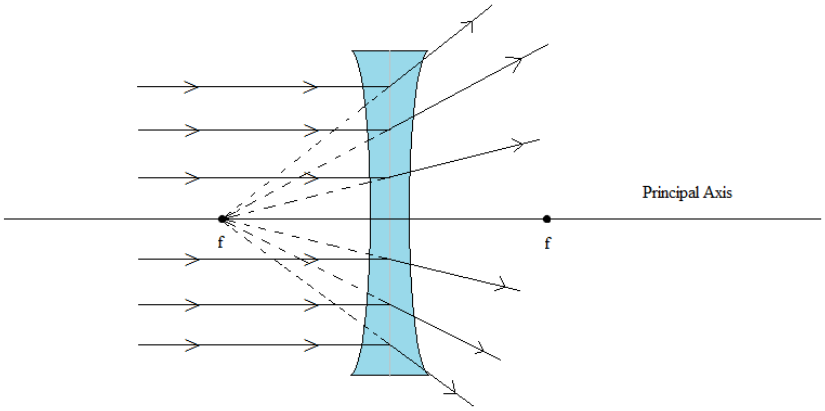
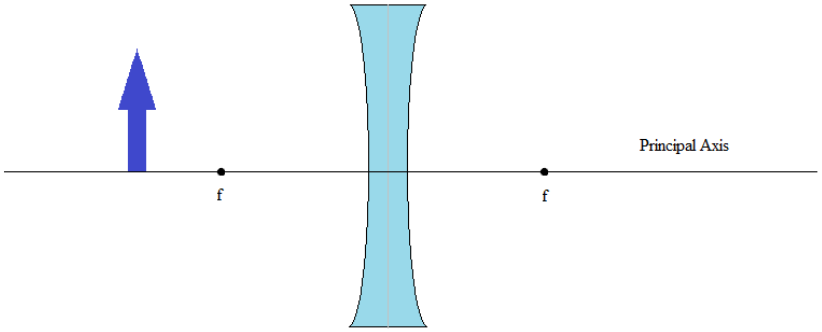
The TEKS only require study of image formation with convex lenses. This supplemental lesson will cover the basics of image formation with concave lenses and curved mirrors.

Concave Lenses

A concave lens is one that is thicker at the edges than it is in the middle, so it tends to cause light to spread out. All light that enters the lens parallel to the principal axis will leave the lens as if it originated from the focus of the lens:



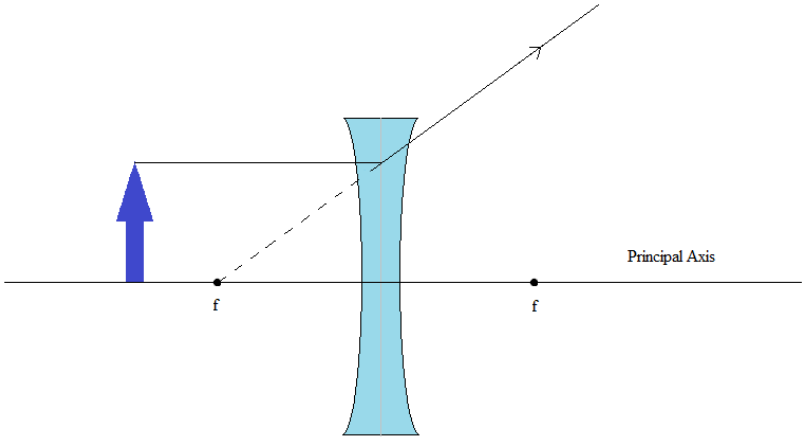
Just as with the convex lens, the object is usually drawn as an arrow.



