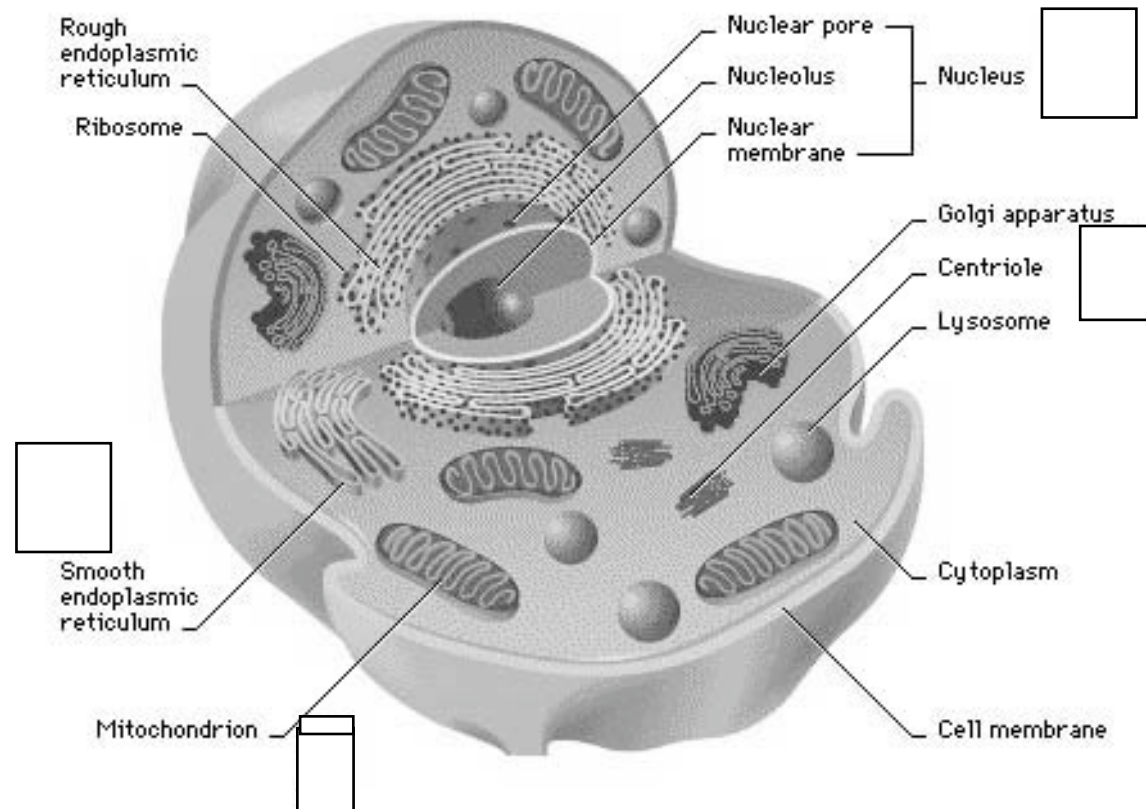


Life

# 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

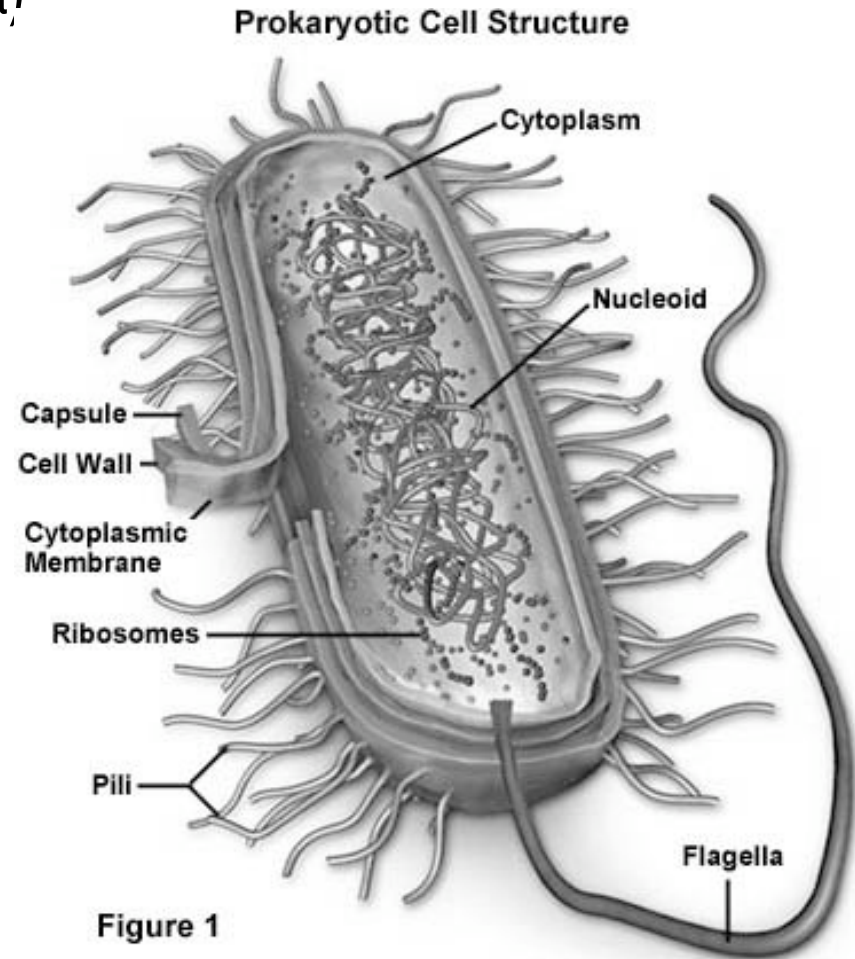
## Prokaryotes (Bacteria and Archaea)

First appeared

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

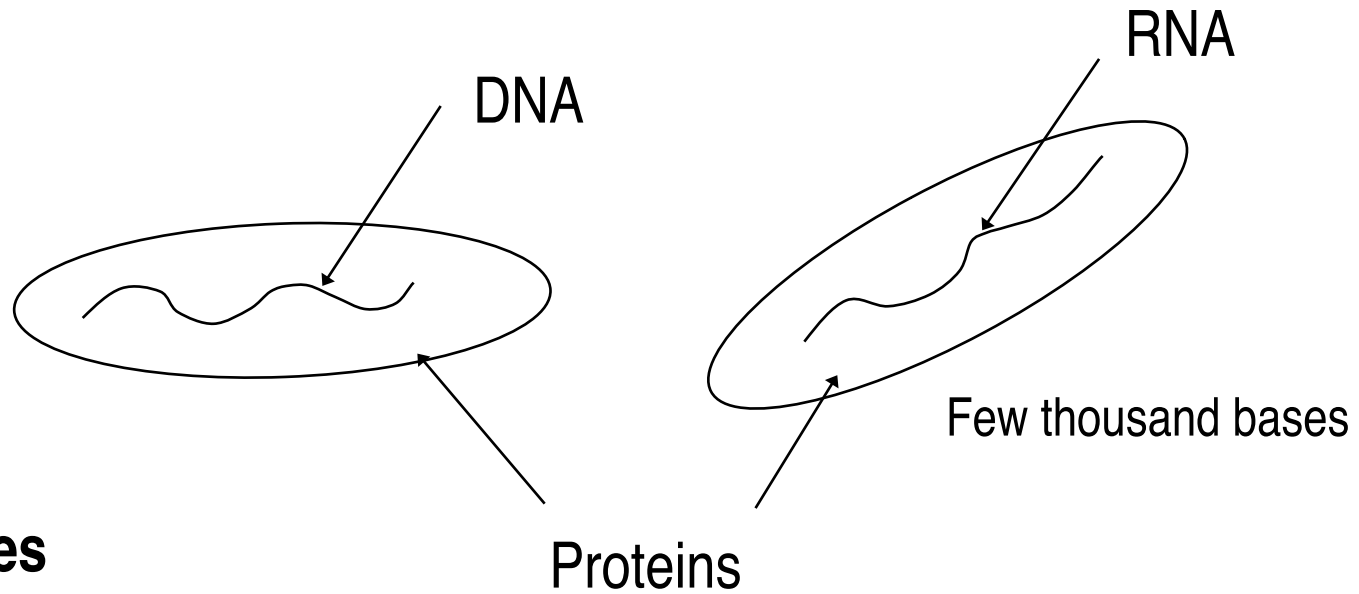
FREE LIVING

Or Parasites



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

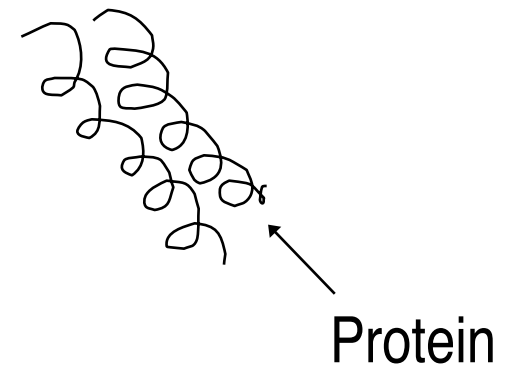
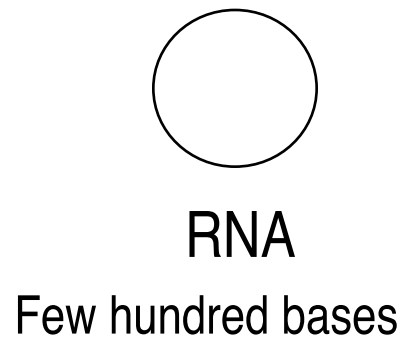
# Viruses



