Physical Properties of Foods

Content

- ➢Emulsions
- ➢Foams

Emulsions

An emulsion is a colloidal system in which a liquid is dispersed as droplets in another liquid with which it is immiscible.

It is liquid-liquid dispersion type.

classified as

- oil-in-water (o/w) :dispersed phase is apolar
- water-in-oil emulsions (w/o): dispersed phase is polar

Terminology

- Macroemulsions

  –At least one immiscible liquid dispersed in another as drops whose diameters generally exceed 10 μm.

  –The stability is improved by the addition of surfactants and/or finely divided solids. Considered only kinetically stable.

- Miniemulsions
- –Emulsion with droplets between 0.1 and 10 μm, reportedly thermodynamically stable.
- Microemulsions

  –Emulsion with droplets below 100 nm.

  –Thermodynamically stable, transparent solution of micelles swollen with solubilizate. Microemulsions usually require the presence of both a surfactant and a cosurfactant (e.g. short chain alcohol)

Terminology

- Creaming

  -less dense phase rises
- Inversion

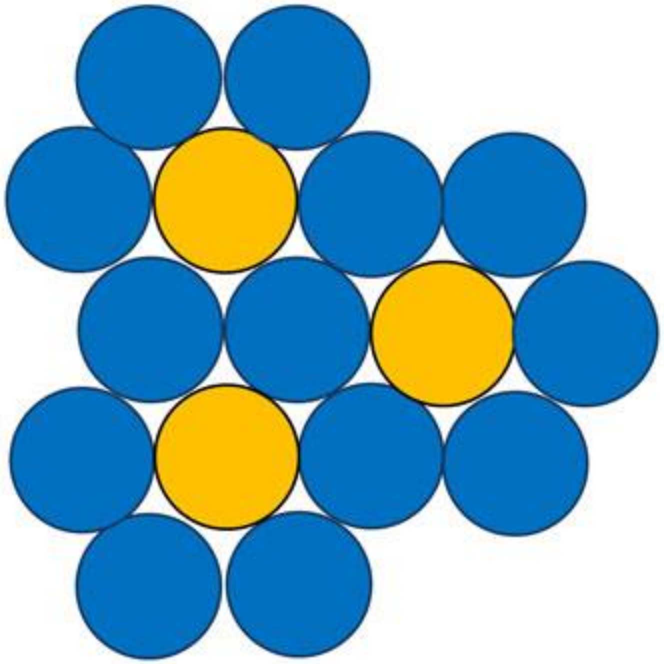
  -internal phase becomes external phase
- Ostwald ripening

  -small droplets get smaller while larger ones grow
- Flocculation

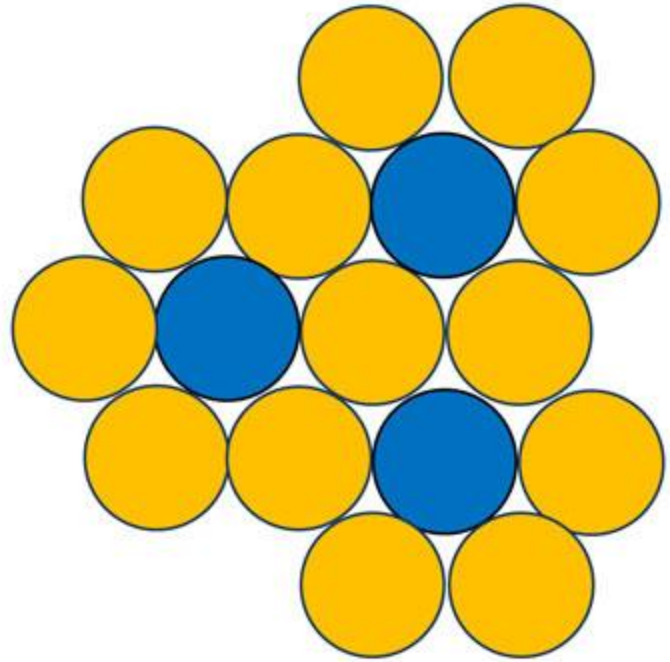
  -droplets stick together
- Coalesence

  -droplets combine into larger ones

***The most important physical property of an emulsion is its stability



Oil-in-Water Emulsion



Water-in-Oil Emulsion

Example of food emulsions

Food	Emulsion type	Dispersed phase	Continuous phase	Stabilization factors
Milk, cream	O/W	Butterfat triglycerides partially crystalline and liquid oils. Droplet size: 1-10 µm Volume fraction: Milk: 3-4% Cream: 10- 30%	Aqueous solution of milk proteins, salts, minerals,	Lipoprotein membrane, Phospolipids, and adsorbed casein.
Ice cream	O/W (aerated to foam)	Butterfat (cream) or vegetable, partially crystallized fat. Volume fraction of air phase: 50%	Water and ice crystals, milk proteins, carbohydrates (sucrose, corn syrup) Approx. 85% of the water content is frozen at –20 ^{o}C.	The foam structure is stabilized by agglomerated fat globules forming the surface of air cells. Added surfactants act as destabilize-rs" controlling fat agglome-ration. Semisolid

