

Digital Image : How To Capture Images

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CIVE 497 – CIVE 700: Smart Structure Technology



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Real-World Scenes and Digital Images



What we see

Camera



Image processing
Computer Vision

0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0

What a computer sees

What is the Pixel?

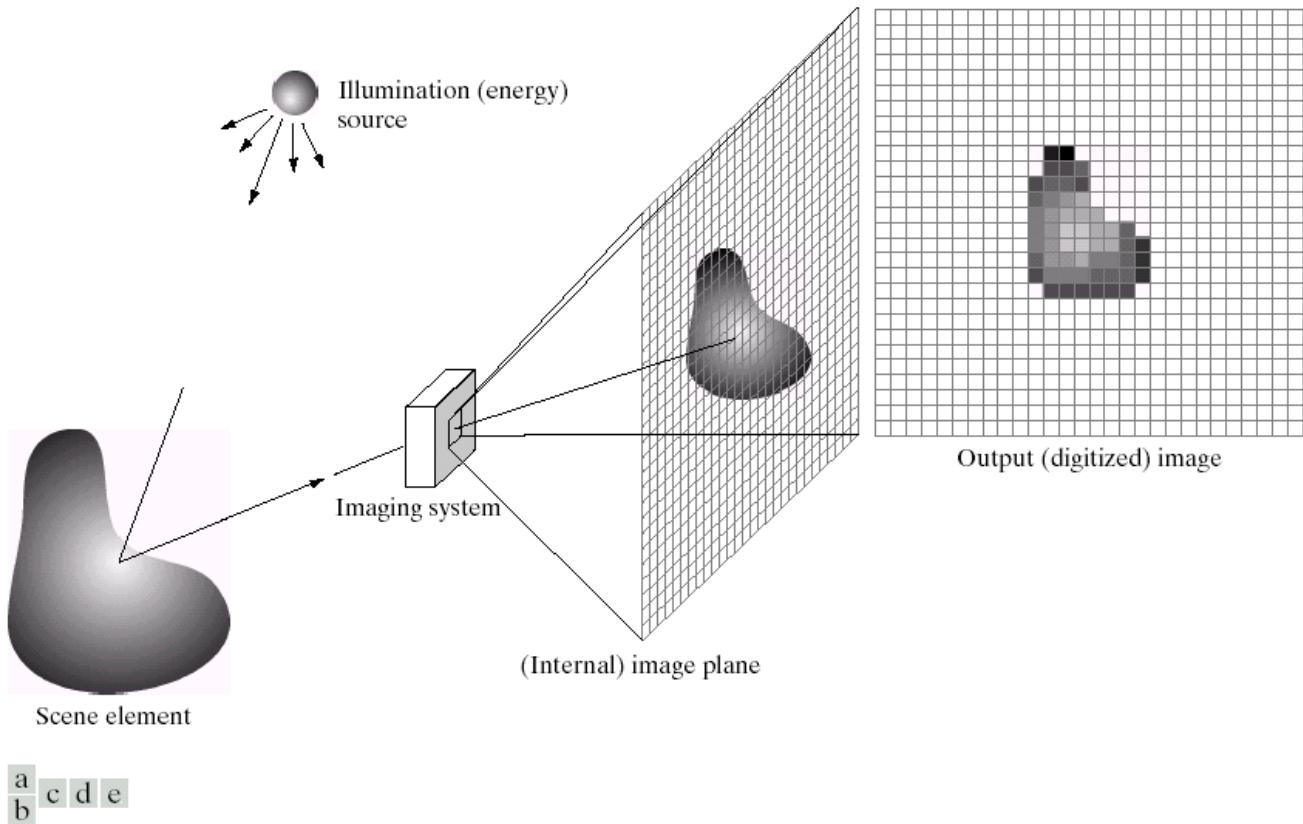


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy (“illumination”) source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

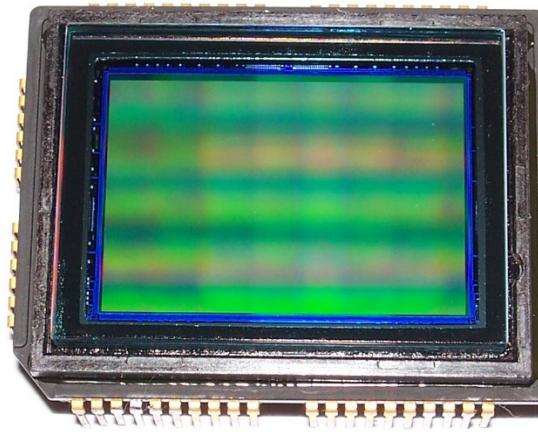
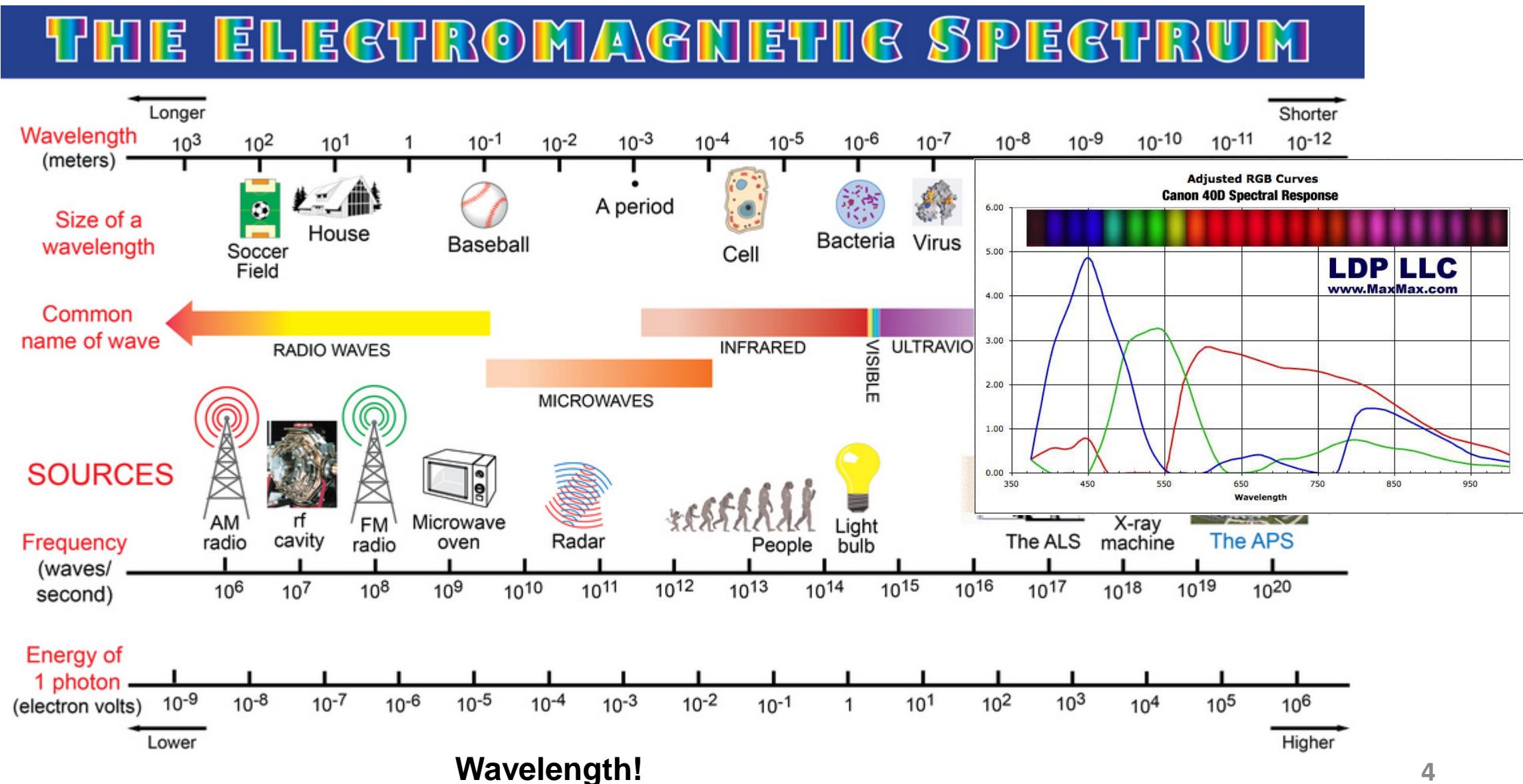


Image sensor

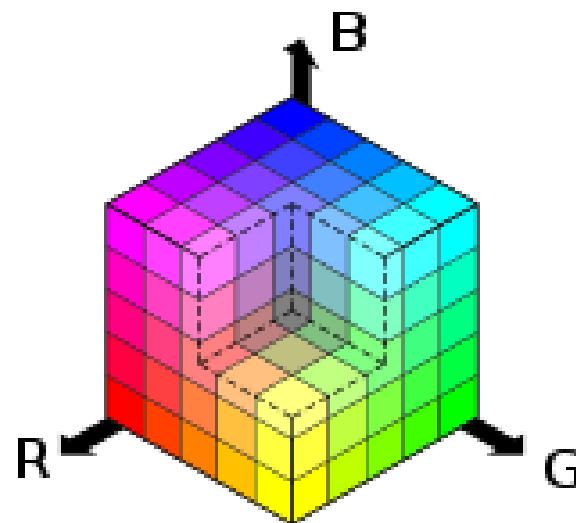
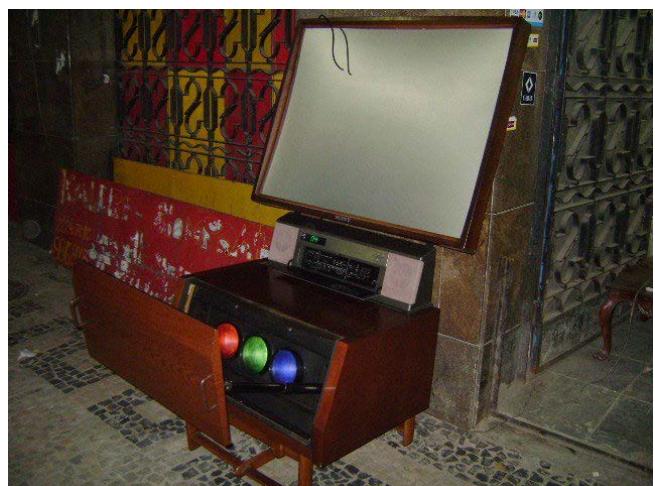
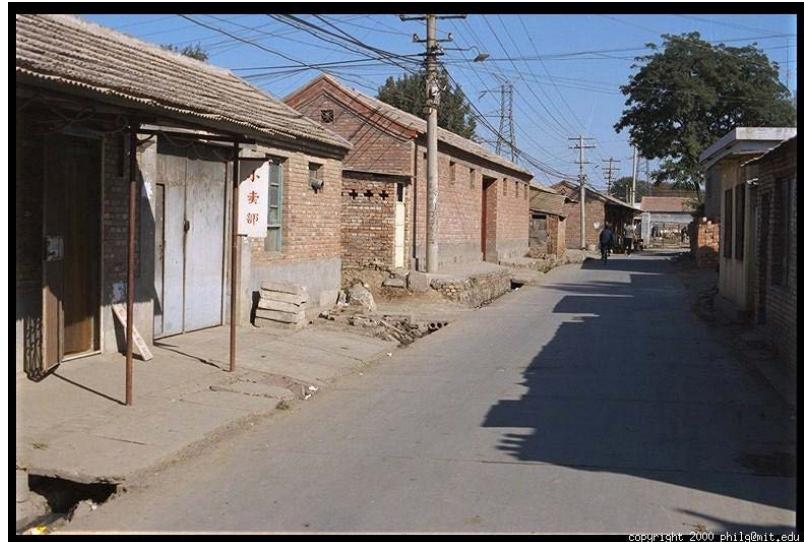


DSLR camera

Visible Light Spectrum



Color Images



R



G

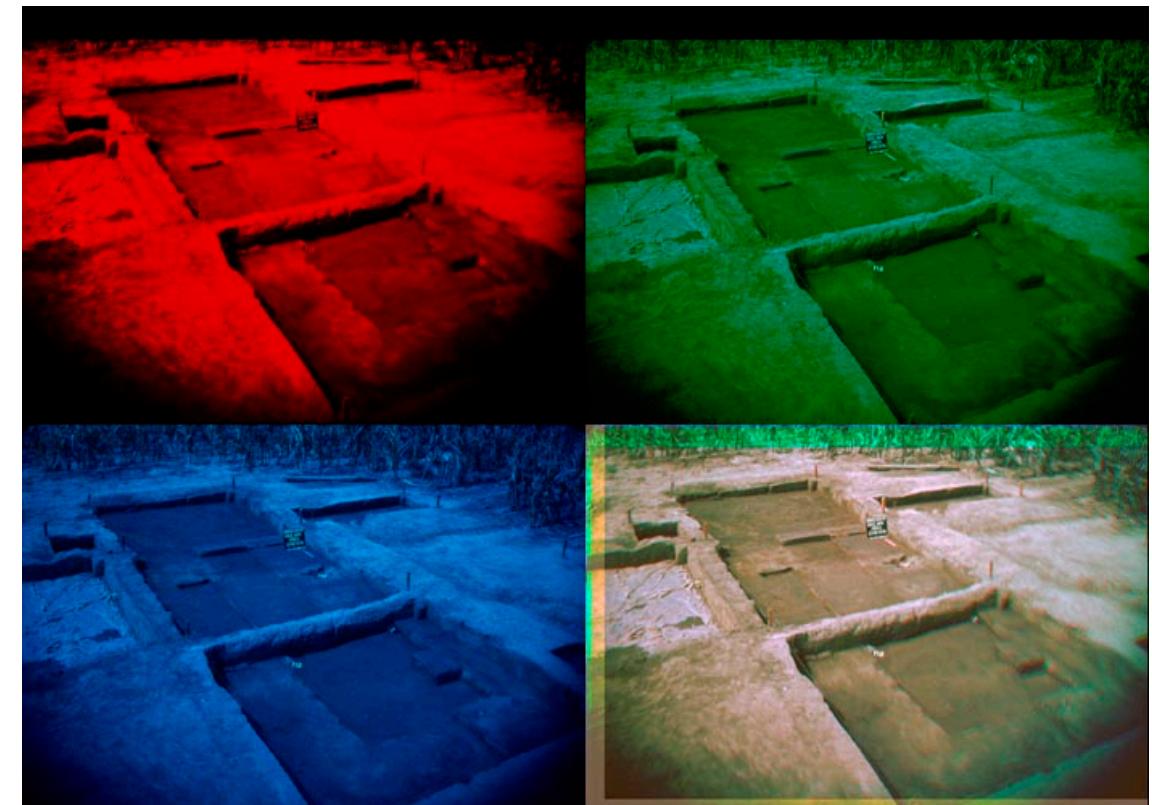


B

RGB Filter

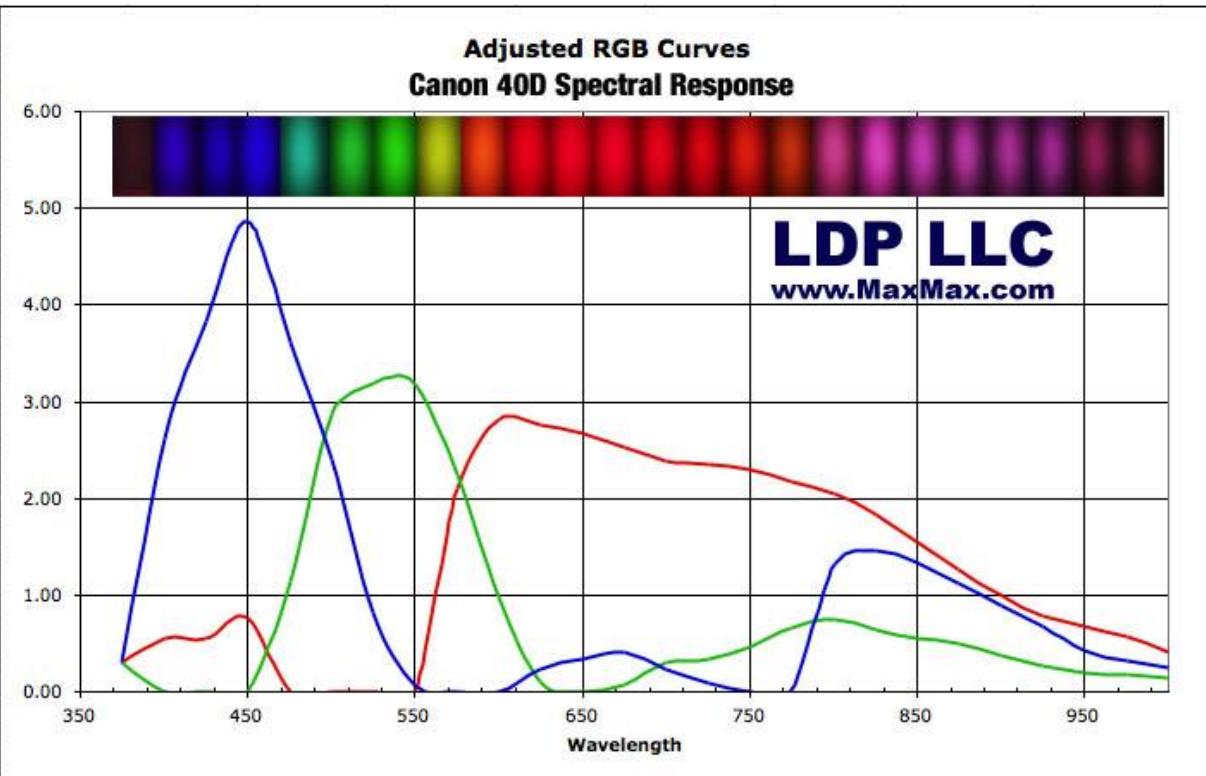


<https://tienda.lunatico.es/RGBUV/IR-Baader-2-filter-set>



<https://www.photo.net/discuss/threads/rgb-filters-for-color-w-b-w-film.414924/>

Spectral Response

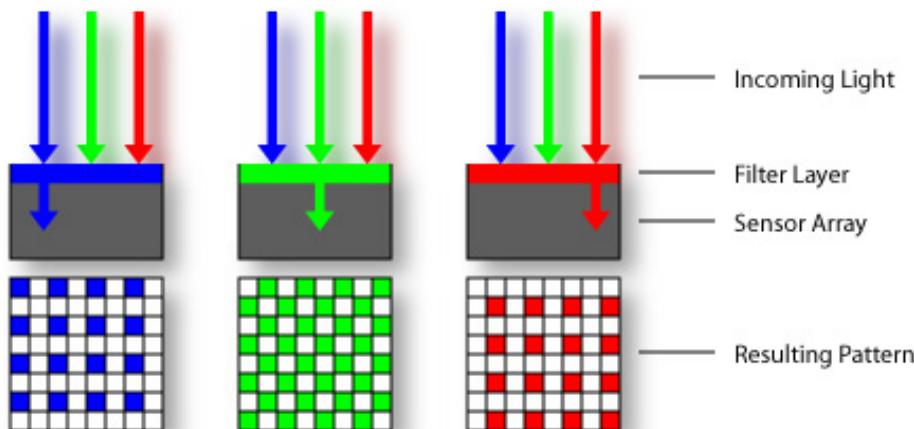
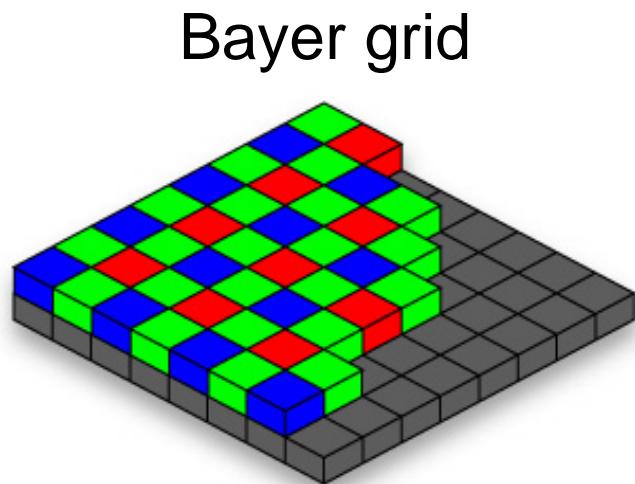


https://maxmax.com/spectral_response.htm



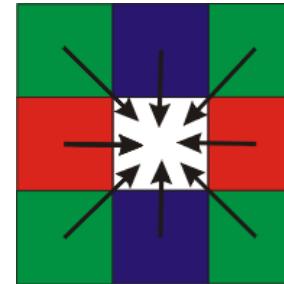
https://en.wikipedia.org/wiki/RGB_color_model#/media/File:Rgb-compose-Alim_Khan.jpg

Color Filter Arrays

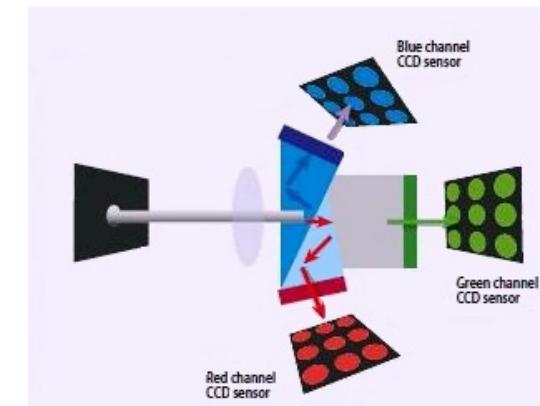


The filter pattern is 50% green, 25% red and 25% blue.

