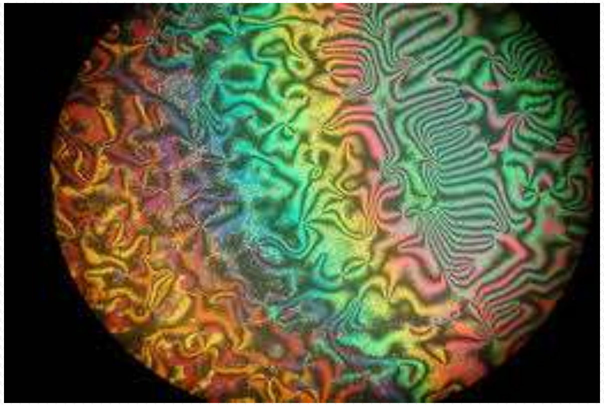
An Introduction to Liquid Crystals



Dr Syed Gohar Taqi Kazimi

Outlines:

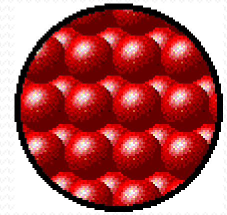
This presentation covers:

- Introduction to liquid crystals
- Characteristics
- Structure of Liquid Crystals
- Classification of liquid crystals
- Applications

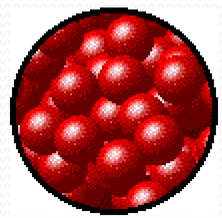
Introduction to Liquid Crystals

STATES OF MATTER

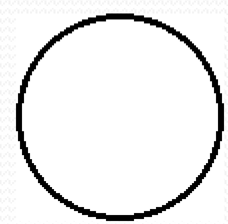
- Common states:
  - solid
  - liquid
  - gas
- Matter can exist in other states



Solid has definite Shape & volume



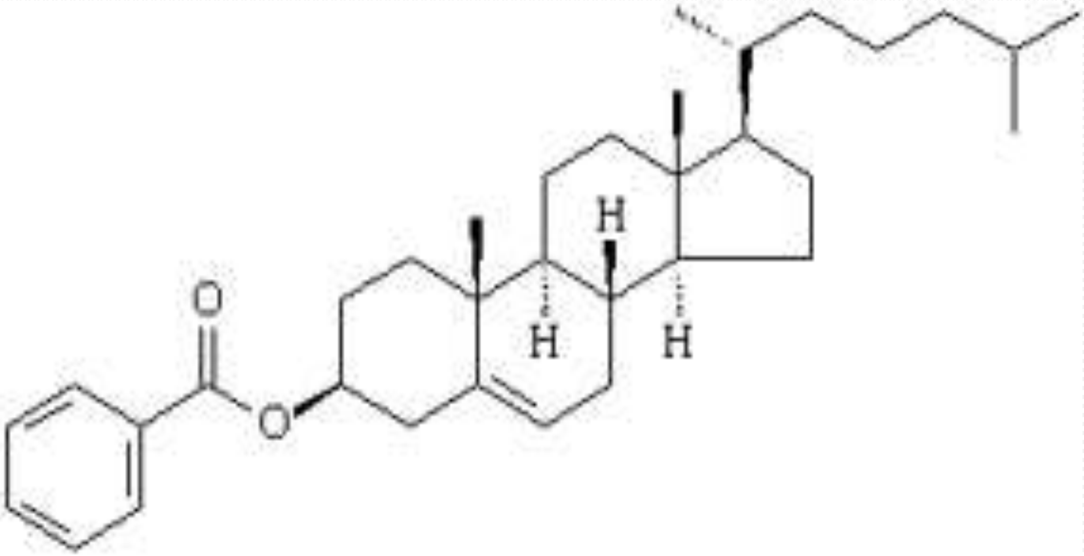
Liquid has definite volume but no Shape



Gas has no definite shape & volume

The study was began in 1888, when an Austrian botanist named Friedrich Reinitzer observed that a material known as cholesteryl benzoate had two distinct melting points (i.e., 145.5^{o}C & 178.5^{o}C) In his experiments, Reinitzer increased the temperature of a solid sample and observed the crystal changing into a hazy liquid. As he increased the temperature further, the material again changed into a clear, transparent liquid. Because of this early work, Reinitzer is often credited with discovering a new phase of matter - the *liquid crystal (Mesophase)*.

Friedrich Reinitzer



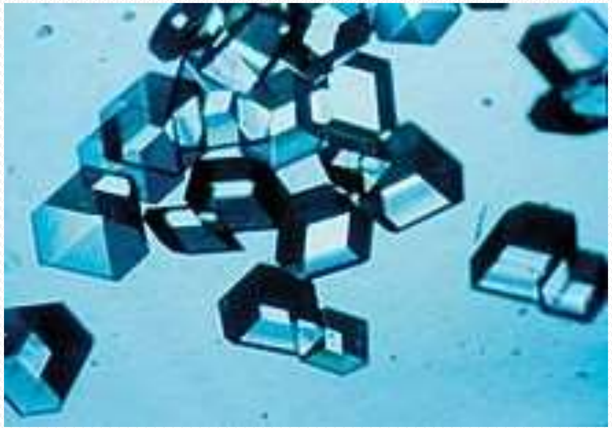
cholesteryl benzoate

Nature of LCs

What is the nature of Liquid Crystal state?

