Lesson 2 Chemical & Physical Properties of Food

Opening remark

- **foods are mixtures of chemicals**
  - Simple as sugar vs complex in milk or muscle foods

- interact to produce:

  sensory, chemical & physical

  characteristics and their behaviour under different conditions

Main Objective

“.. chemical properties of food constituents and how those constituents affect the physical properties of foods”

- Food/ Colloidal Dispersions
- Major/Minor food components

Food/ Colloidal Dispersions

Small particle systems (particles < 600 *microns*)

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

E.g. Foams

- Dispersions of gas in liquid/solid

Cake frostings

- Air beaten into the white is the dispersed phase
- Egg white protein is the continuous phase

Can you think of any other examples?

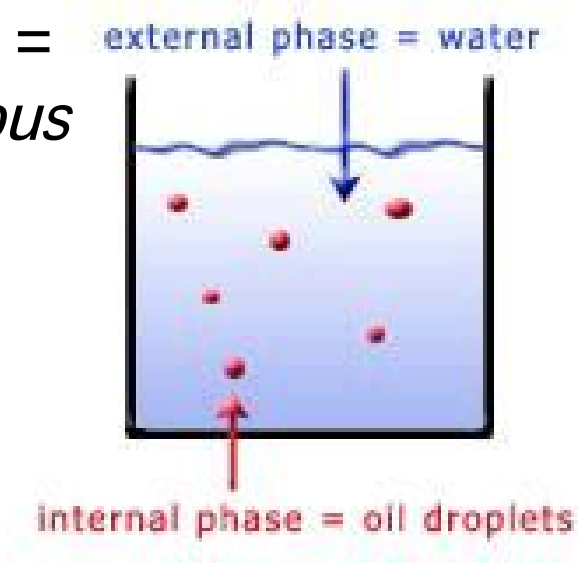
Table 2.1. Food Dispersions

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 (Fig 2.2)

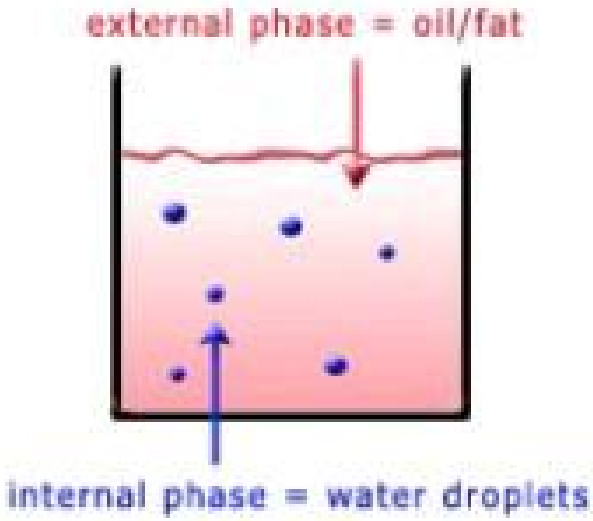
External = *continuous* phase

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)

Question:

Liquid emulsion:

oil/water

Water/oil

Solid Emulsion:

Solid Foam:

Facts about Mayonnaise dispersion

- 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

Nutrition Facts
Serving Size 1 Tbsp (13g)
Servings Per Container **see below

Amount Per Serving	
Calories 90	Calories from Fat 90
	% Daily Value*
Total Fat 10g	15%
Saturated Fat 1.5g	8%
Cholesterol 5mg	2%
Sodium 75mg	3%
Total Carbohydrate 0g	0%
Dietary Fiber 0g	0%
Sugars 0g	
Protein 0g	

Vitamin A 0%	Vitamin C 0%
Calcium 0%	Iron 0%

*Percent Daily Values (DV) are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Sat. Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 - Carbohydrate 4 - Protein 4

INGREDIENTS: SOYBEAN OIL, WHOLE EGGS AND EGG YOLKS, VINEGAR, SALT, SUGAR, LEMON JUICE, NATURAL FLAVORS, CALCIUM DISODIUM EDTA USED TO PROTECT QUALITY.

container size:	**servings per container:
8 fl oz	16
16 fl oz	32
32 fl oz	64
48 fl oz	96

