. It is the result of a mutation in a gene on chromosome 4, which can now be mapped to test people in families with a history of HD. There are about 30 000 people with Huntington's disease in the United States.
Sickle-cell anemia	Sickle-cell anemia is caused by a defective form of hemoglobin resulting from a mutation in a gene on chromosome 11. It decreases the oxygen-carrying ability of red blood cells, which take on a sickled shape, causing anemia and plugged capillaries from red blood cell aggregation. In the United States, about 72 000 people are affected by sickle-cell anemia.
Hemophilia	Hemophilia is the result of one or more defective blood-clotting factors that lead to poor coagulation, excessive bleeding, and internal hemorrhages. There are about 20 000 hemophilia patients in the United States.
Tay–Sachs disease	Tay–Sachs disease is the result of a defective hexosaminidase A, which causes an accumulation of gangliosides and leads to mental retardation, loss of motor control, and early death.



Genetic Code

- RNA
  - Differences from DNA
  - Function & Structure
    - Stems & Loops
  - Types of RNA
    - Messenger (mRNA)
    - Transfer (tRNA)
    - Ribosomal (rRNA)



- Protein Synthesis
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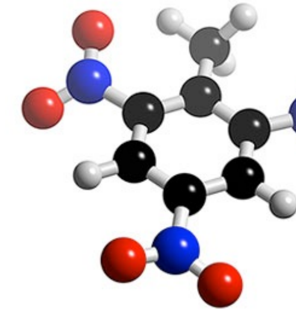
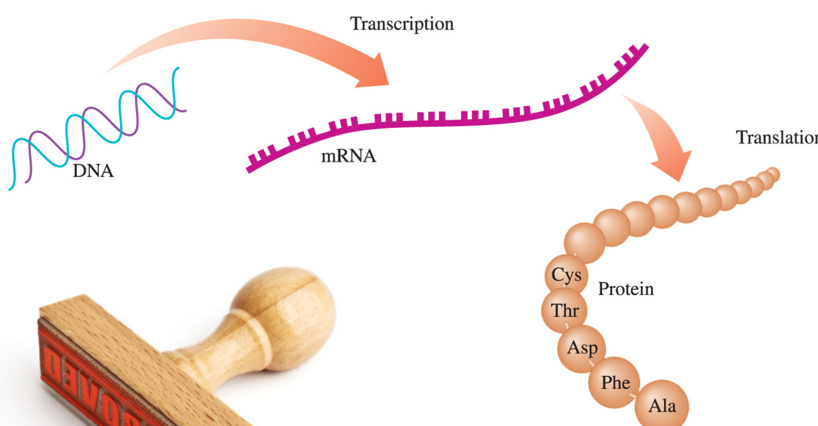
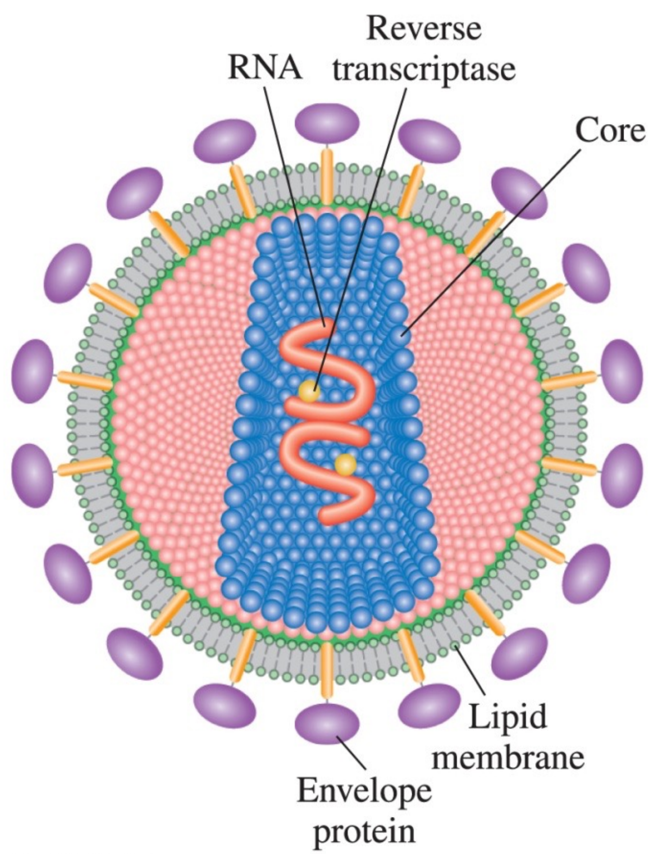
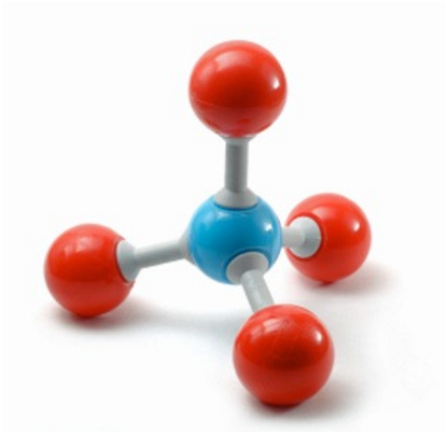