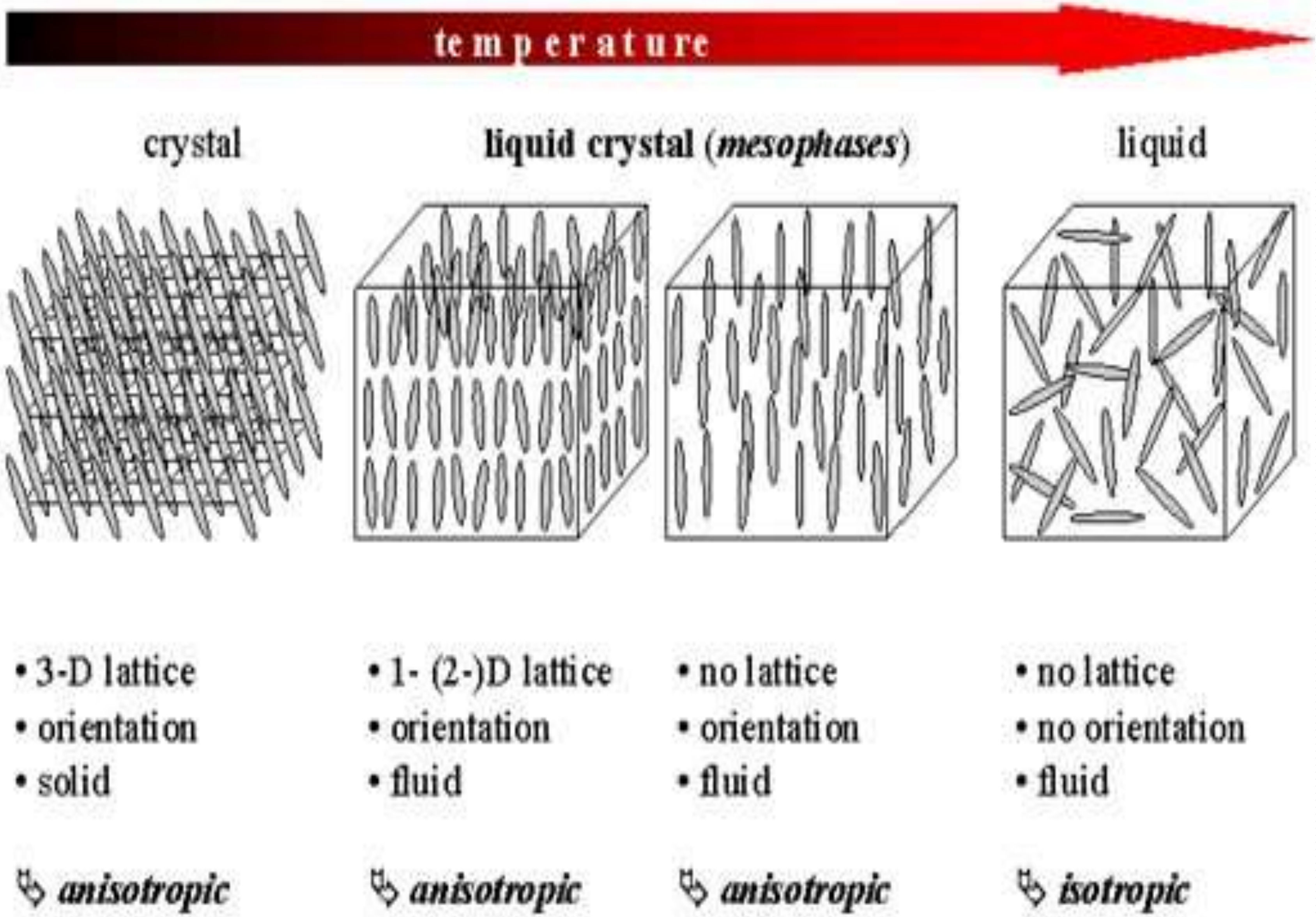
Are LCs Liquid ??

Are LCs Solids??



Are LCs Mixture of liquid and Solids (crystals)?

- A state of matter that occurs between a solid & a liquid state.
- Possess properties, characteristics of both liquids & crystalline solids.
- Also possess properties not found in either liquids or solids.
- May response to external perturbations & some changes colour with temperature


temperature
crystal
liquid crystal (*mesophases*)
liquid
• 3-D lattice
• orientation
• solid
anisotropic
• 1- (2-)D lattice
• orientation
• fluid
anisotropic
• no lattice
• orientation
• fluid
anisotropic
• no lattice
• no orientation
• fluid
isotropic

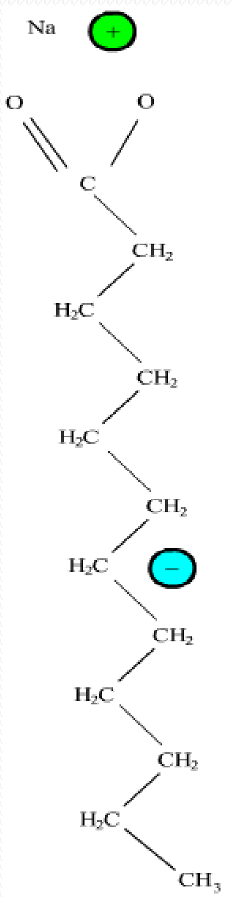
Characteristics of Liquid Crystals

- **Positional order:** Refers to the extent to which an average molecule of molecules show translational symmetry.
- **Orientational order:** Refers to a measure of tendency of molecules to align along the directon (preferred orientation of liquid crystal).
- **Bond order:** It describes a line joining the centers of the nearest molecules without requiring a regular spacing along that line.

