Refraction Basics

Basic Optics, Chapter 16

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  - the **orientation** of images
  - the **status** (i.e., real vs virtual) of images (and objects!)
  - the **magnification** of images

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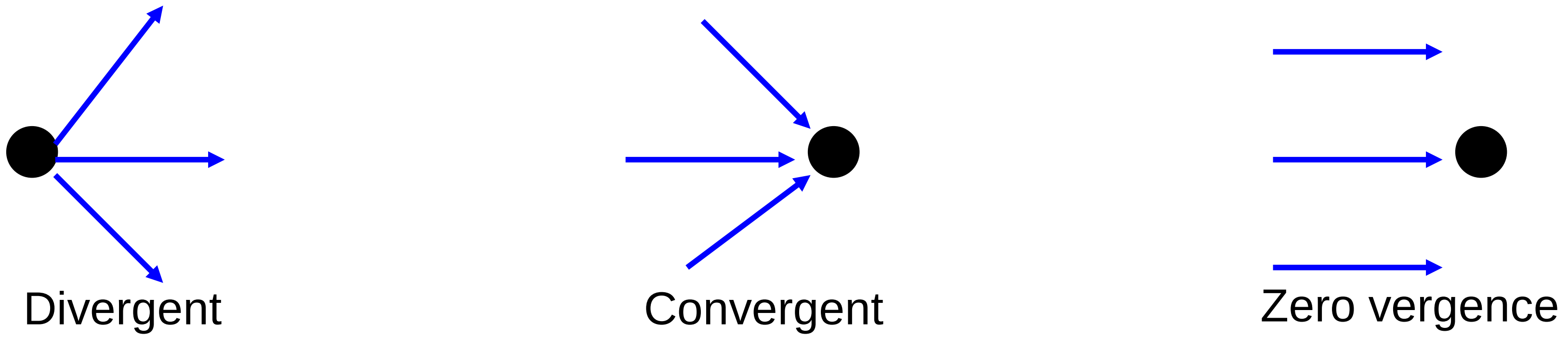
- ***But first, a very brief review…***

Review: *Vergence*

- The term *vergence* describes what light rays are doing in relation to each other
- With respect to a given point, light rays can:
  - spread out (**diverge**)
  - Come together (**converge**)
  - Run parallel (**vergence = zero**)



Review: *Vergence*

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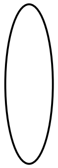
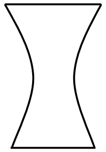
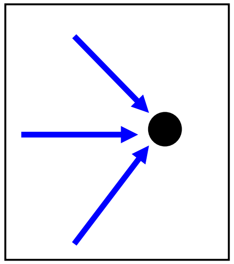
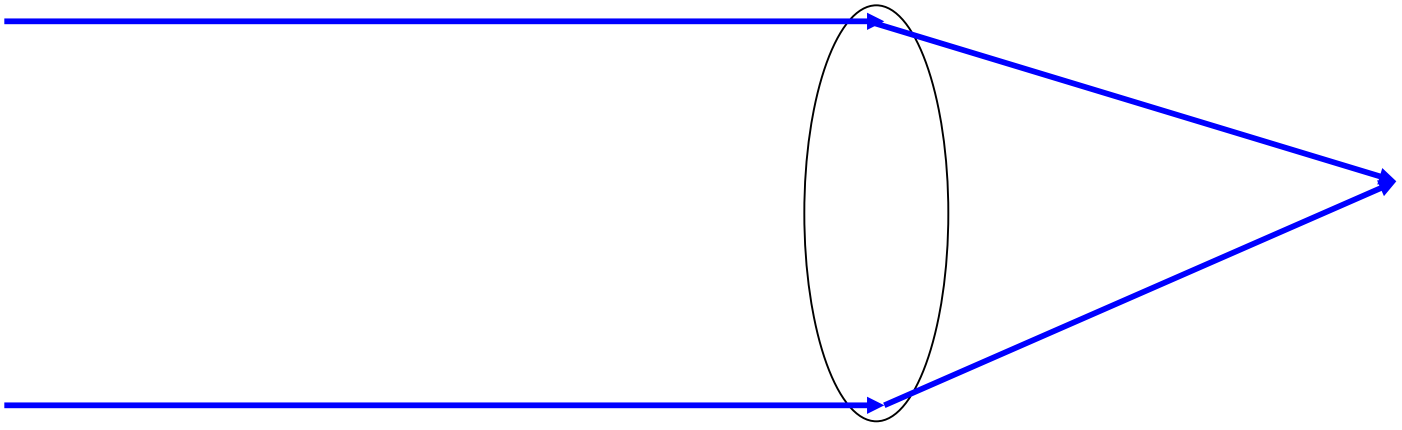
  - Plus 
  - Minus 

Review: *Vergence*

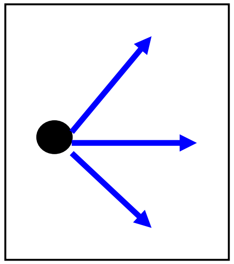
- *Plus* lens: induces convergence

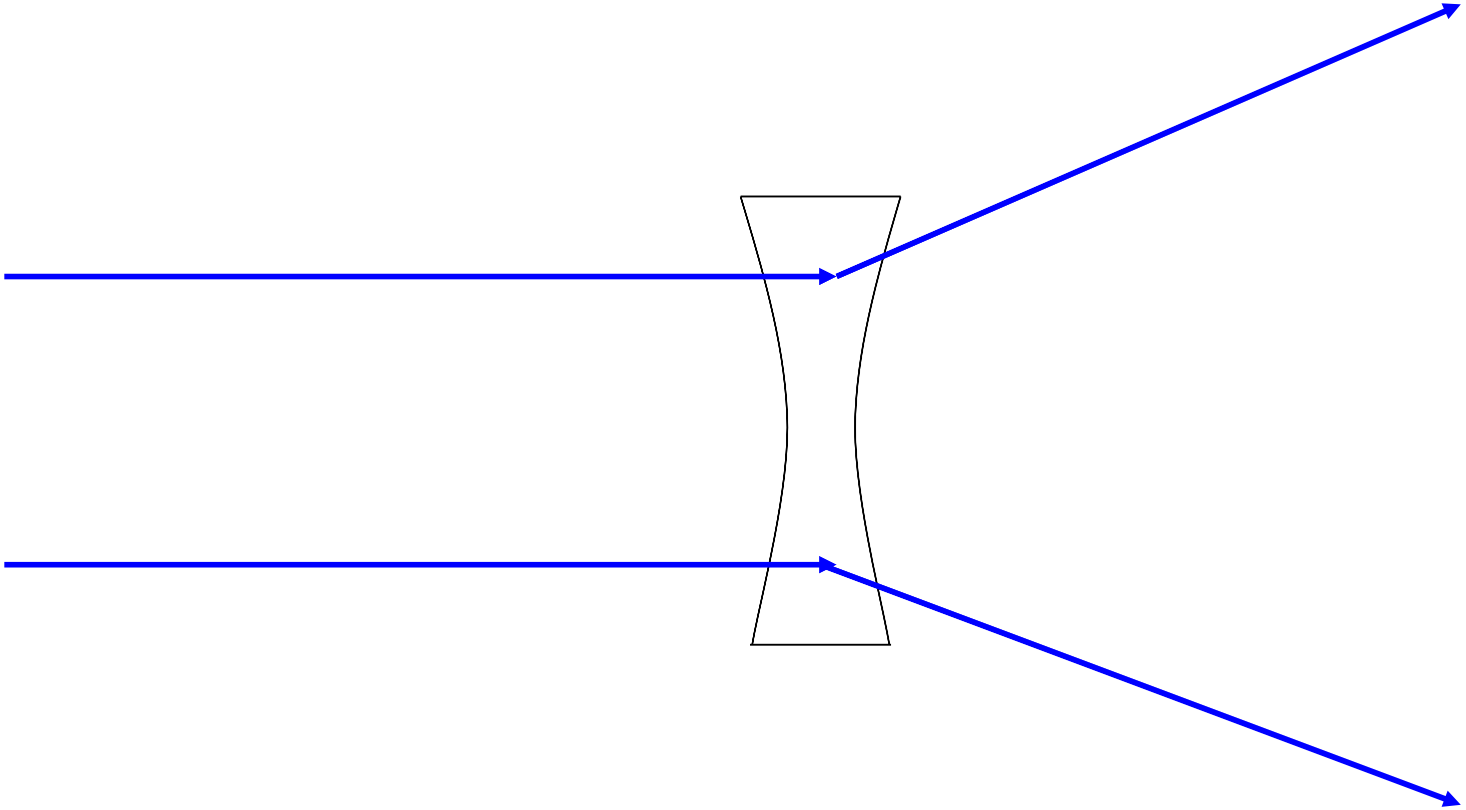




Review: *Vergence*

- *Minus* lens: induces divergence





Refraction

- *Why does light change directions when it passes through a lens?*

Refraction

- *Why does light change directions when it passes through a lens?* Because light slows down when it encounters a substance that is optically ‘more viscous’

(Note: *Viscous*, **not** ‘vicious’)

Refraction

- *Why does light change directions when it passes through a lens?* Because light slows down when it encounters a substance that is optically 'more viscous'
  - Just as you can walk through air faster than you can through water, so light can pass more quickly through some substances than it can others
  - How much the light slows down depends on how optically 'thick' the substance is

Refraction

- *Why does light change directions when it passes through a lens?* Because light slows down when it encounters a substance that is optically 'more viscous'

  - The reverse is true as well—light **speeds up** when passing from an optically more-viscous substance into an optically less-viscous substance!

