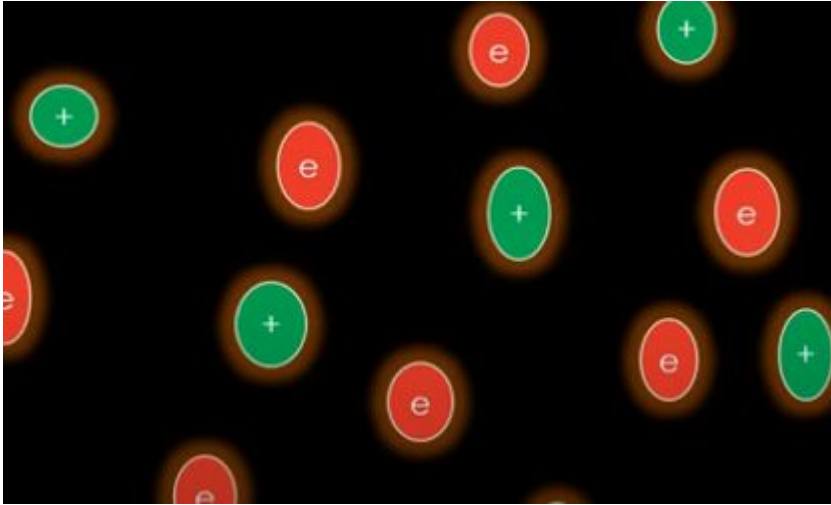


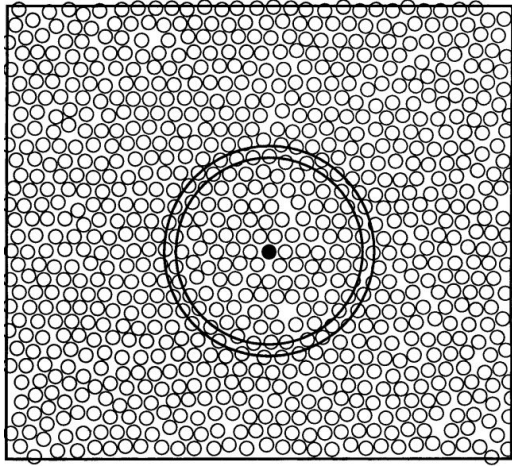
Soft Matter

overview

Matter : Plasma, Gases, Liquids, Solids

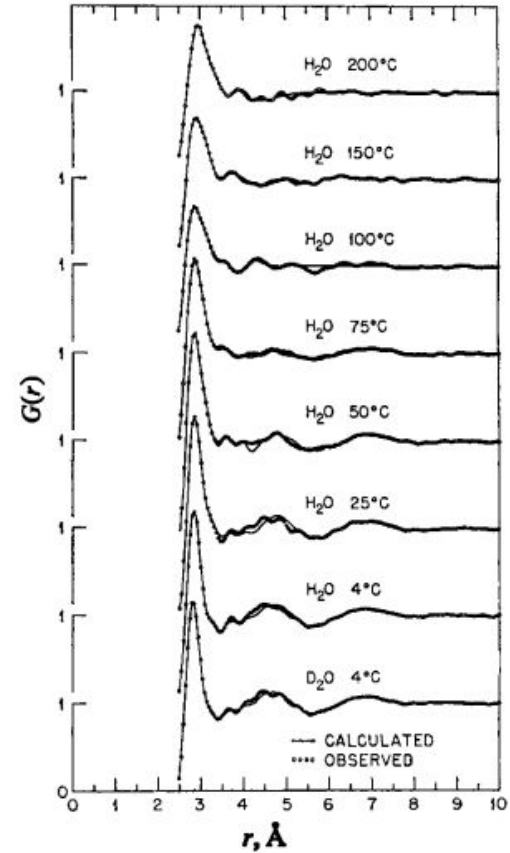
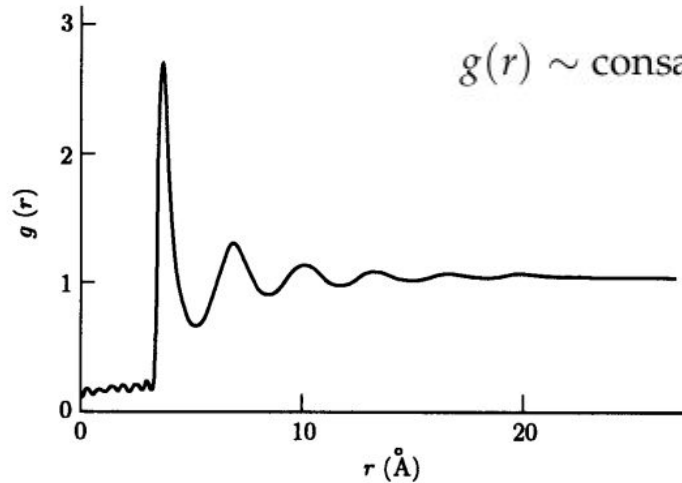


