Nutrition and Metabolism
Chapter 17

• Metabolism

• Sum of all chemical reactions taking place in body is metabolism; 2 parts are Anabolism and Catabolism.
• Anabolism represents build up processes like synthesis of proteins and nucleic acids etc.
• Catabolism represents break up processes like respiration and digestion etc.

• Cellular Respiration

• A Metabolic Pathway
• **Aerobic Harvest of energy**: is the main source of energy for most organisms. It consists of more than 20 reactions (pathway). Each reaction (step) is controlled by a specific enzyme. It has 3 main parts, Glycolysis, Citric Acid Cycle and Electron Transport Chain.

\[
\text{Glucose + 6 } \text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{Energy}
\]

• 4 Main Step of Cellular Respiration

• Glycolysis: Glucose $\rightarrow$ 2 Pyruvate + 2NADH + 2 ATP

• Preparatory Step: Pyruvate $\rightarrow$ Acetyl-CoA + NADH

• Kreb’s Cycle: Acetyl-CoA $\rightarrow$ CO2 + NADH + FADH

• Electron Transport Chain: electrons of NADH + O2 $\rightarrow$ ATP + H2O

• Figure 17.3

• Glycolysis

• **Glycolysis**: It takes place in cytosol. Glucose (6C) is broken down to 2 molecules of Pyruvic Acid (3C).

• **Energy Investment**
• Glucose + 2 ATP $\rightarrow$ P – 6C– P+ 2 ADP
• **Energy Harvest**: uses 2 NAD + 2P and produces 2NADH + 4ATP
• P–6C–P $\rightarrow$ 2 P–3C $\rightarrow$ 2 P–3C–P + 2 NADH + 4 ADP
• 2 P – 3C – P $\rightarrow$ 2 3C (Pyruvic Acid) + 4 ATP
• **Overall Reaction** of Glycolysis:
• Glucose + 2NAD + 2ADP $\rightarrow$ 2 Pyruvic Acid + 2NADH + 2 ATP

• **Fermentation**: In muscles, fermentation is incomplete breakdown of glucose in absence of O2.
• Glucose + 2 ADP $\rightarrow$ 2 lactate + 2 ATP

• **TCA Cycle or Kreb’s Cycle**

• **The Link Reaction**: Each of 2 Pyruvic Acid molecule must change to Acetic Acid (2C) which join CoA to form Acetyl CoA
• Pyruvic Acid (3C) + CoA + NAD $\rightarrow$ Acetyl CoA (2C) + NADH + CO2

• **Citric Acid Cycle**: All the enzymes for Citric Acid Cycle are present in inner chamber of Mitochondria. It is a cyclic event that starts with a 4C acid. 2C Acetyl CoA joins 4C acid and forms 6C acid (Citric). Citric Acid in a series of steps loses 2C in 2 steps and changes back to same 4C acid. First formed acid is Citric Acid and at the end 4C acid is regenerated – so the name Citric Acid Cycle
• **Overall Reaction** of Citric Acid Cycle:
  \[\text{Acetyl CoA (2C)} + 3\text{NAD} + \text{FAD} + \text{ADP} \rightarrow 2 \text{CO}_2 + 3 \text{NADH} + \text{FADH}_2 + \text{ATP}\]
• **Electron Transport Chain**: is a series of H-acceptors and electron-acceptors associated with the inner membrane of Mitochondria.
• **NADH** passes its 2 electrons to first H-acceptor and 2 H+ are pumped out to outer chamber (in between 2 membranes) of mitochondria.
• The remaining acceptors pump out two more H+ pairs to outer chamber by using energy of downhill moving electron pair. So 3 proton pairs are pumped by using the energy of 1 NADH. 3 H+ pairs or 1 NADH produce 3 ATP molecules.
• **O2** is the ultimate acceptor for electrons and H+. ETC and CAC cycle can continue to function only if oxygen is available.
• **FADH2** passes its electrons to 2nd acceptor and only two H+ pairs are pumped out. Hence only 2 ATP molecules are formed per FADH2.
• **ATP Synthesis**: A 2-component system F0-F1 particle acts as ATP Synthase. H+ have higher concentration in outer chamber and return to inner chamber through F0-F1 particles which uses the energy of each pair of H+ to change ADP + P \rightarrow ATP.
• Figure 17.6
  • Alternative Catabolic Pathways
• **Triglycerides** \rightarrow fatty acids + glycerol
• Fatty acids change into Acetyl-CoA and glycerol enters glycolysis to provide energy
• **Glycogen** \rightarrow glucose in muscles and liver
• **Proteins** \rightarrow amino acids enter into glycolysis or Kreb’s cycle to produce ATP
• Figure 17.7
  • Gluconeogenesis
• Formation of glucose from glycerol or amino acids or lactate is Gluconeogenesis. It takes place in kidney and liver.
• Glycerol (breakdown of fats) \rightarrow glucose
• Amino acids (breakdown of proteins) \rightarrow glucose
• Lactate (breakdown of glycogen) \rightarrow glucose
  • Triglycerides and Cholesterol
• Excess glucose is synthesized into Triglycerides. Triglycerides and cholesterol transport in blood bound to plasma proteins.
• **LDL** – low density lipoprotein: supply cholesterol to cells for making cell membranes; also supplies cholesterol to ovaries and testes for synthesis of steroid hormones. Labeled ‘Bad Cholesterol’ because ↑LDL \rightarrow ↑deposition of cholesterol in artery walls and ↑heart attacks
• **HDL** - High density lipoprotein removes cholesterol from blood and tissues including atherosclerotic cholesterol in coronary arteries. It delivers cholesterol to liver and endocrine cells secreting steroid hormones. Designated ‘Good Cholesterol’.
• Better indicator of atherosclerotic heart disease is **LDL/HDL ratio**. Lower this ratio lesser the chances of CVD.
• **Smoking** lowers HDL and ↑LDL/HDL ratio \rightarrow ↑heart attack
• **Lipolysis**: is breakdown of fats into fatty acids and glycerol.
Recap 1 Chapter 17

