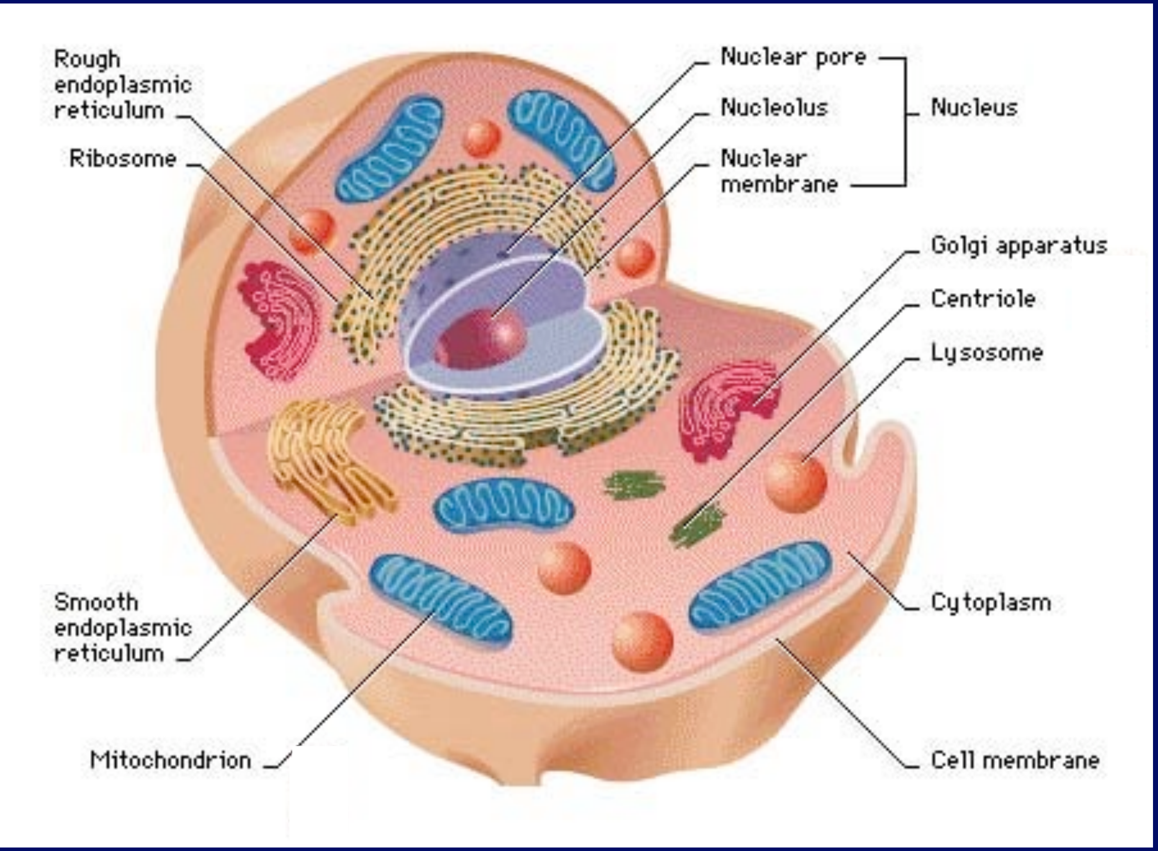
Life

What is necessary for life?

Most life familiar to us: Eukaryotes

FREE LIVING
Or Parasites

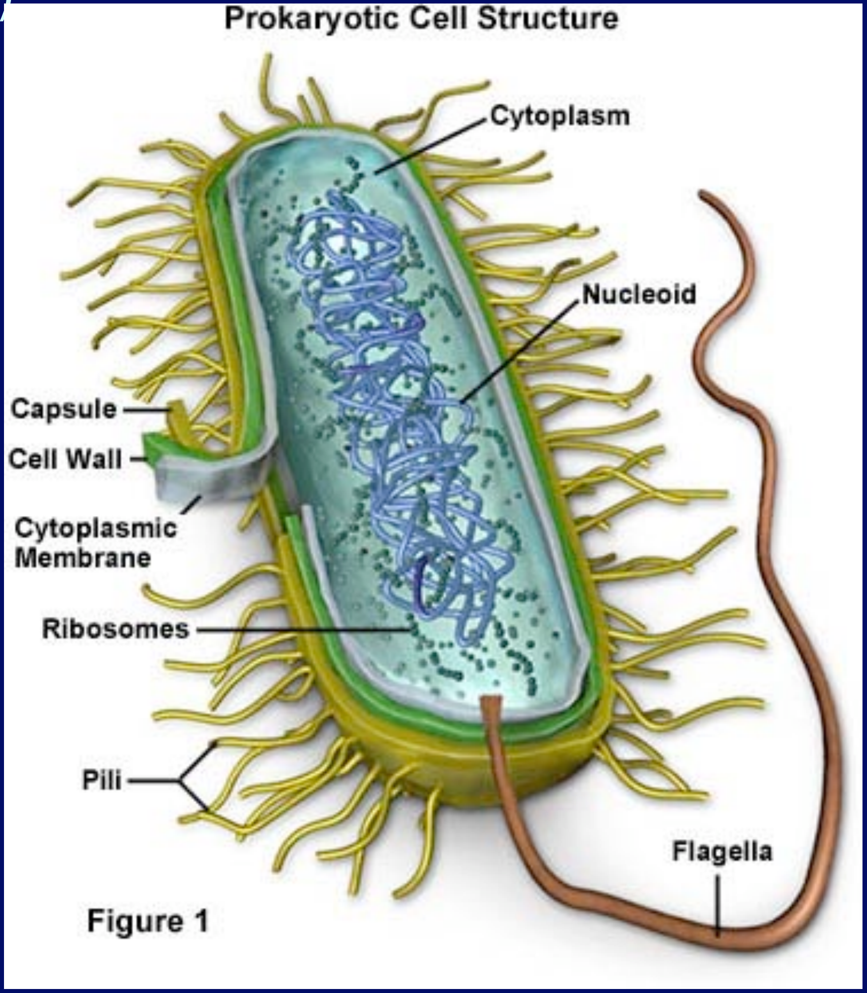


First appeared ~ 1.5 - 2 × 10^9 years ago Requirements: DNA, proteins, lipids, carbohydrates, complex structure, ~ 10^4 - 10^5 genes

Prokaryotes (Bacteria and Archaea)

