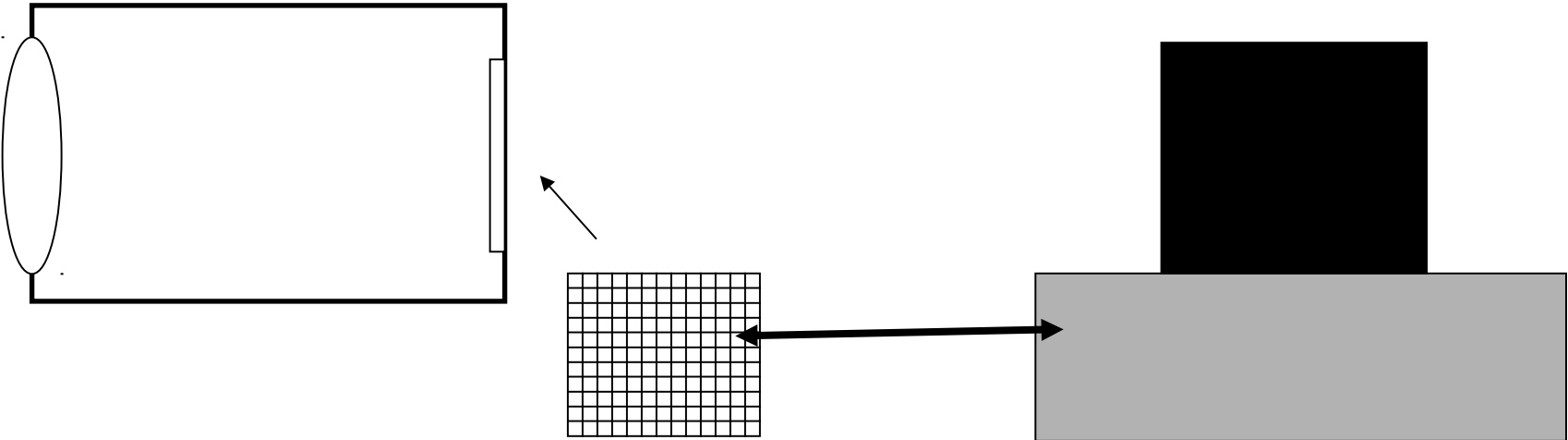
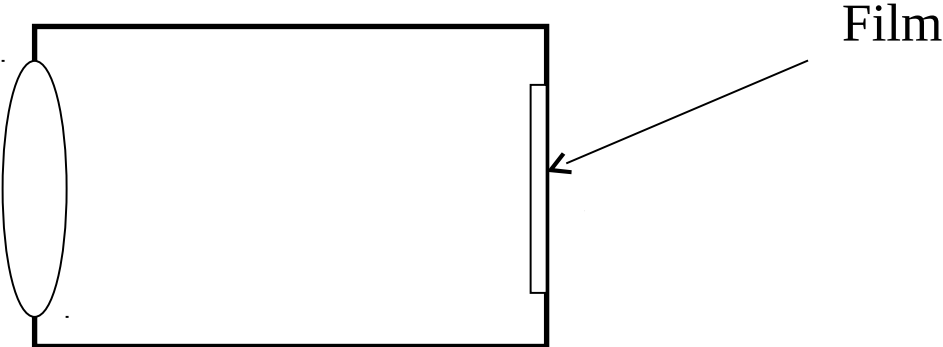


Part 1

Seeing the light...

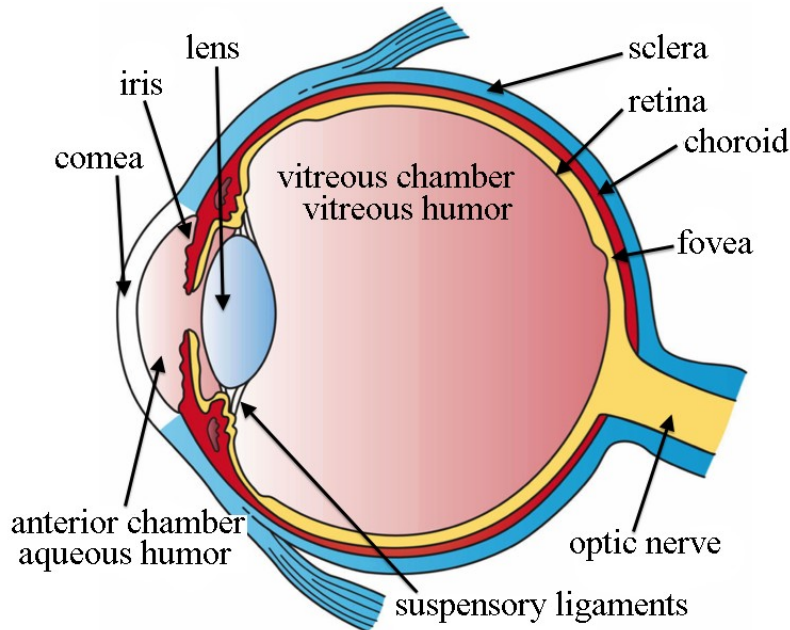
... Vision and Illusion

Camera



Basic Structure of the eye

The human eye is shaped roughly like a ball.



Artwork by Holly Fischer CC BY 3.0

The cornea and lens act together to produce an image on the screen called the retina.

Focus is accomplished by adjusting the shape of the lens.

The iris adjusts the amount of light entering.

The retina is a remarkable piece of work that produces electrical signals sent to the brain for interpretation.

The Retina

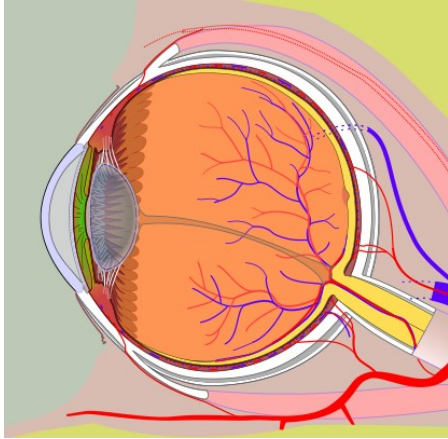
The retina is covered with light detectors of two types.

Rods can detect low intensity light but see only intensity – not color.
120 million of them!

Cones detect color but need brighter light. 6 million.

Cones are more concentrated near center of vision in the area called the fovea. Rods are more concentrated further from the fovea.

Your eye is a camera!



Retina: Millions of
light detectors
(rods and cones)

Optic Nerve

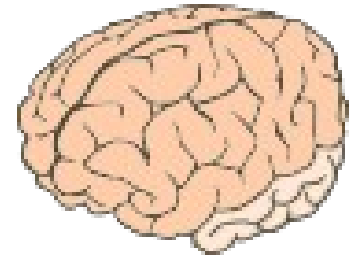
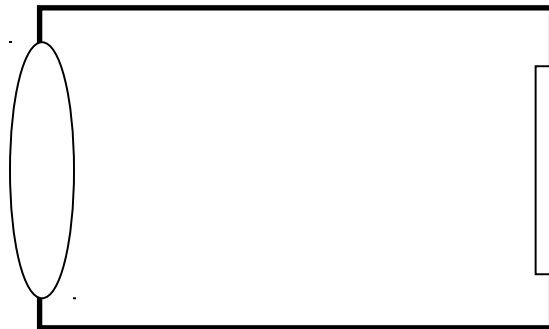
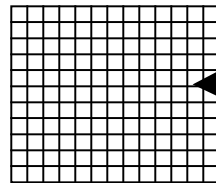


