

How Digital Cameras Work

Mendocino College - Digital Image Manipulation with Photoshop

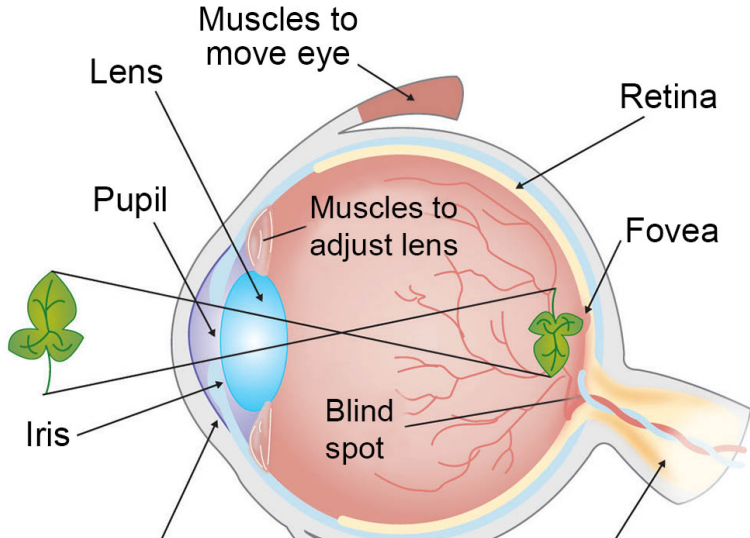


Adobe Photoshop CC

How the Human Eye Works

- First, light passes through the cornea (the clear front layer of the eye).
 - The cornea is shaped like a dome and bends light to help the eye focus.
- Some of this light enters the eye through an opening called the pupil (PYOO-pul).
 - The iris (the colored part of the eye) controls how much light the pupil lets in.
- Light passes through the lens (a clear inner part of the eye).
 - The lens works together with the cornea to focus light correctly on the retina.
- When light hits the retina (a light-sensitive layer of tissue at the back of the eye), special cells called
 - photoreceptors turn the light into electrical signals.
- These electrical signals travel from the retina through the optic nerve to the brain.
 - Then the brain turns the signals into the images you see.

How the Human Eye Works Example



The Retina and Photoreceptors

- The retina also contains the nerves that tell the brain what the photoreceptors are "seeing."
- There are two types of photoreceptors involved in sight: rods and cones.
- Rods work at very low levels of light.
 - We use these for night vision because only a few bits of light (photons) can activate a rod.
 - Rods don't help with color vision, which is why at night, we see everything in a gray scale.
 - The human eye has over 100 million rod cells.
- Cones require a lot more light and they are used to see color.
 - We have three types of cones: blue, green, and red.
 - The human eye only has about 6 million cones.
 - Many of these are packed into the fovea, a small pit in the back of the eye that helps with the sharpness or detail of images.

The diagram illustrates the structure of the human eye and a detailed view of the retina. On the left, a cross-section of the eye shows light entering through the cornea and lens. A box indicates the area shown in the detailed view on the right. The detailed view of the retina shows the following components:

- Light:** Yellow arrows representing light entering the eye.
- 1:** The cornea and lens area.
- 2:** The photoreceptor layer, containing **Cone** and **Rod** cells.
- 3:** The inner plexiform layer, showing the branching of bipolar cells.
- 4:** The outer plexiform layer, showing the branching of Müller cells.
- 5:** The retinal pigment epithelium (RPE) layer, which is adjacent to the **Epithelial cells**.

Additional Resources for How Eyes Work

- How the Eyes Work
 - National Eye Institute
 - <https://www.nei.nih.gov/learn-about-eye-health/healthy-vision/how-eyes-work>
- Seeing Color
 - Arizona State University
 - <https://askabiologist.asu.edu/rods-and-cones>
- Vision for Photography
 - Ron Dexter
 - https://rondexter.com/professional/operation/vision_for_photography.htm

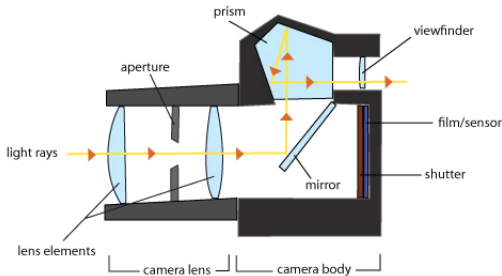
How Film Cameras Work

- Before digital cameras came along, photography involved capturing light rays on silver-based film.
- Light enters the front of the camera through the aperture and lens, then hits a piece of film.
- Film is very sensitive to light:
 - only a tiny amount of light energy is needed to make a photograph and too much light will destroy it.
- To produce a perfect photo, you have to let exactly the right amount of light hit the film, which is called the exposure.
- The exposure depends on two factors:
 - How long the shutter is open, measured in seconds (anywhere from 1/10,000 to 30 seconds)
- How wide the Aperture is open, measured in units called f-stops, such as f/4 and f/8.
 - Smaller f numbers (such as 1) means larger apertures, so more light gets in;
 - Higher f numbers (such as 32) means smaller apertures, so less light is let in.

