

# Fundamentals of Color and Appearance

## Module 2

# How We See Color

Color Science Educational Series



[www.hunterlab.com](http://www.hunterlab.com) | [support.hunterlab.com](mailto:support.hunterlab.com)



Color doesn't exist on its own. It is a complex interaction of physics, chemistry, and biology. It happens when three elements come together:

- Light Source
- Object
- Observer





The **light source** introduces the physics of light—its wavelength composition and energy distribution—providing the illumination necessary to reveal the object's color.



# Fundamentals of Color and Appearance

Module 2:

## How we see Color



The **object** brings chemistry into play. Its molecular structure determines which wavelengths of light are absorbed and which are reflected or transmitted. The reflected or transmitted light waves are the ones we perceive as color.



# Fundamentals of Color and Appearance

Module 2:

## How we see Color



The **observer** introduces biology. Our eyes and brain work in tandem to receive, process, and interpret these light waves as color.



## How we see Color



In combination, the light source, the object, and the observer form the foundation of all color perception:

### Light Source - Physics

In this case, natural sunlight

### Object - Chemistry

The lemons

### Observer - Biology

The girl holding the lemons



# Fundamentals of Color and Appearance

Module 2:

## How we see Color



Let's begin with the first part of the Visual Observing Condition:

The **light source**.





A light source is any physical source of visible light

Natural Daylight



Incandescent



Fluorescent





**Daylight** is our most familiar and balanced source. Although it changes with the time of day and the season, it covers the full visible spectrum.





Incandescent bulbs give off a warm, yellow glow because most of their energy is in the red part of the spectrum.





**Fluorescent** lamps and many LEDs, found in offices and stores, emit light using phosphors, which can shift color appearance depending on their spectral makeup.



# Fundamentals of Color and Appearance

Module 2:

## How we see Color



Even though they all look “white” to us, their spectral content varies widely—and that changes how colors appear.

Next, we’ll explore what those differences look like in spectral power distribution, starting with an understanding of the electromagnetic spectrum.



## How we see Color

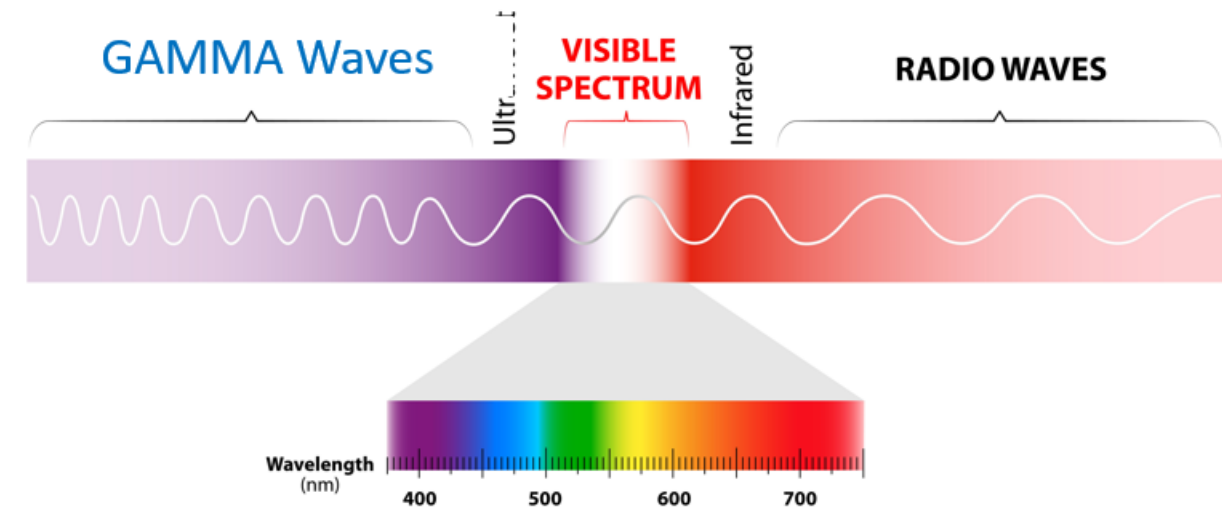


The visible light we see is just a small slice of a much larger system, called the **electromagnetic spectrum**.

It ranges from gamma rays to radio waves, but only a narrow band between three hundred eighty and seven hundred eighty nanometers is visible to the human eye.

← Increasing Frequency      Increasing Wavelength →

### VISIBLE AND INVISIBLE LIGHT





When light contains all these wavelengths blended, we see white light, just like daylight.

But even if two light sources look white, their wavelength mix may differ, which can significantly affect how we see color.





Our understanding of visible light began to change in the 1600s, thanks to **Sir Isaac Newton**.



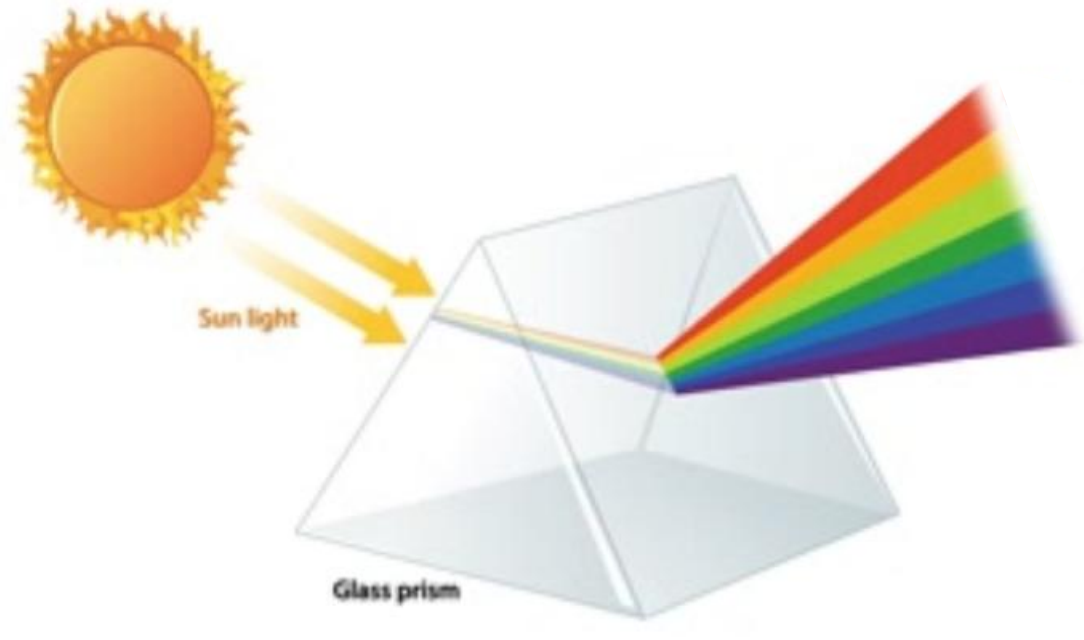
## How we see Color



In 1672, he used a simple glass prism to show that white light isn't a single color, but a blend of many.

