

Carbohydrates

- A. Definition
- B. Roles
- C. Monosaccharides-Chemistry
 - 1. Chirality
 - a. One or more asymmetric carbons
 - b. Linear and ring forms
 - 2. Derivatives: the chemistry of carbohydrates
 - a. Oxidation
 - i. C1
 - ii. C6
 - b. Reduction
 - i. C1/C2
 - ii. Other carbons
 - c. Ester formation
 - d. Amino sugars
 - 3. Polymerization
 - a. The Glycosidic Bond
 - b. Non-covalent bonds in macro-molecular structure
 - c. Disaccharides
- D. Oligosaccharides
 - 1. Glycoproteins & glycolipids
 - 2. O-linked
 - 3. N-linked
 - 4. Sequence determination-ABO
- E. Polysaccharides
 - 1. Polymers of glucose
 - 2. Polymers of disaccharides

Lecture 24 (11/12/25)

TODAY

- Reading: Ch8; 294-296, 263-269; Ch24; 885-890
- Homework: #23

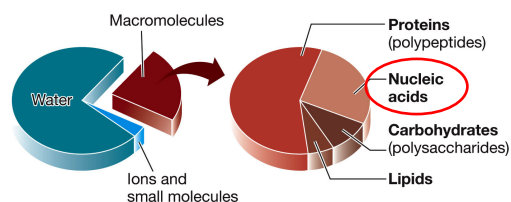
NEXT

- Reading: Ch8; 269-274; Ch24; 881-894
- Homework: #24

Nucleic Acids

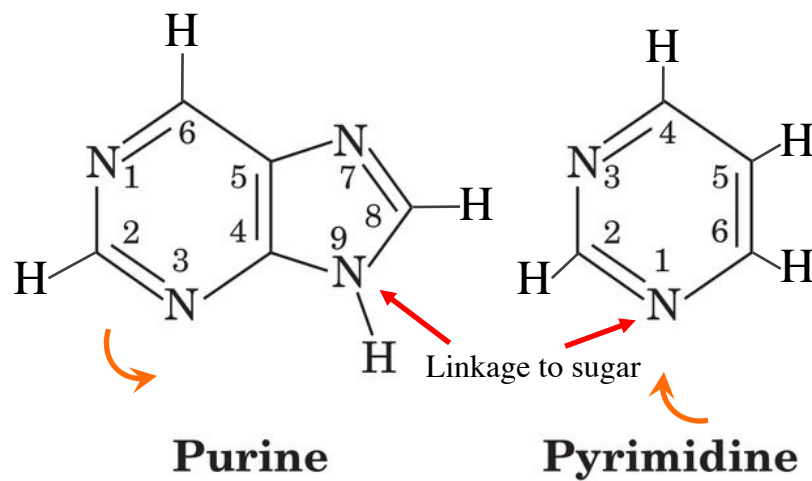
- A. Nucleotides
 - 1. Parts-structure
 - 2. Nomenclature
 - 3. Numbering
 - 4. Properties
- B. Nucleic Acids
 - 1. Polymer: phospho-diester bond
 - 2. H-bonds
 - 3. Roles
 - a. Nucleotides
 - b. Nucleic acids
- C. The 4 S's
 - 1. Size
 - a. genomes
 - b. RNAs
 - 2. Solubility
 - 3. Shape
 - 4. Stability

Nucleotides & Nucleic Acids

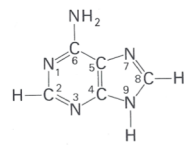


Definition of Nucleotides

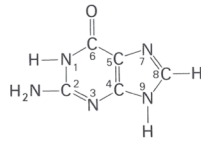
The Nitrogenous Bases of Nucleotides are Derivatives of Purine & Pyrimidine



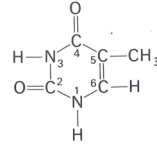
Chemical Structures of Nucleotide Bases



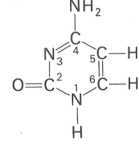
Adenine
(A)



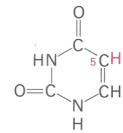
Guanine
(G)



Thymine
(T)

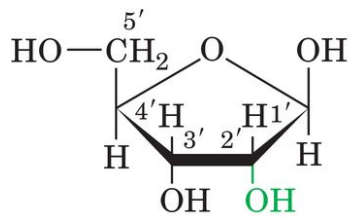


Cytosine
(C)

