Physical Pharmacy

Rheology

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Introduction

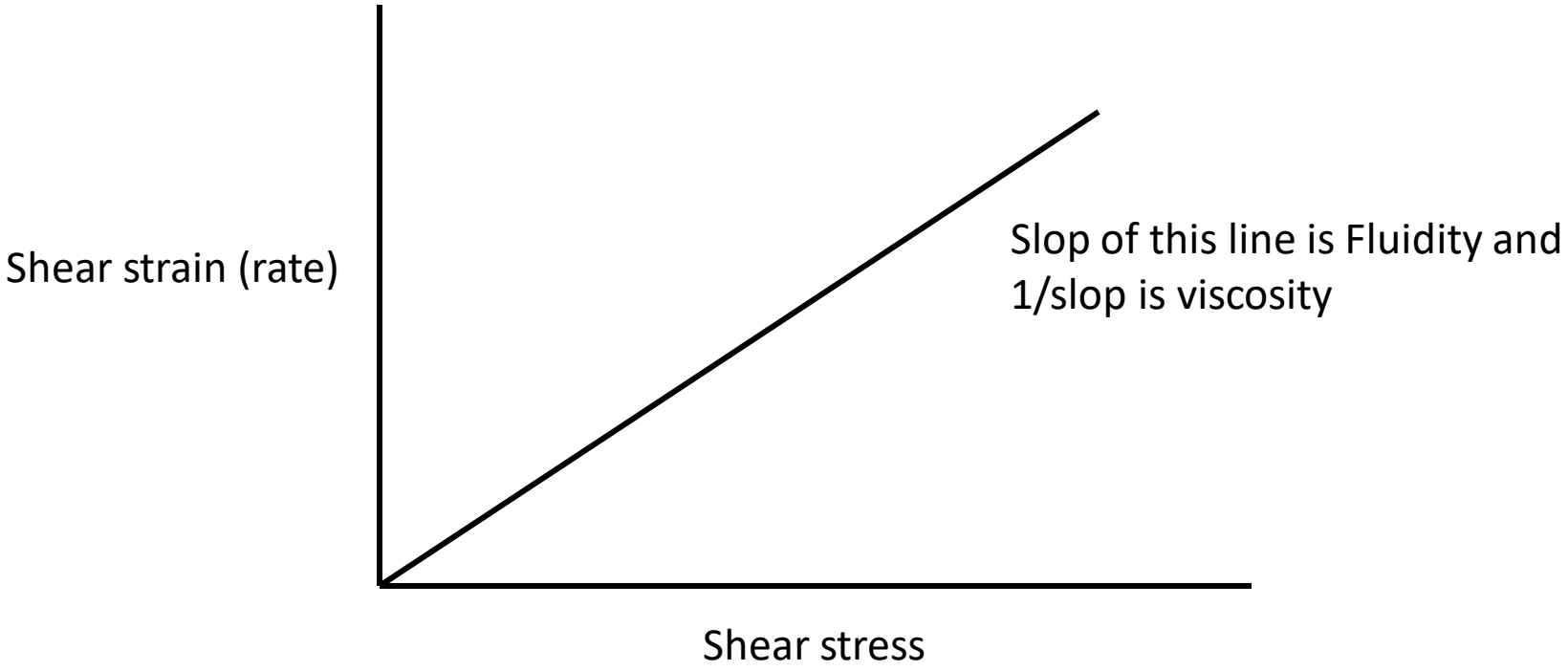
- Rheology: from the Greek rheo (to flow) describes the flow of liquids and the deformation of solids.
- It is involved in the mixing and flow of materials, their packaging into containers, the pouring from the bottle, extrusion from a tube or a passage of the liquid to a syringe needle.