Viruses

- HIV causes AIDS, which destroys the immune system in the body. HIV is a retrovirus that infects and destroys T4 lymphocyte cells, which are involved in the immune response.

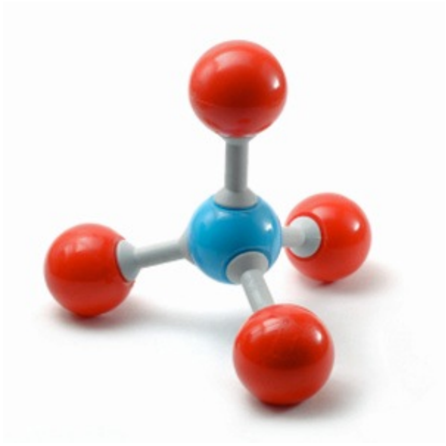




Viruses

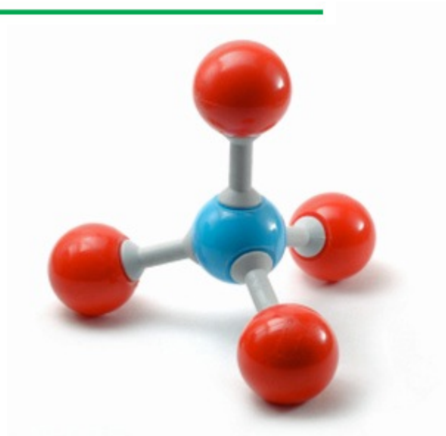
Viruses

- are small particles of 3 to 200 genes that require a host cell to replicate
- contain a nucleic acid—DNA or RNA, but not both—inside a protein coat
- do not have the necessary material, such as nucleotides and enzymes, to make proteins and grow
- replicate by invading a host cell and taking over the machinery and materials necessary for protein synthesis and growth



