Perception: Camera Modeling

Kostas Daniilidis

Can our aerial robots control their flight like gannets?

How can gannets' eyes and brain estimate distance to water!

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Plummeting gannets: a paradigm of ecological optics

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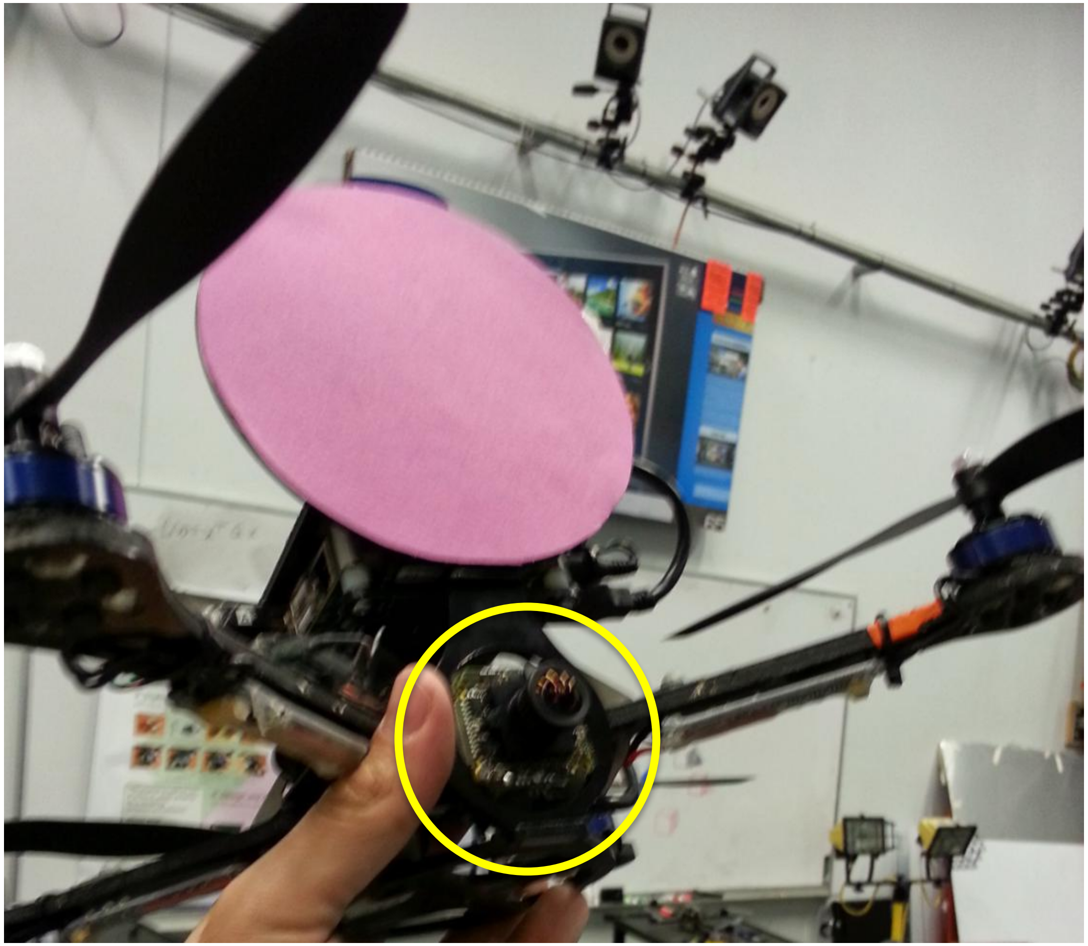
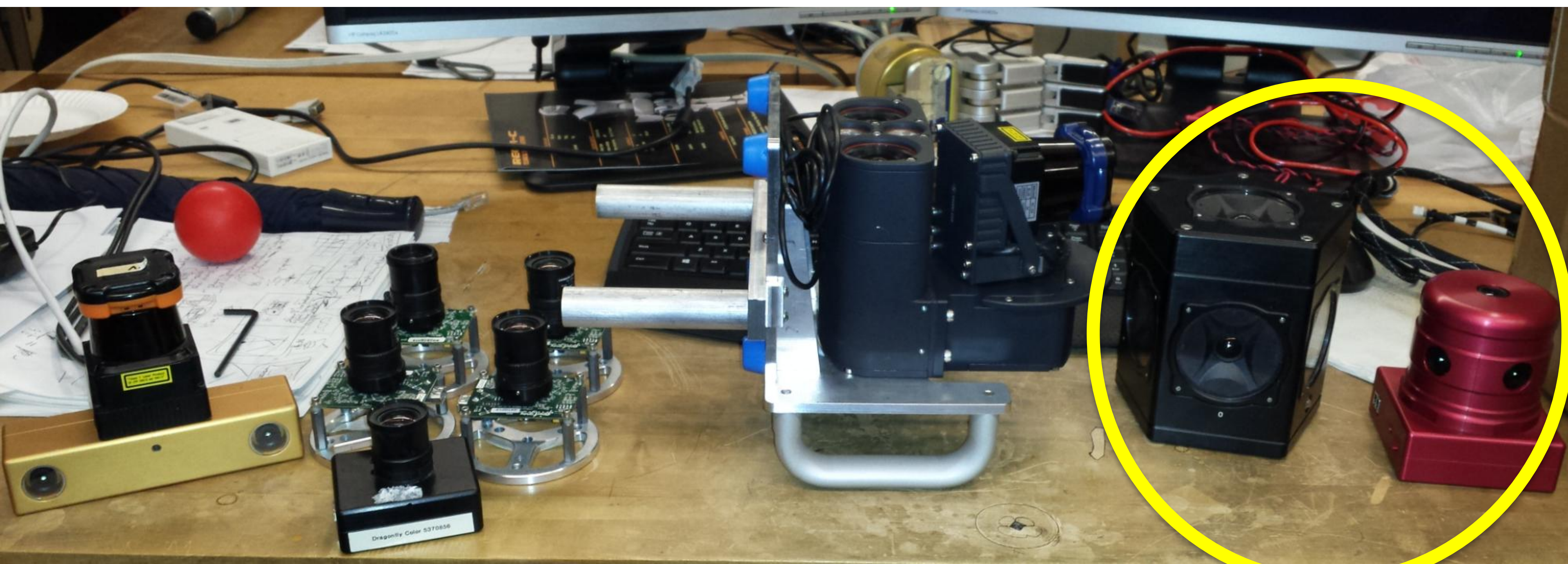
Quadrotor "sees" with a camera



In robotics we use all kinds of cameras!



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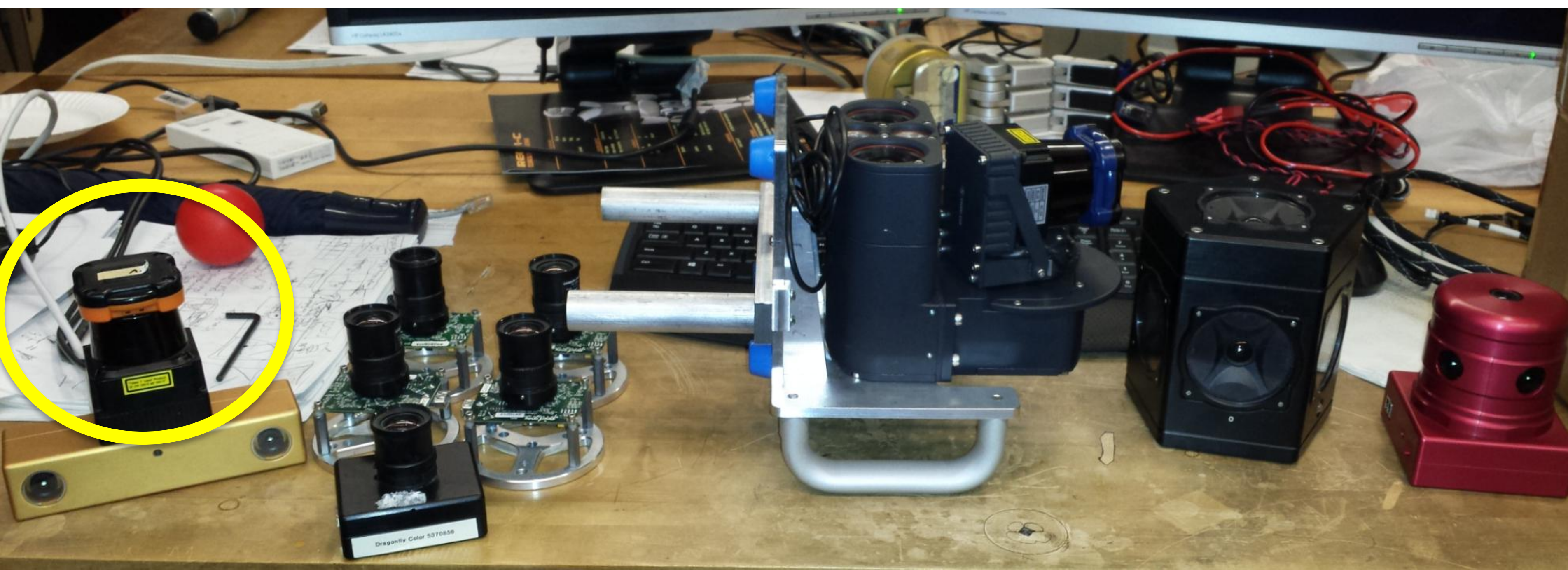

