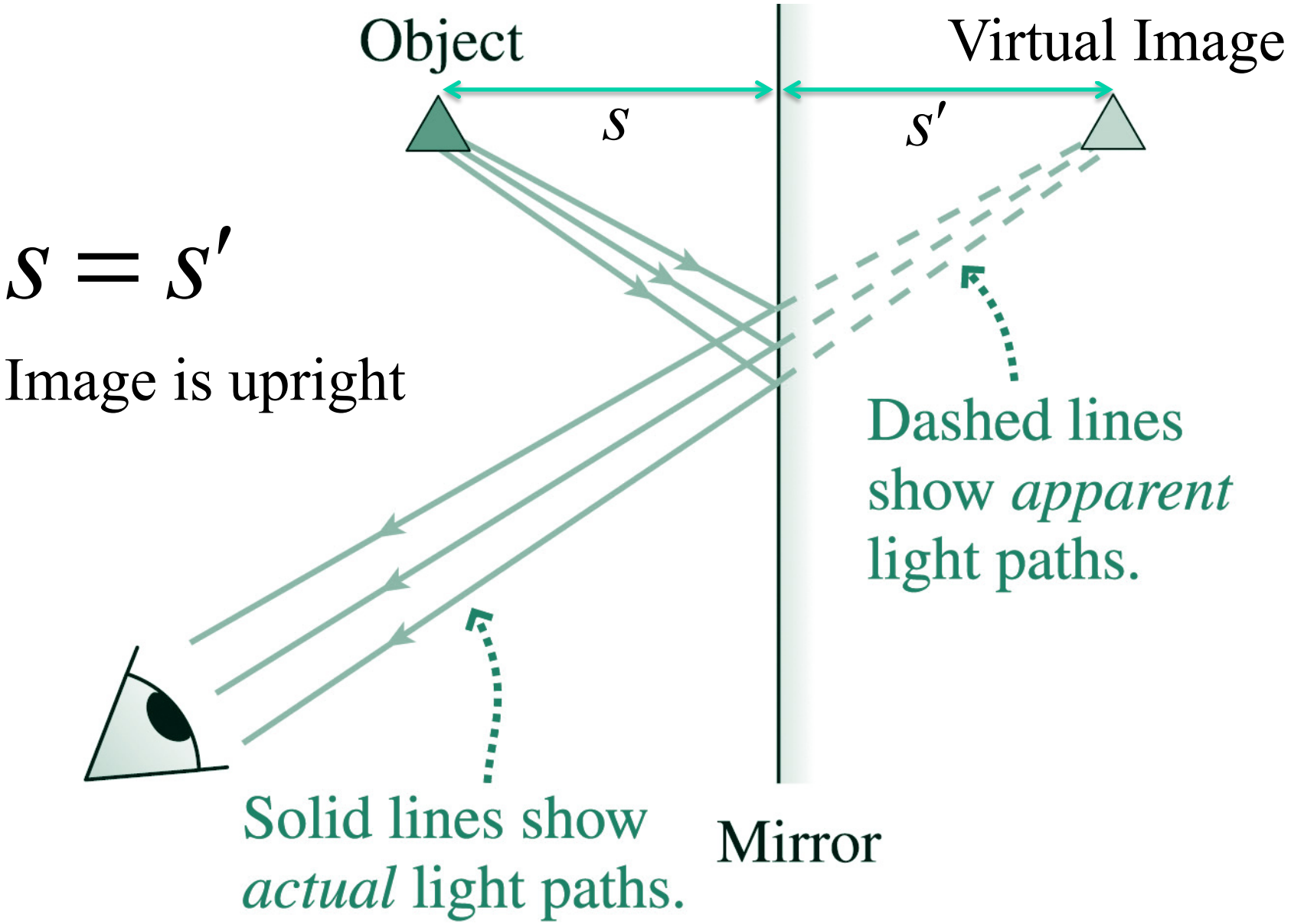
Chapter 31: Images/Optical Instruments
Tuesday November 22nd

- **V. IMPORTANT: Final exam will be in HCB103/316**
  - **HCB316, last names A to J; HCB103, last names K to Z**
- **Mini-exam 6 next Thu. (Chs. 30/31, LONCAPA 21-23)**
- **Check your exam scores online**
- **Still 46 unregistered *i*Clickers, some with excellent scores!**

- Images, mirrors and lenses (Ch. 31)
  - Plane mirrors
  - Curved mirrors (convex and concave mirrors)
  - Ray tracing with curved mirrors
  - The mirror equation
  - Images and ray tracing with lenses
  - The lens equation

Reading: up to page 552 in the text book (Ch. 31)

