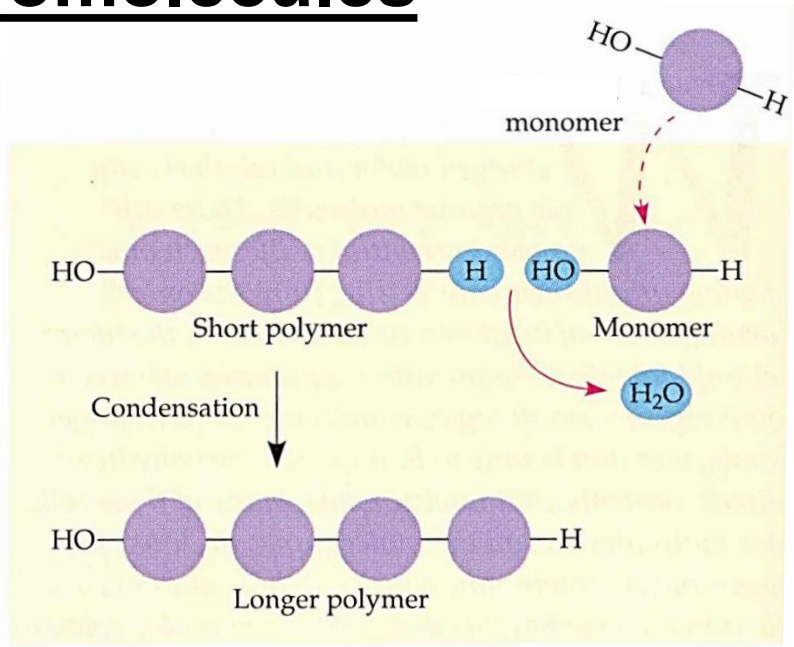
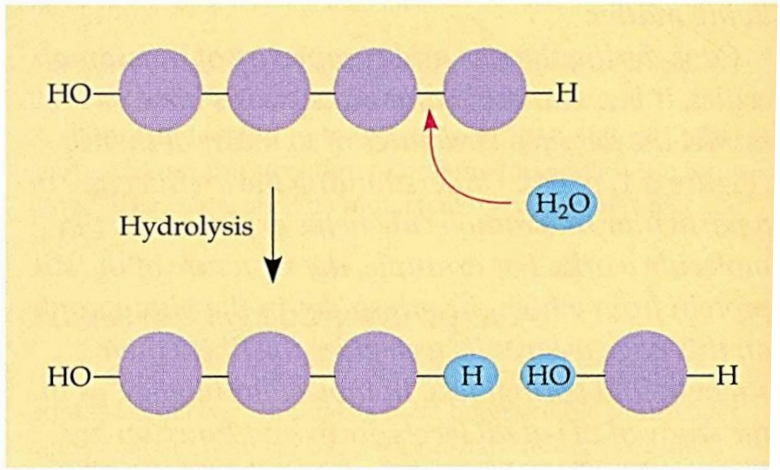
Biological Macromolecules

1. Nucleic acids (DNA, RNA)
2. Proteins
3. Lipids
4. Carbohydrates



(a) Condensation synthesis (dehydration) of a polymer



(b) Hydrolysis of a polymer

Nucleosides, nucleotides, nucleic acids

Nucleic acids:

1. deoxyribonucleic acid (DNA)
    Function: stores the genetic information

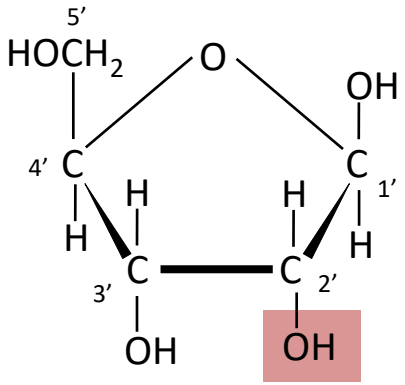
2., ribonucleic acid (RNA)
    Function: protein synthesis

The flow of genetic information (the central dogma)

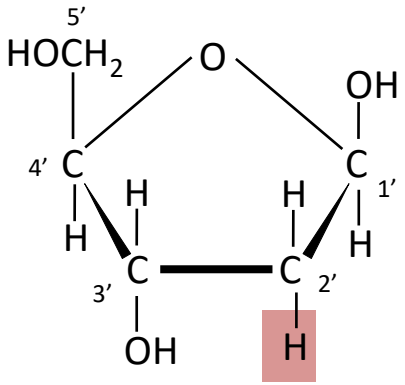
Nucleic acid, nucleotide

- Nucleic acids: polymers, composed of Nucleotides: polynucleotides
- Nucleotides have 3 components:
  1. sugar (pentose)
  2. Base
  3. Phosphate

1. Sugar: pentose



ribose



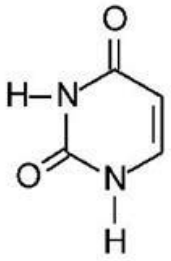
2-deoxyribose

the difference is on the 2’ carbon atom!
ribose: in RNA
deoxyribose: in DNA

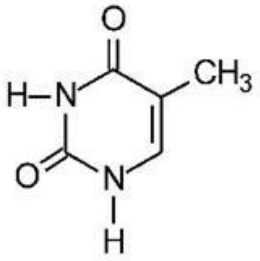
2. Base

- Heterocyclic compounds:
  - they contain nitrogen
  - ring structure (1 or 2)
  - DNA: A,G,C,T, RNA: A,G,C,U
  - the base is bound to the 1’ carbon atom of the pentose

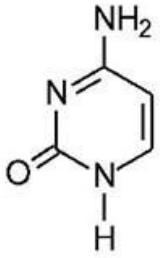
pyrimidines →



Uracil (U)

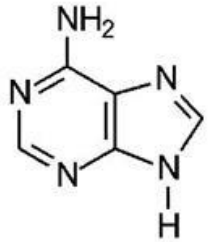


Thymine (T)

