Flüssigkristalle

Liquid Crystals

Historisches

- 1888 Reinitzer (Cholesterolbenzoat)

„Die Substanz zeigt zwei Schmelzpunkte, wenn man sich so ausdrücken darf. Bei 145·5° schmilzt sie zunächst zu einer trüben, jedoch völlig flüssigen Flüssigkeit. Dieselbe wird erst bei 178·5° plötzlich völlig klar. Lässt man sie nun auskühlen, so tritt zunächst eine violette

- Interpretation:
  1889 Lehmann
  “Über fliessende Krystalle”
  Zeitschrift für physikalische Chemie, **4**, 462 – 472.

Otto Lehmann

Microscope with heating stage and polarizing filters (1900)

From a letter to Reinitzer:

"…my new results confirm your [previously] declared view, that the [substance] consists of very soft crystals … It is absolutely homogeneous, and another liquid - as you assumed formerly - is not present … It is of a high interest for the physicist that crystals exist which are of such a considerable softness that one could almost call them liquid."

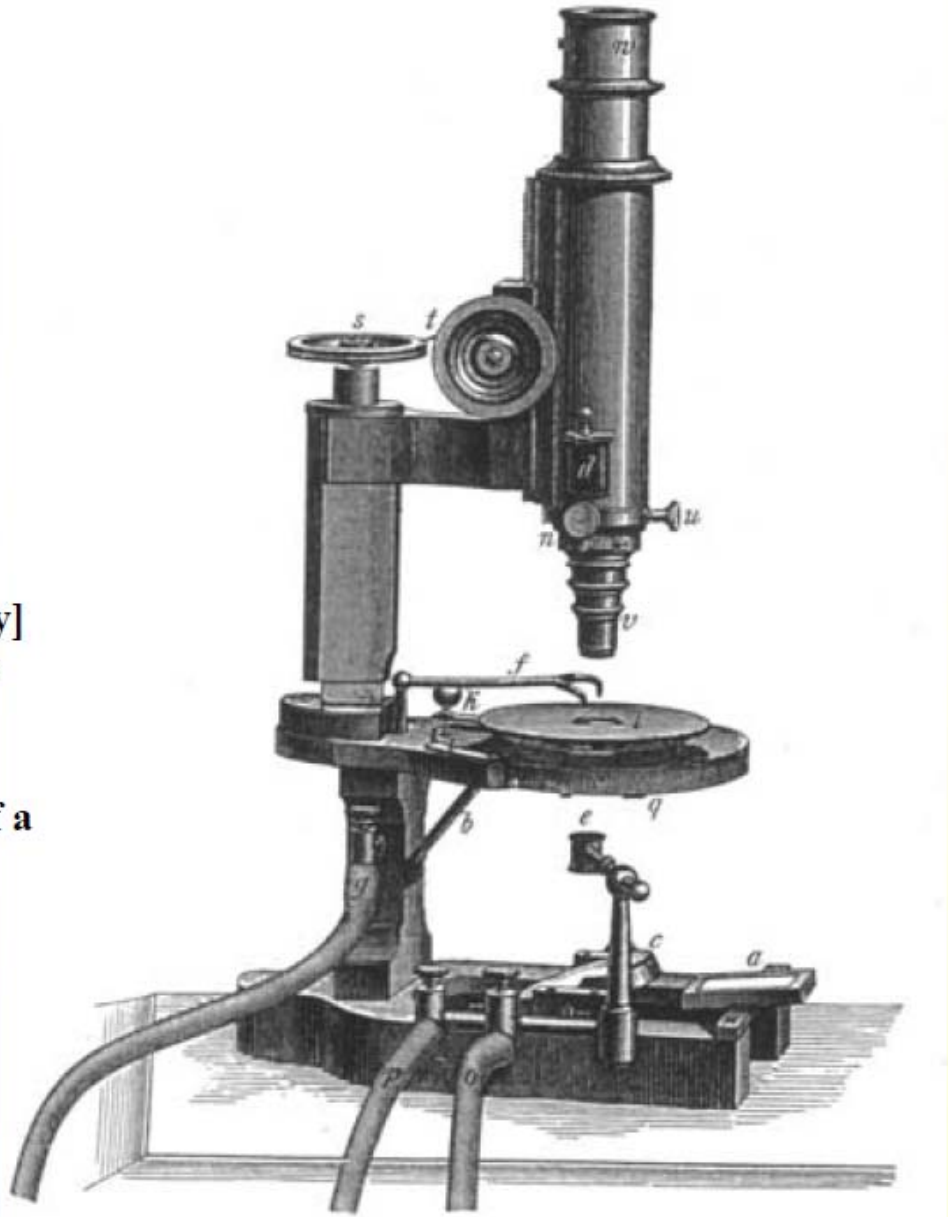
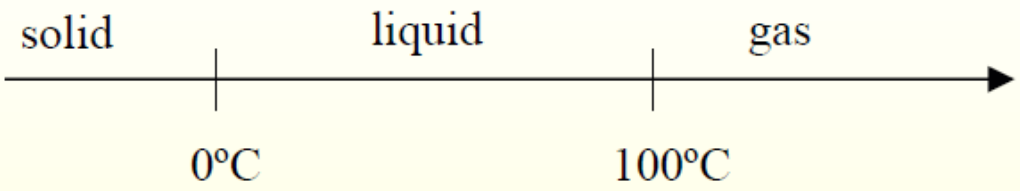


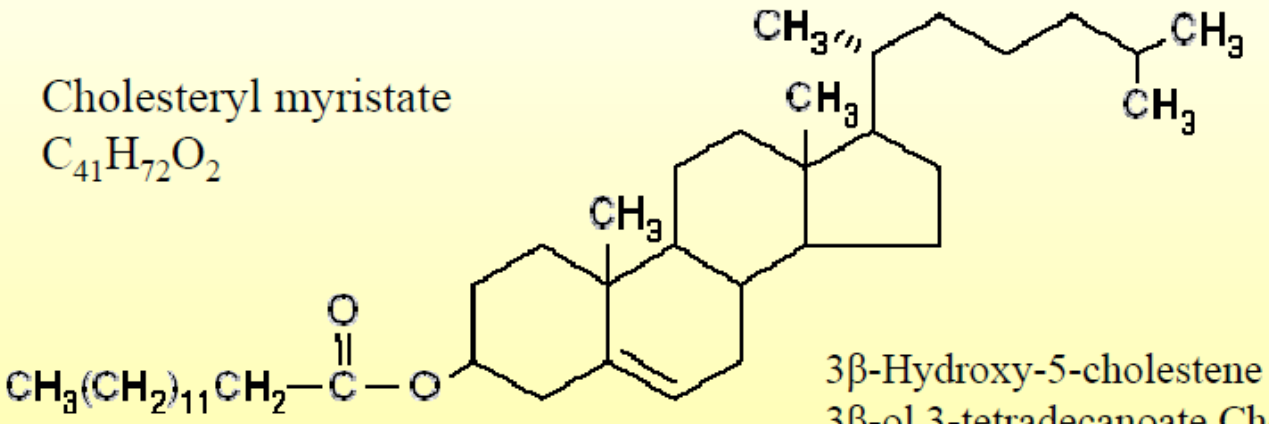
Fig. 20.

Der flüssigkristalline Zustand

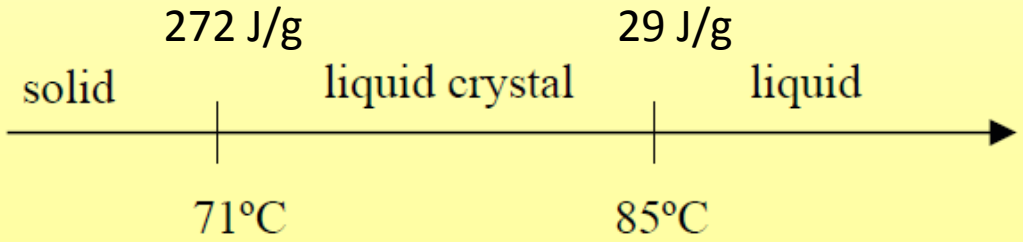
Water, H_2O



Cholesteryl myristate
$C_{41}H_{72}O_2$

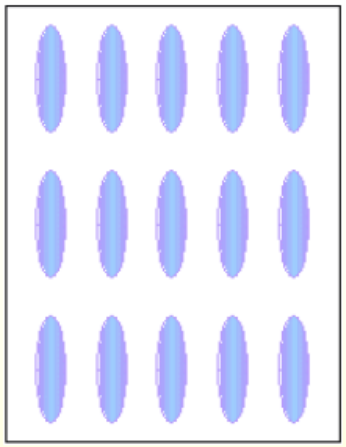


3β-Hydroxy-5-cholestene 3-tetradecanoate 5-Cholesten-3β-ol 3-tetradecanoate Cholesteryl tetradecanoate

