

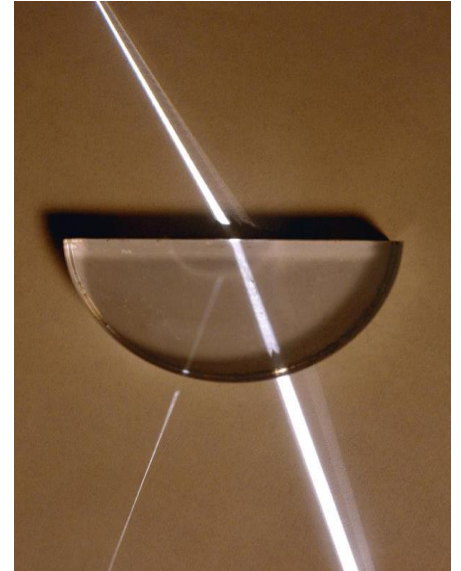
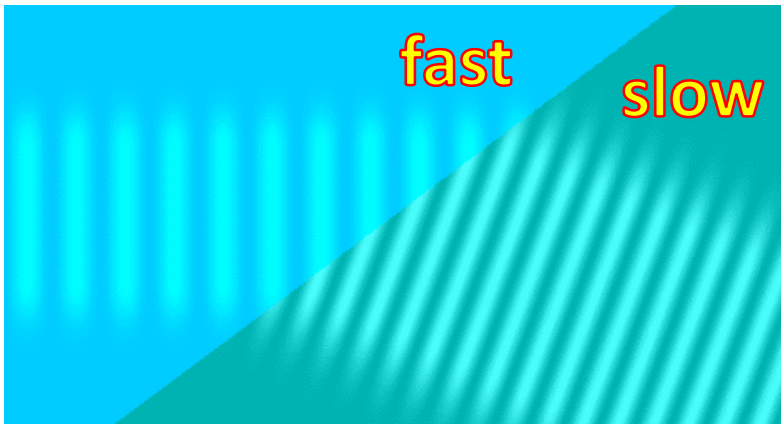
# Refraction in Water



# Refraction

change in the direction of travel at the boundary

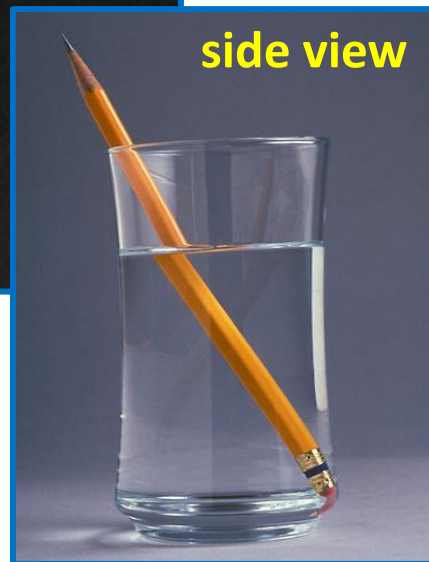
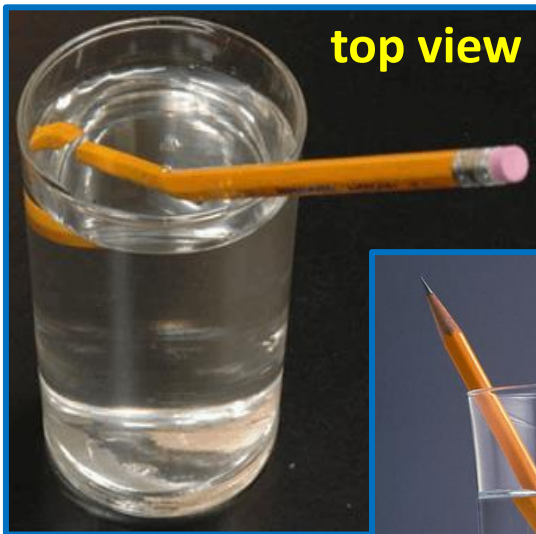
Different materials transmit light at different speeds.



