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' Aperture, Shutter speed Controls of a Camera.

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Lesson Objectives

Exposure Triangle

* Aperture
* Shutter Speed
* ISO

Recall: Focal Length vs. Viewpoint

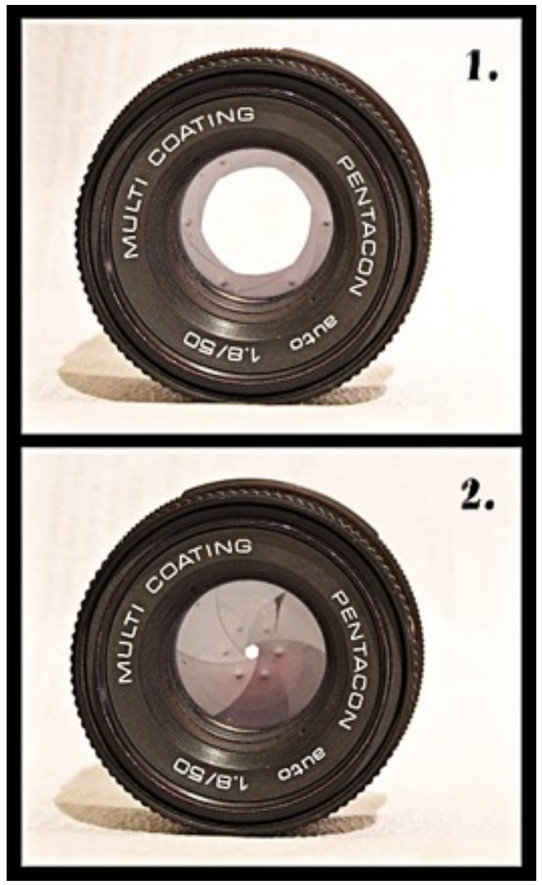
f = 18mm, 35mm sensor
1st Subject: 0.5m away
2nd Subject: 2.0m away

f = 180mm, 35mm sensor
1st Subject: 3.0m away
2nd Subject: 4.5m away

* Changing focal length allows us to move back, and still capture the scene

* Changing viewpoint causes perspective changes

Exposure (H)



Exposure = Irradiance X Time

$$H = E * T$$

Irradiance (E)

