CARBOHYDRATES

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Overview
Carbohydrates

- Sources of Carbohydrates
  - Simple Sugars
  - Complex Carbohydrates
  - Dietary Fiber
- Digestion and Absorption
- Functions
- Blood glucose regulation
- Dietary sweeteners
- Dietary Recommendations

What are Carbohydrates?

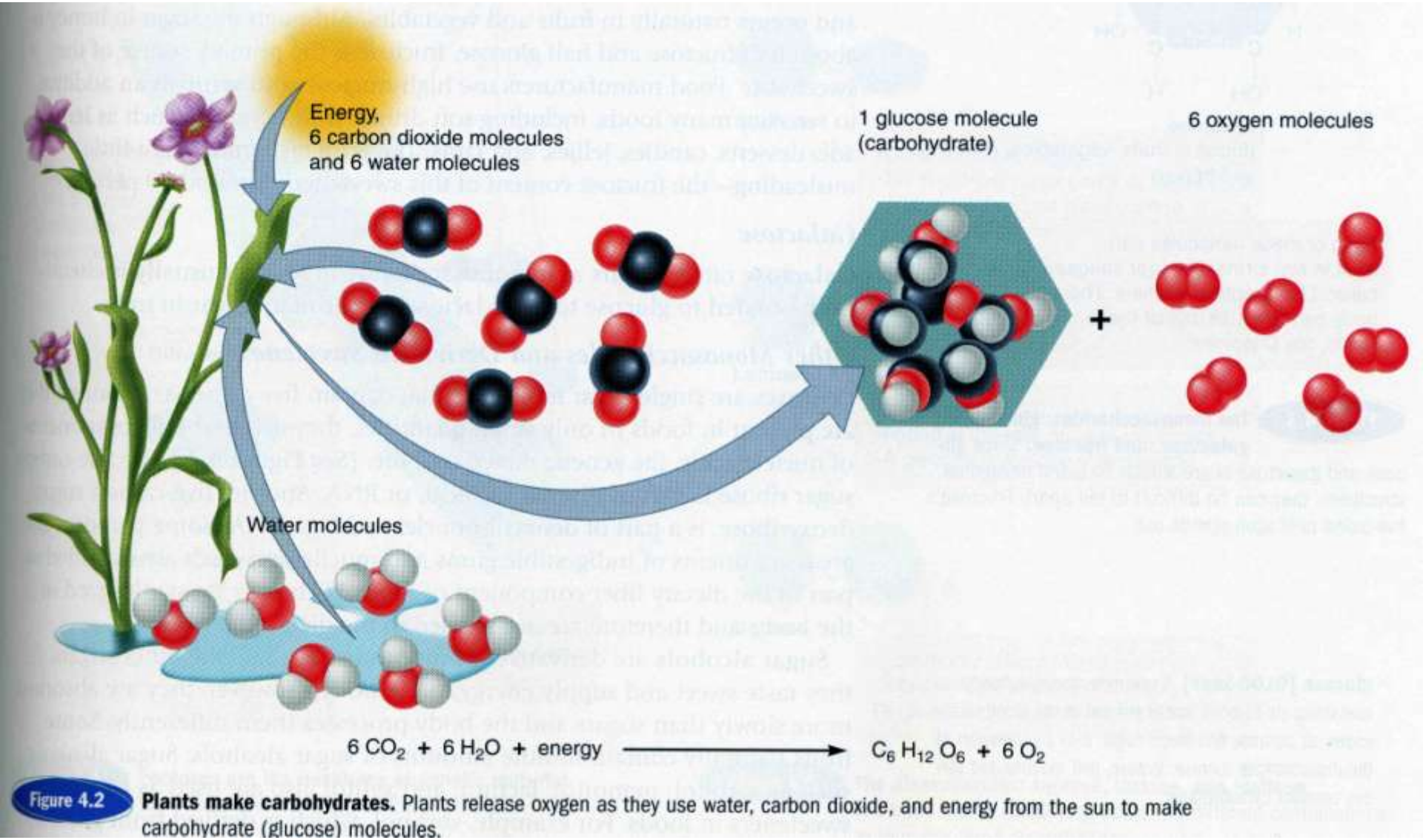


Figure 4.2 **Plants make carbohydrates.** Plants release oxygen as they use water, carbon dioxide, and energy from the sun to make carbohydrate (glucose) molecules.

Types of Carbohydrates

Simple Carbohydrates

- monosaccharides
- disaccharides

Complex Carbohydrates

- oligosaccharides
- polysaccharides
  - glycogen
  - starches
  - fibers

Monosaccharides: Single Sugars

Glucose

- carbohydrate form used by the body, referred to as “blood sugar”
- basic sub-unit of other larger carbohydrate molecules
- found in fruits, vegetables, honey

Glucose

Monosaccharides: Single Sugars

Fructose

- sweetest of the sugars
- occurs naturally in fruits & honey, “fruit sugar”
- combines with glucose to form sucrose

Galactose

- combines with glucose to form lactose, “milk sugar”

Disaccharides

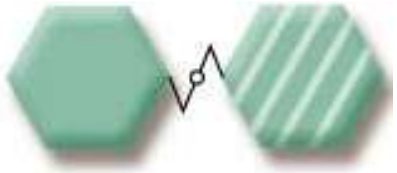
Sucrose (“table sugar”)

- glucose + fructose

Sucrose

Lactose (“milk sugar”)