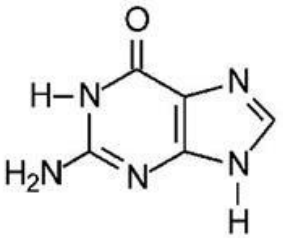


Cytosine (C)

purines →



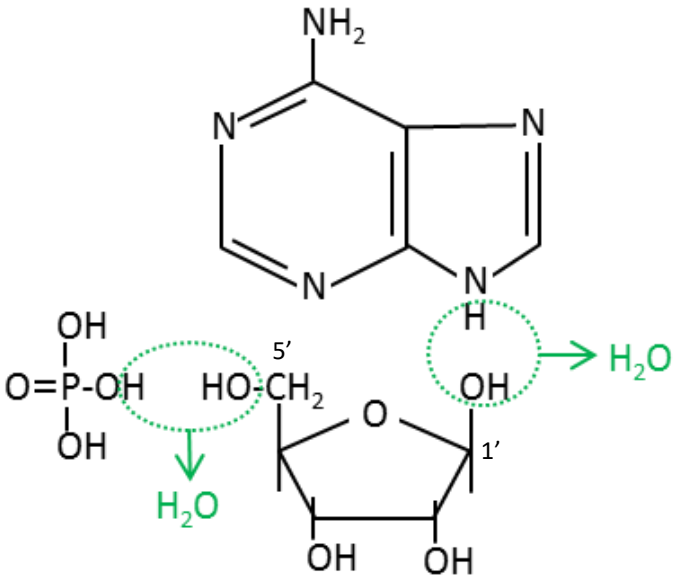
Adenine (A)



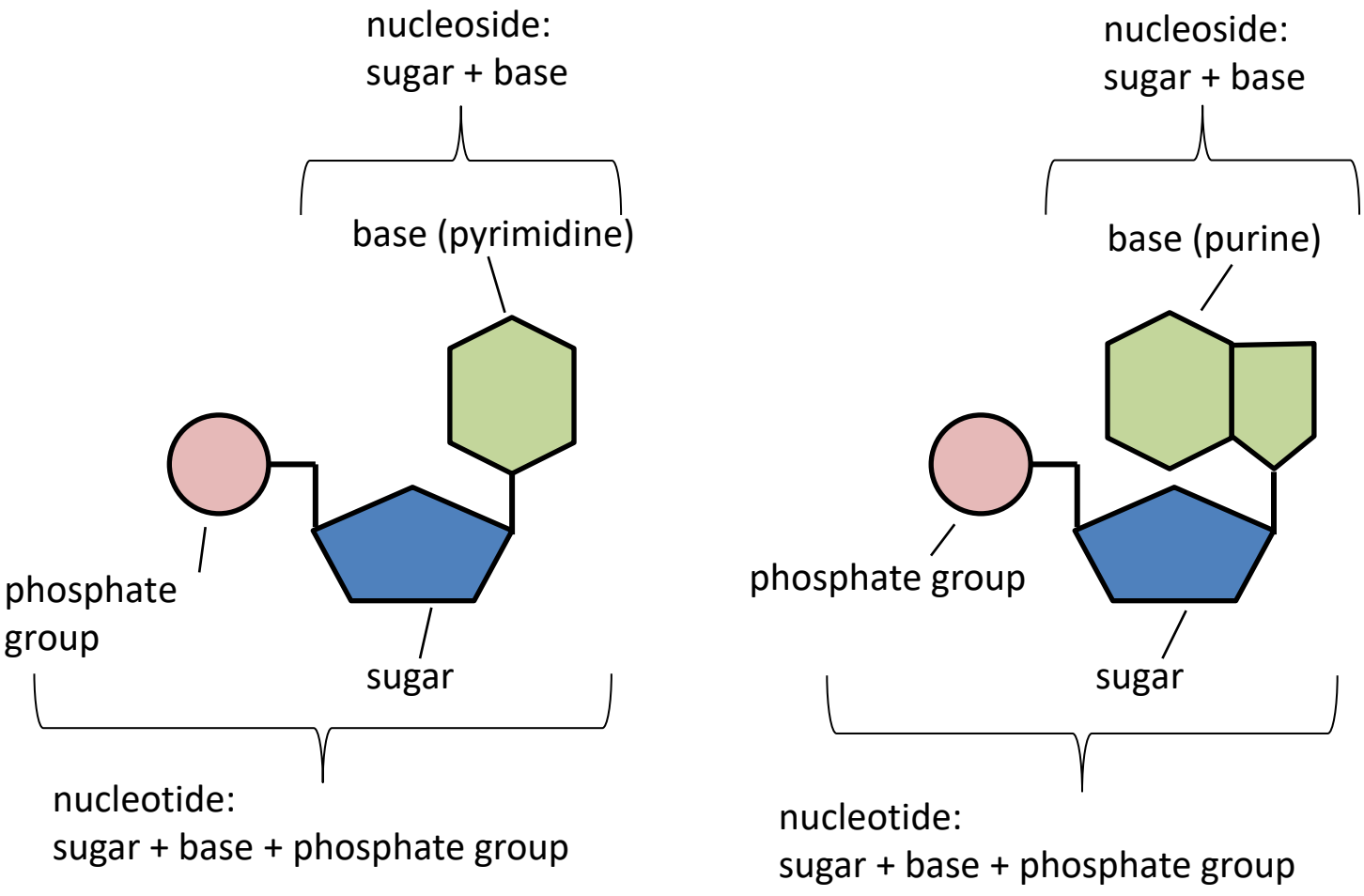
Guanine (G)

3. Phosphate

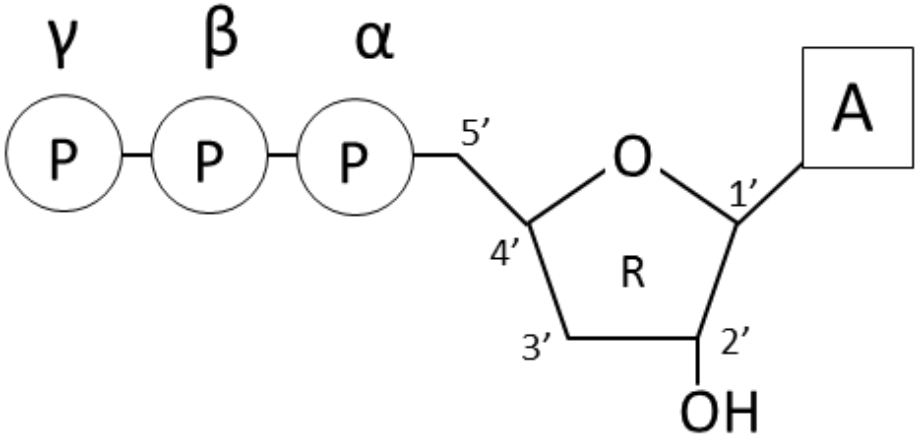
- Phosphate: from phosphoric acid
  - binds to the 5’ carbon of the pentose through a phosphoesterbond



