

Chapter 7

Metabolism: Transformations and Interactions



Energy: Fuel for Work

- Energy source
 - ✓ Chemical energy in carbohydrates, fat, protein
- Food energy to cellular energy
 - ✓ Stage 1: digestion, absorption, transport
 - ✓ Stage 2: breakdown of molecules
 - ✓ Stage 3: transfer of energy to a form cells can use

What is Metabolism?

- Metabolism: the complete set of chemical reactions that occur in living cells.

These processes are the basis of life, allowing cells to grow and reproduce, maintain their structures, and respond to their environments.

Chemical Reactions in the Body

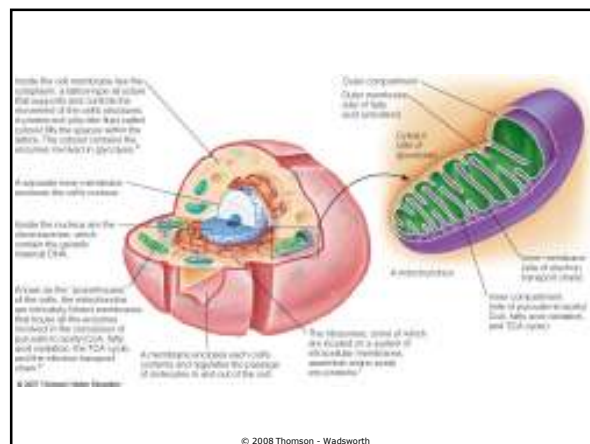
- Plants use the sun's energy to make carbohydrate from carbon dioxide and water.
- This is called photosynthesis.
- Humans and animals eat the plants and use the carbohydrate as fuel for their bodies.
- During digestion, the energy-yielding nutrients are broken down to monosaccharides, fatty acids, glycerol, and amino acids.
- After absorption, enzymes and coenzymes can build more complex compounds.
- In metabolism they are broken down further into energy (ATP), water and carbon dioxide.

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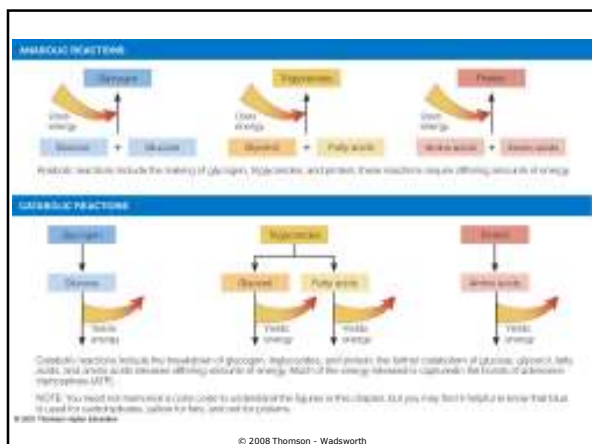
Chemical Reactions in the Body

- Metabolic reactions take place inside of cells, especially liver cells.
- Anabolism is the building up of body compounds and requires energy.
- Catabolism is the breakdown of body compounds and releases energy.

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Chemical Reactions in the Body

- The Transfer of Energy in Reactions—ATP
 - ✓ A high-energy compound called adenosine triphosphate (ATP) is made.
 - ✓ Coupled reactions are chemical reactions that occur simultaneously.

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What Is Metabolism?

- Cell is the metabolic processing center
 - ✓ Nucleus
 - ✓ Cytoplasm
 - Cytosol + organelles
- ATP is the body's energy currency
 - ✓ ATP = adenosine triphosphate
 - ✓ Form of energy groups cells use
- NAD and FAD: transport shuttles
 - ✓ Importat coenzymes in cells
 - ✓ Accept high energy electrons for use in ATP production

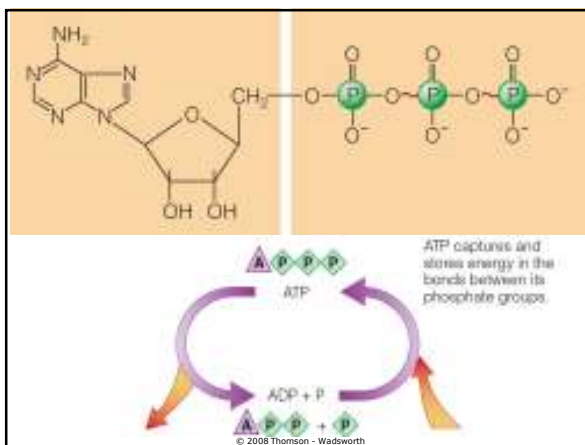
ATP: adenosine triphosphate

Adenosine: Adenine + Ribose

2 high-energy bonds

Inorganic phosphate group

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Chemical Reactions in the Body

- Enzymes and coenzymes are helpers in reactions.
 - ✓ Enzymes are protein catalysts that cause chemical reactions.
 - ✓ Coenzymes are organic molecules that function as enzyme helpers.
 - ✓ Cofactors are organic or inorganic substances that facilitate enzyme action.

