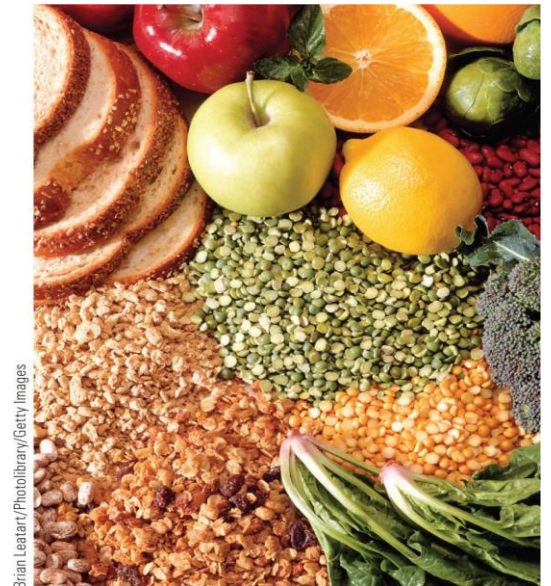


Nutrition and Diet Therapy

Chapter 3: Carbohydrates



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Learning Objectives

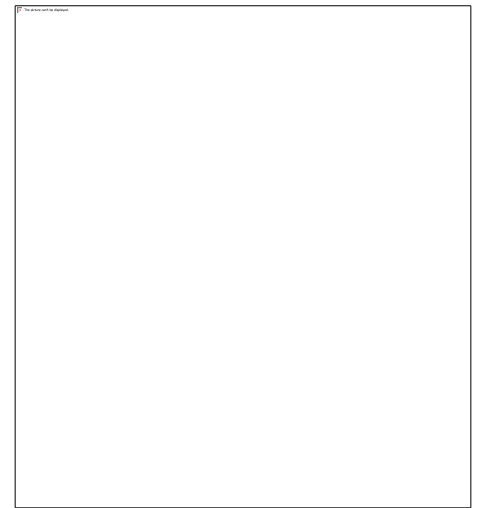
- ❑ Identify the monosaccharides, disaccharides, and polysaccharides common in nutrition and list their major food sources.
- ❑ Summarize carbohydrate digestion and absorption.
- ❑ Explain how hormones control blood glucose concentrations.

Learning Objectives

- ❑ Describe how added sugars can contribute to health problems and how alternative sweeteners may help to limit kcalories and sugar intake.
- ❑ Identify the health benefits of, and recommendations for, starches and fibers.
- ❑ Describe the glycemic index and explain why its use in disease prevention is controversial.

What are Carbohydrates?

- ❑ Definition: energy nutrients composed of monosaccharides
 - "Carbo" = carbon
 - "hydrate" = water
- ❑ Preferred energy source for most of the body's functions
 - Brain depends exclusively on carbohydrates



The Chemist's View

- Dietary **carbohydrates**

- Sugars, starch, and fiber

- Two Categories:

- Simple Carbohydrates (sugars):

- Monosaccharides (single sugars):

- Glucose, fructose, and galactose

- Disaccharides (double sugars):

- Maltose, sucrose, and lactose

- Complex Carbohydrates (polysaccharides):

- Starch

- Fibers

- Glycogen (storage form)

Monosaccharides (Single Sugars)

□ Glucose:

- Simple sugar common in all disaccharides and polysaccharides
- Nearly all the body's cells use glucose as the main energy source
- Also called *blood sugar* or *dextrose*

□ Fructose:

- Sweetest of the sugars
- Made by plants
- "fruit sugar"
- Natural in fruits, honey, & part of table sugar

□ Galactose:

- Only found in nature as a part of disaccharide known as lactose ("milk sugar")
- Broken down to single sugar "galactose" during digestion

Disaccharides (Double Sugars)

- ❑ Two single sugars (monosaccharides) put together
 - Sucrose (**Glucose + Fructose**):
 - ❑ “table sugar” or white sugar
 - ❑ Found in sodas, candy, cakes, frostings, cookies, and other “concentrated sweets”
 - Lactose (**Glucose + Galactose**):
 - ❑ “milk sugar” (principle carbohydrate in milk)
 - Maltose (**Glucose + Glucose**) :
 - ❑ “malt sugar”

Lactose intolerance

- Inability to digest lactose
- Occurs in some people after infancy

To Review...