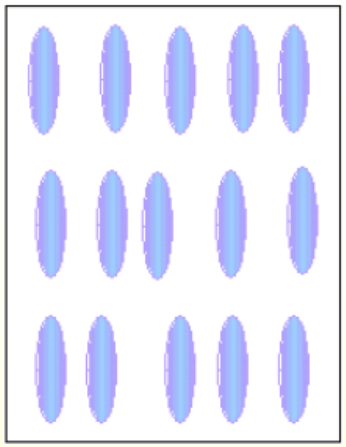


Mehr eine Flüssigkeit als ein Kristall…

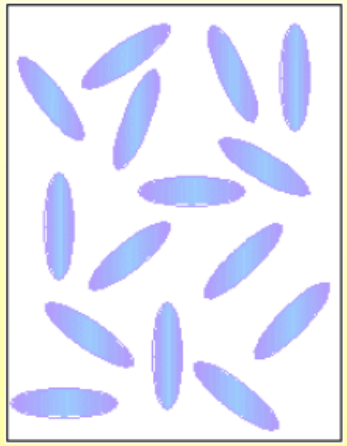
Nematisch/Smektisch/Chloesterisch



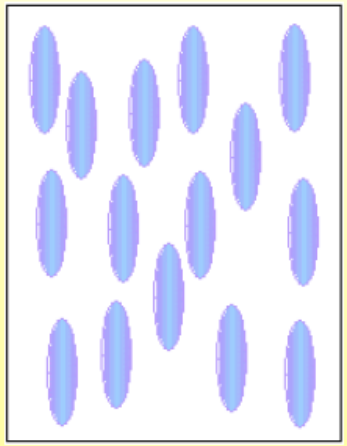
Crystalline Solid



Smectic

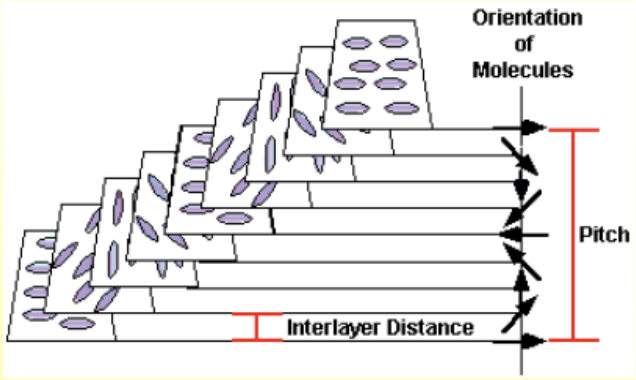


Isotropic Liquid



Nematic

Liquid Crystal:

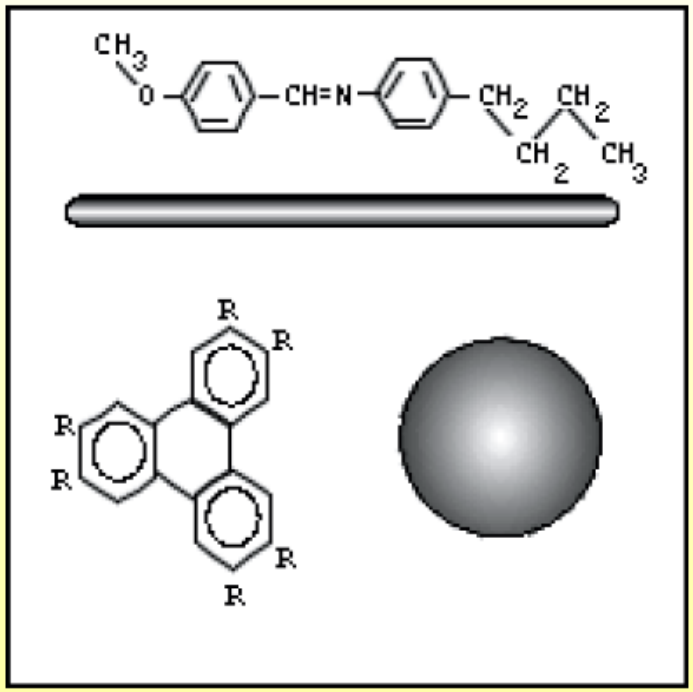


Cholesteric
or
twisted- nematics
or
Chiral nematics

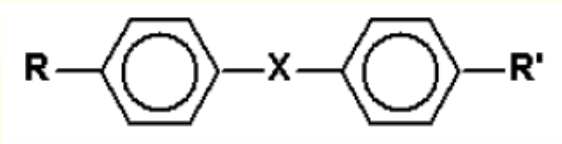
Welche Moleküle formen LCs ?

~1 of 200 molecules form liquid crystals

1) Elongated shape (anisotropic)
2) Must have some rigidity in its central region. Flexible (cooked spagetti-like) molecules do not form a liquid crystal state.
3) Flexible ends seems to be an advantage



Calamatic:



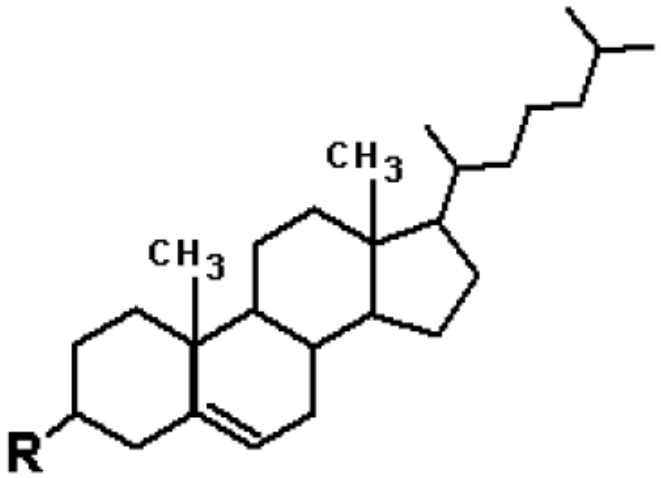
Bridging Group X

- N = N -
- N = NO -
- CH = CH -
- C ≡ C -
- CH = N(O) -
- CH = N -
- O - CO -

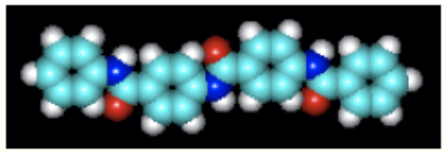
End Groups R, R'

- C_nH_{2n+1} n = 1 to 9
- OC_nH_{2n+1} n = 1 to 9
- C ≡ N
- OOC - OC_nH_{2n+1} n = 1 to 9

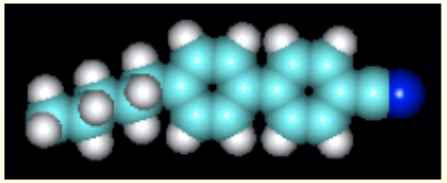
Discotic:



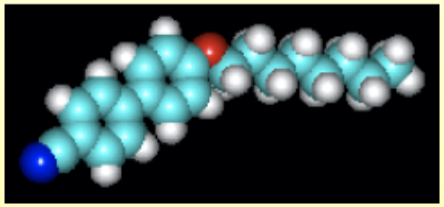
Cholesterol-derivatives



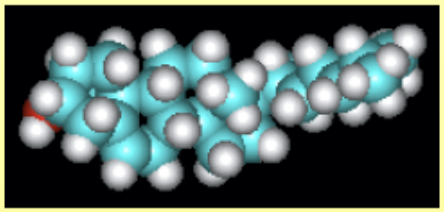
Kevlar - polymeric liquid crystal



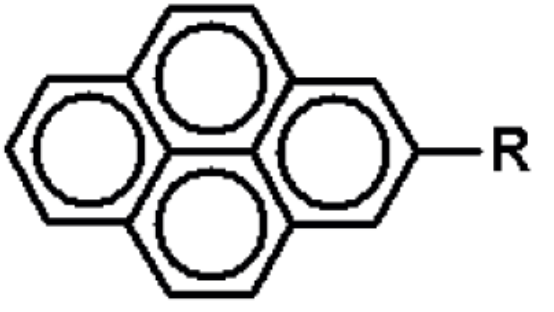
5 -CB



OOCBP

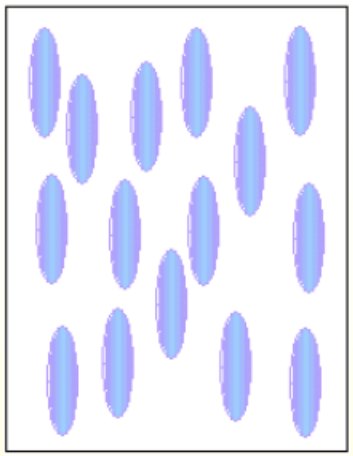


Cholesterol



pyrene-derivatives

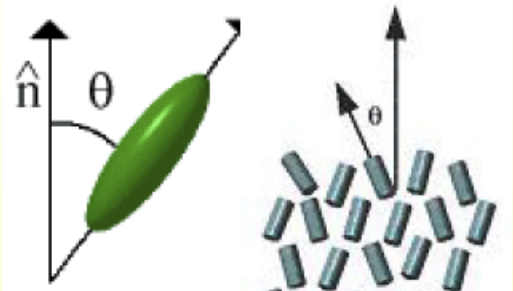
Nematische LCs

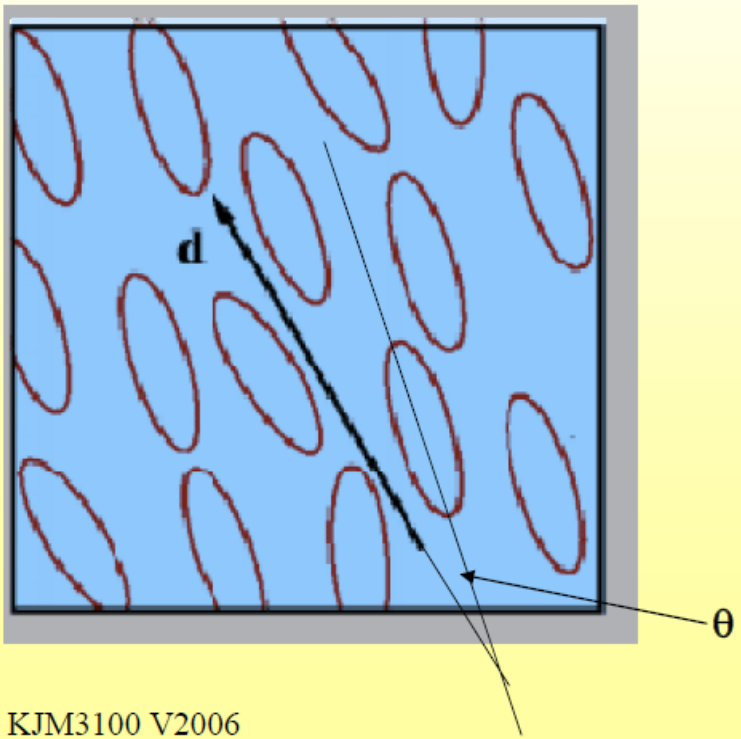


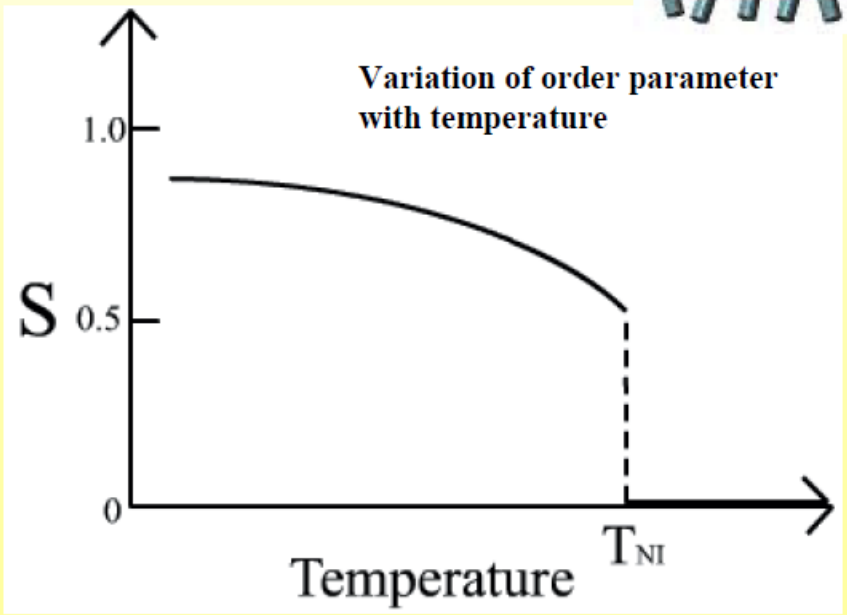
Nematic

No positional order, only rotational order.
Average direction of molecules: the **director**
If there is no orientational disorder the mean angle to the director is 54.74°
(3-dimensional averaging)

Order parameter: $S = \left\langle \frac{3\cos^2\theta - 1}{2} \right\rangle$







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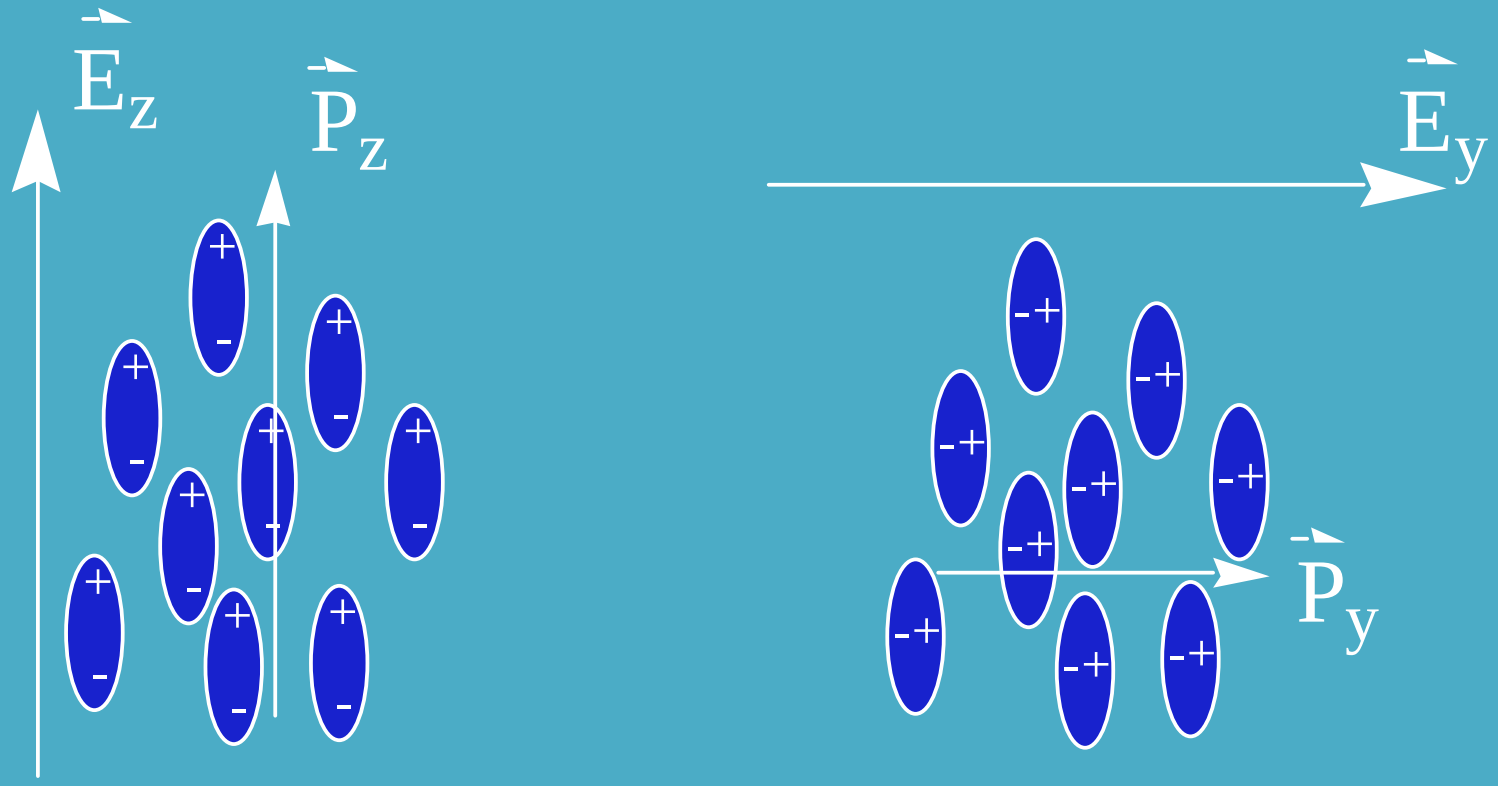
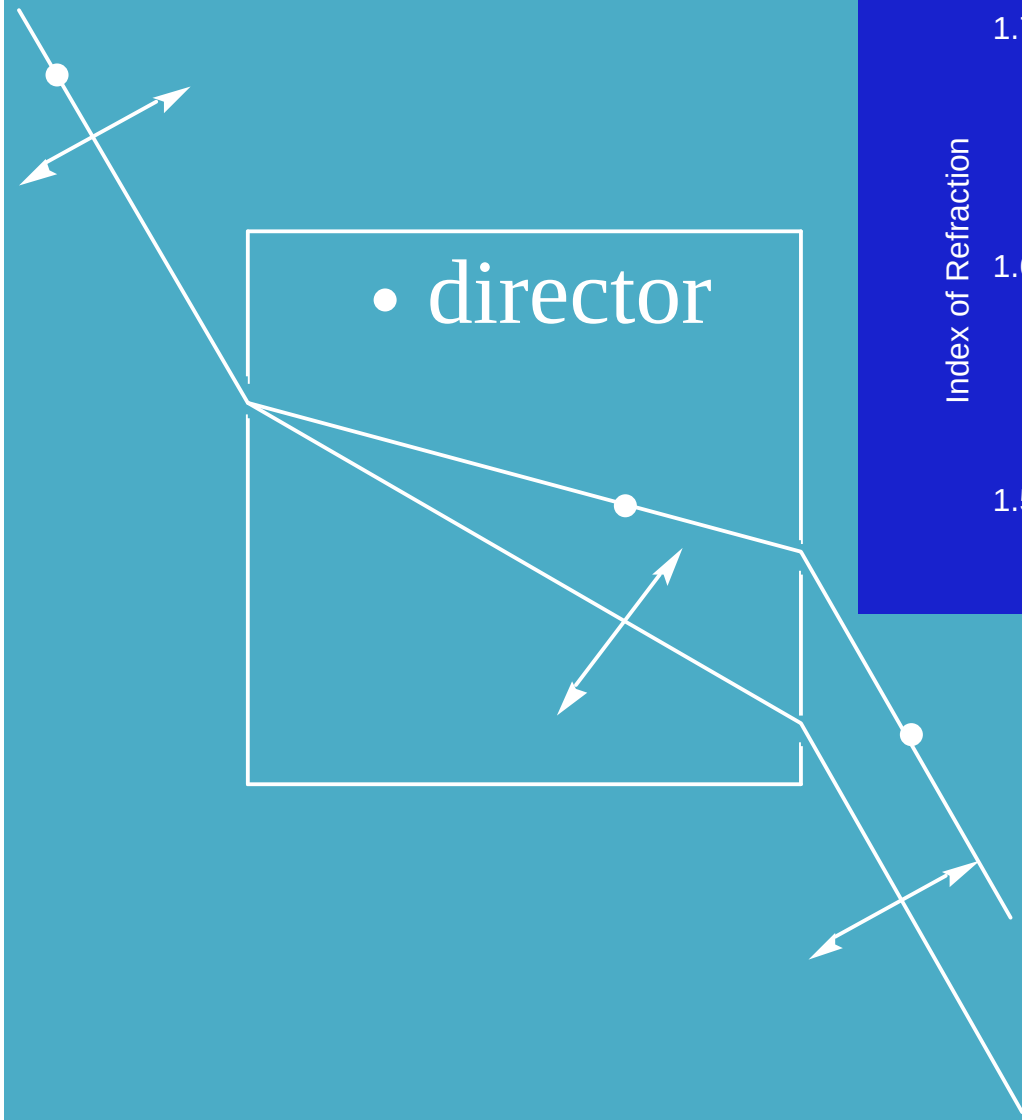
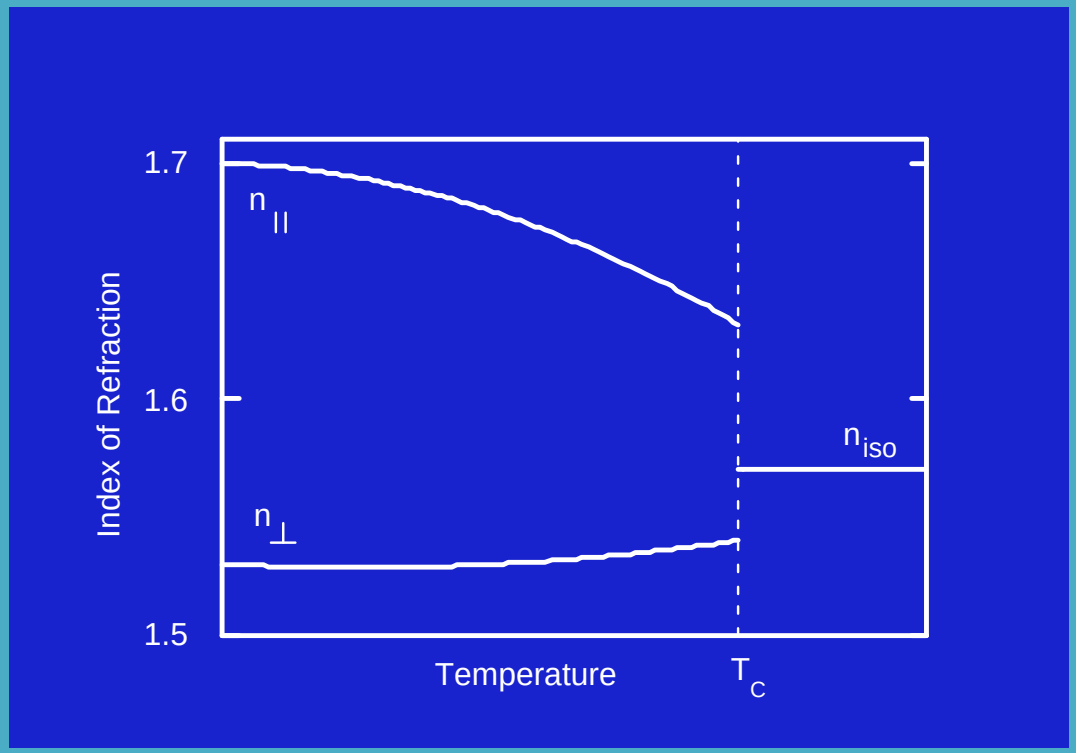
LCs sind in E-Feld polarisierbar



