

 CENGAGE

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# Nutrition for Sport & Exercise

Fifth Edition



## Chapter 4 Carbohydrates

# Chapter Objectives (1 of 2)

By the end of this chapter, you should be able to:

- LO 4.1 Classify carbohydrates according to their chemical composition.
- LO 4.2 Describe the digestion and absorption of carbohydrates.
- LO 4.3 Explain the metabolism of glucose.
- LO 4.4 Describe how muscle glycogen and blood glucose are used to fuel exercise.

# Chapter Objectives (2 of 2)

- LO 4.5 Detail and explain carbohydrate recommendations for athletes, including specific guidelines for intake before, during, and after exercise.
- LO 4.6 Determine the daily carbohydrate needs of an athlete, and select carbohydrate-containing foods to meet the recommended intake.

# Carbohydrates in Food

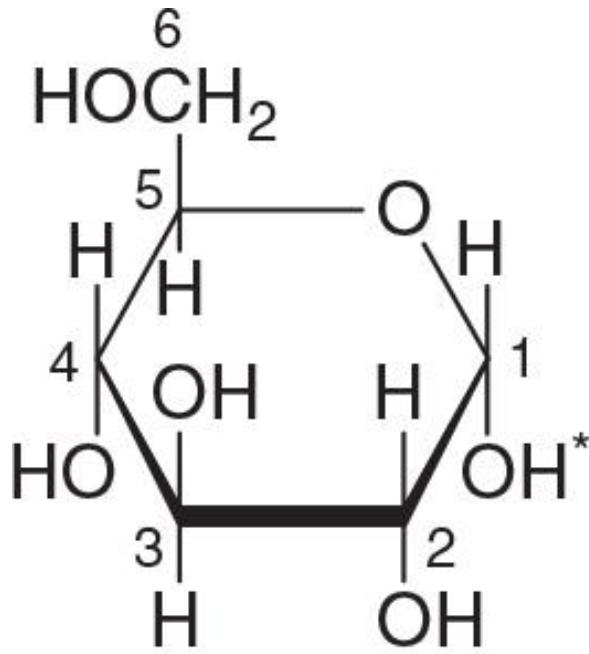
# Carbohydrates in Food

- Monosaccharides
- Disaccharides
- Polysaccharides

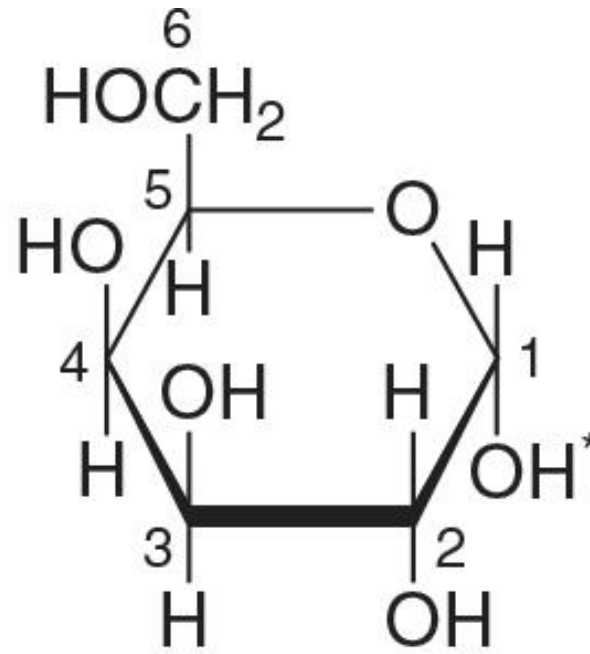


Hurst Photo/Shutterstock.com

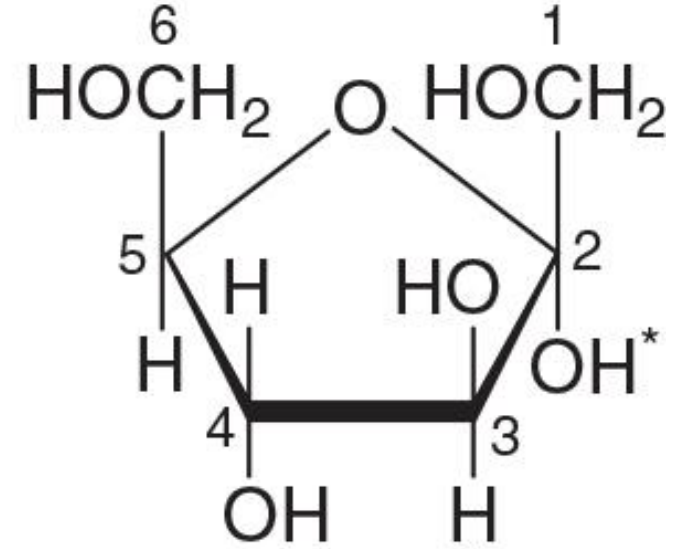
# Chemical Structure of Monosaccharides



D-glucose



D-galactose

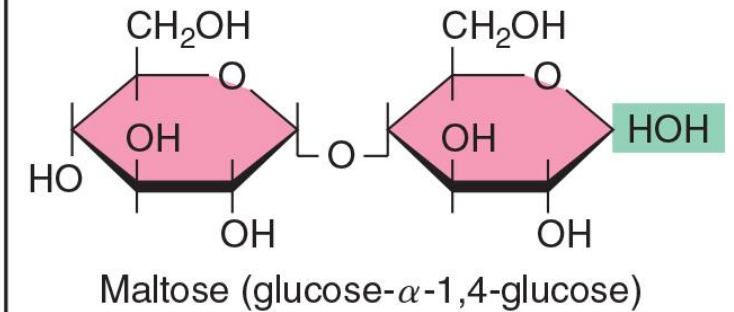
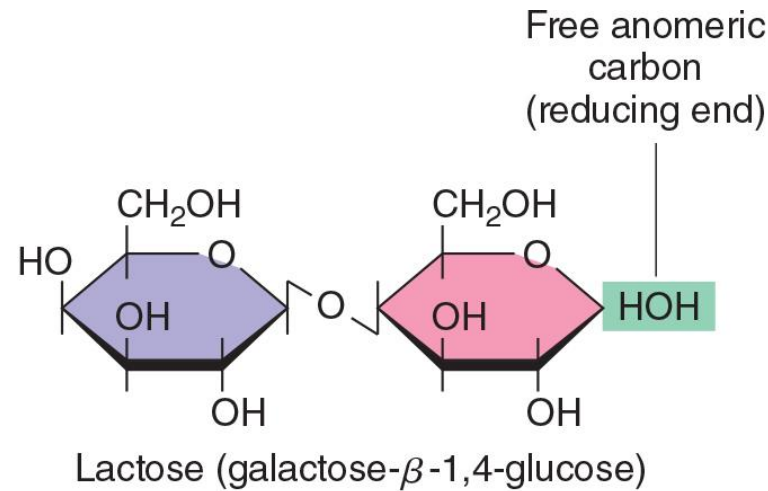
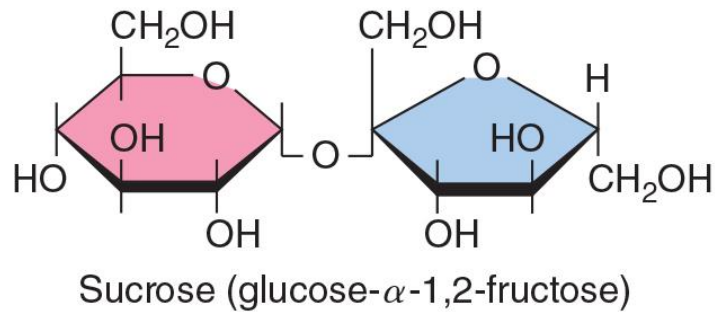


