

COMPUTER IMAGING: BUILD YOUR OWN CAMERA

Vikas Dhiman

David Johnson

Madan Raviganesh

Jason J Corso

June 25, 2015

University of Michigan

MODERN CAMERAS

MODERN CAMERAS



MODERN CAMERAS



ABOUT LIGHT

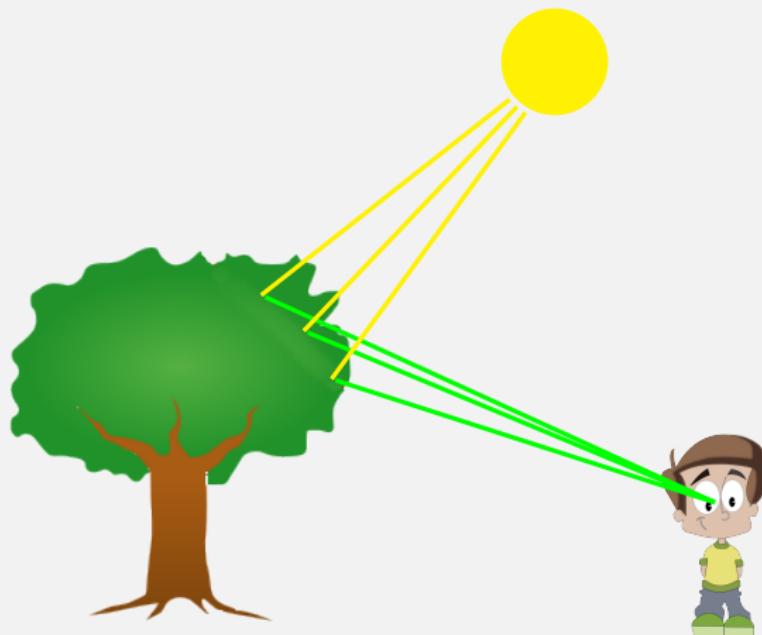
HOW DO WE SEE THINGS?



HOW DO WE SEE THINGS?

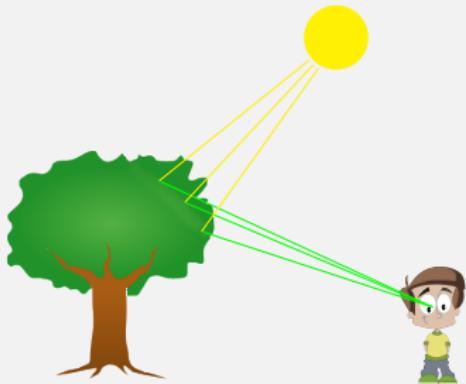


HOW DO WE SEE THINGS?



HOW DO WE SEE THINGS?

- Does the “sight” travel from our eyes to the object?
- or the “light” travels from the object to our eyes?

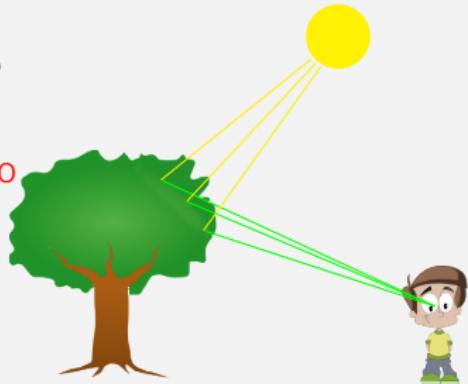


HOW DO WE SEE THINGS?

- Does the “sight” travel from our eyes to the object?

Euclid other Greek philosophers believed so around 300 BC

- or the “light” travels from the object to our eyes?



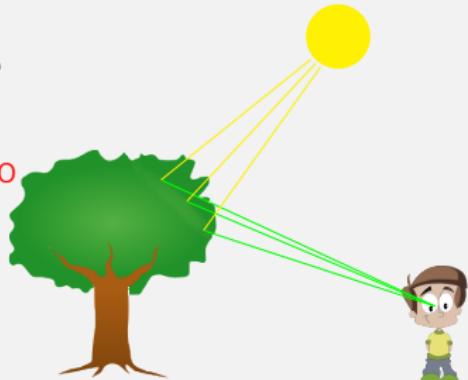
HOW DO WE SEE THINGS?

- Does the “sight” travel from our eyes to the object?

Euclid other Greek philosophers believed so around 300 BC

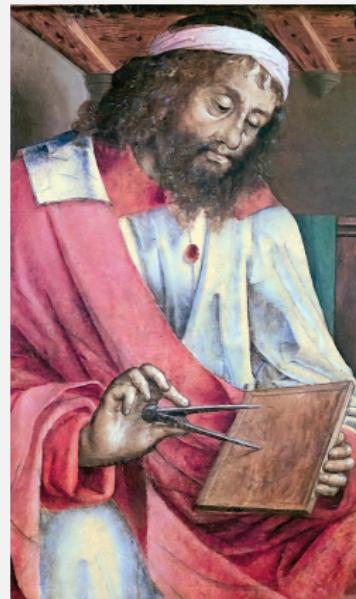
- or the “light” travels from the object to our eyes?

Modern scientists the believe so.



WHAT IS LIGHT?

- Greek philosophers believed that sight was possible because of interaction of fire in eyes and in the sun.
- Euclid, a Greek philosopher, gave us some particular insights about light.



LIGHT TRAVELS IN STRAIGHT LINES

1



¹BBC:Let there be Light (2006).

WHAT IS LIGHT?

Light is something that helps us see things. It travels in straight lines (mostly!!).

MAKING A PINHOLE CAMERA

STEP 1

Take a cup and scotch tape



STEP 2

Cover the open end of cup using the scotch tape



STEP 3

Cut a circular piece of construction paper
to reinforce the cup base.



STEP 4

Pierce a pinhole through the closed end of the cup using a push pin



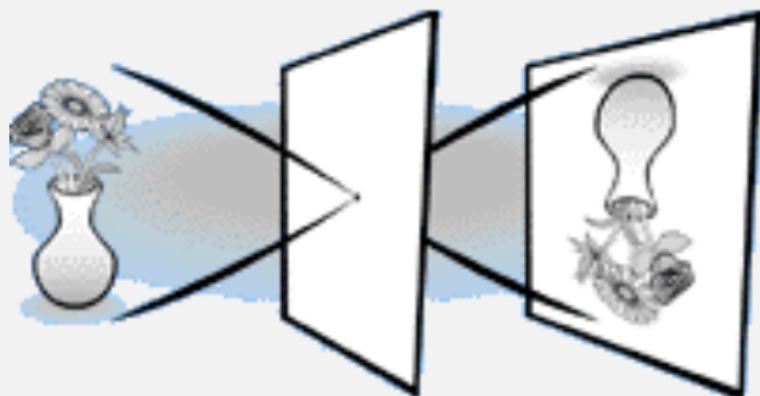
USING THE PINHOLE CAMERA

- Point the bottom of the cup towards the object and scotch tape towards you.
- Hold the cup around one foot away from your eyes.

EXPERIMENT TIME

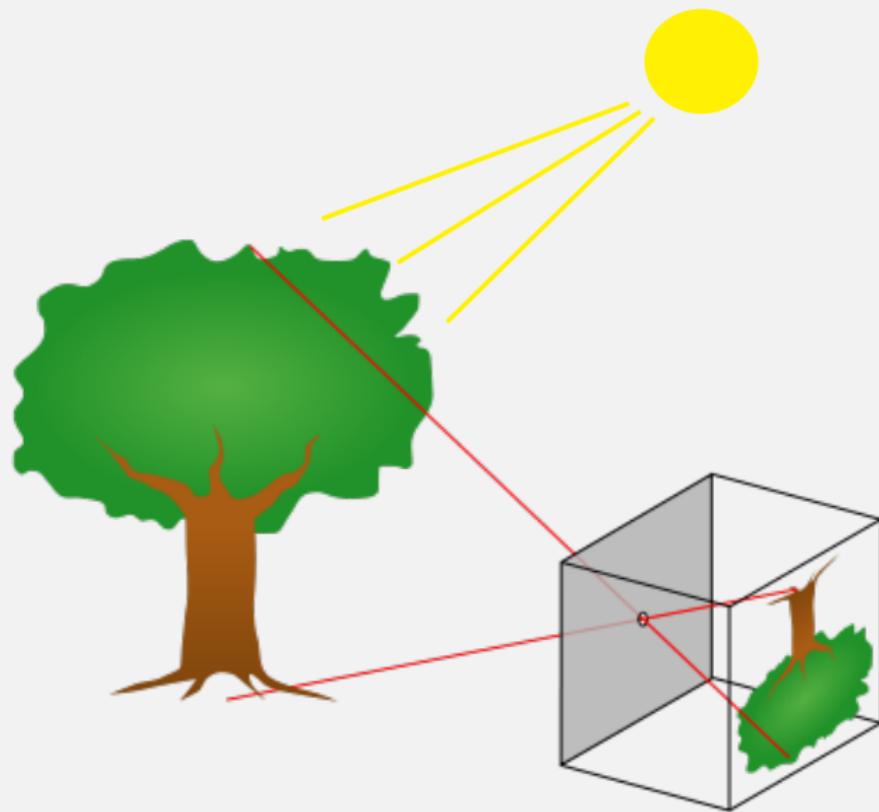
We will turn on the bulb.

DID YOU SEE AN INVERTED IMAGE?