Demosaicing:
Estimation of missing
components from
neighboring values



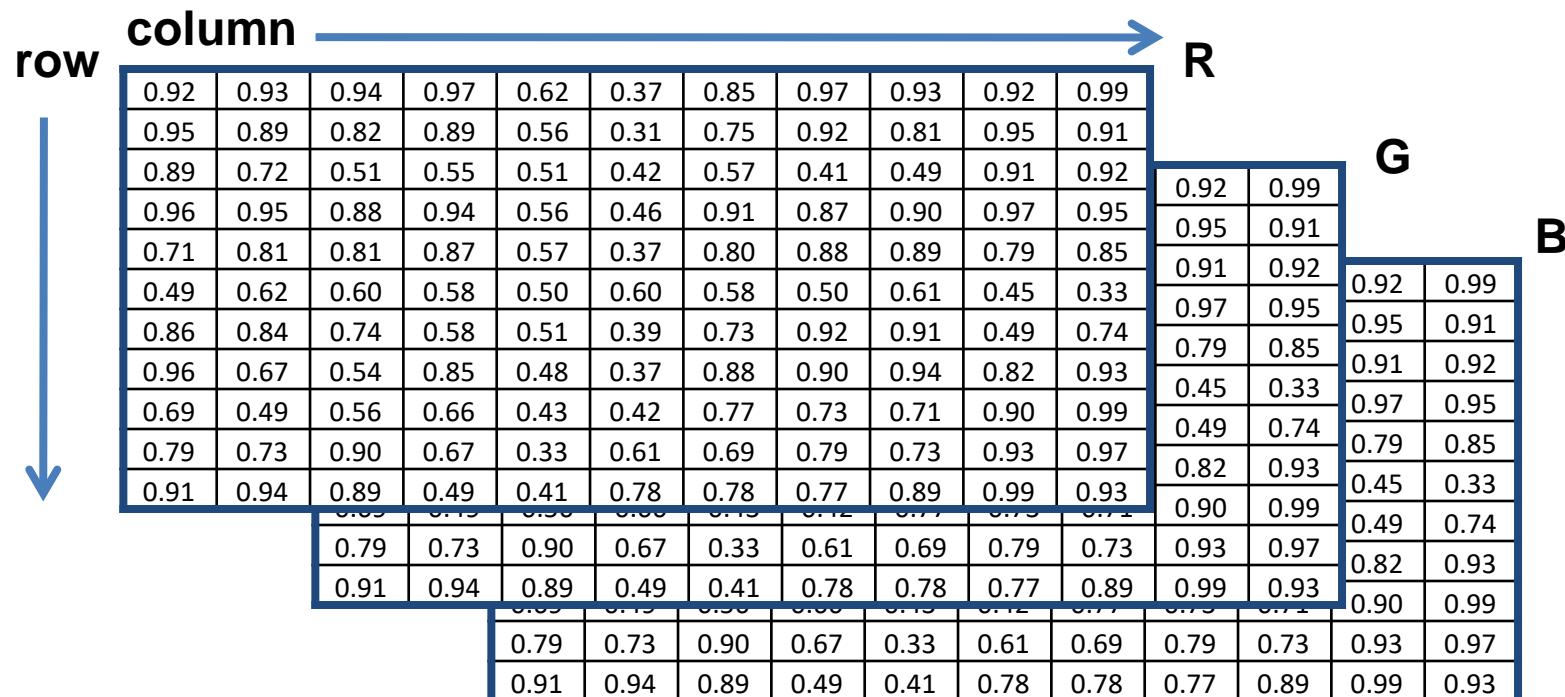
**Monochrome machine vision
camera**



3CCD

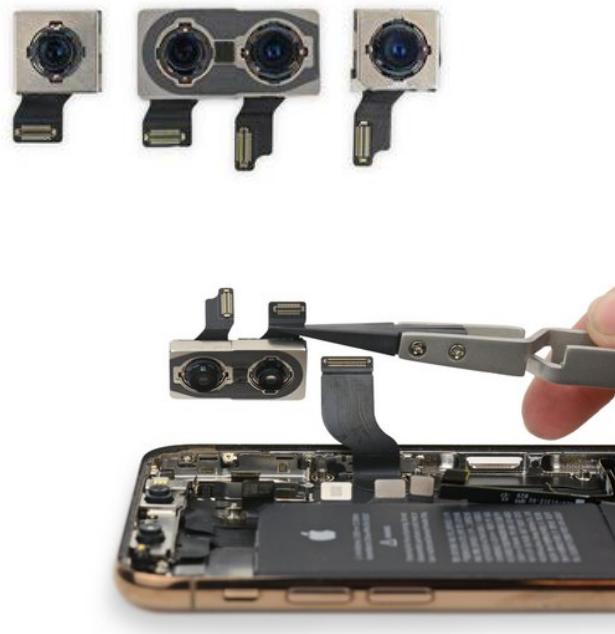
Image File Structure

- Images represented as a matrix
 - Suppose we have a NxM RGB image called “im”
 - $\text{im}(1,1,1)$ = top-left pixel value in R-channel
 - $\text{im}(y, x, b)$ = y pixels down, x pixels to right in the b^{th} channel
 - $\text{im}(N, M, 3)$ = bottom-right pixel in B-channel
 - `imread(filename)` returns a uint8 image (values 0 to 255)
 - Convert to double format (values 0 to 1) with `im2double`



Example: Smart Phones

Apple iPhone XS Max	
Size	157.5 x 77.4 x 7.7 mm (6.2 x 3.05 x 0.30 inches)
Weight	208 grams (7.34 ounces)
Screen size	6.5-inch Super Retina AMOLED display
Screen resolution	2688 x 1242 pixels (458 pixels-per-inch)
Operating system	iOS 12
Storage space	64GB, 256GB, 512GB
MicroSD card slot	No
Tap-to-pay services	Apple Pay
Processor	A12 Bionic
RAM	4GB
Camera	Dual 12MP rear, 7MP FaceTime HD front
Video	2160p at 60 fps, 1080p at 240 fps



Q. difference?

<https://www.ifixit.com/Guide/Image/meta/JyuleQEJbHHs1BrU>
<https://kenrockwell.com/canon/6d-mk-ii.htm>

6D MK II



Image Sensor

26 MP.
24.0 × 35.9mm CMOS.
Anti-alias filter.
5.67 µm pixel pitch.
3:2 aspect ratio.
1.0× [crop factor](#) (full-frame).
Ultrasonic cleaner.

Questions

Product 1: Apple watch with a 4k screen.

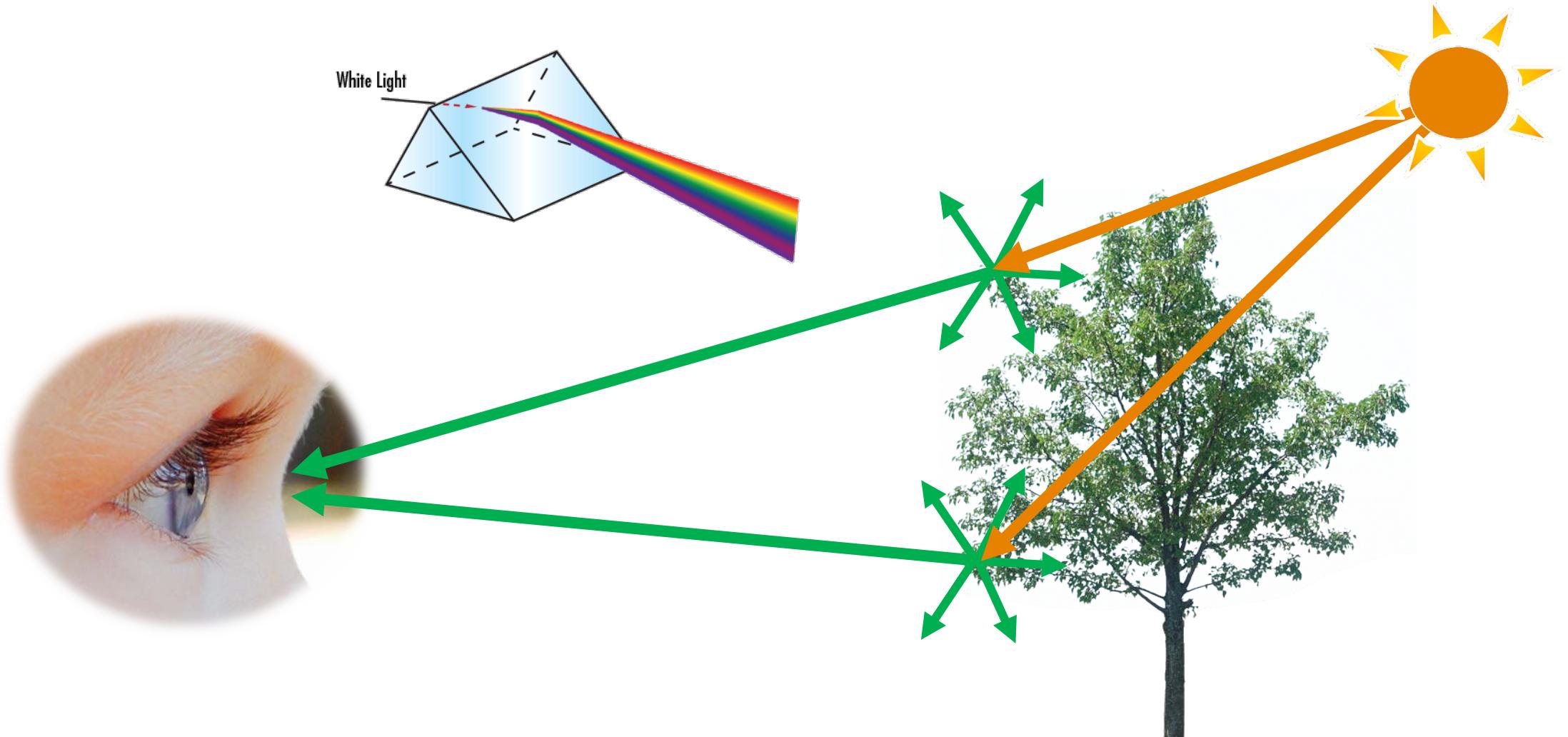
Product 2: 80 inch high-definition full-HD TV.

Product 3: 4k monitor for Skype, Zoom meeting

Product 4: 5-inch smart phone with 4k resolution for VR gaming

Product 5: 8K 80 inch TV for NETFLIX watching

Role of Light to Sight



Rays from the sun reflect off plant and the green rays go in all directions

Camera Sensor



digital sensor
(CCD or CMOS)

Object We Like to Take

real-world
object



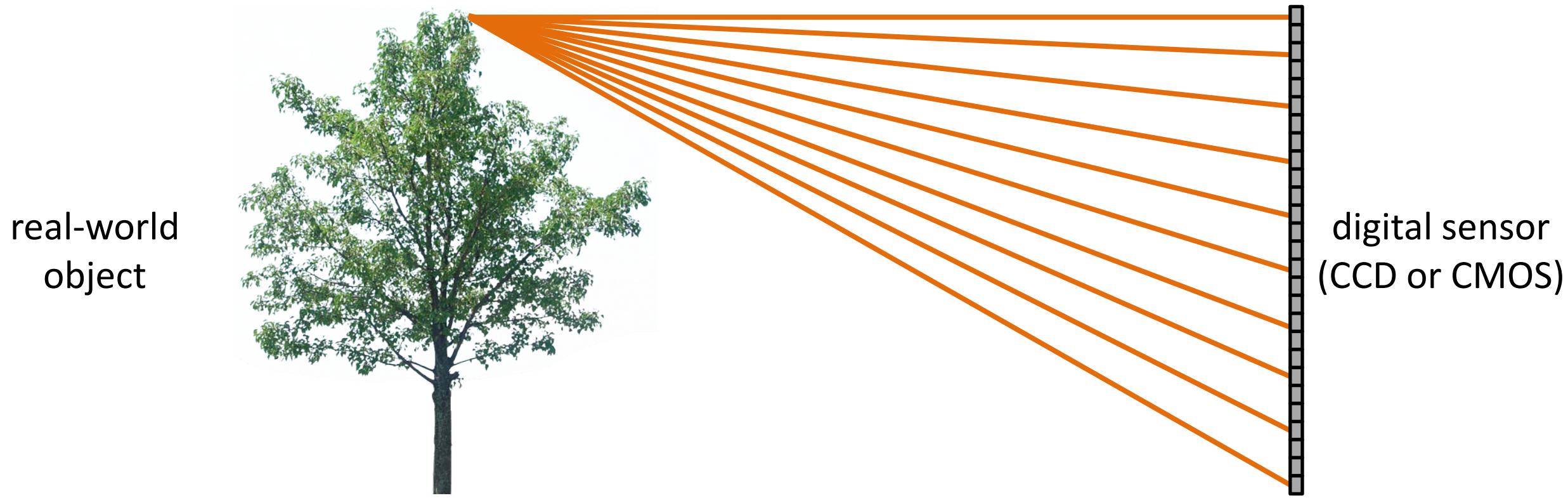
digital sensor
(CCD or CMOS)

What would an image taken like this look like?

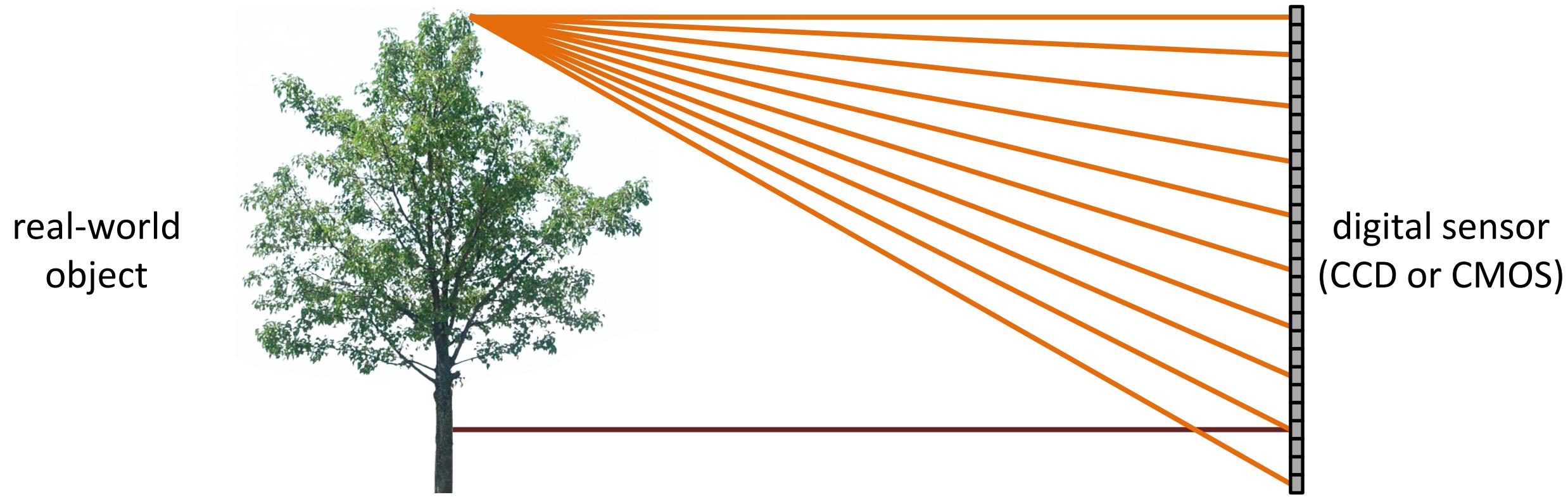
Bare-Sensor Imaging



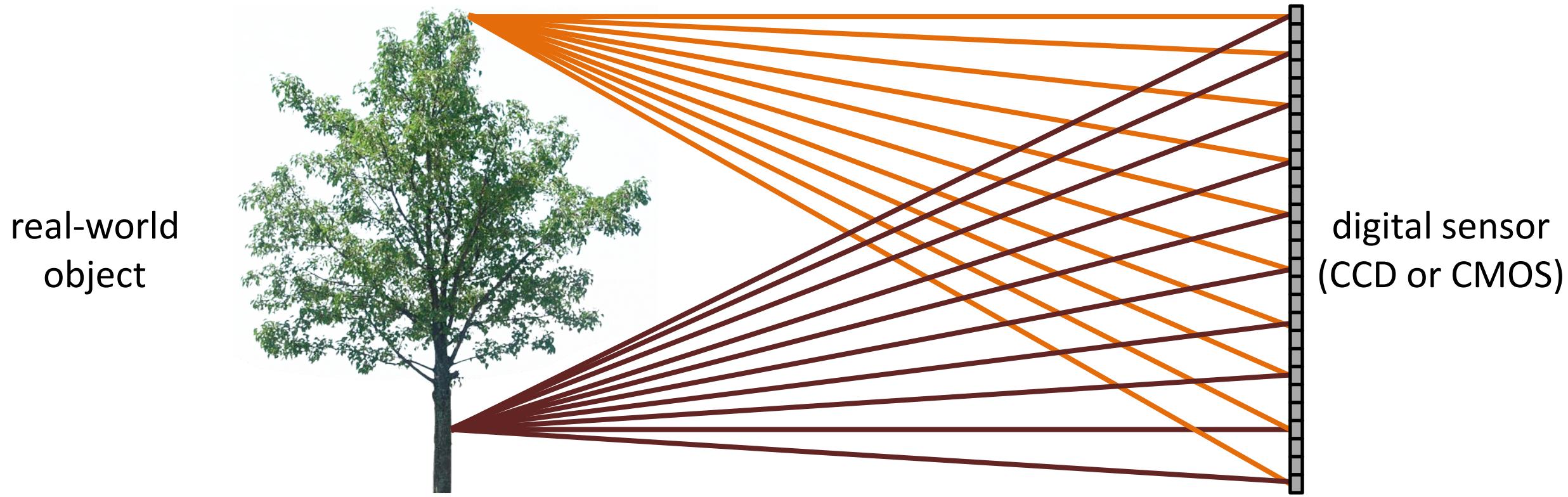
Light Reflect off All Positions on the Object and Goes in All Directions



Light Reflect off All Points on the Object and Goes in All Directions

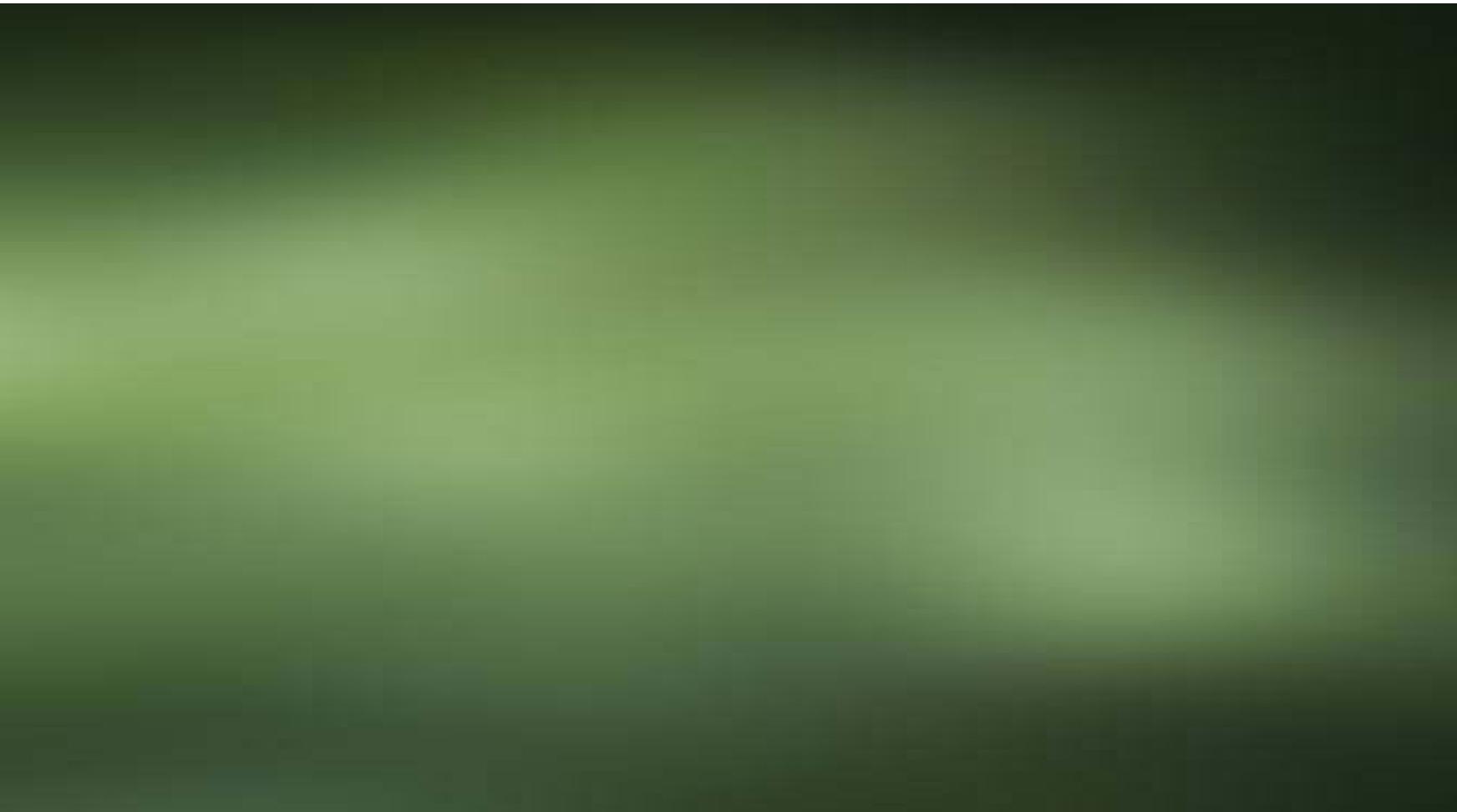


What Does the Image on the Sensor Look Like?



