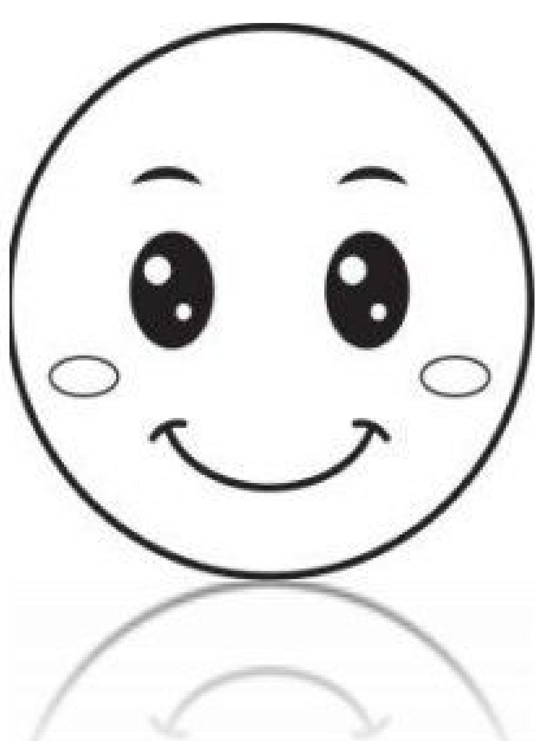
Rheology

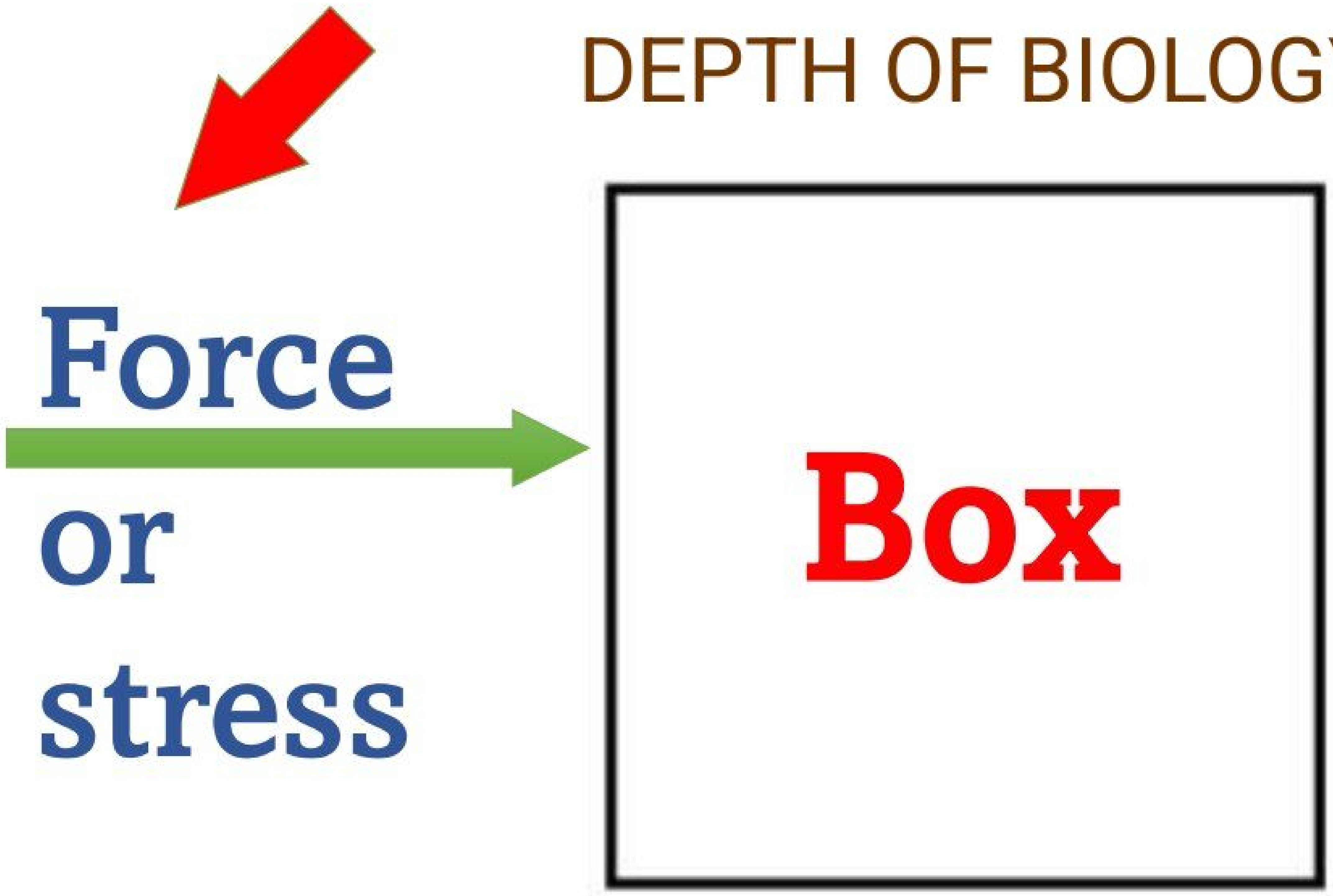
Branch of science

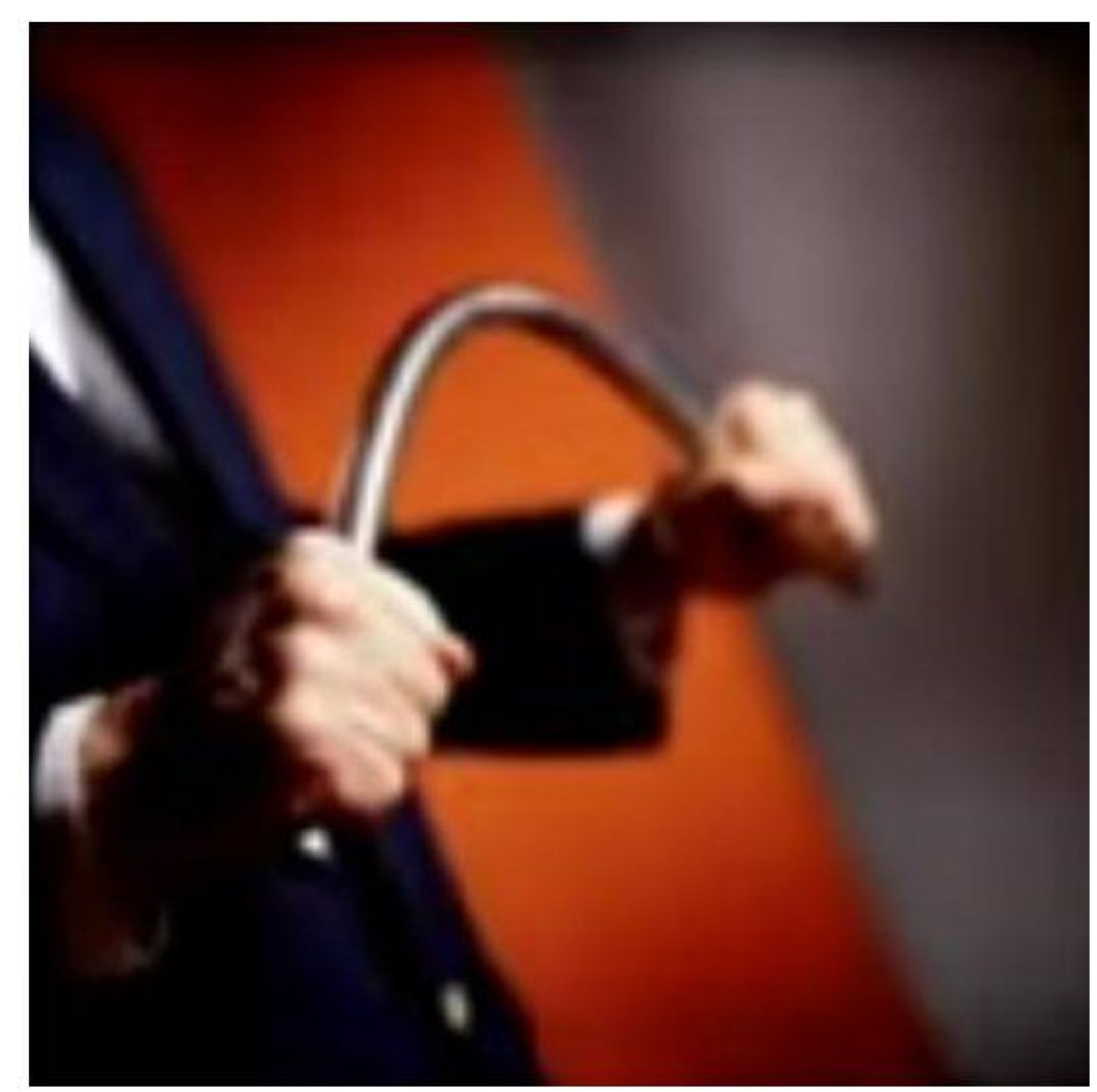
Here we study about flow



Flow in solid ? (Deformation)

Strain





Law of flow

Flow

Newtonian

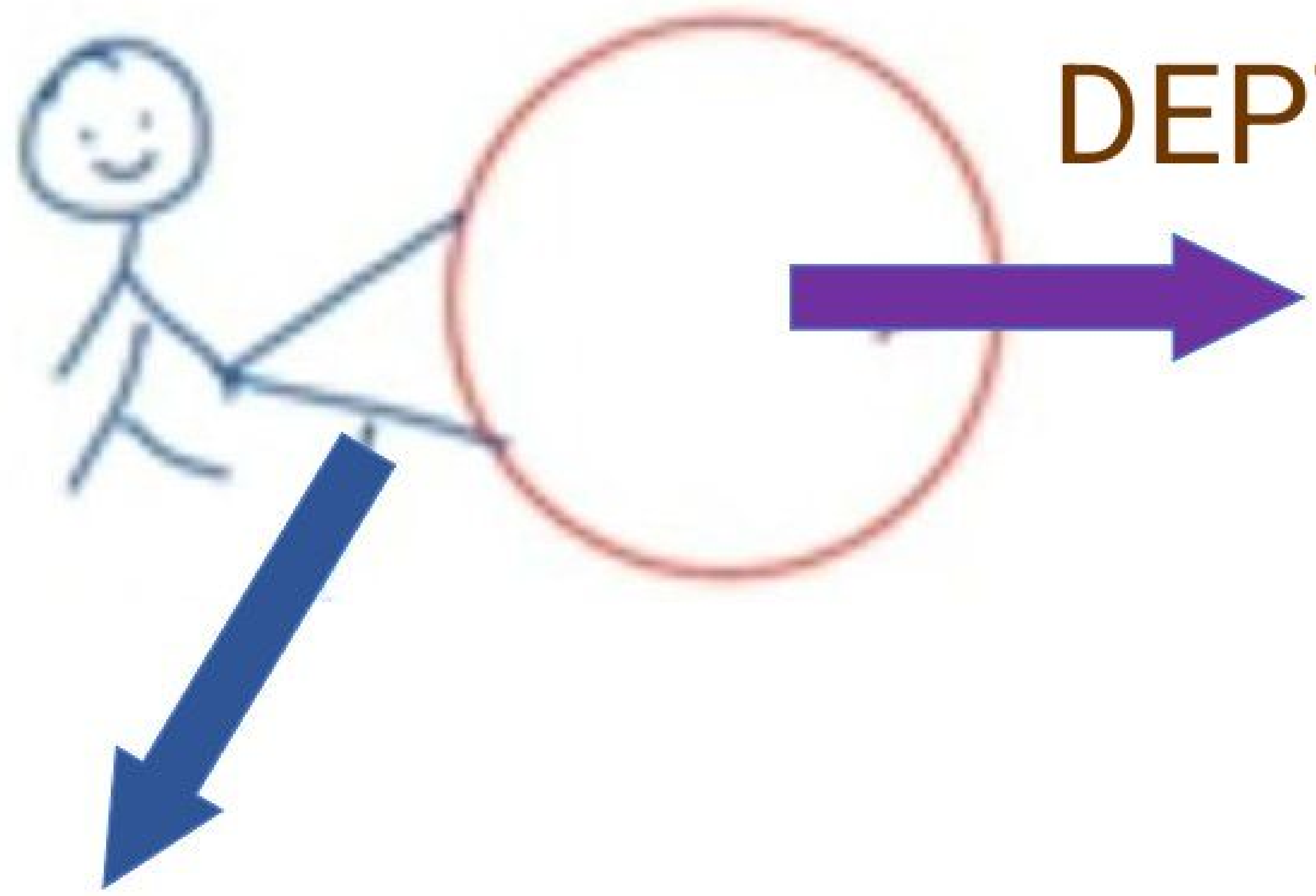
[The Materials / Liquid which follow Law of flow]