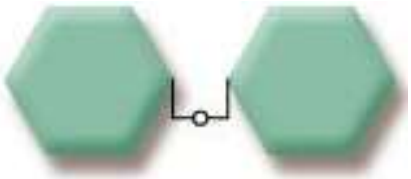
- glucose + galactose



Lactose

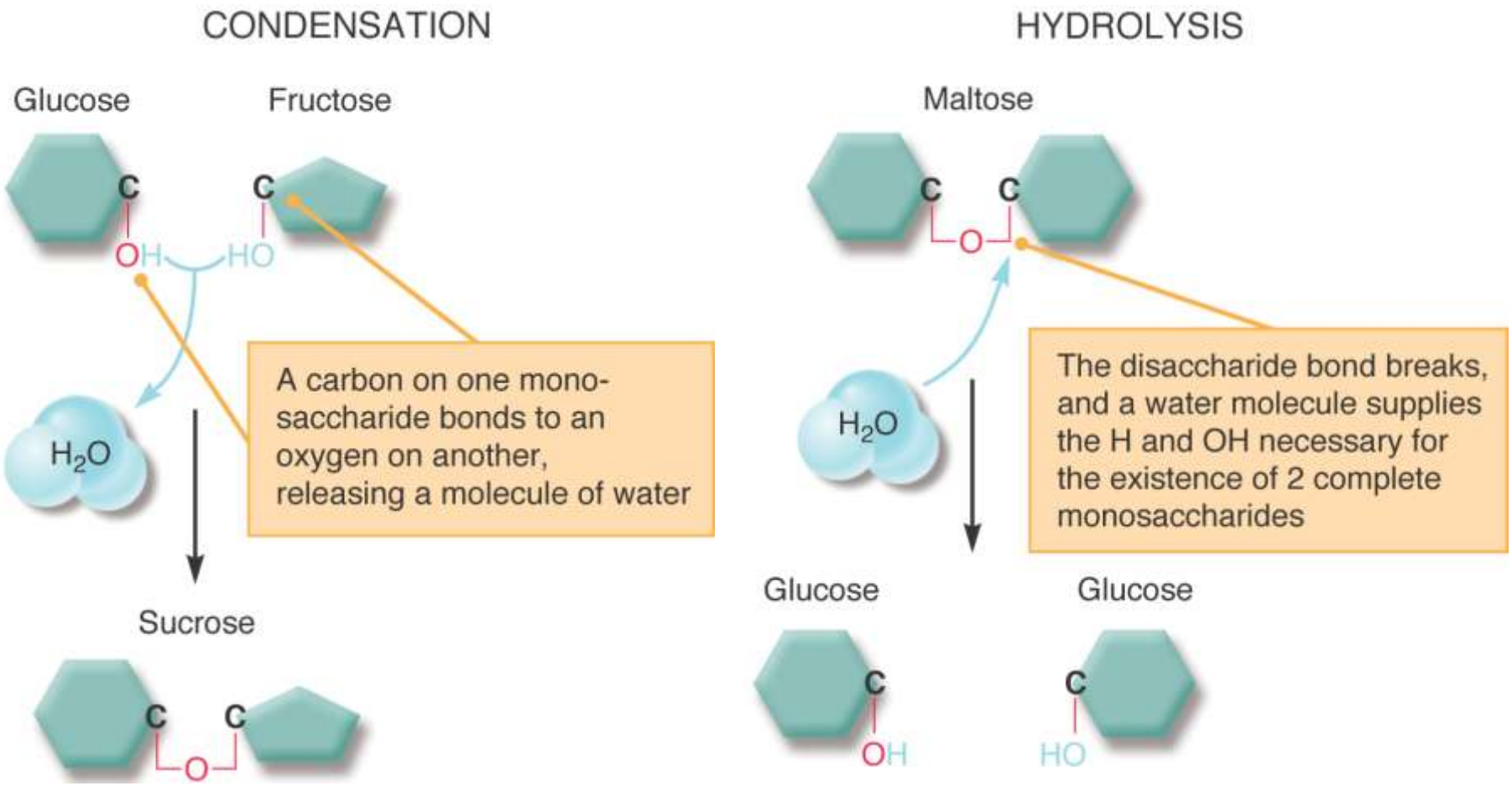
Maltose (“malt sugar”)

- glucose + glucose



Maltose

Joining and Cleaving Sugar Molecules

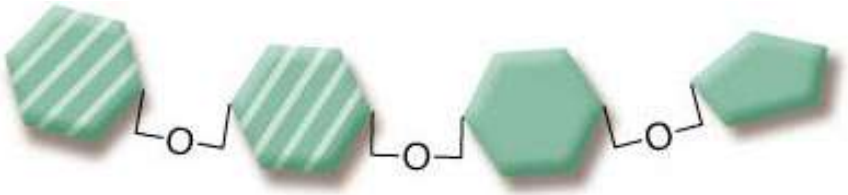


Complex Carbohydrates

Oligosaccharides

- short carbohydrate chains of 3 - 10 monosaccharides
- found in legumes and human milk
- Examples:
  - raffinose
  - stachyose

} cannot be broken down by human enzymes, though can be digested by colonic bacteria

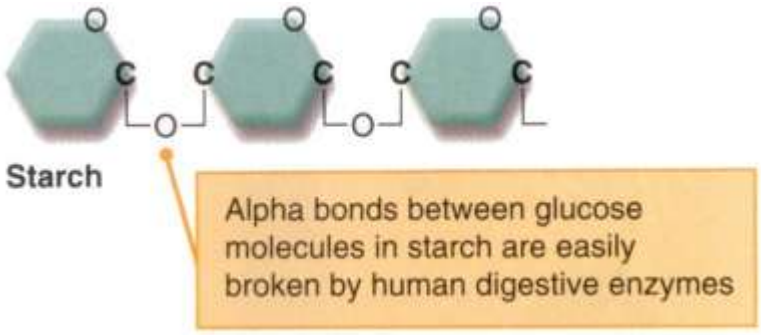


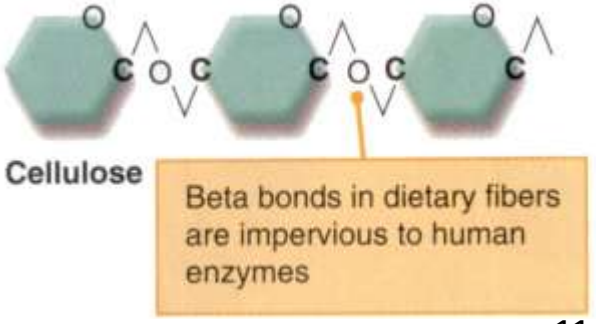
Stachyose

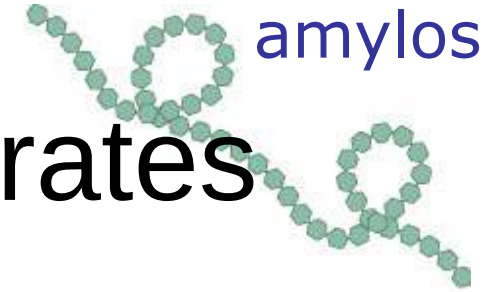
Complex Carbohydrates

Polysaccharides

- long carbohydrate chains of monosaccharides linked by glycosidic bonds
  - alpha (α) bonds (starch)
  - beta (β) bonds (found in fiber)





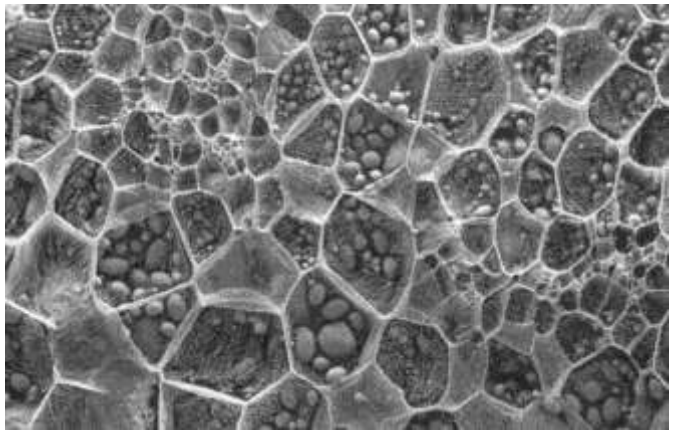


Complex Carbohydrates

Starch

- plant storage form of carbohydrate
- long branched or unbranched chains of glucose
  - amylose
  - amylopectin

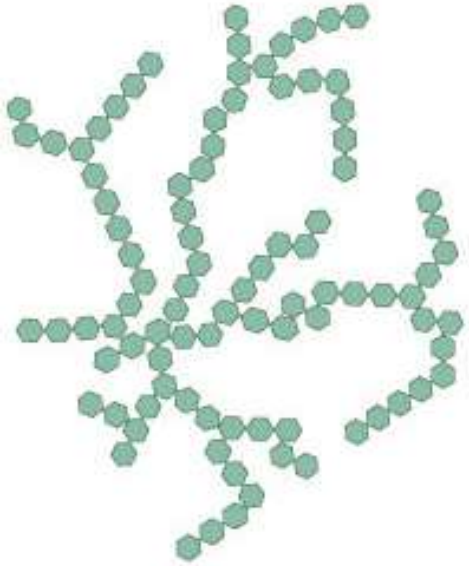
amylopectin



Complex Carbohydrates

Glycogen

- highly branched chains of glucose units
- animal storage form of carbohydrate
  - found in LIVER and MUSCLE
  - Humans store ~ 100g in liver; ~ 400g in muscle
- negligible source of carbohydrate in the diet (meat)