  - How much the light slows down depends on how optically 'thick' the substance is

Refraction

- The ability of a material to slow the passage of light (i.e., its optical viscosity) is expressed as a ratio—the *Refractive Index* (*n*)

$$\frac{\text{Speed of light in vacuum}}{\text{Speed of light in material}} = \text{The } \textit{refractive index } (\boldsymbol{n}) \text{ of the material}$$

Refraction

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Note: Refractive index is a function also of the *wavelength* of light. This is the source of the phenomenon known as chromatic aberration. This will be important later when we discuss the ***duochrome test***.

$$\frac{\text{Speed of light in vacuum}}{\text{Speed of light in material}} = \text{The } \textit{refractive index } (\boldsymbol{n}) \text{ of the material}$$

Refraction

- Because the speed of light in a vacuum is its highest possible speed, ***n cannot*** be < 1.0
  - For practical purposes, $n_{air} = 1.0$

$$\frac{\text{Speed of light in vacuum}}{\text{Speed of light in material}} = \text{The } \textit{refractive index } (\boldsymbol{n}) \text{ of the material}$$

$\not< 1.0$

Refraction

- Some *n* of note:
  - Water: 1.33
  - Aqueous/vitreous: 1.34
  - Spectacle (crown) glass: 1.52
  - High-*n* plastics: up to ~1.9
  - Cornea: 1.376

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Yes and no—more on this in the slide-set entitled *Corneal Optics* in the **Refractive Surgery** section

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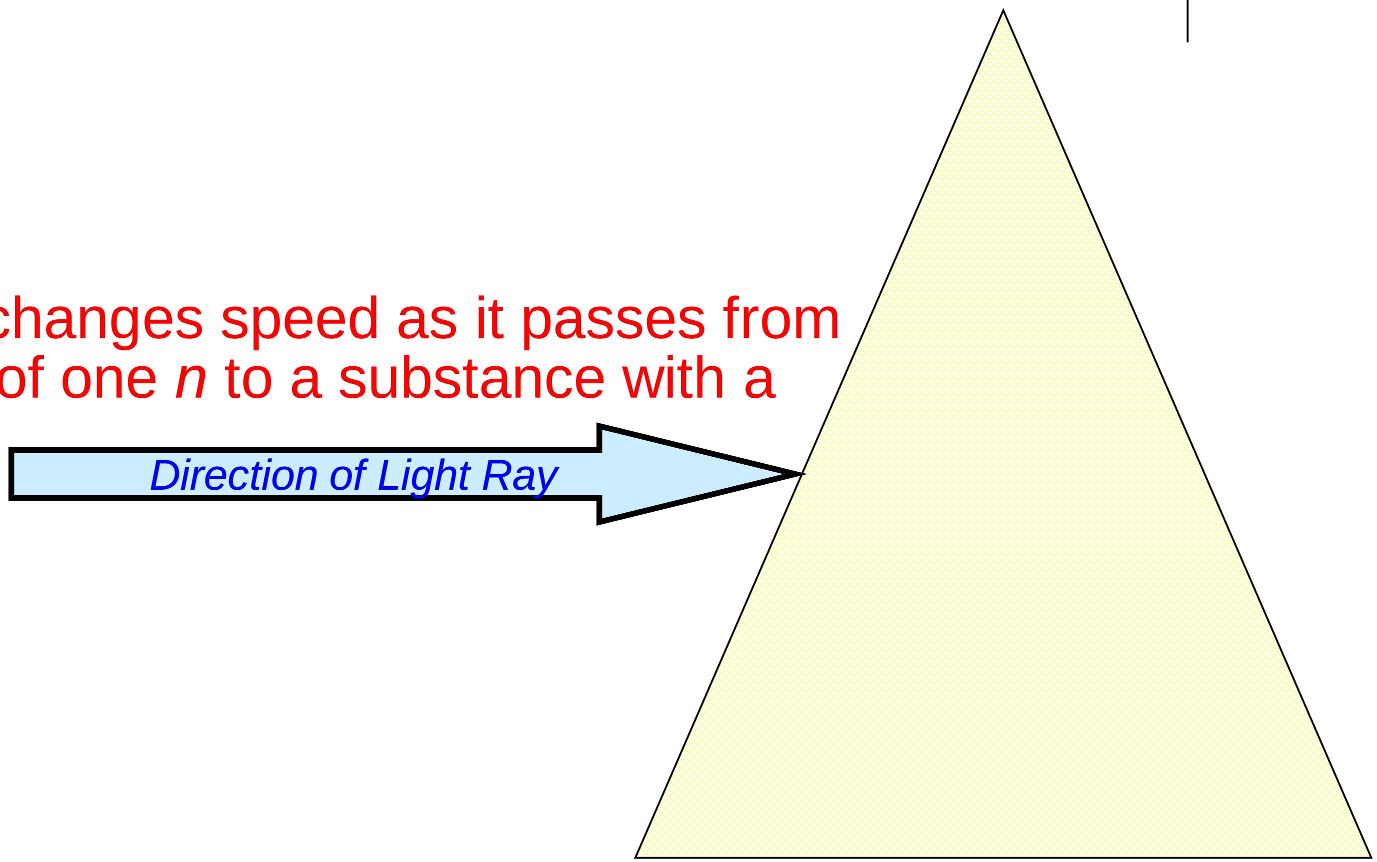
Refraction

OK, so light changes speed as it passes from a substance of one *n* to a substance with a different *n*.



Light in vacuum
(n = 1.0)

Light go Faster!

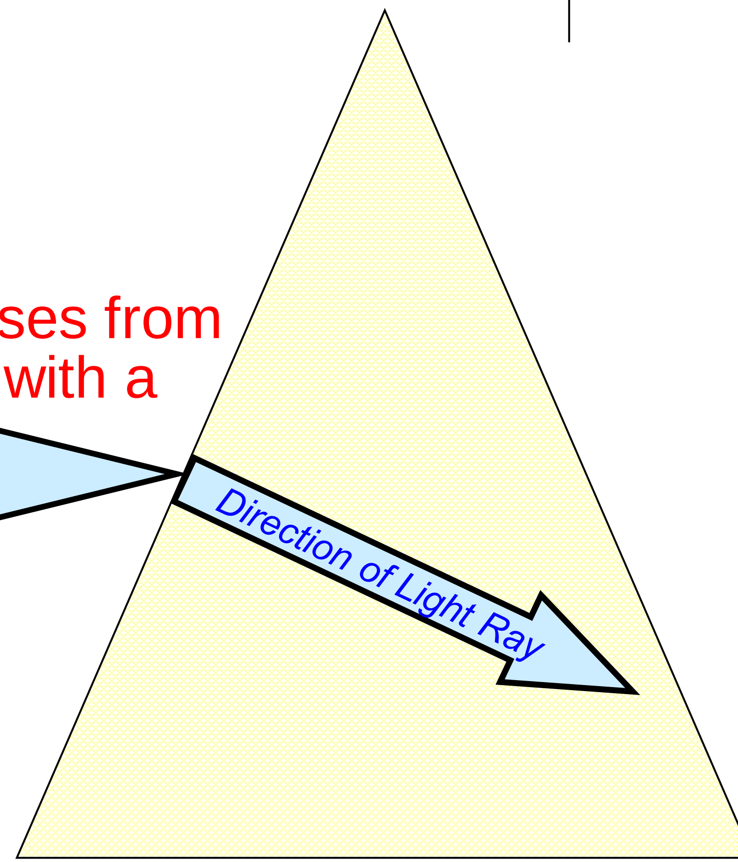
Glass prism
(n = 1.5)

Light go Slower!

Refraction

OK, so light changes speed as it passes from a substance of one *n* to a substance with a different *n*.

But how does this change in ***speed*** lead to a change in ***direction*** (and therefore to refraction)?



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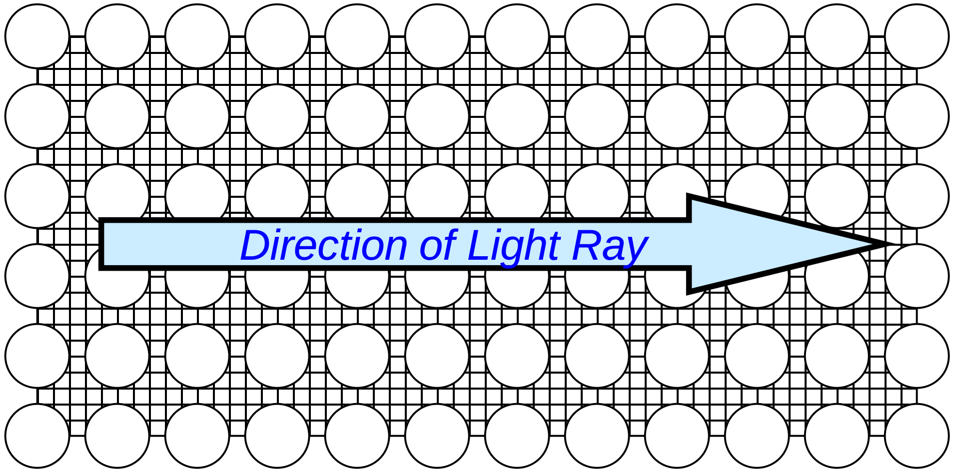
Refraction

How does a change in light's ***speed*** lead to a change in its ***direction***?

Think of a light ray as being composed of individual 'corpuscles' of light that are linked to one another by a flexible mesh of sorts.