Glucose



Fructose



Galactose
(found mostly as
part of lactose)



Sucrose (glucose + fructose)



Lactose (glucose + galactose)



Maltose (glucose + glucose)

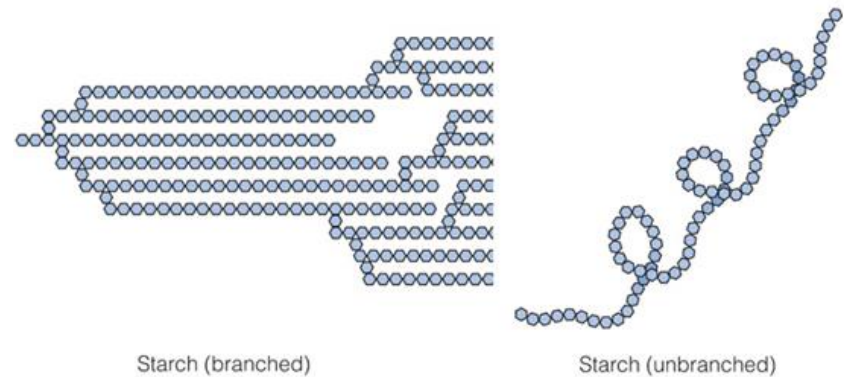
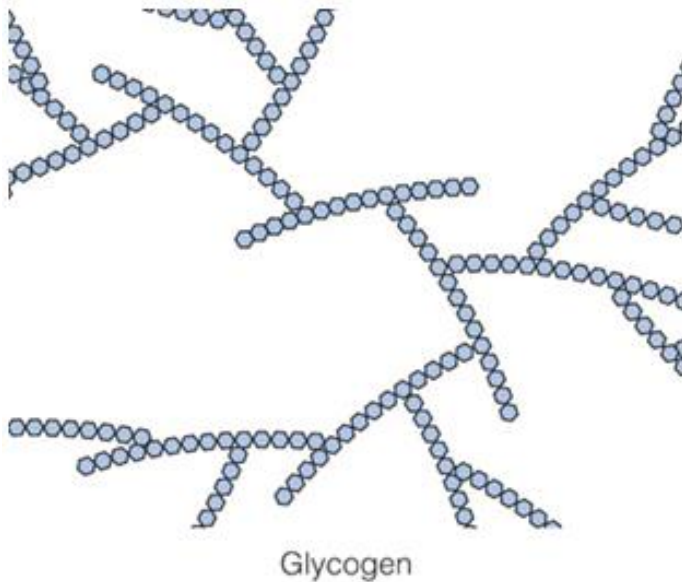


The Polysaccharides: Starch and Glycogen

- ❑ Composed almost entirely of glucose (sometimes other monosaccharides as well)
- ❑ Difference in the way the glucose units are linked together between the two
- ❑ **Starch:**
 - Long, straight or branched chain of hundreds of glucose units
 - Digestion breaks the starch down into glucose units which are then used for energy
 - Storage form of glucose (energy) in plants
- ❑ **Glycogen:**
 - More highly branched chain of glucose units
 - Storage form of glucose (energy) for humans and animals
 - When energy is needed body will break down glycogen stores into glucose for energy
 - Important in physical activity

Polysaccharides

FIGURE 3-2 Glycogen and Starch Compared



A glycogen molecule contains hundreds of glucose units in highly branched chains.

A starch molecule contains hundreds of glucose molecules in either occasionally branched chains or unbranched chains.