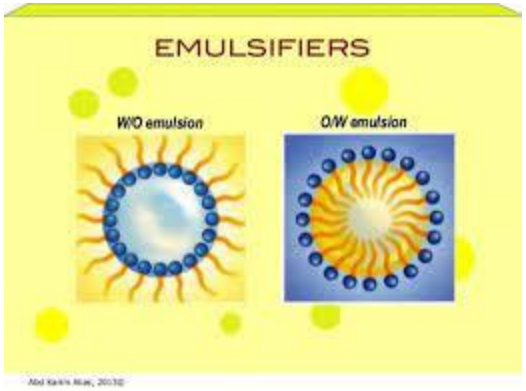
Food	Emulsion type	Dispersed phase	Continuous phase	Stabilization factors
Butter	W/O	Buttermilk: milk proteins, phospholipids, salts. Volume fraction: 16%	Butterfat triglycerides, partially crystallized and liquid oils; genuine milk fat globules are also present.	Water droplets distributed in semisolid, plastic continuous fat phase.
Mayonnaise	O/W	Vegetable oil. Droplet size: 1 – 5 µm. Volume fraction: minimum 65% (U.S. food standard.)	Aqueous solution of egg yolk, salt flavors, seasonings, ingredients, etc. pH: 4.0-4.5	Egg yolk proteins and phosphatides. Lecithin (O/W), cholesterol (W/O)
Salad dressing	O/W	Vegetable oil. Droplet size: 1 – 5 µm. Volume fraction: minimum 30% (U.S. food standard.)	Aqueous solutions of egg yolk, sugar, salt, starch, flavors, seasonings, hydrocolloids, and acidifying ingredients. pH: 3.5-4.0.	Egg yolk proteins and phosphatides combined with hydrocolloids and surfactants, where permitted by local food law

Emulsions

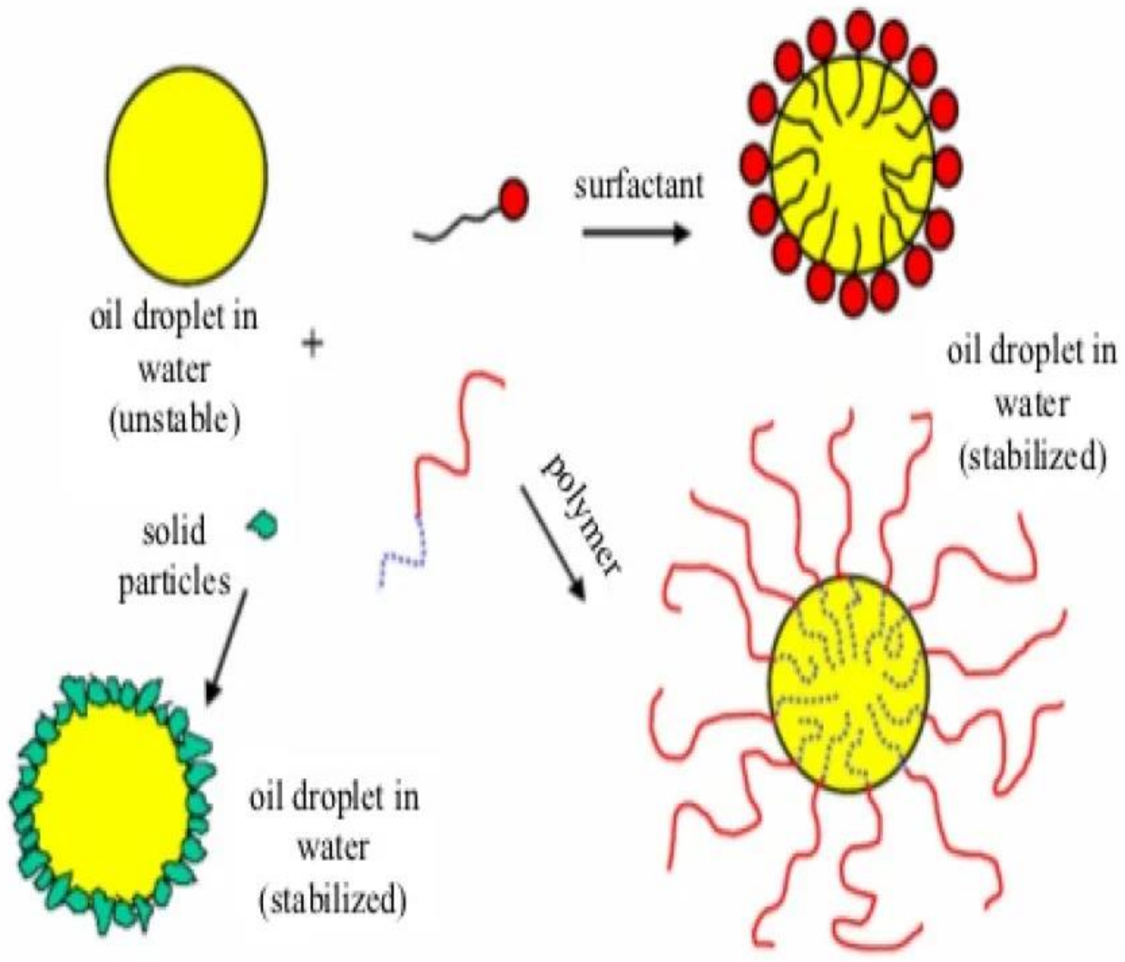
- are not stable on their own.
- When an emulsion is subjected to some stress such as freezing or centrifugation, it may break. That is, the two liquids separate into discrete phases.
- The formation and stability of emulsions is achieved by the addition of emulsifying agents.
- Emulsifying agents reduce the interfacial tension. In this way, the amount of energy required for emulsion formation is reduced.
- Emulsifying agents-surfactants-emulsifiers

Surface active agents, emulsifiers

- Emulsifiers form an adsorbed film around the dispersed droplets and prevent their coalescence..
- Emulsifiers are soluble, to different extent, in both phases.
- Drops without emulsifiers flocculate and coalesce spontaneously.
- In general, emulsions are thermodynamically unstable
- Emulsifiers adsorb to the surface of the droplets.
- If the work of desorption of the emulsifier is high, the coalescence is prevented , and the emulsions are thermodynamically stable.