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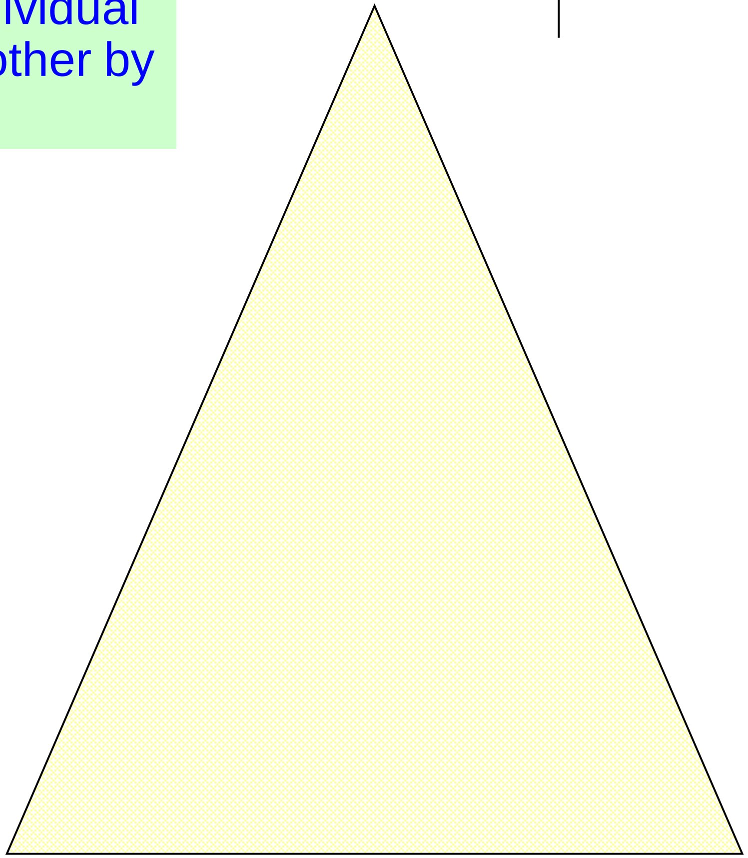

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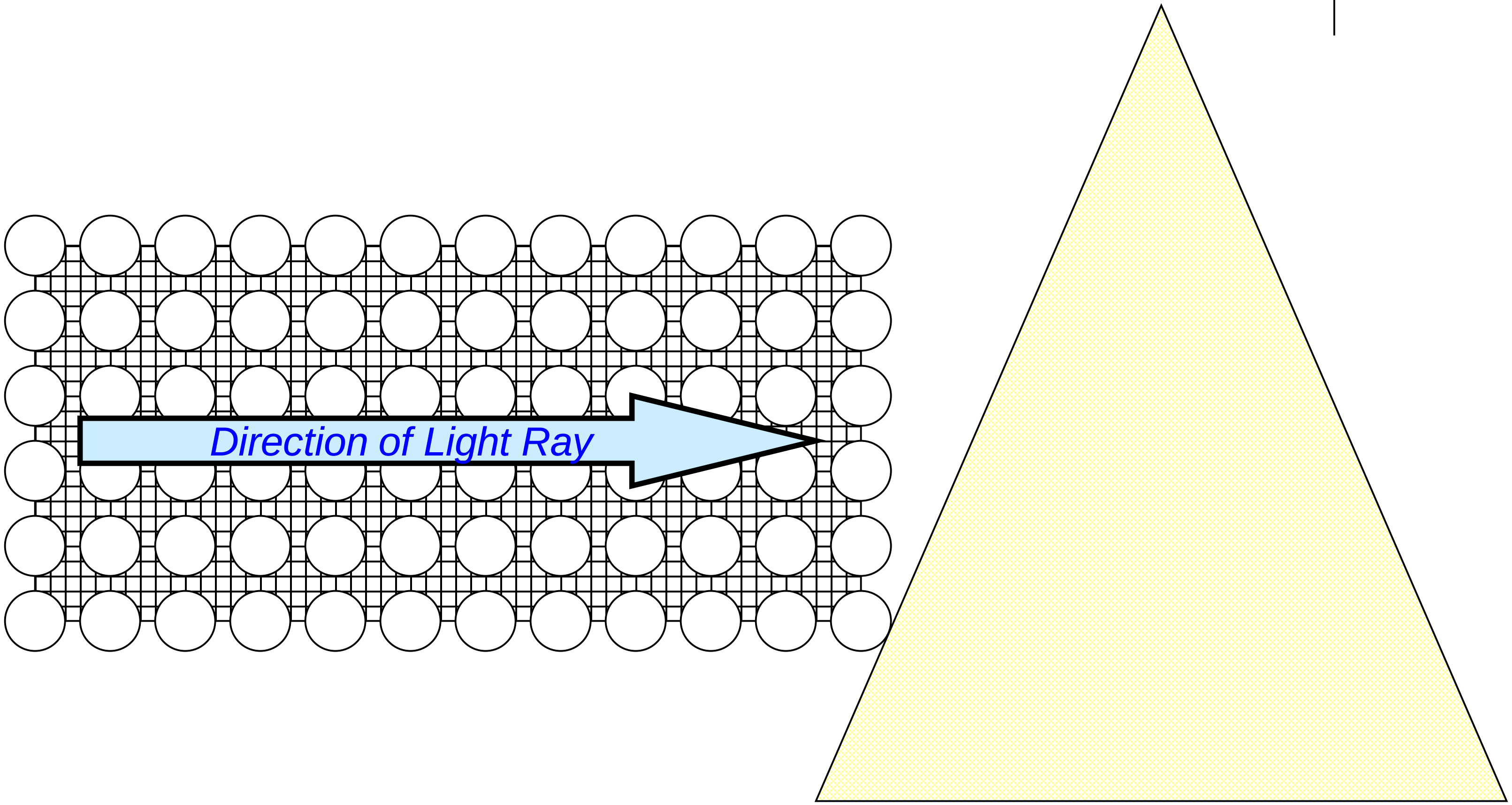

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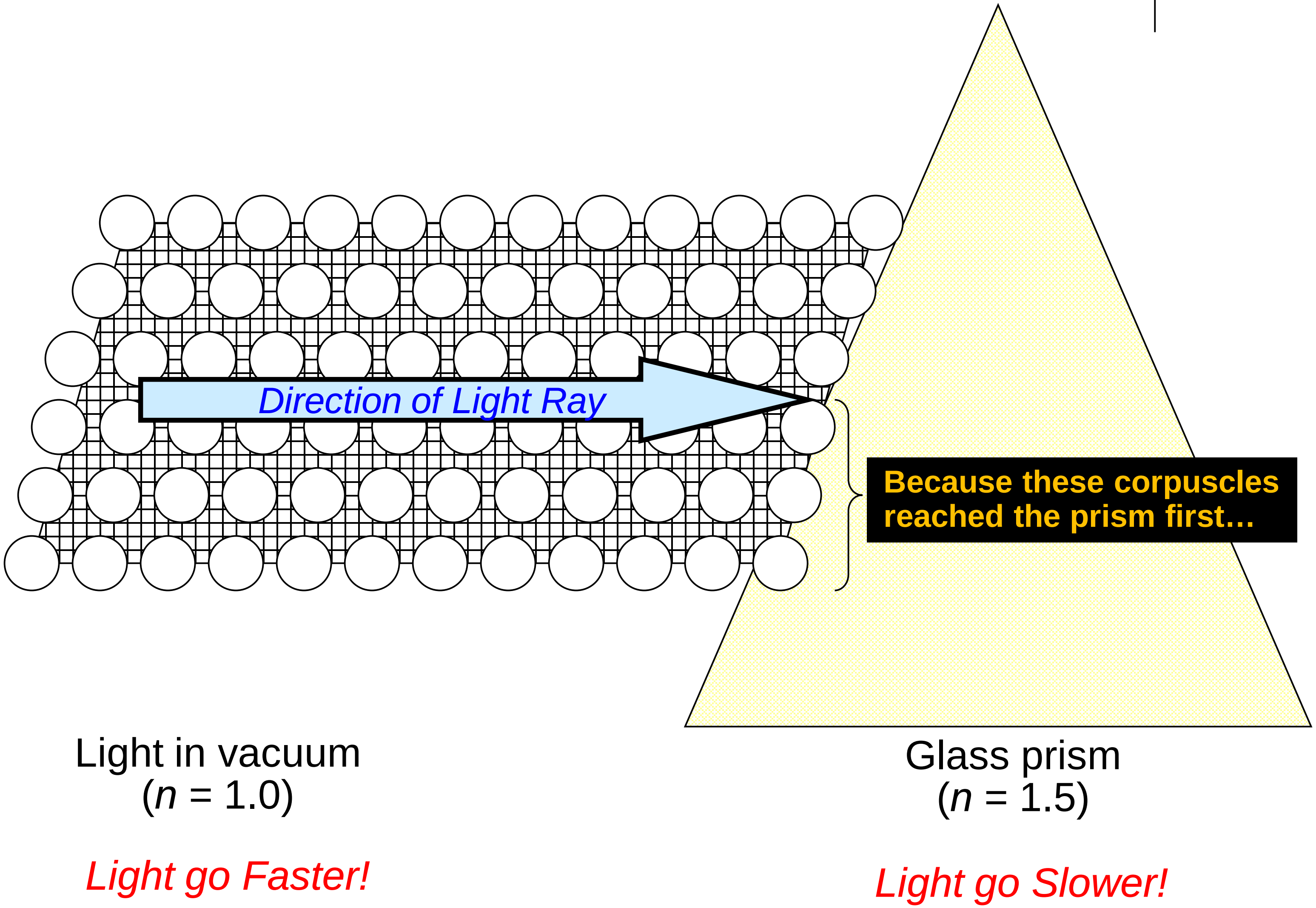