Images with Mirrors

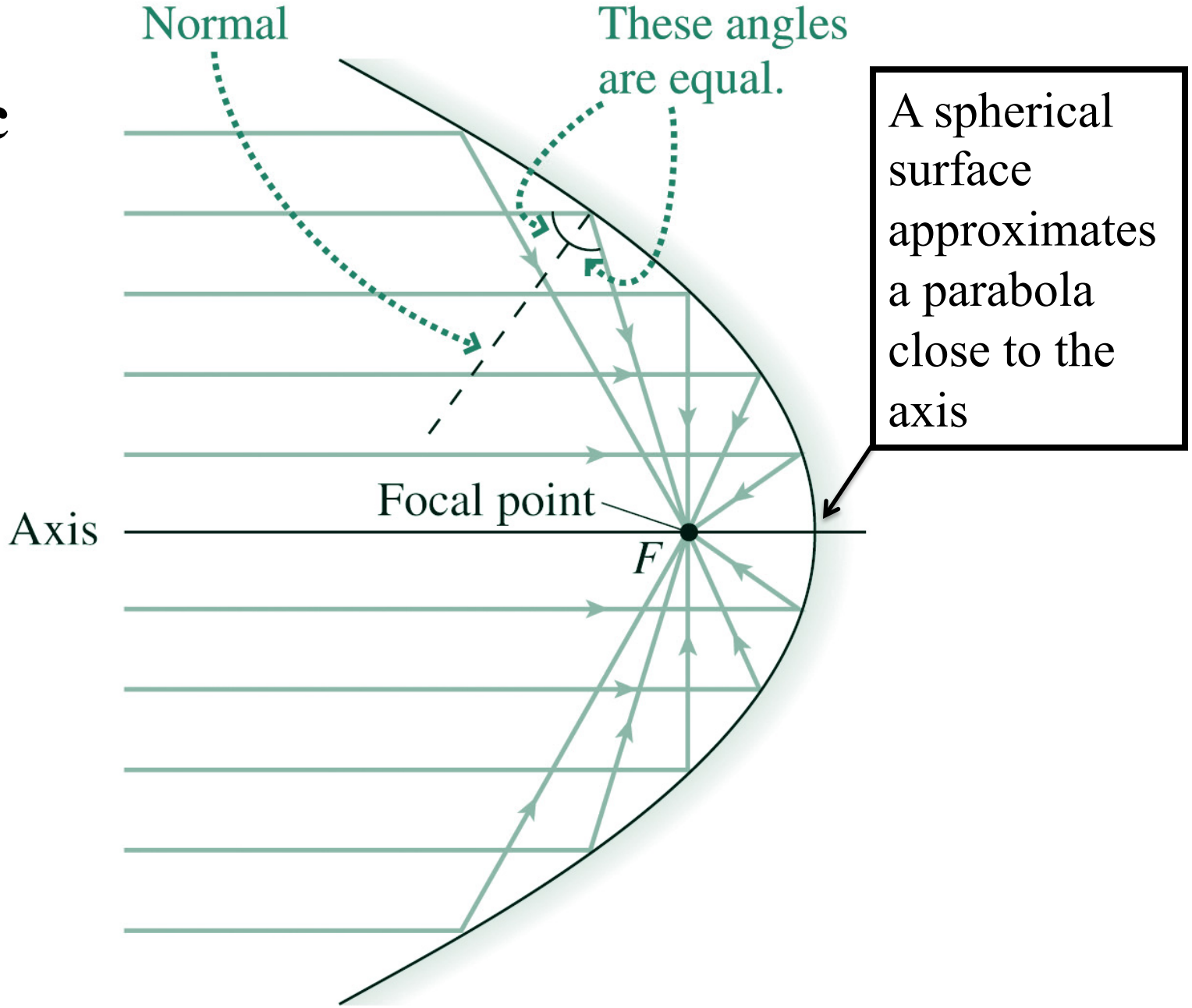


$s = s'$

Image is upright

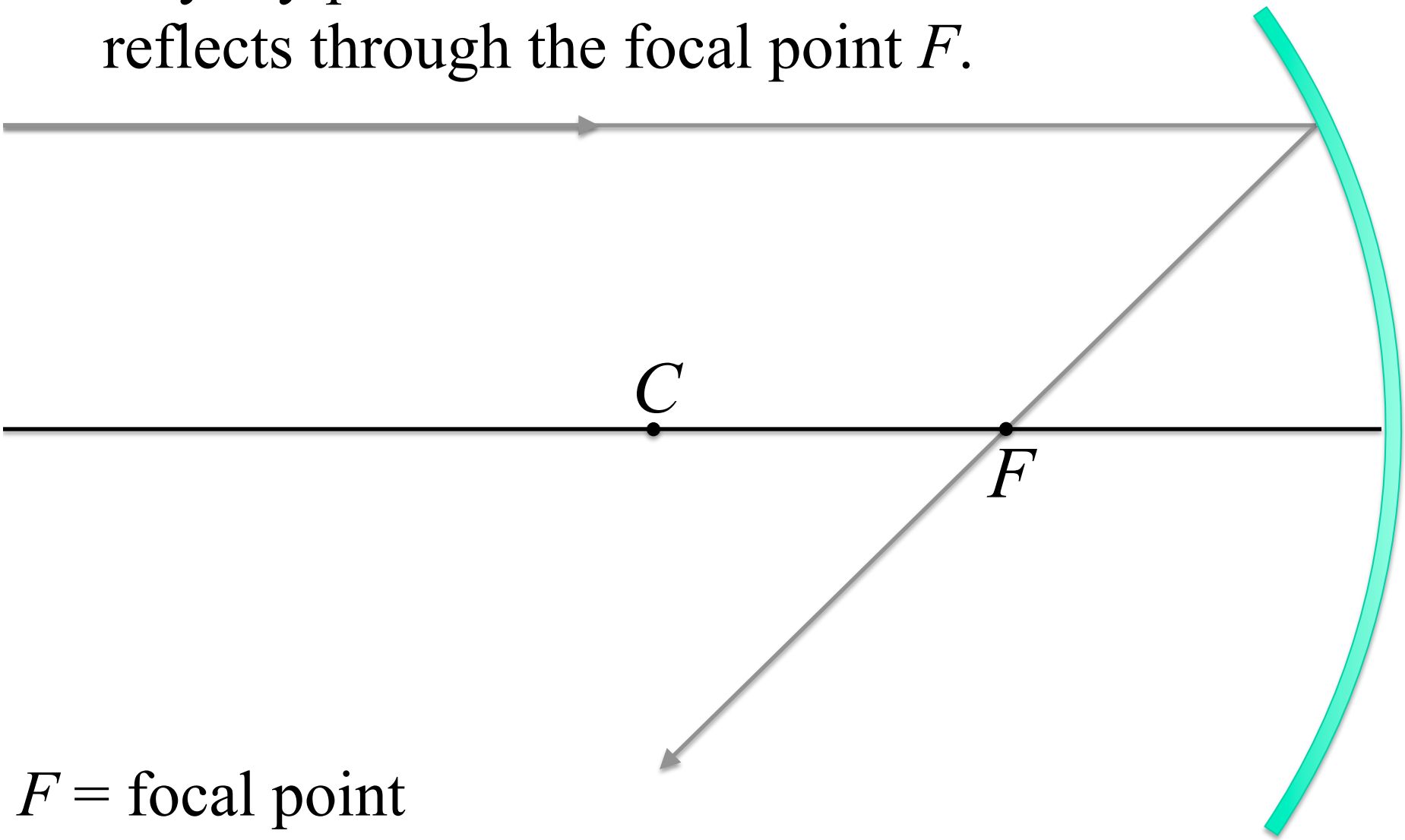
Images with Curved Mirrors

This is a parabolic mirror



Ray Tracing with Mirrors

1. Any ray parallel to the mirror axis reflects through the focal point F.

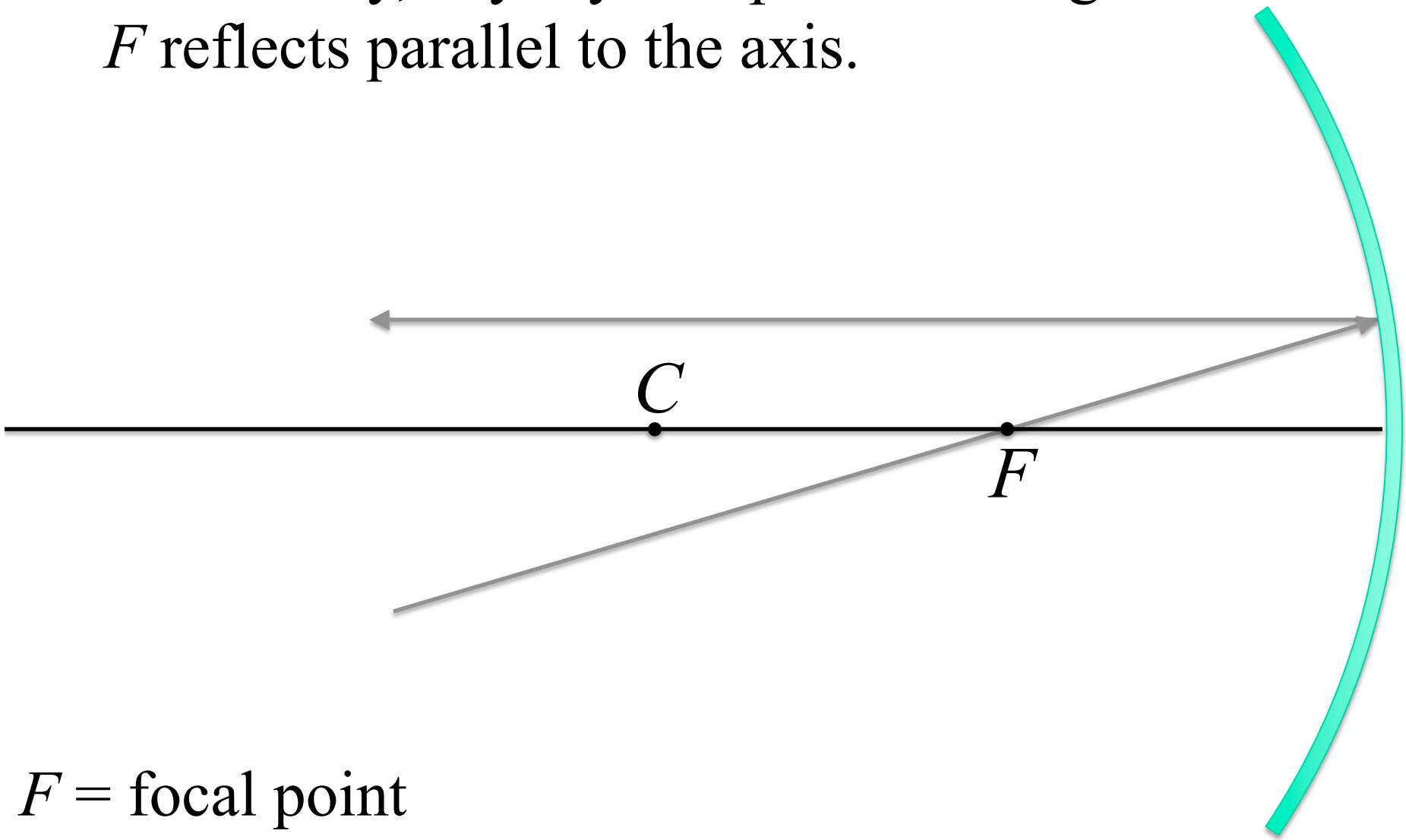


F = focal point

C = center of curvature (= $2f$ for spherical mirror)

Ray Tracing with Mirrors

2. Conversely, any ray that passes through F reflects parallel to the axis.

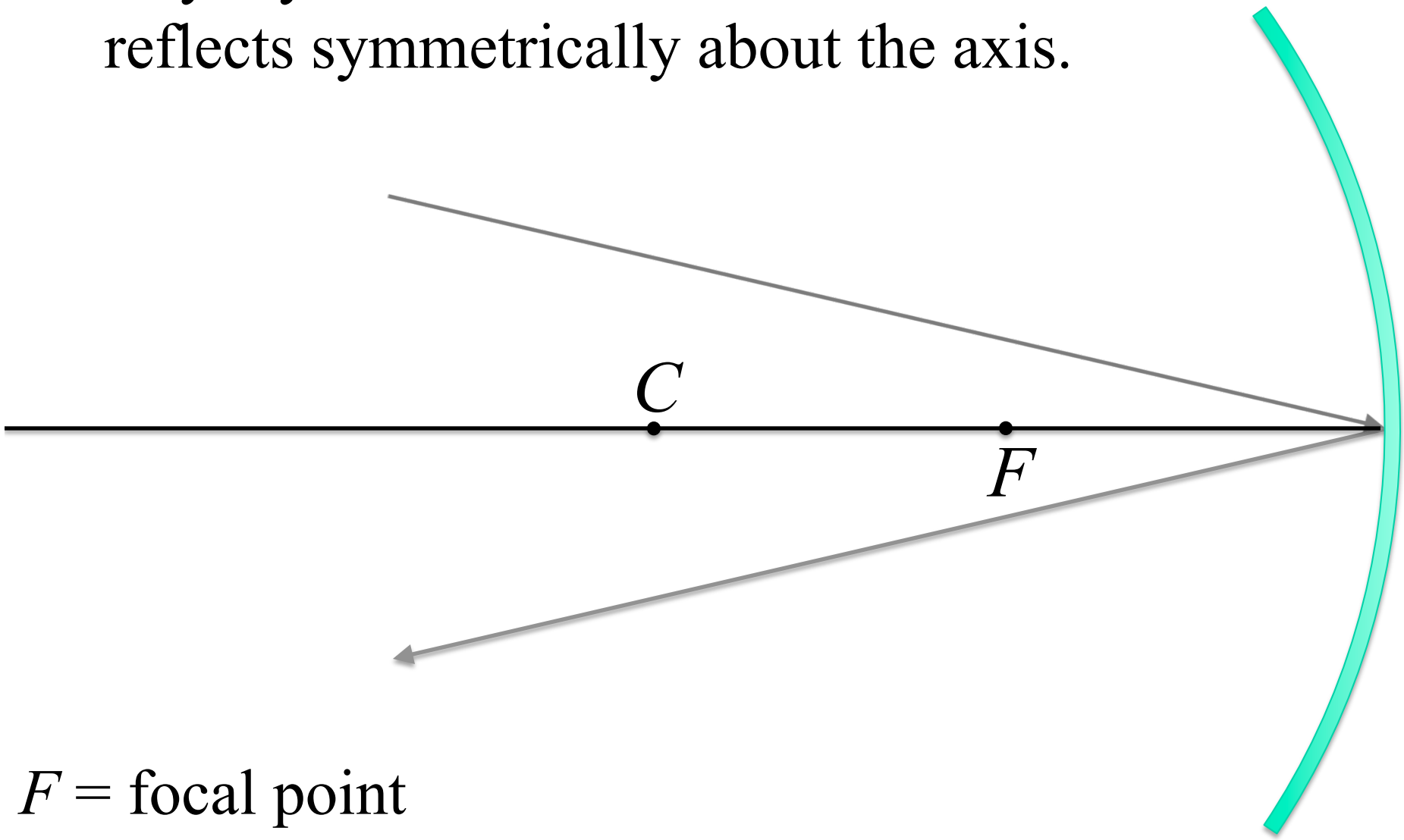


F = focal point

C = center of curvature (= $2f$ for spherical mirror)