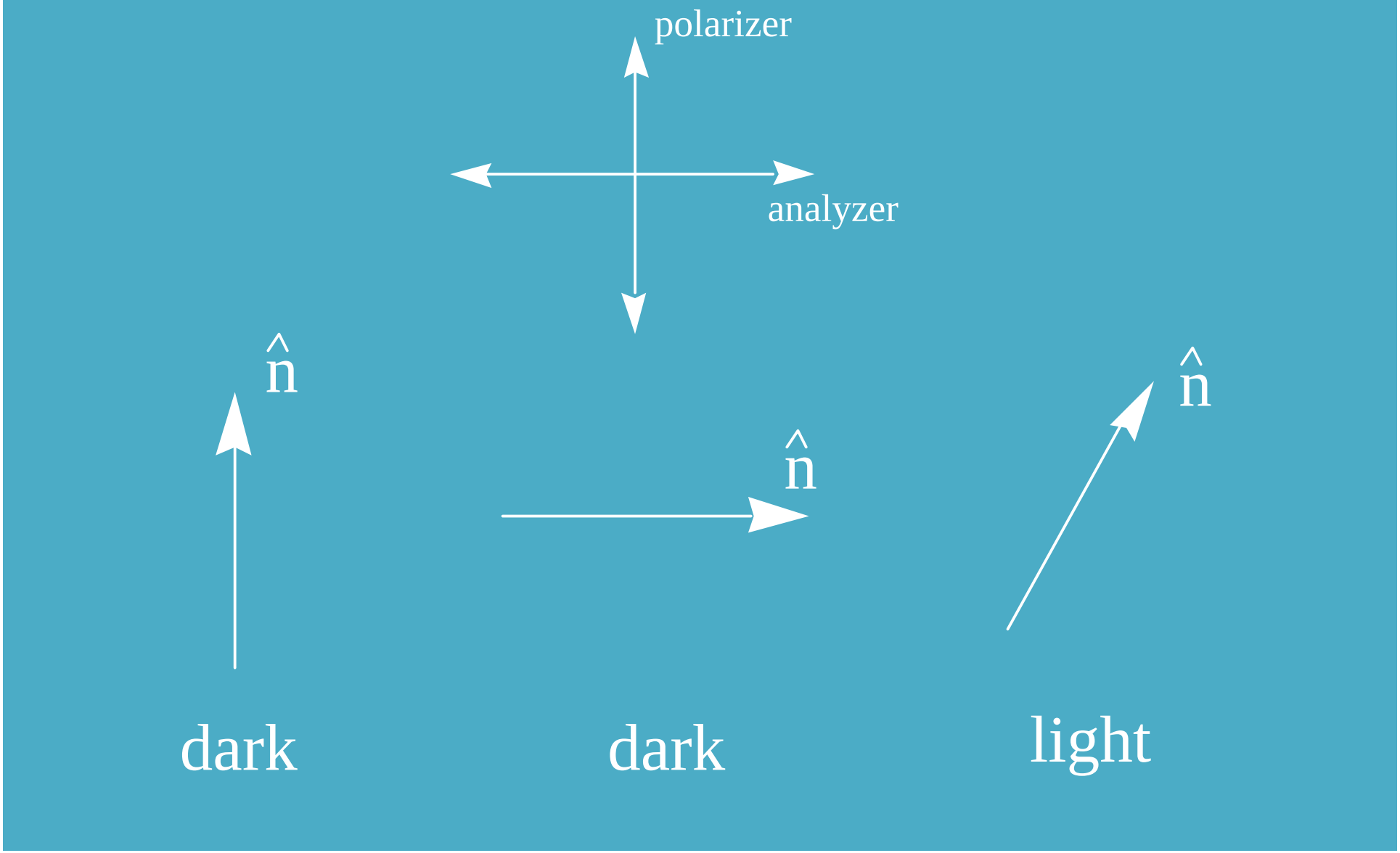
$P_z > P_y \Longrightarrow$ anisotropy

LCs sind doppelbrechend





LCs zwischen gekreuzten Polarisatoren

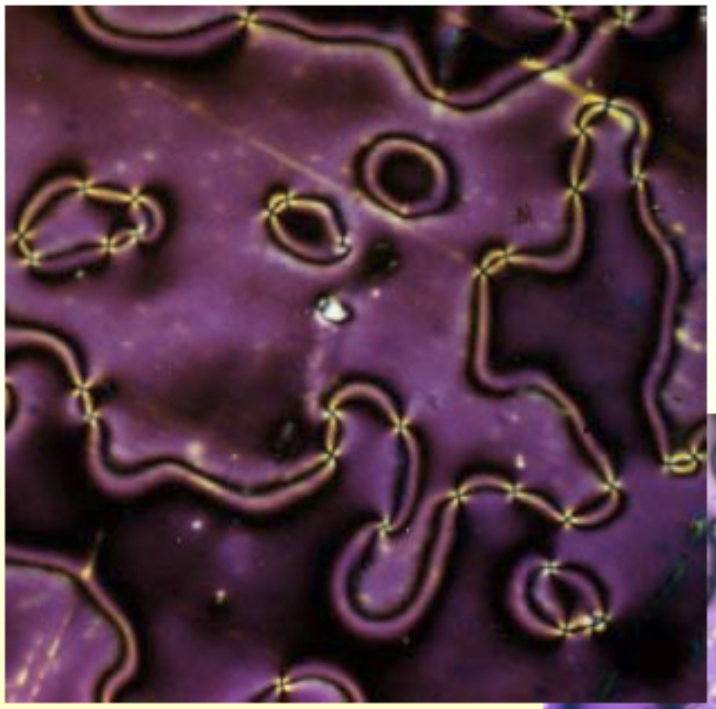


Nematic

Crossed polarizing filters.

