Lesson 2
Chemical & Physical Properties of Food

Opening remark

- **foods are mixtures of chemicals**
- They can be as simple as sugars or complex in milk or muscle foods

- interact to produce:

sensory, chemical & physical

characteristics and their behaviour under different conditions

Lesson Objective

- Compare and contrast food- colloidal dispersions;
- Summarize the **functional properties** of carbohydrates, proteins and fats in foods;
- Distinguish between **caramelization** and the **Maillard** browning reaction and state the importance of these reactions in food;
- Explain the function of **emulsifiers** and **stabilizers** in emulsions;
- Interpret the importance of water, pH, and minor constituents in quality and safety of foods
- Outline the minor constituents of foods

Food/ Colloidal Dispersions

Small particle systems (particles < 600 *microns*)

Particles of one substance are distributed **(dispersed phase)** in another substance **(continuous phase)** without dissolving

Foams

- Dispersions of gas in liquid/solid

- *Cake frostings*
- **Air beaten** into the white is the dispersed phase
- Egg white is the continuous phase

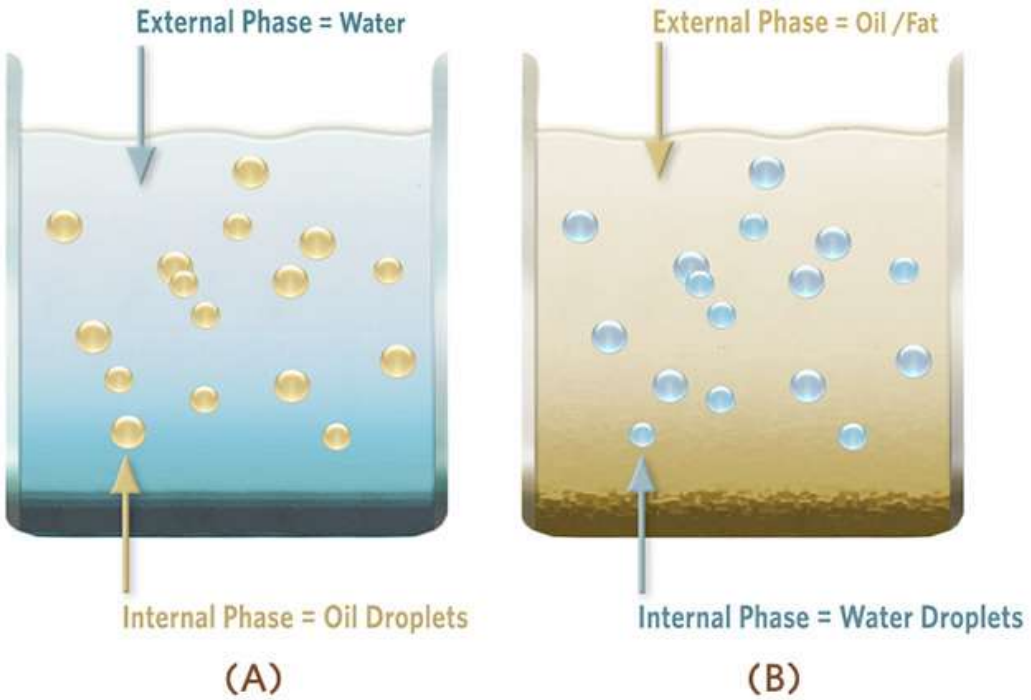
Can you think of any other examples?

Table 2.1. Food Dispersions

Dispersed phase	Continuous phase	Name of Dispersion	Examples
solid	liquid	**Sol**	starches, proteins, some plant polysaccharides in water
liquid	solid	**gel**	starch paste, pectin, proteins (jams, jellies, tofu, gelatin)
gas	liquid	**foam**	whipped egg white and cake frostings
gas	solid	**solid foam**	meringue, ice cream, bread
liquid	liquid	**emulsion**	milk, mayonnaise, salad dressings
liquid	solid	**solid emulsion**	butter, margarine

Emulsions

External = *continuous* phase



Internal = *dispersed* phase

o/w emulsion (**liquid** emulsion)
oil *in* water

eg. milk,

w/o emulsion
water *in* oil

eg. margarine, butter (**solid** emulsion)

Mayonnaise (conventional-homemade) (**liquid** emulsion)

Practice:
what type of emulsion is this?

Home made recipe

- 2 egg yolks
- 3/4 teaspoon salt
- 1/2 teaspoon powdered mustard
- 1/8 teaspoon sugar
- Pinch cayenne pepper
- 4 to 5 teaspoons lemon juice or white vinegar
- 1-1/2 cups olive or other salad oil
- 4 teaspoons hot water

Regular Mayonnaise

Amount Per Portion		%DV
Calories	100kcal	
Fat	10 g	15%
Saturated	1 g	5%
+ Trans	0 g	
Cholesterol	5 mg	
Sodium	95 mg	4%
Carbohydrate	0 g	0%
Fibre	0 g	
Sugars	0 g	
Protein	0.1 g	
Vitamin A		0%
Vitamin C		0%
Calcium		0%
Iron		0%

Low fat Mayonnaise

Amount Per Portion		%DV
Calories	40kcal	
Fat	4 g	6%
Saturated	0.3 g	2%
+ Trans	0 g	
Cholesterol	5 mg	
Sodium	135 mg	6%
Carbohydrate	1 g	1%
Fibre	0 g	
Sugars	0 g	
Protein	0.1 g	
Vitamin A		0%
Vitamin C		0%
Calcium		0%
Iron		0%