Ray Tracing with Mirrors

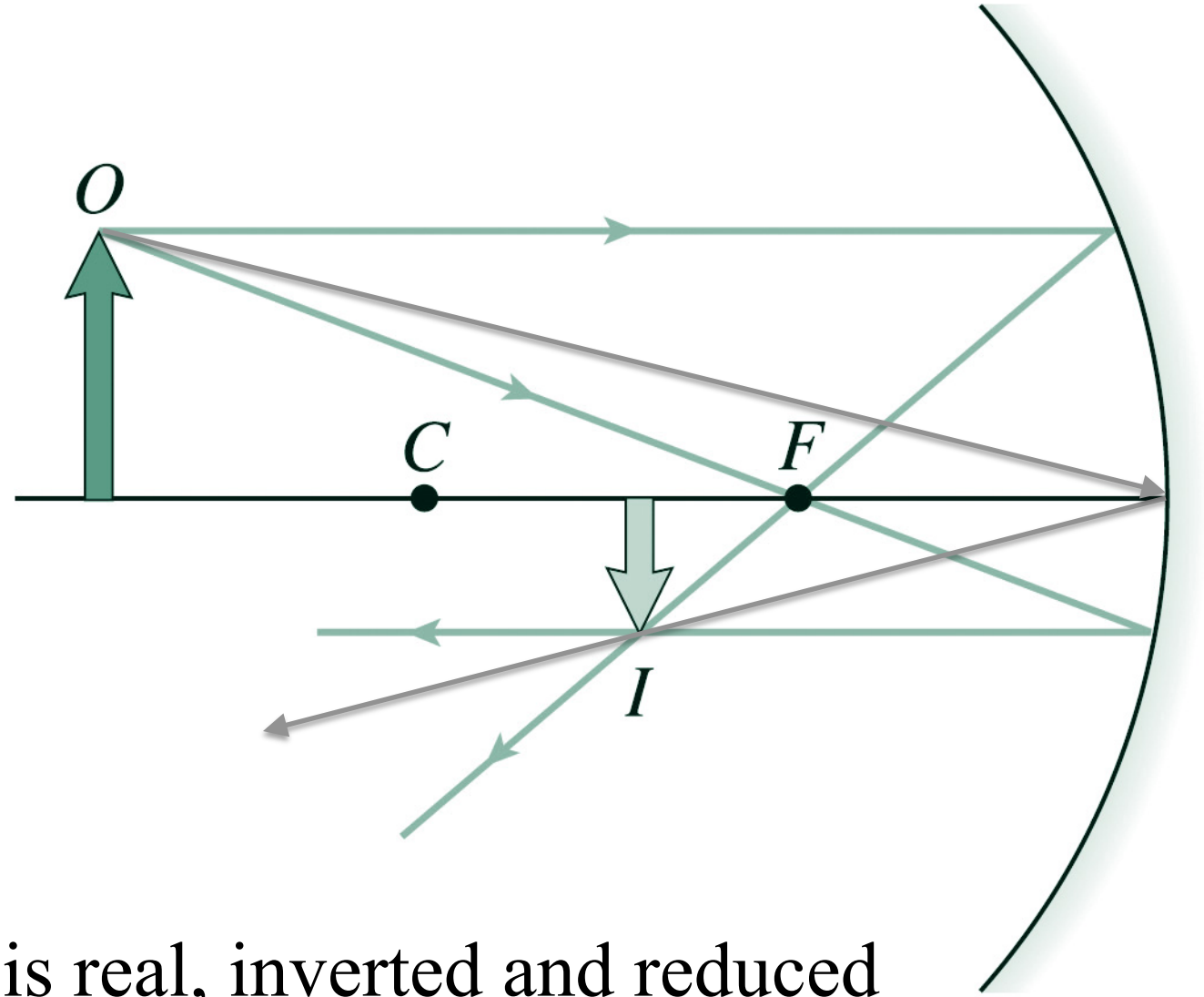
3. Any ray that strikes the center of the mirror reflects symmetrically about the axis.



F = focal point

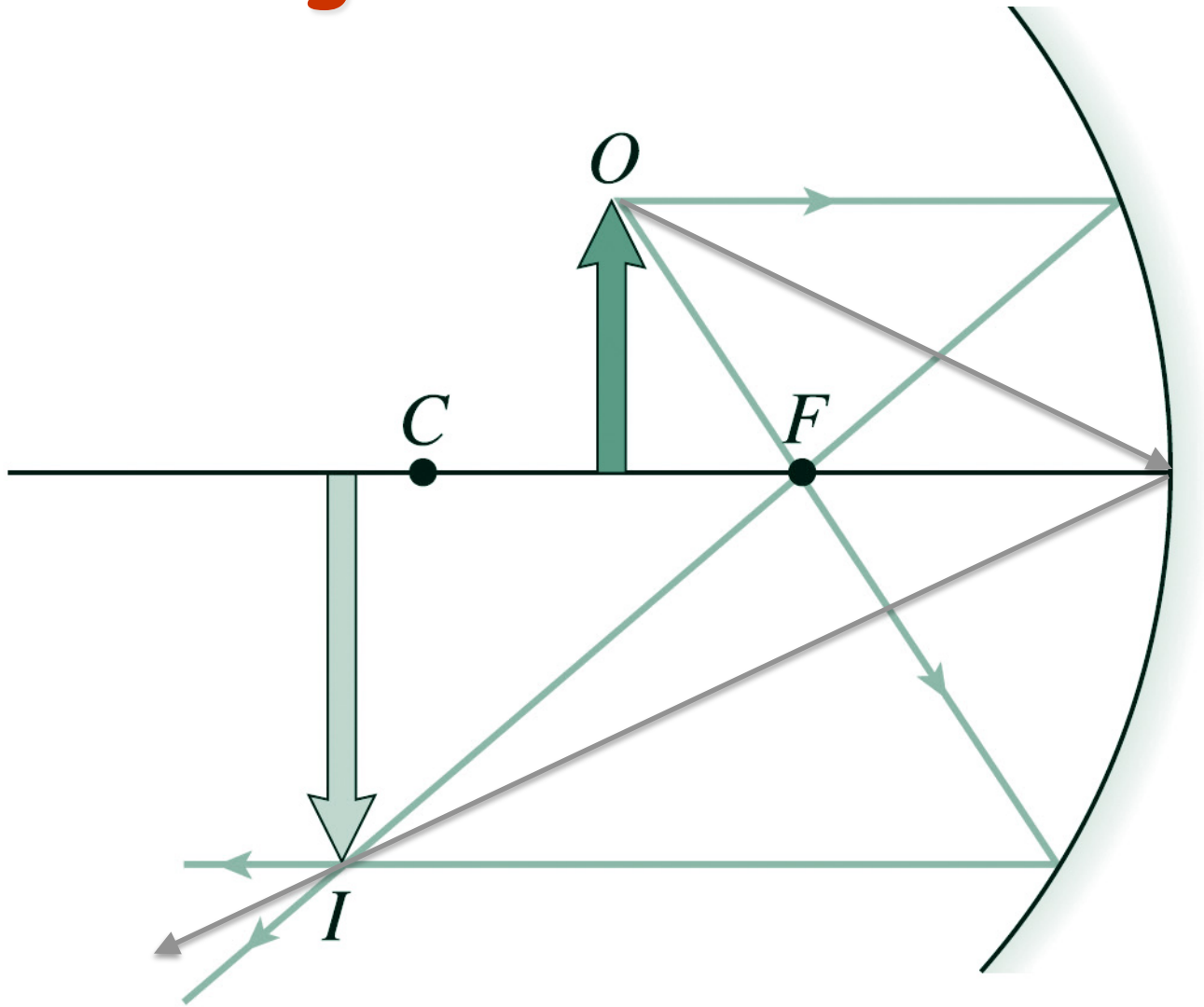
C = center of curvature (= $2f$ for spherical mirror)

Ray Tracing with Concave Mirrors



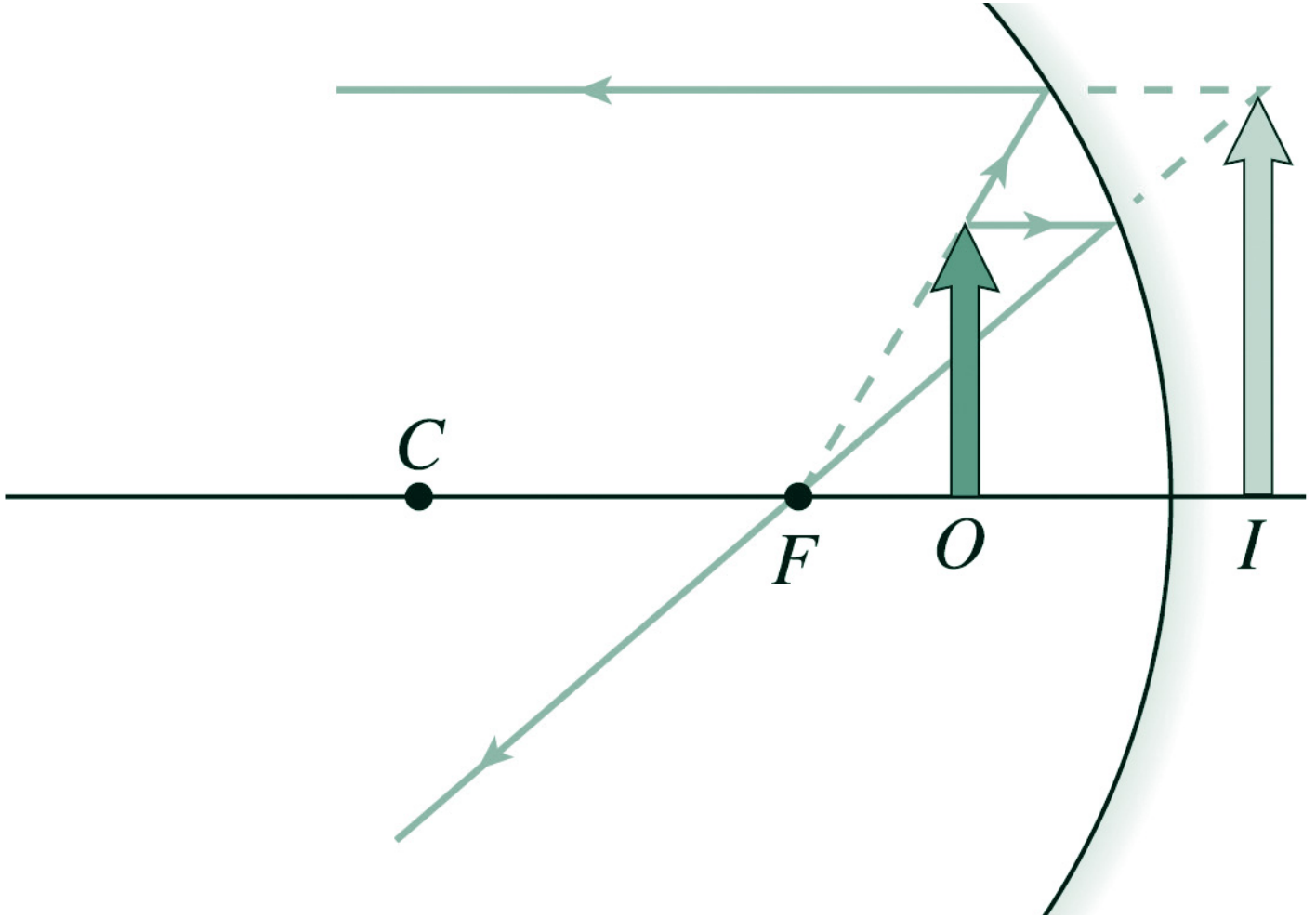
- Image is real, inverted and reduced
- Real implies that light really comes from the image