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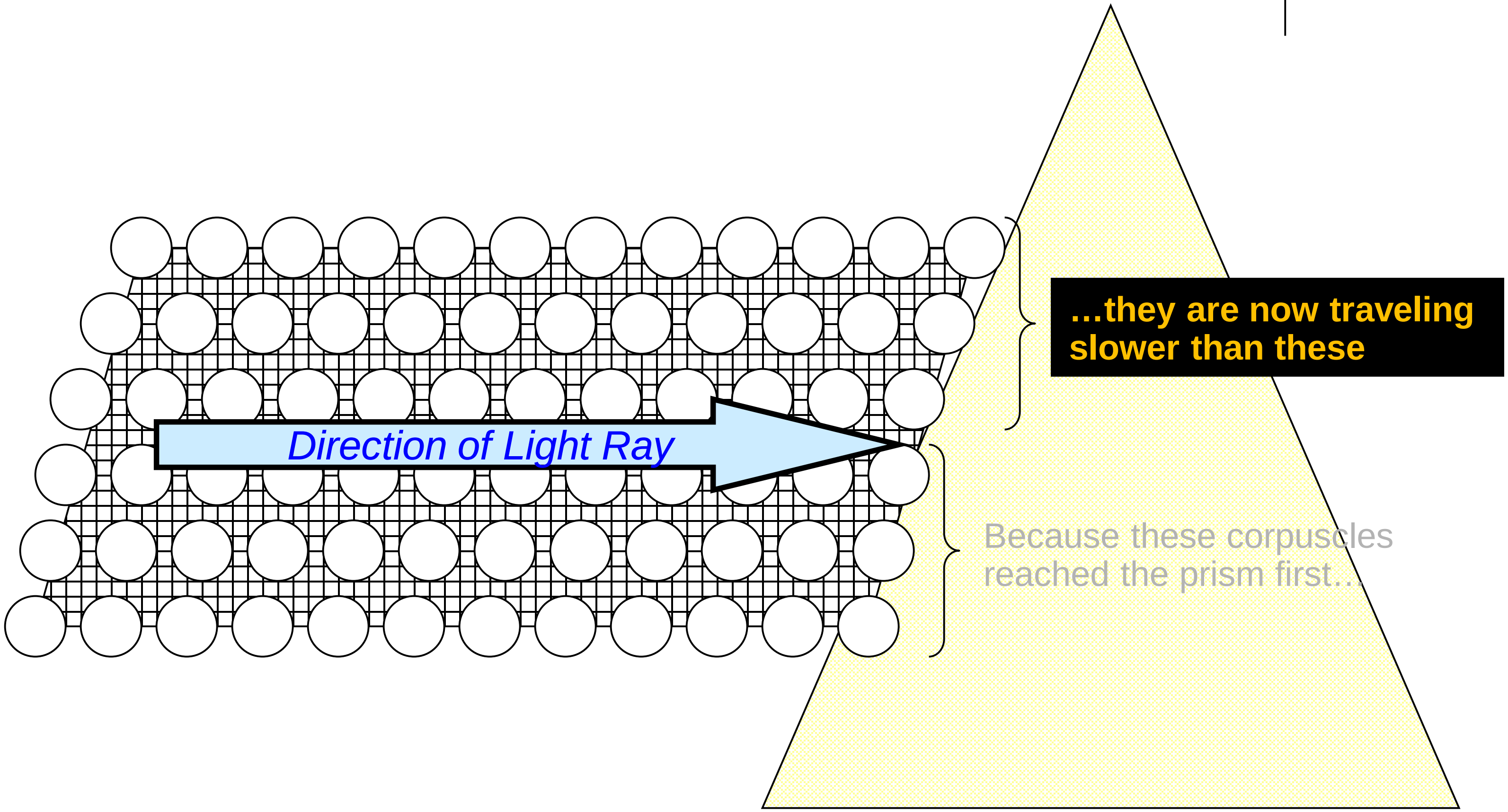

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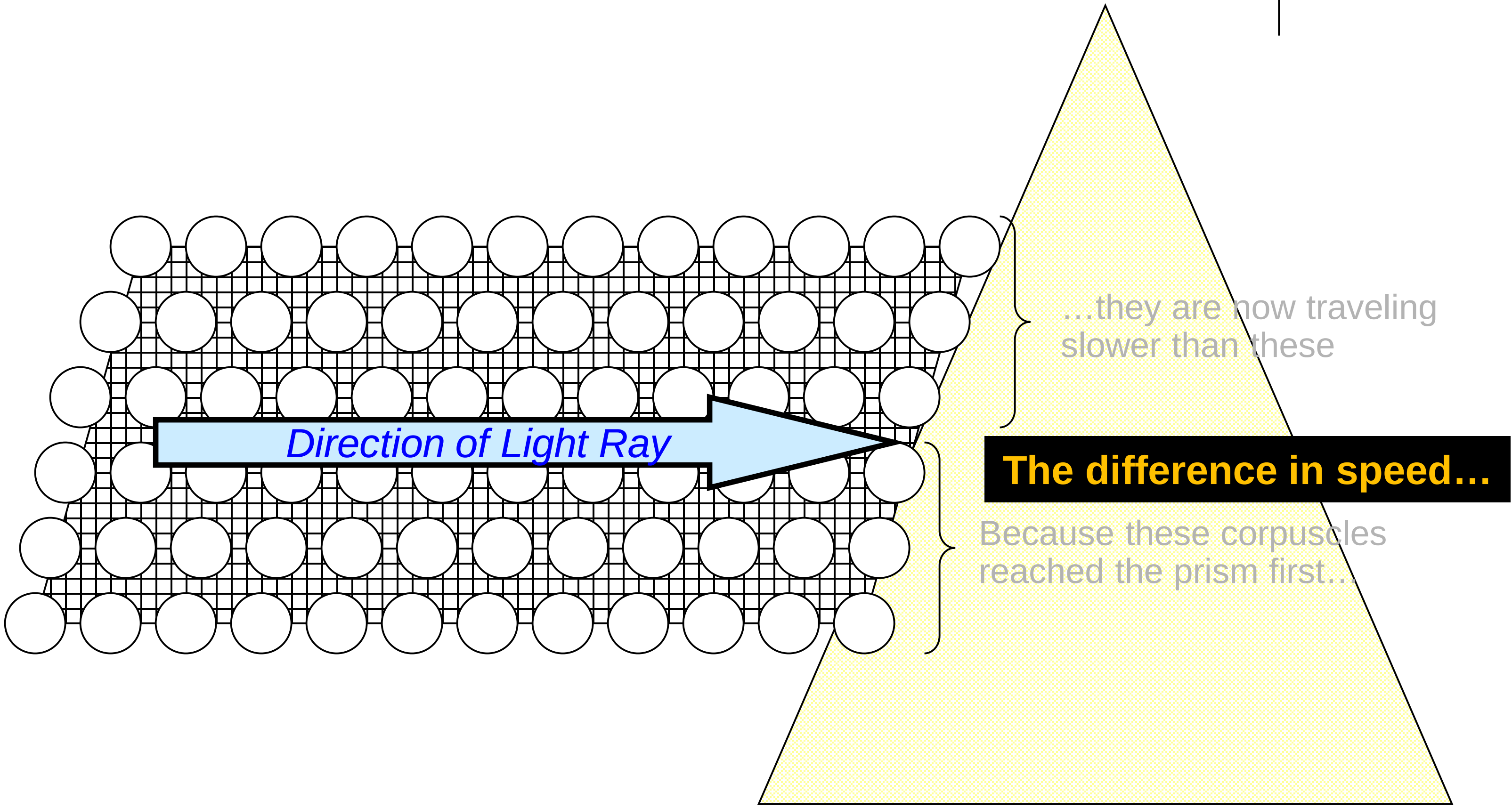

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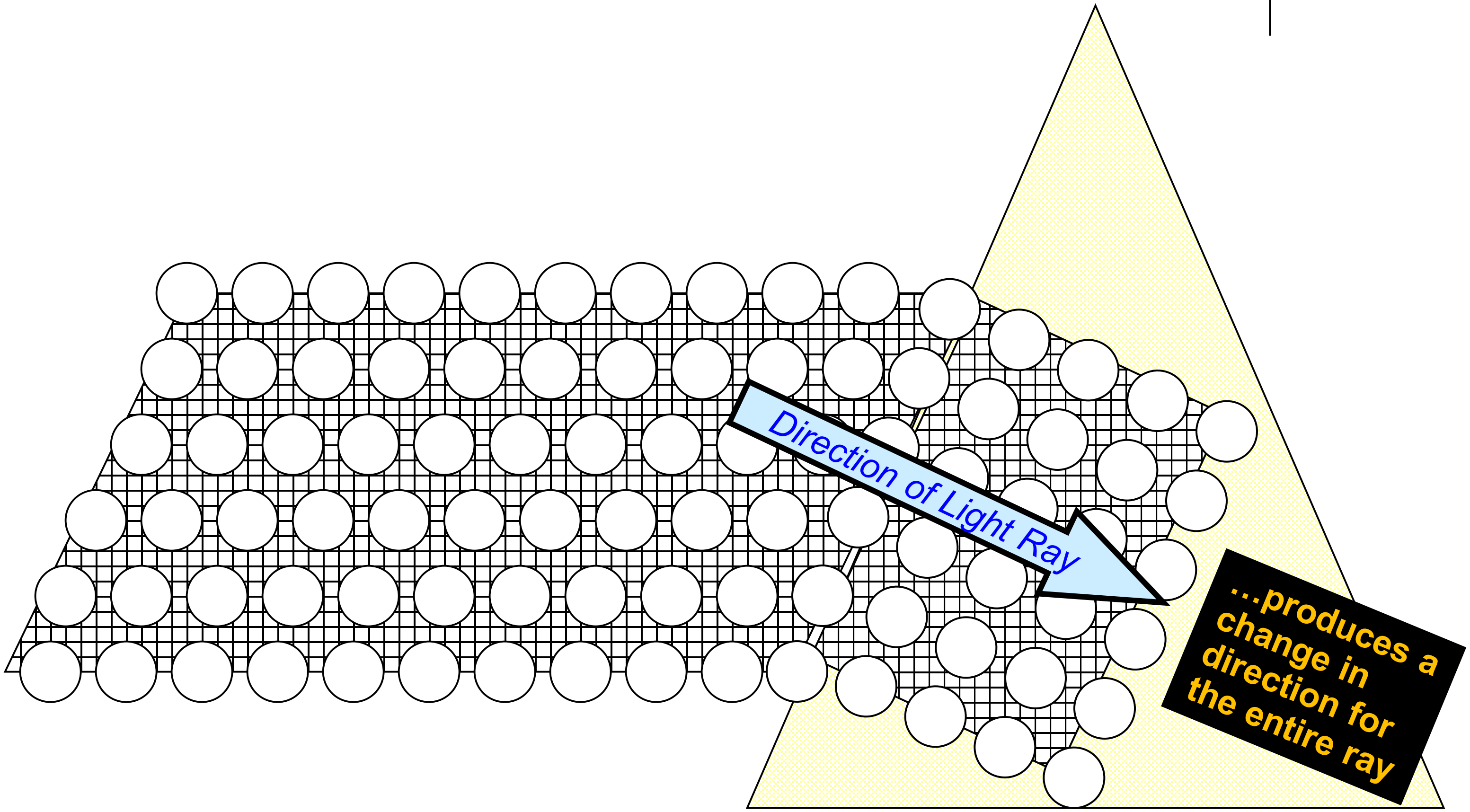

