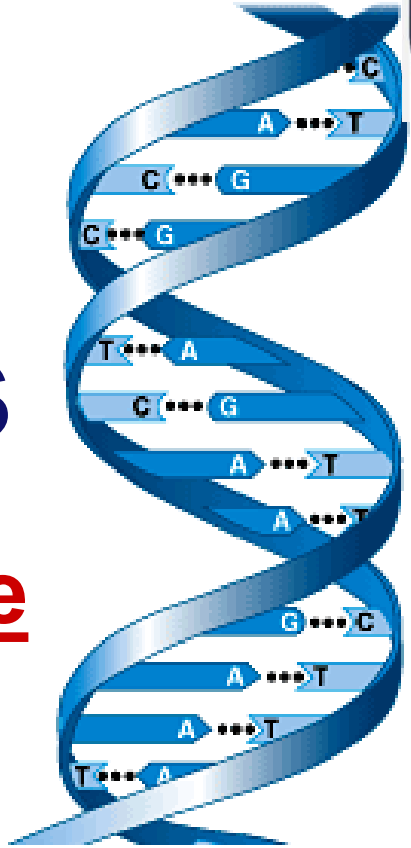
Nucleic Acids

Information storage



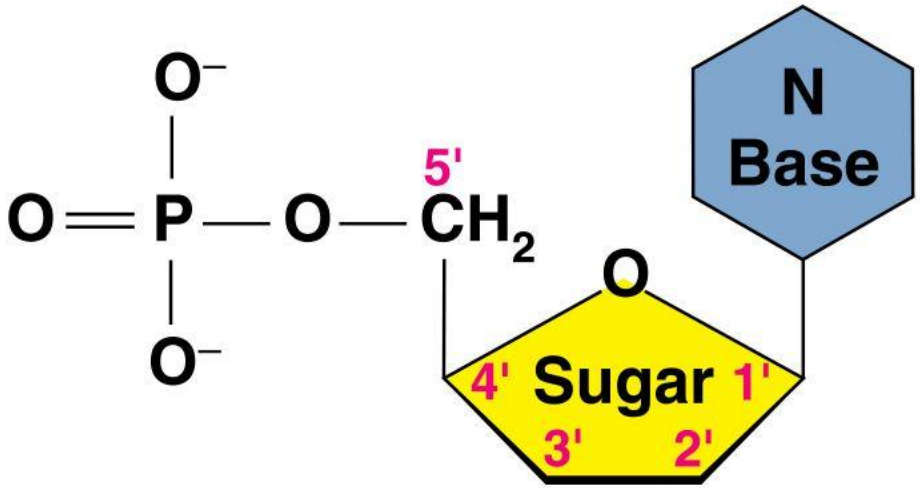
Lecture 8

Dr. Assel Amer Hadi

Nucleic Acids

- Nucleic acids are molecules that store information for cellular growth and reproduction
- There are two types of nucleic acids:

  - deoxyribonucleic acid (DNA) and ribonucleic acid (RNA)
- These are polymers consisting of long chains of monomers called nucleotides
- A nucleotide consists of a nitrogenous base, a pentose sugar and a phosphate group:

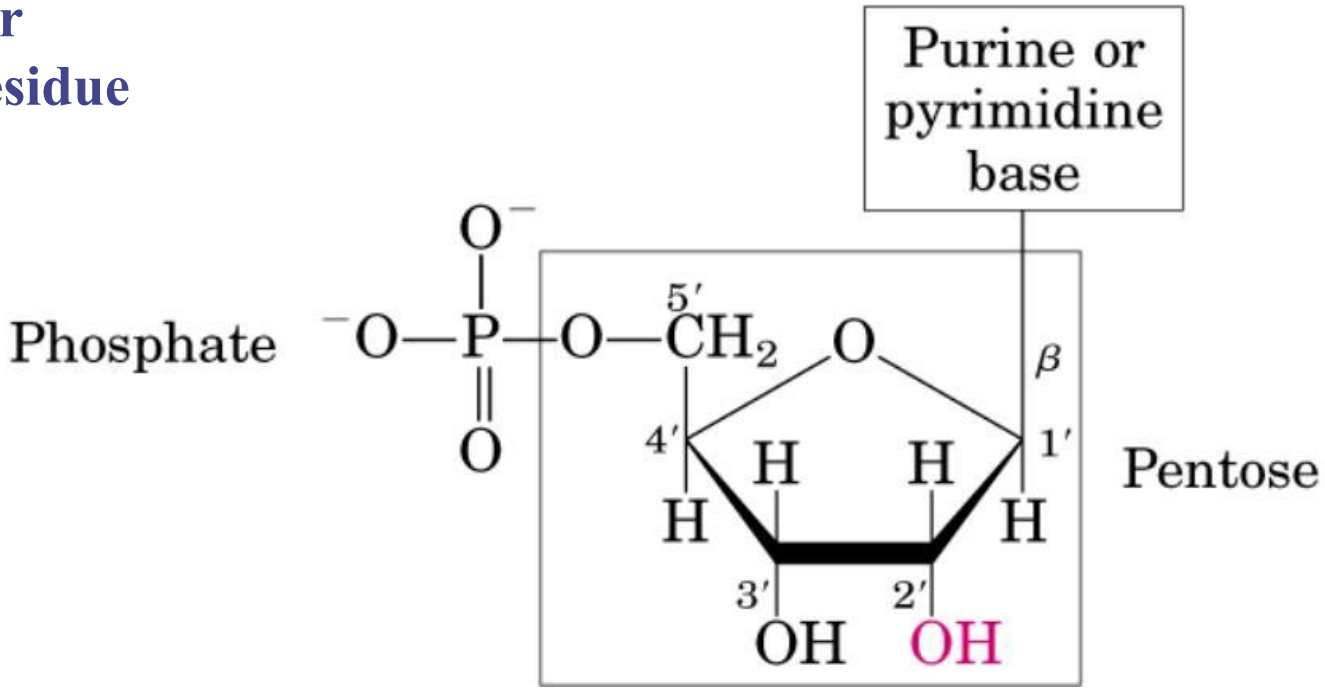


Nucleic Acids

DNA and RNA are nucleic acids, long, thread-like polymers made up of a linear array of monomers called nucleotides

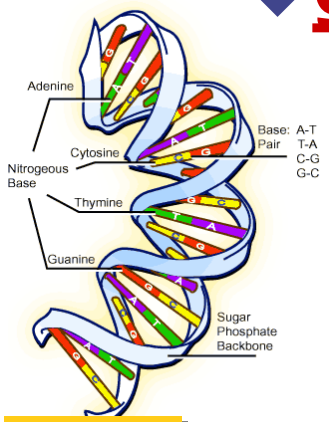
All nucleotides contain three components:

1. **A nitrogen heterocyclic base**
2. **A pentose sugar**
3. **A phosphate residue**

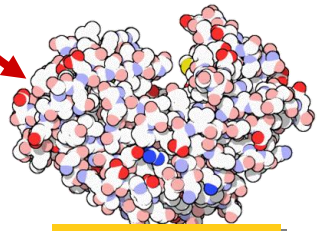


Nucleic Acids

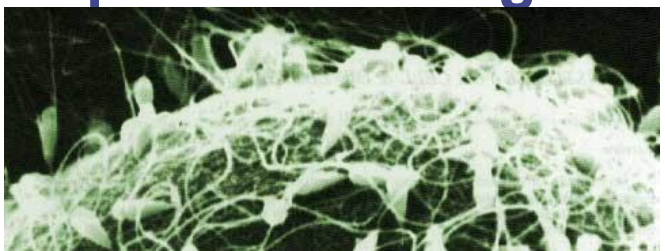
- **Function:**
  - **genetic material**
    1. **stores information**
       - genes
       - blueprint for building proteins
         - DNA → RNA → proteins
    2. **transfers information**
       - blueprint for new cells
       - blueprint for next generation

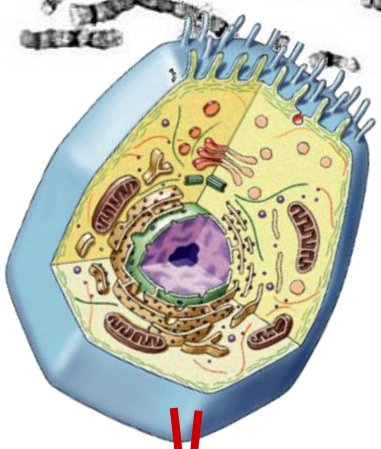


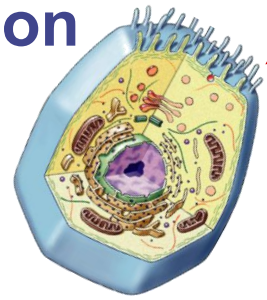
DNA

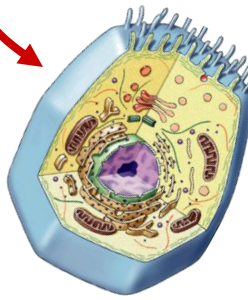


proteins









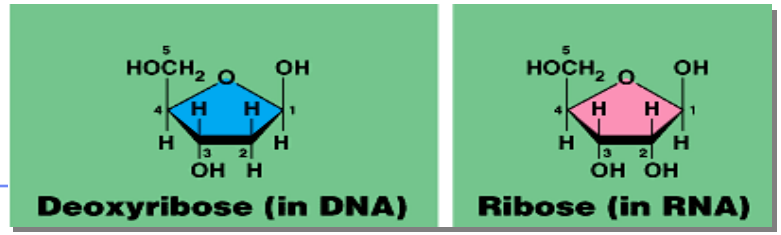
Nucleic Acids

- **Examples:**
  - **RNA** (ribonucleic acid)
    - single helix
  - **DNA** (deoxyribonucleic acid)
    - double helix
- **Structure:**
  - monomers = **nucleotides**

DNA

RNA

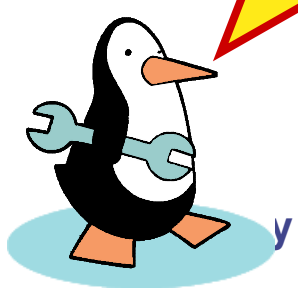
Nucleotides

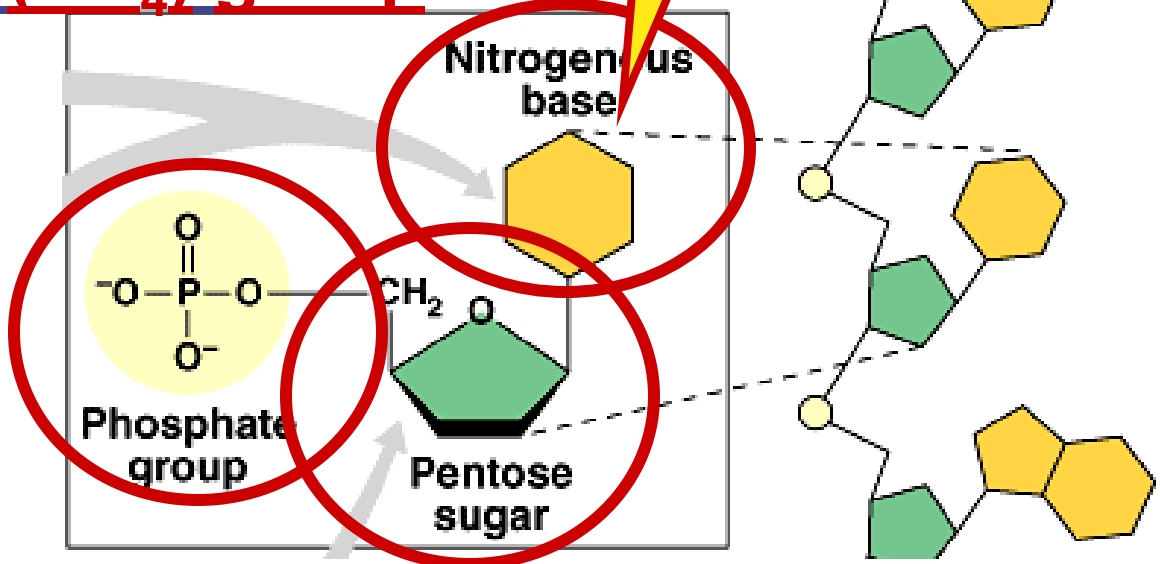


- All nucleotides contain three components:
  - nitrogen base (C-N ring)
  - pentose sugar (5C)
    - ribose in RNA
    - deoxyribose in DNA
  - phosphate (PO_4) group

Nitrogen base
I'm the A,T,C,G or U part!