Low fat Mayonnaise

Nutrition Facts
Serving Size 1 Tbsp (15 g)
Servings Per Container **see below

Amount Per Serving	
Calories 45	Calories from Fat 40
	% Daily Value*
Total Fat 4.5g	7%
Saturated Fat 0.5g	3%
Polyunsaturated Fat 3g	
Monounsaturated Fat 1g	
Cholesterol less than 5mg	0%
Sodium 120mg	5%
Total Carbohydrate 1g	0%
Dietary Fiber 0g	0%
Sugars 0g	
Protein 0g	

Vitamin A 0%	Vitamin C 0%
Calcium 0%	Iron 0%
Vitamin E 6%	Vitamin K 20%

*Percent Daily Values (DV) are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Sat. Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 - Carbohydrate 4 - Protein 4

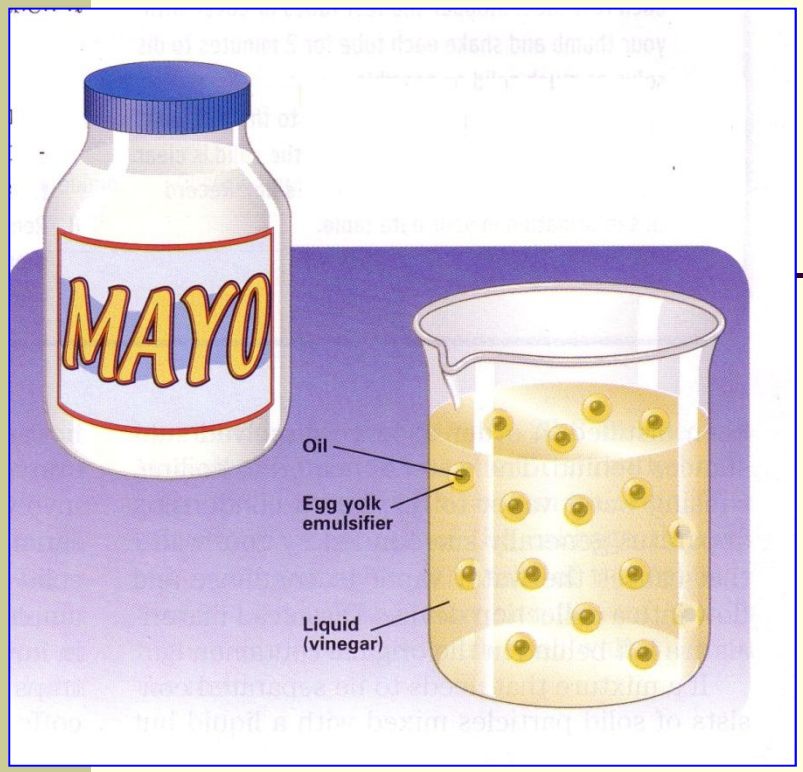
INGREDIENTS: WATER, SOYBEAN OIL, VINEGAR, WHOLE EGGS AND EGG YOLKS, MODIFIED CORN STARCH†, SUGAR, SALT, LEMON JUICE, POTASSIUM SORBATE† AND CALCIUM DISODIUM EDTA USED TO PROTECT QUALITY, XANTHAN GUM†, DLALPHA TOCOPHEROL ACETATE (VITAMIN E) NATURAL AND ARTIFICAL FLAVORS, BETA-CAROTENE† (FOR COLOR), PHYTONADIONE (VITAMIN K).

†INGREDIENTS NOT IN MAYONNAISE

container size: **servings per container:

Note:Low Fat Mayonnaise

- OIL phase dispersed in highest proportion...
- Remains OIL/WATER (not W/O)
- Unstable
- Adding oil- Rate & order important!
  - Emulsifiers needed



Low fat Mayonnaise: the oil is dispersed in vinegar (water), with egg yolk as the emulsifier

Egg yolk surrounds the oil droplets, the droplets are immobilized (can't flow as a liquid would)

Likewise, the water present in the vinegar cannot flow because immobilized oil droplets scattered through.

