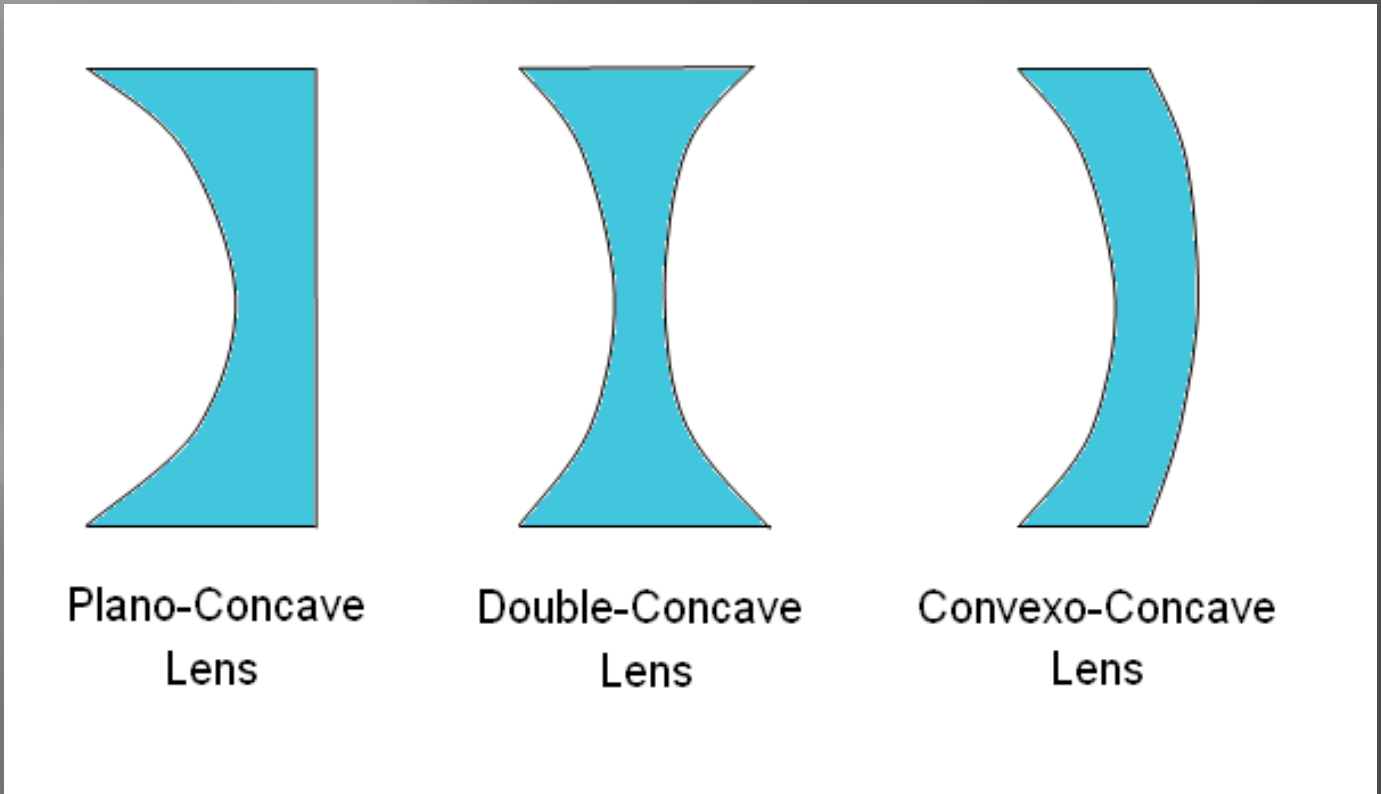
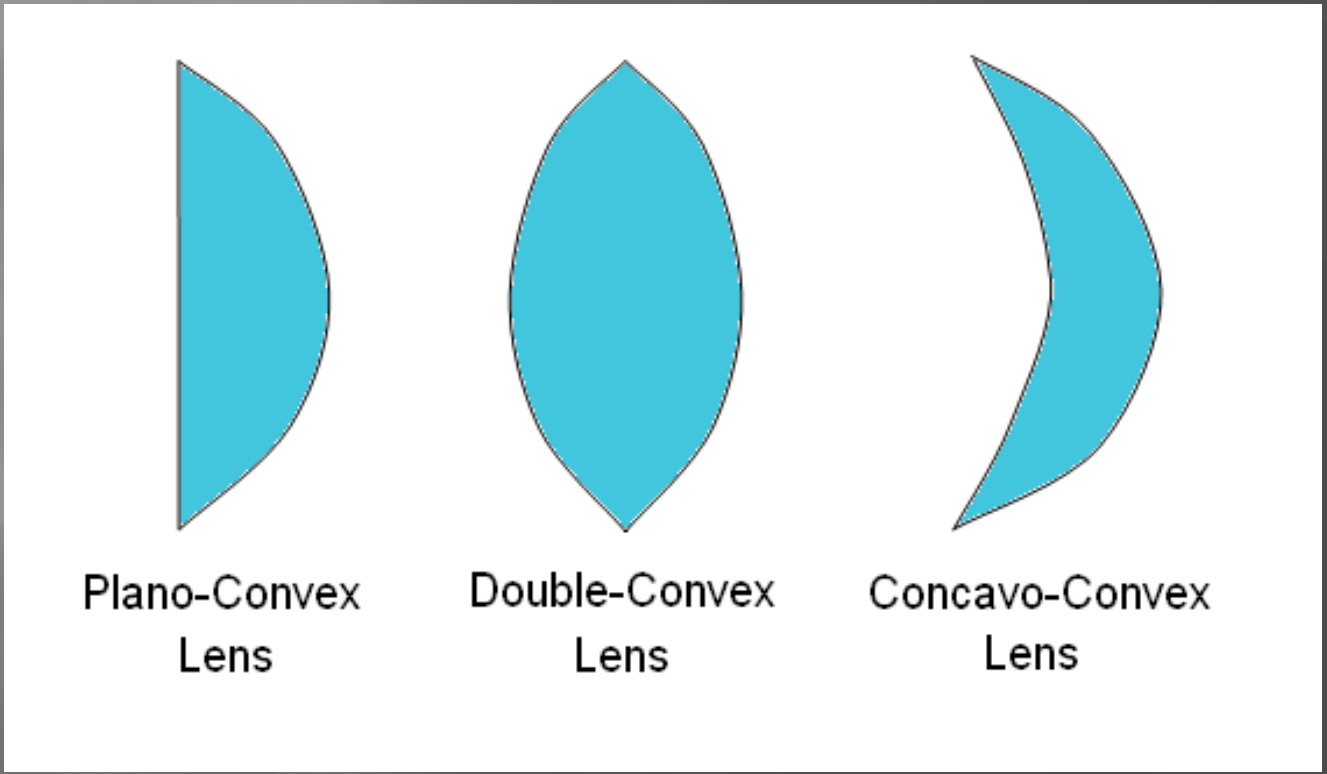
RAY DIAGRAMS