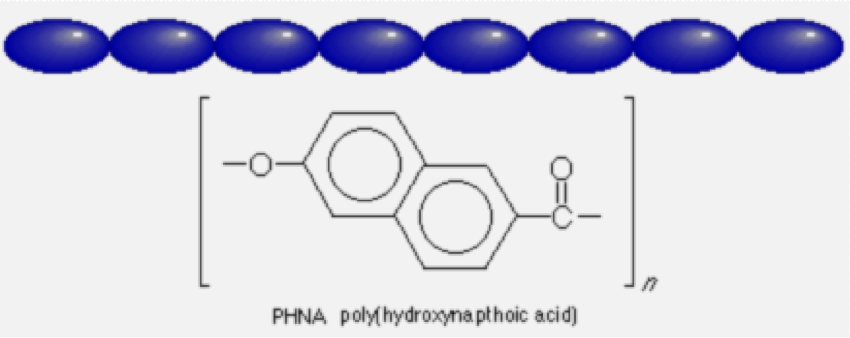
Structure of Liquid Crystal forming Compounds

- Long, narrow, elongated molecules having sufficient molecular interactions.
- Presence of Unsaturation.
- Absence of bulky functional groups.
- Presence of carboxylic acid group at the end of the side chain.

Typical chemical structures



- cholesterol ester
- phenyl benzoates
- surfactants such as polyethylene-oxide, alkali soaps, ammonium salts, lecithin
- paraffins
- glycolipids
- cellulose derivatives



Types of liquid crystals

Thermotropic

- Phase transition depends on temperature
  - Nematic
  - Smectic
  - Cholesteric

Lyotropic

- Phase transition depends on temperature & concentration

Nematic liquid Crystals

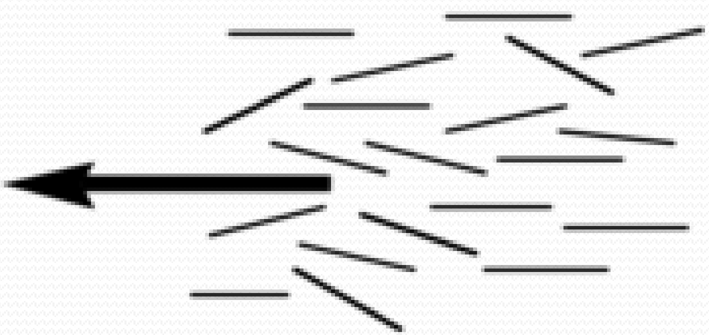
- These are thread like Liquid crystals.
- They posses no translational order, but how ever posses a significant degree of long range orientational order.
- These on heating generally transformed into the isotropic liquids.
- They are mobile in three directions and can rotate about one axis.
- The energy required to deform the nematic phase is so small that even dust particle can distort the structure considerably.

