Physical Properties of Foods

Content

*Surface tension

*Surface activity

Why are surface properties important?

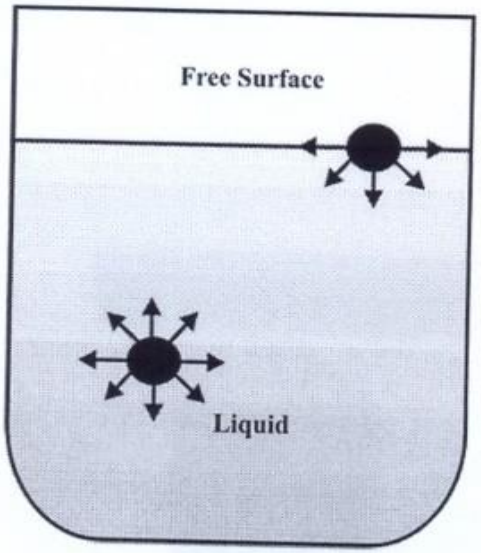
- Many foods are either two-phase systems or mixtures of immiscible liquids. (i.e., a mix of solid, liquid, and gas).
- Therefore there is a boundary between the two phases; this boundary is called either a surface for gas-liquid systems or, an interface for liquid-liquid systems.
- The phases are known as the dispersed phase (the one containing small droplets or particles) and the continuous phase (the phase in which the droplets or particles are distributed).
- Many food systems are also colloid in nature;
- Colloid science is concerned with systems where one or more of the components has dimensions within the range from 1 nm to 1 pm, i.e. systems containing large molecules or small particles.

Examples of food colloidal systems

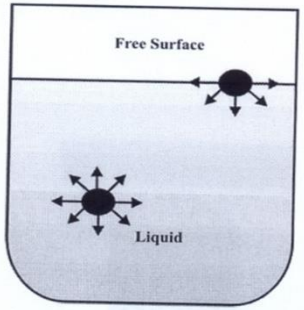
Dispersed phase	**Continuous phase**	**Name**	**Example**
Liquid	Gas	Fog, mist, aerosol	Spray in spray drying
Solid	Gas	Smoke, aerosol	Smoke
Gas	Liquid	Foam, bubble	Whipped cream
Liquid	Liquid	Emulsion	Mayonnaise
Solid	Liquid	Sol, colloidal solution, gel suspension	Cloudy fruit juice, chocolate-flavoured drinks
Gas	Solid	Solid foam	Meringue, bread

Surface tension

- There are forces operating at the gas-liquid surface or at the liquid-liquid interface.
- You might have noticed water in spherical droplets on the surface of a leaf or emerging from tap.
- This can be explained by surface tension.
- A molecule in the bulk of the liquid is attracted all directions that cancel each other. However, on the surface, the molecules are attracted across the surface and inward since the attraction
- of the underlying molecules is greater than the attraction of the vapor molecules on the other side of the surface. Therefore, the surface of the liquid is in a state of tension. This causes water to pull itself into