Defect lines:

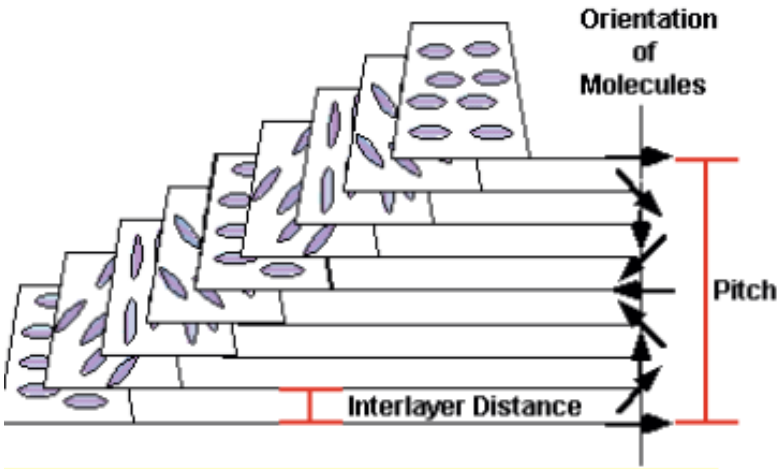
Nematic derived from the Greek word for Thread

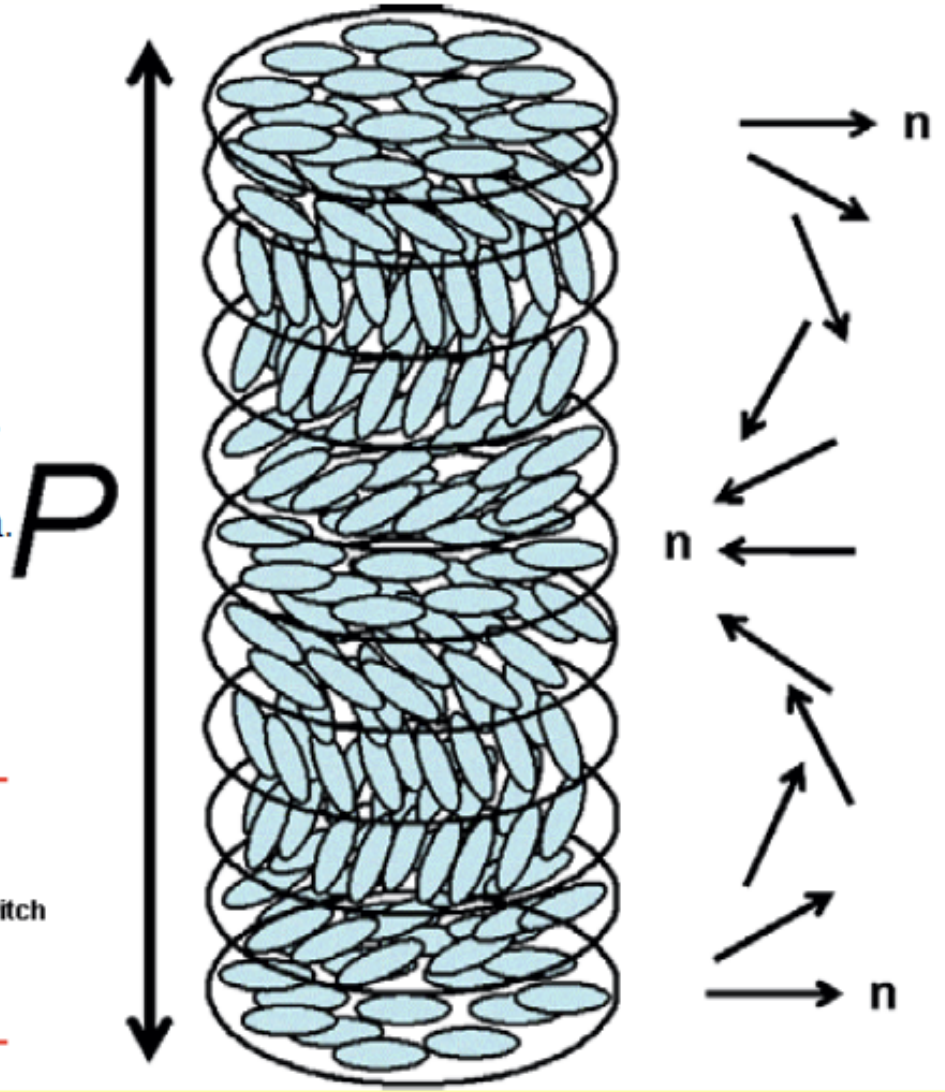


Cholesterische Phase

Chiral nematic
(Cholesteric)
Liquid crystals

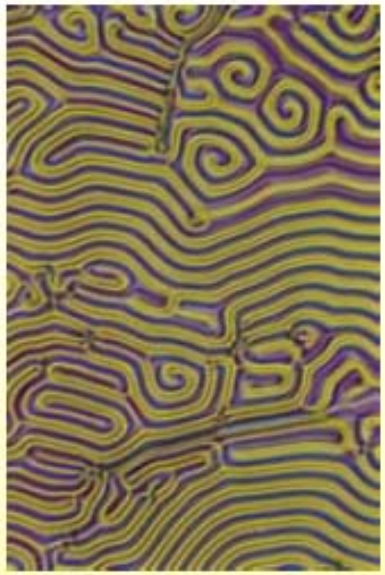
The director is not fixed in space, but rotates through the sample.
The characteristic parameter, the pitch, is the distance along the helix, before the molecules have turned one full turn.

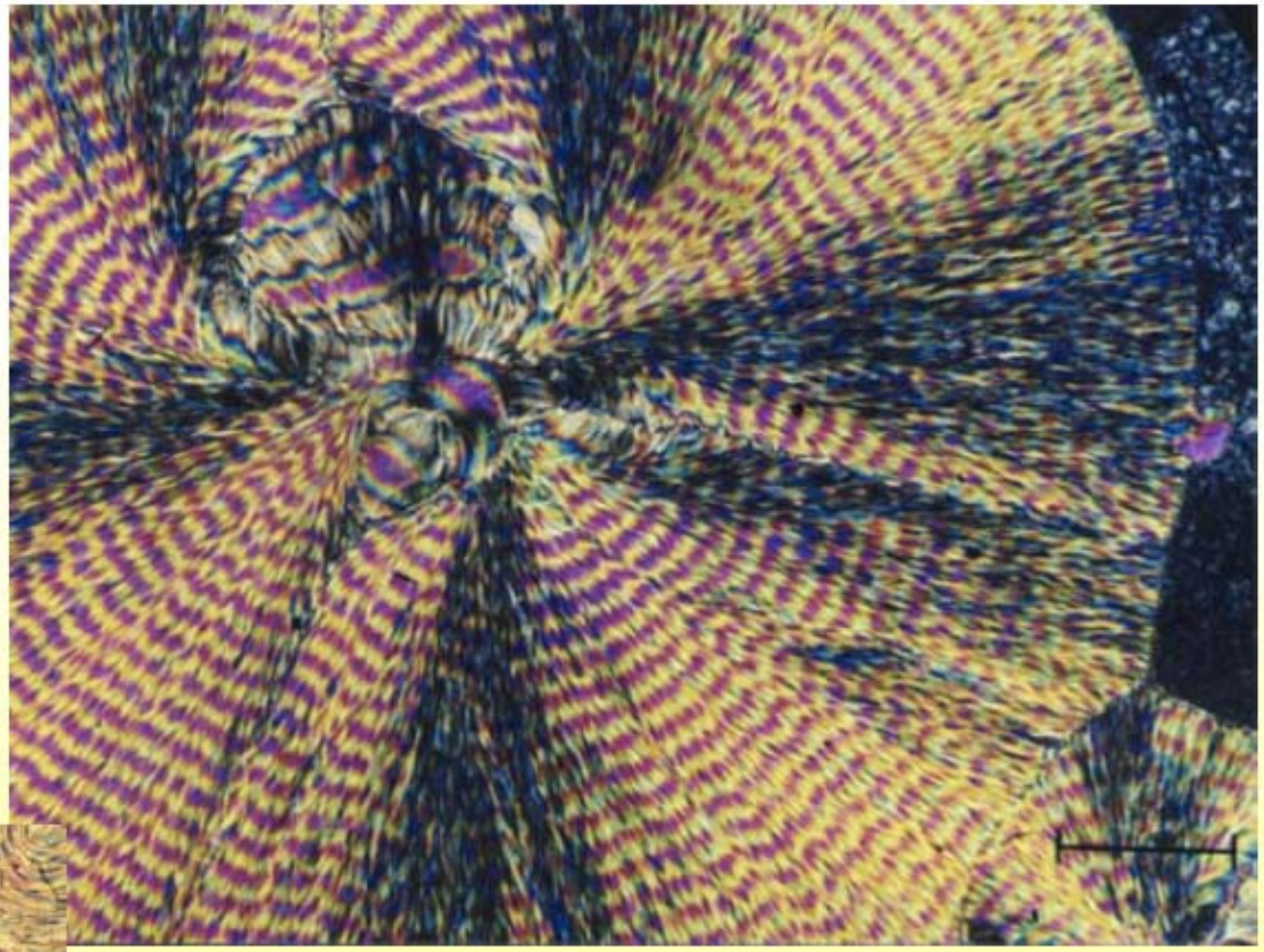


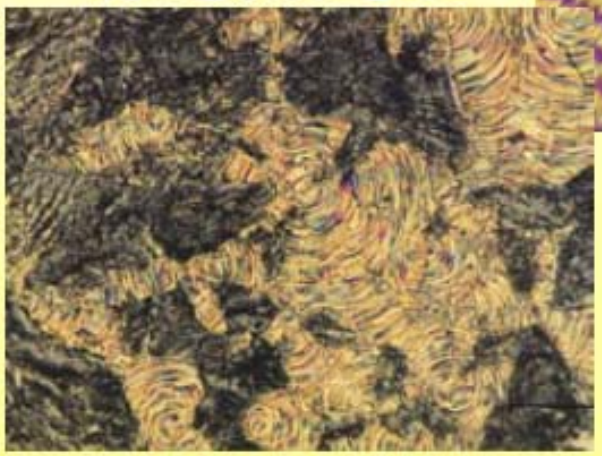


Schematic diagram of a chiral nematic phase with a helical pitch, *P*. **n** is the nematic director for each of the layers shown in the diagram.