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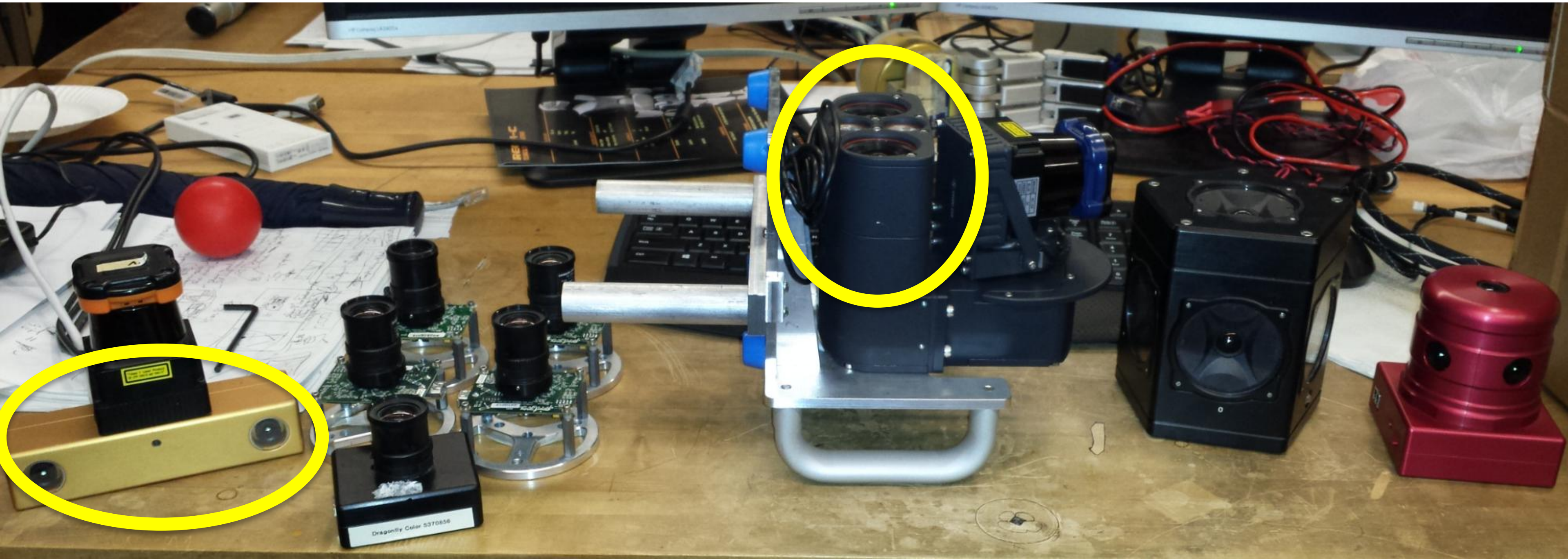
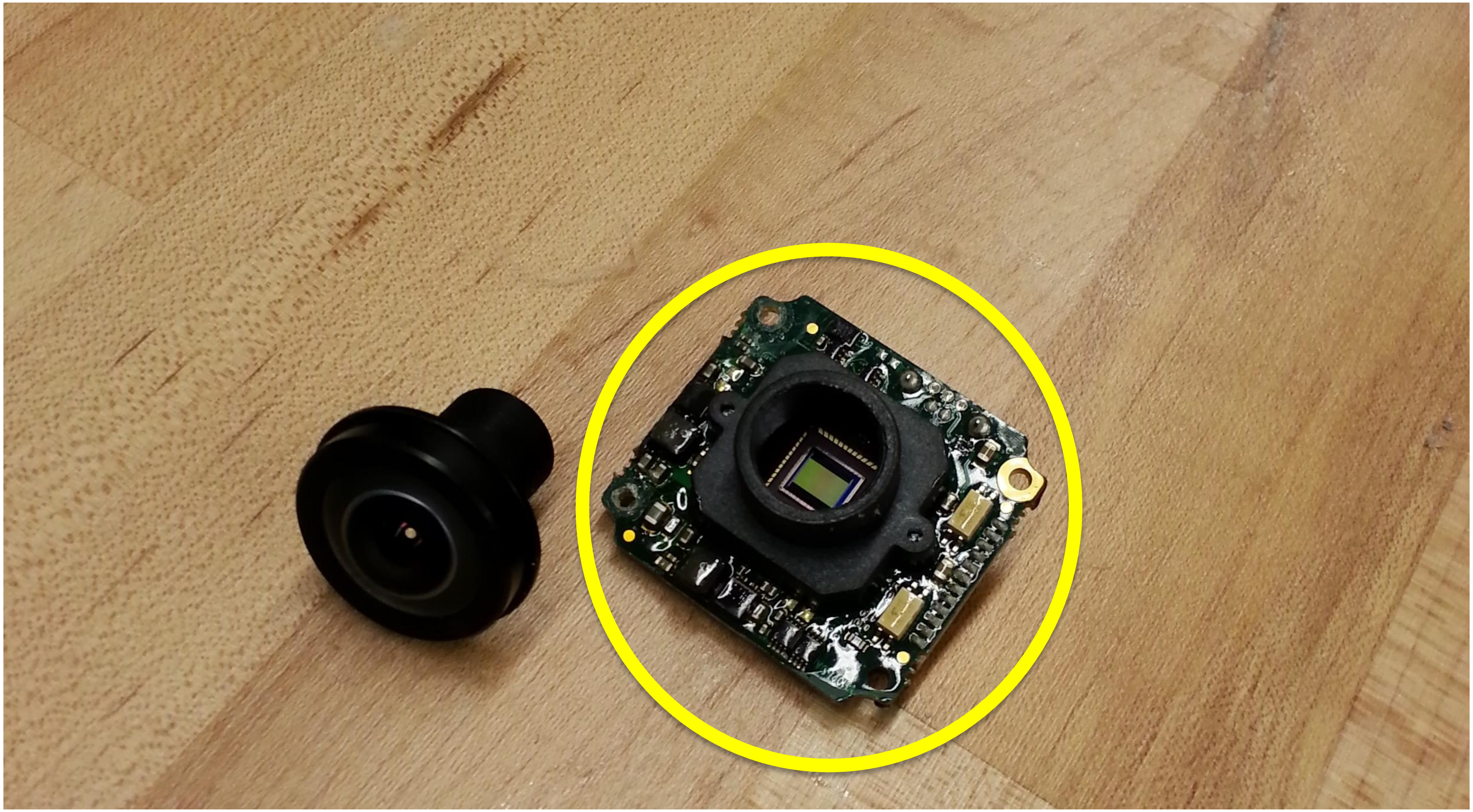


