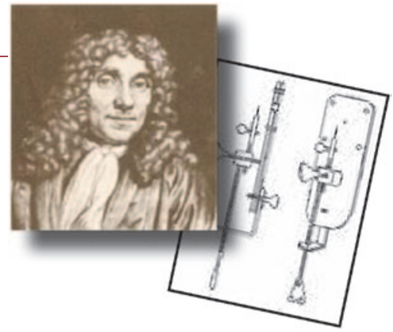

Pioneers in Optics: Pavel Alekseyevich Cherenkov and John Frederick William Herschel

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Pavel Alekseyevich Cherenkov (1904–1990)

The son of Russian peasants, Pavel Cherenkov faced a significant amount of adversity in his life, but he persevered admirably. He was born in the village of Novaya Chigla in the Vornezh province and grew up in a tumultuous time when Russia was engaged in war and revolution. At the age of two, Cherenkov lost his mother, and his father soon remarried, consigning much of his and his sister's upbringing to a stepmother. Later in his life, in 1938, he would also prematurely lose his father, who was killed under Stalin's regime for political reasons. As a child, Cherenkov reportedly exhibited a curious nature, was an avid reader, and performed well in school. In college, he studied mathematics and physics, graduating in 1928 from Vornezh University. Subsequently, in 1930, he married Marya Putintseva, with whom he would have two children. He relocated to Leningrad (now known as St. Petersburg) to embark on postgraduate research at the P.N. Lebedev Institute of Physics in the Academy of Sciences.

Cherenkov's initial postgraduate work in optics was supervised by Sergei Vavilov. However, the primary topic of his original research was of diminished interest by 1934 due to a weak blue background light that interfered with his studies. When he first discovered this light, it was emitted from a bottle of water subjected to radioactive bombardment. The unusual optical phenomenon, which fascinated Cherenkov to such an extent that he spent six years of his life characterizing it, is now known as the Cherenkov effect and is perhaps most familiar to the general public as a bluish glow signifying radioactive material in movies. The Cherenkov effect occurs when charged particles move at speeds greater than the speed of light, causing a portion of the energy to be emitted as a kind of electromagnetic radiation termed Cherenkov radiation. This scenario is made possible by the fact that light travels more slowly through a transparent medium than it does in a vacuum, so that in air, water, and certain other substances, elementary particles may surpass the velocity of light in that medium.

Although early on Cherenkov's devoted study to the optical effect and special form of electromagnetic radiation that now bear his name was derided by some of his colleagues who believed it to be a pointless endeavor, in time the utility of the strange bluish glow would become apparent. Today, the Cherenkov effect is considered invaluable to the field of spectroscopy, as well as to the study of cosmic rays and other high-speed particles. Cherenkov counters, which are specialized instruments that can measure particle velocity by using the light emitted by Cherenkov radiation, have garnered widespread use by experimental scientists studying particle and nuclear physics. Devices known as DIRC-counters (detection of internally reflected Cherenkov light), which measure the angle (termed the Cherenkov angle) from which Cherenkov radiation can be observed with respect to the fast-moving charged particle that causes its release, are also commonly used for physics research.

In 1958, Pavel Cherenkov was awarded the Nobel Prize in Physics for his discovery and characterization of the Cherenkov effect. He shared that year's prize with Ilya Frank and Igor Tamm, the physicists who developed the theoretical explanation of the optical effect. The following year, Cherenkov was rendered full control of the photo-meson processes laboratory at the Lebedev Institute, where he had already gained his doctorate (1940) and been appointed as a full professor of experimental physics (1953). By the time of his death in 1990, Cherenkov had enjoyed a long and successful career that spanned six decades at the institute.

John Frederick William Herschel (1792–1871)

John Herschel was born in Slough, England on March 7, 1792, the only child of renowned scientist and astronomer William Herschel. He received an excellent education, and while studying for his undergraduate degree in mathematics, he instituted the Analytical Society of Cambridge in conjunction with George Peacock and Charles Babbage. The group introduced Leibniz notation into English mathematics to supplant the unwieldy Newtonian symbols. When Herschel graduated from Cambridge in 1813, he was at the top of his class.

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Herschel began to study in London for a career in law in 1814 but changed his mind within a year. He then returned to Cambridge for a brief stint as a teacher of mathematics but left in 1816 to assist in the astronomical research of his aging father. The years they spent working together served as the groundwork from which the younger Herschel would build the rest of his career. In 1820, Herschel was one of the founding members of the Royal Astronomical Society, and when his father died in 1822 he carried on his work, making a detailed study of double stars. In collaboration with James South, he compiled a catalog of observations that was published in 1824. The work garnered the pair the Gold Medal from the Royal Astronomical Society and the Lalande Prize from the Paris Academy of Sciences. Herschel was knighted 1831.