Gas - Liquid - Solid

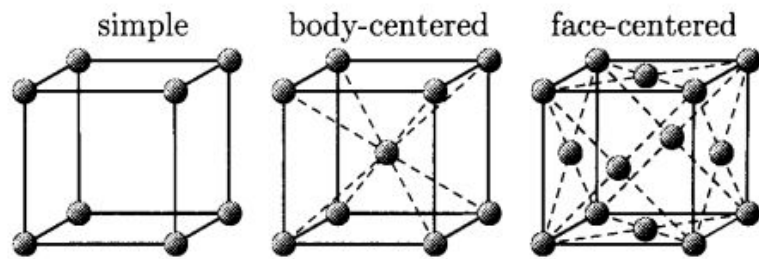


$$g(r) \equiv \frac{1}{4\pi r^2} \frac{dn}{dr}$$

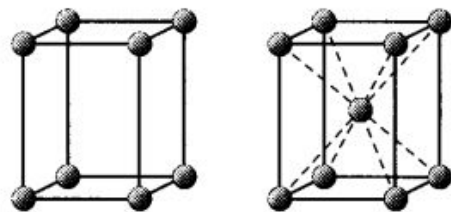
$g(r) \sim \text{constant}$ for $r \rightarrow \infty$



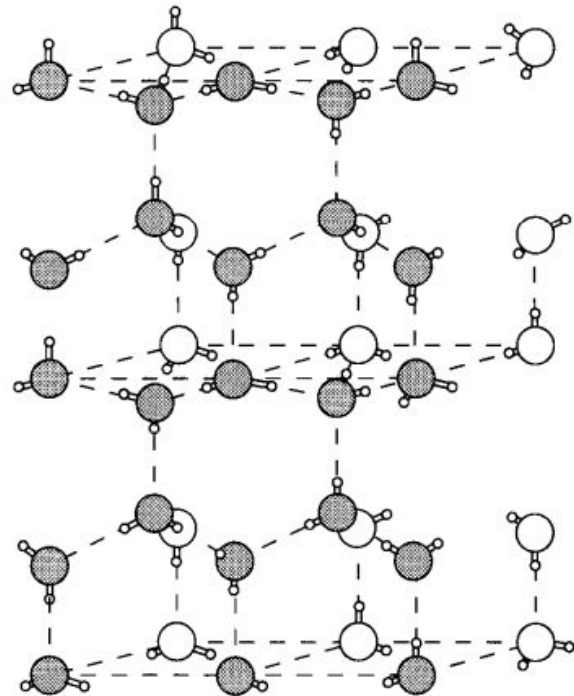
solids



Cubic



Tetragonal



Phases and their transitions

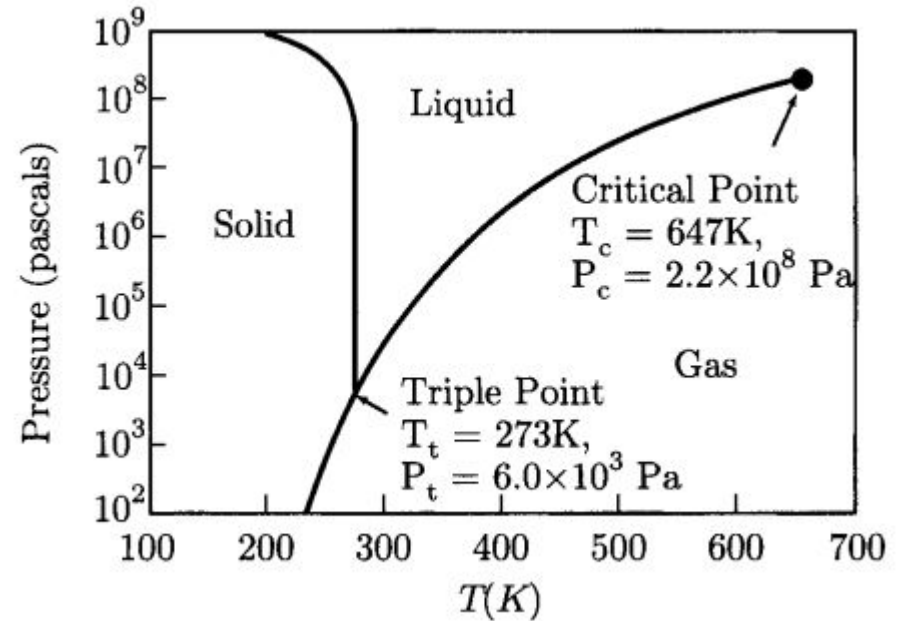
Fluid (liquid + gas)

