Bioorganic chemistry: amino acids,
peptides, proteins, enzymes
Carbohydrates, nucleic acids and lipids.

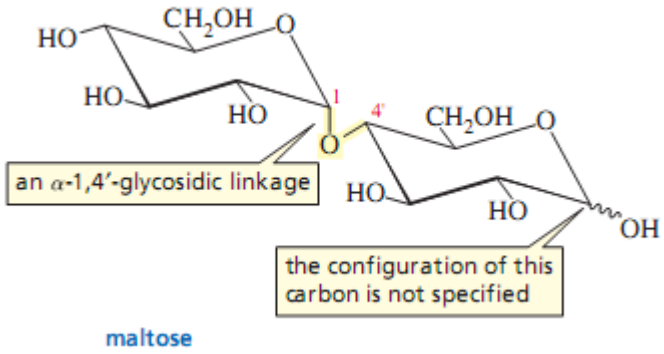
# Carbohydrate

Hydrates of Carbon $C_n(H_2O)_n$

Carbohydrate makes more than the 50%
dry weight of earth biomass.

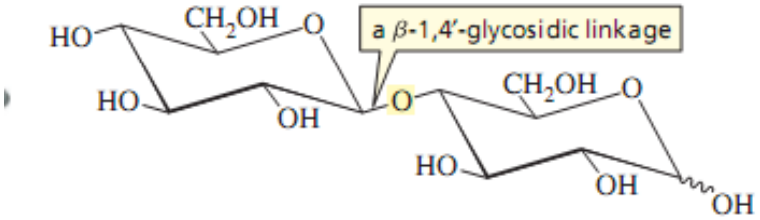
# Disaccharides

**Maltose :** A disaccharide of glucose linked by α-1,4'-glycosidic linkage



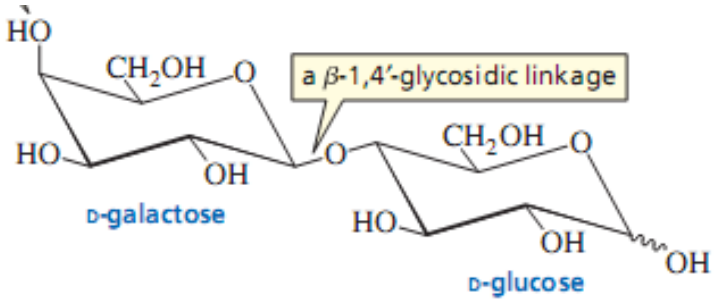

maltose

**Cellobiose :** A disaccharide of glucose linked by β-1,4'-glycosidic linkage

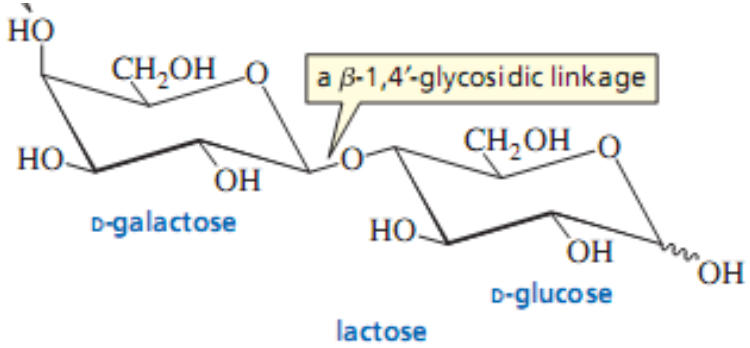


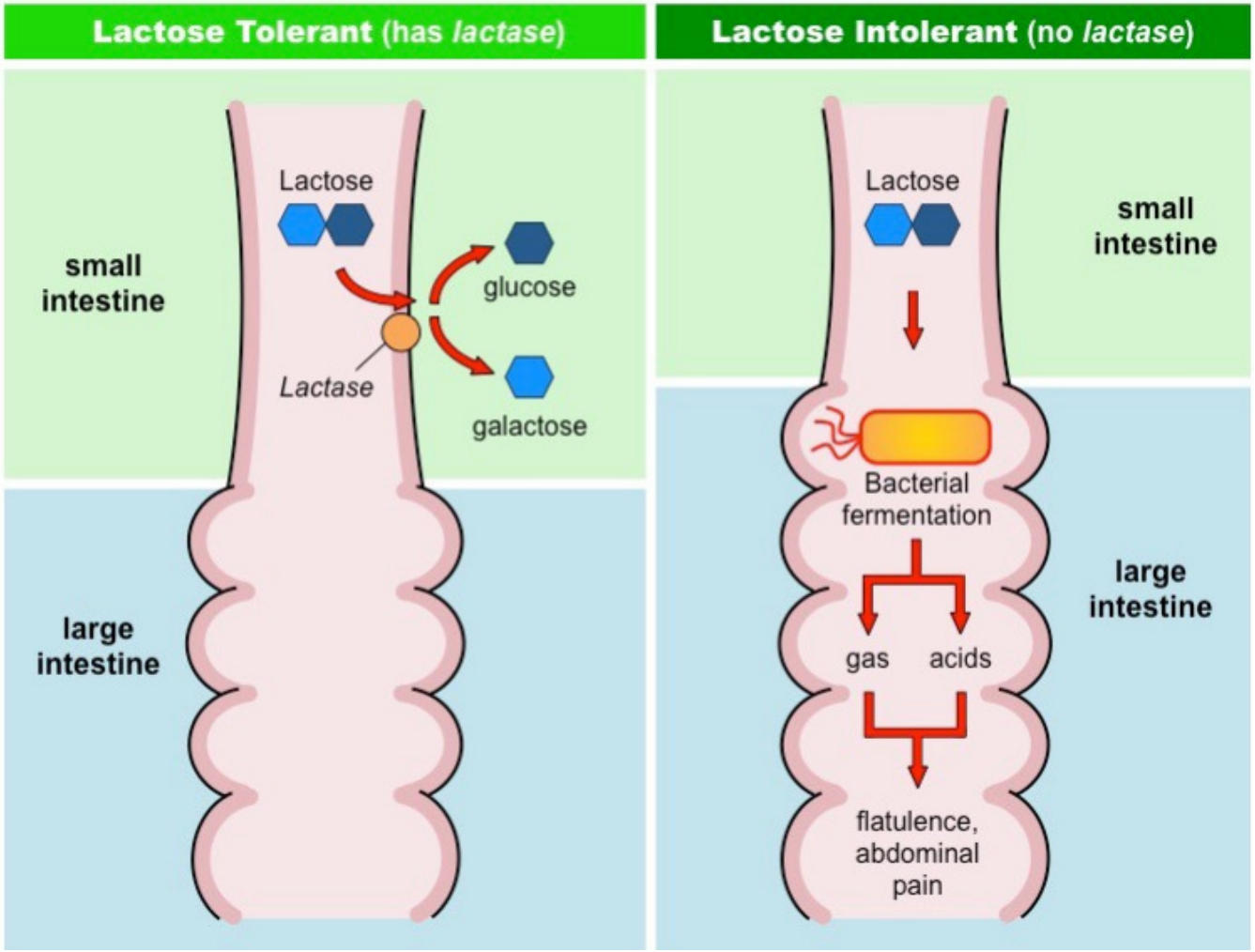

cellobiose

**Lactose :** A disaccharide of D-galactose and D-glucose linked by β-1,4'-glycosidic linkage



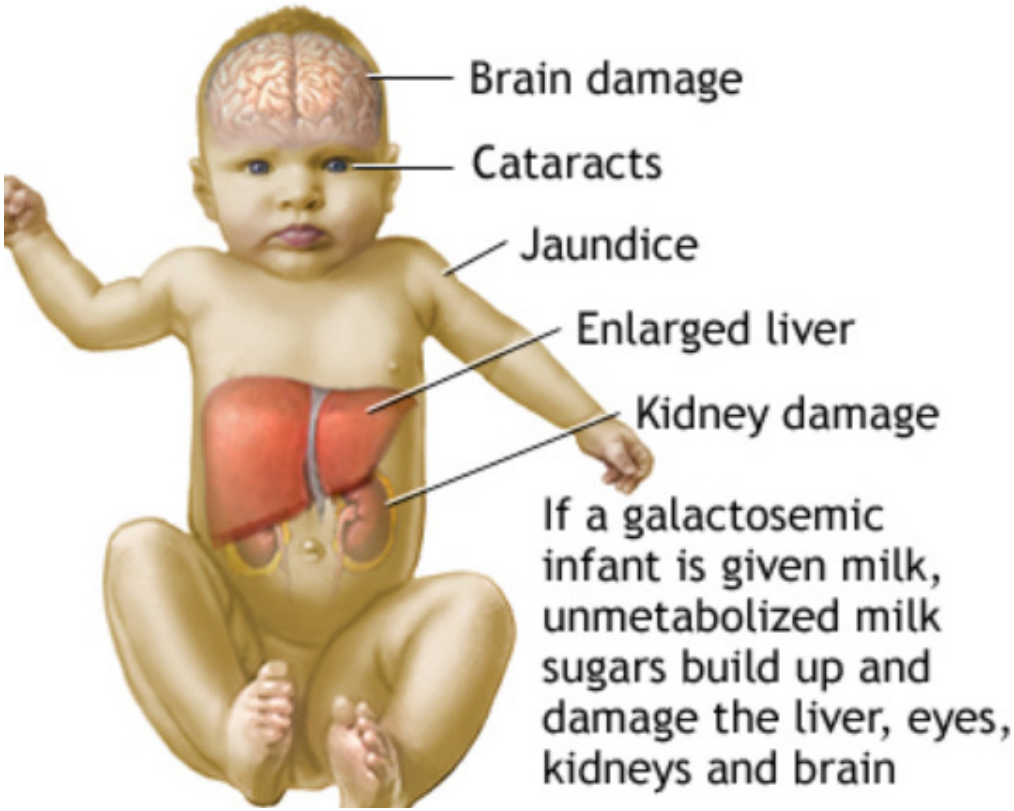

lactose


HO
CH2OH
O
a β-1,4′-glycosidic linkage
HO
OH
D-galactose
O
CH2OH
O
HO
OH
OH
D-glucose
lactose


Lactose Tolerant (has lactase)
Lactose
small intestine
glucose
Lactase
galactose
large intestine
Lactose Intolerant (no lactase)
Lactose
small intestine
Bacterial fermentation
large intestine
gas
acids
flatulence, abdominal pain

## LACTOSE INTOLERANCE

Lactase is an enzyme that specifically breaks the $\beta$-1,4′-glycosidic linkage of lactose. Cats and dogs lose their intestinal lactase when they become adults; they are then no longer able to digest lactose. Consequently, when they are fed milk or milk products, the undegraded lactose causes digestive problems such as bloating, abdominal pain, and diarrhea. These problems occur because only monosaccharides can pass into the bloodstream, so lactose has to pass undigested into the large intestine. When humans have stomach flu or other intestinal disturbances, they can temporarily lose their lactase, thereby becoming lactose intolerant. Some humans lose their lactase permanently as they mature. Approximately 10% of the adult Caucasian population of the United States has lost its lactase. Lactose intolerance is much more common in people whose ancestors came from nondairy-producing countries. For example, only 3% of Danes but 97% of Thais, are lactose intolerant.




## GALACTOSEMIA

After lactose is degraded into glucose and galactose, the galactose must be converted into glucose before it can be used by cells. Individuals who do not have the enzyme that converts galactose into glucose have the genetic disease known as galactosemia. Without this enzyme, galactose accumulates in the bloodstream. This can cause mental retardation and even death in infants. Galactosemia is treated by excluding galactose from the diet.