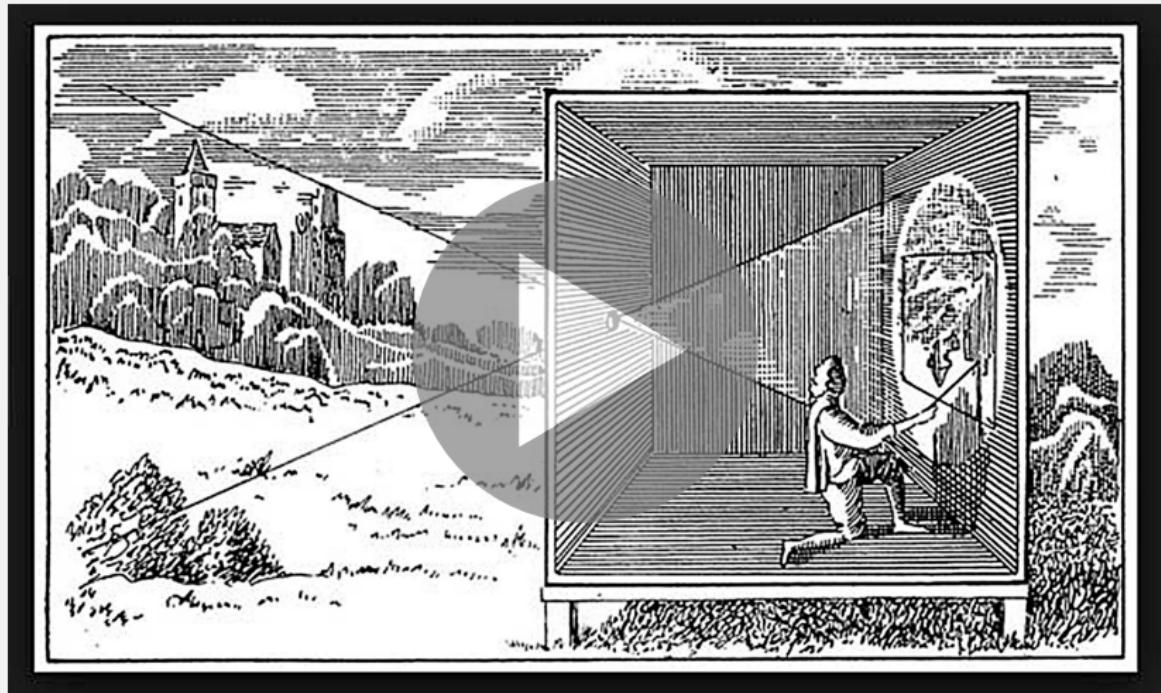


HOW DOES IT WORK

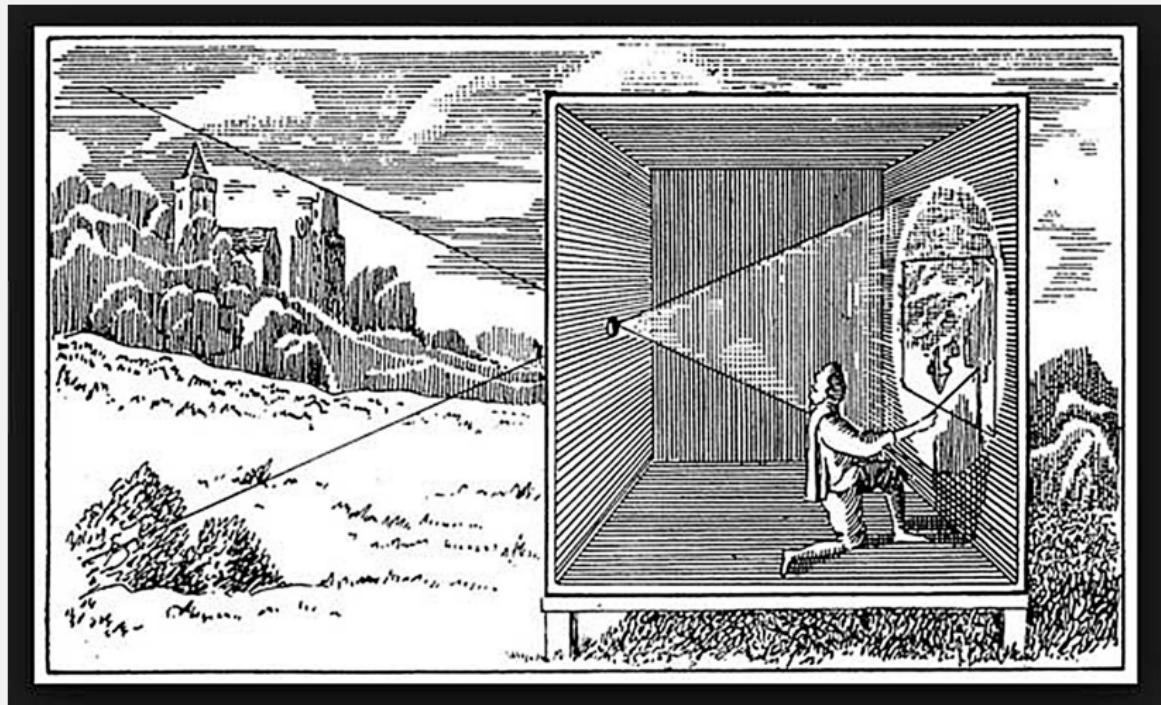
RAY DIAGRAM



CAMERA OBSCURA: CAMERA IN A ROOM



CAMERA OBSCURA: CAMERA IN A ROOM

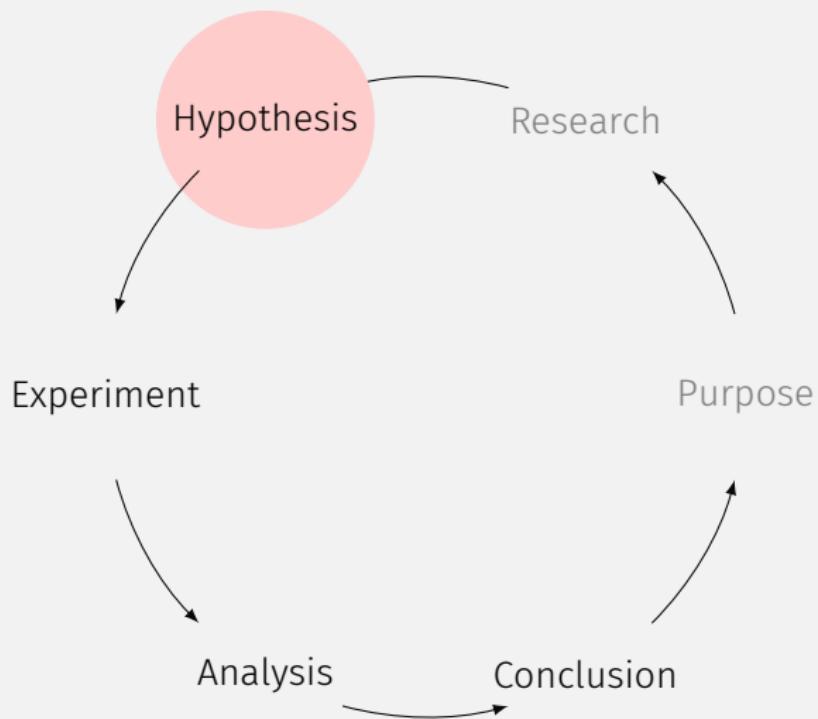


EFFECT OF DISTANCE

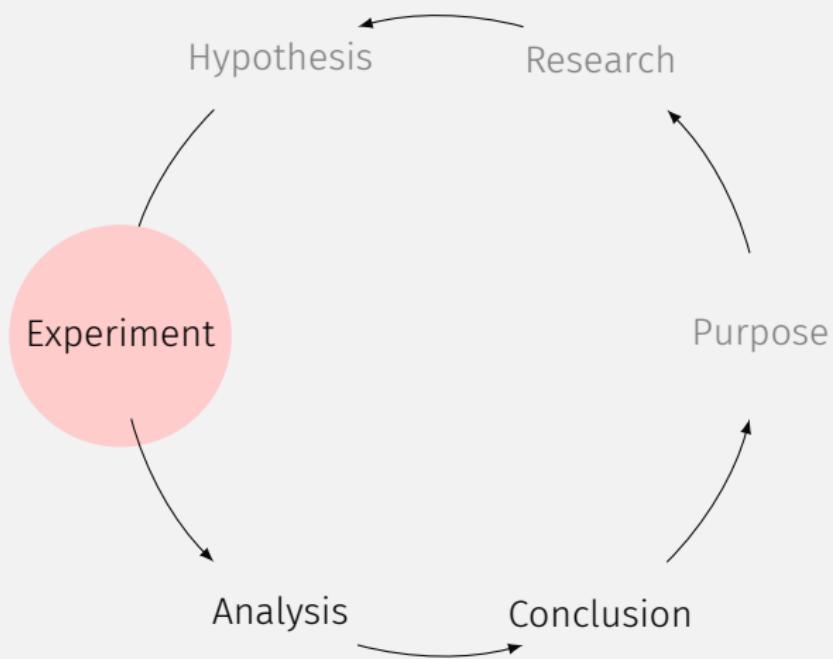
GUESS WHAT HAPPENS

... if you change the distance of the pinhole from the object?

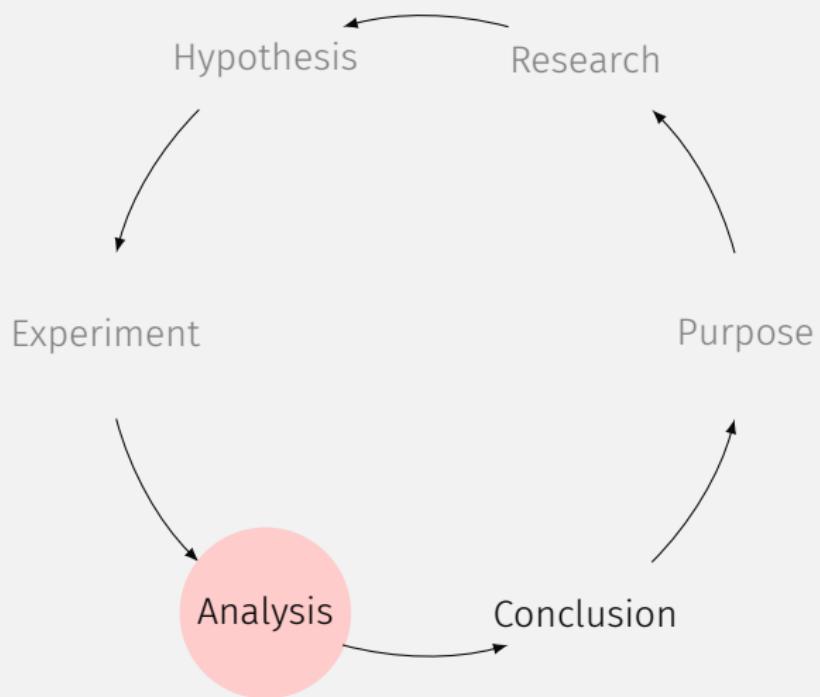
SCIENTIFIC METHOD



SCIENTIFIC METHOD



SCIENTIFIC METHOD



GUESS WHAT HAPPENS

... if you change the distance of the pinhole from the object?

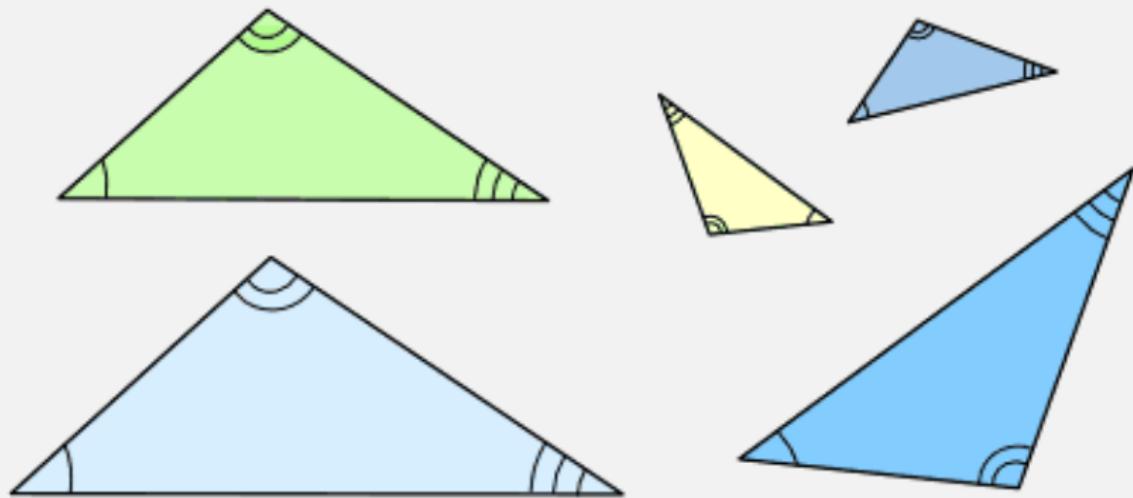
GUESS WHAT HAPPENS

... if you change the distance of the pinhole from the object?
Does it become bigger?

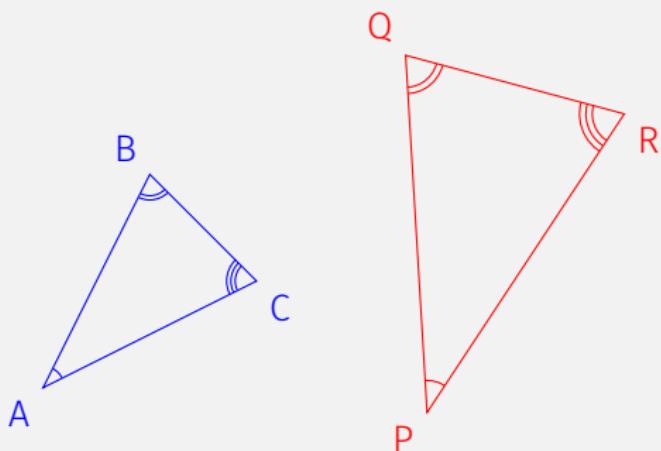
RELATING DISTANCE WITH IMAGE SIZE?

