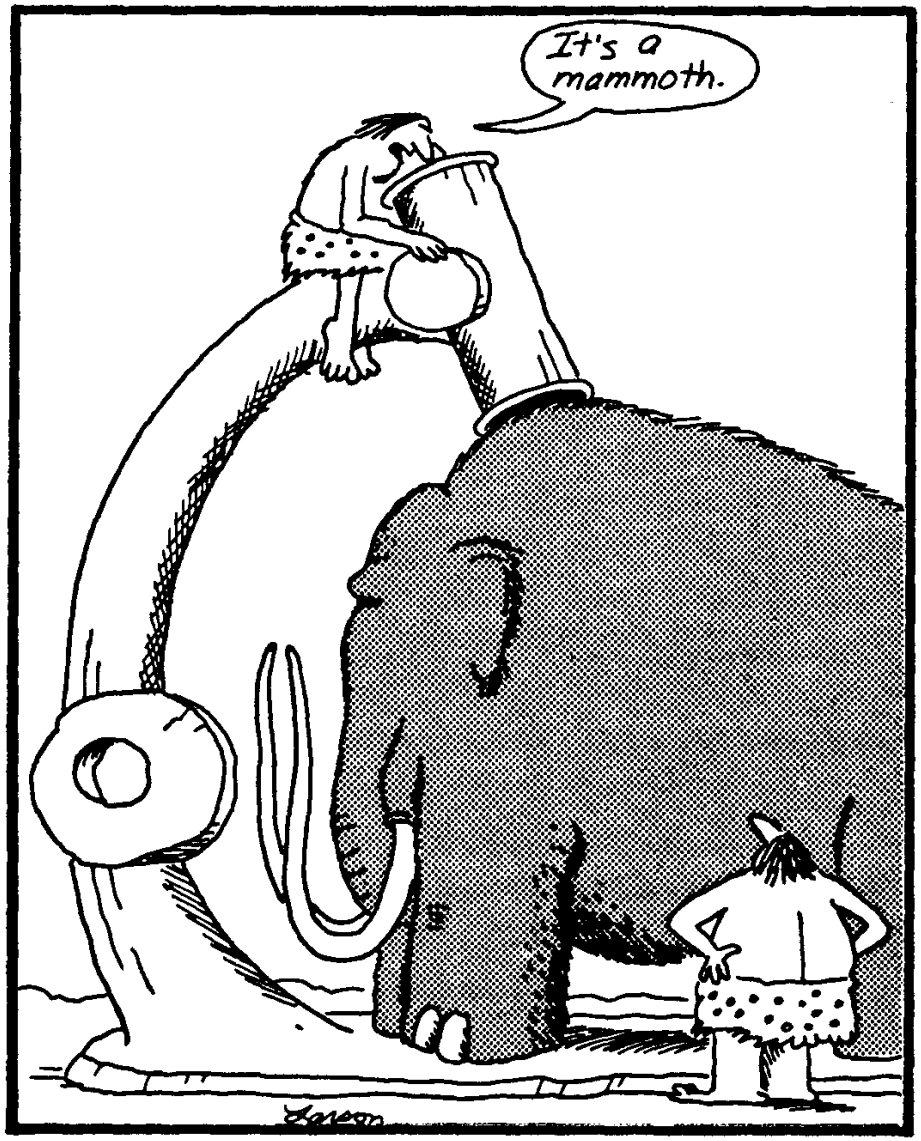
- **Theme Music:**
  Janis Joplin
  Light is Faster Than Sound

- **Cartoon:**
  Gary Larson
  The Far Side



Early microscope

Outline

- Quiz 4
- This week in tutorial and lab
- Recap: Ray principles
- Lenses
- ILD 2: Images (if time)

This week

- Tutorial 5:
  Can and image float in empty space?
- Lab 4: Refraction of light – part 2
  - The goal is to have your section agree to a single value of the result (with an error bar) that arises from combining the results from each group.
  - The big question is: “How do we combine our results?" In order to combine, each group will have to have an error bar – and a good reason why they chose that error bar!
  - The results of each section will be presented in lecture.

Foothold Ideas 1:
The Physics

- Certain objects (the sun, bulbs,…) give off light.
- Light can travel through a vacuum.
- In a vacuum light travels in straight lines (rays).
- Each point on a rough object scatters light, spraying it off in all directions.
- A polished surface reflects rays back again according to the rule: *The angle of incidence equals the angle of reflection*.
- When entering a transparent medium, a light ray changes its direction according to the rule $n_1 \sin\theta_1 = n_2 \sin\theta_2$
- "n" is a property of the medium and $n_{vac} = 1$.