Regular vs Low Fat Mayonnaise

REGULAR MAYONNAISE

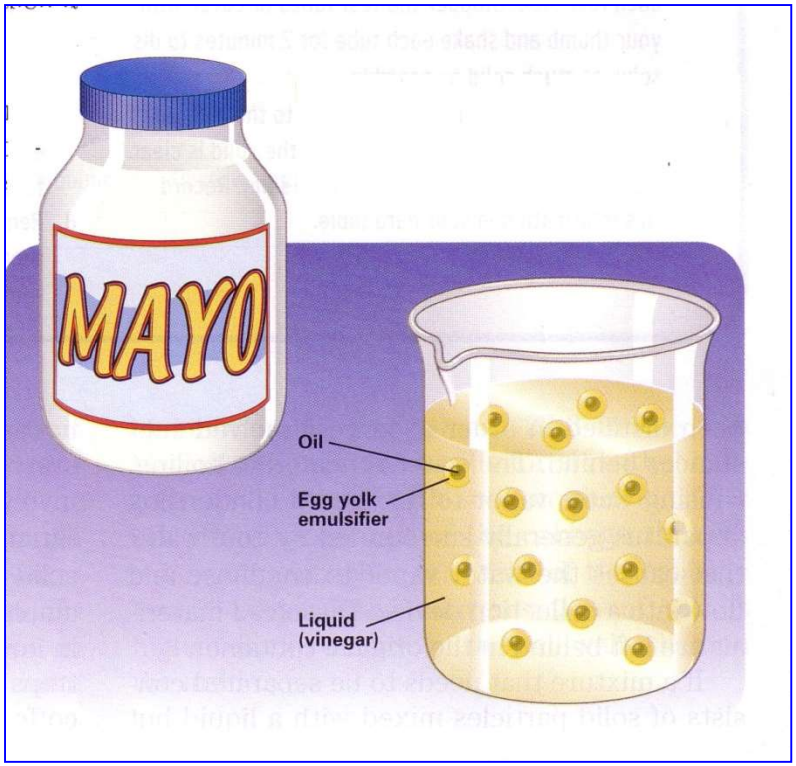
CANOLA OIL, WATER, LIQUID WHOLE EGG, VINEGAR, LIQUID YOLK, SALT, SUGAR, SPICES, CONCENTRATED LEMON JUICE AND CALCIUM DISODIUM EDTA (MAINTAINS FLAVOUR).

LOW FAT MAYONNAISE

WATER, CANOLA OIL, MODIFIED CORN & POTATO STARCH, LIQUID WHOLE EGG, SUGAR, SALT, VINEGAR, CONCENTRATED LEMON JUICE, SORBIC ACID (MAINTAINS QUALITY), SPICES, NATURAL COLOUR, NATURAL FLAVOUR, CALCIUM DISODIUM EDTA (MAINTAINS FLAVOUR).

Note: Low Fat Mayonnaise

- OIL phase dispersed in highest proportion…
- Remains as OIL in WATER (not W/O)
- Unstable
- Adding oil- Rate & order important!
- Other compounds required to compensate for reducing oil



Low fat Mayonnaise:

- the oil is dispersed in vinegar (water), with egg yolk as the **emulsifier**
- Egg yolk components act as connectors between oil and water and don't let them to separate.

Watch the video

http://www.youtube.com/watch?v=cuPpVQ14320

Marshmallow time What dispersion(s) can you find

Marshmallows Ingredients:

Corn Syrup, Sugar, Dextrose, modified Corn Starch, water, Gelatine, Natural and Artificial Food flavour, Tetrasodium pyrophosphate

Guiding Questions

- What is a food Dispersion?
- Can you name all the discussed dispersions with examples?
- What is an emulsion?
- What is the difference between a gel and solid emulsion?
- What is an emulsifier?
- What ingredient acts as an emulsifier in mayonnaise?

Chemical Properties of Food Systems

Chemical Properties of food systems

- Highly depends on the food components (macro and micro)
  - **Macro (major) components**
    - carbohydrates
    - fat
    - protein
    - water
  - **Micro (minor) components**
    - organic acids
    - pigments or colourants
    - vitamins and minerals
    - flavour constituents

Proximate Analysis

- Water
- Carbohydrate
- Protein
- Fat
- Ash....

Major components: (1)
Carbohydrates

Resources

Optional Reading

Position of the Academy of Nutrition and Dietetics: Use of Nutritive and Non-nutritive Sweeteners

Note the difference in Canadian and US definition and regulation

Canadian Nutrient File

https://food-nutrition.canada.ca/cnf-fce/index-eng.jsp

Carbohydrates

- Organic compounds
- Body's main source of energy
- Digestible carbohydrates → ***4 Cal/gram***
- Contribute ~ 50% of daily caloric intake,
- recommended in the form of complex CHs (rather than simple CHs)
- Found mainly in foods from plant sources
- Fruits, vegetables, grain products, legumes

Carbohydrates

Simple carbohydrates (mono and disaccharides)

- eg, table sugar
- Sweetness is determined by their molecular structure & interaction with sensory receptors in the tongue

Complex carbohydrates (polysaccharides)

- eg. starch, fibre (cellulose)

Carbohydrates

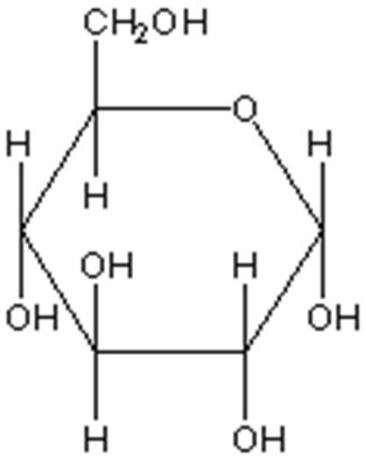
a) Monosaccharides

Glucose, fructose , galactose

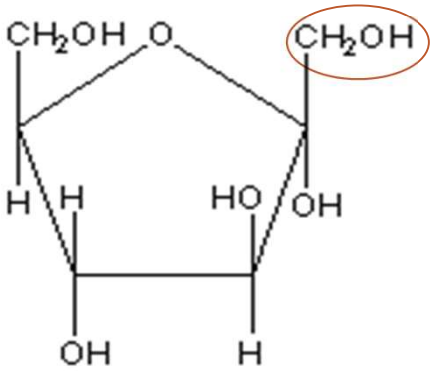
- "Simple sugars", not chemically bonded to other sugar molecules
- They vary on their sweetness
  - see Table 2.2 for sweetness index of various sugars in comparison to sucrose (table sugar)
  - e.g Fructose (140 s.i.) **>** glucose (70-80 s.i.)

