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

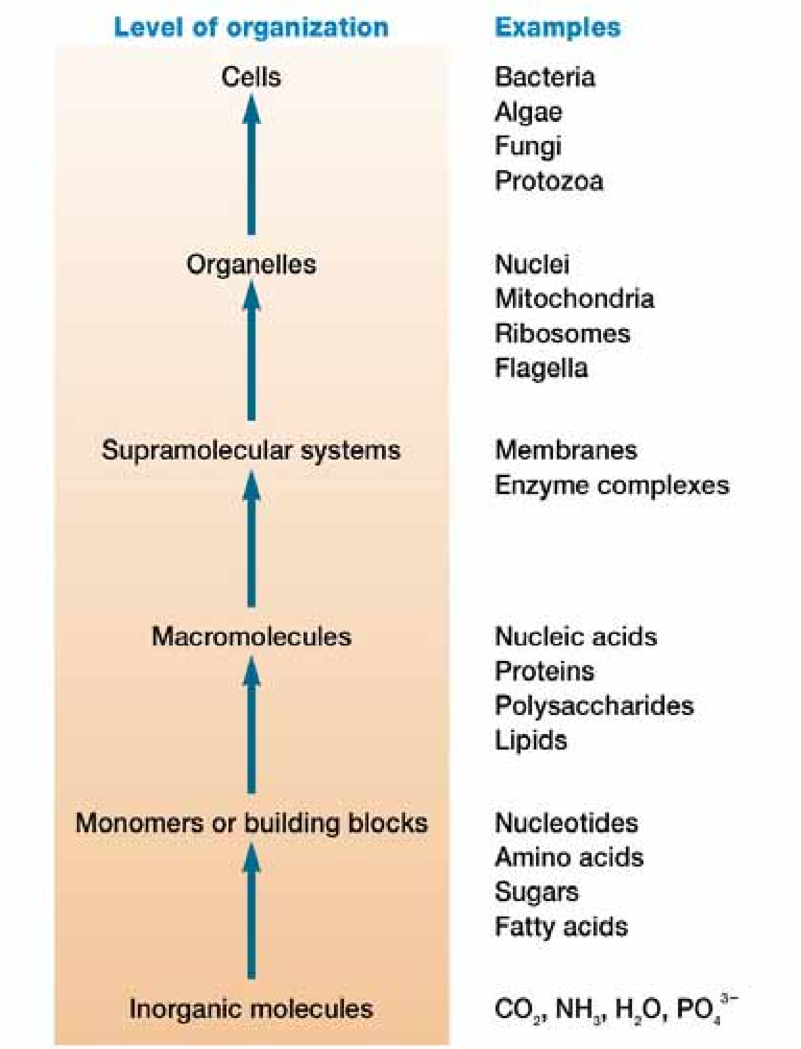


Figure 10.1

Table 10.1 Biosynthesis in *Escherichia coli*

Cell Constituent	Number of Molecules per Cell[a]	Molecules Synthesized per Second	Molecules of ATP Required per Second for Synthesis
DNA	1[b]	0.00083	60,000
RNA	15,000	12.5	75,000
Polysaccharides	39,000	32.5	65,000
Lipids	15,000,000	12,500.0	87,000
Proteins	1,700,000	1,400.0	2,120,000

[a]Estimates for a cell with a volume of 2.25 μm^3, a total weight of 1×10^{-12}g, a dry weight of 2.5×10^{-13}g, and a 20 minute cell division cycle.

[b]It should be noted that bacteria can contain multiple copies of their genomic DNA.

