Microbial Physiology

Microbial Ecology
BSCI 464/MEES 698

Overview

- Metabolic systems of the cell
- Information processing systems of the cell
- Macromolecules
- Cell membranes

The hallmarks of cellular life

1. Metabolism: The cell is able to take matter from the environment, store energy in the form of molecules, and then release energy when needed.
2. Reproduction: The cell is capable of self-replication, either by dividing into two identical cells or by creating a single offspring.
3. Sensitivity: The cell is sensitive to external stimuli, such as changes in temperature, pH, or nutrient levels.
4. Movement: The cell can move from place to place, either by active transport or by chemotaxis.
5. Asexuality: The cell can reproduce asexually, without the need for a partner.
6. Evolution: The cell can evolve over time, adapting to changes in its environment.
The coding functions of the cell

Metabolic systems of the cell

ATP is the major carrier of chemical energy in living cells
High energy phosphate bounds

Energy conservation in the cell

<table>
<thead>
<tr>
<th>Compound</th>
<th>ΔG (kcal/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose-6-phosphate</td>
<td>-12.7</td>
</tr>
<tr>
<td>Acetyl phosphate</td>
<td>-16.8</td>
</tr>
<tr>
<td>ATP</td>
<td>-12.6</td>
</tr>
<tr>
<td>ADP</td>
<td>-11.8</td>
</tr>
</tbody>
</table>

Two mechanisms generate ATP in the cell:

**Oxidative phosphorylation:** generation of ATP by using light energy (photo hetero- and autotrophs)

**Respiration:** production of ATP by oxidation of organic or inorganic compounds (electron donors) coupled with reduction of inorganic or organic electron acceptors (O₂, NO₃, SO₄²⁻, Fe(III), CO₂, fumarate)

**Substrate-level phosphorylation:** synthesis of ATP by direct transfer of high-energy phosphate from a phosphorylated compound to ADP to form ATP
Respiration: electron transport and ATP synthesis

Electrons pass to NADP, which "tends" them into electron carriers.

Electrons flow down a cascade of carriers. Protons are pumped out of the cell, and a charge separation develops.

Protons re-enter the cell. ATP is converted to ADP.

electron transport chain

heterotrophs

autotrophs

Table 1: Thiosulfate- and Sulfate-reducing Bacteria

<table>
<thead>
<tr>
<th>Trait</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>c: continental</td>
<td>10°C</td>
</tr>
<tr>
<td>m: shallow marine</td>
<td>15°C</td>
</tr>
<tr>
<td>d: deep sea</td>
<td>20°C</td>
</tr>
</tbody>
</table>

(-) growth in absence of S²⁻ (Adams, 1995)
Substrate-level phosphorylation

Substrate-level phosphorylation is the synthesis of ATP by direct transfer of a high-energy phosphate from a phosphorylated organic compound to ADP to form ATP.

Glycolysis: 1 glucose is catabolized into 2 lactate, yielding 2 ATP.

Cellular synthesis and biodegradation

All major organic macromolecules are synthesized from intermediates of glycolysis, TCA cycle, and closely related pathways.
All cells encode information in the form of DNA. DNA in all cells is composed of:
- the same four bases: adenine, guanine, cytosine, thymine
- the same sugar (D-ribose)
- assembled in the same chemical structure and stereochemistry
Nucleotides

DNA

RNA

Complementary base pairing twists DNA into a double helix

Space-filling model of double helix

- All cells encode information on the form of DNA
- DNA in all cells is composed of:
  - the same four bases adenine, guanine, cytosine, thymine
  - the same sugar (D-ribose)
  - assembled in the same chemical structure and stereochemistry

- Information in DNA is stored using a *Universal* 3-letter code
The Genetic code

DNA in all cells is composed of
- the same four bases adenine, guanine, cytosine, thymine
- the same sugar (D-ribose)
- assembled in the same chemical structure and stereochemistry

Information in DNA is stored using a Universal 3-letter code

DNA synthesis is handled the same way in all organisms
Semiconservative DNA replication

DNA replication fork

DNA replication

DNA replication fork
- All cells encode information on the form of DNA
  - DNA in all cells is composed of
    - the same four bases: adenine, guanine, cytosine, thymine
    - the same sugar (D-ribose)
    - assembled in the same chemical structure and stereochemistry
- Information in DNA is stored using a *Universal* 3-letter code
- The function of DNA is carried out via transcription into RNA using RNA polymerases

**Bacterial transcription**

RNA is used to direct protein synthesis based on information in DNA

- RNA in all cells has the same structure
- All cells have the same types of RNA: rRNA, tRNA, mRNA
  - These RNAs are very much alike in sequence and structure in all cells

  ex: The rRNA in all organisms are greater than 50% identical in sequence and 80% in structure
Proteins direct most of the cell catalysis and structure

- Proteins in all cells use the same 20 amino acids, synthesized in the same way, and use the same post-translation modification.
Proteins direct most of the cell catalysis and structure

- Proteins in all cells use the same 20 amino acids, synthesized in the same way, and use the same post-translation modification.
- Protein synthesis is carried out via translation in the same way in all organisms.
- Reactions catalyzed: enzymes.
- Structure/function similarity: (amino acid sequence, 3-dimensional structure).
All cells are bound by a lipoprotein membrane

- strictly control what goes in and come out of the cell (transport systems)
- defines the cell, separating inside and outside