Third Canadian Edition

nutrition
a functional approach

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C H A P T E R

4

Carbohydrates: Plant-Derived Energy Nutrients and In Depth

What Are Carbohydrates?
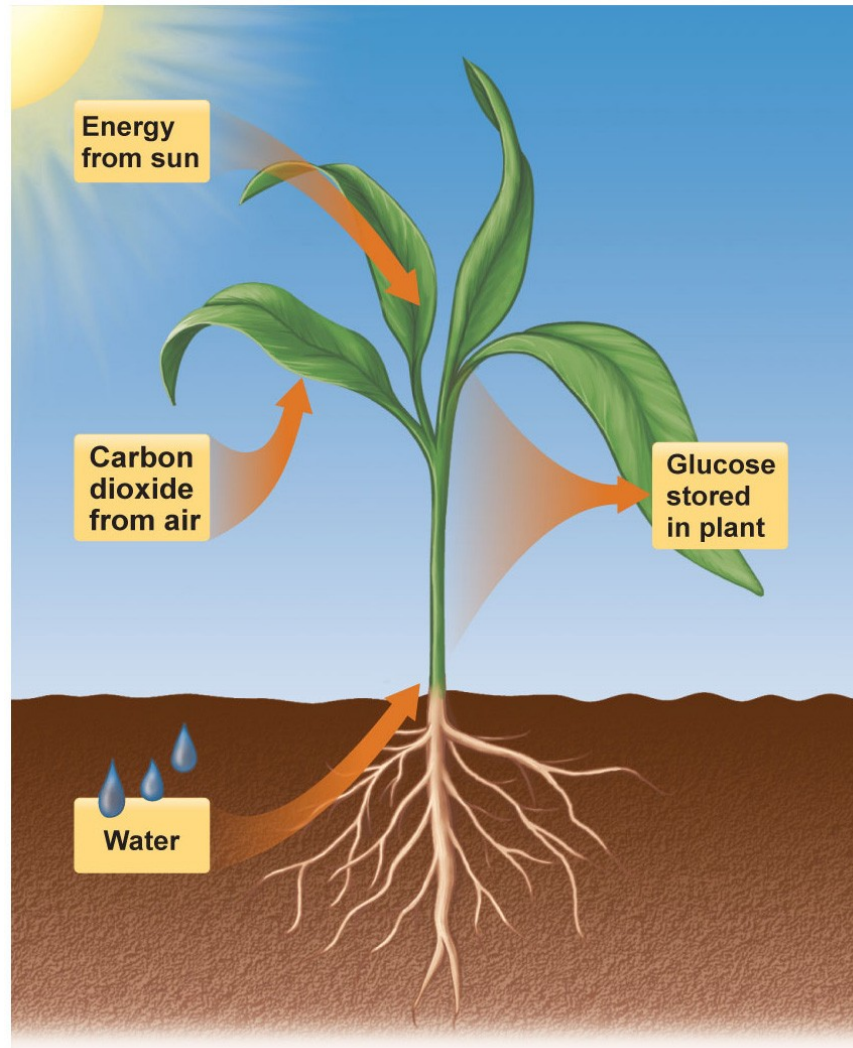
Carbohydrates

- One of the 3 macronutrients
- An important energy source, especially for nerve cells
- Composed of the atoms carbon, hydrogen, oxygen
- Good sources include fruits, vegetables, and grains

What Are Carbohydrates?

Glucose

- The most abundant carbohydrate
- Produced by plants through photosynthesis
- Found in plants as a component of disaccharides and complex carbohydrates
- Principal form of carbohydrate found in blood

Photosynthesis

Energy from sun

Carbon dioxide from air

Glucose stored in plant

Water

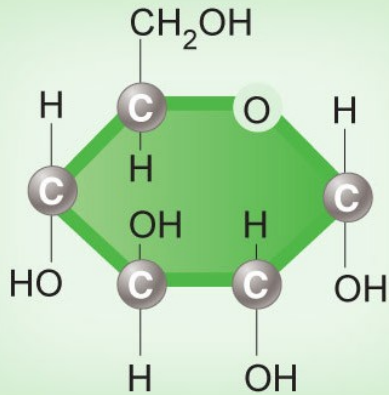© 2012 Pearson Education, Inc.

Figure 4.1

What Are Carbohydrates?

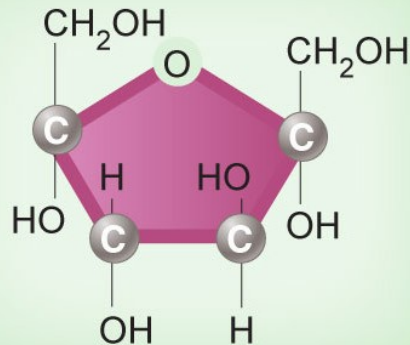Simple carbohydrates contain 1 or 2 molecules

- Monosaccharides contain only 1 molecule
  - Glucose, fructose, galactose, and ribose