- Full rotational and translational symmetry
- No long range order
- No resistance to shear
- Fluids have viscosity

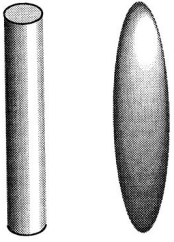
Solids

- Broken rotational and translational symmetry
- Long range order
- Resistance to shear
- Solids have elasticity

Fluid → Solid : symmetry breaking



Liquid Crystals



**No TRUE long range
order,
quasi long range
order**

**Regularly spaced layers, each
molecule is directed perpendicular
to the layers, each layer is
liquid-like.**

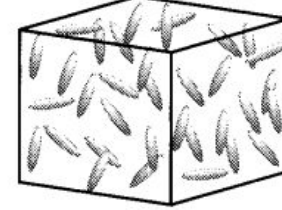
**Molecules are tilted, picks out
a direction in smectic plane**

Smectic A

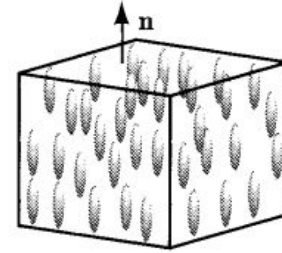
Smectic C

Isotropic

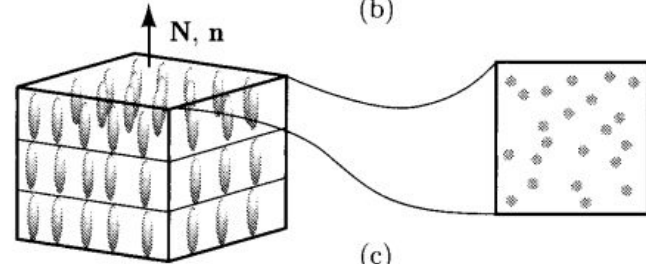
Nematic



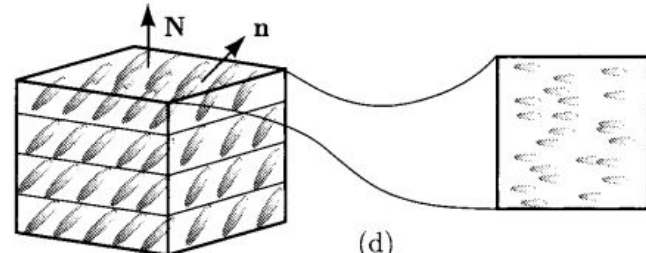
(a)