Non – Newtonian

→ Pseudoplastic

→ Dilatant

Shear stress $\propto$ Shear strain



Object
Movement
Directly proportion to
force apply

Stress
or
Force
or

Shear stress $\propto$ Shear strain

Newtonian Law of flow

→ $\tau \propto dv/dr$

↙ **Shear stress** ↘ **Shear strain**

Shear stress → **Ratio of Shear force (f) to the cross sectional area A**

$$\tau = F/A$$

$\tau \propto dv/dr$

$\tau = \eta \, dv/dr$

Promotional sign can be removed by using η Symbol

Viscosity

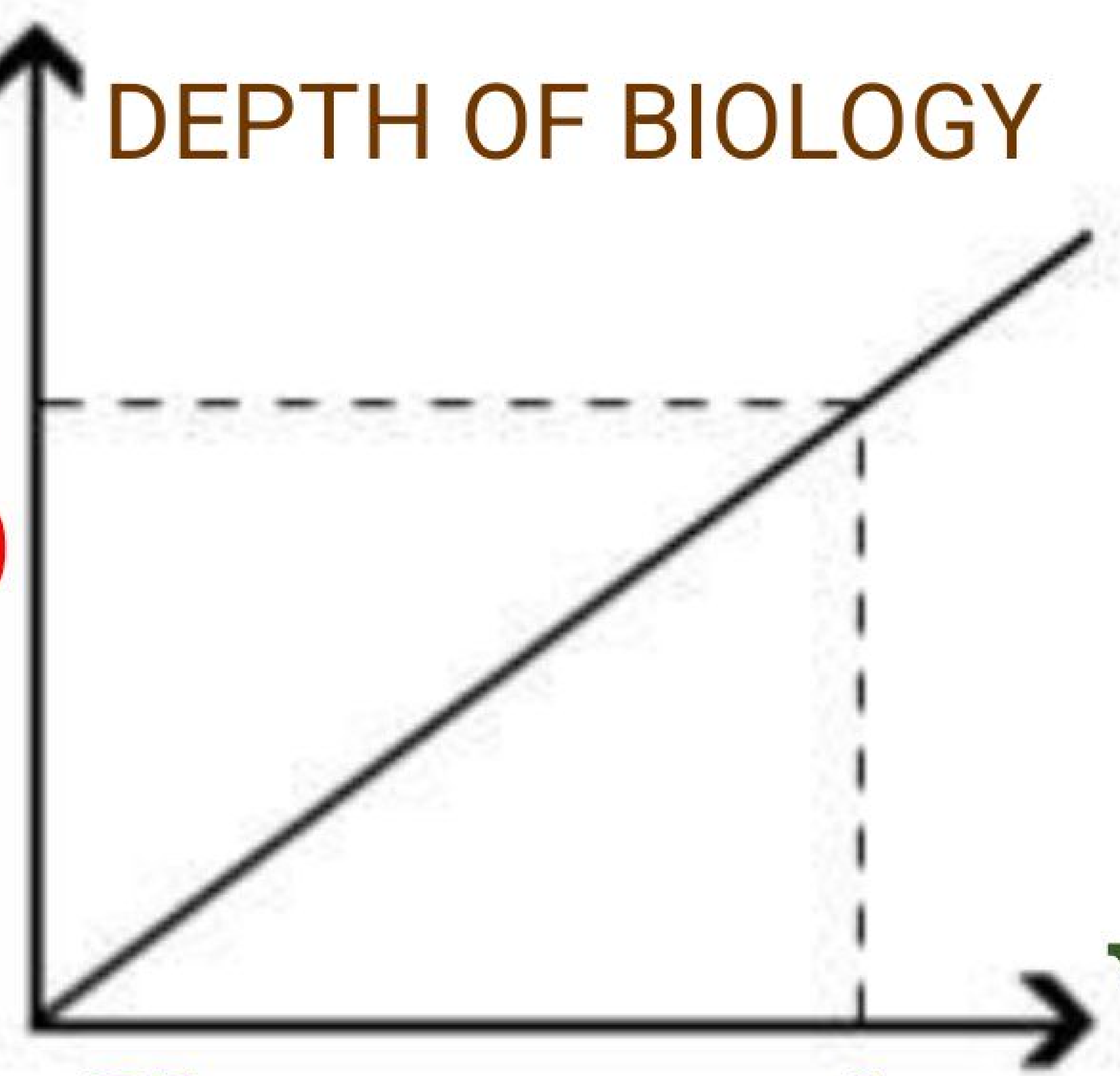
$$F/A = \eta \, dv/dr$$

☆ Viscosity ↑ = Flow ↓

Graph of Newtonian flow

Shearing stress (F/A)

X–axis



Y–axis

Shear strain
dv/dr

Example

- Benzene
- Ethylalcohol
- H_2O

Shear stress $\propto$ Shear strain

☆ Kinematic Viscosity → Denoted by V

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Unit = [m^2/s]

☆ It is the ratio of Viscosity of fluid to its density DEPTH OF BIOLOGY

$$K.V./V = \eta/\rho$$

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η → Viscosity of fluid

Viscosity

It measure resistive flow of fluid

As we know

Viscosity ↑ = Flow ↓

Effect of temperature → In Case of Liquid

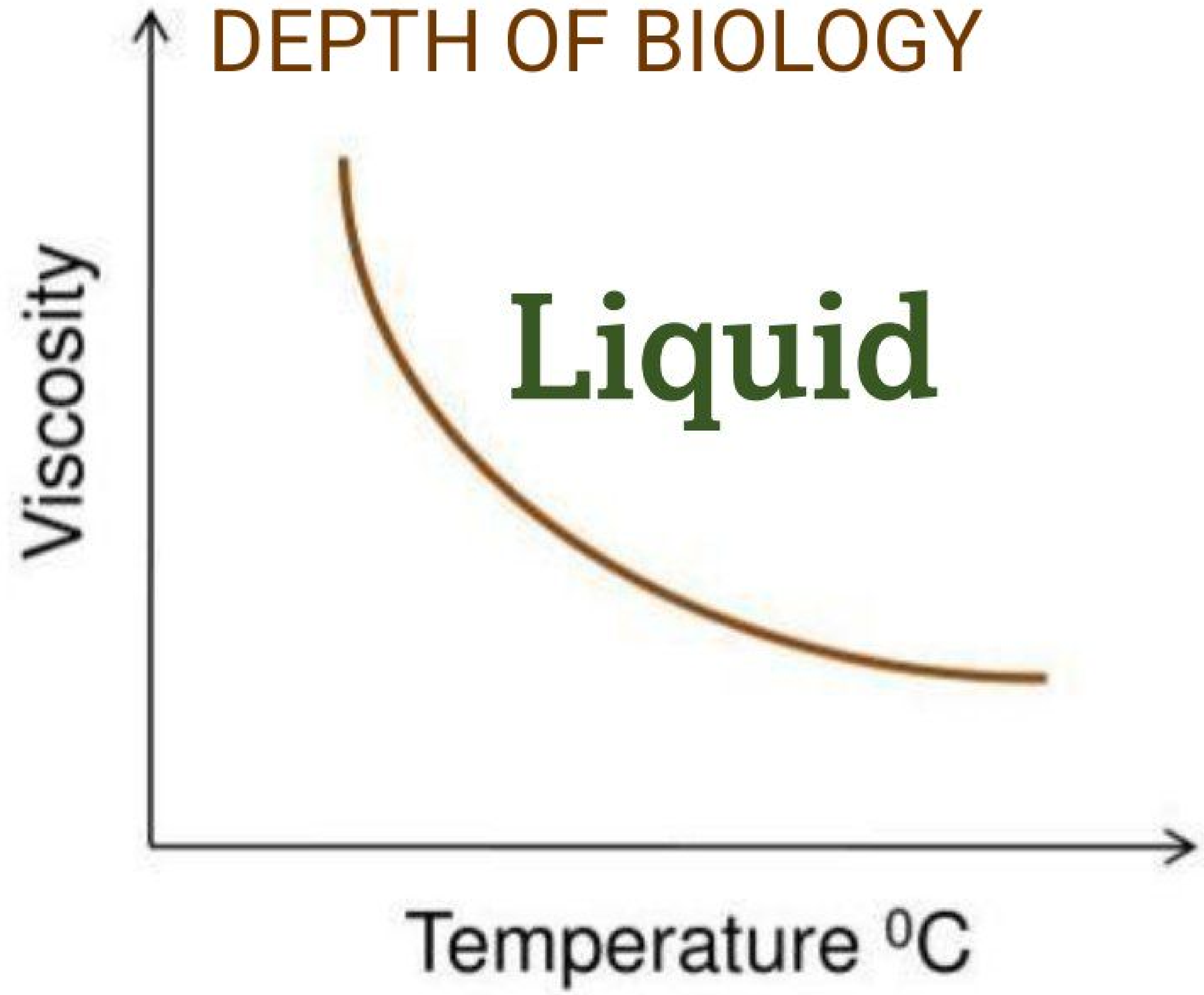
T ↑ V ↓ F ↑

Temperature ↑ Fluid ↑

Viscosity ↓

But In Case of Gas →

T ↑ V ↑ F ↓



☆ Example

In Case of Liquid

Heat → Flow property increases

Lecture - 2

Non-Newtonian flow ⇒

Shear stress ∝̸ Shear strain

Doesn't follow Newtonian law of flow

& Viscosity also alter ↑↓

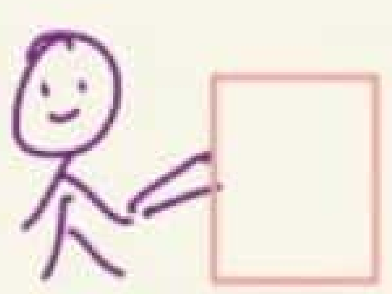
Newtonian flow →

Shear Stress ∝ Shear strain.

Viscosity is also Constant.

Non-Newtonian (3 Types).

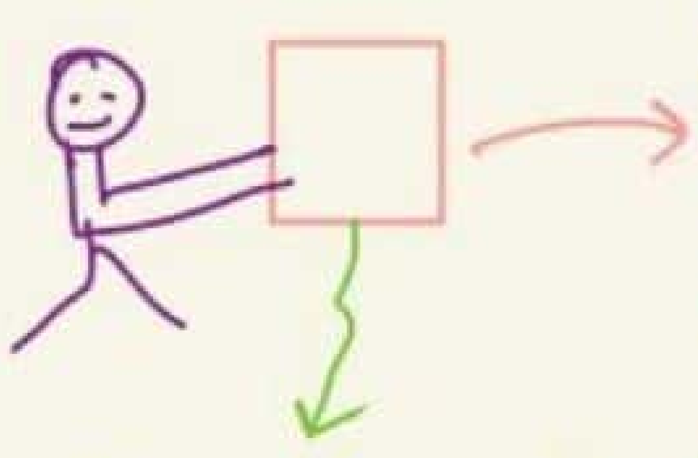
(a) Plastic (b) Pseudoplastic (c) Dilatant.



movm X

Force ✓

(At Initial).



→ Movm ✓

Force ↑↑

Bingham bodies.

force which is responsible for movm (called yield Value)

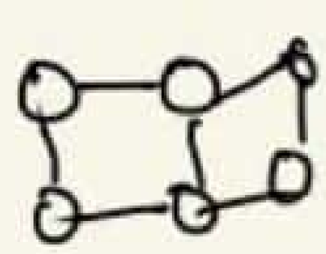
Now, it follow Newtonian Law of flow!

Initial force ?

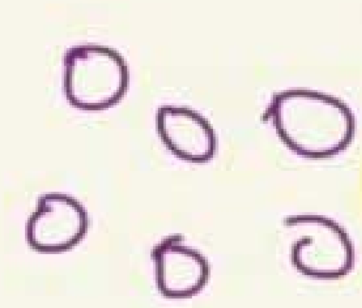
movm X

Intramolecule

force applied



force ↑↑



[movm ✓ Force ↑]

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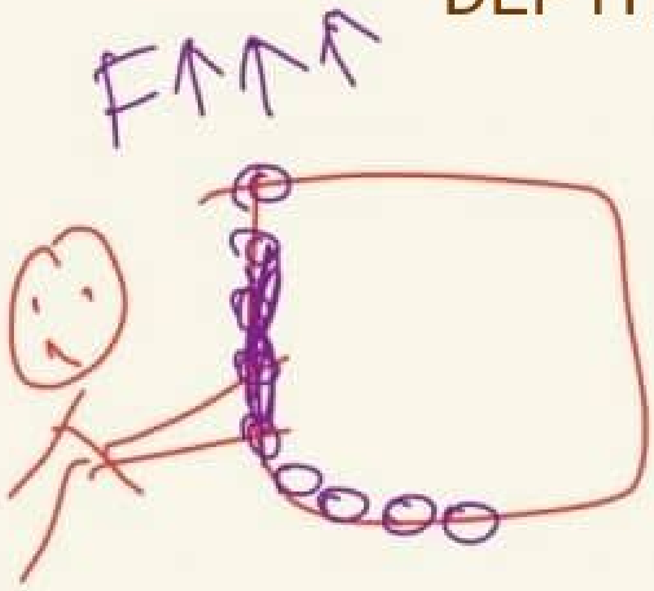

