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Pigment Worlds: An Introduction

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In the Santa Cruz region of Argentina, a cave wall is covered with an orchestra of red ocher handprints. Variations of earth tones, from deep blood red to rose pink, echo as the ocher commingles with a white chalky pigment [FIG. 1]. The mural evokes geology and earth, as the pigments were created from mineral deposits. The harmonic concatenation of hands across the wall presents a visual echo and rhythm that mirror the acoustics of the interior space, so that the voices that echoed ephemerally within the cave become visually transcribed onto the walls. Archaeologists suggest that these works were created by blowing the pigment from the mouth, creating a "halo effect." Some scholars conjecture that this mingling of pigment, breath, and saliva embodied "breathing life" onto the wall, infusing breath's brevity with the endurance of stone mediated through ocher pigment. Instead of carving lines—sculpting and incising—these artists archived their relationship to space and time with pigment and breath. We use this iconic image to begin the volume to demonstrate that pigment is inseparable from the desire of the human species to archive, impress, and create. As Carolyn Boyd argues in her case study, pigment begets life.

But first, **what are pigments?** On a technical level, they are insoluble materials that contain color. Most pigments must be processed to release their color. For example, ultramarine is made from lapis lazuli, a hard stone. The mineral is ground into a powder to create the colorant, then the powder is mixed with a material like pine resin or beeswax to produce a doughlike substance. This material is massaged and worked in a solution of warm ash to separate out the blue pigments, which would be mixed with a binder, perhaps egg yolk, if the artist wanted a tempera paint. This recipe is only one of thousands for extracting a pigment from a naturally occurring substance. Although this book is not intended as a compendium of pigment recipes, we share this process to demonstrate

[FIG. 1]
Cueva de las Manos, UNESCO World Heritage Site, Rio Pinturas Canyon, Santa Cruz Province, Patagonia, Argentina.

that the production of pigments demands labor, time, and knowledge about the natural world.

Today, many pigments are born in a chemist's laboratory. Vantablack, for example, is an engineered super-black pigment consisting of carbon nanotubes that absorb more than 99 percent of all light. This technology is far-removed from the ocher pigments employed in the Argentinian caves that were made by oxidizing clay. Moreover, Vantablack was not originally intended for artistic production. Nevertheless, Anish Kapoor bought the exclusive rights to it and instigated a heated debate about intellectual property and artistic production [FIG. 2]. Yet, Kapoor's purchase of Vantablack belongs in a tradition of artists engaged with technology and trade secrets. Whereas illuminators in medieval guilds might have guarded their recipes in their workshop, Kapoor gained his technical expertise through financial and legal means.

While pigments are one central colorant in our world, dyes are another. Both pigments and dyes are powders extracted from natural and synthetic materials that may be combined with binders to create substances of varying liquidity. Typical binders for paints include animal fat, eggs, linseed oil, and, more recently, acrylic and vinyl polymers, to name only a few. For the most part, pigments are insoluble, and dyes are soluble. In this volume, we focus on pigments and how their insolubility and structure are fundamental to the history of art. When a pigment is combined with animal fat, a common binder for cave painting, it will not dissolve. It retains its structure. In contrast, dye dissolves when mixed with a binder. Typically, dyes are used for textiles whereas pigments are the painter's medium (there are, of course, important exceptions). Dyes absorb into their material support while pigments rest on the surface of their ground—for instance, wood panel or canvas. Moreover, pigments are suspended in their binder, which means that they are constantly in relationship to the material world instead of being absorbed into it.

Pigments and dyes can be made from the same original material, though dyes are often made of organic compounds and pigments are made of inorganic compounds—that is, they do not have carbon-hydrogen bonds. Pigments frequently come from the earth: charcoal and ocher, minerals and rocks. The color known as sienna, for example, is an earth pigment containing iron and sometimes manganese. It will change from yellow to red when heat is applied. Although its chemical composition is found in cave paintings, it was produced in Siena during the Renaissance and bears this geographic history in its name. Stones and semiprecious stones are also sources of pigments. Azurite and malachite, ground into a powder, produce blue and green, respectively. Pigments are also mined or are a by-product of mining. The ore cinnabar (mercury sulfide) and its synthetic form, vermilion, were used interchangeably

[FIG. 2]
Anish Kapoor, *Non-Object Black*, 2019.

until the seventeenth century. Both were valuable detritus created from the mining of mercury.