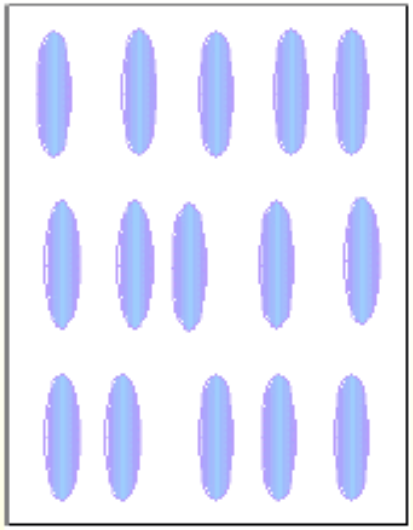
Chiral nematic (Cholesteric) Liquid crystals







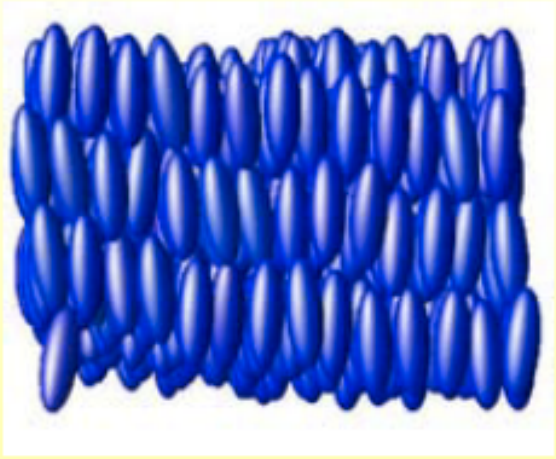
Smektische Phase



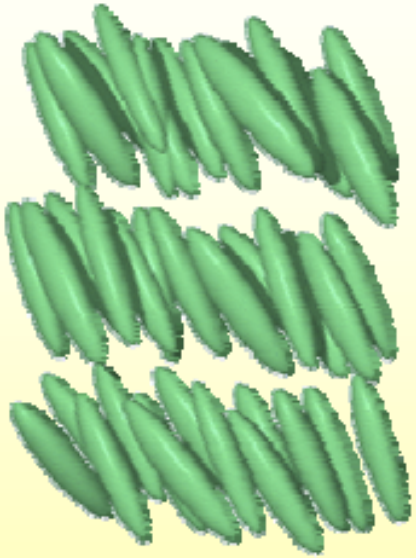
Smectic

Partial orientational and positional order

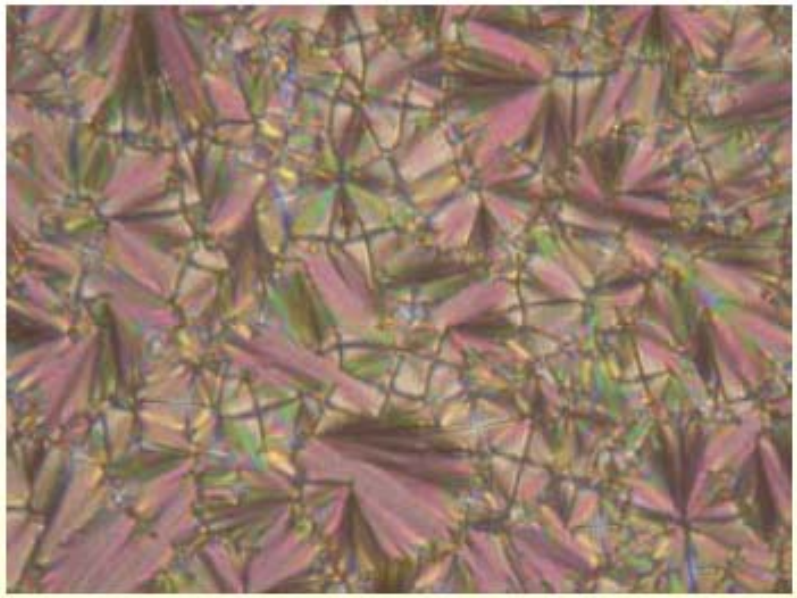
Tendency to organization in planes. Usually no positional order within a plane.

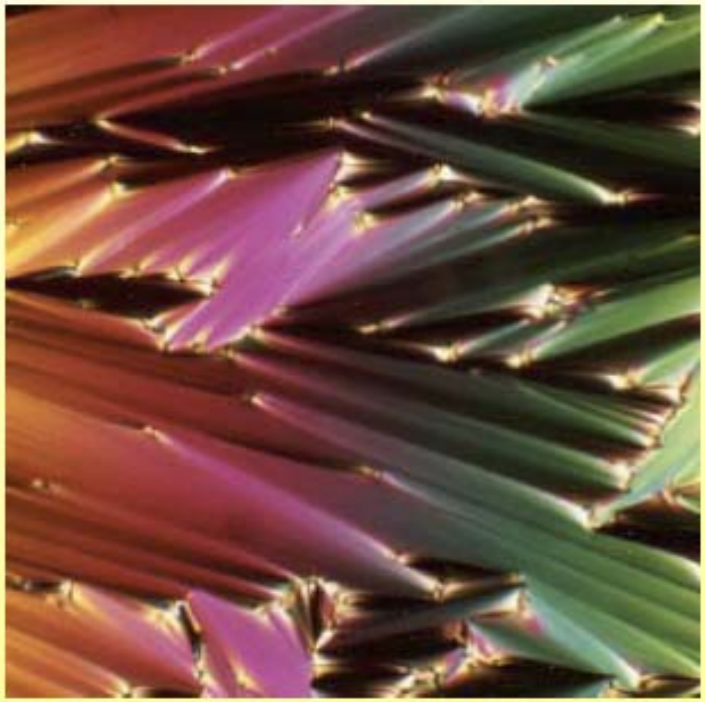


Smectic A



Smectic C





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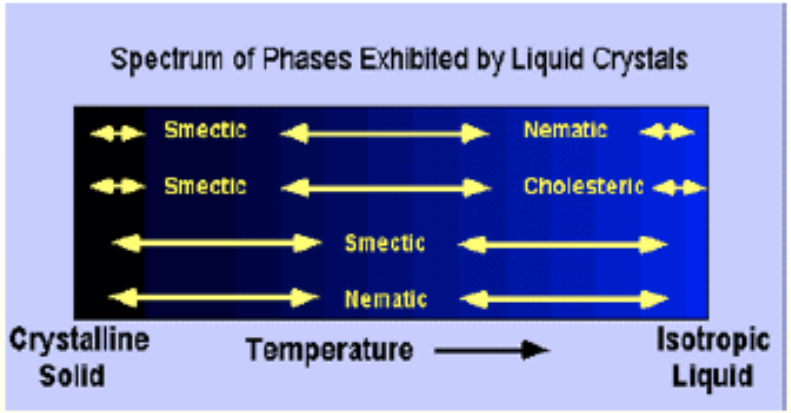
Phasenübergänge in LCs



Higher symmetry: decreasing order

I - isotropic liquid

N - nematic

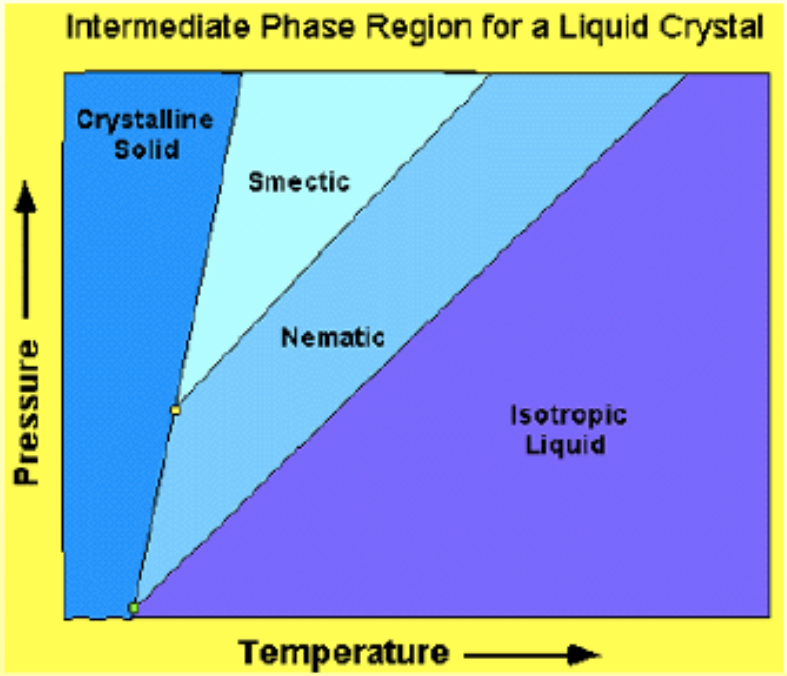
N^A - chiral nematic (formally Ch for cholesteric)