Foothold Ideas 1a
The Model

- Light consists of tiny particles that move very fast.
- The speed of light in a medium is determined by a property of the medium: a potential energy.

$$\frac{1}{2}mv_1^2 + U_1 = \frac{1}{2}mv_2^2 + U_2$$

- Potential energies are lower in dense media so light travels faster in them.
- The index of refraction in a medium is given by

$$n_{med} = \frac{v_{med}}{c}$$

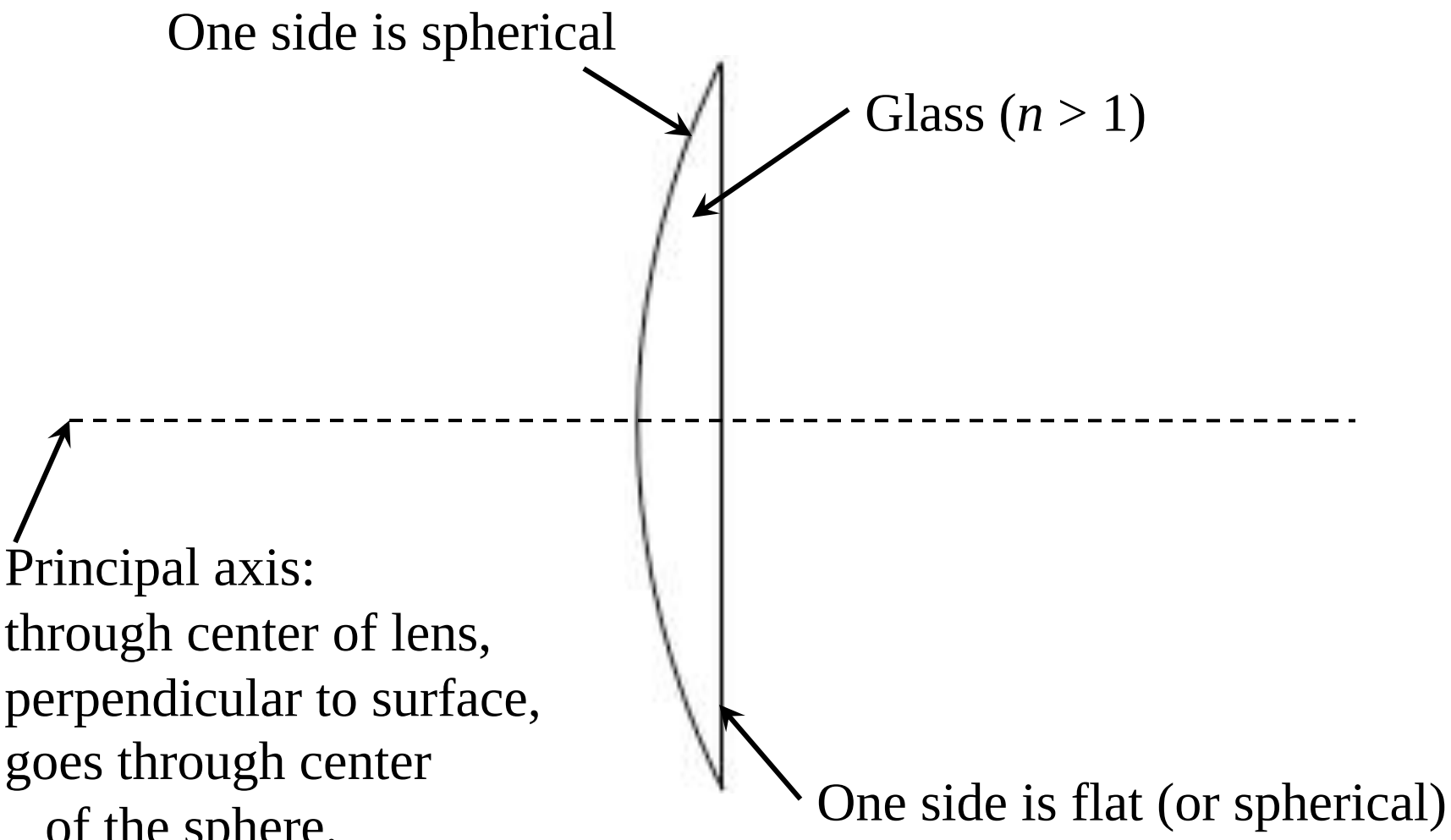
Foothold Ideas 2:
The Psycho-physiology

- We only see something when light coming from it enters our eyes.
- Our eyes identify a point as being on an object by many mechanisms:
  - By tracing rays back to see where they converge.
  - By how they change when we move.
  - By our experience with objects and the world.

