General Chemistry (CH101): Chemistry around Us

Department of Chemistry

KAIST

©Shutterstock/Rawpixel.com

Brewing and Chewing

Chapter 10

We eat and drink for a variety of reasons.

1. Necessary for our survival, providing the nutrients and energy we need
2. Tastes good
3. Makes us feel good
4. Part of our customs and traditions

How do we taste?

©Mitch Hrdlicka/Getty Images

Tongue: a remarkable organ

- an essential nerve center that determines taste

- it helps move food around to aid in our chewing

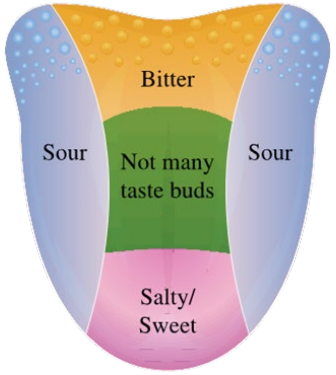
Taste

-Tongue: six basic tastes = sweet, salty, bitter, sour, savory (umami), and fatty

-Mouth: chewiness, crunchiness, oiliness, texture, and viscosity

What is the taste?

This is what I've learned



This is what you're going to learn or have learned

Taste = "a whole bunch of chemical interactions"

Molecules in foods – (interaction) – Molecular sensors on the surface of our tongue

Nerve cells (**chemical receptors** and **ion channels**)

→ Triggers a signal to the brain

$NaCl \rightarrow Na^+ + Cl^-$ (Salt)

$CH_3COOH \rightarrow H^+ + CH_3COO^-$ (Vinegar)

These experiences do not stop at the tongue!!

Interaction with other body parts → mood and health

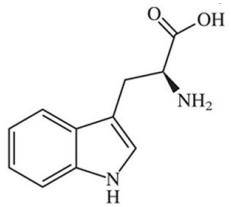
Story of chocolate

Smell = aromatic compounds enter our nostrils and bind with odor receptors in the nasal cavity

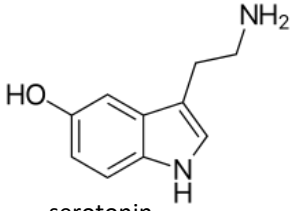
→ Triggers a signal to the brain

Chocolate smell: **>600 chemicals** come together

- **Tryptophan** (a precursor for the serotonin)



