Color

COLOR depends on light. The brightness of light affects the hue and saturation of the spectrum of colors we see as red, yellow, and blue. Color science explains how color is perceived in the human brain and eyes. The spectrum of light, light power, and wavelengths interact with the cones and rods in our eyes.

Objectives:

1. Identify color-matching tools.
2. Explain color-dyeing processes.
3. Explain the chemistry of color pigmentation.

Key Terms:

analogous
batik
Bezold effect
binders
bonding agents
catalysts
chroma
color
color systems
colorants
colorfastness
complementary
compound hues
cross dyeing
digital printing
dye
dye bath
dye penetration
electrostatic charge
fastness properties
fiber dyeing
garment and product dyeing
heat-transfer printing
hue
inorganic
light
metameric
monochromatic
Munsell Color System
organic
piece dyeing
pigments
polymer chains
primary colors
roller printing
RYB color system
saturation
screen printing
secondary color
split-complementary
stock dyeing
tertiary color
tie dyeing
triad
value
vat dyeing
water insoluble
water soluble
wavelength
yarn dyeing

Color and Light

Without light, there would be no color. **Color** is what the eyes see when light strikes an object. It is composed of light made up of different wavelengths and frequencies. **Light** is a type of electromagnetic wave with small bundles of energy that operate at different wavelengths. It travels in the form of light waves that have high and low points. A **wavelength** is the distance between the same locations on adjacent waves. Long wavelengths have low energy and low frequency. In contrast, short wavelengths have high energy and high frequency. Light waves are visible and invisible. Visible waves are the colors of the spectrum: red, orange, yellow, green, blue, indigo, and violet. What the eyes see are wavelengths of the visible colors—a rainbow spectrum. The invisible part of light can be absorbed, reflected, or transmitted.

LIGHT AND THE HUMAN EYE

When all the visible light colors of the spectrum are combined, the eyes see white light. A prism separates white light into individual colors of the rainbow spectrum. Sources of white light are the sun, the stars, and incandescent and florescent light bulbs. When all light is absorbed and no light is reflected, black is seen. Solid objects reflect light, and human eyes see that reflected color.

Sir Isaac Newton

Sir Isaac Newton is credited with first interpreting the rainbow with an experiment that refracted white light with a prism and categorized light into the component colors of the rainbow: red, orange, yellow, green, blue, and violet. Newton proved that light was responsible for color, and he created the first color wheel. ROY G. BIV is a mnemonic device for the rainbow and color wheel colors: red, orange, yellow, green, blue, indigo, and violet.

Metameric

Color is **metameric**—that is, it appears different under various light sources. Under one light source, a color may match another color. However, under another light source, it may not match. For example, fabric colors differ under cool light fluorescent bulbs and warm light fluorescent bulbs. Generally, daylight is the best light for matching colors.

Three-Color Code: Red, Blue, and Green

Different cones and rods in human eyes cause some people to see colors and shades of colors differently. The human brain and eyes perceive color in a three-color code: red, blue, and green. Eyes discern various colors by sensing different wavelengths. Red, blue, and green are "mixed together" in the brain to enable humans to see other colors.

EXPLORING OUR WORLD...

SCIENCE CONNECTION: Color Vision

Human eyes can distinguish 10 million shades of color. Eyes have two kinds of photoreceptors—rods and cones—stimulated by light. There are 120 million rods and 6 million cones in each human eye.

Three main types of cones (red, green, and blue) allow us to distinguish colors and provide sharp spatial acuity. Red cones comprise 63 percent of the cone total, green cones comprise 31 percent, and the more light-sensitive blue cones comprise 6 percent.

Rods are more numerous and are responsible for vision at low light levels. They do not detect color, but they provide good peripheral vision and are good motion sensors. When a person's color-sensing cones are less responsive to incoming light, few colors can be distinguished. As a result, the person is declared color blind. However, the term is misleading because color-deficient people can usually distinguish some colors. If a person is missing one pigment, he or she may find it difficult to see the difference between red and green. Other people may have a hard time seeing blue-green colors. Approximately 1 in 10 men has color blindness, though few women are color blind.

