CELLULAR RESPIRATION

* **<u>cellular respiration:</u>**
- the orderly stepwise transfer of stored energy from food molecules to ATP
- requires O_2 and releases CO_2 and H_2O

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 PO_4's in a cluster
  = the DNA nucleotide Adenosine plus 2 more PO_4'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 PO_4'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^+ & $2e^-$

i.e. NAD^+ (oxidized form) + 2H (from food) ⟶ NADH (reduced form) + H^+

(ii) FAD is reduced by adding 2 H atoms i.e. FAD (oxidized) + 2H ⟶ $FADH_2$ (reduced)

*** NADH & $FADH_2$ 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 $FADH_2$) molecules transfer high energy e^- to the ETC

$$NADH \longrightarrow NAD^+ + H^+ + 2e^-$$

- 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 O_2 (producing H_2O) ⇒ without O_2 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 → O_2

(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