Can you find the distance of the object given the size of object.

SIMILAR TRIANGLES



SIMILAR TRIANGLES



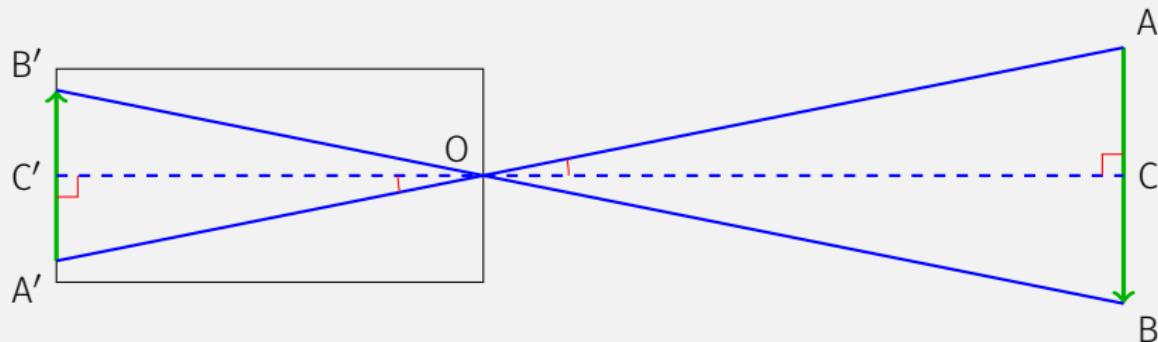
$$\angle ABC = \angle PQR$$

$$\wedge \angle BCA = \angle QRP$$

$$\iff \triangle ABC \sim \triangle PQR$$

$$\iff \frac{AB}{PQ} = \frac{BC}{QR} = \frac{CA}{RP}$$

GEOMETRY OF PINHOLE CAMERA



$$\frac{AC}{OC} = \frac{A'C'}{OC'} \quad (1)$$

$$\frac{\text{Size of object}}{\text{Distance of object}} = \frac{\text{Size of screen}}{\text{Distance of image}} \quad (2)$$

EXERCISE

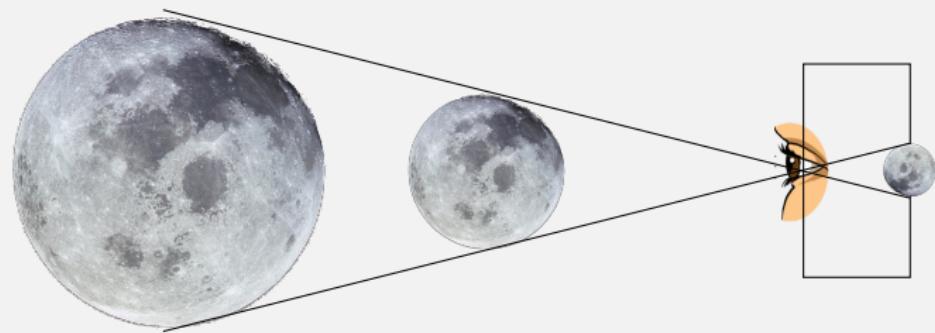
Can we compute the distance of object?

EXERCISE

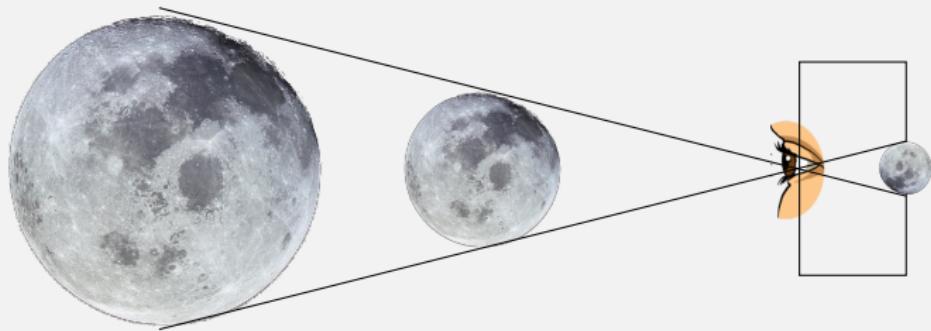
Can we compute the distance of object?

$$\text{Distance of object} = \frac{\text{Size of object}}{\text{Size of image}} \times \text{Distance of screen} \quad (3)$$

DISTANCE AND SIZE OF MOON.



DISTANCE AND SIZE OF MOON.

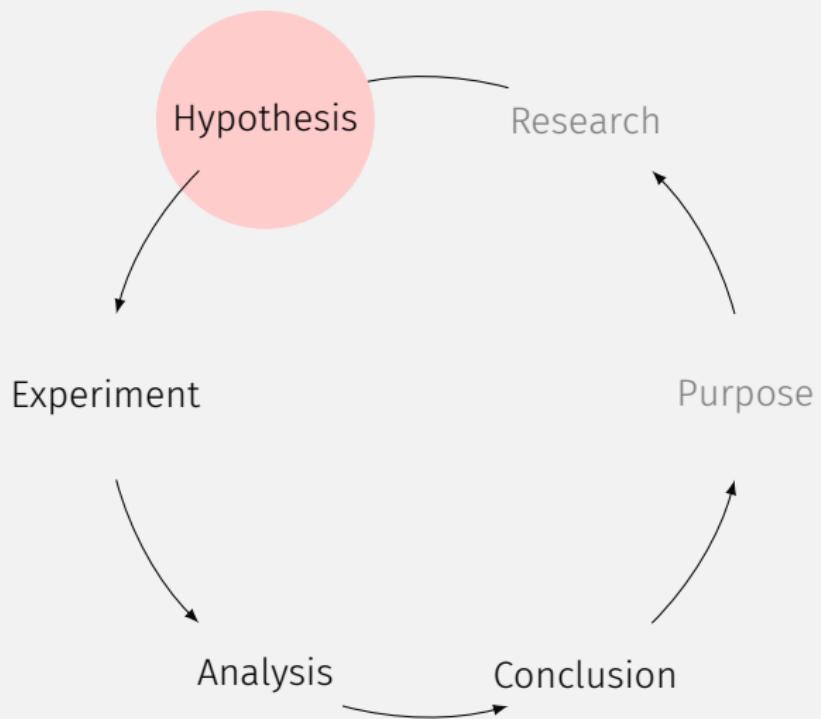


We CANNOT compute both the distance and size of moon from single image.

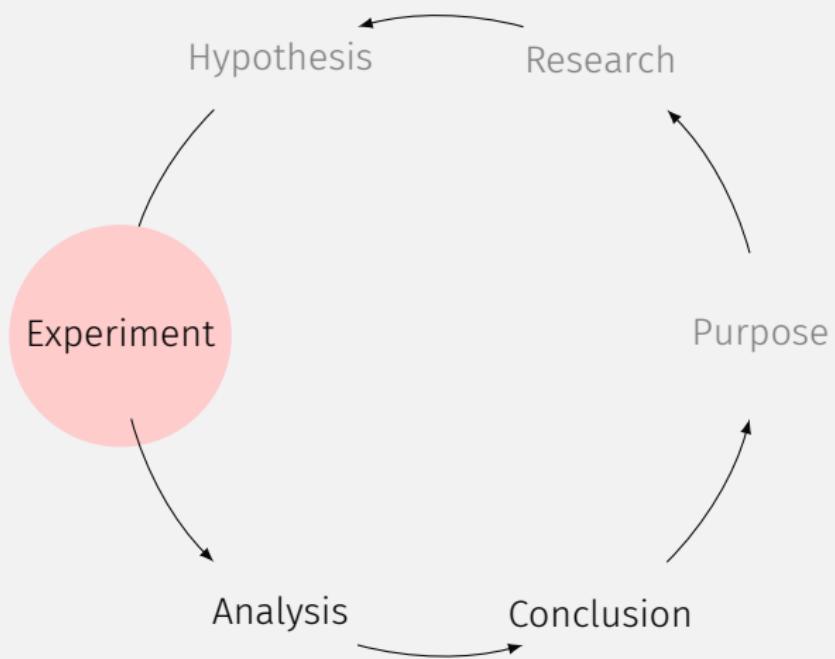
EFFECT OF CHANGE IN SCREEN TO APERTURE

Let's cut the cup along the slit.

