1. Metabolism- all chemical rxns that provide energy and the substances required for cell growth.

   Two types of metabolic rxns.
   1. catabolic- break down complex molecules and release energy.
   2. Anabolic- require energy to build larger molecules.

Mitochondria- make energy
Ribosomes –protein synthesis

Energy is stored as ATP- breaking of phosphate bonds.

ATP is hydrolyzed 7-12 Kcal per ATP 1-2 million reactions a second

\[
\text{ATP} + \text{H}_2\text{O} \rightarrow \text{ADP} + \text{P} + \text{energy} \quad 1-2 \text{ million per second}
\]

2. Digestion- convert large molecules to small ones that can be absorbed by the body.

figure 17.5
A. Digestion of carbohydrates- \(\alpha\)-amylase breaks apart the \(\alpha\)-glycosidic bonds in starches to produce small polysaccharides containing 3-8 glucose units called dextrins. Monosaccharides are small enough to move through intestinal
wall and go into the bloodstream. Used to make ATP or stored in muscle or liver as glycogen.

B. Digestion of proteins- Begins in the stomach, pH = 2. Denatures the protein and pepsin hydrolyzes.
c. Digestion of lipids- enter the small intestine and mix with bile salts from the gall bladder and lipases from the pancreas. Bile salts break the fat globules into smaller droplets called micelles.

3. Important Coenzymes

A. FAD- (flavin adenine dinucleotide) a coenzyme that accepts hydrogen atoms. Produced from riboflavin (vitamin B₂) and adenine diphosphate.
B. NAD\(^+\) (nicotinamide adenine dinucleotide) accepts electrons from oxidation reactions.
C. Coenzyme A (CoA) – carry two carbon groups which are the degradation products of glucose, fatty acids, glycerol, amino acids.

\[
\text{NAD}^+ + \text{OH} \quad \xrightarrow{\text{dehydrogenase}} \quad \text{NADH} + \text{C} - \text{O} + \text{H}^+ \\
\quad \text{reduced} \quad \text{oxidized}
\]

4. Glycolysis- energy from glucose takes place in the cytoplasm anaerobic no oxygen used.

Overhead T-95
Step 1- hexokinase enzyme, accelerated by insulin when glucose levels are high.
Step 2- isomerase
Step 1 through 3 a total of 2 ATP

Step 4- aldolase converts into two molecules and isomerase converts
dihydroxyacetone to glyceraldehyde-3-phosphate.

Summary of glycolysis

\[
\text{Glucose(C}_6\text{) + 2NAD}^+ \xrightarrow[]{} 2\text{pyruvate(C}_3\text{)} + 2\text{NADH} + 2\text{H}^+ + 2\text{ATP}
\]

5. Pathways of pyruvate. 3 possible pathways

1. Aerobic conditions-Acetyl CoA. Max output. moves from cytoplasm
into the mitochondria to be oxidized.

2. Anaerobic- remains in cytoplasm, reduced to lactate, causes muscles to
tire and become sore. Lactate goes to liver where it is converted back to
pyruvate.

3. Anaerobic-Ethanol- microorganisms (mainly yeast) convert sugars to
EtOH in fermentation. CO2 creates bubbles for beer and champagne. 15%
is made from fermentation to get higher need to distill.
6. Citric acid Cycle-energy is stored as NADH, FADH₂, ATP, ends in oxaloacetate.

**Summary:**

**Produces:**
1. 2 CO₂
2. 3 NADH
3. 1 FADH₂
4. 1 GTP goes to ATP

\[
\text{H}_3\text{C} - \text{C} - \text{C} = \text{O} + 3\text{NAD}^+ + \text{FAD} + \text{ADP} + \text{P} \rightarrow 2\text{CO}_2 + 3\text{NADH} + \text{FADH}_2 + \text{ATP}
\]

7. Electron transport chain- hydrogen and electrons from NADH and FADH₂ are transferred to compounds electron carriers. In the presence of oxygen produces almost all of the ATP energy from oxidation of glucose.

A. Electron carriers.
1. Flavin mononucleotide (FMN) coenzyme made of riboflavin (vitamin B₂)

2. Coenzyme Q- derived from quinone and a long carbon chain.

3. Iron- sulfur proteins (FeS) contain iron attached to sulfur. Iron goes from Fe²⁺ to Fe³⁺

4. Cytochromes (cyt) are proteins that carry iron. There are many types. Also have ion go from +2 to +3 as electrons pass through.
8. Chemiosmotic model- energy is released when hydrogen and electrons are released from NADH and H\(^+\) to the electron carriers. The energy is used to pump protons into the intermembrane space. A proton gradient develops in which protons go out a proton channel with an enzyme ATP synthase. As protons flow through ATP synthase energy is released and ATP is formed.

NADH produces 3 ATP
FADH\(_2\) produces 2 ATP

9. Electron Transport Chain- most e carriers are in 3 protein complexes attached to the inner membrane of the mitochondria. All are a proton pump.