A camera is an imaging chip and a lens



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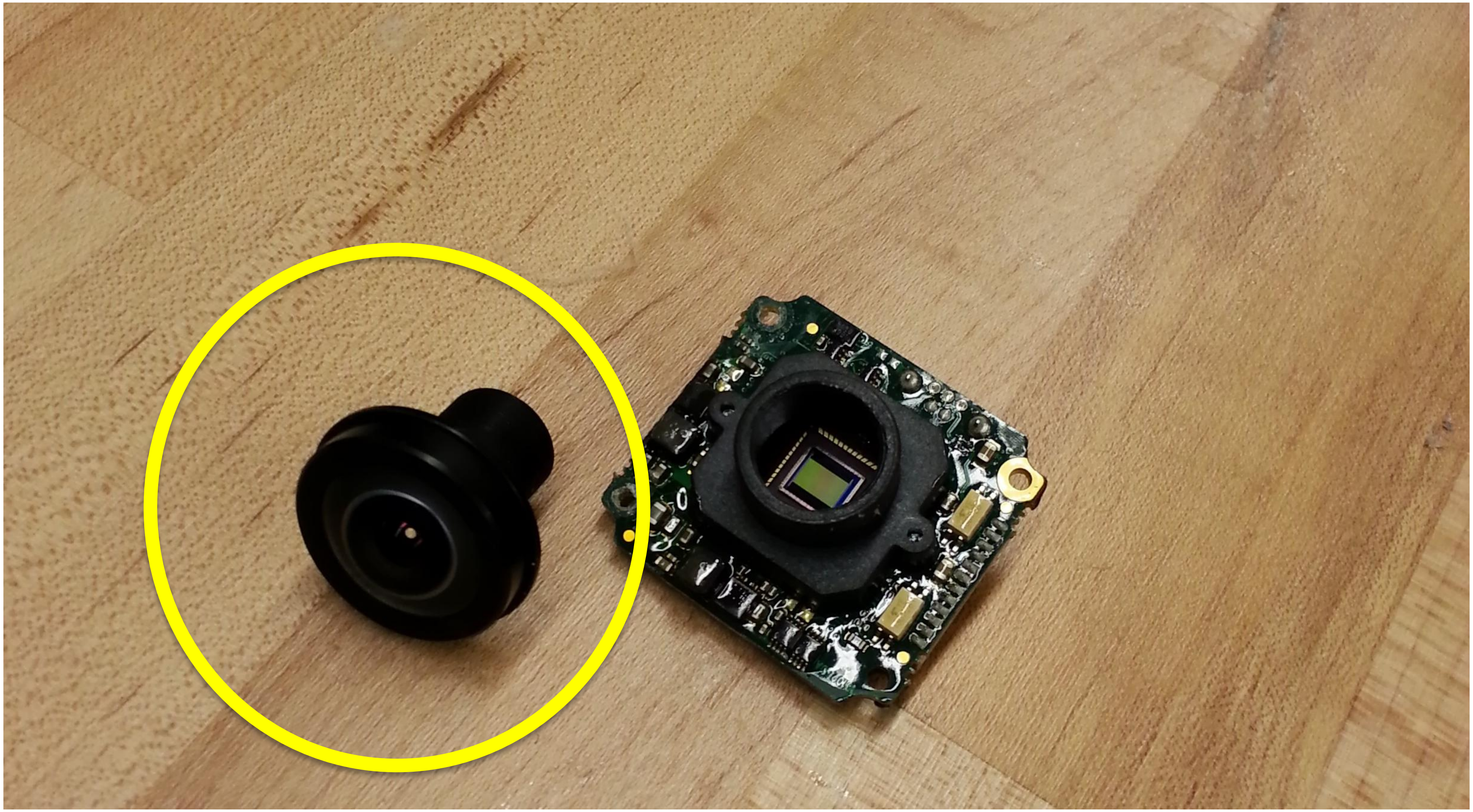
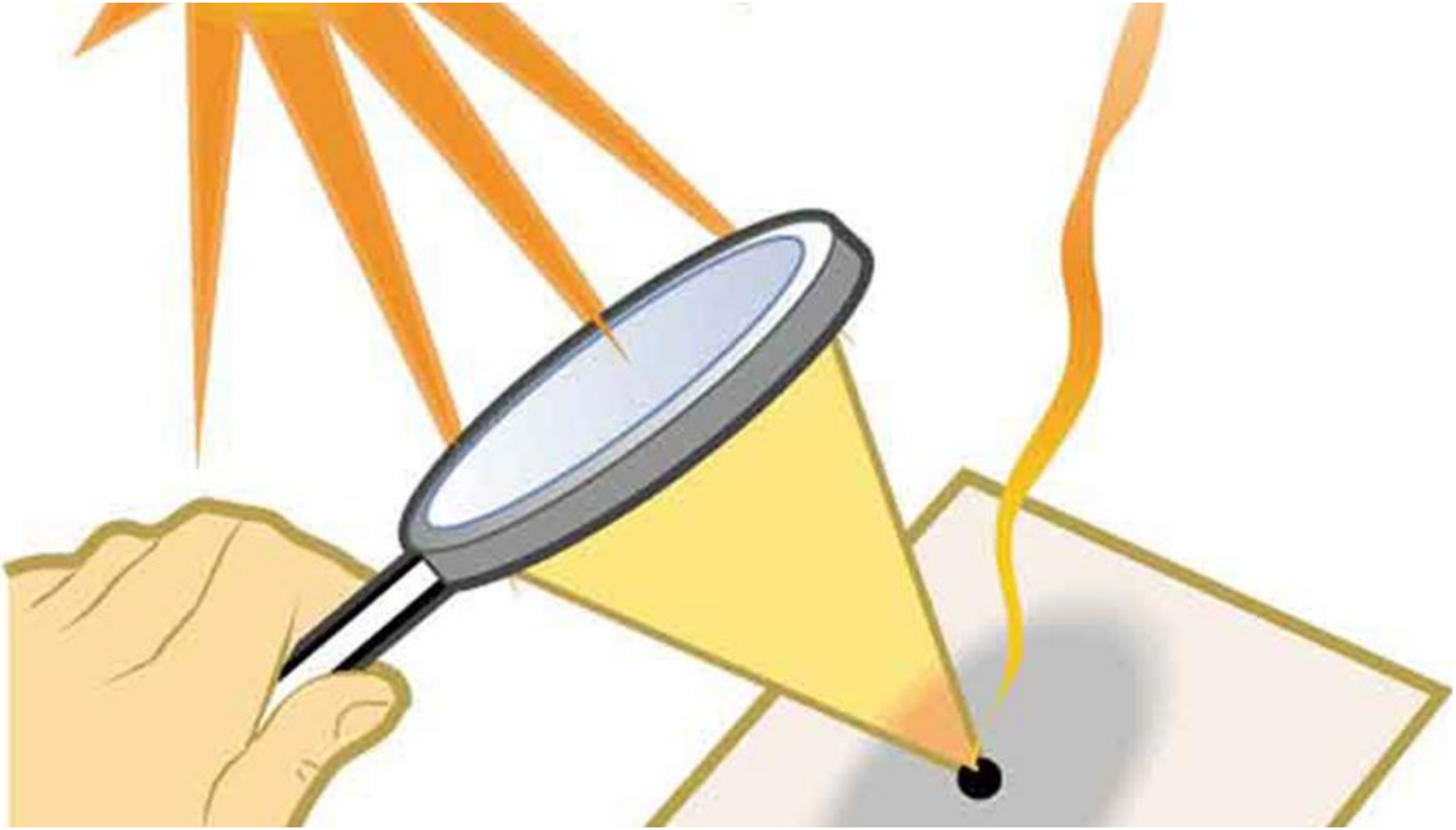
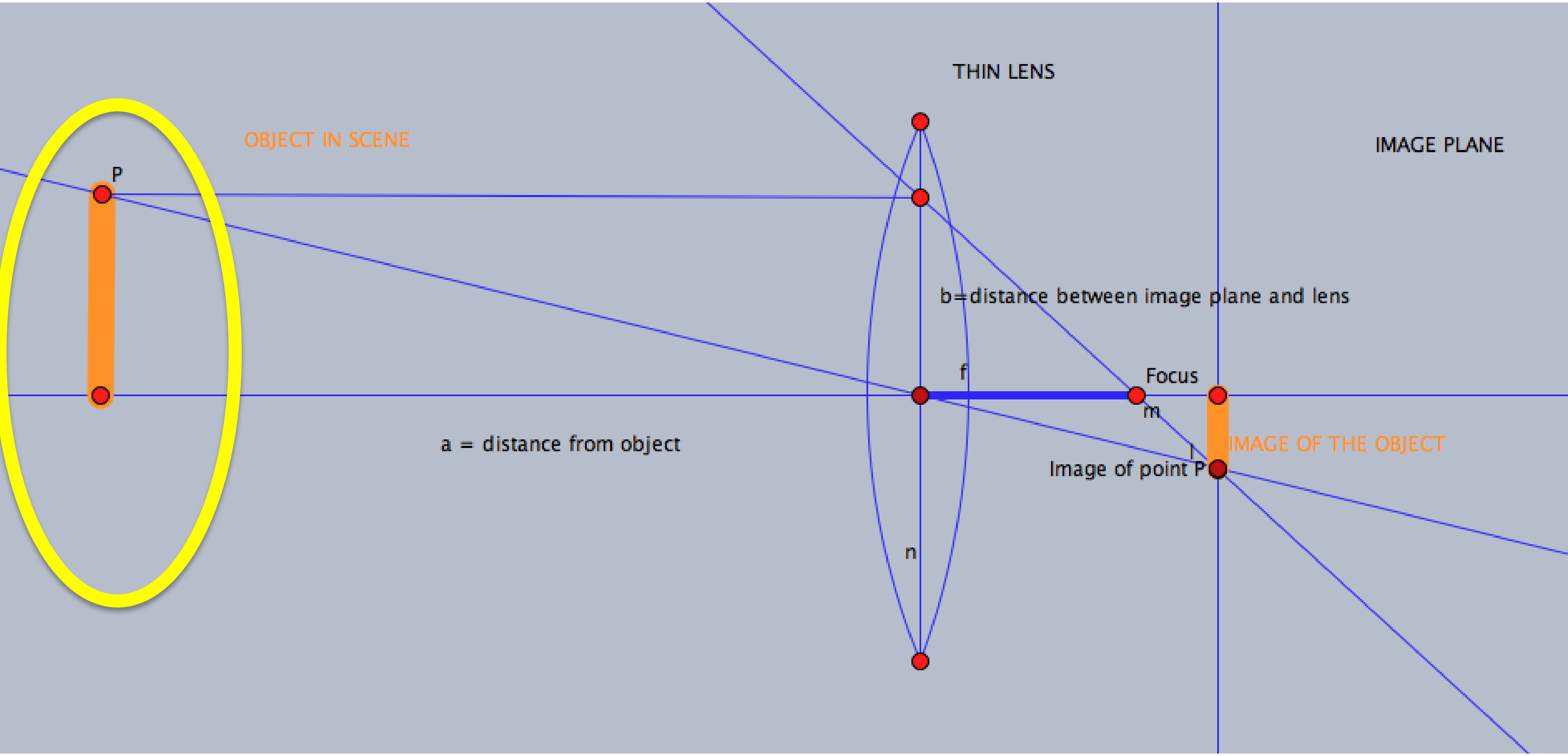


