Metabolism

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, Krebs Cycle and Electron Transport Chain.

Glucose + 6 O2 → 6CO2 + 6 H2O + Energy

4 Main Step of Cellular Respiration

Glycolysis: Glucose → 2 Pyruvate + 2NADH + 2 ATP

Preparatory Step: Pyruvate → Acetyl-CoA + NADH

Krebs Cycle: Acetyl-CoA → CO2 + NADH + FADH

Electron Transport Chain: electrons of NADH + O2 → ATP + H2O

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

Energy Investment

Glucose + 2 ATP → P – 6C– P+ 2 ADP

Energy Harvest: uses 2 NAD + 2P and produces 2NADH + 4ATP

P–6C–P → 2 P–3C → 2 P–3C–P + 2 NADH + 4 ADP

2 P – 3C – P → 2 3C (Pyruvic Acid) + 4 ATP

Overall Reaction of Glycolysis:

Glucose + 2NAD + 2ADP → 2 Pyruvic Acid + 2NADH + 2 ATP

Fermentation: In muscles, fermentation is incomplete breakdown of glucose in absence of O2.

Glucose + 2 ADP → 2 lactate + 2 ATP

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 → Acetyl CoA (2C) + NADH + CO2

Krebs 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: Acety CoA (2C) + 3NAD + FAD + ADP → 2 CO2 + 3 NADH + FADH2 + ATP

Electron Transport Chain

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. 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 Krebs 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 → ATP.

**Alternative Catabolic Pathways**

- **Triglycerides → fatty acids + glycerol**
  Fatty acids change into Acetyl-CoA and glycerol enters glycolysis to provide energy
- **Glycogen → glucose in muscles and liver**
- **Proteins → amino acids enter into glycolysis or Krebs cycle to produce ATP**
- **Gluconeogenesis**

Formation of glucose from glycerol or amino acids or lactate is **Gluconeogenesis**. It takes place in kidney and liver.

- Glycerol (breakdown of fats) → glucose
- Amino acids (breakdown of proteins) → glucose
- Lactate (breakdown of glycogen) → 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 → ↑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 (Cardio-Vascular Disease).

**Smoking** lowers HDL and ↑LDL/HDL ratio → ↑heart attack

**Lipolysis:** is breakdown of fats into fatty acids and glycerol.

Recap1 Chapter 17

1. Pyruvate → Acetyl Co-A + CO2 is ------------
2. Glucose → 2Pyruvate + 2ATP + 2NADH is ---------
3. NADH + O2 + ADP → NAD + ATP + H2O is ---------
4. Acetyl CoA → CO2 + ATP + NADH + FADH is ----------
5. --- ATP are gained in Glycolysis.
6. ------ is glucose (no O2) → Lactate + 2ATP 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 and fat 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
KLF-14 gene is master switch for obesity and cholesterol

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 97°F around 4am and 99°F 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 bowel 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.