Chapter 4

4.1 What Are Carbohydrates?

Carbohydrates

- One of the three macronutrients
- An important energy source, especially for nerve cells
- Composed of the atoms: Carbon, Hydrogen, and Oxygen
- Good sources include fruits, vegetables, and grains

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

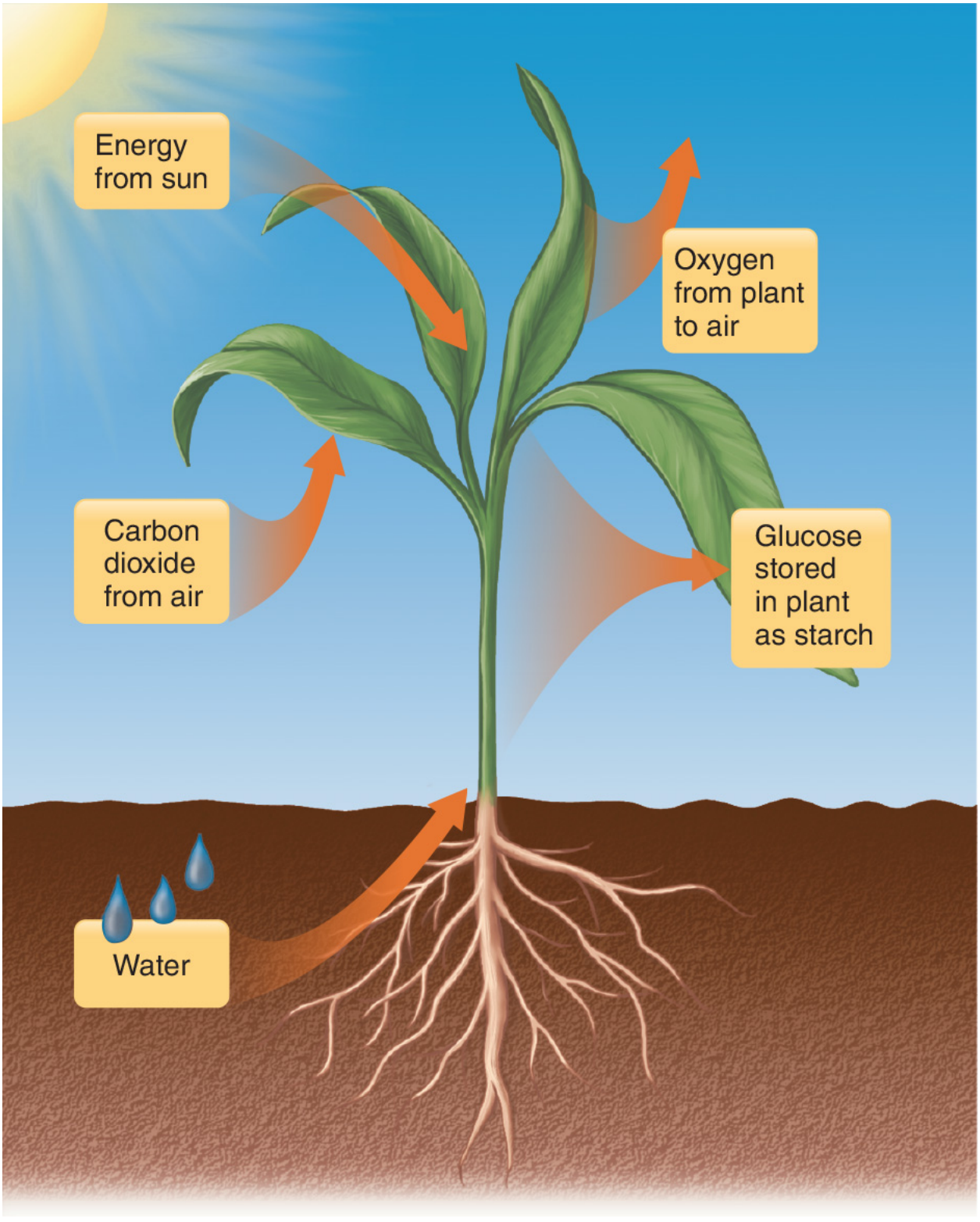


Figure 4.1: Photosynthesis

Simple carbohydrates contain one or two molecules

Monosaccharides contain only one molecule

- Glucose, fructose, galactose, ribose

Disaccharides contain two molecules

- Lactose, maltose, sucrose

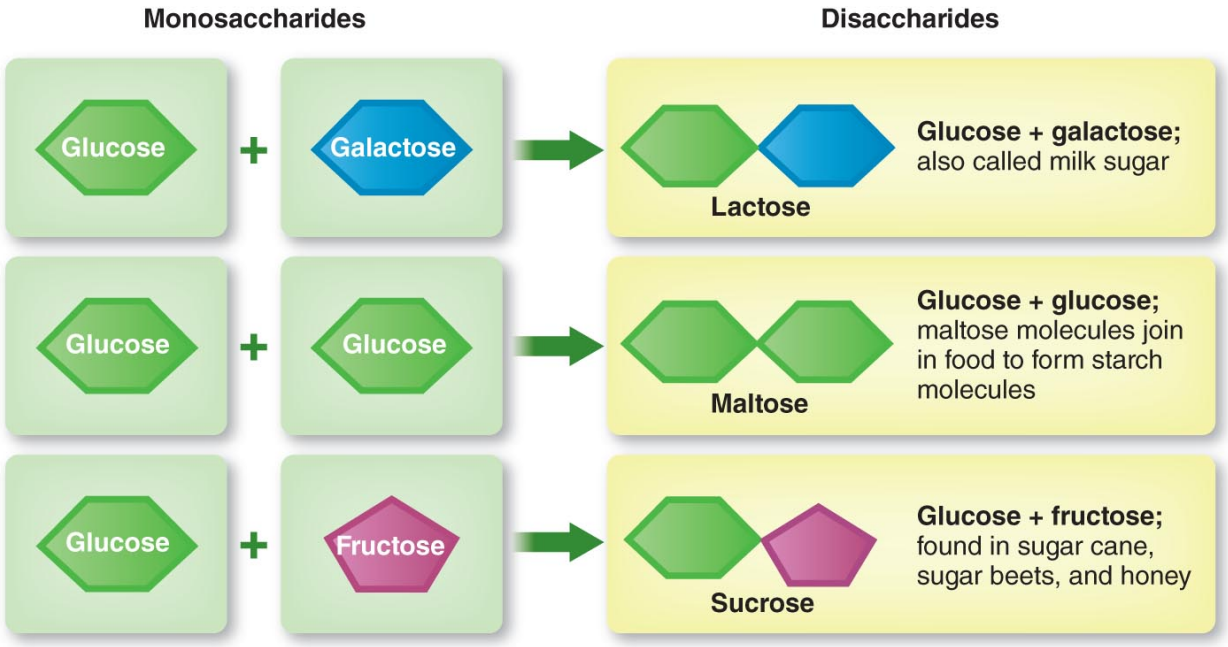
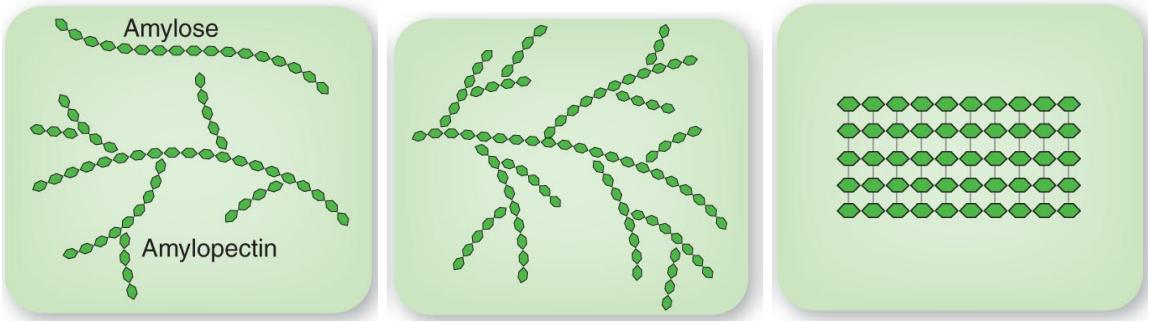


Figure 4.2: Disaccharides



(a) **Starch** – Storage form of glucose in plants; found in grains, legumes, and tubers

(b) **Glycogen** – Storage form of glucose in animals; stored in liver and muscles

(c) **Fiber** – Forms the support structures of leaves, stems, and plants

Figure 4.3: Complex Carbohydrates

4.1.1 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

4.1.2 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

4.1.3 Fiber

Dietary fiber the non-digestible part of plants

- Also classified by solubility

Functional fiber the non-digestible form of carbohydrate with known health benefits, which is extracted from plants and added to foods

- Cellulose, guar gun, pectin, psyllium

Total fiber dietary + function fiber

Soluble fiber

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

Insoluble fiber

- 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 of diverticulosis

4.2 Why Do We Need Carbohydrates

4.2.1 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
- 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
- Sufficient energy intake from carbohydrates prevents production of ketones as an alternative energy source
- Excessive ketones can result in high blood acidity and ketoacidosis
- High blood acidity damages body tissues