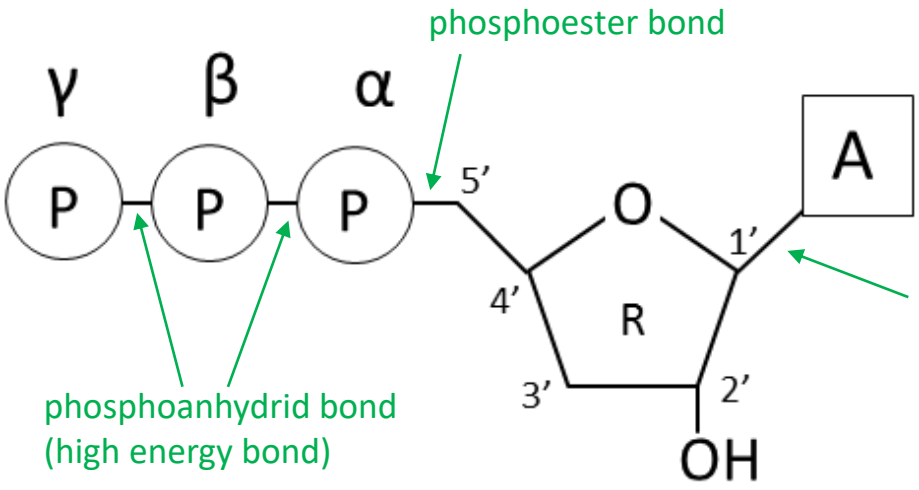
Nucleotide, Nucleoside



Nucleotide

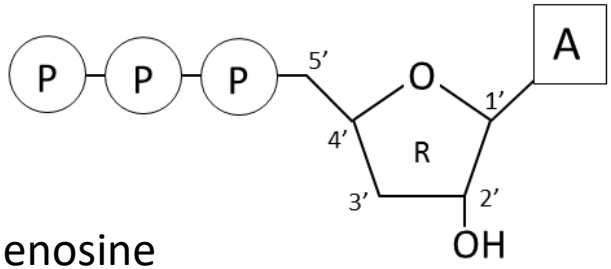


Nucleotide

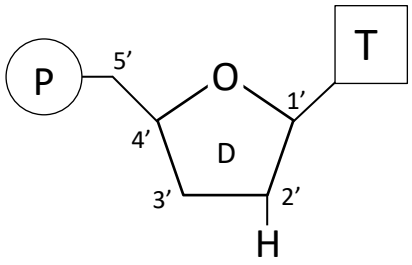

phosphoester bond
γ
β
α
P
P
P
5'
O
A
1'
4'
R
3'
2'
OH
phosphoanhydrid bond
(high energy bond)
glycosidic bond:
• to a nitrogen atom
of the base:
• 1'-1: pyrimidines
• 1'-9: purines

Nucleotide

- Naming of nucleotides: name of the nucleoside + phosphate groups (-monophosphate, -diphosphate, -triphosphate)
  - - Ribonucleosides:
    - Adenosine
    - Guanosine
    - Cytidine
    - Uridine
  - Deoxyribonukleosides:
    - Deoxyadenosine
    - Deoxyguanosine
    - Deoxycytidine
    - Deoxythimidine

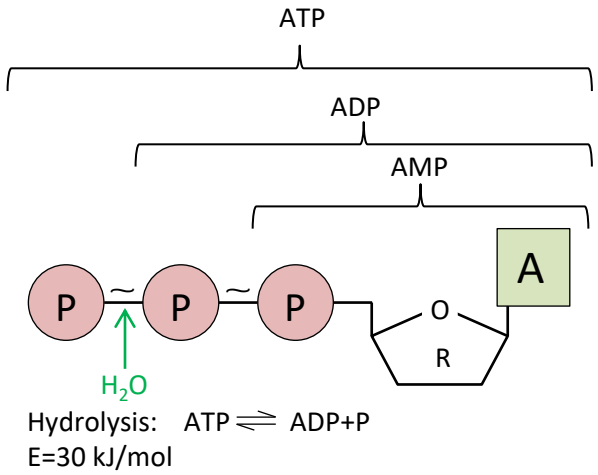


Adenosine triphosphate (ATP)



Eg.: Deoxythymidine monophosphate (dTMP)

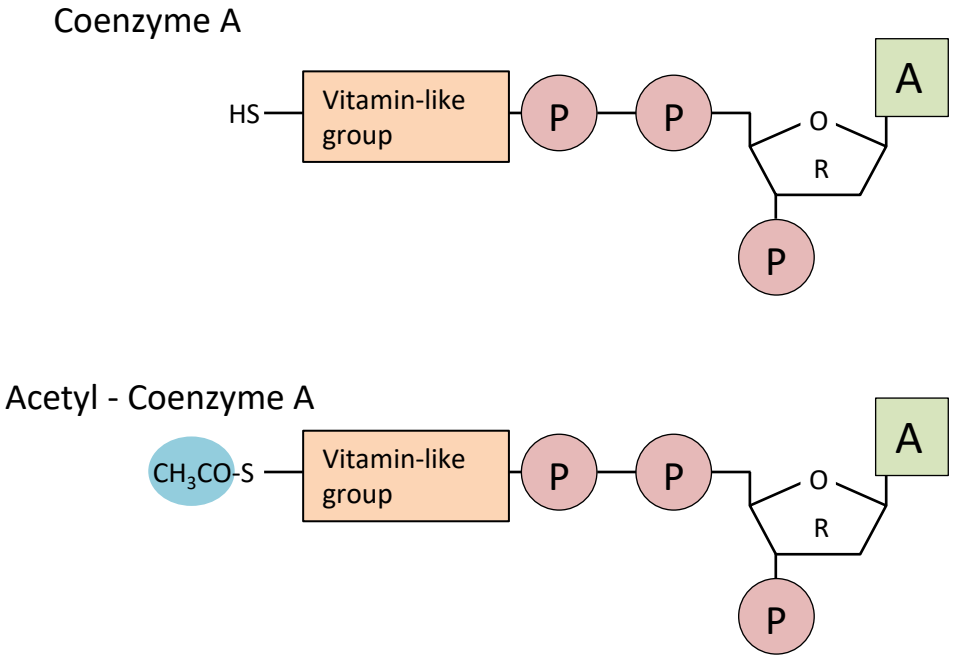
ATP



The ATP molecule is the “energy currency” of the cell. The hydrolysis of the high-energy bonds between the phosphates provides energy for many different biochemical reactions.