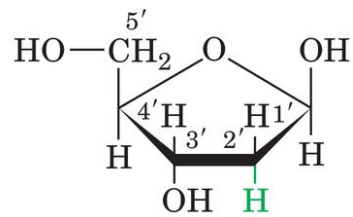


Uracil (U)

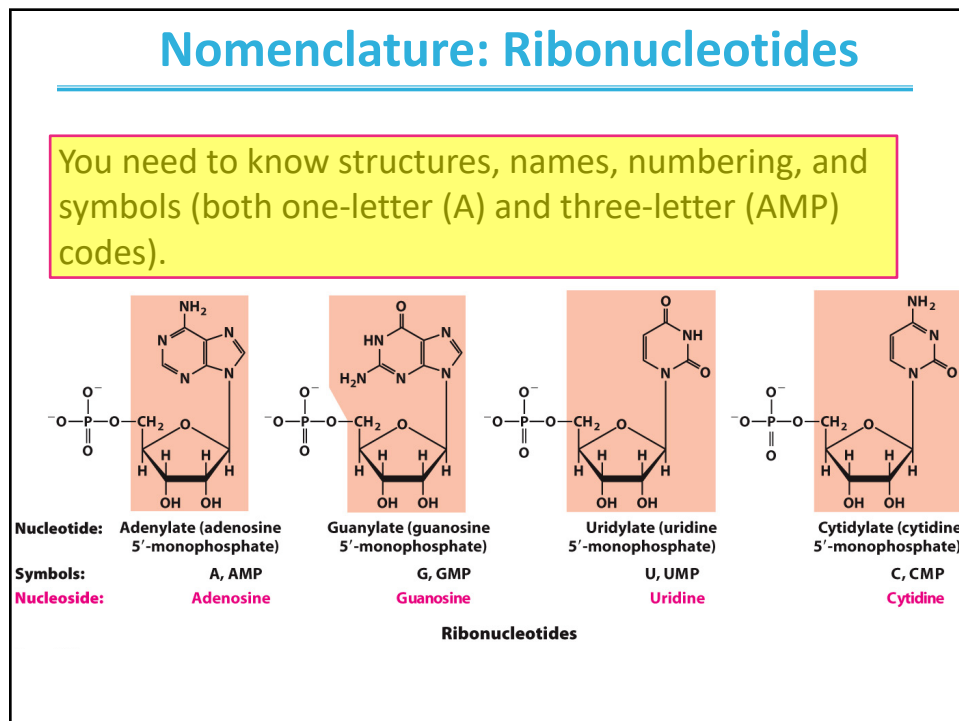
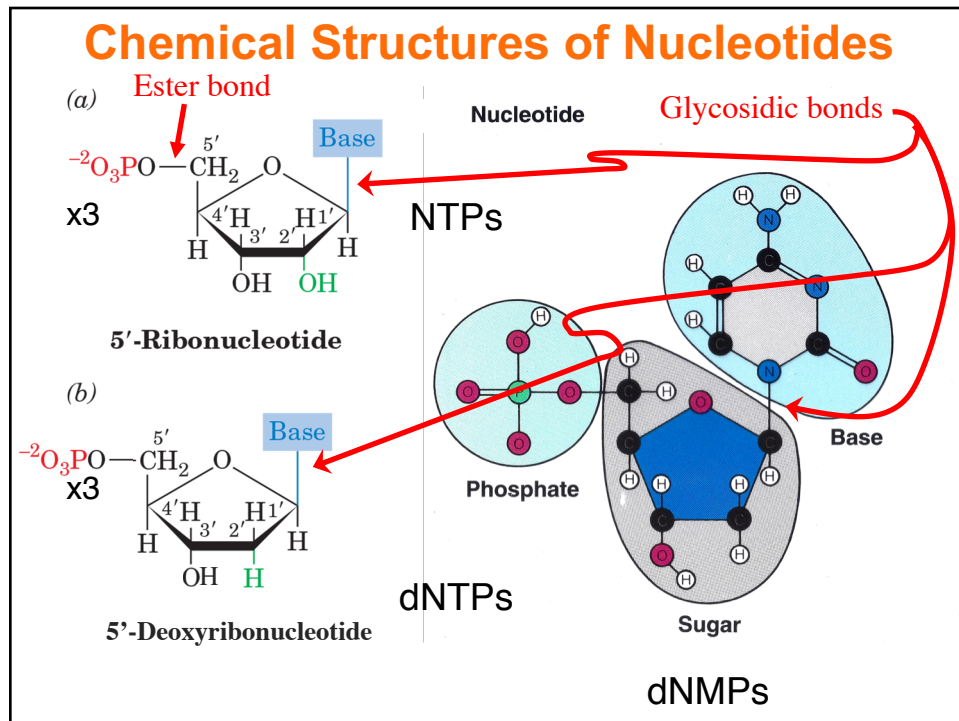
Sugars of Nucleotides are Either Ribose & Deoxyribose