All scene points contribute to all sensor pixels

All Scene Points Contribute to All Sensor Pixels



What can We Do to Make Our Image Look Better?

real-world
object



digital sensor
(CCD or CMOS)

Pinhole Imaging

real-world
object



barrier (diaphragm)



pinhole
(aperture)

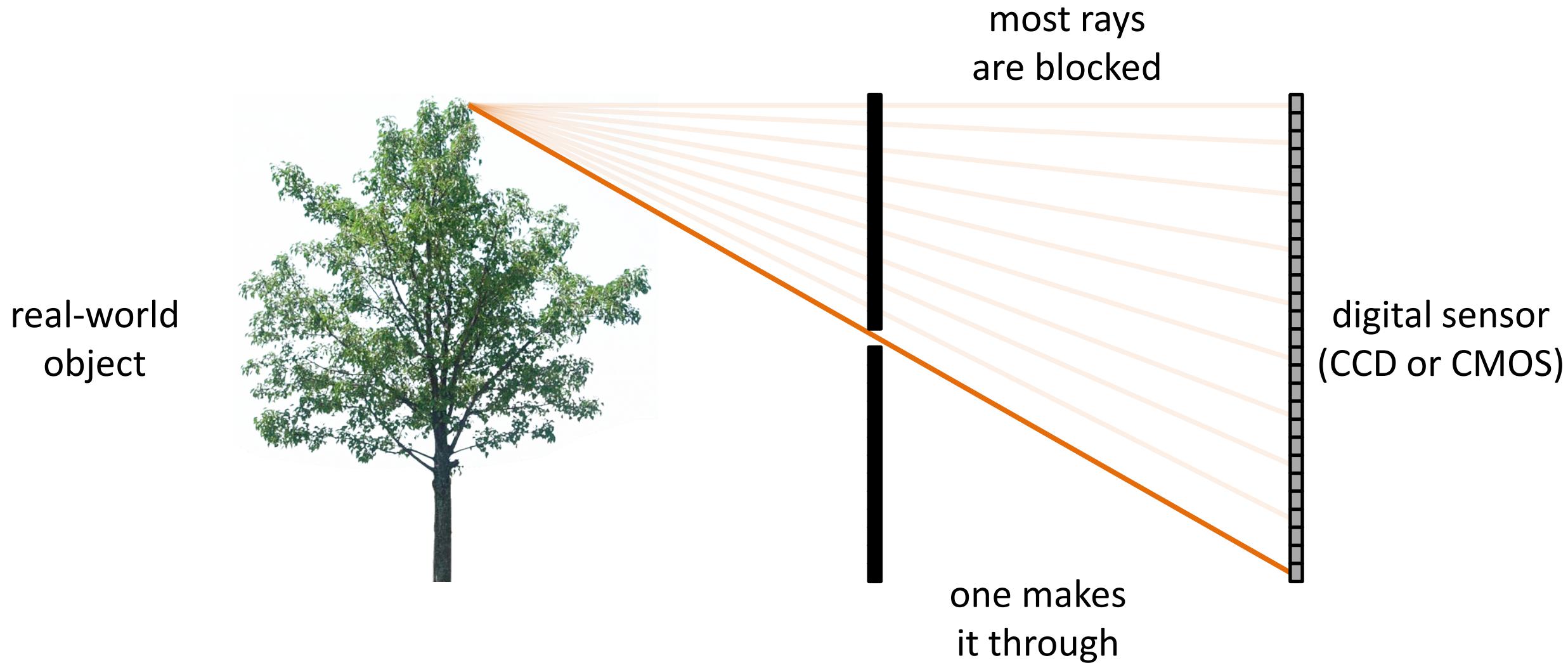


Very small
pinhole

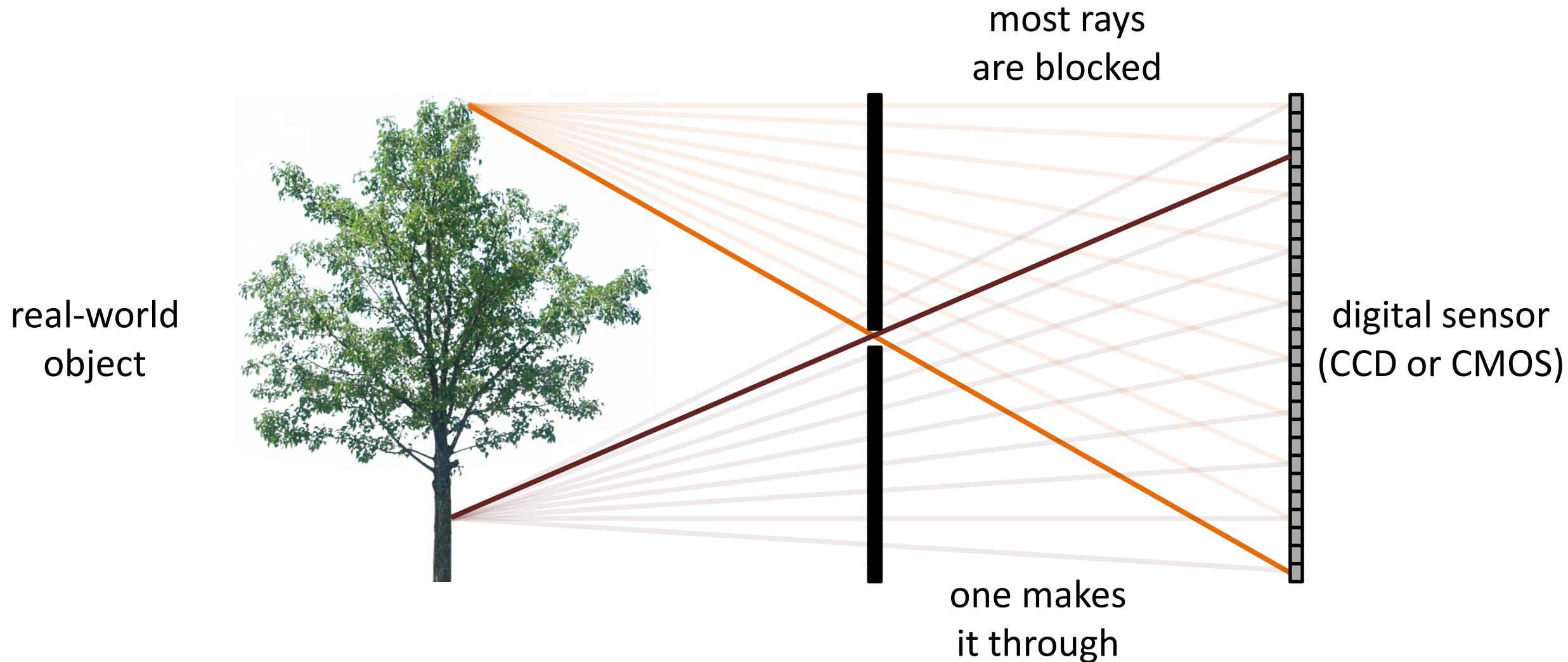


digital sensor
(CCD or CMOS)

Pinhole Imaging

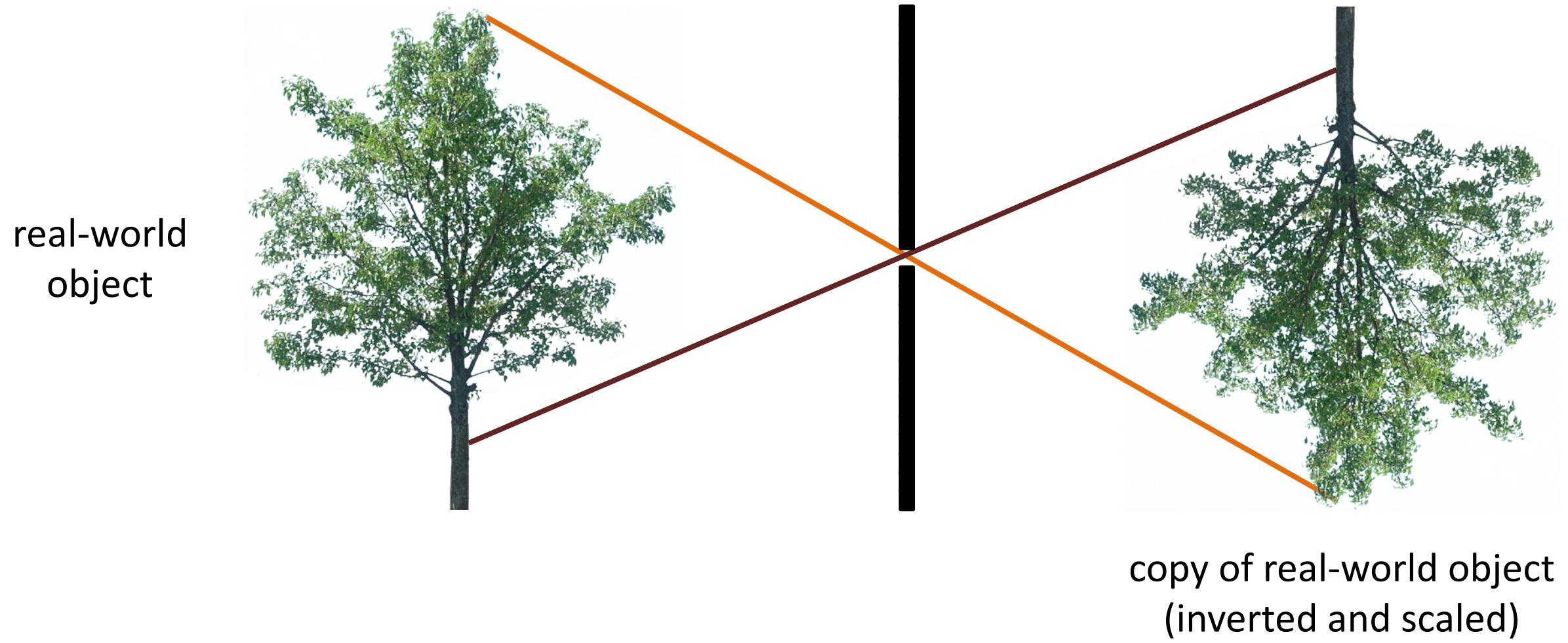


Pinhole Imaging

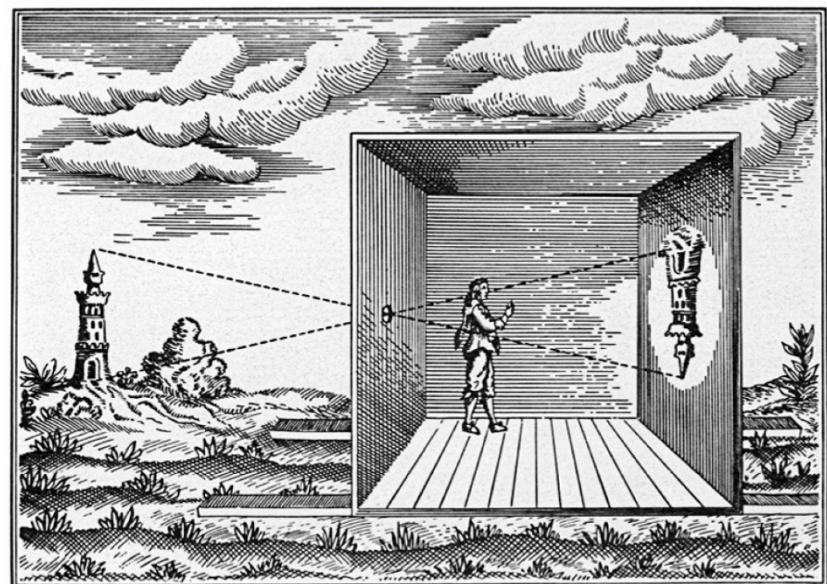
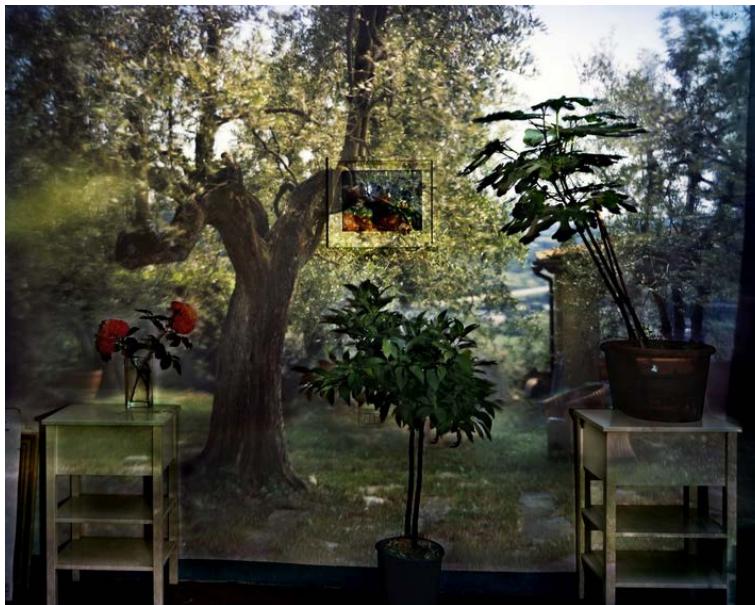


Let's assume that each scene point contributes to only one sensor pixel

Pinhole Imaging: the Object can be Captured !!



Camera Obscura

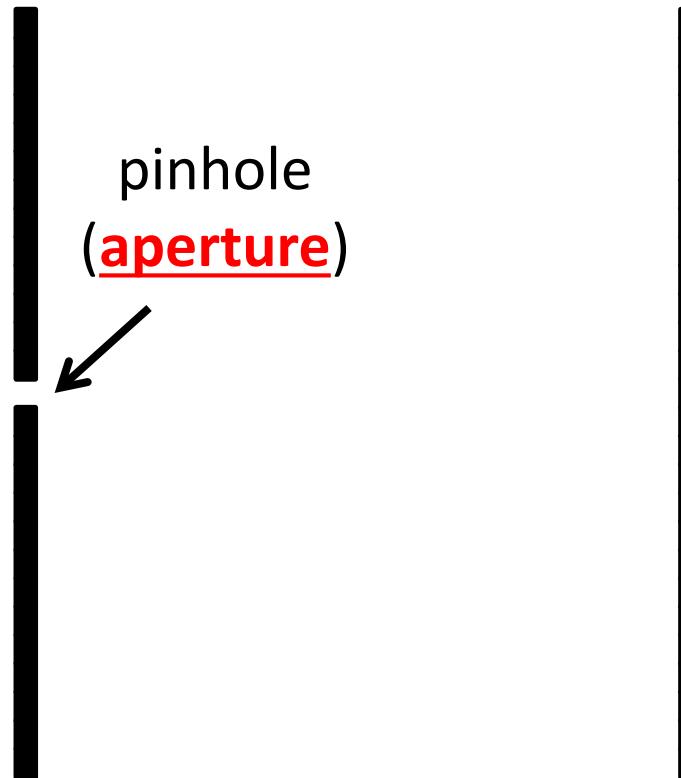


Pinhole Camera Terms (Aperture)

real-world
object



barrier (diaphragm)



digital sensor
(CCD or CMOS)

Pinhole Camera Terms (Camera Center)

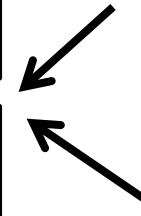
real-world
object



barrier (diaphragm)

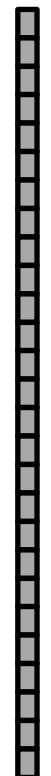


pinhole
(aperture)



camera center (or
optical center)

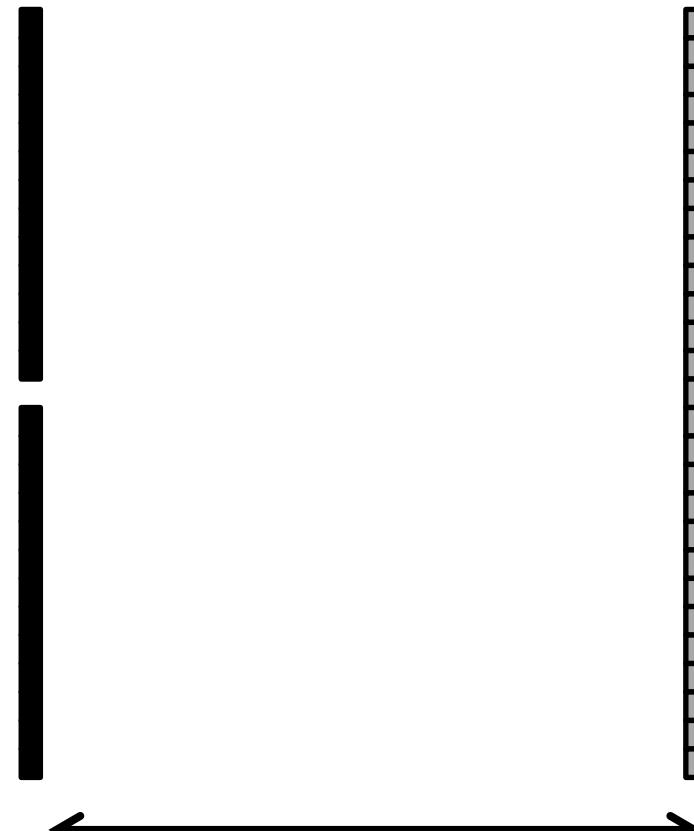
image plane



digital sensor
(CCD or CMOS)

Pinhole Camera Terms (Focal Length)