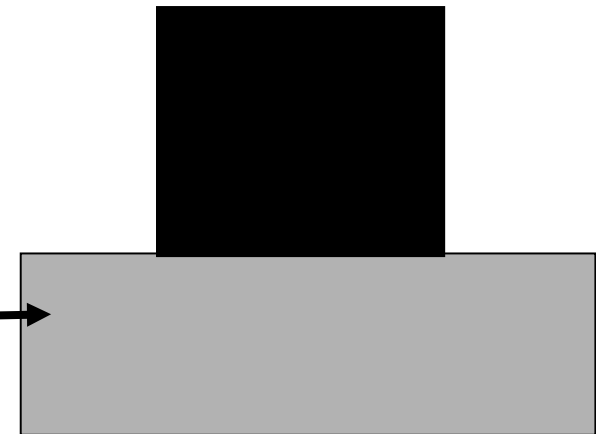
Diagram by Jmarchn
Attribution-Share Alike 3.0 Unported

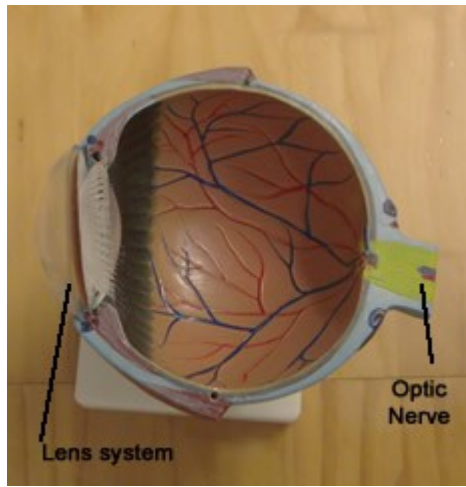


CCD: Millions of
light detectors



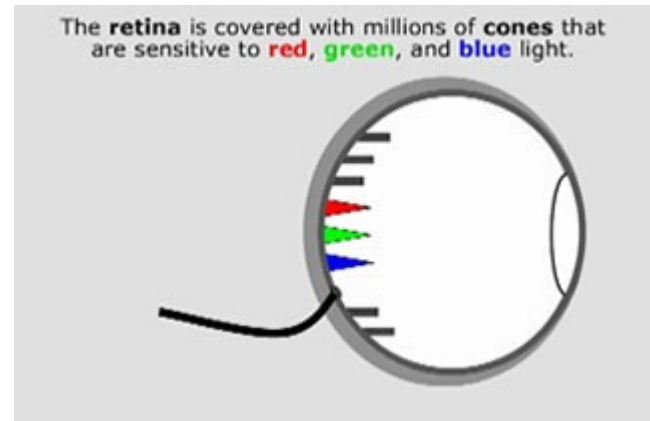
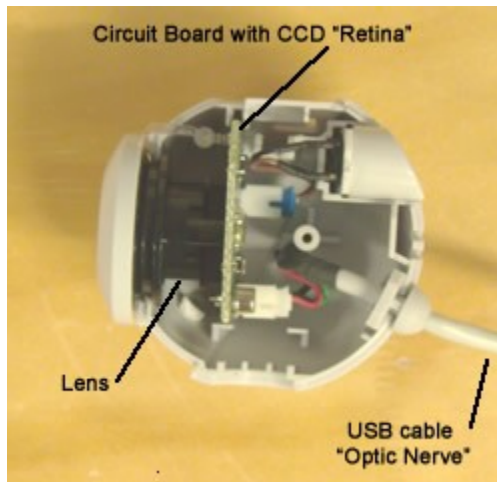
USB





Above: A model of the human eye.

Below: A dissected webcam.



Above: The retina of the human eye.

Below: The "retina" of the webcam and a close-up under a high magnification optical microscope.



One Way Mirror

You probably saw the “one-way” mirror at orientation. Here is an image that shows what it can do. The light bulb is green but its reflection is yellow!



A One Way Mirror will help us learn about RGB technology

At the police station, the police can see the suspects but the suspects cannot see the police.



The person on the outside sees only his own reflection. He can't see what is behind the one-way mirror.

The person on the inside can see out.

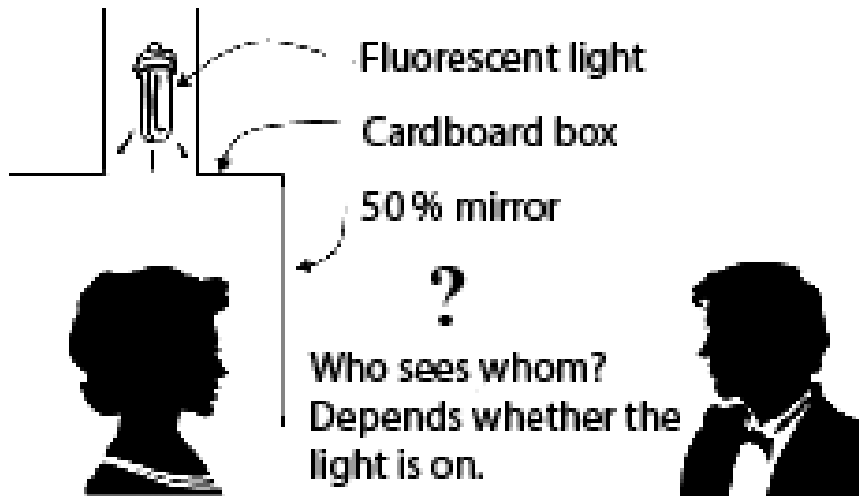
Who is the suspect? Who is the police officer?

Does the mirror block light traveling in one direction but not the other?

One Way Mirror

Impossible! Can't make a mirror that lets light go one way but not the other.
Reversibility of light rays!

So how do they work?

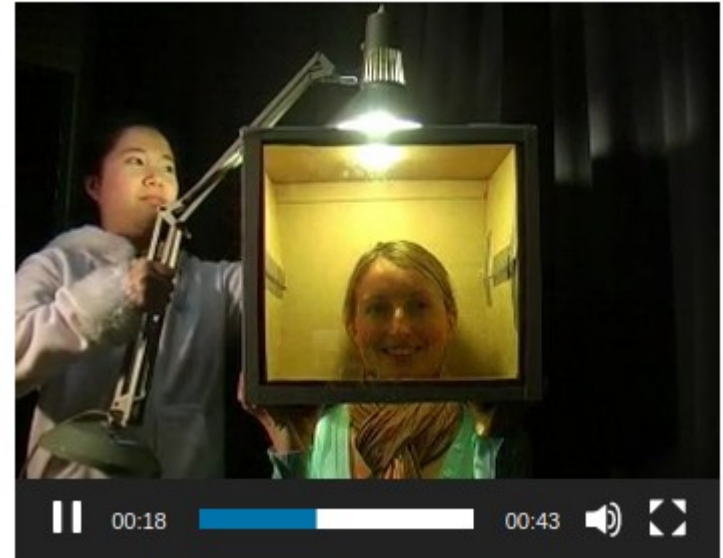


It just depends on which side of the “one way” mirror is illuminated.

“One way” mirror: It just depends on which side of the “one way” mirror is illuminated.



Dark inside, light outside



Light inside, dark outside.

These are frames from a video. If you want, you can download and watch the video [One_Way_Mirror.m4v](#) from the lecture notes.

