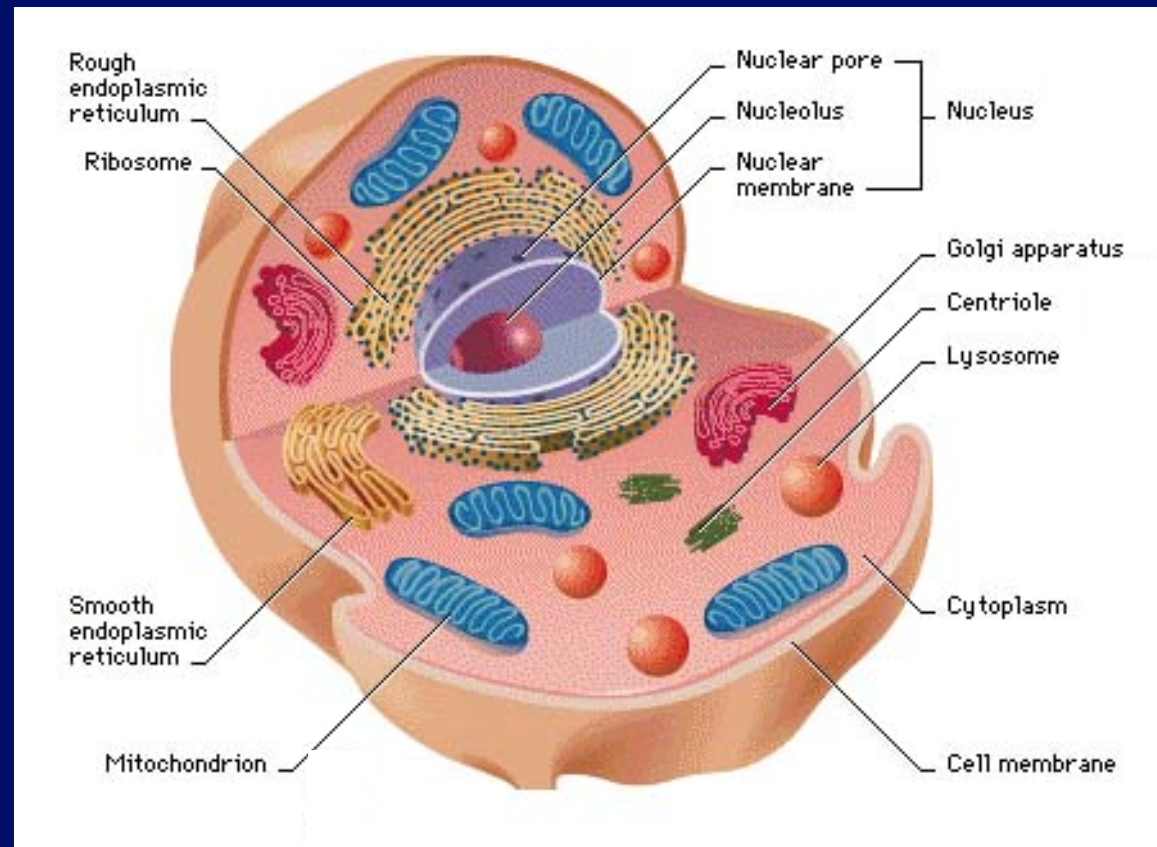


Life

# What is necessary for life?

Most life familiar to us: Eukaryotes

FREE LIVING  
Or Parasites



First appeared  $\sim 1.5 - 2 \times 10^9$  years ago

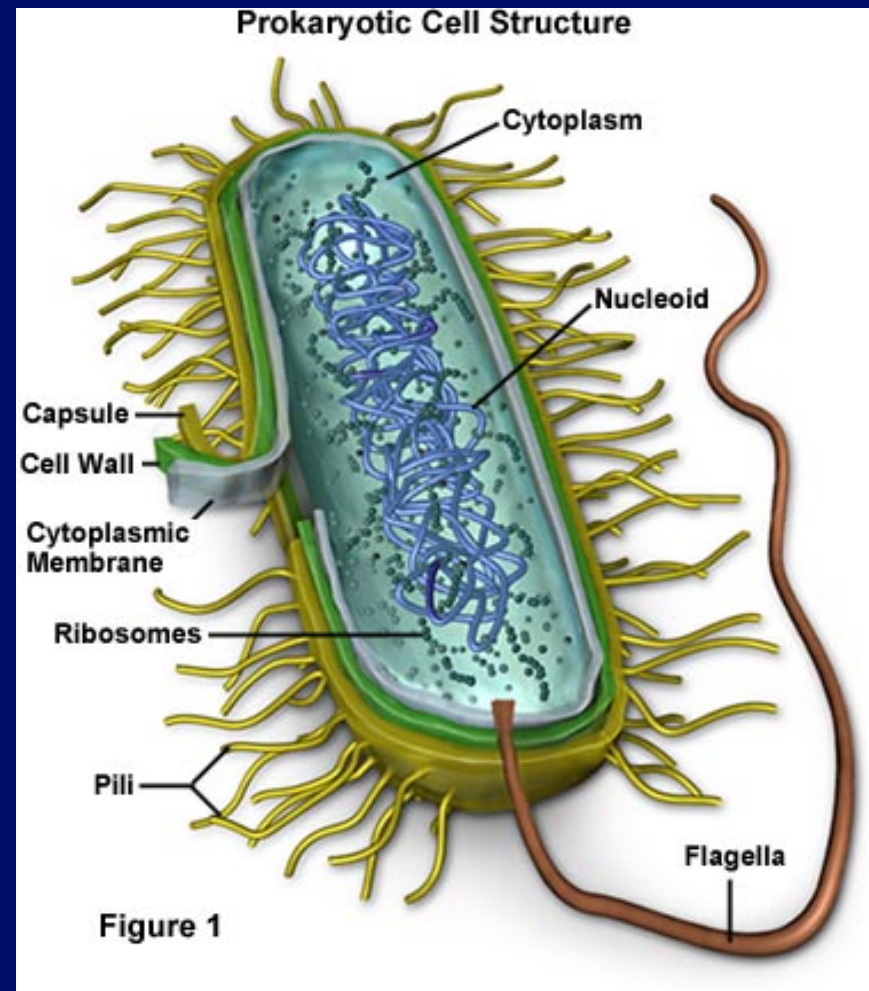
Requirements: DNA, proteins, lipids, carbohydrates,  
complex structure,  $\sim 10^4 - 10^5$  genes

# Prokaryotes (Bacteria and Archaea)

First appeared

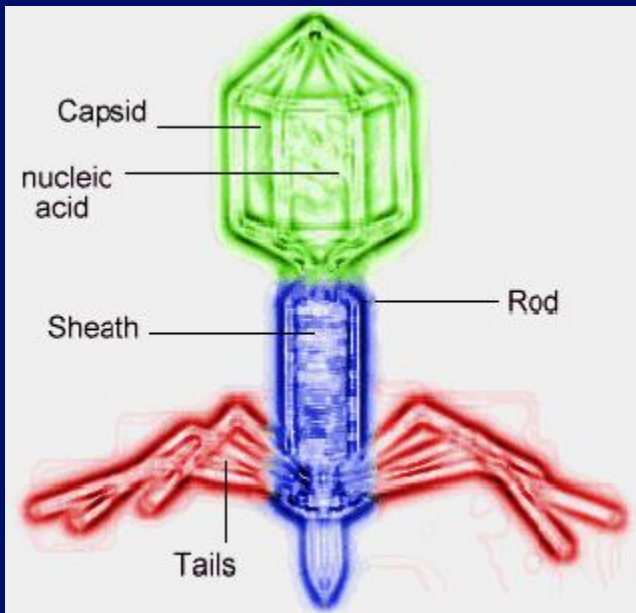
$\sim 3 - 4 \times 10^9$  years ago

FREE LIVING  
Or Parasites

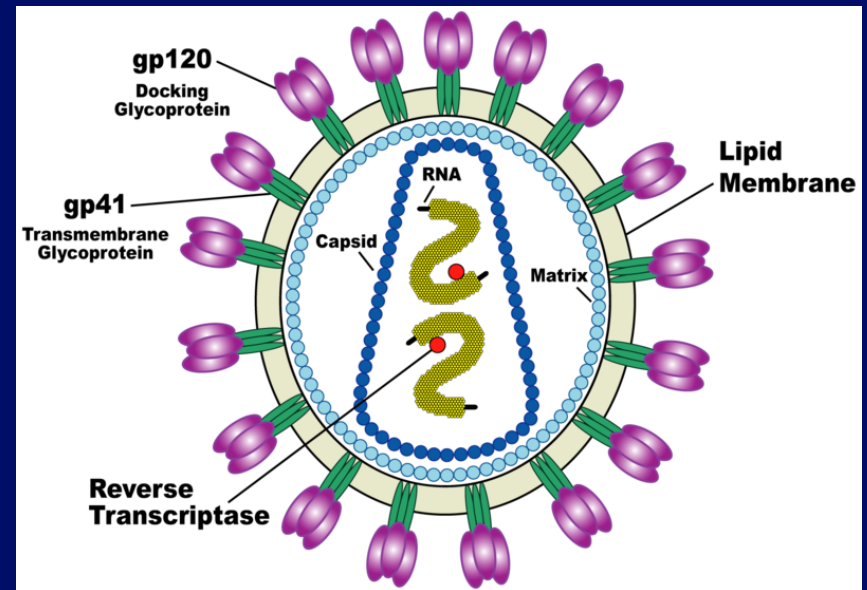


Requirements: DNA, protein, lipids, carbohydrates,  
simpler structure, few thousand genes

# Viruses



DNA, protein

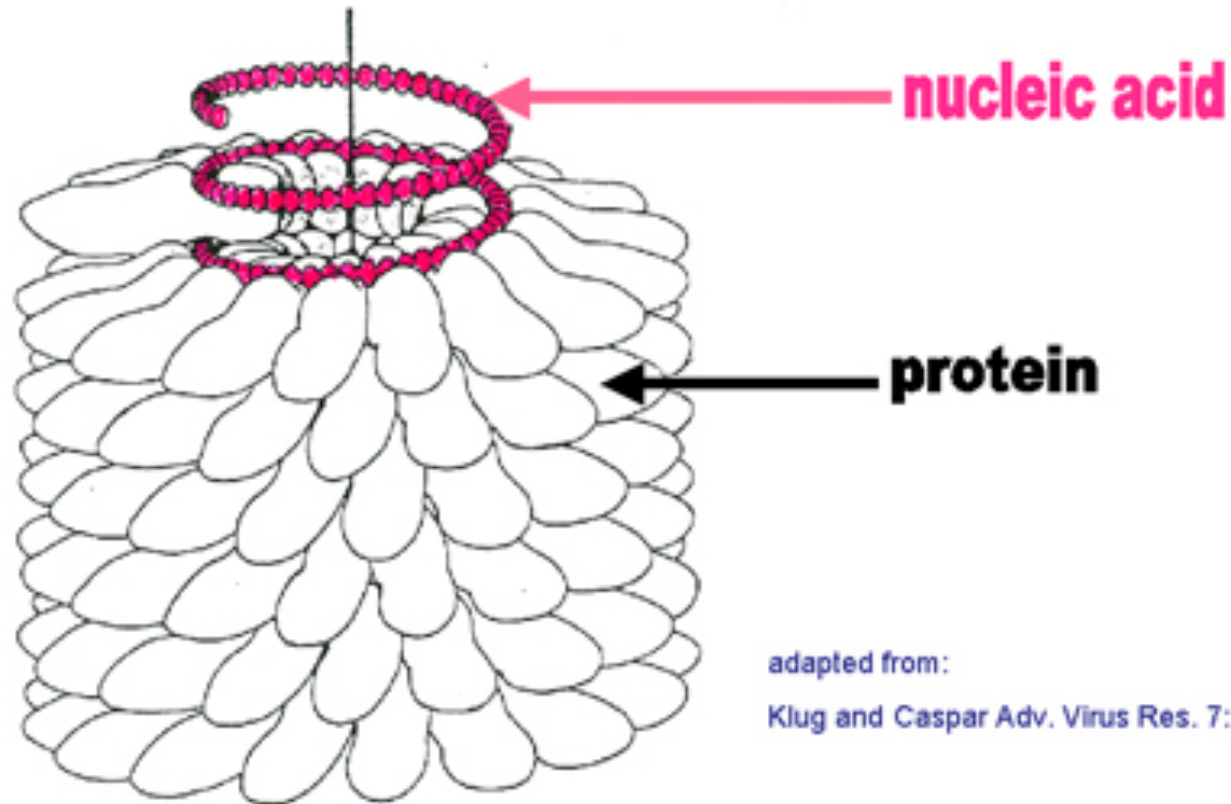


RNA, protein, maybe lipid  
(e.g., HIV)