COLOR MATCHING

Munsell Color System

Color-matching tools exist to assure that colors appear the same as in apparel colors, paint colors, interior colors, and computer colors. Munsell's Color System uses the RYB Color System on a color wheel as a basis for color selection. **Color systems** are scientific methods of organizing color information. The **Munsell Color System**, developed by Albert A. Munsell (1858–1918), was the first organized method to accurately identify colors. It is still recognized as the global standard for color notation. This system makes it possible to denote colors uniformly across all industries, including art, business, science, government, and education.

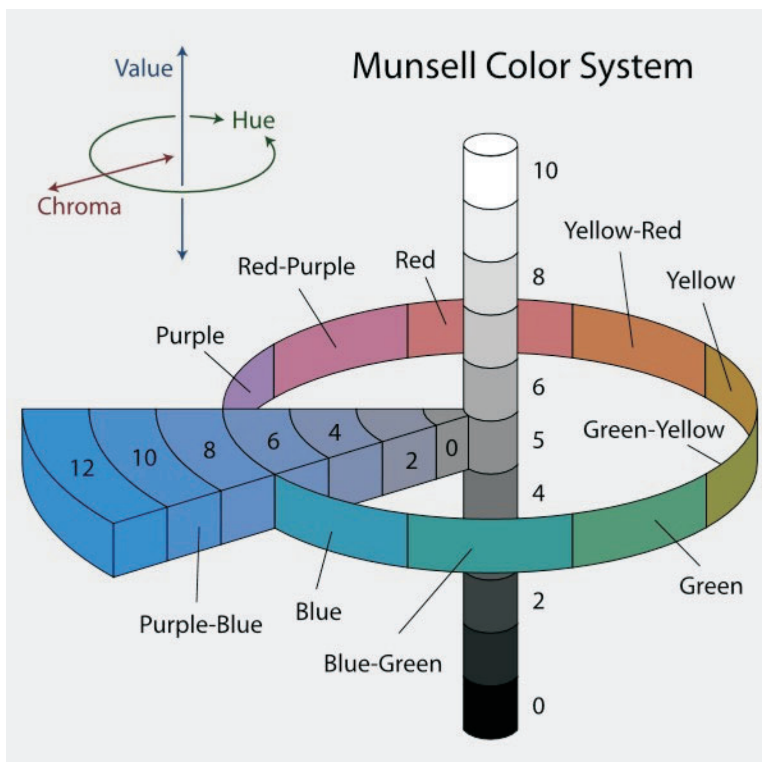

FIGURE 1. Munsell divided color into the three components of hue, value, and chroma. (This image © 2007, Jacob Rus)

Primary colors (colors from which other colors are made) in the Munsell Color System are red, yellow, blue, green, and purple. **Compound hues** are combinations of the primary colors to form secondary colors: yellow-red, green-yellow, purple-blue, and red-purple.

Hue is the name of the pure spectrum colors: red, orange, yellow, green, blue, and violet. Munsell defined hue as "the quality by which we distinguish one color from another."

Value is the relative lightness or darkness of color. Using a scale of value, black represents the total absence of light. Meanwhile, white represents pure light. Between these are a number of divisions graded between black and white. Munsell defined value as "the quality by which we distinguish a light color from a dark one."

Saturation is the intensity, brightness, or dullness of color. A saturated color has high intensity and strength. In addition, a saturated color is very bright. In contrast, an unsaturated color has low intensity and weakness. As a result, it is very dull. **Chroma** is another name for saturation. Munsell said chroma "is the difference from a pure hue to a gray shade."

The RYB Color System

The **RYB Color System** is a color-matching system used primarily in art, art education, textiles, and design settings. RYB stands for red, yellow, and blue—the primary colors in the RYB system. The three colors form a primary color triad and are located equidistant from each other on the color wheel.

- A **secondary color** is a color formed by mixing two primary colors. The secondary colors (orange, purple, and green) are located equidistant from each other on the color wheel. Secondary colors form a secondary color triad: red and yellow form orange; red and blue form purple; and yellow and blue form green.
- A **tertiary color** is a color formed by mixing a primary and a secondary color that are adjacent to each other on the color wheel. Two tertiary color triads are formed on the color wheel because six tertiary colors exist. Six tertiary colors formed by primary colors are red-orange, yellow-orange, yellow-green, blue-green, blue-violet, and red-violet.

