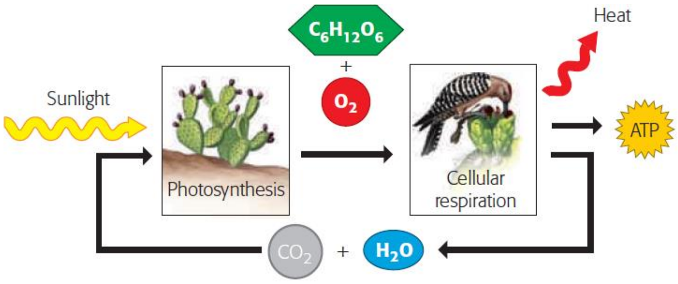
Chapter 6. Cellular Respiration: Obtaining Energy from Food

- **Aerobic capacity**（有氧代谢能力）is the maximum rate at which O2 can be taken in and used by your muscle cells

Within your aerobic capacity	Exceed your aerobic capacity
Metabolism is aerobic(有氧的)	Metabolism is anaerobic(无氧的), produce lactic acid (乳酸)

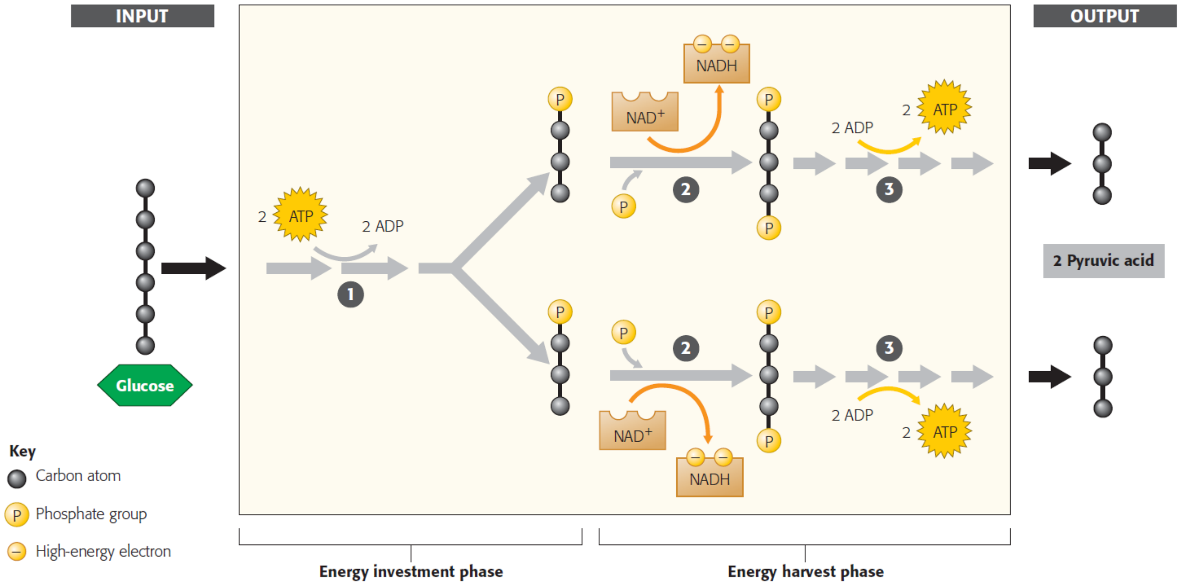
- **Energy Flow and Chemical Cycling in the Biosphere**
  Autotrophs(自养生物) ("self-feeders") are organisms that make all their own organic matter, including carbohydrates, lipids, proteins, and nucleic acids, from nutrients that are entirely inorganic (CO_2, H_2O, minerals)
  Heterotrophs(异养生物) (other-feeders) include humans and other animals and cannot make organic molecules from inorganic ones.
  - **Producers and Consumers**
    Autotrophs (producers) make organic molecules from inorganic nutrients via photosynthesis.
    Heterotrophs (consumers) must consume organic material and obtain energy via cellular respiration.
  - **Chemical Cycling between Photosynthesis and Cellular Respiration**
    The molecular outputs of cellular respiration (mitochondria (线粒体))—CO_2 and H_2O—are the molecular inputs of photosynthesis (chloroplast (叶绿体)), and vice versa. While these chemicals cycle through an ecosystem, energy flows through, entering as sunlight and exiting as heat.