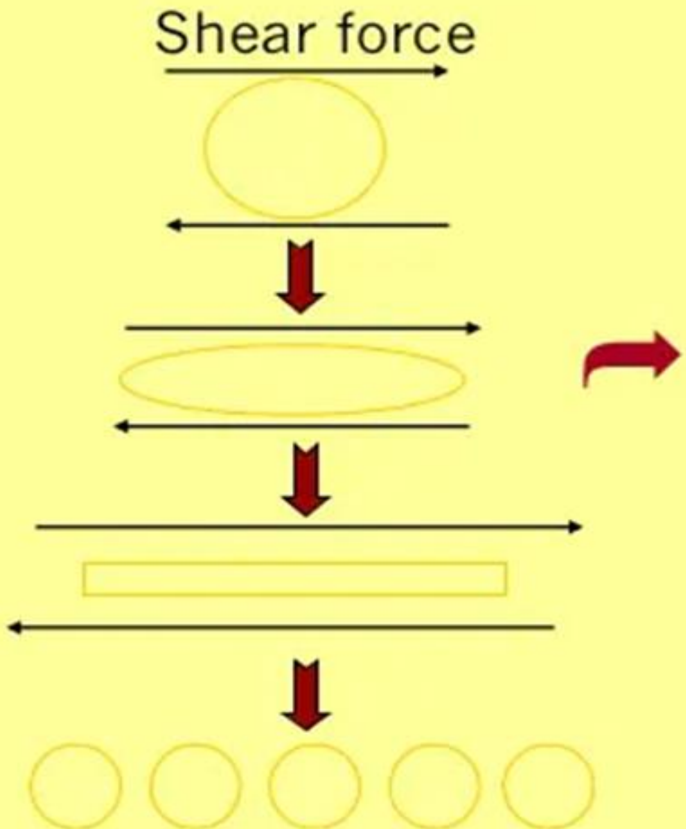
Making emulsions



Formation of Emulsion

- Emulsion formation requires the dispersion of one phase into small droplets ⇒ this results in a massive increase in interfacial area between the dispersed & continuous phase.
- Homogenization is the process by which the dispersed phase is broken into small droplets; high pressure homogenizers (10 – 100 MPa) are now very common.

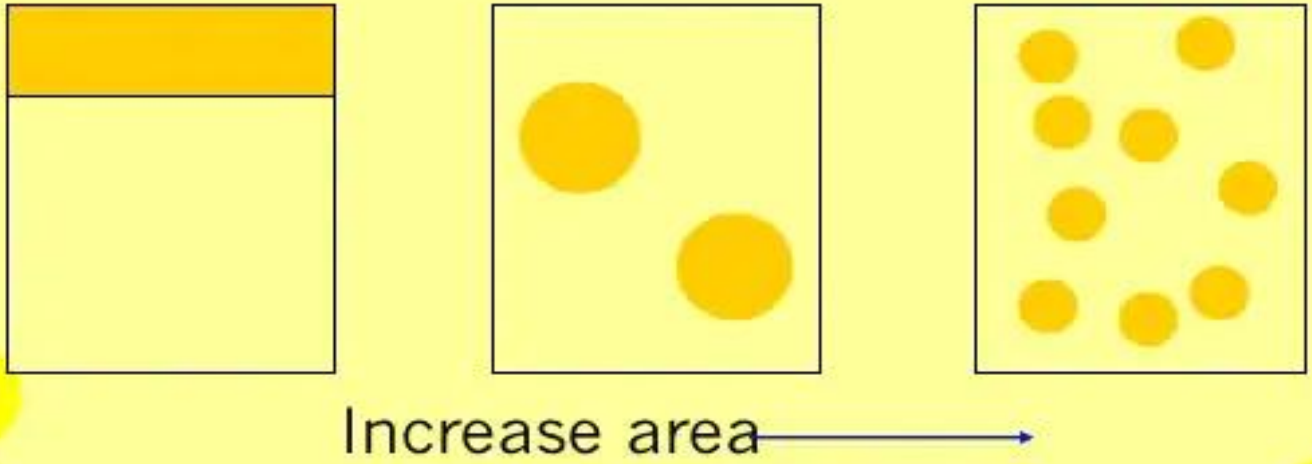
Formation of Emulsion



Importance of Large Interfacial Area

For a fixed composition:

- Decrease size, increase number of particles
- Increase area of interfacial contact



Emulsifiers

- Surface active materials
  - Carbohydrates:

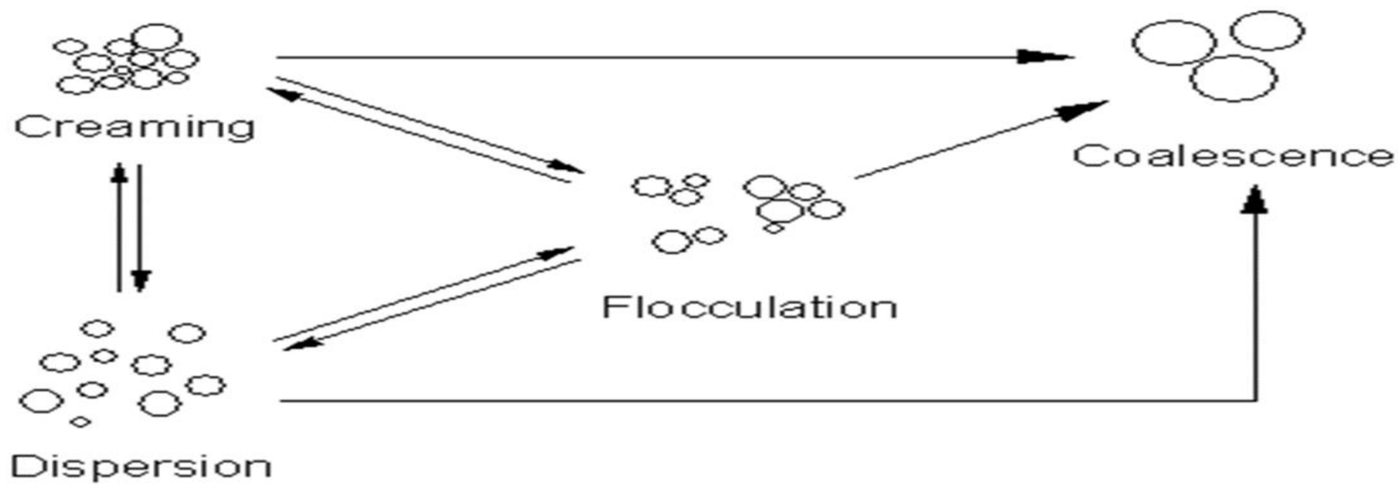
    Acacia gum (gum arabic), tragacanth, agar, pectin → for o/w emulsions
  - Proteins: gelatin, egg yolk, casein → for o/w emulsions.
  - High molecular weight molecules: stearyl alcohol, cetyl alcohol, glyceryl monostearate → for o/w emulsions, derivatives of cellulose, Na carboxymethyl cellulose, cholesterol → for w/o emulsions.
  - Wetting Agents: Anionic, Cationic, Nonionic
- Finely divided solids (Pickering stabilization)
  - Bentonite, clays
  - Silica (fumed)
  - Metal hydroxides (magnesium hydroxide, aluminum Hydroxide) → for o/w emulsions
  - carbon black → for w/o emulsions