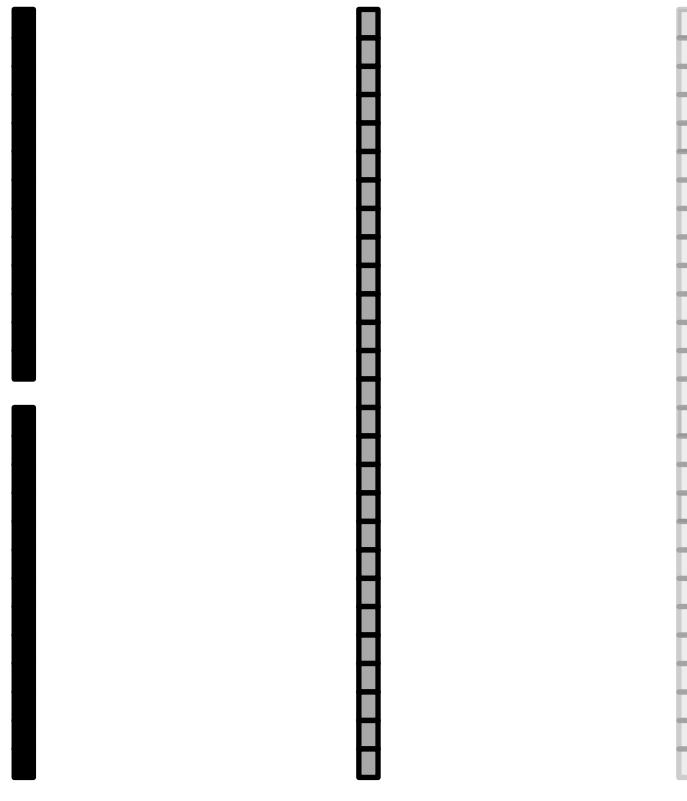
real-world
object



focal length f

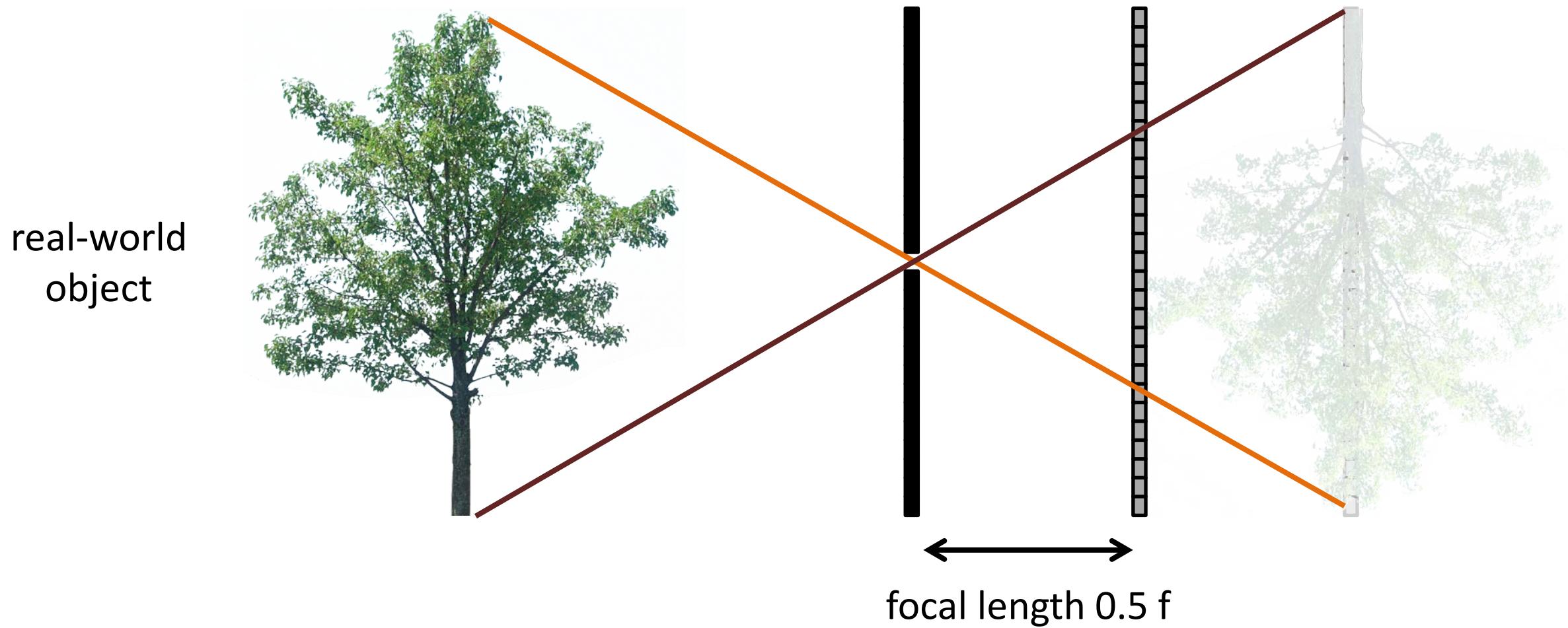
What Happens as We Change the Focal Length?

real-world
object

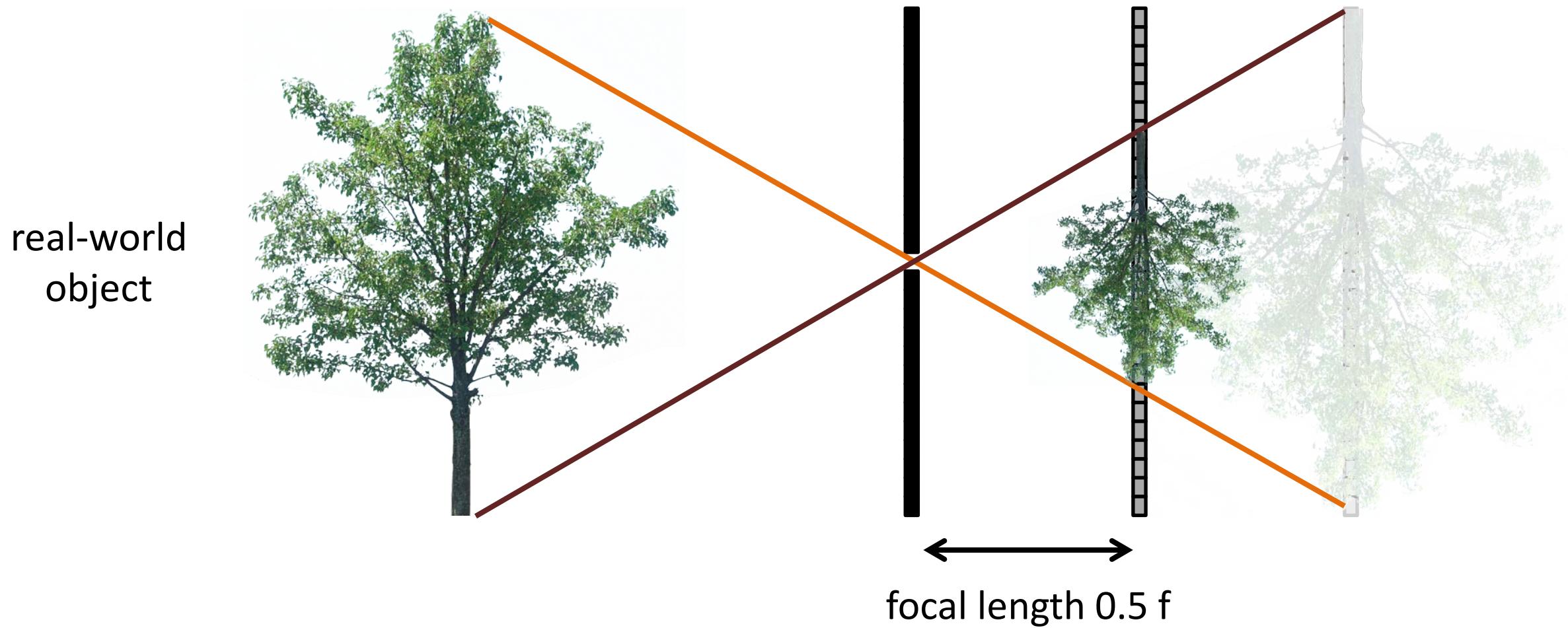


focal length $0.5 f$

What Happens as We Change the Focal Length?



What Happens as We Change the Focal Length?

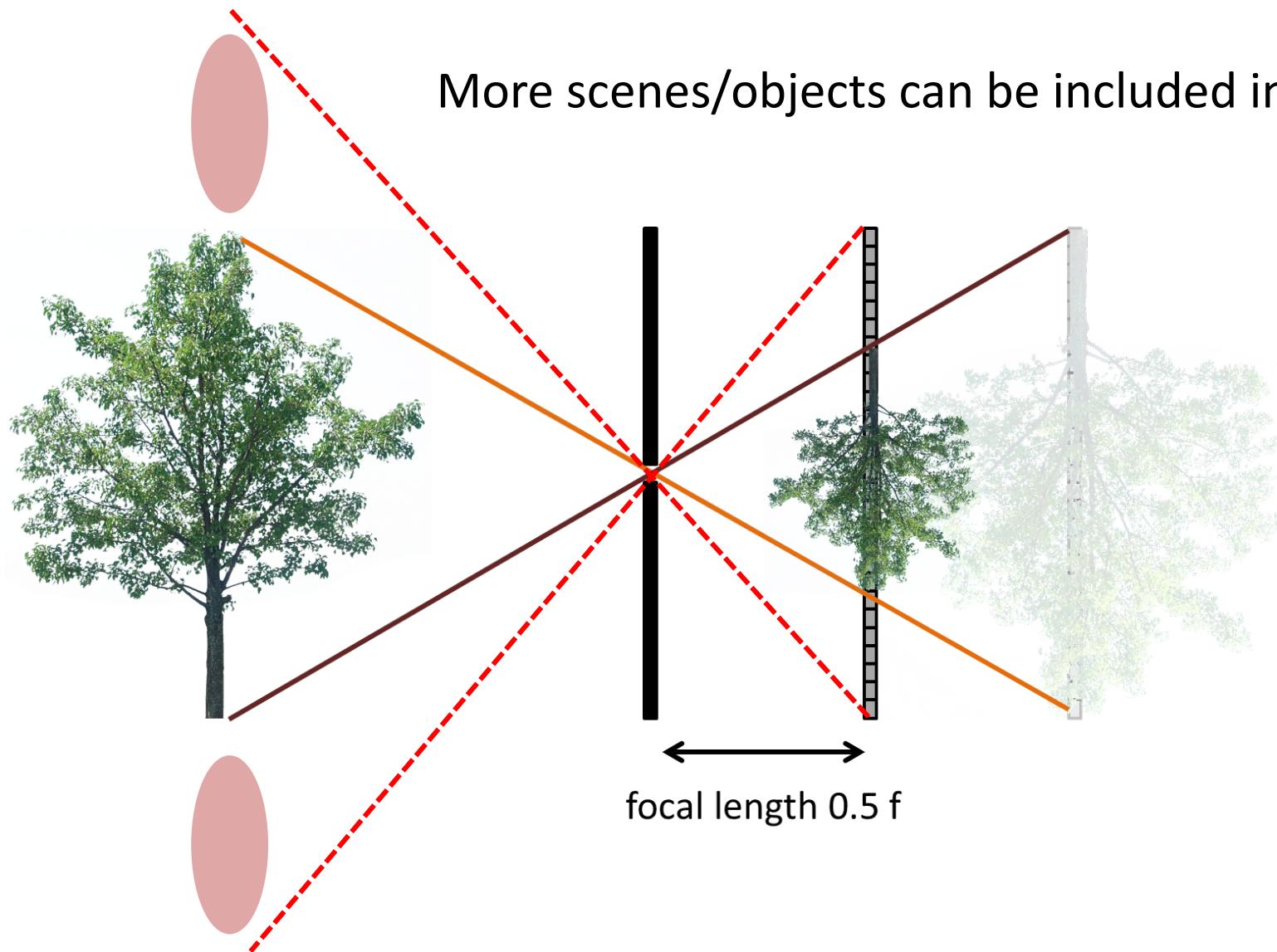


What Happens as We Change the Focal Length?



real-world object

Zoom-in or
Zoom-out

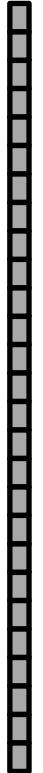


What Happens as We Change the Aperture Size?

real-world
object



pinhole
diameter



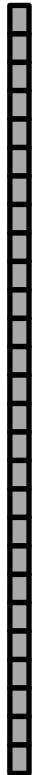
- Ideal pinhole has infinitesimally small size
- In practice that is impossible.

What Happens as We Change the Aperture Size?

real-world
object

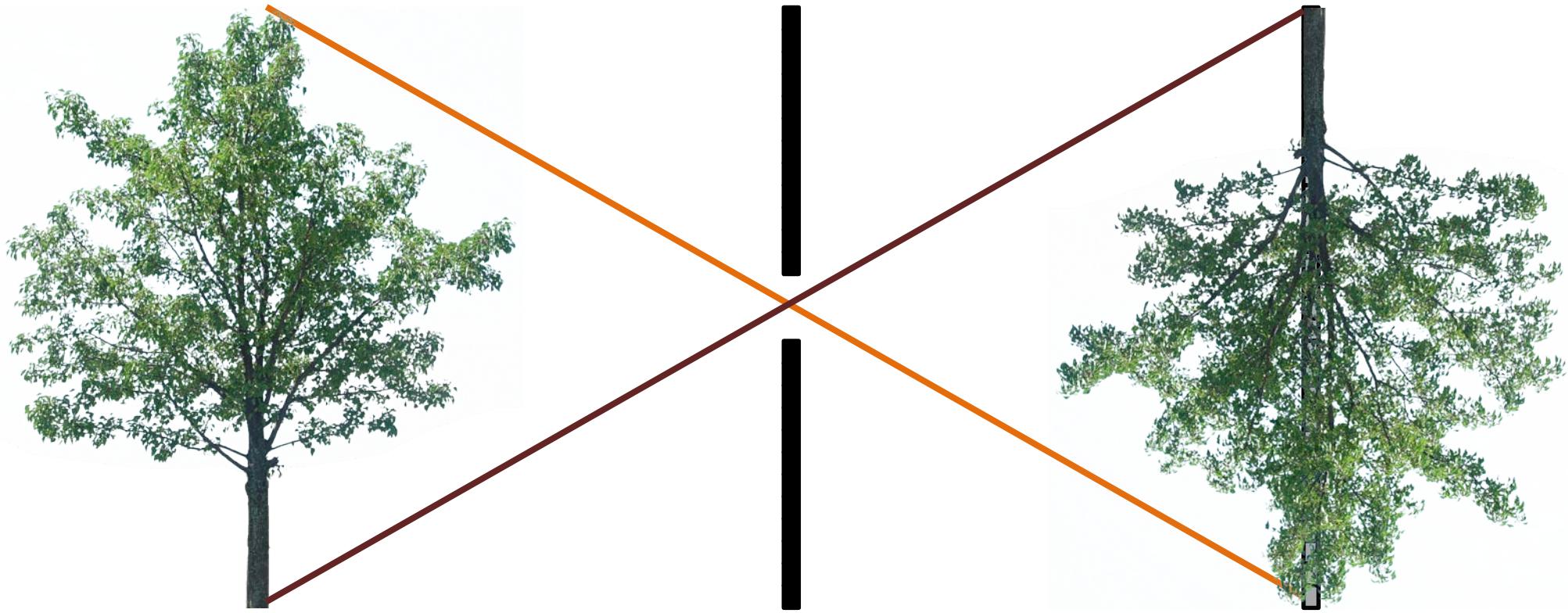


pinhole
diameter



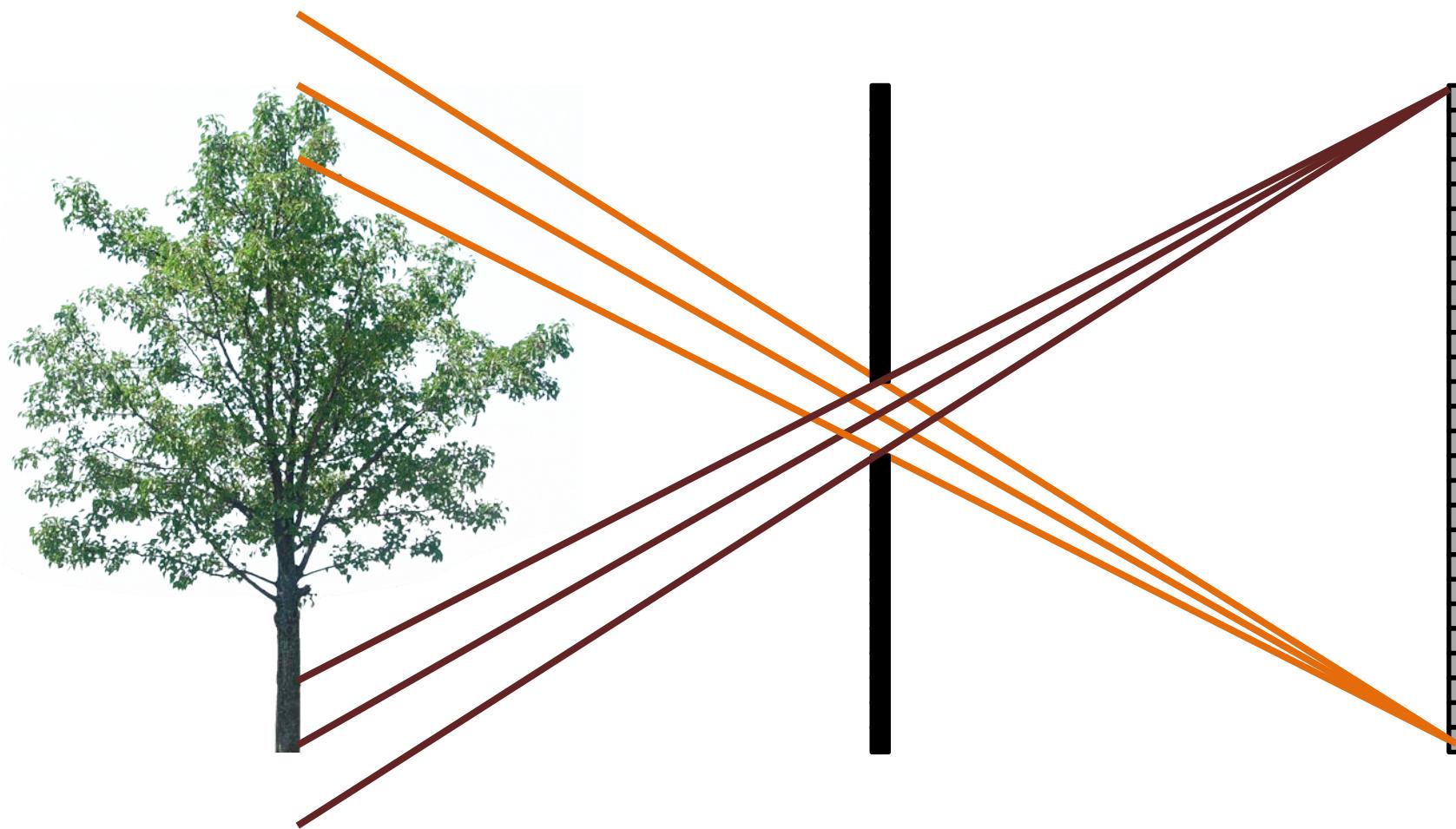
What Happens as We Change the Aperture Size?

real-world
object

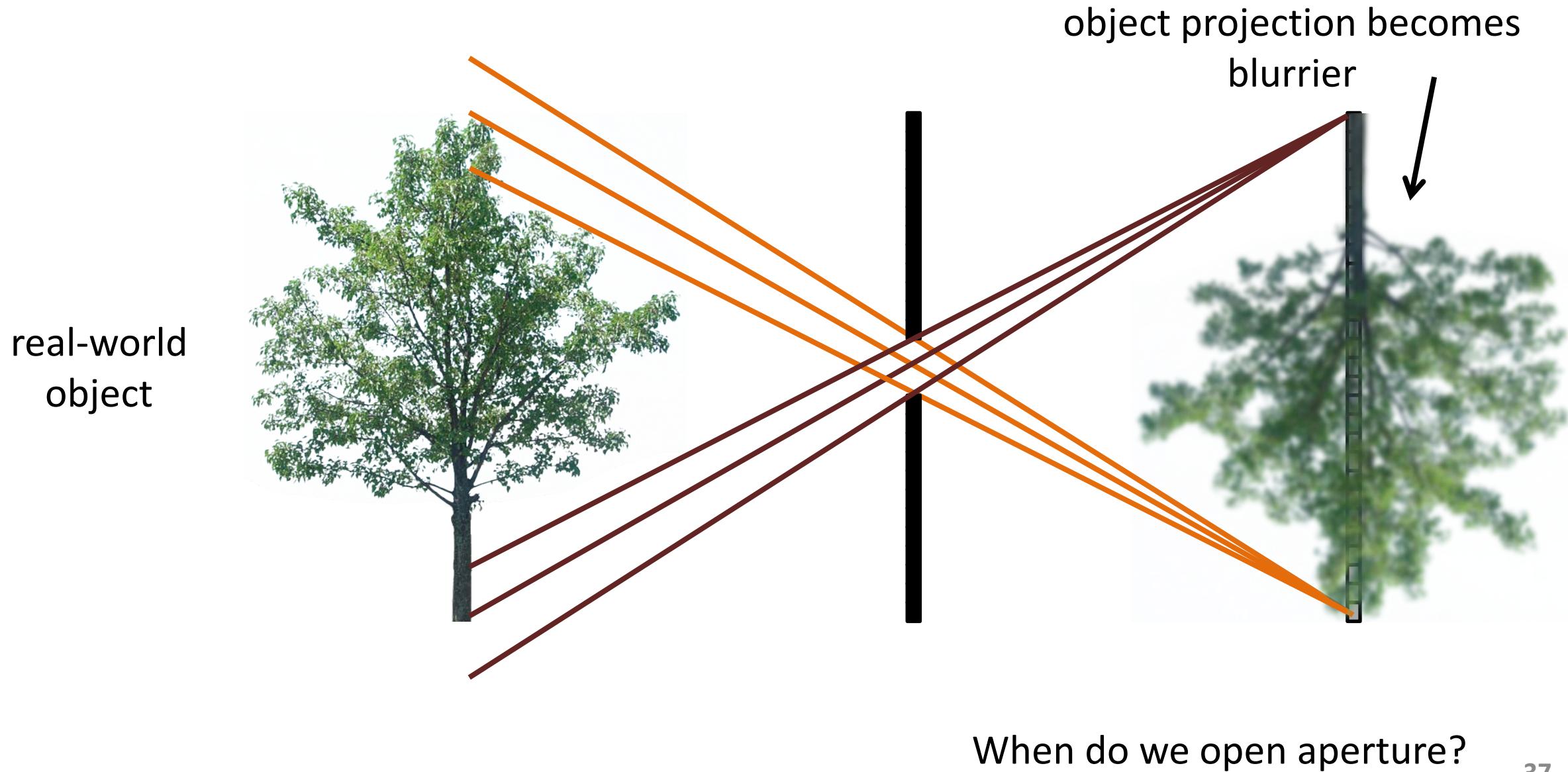


What Happens as We Change the Aperture Size?