Tryptophan



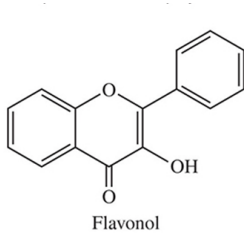
serotonin

Neurotransmitter for happiness

Nose → soothing feelings

Mouth → a pleasing and calm mood

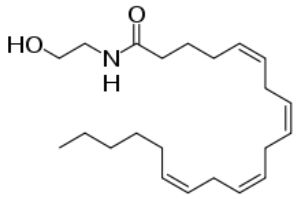
- **Flavonols**



Flavonol

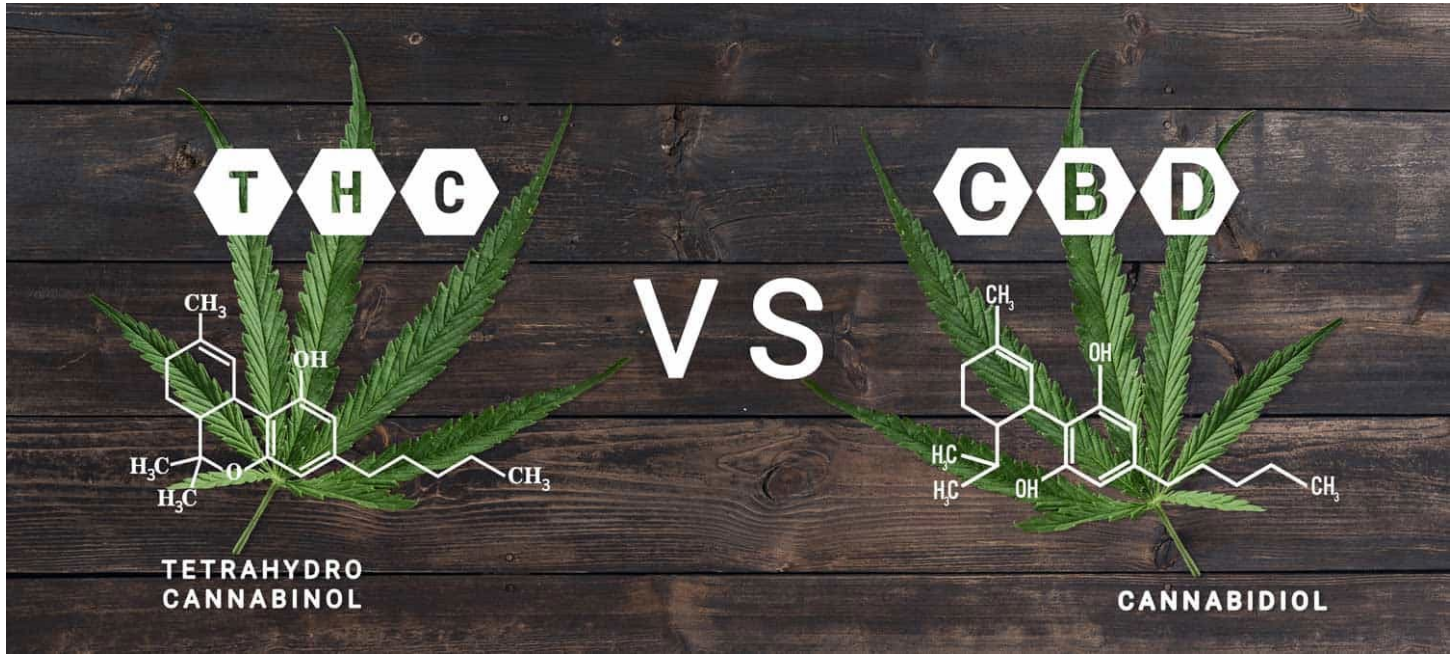
Teas, red wine, fruits…
Antioxidant
healthy heart
Cancer prevention

- **Anandamide**



targets the same brain receptors as **THC** (tetrahydrocannabinol)

Cannabis (marijuana)



Responsible for being high

(psychoactive compound)

= drug

Associated with pain relief

+ certain mental health benefits

(cannot get high)

= medical marijuana

Kitchen = Research Lab

Purpose of cooking

- to make it safe for eating (killing unwanted organisms)

- to make it taste better

- **Table 10.1** Selected Ingredient Measurements Per Dozen Chocolate Chip Cookies

Recipe A	Flour (cups)	Total Sugar (cups)	Butter (cups)	Banking Soda (teaspoons)	Brief Description of Resulting Cookies
A	0.45	0.30	0.20	0.20	"Perfect blend of textures"
B	0.65	0.45	0.27	0.20	"Wonderfully combined textures"
C	0.50	0.27	0.20	0.15	"Crisp bottom, soft top"
D	0.60	0.40	0.20	0.15	"Crisp and crunchy"
E	0.45	0.30	0.20	0.10	"Soft and chewy"
Average	0.53	0.34	0.21	0.16	
Standard Deviation	0.09	0.08	0.03	0.04	

Recipe = Experimental protocols for chemical reactions

- Proportion matters (not the quantity itself!)

- Consistency is the most important thing!

Your Turn 10.5

Crunchy cookies vs chewy cookies

What change in ingredient(s) do you predict causes the difference?

We have all the ingredients, and now it's time to cook!

Boiling pasta

- 1: Prepare enough water to cover the pasta
- 2: Bring water to a boil
- 3: Add uncooked pasta
- 4: Set timer to a cook time for *al dente*
- 5: Remove past from water, add your sauce

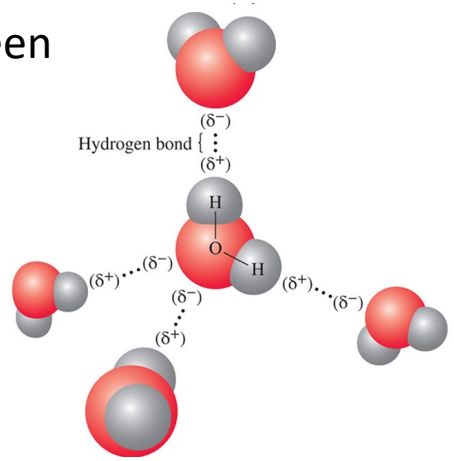
<Scientific principles in the recipe>

1. The laws of thermodynamics

Heat is transferred from objects at a higher temp to objects at a lower temperature!