D-fructose

# Characteristics of Monosaccharides

Chemical name	Sweetness (100 = Sweetness of table sugar)	Glycemic index (based on 100)	Miscellaneous information
Glucose	75	100	In the body, found circulating in the blood and stored as glycogen. In food, generally found as part of disaccharides and polysaccharides (starches). When added to food, glucose is referred to as dextrose.
Fructose	170	19	In the body, found temporarily in the liver before being converted to glucose. In food, found naturally in fruits and vegetables and added to processed foods, often as high-fructose corn syrup.
Galactose	30	Unknown	Found in food only as part of lactose.

# Chemical Structure of Disaccharides



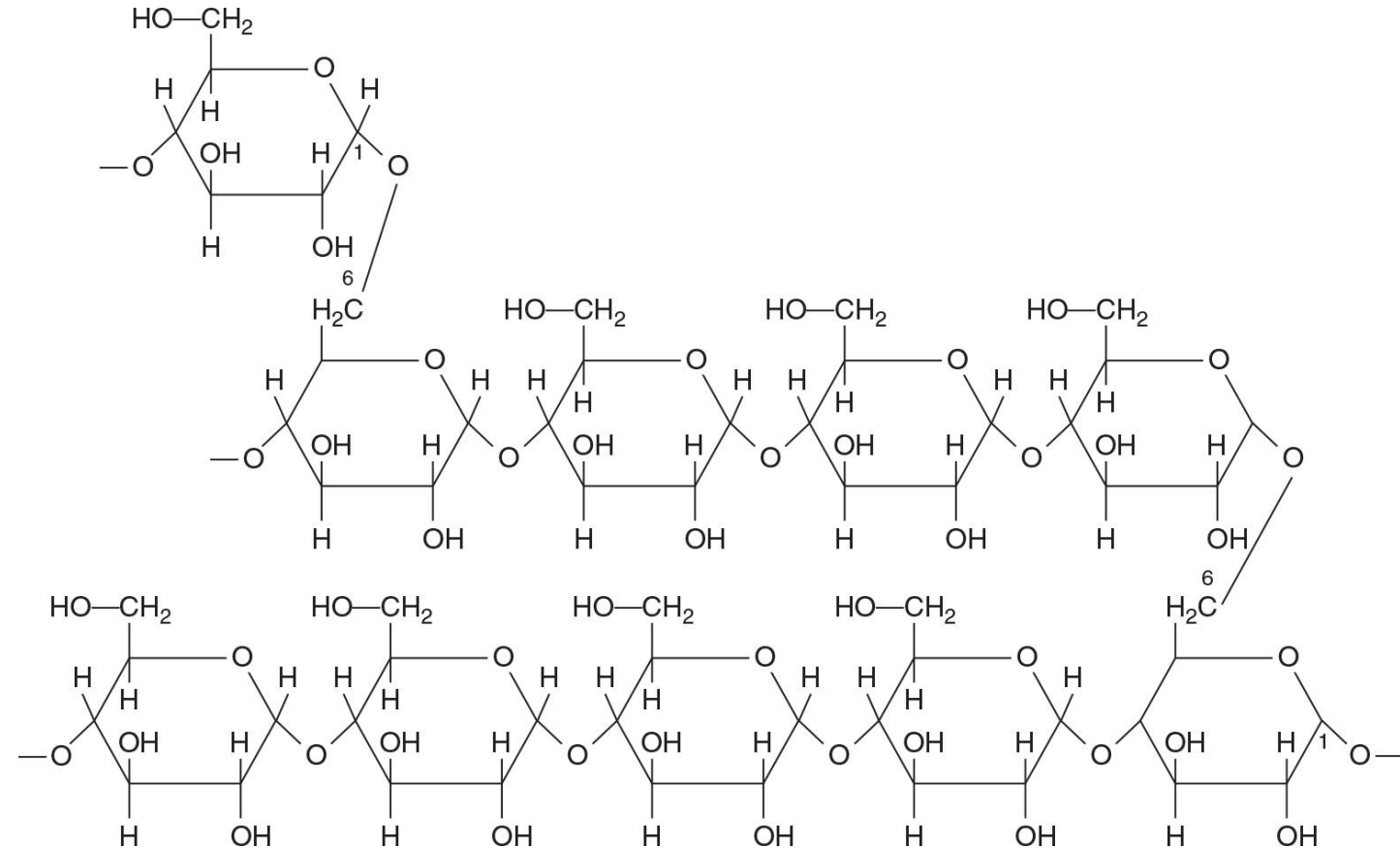


# Characteristics of Disaccharides

Chemical name	Monosaccharide composition	Sweetness (100 = sweetness of table sugar)	Glycemic index (based on 100)	Miscellaneous information
Sucrose	Glucose + fructose	100	68	Found in fruits, vegetables, honey, and maple syrup; sugar beets and sugar cane are processed into white and brown sugar.
Lactose	Glucose + galactose	15	46	Most adults lose their ability to digest lactose (milk sugar).
Maltose	Glucose + glucose	40	105	Minor disaccharide in most diets.