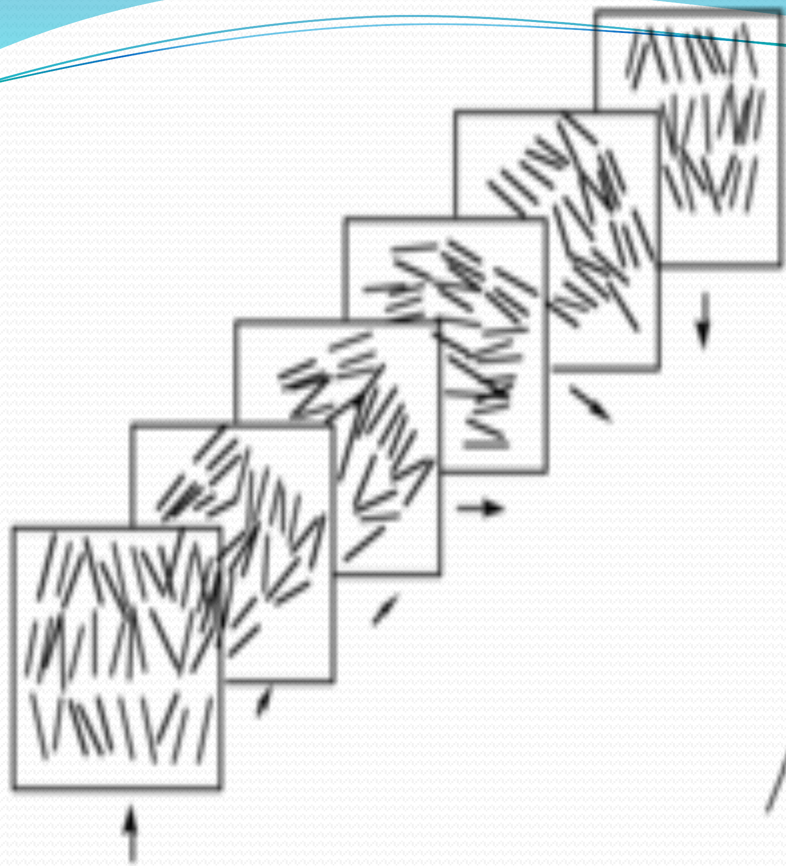
Cholesteric structure

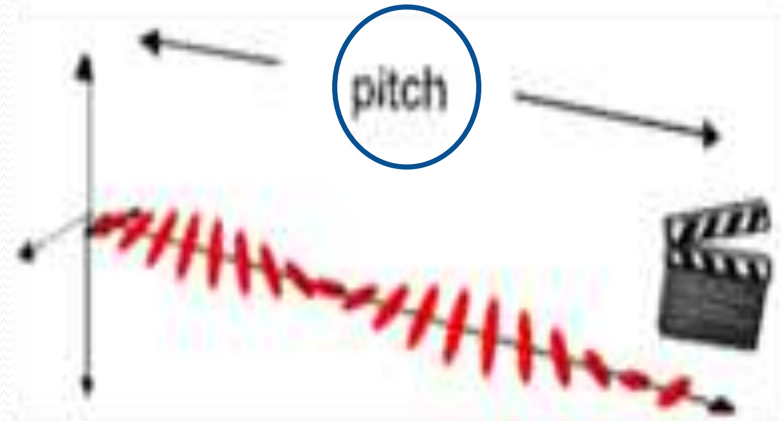
These are another type of nematic LC modification, and so named as many of the compounds in the mesophase are the derivaties of Cholesterol. They lack translational order and their orientational order resembles nematics on local scale, but on long scale resembles a helix.

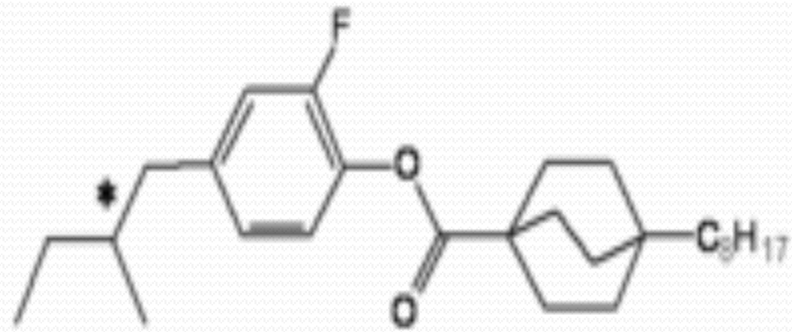
Molecules align in liquid crystal phase

the lack of positional order along the axis of the director









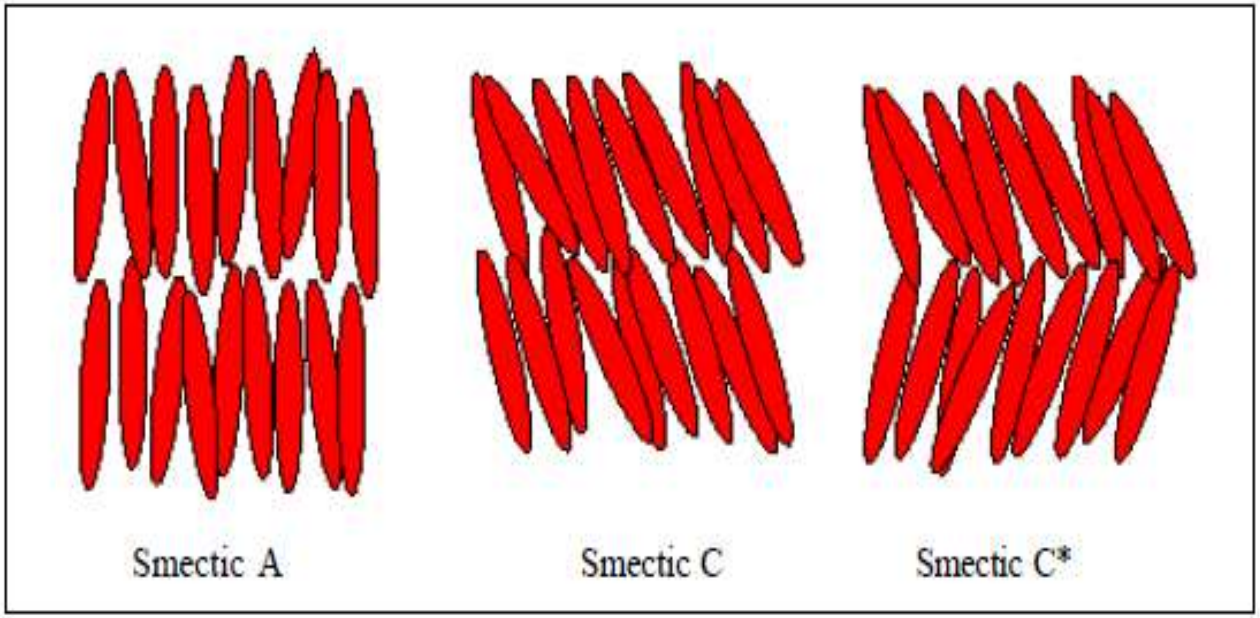
In a cholesteric state the director twists at different levels.