Introduction

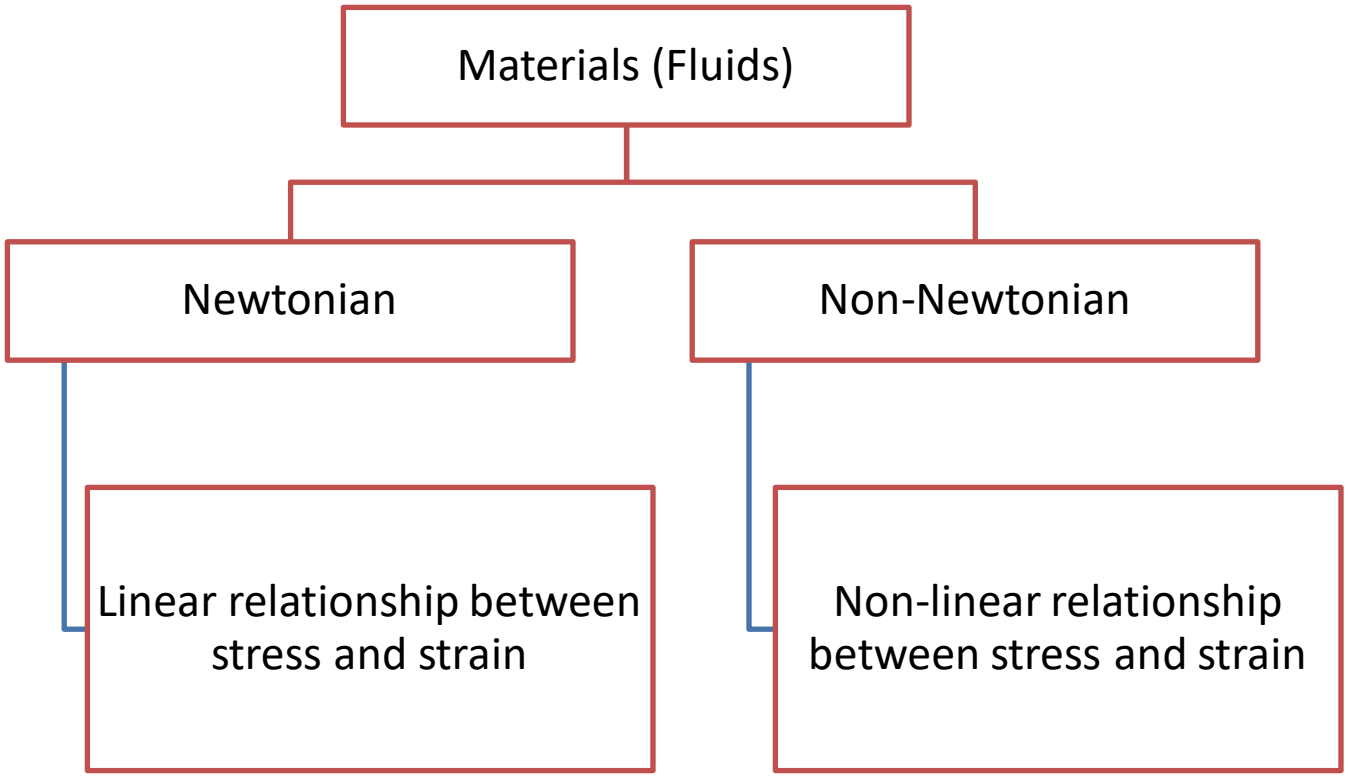
- Rheology can affect the patient's acceptability of the product, physical stability, and biologic availability.

Flow

- Movement of fluid will occur if stress is applied.
- Stress (Shear stress): force per unit area.
- Strain (Rate of shear): Amount of deformation caused by the shear stress
- Viscosity: Resistance of gasses or fluids towards the flow due to shear stress.
- Fluidity (Mobility): is 1/viscosity, Higher mobility means more flow.

