INTERNATIONAL COLLEGE OF PHARMACEUTICAL INNOVATION
国际创新药学院

Interfacial Phenomena I

Course	**BSc(Pharm) & BSc (ATT)**
Year	**2024-2025 II**
Module	**Medicines Pharmaceutics 2**
Lecturer	**Dr. Congcong Xu**

LEARNING OUTCOMES

1. Define the interface
2. State the different types of interfaces
3. Explain what is meant by surface tension and surface free energy
4. Describe how surface tension is measured
5. Relate interfacial phenomena to disperse systems in pharmacy

RECOMMENDED READING

Remington

Essentials of Pharmaceutics

Chapter 19

Interfacial Phenomena

Paul M. Bummer, PhD and Yvonne Perrie, PhD

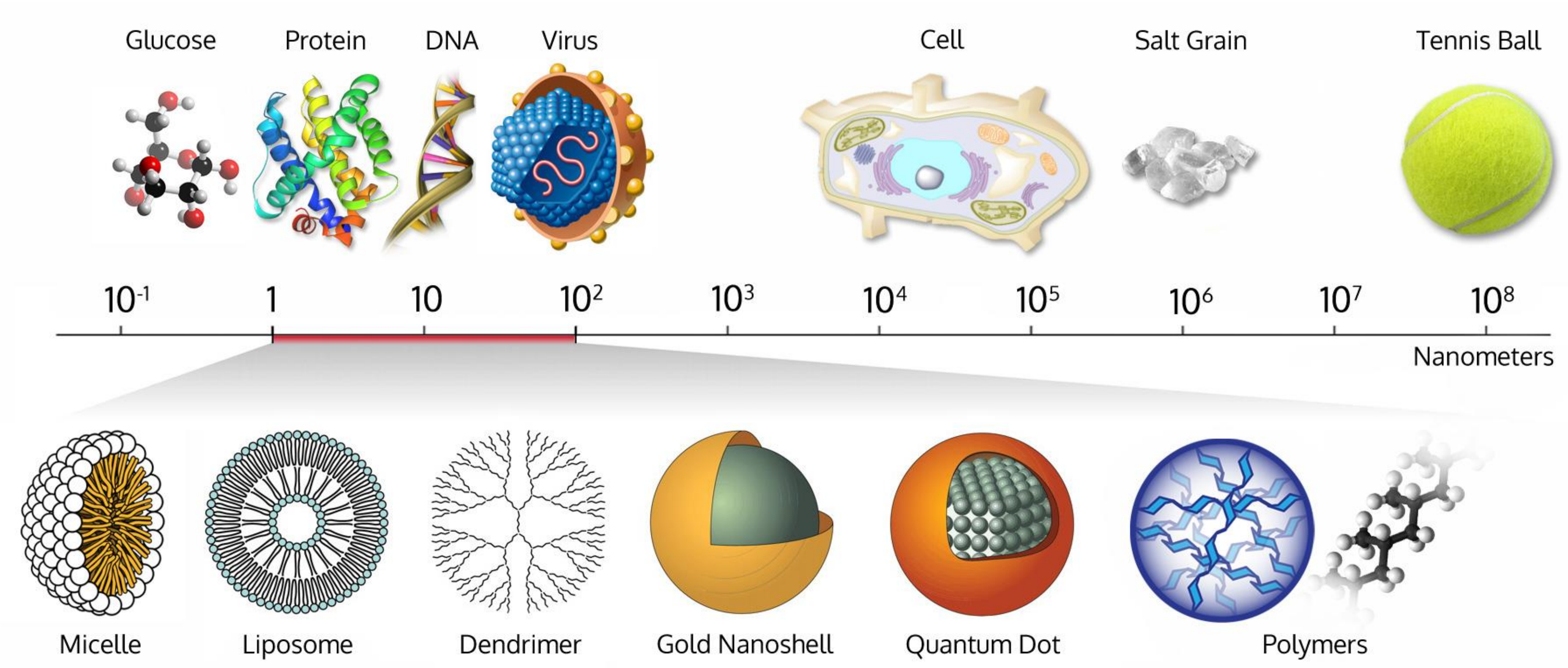
MARTIN'S

PHYSICAL PHARMACY AND PHARMACEUTICAL SCIENCES

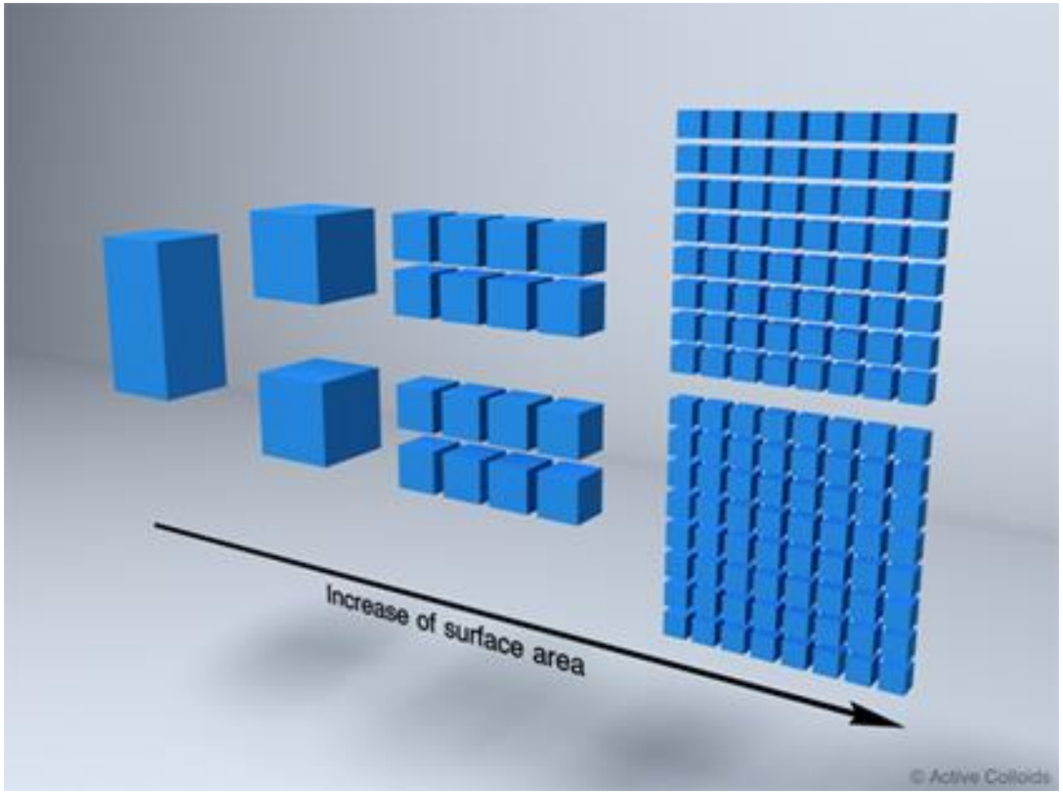
15 INTERFACIAL PHENOMENA

thePoint For additional ancillary materials related to this chapter, please visit thePoint.

