Chapter 7: Cellular Respiration

Organic molecules + $\mathbf{O_2}$ → $CO_2 + H_2O$ *+ Energy*

Part 1: Aerobic Respiration (4 Steps of Glucose Metabolism)

I. **Step 1: Glycolysis *(Fig. 7.4)***
   A. Performed by almost all organisms
   B. Doesn't require O_2
   C. Occurs in cytosol
   D. Breaks glucose in half *(C_6 → 2 C_3)*
      1. *(1 glucose →2 pyruvate)*
   E. Net gain of 2 ATP & 2 (NADH + H^+)
   F. **10 steps in 3 phases:**
      1. Energy Investment Phase
         a. Glucose + Enzyme + 2ATP → 6-Carbon compound + 2 ADP
      2. Cleavage Phase
         a. 6-Carbon compound → 2 G3P
      3. Energy Liberation Phase
         a. 2 G3P → 2 molecules of pyruvate + 4 ATP + **2 NADH:**

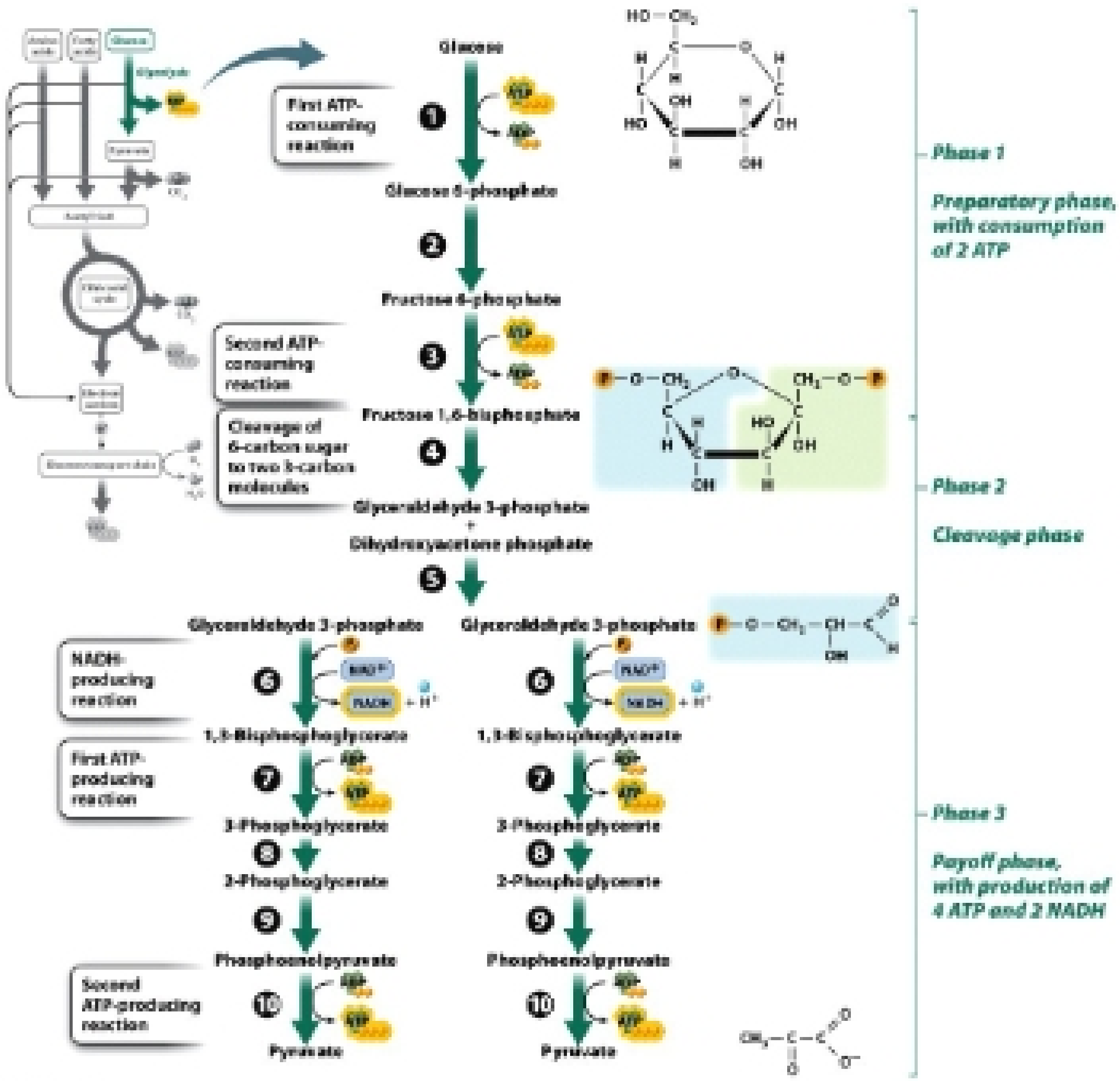

Figure 7.4
Biology: How Life Works