The colors revealed by Newton's prism form what we now call the visible spectrum, remembered by the acronym ROY G BIV - red, orange, yellow, green, blue, indigo, and violet.

This insight remains foundational to modern color science.



# Fundamentals of Color and Appearance

*Module 2:*

## How we see Color

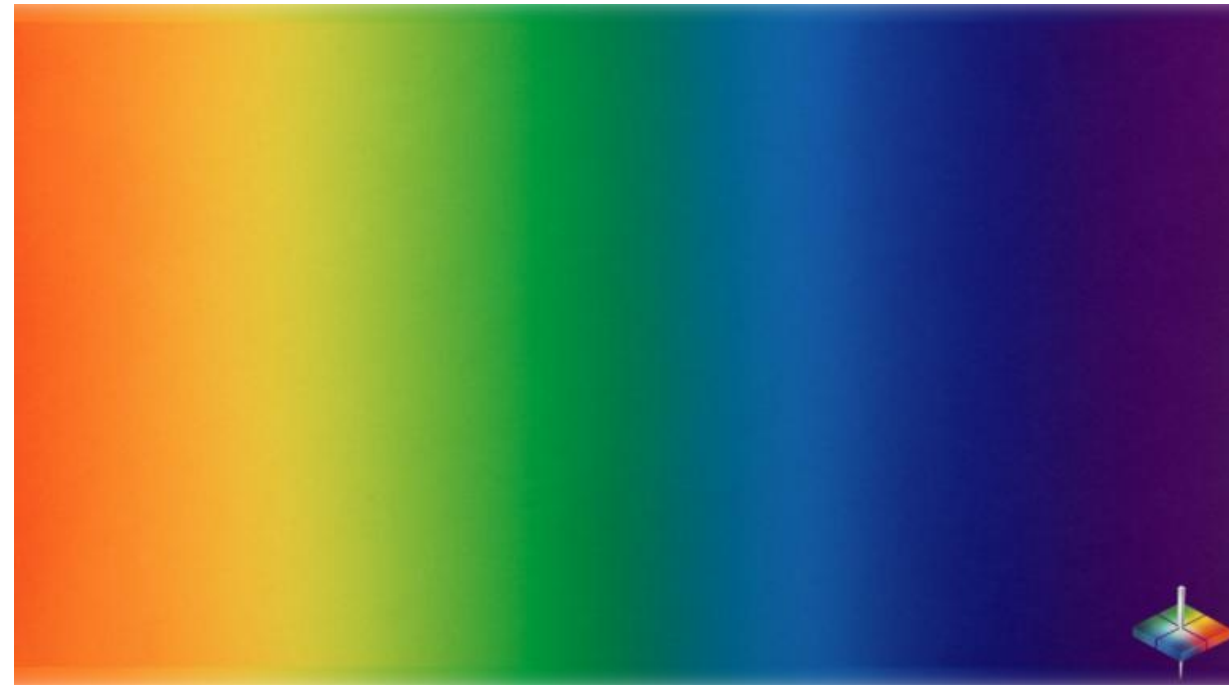


Each of these colors corresponds to a specific wavelength of light, ranging from about three hundred eighty nanometers for violet, to seven hundred eighty nanometers for red.





Although we use discrete names, these colors transition continuously across the spectrum—there are no hard edges.





When all wavelengths in the visible range are present, we perceive white light—but not all white light is created equal.

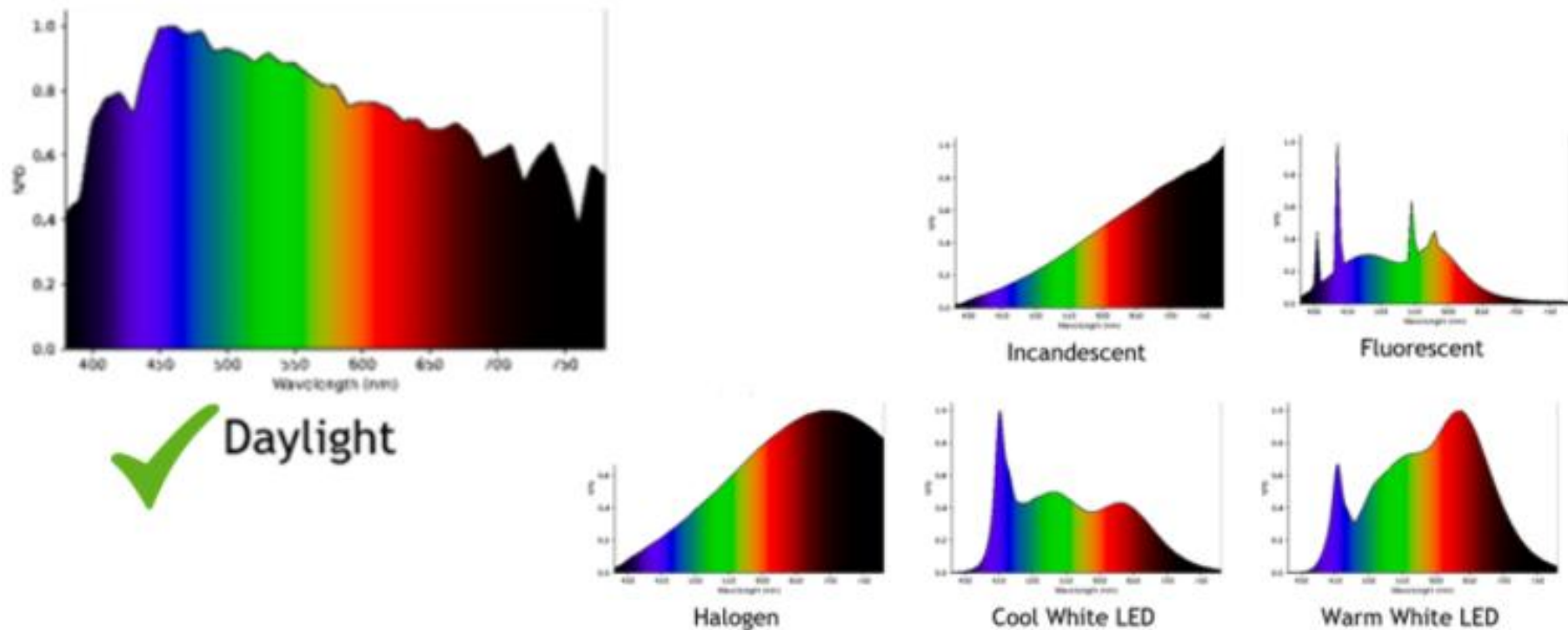
Different light sources may appear white, but they emit very different amounts of energy at different wavelengths.