DISPERSIONS

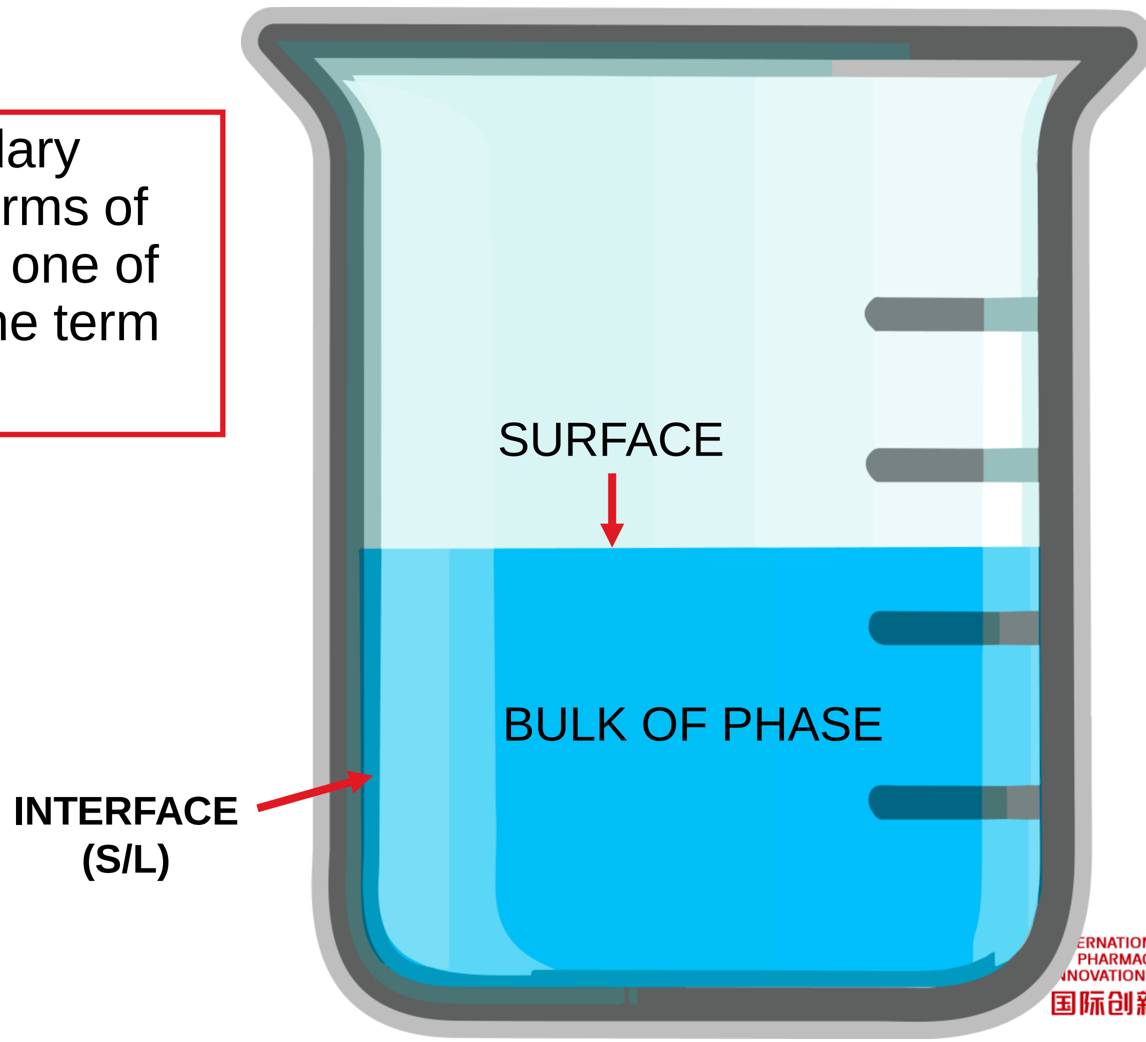


Surface Area



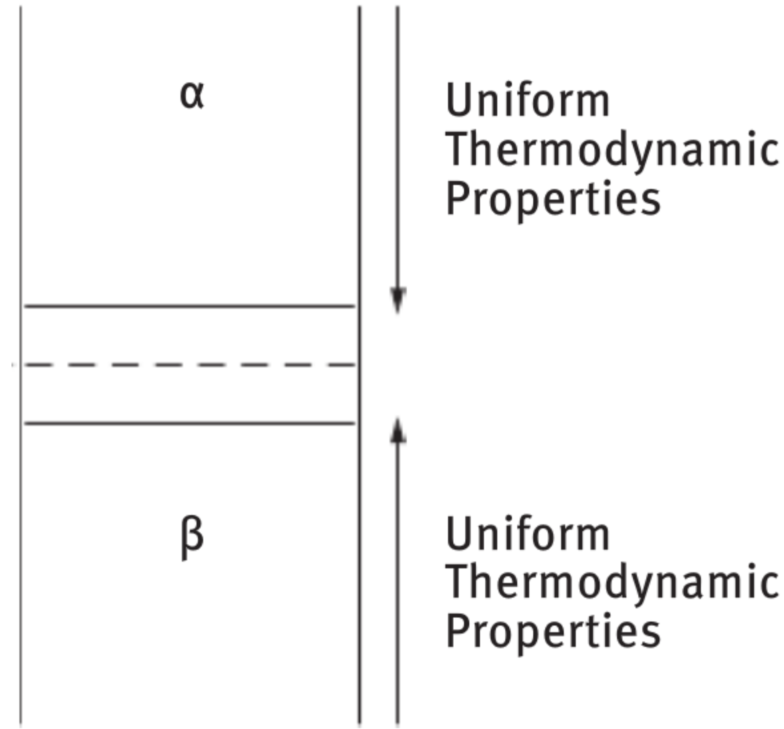
INTERFACE

Interface: is the boundary between two distinct forms of matter (S, L, G). When one of the phases is air/gas the term surface is used.



The interface…..

Immiscible phases α and β come into contact, an interfacial region develops. The interfacial region is not a layer that is one molecule thick; it is a region with thickness δ with properties different from the two bulk phases α and β. In bringing phases α and β into contact, the interfacial regions of these phases undergo some changes, resulting in a concomitant 伴随着的 change in the internal energy



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CLASSES OF INTERFACES

Disperse phase	Continuous phase	Interface	Example