- Disaccharides contain 2 molecules
  - Lactose, maltose, sucrose

Monosaccharides
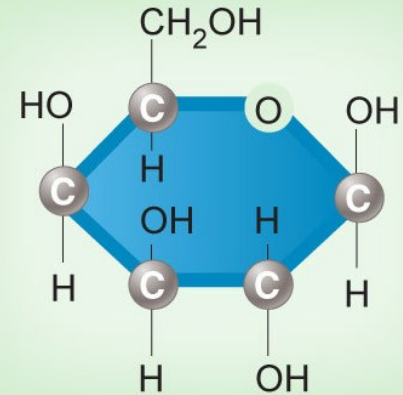

Glucose
Most abundant sugar molecule in our diet; good energy source

Fructose
Sweetest natural sugar; found in fruit, high-fructose corn syrup

Galactose
Does not occur alone in foods; binds with glucose to form lactose

Figure 4.2

Disaccharides

Monosaccharides

Disaccharides

Glucose + Galactose → **Lactose** — Glucose + galactose; also called milk sugar

Glucose + Glucose → **Maltose** — Glucose + glucose; maltose molecules join in food to form starch molecules

Glucose + Fructose → **Sucrose** — Glucose + fructose; found in sugar cane, sugar beets, and honey
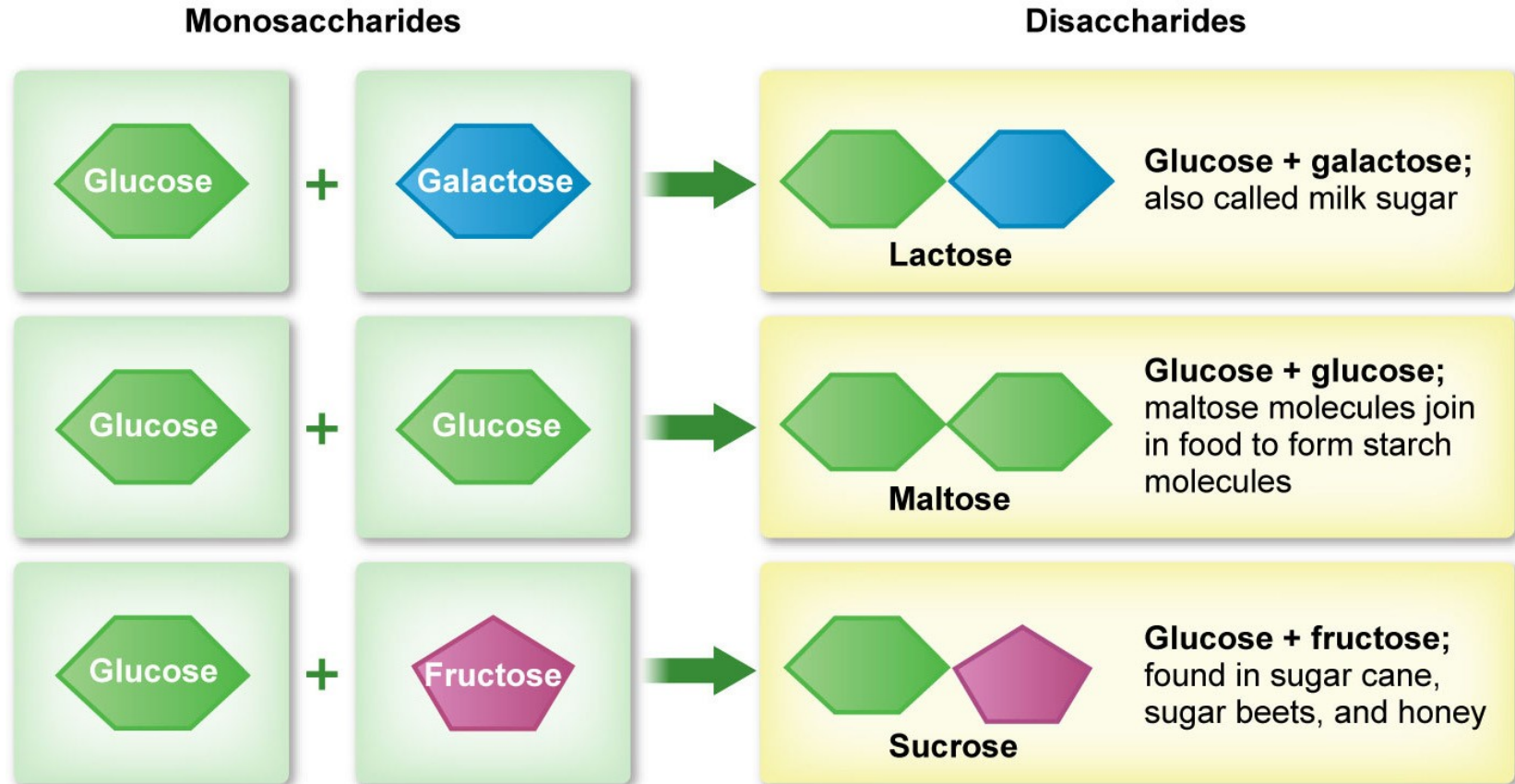
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Figure 4.3

Complex Carbohydrates

Figure 4.4 Polysaccharides include starch, glycogen, and fibre.