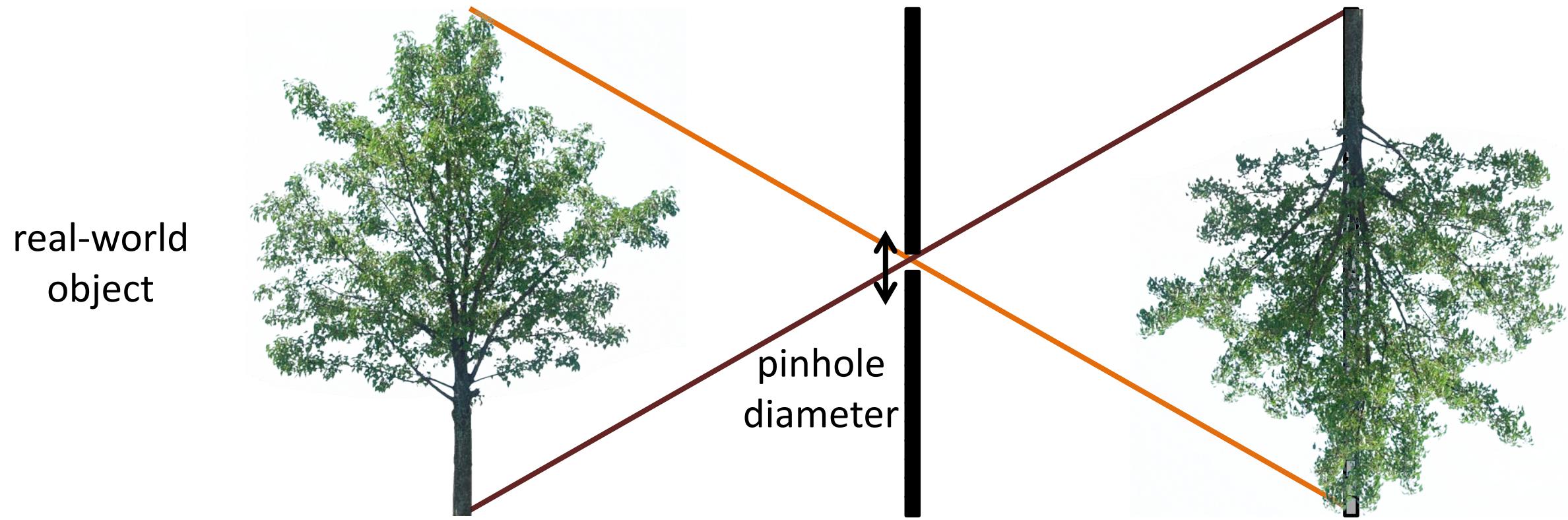
real-world
object



What Happens as We Change the Aperture Size?



Will the Image Keep Getting Sharper the Smaller We Make the Pinhole?

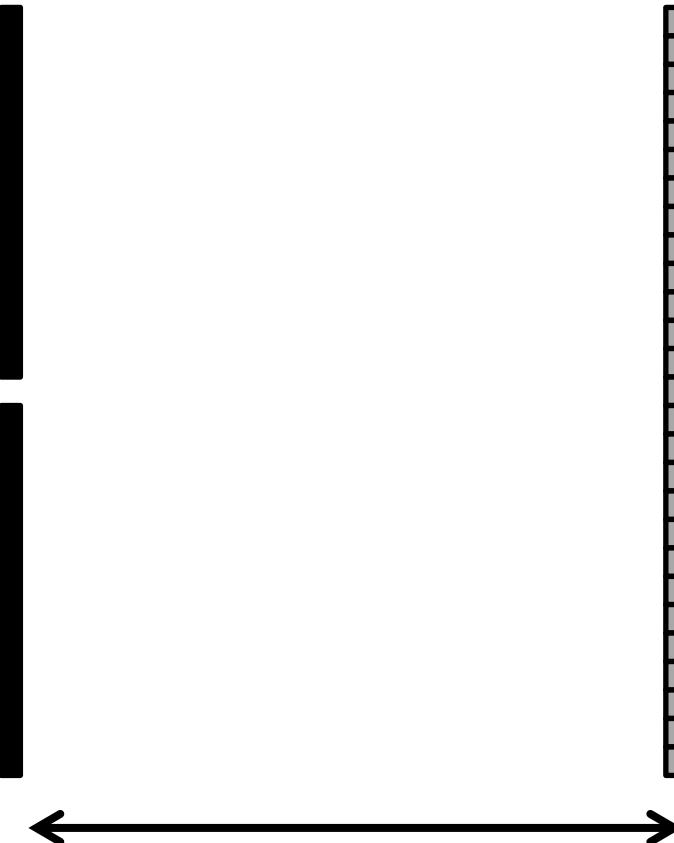


Light Efficiency

real-world
object



pinhole
diameter



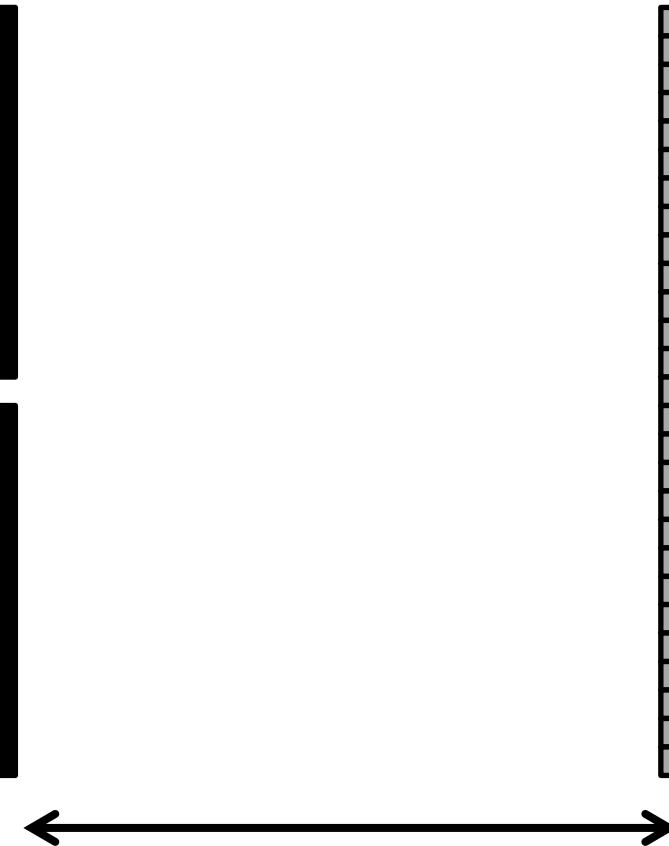
- What is the effect of doubling the pinhole diameter?
- What is the effect of doubling the focal length?

Light Efficiency (Continue)

real-world
object



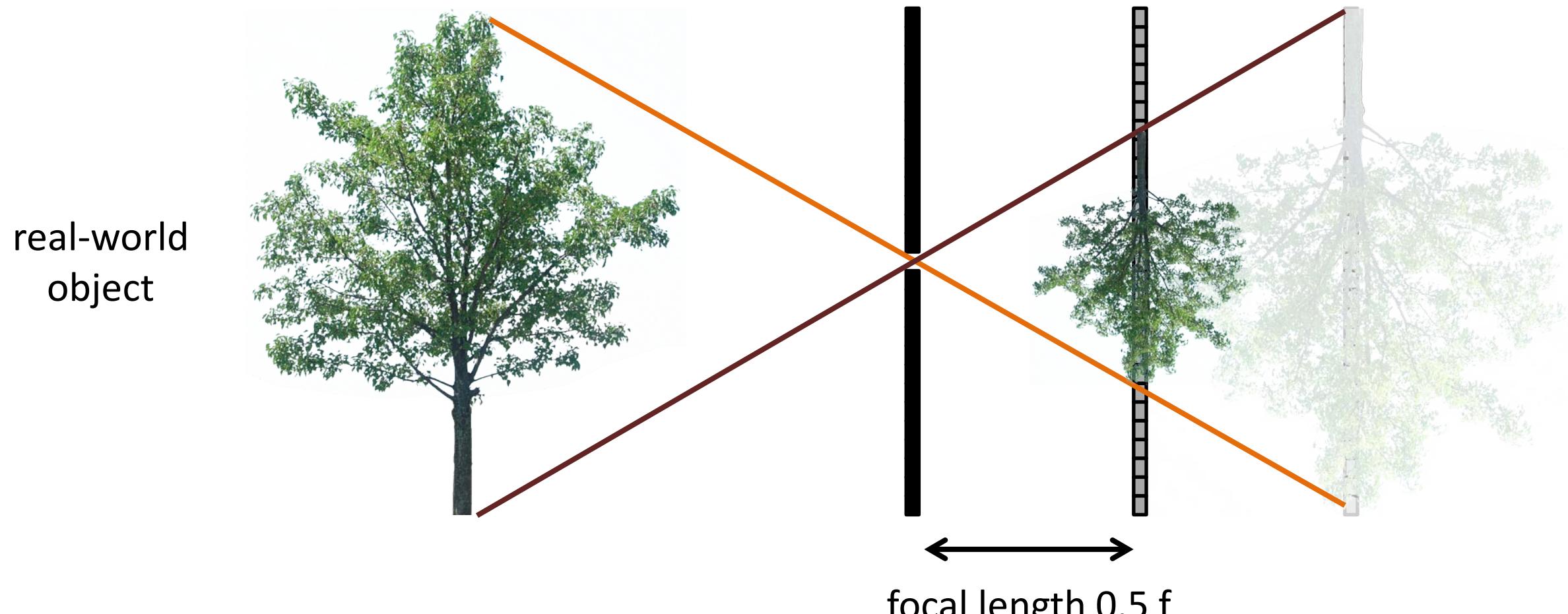
pinhole
diameter



focal length f

- $2 \times \text{pinhole diameter} \rightarrow 4 \times \text{light}$

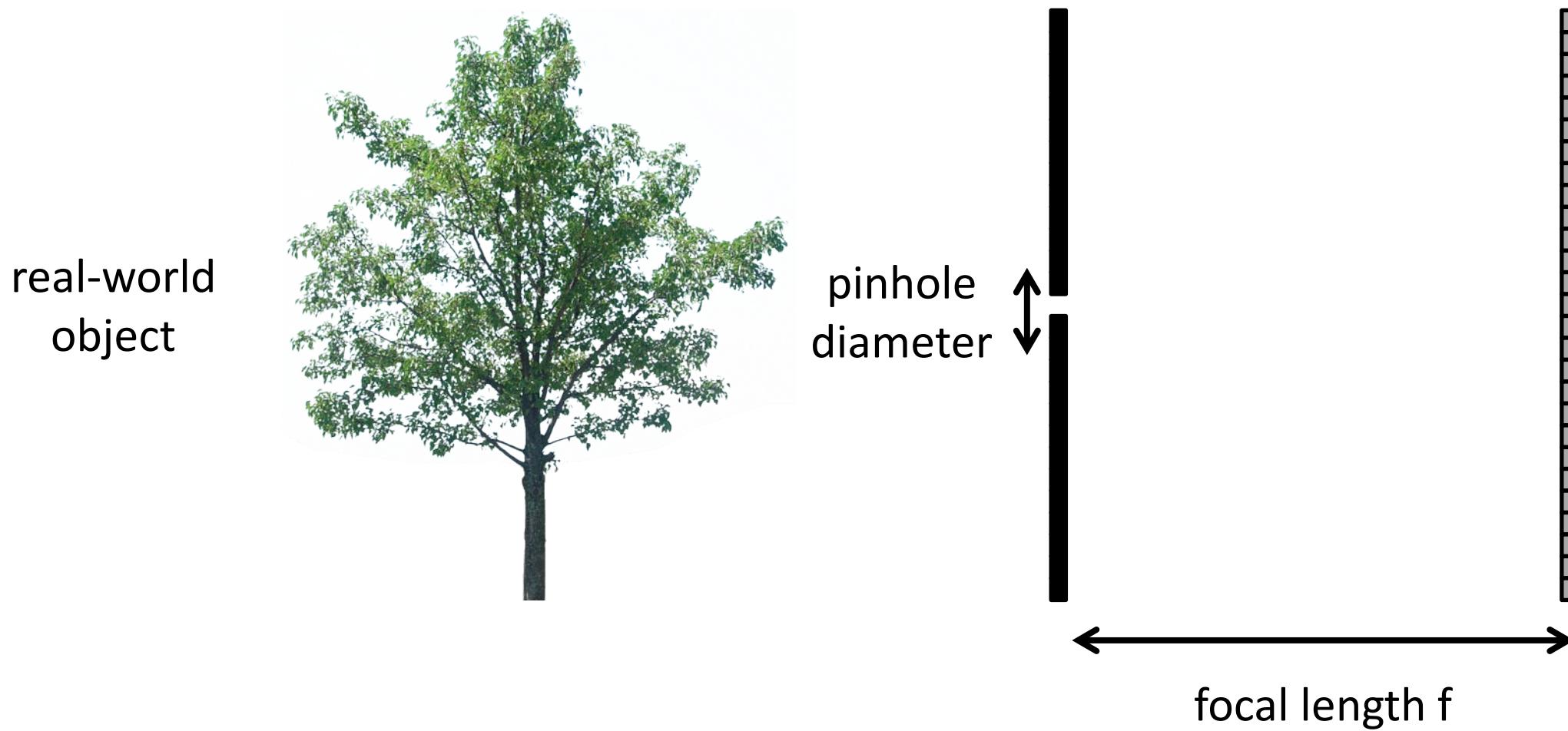
Light Efficiency (Continue)



- $2x$ focal length $\rightarrow \frac{1}{4}x$ light

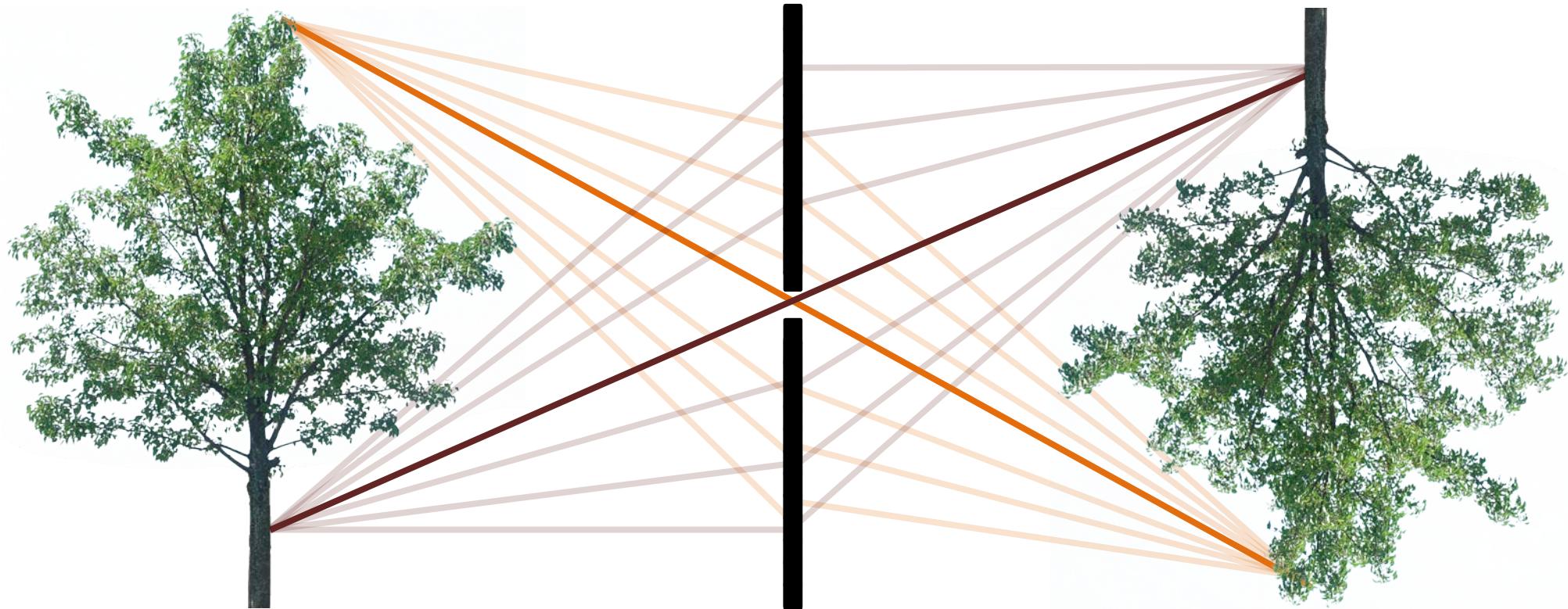
F-Number or F-Stop

A “stop” is a change in camera settings that changes amount of light by a factor of 2



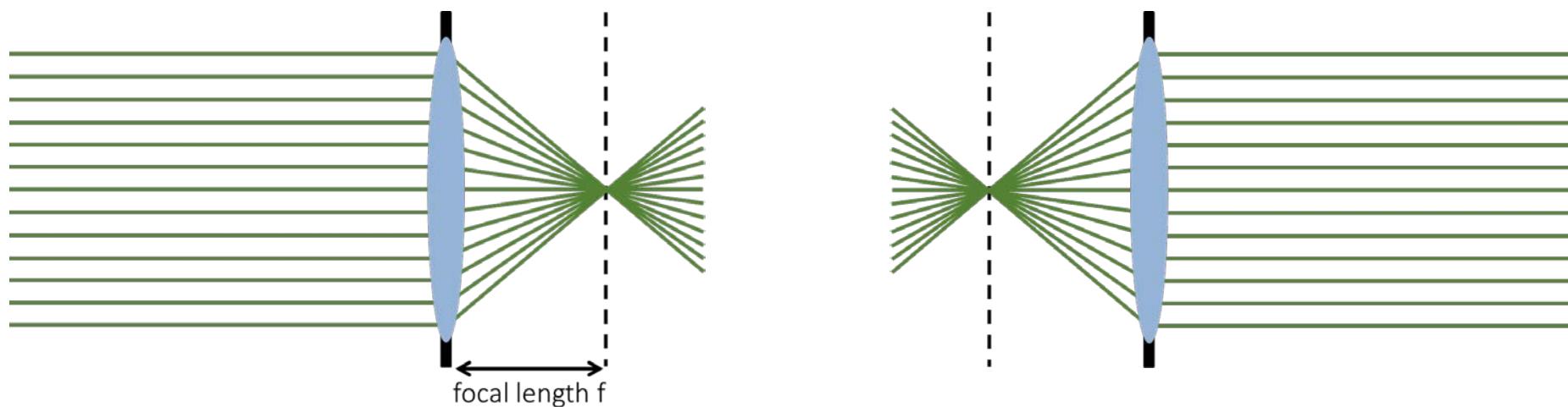
The “f-number” is the ratio: focal length / pinhole diameter

Pinhole Camera



Central rays propagate in the same way for both models!