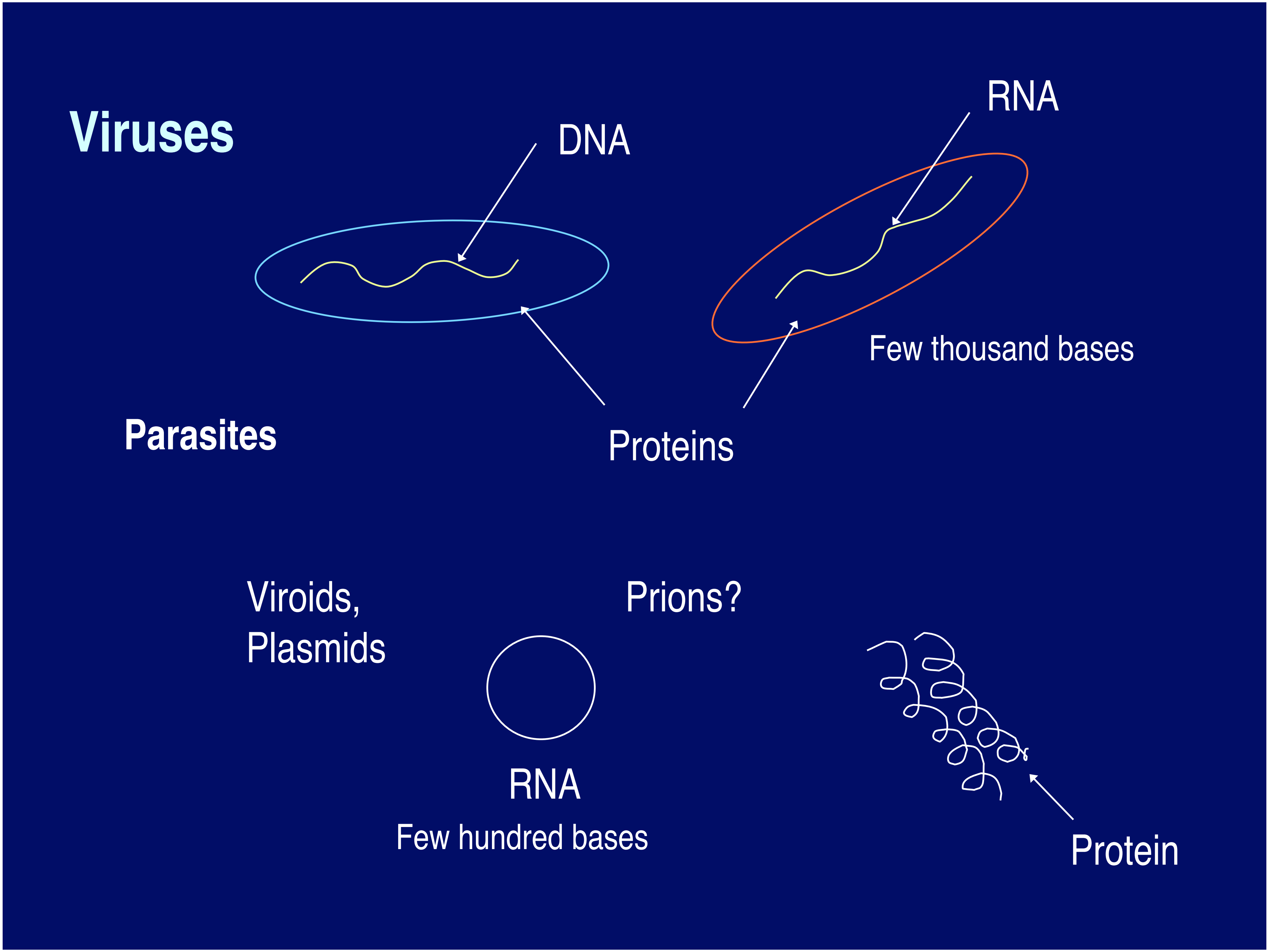
First appeared

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

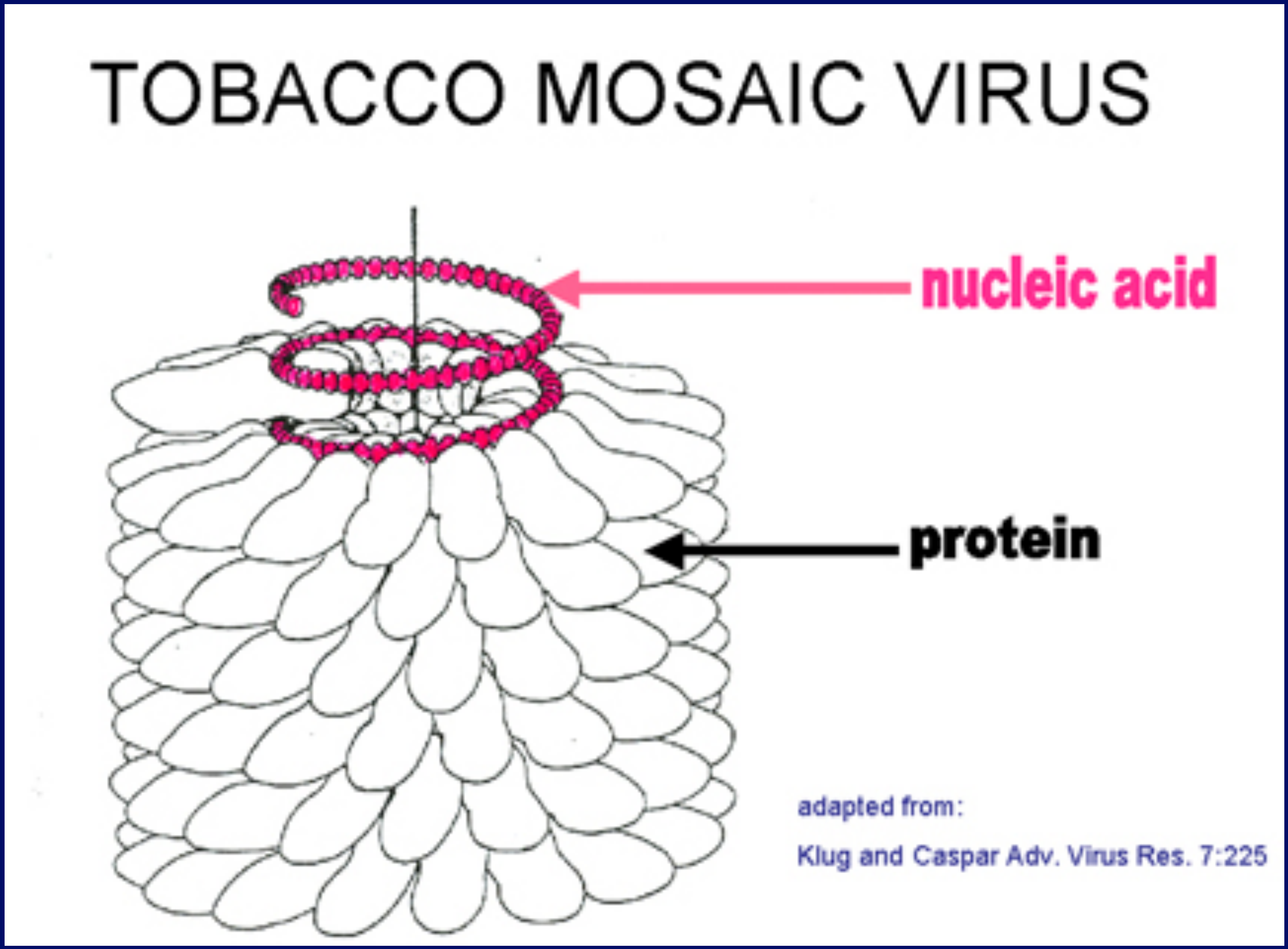


FREE LIVING
Or Parasites

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


Viruses
DNA
RNA
Few thousand bases
Parasites
Proteins
Viroids,
Plasmids
Prions?
RNA
Few hundred bases
Protein

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



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]

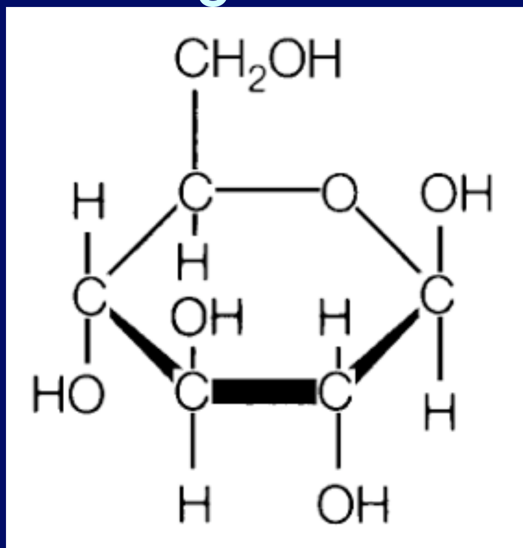
H, C, (O)

Lipids (hydrocarbons + carboxyl)

Membranes + Energy

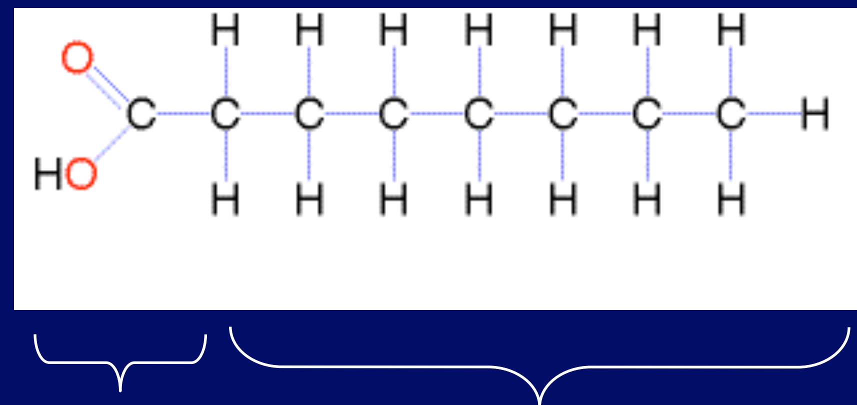
[water-resistant]

