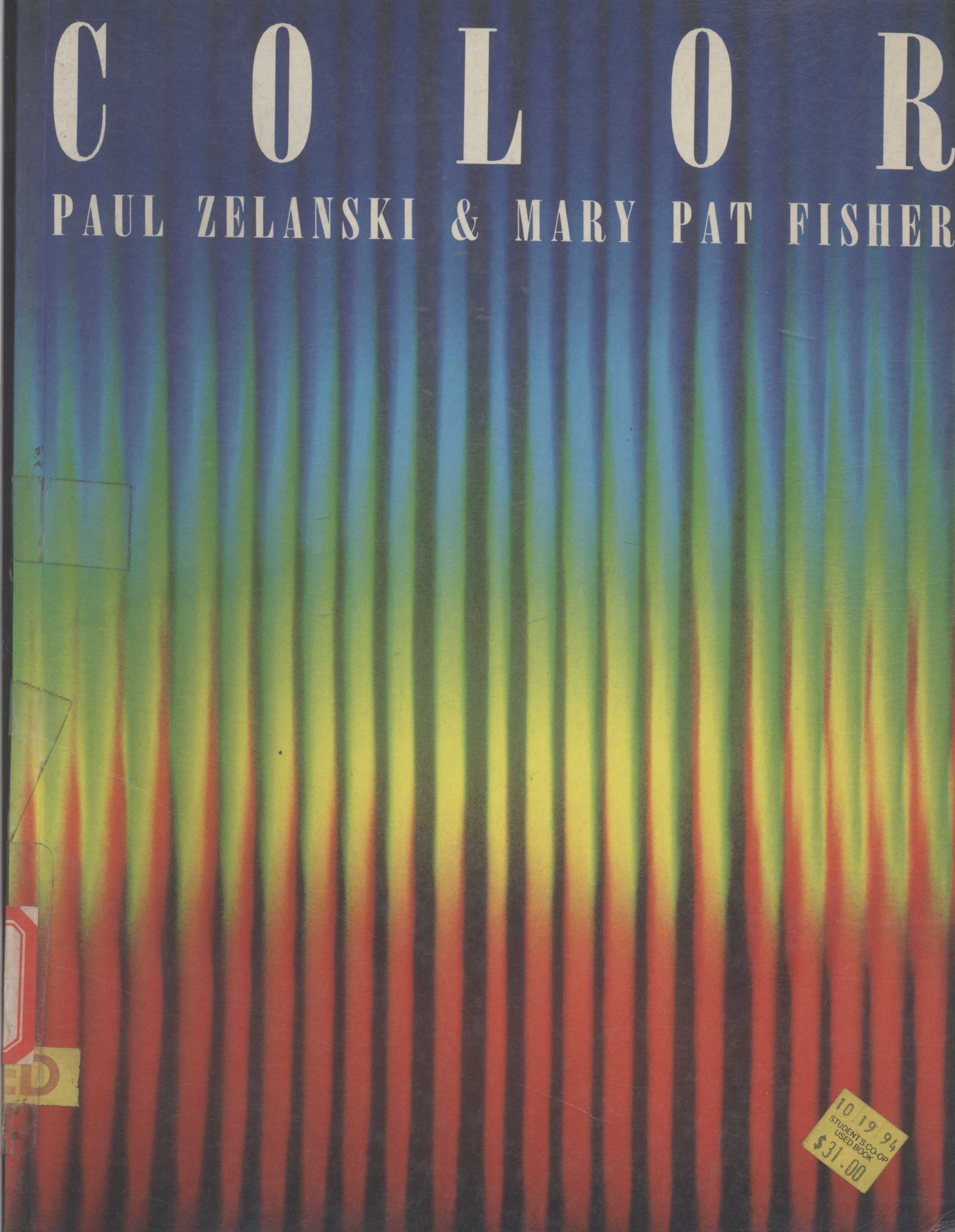

COLOR

PAUL ZELANSKI & MARY PAT FISHER

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Prentice Hall, Englewood Cliffs, New Jersey 07632

To Josef Albers
and his students
and the students of his students

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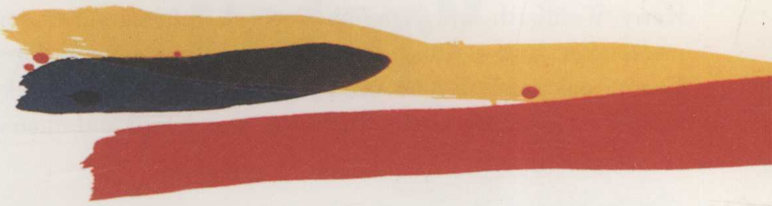


Color is addressed to artists and art students in all media. It provides an informative but non-dogmatic introduction to the many different approaches to understanding color, including aesthetics, science, and psychology. Illustrations for the chapters on color concepts are taken from all disciplines; special aesthetic and practical considerations for color usage in each medium—such as ways that graphic designers use and specify printers' inks—are also discussed in chapters on applied art. The realities of color use are accentuated by direct quotes from working artists. Technical terms are carefully defined in the text and also in a glossary: those appearing in the glossary are printed in small capitals when first used in the text.

