

CHEMICAL PHYSICS

Chameleon compounds

Liquid crystals react to tiny temperature variations by striking color changes

by Ann Ewing

Photos: Liquid Crystal Institute

A nematic liquid begins to form tiny globules (top) as it is cooled below a sharp threshold value.

When the First International Liquid Crystal Conference was held in Kent, Ohio, three years ago, there were fewer than 100 scientists present. The second such conference, also in Kent, in mid-August, drew 225 scientists from 11 countries; the 80-year-old discipline seems to be growing up.

When Dr. A. S. C. Lawrence of Sheffield University, who attended the original international meeting on liquid crystals in 1933, was asked what he thought of the 1968 meeting, the British scientist replied: "Dammed good—it couldn't have happened five years ago."

A liquid crystal is not the contradiction in terms it might seem. It is exactly what it says—a compound that exhibits both the fluid characteristics of a liquid and the optical properties of a crystal.

All of those known so far are organic compounds. They are not rare; about one in 200 organic compounds is a liquid crystal, and there are thousands upon thousands of organic compounds.

The most striking feature of liquid crystals is the series of vivid color changes they undergo with even very slight variations in temperature. This has made them extremely valuable both



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Dr. Lawrence (left) and Dr. Hans Zocher of Brazil discuss crystal research.

for many kinds of medical research and for an increasing number of industrial applications.

Current uses include charting the effects of nerve-blocking drugs, diagnosing cancer, mapping the flow patterns of airframes in wind tunnels and developing color television that can be viewed in direct sunlight.

Liquid crystals were first observed in 1888 by the Austrian botanist Friedrich Reinitzer, who noted that there were two distinct melting points for one organic compound, cholesteryl benzoate. At 145 degrees C. the solid turned to a cloudy liquid; at 179 degrees the liquid became clear.

A German physicist shortly there-

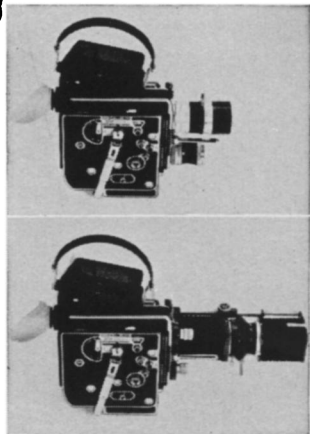
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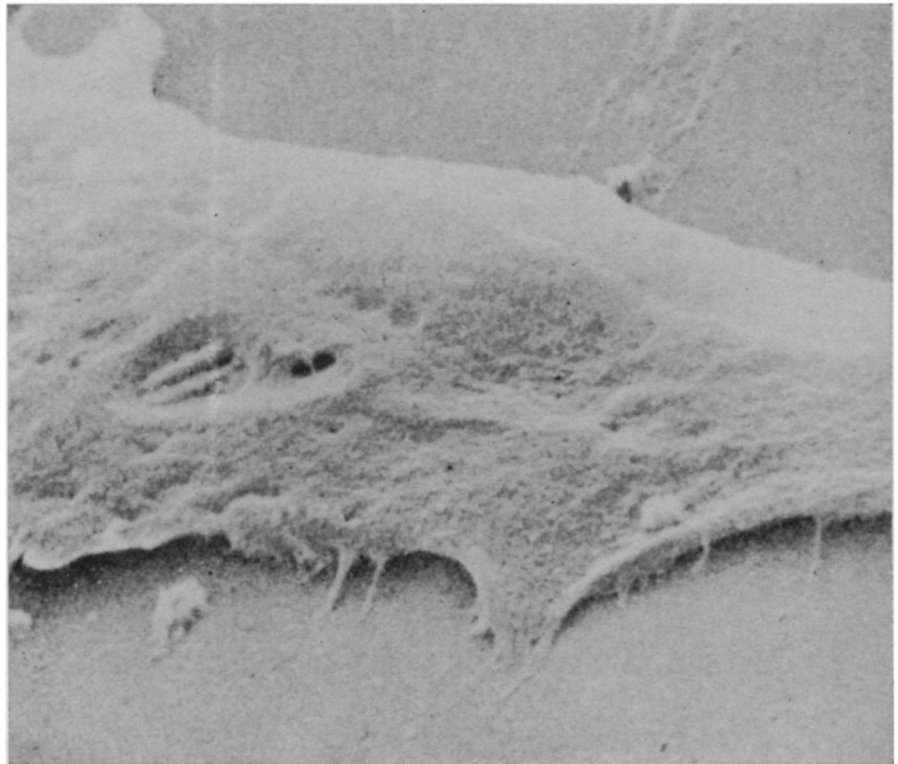