Chemical Properties of food systems

Chemical Properties of food systems

- depend 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

Major components: (1) ***Carbohydrates***

Required reading

- "*Sweeteners: Nutritive and non-nutritive*"
  Food Technology, 40(8)
  Read pp. **195-196, 200-201,** and **204**

Note the difference in Canadian and US definition

1. ***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

1. ***Carbohydrates***

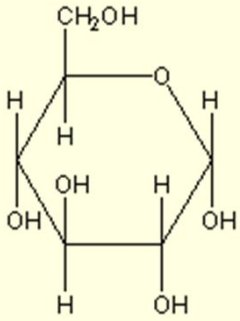
- Simple carbohydrates (mono or disaccharides)
  - eg, table sugar
  - Sweetness determined by their molecular structure & interaction w/sensory receptors in the tongue
- Complex carbohydrates (polysaccharides)
  - eg. starch, fibre (cellulose)

1. Carbohydrates: *Monosaccharides*

a) Monosaccharides

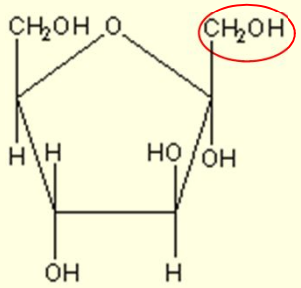
- Glucose, fructose , galactose
- "Simple sugars", not chemically bonded to other sugar molecules
- sweetness of various sugars in comparison to sucrose (table sugar) - Table 2.2
  - Fructose (140 s.i.) > glucose (70-80 s.i.)

1. Carbohydrates: *Monosaccharides*

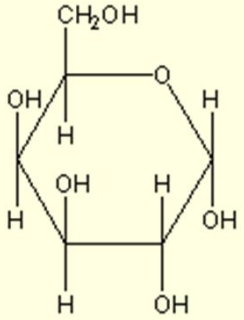


Glucose

γ “unit”



Fructose



Galactose

1. Carbohydrates: *Disaccharides*

b) Disaccharides

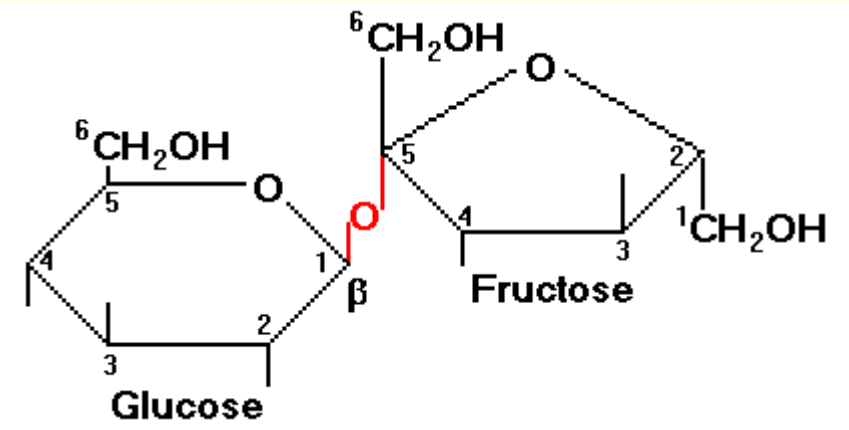
- union of two monosaccharide molecules
- Split back by
  - *enzymes*
  - or by boiling with *dilute acids*

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

(1) 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%

(1) Carbohydrates

(b) Disaccharides- Sucrose

- Sucrose…
  - sucrose hydrolyzed by enzyme (***invertase***)
    - or w/ 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)

(1) Carbohydrates

(b) Disaccharides- Sucrose

- invert sugar...
  - substitutes part of the sucrose in candy making
  - Hygroscopic = Affinity for moisture...
    - prevents chewy candies from drying out (brittle)
  - honey contains glucose and fructose (40:60 ratio) through *invertase* in the honey bee's saliva;

HONEY:

Nectar collected by honey bees:

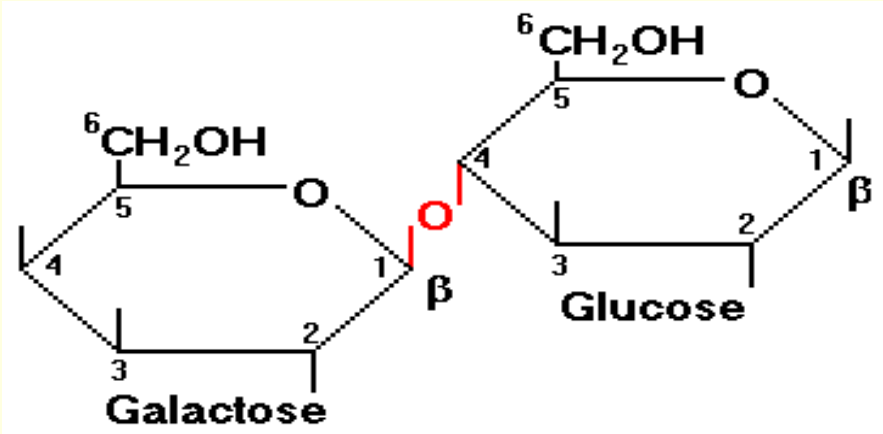
(**sucrose**)

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

(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)

(1) 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?