Magnifying glass

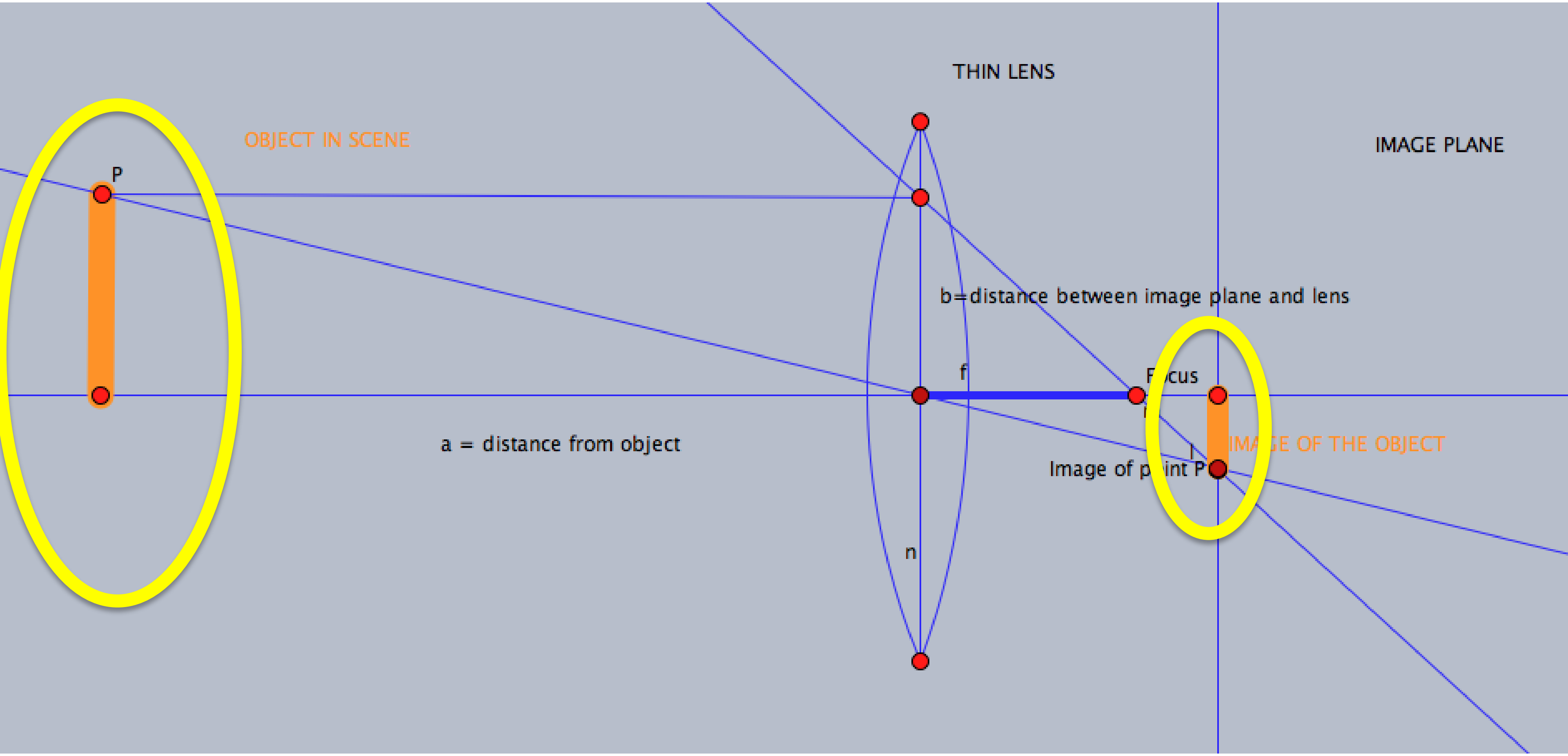


How does a thin lens work



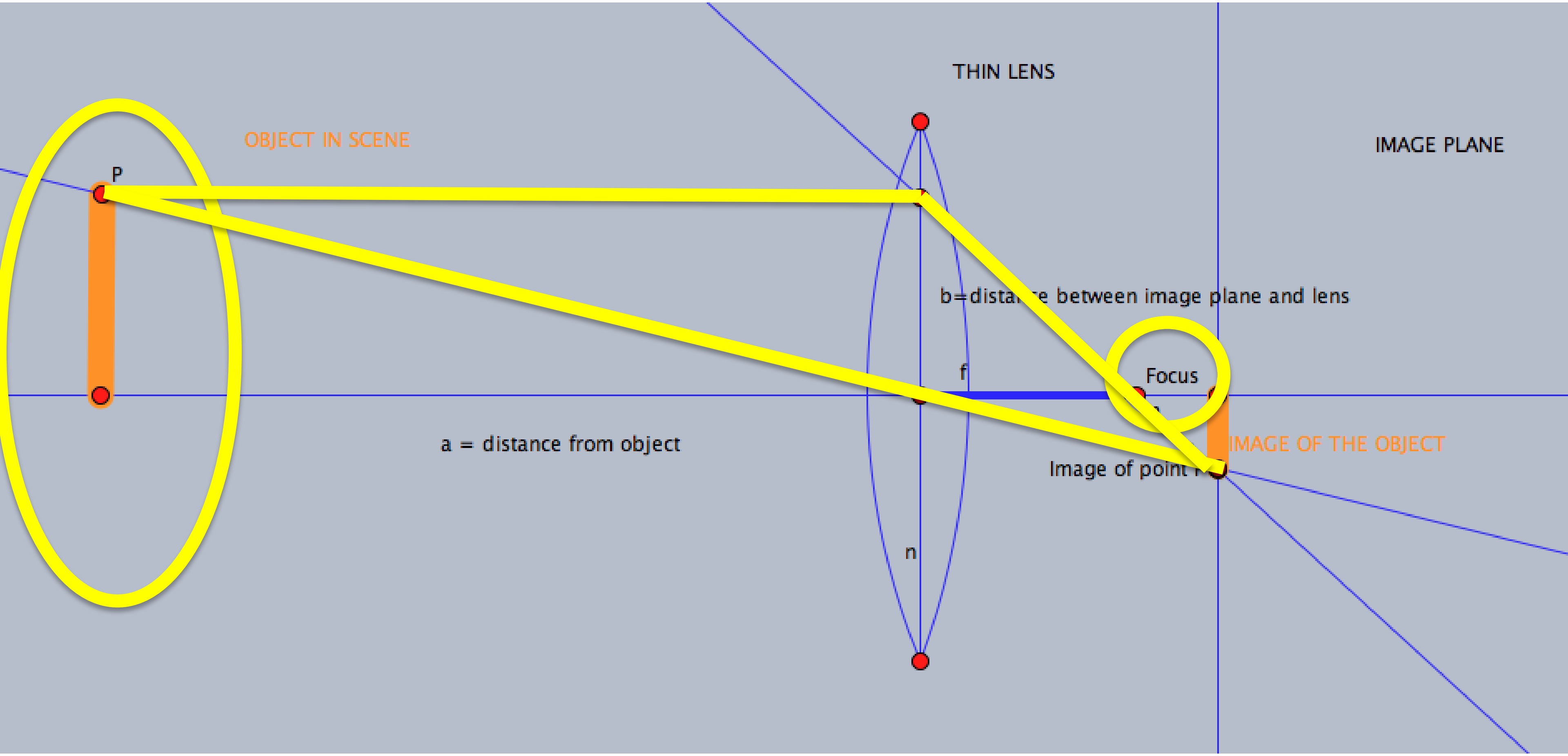
Rays from on object point P converge on a point p on the image plane

How does a thin lens work



Rays from a point P in the scene converge into a point in the image plane

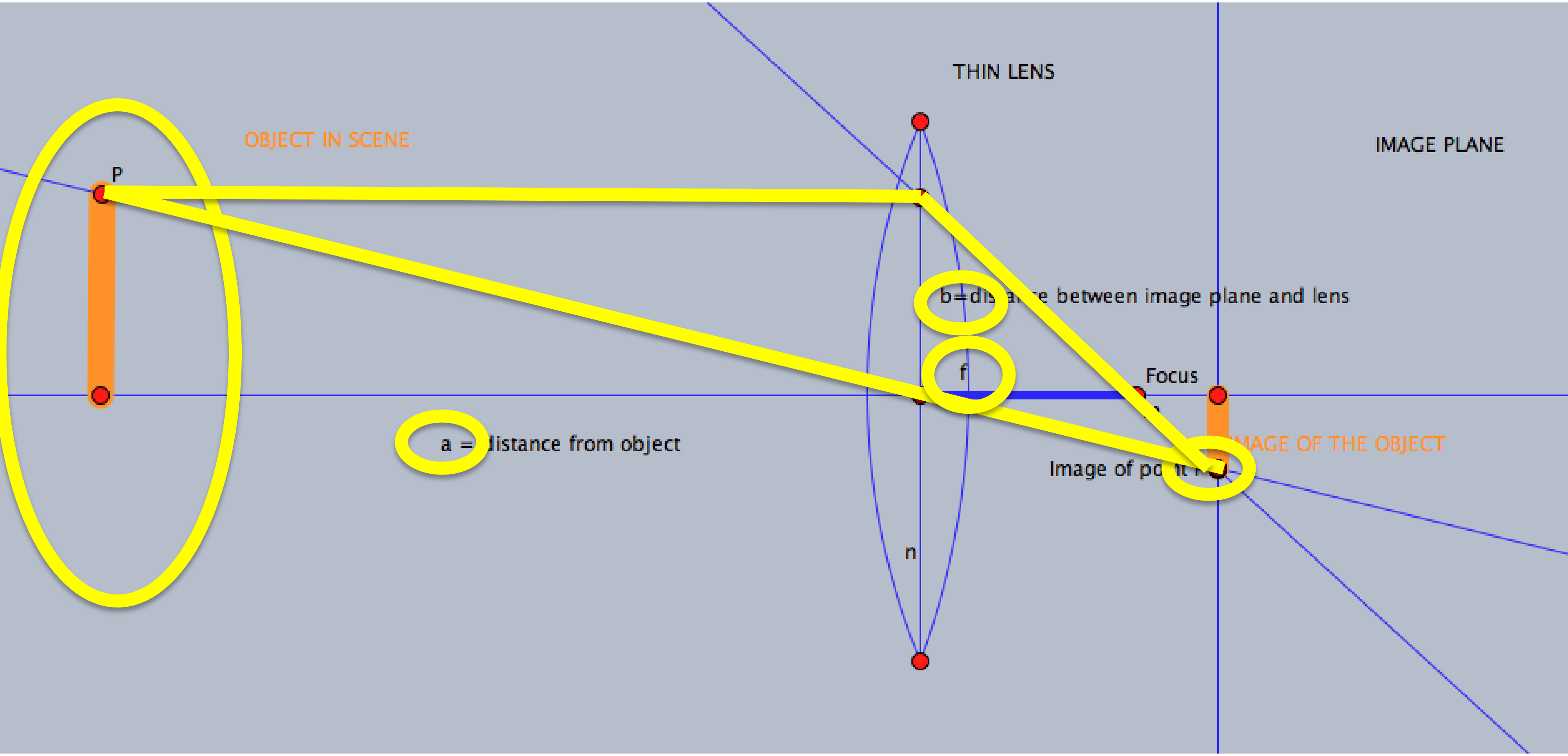
How does a thin lens work



Rays parallel to the optical axis meet the focus after leaving the lens.
Rays through center of the lens do not change direction.