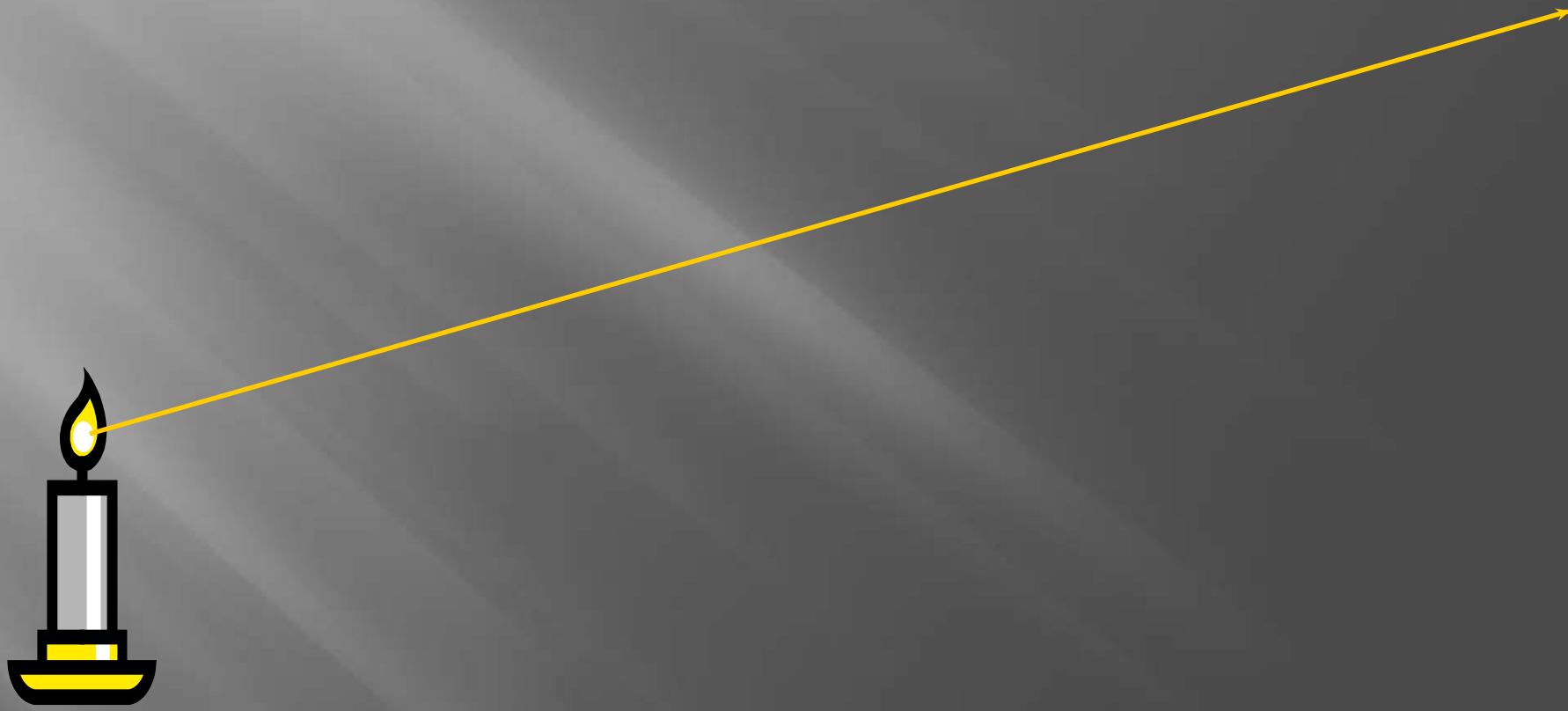
Diverging Lens = Concave



Converging Lens = Convex

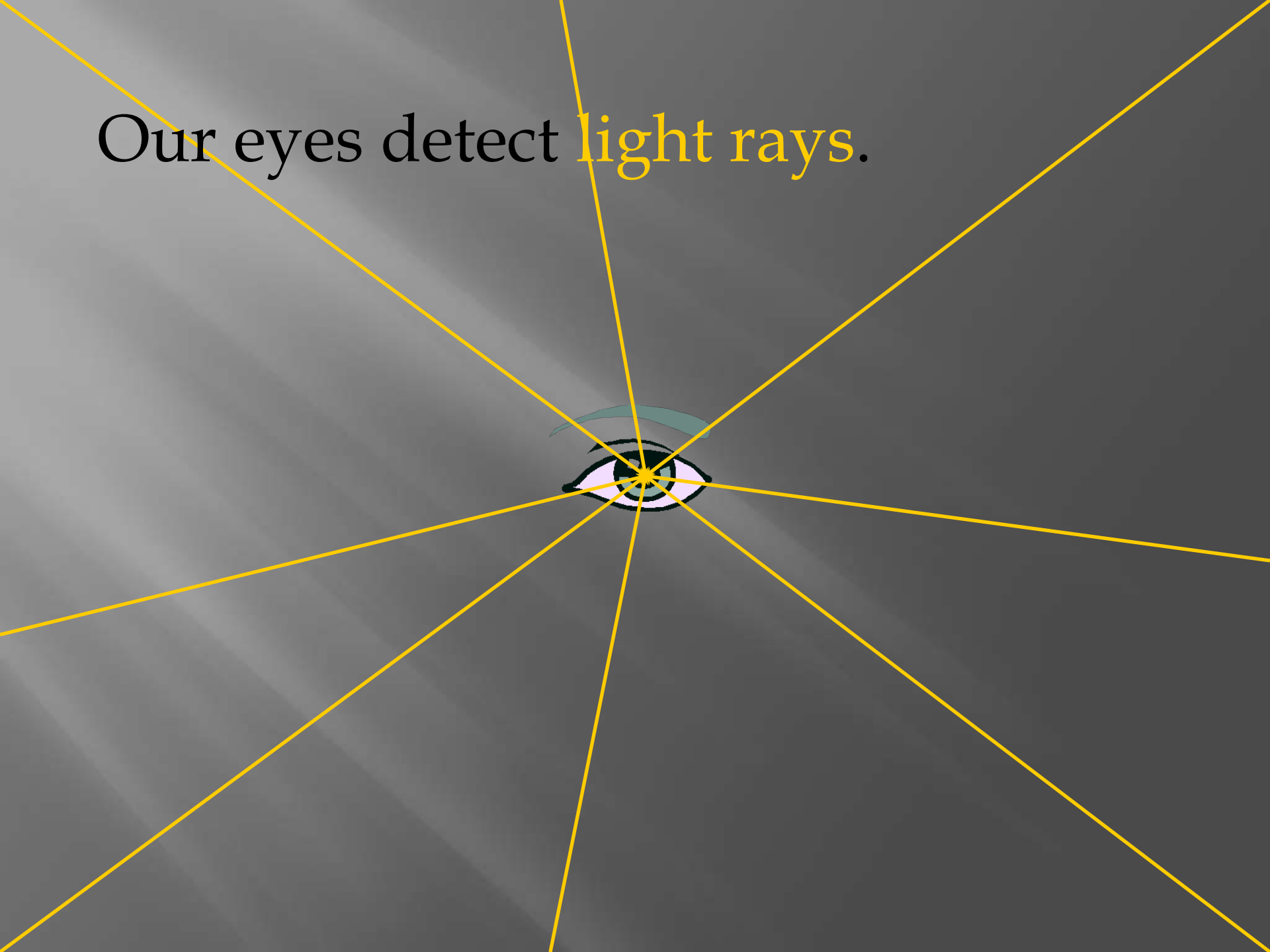


A ray of light is an extremely narrow beam of light.

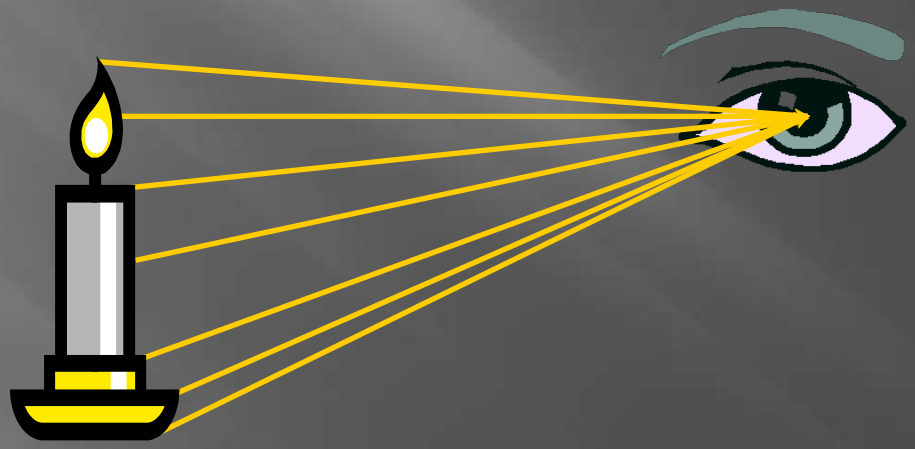


All visible objects emit or reflect **light rays** in all directions.

Our eyes detect light rays.



We see images when
light rays
converge in our eyes.



converge: come together

Mirrors

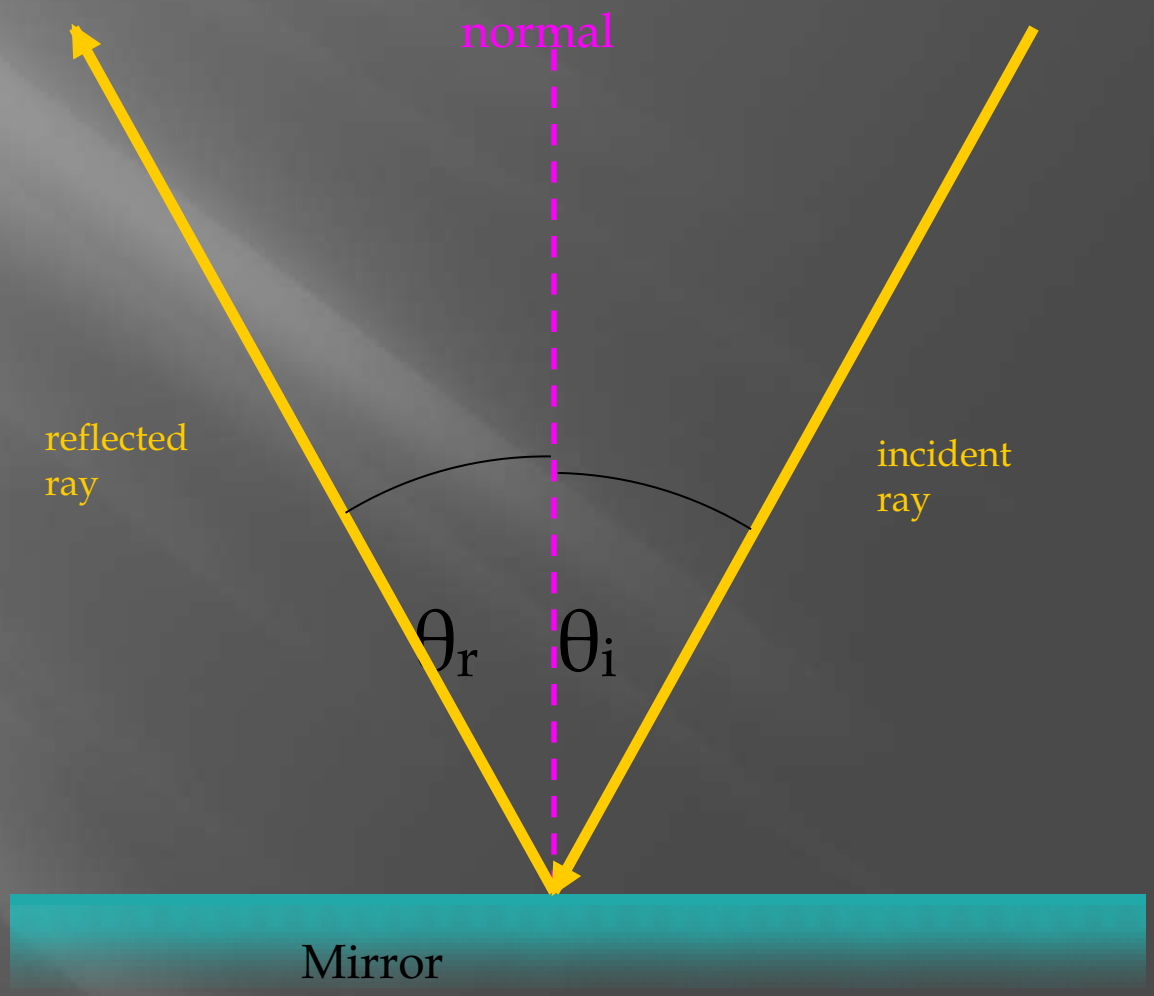
It is possible to see images in mirrors.

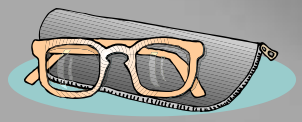
Reflection
(bouncing light)

Reflection is when light changes direction by bouncing off a surface.

When light is reflected off a mirror, it hits the mirror at the same angle (the incidence angle, θ_i) as it reflects off the mirror (the reflection angle, θ_r).

The normal is an imaginary line which lies at right angles to the mirror where the ray hits it.





Lensmaker's Equation

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

f = focal length
d_o = object distance
d_i = image distance

if distance is negative the image is behind the mirror

Magnification Equation

$$m = \frac{h_i}{h_o} = \frac{-d_i}{d_o}$$

m = magnification
h_i = image height
h_o = object height

If height is negative the image is upside down

if the magnification is negative
the image is inverted (upside down)

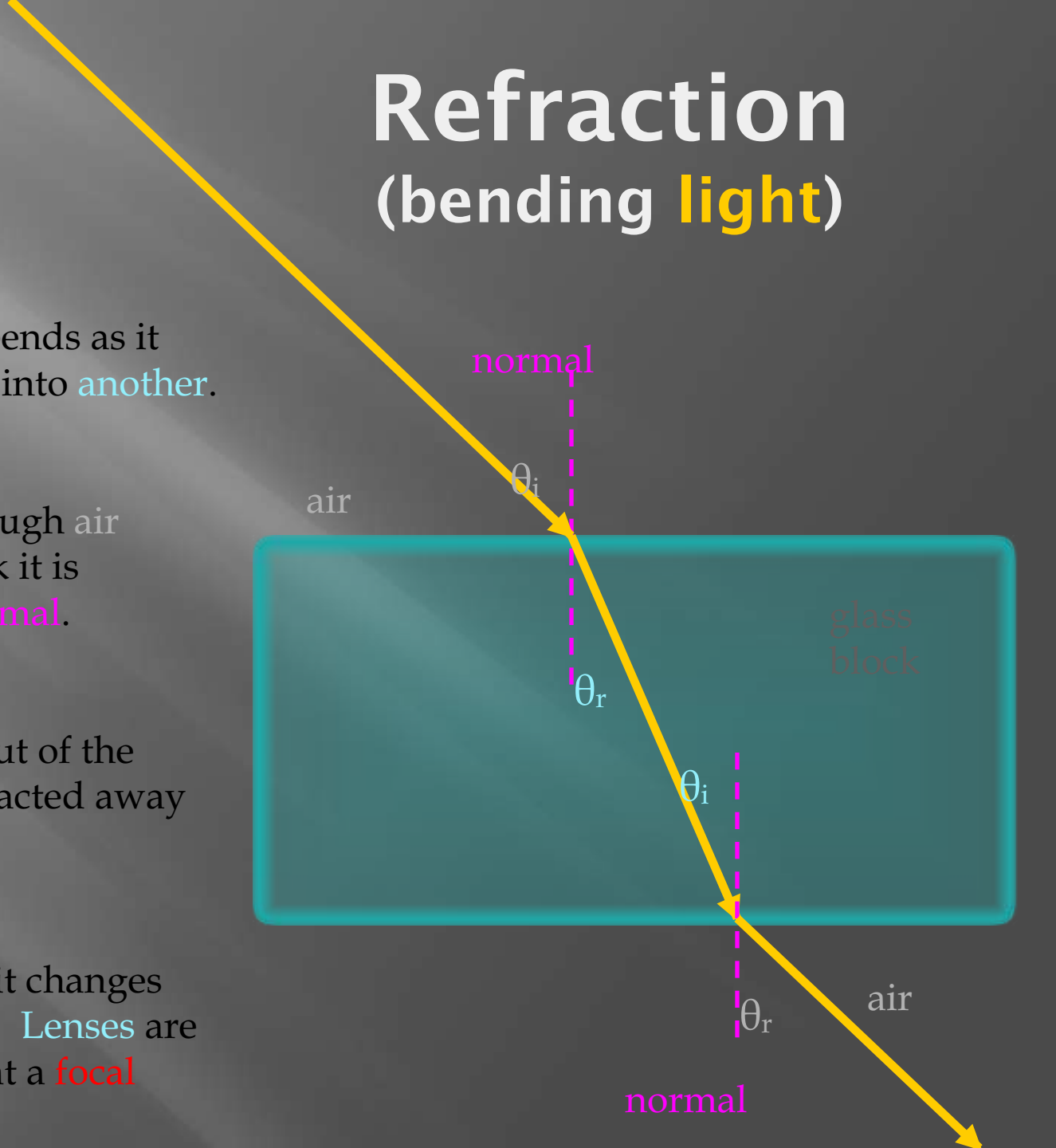
Refraction
(bending light)

