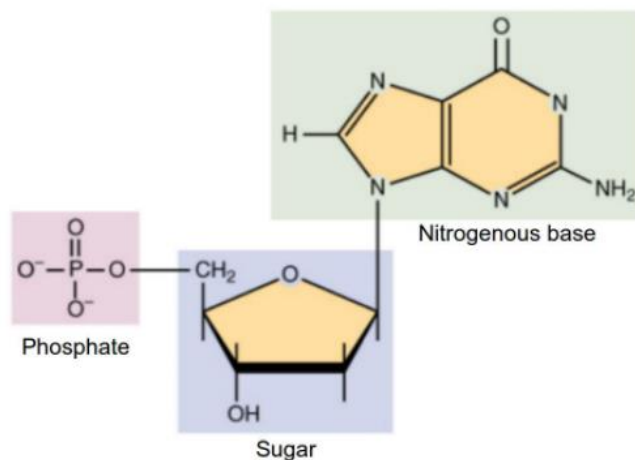


2302272 – Org Chem II – Part IV

Lecture 5

Nucleic acid



Instructor: Asst. Prof. Dr. Tanatorn Khotavivattana
E-mail: tanatorn.k@chula.ac.th

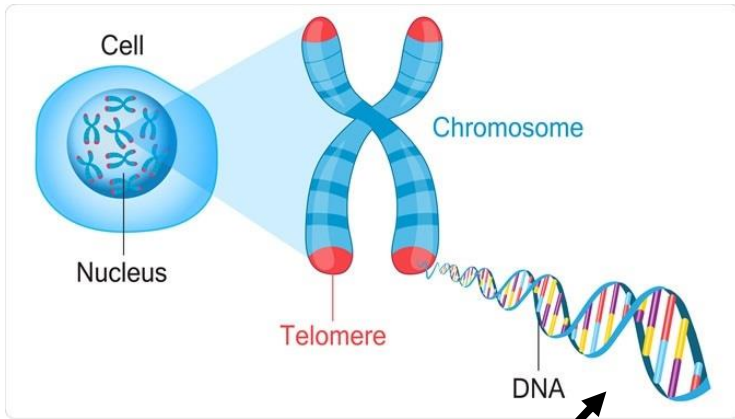
Recommended Textbook:

Chapter 23 in *Organic Chemistry*, 8th Edition, L. G. Wade, Jr., **2010**,
Prentice Hall (Pearson Education)

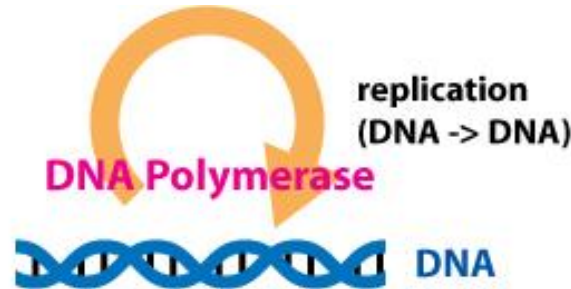
Key concepts:

1) Nucleic acid คืออะไร? สำคัญอย่างไร?

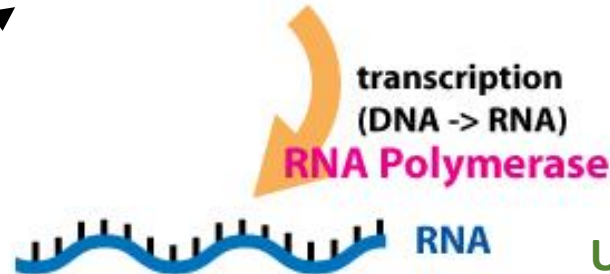
Nucleic acid - Overview



“Central dogma of molecular biology”



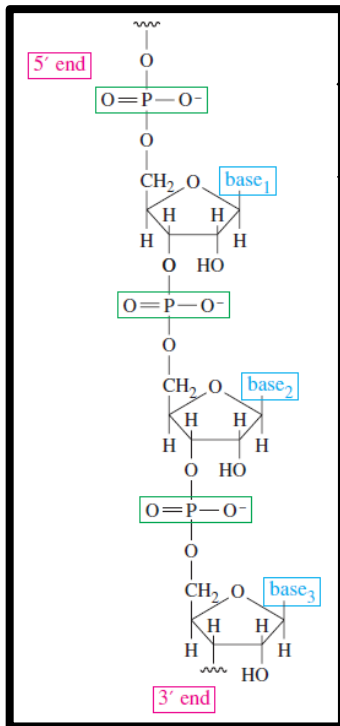
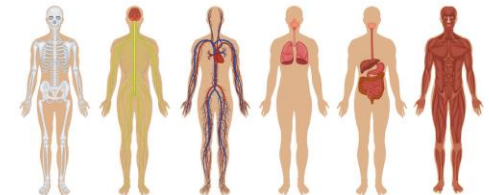
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ATCGATCGTACTTGGTCA



UAGCUAGCAUGAACCAGU



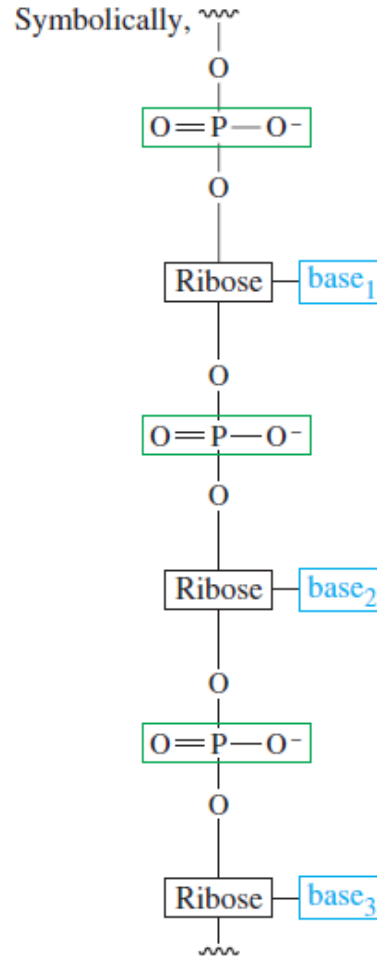
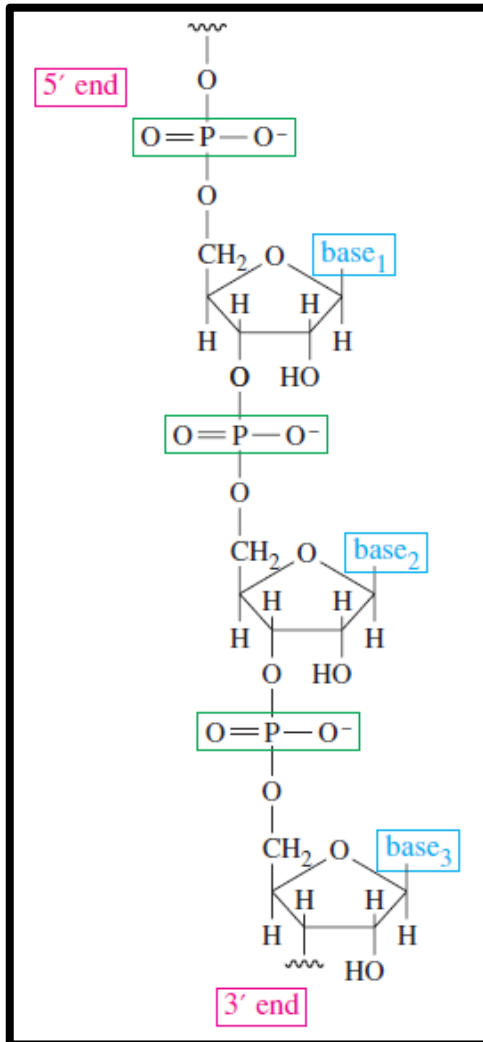
Gly-Val-Ala-Met-Cys-Lys