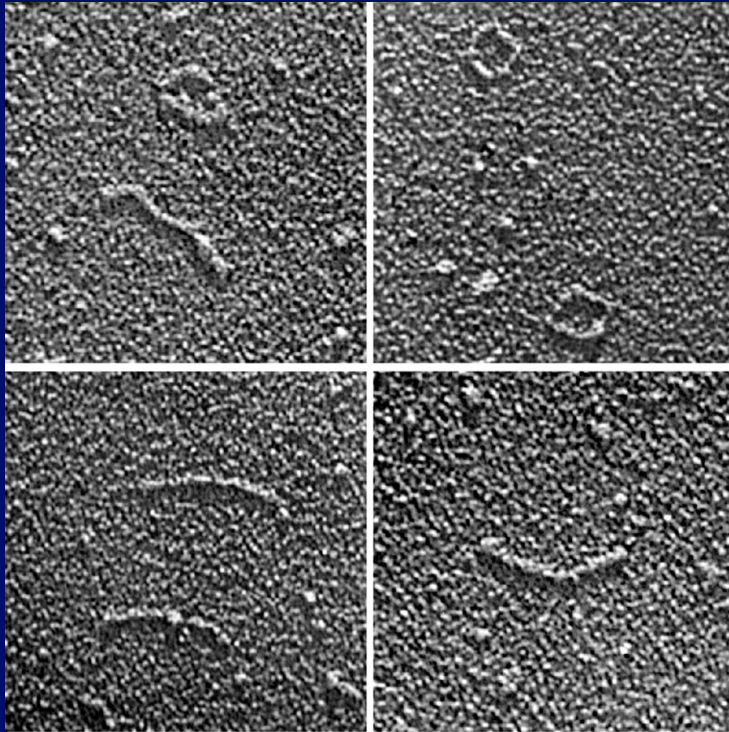
All (?) are parasites. Are they alive?

The tobacco-mosaic virus is made up of a strand of nucleic acid encased in a rod of one kind of protein.

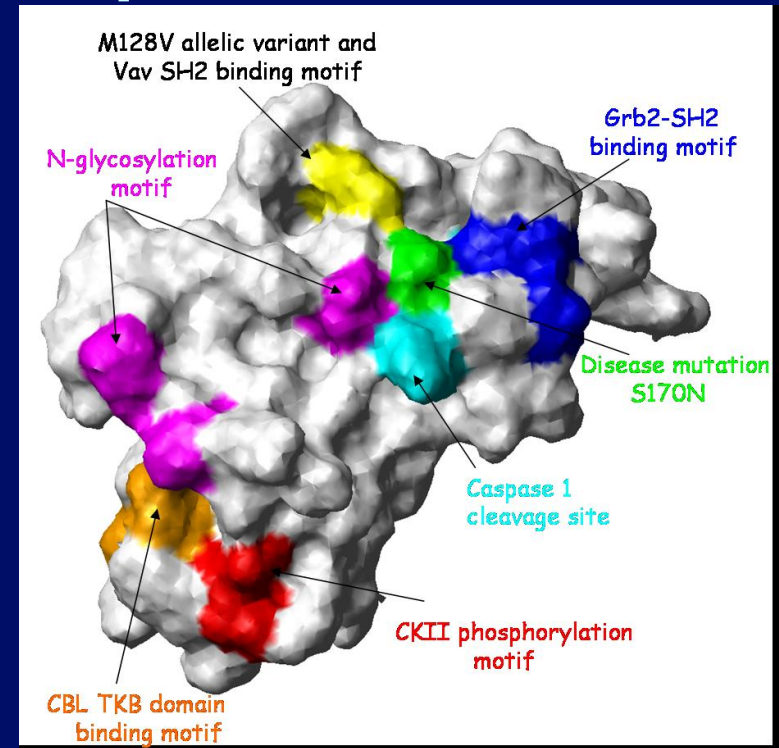
## TOBACCO MOSAIC VIRUS



# Even Simpler



Viroids  
Bare, single-stranded  
RNA



Prions  
Misfolded proteins  
Can induce others to  
Misfold.

# Minimum Requirements for Life

Proteins and Nucleic Acids for simplest possible life.

Or maybe only one?

Lipids and Carbohydrates for any thing more complex than a virus.

These are all macromolecules.

# Macromolecules

H, C, N, O  
(S)

Proteins made of amino acids  
(20 kinds used in proteins)

Construction and catalysis (enzymes)

H, C, N, O  
(P)

Nucleic acids made of nucleotides

base    sugar    phosphate

Polymers made of Monomers



H, C, O

Carbohydrates made of sugars

Energy (food) + structure

[starch]

[cellulose]

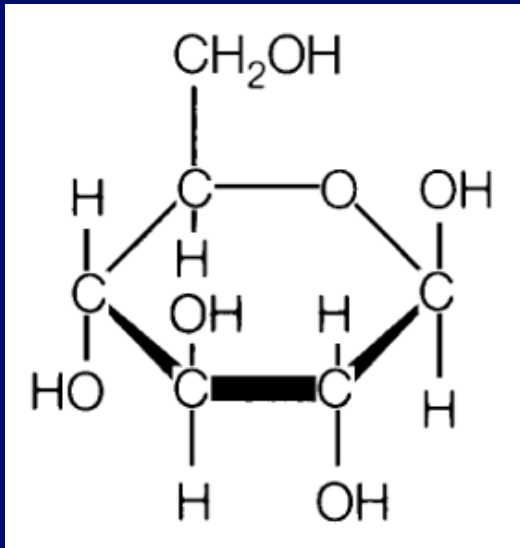
H, C, (O)

Lipids (hydrocarbons + carboxyl)

Membranes + Energy

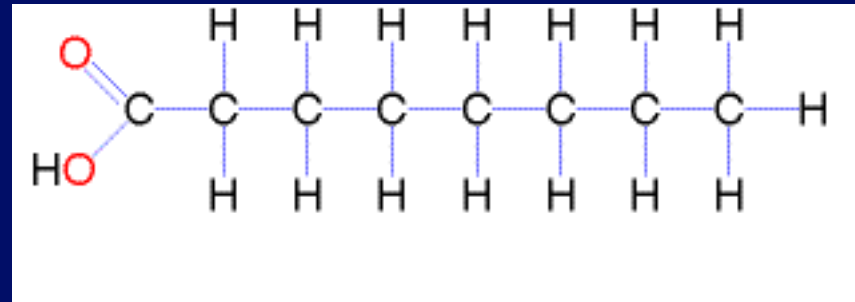
[water-resistant]

# Sugar



Glucose

# Lipids

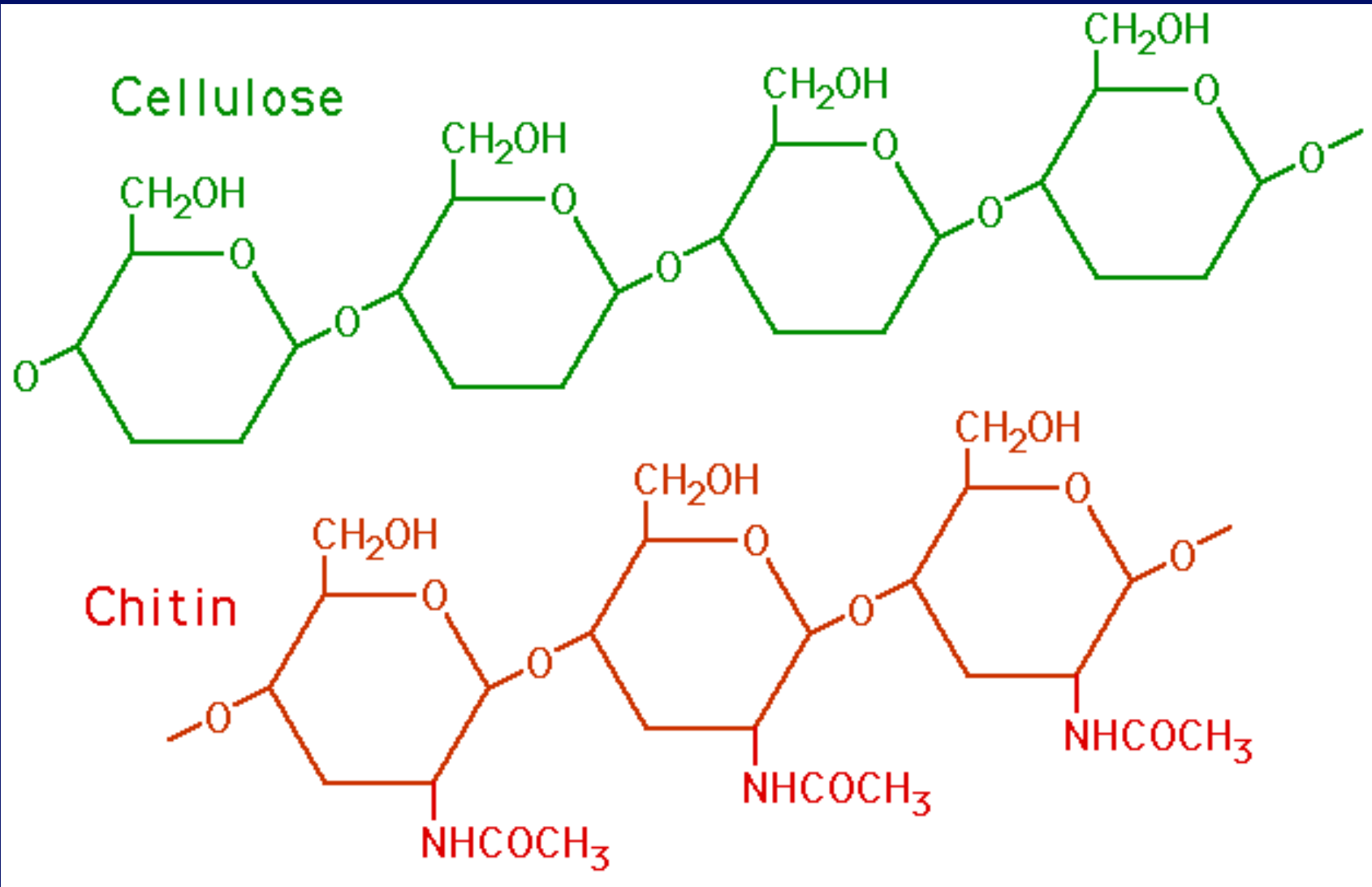


carboxyl

hydrocarbon

Fatty acid is composed of a hydrocarbon chain with a carboxyl group at one end

# Polysaccharides



# Proteins and Nucleic Acids

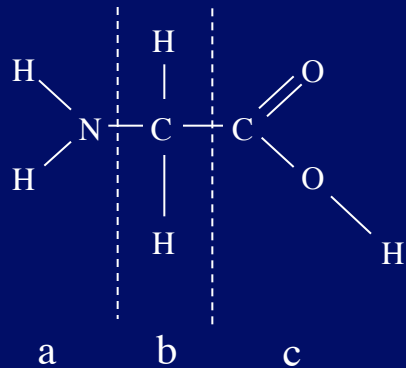
- Proteins
  - Structure
  - Enzymes (catalysts to control reactions)
- Nucleic Acids
  - Information
  - Replication of information: reproduction
  - Instructions for making proteins

