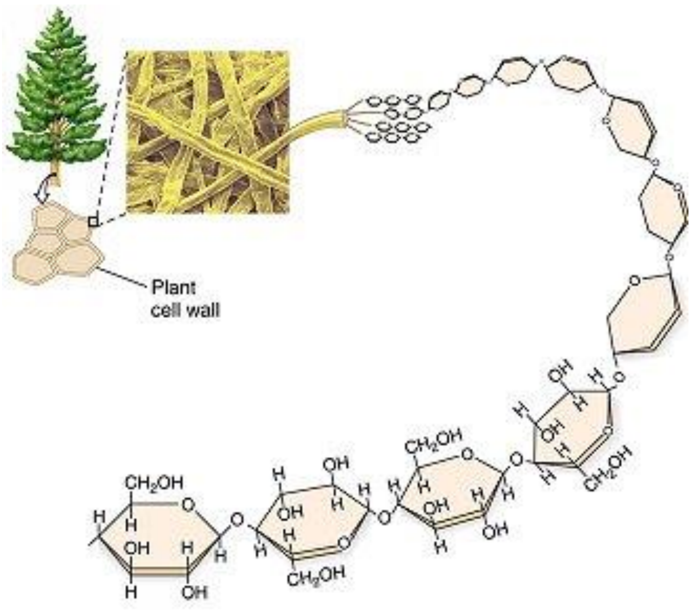
Asst. Prof. Cansu Ekin GUMUS

Polysaccharides

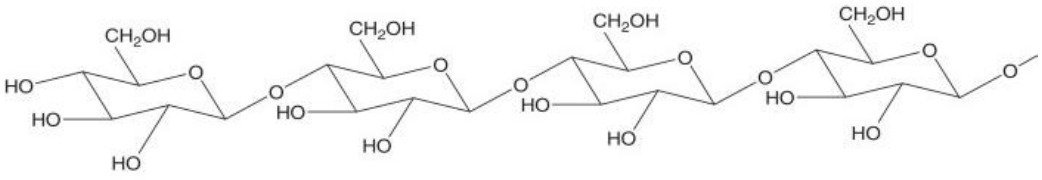
- **Monomers:** *Monosaccharides*
- **Bonds:** *Glycosidic Bonds*



Natures building blocks

Polysaccharides:

- They are polymers of monosaccharides. If they contain10-20 units, they are called oligosaccharide, if they contain more, they are called polysaccharide.
- Most polysaccharides (PSs) have a monomer number of 200-3000 (7 -15 thousand in cellulose and 60 thousand in amylopectin). > 90% by mass of CHs in nature are polysaccharides. (Polysaccharides are commonly called GLICANS).
- If all of the glycoside units consist of the same monomer, it is called a homoglycan (eg starch, cellulose). If different, it is called heteroglycan.



- Each sugar unit in glycans is water-binding, and most of them *hydrate, absorb water, swell,* and *generally dissolve* partially or completely in the presence of water.
- Polysaccharides, like other carbohydrates, control and modify the mobility of water in the food system.
- In an aqueous environment, carbohydrate polymers are surrounded by hydration shells consisting of water molecules that are sometimes called "**bound**". When polymer solutions are subjected to low temperatures, a part of water turns into ice, another part remains in the biopolymer phase and is called "**nonfreezing water**". The amount of non-freezing water does not reflect the amount of bound water, neither can it be used as a measure of strength of polymer-water interactions.

- Most of the polysaccharides are in *helix* structure. Some flat structured homoglycans such as cellulose are flat-ribbon-like.
- Many PSs are used to form gel, modify and control flow properties and texture (at rates of 0.25-0.5%).
- PS solutions create two types of Non-Newtonian flows:

1- Pseudoplastic: As the force increases, the viscosity decreases - generally high molecular weight PSs create this type of flow.

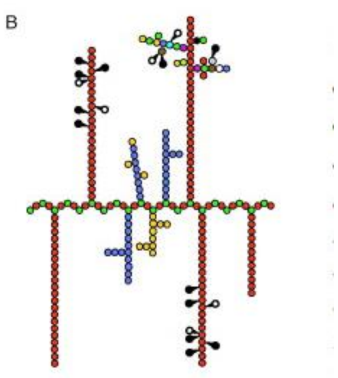
2- Thixotropic: Viscosity reduction does not occur immediately.