Sugar



Glucose

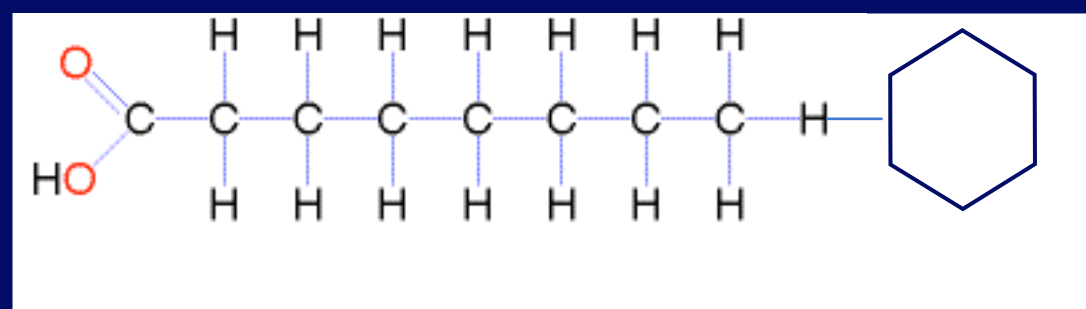
Lipids



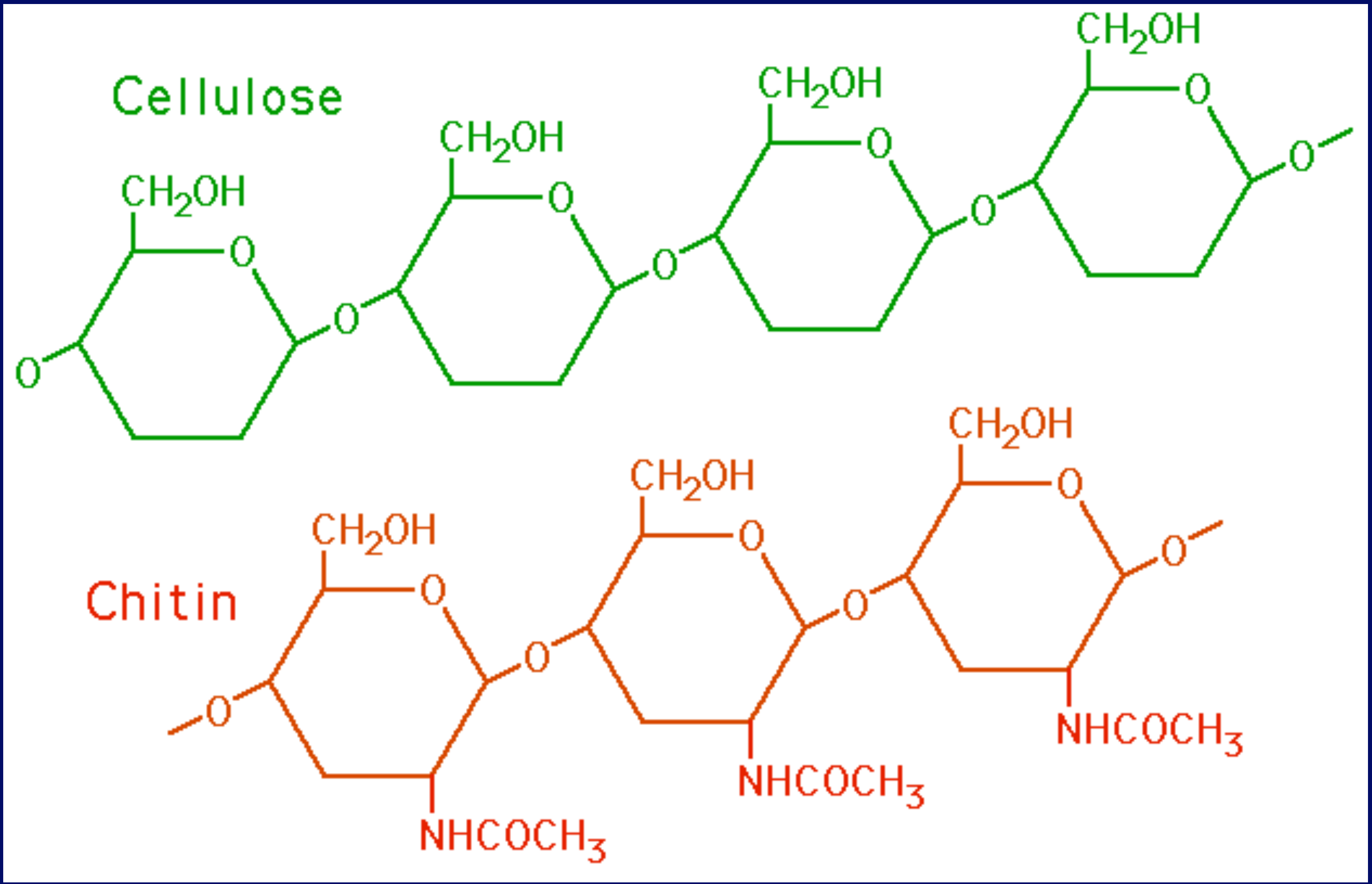
carboxyl

hydrocarbon

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



Polysaccharides

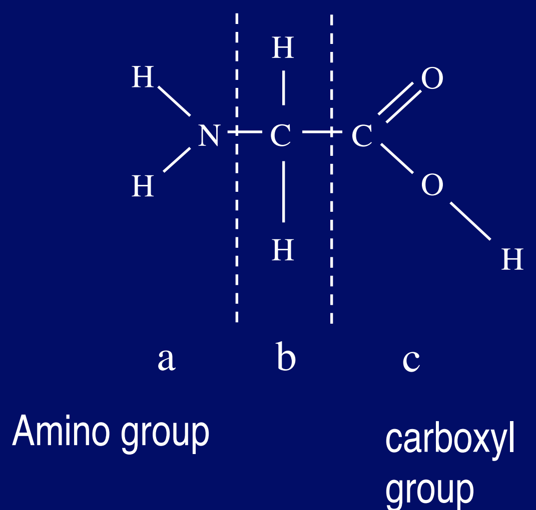


Proteins

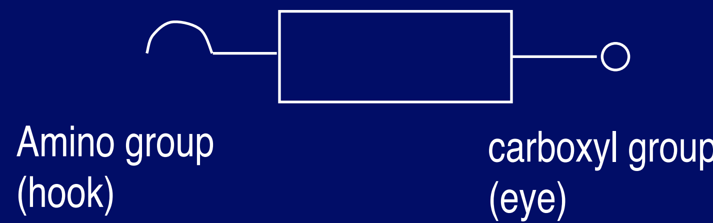
Monomers are amino acids

20 kinds

Glycine

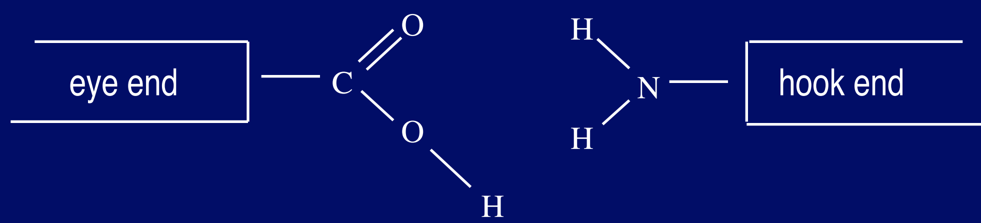


Schematic

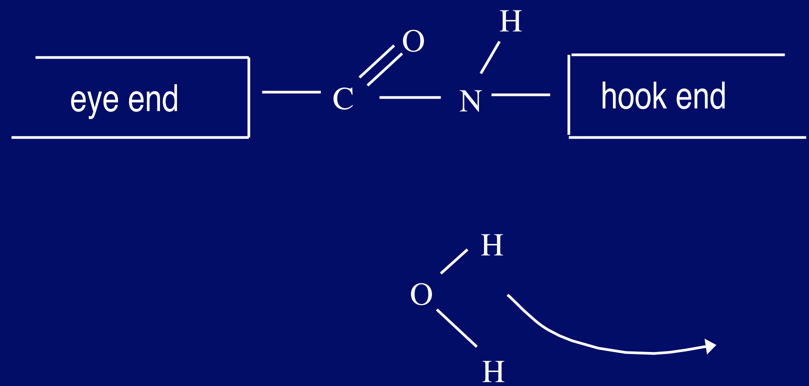


Section of Protein

A Peptide Bond at the Chemical Level

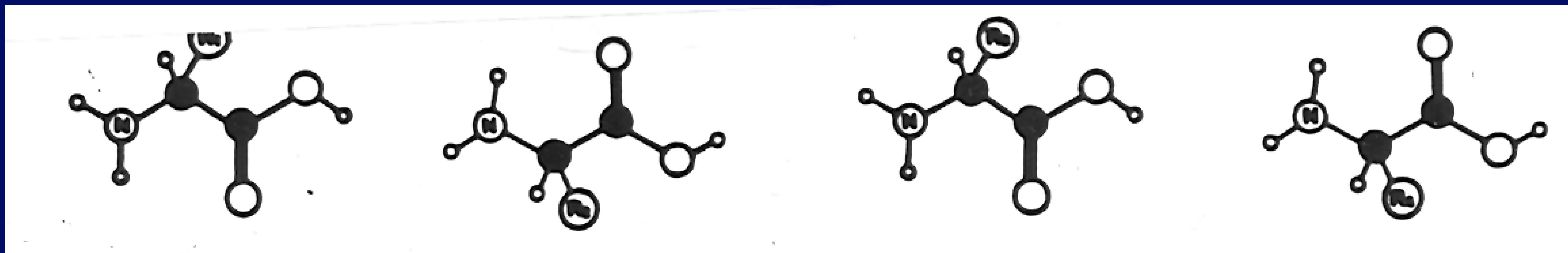


Before

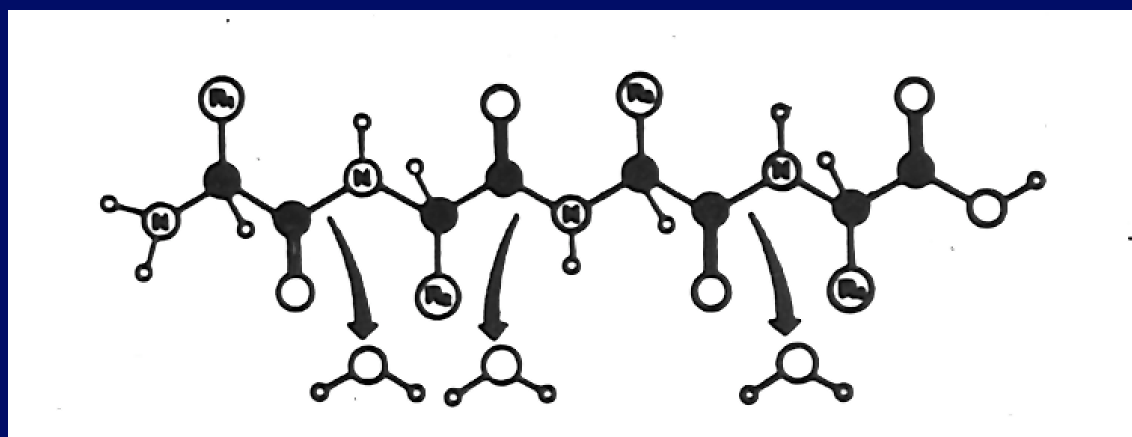


After

Note that a water molecule must be removed



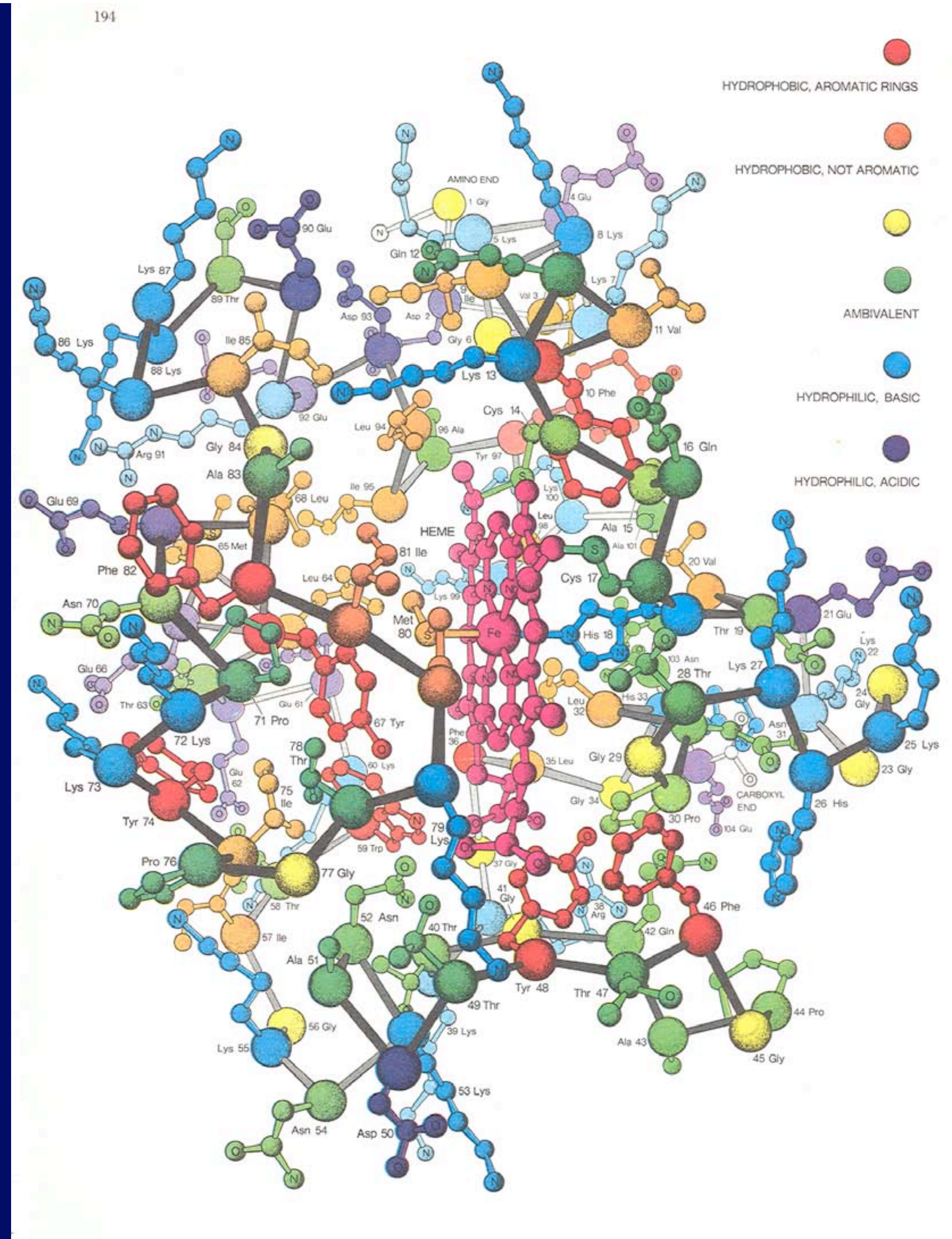
amino acids



protein

A complex protein:

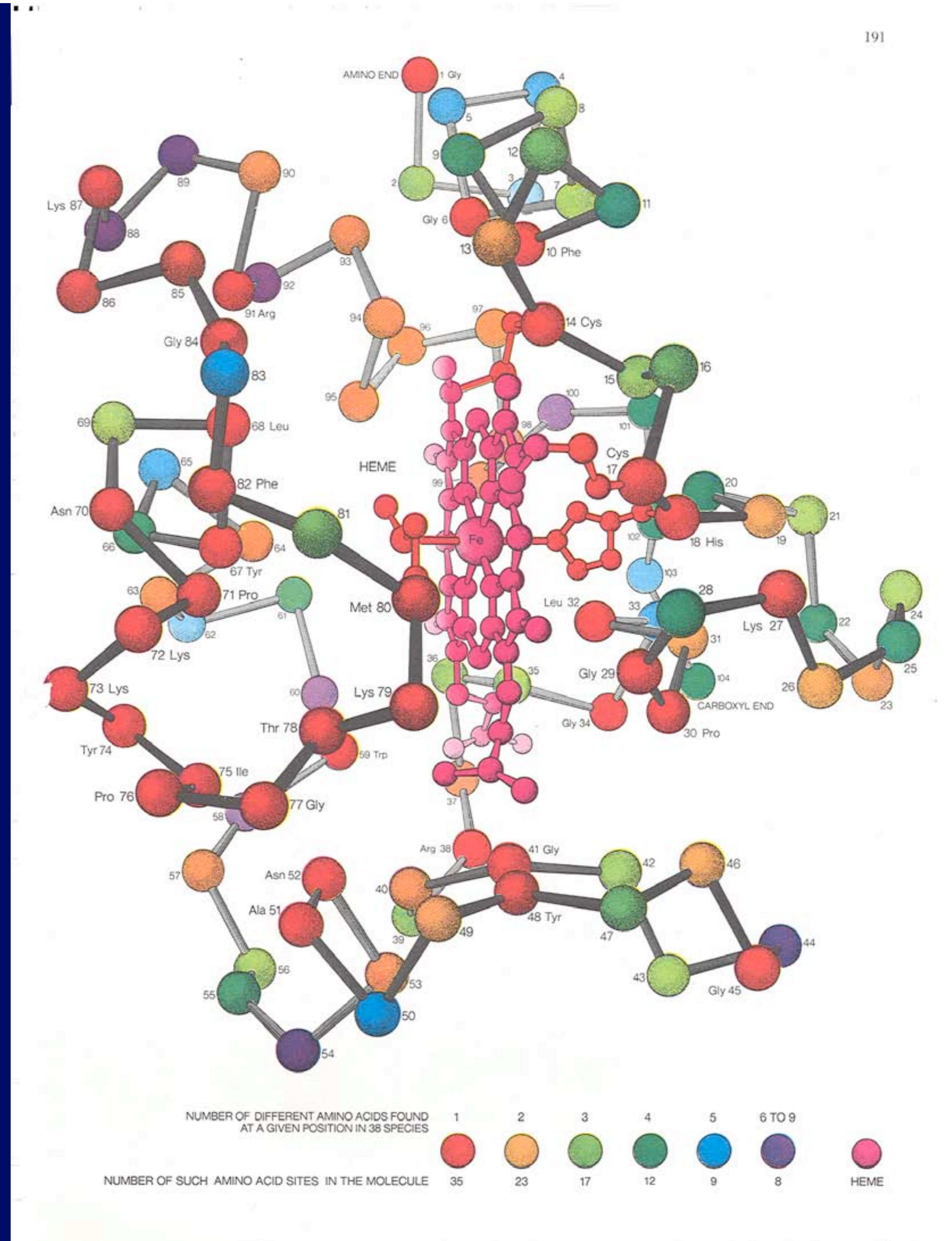
Involved in oxygen use
Each circle is an amino acid



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

Note the “heme”, containing iron.