Sugar	Sweetness Index*
sucrose	**100**
glucose (dextrose)	70 -80
fructose (levulose)	**140**
invert sugar	100 - 130
corn syrup (mixture of glucose, maltose and higher oligo-saccharides)	50
maltose	20
lactose	10 - 20
galactose	60
sorbitol	50
xylitol	100
high fructose corn syrups:	
42% fructose	100
55% fructose	100+
90% fructose	120 - 160

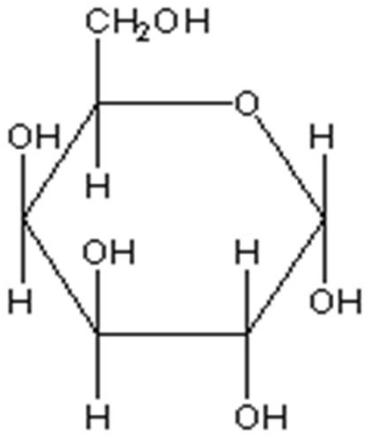
Carbohydrates-Monosaccharides



Glucose



Fructose



Galactose

$C_6H_{12}O_6$

Isomers

Sugar	Sweetness Index*
sucrose	**100**
glucose (dextrose)	70 -80
fructose (levulose)	**140**
invert sugar	100 - 130
corn syrup (mixture of glucose, maltose and higher oligo-saccharides)	50
maltose	20
lactose	10 - 20
galactose	60
sorbitol	50
xylitol	100
high fructose corn syrups:	
42% fructose	100
55% fructose	100+
90% fructose	120 - 160

Carbohydrates

b) Disaccharides

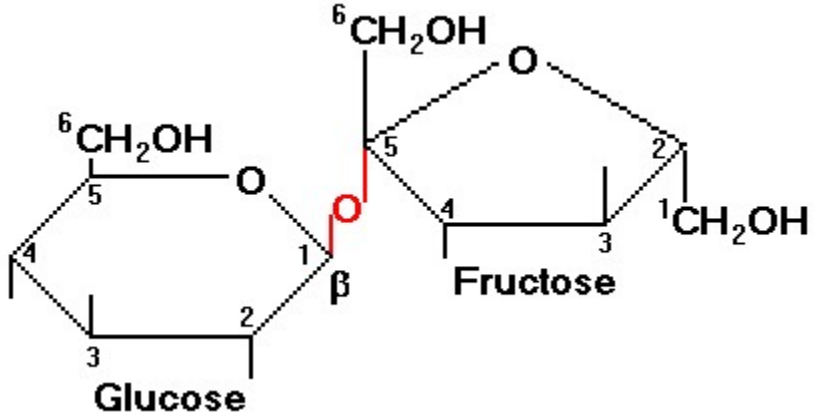
- union of two monosaccharide molecules
- Split back by
  - *enzymes*
  - or by boiling with *dilute acids*

- most important disaccharides in food:
  - sucrose (table sugar)
  - lactose (milk sugar)
  - maltose (malt sugar)

Carbohydrates

(b) Disaccharides- Sucrose

- **Sucrose** (100 s.i.) = glucose - fructose



- Found in a variety of fruits, grasses and roots
  - Peaches, tangerines, pineapples: 6-9%
  - Mangoes: 12%
  - Commercial white sugar: ≥99.5%

Carbohydrates

(b) Disaccharides- Sucrose

- sucrose hydrolyzed by enzyme (***invertase***)or acid

1:1 ratio of glucose:fructose → Invert sugar
(sweeter)

Enzyme/acid

↓

Sucrose + water → glucose + fructose
(342 g) (18 g) (180 g) (180 g)

(360 g)

Carbohydrates

(b) Disaccharides- Sucrose

- **Invert sugar**…

- Substitutes part of the sucrose in candy making
- It is highly **Hygroscopic** (Affinity for moisture)
- prevents chewy candies from drying out (becoming brittle)
  - **honey** contains glucose and fructose (40:60 ratio) through ***invertase*** in the honey bee's saliva;

HONEY:

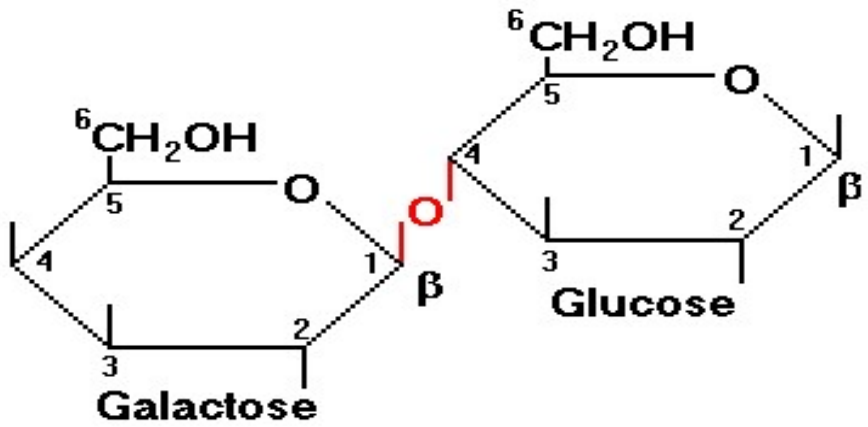
Nectar collected
by honey bees:

(**sucrose**)

hydrolyzed by ***invertase*** in the **bee's saliva**:
glucose and fructose (40:60 ratio)
Why not (1:1)?