- **Gums** are usually considered to be non-starch, water-soluble polysaccharides with commercial importance. When used as ingredients in processed foods, they may be called *hydrocolloids.* All gums have one similar property, i. e., the ability to thicken water and aqueous systems.
- In many gums, temperature increase decreases viscosity. When it cools, viscosity rises again. This should be taken into account in food processing (*except xanthan gum*).
- Polysaccharides can be hydrolyzed. This can occur during processing or storage. Glycoside bonds can also be broken down by acid or enzymes (like in production of HFCS). Especially in the thermal process of acidic foods, undesirable viscosity reductions may occur. More polymer should be used in this case.

Carbohydrates:
Classification of Polysaccharides

Definition: Polysaccharides are polymers of monosaccharides

Chemistry
- Number of monomers
- Type of monomers
- Sequence of monomers
- Bond type



Pectin Structure

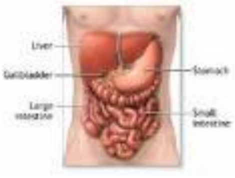
Biological Origin
- Plant cell walls
- Plant exudates
- Microorganisms

Seaweed

Apple

Functional Properties
- Thickening
- Gelation
- Water binding
- Emulsification

Nutritional Properties
- Digestible (Energy)
- Non-digestible (Fiber)

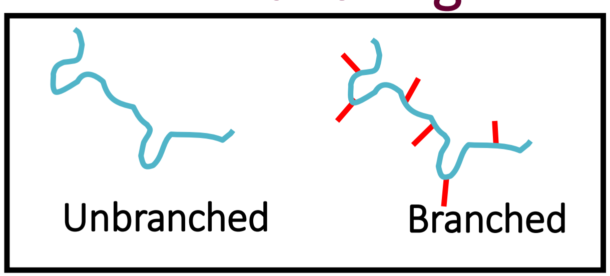


Food Biopolymers:
Proteins & Polysaccharides

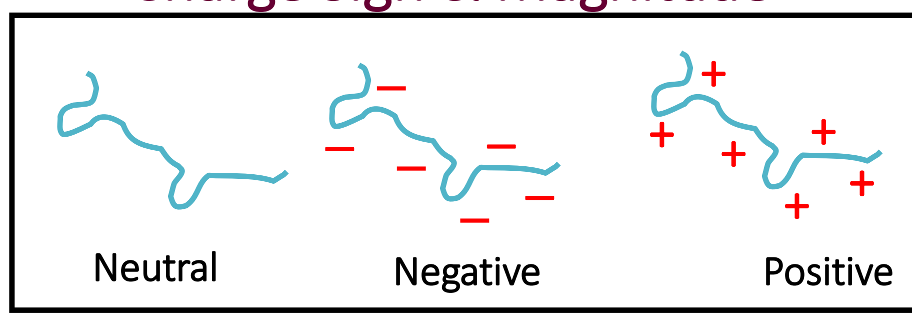
Molecular Weight

Conformation & Flexibility

Branching

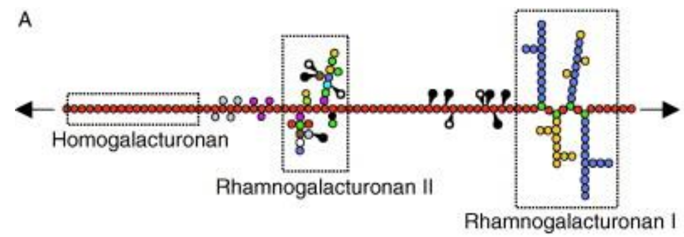


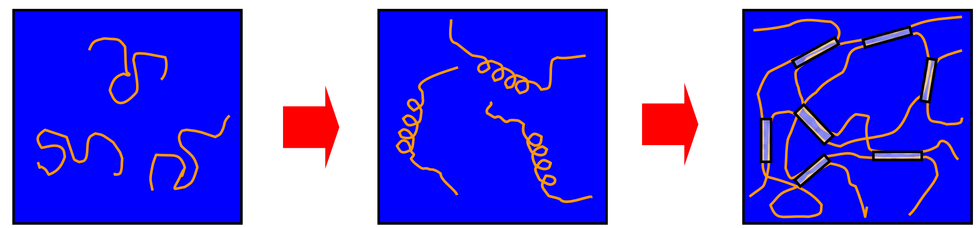
Charge Sign & Magnitude



Food biopolymers vary greatly in origin, properties and performance

Biopolymer Functionality:
Determined by Molecular Chemistry





Chemical Characteristics

- Number of Monomers
- Type of Monomers
- Sequence of Monomers
- Type of bonds
- Position of bonds (Branching)