Liquid	Gas	Liquid aerosol	Fog, liquid sprays
Solid	Gas	Solid aerosol	Smoke dust
Gas	Liquid	Foam	Foam
Liquid	Liquid	Emulsion	Cream, milk
Solid	Liquid	Colloidal suspension(sol), suspension,	Suspension, nanoparticles
Gas	Solid	Solid foam	Expanded polystyrene 聚苯乙烯
Liquid	Solid	Solid emulsion	Opal, pearl
Solid	Solid	Solid suspension	Pigmented有颜色的 plastics

THE ROLE OF INTERFACIAL PHENOMENA

- The interfacial region determines the properties of all disperse systems including suspensions, emulsions and colloids. The larger the interface the more important the role of the structure of the interfacial region.

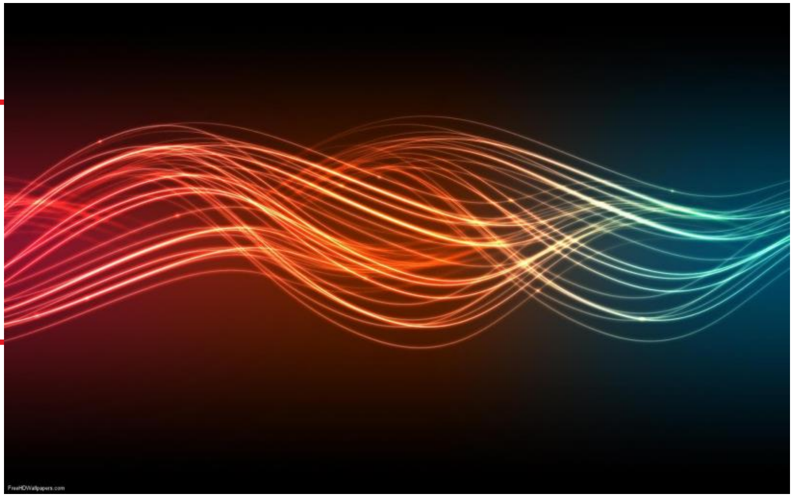
- Understanding the role of interfacial science enables the development of complex systems in a shorter period of time.