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Biosynthesis and Storage

- Making carbohydrate (glucose)
 - ✓ Gluconeogenesis
 - Uses pyruvate, lactate, glycerol, certain amino acids
- Storing carbohydrate (glycogen)
 - ✓ Liver, muscle make glycogen from glucose
- Making fat (fatty acids)
 - ✓ Lipogenesis
 - Uses acetyl CoA from fat, amino acids, glucose
- Storing fat (triglyceride)
 - ✓ Stored in adipose tissue

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Breakdown and Release of Energy

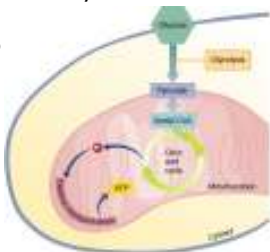
- Extracting energy from carbohydrate

- ✓ Glycolysis

- Pathway splits glucose into pyruvates
 - Transfers electrons to NAD
 - Produces some ATP

- ✓ Pyruvate to acetyl CoA

- Releases CO₂
 - Transfers electrons to NAD



Breakdown and Release of Energy

- Extracting energy from carbohydrate

- ✓ Citric acid cycle

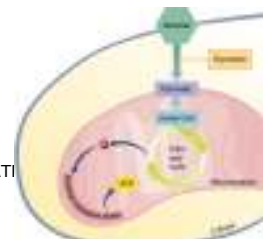
- Releases CO₂
 - Produces GTP (like ATP)
 - Transfers electrons to NAD and FAD

- ✓ Electron transport chain

- Accepts electrons from NAD and FAD
 - Produces large amounts of ATP
 - Produces water

- ✓ End products of glucose breakdown

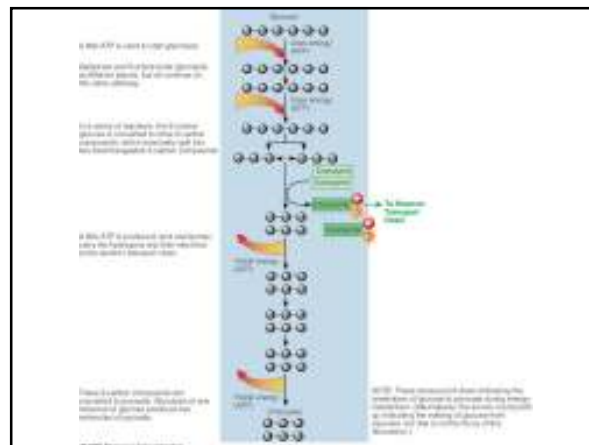
- ATP, H₂O, CO₂



Breaking Down Nutrients for Energy

- The breakdown of glucose to energy starts with glycolysis to pyruvate.
- Pyruvate may be converted to lactic acid anaerobically (without oxygen) and acetyl CoA aerobically (with oxygen).
- Eventually, all energy-yielding nutrients enter the TCA cycle or tricarboxylic acid cycle (or Krebs' cycle) and the electron transport chain.

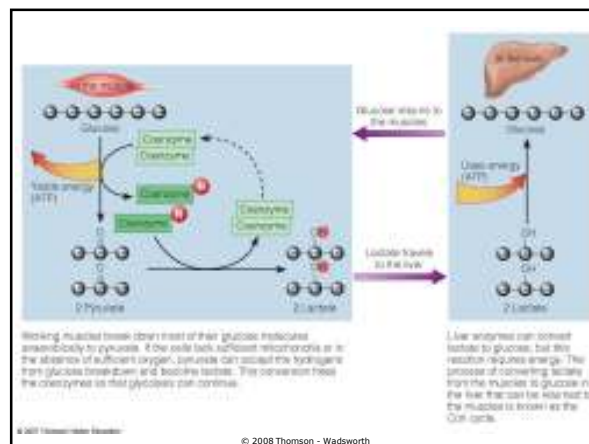
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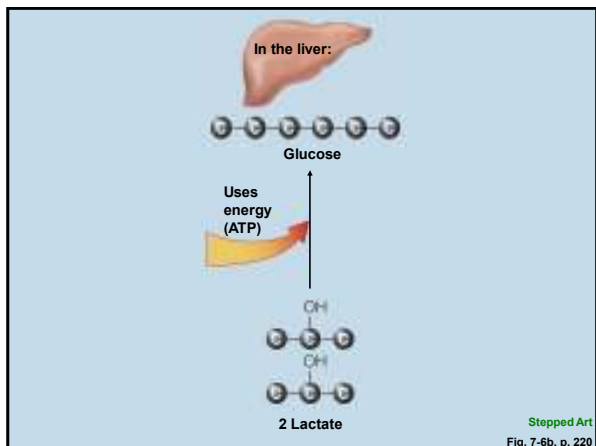


Breaking Down Nutrients for Energy

- Glucose
 - ✓ Glucose-to-pyruvate is called glycolysis or glucose splitting.
 - ✓ Pyruvate's Options
 - Anaerobic - lactic acid
 - Aerobic - acetyl CoA
 - ✓ Pyruvate-to-Lactate
 - Oxygen is not available or cells lack sufficient mitochondria
 - Lactate is formed when hydrogen is added to pyruvate.
 - Liver cells recycle muscle lactic acid through the Cori cycle.