- **Cellular Respiration: Aerobic (需氧的) Harvest of Food Energy**
  - **Cellular Respiration**: aerobic harvesting of chemical energy from organic fuel molecules.
  - **An Overview of Cellular Respiration**
    The overall equation of cellular respiration simplifies a great many chemical steps into one formula:

  - **The Three Stages of Cellular Respiration**
    - **Stage 1: Glycolysis** (糖酵解)
      1. A six-carbon glucose molecule is split in half to form two molecules of pyruvic acid (丙酮酸).
      2. The three-carbon molecules then donate high-energy electrons to NAD+, forming NADH.
      3. Generate four ATP molecules directly when enzymes transfer phosphate groups from fuel molecules to ADP.

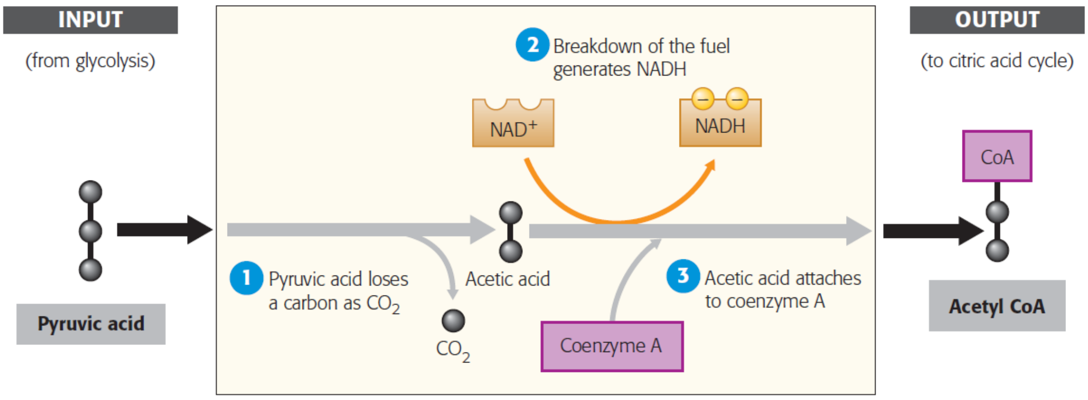
Figure 6.5 Glycolysis. In glycolysis, a team of enzymes splits glucose, eventually forming two molecules of pyruvic acid. After investing 2 ATP at the start, glycolysis generates 4 ATP directly. More energy will be harvested later from high-energy electrons used to form NADH and from the two molecules of pyruvic acid.



✧ **Stage 2: The Citric Acid Cycle** (三羧酸循环)

The pyruvic acid must be converted to a form the citric acid cycle can use.

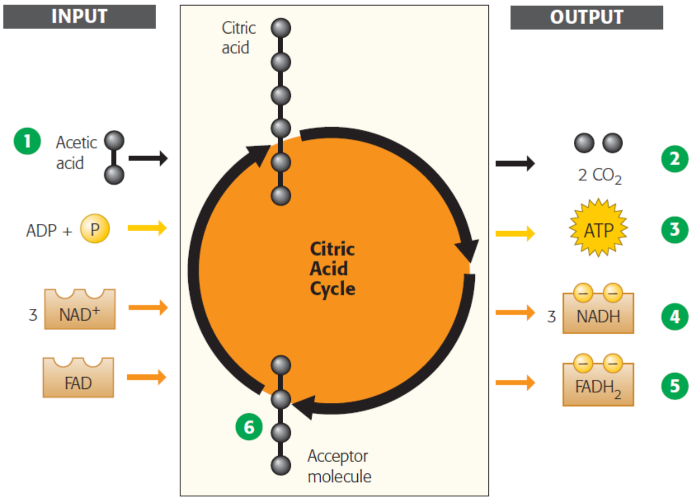
1. Each pyruvic acid loses a carbon as CO_2.The remaining fuel molecules, with only two carbons left, are called acetic acid (乙酸).
2. Electrons are stripped from these molecules and transferred to another molecule of NAD+, forming more NADH.
3. Finally, each acetic acid is attached to a molecule called coenzyme A (辅酶 A) (CoA) to form acetyl CoA(乙酰辅酶 A). The CoA escorts the acetic acid into the first reaction of the citric acid cycle and is then stripped and recycled.