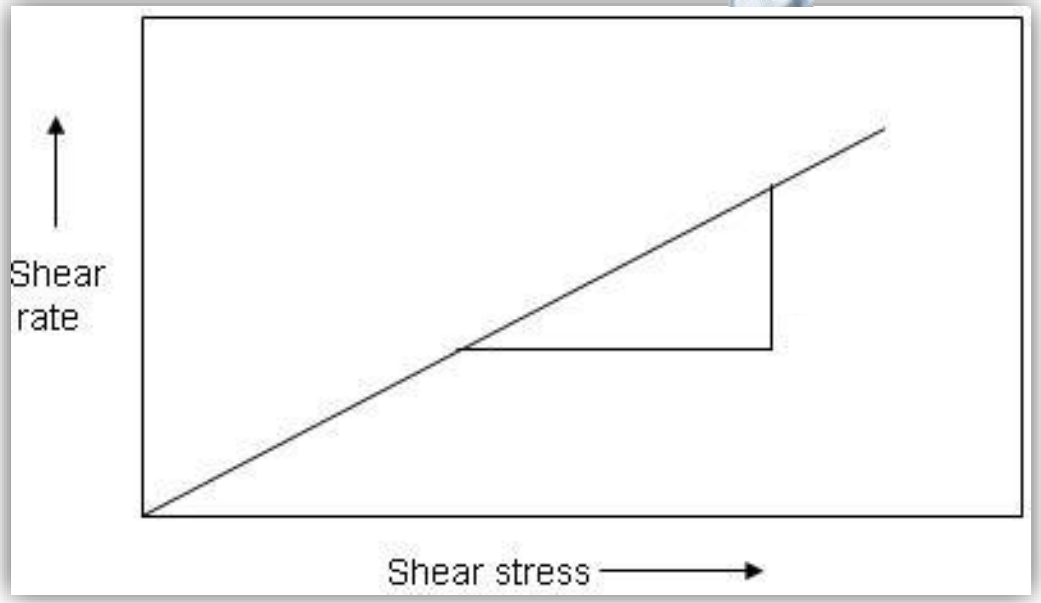


Flow


Materials (Fluids)
Newtonian
Non-Newtonian
Linear relationship between stress and strain
Non-linear relationship between stress and strain

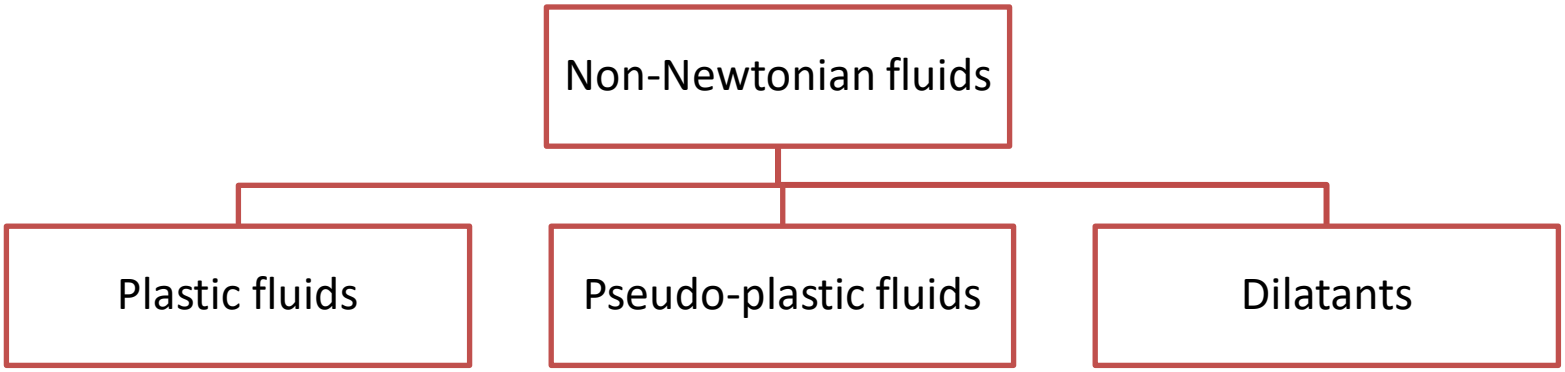
Newtonian Fluids

- Newton assumed that all materials have, at a given temperature, a viscosity that is independent of the shear rate.
- In other words, twice the force would move the fluid twice as fast.