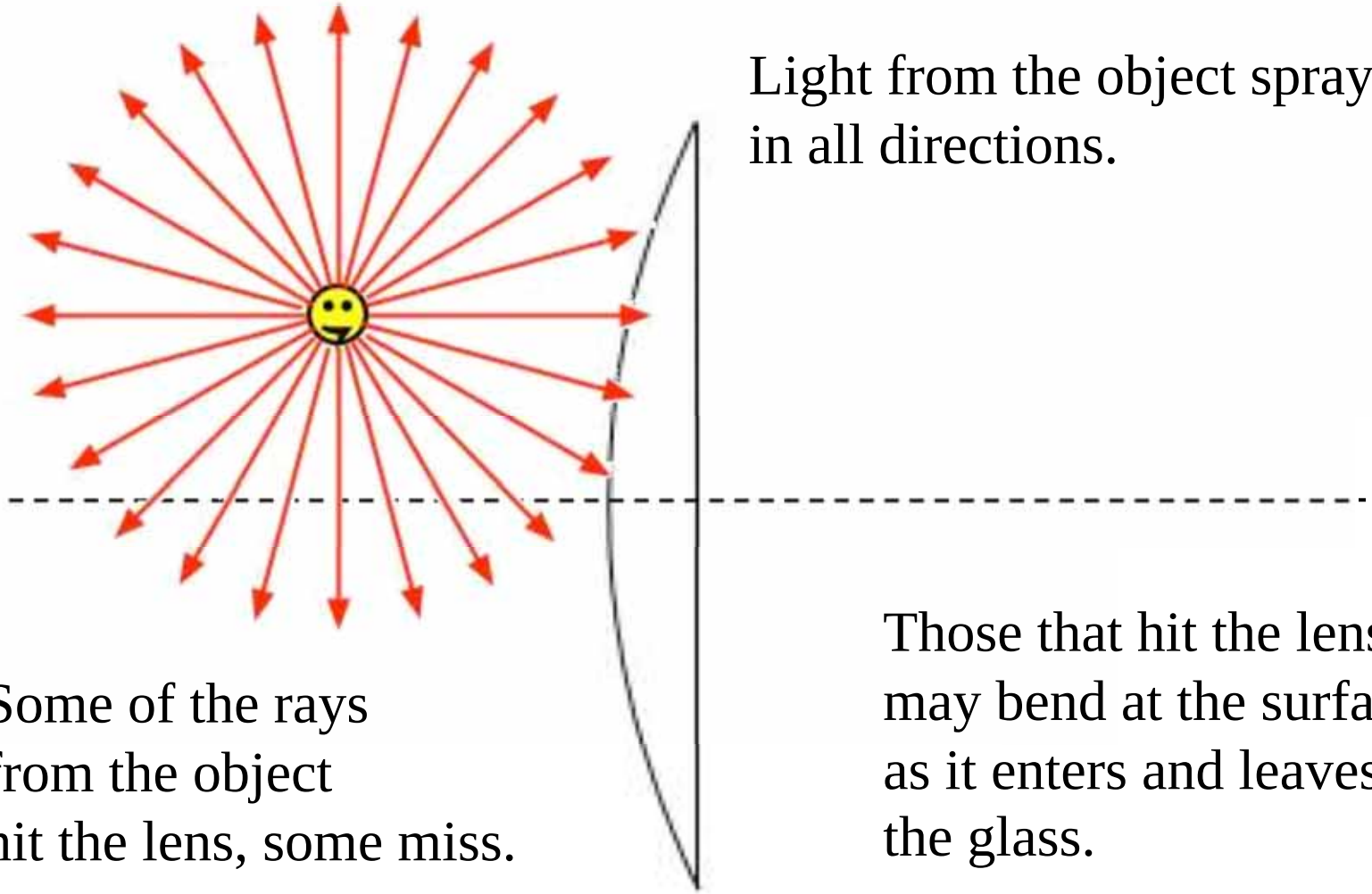
Kinds of Images

- Real
  - When the rays seen by the eye do meet, the image is called real.
  - If a screen is put at the real image, rays scatter in all directions and an image can be seen on the screen, just as if it were a real object.
- Virtual
  - When the rays seen by the eye extrapolate to a point but don't actually meet, the image is called virtual.

A thin lens


One side is spherical
Glass ($n > 1$)
Principal axis:
through center of lens,
perpendicular to surface,
goes through center
of the sphere.
One side is flat (or spherical)