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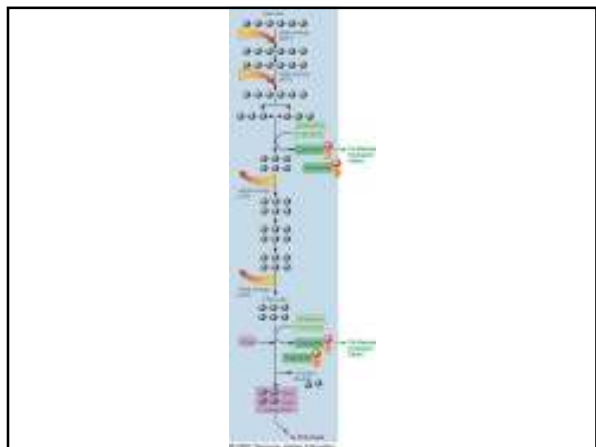
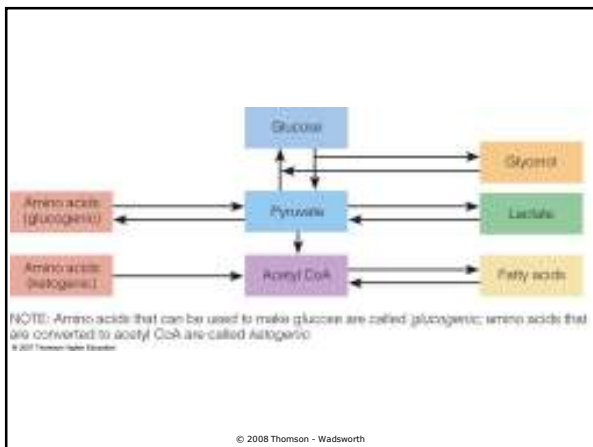
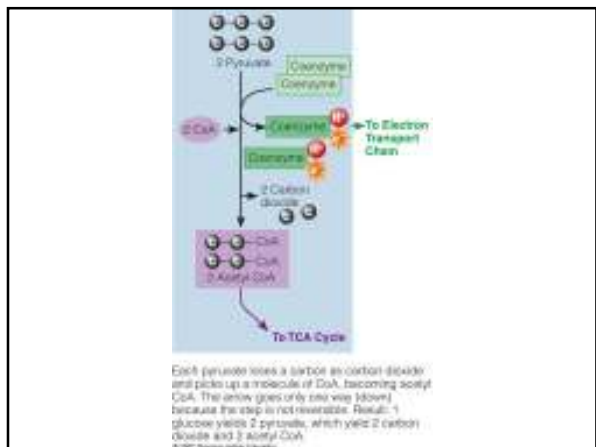




Breaking Down Nutrients for Energy

- Glucose
 - ✓ Pyruvate-to-acetyl CoA is irreversible.
- ✓ Acetyl CoA's Options
 - Synthesize fats when the body has enough ATP
 - Generate ATP when the cell is low in energy

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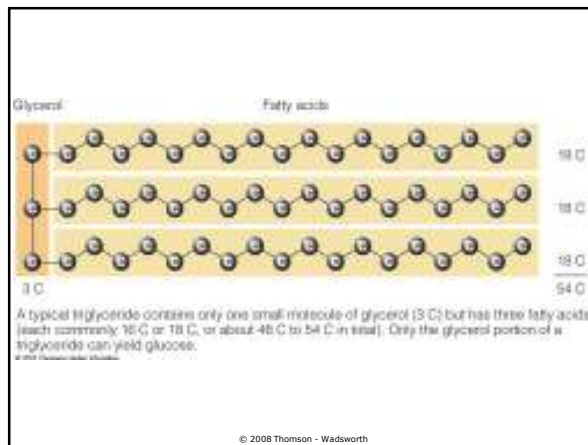
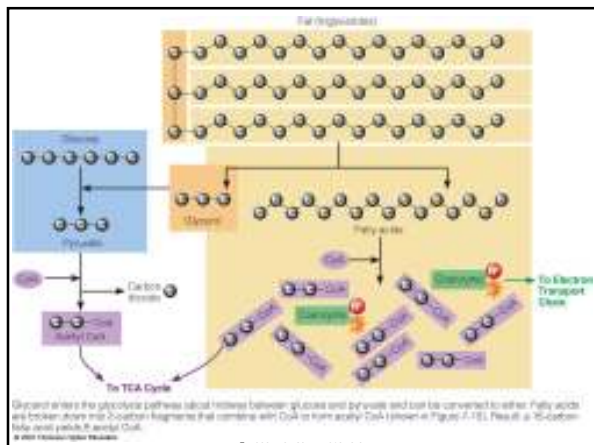
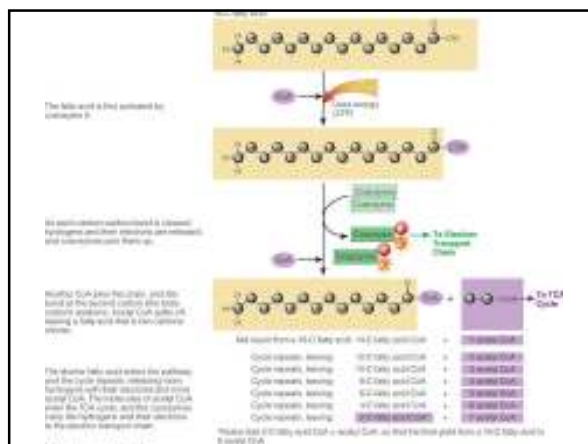
Breakdown and Release of Energy

- Extracting energy from fat
 - ✓ Split triglycerides into glycerol and fatty acids
 - ✓ Beta-oxidation
 - Breaks apart fatty acids into acetyl CoA
 - Transfers electrons to NAD and FAD
 - ✓ Citric acid cycle
 - Acetyl CoA from beta-oxidation enters cycle
 - ✓ Electron transport chain
 - End products of fat breakdown
 - ATP, H₂O, CO₂

Breaking Down Nutrients for Energy

- Glycerol and Fatty Acids
 - ✓ The conversion of glycerol to pyruvate is easy because they are both three-carbon compounds.
 - ✓ Fatty acids-to-acetyl CoA reactions are called fatty acid oxidation.
 - ✓ Fatty acids cannot be used to synthesize glucose. Glucose must be available to provide energy to the red blood cells, brain, and nervous system.