## Parasites

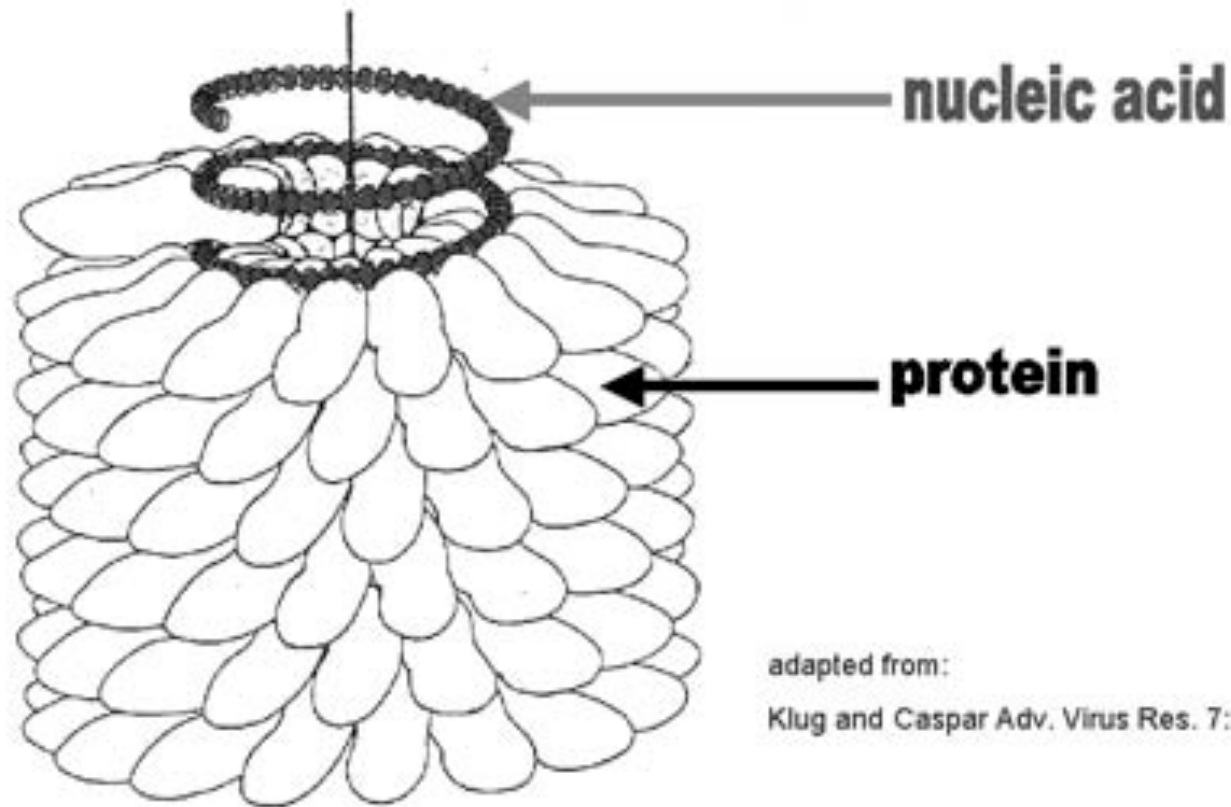
Viroids,  
Plasmids

Prions?



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



# 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)  
Construction and catalysis (enzymes)

H, C, N, O  
(P)

Nucleic acids made of nucleotides

base    sugar    phosphate

Polymers and Monomers

H, C, O

Carbohydrates made of sugars

Energy (food) + structure

[starch]

[cellulose]

H, C, (O)

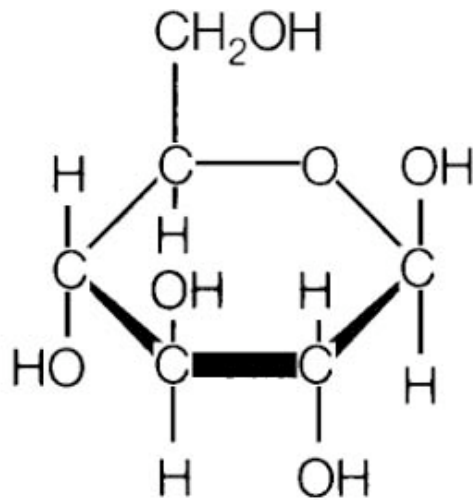
Lipids (hydrocarbons + carboxyl)

Membranes + Energy

[water-resistant]

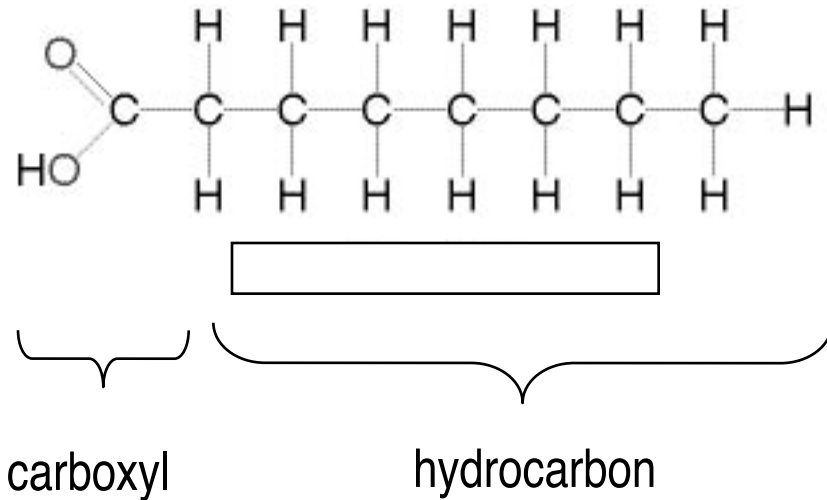


## Sugar

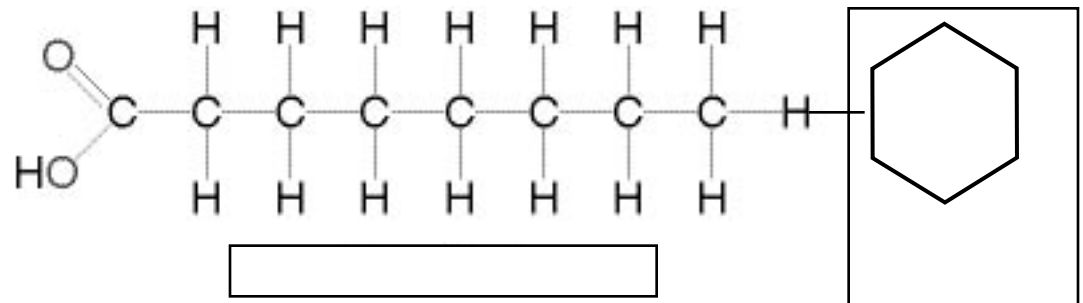


Glucose

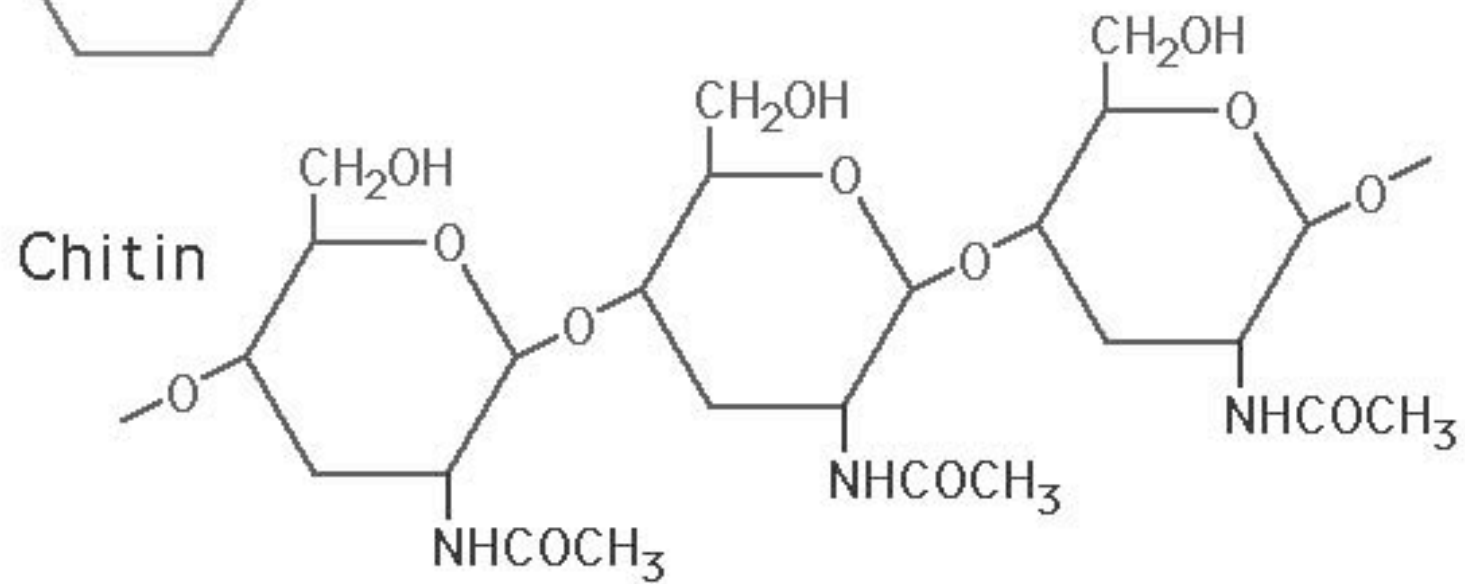
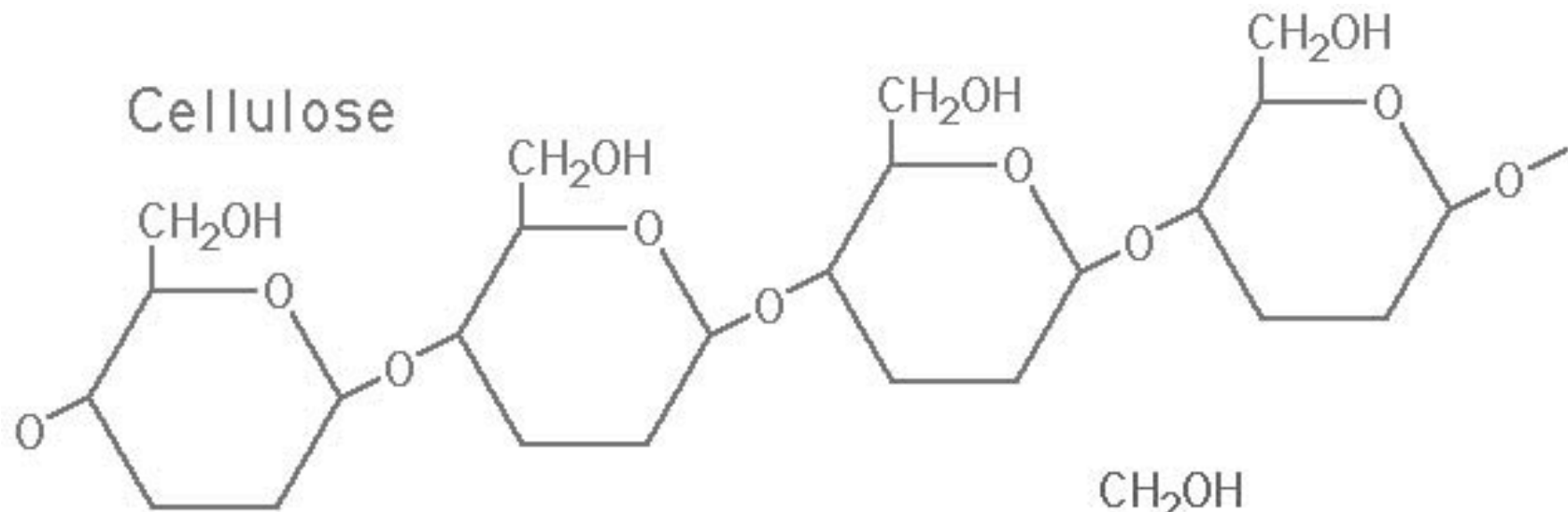
## Lipids