# What Causes Galactosemia

- Galactosemia is inherited.
- A person with galactosemia inherited it from both parents just as he or she inherited hair, skin or eye color.
- This is not something person will outgrow.
- He will always have it.
- Therefore, he may have additional health needs as she/he grows older.
- Galactosemia is not contagious.

## INVERT SUGAR

- Sucrose is **dextrorotatory**,because glucose and fructose(furanose form) are dextrorotatory.
- When sucrose is **hydrolysed** it becomes **levorotatory**(its fructose is released in pyranose form that is levorotatory).
- Levorotatory activity of fructose is more than glucose.
- Because rotation is reversed the process is called **INVERSION** and the products are called **INVERT SUGAR**.

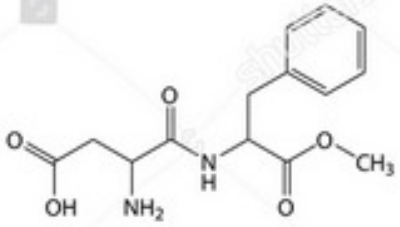
# ARTIFICIAL SWEETENERS

*A quick guide to sugar substitutes*

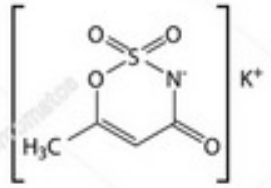
| | CHEMICAL NAME | MARKET ENTRY DATE | POPULAR USES | SWEETNESS |
|---|---|---|---|---|
|   | Aspartame | 1981 | Mainly used as a tabletop sweetener to replace sugar<br>Loses sweetness when heated, thus useful in frozen and uncooked desserts | 200 times sweeter than sugar |
|   | Acesulfame potassium (Ace-K) | 1988 | Frequently used as an ingredient in other sweeteners i.e. Aspartame/Equal<br>Contains no calories or carbohydrates, making it popular with diabetics | 200 times sweeter than sugar |
|   | Saccharin | 1879 (yup!) | Ideal for tabletop use and dissolves easily in liquids<br>Maintains sweetness at any temperature, meaning you can freeze or bake with it | 300-400 times sweeter than sugar |
|   | Sucralose | 1998 | Maintains sweetness when heated, making it popular to bake with<br>Doesn't raise insulin levels so popular among diabetics | 600 times sweeter than sugar |
| neotame | Neotame | 2002 | Not found in packets but is approved as a general tabletop sweetener<br>Currently used in over 1,000 sugar-free products | 7,000-13,000 times sweeter than sugar |

| Relative Sugar Sweetness Scale | |
|---|---|
| *(Sucrose = 1)* | |
| Lactose | 0.16 |
| Galactose | 0.32 |
| Maltose | 0.33 |
| Glucose | 0.74 |
| Sucrose | 1.00 |
| Invert Sugar | 1.25 |
| Fructose | 1.73 |
| Sodium cyclamate | 30 |
| Aspartame | 180 |
| Saccharin | 450 |
| Sucralose | 600 |