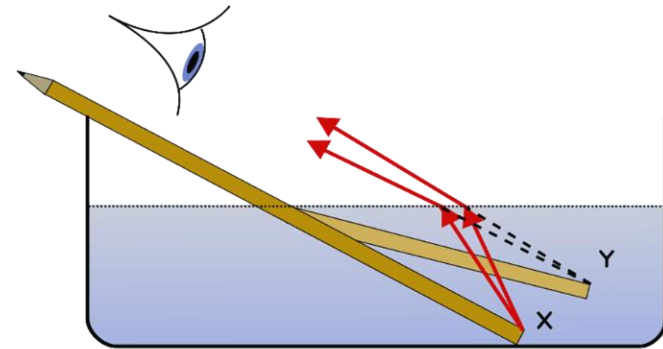
Refraction depends on:

- the **ratio of the speed of light** in the two materials (compared to its speed in the air, in a diamond visible light travels about 2.4 times slower; in water – about 1.33 times slower; in glass – about 1.5 times slower)
- the **angle of incidence**; a ray of light that is **perpendicular** to the surface **is not refracted** at all.

# Pencil Experiment



- The light rays from the upper part of the pencil travel straight to the eye.
- The light rays from the submerged portion of the pencil travel:



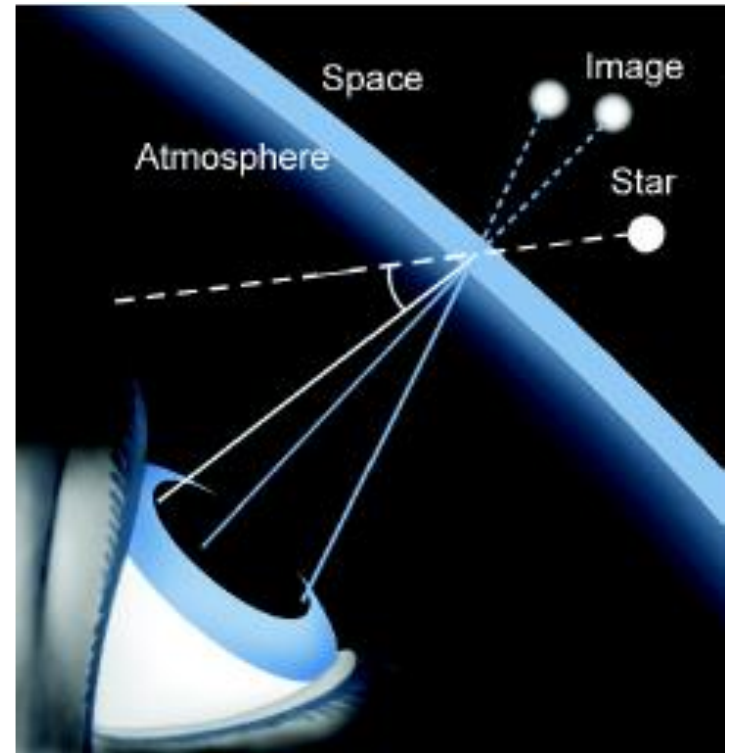
1. through the water,
2. across the water-air boundary, where they refract,
3. through the air ultimately to the eye.

The **eye-brain interaction cannot account for the refraction of light**: our brain judges the object location to be the location where light rays appear to originate from assuming that light rays always travel in straight lines...because when we are babies our brain learns exactly that!



# Twinkle, twinkle, little star...

- The scientific term is “**astronomical scintillation**”.
- Observed from the Earth, a **star** is essentially a **pin-point light source**.
- As starlight travels from space into the Earth’s **atmosphere**, the rays are refracted.
- Since the atmosphere is constantly changing due to turbulence, the amount of refraction also constantly changes.



- This causes the **image of a star** to form in a slightly different part of our eye retina every moment – we perceive it as twinkling.
- Planets usually do not twinkle – why?
- You might actually see a planet twinkling if it appears low at the horizon – why?