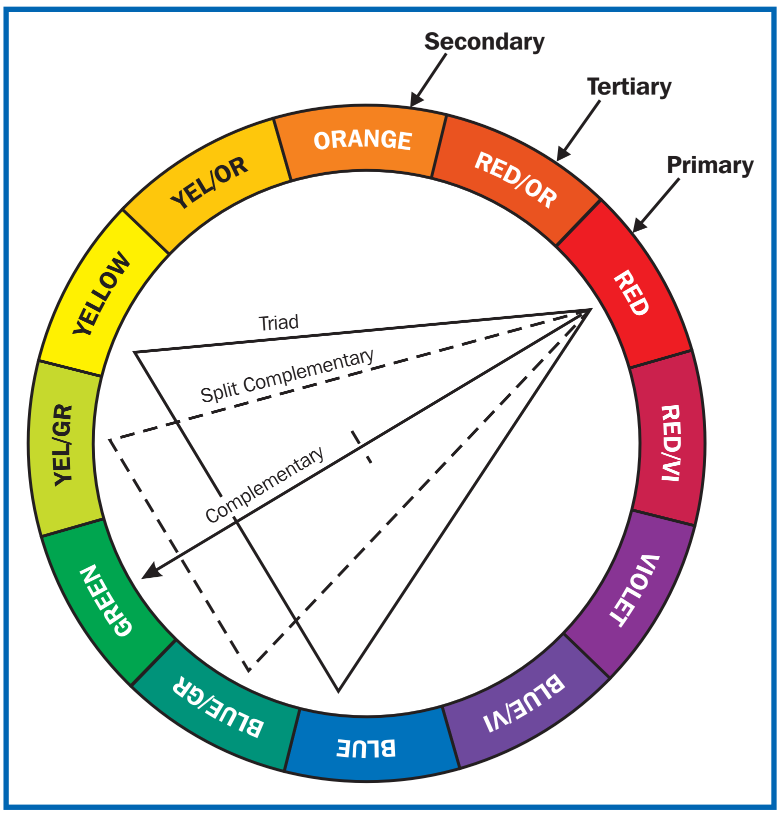

FIGURE 2. Six tertiary colors are made from primary and secondary colors.

COLOR SCHEMES

Color schemes are methods of putting colors together to make them pleasing to the eye. Five color schemes use the RYB color system:

- **Monochromatic** describes a color scheme that coordinates hue with variations from light to dark, such as dark brown, medium brown, and beige.
- **Analogous** describes a color scheme that uses three colors located next to each other on the color wheel, such as yellow-orange, yellow, and yellow-green.
- **Complementary** describes a color scheme that uses colors located directly across from each other on the color wheel, such as red and green.
- **Split-complementary** describes a color scheme that uses a color and the two colors on each side of its complement. For example, red (whose complement is green) is paired with blue-green and yellow-green.
- **Triad** describes a color scheme that uses three colors that form an equidistant triangle on the color wheel (e.g., orange, purple, and green).

Color Dyeing Processes

Colorants

Colorants are substances used to color a material. **Dye** is a chemical substance used to stain and color a material. **Pigments** are finely ground, insoluble particles of color held on the surface of a fiber with the help of bonding agents.

Dye molecules are smaller than pigment molecules and are usually in solution or paste forms. Typically, dye is **water soluble** (dissolvable in water). In addition, dye is organic or carbon-based from once-living matter. Dye is a more expensive colorant than pigments.

Pigments absorb and reflect light. The amount of light affects the spectrum of color. **Bonding agents** are substances that act like glue to hold color particles on the fiber surface; they are also known as **binders**. They are necessary for pigmentation and are used to impart color not only to fabrics but also to plastics, paint, ink, cosmetics, and food.

Dye-Coloring Textiles

Dyes bond chemically with fibers by clinging to and penetrating them with an **electrostatic charge**—a negative and positive exchange. Dye color does not last as long as pigment color. However, dyes have great color strength in that a small amount colors a large amount of fabric. Dyes are applied selectively to fibers because certain fibers (e.g., polyester) do not accept dye well. Dyes have good **fastness properties**—the ability to remain in the fabric and not fade because of laundering, dry-cleaning, or exposure to sunlight.