Amylose		
Amylopectin		
Starch	**Glycogen**	**Fibre**
Storage form of glucose in plants; found in grains, legumes, and tubers	Storage form of glucose in animals; stored in liver and muscles	Forms the support structures of leaves, stems, and plants

Figure 4.4
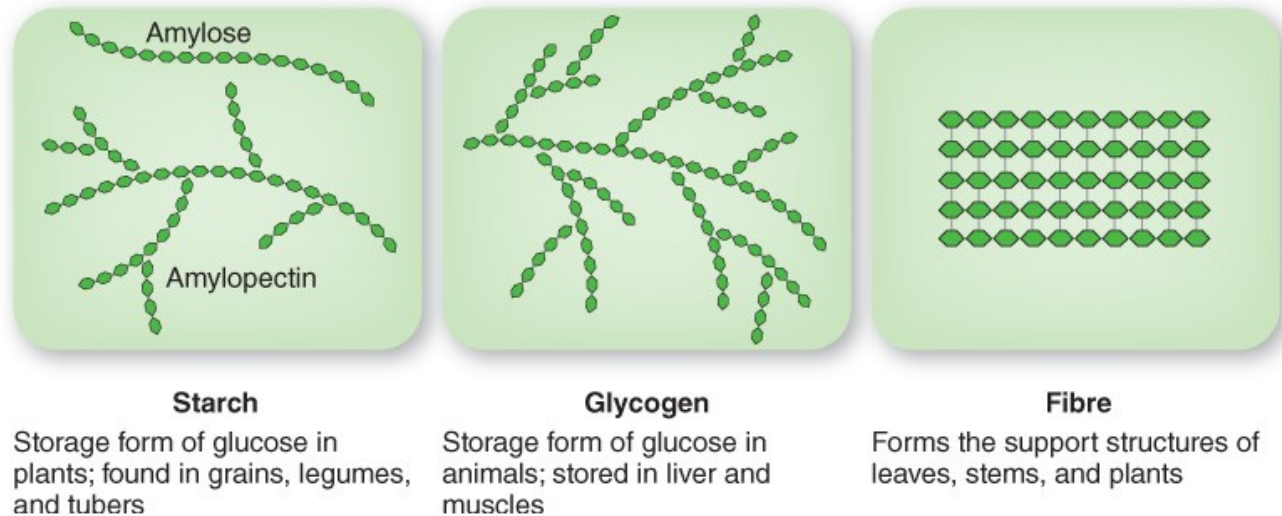
Complex Carbohydrates

Starch

- Plants store glucose as polysaccharides in the form of starch

- Our cells cannot use complex starch molecules as they exist in plants

- So we digest (break down) starch to 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 source of dietary carbohydrate

Complex Carbohydrates

Fibre

- Dietary fibre: the non-digestible part of plants
  - Grains, rice, seeds, legumes, fruits
- Functional fibre: carbohydrate with known health effects, which is extracted from plants and added to foods
  - Cellulose, guar gum, pectin, psyllium
- Total fibre = dietary + functional fibre

Complex Carbohydrates

Dietary fibre is also classified by solubility

Soluble fibre

- Dissolves in water
- 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 fibres

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

Complex Carbohydrates

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Figure 4.6
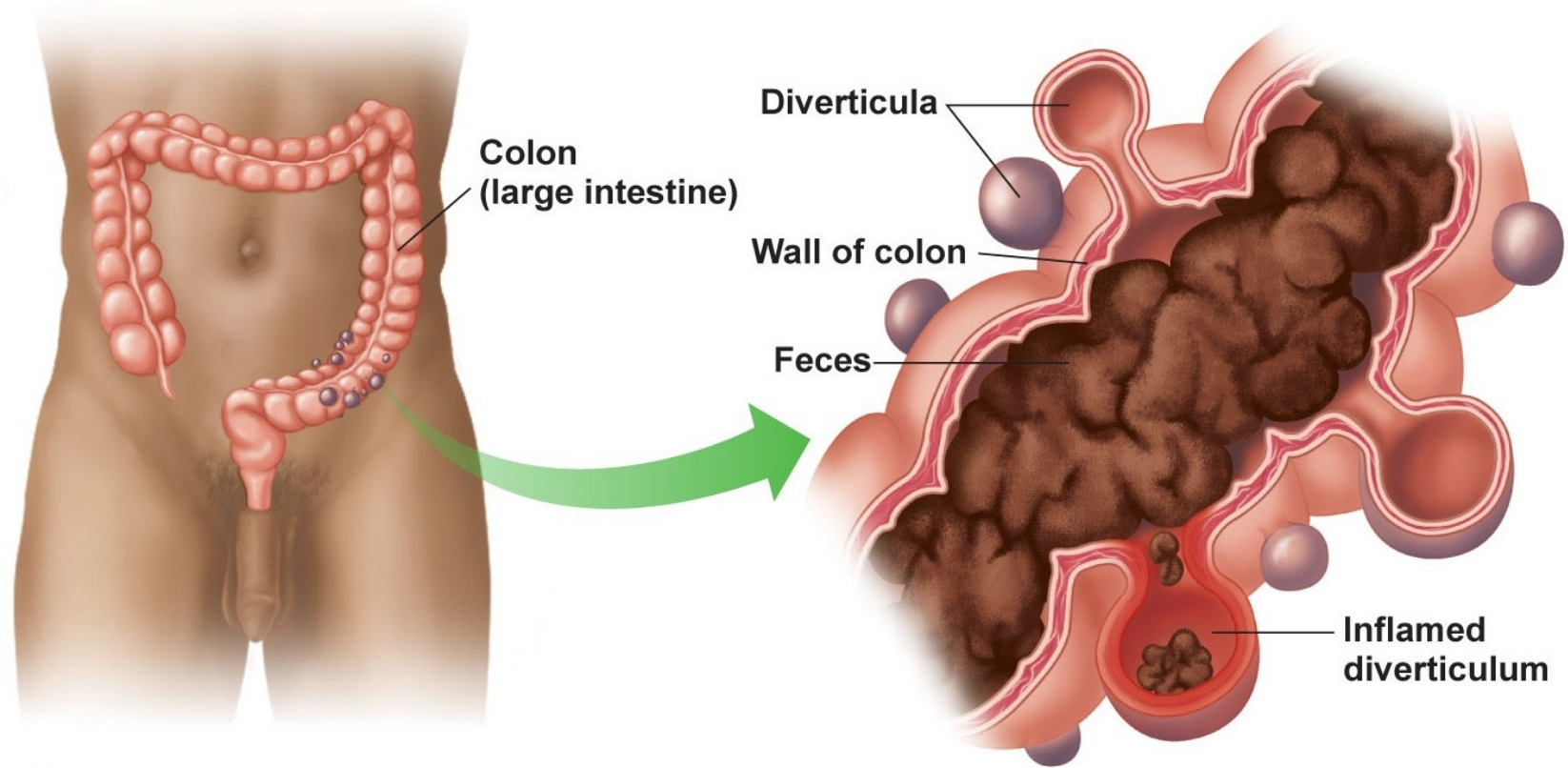
Why Do We Need Carbohydrates?

