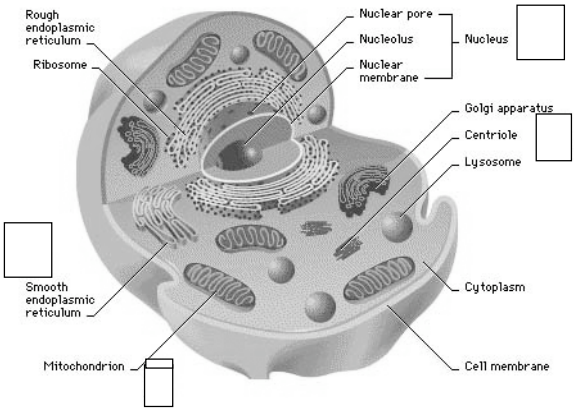
Life

What is necessary for life?

Most life familiar to us: Eukaryotes

FREE LIVING
Or Parasites



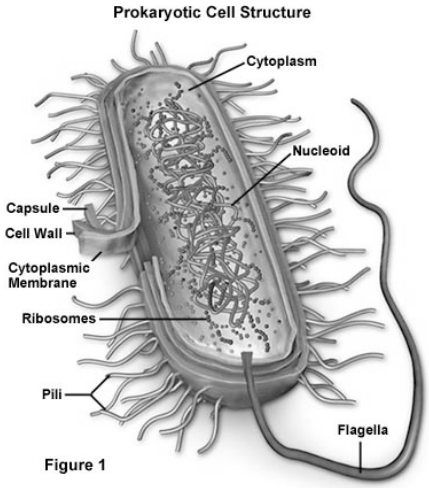
First appeared ~ 1.5 - 2 □ 10^9 years ago
Requirements: DNA, proteins, lipids, carbohydrates, complex structure, ~ 10^4 - 10^5 genes

Prokaryotes (Bacteria and Archaea)

First appeared

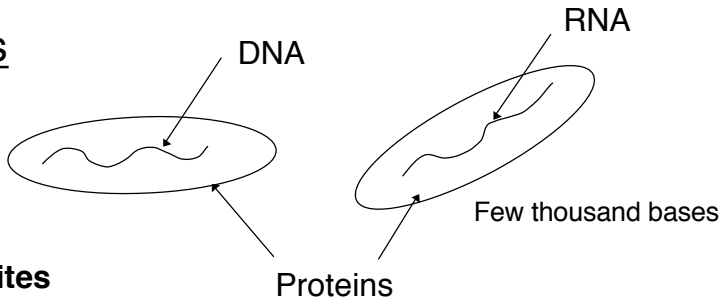
~ 3 - 4 $\square 10^9$ years ago

FREE LIVING
Or Parasites



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

Viruses



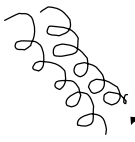
Parasites

Viroids,
Plasmids

RNA

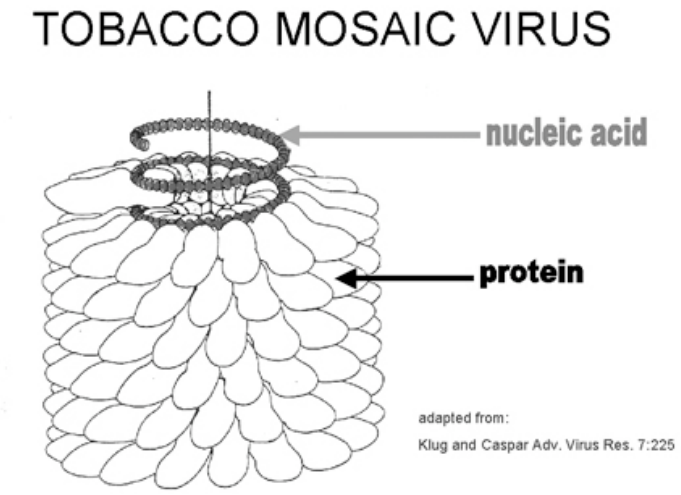
Few hundred bases

Prions?



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)

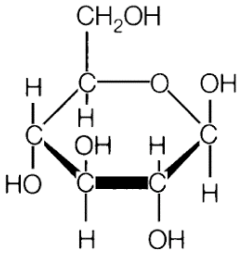
H, C, N, O (P) — Nucleic acids made of nucleotides

base sugar phosphate

H, C, O — Carbohydrates made of sugars
Energy (food) + structure
[starch] [cellulose]

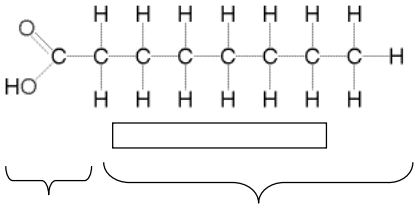
H, C, (O) — Lipids (hydrocarbons + carboxyl)
Membranes + Energy
[water-resistant]

