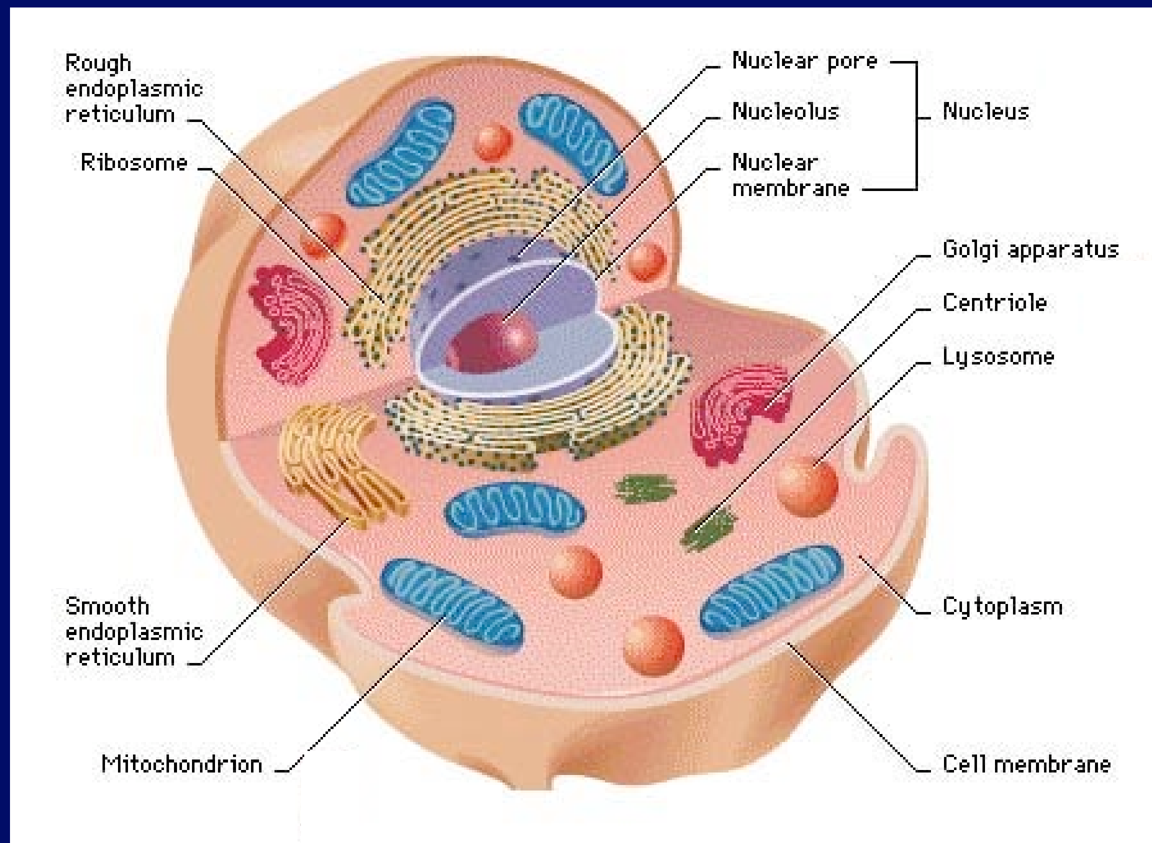
Life

What is necessary for life?

Most life familiar to us: Eukaryotes

FREE LIVING
Or Parasites



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

Prokaryotes (Bacteria and Archaea)

First appeared

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

FREE LIVING
Or Parasites

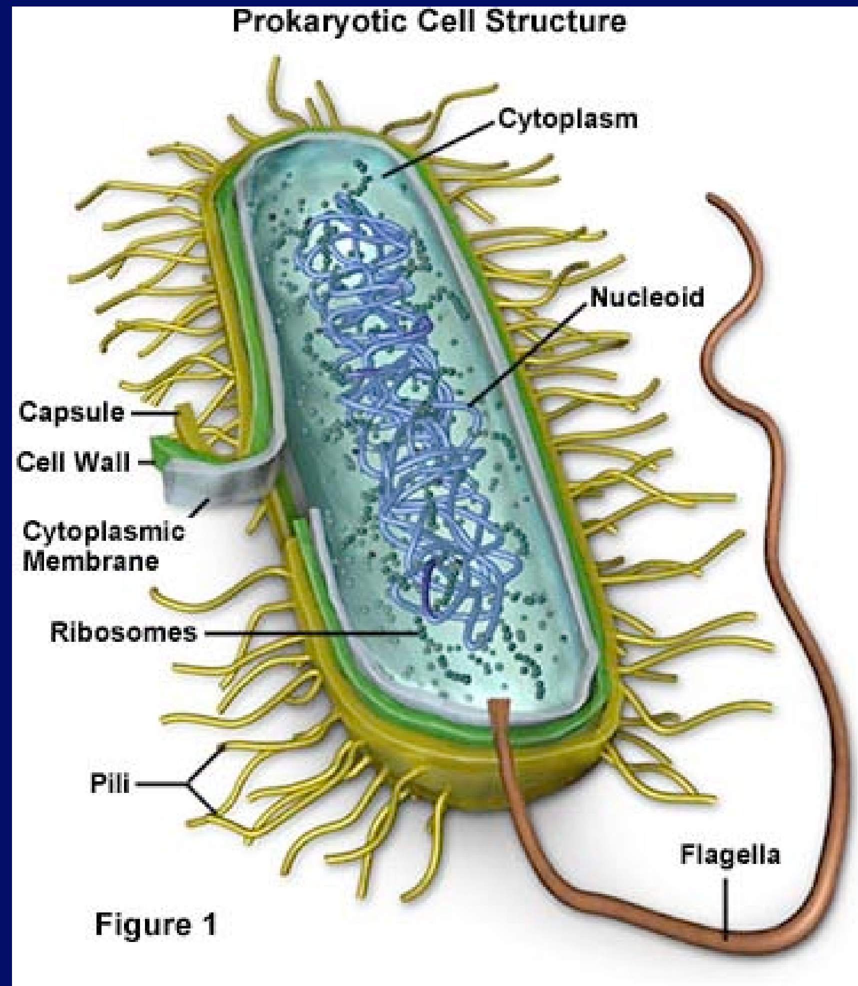
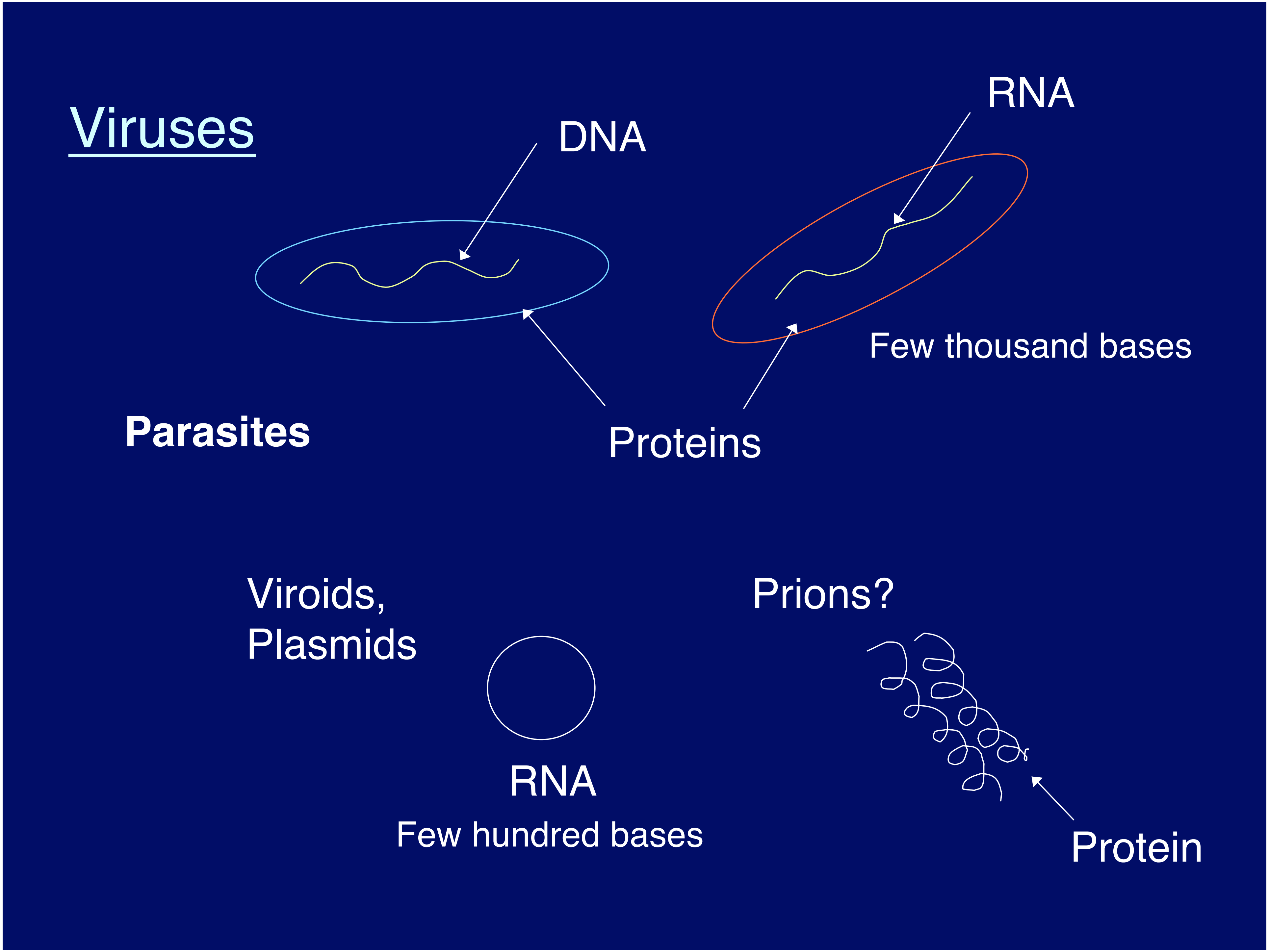
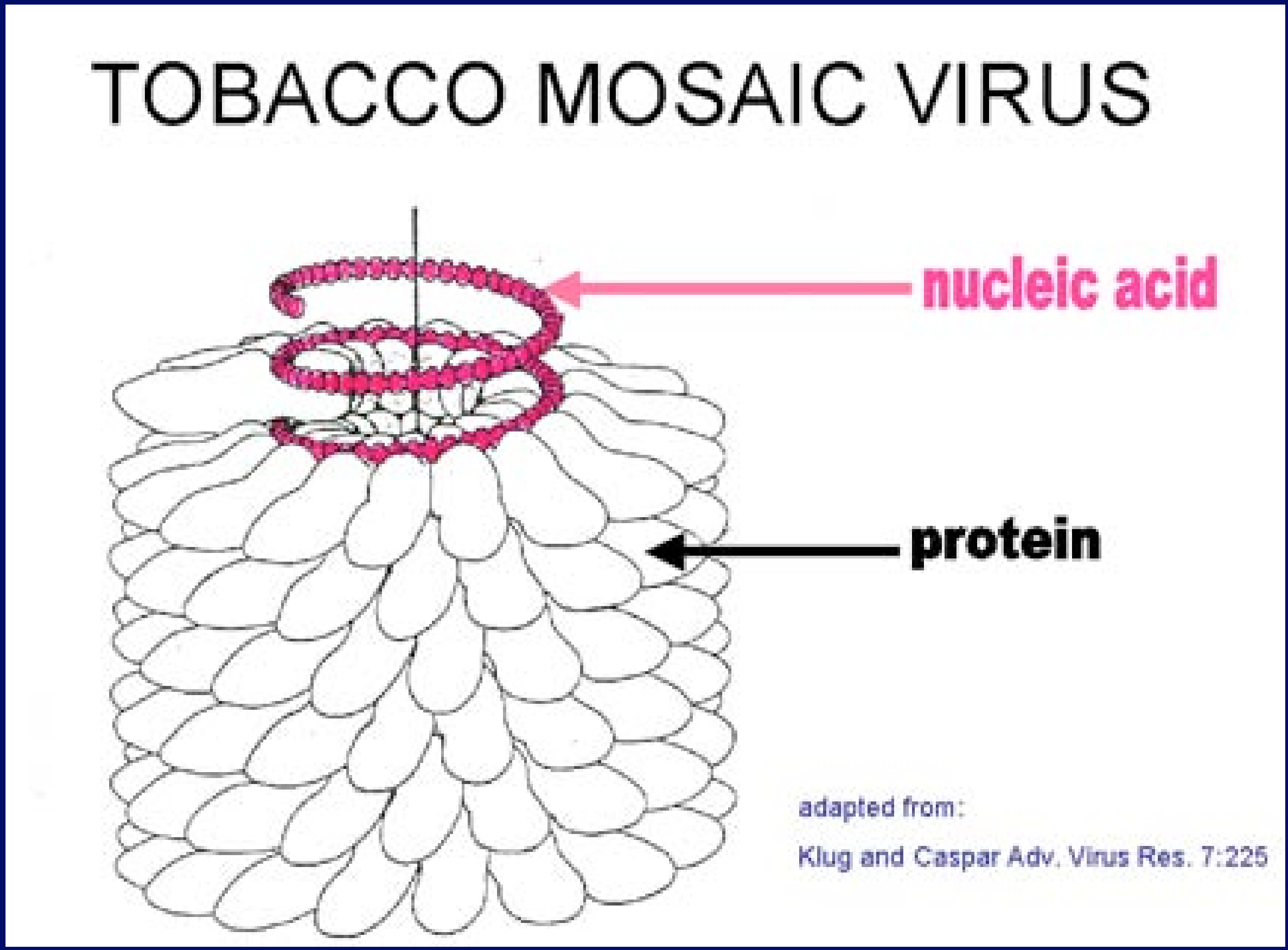


Figure 1

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.