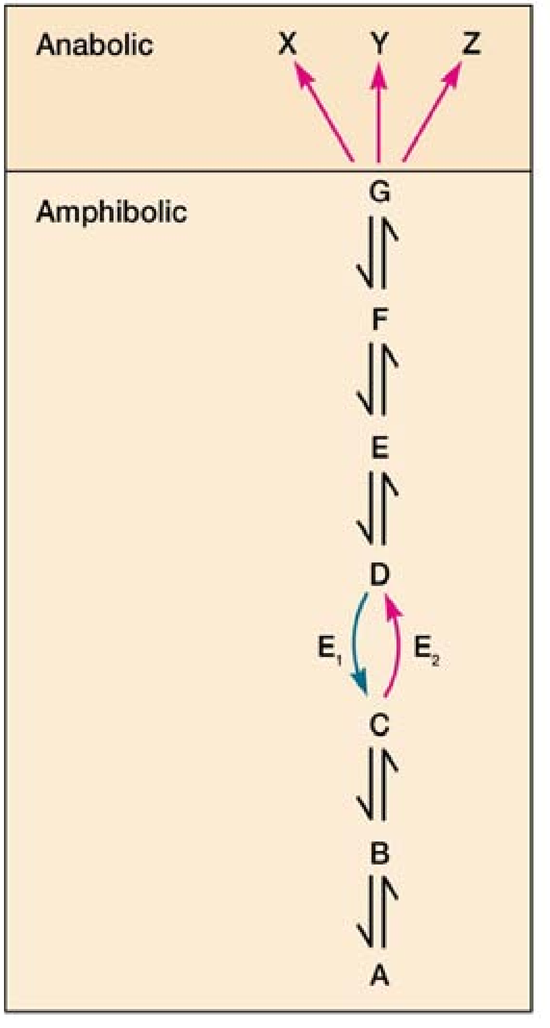
Principles Governing Biosynthesis

- macromolecules are synthesized from 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 CO_2 to ribulose-1,5-bisphosphate (RuBP), forming 2 molecules of 3-phosphoglycerate