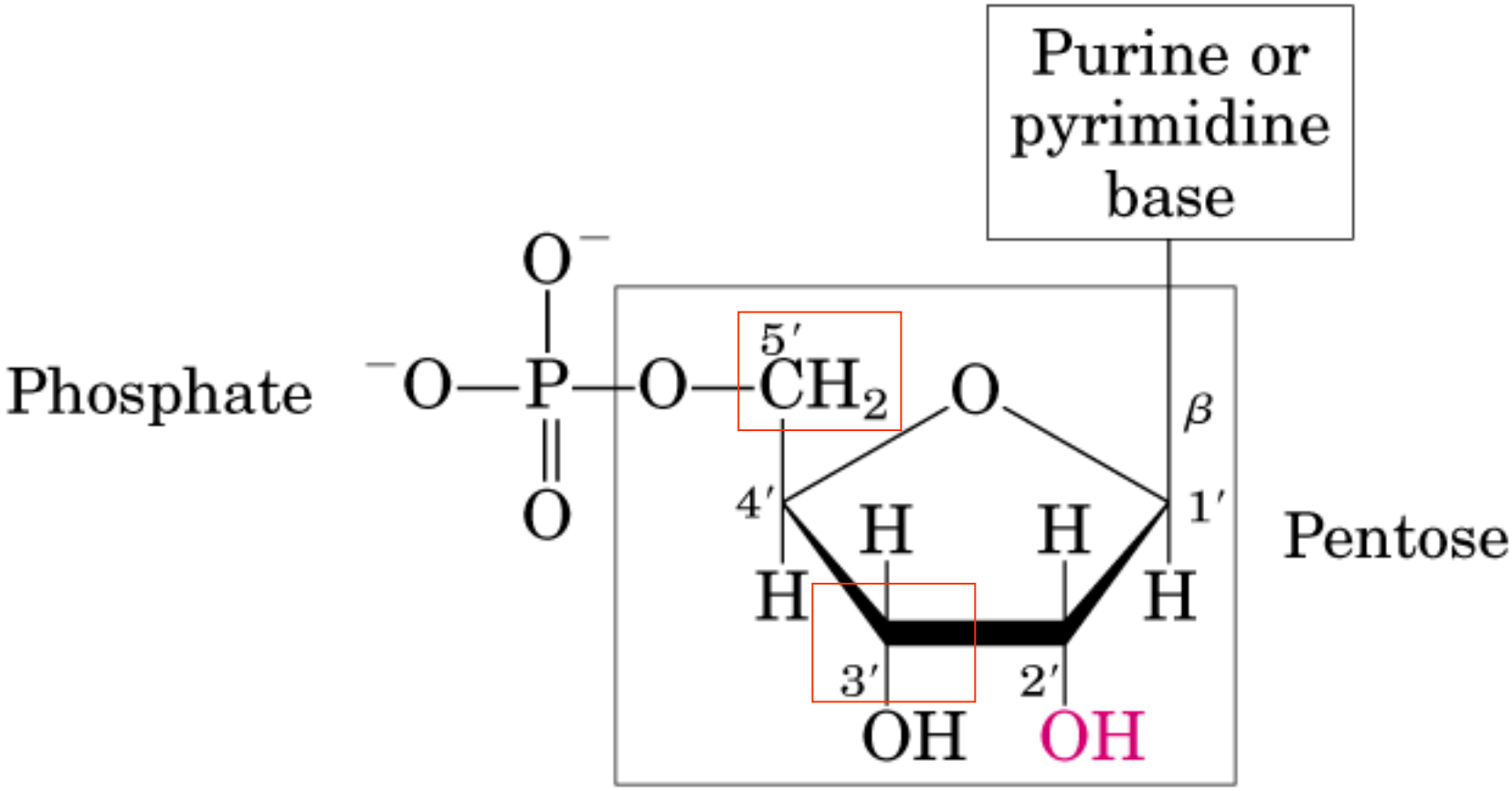
Are nucleic acids charged molecules?





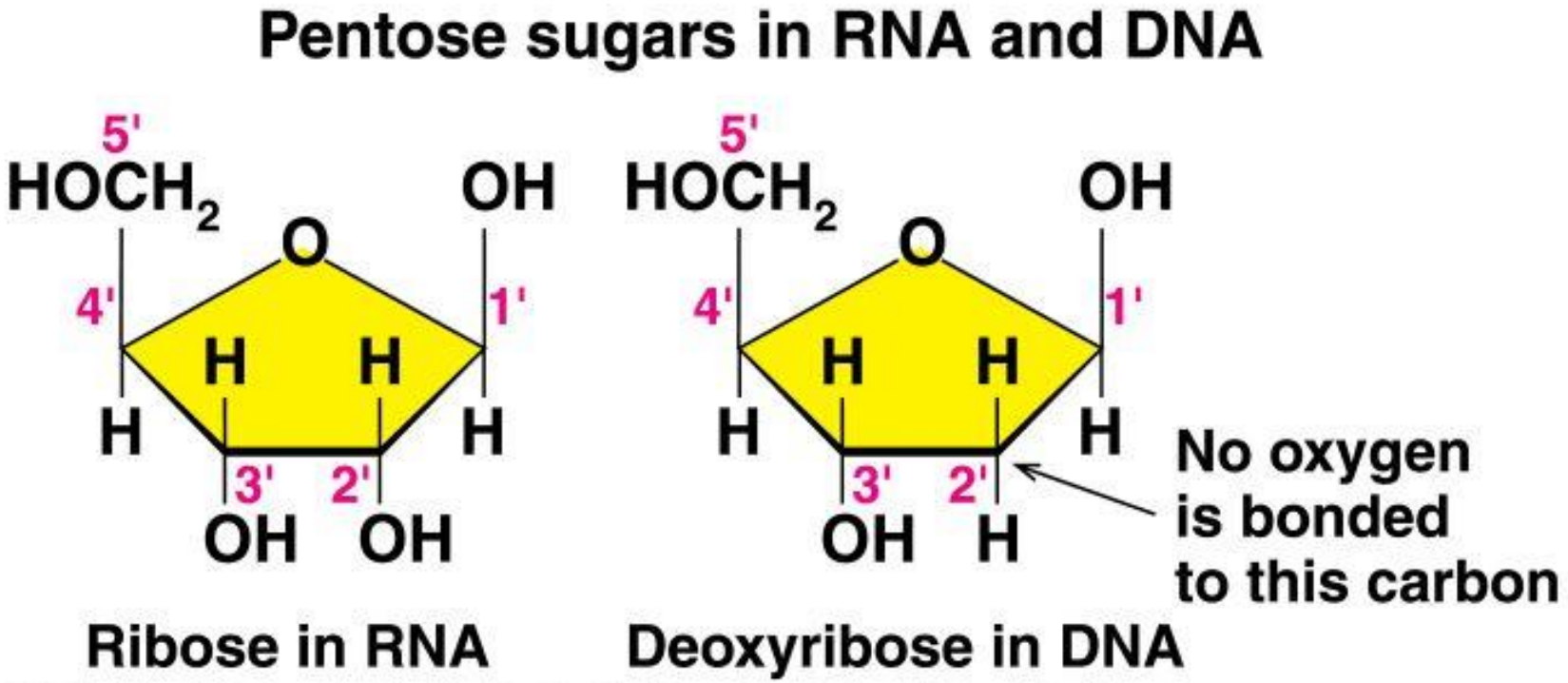
Chemical Structure of DNA vs RNA

Ribonucleotides have a 2'-OH
Deoxyribonucleotides have a 2'-H



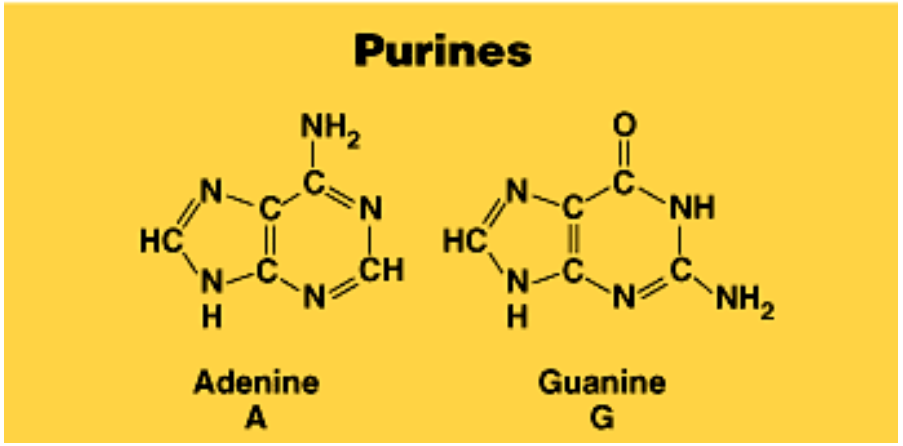
Pentose Sugars

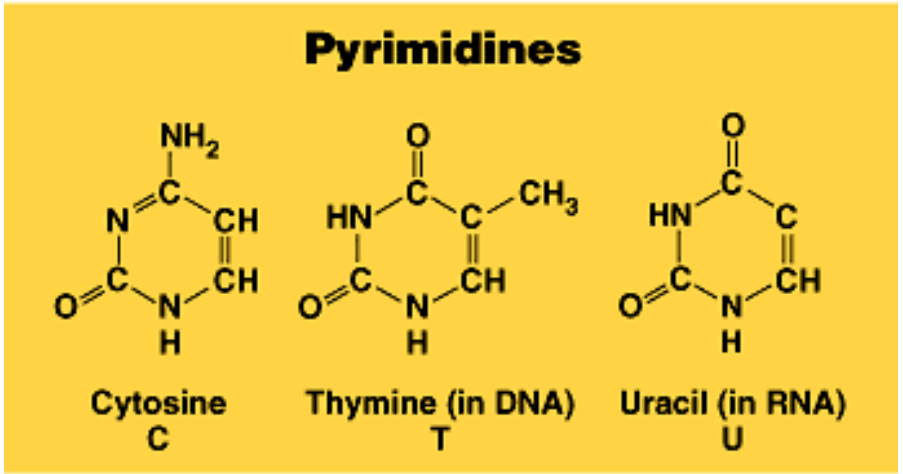
- There are two related pentose sugars:
  - RNA contains ribose
  - DNA contains deoxyribose
- The sugars have their carbon atoms numbered with primes to distinguish them from the nitrogen bases