Nucleic acid

Nucleic acid - Overview

- The backbone of a nucleic acid is a polymer of **ribofuranoside rings** (five-membered rings of the sugar ribose) linked by **phosphate ester groups**.



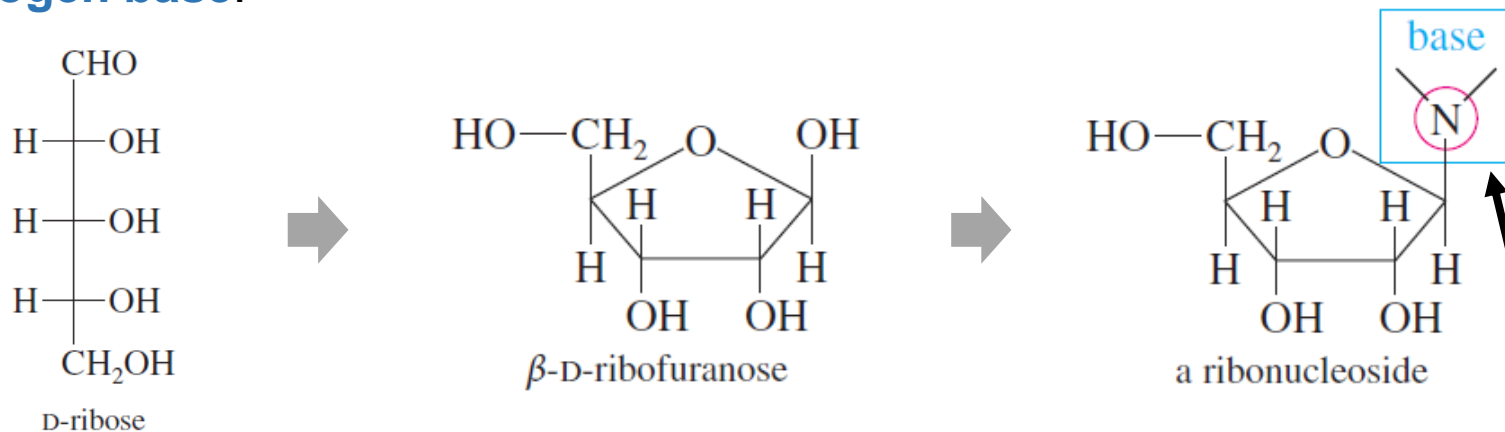
- Each ribose unit carries a **heterocyclic base** that provides part of the information needed to specify a particular amino acid in protein synthesis.
- DNA and RNA each contain four monomers, called **nucleotides**, that differ in the structure of the bases bonded to the ribose units.

Key concepts:

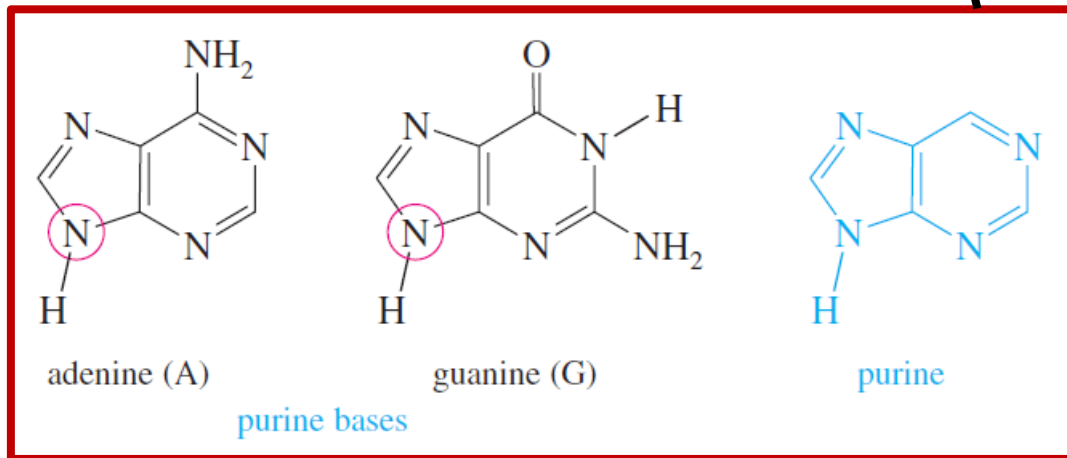
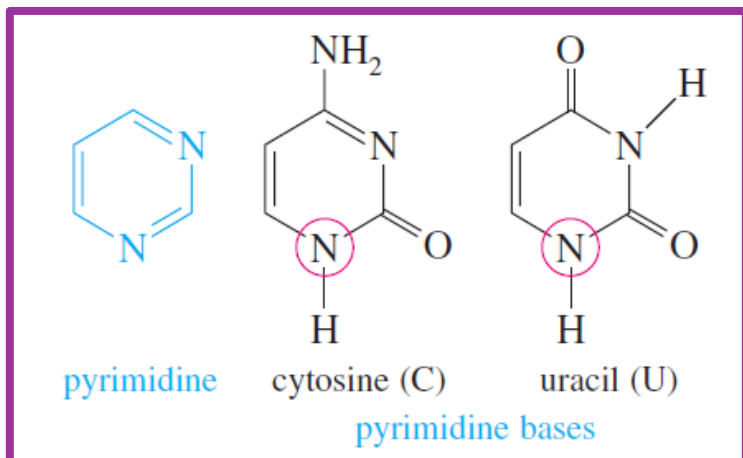
2) Ribonucleoside / Ribonucleotide / RNA เกี่ยวข้องกันอย่างไร และมีโครงสร้างพื้นฐานอย่างไร?

Ribonucleosides

- Ribonucleosides are **components of RNA**.
- A ribonucleoside is a **β -D-ribofuranoside** whose **aglycone is a heterocyclic nitrogen base**.