Carbohydrates
(b) Disaccharides- Lactose

❖**Lactose** (10-20 s.i.) = galactose - glucose



- Cow's milk contains about 4-5%,
- Human milk contains 6-8%
- Fermented by **lactic acid bacteria** (eg yogurt, cheeses) → lactic acid (acidulant, preservative)

Carbohydrates
(b) Disaccharides- Lactose

Lactose intolerance
- Hydrolyzed by the enzyme ***lactase***
- **lactose-hydrolyzed milk**

Critical Thinking question:

Regular vs Lactose-Free (Lactaid) milk
Which one is sweeter and Why?

Regular vs Lactose free milk

Regular 2%

Nutrition Facts
Valeur nutritive
Per 1 cup (250 mL) / par 1 tasse (250 mL)

Amount / Teneur	% Daily Value / % valeur quotidienne
Calories / Calories 130	
Fat / Lipides 5 g	**8** %
Saturated / saturés 3 g + Trans / trans 0.1 g	**16** %
Cholesterol / Cholestérol 20 mg	**7** %
Sodium / Sodium 120 mg	**5** %
Carbohydrate / Glucides 12 g	**4** %
Fibre / Fibres 0 g	**0** %
Sugars / Sucres 12 g	
Protein / Protéines 9 g	
Vitamin A / Vitamine A	10 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	30 %
Iron / Fer	0 %
Vitamin D / Vitamine D	45 %

Lactose free 2%

Nutrition Facts
Valeur nutritive
Per 1 cup (250 mL) / par 1 tasse (250 mL)

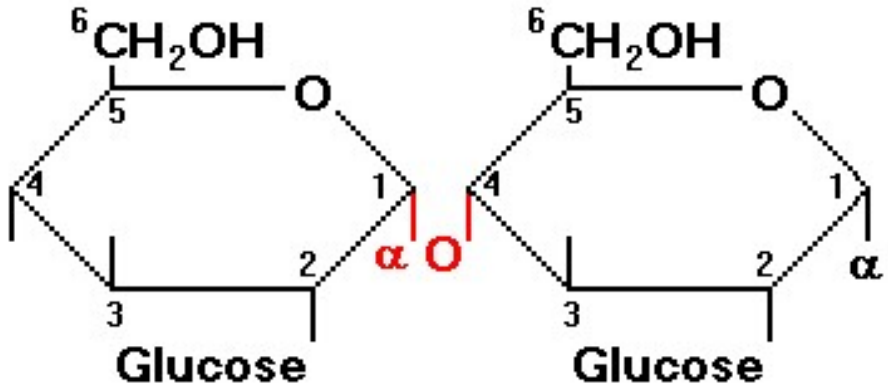
Amount / Teneur	% Daily Value / % valeur quotidienne
Calories / Calories 130	
Fat / Lipides 5 g	**8** %
Saturated / saturés 3 g + Trans / trans 0.1 g	**16** %
Cholesterol / Cholestérol 20 mg	**7** %
Sodium / Sodium 120 mg	**5** %
Carbohydrate / Glucides 12 g	**4** %
Fibre / Fibres 0 g	**0** %
Sugars / Sucres 12 g	
Protein / Protéines 9 g	
Vitamin A / Vitamine A	10 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	30 %
Iron / Fer	0 %
Vitamin D / Vitamine D	45 %

Sugar	Sweetness Index*
sucrose	**100**
glucose (dextrose)	70 -80
fructose (levulose)	**140**
invert sugar	100 - 130
corn syrup (mixture of glucose, maltose and higher oligo-saccharides)	50
maltose	20
lactose	10 - 20
galactose	60
sorbitol	50
xylitol	100
high fructose corn syrups:	
42% fructose	100
55% fructose	100+
90% fructose	120 - 160

Sugar	Sweetness Index*
sucrose	**100**
glucose (dextrose)	70 -80
fructose (levulose)	**140**
invert sugar	100 - 130
corn syrup (mixture of glucose, maltose and higher oligo-saccharides)	50
maltose	20
lactose	10 - 20
galactose	60
sorbitol	50
xylitol	100
high fructose corn syrups:	
42% fructose	100
55% fructose	100+
90% fructose	120 - 160

Carbohydrates
(b) Disaccharides- Maltose

- **Maltose** (20 s.i.) = glucose – glucose



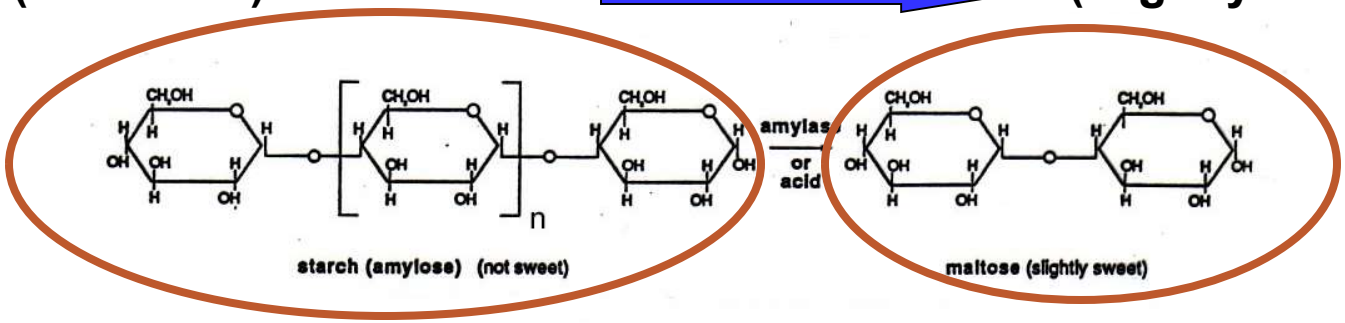
Formed from **starch** by enzymatic (***amylase***) or acid hydrolysis

High Fructose Syrup processing

Starch Amylose
(not sweet)

Amylase or acid

Maltose / malt sugar
(slightly sweet)