Pigments are also derived from plant sources: red from madder root, or gamboge, a yellow or orange resin from the Garcinia tree in Southeast Asia. One well-known pigment—indigo—is extracted from the indigo plant. Indigo arrived in Europe from India in the seventeenth century and transformed the blue-pigment market, offering a less expensive alternative to the ultramarines harvested from lapis lazuli. Indigo was also one of the major cash crops driving the trans-Atlantic slave trade in North America. Therefore, beginning with the first contact between Europeans and Americans and the expansion of global trade in the sixteenth and seventeenth centuries, pigments began to be part of an economic system that was responsible for the rise of exploitative labor.

Cochineal, made from insects, was another red pigment that played a central role in early modern artistic practice. The insects were dried to extract carminic acid, which was then processed into either dyes or pigments. Cochineal was an established part of many cultures in the Americas, and Europeans immediately took an interest in transferring the technology to their own workshops [FIG. 3]. Although cochineal was predominantly important for the textile industry, it was also used by artists as a lake pigment, which is one of several organic pigments. Lake pigments are created when the liquid dye is transformed into a solid substance and combined with a binder—for example, chalk or crushed bones. These pigments produced from organic dyes are often not lightfast. Some paintings by Rembrandt van Rijn (1606–1669) have traces of cochineal, testifying to the impact of the technology on the European market and to the predilection of seventeenth-century European painters for these fugitive materials.

For the most part, synthetic pigments—that is, not derived from nature—developed with the rise of chemistry, though there are earlier examples. The earliest known example is Egyptian blue, made by heating quartz sand, alkali, lime, and copper. It was used extensively in ancient Egyptian tomb paintings until the technology was lost during the Roman period. Ancient Egyptians not only made the first synthetic pigment, but they also introduced a form of painting called *encaustic*, which was used for portraits on mummies such as the one in the Art Institute of Chicago [FIG. 4]. Kept in cool, dry, dark spaces, mummy portraits maintained their original brilliance, which embodied a lifelike rendition of the deceased's face. The artists achieved this effect by binding the pigment with clarified beeswax, so that the image would "shine." The process of encaustic (from the Greek meaning "to burn in") includes mixing pigment with clarified beeswax and also sometimes with resin or tallow and applying the hot material to the surface. This form of painting requires the use of special

[FIG. 3]
Illustration of cochineal collection, in José Antonio de Alzate y Ramírez, *Memoria sobre la naturaleza, cultivo, y beneficio de la grana . . .* (Essay on the nature, cultivation, and benefits of the cochineal insect), 1777. Colored pigment on vellum.

metal tools, and the result comes from the unique properties of wax. Wax is not, however, a stable binder, and when exposed to light or heat, it shifts the properties of paint. Mummy portraits survive mainly because they were locked in dark tombs. Once they were discovered and brought into the light, their brilliance began to fade.

A central fact about pigments is that they are often unstable. Paintings are inherently stable or unstable depending on the use of pigments, binders, and supports. Even stable colorants such as umbers and ochers are constantly mutating, particularly in response to shifting atmospheric conditions. Knowledge about pigments allows for an understanding that nothing in artistic production is fixed. All works of art are on a trajectory of metamorphosis and perhaps even degradation. The study of pigments, therefore, becomes a theorization of time and temporality. As Karin Leonhard articulates in this volume, pigments and their ability to degrade demand that we see objects less like fixed objects and instead like faces and physiognomies that will age. Experience with pigments allows a viewer to perceive the multiple temporalities that are often present in a single work of art as its various materials age at different rates.

This process of degradation becomes even more rapid with the transport of artworks from their original locations as well as climate change and pollution. Pigments, therefore, always exist in relationship to their external environment. Conservators, curators, and scientists determine to what degree to intervene in the life of work. To examine the shifting nature of pigments and their relative stability or instability, conservation scientists have developed a range of techniques that Barbara Berrie outlines in her essay. Intervention with fading pigments presents philosophical challenges to conservators. While there is a desire to preserve the structural integrity of the original work as it was intended by the artist, that presumes a seamless relationship between the work and the maker, even though works of art often express their own integrity beyond the intentions of the artist. The process of time on a work of art, and its multiple subsequent receptions, becomes a part of its history. Painters were often aware that their pigments might be fugitive—that they might lighten, darken, or even disappear—and they often took that into consideration. Works of art, therefore, hold multiple stages in their lives, and we should not expect a painting to look as it did when the artist first put down the brush. Approaching a painting with a material understanding of pigment allows a better understanding of what has been lost and what remains, as David Bomford illustrates in his contribution to this volume.