- Physical stability is an important consideration for all disperse systems especially for lyophobic（疏水的）dispersions like suspensions and emulsions

- Interfacial phenomena transcends several disciplines of science including chemistry, physics, engineering, biological sciences, mathematics.

WHY IS THE INTERFACE DIFFERENT?

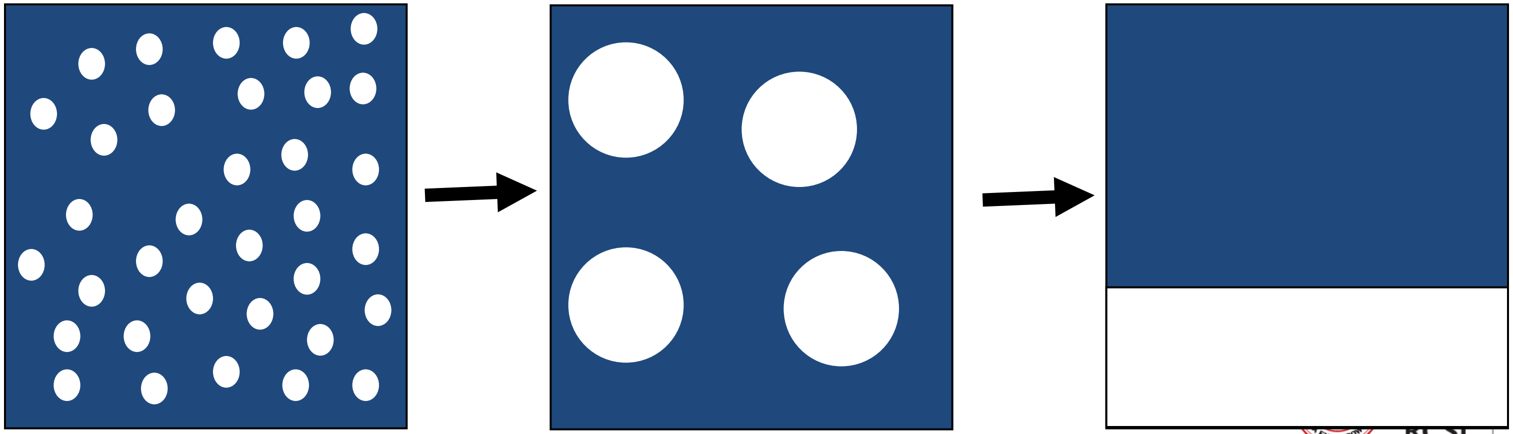
ENERGY IMBALANCE



PRINCIPLE OF ENERGY MINIMISATION

- For a closed system, the internal energy will decrease and approach a minimum value at equilibrium and the entropy熵 will be maximised (for a fixed internal energy).

- In many disperse systems, energy at the interface is **greater than the bulk of the phase**. Therefore dispersions with high surface area (e.g. emulsions, suspensions and nanoparticles) are high energy and tend towards a reduction in surface area to reduce the energy within the system, which ultimately leads to physical instability



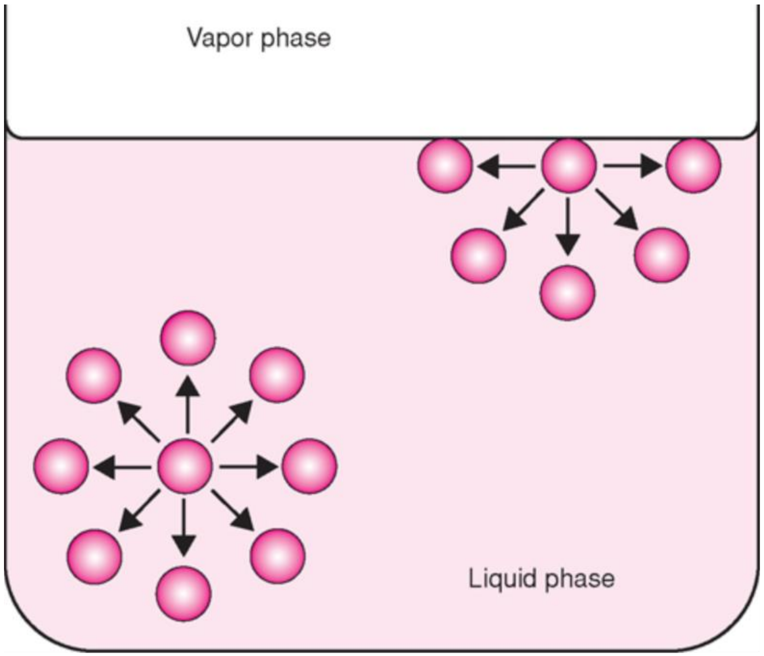
SURFACE BEHAVIOUR

- Molecule at the surface of a liquid are not completely surrounded by other molecules as they are in the bulk of the phase.

