

Advanced Cell Biology. Lecture 7

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Outline

Questions and answers

Nucleic acids

Structure

Other nucleic acids

Macromolecules in cells

Cells and energy

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Previous final question: the answer

Write a sequence complementary to **ATTGGAAGC**
Is it from DNA or RNA?

Previous final question: the answer

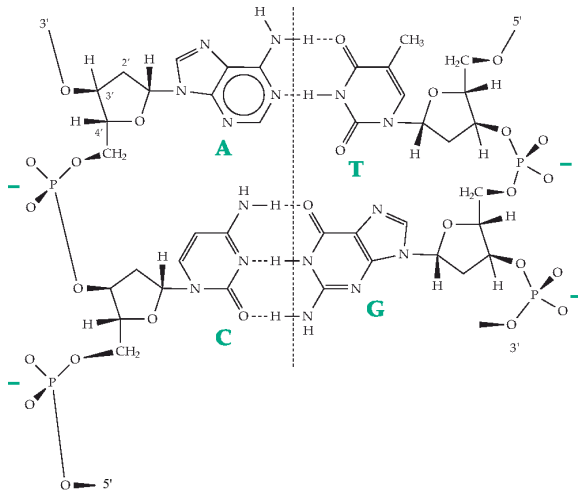
Write a sequence complementary to **ATTGGAAGC**
Is it from DNA or RNA?

- ▶ TAACCTTCG
- ▶ DNA

Nucleic acids

Structure

Hydrogen bonds in complementary strands

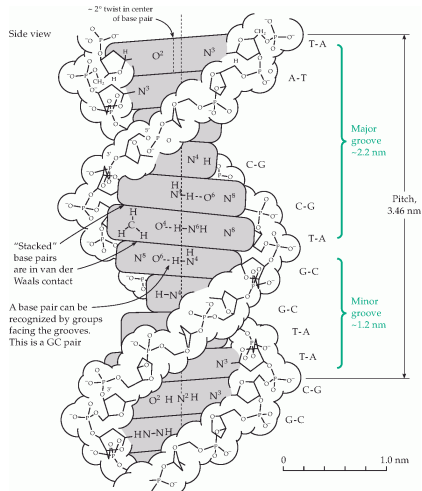


Double helix

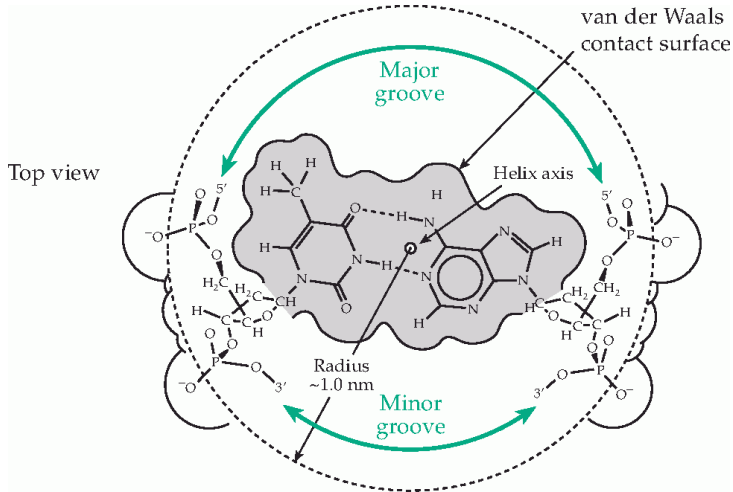
- ▶ DNA form helical structure where phosphate and sugar form “envelope” and bases form a “core”
- ▶ Two grooves: major and minor

- └ Nucleic acids
- └ Structure

DNA double helix



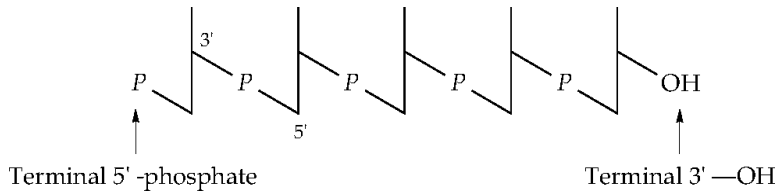
DNA double helix from top



Sequences, ends, abbreviations

- ▶ Since nucleotides are complementary, it is usually only one strand listed
- ▶ Each strand has 3' (-OH) and 5' ends (phosphate)