Life
Composition
Properties and Definitions
Fossil record & Classification

Minimum Requirements for Life

Proteins and Nucleic Acids

(Lipids and Carbohydrates)

Polymers and Monomers

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

H, C, O Carbohydrates made of sugars

Energy (food) + structure

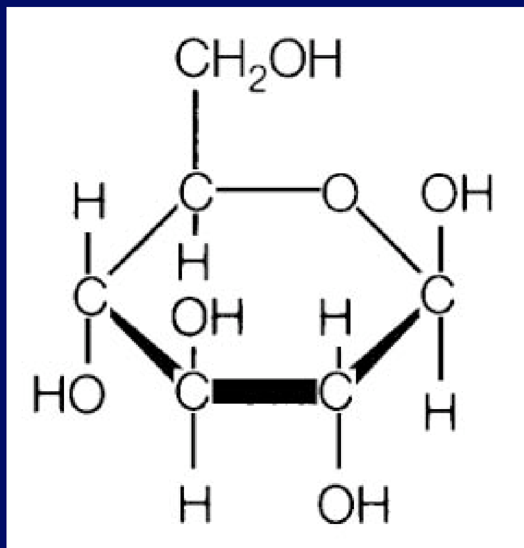
[starch] [cellulose]

H, C, (O) Lipids (hydrocarbons + carboxyl)

Membranes + Energy

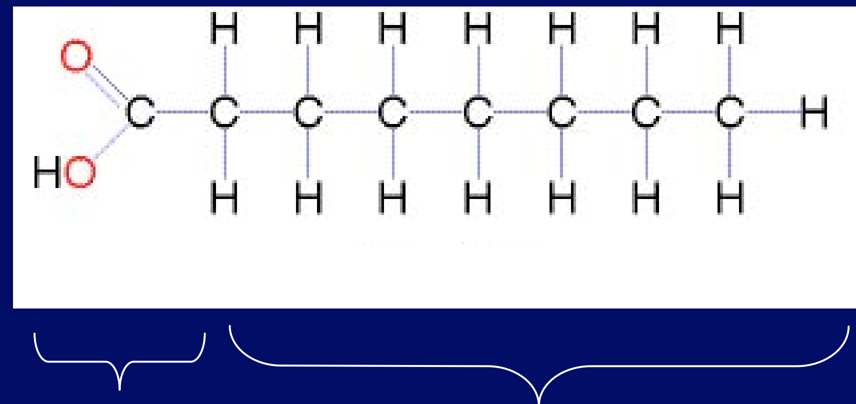
[water-resistant]

Sugar



Glucose

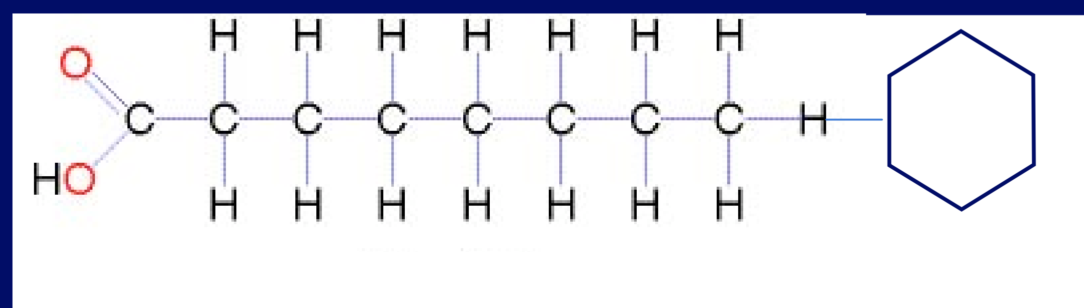
Lipids



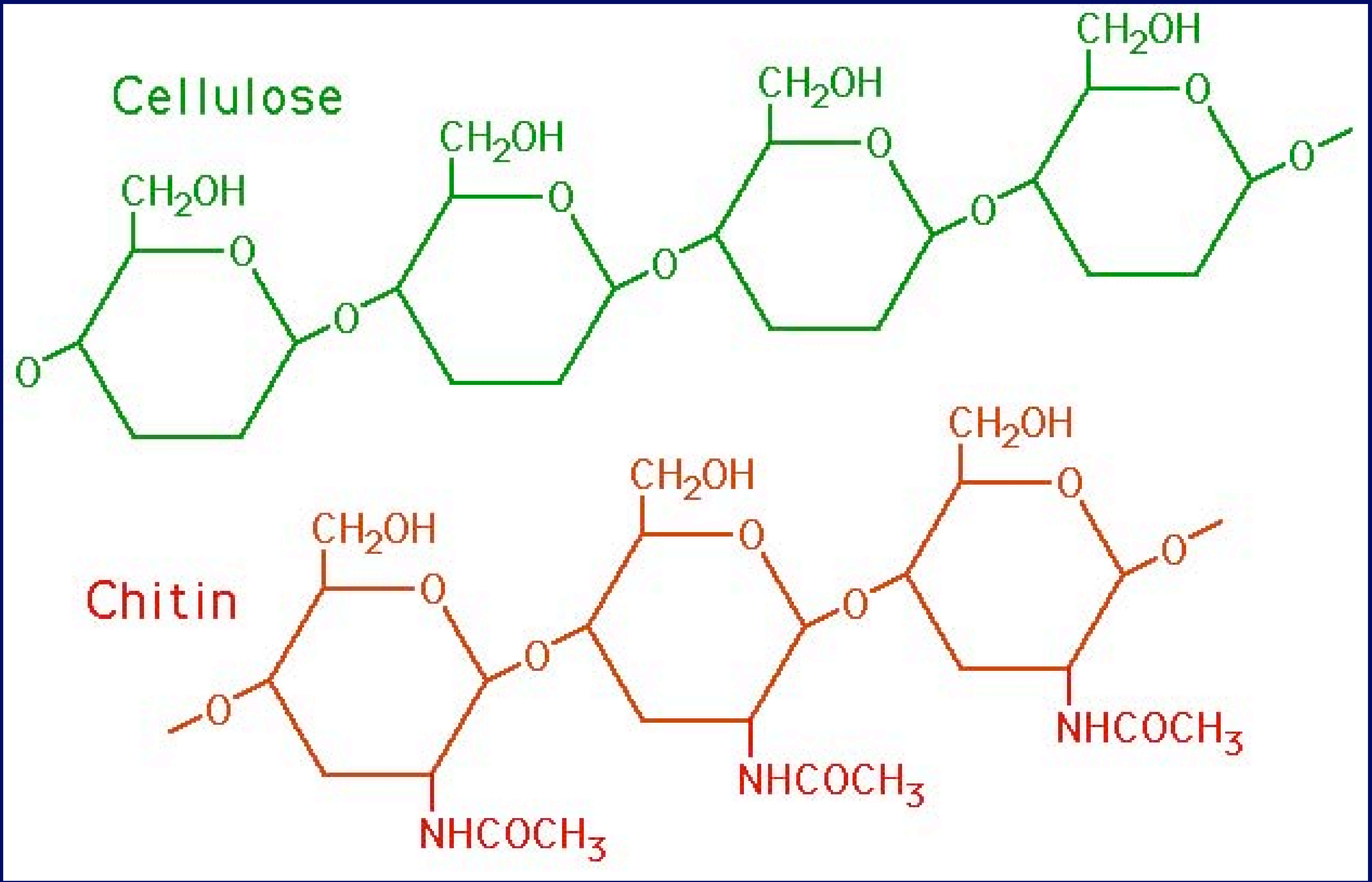
carboxyl

hydrocarbon

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



Polysaccharides

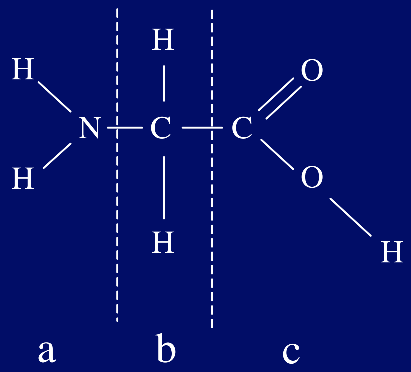


Proteins

Monomers are amino acids

20 kinds

Glycine



Amino group

carboxyl group

Schematic

Amino group (hook)

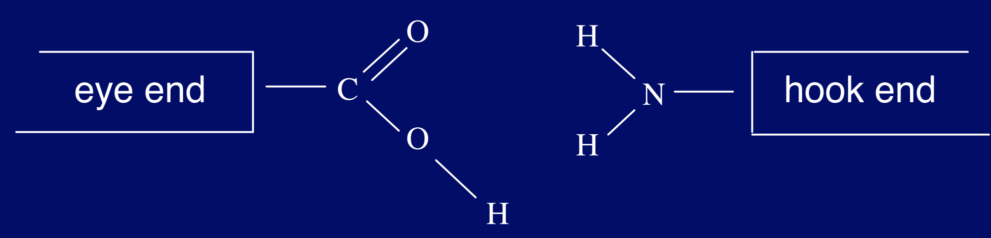
carboxyl group (eye)