# Polysaccharides

- Starch
- Fiber
- Glycogen



# Classifying Carbohydrates

- There is no single way to classify carbohydrates
  - Sugars and starches
  - Simple and complex
  - Minimally processed (“quality”) vs. highly processed
  - “Good” vs. “bad”

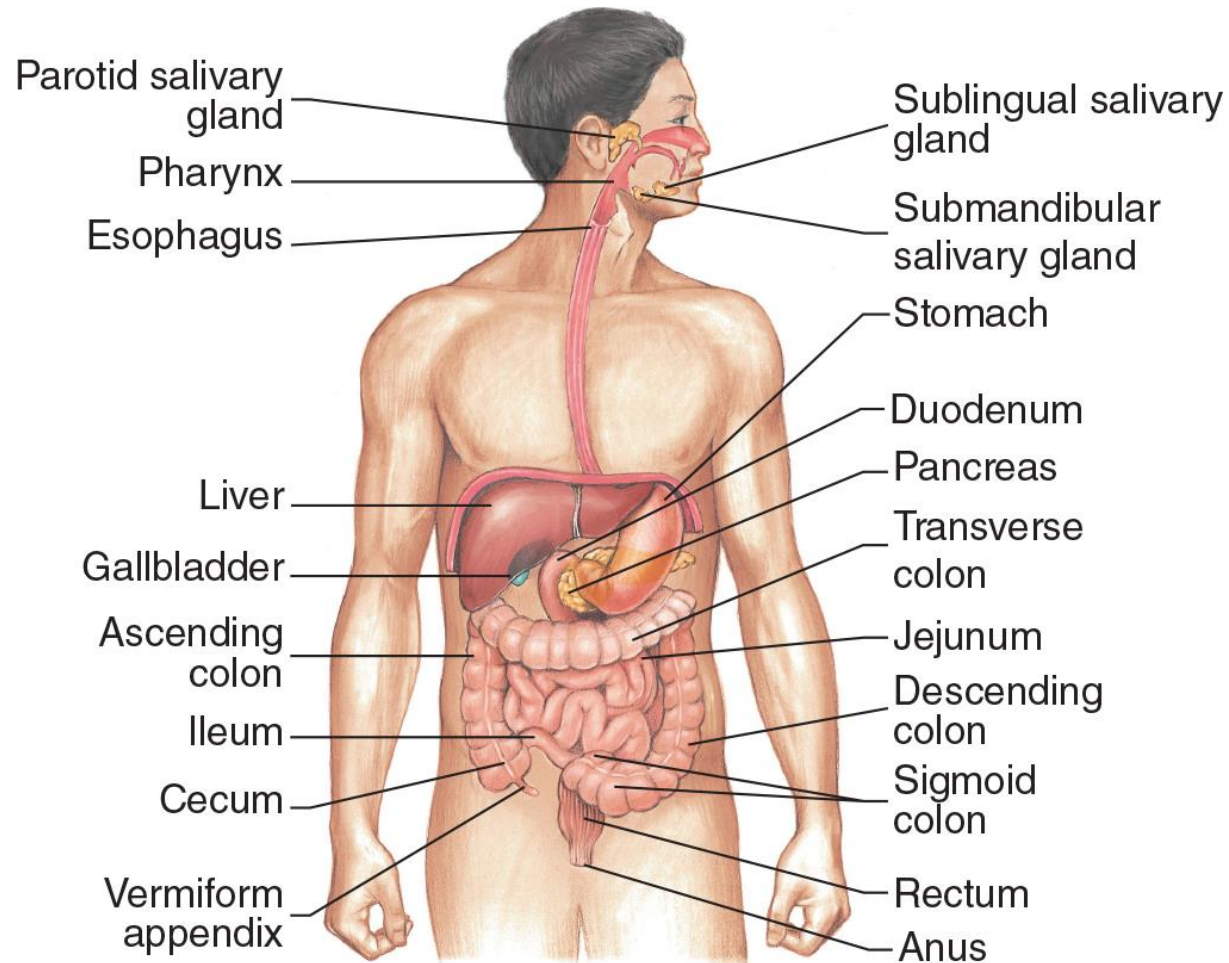
# Knowledge Check 1

Carbohydrates are found in the body predominantly in the form of \_\_\_\_\_ (mostly in the blood) and in the storage form of \_\_\_\_\_ (predominantly in muscle and liver tissue).

- a) galactose, glucose
- b) glucose, starch
- c) glucose, glycogen
- d) sucrose, glucose

# Digestion, Absorption, and Transportation of Carbohydrates

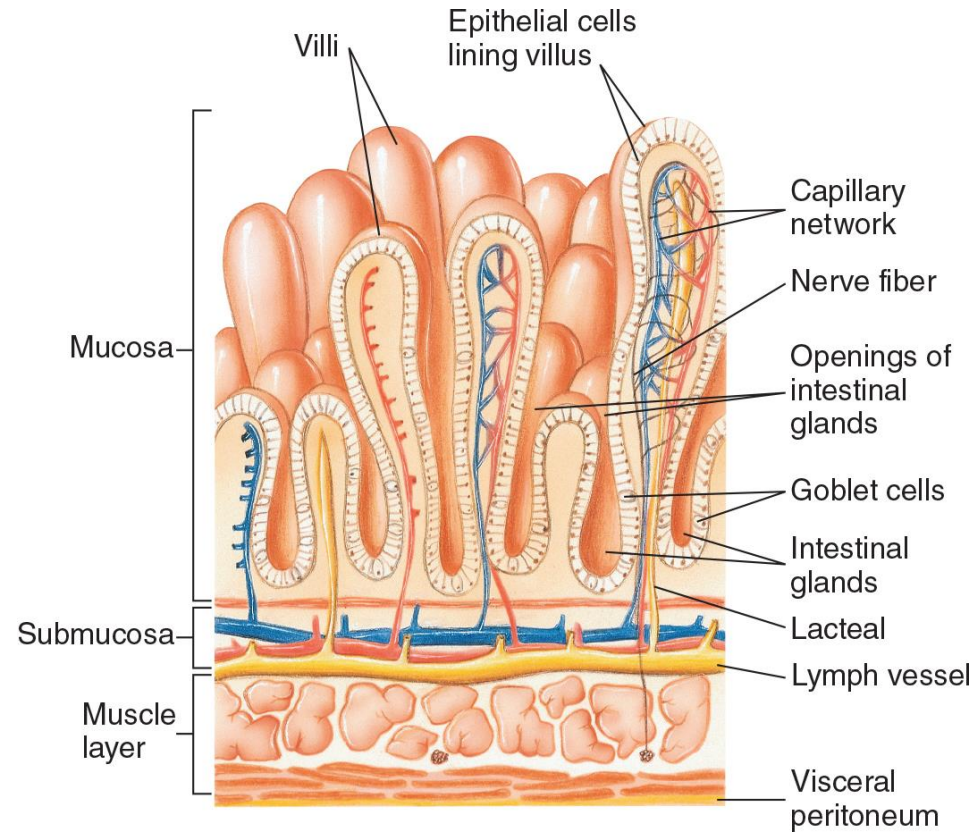
# The Human Digestive Tract



# Knowledge Check 2

- The majority of digestion takes place in the \_\_\_\_\_. The majority of absorption takes place in the \_\_\_\_\_.
- a) stomach, small intestine
- b) stomach, large intestine
- c) small intestine, small intestine
- d) small intestine, large intestine

