

Computational Photography

- * Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and collaborating on, and sharing photographs.



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Cameras, Optics, and Sensors

* Cameras' Lenses and Impact
of Focal Length on Photography

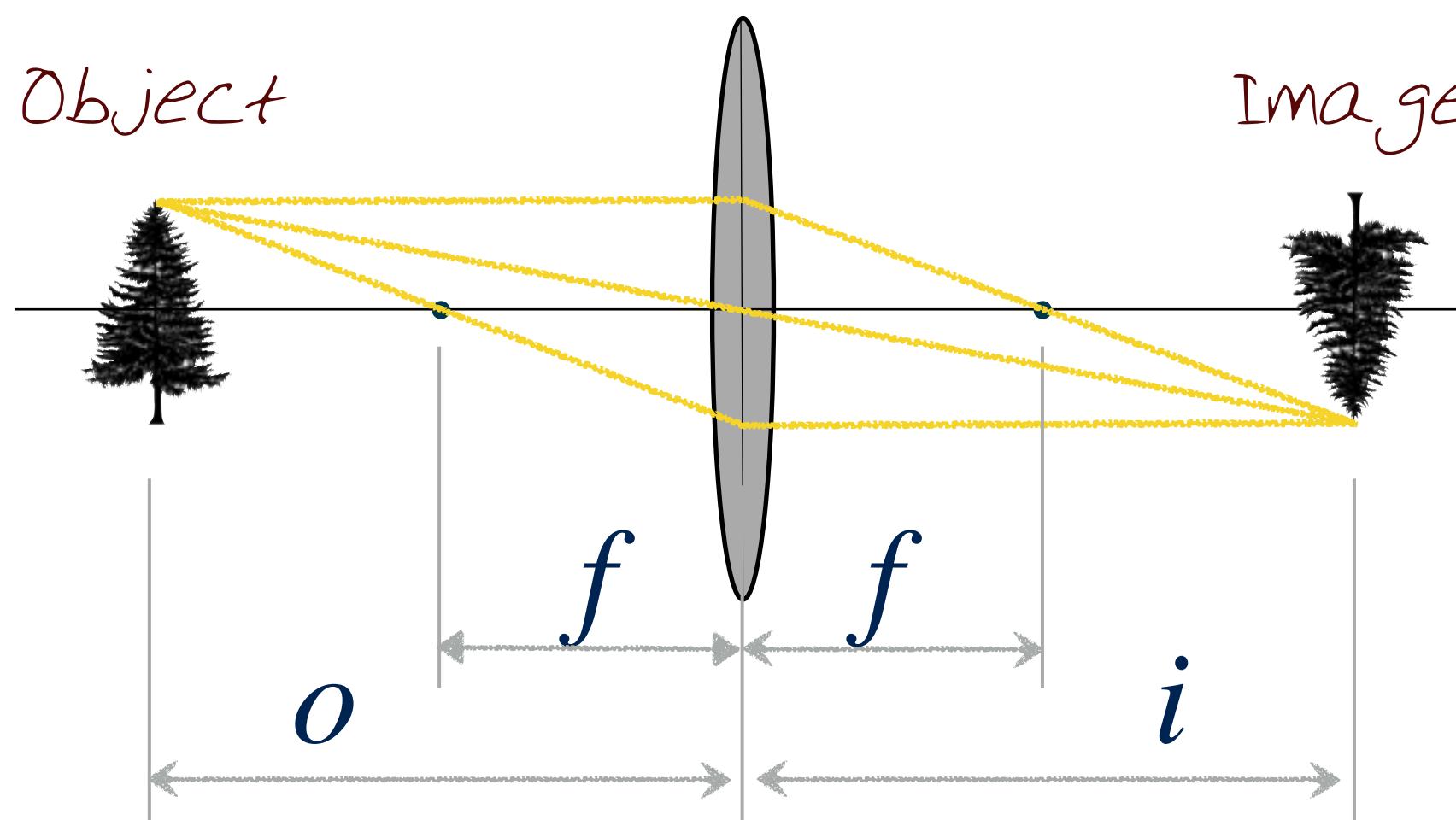


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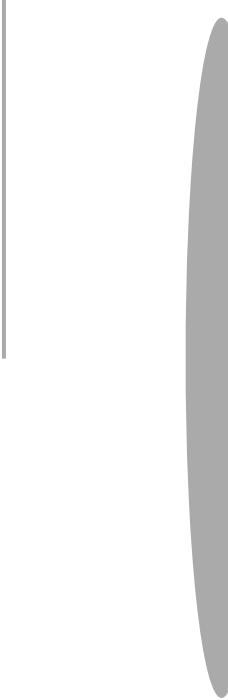
1. Focal Length
2. Field of View (FOV)
3. Sensor Size
4. Image Formation & Capture
5. Perspective Projection