Energy

- Fuel daily activity
- Fuel exercise
- Help preserve ("spare") protein for other uses
- Sources high in fibre reduce risk for obesity, heart disease, and diabetes

Why Do We Need Carbohydrates?

Energy

- Each gram of carbohydrate = 17 kJ/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
- During intense exercise, carbohydrate will supply 2/3 or more of the total energy needed

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

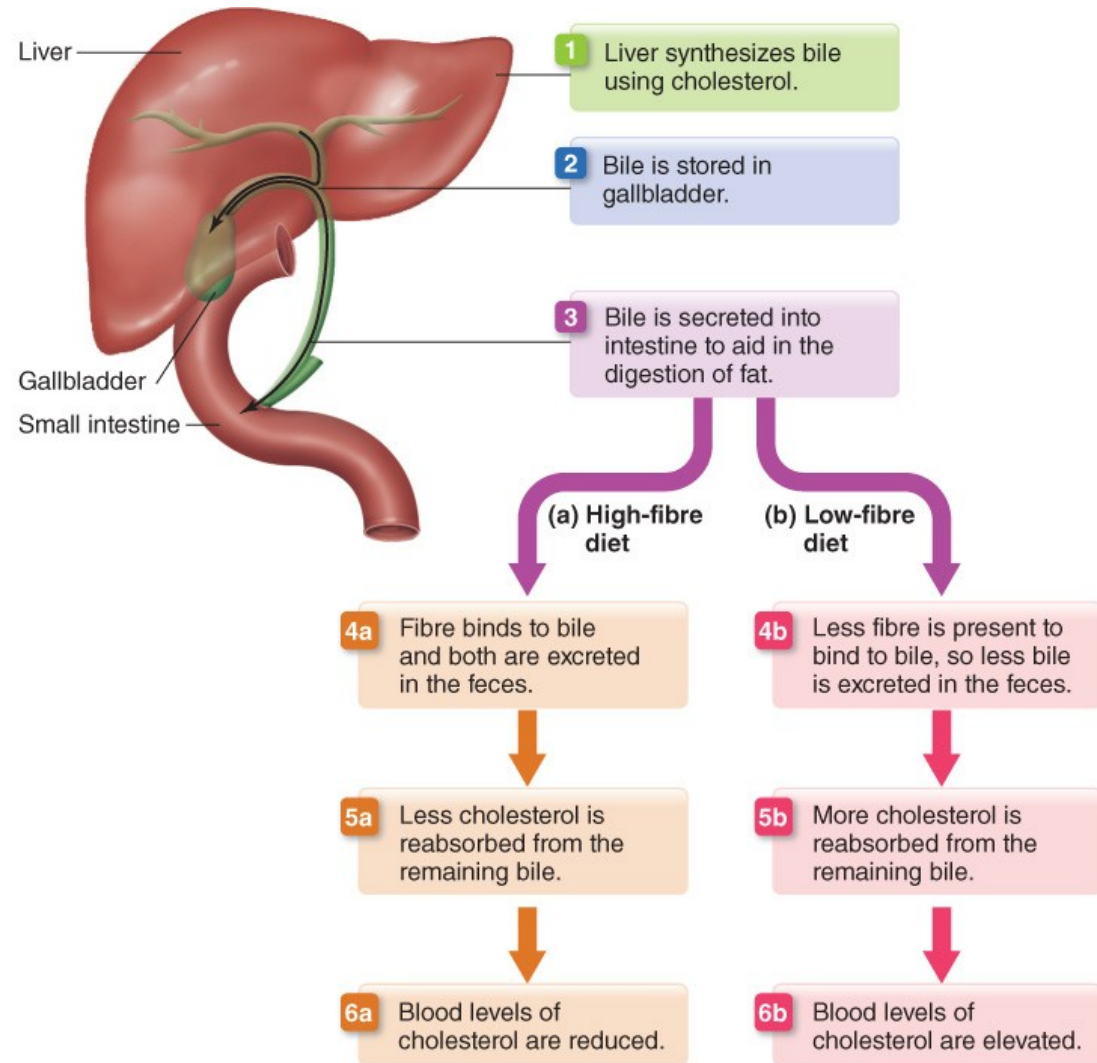- High blood acidity damages body tissues

Why Do We Need Carbohydrates?