An object viewed through a thin lens

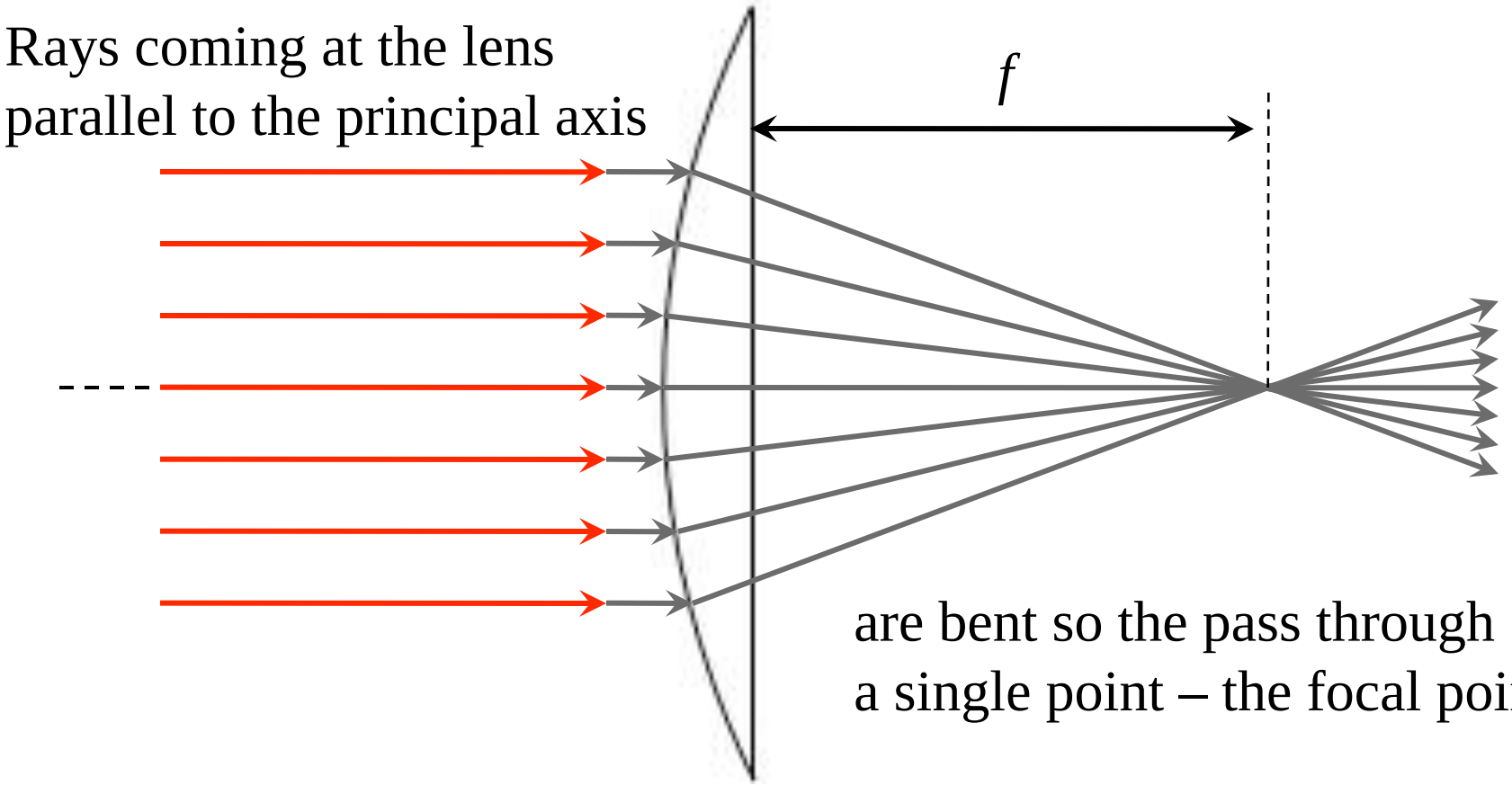


Light from the object sprays out in all directions.

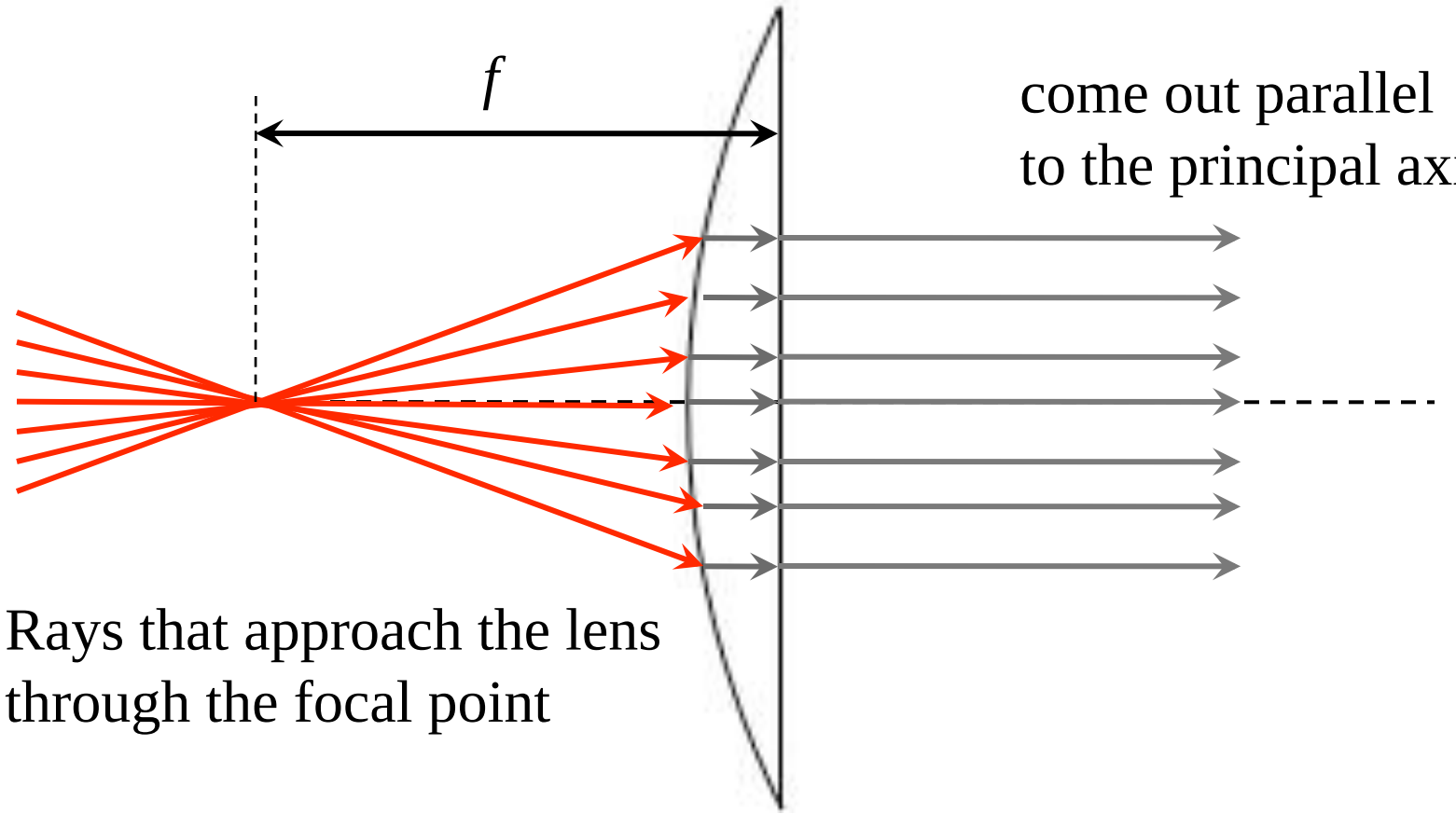
Some of the rays from the object hit the lens, some miss.

