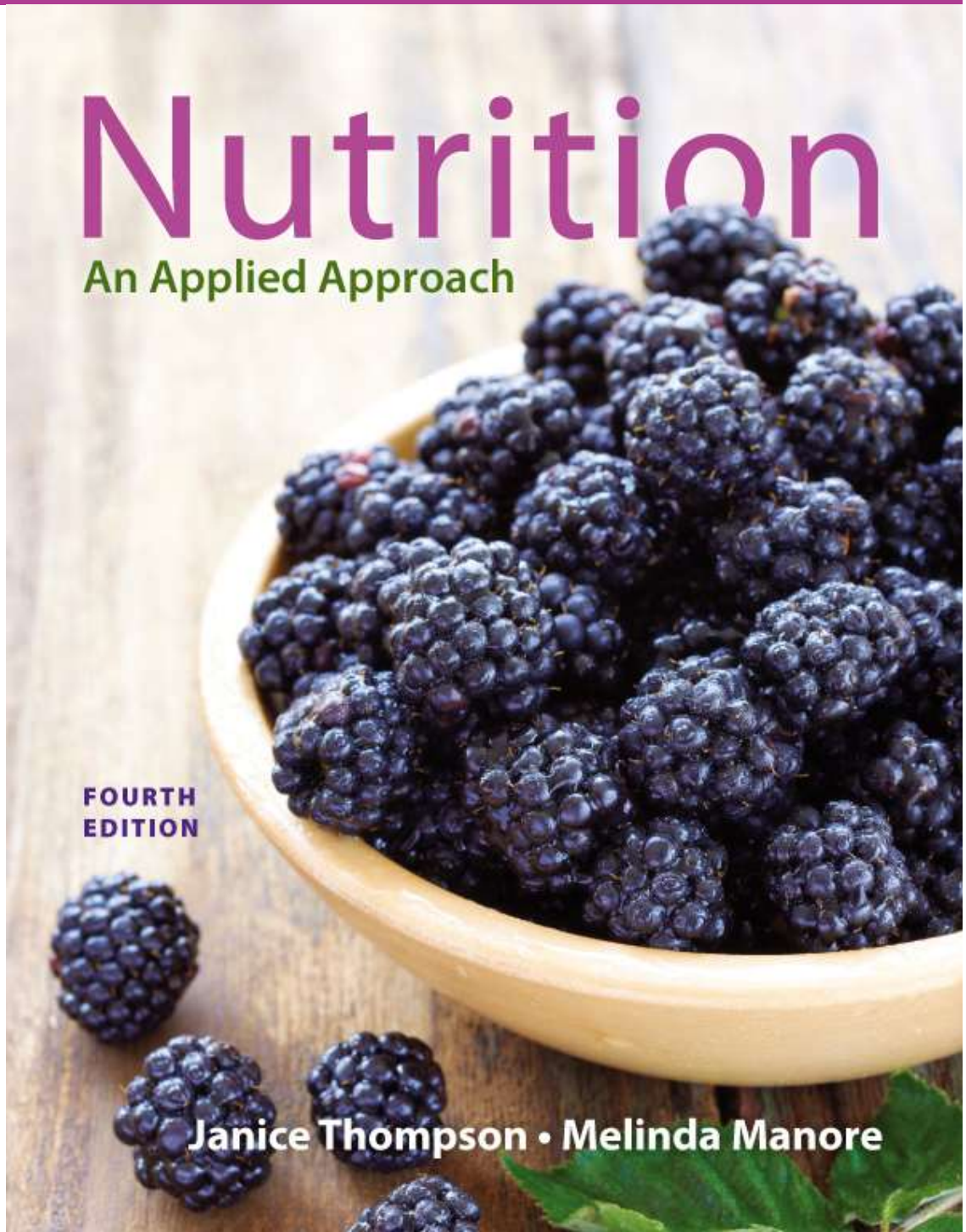
Chapter 4: Carbohydrates: Plant-Derived Energy Nutrients, and In Depth 4.5, Diabetes



What Are Carbohydrates?

Carbohydrates

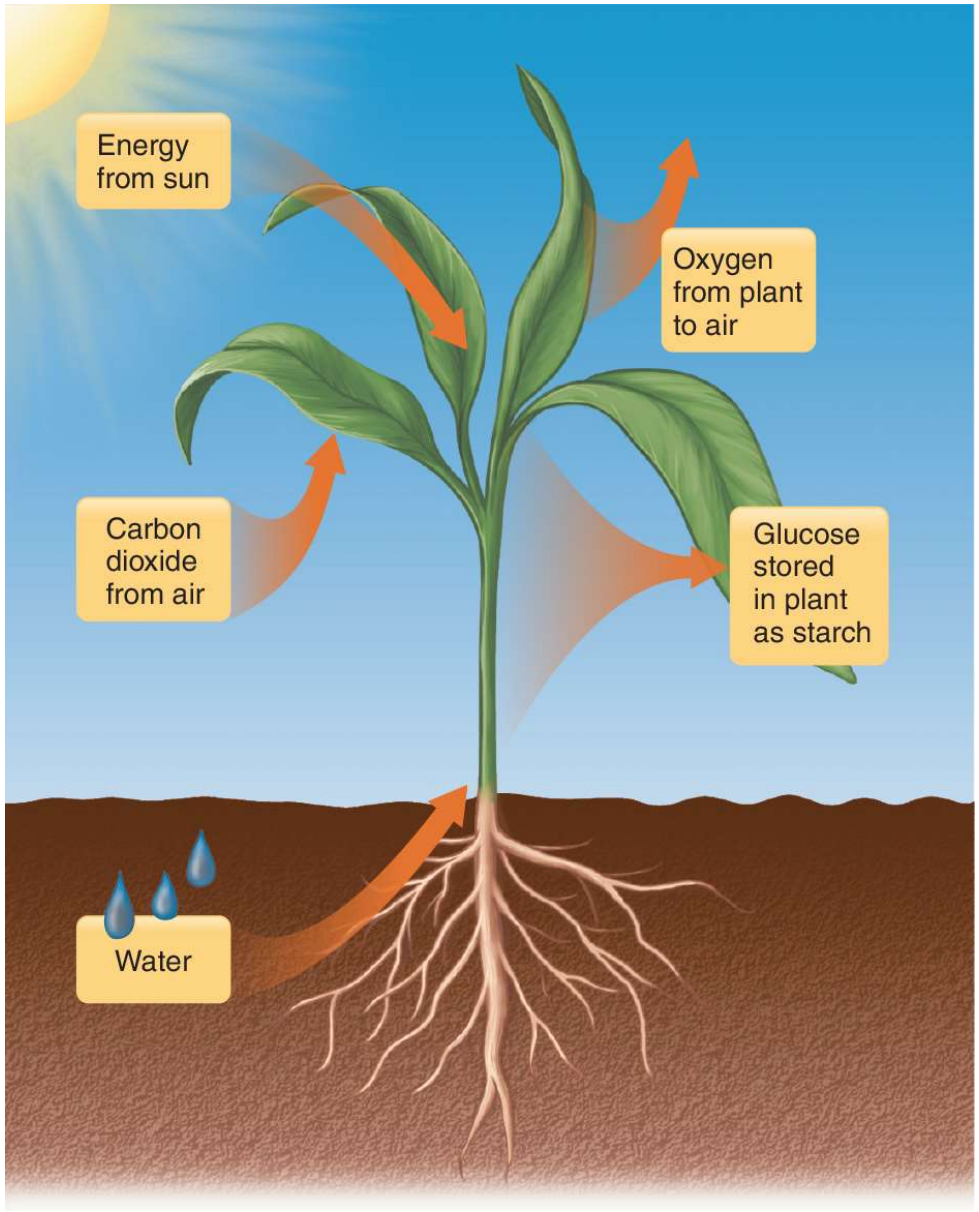
- One of the three macronutrients
- An important energy source, especially for nerve cells
- Composed of the atoms carbon, hydrogen, oxygen
- Good sources include fruits, vegetables, grains

What Are Carbohydrates?

Glucose

- The most abundant carbohydrate
- Produced by plants through photosynthesis
- The preferred source of energy for the brain
- An important source of energy for all cells