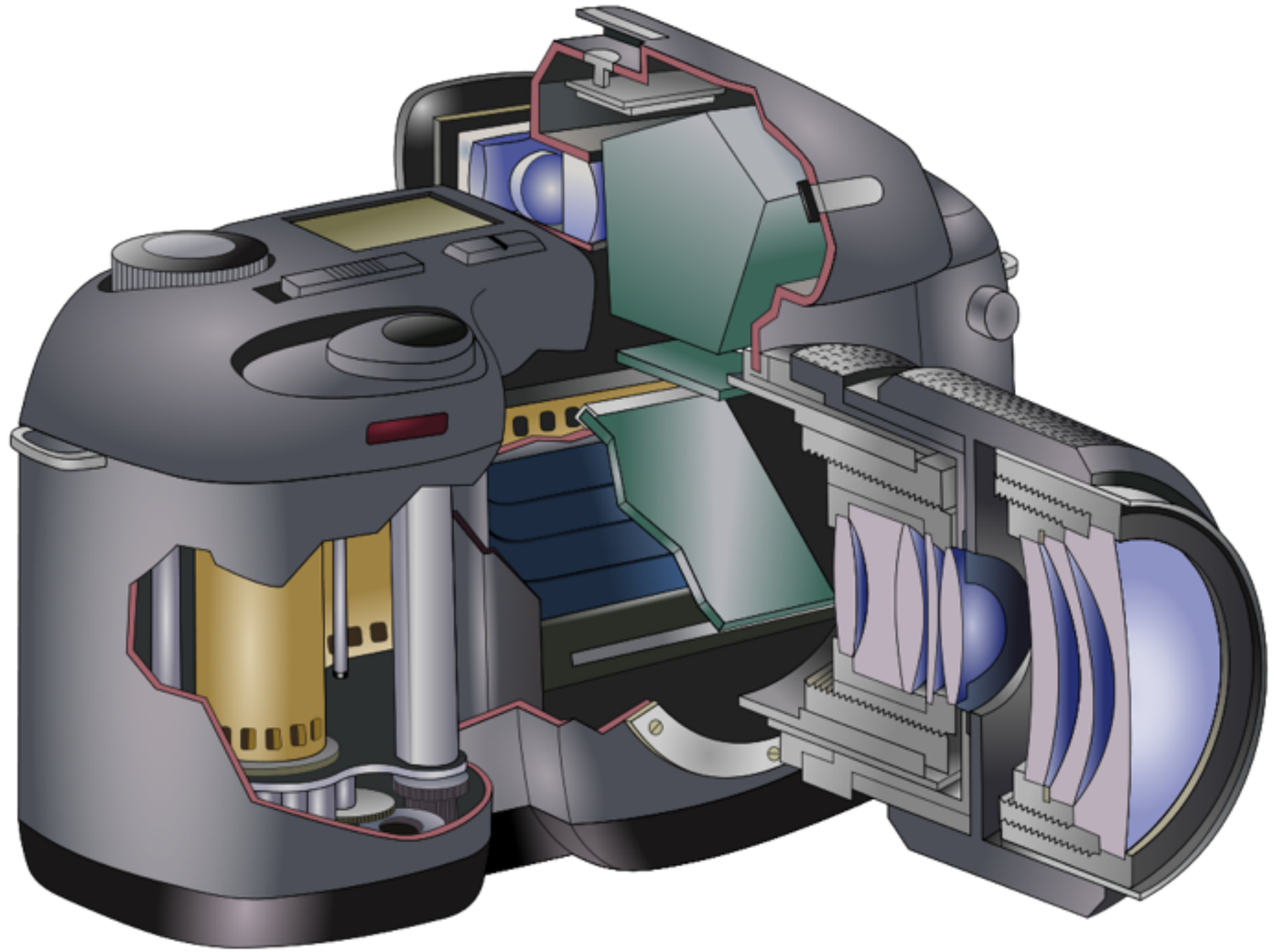
* Amount of light falling on a unit area of sensor per second
* Controlled by lens **aperture**

Exposure Time (T)