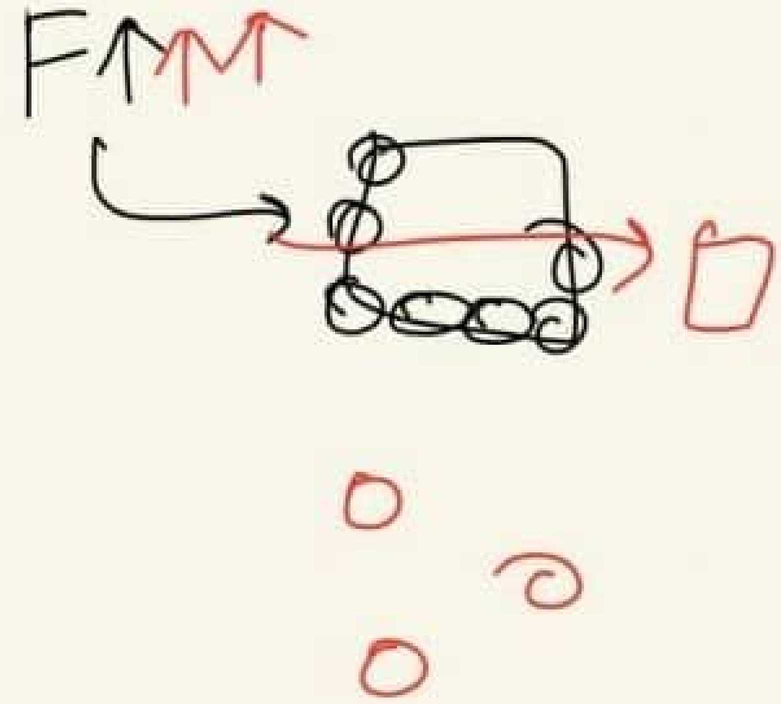

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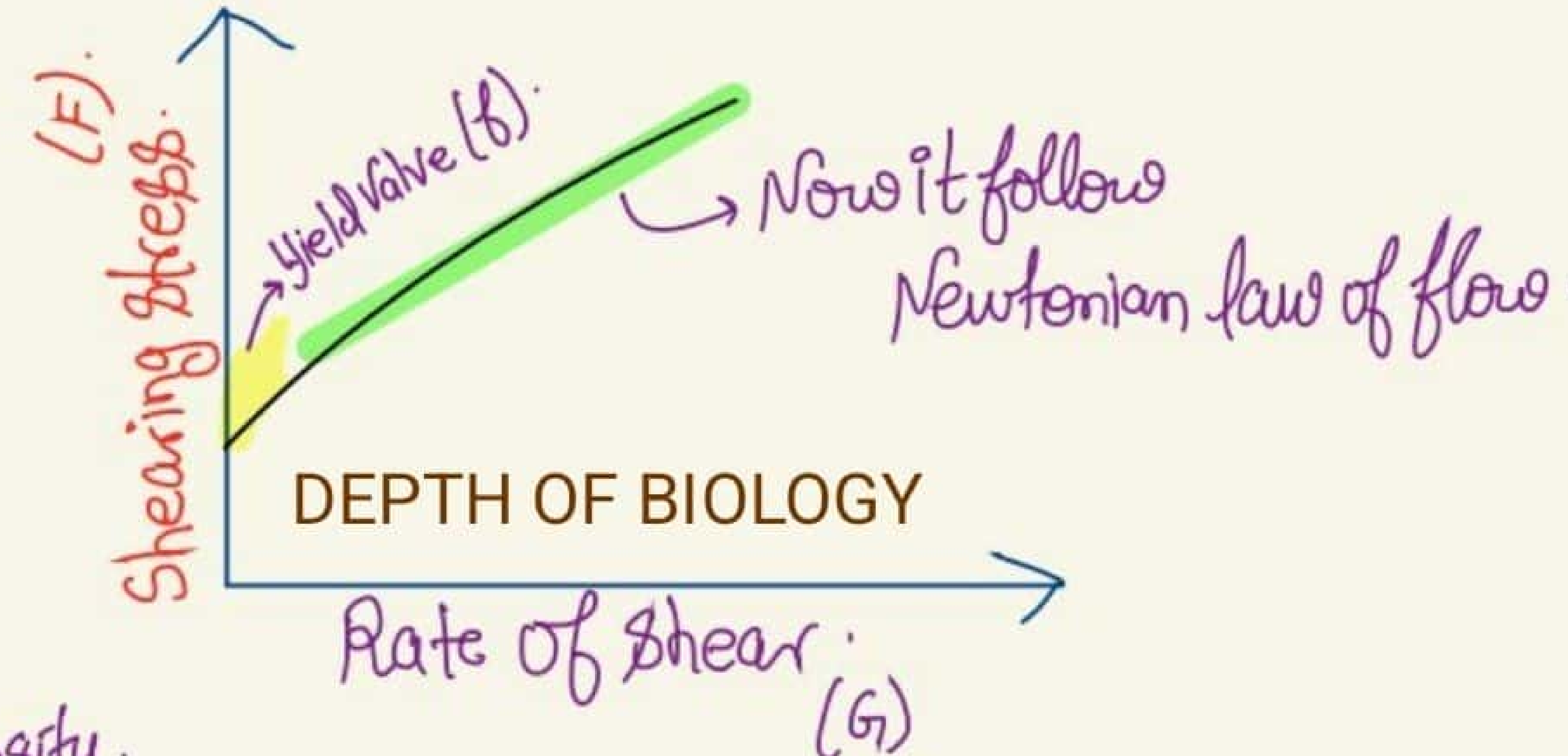
ⓐ Plastic → Graph.



μ = Viscosity.

As, we know ⇒ Shear Stress ∝ Shear Strain.

$$(F - f) \propto G$$

$$F - f = \mu G$$

Plastic Viscosity ← $\boxed{\mu = \frac{F - f}{G}}$ → rate of shear.

eg ⇒ Plastic flow ⇒ Flocculated Suspension

(2) Pseudoplastic flow ⇒

In this flow (Pseudoplastic) → Non-Newtonian.

↓

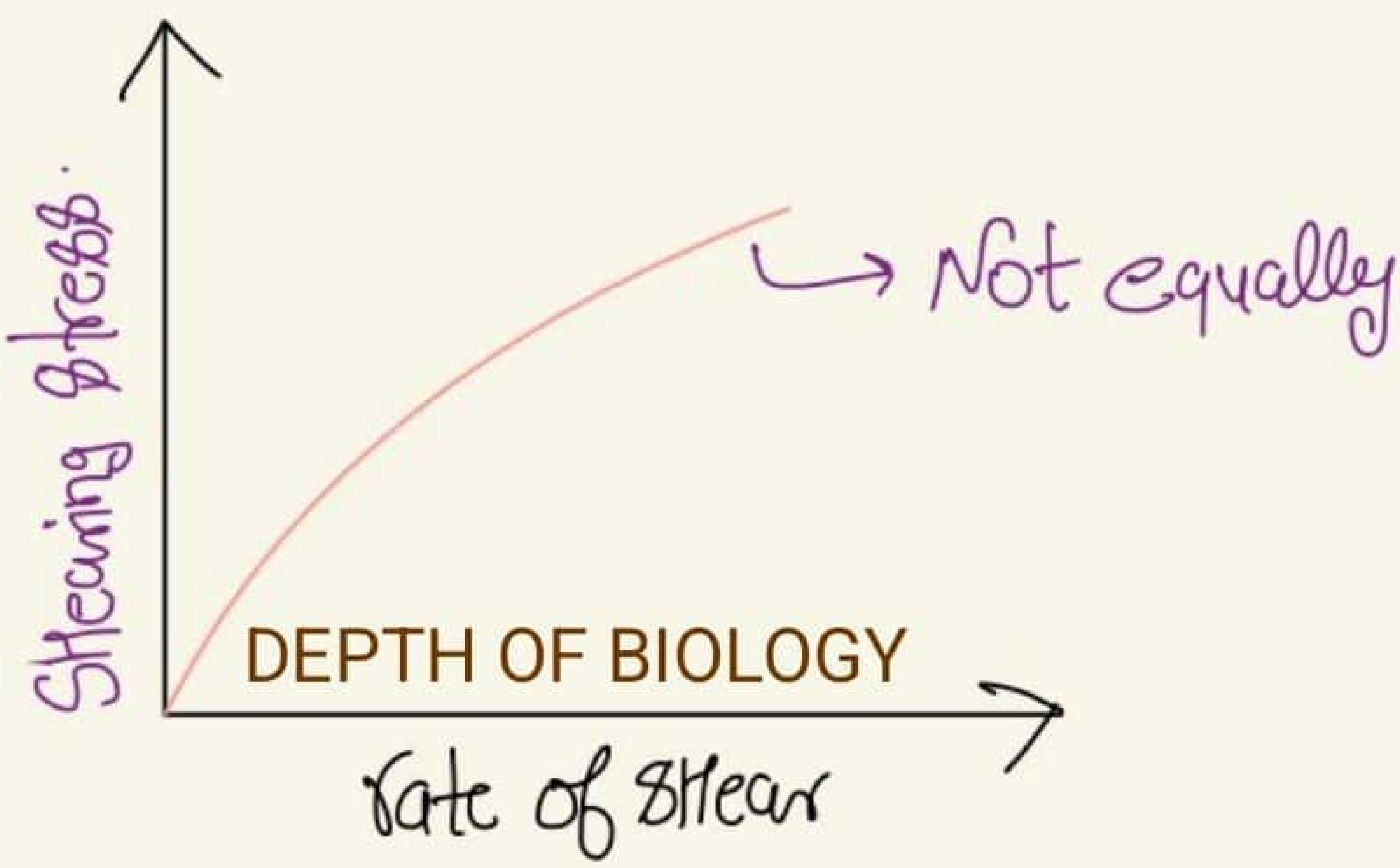
Viscosity is decreases after applying Shear Stress.

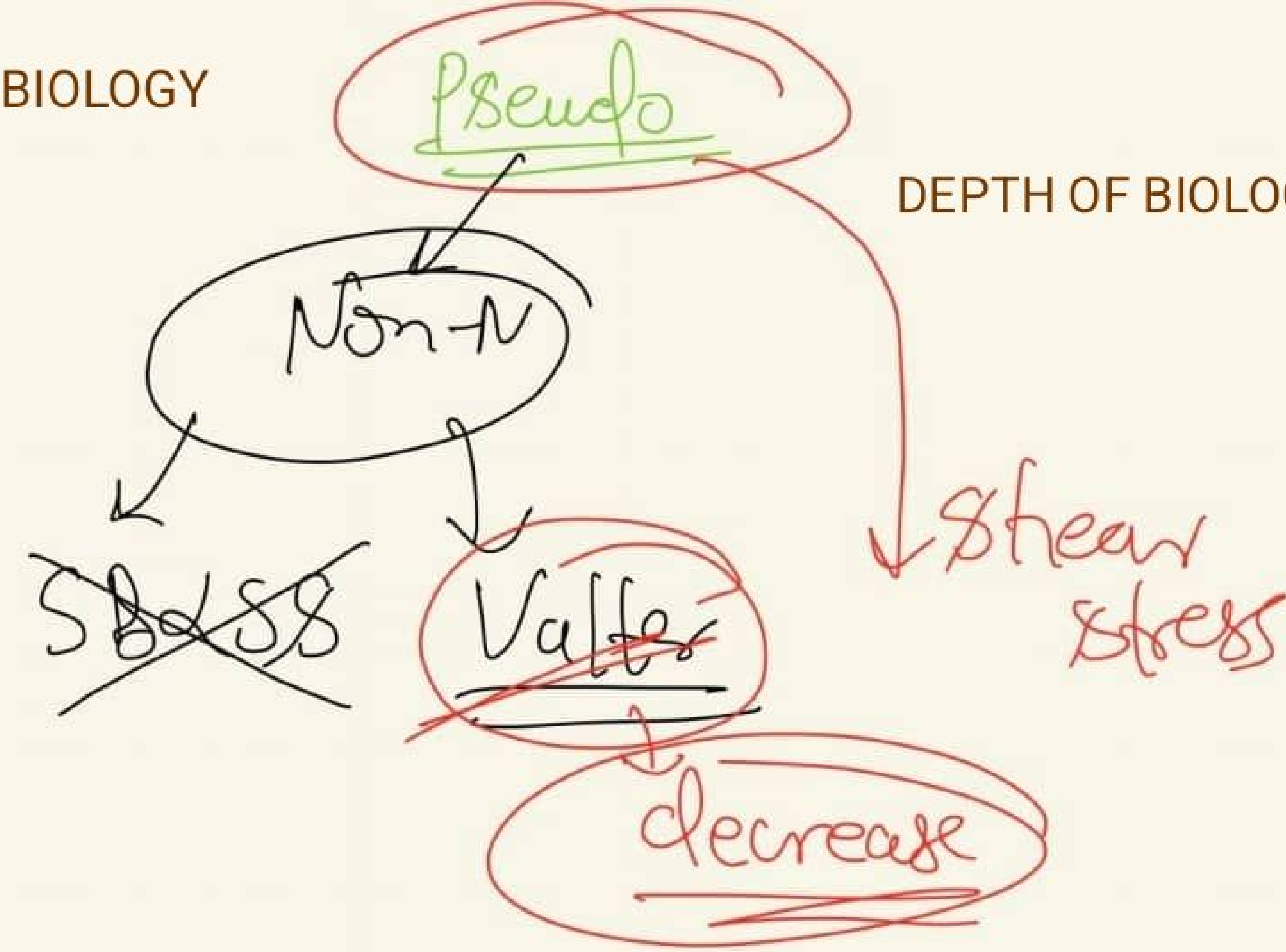
★ It doesn't have any Yield point.

eg ⇒ Blood, Sand in Water, Honey.

Shear Stress —apply→ Viscosity ↓ ⟶ flow property ↑.

Shear Stress ↑ ⟶ Shear Strain (but Not Linearly or equally).




Pseudo
Non-N
Shear stress
decrease

Plastic vs Pseudoplastic Flow

	Plastic Flow	Pseudoplastic Flow
DEFINITION	Plastic flow is a chemical phenomenon that describes the flowing behavior of a material after applying stress which reaches a critical value	Pseudoplastic flow exhibits the behavior of both Newtonian flow and plastic flow
DESCRIPTION	Describes the flowing behavior of a material after application of stress	Describes that fluid shows both Newtonian and plastic flow
EXAMPLES	Bending a piece of metal or pounding it into a new shape	Blood, sand in water, honey, etc.