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



# Polysaccharides

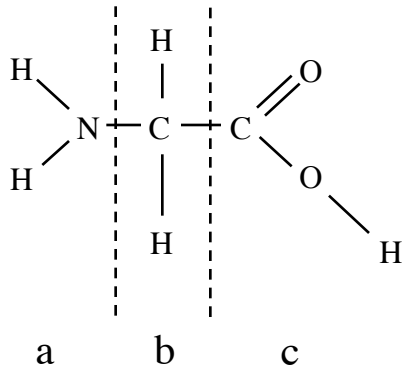


# Proteins

Monomers are amino acids

20 kinds

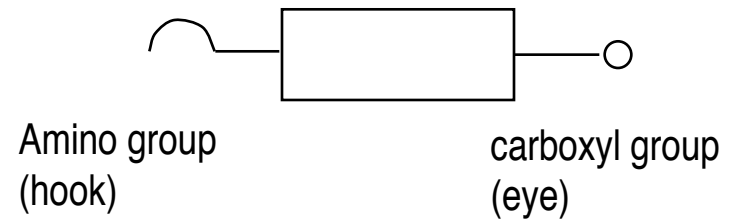
Glycine



Amino group

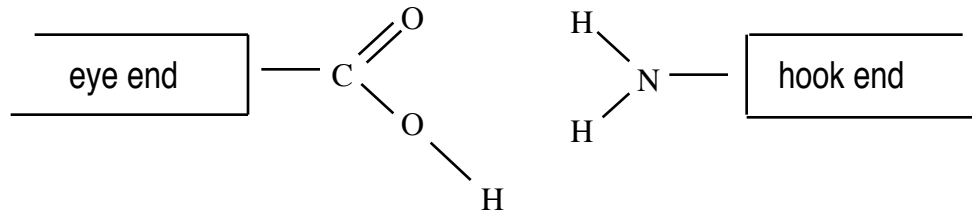
carboxyl group

Schematic

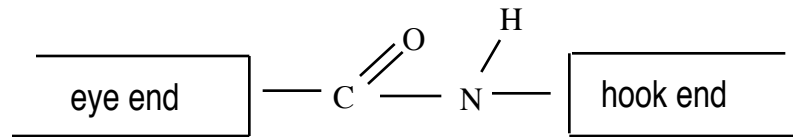


Section of Protein

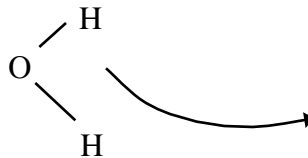
## A Peptide Bond at the Chemical Level



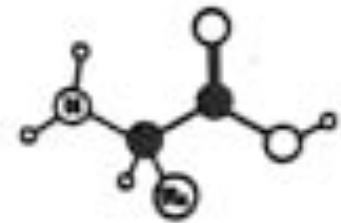
Before



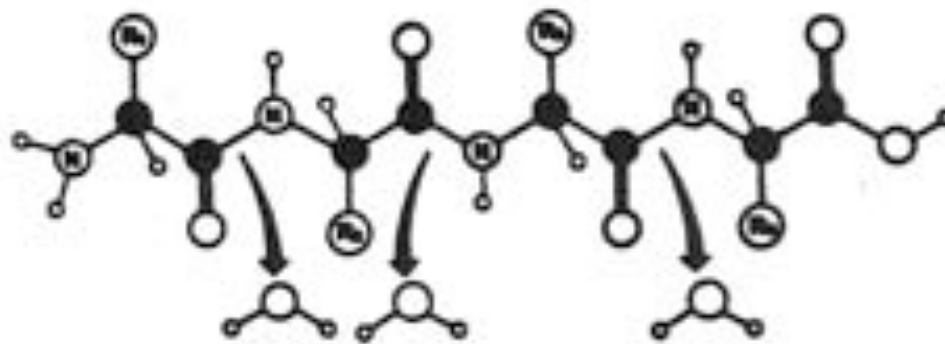
After



Note that a water molecule must be removed

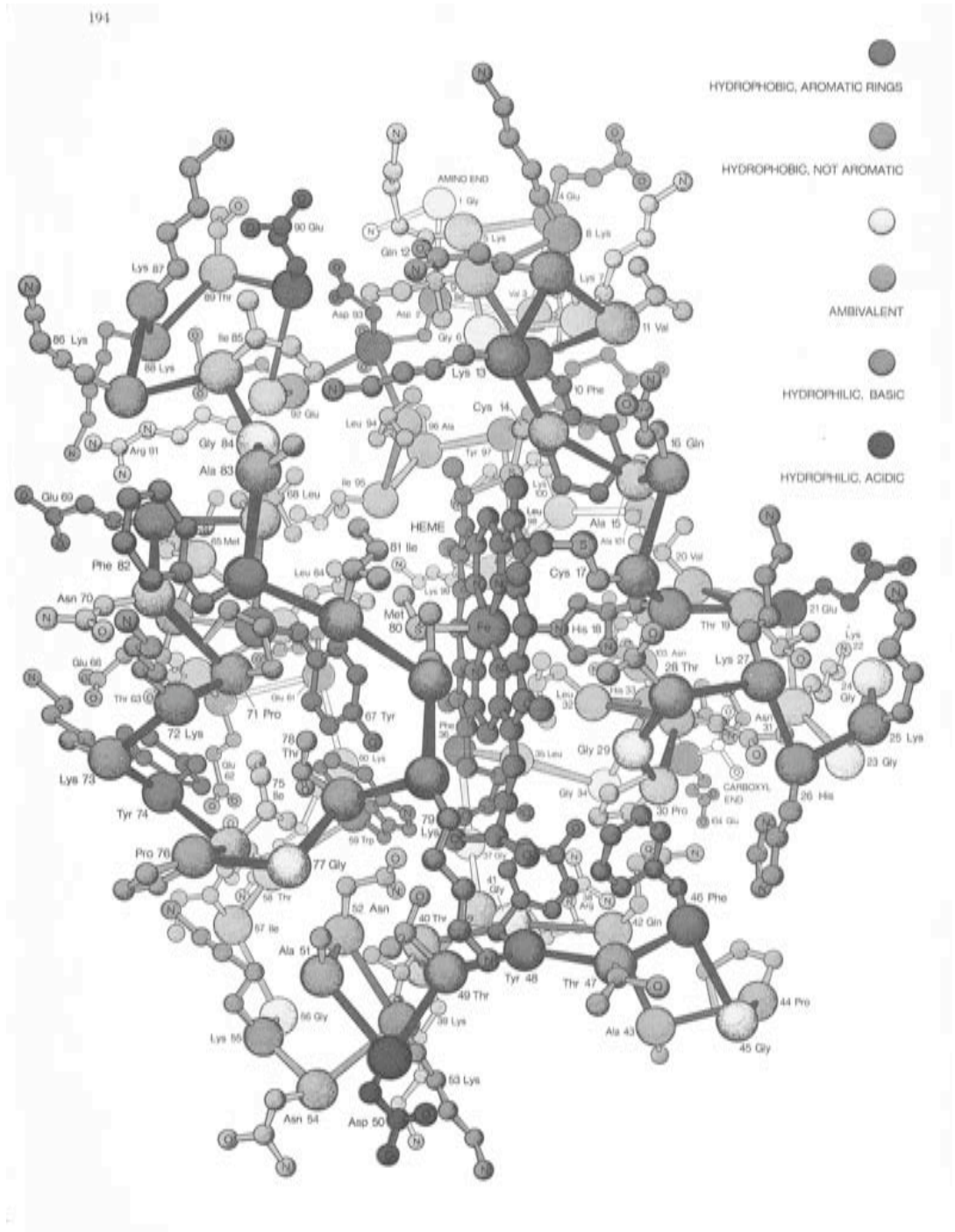


amino acids



protein

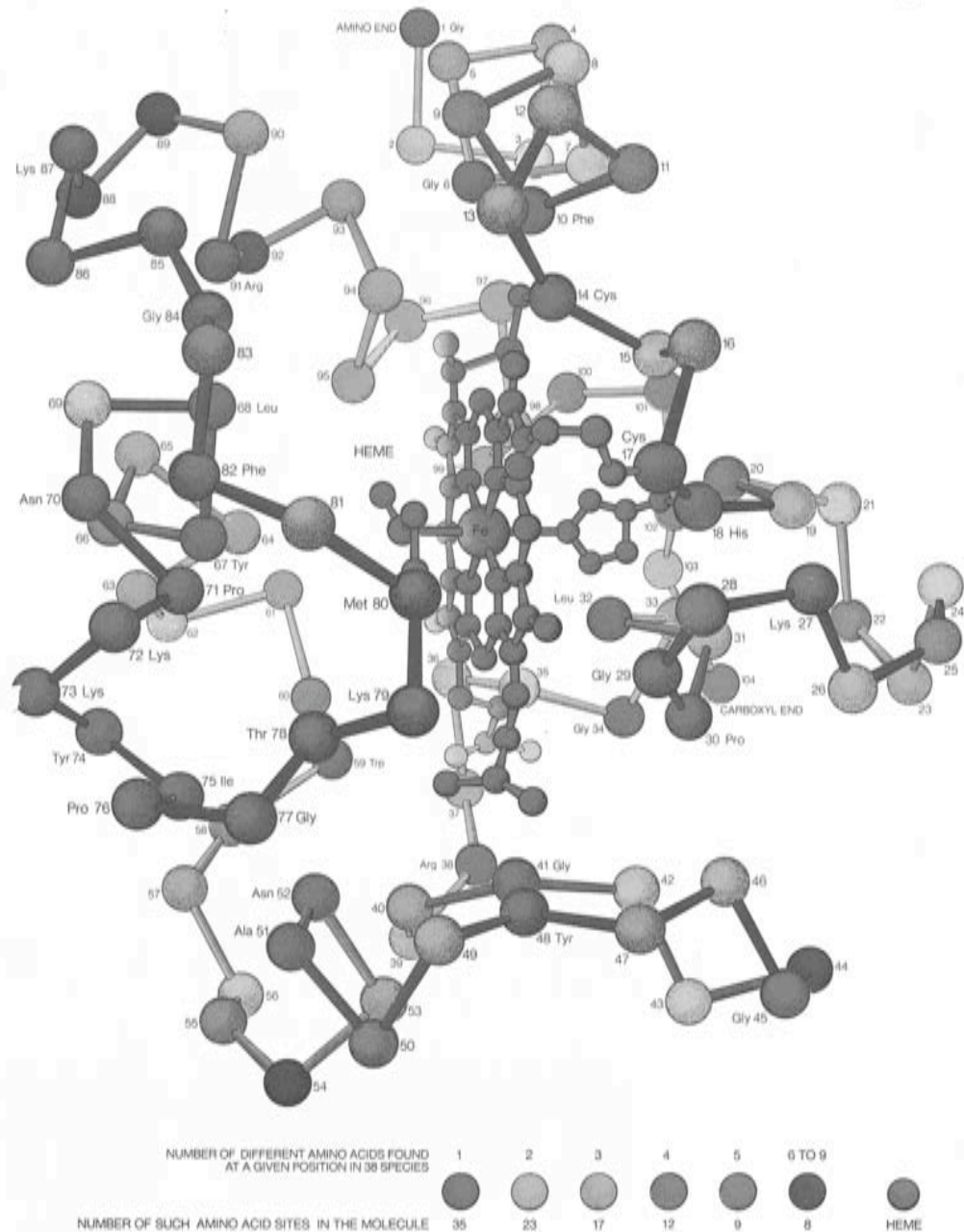
Each circle is an amino acid



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

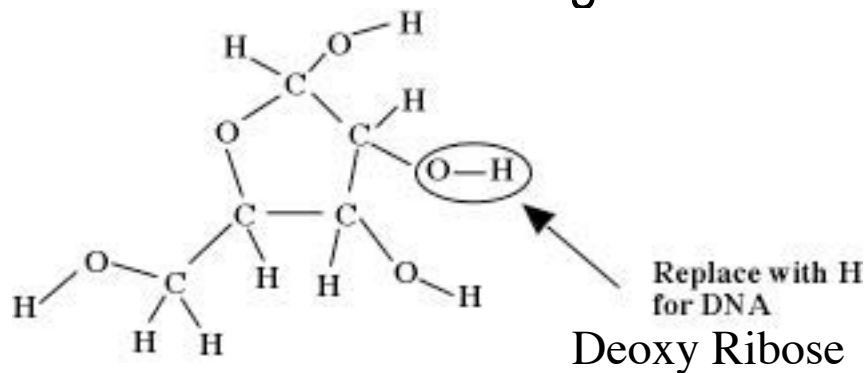


# Nucleic Acids

(DNA, RNA)