# How we see Color



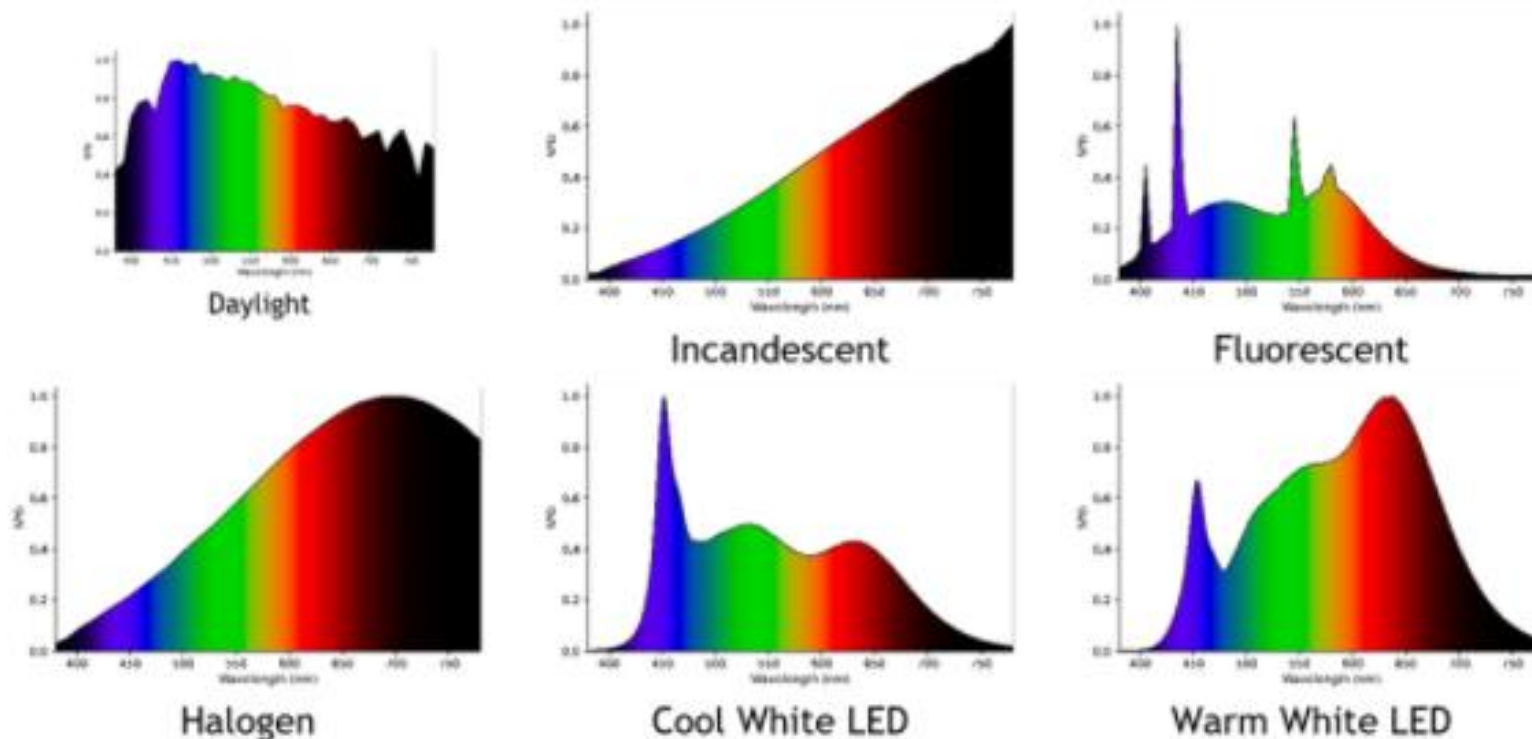
Daylight, shown here with a check mark, is considered the gold standard because of its broad and even spectral distribution, or **SPD**. It provides the most balanced illumination for accurate color evaluation.



## How we see Color



In contrast, Incandescent, Halogen, Fluorescent, and LED lights often have uneven SPDs, with peaks or gaps that can dramatically shift color appearance.



# Fundamentals of Color and Appearance

Module 2:

## How we see Color

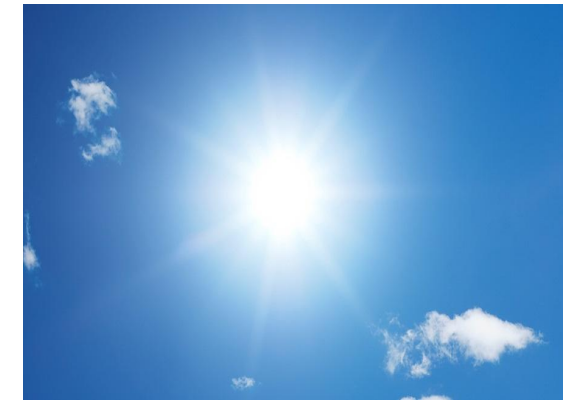


Light Source

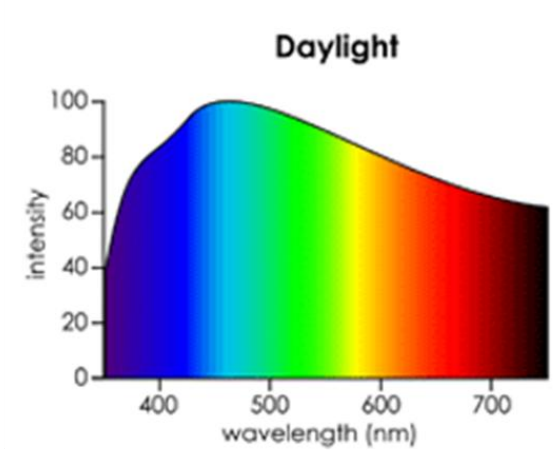
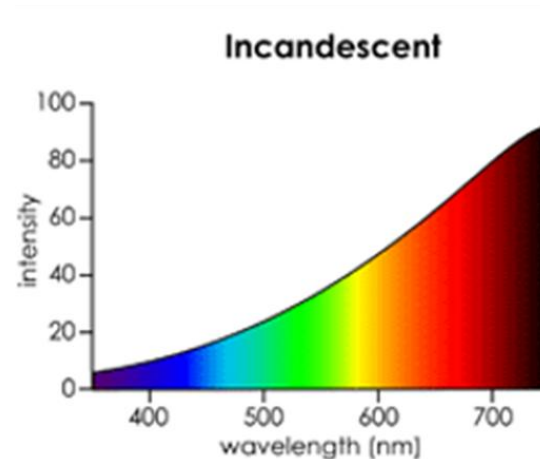
Different light sources don't just look different. They emit different amounts of energy at different wavelengths.