True familiarity with the potentials of color requires first-hand experience and experimentation. For lab courses a special instructors' manual of studio problems with papers, paints, and colored lights is available. Those honoring the experiential teaching methods of the great colorist Josef Albers might like to begin with the first two chapters to develop a general orientation and a basic vocabulary before launching into studio work, and continue with the more theoretical and practical material introduced later in the book once students have made some practical discoveries on their own. Paul Zelanski is a former student of Albers and has found this method highly successful in thirty years of teaching color.

ACKNOWLEDGEMENTS

In addition to our source of inspiration, the late Josef Albers, we would like to thank many people who have helped with the preparation of this book. At John Calmann and King, who produced this book in England, our former editor Peter Zombory-Moldovan's creative vision sustained the book in its initial stages. His successor, Rosemary Bradley, editor Carolyn Yates, picture researcher Helena Beaufoy, and designer Richard Foenander have been a pleasure to work with. Norwell F. Therien, our American editor at Prentice-Hall, believed in the book and contributed useful suggestions, as did Laurence King, our dear friend and managing director at John Calmann and King.

Artists who willingly shared their expertise include color theorist Arthur Hoener, graphic designer Peter Good, computer graphics specialists Walter Bender and Rick Ford, colorist Nathaniel Jacobson, ceramicist Minnie Negoro, art historian Harold Spencer, handweaver Pat McMullan, watercolorist Wilma Keyes, Harry Mercer of the American Association of Textile Chemists and Colorists, color psychologists Harry Wohlfarth and Kenneth Peacock, photographer and printmaker Roger Crossgrove, photography engineer Jerry Coutu, and painters John Gregoropoulos and Harold Pattek, in addition to those artists whom we interviewed and quoted in the text and those who helped in locating the images we wanted. Russell Woody of Binney and Smith has been involved with us for years in developing ways of teaching color. Photographer Beverly Dickinson has been most cooperative in creating fine transparencies of artworks. Special thanks to John Fawcett, who shares not only office space but also his ideas and methods for improving the teaching of color theory.

As ever, we wish to thank Annette Zelanski, whose encouragement and editorial wisdom has sustained us through the co-authorship of four art textbooks.