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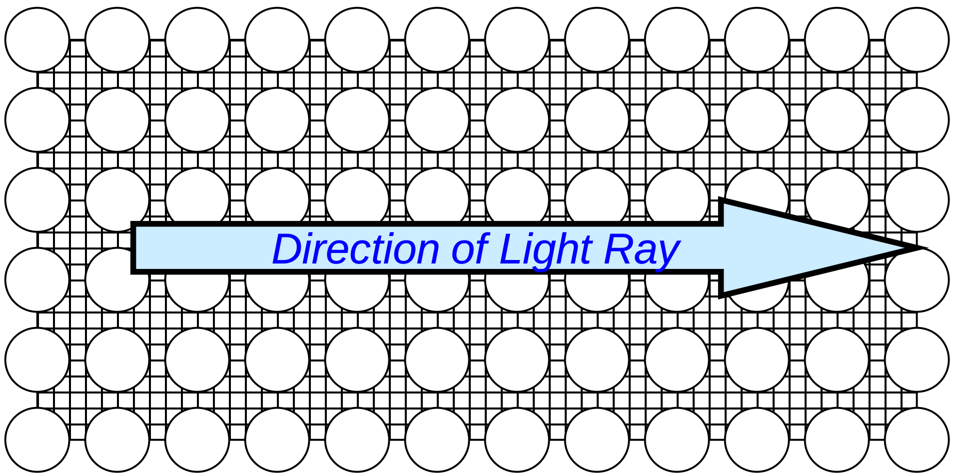
Note that if the refractive medium is hit 'head on'…



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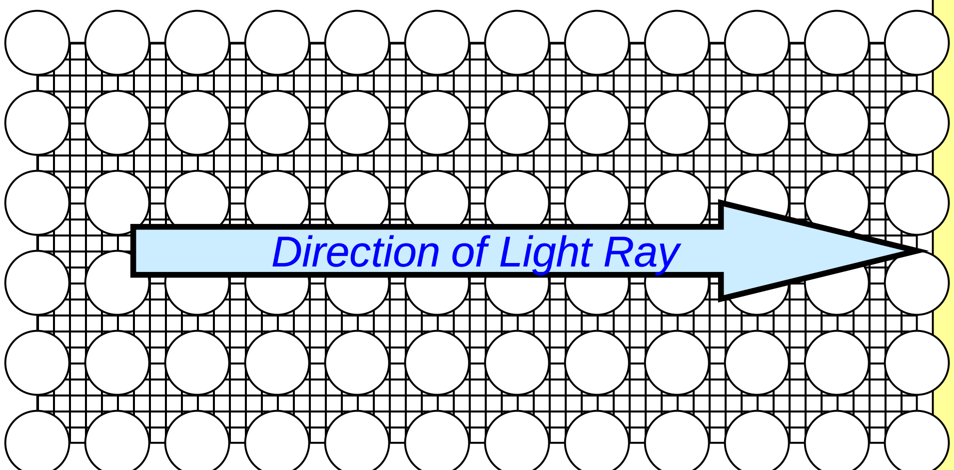

…all the corpuscles slow down at the same time.

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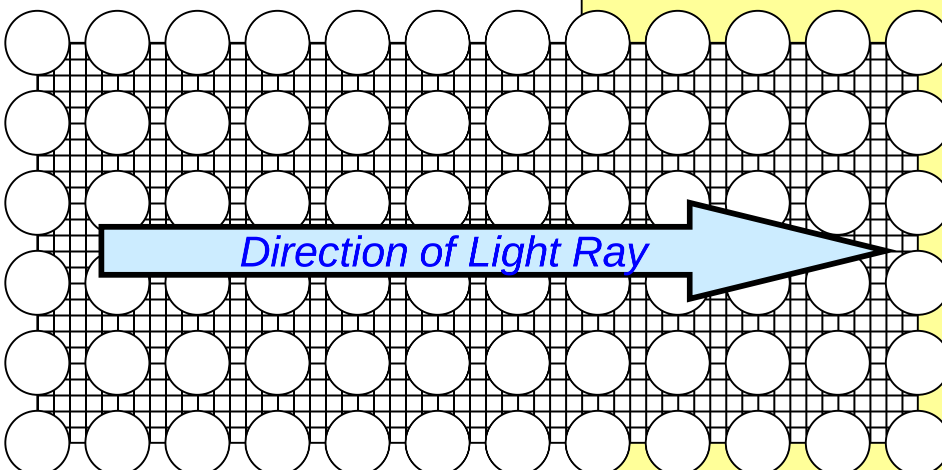

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So there is no ***relative*** slowing, and thus no change in direction

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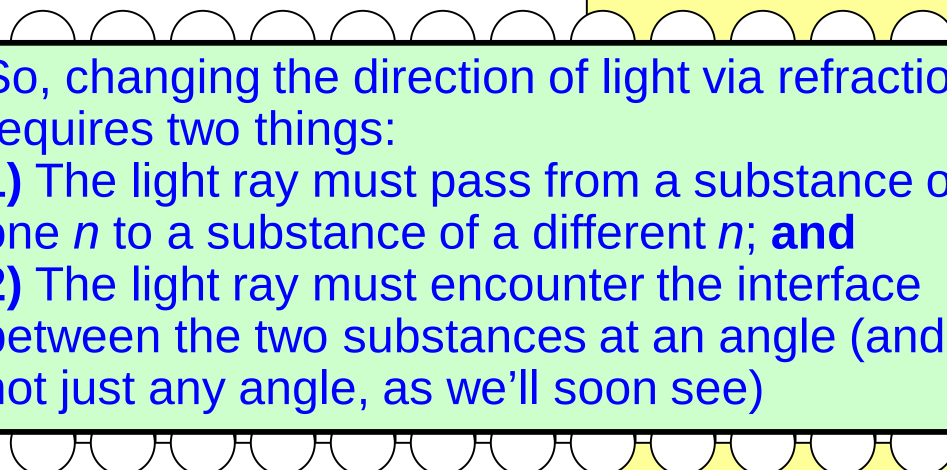

So, changing the direction of light via refraction requires two things:
1) The light ray must pass from a substance of one *n* to a substance of a different *n*; **and**
2) The light ray must encounter the interface between the two substances at an angle (and not just any angle, as we'll soon see)