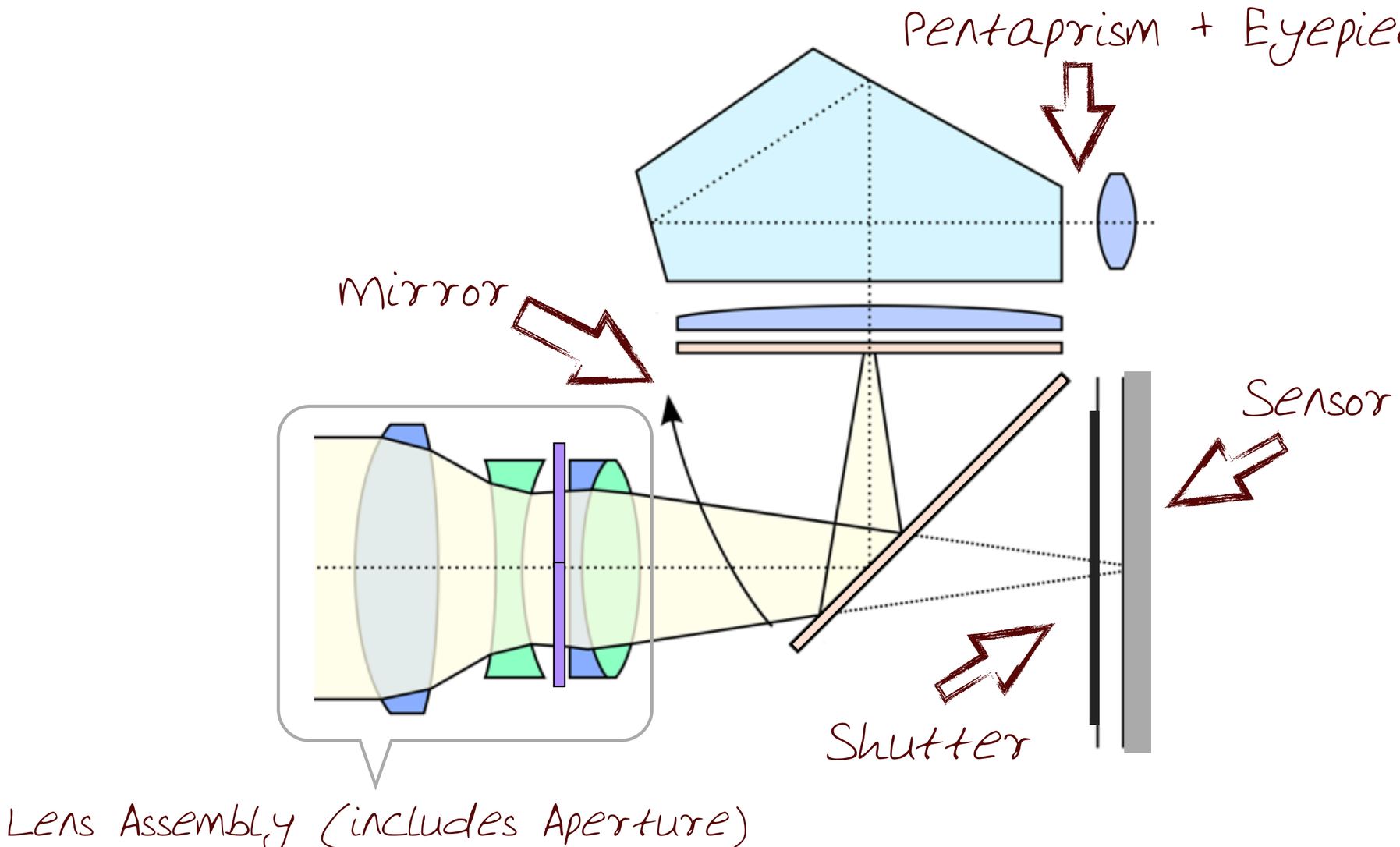
* How long the **shutter** is kept open

commons.wikimedia.org

Inside a Camera (an SLR)



Inside a Camera (an SLR)



Adapted from commons.wikimedia.org/

Shutter Speed (1st Example)

http://commons.wikimedia.org/wiki/File:Shutter_speed_waterfall.gif

- Amount of time the sensor is exposed to light
- Usually denoted in fractions of a second (1/2000, 1/1000, ..., 1/250, ..., 1/60, ..., 1/15, ..., 15, 30, Bulb)
- Effects of Motion Blur to Streaks

Shutter Speed (2nd example)

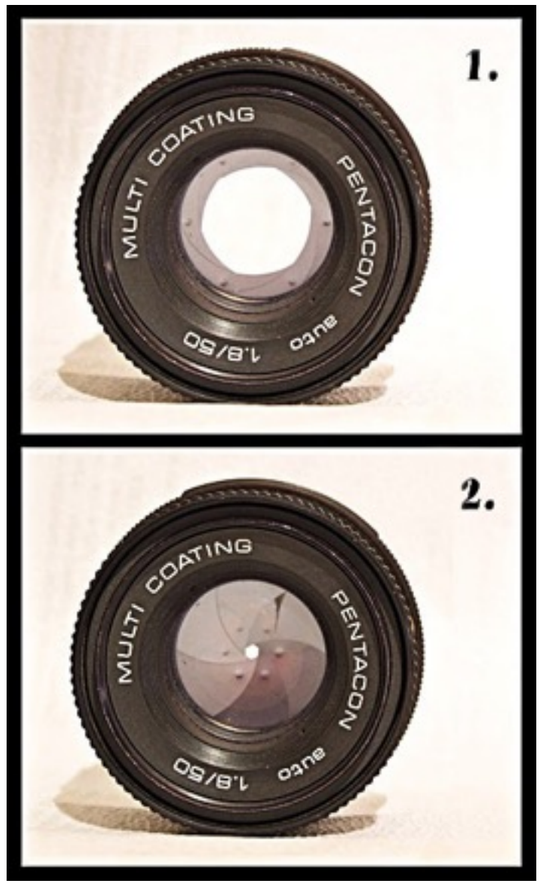
1/125 second

http://everydayhdr.com/wp-content/uploads/2012/09/Waterfall-Aperture-Compare.jpg

Shutter Speed (3rd Example)