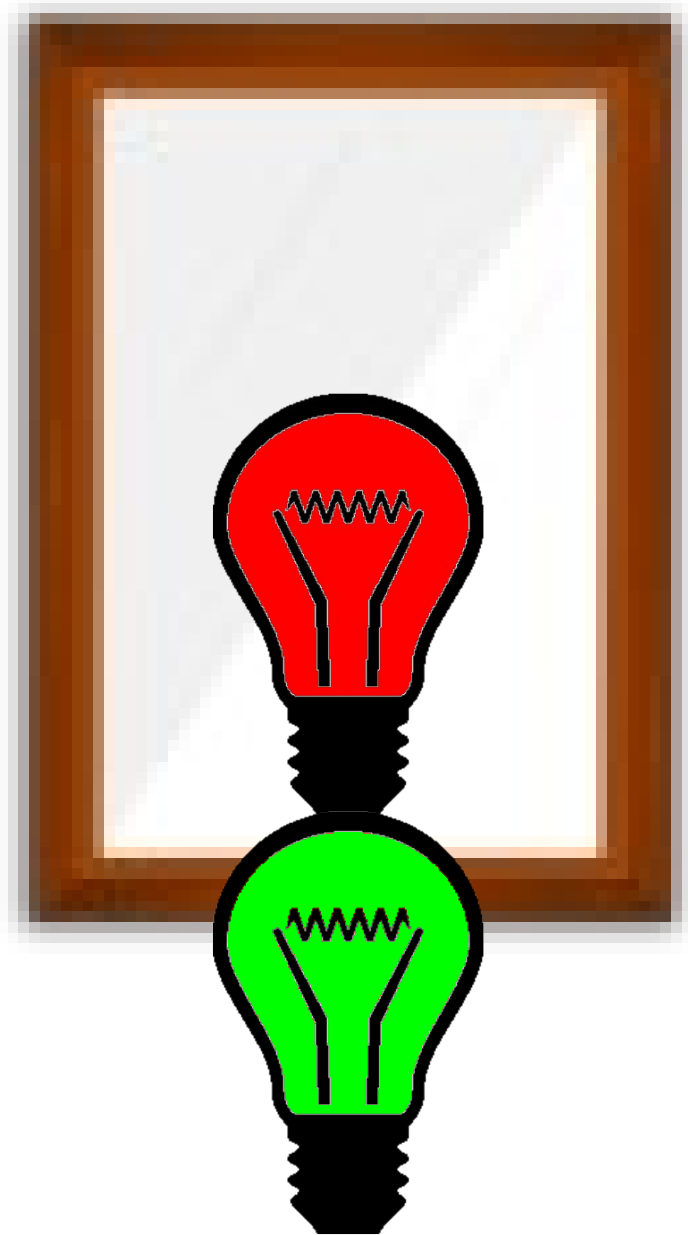
The yellow reflection from a green light bulb?

The trick is to put a red bulb inside the mirror box.

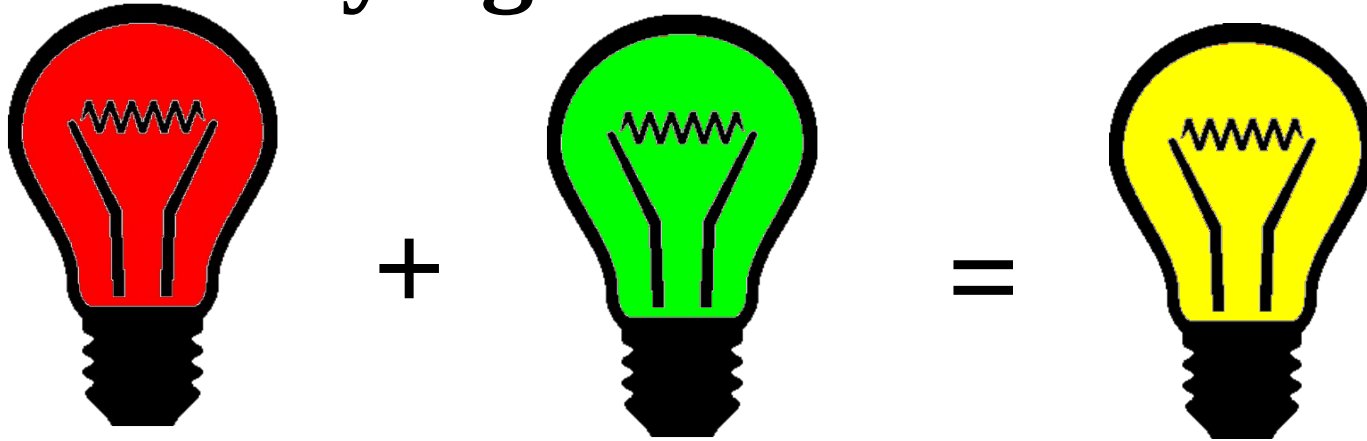
Red on, Green off: you see the red bulb.

Red off, Green on: you see the reflected green bulb.

Both on: red and green combine to make yellow.



Primary lights

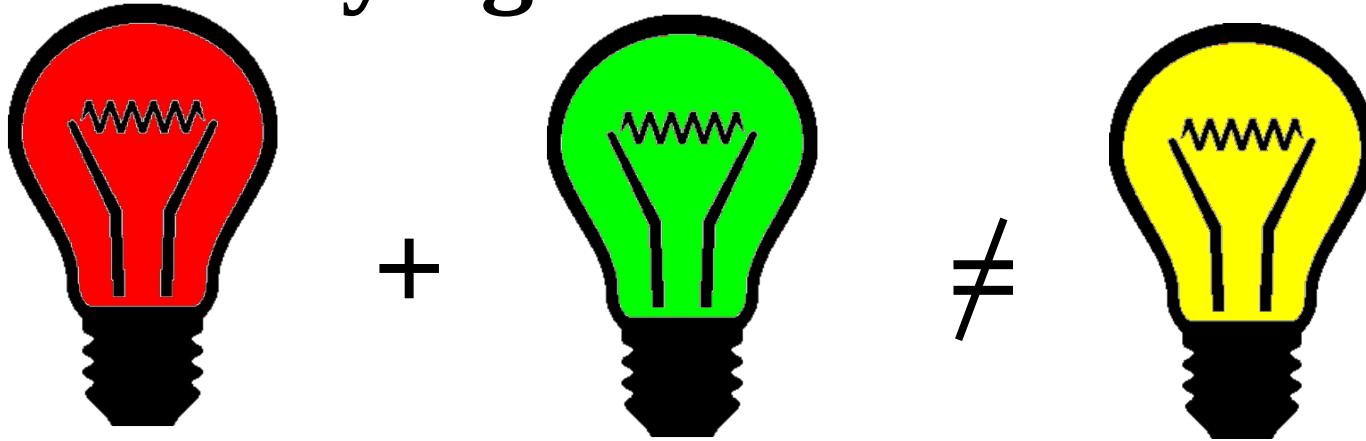


But they don't! Red and green combining to make yellow is actually not quite right. You may have learned about the primary lights in school, but the story is more complicated.

R +G makes FAKE yellow!

("perceptive" yellow)

Primary lights



Light is a wave. Red is low frequency (low pitch) light, yellow is medium, and green is high frequency light. Blue is higher frequency yet.

Sound is a wave. You can try combining a high pitch sound and a low pitch sound. Get your mate to help you. You will not get a medium pitch!