Section of Protein

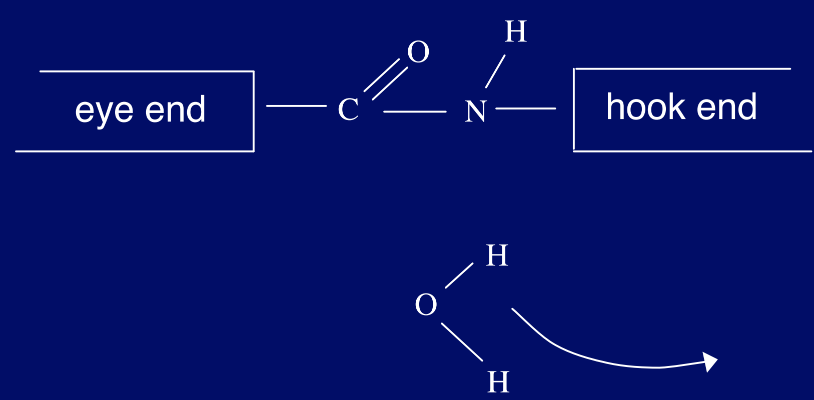
Peptide Bond

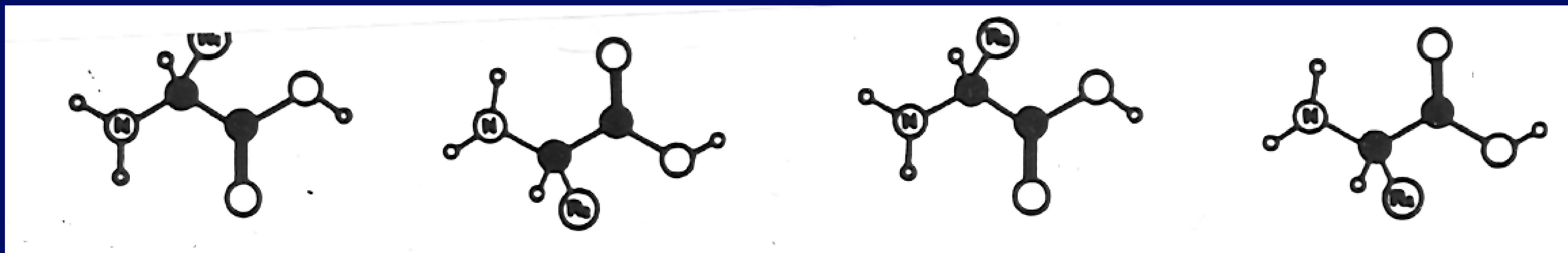
Chemical Level

Before

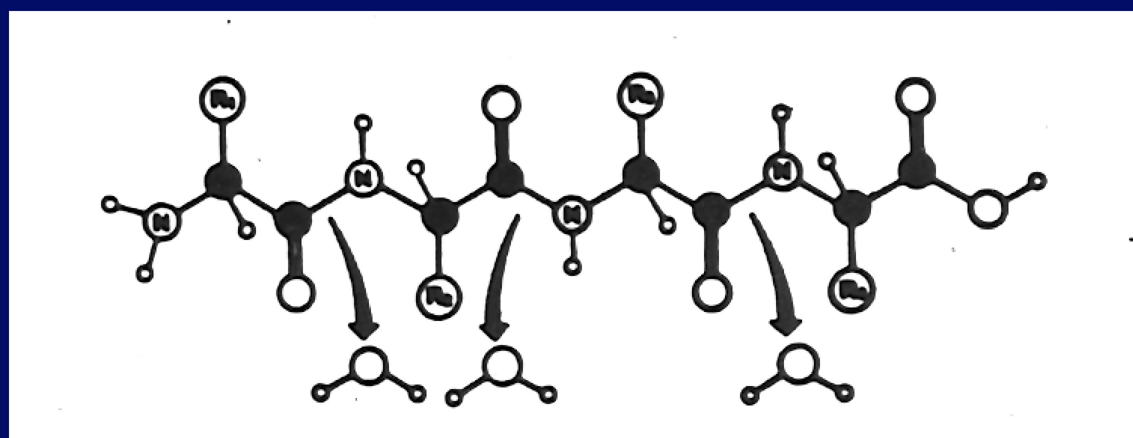


After

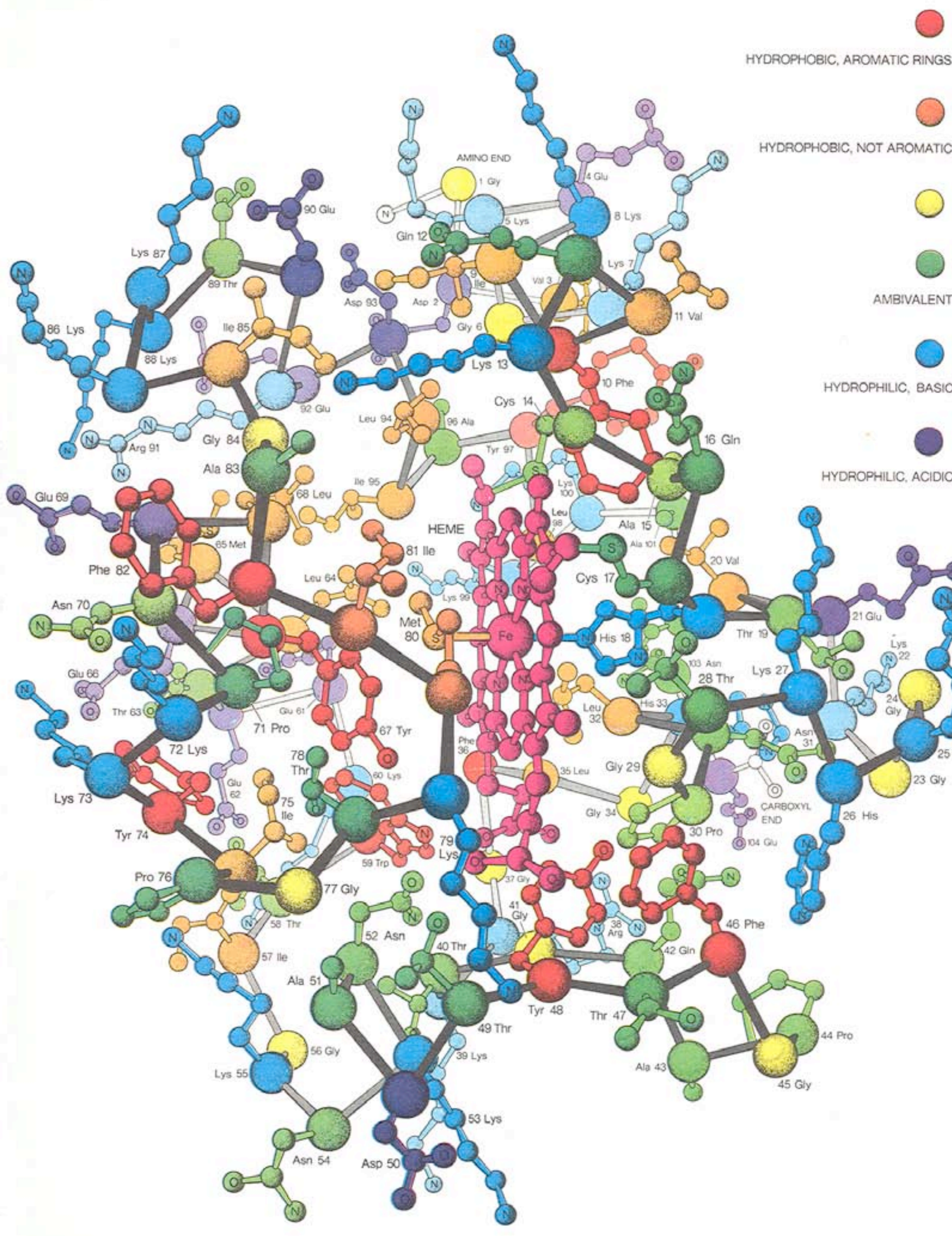


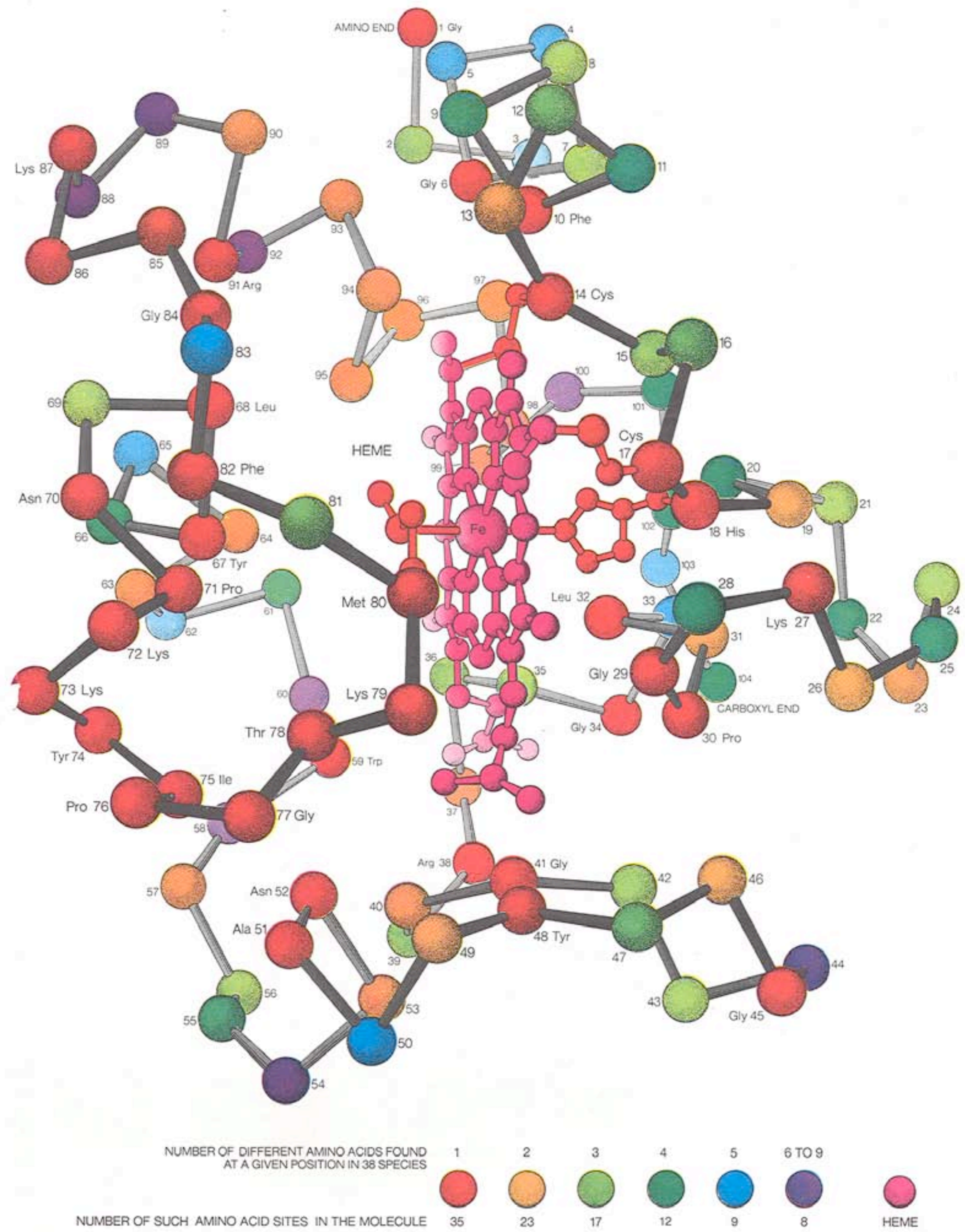


amino acids



protein

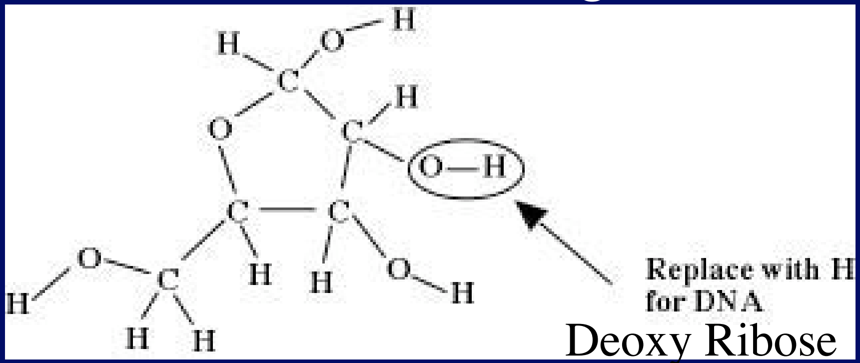

HYDROPHOBIC, AROMATIC RINGS
HYDROPHOBIC, NOT AROMATIC
AMBIVALENT
HYDROPHILIC, BASIC
HYDROPHILIC, ACIDIC
AMINO END
1 Gly
4 Glu
5 Lys
8 Lys
Gln 12
Lys 7
90 Glu
Lys 87
89 Thr
Asp 93
Asp 2
Val 3
11 Val
86 Lys
Ile 85
88 Lys
Gly 6
Lys 13
10 Phe
92 Glu
Cys 14
Leu 94
96 Ala
16 Gln
Arg 91
Gly 84
Tyr 97
Ala 83
68 Leu
Ile 95
Glu 69
HEME
Ala 15
65 Met
81 Ile
Phe 82
Leu 64
Cys 17
20 Val
Lys 99
Asn 70
Met 80
Fe
His 18
Thr 19
21 Glu
Lys 22
Glu 66
103 Asn
Lys 27
28 Thr
24 Gly
Thr 63
Glu 61
His 33
Leu 32
71 Pro
67 Tyr
72 Lys
Asn 31
25 Lys
78 Thr
60 Lys
35 Leu
Gly 29
23 Gly
Lys 73
Glu 62
75 Ile
Gly 34
CARBOXYL END
26 His
30 Pro
104 Glu
Tyr 74
79 Lys
59 Trp
Pro 76
77 Gly
37 Gly
41 Gly
38 Arg
46 Phe
58 Thr
52 Asn
40 Thr
42 Gln
57 Ile
Ala 51
Tyr 48
Thr 47
49 Thr
44 Pro
56 Gly
39 Lys
Ala 43
Lys 55
45 Gly
53 Lys
Asn 54
Asp 50


AMINO END
1 Gly
HEME
Fe
Lys 87
91 Arg
Gly 84
68 Leu
82 Phe
Asn 70
67 Tyr
71 Pro
Met 80
72 Lys
73 Lys
Lys 79
Thr 78
Tyr 74
75 Ile
Pro 76
77 Gly
59 Trp
Gly 6
10 Phe
14 Cys
Cys 17
18 His
Leu 32
Lys 27
Gly 29
Gly 34
30 Pro
CARBOXYL END
Arg 38
41 Gly
Asn 52
Ala 51
48 Tyr
Gly 45
NUMBER OF DIFFERENT AMINO ACIDS FOUND AT A GIVEN POSITION IN 38 SPECIES
1
2
3
4
5
6 TO 9
NUMBER OF SUCH AMINO ACID SITES IN THE MOLECULE
35
23
17
12
9
8
HEME

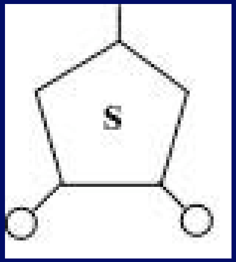
Nucleic Acids (DNA, RNA)

Made of sugars, phosphates, bases

Sugar

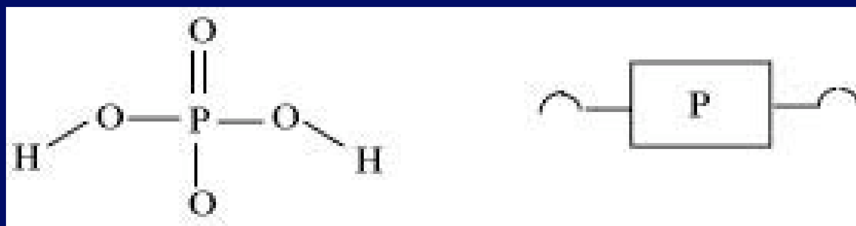


Schematic



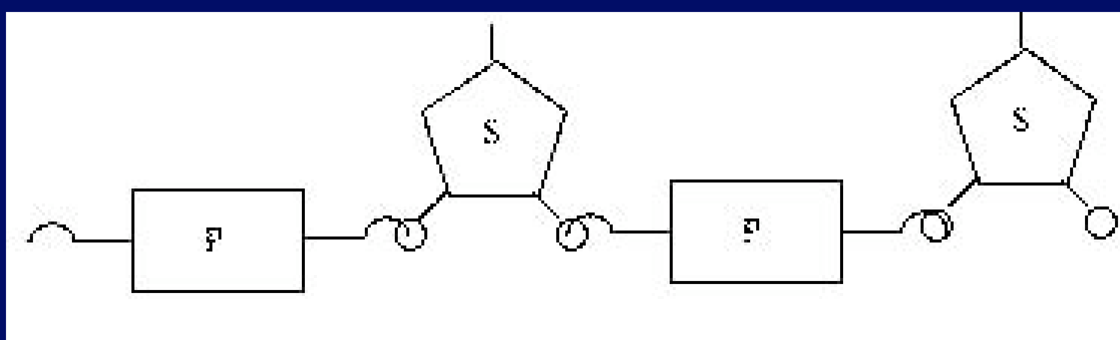
Ribose Sugar
5C, 5O, 10 H

phosphate



sugars & phosphates linked

phosphodiester bonds

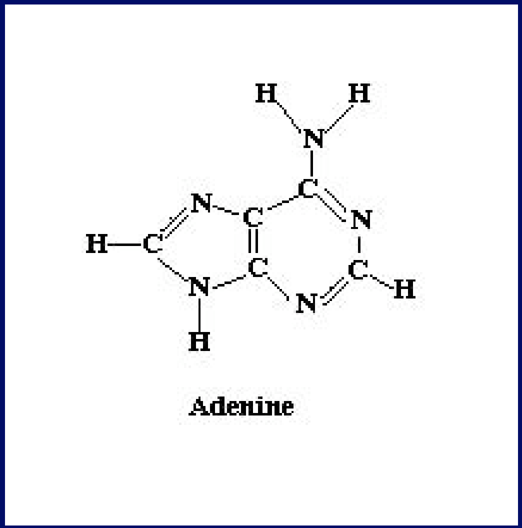


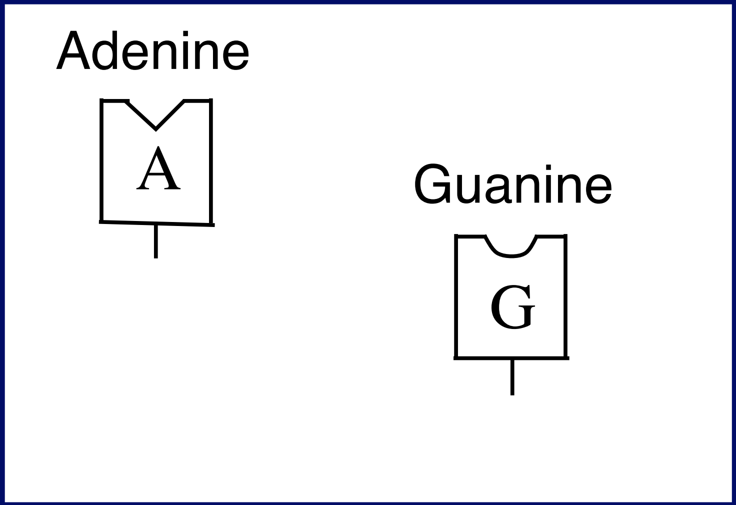
Segment of side of ladder structure

Nucleic Acids (cont.)