http://commons.wikimedia.org/wiki/File:Windflower-05237-nevit.JPG

Aperture



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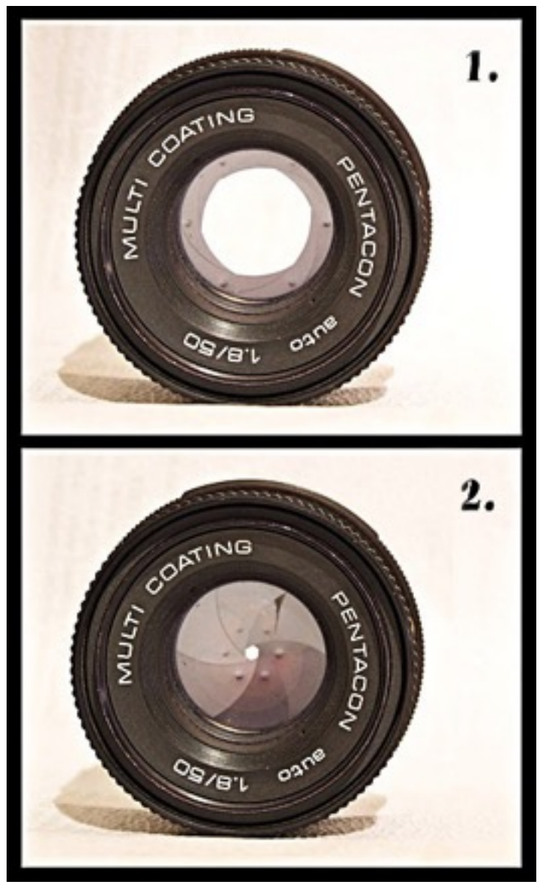
Irradiance on Sensor ➔ The amount of light captured is proportional to the Area of the Aperture (opening).

$$Area = \pi \left(\frac{f}{2N} \right)^2$$

* **f** is the the focal length. What is the diameter of the Aperture?
* Aperture Number **N** usually written as **f/N**

Aperture



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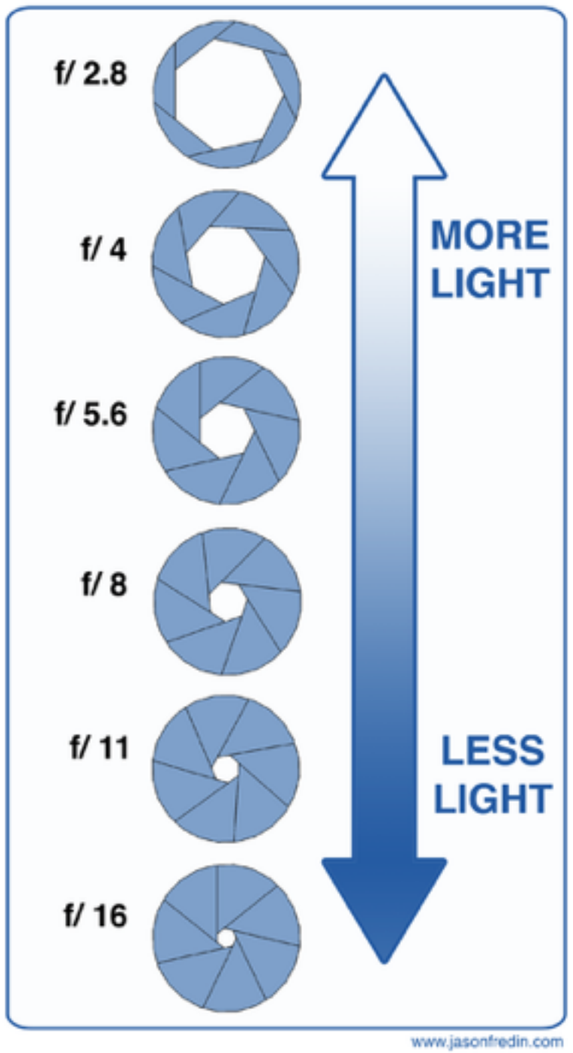
- Focal length: **f**
- Aperture Number: **N** (usually written **f/N**)
- Aperture Number gives irradiance irrespective of the lens in use