2. High latent heat of water (ability to absorb significant amounts of heat)

This is due to strong hydrogen bonding between neighboring water molecules



Your Turn 10.10

The “perfect quesadilla” can be made with two large flour tortillas (200 g/tortilla) and 1 cup of cheese (50 g)

a. You open the refrigerator and find 350 g of cheese that is about to expire. If you use all of the cheese, how many quesadillas can you make?

b. If you have a total of eight tortillas, which ingredient will be completely consumed and which will be the “limiting reagents”

Your Turn 10.10

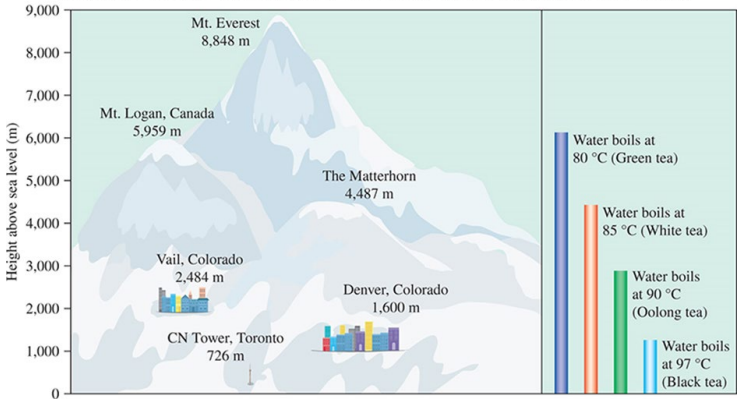
What would happen if you add salt and/or olive oil while boiling pasta?

Boiling temperature vs Pressure

Boiling point: vapor pressure above the liquid >= the ambient pressure acting on the liquid

- Higher altitude = lower boiling point

- A pressure cooker = higher boiling point



Where sugar?

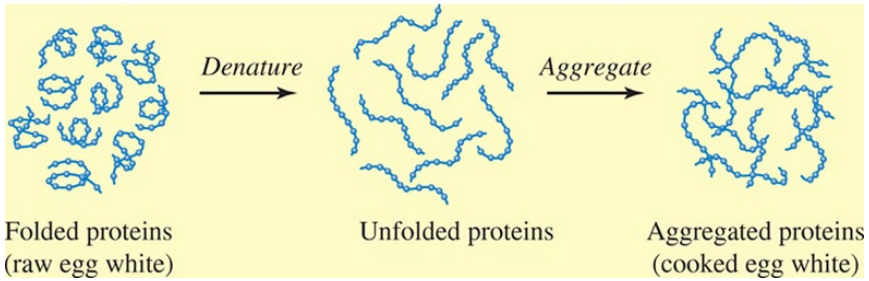
Physical and Chemical Food Transformation

Thermodynamics

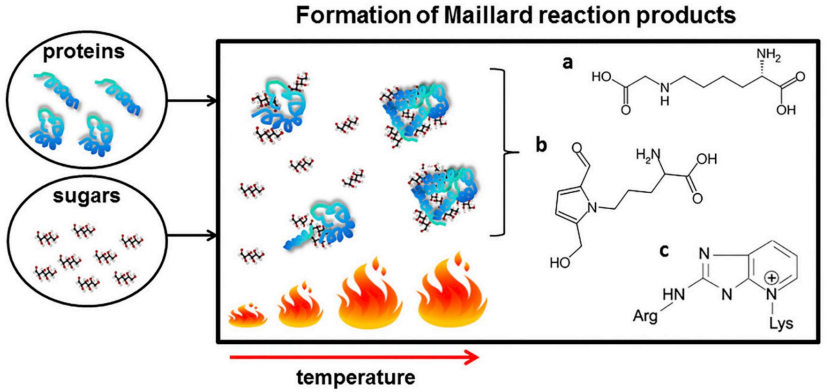
Stove flame → pan → butter (solid to liquid)→ egg (raw to fried)

Physical change **Chemical change**

Translucent portion of the egg → an opaque white solid



The edge of the white → crispy brown (texture + flavor)



Maillard reaction
(“my-yar”/“my-yard”)
Sugar binds to protein

https://www.acs.org/pressroom/reactions/library/maillard-the-most-delicious-chemical-reaction-in-the-world.html

What's It Like To Learn Math 0:30 (youtube.com)

