Color in a new Light

Name a topic that links science, history, art, and culture. How about color?

Let’s follow the theme of color through the vast collections of the Smithsonian Libraries, and make a few unexpected connections and discoveries.

Most of us take color for granted. We simply see it the moment that light beams from or reflects off an object, enters our eyes, and is processed by our brains. But do we stop to think what color actually is?

Journeying through the collections of the Smithsonian Libraries — from chemistry to catalogs, from colorblind tests to couture — we might see color in a new light.

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Newton’s Rainbow

In the 1660s, English physicist and mathematician Isaac Newton began a series of experiments with sunlight and prisms. He demonstrated that clear white light was composed of seven visible colors.

By scientifically establishing our visible spectrum (the colors we see in a rainbow), Newton laid the path for others to experiment with color in a scientific manner. His work led to breakthroughs in optics, physics, chemistry, perception, and the study of color in nature.

Aristotle developed the first known theory of color believing it was sent by God from heaven through celestial rays of light. He suggested that all colors came from white and black (lightness and darkness) and related them to the four elements — water, air, earth, and fire. Aristotle’s beliefs on color were widely held for over 2000 years until being replaced by those of Newton.
Opticks, one of the great works in the history of science, documents Newton's discoveries from his experiments passing light through a prism. He identified the ROYGBIV colors (red, orange, yellow, green, blue, indigo, and violet) that make up the visible spectrum. The visible spectrum is the narrow portion within the electromagnetic spectrum that can be seen by the human eye. Other forms of electromagnetic radiation, waves of energy, that we cannot see include radio, gamma and microwaves. The cells in our eyes called cones are sensitive to the wavelengths found in the visible spectrum. They allow us to see all the colors of the rainbow.

Johann Wolfgang von Goethe
Zur Farbenlehre (Theory of Colors)
Tübingen: J. G. Cotta'schen Buchhandlung. 1810

Goethe challenged Newton's views on color, arguing that color was not simply a scientific measurement, but a subjective experience perceived differently by each viewer. His contribution was the first systematic study on the physiological effects of color. Goethe's views were widely adopted by artists. Although Goethe is best known for his poetry and prose, he considered Theory of Colors his most important work.
This very rare book formed the foundation for modern color printing. Le Blon was the first to outline a three-color printing method using primary colors (red, yellow, blue) to create secondary colors (green, purple, orange). He makes an important distinction between "material colors," as used by painters, and colored light, which was the focus of Newton’s color theories. Le Blon’s distinction marks the first documentation of what is now referred to as additive and subtractive color systems. Rainbows, TVs, computer screens and mobile devices all emit light and are examples of an additive color system (the subject of Newton’s Opticks). Red, green and blue are the primary additive colors and when combined they produce transparent white light. Books, paintings, grass and cars are examples of a subtractive color system which is based on the chemical makeup of an object and its reflection of light as a color. Subtractive primary colors - blue, red, and yellow - are often taught to us as children, and when mixed together they create black.
These colorful line diagrams reveal the chemical compositions of metals. When a pure metal is burned and viewed through a spectroscope, each element gives off unique spectra, a sort of color fingerprint. This method, called spectral analysis, led to the discovery of new elements, and marked the first steps towards quantum theory.

Can you see the numbers in the circles? 4.5 percent of the population cannot see the entire visible spectrum, a condition called color vision deficiency, or color blindness. Ishihara plates are used to test patients for the various types of color blindness.
Can you find the animal hiding in this image? Camouflage uses color to conceal forms by creating optical illusions. American artist Abbott Thayer introduced the concept of disruptive patterning, in which an animal’s uneven markings can disguise its outline. In this illustration Thayer shows how a peacock can disappear into its surroundings.

Thayer, an American artist, devoted much of his life to understanding how animals conceal themselves in nature for survival. In his book, Concealing Coloration in the Animal Kingdom, Thayer presented his beliefs of protective coloration as an essential factor in evolution helping animals disguise themselves from predators. He received much praise and criticism. He was extreme in his views arguing that all animal coloration was for protective purposes and failing to recognize other possible reasons such as sexual selection – characteristics for attracting a mate. Teddy Roosevelt most notably attacked his theories by pointing out that this concealment doesn’t last all season, or even all day, but was dependent on a single frozen moment in time. Despite these shortcomings, Thayer went on to be the first to propose camouflage for military purposes. Although his suggestions were initially rejected, his former students were among the founders of the American Camouflage Society in 1916 and his theories were eventually adopted and are still used today.