Recall: Ray Tracing with Lenses

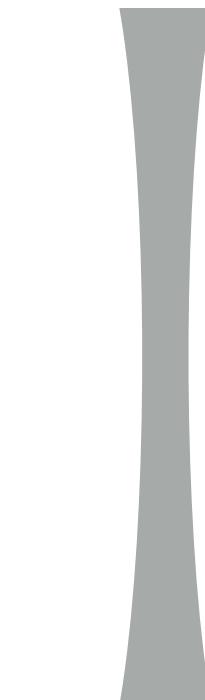


Thin lens equation

$$\frac{1}{O} + \frac{1}{i} = \frac{1}{f}$$

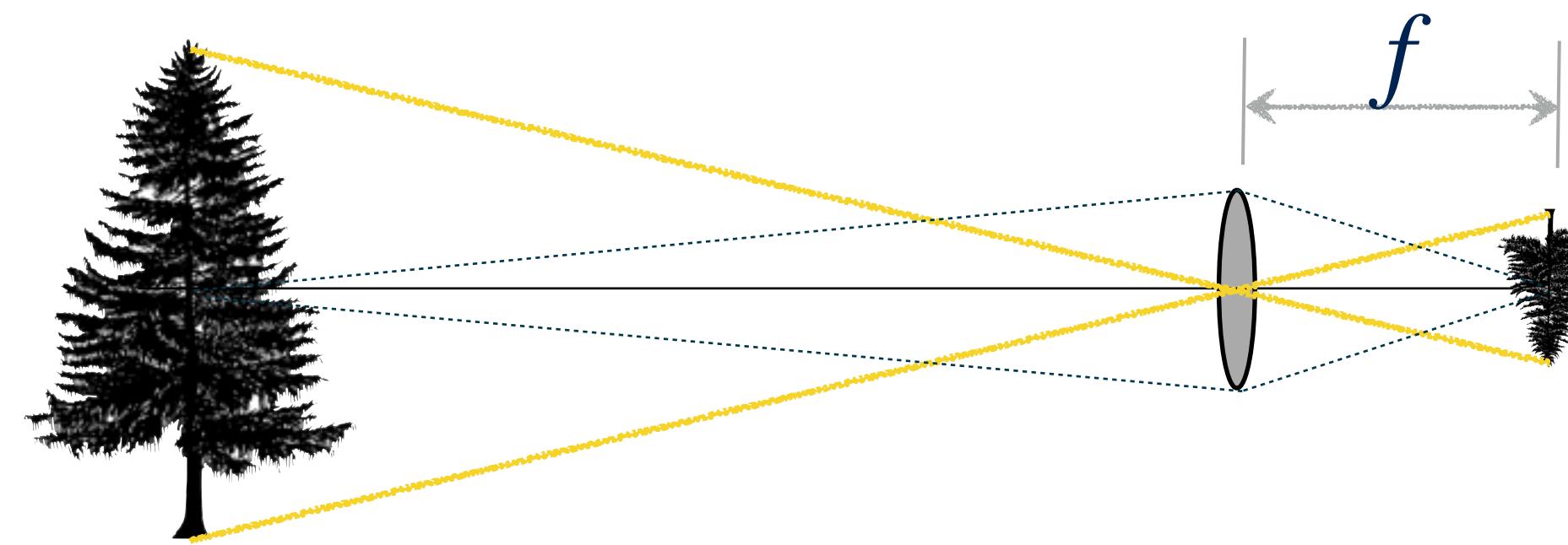


CONVEX

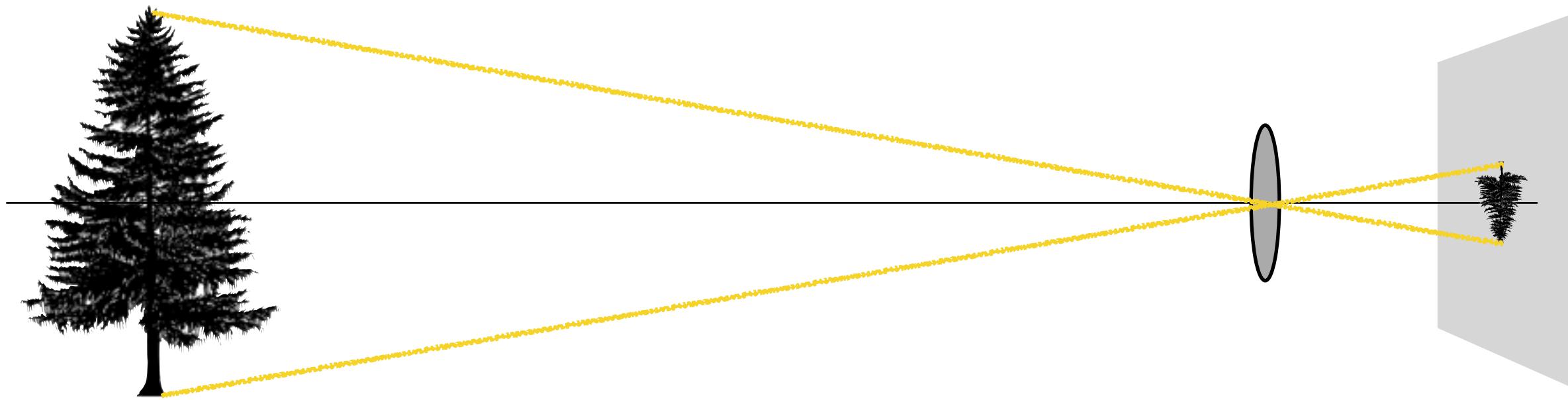
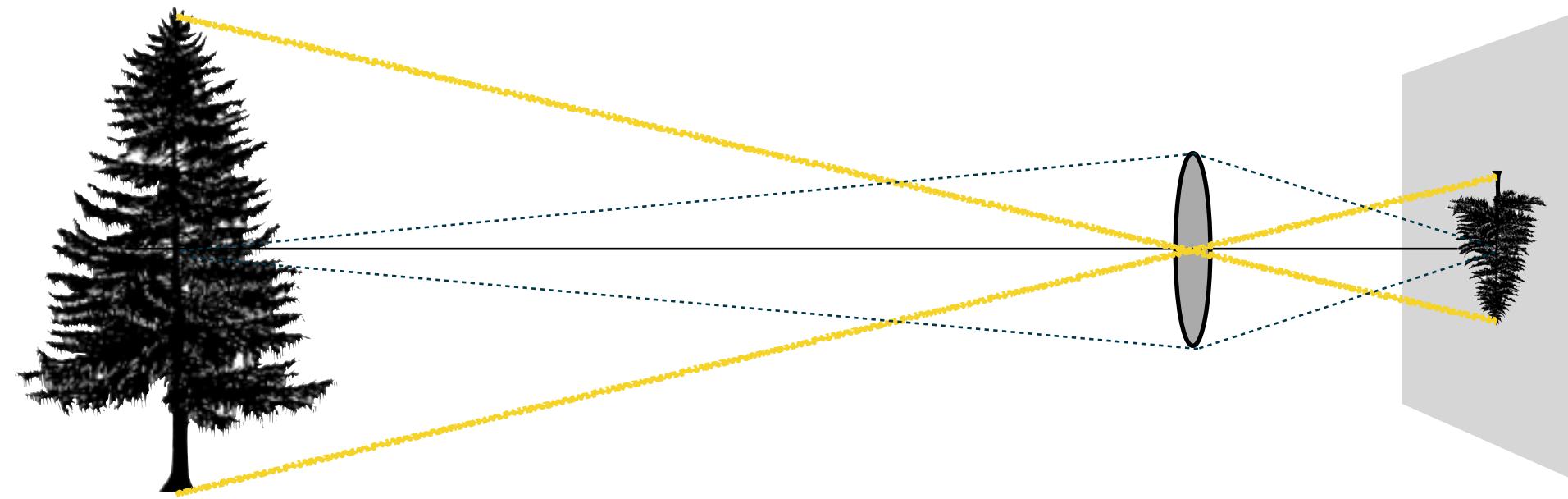


CONCAVE

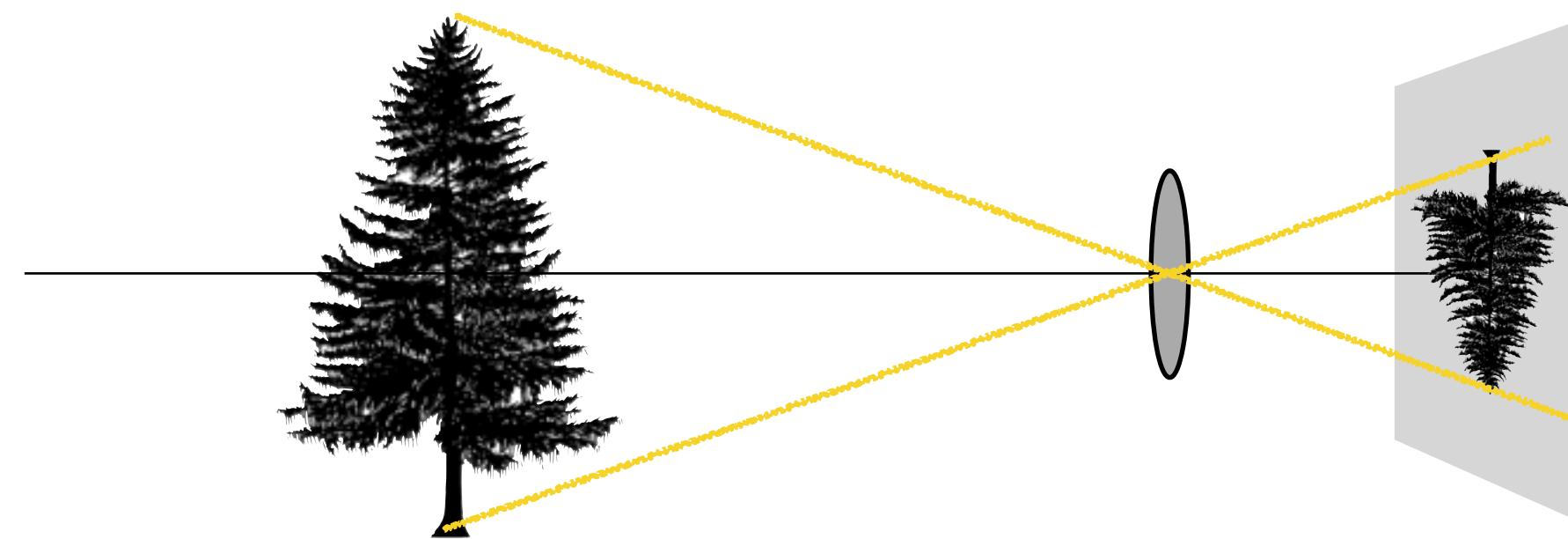
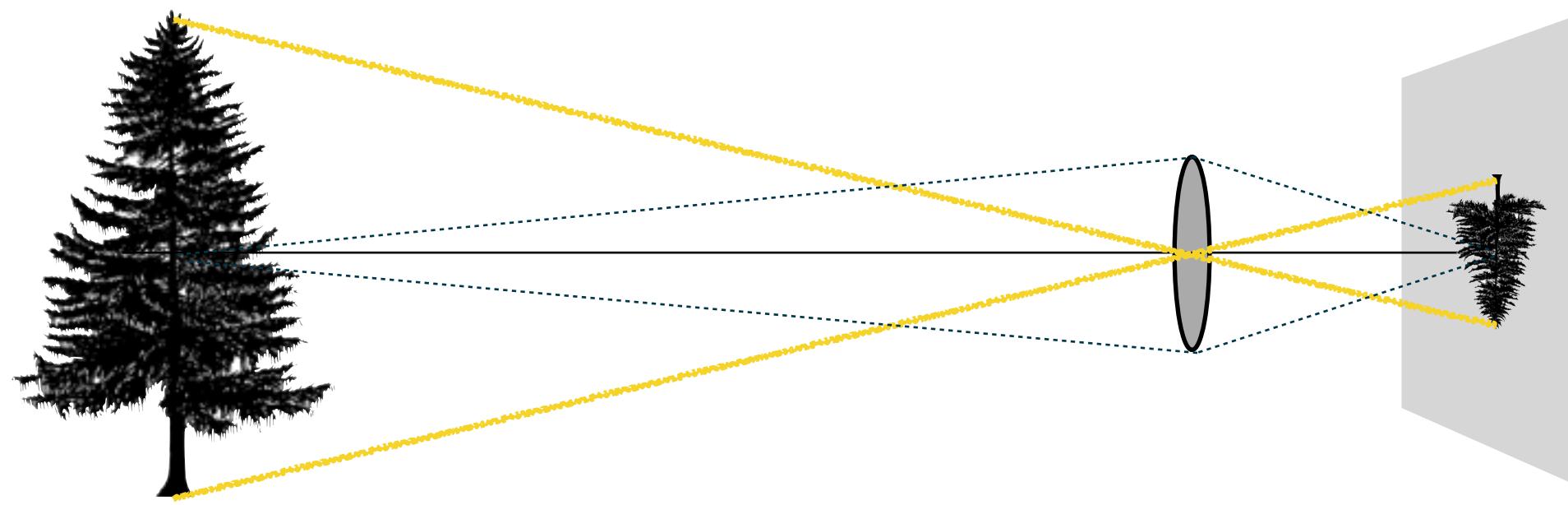
Image Formation