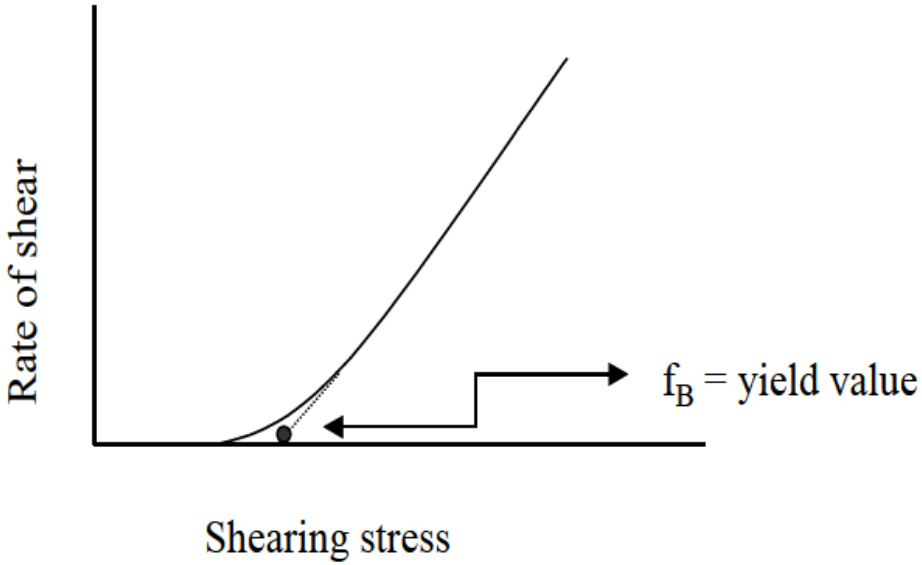
- Linear relationship between Stress and Strain
- 1/Slope of the line is **Viscosity (ŋ)**

Non-Newtonain fluids



Non-Newtonain fluids - Plastic fluids

- No flow occurs in response to shear stress until a certain transition point is reached (**Yield value**)
- Yield value: Minimum shear stress required by system before it deforms and begins to flow *(how this affects quality of the below cream?)*



Non-Newtonain fluids - Plastic fluids

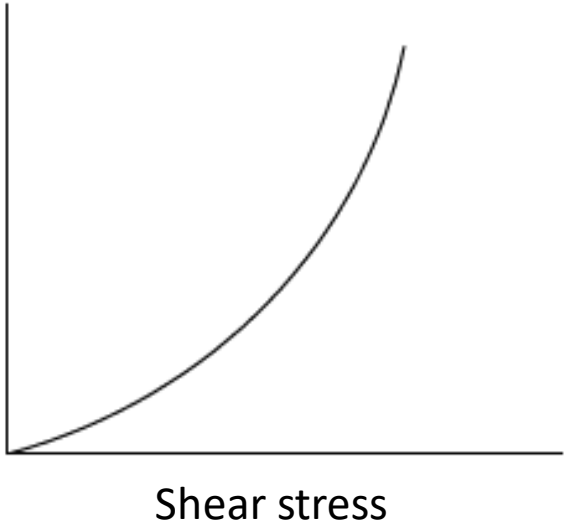
- **Mechanism**:

A certain force is needed to break the bonds between the particles of the substance before it starts to flow (Yield value)

Non-Newtonain fluids – Pseudo-plasic fluids

- Also called **Shear Thinning fluids**
- High viscosity at rest but flow immediately after shaking (stress).