Glycogen

Complex Carbohydrates

Fiber

Dietary Fiber

- non-digestible carbohydrates (chains of monosaccharides) and lignin that are intact and intrinsic in plants (includes oligosaccharides)

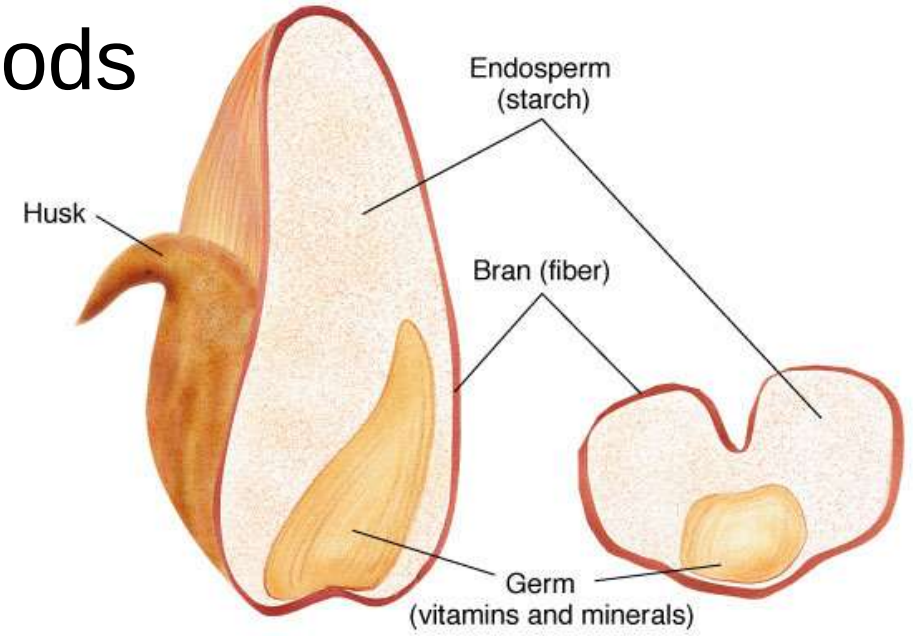
Functional Fiber

- isolated, non-digestible carbohydrates that have beneficial physiological effects in humans

Complex Carbohydrates

Fiber cont.

- dietary fiber found in all types of plant foods
- refining removes fiber from whole grains and other foods

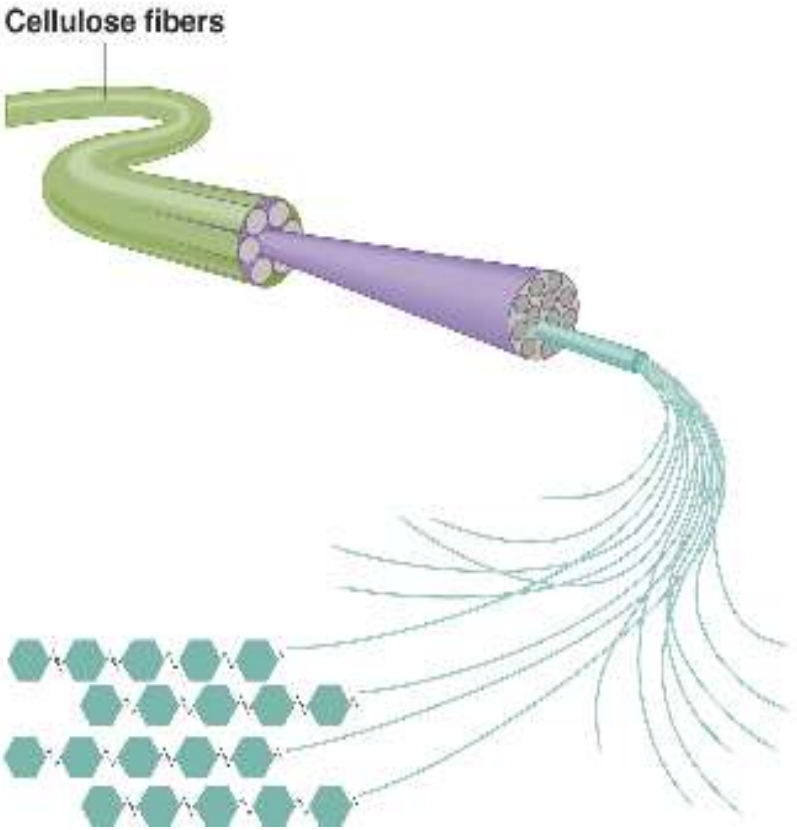


Complex Carbohydrates

Fiber cont.

- types of non-starch polysaccharides include:

cellulose
hemicelluloses
pectins
gums & mucilages
β-glucans
chitin & chitosan
lignans