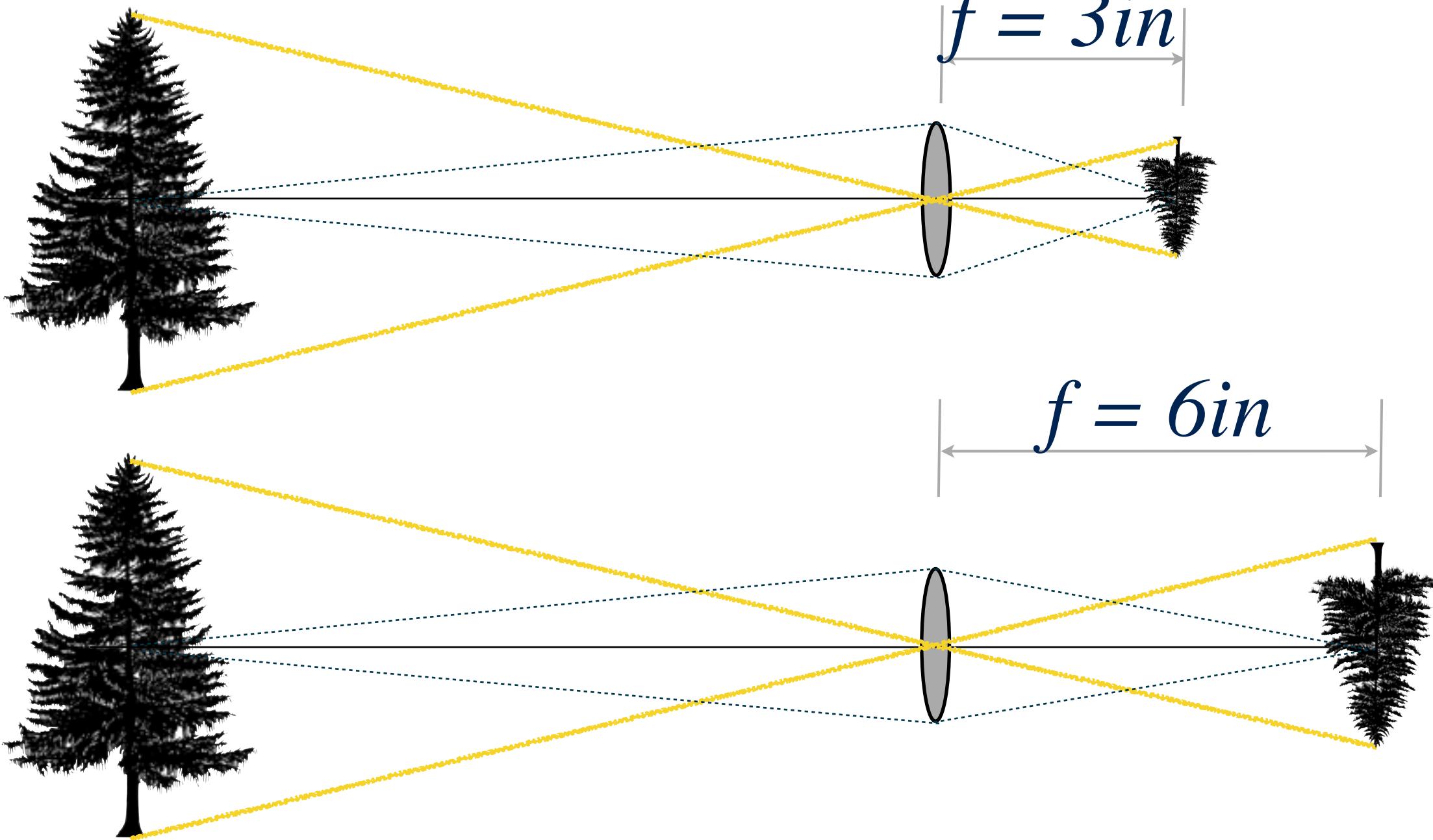
Changing object distance



Changing distances!