Types of nucleotides

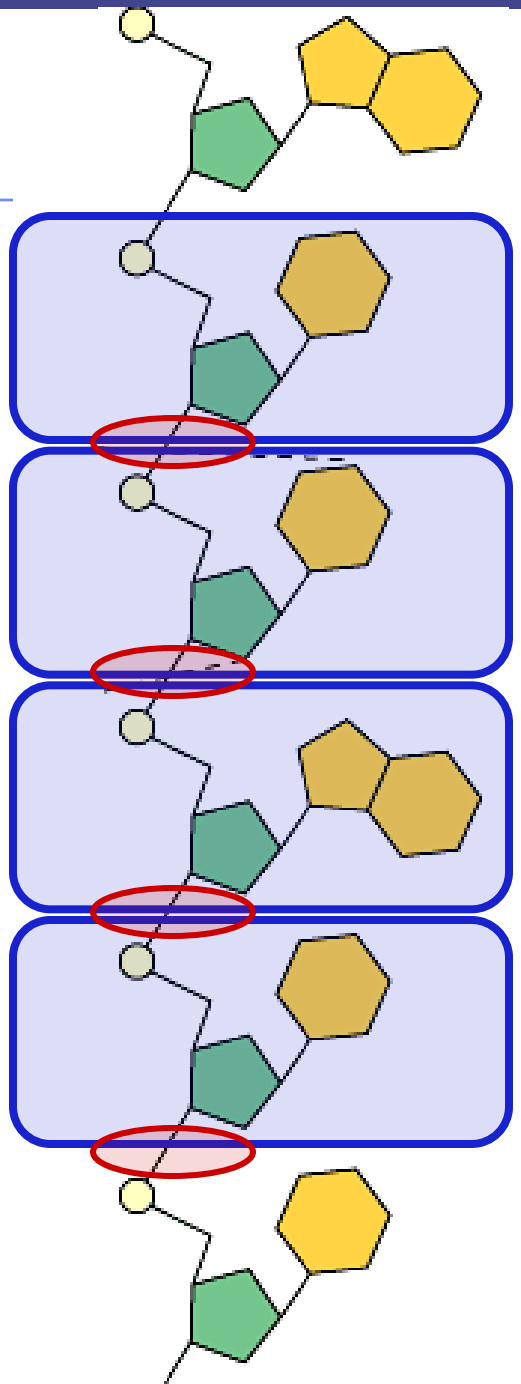
- 2 types [have different N bases]
  1. purines
     - double ring N base
     - adenine (A)
     - guanine (G)
  2. pyrimidines
     - single ring N base
     - cytosine (C)
     - thymine (T)
     - uracil (U)





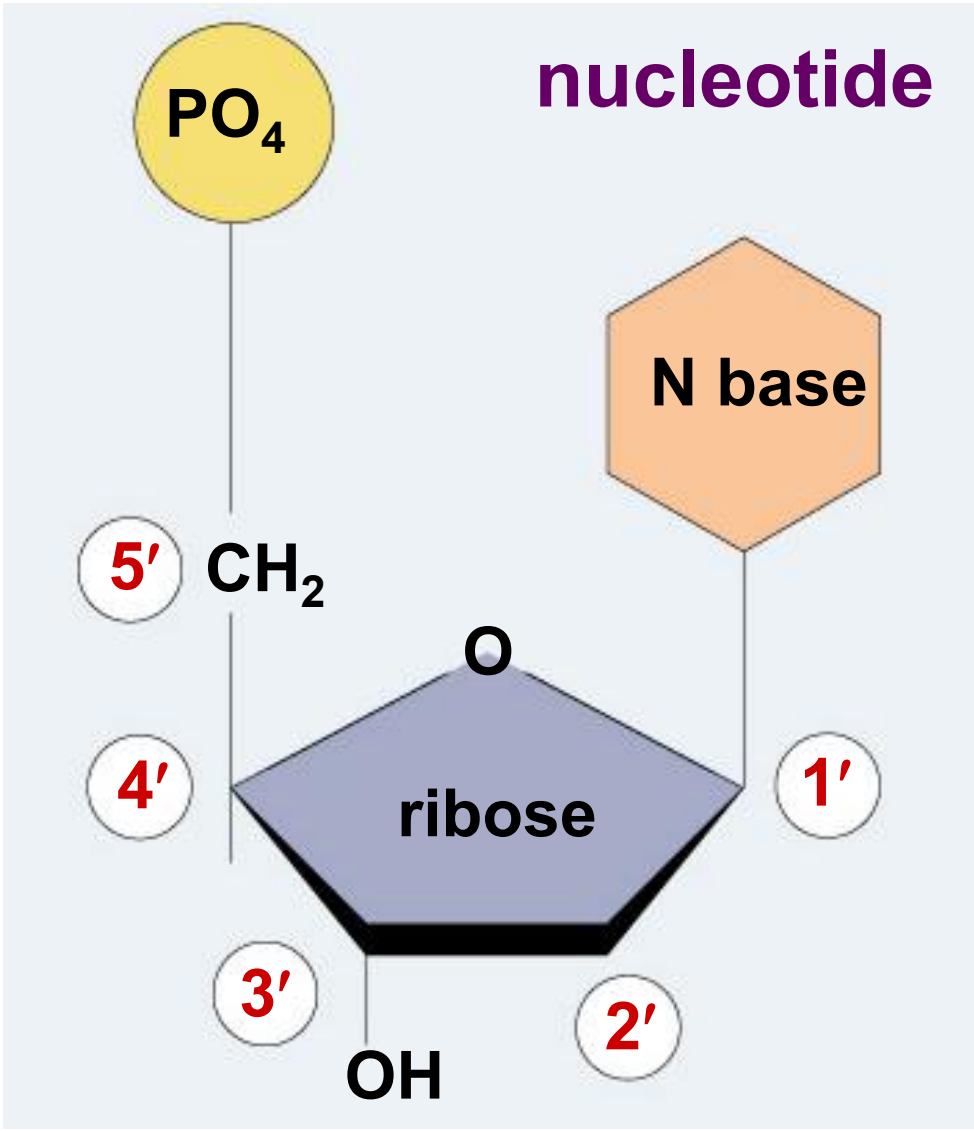
Nucleic polymer

- **Backbone**
  - sugar to PO_4 bond
  - **phosphodiester bond**
    - new base added to sugar of previous base
    - polymer grows in one direction
  - N bases hang off the sugar-phosphate backbone



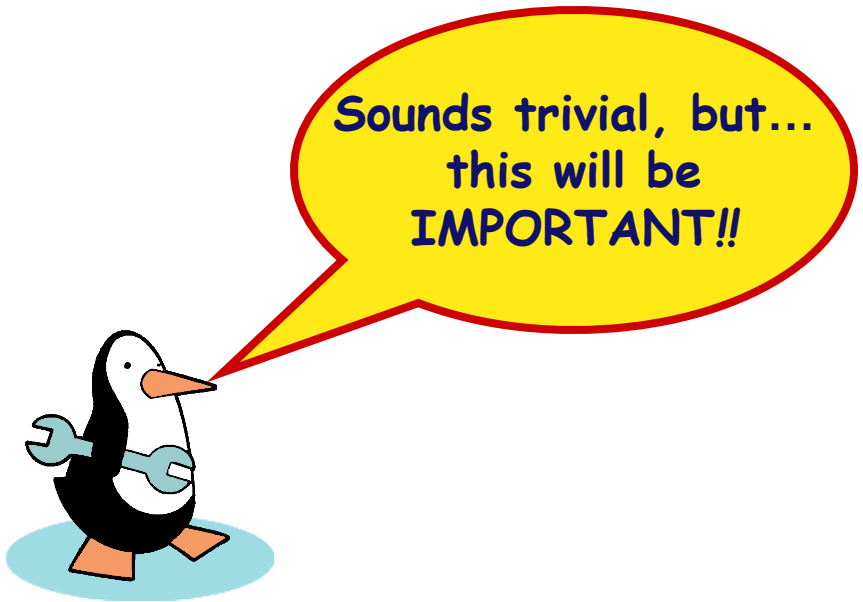
Directionality of DNA

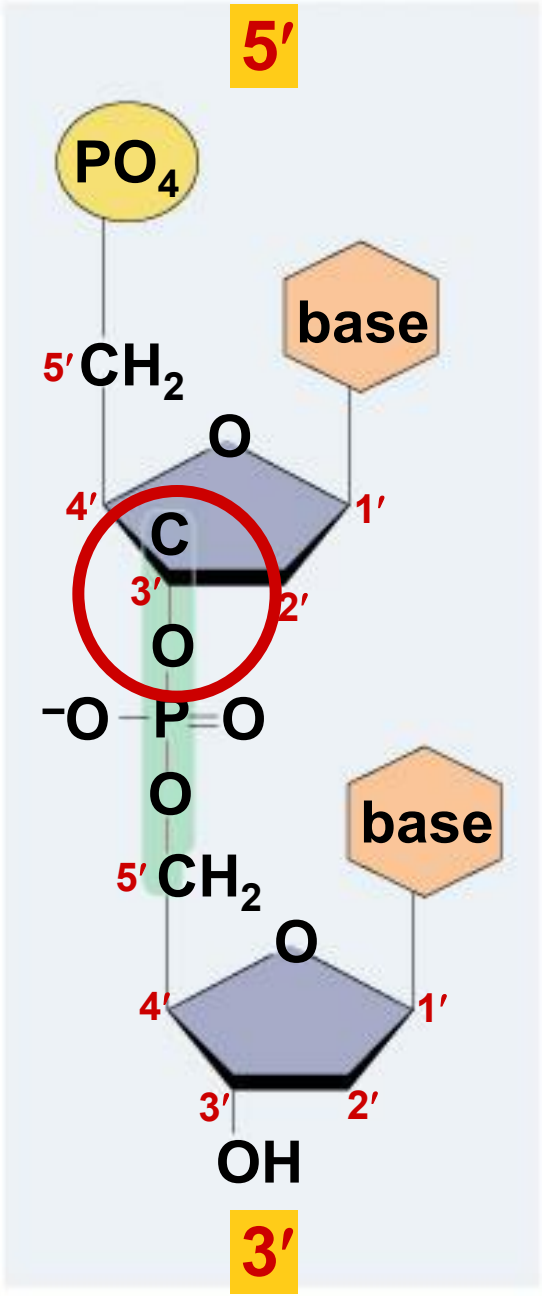
- You need to number the carbons!
  - it matters!