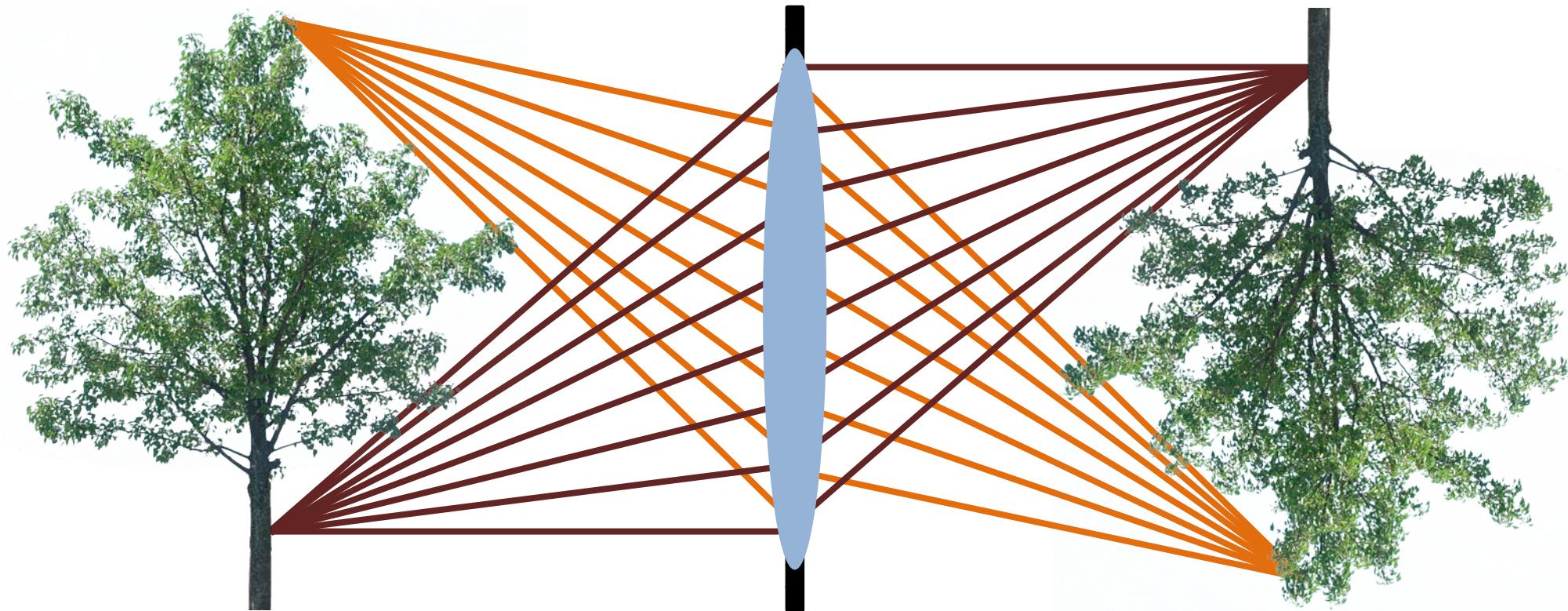
Thin Lens Model



Thin Certain rays follow simple rules when passing through a thin lens, in the paraxial ray approximation:

- Any ray that enters parallel to the axis on one side of the lens proceeds towards the focal point F on the other side.
- Any ray that arrives at the lens after passing through the focal point on the front side, comes out parallel to the axis on the other side.
- Any ray that passes through the center of the lens will not change its direction.

Replace the Pinhole with Lens

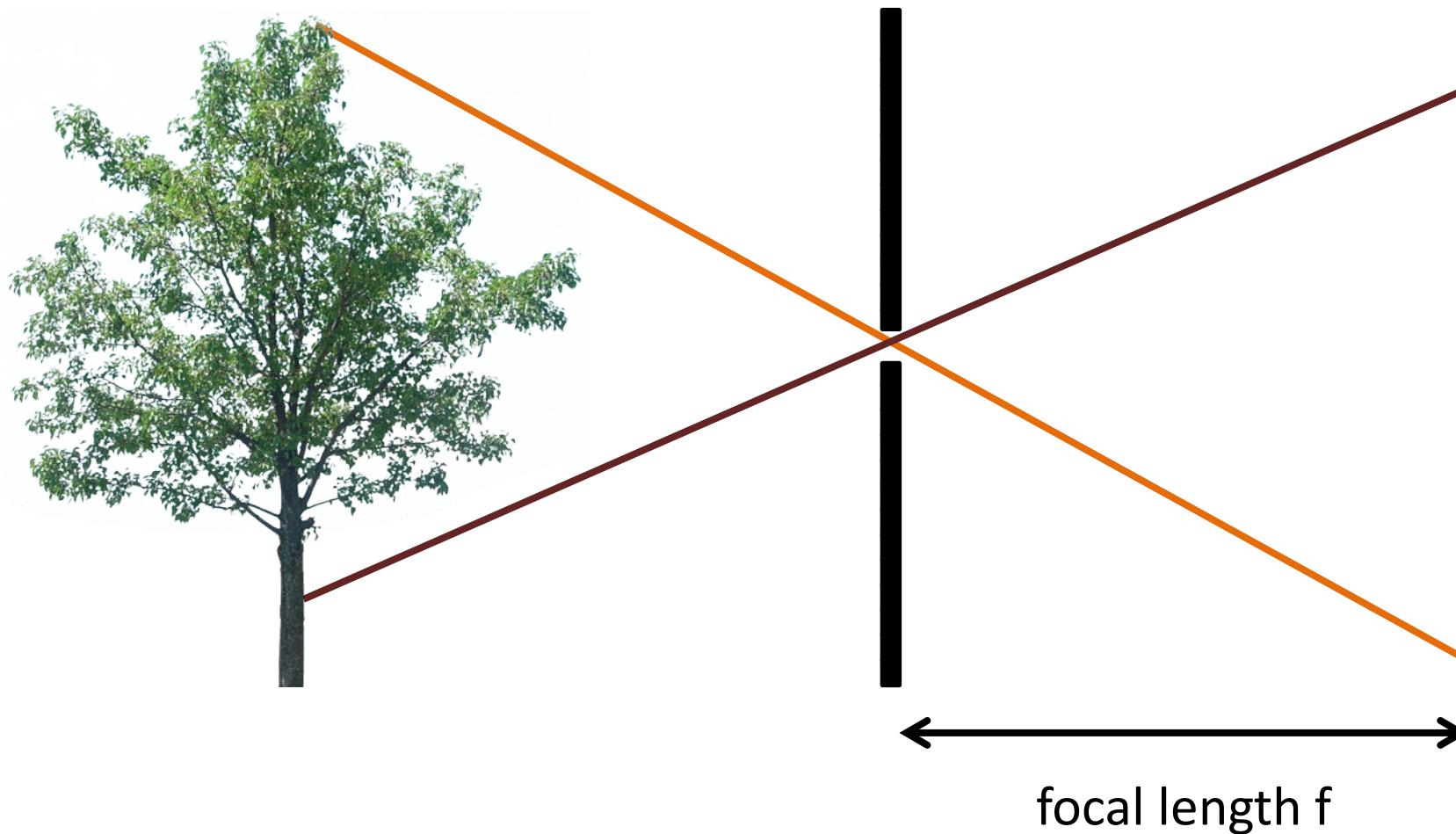


Lenses map “bundles” of rays from points on the scene to the sensor.

How does this mapping work exactly?

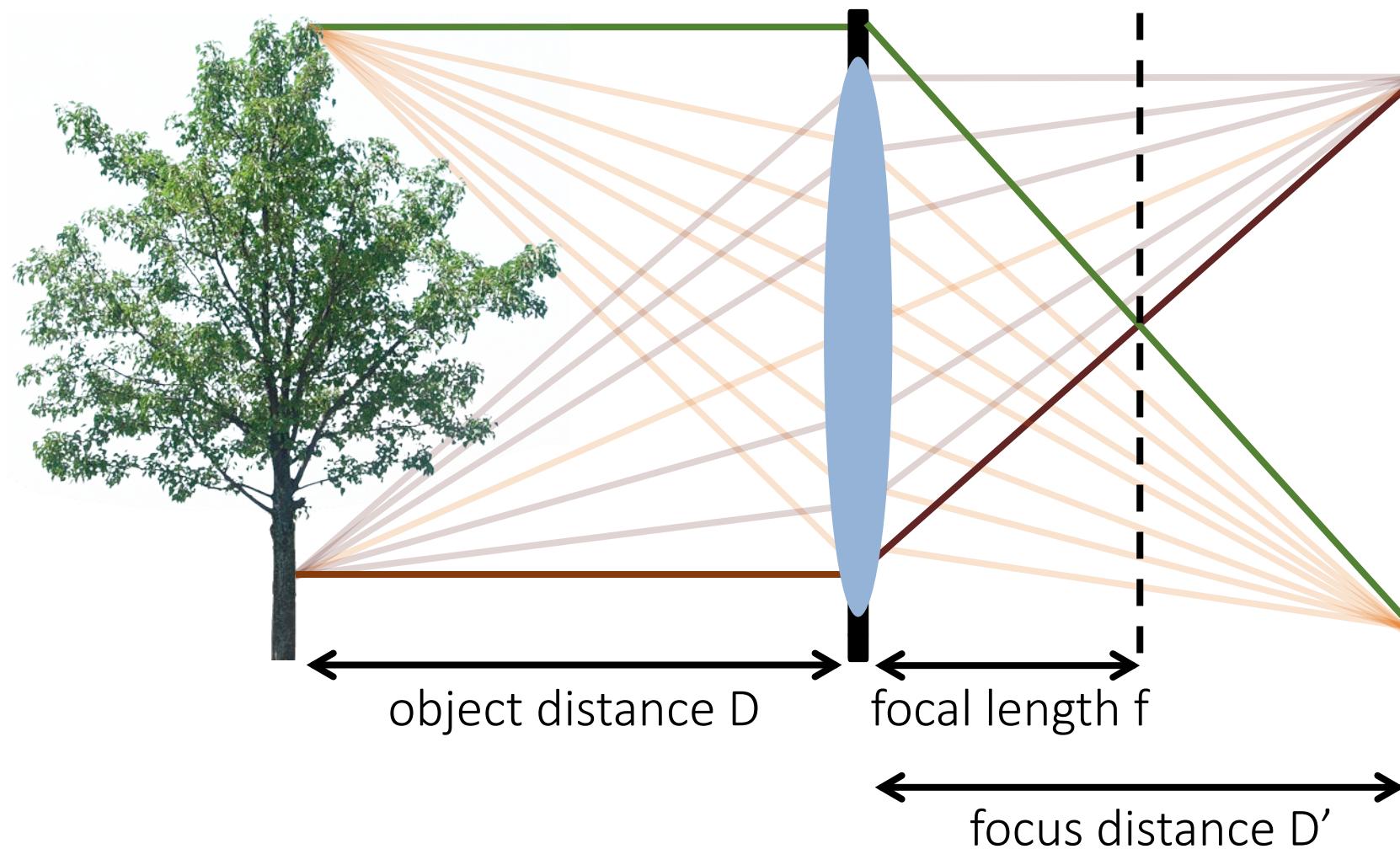
Focal Length in a Pinhole Camera

In a pinhole camera, focal length is distance between aperture and sensor

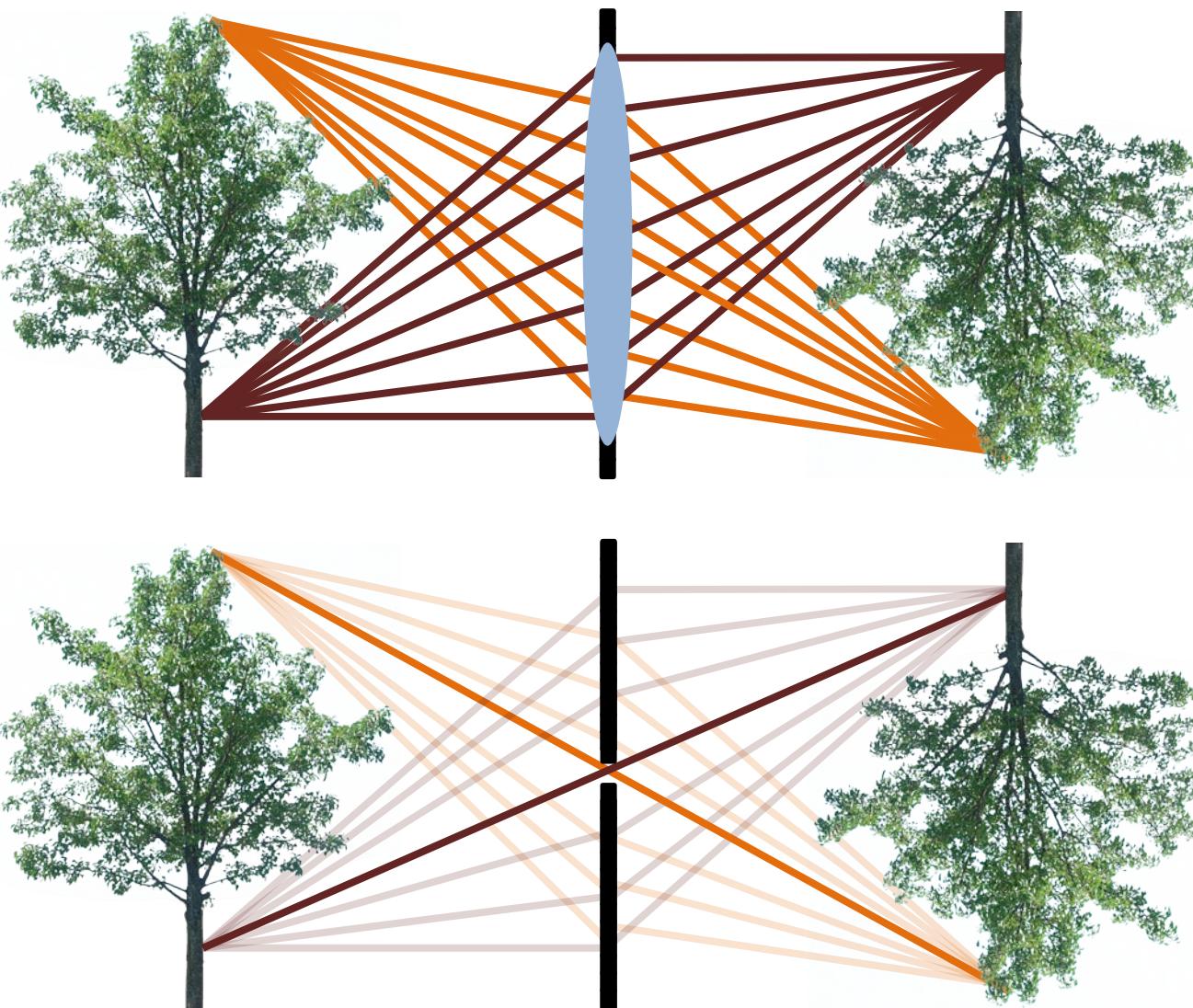


Focal Length in a Lens Camera

In a lens camera, focal length is distance where parallel rays intersect



Describing Both Lens and Pinhole Cameras



We can derive properties and descriptions that hold for both camera models if:

- We use only central rays.
- We assume the lens camera is in focus.
- We assume that the focus distance of the lens camera is equal to the focal length of the pinhole camera.

Understanding the Language of Photography

- Aperture
- Depth of field
- Exposure
- F-Number
- ISO
- RAW
- Shutter speed
- Flash
- Shutter prior mode
- Aperture prior mode
- Tripod
- Aspect Ratio
- Focal length
- Long exposure

<https://www.creativelive.com/blog/common-photography-terms/>

DSLR Cheat Sheet

**PHOTOGRAPHY
CHEAT
SHEET**
RELOADED!

CAMERA MODES

M	MANUAL	M
Av	APERTURE PRIORITY	A
Tv	SHUTTER PRIORITY	S
P	PROGRAM	P
	AUTOMATIC	AUTO

WHITE BALANCE

	AWB AUTO
	DAYLIGHT
	CLOUDY
	SHADE
	TUNGSTEN
	FLUORESCENT
	FLASH
	CUSTOM

APERTURE

Regulates the film's or image sensor's degree of exposure to light

WIDE F/1.6 F/2.8 F/4 F/5.6 F/8 F/11 F/16 NARROW

BRIGHTER DARKER

DEPTH OF FIELD SHARP IMAGES

SHUTTER SPEED

The effective length of time a camera's shutter is open

FAST! SLOW...
1/1000s 1/500s 1/250s 1/125s 1/60s 1/30s 1/15s 1/8s 1/4s 1/2s 1s 2s 15s BULB

DARKER BRIGHTER

SLOW FAST

ISO

Film speed/measure of sensitivity to light

Slow 100 200 400 800 1600 3200 FAST
Less sensitive More sensitive

DARKER BRIGHTER

OUTDOORS INDOORS NIGHT



DSLR CHEATSHEET

for beginners

DSLR

Digital Standard Lens Reflex — the mirror that's placed between the image sensor and the lens.

SENSOR

The part of your camera that detects and records your image.

LENS

Used in conjunction with a camera body and mechanism to make images of objects.

APERTURE

Determines the amount of light that gets in. The aperture of your lens is measured in f-stops, such as f2, f11, etc.

DEPTH OF FIELD

Refers to how much of your image will be in focus.

ISO

Determines how sensitive your image sensor is. High ISO is more sensitive to light, but adds grain.

SHUTTER SPEED

The length of time when the film or digital sensor inside the camera is exposed to light.

EXPOSURE TRIANGLE

Three components of a perfect image: shutter speed, aperture, and ISO.

FLASH

Devices used to add extra light to a scene. They can be attached to your DSLR or held separately.

REMOTE

Completes the same function as the shutter button on your camera, but can be pressed at a distance.

FILTER

An accessory used to change the color or type of light that comes into your lens. Screwed or clipped to your lens.

METER

The stepped bar that looks like a ruler that's on the bottom of your viewfinder or on your display.

BOKEH

The blur effect produced in the out-of-focus parts of an image, taken with a narrow depth of field.

TRIPOD

A three-legged mount that holds your camera steady.

RULE OF THIRDS

Break the image into 9 squares, placing subjects at their intersections.

HDMI

High-definition Multimedia Interface. Many DSLRs integrate it to transmit crystal-clear digital video.

PHOTOGRAPHY CHEATSHEET

EXPOSURE

www.photographerabroad.com

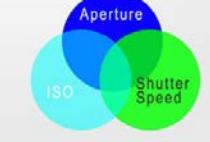


The 3 aspects of Exposure:

1) Aperture (Depth of field)

2) Shutter Speed (Duration)

3) ISO (Sensitivity to light)



Aperture

Aperture controls the size of the opening through which light passes. A larger opening allows in more light, while a smaller opening lets in less light. The size of the aperture can be changed by opening or closing the iris diaphragm. The f-number is the ratio of the focal length to the diameter of the aperture. An f/2.8 creates a shallow depth of field, while an f/22 creates a deep depth of field. Smaller apertures result in sharper images because the sensor receives more light and better depth of field.