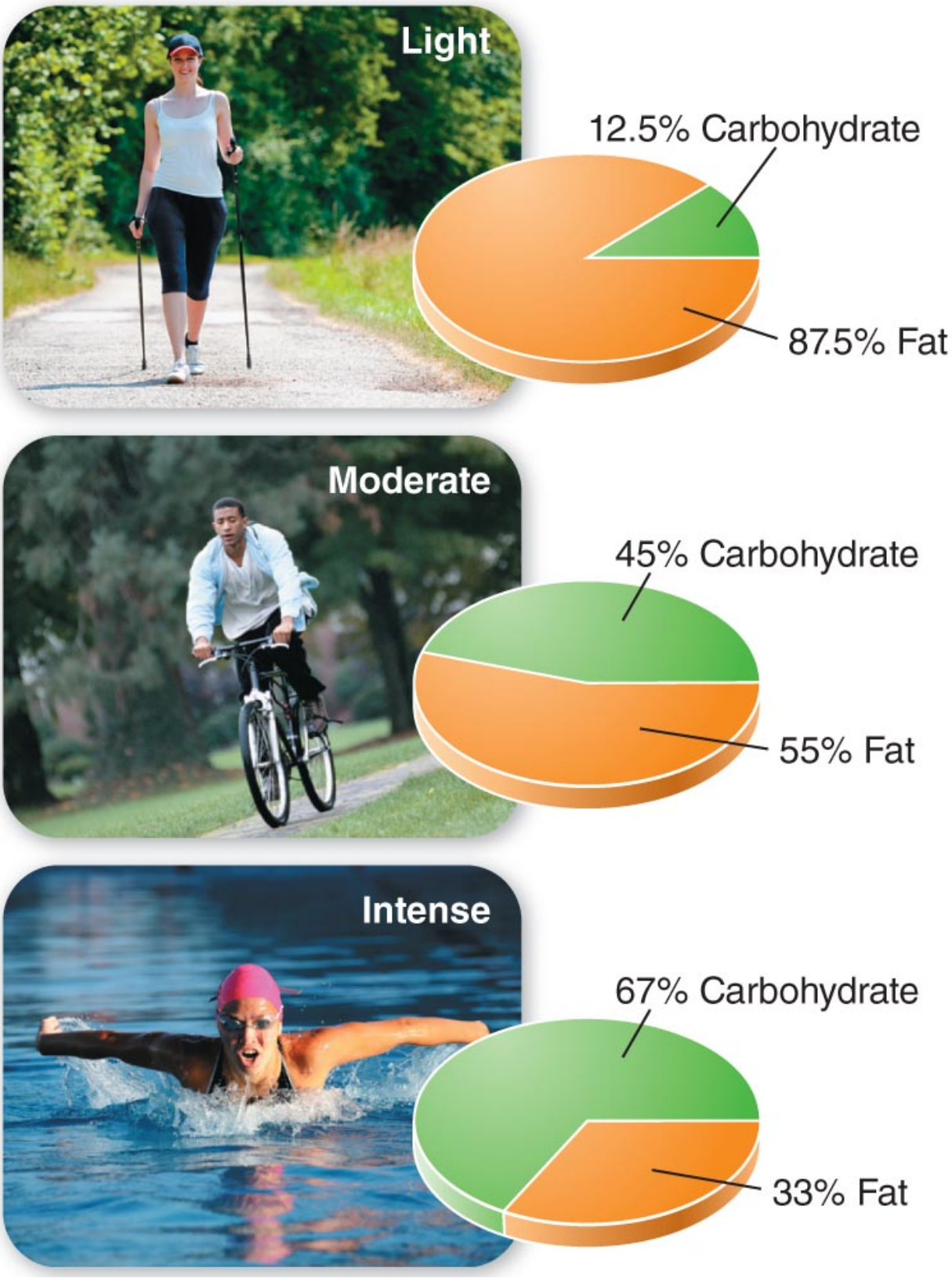


Figure 4.4: Carbohydrate Use by Exercise Intensity

4.2.2 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 of type 2 diabetes
- Reduces risk of diverticulosis