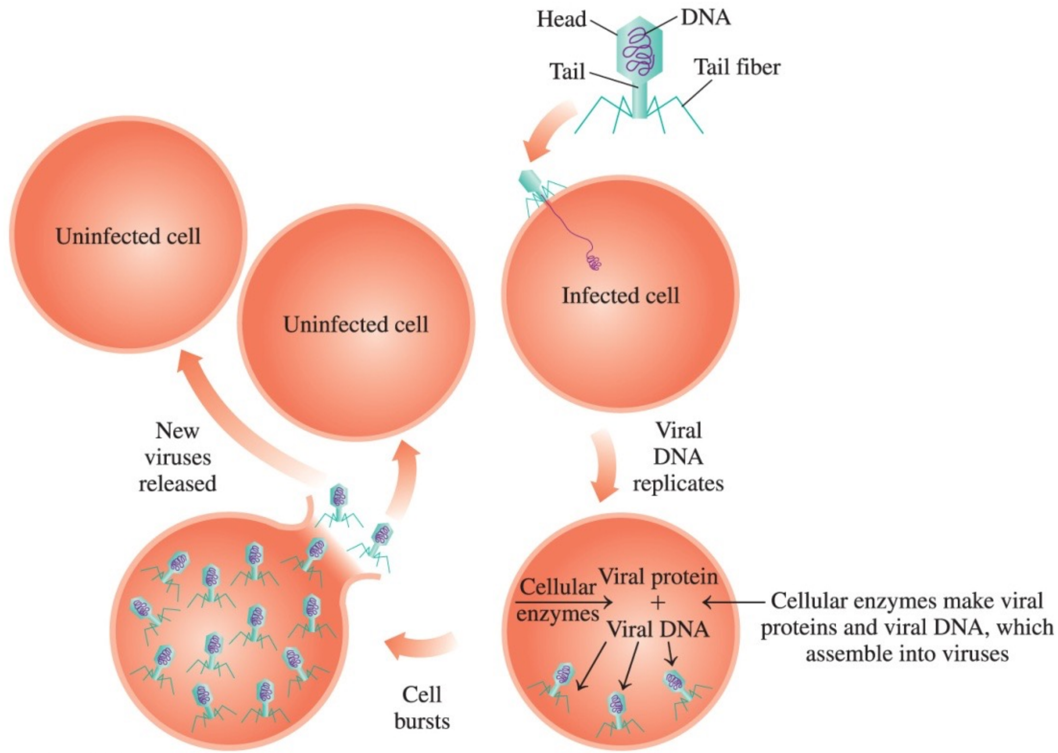
Some Diseases Caused by Viruses

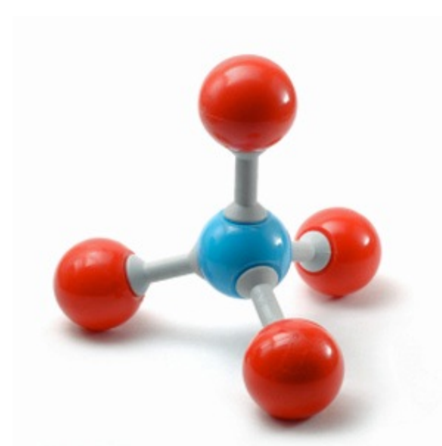
Disease	Virus
Common cold	Coronavirus (over 100 types), rhinovirus (over 110 types)
Influenza	Orthomyxovirus
Warts	Papovavirus
Herpes	Herpesvirus
HPV	Human papilloma virus
Leukemia, cancers, AIDS	Retrovirus
Hepatitis	Hepatitis A virus (HAV), hepatitis B virus (HBV), hepatitis C virus (HCV)
Mumps	Paramyxovirus
Epstein–Barr	Epstein–Barr virus (EBV)
Chicken pox (shingles)	*Varicella zoster* virus (VZV)



Viruses

- A virus
  - attaches to the host cell and injects its viral DNA
  - uses the host cell's amino acids to synthesize viral protein
  - uses the host cell's contents to make viral RNA
- When the cell bursts, the new viruses are released to infect other cells.

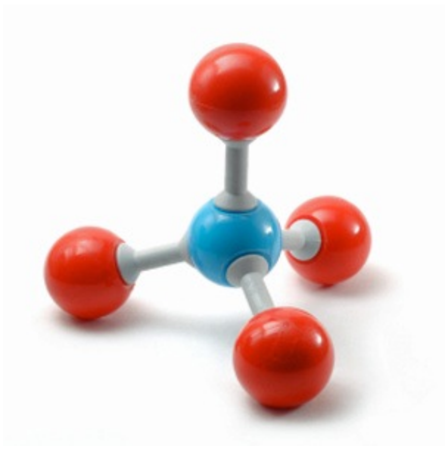




Viral Infection

A viral infection begins when

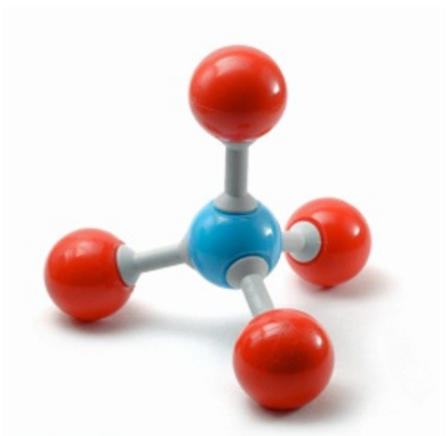
- a virus enzyme makes a hole in the host cell wall
- the viral nucleic acids enter and mix with the materials in the host cell
- the host cell begins to replicate the viral DNA (if the virus contains DNA)
- viral DNA produces viral RNA, and a protease processes proteins to produce a protein coat to form a viral particle that leaves the cell
- the cell synthesizes so many virus particles that it releases new viruses to infect more cells