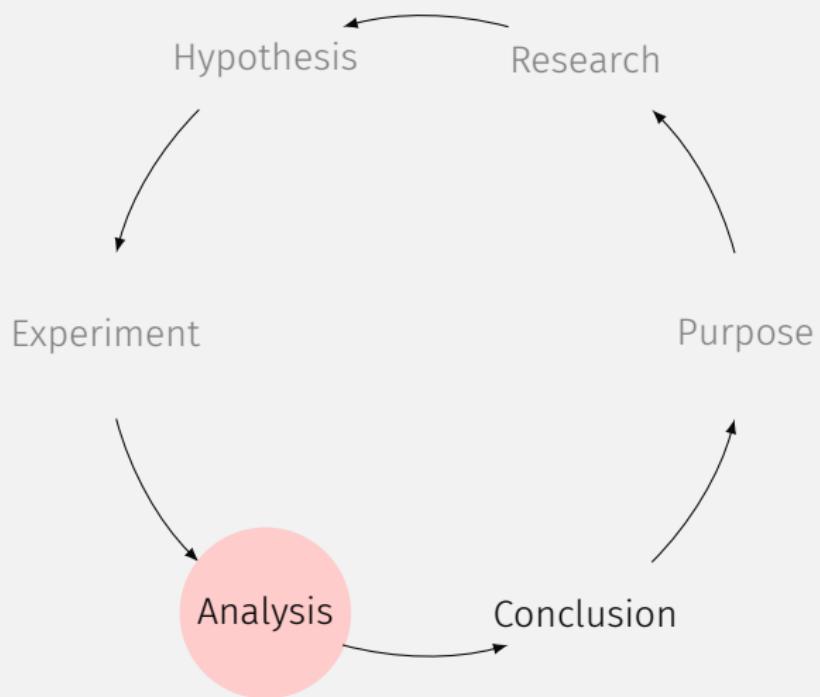
SCIENTIFIC METHOD



SCIENTIFIC METHOD



SCIENTIFIC METHOD

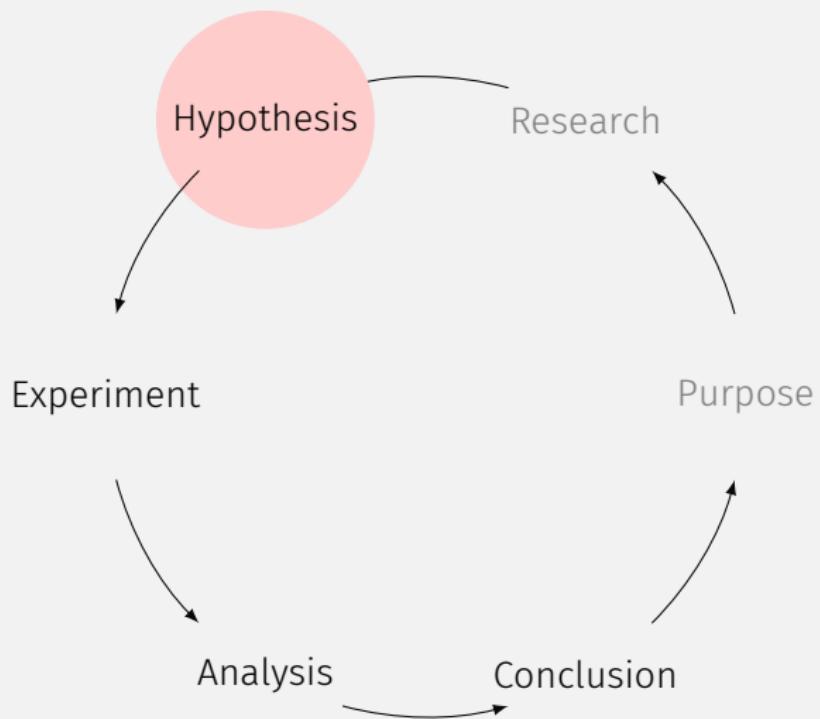


EFFECT OF APERTURE SIZE

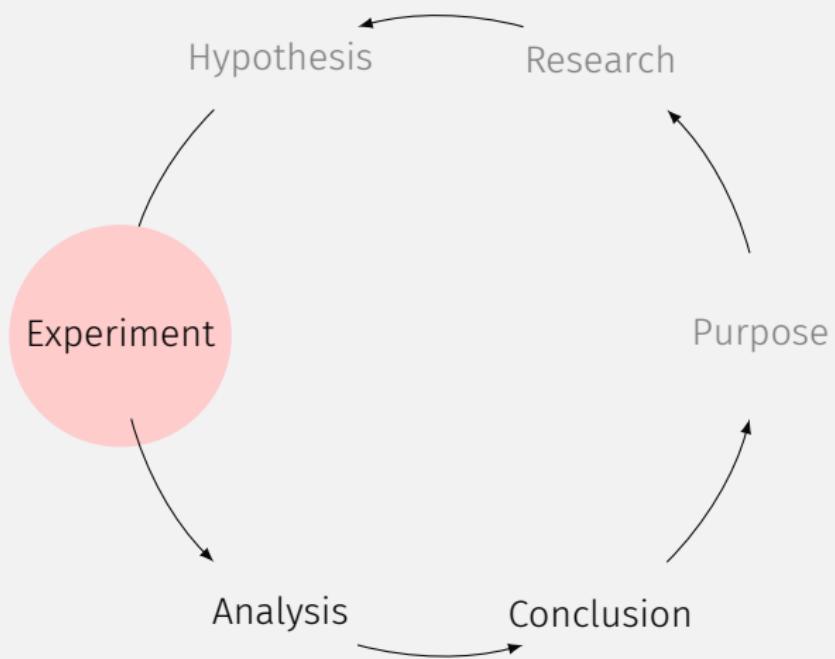
GUESS WHAT HAPPENS?

... if we make the pinhole a little bigger.

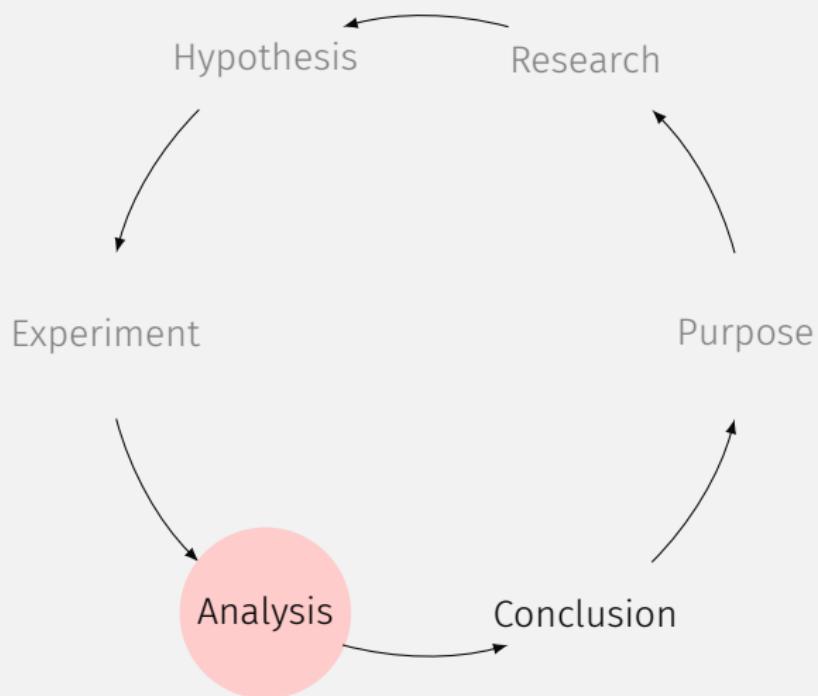
SCIENTIFIC METHOD



SCIENTIFIC METHOD



SCIENTIFIC METHOD



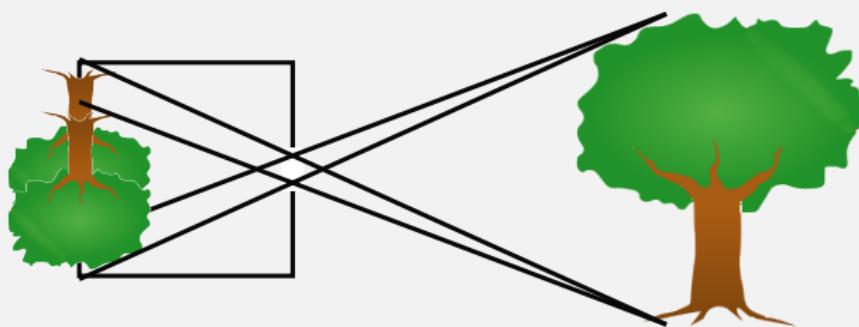
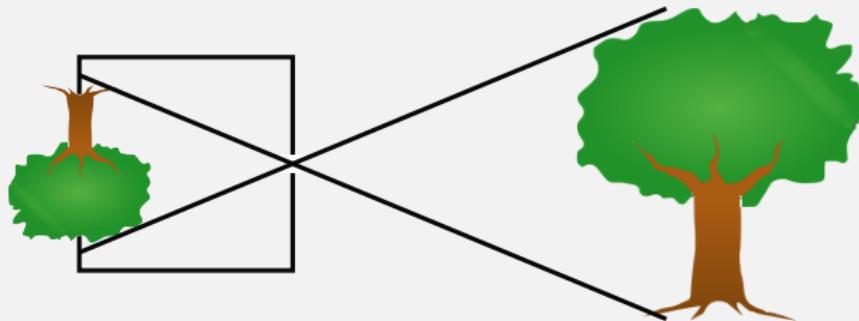
GUESS WHAT HAPPENS?

... if we make the pinhole a little bigger.

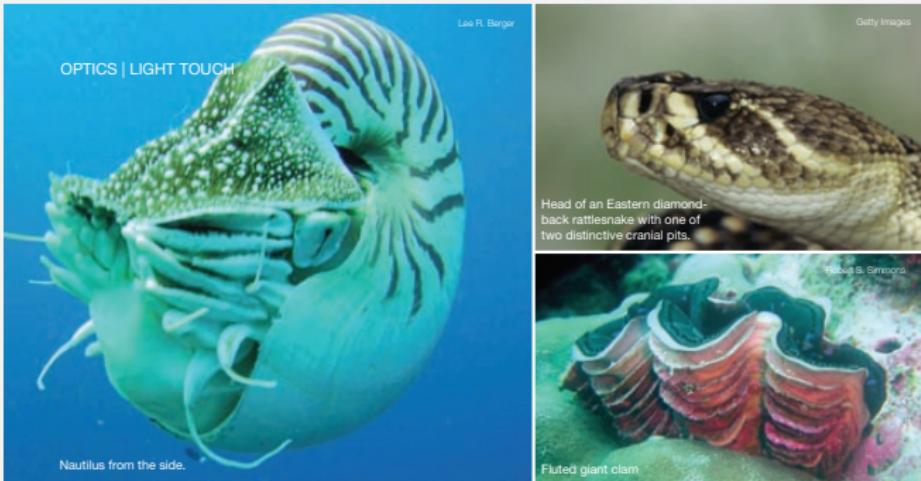
GUESS WHAT HAPPENS?

... if we make the pinhole a little bigger.
Image becomes brighter but blurred

WHY?



FUN FACT!!



The Eye in the Spiral: Animals with Pinhole Visual Systems

Stephen R. Wilk

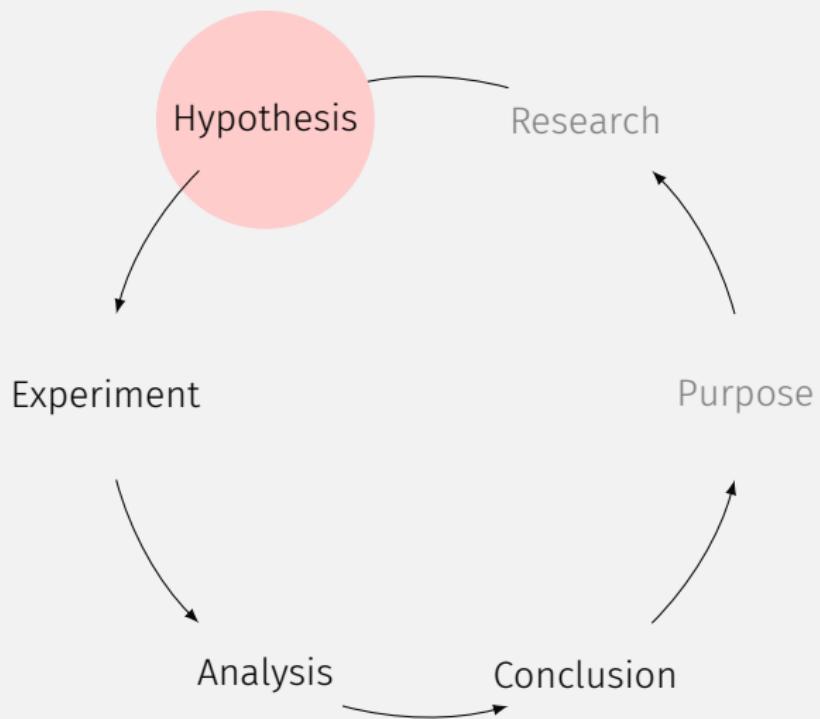


NUMBER OF APERTURES

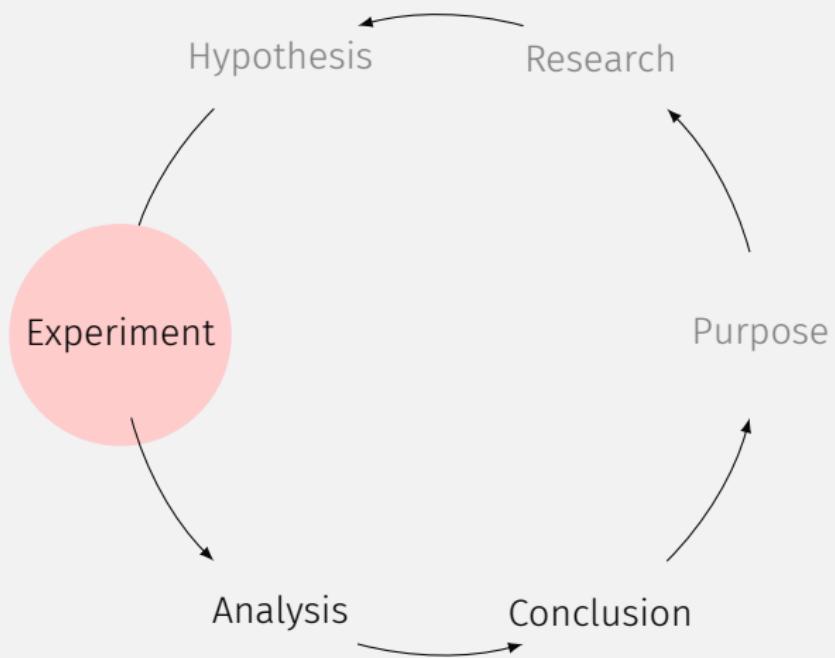
GUESS WHAT HAPPENS

... if we make multiple holes around the pinhole?