Interactions of water molecules inside and near the surface of liquid

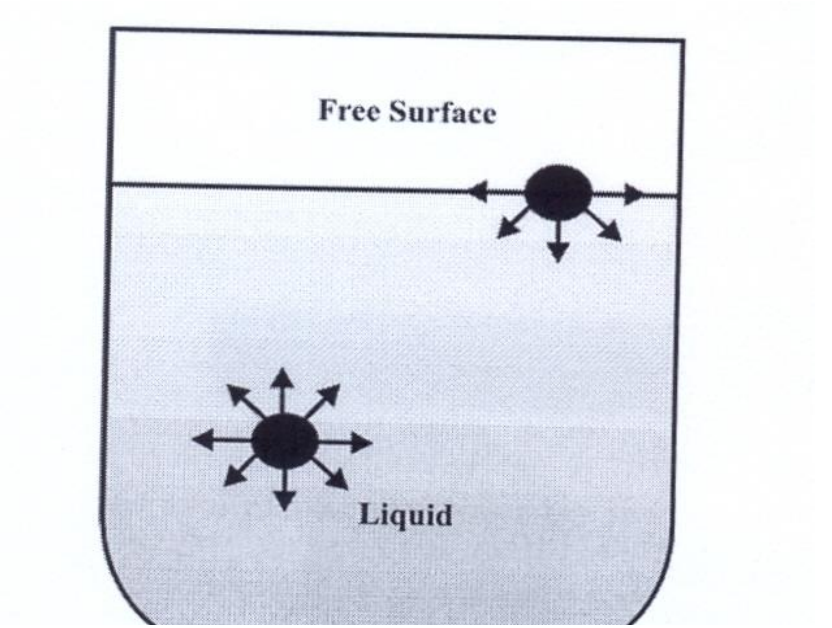


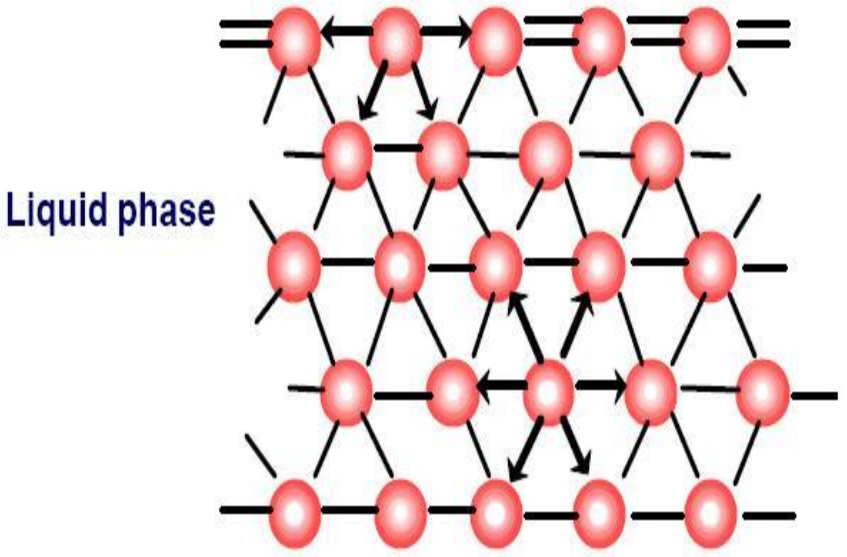
- a spherical shape which has the least surface area. Molecules at the surface of the liquid are attracted inward because of the van der Waals intermolecular attractions. This creates a force in the surface that tends to minimize the surface area and this force is known as surface tension.
- Surface tension can be defined as the tendency of a surface of a liquid to behave like a stretched elastic membrane. If the
- surface is stretched, the free energy of the system is increased.

Surface tension

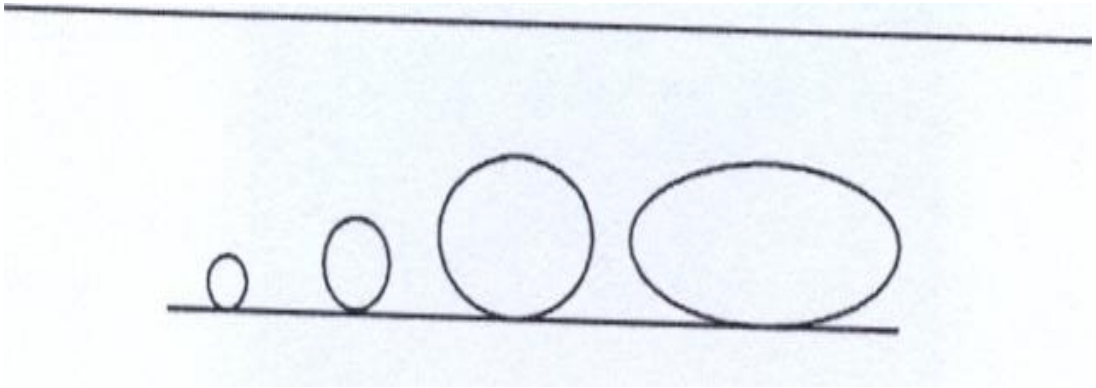
- These forces acting on the surface and attempting to minimize the surface of the fluid are known as surface tension forces.
- Water has a very high surface tension value. Liquids which have high surface tension values also have high latent heat values.