Made of sugars, phosphates, bases

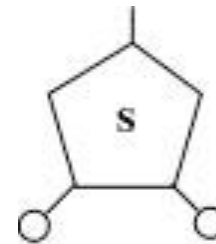
Sugar



Ribose Sugar

5 C, 5 O, 10 H

Schematic

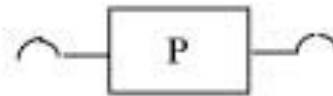
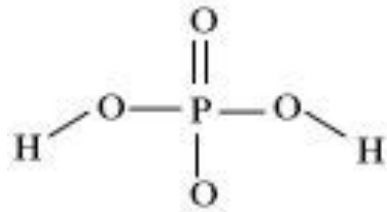


Ribonucleic acid (RNA) uses ribose sugar;

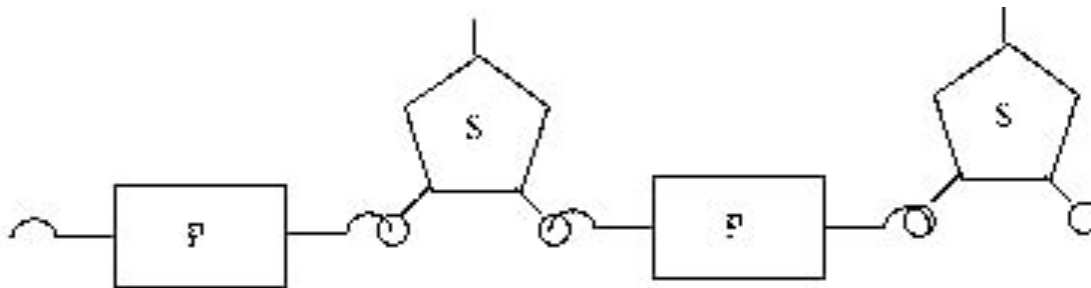
Deoxyribonucleic acid (DNA) uses deoxyribose sugar



phosphate



sugars & phosphates linked  
phosphodiester bonds

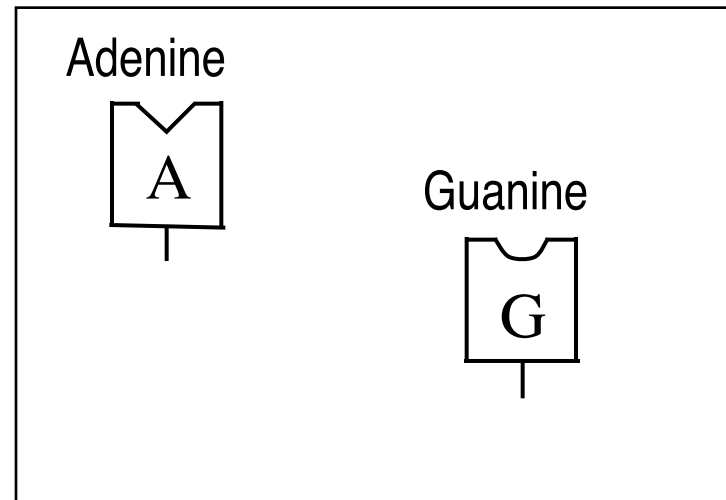
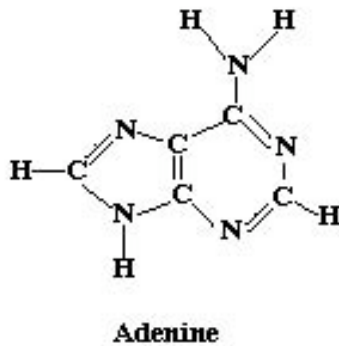


Segment of side of ladder structure

# Nucleic Acids (cont.)

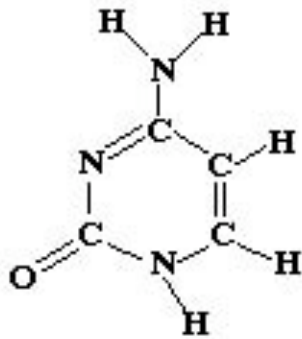
Bases: Carry Genetic Code

Purines



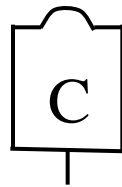
Equal numbers of C and N

# Pyrimidines

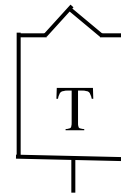


Cytosine

More C than N



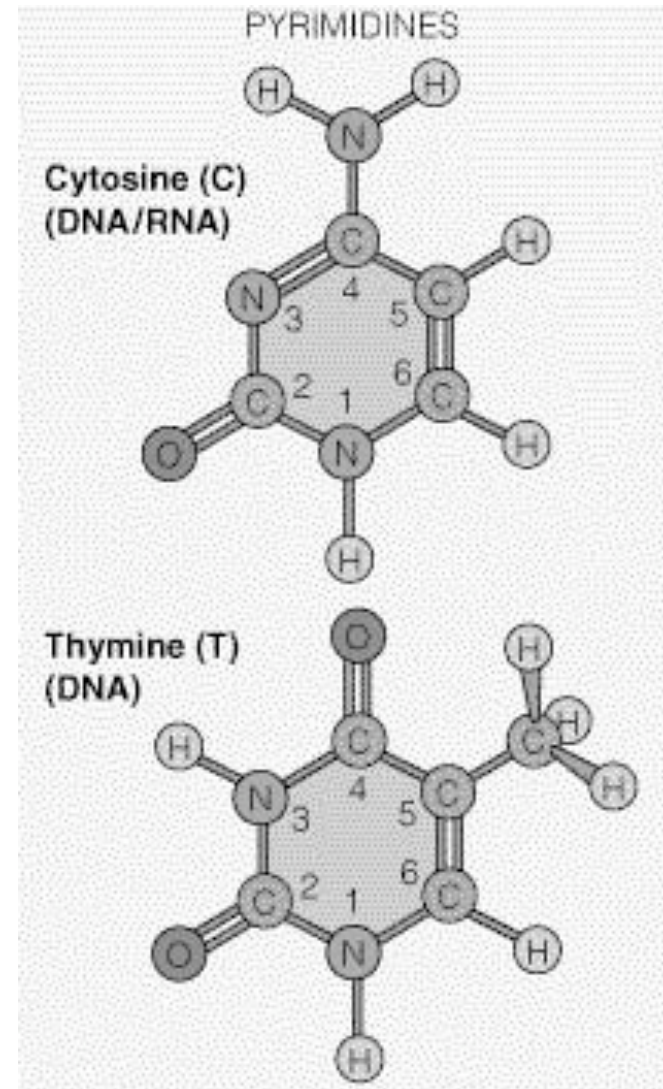
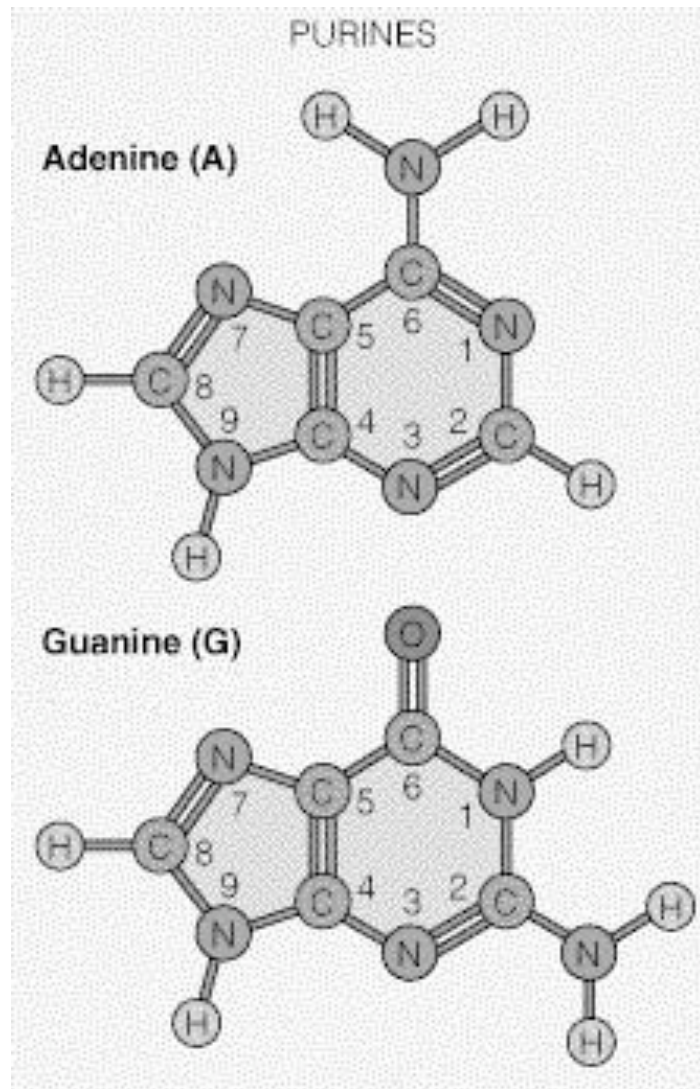
Cytosine