Reverse Transcription

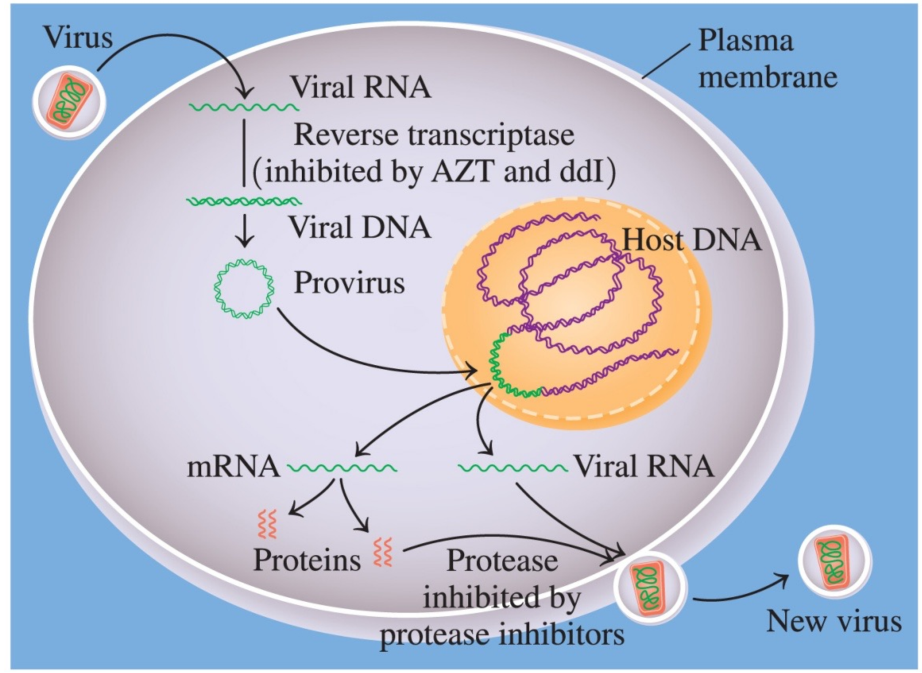
In reverse transcription,

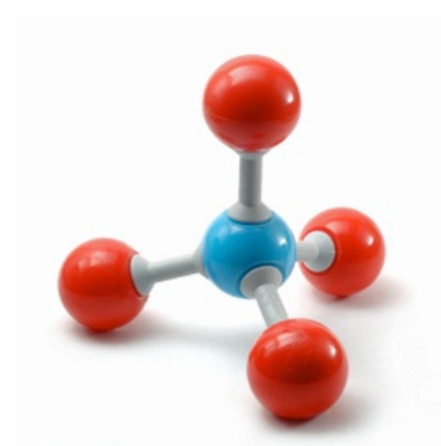
- a retrovirus, which contains viral RNA but no viral DNA, enters a cell
- the viral RNA uses *reverse transcriptase* to produce a viral DNA strand
- the viral DNA strand forms a complementary DNA strand
- the new DNA uses the nucleotides and enzymes in the host cell to synthesize new virus particles



Reverse Transcription

- After a retrovirus injects its viral RNA into a cell, it forms a DNA strand by reverse transcription.
- The DNA forms a double-stranded DNA called a provirus, which joins the host cell's DNA.
- When the cell replicates, the provirus produces the viral RNA needed to produce more virus particles.





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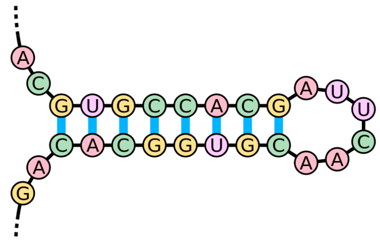

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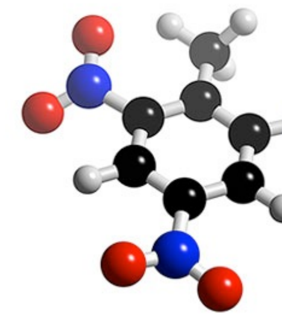

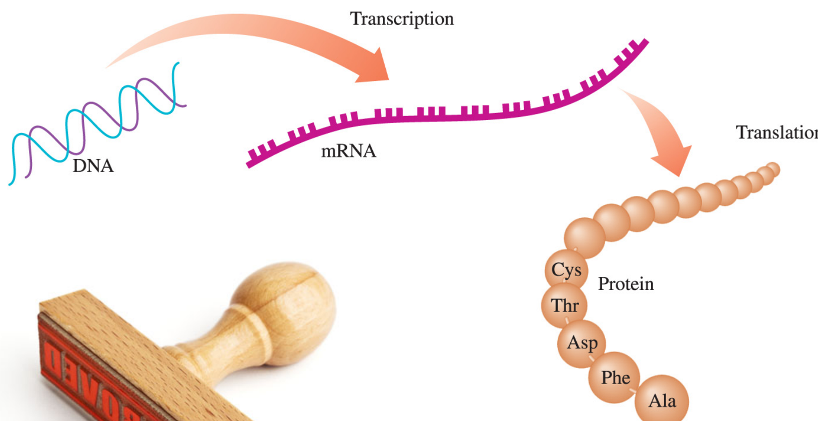

Questions?