Refraction is when light bends as it passes from one medium into another.

When light traveling through air passes into the glass block it is refracted towards the normal.

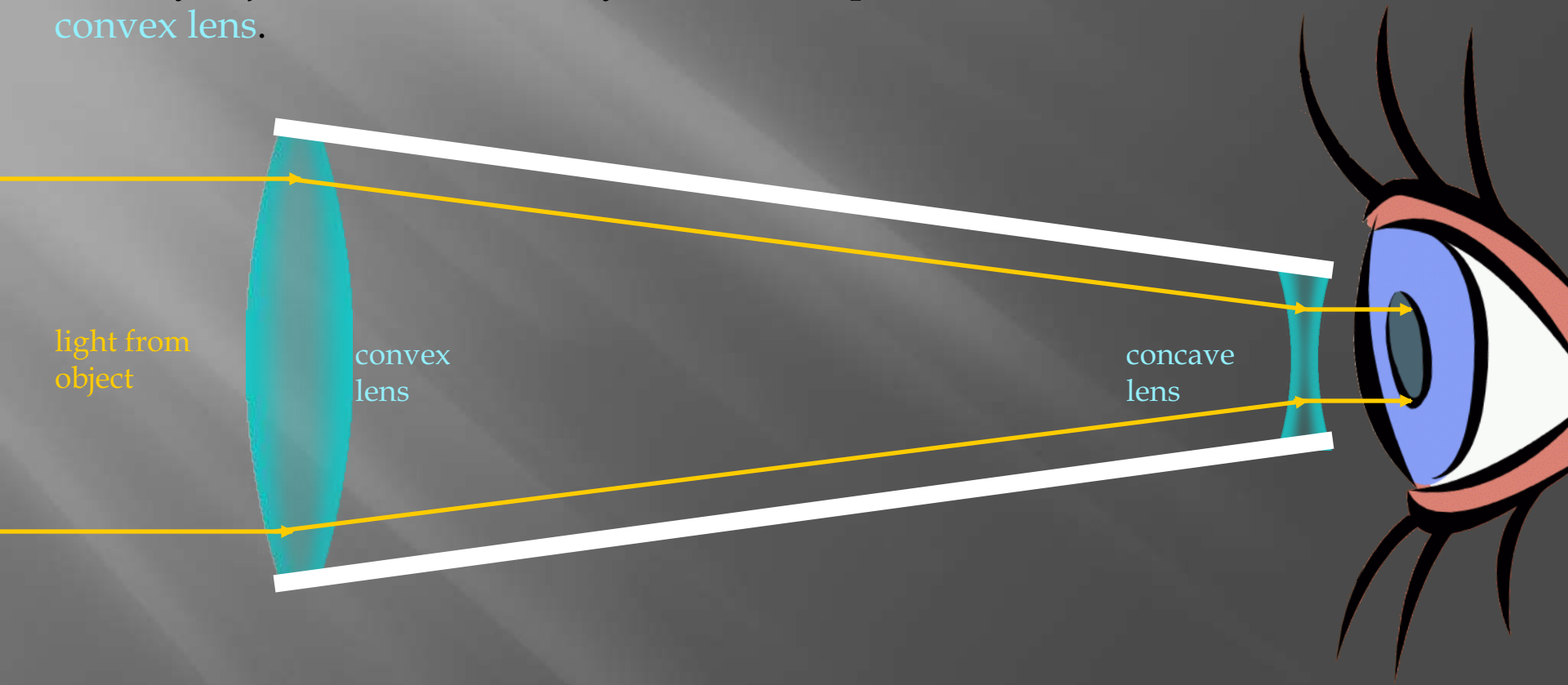
When light passes back out of the glass into the air, it is refracted away from the normal.

Since light refracts when it changes mediums it can be aimed. Lenses are shaped so light is aimed at a focal point.



Lenses

The first telescope, designed and built by Galileo, used lenses to focus light from faraway objects, into Galileo's eye. His telescope consisted of a concave lens and a convex lens.



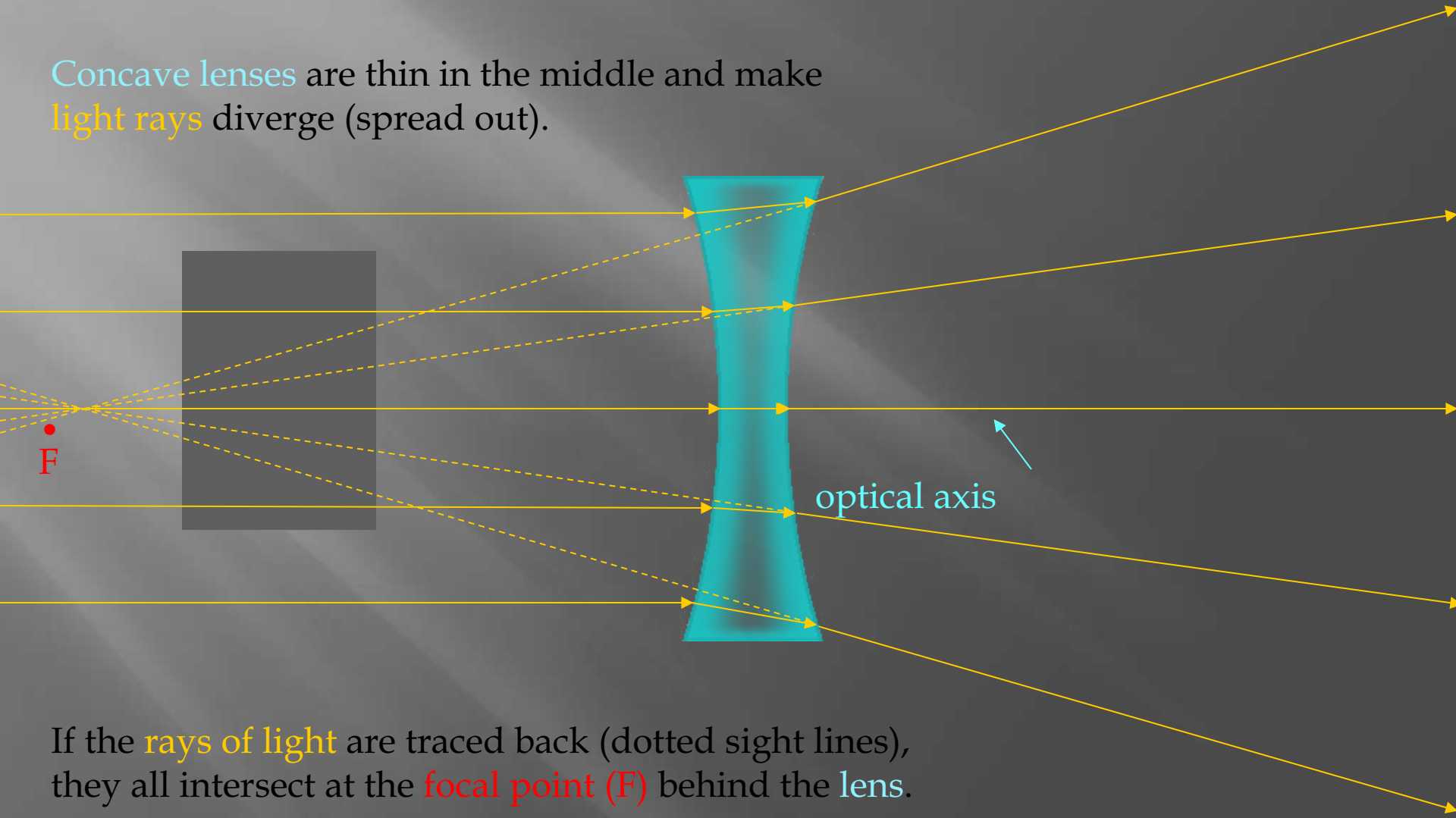
Light rays are always refracted (bent) towards the thickest part of the lens.

Rules for Concave Lens (Divergence)

1. An incident ray traveling parallel to the principal axis of a diverging lens will refract through the lens and travel in line with the focal point.
2. An incident ray traveling towards the focal point on the way to the lens will refract through the lens and travel parallel to the principal axis.
3. An incident ray that passes through the center of the lens will in affect continue in the same direction that it had when it entered the lens.

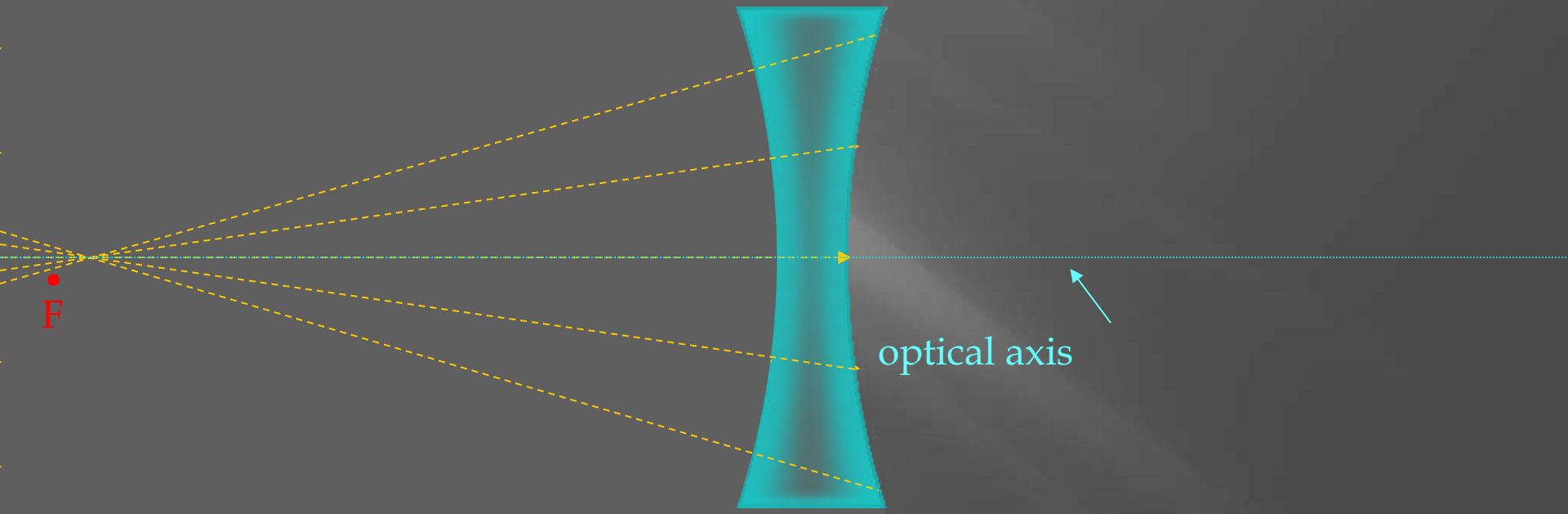
Concave Lenses

Concave lenses are thin in the middle and make light rays diverge (spread out).