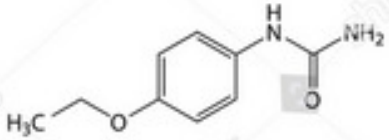
# Artificial Sweeteners



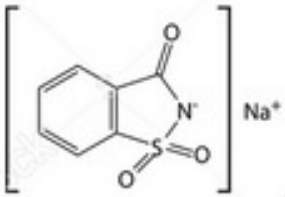
Aspartame (E951)



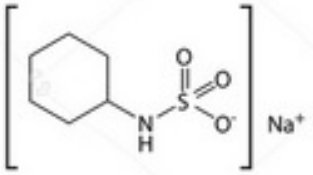
Acesulfame (E950)



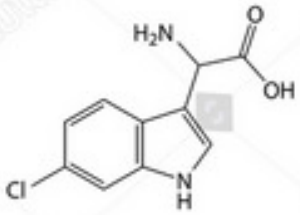
Dulcin



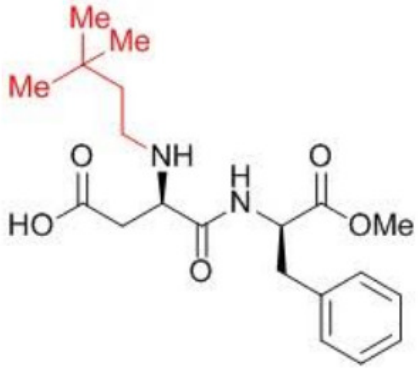
Saccharin (E954)



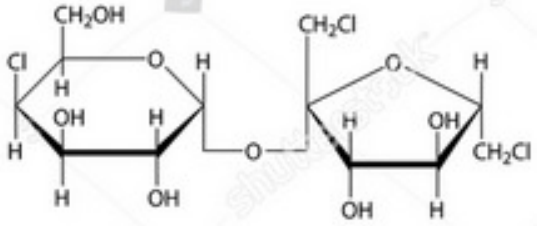
Cyclamate (E952)



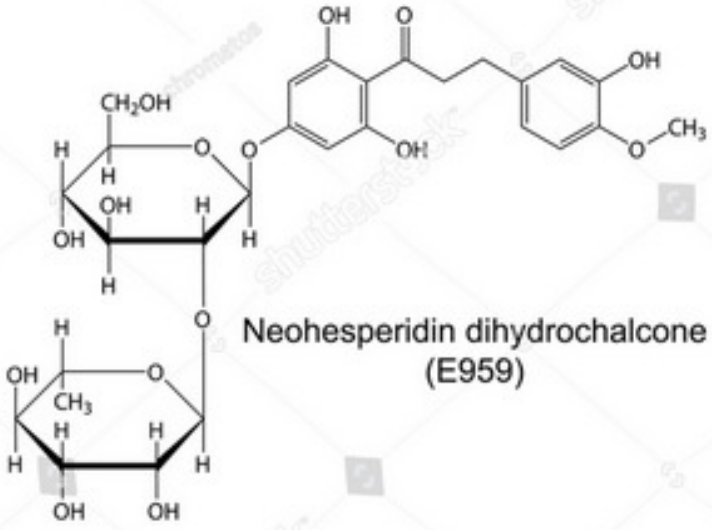
6-Chloro-Tryptophan



**Neotame**

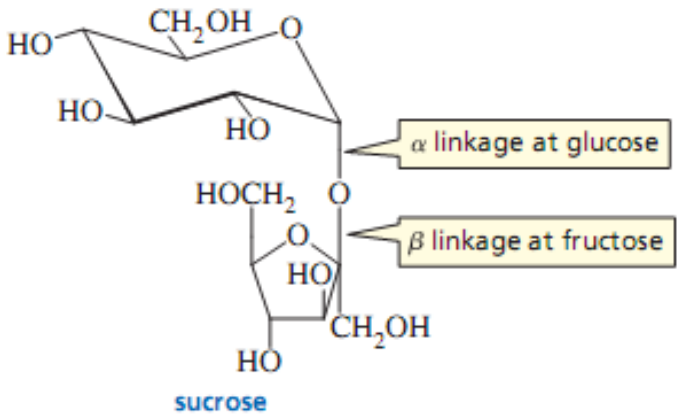


Sucralose (E959)



Neohesperidin dihydrochalcone (E959)

**Sucrose:** A disaccharide of D-Glucose and D-fructose linked by α-1,4'-glycosidic linkage




**Inverted Sugar:**

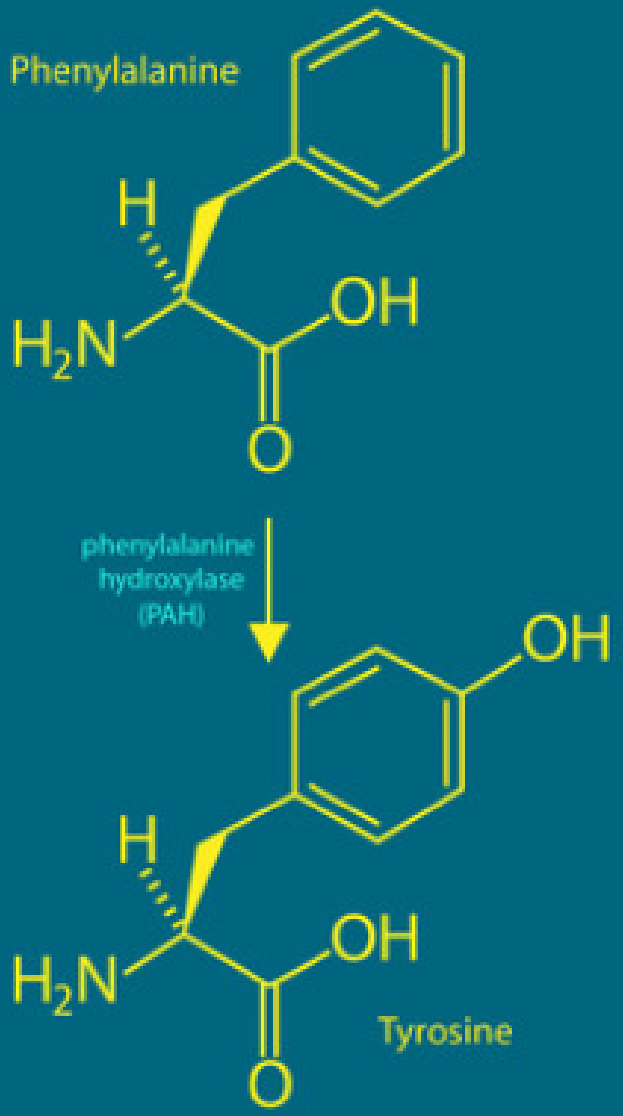
Sucrose has a specific rotation of +66.5°. When it is hydrolyzed, the resulting equimolar mixture of glucose and fructose has a specific rotation of −22.0°. Because the sign of the rotation changes when sucrose is hydrolyzed, a 1 : 1 mixture of glucose and fructose is called *invert sugar*. The enzyme that catalyzes the hydrolysis of sucrose is called *invertase*. Honeybees have invertase, so the honey they produce is a mixture of sucrose, glucose, and fructose. Because fructose is sweeter than sucrose, invert sugar is sweeter than sucrose. Some foods are advertised as containing fructose instead of sucrose, which means that they achieve the same level of sweetness with a lower sugar content.