For example, incandescent bulbs emit strongly in the yellow and red regions, giving off a warm, amber glow. In contrast, daylight, has a more balanced spectral distribution across the visible range. That's why it appears more neutral and is used as a reference for color evaluation.

This matters because the appearance of an object depends on the light it's viewed under.



CIE Illuminant





Now that we've explored the role of the light source, let's move to the second key element of the Visual Observing Condition.

The Object.

**Visual Observing  
Condition**

**Object**



# How we see Color



When you look at these lemons, your brain says, "They are yellow."

The lemons are not actually yellow. They are simply reflecting specific wavelengths from the light shining on them. Color isn't a property of the object itself; it's the result of how light interacts with it.

Let's look closer at how this interaction works.



# Fundamentals of Color and Appearance

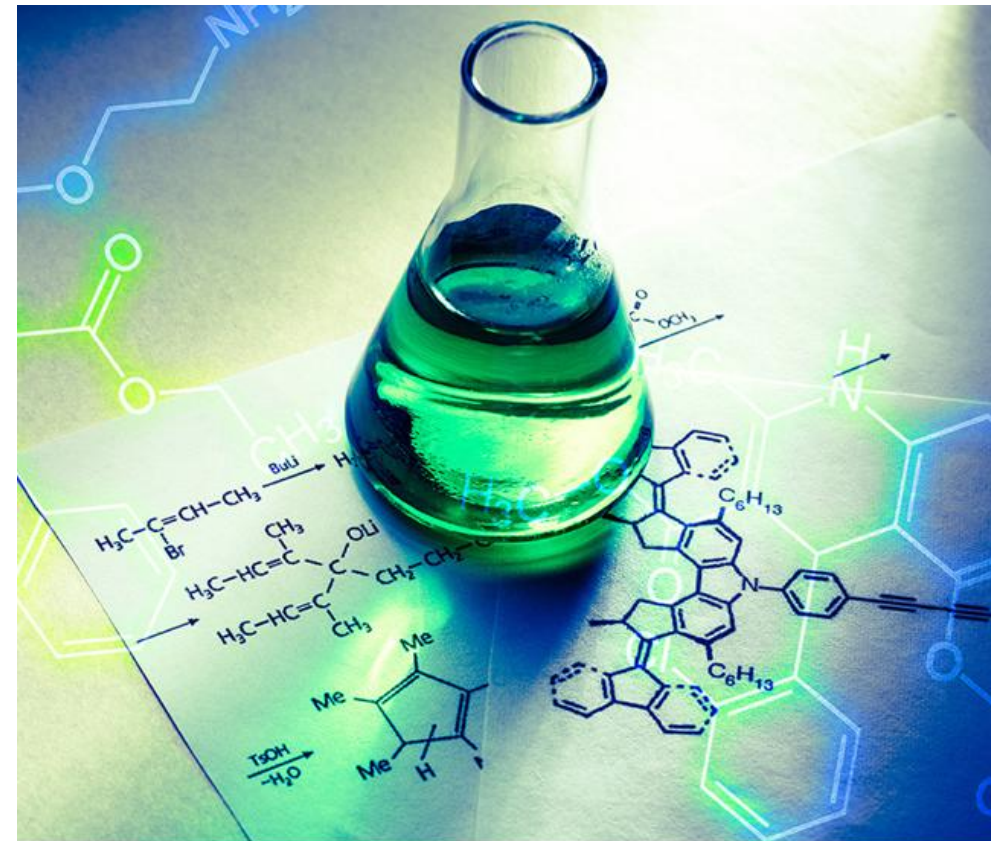
Module 2:

## How we see Color



At the molecular level, objects are made of compounds that interact with light in specific ways.

These molecules absorb some light wavelengths and reflect or transmit others.



## How we see Color



Take our lemon example. Its surface absorbs blue, violet, and green wavelengths, and reflects light in the yellow to red range. When the reflected light from the lemon reaches our eyes, the brain perceives it as yellow.

So again, we're not seeing the object's color. We're seeing the color of the light it reflects.

Now, let's look at a few more familiar examples.



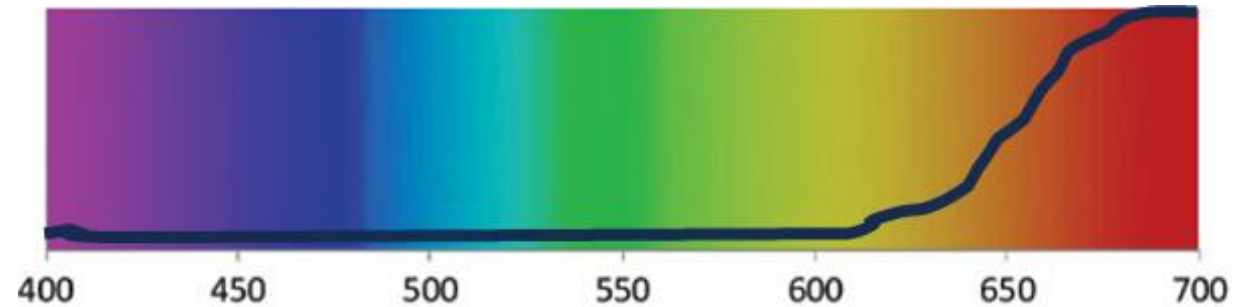
# Fundamentals of Color and Appearance

Module 2:

## How we see Color

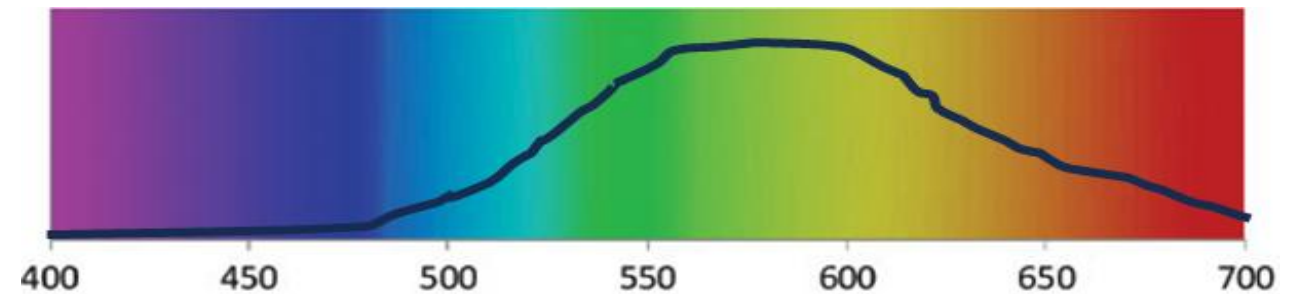


A strawberry absorbs most shorter wavelengths, like blue and green, but reflects longer wavelengths, above 650 nanometers which fall in the red region.





