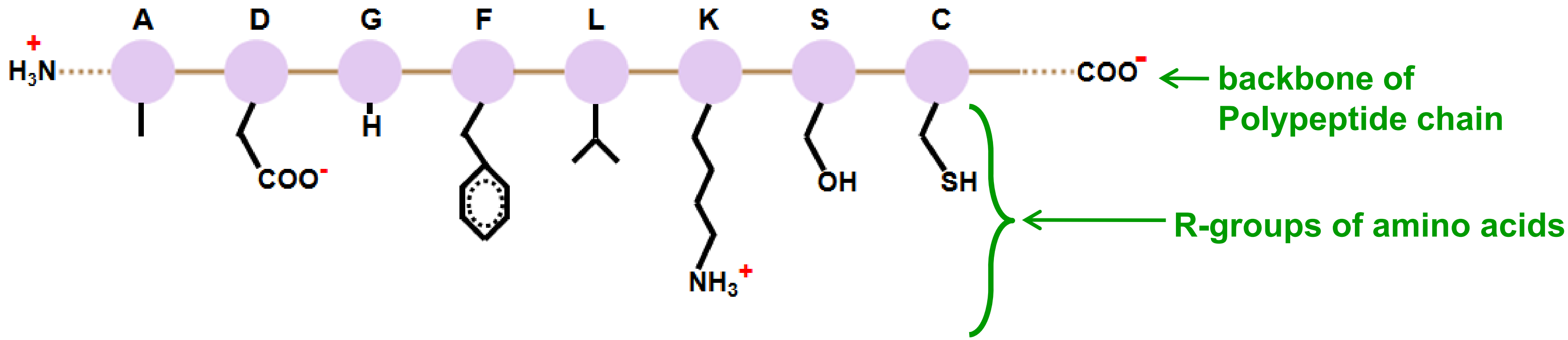
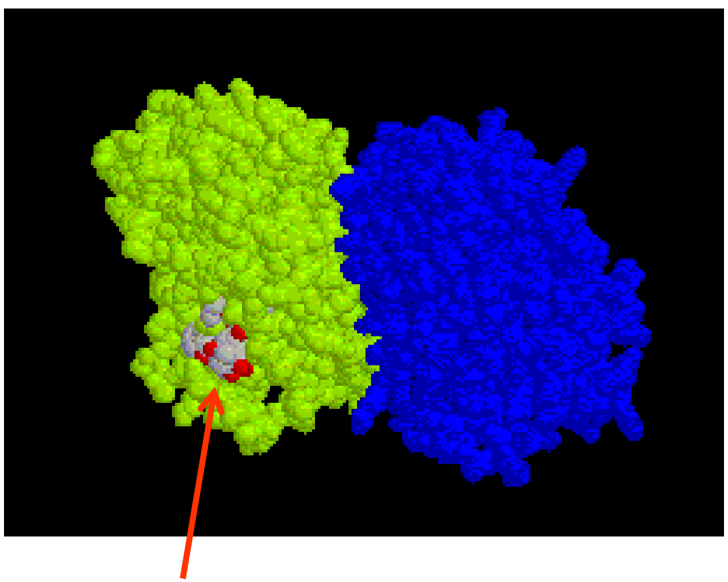
BIO 311C
Spring 2010

Lecture 16 –Monday 1 March

Primary Structure of a portion of a polypeptide chain



Native conformation of a dimeric protein, cytoplasmic tubulin



The native conformation of the protein illustrated here requires the correct primary structure (also called the 1° structure), secondary (2°) structure and tertiary (3°) structure of each of its two polypeptide chains. It also requires bonding between the two polypeptide chains to produce a correct quaternary (4°) structure of the protein. Each of the two polypeptide chains is called a subunit of the protein.

Before tubulin can assemble into a microtubule, it not only must be in the correct conformation, but it also requires another molecule, ATP, to bind to one of its two subunits.

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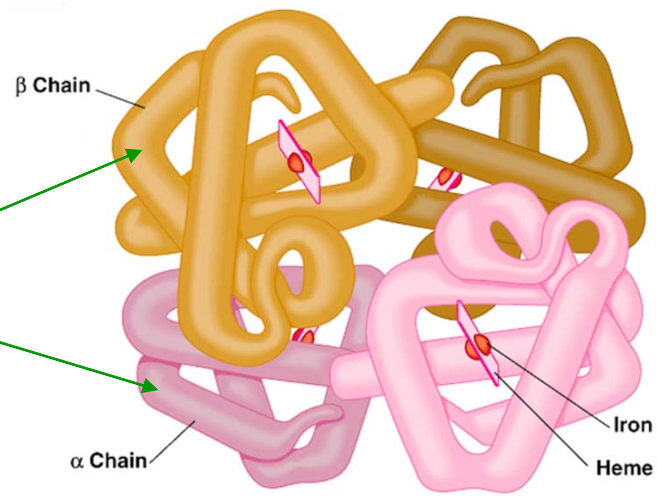
Hemoglobin is a conjugated tetrameric protein.

From Fig. 5.21, p. 83, of textbook

apoprotein
subunits



prosthetic group

Proteins that include one or more component in addition to polypeptide chain(s) are called <u>conjugated</u> <u>proteins</u>.

The polypeptide-chain portion of a conjugated protein is called an <u>apoprotein</u>.

The non-polypeptide-chain component of a conjugated protein is called a <u>prosthetic</u> <u>group</u>.

Proteins whose correct conformation and normal function do not require any prosthetic group are called <u>simple</u> <u>proteins</u>.

Prosthetic groups are often a small organic molecule or an inorganic ion.

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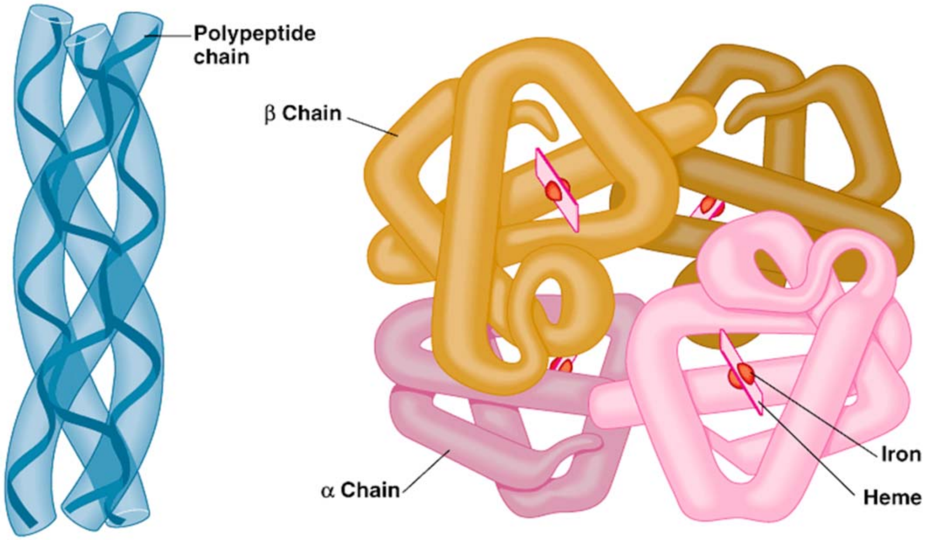
Most Proteins can be categorized as either fibrous proteins or globular proteins.



collagen,
a fibrous protein

hemoglobin,
a globular protein

Fibrous proteins are very elongated and do not have a pronounced tertiary structure.