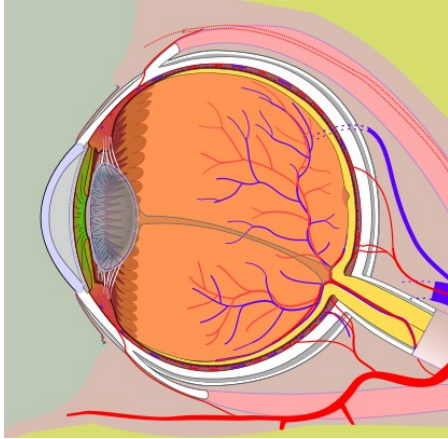
A high frequency wave + a low frequency wave = a medium frequency wave is just incorrect.

Primary lights



So why do we see yellow?

Your eye is a camera!



Retina: Millions of
light detectors
(rods and cones)

Optic Nerve

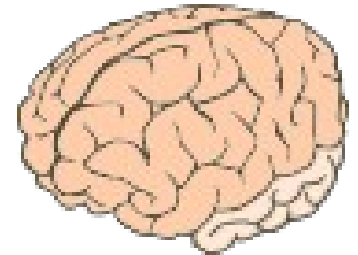
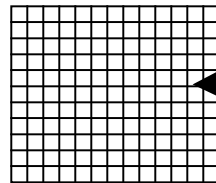


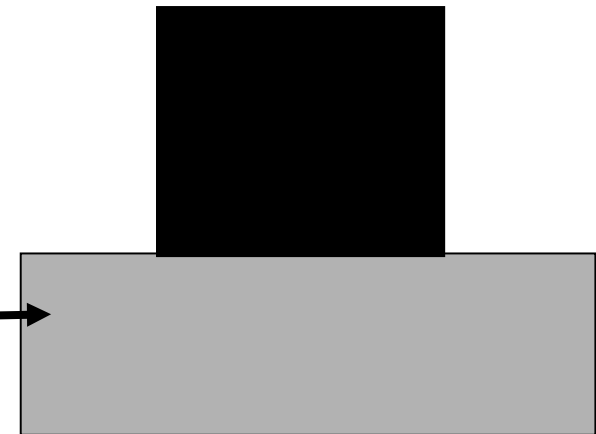
Diagram by Jmarchn
Attribution-Share Alike 3.0 Unported