A lime absorbs blue-violet and deep red light, and reflects wavelengths between 500 and 600 nanometers giving it a yellow-green appearance.



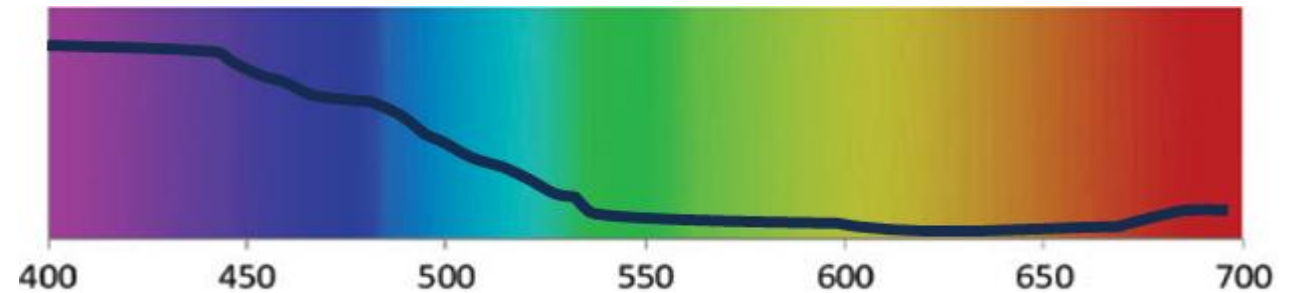
# Fundamentals of Color and Appearance

Module 2:

## How we see Color



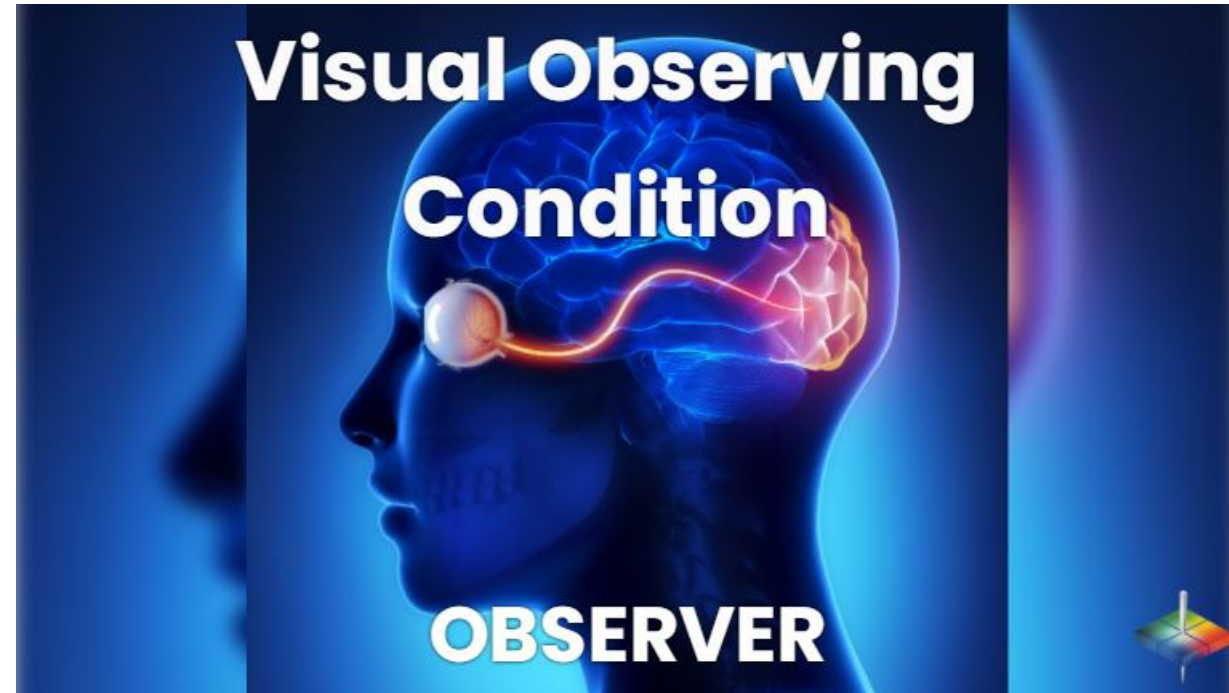
A blueberry reflects mostly shorter wavelengths from 400 to 500 nanometers and absorbs the longer ones, which is why it appears blue.





Next, we'll explore the third and final element of the Visual Observing Condition.

The Observer.