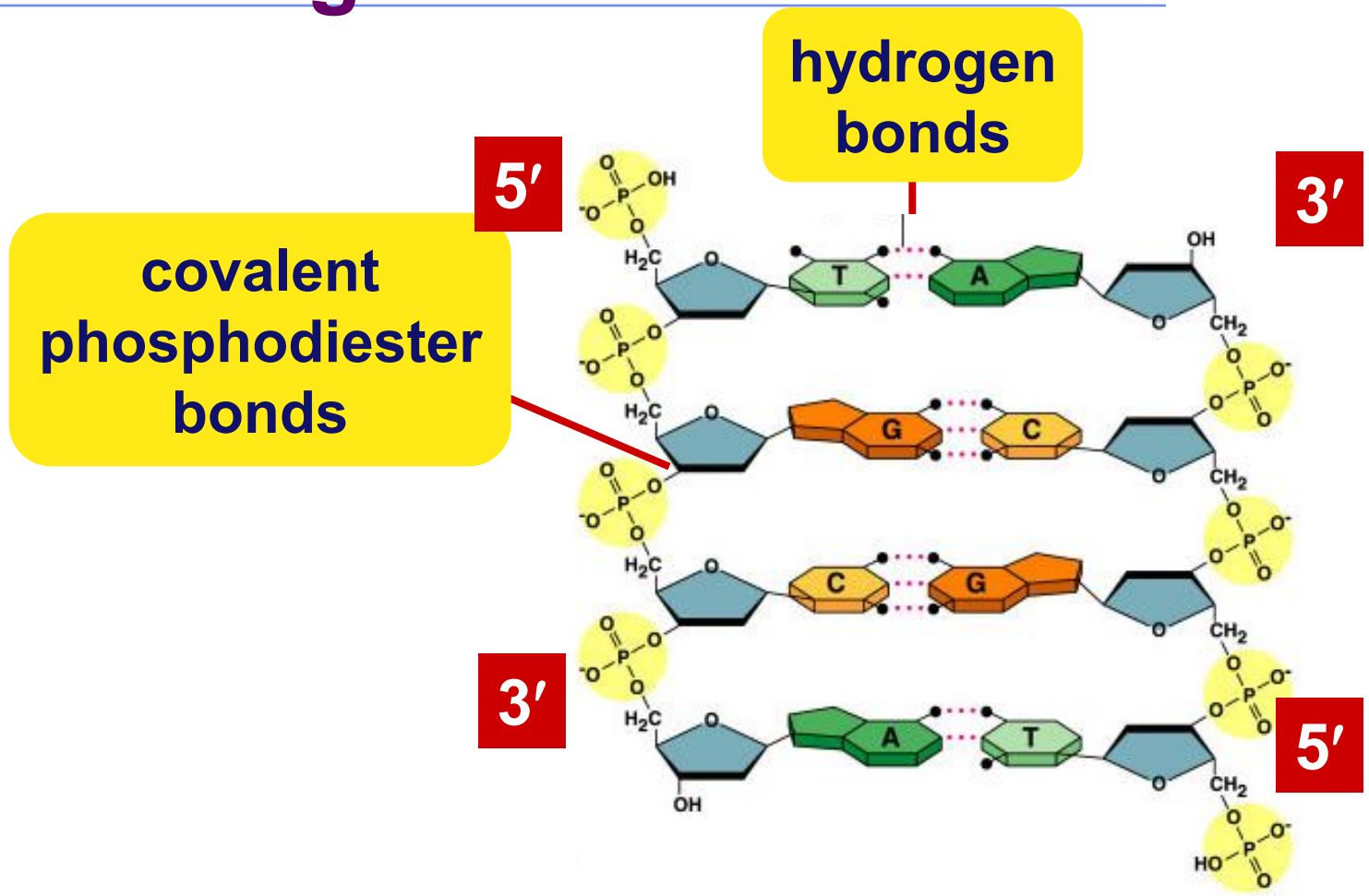
The DNA backbone

- Putting the DNA backbone together
  - refer to the 3′ and 5′ ends of the DNA
    - the last trailing carbon





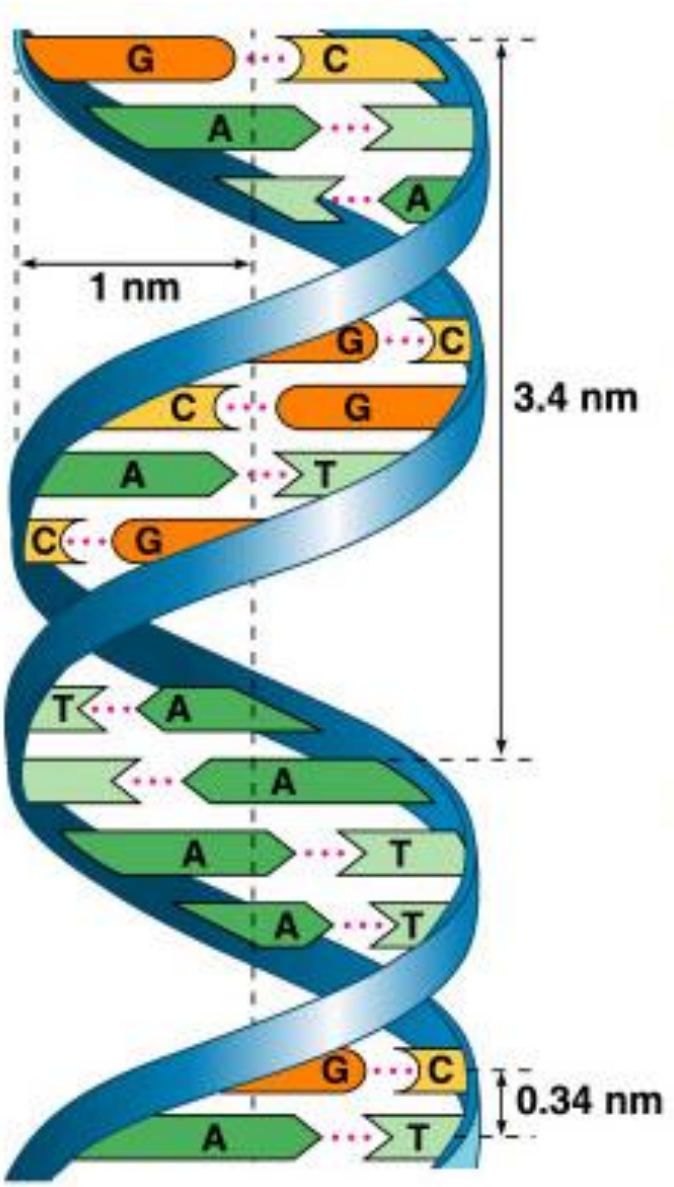
Bonding in DNA



….strong or weak bonds? Why?
Remember Hydrogen Bonds A-T (2) and C-G (3)

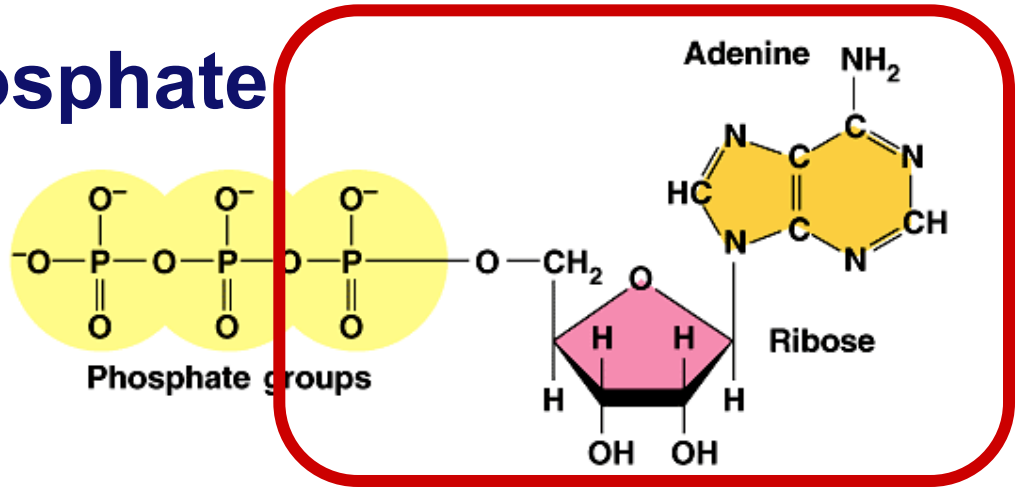
DNA molecule

- Shape:
- Double helix
  - H bonds between bases join the 2 strands
    - A :: T
    - C :: G

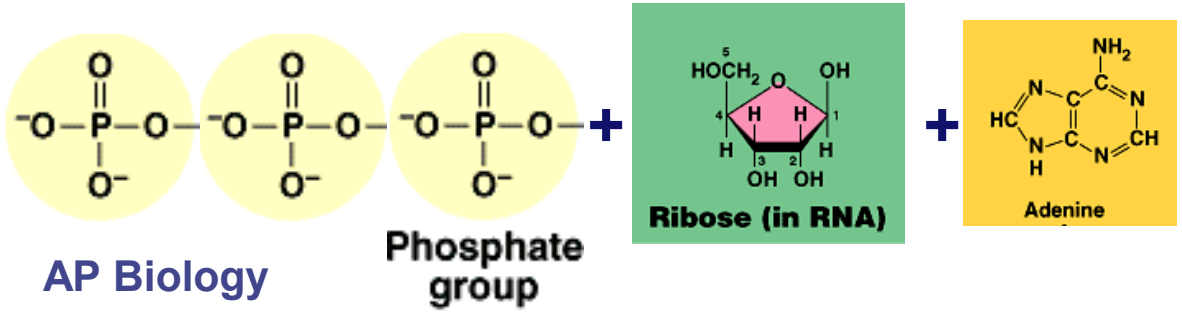


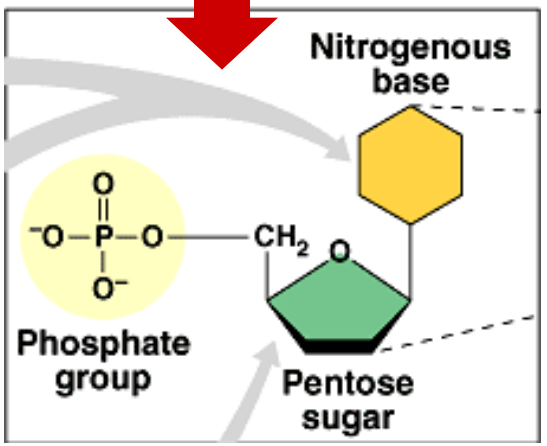
Another interesting note…

- **ATP**
  Adenosine triphosphate



- **modified nucleotide**
  - **adenine (AMP) + P_i + P_i**

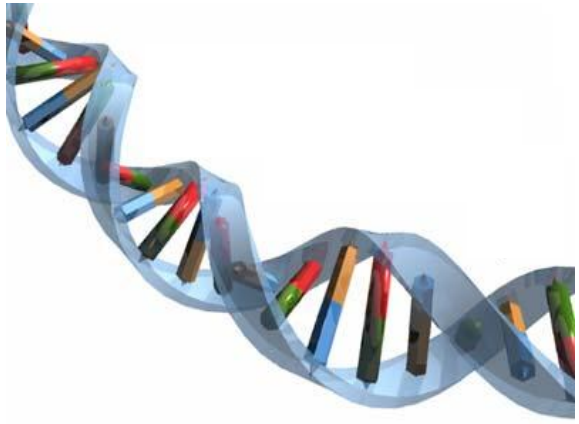




3 differences between DNA and RNA

DNA structure

- Has deoxyribose as a sugar
- Double strand – double helix
- Has thymine as a base

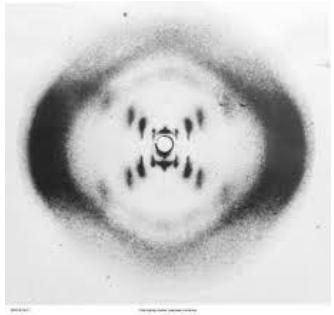


RNA structure

- Has ribose as a sugar instead of deoxyribose
- Is generally single-stranded
- Has uracil instead of thymine

Scientists:

- Erwin Chargaff – studied amounts of nitrogenous bases in DNA (base pair rule)
- Rosalind Franklin – 1952 – X-ray diffraction to get pattern from structure of DNA - Responsible for the molecular structure
- James Watson & Francis Crick – 1953 – published model and paper on DNA structure as a double helix



Nucleotide Function

1- Building blocks for DNA and RNA

2- Intracellular source of energy - Adenosine triphosphate (ATP)