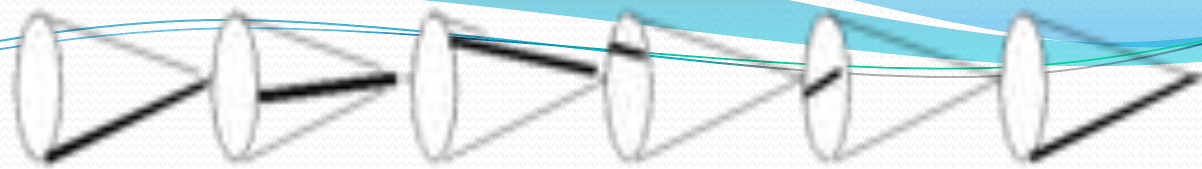
The pitch is the period for the director to rotate 180 degrees.
The pitch of the twist is quite sensitive to temperature.

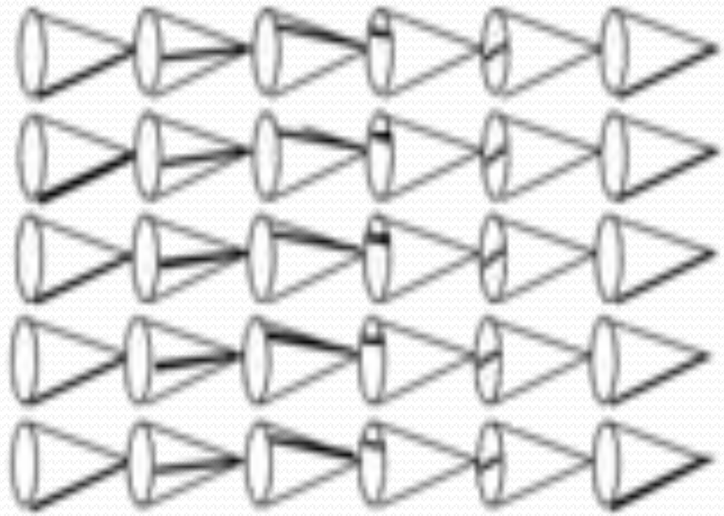
Smectic Liquid Crystals

- The word Smectic is derived from Greek for soap.
- The molecules show a degree of translational order not shown in nematics.
- The molecules maintain general orientation order of nematics, but align themselves in layers or planes.
- There are eight smectic structures labeled from A to H. Out of which three A, C and C* are important.

The smectics A, C, D and F are unsaturated smectics and B, E and G are saturated smectics.





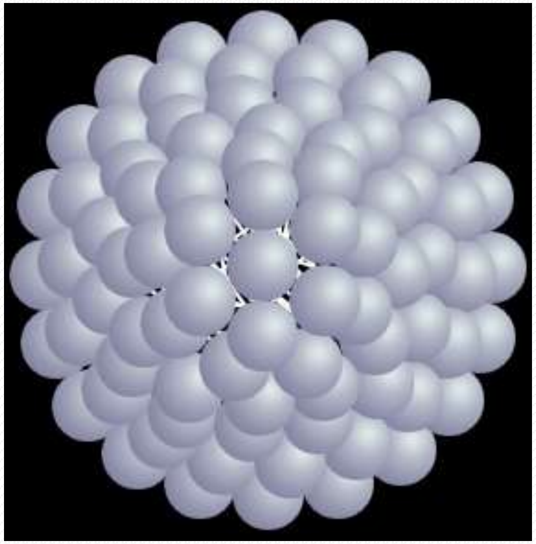


Smectic C* molecules are visualized as cones showing possible orientations of the dipole

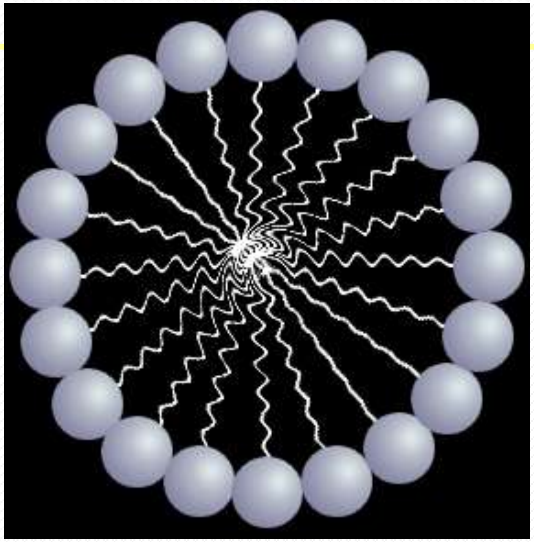
Lyotropic Liquid Crystals

- These mesophases occur in concentrated solutions of an isotropic solvent (usually water).
- Lyotropic mesophases are important in soaps, gels and colloids, and are of great interest in biology.
- The stability of these mesophases are influenced by both temperature and concentration.