# Proteins

Monomers are amino acids

20 kinds

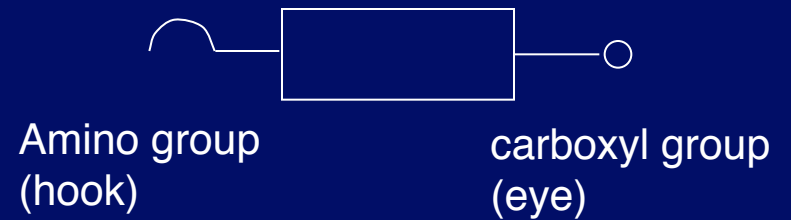
## Glycine



Amino group

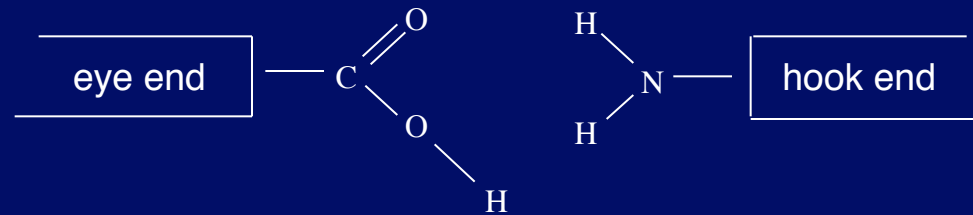
carboxyl group

## Schematic

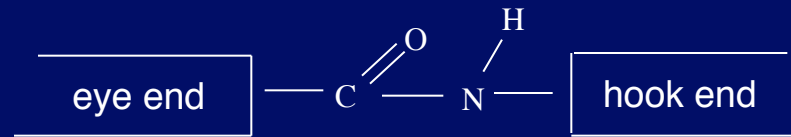


Section of Protein

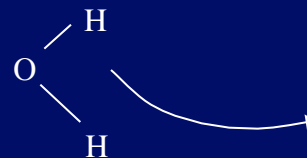
## A Peptide Bond at the Chemical Level



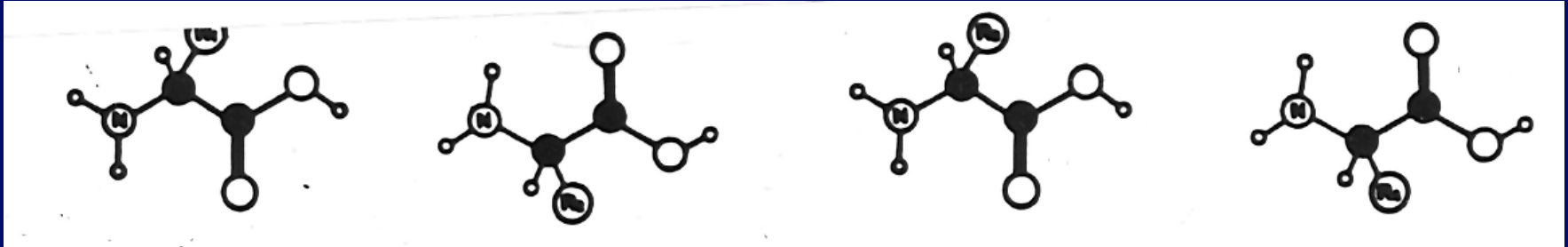
Before



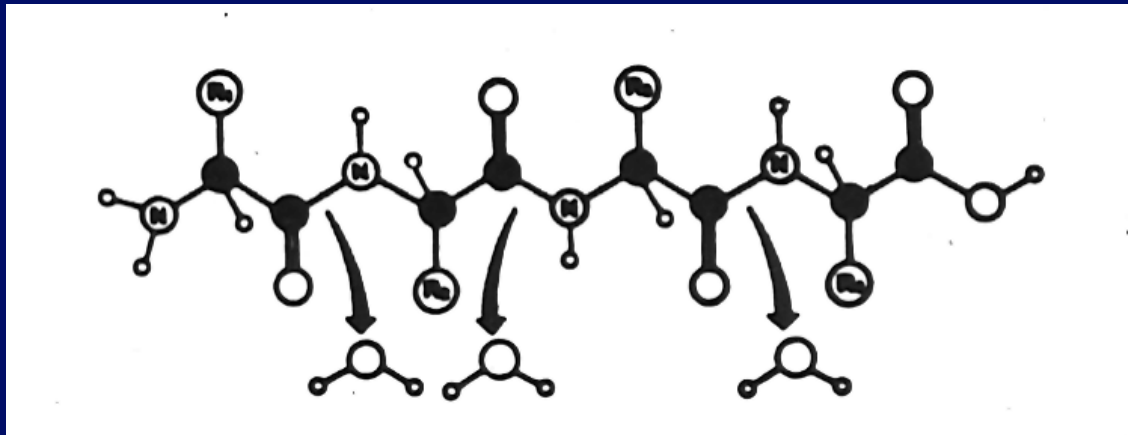
After



Note that a water molecule must be removed



amino acids



protein

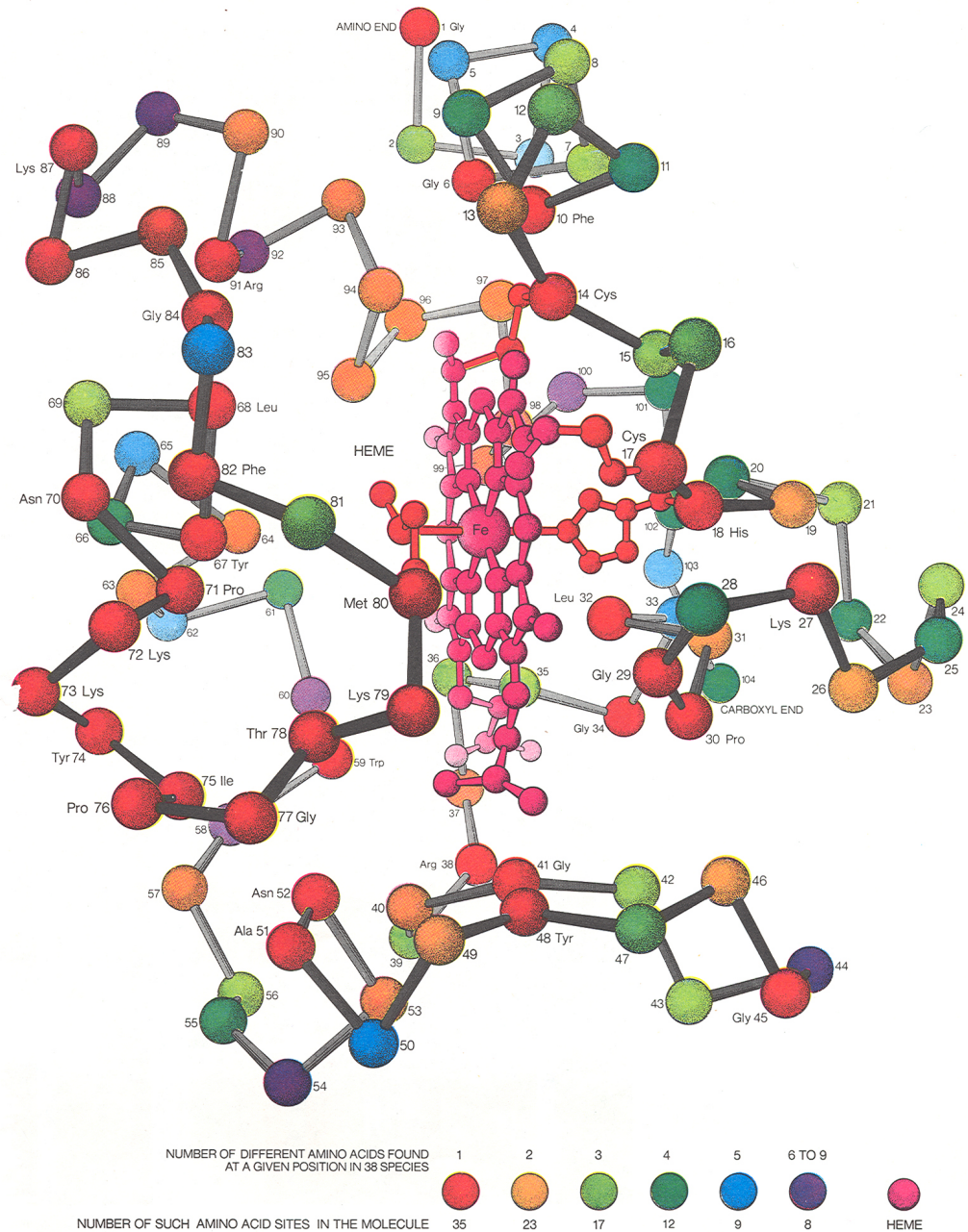




Stripped down view  
Can you find the  
amino end and the  
carboxyl end?

Note the “heme”,  
containing iron.

