# Applications Activity: Liquid Crystal Sensors
## *Supplemental Materials*

## Liquid Crystal Sensors—Materials

*Specialty Bottle*
http://www.specialtybottle.com
206-340-0459
$.51 per glass vial

*Sigma-Aldrich*
http://www.sigmaaldrich.com
aldtchsv@sial.com
800-325-3010

Cholesteryl oleyl carbonate
Product No. 151157
CAS No. 17110-51-9
$12.10 for 5g

Cholesteryl pelargonate 97 %
Product No. C78801
CAS No. 1182-66-7
$23.50 for 25g

Cholesteryl benzoate 98 % (2,4-dichlorobenzoate was not available, but this should work too according to the literature)
Product No. C75802
CAS No. 604-32-0
$28.30 for 25g

*Science Kit & Boreal Laboratories*
http://sciencekit.com
Temperature sensitive liquid crystal sheets (12 x 12 inch)
WW3072375 (68 - 77°F)
WW3072374 (77 - 86°F)
WW3072373 (86 - 95°F)
WW3072371 (95 - 104°F)

***Authors***
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# Liquid Crystals

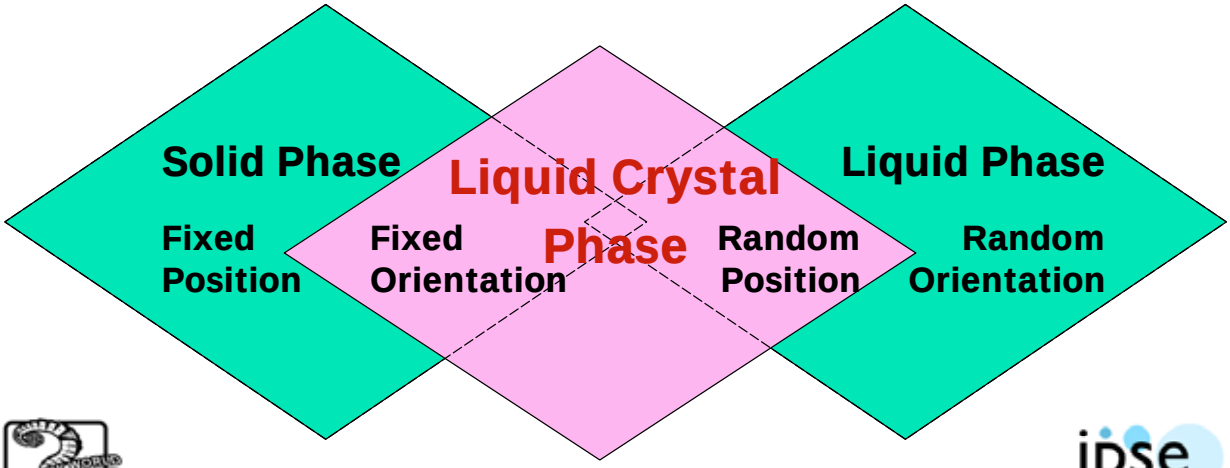
University of Wisconsin-Madison
Internships in Public Science Education
Beixin Julie He and Jeffrey S. Maxwell
Spring 2004

## Applications of Liquid Crystals

- LC displays
- Thermometers for circuit boards, battery condition testers, etc.
- Mood rings
- Paints
- Shampoos and body wash