- The four bases commonly found in RNA are divided into two classes:



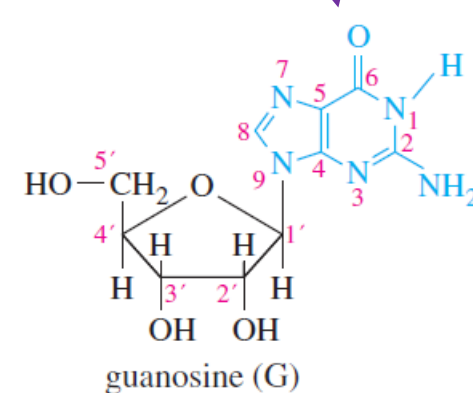
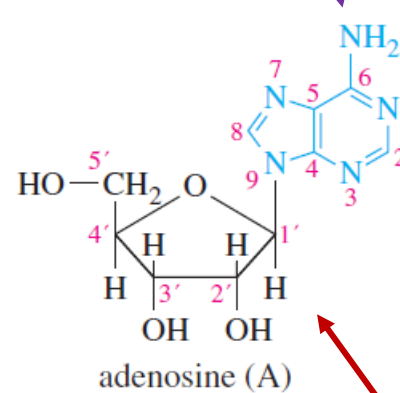
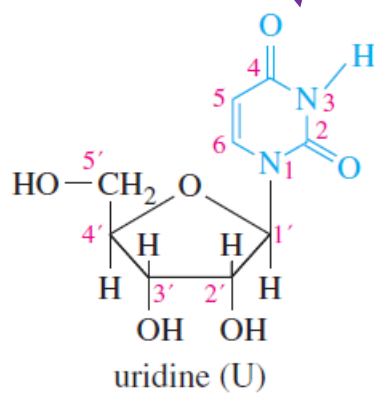
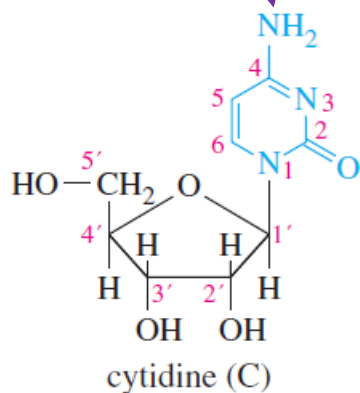
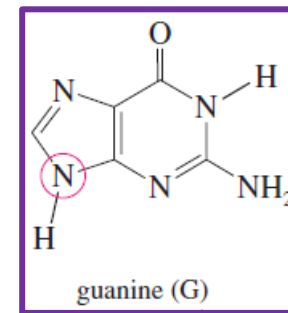
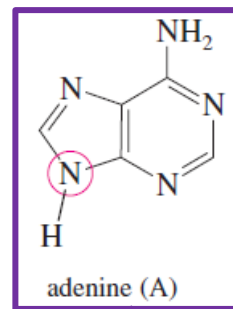
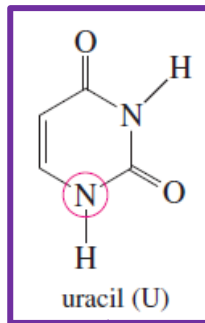
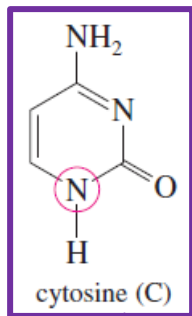
The monocyclic compounds called **pyrimidine**

Bicyclic compounds are called **purine**

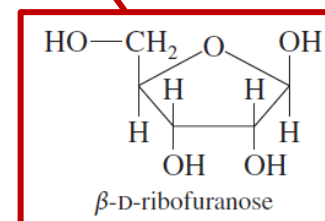
Ribonucleosides

- The four common ribonucleosides are cytidine, uridine, adenosine, and guanosine

Heterocyclic nitrogen base



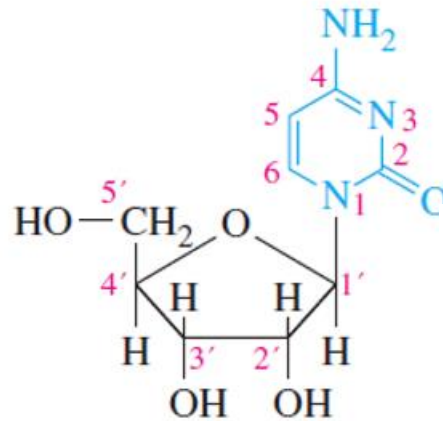
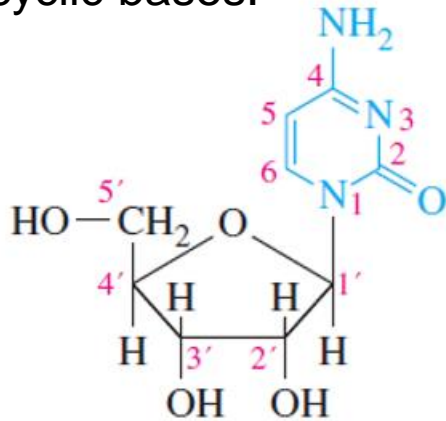
Ribonucleosides



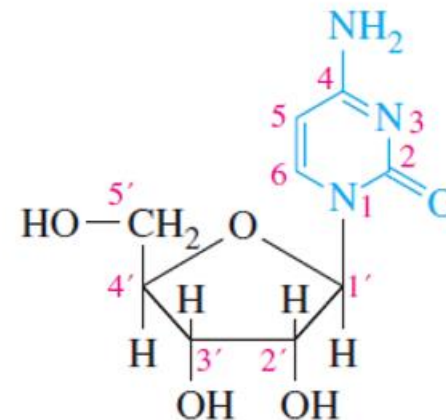
Ribose

Ribonucleotides

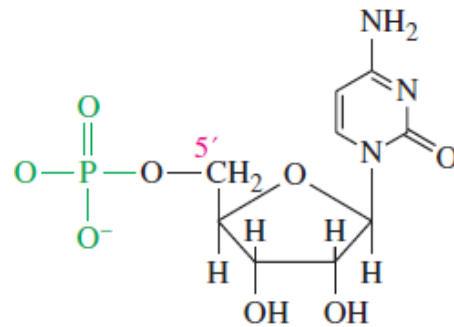
- RNA consists of **ribonucleosides bonded together into a polymer**.
- This polymer **cannot be bonded by glycosidic linkages** like those of other polysaccharides because the glycosidic bonds are already used to attach the heterocyclic bases.



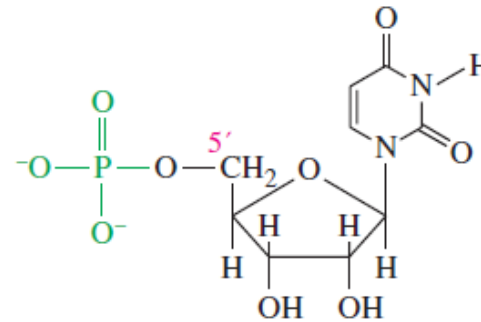
- Instead, the ribonucleoside units are linked by **phosphate esters**.