Paul Zelanski
Mary Pat Fisher

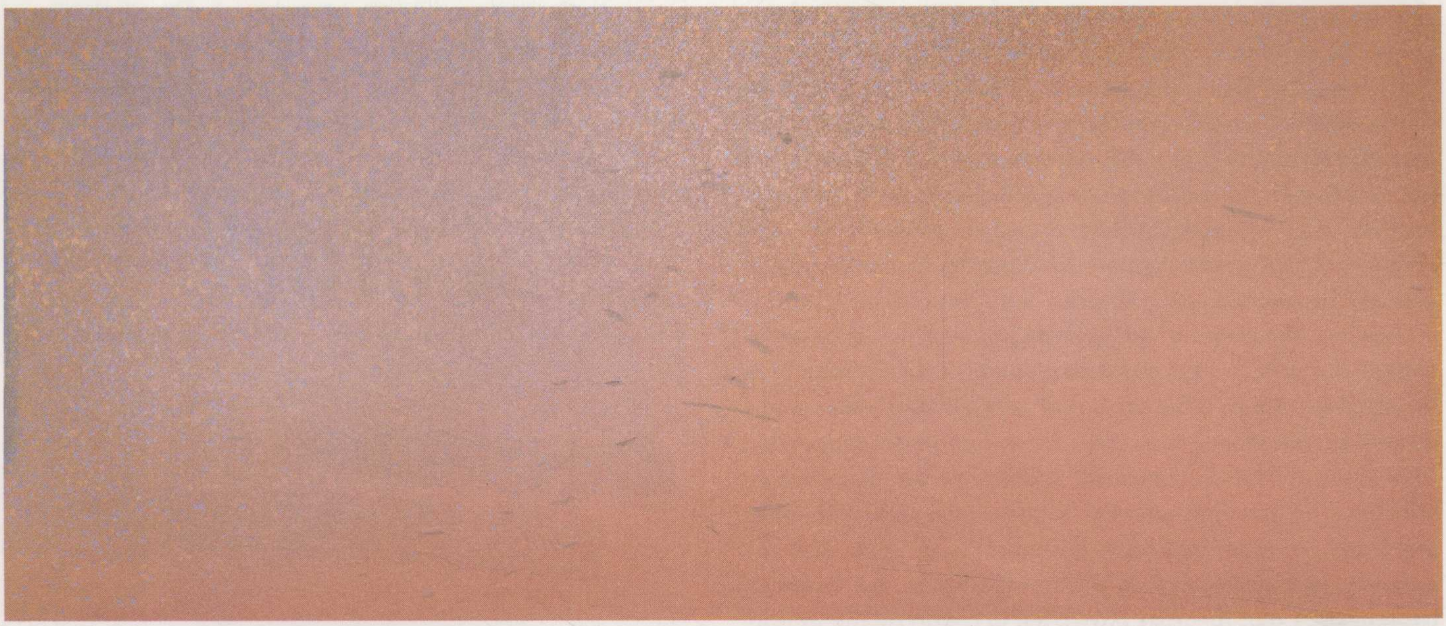
1

Why Study Color?

Color is perhaps the most powerful tool at the artist's disposal. It affects our emotions beyond thought and can convey any mood, from delight to despair. It can be subtle or dramatic, capture attention or stimulate desire. Used more boldly and freely today than ever before, color bathes our vision with an infinite variety of sensations, from clear, brilliant hues to subtle, elusive mixtures. Color is the province of all artists, from painters and potters to landscape and product designers.

Because the possibilities of color are ceaseless, the art of using color well is an open-ended, complex discipline which incorporates many different points of view and poses many questions. Scientists have tried for centuries to understand what creates colors in our world, and how we see them; yet we still have no absolute answers to these questions. Theories put forth by those studying the physics of light and the anatomy and physiology of vision still lie in the realm of hypothesis. Color theorists have tried to condense the infinite number of visible color variations into a few basic colors and to form theories about their relationship. But no one color theory has been generally adopted as satisfactorily explaining all color phenomena. Psychologists are studying the impact of various colors on our emotions and health, but they find that individuals tend to differ in their responses. Art historians analyze the different ways in which color has been used in different times and places. Those interested in design try to discern how colors affect compositional factors, such as unity, emphasis, balance, contrast, and spatial awareness. Other specialists offer suggestions and attempts at standardization in the realms of mixing colors with lights and pigments, for there is a special science of color creation for each discipline.

To tap into the tremendous potential of color, artists must explore all of these intellectual approaches. The answers they will find, however, are only partial. Each separate way of looking at color is as incomplete as the proverbial blind men who seize different parts of an elephant and try to describe the whole creature based on the piece they are holding: "It's a leathery cylinder." "It's a hairy tail." "It's a great flapping ear." "It hangs down from the sky and blows air out of two holes." Once you have read Chapter 2 ("Color Basics," which discusses the physical properties of color), can you explain the mysterious and beautiful effects of Jules Olitski's *Twice Disarmed* (**1.1**) using what you have learned about wavelengths? After you have studied Chapter 3 ("Perceiving



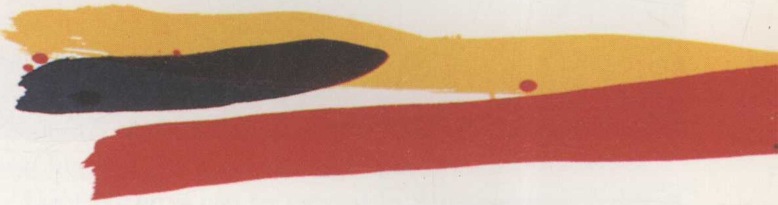
1.1 Jules Olitski, *Twice Disarmed*, 1968 Acrylić on canvas, 9ft 10ins × 16ft (2.9 × 4.8m). The Metropolitan Museum of Art, New York. Gift of Mr and Mrs Eugene M. Schwartz. What is Olitski doing with color here? How? What colors does he create? How do you see them? How do they affect you?

Colors") can you explain the experience in terms of color perception? Or can it be analyzed only in terms of the psychological effects of colors (Chapter 4), pigment mixing (Chapter 7) color interactions (Chapter 9), or the historical and cultural use of color (Chapter 10)? Obviously not, although all these perspectives and those explored in other chapters increase the amount of elephant you can grasp.

Beyond these very important perspectives lies direct experience with color. Actually working with color, exploring its characteristics and potentials, carefully observing how colors work together, will teach you in ways that no theory can. The theories are useful ways of narrowing the field of exploration. Intellectual information provides a general map so that you do not have to wander randomly through the myriad halls of color. Beyond the intellect, one works intuitively, experimentally, with all senses alert. Only in this way can you discover the realities of color—and the journey is endless.