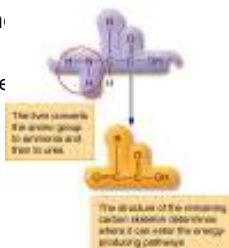
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Breakdown and Release of Energy

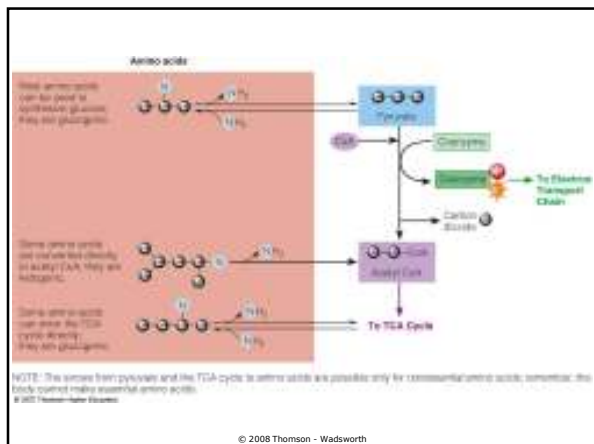
- Extracting energy from protein
 - ✓ Split protein into amino acids
 - ✓ Split off amino group
 - Converted to urea for excretion
 - ✓ Carbon skeleton enters breakdown pathways
 - ✓ End products
 - ATP, H₂O, CO₂, urea



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Breaking Down Nutrients for Energy

- Amino Acids
 - ✓ Amino acids can be converted to acetyl CoA after deamination.
 - ✓ Amino Acids-to-Glucose – a fairly good source of glucose when carbohydrate is not available



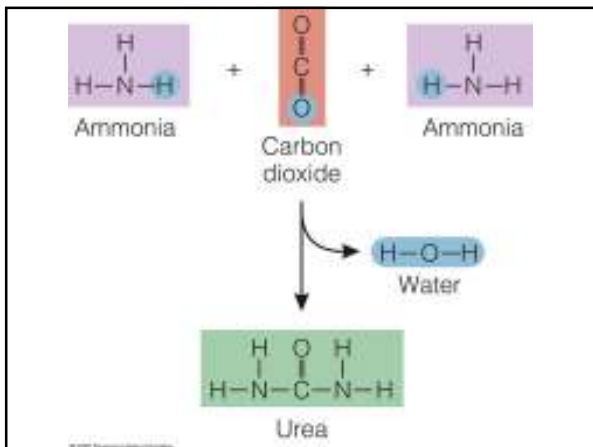
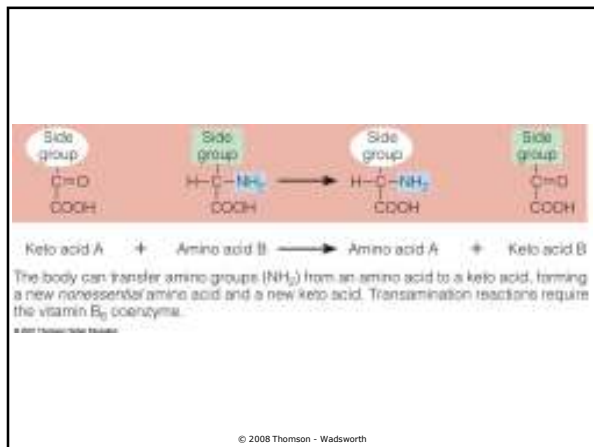
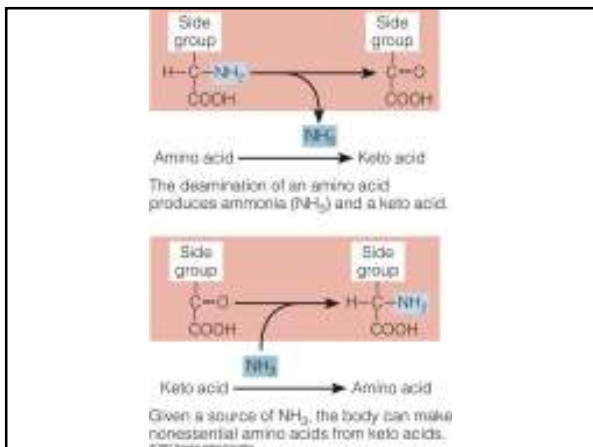
Breaking Down Nutrients for Energy

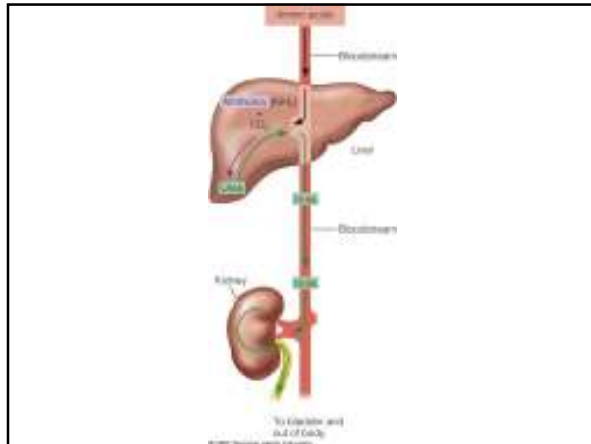
- Amino Acids
 - ✓ Deamination results in two products:
 - Keto acid
 - Ammonia
 - ✓ Transamination is the transfer of the amino group from an amino acid to a keto acid.
 - ✓ Ammonia is converted to urea—a much less toxic compound—in the liver.
 - ✓ Urea is excreted through the kidneys to rid the body of unused nitrogen.