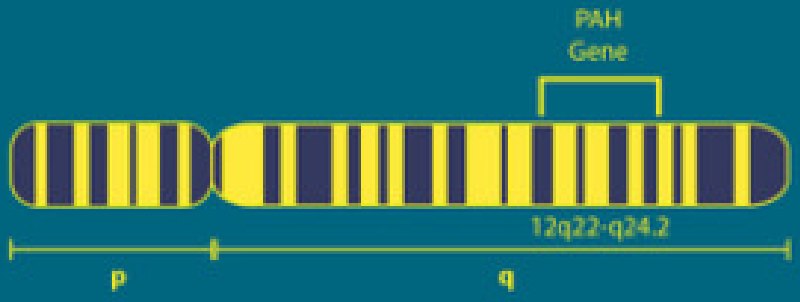
# Who can not tolerate Aspartame and Neotame?

## WHAT IS PKU?

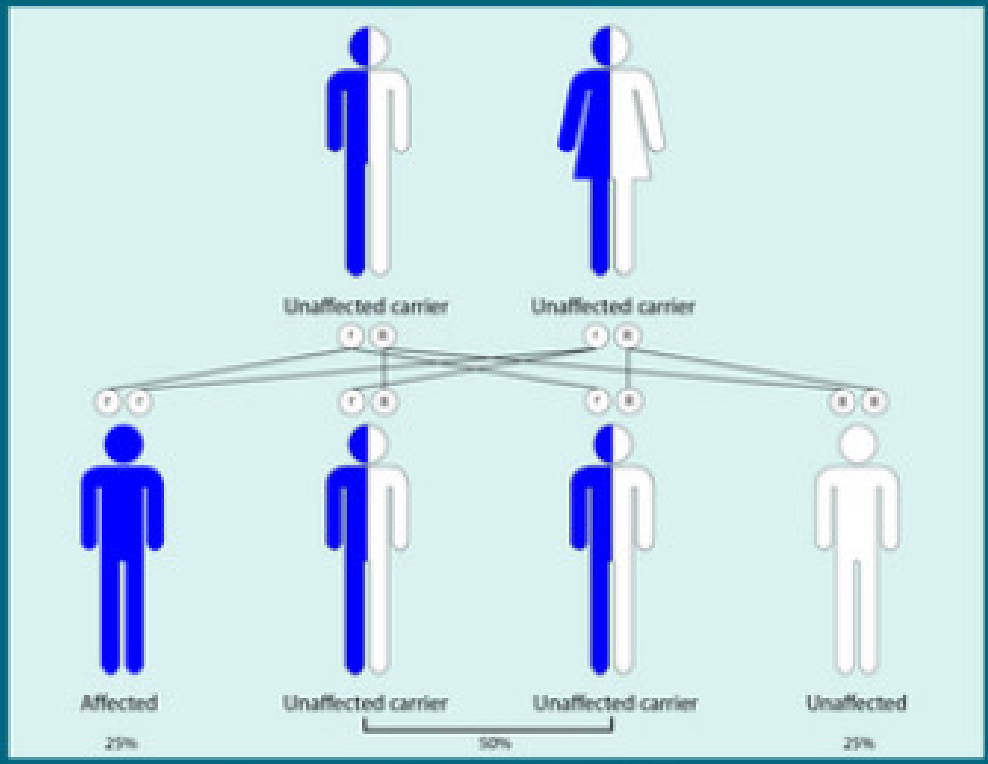
PKU (phenylketonuria), in its "classic" form, is a rare, inherited metabolic disease that results in mental retardation and other neurological problems when treatment is not started within the first few weeks of life. .

# Phenylketonuria (PKU)




Chromosome 12




Autosomal Recessive Inheritance

# Overview

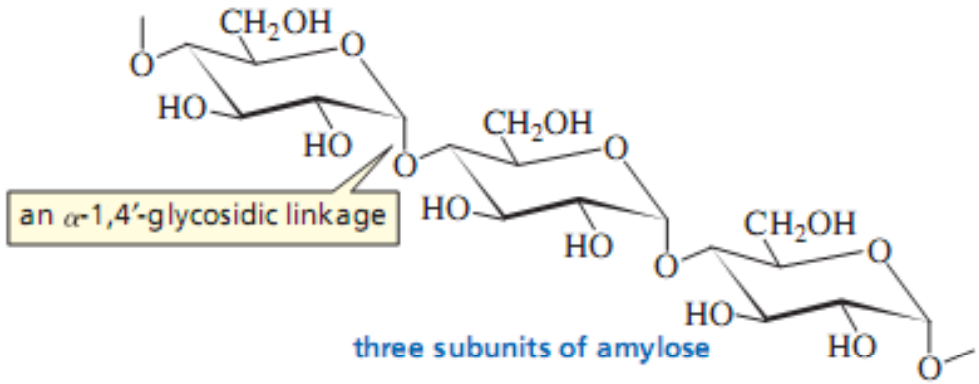
- Untreated PKU can lead to intellectual disability, seizures, and other serious medical problems.
- Patients who are diagnosed early and maintain a strict diet can have a normal life span with normal mental development.
- PKU is rare – it is estimated to affect 1 in every 10,000 babies.