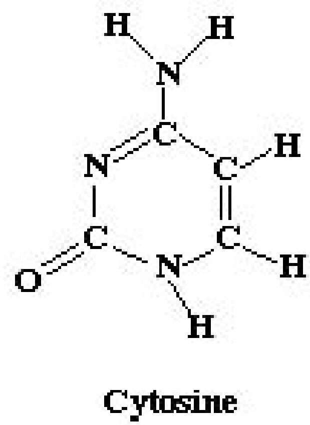
Bases: Carry Genetic Code

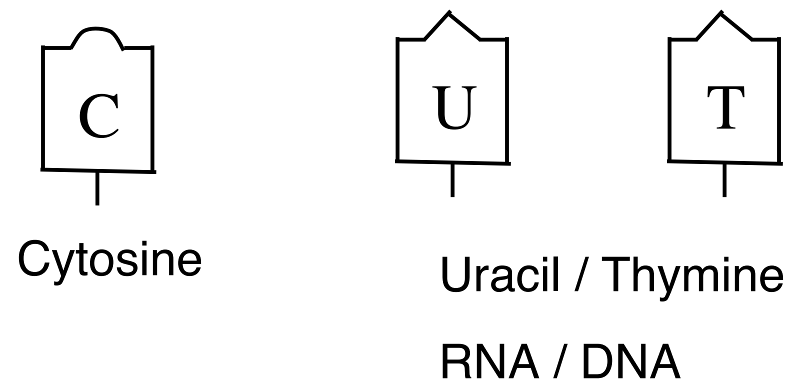
Purines



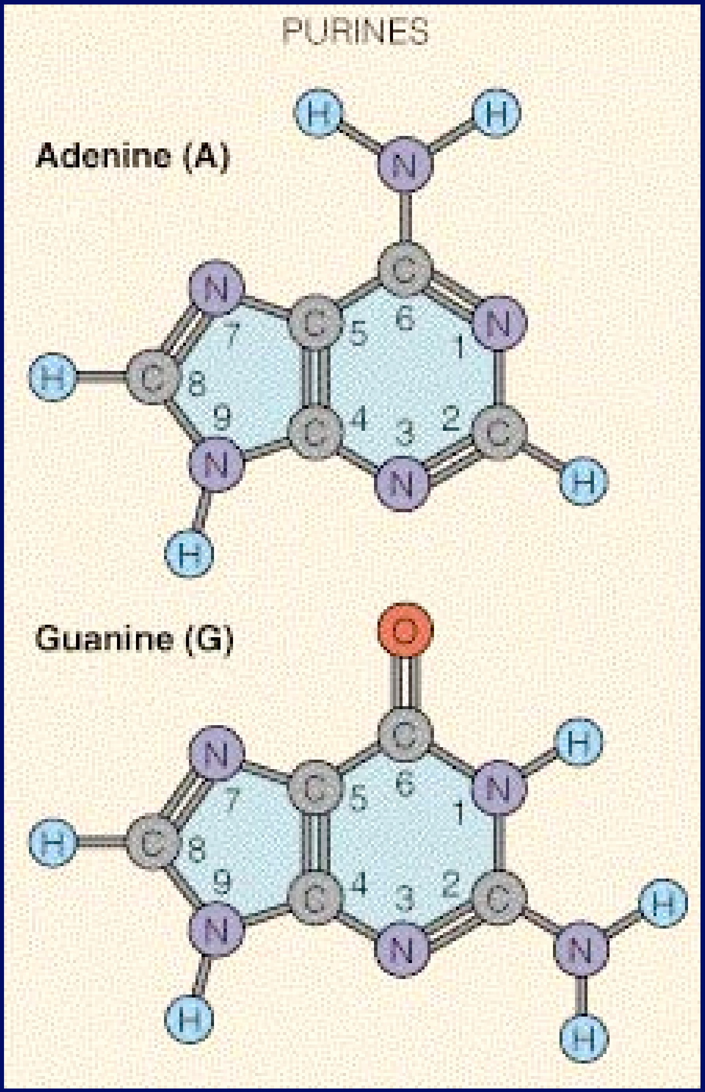


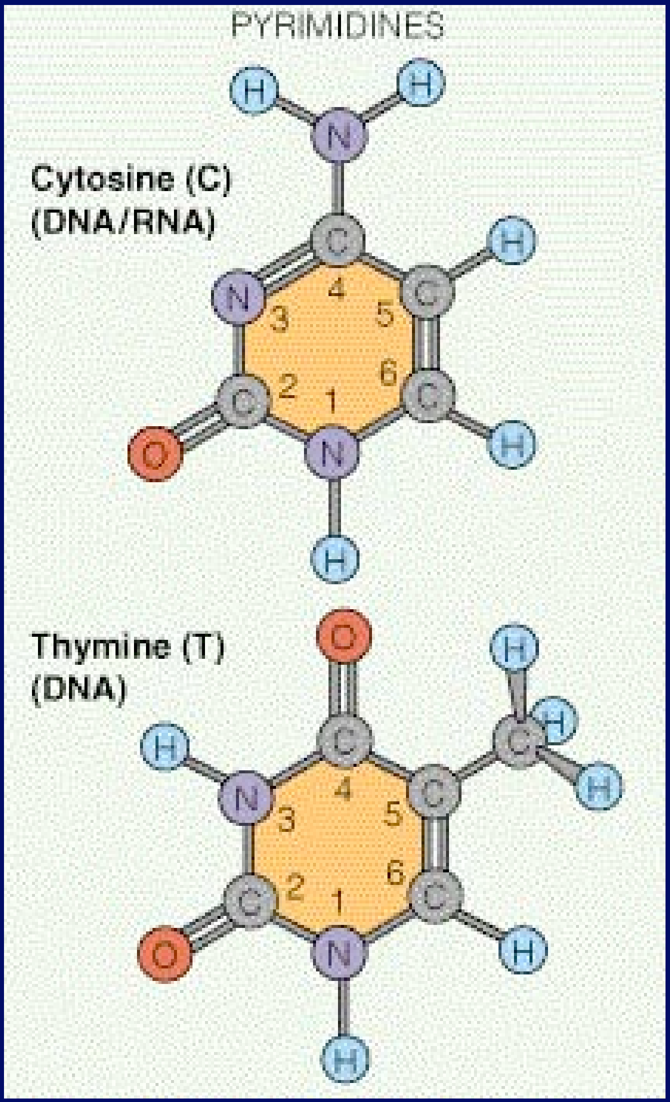
Pyrimidines

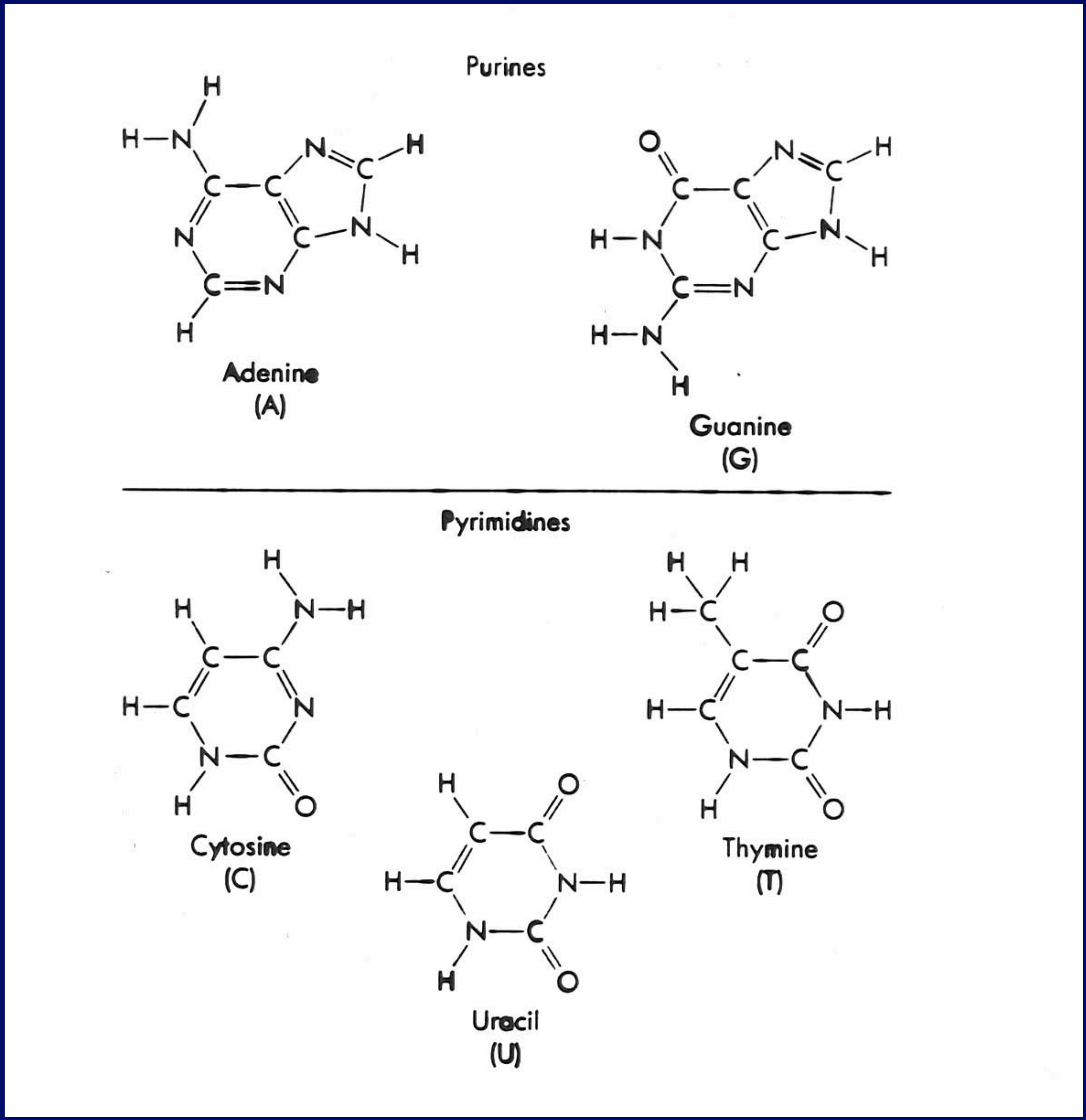




Bases in Nucleic acids: Purines and Pyrimidines





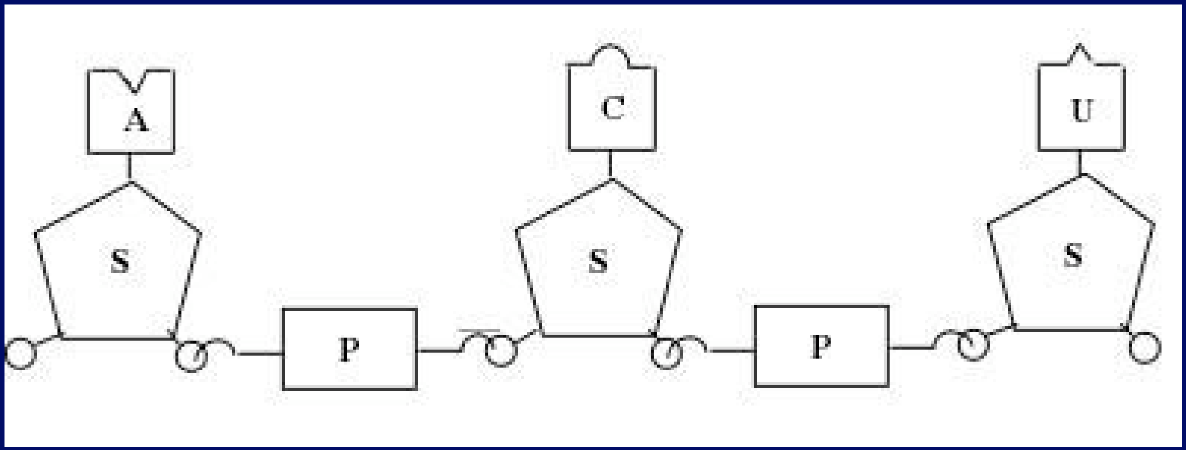


Purines

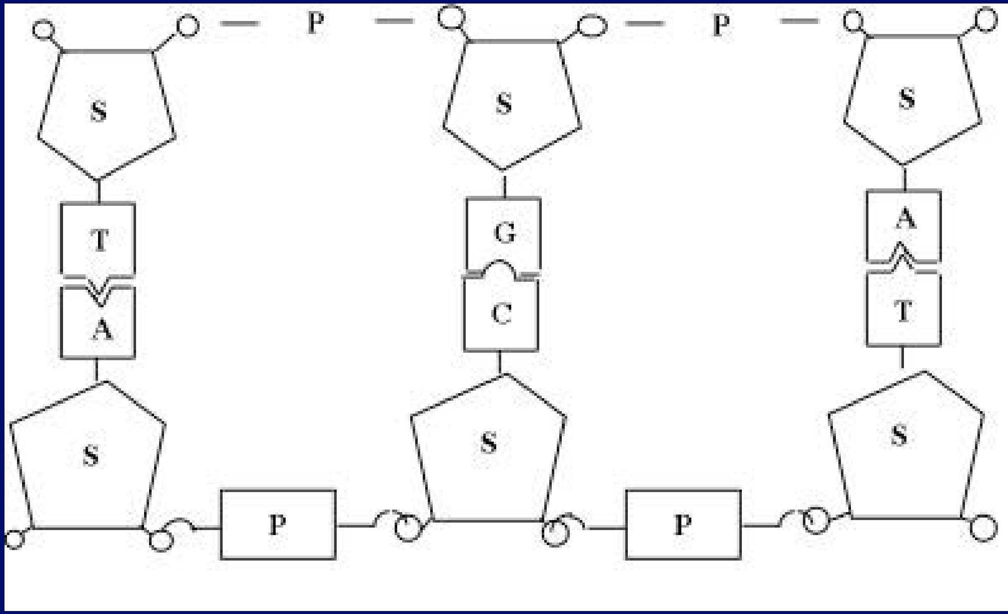
Pyrimidines

Nucleic Acids (cont.)