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Biosynthesis and Storage

- Making ketone bodies (ketogenesis)
 - ✓ Made from acetyl CoA
 - Inadequate glucose in cells
- Making protein (amino acids)
 - ✓ Amino acid pool supplied from
 - Diet, protein breakdown, cell synthesis





Breaking Down Nutrients for Energy

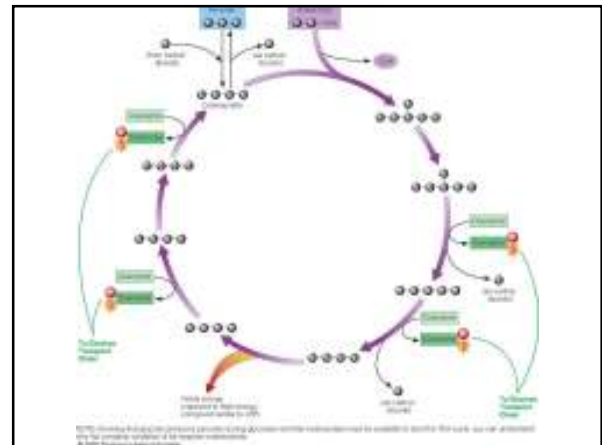
- Breaking Down Nutrients for Energy—In Summary
 - ✓ Glucose and fatty acids are primarily used for energy, amino acids to a lesser extent.
 - ✓ Glucose is made from all carbohydrates, most amino acids and the glycerol portion of fat.
 - ✓ Protein is made from amino acids.
 - ✓ Glucose can be made into nonessential amino acids if nitrogen is present.
 - ✓ All energy-yielding nutrients consumed in excess can contribute to fat storage.

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Breaking Down Nutrients for Energy

- The Final Steps of Catabolism
 - ✓ The TCA cycle contains a 4-carbon compound called oxaloacetate that has a critical role.

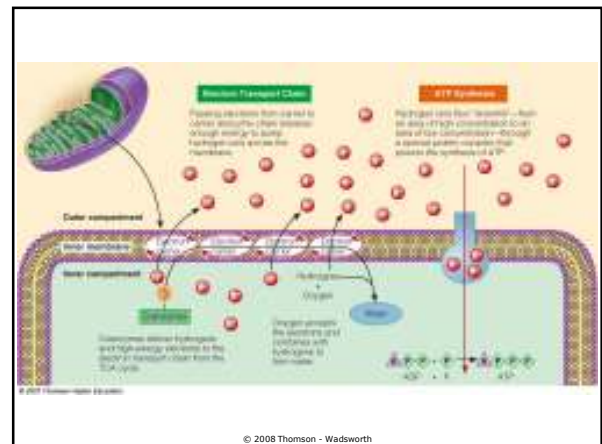
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Breaking Down Nutrients for Energy

- The Final Steps of Catabolism
 - ✓ The Electron Transport Chain
 - Consumes oxygen
 - Produces carbon dioxide and water
 - Produces energy as ATP

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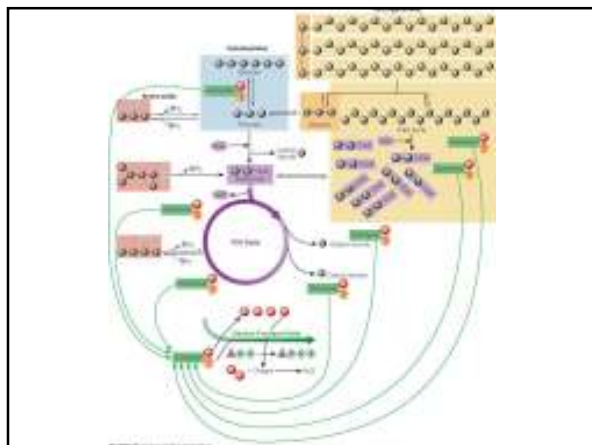
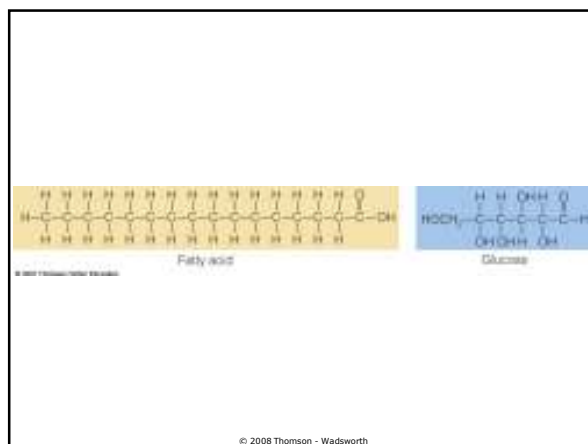


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Breaking Down Nutrients for Energy

- The Final Steps of Catabolism
 - ✓The kCalories-per-Gram Secret Revealed
 - Fat provides 9 kcal/gram.
 - Carbohydrate provides 4 kcal/gram.
 - Protein provides 4 kcal/gram.
 - Fat provides more energy because the bonds in fat molecules are easily oxidized and result in more ATP.