- A molecule in a liquid in a container develops a force of attraction in all directions.
- But on the surface (gas-liquid surface), the molecules create an inward and transverse attraction force to the surface.
- Because the gravitational force of the molecules below is greater than the gravitational force of the gas molecules the liquid surface is in tension.





- This forces the water to be spherical.
- Because the sphere creates a minimum surface area in a given volume.
- Molecules on the liquid surface create attraction towards the bottom of the surface due to van der Waals bonds between the molecules.
- This attraction creates a force to reduce the surface area. This force is surface tension.
- Surface tension tends to hold the liquid surface like an elastic membrane.
- When the surface is stretched, the free energy of the system increases.



- The smallest droplet in the shape is almost the most perfect spherical, as it has the least surface area per unit volume.
- As the size increases, the shape of the sphere becomes flatter due to the weight.
- Therefore, weight is more important for particles with large size.

Surface tension

- Surface tension is the force per unit length acting on a given surface.

  Symbol :γ, unit N/m veya mN/m veya dyn/cm dir.

  $$\gamma = \frac{N}{m}$$

- The forces acting on the surface that try to reduce the surface area are called surface tension forces.

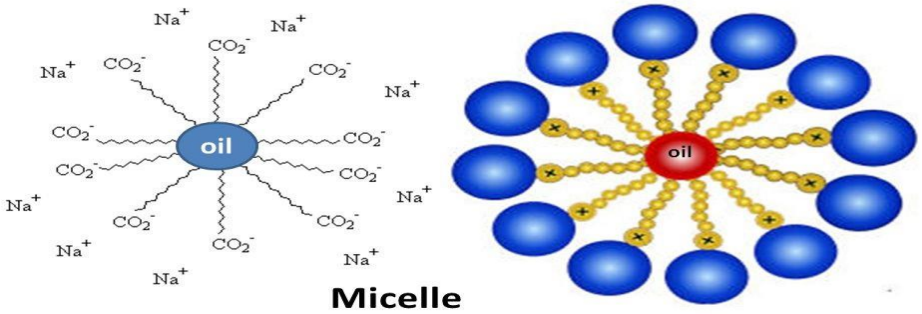
Surface tension values of some liquids and foods (at 20^{o}C,mN/m)

Liquid/food	Surface tension	Liquid/food	Surface tension
Water	72	Milk	42-52
Ethanol	22	Skimmed milk (0.04% fat)	51
Methanol	23	Milk (2.4% fat)	46.7
Glycerol	64	Cream (34% fat)	45
Chloroform	27	Sunflower oil	33.5
Mercury	435.5	Olive oil	33
Wine (10.8%ethanol)	46.9	Diluted wine (2.7%h etanol)	60.9

Surface activity

- Substances that reduce the surface tension of a liquid at very low concentrations are called surface active.
- Emulsifiers and hydrocolloids are good examples for surface-active materials.
- These materials have both polar or hydrophilic and nonpolar or lipophilic groups.
- They orient themselves at the interface between the two phases. These substances concentrate at the surface and give large decreases in surface tension.

Hydrophilic and hydrophobic groups



Micelle

Surface activity

- Many materials such as short-chain fatty acids and alcohols are soluble in both water and liquids that are immiscible with water (such as oils and organic solvent). Normally such materials have a polar or hydrophilic moiety, e.g. COOH and OH, and non-polar or lipophilic groups.
- These substances will orientate themselves at the interface between the two phases with the polar group dissolved in the aqueous phase, and the non-polar group dissolved in the oil phase, because this is the most stable configuration

  form from an energy standpoint.
- The strong adsorption of these materials at surfaces or interfaces, often as a monomolecular layer, is termed surface

  activity.

Surface activity

- Surface-active components or surfactants will decrease the surface tension of water considerably at very low concentrations, and the concentration of surface-active components will always be higher at the interface or surface than in the bulk of the solution.
- Many naturally occurring food constituents exhibit surface activity,

e.g.