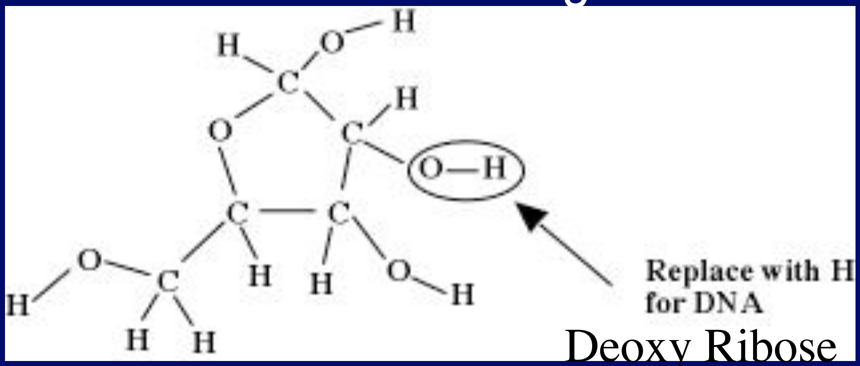
Function depends on structure, which depends on folding, which depends on order of amino acid bases



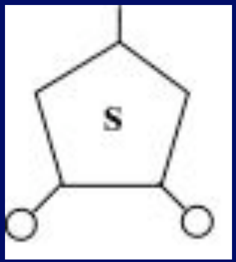
Nucleic Acids (DNA, RNA)

Made of sugars, phosphates, bases

Sugar



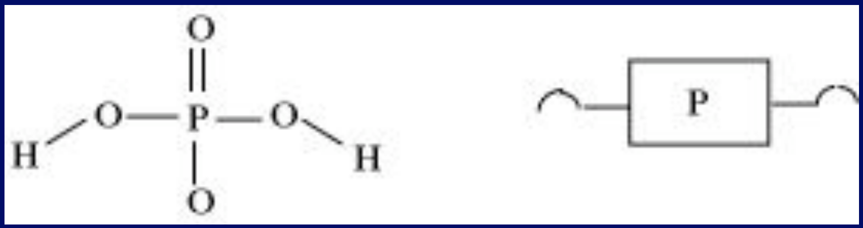
Schematic



Ribose Sugar
5 C, 5 O, 10 H

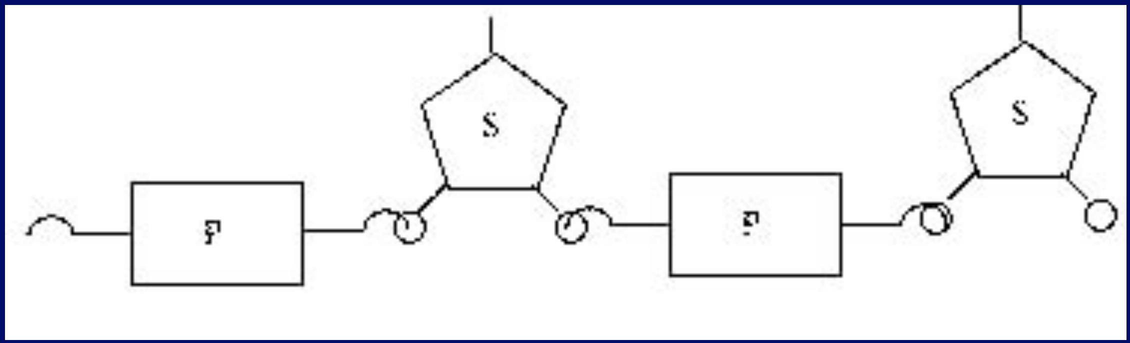
Ribonucleic acid (RNA) uses ribose sugar;
Deoxyribonucleic acid (DNA) uses deoxyribose sugar

phosphate



sugars & phosphates linked

phosphodiester bonds

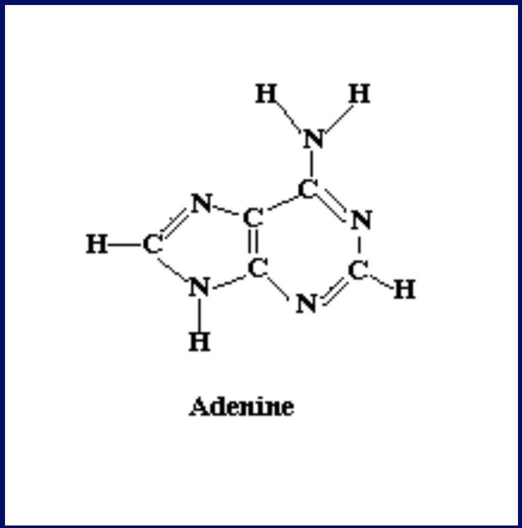


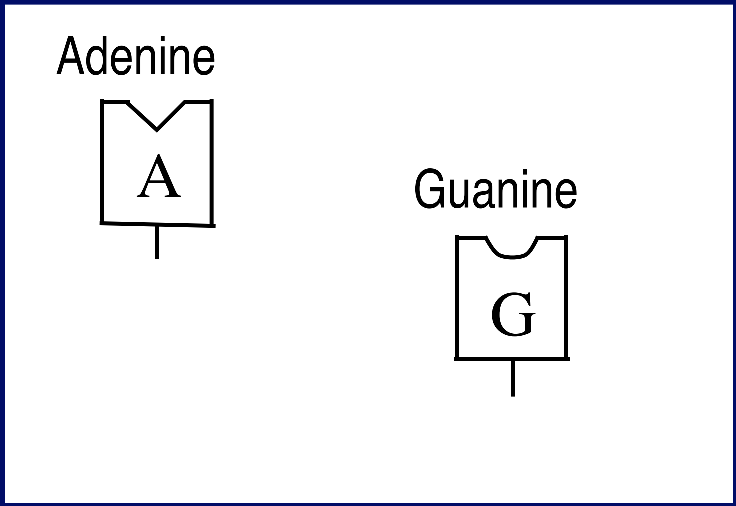
Segment of side of ladder structure

Nucleic Acids (cont.)