Ribose

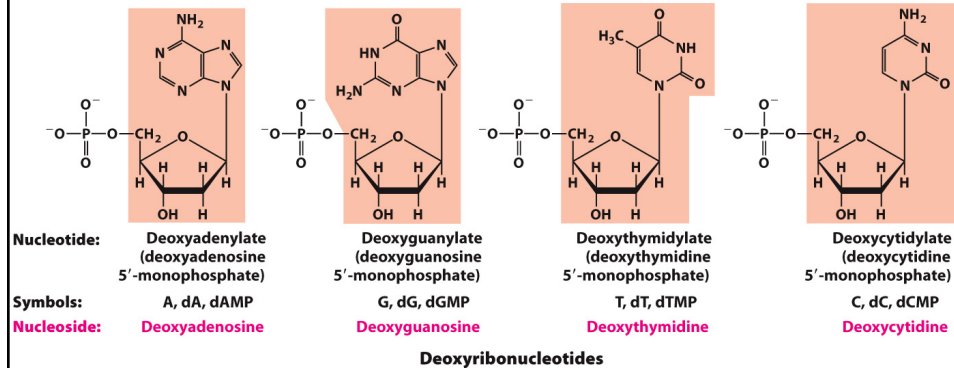


Deoxyribose



Nomenclature: Deoxyribonucleotides

You need to know structures, names, numbering, and symbols (both two-letter (dA) and four-letter (dAMP) codes).



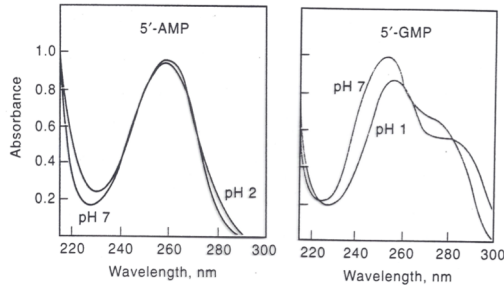
Nucleotides: Nomenclature

Nucleotide and nucleic acid nomenclature

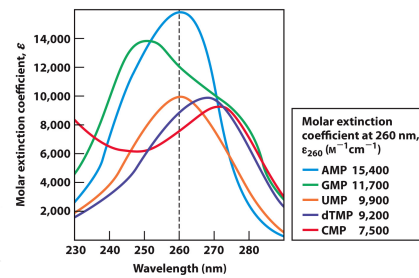
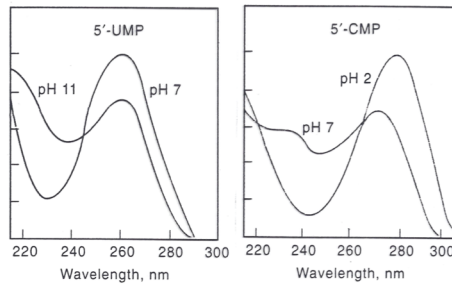
Base	Nucleoside*	Nucleotide*	Nucleic acid
	-ine	-osine	-ylate
Purines			
Adenine	Adenosine Deoxyadenosine	Adenylate Deoxyadenylate	RNA DNA
Guanine	Guanosine Deoxyguanosine	Guanylate Deoxyguanylate	RNA DNA
Pyrimidines	-idine	-idylate	
Cytosine	Cytidine Deoxycytidine	Cytidylate Deoxycytidylate	RNA DNA
Thymine	Thymidine or deoxythymidine	Thymidylate or deoxythymidylate	DNA
Uracil	Uridine	Uridylate	RNA

*Nucleoside and nucleotide are generic terms that include both ribo- and deoxyribo- forms. Note that here ribonucleosides and ribonucleotides are designated simply as nucleosides and nucleotides (e.g., riboadenosine as adenosine) and deoxyribonucleosides and deoxyribonucleotides as deoxynucleosides and deoxynucleotides (e.g., deoxyriboadenosine as deoxyadenosine). Both forms of naming are acceptable, but the shortened names are more commonly used.