$$Area = \pi \left(\frac{f}{2N} \right)^2$$

- f/2.0 on 50mm lens → aperture = 25mm
- f/2.0 on 200mm lens → aperture = 100mm
- Low f-number (**N**) on telephoto lens means BIG lens

Aperture

$$Area = \pi \left(\frac{f}{2N} \right)^2$$



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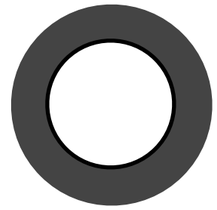
* Doubling **N** reduces **A** by **4X**, and therefore reduces light by **4X**
* from f/2.8 to f/5.6 cuts light by 4X
* to cut light by 2X, increase **N** by $\sqrt{2}$

f/22
f/18
f/14
f/11
f/8
f/5.6
f/4.0
f/3.5

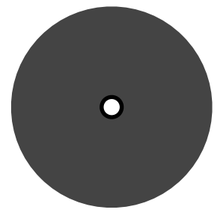
f/22

f/11

f/3.5

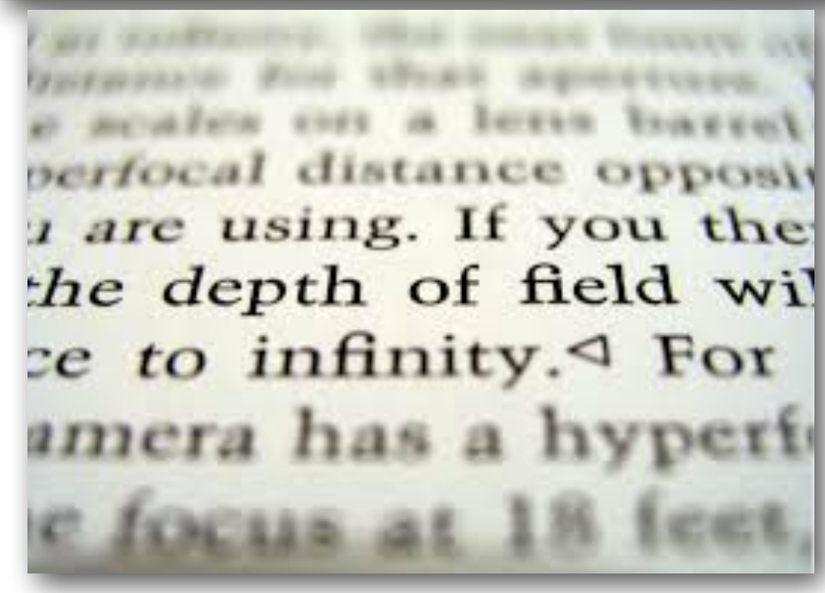


f/3.5



f/22

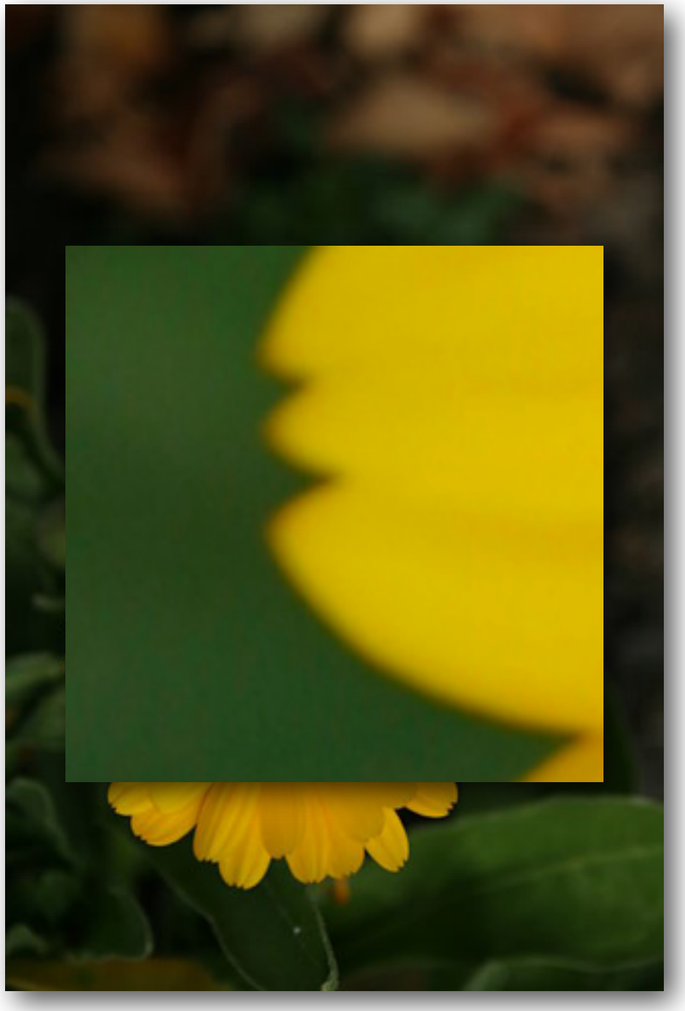
Photographic Values of Aperture/Shutter/Focal L.



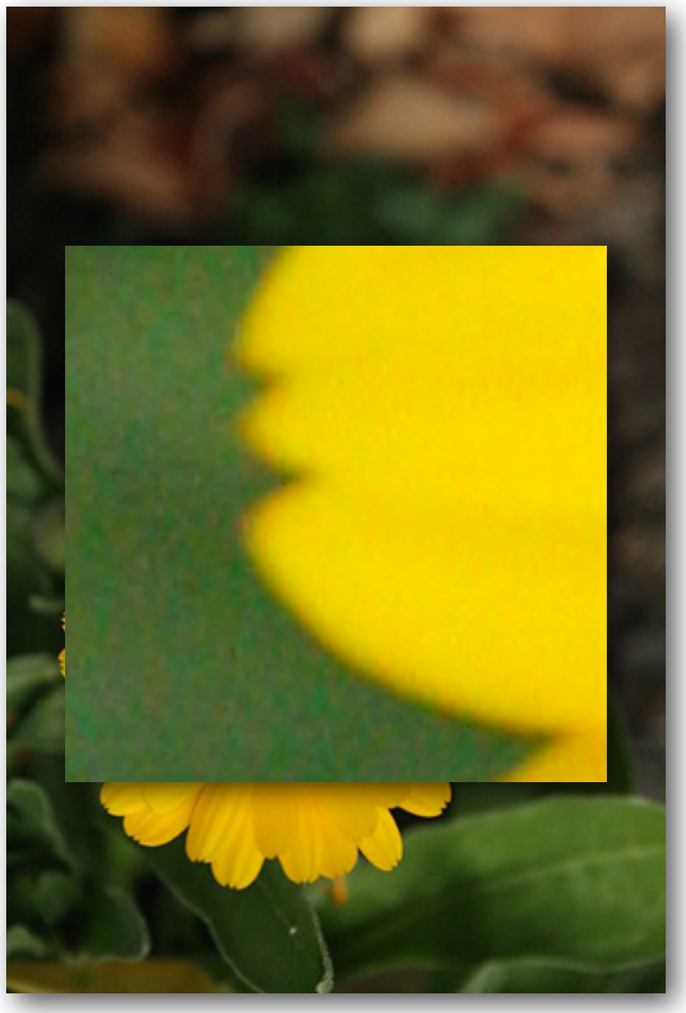
Images: commons.wikimedia.org

https://www.youtue.com/watch?v=RAe30VG5CI4

ISO (Sensitivity)