Molecular Characteristics

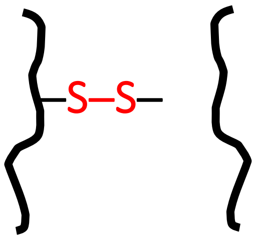
- Molecular Weight
- Conformation
- Aggregation
- Surface Activity

Functional Characteristics

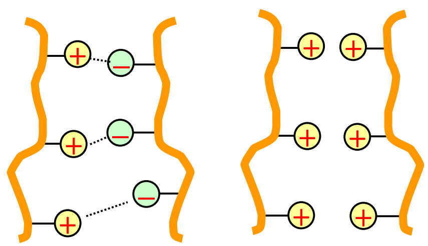
- Solubility
- Thickening & Gelling
- Stabilization
- Emulsifying and Foaming

Intermolecular Interactions

Covalent bond

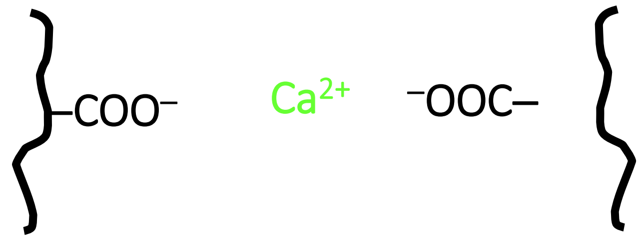


Electrostatic interactions

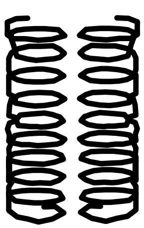


Attraction Repulsion

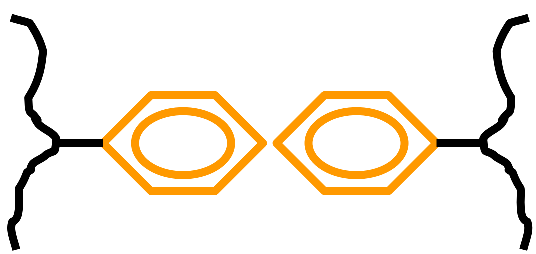
Salt bridge



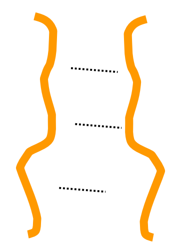
Hydrogen bonding



Hydrophobic attraction



VDW attraction



Major Functional Properties of Food Biopolymers

- Texture Modifiers – Modify texture or mouthfeel of foods, *e.g.*, thickening and gelling agents
- Stabilizers – Retard movement of droplets or other particulate matter
- Water binders – Hold water within food product & prevent syneresis
- Emulsifiers & Foaming Agents – Facilitate emulsion or foam formation & stability
- Encapsulants – Encapsulate flavors or other functional ingredients

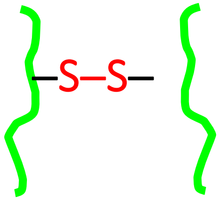
Texture Modifiers & Stabilizers:

Thickening & Gelling Agents

Mode of Operation:

- Thickening Agents: – increase viscosity because of their large molecular dimensions

- Gelling Agents – form gels because of their ability to form intermolecular cross-links



Thickening & Gelling Agents
Typical Food Ingredients

Polysaccharides

- Agar, Alginic acid, Alginate, Carrageenan, Guar gum, Gellan gum, Curdlan, Modified Celluloses, Modified starches, Pectins, Xanthan

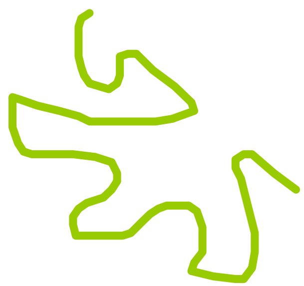
Proteins

- Gelatin, Whey, Casein, Soy, Egg

3 major structures of polymers:

Globular

rigid and compact

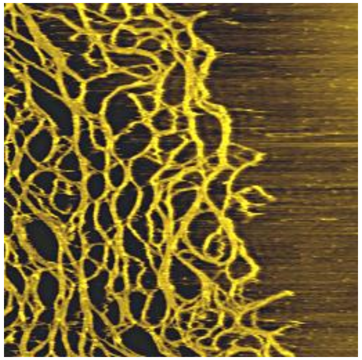


Random coil

flexible, open structure

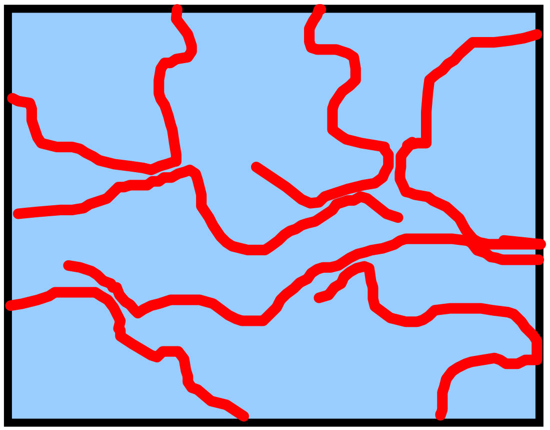
Rod-like

rigid



Xanthan Gum

Gelling Agents:
Molecular Basis of Functionality



Why do some biopolymers form gels?
What determines gel characteristics?

Food Gels:

Many Different Gel Types

Gell-O
- Flexible Proteins
- Cold-set
- Reversible

Pudding
- Starch
- Cold/Heat-set
- Irreversible

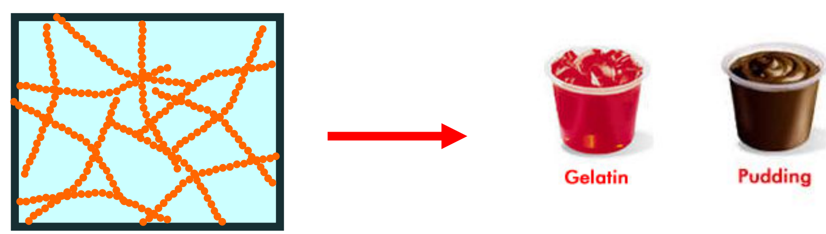
Eggs
- Globular Proteins
- Heat-set
- Irreversible

Deserts
- Polysaccharides
- Ca^{2+}-set
- Irreversible

Food Gels:
Many Different Gel Properties

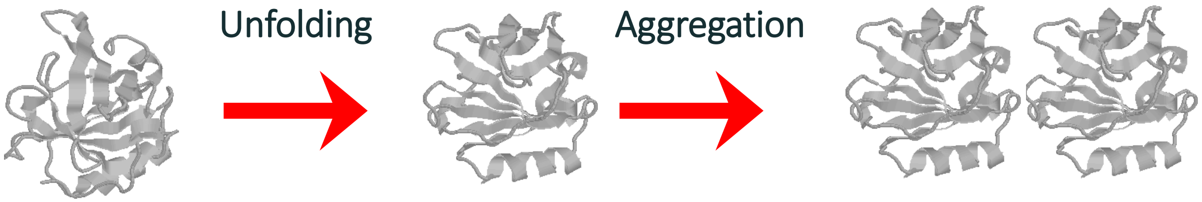
Gel Property	Nature	Origin
Texture	*Weak to Strong; Elastic to Rubber*	*Bond density & Strength*
Appearance	*Clear to Opaque*	*Size & Number of Structural entities*
WHC	*Poor to Good*	*Size & Number of pores*
Behavior	*pH, I or T set*	*Origin of cross-linking*

Large pores>> small capillary forces>>>low WHC
Small pores>>large capillary foces>>>high WHC



Gelation Mechanisms:

Globular Proteins (Whey, Egg, Soy)