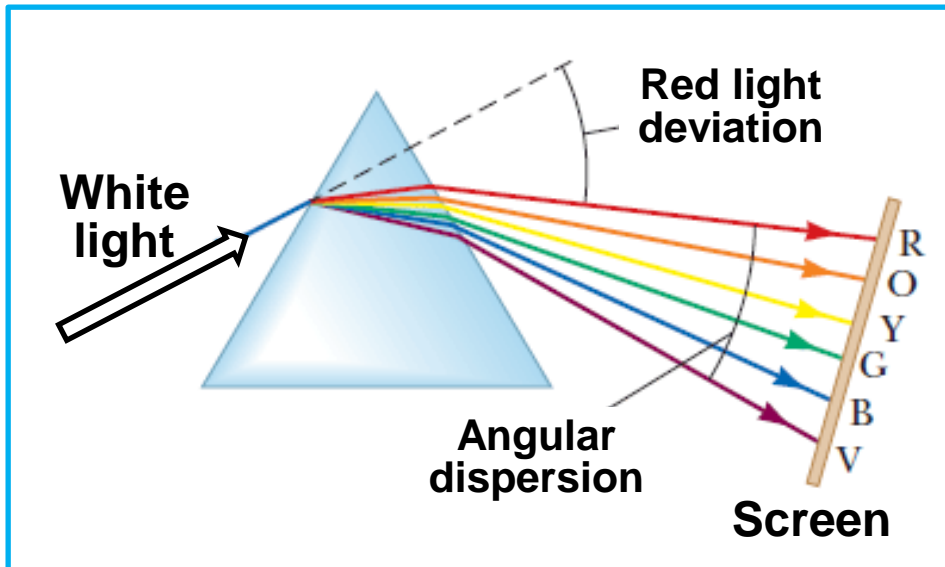
# Dispersion of Light

splitting of light into its component colors

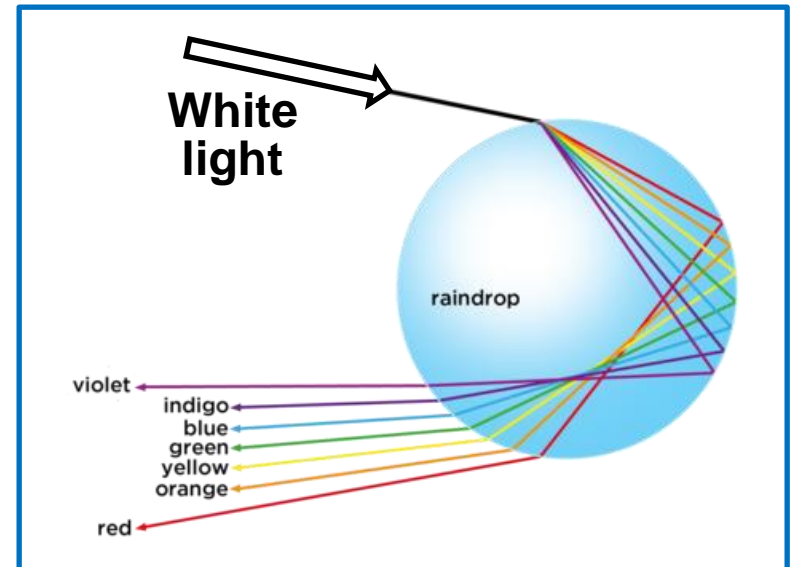
Different colors (wavelengths) of light *travel at different speed in the same material* and therefore refract differently:

- **Red** (longer wavelength) is **bent less**.
- **Violet** (shorter wavelength) is **bent more**.
- This allows for separation of colors in certain geometries.