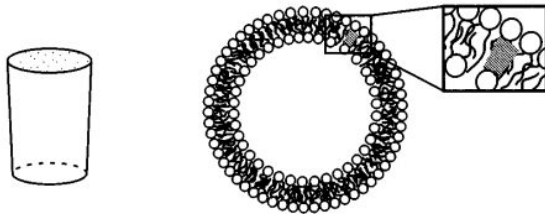
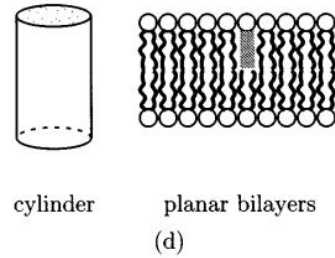
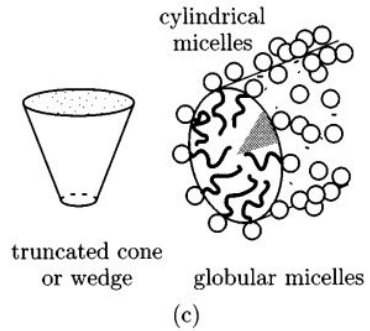
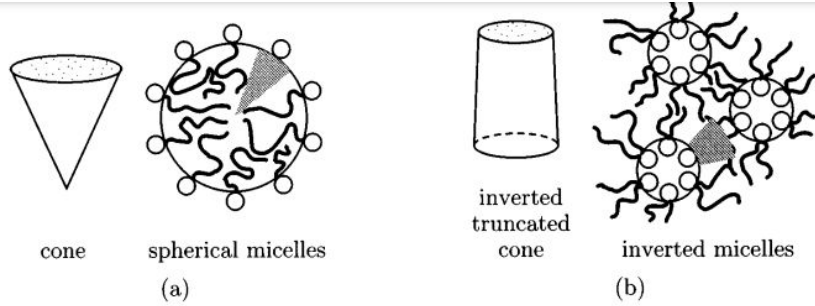
(b)



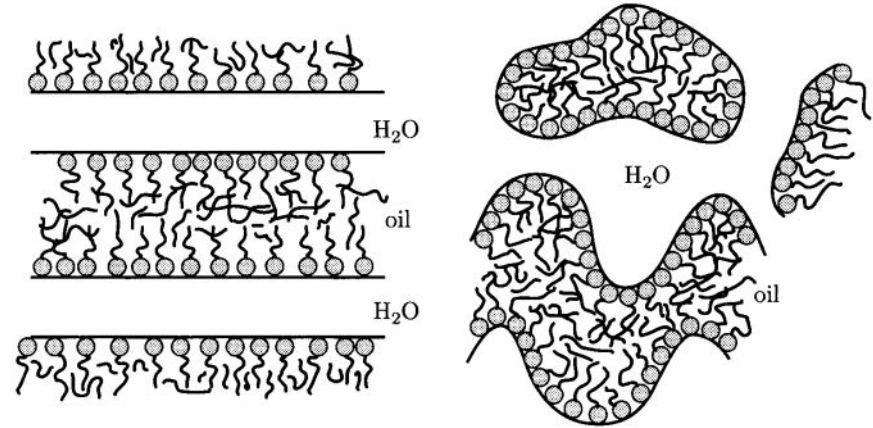
(c)



(d)

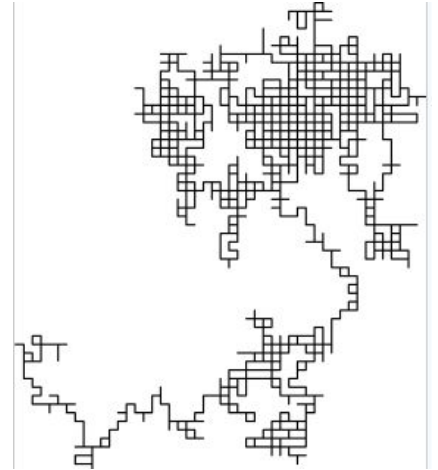
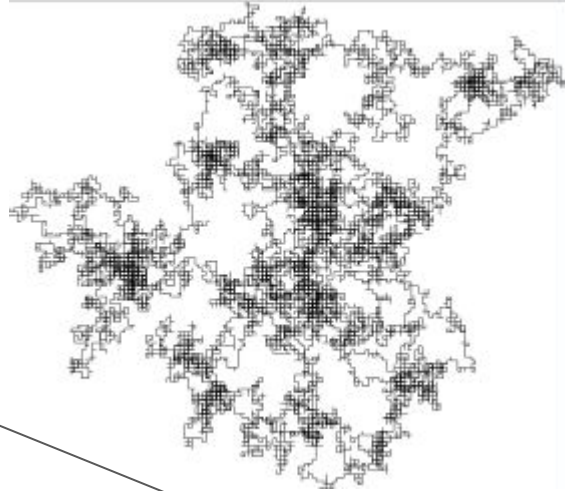
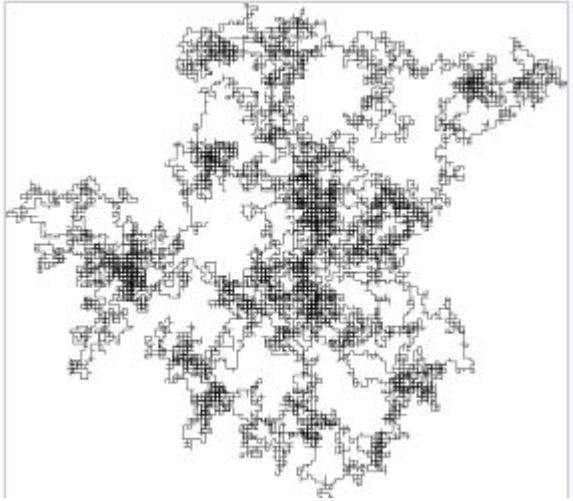