The colorful pattern on this German aircraft from World War I is called lozenge camouflage. Its disruptive pattern applied Abbott Thayer’s theories in an effort to inhibit enemy observation from the air and on the ground.
Making Color

Until the mid-1800s, all dyes came from natural sources, such as insects, roots, or minerals. Producing them was difficult and expensive.

In 1856, an 18-year-old English chemist, William Henry Perkin, accidentally discovered one of the first synthetic dyes. In search of a treatment for malaria, Perkin experimented with coal tar, a thick, dark liquid by-product of coal-gas production. His experiment failed but left behind an oily residue that stained silk a brilliant purple. He called the dye mauveine.

Perkin’s purple changed history. He applied for a patent and abandoned the lab for the path of manufacturing. He paved the way for modern chemistry to move into industrial applications, and indirectly led to advances in modern medicine, explosives, photography, and plastics.

Sea snails like these are found around the world. When poked (milked) or crushed, they secrete a substance that was used for making purple dye as early as 1570 BC. Thousands of snails were needed to color a single robe, and for centuries purple dye was more valuable than silver and worn only by royalty.

Mixtec weavers in Oaxaca, Mexico, color locally grown cotton with natural dyes — including the rare purple tixinda, extracted from the *Plicopurpurea pansa* mollusk. The introduction of synthetic dyes and the decline of mollusk populations have greatly reduced the production of natural purple dye.
When coal was carbonized to make coke (a fuel), or gasified to make coal gas, one of its by-products was coal tar.

William Henry Perkin presented a sample of dyed silk to American industrialist William John Matheson, founder of the National Aniline and Chemical Company. Matheson in turn donated it to the Smithsonian.

Perkin's new purple took the fashion world by storm. First appearing in Paris and London, it quickly spread to America and was heavily featured in popular women's magazines of the day.
Synthetic dyes became big business after 1860, with Germany in the lead. This BASF dye sample catalog displays the vibrant variety of new synthetic colors. Founded in Germany in 1865 to manufacture dyes, BASF is one of the oldest chemical companies in existence today.

You don't need to be a chemist to dye feathers! This instruction manual provides "simple" recipes using natural and synthetic dyes, encouraging readers to pursue the "profitable business" of feather dyeing. Ostrich feathers were a major fashion accessory in the late 1800s and early 1900s, adorning hats and dresses.
Matching Color

I say green; you say green. How do we know we’re talking about the same color?

Color charts, created as early as the 1600s, included color samples and names, providing a standard for others to follow. These charts helped naturalists to identify plants and animals and helped manufacturers to produce consistent dyes and paints.

The mass production of synthetic dyes in the 1800s demanded improved color-classification systems. A variety of color models and instruments were created; many are still in use today. However, color remains elusive to scientists and color experts, who have yet to discover a truly uniform color model.

This table is one of the earliest known color charts. Waller created it as a tool for describing plants and animals. Collectors and scientists could compare their specimens to this table and use the names provided to identify the colors of leaves, bark, flowers, feathers, plants, and animals.
One of only four known copies in the world, this early manual on the preparation of colors contains 2,592 hand-colored natural dye specimens, along with details on how to apply them to silk, cotton, wool, leather, wood, bone, paper, and other materials.

Board game pioneer Milton Bradley (also a manufacturer of crayons and watercolors) was fascinated with finding a precise method for identifying and reproducing colors. Smithsonian ornithologist Robert Ridgway adopted Bradley’s color philosophy in his own work, devising a system for naming the colors of birds. Each made significant contributions to the standardization of colors.
Bradley sought to educate adults and children about the physics and psychology of color. In his book *Elementary Color* he emphasized that color instruction for children should employ a simple naming system. He promoted his color wheel as a device that could scientifically match and measure colors. When spun rapidly, overlapping colored disks mix colors before your eyes. Different combinations of disks create a multitude of hues based on measured proportions.