ISO 100



ISO 1600

* Third Variable in getting the right Exposure
* Film: Sensitivity vs. Grain (of film)
* Digital: Sensitivity vs. Noise (of sensor)
* Linear: 200 ISO needs half the light of 100 ISO

Images: commons.wikimedia.org

f/4.0

f/5.0

f/5.6

1/10 1/20 1/40 1/100 1/160 1/320 1/640 1/1250 1/2500

f/7.1

f/9.0

f/13.0

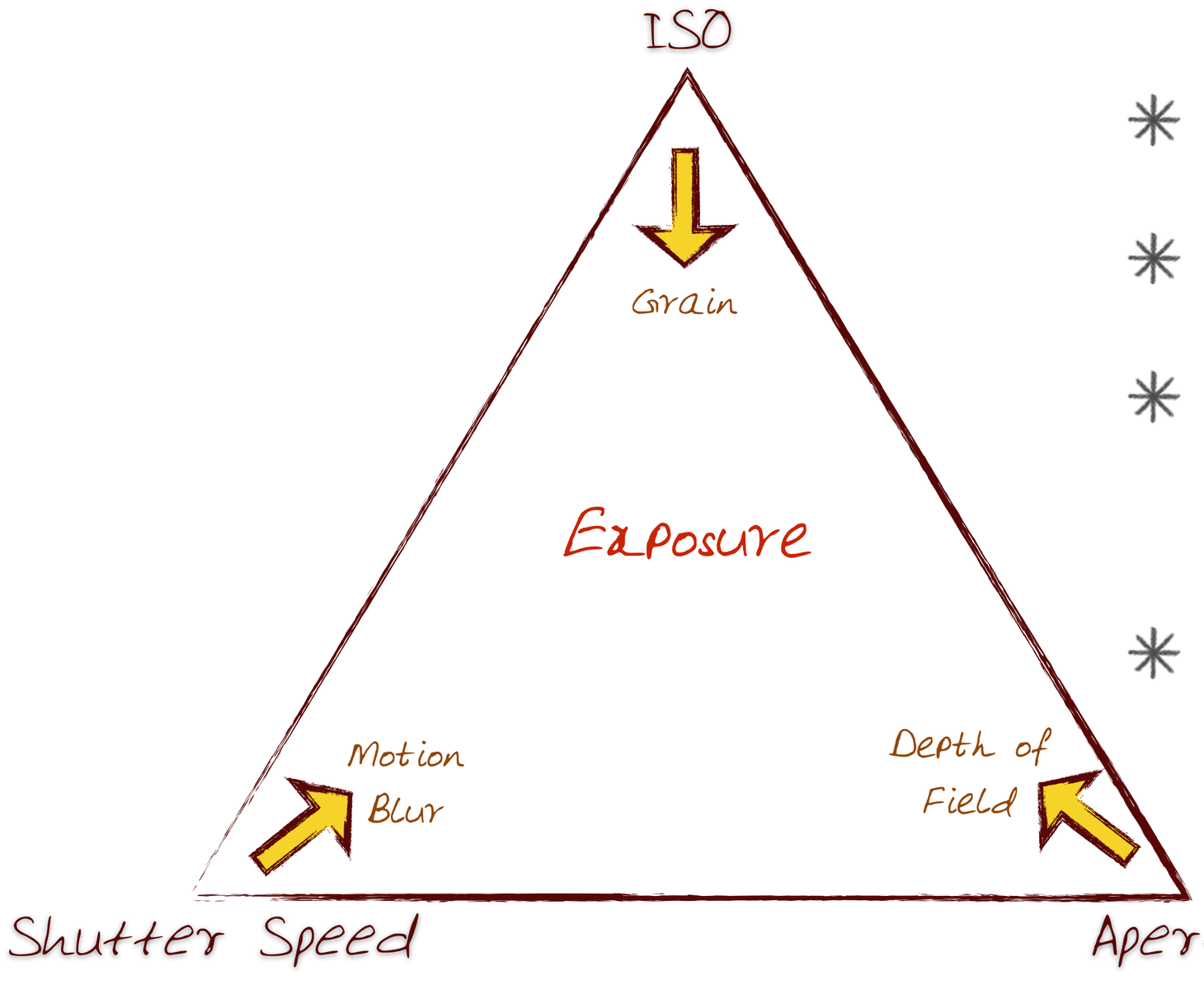
f/20.0

f/5.6

1/10 1/20 1/40 1/100 1/160 1/320 1/640 1/1250 1/2500

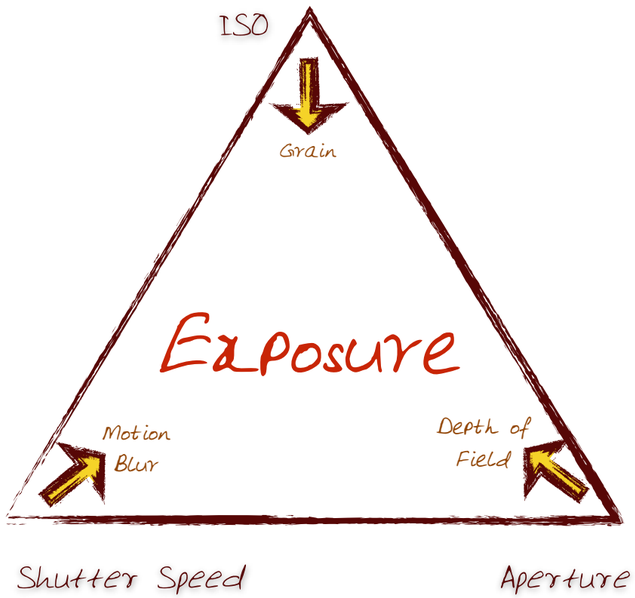
100 200 800 1600 3200 6400

Exposure Triangle



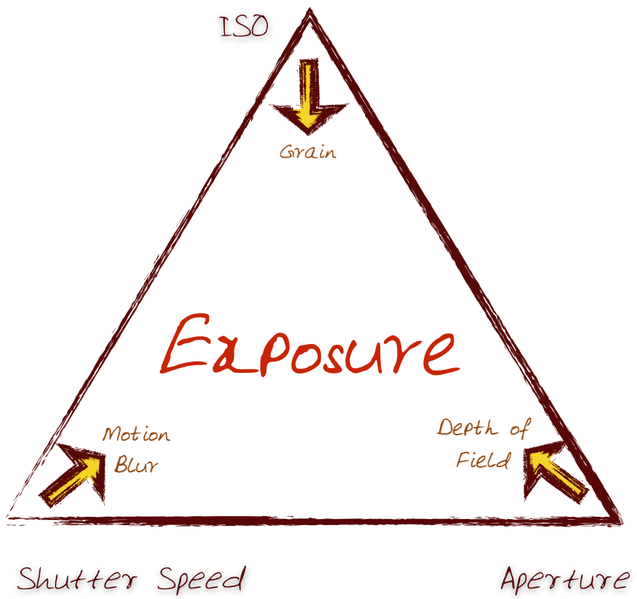
* Aperture opening
* Shutter Speed
* Sensor/Film Sensitivity (ISO)
* OPTIMIZED to get a "desired" exposure

Recap: Exposure



* Exposure (H) = Irradiance (E) **X** Time (T)
* Irradiance (E): Controlled by Aperture opening
* Lowering by $1/f$ stop doubles H (as Aperture opens more)
* Lowering by $2/f$ stops doubles depth of field (DoF).

Recap: Exposure



* Exposure (H) = Irradiance (E) X Time (T)
* Exposure Time (T): Controlled by Shutter Speed
  * Doubling T doubles H
  * Doubling T doubles Motion Blur
* ISO: Doubling ISO needs half the light

Summary

* Presented how a camera operates
* Brought together the concepts Aperture Opening, Shutter Speed and Film Sensitivity (ISO) for optimizing Photographic Exposure
* Discussed the Exposure Triangle and how it combines various aspects of photography

Next Class

Cameras' Sensors

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/.
  - List will be available on website.
- Some Slides adapted from Mark Levoy.

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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