Ray Tracing with Concave Mirrors



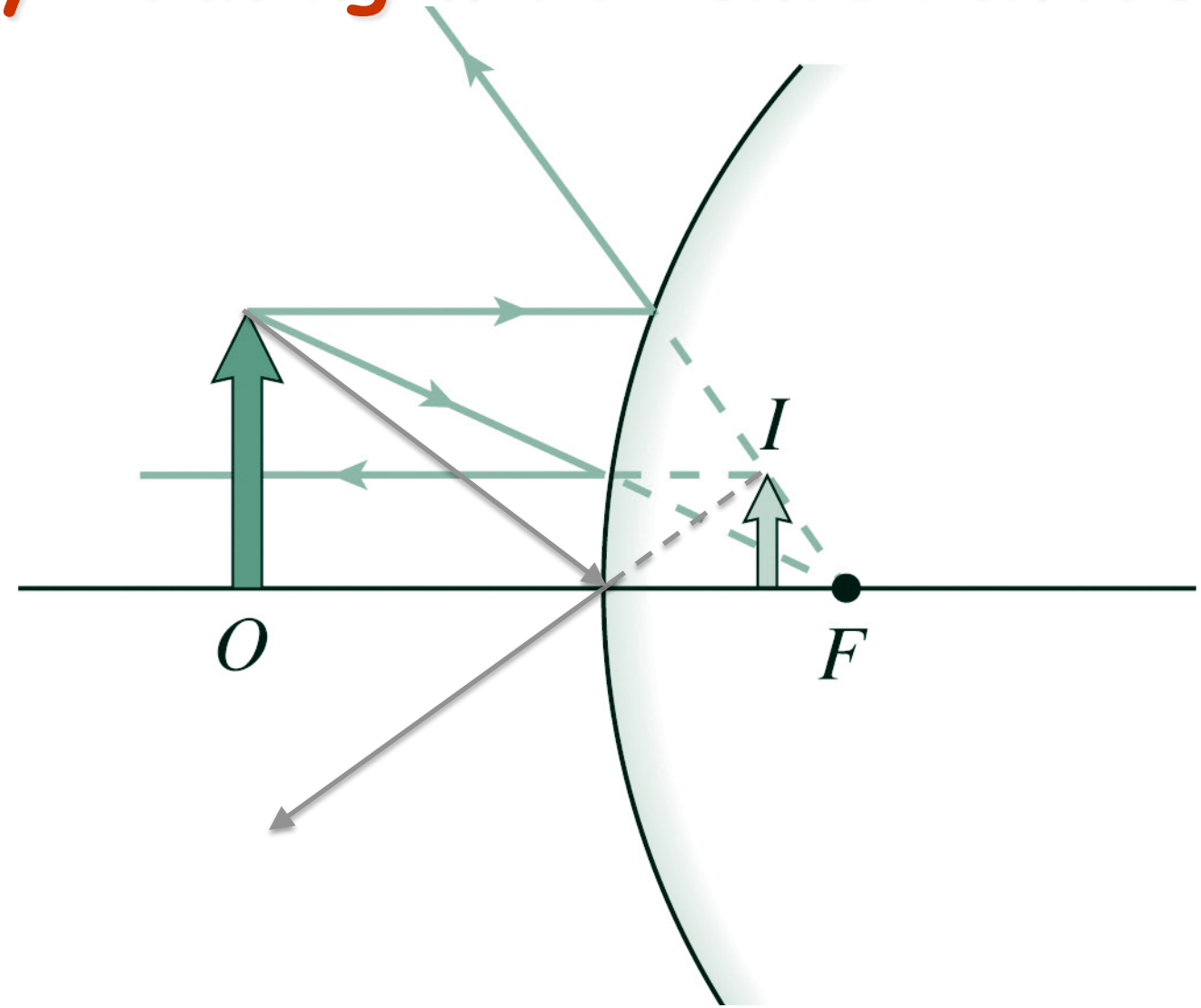
- Image is <u>real</u>, <u>inverted</u> and <u>enlarged</u>
- Real implies that light really comes from the image

Ray Tracing with Concave Mirrors



- Image is virtual, upright and enlarged
- Virtual implies no light actually came from image

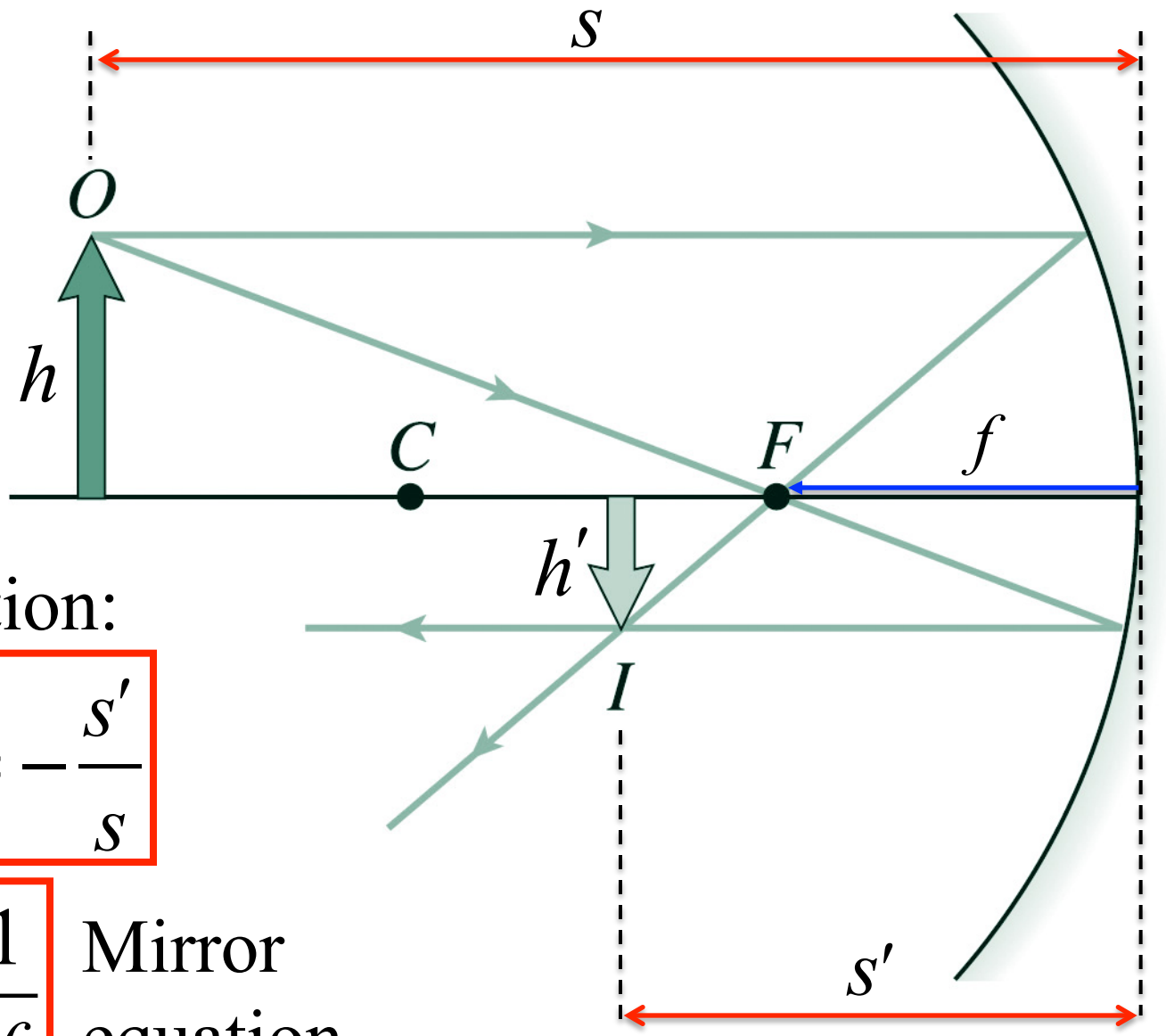
Ray Tracing with Convex Mirrors



- Image is always virtual, upright and reduced
- Virtual implies no light actually came from image