2

Color Basics



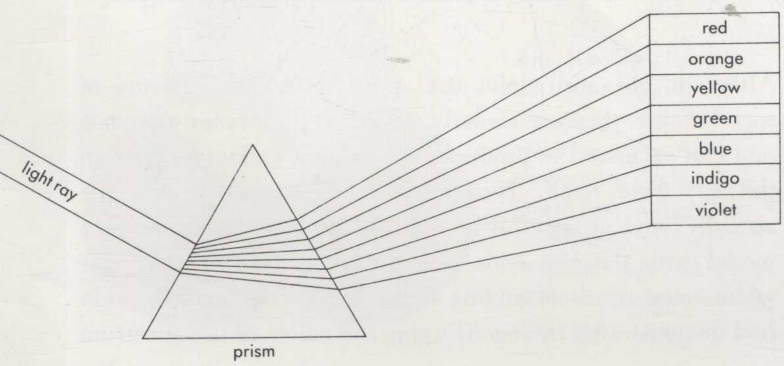
To develop a vocabulary for talking about colors, we must delve briefly into the physical properties of what we see as colors. While this vocabulary is useful, it is not always precise, for much of it is based on theoretical or scientific observations that do not necessarily hold true in artistic practice. And although the same terms are often used for describing colored lights and colored pigments, such as paints, they are quite different phenomena. When talking about colors, it must be made quite clear to which of these one is referring.

THE PHYSICS OF LIGHT

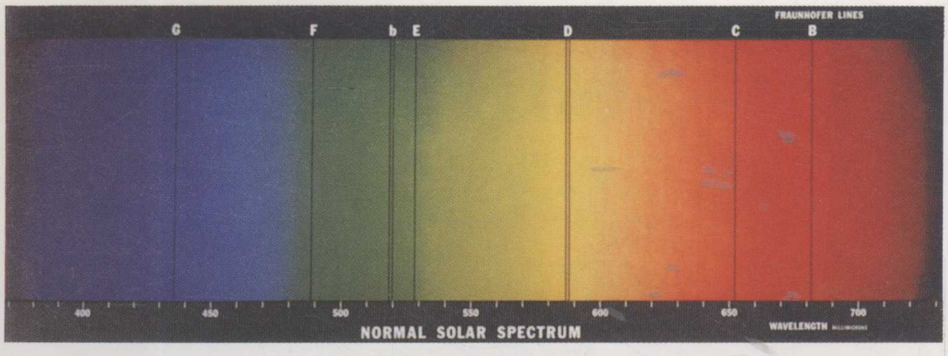
Physicists explain color as a function of light. A current theory is that energy from the sun consists of a series of separate energy packets, or quanta, traveling as continuous electromagnetic waves. They stimulate color sensations in our visual perception when they strike objects.

In the seventeenth century, the great physicist and mathematician Sir Isaac Newton (see Chapter 6) conducted a series of experiments demonstrating, among other things, that sunlight contains all the colors of the rainbow. He admitted a ray of daylight into a darkened room through a hole in a windowshade and placed a glass prism where the ray would pass through it. As it did so and then came out the other side, the ray of white light was bent, or REFRACTED, breaking it down into its constituent colors which could be seen on a white wall beyond, as shown in Figure **2.1**.

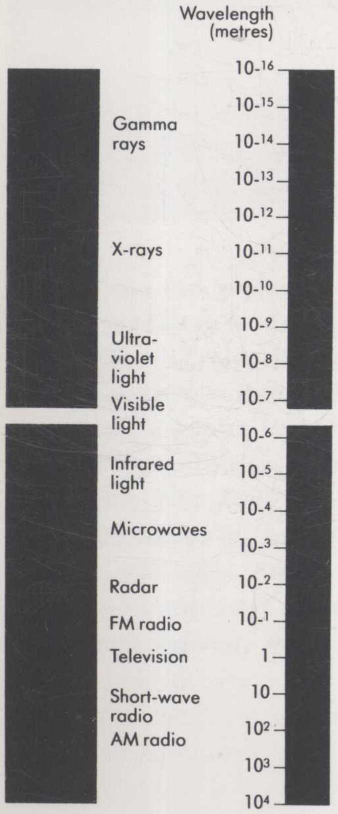
Newton identified seven basic colors in the breakdown: red, orange, yellow, green, blue, indigo, and violet. Each is now thought to correspond to a certain portion of the range of wavelengths of radiant energy that can be distinguished by



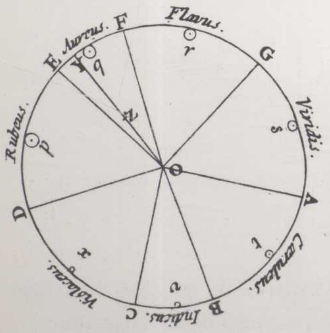
2.1 A modern rendition of Newton's experiment, breaking white light into the colors of the spectrum by passing it through a prism.