CCD: Millions of
light detectors

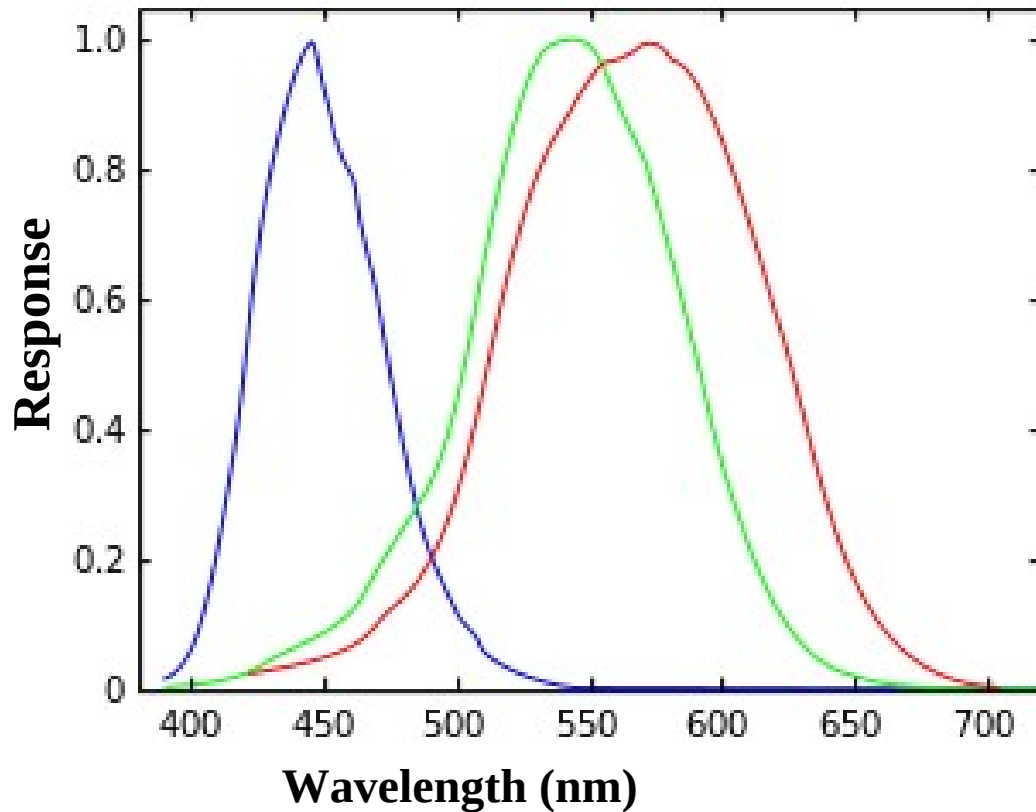


USB



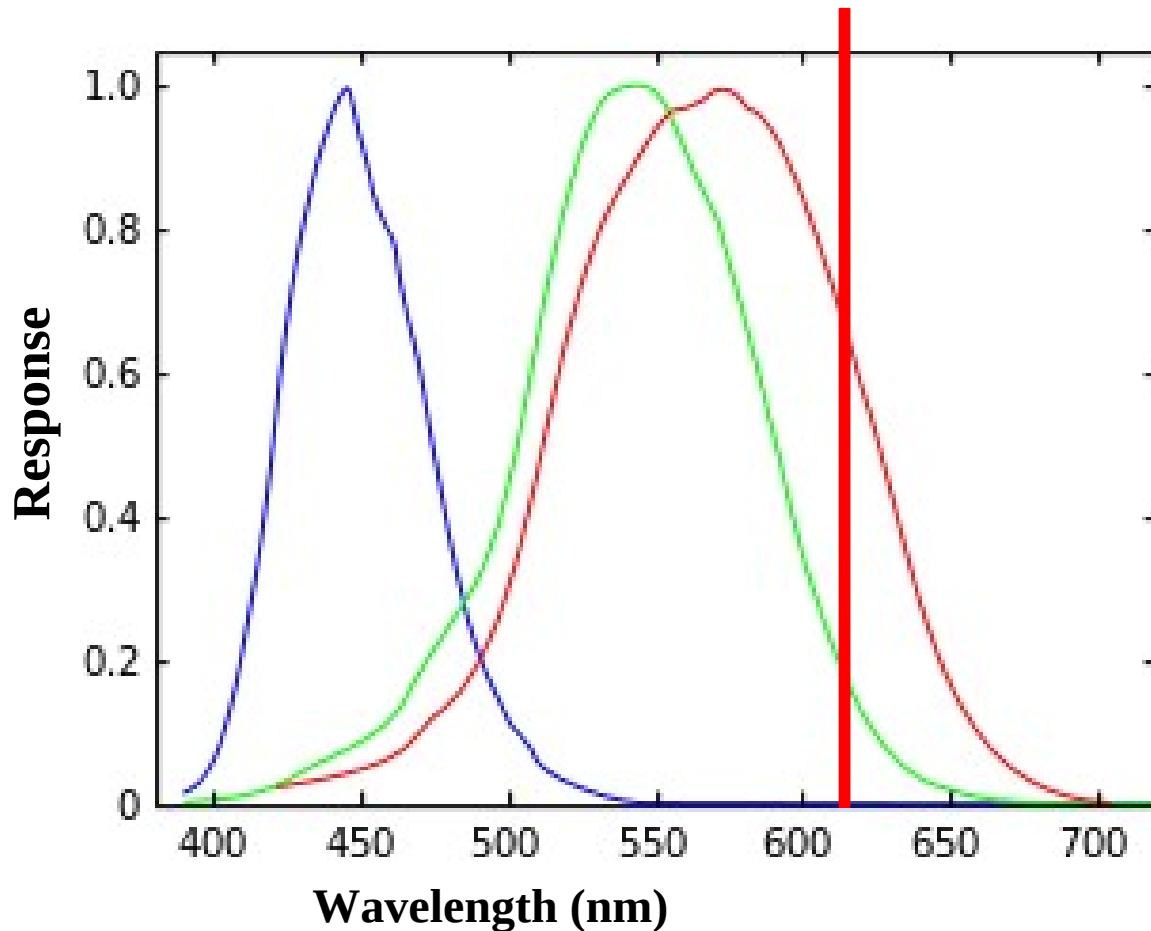
Rods and Cones

Most people have three kinds of cones: **R****G****B**



**Diagram adapted from the Wikipedia article on cone cells.
Vanessaezekowitz at en.wikipedia**

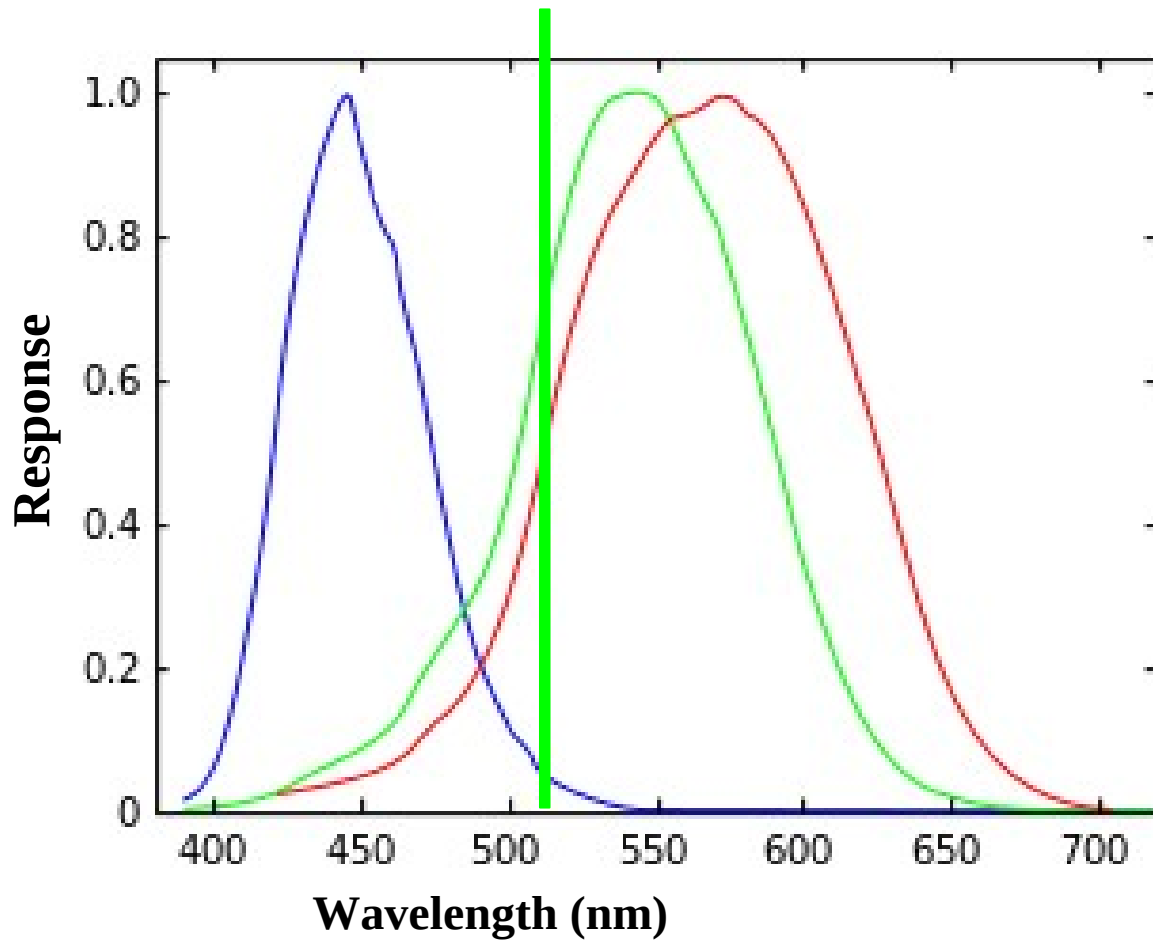
Rods and Cones



Red light enters the eye:
Red cones send data to the brain.

Diagram adapted from the Wikipedia article on cone cells.
Vanessaezekowitz at en.wikipedia

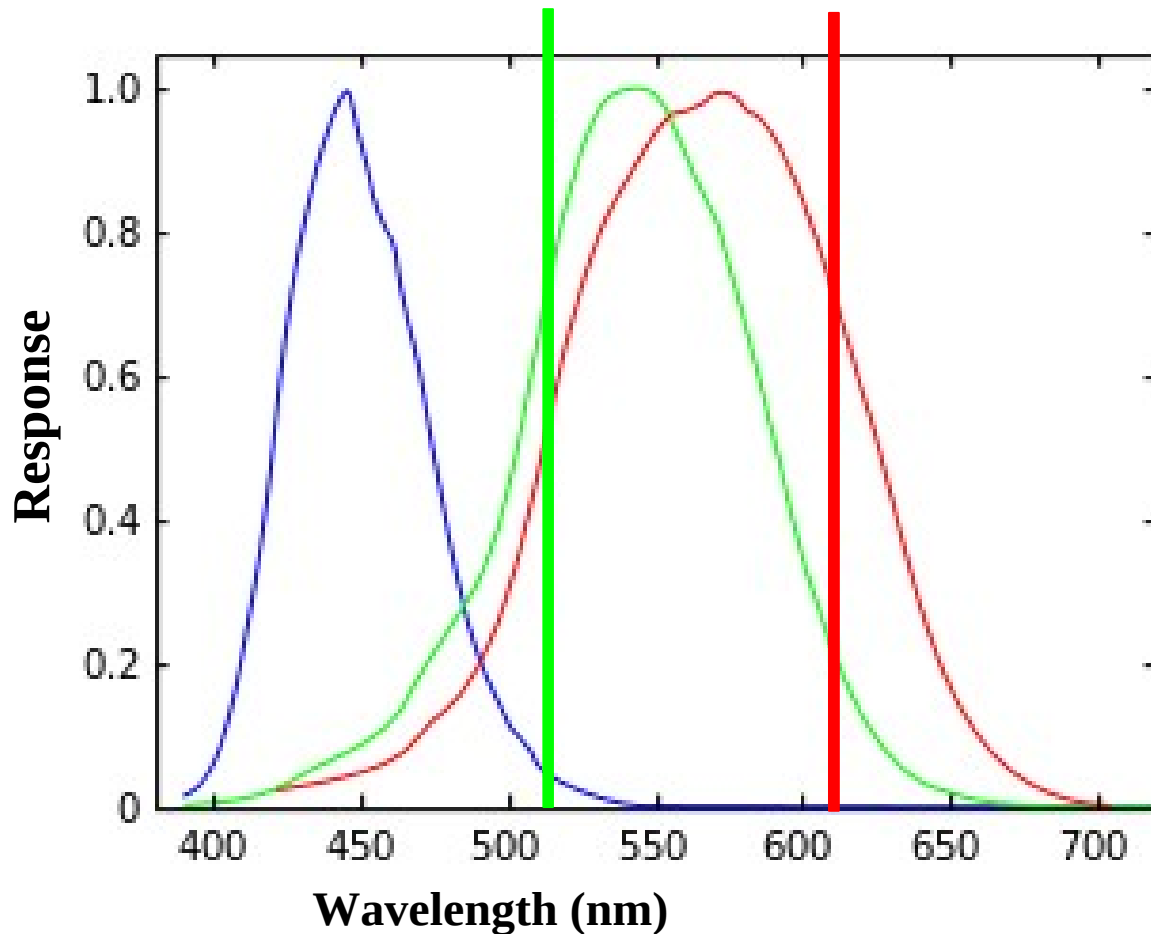
Rods and Cones



Green light enters the eye:

Green cones send data to the brain.