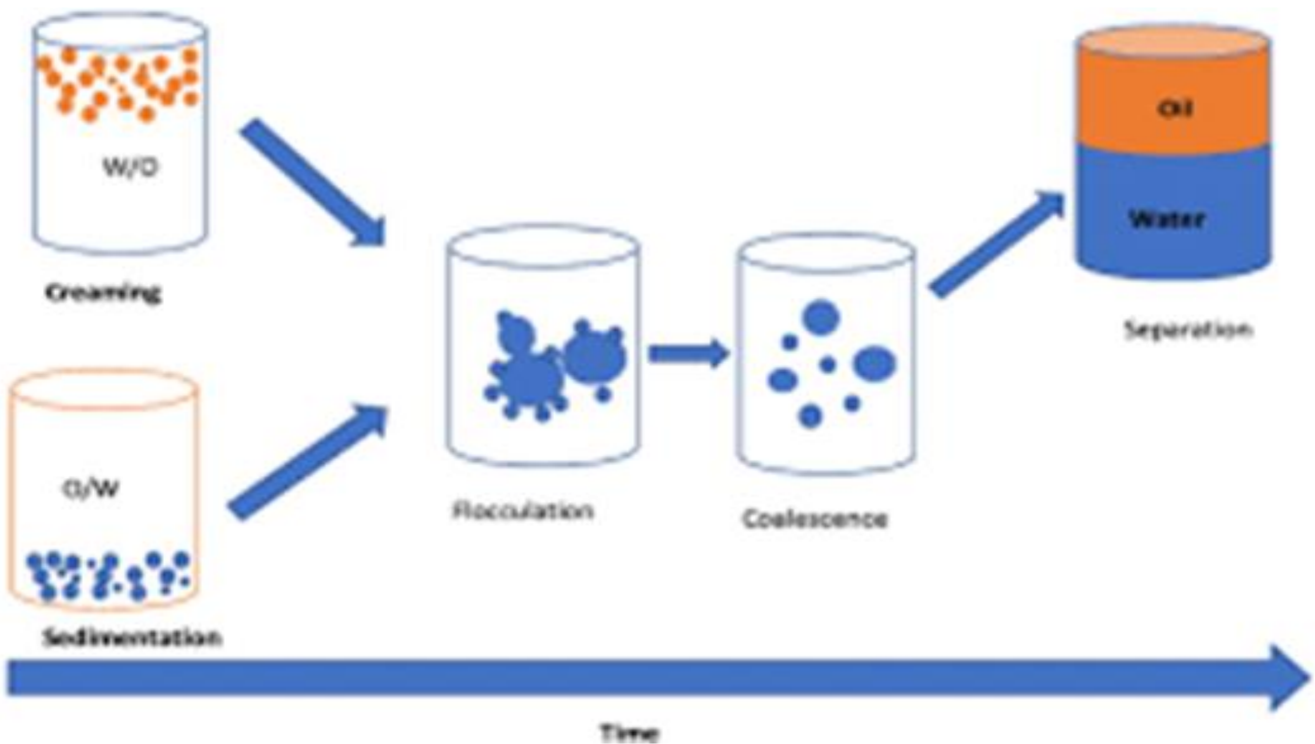
Emulsion stability

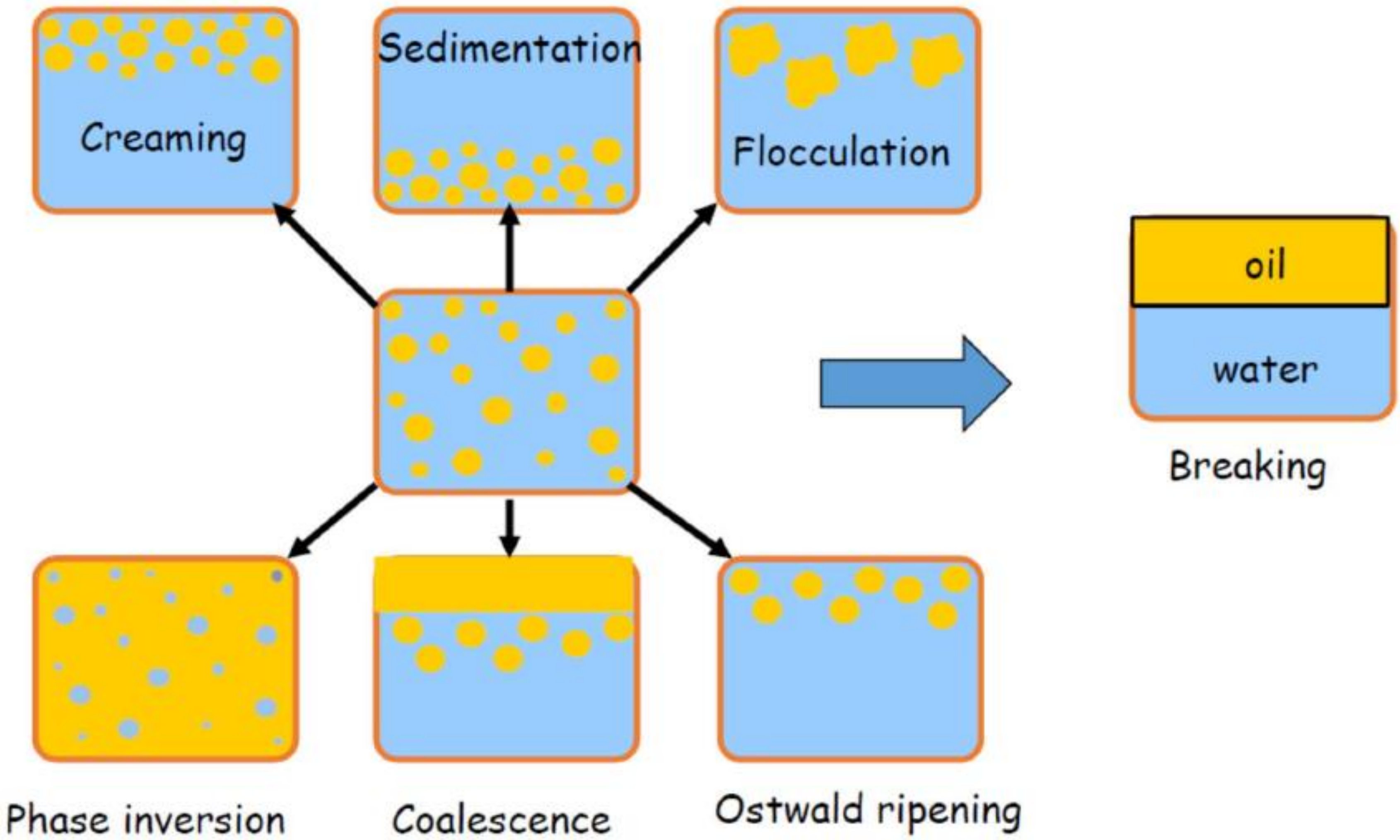
- The term “emulsion stability” can be used with reference to three different phenomena
  – creaming (or sedimentation)
  – flocculation
  – breaking of the emulsion due to the droplet coalescence.

- Eventually the dispersed phase may become a continuous phase, separated from the dispersion medium by a single interface

- The time taken for phase separation may be anything from seconds to years, depending the emulsion formulation and manufacturing condition.


Creaming
Coalescence
Flocculation
Dispersion


W/O
Creaming
O/W
Sedimentation
Flocculation
Coalescence
Oil
Water
Separation
Time



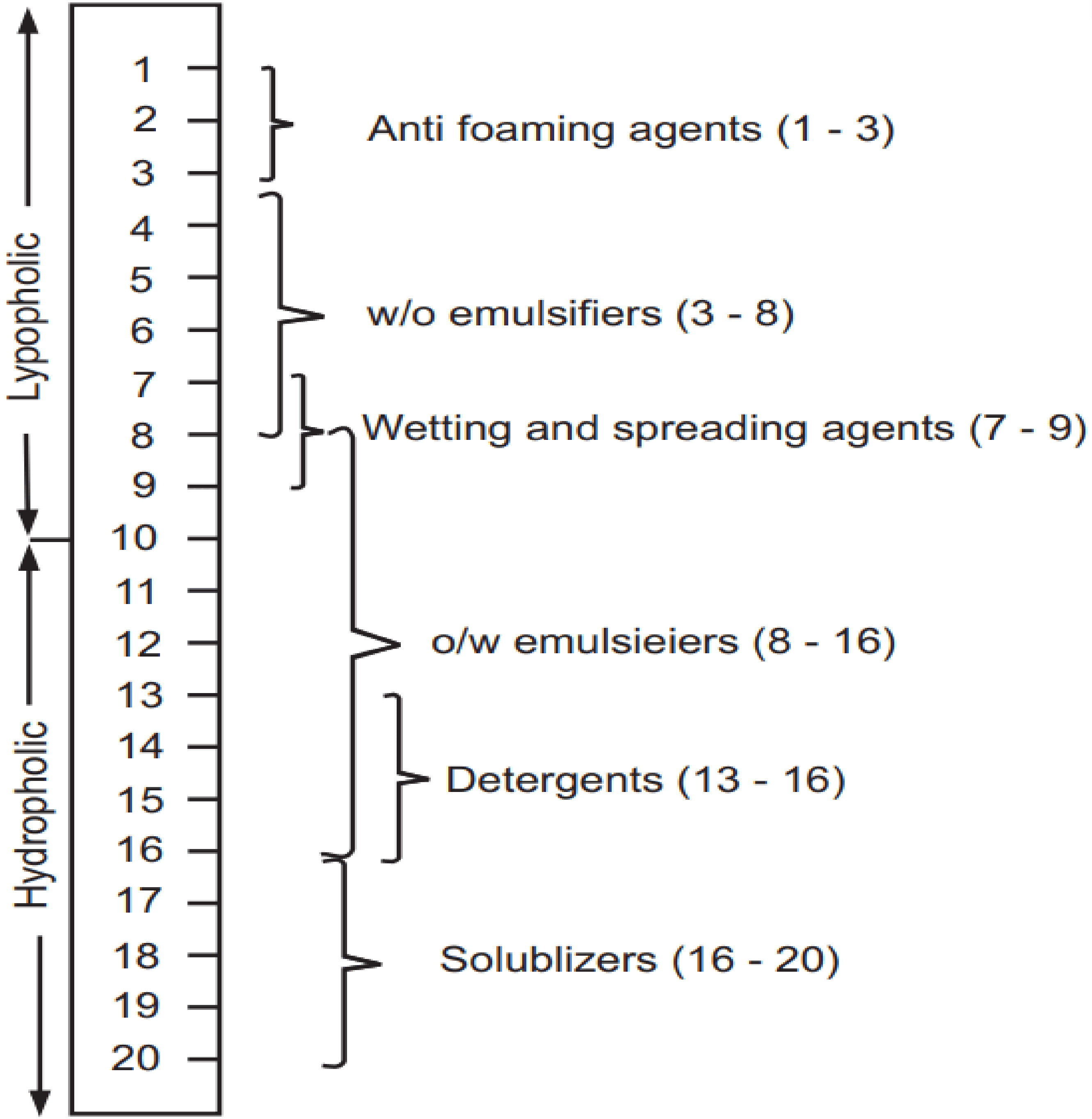
Creaming
Sedimentation
Flocculation
oil
water
Breaking
Phase inversion
Coalescence
Ostwald ripening