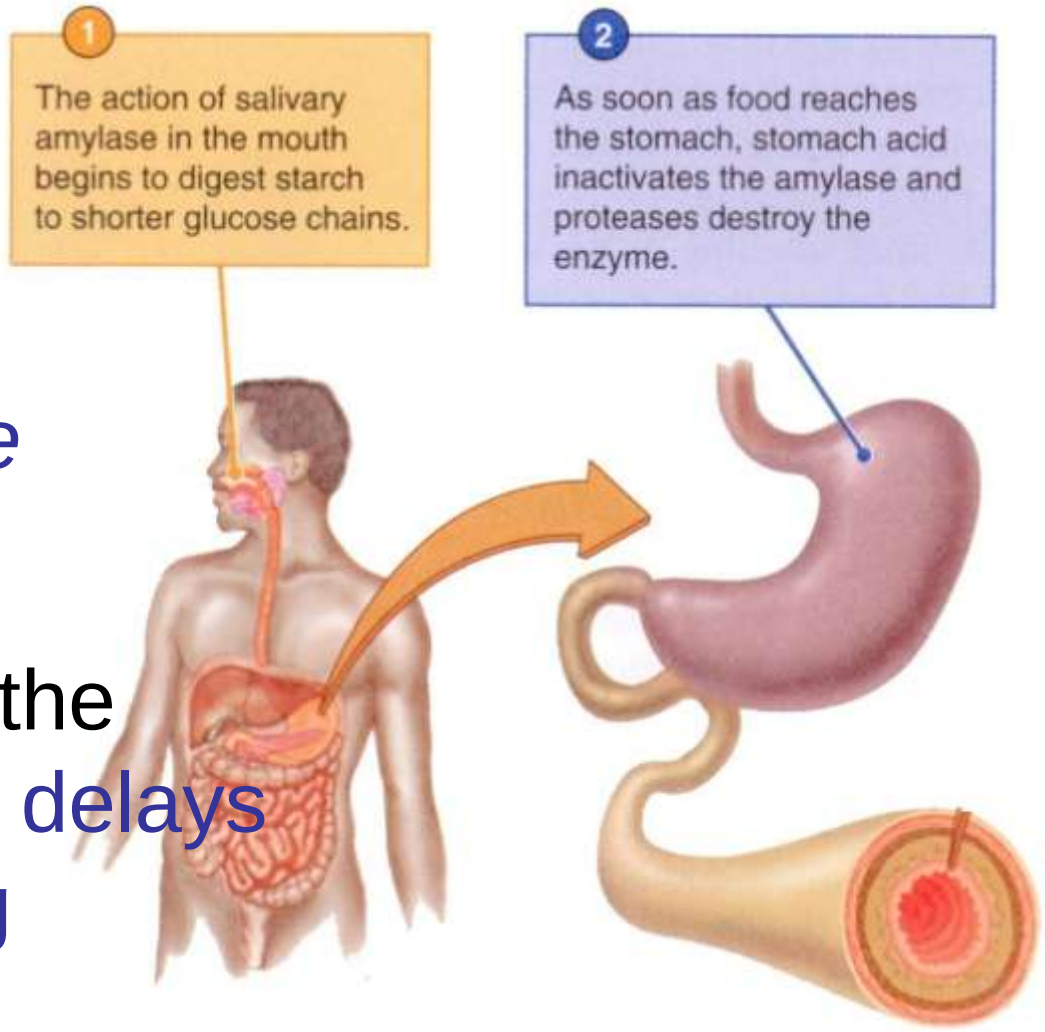
Digestion & Absorption

1. Mouth

- chewing
- *salivary amylase*

2. Stomach

- fibers remain in the stomach longer, delays gastric emptying



Digestion & Absorption

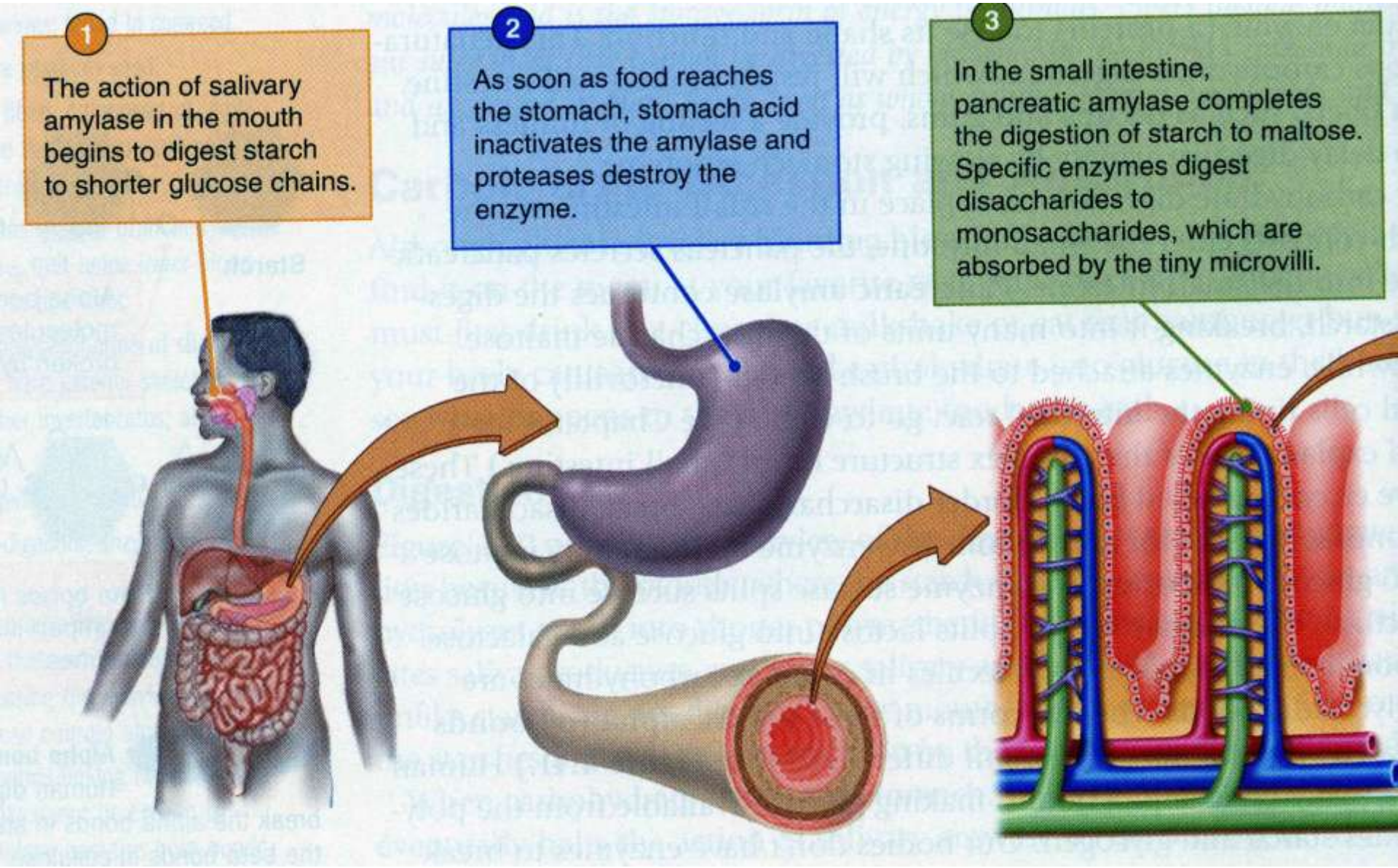
Small Intestine

- pancreas secretes enzyme *pancreatic amylase*
- enzymes located on the cell membranes of the intestinal epithelial cells complete digestion

