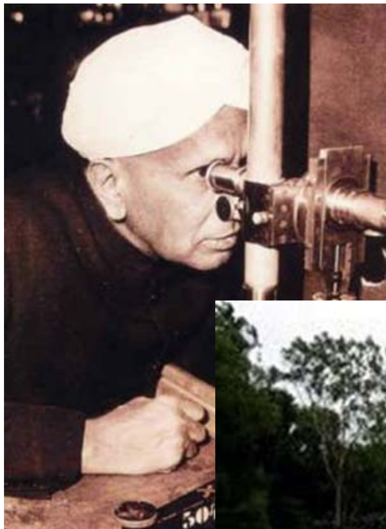

The Curious Case of Soft Matter

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My research interests: structure, dynamics, phase behavior and flow of ‘soft’ materials:

Panta rei: “everything flows” (Heraclitus circa 500 BC)

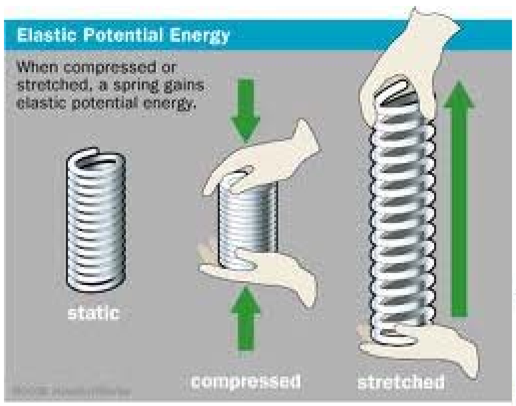
Given enough time even mountains will flow! (The mountains flowed before the lord: Deborah, prophetess of the God of the Israelites)

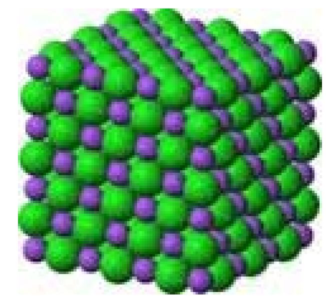
Soft materials are those materials that show solid-like and liquid-like behaviors at time scales that are accessible in the laboratory: few seconds to few hours . They can go fro solid to liquid under the imposition of rather small forces.

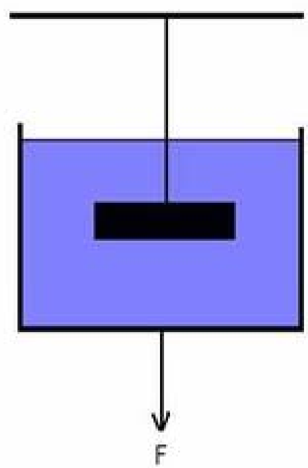
Solids and liquids

1. Rigid
2. Does not flow
3. Retains its shape and volume
4. Atoms packed very tightly together
5. Stores energy

Hookes law $\sigma = E\gamma$







1. Flows
2. Takes the shape of the container
3. Retains its volume but not shape
4. Dissipates (loses) energy

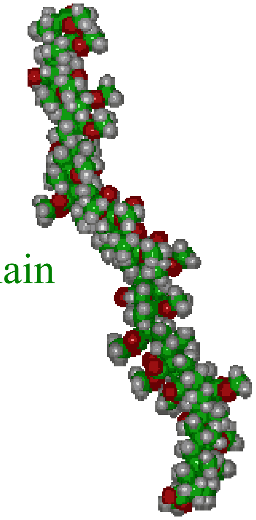
Newton's law of viscosity $\sigma = \eta\dot{\gamma}$

Examples of soft materials

Sand

Foam

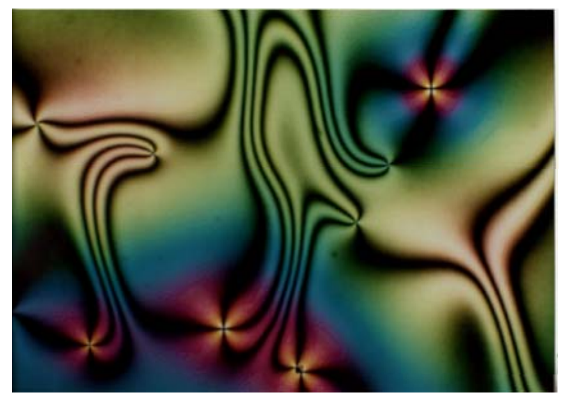
Polymer chain
(Plastics)



toothpaste

Paint

Clay



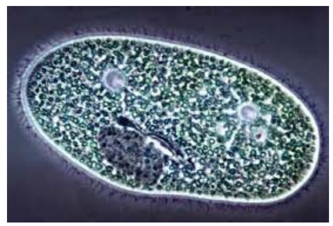
Liquid crystal

What is Soft Matter?

> What do we mean by soft matter? Americans prefer to call it "complex fluids". This is a rather ugly name which tends to discourage the young students. But it does indeed bring in two of the major features: complexity and flexibility.
>
> P.-G de Gennes, Nobel Lecture, December 9, 1991

Pierre de Gennes , Orsay, FRANCE, (1932-2007).