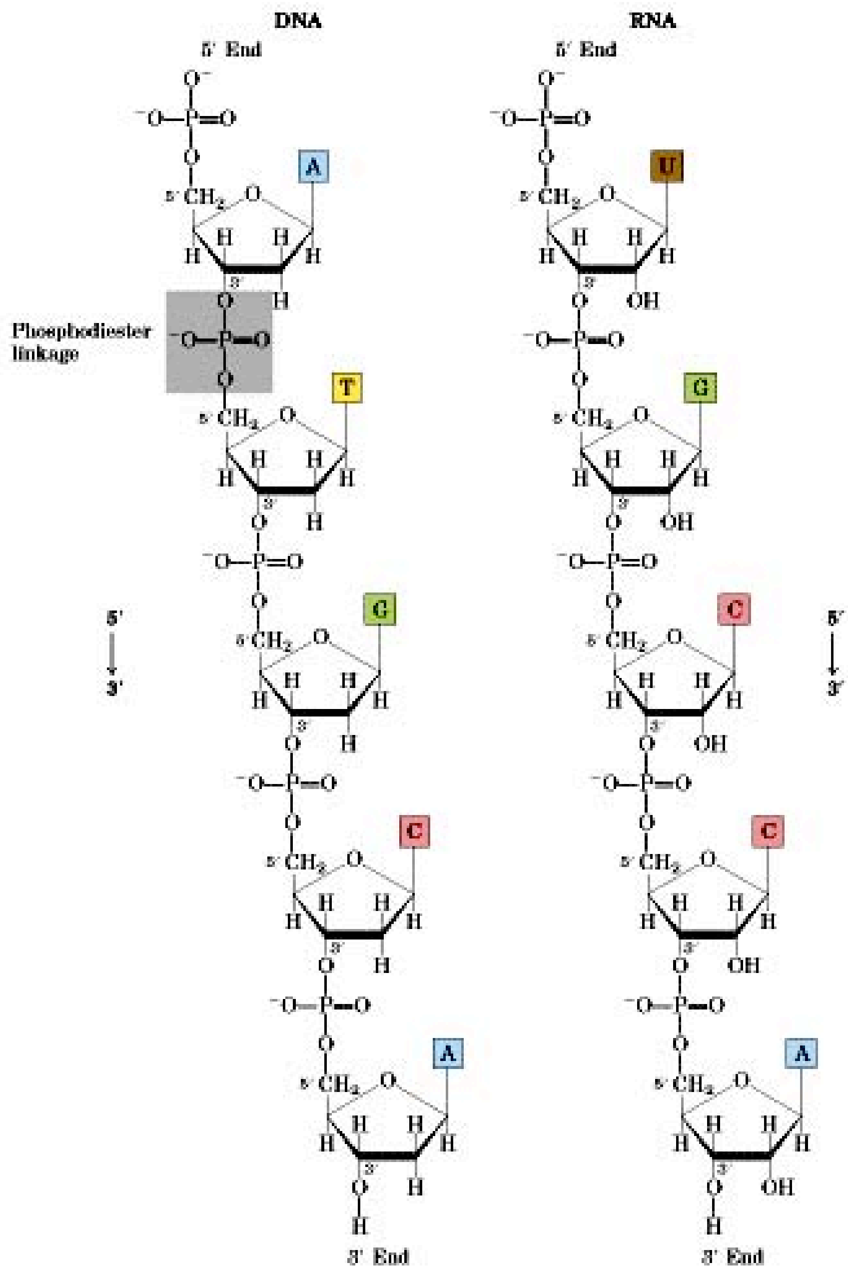
Segment of RNA



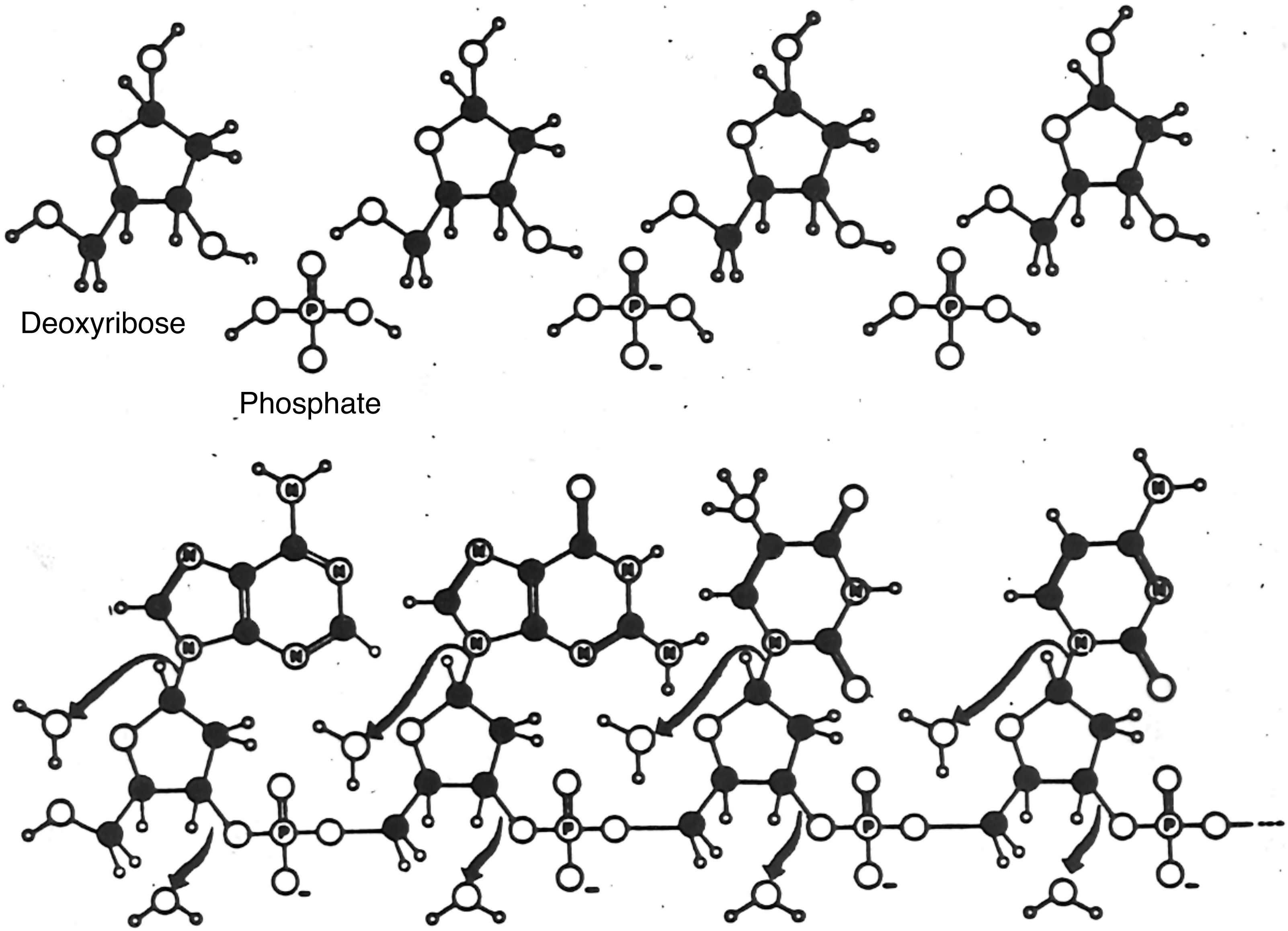
Segment of DNA



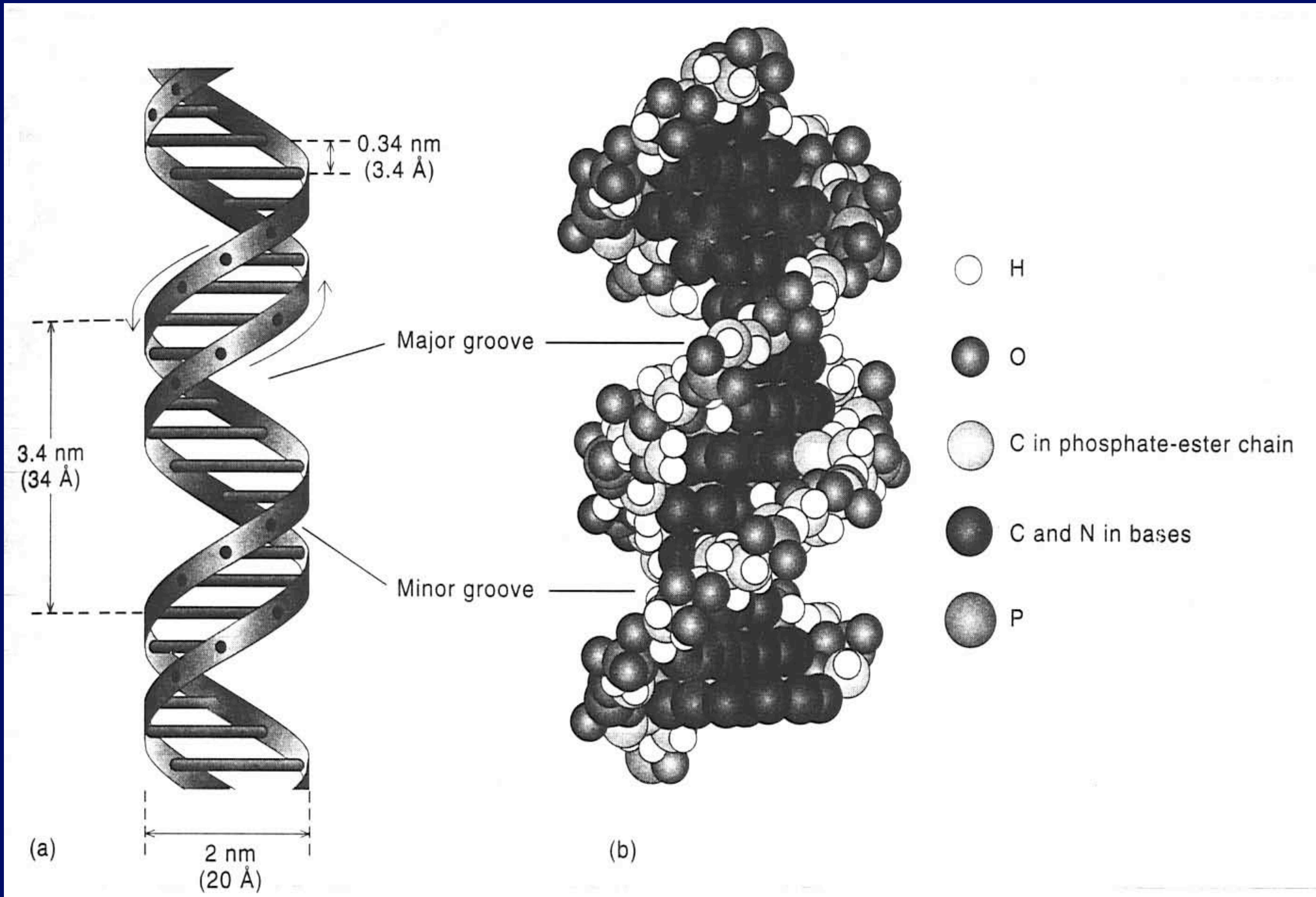
Note that T replaces U in DNA

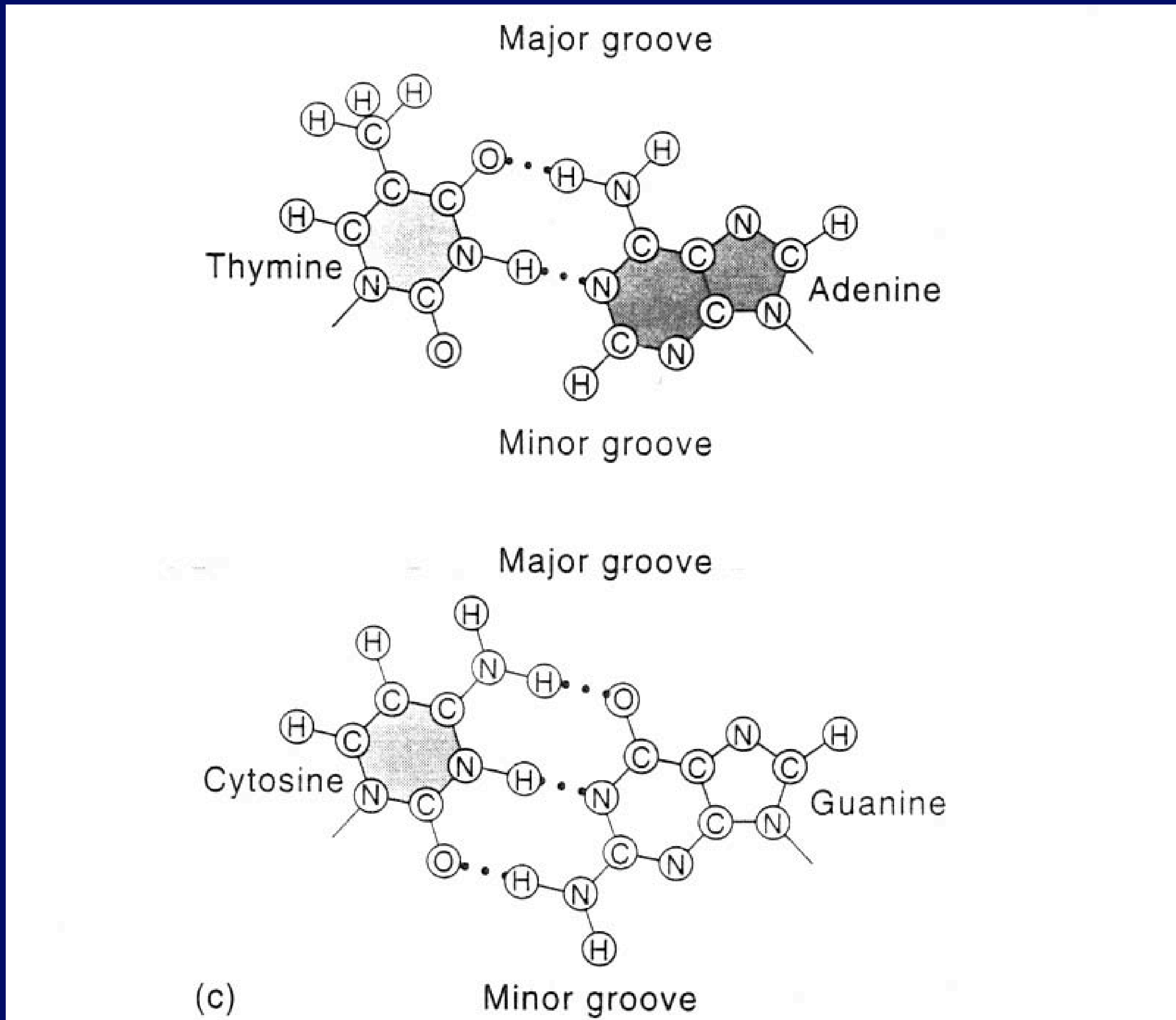


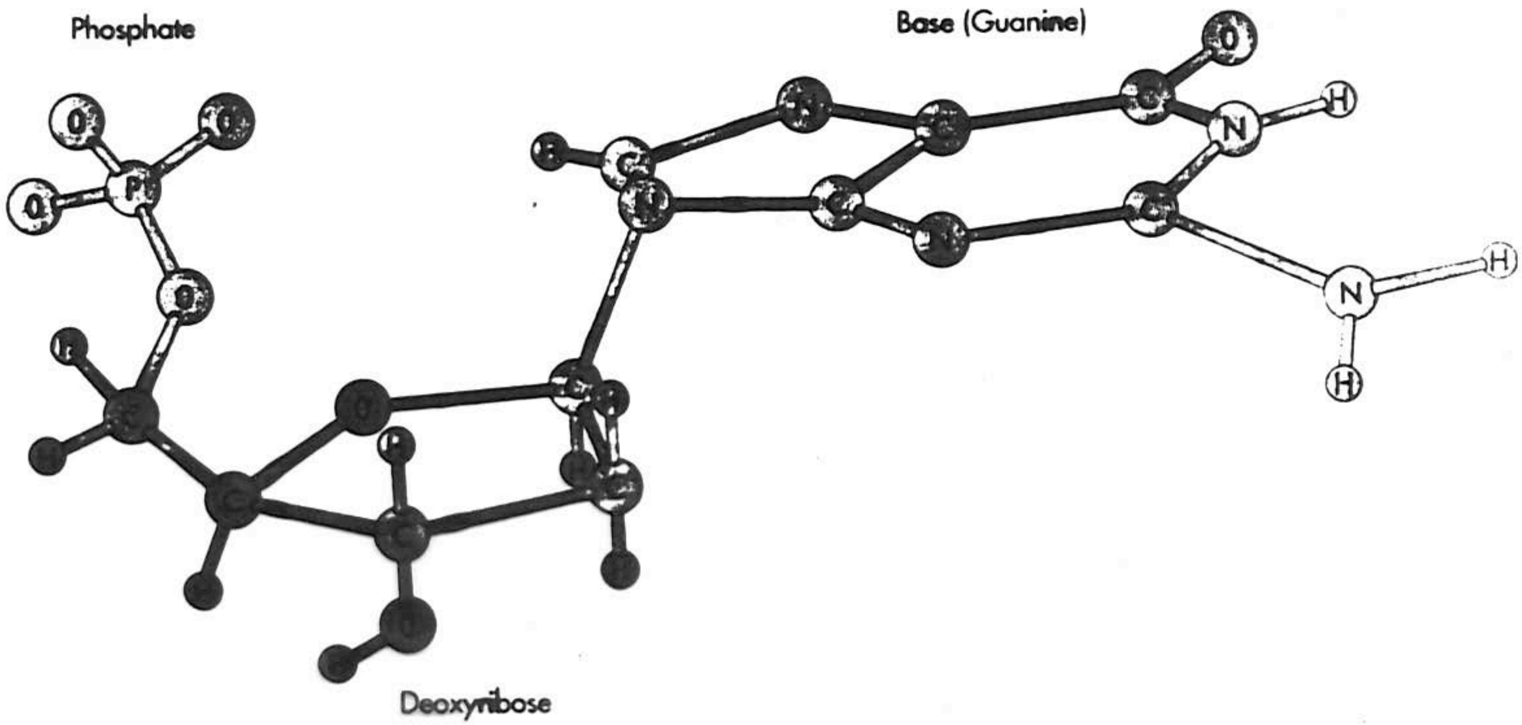
DNA
RNA
5′ End
3′ End
Phosphodiester linkage
5′
3′

