Chapter 7: Cellular Respiration

*Organic molecules + **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:**

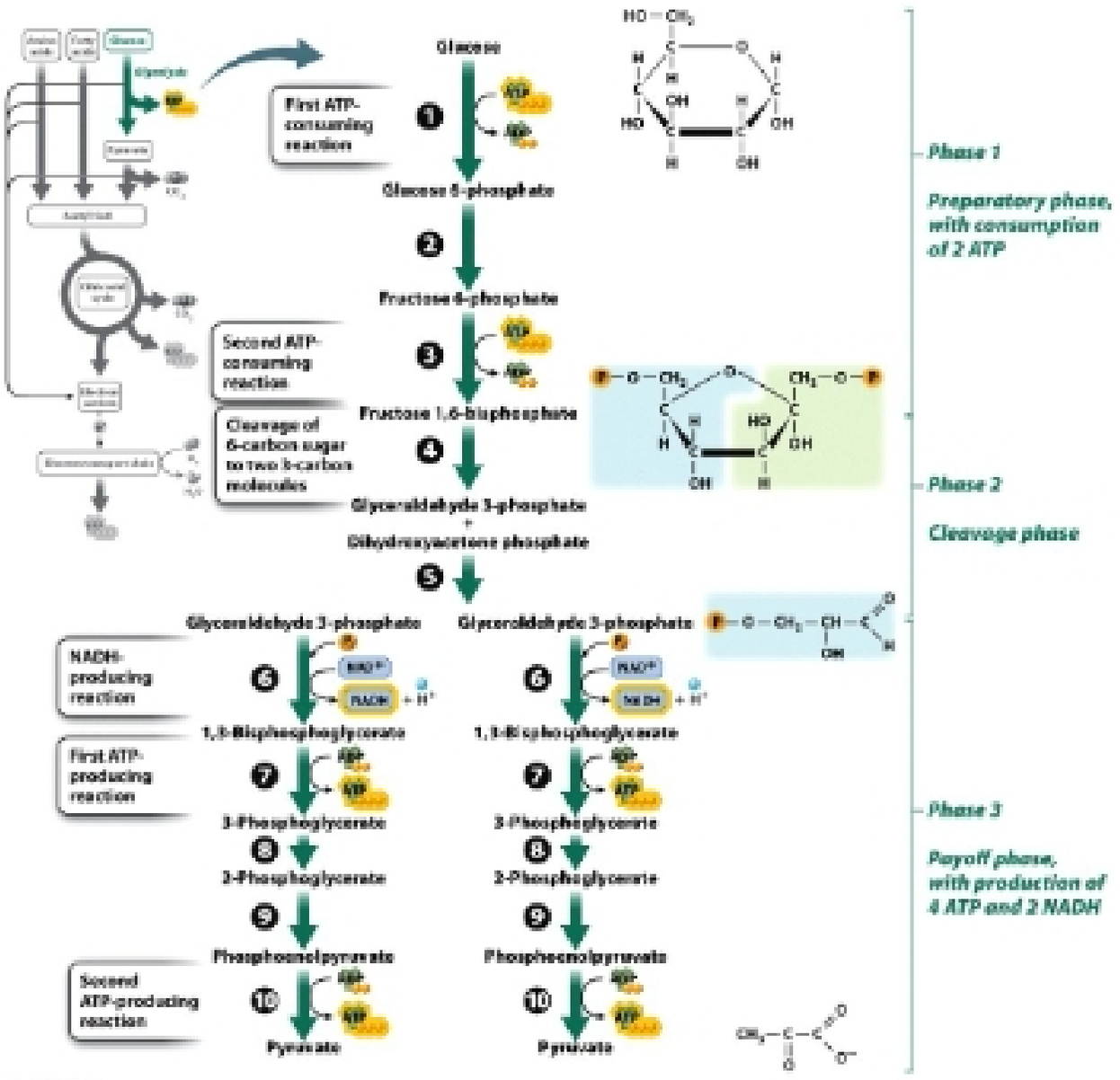

Figure 7.4
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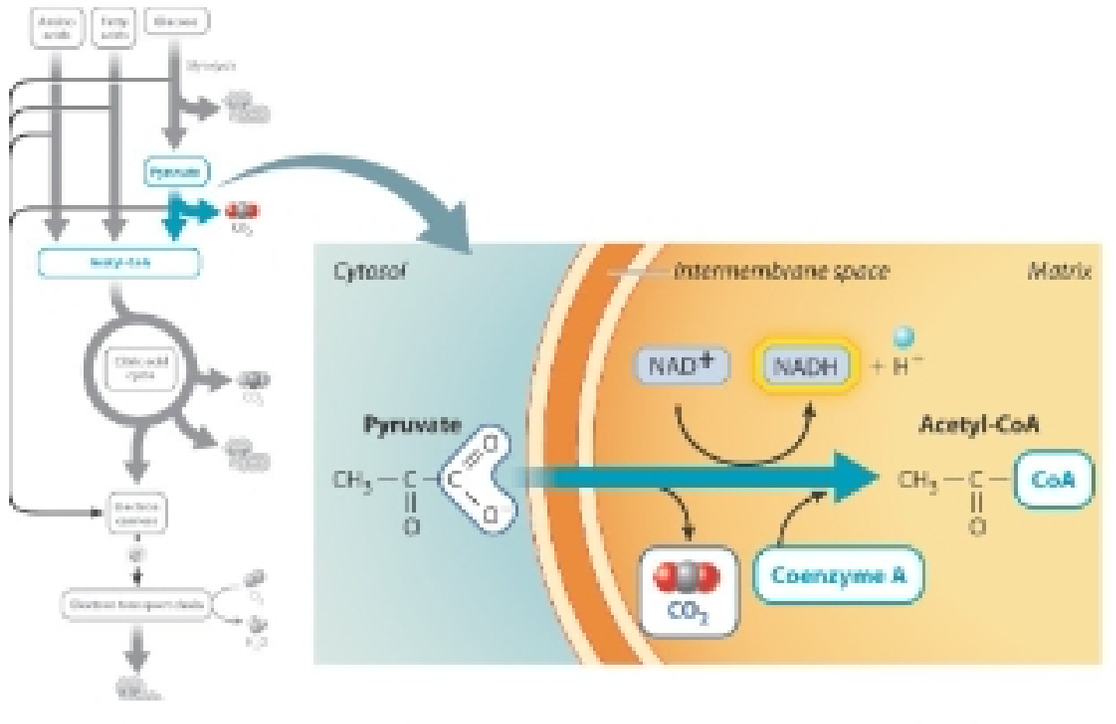
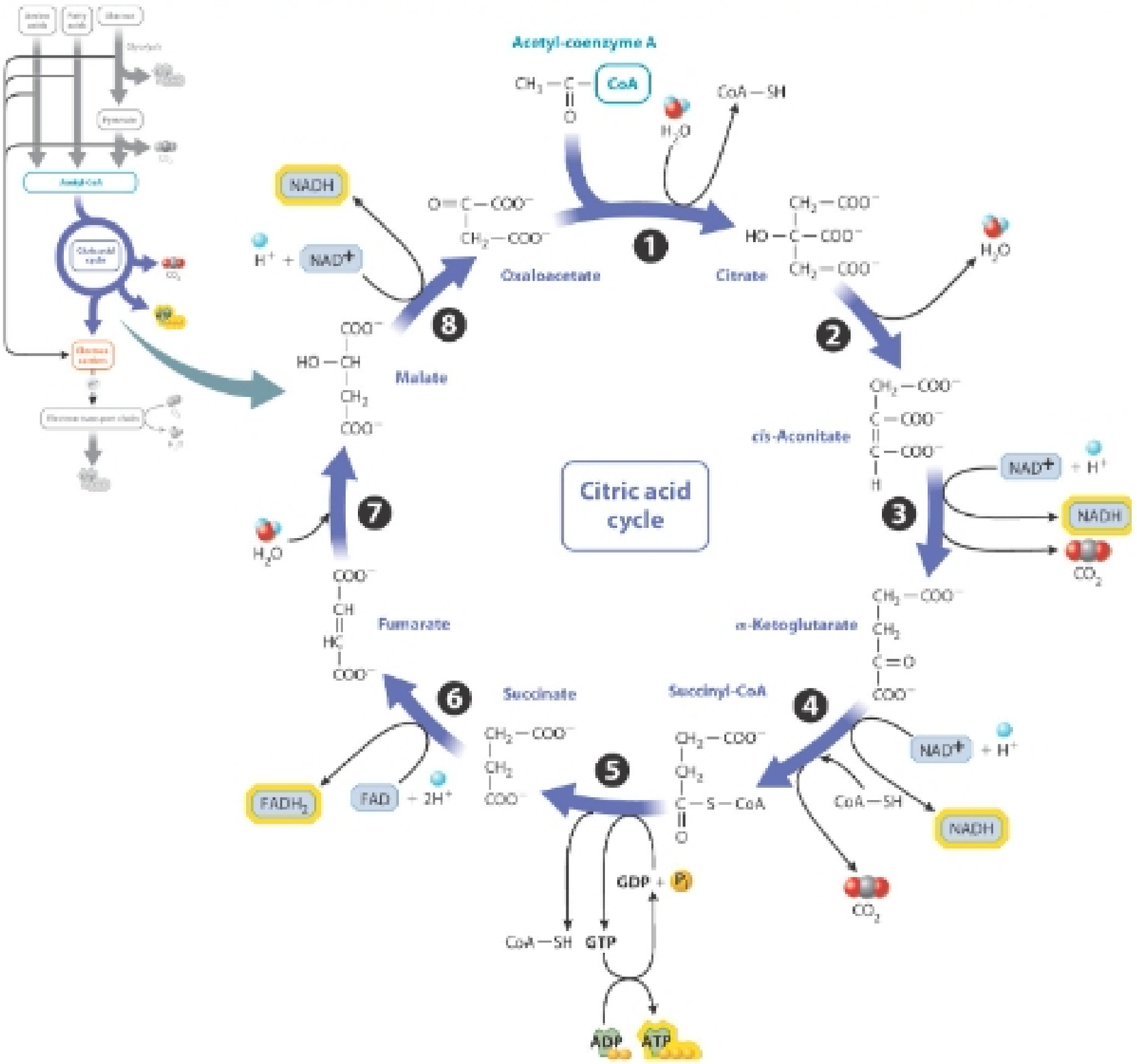
- **G. NADH & Redox Reactions**
  1. $NAD^+ + 2e^- + H^+$ ➔ NADH **(redox rxn.)**
     - **a.** NAD^+ reduced (gains energy); Pyruvate oxidized (loses energy)
     - **b.** NADH is an "energy intermediate"
  2. Redox Reactions
     - **a.** Oxidized molecules tend to lose H
       - **i.** Tend to have 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. Step 3: Citric Acid Cycle (Krebs Cycle) (Fig. 7.7)

- **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)***



Breakdown of 1 glucose (so far):

Process	ATP	NADH	$HADH_2$	CO_2	Other
Glycolysis	2	2	--	--	2 Pyruvate
Pyruvate breakdown	--	2	--	2	2 Acetyl-CoA
Krebs	2	6	2	4	--
Total	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**