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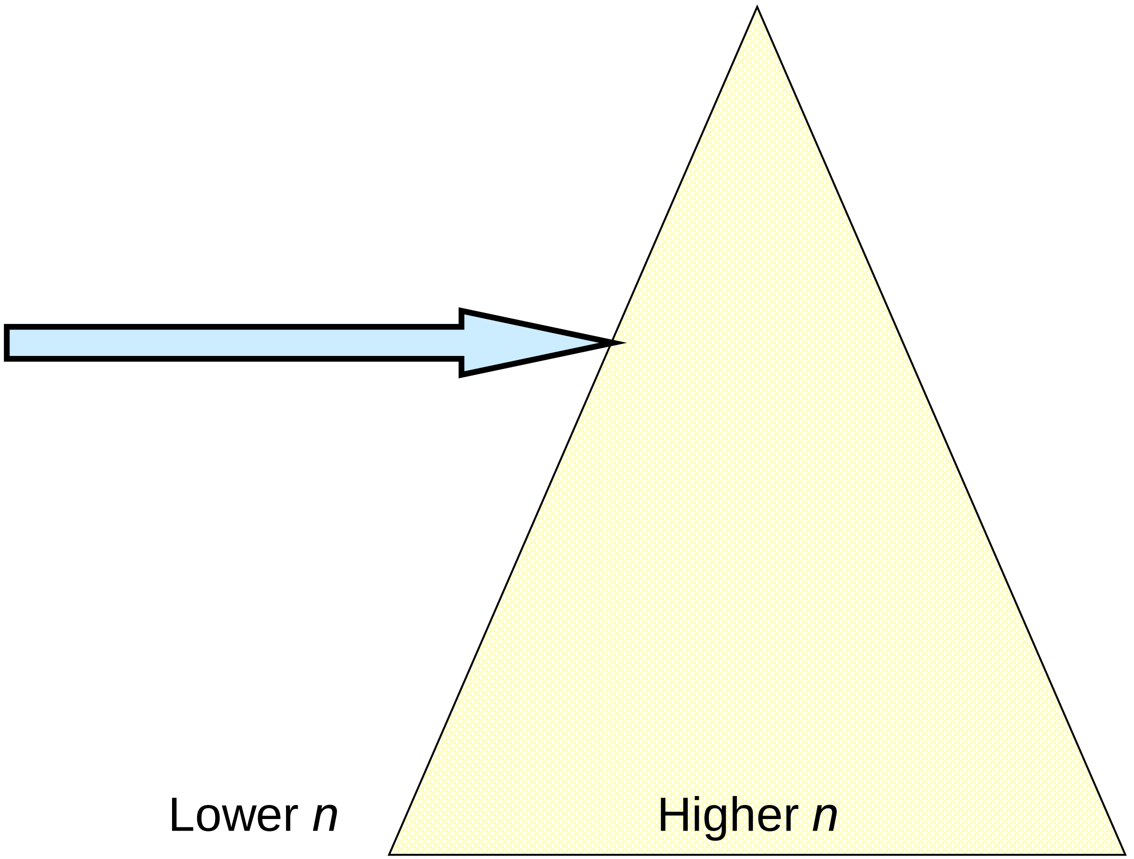
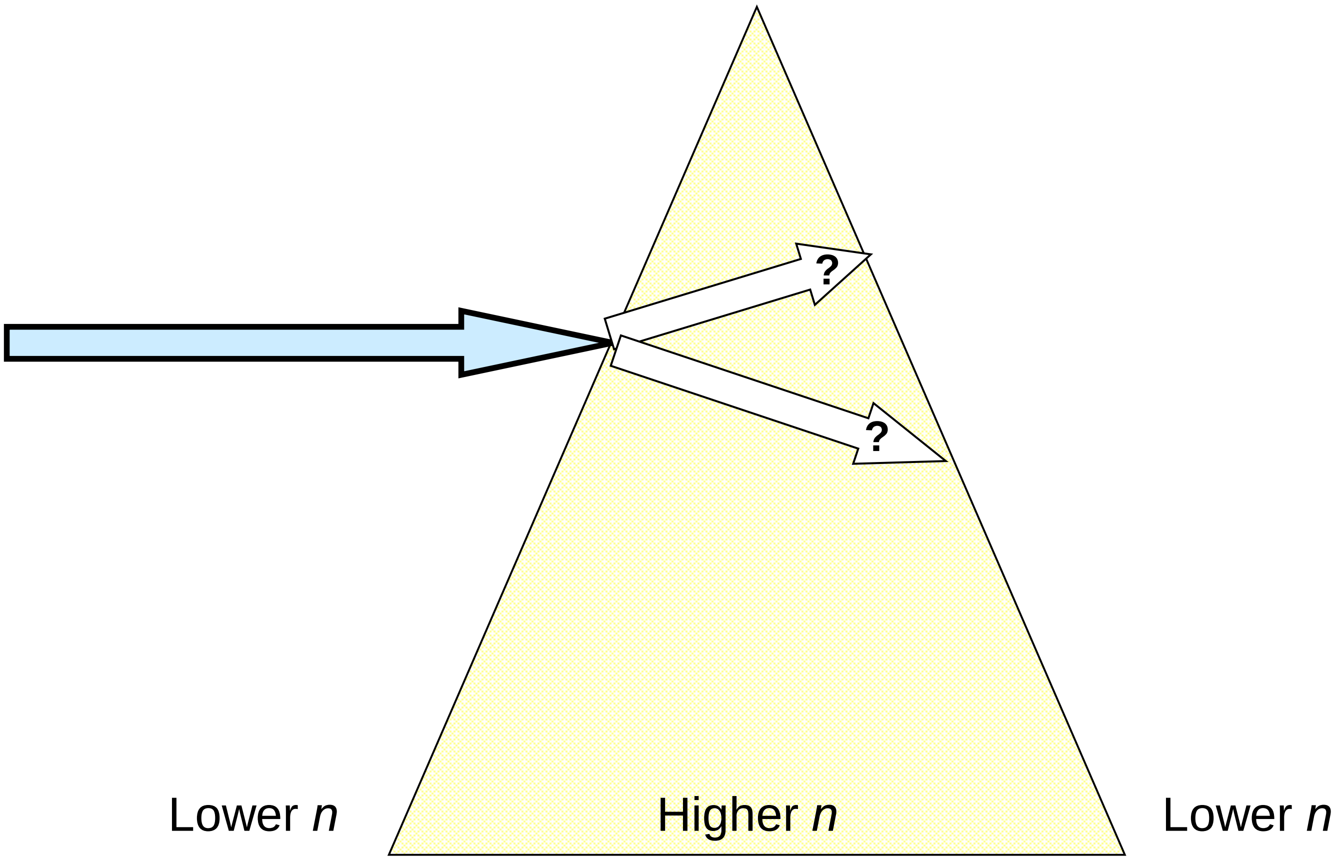


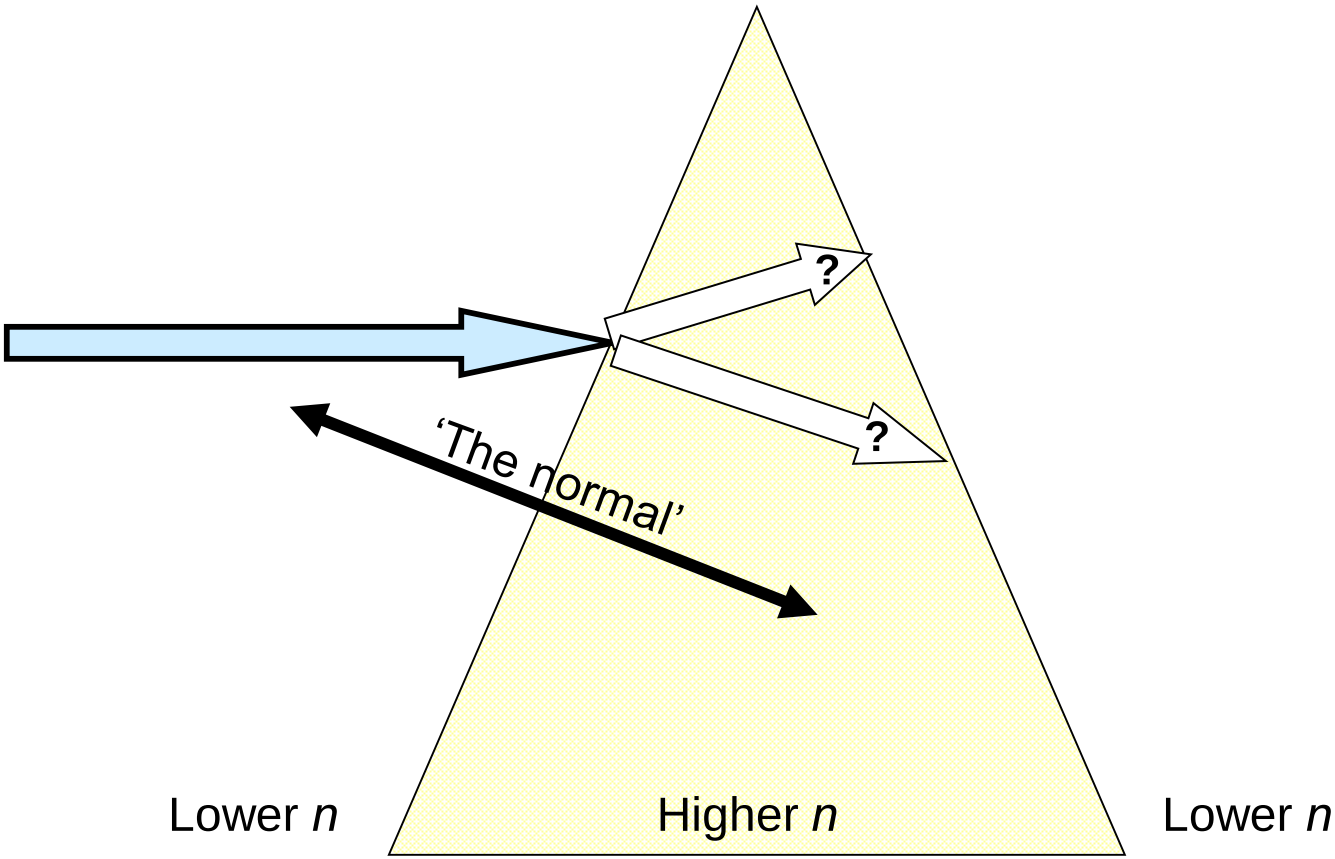
A light ray is encountering a prism…

Refraction



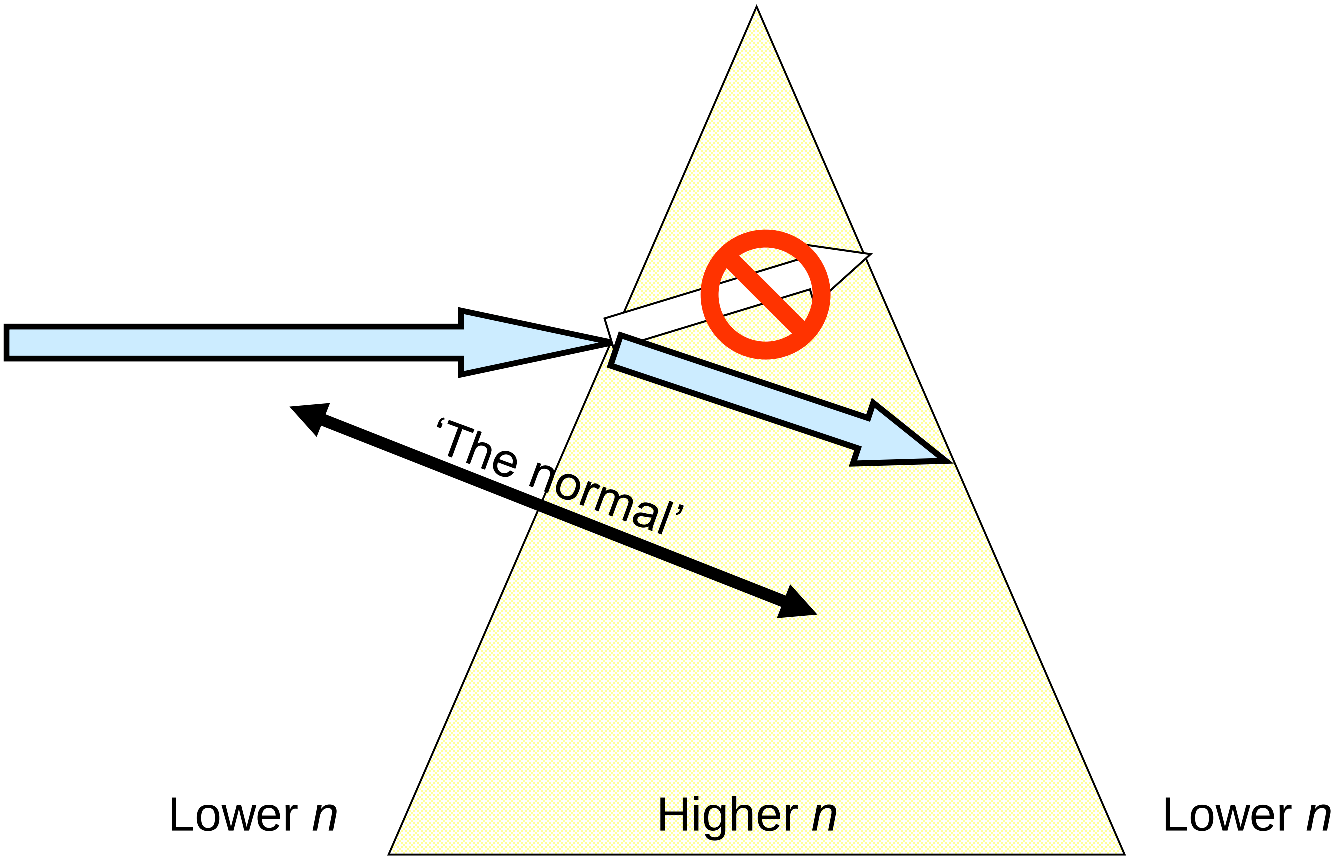
A light ray is encountering a prism…Which way will the ray be refracted?