# What are liquid crystals?

- Phase for some organic compounds
- Properties of both liquids & solids

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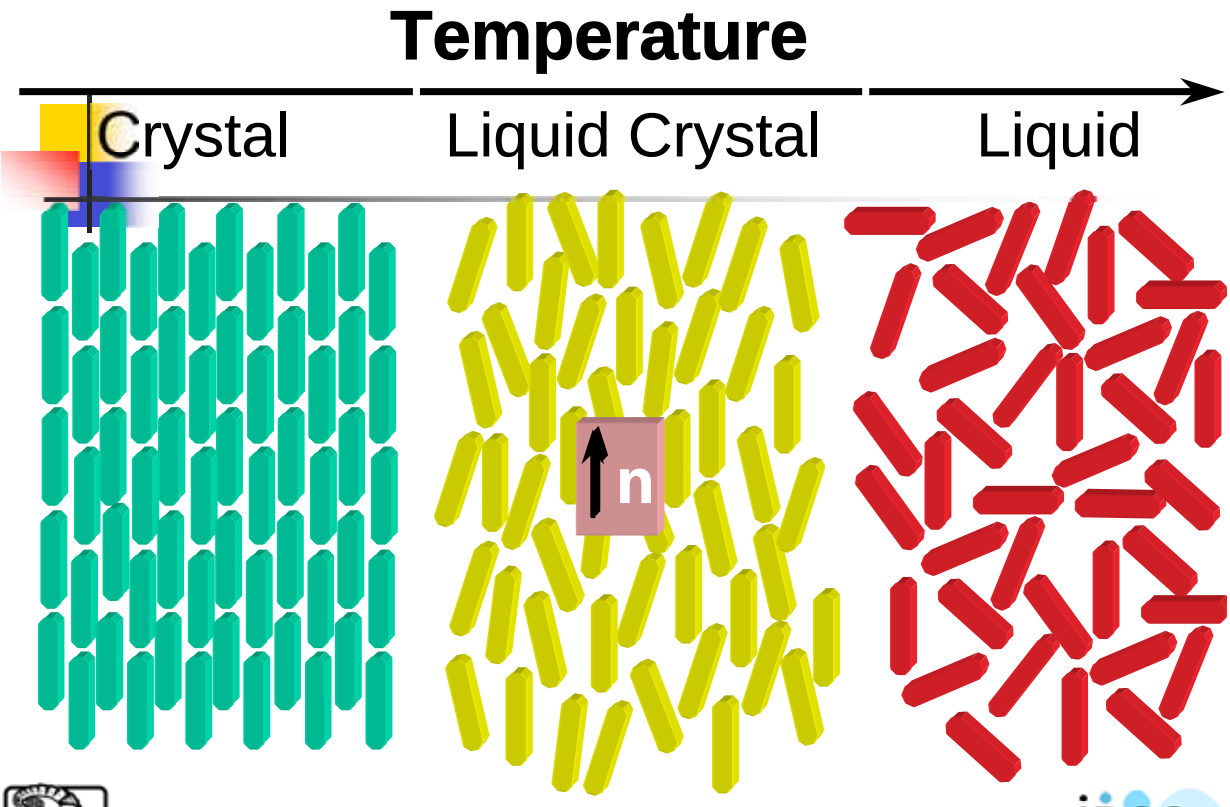


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# History of Liquid Crystals

- Discovered in 1888 by Friedrich Reinitzer in the heating of cholesteryl benzoate
- Name was coined by Otto Lehmann, who visualized LC's w/ heated microscope
- Applications developed in 1960s

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# Liquid Crystal Structures

- Rod- or disk-shaped, polar molecules
- Lie parallel to a specific axis called the director (n)
- Constant director maintained w/in a certain distance that encloses a domain
- Fluidity via translation of domains

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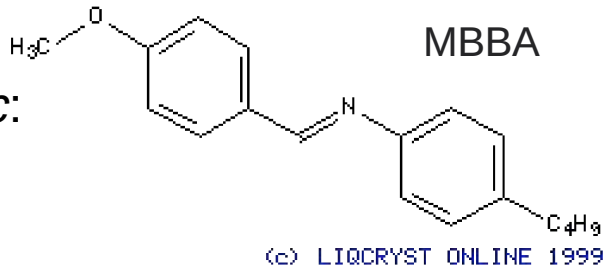
# Liquid Crystal Molecules

- Two types of chemicals exist in LC phase
  - *Thermotropic*: conjugated double bonds




  - *Lyotropic*: amphiphilic (water-loving)

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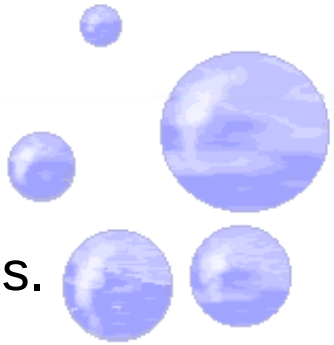
# Bubbles



- Bubbles are *lyotropic* liquid crystals.
- Thickness of bubbles determines the colors of light they reflect

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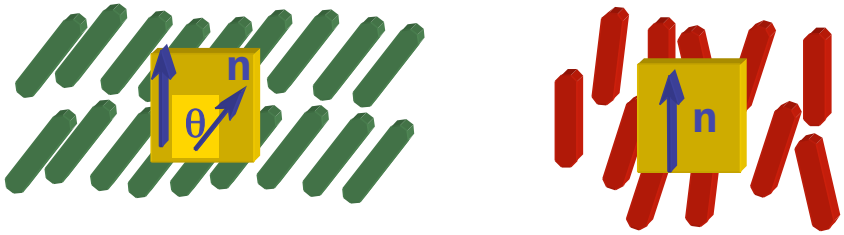
# Polymorphism of LC's