Following is the process for dyeing fibers or fabric:

1. Place the dye in solution. Use water, heat, and steam to dissolve or disperse the dye.
2. Add catalysts or agents (e.g., acids, salts, or bases) to the solution. **Catalysts** are substances that speed up reactions and increase the ability of dye to penetrate fibers or fabric.
3. Agitate the fibers or fabric while in solution.
4. Apply heat to the dye and fibers or fabric in solution. Raising the solution's temperature assures that the maximum amount of dye is absorbed. Dye reacts with surface molecules first during the dyeing process. Moisture and heat cause **polymer chains** (large molecules composed of repeating structural units) to swell and expand. Expanded polymer chains allow the dye to penetrate to the interior of the fibers.
5. Cool the dye. When the fibers or fabric cools, the dye is trapped inside the polymer, and the dye has permeated the fibers or fabric.
6. Rinse the dyed fibers or fabric.
7. Dry the dyed fiber or fabric to "lock" the dye into the polymer.

Dyeing Types

- **Fiber dyeing** (or **stock dyeing**) is the application of dye directly to fibers before they are spun into yarn. An early addition of color at the fiber level adds to the uniformity of color in the yarn, fabric, garment, or other product. For synthetic fibers, the dye is added to the solution prior to being forced through spinners.
- **Yarn dyeing** is the application of the color after fibers have been spun into yarn. The yarn is wound on tubes and is placed in a **dye bath** (dye in a solution). Yarn dyeing may result in some variation in color in the fabric or garment.
- **Piece dyeing** is the application of the color after the fabric has been woven or knitted. Most piece-dyed fabrics are solid colors.
- **Garment and product dyeing** is the application of the color after an item is constructed. Buttons, zippers, and thread may pose problems, as they may dye differently than the garment or product.
- **Cross dyeing** is mixing two dyes in one dye bath to color different fibers and produce a multicolored fabric. In a blended-fiber fabric, one dye colors one fiber, and the other dye colors the other fiber. The result may be a blue and green striped fabric when using blue and green dye.
- **Dye penetration** is the depth to which the dye enters the item being dyed. Dye penetrates best and adds uniformity to yarn, fabric, or a garment when loose fibers are in a free-moving liquid dye.
- The **Bezold effect** is a merging of two colors that produce an optical illusion of a third color. This effect is often noted in small prints and in yarn-dyed fabrics when small areas of color are interspersed.

- **Colorfastness** is the retention of the original hue. The color remains consistent when a garment is dry-cleaned as well as when it is exposed to sunlight, perspiration, or abrasion. Colorfastness is a desirable attribute of a dye.

Dyeing Techniques

- **Vat dyeing** is a process that uses a chemically complex special class of water-insoluble dyes. Dyes that are **water insoluble** (not dissolvable in water) are incapable of dyeing fibers when used alone. Therefore, chemicals are added to the vat dye to change it to an alkaline solution. When the dye is absorbed into the fibers, the dye returns to an insoluble state. As a result, the dye has excellent wash and fastness properties. Vat dyeing is usually done in a large bucket or tub.
- **Batik** is a hand-dyeing process that uses wax to make designs on fabric. To create a batik pattern, drip a wax design onto the fabric. Then place the fabric in a dye solution. The fabric is dyed except for the wax design. Rinse the dye out of the fabric, and remove the wax by pressing the fabric between paper towels with a hot iron or by boiling the fabric in a solvent.
- **Tie dyeing** is a treatment in which a fabric design is produced by preventing parts of the fabric from having access to the dye. You can tie dye by wrapping the fabric or garment with rubber bands or tying it with string. Then submerge the wrapped item in a dye solution. Remove it from the dye solution. Next, remove the rubber bands or string to reveal a design where the dye did not reach the fabric. In mass production settings, the fabric is twisted like a rope and tied before it is submerged into the dye solution. The tie-dye design is produced when the fabric is untwisted.

FIGURE 3. This batik design used wax to create the butterfly pattern.