maltose —***maltase***→ glucose + glucose

sucrose —***sucrase***→ glucose + fructose

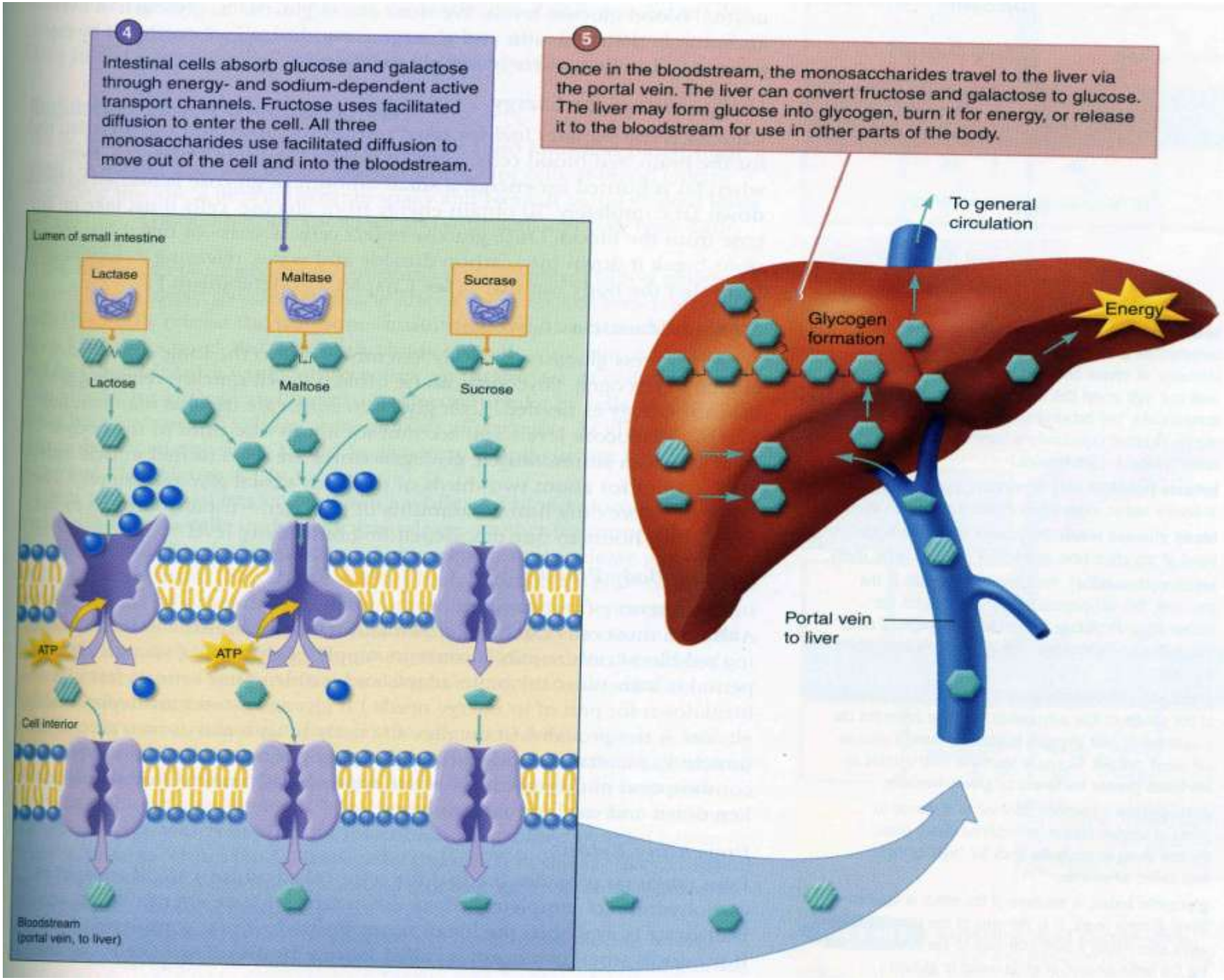
lactose —***lactase***→ glucose + galactose


1
The action of salivary amylase in the mouth begins to digest starch to shorter glucose chains.
2
As soon as food reaches the stomach, stomach acid inactivates the amylase and proteases destroy the enzyme.
3
In the small intestine, pancreatic amylase completes the digestion of starch to maltose. Specific enzymes digest disaccharides to monosaccharides, which are absorbed by the tiny microvilli.

Digestion & Absorption

Small Intestine cont.

- only monosaccharides can be absorbed
  - glucose & galactose absorbed by ACTIVE TRANSPORT
  - fructose absorbed by FACILITATED DIFFUSION
- all three monosaccharides travel in the portal vein to the liver
- three fates of glucose at the liver
  - Energy, storage as glycogen, released to blood


4
Intestinal cells absorb glucose and galactose through energy- and sodium-dependent active transport channels. Fructose uses facilitated diffusion to enter the cell. All three monosaccharides use facilitated diffusion to move out of the cell and into the bloodstream.
5
Once in the bloodstream, the monosaccharides travel to the liver via the portal vein. The liver can convert fructose and galactose to glucose. The liver may form glucose into glycogen, burn it for energy, or release it to the bloodstream for use in other parts of the body.
Lumen of small intestine
Lactase
Maltase
Sucrase
Lactose
Maltose
Sucrose
ATP
ATP
Cell interior
Bloodstream (portal vein, to liver)
To general circulation
Glycogen formation
Energy
Portal vein to liver

Digestion & Absorption

Large Intestine

- resistant starches and fibers may be digested by bacteria
  - produces ***short chain fatty acids***
    - absorbed by the intestine and used for energy (dietary fiber yields about 2 kcal/g)
    - other health benefits (more later in semester)

Lactose Intolerance

- occurs as a result of insufficient lactase & low lactase activity
- lactose molecules from milk remain in the intestine undigested
- **lactose intolerance ≠ milk allergy**
- undigested lactose digested by bacteria producing irritating acid and gas
  - symptoms include bloating, abdominal discomfort, diarrhea

Lactose Intolerance

- individuals who consume little or no milk products may be at risk of developing nutrient deficiencies
- dairy options: yogurt, aged cheddar, small quantities of milk (~ ½ cup), acidophilus milk, cottage cheese
- best to consume with other foods and spread intake throughout day
- gradual increases in milk intake may cause intestinal bacteria to adapt

Alternatives to Milk

1. Calcium

- canned fish with bones, bone soup stock, broccoli, cauliflower, bok choy, calcium fortified beverages, blackstrap molasses

2. Vitamin D

- 15 minutes exposure to SUNLIGHT several times per week
- fortified margarine, fortified cereals, fatty fish (herring, tuna, salmon, sardines), fortified soy or rice milk

3. Riboflavin

- beef, chicken, liver, clams, mushrooms, broccoli, breads, fortified cereals

Functions of Carbohydrates

1) Energy

- glucose fuels the work of most of the body's cells
  - preferred fuel of NERVOUS TISSUE (the brain, nerves) and RED BLOOD CELLS (RBC)
- excess glucose is stored as GLYCOGEN in liver and muscle tissue

Functions of Carbohydrates

2) Sparing Body Protein

- if diet does not provide enough glucose, then other sources of glucose must be found
- if carbohydrate intake **< 50 - 100 g**, body protein will be used to make glucose
- an adequate supply of carbohydrate spares body proteins from being broken down to synthesize glucose

Functions of Carbohydrates

3) Preventing Ketosis (Anti-ketogenic)

- carbohydrates required for the complete metabolism of fat
- incomplete fat metabolism produces KETONES
- an adequate supply of carbohydrate (> 50 – 100 g per day) prevents KETOSIS

Fiber

- beneficial for weight control by contributing to satiety & delay gastric emptying
- soluble fibers lower blood cholesterol to help reduce risk of cardiovascular disease
- minimizes risk of and helps control Type II Diabetes
- insoluble fibers help promote intestinal health by enlarging stool size and easing passage of stool

Soluble Fiber

- examples include gums, pectins, mucilages, some hemicelluloses
- functions:
  - delay gastric emptying
  - slow transit through the digestive system
  - delay glucose absorption
  - bind to bile, help decrease cholesterol
- food sources: fruits

Insoluble Fiber

- examples include cellulose, hemicellulose
- functions:
  - speed transit through the digestive tract
  - delay glucose absorption
  - increase fecal weight and soften stool to ease passage
  - reduces risk of hemorrhoids, diverticulitis and appendicitis
- food sources: cereal grains, legumes, vegetables, nuts

Fiber: Too much of a good thing?