One of the most well-known projects in recent decades to bridge the world of original appearance with historical degradation took place at the Harvard Art Museums with murals painted by Mark Rothko (1903–1970) in the 1960s [FIG. 5]. The murals consist of five canvases created with

[FIG. 4]
Portrait of a Man Wearing a Laurel Wreath. Egypt, early to mid-2nd century. Lime (linden) wood, beeswax, pigments, gold, textile, natural resin. Art Institute of Chicago, Gift of Emily Crane Chadbourne (1922.4798).

shifting variations of red and rectangular shapes. Rothko painted on an unprepared canvas and eschewed commercial paints, preferring to experiment with pigments and binders. His paintings are, therefore, not only an exploration of color and form on a monumental scale but also the representation of his knowledge about the materials of his craft. Almost immediately after their installation, the murals changed dramatically, becoming darker and losing the brightness of the original red. To give viewers a sense of the original works, the conservation team at Harvard Art Museums installed a light projector. When beams of light reflect off the canvas, the conservators achieve the glow of the original works. When the projectors are turned off, the viewers see the dramatic shift in hue and pigment. This technique was noninvasive, yet it allowed viewers to appreciate the metamorphosis of the works over nearly a half-century. The installation created conditions for the works to exist both as historical artifacts marked by degradation and time and as paintings that could be returned to their brilliant red created by Rothko.

The Harvard Art Museums have a legacy of conservation, science, and the study of pigments. In the early twentieth century, Edward Forbes—a leader in museums and conservation—amassed a collection of thousands of pigments to be kept at the Fogg Museum. For Forbes, the collection was a means to better understand the material history of painting in order to know the past, to conserve it for the future. As he wrote, "We are born to die; these frescoes are born to live." Collecting and mining pigments ensured that works of art would exist for generations, as conservators could utilize the historical collection to create pigments like those used centuries earlier. Forbes also realized that works of art are breathing objects that react to their environments. He pointed out that furnaces and heating systems often destroy paintings and their sensitive surface structures formed by pigments and binders. For example, the dryness in the air from heat might cause pigments suspended on the surface of their ground to swell, shrink, and ultimately detach from the support.

The Forbes Pigment Collection at the Harvard Art Museums demonstrates the ways in which trade networks, colonial expansion, and exploitation of labor and natural resources were central to the history of painting and its materials, a history that remains within the labels and names of many pigments on display [FIG. 6]. It tells a geographic history of art and reminds us how color is often derived from specific geographic areas; labels describe the fossil resin of amber "found on the shores of the Baltic sea" and the gum Arabic from acacia "growing in Africa, India, and Australia." Like the encyclopedic collections of the Harvard Art Museums, the Forbes Pigment Collection embodies the geographic and temporal ambitions of a universal collection. Nevertheless, the names of the pigments and their extraction mirror the same histories

[FIG. 5]
Mark Rothko, *Panel One* (*Harvard Mural Triptych*), 1962. Egg tempera and distemper on canvas, 267.3 × 297.8 cm. Harvard Art Museums/Fogg Museum, Transfer from Harvard University, Gift of the Artist (2011.638.1).

[FIG. 6]
Forbes Pigment Collection and Gettens Collection of Binding Media and Varnishes at Harvard Art Museums' Straus Center for Conservation and Technical Studies.

of exploitation and colonialism that have been central to the concept and formation of collections since the sixteenth century. As a resource for study, it is invaluable. Yet, like the plants and parasites of indigo and cochineal, many specimens in the Forbes collection contain their own microhistories of agricultural development under industrial capitalism and violent extraction.

Forbes was not the only scientist, conservator, and artist who took an interest in building a collection of pigments at the turn of the twentieth century. George Washington Carver (ca. 1864–1943), born enslaved at the end of the Civil War, was one of the foremost agricultural scientists of the twentieth century and an innovator in the science of pigments. His writings about sustainable practices in farming, particularly aimed at farmers struggling to make a living from land that was destroyed by the monoculture of the plantation economy, were formative for twentieth-century agriculture. At Tuskegee University, where he was the head of the Department of Agriculture, Carver wrote on a variety of topics, from the importance of crop rotation to introducing new cash crops that would add nutrients to the soil. He was also a painter and created pigments from the Alabama soil that local farmers could use to paint their houses. For him, these pigments allowed the development of an aesthetic language for buildings that were often overlooked: "No place can be called a school in the truest sense that has no pictures on the wall, no paint or whitewash on the buildings, either inside or outside, no trees, shrubs, vines, grasses or properly laid out walks and paths, which appeal to the child's aesthetic nature and sets before him the most important of all secular lessons—order and system." For Carver, making pigments to beautify the vernacular architecture with the local Alabama clays and soil was a means to create a visual vocabulary. Carver saw the local landscape as a resource for agricultural innovation and artistic materials. "Of the many attractive features of our beautiful country," he wrote, "I think there is possibly none that elicit such universal admiration and praise as the vast deposits of multi-colored clays, ranging from snow-white, through many gradations, to the richest Sienna and Indian reds on the one hand, and from the deepest yellow ochre to the palest cream tintings on the other." Carver also created pigments from tomato vines, Osage oranges, radishes, wood ashes, the bark of maple trees, dandelions, and sweet potato peels and vines.