The citric acid cycle finishes extracting the energy of sugar by dismantling the acetic acid (柠檬酸) **molecules all the way down to CO2.**

1. Acetic acid (乙酸) joins a four-carbon acceptor molecule to form a six-carbon product called citric acid (for which the cycle is named). For every acetic acid molecule that enters the cycle as fuel,
2. two CO2 molecules eventually exit as a waste product. Along the way, the citric acid cycle harvests energy from the fuel.
3. Some of the energy is used to produce ATP directly. However, the cycle captures much more energy in the form of NADH and a closely related electron carrier called FADH2.
4. All the carbon atoms that entered the cycle as fuel are accounted for as CO2 exhaust, and the four-carbon acceptor molecule is recycled.

► Figure 6.8 The citric acid cycle.



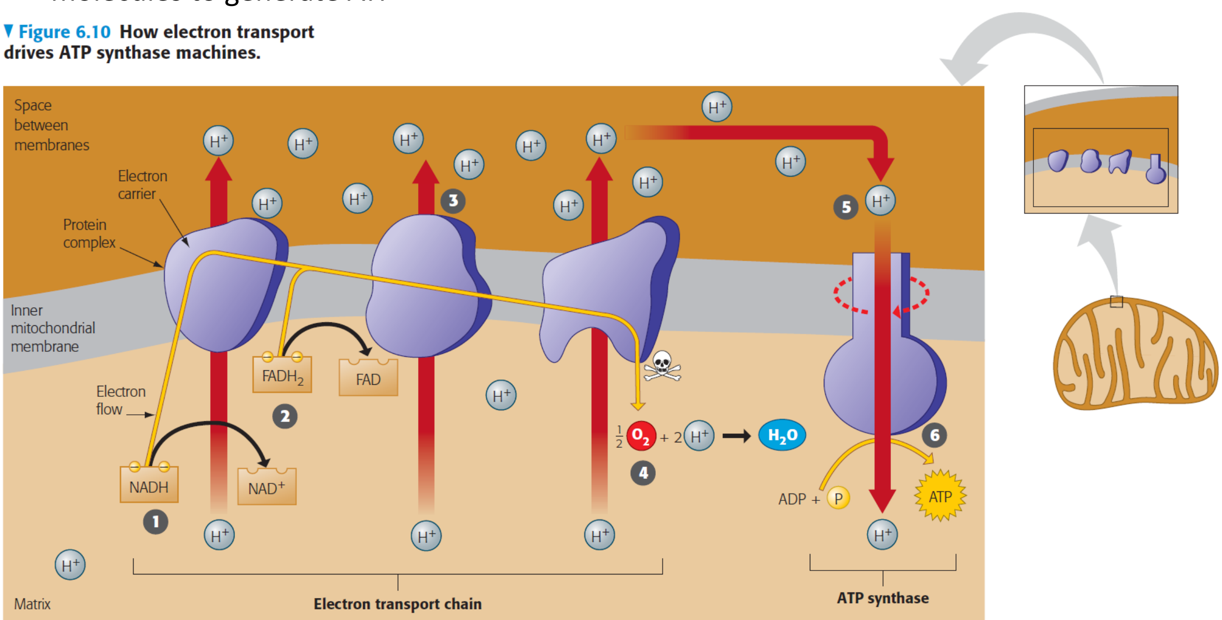
✧ Stage 3: Electron Transport

1. The transfer of electrons from organic fuel (food) to NAD+ converts it to NADH.
2. The rest of the staircase consists of an electron transport chain.