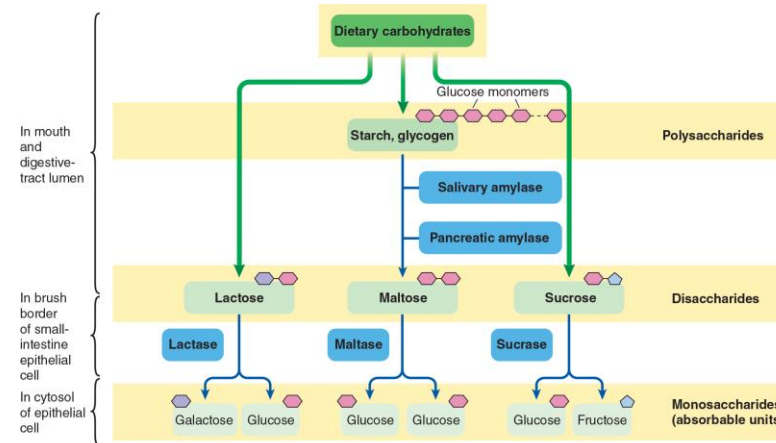
# The Structure of the Small Intestine



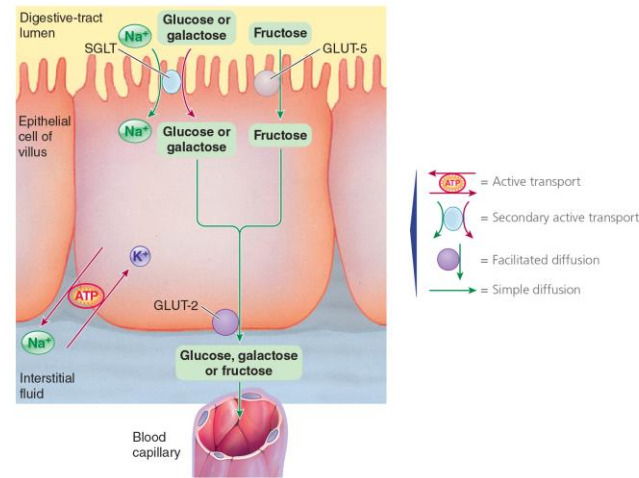
Enlarged view of a small portion of the intestinal wall. Some of the villi have been opened to show the blood and lymph vessels within.