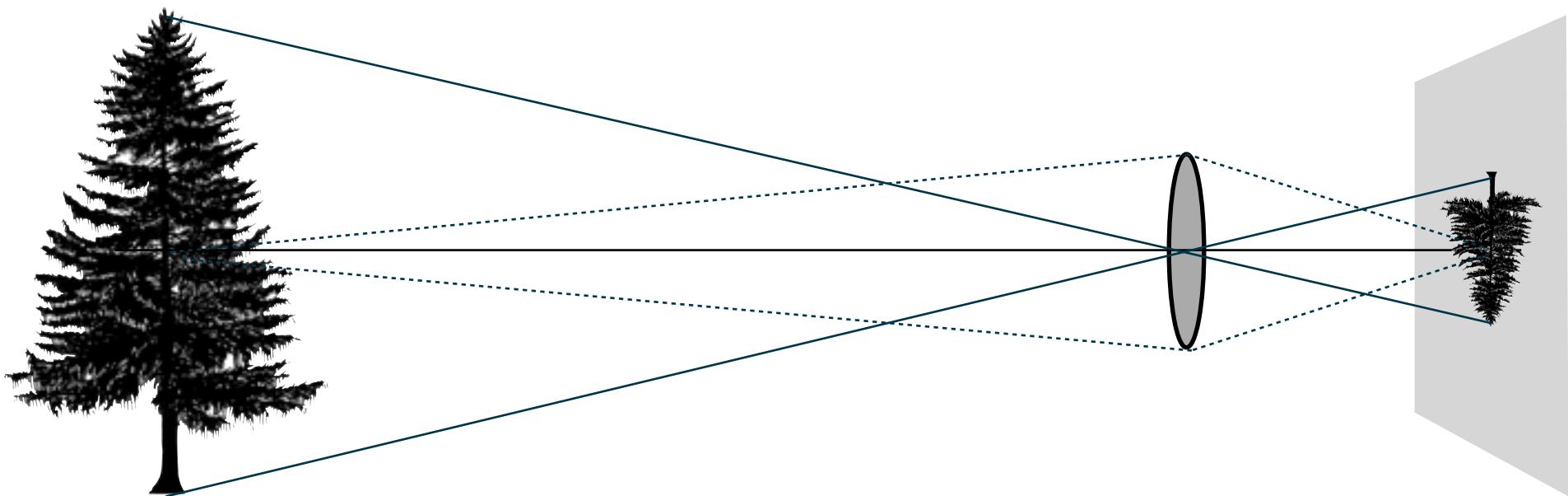
Changes in Focal Length



* Longer or shorter f

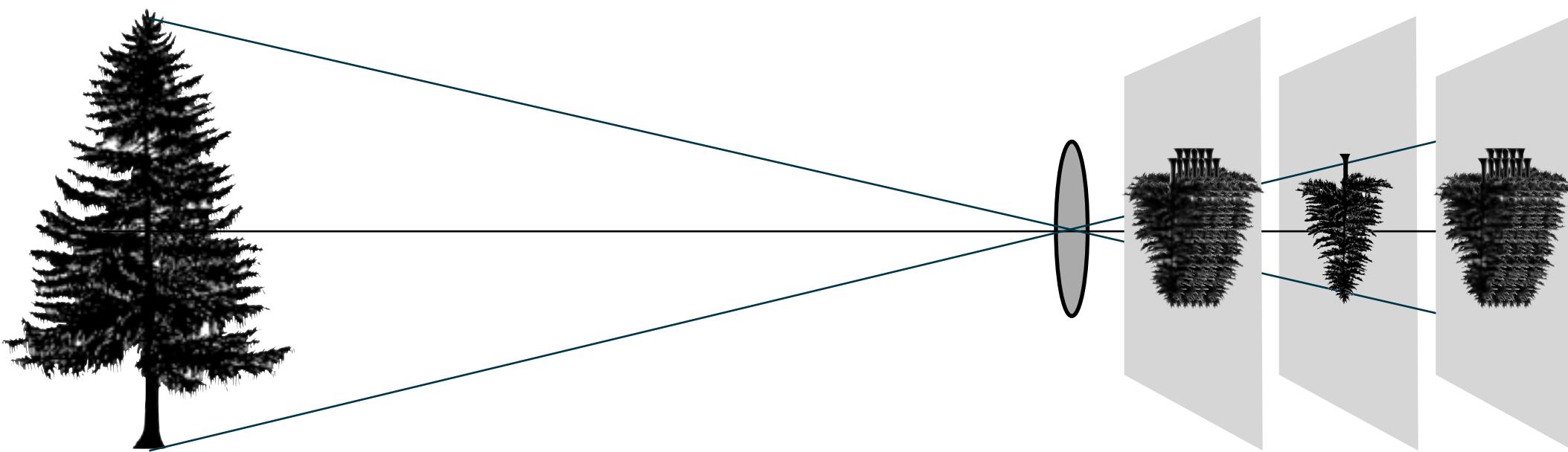
* focal lengths are specific to lenses

Focussing

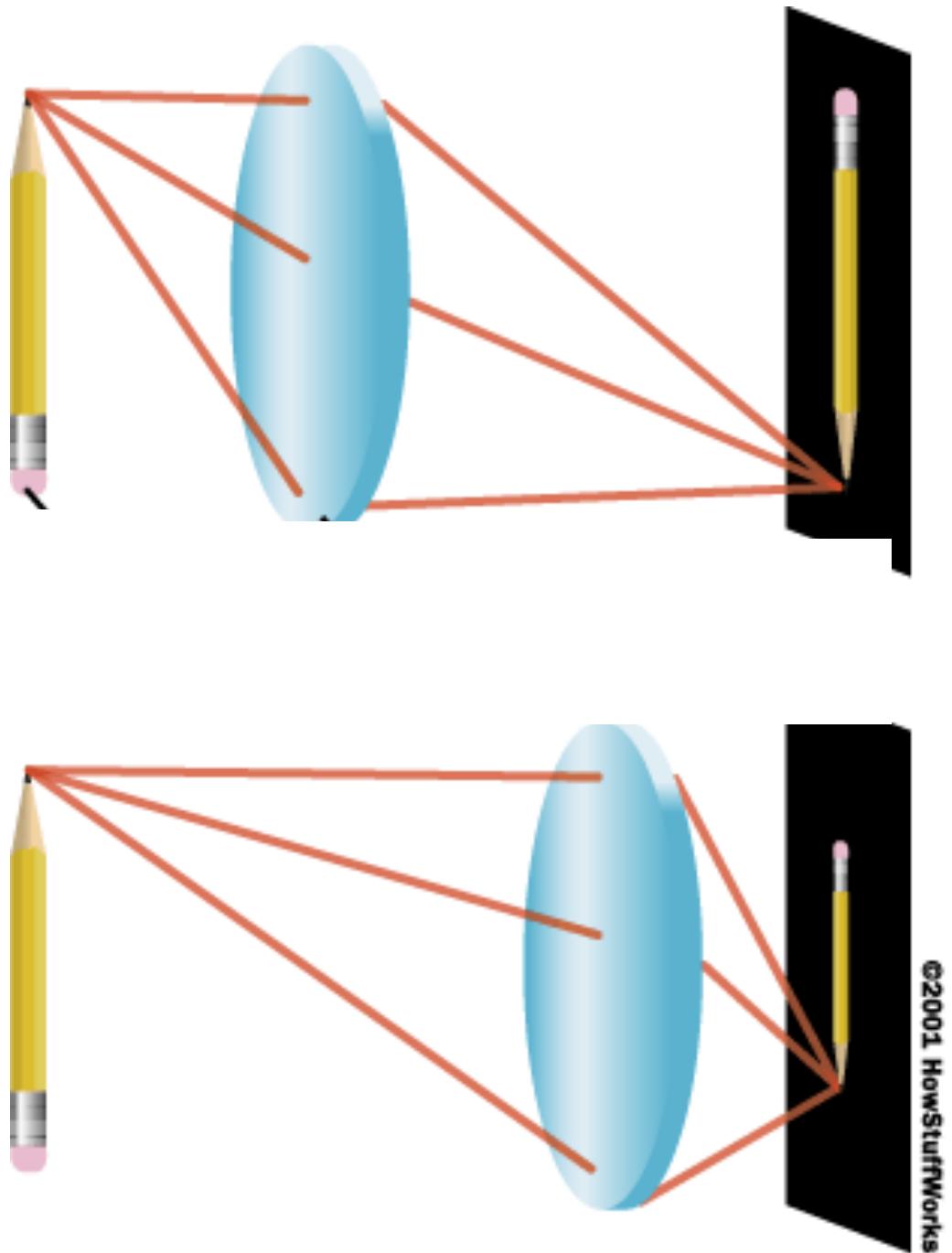


*