1. Pyruvate $\rightarrow$ Acetyl Co-A + CO2 is ----------
2. Glucose $\rightarrow$ 2Pyruvate + ATP + NADH is ----------
3. NADH + O2 + ADP $\rightarrow$ NAD + ATP + H2O is ----------
4. Acetyl CoA $\rightarrow$ CO2 + ATP + NADH is ----------
5. --- ATP are gained in Glycolysis.
6. ----- is glucose (no O2) $\rightarrow$ Lactate + ATP in muscles.
7. -----ATP are gained in aerobic breakdown of 1 glucose.
8. -----is synthesis of glucose from glycerol and amino acids.
9. Total ATP produced by complete breakdown of 1 glucose --
10. When glucose is low, ---- and ---- are sources of energy.
11. ------lipoproteins are bad for heart and ----lipoproteins are good for it.
   - Balanced Diet
   - Specific for each individual and population group
   - Has all the nutrients needed for maintaining homeostasis
   - Should include adequate supplies of water, essential fatty acids, essential amino acids, minerals and vitamins.
   - Fibers in diet for bowl movements to avoid constipation.
   - Intake of fat calories must be <30% of total calories
   - Americans need to replace non-vegetarian, fried, fast foods rich in sugar with many servings of fruit, vegetable, cereals and beans.
   - Americans need to cook frequently at home to avoid obesity and related problems like T2DM = Type 2 Diabetes Mellitus, hypertension and Cardiovascular diseases
   - Vitamins
   - Fat Soluble: A, D, E and K
   - Water Soluble: B-complex and C
   - Vitamin A needed for maintaining epithelia and making visual pigments; deficiency causes Night blindness
   - Vitamin D needed for healthy bones, synthesized from cholesterol by skin in sunlight; deficiency causes Rickets.
   - Vitamin E is strong antioxidant
   - Vitamin K is essential for making prothrombin; deficiency causes bleeding disease
   - B-complex vitamins act as coenzymes in carbohydrate, protein, lipid and nucleic acid metabolisms.
   - Vitamin C is antioxidant, citrus fruits are rich source; deficiency causes Scurvy – a bleeding gums disease
   - Regulation of body temperature
   - Body temperature follows a daily rhythm 97F° around 4am and 99F° between 4-8pm
   - Cold induces
   - ↑vasoconstriction of skin vessels
• ↑ shivering
• ↓ in surface area by curling
• Behavior response of putting on warmer clothes
• Heat stimulates
• Reverse of above 4 processes and sweating
• Fever is elevation of temperature to increase effectiveness of immune system. Effective range is between 96 and 106°F. Brain damage occurs in temperature >106°F.
• Heat stroke is caused at temp. >110°F and hypothermia is caused in temp. <92°F

Recap 2 Chapter 17

1. Balanced diet should have fat calories > ----% of total calories.
2. ------- in diet for bowl movements to avoid constipation
3. --- and --- are fat soluble vitamins; --- and --- are water soluble vitamins.
4. We need ---- vitamin for healthy bones and ---- vitamin for night vision.
5. -----vitamins act as coenzymes in different metabolisms.
6. --- and --- are antioxidant vitamins that protect us against damage to proteins and nucleic acids from free radicals.
7. Americans need to cook food frequently at home and eat a lot of ----, ----, ----, and ----.
8. Eating fried, mainly non-vegetarian, sugary fast foods causes obesity leading to ------ and ----- diseases.
9. Effective range of body temperature is ---- to ----°F.