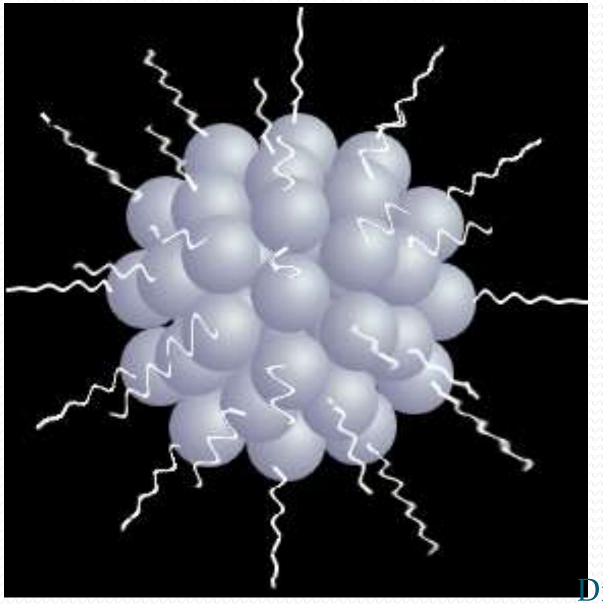
The *Lyotropic* Phases



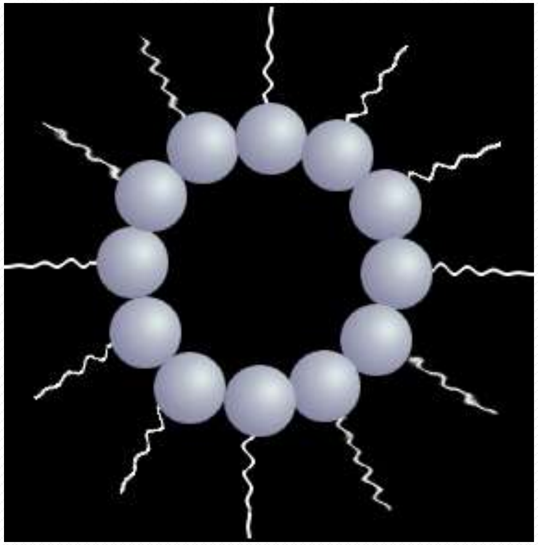
micelle



cross section



reverse
micelle



cross section

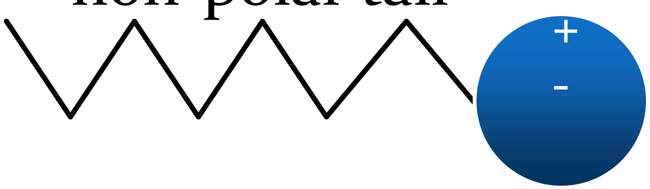
Broad Classification

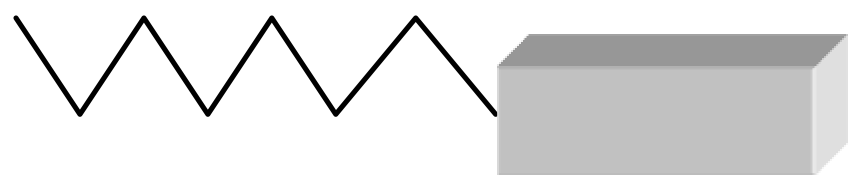
Lyotropics

Amphiphilic molecules, polar and non-polar parts form liquid crystal phases over certain concentration ranges when mixed with a solvent

Thermotropics

Molecules consisting of a rigid core and flexible tail(s) form liquid crystal phases over certain temperature ranges.