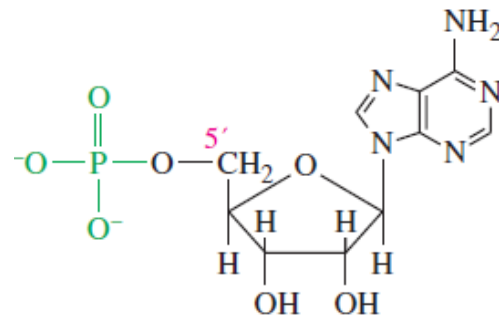
- The **5'-hydroxyl group** of each ribofuranoside is **esterified by phosphoric acid**. A **ribonucleoside that is phosphorylated at 5' its carbon** is called a **ribonucleotide**



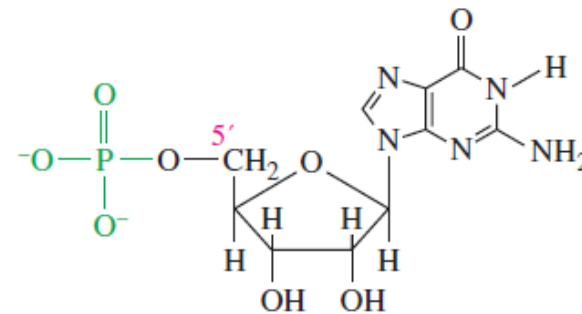
cytidine monophosphate,
CMP (cytidylic acid)



uridine monophosphate,
UMP (uridylic acid)



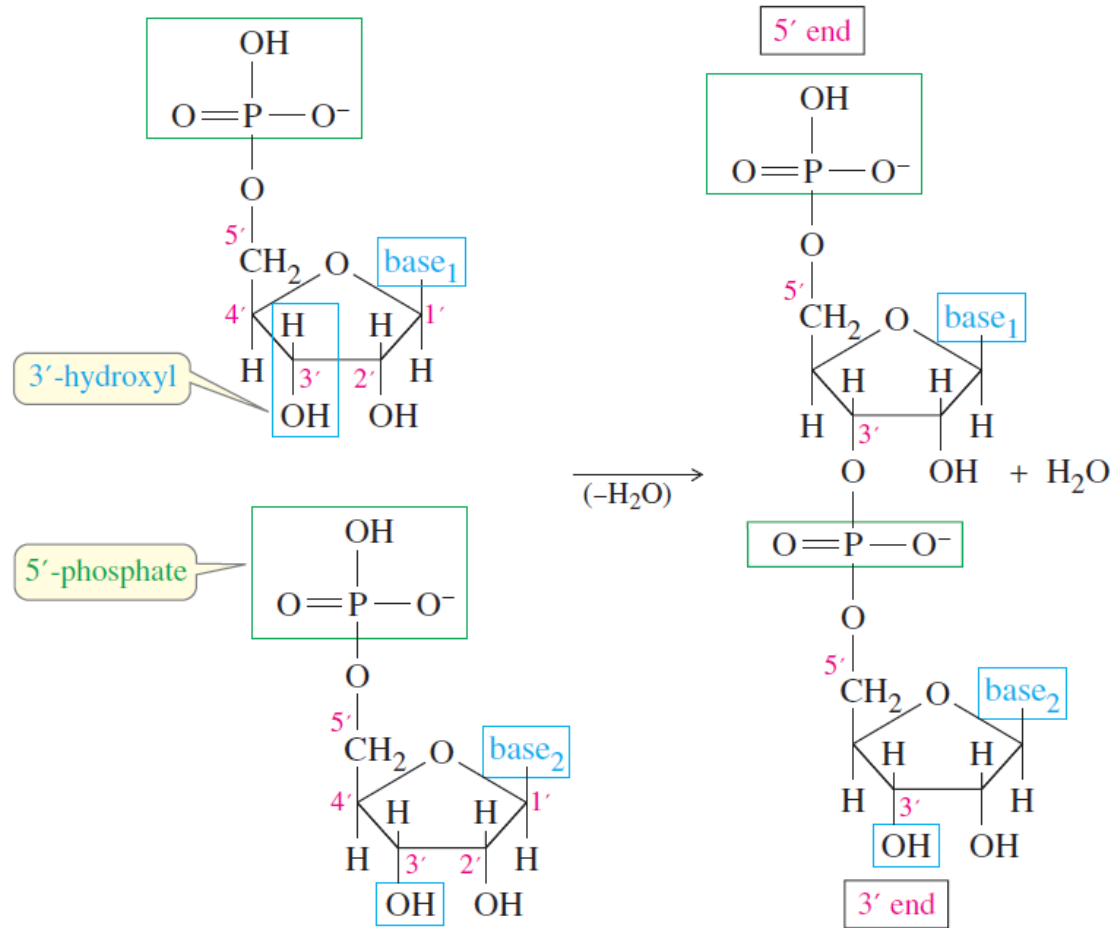
adenosine monophosphate,
AMP (adenylic acid)



guanosine monophosphate,
GMP (guanidylic acid)

- By convention, the phosphate groups are usually written completely ionized.

- Two nucleotides are joined by a **phosphate ester linkage** between the **5'-phosphate group** of one nucleotide and the **3'-hydroxyl group** of another.



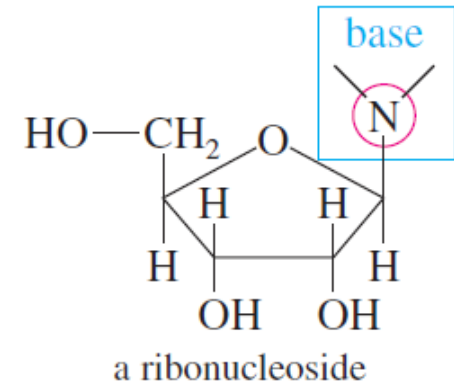
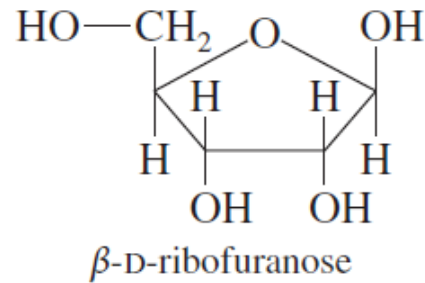
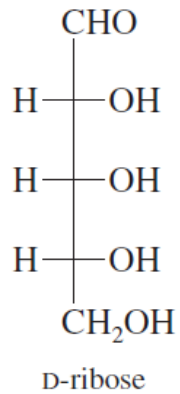
- The RNA polymer consists of many nucleotide units bonded this way.
- A molecule of RNA always has two ends: **3' end** and **5' end**

Key concepts:

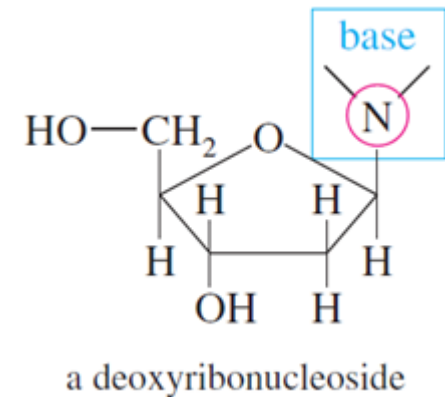
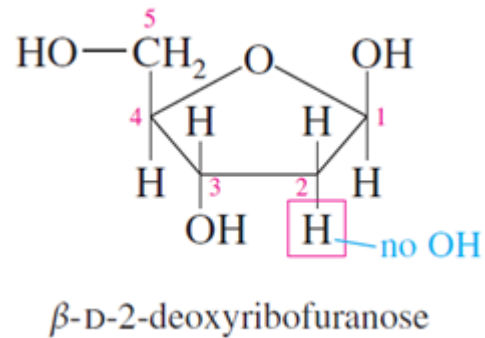
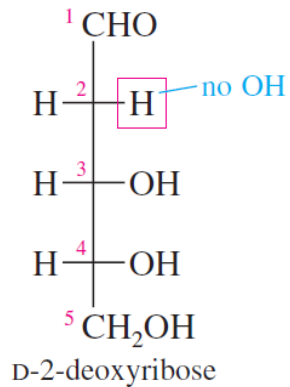
3) โครงสร้างพื้นฐานของ DNA กับ RNA แตกต่างกันอย่างไ?