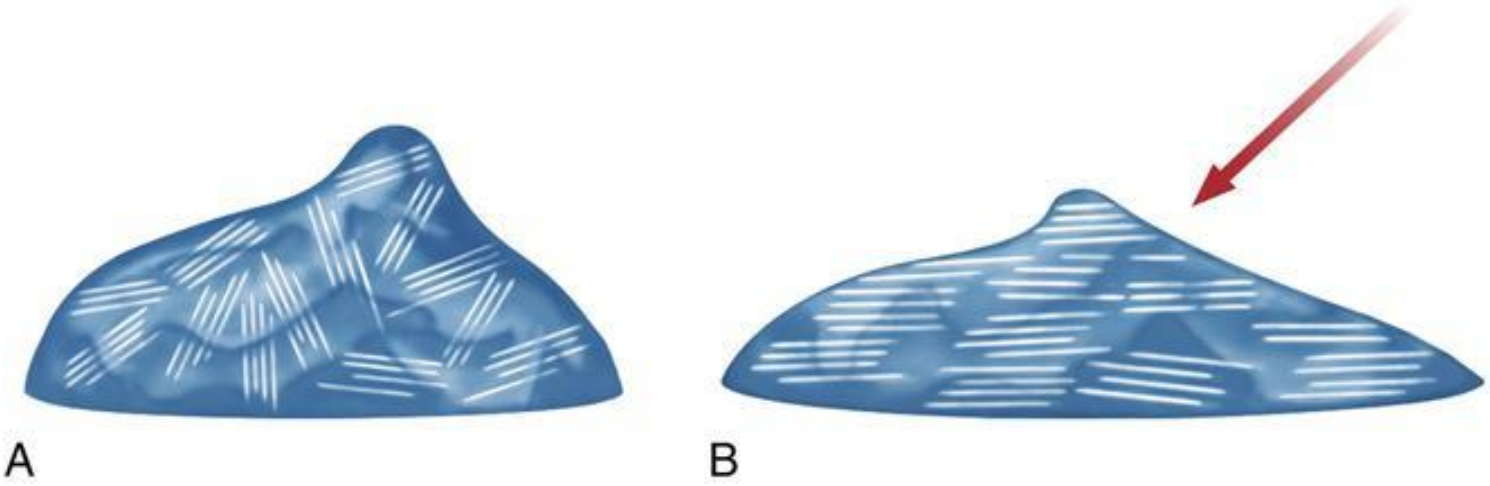
- Slop of the curve at any point is mobility (analogous to fluidity in Newtonian systems).
- 1/slop is viscosity
- *Note that mobility and viscosity change along the line.*



Non-Newtonain fluids – Pseudo-plasic fluids

- **Mechanism :**

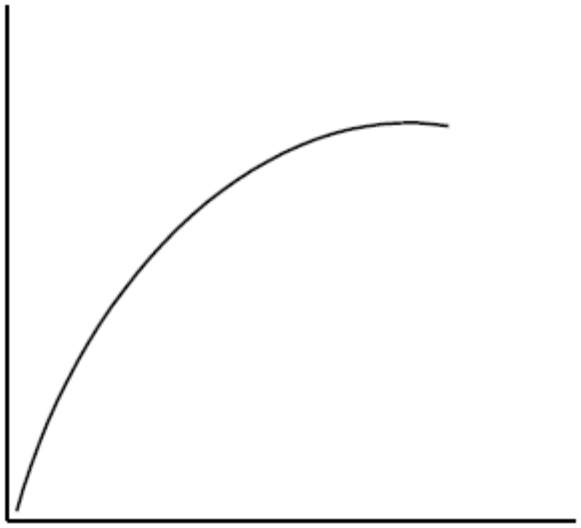
- At rest there is irregularity and entanglement of the chains of the polymer or the building blocks of the substance but with application of shear they rearrange and orient according to the direction of the applied force, with this the viscosity seems to decrease and the material starts to flow more.



Non-Newtonain fluids - Dilatant Fluids

- Also called **shear thickening fluids**
- Opposite of pseudo-plastics
- Suspensions with high solid content (usually more than 50%) usually have this property.
- Stress causes increase in viscosity.