Sugar

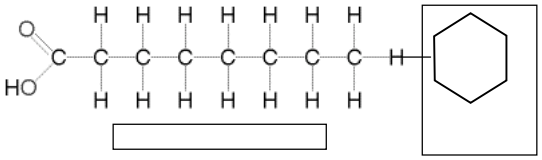


Glucose

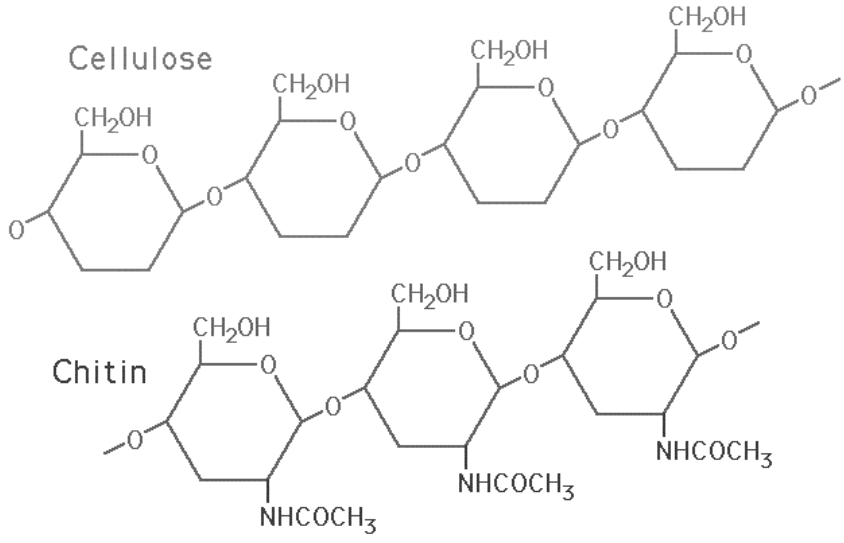
Lipids



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



Polysaccharides

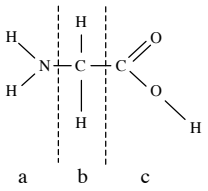


Proteins

Monomers are amino acids

20 kinds

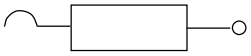
Glycine



Amino group

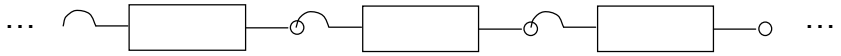
carboxyl group

Schematic



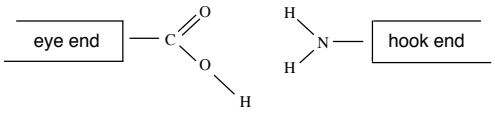
Amino group (hook)

carboxyl group (eye)