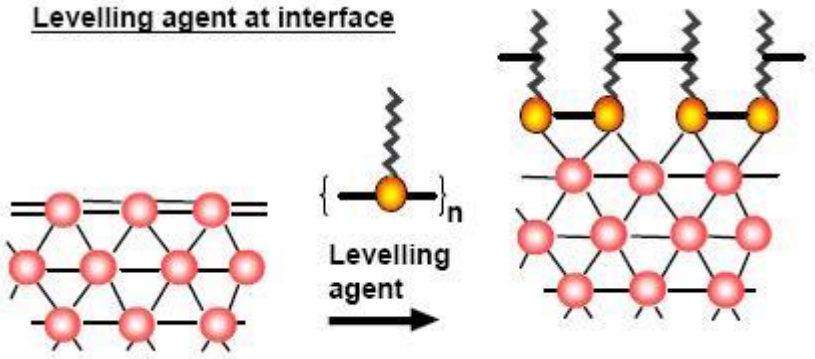
alcohols,

fatty acids,

phospholipids,

proteins and

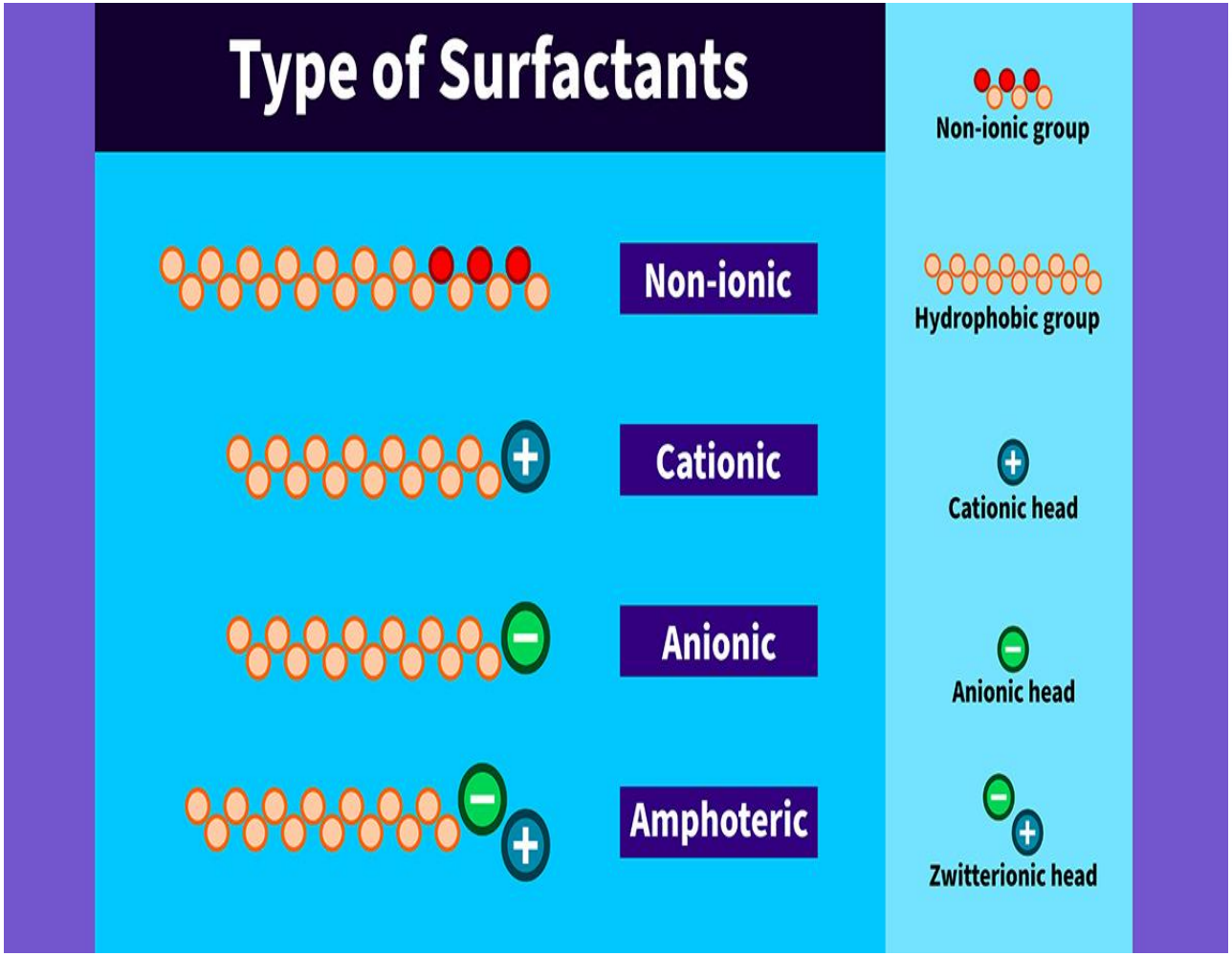
tannins.