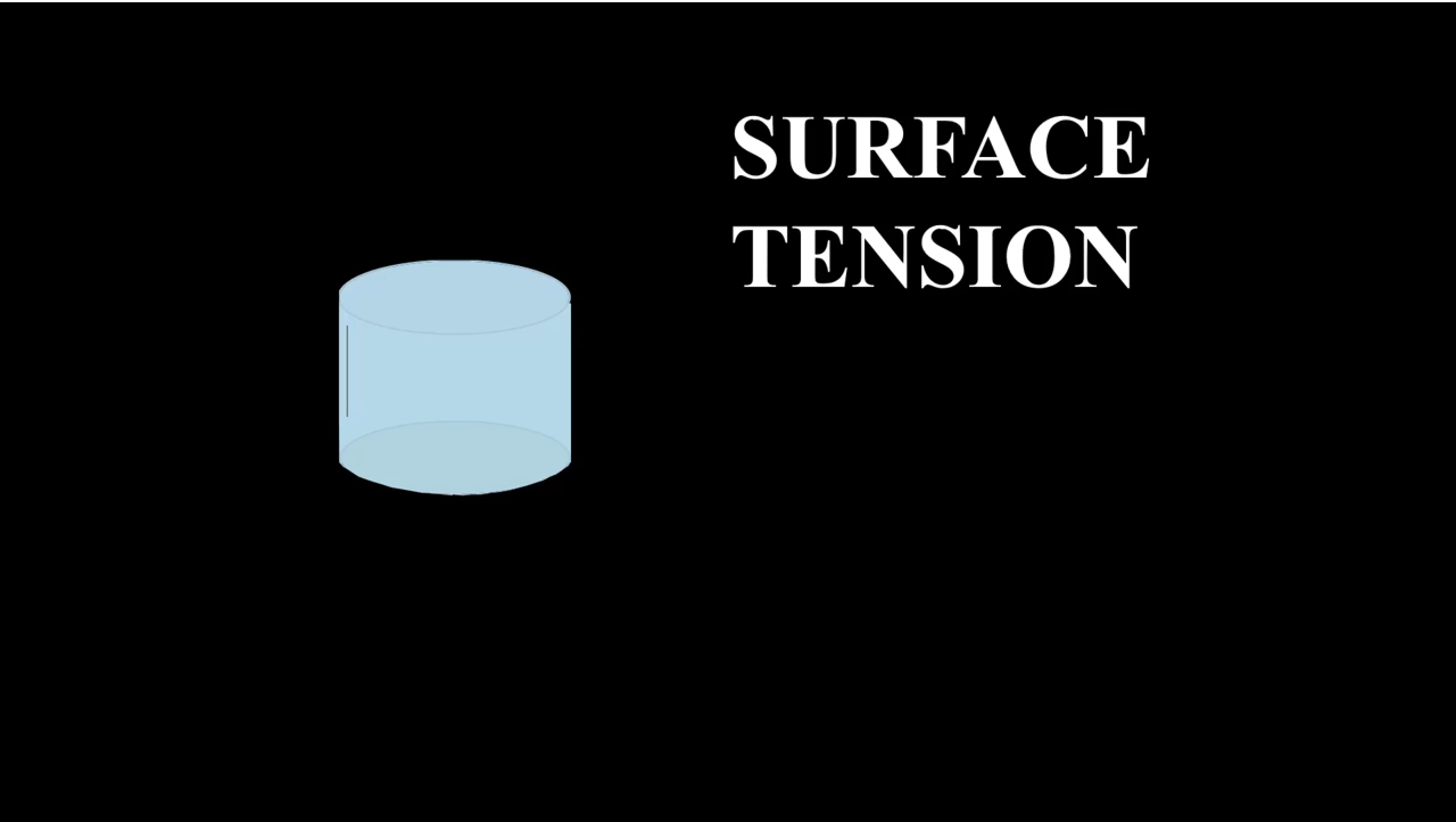
- As a result there is a net inward（向内的）force of attraction exerted on a molecule at the surface from the molecules in the bulk solution, which results in a tendency for the surface to contract.

- The contraction of the surface is spontaneous自发的; that is, it is accompanied by a decrease in free energy.

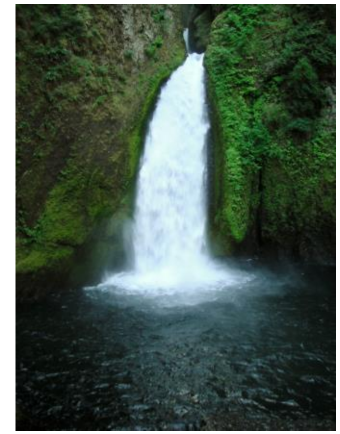
- The contracted surface thus represents a minimum free energy state and any attempt to expand the surface must involve a increase in the free energy.



SURFACE TENSION表面张力

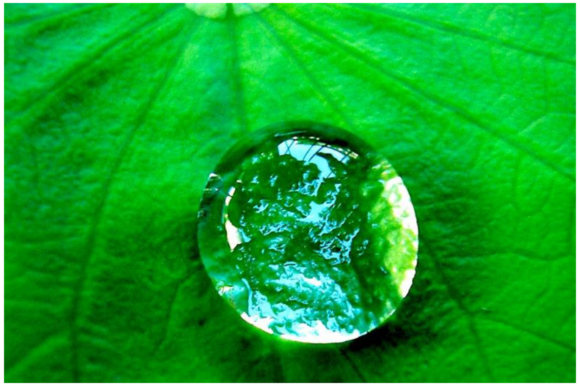


SURFACE FREE ENERGY表面自由能



KEY CONCEPT: To move a molecule from the inner layers to the surface, work needs to be done against the force of surface tension. In other words, each molecule near the surface of liquid possesses a certain excess of potential energy as compared to the molecules in the bulk of the liquid. The higher the surface of the liquid, the more molecules have this excessive potential energy. Therefore, **if the surface of the liquid increases (e.g., when water is broken into a fine spray), the energy of the liquid also increases.** Because this energy is proportional to the size of the free surface, it is called a surface free energy. Each molecule of the liquid has a tendency to move inside the liquid from the surface; therefore, the liquid form with minimal free surface and with minimal surface energy. For example, liquid droplets tend to assume a spherical shape because a sphere has the smallest surface area per unit volume.