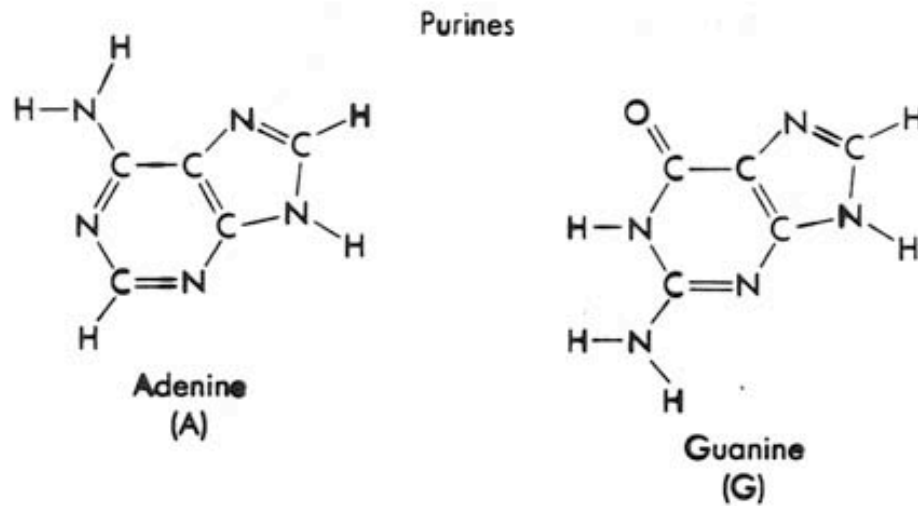


Uracil / Thymine

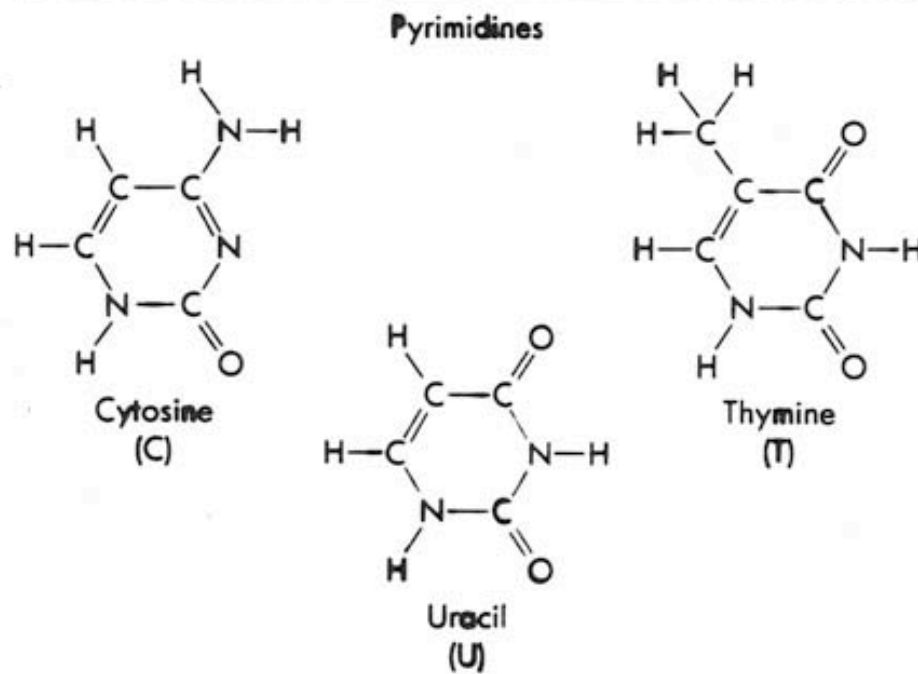
RNA / DNA

## Bases in Nucleic acids: Purines and Pyrimidines





Purines

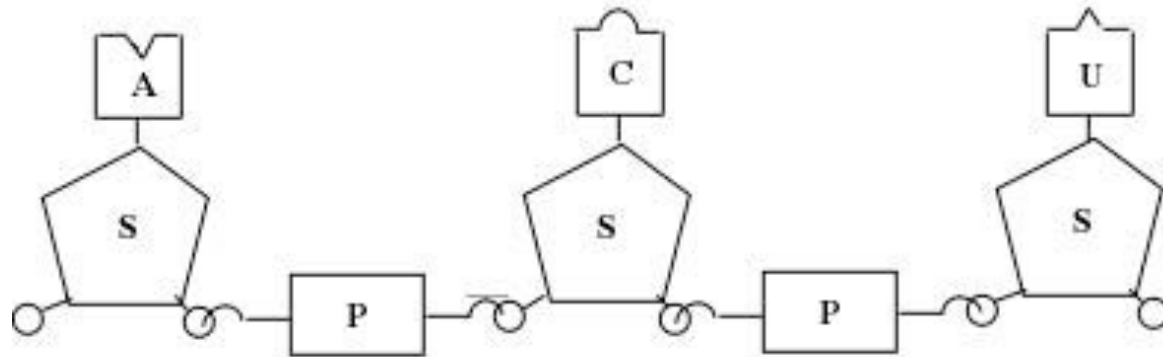


Pyrimidines

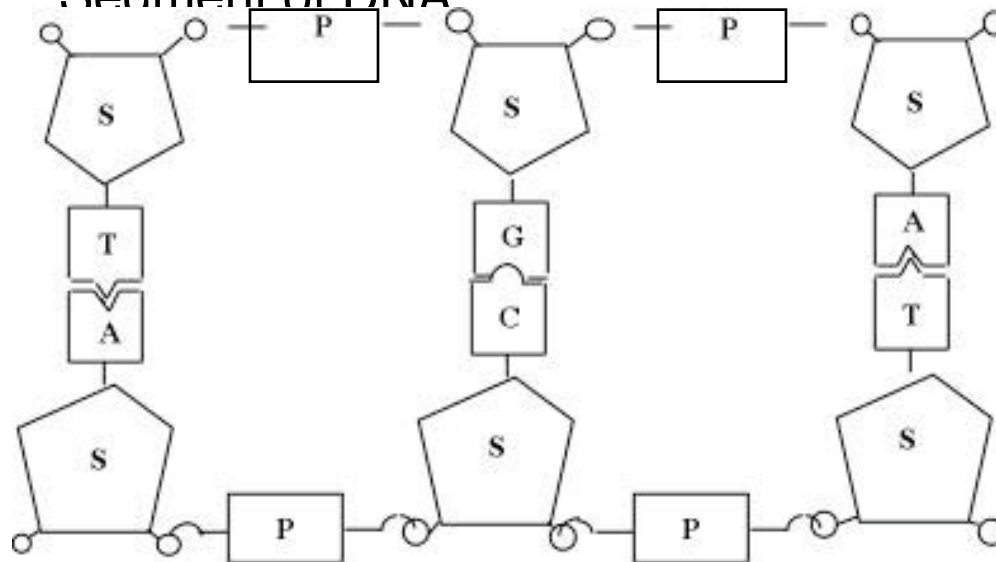
Note Uracil

# Nucleic Acids (cont.)

## Segment of RNA

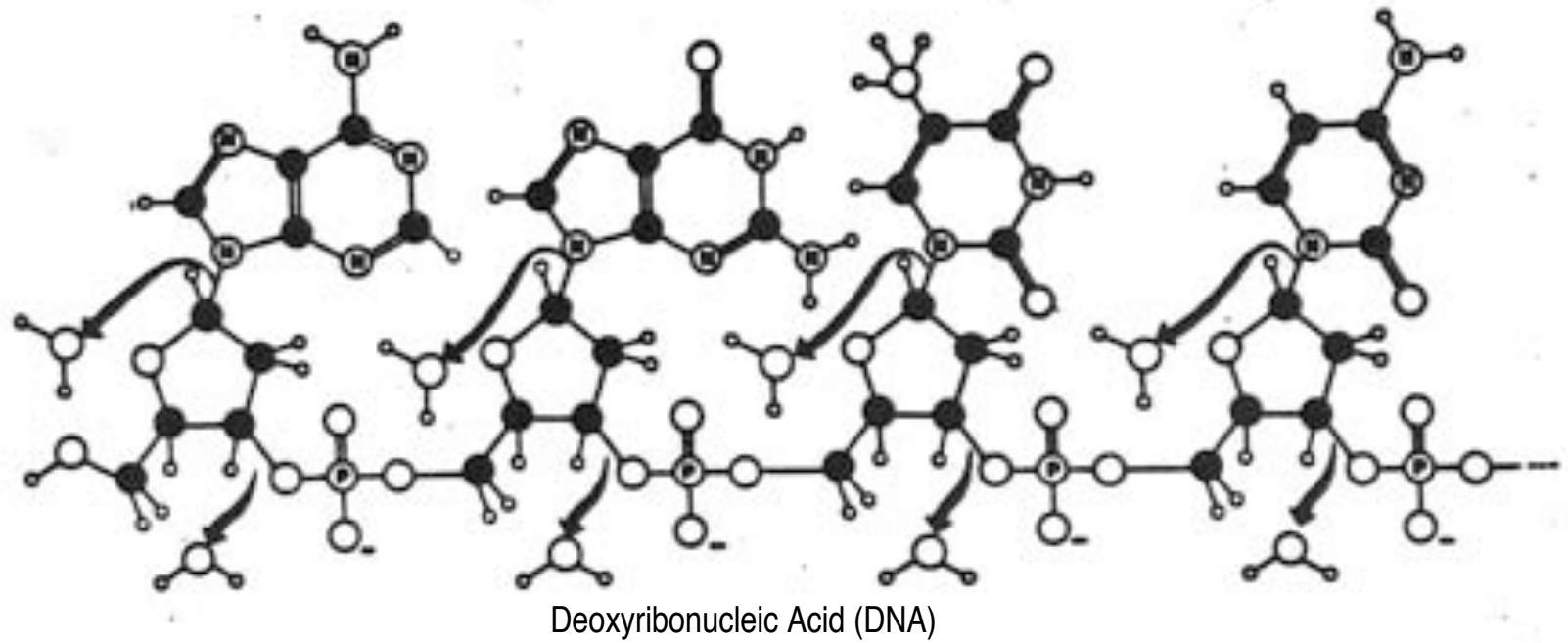
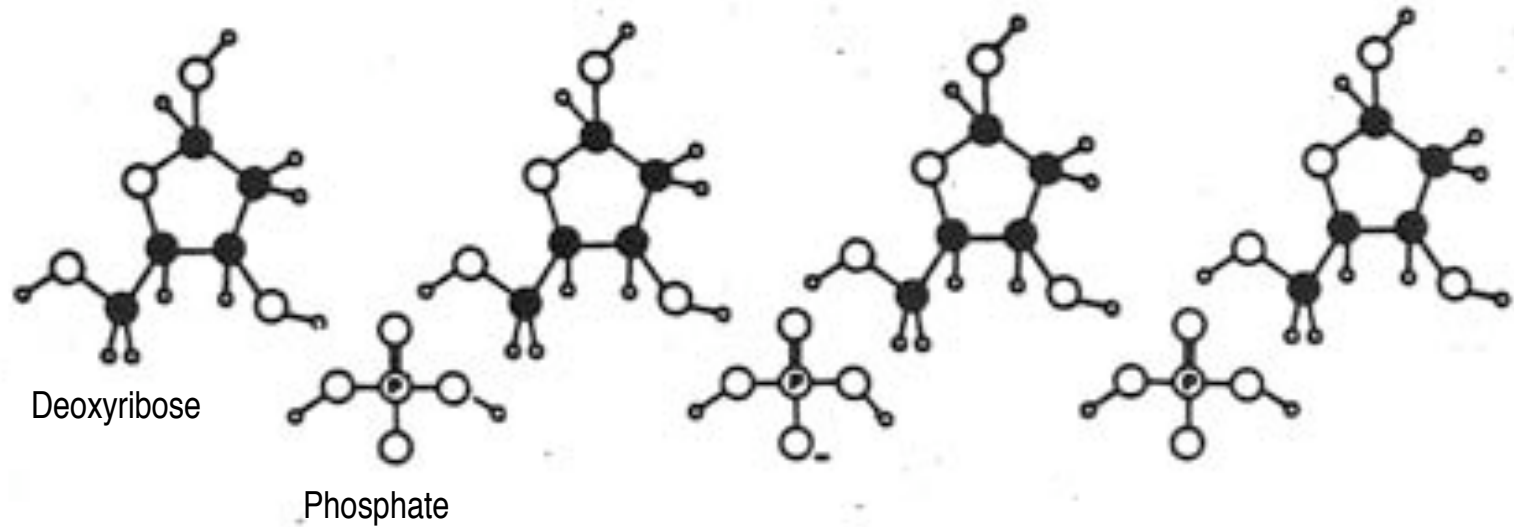