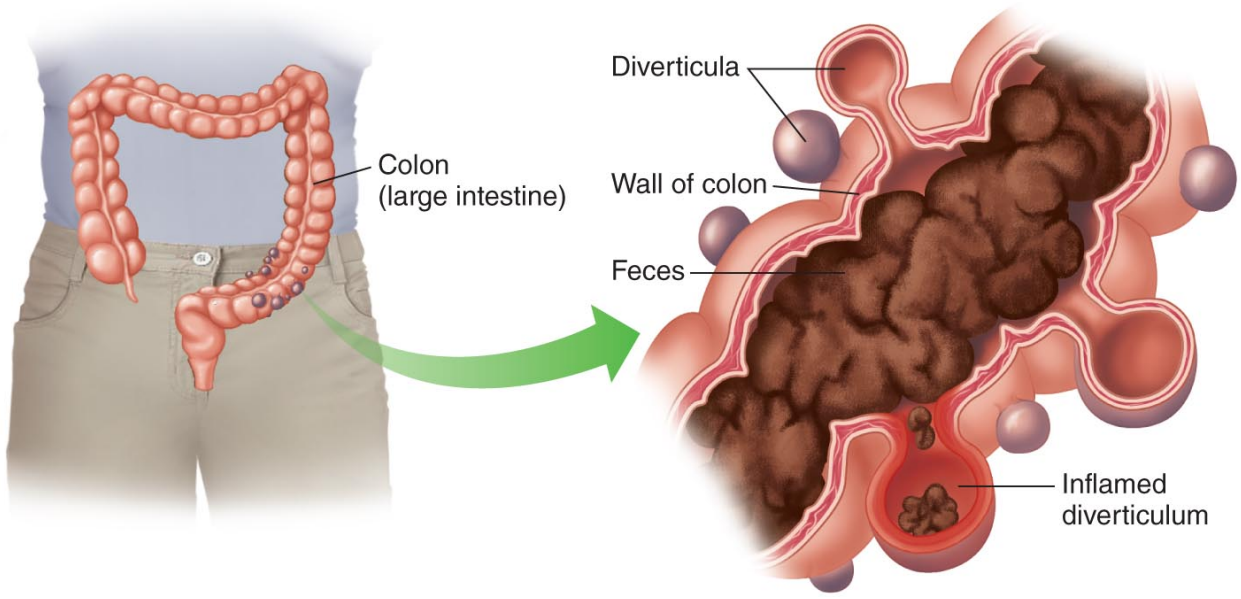


Figure 4.5: Diverticulosis

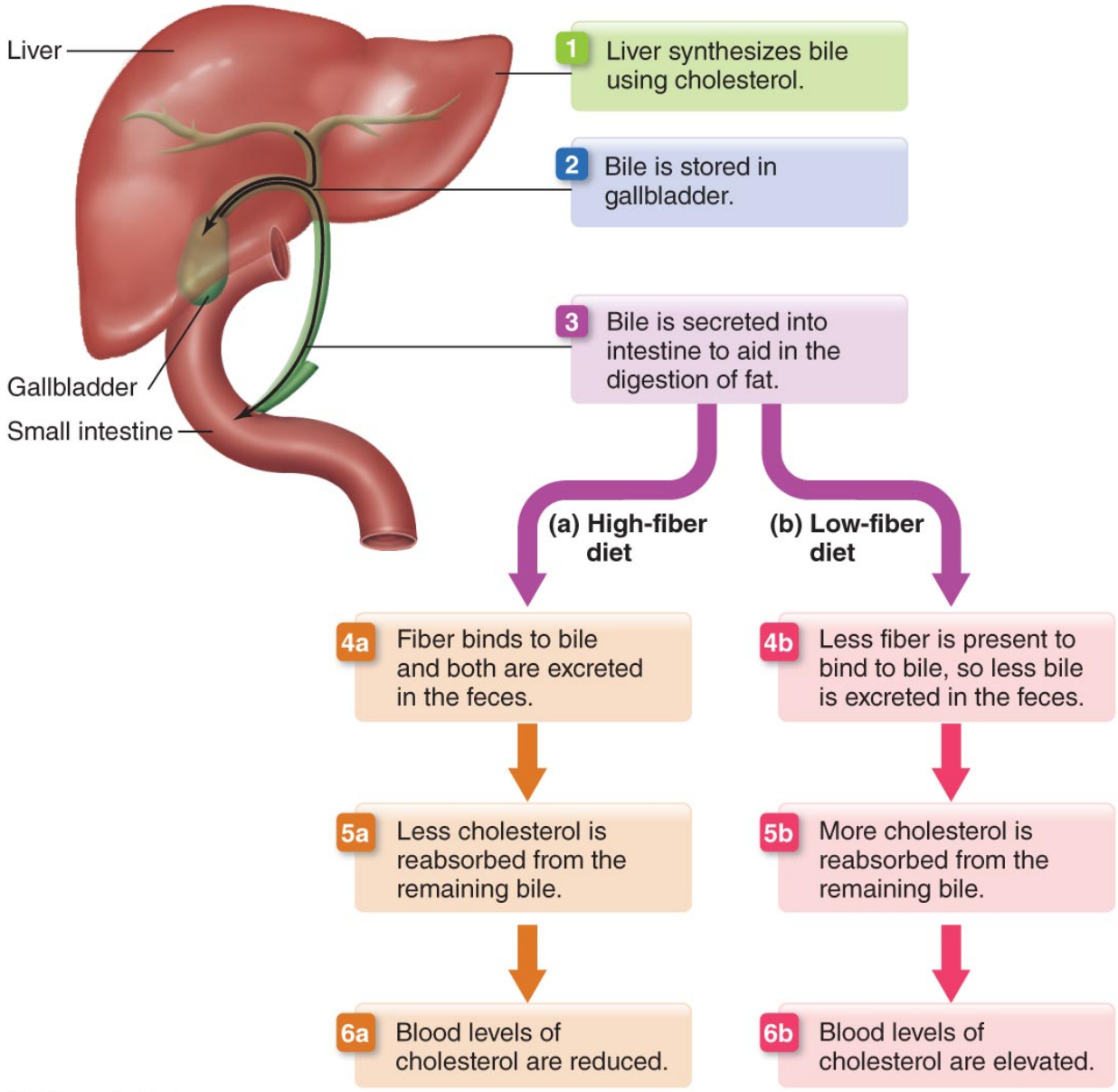


Figure 4.6: Fiber May Help Decrease Blood Cholesterol

4.3 Digestion of Carbohydrates

- Most chemical digestion of carbohydrates occurs in the small intestine

4.3.1 Pancreatic amylase

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

- 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
- 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