Photosynthesis

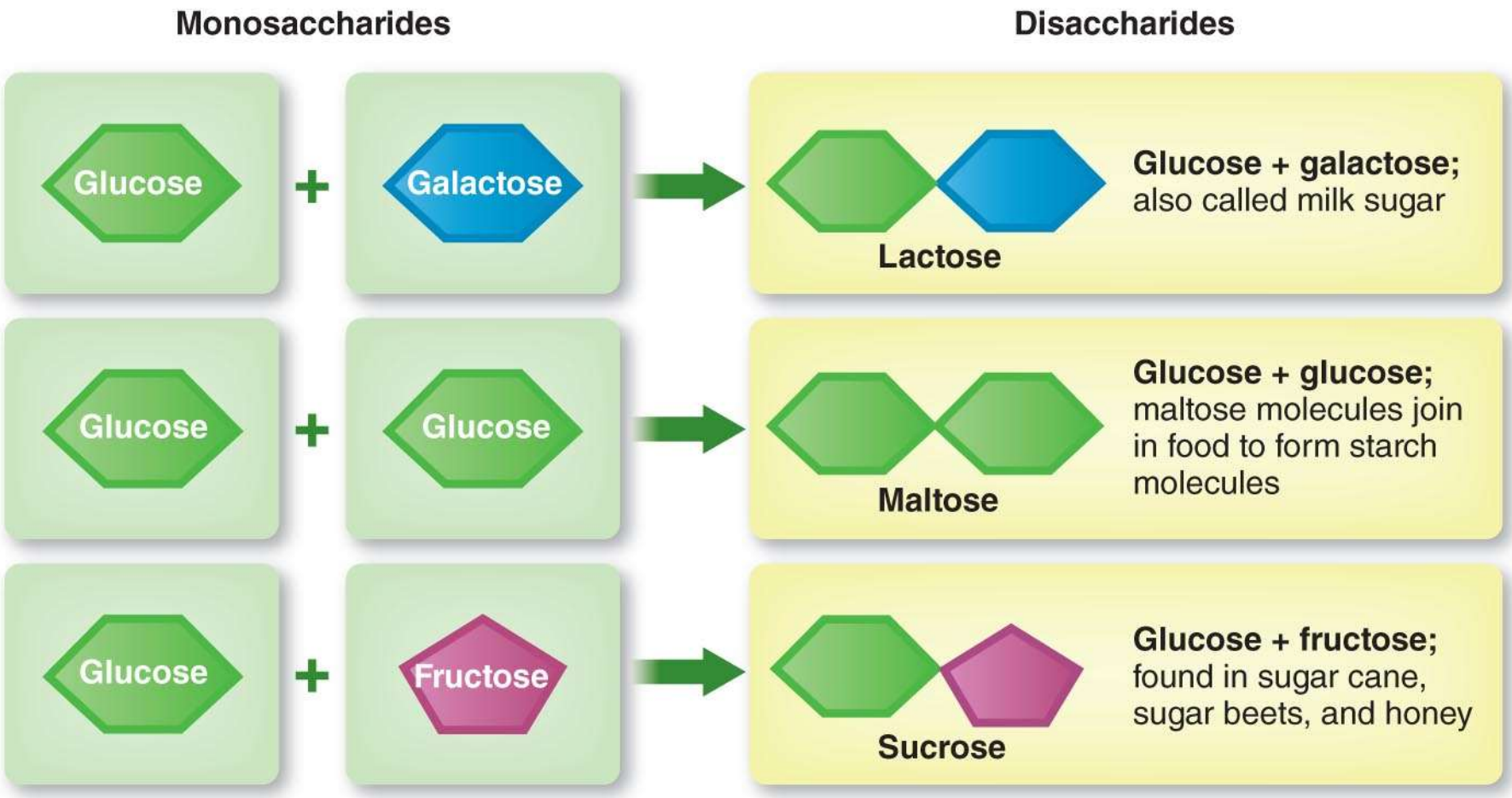


What Are Carbohydrates?

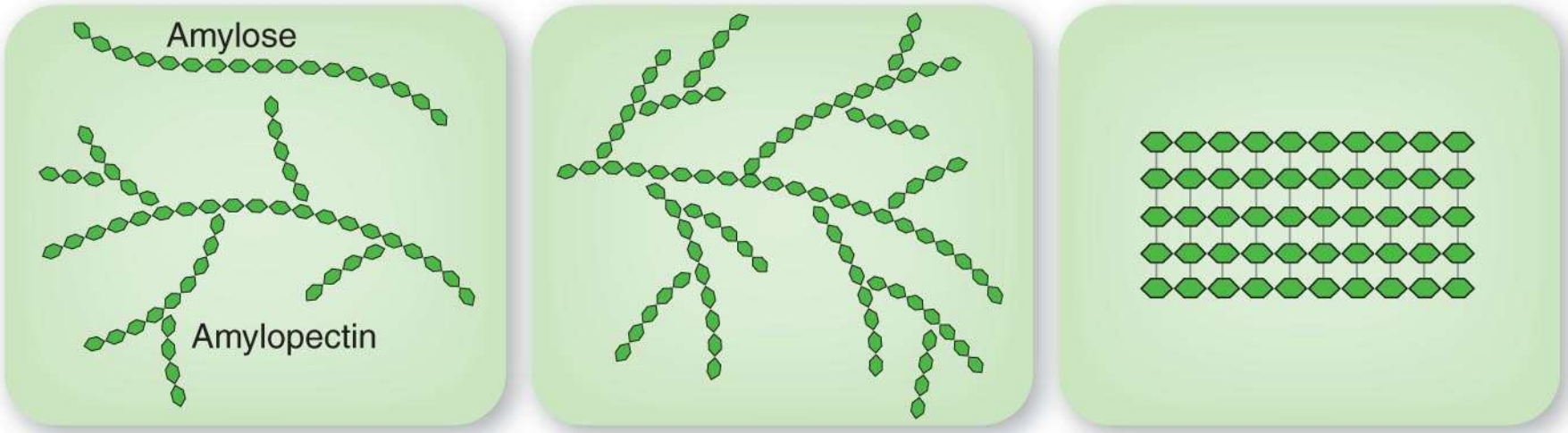
Simple carbohydrates contain one or two molecules

- Monosaccharides contain only one molecule
  - Glucose, fructose, galactose, ribose
- Disaccharides contain two molecules
  - Lactose, maltose, sucrose

Disaccharides



Complex Carbohydrates



Starch

Storage form of glucose in plants; found in grains, legumes, and tubers

Glycogen

Storage form of glucose in animals; stored in liver and muscles

Fiber

Forms the support structures of leaves, stems, and plants

Complex Carbohydrates

Starch

- Plants store glucose as polysaccharides in the form of starch
- Our cells cannot use complex starch molecules exactly as they occur in plants
- We digest (break down) starch into glucose
- Grains, legumes, and tubers are good sources of dietary starch

Complex Carbohydrates

Glycogen

- Animals store glucose as glycogen
- Stored in our bodies in the liver and muscles
- Not found in food and therefore not a dietary source of carbohydrate

Complex Carbohydrates

Fiber

- Dietary fiber: the nondigestible part of plants
- Functional fiber: nondigestible form of carbohydrate with known health benefits, which is extracted from plants and added to foods
  - Cellulose, guar gum, pectin, psyllium
- Total fiber = dietary + functional fiber

Complex Carbohydrates

- Dietary fiber is also classified by solubility

Soluble fiber

- Dissolves in water
- Viscous and fermentable
- Easily digested by bacteria in the colon
- Found in citrus fruits, berries, oats, and beans
- Reduces risk for cardiovascular disease and type 2 diabetes by lowering blood cholesterol and glucose levels

Complex Carbohydrates

Insoluble fibers

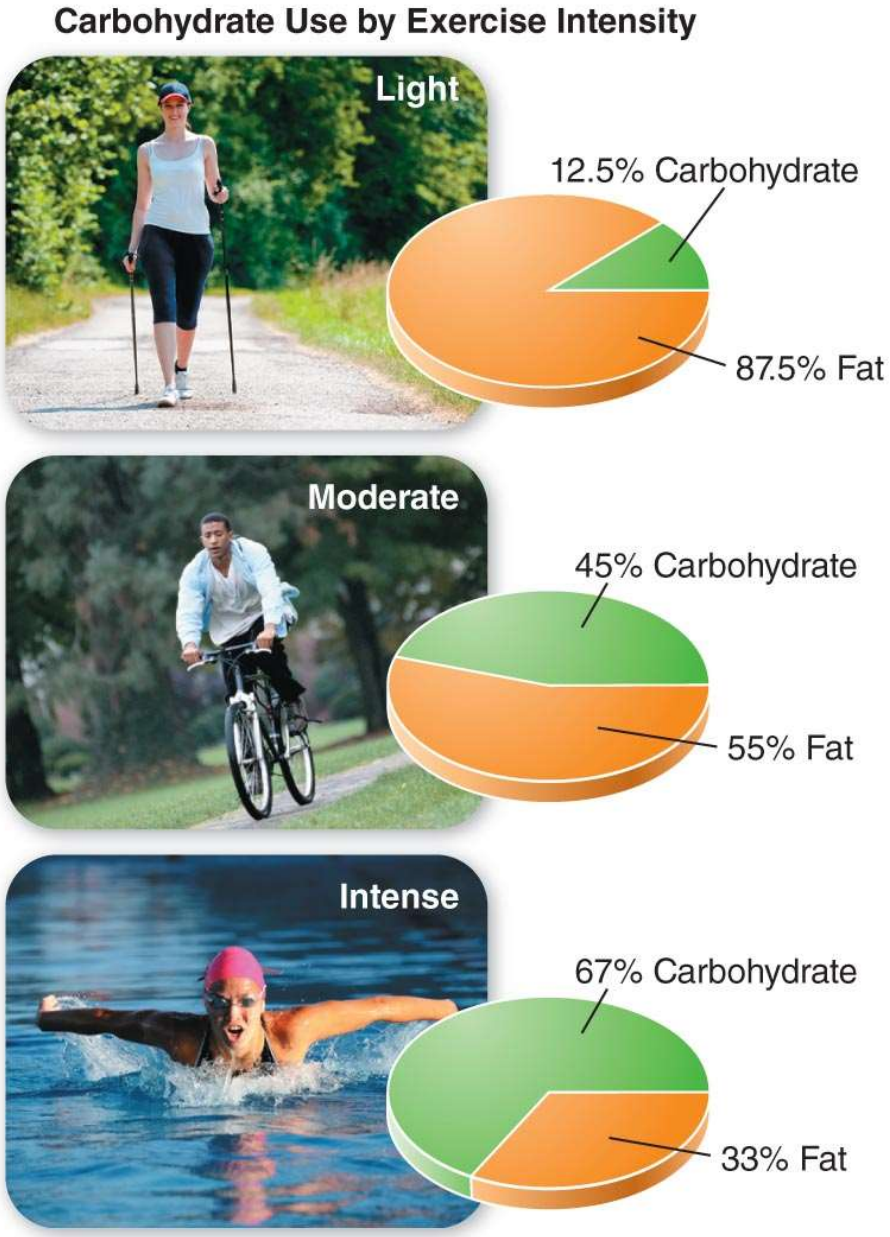
- Generally do not dissolve in water
- Found in whole grains (e.g., wheat, rye, brown rice) and many vegetables
- Promote regular bowel movements, alleviate constipation, and reduce risk for diverticulosis

Why Do We Need Carbohydrates?

Energy

- Fuel daily activity
- Fuel exercise
- Help preserve protein for other uses
  - When the diet does not provide enough carbohydrates, the process of gluconeogenesis converts proteins in blood and tissue into glucose

Carbohydrate Use by Exercise Intensity



Why Do We Need Carbohydrates?

Energy

- Each gram of carbohydrate = 4 kcal
- Red blood cells rely *only* on glucose for their energy supply
- Both carbohydrates and fats supply energy for daily activities
- Glucose is especially important for energy during exercise

Why Do We Need Carbohydrates?