Excessive amounts of fiber may lead to:

- displacement of other foods in the diet
- intestinal discomfort
- interference with the absorption of other nutrients

Regulation of Blood Glucose

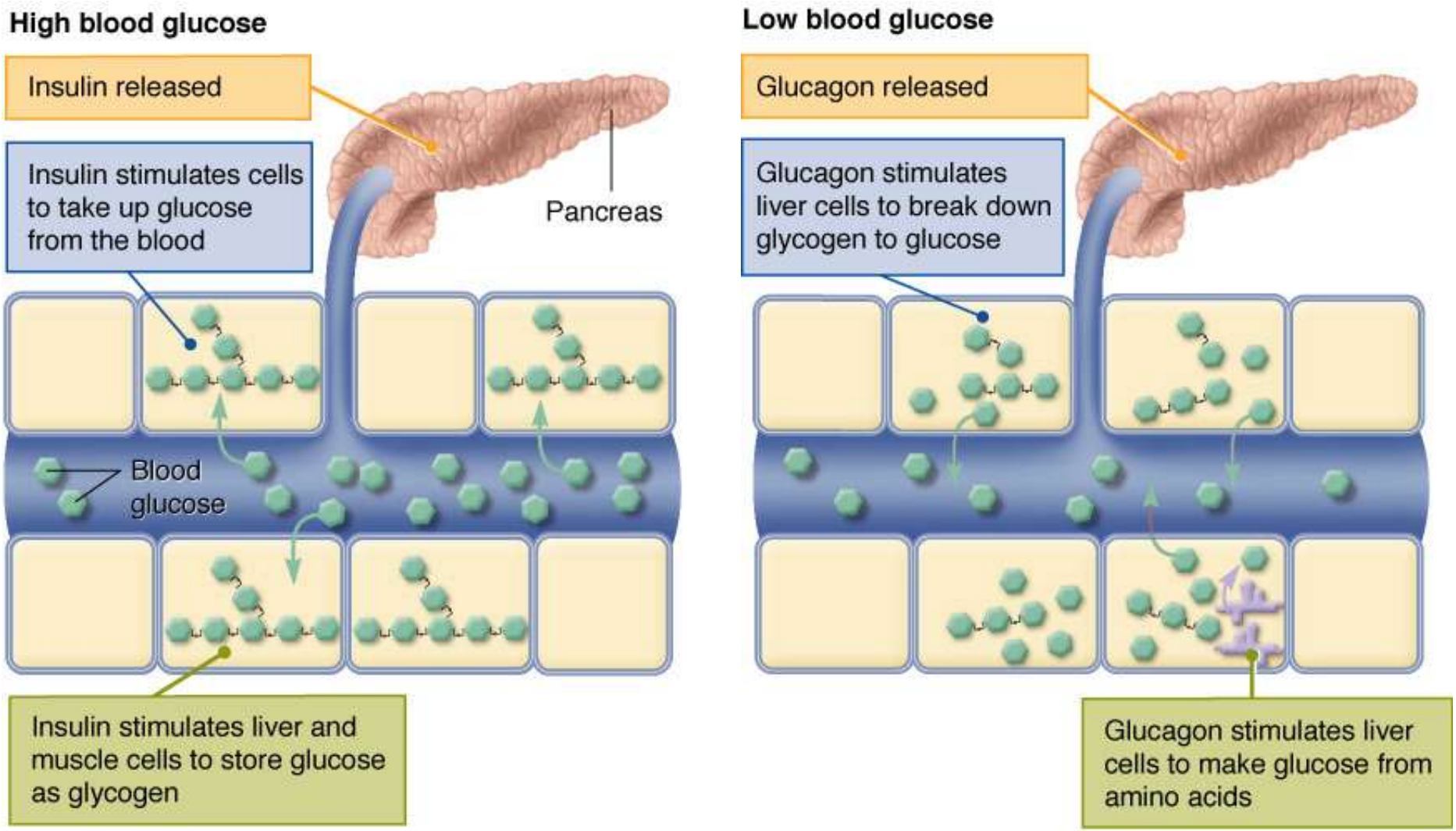
Optimal functioning of the body is dependant on keeping levels of glucose within certain parameters.

Elevated blood glucose = Hyperglycemia

Low blood glucose = Hypoglycemia

The ENDOCRINE SYSTEM is primarily responsible for regulating blood glucose. The two main hormones are INSULIN and GLUCAGON.

Regulation of Blood Glucose



Diabetes Mellitus

- a disorder of energy metabolism due to failure of insulin to regulate blood glucose
- results in hyperglycemia
- acute symptoms include thirst, increased urine production, hunger
- long term consequences include increased risk of heart disease, kidney disease, blindness, neural damage
- two forms: Type I and Type II

Diabetes Mellitus

Type I

- accounts for about 10% of cases
- occurs when **β cells** of the pancreas are destroyed
  - insulin cannot be synthesized
- without insulin, blood glucose levels rise because the tissues are unable to access the glucose
- death occurs shortly after onset unless given injections of insulin

Diabetes Mellitus

Type II

- occurs when cells of body are unable to respond to insulin
- called “insulin insensitivity” or “insulin resistance”
- blood glucose levels rise
- insulin secretion increases in an attempt to compensate
  - leads to **hyperinsulinemia**

Hypoglycemia

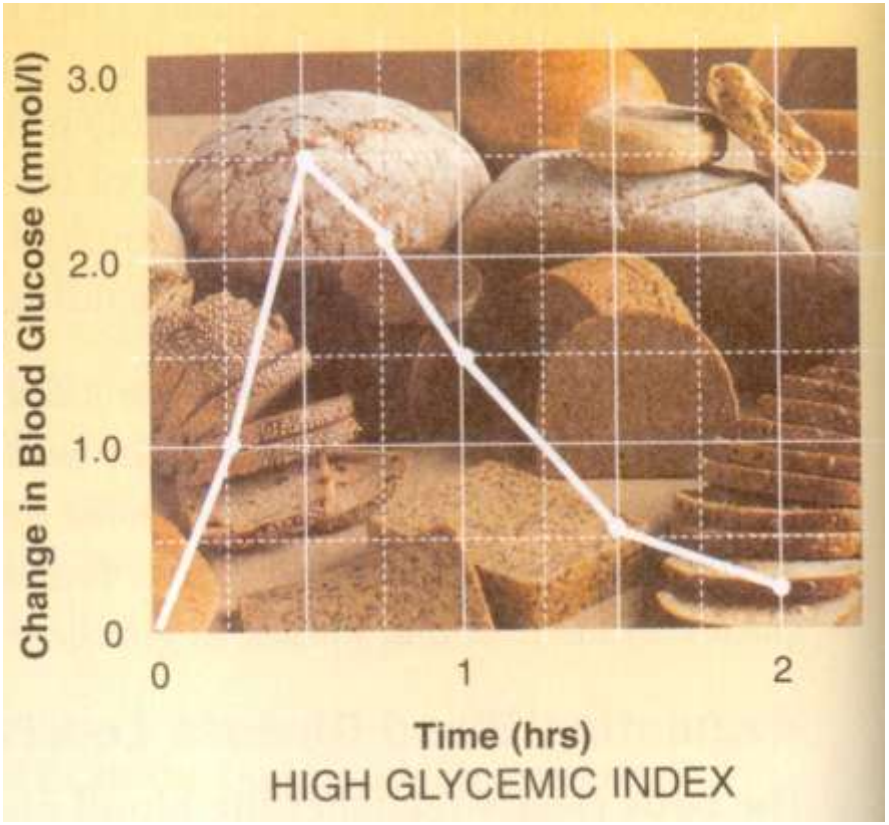
- dramatic drop in blood glucose
- symptoms similar to an anxiety attack: rapid weak heart beat, sweating, anxiety, hunger, trembling, weakness
- RARE in healthy people
- may occur as a result of poorly managed Diabetes or other causes:
  - reactive hypoglycemia
  - fasting hypoglycemia