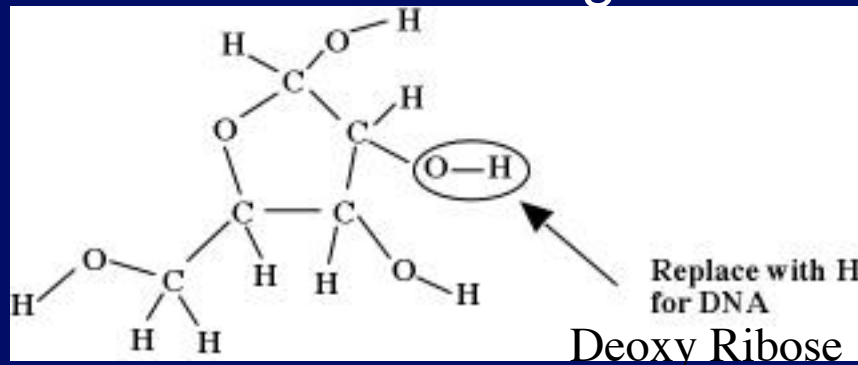
Function depends on  
structure, which  
depends on folding,  
which depends on  
order of amino acid  
bases



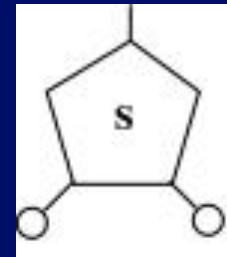
# Nucleic Acids (DNA, RNA)

Made of sugars, phosphates, bases

Sugar



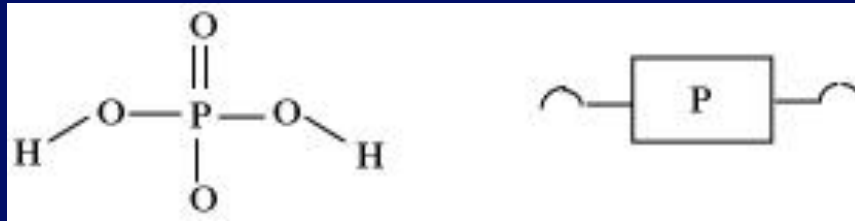
Schematic



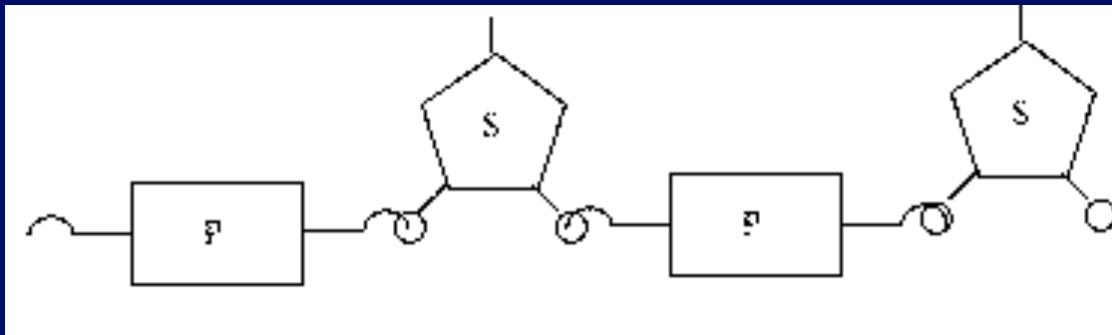
Ribose Sugar  
5 C, 5 O, 10 H

Ribonucleic acid (RNA) uses ribose sugar;  
Deoxyribonucleic acid (DNA) uses deoxyribose sugar

phosphate



sugars & phosphates linked  
phosphodiester bonds

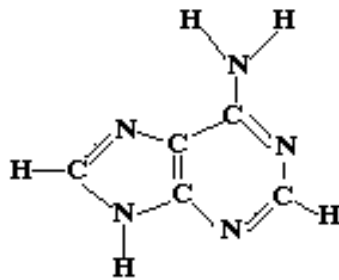


Segment of side of ladder structure

# Nucleic Acids (cont.)

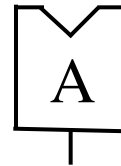
Bases: Carry Genetic Code

Purines



Adenine

Adenine

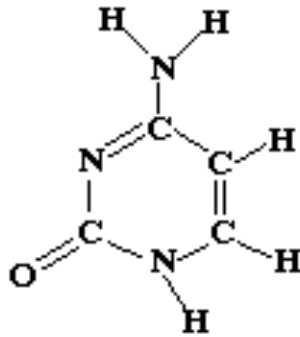


Guanine



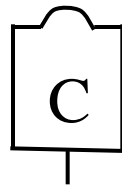
Equal numbers of C and N

# Pyrimidines

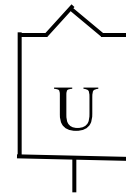


Cytosine

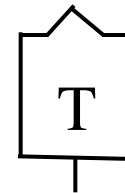
More C than N



Cytosine

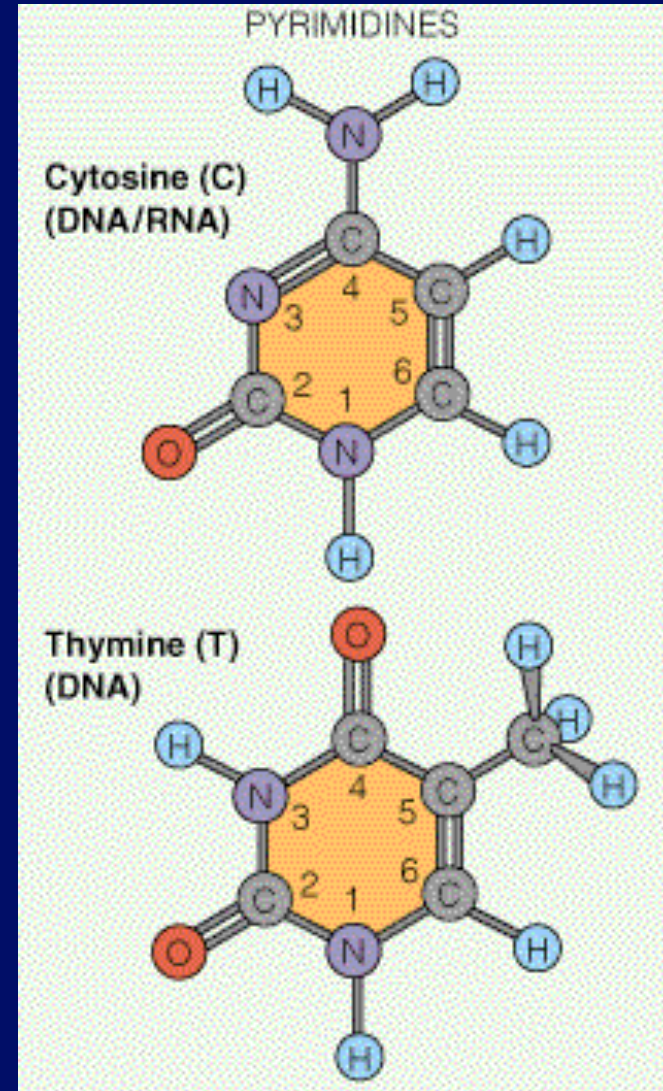
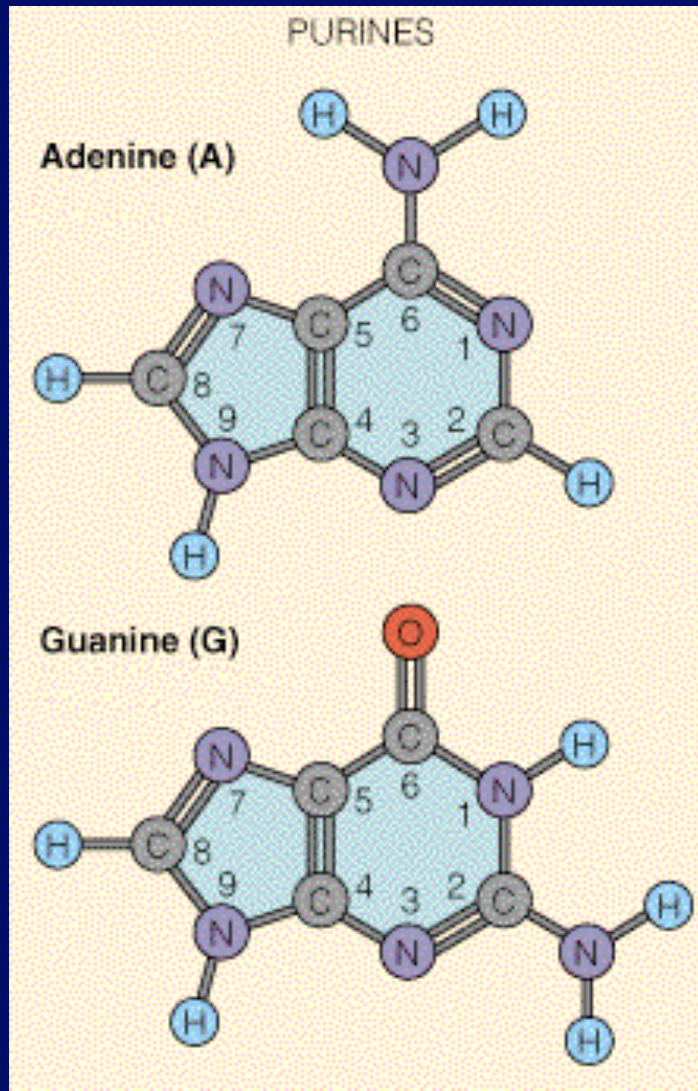


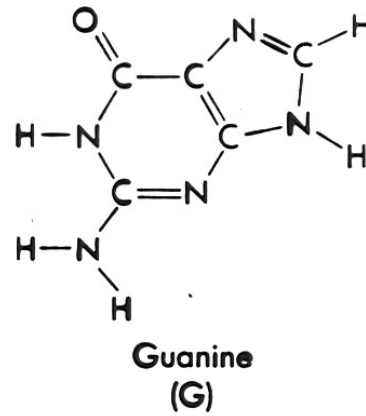
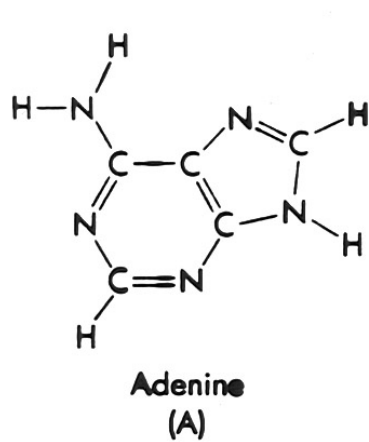
Uracil / Thymine



RNA / DNA

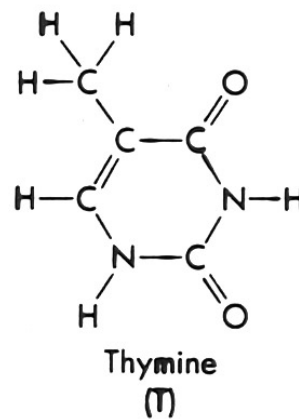
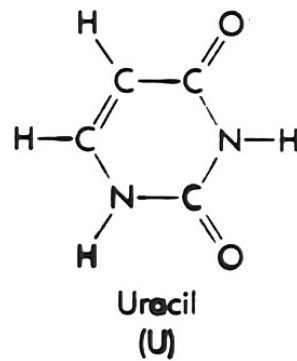
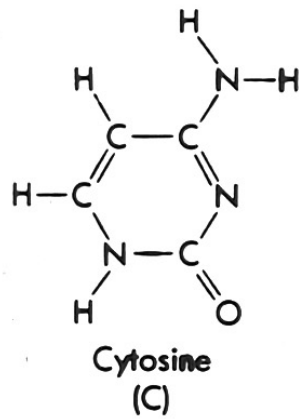
# Bases in Nucleic acids: Purines and Pyrimidines