These illustrations from *Color Problems: A Practical Manual for the Lay Student of Color* demonstrate the principles of mixing colors using the Bradley color wheel. Spinning these color combinations (in the proportions shown) produces the gray shade in the center square. The center also shows the proportions of black and white needed to achieve the same results. (Surprise! Gray is not always an issue of black and white!)
Ridgway, the Smithsonian's first curator of birds, used color as a tool to help identify bird species. Unsatisfied with existing color standards, he created his own color dictionary for naturalists in 1886. His expanded edition of 1912 contains 1,115 named colors. Some names directly refer to bird species. Look for "Warbler green" on this chart.

Leaf-warblers, a species found mostly in Europe, Asia, and Africa, come in many leaf-like colors. Do these warblers match the "Warbler green" on Ridgway's chart?

Albert Munsell was an American painter, teacher of art, and inventor of the Munsell color system. Using numbers to identify colors (Munsell disliked "foolish" color names), the Munsell system continues to influence color theory and practice today.
As manufacturers improved their ability to reproduce any color imaginable, the problem of choice arose. How do consumers decide what colors they want? How do designers know what colors to offer?

Experts published guides to color harmonies, and in time a new profession emerged: corporate colorists. From forecasting color trends to creating pleasing environments, from car paints to kitchenware, their work is seen everywhere, yet they remain largely invisible.

The Smithsonian Libraries have this field covered, from works on color psychology and optical tricks, to trade catalogs and color chips.
Colorful dots demonstrate "simultaneous contrast," the optical effect that two colors have on each other. The French chemist Chevreul was hired by a textile manufacturer to improve the "murky" color of their dyes. He discovered that it was not the dyes, but the placement of colors next to one another, that made them appear more or less vibrant.

Inspired in part by Chevreul's theories, artist and art educator Josef Albers published a landmark study of color phenomena.

Stare at the red circle for 30 seconds then look at the white circle — what color do you see? You have just experienced "successive contrast," or afterimage. Josef Albers' masterwork examines a wide range of color phenomena in 150 plates.

*Plate from*  
Jøsøf Albers  
Interaction of Color  

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*Édouard Guichard*  
*Die Harmonie der Farben*  
[The harmony of colors]  
Purchased by the Margaret F. Macnab Endowment

*Harmony of Colors* contains 166 spectacular full-color plates with 1,300 color combinations. Architect and decorator Édouard Guichard promoted the concept of color harmony for the design of wallpaper, curtains, upholstery, and paint schemes in architecture and interior design.
In the late 1800s, the range of available paint colors expanded exponentially, making possible the multi-colored paint schemes of the Victorian age. Victorian homeowners typically applied harmonies of three to five colors.
This trace catalog shows that cars and horse-drawn coaches were available in a wide variety of colors in the 1890s. Founded in Brooklyn in 1883, the Benjamin Moore company is best known today for their innovative interior and exterior house paints. Smithsonian Libraries has a collection of Benjamin Moore trade catalogs that can be viewed here.

Bold colors were introduced to common household objects in the first half of the 20th century. In 1936, the Homer Laughlin China Company introduced Fiesta Dinnerware in five vivid colors. Brilliant orange-red had uranium oxide in the glaze, which made the product slightly radioactive. The color was discontinued in 1944.

In the 20th century, advisory groups arose for the purpose of forecasting and managing color trends for fashion, home decor, and advertising. Sample books announced color palettes for each season.
Exhibition Events

Indoor Recess
Smithsonian Libraries Presents: INDOOR RECESS a lunchtime getaway
Featuring your favorite classes as a kid, Library and Art!

#ColorOurCollections Coloring Event
From February 1-5, 2016 the New York Academy of Medicine (NYAM) is encouraging cultural institutions and crayon enthusiasts to join together for #ColorOurCollections. Institutions such as NYAM, the Biodiversity Heritage Library and the Smithsonian Libraries will provide inspiration and coloring sheets for artists of all ages to fill in. Colorers can share their creations on social media by tagging the organization and using the hashtag #ColorOurCollections.

View books from Color in a New Light and more!
View the Digital Library
View Benjamin Moore trade catalog collection

As part of the #ColorOurCollections event, we've created a coloring booklet. Download and share!
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