# Carbohydrate Digestion and Absorption



(a) Carbohydrate digestion



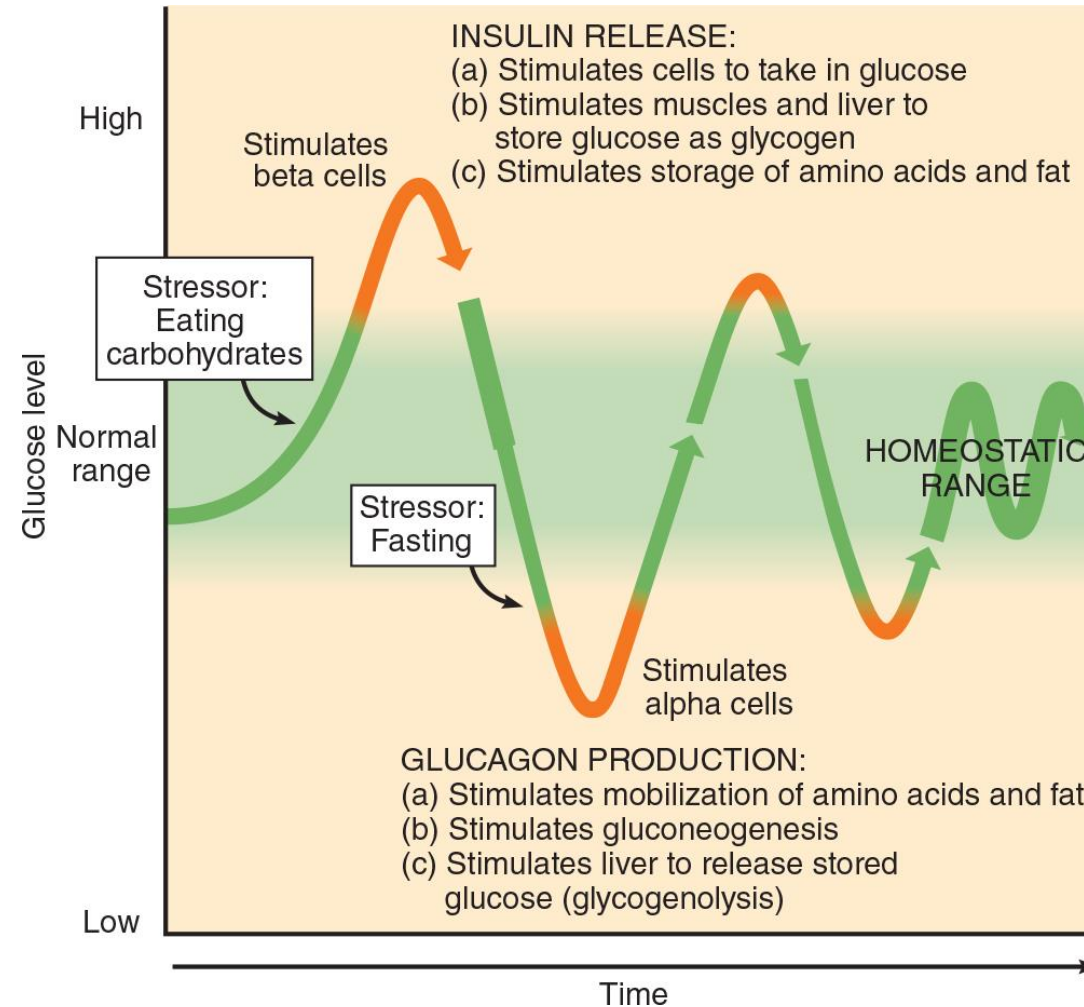
(b) Carbohydrate absorption

# Metabolism of Glucose in the Body

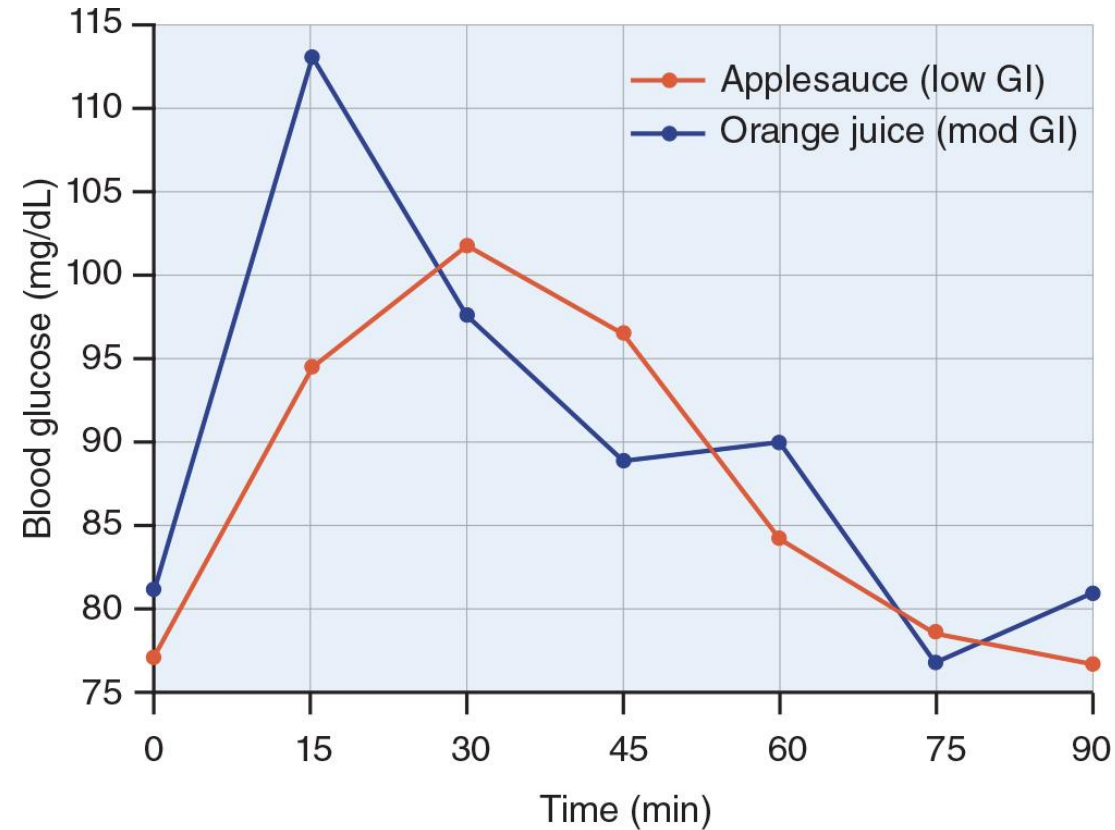
# Glucose Metabolism

- Involves many metabolic pathways, which include:
  - The regulation of blood glucose concentration
  - The immediate use of glucose for energy
  - The storage of glucose as glycogen
  - The use of excess glucose for fatty acid synthesis
  - The production of glucose from lactate, amino acids, or glycerol

