Lecture 8: Microbial Metabolism - Electron transport, chemiosmotic ATP production, fermentation

In bacteria capable of respiration, the electrons carried by NADH and FADH$_2$ can be used for further ATP synthesis via oxidative phosphorylation.

- Respiratory electron transport chains consist of a series of membrane-bound carrier molecules that cycle between reduced and oxidized states (Tortora et al., Figure 5.13).
  - Among the carrier molecules are flavoproteins and cytochromes.
  - Some of the carriers pick up protons from the cytoplasm when they are reduced and release them to the outside of the membrane when they are oxidized; this is the way that the characteristic proton gradient is produced.

- In the final step of electron transport, electrons are transferred to a terminal electron acceptor.
  - In aerobic respiration, this terminal electron acceptor is O$_2$.
  - In anaerobic respiration, this terminal electron acceptor may be nitrate or sulfate.

- Because electron transport produces ATP through oxidative phosphorylation, we can look at the electron-carrying coenzymes in terms of their potential ATP yield.
  - From each pair of electrons donated by NADH, enough "proton-motive force" is generated to synthesize three molecules of ATP.
  - From each pair of electrons donated by FADH$_2$, enough "proton-motive force" is generated to synthesize two molecules of ATP (FADH$_2$ donates its electrons "further down" the electron transport chain).

The chemiosmotic mechanism for ATP synthesis, which operates in oxidative phosphorylation and in photophosphorylation, was first proposed by Peter Mitchell in 1961.

- It had long been a mystery how electron transport could be coupled to phosphorylation of ATP.
- The key is that one of the things that happens during electron transport is active transport of protons across a membrane.
  - This is the plasma membrane in procaryotes and the inner mitochondrial membrane or thylakoid membrane of chloroplasts in eucaryotes.
  - The resulting proton gradient is a source of potential energy.
- The protons on the side of the membrane with the higher proton concentration can "diffuse" across the membrane through a membrane-bound ATPase (Tortora et al., Figure 5.14, 5.15), which catalyzes phosphorylation of ADP to ATP.
- In one unusual group of procaryotes, the halobacteria, the "proton pump" is a molecule of bacteriorhodopsin rather than an electron transport chain (see "Microbiology Highlights" box in Tortora et al., p. 128).

Fermentation occurs when an organism either lacks respiratory electron transport chains or is not in an environment where terminal electron acceptors are available.

- In this situation, electrons transferred during reduction of NAD$^+$ to NADH cannot be used to synthesize ATP.
- However, NADH must still be reoxidized to NAD$^+$ in order for glycolysis to continue.
  - This is accomplished by oxidation of NADH during metabolic pathways that start with the pyruvic acid produced from glycolysis (Tortora et al., Figure 5.17a).
  - The characteristic fermentation end-products include alcohols and organic acids (Tortora et al., Figure 5.17b).