ADENOSINE TRIPHOSPHATE: THE ENERGY CURRENCY

- The energy in food does not transfer directly to cells for biologic work. Rather, energy from macronutrient oxidation is harvested and funneled through the energy-rich compound adenosine triphosphate (ATP).
- In essence, the energy donor–energy receiver role of ATP represents the cells' two major energy transforming activities:

  1. Extract potential energy from food and conserve it within the bonds of ATP
  2. Extract and transfer the chemical energy in ATP to power biologic work

- ATP serves as the ideal energy-transfer agent. It "traps" within its phosphate bonds a large portion of the original food molecule's potential energy. ATP also readily transfers this trapped energy to other compounds to raise them to a higher activation level.
- The cell contains other high-energy compounds (e.g., phosphoenolpyruvate; 1,3, diphosphoglycerate; phosphocreatine), but ATP is the most important.
- The bonds that link the two outermost phosphates (symbolized) represent high-energy bonds because they release considerable useful energy during hydrolysis. A new compound, adenosine diphosphate (ADP) forms when ATP joins with water, catalyzed by the enzyme adenosine triphosphatase (ATPase).

$$\mathrm{ATP} + \mathrm{H_2O} \xrightarrow{\mathrm{ATPase}} \mathrm{ADP} + \mathrm{P_i} - \Delta \mathrm{G}\ 7.3\ \mathrm{kCal} \cdot \mathrm{mol}^{-1}$$

- This reaction generates considerable free energy, making ATP known as a high-energy phosphate compound. Infrequently, additional energy releases when another phosphate splits from ADP.
- The energy liberated during ATP breakdown directly transfers to other energy-requiring molecules.
- In muscle, the energy stimulates specific sites on the contractile elements to activate the molecular motors that power muscle fibers to shorten. Energy from ATP hydrolysis powers all forms of biologic work; thus, ATP constitutes the cell's "energy currency.

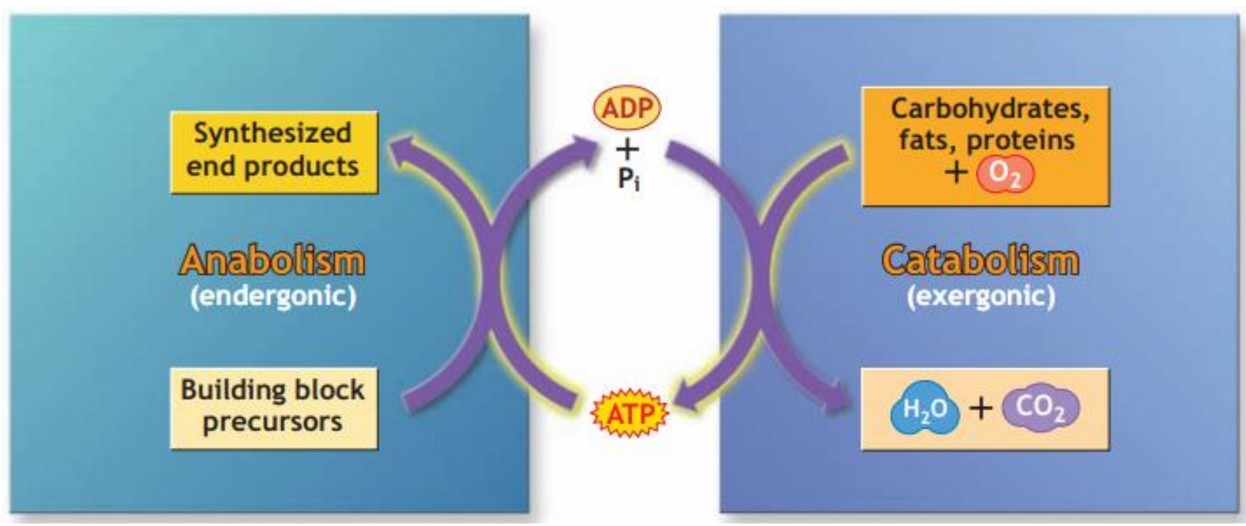

Figure 6.3 Catabolism–anabolism interactions. Continual recycling of ATP for biologic work from intracellular ADP, Pi , and energy released from stored macronutrients.

- ATP splits almost instantly without oxygen. This capability to hydrolyze ATP anaerobically to generate rapid energy transfer would not occur if energy metabolism required oxygen at all times.

- Bodily movements requiring this type of energy include sprinting 10 seconds for a bus, lifting an object, swinging a golf club, spiking a volleyball, or performing a pull-up or push-up.
- The body maintains a continuous ATP supply through different metabolic pathways: Three reactive processes that harness cellular energy to generate ATP aerobically—
  - the citric acid cycle,
  - B- oxidation,
  - respiratory chain—reside within the mitochondria.

ATP: A Limited Currency

- Cells contain a small quantity of ATP and must therefore continually resynthesize it at its rate of use. Only under extreme exercise conditions do ATP levels in skeletal muscle decrease.
- A limited ATP supply provides a biologically useful mechanism to regulate energy metabolism. By maintaining only a small amount of ATP, its relative concentration changes rapidly in response to only a minimal ATP decrease.
- Any increase in energy requirement immediately disrupts the balance between ATP and ADP and Pi. As one might expect, increases in energy transfer depend on exercise intensity.
- The body stores only 80 to 100 g (about 3.0 oz) of ATP at any time under normal resting conditions. This quantity makes available each second approximately 2.4 mmol of ATP per

kg wet muscle weight, or about 1.44 1010 molecules of ATP. This represents enough intramuscular stored energy to power several seconds of explosive, all-out exercise.

- Thus, ATP alone does not represent a significant energy reserve. A sedentary person resynthesizes an amount of ATP each day equal to about 75% of body mass.
- For an endurance athlete who generates 20 times the resting energy expenditure throughout a 2.5-hour marathon race, this amounts to 80 kg of ATP resynthesis during the run! To appreciate the tremendous quantity of ATP production over the adult portion of a lifespan.