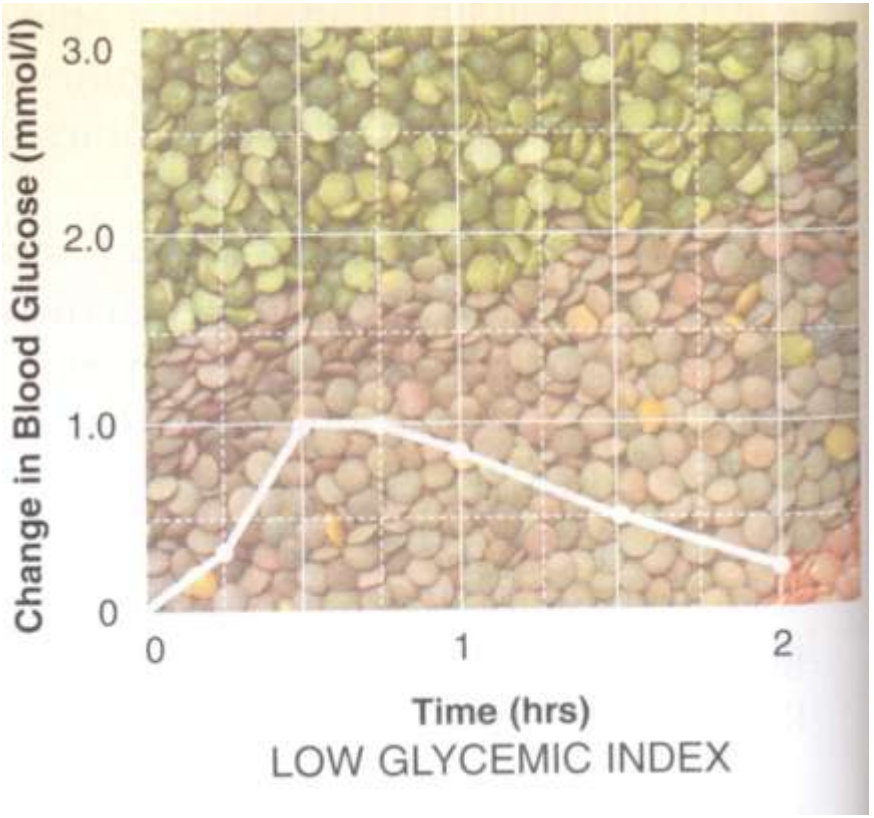
The Glycemic Index

- a measure of the extent to which a food raises blood glucose concentration & elicits an insulin response compared to pure glucose

Low	Moderate	High
pasta	banana	white bread
baked beans bran cereals	orange juice	cornflakes
apples	ice cream	potatoes
milk		jelly beans
		watermelon

The Glycemic Index





The Glycemic Index cont.

Glucose	100
Baked potato	85
Jelly bean	78
Honey	73
Bagel	72
Sucrose	65
Boiled new potato	62
Brown rice	55
Chocolate	49
Boiled carrots	47
Orange	44
Spaghetti	42
Apple	38
Skim milk	32
Lentils	29
Fructose	23

The Glycemic Index cont.

The Theory…

- consuming foods with a **low** glycemic index will minimize dramatic fluctuations in blood glucose
- this reduces the need for insulin secretion and may help manage Type II Diabetes

Evidence?

The Glycemic Index cont.

In Practice…

- the glycemic effect of a food may vary if consumed with other foods
- few foods have had their glycemic index determined
- the factors that contribute to a food's glycemic index are not fully understood and estimating the glycemic index is not intuitive
- eating **several small meals frequently** has similar metabolic effects on blood glucose as does consuming low glycemic index foods
- evidence of benefits is based on epidemiological studies

Sugar

In 2006, Canadians consumed an average 61 g/day of “added sugars” (> 14 tsps!)

A lot of sugar comes in sugar sweetened beverages


SUGAR
ONE DAY
11.9 teaspoons
ONE WEEK
1.7 cups
ONE MONTH
7.5 cups
ONE YEAR
45.3 pounds
LIFETIME
3,550 pounds

Sugar

Intrinsic sugars

- from intact fruits & vegetables

Added sugars

- saccharides added to foods & beverages by manufacturer, cook, or consumer

Free sugars

- added sugars + concentrated sugars (i.e. from honey, syrups, and juices)

Sugar

Why is sugar added to foods?

- flavour enhancement
- provide texture and colour
- permits fermentation
- adds bulk
- acts as a preservative
- balance acidity

Risks of Excess Consumption?

Which of the following are risks of excess sugar consumption?

- nutrient deficiencies?
- development of dental caries?
- development of Type II Diabetes? Obesity?
- hyperactivity in children?

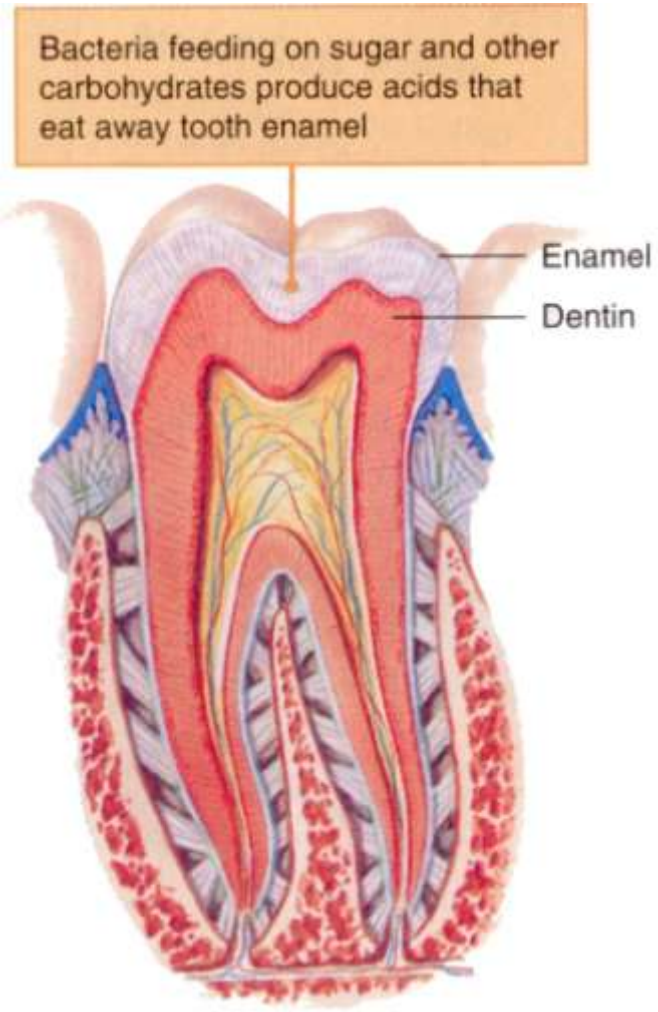
Empty Calories?