The Fibers

- ❑ Fiber of plants make up the plant cell walls
- ❑ Also polysaccharides
- ❑ Bonds cannot be broken by human digestive enzymes
- ❑ Fibers include:
 - Polysaccharides: cellulose, hemicellulose, pectins, gums, mucilages
 - Nonpolysaccharide: lignins

Fiber

□ Types of fiber:

- Cellulose: main component in plant cell walls; in all vegetables, fruits, and legumes
- Hemicellulose: main component of cereal fibers
- Pectins: in vegetables and fruits; used to thicken jellies
- Gums & mucilages: similar structures; used as food additives or stabilizers
- Lignins: tough, woody parts of plants; found in few foods

□ Soluble vs. Insoluble:

- Soluble – fibers that DO dissolve in water
 - Form gels easily digested by bacteria in large intestine
 - Associated with lower risk of chronic disease
 - Ex.- Pectin
- Insoluble – fibers that DO NOT dissolve in water
 - Aid digestive system by easing elimination

Regulation of Blood Glucose

- ❑ Blood glucose homeostasis regulated by **insulin** and **glucagon**
- ❑ Insulin
 - Facilitates glucose uptake by muscles and adipose tissue
 - Stimulates glycogen synthesis in the liver
- ❑ Glucagon
 - Breaks down glycogen into glucose molecules when blood sugar is too low

Glycogen Used for Energy

- ❑ Glycogen stored in liver
- ❑ Body must break down glycogen stores for energy when a person does not eat adequate amounts of CHO's
- ❑ Once glycogen stores are gone, body must turn to the two other energy nutrients...protein & fat.

Fat Used as Energy

- ❑ Body can store almost unlimited quantities of fat
 - Fat stores almost never run out
- ❑ Used to meet about half of the body's energy needs
- ❑ Brain and nerves **can only use glucose** for energy:
 - After long periods of glucose deprivation brain and nerve cells rely on ketones for energy

Protein Used for Energy

- ❑ Stored in muscles and lean body tissue
 - Start breaking down muscles and lean tissue
- ❑ CHO's are "protein sparing"
- ❑ Death occurs after 50% of body's protein is used up
 - Will occur even in obese person

Health Effects of Sugars...

- ❑ Obesity
- ❑ Heart Disease
- ❑ Diabetes
- ❑ Nutrient Deficiencies/Behavior
- ❑ Dental Caries



Sugar and Obesity

- ❑ Supportive role shown, but no definite cause-and-effect relationship proven
- ❑ Obesity increases in a population as added sugar consumption increases
 - Foods high in sugar are often also high in fat and high in kcalories (ex-sugar-sweetened beverages)
 - Physical activity seems to decline as sugar consumption increases
- ❑ Obesity epidemic:
 - Increase in the intake of food energy
 - Increase in the intake of concentrated sweets & soft drinks

Sugar and Heart Disease

- Heart disease

- **Fructose** can lead to unhealthy build-up of lipids in heart and arteries

Sugar and Diabetes

- ❑ Excess sugar intake does not directly cause diabetes.
- ❑ Excess body fat is a known risk factor for Type II diabetes.
 - Sugar may be a causative factor in the development of diabetes only when it contributes to a person's excess body fat.



Sugar and Behavior

- ❑ Nutrient deficiencies
 - Foods high in sugar often very low in nutrients
- ❑ Does sugar cause hyperactivity or aggressive behavior in children?
 - Has not been proven
 - When sugary foods replace nutrient-dense foods in a child's diet, nutrient deficiencies may occur

Sugar and Dental Caries

- ❑ Does sugar contribute to dental caries?
 - Yes
- ❑ All carbohydrate-containing foods can produce bacterial growth in the mouth
 - Depends on:
 - ❑ Length of time food in mouth
 - ❑ How sticky food is, how often food is eaten, if the teeth are brushed afterwards

Sugars

- ❑ DRI did not set a Tolerable Upper Intake Level, but most people need to limit their intake of added sugars
 - *Dietary Guidelines for Americans* recommends limiting daily intake to less than 10% of total kcalories
- ❑ World Health Organization concurs
 - Greater benefits expected from an intake of less than 5 % of day's total kcalories