| Crystalline | Smectic | Nematic | Liquid |
|---|---|---|---|

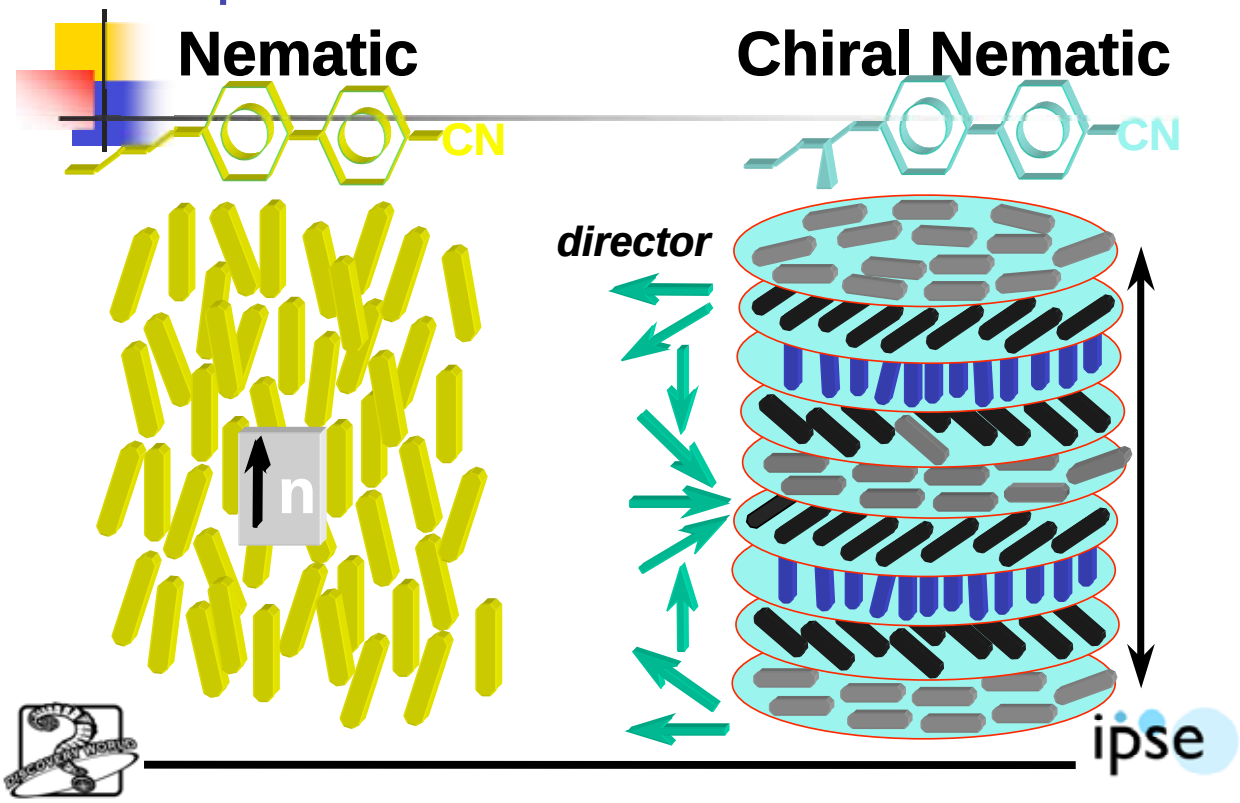
Temperature



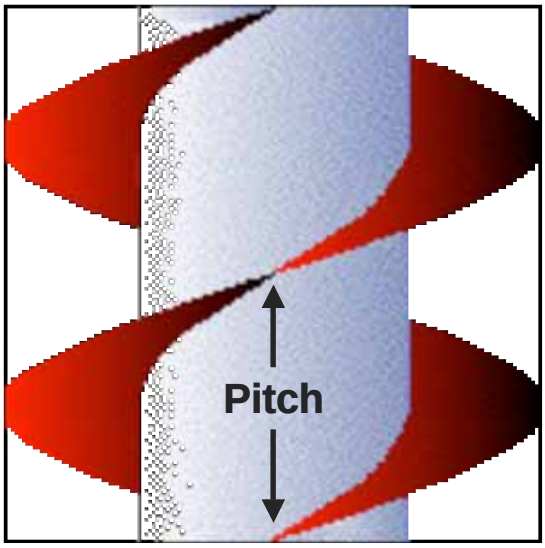

# Chirality in Liquid Crystals

- Chiral molecules
  - have non-super-imposable mirror images
  - influence each other's orientation
- Chiral compounds can assume different mesophases.