Fibre

- May reduce the risk of colon cancer
- May reduce the risk of heart disease
- Can enhance weight loss
- Helps prevents hemorrhoids, constipation, and diverticulosis
- May lower the risk for type 2 diabetes

Why Do We Need Carbohydrates?

▶ **Figure 4.7** How fibre might help decrease blood cholesterol levels. **(a)** When eating a high-fibre diet, fibre binds to the bile that is produced from cholesterol, resulting in relatively more cholesterol being excreted in the feces. **(b)** When a lower-fibre diet is consumed, less fibre (and thus less cholesterol) is bound to bile and excreted in the feces.

Liver

1 Liver synthesizes bile using cholesterol.

2 Bile is stored in gallbladder.

Gallbladder

Small intestine

3 Bile is secreted into intestine to aid in the digestion of fat.

(a) High-fibre diet

(b) Low-fibre diet

4a Fibre binds to bile and both are excreted in the feces.

4b Less fibre is present to bind to bile, so less bile is excreted in the feces.

5a Less cholesterol is reabsorbed from the remaining bile.

5b More cholesterol is reabsorbed from the remaining bile.

6a Blood levels of cholesterol are reduced.

6b Blood levels of cholesterol are elevated.

Figure 4.7

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
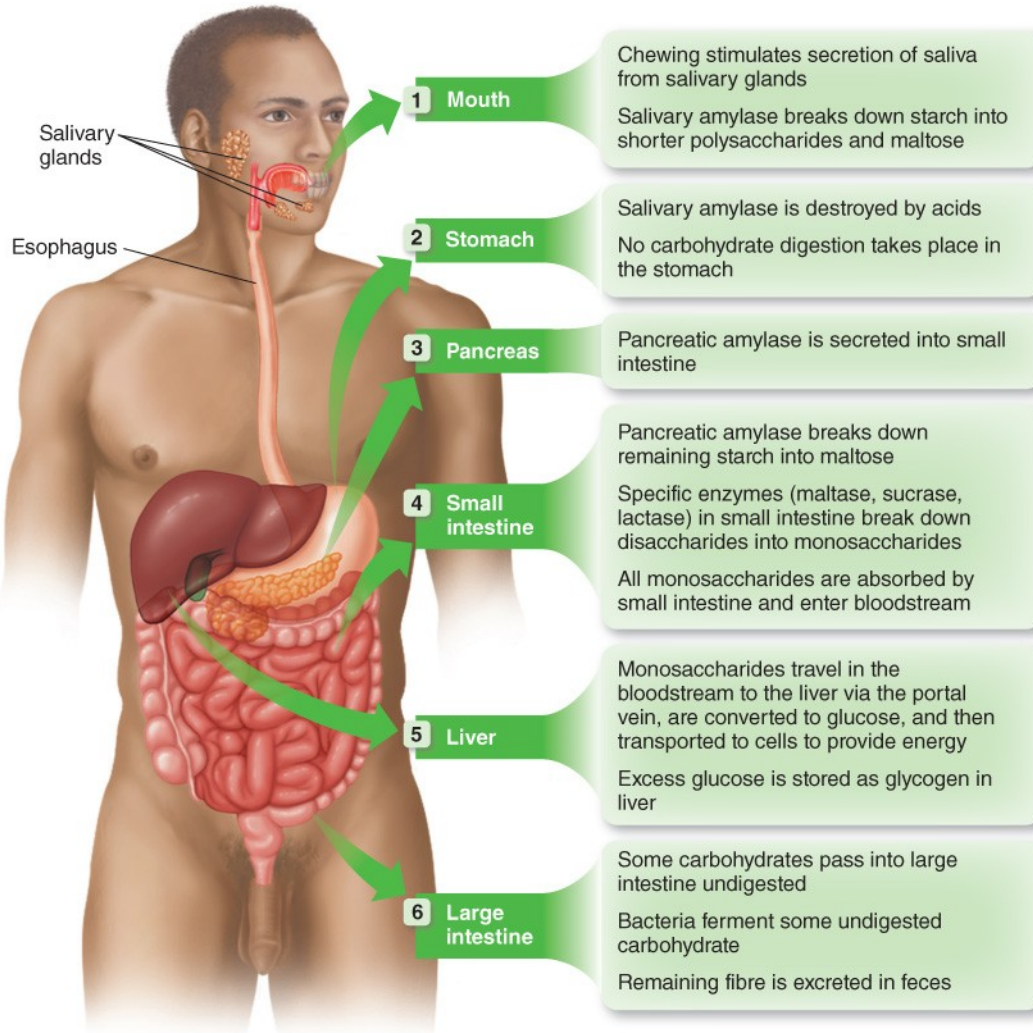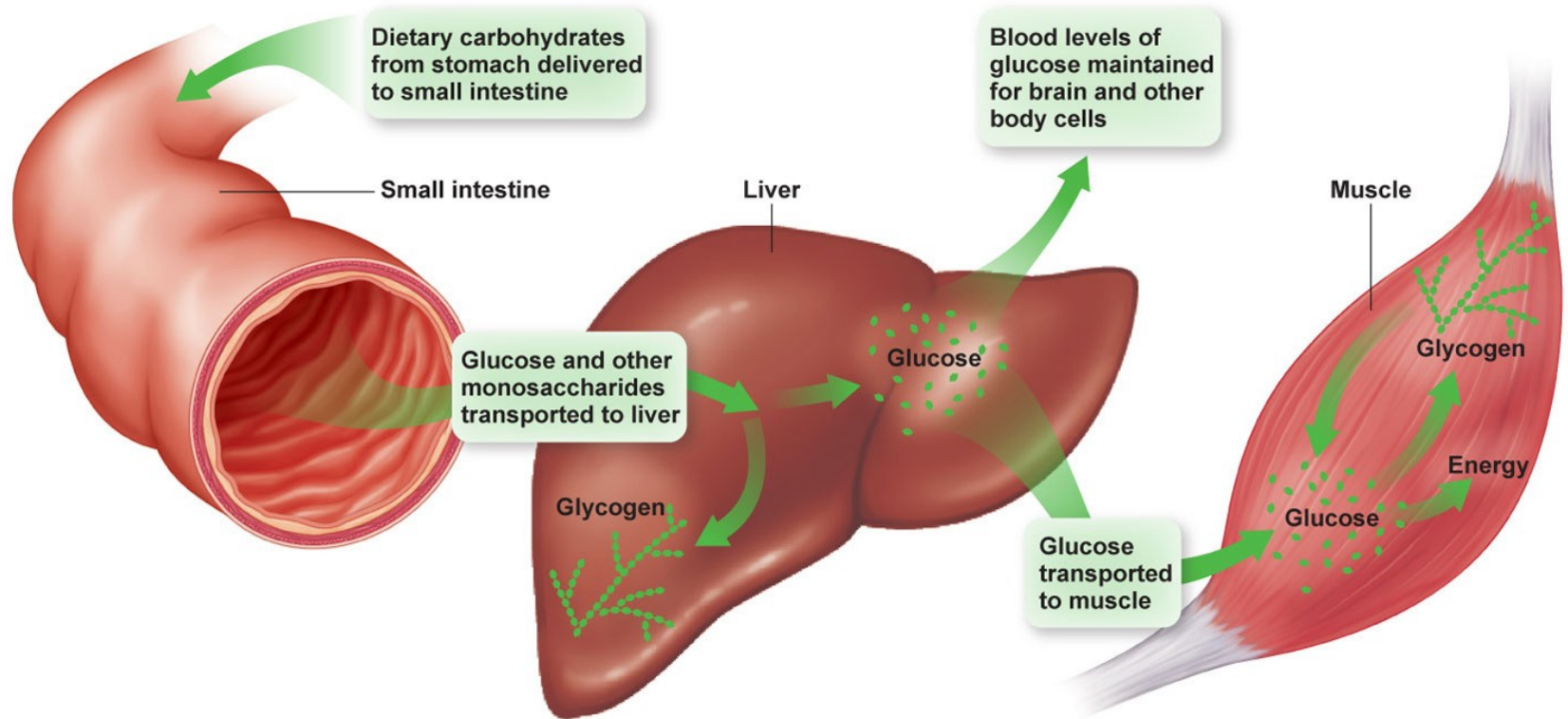
Digestion of Carbohydrates