Those that hit the lens may bend at the surface as it enters and leaves the glass.

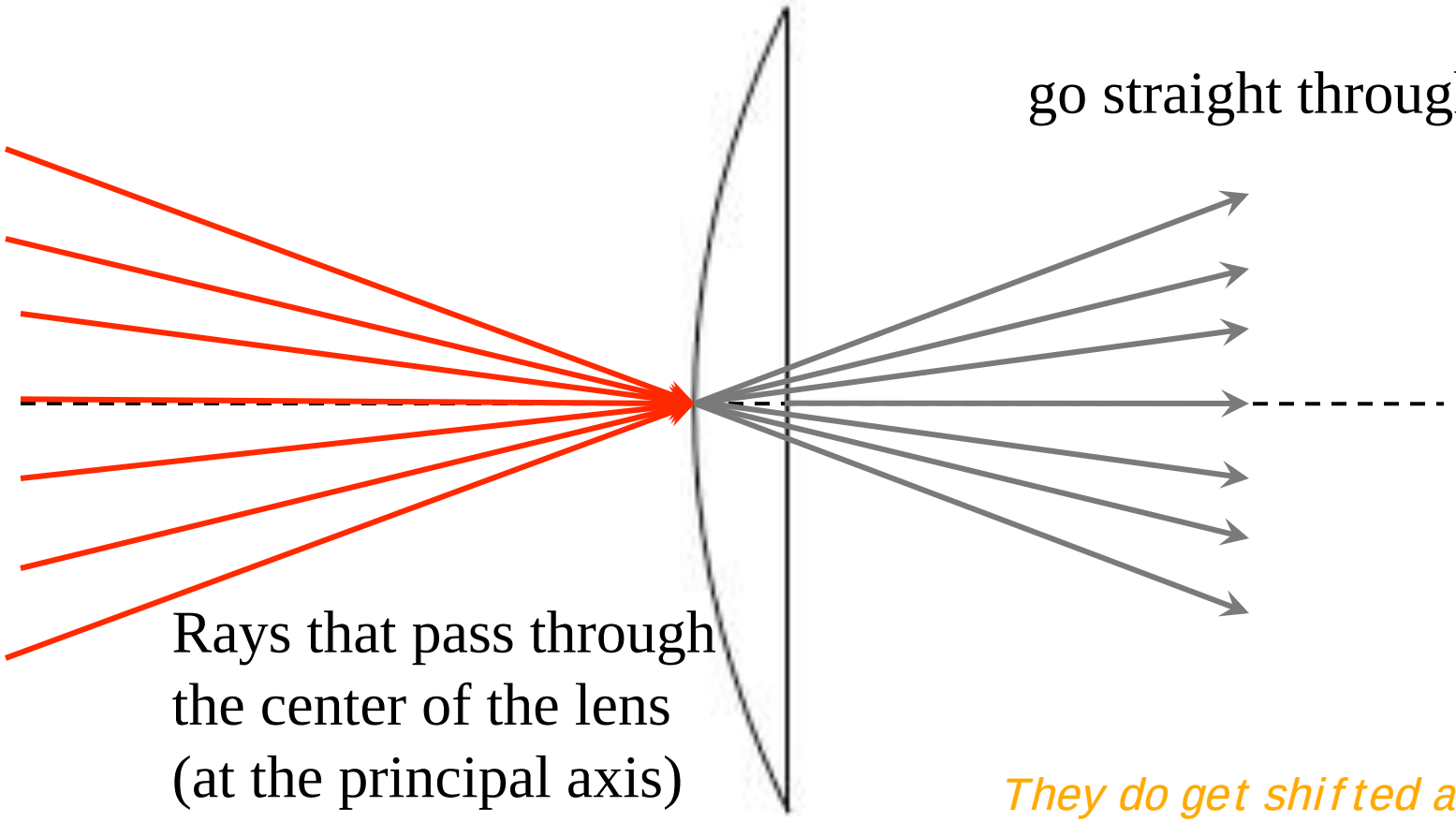
Principal (easy-to-figure-out) rays: focal point (far side)



Principal (easy-to-figure-out) rays: focal point (nearside)