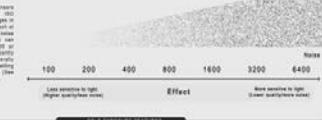
Shutter Speed

Shutter speed controls the duration in which the cameras image sensor is exposed to light and thus defines motion blur. Shutter speed is measured in seconds. A slow shutter speed allows more light and movement to reach the sensor, whereas a fast shutter speed allows less light and movement to reach the sensor to capture the action of moving subjects. A slow shutter speed may be needed for shutter speeds slower than 1/60th of a second, the camera's shake may be reduced in the fast range.



ISO

ISO is the camera's image sensor sensitivity to light. A higher ISO allows the camera to capture images in low light conditions. However, the presence of increased noise makes the image appear grainy. Most digital cameras range up to 10,000 or higher. ISO is a key factor in affecting image quality. Generally, the lower the ISO, the better the image will be. However, it should be used when possible (see your camera's manual for details).



DSLR EXPOSURE FEATURES

Metering

A DSLR's light meter judges the proper exposure for rendering the right amount of light and avoiding overexposure or underexposure.

Most cameras have 2-3 modes of metering: Matrix, Center-weighted and Spot.

Metering Modes

Matrix: Evaluates the overall scene to determine the proper exposure.

Center-weighted: Measures the light from the center of the frame and applies it to the entire image.

Exposure Meter

Under Exposed: Underexposed images appear dark and lack detail. Overexposed: Overexposed images appear bright and lack detail. Properly Exposed: Properly exposed images appear balanced.

The Histogram

The histogram measures pixel intensity distribution of three values across an image. The x-axis represents the number of pixels, the y-axis represents the intensity of highlights. The histogram is a useful tool for determining the exposure settings against 100% gray. Note: some tools are reversed.

Version 1.0

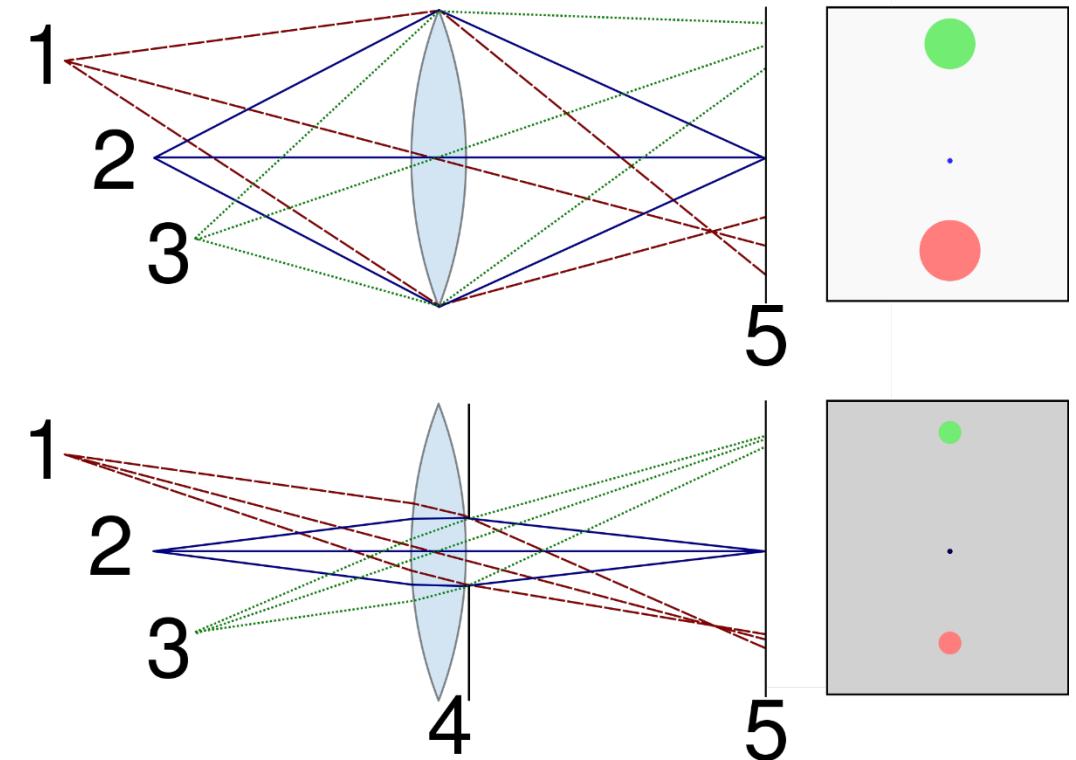
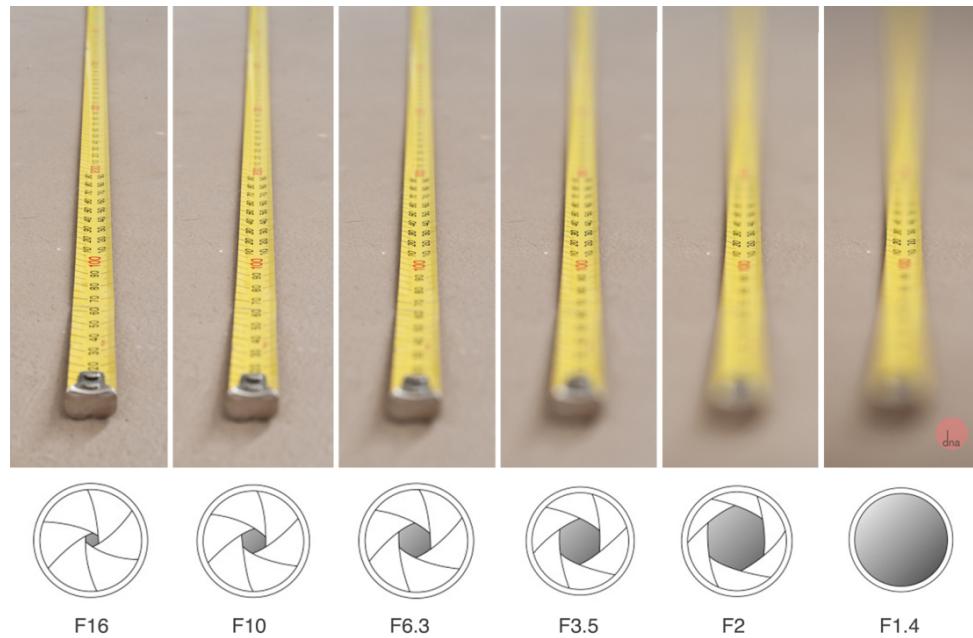
www.photographerabroad.com

pa

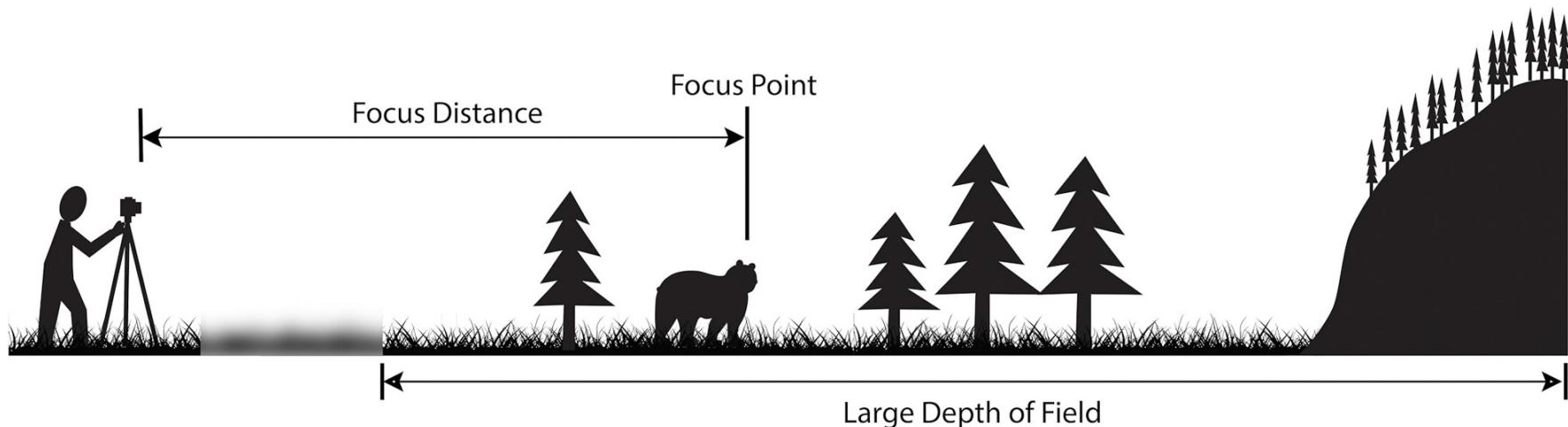
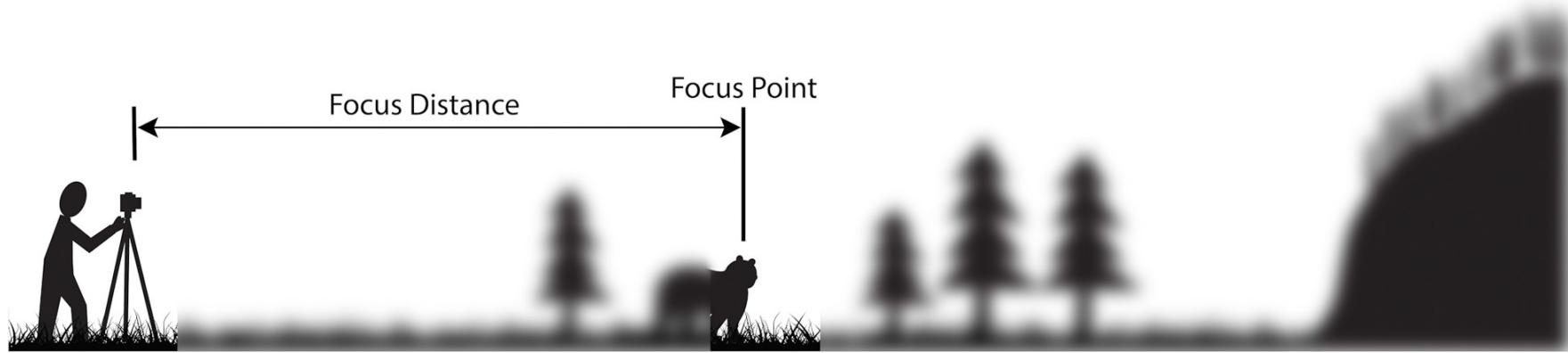
Why Do We Use a Tripod?

- When you need to be flexible
- **When taking nighttime shots and sunsets**
- **When you are using a zoom**
- When you are taking action shots and doing sport photography
- When you are doing natural photography

Effect of Aperture



Understanding Depth of Field



Different Depth of Fields



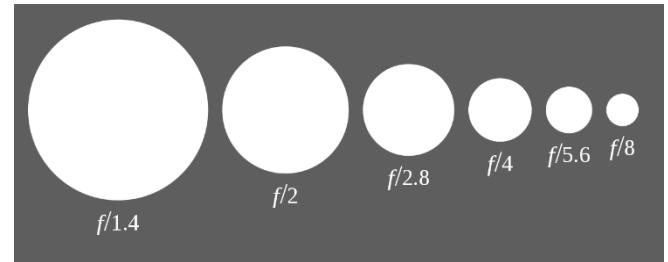
Q. Why is it better? resolution?

F-Number or F-Stop

The f-number N is given by:

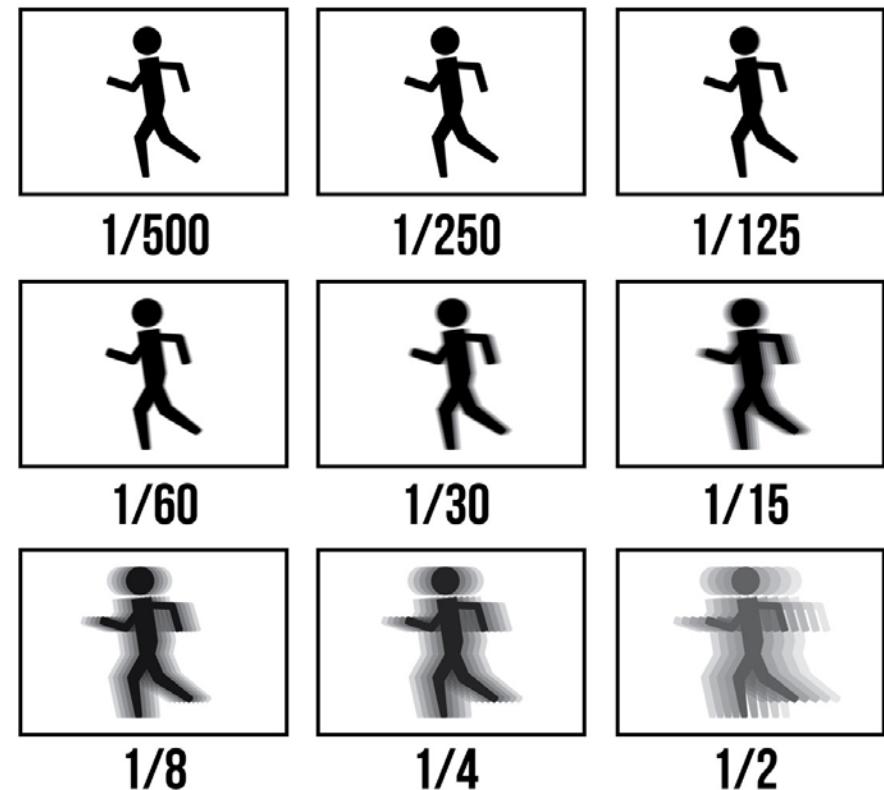
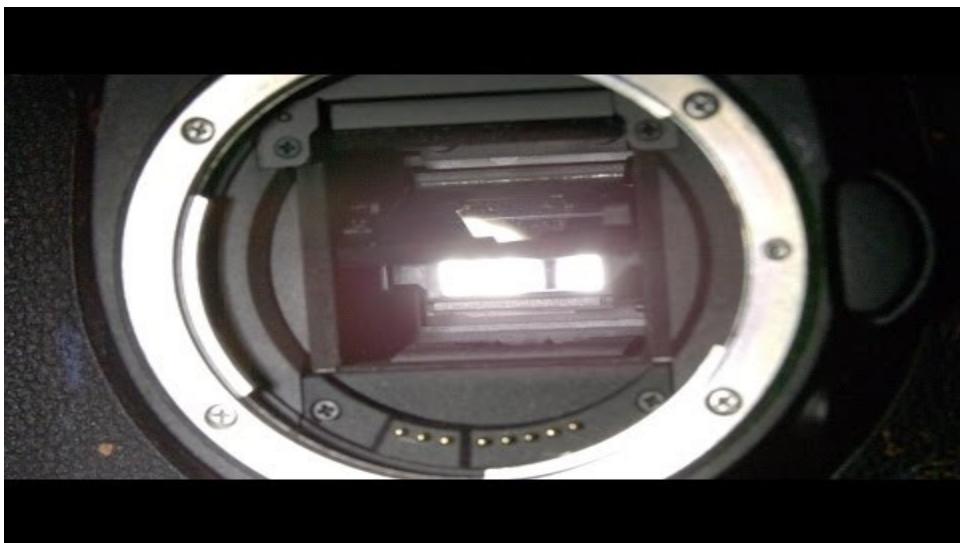
$$N = \frac{f}{D}$$

where f is the [focal length](#), and D is the diameter of the entrance pupil ([effective aperture](#)). It is customary to write f-numbers preceded by $f/$, which forms a mathematical expression of the entrance pupil diameter in terms of f and N .^[1] For example, if a lens's focal length is 10 mm and its entrance pupil diameter is 5 mm, the f-number is 2, expressed by writing "f/2", and the aperture diameter is equal to $f/2$, where f is the focal length.



The amount of light entering in the lens

Effect of Shutter Speed

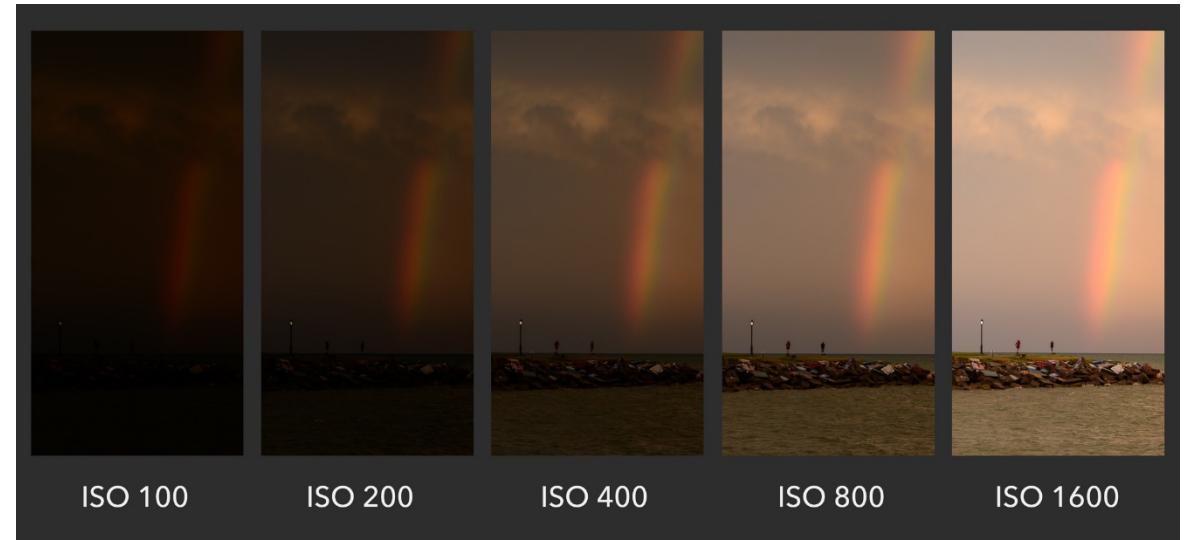


<https://www.creativelive.com/photography-guides/what-is-shutter-speed>

Example: Night Photography



Effect of ISO

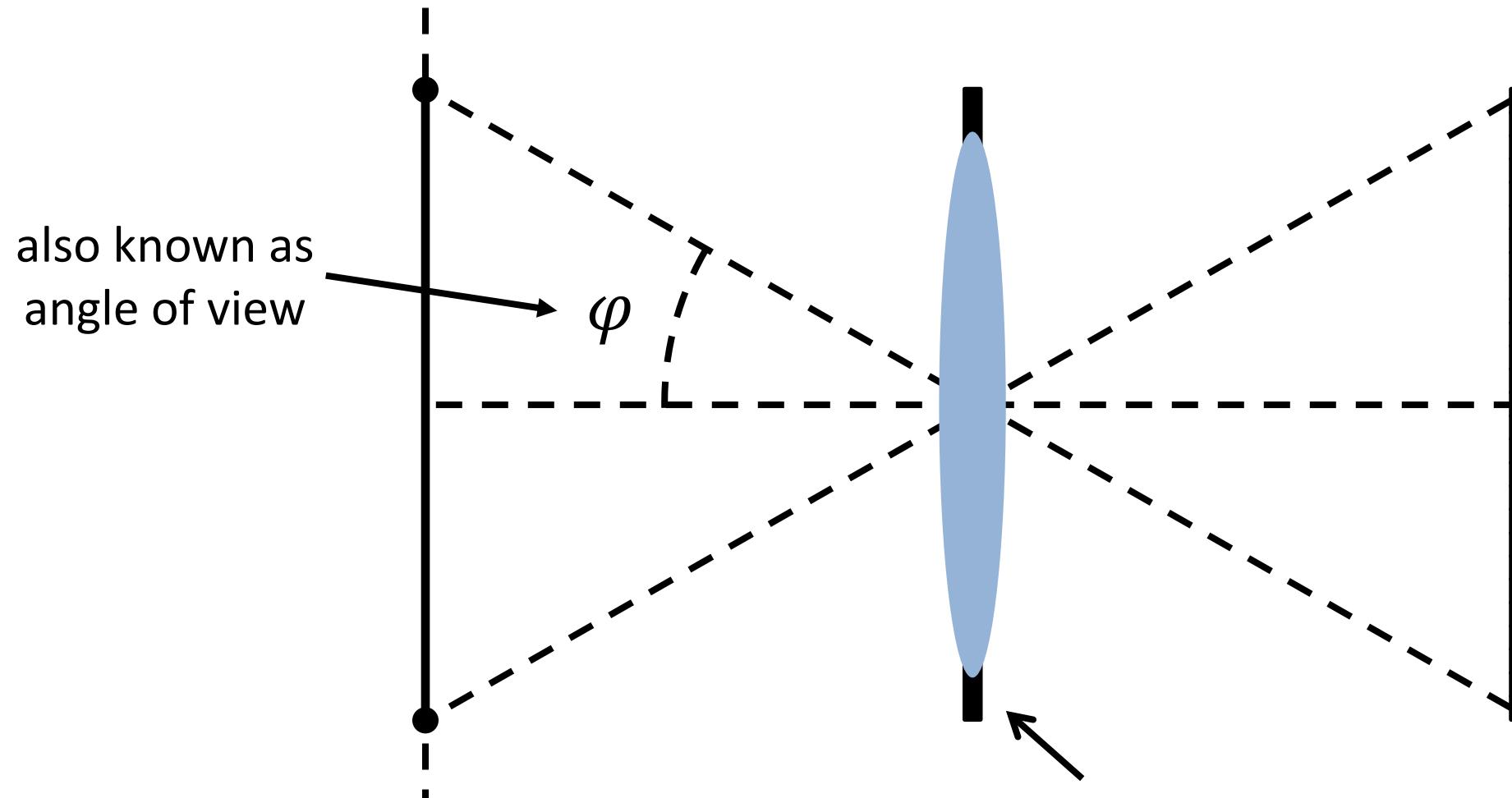


<https://www.shawacademy.com/blog/everything-you-need-to-know-about-iso/> <https://photographylife.com/what-is-iso-in-photography>

