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Julius Planer. A pioneer in the study of liquid crystals

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ABSTRACT

This article based on the archival documents and scientific periodicals, for the first time reveals a discoverer of so called transitional phase of the substance from the solid state to liquid – the liquid crystals. This fundamental discovery has been made by the Austrian scientist Julius Planer at the Lviv University in 1861.

The physics of liquid crystals is still a quite young branch of science. But the use of its achievements has made a revolution in industrial processes, thus turning unimaginable ideas into reality [1].

Nowadays liquid crystals are used widely for displaying information (clocks, electronic notetakers, calculators, TV), in the radio engineering, laser technologies, holography, medicine, pharmacology, biology, chemistry, engineering etc. Extensive information on liquid crystals has been obtained, but they still remain mysterious, probably because of their incomprehensible and to a certain extent inconsistent name.

Indeed, liquid crystals exhibit properties of both solid and liquid. They represent a unique mesomorphic (from the Greek language "*mesos*" as intermediate, transitional) phase of substance, which is generally called "*liquid crystalline*" by the scientists.

The fundamental property of liquid crystals is orientational degree of freedom of anisometric constituent molecules that defines the macroscopic order of long axes in space, which stipulates anisotropy of physical properties of liquid crystals. This causes unique characteristics of the ordered structure sensitive to external influences (temperature, pressure, electric and magnetic field etc.).

The history of the discovery of the liquid-crystal state goes back a century and a half, though most of monographs and reviews on this topic consider a much shorter period of time. Today it is hard to find any other epochal discovery in the history of science that would have had such difficult way to the recognition and practical application. Traditionally, the history of science considers that the priority of this discovery belongs to the Austrian botanist Friedrich Reinitzer and the German crystallographer Otto Lehmann from the Rhenish-Westphalian Technical University in Aachen.

It is worth saying that Otto Lehmann was a student of the prominent physicist August Kundt from the Strasbourg University, who also taught the Ukrainian physicist and electrician Ivan Puluj and the Russian physicist and experimentalist Piotr Lebedev.

Reinitzer, working as an assistant to Professor Weiss in the Institute of Plant Physiology at the German Technical University in Prague, studied derivatives of cholesterol, including the ester of cholesterol and benzoic acid cholesteryl benzoate. He unexpectedly discovered that this compound had two melting points and a transitional phase between solid and transparent liquid - a so-called opacification phase. This phase strongly scattered incident light. He also observed changes in bright colours of the melted substance during the thermocycles of heating–cooling. The results of these experiments were published in 1888 in the Austrian monthly magazine "Monatshefte für Chemie" [2].

Reinitzer did not manage to explain new effects by himself and applied for assistance to the German physicist Otto Lehmann. Lehmann, using a polarizing microscope which he had upgraded himself, discovered that the transitional phase had a crystal-like structure because the substance in this phase was anisotropic (from the Greek word "*anisos*" - unequal). In fact, anisotropy in the physics of crystals is an inequality of mechanical, optical, thermal and other physical properties of the substance in different directions. Since anisotropy is a typical feature of the solid crystal and the substance in the opasification phase was liquid, the scientist proposed a term "*the liquid crystal*" [3].

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But even after those publications scientists did not acknowledge liquid crystals for a long period of time because even the fact of their existence could destroy the theory generally accepted at that time about three aggregate states of the substance: solid, liquid, and gaseous. That was the reason why the epochal finding of Reinitzer could not find its practical application for a long time. For the sake of justice, it is worth mentioning that both Friedrich Reinitzer and Otto Lehmann cited in their publications works of Julius Planer (Fig. 1), a Professor of Anatomy at the Lviv University, who in 1861 observed and scientifically described an optical effect that lately became the characteristic property of the liquid-crystal state of the substance [4].

What did Planer observe and describe in his article? And how does the modern science explain that effect? [5].

Planer, examining characteristics of cholesteryl chloride (another cholesterol-derived compound) under a microscope, observed its unique optical characteristics and noted: "*Cholesterol chloride melts approximately at the boiling point and its melted crystals in the process of cooling demonstrate bright violet colour under the incident light and yellow-green in the transitional phase*".

As it is known now, cholesterol chloride is a classic representative of the cholesteric liquid crystals (or of the cholesteric mesophase). The structure of the cholesteric has a helical axis of symmetry, and the asymmetric (chiral) structure of molecules in this mesophase causes its special optical characteristics.

The work of Planer is considered to be the first documentary scientific observation of physical properties of thermotropic cholesteric liquid crystals and their transition phase. Due to Planer's discovery, the history of studies of the liquid crystals has begun from cholesterol [6].

The theoretic explanations of colour changes in liquid crystals, or, in other words, of selective reflection of light by the planar structure of the cholesteric liquid-crystal phase, were first made by Mauguin [7] and further developed by de Vries, the French physicist, almost a century (in 1951) after experiments of Planer. Later, in 1963, James Ferguson from the US, on the basis of this most important property of the liquid crystals to change colour with the application of temperature, recorded the invisible to the human eye thermal infrared rays. After he had patented this discovery (U.S. Patent № 3,114,836), the interest to liquid crystals expanded dramatically. In 1991 Pierre-Gilles de Gennes, the French theoretical physicist was awarded the Nobel Prize in Physics "*for discovering that methods developed for studying order phenomena in simple systems can be generalized to more complex forms of matter, in particular to liquid crystals and polymers*".