Bases: Carry Genetic Code

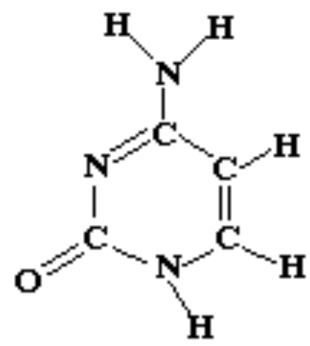
Purines





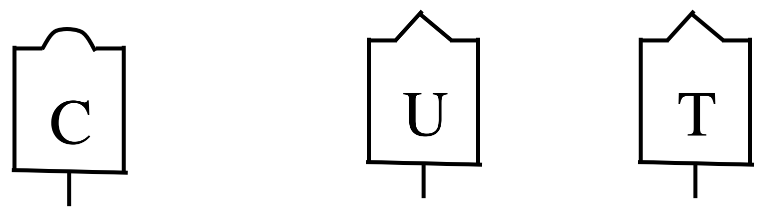
Equal numbers of C and N

Pyrimidines



Cytosine

More C than N

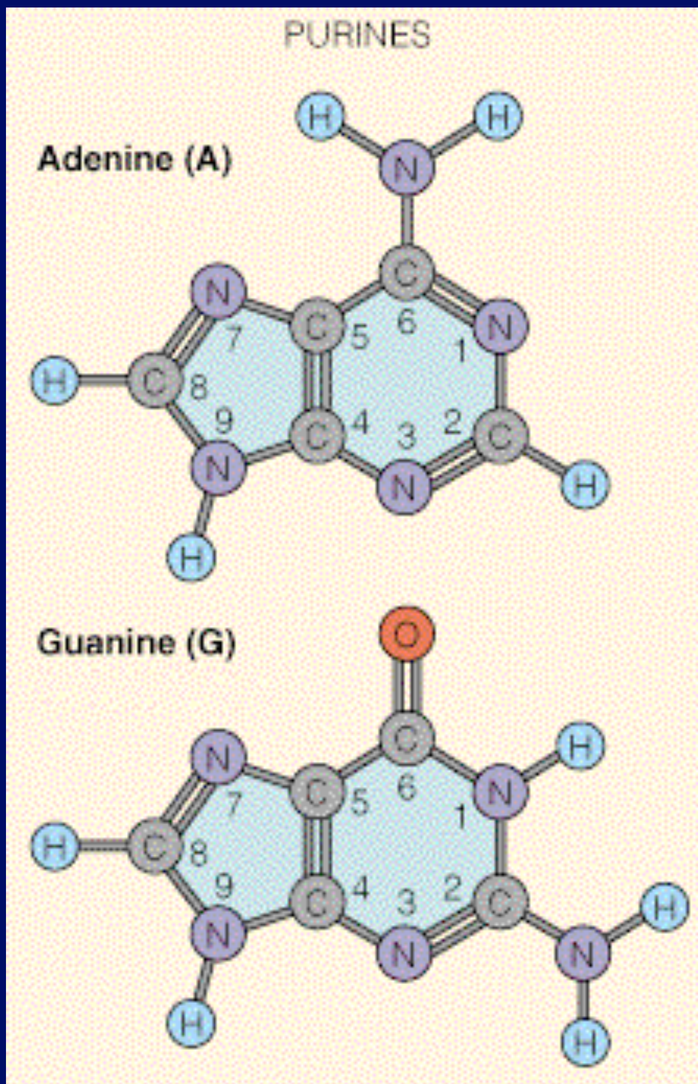


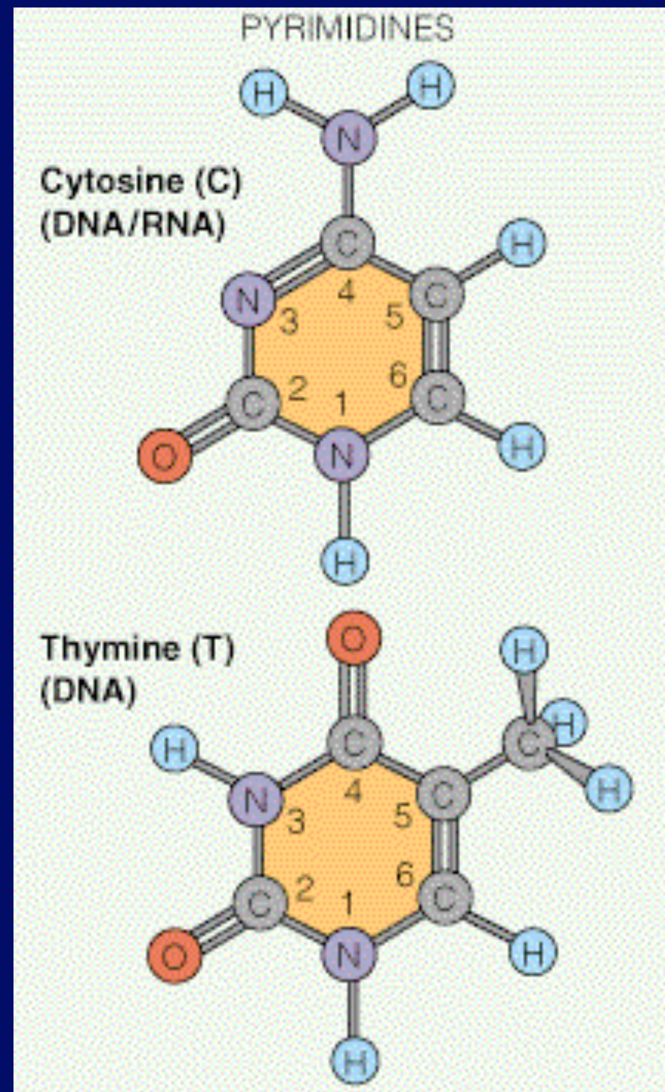
Cytosine

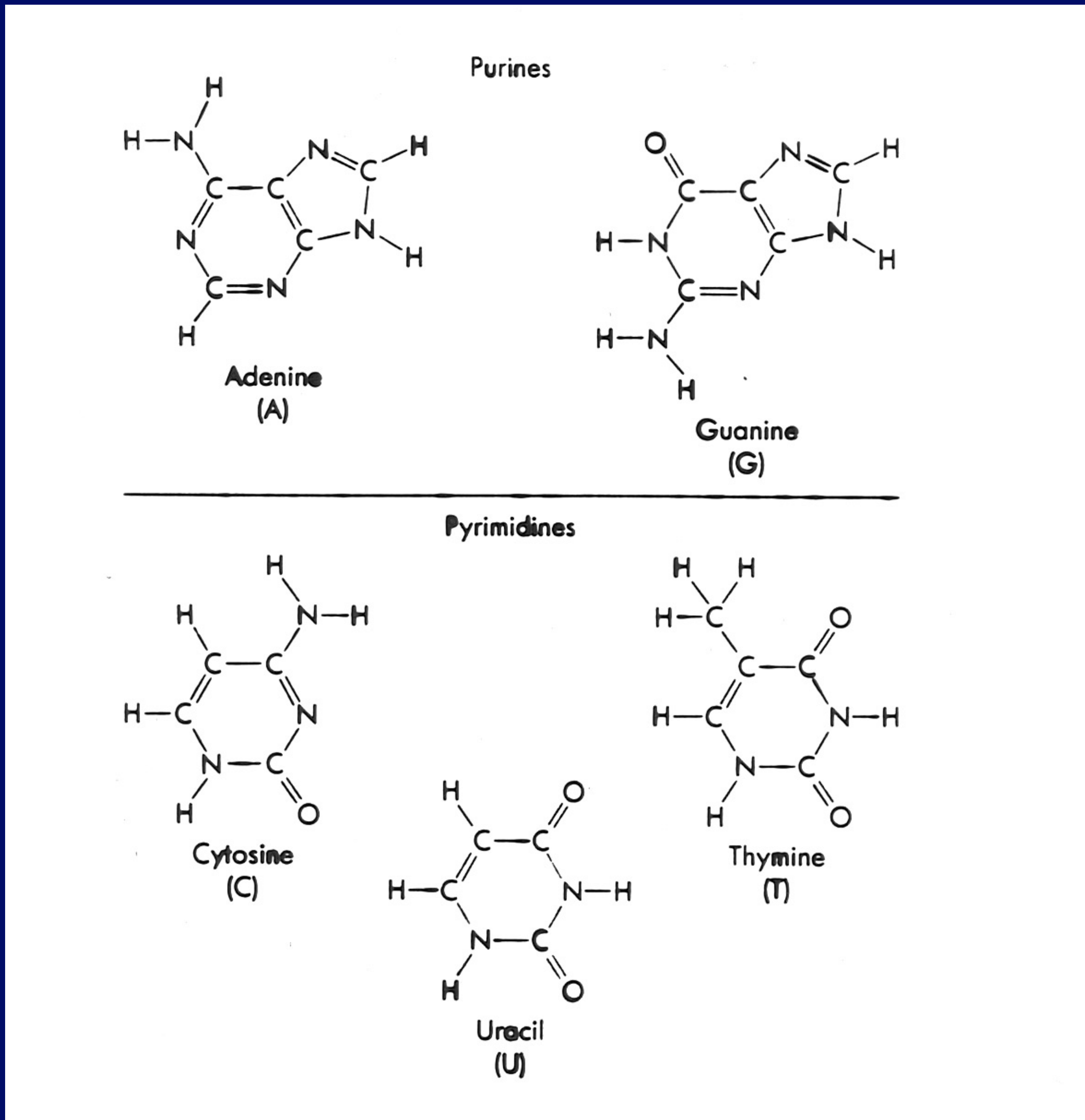
Uracil / Thymine

RNA / DNA

Bases in Nucleic acids: Purines and Pyrimidines







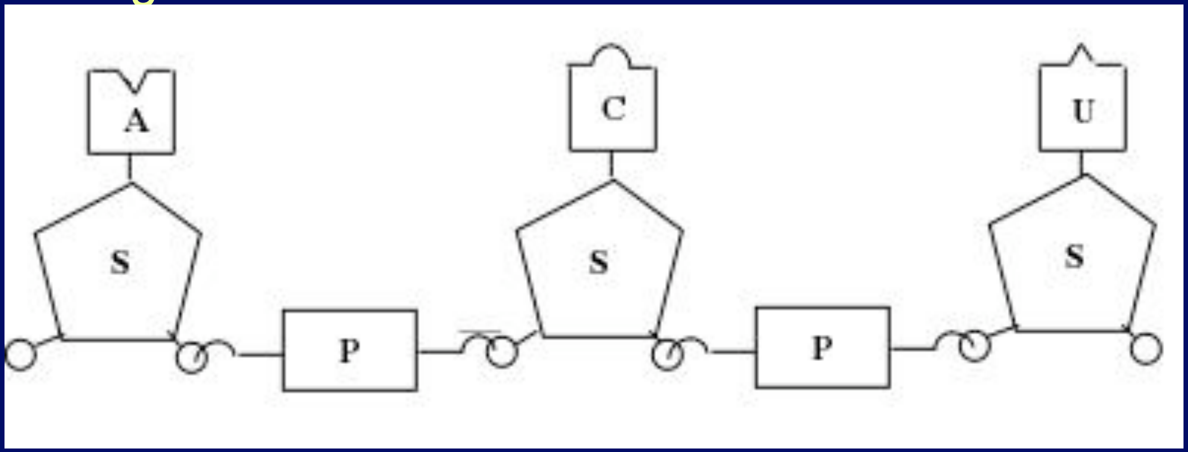
Purines

Pyrimidines

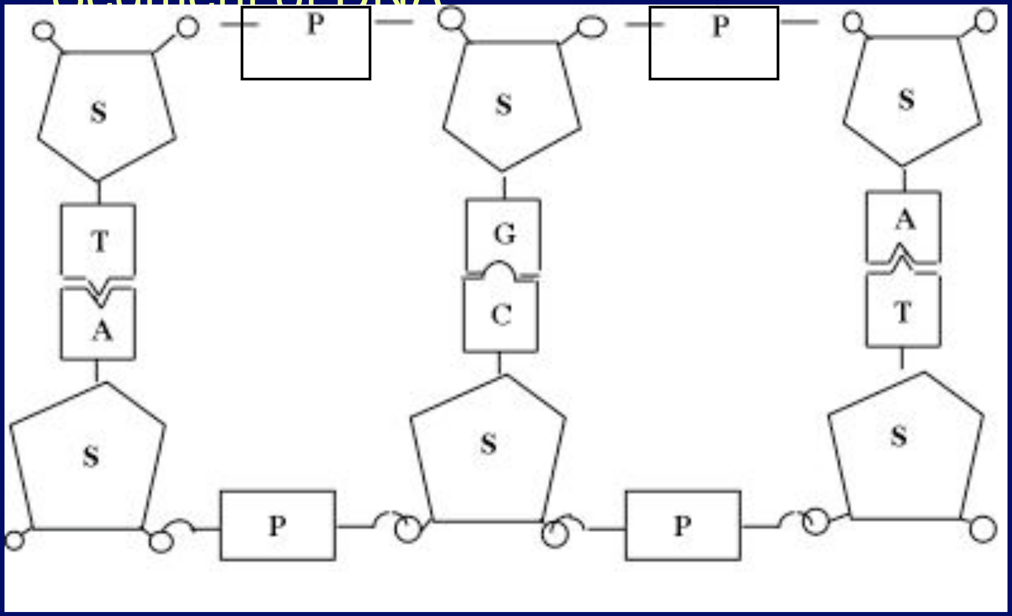
Note Uracil

Nucleic Acids (cont.)