1. **Complex 1**- NADH dehydrogenase- transfers hydrogen and electrons to FMN

\[
\begin{align*}
\text{Flow of electrons} \\
\text{NADH} + H^+ &\quad \text{NAD}^+ \text{ (back to citric acid cycle)} \\
\text{FMN} &\quad \text{FMNH}_2 &\quad \text{FeS} &\quad \text{Coenzyme Q}
\end{align*}
\]

2. Mobile electron carrier Coenzyme Q- mobile compound not attached to a protein complex so it can move freely around. Transports electrons from the first complex to the second. Also at this point the following reaction takes place. Coenzyme Q has lower energy so FADH\(_2\) enter the e transport at lower energy than e from NADH\(_2\).

\[
Q + \text{FADH}_2 \rightarrow \text{QH}_2 + \text{FAD}
\]
2. **Complex 2** - Electrons from QH2 pass to cyt b and then to cyt c1. How e are passed down through the chain by Fe.

\[
\text{Cytochrome-Fe}^{2+} \rightarrow \text{cytochrome-Fe}^{3+} \\
\text{Reduced} \quad \text{oxidized}
\]

3. **Complex 3** - Cytochrome c Oxidase- cyt a₃–electrons are donated from cyt a₃ to water.

\[
\text{Cytochrome-a₃} \rightarrow 2e^- + 1/2 O_2 + 2H^+ \rightarrow H_2O
\]

10. ATP energy from glucose-

Aerobic → 1 glucose → 2CoA → citric acid cycle

(in cytoplasm) → glycolysis → 2ATP + 2NADH + 2H⁺ + pyruvate

(in mitochondria) citric acid → 2 CO₂ + 3 NADH + FADH₂ + ATP)

cytoplasmic NADH from glycolysis needs to go into mitochondria.
In order to do this H and electrons are transferred to FAD.

\[
\text{NADH} + H^+ + \text{FAD} \rightarrow \text{NAD}^+ + \text{FADH}_2
\]

FADH₂ makes 2ATP

NADH in mitochondria makes 3 ATP

Glycolysis - glucose mitochondria 2 pyruvate + 6ATP

\[
2 \times 2\text{NADH} = 4\text{ATP} \quad 2\text{ATP} \text{ from direct phosphorylation}
\]

2pyruvates enter mitochondria-

2pyruvate mitochondria → 2acetylCoA + 2CO₂ + 6ATP + 2NADH
ATP citric acid cycle

\[
3 \text{NADH} \times 3 \text{ATP} = 9 \text{ATP} \\
\text{1FADH}_2 \times 2 \text{ATP} = 2 \text{ATP} \\
\text{1GTP} \times \text{1ATP} = \text{1ATP} \\
12 \text{ATP}
\]

\[
\text{2acetyl CoA} = 24 \text{ATP} + 4 \text{CO}_2
\]

Oxidation of fatty acids-
When glycogen and glucose levels low will consume triglycerides in adipose tissue (fat cells)

oxidation of triglycerides provides 6 times ATP as glucose

show overheads.

Ex. From book 14-carbon mystic acid.

Activation –2ATP

\[
7 \text{acetylCoA} \times 12 \text{ ATP (citric acid cycle)} = 84 \text{ ATP} \\
6 \text{FADH}_2 \times 2 \text{ATP (electron transport chain)} = 12 \text{ ATP} \\
6 \text{NADH} \times 3 \text{ATP (electron transport chain)} = 18 \text{ ATP} \\
112 \text{ ATP}
\]

Amino Acid metabolism-

\[
\begin{align*}
\text{NH}_3^+ \H_2\text{COO-}_{R_1} & + \H_2\text{COO-}_{R_2} & \text{transaminase} \\
\text{amino acid} & \text{keto acid} & \H_2\text{COO-}_{R_1} & + \H_2\text{COO-}_{R_2} \\
\alpha\text{-keto acid} & \text{new amino acid}
\end{align*}
\]
For many amino acids

\[
\text{NH}_3^+ + \text{H} - \text{C} - \text{COO}^- + \text{O} - \text{C} - \text{COO}^- \xrightarrow{\text{transaminase}} \text{H} - \text{C} - \text{COO}^- + \text{NH}_3^+ + \text{H} - \text{C} - \text{H} - \text{C} - \text{H} - \text{COO}^- + \alpha\text{-keto acid} + \text{glutamate}
\]

\[
\text{NH}_3^+ + \text{HC} - \text{COO}^- + \text{H} - \text{C} - \text{H} - \text{C} - \text{H} - \text{COO}^- + \text{NAD}^+ + \text{H}_2\text{O} \xrightarrow{\text{\alpha-ketoglutarate}} \text{+NH}_4^+ + \text{H} - \text{C} - \text{H} - \text{C} - \text{H} - \text{COO}^- + \text{+NADH + H}^+
\]

alpha ketoglutarate goes to citric acid cycle or glycolysis

Urea Cycle-used to get rid of toxic ammonium.

\[
\text{CO}_2 + \text{+NH}_4 + 2\text{ATP} + \text{H}_2\text{O} \rightarrow \text{H}_2\text{N-C-O-P-O}^- + 2\text{ATP} + \text{P} + 3\text{H}^+
\]

\[
\text{H}_2\text{N-C-O-P-O}^- \rightarrow \text{NH}_3^+ + \text{H} - \text{C} - \text{H} - \text{C} - \text{H} - \text{NH}_3^+ + \text{H} - \text{C} - \text{H} - \text{C} - \text{H} - \text{COO}^- + \text{urea} + \text{ornithine}
\]
\[ \alpha\text{-amino acid} \rightarrow \alpha\text{-ketoglutarate} \rightarrow \text{glutamate} \rightarrow \text{NADH} + \text{NH}_4^+ \rightarrow \text{NAD}^+ + \text{H}_2\text{O} \rightarrow \text{urea} \]

- Transamination
- Oxidase deamination
- Urea cycle