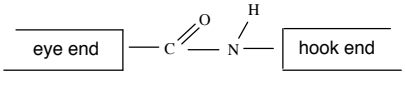
Section of Protein

Peptide Bond

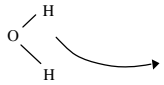


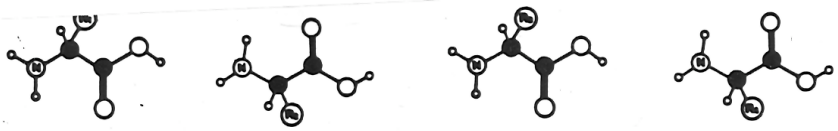
Before

Chemical Level

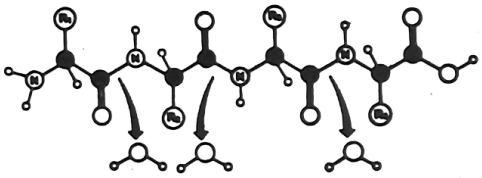


After

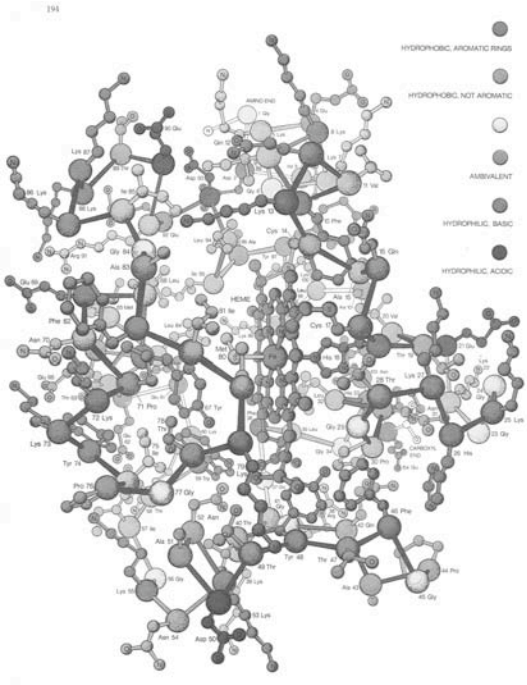


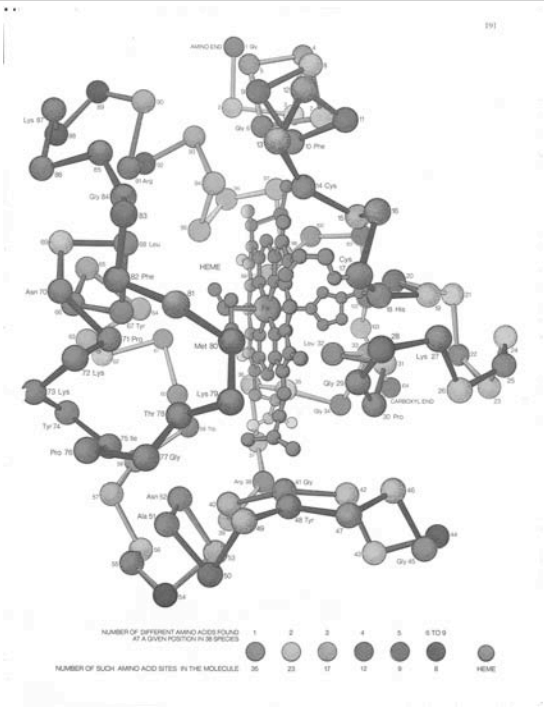


amino acids



protein

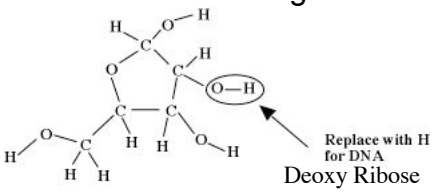




Nucleic Acids (DNA, RNA)

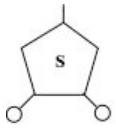
Made of sugars, phosphates, bases

Sugar



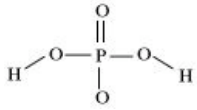
Deoxy Ribose

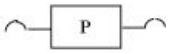
Schematic



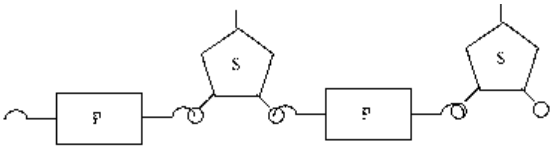
Ribose Sugar
5C, 5O, 10 H

phosphate





sugars & phosphates linked
phosphodiester bonds

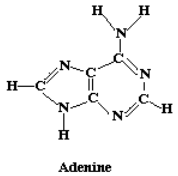


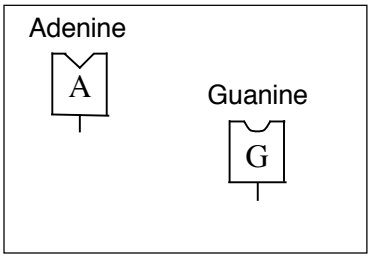
Segment of side of ladder structure

Nucleic Acids (cont.)