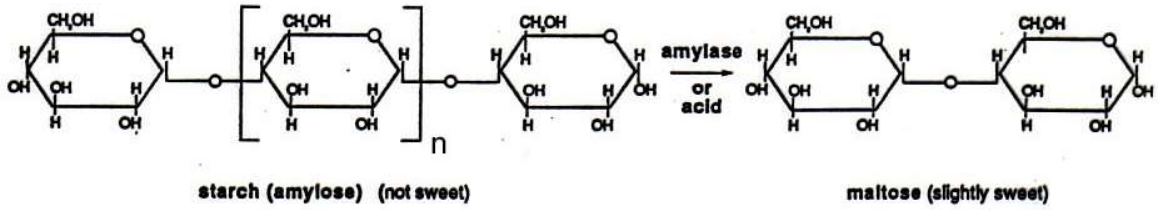


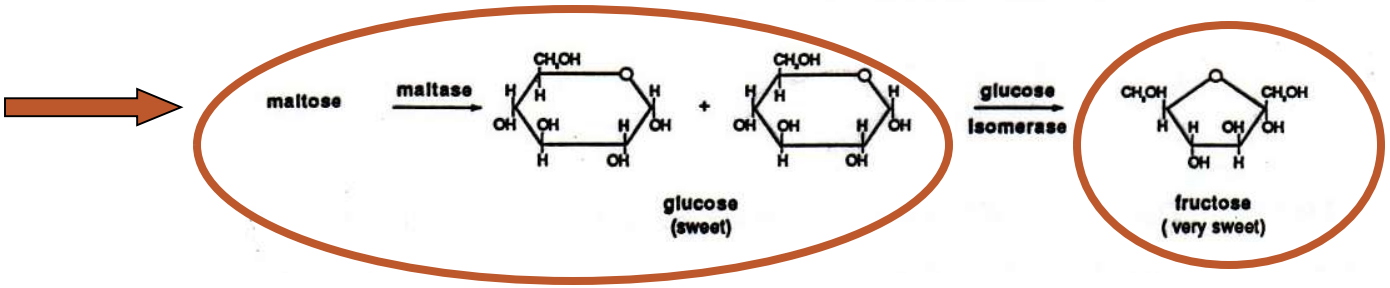
High Fructose Syrup processing

Starch Amylose
(not sweet)

Amylase or acid

Maltose / malt sugar
(slightly sweet)





Hydrolysis w/ enzyme *maltase*:

glucose + glucose
(sweet)

Glucose isomerase

Isomerization*:*

HFS

(very sweet)

90%

Sugar	Sweetness Index*
sucrose	**100**
glucose (dextrose)	70 -80
fructose (levulose)	**140**
invert sugar	100 - 130
corn syrup (mixture of glucose, maltose and higher oligo-saccharides)	50
maltose	20
lactose	10 - 20
galactose	60
sorbitol	50
xylitol	100
high fructose corn syrups:	
42% fructose	100
55% fructose	100+
90% fructose	120 - 160

Carbohydrates

Functional properties of simple carbohydrates

- **Sweetening power**
- Reactants in non-enzymatic browning
- Crystallization
- Viscosity/mouthfeel
- Fermented by microorganisms
- Antimicrobial agents
- Humectancy (water retention)

Guiding Questions

- Name mono and di-saccharides you learned in this course.
- What is an invert sugar?
- What are the sugars in Nectar and Honey?
- What is HFS and how is it made? Describe the role of enzymes.
- What are the functional properties of simple carbohydrates?

Critical Thinking Questions

- Compare and contrast Invert sugar and High Fructose syrup.

- Honey bees use invertase to convert Sucrose to Fructose and Glucose. Why the ratio of Glucose and Fructose in Honey is not 1:1?

Carbohydrates

Functional properties of simple Carbohydrates

- **Sweetening power**
  - sweetness index (s.i.)

- Sweetness is not necessarily correlated to calories!
  - eg. fructose and lactose both have 4 Cal/gram
  - yet fructose is 7X sweeter than lactose
  - only need 1/7th as much fructose for an equivalent sweetening power to lactose!
  - Therefore 1/7th less caloric intake

Carbohydrates
Functional properties of simple carbohydrates

- **Reactants in non-enzymatic browning:**

1. **Caramelization**

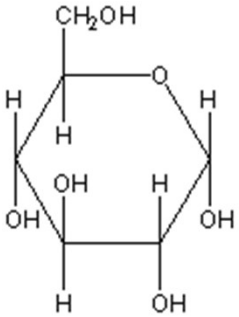
(110-203 °C)

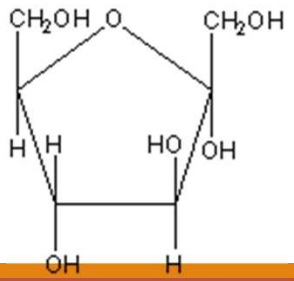
- heating **sugar alone** to high temp (200°C)
  - Aroma compounds (caramel, butterscotch flavours) & brown pigments
    - eg. caramel candies, toffees
  - colour used in cola beverages is created by caramelizing sucrose

Carbohydrates
Functional properties of simple carbohydrates

- **Reactants in non-enzymatic browning**:
  2. **Maillard browning**
     - Reducing sugar + amino compounds
       - reducing sugars contain a *"free"* OH on the position next to the O in the ring structure
         - eg., glucose, fructose, galactose, lactose
         - *sucrose* is a **non-reducing** sugar

e.g. proteins or amino acids





but can be hydrolyzed to glucose and fructose by high temp or acid ...