2.2 Colors of the visible spectrum are here identified as regions of certain wavelengths, measured in millimicrons (nanometers). The dark "Fraunhofer" lines represent some of the fine dark lines seen in a pure spectrum, revealing wavelengths that are missing in the light sample.



2.3 In the electromagnetic spectrum, only a very small portion of all radiant energy can be seen by humans.



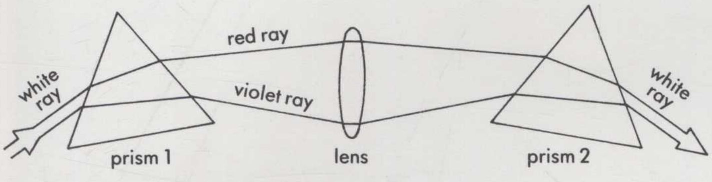
2.4 Newton's proposed color wheel, created by joining the two ends of the visible spectrum. Although this model does not correspond to the linear array of wavelengths, it is useful for analyzing relationships among colors.

the human eye, called the VISIBLE SPECTRUM. A WAVELENGTH is the distance between crests in a wave of energy. Wavelengths in the visible spectrum are measured in NANOMETERS, each of which is only one-billionth of a meter. Differences between colors involve tiny differences in wavelengths. Figure **2.2** shows the designation of SPECTRAL HUES, or the colors that can be seen in a rainbow, in terms of the wavelengths indicated by each hue name. "Red," for instance, is the name given to everything from about 625 nanometers to 740 nanometers, although we can distinguish many gradually differing reds within that range, some of them merging into the area we call "orange." Red has the longest wavelengths; violet has the shortest.

Beyond red and violet at each end of the visible spectrum lie wavelengths of radiant energy that humans cannot see, beginning with infrared and ultraviolet. As illustrated in Figure **2.3**, the electromagnetic spectrum comprises radiations from the universe ranging from gamma rays to radio waves. The greatest portion of this spectrum is invisible to human sight.

ADDITIVE COLOR RELATIONSHIPS

Although red and violet are quite different in terms of wavelengths, they are visually similar at their outer extremes and can be mixed to produce purples that cannot be seen in the spectrum itself. Newton therefore proposed that the straight band of spectral hues could be bent into a circular model with the two ends joined (**2.4**). At its center was white—the result of mixing lights of all colors, as Newton had demonstrated by reconverging the colors of the spectrum

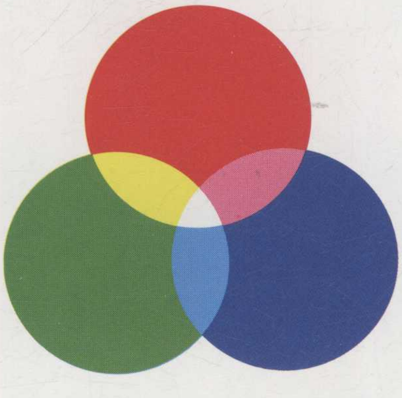


2.5 Newton demonstrated that white light is the composite of all spectral hues by breaking it down into the visible spectrum and then converging these rays through a second prism back into white light.

through a second prism into a single ray of white light (**2.5**). In Newton's color circle, as one moved outward from the center, as in point Z (2.4), the more "intense" the color would become. "If Z fall upon the Circumference," Newton wrote in his *Opticks*, "the Colour shall be intense and florid in the highest Degree." And if Z were on or near the line between O (the center) and D (the point between red and violet), "the Colour compounded shall not be any of the prismatic Colours, but a purple, inclining to red or violet, accordingly as the point Z lieth on the side of the line DO towards E or towards C."[1]

This was the first COLOR WHEEL—an attempt to illustrate visual relationships among hues. Newton's color circle was adopted by many later aesthetic theorists as a way of explaining relationships between different colors.

Color theorists often speak of the colors in light as ADDITIVE: the more they are mixed with other colors, the lighter they become. White light can even be recreated by mixing only three carefully-chosen colored lights: green, blue-violet, and orange-red. These same colors can be used to mix most of the colors that humans can distinguish, but cannot themselves be mixed from other colors. They are therefore known as PRIMARY COLORS. As illustrated in Figure **2.6**, where the primaries orange-red and green overlap, they create yellow; green and blue-violet can be mixed to form indigo (known as cyan in printing and photography); and blue-violet and orange-red overlap to form magenta. The yellow, cyan, and magenta formed by mixing two primaries are called SECONDARY COLORS; in light mixtures, these are more luminous than the primary colors. White, as we have seen, results from mixing all three primary colors together at the proper intensities; black is the absence of all light.