His work demonstrates that pigments and their extraction from the earth can tell local histories and stories, demonstrating the intersections among the sciences of food, medicine, and art. For Carver, who always reminded farmers to "be kind to the soil," making pigments from Alabama clay was a means to build a new society from the ruins of plantations and the slave trade [FIG. 7]. His work in local pigments and ecologies allowed agricultural society in the South to recuperate, following the

[FIG. 7]
George Washington Carver (1864–1943) and His Art.
Photograph.

devastation of the global trade in cotton. Carver's work was also an early form of conservation of the earth itself. Carver's legacy testifies that the history of art conservation has always intimately been connected to the earth. Pigments tell stories about survival, as they are not only made from earth, but they also track our relationship to the earth as a site of worship, extraction, development, plenitude, and exhaustion.

How might knowing more about pigments change how we look at painting? This book is not intended as a complete history of pigments across time. We focus primarily on organic rather than inorganic pigments. This book is an introduction to what constitutes a pigment and a study in method, engaging with a variety of specialists who are knowledgeable about pigments from different perspectives and demonstrate how that understanding impacts their writing about art. All the essays in this book articulate the vital work happening across disciplines as art historians, scientists, anthropologists, and conservators enter into conversation with one another.

In the longer essays, art historian Karin Leonhard and conservation scientist Barbara Berrie introduce the language needed to think about pigment. Leonhard discusses the critical vocabulary and theoretical structure around color and pigment in early modern European painting, outlining the theorization in relationship to discourses on light and perception. Berrie offers key terms in the conservation science of pigment that will be a resource for readers looking to understand the tools at play in the scientist's laboratory. The case study by conservator David Bomford examines the impact of pigment and discoloration on European painting. The other four case studies explore pigment beyond the context of European painting, recognizing the limitations of thinking about pigment from that perspective. Carolyn Boyd demonstrates how technical study of pigment contextualizes the White Shaman Mural from nearly five thousand years ago in the American Southwest and Coahuila, Mexico. Technical analysis reveals that the artists did not use the readily available red ocher pigment but instead produced a red pigment from yellow siltstones using a labor-intensive process. As she argues, the difficulty of making the red pigment imbues the mural cycles with fire and life, so that they not only represent creation but also embody it within their material construction. Boyd's case demonstrates how to interweave technical analysis into an essay to make an argument about cosmological meaning.

Quincy Ngan considers copper-based pigments in relationship to ancient Chinese bronzes from the Shang and Zhou dynasties (ca. 1600–256 BCE) and their enduring impact on Chinese painting into the nineteenth century. Drawing on technical analysis, Ngan traces the transmediality of copper-based pigments in Chinese art from ancient bronzes to nineteenth-century painting. Gabriela Siracusano illustrates the importance of technical analysis of pigment to historicize the Amerindian artists working between Indigenous and colonial painting practices. Siracusano calls her method an “archaeology of making,” bringing together chemical analysis and art history to study the ongoing legacy of ancestral material memory realized in the choice of pigment for Amerindian artists working in the Viceroyalty of Peru.

For the most part, these essays focus on pigment and its role in temporality, sacred geographies, and infusing objects with human presence and ancestral histories. Yet, the final essay, by Anne Lafont, demonstrates how the perception of pigment—particularly skin pigment—dehumanized and refused presence to those whose skin color was not white, a history of science and race that is necessary to contextualizing the ongoing legacy of racism today and its impact on certain technologies such as color printing. Lafont demonstrates how the concept of pigment in regard to skin color enters the history of art at the same time as innovations in pastel and color printing, so that artists “prepared the scholar’s eye” to recognize variations in skin color. Lafont’s essay makes clear that the study and recognition of pigments in European art cannot be dissociated from the formation of the discipline of art history itself in the eighteenth century.