$$\frac{1}{f} = \frac{1}{a} + \frac{1}{b}$$

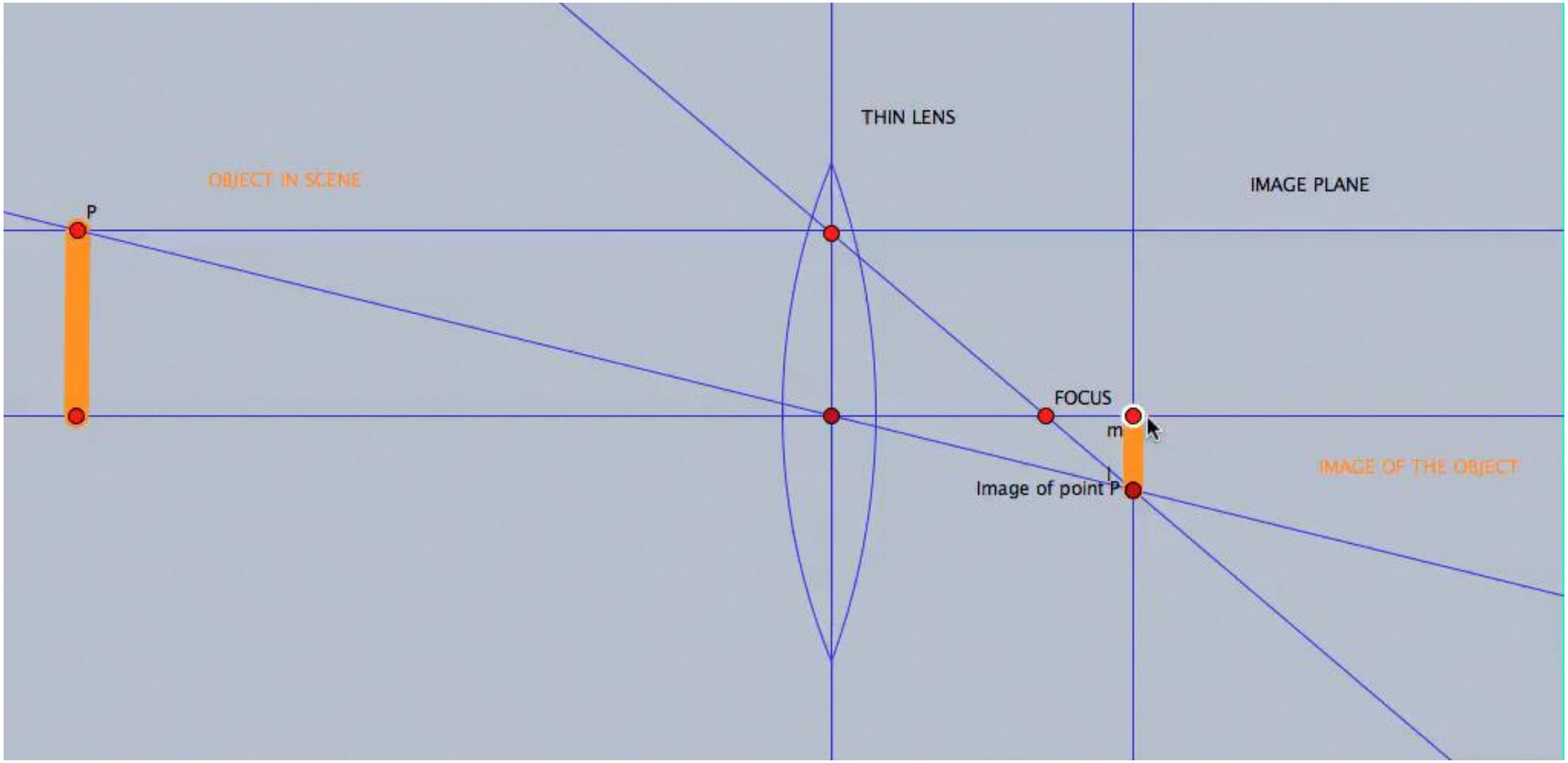
How does a thin lens work



These rays meet at one point if

$$\frac{1}{f} = \frac{1}{a} + \frac{1}{b}$$

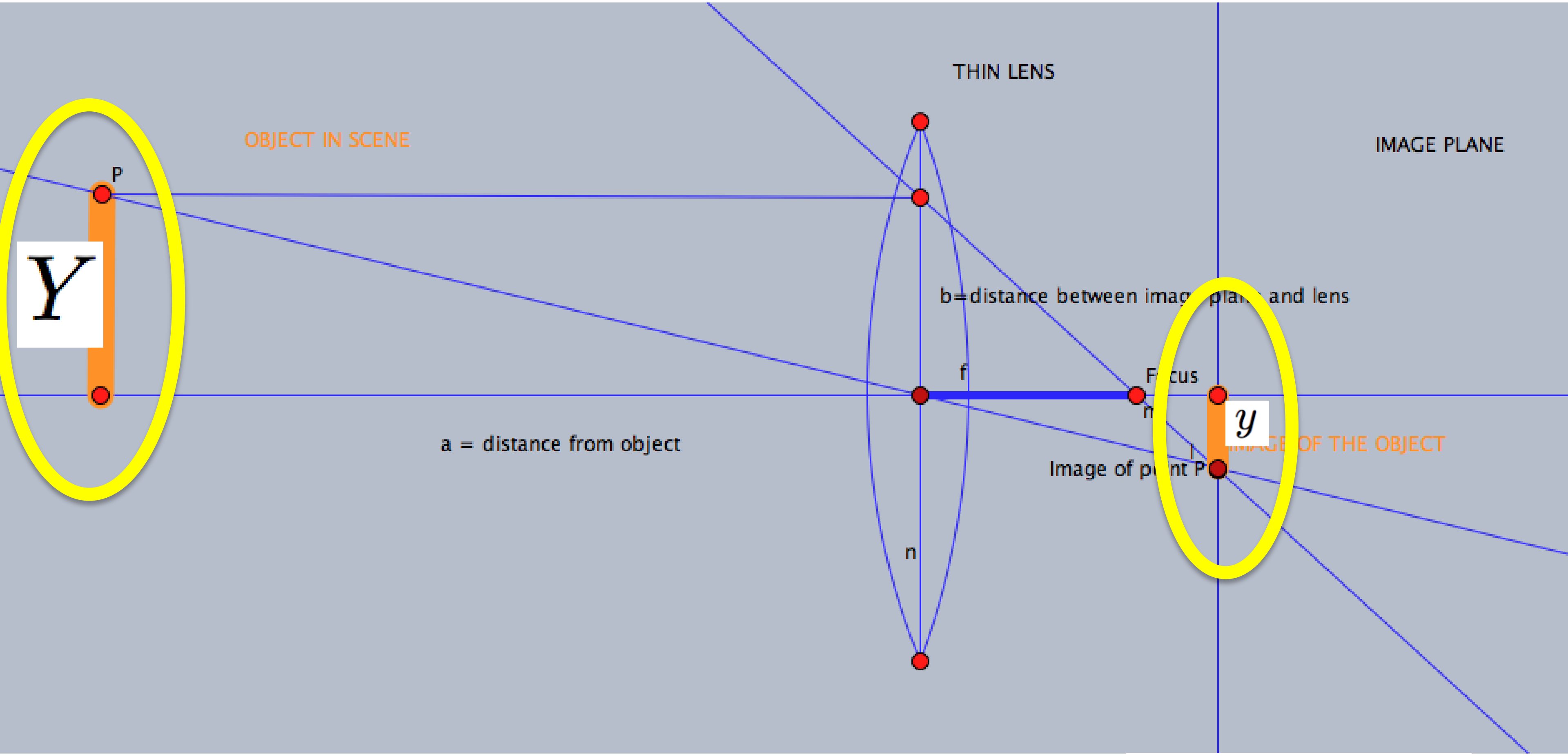
