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An Anthology of Violet in Science

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A 19th-century mistake in synthesizing an antimalarial drug led to the first mass-produced violet dye and set off the commercial synthetic dye industry. Far after its last use nearly 3000 years ago, a purple pigment resurfaced when scientists discovered its peculiar magnetic and quantum behaviors. One type of purple bacteria thrives on toxic hydrogen sulfide and is used to treat contaminated wastewater. These are only a handful of the many faces that the color violet has worn across science history. From the dye industry to modern biochemical research and bioremediation, violet has been on an incredible adventure through scientific developments.

EARLY PIGMENTS

One of the earliest and most famous pigments is Tyrian purple, a biological pigment derived from sea snail secretions, which was discovered around 1000 BCE. The process of extracting the mucous was very laborious; since the snails that made it are only about three inches across, thousands of snails would produce only a small amount of dye. Later, people found other sources to create purple colorants. Han purple was developed after Tyrian purple and was also used primarily in the BCE years. As an early synthetic purple pigment, Han purple came not from living organisms, but was manufactured by reacting barium, copper, and silicon minerals with each other at very

Figure 1: Sea snail. *The sea snail Haustellum brandaris, one species from which people harvested Tyrian purple. Image licensed under CC BY-SA 3.0.*

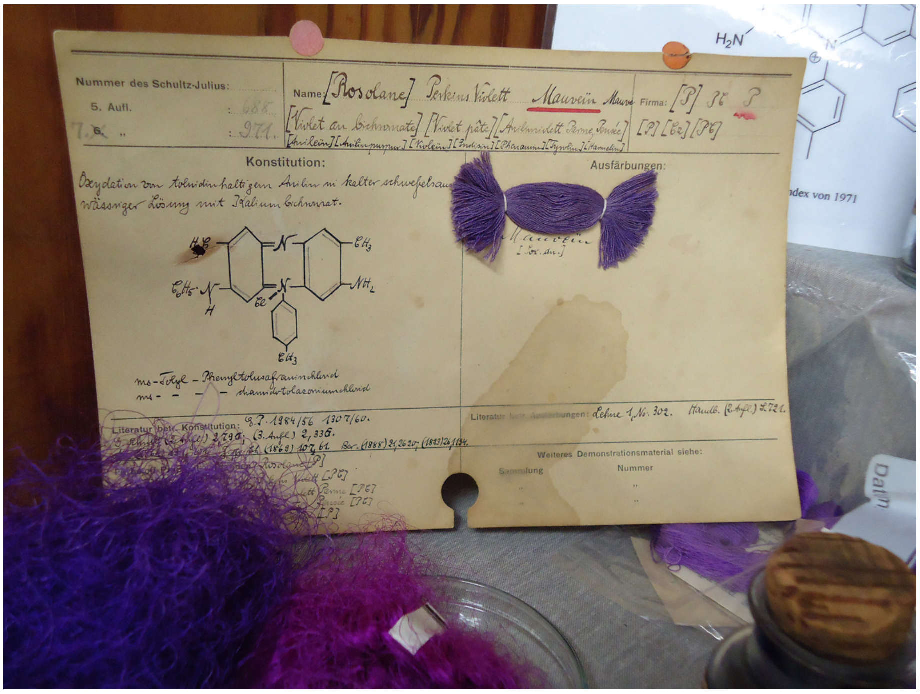


Figure 2: Mauveine sample. *Samples of mauveine alongside its chemical structure and descriptions at the Historial Dye Collection of the Technical University of Dresden. Image licensed under CC0 1.0.*

"Han purple's unusual magnetic behavior provides the first example of reduced dimensionality, which could illuminate the elusive behaviors of electrical resistance and magnetic fields."

high temperatures.

Both Tyrian and Han purples are early ancestors of the biological and synthetic colorings that were to come. They also characterize the serendipity of science well. Both pigments have unique, unexpected properties beyond their well-known associations with color. Tyrian purple is also a good semiconductor and can be used in circuits.[1] Han purple "loses a dimension" when placed in cold and magnetic conditions.[2] Researchers analogized this concept to a Rubik's cube. It is as if each layer of the cube acts independently, and the cube is reduced from a 3-D structure into separate 2-D layers. Han purple's unusual magnetic behavior provides the first example of reduced dimensionality, which could illuminate the elusive behaviors of electrical resistance and magnetic fields.