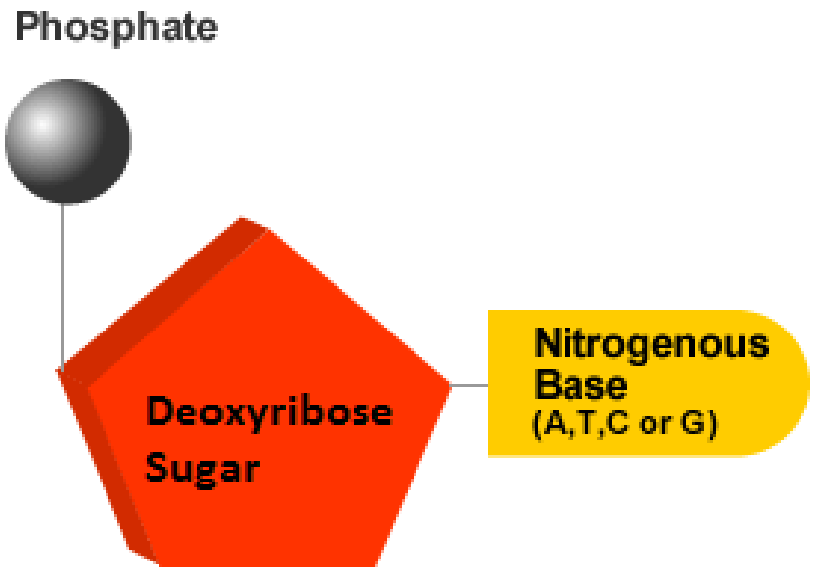
3- Second messengers - Involved in intracellular signaling (e.g. cyclic adenosine monophosphate [cAMP])

4- Intracellular signaling switches (e.g. G-proteins)

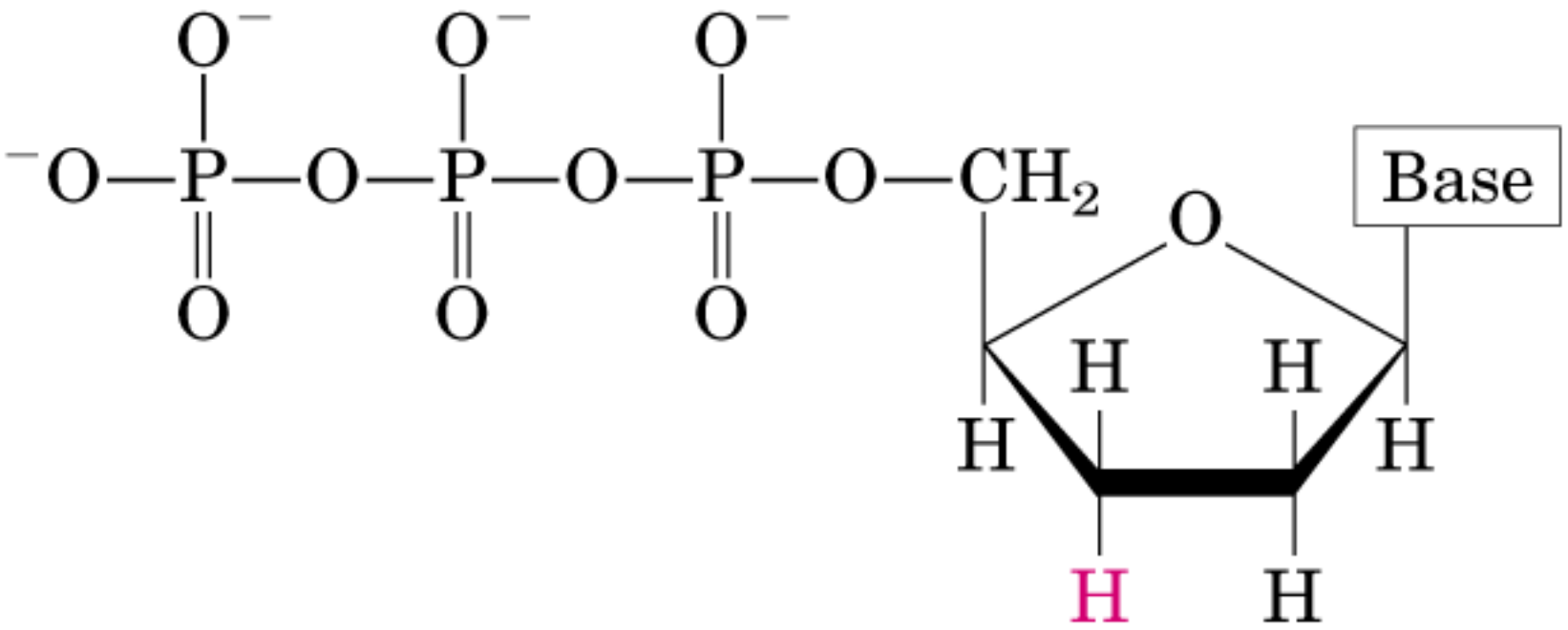
- It is the order of these **base pairs** that determines **genetic makeup**

- One **phosphate** + one **sugar** + one **base** = one **nucleotide**

- Nucleotides are the **building blocks** of DNA – thus, each strand of DNA is a string of **nucleotides**



Sanger dideoxy sequencing incorporates dideoxy nucleotides, preventing further synthesis of the DNA strand



ddNTP analog

base（purine、pyrimdine）+ribose（deoxyribos

N-glycosyl linkage

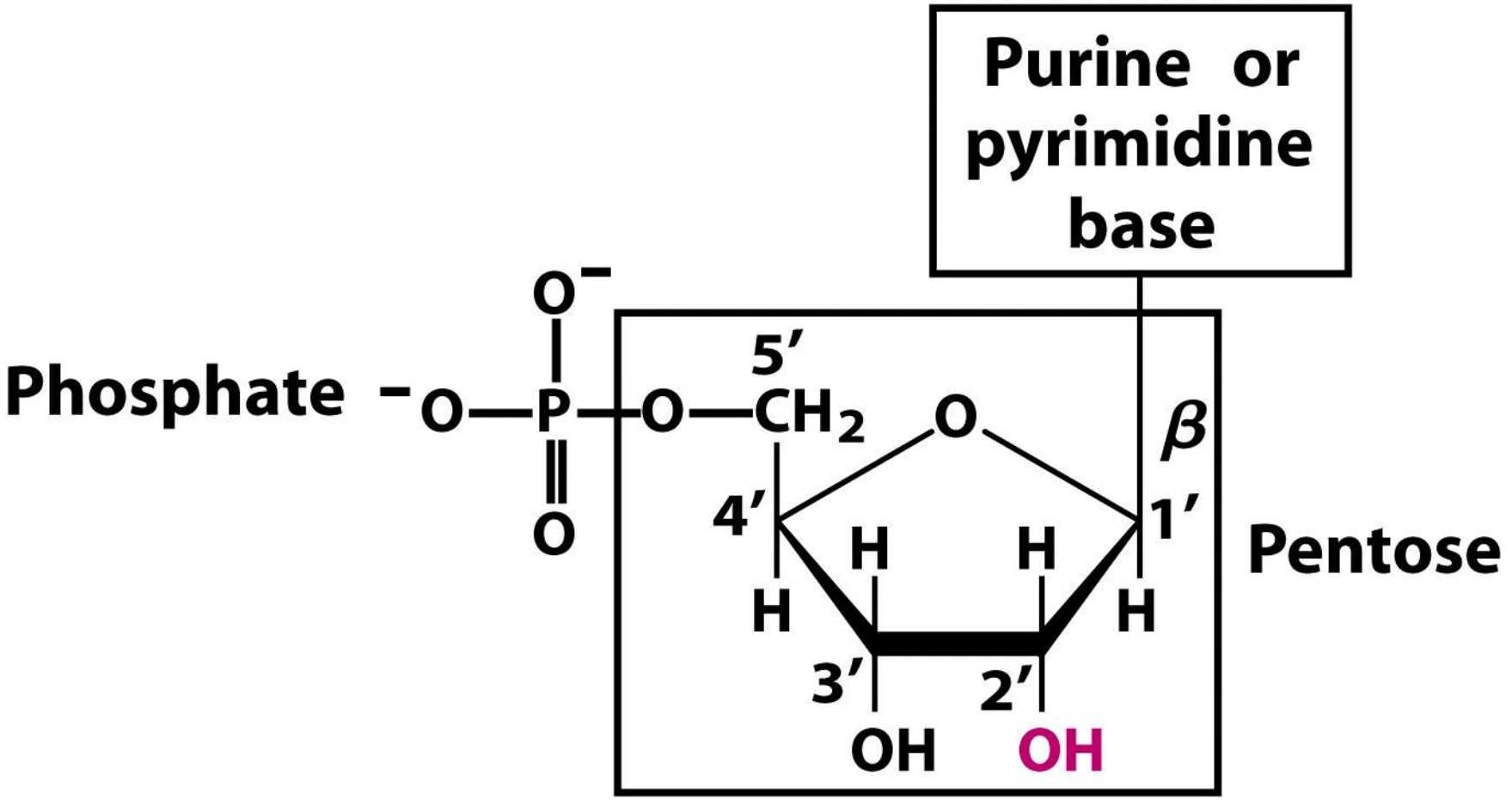
nucleoside+phosphate

phosphoester linkage

nucleotide

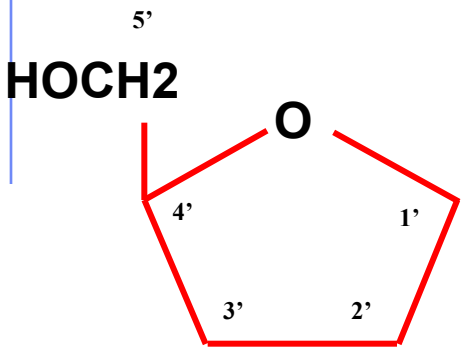
phosphodiester linkage

nucleic acid

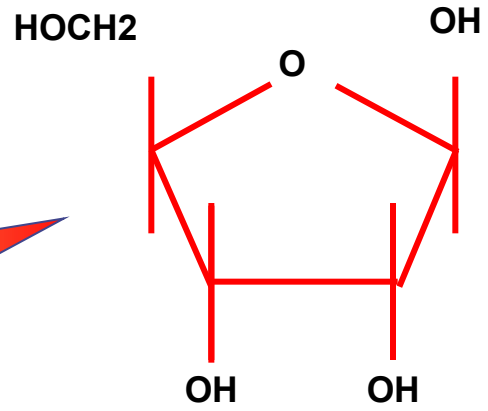

Purine or pyrimidine base
Phosphate
O⁻
O
P
O
O
5′
CH2
O
β
4′
1′
H
H
H
H
3′
2′
OH
OH
Pentose