# Mesophases of Chiral Molecules

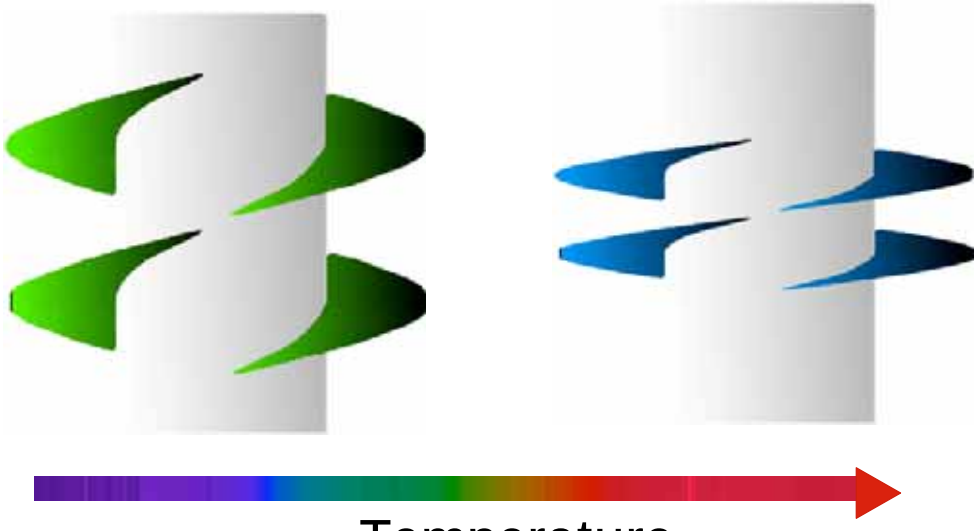



# Relationship b/w Pitch and Color Change

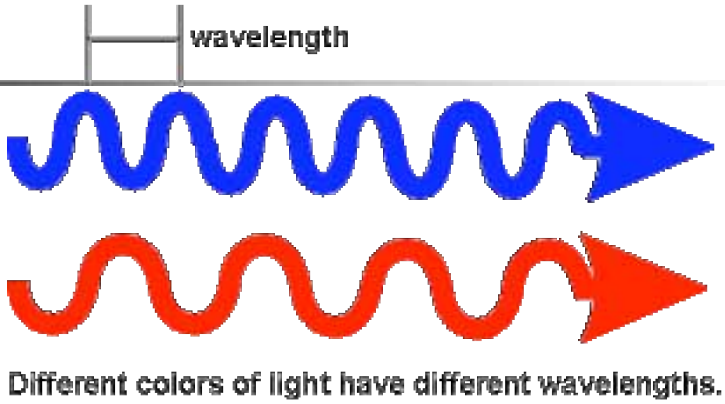



- Pitch affects the scattering of light
- Color changes because pitch changes

# Increasing temperature decreases pitch




# Light Is a Wave




Different colors of light have different wavelengths.

- White light = Mixture of all the colors of light
- Different than a mixture of paints and/or other media

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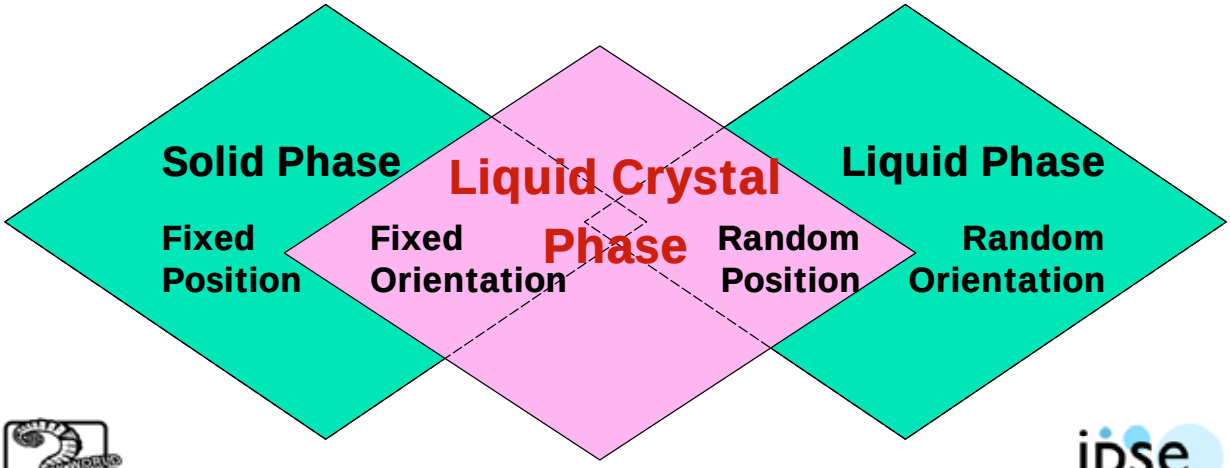