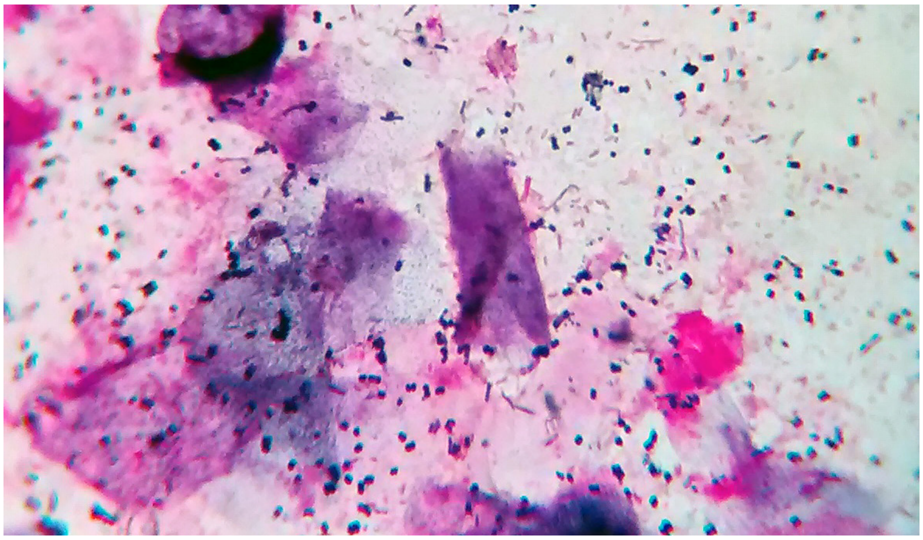
BEGINNINGS OF SYNTHETIC DYES: THE ANILINES

One violet colorant arose from an accident. The 19th century chemist William Perkin wanted to synthesize the antimalarial quinine, but failed.[3,4,5] Perkin's contemporaries valued quinine as a treatment for malaria and consumed it as a clear, bitter beverage called tonic water. Perkin was interested in finding a synthetic route to replace the process of extracting quinine from cinchona tree bark. He chose to work with anilines (a structural family of compounds with characteristic phenyl-amino pairings) because he thought they had similar chemical formulae to quinine.

Perkin's experiment produced a vibrant purple solution that looked nothing like quinine.[3,5] Undeterred, Perkin turned his supposed failure into a happy happenstance that launched the beginning of the mass-produced synthetic dye industry. Perkin's faulty antimalarial adhered well to cloth, looked appealing, and could be made with the then-common coal tar.

Practical, attractive, and scalable, Perkin's new dye had all the ingredients of a prosperous product. At this time, Tyrian purple was still the dominant violet colorant, and people were dissatisfied with the hassle

Figure 3: Crystal violet in action. *A sample of saliva stained with crystal violet and other reagents. Cells stained with crystal violet appear purple. Cells that did not retain crystal violet were colored with a pink counterstain. Image licensed under CC BY-SA 4.0.*



it took to produce a pinch of purple.[3,4,5] Perkin took advantage of this purple deficit and manufactured his new mauve dye at a commercial scale. Mauveine (also known as aniline purple) became enormously popular in the years after Perkin's discovery, and although it would fade from the public frenzy within a decade, the broader synthetic dye industry was climbing fast. Perkin tweaked his original recipe and produced safranin, pseudo-mauveine, and more derivatives. Fellow dye-makers propagated and expanded upon his methods, synthesizing a rainbow of new colors.

Aniline dyes eventually expanded from staining fabric to staining cells. The most famous aniline in molecular biology is crystal violet. It stains DNA in a way such that ultraviolet light is not required for visualization.[6] It is also used to differentiate the gram positive and gram negative types of bacteria, which is critical for determining which antibiotics are useful against an infection. Safranin and fuchsine are two other aniline dyes that are used as a counterstain to crystal violet during Gram staining. Cells are first exposed to crystal violet, which is then washed out and replaced with either a safranin or fuchsine counterstain. Bacteria that have retained the purple crystal violet are deemed gram-positive, and the bacteria dyed pink by the counterstain are considered gram-negative. This procedure is fast and effective for classifying a large number of bacterial species.

Crystal violet has also been used to combat bacterial, fungal, and parasitic infections.[7] It is a popular alternative to penicillin and is still used to treat fungal infections, but like other members of its aniline family, it has enough carcinogenic properties that California's Proposition 65 has added crystal violet (under the name "gentian violet") to its list of potentially harmful substances.[8] The balance between crystal violet's abundant short-term benefits as a colorant and antiseptic and its serious long-term health risks still requires more research to establish.

BEYOND SYNTHETIC DYES, INTO THE ENVIRONMENT

Figure 4: Wastewater lagoon. *Wastewater lagoons often contain bacteria that metabolize manure under anaerobic conditions. Image licensed under CC BY-ND 2.0.*

Violets are abundant as dyes and stains, but they are also relevant in environmental remediation, particularly through a group of purple bacteria. Like many microbes, purple bacteria use photosynthesis to generate energy, just with a slight deviation. Unlike most photosynthetic organisms that use water and carbon dioxide to form sugar and oxygen, purple bacteria use sulfur, iron, or hydrogen in place of water due to the presence of bacteriochlorophylls (which also gives them their reddish-purple coloring).[9] Thus, purple bacteria find their niches in the salty, acidic, and warm habitats that other photosynthetic organisms would not survive in.