What happens when we move b, the image plane



Moving the image plane is what we call (de-) focusing !
Image starts blurring!

$$\frac{1}{f} \neq \frac{1}{a} + \frac{1}{b}$$

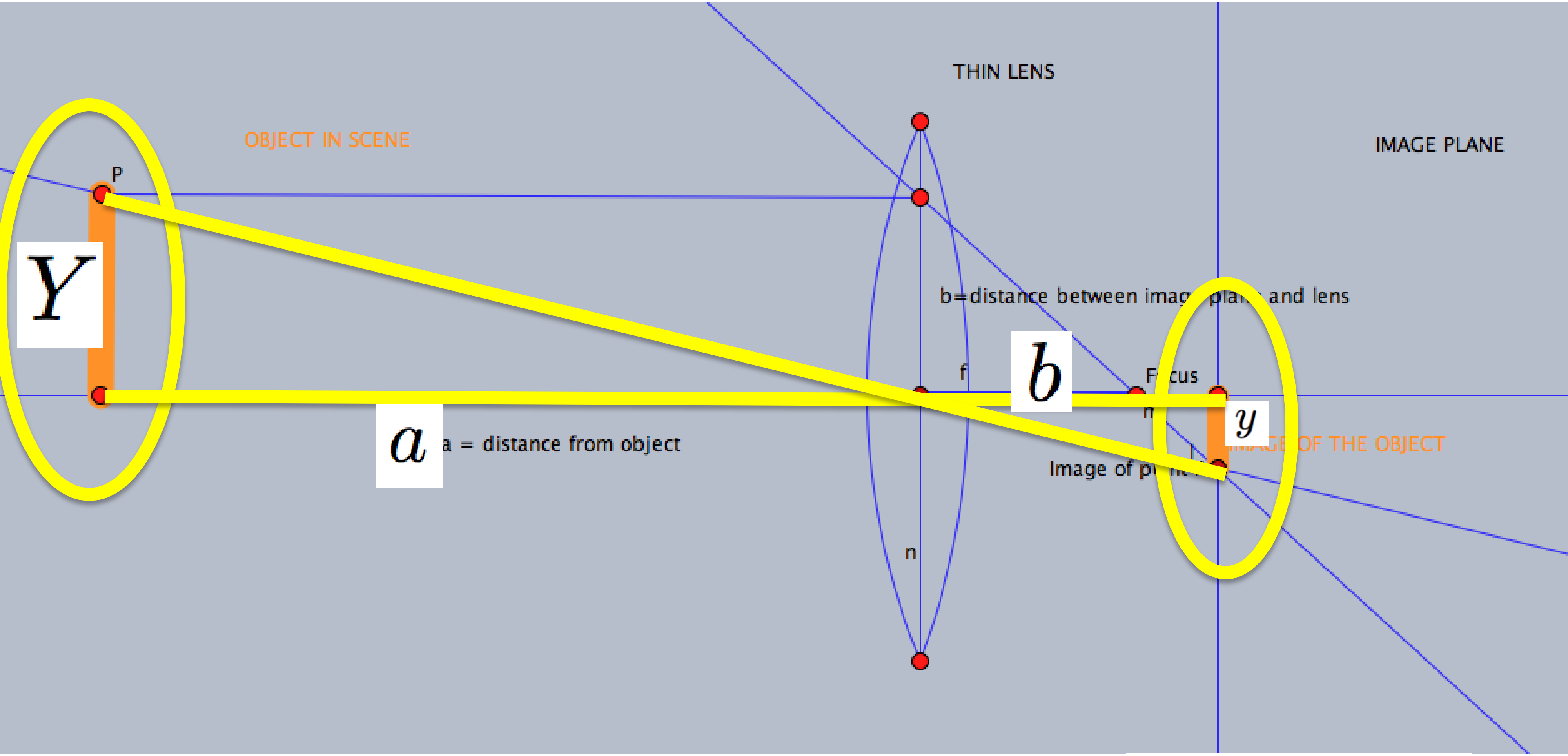
Perspective projection: size of object image