- 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%

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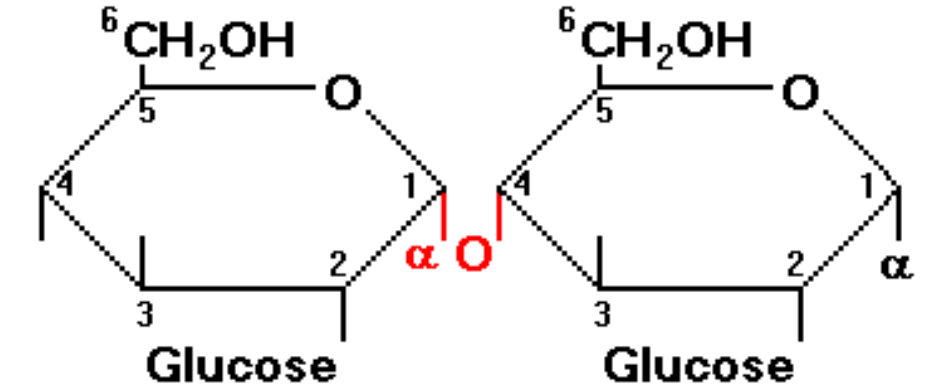
Carbohydrate / Glucides 12 g	**4** %
Fibre / Fibres 0 g	**0** %
Sugars / Sucres 12 g	
Protein / Protéines 9 g	
Vitamin A / Vitamine A	10 %
Vitamin C / Vitamine C	0 %
Calcium / Calcium	30 %
Iron / Fer	0 %
Vitamin D / Vitamine D	45 %

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

(1) Carbohydrates

(b) Disaccharides- Maltose

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

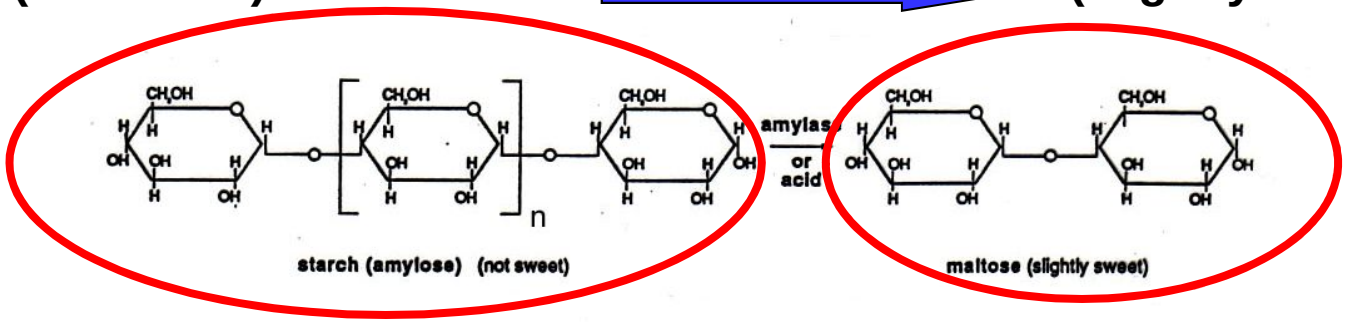


- Formed from starch by enzymatic (*amylase*) or acid hydrolysis →

Starch Amylose
(not sweet)

Amylase or acid

Maltose / malt sugar
(slightly sweet)