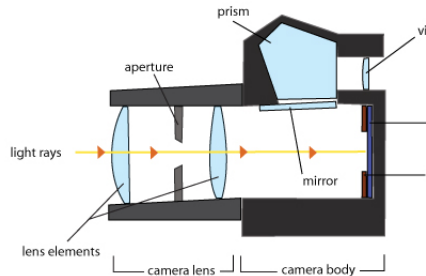
How Film Cameras Work Example

How an SLR Camera Works

Viewfinder Mode: mirror down



Picture-taking Mode: mirror up



Lenses in the Lens

- A camera lens is actually several lenses combined into one unit.
 - A single converging lens could form a real image on the film, but it would be warped by a number of aberrations.
- One of the most significant warping factors is that different colors of light bend differently when moving through a lens.
 - This chromatic aberration essentially produces an image where the colors are not lined up correctly.
- Cameras compensate for this using several lenses made of different materials.
 - The lenses each handle colors differently, and when you combine them in a certain way, the colors are realigned.
- A standard 50 mm lens doesn't significantly shrink or magnify the image.

Lens Example



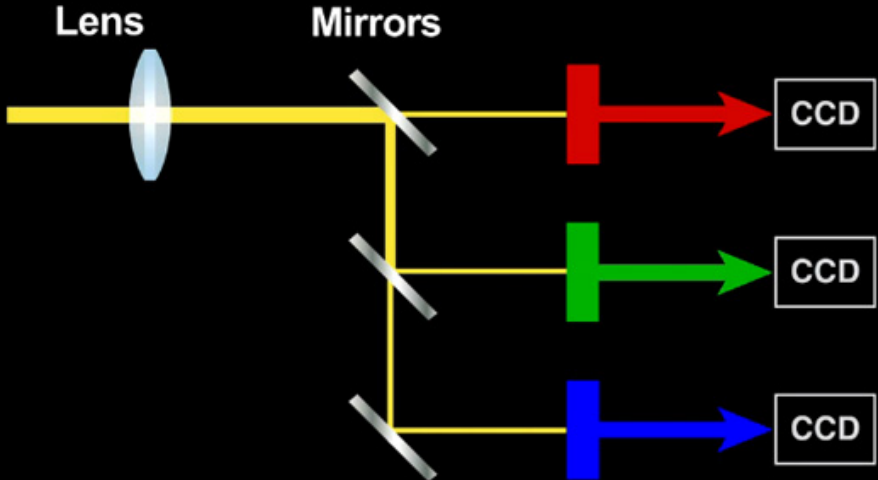
Additional Resources for How Film Cameras Work

- 35mm Film cameras
 - By: Chris Woodford
 - <https://www.explainthatstuff.com/how-film-cameras-work.html>
- How Cameras Work
 - By: Tom Harris
 - <https://electronics.howstuffworks.com/camera.htm>

How Digital Cameras Work

- Instead of film, a digital camera has a sensor that converts light into electrical charges.
- The image sensor employed by most digital cameras is a charge coupled device (CCD).
 - Some cameras use complementary metal oxide semiconductor (CMOS) technology instead.
 - Both CCD and CMOS image sensors convert light into electrons.
- Once the sensor converts the light into electrons, it reads the value (accumulated charge) of each cell in the image.
- Each photosite is colorblind. It only keeps track of the total intensity of the light that strikes its surface.
 - In order to get a full color image, most sensors use filtering to look at the light in its three primary colors.
 - Once the camera records all three colors, it combines them to create the full spectrum.

How Digital Cameras Work Example



Exposure and Focus

- Just as with film, a digital camera has to control the amount of light that reaches the sensor.
 - The two components it uses to do this, the aperture and shutter speed, are also present on conventional cameras.
- The camera also has to adjust the lenses to control how the light is focused on the sensor.
- The focal length, however, is one important difference between the lens of a digital camera and the lens of a 35mm camera.
 - The focal length is the distance between the lens and the surface of the sensor.
 - Sensors are in general smaller than a piece of 35mm film.
 - In order to project the image onto a smaller sensor, the focal length is shortened by the same proportion.

Additional Resources for the How Digital Cameras Work

- DIGITAL CAMERA SENSOR SIZES

- By: Cambridge in Colour
- <https://www.cambridgeincolour.com/tutorials/digital-camera-sensor-size.htm>

- Digital cameras

- By: Chris Woodford
- <https://www.explainthatstuff.com/digitalcameras.html>

Comparing Eyes to Cameras

- The focal length of the eye is about 17 mm (2/3").
- We see almost 180 degrees wide, 120 degrees high
- If you think of the eye as a camera, then:
 - The Cornea would be the Lens.
 - The Iris would be the Aperture.
 - The Retina would be the Film.