Energy

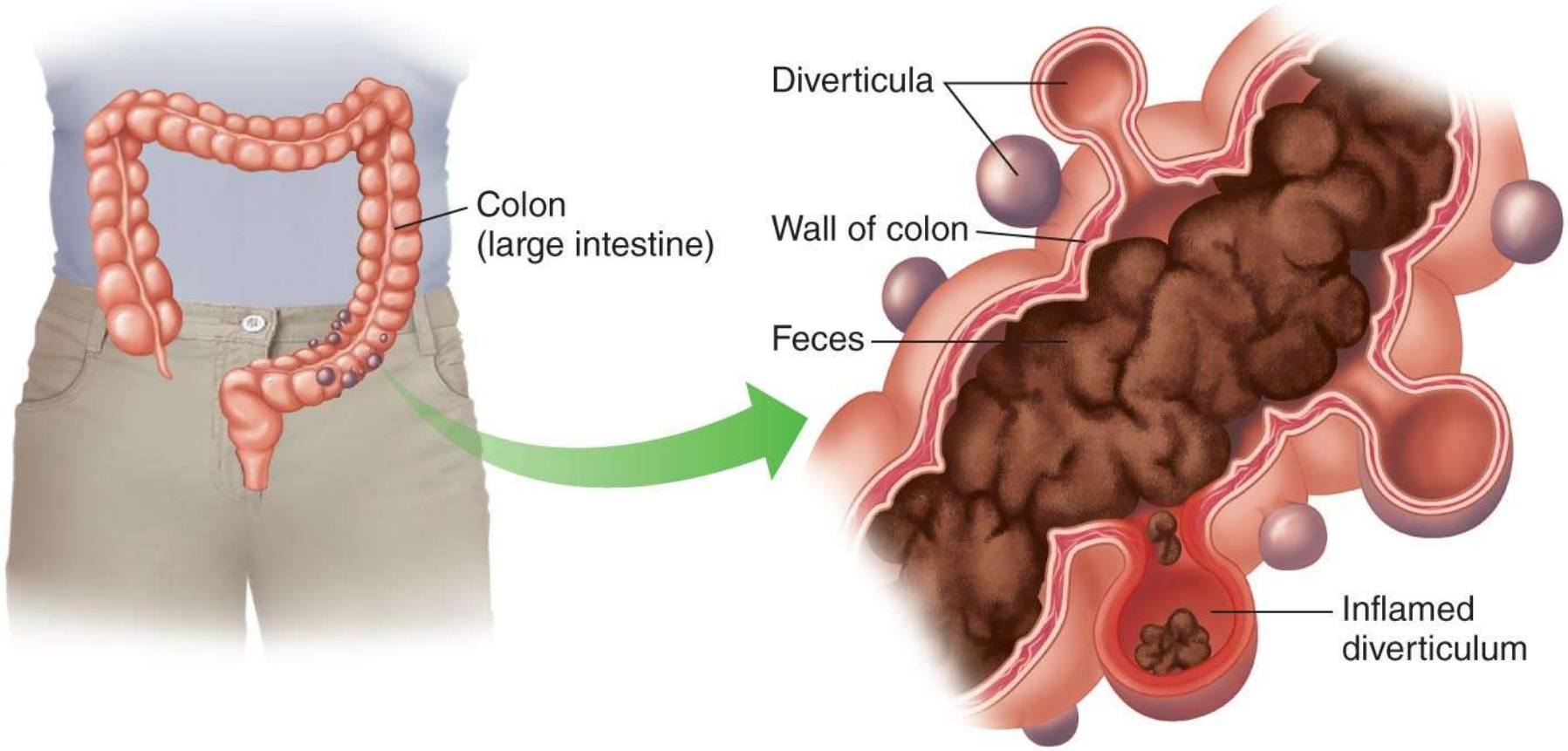
- Sufficient energy intake from carbohydrates prevents production of ketones as an alternate energy source
- Excessive ketones can result in high blood acidity and ketoacidosis
- High blood acidity damages body tissues

Why Do We Need Carbohydrates?

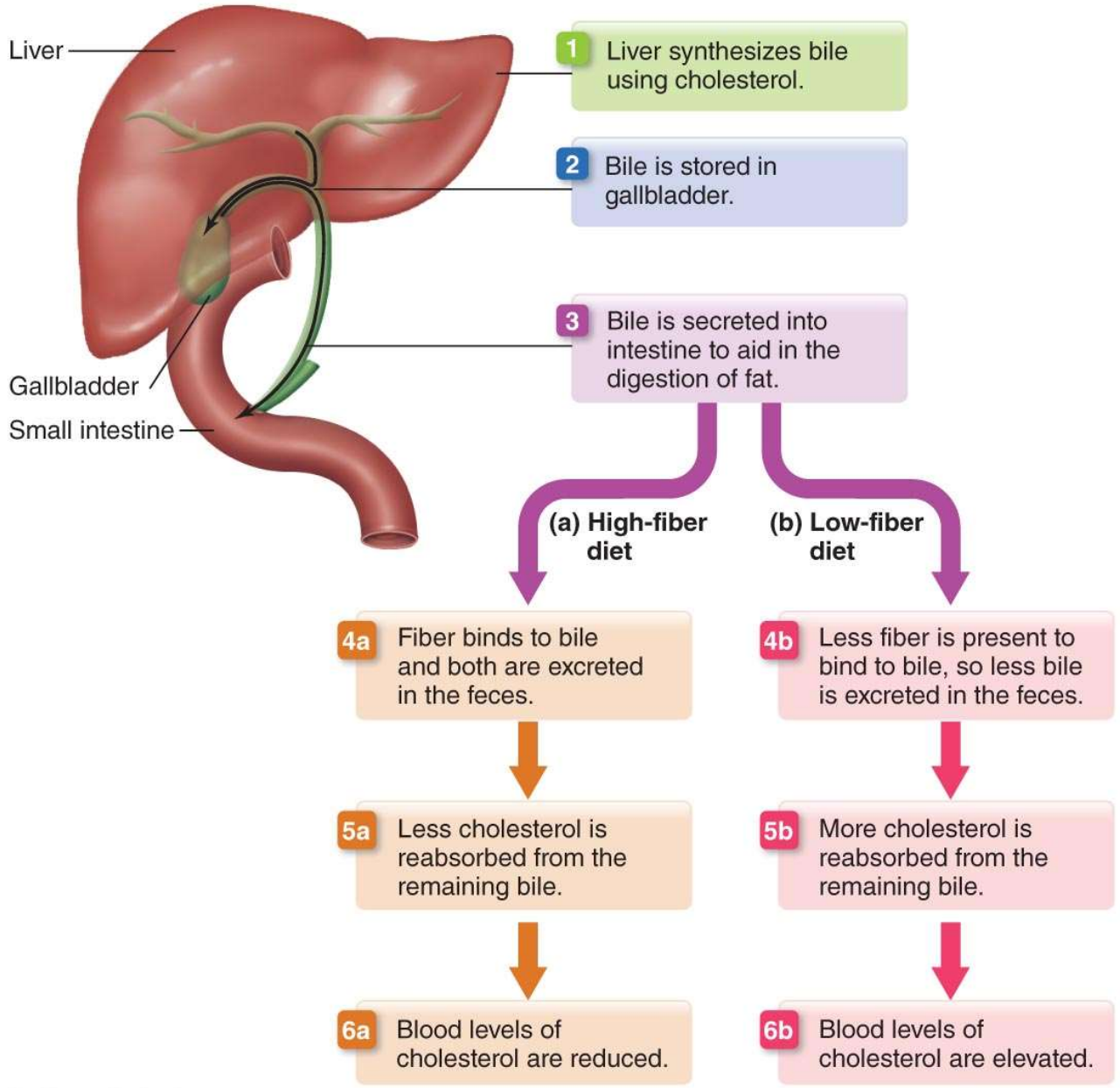
Fiber

- May reduce the risk of colon cancer
- Promotes bowel health by helping to prevent hemorrhoids and constipation
- May reduce the risk of heart disease
- May enhance weight loss
- May lower the risk for type 2 diabetes
- Reduces risk for diverticulosis