Lipids



Water, oil, and soap

Self-similarity



$$\langle R^2 \rangle \sim N.$$

zoom
in

Fractals

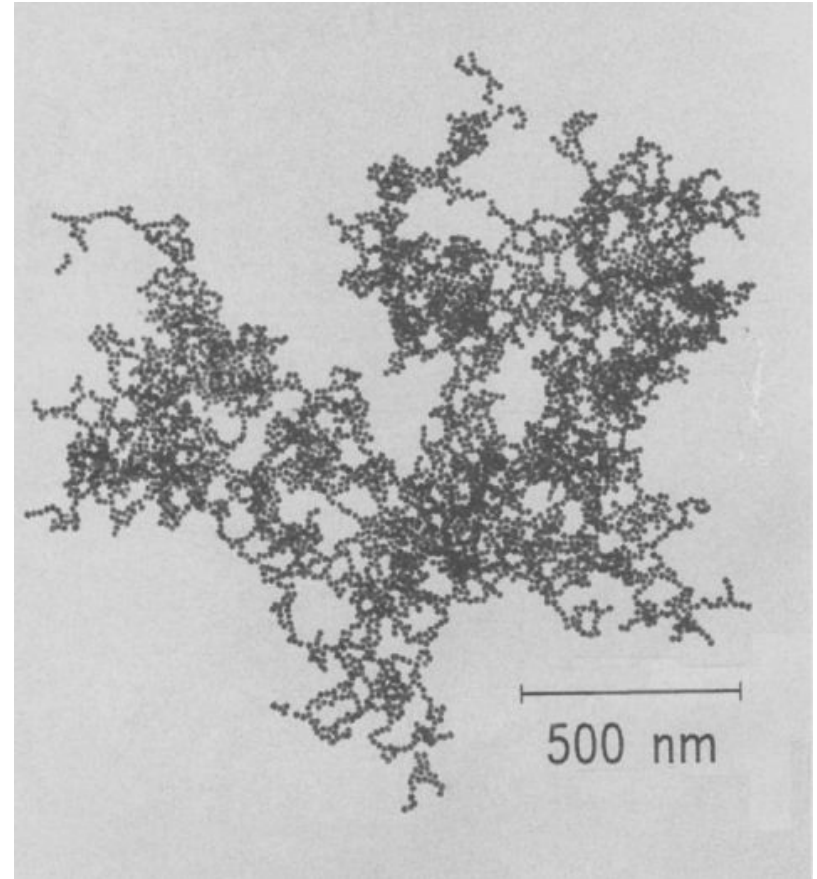
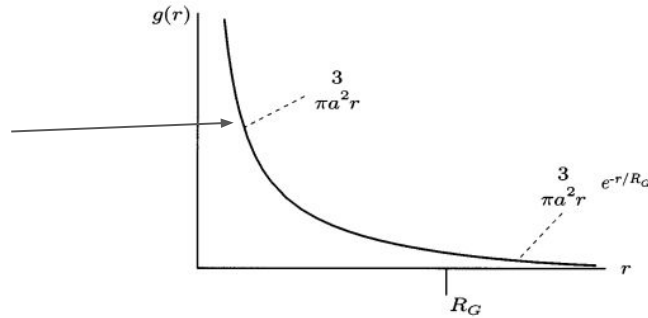
$$\langle R^2 \rangle \sim N.$$