A F
C G
C* H
B
E
— smectics

K - crystals

K_1 - highest temperature crystals

K_2 - second highest temperature crystals

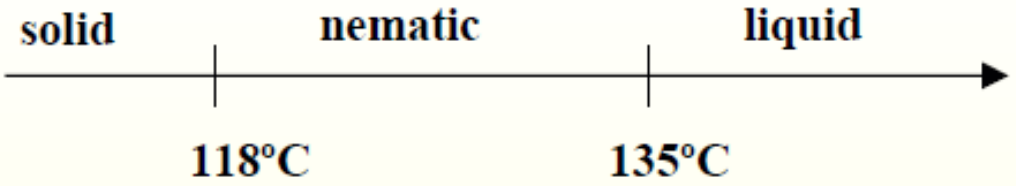


K-H-S_K-E-G-J-L-F-S_I-B-C-A-N-I

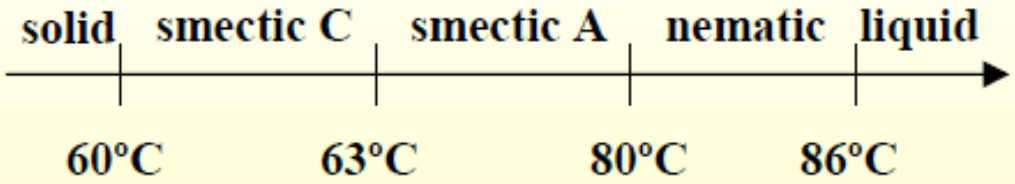
decreasing order

Phase transitions

PAA, p-azoxyanisole

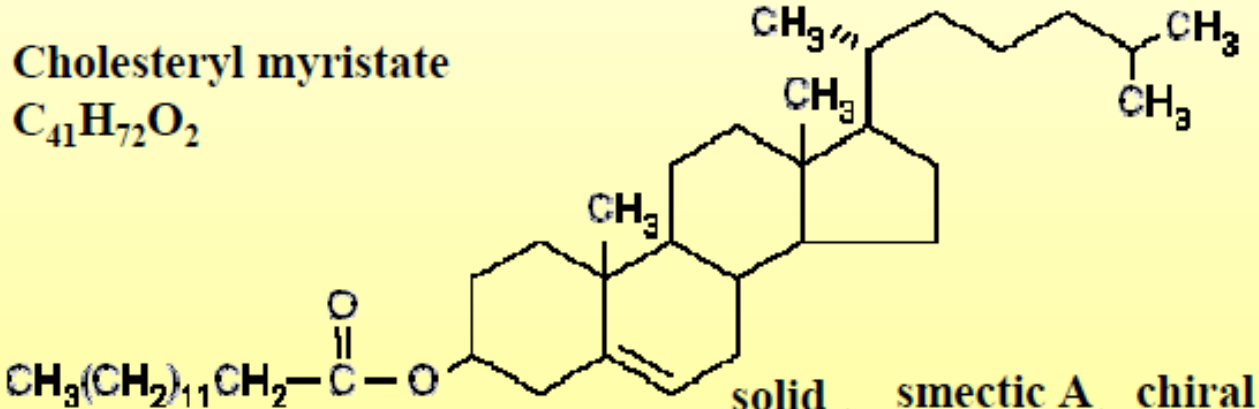


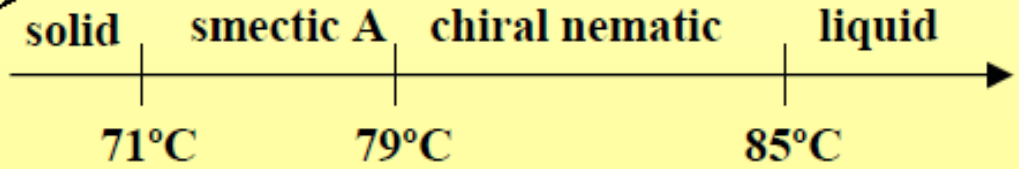
4-n-pentylbenzen-4'-n-decyloxybenzoate



Cholesteryl myristate

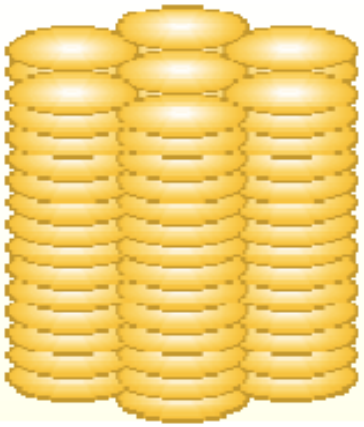
$C_{41}H_{72}O_2$



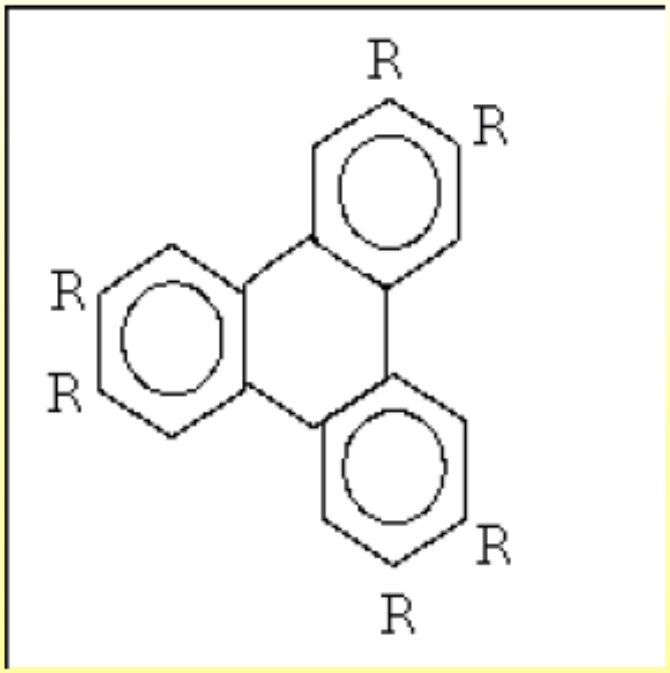


Kolumnare Phase

Discotic phases



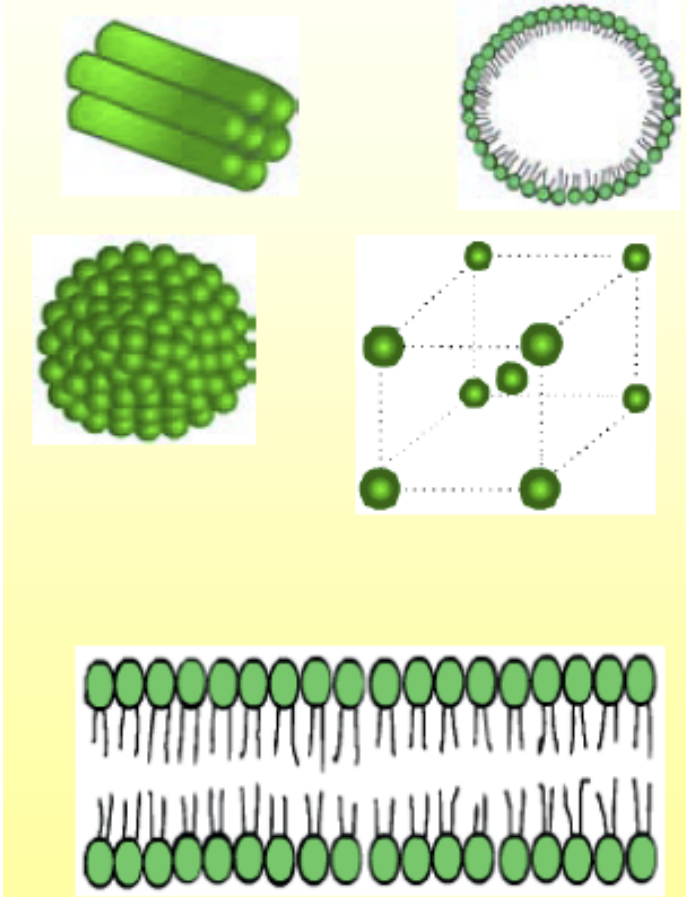
Disc-shaped molecules
Columnar organized liquid crystals
Nematic or smecic organization