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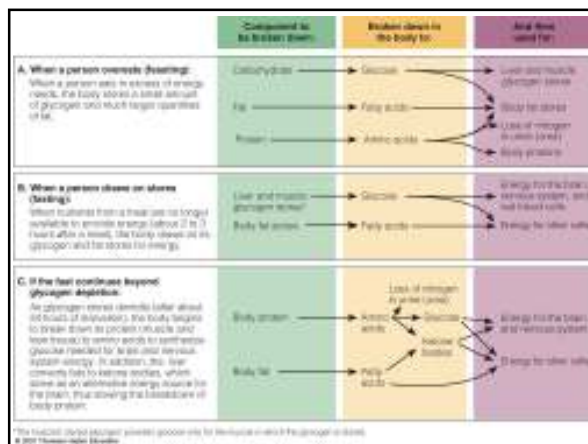
Regulation of Metabolism

- Regulating hormones
 - ✓Insulin
 - ✓Glucagon
 - ✓Cortisol
 - ✓Epinephrine

Energy Balance

- When energy intake exceeds energy output, there is a gain in weight.
- Excess energy can come from protein, fat or carbohydrate.
- Fat is the most efficient in being stored as fat.

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Energy Balance

- Feasting—Excess Energy
 - ✓ Excess protein is converted to fat but this is inefficient and indirect. Its priority is other roles.
 - ✓ Excess carbohydrate is converted to fat but this is inefficient and indirect. Its priority is glycogen stores.
 - ✓ Excess fat is efficiently converted to fat.
- The transition from feasting to fasting draws on reserves.

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Energy Balance

- Fasting—Inadequate Energy
 - ✓ Glucose Needed for the Brain
 - ✓ Protein Meets Glucose Needs
 - ✓ The Shift to Ketosis
 - Ketones are produced when glucose is not available.
 - ✓ Ketosis causes a suppression of the appetite.
 - ✓ Slowing of Metabolism

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1 The first step in the formation of ketone bodies is the condensation of two molecules of acetyl CoA and the removal of the CoA to form a compound that is converted to the first ketone body.

2 This ketone body may lose a molecule of carbon dioxide to become another ketone.

3 Or, the acetoacetate may add two hydrogens, becoming another ketone body (beta-hydroxybutyrate). See Appendix C for more details.

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Energy Balance

- Fasting—Inadequate Energy
 - ✓ Symptoms of Starvation
 - Muscle wasting
 - Decreased heart rate, respiratory rate, metabolic rate, and body temperature
 - Impaired vision
 - Organ failure
 - Decreased immunity
 - Depression, anxiety, and food-related dreams

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Alcohol and Nutrition



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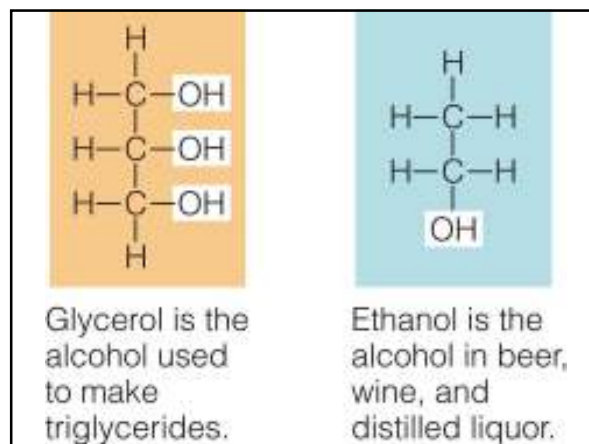
Alcohol and Nutrition

- Alcohol (drinking) = ethyl alcohol, ethanol
- The metabolism of alcohol is handled differently in the body.
- Alcohol interferes with metabolism and impairs health and nutrition.
- There are potential health benefits to consuming moderate amounts of alcohol.

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Does Alcohol Have Benefits?

- **Moderate** Alcohol Consumption
 - ✓ Defined as ≤ 2 drinks per day for men, and ≤ 1 drink for women
 - ✓ Can be compatible with good health:
 - Lower risk of CVD
 - Increased insulin sensitivity
 - Increased bone mineral content
 - Decreased risk of dementia
 - Decreased risk of bacterial infections in stomach
 - May supply some B vitamins and iron
- Benefits observed in middle age & older adults
- Relaxation and socialization



Alcohol in Beverages

- Beer, wine and distilled liquor (hard liquor)
- Alcohol behaves like a drug, therefore altering body functions.
- Moderation of drinks
 - ✓ 5 ounces of wine
 - ✓ 10 ounces of wine cooler
 - ✓ 12 ounces of beer
 - ✓ 1 ½ ounces distilled liquor (80 proof)

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Alcohol and its Sources

- Fermentation
 - Yeast cells metabolize sugar to make alcohol
- Alcoholic beverages
 - Beer: 5-6% alcohol
 - Wine: 8-14% alcohol
 - Liquor: 35-45% alcohol
- "Proof" is twice the alcohol percentage
 - The amount of ethanol contained in an alcoholic beverage is stated on the label
 - 50% alcohol = 100 proof
 - Hard liquor > wine > beer

Alcohol in the Body

- Quickly absorbed
- Carbohydrates decrease the absorption of alcohol.
- Alcohol dehydrogenase breaks down alcohol in the stomach.
- Women absorb more alcohol than men.