# Regulation of Blood Glucose

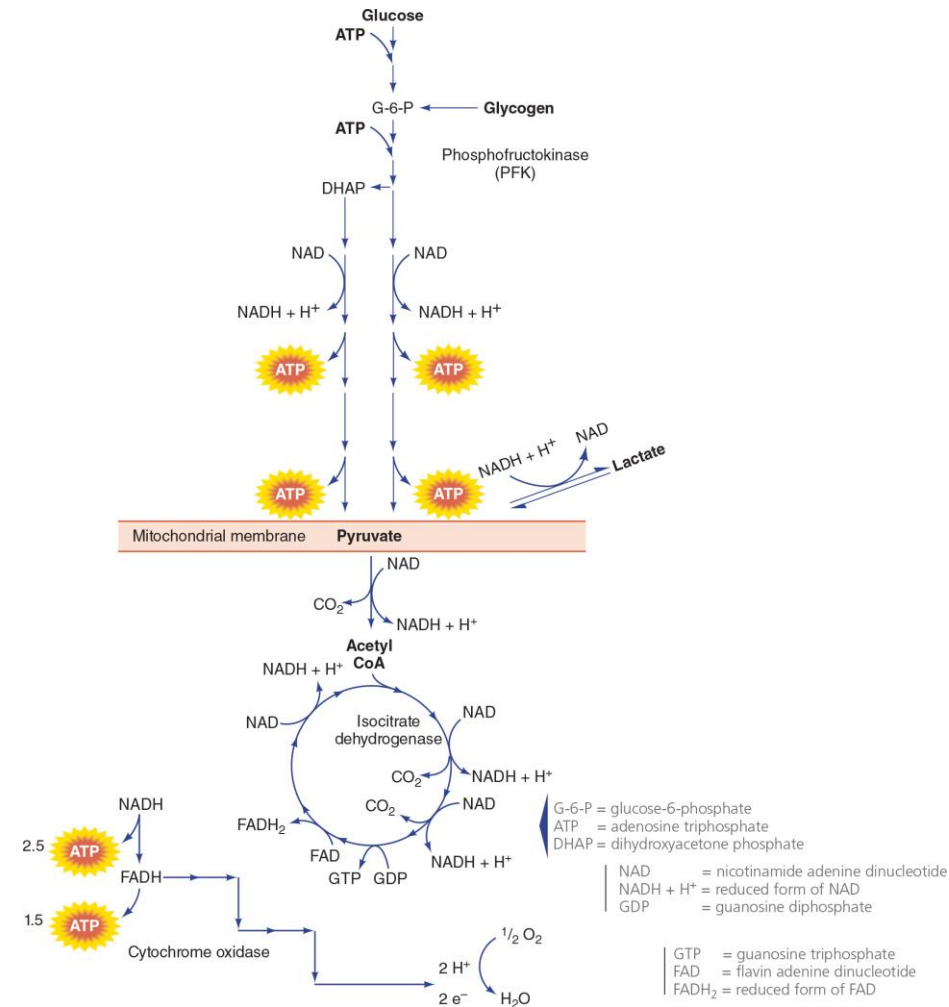


# Glycemic Response



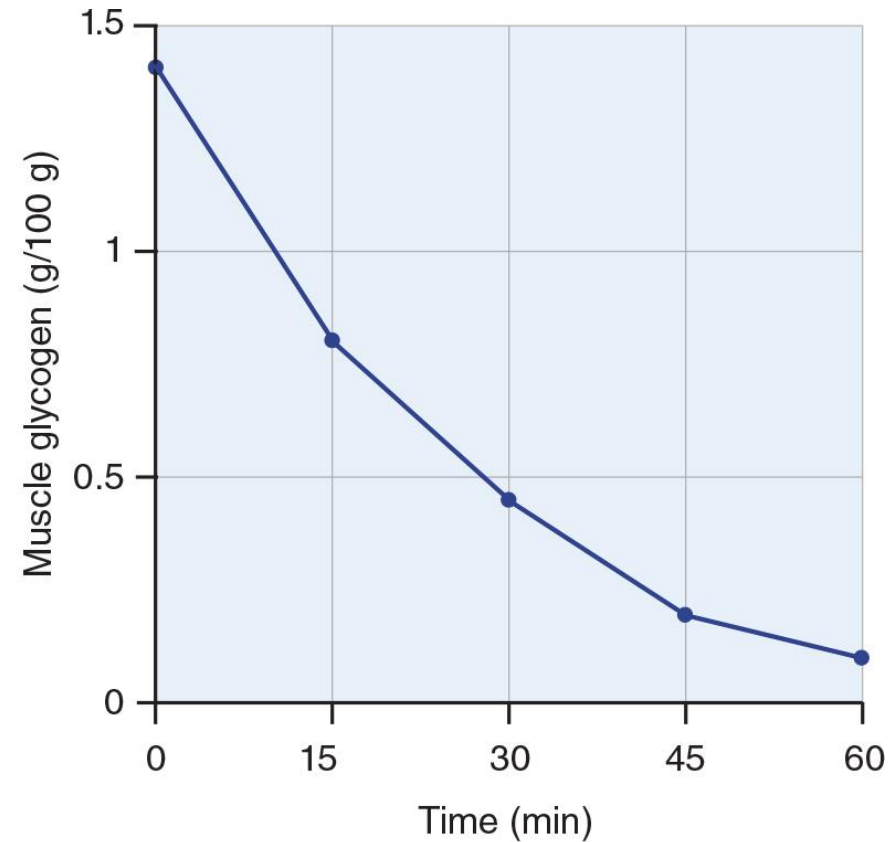
mg/dL = milligrams per deciliter  
mod = moderate  
min = minutes

# Metabolism of Carbohydrate



# Carbohydrates as a Source of Energy for Exercise

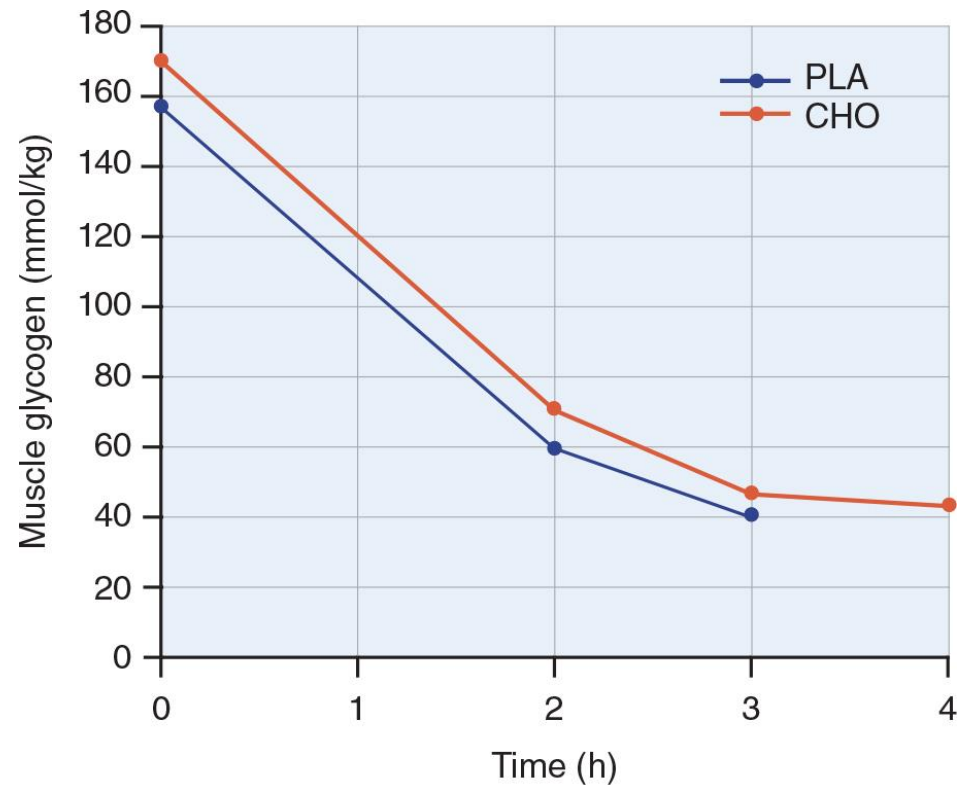
# Use of Muscle Glycogen During Exercise