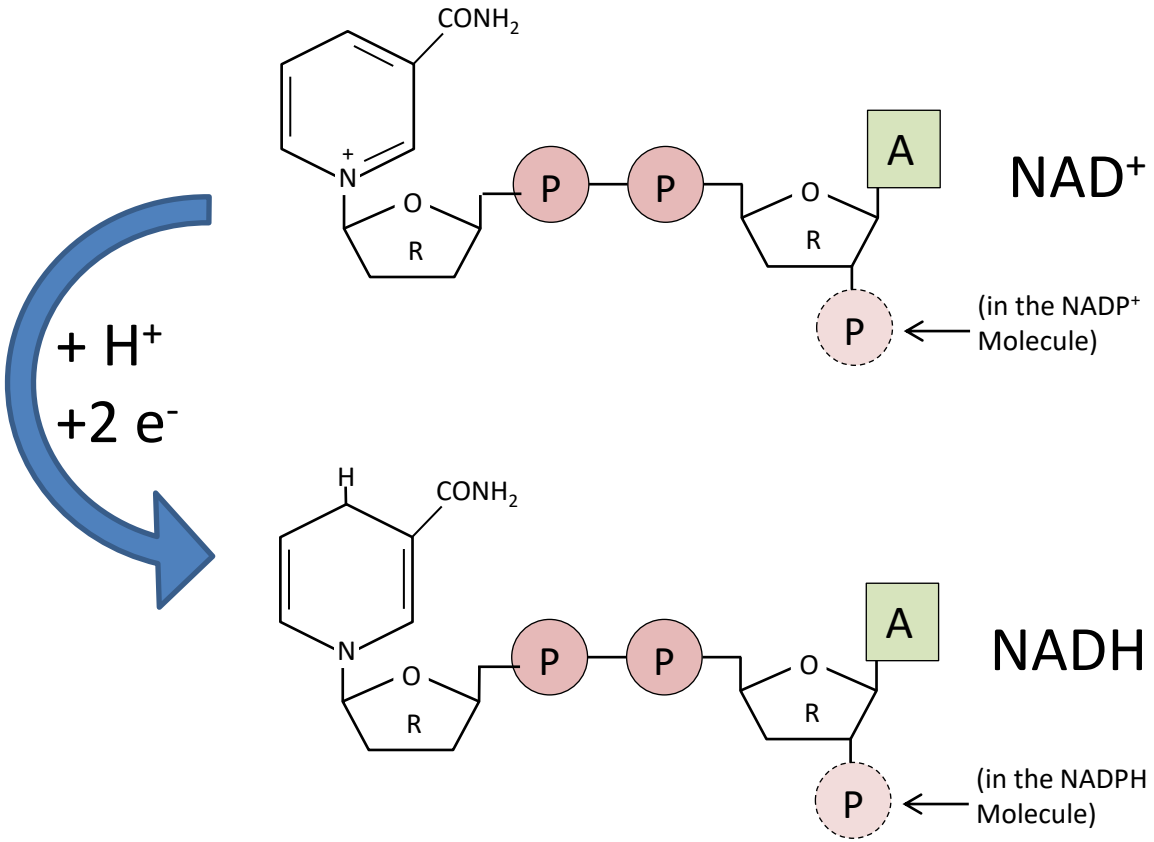
GTP: has similar roles

Additional Important nucleotides in the cell: coenzyme A



Its important function is to carry the acetyl group during the metabolism of different molecules, e.g. aerobic breakdown of glucose in mitochondria.

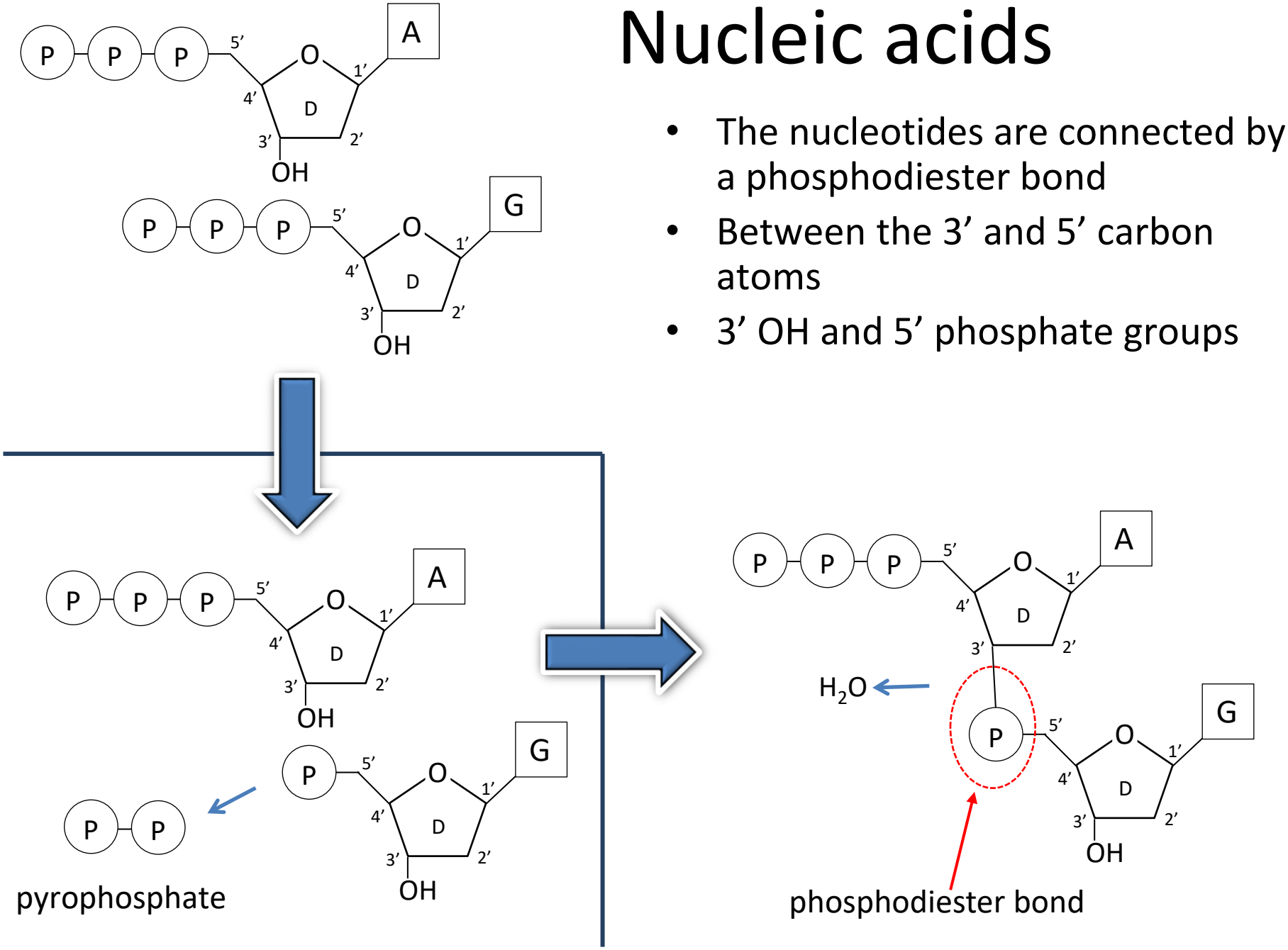
Additional Important nucleotides in the cell: NAD^+ and NADH