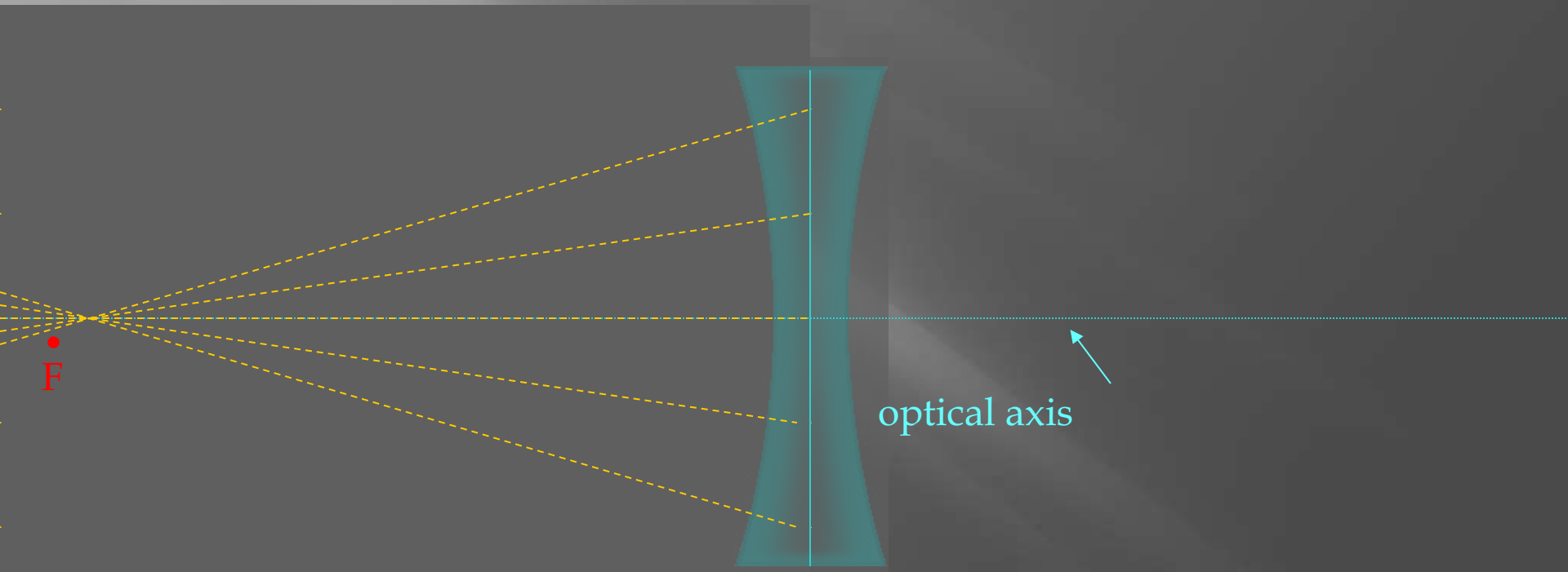
If the rays of light are traced back (dotted sight lines), they all intersect at the focal point (F) behind the lens.

Concave Lenses



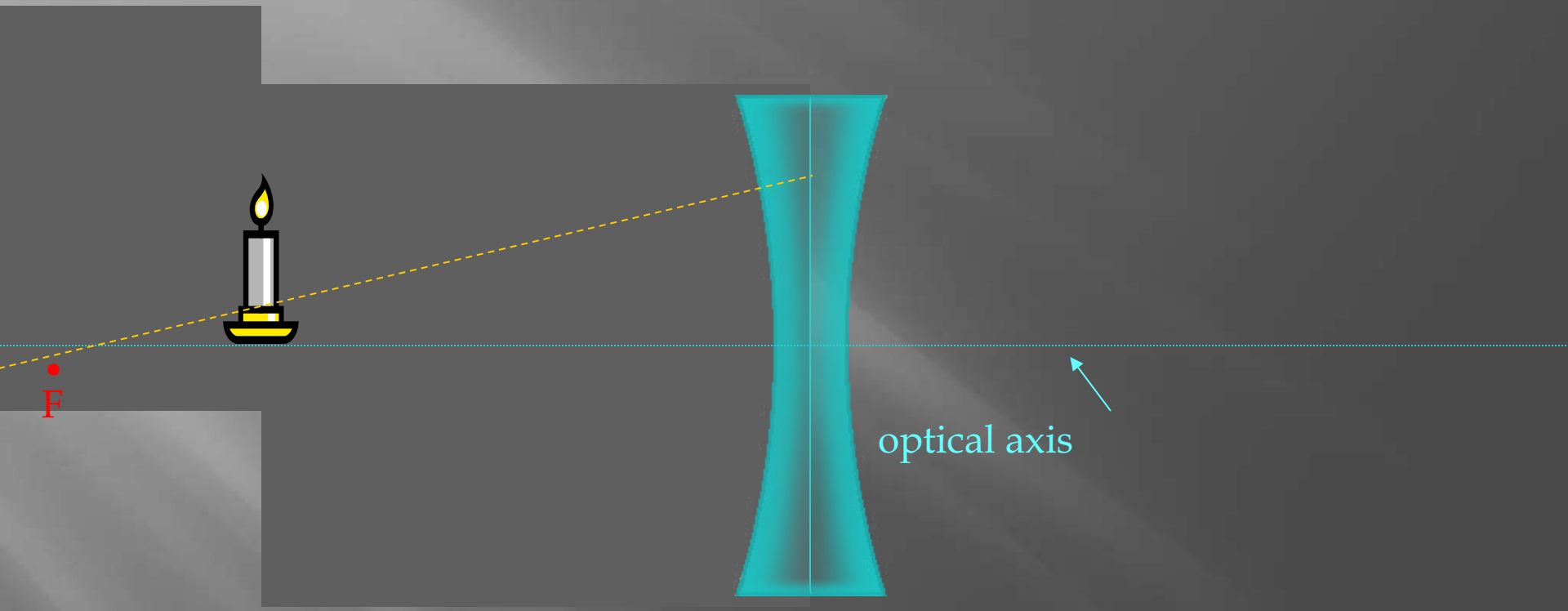
The light rays behave the same way if we ignore the thickness of the lens.
Light rays that come in parallel to the optical axis diverge from the focal point.

Concave Lenses



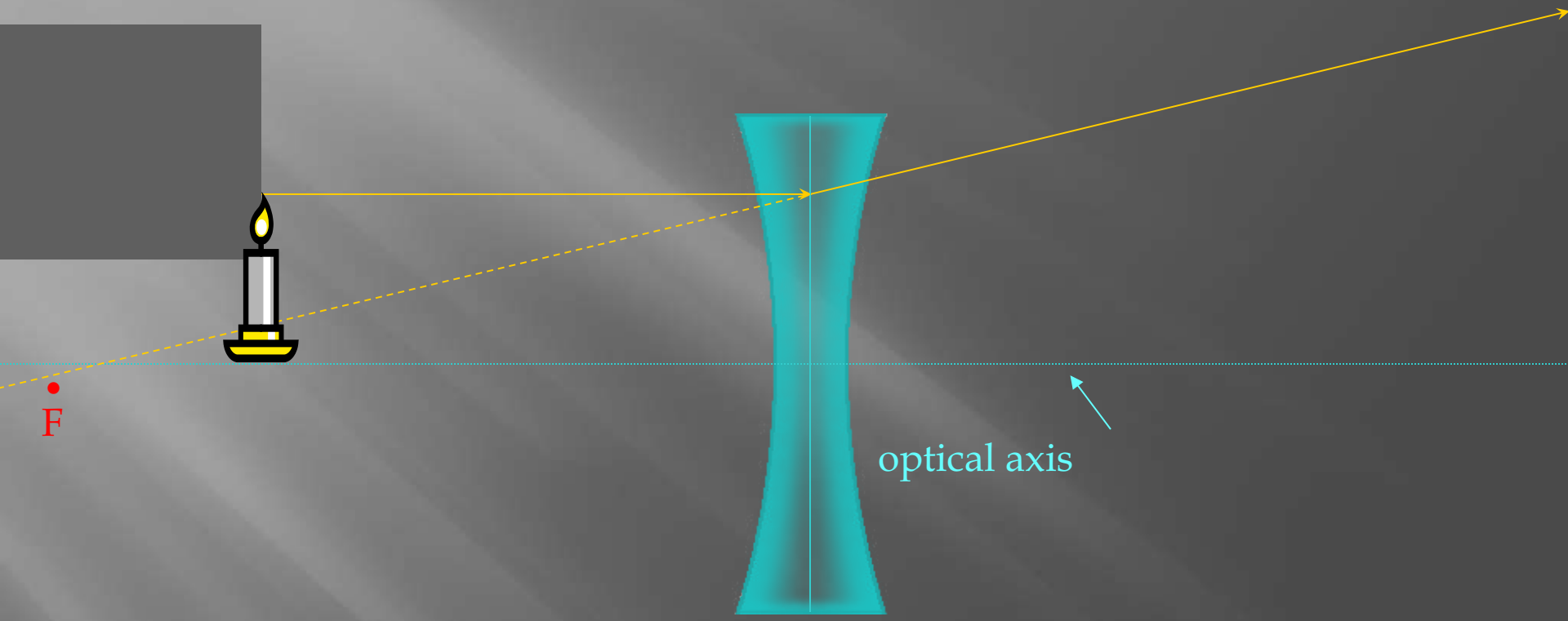
Light rays that come in parallel to the optical axis still diverge from the focal point.

Concave Lens
(example)



The first ray comes in parallel to the optical axis and refracts from the focal point.