Principal (easy-to-figure-out) rays: central rays



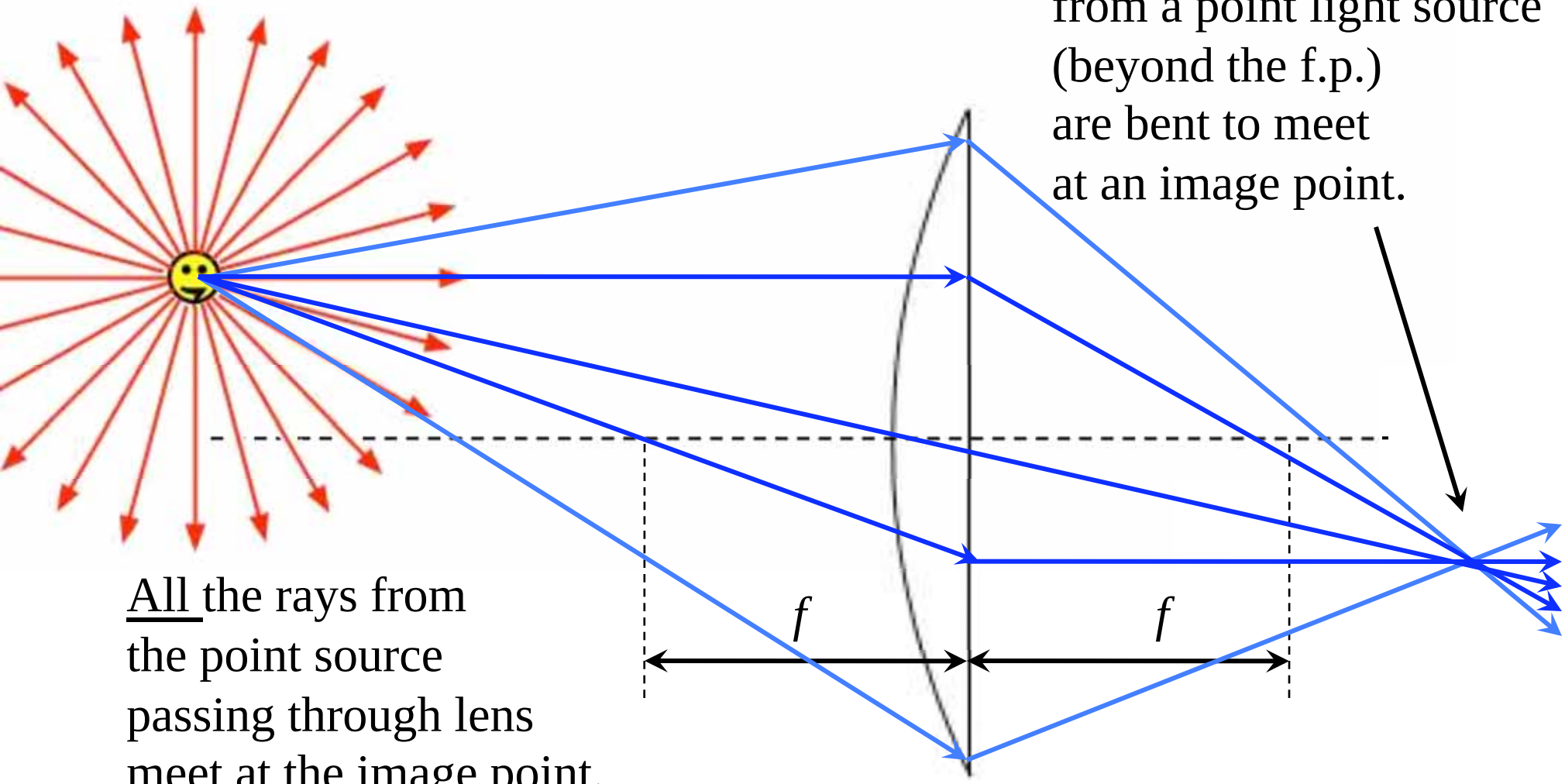
go straight through.

Rays that pass through the center of the lens (at the principal axis)

They do get shifted a little, but don't worry about it!

Principal (easy-to-figure-out) rays

The principal rays
from a point light source
(beyond the f.p.)
are bent to meet
at an image point.