Health Effects of Sugars and Alternative Sweeteners

BOX 3-1 Reduce Intakes of Added Sugars

- ❑ Use less table sugar when preparing meals and at the table.
- ❑ Use your sugar kcalories to sweeten nutrient-dense foods (such as oatmeal) instead of consuming empty-kcalorie foods and beverages (such as candy and soda).
- ❑ Replace empty kcalorie-rich regular sodas, sports drinks, energy drinks, and fruit drinks with water, fat-free milk, 100% fruit juice, or unsweetened tea or coffee.
- ❑ Use sweet spices such as cinnamon, nutmeg, allspice, or clove.
- ❑ Select fruit for dessert. Eat less cake, cookies, ice cream, other desserts, and candy. If you do eat these foods, have a small portion.
- ❑ Warm up sweet foods before serving (heat enhances sweet tastes).
- ❑ Read the Nutrition Facts on labels to choose foods with less sugar and less added sugar.

Recognizing Sugars

- ❑ “Sugar” on food labels:
 - Brown sugar, concentrated fruit juice sweetener, confectioners’ sugar, corn sweeteners, corn syrup, dextrose, fructose, galactose, glucose, granulated sugar, high-fructose corn syrup (HFCS), honey, invert sugar, lactose, levulose, maltose, maple sugar, molasses, raw sugar, sucrose, turbinado, white sugar
- ❑ 1 teaspoon of white sugar =
 - 1 t brown sugar, candy, jam, jelly, corn sweetener, syrup, honey, molasses, maple sugar
 - 1 T ketchup
 - 1 ½ ounces carbonated soft drink



Recognizing Sugars

BOX 3-2 Glossary of Added Sugars

- **Brown sugar:** refined white sugar with molasses added; 95 percent pure sucrose.
- **Concentrated fruit juice sweetener:** a concentrated sugar syrup made from dehydrated, deflavored fruit juice, commonly grape juice; used to sweeten products that can then claim to be “all fruit”.
- **Confectioner’s sugar:** finely powdered sucrose; 99.9 percent pure.
- **Corn syrup:** a syrup, mostly glucose, partly maltose, produced by the action of enzymes on cornstarch. It may be dried and used as corn syrup solids.
- **Dextrose, anhydrous dextrose:** forms of glucose.
- **Evaporated cane juice:** raw sugar form which impurities have been removed.
- **Granulated sugar:** white sugar.
- **High-fructose corn syrup (HFCS):** a widely used commercial caloric sweetener made by adding enzymes to cornstarch to convert a portion of its glucose molecules into sweet-tasting fructose.
- **Honey:** a concentrated solution primarily composed of glucose and fructose; produced by enzymatic digestion of the sucrose in nectar by bees.
- **Invert sugar:** a mixture of glucose and fructose formed by the splitting of sucrose in an industrial process. Sold only in liquid form and sweeter than sucrose, invert sugar forms during certain cooking procedures and works to prevent crystallization of sucrose in soft candies and sweets.
- **Malt syrup:** a sweetener made from sprouted barley.
- **Maple syrup:** a concentrated solution of sucrose derived from the sap of the sugar maple tree, mostly sucrose. This sugar was once common but is now usually replaced by sucrose and artificial maple flavouring.
- **Molasses:** a thick, brown syrup left over from the refining of sucrose from sugar cane. The major nutrient in molasses is iron, a contaminant from the machinery used in processing it.
- **Raw sugar:** the first crop of crystals harvested during sugar processing. Raw sugar cannot be sold in the United States because it contains too much filth (dirt, insect fragments, and the like). Sugar sold as “raw sugar” is actually evaporated cane juice.
- **Turbinado (ter-bih-NOD-oh) sugar:** raw sugar from which the filth has been washed; legal to sell in the United States.
- **White sugar:** granulated sucrose or “table sugar,” produced by dissolving, concentrating, and recrystallizing raw sugar; 99.9 percent pure.

Recognizing Sugars

TABLE 3-3 Sample Nutrients in Sugars and Other Foods

The indicated portion of any of these foods provides approximately 100 kcalories. Notice that – for a similar number of kcalories and grams of carbohydrate – milk, legumes, fruits, grains, and vegetables offer more of the other nutrients than do the sugars.