NAD^+ (=Nicotinamide adenine dinucleotide)
and NADP (=Nicotinamide adenine dinucleotide phosphate) molecules. Their important function is to carry high energy electrons and protons - NADH: most importantly in the metabolism of glucose with the help of mitochondria; NADPH: in certain biosynthetic processes.

Nucleic acids

- The nucleotides are connected by a phosphodiester bond
- Between the 3’ and 5’ carbon atoms
- 3’ OH and 5’ phosphate groups



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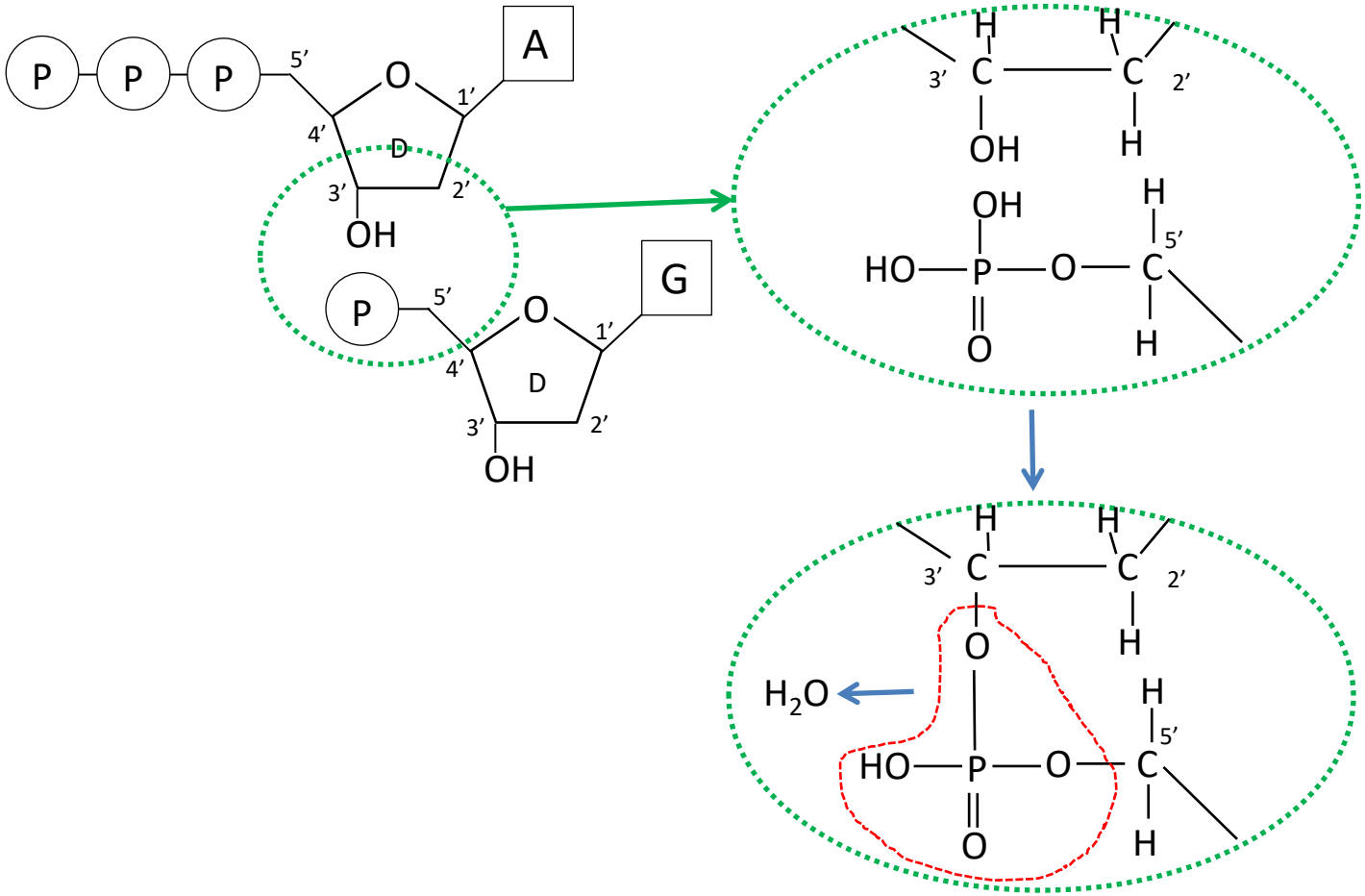
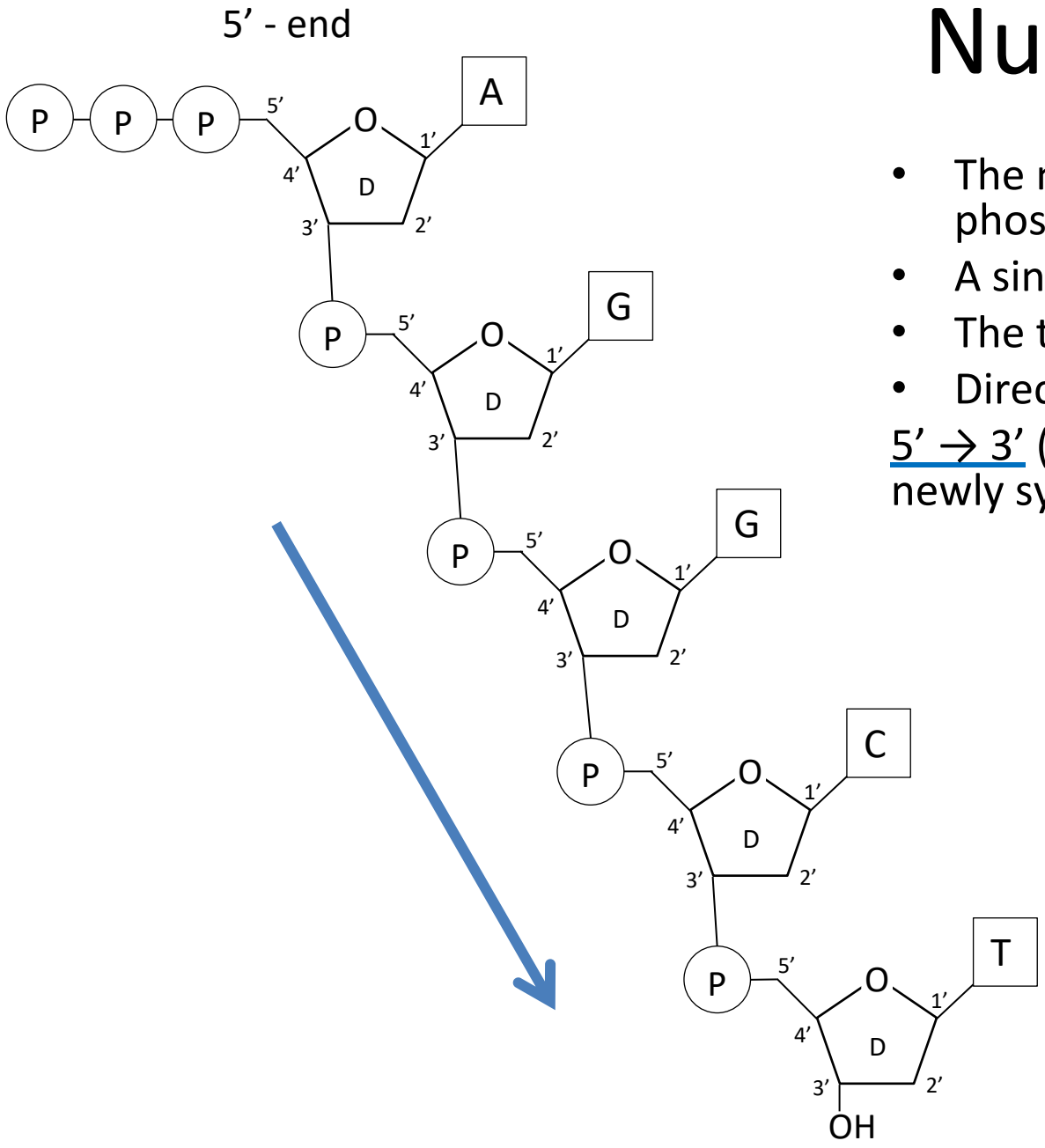