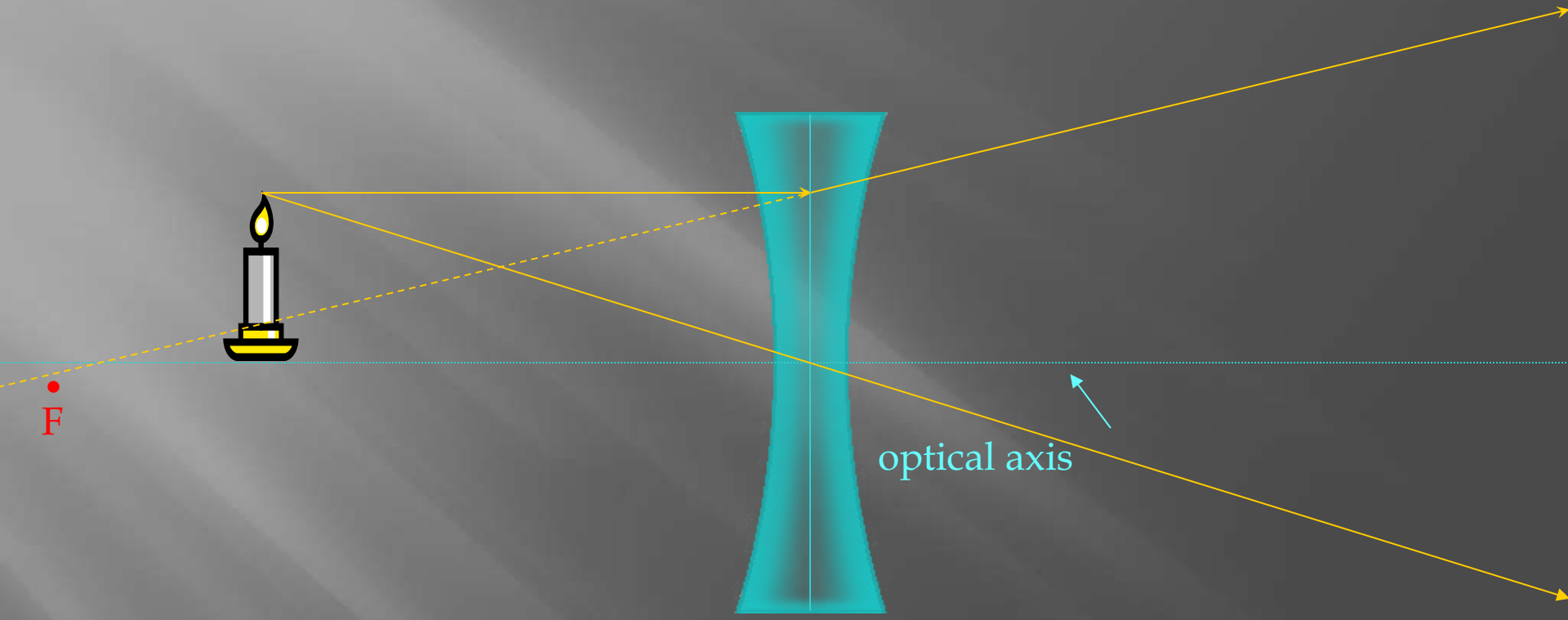
Concave Lens
(example)



The first ray comes in parallel to the optical axis and refracts from the focal point.

The second ray goes straight through the center of the lens.

Concave Lens
(example)

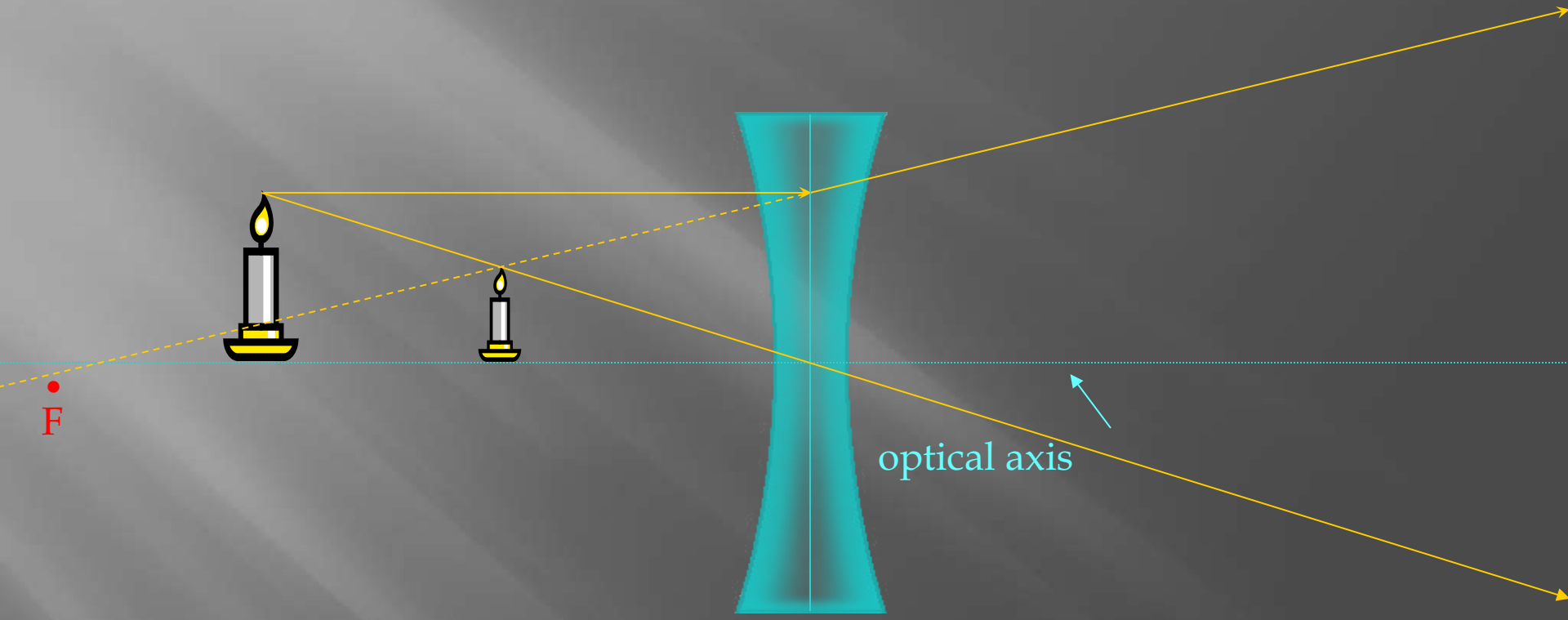


The first ray comes in parallel to the optical axis and refracts from the focal point.

The second ray goes straight through the center of the lens.

The light rays don't converge, but the sight lines do.

Concave Lens
(example)



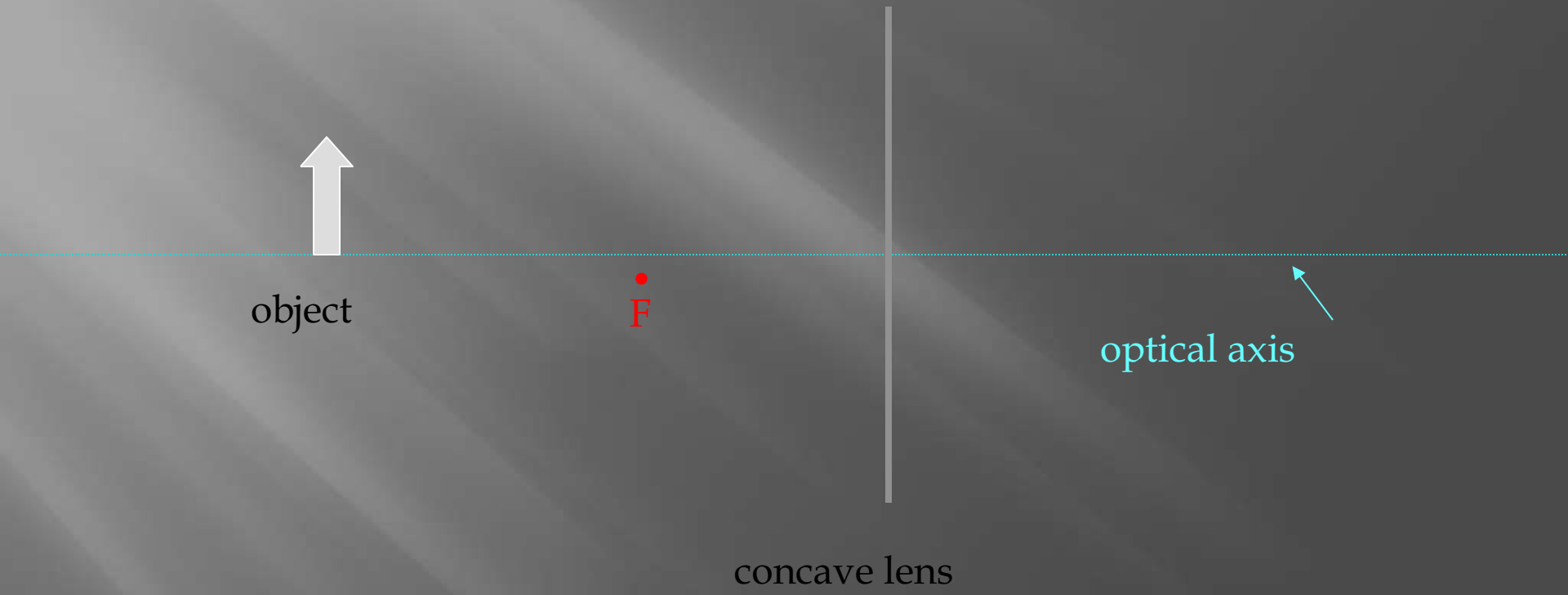
The first ray comes in parallel to the optical axis and refracts from the focal point.

The second ray goes straight through the center of the lens.

The light rays don't converge, but the sight lines do.