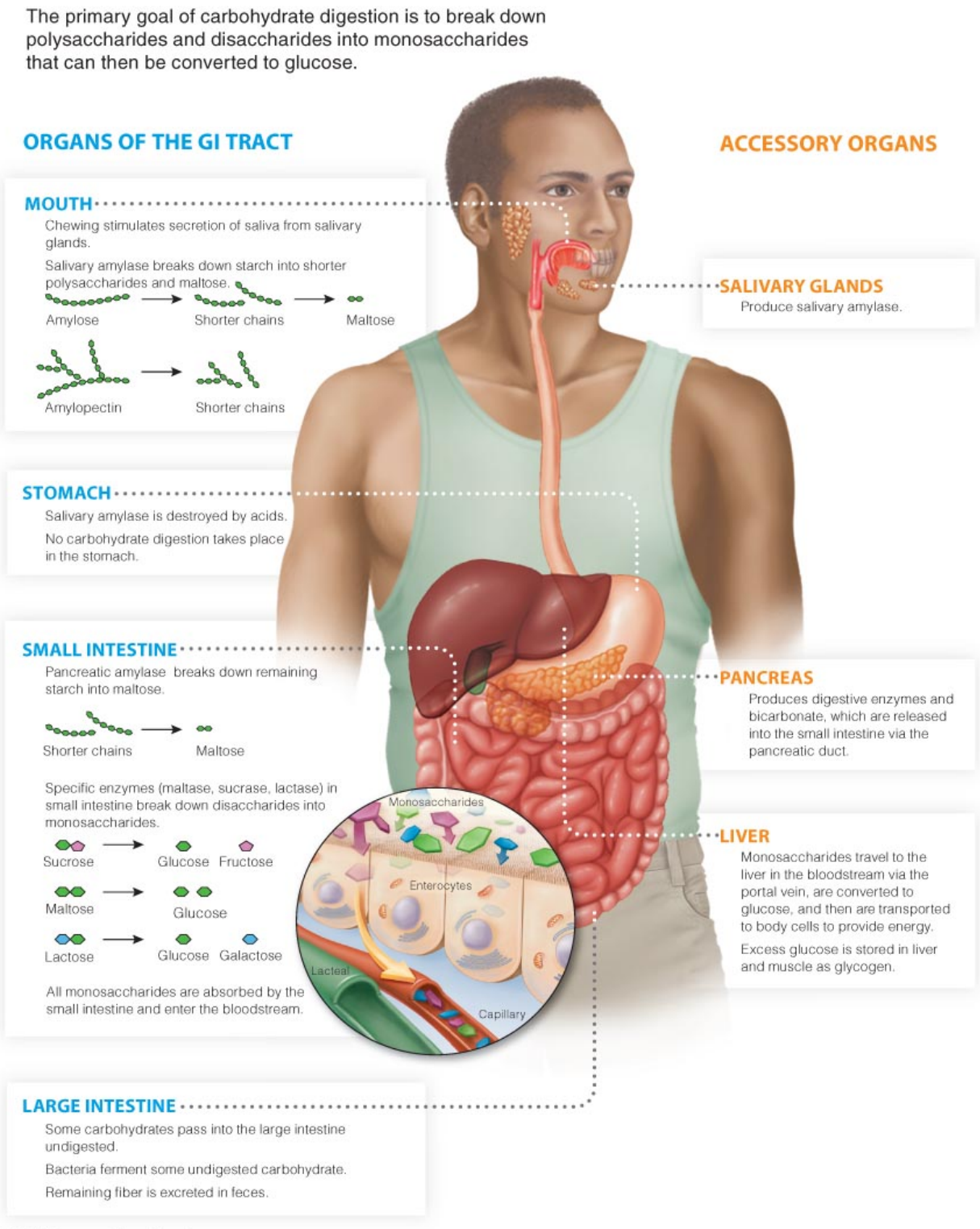


Figure 4.7: Digestion of Carbohydrates

4.4 Regulation of Blood Glucose

4.4.1 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

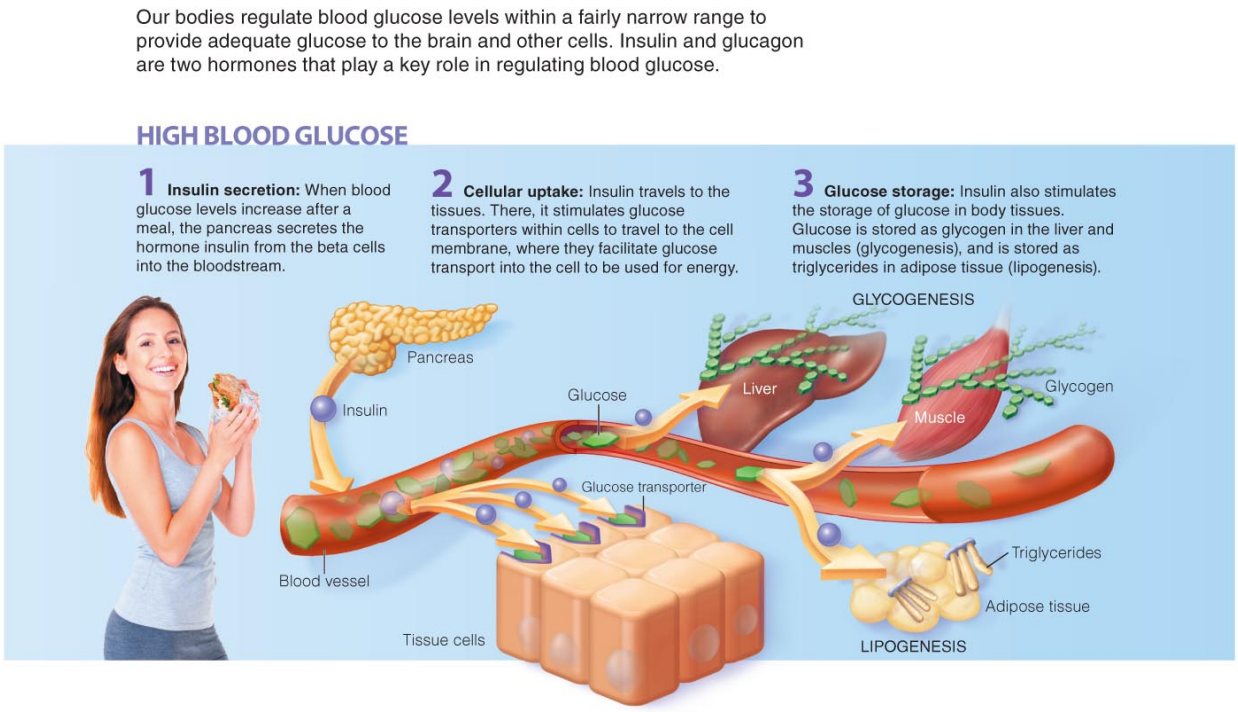


Figure 4.8: Regulation of Blood Glucose: Insulin

4.4.2 Glucagon

- Another hormone secreted by the pancreas
- Stimulates the breakdown of glycogen to glucose to make glucose available to cells of the body
- Stimulates gluconeogensis–the production of "new" glucose from amino acids