Ray Tracing with Concave Mirrors

$C = 2f$ for spherical mirror



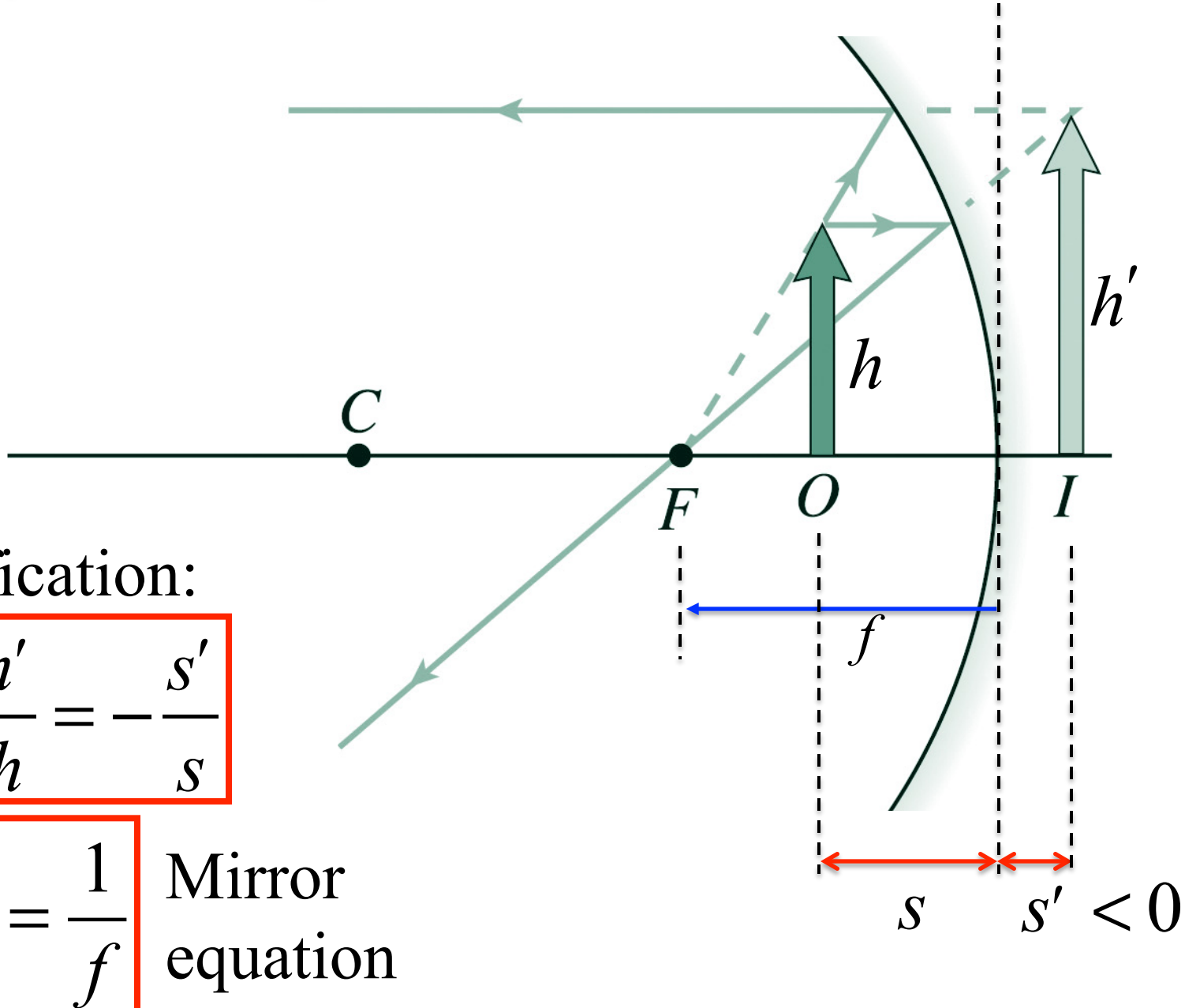
Magnification:

$$M = \frac{h'}{h} = -\frac{s'}{s}$$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

Mirror equation

Ray Tracing with Concave Mirrors



Magnification:

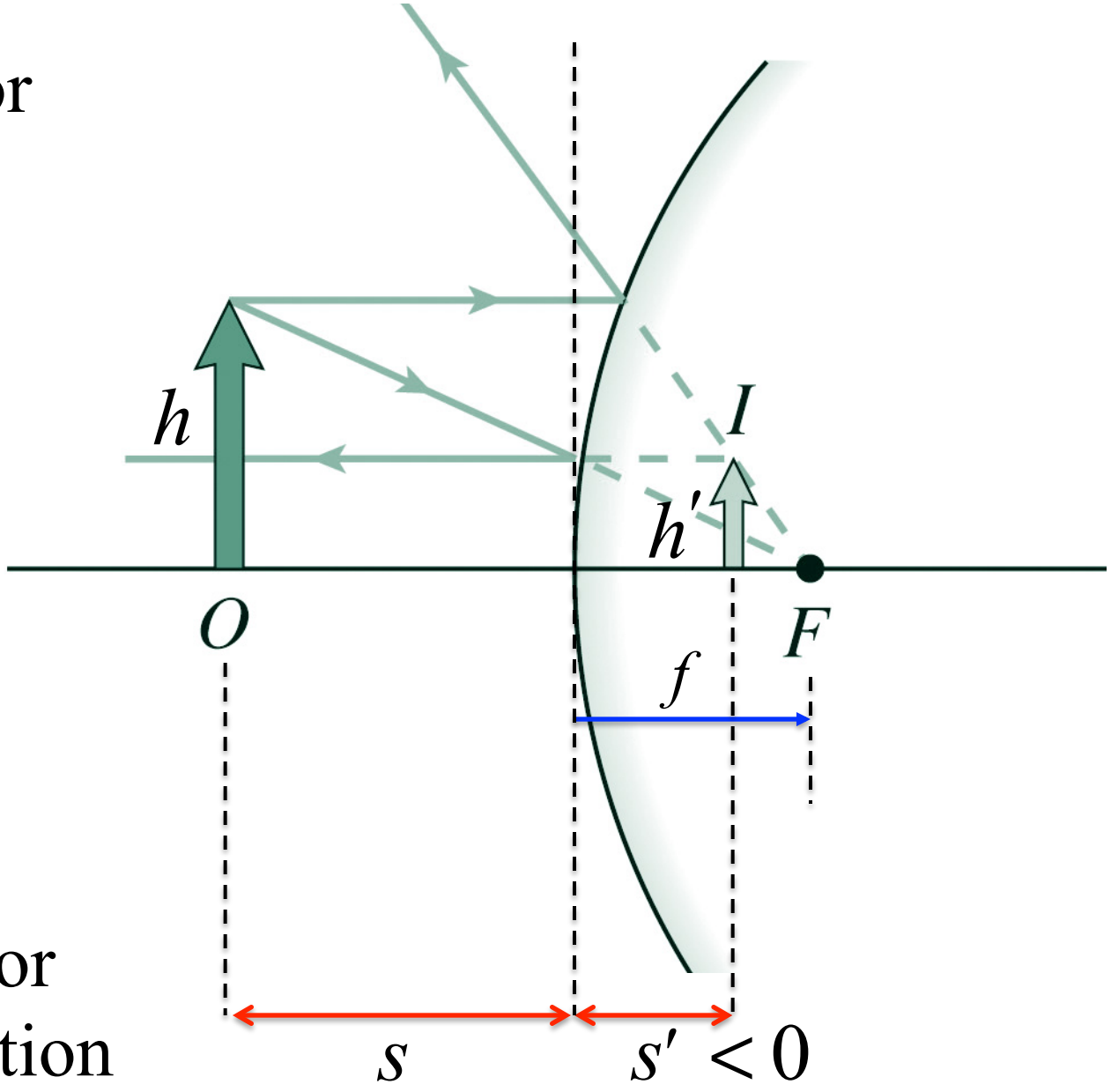
$$M = \frac{h'}{h} = -\frac{s'}{s}$$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

Mirror equation

Ray Tracing with Convex Mirrors

Focal length, f, for concave mirror is negative ($f < 0$)



Magnification:

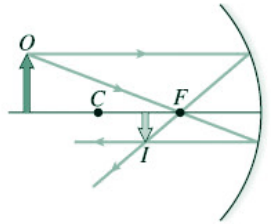
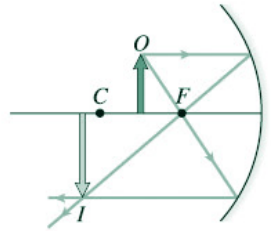
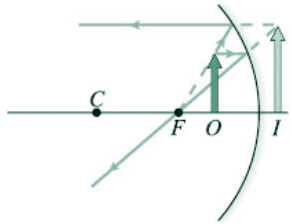
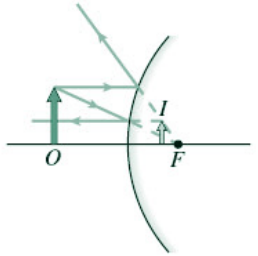
$$M = \frac{h'}{h} = -\frac{s'}{s}$$