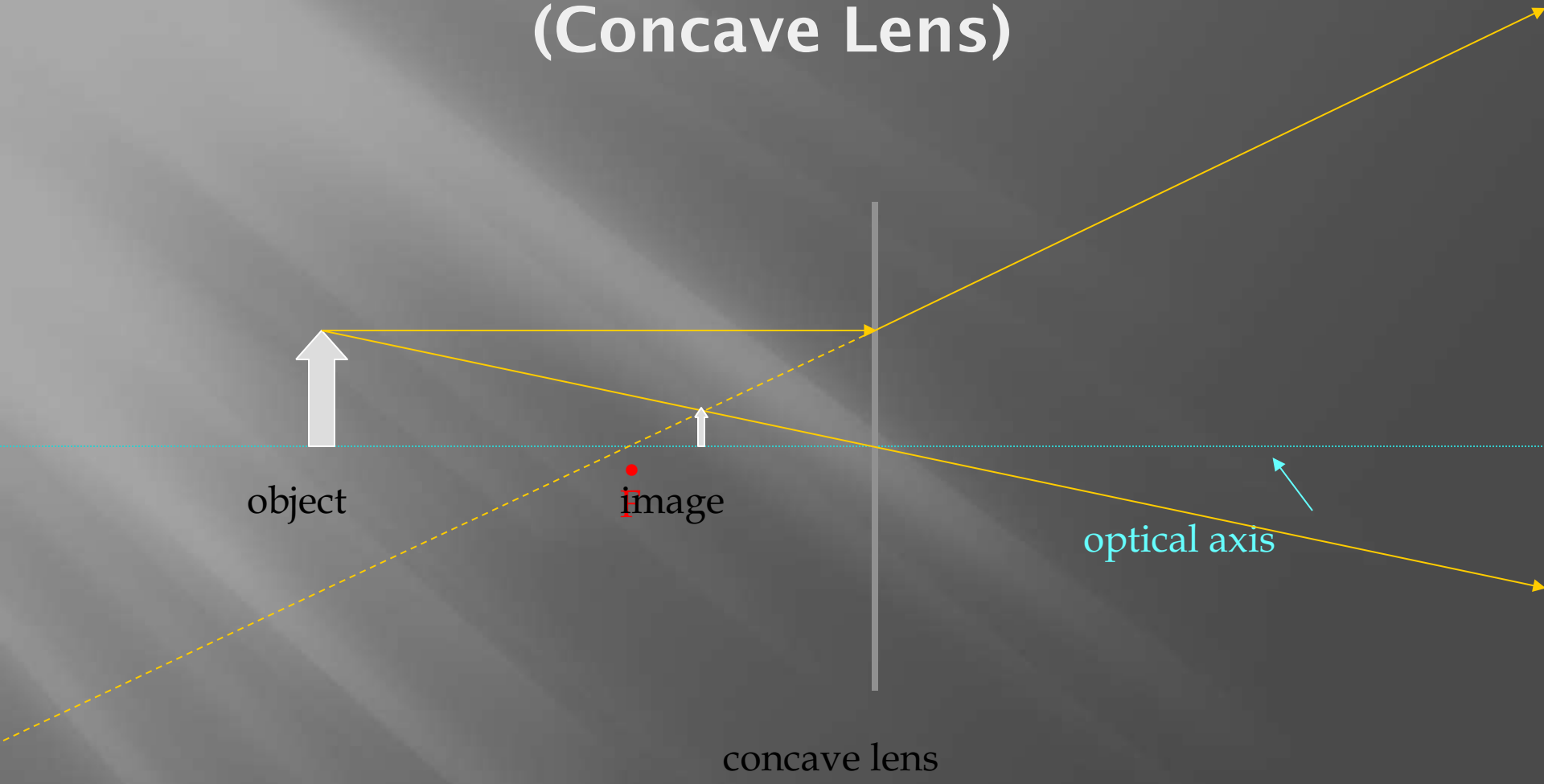
A virtual image forms where the sight lines converge

Your Turn
(Concave Lens)



- Note: lenses are thin enough that you just draw a line to represent the lens.
- Locate the image of the arrow.

Your Turn
(Concave Lens)



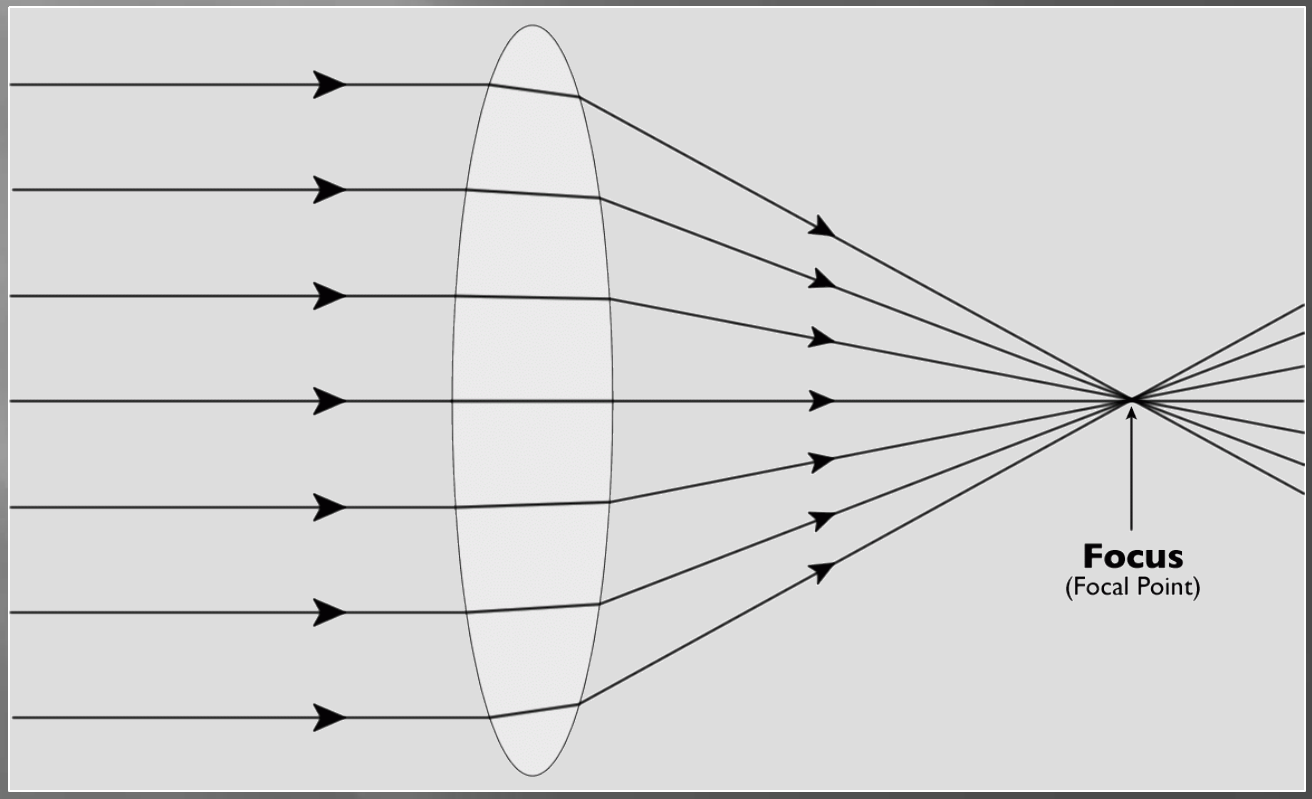
- Note: lenses are thin enough that you just draw a line to represent the lens.
- Locate the image of the arrow.

Rules for Convex Lens (Convergence)

1. An incident ray traveling parallel to the principal axis of a converging lens will refract through the lens and travel through the focal point on the opposite side of the lens.
2. An incident ray traveling through the focal point on the way to the lens will refract through the lens and travel parallel to the principal axis.
3. An incident ray that passes through the center of the lens will continue in the same direction that it had when it entered the lens.

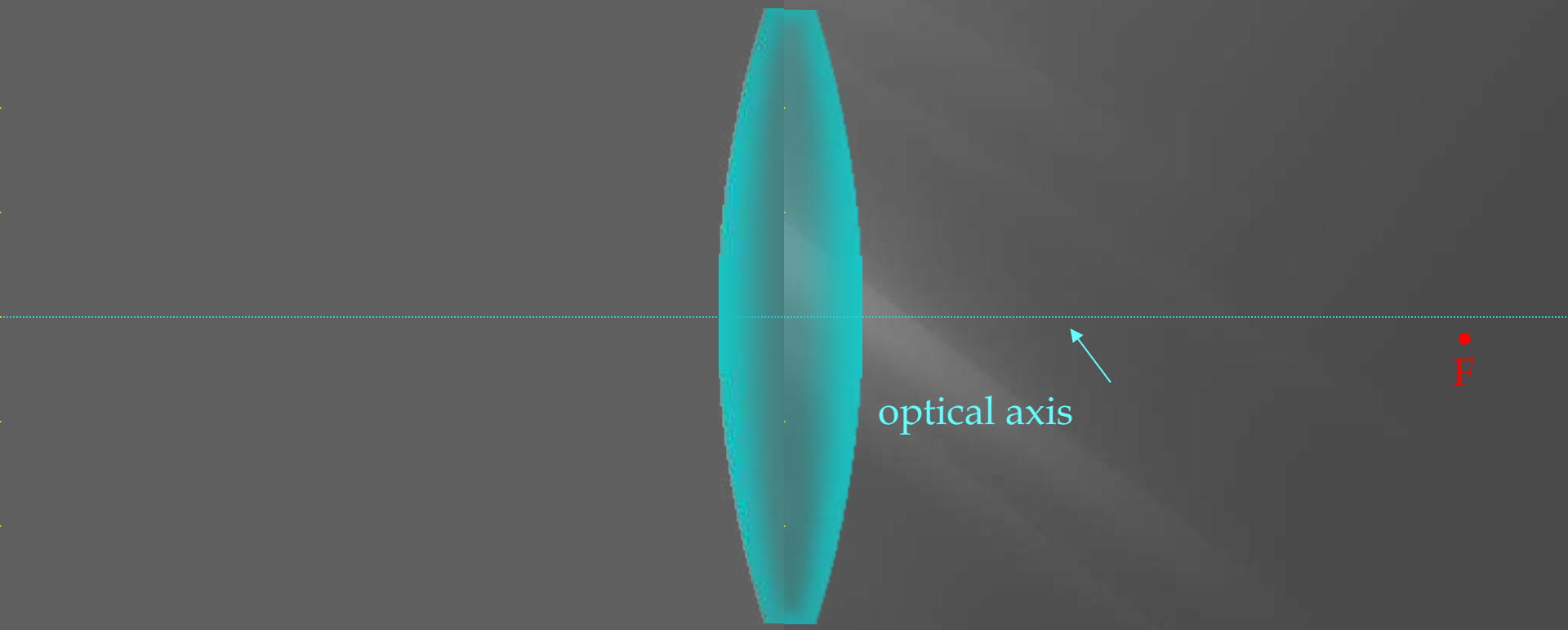
Convex Lenses

Convex lenses are thicker in the middle and focus light rays to a focal point in front of the lens.

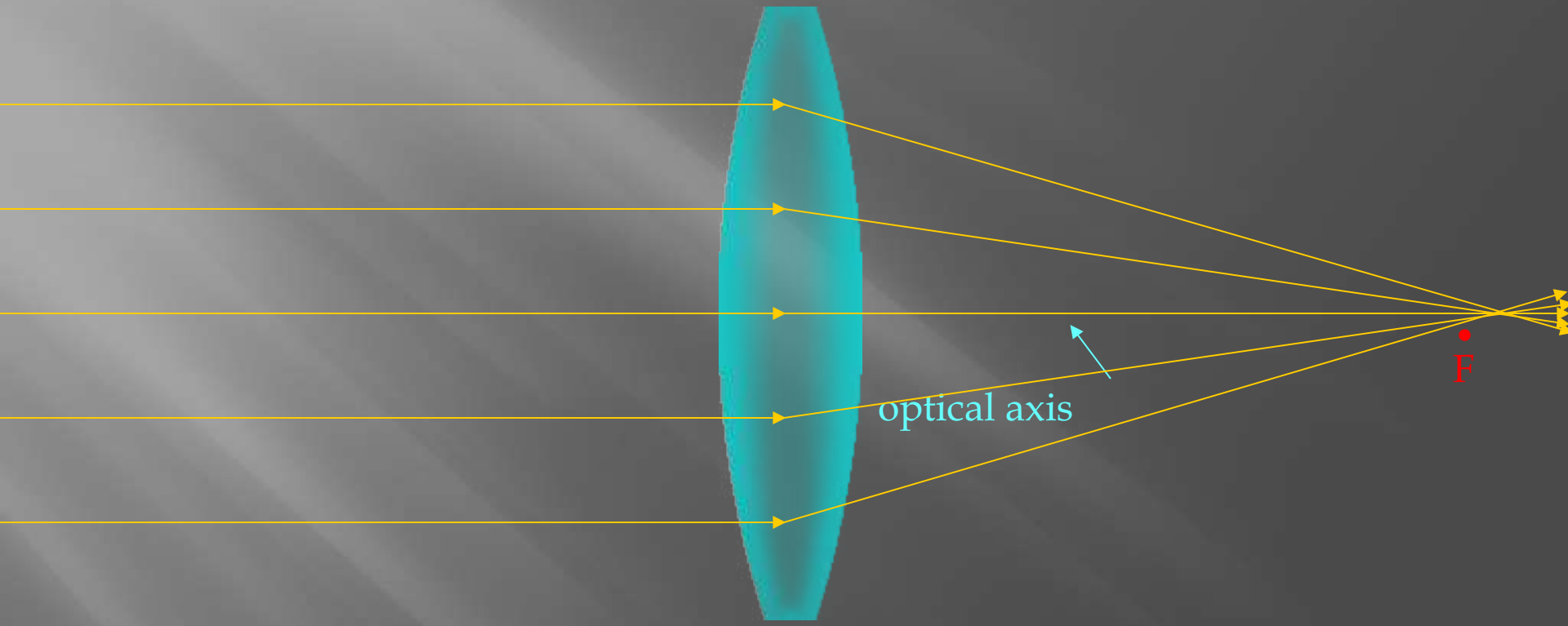


The focal length of the lens is the distance between the center of the lens and the point where the light rays are focused.