**Self-similarity is
characterised by
power-laws**

$$n(r) \propto r^2$$

$$g(r) \equiv \frac{1}{4\pi r^2} \frac{dn}{dr}$$

$$g(r) \sim \frac{1}{r}$$



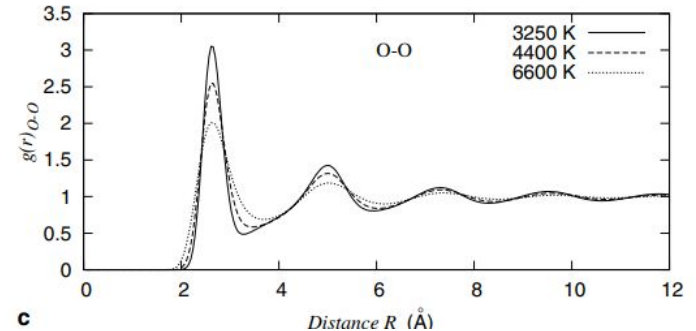
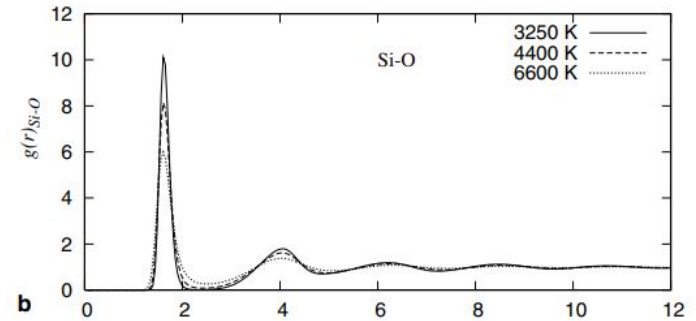
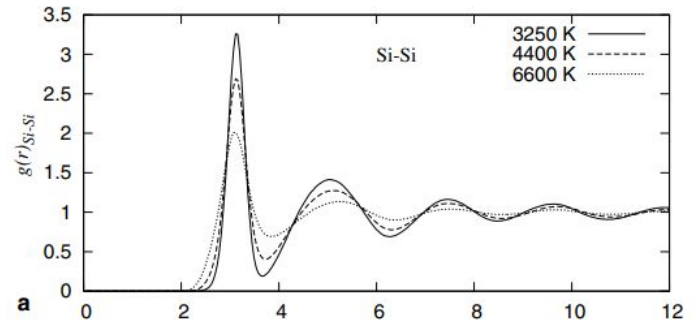
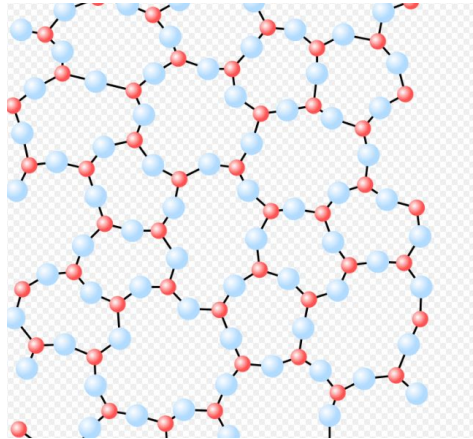
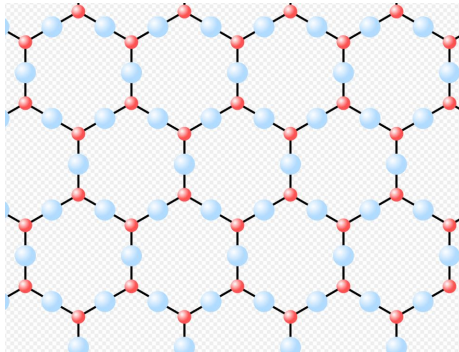
Fractal aggregate of gold particles