3' and 5' ends



Abbreviations for nucleic acids components

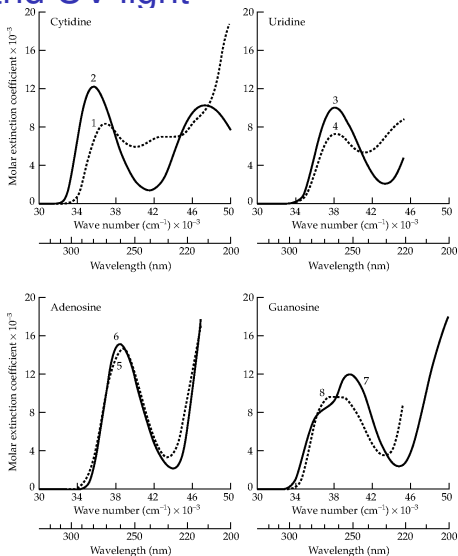
Base:	Uracil (Ura)	Cytosine (Cyt)	Adenine (Ade)	Guanine (Gua)
Nucleoside:	Uridine (Urd or U)	Cytidine (Cyd or C)	Adenosine (Ado or A)	Guanosine (Guo or G)
5'-Nucleotide:	Uridine 5'-phosphate or 5'-uridylic acid (Urd-5'-P or UMP)	Cytidine 5'-phosphate or 5'-cytidylic acid (Cyd-5'-P or CMP)	Adenosine 5'-phosphate or 5'-adenylic acid (Ado-5'-P or AMP)	Guanosine 5'-phosphate or 5'-guanylic acid (Guo-5'-P or GMP)

Abbreviations for nucleotide sequences

U,T,C,A,G	Uracil, thymine, cytosine, adenine, guanine
Y or Pyr	Pyrimidine (T or C)
R or Pur	Purine (A or G)
M	Amino base (A or C)
K	Keto base (G or T)
S	Strongly pairing (G or C)
W	Weakly pairing (A or T)
H	Not G (any other base)
B	Not A
V	Not T or U
D	Not C
N	Any base

- └ Nucleic acids
- └ Structure

Nucleotides and UV light



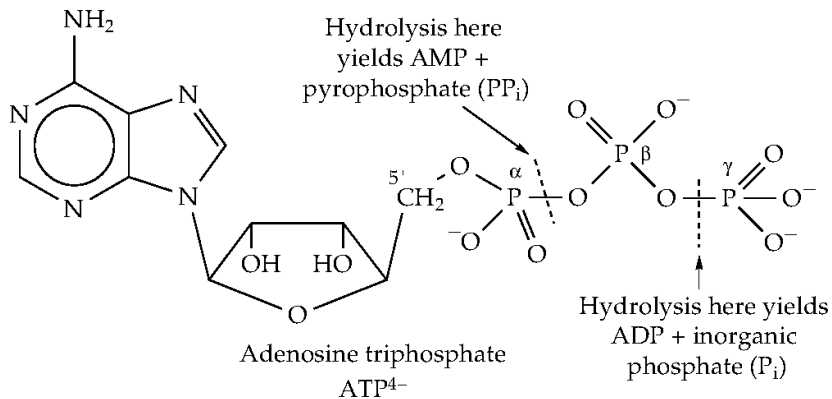
Nucleic acids

Other nucleic acids

ATP

- ▶ ATP (**adenosine-triphosphate**) is **coenzyme** (ferment helper), derivative of ribose, adenine and three phosphoric acids
- ▶ Contain two highly energetic bonds

ATP



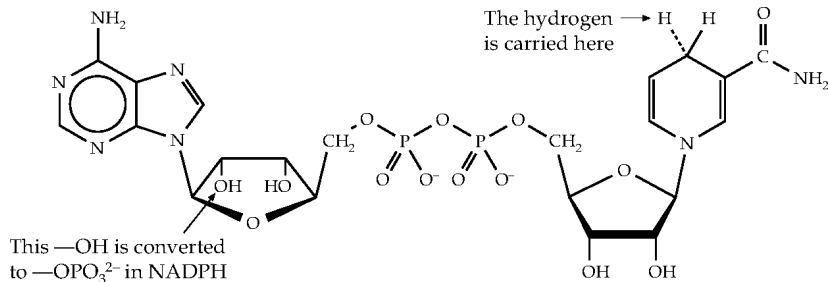
ATP movie

ATP movie

NADP

- ▶ NADP, **nicotinamide adenine dinucleotide phosphate** is a coenzyme, derivative of adenine
- ▶ Typically, used as hydrogen carrier
- ▶ Has a medical name “vitamin B₃”