SURFACE FREE ENERGY

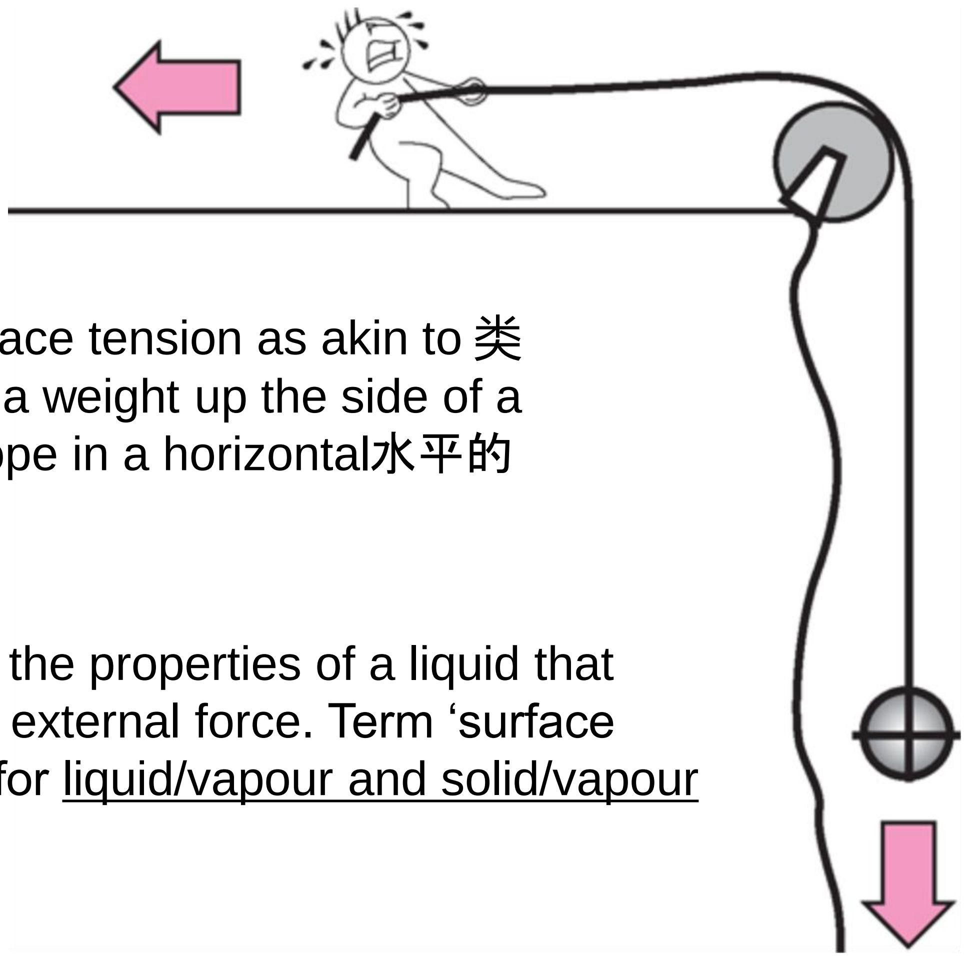


Surface Free Energy: Is defined as the work (w) required to increase the surface area A by 1 m^2

$$w = \gamma \, \Delta A$$

- Each molecule at the interface of a liquid possesses an excess of energy compared to bulk of liquid.
- Surfaces therefore contract spontaneously and form the lowest possible surface-to-volume ratio, to minimize energy of the system.
- Surface energy will always pull an isolated volume of liquid into a spherical shape.
- Increase surface area requires increased work to over come the internal attractive forces

SURFACE TENSION



Visualization of surface tension as akin to 类似于a person lifting a weight up the side of a cliff by pulling the rope in a horizontal水平的 direction.