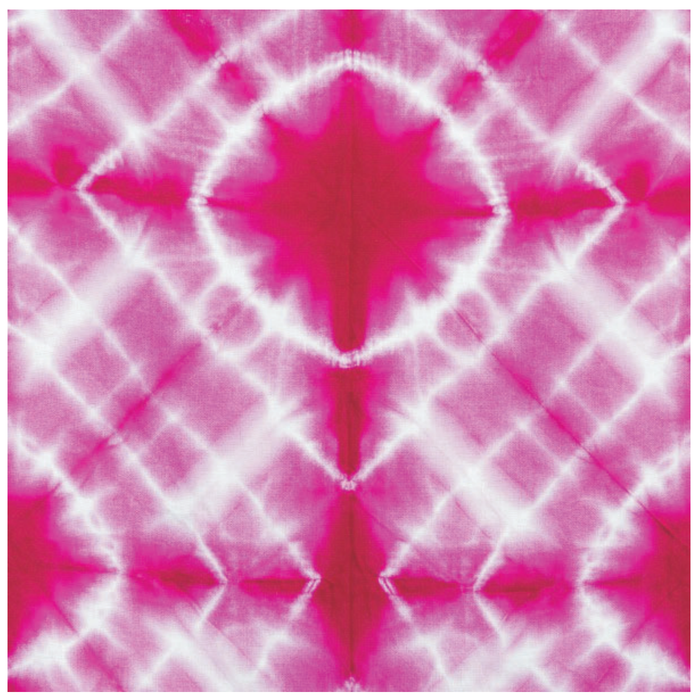

FIGURE 4. Tie-dye treatments are produced by preventing parts of the fabric from having access to dye. It's easy to see which parts of the fabric had no access to the dye.

The Chemistry of Color Pigmentation

PIGMENTS

As stated earlier, pigments are finely ground, insoluble particles of color held on the surface of a fiber with the help of bonding agents. Bonding agents act like glue or paste and are activated by catalysts or heat. Pigments reflect and scatter (rather than absorb) light to give a fabric or product color. They can be applied at the fiber, yarn, fabric, garment, or product stage. Generally, pigments are added to manufactured fibers during the liquid spinning stage. Pigments may be inorganic or organic. If the pigment is **inorganic**, the substance is made of chemical elements that contain no carbon atoms. If the pigment is **organic**, the substance is derived from living matter and contains carbon atoms.

Pigment Characteristics

The mechanical application to fibers and fabrics makes pigments more versatile than dyes, and pigments cost less than dyes to apply. Pigmentation does not require a rinse cycle to remove excess particles, so it is more environmentally friendly than dyeing. Also, pigments offer an extensive color range, have greater color control than dye, and have excellent fastness properties.

PRINTING TECHNIQUES

- **Roller printing** is a printing process to add design to a fabric by printing the design on a roller. Fabric is passed through rollers to add layers of color and designs. When several rollers are used on a single fabric, each roller has a different color or design.
- **Screen printing** is a printing method in which an ink pigment is directly applied to the surface of a fabric to create an image. The ink pigment is pressed through a very fine mesh screen with areas blocked off by a stencil. The blocked-off stencil areas create the design.