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Pyrimidines



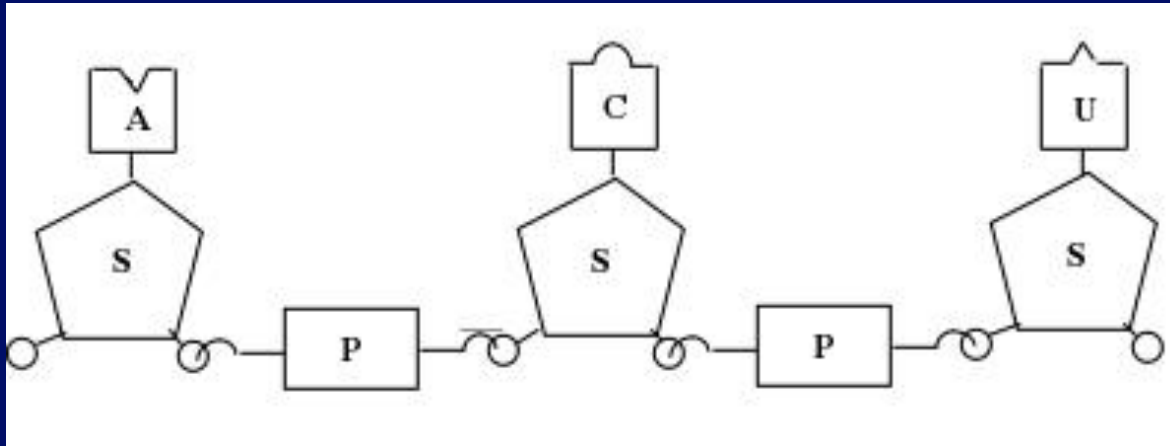
Purines

Pyrimidines

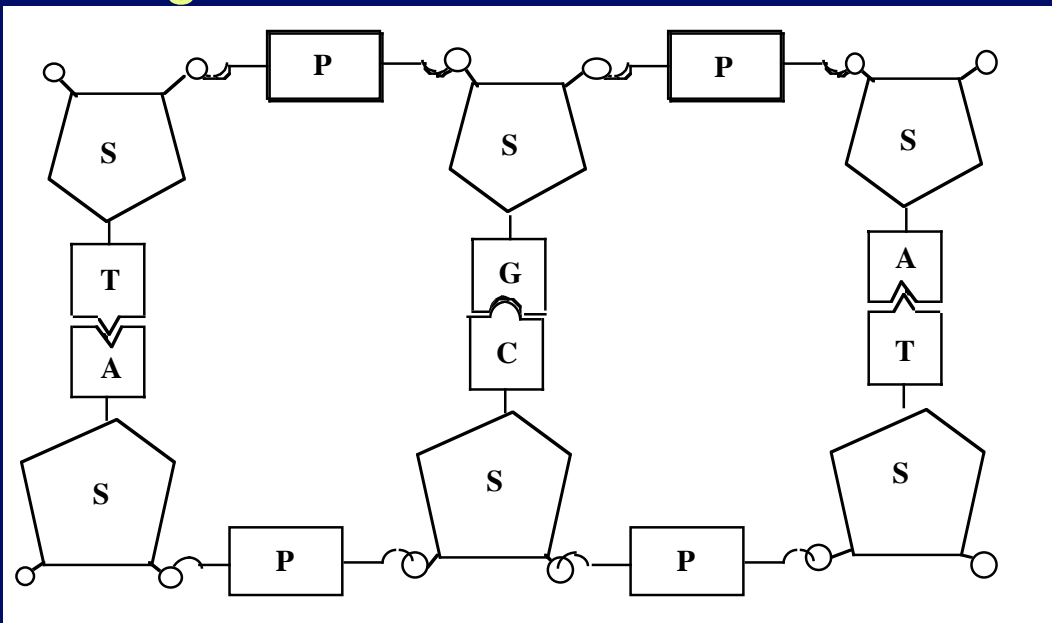
Note Uracil

# Nucleic Acids (cont.)

## Segment of RNA



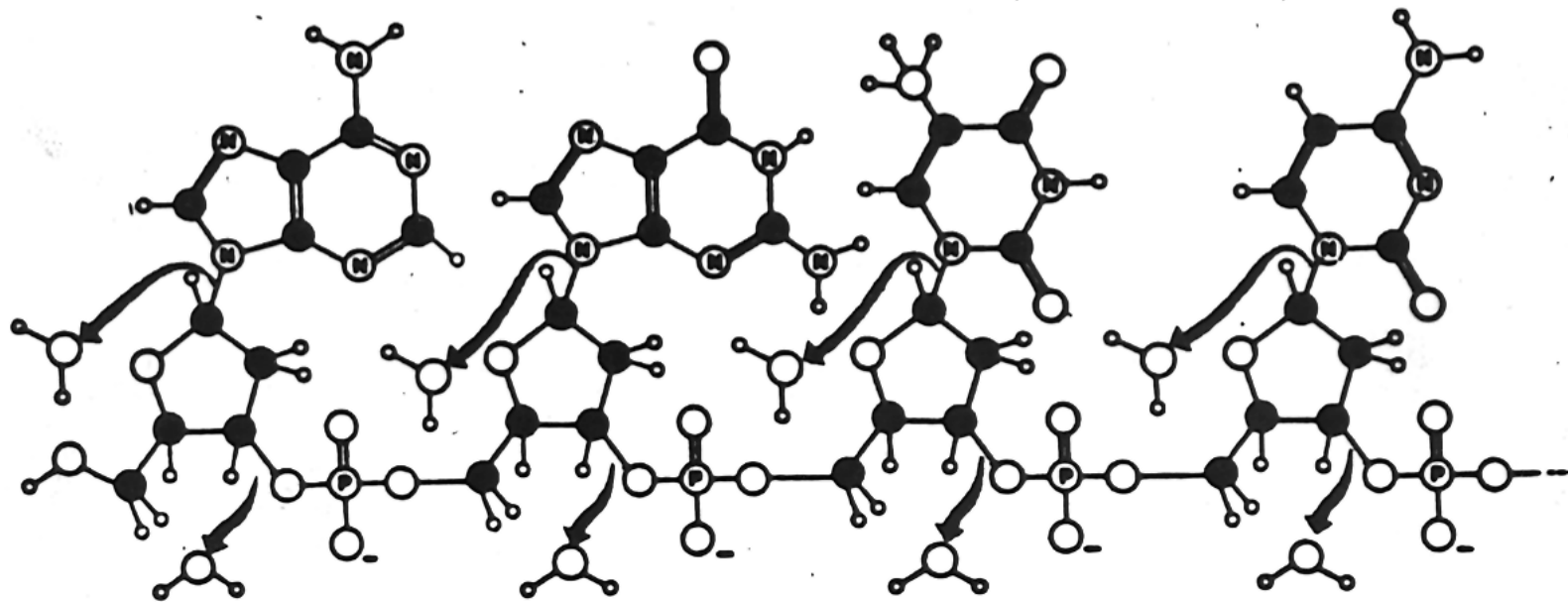
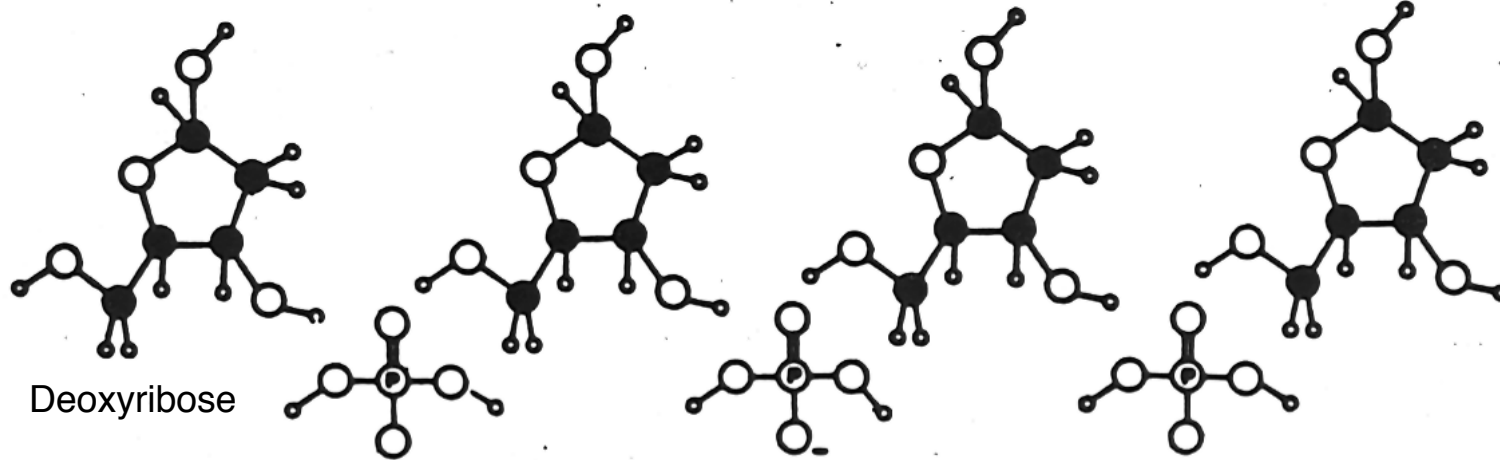
## Segment of DNA