Foods	Size of 100 kCal Portion	Carbohydrate (g)	Protein (g)	Calcium (mg)	Iron (mg)	Vitamin A (µg)	Vitamin C (mg)
Foods: Milk, 1 % low-fat	1 c	12	8	300	0.1	144	2
Foods: Kidney beans	½ c	20	7	30	1.6	0	2
Foods: Apricots	6	24	2	30	1.1	554	22
Foods: Bread, whole wheat	1½ slices	20	4	30	1.9	0	0
Foods: Broccoli, cooked	2 c	20	12	188	2.2	696	148
Sugars: Sugar, white	2 tbs	24	0	trace	trace	0	0
Sugars: Molasses, blackstrap	2½ tbs	28	0	343	12.6	0	0.1
Sugars: Cola beverage	1 c	26	0	6	trace	0	0
Sugars:Honey	1½ tbs	26	trace	2	0.2	0	trace

Alternative Sweeteners: Sugar Alcohols

- ❑ **Carbohydrates** that have less kcalories than sucrose
- ❑ Not absorbed completely in the body
- ❑ “Nutritive Sweeteners”
- ❑ Occur naturally in fruits and vegetables
- ❑ Fermented to gases in the large intestines:
 - Gas, abdominal discomfort, diarrhea
- ❑ DO NOT contribute to dental caries
 - Seen in chewing gum, breath mints
- ❑ Ex.-maltitol, mannitol, sorbitol, isomalt, lactitol, xylitol

Alternative Sweeteners: Artificial Sweeteners

- ❑ NOT carbohydrates
- ❑ Yield no energy: “Nonnutritive sweeteners”
- ❑ Do not promote dental caries
- ❑ Ex.-acesulfame potassium, alitame, aspartame, cyclamate, saccharin, sucralose

Non-Nutritive Sweeteners

TABLE 3-4 U.S.–Approved Nonnutritive Sweeteners

Sweetener	Chemical Composition	Digestion/ Absorption	Relative Sweetness ^a	Energy (kcal/g)	Body Weight and Estimated Equivalent ^b	Comments
Acesulfame potassium or ACEK (AY-sul-fame)	Potassium salt	Not digested or absorbed	200	0	15 (23 packets of sweetener)	Approved as a sweetener and flavor enhancer in foods (except in meat and poultry)
Advantame (ad-VAN-tame)	Aspartame derivative, similar to neotame	Rapidly, but poorly absorbed	20,000	0	32.8 (4920 packets of sweetener)	Approved as a sweetener and flavor enhancer in foods (except in meat and poultry)
Aspartame (ah-SPAR-tame or ASS-par-tame)	Amino acids (phenylalanine and aspartic acid) and a methyl group	Digested and absorbed	200	4 ^f	50 ^g (75 packets of sweetener)	Approved as a sweetener and flavor enhancer in foods.
Luo han guo ^h	Curcubine, glycosides extracts from <i>Siraitia grosvenorii</i> swingle fruit (also known as monk fruit)	Digested and absorbed	175	1	Not determined	GRAS ⁱ
Neotame (NEE-oh-tame)	Aspartame with an additional side group attached	Not digested or absorbed	10,000	0	0.3 (23 packets of sweetener)	Approved as a sweetener and flavor enhancer in foods (except in meat and poultry)
Saccharin (SAK-ah-ren)	Benzoic sulfimide	Rapidly absorbed and excreted	400	0	15 (45 packets of sweetener)	Approved as a sweetener only in certain special dietary foods and as an additive used for certain technological purposes.

Non-Nutritive Sweeteners

TABLE 3-4 U.S.–Approved Nonnutritive Sweeteners (continued)

Sweetener	Chemical Composition	Digestion/ Absorption	Sweetness Relative to Sucrose ^a	Energy	Acceptable Daily Intake (ADD and Estimated Equivalent ^b	Approved Uses
Stevia (STEE-vee-ah)	Glycosides found in the leaves of the <i>Stevia rebaudiana</i> herb	Digested and absorbed	300	0	4 (9 packets of sweetener)	GRAS ^c
Sucralose (SUE-kra-lose)	Sucrose with Cl atoms instead of OH groups	Not digested or absorbed	600	0	5 (23 packets of sweetener)	Approved as a sweetener in foods.