NADPH

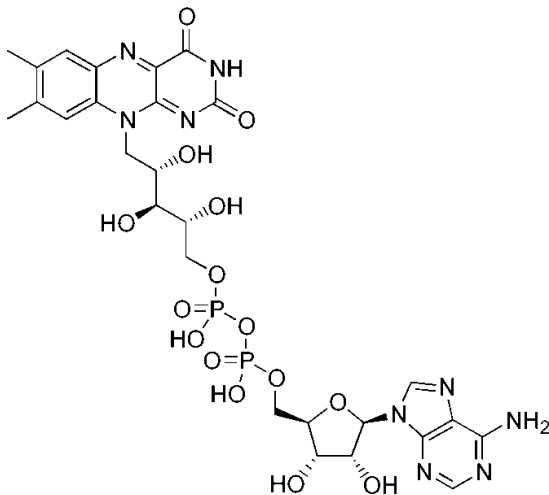


The reduced coenzyme NADH

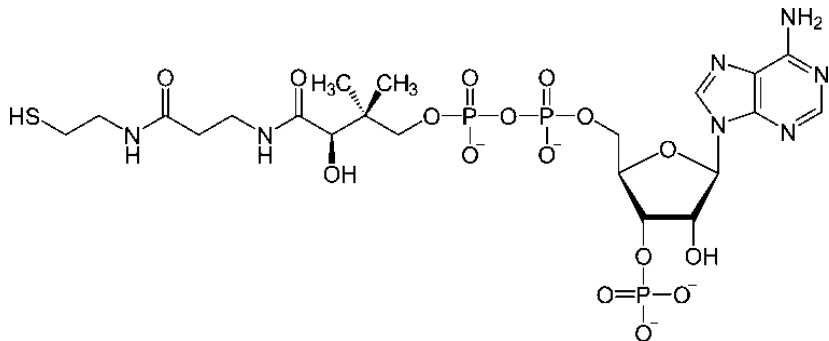
Other nucleotide coenzymes

- ▶ FAD, **flavin adenine dinucleotide**, vitamin B₂
- ▶ CoA, **coenzyme A**, vitamin B₅
- ▶ Both are extremely important for cell respiration

FAD



CoA



Most frequent macromolecules

- ▶ Polymer molecules generate most of cell dry weight (30% of total weight)
- ▶ Proteins are 15%, nucleic acids 7%, lipids and polysaccharides 2% each

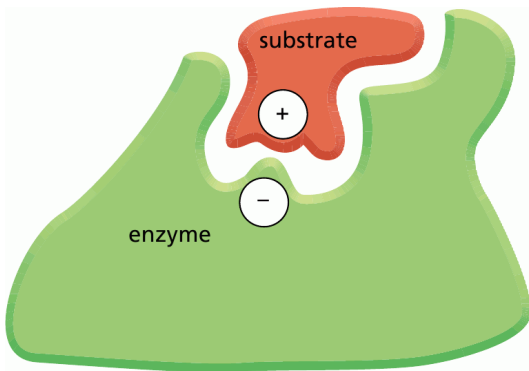
Noncovalent bonds, conformations and binding

- ▶ Non-covalent bonds are responsible from shaping of macromolecules
- ▶ Almost every macromolecule has different shaping variants—**conformations**
- ▶ Intermolecular binding is also due to noncovalent bonds

Types of noncovalent bonds

- ▶ Hydrophobic forces
- ▶ Van der Waals attractions: due to fluctuation of electric charges
- ▶ Electrostatic, including hydrogen

Binding with noncovalent (electrostatic) bonds



Metabolism

- ▶ **Metabolism** is the sum of all chemical reactions in living organism
- ▶ **Catabolism** is the part of metabolism responsible for degrading complex molecules
- ▶ **Anabolism** is the opposite part

Metabolism

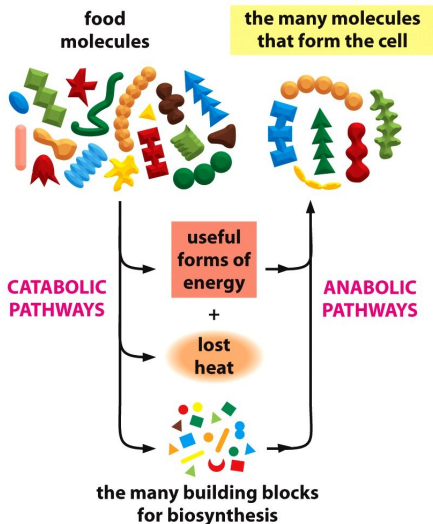


Figure 3-2 Essential Cell Biology 3/e (© Garland Science 2010)