Carbohydrates
Functional properties of simple carbohydrates

- Products of Maillard browning reaction:
  - Low molecular weight (Intermediate Compounds) (aroma/flavours – both desirable and undesirable)
  - High molecular weight polymers (melanoidins) (brown-black pigments)
  - E.g. *toast, roasted coffee, potato chips, bread*
  - *Sunless tanning lotions too!*

Watch

https://www.youtube.com/watch?v=NtwwjRYNw9c

Carbohydrates
Functional properties of simple carbohydrates

- **Crystallization**
  - Sugars can exist in both soluble (as syrup) and crystalline states
  - Crystallized from solution = e.g. table sugar *(sucrose)* from the sugar cane juice

Watch

https://www.youtube.com/watch?v=VpOU0Fo7QfU

Carbohydrates
Functional properties of simple carbohydrates

- **Body (Viscosity) and mouthfeel**
- **Fermented by microorganisms**
- **Antimicrobial Agents**
  - *(Lesson 5)*

Functional properties of simple carbohydrates

- Humectancy (Affinity for moisture)
  - Simple carbohydrates are hygroscopic
  - Affects state of water in food systems

Sticky lollipops…

Invert sugars [fructose, glucose] **are very *hygroscopic*,**

- **Attract water from the atmosphere**

Functional properties of simple carbohydrates

Chocolates with liquid centers

Do you know the secret?

Functional properties of simple carbohydrates

Ripening phenomenon

- **Invertase** is added to the crystallized firm center
- Storage facilitates the **ripening** of the product
  - Enzyme slowly ***inverts*** sucrose to **mixture of sucrose, fructose & glucose**
- This mixture does not crystallize easily since invert sugar is highly hygroscopic (vs. sucrose alone)
- Produces a soft (syrupy)center

Critical Thinking Questions

- Compare and contrast Caramelization and Maillard Reaction.
- How can sucrose get involved in both reactions?
- How invertase can be used in production of liquid/creamy centred chocolate?

Carbohydrates: *Polysaccharides*

Polysaccharides

- High molecular weight polymers or long chains of monosaccharide units
  - Eg. cellulose, starch = polymers of glucose
- Form part of cellular structure & firmness of tissues (eg. cellulose, pectins, gums)
- Energy reserve of animals & plants (eg. Glycogen, starch)

Carbohydrates:
c) Polysaccharides

Sources: plants, seaweed, plant exudates, microbial products

- **Differ from simple sugars**:
  - Usually insoluble in water & tasteless

- Applications in food: thickening, suspending solids, stabilizers or gelling agents

Carbohydrates:
c) Polysaccharides

- Pectin
- Agar
- Alginates
- Gum arabic/acacia
- Carrageenan
- Xanthan gum
- Starch
- Cellulose, hemicellulose

Carbohydrates
c) Polysaccharides

- **Pectins**
  - From plant tissues
  - Used as gelling agents for jams and jellies
  - Contribute to viscosity (resistance to flow) of ketchup and tomato paste
  - Affects the overall mouthfeel of foods
  - Help maintain particles in suspension in orange juice and unclarified apple juice

Carbohydrates:
c) Polysaccharides

- **Alginates**
  - Extracted from seaweed
  - Suspending & thickening agents
    - salad dressings, puddings, pie fillings, ice cream, sherbet and icings.

Carbohydrates
c) Polysaccharides

- **Carrageenan (Irish moss extract)**
  - Extracted from seaweed
  - Suspending agent & stabilizer in dairy products
    - cocoa particles suspended in chocolate milk
    - Stabilizer in ice cream

https://commons.wikimedia.org/wiki/File:Chondrus_crispus.jpg

Carbohydrates
c) Polysaccharides

- **Xanthan gum**
  - Extracted from bacteria (*Xanthomonas campestris*)
  - used for the control of viscosity
  - Used as suspending agent (salad dressings)
  - Provide “loaf structure” in **wheat-free** bread