Despite radically different time periods and geographic areas, all the cases offer modes by which to engage technical analysis with art-historical methods to narrate complex histories in which color and pigment are not merely mimetic or symbolic but reorient art history. This short book is intended only as an introduction to thinking about pigment as a method in art history, introducing the work of scholars who use a technical understanding of pigment in relationship to other models of art-historical analysis. While the book can be read in any order, the essays collectively demonstrate how pigment illuminates the interaction between nature and culture. Studying the history of art through the lens of pigment reveals that artists often depicted the natural world and depended on the physical world for their materials—from rock to parasitic insect. Pigments themselves are creative works, held within each coarsely ground molecule of powder. They are laborious, time-consuming, and imaginative endeavors, and most great painters have studied not only line and form but also the qualities of the material world through pigments and binders. Pigment demonstrates the insoluble nature of color and how we have left our mark on the surface of this earth through the extraction of reds, blues and violets, greens and yellows across the visible and the invisible spectrum, a history that is as much about art as our relationship to nature and to one another.

Pigment Histories in European Painting

Karin Leonhard

A few years ago, over a cup of coffee in Berlin, the following conversation took place between a conservation scientist and an art historian: "When looking at a painting, you say, 'The Madonna is wearing a blue cloak,' while we say, 'The Madonna's cloak is painted with lapis lazuli'" [FIG. 8]. They were referring to a divergent focus inasmuch as art historians refer to the perception of a viewer ("we see a blue color"), while art technologists or conservators emphasize the material substance inducing this perception ("we see pigments such as lapis lazuli").

It was a friendly exchange, but the sting remained: What do we, as art historians, really know about the material nature of the artworks we study so closely? During my studies, this issue was hardly raised, and the differences between artistic techniques, pigments, coloring agents, and binders barely seemed worth mentioning. Much has changed since then, and the material turn in the humanities has drawn new attention to the colorants used and their artistic or artisanal application as a meaningful part of a work of art. Another realization has also changed the discipline of art history. Once we understand that paintings are *physical* objects that travel across space and time and may sustain damage or age in the process, our own perception is called into question. Do we know what a painting or artwork looked like when it was created? What are we seeing in a museum? To what extent has time already been at work, in the form of a chemical aging process or a history of restoration?

Transforming Nature into Art

For the Russian avant-garde painter Wassily Kandinsky (1866–1944), the sight of paint coming out of a tube amounted to a lavish feast for the senses. In 1879 he bought himself a box of oil paints: "When I was thirteen or fourteen, I bought a paintbox with oil paints from money slowly saved up. The feeling I had at the time—or better: the experience of the color coming out of the tube—is with me to this day. A pressure of the fingers—and jubilant, joyous, thoughtful, dreamy, self-absorbed, with deep seriousness, with bubbling roguishness, with the sigh of liberation, with sensitive unstableness of balance came one after another these unique beings we call colors—each alive in and for itself, independent, endowed with all necessary qualities for further independent life and ready and willing at every moment to submit to new combinations, to mix among themselves and create endless series of new worlds." His fascination with being able to press lightly on the tube from a paintbox to create an entire work, gushing out from the tube as if by itself, led to works with a cosmological quality. In his paintings, wars are waged between colors and forms, and harmonies are created that are indebted to the sensation of gushing paint from a tube that he explained in his autobiography [FIG. 9].

Kandinsky used industrially produced paints that he bought in tubes or a paintbox—a recent invention that we should not take for granted. The history of the paintbox, developed in the nineteenth century in the wake of plein air painting, is worth a study of its own. In earlier centuries, artists made their own paints. Painters or their apprentices painstakingly ground the pigments then added binding agents to make them spreadable. These agents were water-soluble for book illumination, oil-soluble for panel and canvas painting and polychrome decoration, and lime-binding for wall painting. Depending on the colorant and the painting technique, the pigments were mixed in shells or arranged on palettes, or small linen cloths were soaked in the paint so it could be stored and reused for a prolonged period.

[FIG. 8]
(above) Sassoferrato, *The Virgin in Prayer*, 1640–50. Oil on canvas, 73 × 57.7 cm. National Gallery, London, Bequeathed by Richard Simmons, 1846 (NG200). (opposite) Lapis lazuli from Badakhshan Province, Afghanistan.

[FIG. 9]
Wassily Kandinsky,
Palette, ca. 1939. Wood.
© Musée National d'Art
Moderne / Centre Georges
Pompidou, Bequest of
Nina Kandinsky, 1981.