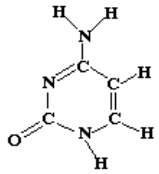
Bases: Carry Genetic Code

Purines

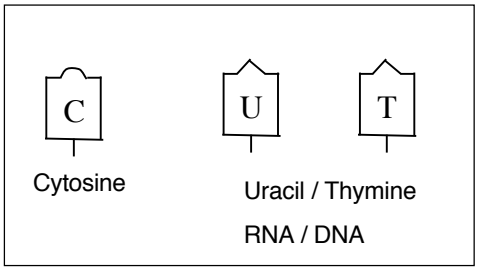




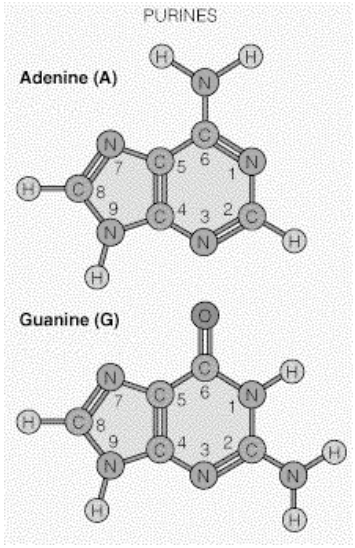
Pyrimidines

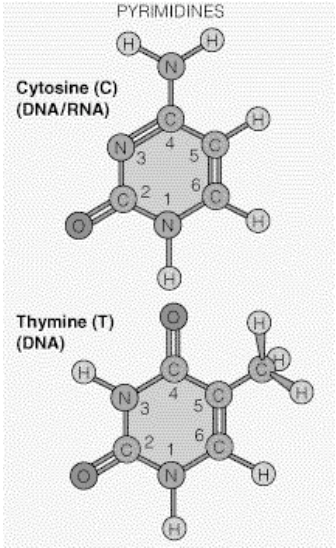


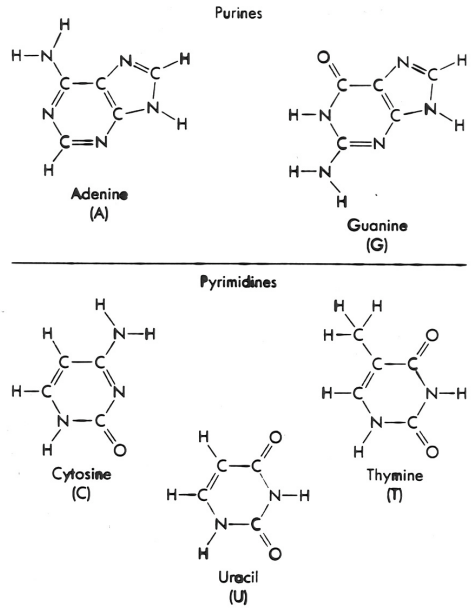
Cytosine



Bases in Nucleic acids: Purines and Pyrimidines





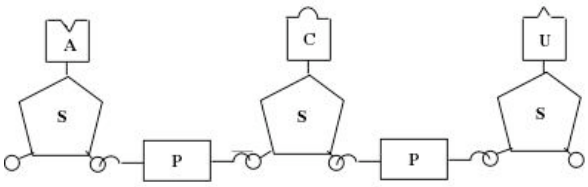


Purines

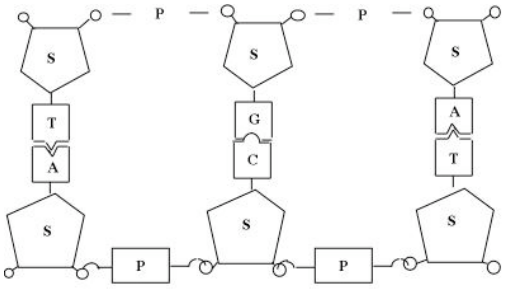
Pyrimidines

Nucleic Acids (cont.)