Nucleic Acid Bases, Nucleosides, and Nucleotides

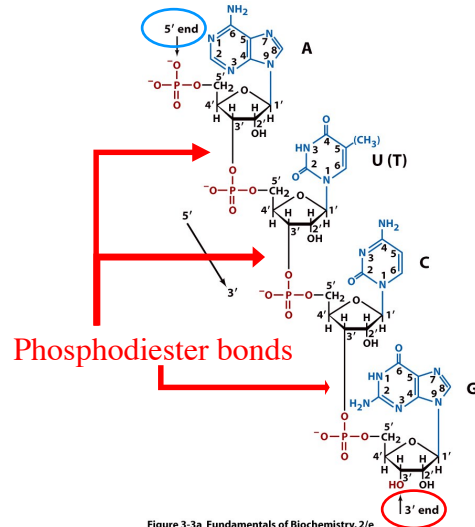


Nucleotide	Extinction Coefficient at pH 7.0 ($M^{-1}cm^{-1}$) $\times 10^3$	λ_{max} (nm)
AMP	15.4	260
GMP	11.7	248
CMP	7.5	280
dTMP	9.2	270
UMP	9.9	260



Definition of Nucleic Acids

Nucleic acid – polymer of nucleotides – directionality 5'→3'



When you write a sequence:

ATCG

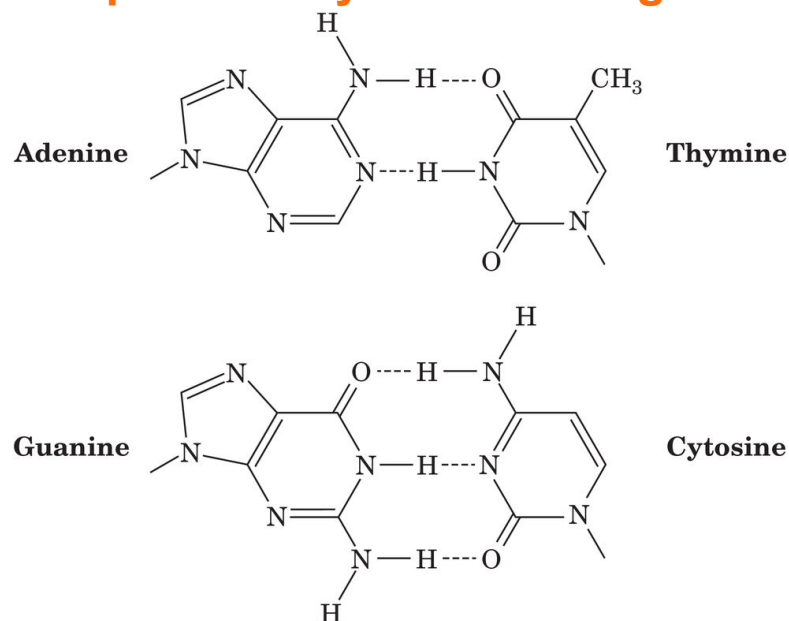
It is assumed that the 5'-end is on the left and the 3'-end is on the right, unless otherwise labeled.

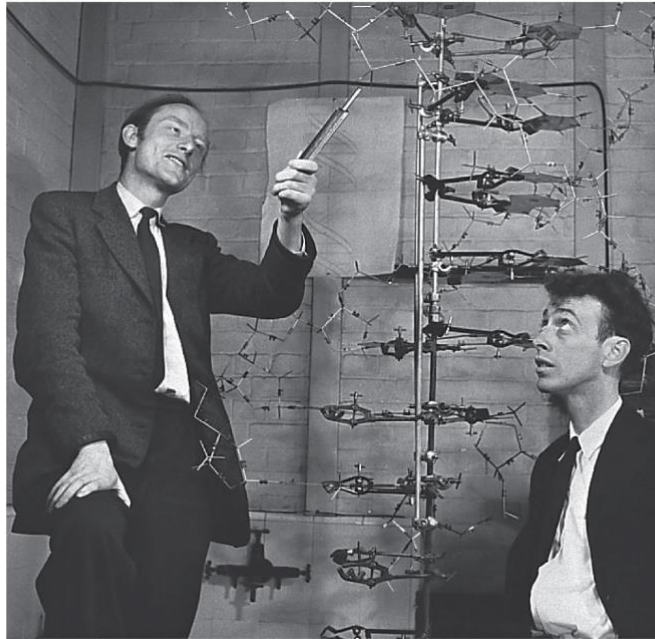
5'-ATCG-3'