Hydrophilic- lipophilic balance (HLB)

- A practical (arbitrary) scale defining the relative balance between hydrophilic and lipophilic character of a surfactant
- Used mainly for non-ionic detergents
- Two definitions in use:

- *Griffin's method*: HLB= $20xM_h/M$ (where M_h is the molar mass of the hydrophilic part of the molecule and M the molar mass of the whole molecule

- Davies' method: HLB= $(7 + n_h - n_l$ (n_h: number of hydrophilic groups, n_l:number of lipophilic groups)


Lypophoilic
Hydrophoilic
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Anti foaming agents (1 - 3)
w/o emulsifiers (3 - 8)
Wetting and spreading agents (7 - 9)
o/w emulsieiers (8 - 16)
Detergents (13 - 16)
Solublizers (16 - 20)

HLB values: applications

HLB = 7 + (number of hydrophilic groups) – (number of lipophilic groups)

Applications by HLB

HLB value	Uses surface
3-6	For W/O emulsions
7-9	Wetting agents
8-15	For O/W emulsions
13-15	Detergents
15-18	Solubilizers

Dispersibility in water by HLB

<3	Non
3-6	Poor
6-8	Unstable milky dispersions
8-10	Stable milky dispersions
10-13	Translucent dispersion/solution
>13	Clear solution

Foams

What is foam?

- a mass of small bubbles formed on or in liquid, typically by agitation or fermentation.
- "a beer with a thick head of foam"
- Foam a stable aggregation of bubbles of lower density than oil or water.
- It could be describe a food foam as a very light food, considering its volume. Foams do indeed have a very low density (which is the weight per volume). A large volume of foam can still be very light.

Foams

- Foam is a two-phase system containing a mass of gas bubbles dispersed in a liquid or solid.

- Gas bubbles are separated from each other by a solid or liquid thin film.

- It is the dispersion of a hydrophobic liquid in a hydrophilic liquid such as oil water emulsions.

- In foam, unlike emulsions, the disperse phase is not colloidal and is also referred to as "coarse dispersion" because the bubbles are quite large.

- The main difference from emulsions is quantitative. Therefore, their properties are quite different from emulsions.