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

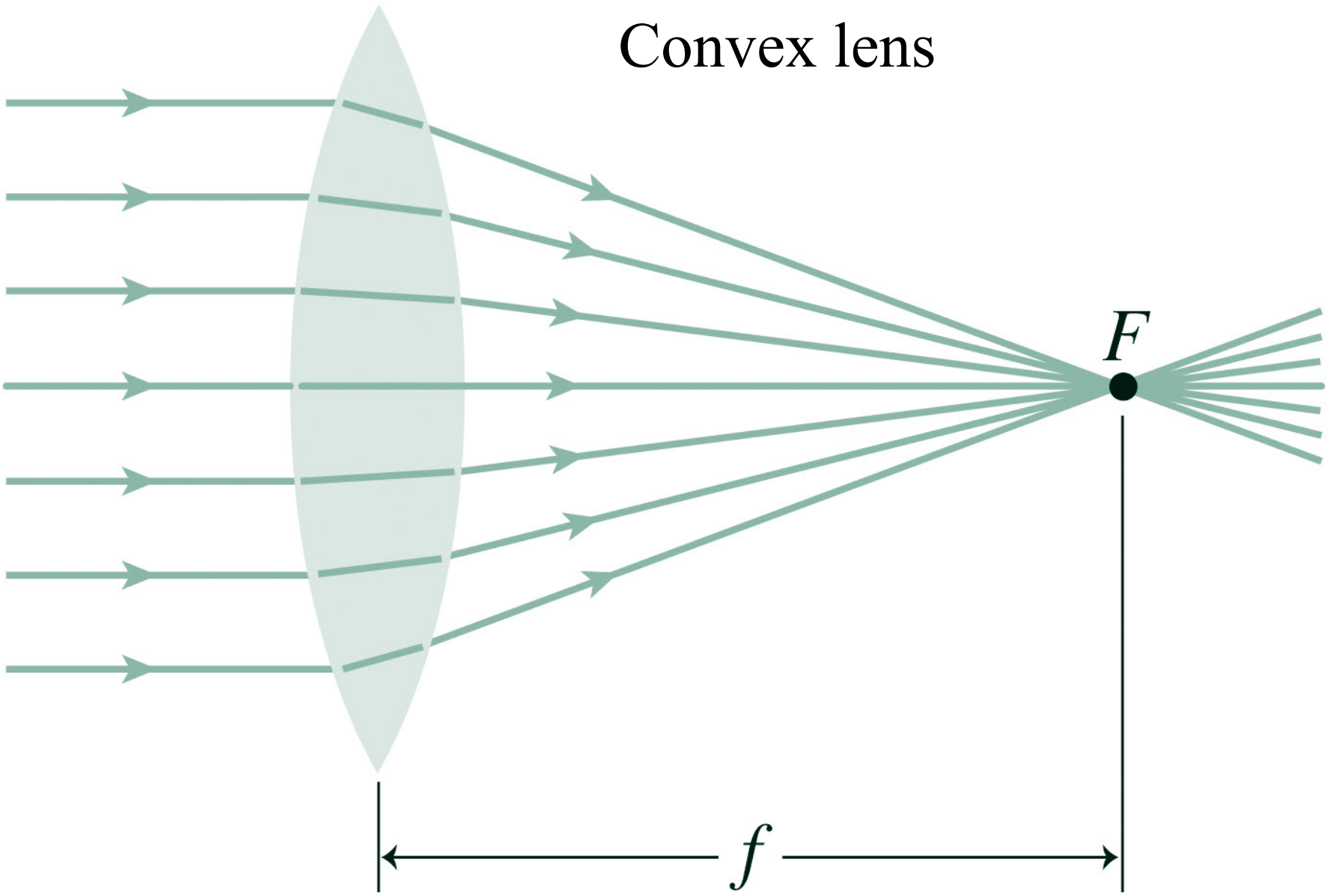
Mirror equation

Summary for curved mirrors

Table 31.1 Image Formation with Mirrors: Sign Conventions

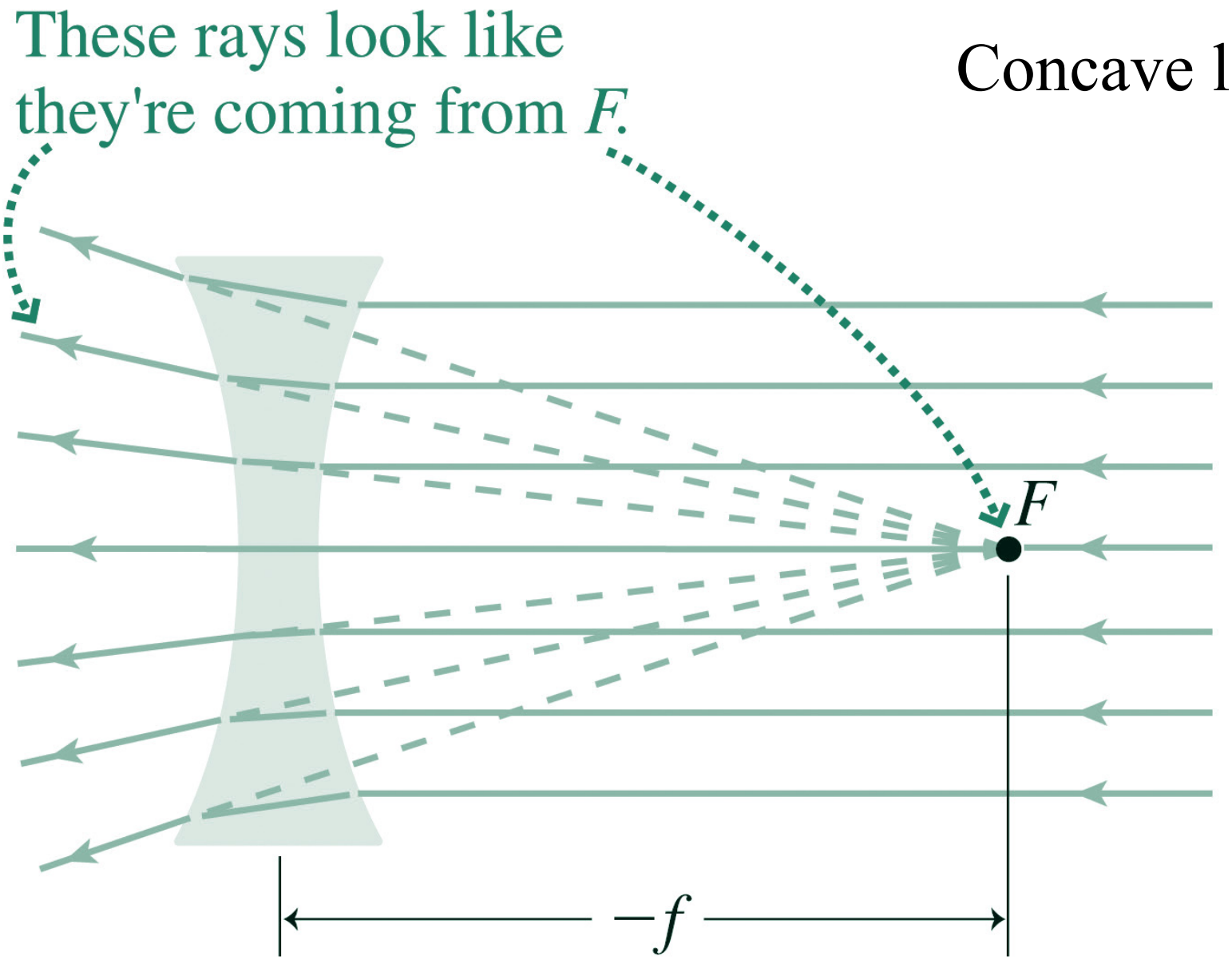
Focal Length, f	Object Distance, s	Image Distance, s'	Type of Image	Ray Diagram
+ (concave)	+ (in front of mirror) $s > 2f$	+ (in front of mirror) $s' < 2f$	Real, inverted, reduced	
+ (concave)	+ (in front of mirror) $2f > s > f$	+ (in front of mirror) $s' > 2f$	Real, inverted, enlarged	
+ (concave)	+ (in front of mirror) $s < f$	− (behind mirror)	Virtual, upright, enlarged	
− (convex)	+ (in front of mirror)	− (behind mirror)	Virtual, upright, reduced	

Images with Lenses



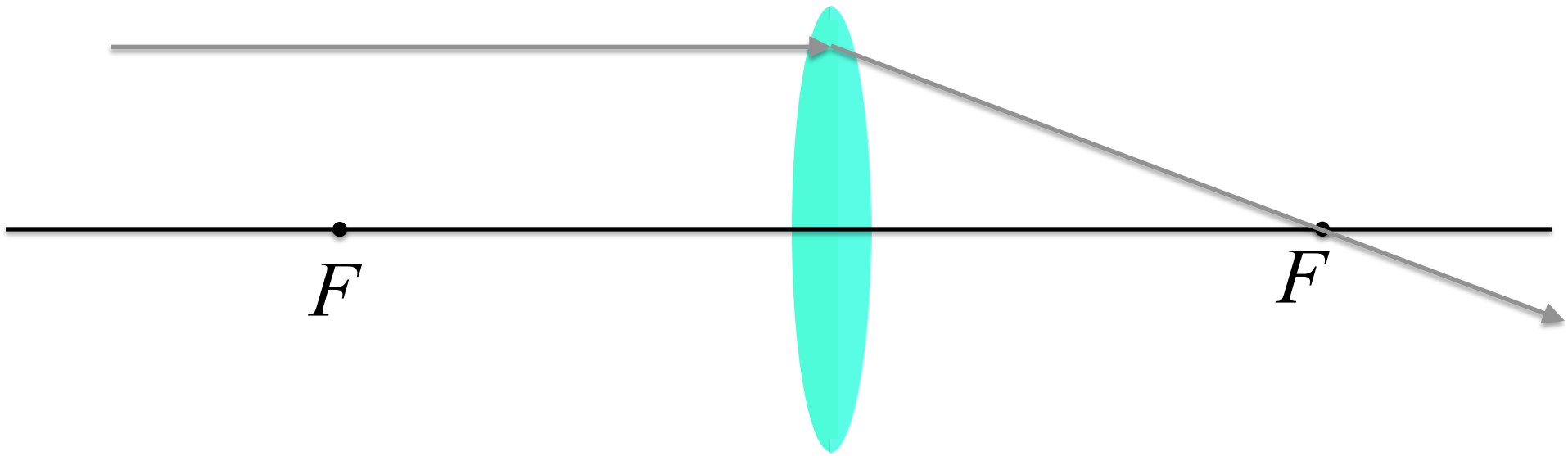
Images with Lenses

Concave lens



Ray Tracing with Lenses

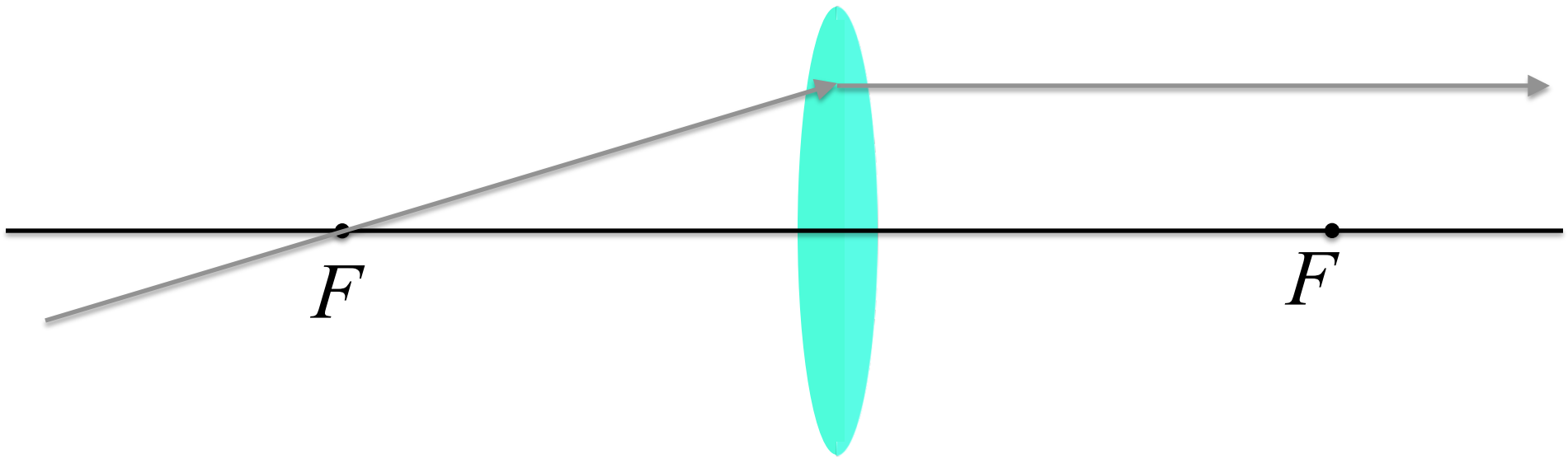
1. Any ray parallel to the lens axis refracts and then passes through the focal point F on the other side.