Starch Amylose
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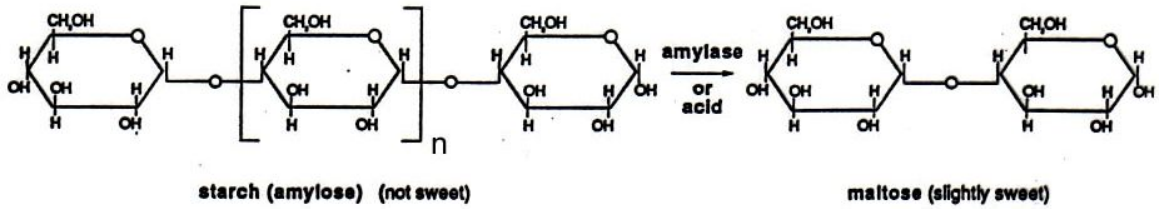
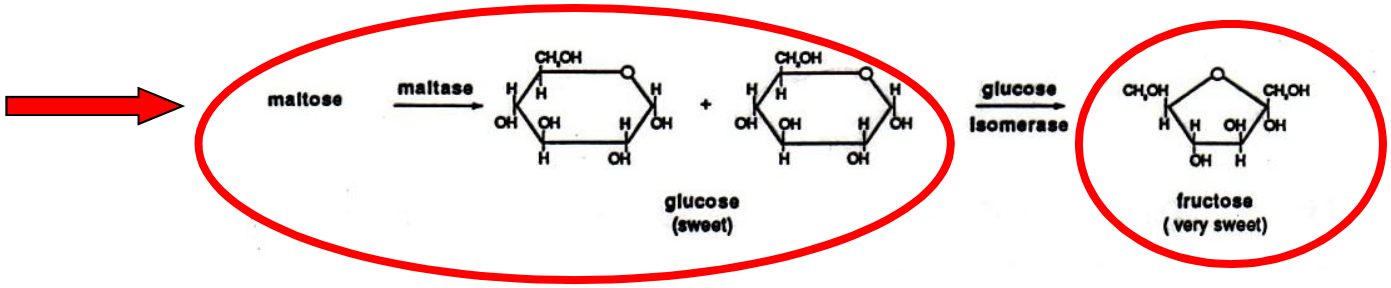




Hydrolysis w/ enzyme *maltase*:

glucose + glucose
(sweet)

Glucose isomerase

Isomerization*:*

HFCS
(very sweet)

90%

(1) Carbohydrates

Functional properties of simple carbohydrates

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

(1) Carbohydrates

Functional properties of simple carbohydrates

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

- Sweetness is not correlated to calories!
  - eg. fructose and lactose both 4 Cal/gram

    yet fructose is 7X sweeter than lactose

  - only need 1/7th as much fructose for an equivalent sweetening power to lactose! → 1/7th less caloric intake

Functional properties….

- **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

http://www.youtube.com/watch?v=4uXQ2Uoaa_M&feature=related

Functional properties….

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

Functional properties….

- Reactants in non-enzymatic browning:
  1. Caramelization
  - 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

Functional properties….

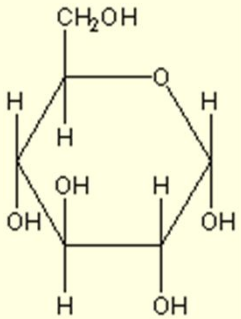
- **Reactants in non-enzymatic browning**:

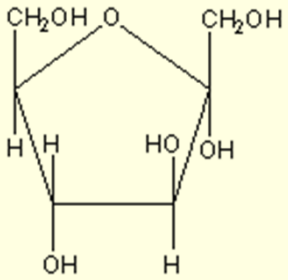
  2. **Maillard browning**

  - Reducing sugar + amino compounds

    e.g. proteins or amino acids

    - 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





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

Functional properties….

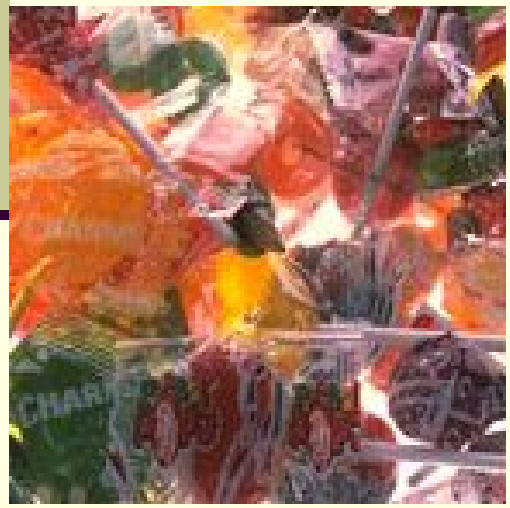
- Products of Maillard browning reaction:
  - Low molecular weight (Intermediate Compouds) (aroma/flavours – both desirable and undesirable)
  - High molecular weight polymers (melanoidins) (brown-black pigments)
  - E.g. *toast, roasted coffee, potato chips, bread*
  - *Sunless tanning lotions too!*

Watch

- *http://www.youtube.com/watch?v=KhLZ2_KTqf4*

Functional properties….