aRelative sweetness is determined by comparing the approximate sweetness of a sugar substitute with the sweetness of pure sucrose, which has been defined as 1.0. Chemical structure, temperature, acidity, and other flavors of the foods in which the substance occurs all influence relative sweetness.

bThe Acceptable Daily Intake (ADI) is the estimated amount of a sweetener that individuals can safely consume each day over the course of a lifetime without adverse effects. The Estimated Equivalent is the number of packets of sweetener a person needs to consume to reach the ADI based on a person weighing 60 kg (132 lb).

cMarketed under the trade names Sunett and Sweet One.

dRecommendations from the WHO limit acesulfame K intake to 9 mg per kilogram of body weight per day.

eMarketed under the trade names NutraSweet, Equal, and Sugar Twin.

fAspartame provides 4 kcal per gram, as does protein, but because so little is used, its energy contribution is negligible. In powdered form, it is sometimes mixed with lactose, however, so a 1-g packet may provide 4 kcal.

gRecommendations from the WHO and in Europe and Canada limit aspartame intake to 40 mg per kilogram of body weight per day.

hMarketed under the trade name Fruit-Sweetness.

iGRAS = generally recognized as safe. The GRAS list is subject to revision as new facts become known. For stevia, only one highly refined extract (known as Rebaudioside A) has been granted GRAS status; whole-leaf stevia and other extracts have not been approved.

jMarketed under the trade names Sweet'N Low, Sweet Twin, and Necta Sweet.

kMarketed under the trade names SweetLeaf, Purevia, Truvia, and Honey Leaf.

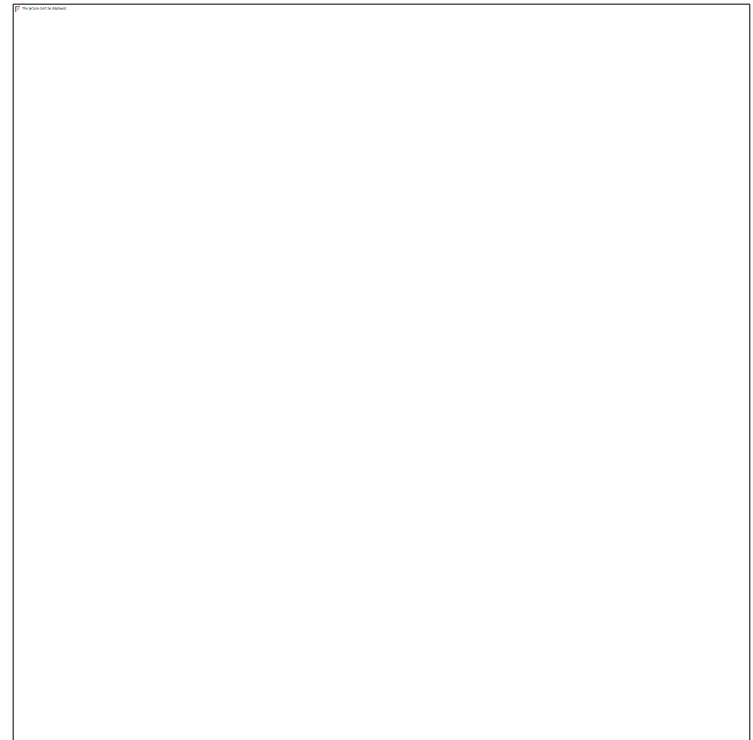
lMarketed under the trade name Splenda.

Aspartame and PKU

- ❑ People with metabolic disorders known as phenylketonuria (PKU) cannot dispose of phenylalanine properly
- ❑ Phenylalanine- amino acid found in aspartame
- ❑ Labels of products with aspartame must contain information for individuals with PKU

Do Artificial Sweeteners Help People with Weight Control?