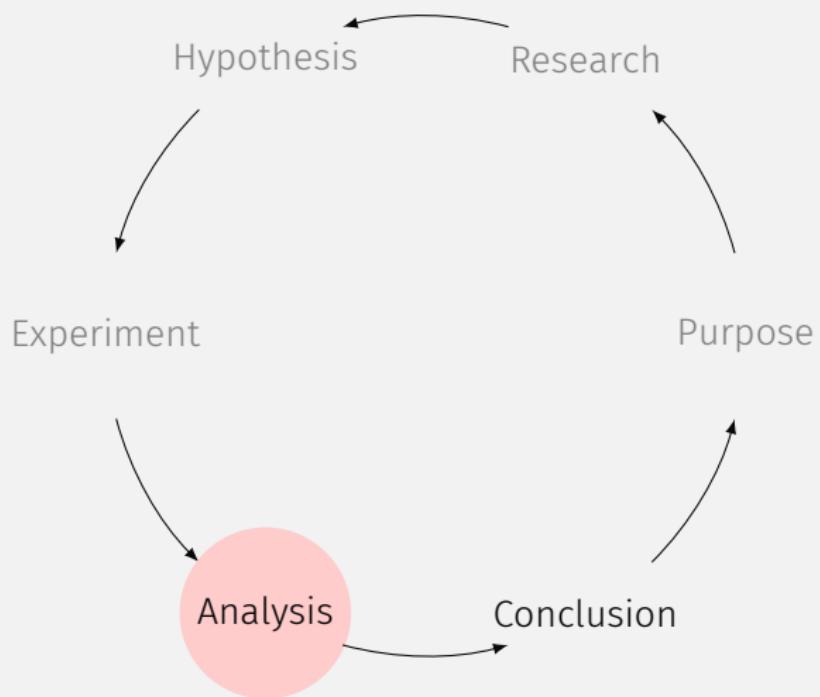
SCIENTIFIC METHOD



SCIENTIFIC METHOD



SCIENTIFIC METHOD



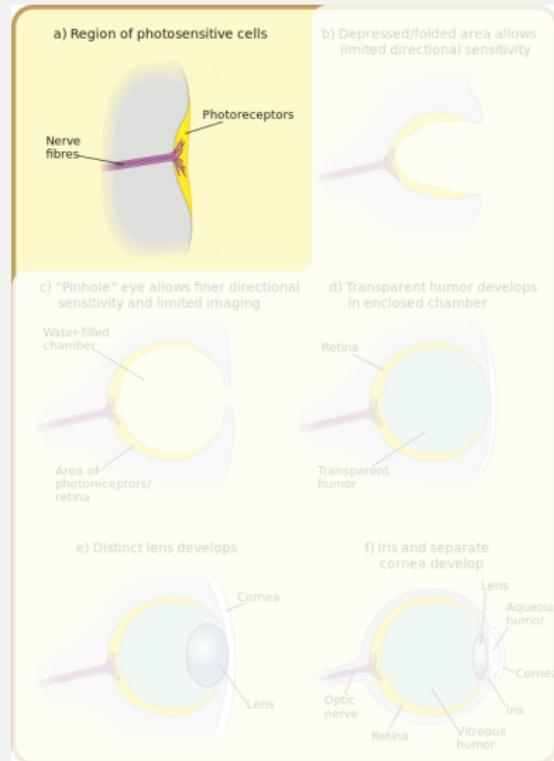
GUESS WHAT HAPPENS

... if we make multiple holes around the pinhole?

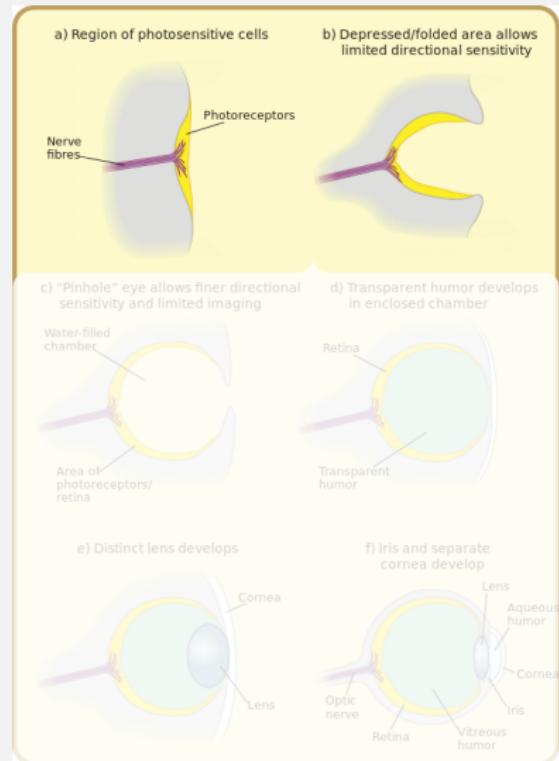
GUESS WHAT HAPPENS

... if we make multiple holes around the pinhole?
Did you get multiple images?