- Affinity for moisture (hygroscopic)
- influence state of water in food systems
  - Candies



Sticky lollipops…

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

• Attract water from the atmosphere

Functional properties….

Chocolates with cream centers

Do you know the secret ?

Properties of simple carb…

- **Ripening…**
  - Invertase is added to the crystallized firm center
    - Storage
    - Enzyme slowly *inverts* sucrose = mixture of sucrose, fructose & glucose
  - This mixture does not crystallize easily (vs. sucrose alone) = soft centers

1. Carbohydrates: *Polysaccharides*

1. 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)

1. Carbs: *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

1. Carbohydrates: *Polysaccharides*

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

Carbohydrates:

c) Polysaccharides- others…

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

Carbohydrates:
c) Polysaccharides- others…

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

(1) Carbohydrates:

c) Polysaccharides- others…

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

(1) Carbohydrates:

c) Polysaccharides- others…

- 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

- Jelly beans: gum arabic (*gum acacia*) - thickening agent
  - from the sap of certain trees
- Ice cream: carrageenan from seaweed and guar gum

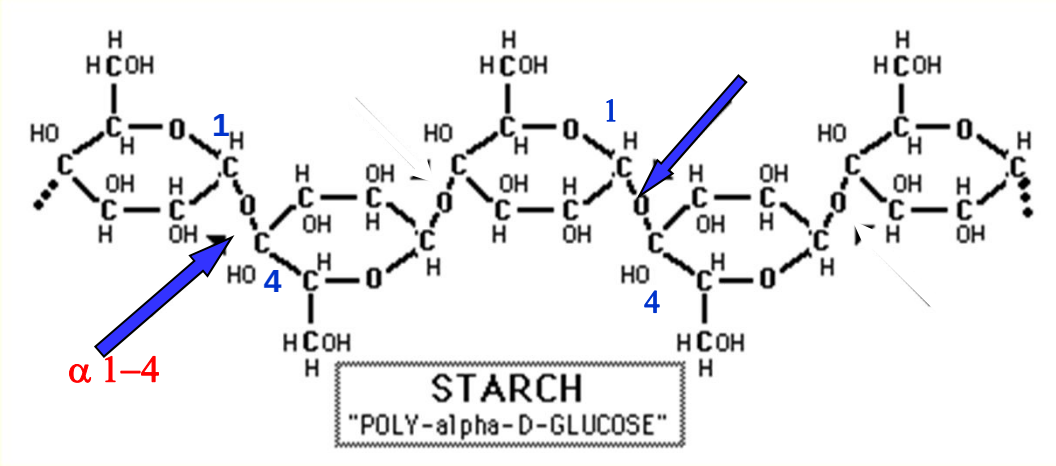
(1) Carbohydrates:

c) Polysaccharides- Starch

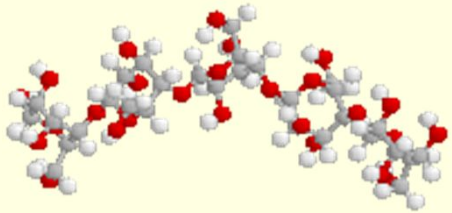
❖ Starch

- Polymers of glucose (> 500 glucose molecules)