Compare:

	Honey	Coke	Apricots
Size of 100 kcal portion	1.5 tbsp	1 cup	6
Carbohydrate (g)	26	26	24
Protein (g)	trace	0	2
Calcium (mg)	2	6	30
Vitamin A (μg)	0	0	554
Vitamin C (mg)	trace	0	22

Dental Caries

Sugars, whether consumed from the diet or from complex carbohydrates partially digested in the mouth, contribute to tooth decay.



Which is more cariogenic?

more likely to cause cavities

Reducing risk of caries formation

- eat sugary foods with meals
- limit between meal snacks containing sugars and starches
- brush and floss teeth regularly
- if brush and flossing not possible, rinse teeth with water or chew sugar-free gum

Nutritive & Artificial Sweeteners

Nutritive Sweeteners

- imparts sweetness and provides energy
- includes natural sweeteners, refined sweeteners, and sugar alcohols

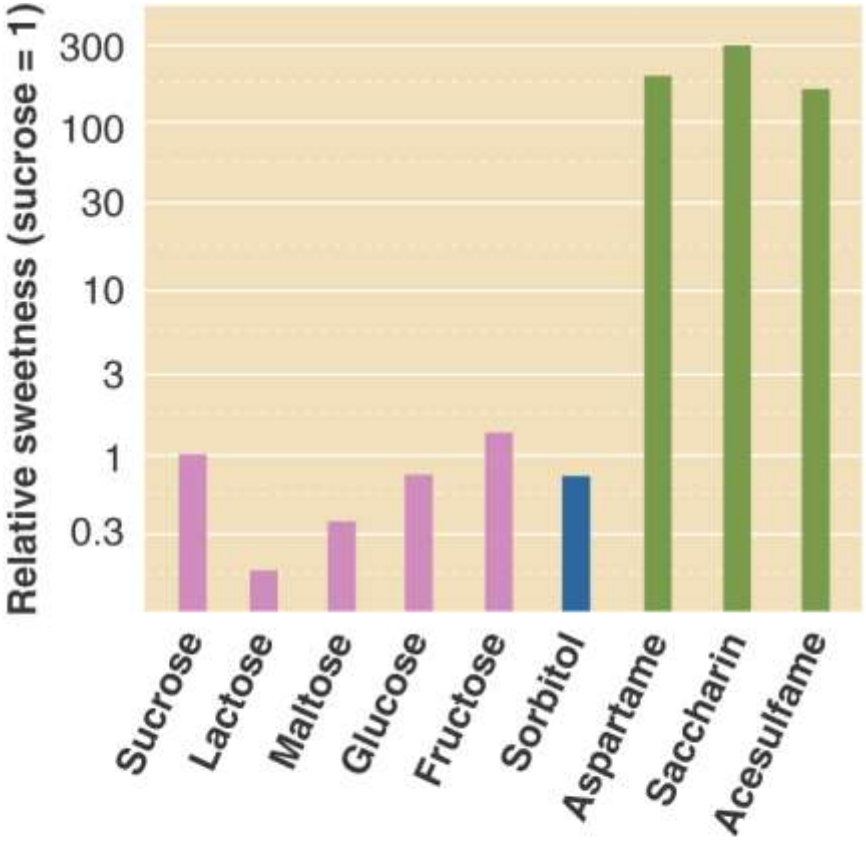
Refined Sweeteners

- composed of simple sugars extracted from other foods

Non-Nutritive (Artificial) Sweeteners

- impart sweetness but provide a negligible amount of energy

Nutritive & Artificial Sweeteners



Sugar Alcohols

- examples: sorbitol, mannitol, xylitol
- considered sugar replacers: use similar amount as sugar and provide about 2 kcal per gram
- only found in commercial foods (common in chewing gum)
- bacteria that produce cavity causing acid don’t metabolize sugar alcohols

Artificial Sweeteners

Aspartame

- 200x sweeter than sugar, yields 4 kcal per gram
- made of two amino acids:

PHENALANINE & ASPARTIC ACID

- individuals with PKU (genetic disorder) cannot convert **phenylalanine** to **tyrosine** effectively, increase's in blood phenylalanine concentration can be toxic

Artificial Sweeteners

Saccharin

- one study found that excess may cause bladder cancer in rats, but longitudinal human studies show no support for saccharin causing bladder cancer

Acesulfame K

- cannot be digested by the body thus provides no energy
- not affected by heat so can be used in cooking
- 200x sweeter than table sugar

Artificial Sweeteners

Sucralose

- made from sugar but does not contribute to energy because it is not digested
- approved by the FDA in U.S. in 1998, used in Canada since 1992
- sold under trade name Splenda
- 600x times sweeter than table sugar

Can sugar free help with weight loss?

How much carbohydrate do I need?

AMDR (Adults)

- **45 - 65%** of total average energy intake

RDA for Carbohydrates (Adults) = **130 g per day**

Daily Value (2000 kcal diet) = **300 g per day**

AI for Fiber (Adults)*

- Men: **38 g per day**
- Women: **25 g per day**

Sugar = **max 10% of energy intake**

**Note: after age 50, recommendations decrease to 30 and 21 g per day for men and women respectively.*

Sources of Carbohydrates

What do you need to eat to meet carbohydrate recommendations?

1 cup skim milk	= 12 g
1 cup non-fat yogurt (plain)	= 19 g
1 apple with skin (2.75” diameter)	= 21 g
1 orange (2.5” diameter)	= 15 g
1 slice bread (whole wheat)	= 13 g
1 cup Raisin Bran	= 47 g
1 cup white rice (enriched, cooked)	= 45 g
½ cup black beans (cooked)	= 20 g
½ cup carrots (boiled)	= 8 g
1 baked potato with skin	= 51 g

Grams of Carbohydrates in Food

What do you need to eat to meet fiber recommendations?

1 apple with skin (2.75” diameter)	= 3.7 g
1 peach (peeled, 2.5” diameter)	= 2.0 g
½ cup blueberries	= 2.0 g
½ cup lentils	= 7.8 g
½ cup broccoli (chopped)	= 3.0 g
½ cup sweet red pepper (raw, chopped)	= 1.0 g
½ cup peanuts (dried, salted)	= 6.0 g
½ cup almonds (dried, unsalted)	= 7.5 g
1 slice bread (whole wheat)	= 2.0 g
baked potato with skin	= 5.0 g

Grams of Fiber in Food

Carbohydrates in the Diet

Increase complex carbohydrate intake: whole grains, legumes, vegetables

- eat more breads, cereals, pasta, rice, fruits, vegetables & legumes
- eat fruits and vegetables with the peel
- add fruits to muffins and pancakes
- add legumes to casseroles and mixed dishes as a meat substitute

Sugar Recommendations

DRI:

- < 10% of average daily energy intake should be from sugars

Tips for limiting sugar intake:

- use **food labels** determine amount of sugar in products
- use **ingredient lists** to identify multiple sugar sources and added sugars
- use less added sugar
- limit soft drinks, juice, sugary cereals, candy
- choose fresh or frozen fruits