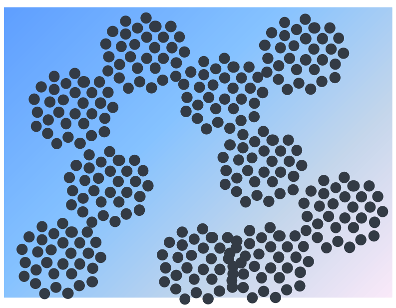
Unfolding

Aggregation

Hydrophobic groups exposed

Hydrophobic effect: hydrophobic groups aggregate

Network Formation



Large 3D protein aggregates
No longer transparent

Physical Properties

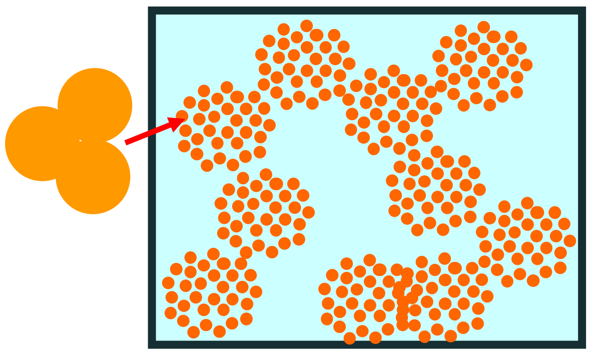
Irreversible!

Gelation Mechanisms:

Globular Proteins (Whey, Egg, Soy)

Weak repulsive forces

(pH ≈ pI, High I)



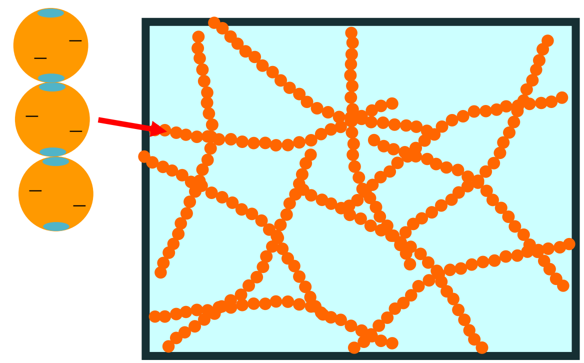
Particulate gel

Key Properties:

- Opaque
- Rubbery
- Poor WHC

Stronger repulsive forces

(pH away from pI, Low I)