Deoxyribonucleosides vs. Ribonucleosides #1

Ribonucleosides

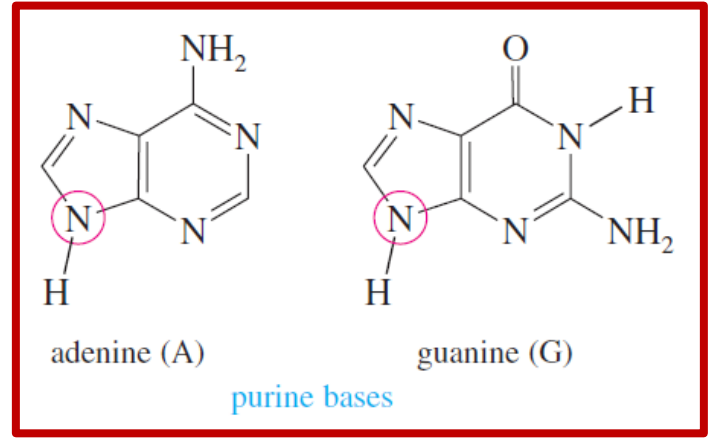
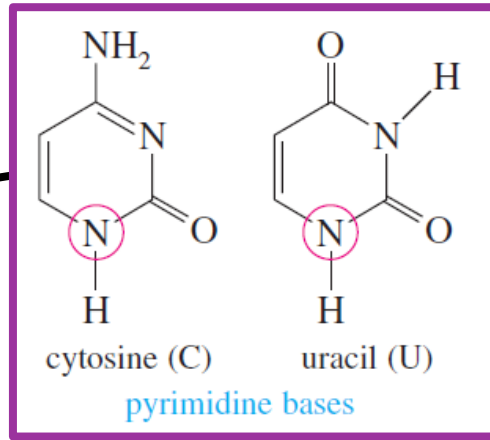
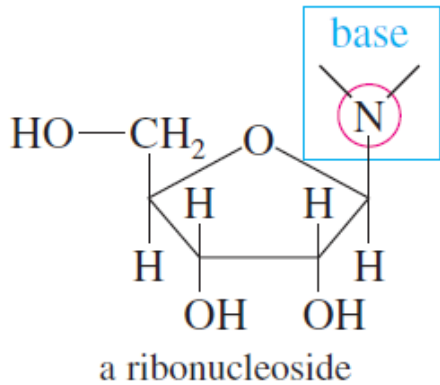


Deoxyribonucleosides

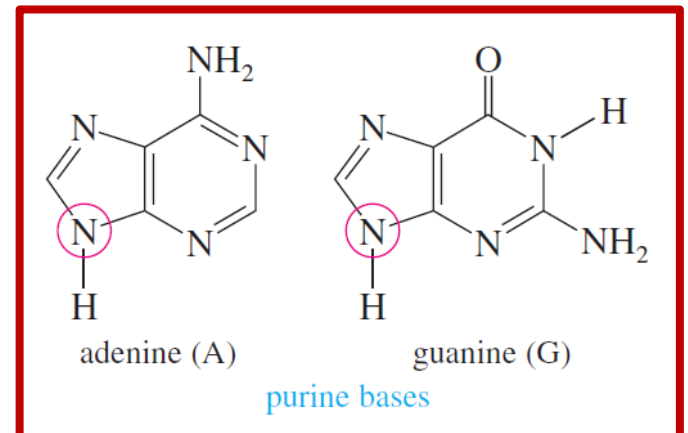
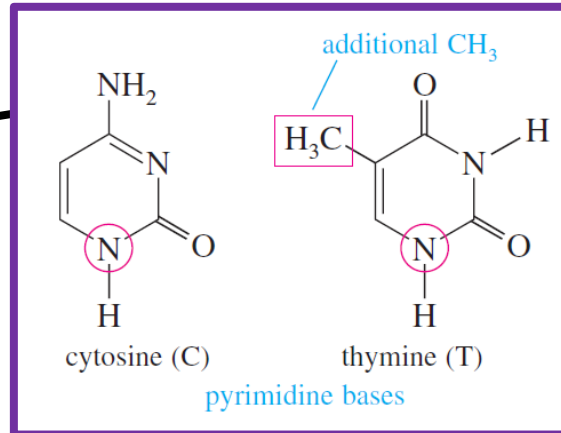
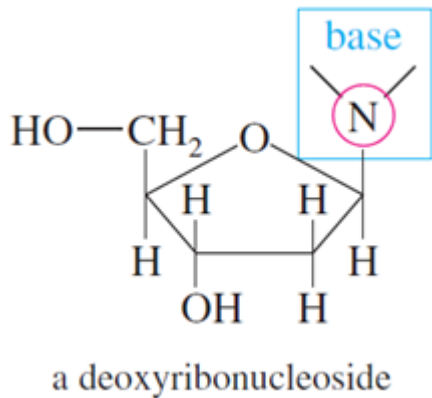