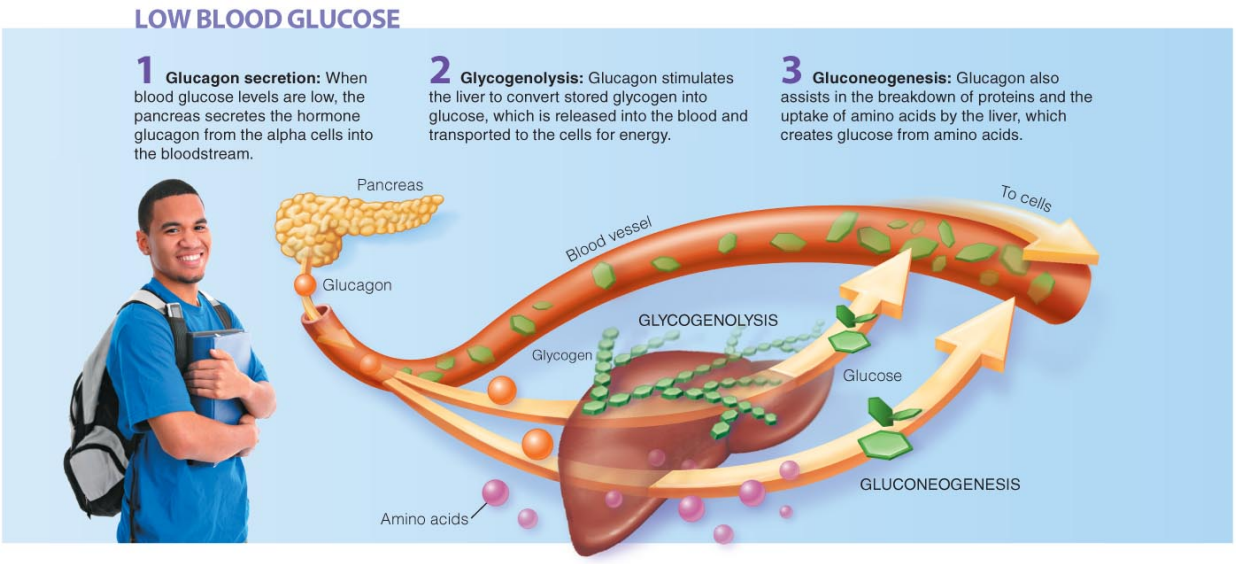


Figure 4.9: Regulation of Blood Glucose: Glucagon

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

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

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

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

- Considered a more useful tool than glycemic index

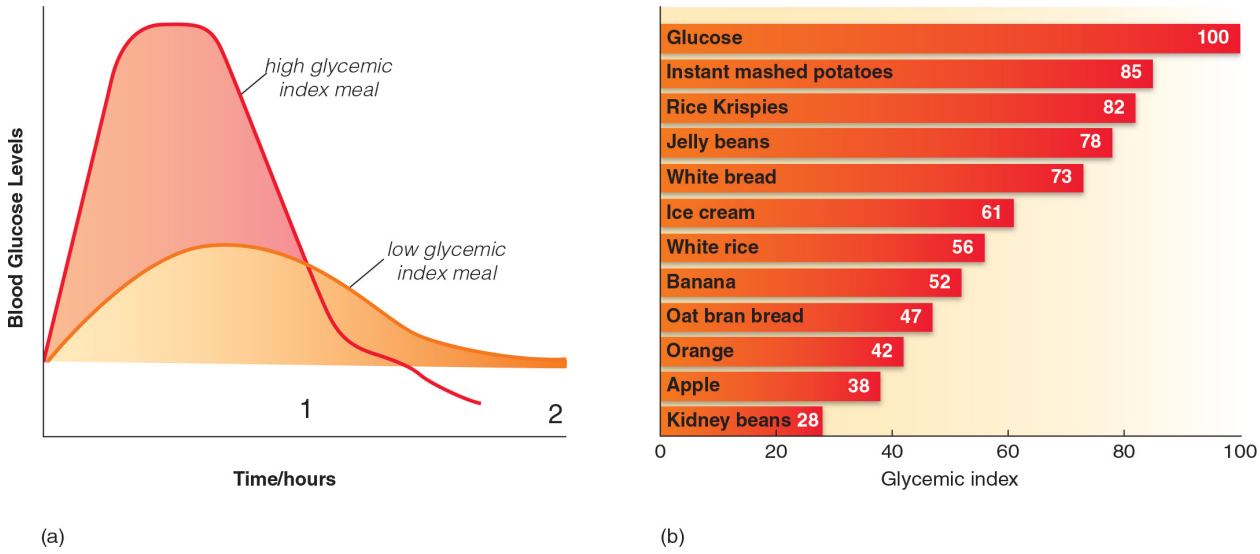


Figure 4.10: Regulation of Blood Glucose

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

4.5 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
- 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
- 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 of diabetes
  - Associated with obesity
- 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