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Alcohol Absorption

- No digestion required
- Absorbed from mouth, esophagus, stomach, and small intestine
- Via simple diffusion
- Absorption slowed by food

Alcohol Absorption

- Depends on
 - ✓ Rate of stomach emptying
 - ✓ Intake of certain drugs
 - ✓ Type of beverage consumed
- Distributed wherever water is found in the body
- Moves easily through the cell membranes
 - ✓ Damage the cell membranes
 - ✓ Liver cell damage

Alcohol Metabolism in the Stomach

- Empty stomach:
 - ✓ 20% absorbed directly across the stomach wall
 - ✓ Reaches brain within one minute
- With food:
 - ✓ Slows diffusion of alcohol into stomach wall
 - ✓ Slows entry into highly absorptive small intestine

Alcohol Metabolism

- Some ethanol is metabolized by the stomach cells
- Majority of the ethanol is metabolized by the liver
- Alcohol cannot be stored and has priority in metabolism

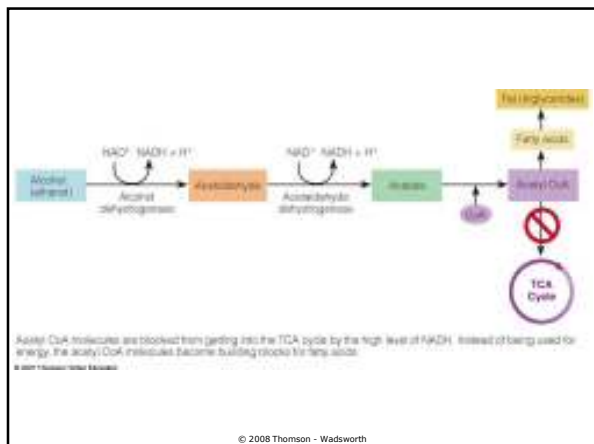
Alcohol Arrives in the Liver

- Accumulation of fatty acids
- Alcohol dehydrogenase breaks down alcohol to acetaldehyde.
- Alcohol abuse has damaging effects.
- Coenzyme NAD

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The conversion of alcohol to acetyl CoA requires the 8 electrons from its oxidation in its role as the coenzyme NAD. When the electrons (and/or alcohol) are removed in plants and animals from NAD. This NAD is used up and NADH accumulates. (Note: Slowly acetyl CoA is converted to NADH + H+.)

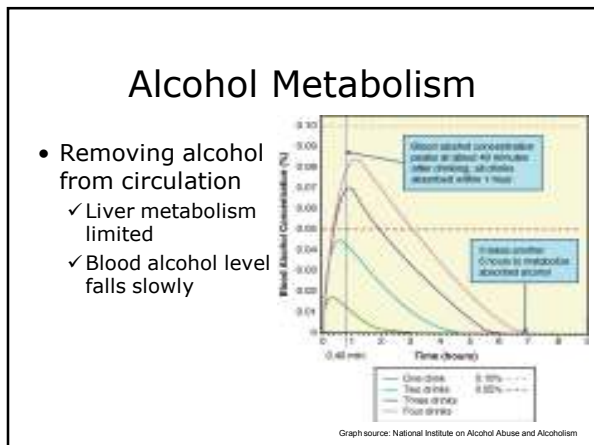
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Alcohol Disrupts the Liver

- Development of a fatty liver is the first stage of liver deterioration.
- Fibrosis is the second stage.
- Cirrhosis is the most advanced stage of liver deterioration.
- Microsomal ethanol-oxidizing system (MEOS) metabolizes alcohol and drugs.

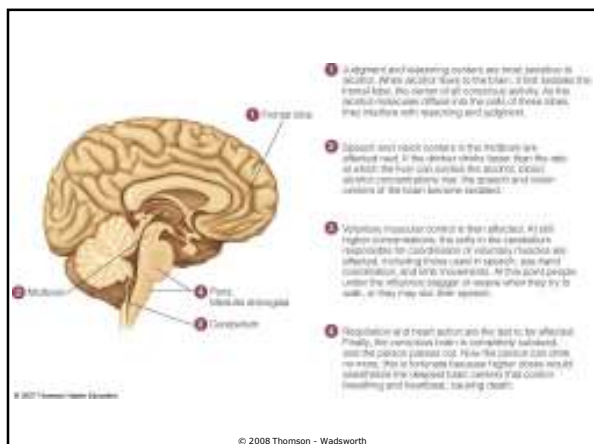
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Alcohol Arrives in the Brain

- Alcohol acts as a narcotic, anesthetizes pain
- Alcohol suppresses antidiuretic hormone (ADH) resulting in the loss of body water.

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When Alcohol Becomes a Problem

- Alcohol in the brain and nervous system
 - ✓ Depressant; affects all parts of brain
- Alcohol's effect on GI system
 - ✓ Blood alcohol concentration

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TABLE H7-1 Alcohol Doses and Approximate Blood Level Ranges for Men and Women