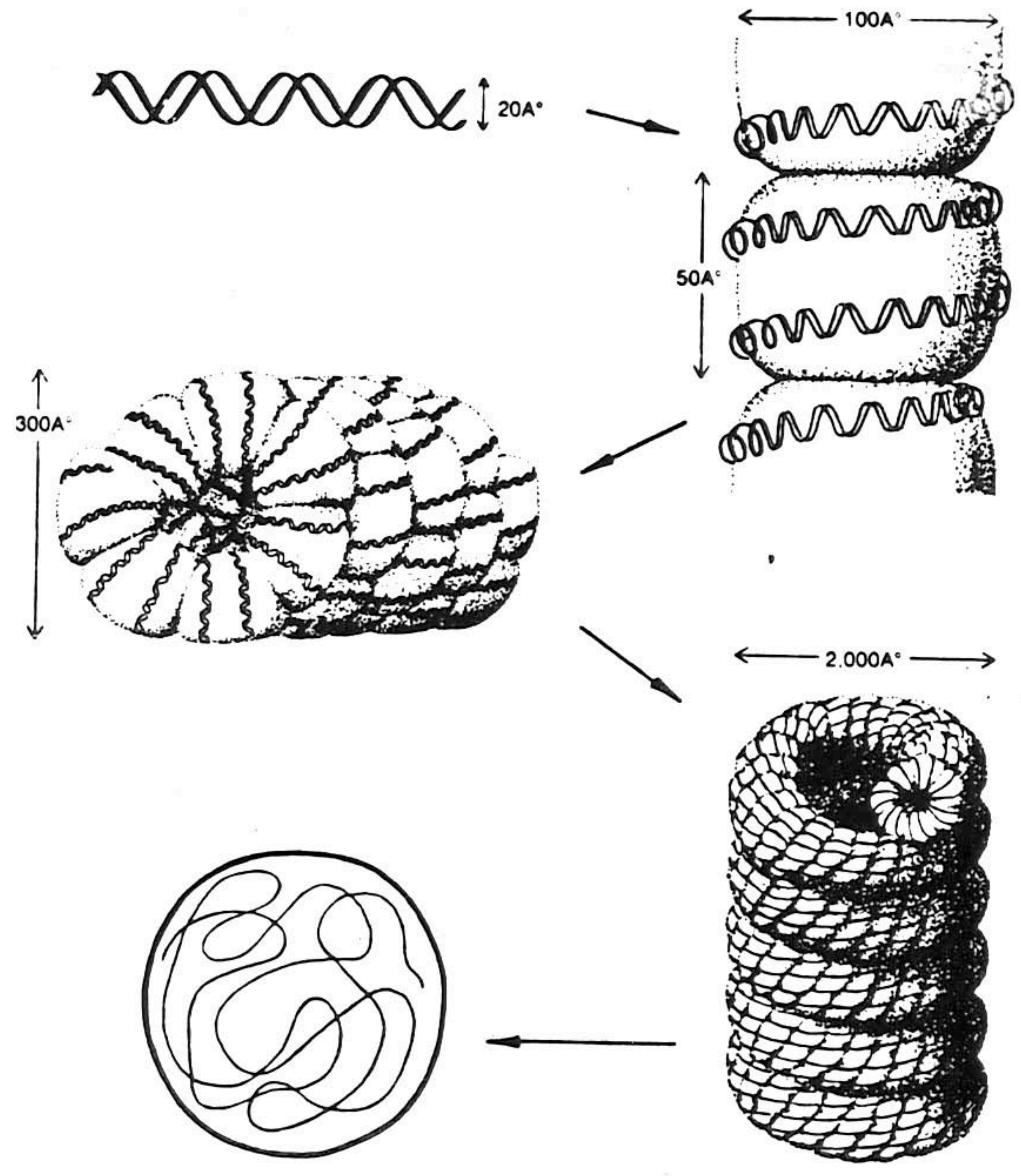


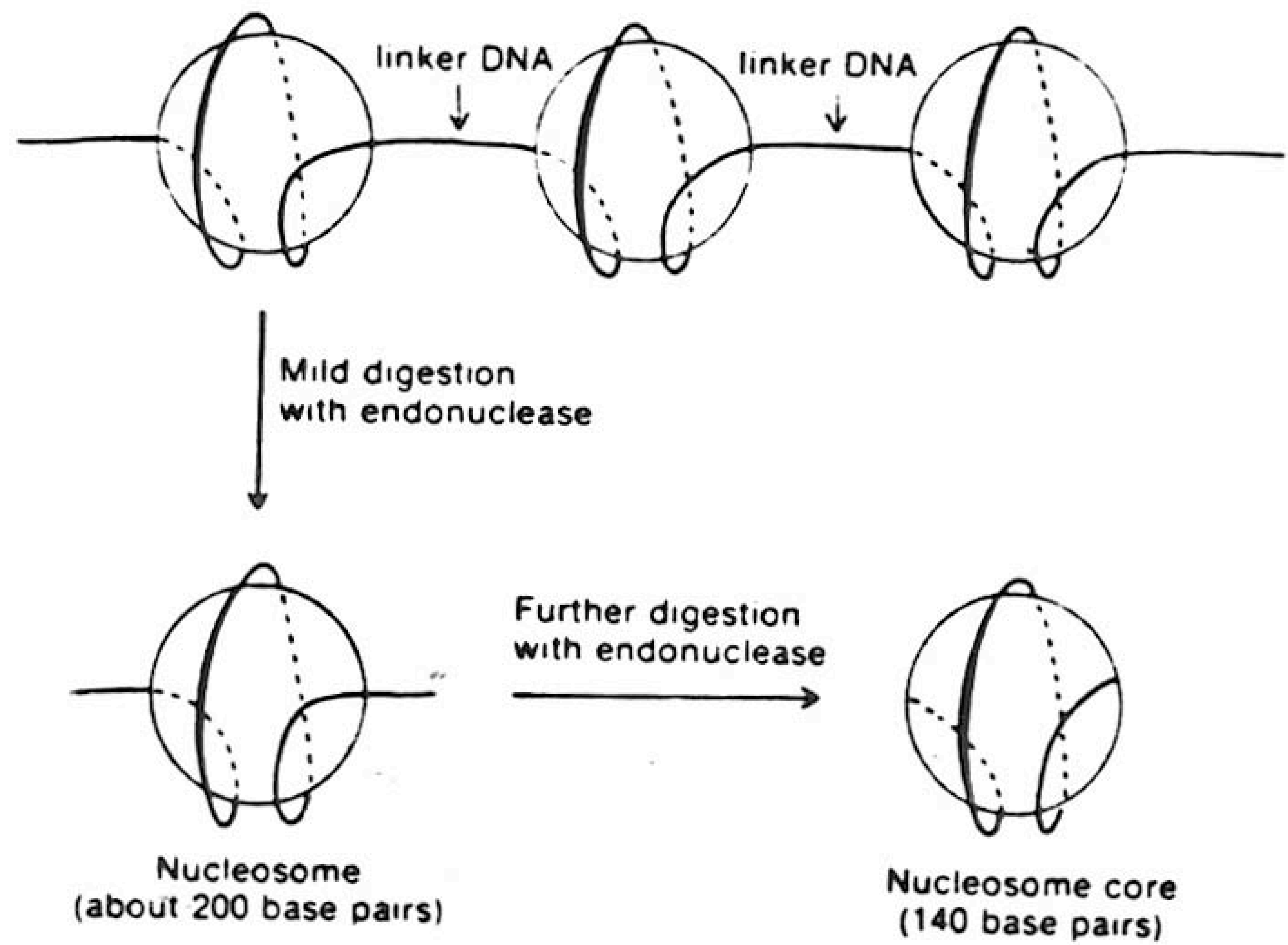
Deoxyribonucleic Acid (DNA)


0.34 nm
(3.4 Å)
3.4 nm
(34 Å)
Major groove
Minor groove
(a)
2 nm
(20 Å)
(b)
H
O
C in phosphate-ester chain
C and N in bases
P

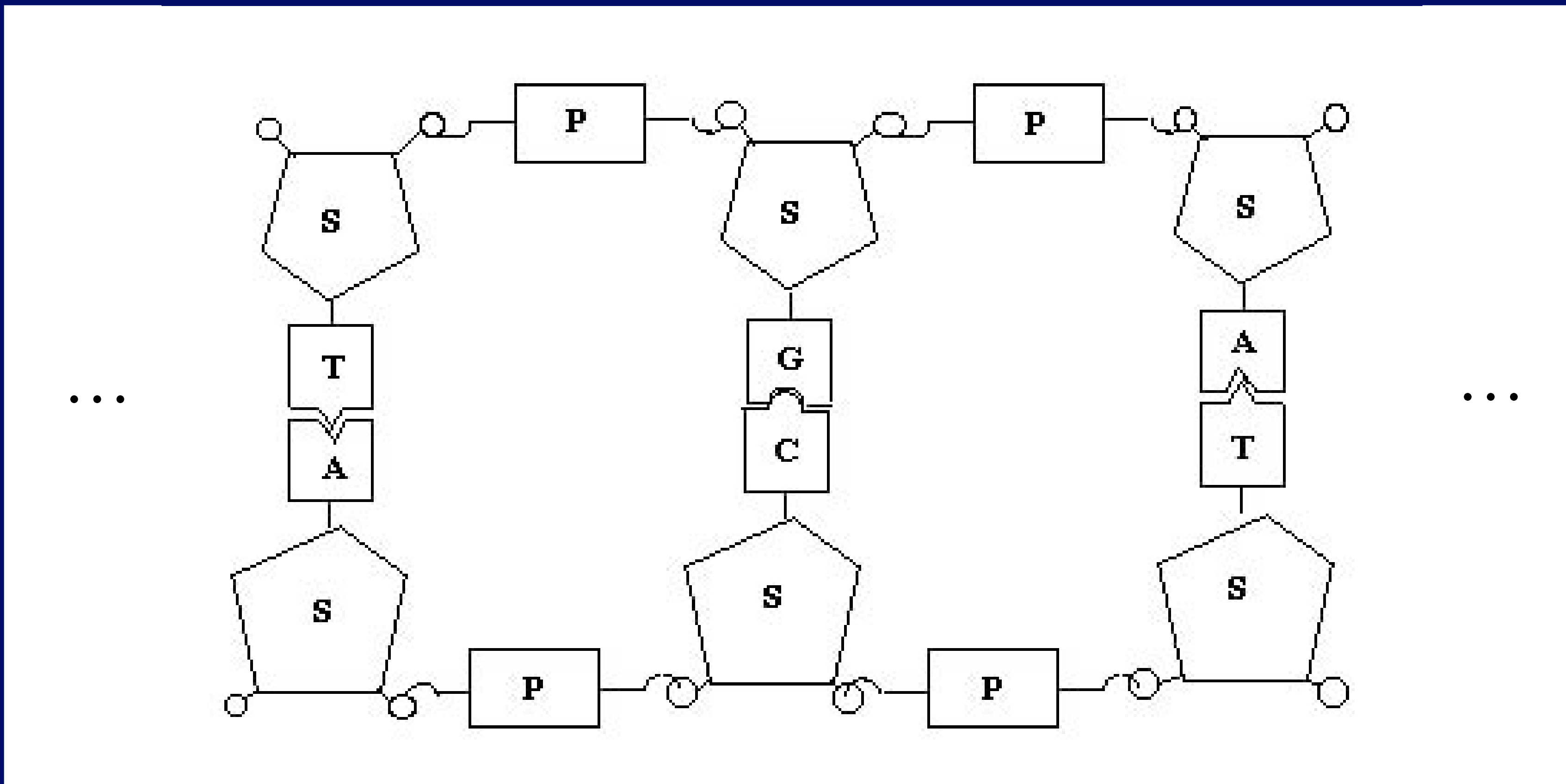

Major groove
Thymine
Adenine
Minor groove
Major groove
Cytosine
Guanine
(c)
Minor groove


Phosphate
Base (Guanine)
Deoxyribose


20A°
100A°
50A°
300A°
2.000A°


linker DNA
linker DNA
Mild digestion
with endonuclease
Further digestion
with endonuclease
Nucleosome
(about 200 base pairs)
Nucleosome core
(140 base pairs)