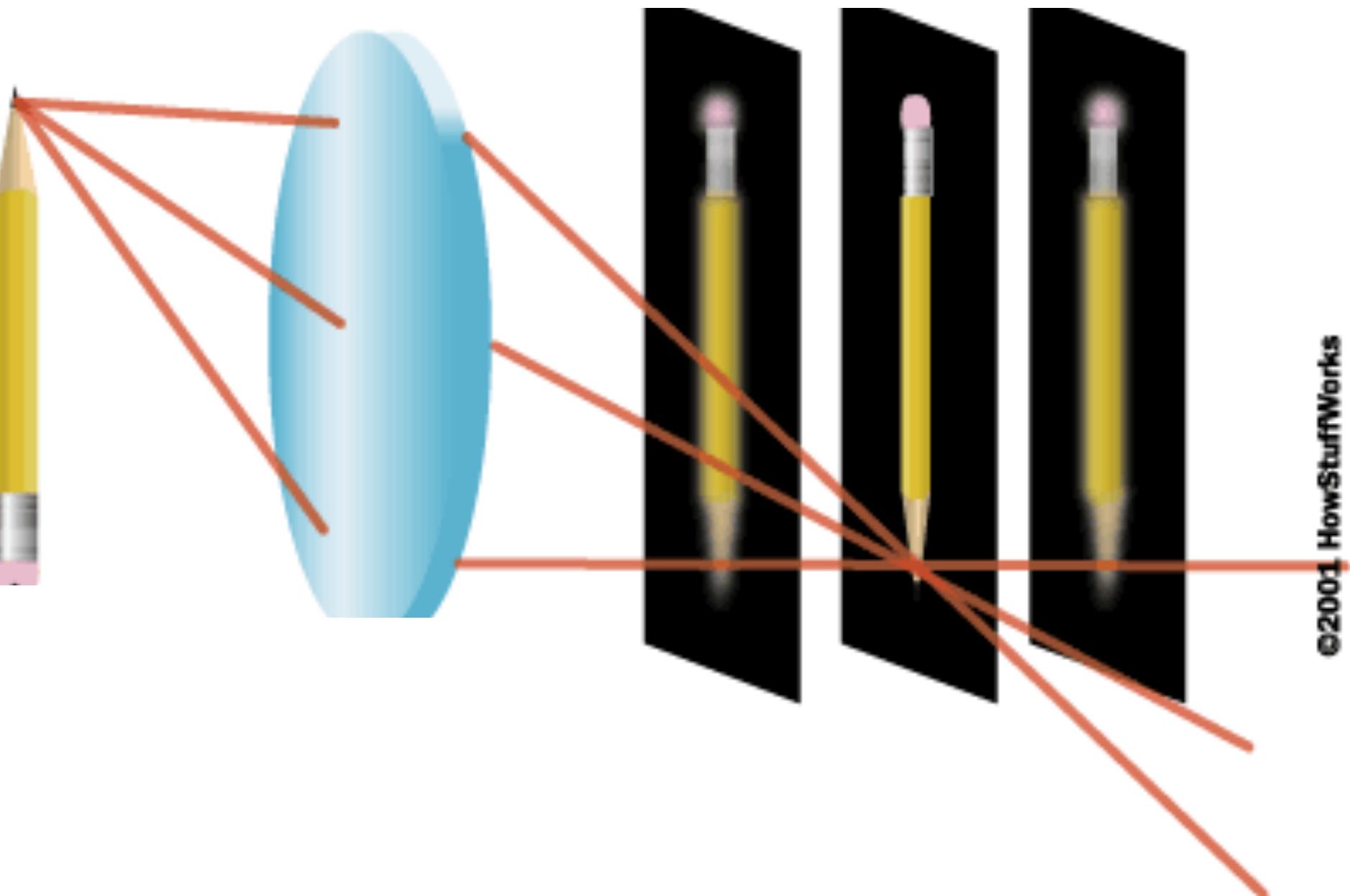
focusing:
moving
sensor back
(or
forward)
wrt to lens



Focussing

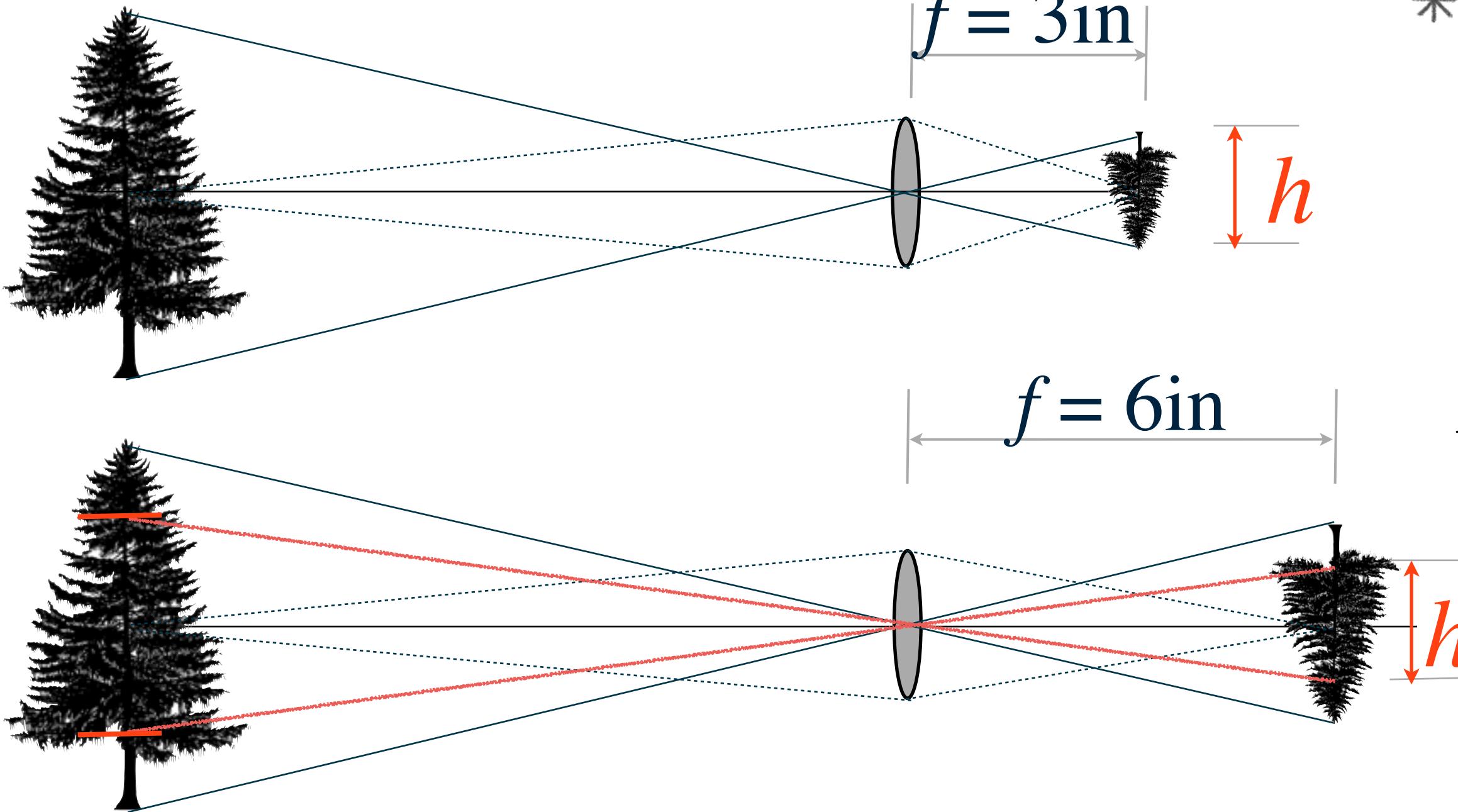


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from howstuffworks.com

Field of View (FOV)