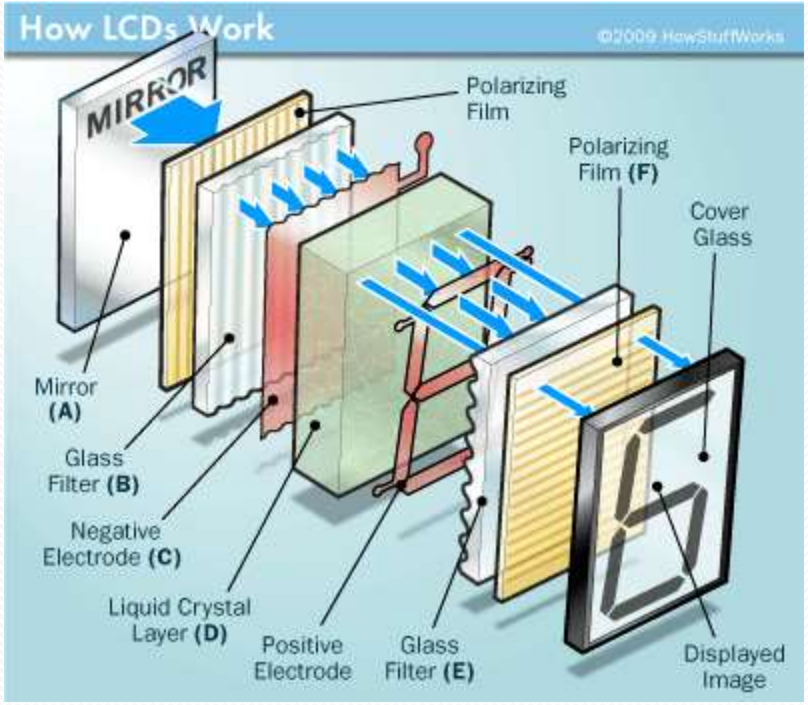


Applications of Liquid Crystals

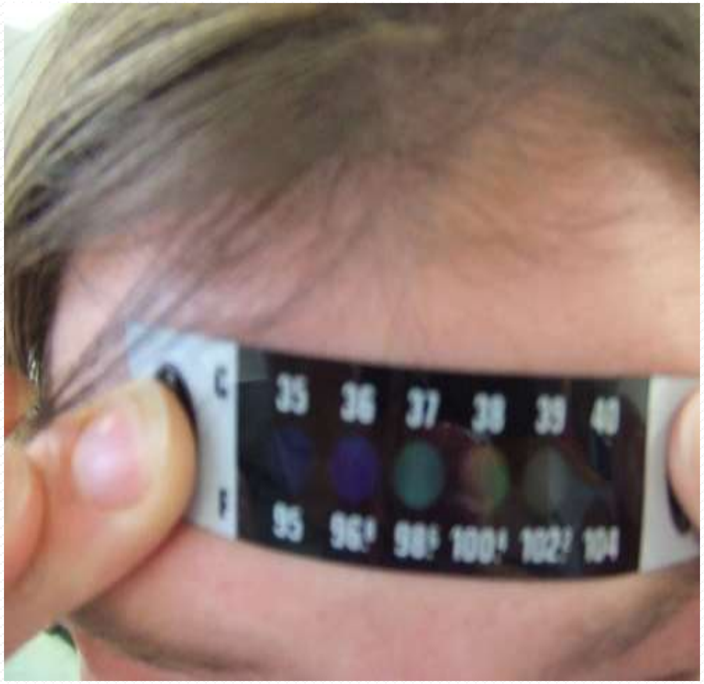
Liquid crystal technology has had a major effect many areas of science and engineering, as well as device technology. Applications for this special kind of material are still being discovered and continue to provide effective solutions to many different problems.

Liquid Crystal Displays

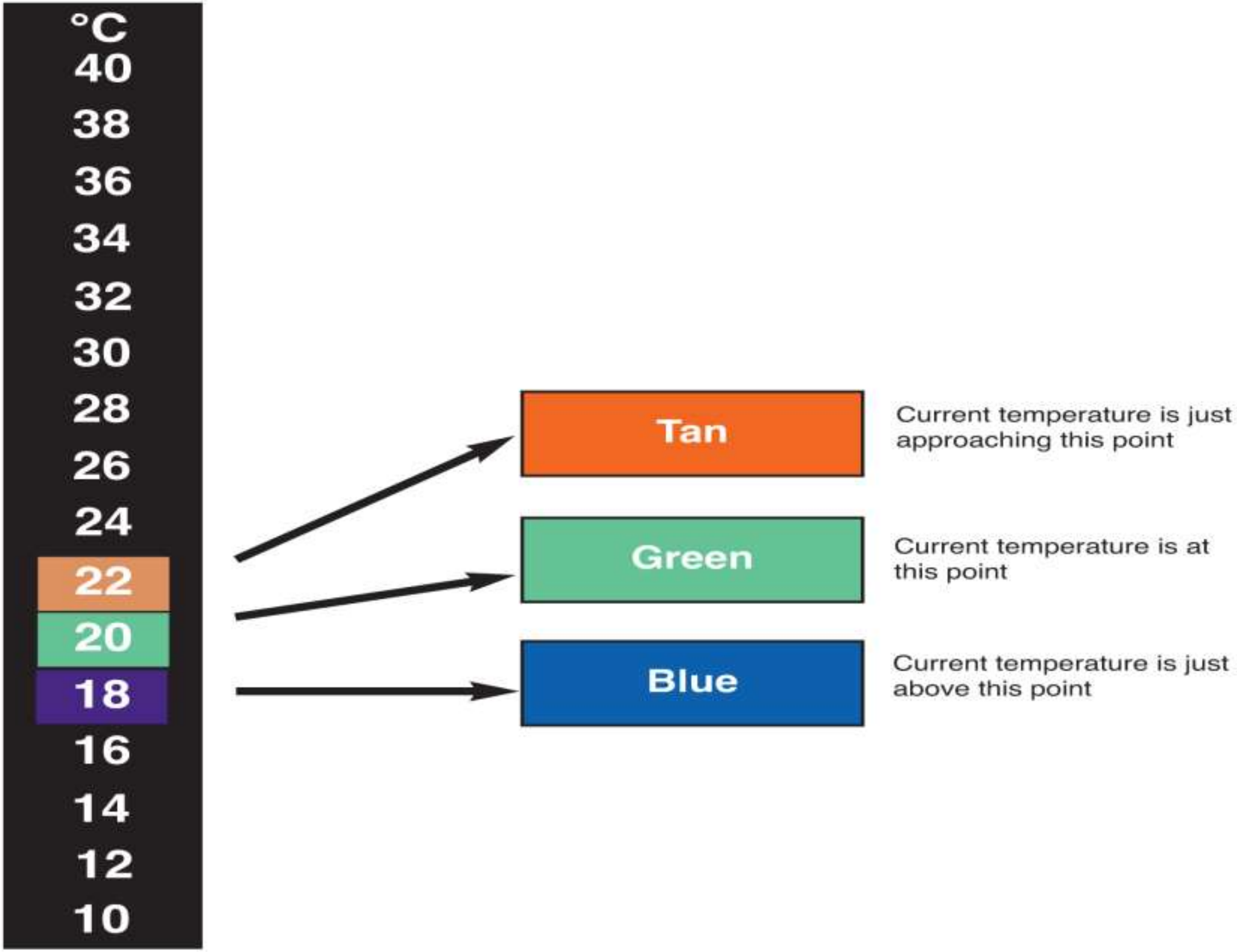
The most common application of liquid crystal technology is liquid crystal displays (LCDs.)