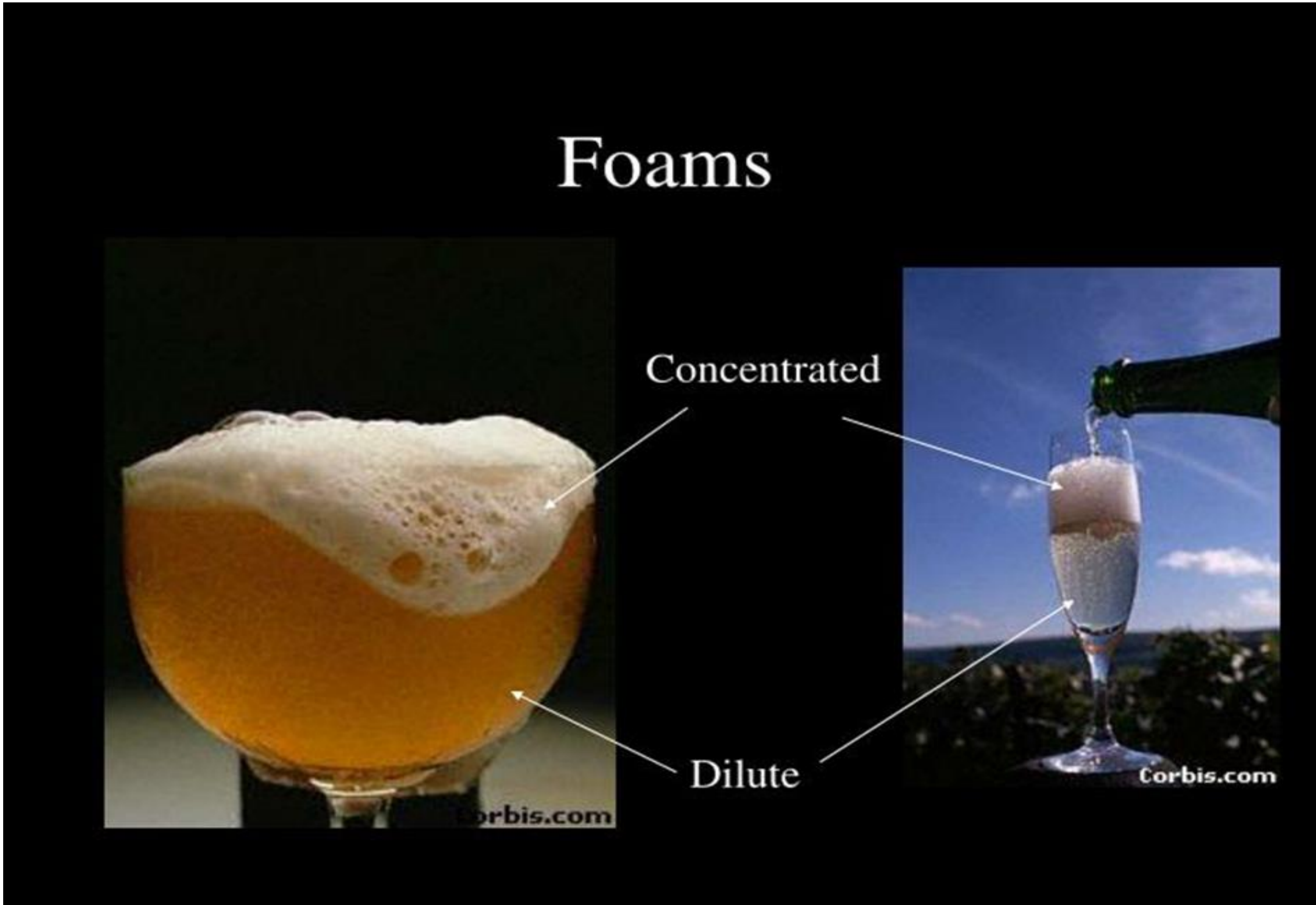
Comparison of foam and emulsion

Feature	Foam	Oil in water emulsion	Water in oil emulsion	Unit
Bubble/droplet diameter	10^{-3}	10^{-6}	10^{-6}	m
Bubble/droplet number	10^{9}	10^{17}	10^{17}	number/m^3
Interfacial tension	0.04	0.006	0.006	N/m
Laplace pressure	10^{2}	10^{4}	10^{4}	Pa
Time*	10^{-3}	10^{-6}	10^{-5}	

*Time for foam or emulsion formation.

Foams

- make significant contributions to the texture and volume of food.
- Air penetration into the structure reduces the density of the product.
- For foam formation, the surface tension of the liquid forming the continuous phase should be low.
- low surface tension; causes the liquid to expand, spread easily and not stick.
- The high surface tension of the liquid causes the foam to collapse quickly because the molecules tend to stick together.

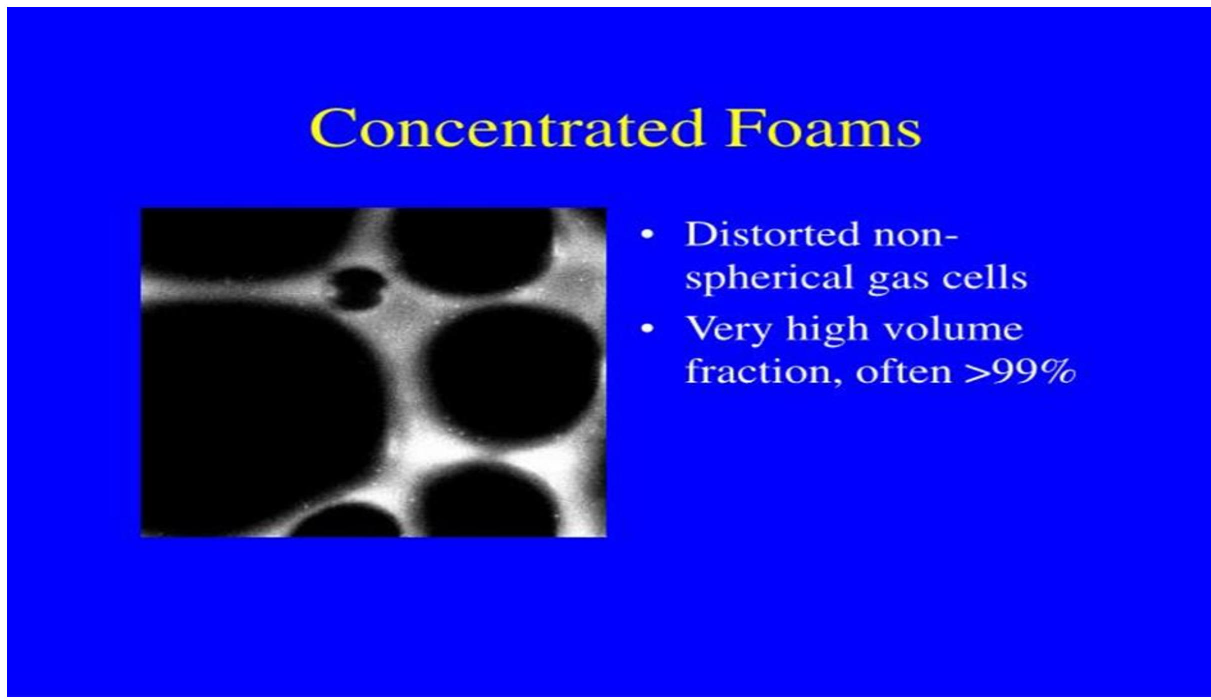

Foams
Concentrated
Dilute
Corbis.com

Dilute Foams

- Somewhat similar to emulsions
- Various modes of formation
- Large (~mm) spherical bubbles
- Very fast creaming
- Ostwald ripening

Concentrated foams

- Distorted non-spherical gas cells
- Very high volume fraction, often >99%



Ostwald ripening

- Foams will almost always contain smaller as well as larger sized bubbles. Ostwald ripening describes how the smaller bubbles in a foam will merge with larger bubbles over time. This is because gas slowly diffuses through the liquid separating the two bubbles, moving from the smaller to the larger bubble.