Segment of DNA



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

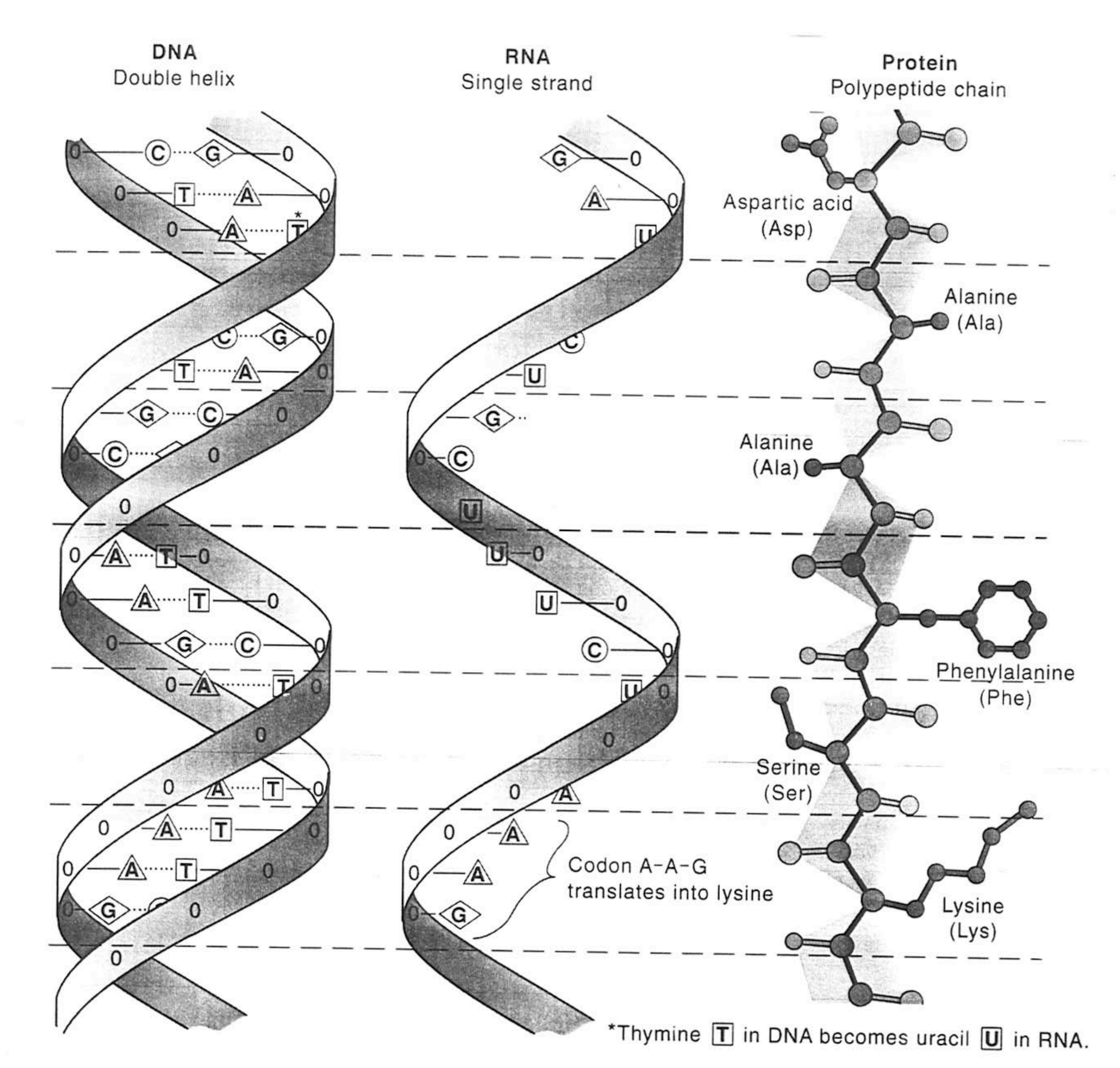
3 base sequence → Amino Acid

Gene

Sequence of codons → Protein

1 gene → 1 protein

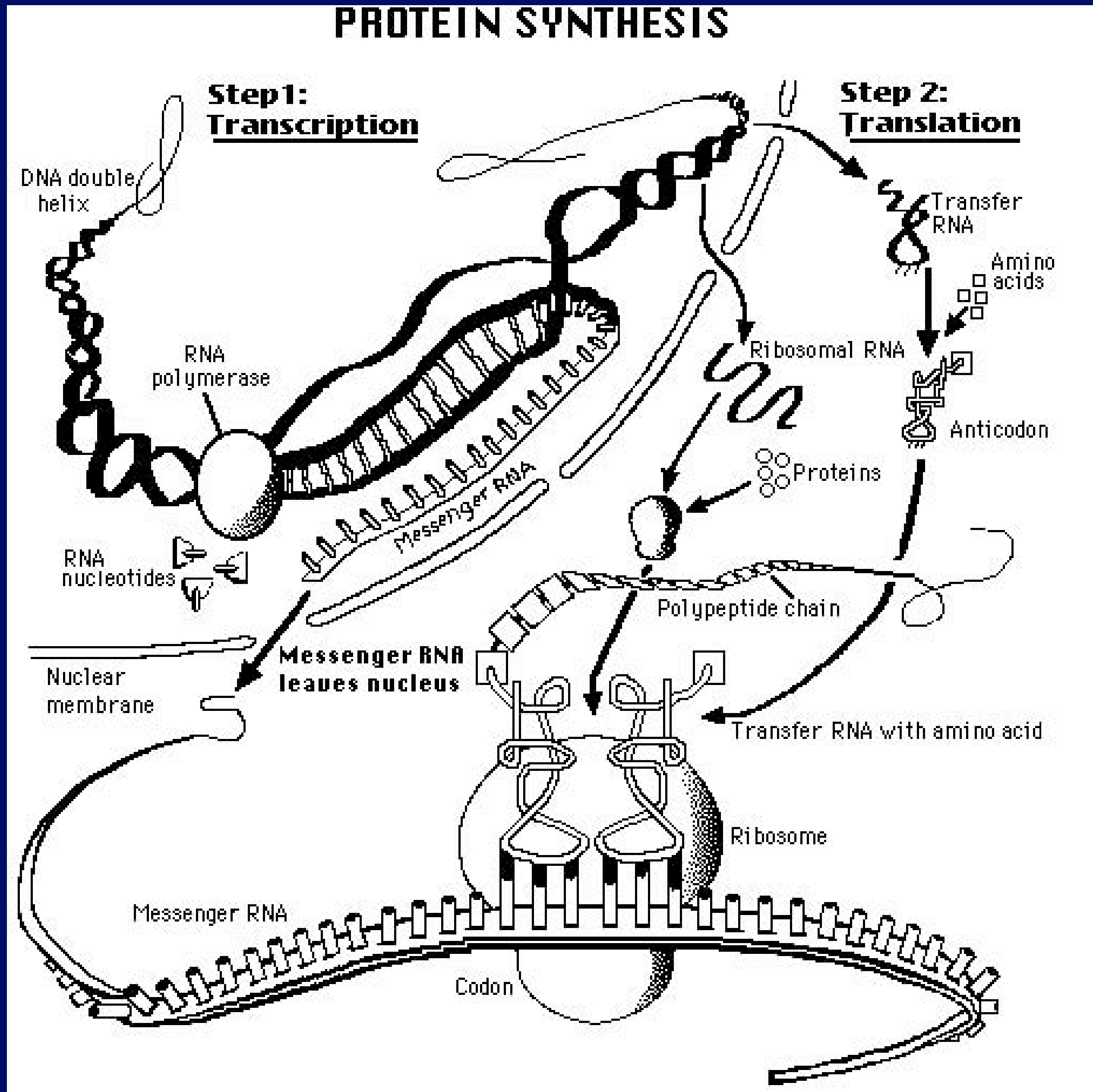
e.g.	tobacco mosaic virus	4 genes
	bacteria	~ 10^3 genes
	human cell	~ 30,000 - 40,000 genes

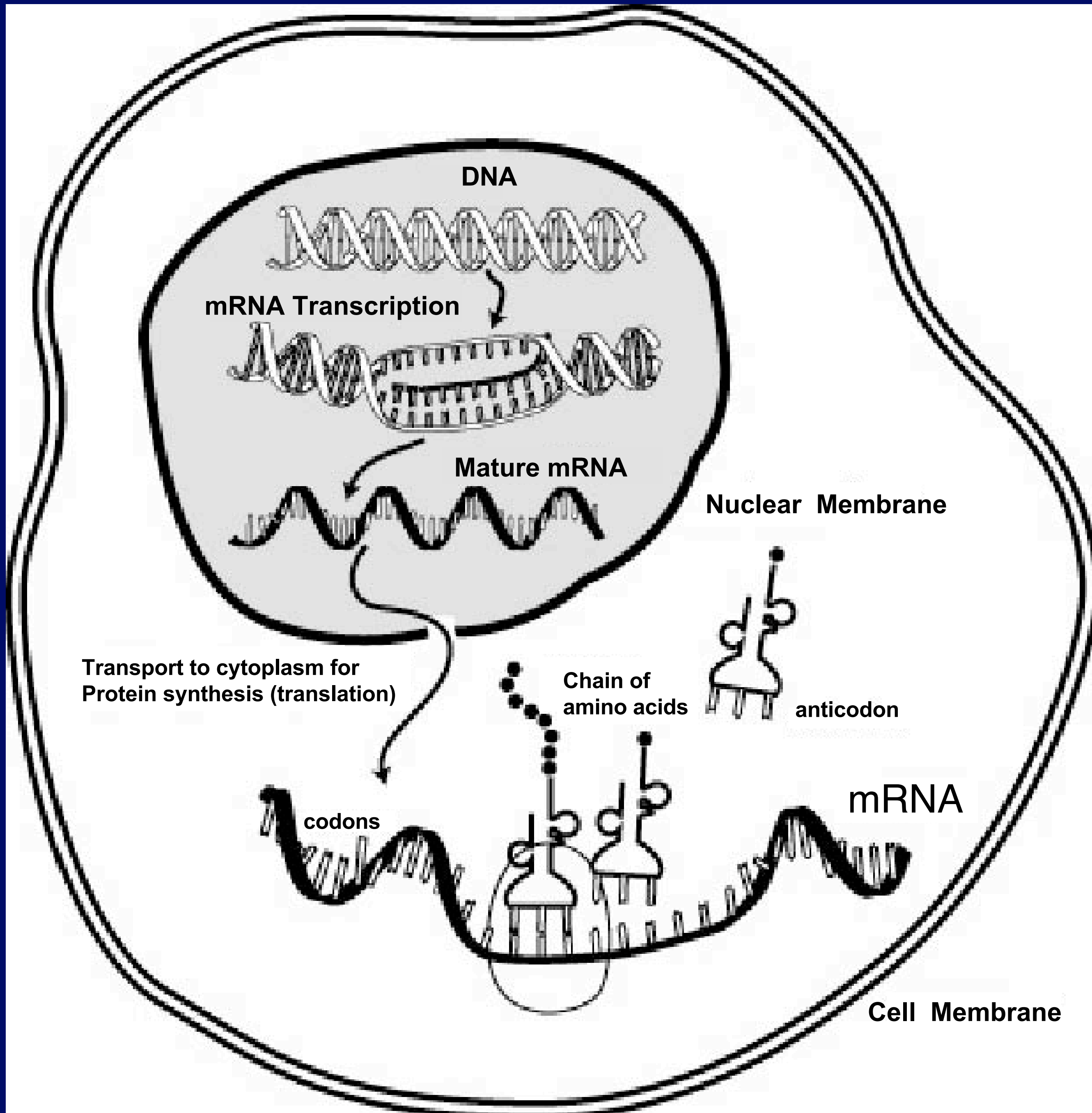

DNA
Double helix
RNA
Single strand
Protein
Polypeptide chain
Aspartic acid
(Asp)
Alanine
(Ala)
Alanine
(Ala)
Phenylalanine
(Phe)
Serine
(Ser)
Lysine
(Lys)
Codon A-A-G
translates into lysine
*Thymine T in DNA becomes uracil U in RNA.

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

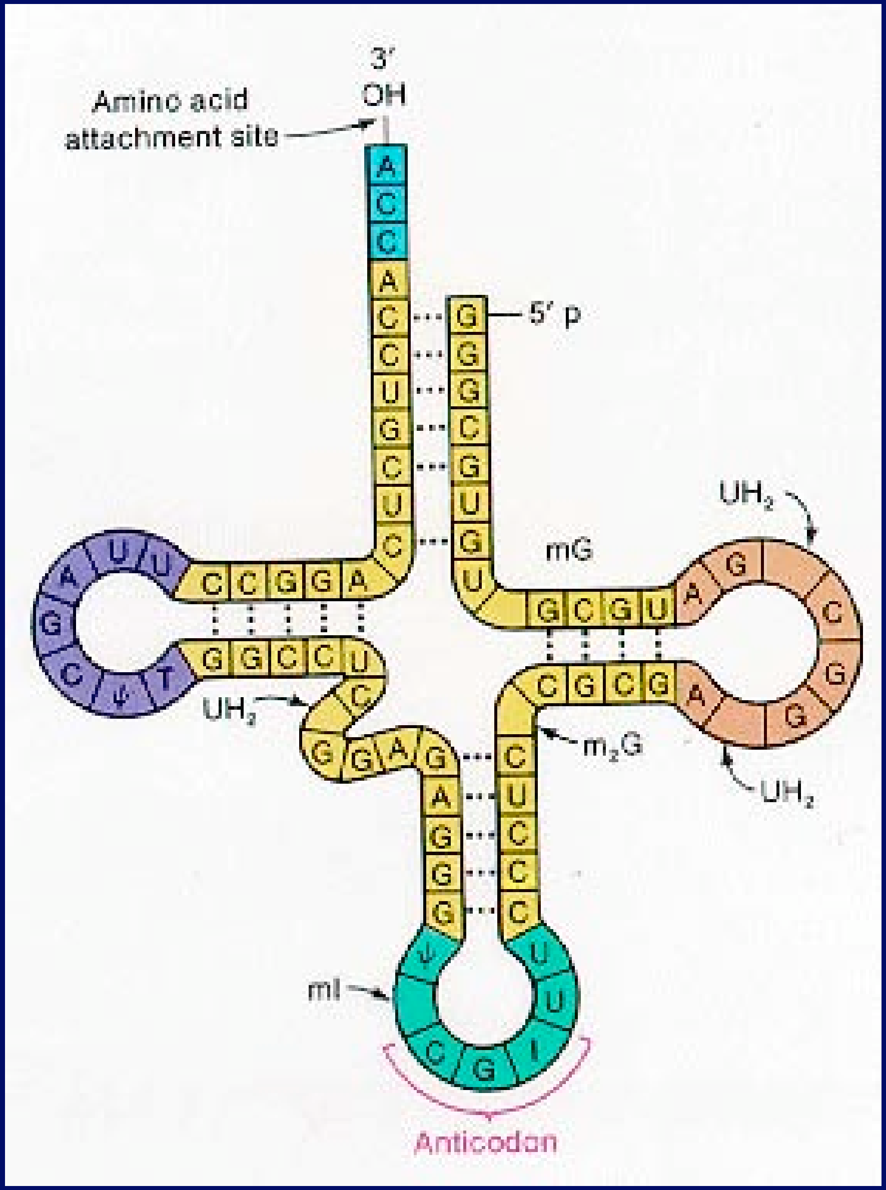
Amino Acids

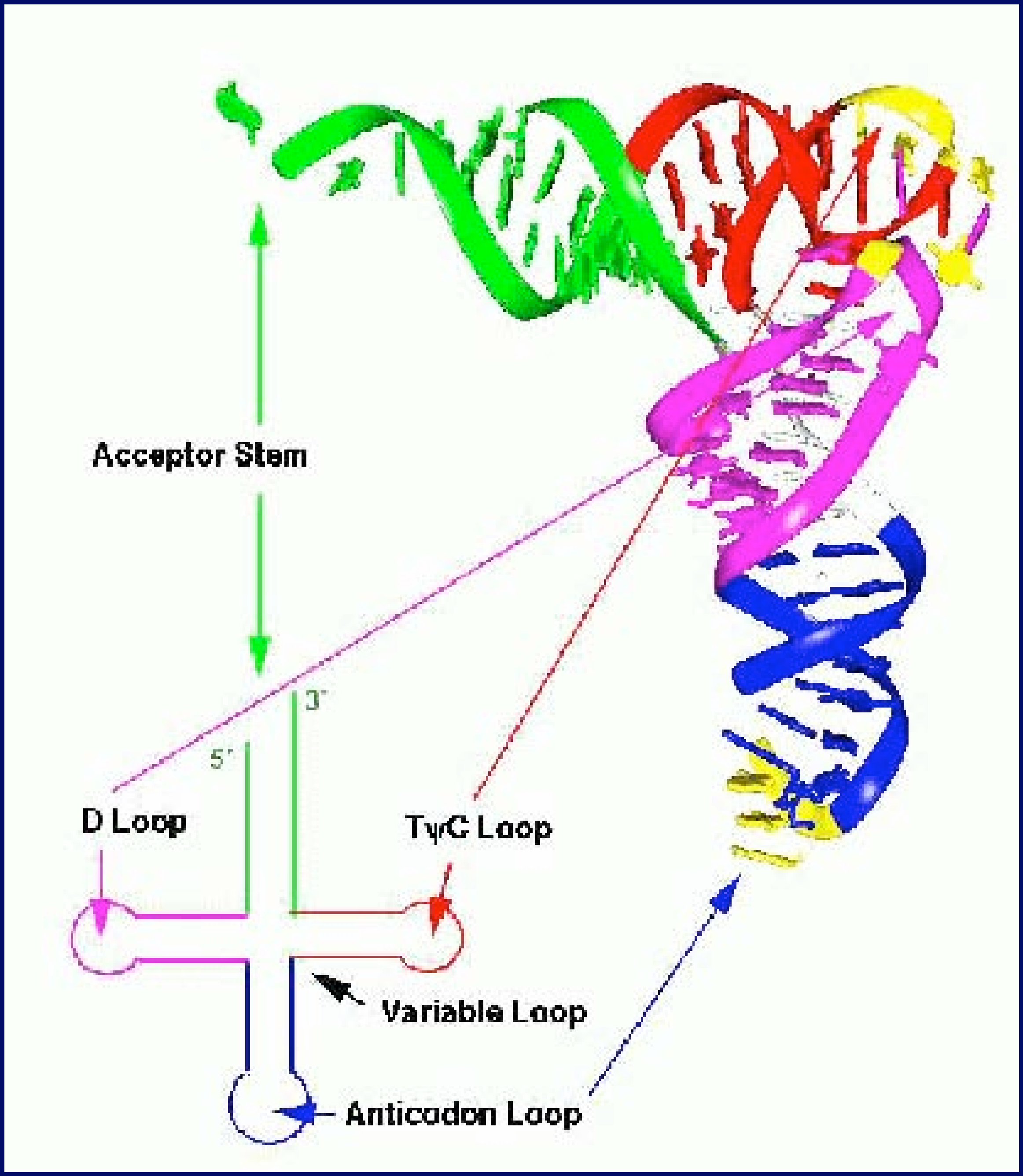

PROTEIN SYNTHESIS
Step1:
Transcription
Step 2:
Translation
DNA double
helix
Transfer
RNA
Amino
acids
RNA
polymerase
Ribosomal RNA
Anticodon
Messenger RNA
Proteins
RNA
nucleotides
Polypeptide chain
Nuclear
membrane
Messenger RNA
leaves nucleus
Transfer RNA with amino acid
Ribosome
Messenger RNA
Codon