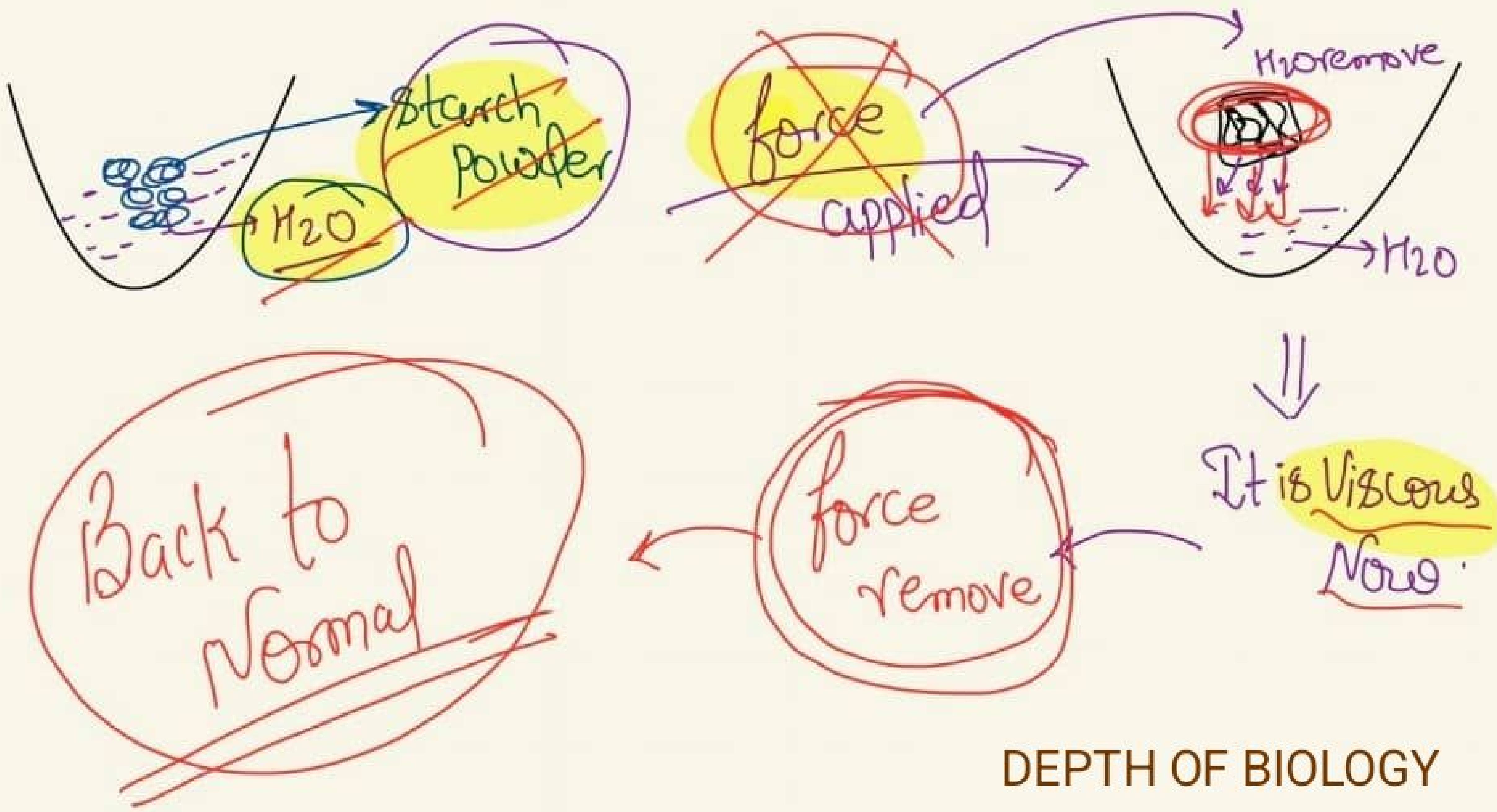
③ Dilatant flow ⇒ [Also Called Shear Thickening System]

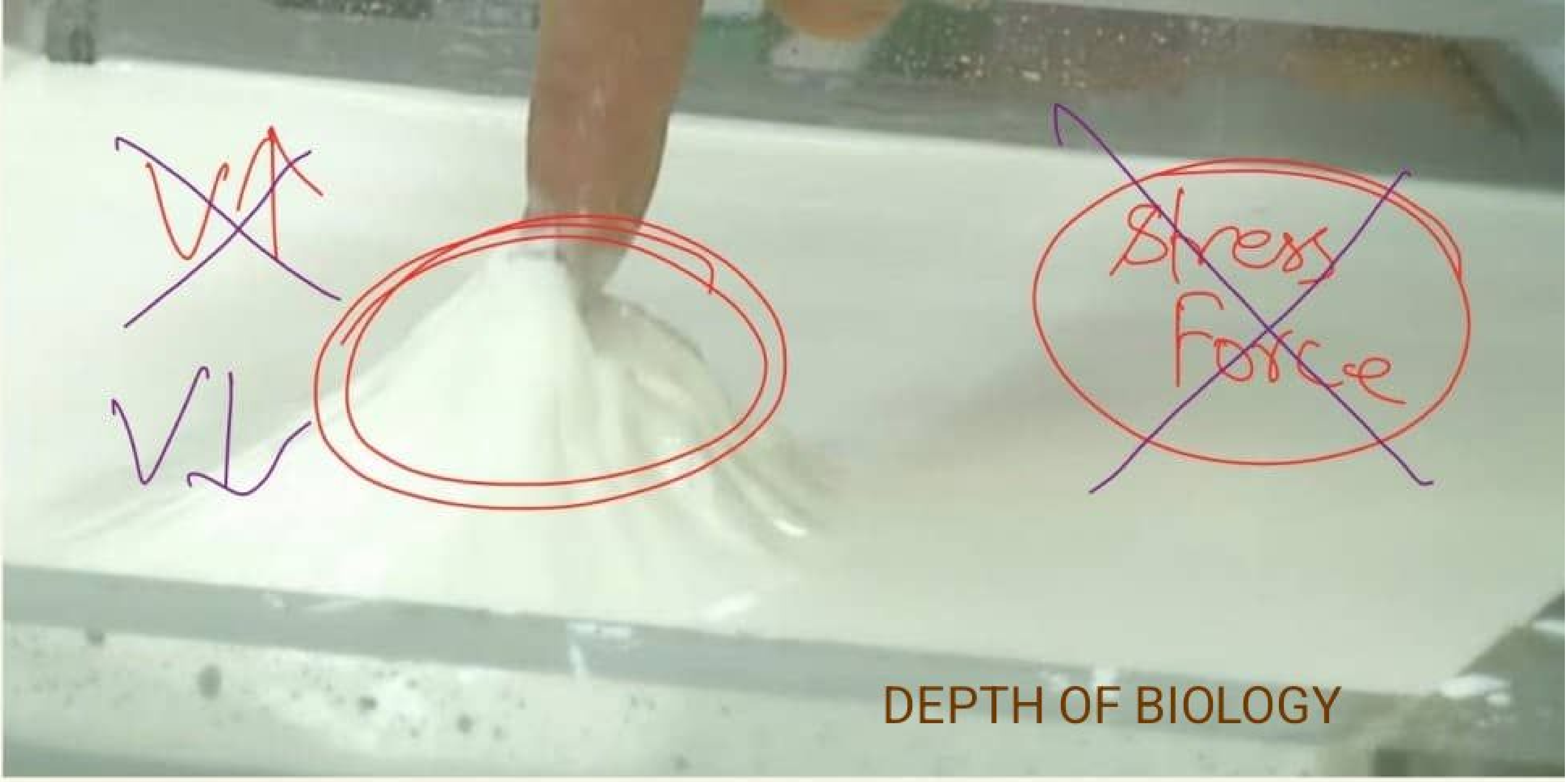
Shear stress ↑ ⇒ Viscosity ↑

☆ This flow is Inverse to Pseudoplastic flow (V↓).

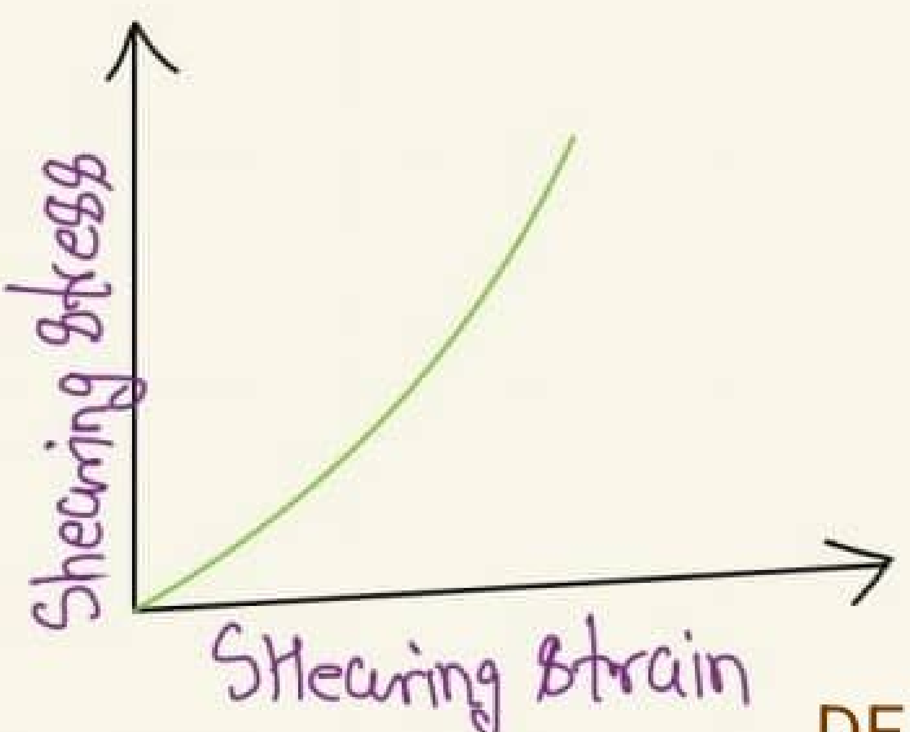
eg ⇒ Starch powder in water.

☆ If shear stress is removed then dilatant system return to it's original state or fluidity.





Dilant flow Graph



Thixotropy

Stirring ← Thixo · tropy → Change

Time – Dependent

Progressive (↓)se in Viscosity with time for a Constant applied Shear Stress.

[followed by Gradual recovery when the Stress is removed]

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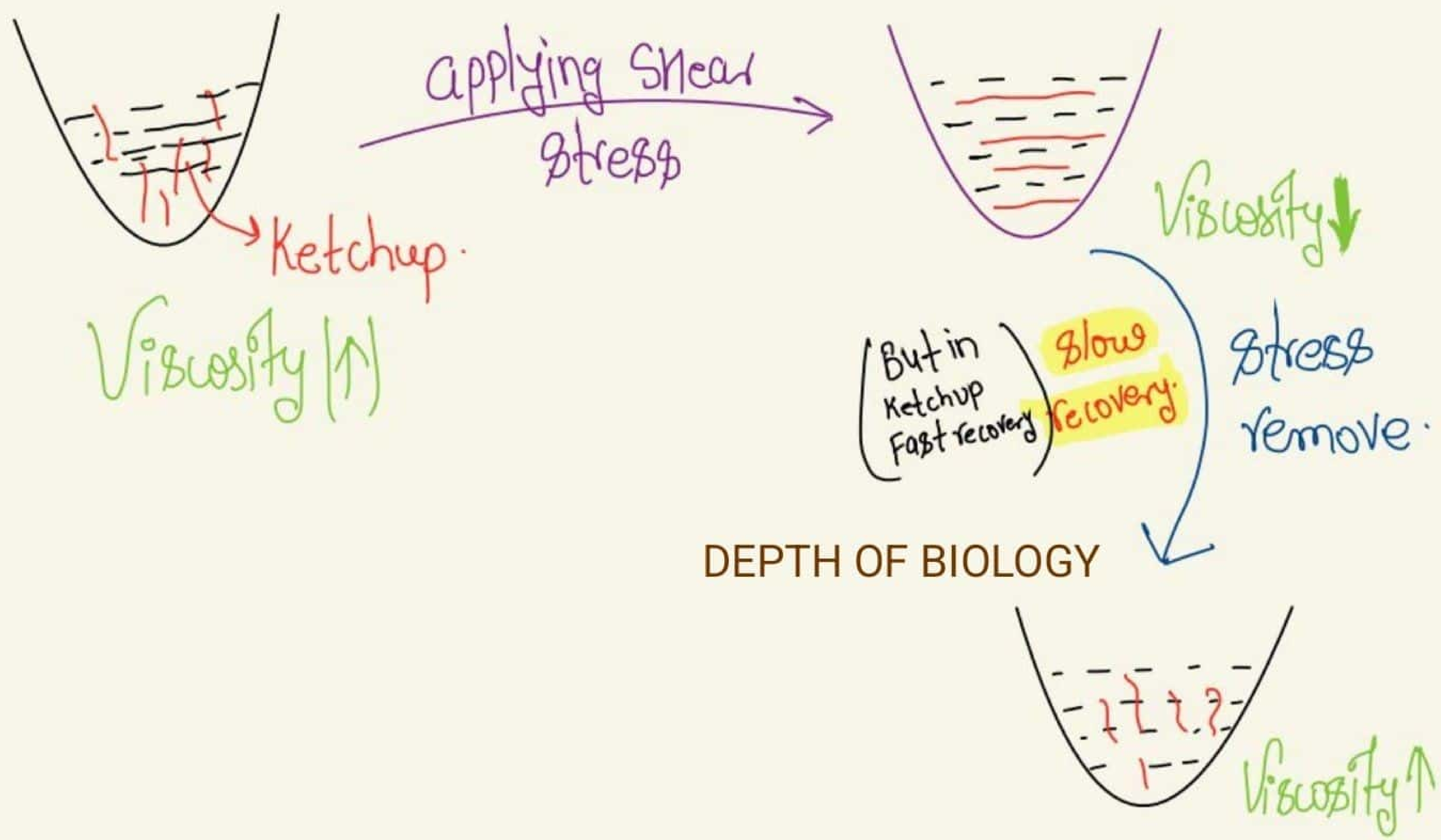
☆ Thixotropy is also Called ⇒ Gel–Sol–Gel Transformation



