Anabolism

- synthesis of complex molecules and cellular structures
- turnover
  - continual degradation and resynthesis of cellular constituents
- rate of biosynthesis approximately balanced by rate of catabolism
- requires much energy

Figure 10.1
<table>
<thead>
<tr>
<th>Cell Constituent</th>
<th>Number of Molecules per Cell&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Molecules Synthesized per Second</th>
<th>Molecules of ATP Required per Second for Synthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNA</td>
<td>1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.00083</td>
<td>60,000</td>
</tr>
<tr>
<td>RNA</td>
<td>15,000</td>
<td>12.5</td>
<td>75,000</td>
</tr>
<tr>
<td>Polysaccharides</td>
<td>39,000</td>
<td>32.5</td>
<td>65,000</td>
</tr>
<tr>
<td>Lipids</td>
<td>15,000,000</td>
<td>12,500.0</td>
<td>87,000</td>
</tr>
<tr>
<td>Proteins</td>
<td>1,700,000</td>
<td>1,400.0</td>
<td>2,120,000</td>
</tr>
</tbody>
</table>

<sup>a</sup>Estimates for a cell with a volume of 2.25 $\mu$m$^3$, a total weight of $1 \times 10^{-12}$g, a dry weight of $2.5 \times 10^{-13}$g, and a 20 minute cell division cycle.

<sup>b</sup>It should be noted that bacteria can contain multiple copies of their genomic DNA.
Principles Governing Biosynthesis

- macromolecules are synthesized from a limited number of simple structural units (monomers)
  - saves genetic storage capacity, biosynthetic raw material, and energy
- many enzymes used for both catabolism and anabolism
  - saves materials and energy
More principles…

• catabolic and anabolic pathways are not identical, despite sharing many enzymes
  – permits independent regulation

Figure 10.2
More principles…

• breakdown of ATP coupled to certain reactions in biosynthetic pathways
  – drives the biosynthetic reaction to completion
• in eucaryotes, anabolic and catabolic reactions located in separate compartments
  – allows pathways to operate simultaneously but independently
More principles…

• catabolic and anabolic pathways use different cofactors
  – catabolism produces NADH
  – NADPH used as electron donor for anabolism

• large assemblies (e.g., ribosomes) form spontaneously from macromolecules by self-assembly
Calvin cycle

• in eucaryotes, occurs in stroma of chloroplast

• in cyanobacteria, some nitrifying bacteria, and thiobacilli, may occur in carboxysomes
  – inclusion bodies that contain ribulose-1,5-bisphosphate carboxylase (rubisco)

• consists of 3 phases
The Carboxylation Phase

- rubisco catalyzes addition of CO₂ to ribulose-1,5-bisphosphate (RuBP), forming 2 molecules of 3-phosphoglycerate

Figure 10.3
The Reduction Phase

- 3-phosphoglycerate reduced to glyceraldehyde 3-phosphate

Figure 10.4
The Regeneration Phase

- RuBP regenerated
- carbohydrates (e.g., fructose and glucose) are produced

Figure 10.4
Summary

\[ 6\text{CO}_2 + 18\text{ATP} + 12\text{NADPH} + 12\text{H}^+ + 12\text{H}_2\text{O} \]

\[ \downarrow \]

\[ \text{glucose} + 18\text{ADP} + 18\text{P}_i + 12\text{NADP}^+ \]
Synthesis of Sugars and Polysaccharides

• gluconeogenesis
  – used to synthesize glucose and fructose from noncarbohydrate precursors

• sugar nucleoside diphosphates
  – important in synthesis of other sugars, polysaccharides, and bacterial cell walls
Gluconeogenesis

- generates glucose and fructose
  - most other sugars made from them
- functional reversal of glycolysis
  - 7 enzymes shared
  - 4 enzymes are unique to gluconeogenesis
Figure 10.5
Anaplerotic CO$_2$ fixation

Phosphoenolpyruvate (PEP) carboxylase:
PEP + CO$_2$ → oxaloacetate

Pyruvate carboxylase:
pyruvate + CO$_2$ → oxaloacetate

Figure 10.17