Situations that Affects How You Choose an ISO

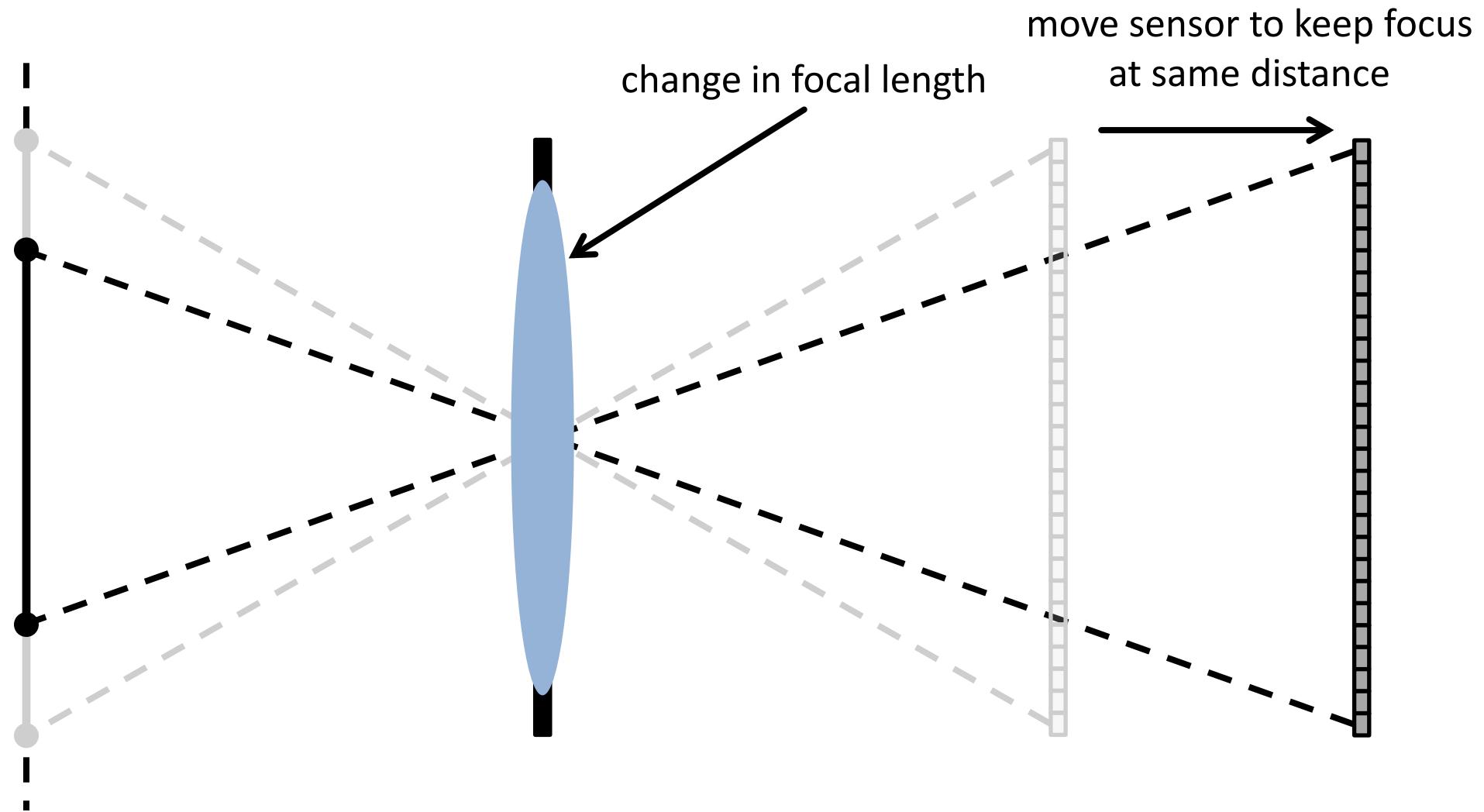
- If your subject is moving and you're trying freeze the motion for a still, a higher ISO will allow for a faster shutter speed.
- If you're using a tripod to stabilize your camera, you can usually get away with a slower shutter speed, which in turn allows you to use a lower ISO. Note that a tripod doesn't help you freeze subject motion, however.
- If you're shooting an image that doesn't require a large depth-of-field, you can increase the aperture (thus allowing more light into the lens) and use a lower ISO.
- If you're shooting with artificial light — e.g., a flash — you can typically get away with a lower ISO setting.

Field of view



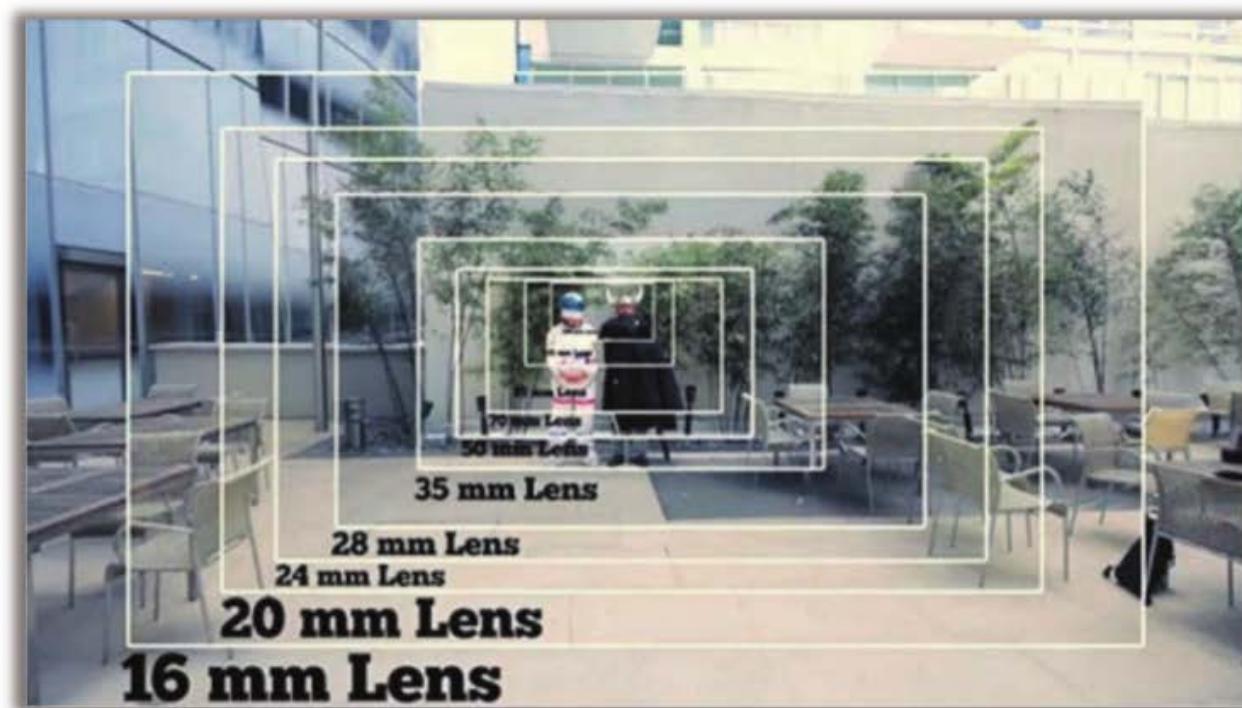
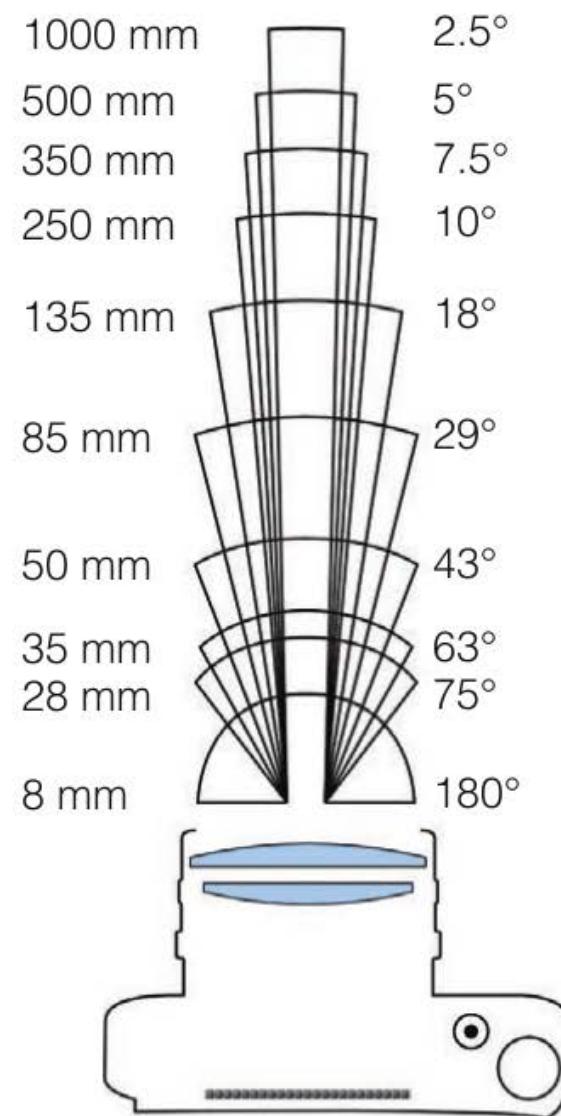
Note: here I drew a lens, but I could have just as well drawn a pinhole

Field of View (Continue)



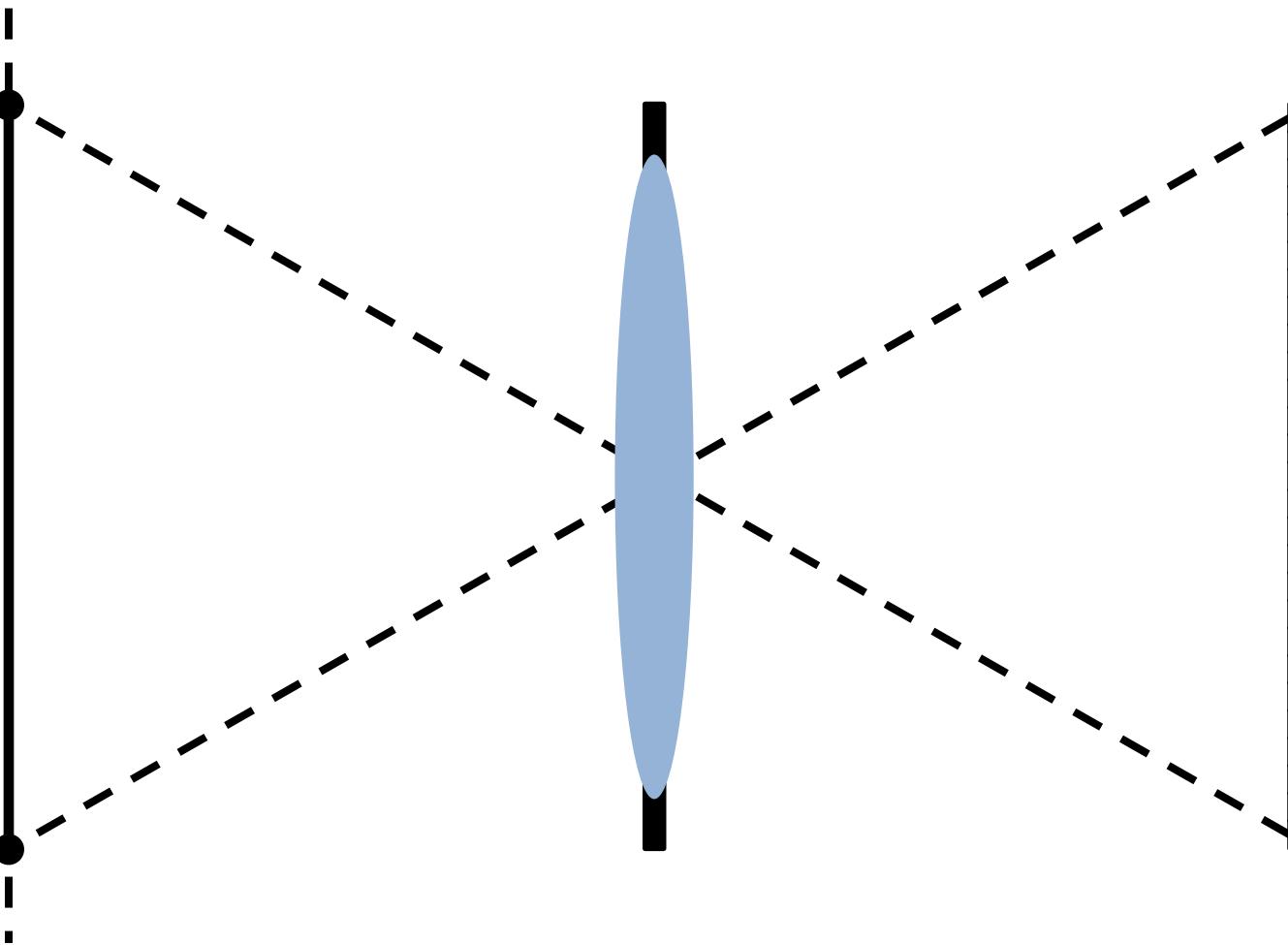
- What happens to field of view when we increase focal length? → It decreases.

Field of View (Continue)



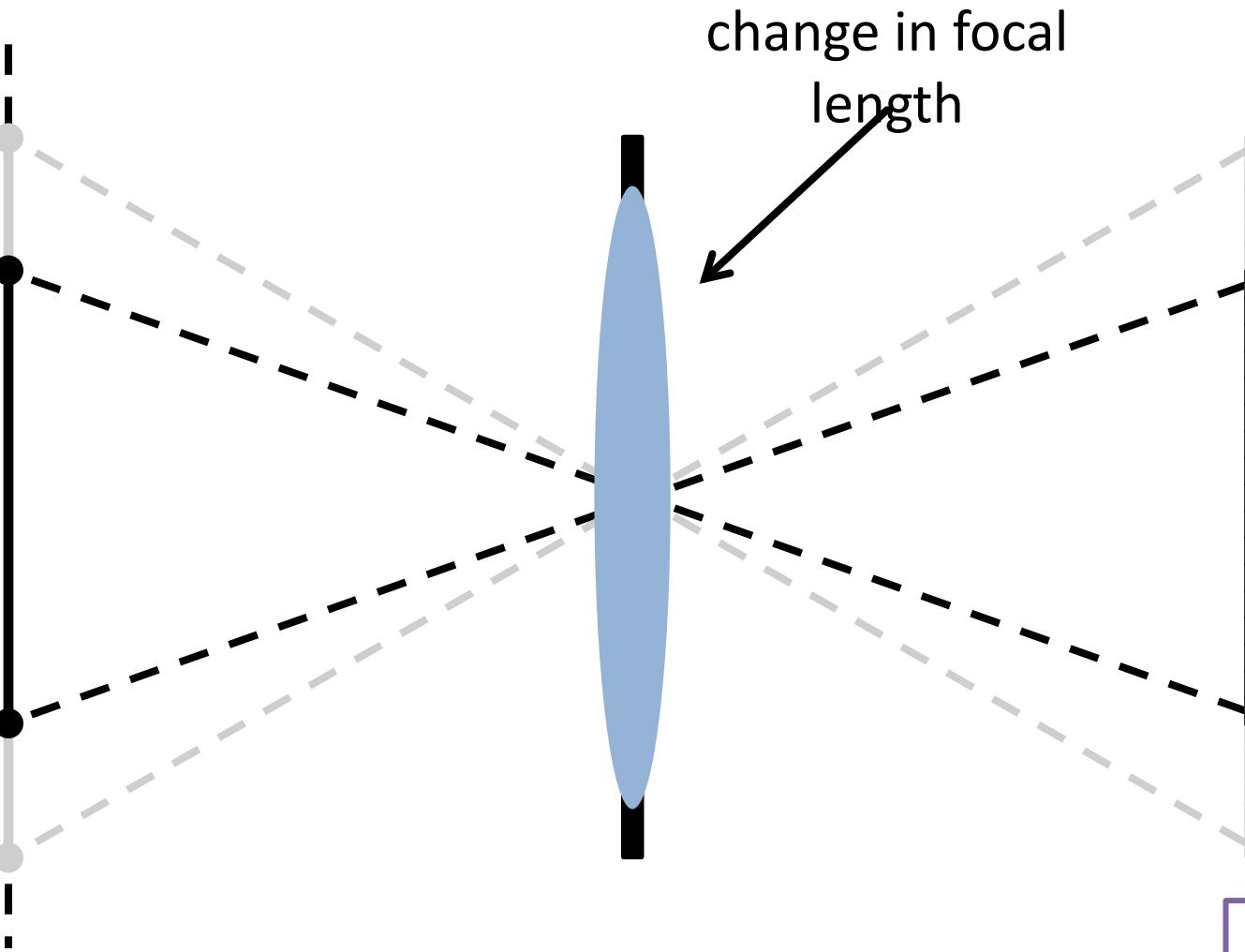
Andrew McWilliams

Field of View Depending on Sensor Size



- What happens to field of view when we reduce sensor size?

Field of View Depending on Sensor Size



Q. Your smartphone?

- What happens to field of view when we reduce sensor size? → It decreases.

Field of View Depending on Sensor Size

Medium format (Kodak KAF 39000 sensor)

35 mm "full frame"

APS-H (Canon)

APS-C (Nikon DX,
Pentax, Sony)

APS-C (Canon)

1" (Sony, Nikon)

Foveon (Sigma)

Four Thirds

2/3"

1/1.8"

1/2.5"



How much field of view is
cropped when using a sensor
smaller than full frame.

Example: Ultra Telephoto Prime Lens



Example: Macro Videography



DSLR Camera (Shutter Priority vs Aperture Priority Modes)

Mode P (Programmed Auto)

The camera automatically adjusts aperture and shutter speed for optimal exposure, but the photographer can choose from different combinations of aperture and shutter speed that will produce the same exposure. This is known as flexible program.

Mode S (Shutter-Priority Auto)

The photographer chooses the shutter speed and the camera automatically adjusts aperture for optimal exposure.

Mode A (Aperture-Priority Auto)

The photographer chooses the aperture and the camera automatically adjusts shutter speed for optimal exposure.

Mode	Shutter Speed	Aperture
P (programmed auto)	Selected by camera	Selected by camera
S (shutter-priority auto)	Selected by photographer	Selected by camera
A (aperture-priority auto)	Selected by camera	Selected by photographer
M (manual)	Selected by photographer	Selected by photographer

Slide Credits

- Lecture notes: Rob Fergus.
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