# Polysaccharides

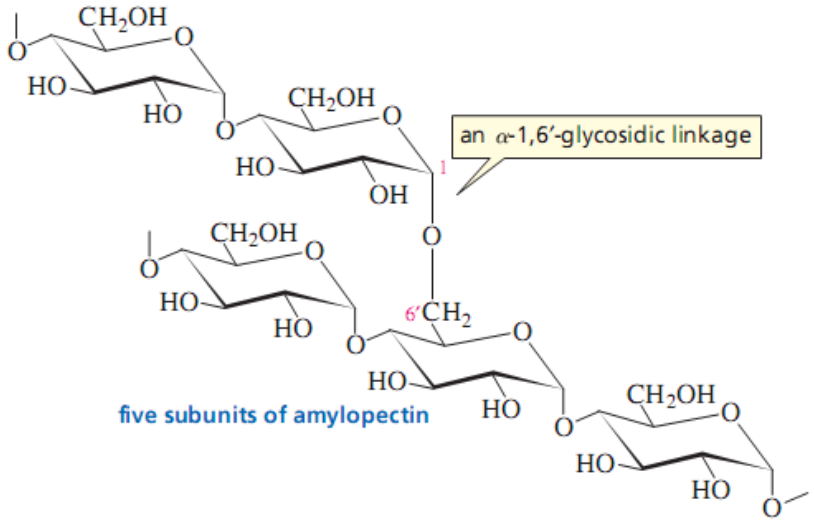
**Starch and Cellulose are the most common**

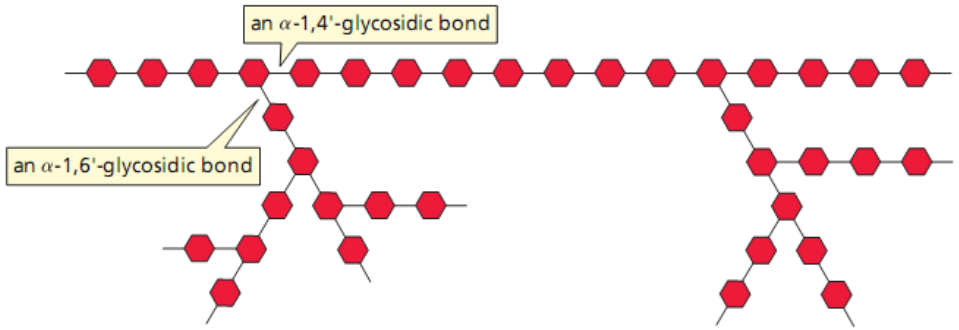
**Starch is a mixture of two different polysaccharide: amylase (~20%) and amylopectin (~80%)**

**Amylase is composed of chain of D-glucose units join by α-1,4' glycosidic linkage.**

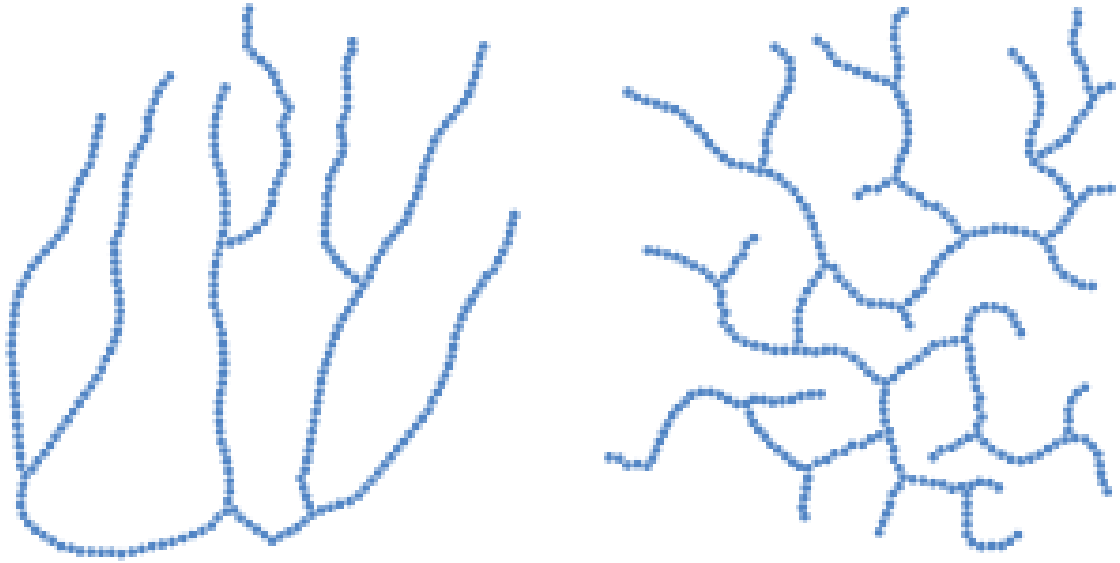



**Amylopectin is composed of chain of D-glucose units join by α-1,4' glycosidic linkage and α-1,6'-glycosidic linkage.**



**Glycogen : Similar to amylopectin except more branching is observed.**

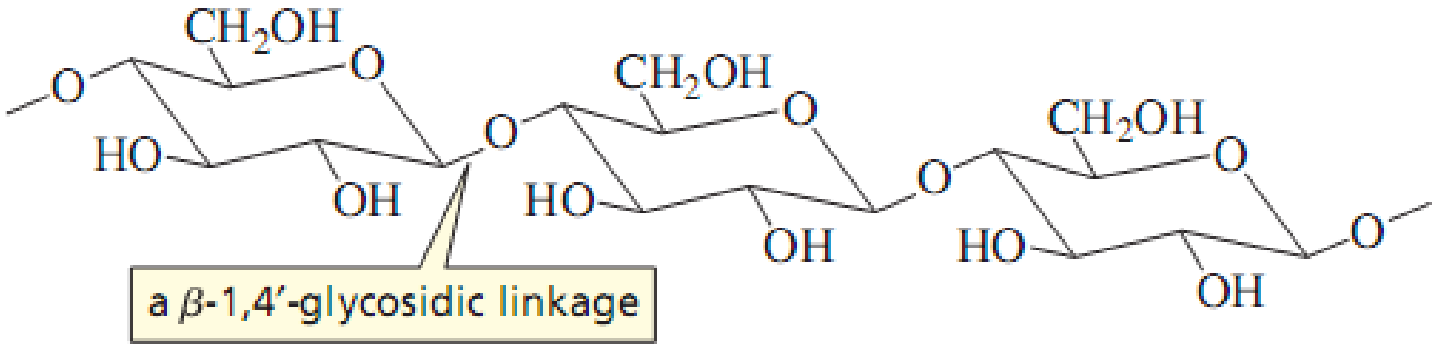



**Animals store their excess glucose in a polysaccharide. The branching point occur every 10 residues, where are those in amylopectin occur about every 25 residue. When body needs many individual glucose units can be simultaneously removed from the ends of many branches**

## WHY THE DENTIST IS RIGHT

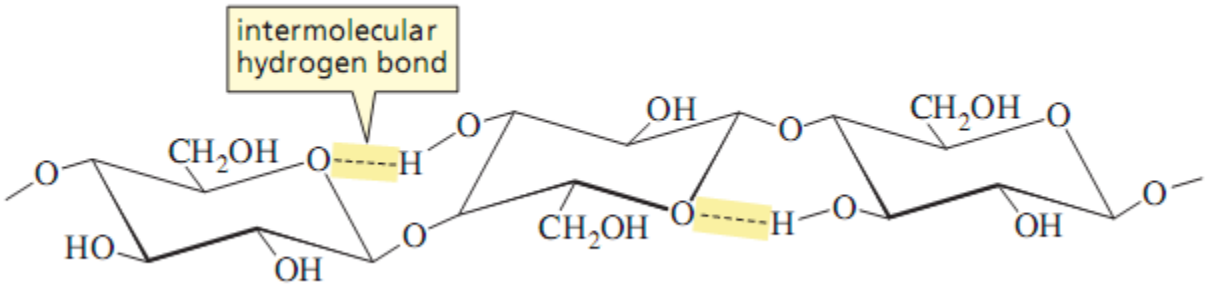
Bacteria found in the mouth have an enzyme that converts sucrose into a polysaccharide called dextran. Dextran is made up of glucose units joined mainly through $\alpha$-1,3′- and $\alpha$-1,6′-glycosidic linkages. About 10% of dental plaque is composed of dextran. This is the chemical basis of why your dentist cautions you not to eat candy.