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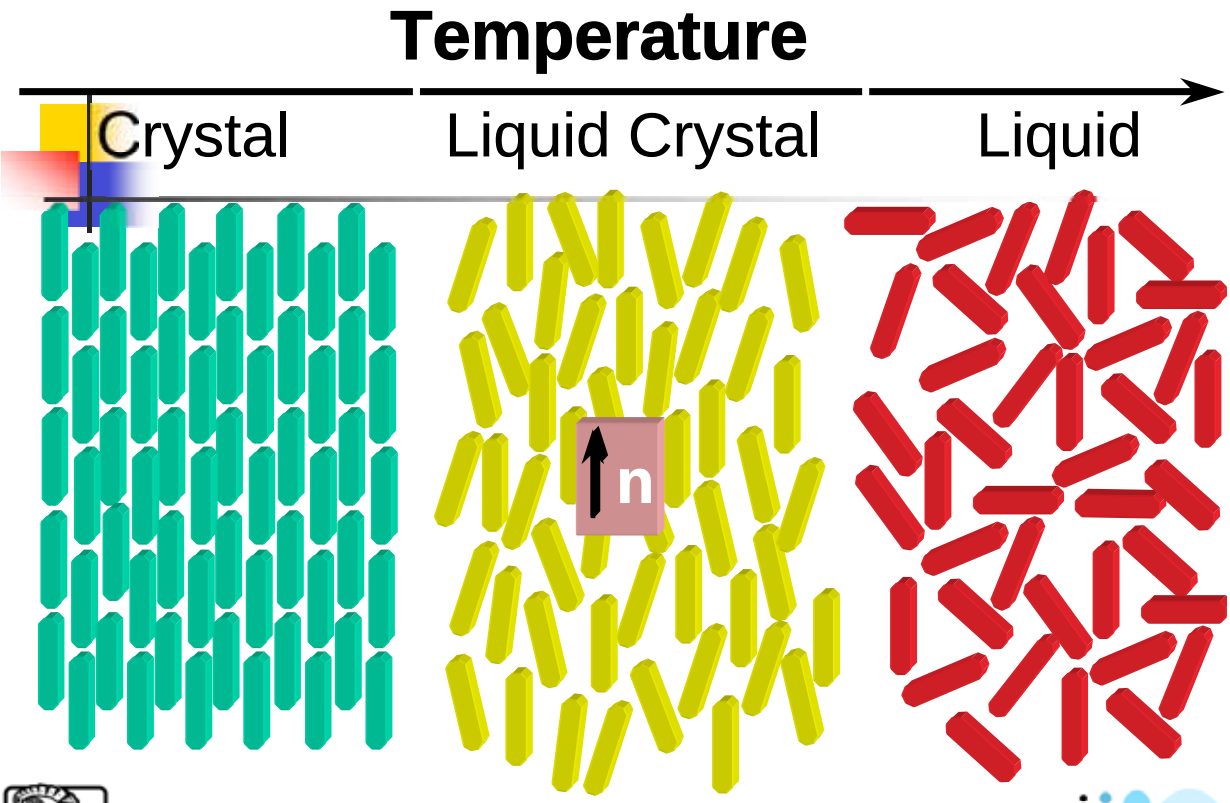


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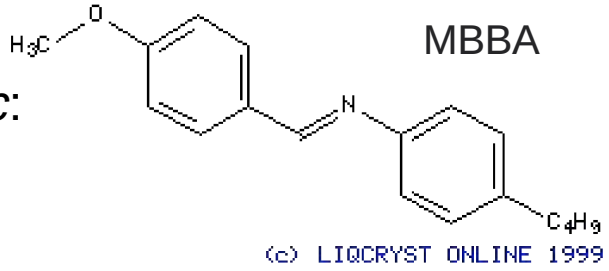


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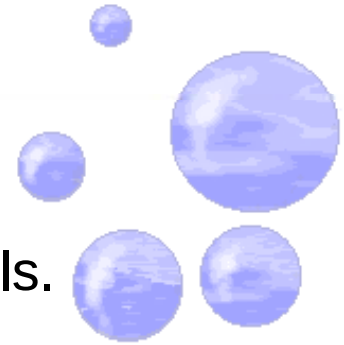