Globular proteins are folded into a rounded three-dimensional shape.

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Some Ways of Classifying a Protein

I. According to the number of polypeptide chains it contains

A. Monomeric proteins contain only one polypeptide chain.

B. Oligometric proteins contains two or more polypeptide chains.

II. According to whether its structure contains components other than polypeptide chains

A. Simple proteins contain nothing other than polypeptide chain(s).

B. Conjugated proteins include a prosthetic group in the structure.

III. According to how it folds

A. Fibrous proteins remain extended such that they don't have a tertiary structure.

B. Globular proteins fold into a rounded structure.

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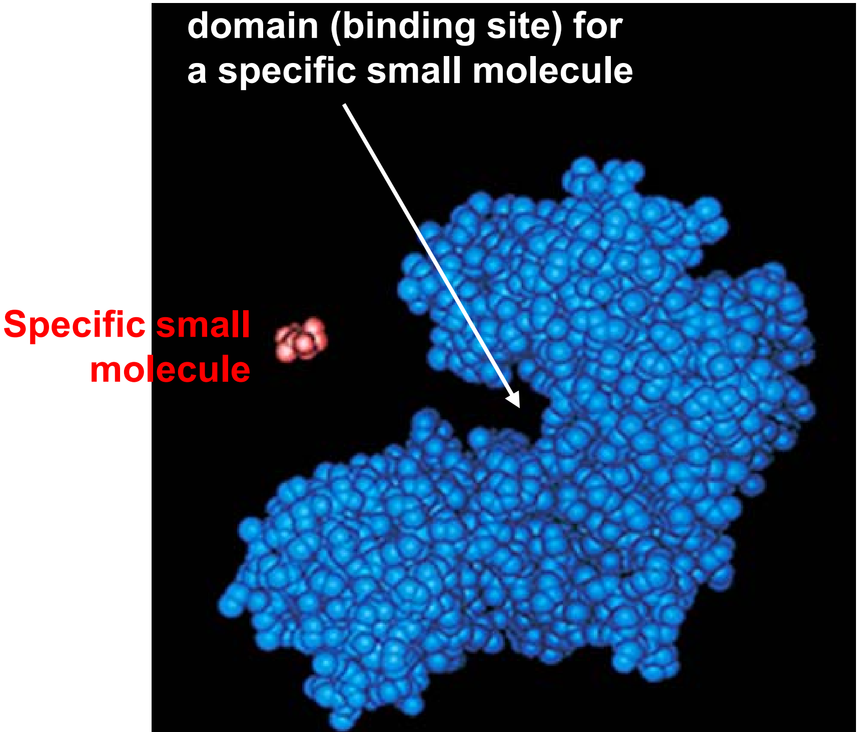
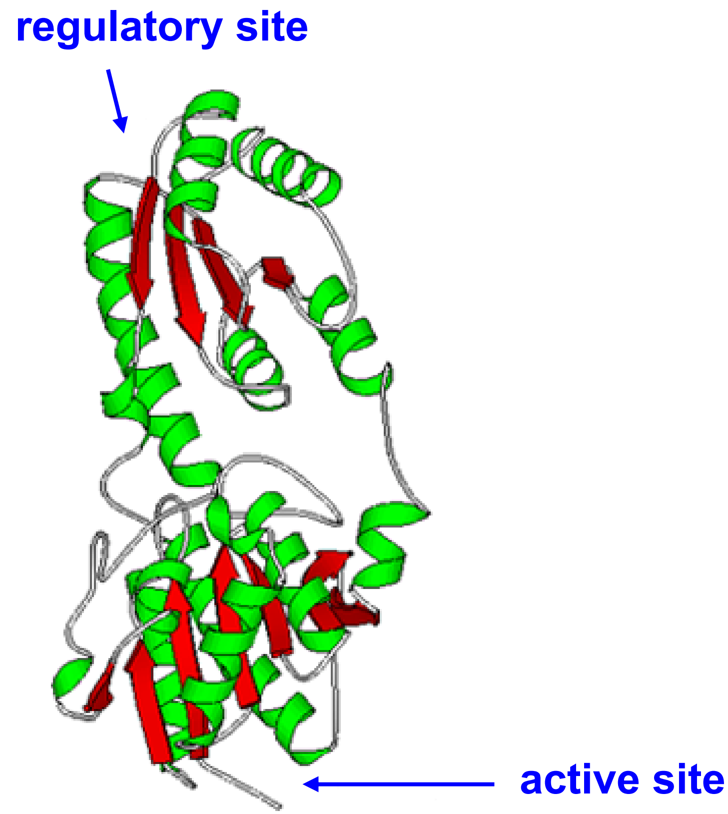
Domains of Proteins



Lysozyme
(space-filling model)



Phosphofructokinase
(ribbon model)

A <u>domain</u> of a protein in its native conformation is a specific region (site) of the protein that has a defined function.

Some proteins have several domains, each of which differs in its function from the functions of all other domains of the protein.

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Levels of Organization of a Protein

Primary structure (1°) structure:

The specific sequence of amino acids in its polypeptide chain(s), starting from the N-terminal end.

Secondary (2°) structure:

The conformation of various portions of its polypeptide chain(s), determined by hydrogen bonding between atoms of peptide bonds. The most common secondary-structure conformations are an α–helix and a β–sheet (pleated sheet).

Tertiary structure (3°) structure:

The 3-dimensional conformation of each of its polypeptide chain(s), determined In part by its secondary structure and in part by chemical bonding between R-groups of its amino acids.

Quaternary (4°) structure, applies only to oligomeric proteins.

The three dimensional conformation of an oligomeric protein is determined by binding between polypeptide chains due to chemical bonding between amino-acid R-groups projecting from its individual polypeptide chains.

Note: the amino acid sequence (primary structure) of the polypeptide chain(s) of a protein ultimately determines which secondary, tertiary and quaternary structures are favored.