Diverticulosis



Fiber May Help Decrease Blood Cholesterol



Digestion of Carbohydrates

- Most chemical digestion of carbohydrates occurs in the small intestine

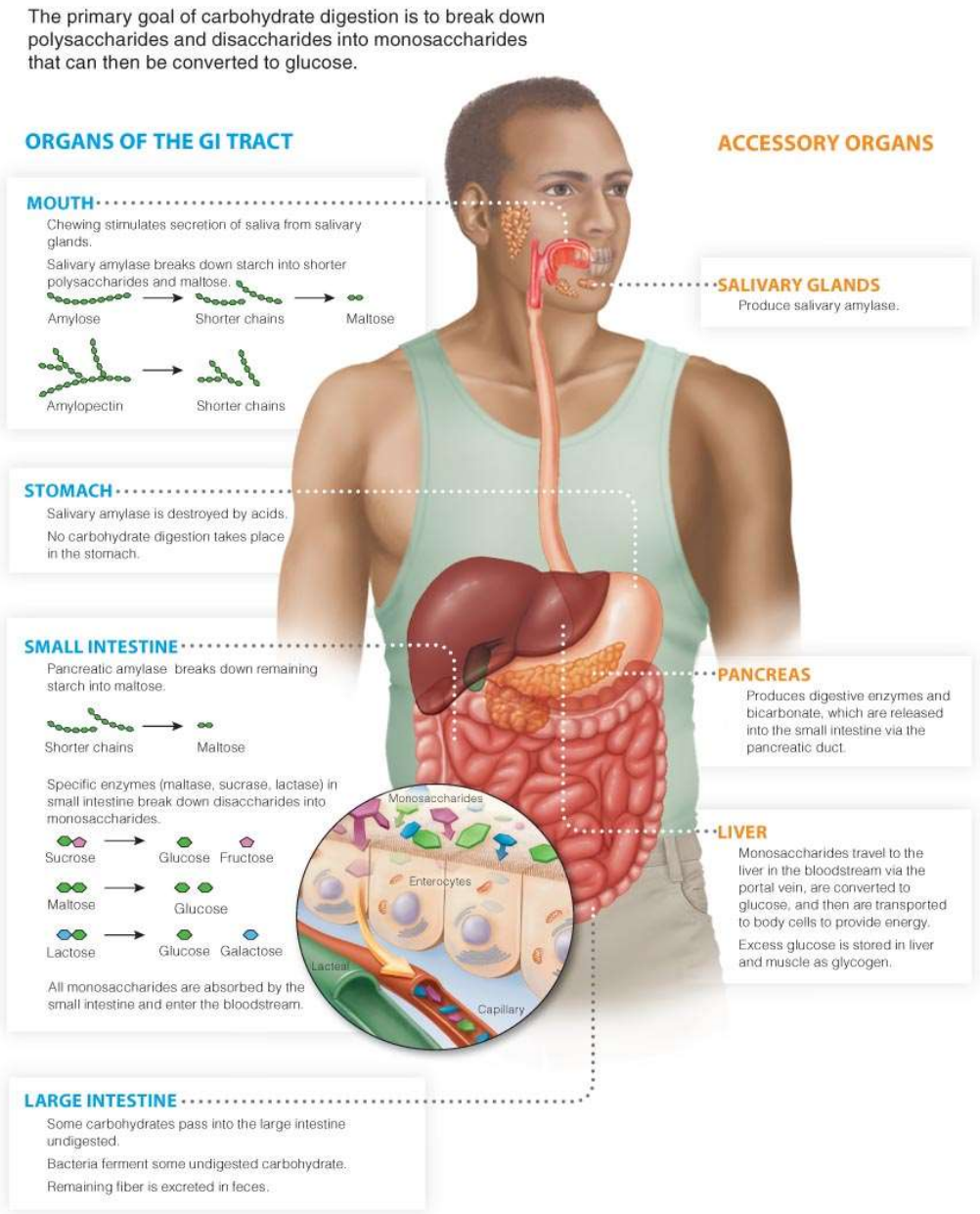
Pancreatic amylase

- Enzyme produced in the pancreas and secreted into the small intestine
- Enzymatically digests starch to maltose

Digestion of Carbohydrates

- Additional enzymes secreted by cells that line the small intestine (mucosal cells) digest disaccharides to monosaccharides
- These enzymes include maltase, sucrase, and lactase
- Monosaccharides are absorbed into the cells lining the small intestine and then enter the bloodstream

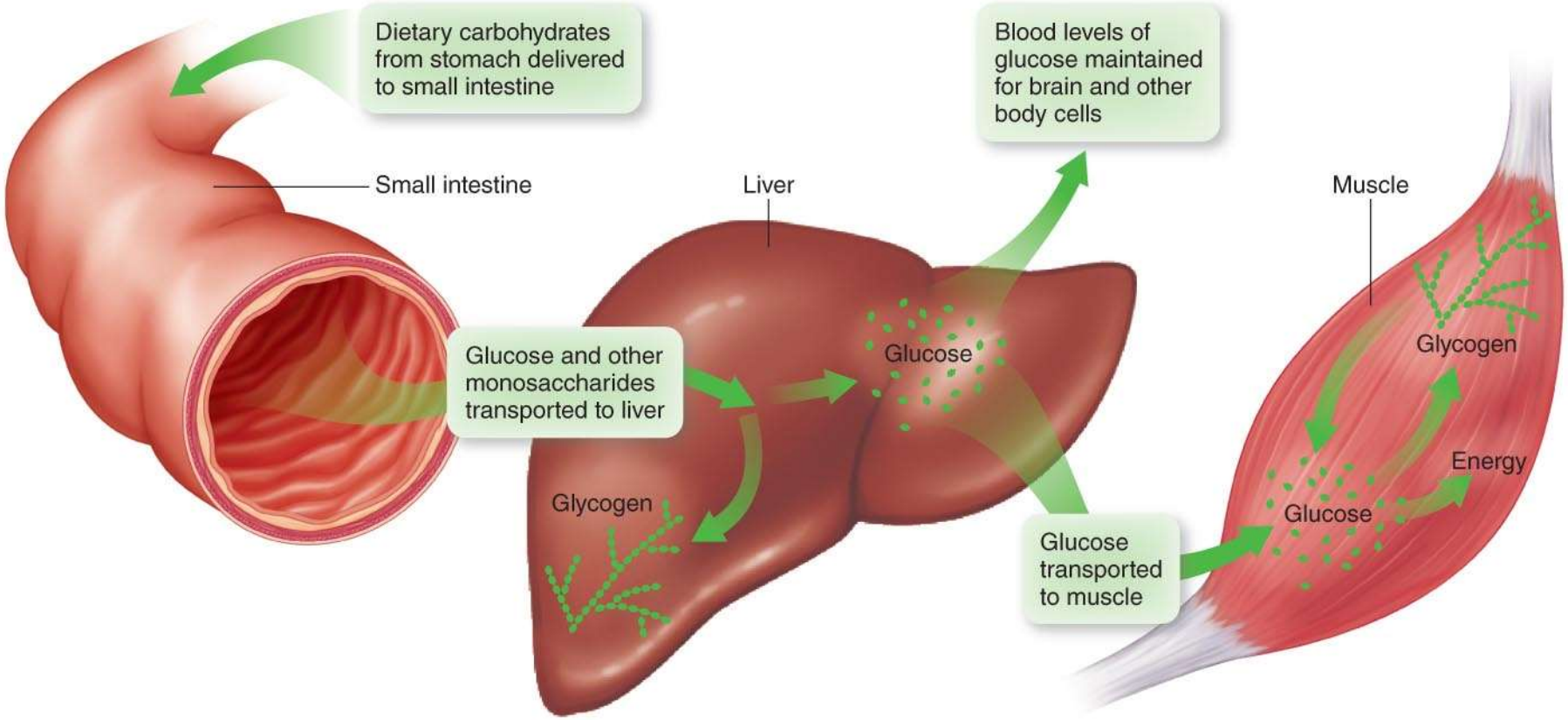
Digestion of Carbohydrates



Digestion of Carbohydrates

- Most monosaccharides are converted to glucose by the liver
  - Glucose is released into the bloodstream to provide immediate energy
  - Excess glucose is converted to glycogen and stored in the liver and muscles

The Process of Glycogenesis



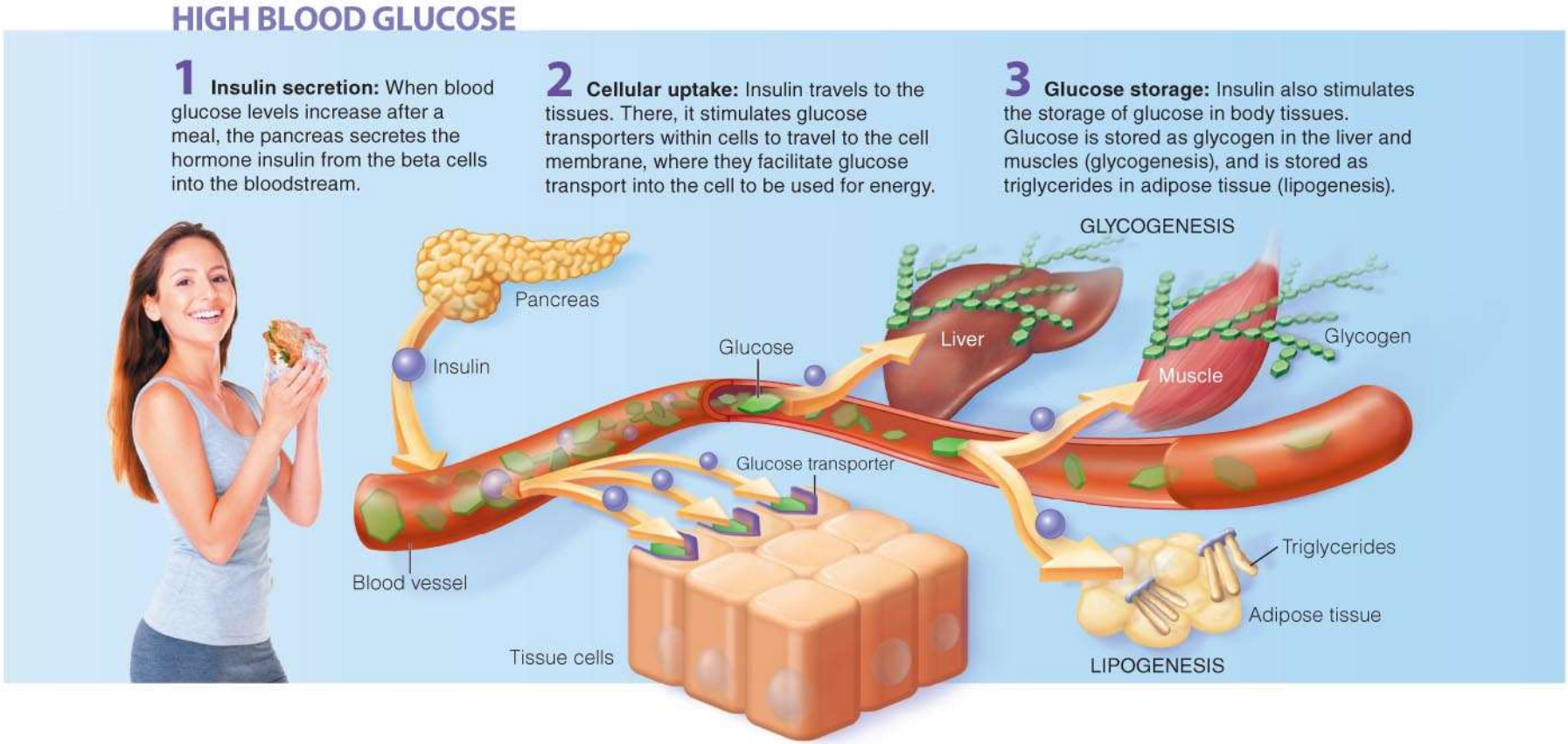
Regulation of Blood Glucose: Insulin

Insulin

- A hormone secreted by the pancreas
- Transported in our blood throughout the body
- Helps transport glucose from the blood into cells
- Stimulates the liver and muscles to take up glucose and convert it to glycogen

Regulation of Blood Glucose: Insulin

Our bodies regulate blood glucose levels within a fairly narrow range to provide adequate glucose to the brain and other cells. Insulin and glucagon are two hormones that play a key role in regulating blood glucose.