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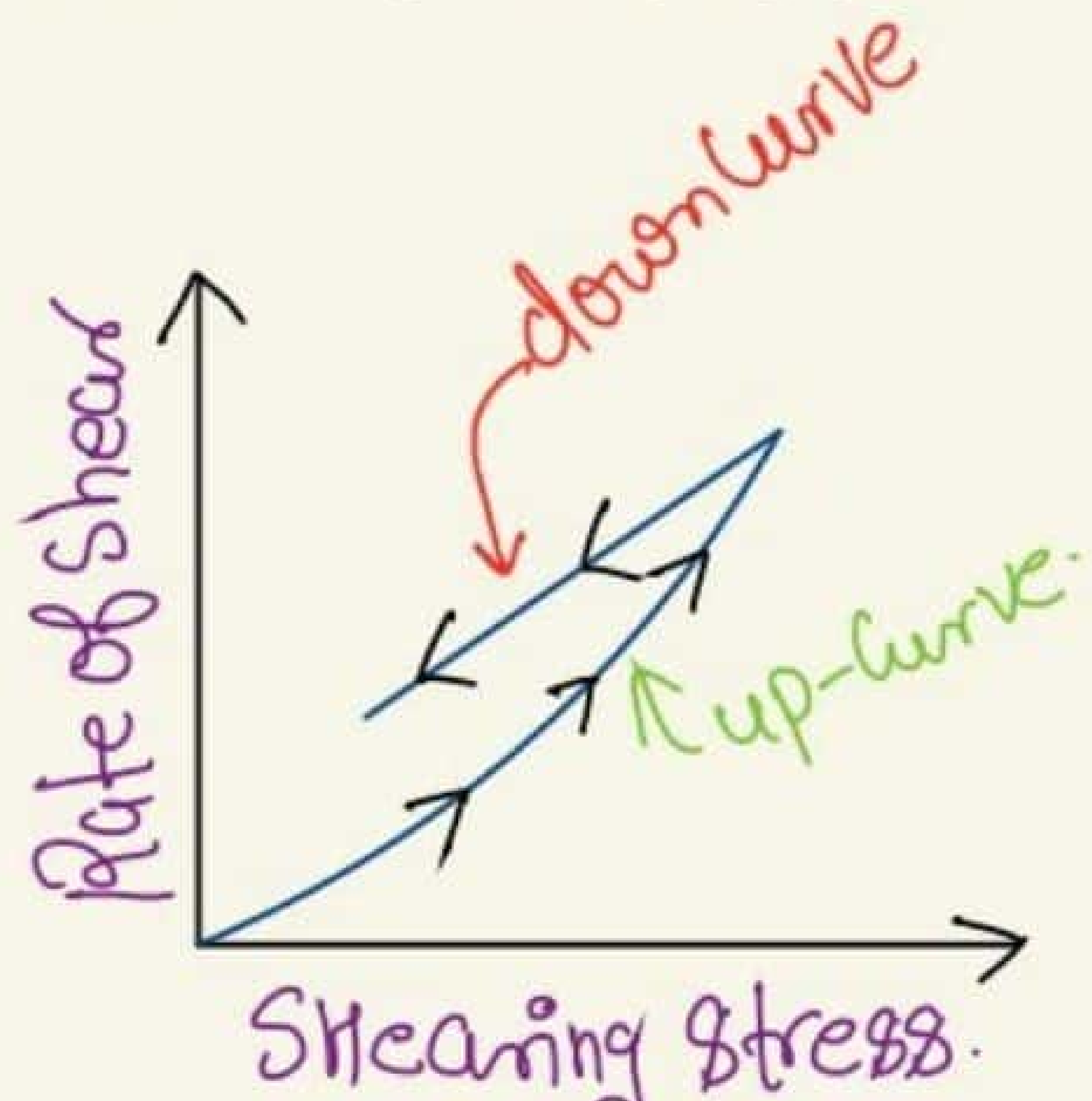
Many Kinds of Paints & Inks ⇒ Plastisols → Used in silkscreen Textile Printing.

⇓

Exhibit Thixotropic Qualities



→ Hysteresis Loop.

⇓

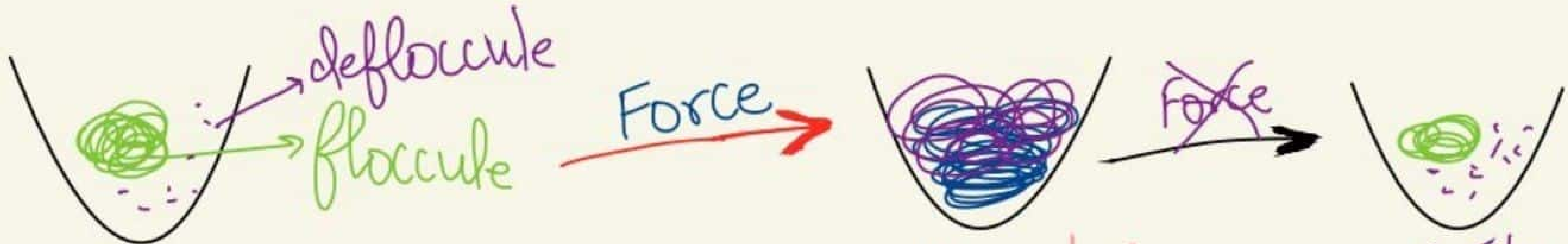
Up & down Curve of Thixotropic System.

Anti-Thixotropy / Negative Thixotropy.

Shear stress apply करने पर ⇒ Viscosity ↑

Sol —Force→ Gel —-Force→ Sol.

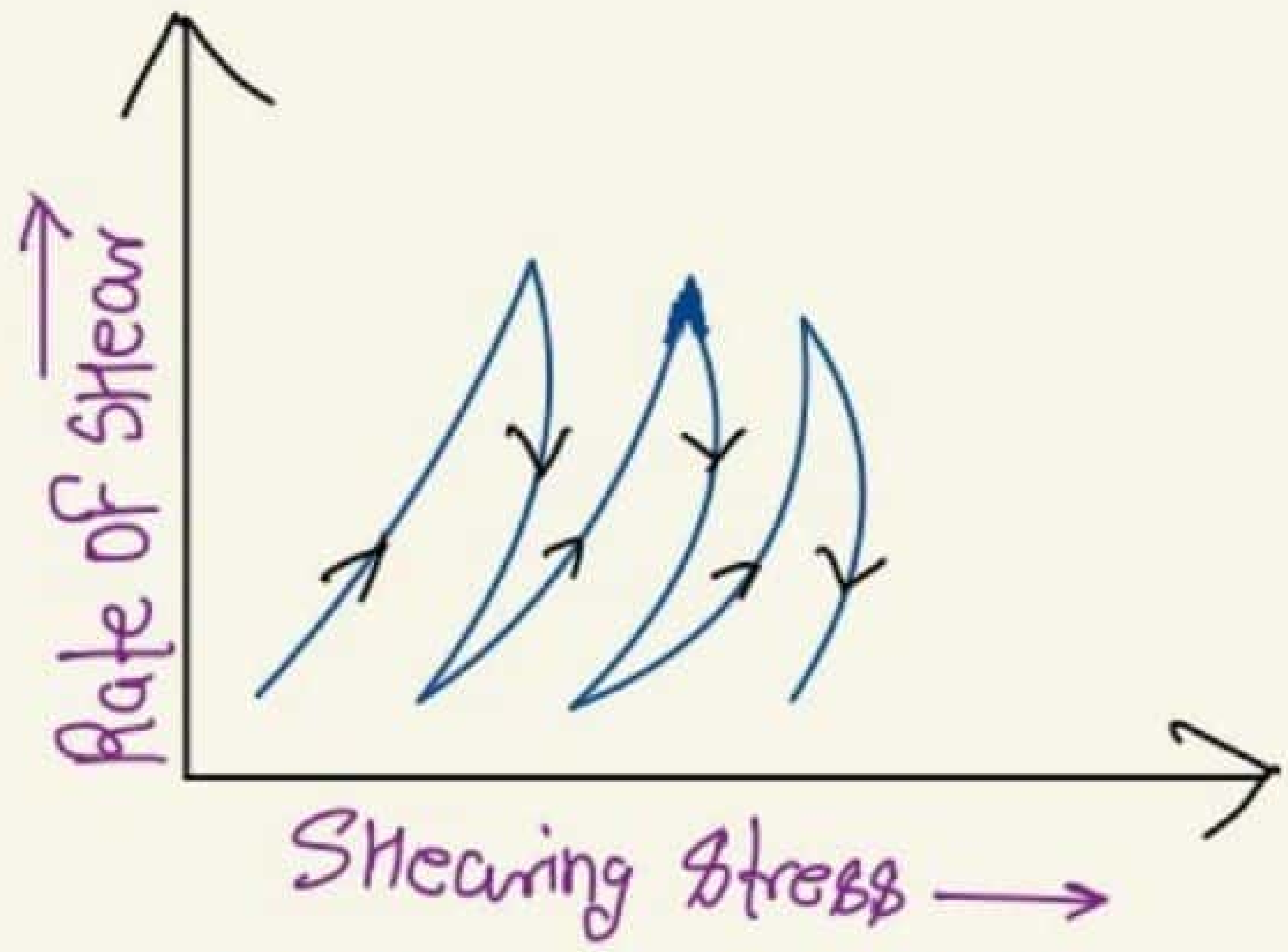
Viscosity (↓) Viscosity (↑) (Viscosity ↓)



Viscosity ↓ Viscosity ↑ V↓

Graph →

(Negative Thixotropy)

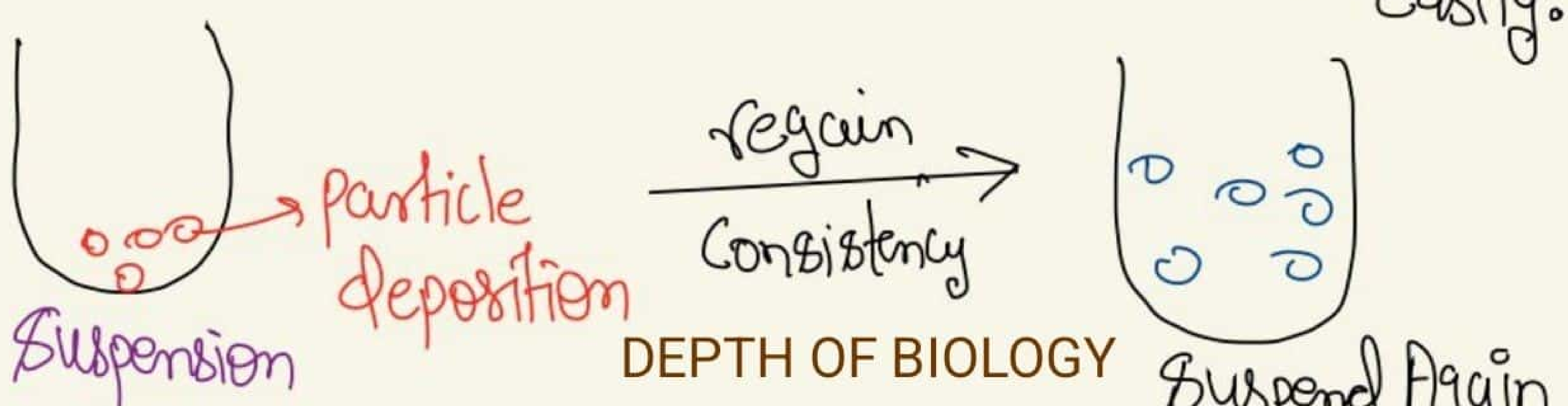


Application of Thixotropy.

- Thixotropy is desirable property in Liquid Pharmaco System.

① High Consistency in Container Yet pour are spread easily.

②



③ It is also desirable with Emulsion, Lotion, Cream, ointment & Parentral Suspension to be Used for Intramuscular depot Therapy.

Thixotropy in formulation

1. Consistency ✓✓ ↙ Pour Liq. Spread easily.

- ***Thixotropy in Formulation***
- Thixotropy is a desirable property in liquid pharmaceutical systems that ideally should have a high consistency in the container, yet pour or spread easily.
- For example, a well-formulated thixotropic suspension will not settle out readily in the container, will become fluid on shaking, and will remain long enough for a dose to be dispensed.
- Finally, it will regain consistency rapidly enough so as to maintain the particles in a suspended state.

- A similar pattern of behavior is desirable with emulsions, lotions, creams, ointments, and parenteral suspensions to be used for intramuscular depot therapy.

Determination of viscosity, capillary, falling Sphere, rotational viscometers

⇒ **Viscosity** ⟶ It is an expression of the resistance of a fluid to flow Under applied stress.

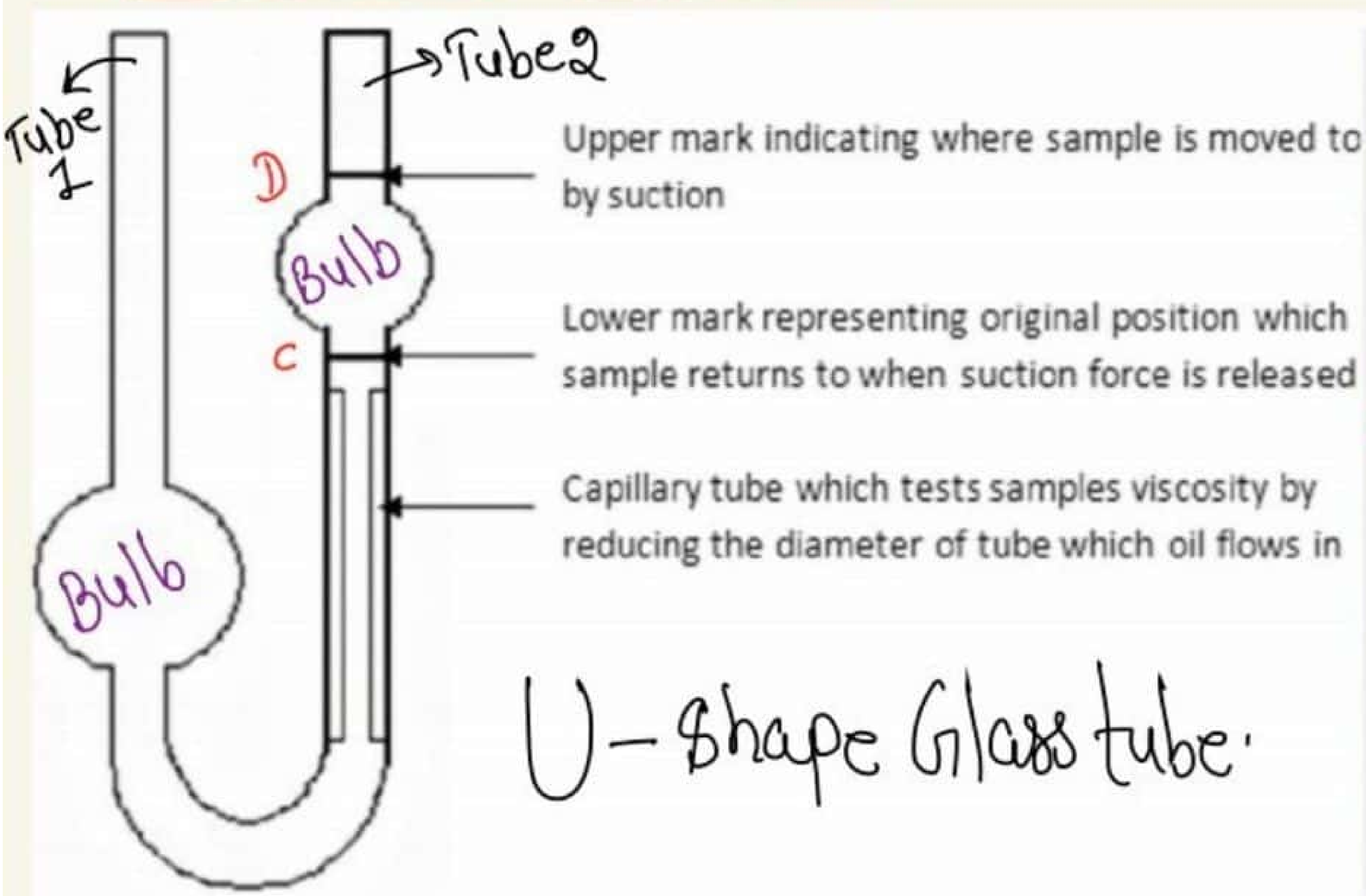
Viscosity ↑ Resistance ↑ flow ↓

Viscometer → device/Instrument ⇒ Used to measure Viscosity.