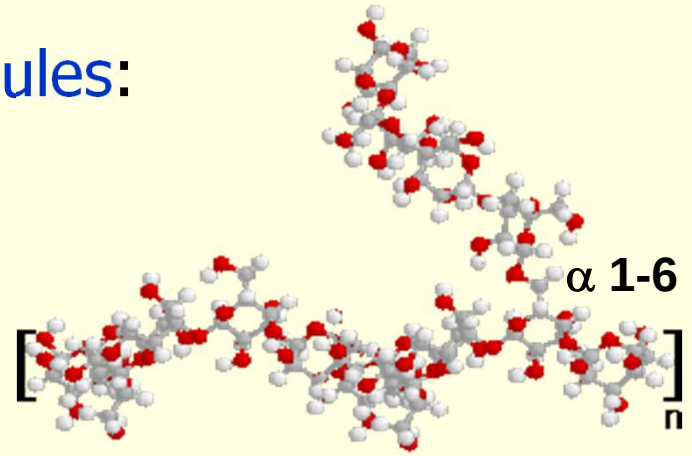
  Linked by α-1,4
- Digestible



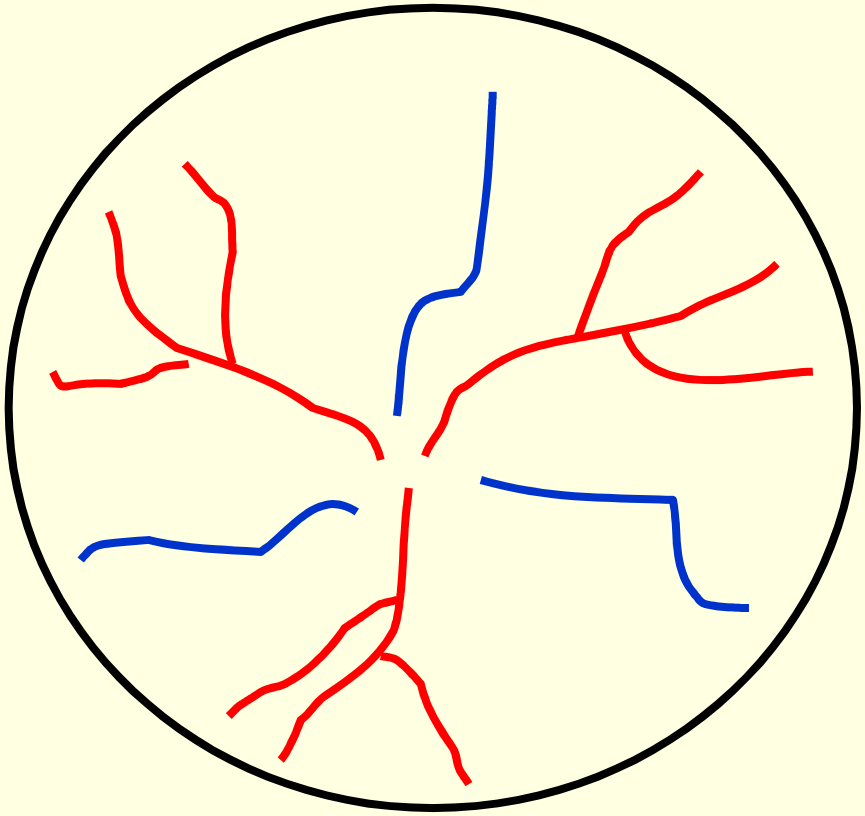
- Starch…
  - Present in plant materials as ‘starch granules’
    - starch molecules in the form of densely packed bundles
  - Two parts of starch molecules:



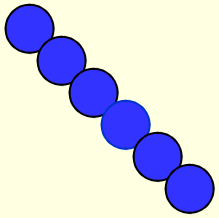
Amylose
(linear)



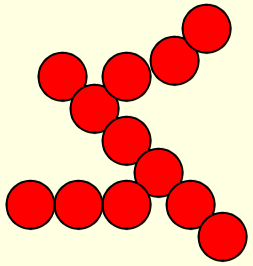
Amylopectin
(branched)



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



- **Amylose** molecules contribute to gel formation:
  - the linear chains
  - orient parallel to each other,
  - moving close enough together to bond (Hydrogen bonds)



- Branched amylopectin molecules give viscosity to the cooked paste.
  - Side chains- bulky shape
  - keeps them from bonding together
    - not contribute to gel formation