Note that T replaces U in DNA

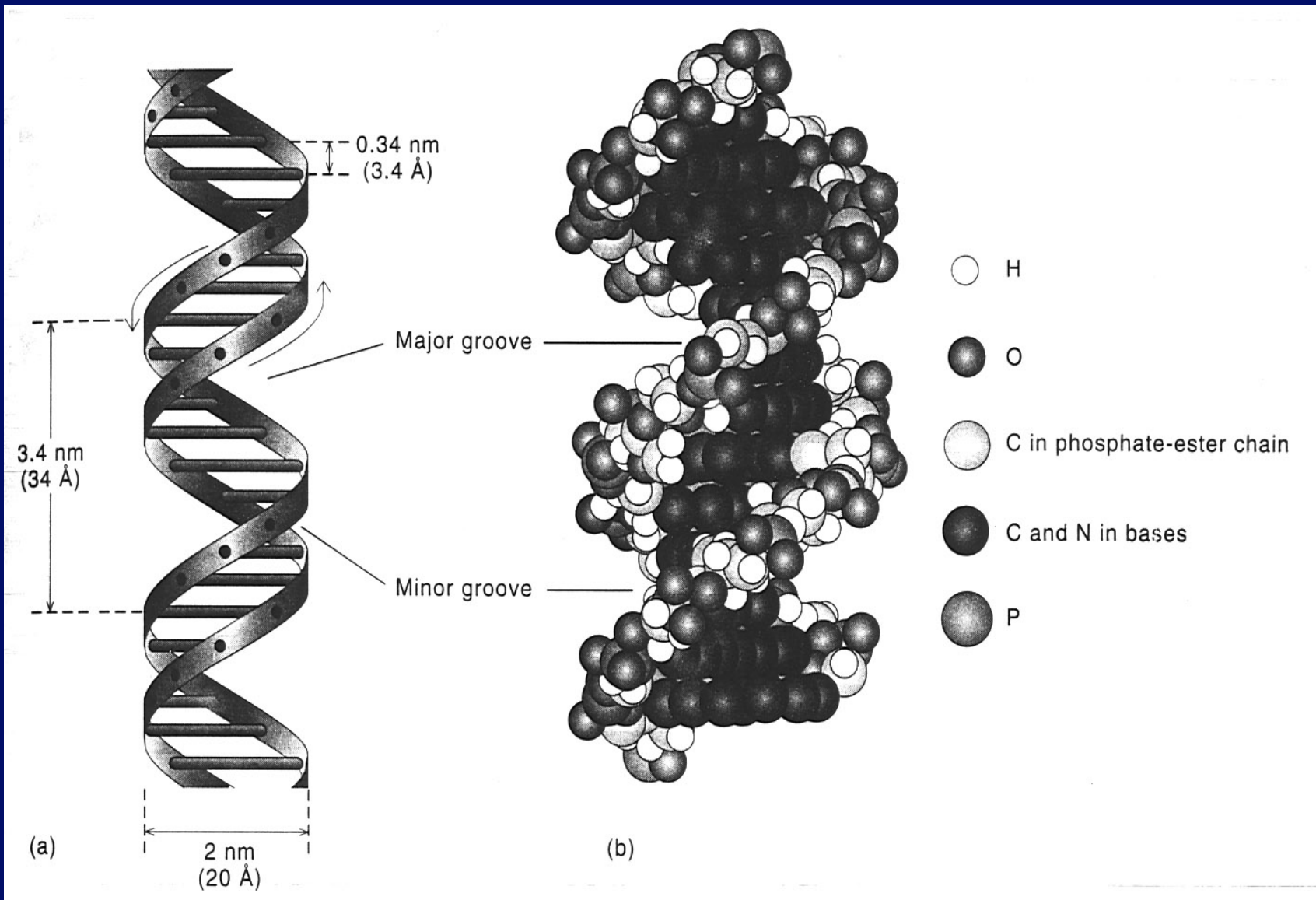


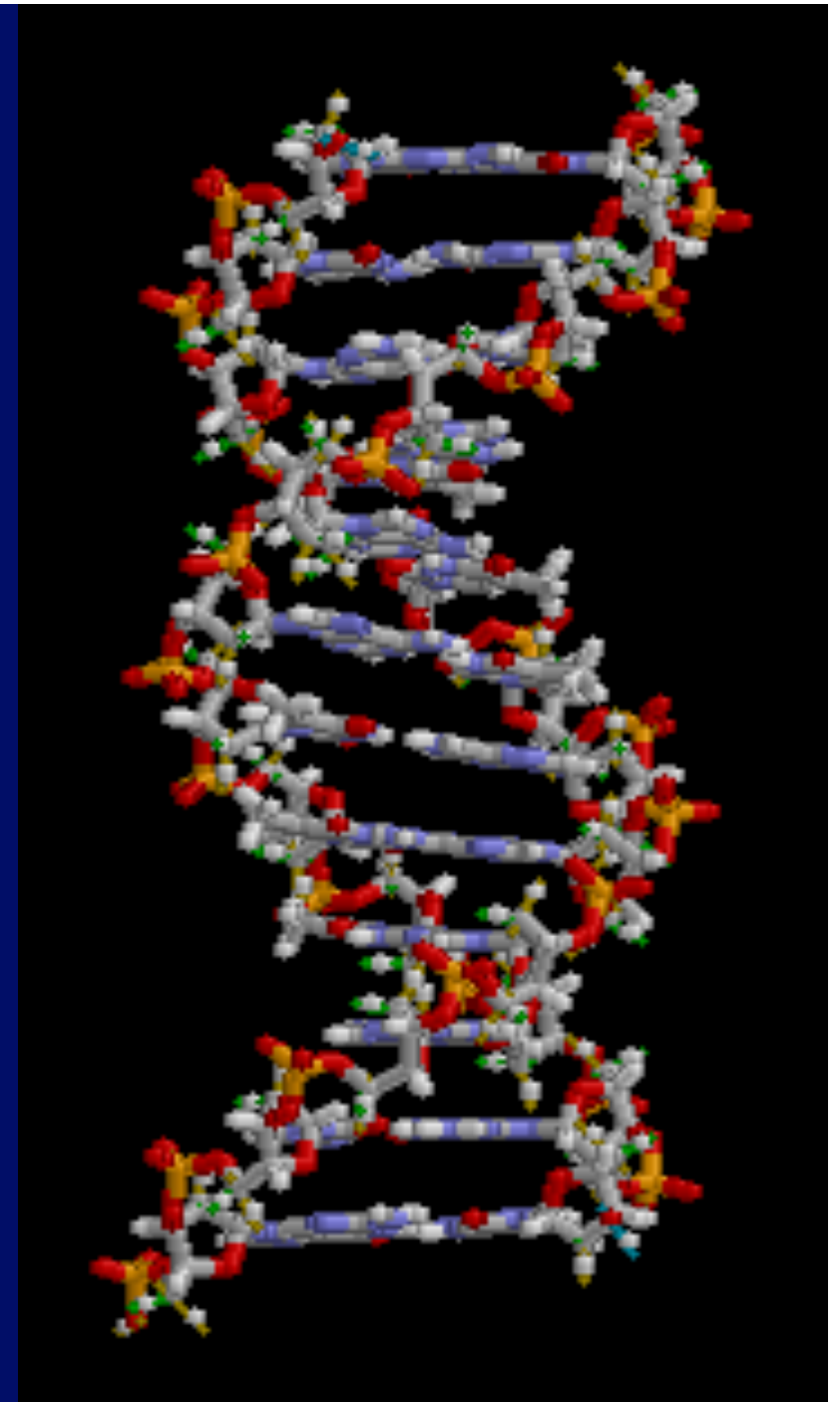
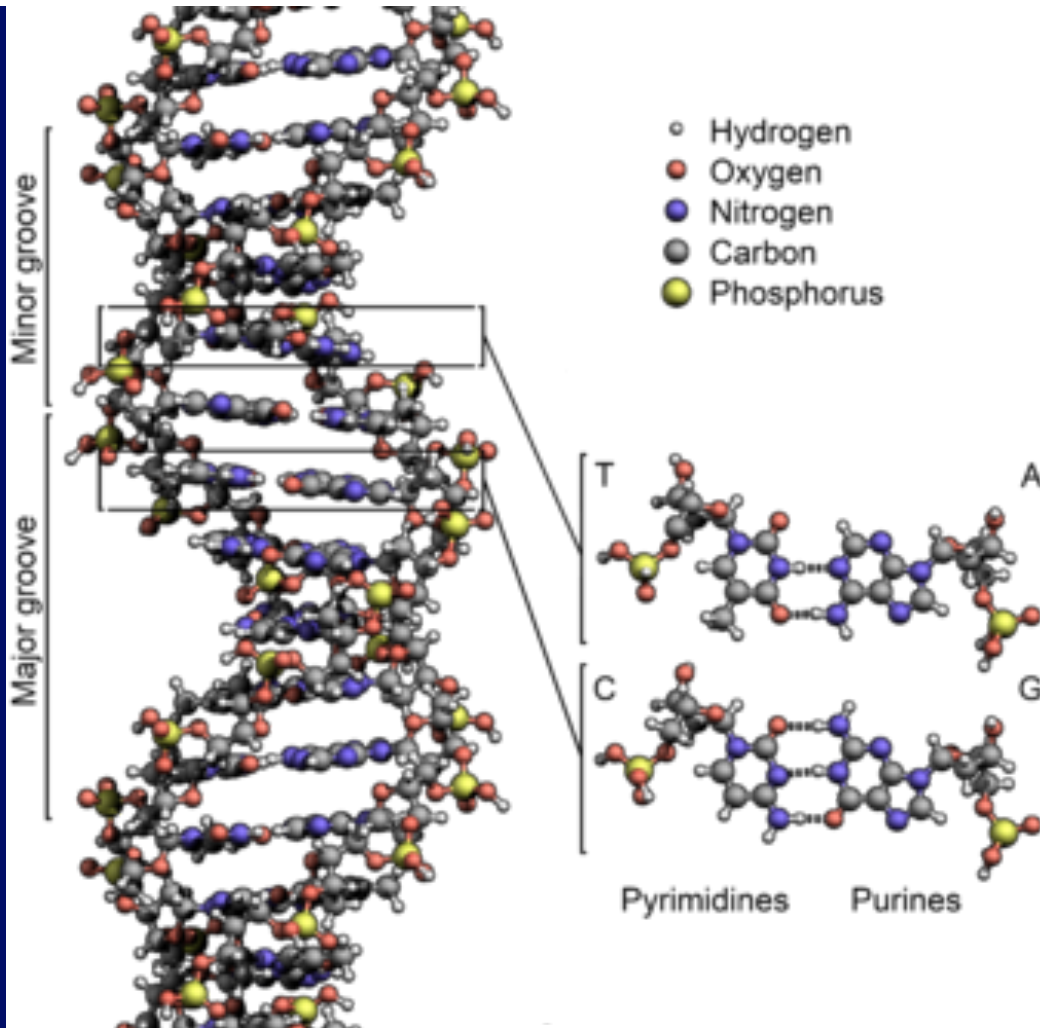
# At the Chemical Level



Deoxyribonucleic Acid (DNA)

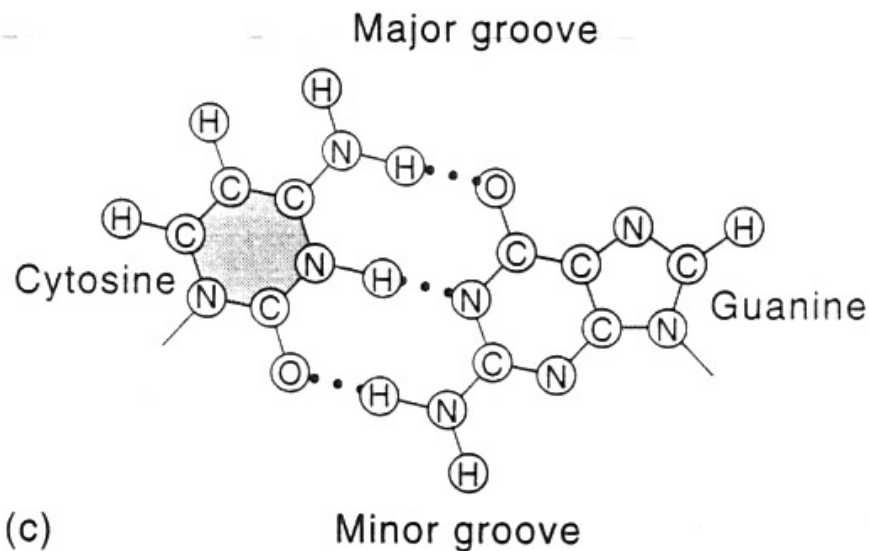
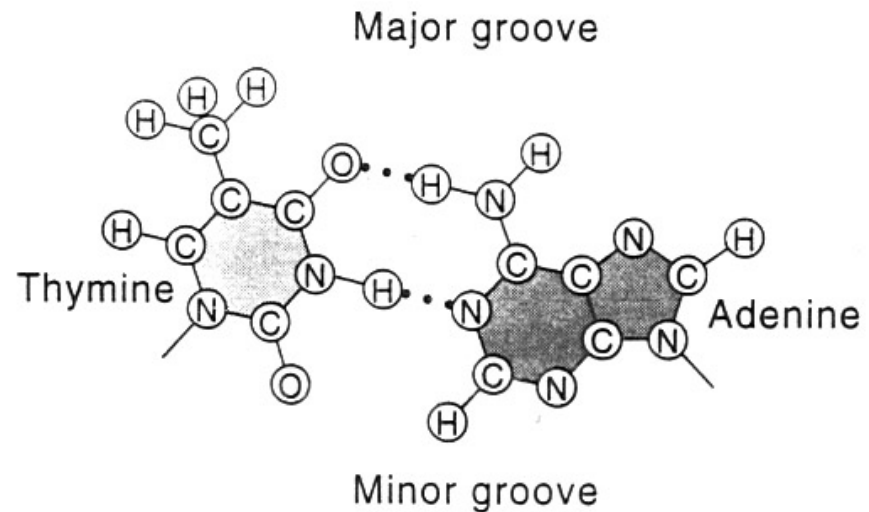
# The two strands of DNA form a double helix, connected between bases by hydrogen bonds