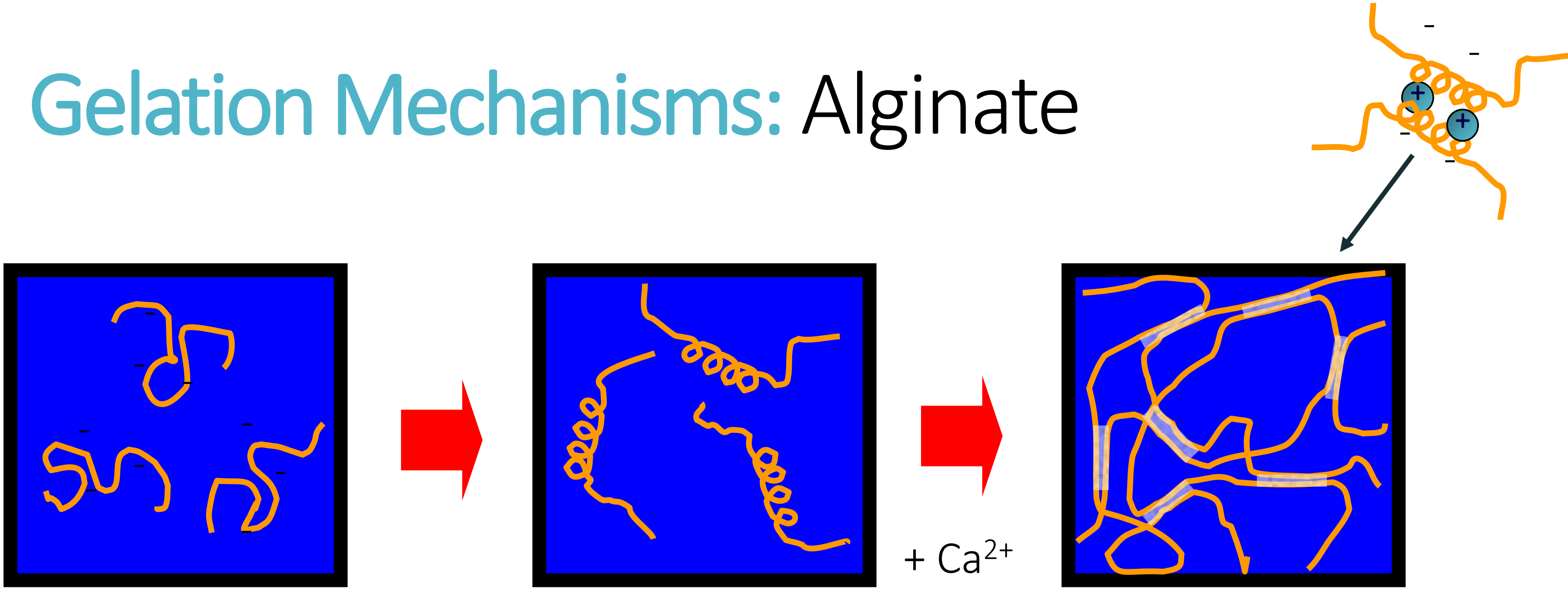


Filament gel

Key Properties:

- Transparent
- Elastic
- Good WHC

Gelation Mechanisms: Alginate



Random Coil (Solution)

Helical (Solution)

Irreversible!

Cross-links (Gel)

Alginate is a polysaccharide obtained from seaweed

Gel Properties

- Ca^{2+}-setting (Ion-bridging)
- Filamentous (alginate molecules)
- Transparent (Thin structural units)
- Good WHC (small uniform pores)

Thickening & Gelling Agents
Selection Criteria

Physicochemical Characteristics

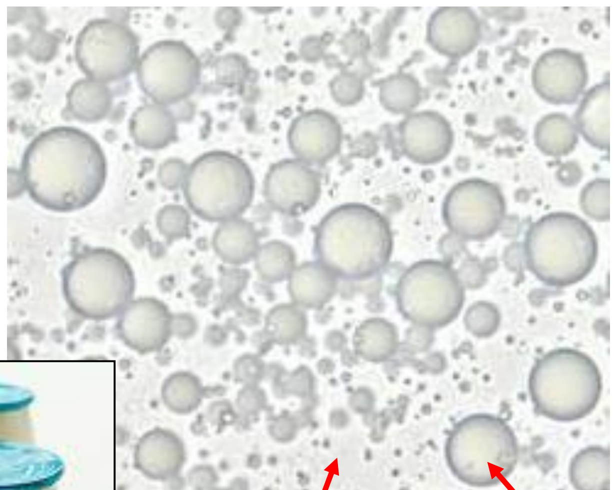
- Texture: *Viscosity, Gel strength, Gelation Temperature, Reversibility, Fracture Properties, etc*
- Dispersion & Solubility Characteristics
- Appearance: *Clear, Cloudy, Opaque*
- Environmental Sensitivity (pH, T, I)
- Ingredient Compatibility

Other Characteristics

- Legal Status
- Label Friendliness
- Cost, Reliability of Supply

Emulsions

An emulsion consists of two immiscible liquids (usually oil and water), with one liquid being dispersed as small spherical droplets in the other liquid.



Characteristics:

- Thermodynamically <u>unstable</u>
- Particle Diameter (0.1 to 100 μm)
- Optically Opaque
- Low Surfactant-to-Oil ratio (<1:10)
- High Surface Area (3 m^2/g)

Food Emulsions

Milk & Beverages

Sauces & Dips

Mayonnaise & Salad Dressings

Butter & Spreads

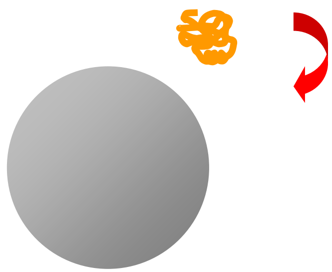
Ice Cream & Deserts

Powdered Products (Creamers, soups, gravies)

A diverse group of products with various appearances, textures, stabilities and flavors, but structural similarities