Rods and Cones



Red and Green light enters the eye:

Red and Green cones send data to the brain.

Rods and Cones

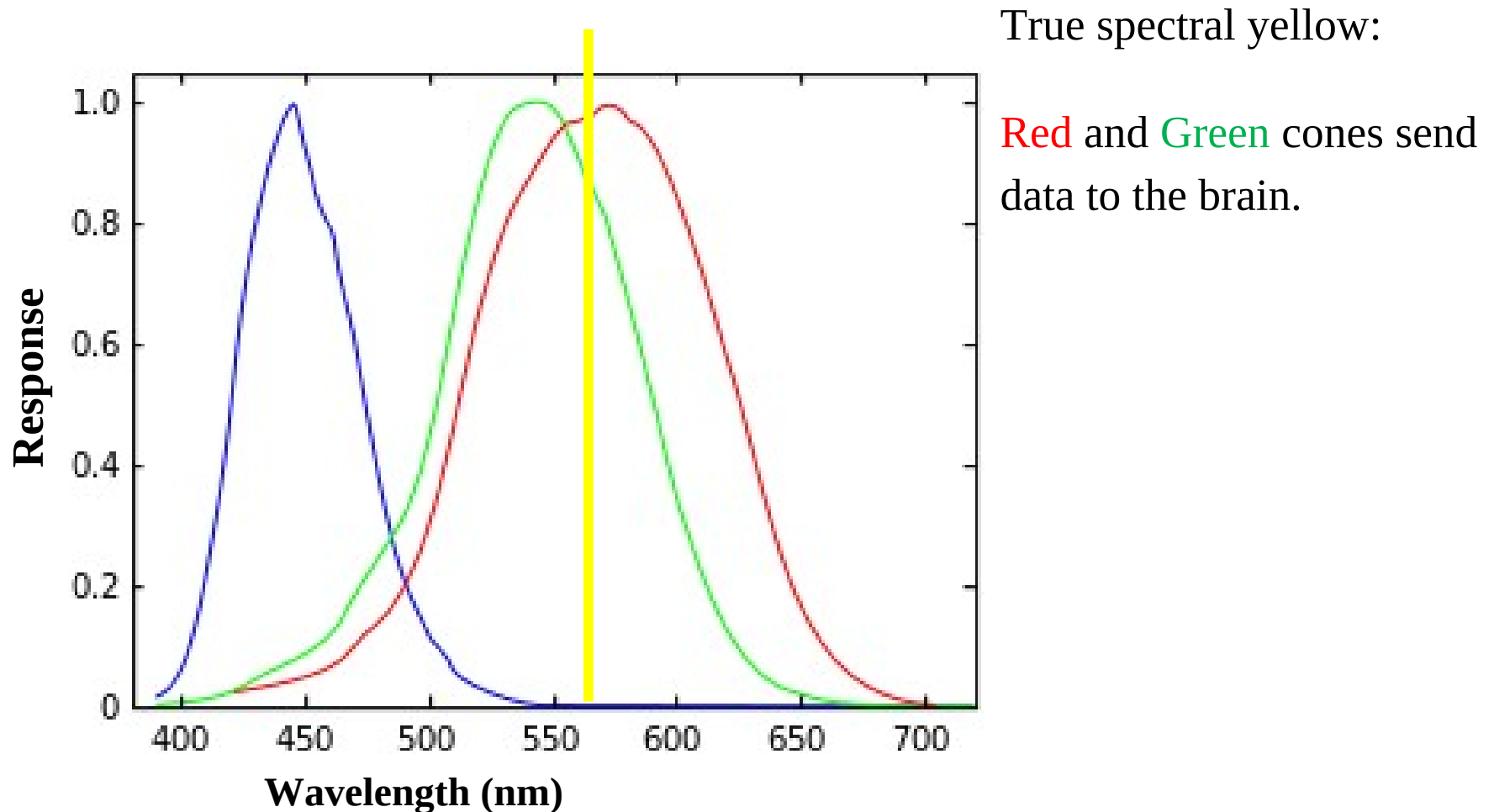
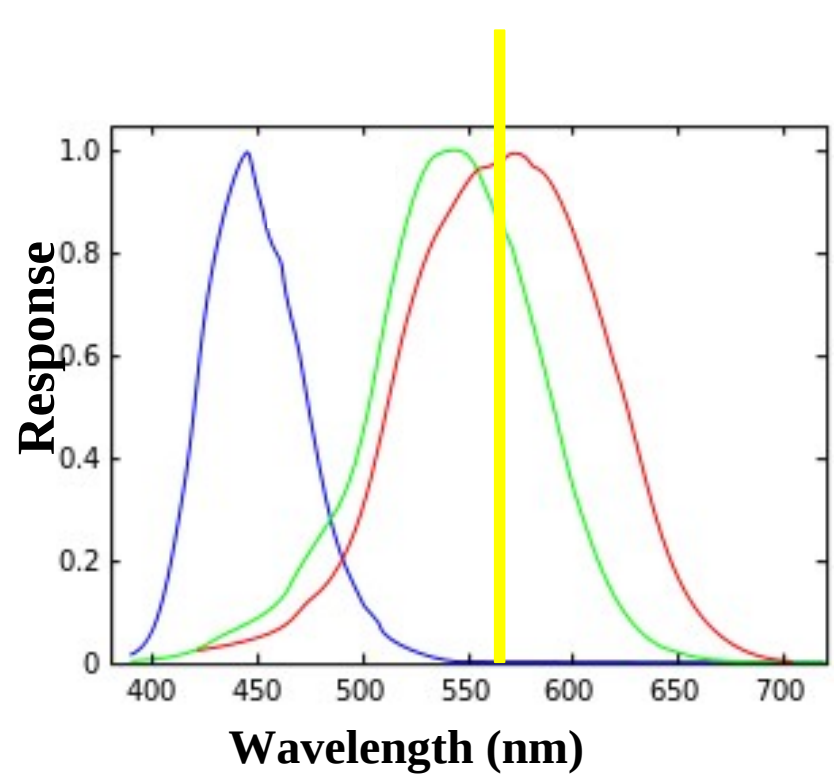
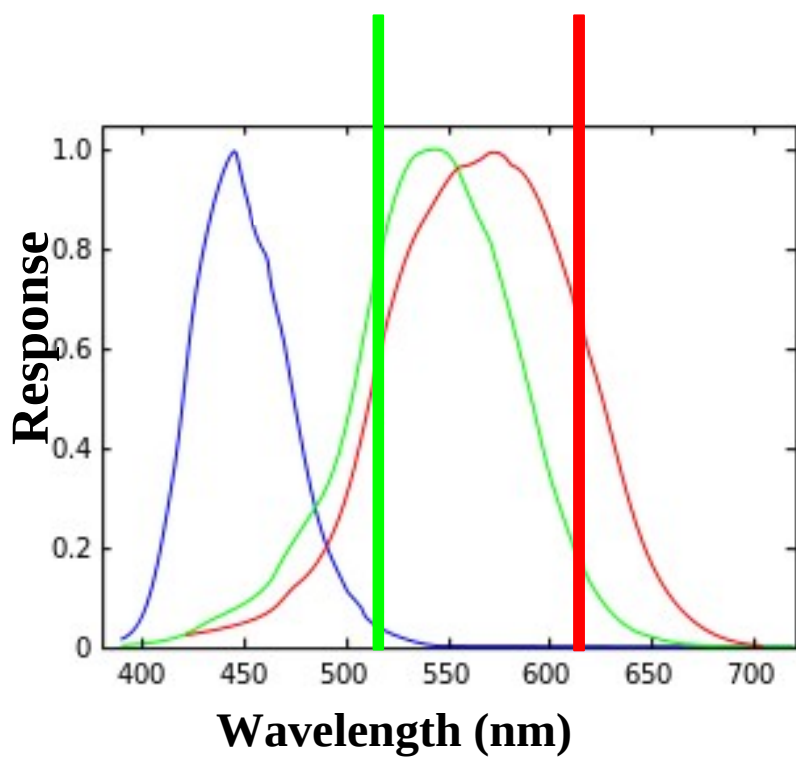