Refraction



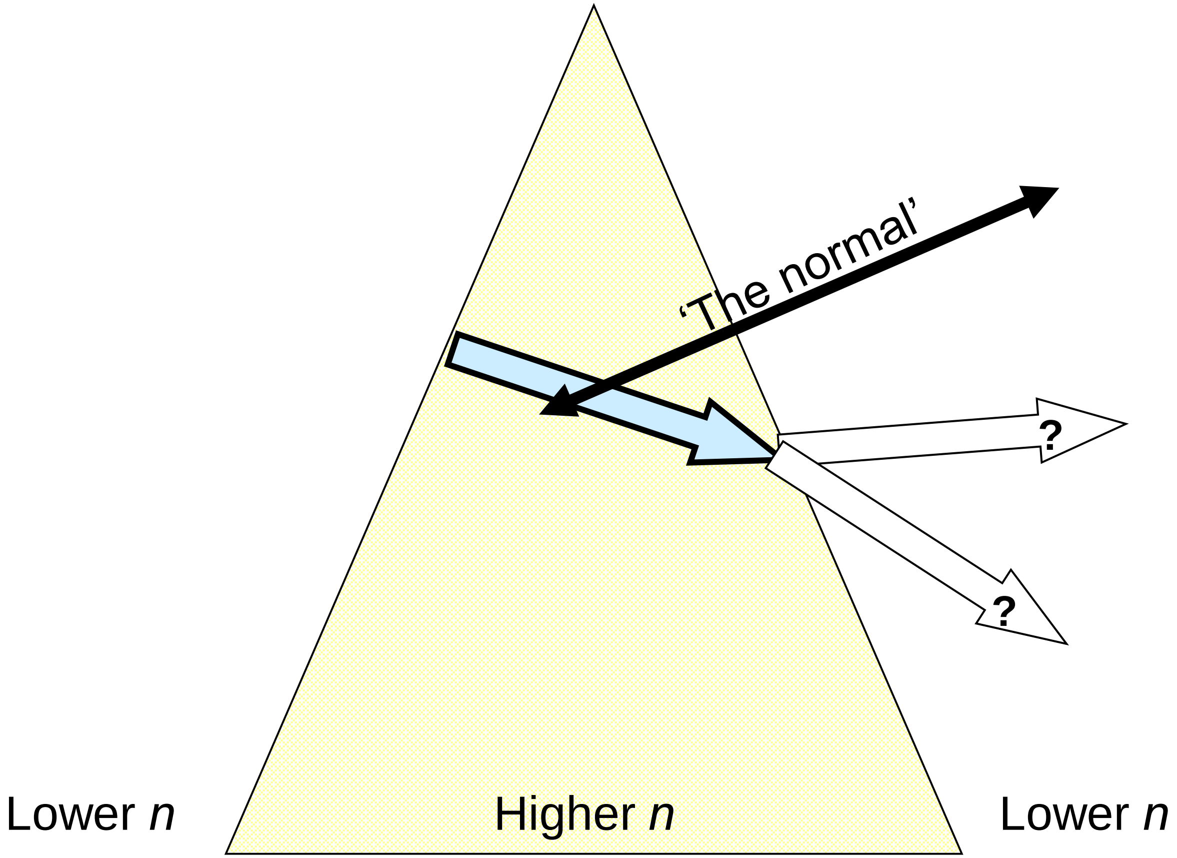
A light ray is encountering a prism…Which way will the ray be refracted?
To answer this we have to introduce a concept with a peculiar name: ***The normal***.
The normal is simply an imaginary line perpendicular to the refractive interface.

Refraction



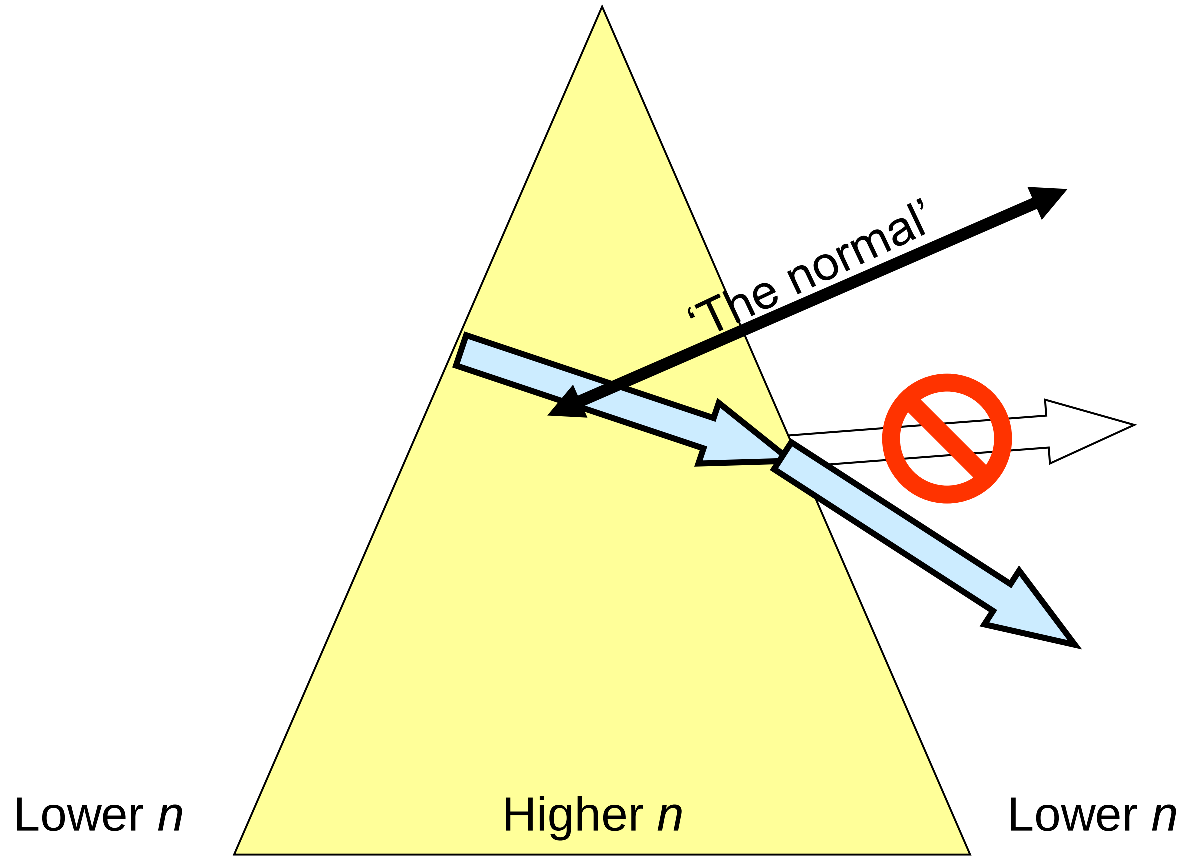
When a ray passes from a material of lower *n* to one of higher *n*, the ray is deflected **toward** the normal (*how much* it deflects is a function of the angle of incidence and the *n*s of the substances—more shortly).