In 1833, Herschel decided to temporarily relocate with his family to Cape Colony, South Africa, in order to observe the skies not visible in England. Herschel's research was carried out at a brisk rate, and by the time they ventured home four years later, he had amassed an amazing amount of data. He had made catalogs of nebulae and double stars, had described the Magellanic clouds, which are only visible in the southern hemisphere, and had made a study of the intensity of solar radiation using an actinometer, a device he invented in 1825.

Upon his return to England, Herschel began analyzing the data he had compiled in Africa, but he also experimented in photography, a field he had made advances in previously. A skilled chemist, Herschel had discovered in 1819 the solvent power of sodium hyposulfite on otherwise insoluble silver salts, which was the prelude to it being used as a fixing agent in photography. In 1839, he developed a technique for creating photographs on sensitized paper, independently of William Fox Talbot, but did not attempt to commercialize the process. However, Herschel published several papers on photographic processes and was the first to use the terms "positive" and "negative" in reference to photography.

During the following decade, Herschel carried on a number of different projects. Expanding on the work of his father, he researched infrared light, discovering in 1840 the existence of Fraunhofer lines within that spectral region. He also wrote a popular laymen's guide to astronomy, which was published in 1849, and released a volume at the Cape of Good Hope in 1847 entitled *Results of Astronomical Observations, Made During the Years 1834–38*.

Particularly important to the future of science, in 1845 Herschel reported the first observation of the fluorescence of a quinine solution in sunlight. The following is an excerpt of his findings as presented to the Royal Society of London:

"The sulphate of quinine is well known to be of extremely sparing solubility in water. It is however easily and copiously soluble in tartaric acid. Equal weights of the sulphate and of crystallized tartaric acid, rubbed together with addition of a very little water, dissolve entirely and immediately. It is this solution, largely diluted, which exhibits the optical phenomenon in question. Though perfectly transparent and colorless when held between the eye and the light, or a white object, it yet exhibits in certain aspects, and under certain incidences of the light, an extremely vivid and beautiful celestial blue colour, which, from the circumstances of its occurrence, would seem to originate in those strata which the light first penetrates in entering the liquid, and which, if not strictly superficial, at least exert their peculiar power of analyzing the incident rays and dispersing those which compose the tint in question, only through a very small depth within the medium.

"To see the colour in question to advantage, all that is requisite to dissolve the two ingredients above mentioned in equal proportions, in about a hundred times their joint weight of water, and having filtered the solution, pour it into a tall narrow cylindrical glass vessel or test tube, which is to be set upright on a dark colored substance before an open window exposed to strong daylight or sunshine, but with no cross lights, or any strong reflected light from behind. If we look down perpendicularly into the vessel so that the visual ray shall graze the internal surface of the glass through a great part of its depth, the whole of that surface of the liquid on which the first light strikes will appear of a lively blue …

"If the liquid be poured into another vessel, the descending stream gleams internally from all its undulating inequalities, with the same lively yet delicate blue colour, … thus clearly demonstrating that contact with a denser medium has no share in producing this singular phenomenon.

"The thinnest film of the liquid seems quite as effective in producing this superficial colour as a considerable thickness. For instance, if in pouring it from one glass into another, … the end of the funnel be made to touch the internal surface of the vessel well moistened, so as to spread the descending stream over an extensive surface, the intensity of the colour is such that it is almost impossible to avoid supposing that we have a highly colored liquid under our view."

In a footnote to the report Herschel points out that he was writing from memory, having carried out the experiment more than twenty years before. Nevertheless, his reminiscence was enough to spark further exploration, eventually resulting in the modern understanding of fluorescence. In fact, even today, quinine is one of the most commonly used fluorophores for spectroscopy, enjoyed by many for the strange but beautiful fluorescence that was first observed, but unable to be explained, by Herschel.

In 1850, Herschel's scientific work was put on hold when he was appointed Master of the Mint. Apparently unhappy in his new line of work, he suffered a nervous breakdown in 1854 and resigned from the position two years later. Herschel returned to his love of astronomy during his remaining years and continued to add to his catalogs of stars. When he died on May 11, 1871, he was appropriately buried in Westminster Abbey amid other distinguished scientists.

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