Segment of RNA

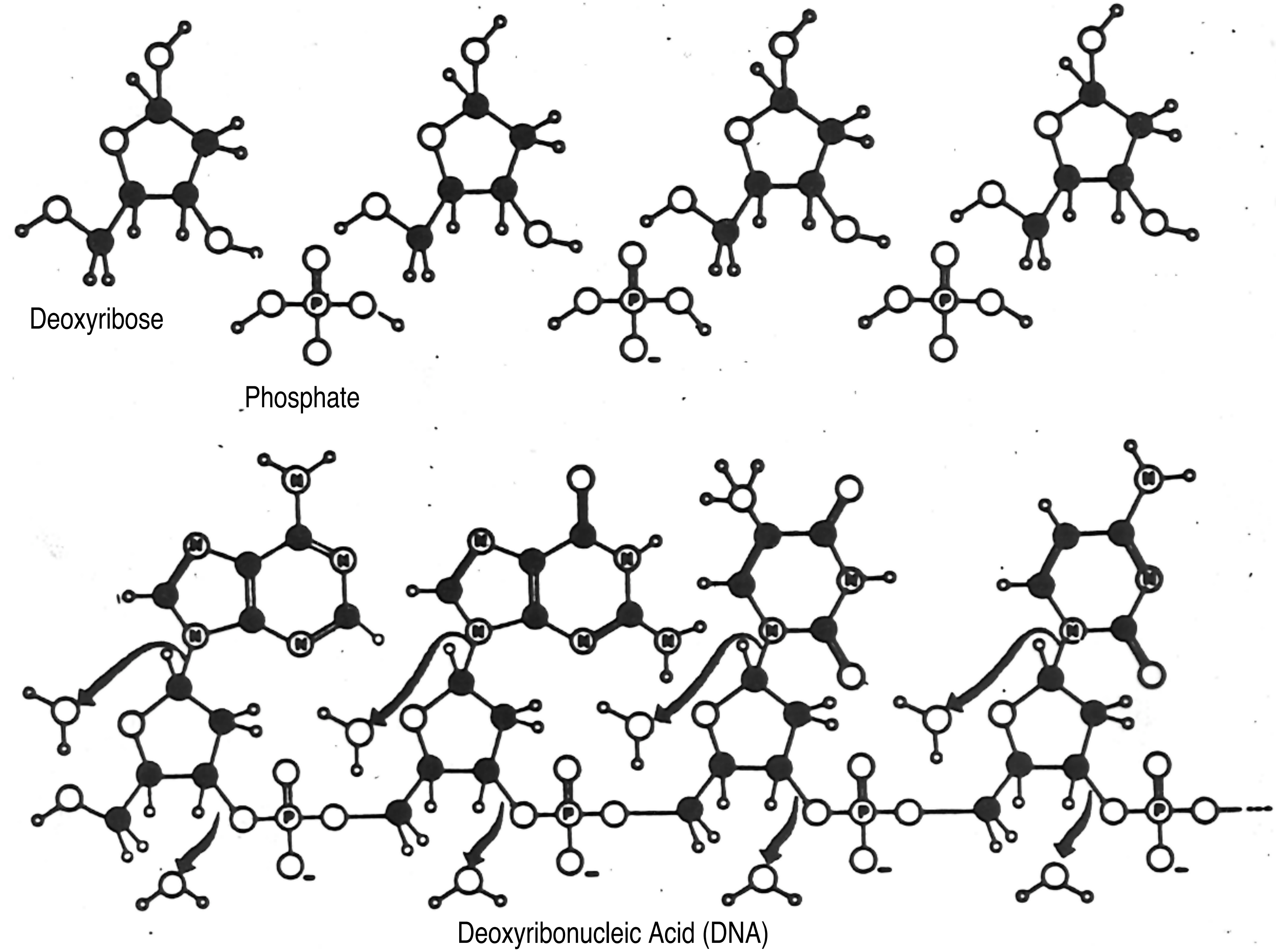


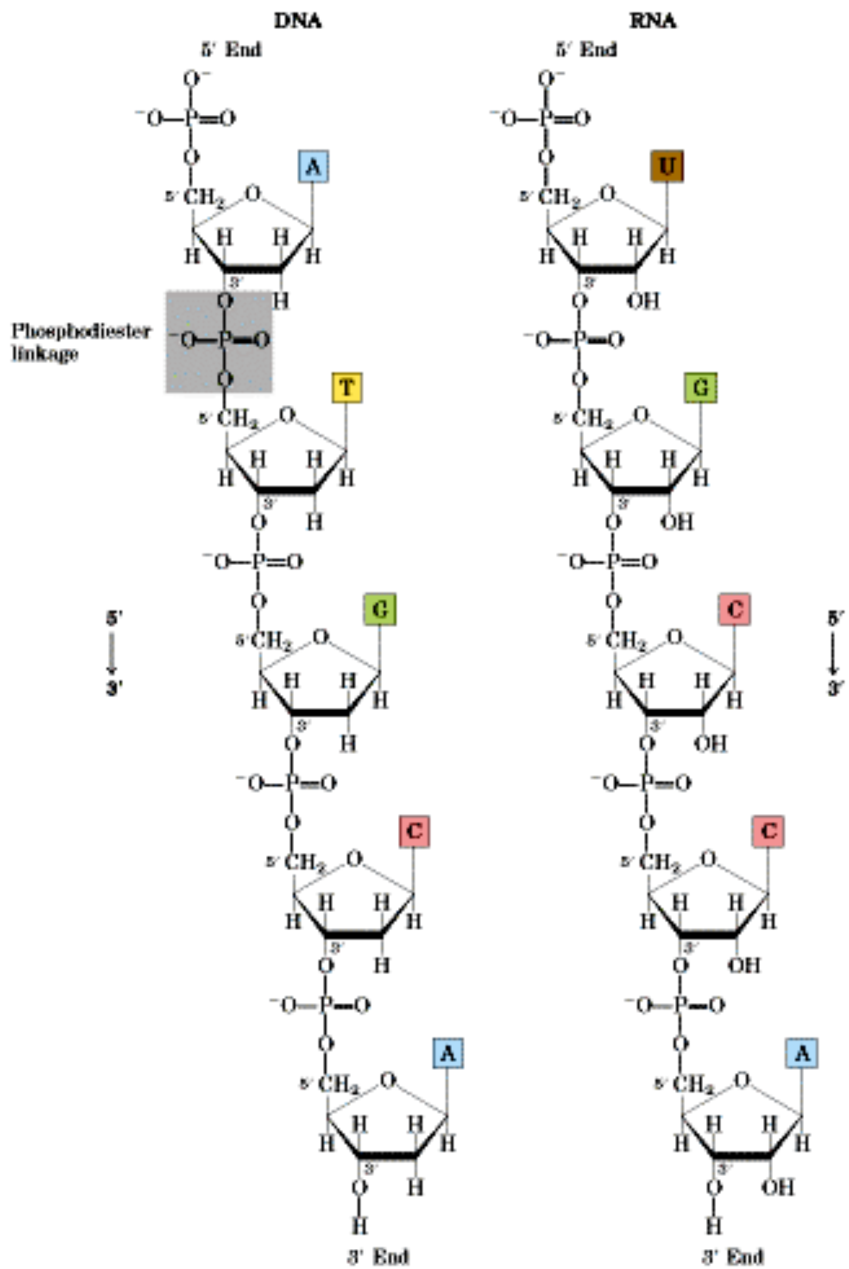
Segment of DNA



Note that T replaces U in DNA

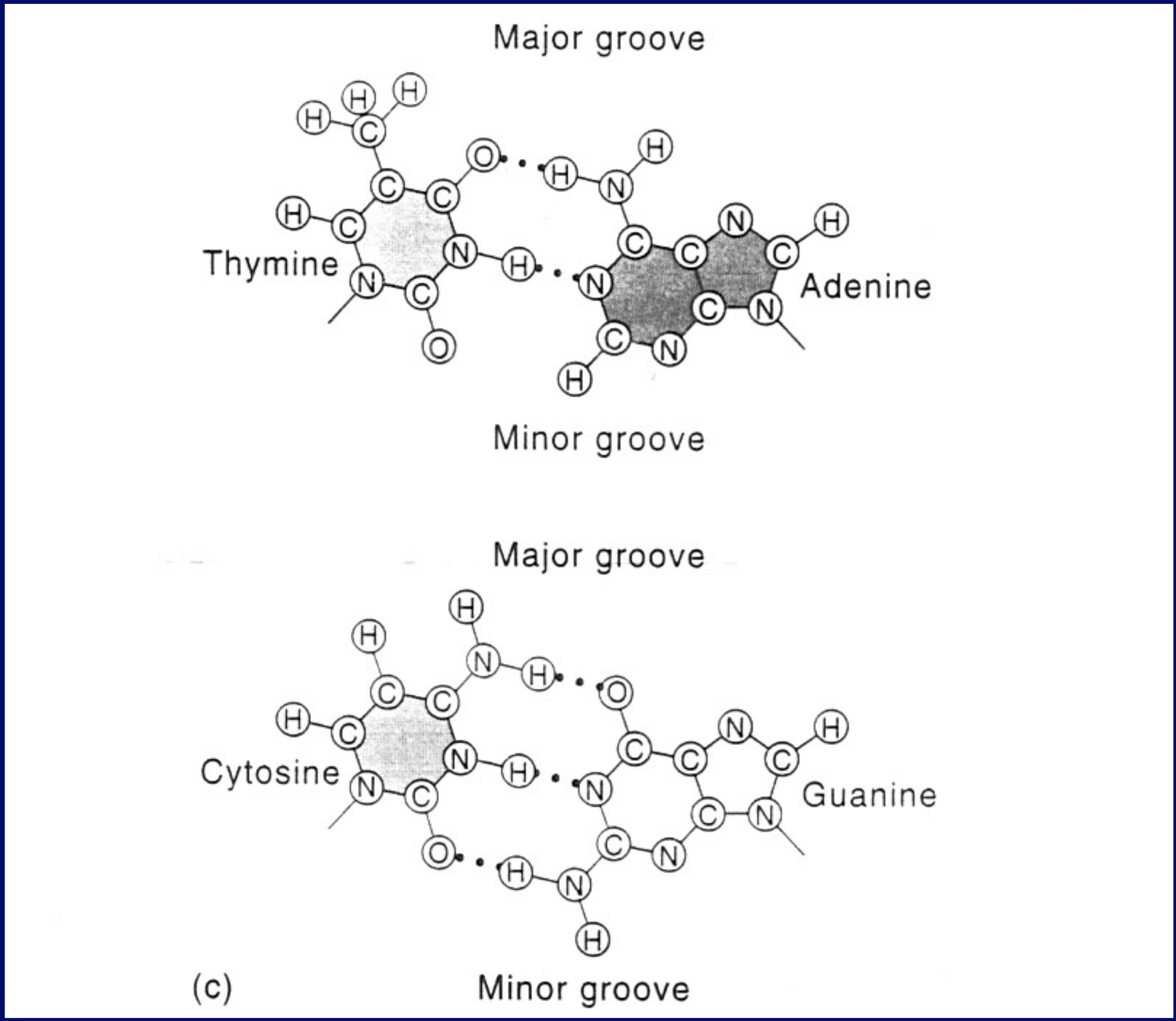
At the Chemical Level