Deoxyribonucleosides vs. Ribonucleosides #2

Ribonucleosides



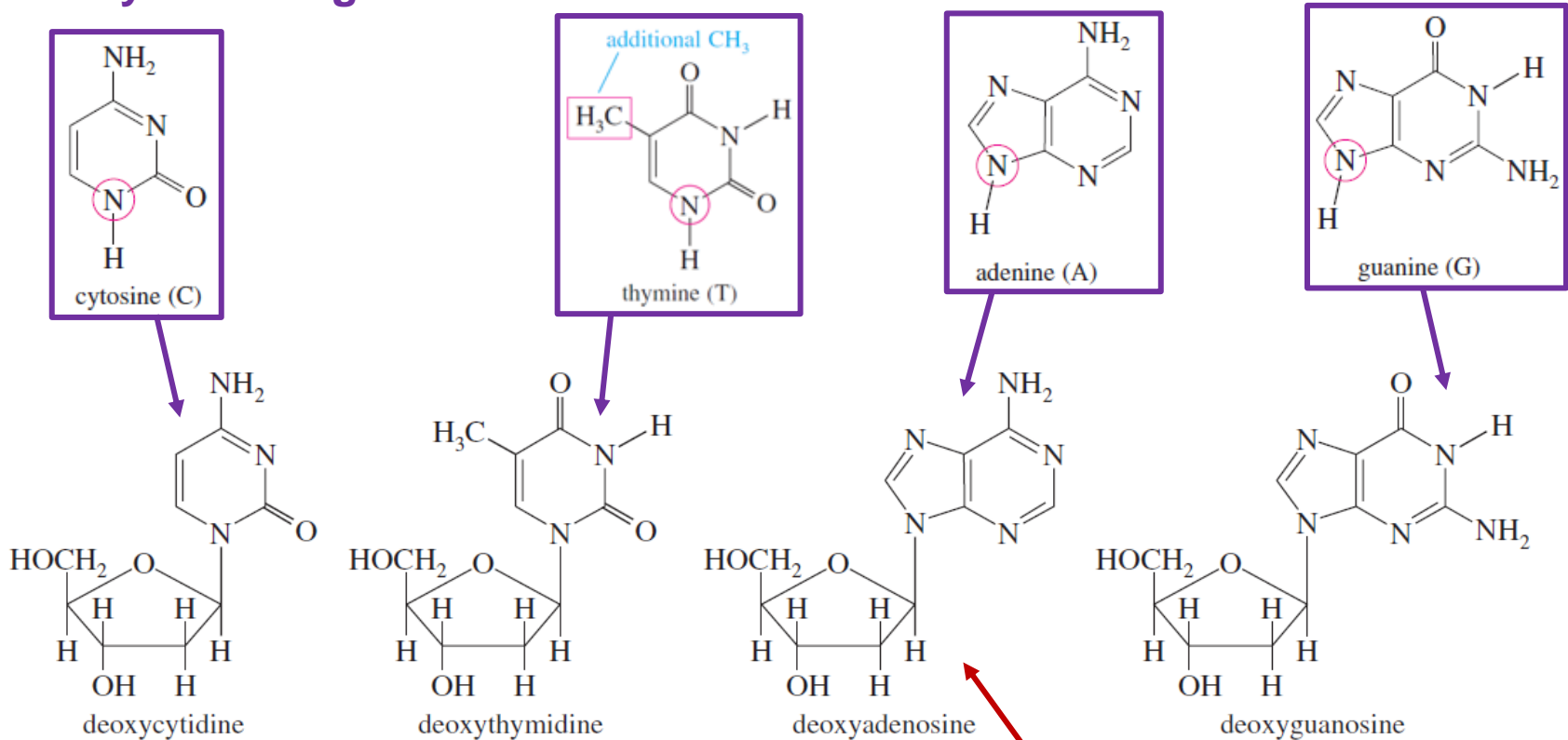
Deoxyribonucleosides



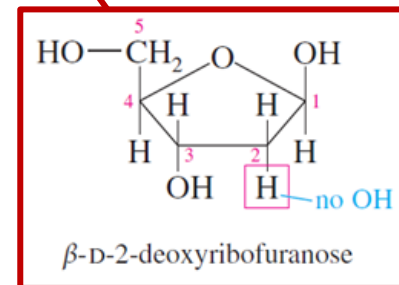
Deoxyribonucleosides

- The four common deoxyribonucleosides that make up DNA

Heterocyclic nitrogen base



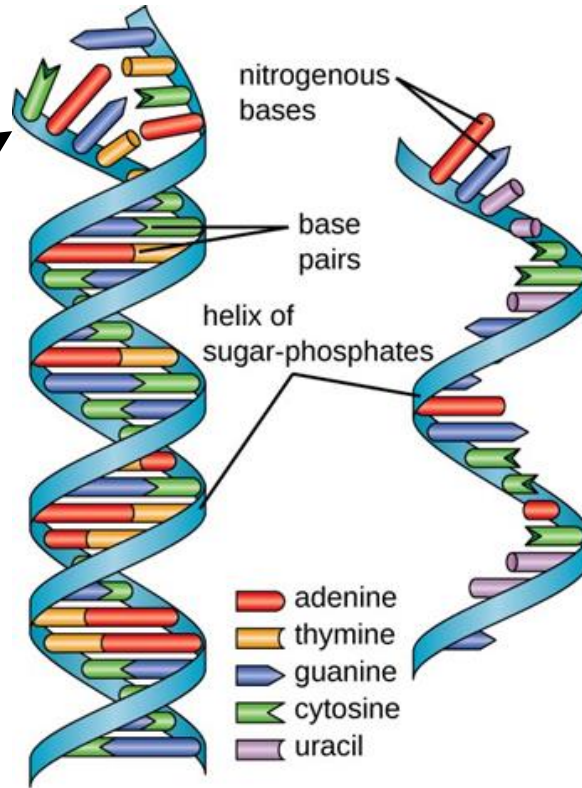
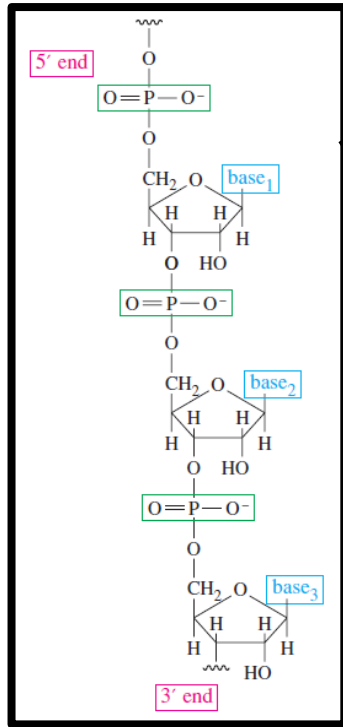
Deoxyribonucleosides



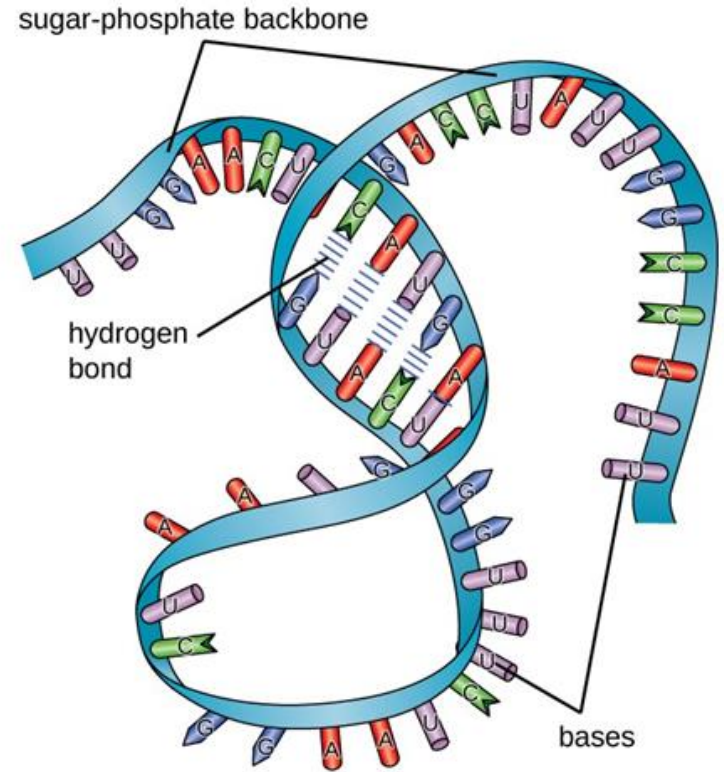
Deoxyribose

Key concepts:

4) โครงสร้างสามมิติของ DNA กับ RNA เป็นอย่างไร?