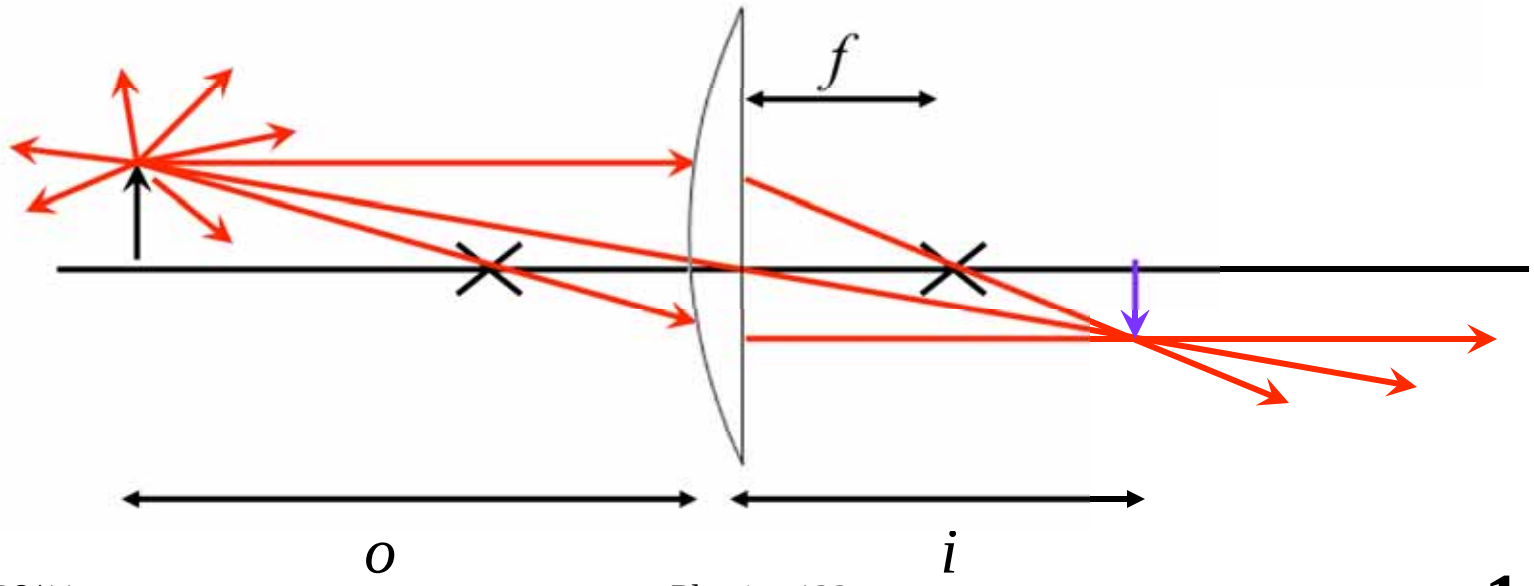


All the rays from
the point source
passing through lens
meet at the image point.

The Lens Equation

- For a thin lens

$$\frac{1}{o}+\frac{1}{i}=\frac{1}{f} \qquad \frac{h'}{h}=\frac{i}{o}$$

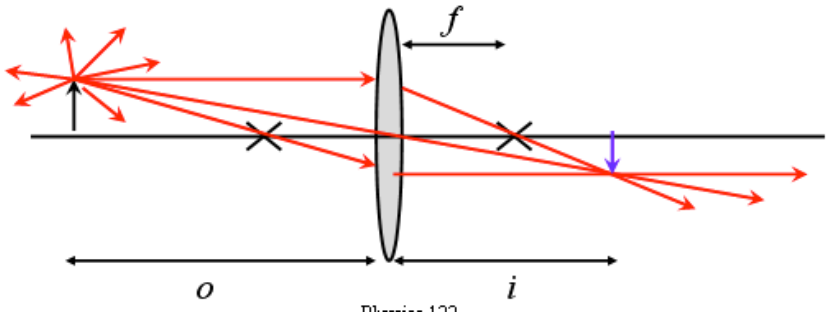


Unifying Equation for Lenses

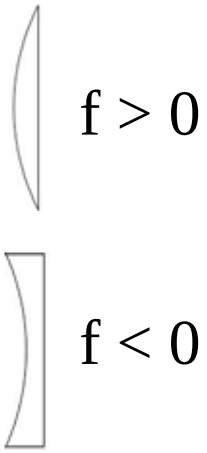
- If we treat our lens quantities as "signed" and let the signs carry directional information, we can unify all the situations in a single set of equations.