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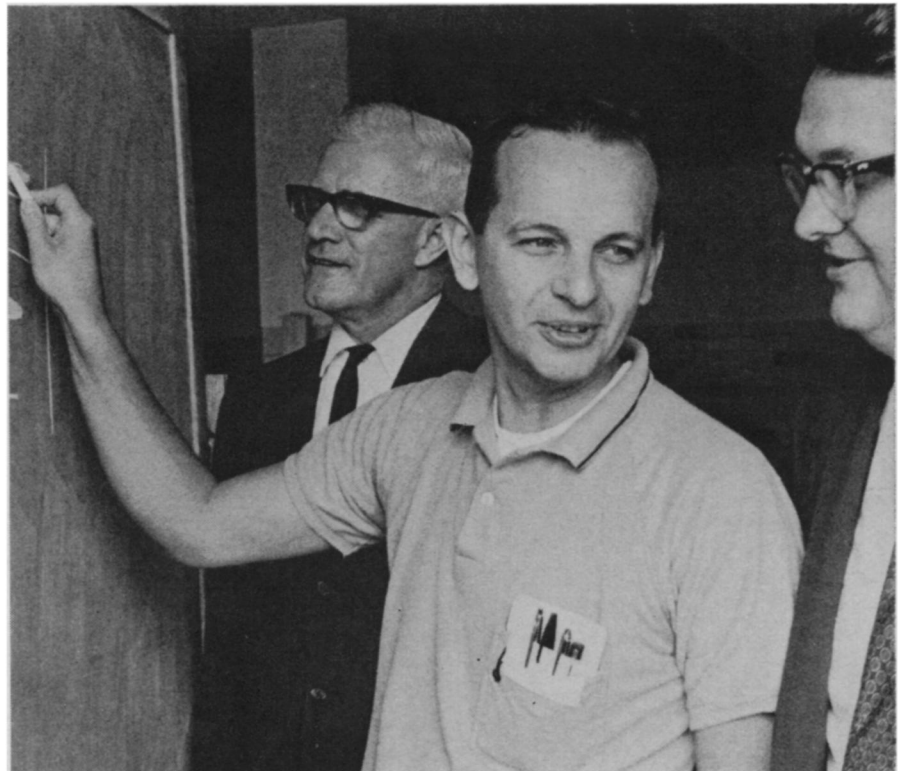
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Dr. E. J. Ambrose

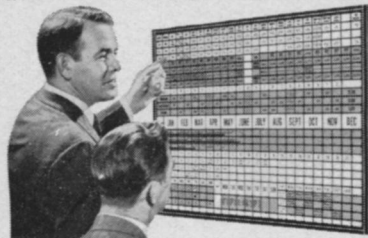
Wave-like motion of cancerous surface membrane, magnified 3,000 times.

Dr. Heilmeyer sketches host-guest interaction for Drs. Brown (left) and Ferguson.



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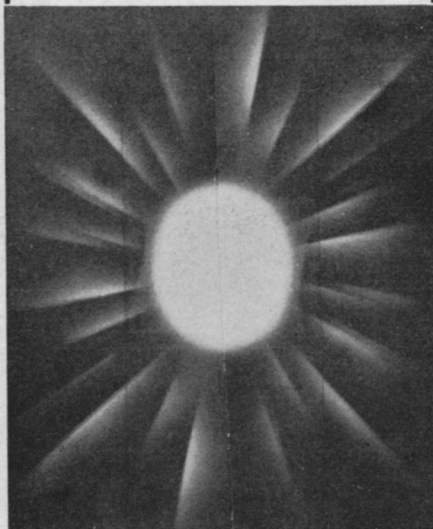
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after found that the cloudy phase contained areas that seemed to have a crystal-like structure. He suggested the name liquid crystal; arguments have followed, but the name stays on.