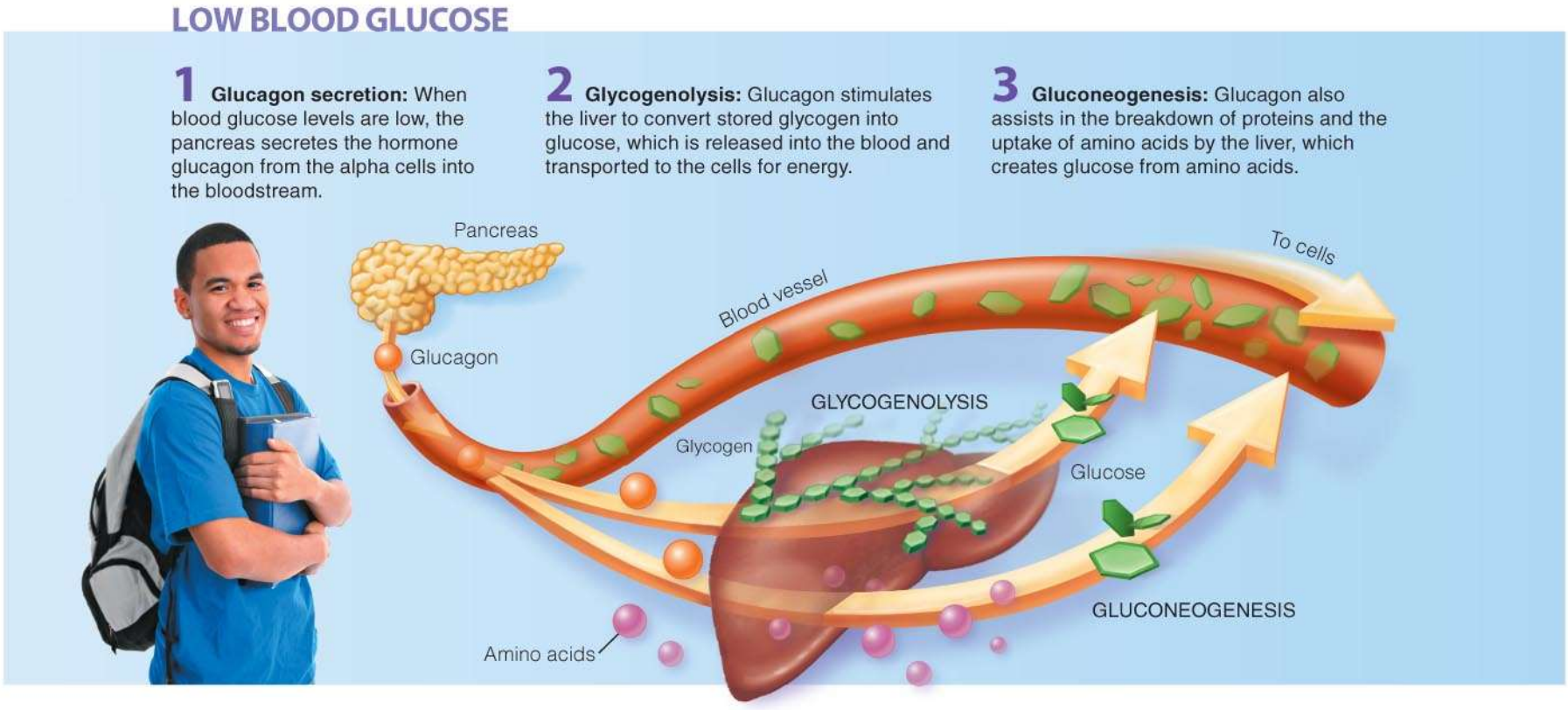


Regulation of Blood Glucose: Glucagon

Glucagon

- Another hormone secreted by the pancreas
- Stimulates the breakdown of glycogen to glucose to make glucose available to cells of the body
- Stimulates gluconeogenesis—the production of “new” glucose from amino acids

Regulation of Blood Glucose: Glucagon



Regulation of Blood Glucose

- Fructose does not stimulate the release of insulin
  - Fructose is metabolized differently than glucose
  - Absorbed further down in the small intestine

Regulation of Blood Glucose

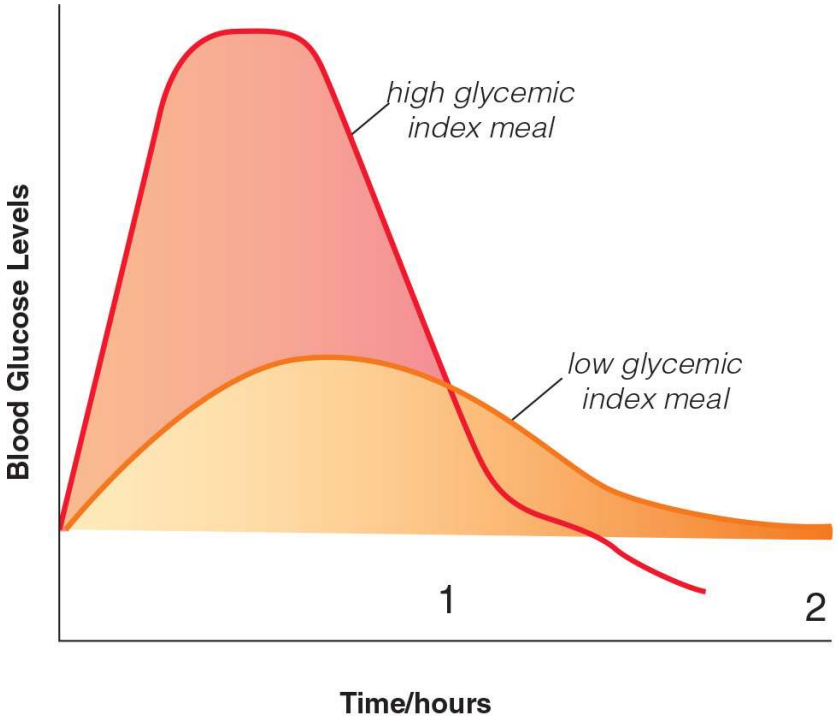
Glycemic index: a measure of a food's ability to raise blood glucose levels

- Foods with a low glycemic index cause low to moderate fluctuations in blood glucose

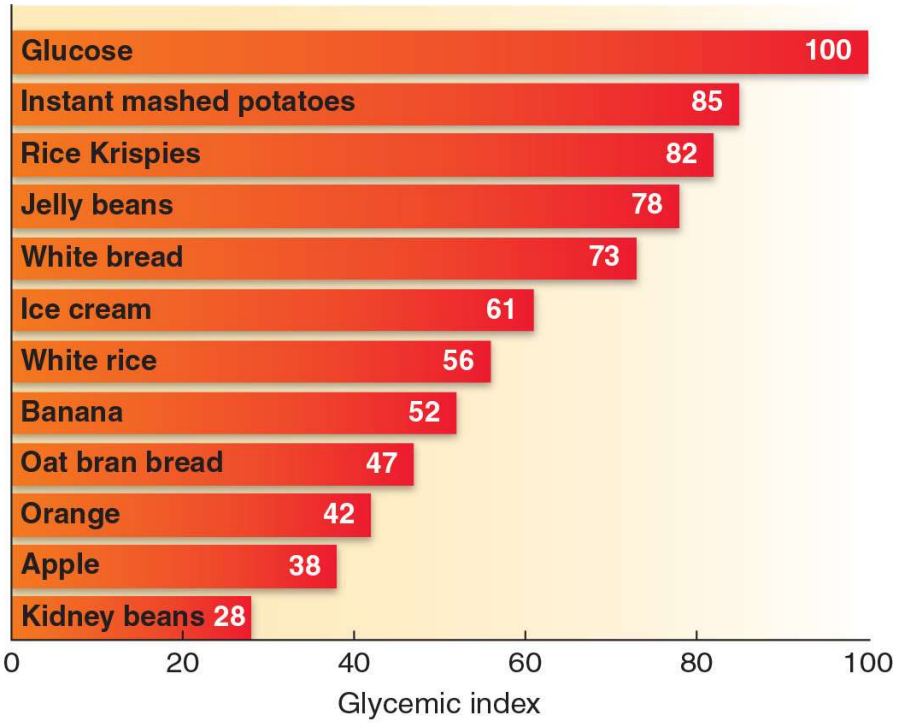
Glycemic load: amount of carbohydrate in a food multiplied by its glycemic index

- Considered a more useful tool than glycemic index

Regulation of Blood Glucose



(a)



(b)

Regulation of Blood Glucose

- Foods and meals with a lower glycemic load
  - Are better for people with diabetes
  - Are generally higher in fiber
  - May reduce the risk for heart disease and colon cancer
  - Are associated with a reduced risk for prostate cancer

How Much Carbohydrate Should We Eat?

- The Recommended Dietary Allowance (RDA) for carbohydrate is 130 g per day just to supply the brain with glucose
  - 45–65% of daily calorie intake should be in the form of carbohydrates
  - Focus on foods high in fiber and low in added sugars

Dietary Recommendations

TABLE 4.1 Dietary Recommendations for Carbohydrates

Health and Medicine Division of the National Academies of Science Recommendations*	2015–2020 Dietary Guidelines for Americans†
Recommended Dietary Allowance (RDA) for adults 19 years of age and older is 130 g of carbohydrate per day. The Acceptable Macronutrient Distribution Range (AMDR) for carbohydrate is 45–65% of total daily energy intake. Added sugar intake should be 25% or less of total energy intake each day.	Consume a healthful eating pattern that accounts for all foods and beverage within an appropriate Calorie level. A healthful eating pattern includes: a variety of vegetables from all subgroups (dark green, red and orange, legumes, starch and other); fruits (especially whole fruits); grains (at least half of which are whole grains); fat-free or low-fat dairy; a variety of protein foods; and oils. Consume less than 10% of Calories per day from added sugars.

*Data from: Health and Medicine Division of the National Academies of Science, Food and Nutrition Board, 2005. *Dietary Reference Intakes for Energy, Carbohydrates, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients)*. Washington, DC: The National Academy of Sciences. Reprinted with permission.

†Data from: U.S. Department of Health and Human Services and U.S. Department of Agriculture. *2015–2020 Dietary Guidelines for Americans,* 8th edn.

How Much Carbohydrate Should We Eat?

- Most Americans eat too much added sugar
  - Sugars are added to foods during processing or preparation
  - Most common source is soft drinks
  - Typical sources are cookies, candy, fruit drinks
  - Unexpected sources include peanut butter, flavored rice mixes, salad dressing
  - Added sugars are not chemically different from naturally occurring sugars, but have fewer vitamins

How Much Carbohydrate Should We Eat?