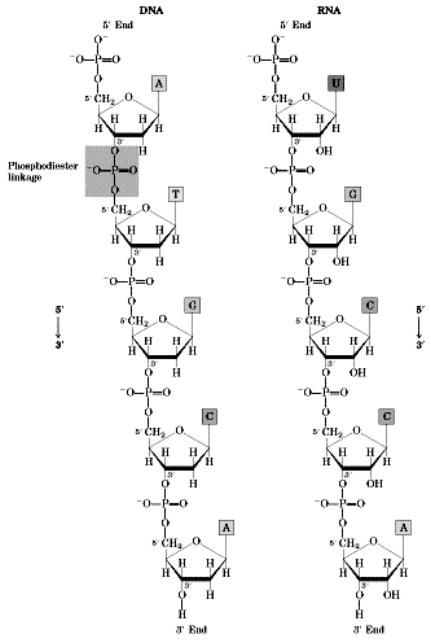
Segment of RNA

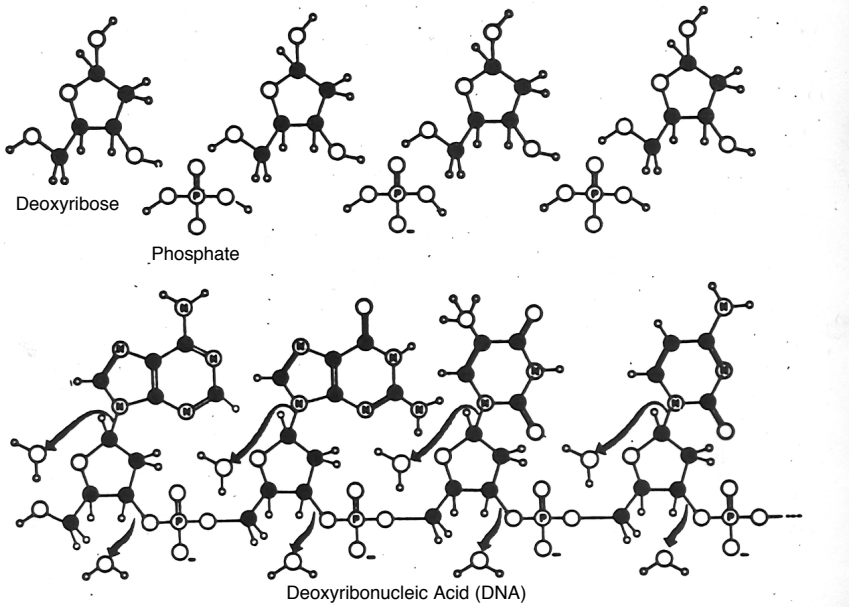


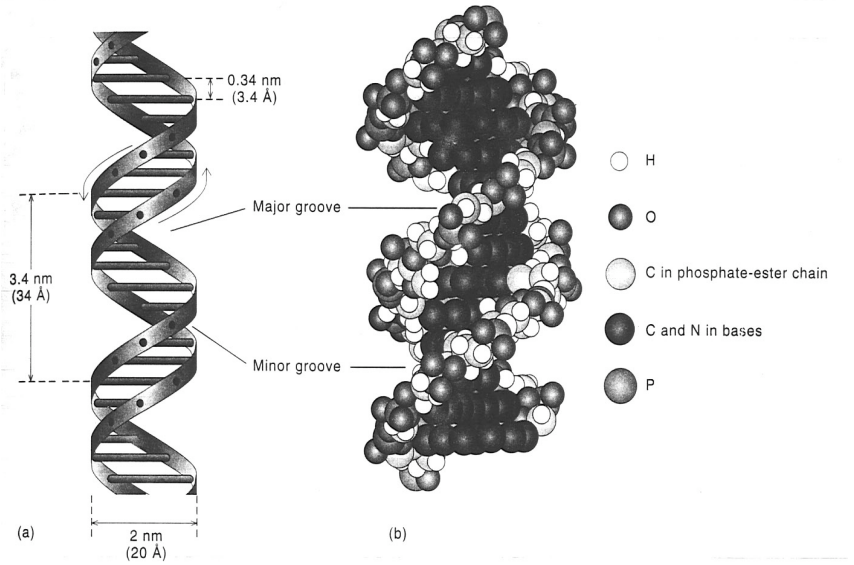
Segment of DNA

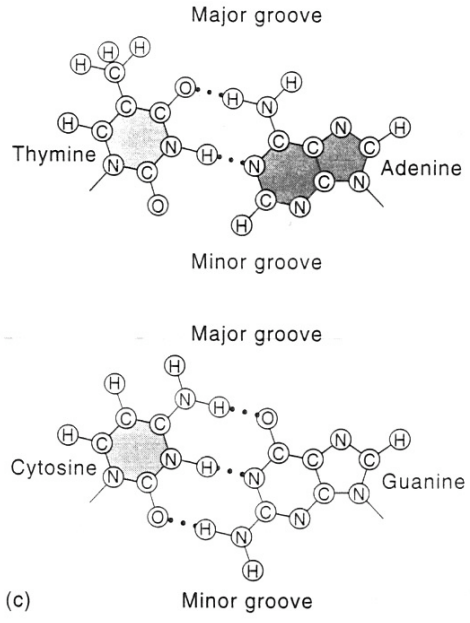


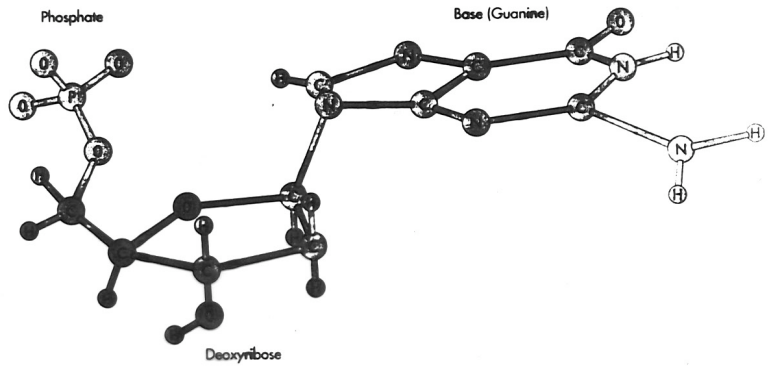
Note that T replaces U in DNA

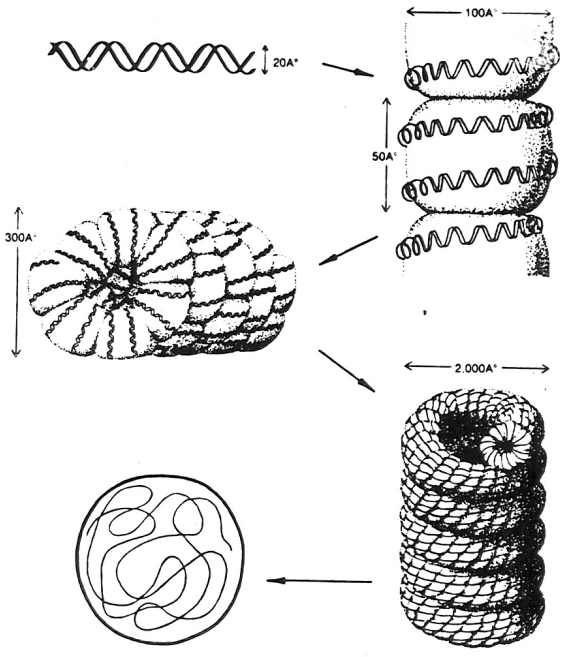

DNA
RNA
5′ End
5′ End
Phosphodiester linkage
A
T
G
C
A
U
G
C
A
5′
3′
3′ End
3′ End