Physical and Chemical Food Transformation

***Sous Vide* ("under vacuum" in French)**

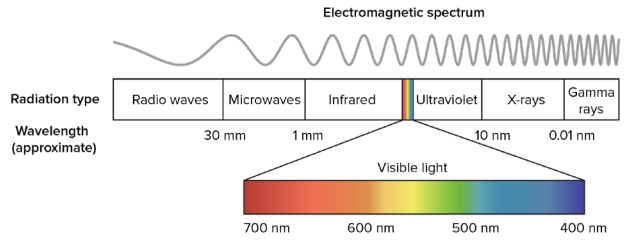
= Water as the medium + lower temperature + longer process + ingredients in a vacuum bag

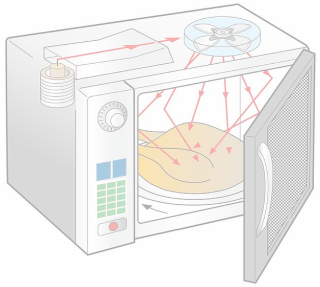
(*i.e.,* ~50 C for > 6 hr)

- Food never actually contacts the water
- Bags with air bubbles → float in water → uneven heating
- No extra volume → water does not evaporate from the food
  → food stays juicy
- No Maillard reaction due to the lower temperature

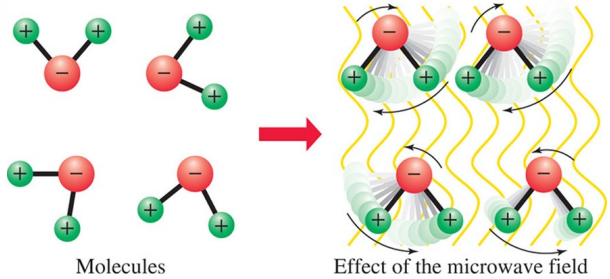
Microwave

Microwave (lower E & longer wavelength) is not sufficient to rupture chemical bonds





1. **Water, fat, and sugar** absorb the microwave radiation
2. Rotation of these molecules (2.5 million times/s)
3. Easily bump into one another → production of heat



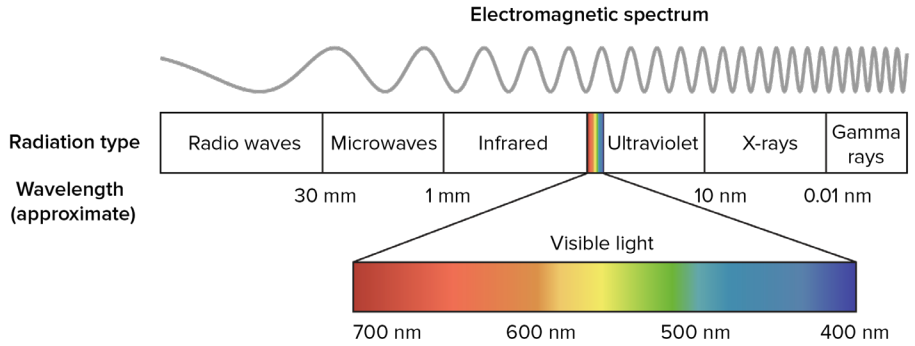
- Microwaves penetrate ca. 1~1.5 inches → inefficient for thicker foods
- **Metals** do not absorb microwave but reflect → aluminum on the sides of the over
  → prevent the microwaves from escaping! (efficiency and safety)
- Aluminum foil in a microwave oven?? (safe? or not?)

https://youtu.be/0yi6EzAK66s

Your Turn 10.14

A company claims to have a new type of cooking apparatus using radio waves to cook

What is your opinion on that?



Your Turn 10.15

Sketch and compare the differences in heat transfer (in microwave vs conventional oven)

No-Heat Food Preparation

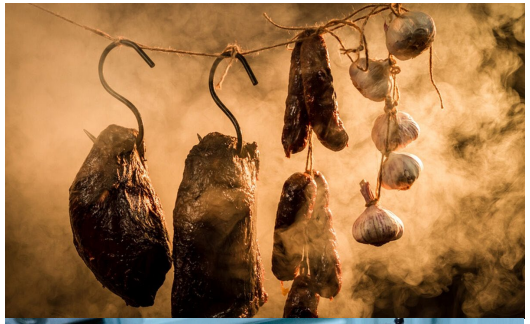
Microbes in food need water to survive → removing water can preserve food items