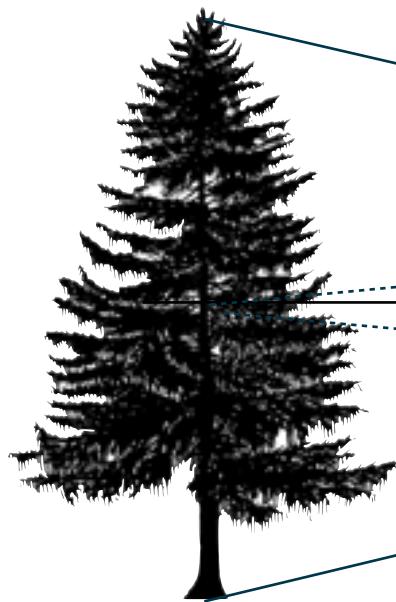


* Field of View (FOV) depends on sensor size, h

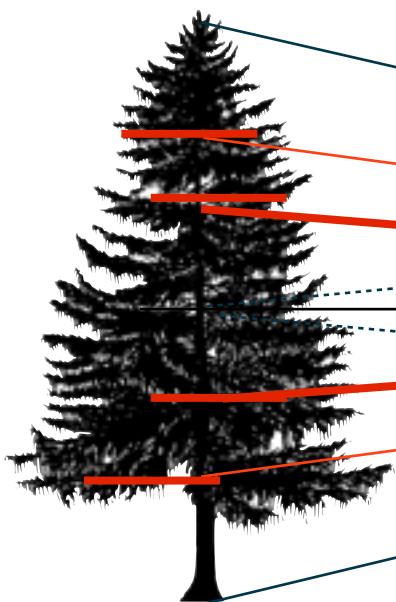
$$FOV = 2 \tan^{-1} \frac{h}{2f}$$

Slide adapted from mark Levoy

Field of View (FOV) Sensor Size



* sensor size
small, FOV is
small too



* smaller
sensors have
fewer pixels,
or noisier
pixels

$$FOV = 2 \tan^{-1} \frac{h}{2f}$$

Slide adapted from Mark Levoy

12 mm

24mm

50mm

85mm

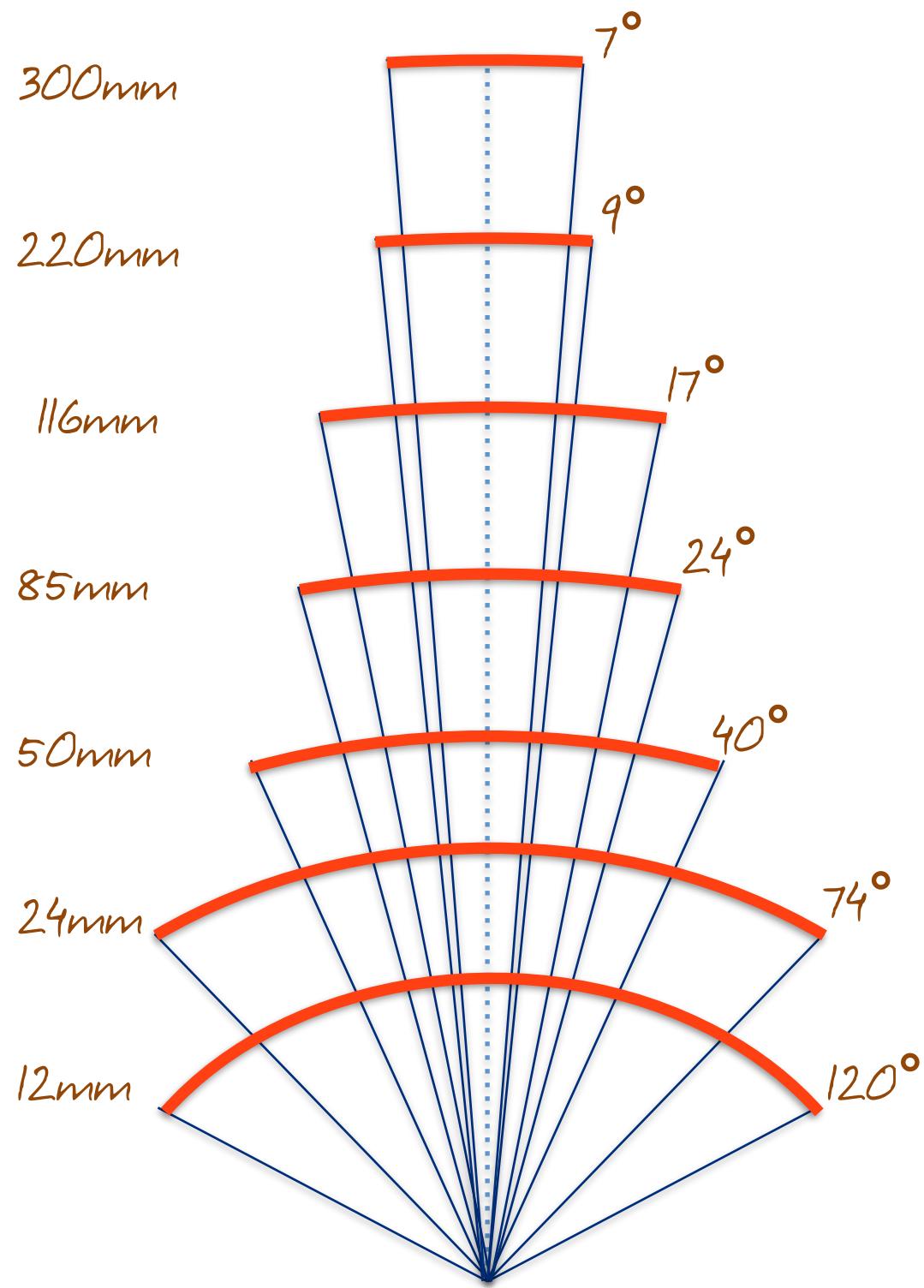
116mm

220mm

300mm



Focal Length and Field of View (FOV)



Photos by Henrik Christensen

Sensor Sizes

8.8 X 6.6 mm
(1:2) micro 2/3

4.54 X 3.52mm
(iPhone 5)

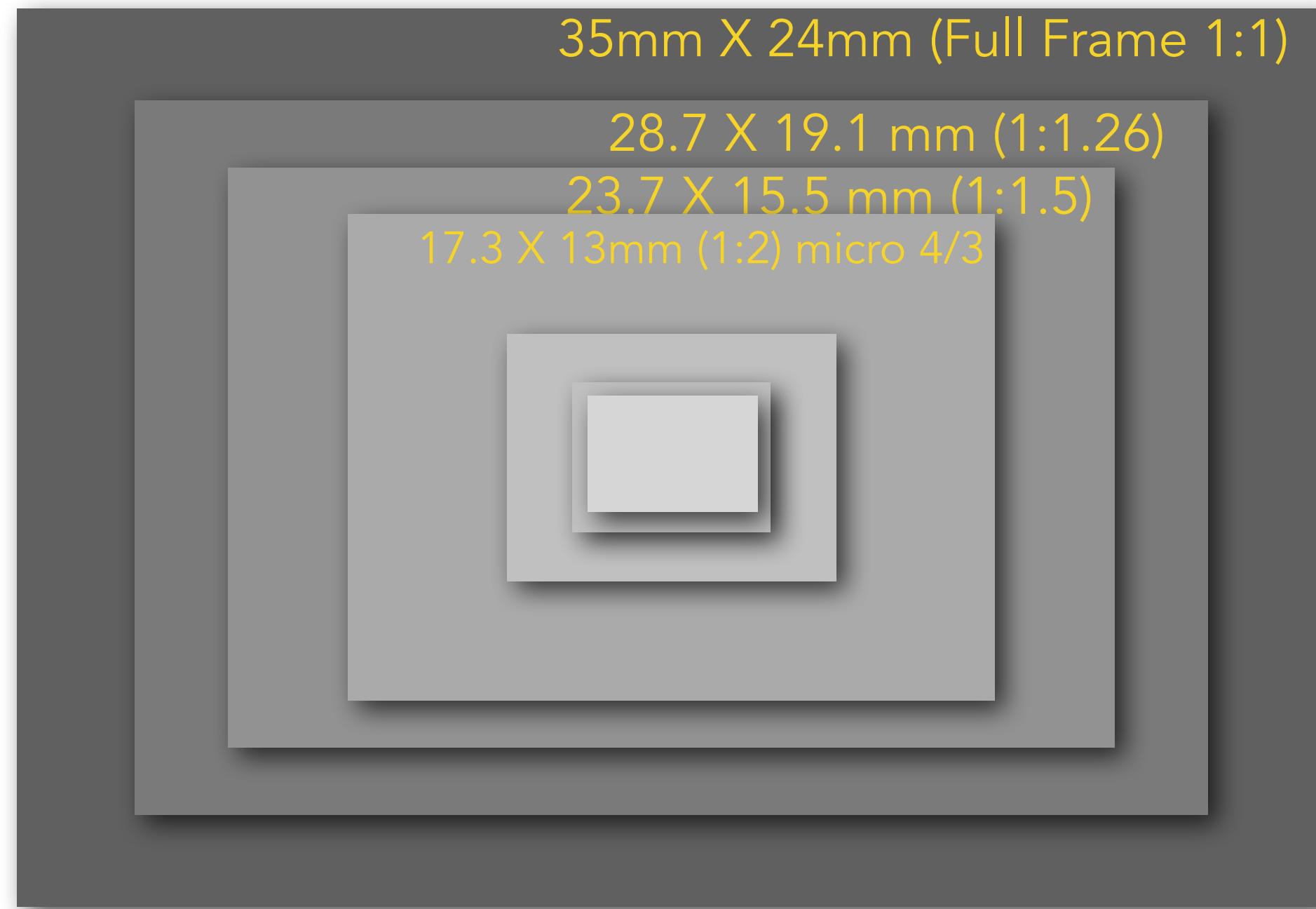
35mm X 24mm (Full Frame 1:1)