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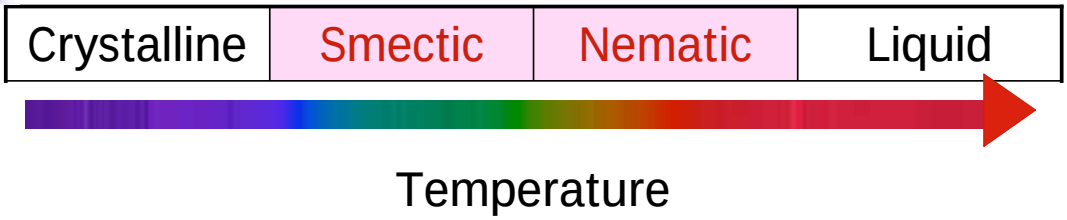


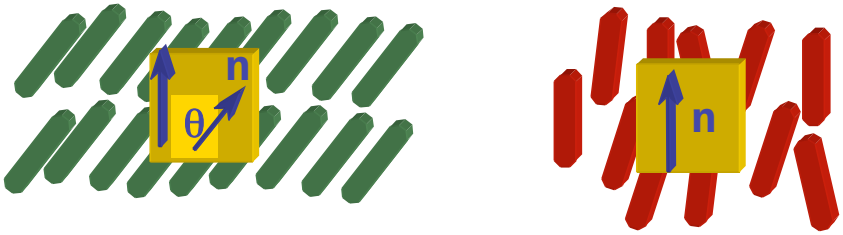


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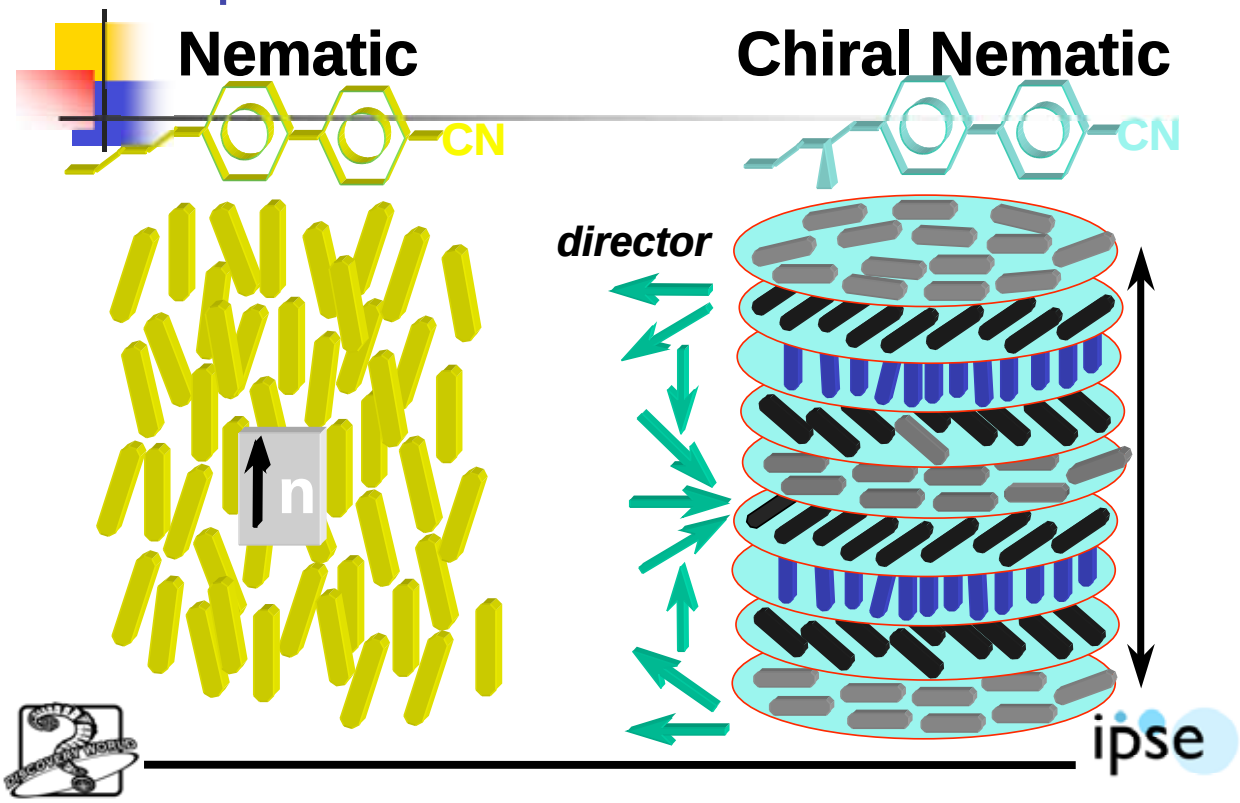