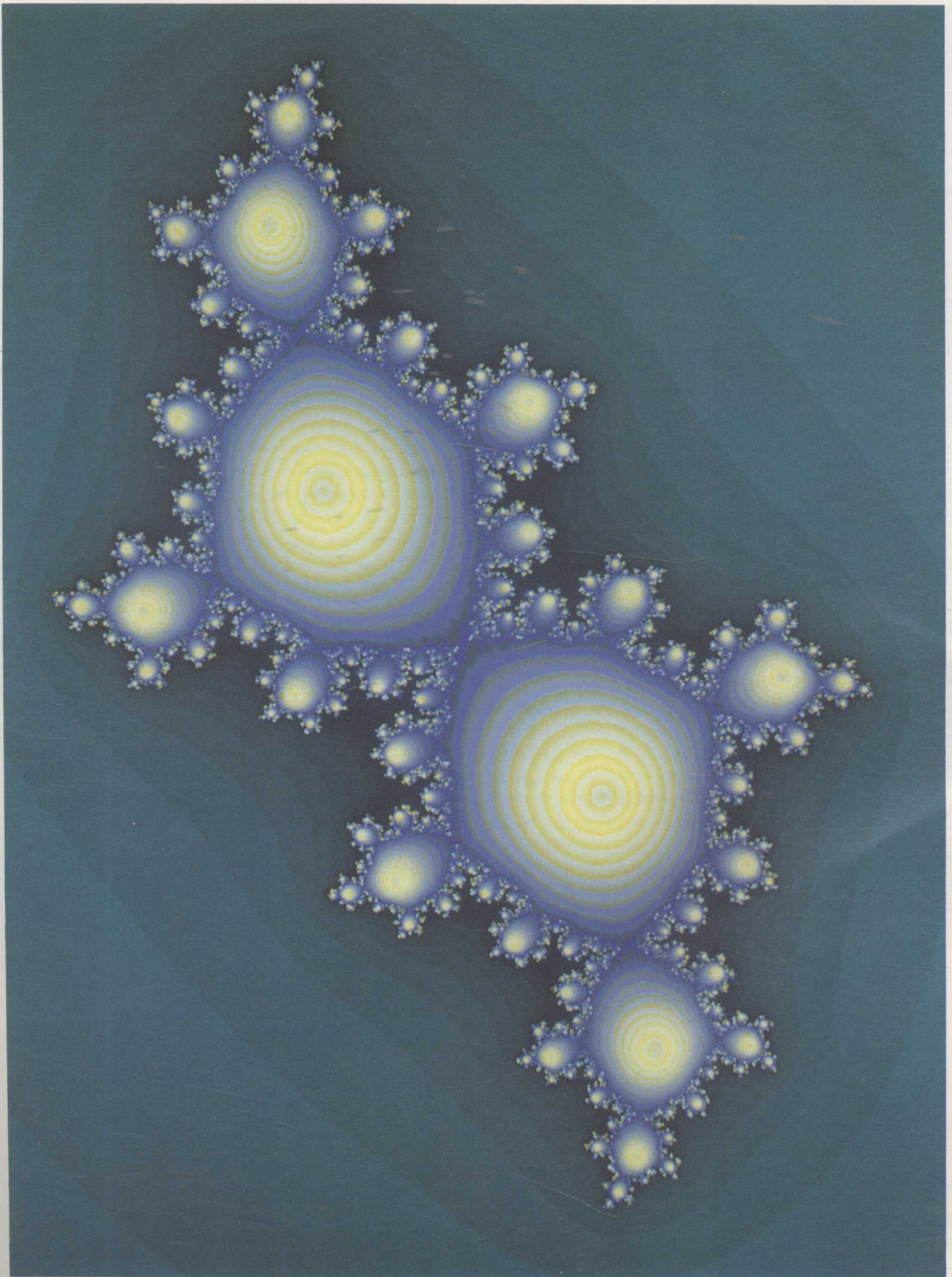
2.6 If colored lights in the light primaries red-orange, green, and blue-violet are projected in overlapping circles, they mix to form the light secondaries, yellow, magenta, and cyan. Where all three primaries overlap, they produce white.

Light mixtures can be created by superimposing lights of different colors, by showing two different colors in rapid succession, or by presenting small points of different colors so close to each other that they are blended by our visual apparatus. In the past, experiments with light mixing had to be done by projecting and overlapping colored lights on a wall. However, the advent of computer graphics has opened a vast world of instantaneous and mechanically precise light mixing for aesthetic exploration. Cathode ray tubes used in video receivers and computer graphics monitors have three electron guns corresponding to the light primaries. When the beams from these guns strike the light-sensitive PHOSPHORS on the surface of the screen in varying combinations and intensities, they can create a great array of luminous color sensations.