Second law of thermodynamics

- ▶ Thermodynamic definition (Rudolf Clausius): *No process is possible whose sole result is the transfer of heat from a body of lower temperature to a body of higher temperature.*
- ▶ Simplistic definition: *In isolated system, disorder is always increasing*
- ▶ To revert initial order, energy should be spent
- ▶ Generally speaking, **entropy** is a measure of disorder (better—measure of randomness)
- ▶ In strict sense, entropy is $dS = \frac{\delta Q}{T}$, where Q is amount of heat and T —absolute temperature (constant)

Entropy

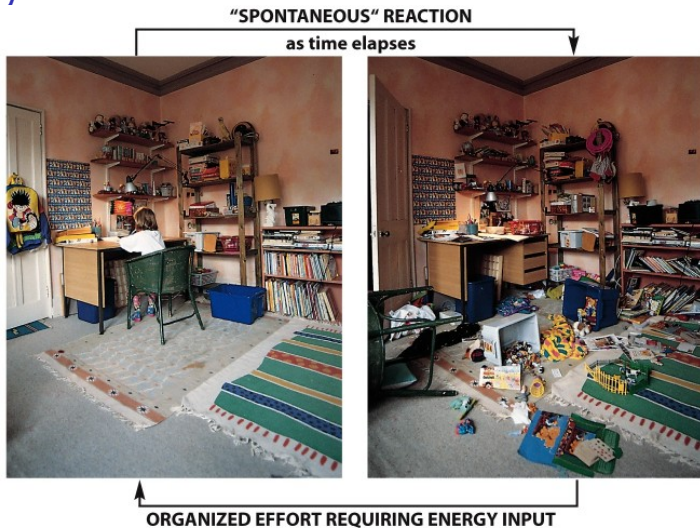
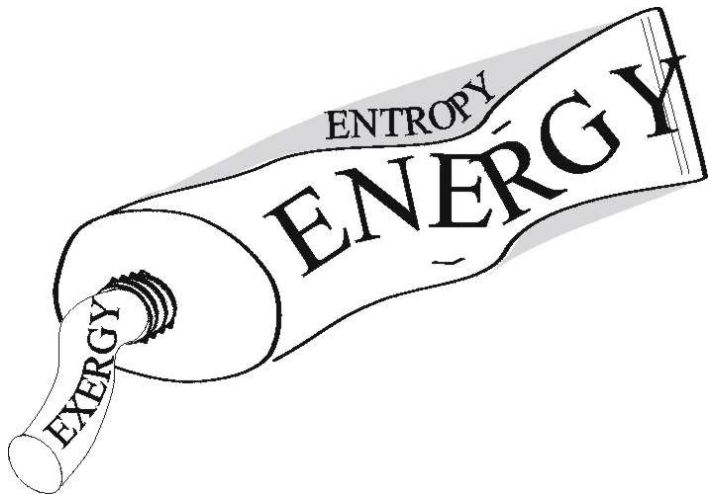


Figure 3-4 Essential Cell Biology 3/e (© Garland Science 2010)

Triumph of entropy: “post-apocalyptic world”



Entropy explained: energy tube



Different forms of energy

- ▶ Mechanical energy: potential and kinetic
- ▶ Heat energy
- ▶ Electromagnetic energy
- ▶ All forms are inconvertible; and **first law of thermodynamics** says that *energy never disappears*, it only changes its form

Photosynthesis

- ▶ The way of transforming light energy to energy of chemical bonds
- ▶ The schematic description is:
light energy + CO_2 + H_2O \rightarrow sugars + O_2 + heat energy
- ▶ Part of anabolism

Cellular respiration

- ▶ Almost opposite process
- ▶ Schematic description:
sugars + O₂ → CO₂ + H₂O + chemical energy (ATP)
- ▶ Part of catabolism

Oxidation and electron transfer

- ▶ Cellular respiration is based on oxidation, taking electrons off
- ▶ Converse reaction is reduction; together they are *redox* reactions
- ▶ For organic molecules, typical oxidation sequence is:
carbohydrates → alcohols → aldehydes → organic acids
→ CO₂

Enzymes and energy of activation

- ▶ Most of processes need the *energy of activation*
- ▶ **Enzymes** could lower activation barriers