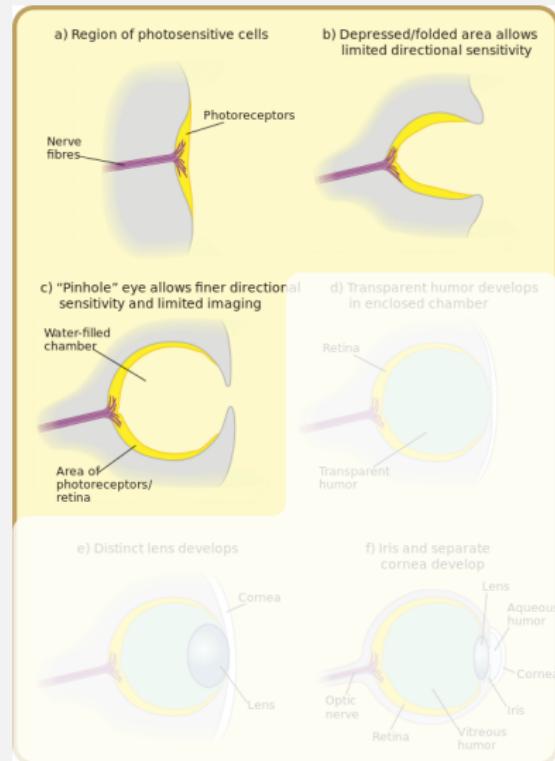
EVOLUTION OF EYE



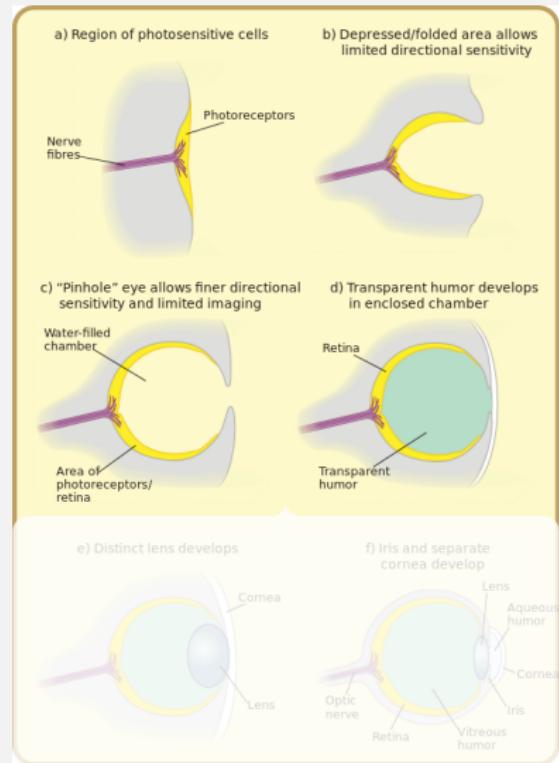
EVOLUTION OF EYE



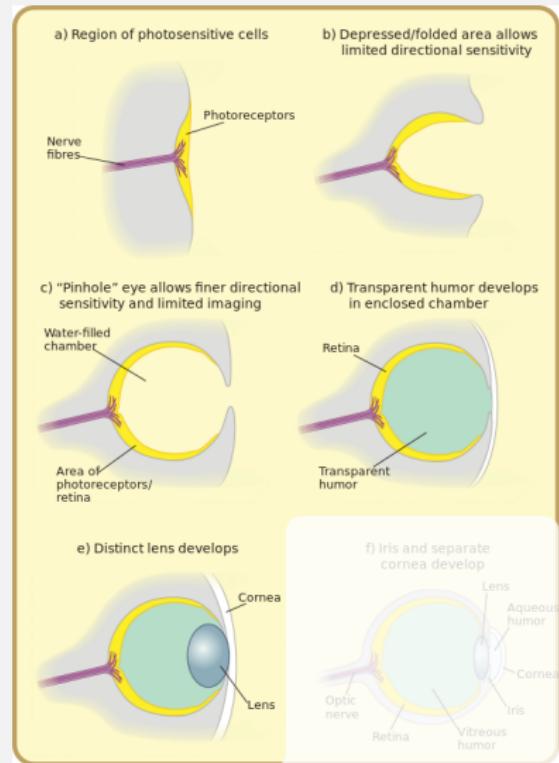
EVOLUTION OF EYE



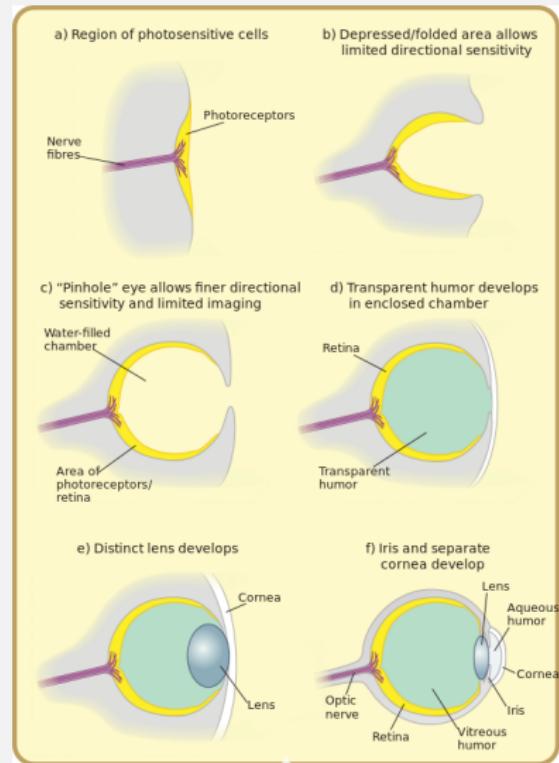
EVOLUTION OF EYE



EVOLUTION OF EYE



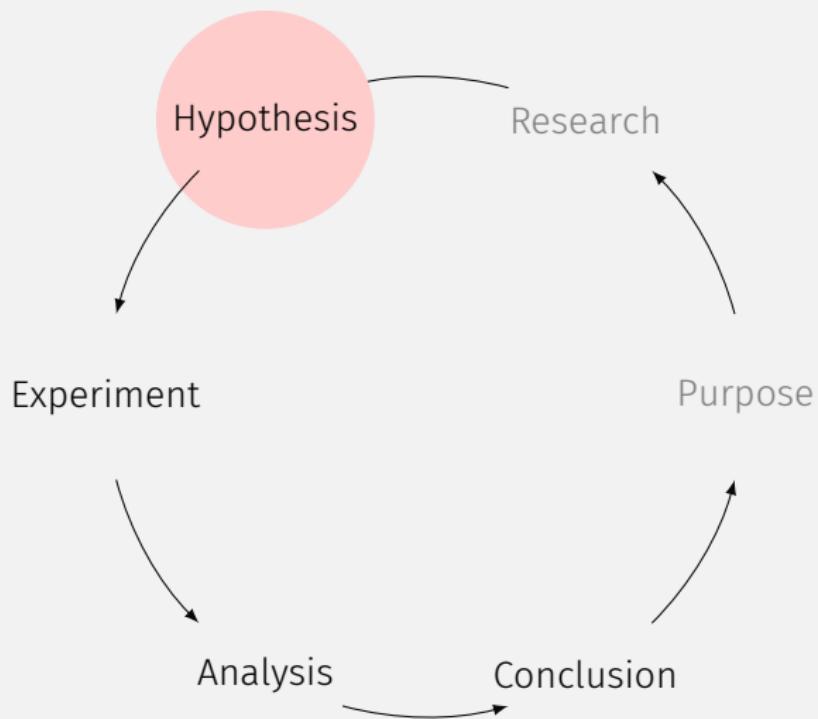
EVOLUTION OF EYE



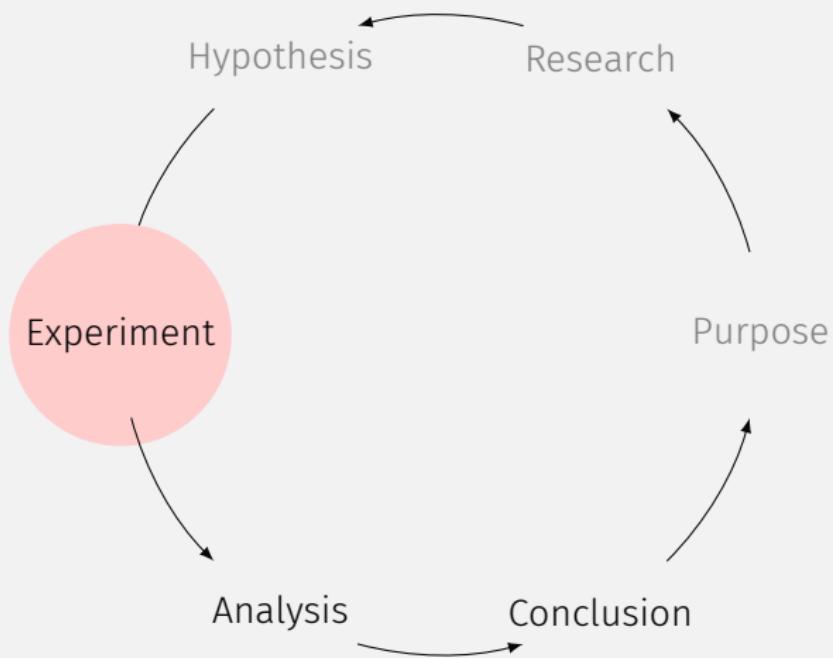
INTRODUCING LENS

We want to find out a lens that will make our camera better.

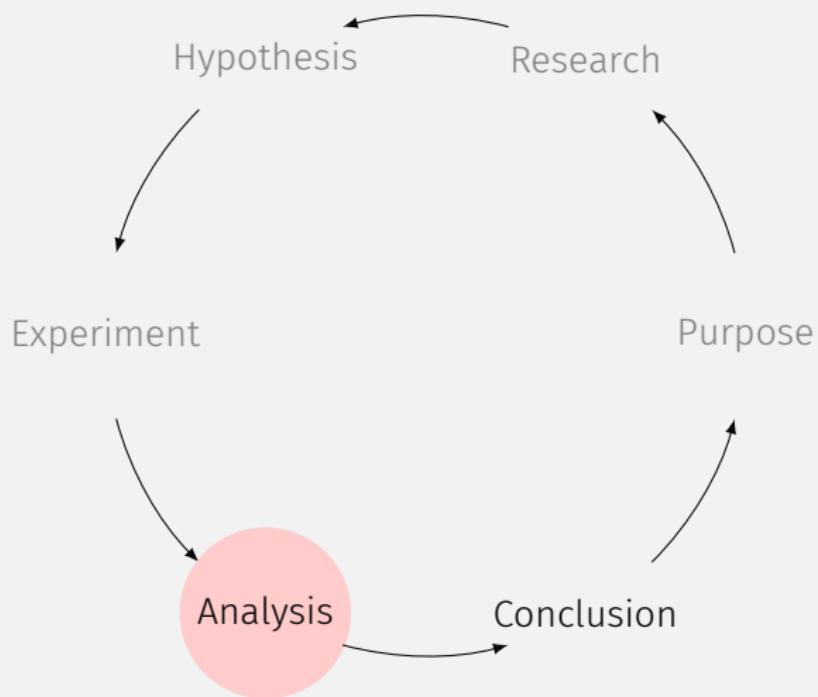
SCIENTIFIC METHOD



SCIENTIFIC METHOD



SCIENTIFIC METHOD



LENSES

INTRODUCING LENS

Add the double convex lens in front of multiple pinholes?

INTRODUCING LENS

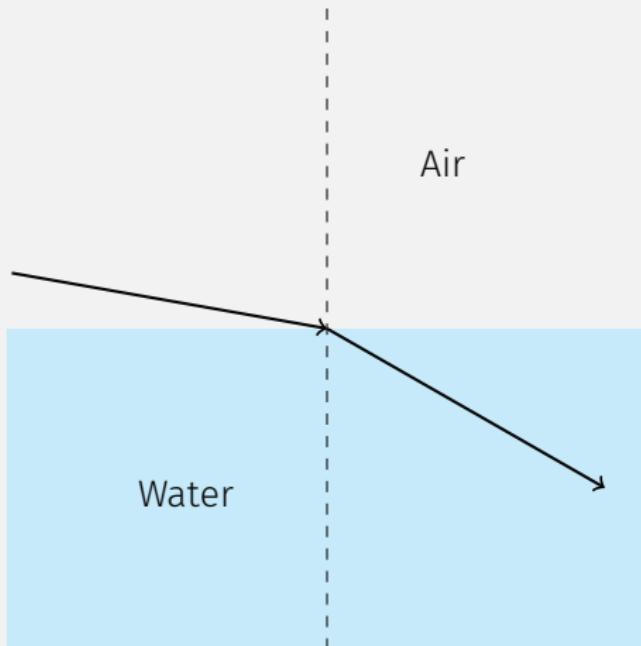
Add the double convex lens in front of multiple pinholes?
Do you see all images merging into one?
What happened?

UNDERSTANDING REFRACTION



REFRACTION

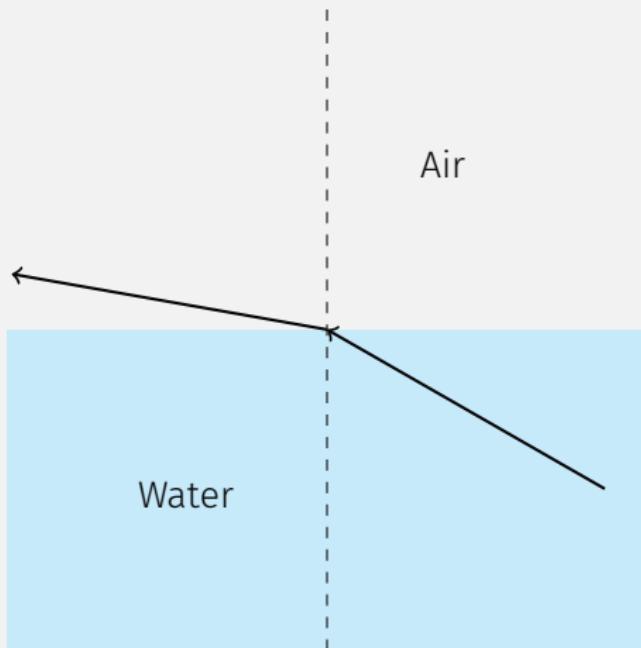
Light bends towards normal when enters a denser medium



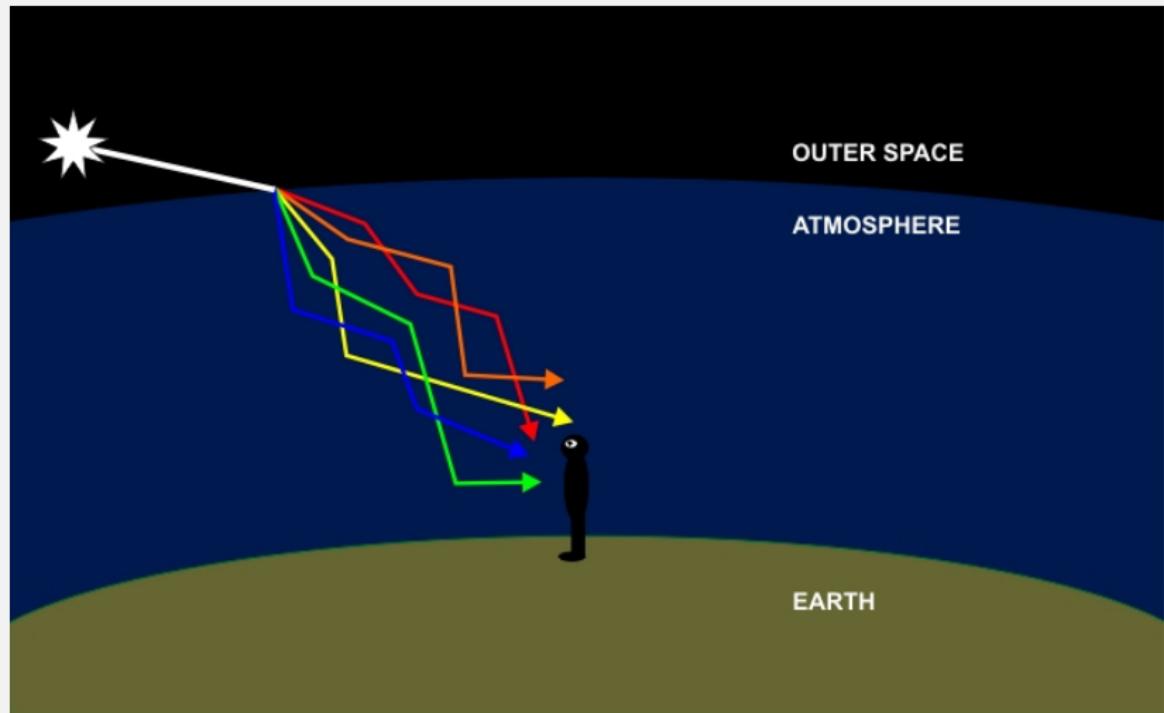
REFRACTION

Light bends towards normal when enters a denser medium

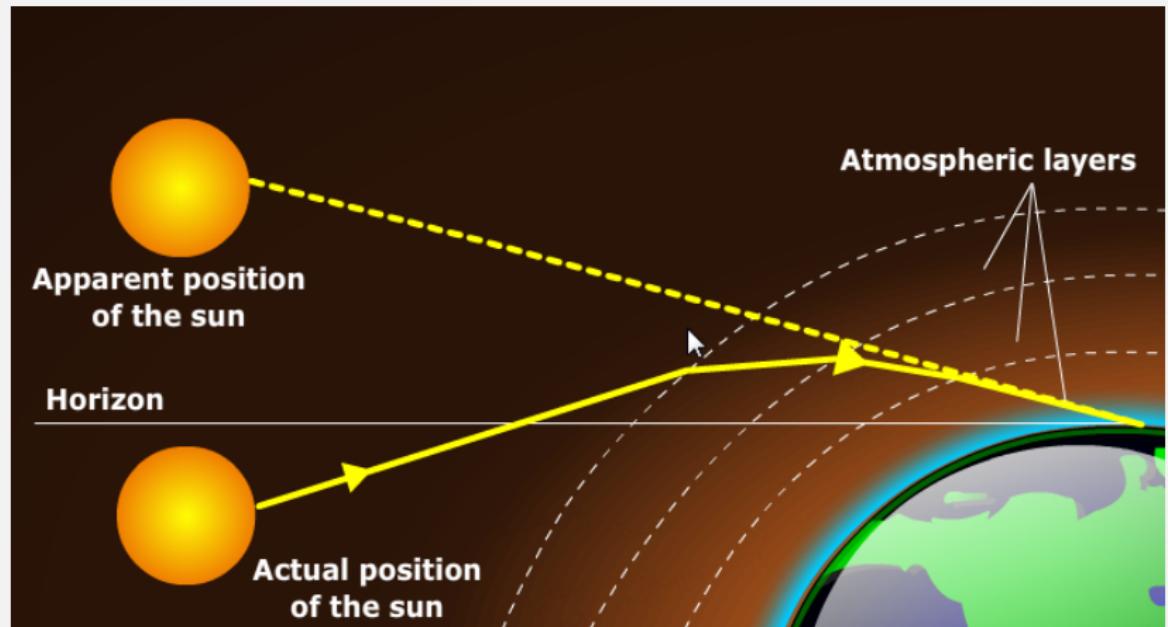
Light bends away from normal when enters a lighter medium