Complexity →



Paramecium

→ wait for a few billion years

Us!

Flexibility (a story of boots) →

→ Rubber tree

Rubber Tyres (Charles Goodyear) ← Rubber boots (Native American) ←

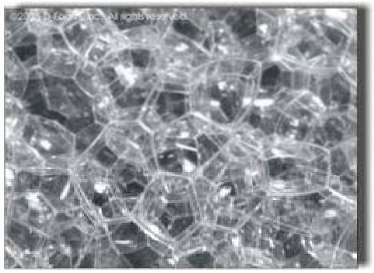
Those in-between ‘squishy’ materials and the science of viscoelasticity (non-Newtonian flow)

Blood, polymer, paint, foam, food lie in between ideal the ideal elastic solid and the ideal viscous fluid

Silly Putty/ slime:
G is a function of time

Marmalade, foam:
η is a fn. of rate of deformation

Paint is thixotropic: it shear thins and then thickens immediately after the paint brush is withdrawn.



Why do we study soft materials in the laboratory?

✓ Big and slow!
→ You can study them with a microscope, by autocorrelating scattered light intensity and even with a commercial digital camera

✓Can be pushed very easily! Go from solid-like to liquid-like on the application of very small applied forces.
→ You can study them by applying forces easily accessible in the laboratory

✓Distinctive physics: interesting at several length scales.

✓ Excellent model systems to understand materials hard to do experiments with. Very important technological, pharmaceutical applications.
Eg: glasses and convection, plastics and drug delivery etc.

Persistent holes and 'cornstarch monsters' in vibrated cornstarch!
(demonstrated by Prakhyat and Rajib at RRI)

Cornstarch in water 35% w/w vibrated on a shaker (sinusoidal vibrations 1 mm amplitude and 110 Hz frequency)

First we see ripples, then we see persistent holes and eventually cornstarch monsters

Cornstarch dilates or shear-thickens

(when you pull or push or shake or stir it hard, it becomes thicker!)

When you run fast on a pool of cornstarch, it behaves like a solid, BUT
When you stand on the same pool, you sink!
(http://www.youtube.com/watch?v=GorX5iVxHAw)

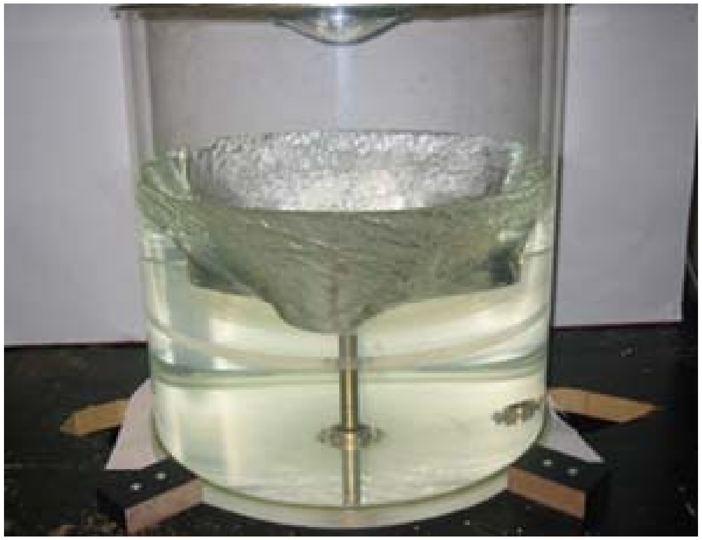
An experiment with shampoo or liquid hand soap

The Kaye effect: when shampoo/ soap is poured on a slanted surface, a heap forms, And occasionally a secondary jet emerges from the heap in random directions.

http://www.youtube.com/watch?v=yxTjgOWo0ts

This is also seen in paints and is due to shear thinning: the down-going stream "slips" off the pile it is forming, and due to a thin layer of shear-thinned liquid acting as a lubricant, it does not combine with the pile. When this stream encounters a dimple in the pile, it will shoot up, giving rise to this effect.

Experiment with some polymers - I



Stirring water

Stirring polymers

The Weissenberg effect: rod climbing effect in stirred polymer solutions

In contrast, if water is stirred, the surface is concave due to inertial forces (the water surface is highest at the sides and at the lowest at the center)

http://www.youtube.com/watch?v=npZzlgKjs0I

Experiment with some polymers - II

The Barus effect: a polymer solution forced out through the hole of a tube, swells a lot spontaneously!

In contrast, water maintains the same radius

http://www.youtube.com/watch?v=KcNWLIpv8gc

Experiment with some polymers - III

Fano flow: a polymer solution or egg white can be drawn out with a syringe (siphoned out) even when the syringe/ syphon is way above the surface of the polymer solution/ egg white!
http://www.youtube.com/watch?v=aY7xiGQ-7iw

Look around, ask questions, there is science everywhere!!

Thank you for your attention!