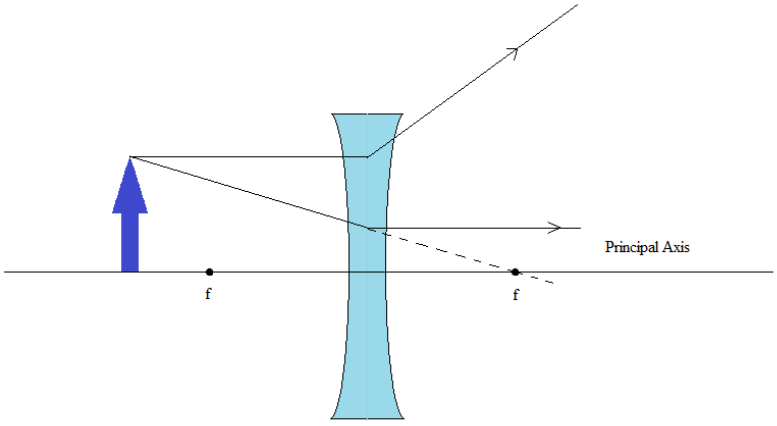
The picture shows that the concave lens also has two focal points. I will refer to the one closer to the object as the near focus and the one on the other side of the lens as the far focus.

Images are located by drawing three principal rays very similar to those drawn for convex lenses

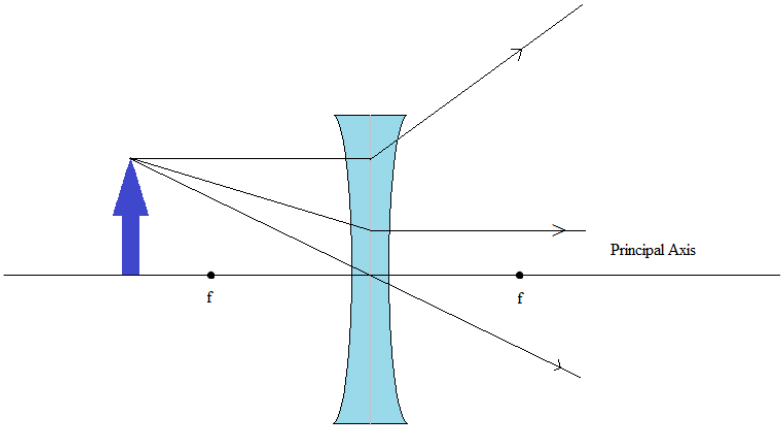
1) A ray that travels from the object to the lens parallel to the principal axis will leave the lens as if it originated from the near focus



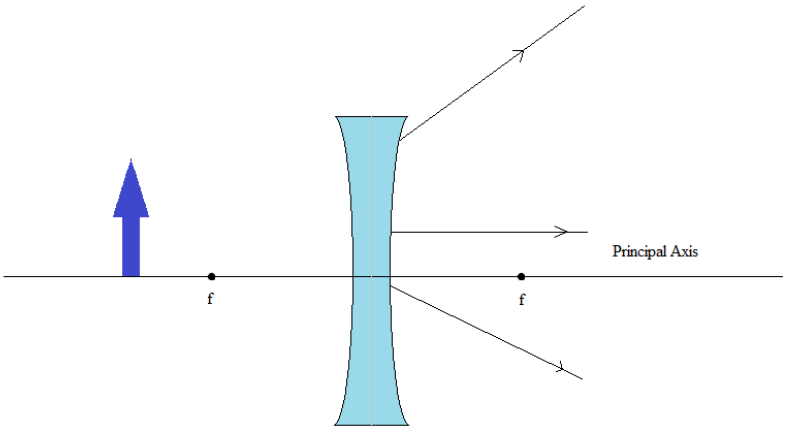
2) A ray that is aimed at the far focus of the lens will bend to leave the lens parallel to the principal axis



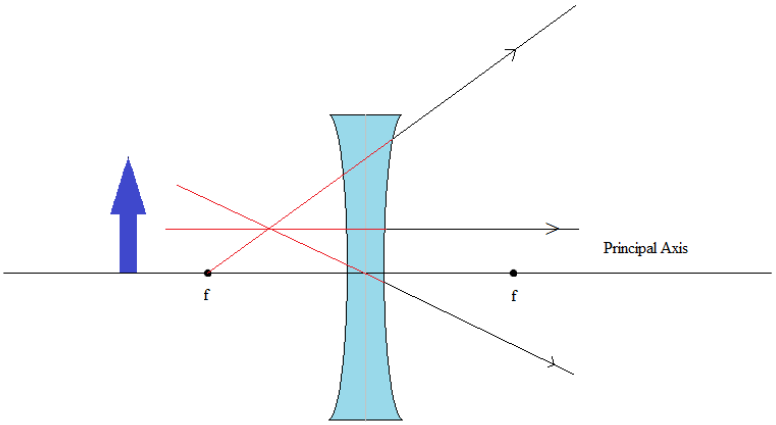
3) A ray that hits the lens at the principal axis will continue to travel straight.