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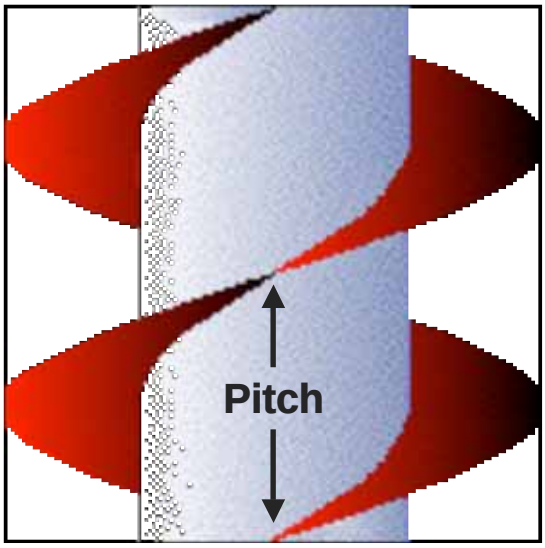


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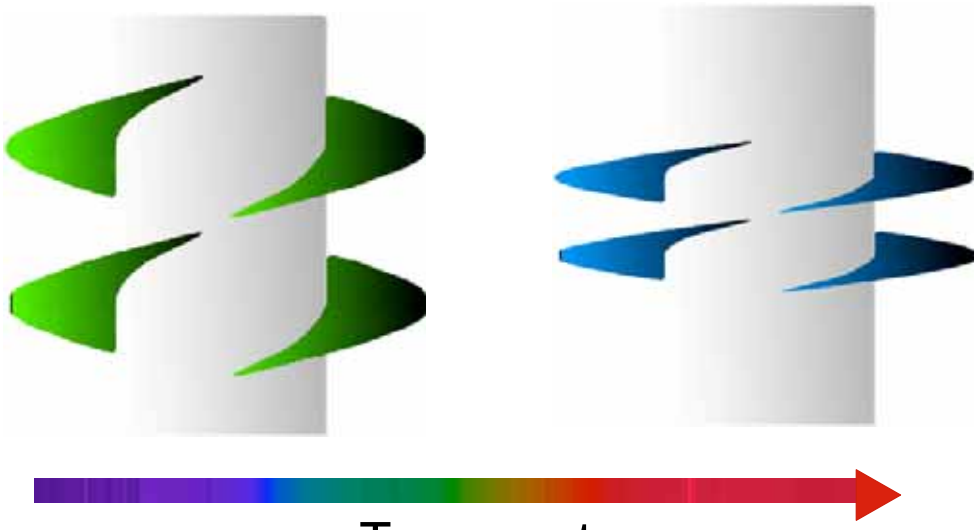


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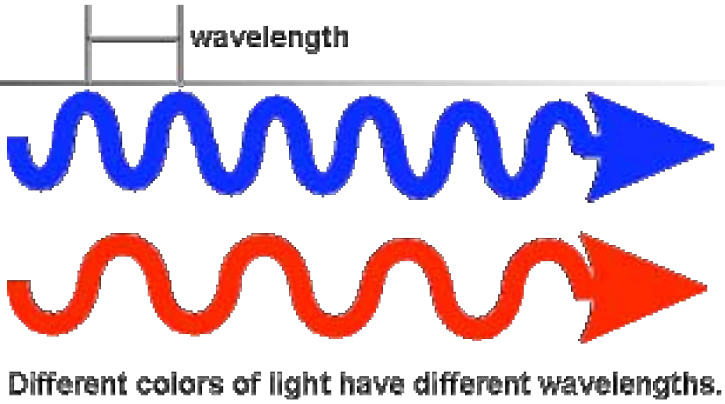


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# Brainstorming: Properties of a Liquid Crystal

1. What are some properties of a liquid? Is a liquid hard or soft? Can it flow or does it stay in one place even when there is space for it to move around?

2. What are some properties of a solid (for example a crystal)? Is a solid hard or soft? Can it flow or does it stay in one place even when there is space for it to move around?

3. A liquid crystal is a phase of matter between a liquid and a crystal. Based on your answers to questions one and two, what do you think are the properties of a liquid crystal?

4. At a high temperature, is a substance more likely to be a liquid or a solid? (Hint: Think of water.)

5. At a low temperature, is a substance more likely to be a liquid or a solid? (Hint: Think of water.)

6. At what temperature do you think a substance might be a liquid crystal? Will the temperature be high, low, or in the middle?

# Brainstorming: Properties of a Liquid Crystal [ANSWERS]

1. What are some properties of a liquid? Is a liquid hard or soft? Can it flow or does it stay in one place even when there is space for it to move around??