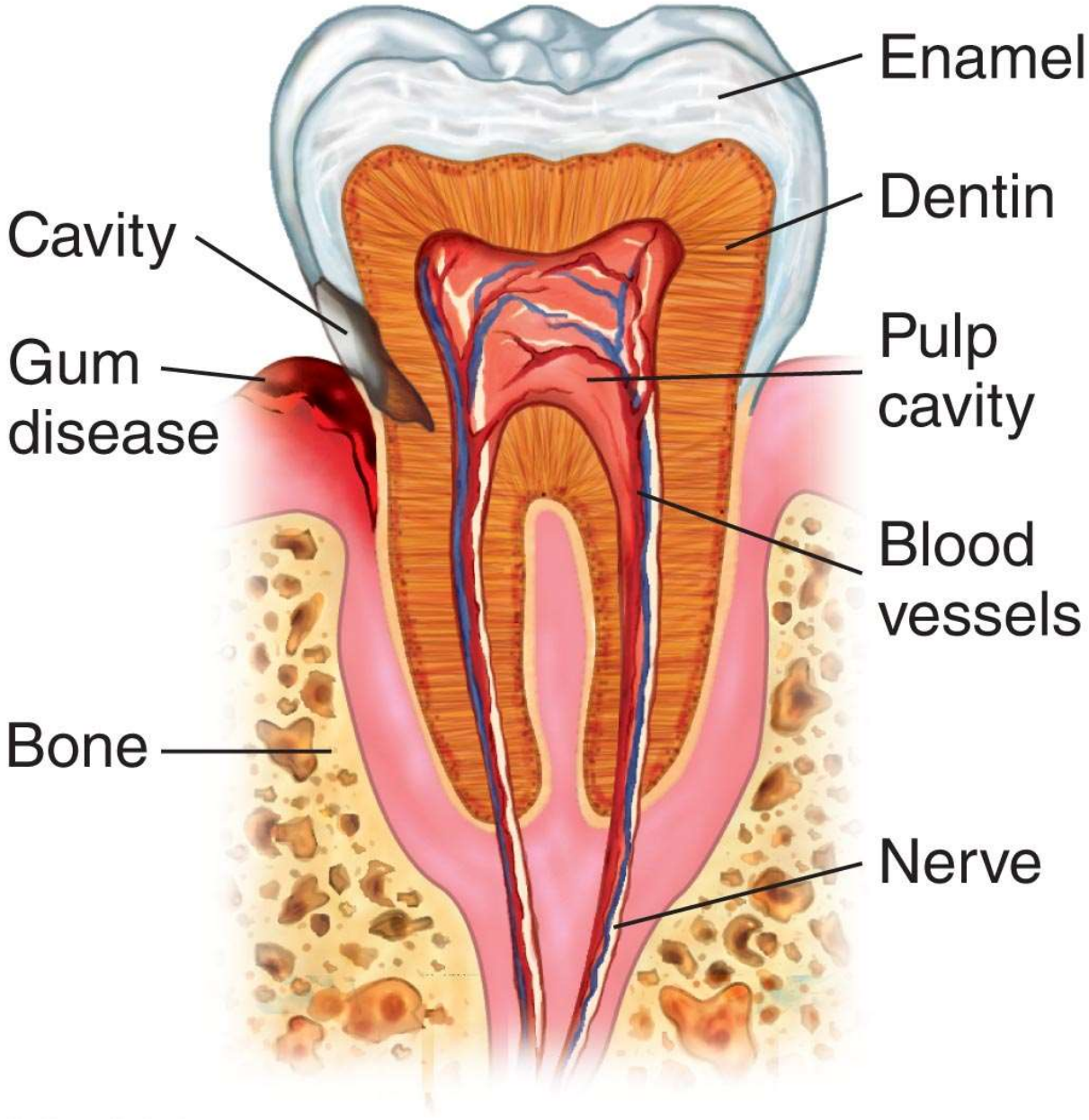
TABLE 4.2 Forms of Sugar Commonly Added to Foods

Name of Sugar	Definition
Brown sugar	A highly refined sweetener made up of approximately 99% sucrose and produced by adding to white table sugar either molasses or burnt table sugar for coloring and flavor.
Cane sugar	Sucrose that has been extracted from sugarcane, a tropical plant naturally rich in sugar.
Concentrated fruit juice sweetener	A form of sweetener made with concentrated fruit juice, commonly pear juice.
Confectioner's sugar	A highly refined, finely ground white sugar; also referred to as powdered sugar.
Corn sweeteners	A general term for any sweetener made with corn starch.
Corn syrup	A syrup produced by the partial hydrolysis of corn starch.
Dextrose	An alternative term for glucose.
Fructose	A monosaccharide that occurs in fruits and vegetables; also called levulose, or fruit sugar.
Galactose	A monosaccharide that joins with glucose to create lactose.
Granulated sugar	Another term for white sugar, or table sugar.
High-fructose corn syrup	A type of corn syrup in which part of the sucrose is converted to fructose, making it sweeter than sucrose or regular corn syrup; most high-fructose corn syrup contains 42% to 55% fructose.
Honey	A sweet, sticky liquid sweetener made by bees from the nectar of flowers; contains glucose and fructose.
Invert sugar	A sugar created by heating a sucrose syrup with a small amount of acid; inverting sucrose results in its breakdown into glucose and fructose, which reduces the size of the sugar crystals; because of its smooth texture, it is used in making candies and some syrups.
Levulose	Another term for fructose, or fruit sugar.
Mannitol	A type of sugar alcohol.
Maple sugar	A sugar made by boiling maple syrup.
Molasses	A thick, brown syrup that is separated from raw sugar during manufacturing; it is considered the least refined form of sucrose.
Natural sweeteners	A general term used for any naturally occurring sweeteners, such as fructose, honey, and raw sugar.
Raw sugar	The sugar that results from the processing of sugar beets or sugarcane; it is approximately 96% to 98% sucrose; true raw sugar contains impurities and is not stable in storage; the raw sugar available to consumers has been purified to yield an edible sugar.
Sorbitol	A type of sugar alcohol.
Turbinado sugar	The form of raw sugar that is purified and safe for human consumption; sold as "Sugar in the Raw" in the United States.
White sugar	Another name for sucrose, or table sugar.
Xylitol	A type of sugar alcohol.

How Much Carbohydrate Should We Eat?

- Sugars are blamed for many health problems
  - Can cause dental problems and tooth decay
  - No proven association with childhood hyperactivity; long-term effects not known
  - Associated with increased “bad cholesterol” and decreased “good cholesterol”
  - Associated with a higher risk for diabetes
  - Associated with obesity

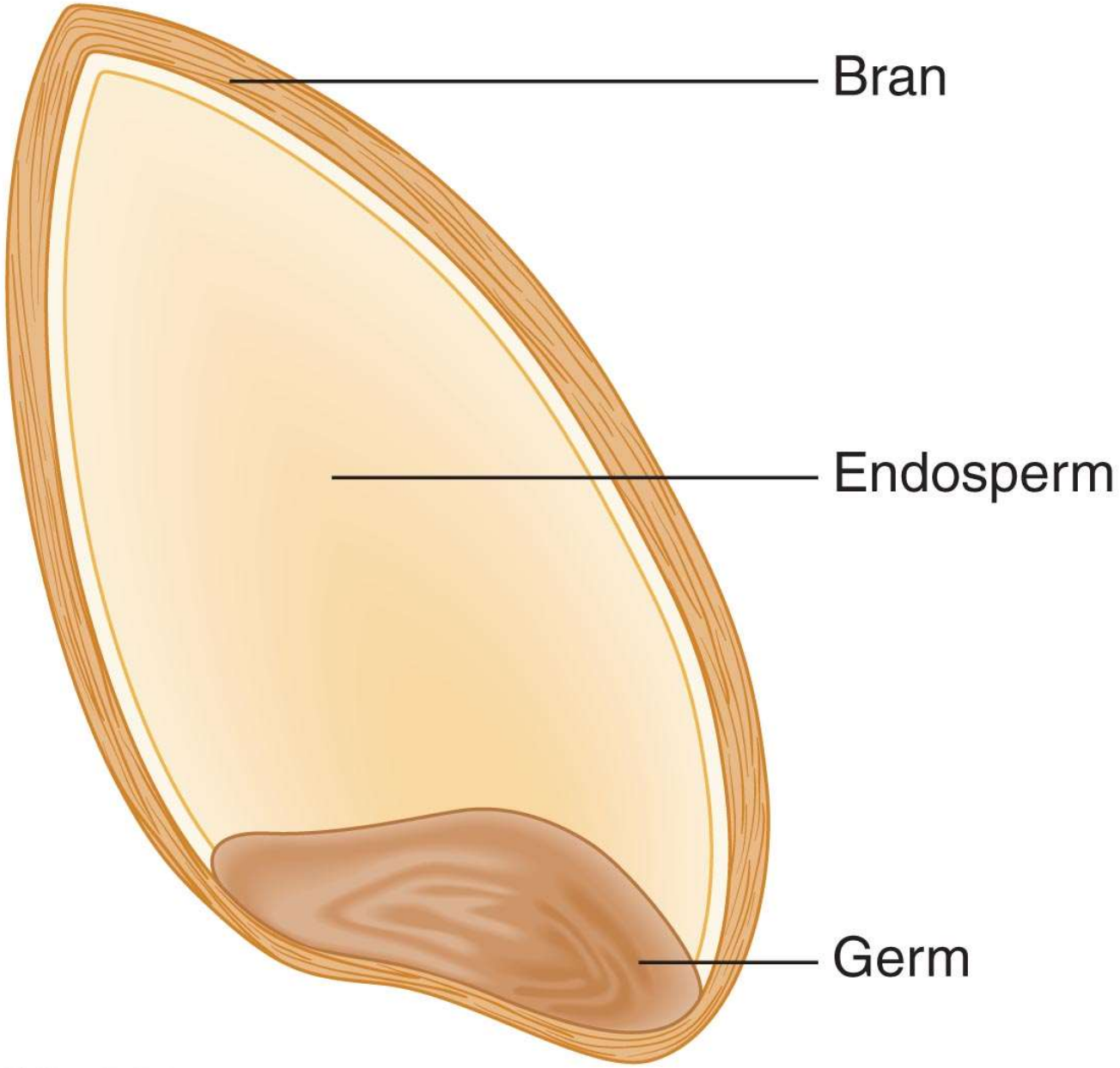
Sugars and Tooth Decay



How Much Carbohydrate Should We Eat?