3'-GCTA-5' same molecule

Figure 3-3a Fundamentals of Biochemistry, 2/e
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Complementary Base Pairing in DNA

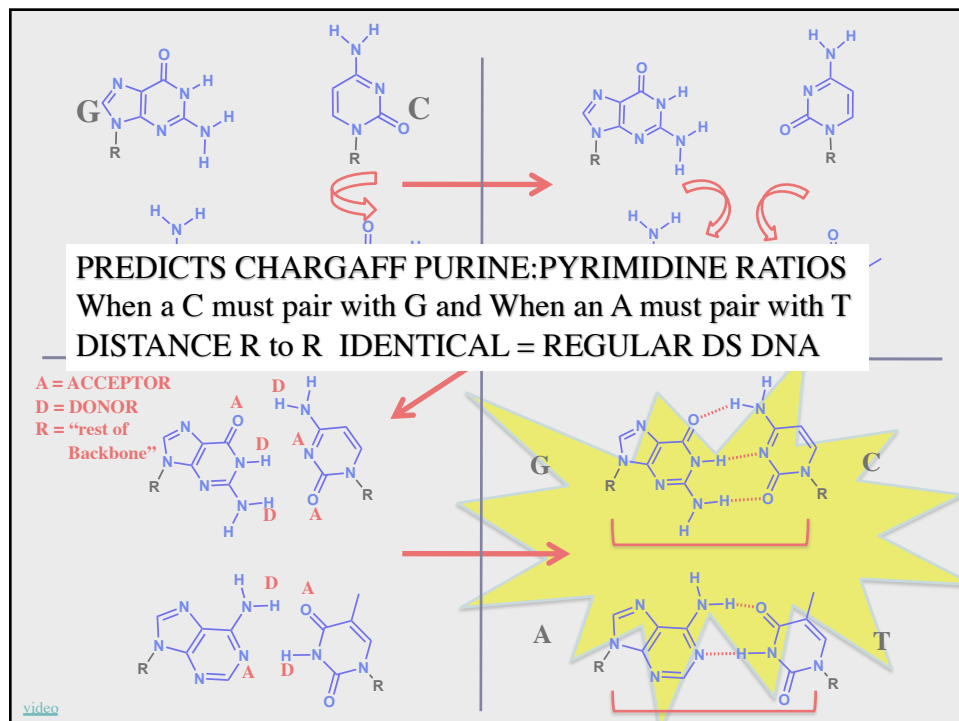
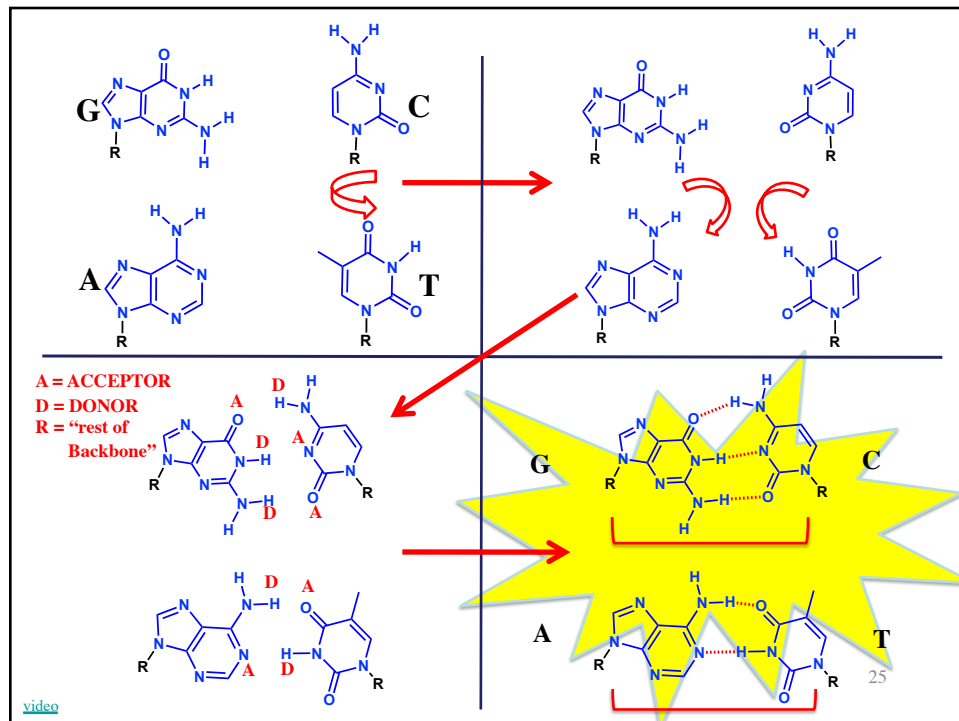