g = gram  
min = minutes  
g/100 g = g glycogen per 100 g of tissue

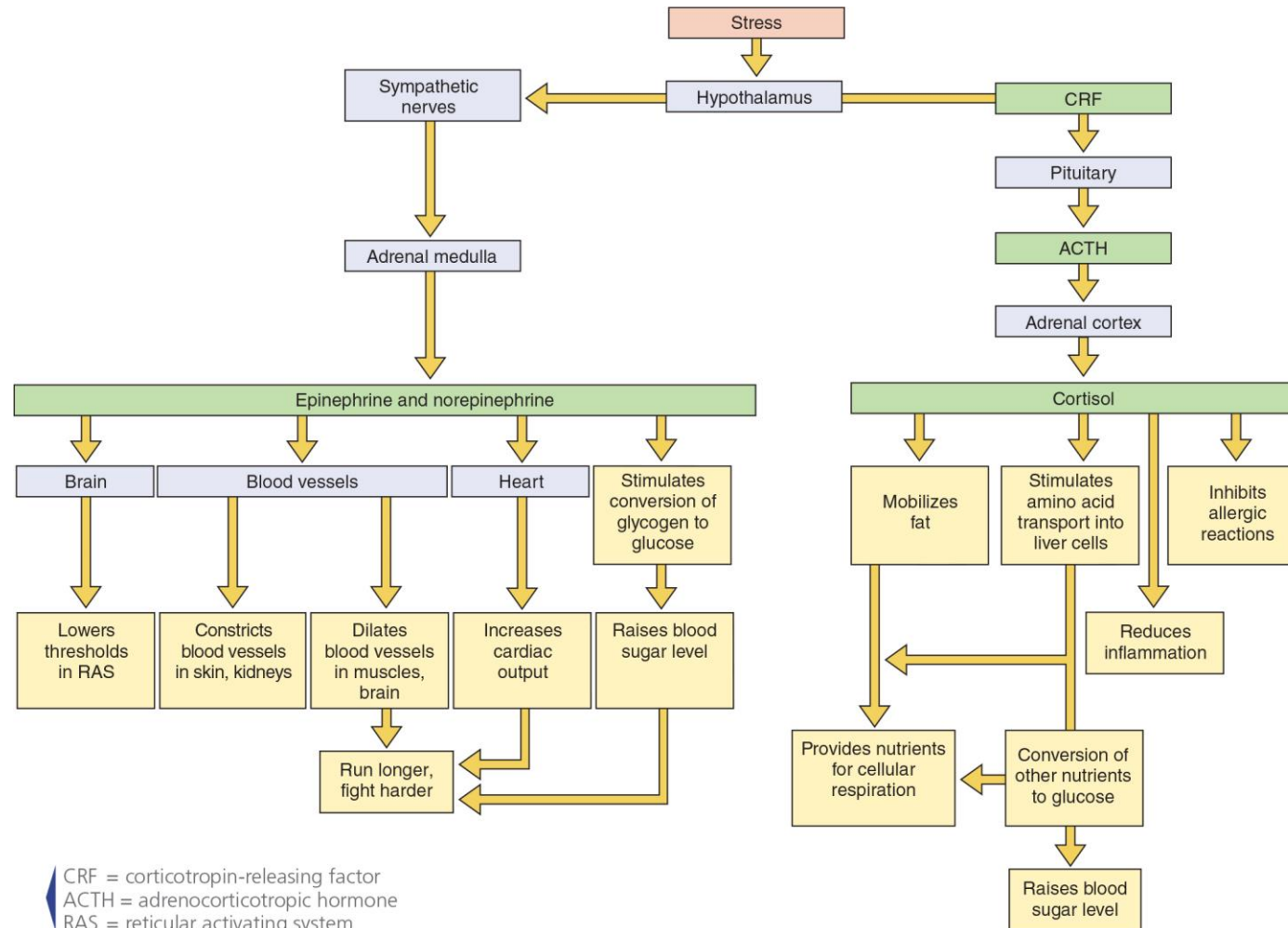


# Muscle Glycogen Use and Carbohydrate Consumption During Exercise



mmol/kg = millimoles per kilogram  
PLA = placebo  
CHO = carbohydrate  
h = hour

# Physiological Response to Stress



# Carbohydrate Recommendations for Athletes

# Carbohydrate Recommendations Based on Duration for Low-Intensity Exercise (1 of 2)

Exercise intensity and duration	Examples of sports	Daily carbohydrate recommendation (energy intake must be adequate)
Low-intensity or short-duration skill-based activities	Curling, Shooting, Archery	3–5 g/kg
Low intensity, long-duration (more than 1 hour)	Golf, Baseball, Softball	5–7 g/kg

# Carbohydrate Recommendations Based on Duration for Low-Intensity Exercise (2 of 2)

Exercise intensity and duration	Examples of sports	Daily carbohydrate recommendation (energy intake must be adequate)
Moderate-intensity, moderateduration (30 to 60 minutes)	10 km running (elite runners finish in 30 minutes)	6–8 g/kg
Intermittent high-intensity, moderateto long-duration (more than 1 hour)	Soccer (football), Basketball, Ice hockey, Field hockey, Lacrosse, Tennis, Water polo	6–8 g/kg; 8–10 g/kg during heavy training and competition
Moderate- to high-intensity, long-duration (1 to 3 hours per day)	Distance running (marathon), Distance swimming, Distance cycling, Nordic (cross country) skiing	6–10 g/kg during periods of heavy training and competition
Moderate-intensity, ultralong-duration (more than 4 to 5 hours per day)	Ultradistance running, Ultradistance swimming, Ultradistance cycling, Triathlon, Adventure sports	8–12 g/kg depending on the stage of training
Other	Bodybuilding, American football	5–10 g/kg depending on the stage of training 5–8 g/kg; varies according to position

# Carbohydrate Recommendations Based on Duration for High-Intensity Exercise

Exercise intensity and duration	Examples of sports	Daily carbohydrate recommendation (energy intake must be adequate)
Very high-intensity, very short-duration (less than 1 minute)	Field events such as shot put, discus, or high jump, Track sprints (50–200 m), Swimming sprints (50 m), Sprint cycling (200 m), Weight lifting, Power lifting, Bobsled (running start)	5–7 g/kg
High-intensity, short-duration (1 to 30 minutes continuous)	Track (200–1,500 m), Swimming (100–1,500 m), Cycling (short-distance), Rowing (crew), Canoeing/Kayaking (racing), Skiing (downhill racing), Figure skating, Mountain biking	5–7 g/kg
High-intensity, short-duration (1 to 30 minutes with some rest periods)	Gymnastics, Wrestling, Boxing, Fencing, Judo, Tae kwon do	5–7 g/kg

# Pre-Packaged Pre-Exercise Products

Product	Serving size	Energy (kcal)	CHO (g)	Fiber (g)	Protein (g)	Fat (g)	Recommended timing
Gatorade Prime®, Sports Fuel Drink	118 mL pouch	110	25	1	0	0	15 minutes before exercise
Gatorade Prime® Energy Chews	6 chews (30g )	100	24	0	0	0	15 minutes before exercise
Nutrament	12 fl oz	360	52	0	16	10	3–4 hours before exercise