Nucleotide Structure - 1
Sugars

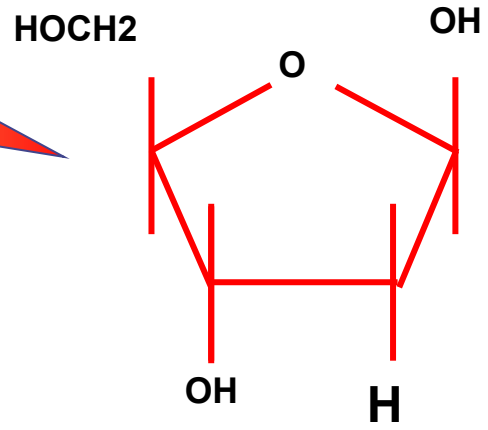
Generic Ribose Structure



Ribose



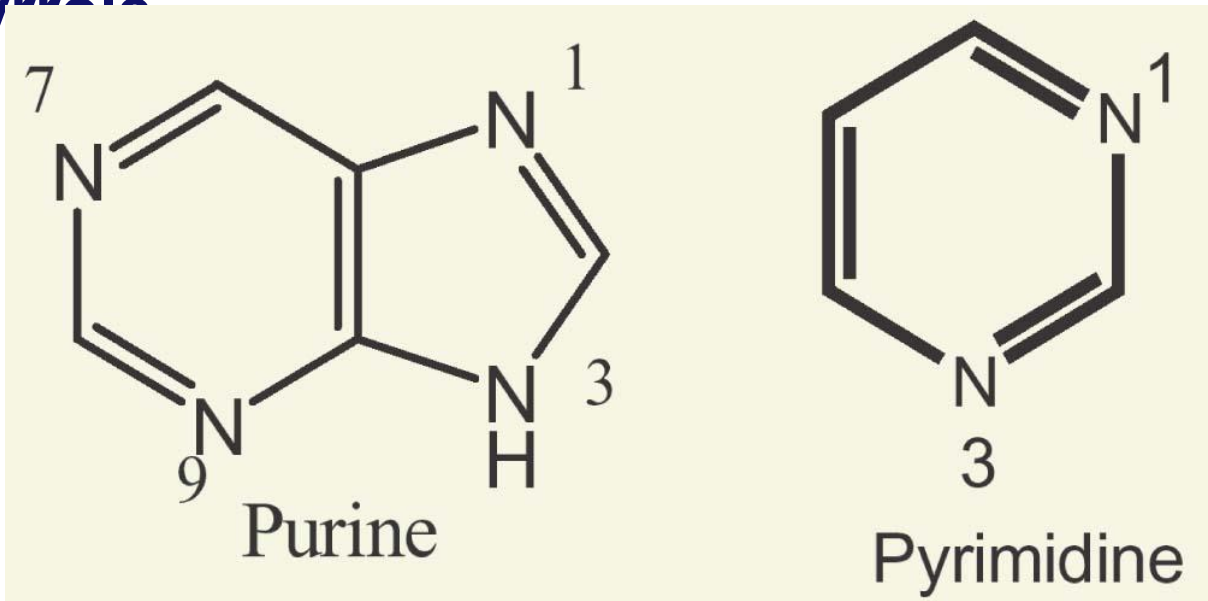
Deoxyribose



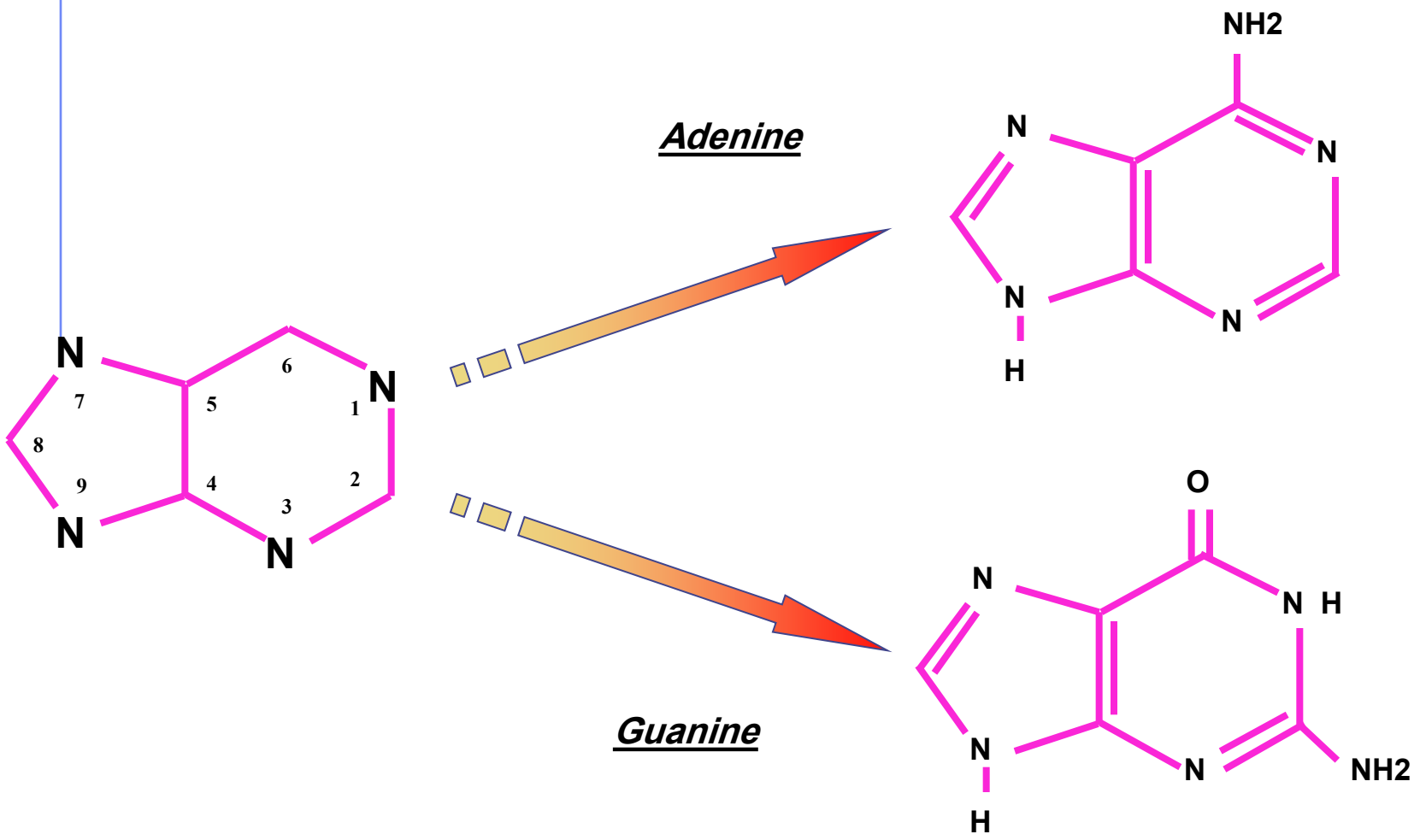
N.B. Carbons are given numberings as a prime

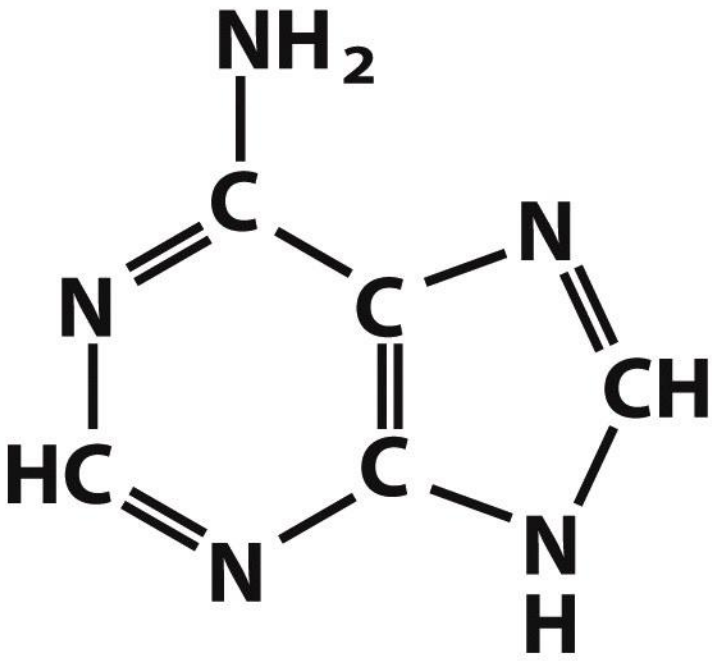
Purine and Pyrimidine

- Pyrimidine contains two pyridine-like nitrogens in a six-membered aromatic ring
- Purine has 4 N's in a fused-ring structure. Three are basic like pyridine-like and one is like that in pyrrole