ⓐ **Capillary Viscometer** ⇒ (Ostwald Viscometer)

Or

U-tube Viscometer



☆ Mostly for Newtonian fluid.

⇒ 2 bulbs are ⊕nt in Ostwald Viscometer.

⇒ Suction tube will be apply. [at tube-2 site]

Working / Principle ⇒ ① At first we have to fix Viscometer in a stand in Vertical position.

② Now take Standard fluid whose Viscosity & density is known.

③ filled the fluid Via tube 1 upto Mark.

④ Now suck the Liq. with the Help of Suction tube which is already applied on tube-2

⇓

fluid Suck from bulb A to bulb B.

⇓

after this fluid flow from C → D [Point].

When fluid reaches at D point · then stop the working of suction tube

⇓ after this.

This Liq. again comes downwards [due to Gravity]

⇓

Liq. fall from D to C (Timer On) & Time Noted

Now, filled second Liq. whose Viscosity & density is Unknown (density → maybe known.)

⇓

follow the same procedure & Note the time.

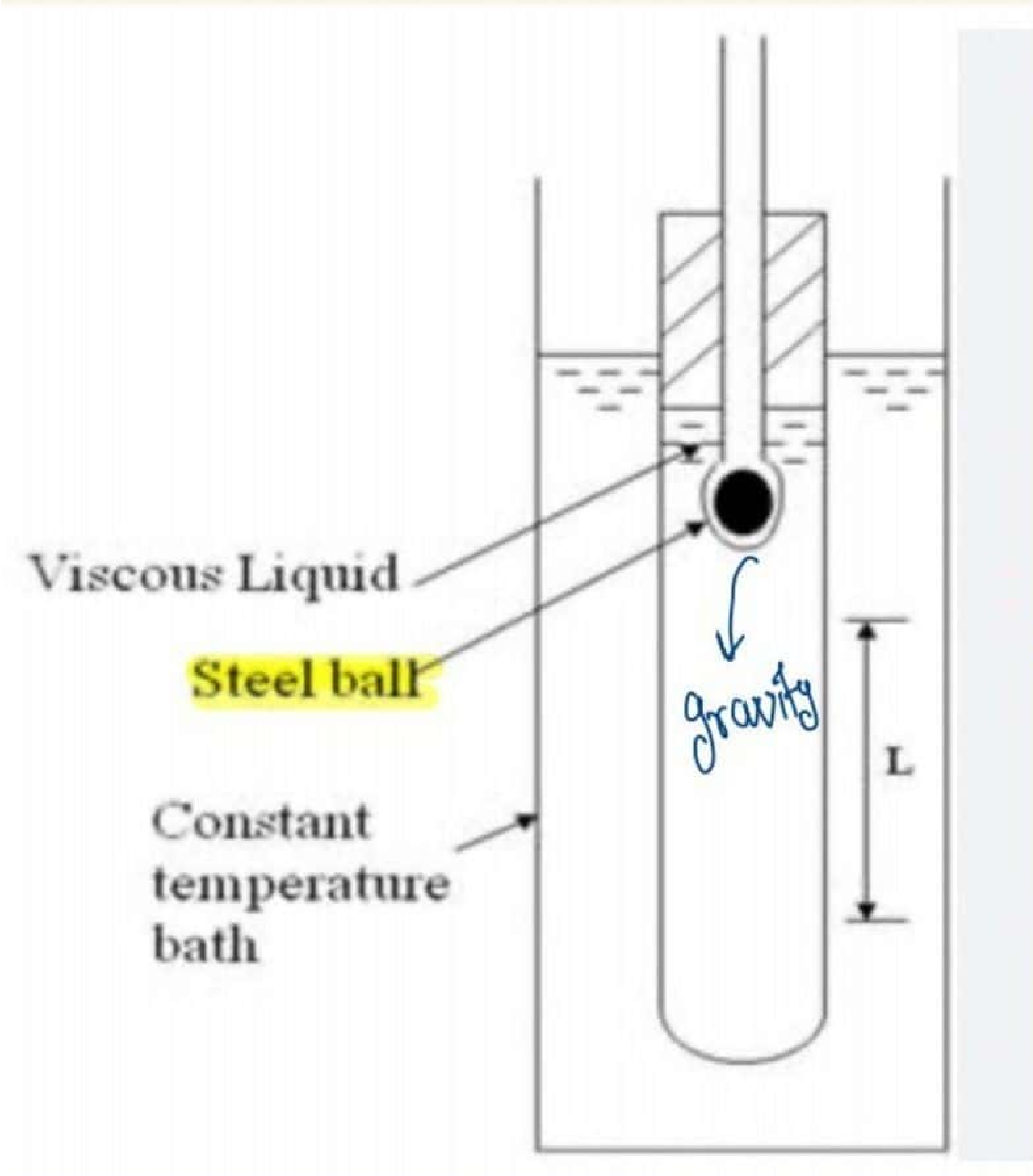
⇓

Now, Compare the time ⇒

$$\frac{\eta_1}{\eta_2} = \frac{\rho_1 t_1}{\rho_2 t_2}$$

- η_1 → Viscosity of test Liq.
- η_2 → Viscosity of Stand. Liq.
- ρ_1 → density of Test Liq.
- t_1 → time taken by Test Liq.
- ρ_2 → density of Standard Liquid.
- t_2 → Time taken by Standard Liq.

Falling Sphere Viscometer.



- Based on the principle of Stokes Law.

The force that retard a sphere moving through a viscous fluid.

In this appratus ⇒

- A steel ball is placed
- Temp. must be constant in this appratus.
- Viscous Liq. is filled

Eg ⇒

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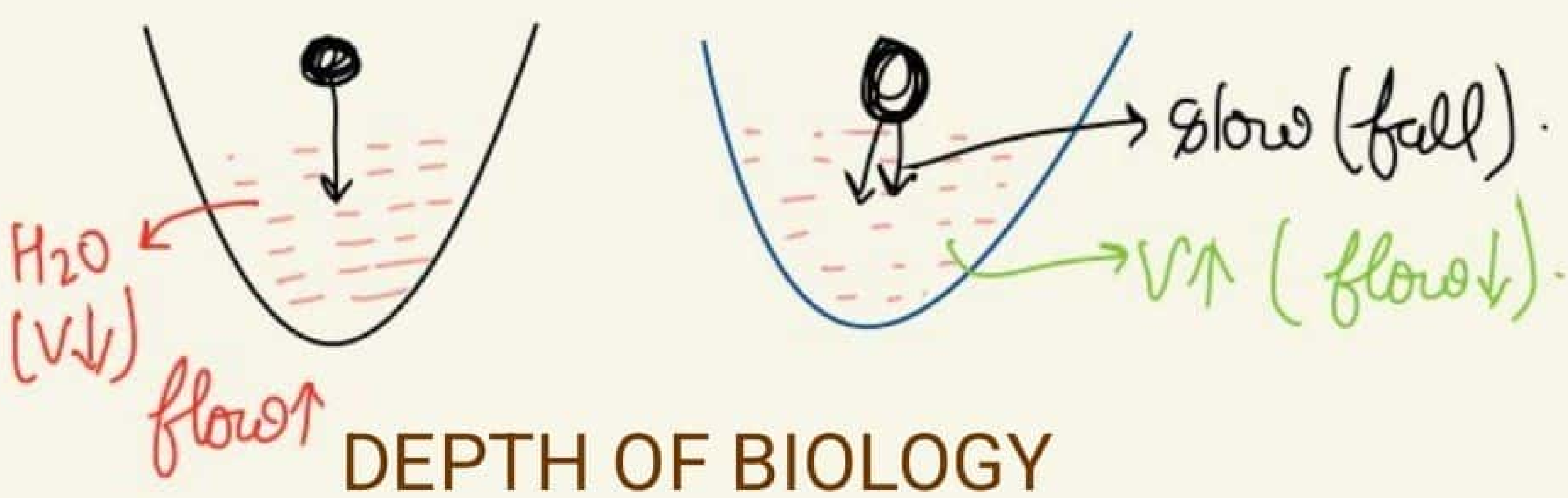

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Working → Steel ball is fall down due to Influence of gravity

⇓

Movment of ball is depend Upon it's radius & Viscosity.

If Viscosity is (↑) then movment is slow & Vice Versa.

Time Noted (In which ball is fall & reach end).

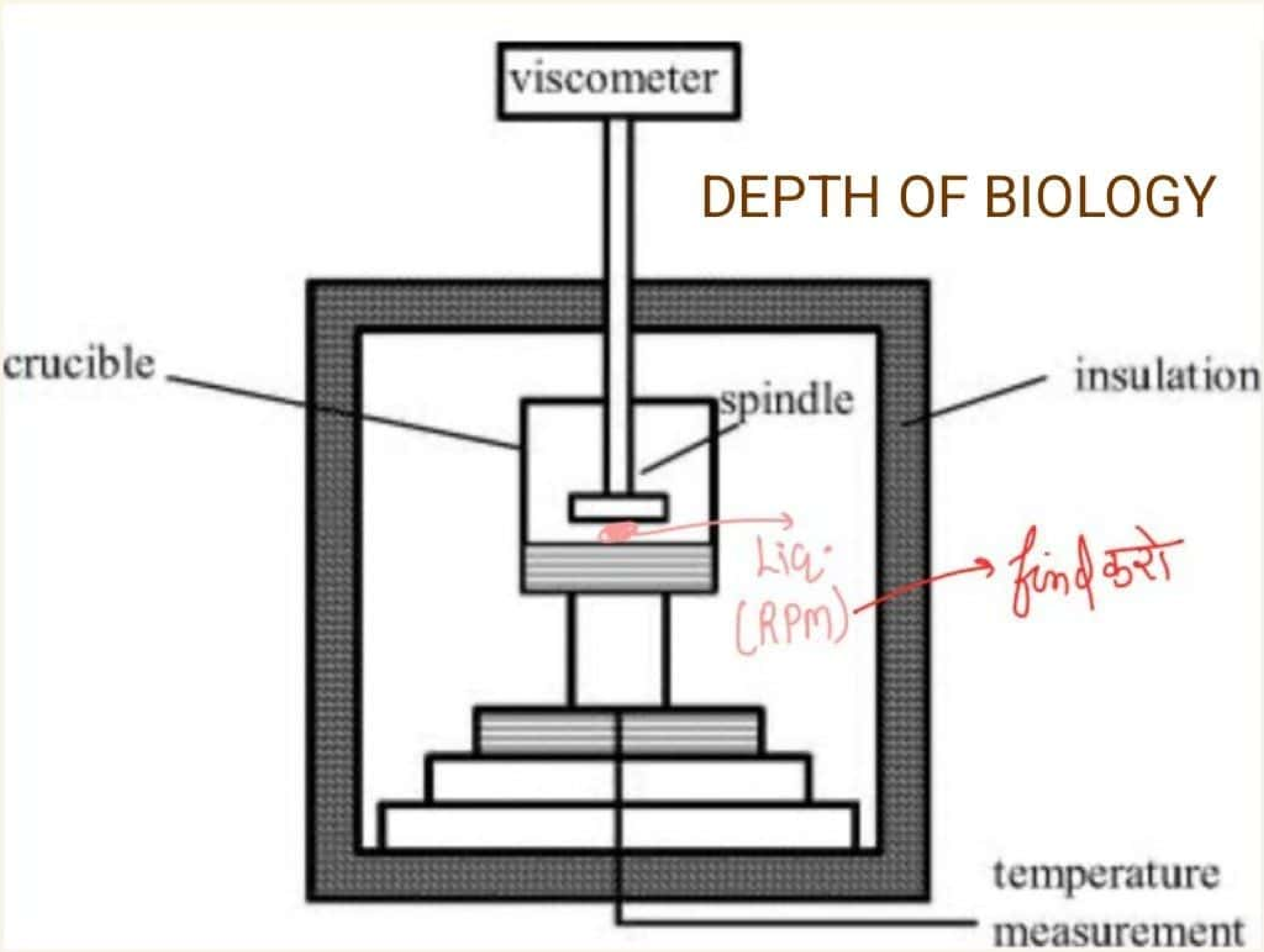
Formula ⇒

$$\eta = t\,(S_b - S_F)\cdot B$$

- η → Viscosity of Test Liq.
- t → time taken by ball to fall down.
- S_b → specific gravity of ball
- S_F → specific gravity of fluid.
- B → Constant.