Research on liquid crystals continued until the early 1930's, when interest began to dwindle. One reason was the apparent belief that all important problems in this area had been solved; another was the seeming lack of practical applications.

There was a renewal of interest in liquid crystals in the late 1950's.

Exactly who sparked this revival and precisely when is an area of some disagreement among the experts, who nevertheless agree in giving credit to Dr. Glenn H. Brown and Dr. James L. Ferguson, now director and associate director, respectively, of Kent State University's Liquid Crystal Institute.

In the **U.S.S.R.**, a group headed by Dr. I. G. Chistyakov of the Pedagogical Institute at Iwanowo undertook a comprehensive study of liquid crystals in the early 1960's.

Because other Europeans are also very active in studying liquid crystals, the next international conference may be held in Europe. The problem with that is money, since much of the financing for both Kent State conferences has come from American industry.

Whether European firms will give equivalent support will be investigated by a planning committee. Its members will have to work quickly, since the growth of interest in liquid crystals is high; the next conference will be held within two years instead of three.

Liquid crystals come in three varie-

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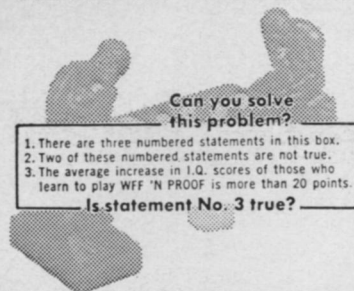
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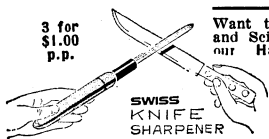
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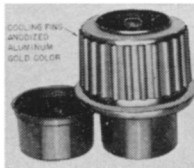
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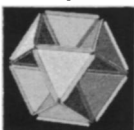
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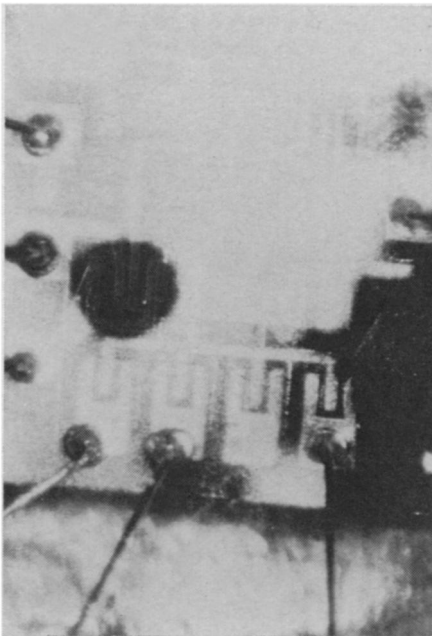
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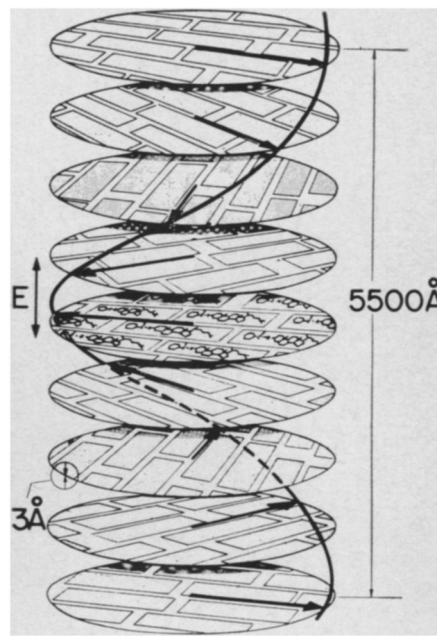


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Cholesteric liquid crystal's helix.

ties, based on a system devised in 1922. One is called nematic, from the Greek word for thread. Molecules in a nematic liquid crystal are arranged much like pencils in a long box—they can roll back and forth or slip lengthwise while remaining completely parallel to each other.