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Examples of Some General Functions Performed by Proteins in Cells

Textbook Table 5.1 is a somewhat overlapping list of protein functions.

Enzymes are proteins.

example: textbook Fig 5.19 - lysozyme

Many structural components of cells are proteins.

example: textbook Table 6.1: intermediate filaments

Moveable structures in cells are based on protein function.

example: textbook Table 6.1 – actin filaments and microtubules

Proteins are major components of biological membranes.

example: textbook Fig. 7.8 – transmembrane protein

Proteins are a major component of ribosomes.

Textbook Fig. 17.16a gives an idea of the complexity of a ribosome, which contains dozens of proteins.

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cont. →

Examples of Some General Functions Performed by Proteins in Cells (cont.)

Proteins are a major component of chromatin

example: textbook Fig. 16.21 - histones

Hemoglobin and other oxygen-carrying molecules are proteins.

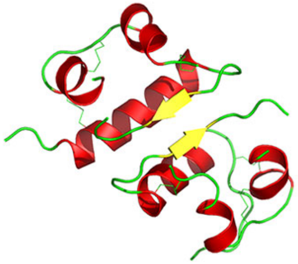
example: textbook Fig 5.20 - hemoglobin

Antibodies are proteins.

example: textbook Fig. 5.20

Many animal hormones are proteins and oligopeptides.

example: insulin



A ribbon model of insulin

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Some General Differences Between Polypeptides and Polysaccharides

Polysaccharides have a regular repeating pattern of monomers, while polypeptides do not.

Many polysaccharides occur as branched polymers while polypeptides occur only as straight-chain polymers.

Conformations of polysaccharides are determined by association with with themselves, with each other, and with various other kinds of molecules by hydrogen bonding. The conformations of polypeptides also depends on hydrogen bonds, but also on various other kinds of bonding such as disulfide bonds, hydrophobic bonding, etc. molecules by hydrogen bonding, but also utilize a variety of other kinds of bonding for these associations.

Polypeptides perform a much more diverse range of functions in cells than do polysaccharides.

Polypeptides are a class of “information molecules” in cells, while polysaccharides are not.

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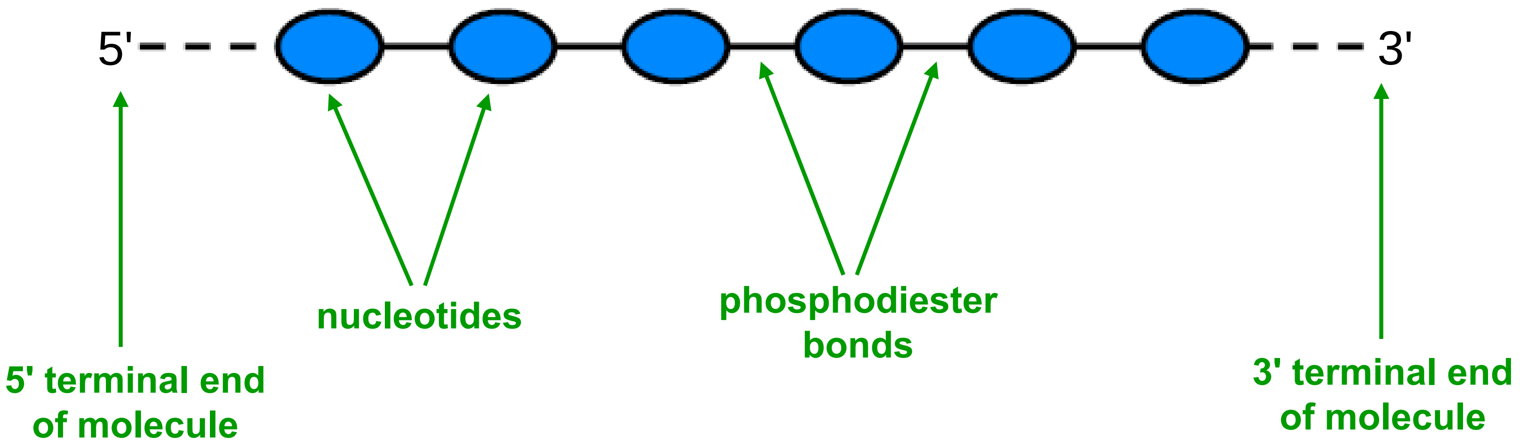
Illustration of a Polynucleotide Chain



Polynucleotide chains are un-branched polymers.

The monomers of polynucleotide chains are nucleotides.

The bonds between nucleotides are phosphodiester bonds.

Polynucleotide chains have two distinct ends, a 5' end and a 3' end.

The relationship between a polynucleotide chain and a nucleic acid is similar to the relationship between a polypeptide chain and a protein.

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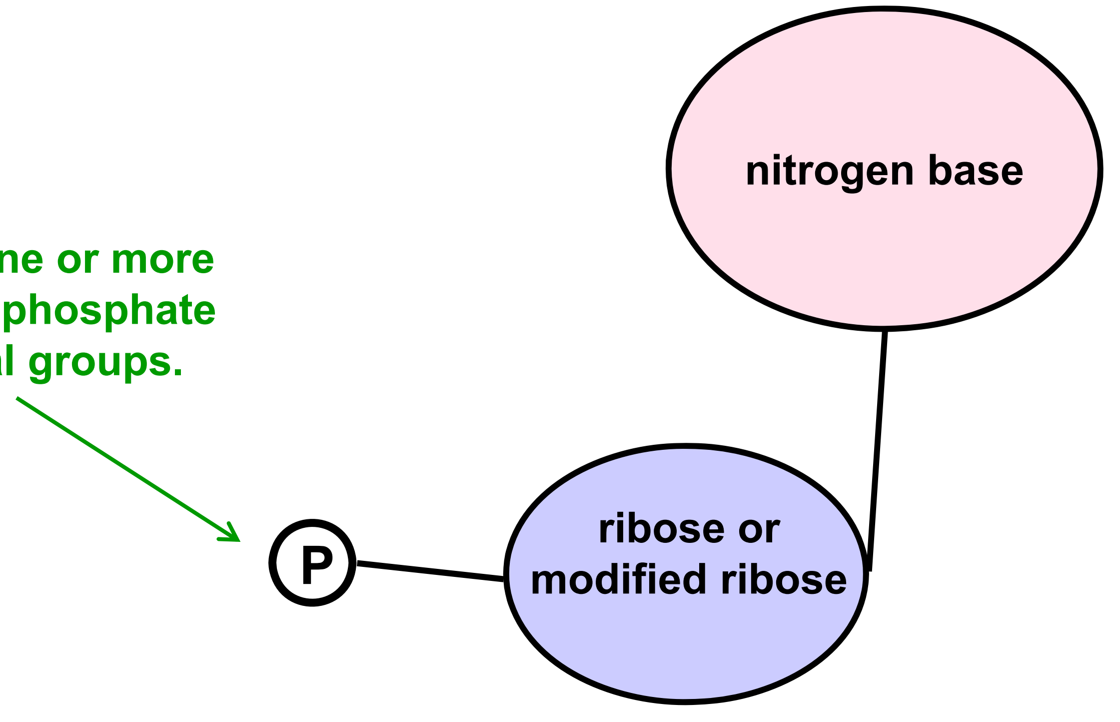
The Three Components of a Nucleotide