Convex Lenses

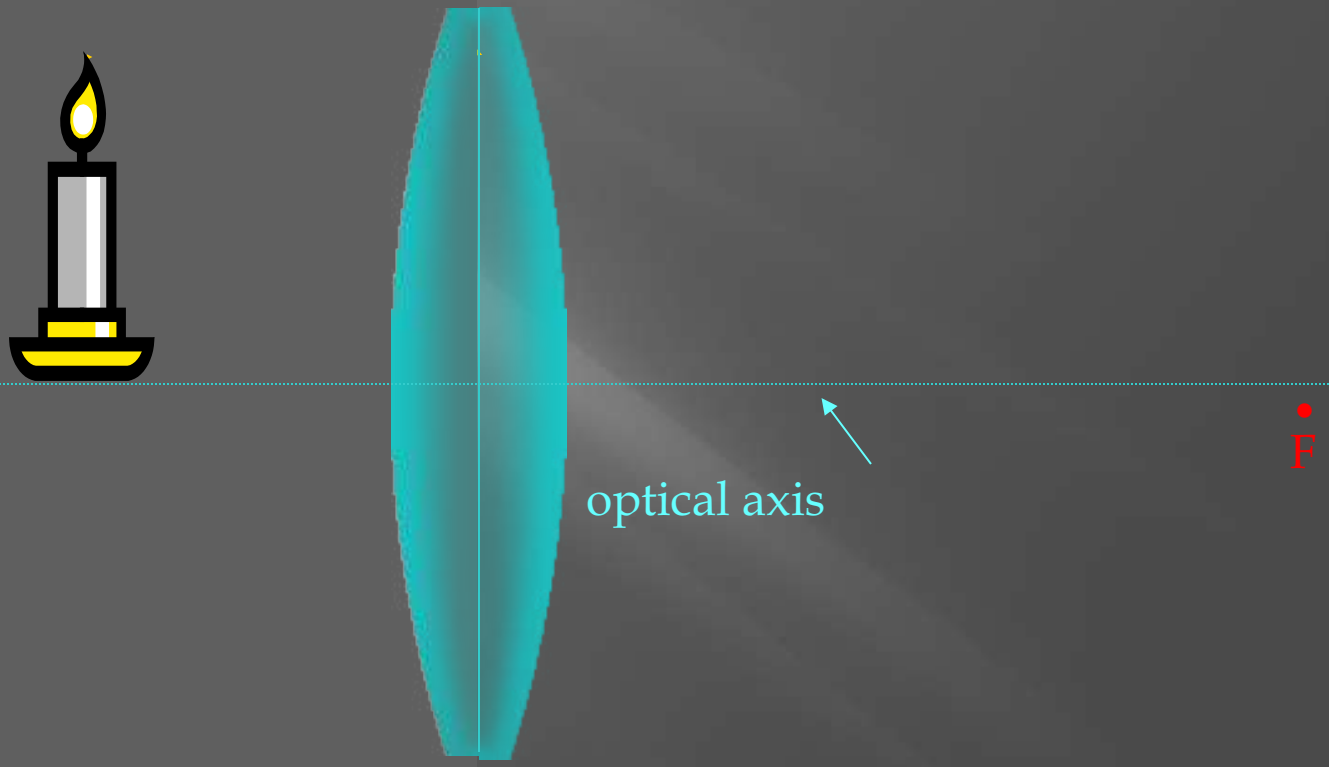


Convex Lenses



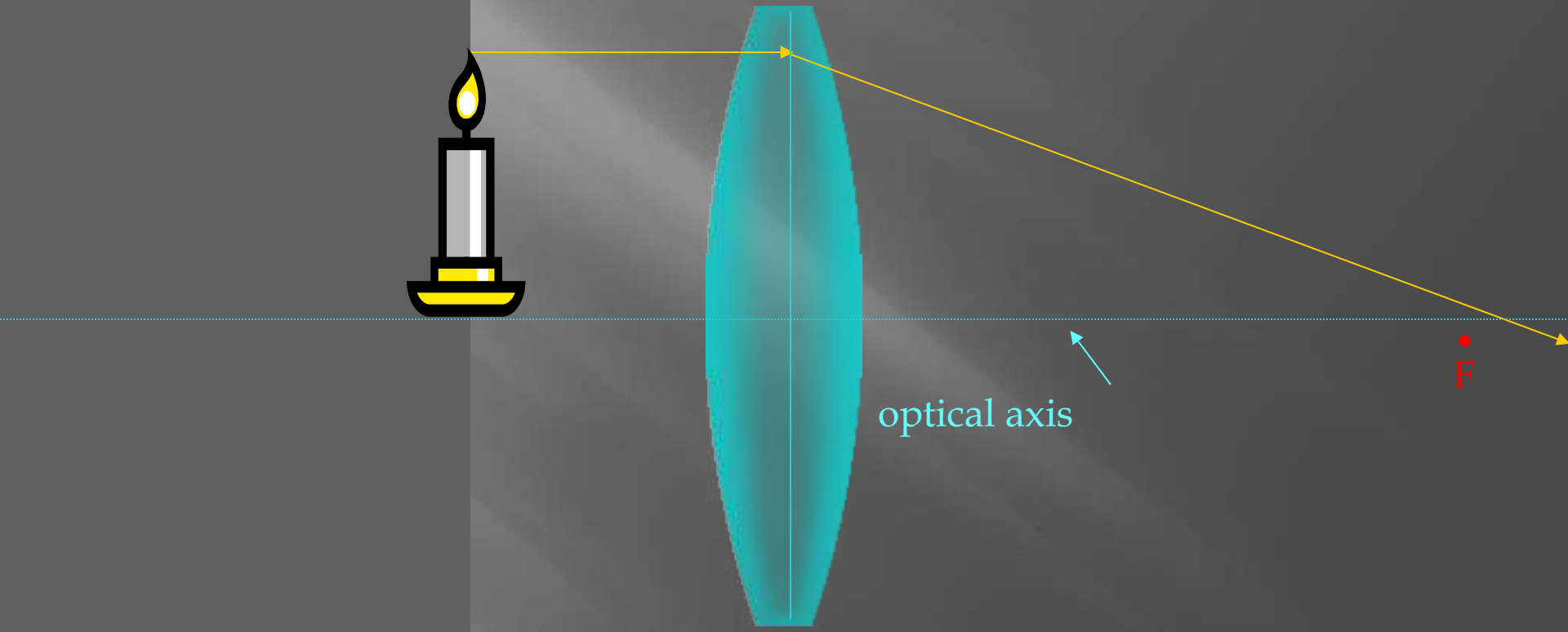
Light rays that come in parallel to the optical axis converge at the focal point.

Convex Lens
(example)



The first ray comes in parallel to the optical axis and refracts through the focal point.

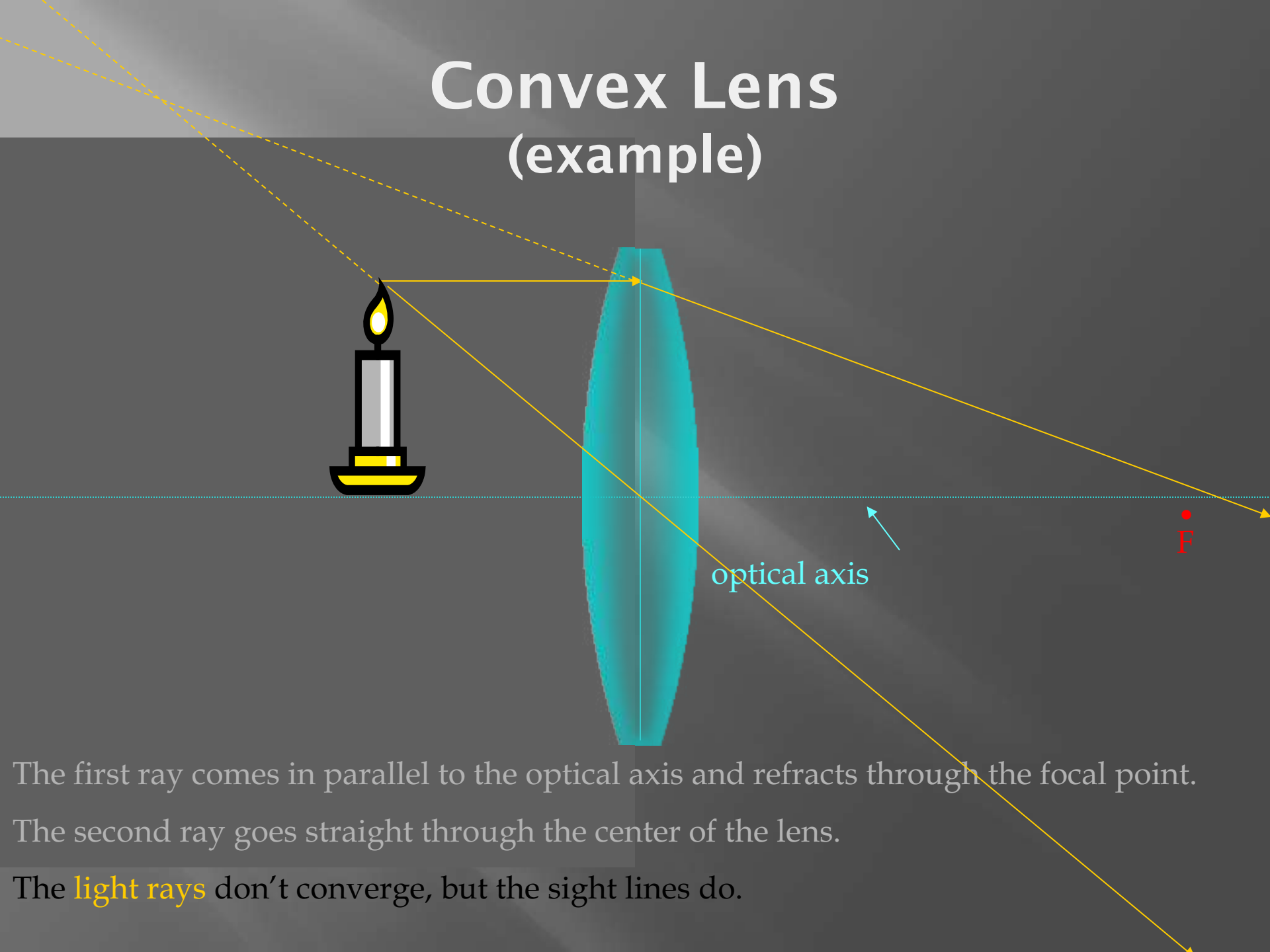
Convex Lens
(example)



The first ray comes in parallel to the optical axis and refracts through the focal point.