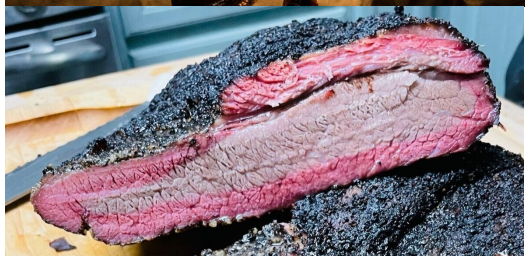
Drying

Salting

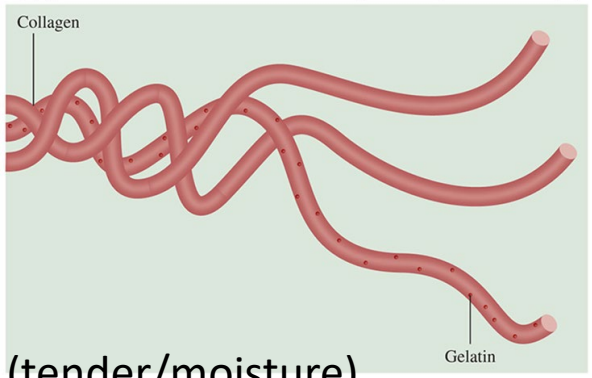
- An application of osmosis
- Nitrites (NO_2^-) and nitrate (NO_3^-)
  → kill bacteria + add flavor
- They break down further into NO
  → binds to iron in heme
  (prevents oxidation)

Smoking





- heat-transfer over long time
- The collagen converts to gelatin (tender/moisture)
- **The smoke ring:** NO_2 from smoke interacts with meat → more acidic → pink color



No-Heat Food Preparation

Microbes in food need water to survive → removing water can preserve food items

Acidic marinades

ceviche

- Another way to cause **chemical changes**
- Denature proteins = much like the heat
- Higher-acidic environment kills microbes

Pickling

Sauerkraut

- Wet-curing process that uses both salts and acids
- Acidic marinades = fast

  but pickling takes weeks to months

Three phases of foods (liquid, solid, and GAS)

Foods are mostly solid and liquid, but **gas can be the cherry on the cake!**

The wonderful aroma
= chemicals in food form gases

Carbonated beverages
= carbon dioxide (CO_2)

Henry's law

$$C = kP$$

C= [gas] in the liquid
k = constant
P = pressure of the gas in the bottle

The minute the seal is broken
→ P decreases
→ C decreases
→ Eruption!!

Trapping of agas in a liquid = a frothy mixture = THE FOAM

Your Turn 10.#

Explain the eruption when Mentos is added to soda

Diet Coke and Mentos (youtube.com)

Your Turn 10.21

Using Henry's law, compare the concentration of dissolved carbon dioxide in a sealed 500 mL bottle of Coke with a CO_2 pressure of 1.25 atm, to that after the bottle is opened at 25C.

The Henry's law constant for CO_2 is 0.031 mol/L atm. How much CO_2 (in grams) escapes after the bottle has been opened?

Three phases of foods (LIQUID, solid, and gas)

Liquid-liquid phase separation (LLPS)

Oil and water do not mix (oil = nonpolar, water = polar)

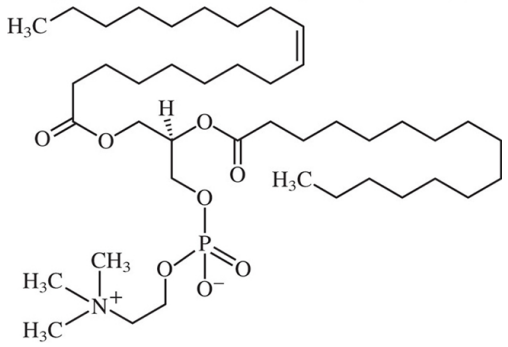
But the two can be held together with some assistant