Diagram adapted from the Wikipedia article on cone cells.
Vanessaezekowitz at en.wikipedia



Same! The combination of red and green causes the same electrical response in the cones that the true (spectral) yellow causes. So they look the same. You can adjust the shade of yellow by varying the amounts of red and green you use.

That is the essence of RGB technology. You use varying amounts of R, G, B to cause the electrical response you need in the cones to simulate (fake) the colour you want.

Next up: Part 2:

What is an image anyway?

What is an image anyway?

Review

Most people have three kinds of cones: **RGB**, and this is what makes Red, Green and Blue “primary” colours to us.

We can simulate (fake) pretty much any colour by adding the right amounts of R, G, B. These simulated colours are called **perceptive colours**.

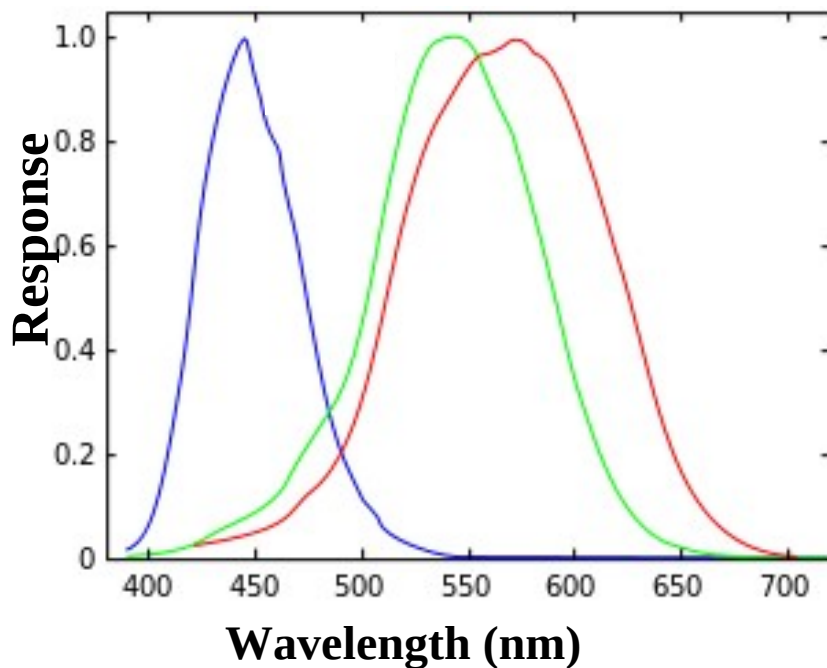


Diagram adapted from the Wikipedia article on cone cells.
Vanessaekowitz at en.wikipedia

What is an image anyway?

Let's use a microscope or strong magnifier to look at a yellow patch on the computer screen.



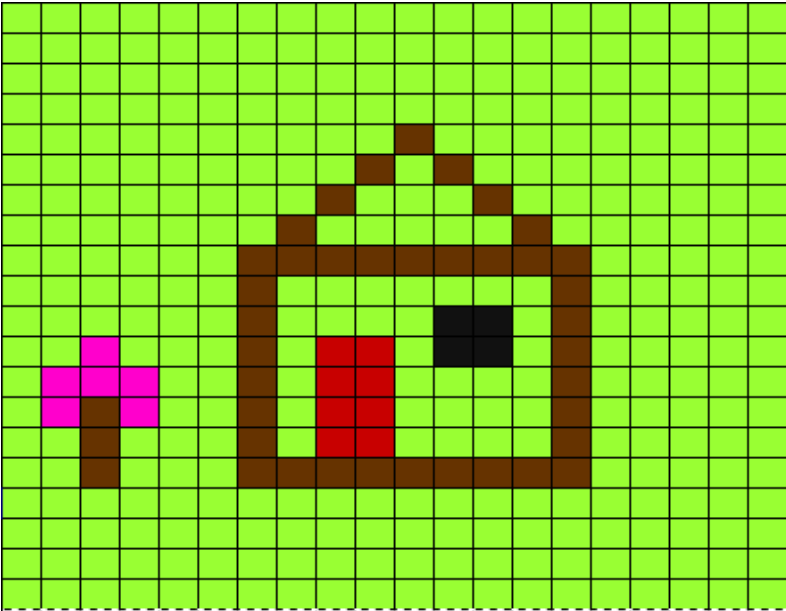
Red and Green Dots! Just like the mirror trick – there is no real yellow.

The red and green dots are too close together for you to see them separately so you see them as one light. Red and green together cause the same response in the cones that true (spectral) yellow would and so this fools you into seeing yellow!

That's pretty much a definition of RGB technology.

What is an image anyway?

On the screen it is a lot of colour “pixels” that make up the image.



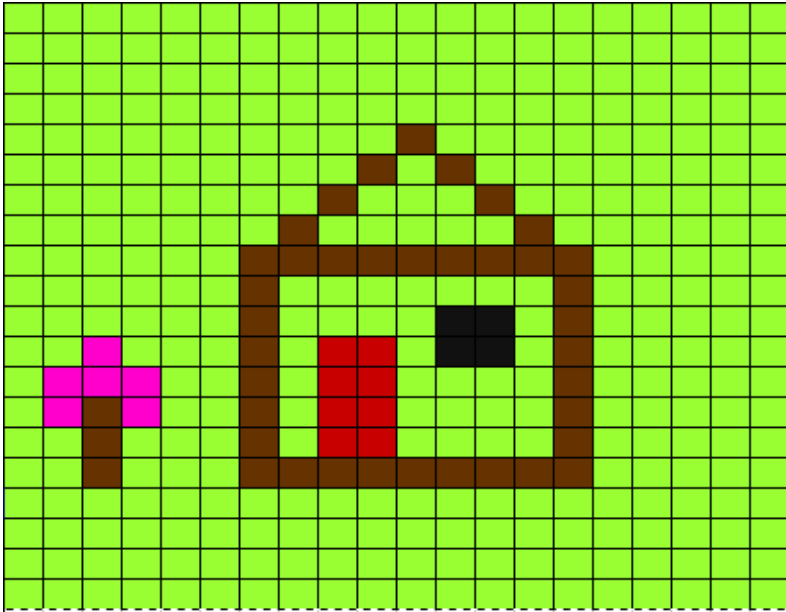
A 20 x 20 image
with 400 pixels

But each pixel is made up of a red dot, green dot, and blue dot (RGB) that can be dark, partly lit up, or fully lit up: 0 (off) – 255 (fully on).