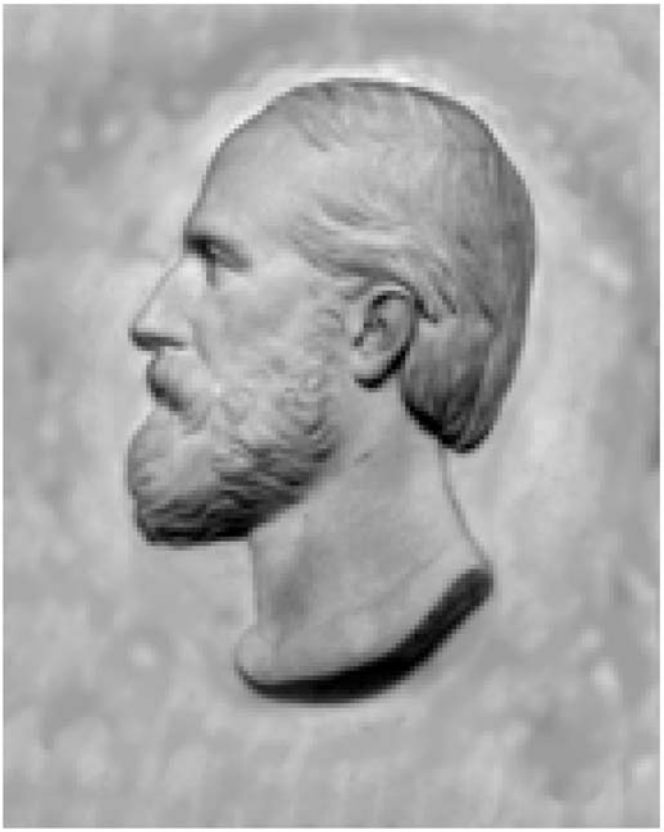

Fig. 1. Bas-relief portrait of Julius Planer (13.08.1827–25.07.1881).

The phenomenon of colour changes of cholesterics caused by changes in temperature, apart from Planer and prior to Reinitzer, was also observed by two other scientists. In 1872 Wilhelm Loebisch, a chemist and a physician, working in the Vienna chemical laboratory of the famous Professor Glazivetz, synthesized cholesterylamine and described its colour changes at 104 degrees Celsius from colourless to bluish-violet. He also informed about the same effect with cholesterylchloride [8]. Finally in 1887, on the eve of the known experiments of Reinitzer, Boguslaw Raymann, a chemist and the then Associate Professor at the Czech Technical University, while synthesizing cholesterylacetate and cholesterylchloride, also observed colour changes of these chemical agents from green to reddish-orange during their melting-cooling cycles [9].

Reinitzer in his famous publications made references to works and commented experimental observations of Planer, Loebisch and Raymann. It is an interesting fact that all four scientists, involved into the mentioned discovery, were citizens and worked at the Universities of the Austrian (later the Austro-Hungarian) empire in the medical and biological spheres.

At the end of XX – at the beginning of XXI century there were efforts in serious scientific monographs on liquid crystals to restore historical justice of the discoverer of liquid crystals. In 2005 the French scientists P. Oswald and P. Pieranski issued a monograph (618 pages) where they acknowledged the priority of Planer, together with Reinitzer, in the discovery of liquid crystals: "*The biologist Planer in 1861 and Reinitzer in 1888 noticed opaqueness of cholesterol and its iridescent colours…*" [10].

Another scientific monograph published in 1996 admits the fact of discovering liquid crystals by Planer: "*The discovery of liquid crystals (Planer 1861 [4]; Reinitzer [2]) and one of their first applications – the use of encapsulated cholesteric liquid crystals in thermometers (Jones [11]; McDonnell [12]) - were due to this phenomenon*" [13]. Authors of a book [14] issued in 2001 write: "*Probably even the first observation of liquid crystals by Planer (1861) [4] and Reinitzer [2] were due to the conspicuous selective reflection of the helical structure that occurs in chiral liquid crystals*". The name of Planer has been also mentioned in scientific studies of Ukrainian and Russian researchers [5,6,15,16].

Archival documents stored at the State archive of the Lviv oblast and at the Rare books Department of the Scientific Library of the Ivan Franko Lviv National University, allowed us to review for the first time a life and scientific career of Julius Planer in the Ukrainian territories.

Planer was born on August 13th 1827 in Doebling, a modern prestigious district of Vienna. In 1845–49 he studied at the Medical Department of the famous University of Vienna. During 1850–1854 he worked in Vienna as a first assistant to the world-known Austrian scientist and physician Carl von Rokitansky (the latter released a "*revolution*" in medicine by making morbid anatomy a basis of pathology and scientific medicine; established the New medical school in Vienna). Planer, being a young-aged man, received the degree of Professor in Anatomy and Physiology in 1851. He published well-known scientific studies [16] in the sphere of relations between pigmentation (changes of colour and emergence of pigment granules) of the human blood and different severe diseases; he also practically studied human anatomy in a municipal morgue. At that time medical scientific circles ascertained achievements of the young explorer. His name was ranked in the medical literature with famous German and Austrian pathologists Johann Meckel (a pioneer of teratology that deals with birth defects and human embryonic abnormalities), Alexander Ecker (discovered and

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