- This movement of gas is caused by a pressure difference inside bubbles. The pressure within smaller bubbles is higher than that in larger bubbles. As such, there is a driving force for the gas to diffuse from one to the other bubble.

Coalescence

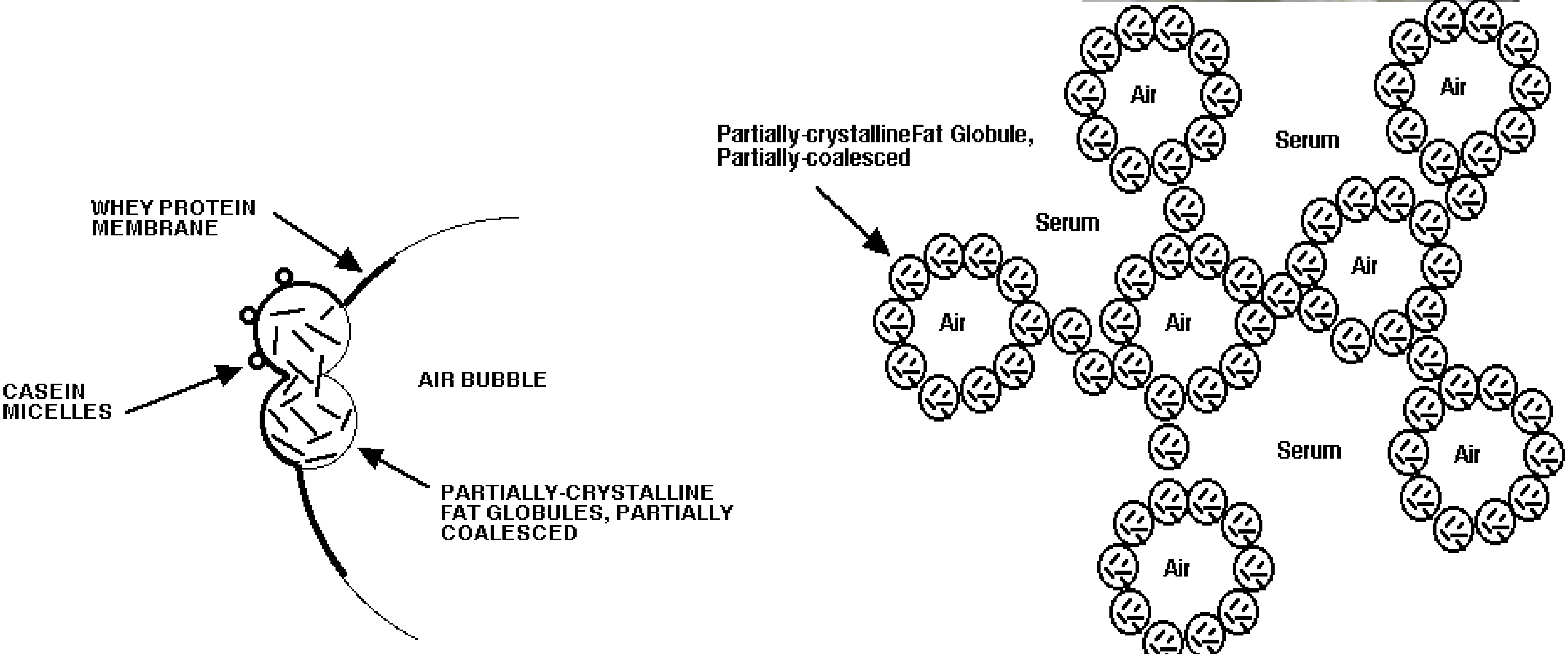
- Another way a foam can lose its final structure is by two bubbles merging with one another. In this case the film that separates the two bubbles breaks which causes the two to come together and form one bubble.
- Whereas Ostwald ripening is driven by a pressure difference and diffusion of gases, coalescence is governed by the strength of the liquid layer between the bubbles. Even though the effect is the same of the two, this difference in mechanism means that you will have to use different tools to prevent either from happening.
- Beer foams disappearing and shrinking considerably within a minute.

Egg white foam

- made from water, protein and small amounts of minerals and sugar.
- When egg whites are whipped, air enters, the proteins are denatured (opened) and their hydrophilic/hydrophobic sides are exposed.
- The hydrophilic part is directed towards the water molecules and the hydrophobic part towards the air side.
- Cross-linking between protein molecules gives stability to the foam.

- Whipped cream

made by mixing the cream containing 30% fat with air at high speed.



(Not to scale)

Foaming agent

- A substance that causes a liquid to turn into a foam to form a gas under certain conditions.

Antifoaming agent (anti-foaming)

- An anti-foaming agent is used to prevent or reduce foaming in foods. It is added to drinks such as cola and sprites.
- Anti-foams: added to existing foams, in the form of small droplets, which spread on the lamellae, thinning and breaking them.
- Foam breaking: mechanical-, shock- or compression waves, ultrasonics, rotating discs, heating, electrical sparks