If you look only at the ray going through the center of the lens

$$\frac{Y}{a} = \frac{y}{b}$$

Perspective projection: size of object image



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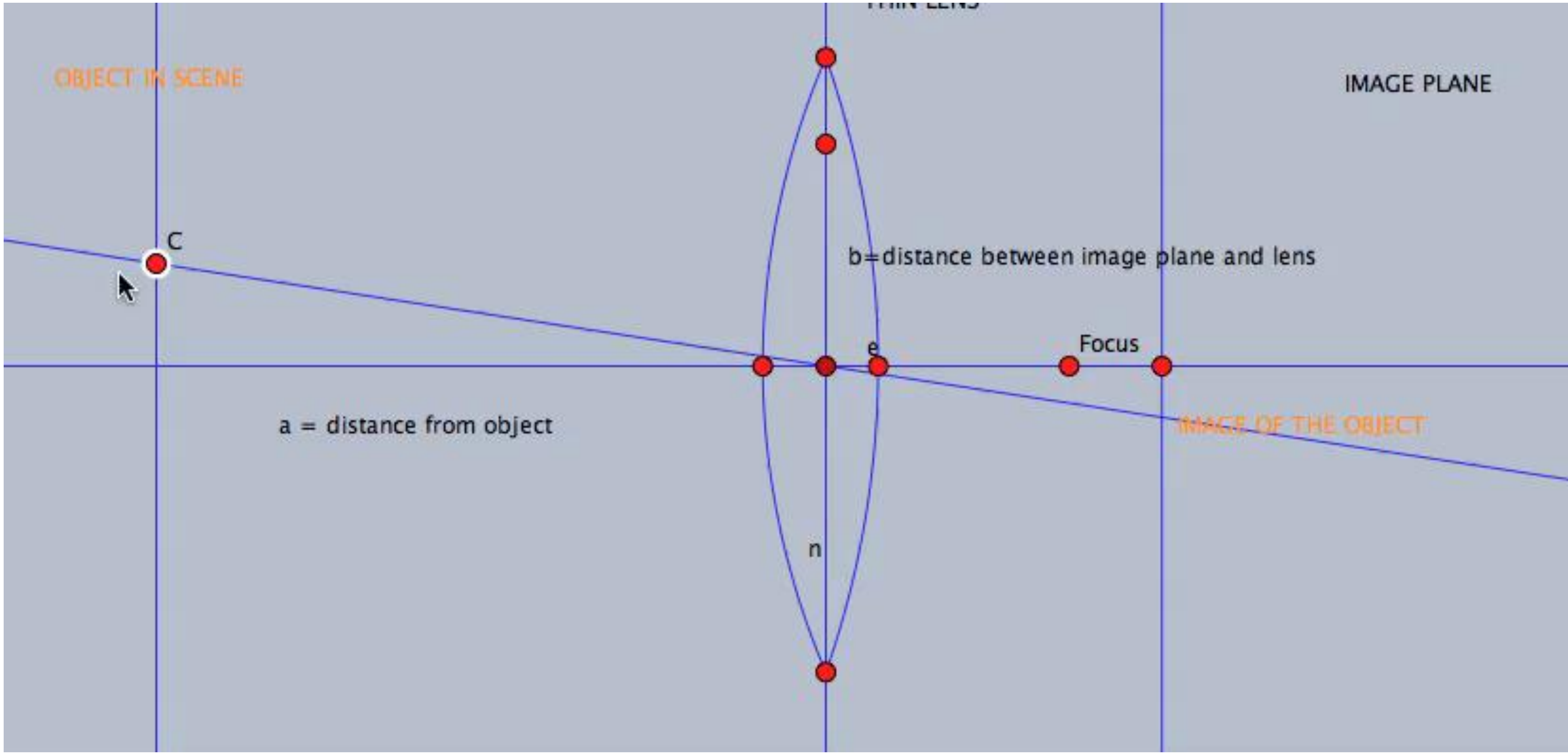
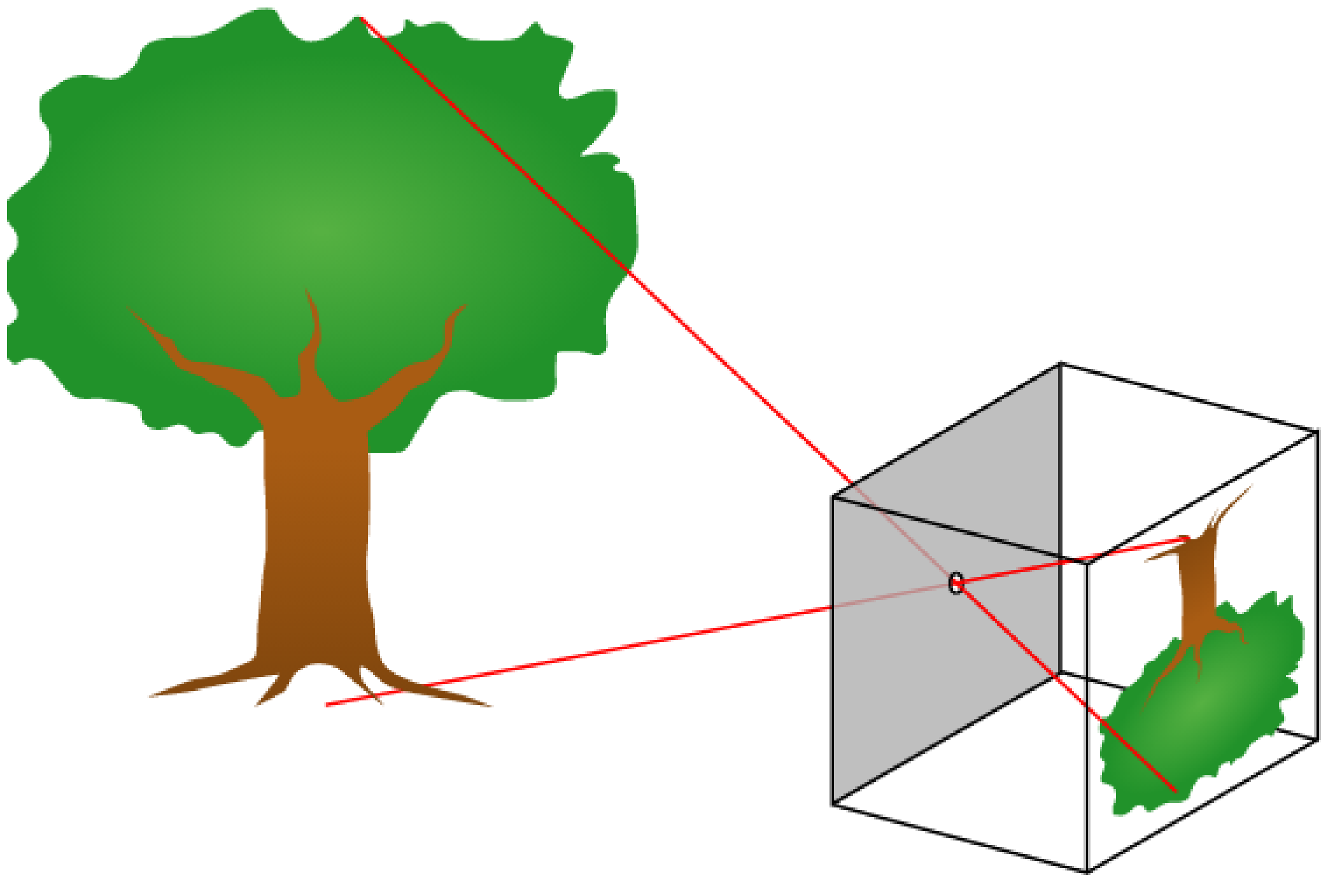
Perspective projection