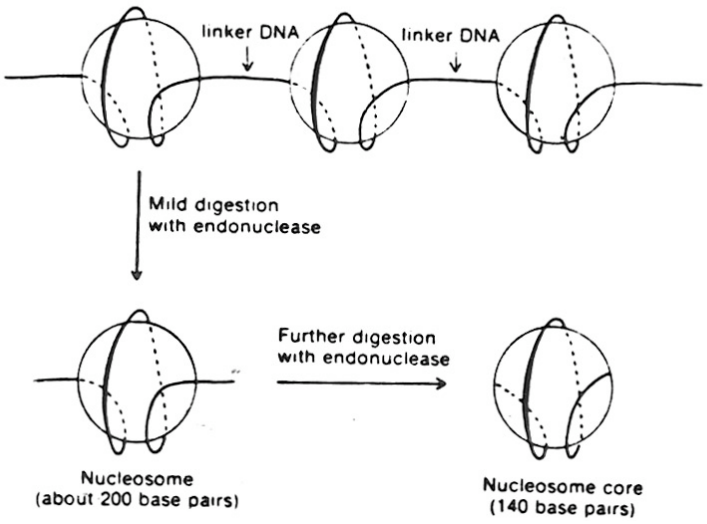

Deoxyribose
Phosphate
Deoxyribonucleic Acid (DNA)


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

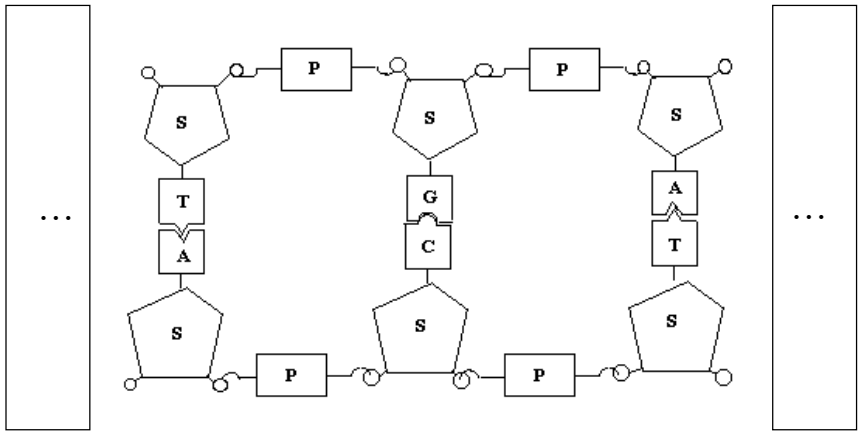

Major groove
Thymine
Adenine
Minor groove
Major groove
Cytosine
Guanine
(c)
Minor groove