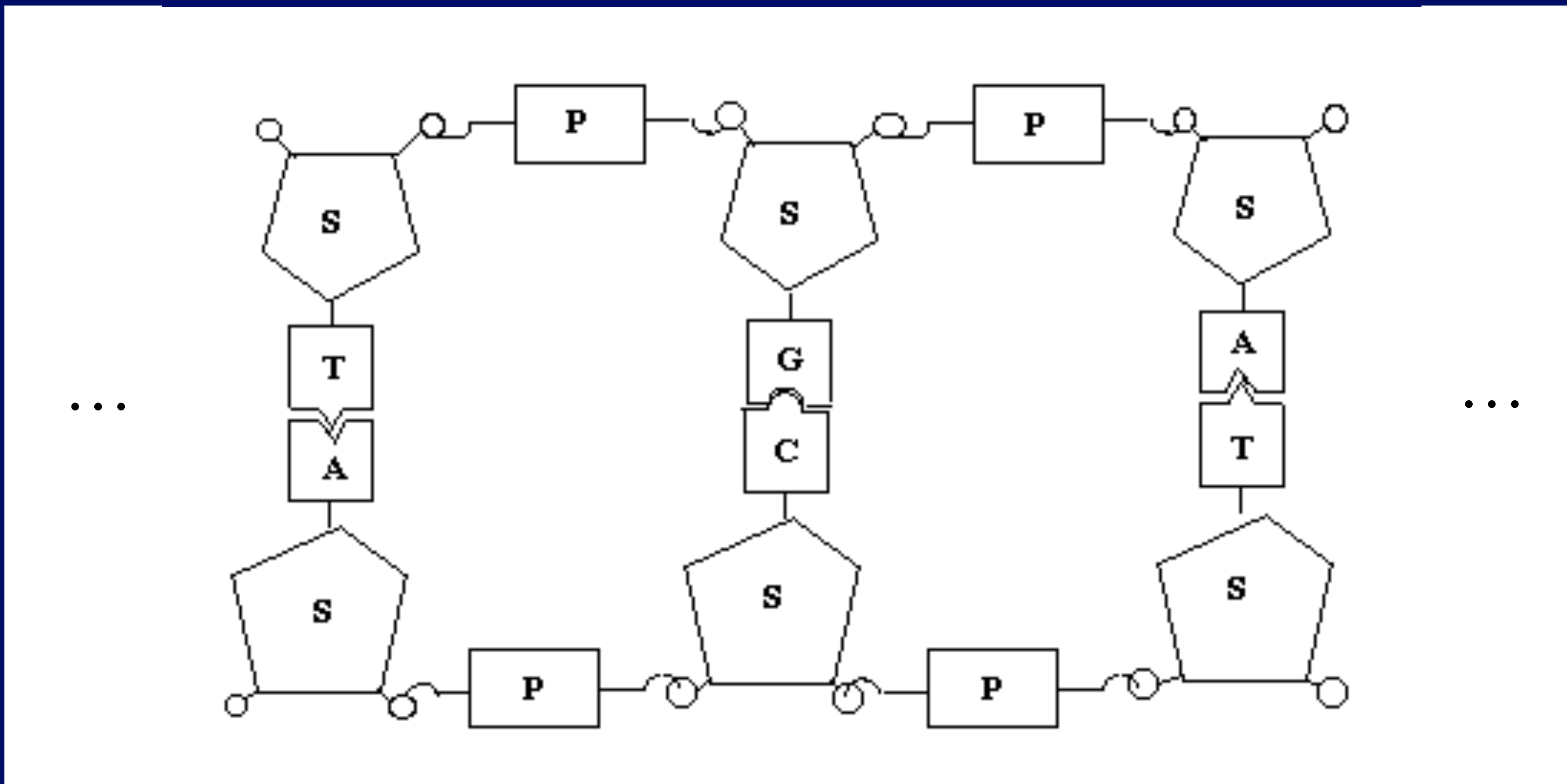


DNA
RNA
5′ End
5′ End
Phosphodiester linkage
5′
3′
5′
3′
3′ End
3′ End

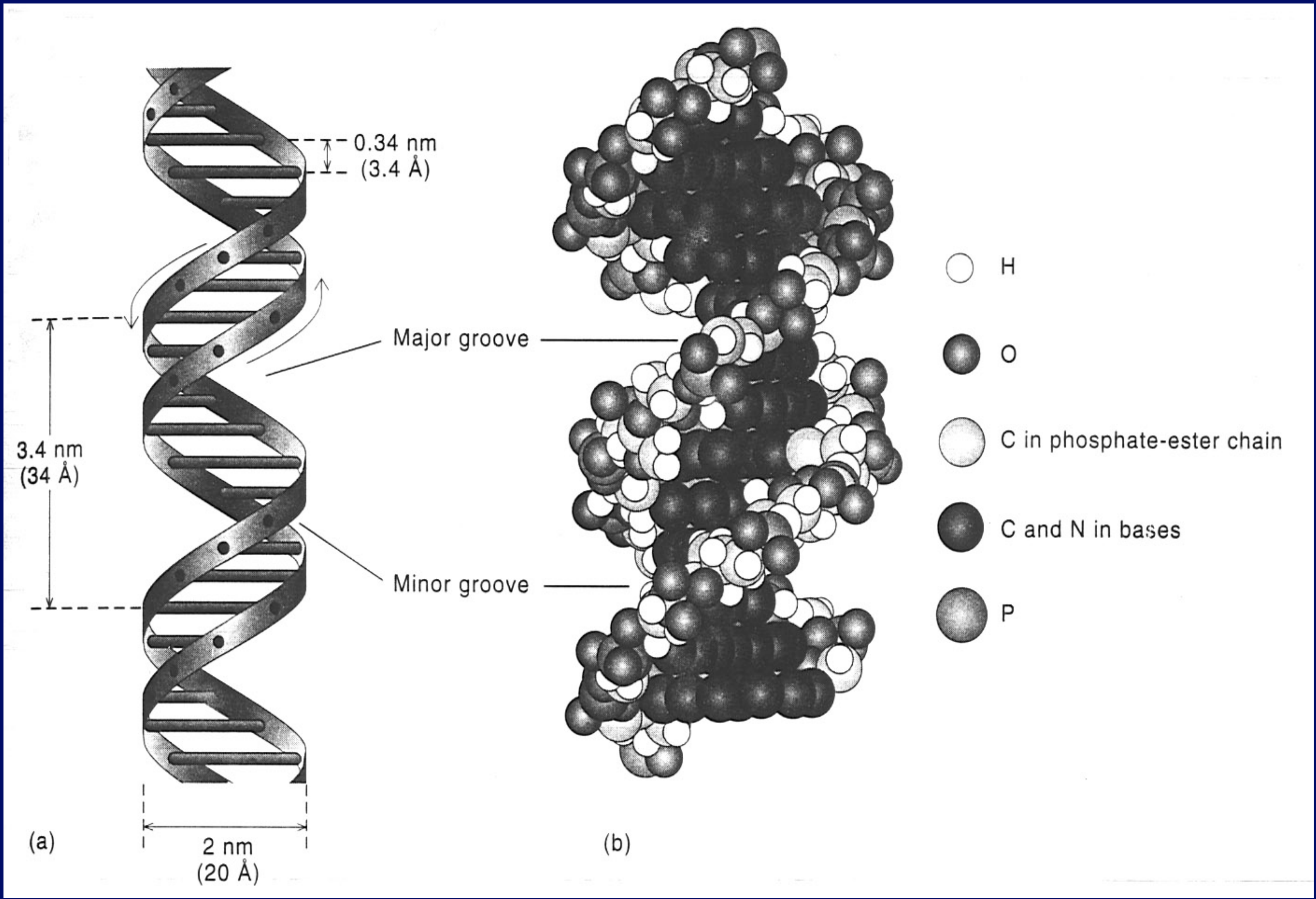
Hydrogen Bonds (weak) connect the bases across the two sides of DNA