$$\frac{1}{f} = \frac{1}{i} + \frac{1}{o} \qquad \frac{h'}{h} = \frac{i}{o}$$

	i < 0	i > 0	
h > 0	o > 0	o < 0	h´< 0
h < 0			h´> 0



"standard" arrangement

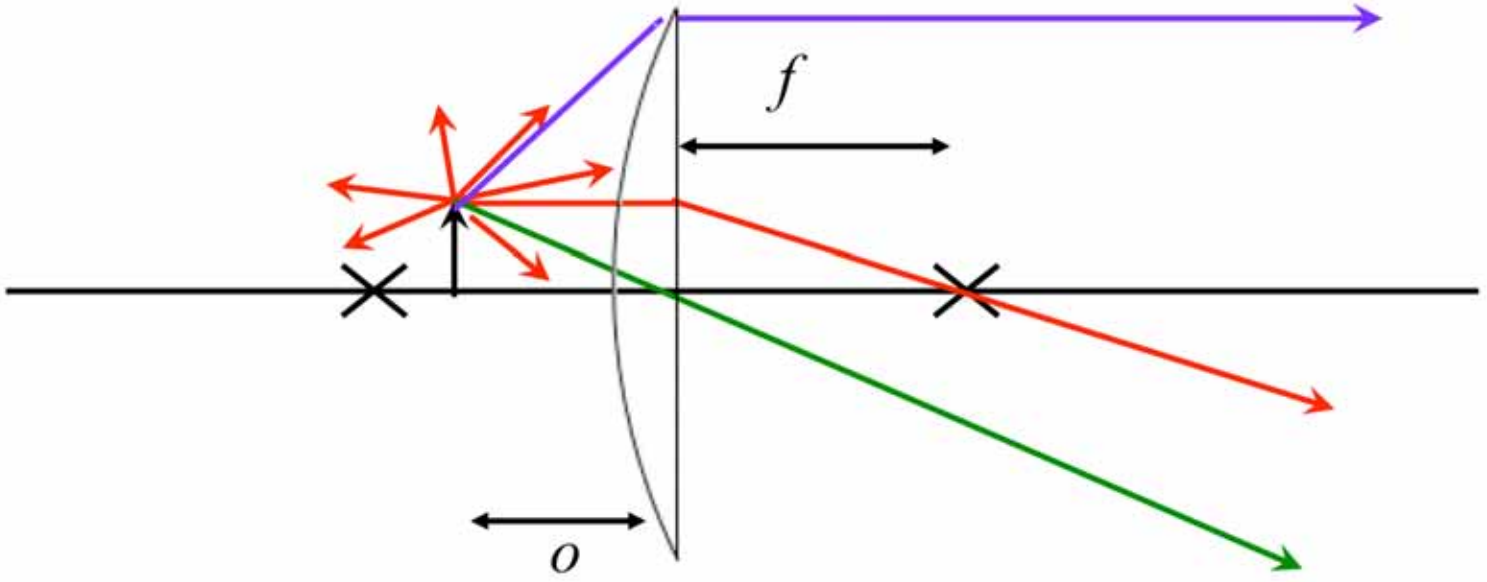


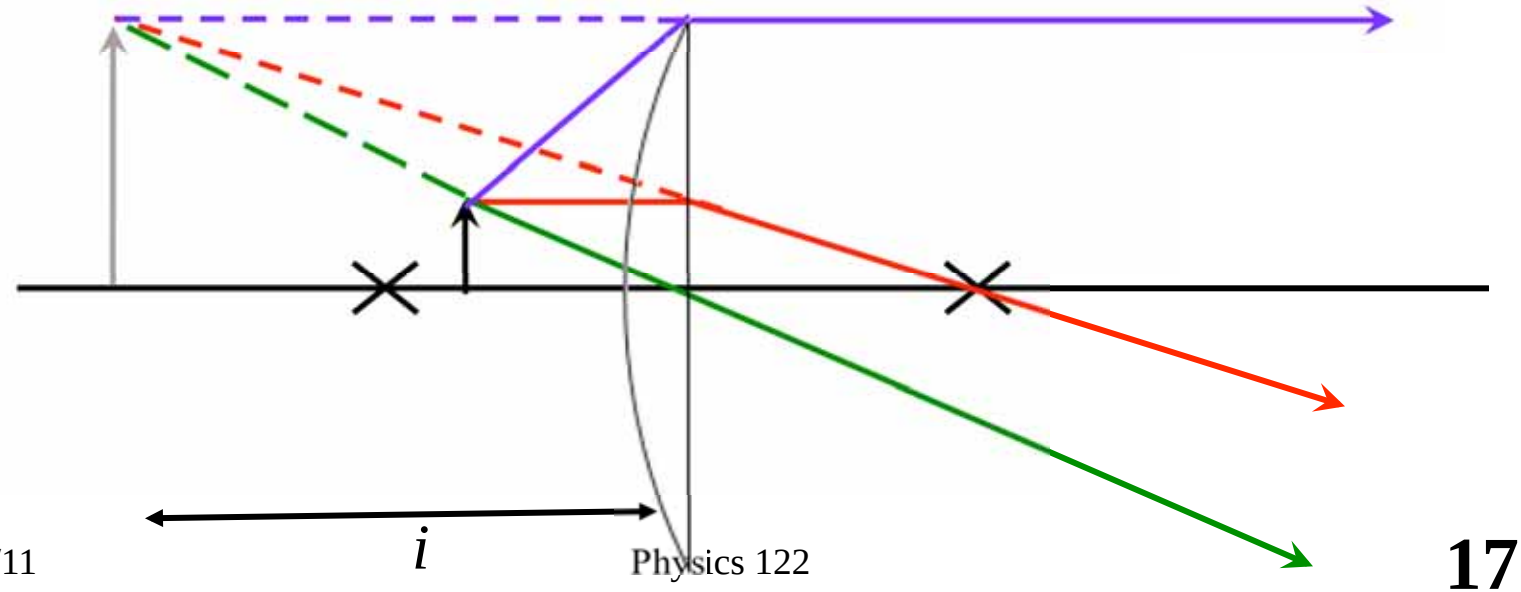
The Magnifying Glass

- What happens if the object is inside the focal point (closer to the lens)?

$$\frac{1}{o}+\frac{1}{i}=\frac{1}{f} \qquad \frac{h'}{h}=\frac{i}{o}$$

- If $o < f$ then $1/o > 1/f$.
  So $1/i = 1/f - 1/o < 0$.
- If $i < 0$, then $h' < 0$.
- The image is virtual and oriented upward.

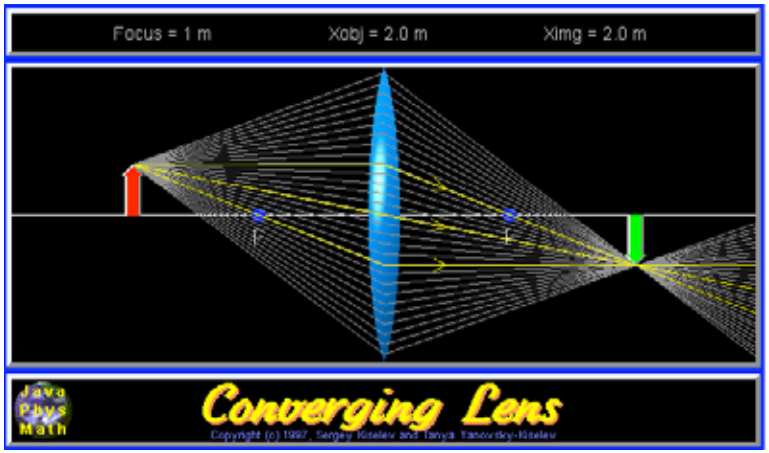

f
o


i

Exploring Lenses

- Converging

http://www.physics.uoguelph.ca/applets/Intro_physics/kisalev/java/clens/index.html



- Diverging

http://www.physics.uoguelph.ca/applets/Intro_physics/kisalev/java/dlens/index.html