28.7 X 19.1 mm (1:1.26)

23.7 X 15.5 mm (1:1.5)

17.3 X 13mm (1:2) micro 4/3

7.25 X 5.33mm



Focal Length vs. Viewpoint



$f = 18\text{mm}$, 35mm sensor

Distance to 1st Subject = 0.5m Distance to 1st Subject = 3.0m

Distance to 2nd Subject = 2.0m Distance to 2nd Subject = 4.5m



$f = 180\text{mm}$, 35mm sensor

- * Changing focal length allows us to move back, and still capture the scene
- * Changing viewpoint causes perspective changes
- * See the "vertigo" effect from Hitchcock movies

Camera as a Window in a 3D World



Geometry (Perspective)

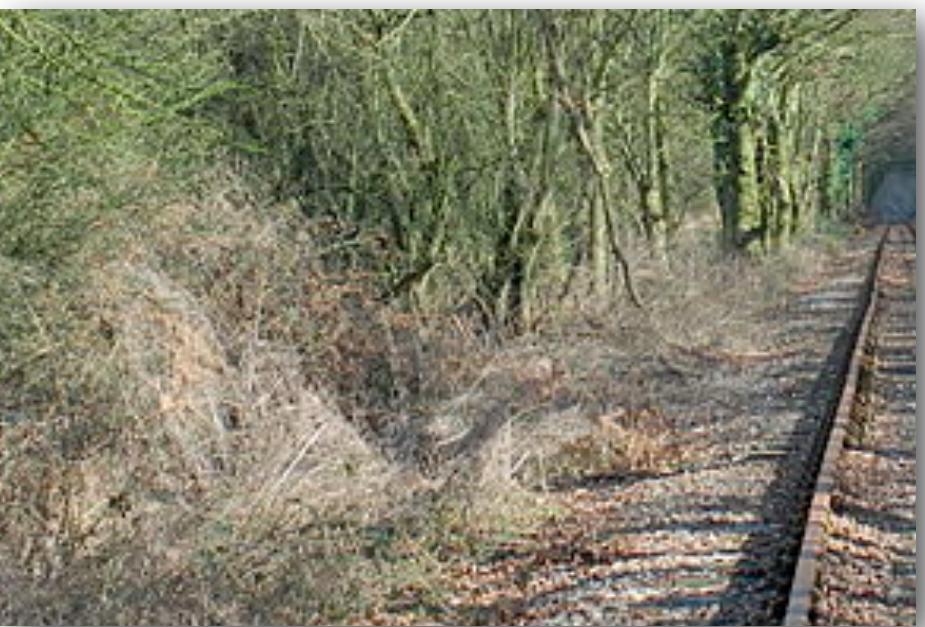
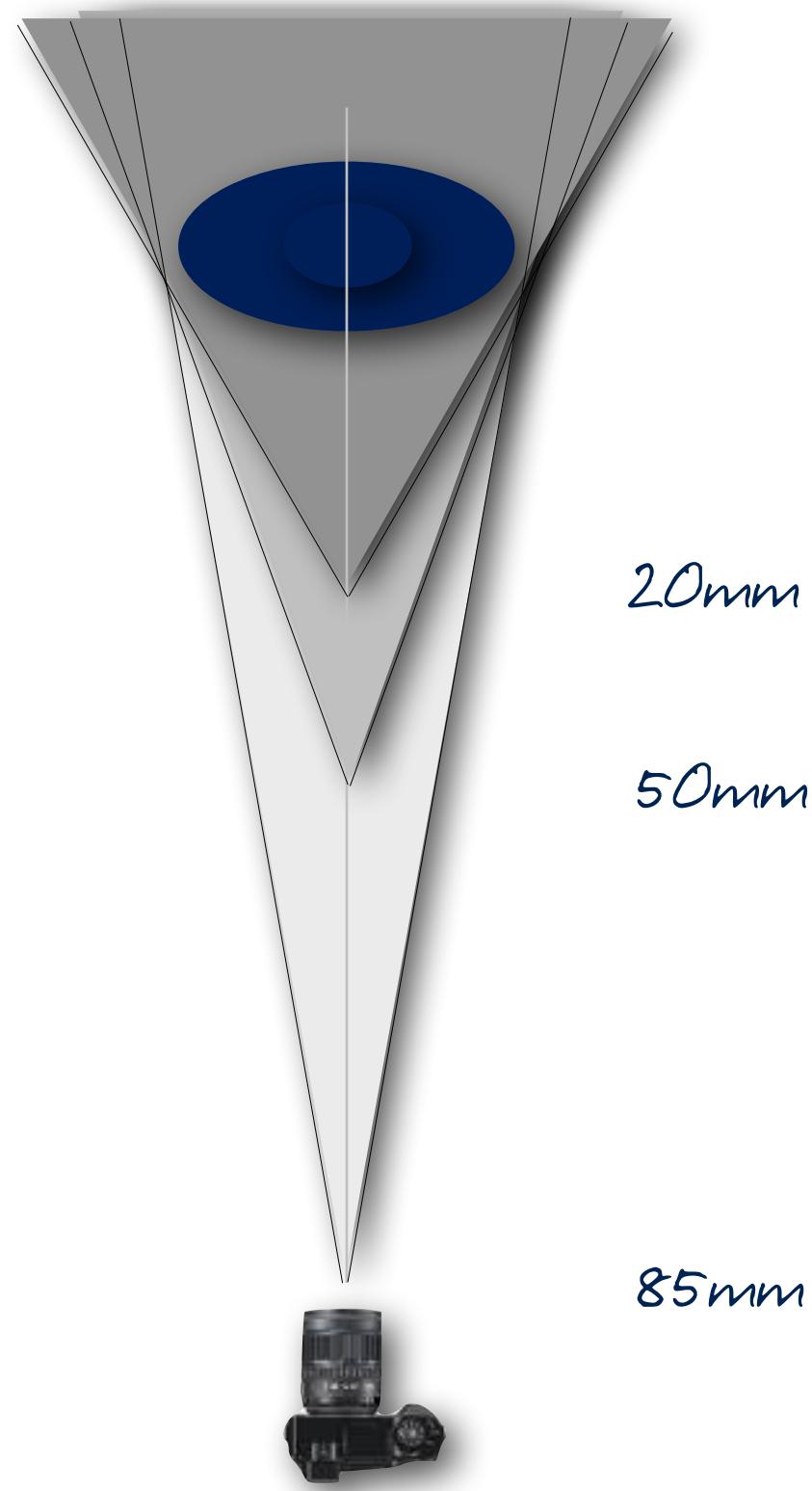
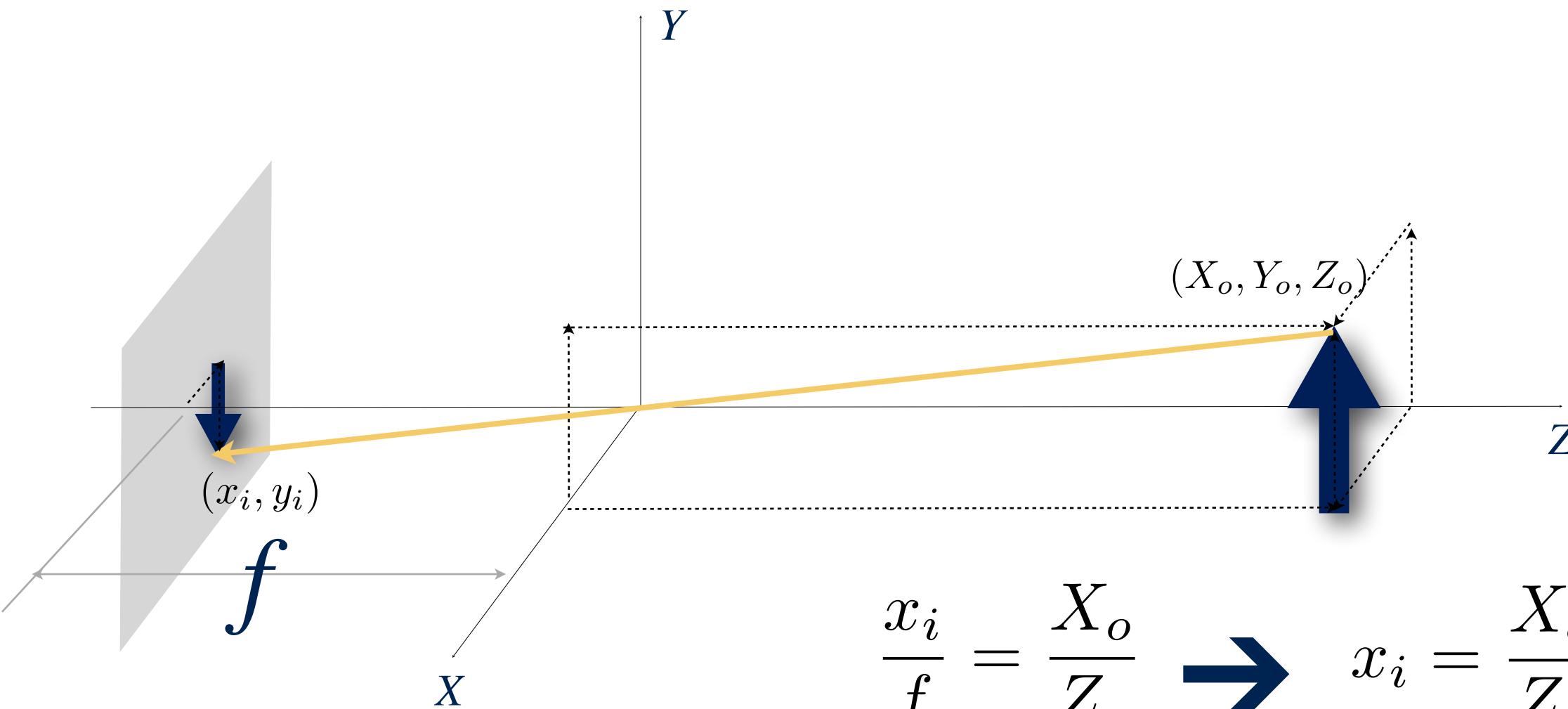