The ways in which colors were extracted varied as well. While some pigments had to be dug from the earth then ground into powder, washed, and slurried for use, colorants of animal origin were often boiled or subjected to chemical processes. The production process was at times harmful to health. Just think of the manufacture of toxic lead white paint, made from strips of lead that were rolled into spirals and placed in stoneware vessels over sharp vinegar. The vessels, in turn, were loosely covered and buried in horse manure or used tanner's bark in an oxidation room. Heat and carbon dioxide produced from decomposition caused the metallic lead to change into lead white. Verdigris was similarly obtained by attaching strips of copper to the inside of a hollowed-out block or wooden barrel with vinegar at the bottom and burying the container in manure. The verdigris that formed on the copper surfaces could be scraped off and used as paint. The instructions for making pigment from natural materials such as minerals, plants, and other organic substances circulated in workshops and were passed on orally from one generation to the next. Occasionally, they were also compiled in written workshop records and collections of recipes that also addressed the addition of binding agents and mixing with other colors. Such source texts are crucial for an understanding of historical processes. The scientific identification of a pigment may tell us its chemical composition, but to understand how certain paints were produced in the past we need contemporary recipes and thus are forced to adopt a cultural-historical perspective on artistic techniques and materials.

After the invention of the printing press, the practical knowledge of color moved from medieval manuscripts into printed works such as treatises, artists' manuals, and large-scale volumes on medicine and botany. Early modern printers and publishers also produced a slew of pharmaceutical literature, ranging from costly hand-colored herbaria to inexpensive "daily companions." Such manuals were popular because, as their introductions announced, they tended to "summarize the magical and physical properties of trees and herbs as well as their healing powers against nearly every disease." In addition, there was a veritable boom in the publication of "Books of Wonder" or "Books of Secrets" that provided recipes for color extraction and instructions about engraving, making ink, gilding, and varnishing as well as cosmetics. They were often bound together with books on the arts of dyeing and distilling, and all the texts drew connections between man-made paints and natural resources. In 1677 the German physician, botanist, and naturalist Johann Sigismund Elsholtz (1623–1688) refers to "the so great variety of Colour in the Herbs, Roots, Leaves and Flowers from whence they were distilled" in the introduction to his *Curious Distillatory; or, The Art of Distilling Coloured Liquors, Spirits, Oyls, etc. from Vegitables, Animals, Minerals and Metals*.

In *Mysteryes of Nature and Art* (1634) John Bate describes colors that "are either merely tinctures of vegetables, or substances of minerals, or both: . . . Vegetables are rootes, juces, berries, and such like things as grow out of the earth. Minerals are such as are dig'd out of the earth, as earth, and stones, & c."

Until well into the seventeenth century, the power ascribed to colors was discussed in terms of psychological perception and a belief that they had material properties because they were obtained from plants, berries, roots, earth, stones, and minerals. In fact, the scholarly consensus was that the origin, effect, and meaning of colors, whether observed in nature or created on the painter's palette, needed to be discussed together because each shade was the result of a physical mixture of elements. As such, each was also suitable for painting. As the Italian artist and priest Matteo Zaccolini (1574–1630) points out in his 1618–22 treatise *De colori*, we need to imagine that the painter's palette is created from the same four basic elements that shape the entire universe. The earth with its minerals as the basis has produced the spectrum of colors through a combination with water, air, and fire. When a painter applies these colors to the canvas, he or she is handling the same substances and qualities prevalent in nature. As Zaccolini explains, it is as if natural materials, once they appear on the picture surface, transform from earth and minerals into something cosmic. Because the pigments of the painter are obtained from organic and inorganic substances in nature, they were thought of as both artificial and natural colors. The art-theoretical dialogue *Il Figino* (1591) argues that with the brush "the true can be imitated with the false, until the true is vanquished by the false, which now appears truer than the truth"—that is, "until fruits and flowers are but shadows of those depicted ['shaded'] with colors."

Pigment versus Color

The word "pigment" is derived from the Latin *pigmentum*, meaning "color," "makeup," or "spice, aromatic substance," and is etymologically close to the Latin verb *pingere* (*pictum*), meaning to paint or to decorate. *Pharmakeia* (φαρμακεία) is another ancient term for pigments in treatises on color, demonstrating a proximity between pharmacology and painting that also involved models of transmission, aesthetic infection, and/or healing. *Pharmakeia* are substances that are as useful as they are harmful and toxic, and it is interesting to see how the discourse on their medicinal use resembles the discourse of painters on the uses and effects of paints.

The close relationship between painting, cosmetics, and medicine will be discussed below. First, it is important to understand that pigments are colorants but should not be equated with the "colors" of objects. "Pigment" covers or colors materials. The term *color*, likewise derived from Latin, refers to the impressions induced in the viewer's perception by pigments—that is, a sensory experience. The Dutch painter and art theorist Gerard de Lairesse (1641–1711), for example, understood the colors (paints) on the canvas in two ways: as pigments to be mixed and as colors when viewed aesthetically. Color or paint material ("pigment," "colorant," "paint") and color perception ("color") are inextricably linked but by no means the same thing.