**Cellulose :** **Similar to starch but the linkage is β-1,4'-glycosidic instead of α-1,4'-glycosidic.**



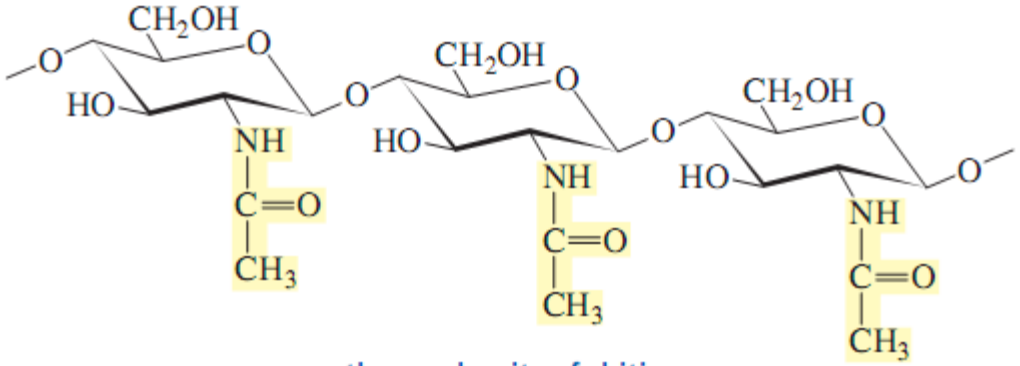

**Most animals have α-glycosidase enzyme which hydrolyze α-1,4'-glycosidic bond to give glucose but there is no corresponding β-glycosidase enzyme to hydrolyze cellulose.**

**Figure 22.4** ▶
The $\beta$-1,4′-glycosidic linkages in cellulose form intramolecular hydrogen bonds, which cause the molecules to line up in linear arrays.



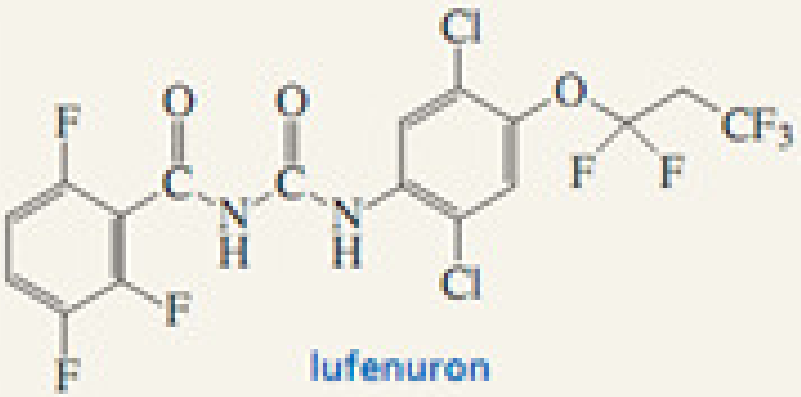

**Chitin: Similar to cellulose having β-1,4'-glycosidic linkage which is the structural component of crustaceans (e.g. lobsters, crabs, and shripms). But N-acetylamino group is present instead of OH at the C-2 position.**

▲ The shell of this bright orange crab from Australia is composed largely of chitin.

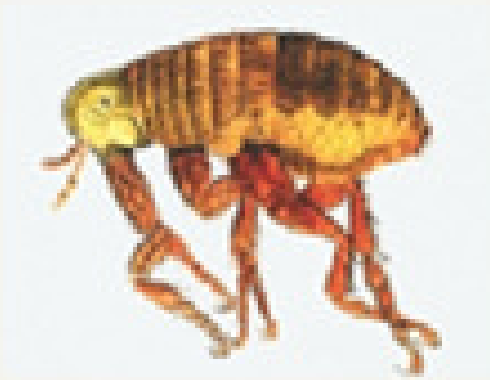


# CONTROLLING FLEAS

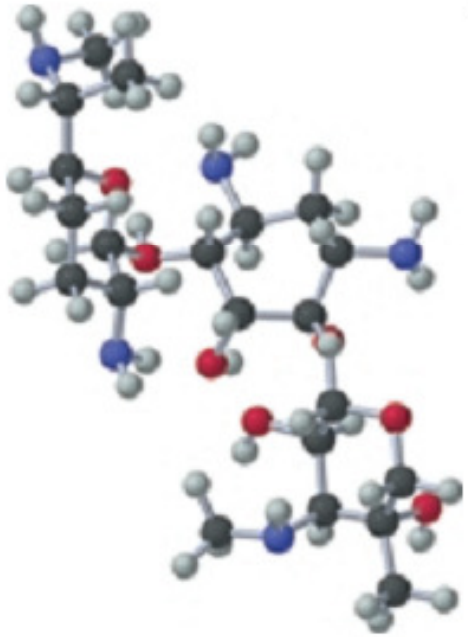
Several different drugs have been developed to help pet owners control fleas. One of these drugs is lufenuron, the active ingredient in Program®. Lufenuron interferes with the production of chitin. Since the exoskeleton of a flea is composed primarily of chitin, a flea cannot live if it cannot make chitin.