May be one or more
than one phosphate
functional groups.



highly abbreviated illustration
of the structure of a nucleotide

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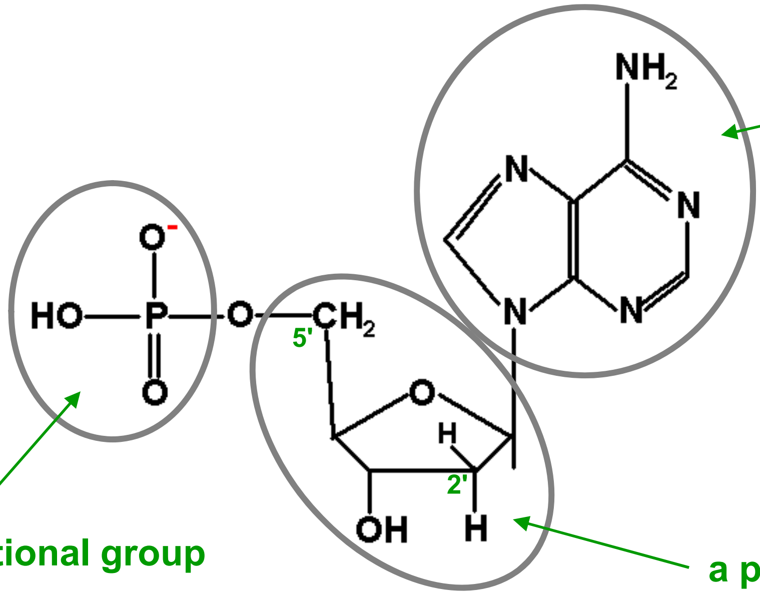
Example

Structure of the Nucleotide 2-deoxy-AMP



a nitrogen "base"
(this specific nitrogen base is called adenine.)

a phosphate functional group

a pentose sugar
(the one shown here is the modified sugar called 2'-deoxyribose)

A nucleoside is a nitrogen base covalently bonded to a pentose sugar.

A nucleotide is a nucleoside covalently bonded to one or more phosphate functional groups. In this case the phosphate is bonded through the 5th carbon atom of the sugar. Thus, it may be called a nucleoside-5'-phosphate.

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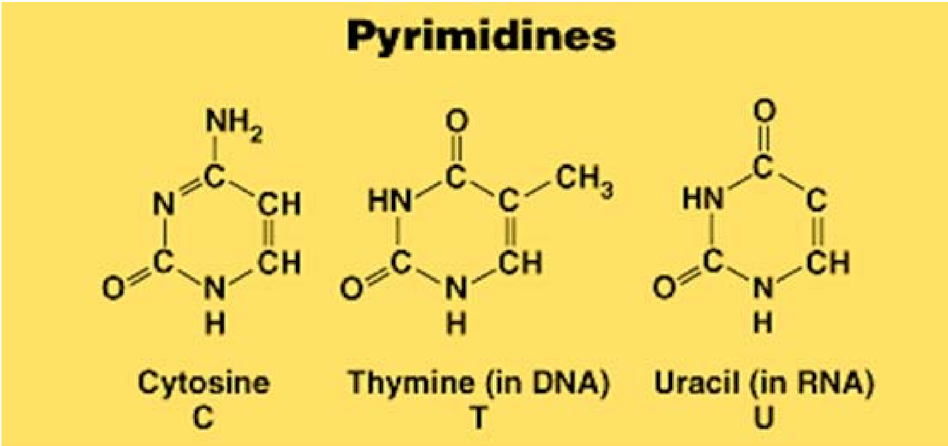
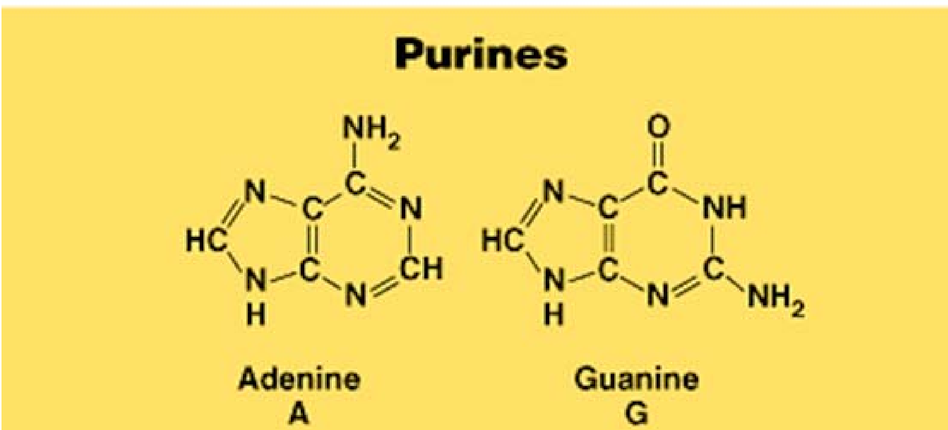
Nitrogen Bases That Occur in Nucleotides

From textbook Fig. 5.27, p. 87



Pyrimidines contain only one ring.



Purines contain two rings.

They are called bases because the nitrogen atoms of these molecules make them somewhat basic (alkaline).

Strictly speaking, these one letter designations refer to nucleosides, the nitrogen base with a pentose sugar attached.