Figure 4.8 A review of carbohydrate digestion and absorption.

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Figure 4.8

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
- Fibre passes through small intestine undigested and enters the colon
- Remaining fibre adds bulk to stools and is excreted

Storage of Glycogen

Dietary carbohydrates from stomach delivered to small intestine

Small intestine

Glucose and other monosaccharides transported to liver

Glycogen

Liver

Glucose

Blood levels of glucose maintained for brain and other body cells

Glucose transported to muscle

Muscle

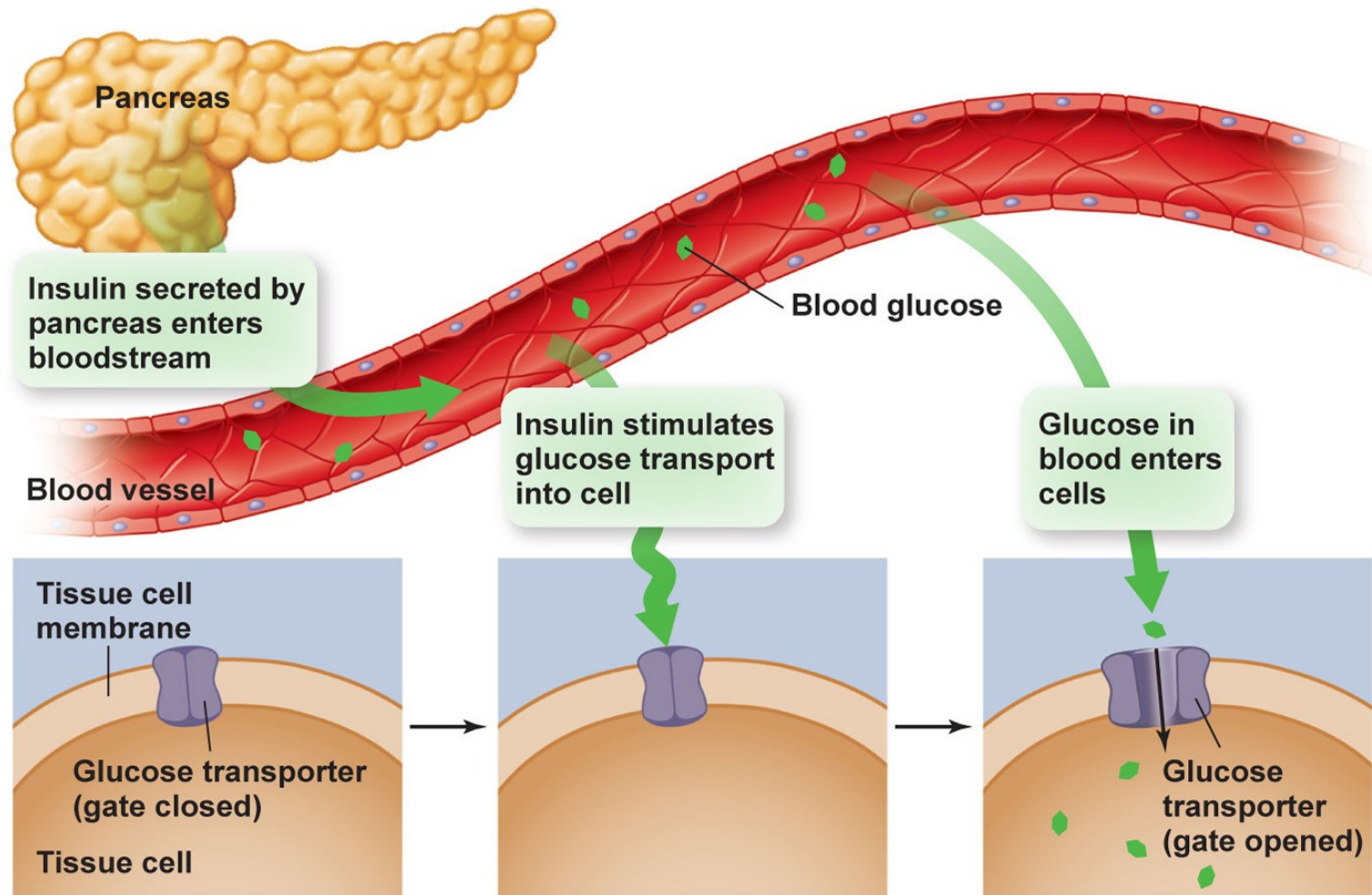Glycogen

Glucose

Energy

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Figure 4.9

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

Pancreas

Insulin secreted by pancreas enters bloodstream

Blood vessel

Blood glucose

Insulin stimulates glucose transport into cell

Glucose in blood enters cells

Tissue cell membrane

Glucose transporter (gate closed)

Tissue cell

Glucose transporter (gate opened)
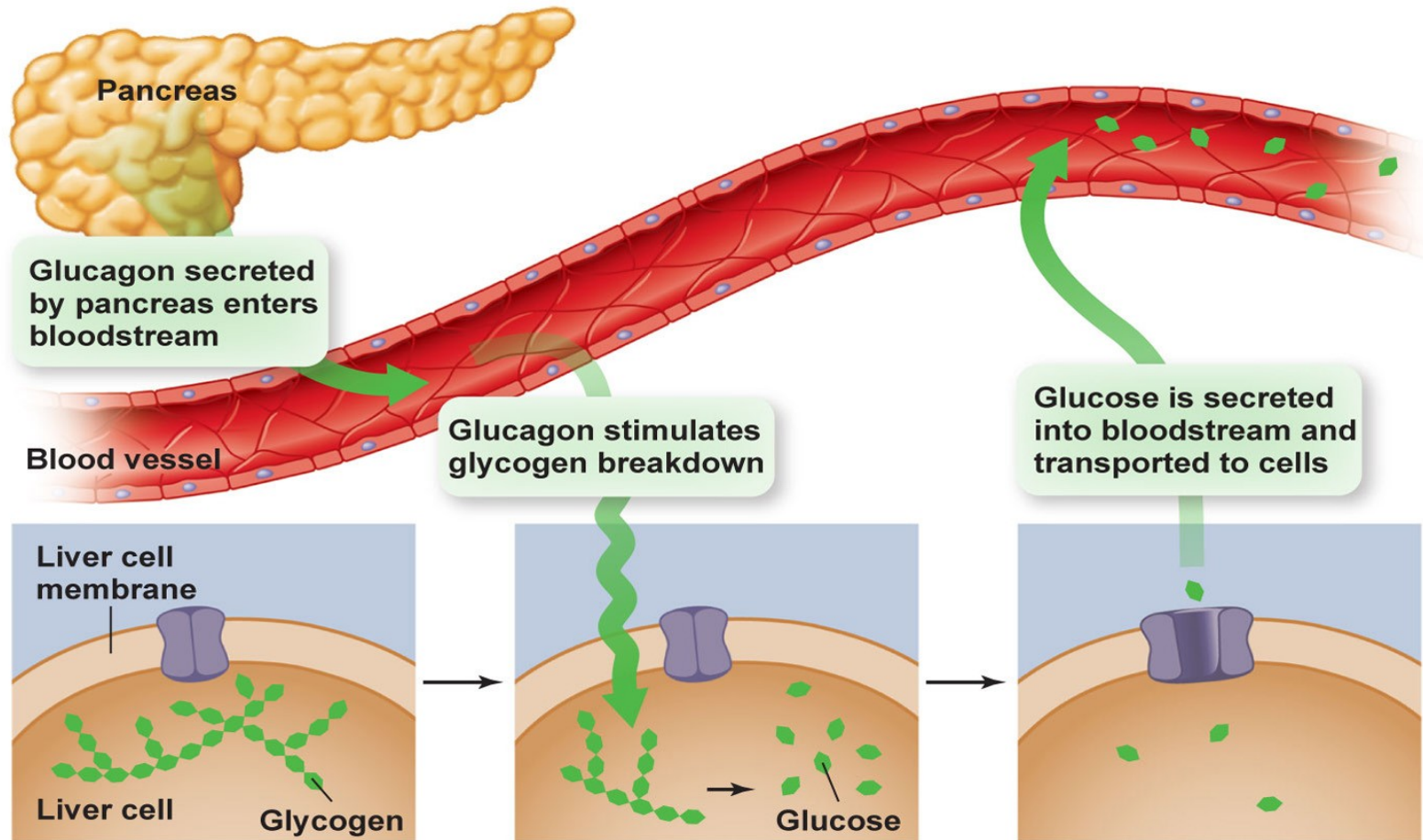
(a)