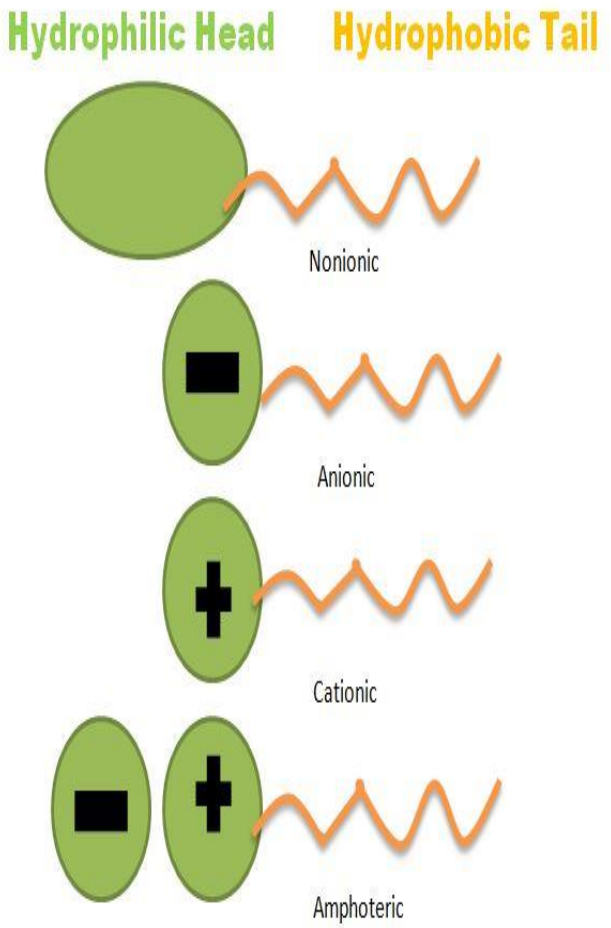


Surface-active substances

- Surface-active agents are widely used as emulsifying agents and detergents.
- As small amounts of a surface-active component are added to a solution, the surface tension decreases until a point is reached where further addition results in no more decrease.
- The concentration, corresponding to this levelling-off, is known as the critical micelle concentration. At concentrations above the critical micelle concentration, the molecules are clustered together in micelles, which act as a pool or reservoir of molecules.
- Molecules are free to dissociate from the micelle and move to the surface of interest.