- Most Americans eat too little fiber-rich carbohydrates
- The Adequate Intake (AI) of fiber is 14 grams per 1,000 kcal in the diet daily (or 25 g for women; 38 g for men)
- Whole-grain foods (grains, vegetables, fruits, nuts, legumes) are much more healthful sources than foods with added sugar or fiber
  - Whole grains are kernels that retain the bran, endosperm, and germ

Whole Grain



Recognizing Carbohydrates on the Label

Nutrition Facts

Serving Size: 3/4 cup (30g)
Servings Per Package: About 14

Amount Per Serving	Cereal	Cereal With 1/2 Cup Skim Milk
Calories	120	160
Calories from Fat	15	15
	% Daily Value**	
Total Fat 1.5g*	2%	2%
Saturated Fat 0g	0%	0%
Trans Fat 0g		
Polyunsaturated Fat 0g		
Monounsaturated Fat 0.5g		
Cholesterol 0mg	0%	1%
Sodium 220mg	9%	12%
Potassium 40mg	1%	7%
Total Carbohydrate 26g	9%	11%
Dietary Fiber 1g	3%	3%
Sugars 13g		
Other Carbohydrate 12g		
Protein 1g		

INGREDIENTS: Corn Flour, Sugar, Brown Sugar, Partially Hydrogenated Vegetable Oil (Soybean and Cottonseed), Oat Flour, Salt, Sodium Citrate (a flavoring agent), Flavor added [Natural & Artificial Flavor, Strawberry Juice Concentrate, Malic Acid (a flavoring agent)], Niacinamide (Niacin), Zinc Oxide, Reduced Iron, Red 40, Yellow 5, Red 3, Yellow 6, Pyridoxine Hydrochloride (Vitamin B6), Riboflavin (Vitamin B2), Thiamin Mononitrate (Vitamin B1), Folic Acid (Folate) and Blue 1.

(a)

Nutrition Facts

Serving Size: 1/2 cup dry (40g)
Servings Per Container: 13

Amount Per Serving	
Calories	150
Calories from Fat	25
	% Daily Value*
Total Fat 3g	5%
Saturated Fat 0.5g	2%
Trans Fat 0g	
Polyunsaturated Fat 1g	
Monounsaturated Fat 1g	
Cholesterol 0mg	0%
Sodium 0mg	0%
Total Carbohydrate 27g	9%
Dietary Fiber 4g	15%
Soluble Fiber 2g	
Insoluble Fiber 2g	
Sugars 1g	
Protein 5g	

INGREDIENTS: 100% Natural Whole Grain Rolled Oats.

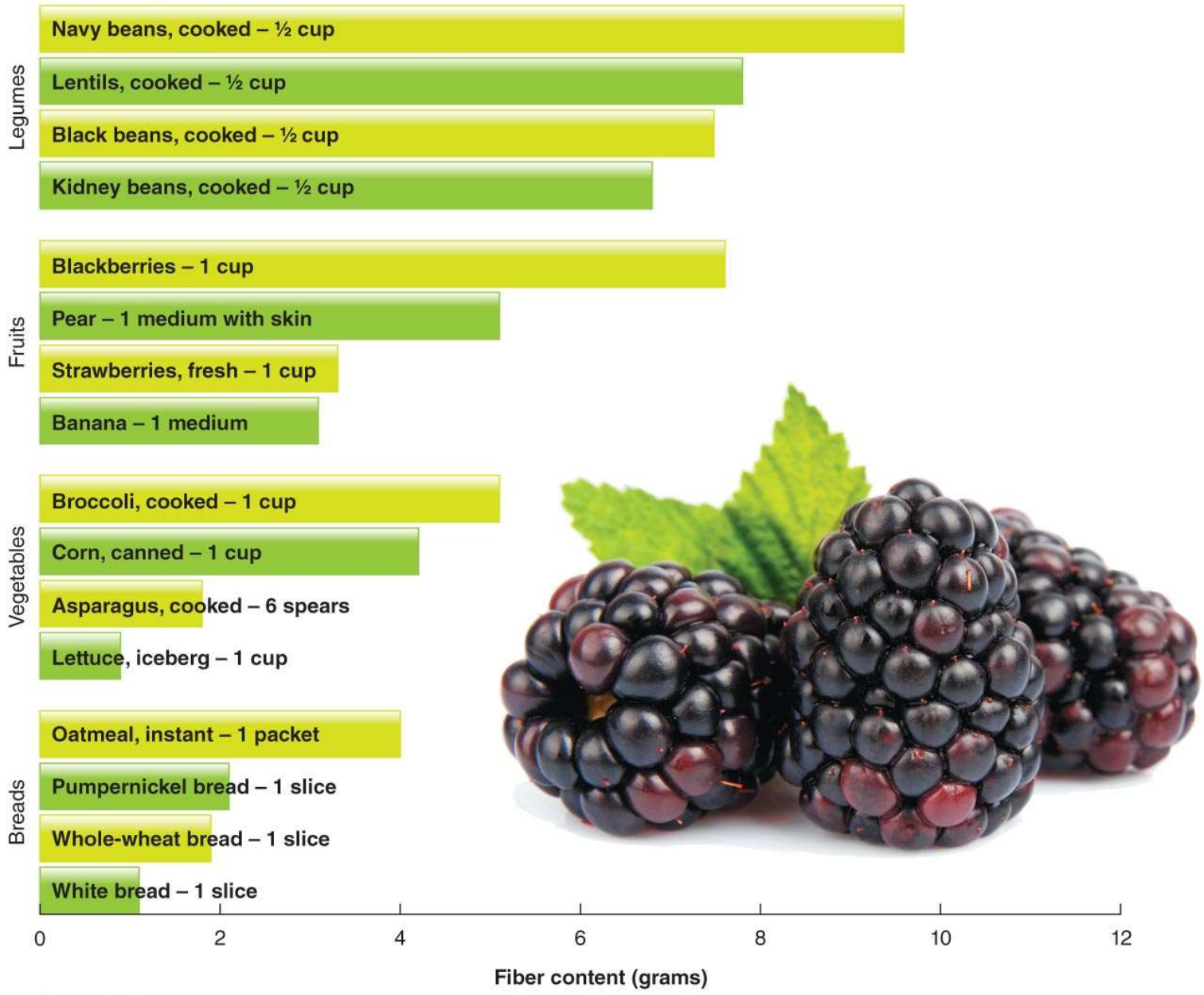
(b)

Terms for Grains and Cereals on Labels

TABLE 4.3 Terms Used to Describe Grains and Cereals on Nutrition Labels

Term	Definition
Brown bread	Bread that may or may not be made using whole-grain flour. Many brown breads are made with white flour with brown (caramel) coloring added.
Enriched (or fortified)	Enriching or fortifying involves adding nutrients back to refined foods. In order to use this term in grain products in the United States, a minimum amount of iron, folate, niacin, thiamin, and riboflavin must be added. Other nutrients can also be added.
Refined	Refining involves removing the coarse parts of food products; refined wheat flour is flour in which all but the internal part of the kernel has been removed.
Stone ground	This term refers to a milling process in which limestone is used to grind any grain. Stone ground does not mean that bread is made with whole grain because refined flour can be stone ground.
Unbleached flour	Unbleached flour has been refined but not bleached; it is very similar to refined white flour in texture and nutritional value.
Wheat flour	This term refers to any flour made from wheat; it includes white flour, unbleached flour, and whole-wheat flour.
White flour	White flour has been bleached and refined. All-purpose flour, cake flour, and enriched baking flour are all types of white flour.
Whole-grain flour	This flour is made from grain that is not refined; whole grains are milled in their complete form with only the husk removed.
Whole-wheat flour	Whole-wheat flour is an unrefined, whole-grain flour made from whole-wheat kernels.

Fiber Content of Common Foods



Alternative Sweeteners

Nutritive sweeteners

- Contain 4 kcal energy per gram
- Sucrose, fructose, honey, brown sugar

Sugar alcohols

- Contain 2–3 kcal energy per gram
- Have the benefit of a decreased glycemic response and decreased risk of dental caries

Non-nutritive (alternative) sweeteners

- Provide little or no energy
- Developed to sweeten foods without the usual risks

Alternative Sweeteners

- No Acceptable Daily Intake (ADI) has been set for saccharin (e.g., “Sweet’N Low”), but it has been removed from the list of cancer-causing agents
- ADIs have been established for
  - Acesulfame-k (e.g., “Sweet One,” “Sunette”)
  - Aspartame (e.g., “Equal”)
  - Sucralose (e.g., “Splenda”)

Alternative Sweeteners

TABLE 4.4 Foods and Beverages That a Child and an Adult Would Have to Consume Daily to Exceed the ADI for Aspartame

Foods and Beverages	50-lb Child	150-lb Adult
12 fl. oz carbonated diet soft drink *or*	5.6	17
8 fl. oz powdered soft drink *or*	11	34
4 fl. oz gelatin dessert *or*	14	42
Packets of tabletop sweetener	32	97