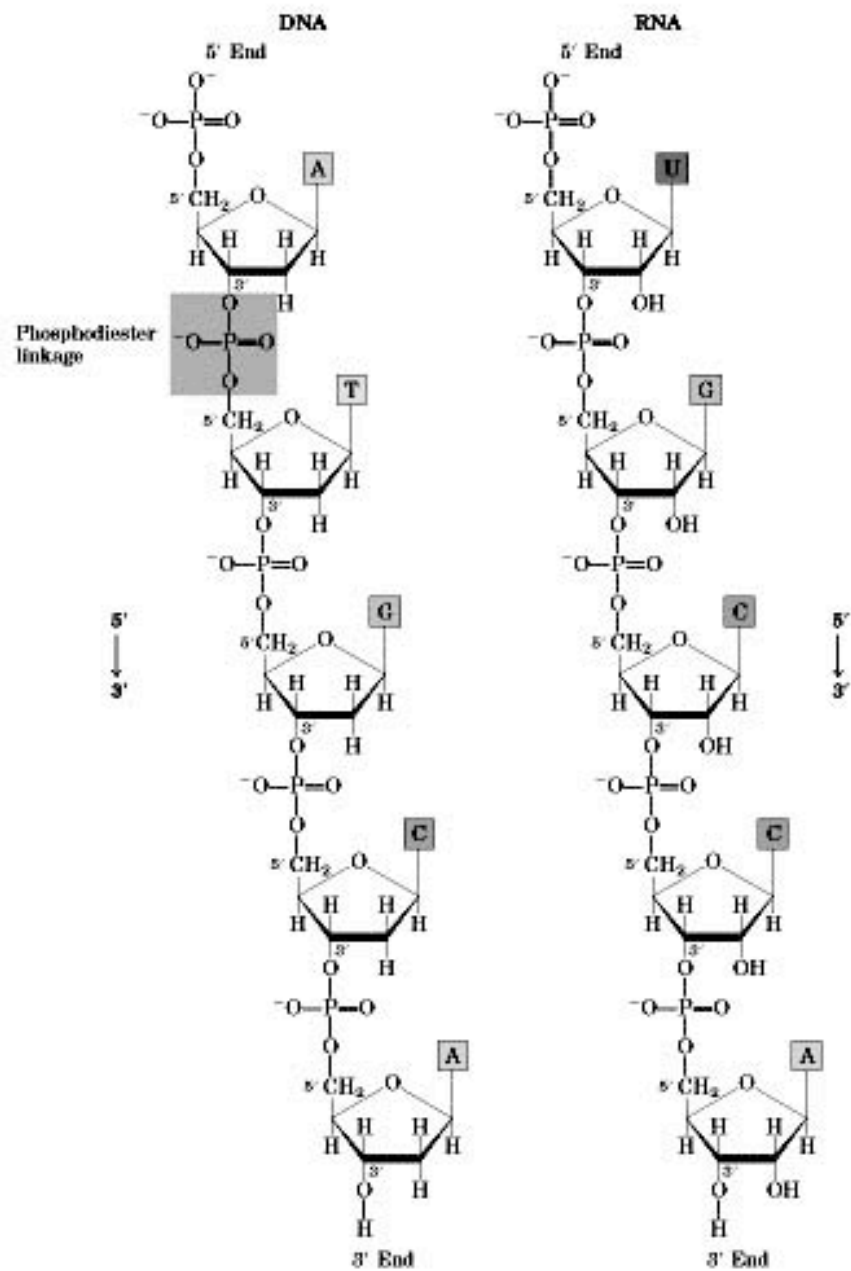
## Segment of DNA



Note that T  
replaces U in DNA

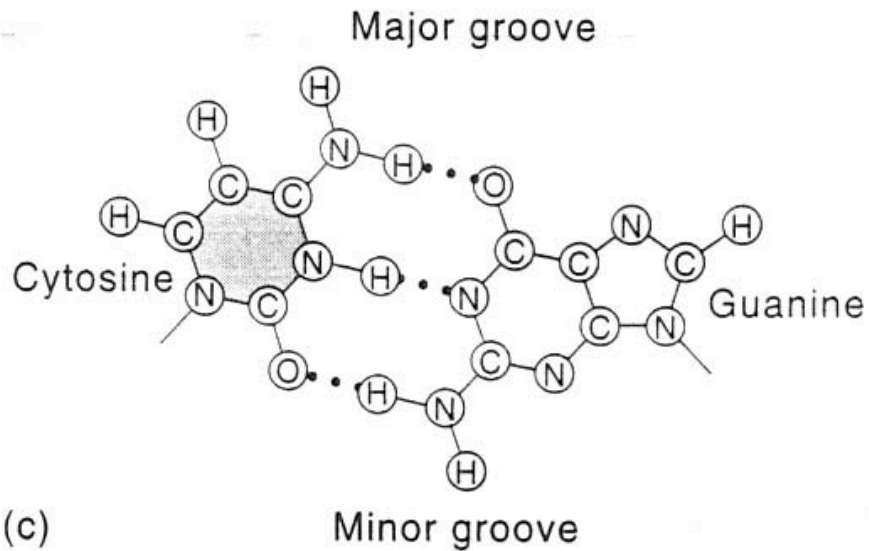
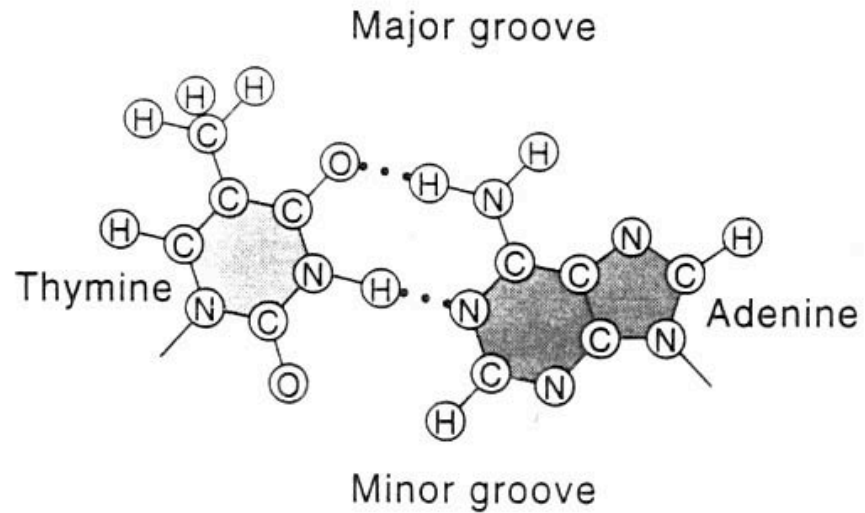
## At the Chemical Level