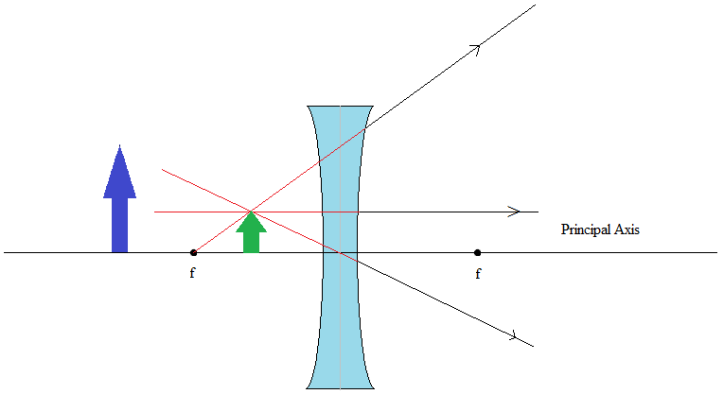
This now leaves us with three light rays that are spreading away from each other:



Your eye and brain work together to follow the light back to where they appear to cross



This is where the image is formed:



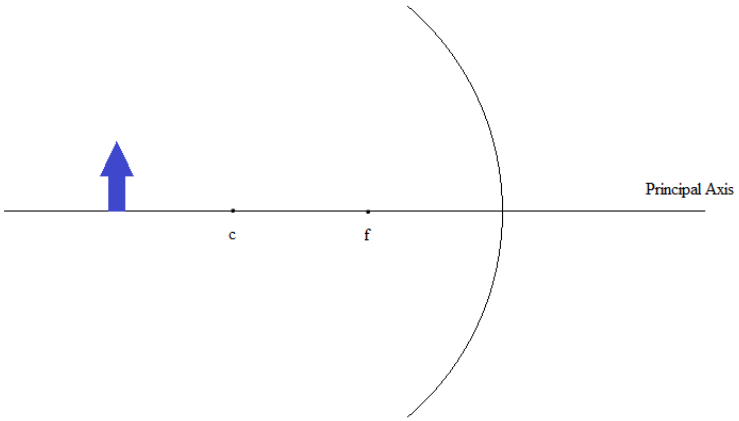
This image is virtual because it is formed by tracing back diverging rays. It is also upright and smaller. A concave lens will always form upright virtual smaller images.

Curved Mirrors

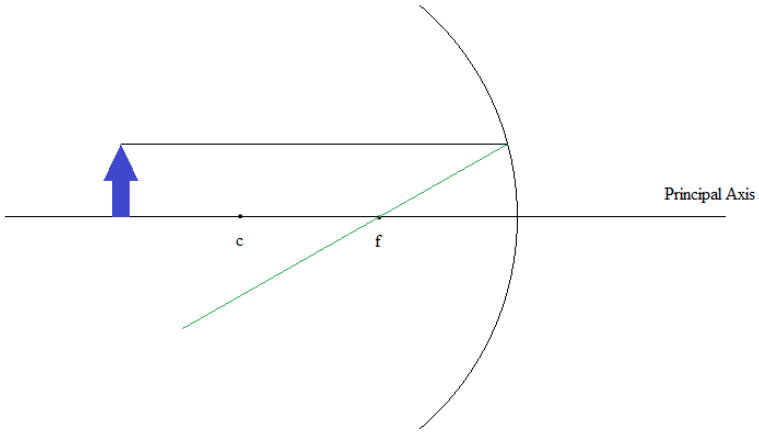
There are two types of curved mirrors that we will consider: concave mirrors with the reflective surface on the inside of the curve, and convex mirrors with the reflective surface on the outside of the curve. Just like with lenses, we can define a focus of a curved mirror, but with mirrors we have another special point: the center of curvature. The center of curvature is a point that would be at the center of the circle that would be formed if we were to extend the curve of the mirror. The center of curvature is twice as far from the mirror as the focus.