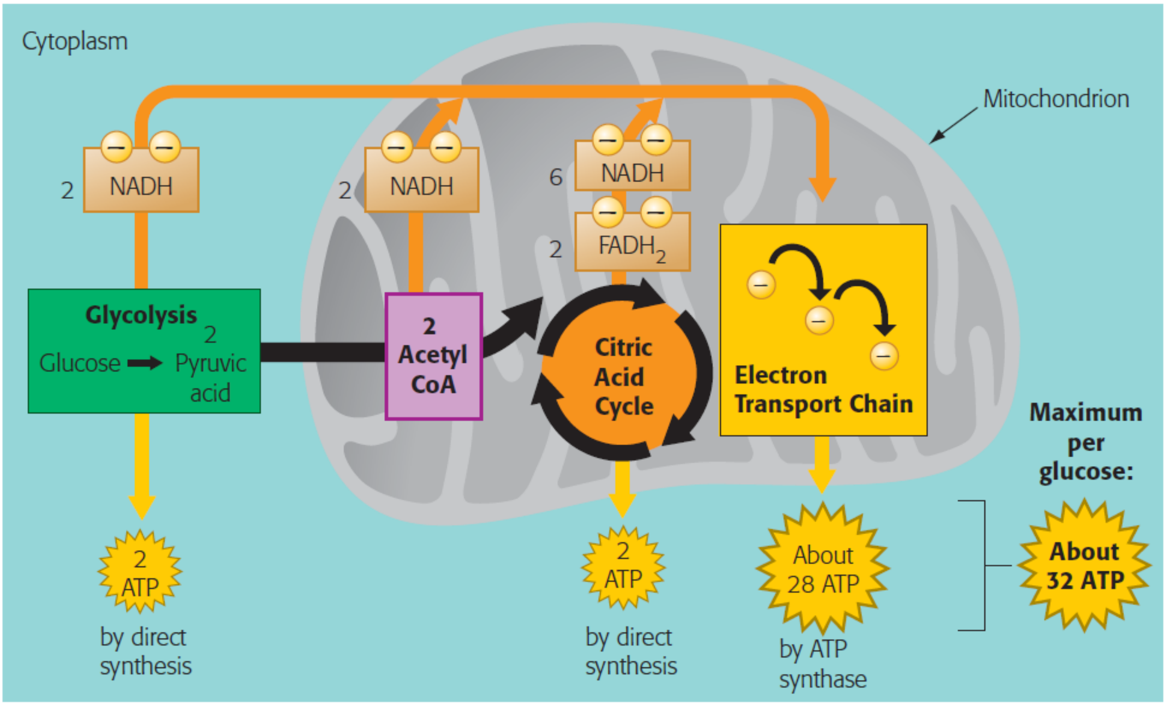
ATP Synthesis

1. NADH and
2. FADH2 transfer electrons to an electron transport chain.
3. The electron transport chain uses this energy supply to pump H+ across the inner mitochondrial membrane (线粒体内膜).
4. Oxygen pulls electrons down the transport chain.
5. The H+ concentrated on one side of the membrane rushes back “downhill” through an ATP synthase. This action spins a component of the ATP synthase, just as water turns the turbines in a dam.
6. The rotation activates parts of the synthase molecule that attach phosphate groups to ADP molecules to generate ATP

▼ Figure 6.10 How electron transport drives ATP synthase machines.



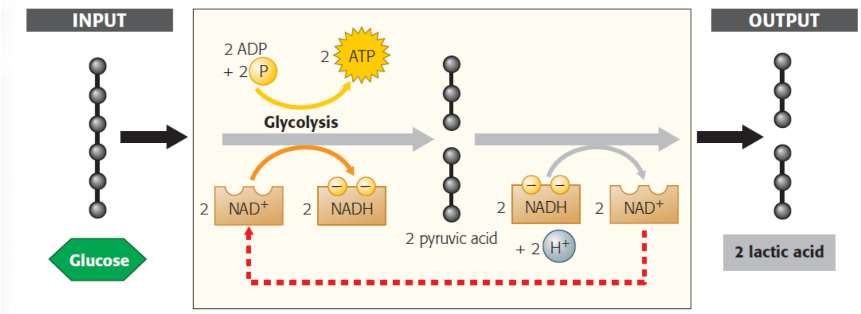
■ The Results of Cellular Respiration



- **Fermentation: Anaerobic Harvest of Food Energy**
  - **Fermentation in Human Muscle Cells**

    When muscle cells consume ATP faster than O2 can be supplied for cellular respiration, the conditions become anaerobic, and muscle cells will begin to regenerate ATP by fermentation. The waste product under these anaerobic conditions is lactic acid. The ATP yield per glucose is much lower during fermentation (2ATP) than during cellular respiration (about32ATP).

▼ Figure 6.13 Fermentation: producing lactic acid. Glycolysis produces ATP even in the absence of O_2. This process requires a continuous supply of NAD^+ to accept electrons from glucose. The NAD^+ is regenerated when NADH transfers the electrons it removed from food to pyruvic acid, thereby producing lactic acid (or other waste products, depending on the species of organism).



  - **Fermentation in Microorganisms**

    Yeast and some other organisms can survive with or without O2. Wastes from fermentation can be ethyl alcohol, lactic acid, or other compounds, depending on the species.