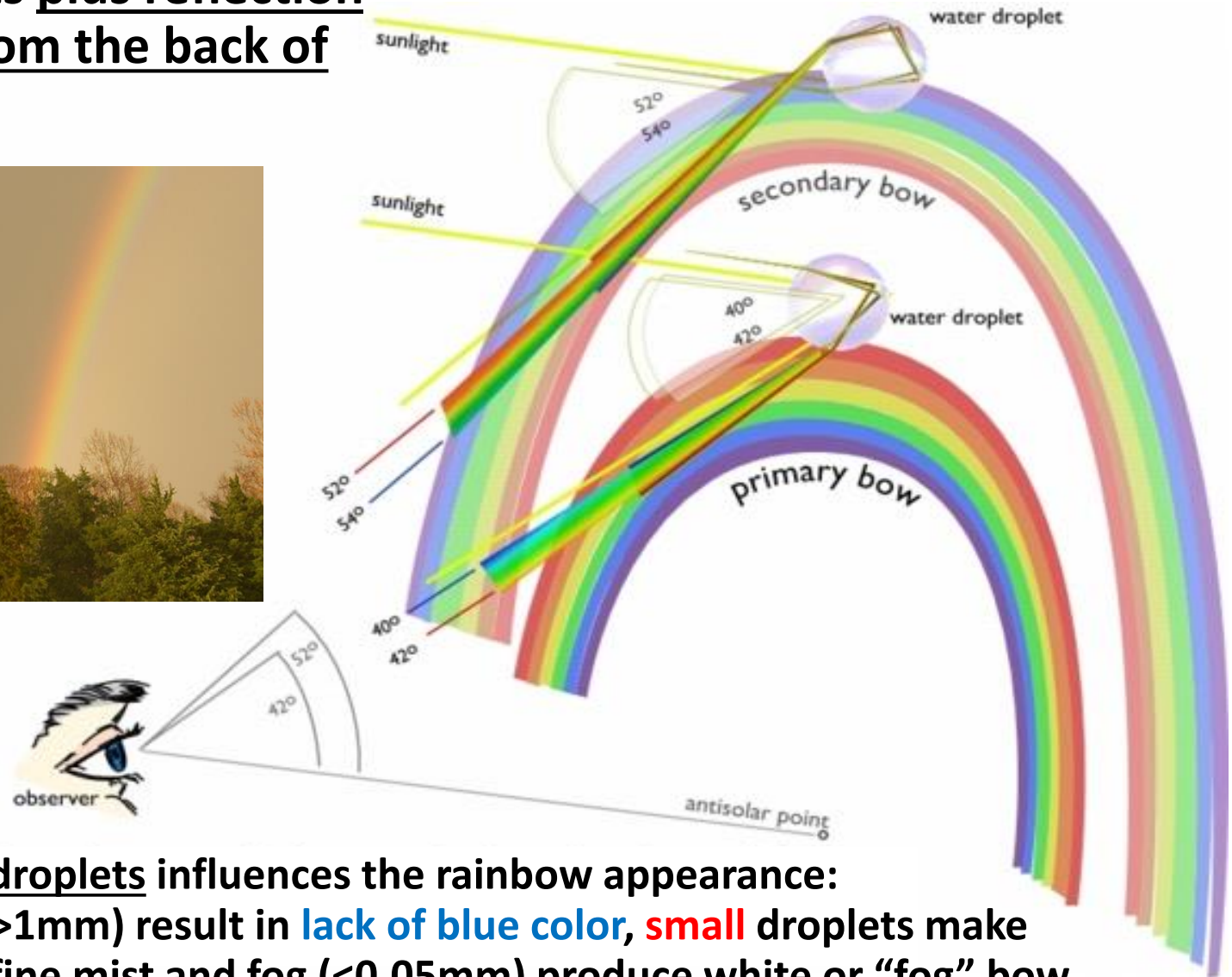
## Glass prism



## Water droplet



**Rainbows** result from refraction of sunlight in falling water droplets plus reflection of the light from the back of the droplet.



The size of the droplets influences the rainbow appearance: **large** droplets (>1mm) result in **lack of blue color**, **small** droplets make **red disappear**; fine mist and fog (<0.05mm) produce white or “fog” bow.



# Rainbows...in your backyard!



All you need is small **water droplets** and bright **sunlight!**



Can you see the **rainbow** when the Sun is overhead?

Can you see the full circle?

**Think again 😊**

All you  
need to do  
is  
position  
yourself  
between  
the Sun  
and the  
raincloud  
and look  
down!



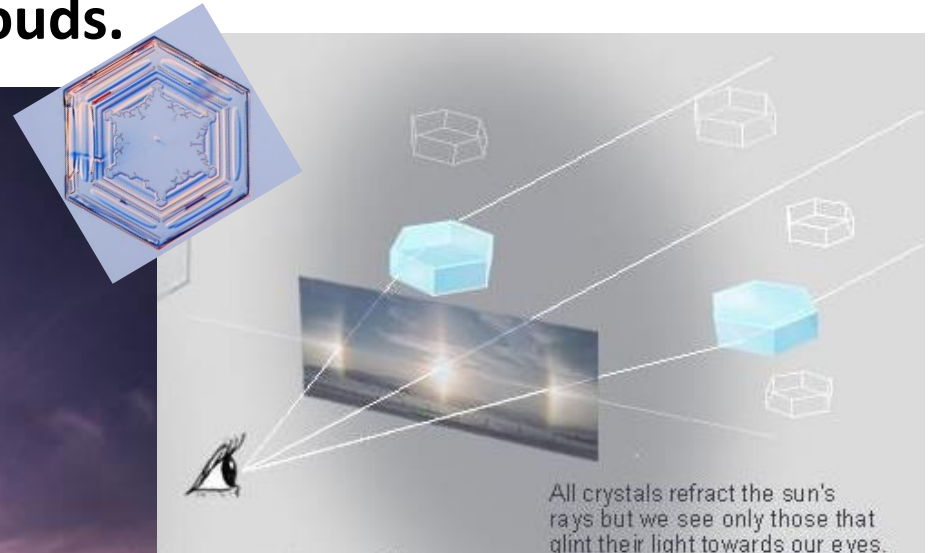
**The Glory**



What happens to light if we have **ice crystals in the air** instead of water droplets?

## The Sun Halo and the Sun Dogs

formed by light refraction in **horizontally floating hexagonal plate ice crystals** high in the cirrus clouds.



The Sun Halo and the Sun Dogs occur world-wide but more common in cold climates.