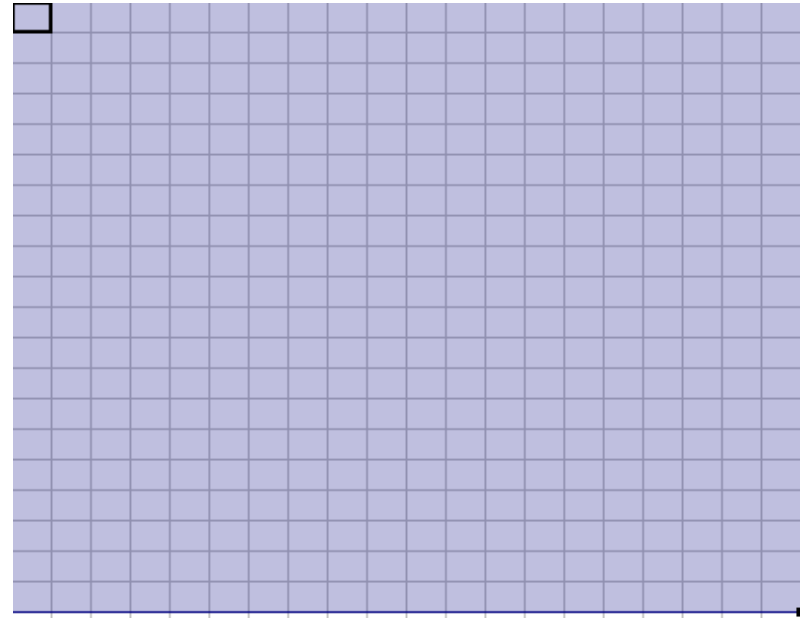
The pixels are too small to see individually without a strong magnifier, but with one you can see the individual R, G, B lights within each pixel.

So that's 1 byte per colour per pixel, 3 bytes per pixel.

What is an image anyway?



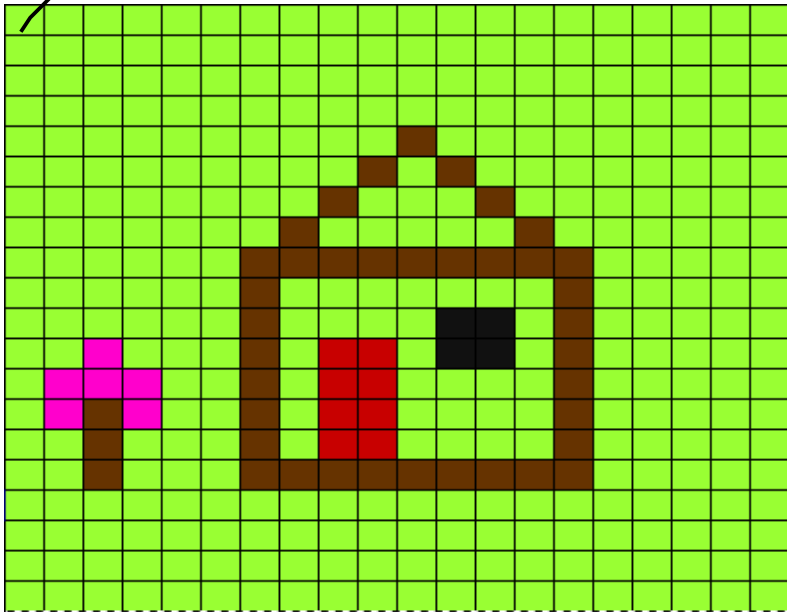
On the screen our 20x20 image is 400 colour “pixels” that make up the image.



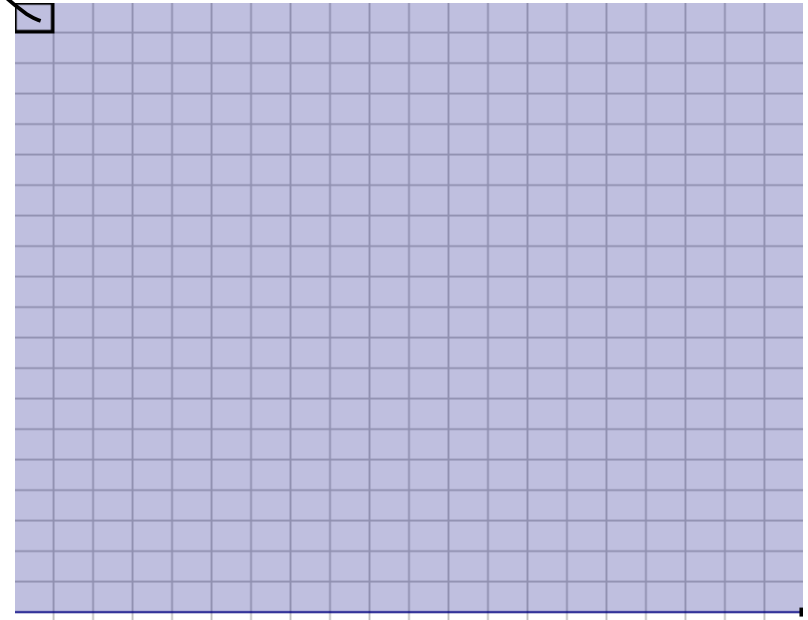
In the memory it's a 20 x 20 array. Each array element has a number that tells us the amount of R (0-255), G (0-255), and B (0-255). We will see how to calculate that later.

What is an image anyway?

The number in array element (0,0) gives the colour in the corresponding (top left) pixel



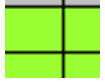
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Colour Numbers

The number in array element (0,0) gives the colour in the corresponding (top left) pixel



This colour is actually

$$R = 153$$

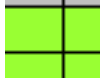
$$G = 255$$

$$B = 51$$

Again that's 3 bytes, 24 bits of data since each of RGB ranges from 0 - 255.

Colour Numbers

The number in array element (0,0) gives the colour in the corresponding (top left) pixel



This colour is actually

$$R = 153 = 10011001$$

$$G = 255 = 11111111$$

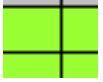
$$B = 51 = 00110011$$

Then use bit shifting to put the R highest, G next, B lowest:

$$\text{Colour} = 10011001\ 11111111\ 00110011$$

Colour Numbers

The number in array element (0,0) gives the colour in the corresponding (top left) pixel



This colour is actually

$$R = 153 = 10011001$$

$$G = 255 = 11111111$$

$$B = 51 = 00110011$$

Then use bit shifting to put the R highest, G next, B lowest:

$$\text{Colour} = 10011001 \ 11111111 \ 00110011$$

\swarrow \swarrow
 256^2 256

$$\text{Equivalent to Colour} = R * 256 * 256 + G * 256 + B = 10092339$$

What is an image anyway?

On a screen:

A lot of little colour patches called “pixels” that each contain a red light, green light, blue light. Fools us into seeing colours – called “perceptive colours.”

In memory:

An array with colour numbers calculated from

Colour = $R*256*256 + G*256 + B = 10092339$ (for example)

On paper:

Something about CMYK?? We’ll talk about that in tutorial.

That’s what an image is!

And that's what an image is.