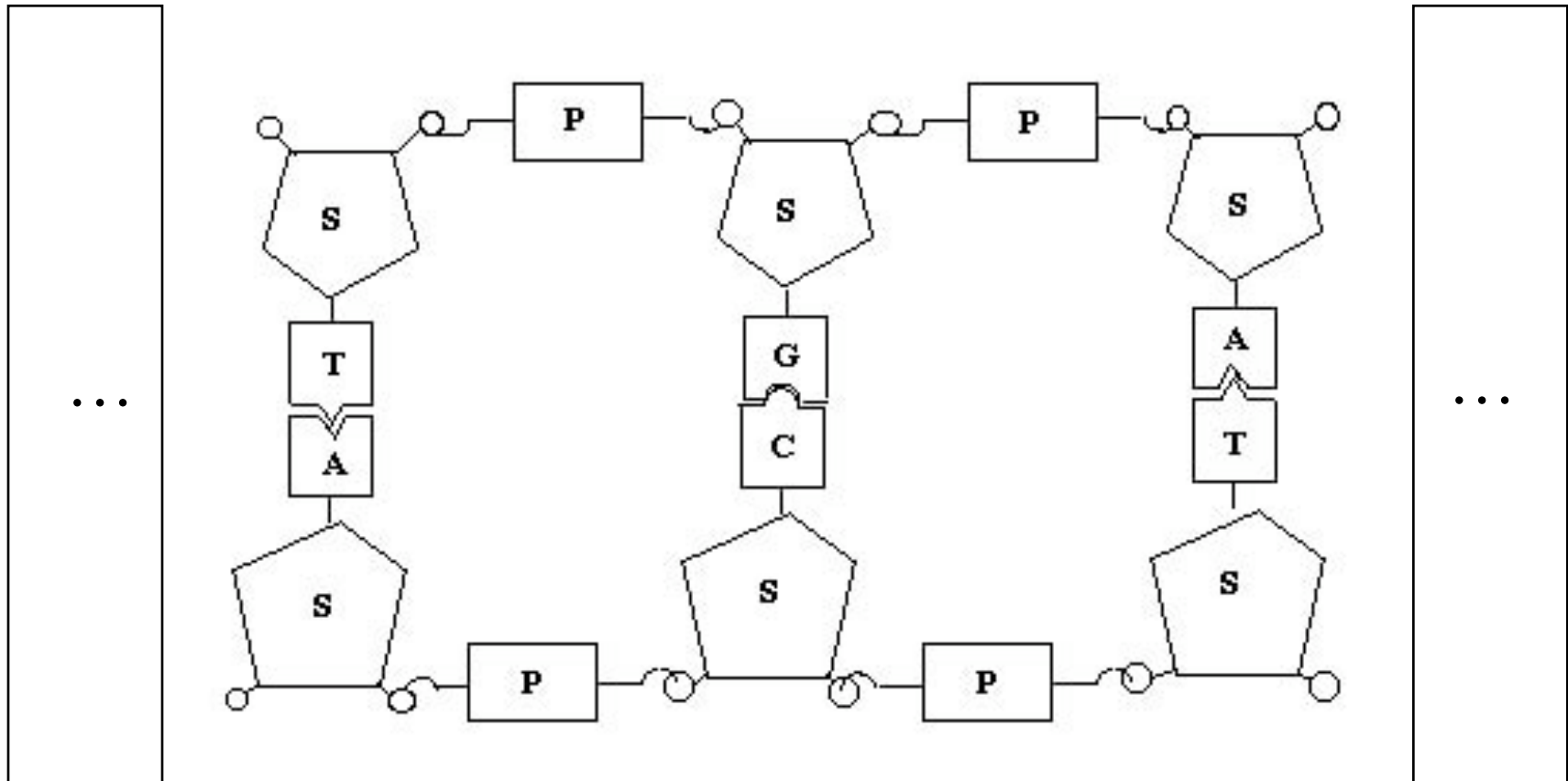


# Hydrogen Bonds (weak) connect the bases across the two sides of DNA

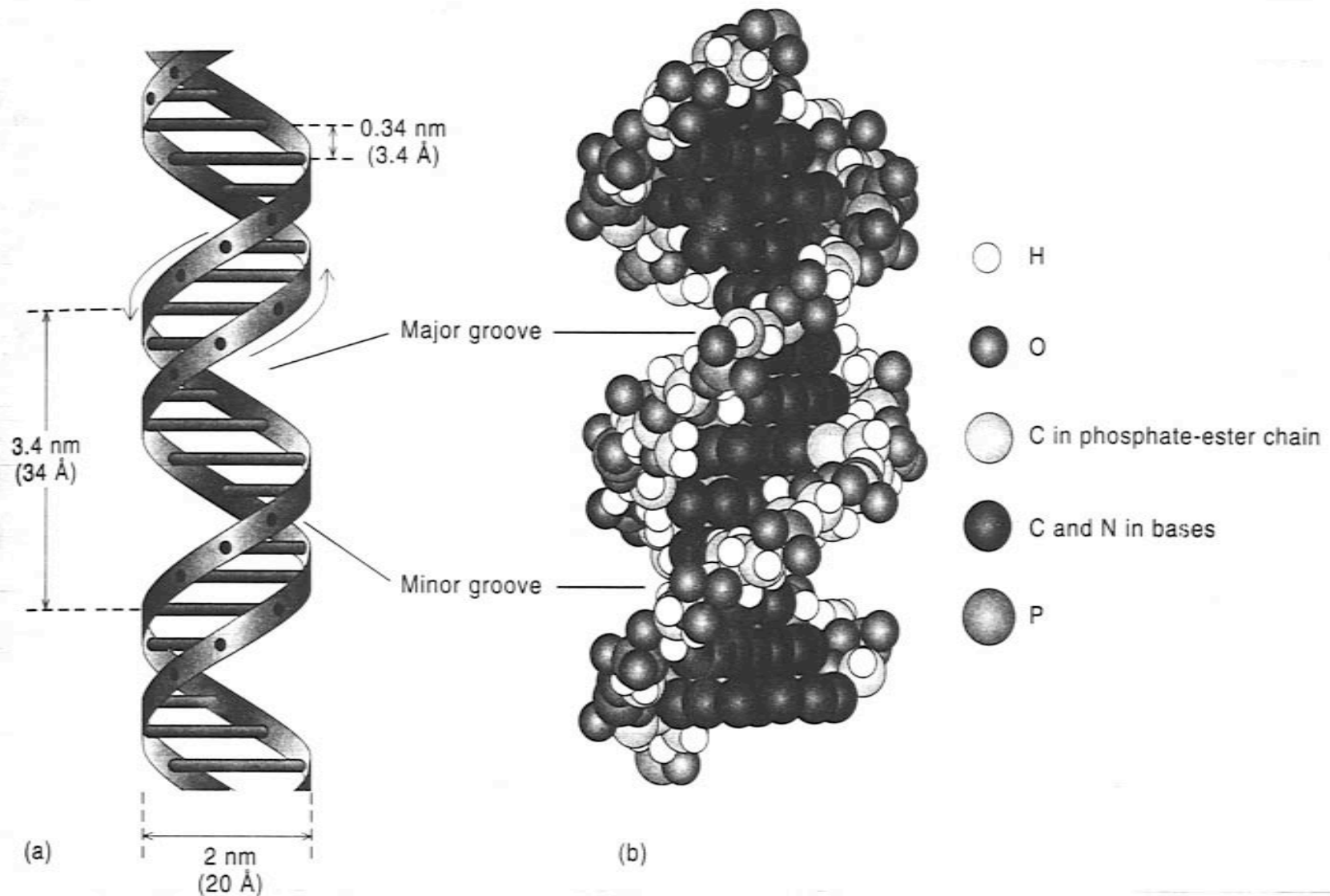


(c)

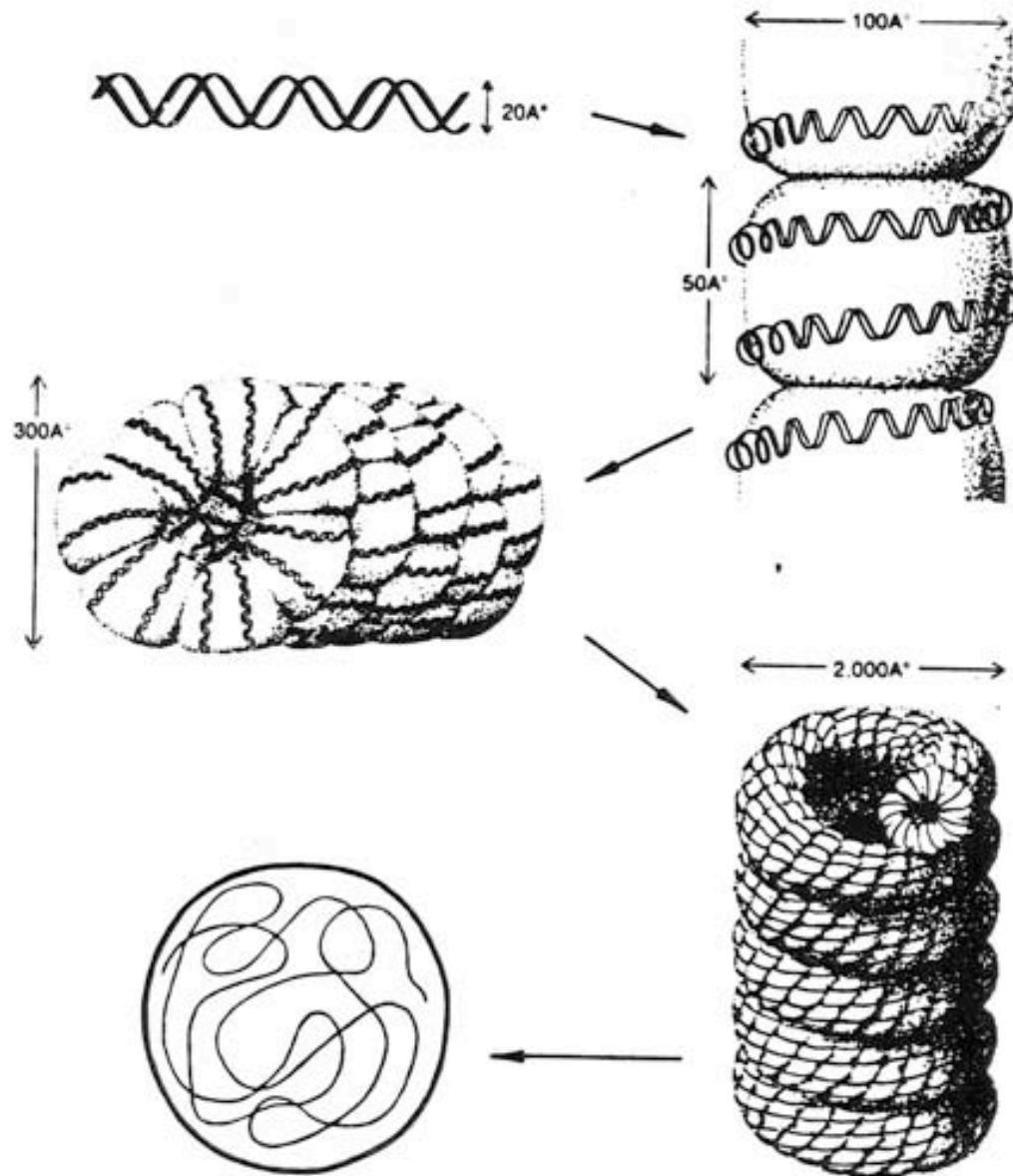
# Segment of DNA



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



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            G - C  
- U

⇒ Replication of order  
(reproduction)

Nucleic Acid - Protein  
└ Genetic Code ↗

# Codon

3 base sequence specifies an Amino Acid

# Gene

Sequence of codons specifies a Protein

a gene specifies a protein

e.g.	tobacco mosaic virus	4 genes
	bacteria	$\sim 10^3$ genes
	human cell	$\sim 25,000$ genes