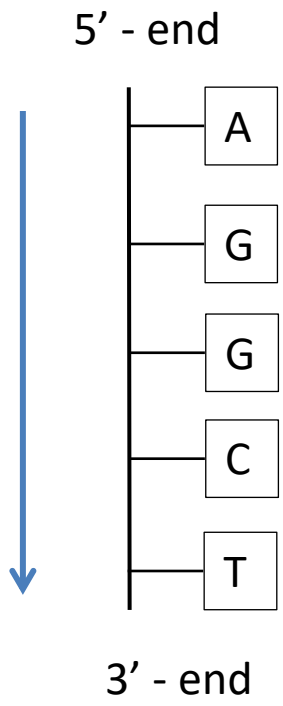
Nucleic acids



- The nucleotides are connected by phosphodiester bonds
- A single strand is formed
- The two ends: the 5’ and the 3’ end
- Direction of synthesis:

5’ → 3’ (according to the ends, on the newly synthesized strand)

Nucleic acids



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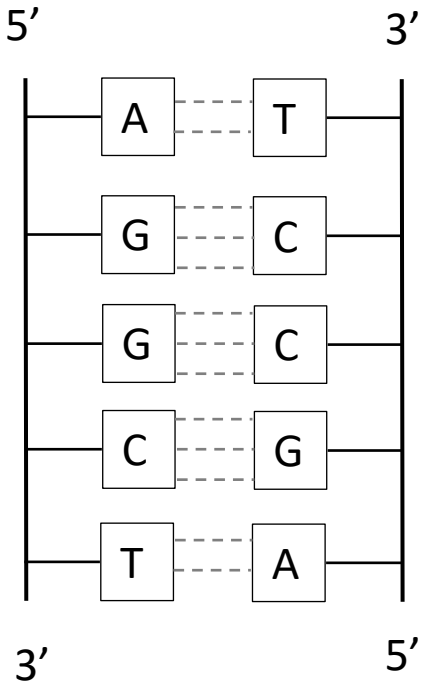
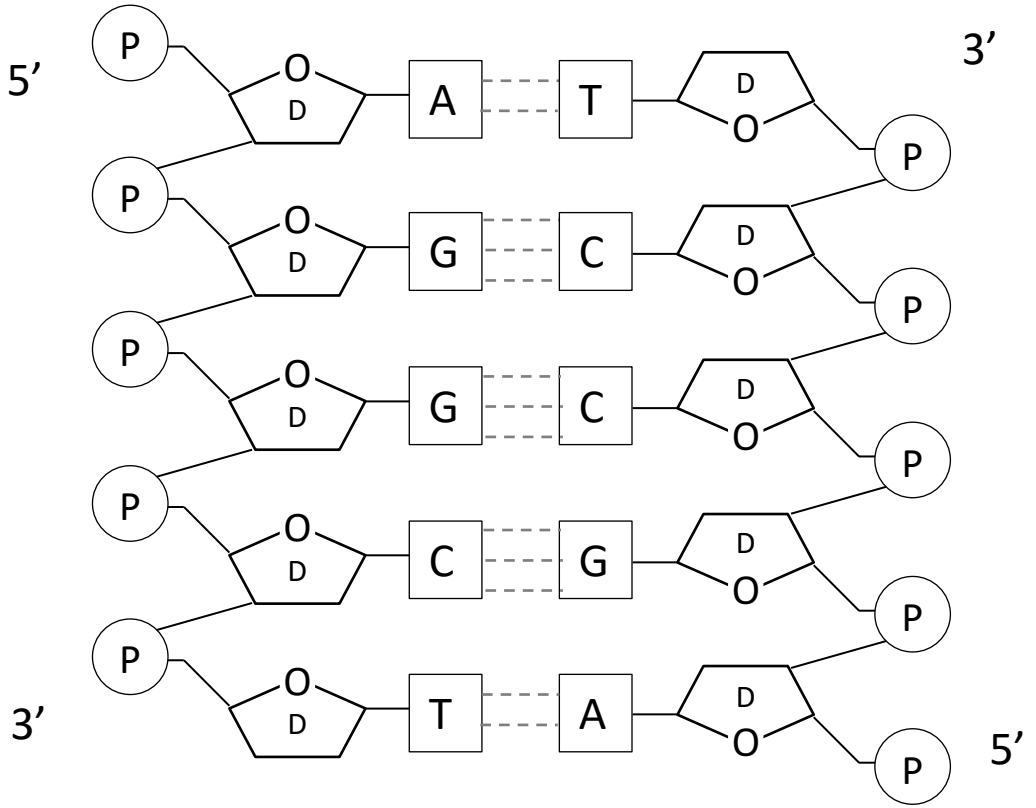
The double stranded molecule