Surface-active components





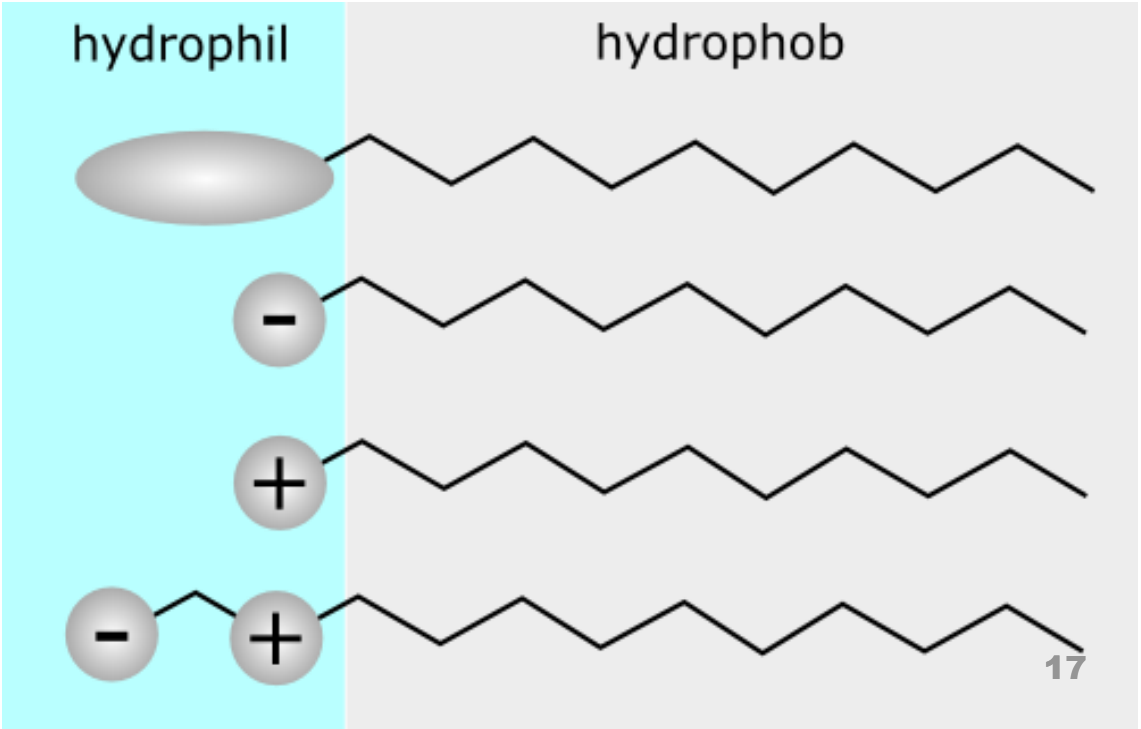
Surfactants

non-ionic,

anionic,

kationic,

amphoteric



Temperature effect on surface tension

The surface tensions of most liquids decrease as the temperature increases and, at temperatures not too near the critical temperature, the relationship is almost linear. In the region of the critical temperature, the surface tension value becomes very low, as the intermolecular cohesive forces approach zero.

Surface tension values of ethyl alcohol and water in the range of 0-30°C

Liquid	Surface tension value (mN/m)			
	0°C	10°C	20°C	30°C
Ethyl alcohol	24.05	23.61	22.75	21.89
Water	75.60	74.22	72.75	71.18

Interfacial tension

- At the boundary of two immiscible liquids, there will be an imbalance of intermolecular forces; this gives rise to the phenomenon of interfacial tension.
- Interfacial tensions usually lie between the individual surface tensions of the liquids in question.

Table 6.5 — Interfacial tension values between water and the following components.

Component	Temperature (°C)	Interfacial tension (mN m^{-2})
n-hexane[a]	20	51.1
Carbon tetrachloride[a]	20	45.0
Benzene[a]	20	35.0
Trioleum[b]	25	14.6
Mercury[c]	20	375.0
Peanut oil[b]	25	18.1
Cotton seed oil[b]	25	14.9
Olive oil[b]	25	17.6
Coconut oil[b]	25	12.8
n-octanol[c]	20	8.5

Interfacial tension

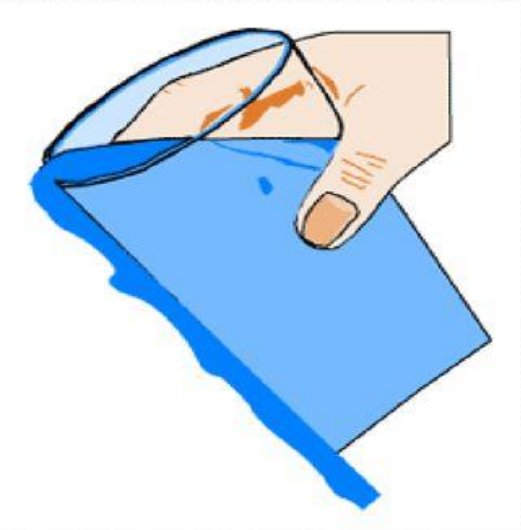
- Generally speaking, the higher the interfacial tension, the lower is the solubility of the solvents in each other.
- To facilitate emulsification, the interfacial tension between water and oil should be reduced to below 10 mN/m. Many of the available emulsifying agents and detergents work in this way by lowering the interfacial tension.