   Possible answers: *Liquids are wet, fluid-like, and soft. They can be easily penetrated. When a container is completely filled with a liquid, the liquid can take the shape of that container.*

2. What are some properties of a solid (for example a crystal)? Is a solid hard or soft? Can it flow or does it stay in one place even when there is space for it to move around?

   Possible answers: *Solids are hard and rigid materials. They are not as flexible as liquids because their atomic arrangement is more structured. It requires more force to break solids than to penetrate liquids. Solids do not take the shape of their containers.*

3. A liquid crystal is a phase of matter between a liquid and a crystal. Based on your answers to questions one and two, what do you think are the properties of a liquid crystal?

   *A liquid crystal has some properties of a solid and some properties of a liquid. Liquid crystals are like liquids because they're fluid-like. Liquid crystals are also like solids because their atoms are somewhat structured.*

4. At a high temperature, is a substance more likely to be a liquid or a solid? (Hint: Think of water.)

   *At a high temperature, a substance is more likely to be in the liquid phase because the material is more flexible and its structure less ordered.*

5. At a low temperature, is a substance more likely to be a liquid or a solid? (Hint: Think of water.)

   *At a low temperature, a substance is more likely to be in the solid phase because the material is more rigid and its atomic structure more compact.*

6. At what temperature do you think a substance might be a liquid crystal? Will the temperature be high, low, or in the middle?

   *If a material is a solid at a low temperature and a liquid at a high temperature, then the liquid crystal phase should be at a temperature that's between high and low.*

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**Liquid Crystal Temperature Sensors**

Two properties of liquid crystals make them ideal sensors. The first is their sensitivity to changes in their surroundings. The second is their visual effects; they change color when they sense a change. Because of these properties, we can use liquid crystal sensors to "see" what our eyes can't!

Directions:

1. Place your hand on the tabletop to give some warmth from your fingers and palm to the table. Keep your hand still while doing this. Remove your hand.

Look closely. Can you see a handprint on the table with your eyes?

Place a liquid crystal sensor on top of your invisible handprint. Can you see your handprint now? Test each of the liquid crystal sensors and record your observations below.

| Liquid Crystal Thermal Sheet | What do you observe? |
|---|---|
| **A** | |
| **B** | |
| **C** | |
| **D** | |

2. Take turns holding and touching different objects (e.g., coins, refrigerator magnets) without showing each another. Use the liquid crystal sensors to "see" which object was being held. Record your observations and consider the following questions: Do some objects work better than others? Why? Do some sensors work better than others? Can you sense cold as well as heat with any of the sensors?

3. Just as some liquid crystal sensors can measure temperature, others can sense movement and pressure, chemicals (e.g., pollution, poisons), biological agents (e.g., viruses, bacteria), and electricity.

   With your group, brainstorm some potential inventions that would use liquid crystal sensors. Write your ideas below. For example, it might be good to have road signs that say "Watch out for ice" when the temperature drops below freezing and plates that say "Clean me" when bacteria or dirt are present.

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# Liquid Crystal Thermal Sheets

Directions:
You have been given four liquid crystal sheets, labeled A through D. Each sheet is made of a different material that changes color at a different range of temperatures. Your challenge is to determine the temperature range of each sheet.

1) Touch each LC sheet with your fingers. What happens? Write you answers in the table below.

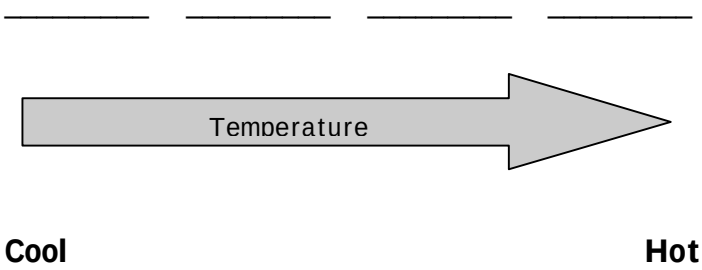
2) Warm your hands with the hand warmer. Touch each LC sheet and record your observations in the table.

3) If there is a sheet that you could not get to change color, do you think that it is broken? If it is not broken, what might you do to change its color?

| LC Sheet | A | B | C | D |
|---|---|---|---|---|
| Normal Hands | | | | |
| Warm Hands | | | | |

4) What color corresponds to warmer temperatures? What color corresponds to colder temperatures? Can the same temperature (e.g. your hand) produce a different color on different sheets? If yes, why do you think this might be? If not, why not?

5) Order the LC sheets (A-D) on the scale below based on the temperature range they respond to.

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