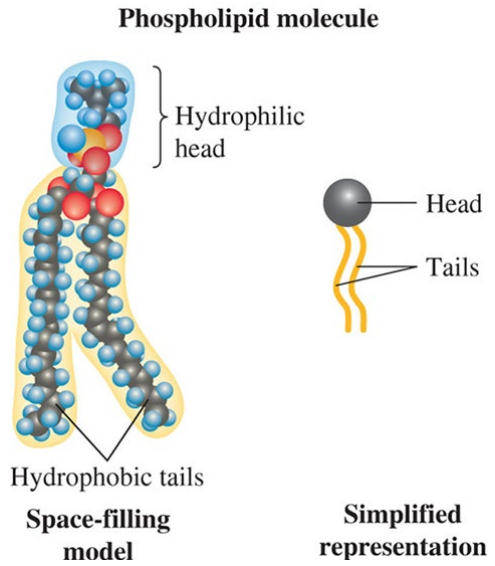
= EMULSION

A way to create more permanent emulsion can be made by emulsifying agent

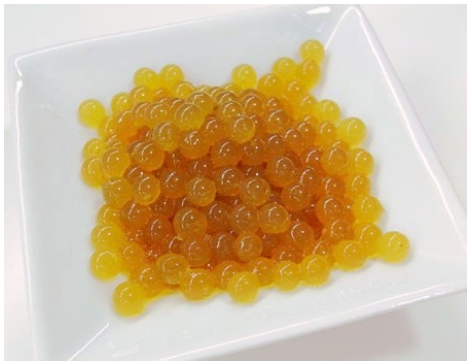
- **Amphiphilic** = attracted to both nonpolar and polar

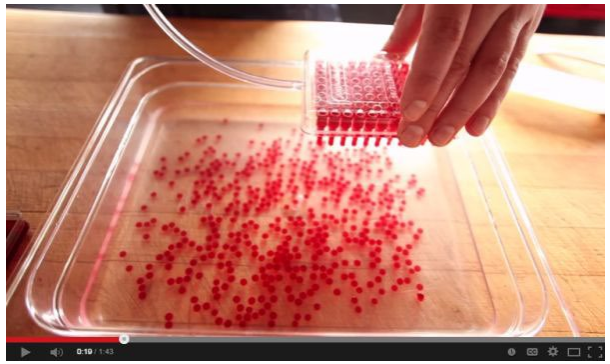
(i.e., lecithin in the egg yolk → mayo)



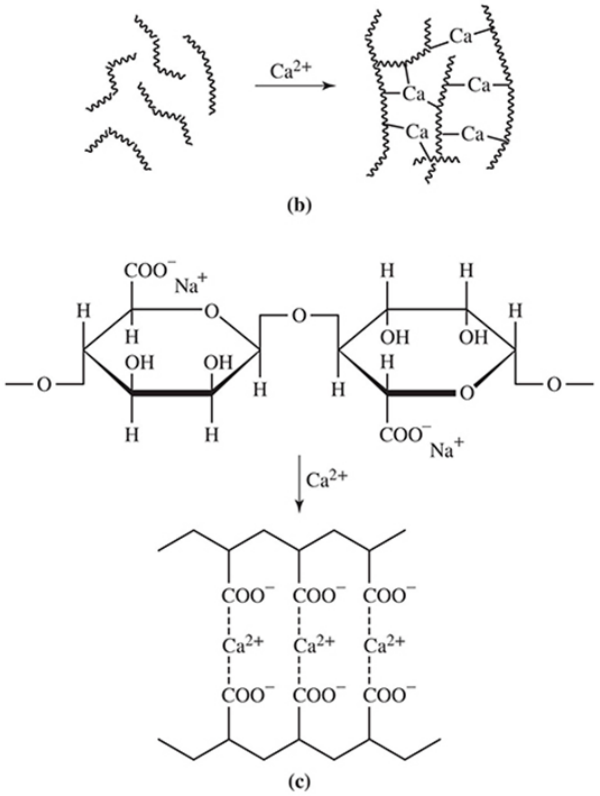


Three phases of foods (LIQUID, SOLID, and gas)





Spherification by using liquid to solid transition



The long carbohydrate chains (sodium alginate) float around unconnected

+ calcium ions

→ Forms a larger molecular network (=solidify)

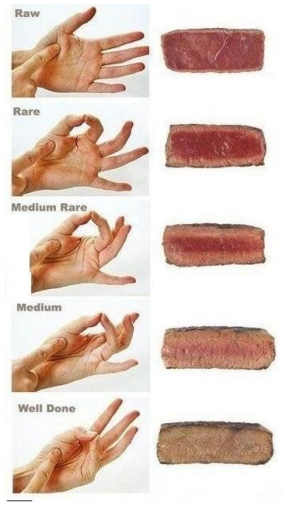
Is my food ready?

M.R. Temp?