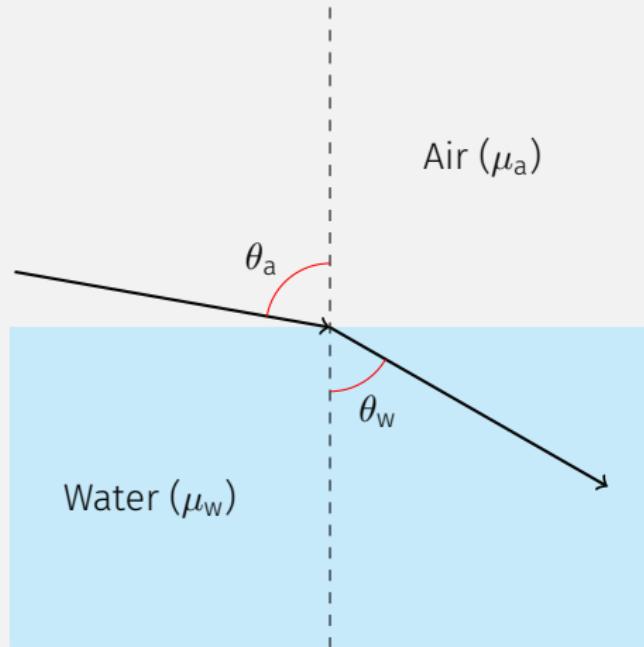
REFRACTION IN NATURE: TWINKLING STARS



REFRACTION IN NATURE: LONGER DAYS

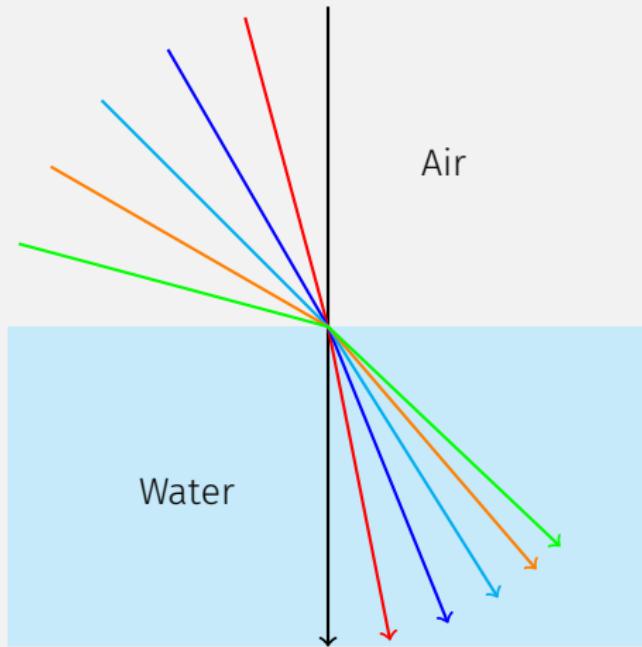


SNELL'S LAW

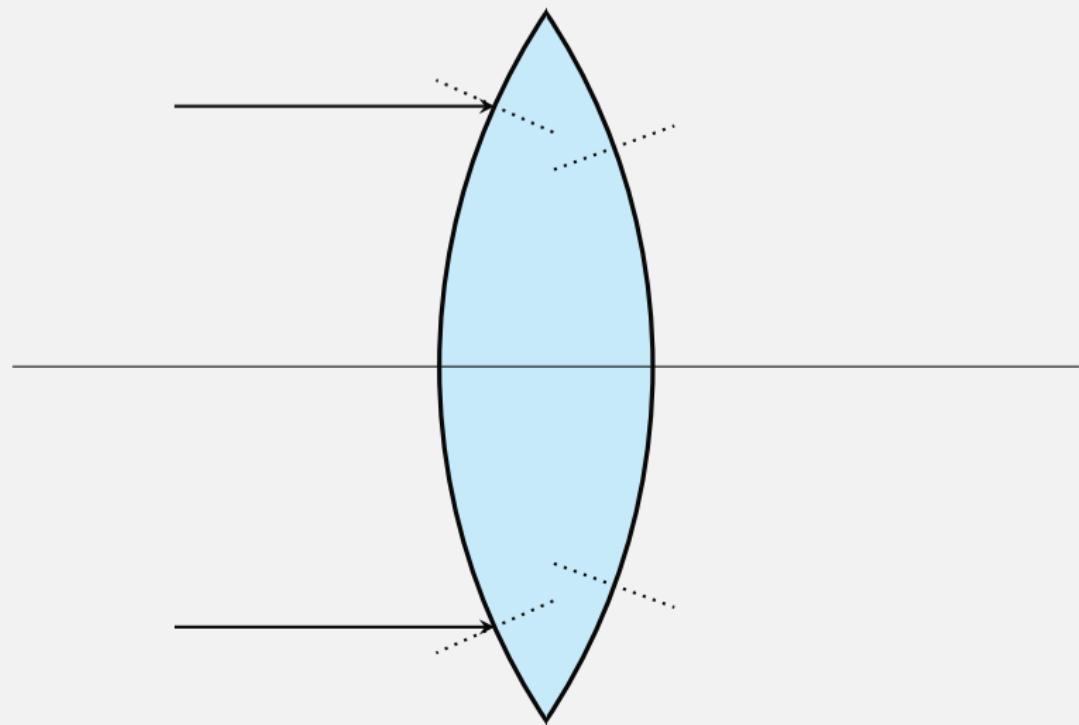


$$\frac{\sin \theta_a}{\sin \theta_w} = \frac{\mu_w}{\mu_a}$$

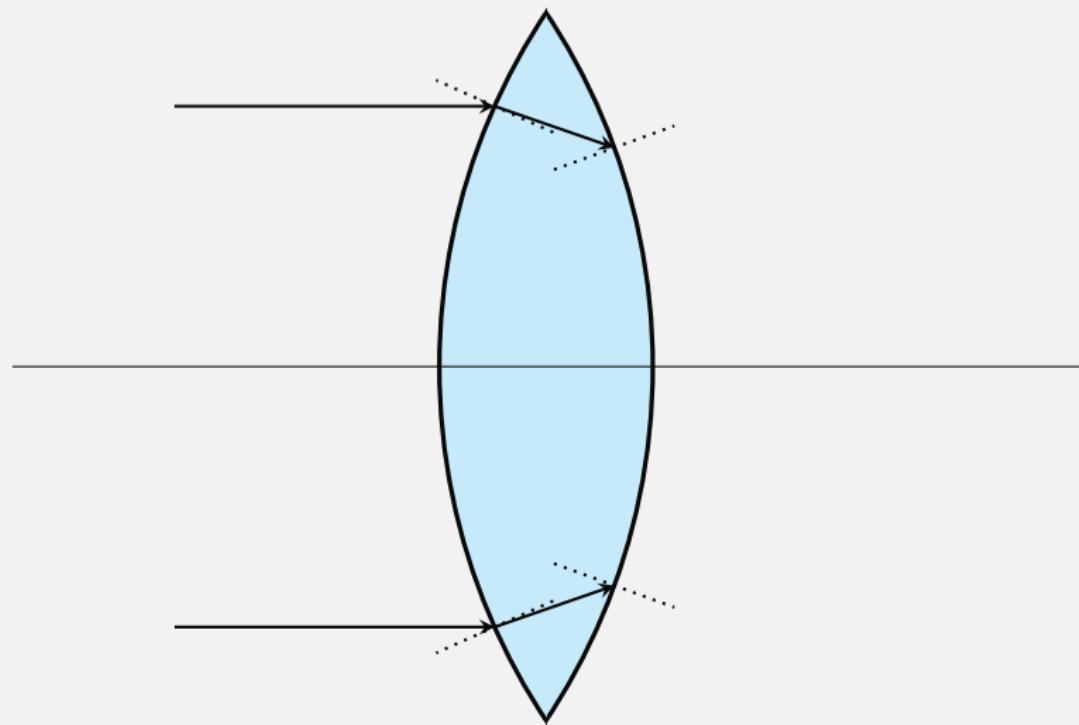
SNELL'S LAW



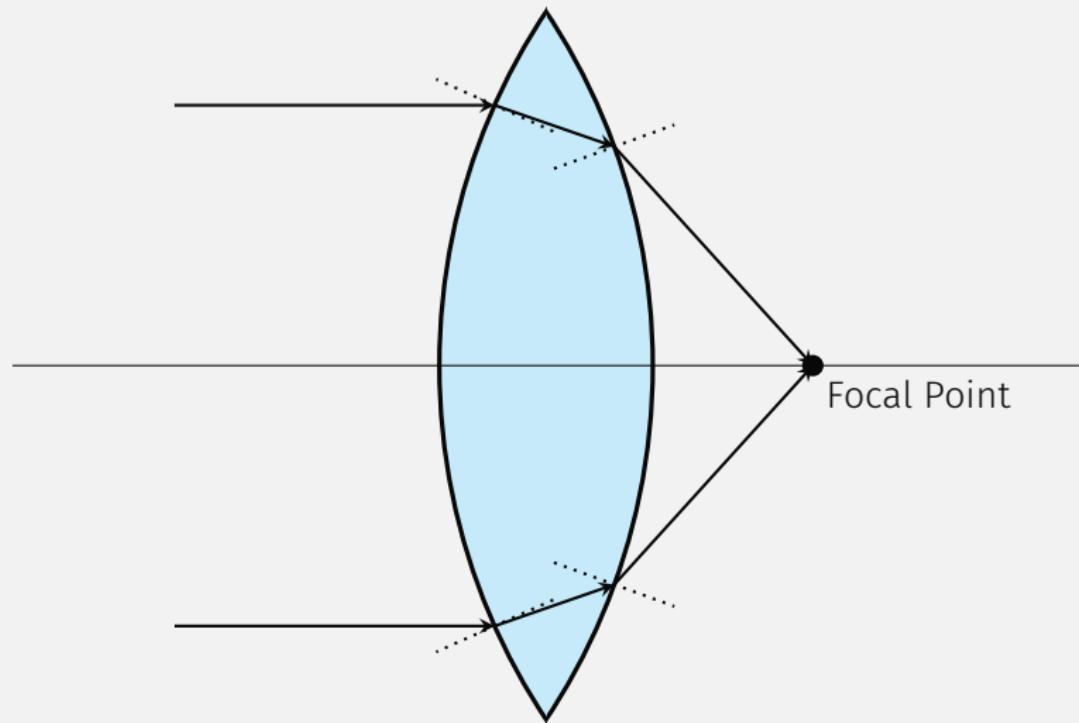
REFRACTION AT LENS



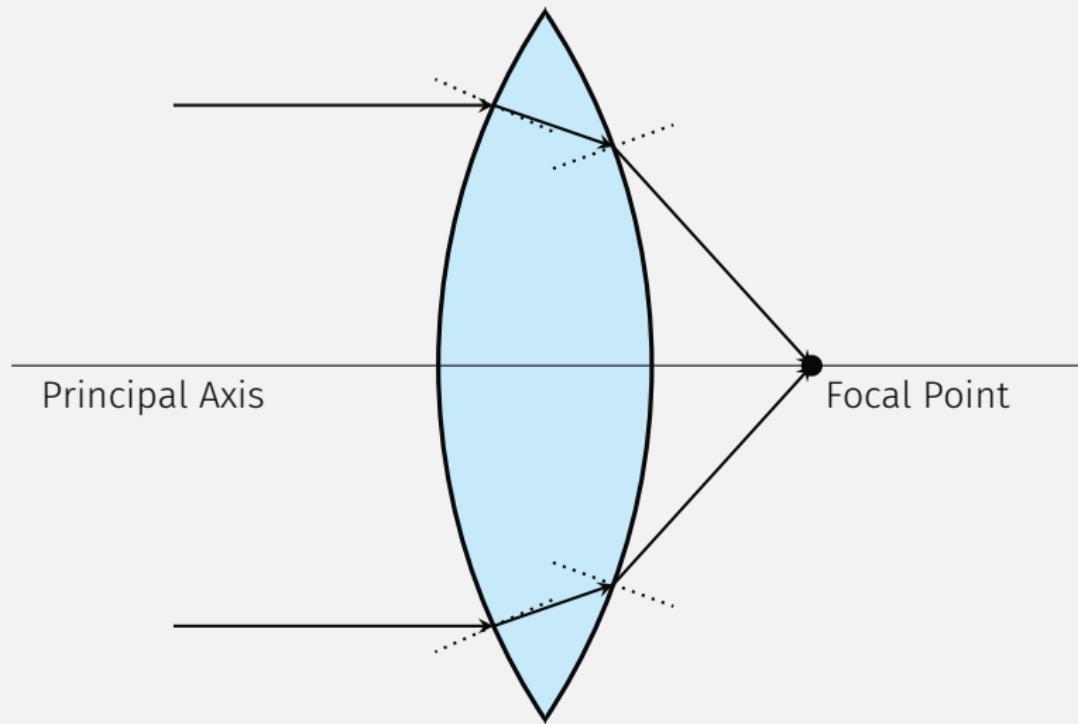
REFRACTION AT LENS



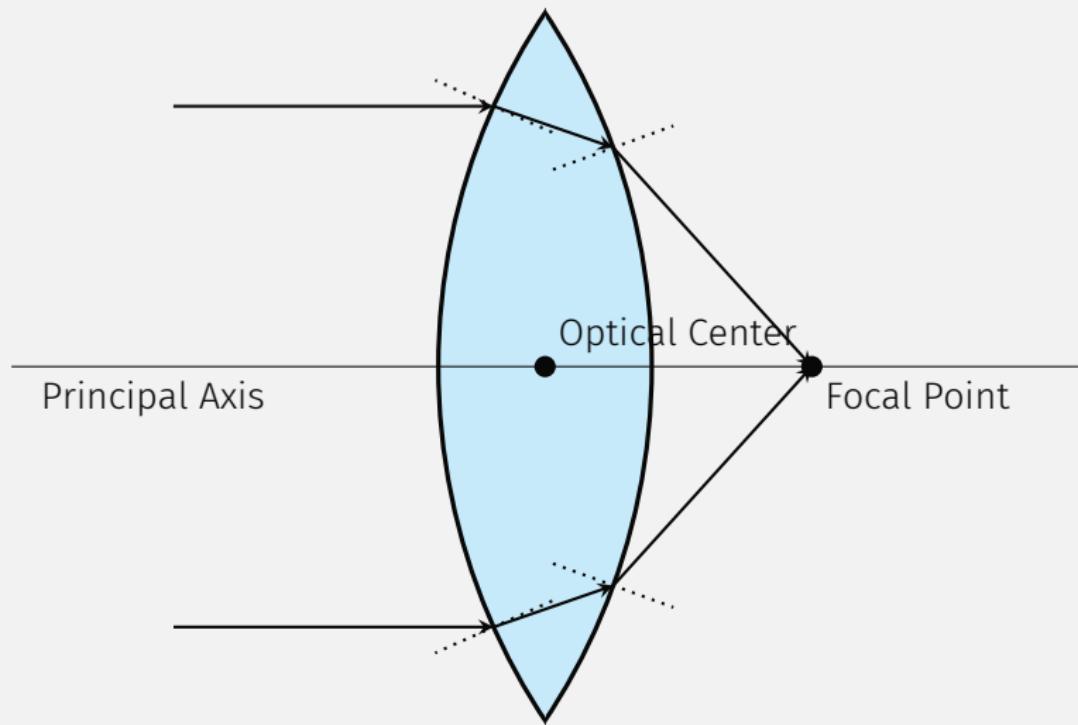
REFRACTION AT LENS



REFRACTION AT LENS



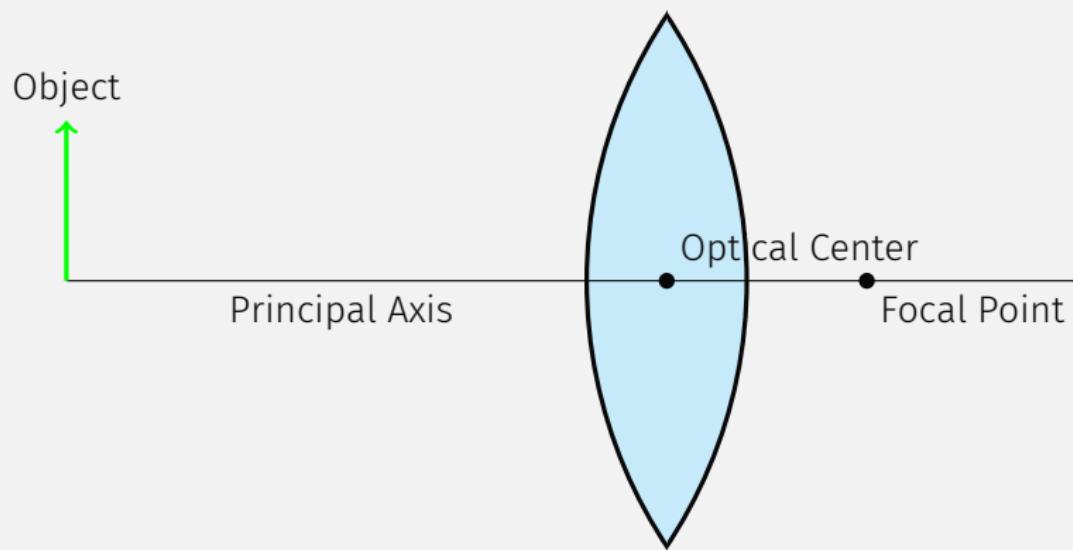