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

Starch gelatinization…

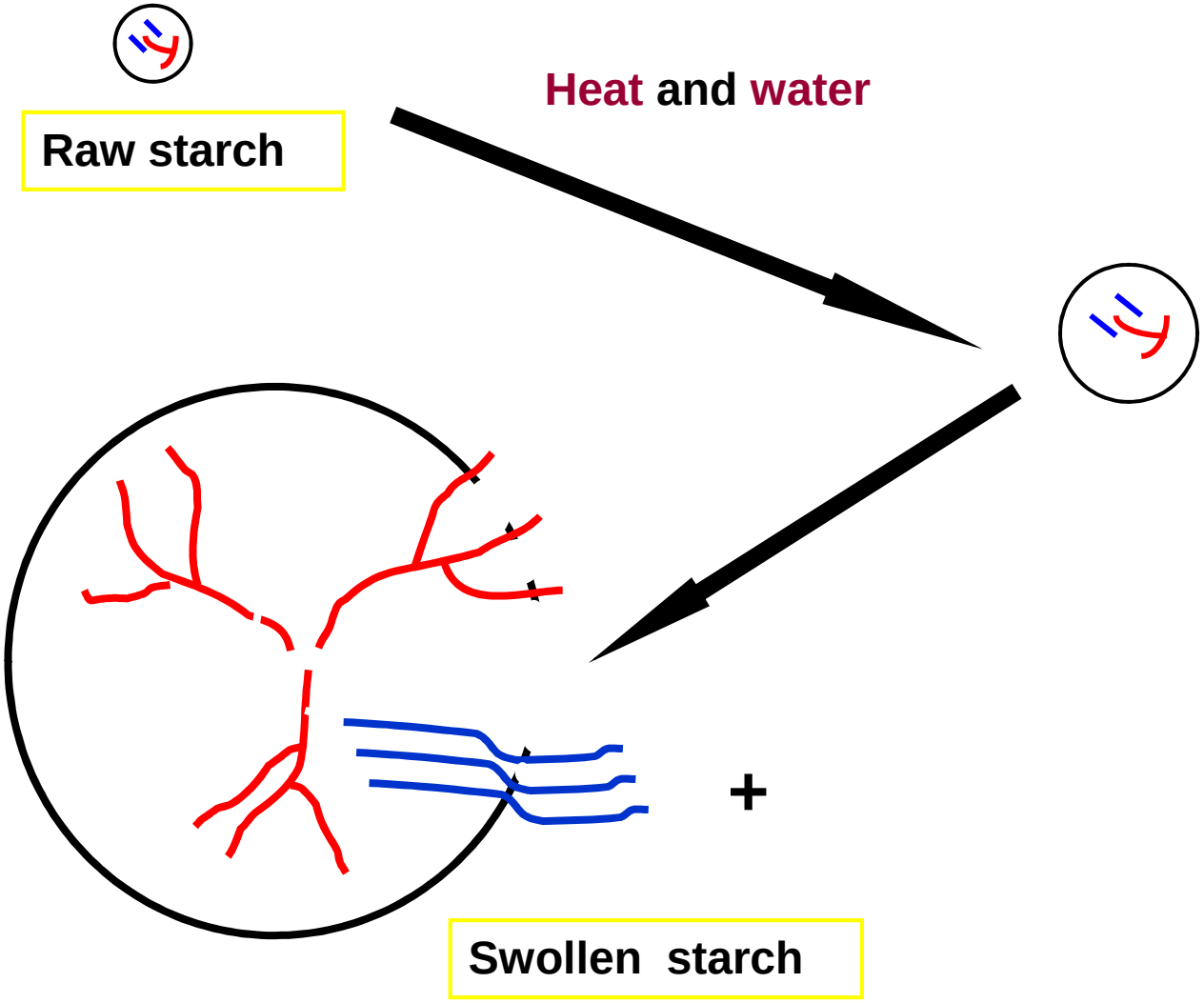
Raw starch

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…



(1) 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
    - "retrogradation"
  - loss of water holding capacity, toughening of food, gritty texture
    - eg. *Stale bread, gritty starch puddings*
  - Accelerated by Refrigeration temperatures
  - partially reversed by heating

(1) Carbohydrates:

c) Polysaccharides- Cellulose

- **Cellulose**
  - Most abundant of all CH polymers
  - Plant cell wall material
  - linear chains of glucose units
    - Linked by β- 1,4
    - INDISGESTIBLE
      - Part of dietary fiber component of foods

starch α- 1,4, 1-6 = **digestible**

cellulose β- 1,4 = **indigestible**

- **Both = 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

Use of Nutritive and Nonnutritive Sweeteners
Class slides and posted lessons

From the information provided in the article, can you answer the following:

- What are sugars?
- What are the *principle sugars* in honey?
- How are HFCS made? Why are they used in low-calorie products?
- Why are sugar alcohols used in chewing gum?
- Name the sugar alcohols that are less sweet than sucrose
- Which sugar alcohol is known to have a *laxative effect* and why?