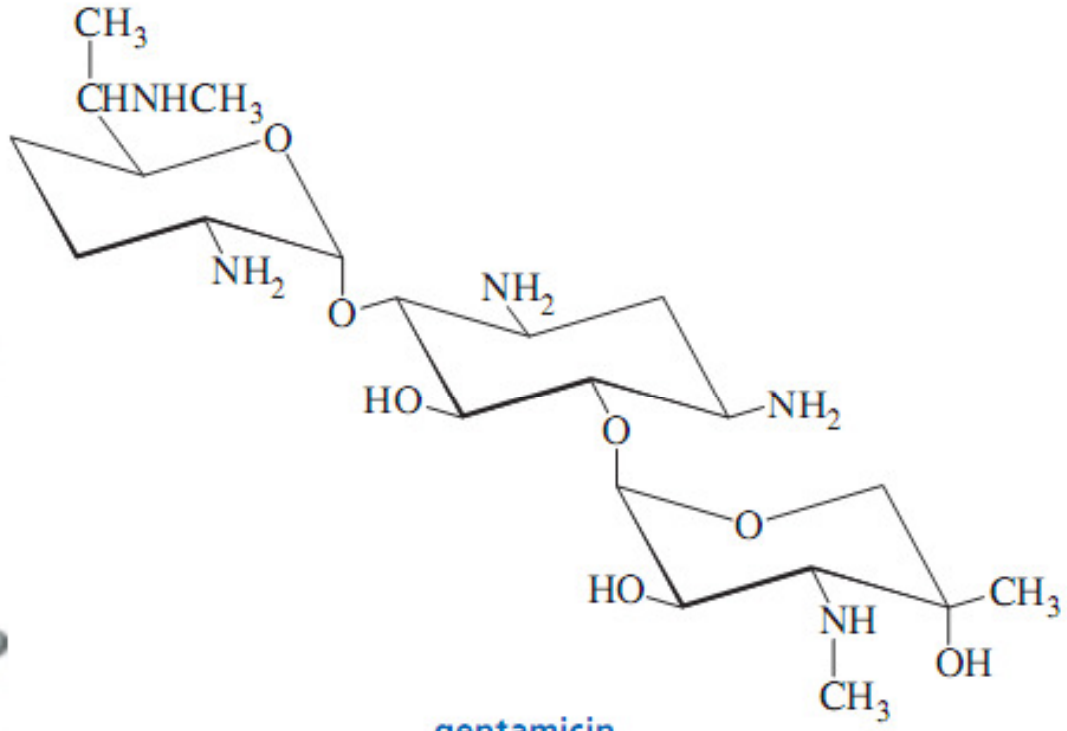



lufenuron



## Some Naturally Occurring Products Derived from Carbohydrates

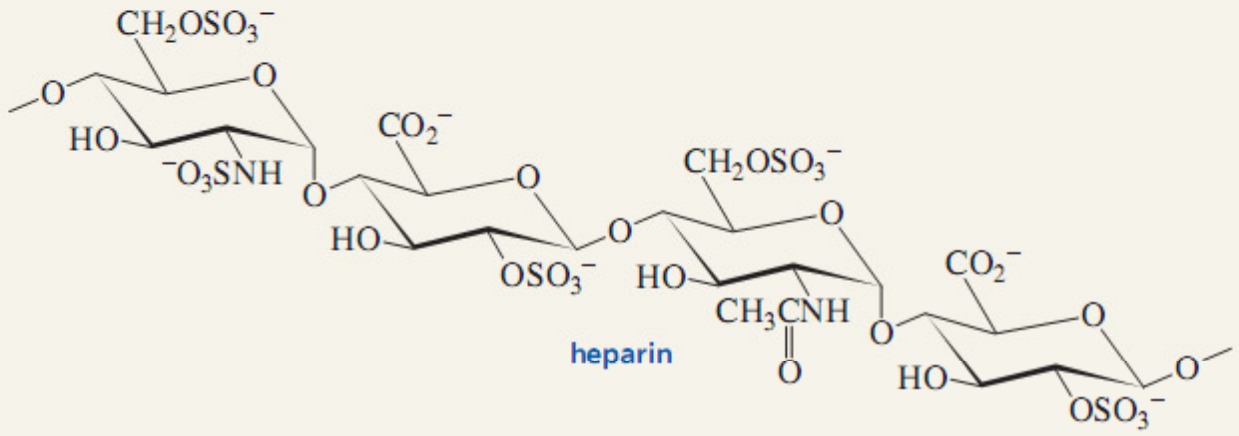





gentamicin
an antibiotic

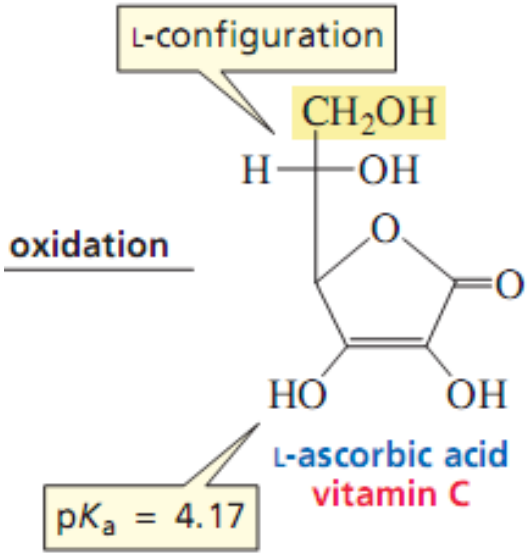
## HEPARIN

Heparin is an anticoagulant that is released to prevent excessive blood clot formation when an injury occurs. Heparin is a polysaccharide made up of glucosamine, glucuronic acid, and iduronic acid subunits. The C-6 OH groups of the glucosamine subunits and the C-2 OH groups of the iduronic acid subunits are sulfonated. Some of the amino groups are sulfonated and some are acetylated. Thus, heparin is a highly negatively charged molecule, found principally in cells that line arterial walls. Heparin is widely used clinically as an anticoagulant.



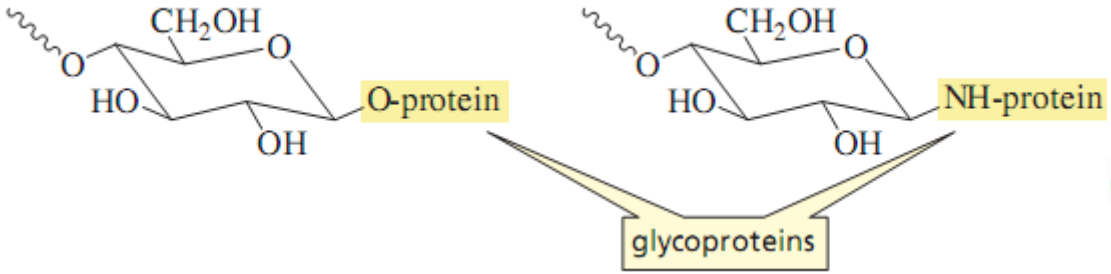

## VITAMIN C

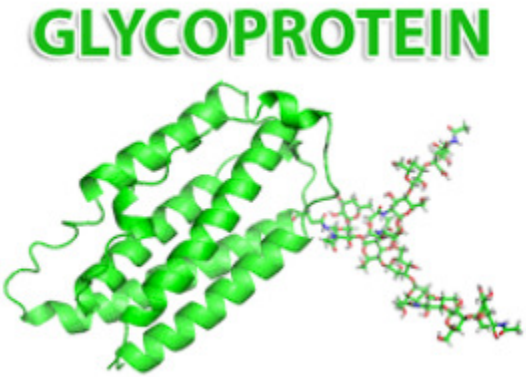
Vitamin C traps radicals formed in aqueous environments (Section 9.8). It is an antioxidant because it prevents oxidation reactions by radicals. Not all the physiological functions of vitamin C are known. What is known, though, is that vitamin C is required for the synthesis of collagen, which is the structural protein of skin, tendons, connective tissue, and bone. If vitamin C is not present in the diet (it is abundant in citrus fruits and tomatoes), lesions appear on the skin, severe bleeding occurs about the gums, in the joints, and under the skin, and wounds heal slowly. The disease caused by a deficiency of vitamin C is known as *scurvy*. British sailors who shipped out to sea after the late 1700s were required to eat limes to prevent scurvy. This is how they came to be called "limeys." Scurvy was the first disease to be treated by adjusting the diet. *Scorbutus* is Latin for "scurvy"; *ascorbic*, therefore, means "no scurvy."