Color Today and in the Past

Any discussion of pigments must therefore address color. Nowadays, we would say that color is a sensation, a perception, and not a thing in itself. Our eyes register, and our brain constructs, color from a small part of the electromagnetic (EM) spectrum, the radiation that suffuses the universe. The EM spectrum spans a vast range of energetic radiation, from high-energy gamma rays to low-energy radio waves and beyond the two ends. The human eye is sensitive to only a tiny portion of this energy continuum, comprising wavelengths from about 390 to 750 nanometers (a nanometer is one billionth of a meter) and aptly referred to as "the visible." When the entire range of the visible spectrum reaches our eyes at the same time, we see "white," meaning no specific color at all. When the visible spectrum is scattered by a prism or water droplets, our eye/brain combination perceives the smaller, discrete energy ranges as different colors. We are able to perceive millions of shades of color and appreciate nuances and subtle differences between colors.

Pigments, on the other hand, are colored substances that absorb and/or reflect parts of the visible spectrum. White pigments do not absorb any part of the visible spectrum, while black pigments absorb it completely. Red pigments absorb all visible light except red light because they either allow it to pass through (transparent pigment) or reflect it (opaque pigment). Similarly, yellow pigments absorb the wavelengths in the blue portion of the visible spectrum and transmit or scatter all longer wavelengths (green and red) of the visible spectrum. This optical explanation of color phenomena gained acceptance by the end of the seventeenth century with the gradual establishment of so-called spectral color theory. For a long time, a different understanding of color prevailed, and we need to be familiar with it when looking at early modern artworks. Ever since antiquity, all colors were believed to come from a mixture of white and black (or, rather, light and dark) and to be linked to the four elements: water, air, earth, and fire. In medieval and early modern texts, the use of colors in painting corresponded to divine creation or the creation of the universe. Between light and darkness, colors shine like gems of varying purity. The resulting color values (hues) were understood as various levels of brightness that were explained by greater proximity to the poles of light or darkness. For this reason, the luminosity of colors was a factor in the evaluation of art, as the intensity and brightness of a color was understood as an indicator of the diaphaneity of the material. The purer and more radiant a hue, the less material-based it was in contemporary eyes. Accordingly, repeated attempts were undertaken to create hue scales and relate them to the color sequence of the rainbow.

Another concept of this earlier tradition was the assumption that color represents a stable property of things—a quality inherent in them. Within contemporary color theory, this concept was referred to as "real" or "proper" color (*colores proprii*), meaning that the colors perceived corresponded to natural bodies that possessed those colors. Pigment colors that were directly extracted from a plant or a mineral by grinding or distilling fell under this category. Following the logic of the period, colors are "real" if they represent qualities inherent in a physical object. In turn, "apparent" colors change their appearance depending on the position of the spectator and might not convey any information about the "real" color of the object at all. Apparent colors do not necessarily correspond to a physical object displaying those colors. Instead, they depend on the interplay between light and shadow and on the reflection of other colored objects surrounding them. For this reason, they belong to a temporal world that shifts its chromatic appearance by the moment. Albrecht Dürer's (1471–1528) *Self-Portrait* [FIG. 10] is perhaps the most famous example of the use of such a terminological distinction. He inscribed his painting at the top right: "This is how I, Albrecht Dürer from Nuremberg, painted myself with proper colors at the age of 28 years [Albertus Durerus Noricus / ipsum me proprijs sic effin / gebam coloribus aetatis / anno XXVIII]," thereby emphasizing the verisimilitude of his portrait. By contrast, the colors of the rainbow or the iridescent colors of bird feathers and butterfly wings appeared fleeting and ephemeral to the early modern eye. That is one reason why, in painting, intermediary figures such as angels, nymphs, and otherworldly messengers were depicted with *colori cangianti*, or iridescent colors. They are not of this world but instead move between different worlds, and this incorporeal or unstable state can be expressed through color.

Spectrum versus Pigment

The history of culture is always a history of color. Conversely, color is not universal but culturally and historically coded. Art historians examine the historical significance of colors through the study of, among other things, written sources in a variety of fields—recipe books, treatises on painting, optical treatises, natural philosophical writings, and literary texts. This knowledge is indispensable for the contextualization of artworks and leads to changed, and sometimes surprisingly new, perspectives.

[FIG. 10]
Albrecht Dürer, *Self-Portrait with Fur-Trimmed Robe*, 1500. Oil on limewood, 67.1 × 48.9 cm. Alte Pinakothek, Munich (537).