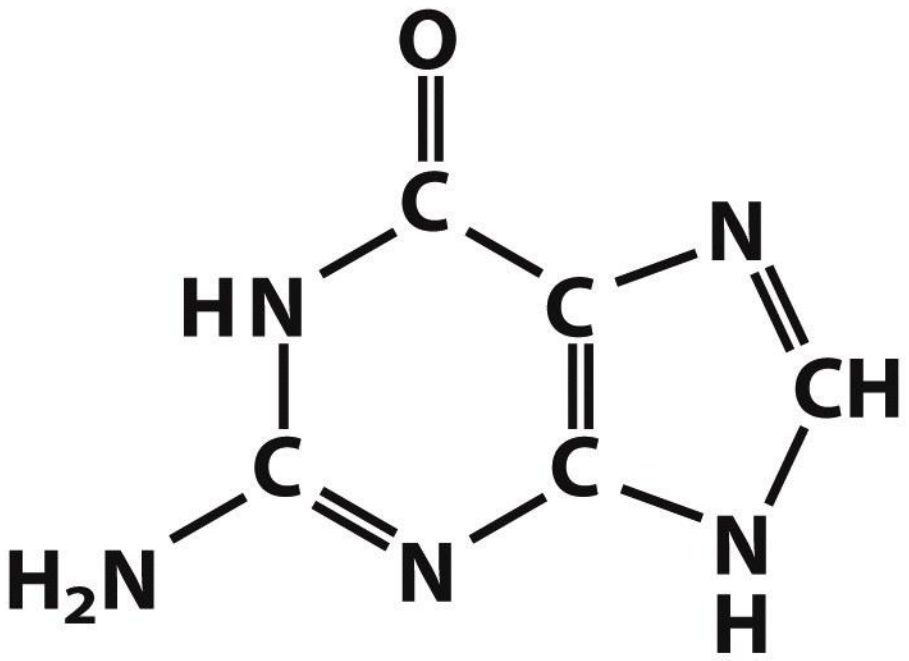


Nucleotide Structure - 2
Bases - Purines





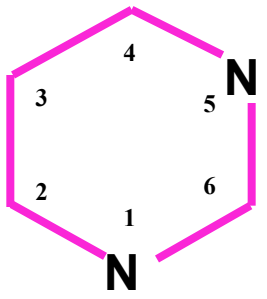
Adenine



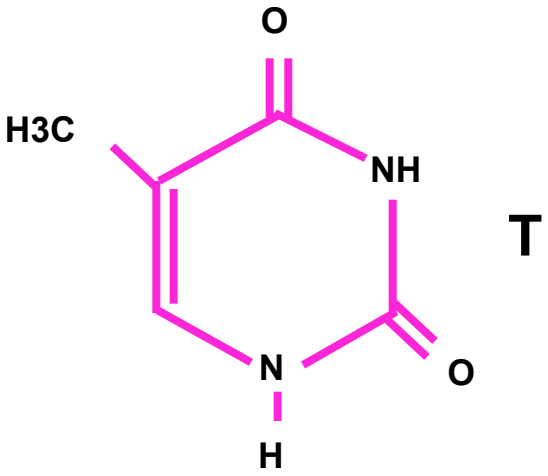
Guanine

Purines

Nucleotide Structure - 3
Bases - Pyrimidines

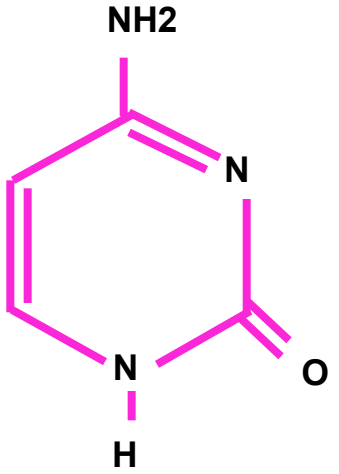


Thymine



T

Cytosine



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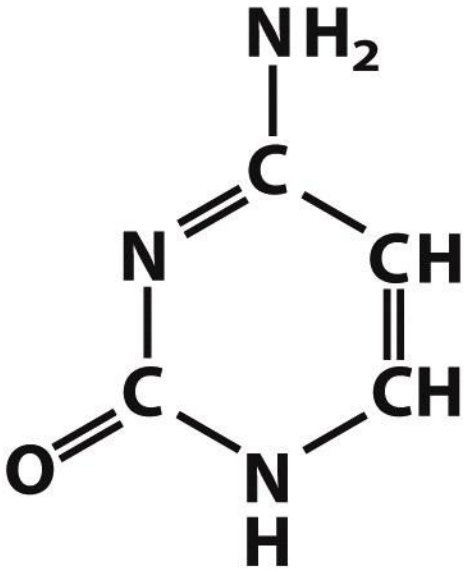
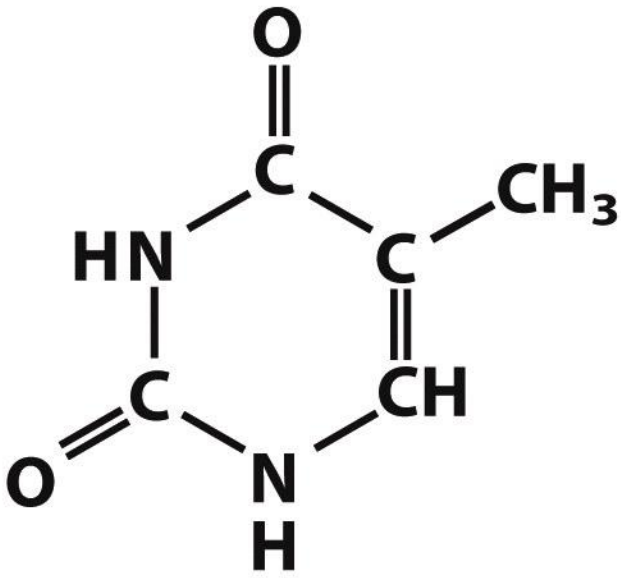
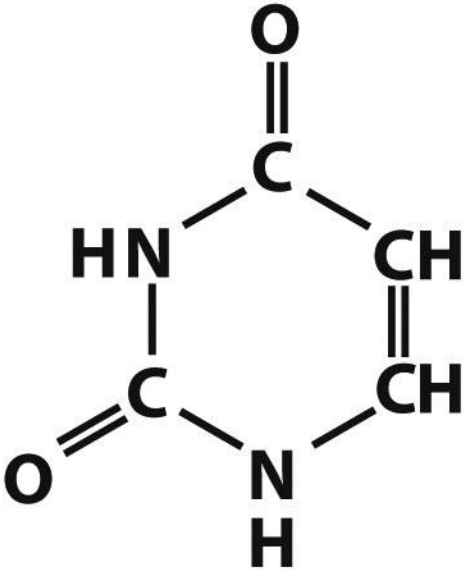


Cytosine

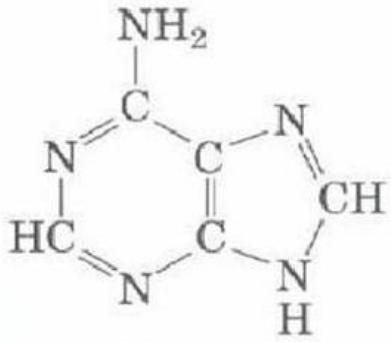


Thymine
(DNA)

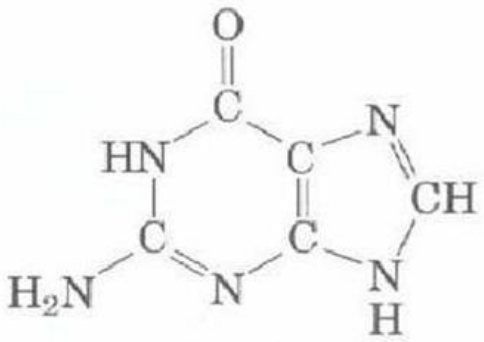


Uracil
(RNA)

Pyrimidines

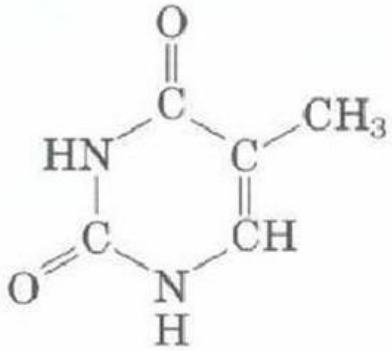


Adenine

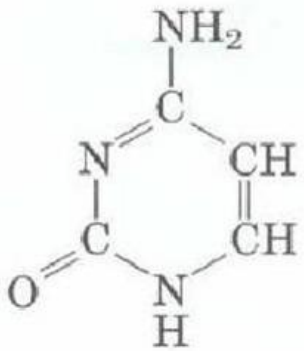


Guanine

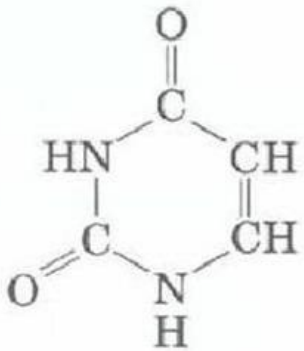
Purines



Thymine
(DNA)



Cytosine



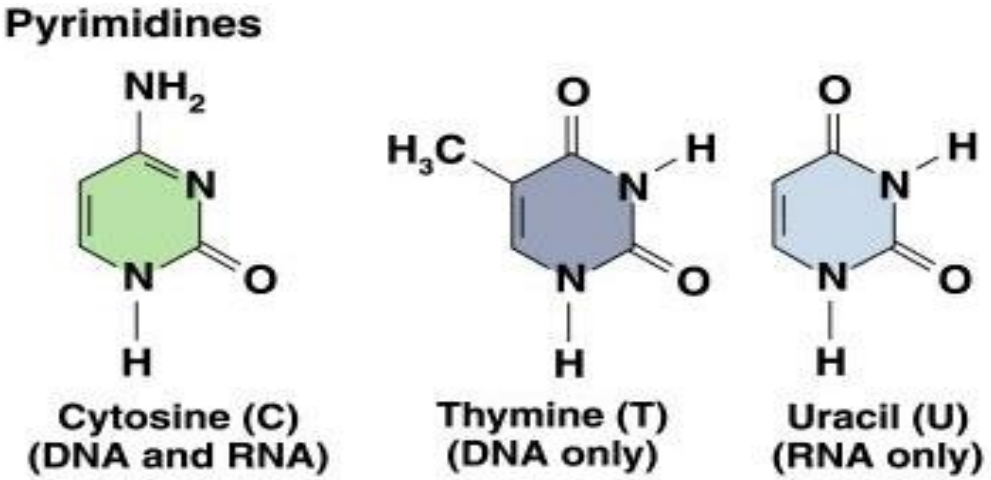
Uracil
(RNA)

Pyrimidines

Nitrogen Bases

- The nitrogen bases in nucleotides consist of two general types:

  - purines: adenine (A) and guanine (G)
  - pyrimidines: cytosine (C), thymine (T) and Uracil (U)

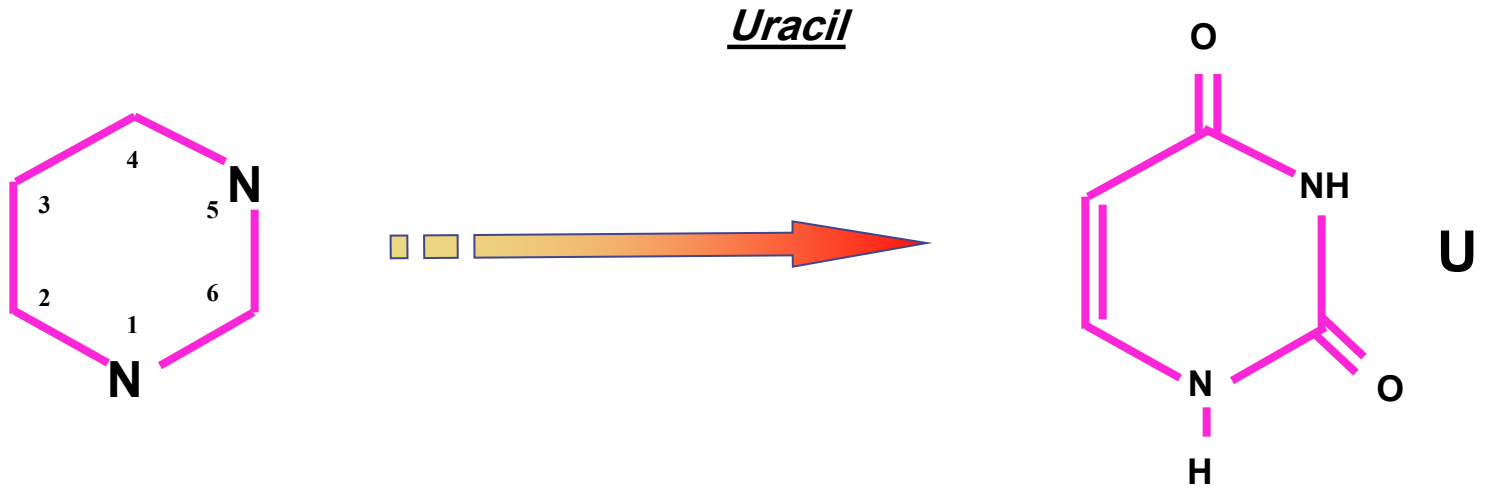


Nucleotide Structure - 4
Bases - Pyrimidines

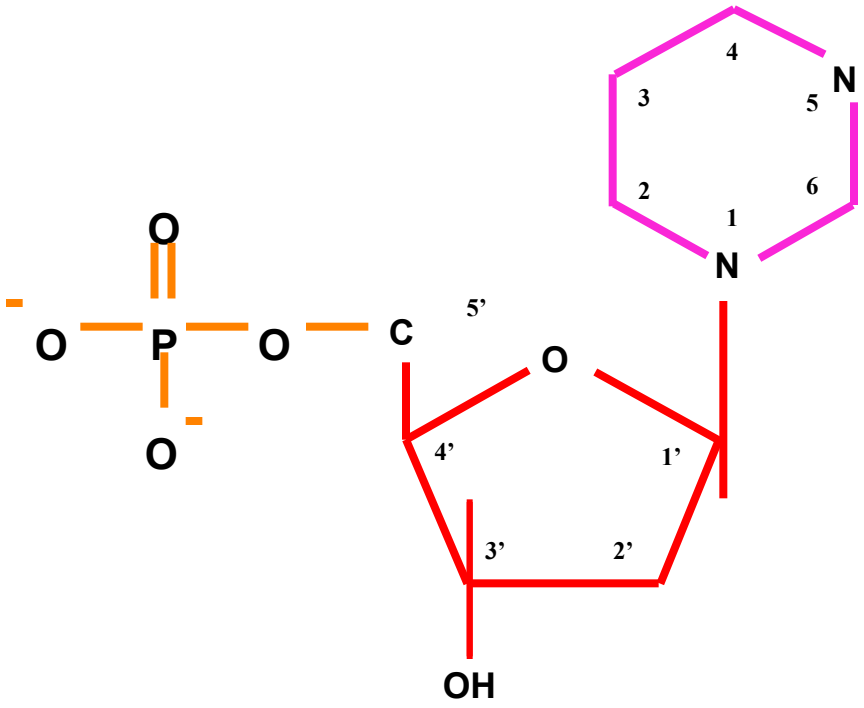
Thymine is found ONLY in DNA.