gum arabic (*gum acacia*) - thickening agent - candies

- from the sap of certain trees

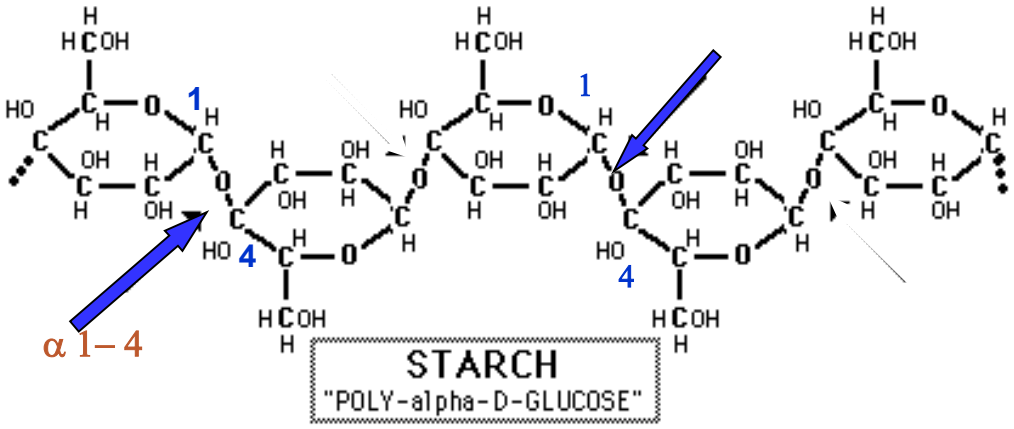
carrageenan from seaweed and

guar gum from guar beans

Carbohydratesc) Polysaccharides- Starch

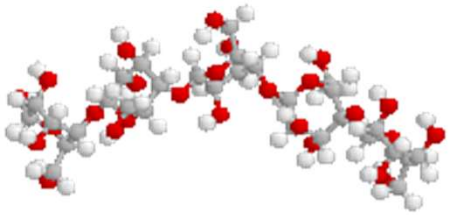
❖Starch

- Polymers of glucose (> 500 glucose molecules) Linked by **a-1,4**
- Digestible

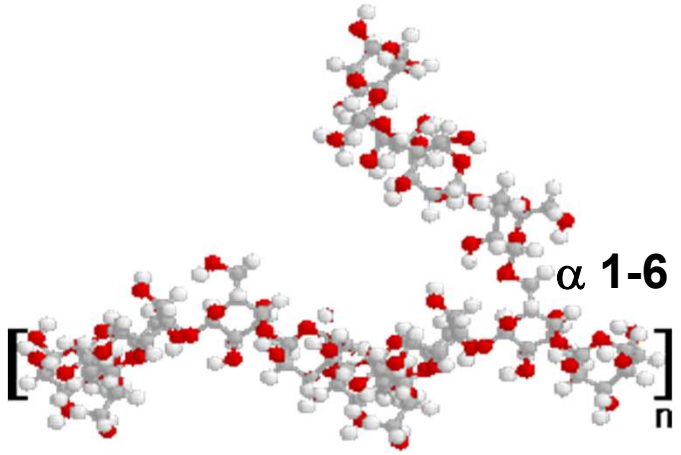


Carbohydrates
c) Polysaccharides- Starch

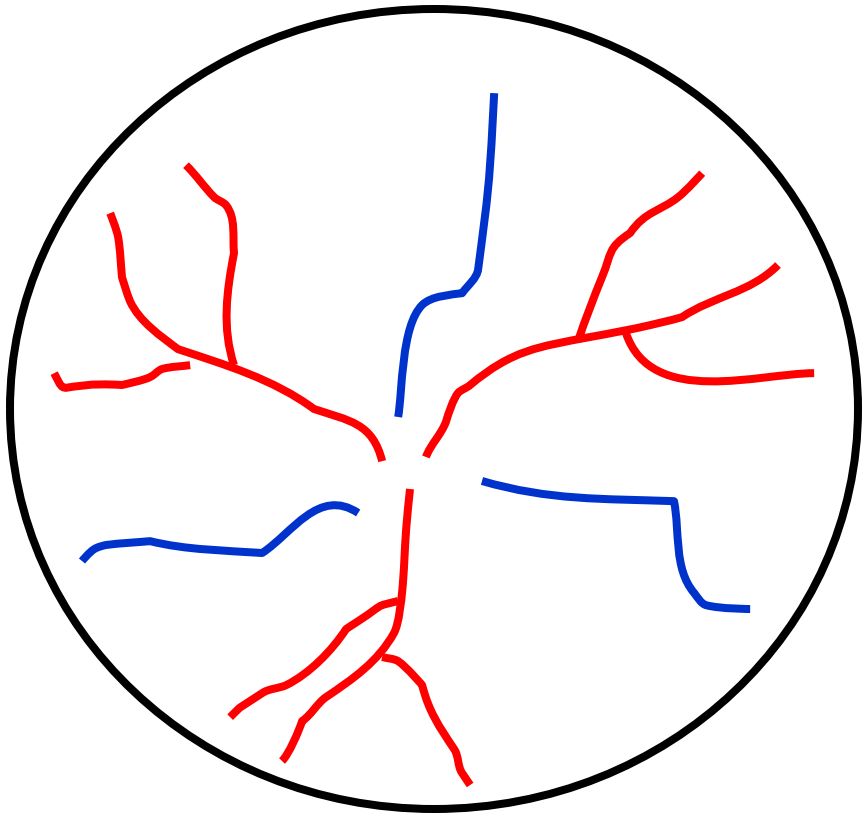
- **Starch…**
  - Present in plant materials as ‘starch granules’
    - starch molecules in the form of densely packed bundles
  - Two parts of starch molecules:



Amylose
(linear)



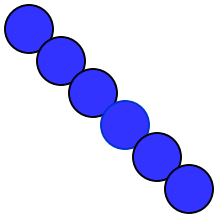
Amylopectin
(branched)



- **Starch granules contain both linear amylose and branched amylopectin**
  - normal corn starch has 1:3 amylose:amylopectin

Carbohydrates
c) Polysaccharides- Starch

Amylose molecules contribute to gel formation:

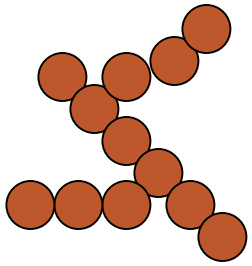


- the linear chains
- orient parallel to each other,
- moving close enough together to bond (Hydrogen bonds)

Carbohydrates

c) Polysaccharides- Starch

Branched **amylopectin** molecules give viscosity to the cooked paste.



- Sidechains- bulky shape
- keeps them from bonding together
- Does not contribute to gel formation

Carbohydrates

c) Polysaccharides- Starch

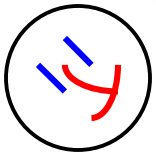
- **Starch…**
  - insoluble in cold water….but
  - "**gelatinization**"
    - **heating** + **water**,
    - starch granules swell and eventually burst
      - starch molecules absorb water