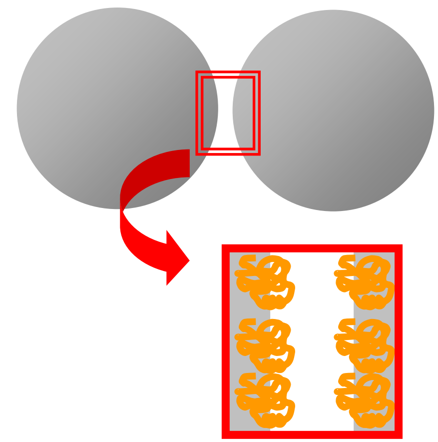
Emulsifiers:
Modes of Operation in Foods

Formation



- Rapidly adsorb
- Lower interfacial tension
- Facilitate breakup

Stabilization

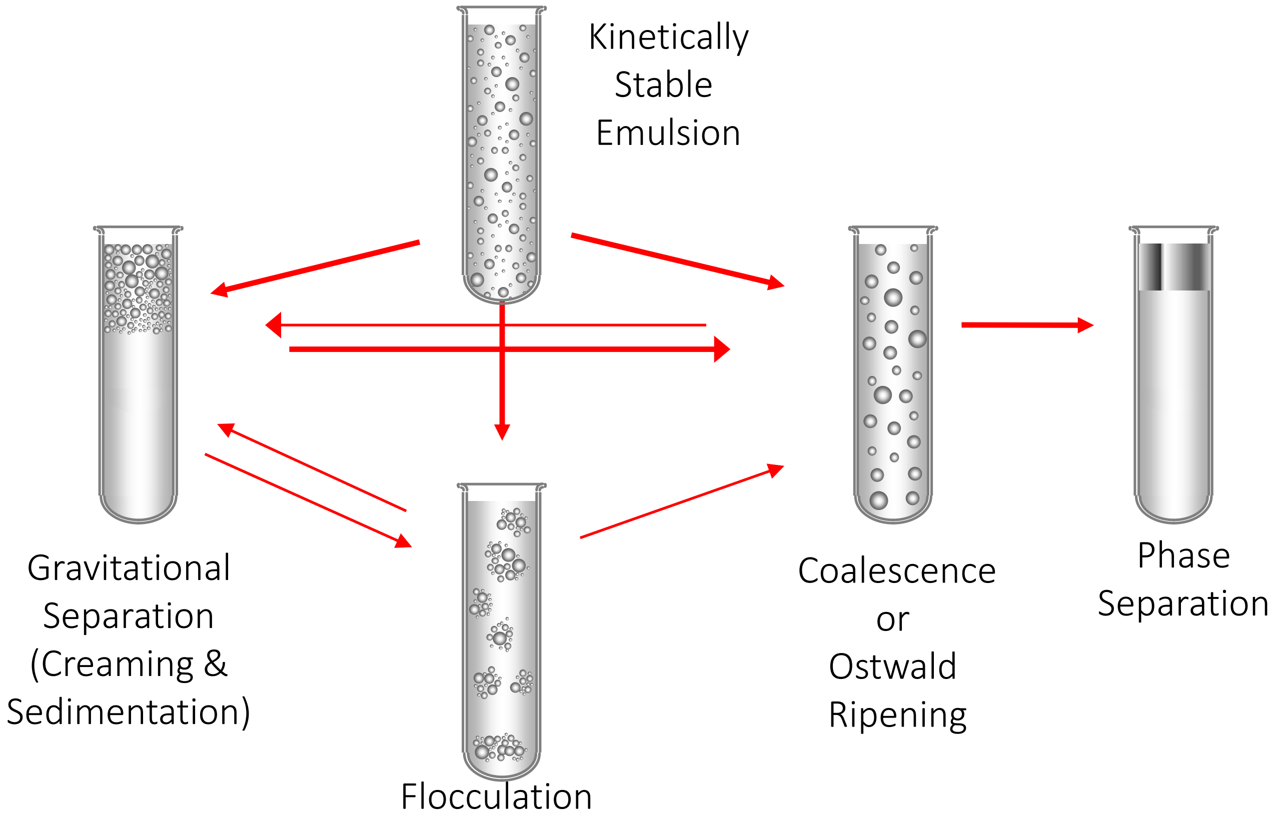


- Generate repulsive forces
- Form resistant membrane
- Prevent Coalescence

Emulsifier: A surface-active molecule that adsorbs to an oil-water interface and forms a protective membrane