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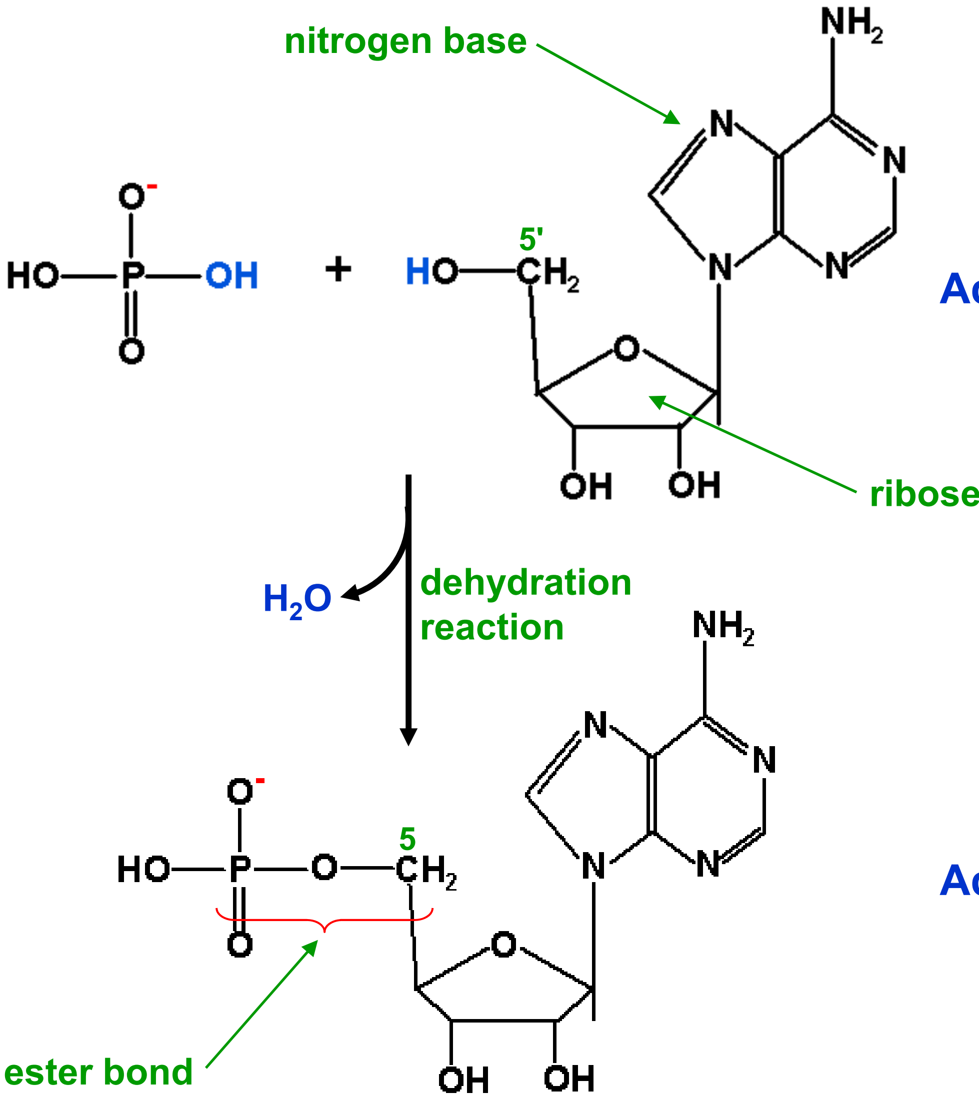
Formation of the Nucleotide AMP



[acid + alcohol]

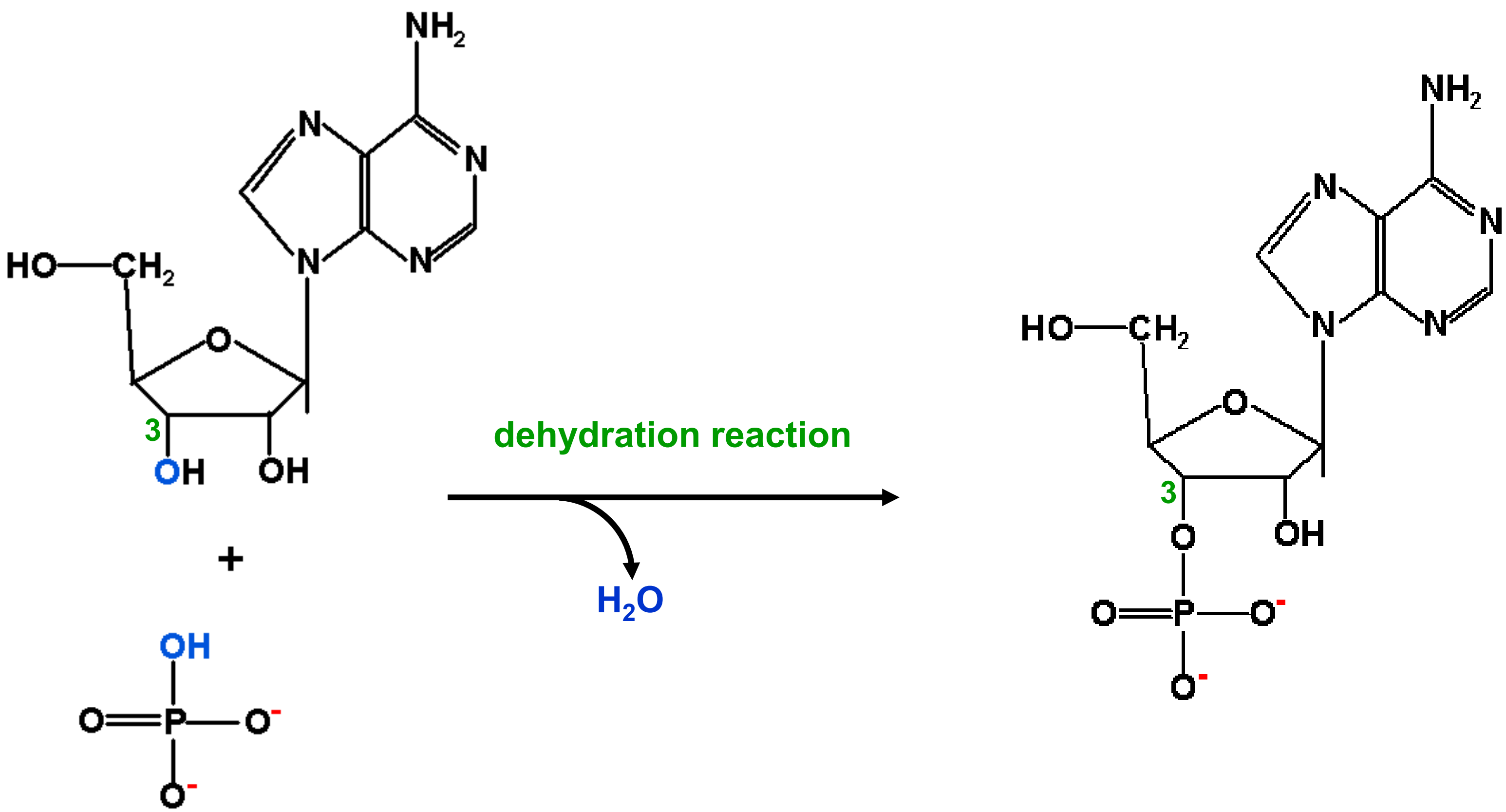
Adenosine (A) + Inorganic phosphate (P_i)

Adenosine monophosphate (AMP) + H_2O

[ester + water]

The product is more accurately called adenosine-5'-monophosphate (5’-AMP) since the phosphate is attached to the alcohol functional group representing of the 5[th] carbon atom of the ribose.