Starch gelatinization

Raw starch

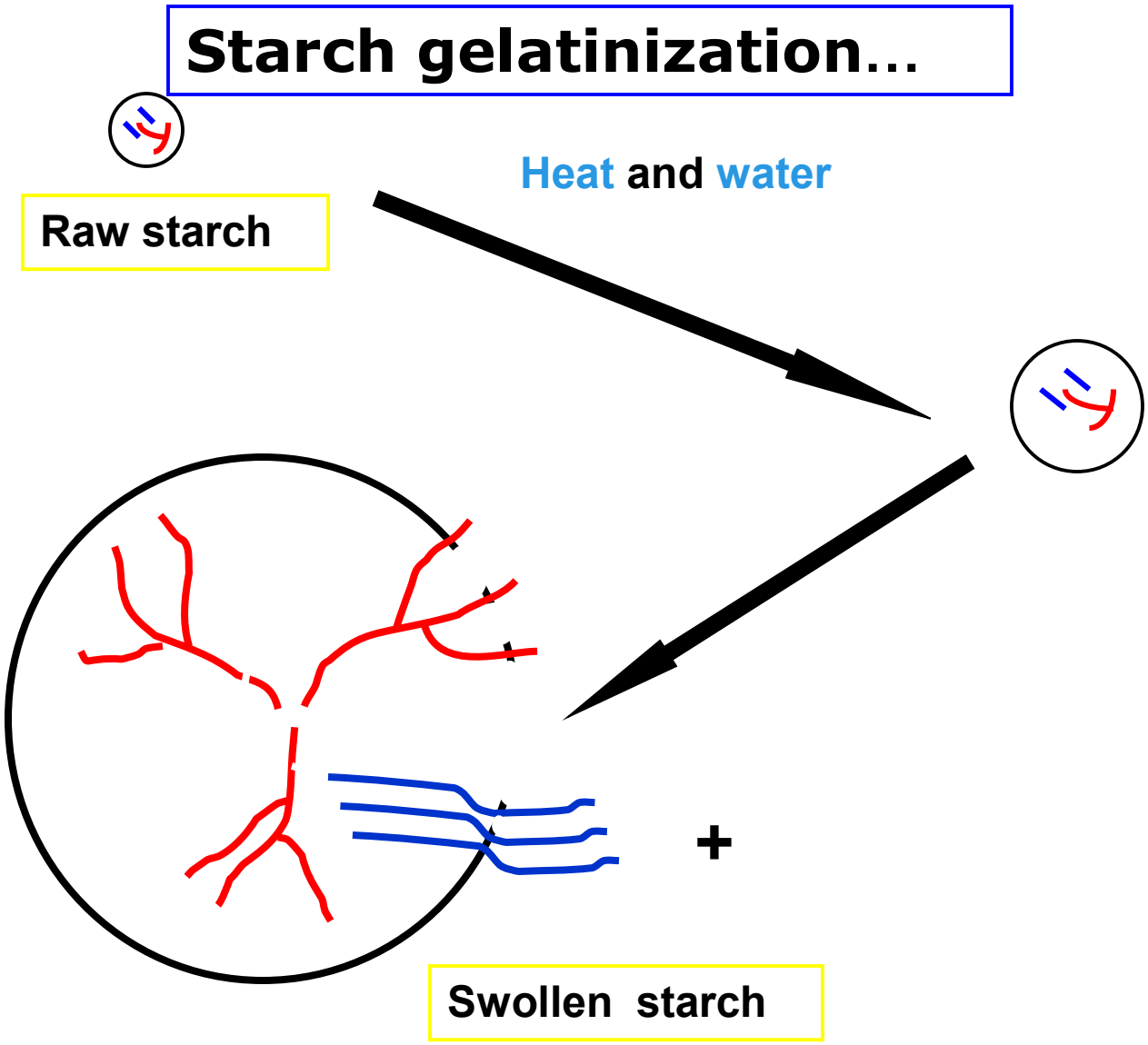
Heat and water

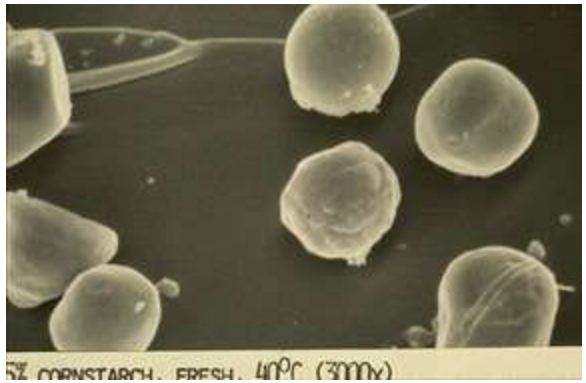
When starch is **heated** in **water**, the bonds joining amylose + amylopectin are weakened



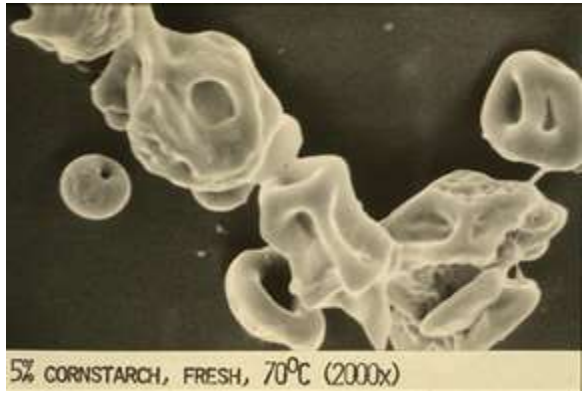
This allows water molecules to "move in" and form H-bonds

Starch gelatinization…





corn starch granules at 40°C



corn starch granules at 70°C
swelling, gelatinization

corn starch granules at 85°C
gelatinization complete

SEM from Oregon State University

Carbohydrates
c) Polysaccharides- Starch

After gelatinization (i.e. upon cooling, cold storage):

- **linear amylose** chains orient back into *crystalline zones* (intermolecular H-bonding)
  - form aggregates; syneresis (loss) of water
  - The phenomenon is called "**retrogradation**"
    - Causes loss of water holding capacity, toughening of food, gritty texture (eg. *Stale bread, gritty starch puddings)*
    - Accelerated by Refrigeration temperatures
    - partially reversed by heating

Carbohydrates

c) Polysaccharides- Cellulose

- **Cellulose**
  - Most abundant of all Carbohydrate polymers
  - Plant cell wall material
  - Linear chains of glucose units
  - Linked by b- 1,4
  - INDIGESTIBLE
  - Part of the dietary fiber component of foods

Carbohydrates

c) Polysaccharides- Starch

starch α- 1,4, 1-6 => **digestible**

cellulose **b**- 1,4 => **indigestible**

- **Both are chains of glucose units**

Functional" properties of Polysaccharides

- **Stabilizers/Thickeners/viscosity**
  - Keep compounds, mixtures or solutions from changing state.
  - Act as thickening agents by increasing the viscosity of the continuous phase
- **Gelling agents** (form gels L/S); **gelatinization**
- **Fat replacers**

Guiding Questions

- Name the polysaccharides discussed in this Lesson.
- What are the sources and specific functions of these polysaccharides :
  - Xanthan gum, Carrageenan, Alginates, Gum Arabic (Acacia), Guar gum
- What is gelatinization and how it is accelerated?
- What is retrogradation and how it is accelerated?
- What are the functional properties of polysaccharides?
- Compare and Contrast Cellulose and Starch.