Provide a certain temperature → time for heat transfer → food to be ready (flavor/texture)

Quantitative information (temperature)

Qualitative information (textures/firmness)

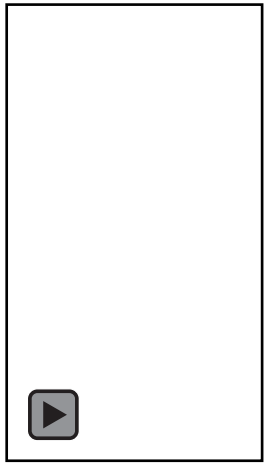


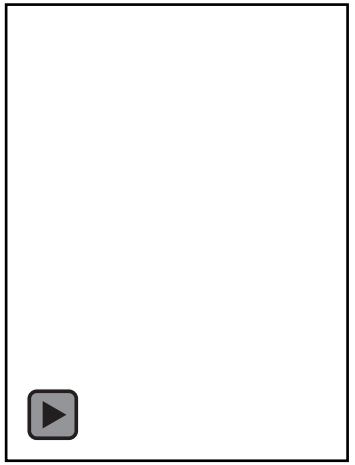
Quantitative criteria can give a high **reproducibility**

Let’s make some beer!

<Beer brewing>

Sugar concentration determines if your beer is ready to go!
- As the **yeast consumes the sugar**, the **density of your beer decreases**



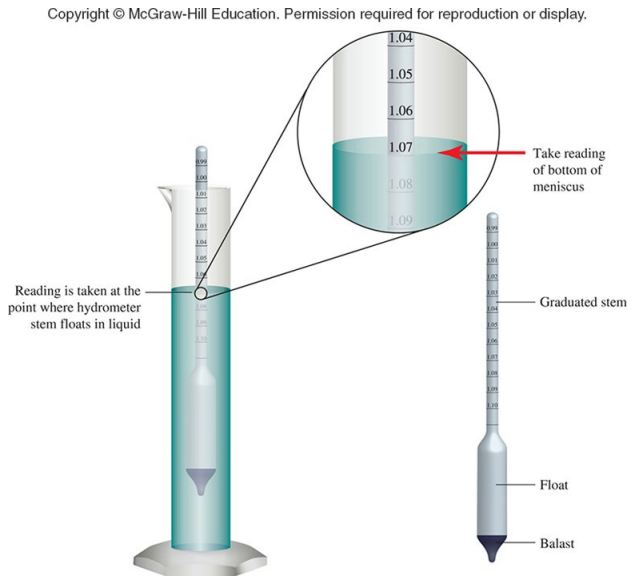


@Cupertino, California

Let's make some beer!

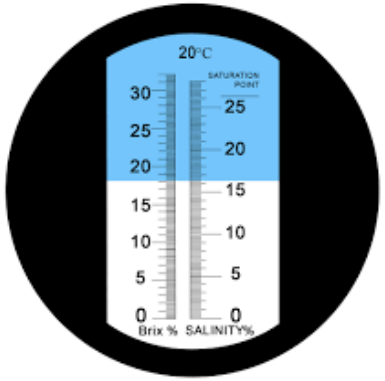
<Beer brewing>

Sugar concentration determines if your beer is ready to go!
- As the **yeast consumes the sugar**, the **density of your beer decreases**



Hydrometer

Refractometer



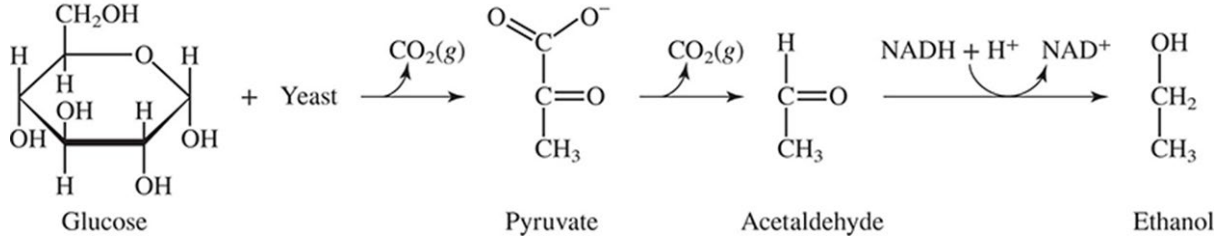
1 Brix
= 1 g sugar / 100 g water

The higher the density of a solution,
the more the light will bend

Let's make some beer!

<Beer brewing>

Fermentation: anaerobic metabolism of sugar by yeast



<Bread baking>

Bread dough utilizes the same yeast fermentation
→ Ethanol evaporates during the baking process
→ Airy texture of bread

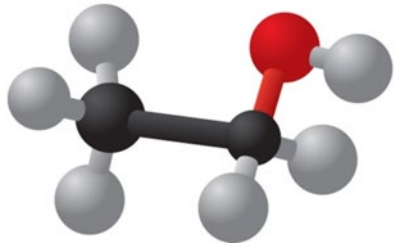
vs Whiskey?

Let's make some beer!