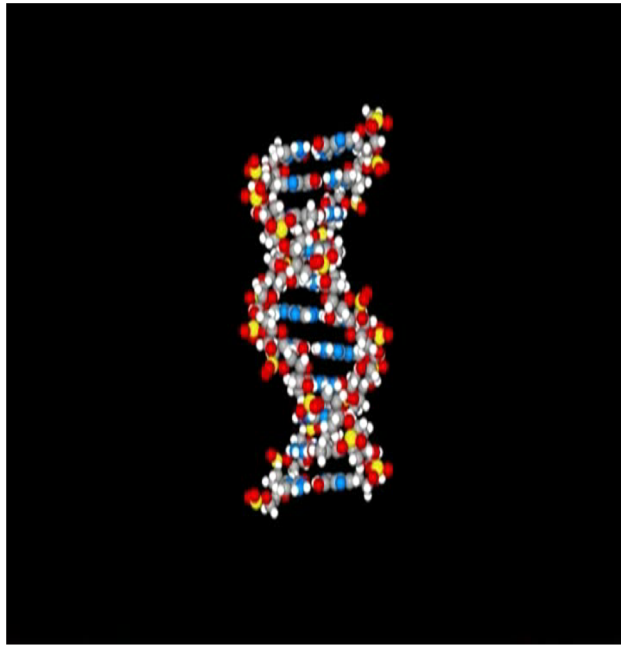


All they knew were Chargaff's rules: $G=C$ & $A=T$

By the early 1950s, the greatest unsolved mystery in science was the secret of life itself - the process by which all living things have reproduced themselves, generation upon generation, since the very beginnings of life on earth.

Although the mystery had a name, the "gene," no one knew what it was or how it worked.





Watson-Crick Base Pairs

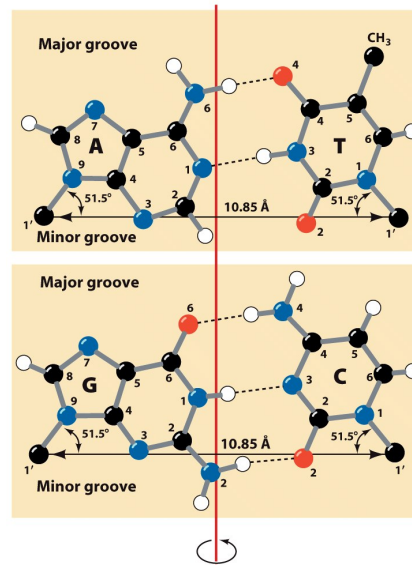
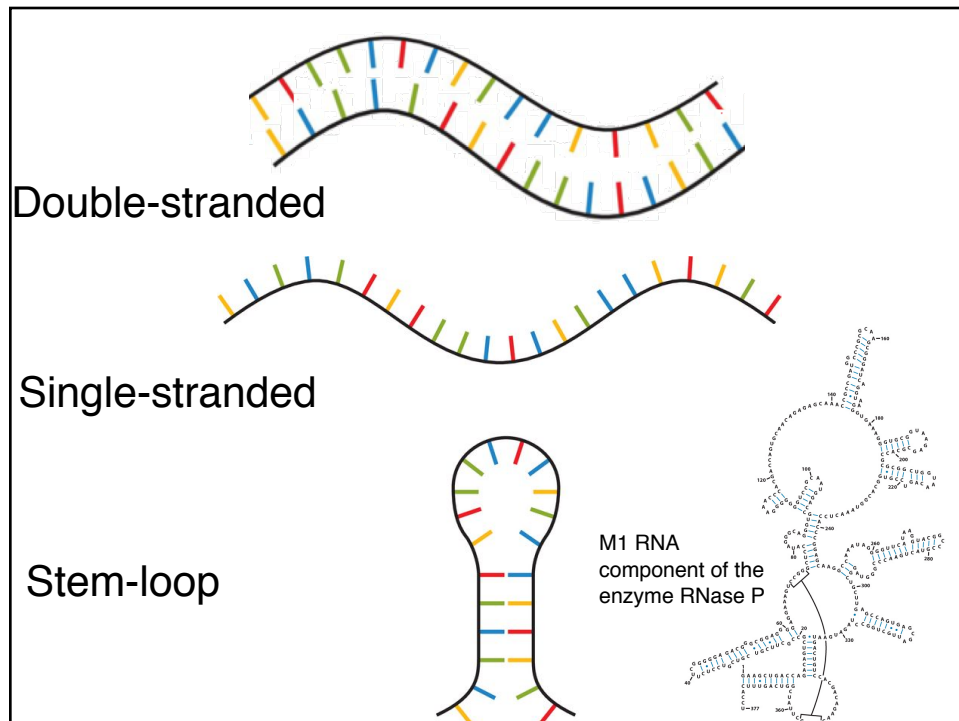