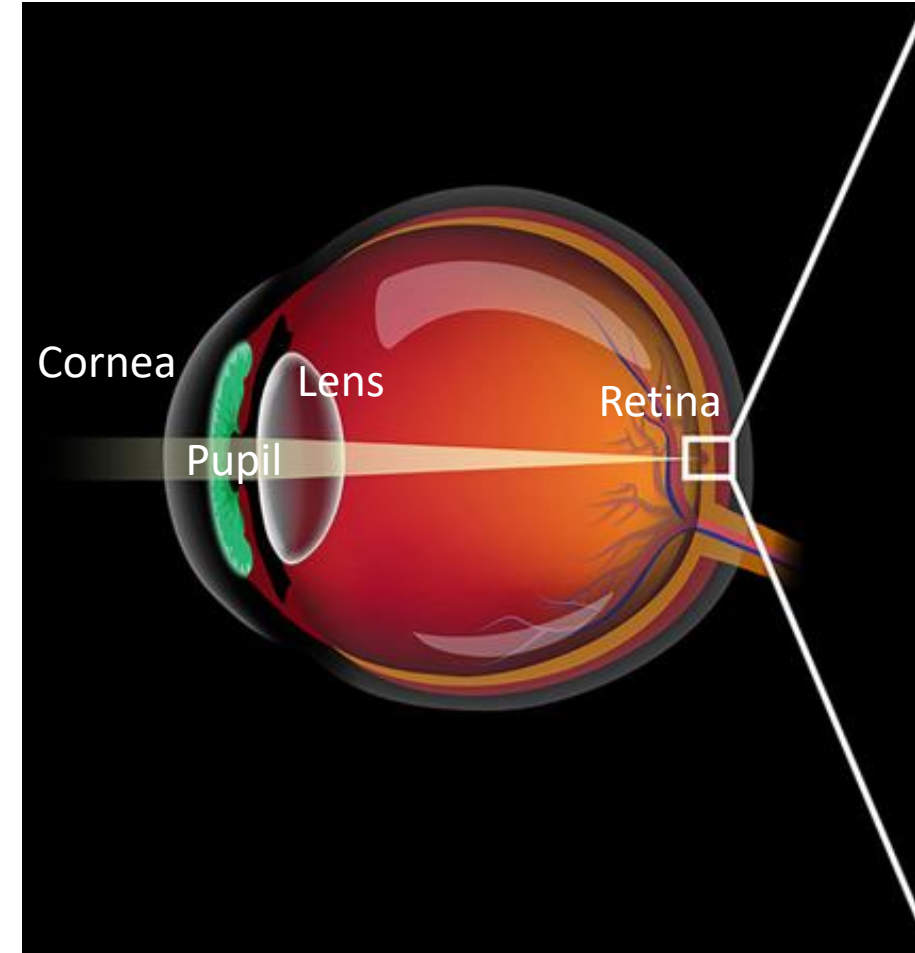
# How we see Color



When light enters the eye, it first passes through the **cornea** which is the transparent, curved outer layer that begins to focus the light. It then moves through the **pupil**, which is controlled by the iris to regulate how much light enters.

From there, the light reaches the **lens**, which fine tunes the focus and directs the image onto the **retina** at the back of the eye.

This retina is lined with light sensitive cells that convert the light into electrical signals.

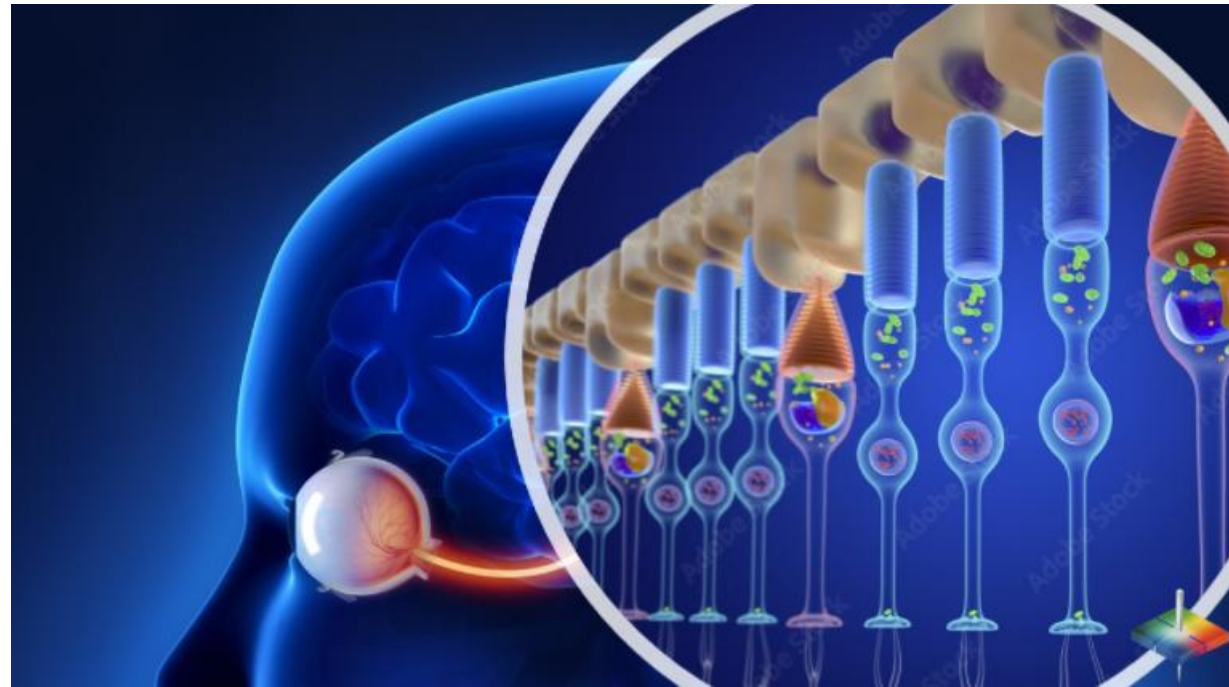


## How we see Color



Once light reaches the retina, the real magic begins.

The retina contains two types of light-sensitive cells called photoreceptors: rods and cones.



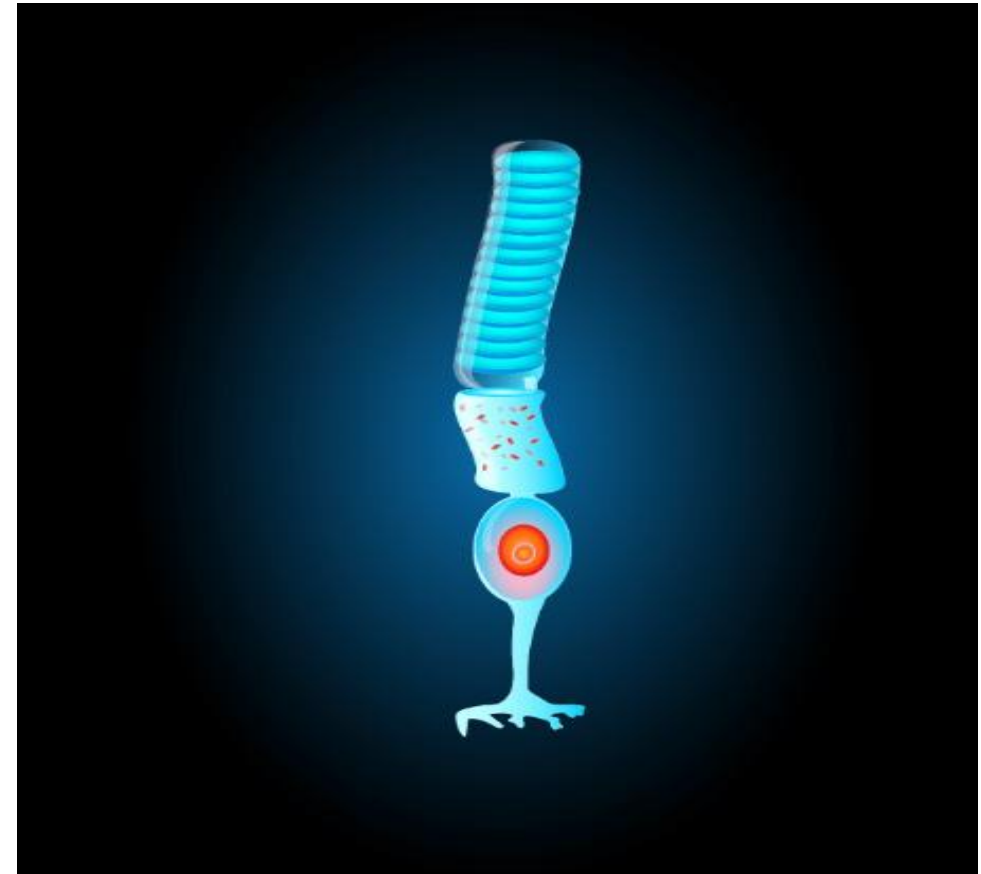
# How we see Color



Rods are incredibly sensitive to light. They help us see in dim or nighttime conditions.