Alcohol	Body Weight in Pounds—Men										Body Weight in Pounds—Women									
	150	120	100	80	60	40	20	10	5	2.5	150	120	100	80	60	40	20	10	5	2.5
1	0.02	0.03	0.04	0.05	0.07	0.10	0.15	0.20	0.25	0.30	0.02	0.03	0.04	0.05	0.07	0.10	0.15	0.20	0.25	0.30
2	0.04	0.06	0.08	0.10	0.14	0.20	0.30	0.40	0.50	0.60	0.04	0.06	0.08	0.10	0.14	0.20	0.30	0.40	0.50	0.60
3	0.06	0.09	0.12	0.15	0.21	0.30	0.45	0.60	0.80	1.00	0.06	0.09	0.12	0.15	0.21	0.30	0.45	0.60	0.80	1.00
4	0.08	0.12	0.16	0.20	0.28	0.40	0.60	0.80	1.10	1.40	0.08	0.12	0.16	0.20	0.28	0.40	0.60	0.80	1.10	1.40
5	0.10	0.15	0.20	0.25	0.35	0.50	0.75	1.00	1.30	1.70	0.10	0.15	0.20	0.25	0.35	0.50	0.75	1.00	1.30	1.70
6	0.13	0.20	0.26	0.33	0.45	0.65	1.00	1.30	1.70	2.20	0.13	0.20	0.26	0.33	0.45	0.65	1.00	1.30	1.70	2.20
7	0.17	0.25	0.33	0.42	0.55	0.80	1.20	1.60	2.10	2.80	0.17	0.25	0.33	0.42	0.55	0.80	1.20	1.60	2.10	2.80
8	0.22	0.32	0.42	0.53	0.70	1.00	1.50	2.00	2.60	3.40	0.22	0.32	0.42	0.53	0.70	1.00	1.50	2.00	2.60	3.40
9	0.28	0.40	0.52	0.65	0.85	1.20	1.80	2.40	3.10	4.00	0.28	0.40	0.52	0.65	0.85	1.20	1.80	2.40	3.10	4.00
10	0.35	0.50	0.64	0.80	1.05	1.50	2.20	2.90	3.70	4.80	0.35	0.50	0.64	0.80	1.05	1.50	2.20	2.90	3.70	4.80

NOTE: Excessive drinking while the blood-alcohol level is 0.08 (0.08 percent alcohol) or higher, for 2 hours, is a leading cause of alcohol-related deaths. © 2008 Thomson - Wadsworth

Alcohol Metabolism: Gender Differences

Body composition
Women have a higher percentage of fat than men (size for size women have less water than men to dilute alcohol).

Less enzyme activity
Alcohol dehydrogenase, the primary enzyme involved in the metabolism of alcohol, is up to 40% less active in women than in men.



Body size
Women are smaller on average than men (smaller liver and less liver water).

Hormonal fluctuations
Women typically have a heightened response to alcohol when they are about to have their period, or when taking birth control pills.

TABLE H7-2 Alcohol Blood Levels and Brain Responses

Blood Alcohol Concentration	Effect on Brain
0.05	Impaired judgment, relaxed inhibitions, altered mood, increased heart rate
0.10	Impaired coordination, delayed reaction time, exaggerated emotions, impaired peripheral vision, impaired ability to operate a vehicle
0.15	Slurred speech, blurred vision, staggered walk, seriously impaired coordination and judgment
0.20	Double vision, inability to walk
0.30	Uninhibited behavior, stupor, confusion, inability to comprehend
0.40 to 0.60	Unconsciousness, shock, coma, death (cardiac or respiratory failure)

NOTE: Blood alcohol concentration depends on a number of factors, including alcohol in the beverage, the rate of consumption, the person's gender, and body weight. For example, a 175-pound female can become legally drunk (0.08 concentration) by drinking four beers in an hour, whereas a 225-pound male consuming that amount at the same rate would have a 0.05 blood alcohol concentration.

- ## When Alcohol Becomes a Problem
- Alcohol and the liver
 - ✓ Fatty liver
 - ✓ Fibrosis
 - ✓ Cirrhosis
 - Fetal alcohol syndrome
 - ✓ Physical abnormalities
 - ✓ Mental retardation
 - ✓ Low birth weight; poor growth



- ## Cirrhosis
- Fatty infiltration of the liver
 - ✓ Response to increased synthesis of fat from accelerated acetyl-CoA production
 - ✓ Enlarged fat cells choke off nutrient and O₂ supply to liver cells
 - ✓ Engorged fat cells burst and die
 - ✓ Scar tissue
 - ✓ 50% chance of death within 4 years
 - ✓ Is the second leading cause for a liver transplant

Liver Damage Due to Alcohol

- Build-up of acetaldehyde (toxic)
- Increased free radical production
 - ✓ Inhibits antioxidative mechanisms
 - ✓ Destroy cell membranes, DNA
 - ✓ Inflammation
- Advanced stages of liver damage are not reversible

Alcoholics and Malnutrition

- Poor diet
 - ✓ Alcohol – energy but no nutrients
 - ✓ Economic factors
 - ✓ Lack of interest in food; problems
- Vitamin deficiencies
 - ✓ Alcohol interferes with vitamin metabolism
 - ✓ Vitamins: Folate (cancer), thiamin, niacin, A, B6, B12 (intrinsic factor), C (scurvy), (Reduced calcium absorption) E (tunnel vision), K (blood clotting)
 - ✓ Minerals: Mg, Zn, Iron



Alcohol's Short-Term Effects

- Accidents, fatalities, and breaking the law
- Binge drinking can result in death.

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Alcohol's Long-Term Effects

- Abuse during pregnancy
- Third leading cause of preventable death

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Alcohol's Long-Term Effects

<ul style="list-style-type: none"> • Health Effects of Heavy Alcohol Consumption <ul style="list-style-type: none"> ✓ Arthritis ✓ Cancer ✓ Fetal alcohol syndrome ✓ Heart disease ✓ Hyperglycemia ✓ Hypoglycemia 	<ul style="list-style-type: none"> ✓ Infertility ✓ Kidney disease ✓ Liver disease ✓ Malnutrition ✓ Nervous disorders ✓ Obesity ✓ Psychological disturbances
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Personal Strategies

- Serve and consume nonalcoholic beverages.
- Drink slowly and consume alcohol moderately.
- Do not drive.

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