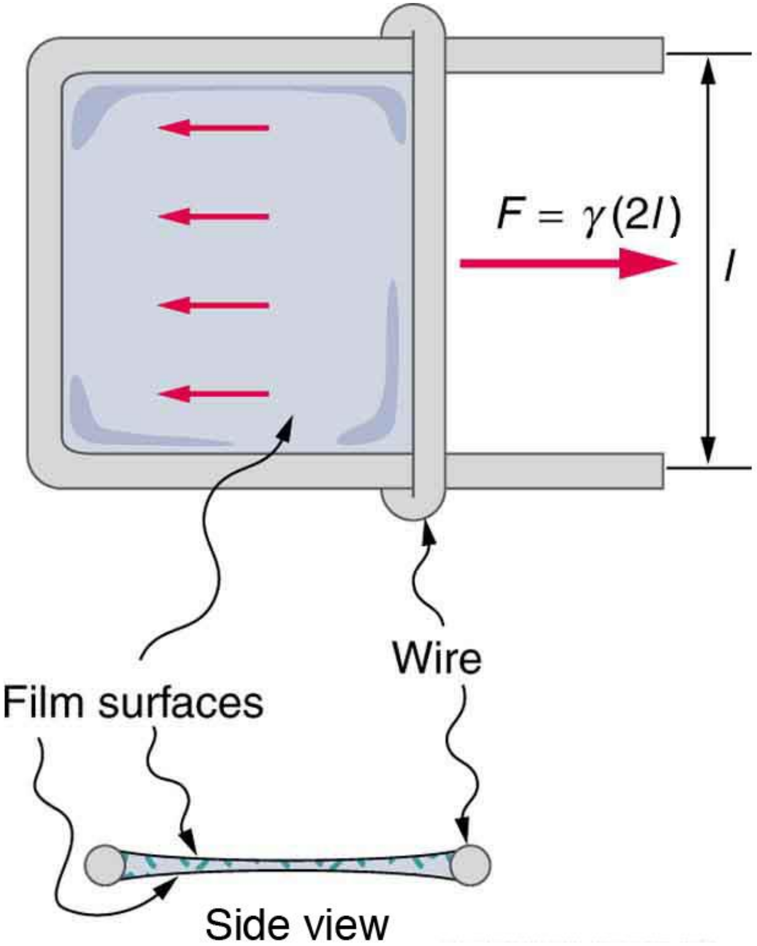
- Surface tension is the properties of a liquid that allows it to resist an external force. Term ‘surface tension’ often used for liquid/vapour and solid/vapour interfaces

SURFACE TENSION

Surface Tension: Force acting at right angles to a line 1 m in length along the surface

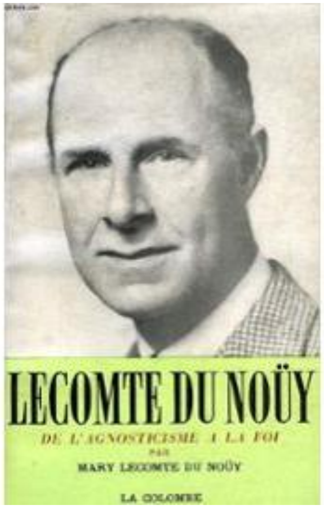
$$\gamma = \frac{F}{2l}$$

A soap film is formed over a given area can be stretched by applying a force *f* (such as a hanging mass) to the movable bar, length *L*, which acts against the surface tension of the soap film. When the mass is removed, the film will contract owing to its surface tension. The surface tension, *γ*, of the solution forming the film is then a function of the force that must be applied to break the film over the length of the movable bar in contact with the film. Because the soap film has two liquid–gas interfaces (one above and one below the plane of the paper), the total length of contact is in fact equal to twice the length of the bar.