<Beer brewing>

Different sugar sources

- fruits (wine and ciders), grains (beer), rice (sake), honey, sugarcane…..

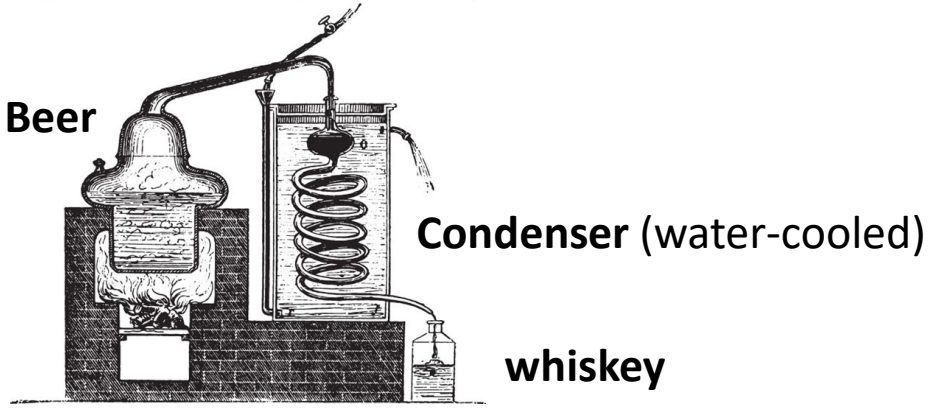


<Ethanol>

- Both fat- and water-soluble (hydrocarbon and –OH group)
- Small in size (46 g/mol)

→ This allows ethanol to travel anywhere through membrane
(Best way of consuming ginseng)

Distillation (liquors)



Distillation = a purification technique based on the boiling temperature difference
(b.p. of ethanol < b.p. of water)

Methanol = by-product of the process **(license required!)**
- 10 mL of methanol = blindness
- 30 mL of methanol = fatal

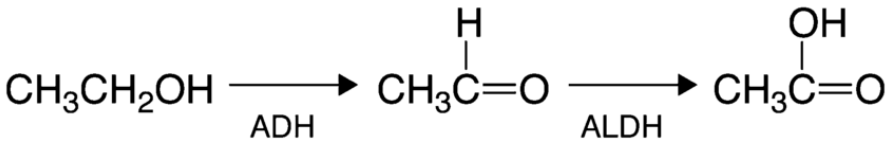
Alcohol consumption → brain blocks the creation of the hormone, *vasopressin*
→ Kidneys send water out through urine → Electrolytes are lost (urination)
→ HANGOVER!!

(250 mL of alcoholic beverage >> body to expel 800~1000 mL of water)

How Is Whiskey Made? (youtube.com)

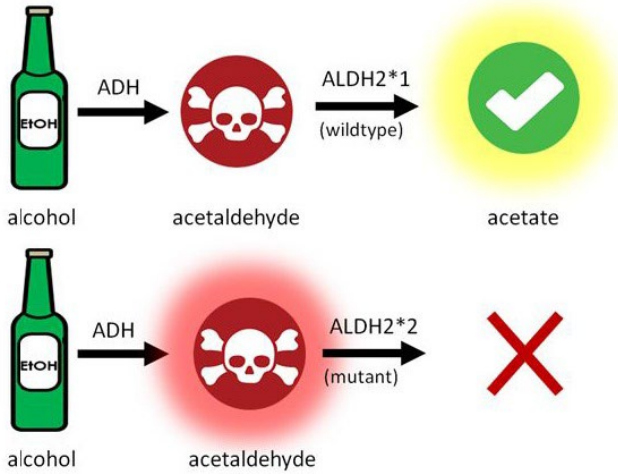
The next day….

Ethanol Acetaldehyde Acetic acid



ADH alcohol dehydrogenase

ALDH aldehyde dehydrogenase



Alcohol flush (ALDH2 Asian flush)

-accumulation of acetaldehyde

Chemical mechanisms of getting a hangover
Why do grain-based alcoholic beverage give a severe hangover?
Suggest chemistry that can mediates a hangover
What is the relationship between a healthy diet and Maillard products?
How do Sous Vide cooking processes soften meats?
Talks about the chemical processes related to fish going bad quickly.

숙취 발생의 화학적이유
곡주가 숙취 더 심한이유
숙취 제거를 위한 chemistry
마이아르 음식과 건강간의 상관관계
수비드 음식이 부드러운 이유
생선이 빨리 상하는 것과 관련된 chemistry