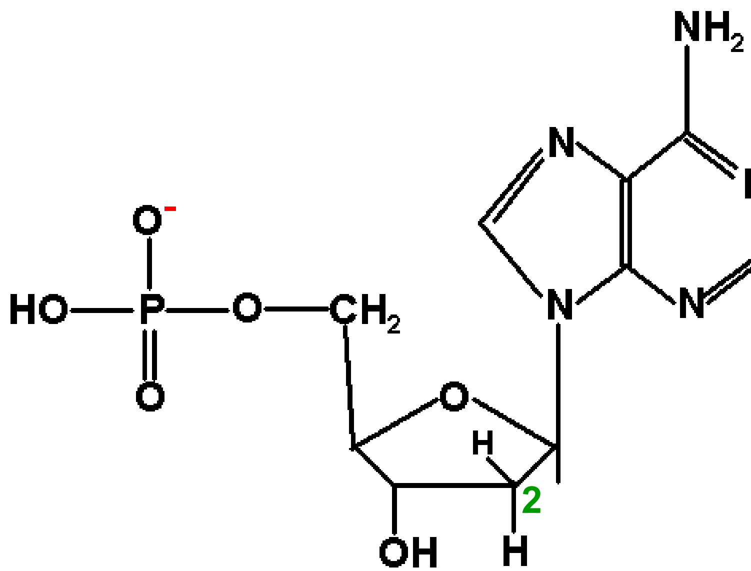
Formation of Adenosine-3'-monophosphate



$$A + P_i \longrightarrow \text{3'-AMP} + H_2O$$

*

The nucleotide dAMP



This molecule is identical to AMP except it contains the modified sugar 2-deoxy-D-ribose instead of the sugar D-ribose.

This molecule could accurately be called 2'-deoxy-D-ribose-5' phosphate. Generally the 5' designation is left out when the phosphate is attached to the 5th carbon atom of the sugar. The designation " 2'-deoxy " is usually abbreviated as " d ". Thus, the name of this molecule can be designated as dAMP.

Would it be possible to make 2'-AMP from A + P_i in a dehydration reaction? (see previous slide)

Would it be possible to make 2'-dAMP from dA + P_i in a dehydration reaction?

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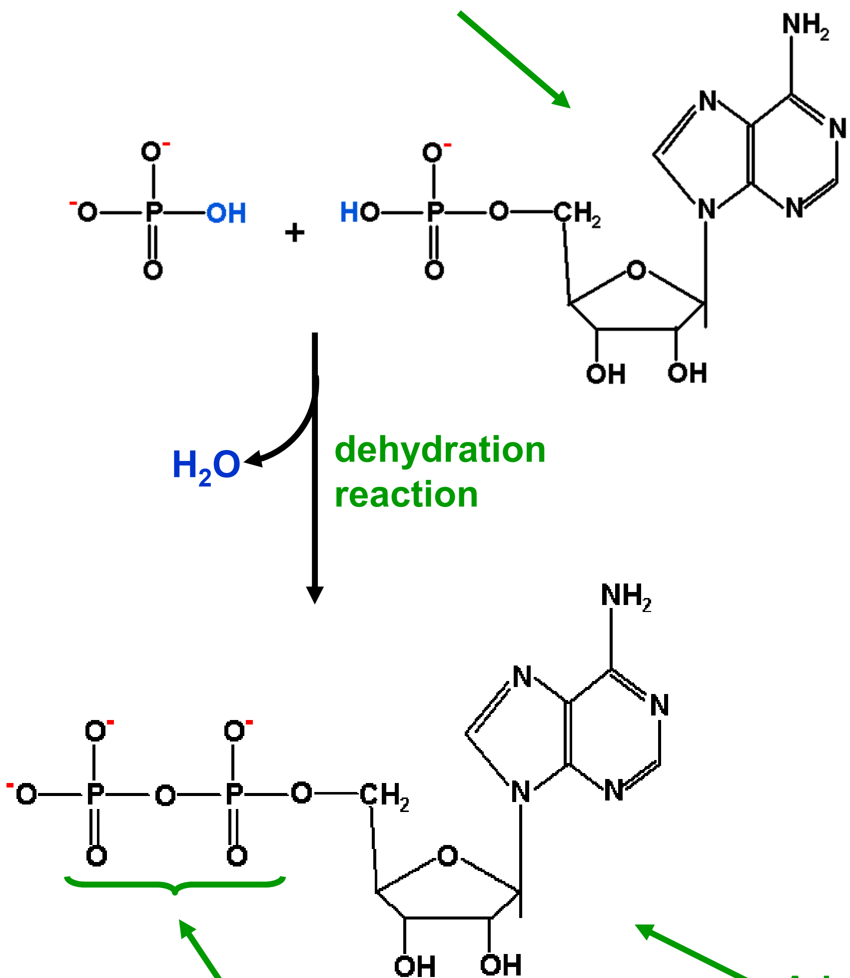
Two phosphate functional groups can be covalently bonded together to form an acid-anhydride bond.

Adenosine-5’-monophosphate (AMP)



acid anhydride bond

Adenosine-5’-diphosphate (ADP)

[acid + acid]

AMP + P$_i$)

ADP + H$_2$O

[anhydride + water]