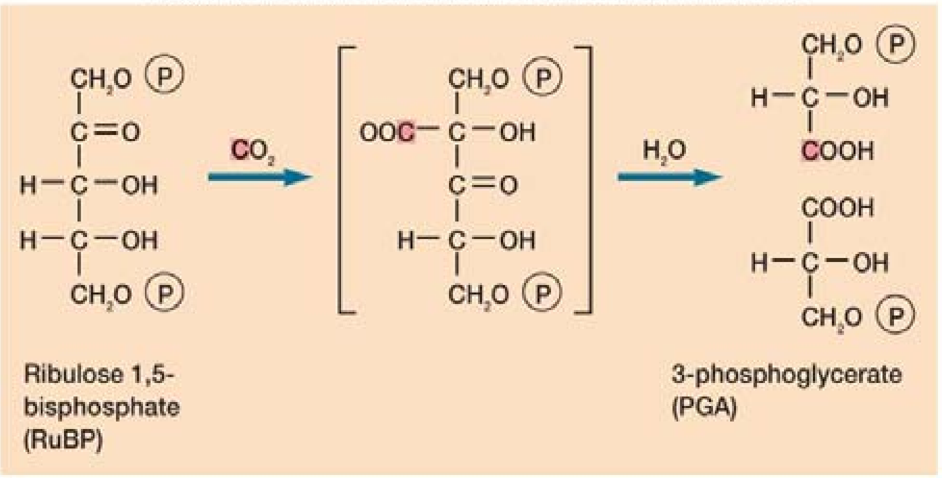


Figure 10.3

The Reduction Phase

- 3-phospho-glycerate reduced to glyceraldehyde 3-phosphate

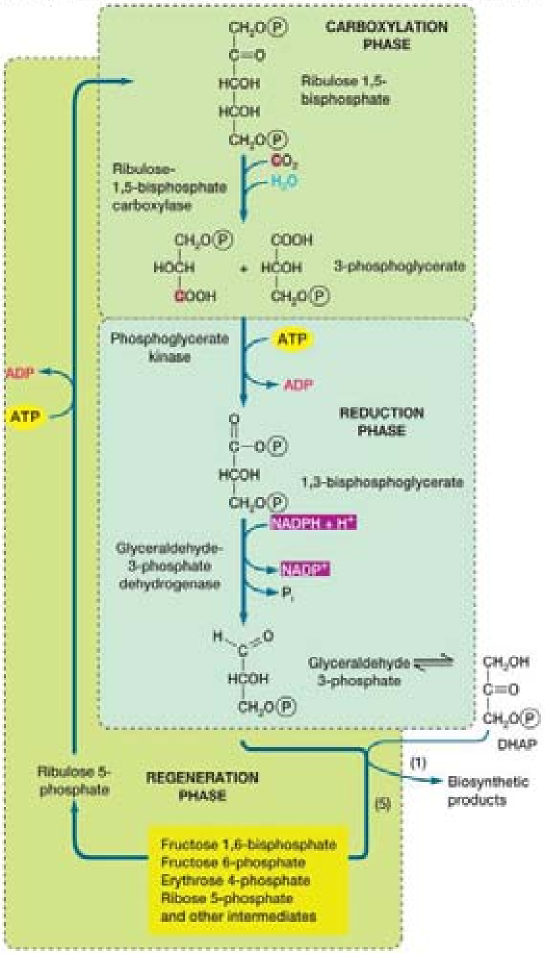


Figure 10.4

The Regeneration Phase

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

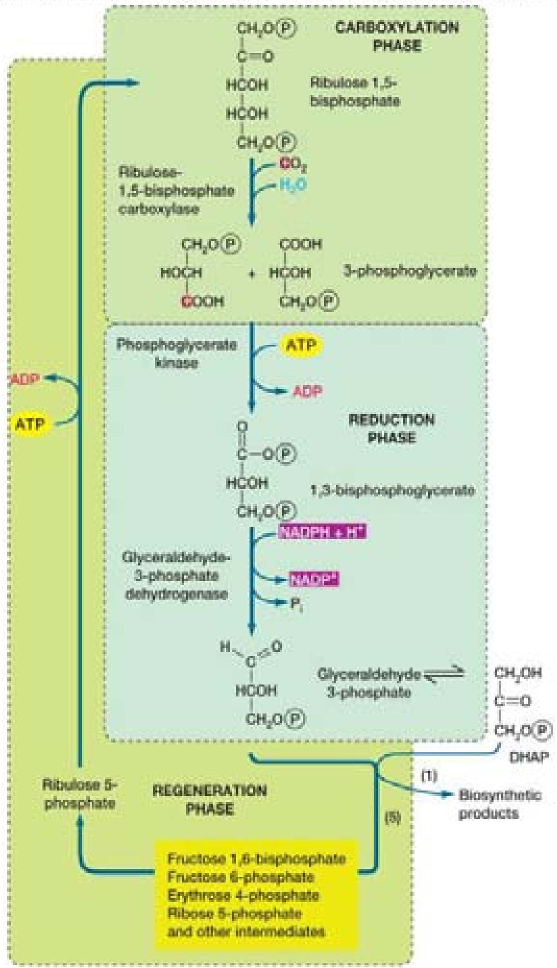


Figure 10.4

Summary

$6CO_2 + 18ATP + 12NADPH + 12H^+ +$
$12H_2O$

$$\downarrow$$

$glucose + 18ADP + 18P_i + 12NADP^+$

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

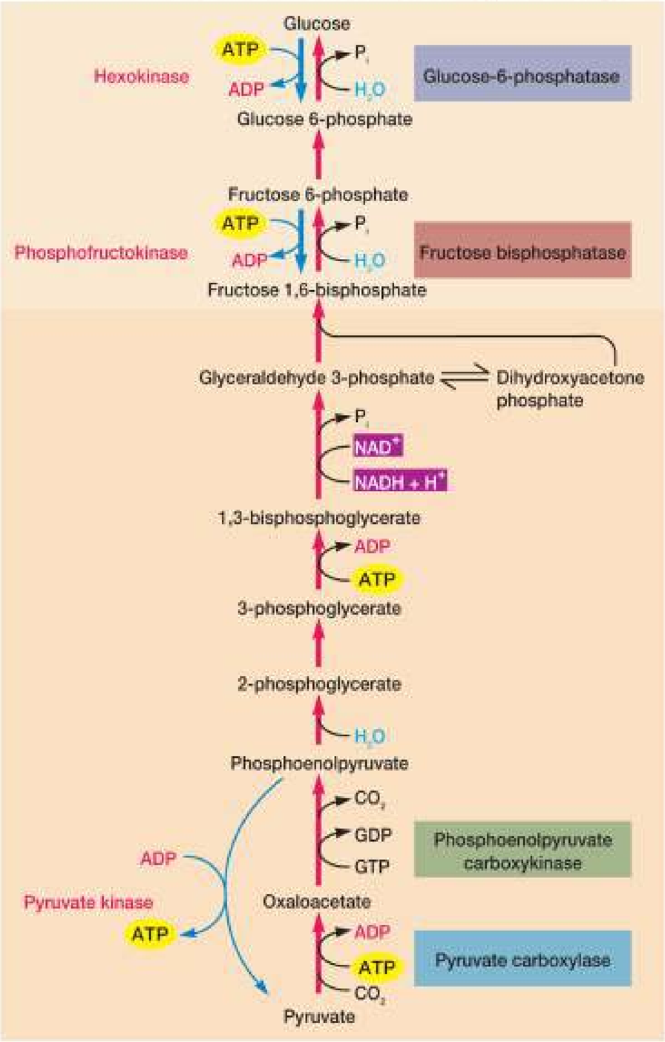
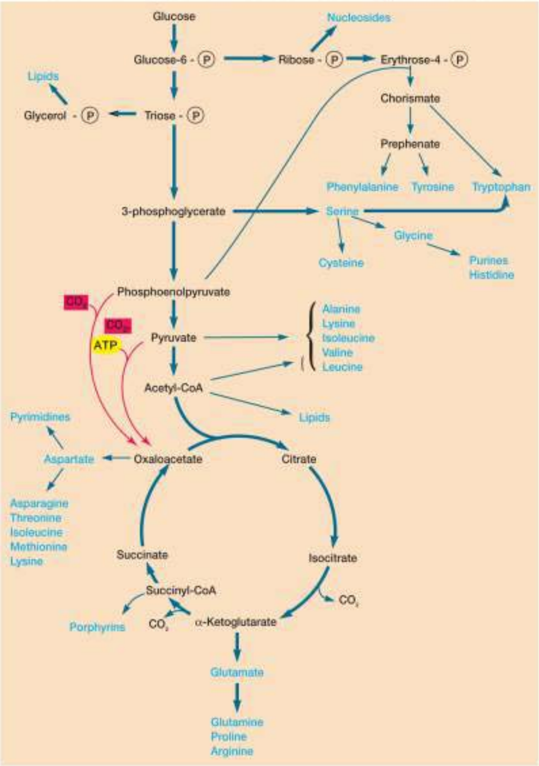

Glucose
ATP
Hexokinase
ADP
P_i
H_2O
Glucose-6-phosphatase
Glucose 6-phosphate
Fructose 6-phosphate
ATP
Phosphofructokinase
ADP
P_i
H_2O
Fructose bisphosphatase
Fructose 1,6-bisphosphate
Glyceraldehyde 3-phosphate
Dihydroxyacetone phosphate
P_i
NAD^+
$NADH + H^+$
1,3-bisphosphoglycerate
ADP
ATP
3-phosphoglycerate
2-phosphoglycerate
H_2O
Phosphoenolpyruvate
CO_2
GDP
GTP
Phosphoenolpyruvate carboxykinase
ADP
Pyruvate kinase
ATP
Oxaloacetate
ADP
ATP
CO_2
Pyruvate carboxylase
Pyruvate

Figure 10.5

Anaplerotic CO_2 fixation

phosphoenol-pyruvate (PEP) carboxylase: PEP + CO_2 → oxaloacetate



pyruvate carboxylase: pyruvate + CO_2 → oxaloacetate

Figure 10.17