

CELLULAR RESPIRATION

* **cellular respiration:**

- the orderly stepwise transfer of stored energy from food molecules to ATP
- requires O₂ and releases CO₂ and H₂O

I. **SOME MOLECULAR BASICS OF CELL RESPIRATION**

A) **Energy Coupling:**

exergonic reactions = net "loss" of energy

endergonic reactions = net "gain" of energy

⇒ cells use energy made available from exergonic reactions to drive endergonic ones

B) **Adenosine triphosphate (ATP)** Tortora (10th to 12th ed.) Fig 25.1 OR Martini (8th ed.) Fig 25-1

- nearly all cellular work depends on energy coupling to ATP hydrolysis
- each cell uses 10 million molecules of ATP/sec
- humans "consume" bodyweight in ATP/day ⇒ cells regenerate ATP from ADP
- ATP consists of adenine (a nitrogenous base), ribose (a 5C sugar) & 3 PO₄'s in a cluster
= the DNA nucleotide Adenosine plus 2 more PO₄'s Fig 2.25 in T10-T12 OR Fig 2-24 in M8
- hydrolysis (ATP → ADP + P_i) is highly exergonic due to the negative charges of adjacent PO₄'s repelling each other (note: not really a "high energy bond")

C) **Redox Reactions: = Reduction-Oxidation**

- involve the transfer of electrons (e⁻) from 1 molecule to another

reduction = gain of an electron (e⁻) **oxidation = loss of e⁻**

- the transfer of an e⁻ from a sodium atom to a chlorine atom is a simple redox reaction
⇒ Cl reduced to Cl⁻ & Na oxidized to Na⁺ Fig 2.4 (T10-T12) OR Fig 2-3 (M8)
- reduction can be the addition of an e⁻ by itself **or the addition of an H atom** (i.e. an e⁻ along with an H nucleus which consists of a single proton and is often written as H⁺)
- redox reactions release energy when the e⁻ move from one molecule to a second molecule where they have less energy
- **cellular respiration involves a series of many redox reactions** that oxidize food molecules and slowly release energy
⇒ much more efficient than releasing all the energy at once
⇒ **each glucose yields 36-38 ATP** (≈ 40% efficient) & the remaining energy is "lost" as heat

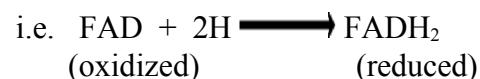
D) **H Carriers (Electron Shuttles)**

- during the break-down of glucose, most H's (& their accompanying high energy e⁻) are first used to reduce two special molecules called H carriers:

(i) NAD⁺ is reduced to NADH by the addition of 1 H⁺ & 2e⁻



(ii) FAD is reduced by adding 2 H atoms



* NADH & FADH₂ eventually transfer the high energy e⁻ to the electron transport chain (ETC) in mitochondria (see below) where they are used to produce ATP

E) Two Mechanisms Generate ATP

(i) **Substrate Level Phosphorylation:**

- a phosphorylated reactant transfers a phosphate directly to ADP
- requires an enzyme but **does not require an electron transport chain (ETC)**
- occurs at steps in glucose break-down that "release" lots of energy

(ii) **Oxidative Phosphorylation (Chemiosmosis)**

- mitochondria have 2 membranes forming 2 compartments **Fig 3.23 in T10-T12 OR Fig 3-9 in M8**
 - ⇒ a group of related chem. reactions
 - can be completed more efficiently
 - by placing all the required enzymes
 - within one membrane or compartment
- the ETC is a series of molecules ("electron carriers") in the inner mito. membrane **Fig 8 in manual; Fig 25.9 & 25.8 in T10-T12 OR Fig 25-5 in M8**

Step 1: The ETC Uses the Energy from NADH to Make an H⁺ Gradient

- NADH (and FADH₂) molecules transfer high energy e⁻ to the ETC

$$\text{NADH} \longrightarrow \text{NAD}^+ + \text{H}^+ + 2\text{e}^-$$

- the e⁻ then move through the ETC as each subsequent carrier molecule first accepts the e⁻ (becoming reduced) and then passes the e⁻ on (becoming oxidized)
- the e⁻ keep moving because each e⁻ carrier has more affinity for the e⁻ than the previous carrier
 - ⇒ e⁻ become more stable and have less energy ⇒ energy is released
- the final e⁻ acceptor is O₂ (producing H₂O) ⇒ without O₂ the ETC stops
- some carriers accept H⁺ and e⁻, BUT others accept only e⁻
- **ETC carriers act as proton pumps:** H⁺ are picked up in the matrix and released in the inter-memb. space ⇒ **creates an H⁺ gradient** across the inner mit. memb.
 - ⇒ this "electrochemical gradient" favours the return of H⁺ to the matrix

Step 2: ATP Synthase (a membrane protein) allows H⁺ to flow back across the membrane & couples this movement to ATP generation

SUMMARY: **Fig 25.2 in T10-12 OR Fig 25-6 in M8 (OR Fig on handout next class)**

- (i) the overall path of e⁻ is: food → NADH → ETC → O₂
- (ii) the overall path of most of the captured energy is:
food → NADH → ETC → H⁺ gradient → ATP synthase → ATP

TEXTBOOK QUESTIONS FOR REVIEW:

Tortora (10th to 12th ed.): - Figure Questions 25.1, 25.8 & 25.9
- Self-Quiz Questions 15 parts a, b, e, f, i, l, m, p, & q

Martini (8th ed.): - Checkpoint Questions 1, 2 & 3
- Review Questions 1, 3 & 10