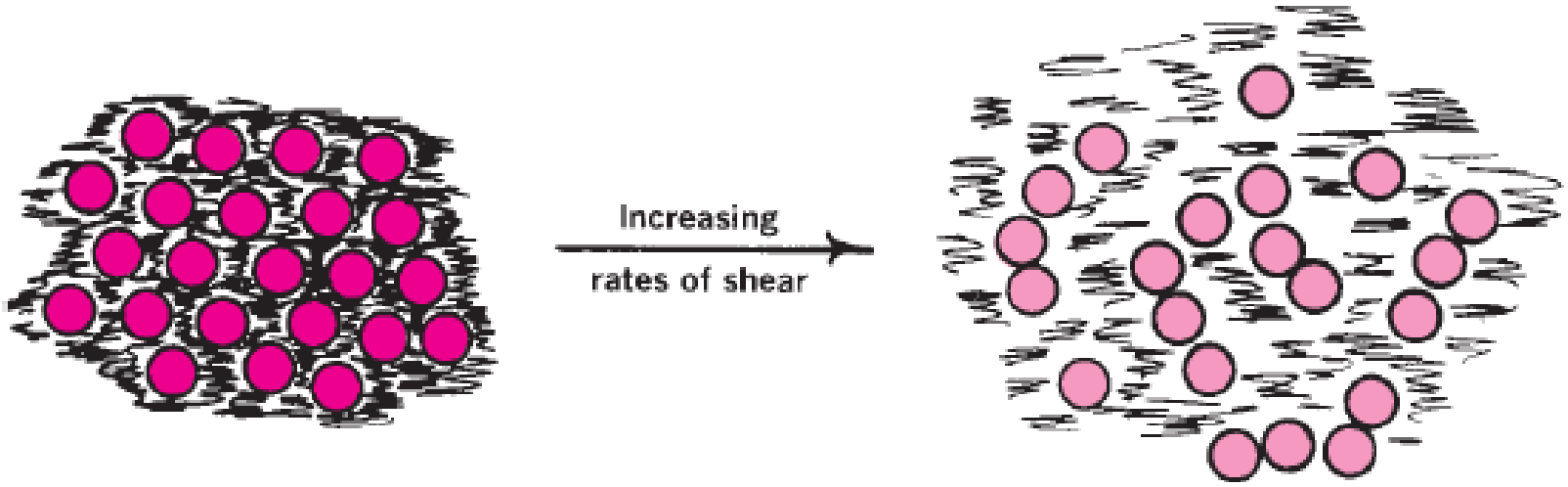
Watch Video

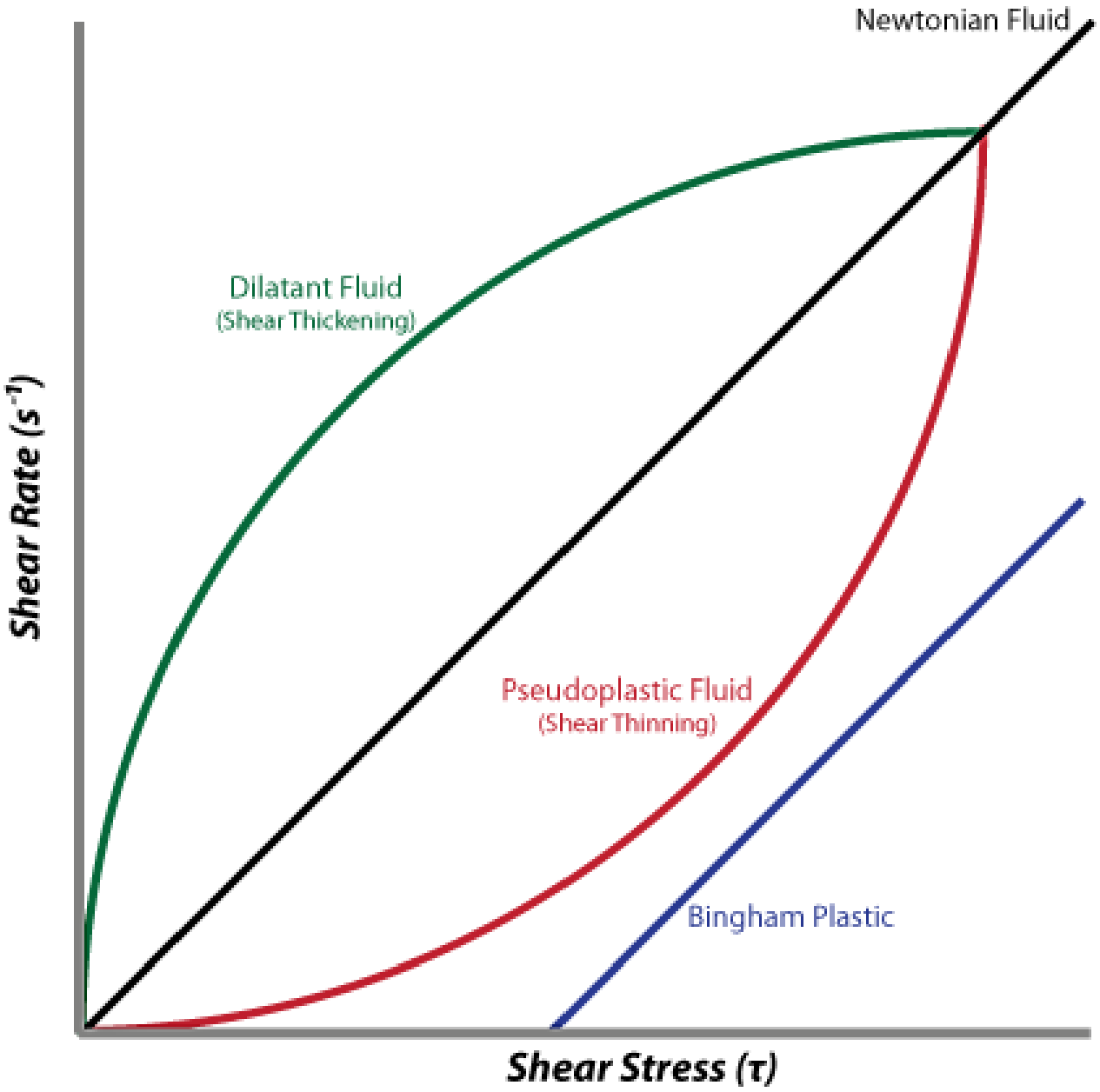


Non-Newtonain fluids - Dilatant Fluids

- **Mechanism:**

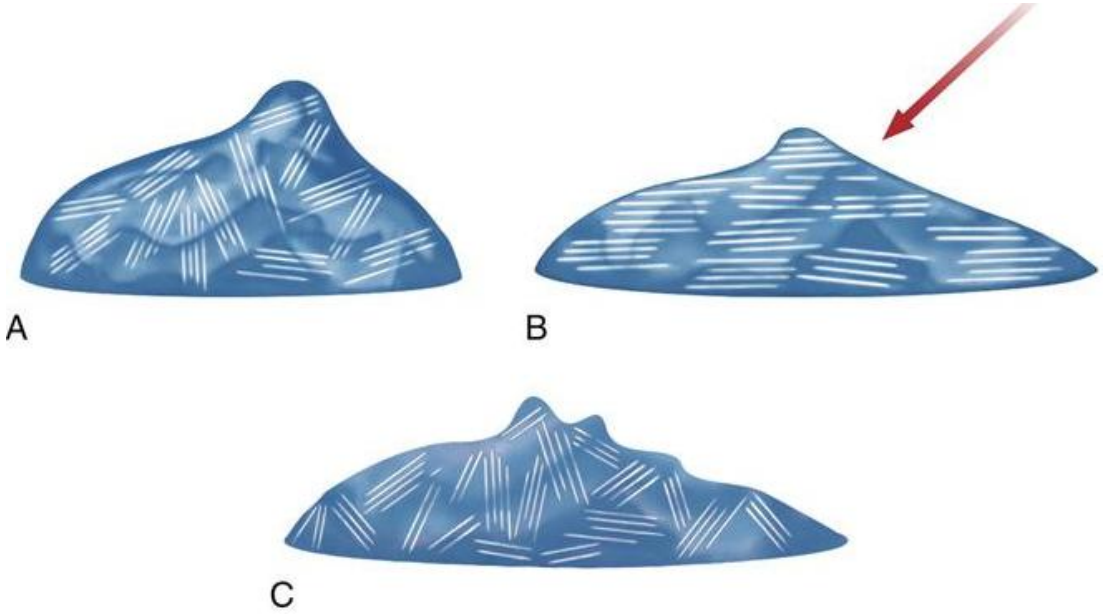
- With shear (stress) there will be sudden formation of vacuum gaps in between cluster of material particles which is where the solvent fails to remain in contact with the particles due to very high solute content. This leads to a sudden increase of viscosity and decrease of flow.




Newtonian Fluid
Dilatant Fluid
(Shear Thickening)
Pseudoplastic Fluid
(Shear Thinning)
Bingham Plastic
Shear Rate (s^{-1})
Shear Stress (τ)