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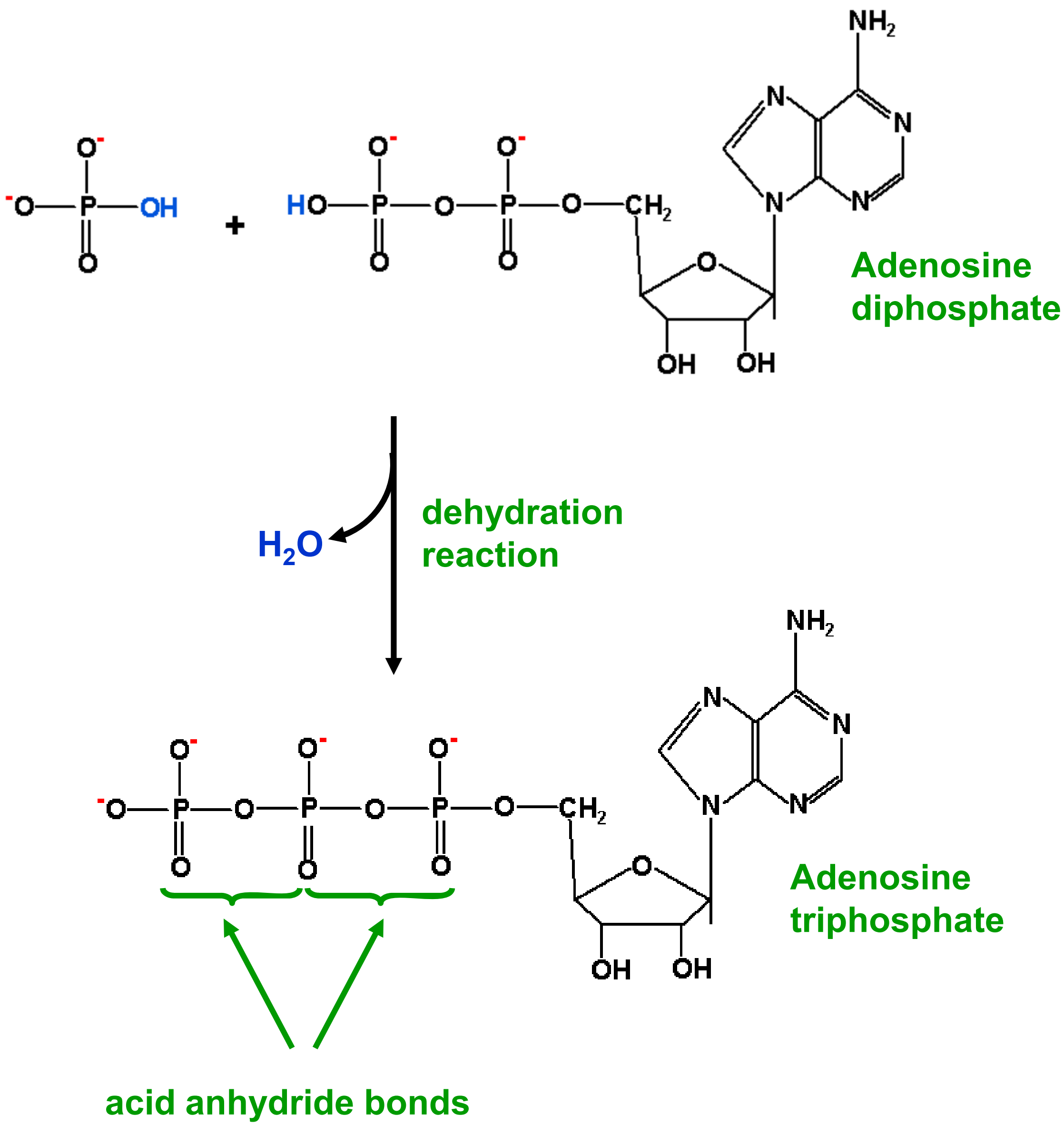
Three phosphate functional groups can be covalently bonded together linearly to form two acid anhydride bonds.



[acid + acid]

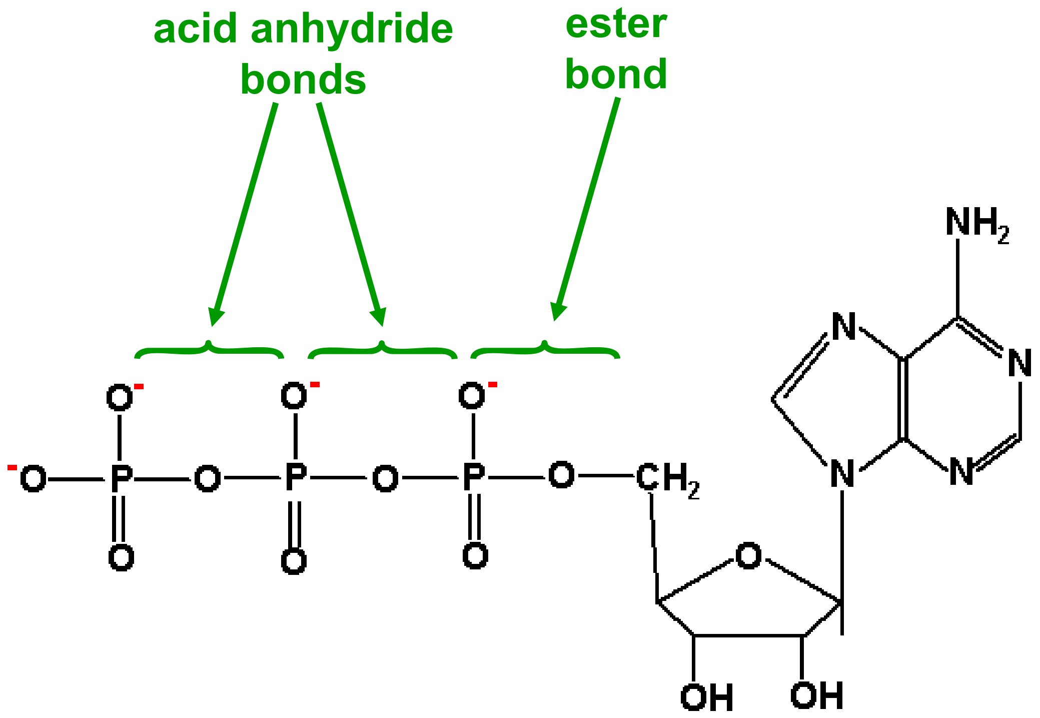
ADP +P_i)

ATP + H_2O

[anhydride + water]

*

Acid anhydride bonds are chemically different from ester bonds.