Phosphate
Base (Guanine)
Deoxyribose


20A°
100A°
50A°
300A°
2,000A°



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

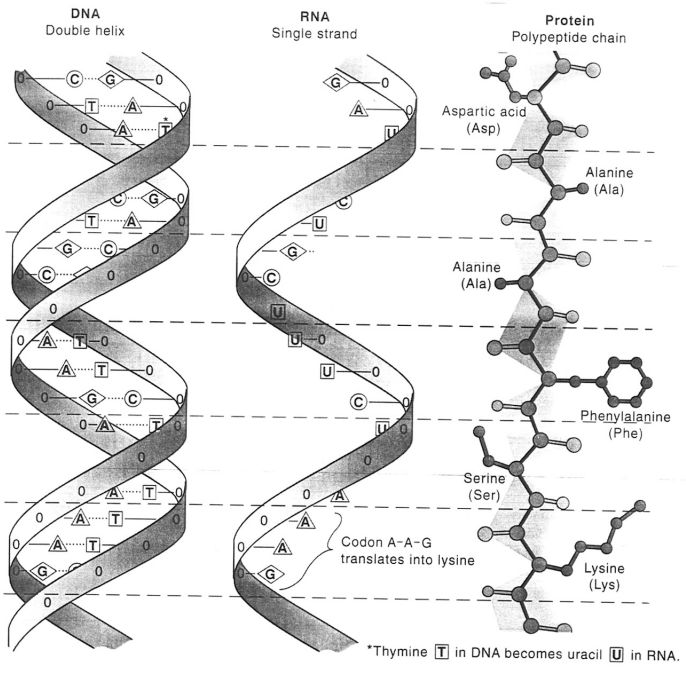
3 base sequence ⟶ Amino Acid

Gene

Sequence of codons ⟶ Protein

1 gene ⟶ 1 protein

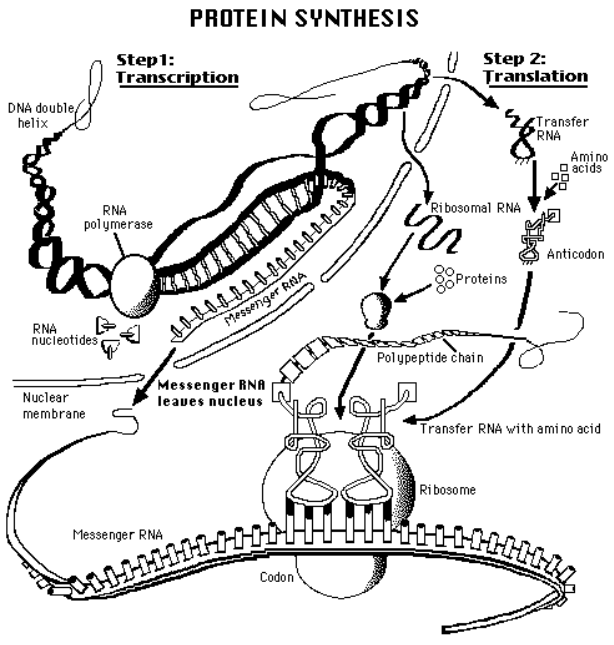
e.g.	tobacco mosaic virus	4 genes
	bacteria	~ 10^3 genes
	human cell	~ 30,000 - 40,000 genes

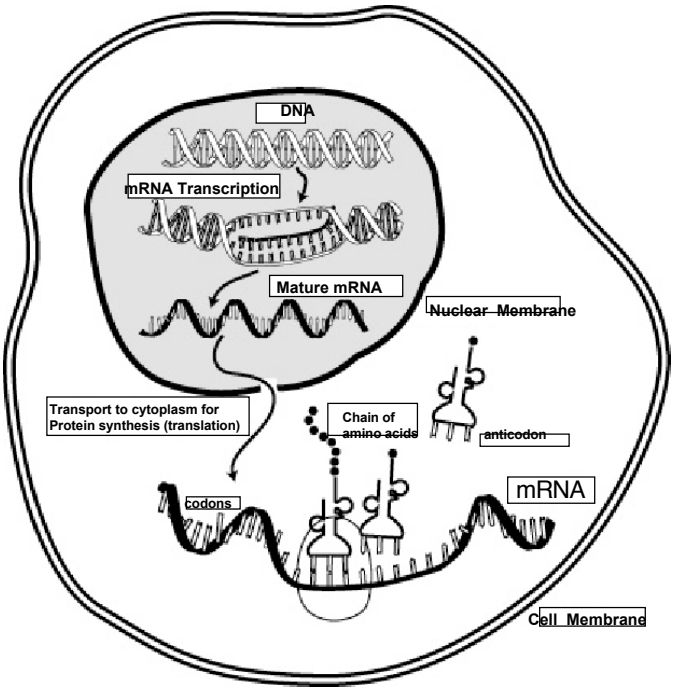


For mRNA Genetic Code

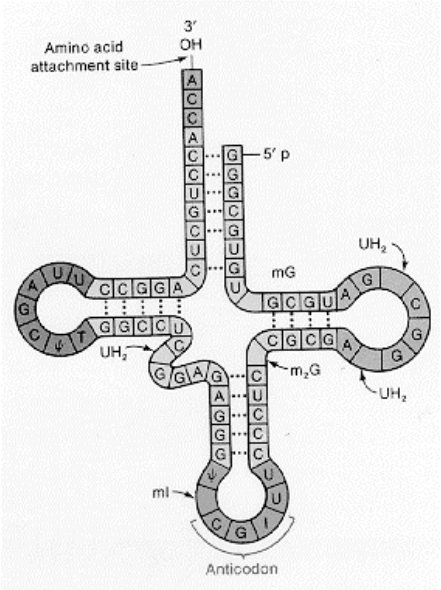
First RNA Base	U	C	A	G	Third RNA BASE
U	Phenylalanine	Serine	Tyrosine	Cysteine	U
	Phenylalanine	Serine	Tyrosine	Cysteine	C
	Leucine	Serine	Stop	Stop	A
	Leucine	Serine	Stop	Tryptophan	G
C	Leucine	Proline	Histidine	Arginine	U
	Leucine	Proline	Histidine	Arginine	C
	Leucine	Proline	Glutamine	Arginine	A
	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