Figure 24-1
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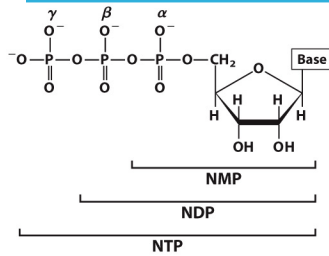
Roles of Nucleotides

The most well known is ATP:

Important roles of other nucleotides:

- Energy rich (high energies of hydrolysis, but kinetically stable)
besides ATP, includes: GTP, CTP, UTP
- Carrier molecule (key intermediates in metabolism)
UDP-sugars, CDP-lipids, NADH, FAD
- Secondary messengers (cAMP, cGMP)
- Other cofactors for enzymes

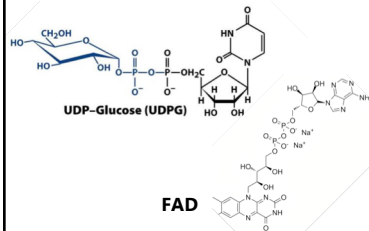
Other Functions of Nucleotides: Energy Source



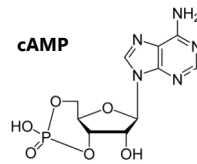
Abbreviations of ribonucleoside 5'-phosphates			
Base	Mono-	Di-	Tri-
Adenine	AMP	ADP	ATP
Guanine	GMP	GDP	GTP
Cytosine	CMP	CDP	CTP
Uracil	UMP	UDP	UTP

Abbreviations of deoxyribonucleoside 5'-phosphates			
Base	Mono-	Di-	Tri-
Adenine	dAMP	dADP	dATP
Guanine	dGMP	dGDP	dGTP
Cytosine	dCMP	dCDP	dCTP
Thymine	dTMP	dTDP	dTTP

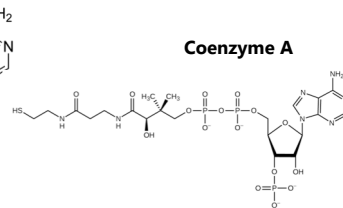
Carrier molecules



Secondary messengers



Other cofactors for enzymes



Roles of Nucleic Acids

- Information storage
- Information retrieval
- Information translation
- Information processing
- Information preservation

Key experiments by Griffiths, Avery, and Hershey & Chase

The 4 S's
Size
Solubility
Shape
Stability

The 4 S's
Size
Solubility
Shape
Stability

Nucleic Acids: Size

Genome Sizes

TABLE 28-2. SIZES OF SOME DNA MOLECULES

Organism	Number of base pairs (kb) ^a	Contour length (μm)
Viruses		
Polyoma, SV40	5.1	1.7
λ Bacteriophage	48.6	17
T2, T4, T6 bacteriophage	166	55
Fowlpox	280	193
Bacteria		
<i>Mycoplasma hominis</i>	760	260
<i>Eschericia coli</i>	4,700	1,600
Eukaryotes		
Yeast (in 17 haploid chromosomes)	13,500	4,600
<i>Drosophila</i> (in 4 haploid chromosomes)	165,000	56,000
Human (in 23 haploid chromosomes)	2,900,000	990,000
Lungfish (in 19 haploid chromosomes)	102,000,000	34,700,000

^a kb = kilobase pair = 1000 base pairs (bp).

Source: Kornberg, A. and Baker, T.A., *DNA Replication* (2nd ed.), p. 20, Freeman (1992).