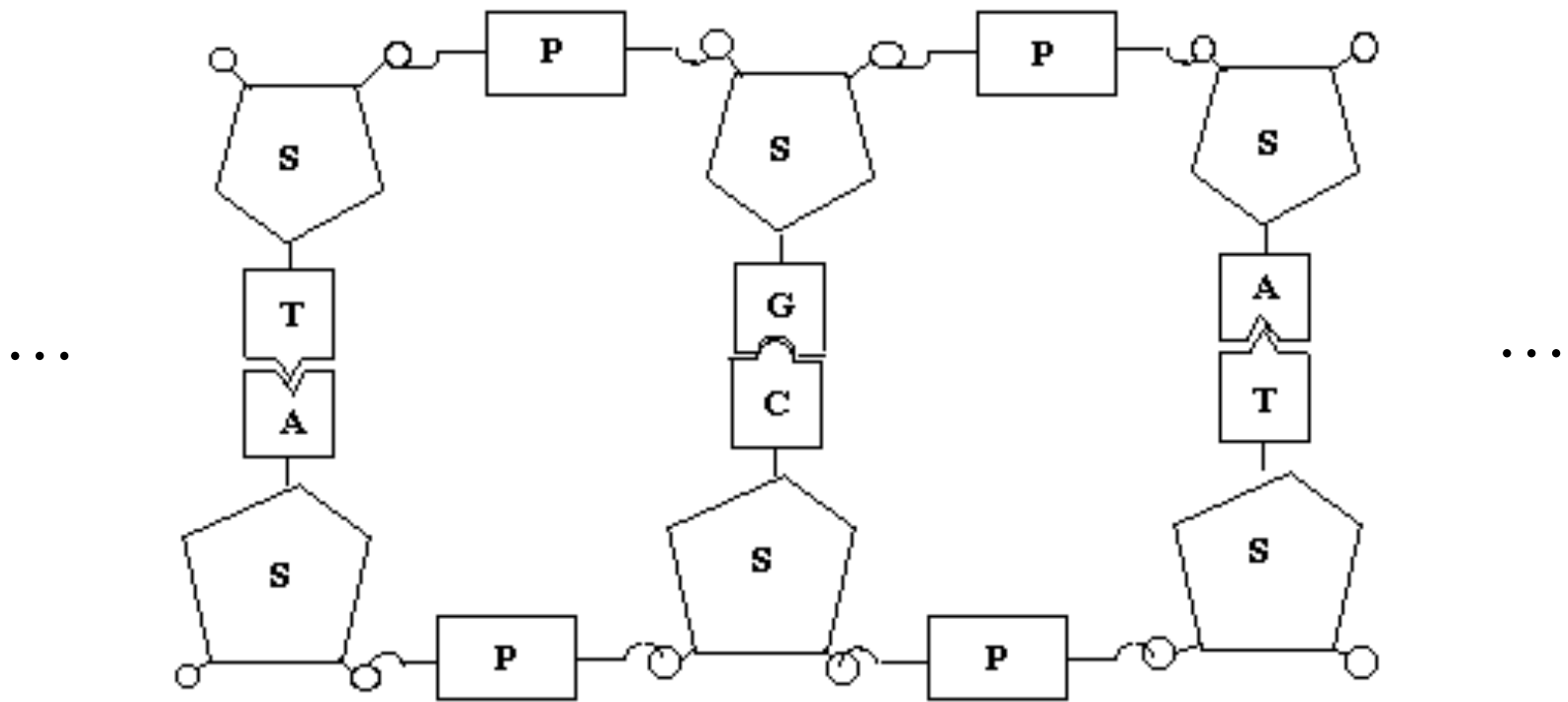


Model of a short segment of DNA showing all the atoms

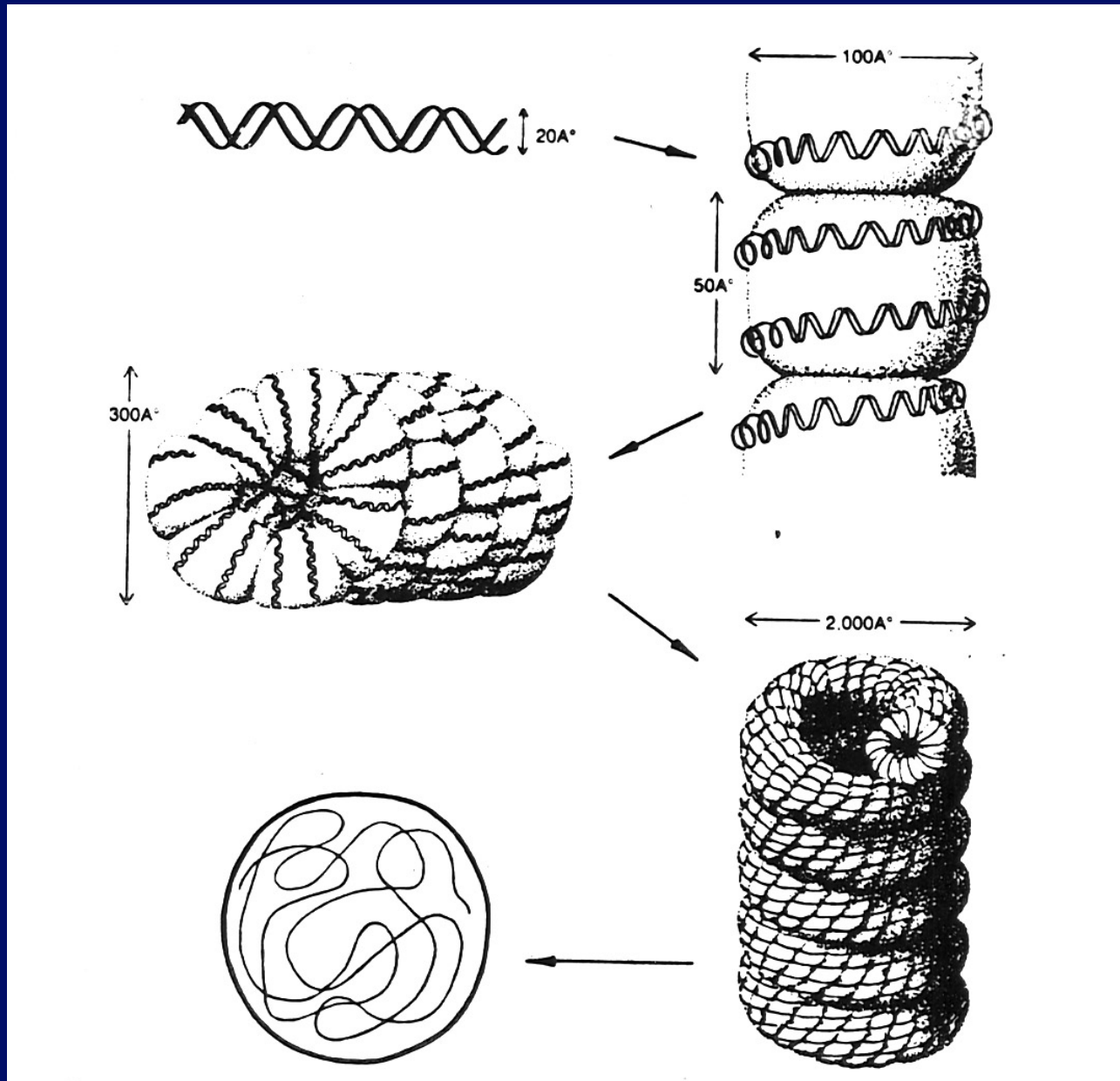
# Hydrogen Bonds (weak) connect the bases across the two sides of DNA



# Segment of DNA



# Further wrapping to make compact chromosome



# Information Storage

- Nucleic acids store information
- The information specifies proteins
- The information can be replicated
- This allows inheritance

## Base pairing rules

A - T (DNA)                      G - C  
- U (RNA)

⇒ Replication of order  
(reproduction)

Nucleic Acids and Proteins communicate  
through the **Genetic Code**



# Codons and Genes

## Codon:

A 3 base sequence that specifies an **Amino Acid**

## Gene:

A sequence of codons that specifies a **Protein**

e.g.	tobacco mosaic virus	4 genes
	bacteria	$\sim 10^3$ to $10^4$ genes
	human cell	$\sim 23,000$ genes