Another class is called smectic, from the Greek word for soap. In these compounds, the molecules are arranged in neat rows, comparable to a field of corn. A common example of a smectic liquid crystal is the layers forming the inner and outer surfaces of a soap bubble.

The third type, known as cholesteric, has a molecular structure characteristic of a large number of compounds containing cholesterol, which does not have a liquid crystal phase by itself. Cholesteric liquid crystals are packed like the nematic, with the long axes parallel; their direction, however, is displaced slightly in adjacent layers, the overall effect is that of a helical path.

Most cholesteric substances are colorless as liquids. When cooled through their liquid crystal phase, they undergo a series of bright color changes. The rate of change from color to color, as well as the exact temperature at which specific color changes occur, are invariable for any given compound.

Mixtures of these materials have, therefore, found application for measuring surface temperatures, as well as temperature variations. This property is the basis for nondestructive testing of such industrial equipment as metal castings, semiconducting devices, printed circuit

assemblies and other items in which flaws produce differential heat flow.

It is also the basis on which doctors at the University of Washington School of Medicine, working with researchers from the Boeing Co., are using liquid crystals to evaluate blood circulation following surgery to relieve chronic pain, according to Boeing's Dr. Wayne Woodmansee. They hope to determine if blood circulation improves following surgery.

Pain arising from various kinds of spasms can often be relieved by blocking the sympathetic nervous system. This block is followed by dilatation of those vessels whose nerve supply has been cut off. If circulation is not improved, amputation may be necessary.

Changes in the temperatures of neurological and vascular pathways are accurately reflected by color variations in liquid crystals painted on the skin; the higher the blood flow, the warmer the skin.

The ability of liquid crystals to reflect very small temperature changes in the human body is also being used in cancer research at Roswell Park Memorial Hospital in Buffalo, N.Y., to determine whether tumors are malign.

Areas of suspected cancer are coated with carbon black, then covered with a layer of liquid crystals, says Dr. James F. Holland. Warmer regions, indicating malignancy, appear blue; benign tumors appear reddish. By prepainting the suspected areas, surgeons can determine exactly where surgery should be performed.

Changes in the colors of liquid

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crystals coated on airframes in wind tunnels give "detailed and subtle observations not possible with conventional techniques," says Dr. Enrique J. Klein of the National Aeronautics and Space Administration's Ames Research Center at Moffett Field, Calif. His studies have shown that the "entire surface can be considered to be instrumented, not just a number of preselected points."

Dr. E. J. Ambrose of the Chester Beatty Research Institute in London points out that a living cell requires stability combined with mobility, which can be wavelike at the cell surface (SN: 8/31, p. 215), for living processes to take place. Liquid crystalline structure, he believes, contributes to the stability. The aim of research at the Institute is to prevent the alteration of cell membranes that results in cancerous growth.

The search by scientists at RCA Laboratories in Princeton, N.J., for new commercial uses is described by Dr. George H. Heilmeyer, who directs the effort; it includes the alignment of guest dyes in a host liquid (SN: 8/31, p. 215). This is still very early in its research stage.

But another use is much further along, though RCA scientists will admit only that a new electro-optic effect, called dynamic scattering, is in the model stage. Its widespread possible uses were highly publicized by RCA last May, but not until the meeting did liquid crystal experts have a chance to check on many of the details. The consensus: interesting, but we would like more specifics. RCA is protecting its patent rights, so many technical questions remain unanswered.

What the RCA scientists have found is that nematic liquid crystals can be made opalescent and, therefore reflecting, by the application of an electric voltage. The temperature range over which this occurs is from below freezing to the boiling point of water, for the substance anisylidene para-amino-phenylacetate (SN: 6/22, p. 598).

Liquid crystals also offer a solution to the problem of detecting imperfections in micro-electronic circuits, some of which have densities of some 20,000 elements per square centimeter. The entire integrated circuit can be sprayed with the appropriate mixture of organic compounds, depending upon the temperature sensitivity desired. When an electric current is applied, defective components show color differential.

Such testing can be carried out in the factory, then repeated by a serviceman in the home. This application of liquid crystals (SN: 8/31, p. 215) was outlined to the conference by Dr. G. V. Lukianoff of International Business Machines Corp.



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