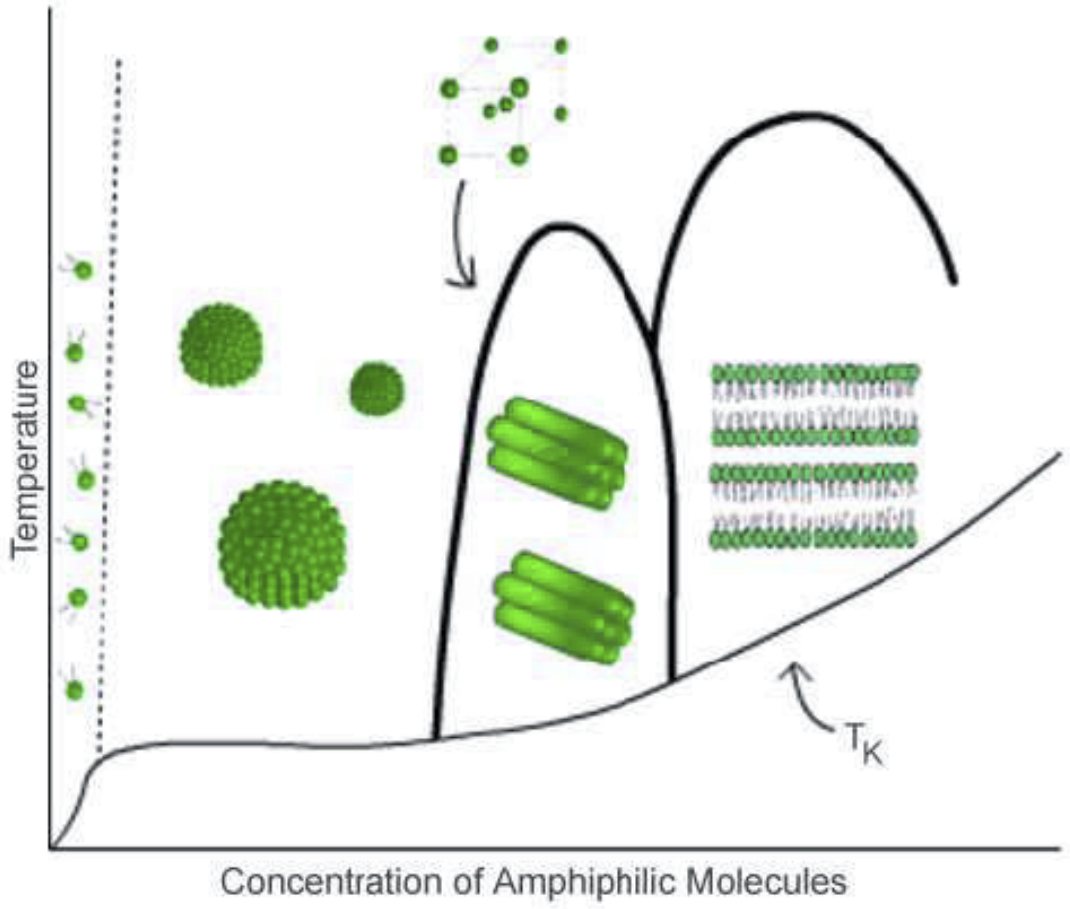


Lyotrophe LCs

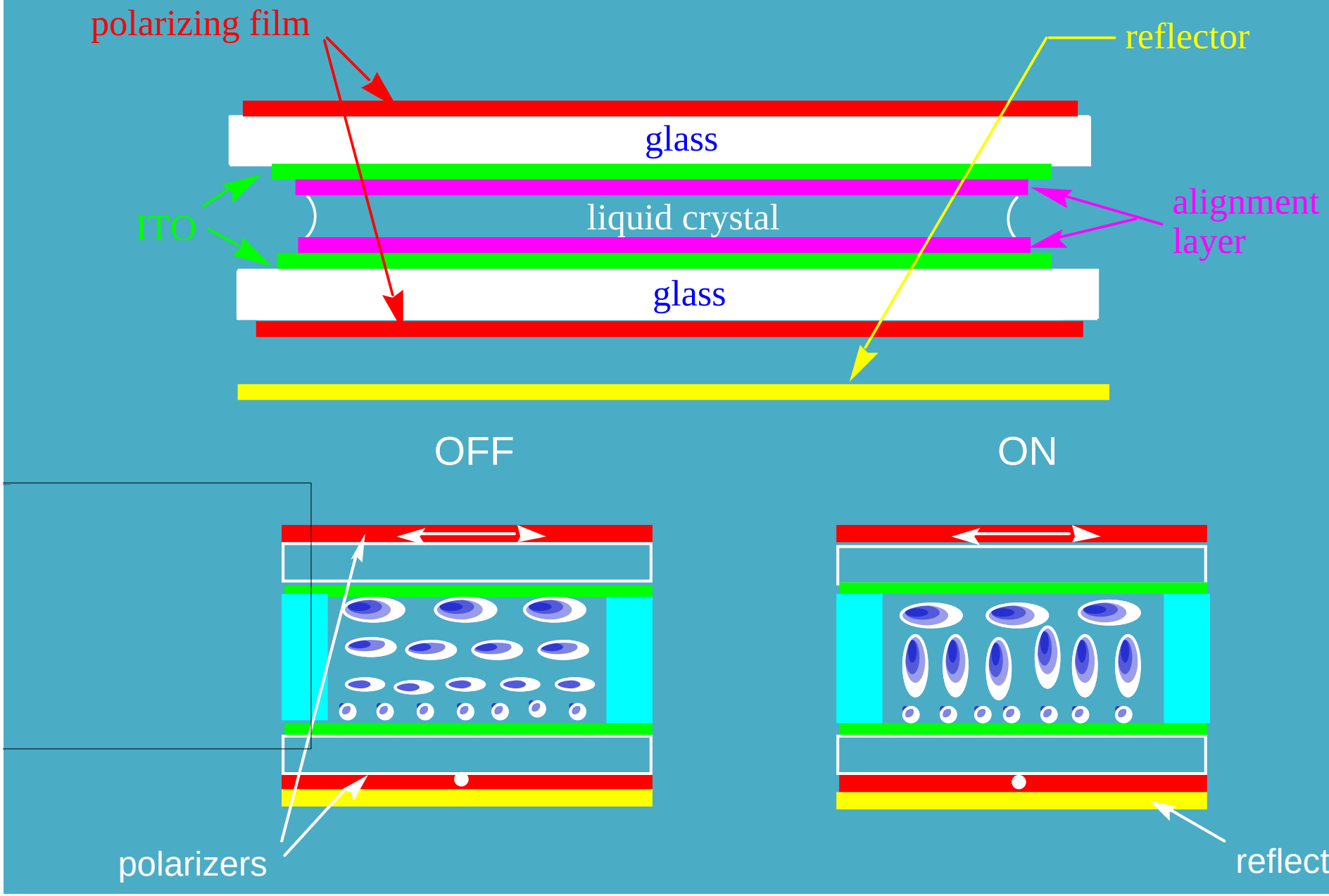
Lyotropic Liquid Crystals

Lyotropic liquid crystals are multi component systems formed in mixtures of amphiphilic molecules and a polar solvent. Amphiphilic molecules are consisted of a hydrophilic polar head attached to a hydrophobic hydrocarbon tail containing one or two alkyl chains.

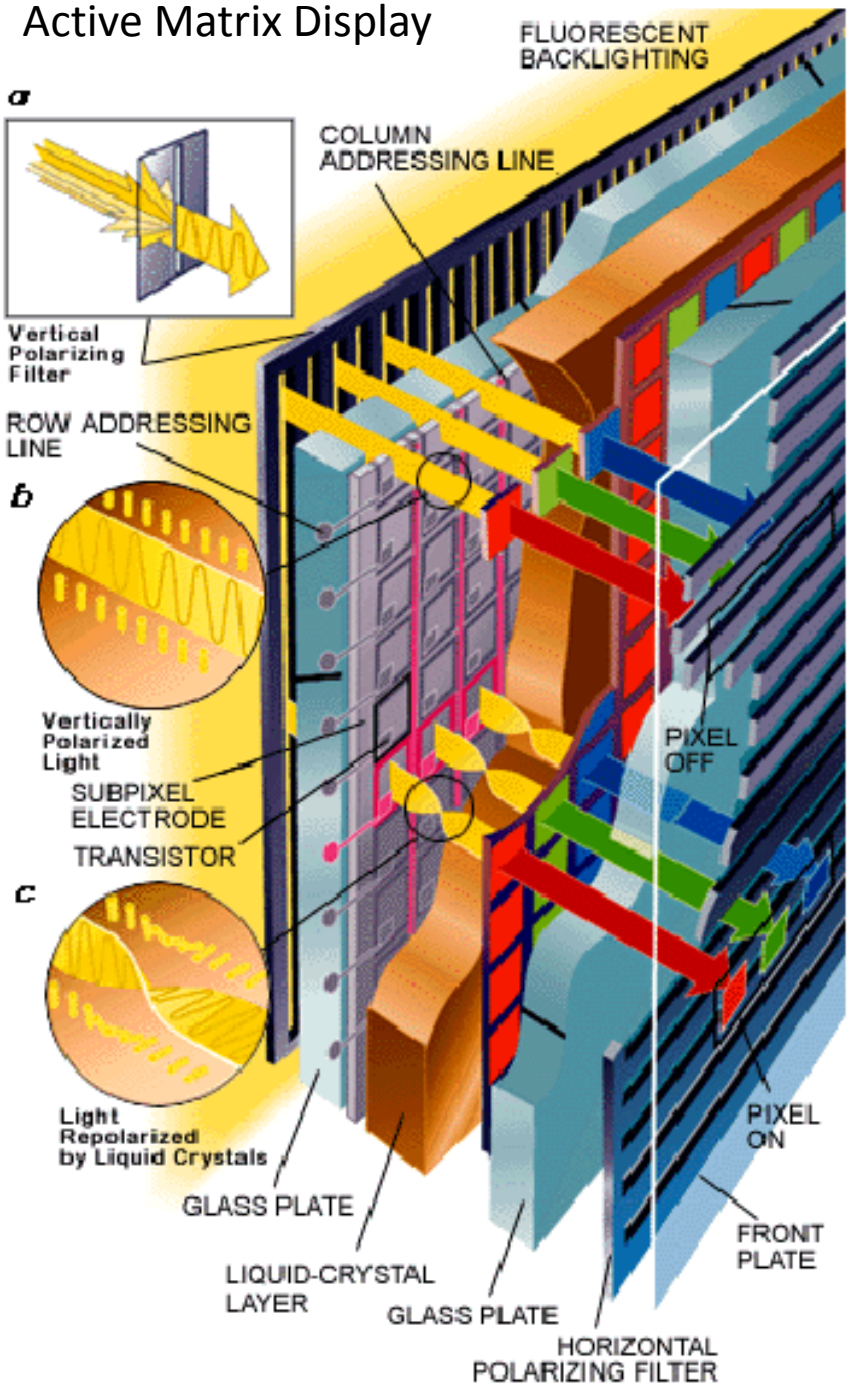




Twisted nematische LC Displays



Active Matrix Display



Twisted (TN-LCD)vs. Super twisted (STN-LCD)