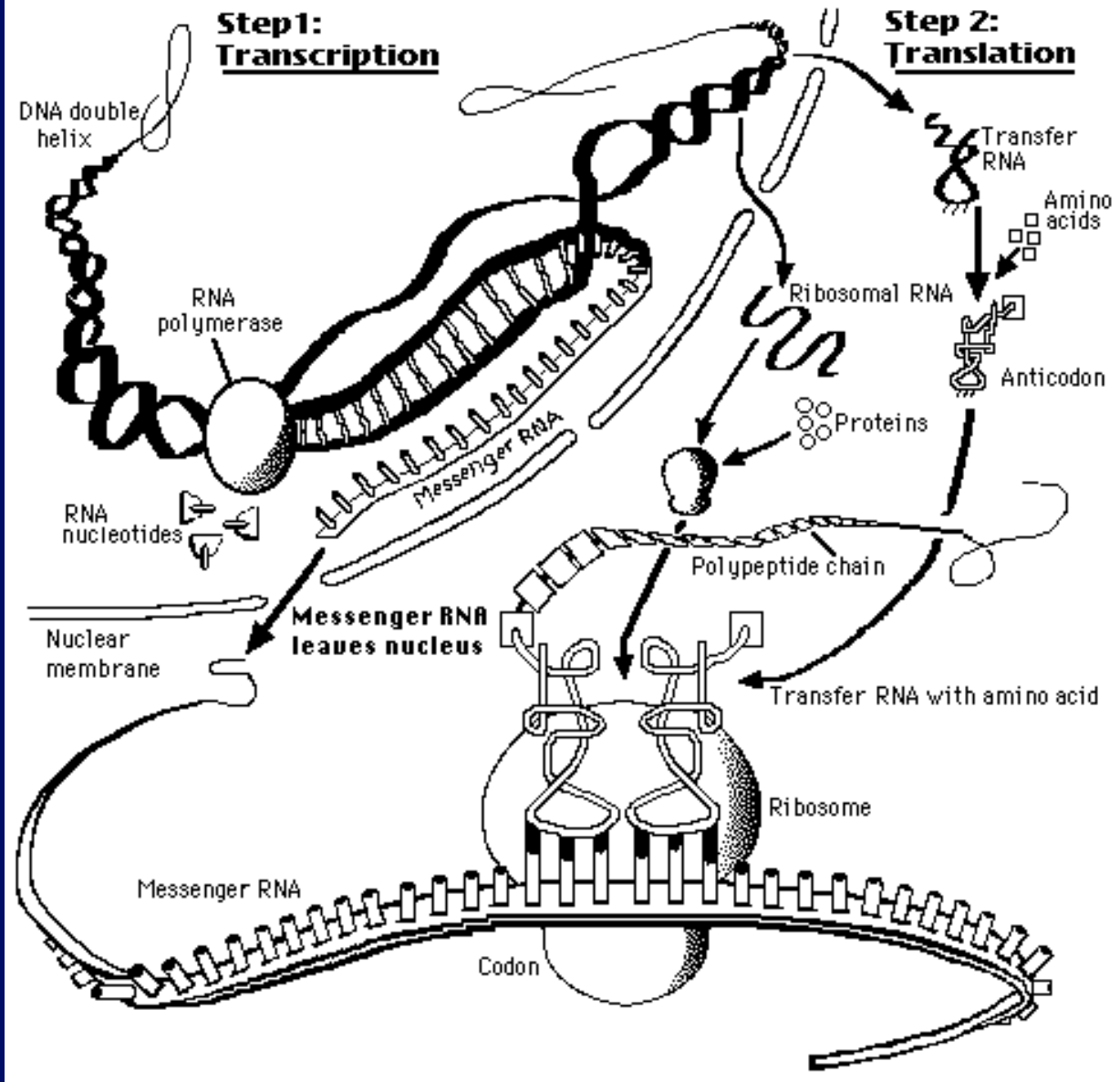
# For mRNA

# Genetic Code

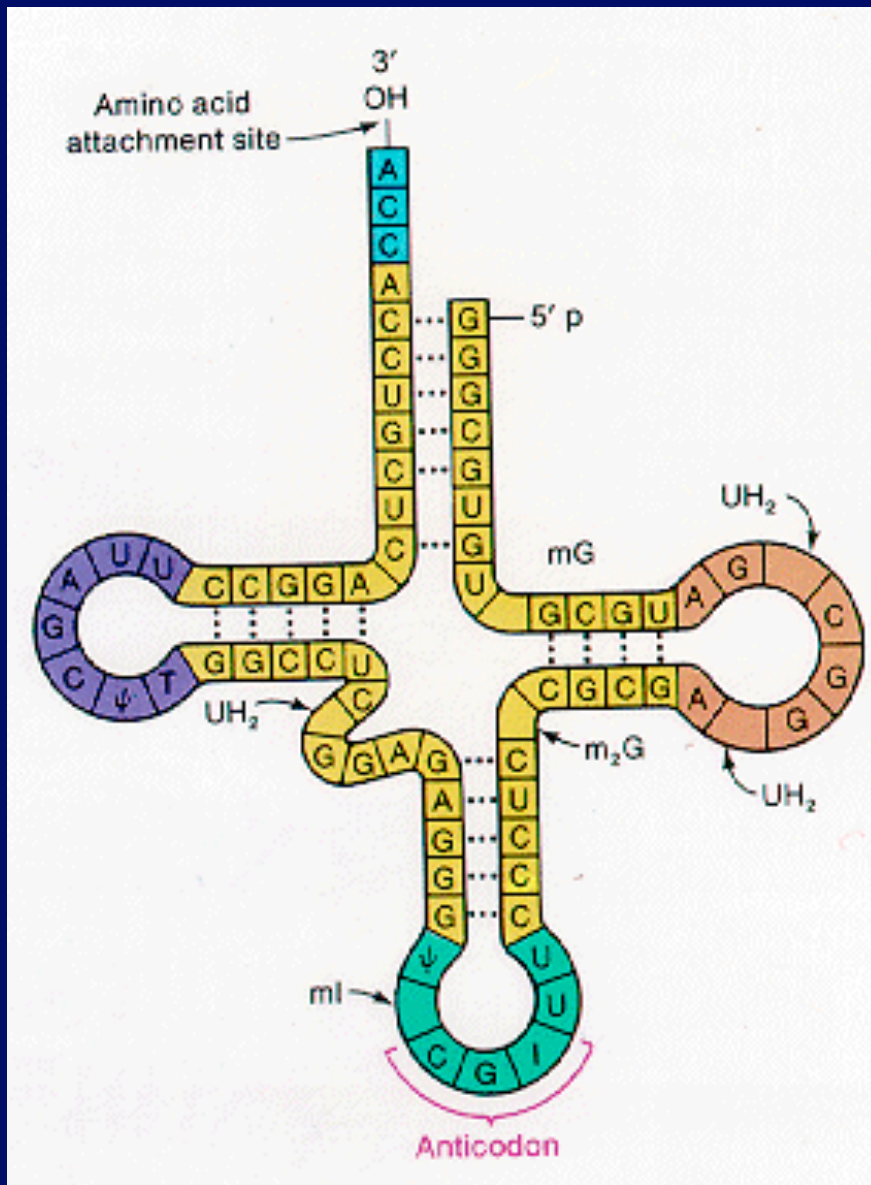
First RNA Base	Second RNA Base				Third RNA BASE
	U	C	A	G	
U	Phenylalanine	Serine	Tyrosine	Cysteine	U
	Phenylalanine	Serine	Tyrosine	Cysteine	C
	Leucine	Serine	Stop	Stop	A
	Leucine	Serine	Stop	Tryptophan	G
C	Leucine	Proline	Histidine	Arginine	U
	Leucine	Proline	Histidine	Arginine	C
	Leucine	Proline	Glutamine	Arginine	A
	Leucine	Proline	Glutamine	Arginine	G
A	Isoleucine	Threonine	Asparagine	Serine	U
	Isoleucine	Threonine	Asparagine	Serine	C
	Isoleucine	Threonine	Lysine	Arginine	A
	Start/Methionine	Threonine	Lysine	Arginine	G
G	Valine	Alanine	Aspartic Acid	Glycine	U
	Valine	Alanine	Aspartic Acid	Glycine	C
	Valine	Alanine	Glutamic Acid	Glycine	A
	Valine	Alanine	Glutamic Acid	Glycine	G

Amino Acids

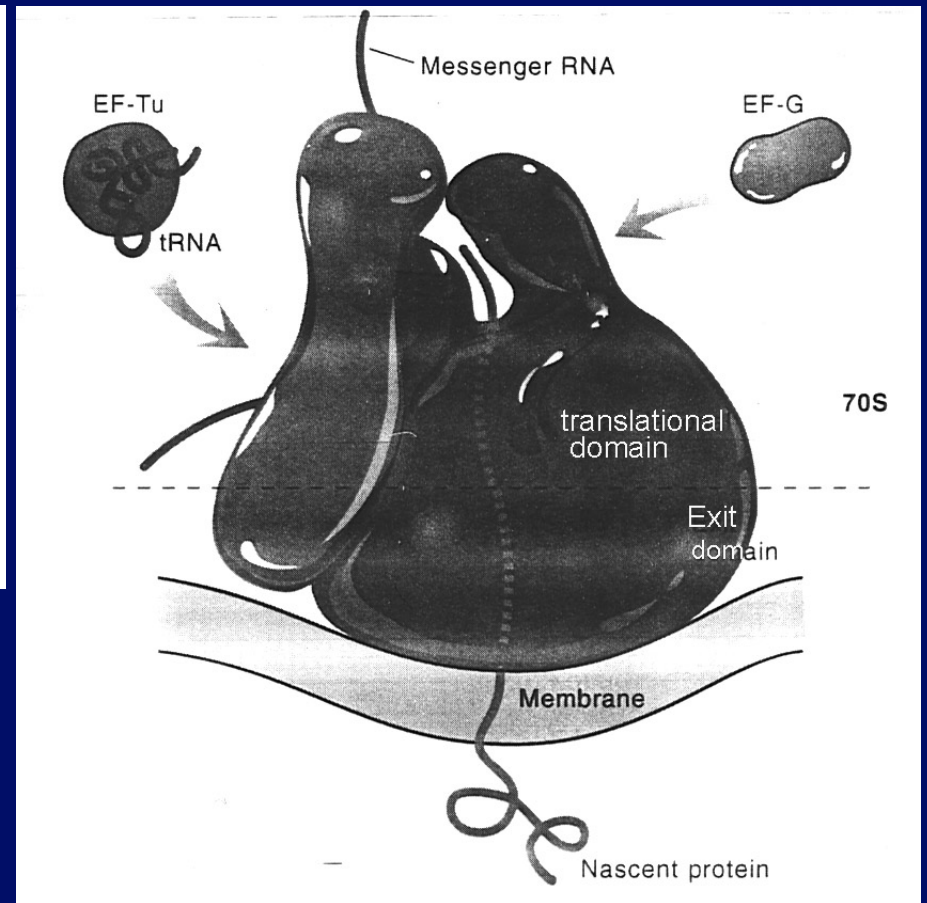
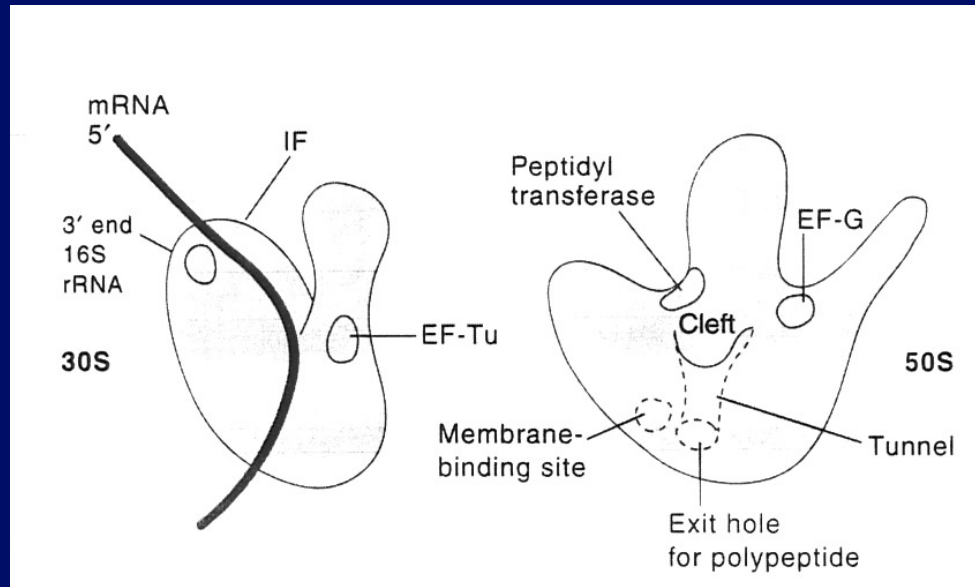
# PROTEIN SYNTHESIS



# Structure of a tRNA



# Translation



# Variations in the Code

## 1. “Wobble” Bases

The third base in a codon can sometimes vary.

tRNA

U

G

mRNA

A or G

C or U

Comparison to genetic code  $\Rightarrow$  no change  
in amino acids

# For mRNA

# Genetic Code

First RNA Base	U	C	A	G	Third RNA BASE
U	Phenylalanine	Serine	Tyrosine	Cysteine	U
	Phenylalanine	Serine	Tyrosine	Cysteine	C
	Leucine	Serine	Stop	Stop	A
	Leucine	Serine	Stop	Tryptophan	G
C	Leucine	Proline	Histidine	Arginine	U
	Leucine	Proline	Histidine	Arginine	C
	Leucine	Proline	Glutamine	Arginine	A
	Leucine	Proline	Glutamine	Arginine	G
A	Isoleucine	Threonine	Asparagine	Serine	U
	Isoleucine	Threonine	Asparagine	Serine	C
	Isoleucine	Threonine	Lysine	Arginine	A
	Start/Methionine	Threonine	Lysine	Arginine	G
G	Valine	Alanine	Aspartic Acid	Glycine	U
	Valine	Alanine	Aspartic Acid	Glycine	C
	Valine	Alanine	Glutamic Acid	Glycine	A
	Valine	Alanine	Glutamic Acid	Glycine	G

Amino Acids

2. Some organisms use slightly different codes, with one or more changes in codon translation.

First seen in mitochondrial DNA.

Now known in some nuclear DNA

The code has evolved since the last common ancestor (But not much).



# Summary

1. Atoms needed: H, C, O, N, small amounts of P (phosphorus), S (sulfur)
2. Two basic molecules needed for life: proteins, nucleic acids
3. Both are polymers - made of simpler monomers. The monomers function as words or letters of alphabet. Information is the key.

## Summary (cont.)

4. Proteins and nucleic acids closely linked at fundamental level. Communicate through genetic code. All organisms have almost the same genetic code. It must have originated very early in evolution of life.
5. In present day organisms, protein synthesis must be directed by nucleic acids, but nucleic acid reading or replication requires enzymes (proteins). Chicken-Egg problem

# Some Movies of Processes

- From the Virtual Cell Animation collection, Molecular and Cellular Biology Learning Center
  - <http://vcell.ndsu.nodak.edu/animations/home.htm>
  - Needs Windows media player
- Another option:
  - [http://highered.mcgraw-hill.com/sites/0072507470/student\\_view0/chapter3/](http://highered.mcgraw-hill.com/sites/0072507470/student_view0/chapter3/)
  - And look for mRNA synthesis and How translation works.