DNA



RNA

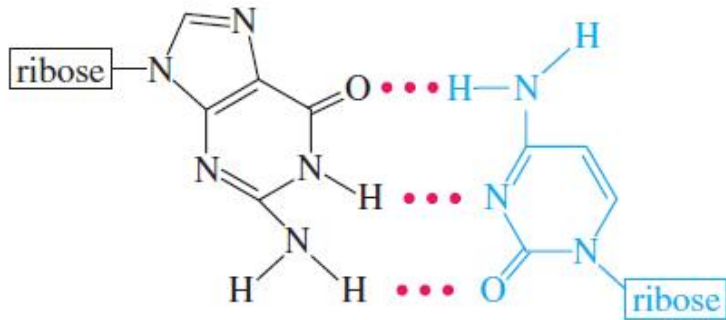
RNA

- **DNA** is typically **double stranded**, whereas **RNA** is typically single **stranded**.
- Although it is single stranded, RNA can **fold upon itself**, with the folds stabilized by short areas of complementary base pairing within the molecule, forming a three-dimensional structure.

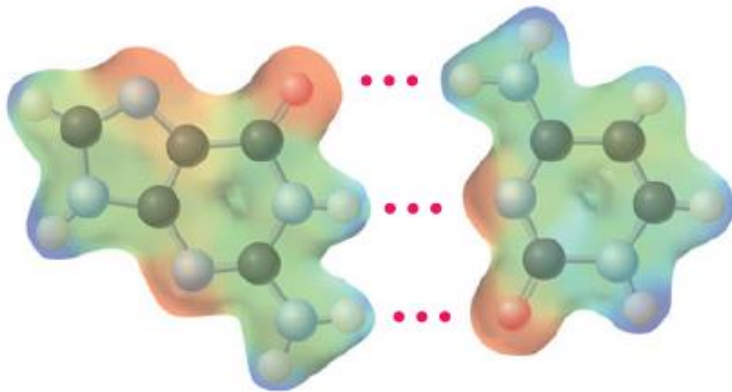
Base pairing

- Each pyrimidine base forms a stable hydrogen-bonded pair with only one of the two purine bases

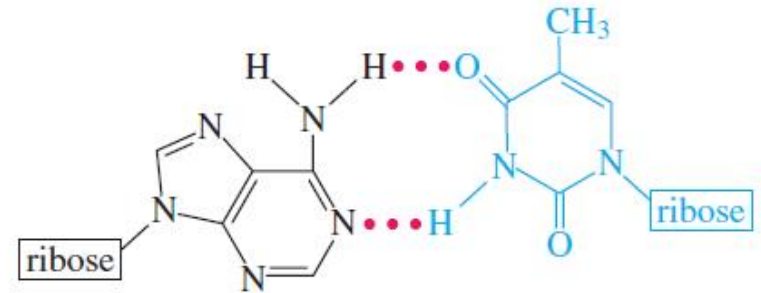
Cytosine forms a base pair, joined by **three hydrogen bonds**, with **guanine**.



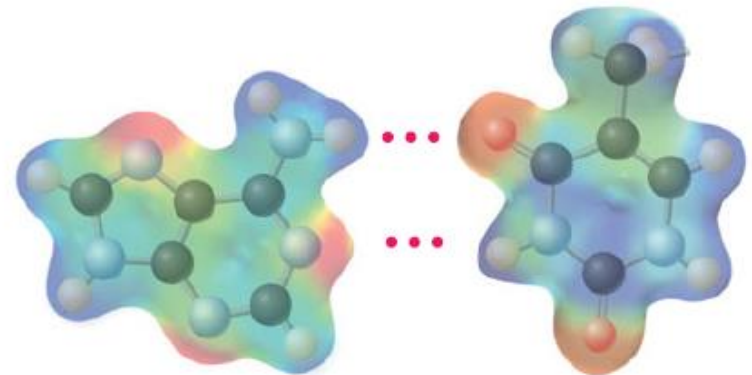
guanine G ⋮ C cytosine



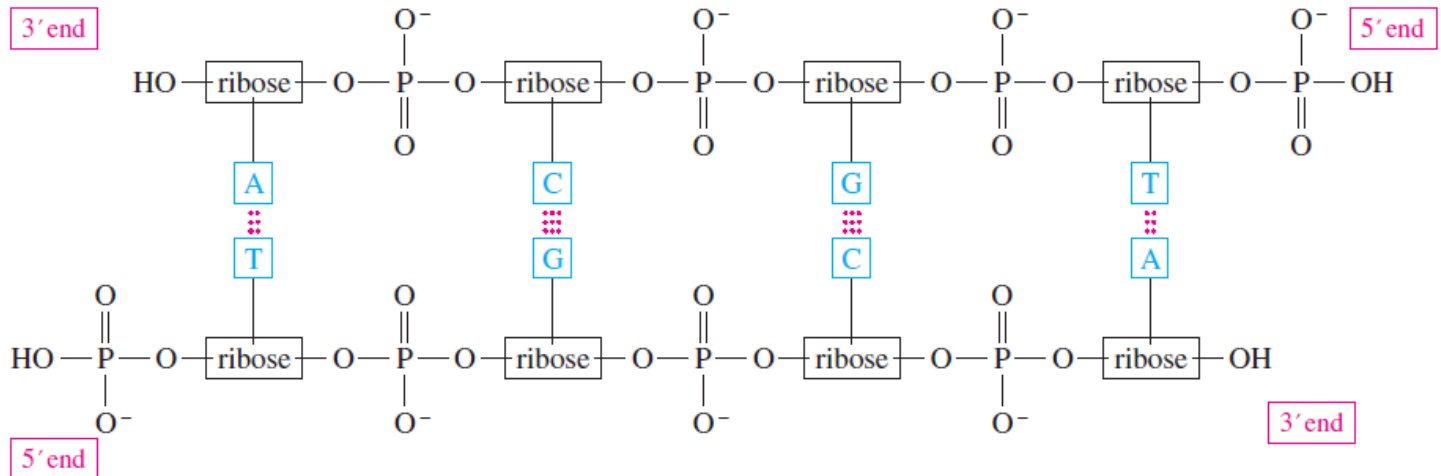
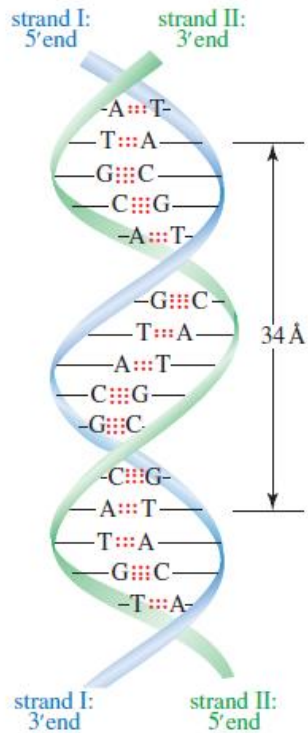
Thymine (or **uracil** in RNA) forms a base pair with **adenine**, joined by **two hydrogen bonds**.