☆ More Accurate & Less time Consuming.

③ Rotational Viscometer ⇒ Measure the Viscosity of a Liq. by turning a spindle in a cup.

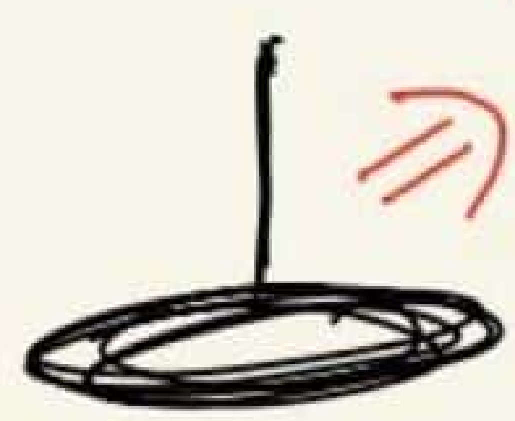


☆ This Viscometer are Used for both Newtonian & Non-Newtonian flow.

Rotational viscometers measure the viscosity of the sample by turning a spindle in a cup. You can determine viscosity by measuring the torque on a vertical shaft that rotates a spindle.

☆ More Viscous Liq. ⇒ RPM ↓

☆ Less Viscosity Liq. ⇒ RPM ↑



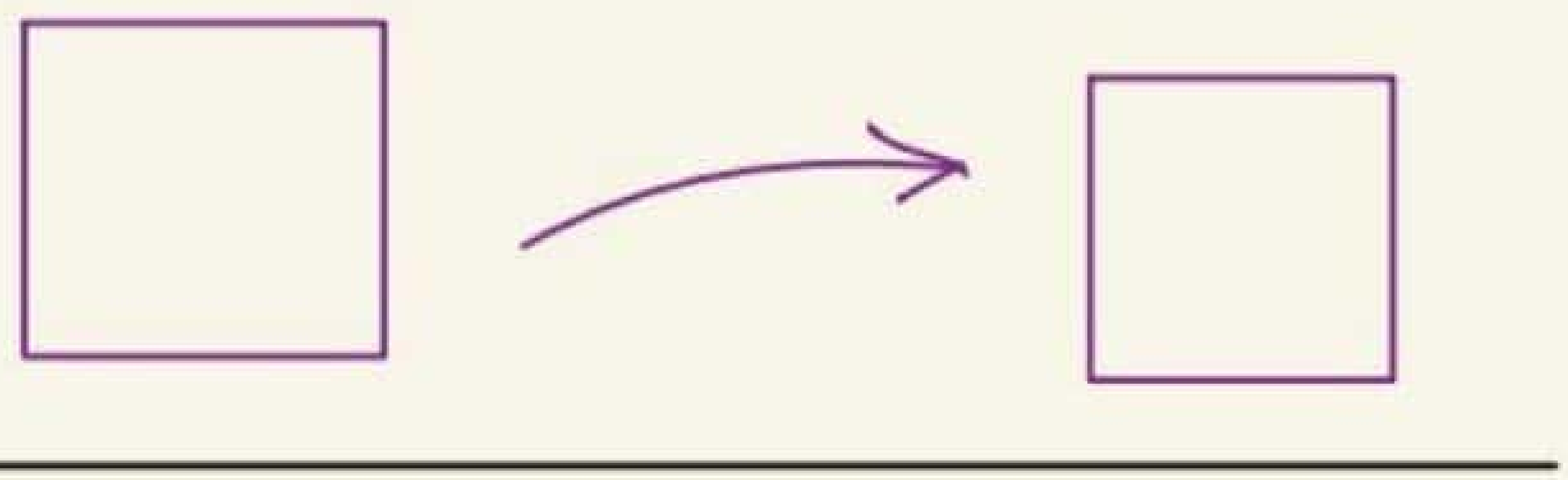
τ (Torque) ⇒ is also produced during rotation

Formula →

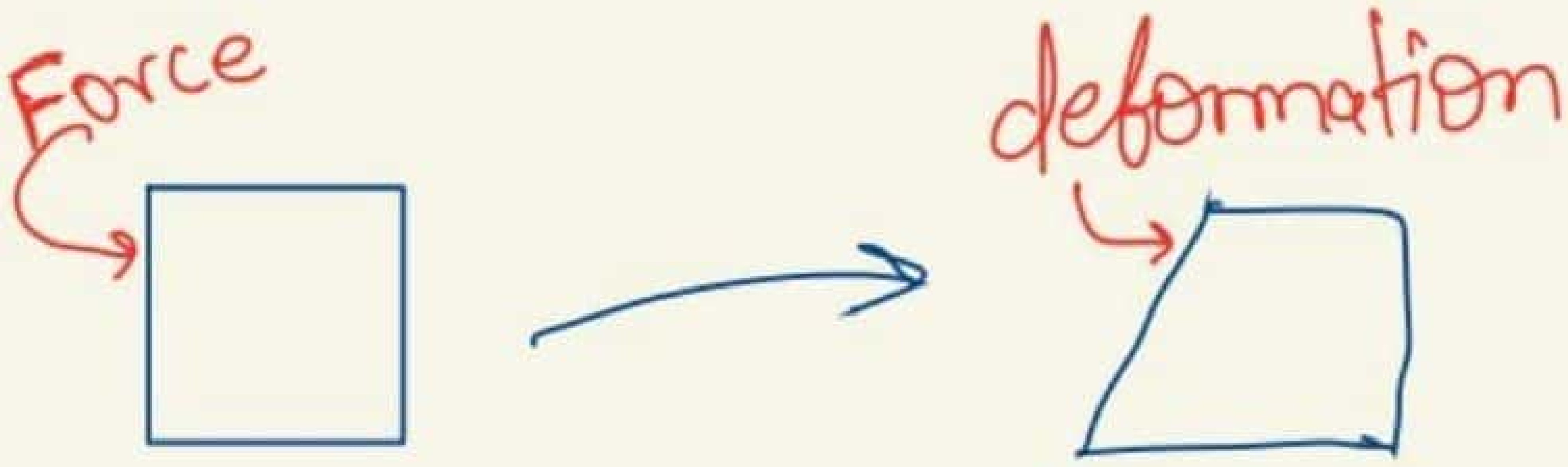
$$\eta = K \frac{T}{v}$$

- η → Viscosity of test Liq.
- K → Constant.
- T → Torque.
- v → rpm

• Deformation of Solid

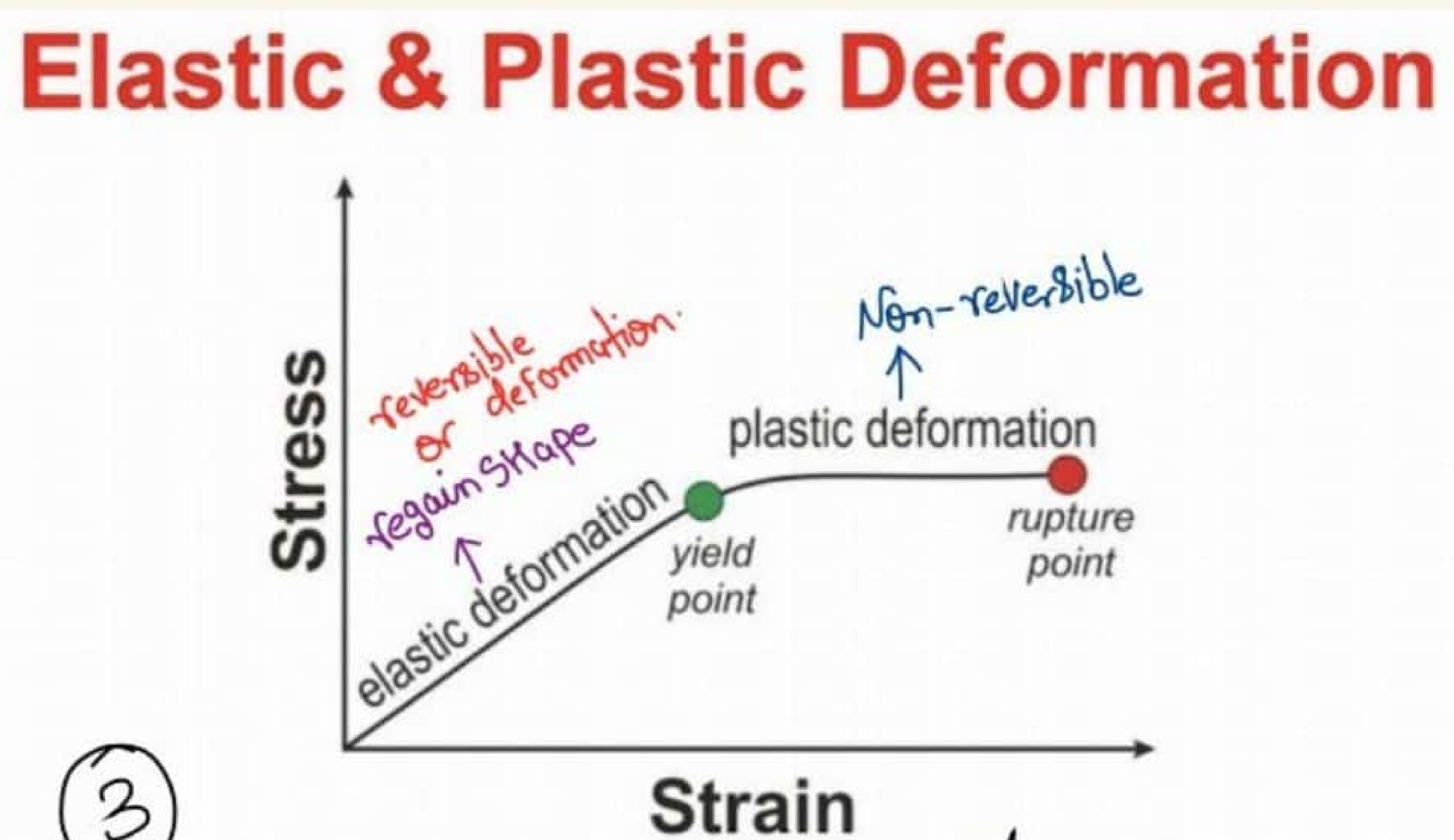


⇒ Movement ✓
flow ✗



[Shape, Lenght area alter]

① Plastic & Elastic deformation ⇒



② • Strain (ε)
⇓
Measure amount of deformation.

③ (σ) • Shear Stress → force apply on solid to deform it.

$$S.S = \frac{Force}{Area}$$

4 Heckle Equation

⇒ It is Most Useful Method for Estimating the Volume reduction Under the Compression pressure in Pharmacy