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Figure 4.10a

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

Pancreas

Glucagon secreted by pancreas enters bloodstream

Blood vessel

Glucagon stimulates glycogen breakdown

Glucose is secreted into bloodstream and transported to cells

Liver cell membrane

Liver cell

Glycogen

Glucose

(b)

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Figure 4.10b

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 mild fluctuations in blood glucose level

  - Are better for people with diabetes

  - Are generally higher in fibre

  - May reduce the risk of heart disease, colon cancer, and prostate cancer

How Much Carbohydrate?

- RDA is 130 g/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 fibre and low in added sugars

How Much Carbohydrate?

Adult Canadians obtain approximately 50% of energy from carbohydrate – 21% is from added sugar

- Sugars added to foods during processing or preparation
- One common source is soft drinks
- Typical sources are cookies, candy, fruit drinks
- Unexpected sources include peanut butter, flavoured rice mixes, canned soups
- Added sugars are not chemically different from naturally occurring sugars, but have fewer vitamins, minerals, and fibre

How Much Carbohydrate?

Problems associated with eating too much sugar

- Can cause dental problems and tooth decay
- No association with childhood hyperactivity proven; long-term effects not known
- Associated with increased levels of "bad cholesterol"
- Associated with decreased levels of "good cholesterol"
- Does not cause diabetes but may contribute to obesity

How Much Carbohydrate?

Most North Americans eat far too little fibre-rich carbohydrate

The AI of fibre 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 fibre

Alternative Sweeteners

Nutritive sweeteners

- Contain 17 kJ/4 kcal energy per gram
- Sucrose, fructose, honey, brown sugar

Sugar alcohols

- Contain 2–3 kcal energy per gram
- Have decreased glycemic response and increase risk for tooth caries

Non-nutritive (alternative) sweeteners

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

Alternative Sweeteners

No ADI has been set for saccharin (e.g., "Sweet 'N Low"), but Health Canada is considering its use as a sweetener in certain foods (2010)

ADIs have been established for

- aspartame (e.g., "Equal")
- acesulfame-K (e.g., "Sweet One," "Sunette")
- sucralose (e.g., "Splenda")

Alternative Sweeteners

Stevia

- Plant-based sweetener

- Leaves and compounds from leaves can be used to sweeten food

- Stevia and extracts have been approved by Health Canada for use in Natural Health Products as both a medicinal and non-medicinal ingredient (2010)

In Depth: Diabetes

Diabetes

- Inability to regulate blood glucose levels
- 3 types:
  - Type 1 diabetes
  - Type 2 diabetes
  - Gestational diabetes
- Uncontrolled diabetes can cause infections, nerve damage, kidney damage, blindness, seizures, stroke, cardiovascular disease, and can be fatal

In Depth: Diabetes

TABLE 1   Symptoms of Type 1 and Type 2 Diabetes

Type 1 Diabetes	Type 2 Diabetes*
Frequent urination	Any of the type 1 symptoms
Unusual thirst	Frequent infections
Extreme hunger	Blurred vision
Unusual weight loss	Cuts/bruises that are slow to heal
Extreme fatigue	Tingling/numbness in the hands or feet
Irritability	Recurring skin, gum, or bladder infections

Source: Adapted from the American Diabetes Association, Diabetes Basics. Symptoms. www.diabetes.org/diabetes-basics/symptoms/.
*Some people with type 2 diabetes experience no symptoms.

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Table 1 In Depth

In Depth: Diabetes

Type 1 diabetes

- Accounts for about 10% of all cases
- Body does not produce enough insulin
- Creates high blood sugar (glucose) levels, and key sign: frequent urination
- May lead to ketoacidosis, coma, death
- May be an autoimmune disease
- Most frequently diagnosed in adolescents, and has a genetic link

In Depth: Diabetes

Type 2 diabetes

- 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

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 risks, 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

- Eating slightly fewer carbohydrates and slightly more protein and fat may help regulate blood glucose levels; consult a dietitian

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