Strange materials : Glasses

No long range order

But they have shear elastic modulus

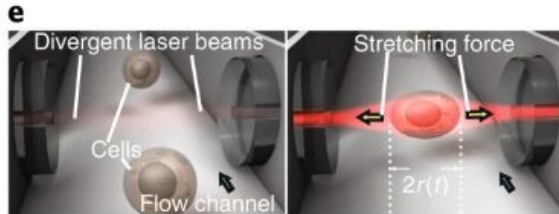
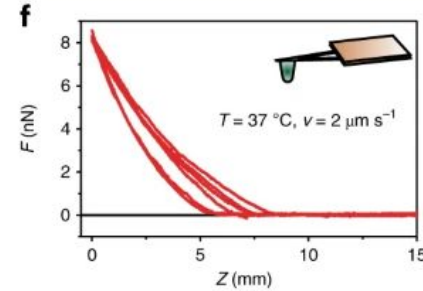
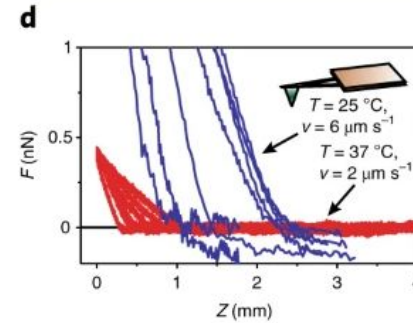
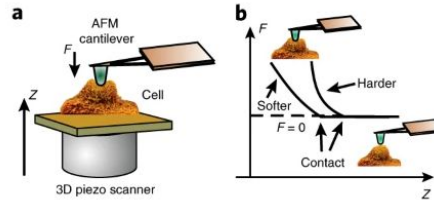
And do not flow (maybe)



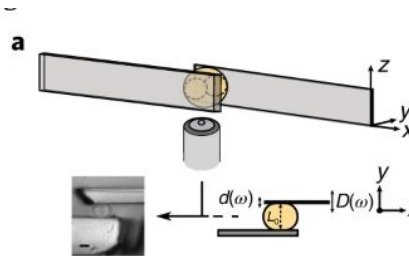
Strange material : biology

- Both elastic and viscous !
- Elastic modulus depends on how it is measured -- type of probe, speed of experiment..
- Large fluctuations.
-

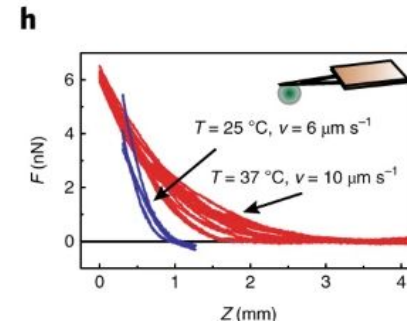
Fig. 2: AFM measurements.



trapping & stretching
whole cells



whole cell
rheometer



Living/Active matter



FIG. 5 (color). A remarkable demonstration of polar order in a sardine school. Figure from Jon Bertsch, from underwater images from the Sea of Cortez: <http://www.thalassagraphics.com/blog/?p=167>.