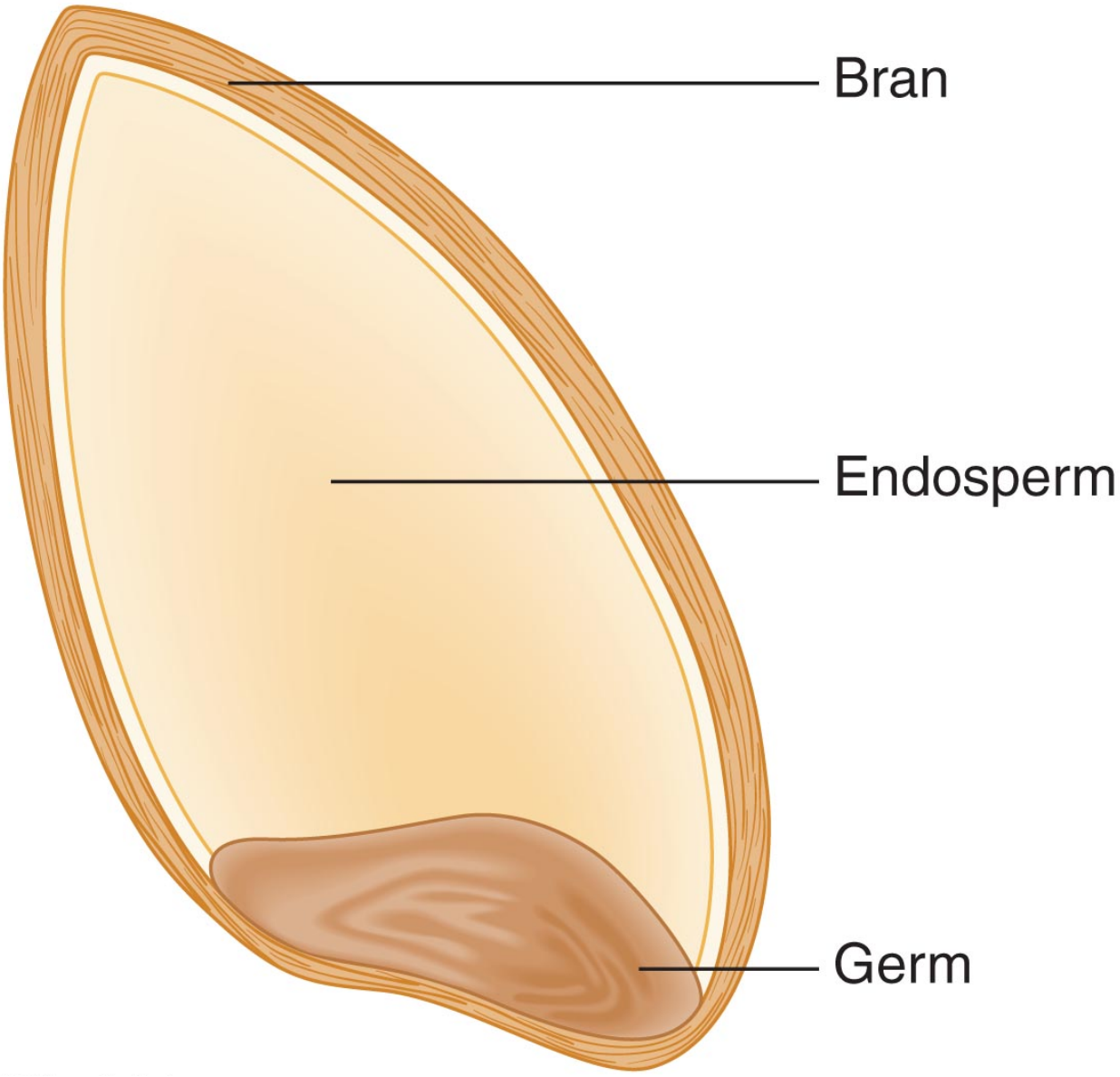


Figure 4.11: Whole Grain

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% of less of total energy intake each day.	Consume a healthful eating pattern that accounts for all foods and beverages 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.

*Data from:

Table 4.2: Forms of Sugar Commonly Added to Foods

Name of Sugar	Definition
Brown sugar	A highly refined sweetener made up approximately 99% sucrose and produced by adding to white table sugar either molasses or burnt table sugar for clothing 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 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 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.
Natural sweeteners	A general term used for any naturally occurring sweeteners, such as fructose, honer, 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

4.6 Alternative Sweeteners

4.6.1 Nutritive sweeteners

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

4.6.2 Sugar alcohols

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

4.6.3 Non-nutritive (alternative) sweeteners

- Provide little or no energy
- Developed to sweeten foods without the usual risks
- 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 "Sweet One", "Sunette"

  Aspartame "Equal"

  Sucralose "Splenda"

4.7 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

4.7.1 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 and death
- Classified as an autoimmune disease
- Most frequently diagnosed in adolescents
- Has a genetic link

4.7.2 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 pre-diabetes
- Eventually the pancreas may become unable to produce any insulin

4.8 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)

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

Figure 4.12: Diabetes Testing and Diagnosis

4.8.1 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 of type 2 diabetes
- Increased age increases risk, but younger people and children are now commonly diagnosed

4.8.2 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
- 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