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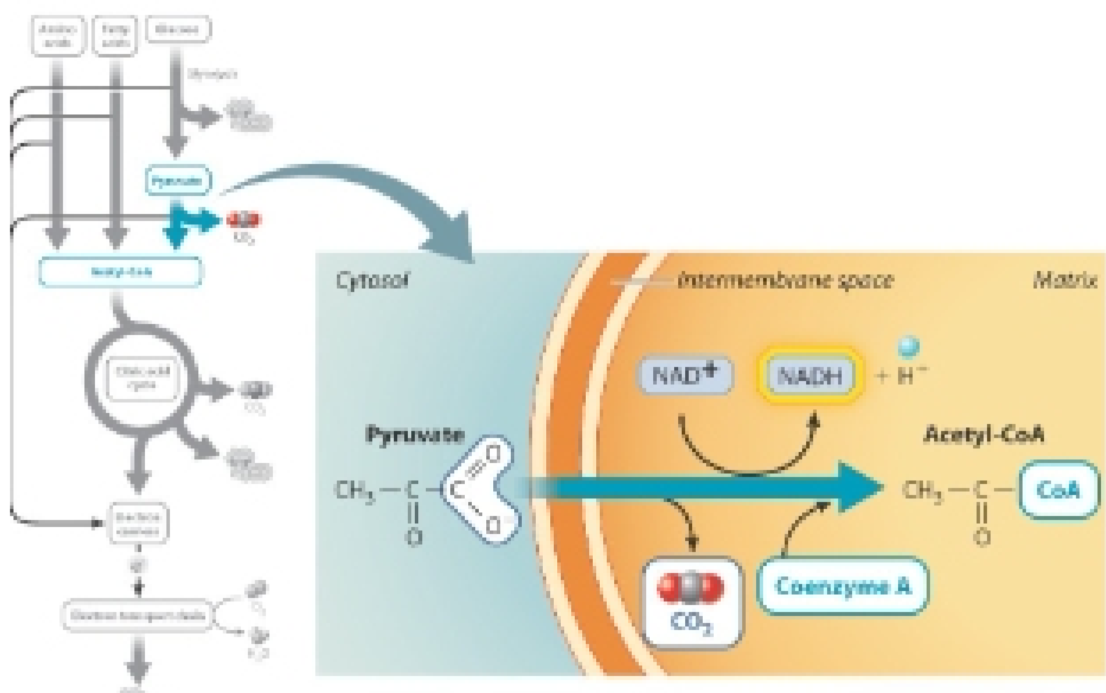
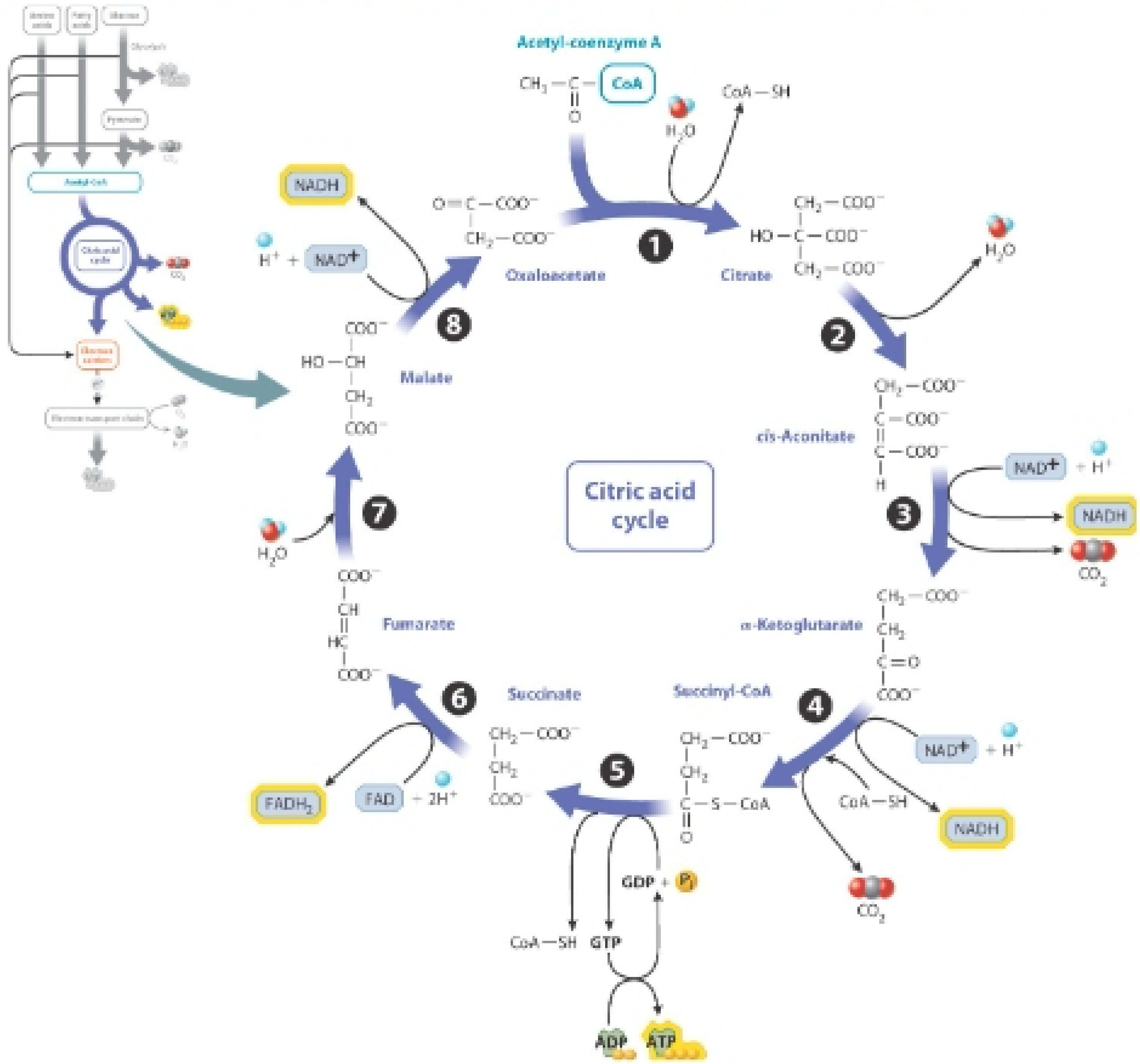
   G. **NADH & Redox Reactions**
      1. $NAD^+ + 2e^- + H^+$ → NADH **(redox rxn.)**
         a. NAD^+ reduced (gains energy); Pyruvate oxidized (loses energy)
         b. NADH is an "energy intermediate"
      2. Redox Reactions
         a. Oxidized molecules tend to lose H
            i. Tend to have C-O bonds, not C-H nonds
            ii. Follow H to follow electrons
   H. ATP in glycolysis is generated by an enzyme (substrate level phosphorylation)
      1. Phosphoenolpyruvate (1 phosphorous) and ADP combine on an enzyme to form ATP + pyruvate
   I. Pyruvate is transported into mitochondria & breakdown continues—