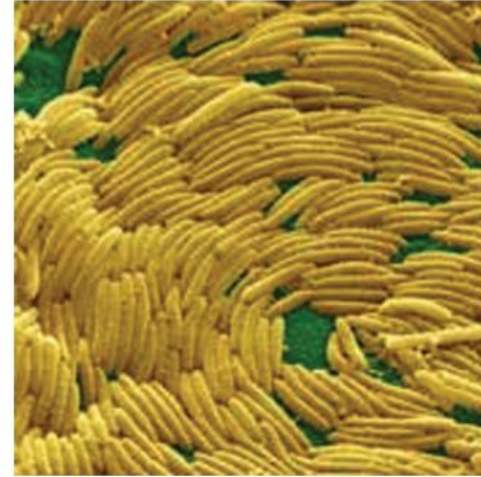
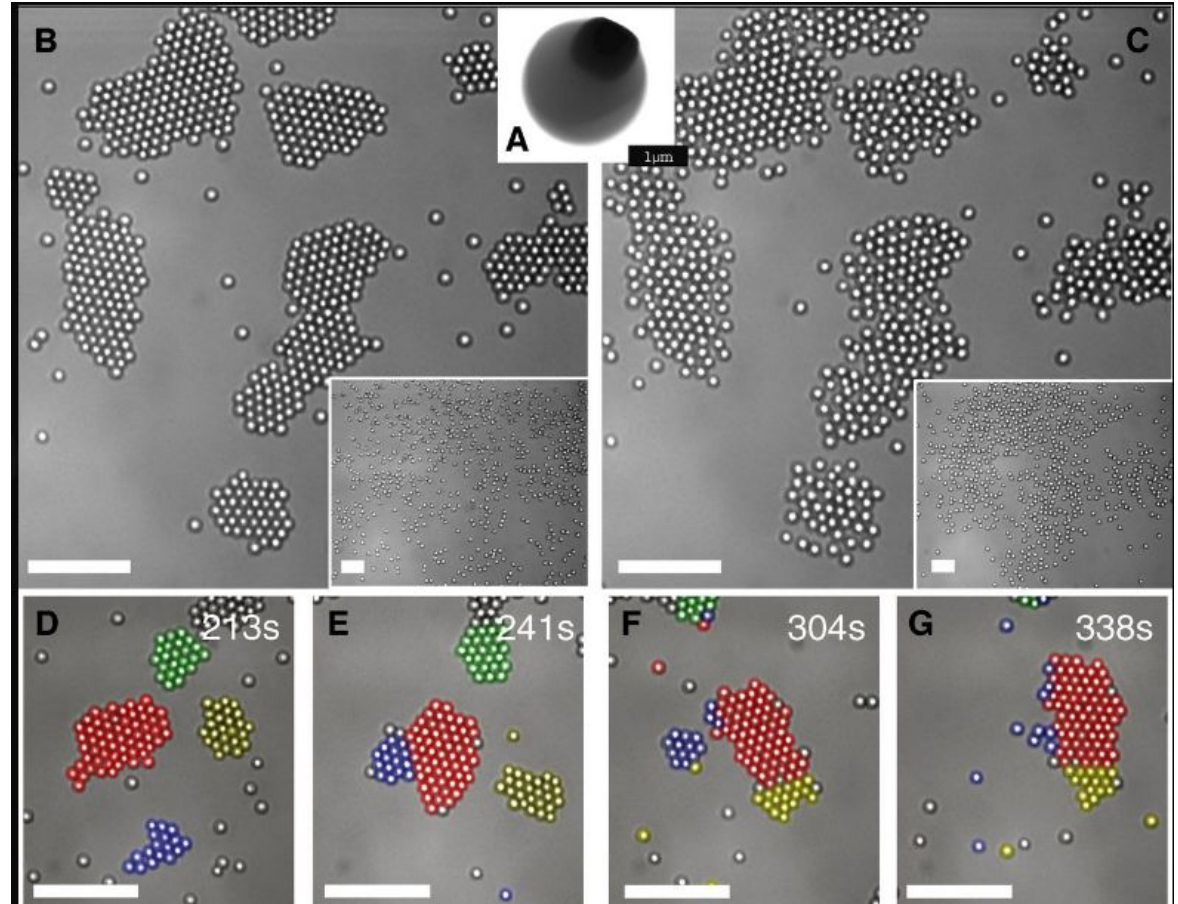


FIG. 1 (color). Liquid-crystalline order in a myxobacterial flock. Figure from Gregory Velicer (Indiana University Bloomington) and Juergen Bergen (Max-Planck Institute for Developmental Biology).

Living/Active matter

Fig. 1 **(A)** Scanning electron microscopy (SEM) of the bimaterial colloid: a TPM polymer colloidal sphere with protruding hematite cube (dark). **(B)** Living crystals assembled from a homogeneous distribution (inset) under illumination by blue light. **(C)** Living crystals melt by thermal diffusion when light is extinguished: Image shows system 10 s after blue light is turned off (inset, after 100 s). **(D to G)** The false colors show the time evolution of particles belonging to different clusters. The clusters are not static but rearrange, exchange particles, merge (D $\rightarrow$ F), break apart (E $\rightarrow$ F), or become unstable and explode (blue cluster, F $\rightarrow$ G). For (B) to (G), the scale bars indicate 10 μm . The solid area fraction is $\Phi_s \approx 0.14$.



Theory

- **Effective theories**
- **Equilibrium and non-equilibrium.**
- **Nonlinear**

Bibliography

- The images in slide 3 to 7 are from the first two chapters of the book "Principles of condensed matter physics" by Chaikin and Lubensky (henceforth CL)
- The plots of random walk are from the wikipedia page on random walk.
- The fractal gold cluster is from CL
- The molecular structure of silicate glass is from the wikipedia page on glass. The pair distribution function is from Chemical Physics 321 (2006) 69–74 . These are results of computer simulation.
- The pictures on slide 11 are from Nature Methods volume 15, pages 491–498 (2018)
- The pictures of active material on slide 12 are from REVIEWS OF MODERN PHYSICS, volume 85, page 1143, (2013).
- The example of active janus particle is from SCIENCE, volume 339, pages 936-940 (2013)