For mRNA

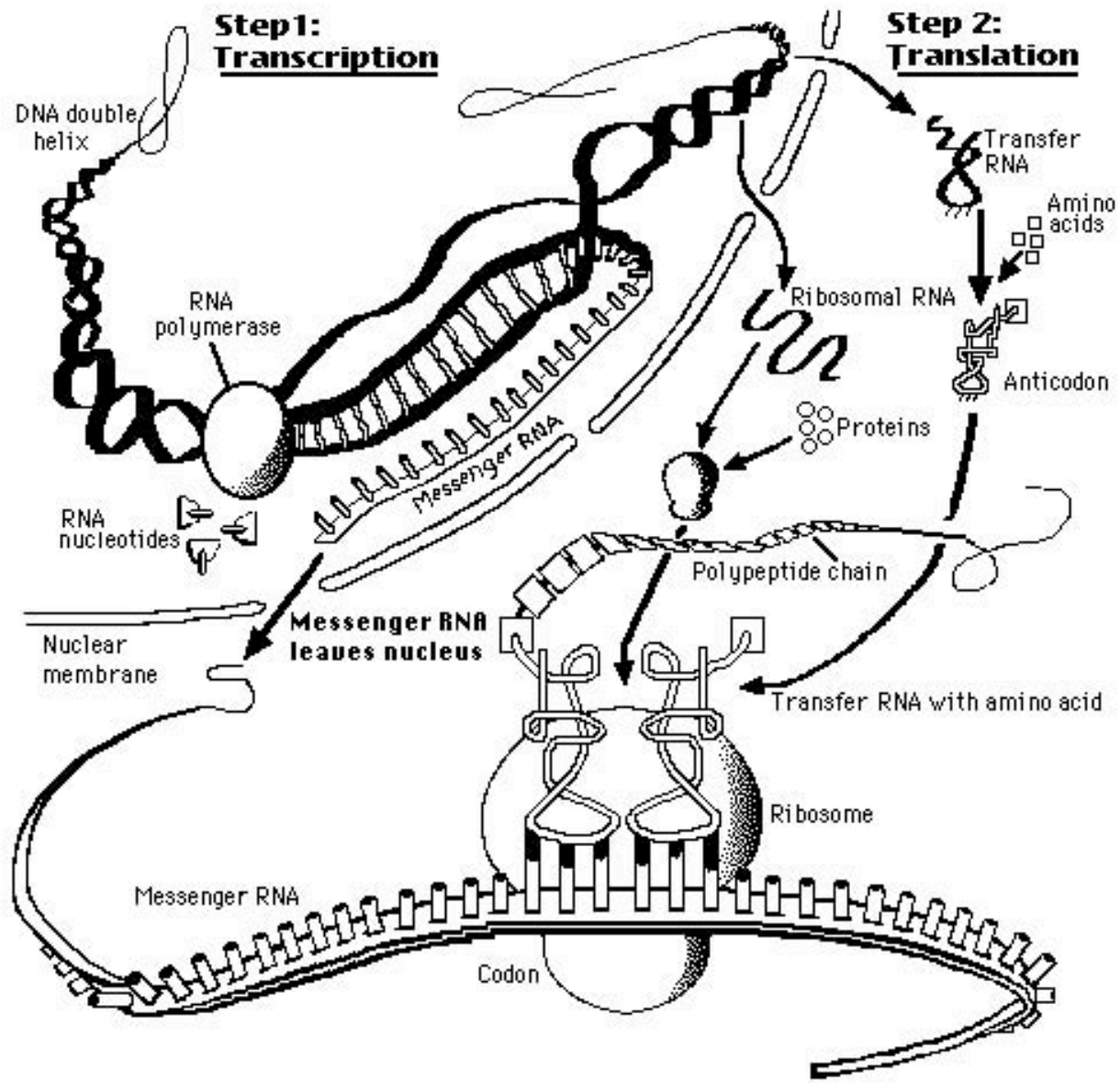
## Genetic Code

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

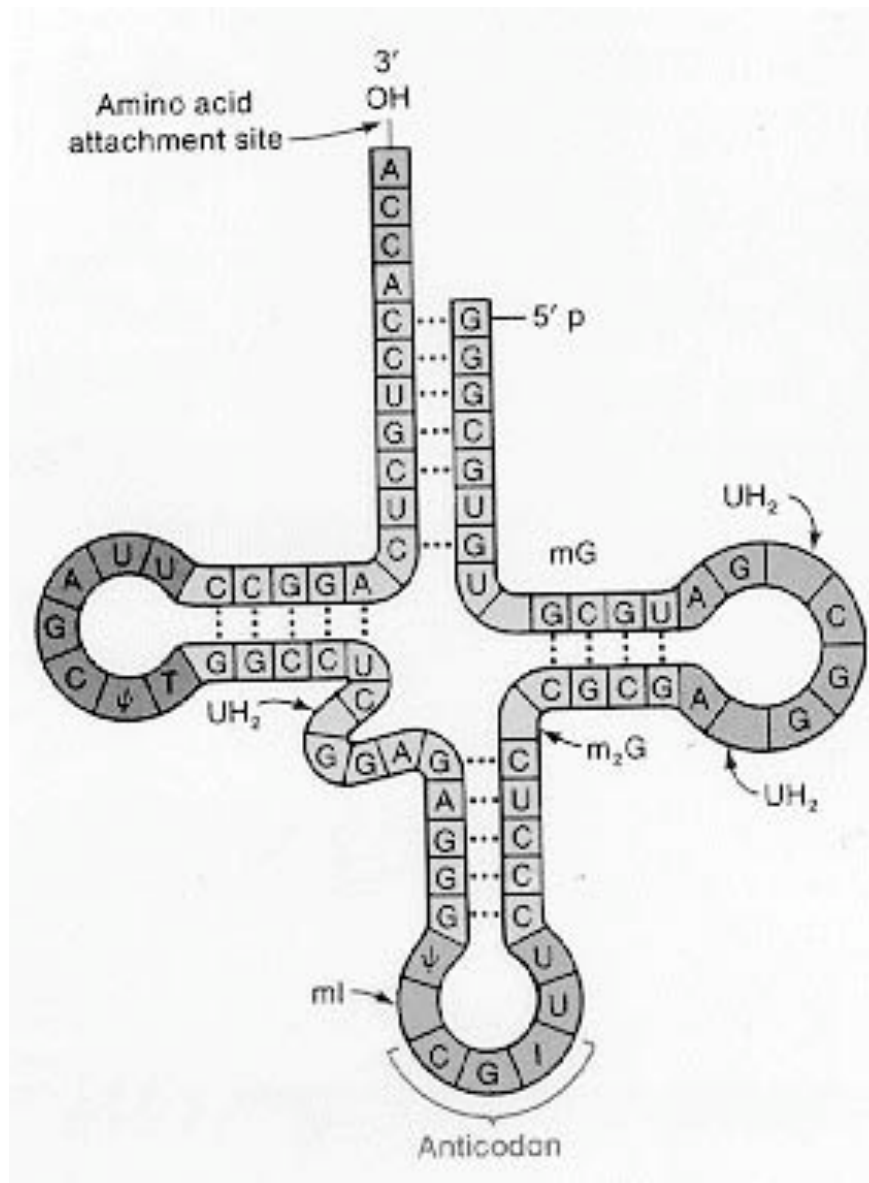
Amino Acids



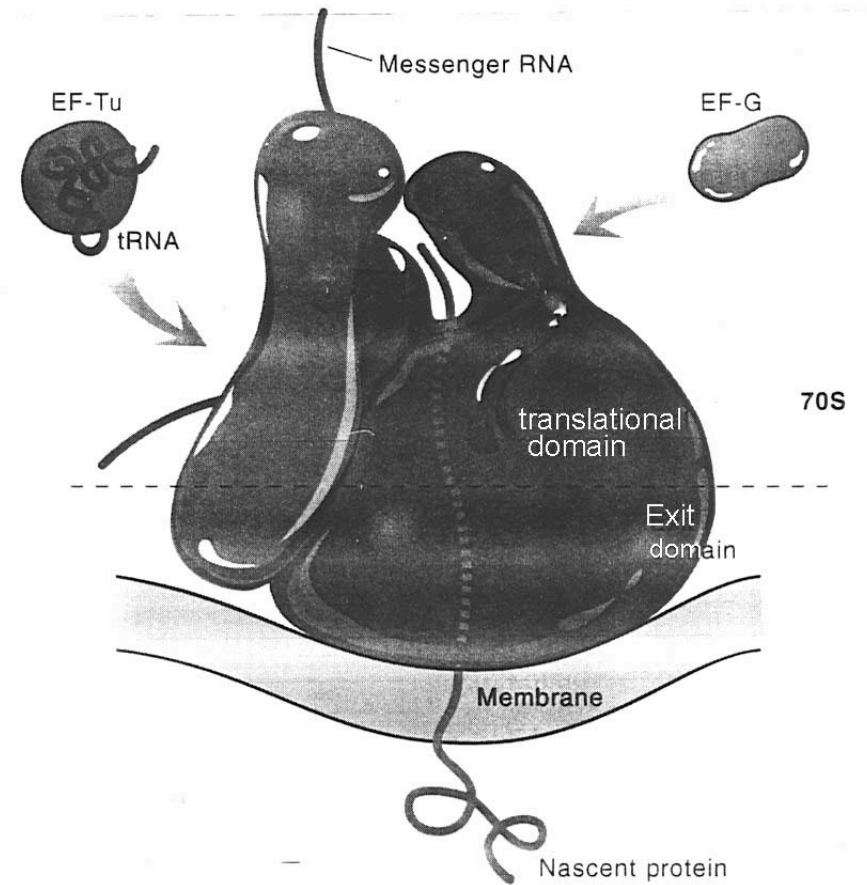
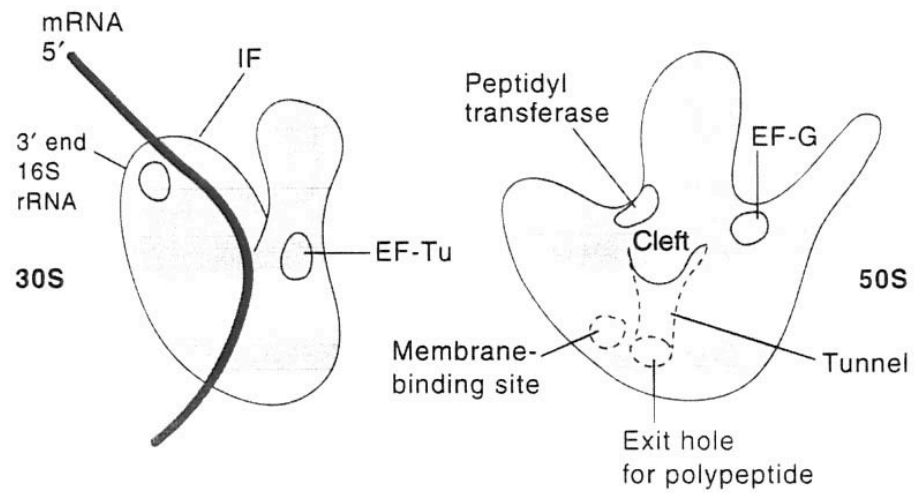
# PROTEIN SYNTHESIS



# 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)
3. Two basic molecules needed for life: proteins, nucleic acids
5. 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

- Animation of transcription (making mRNA)
  - <http://vcell.ndsu.nodak.edu/animations/transcription/movie.htm>
- Animation of translation (making protein)
  - <http://vcell.ndsu.nodak.edu/animations/translation/movie.htm>
- Both from Virtual Cell Animation collection, Molecular and Cellular Biology Learning Center