In the fractal computer image shown in Figure **2.7**—the beautiful visual expression of a mathematical formula—the lightest areas occur where the rays are most concentrated and the darkest areas where the rays are least concentrated. The stunning yellows are entirely mixed; there is no yellow gun in a cathode ray tube. If you examine a yellow image on a television screen very closely, you can see that it is formed by the juxtaposition and overlapping of orange-red and green bits of light (8.3).

PIGMENT COLORS

Colors seen on the surface of objects operate in a very different way from those seen in beams of light. When daylight or some other kind of incident light strikes a surface, certain wavelengths may be absorbed and others reflected by its PIGMENTS, or coloring matter. The REFLECTED wavelengths



blend to form the color "seen" by the viewer. To cite a simple example, the surface of an apple absorbs all wavelengths except those which create the sensation of red; these are reflected into the eye of the viewer. An object that appears black absorbs almost all wavelengths (in the darkest of pigments, carbon black, 97 per cent of the incident light is absorbed). In theory, a surface that appears white absorbs no wavelengths; all are reflected and mixed. This ideal is never met in practice; the closest one can come is to coat cold metal with magnesium oxide smoke, resulting in absorption of only two per cent of the incident light.

In traditional color theory, there are three pigment colors—red, blue, and yellow—that cannot be mixed from other colors and from which all other colors can be mixed. These characteristics would define them as primary colors. However, with pigments, the ability to mix all other colors from only three primaries is possible only in printers' inks and color photography.

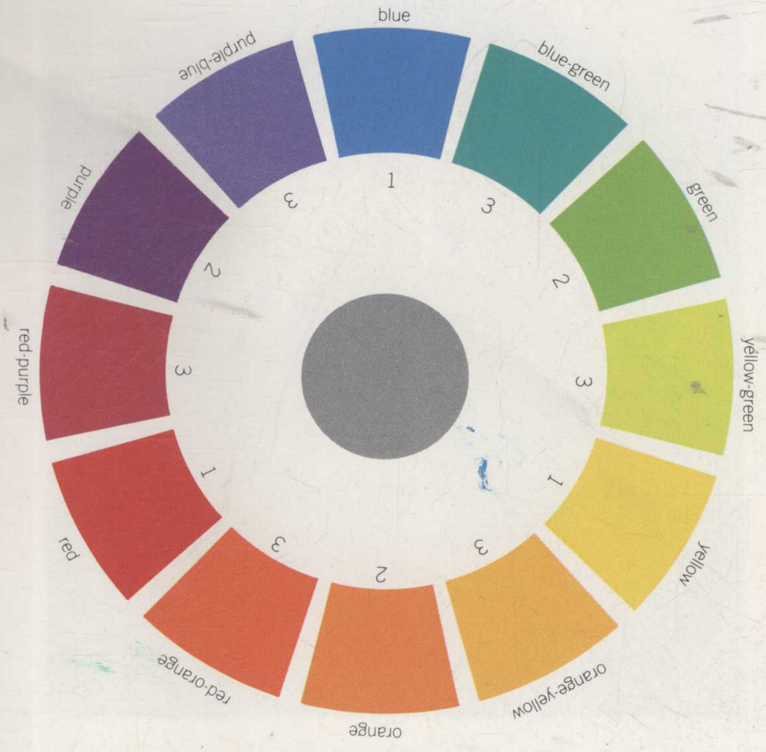
R, B, Y

Transparent inks or photographic dyes in chrome yellow, magenta, and cyan, plus black, and the white of the paper can be used to approximate most colors that the eye can see. But in paint mixing, it is not possible to mix all colors from any basic three primaries. Some theorists would therefore add green to the list of paint pigment primaries to make more mixtures possible. The color standardist Albert Munsell proposed five pigment primaries: green, blue, purple, red, and yellow (which he called PRINCIPAL HUES). We recommend that new students use ten paint colors and mix all others from them. These pigment mixing issues will be dealt with in detail in Chapter 7; the point here is that the concept that only three primaries exist is more theoretical than real when one is dealing with paint pigments rather than lights.

Be this as it may, mixtures of the pigment primaries red, blue, and yellow theoretically yield the pigment secondaries orange, green, and purple. When these secondaries are mixed with their adjacent primaries, they yield TERTIARY COLORS: red-purple, red-orange, yellow-orange, yellow-green, blue-green, and blue-purple. If one starts with three primaries, one gets three secondaries and six tertiaries, giving a total of twelve colors, as shown in Figure **2.8**.