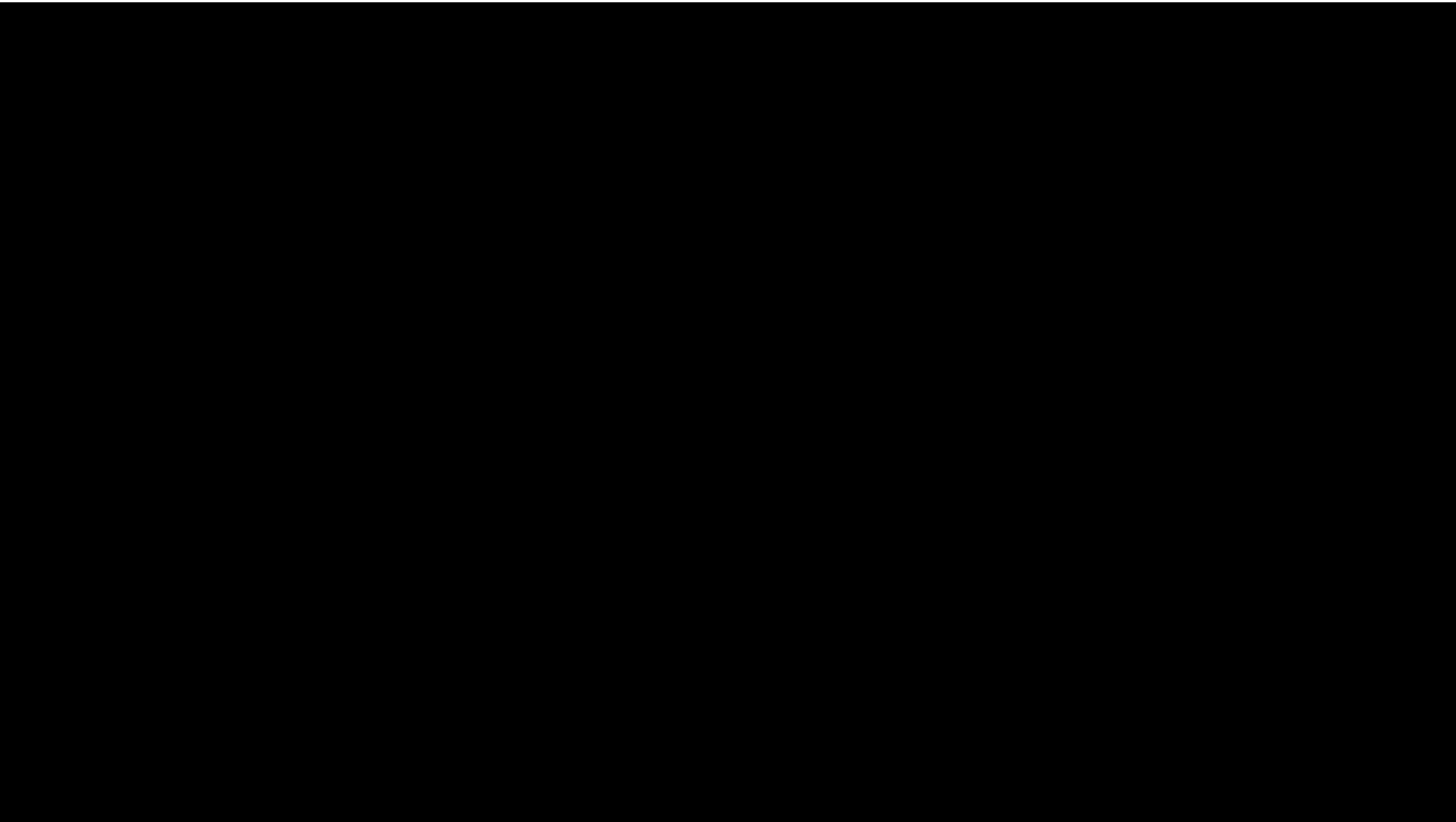


Measurement of Surface and Interfacial Tensions

(1) Ring Method (Du Nuoy)
(2) Wilhelmy Plate Method
(3) Drop Weight and Drop Volume
(4) Capillary Rise



RING METHOD (DU NUOY)



DROP WEIGHT AND DROP VOLUME

EXAMPLE SURFACE TENSION VALUES (20ºC)

Substance	Surface tension	Interfacial tension
Water	72	—
Glycerol	63	—
Octane	22	51
Octanol	27	8.5
Mercury	485	415

INTERFACIAL TENSIONS

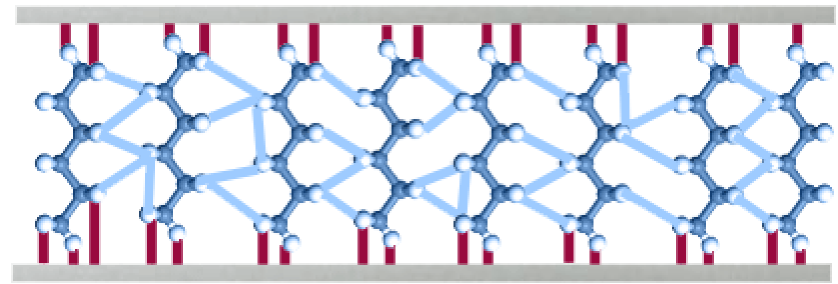
- *Interfacial tension* is the force per unit length existing at the interface between two immiscible phases. in the general sense, all tensions may be referred to as *interfacial tensions*, this term is most often used for the attractive force between immiscible liquids.
  - **Liquid–Liquid interface (γ_{LL})**
  - **Solid–Solid interface (γ_{SS})**
  - **Liquid–Solid interface (γ_{LS})**

- The term *surface tension* is reserved for liquid–vapour (γ_{Lv}) solid–vapour (γ_{sv}) tensions

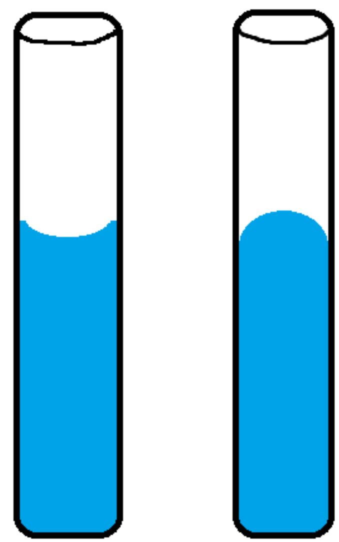
- interfacial tensions are less than surface tensions because the **adhesive forces** between two liquid phases forming an interface are greater than when a liquid and a gas phase exist together. if two liquids are completely miscible, no interfacial tension exists between them.

ADHESION AND COHESION

- **Adhesion附着力**: Forces of attraction between dissimilar molecules.
- **Work of adhesion (W_A)**: Work required break the attraction between dissimilar molecules.



- **Cohesion内聚力**: Forces of attraction between similar molecules.
- **Work of Cohesion (W_C)**: Work required break the attraction between similar molecules.



INTERFACIAL PHENOMENA IN PHARMACEUTICAL SCIENCE

- Interfacial phenomena manifests in several manufacturing processes
  - Wetting
  - Suspension
  - Emulsification
  - Detergency去垢
  - Granulation
  - Foaming发泡
  - Surfactant science
- Every formulation must interaction at one of more interfaces in the body
  - Spreading
  - Dissolution
  - Adhesion
  - Sorption

CONTACT INFORMATION

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