REFRACTION AT LENS



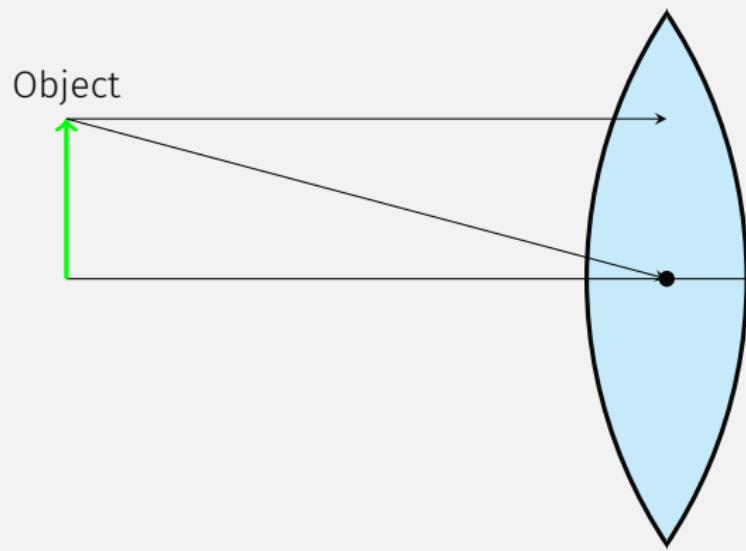
RULES BY WHICH YOU CAN DRAW RAY DIAGRAMS

- Rays parallel to Principal axis converge to the focal point.
- Rays passing through optical center do not change direction.

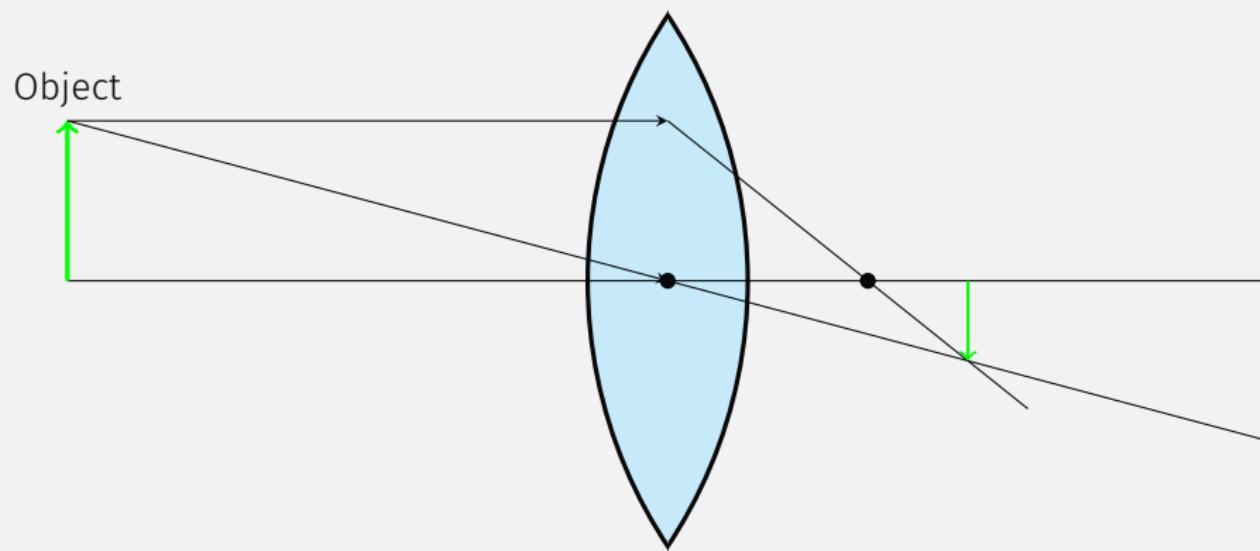
EXAMPLE



EXAMPLE



EXAMPLE



INTERACTIVE ANIMATION

<http://www.pbslearningmedia.org/resource/lspso7.sci.phys.energy.geomettoptics/geometric-optics/>

HISTORY OF PHOTOGRAPHY



FILM CAMERAS



DIGITAL CAMERAS



QUESTIONS TO THINK ABOUT

- What is colored light?
- Why do we see things in color?
- How is rainbow formed?