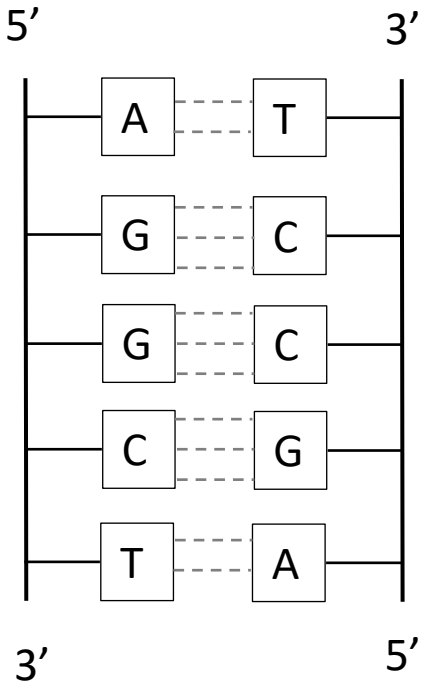
- Two strands combine to form a **double-stranded** molecule
- the two strands are connected by **hydrogen bonds** between the bases (**complementary base-pairing**):
  - **A=T** (2 H-bonds), **G≡C** (3 H-bonds)
  - The two **complementary** strands run **antiparalel** (the 5'-3' ends are opposite

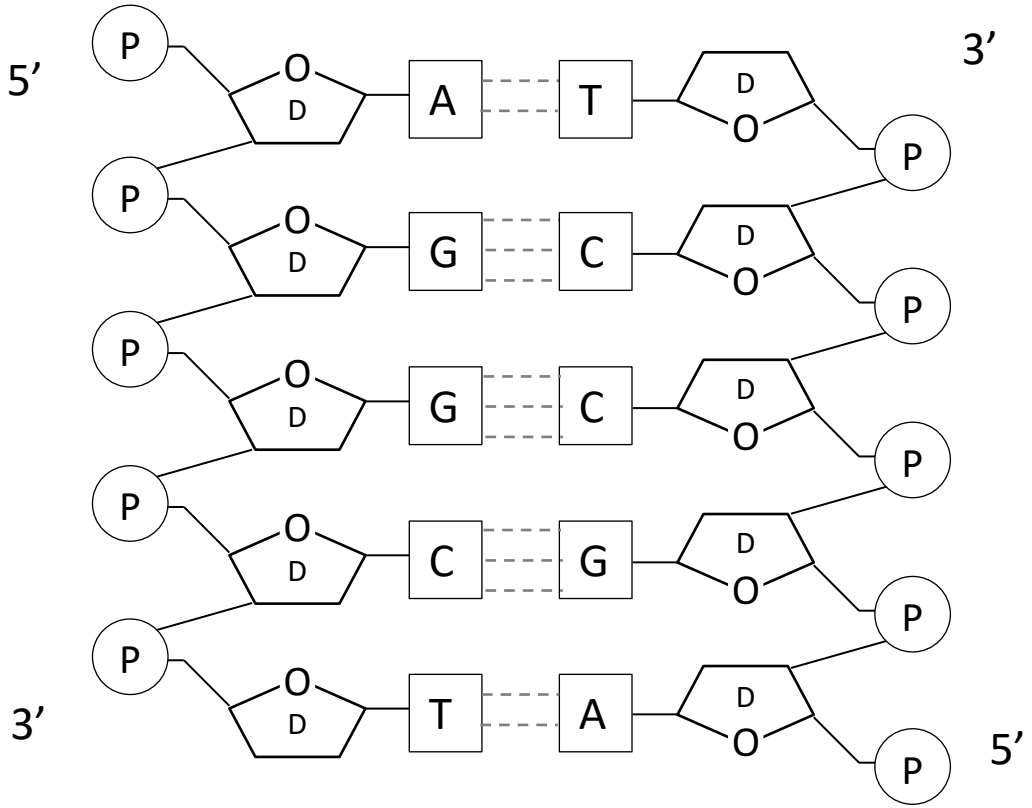




The double stranded molecule

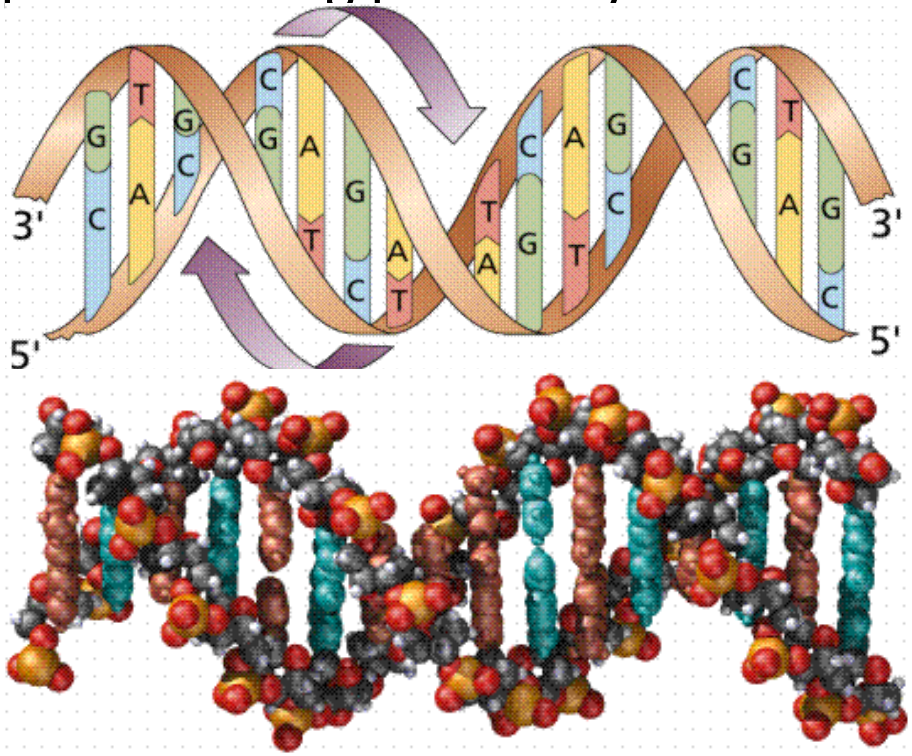
- RNA can also have double stranded regions
- **A=U** (2 H-bonds)





DNA : the double stranded molecule

- The double stranded molecule is wound up to a spiral form:
- DNA double helix
- The **nucleotide sequence (=base sequence)** carries the genetic information, this information will be translated into amino-acid sequence during protein synthesis.