There is only one kind of rod, and it can't distinguish between different wavelengths. They detect light vs. darkness; they don't detect color.

That's why when the lights are low, your color vision fades. It's your rods taking over, sending a simple message to your brain - light, or no light.



## How we see Color



While rods help us see in the dark, cones give us color vision.

Cones contain photopigments that are molecules that respond to specific wavelengths of light.

There are three types of cones that allow us to see color. These are: **S** cones, **M** cones and **L** cones.

Let's take a closer look at how each one contributes to what we see.



# How we see Color



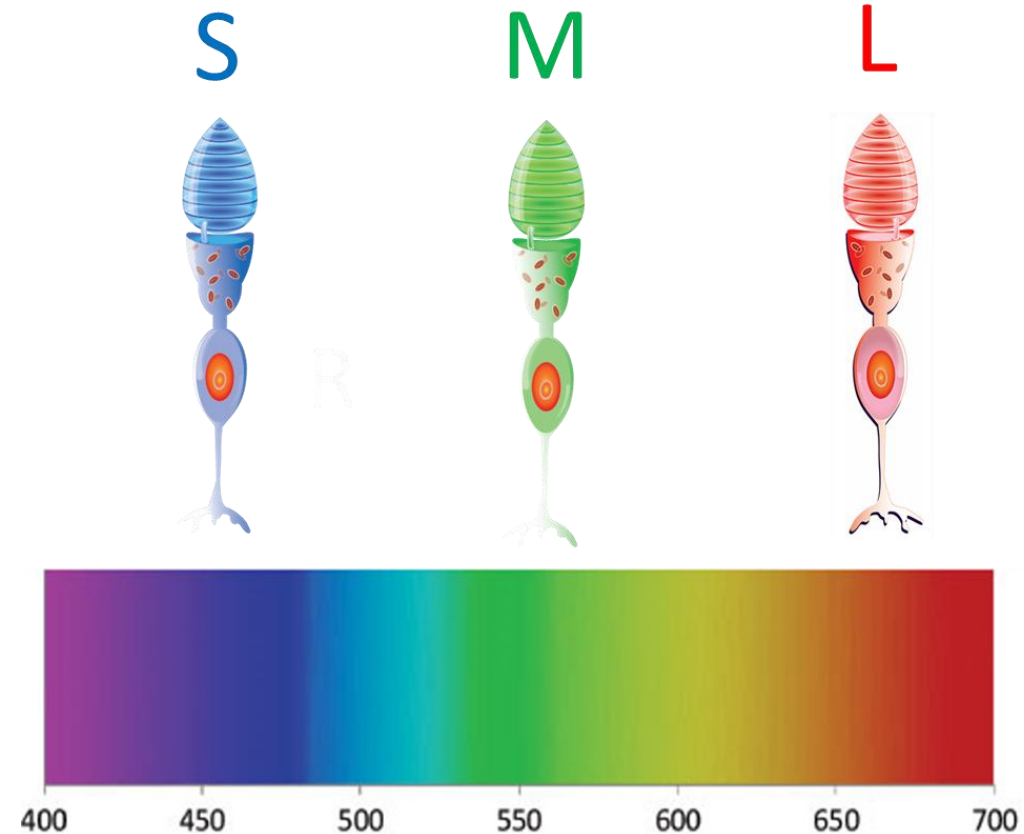
**S-cones** respond to short light wavelengths, mainly blue-violet light.

**M-cones** respond to medium light wavelengths, from green to yellow.

**L-cones** are most sensitive to longer light wavelengths, from yellow to red.

Cone responses overlap, which means a single wavelength stimulates multiple cones to different degrees. The brain precisely blends those signals to interpret the millions of colors that we see.

This is the basis of **trichromatic color vision** and is at the core of how we see and interpret color.

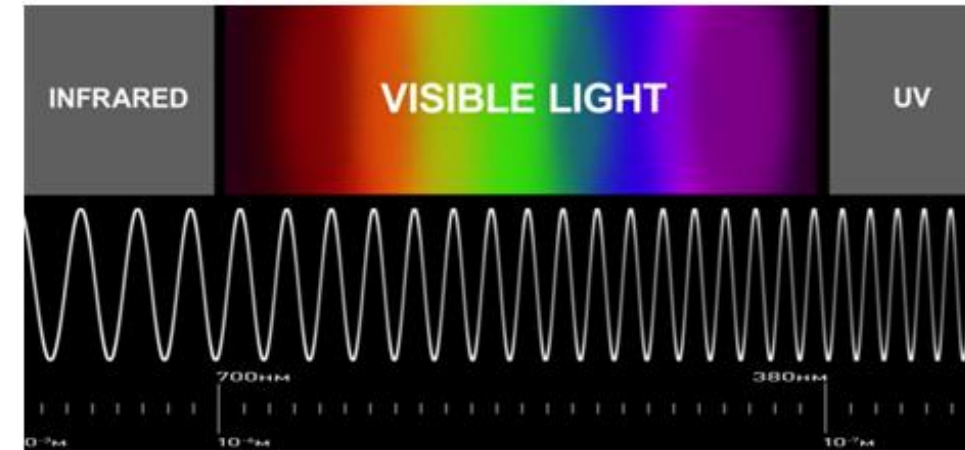




As we discussed earlier in this module, the visible light we see is just a small slice of the much larger electromagnetic spectrum.

Within the visible light, we also learned that the shorter the wavelength, the higher the frequency.

Blue and violet light have short wavelengths and oscillate rapidly, while red light has longer, slower waves with lower frequency.