Energy of activation

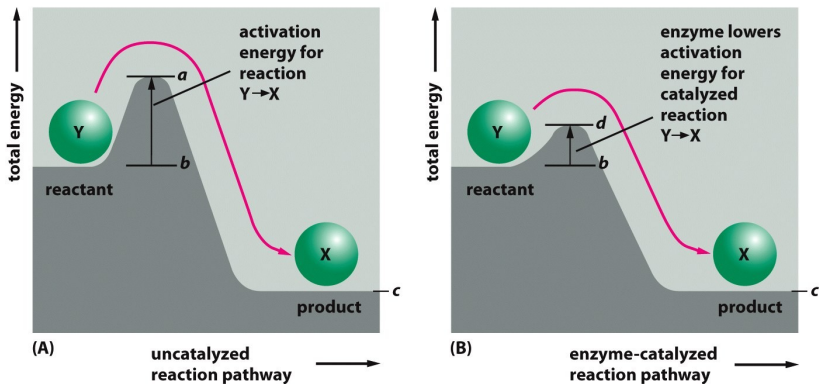


Figure 3-12 Essential Cell Biology 3/e (© Garland Science 2010)

Catalysis movie

Enzyme terminology: catalysis and substrate

- ▶ Enzyme binds with **substrate**,
- ▶ then catalyze conversion of substrate into **product**,
- ▶ and returns untouched to the initial state

Catalysis terms

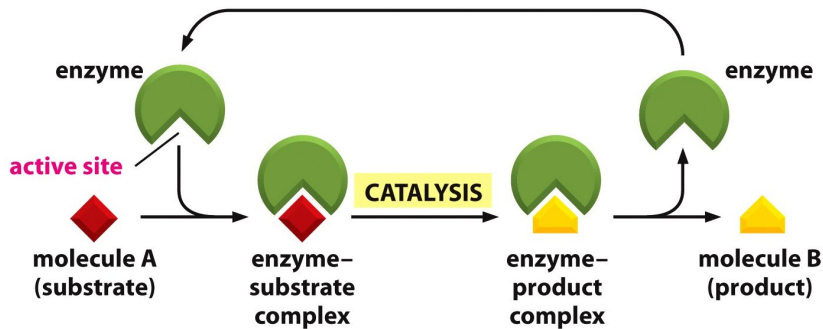


Figure 3-15 Essential Cell Biology 3/e (© Garland Science 2010)

Enzyme performance

- ▶ Two numbers are used for measuring enzyme performance: V_{\max} and K_M
- ▶ V_{\max} is maximal available reaction rate
- ▶ K_M is the concentration of substrate when the rate is $V_{\max}/2$

Enzyme performance

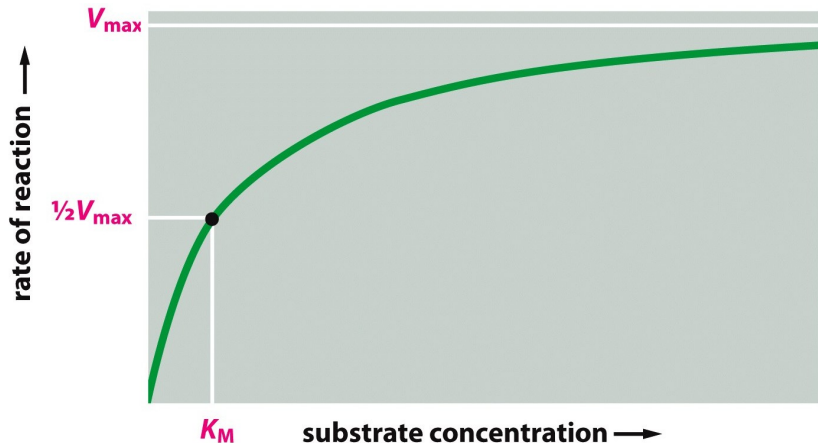


Figure 3-24 Essential Cell Biology 3/e (© Garland Science 2010)

Final question (3 points)

Final question (3 points)

How living organisms are working against the second law of thermodynamics?

Summary

- ▶ The second law of thermodynamics is about increasing entropy
- ▶ All metabolic reactions need energy

For Further Reading



A. Shipunov.

Advanced Cell Biology [Electronic resource].

2011—onwards.

Mode of access: `http:`

`//ashipunov.info/shipunov/school/biol_250`



B. Alberts et al.

Essential Cell Biology. 3rd edition.

Garland Science, 2009.

Chapter 2, Chapter 3: 58–100.