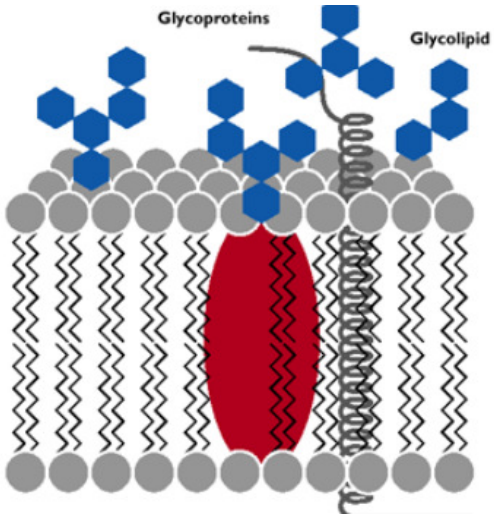
# Carbohydrates on Cell Surfaces

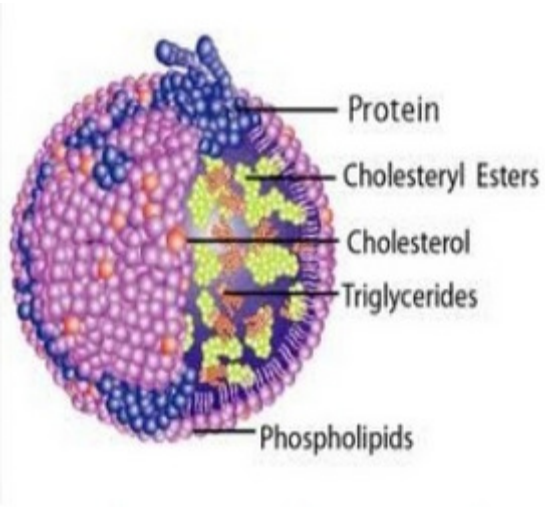
**Glycoprotein:** **Protein bound to polysaccharide i.e. (glyco + protein) i.e. carbohydrate + protein**




**Glycolipid:** **(glyco + lipid) i.e. carbohydrate + lipid**

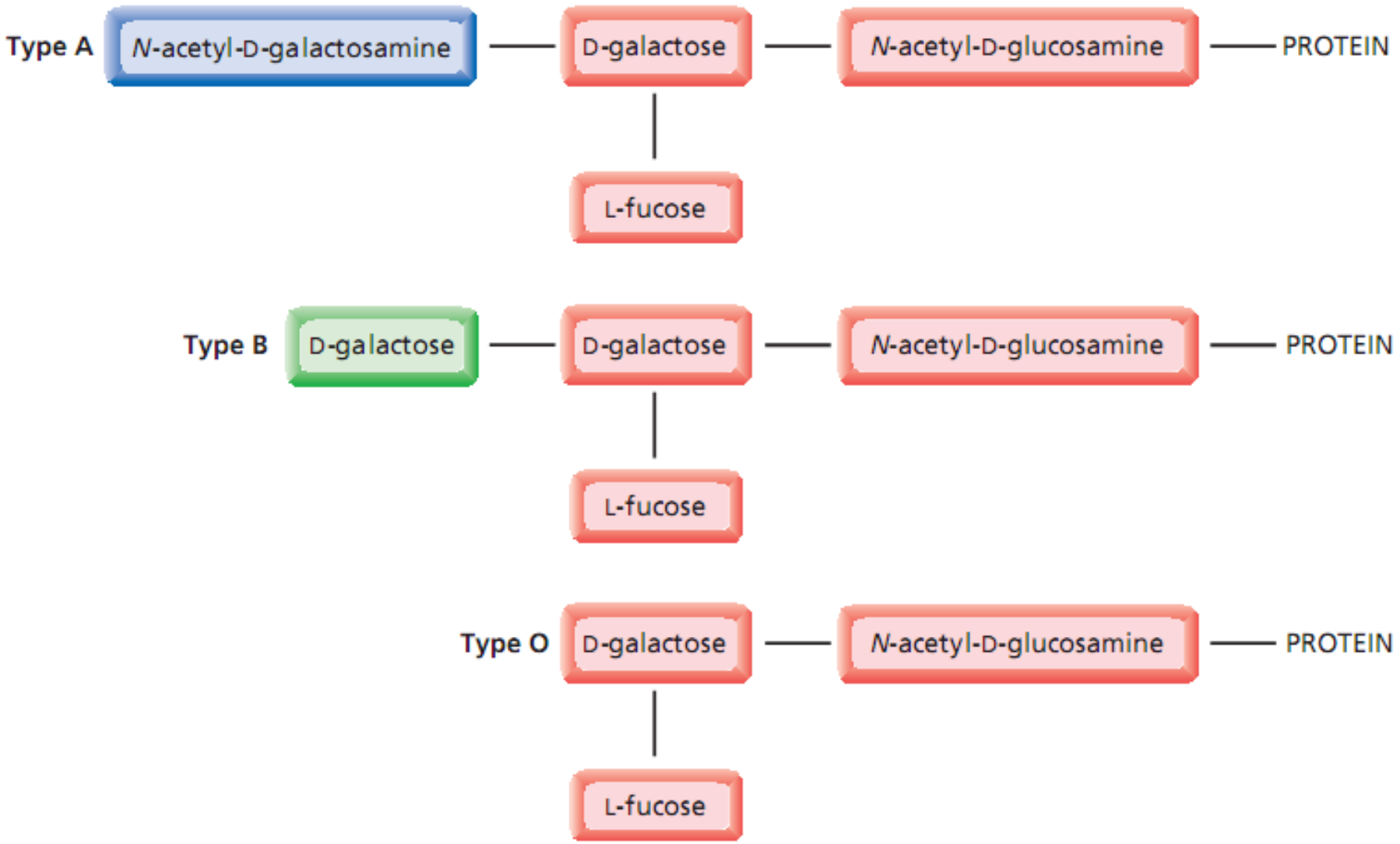



**Lipoprotein:** **(lipo + protein) i.e. lipid + protein**

# BLOOD TYPES

| TYPE | YOU CAN GIVE BLOOD TO | YOU CAN RECEIVE BLOOD FROM |
|---|---|---|
| A+ | A+ , AB+ | A+ , A- , O+ , O- |
| O+ | O+ , A+ , B+ , AB+ | O+ , O- |
| B+ | B+ , AB+ | B+ , B- , O+ , O- |
| AB+ | AB+ | Everyone |
| A- | A+ , A- , AB+ , AB- | A- , O- |
| O- | Everyone | O- |
| B- | B+ , B- , AB+ , AB- | B- , O- |
| AB- | AB+ , AB- | AB- , A- , B- , O- |


Type A
N-acetyl-D-galactosamine
D-galactose
N-acetyl-D-glucosamine
PROTEIN
L-fucose
Type B
D-galactose
D-galactose
N-acetyl-D-glucosamine
PROTEIN
L-fucose
Type O
D-galactose
N-acetyl-D-glucosamine
PROTEIN
L-fucose