Thixotropy

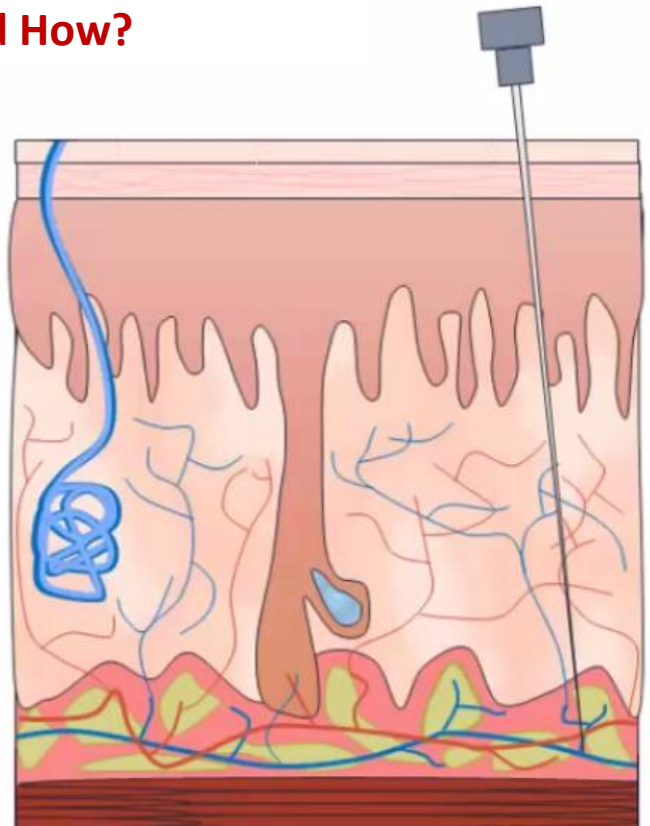
- Thixotropic materials have a time-dependent reversible viscosities.
- They are shear thinning materials which return to their pre-shear conditions when stress is removed.
- Their decrease in viscosity with application of stress is also time-dependent which mean longer the fluid undergoes shear stress, the lower its viscosity and after shear stress has been removed it takes some time for them to return to the original state.



Thixotropy

- It takes some time till the shear thinned fluid will return to its original state.

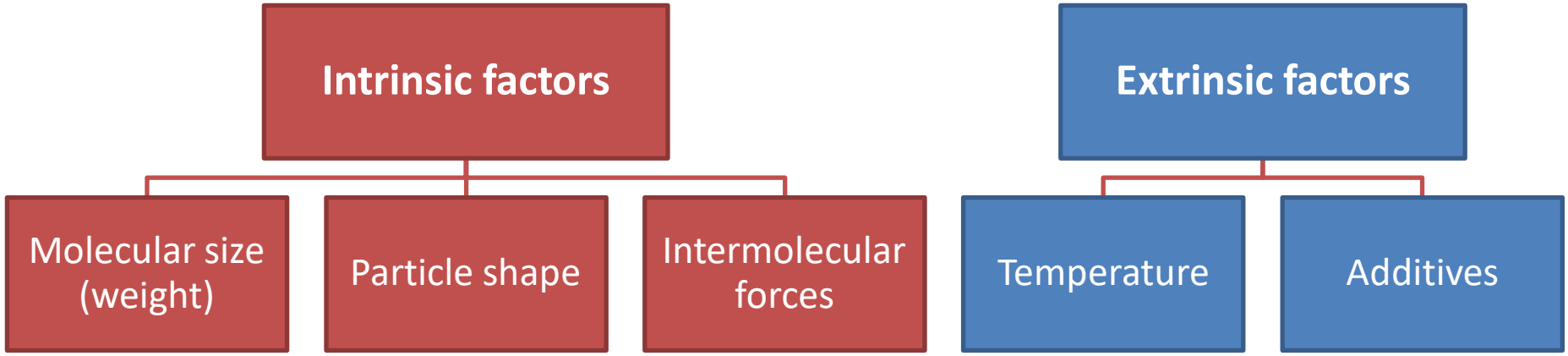
- This property is very useful in pharmaceutical applications.
  - Desirable property for suspensions and emulsions. **Why and How?**
  - For sustained drug delivery system. **Why and How?**



Read about

1. **Intramuscular depot injections**
2. **Relation between thixotropy and stability of suspensions**

Factors affecting viscosity



- Viscosity of liquids decrease with temperature
- Viscosity of gases increase with temperature

Why?

Capillary Viscometer

Falling-Sphere Viscometer

Cup-and-Bob Viscometer

Cone-and-Plate Viscometer

Questions?