Purple sulfur bacteria, a category of purple bacteria, are especially valuable for their bioremediation capacities. When organic matter decomposes in an environment without oxygen, hydrogen sulfide usually forms. Hydrogen sulfide is an odorous, corrosive, flammable, and toxic gas often found in wastewater treatment lagoons. While most microbes shy away from sulfur-rich environments, it's the perfect setting for purple sulfur bacteria that abhor oxygen and require sulfur to photosynthesize.[9,10] They can take in hydrogen sulfide and methane, in turn releasing non-toxic substances. This is especially significant when animal manure is present in wastewater, because processing manure releases a buffet of harmful substances, including hydrogen sulfide and methane. Purple sulfur bacteria provide an optimistic solution to this type of environmental contamination.

CONCLUSION

From the textile industry to environmental remediation, violet has starred in a series of anecdotes that cast the color in chemical, biological, and physical filters. It has represented wealth and power, ignited an entire industry, revolutionized bacterial classification, and detoxified contaminated wastewater. While each violet anecdote remains in progress, together they have established an exciting foundation for new discoveries to reshape the scientific fields we are familiar with, and for the next stories about violet to emerge.

> "The balance between crystal violet's abundant short-term benefits as a colorant and antiseptic and its serious long-term health risks still requires more research to establish."

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REFERENCES

1. Glowacki, E. D., Leonat, L., Voss, G., Bodea, M., Bozkurt, Z., Ramil, A. M., Irimia-Vladu, M., Bauer, S., & Sariciftci, N. S. (2011). Ambipolar organic field effect transistors and inverters with the natural material Tyrian Purple. *AIP Advances*, *1*(4), Article 042132. https://doi.org/10.1063/1.3660358
2. Levy, D. (2006, June 2). 3-D insulator called Han Purple loses a dimension to enter magnetic 'Flatland.' *Stanford News*. https://news.stanford.edu/news/2006/june7/flat-060706.html
3. Cova, T. F. G. G., Pais A. A. C. C., & de Melo, J. S. S. (2017). Reconstructing the historical synthesis of mauveine from Perkin and Caro: Procedure and details. *Scientific Reports*, *7*, Article 6806. https://doi.org/10.1038/s41598-017-07239-z
4. Cartwright, R. A. (1983). Historical and modern epidemiological studies on populations exposed to N-substituted aryl compounds. *Environmental Health Perspectives*, *49*, 13–19. https://doi.org/10.1289/ehp.834913
5. Ball, P. (2006). Perkin, the mauve maker. *Nature*, *440*, 429. https://doi.org/10.1038/440429a
6. Yang, Y., Jung, D., Bai, D., Yoo, G., & Choi, J. (2001). Counterion-dye staining method for DNA in agarose gels using crystal violet and methyl orange. *Electrophoresis*, *22*(5), 855–859. https://doi.org/10.1002/1522-2683()22:5<855::AID-ELPS855>3.0.CO;2-Y
7. Maley, A. M. & Arbiser, J. L. (2013). Gentian Violet: A 19th century drug re-emerges in the 21st century. *Experimental Dermatology*, *22*(12), 775–780. https://doi.org/10.1111/exd.12257
8. Sun, M., Ricker, K., Osborne, G., Marder, M. E., & Schmitz, R. (2019). *Evidence on the carcinogenicity of Gentian Violet.* Office of Environmental Health Hazard Assessment, California Environmental Protection Agency. https://oehha.ca.gov/media/downloads/crnr/gentianviolethid011719.pdf
9. Vasiliadou I. A., Berná, A., Manchon, C., Melero, J. A., Martinez, F., Esteve-Nuñez, A., & Puyol1, D. (2018). Biological and bioelectrochemical systems for hydrogen production and carbon fixation using purple phototrophic bacteria. *Frontiers in Energy Research*, *6*, Article 107. https://doi.org/10.3389/fenrg.2018.00107
10. Hädicke, O., Grammel H., & Klamt S. (2011). Metabolic network modeling of redox balancing and biohydrogen production in purple nonsulfur bacteria. *BMC Systems Biology*, *5*, Article 150. https://doi.org/10.1186/1752-0509-5-150

IMAGE REFERENCES

11. *Banner*: Image created by author.
12. *Figure 1*: Violante, M. (2007). *Haustellum brandaris 000* [Photograph]. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Haustellum_brandaris_000.jpg
13. *Figure 2*: JWBE. (2012). *Historische Farbstoffsammlung DSC00350* [Photograph]. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Historische_Farbstoffsammlung_DSC00350.JPG
14. *Figure 3*: Microrao. (2015). *Gram stain saliva* [Photograph]. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Gram_stain_saliva.jpg
15. *Figure 4*: Steve. (2007). *Vanguard Farms Influent to Lagoon 2* [Photograph]. Flickr. https://www.flickr.com/photos/picstever/855679600