F = focal point; one each side (equidistant from lens)

Ray Tracing with Lenses

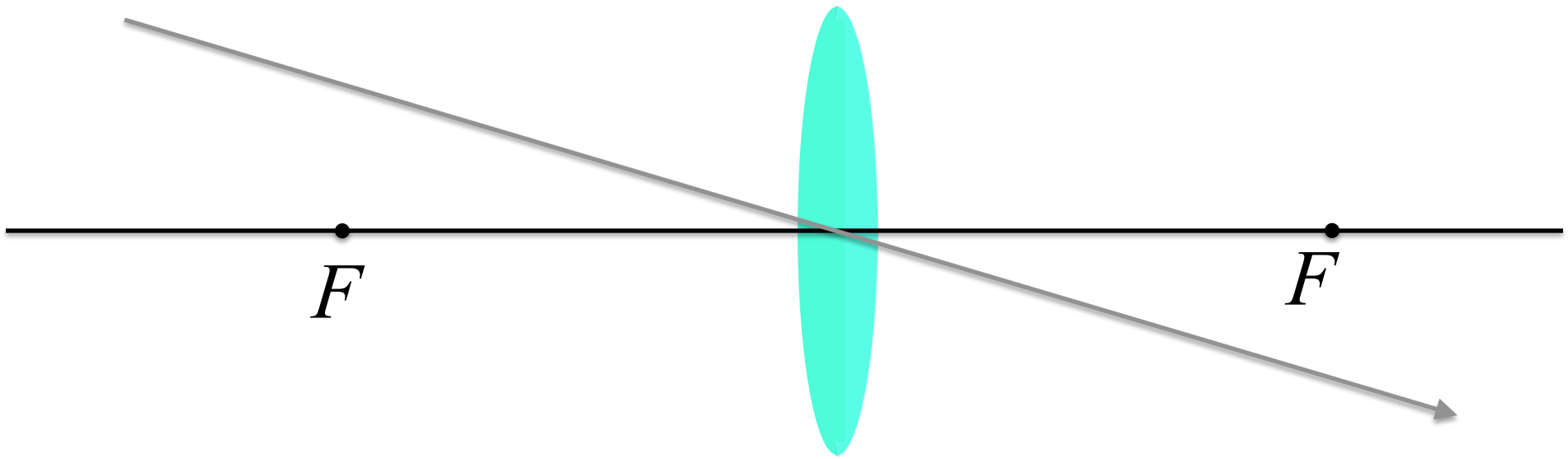
2. Conversely, any ray that passes through the focal point *F* will emerge from the lens parallel to its axis.



F = focal point; one each side (equidistant from lens)

Ray Tracing with Lenses

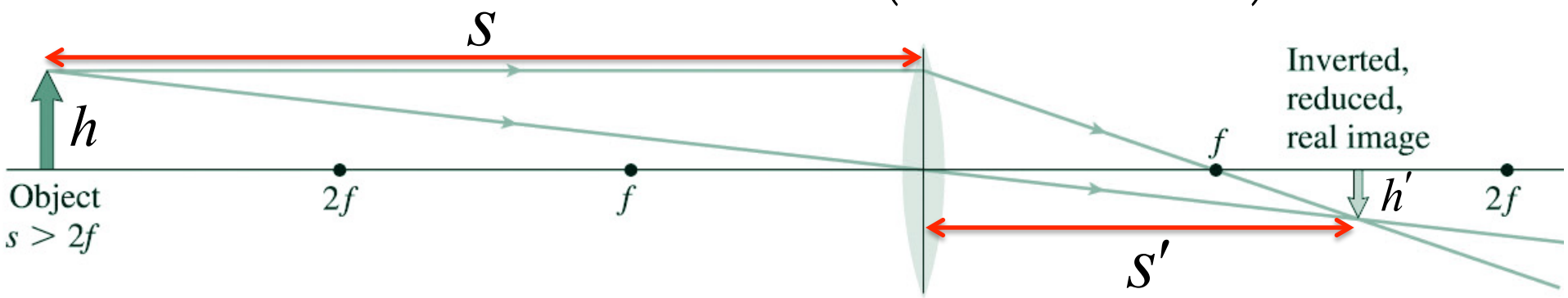
3. Any ray that passes through the center of the lens will not be deflected.

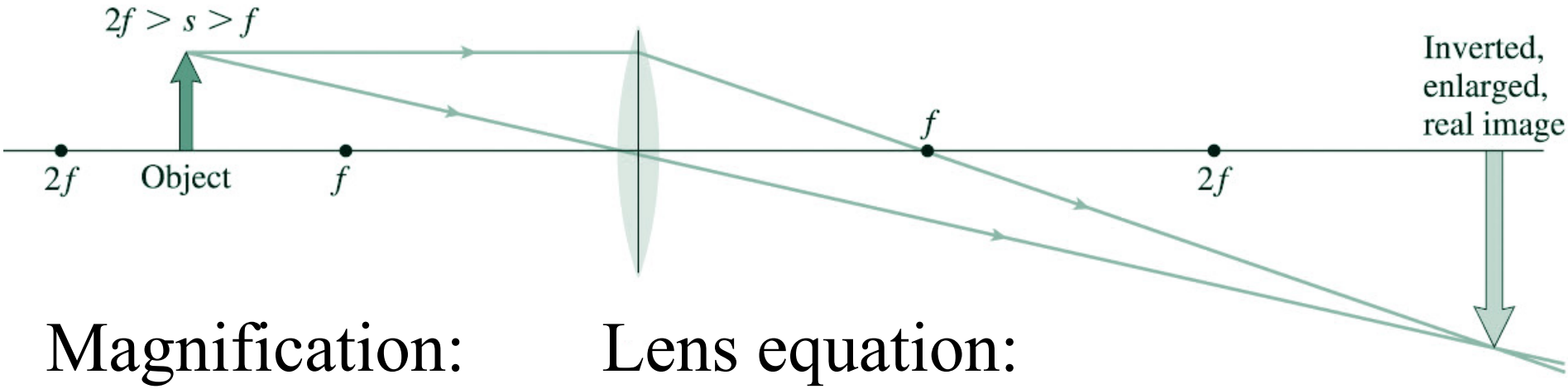


F = focal point; one each side (equidistant from lens)

Ray Tracing with Convex Lenses

Real image other side of lens $\left(f > 0,\ s' > 0\right)$





Magnification:

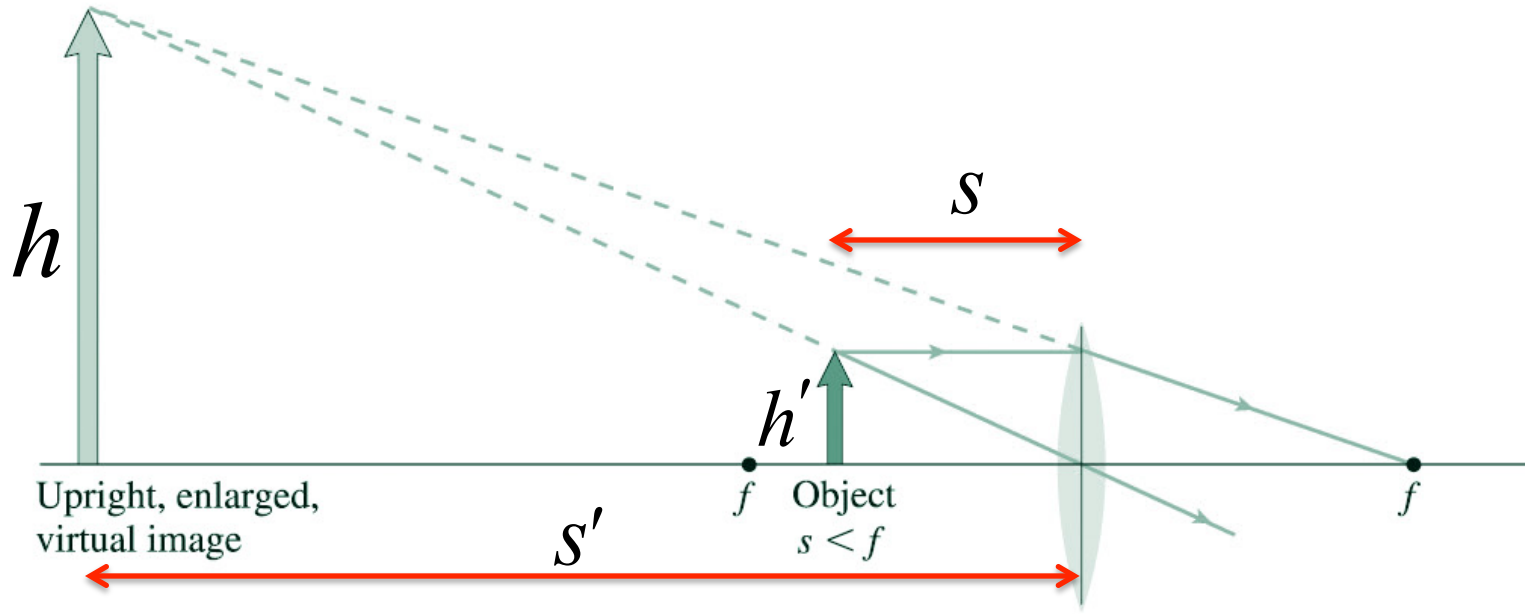
$$M = \frac{h'}{h} = -\frac{s'}{s}$$

Lens equation:

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

Ray Tracing with Convex Lenses

Virtual image same side of lens $\left(f > 0,\ s' < 0\right)$



Magnification:

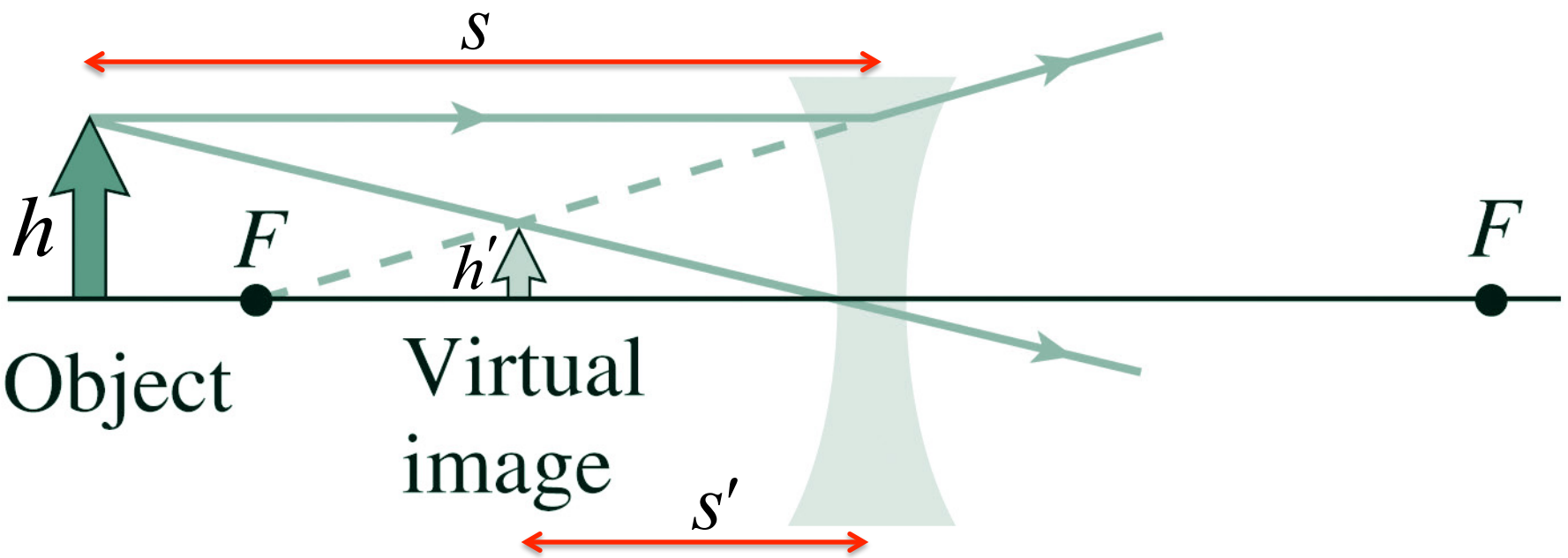
$$M = \frac{h'}{h} = -\frac{s'}{s}$$

Lens equation:

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

Ray Tracing with Concave Lenses

Virtual image same side of lens $\left(f < 0,\ s' < 0\right)$



Magnification:

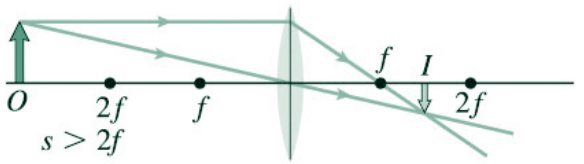
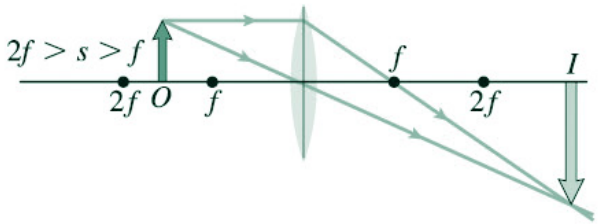
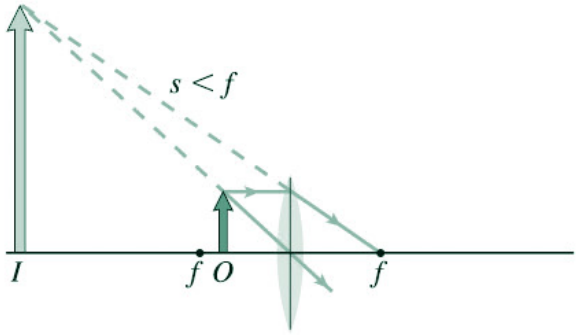
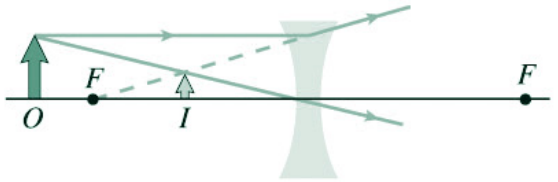
$$M = \frac{h'}{h} = -\frac{s'}{s}$$

Lens equation:

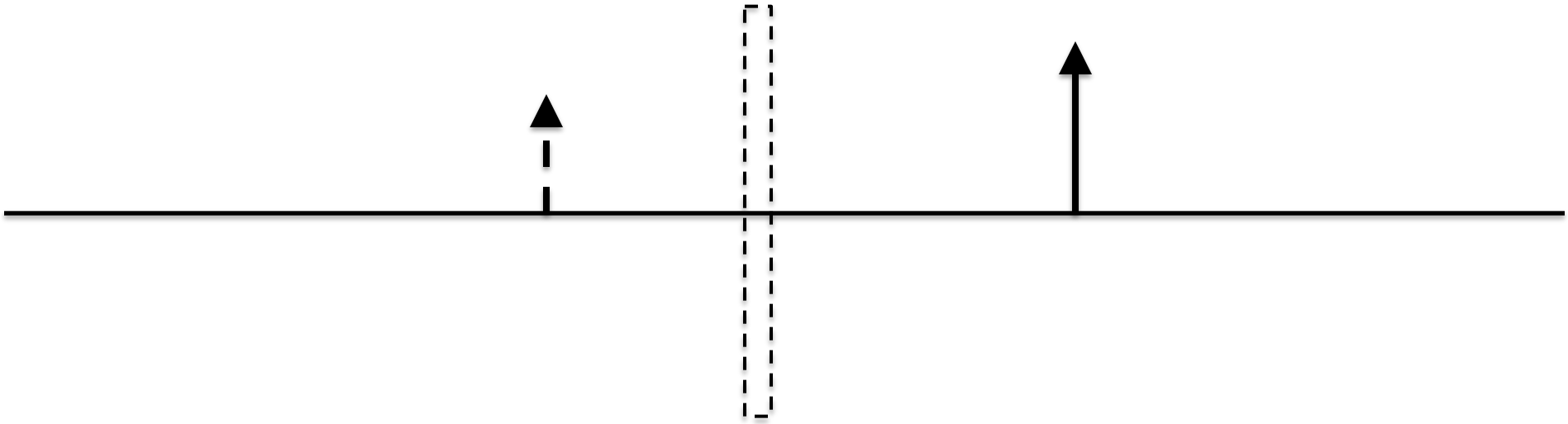
$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

Summary for Lenses

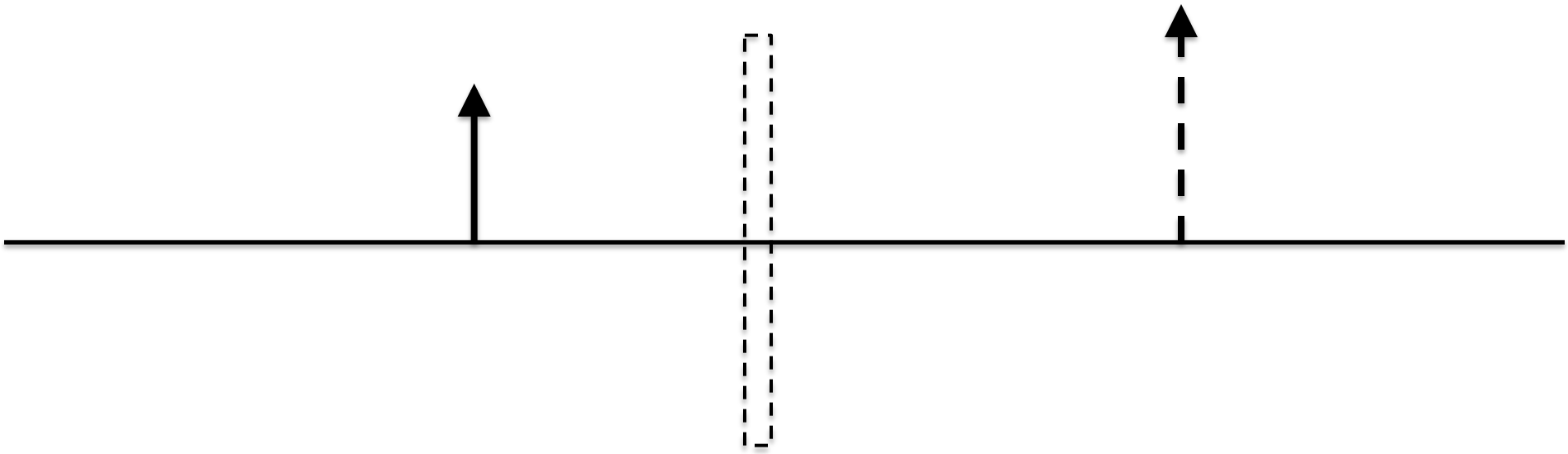
Table 31.2 Image Formation with Lenses: Sign Conventions

Focal Length, f	Object Distance, s	Image Distance, s'	Type of Image	Ray Diagram
+ (convex)	+ $s > 2f$	+ (opposite side of lens) $2f > s' > f$	Real, inverted, reduced	
+ (convex)	+ $2f > s > f$	+ (opposite side of lens) $s' > 2f$	Real, inverted, enlarged	
+ (convex)	+ $s < f$	− (same side of lens)	Virtual, upright, enlarged	
− (concave)	+	− (same side of lens)	Virtual, upright, reduced	

Example Problems: Which Optical Element?



Example Problems: Which Optical Element?



Example Problems: Which Optical Element?