Liquid Crystal Thermometers

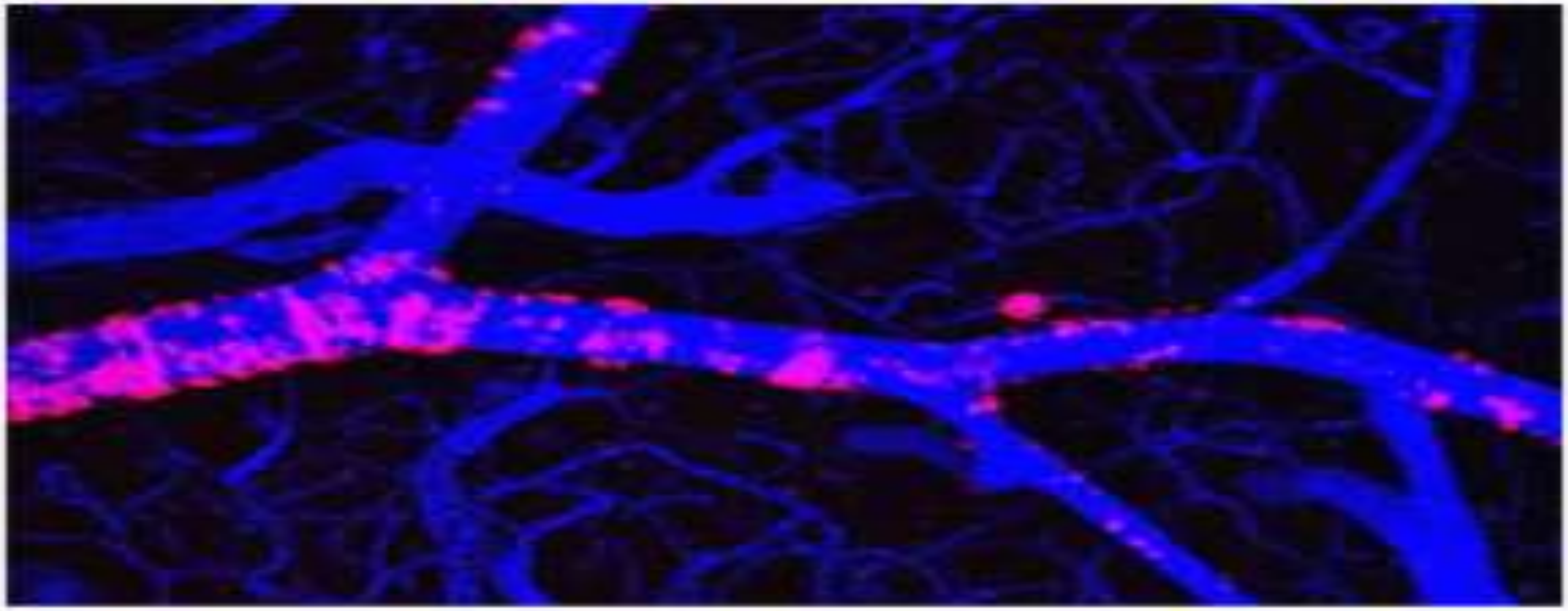


Cholesteric liquid crystals reflect light with a wavelength equal to the pitch. Because the pitch is dependent upon temperature, the color reflected also is dependent upon temperature. Liquid crystals make it possible to accurately gauge temperature just by looking at the color of the thermometer. By mixing different compounds, a device for practically any temperature range can be built.


°C
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
Tan
Current temperature is just approaching this point
Green
Current temperature is at this point
Blue
Current temperature is just above this point

Optical Imaging

An application of liquid crystals that is only now being explored is optical imaging and recording. In this technology, a liquid crystal cell is placed between two layers of photoconductor. Light is applied to the photoconductor, which increases the material's conductivity. This causes an electric field to develop in the liquid crystal corresponding to the intensity of the light. The electric pattern can be transmitted by an electrode, which enables the image to be recorded.



Optical imaging of amyloid deposits (red) in living mouse brain blood vessels in a mouse model of Alzheimer's Disease. *Garcia-Alloza et al., J. Neurochem*, 2007.

Other Liquid Crystal Applications

- They are used for nondestructive mechanical testing of materials under stress. This technique is also used for the visualization of RF (radio frequency) waves in waveguides.
- They are used in medical applications where, for example, transient pressure transmitted by a walking foot on the ground is measured. Low molar mass (LMM) liquid crystals have applications including erasable optical disks, full color "electronic slides" for computer-aided drawing (CAD), and light modulators for color electronic imaging.

Thank You