Images are found with ray diagrams very similar to those drawn with lenses. The major difference is that the light bounces off the mirror instead of passing through.

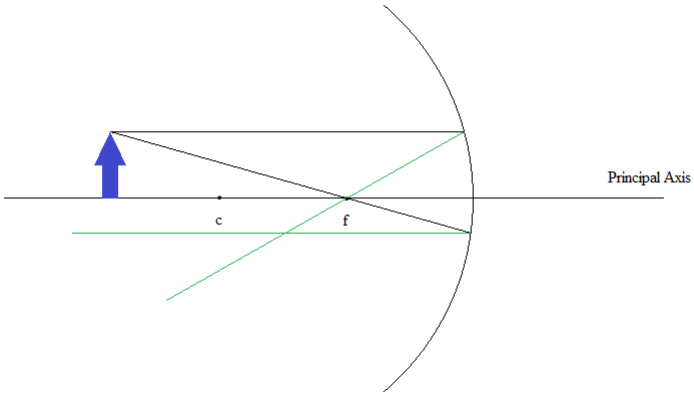
First, let's look at the concave mirror. Just as with lenses, an object is usually represented by an arrow:



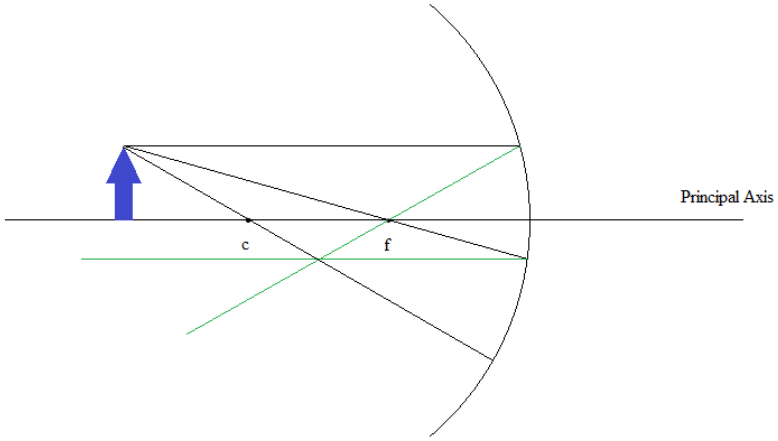
1) A ray that leaves the object an travels parallel to the principal axis will reflect back through the focus



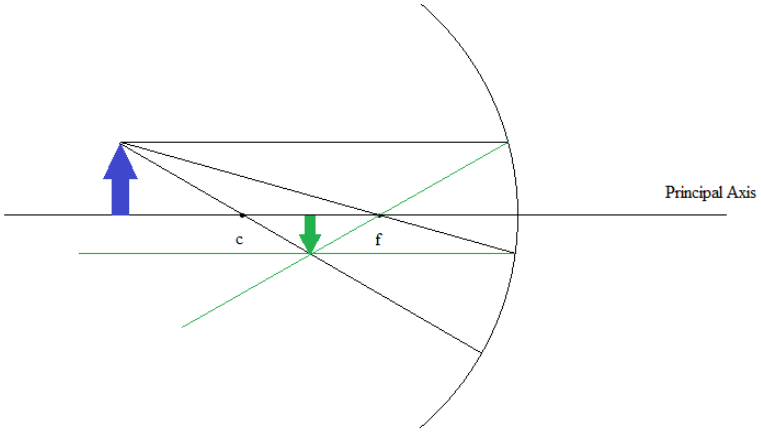
2) A ray that leaves the object and passes through the focus will reflect back parallel to the principal axis



3) A ray that leaves the object and passes through the center of curvature will reflect back through the center of curvature



The point at which these light rays cross is where we will find the image:

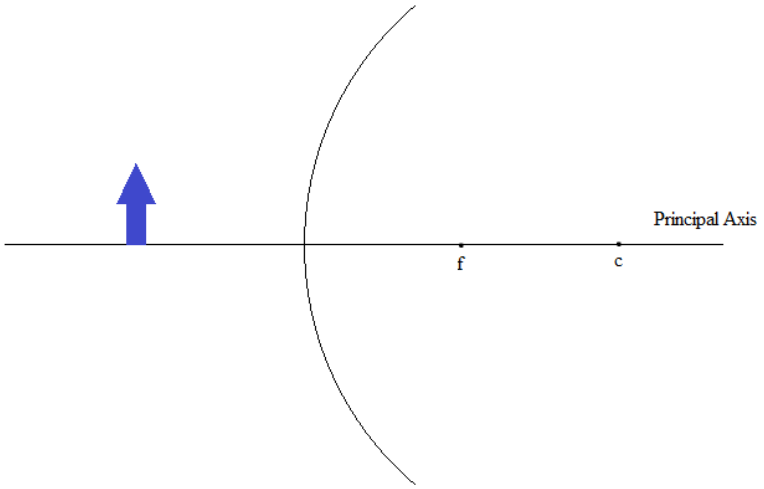


This image is located where actual light rays are crossing, so it is a real image. It is also inverted and smaller.

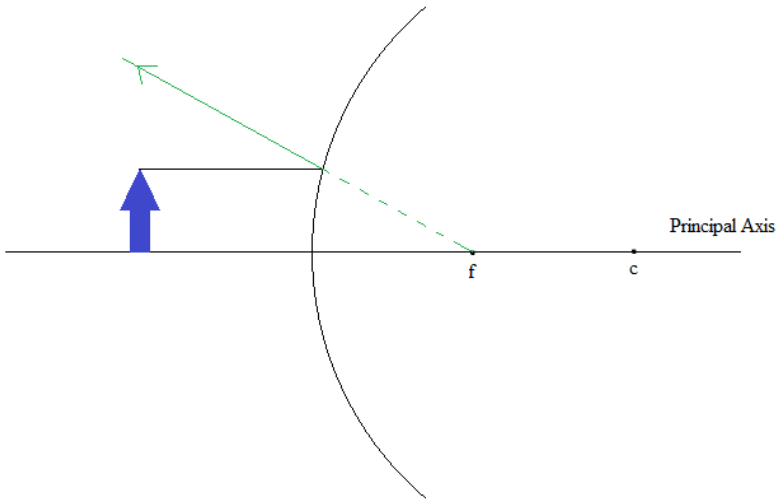
Here is a table showing the types of images formed by concave mirrors based on the placement of the object.

Object Position	Upright or Inverted	Larger or Smaller	Real or Virtual
Outside c	inverted	smaller	real
At c	inverted	same size	real
Between c and F	inverted	larger	real
At F	no image	no image	no image
Between F and mirror	upright	larger	virtual

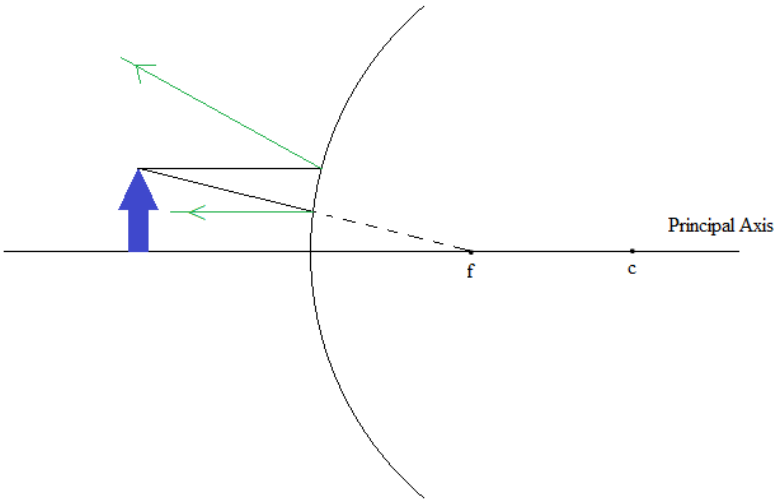
Now we can look at the images formed by a convex mirror:



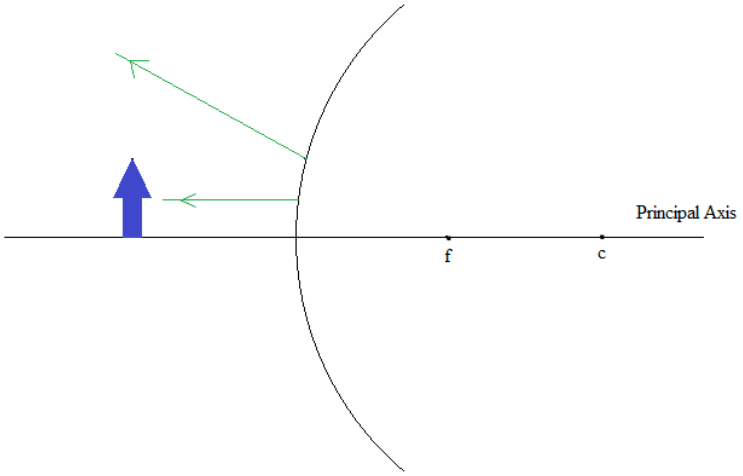
1) A ray that leaves the object and travels parallel to the principal axis will reflect as though it came from the focus



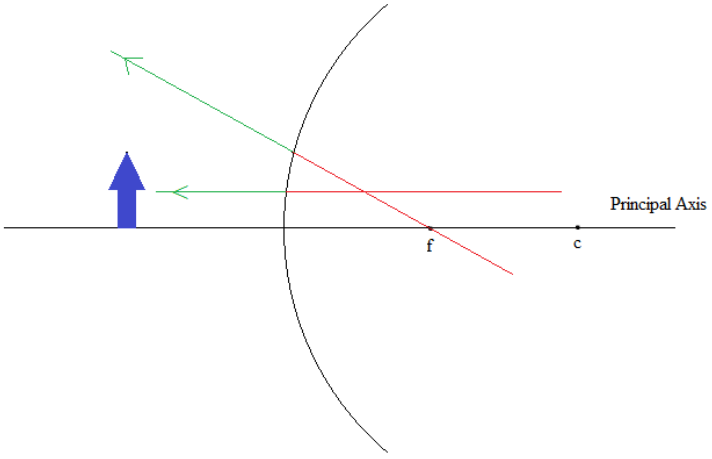
2) A light ray that leaves the object aimed at the focus will reflect parallel to the principal axis



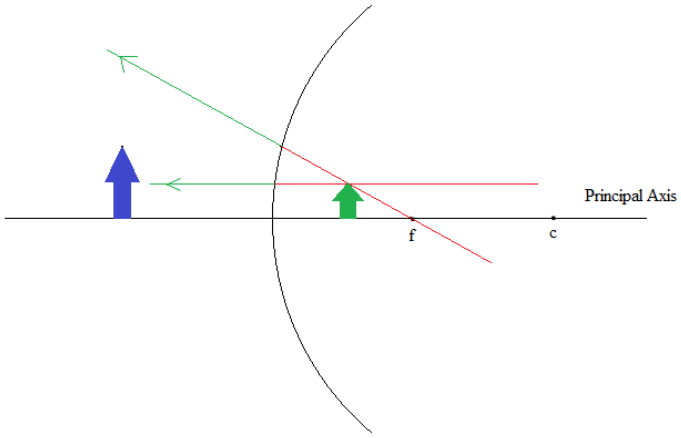
This leaves us with two diverging light rays



Your eye and brain work together to follow the light back to where they appear to cross



This is where the image is formed



This image is located behind the mirror and was found by tracing back the origin of diverging light rays, so it is virtual. It is also upright and smaller. Convex mirrors always make upright virtual smaller images.
It is seldom drawn, but a light ray that leaves the object aimed at the center of curvature will bounce directly back as shown