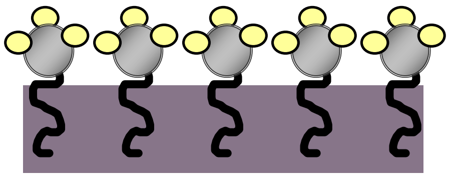
Must operate under environmental conditions encountered in foods

Emulsion Stability:
Instability Mechanisms



Common Food Emulsifiers

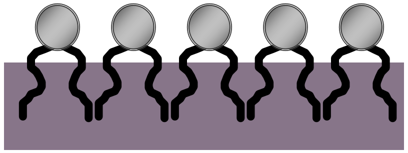
Small Molecule Surfactants



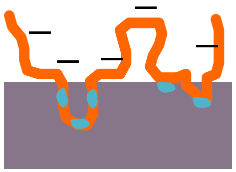
- Tweens, Spans, fatty acids
- Sucrose esters, polyglycerol esters

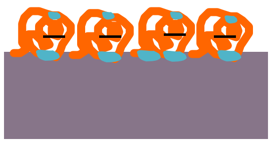
Phospholipids

- Egg, soybean, milk



Biopolymers



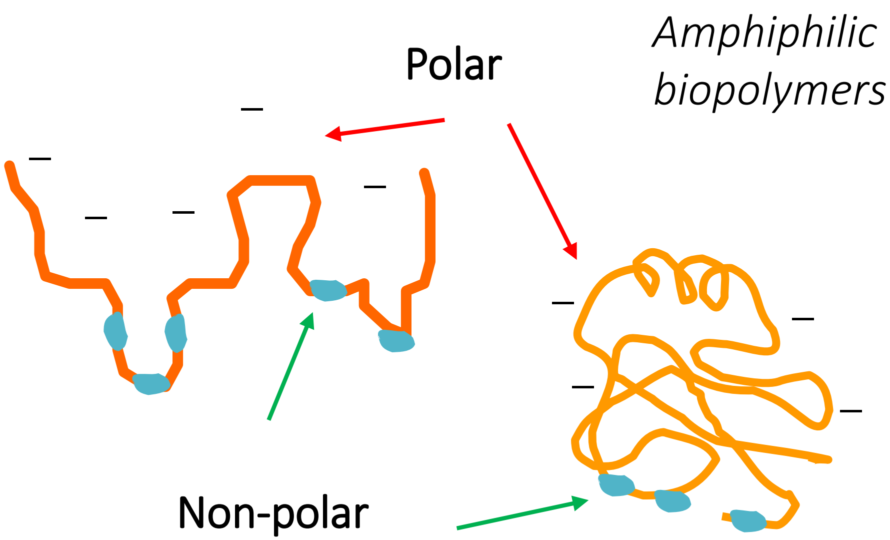


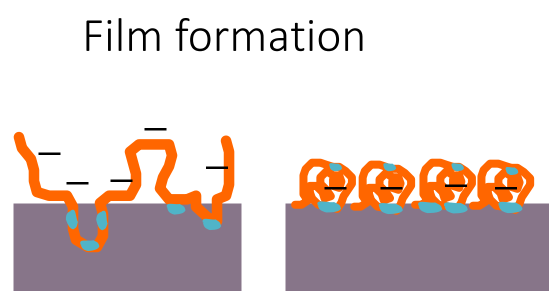
- whey, casein, egg, gelatin, soy
- modified starch, gum arabic, modified cellulose

Biopolymer Characteristics
Surface Activity and Film Formation

Emulsifier Properties

– Ability to adsorb to oil-water interface
– Ability to protect droplets against aggregation





- Repulsive interactions
- Resistance to rupture

Emulsifiers
Selection Criteria

Physicochemical Characteristics

- Emulsion Formation
  - *Amount Needed*
  - *Smallest Droplet Size Produced*
- Emulsion Stability
  - *Environmental Sensitivity (pH, T, I Dispersion & Solubility Characteristics*
- Ingredient Compatibility

Other Characteristics

- Legal Status
- Label Friendliness
- Cost, Reliability of Supply

Biopolymers play many functional roles in foods

- Thickening & Gelling
- Water holding & Binding
- Emulsifying & Foaming
- Biological Activity

- An understanding of the physicochemical principles underlying their behavior can help in selecting the most appropriate biopolymer ingredient for specific applications