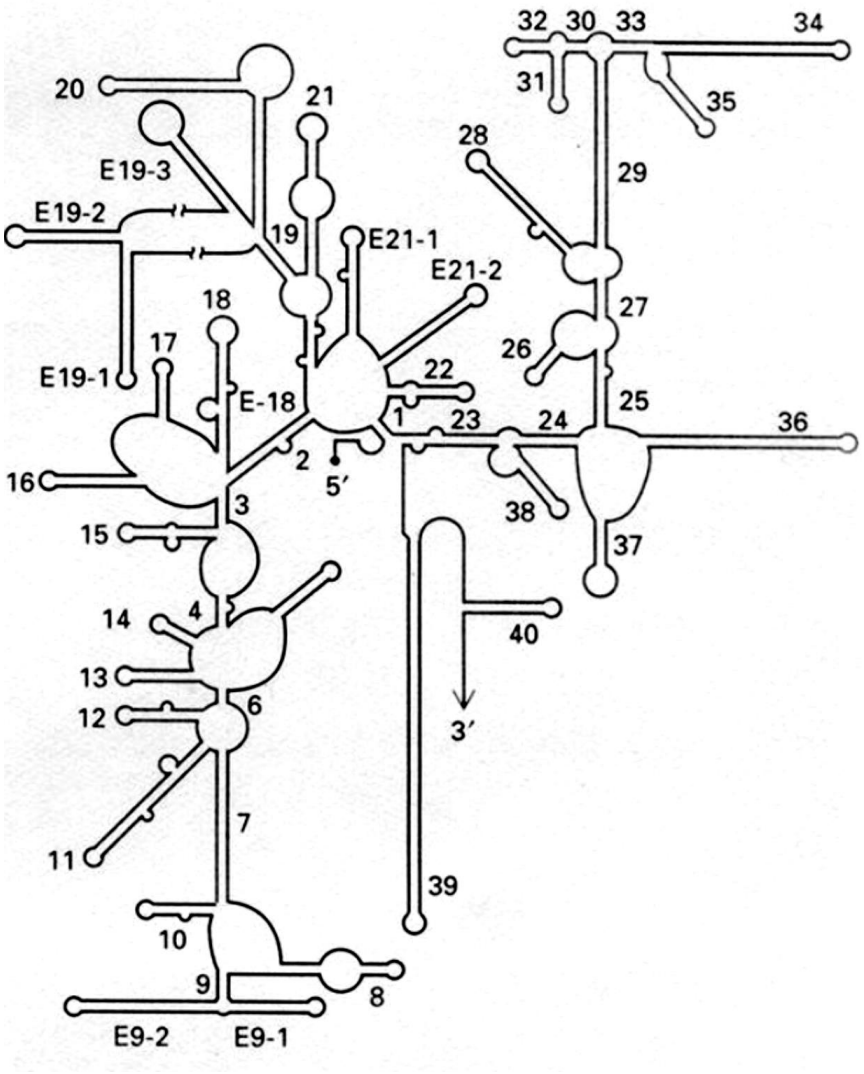


DNA, the double helix. (Purves et al., Life: The Science of Biology, 4th Edition)

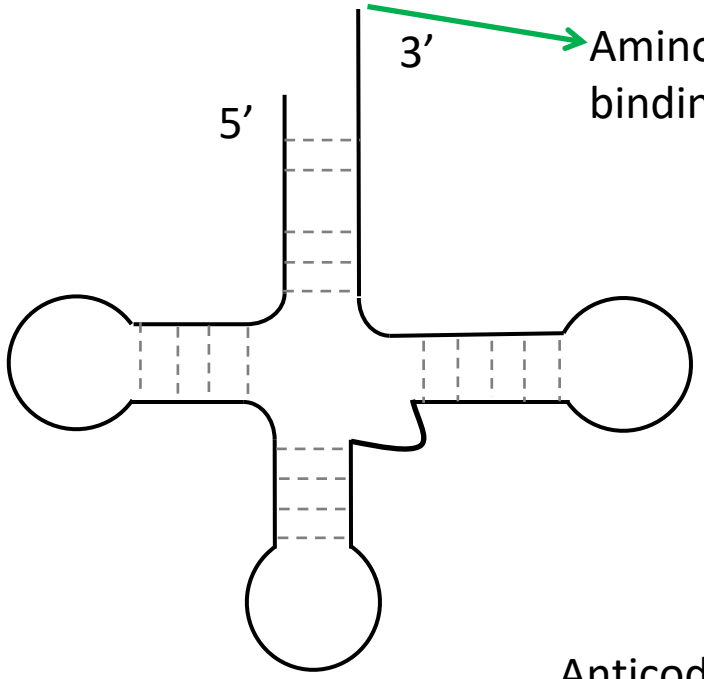
The 3 major types and structure of RNA

- **mRNA**= **messenger RNA**: carries the information from the DNA to the site of protein synthesis. Single stranded.
- **rRNA**= **ribosomal RNA**: components of the ribosome, which is the site of protein synthesis (translation). rRNA forms self-complementary double-stranded regions, hairpin loops.
- **tRNA** = **transfer** RNA: it carries the amino acids to the site of protein synthesis, has an **adapter** role. (it bonds to the mRNA in a complementary way) It has a „cloverleaf" structure.

rRNA


32
30
33
34
31
35
20
21
28
29
E19-3
E19-2
19
E21-1
E21-2
27
18
17
26
E19-1
22
E-18
25
1
23
24
36
2
5′
16
3
38
15
37
14
4
40
13
6
12
3′
7
11
39
10
9
8
E9-2
E9-1

tRNA


3′
Amino acid binding site
5′
Anticodon loop (mRNA binding site)