# Carbohydrate Intake During Exercise

Exercise intensity and duration	Sport or event	Recommended carbohydrate intake to enhance performance*
High-intensity exercise less than 45 minutes	Running (sprints up to 10 km); cycling (track cycling, short criteriums); swimming (sprints up to 1500 m); crew (rowing)	None
High-intensity exercise (continuous or intermittent) approximately 45–60 minutes	Team sports, such as basketball, lacrosse, water polo, or ice hockey; cycling time trials	0–30 g/h, or mouth rinse
High-intensity exercise (intermittent) approximately 90 minutes	Team sports, such as soccer; skilled recreational tennis players; team or individual handball, racquetball, or squash	30–60 g/h
Moderate to vigorous exercise more than 2 hours	Backpacking, hiking; recreational cycling	30–60 g/h**
High-intensity exercise more than 2 hours	Marathon running; sprint and Olympic distance triathlon; 50 km ski racing; professional tennis match	30–60 g/h**
Ultraendurance competitions lasting many hours or repeated over days	Ironman® length triathlons; cycling stage races, adventure racing	up to 90 g/h**



# Translating Daily Carbohydrate Recommendations to Food Choices

# Serving Guidelines for Carbohydrate-Containing Food Groups

Food group	Servings/1,800 kcal	Servings/2,000 kcal	Servings/2,600 kcal	Servings/3,100 kcal
Fruits	4	4–5	5–6	6
Vegetables	3–4	4–5	5–6	6
Grains*	6	6–8	10–11	12–13
Nuts, seeds, and legumes	3–4 per week	4–5 per week	1	1
Fat-free or low-fat dairy products	2–3	2–3	3	3–4
Sweets and added Sugar**	3 or less per week	3 or less per week	≤2	≤2

# Application Activity

Let's take a look at the carbohydrate needs for a fictional athlete who weighs 166 pounds (75 kilograms):

1. Assume the athlete has 7g/ kg body weight and determine the estimated total daily carbohydrate needs using Table 4.10 (p. 138 in the text). Determine the total energy needs based on 70% of calories coming from carbohydrates.
2. Create a 1-day meal plan that meets the estimated carbohydrate needs and follows the guidelines for number of servings in Table 4.12 (p. 141 in the text). Focus only on planning the carbohydrate-containing foods and meeting those estimated needs.

# Discussion Activity: Debrief

- Did you find meeting the estimated daily carbohydrate needs difficult from a planning perspective? What was or wasn't challenging when planning the day?
- How might meeting estimated daily carbohydrate needs even more difficult for a busy student athlete? What are some ideas or shortcuts that could help an athlete get the proper amount and servings of carbohydrate-containing foods each day?

# Easy-to-Store and Prepare Carbohydrate-Containing Foods

Carbohydrate-containing food	Storage and preparation tips
Bread or bagels	Keep in freezer. Put in toaster twice.
Waffles	Buy frozen waffles and heat in toaster. Top with syrup or jam.
Pancakes	Buy pourable pancake mix. Add water and cook. Top with syrup or jam.
Cereal	Add shelf-stable ultrahigh temperature (UHT) milk, which does not need refrigeration until it is opened. Cereal can also be used as a topping for yogurt.
Oatmeal or grits	Buy instant oatmeal or grits packages, and add hot water.
Pasta	Cook dry or frozen pasta noodles. Heat a jar of tomato-based spaghetti sauce. Combine.
Tortillas (fresh or frozen) and beans (canned)	Spoon canned beans on tortilla (add cheese if desired). Microwave 1 minute. Add salsa and fold.
Fruits	Apples and bananas tend to last longer than fresh berries or stone fruits (for example, peaches or nectarines). If fruits get overripe add to smoothies.
Vegetables	Fresh carrots tend to last a long time when stored in a cool place. Frozen or canned vegetables are easy to store and prepare.
Canned beans	Most kinds of beans can be purchased in cans and only need to be reheated.
Milk	Milk that has been processed using UHT pasteurization can remain on the shelf until opened.
Frozen entrées	Several brands specialize in “healthy” frozen entrées that contain high-carbohydrate, moderate protein, low-fat, and low-sodium meals.
Nuts	Unopened jar or cans can remain on the shelf; after opening, nuts can be stored in the freezer.

# Artificial (Nonnutritive) Sweeteners

Artificial sweetener	Description
Acesulfame potassium (Acesulfame K or Sunett®)	<ul style="list-style-type: none"><li>• Often mixed with other artificial sweeteners such as aspartame</li></ul>
Aspartame (NutraSweet®, Equal®)	<ul style="list-style-type: none"><li>• Made of two amino acids, L-aspartic acid and L-phenylalanine</li><li>• Warning label is required because those with phenylketonuria cannot metabolize the phenylalanine</li><li>• Food and Drug Administration (FDA) approved. Opponents question its safety on the basis that it causes seizure, headache, memory loss, and mood change.</li></ul>
Neotame	<ul style="list-style-type: none"><li>• Intensely sweet (7,000 to 13,000 times sweeter than sugar)</li></ul>
Saccharin (Sweet 'n Low®)	<ul style="list-style-type: none"><li>• Oldest artificial sweetener (discovered in 1879)</li><li>• Once thought to be a cause of bladder cancer, but studies in humans do not support this association</li><li>• Often found in restaurants as single-serving packets</li></ul>
Stevia	<ul style="list-style-type: none"><li>• Herb known for its sweet-tasting leaves</li><li>• May have a beneficial effect on blood glucose and insulin levels</li></ul>
Sucralose (Splenda®)	<ul style="list-style-type: none"><li>• Derived from sugar but is not digestible because of the substitution of three chlorine atoms for three OH groups</li><li>• Also contains maltodextrin, a starch, which gives it bulk so that it will measure like sugar in recipes</li></ul>

# FODMAP-Containing Foods

Short-chain Carbohydrate	Examples	Foods
Oligosaccharides	Fructan, galacto-oligosaccharide, inulin	Onions, beets, cabbage, garlic, apples, watermelon, wheat, rye, beans and legumes (soy, garbanzo beans, lentils)
Disaccharides	Lactose	Milk, yogurt, cheese, ice cream
	Sucrose	Sugar-sweetened foods
Monosaccharides	Fructose	Fruits, honey, foods with fructose added (many sweetened foods and beverages)
Polyols	Sorbitol, mannitol	Fruits (apples, peaches, pears, plums, cherries), vegetables (avocado, cauliflower, mushrooms, sweet corn), chewing gum

# Summary (1 of 2)

Now that the lesson has ended, you should have learned how to:

- Classify carbohydrates according to their chemical composition.
- Describe the digestion and absorption of carbohydrates.
- Explain the metabolism of glucose.
- Describe how muscle glycogen and blood glucose fuel exercise.



# Summary (2 of 2)

- Detail and explain carbohydrate recommendations for athletes, including specific guidelines for intake before, during, and after exercise.
- Determine the daily carbohydrate needs of an athlete, and select carbohydrate-containing foods to meet the recommended intake.