Compression

↓

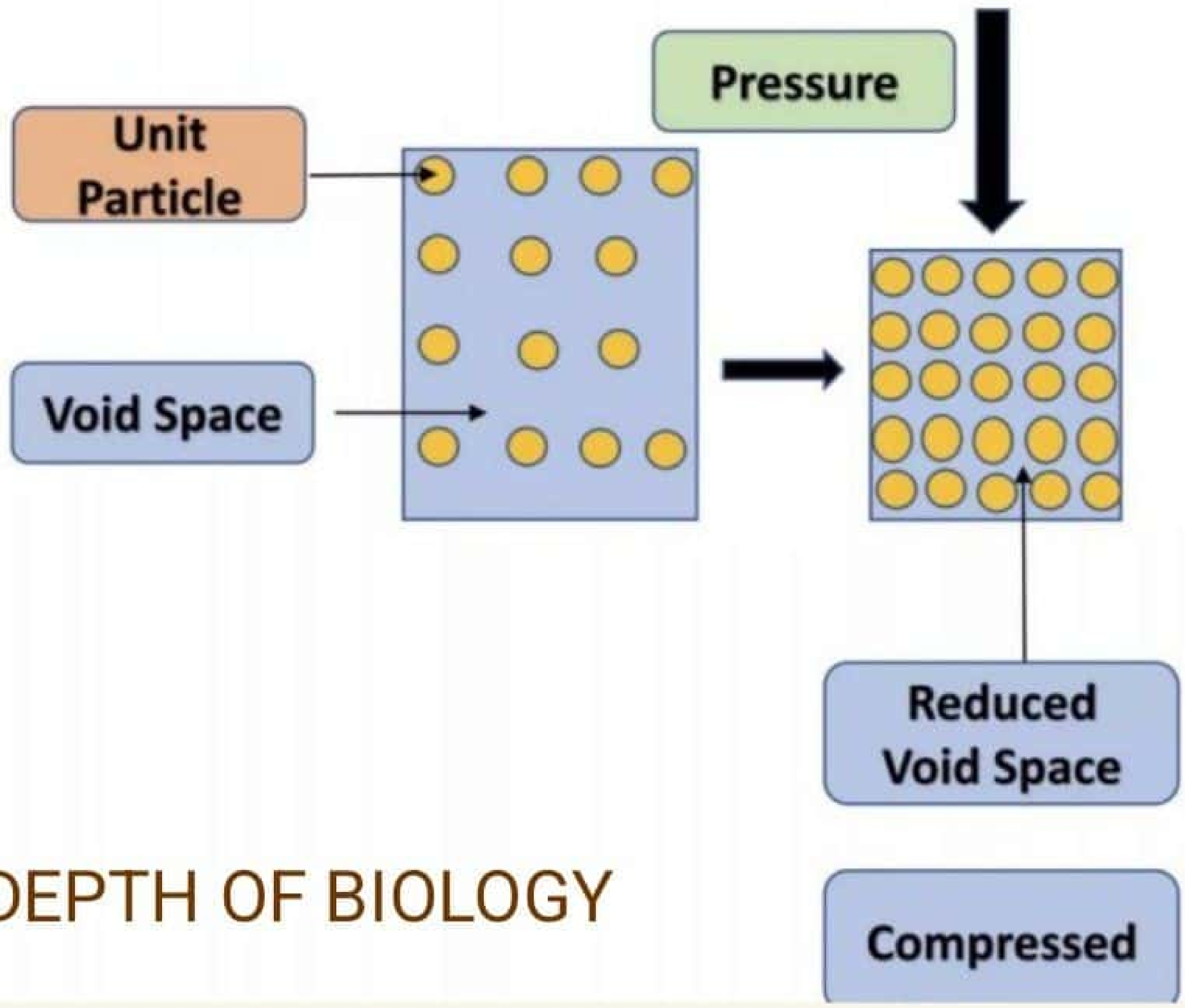
Reduction in bulk volume of a material

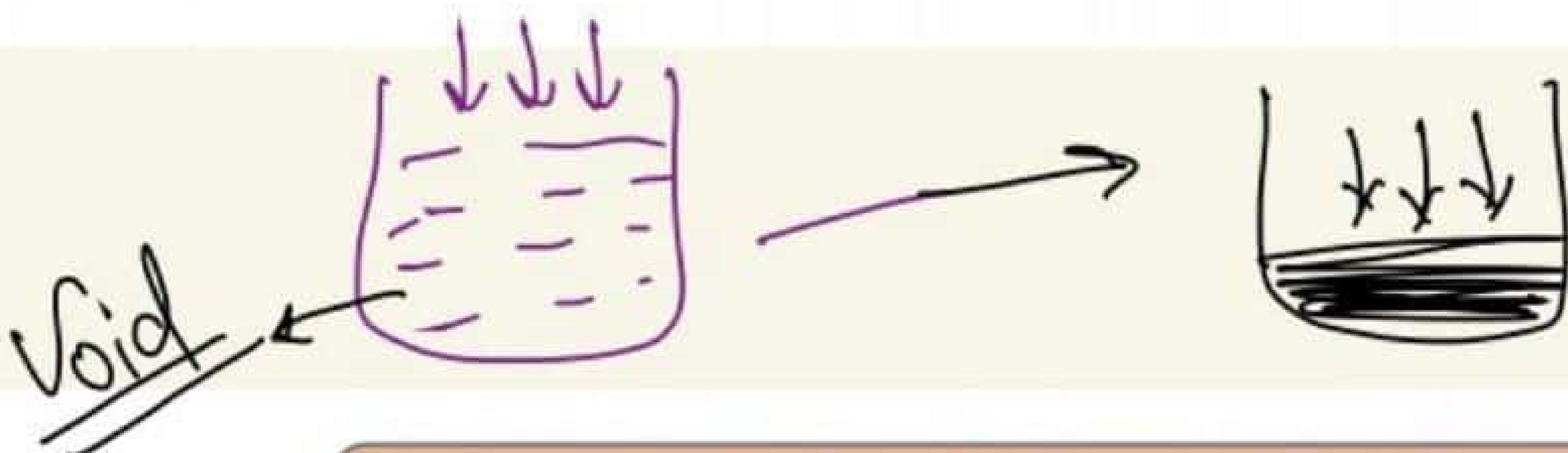
↓

By removal of gaseous phase (Void)

↓

By application of Force/ Pressure





$$\ln(1/1-D) = KP + A$$

Where,

D is **relative density** of tablet (tablet density/true powder density)

P is the **applied pressure**

K is the **slope** of the straight line portion of Heckel Plot

A is the **intercept.**

☆ follow Ist Order Kinetics.

Type of Materials

On basis of Heckel Plot

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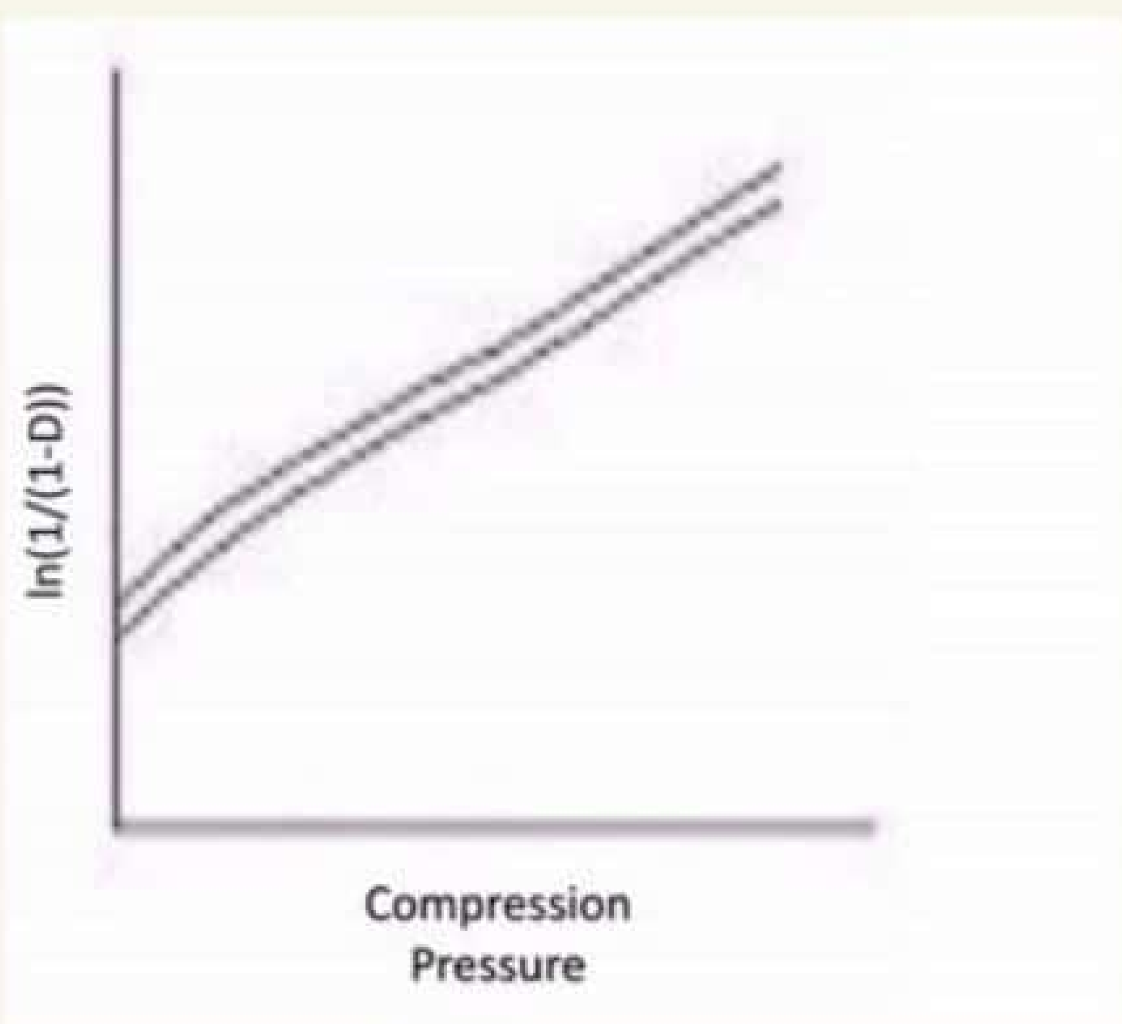
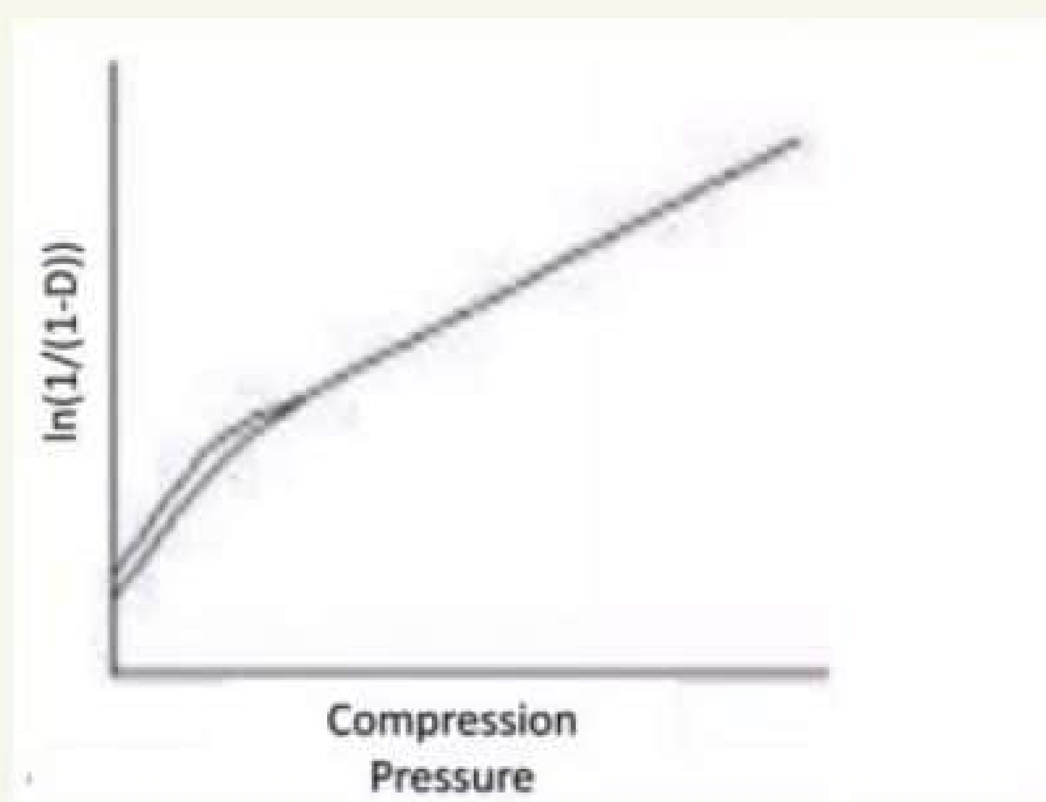
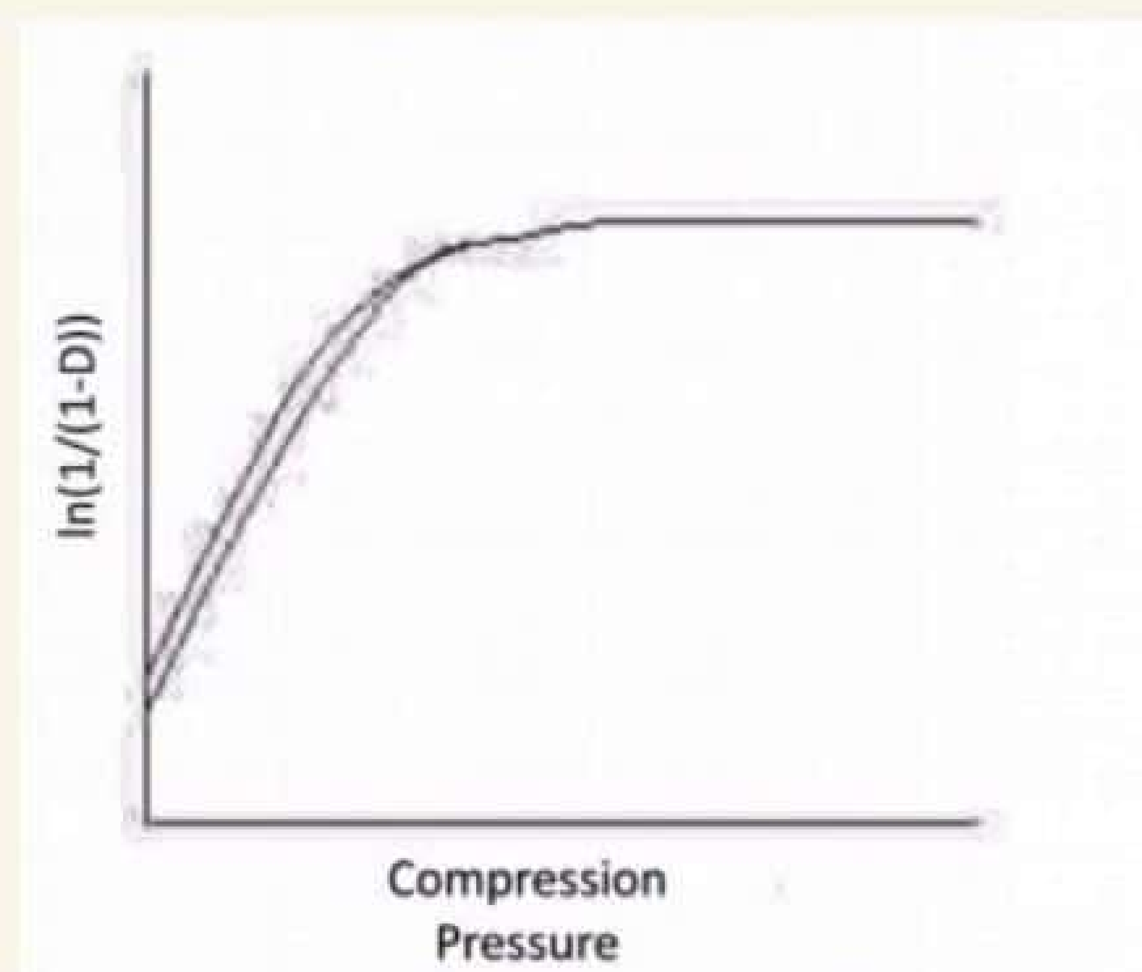
Type A	Type B	Type C
Soft, Readily undergo plastic deformation	Harder materials, Higher yield pressure, First brittle fracture then plastic flow	Rearrangement stage is absent, Densification is due to plastic deformation



A



B



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(5) Elastic Modulus

Ratio of Stress & Strain

The Elastic Modulus is the measure of the stiffness of a material. In other words, it is a measure of how easily any material can be bend or stretch.

- Elastic Modulus ⇒ $\frac{\text{Shear Stress}}{\text{Shear Strain}}$

$EM \propto \text{Stress}$ $EM \propto \frac{1}{\text{Strain}}$