ATP

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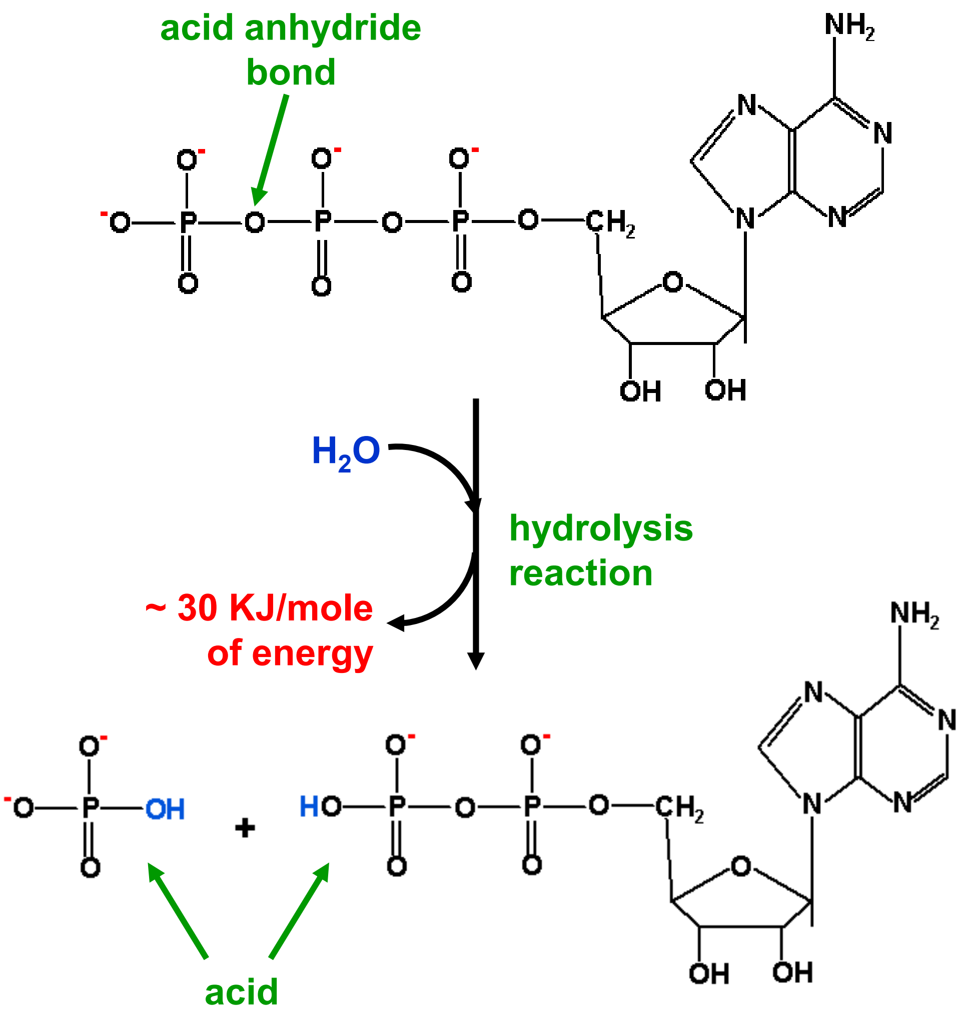
Hydrolysis of a phosphate anhydride bond in each molecule of a mole of identical molecules releases approximately 30 KJ of energy.



ATP + H_2O

[anhydride + water]

~ 30 KJ/mole

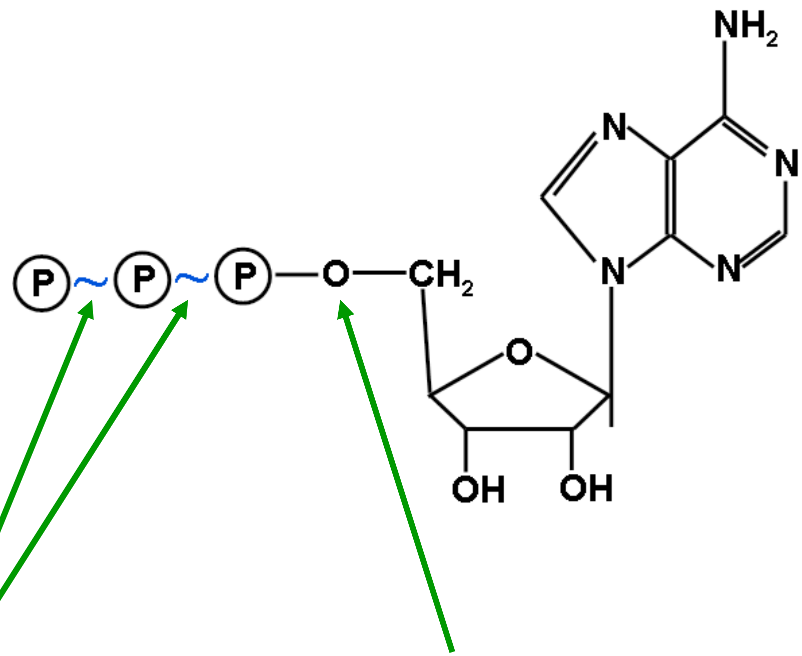
[acid + acid]

ADP +P_i)

*

Note: this is exactly the reverse of a dehydration reaction shown previously.

Abbreviated Structure of ATP



acid anhydride bonds
("high-energy" bonds)
Energy of hydrolysis approx. 30 kJ/mole

ester bond
(not a “high-energy” bond)
Energy of hydrolysis approx. 15 kJ/mole

High-energy phosphate bonds are often shown as: ~

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Some Nucleosides and Nucleotides of Importance in living Cells

	nucleosides	nucleotides		
contain 2-deoxy-D-ribose	dA	dAMP	dADP	dATP
	dT	dTMP	dTDP	dTTP
	dC	dCMP	dCDP	dCTP
	dG	dGMP	dGDP	dGTP
contain D-ribose	A	AMP	ADP	ATP
	U	UMP	UDP	UTP
	C	CMP	CDP	CTP
	G	GMP	GDP	GTP

contained in DNA

contained in RNA

contain high energy phosphate bonds

*

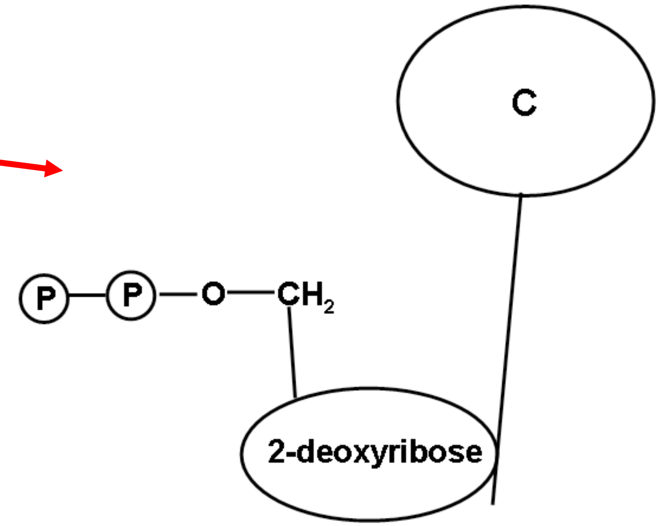
Abbreviated Structure of the Nucleotide “dCDP”

dA
dT
dC
dG

dAMP	dADP	dATP
dTMP	dTDP	dTTP
dCMP	dCDP	dCTP
dGMP	dGDP	dGTP

A
U
C
G

AMP	ADP	ATP
UMP	UDP	UTP
CMP	CDP	CTP
GMP	GDP	GTP



You should be able to draw the abbreviated structure of a nucleotide (as shown at right) from its name (as shown in the table).

The bond between the two phosphates in this molecule is a “high-energy” (acid anhydride) bond, but it is not shown here as a ~ since that symbol is not generally shown unless its hydrolysis is to used as a source of energy in a cell.

*