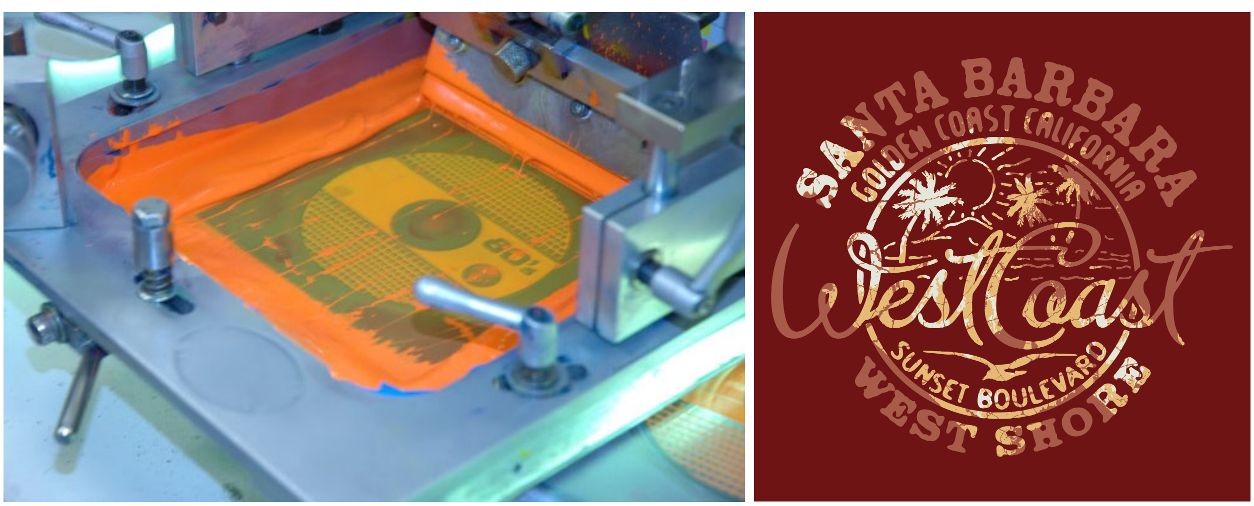

FIGURE 5. This DVD screen printer screens the ink automatically across the surface to be printed. The Santa Barbara design is an example of the screen-printing technique.

- **Heat-transfer printing** is a method of printing fabrics by transporting a printed design from paper to fabric via heat and pressure. Heat-transfer techniques are common in the T-shirt industry. The process begins by printing the dye transfer on paper. The paper is placed on fabric. Then heat and pressure are applied to the paper on the fabric to make the dye on the paper change to gas. Gas moves from the paper to the fabric and prints the design.
- **Digital printing** is the process of printing a computer-created design on fabric or other media. The digital design is transferred from the computer to an ink-jet printer, which then transfers the ink to the fabric. Digital printing is efficient and uses no water.

Summary:

Color is what the eyes see when light strikes an object. Color is metameric, so it appears different under various light sources. When all the visible light colors of the spectrum are combined, white light is seen. When all light is absorbed and no light is reflected, black is seen. Since color is around us all the time, we do not usually give it much thought, but colors produce surprising effects in the way they mix together.

The Munsell Color System is recognized as the global standard for color notation. Munsell named five principal colors (red, yellow, green, blue, and purple) and four intermediate colors (yellow-red, green-yellow, purple-blue, and red-purple).

The RYB Color System uses red, yellow, and blue as its primary colors. A secondary color is formed by mixing two primary colors. A tertiary color is formed by mixing a primary and a secondary color (i.e., red-orange, yellow-orange, yellow-green, blue-green, blue-violet, or red-violet).

Colorants are substances used to color a material. Dye is a chemical substance used to stain and color a material. Pigments, however, are more versatile than dyes since they are applied directly to fibers and fabrics. Pigments cost less than dyes to apply. Both dyes and pigments are applied to fibers, fabrics, and garments in a variety of methods. An important characteristic of all color methods is colorfastness (an article's ability to retain its original hue) when a garment is dry-cleaned or exposed to sunlight, perspiration, or abrasion.

Checking Your Knowledge:

1. Explain the relationship between light and color.
2. What is the significance of ROY G. BIV in relation to Sir Isaac Newton?
3. Define monochromatic, analogous, complementary, split-complementary, and triad color schemes.

4. What are the different properties of dyes and pigments? Which are less expensive to use?
5. Explain the printing processes of roller printing, screen printing, heat-transfer printing, and digital printing.

Expanding Your Knowledge:

The American Association of Textile Chemists and Colorists (AATCC) website links professionals to three interest groups: Chemical Applications (colorants, finishes, and polymers), Concept 2 Consumer (textile, apparel, and home fashion manufacturers and retailers), and Materials (fiber and fiber products). The association now has a Student Intern Site link to view open internships and to post your résumé. For more information, visit the AATCC Textile JobSite at http://www.aatcc.org/JobSite/index.htm.

Web Links:

Light

http://science.howstuffworks.com/light.htm

The Science of Light

http://www.learner.org/teacherslab/science/light/

Color Combinations and Color Schemes

http://www.colorcombos.com/

Batik Images

http://images.search.yahoo.com/search/images?_adv_prop=image&fr=aaplw&va=batik+dyeing