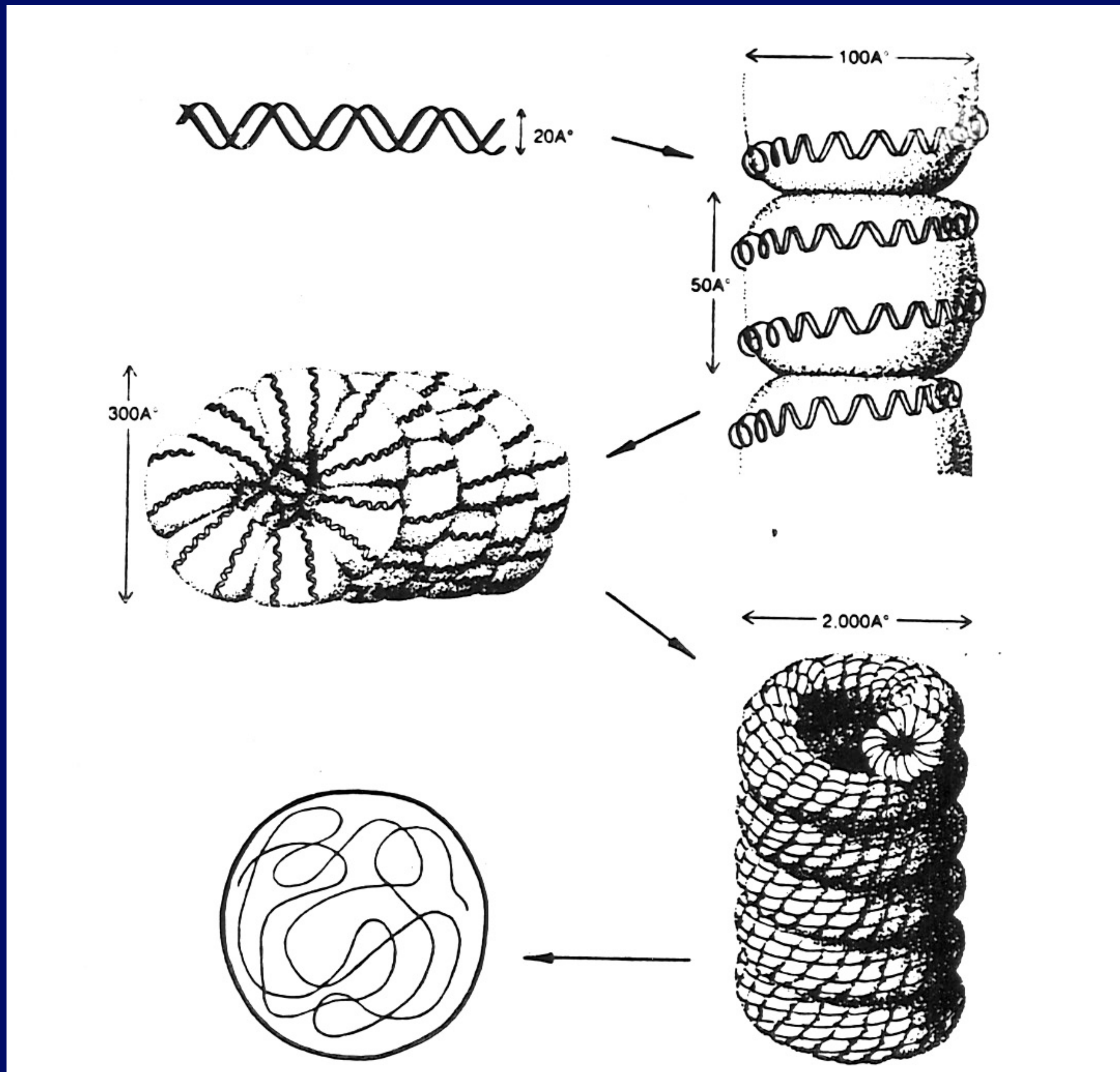
Segment of DNA



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

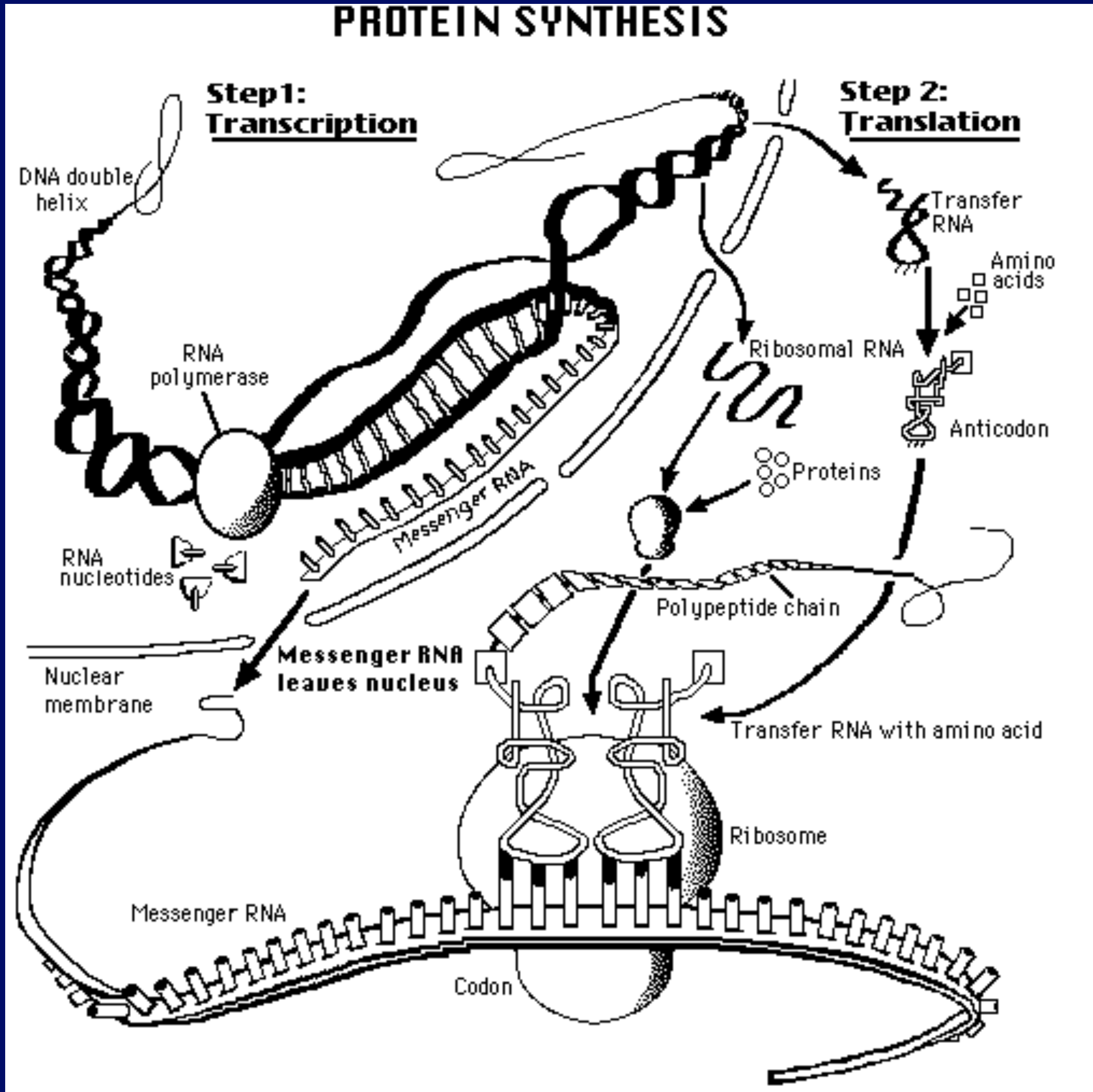
e.g.	tobacco mosaic virus	4 genes
	bacteria	~ 10^3 genes
	human cell	~ 25,000 genes

For mRNA

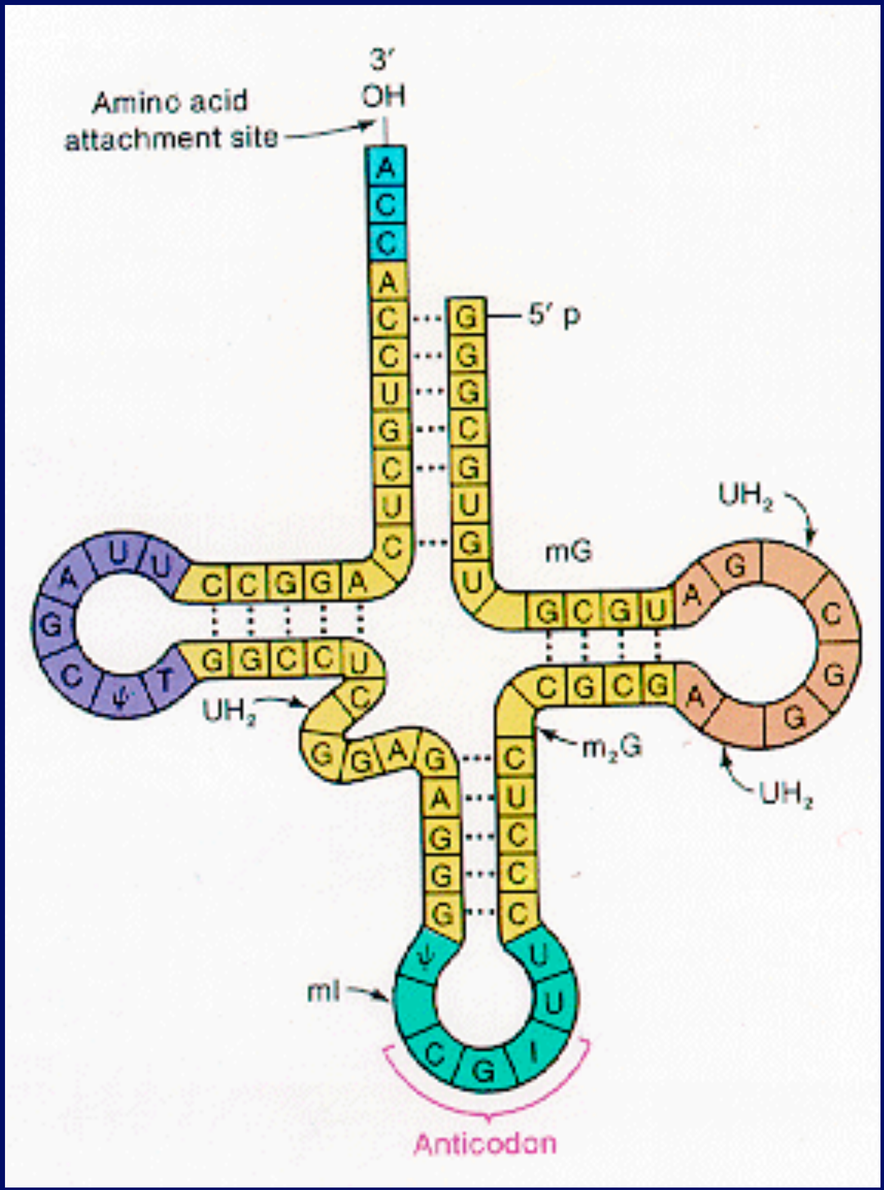
Genetic Code

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

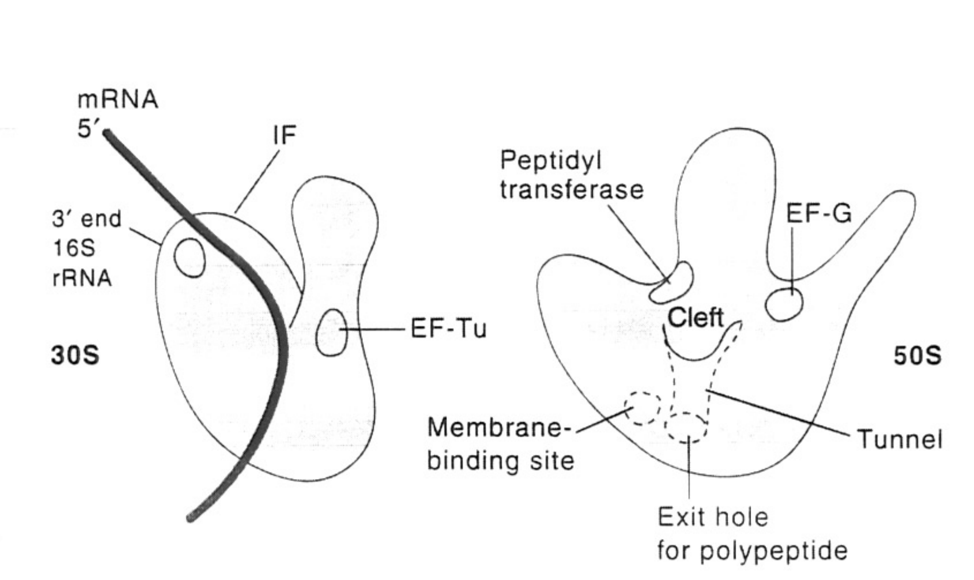
Amino Acids

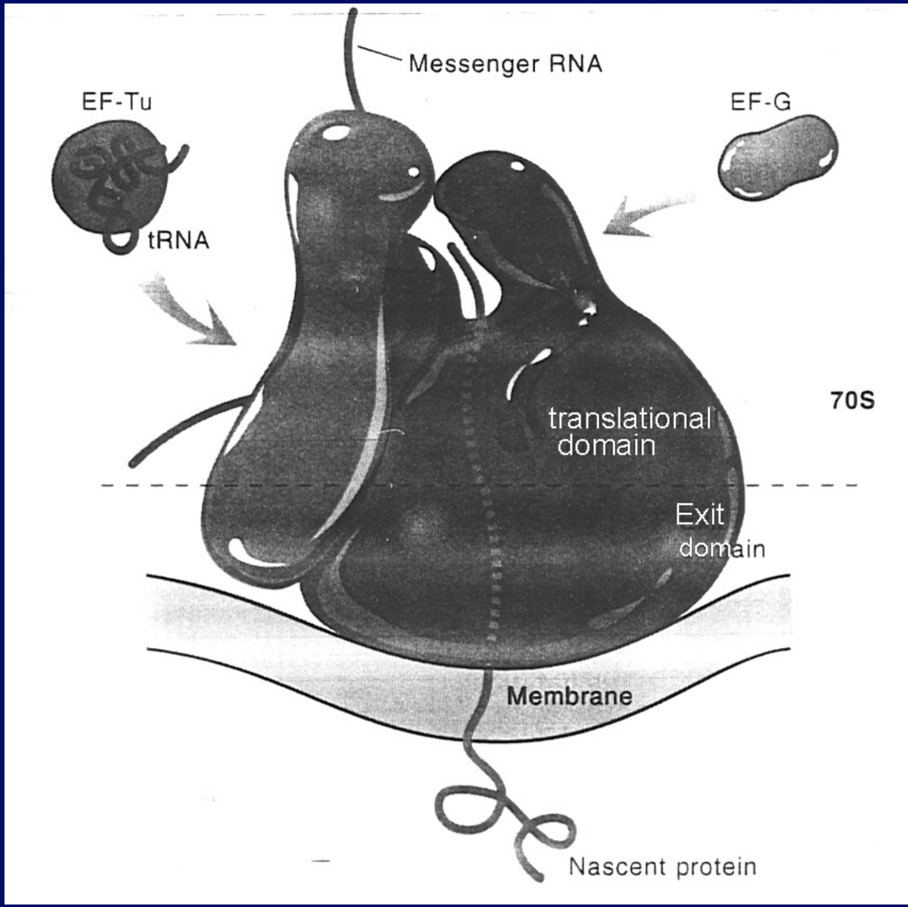

PROTEIN SYNTHESIS
Step1:
Transcription
Step 2:
Translation
DNA double helix
RNA polymerase
Messenger RNA
RNA nucleotides
Transfer RNA
Amino acids
Ribosomal RNA
Anticodon
Proteins
Polypeptide chain
Nuclear membrane
Messenger RNA leaves nucleus
Transfer RNA with amino acid
Ribosome
Messenger RNA
Codon

Structure of a tRNA



Translation





Variations in the Code

1. "Wobble" Bases
   The third base in a codon can sometimes vary.

tRNA	mRNA
U	A or G
G	C or U

Comparison to genetic code $\Longrightarrow$ 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