Interfacial tension between water and butter oil at 40°C with selection of milk proteins

Protein	Interfacial tension ($mN\ m^{-1}$)
Water–butter oil	19.2
0.2% euglobulin	18.0
0.2% β lactoglobulin	14.0
0.2% α-lactalbumin	11.0
0.2% interfacial protein	11.0

Adhesion and cohesion

What is Adhesion?



- Polarity makes water molecules attract to other water molecules (cohesion)
- Additionally, water molecules can be attracted to other substances.
- Adhesion: water's natural tendency to cling to certain substances
  - This causes capillary action

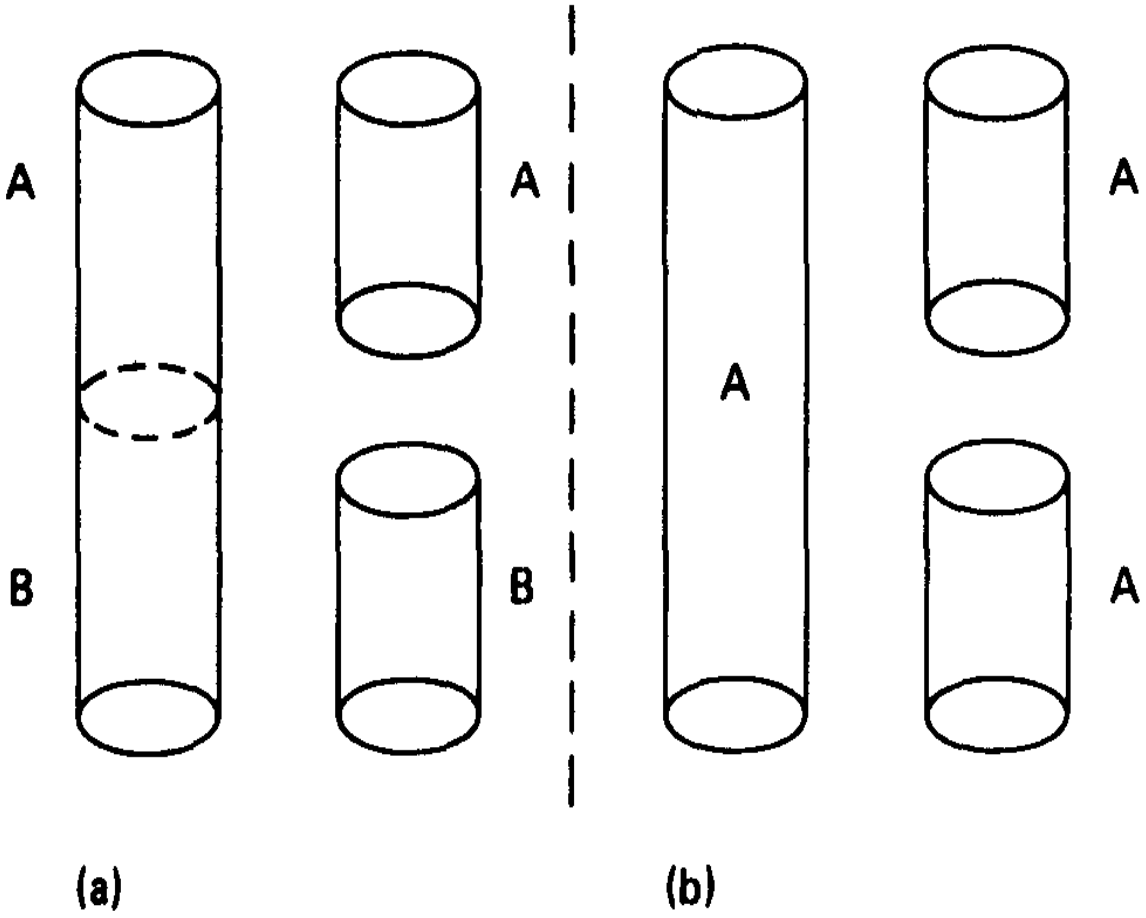
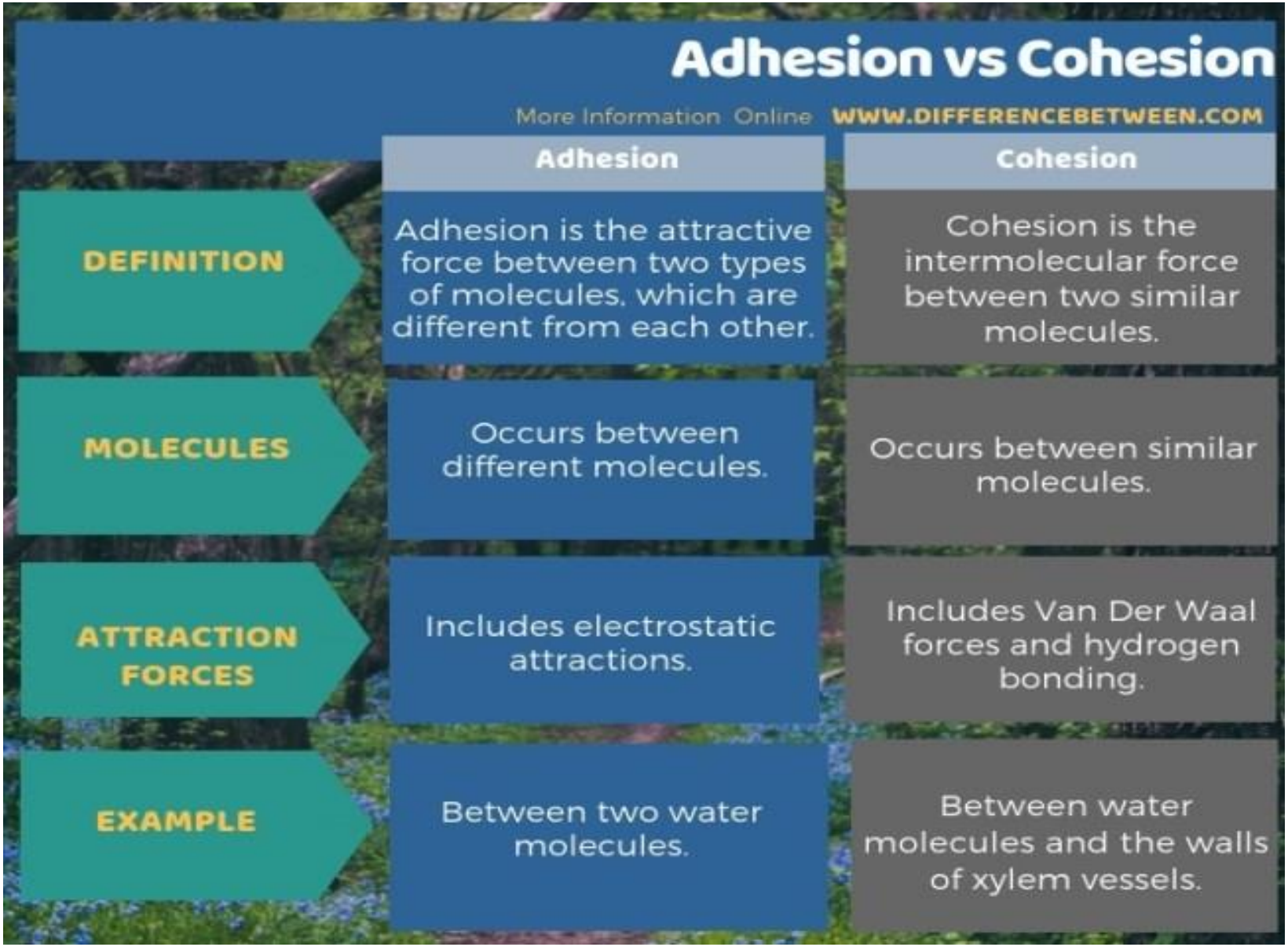


Fig. 6.7 — (a) work of adhesion; (b) work of cohesion.


Adhesion vs Cohesion
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Adhesion
Cohesion
DEFINITION
Adhesion is the attractive force between two types of molecules, which are different from each other.
Cohesion is the intermolecular force between two similar molecules.
MOLECULES
Occurs between different molecules.
Occurs between similar molecules.
ATTRACTION FORCES
Includes electrostatic attractions.
Includes Van Der Waal forces and hydrogen bonding.
EXAMPLE
Between two water molecules.
Between water molecules and the walls of xylem vessels.