It seems almost incomprehensible today that color was considered an integral part of the material world rather than a part of light. The colored appearance of an object (plant, animal, human being) provided information about a fundamental property of the object and lent it its individuality. Hence, Dürer wrote that he portrayed himself in "proper colors": painting produced physical equivalents of reality that were not subject to the vagaries of time. As long as the location of colored appearances was rooted in the physical world, such a claim would hold. But it changed the moment color shifted to the eye of the spectator, meaning the moment light was identified as the source of color. With the transition from a medieval to a mechanical natural philosophy, colors came to be considered light-induced sensations in the brain of the beholder. René Descartes (1596–1650), for example, remarked in 1637 on the senselessness of distinguishing between real and disembodied colors since all colors represented nothing but phenomena and were equally true and false. The hierarchy changed accordingly, and the spectral colors gained conceptual primacy over object, or "real," colors. Drawing on these theories, which inextricably linked the study of color to the study of light, Newton established a color theory on the sole basis of experiments on the refraction of light. In 1704 he published his *Opticks* as a summary of decades of research. The critical experiment presented in this work (Newton himself used the phrase "experimentum crucis") disproved all previous theories of color. When passing through a prism, sunlight was refracted into the spectrum. The experiment showed that it could then be recomposed into white light. Newton concluded that white light was not simple and homogeneous, as previously believed, but instead composed of colored rays of light. His definition of color had considerable consequences as each color appears solely as the result of a selective reflection of white light. Objects, therefore, must obtain their colors by reflecting certain rays of light while absorbing others. Accordingly, permanent object colors result exclusively from the varying reflective and refracting behaviors of their surfaces. Now color was created through surfaces off which light—which contains the entire color spectrum—is refracted and reflected. However, the role of light in color theory conflicted with artistic concerns about the materiality of paint and the laws of physical pigment mixtures.

Art versus Nature

For many centuries, a central concern of painters was creating shades of color that were as pure and luminous as possible and that matched the radiance of the rainbow. At the same time, they wanted to achieve a wide range of shades and nuances, either by using different colorants or all sorts of color mixtures. The two concerns were difficult to reconcile because in the eyes of contemporaries any attempt at mixing colors clouded their purity and was understood as a process of contamination, a "fading" or "deflowering."

The antagonism between the luminous spectral colors and the artificial pigments that imitated them defined early modern art in a variety of ways, especially in the development of still-life and landscape painting. The relationship between nature and art was central to these two genres since the latter was understood as a "second nature." This relationship, which was also a competitive one, is obviously of particular interest to art historians. The two models of "natural" and "artificial" coloring are often chiastically intertwined in art theory. On the one hand, nature is said to work like an artist because it colors and paints things. On the other hand, the artist resembles nature in his ability to deceptively imitate its colors with pigments. It is easy to see how the two concepts are closely correlated, not least because seventeenth-century color theory, as long it was concerned with physical or pigment colors, focused on material processes of mixing and coloring.

In Cornelis de Heem's (1631–1695) *Still Life with Parrot and Basket of Fruits and Flowers* [FIG. 11], for example, the artist engages with the theme of the bird onomatopoetically, imitating nature in a parable of mimetic visual forms. A large parrot with iridescent glowing plumage sits on a basket that has tipped over due to its weight, scattering its contents of colorful flowers and fruit on a tabletop. What draws the viewer's attention, however, is not only that the bird's splayed-out tail feathers are painted with loose brushstrokes and that the movement of the artist's hand can be traced via paint but also that the stripes of feathers extend across the width of the canvas like a rainbow. The light does not illuminate the feathers and the flowers from the outside but rather is inherent to them. The pictorial field glows and is transformed into a vibrating particulate universe made of light particles or pigments. Pigment and color are interrelated, as light passes through the painterly field as a coloring force, taking on a material form. Such a visualized connection of color corresponds to the blooming and waning spectrum of the rainbow. The seventeenth-century theorist Gerard de Lairesse accordingly advised flower painters to arrange the colors on the canvas so "that by the placement of one next to another a welcome blend of color is produced, one that is pleasing to the eye and satisfies it: this includes placing strong and flaming ones side by side with weak ones in such a way that they represent a charming rainbow."

Natural and Artificial Color

Color and pigment are central to understanding the relationship between art and nature in early modern painting. The Dutch painter and art

[FIG. 11]
Cornelis de Heem, *Still Life with Parrot and Basket of Fruits and Flowers,* ca. 1680s. Oil on wood, 85 × 119.5 cm. Galerie de Jonckheere, Paris.

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