The second ray goes straight through the center of the lens.

Convex Lens
(example)

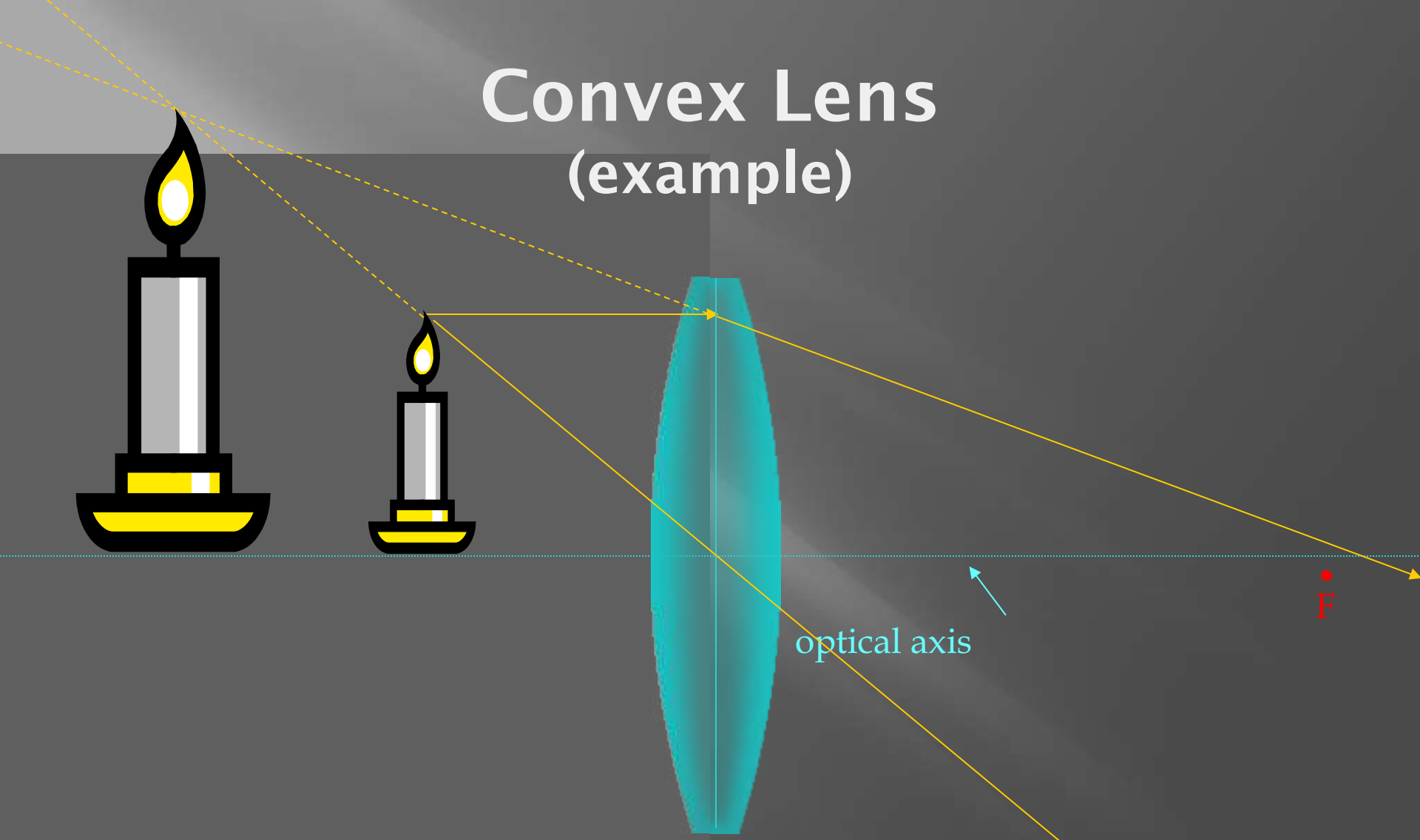


The first ray comes in parallel to the optical axis and refracts through the focal point.

The second ray goes straight through the center of the lens.

The light rays don't converge, but the sight lines do.

Convex Lens
(example)



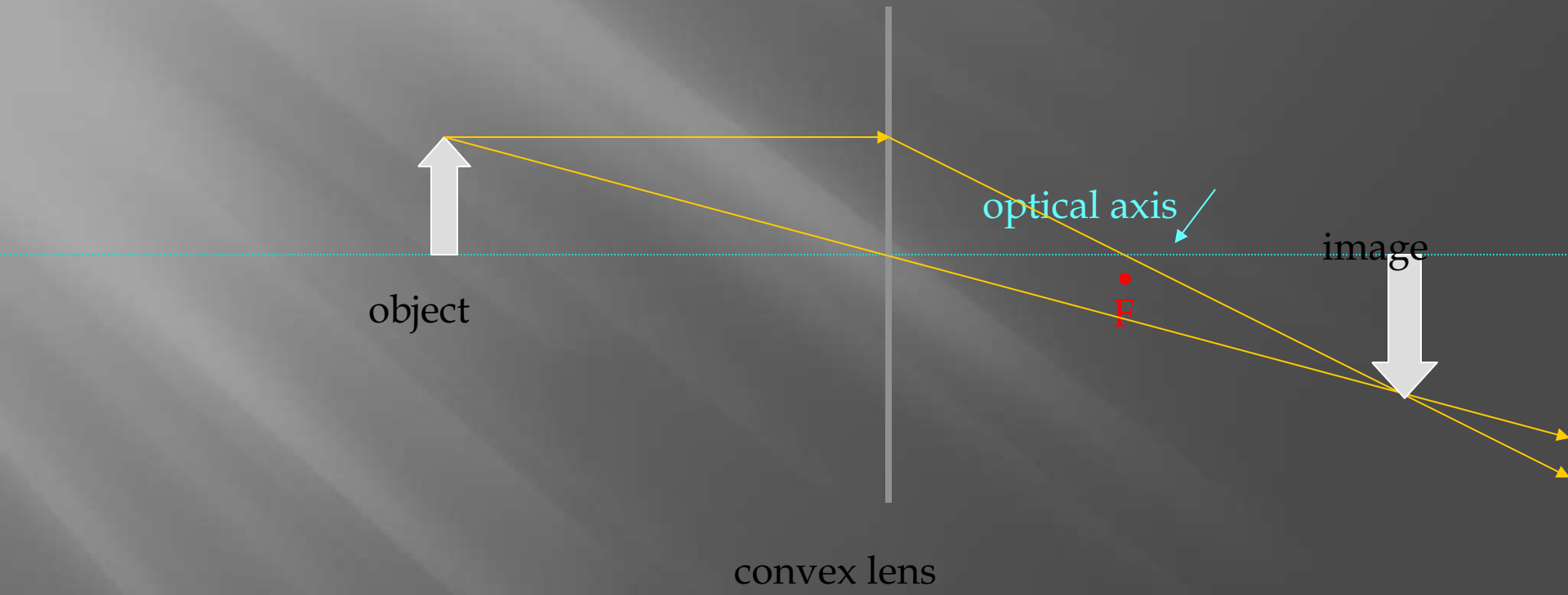
The first ray comes in parallel to the optical axis and refracts through the focal point.

The second ray goes straight through the center of the lens.

The light rays don't converge, but the sight lines do.

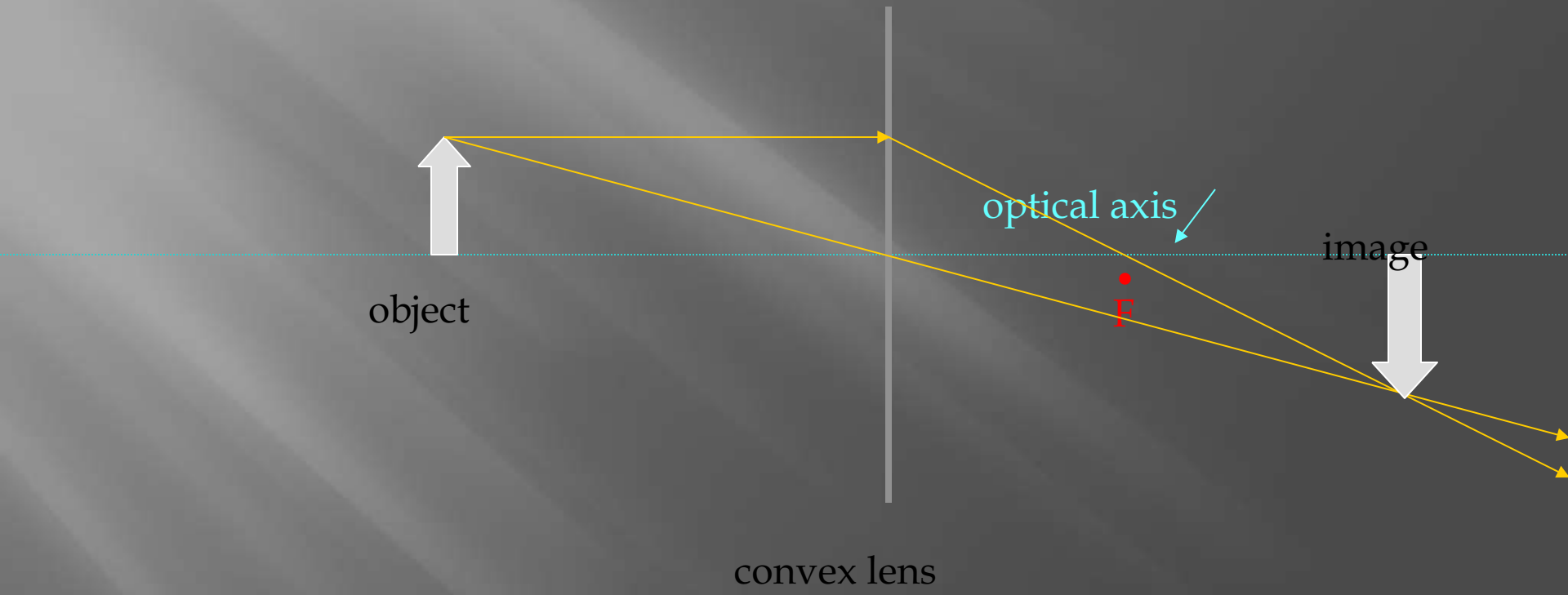
A virtual image forms where the sight lines converge

Your Turn
(Convex Lens)



- Note: lenses are thin enough that you just draw a line to represent the lens.
- Locate the image of the arrow.

Your Turn
(Convex Lens)



- Note: lenses are thin enough that you just draw a line to represent the lens.
- Locate the image of the arrow.

Thanks/Further Info

- Faulkes Telescope Project: Light & Optics by Sarah Roberts
- Fundamentals of Optics: An Introduction for Beginners by Jenny Reinhard
- PHET Geometric Optics (Flash Simulator)
- Thin Lens & Mirror (Java Simulator) by Fu-Kwun Hwang