In RNA, thymine is replaced by uracil

Uracil and Thymine are structurally similar



Nucleotide Structure - 4
Base-Sugar-PO4



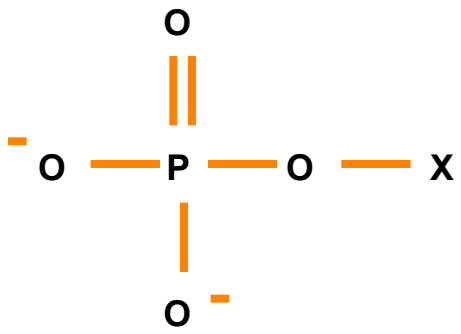
Monophosphate

Nucleotide Structure - 4
Phosphate Groups

Phosphate groups are what makes a nucleoside a nucleotide

Phosphate groups are essential for nucleotide polymerization

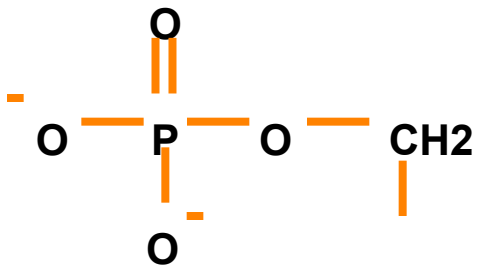
Basic structure:



Nucleotide Structure - 4
Phosphate Groups

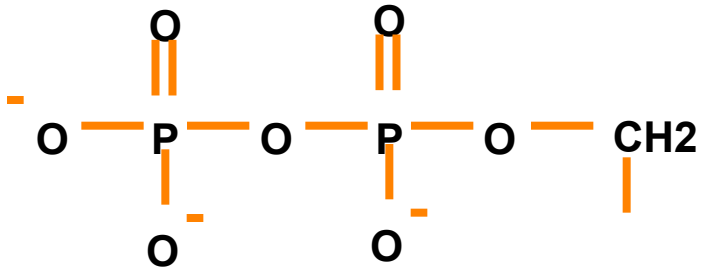
Number of phosphate groups determines nomenclature

Monophosphate
e.g. AMP



Free = inorganic phosphate
(Pi)

Diphosphate
e.g. ADP

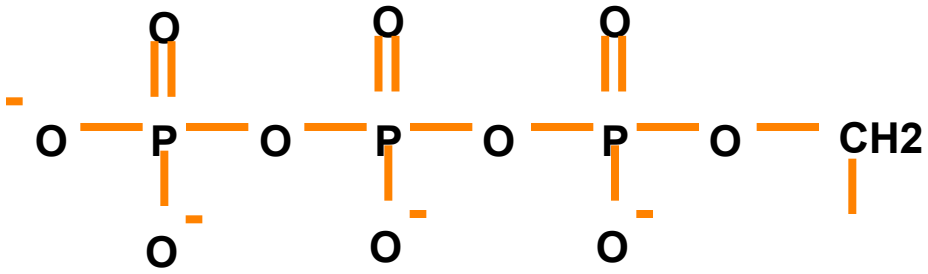


Free = Pyro- phosphate
(PPi)

Nucleotide Structure - 4
Phosphate Groups

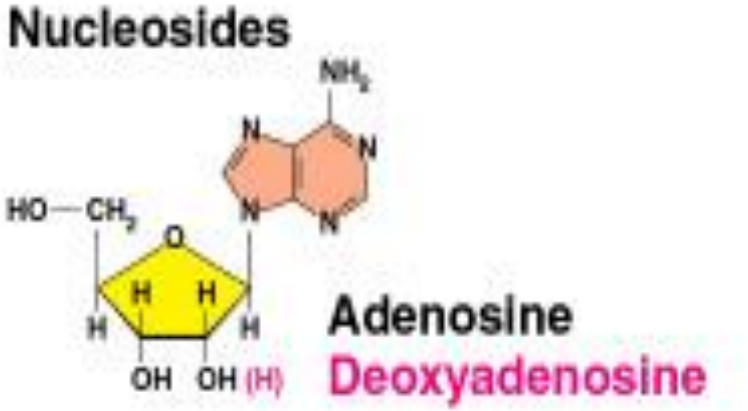
Triphosphate
e.g. ATP

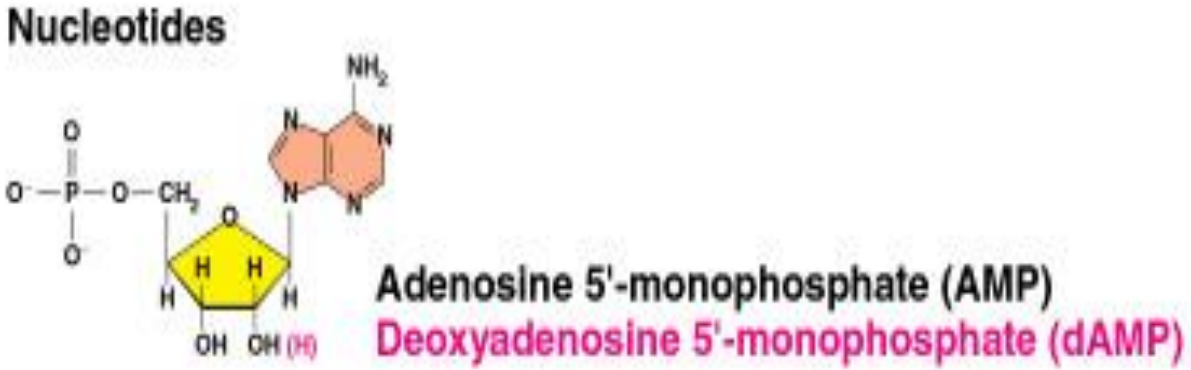
No Free form exists



Nucleosides and Nucleotides

- A nucleoside consists of a nitrogen base linked by a glycosidic bond to C1' of a ribose or deoxyribose
- Nucleosides are named by changing the the nitrogen base ending to *-osine* for purines and *–idine* for pyrimidines
- A nucleotide is a nucleoside that forms a phosphate ester with the C5' OH group of ribose or deoxyribose
- Nucleotides are named using t nucleoside followed by *5'-mon*



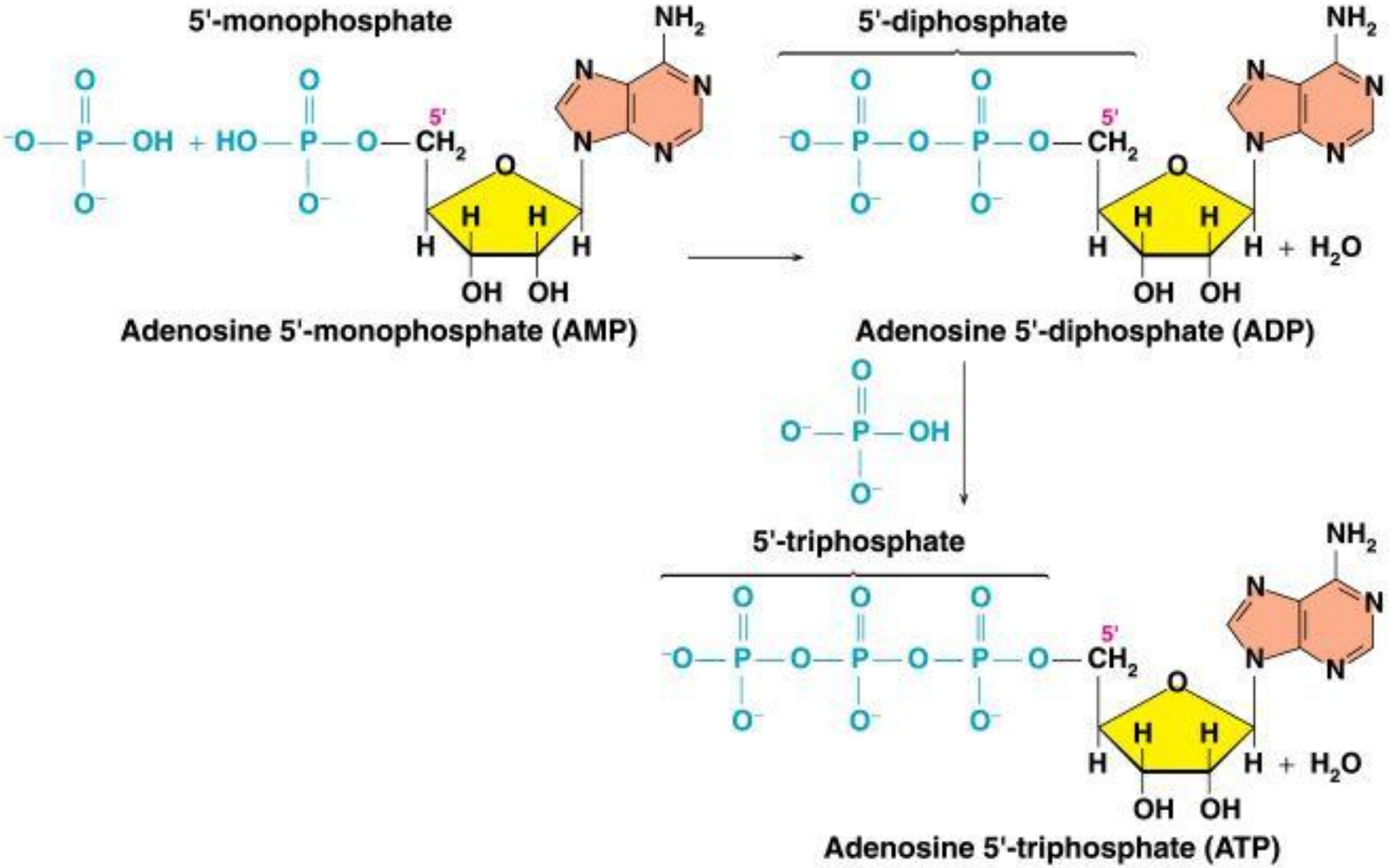


Names of Nucleosides and Nucleotides

Base	Nucleosides	Nucleotides
RNA		
Adenine (A)	Adenosine (A)	Adenosine 5'-monophosphate (AMP)
Guanine (G)	Guanosine (G)	Guanosine 5'-monophosphate (GMP)
Cytosine (C)	Cytidine (C)	Cytidine 5'-monophosphate (CMP)
Uracil (U)	Uridine (U)	Uridine 5'-monophosphate (UMP)
DNA		
Adenine (A)	Deoxyadenosine (A)	Deoxyadenosine 5'-monophosphate (dAMP)
Guanine (G)	Deoxyguanosine (G)	Deoxyguanosine 5'-monophosphate (dGMP)
Cytosine (C)	Deoxycytidine (C)	Deoxycytidine 5'-monophosphate (dCMP)
Thymine (T)	Deoxythymidine (T)	Deoxythymidine 5'-monophosphate (dTMP)

AMP, ADP and ATP

- Additional phosphate groups can be added to the nucleoside 5’-monophosphates to form diphosphates and triphosphates
- ATP is the major energy source for cellular activity



Thank you