- An object of the same size coming closer results on a larger image
- A point moving on the same ray does not change its image

$$\frac{Y}{a} = \frac{y}{b}$$

Perspective projection = Pinhole Model



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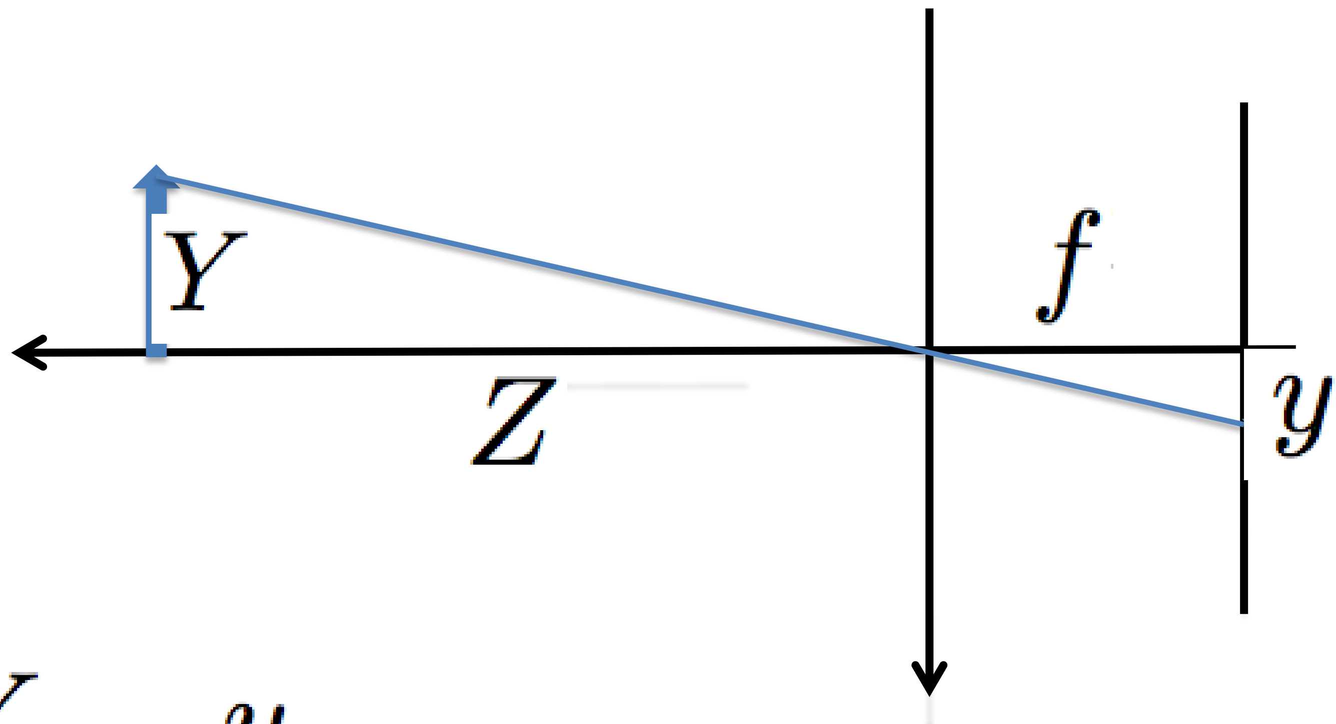
Pinhole model



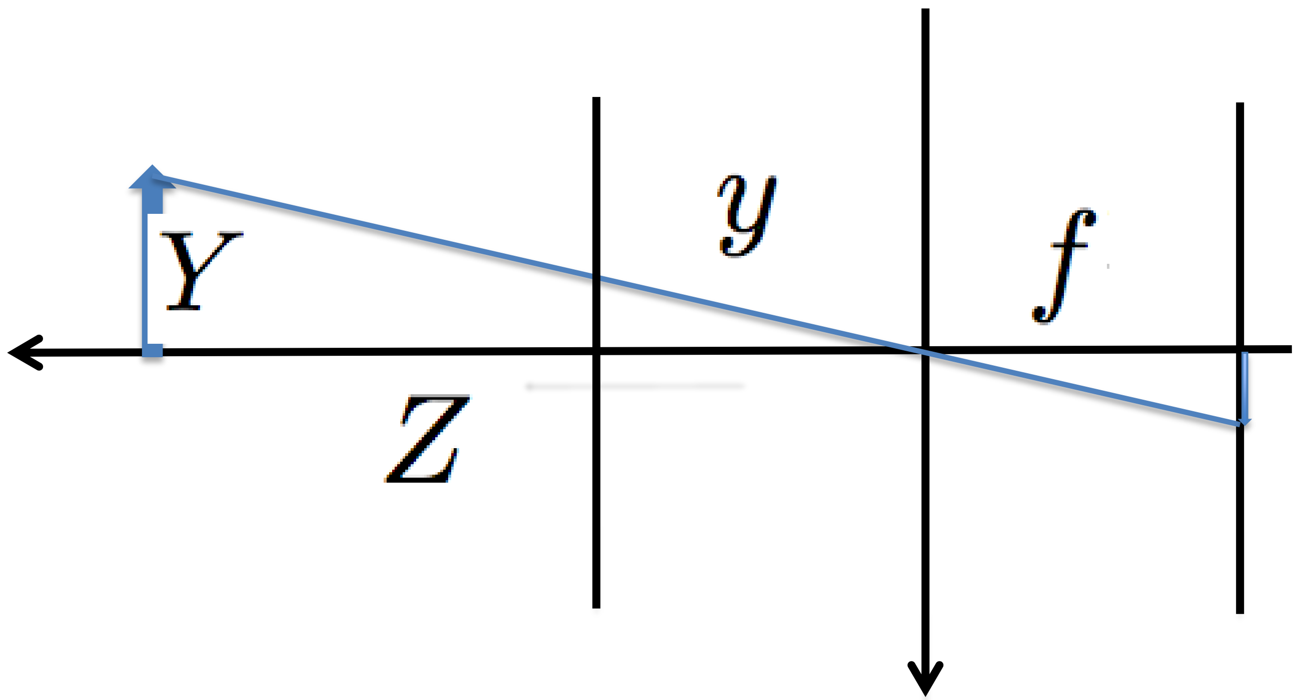
$$\frac{Y}{Z} = \frac{y}{b}$$

$$Z = a$$

If we replace b with f and include a minus because object image is upside down….

$$y = -f\frac{Y}{Z}$$

Pinhole model used in computer vision and robotics



... amd assume that image plane is in front of the lens

$$y = f\frac{Y}{Z}$$

What is the effect of f=b ?

- Theoretically, we expect an offset in the x and y coordinates caused by the error (f-b).
- If the object is on focus:

$$\frac{b-f}{f} = \frac{b}{Z}$$

Relative error depends on the ratio of focal length to depth !
This would matter if we would actually use the f from specs of the camer

In practice we use a process called calibration,
yielding the f that best satisfies

$$y = f\frac{Y}{Z}$$