# Fundamentals of Color and Appearance

Module 2:

## How we see Color



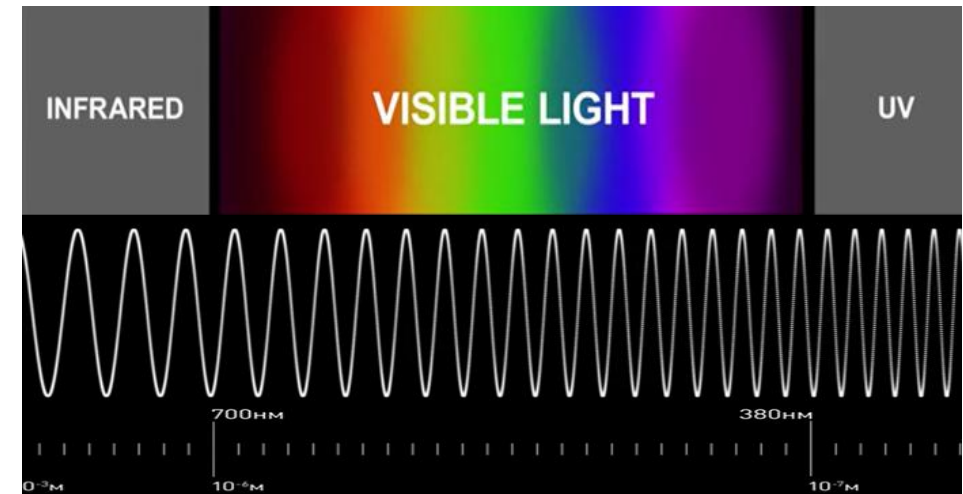
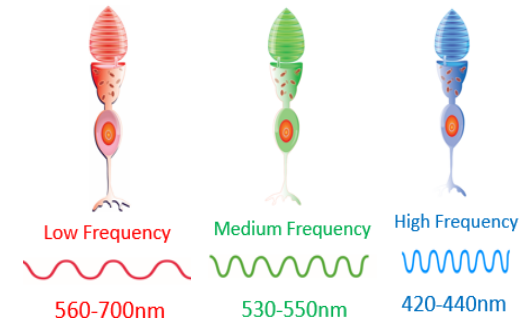
Our cone cells are tuned to respond to these specific wavelength frequencies.

**S-cones** are most responsive to the shorter wavelength, higher frequency visible light, between about four hundred twenty to four hundred forty nanometers.

**M-cones** are most responsive to the medium-wavelength, medium frequency visible light, between approximately five hundred thirty and five hundred fifty nanometers.

**L-cones** are most responsive to the longer-wavelength, lower frequency visible light, between approximately five hundred sixty to seven hundred nanometers.

These frequency-based responses allow us to distinguish color across the visible spectrum, translating wave energy into the rich experience of color perception.



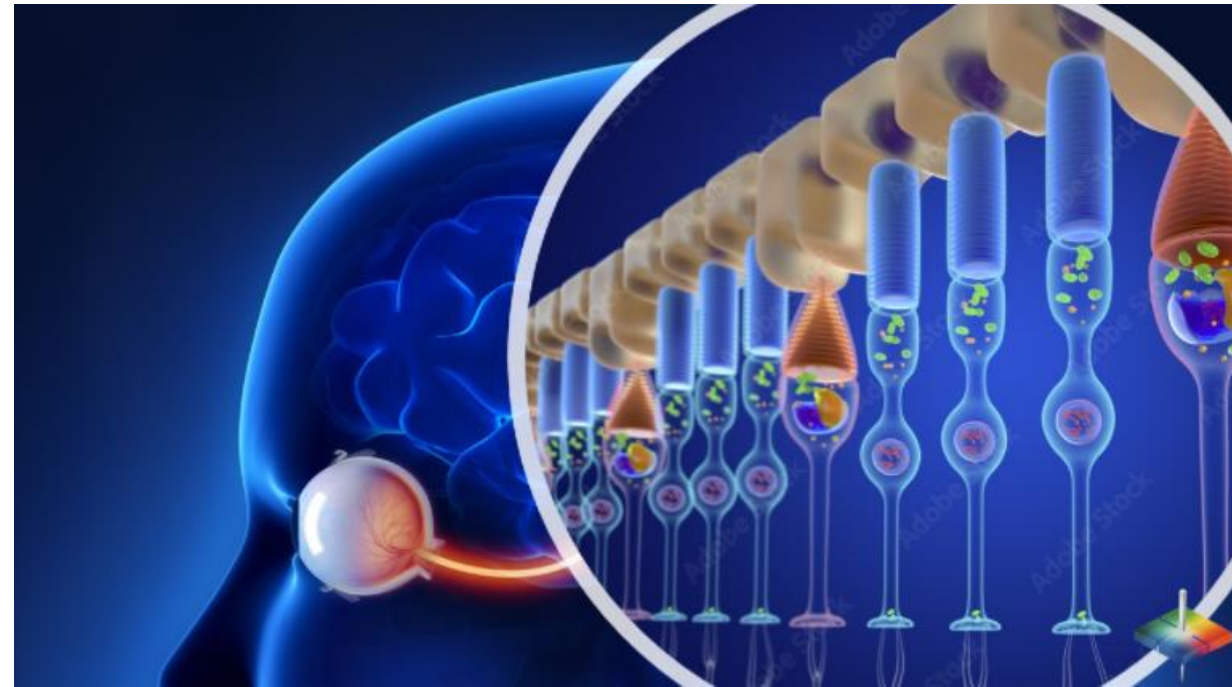
# How we see Color



What we perceive as color happens after those signals reach the brain.

When specific wavelengths stimulate cone cells, they send electrical signals through the **optic nerve** to the **visual cortex** that interprets what we see.

But no single cone says, "this is red" or "this is blue." Instead, the brain compares the responses of each cone type.



# Fundamentals of Color and Appearance

Module 2:

## How we see Color



If all three cones are equally active, we see white.





If only S-cones are active, we see blue.





If L- and M-cones are strong, we perceive yellow.





This signal-blending process occurs in milliseconds, enabling us to see over 10 million colors.



## How we see Color



When the three components of the visual observing condition, light, object and observer align, we create what's known as the Visual Observing Condition.

And that's when color comes to life.

Understanding this foundational concept provides us with a lens to explore the rest of color science, and we're just getting started.



# Fundamentals of Color and Appearance

Module 2:

## How we see Color



Thank you for joining us on this journey through color science.

In Module 3 of our Fundamentals of Color and Appearance series, we'll explore **Color Attributes and Color Systems**, where we examine how color is defined, classified, and communicated in both visual and instrumental workflows.

And be sure to visit [hunterlab.com](http://hunterlab.com) to learn more about how our solutions can help you achieve color confidence, every time, or to schedule a consultation with one of our color experts.

Fundamentals of Color and Appearance

Module 3

Color Attributes and Color Systems

Color Science Educational Series



[www.hunterlab.com](http://www.hunterlab.com) | [support.hunterlab.com](mailto:support.hunterlab.com)

Schedule a free color consultation  
with our experts



[www.hunterlab.com](http://www.hunterlab.com)