2.7 (Left) **Heinz-Otto Peitgen and Peter H. Richter, fractal image based on the process $x \to x^2 + c$.**

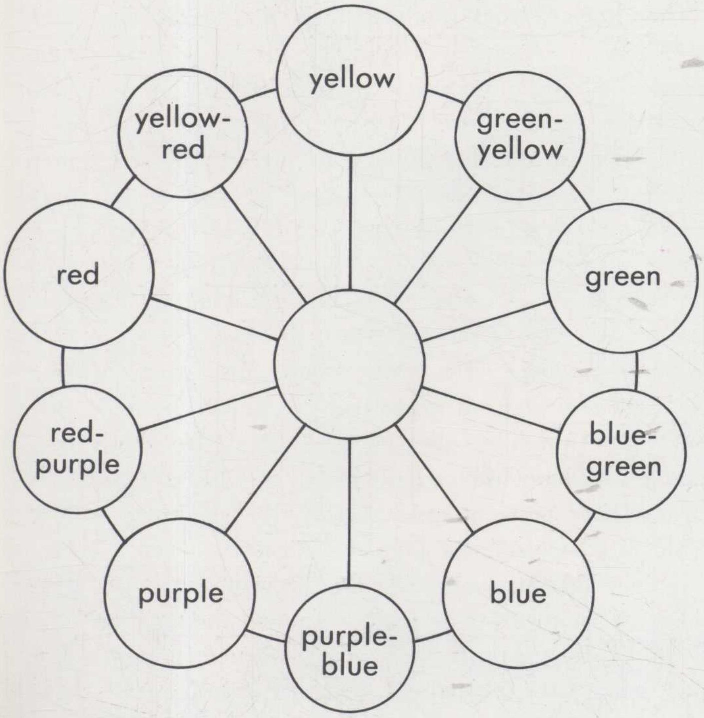
2.8 (Below) On the conventional color wheel of pigment hues, the primaries are red, blue, and yellow; the secondaries are orange, green, and purple; and the tertiaries are mixtures of adjoining primaries and secondaries. If colors are mixed with their complement, lying opposite on the wheel, a neutral gray is created, as indicated in the center.



SATURATION, HUE, VALUE

Between each of these twelve colors are many more possible gradations as adjacent colors are mixed. It is also possible to mix colors that are not adjacent to each other. Mixing those that lie opposite each other on the color wheel, for example, tends to yield a chromatic gray. Two colors that are opposite each other on the color wheel are called COMPLEMENTARIES. As we will see in Chapter 9, although complementary colors gray each other when mixed, they tend to intensify each other optically when placed side by side.

The degree to which colors are grayed by being mixed with their complementaries is called SATURATION, also known as "intensity." In their purest, most brilliant state, they are at maximum saturation; as they become more and more neutral,



2.9 Color theorists have proposed other color models, including this one by Albert Munsell, which is based on five principal colors and the intermediate colors that can be obtained by mixing them.

they are said to be low in saturation. In Figure 2.8, colors decrease in saturation as they approach the gray in the center of the wheel.

The matching up of complementaries is not a precise science, however. The twelve-point wheel shown in Figure 2.8 is only one of many suggested models for color relationships. Drawing a line through the center of this wheel shows yellow and purple, red and green, and orange and blue to be pairs of complementaries. But the ten-point color wheel that results from Albert Munsell's five primaries (**2.9**) yields slightly different results: yellow is the complement of purple-blue, green of red-purple. Only the pairing of blue and yellow-red (orange) remains the same as on the twelve-point wheel. Because the mixtures and intensifying interactions between complementaries are of great importance in some approaches to color usage, artists must experiment and observe carefully to see which combinations best produce the effects they seek.

Saturation is not the only way of describing the variations among colors. HUE is the quality we identify by a color name, such as "red" or "purple." It corresponds to the distinctive wavelength of a color. A third property of colors is VALUE, sometimes known as "brightness" when light mixtures are being discussed. Value is the degree of lightness or darkness in a color and in pigment mixtures can be adjusted by the addition of black or white. The potential gradations are infinite, though there is a finite limit to the number of differences in value humans can distinguish. Georgia O'Keeffe's *Black Iris* (**2.10**) is executed solely in values of purple and red-purple, from near-white to near-black. The lightest values are referred to as "high," the darkest as "low."

When pigments of equal value are mixed, the resulting color is darker rather than lighter, since more wavelengths are absorbed. Because this process subtracts from the light

2.10 **GEORGIA O'KEEFFE, *Black Iris*, 1926** Oil on canvas, 33 × 24ins (83.8 × 60.9cm). The Metropolitan Museum of Art, New York. The Alfred Stieglitz Collection. The subtle color variations in this painting are based on value gradations in a single area of the color wheel: purples and red-purples.