Image: Wikimedia Commons



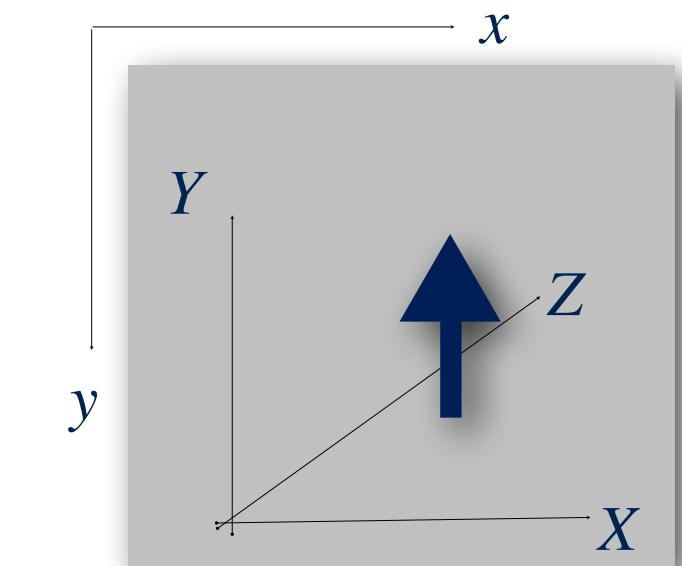
A Camera Model



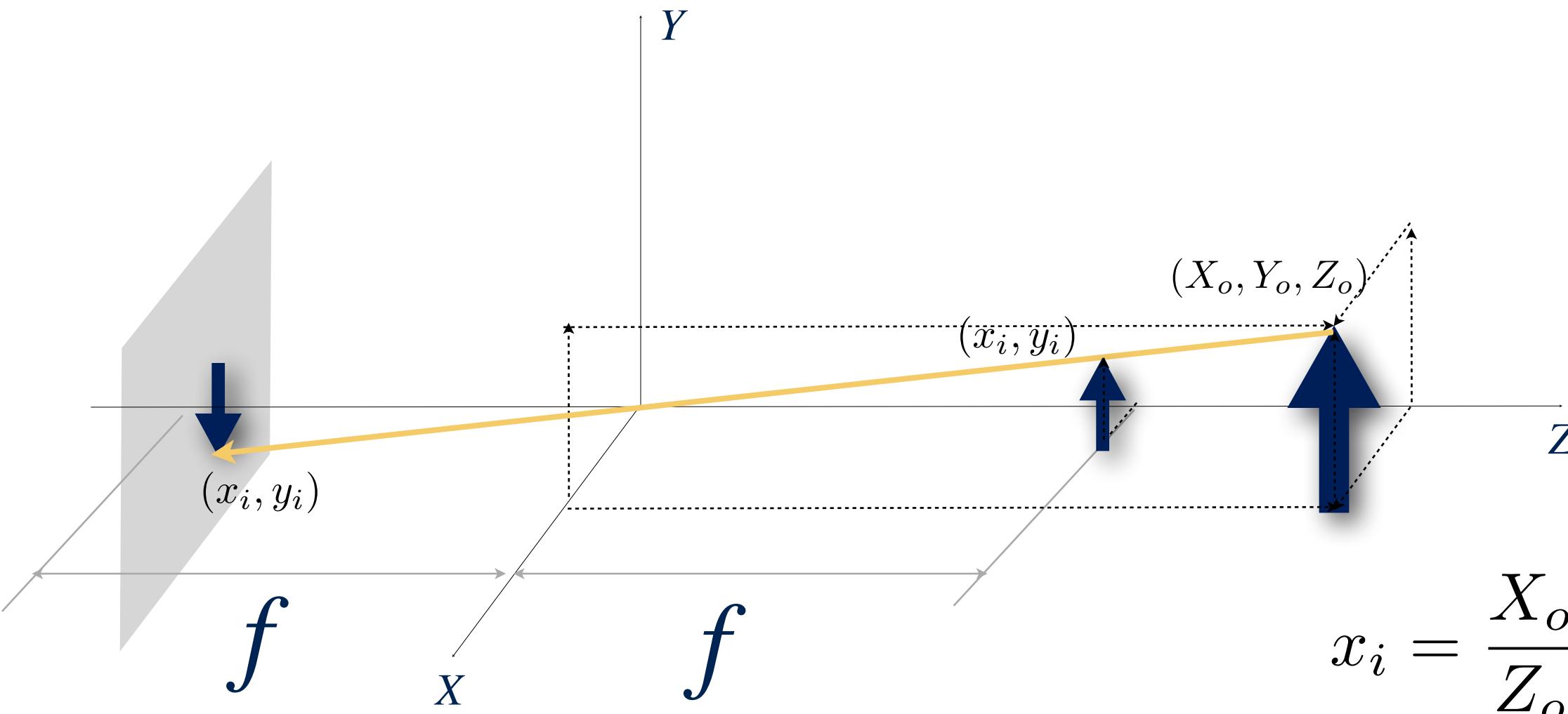
Using similar triangles

$$\frac{x_i}{f} = \frac{X_o}{Z_o} \rightarrow x_i = \frac{X_o}{Z_o} f$$

$$\frac{y_i}{f} = \frac{Y_o}{Z_o} \rightarrow y_i = \frac{Y_o}{Z_o} f$$

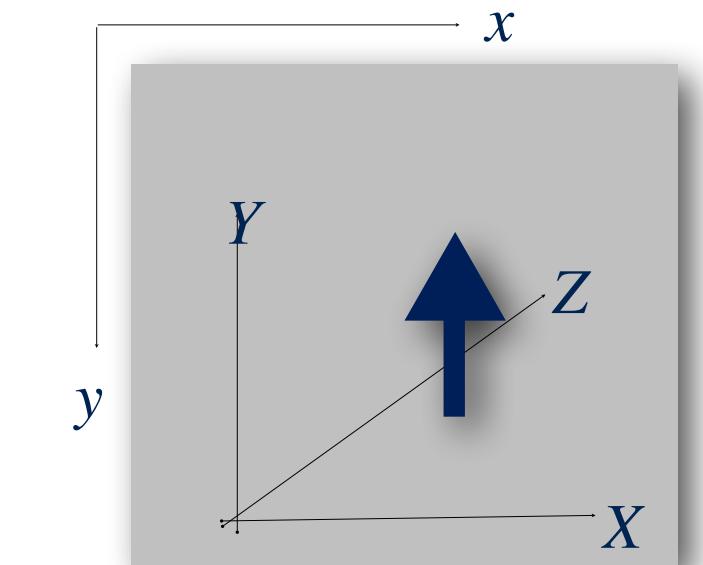


A Camera Model: Perspective

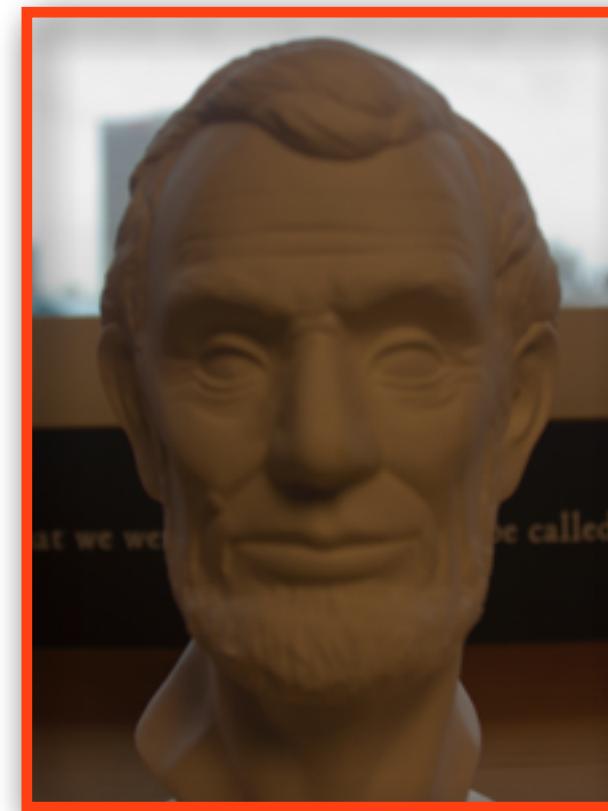
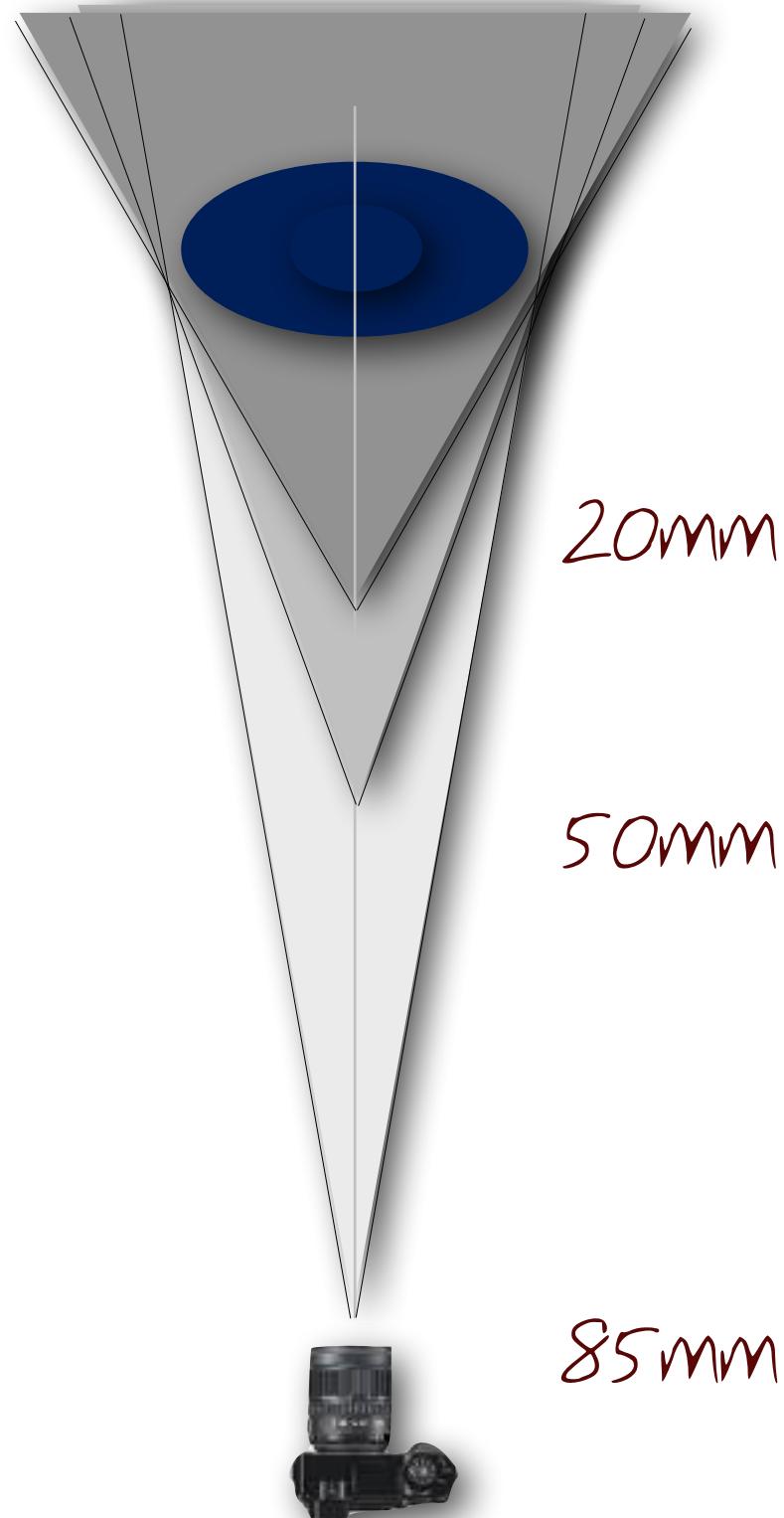


$$x_i = \frac{X_o}{Z_o} f$$

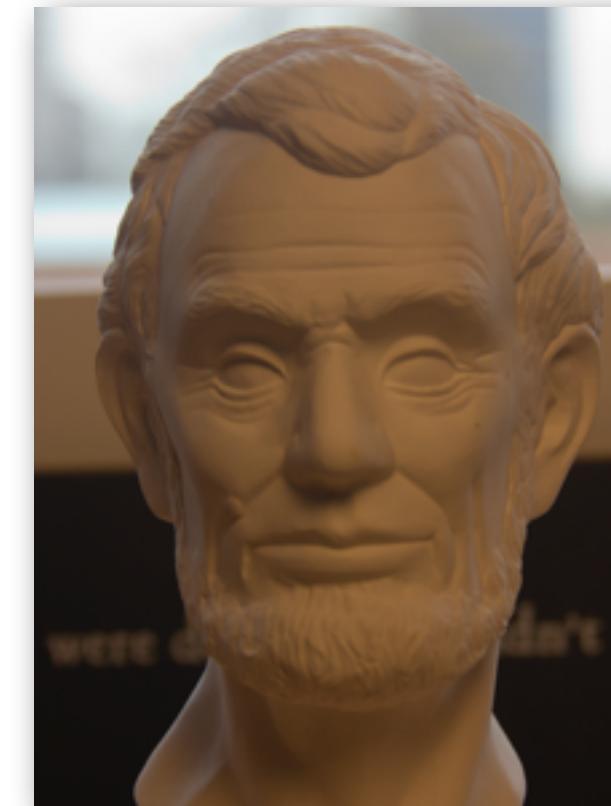
$$y_i = \frac{Y_o}{Z_o} f$$



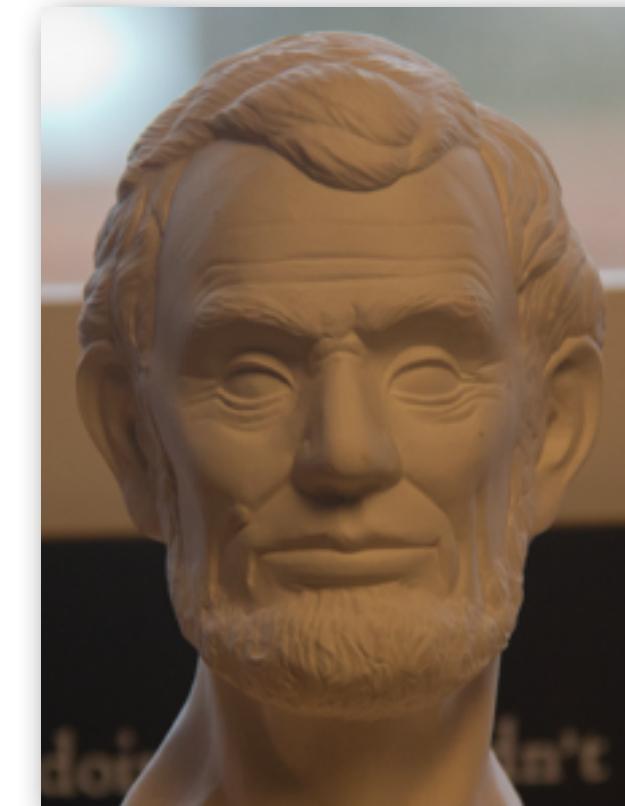
Focal Length for Portraits



20
mm



50
mm



85
mm

Traditionally, 75-135mm focal length
(I prefer 85mm) are used for Portraits

Summary



- * Brought together the concepts of Focal Length, FOV and Sensor Size
- * Discussed the impact of Focal Length on Image Formation/Capture
- * Explained Perspective Projection for a camera with a Focal Length

Neat Class

- * Camera
- * Exposure Triangle
- * Aperture
- * Shutter Speed
- * ISO





Credits

- * For more information, see
 - * Hecht, E. (2002) Optics, 4th ed. Reading, MA: Addison-Wesley and
 - * London, B., Stone, J., & Upton, J. (2011), Photography, 10th ed. Upper Saddle River, NJ: Prentice Hall.
- * Some images retrieved from
 - * <http://commons.wikimedia.org/>.
 - * <http://electronics.howstuffworks.com/camera1.htm>
 - * List available on website.
- * Some Slides adapted from mark Levoy.
- * Photos by Henrik Christensen and Irfan Essa.

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