adenine A ⋮ T thymine



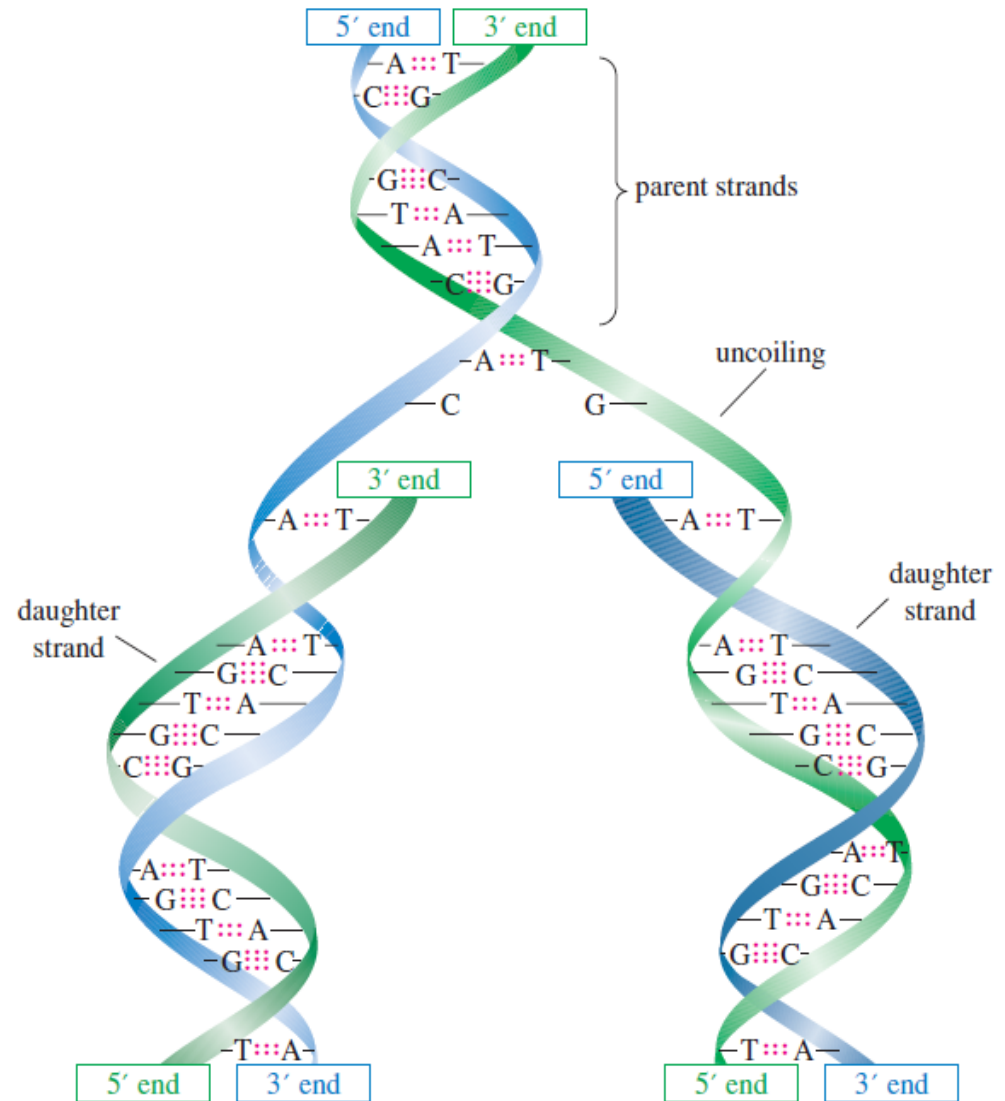
- DNA contains **two complementary polynucleotide chains held together by hydrogen bonds between the paired bases.**



- The two strands are **antiparallel**: One strand is arranged 3' → 5' from left to right, while the other runs 5' → 3' in the opposite direction, from left to right.

The Double Helix of DNA

- When DNA undergoes replication (in preparation for cell division), an enzyme uncoils part of the double strand.
- Individual **nucleotides naturally hydrogen bond to their complements** on the uncoiled part of the original strand.
- a **DNA polymerase** enzyme couples the nucleotides to form a new strand.

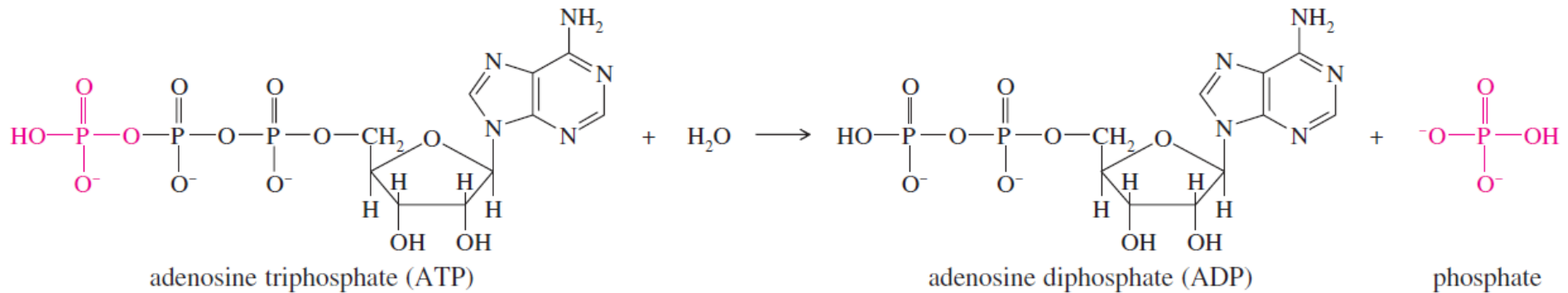


Key concepts:

5) นอกเหนือจากการเป็น monomer ของ DNA และ RNA แล้ว nucleotide สามารถทำหน้าที่อะไรได้อีกบ้าง?

ATP: An Energy Source

- When glucose is oxidized in the living cell, the **energy released is used to synthesize adenosine triphosphate (ATP)**, an anhydride of phosphoric acid.
- As with most anhydrides, **hydrolysis of ATP is highly exothermic**. The hydrolysis products are adenosine diphosphate (ADP) and inorganic phosphate.



$$\Delta H^\circ = -31 \text{ kJ/mol } (-7.3 \text{ kcal/mol})$$

Additional functions of nucleotides

NAD: A Coenzyme

Nicotinamide adenine dinucleotide (NAD) is one of the principal **oxidation-reduction reagents** in biological systems.