II. **Step 2: Pyruvate Breakdown (Acetyl Co-A Synthesis) *(Fig. 7.6)***
   A. Pyruvate dehydrogenase removes CO_2 from 3-C pyruvate
   B. 2-C acetyl combines with CoA
   C. Per pyruvate: 1 acetyl CoA, 1 NADH, 1 CO_2



III. <u>Step 3: Citric Acid Cycle (Krebs Cycle) (Fig. 7.7)</u>

- **A.** Each acetyl group is oxidized to 2 CO_2
- **B.** Acetyl (2-C) removed & attatched to oxaloacetate (4-C → Citrate (6-C)
- **C.** Cycle releases 2 CO_2, 1 ATP, 3NADH, 1 $FADH_2$
- **D.** Oxaloacetate is regenerated
- **E.** Regenrates high energy compounds by incorporating & then breaking down acetyl group ***(see Fig. 7.7)***



<u>Breakdown of 1 glucose (so far):</u>

<u>Process</u>	**<u>ATP</u>**	**<u>NADH</u>**	**<u>$HADH_2$</u>**	**<u>CO_2</u>**	**<u>Other</u>**
<u>Glycolysis</u>	2	2	--	--	2 Pyruvate
<u>Pyruvate breakdown</u>	--	2	--	2	2 Acetyl-CoA
<u>Krebs</u>	2	6	2	4	--
<u>Total</u>	4	10	2	6	--

IV. Oxidative Phosphorylation (Electron Transport Chain + ATP Synthesis)

A. Uses NADH & $FADH_2$ to make ATP

B. "Oxidative Phosphorylation" includes the ETC & phosphorylation of ADP via ATP Synthase

1. **Electron Transport Chain**
    a. Composed proteins or small organic molecules
    b. Accept & release electrons in a series of redox reactions
    c. Electrons lose energy as they move through ETC
    d. Electron movement generates H^+ electrochemical gradient (proton-motive force)

C. **Process of Oxidative Phosphorylation**

1. **NADH donates electrons to complex I; complex I accepts them & pumps H^+ across membrane**

2. $FADH_2$ transfers electrons to complex II

3. **Electrons move to CoQ (Or U, for ubiquinone), forming $CoQH_2$**

4. Electrons donated from $CoQH_2$ to complex III; H^+ pumped across membrane
    a. H^+ accumulating on bottom of diagram (inside) – making acidic environment
    b. Protons (H^+) being pumped across membrane at complex I & complex III so far

5. **Electrons transferred to Cc**

6. Electron transferred to IV. IV pumps H^+ across the membrane and transfers electrons to the final electron acceptor, an oxygen atom, resulting in H_2O formation – **electron transport chain ends**
    a. Products of electron transport chain – H_2O & the H^+ gradient

7. **H^+ gradient used by ATP synthase to make ATP**