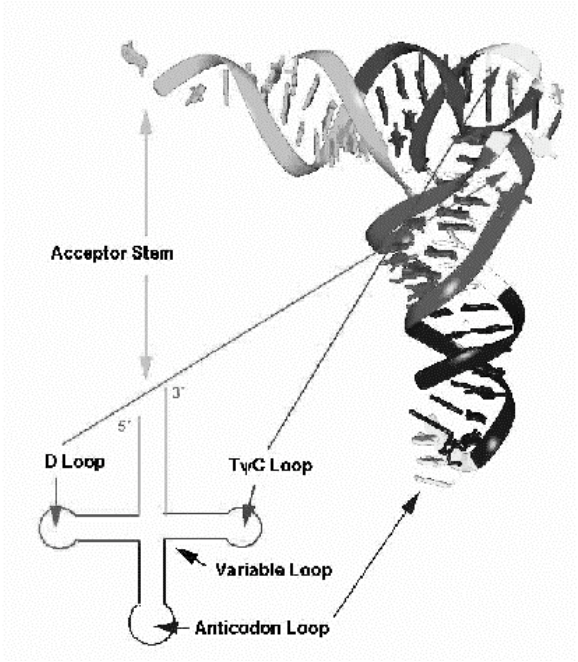
Amino Acids



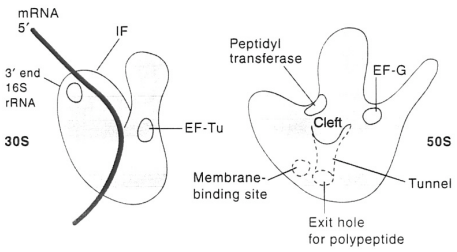


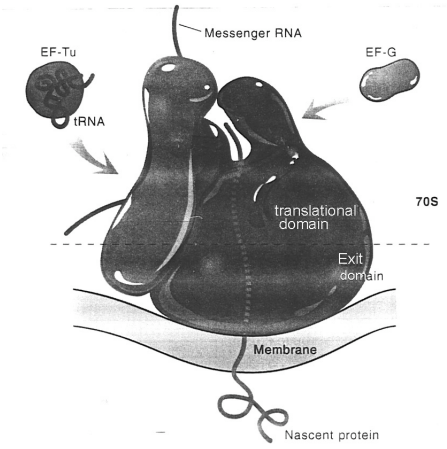
Structure of a tRNA

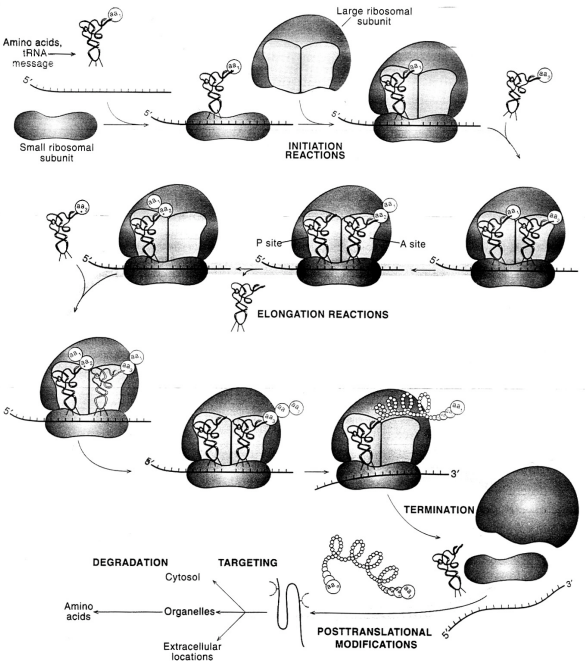


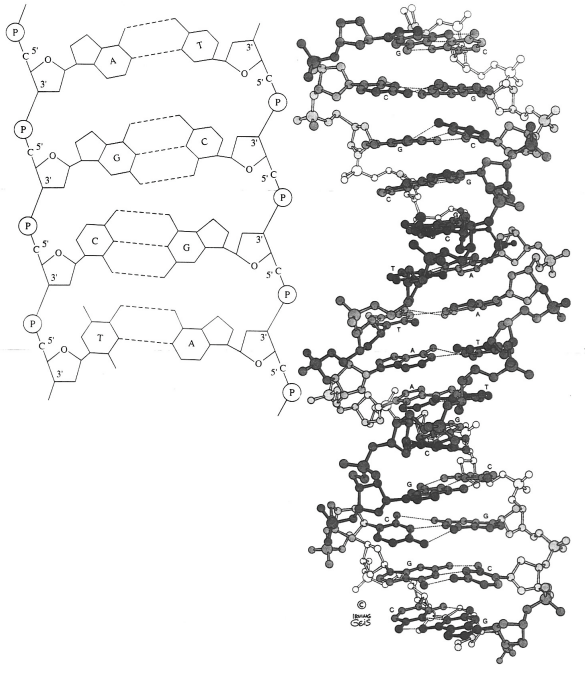


Translation






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



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