DNA
mRNA Transcription
Mature mRNA
Nuclear Membrane
Transport to cytoplasm for
Protein synthesis (translation)
Chain of
amino acids
anticodon
mRNA
codons
Cell Membrane

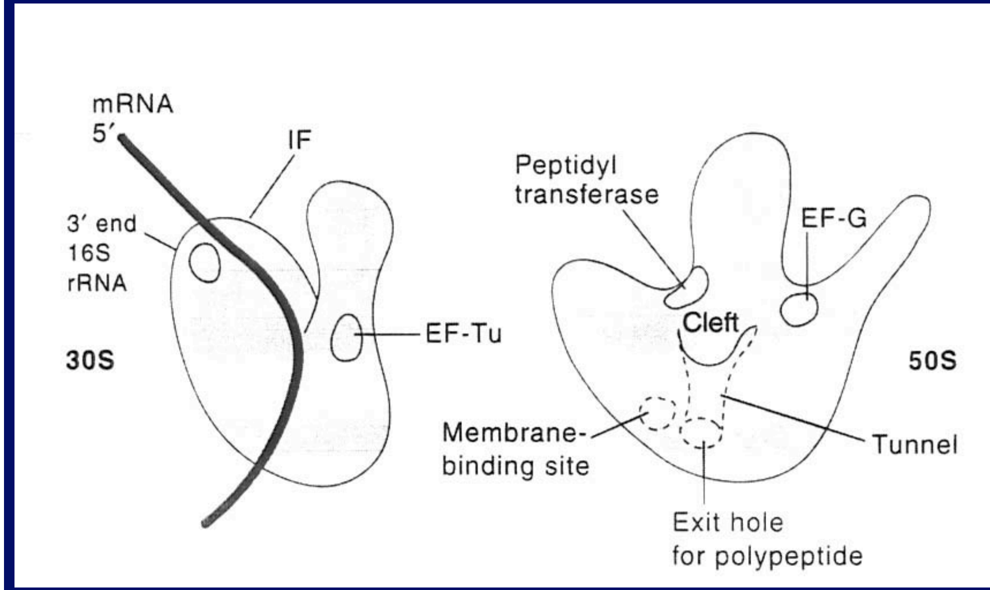
Structure of a tRNA

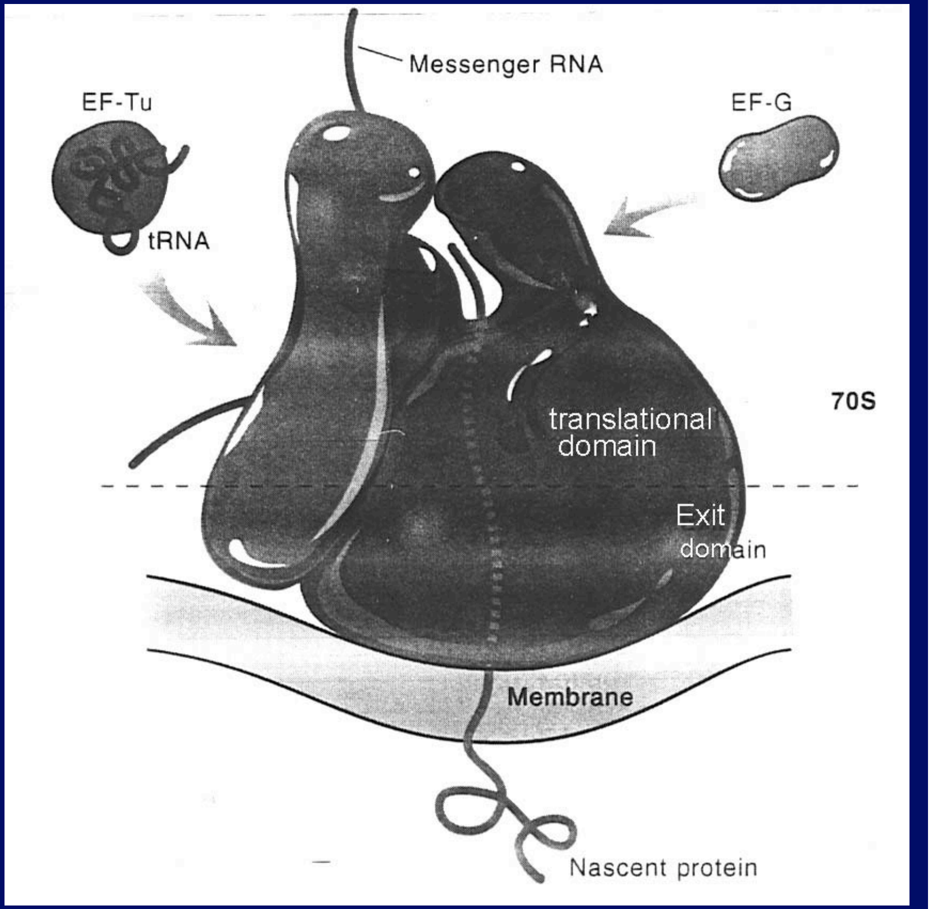


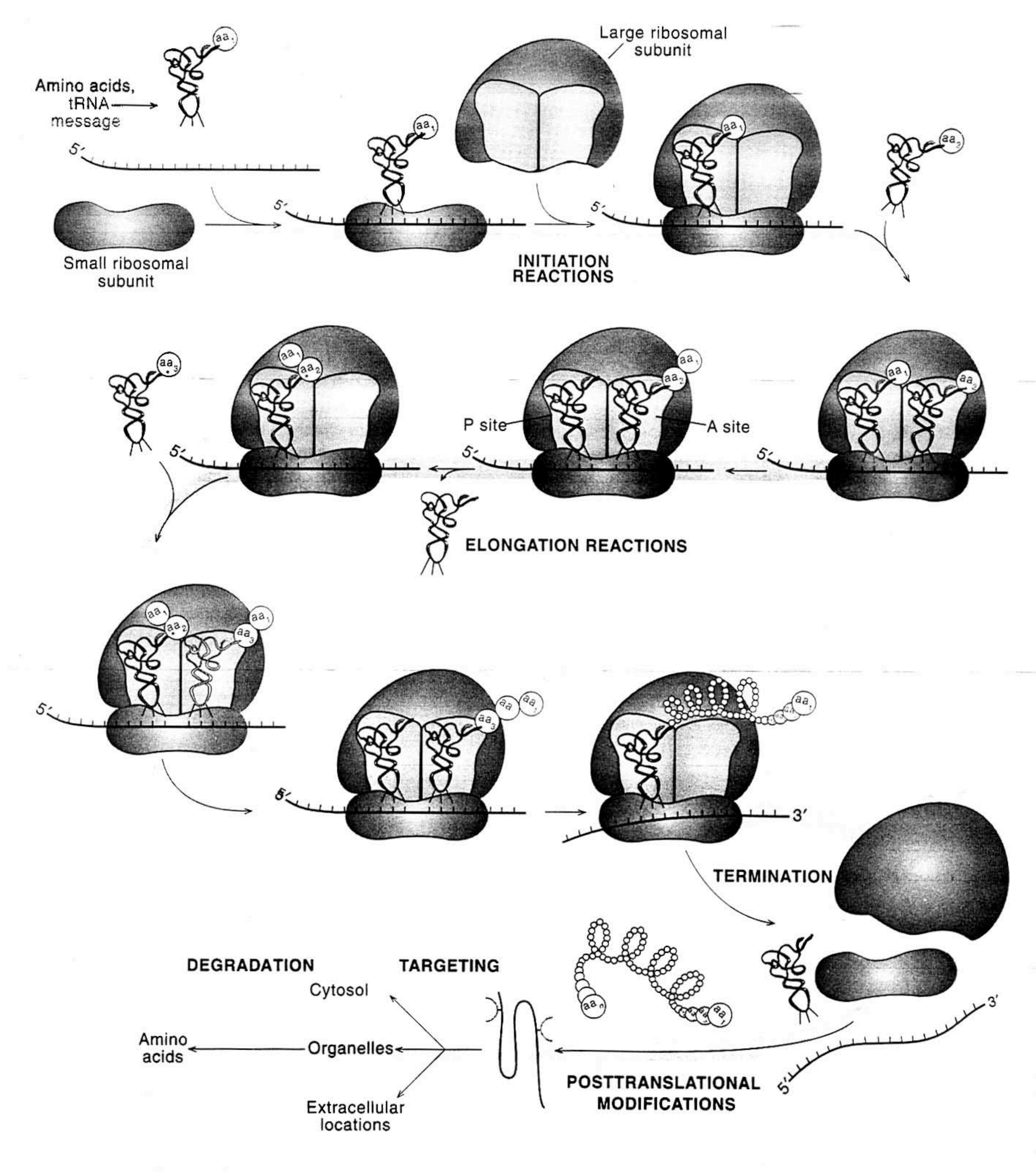


Acceptor Stem
3'
5'
D Loop
TψC Loop
Variable Loop
Anticodon Loop

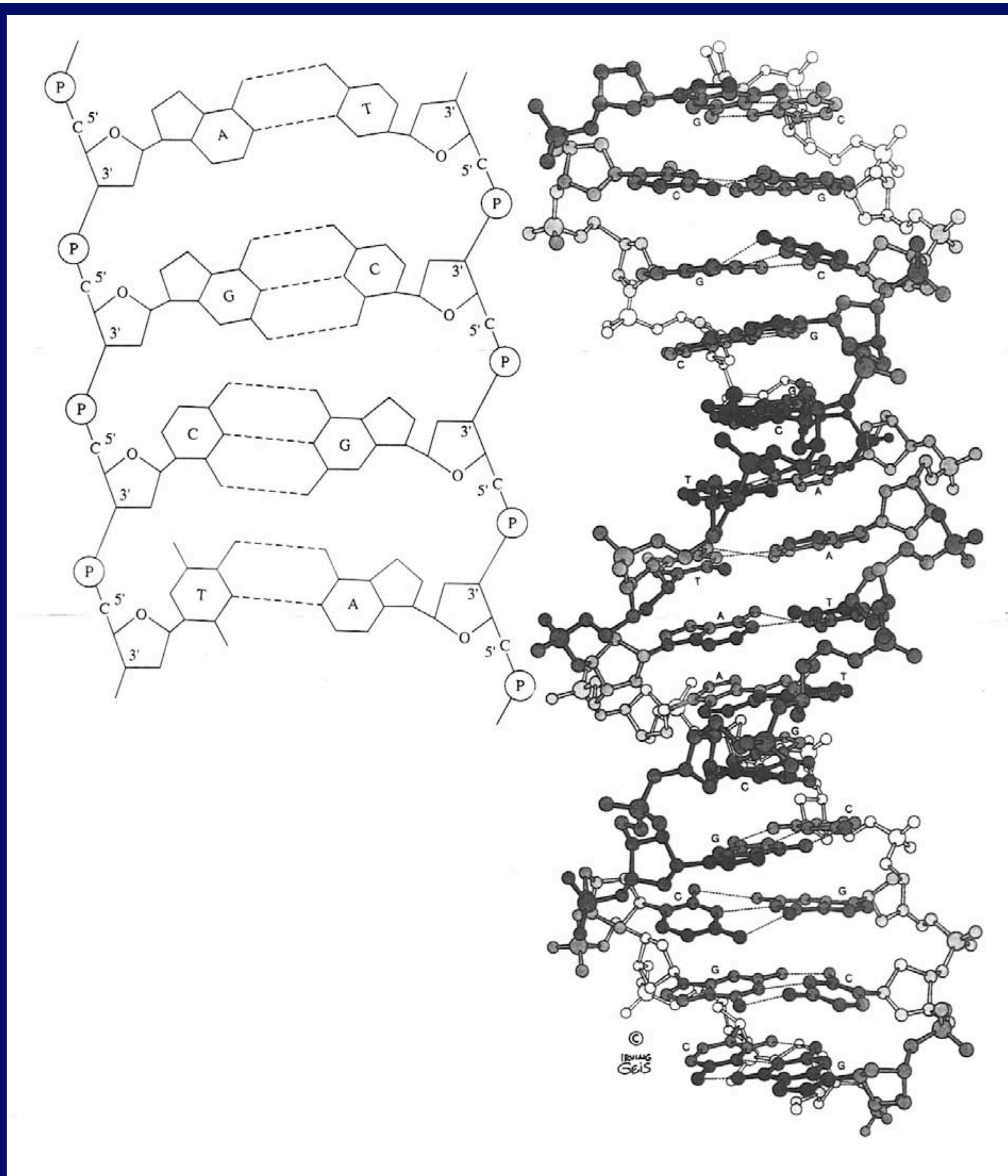
Translation







Amino acids,
tRNA
message
Large ribosomal
subunit
Small ribosomal
subunit
INITIATION
REACTIONS
P site
A site
ELONGATION REACTIONS
TERMINATION
DEGRADATION
TARGETING
Cytosol
Amino
acids
Organelles
Extracellular
locations
POSTTRANSLATIONAL
MODIFICATIONS



A
T
G
C
C
G
T
A
P
5'
3'
O
© IRVING GEIS

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 → no change in 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