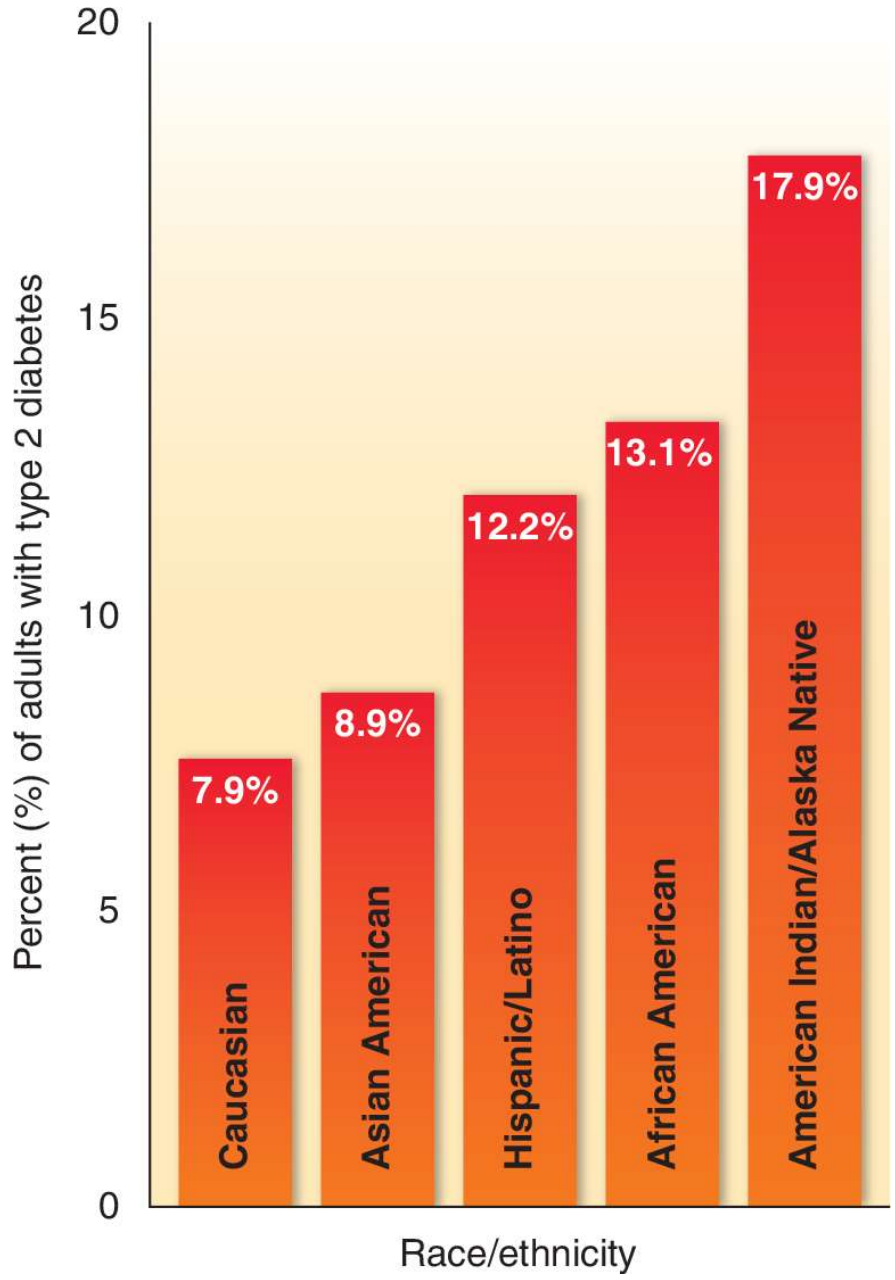
Data from: Academy of Nutrition and Dietetics. 2015. "Sugar Substitutes: How Much Is Too Much?" http://www.eatright.org/resource/food/nutrition/dietary-guidelines-and-myplate/sugar-substitutes-how-much-is-too-much.

In Depth: Diabetes

Diabetes

- Inability to regulate blood glucose levels
- Hyperglycemia—in which glucose levels are higher than normal—becomes chronic
- Three types
  - Type 1 diabetes
  - Type 2 diabetes
  - Gestational diabetes
- Uncontrolled diabetes can cause infections, nerve damage, kidney damage, blindness, seizures, stroke, and cardiovascular disease, and can be fatal

Diabetes



Symptoms of Diabetes

TABLE 1 Symptoms of Type 1 and Type 2 Diabetes

Type 1 Diabetes	Type 2 Diabetes*
Increased or frequent urination	Any of the type 1 signs and symptoms
Excessive thirst	Greater frequency of infections
Constant hunger	Sudden vision changes
Unexplained weight loss	Slow healing of wounds or sores
Extreme fatigue	Tingling or numbness in the hands or feet
Blurred vision	Very dry skin

*Some people with type 2 diabetes experience no symptoms.

Data adapted from: U.S. Dept. of Health and Human Services, National Diabetes Information Clearinghouse (NDIC). Available at http://www.niddk.nih.gov/health-information/health-topics/Diabetes/your-guide-diabetes/Pages/index.aspx#signs and from the Centers for Disease Control and Prevention, Basics about Diabetes, available at http://www.cdc.gov/diabetes/basics/diabetes.html.

In Depth: Diabetes

Type 1 diabetes

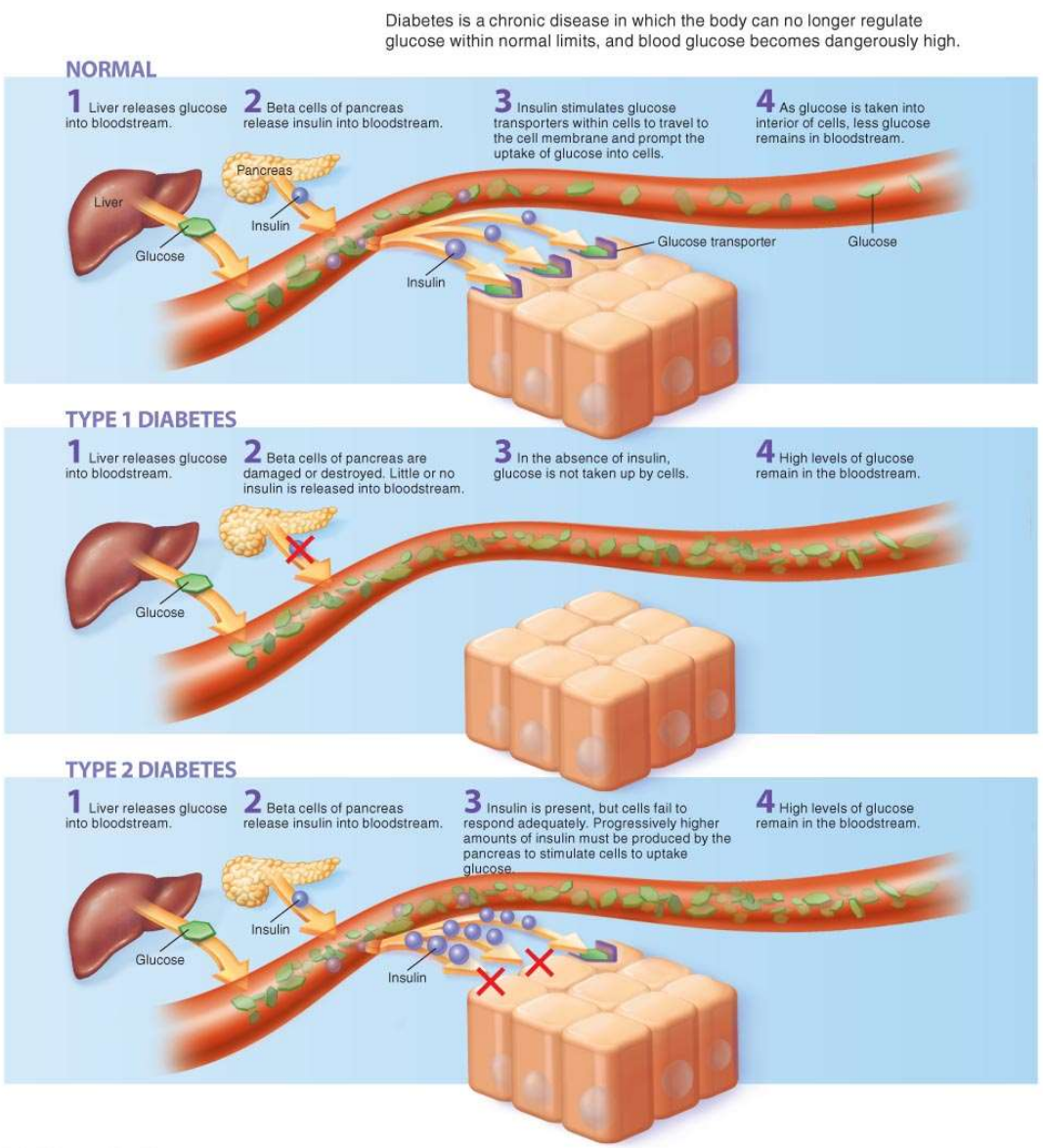
- Accounts for about 5% of all cases
- Body does not produce enough insulin
- Creates high blood sugar (glucose) levels
- Key warning sign is frequent urination
- May lead to ketoacidosis, coma, death
- Classified as an autoimmune disease
- Most frequently diagnosed in adolescents
- Has a genetic link

In Depth: Diabetes

Type 2 diabetes

- Accounts for 90–95% of cases
- Develops progressively over time
- Body cells become insensitive or unresponsive to insulin
- Obesity is most common trigger
- Variations include insulin resistance, impaired fasting glucose, and prediabetes
- Eventually the pancreas may become unable to produce any insulin

Type 2 Diabetes by Race/Ethnicity



Diabetes Testing and Diagnosis

- Three blood tests can be used to diagnose diabetes
  - Fasting plasma glucose (FPG)
  - Oral glucose tolerance (OGT)
  - Glycosylated hemoglobin test (HbA1c)

Diabetes Testing and Diagnosis

Diagnosis	Fasting Plasma Glucose (mg/dL)	Oral Glucose Tolerance Test (mg/dL)	A1C (percent)
Diabetes	126 or above	200 or above	6.5 or above
Prediabetes	100 to 125	140 to 199	5.7 to 6.4
Normal	99 or below	139 or below	About 5

In Depth: Diabetes

Who is at risk?

- Obesity, genetics, physical inactivity, and poor diet increase overall risk
- Metabolic syndrome (high waist circumference, high blood pressure, high blood lipids and glucose) increases risk for type 2 diabetes
- Increased age increases risk, but younger people and even children are now commonly diagnosed

In Depth: Diabetes

Prevention and control

- Eat a healthful diet, get daily exercise, keep a healthful body weight
- Limit intake of added sugars
- Choose fiber-rich foods like whole grains
- Limit consumption of red meat and processed meat

In Depth: Diabetes

Prevention and control

- Avoid alcoholic beverages, which can cause hypoglycemia
- Healthful lifestyle choices can prevent or delay onset of type 2 diabetes
- Oral medications and/or insulin injections may be required once diabetes has been diagnosed