- ❑ Lower kcalories if they replace sugar
- ❑ Must also follow overall healthy diet & include physical activity



Carbohydrates: Food Sources

- ❑ Grains, Vegetables, Fruits, Milk
 - Each class contributes different amounts of carbohydrates per serving
- ❑ Diet rich in complex carbohydrates (starches and fibers) can help to control body weight and reduce the risk of certain diseases (cancer, heart disease, diabetes, dental caries, GI disorders, etc.)
 - Emphasis on whole grains, vegetables, legumes, and fruit

Carbohydrates: Disease Prevention

□ Heart disease

- Diets rich in whole grains, legumes, and vegetables (especially whole grains) may protect against heart disease and stroke
- Soluble fibers (oat bran, barley, and legumes) lower blood cholesterol

Carbohydrates: Disease Prevention

□ Diabetes

- Some fibers delay passage of nutrients from stomach into small intestine
 - Slows glucose absorption
- **Glycemic response:** describes how quickly glucose is absorbed after a meal
 - Slow absorption, modest rise, and steady decline are desired

Carbohydrates: Disease Prevention

□ GI health

■ Soluble and insoluble fibers

- Keep contents of intestinal tract moving easily
- May protect against diverticular disease

□ Cancer

- Studies show increasing dietary fiber protects against colon cancer

Carbohydrates: Disease Prevention

□ Weight management

- Fiber-rich foods tend to be low in fats and added sugars, yielding less energy per bite
 - Promote feeling of fullness as they absorb water
- High-fiber foods better than commercial fiber preparations

Carbohydrates: Disease Prevention

Harmful Effects of Excessive Fiber Intake:

- ❑ May bind with minerals, resulting in losses with excretion
- ❑ Individuals with marginal overall food intake may not meet energy or nutrient needs with high-fiber diets
 - Malnourished, elderly, young children on vegan diets especially vulnerable
- ❑ Dehydration also a risk

FIGURE 3-5

Characteristics, Sources, and Health Effects of Fibers

People who eat these foods...	obtain these types of fibers...	with these actions in the body...	and these probable health benefits...
Barley, oats, oat bran, rye, fruits (apples, citrus), legumes (especially young green peas and black-eyed peas), seaweeds, seeds and husks, many vegetables, fibers used as food additives	Viscous, soluble, more fermentable • Gums • Pectins • Psyllium^a • Some hemicellulose	• Lower blood cholesterol by binding bile • Slow glucose absorption • Slow transit of food through upper GI tract • Hold moisture in stools, softening them • Yield small fat molecules after fermentation that the colon can use for energy • Increase satiety	• Lower risk of heart disease • Lower risk of diabetes • Lower risk of colon and rectal cancer • Increased satiety and may help with weight management
Brown rice, fruits, legumes, seeds, vegetables (cabbage, carrots, brussels sprouts), wheat bran, whole grains, extracted fibers used as food additives	Nonviscous, insoluble, less fermentable • Cellulose • Lignins • Resistant starch • Hemicellulose	• Increase fecal weight and speed fecal passage through colon • Provide bulk and feelings of fullness	• Alleviate constipation • Lower risk of diverticulosis, hemorrhoids, and appendicitis • Lower risk of colon and rectal cancer

Carbohydrate: Recommendations

- ❑ Should contribute to 45-65% total kcal (about half of daily energy)
- ❑ About 300 gm/day based on 2000 kcal diet
- ❑ Most should come from starch/fiber not sugars
- ❑ Fiber: encourage whole grains, vegetables, fruits, and legumes
 - Approximately 20-35 grams/day
- ❑ Substitute plant sources of proteins (legumes) for some animal sources
 - Consume recommended amounts of fruits and vegetables

Carbohydrates: Food Sources

□ Grains

- Most foods from group provide about 15 grams carbohydrate, mostly starch
- Limit refined grains

□ Vegetables

- Some are major sources of starch
 - Provide 15 grams carbohydrate
- Non-starchy vegetables
 - About 5 grams carbohydrate

Carbohydrates: Food Sources

□ Fruits

- Typical ½ cup serving provides about 15 grams carbohydrate
- Sugar concentrations vary
- No more than ½ of day's fruit should be from juice

□ Milk and milk products

- One cup of milk or yogurt provides 12 grams carbohydrate

Carbohydrates: Food Sources

❑ Protein foods

- Almost no carbohydrates provided from these foods
- Exceptions: nuts and dried beans
 - ❑ ½ cup dried beans provides 15 grams