TABLE 3-3 Some Sequenced Genomes

Organism	Genome Size (kb)	Number of Chromosomes
<i>Mycoplasma genitalium</i> (human parasite)	580	1
<i>Rickettsia prowazekii</i> (putative relative of mitochondria)	1,112	1
<i>Haemophilus influenza</i> (human pathogen)	1,830	1
<i>Escherichia coli</i> (human symbiont)	4,639	1
<i>Saccharomyces cerevisiae</i> (baker's yeast)	12,070	16
<i>Plasmodium falciparum</i> (protozoan that causes malaria)	23,000	14
<i>Caenorhabditis elegans</i> (nematode)	97,000	6
<i>Arabidopsis thaliana</i> (dicotyledonous plant)	119,200	5
<i>Drosophila melanogaster</i> (fruit fly)	180,000	4
<i>Oryza sativa</i> (rice)	389,000	12
<i>Danio rerio</i> (zebra fish)	1,700,000	25
<i>Gallus gallus</i> (chicken)	1,200,000	40
<i>Mus musculus</i> (mouse)	2,500,000	20
<i>Homo sapiens</i>	3,038,000	23

Nucleic Acids: Size

Genome Sizes

(from DNA sequence)

TABLE 24-2 DNA, Gene, and Chromosome Content in Some Genomes

	Total DNA (bp)	Number of chromosomes ^a	Approximate number of genes
<i>Escherichia coli</i> K12 (bacterium)	4,641,652	1	4,494 ^b
<i>Saccharomyces cerevisiae</i> (yeast)	12,157,105	16 ^c	6,340 ^b
<i>Caenorhabditis elegans</i> (nematode)	90,269,800	12 ^d	23,000
<i>Arabidopsis thaliana</i> (plant)	119,186,200	10	33,000
<i>Drosophila melanogaster</i> (fruit fly)	120,367,260	18	20,000
<i>Oryza sativa</i> (rice)	480,000,000	24	57,000
<i>Mus musculus</i> (mouse)	2,634,266,500	40	27,000
<i>Homo sapiens</i> (human)	3,070,128,600	46	20,000

Note: This information is constantly being refined. For the most current information, consult the websites for the individual genome projects.

^aThe diploid chromosomes number is given for all eukaryotes except yeast.

^bIncludes known RNA-coding genes.

^cHaploid chromosomes number. Wild yeast strains generally have eight (octoploid) or more sets of these chromosomes.

^dNumber for females, with two X chromosomes. Males have an X but no Y, thus 11 chromosomes in all.

Nucleic Acids: Size

RNA Sizes

Table 5-1
RNA molecules in *E. coli*

Type	Relative amount (%)	Sedimentation coefficient (S)	Mass (kd)	Number of nucleotides
Ribosomal RNA (rRNA)	80	23	1.2×10^3	3700
		16	0.55×10^3	1700
		5	3.6×10^1	120
Transfer RNA (tRNA)	15	4	2.5×10^1	75
Messenger RNA (mRNA)	5	Heterogeneous		

The 4 S's

Size

Solubility

Shape

Stability

Nucleic Acids: Solubility

The polymer is a poly-anion

The pK_a of the phosphodiester is ~ 2.0

Consequences:

1) A counter ion:

required for solubility and stability.

usually Na^+ , K^+ , and/or Mg^{+2}

in cell, also use of polyamines; spermine & spermidine.

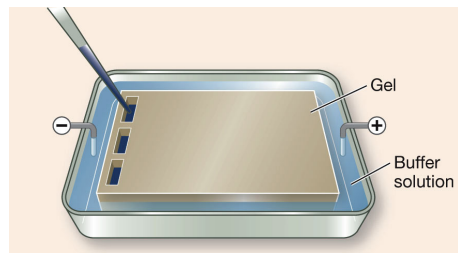
2) Easily separated by electrophoresis:

Every nucleotide has one (1) negative charge.

so charge/mass ratio is constant.

so can separate by size (similar in concept to SDS-PAGE).

Nucleic Acids: Solubility



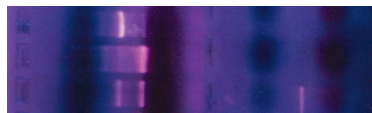
Nucleic acids can be separated by **gel electrophoresis**.

Polymers can be placed in a well in a semisolid gel and an electric field is applied across the gel.

Negatively charged Nucleic acids move towards positive end.

For polymers of the same shape, smaller polymers travel faster than larger polymers.

For polymers of the same size, more compact topologies travel faster than less compact ones.



The 4 S's

Size

Solubility

Shape

Stability

Nucleic Acids: Shape

ANTIPARALLEL dsDNA



PARALLEL dsDNA