Carbohydrates: Food Labels

□ Labels list:

- Amount (in grams) total carbohydrate, including starch, fiber, and sugars, per serving
 - Starch is the difference of fiber+ sugar – total CHOs
 - Sugar reflects added and natural sugars
- Percent of Daily Values for individual consuming 2000-kcal diet

Carbohydrates: Health Claims

- ❑ FDA-authorized health claims
 - Fiber-containing grain products, fruits, and vegetables reduce cancer risk
 - Fruits, vegetables, and grain products containing fiber reduce coronary heart disease risk
 - Soluble fiber from whole oats and psyllium seed husk reduces heart disease risk
 - Whole grains reduce risk of heart disease and certain cancers

So How Important Are Carbohydrates in Our Diet?

- ❑ VERY!
- ❑ Carbohydrates are the preferred energy source.
- ❑ Should make up majority of our diet compared to protein and fat
 - 45-65% of total kcal
- ❑ Rely on CHOs for adequate energy for brain and nerves and to prevent breakdown of muscles and lean tissue

Nutrition in Practice

The Glycemic Index in Nutrition Practice

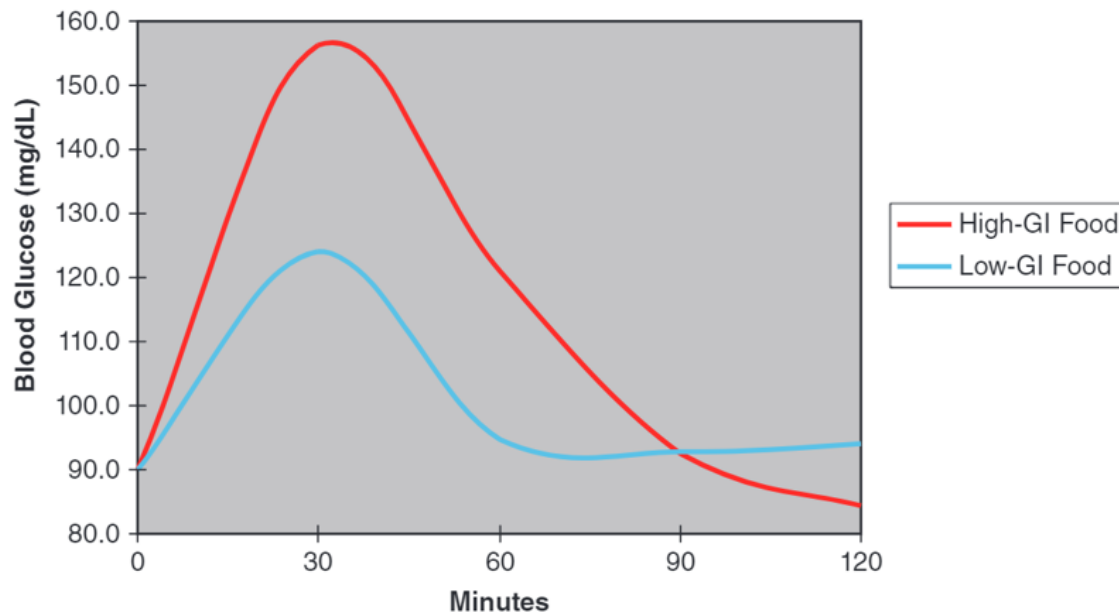
- ❑ **Glycemic index** measures how quickly carbohydrate in food is absorbed
- ❑ Factors that influence glycemic index (GI)
 - Starch structure, fiber content, presence of fat and protein, food processing, mixture of foods in a meal, and individual glucose tolerance
- ❑ Some research indicates low-GI diet may decrease risk for some chronic diseases
 - More research needed to confirm

Nutrition in Practice

The Glycemic Index in Nutrition Practice

Figure NP3-1 Blood Glucose Response to High-GI and Low-GI Foods

Foods that are digested slowly have a low glycemic index. These foods cause a gradual and more moderate response in blood glucose than do foods with a high glycemic index.



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