Refraction



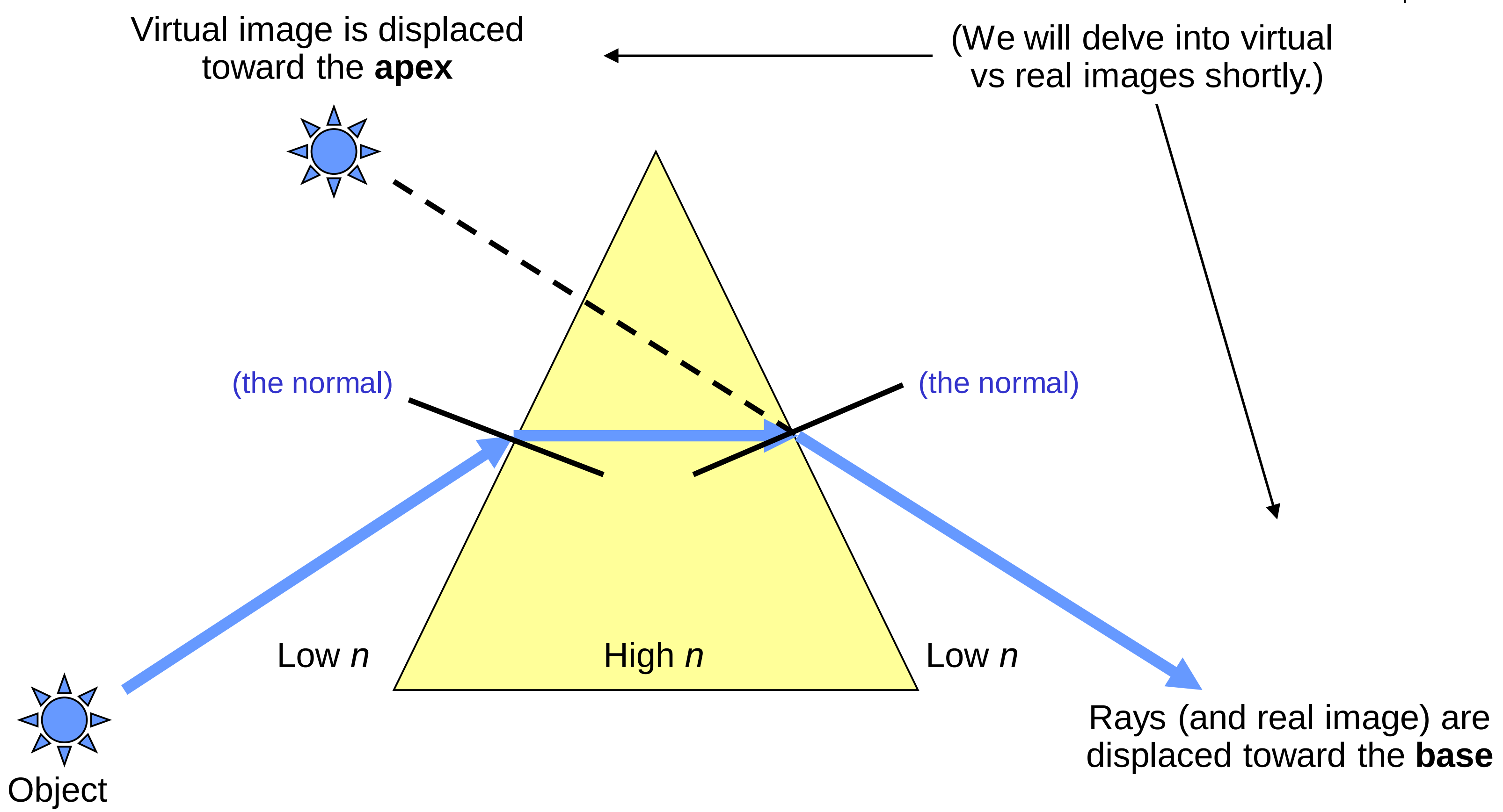
*What about when the ray passes from a higher-*n *substance to a lower* n*?*

Refraction



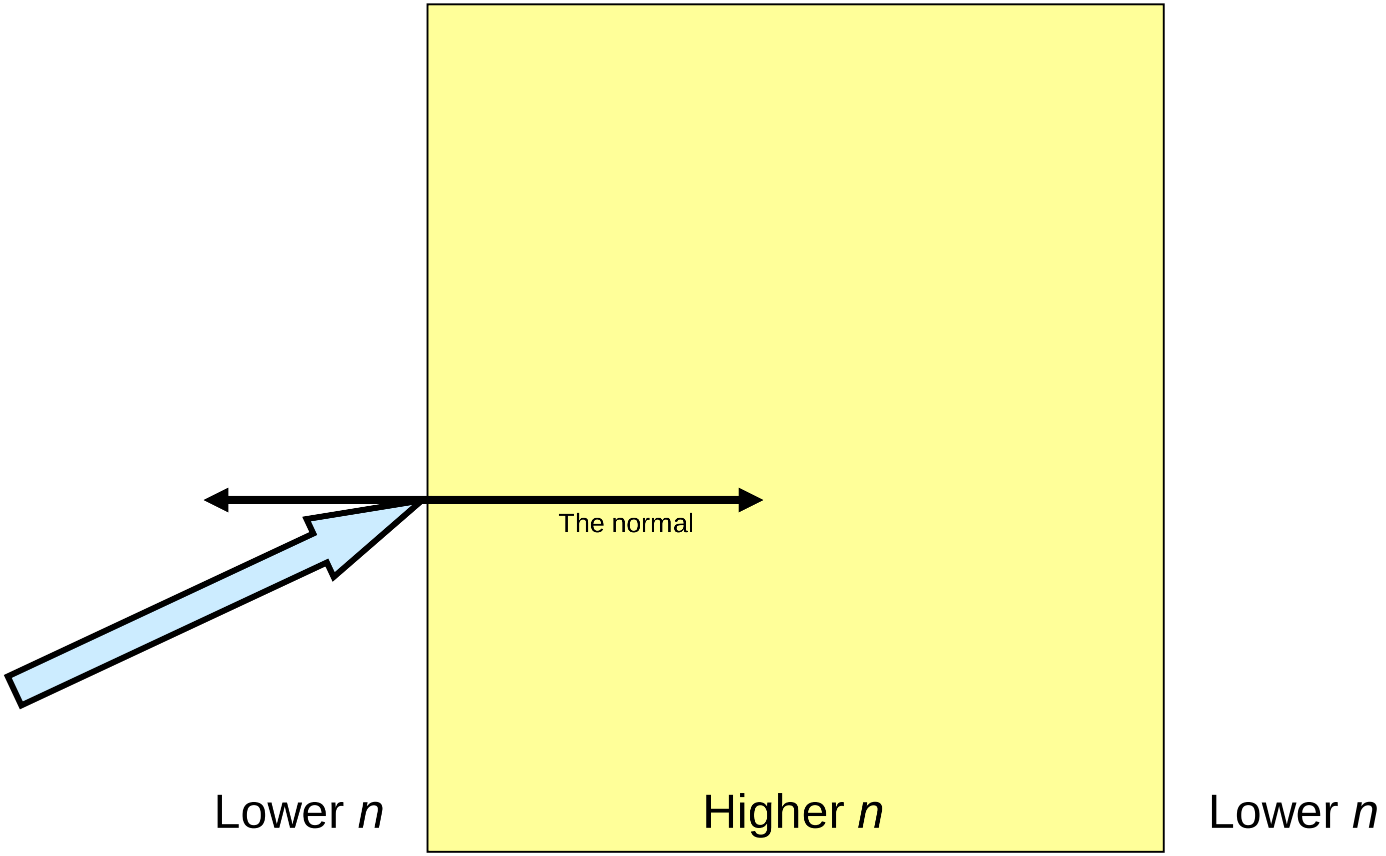
When a ray passes from a material of higher *n* to one of lower *n*, the ray is deflected **away** from the normal.

Refraction



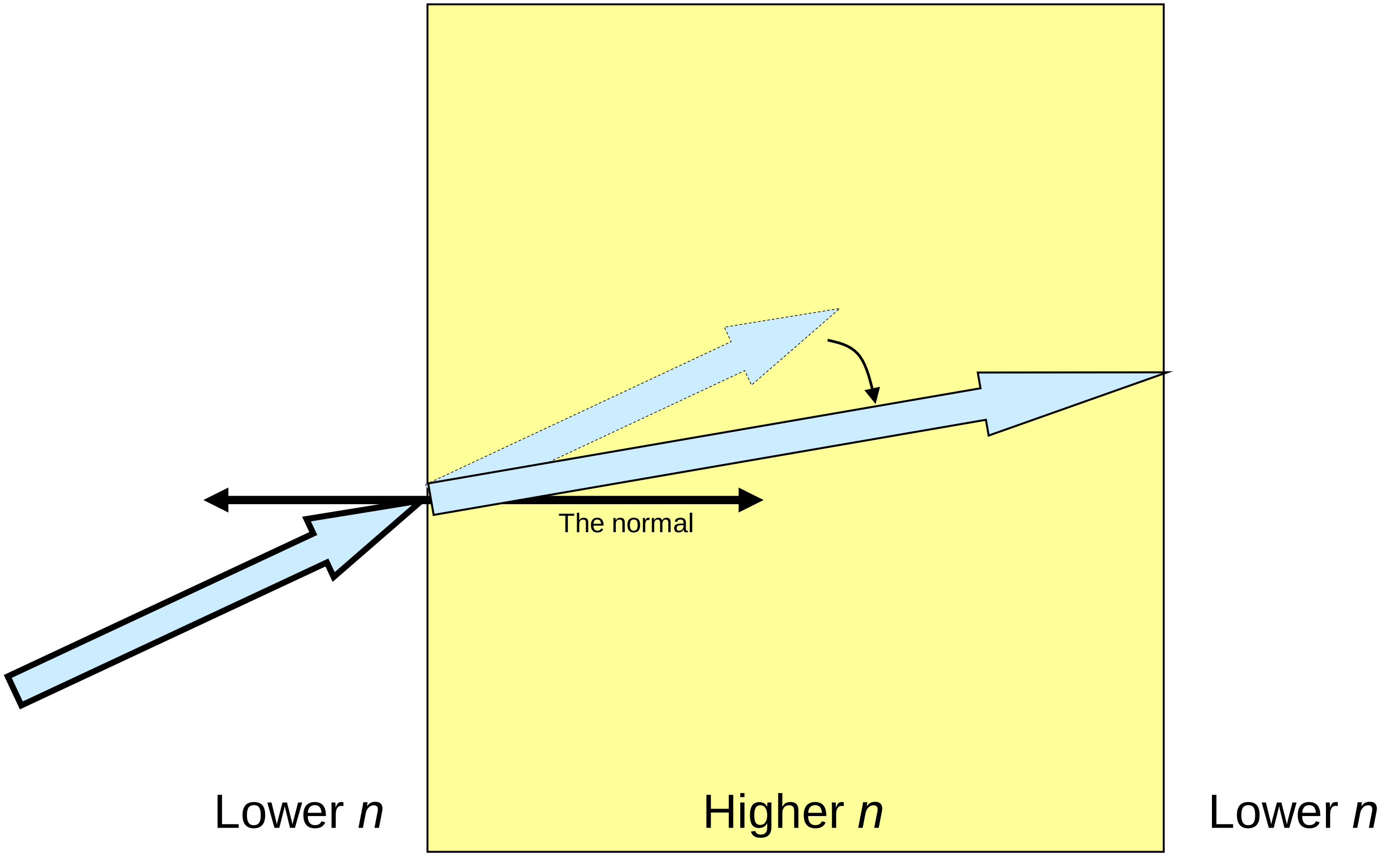
If you think about it, all of this goes along with what you already know about the effect of prisms on light and images

Refraction



What if the prism is *rectangular* in shape?

Refraction



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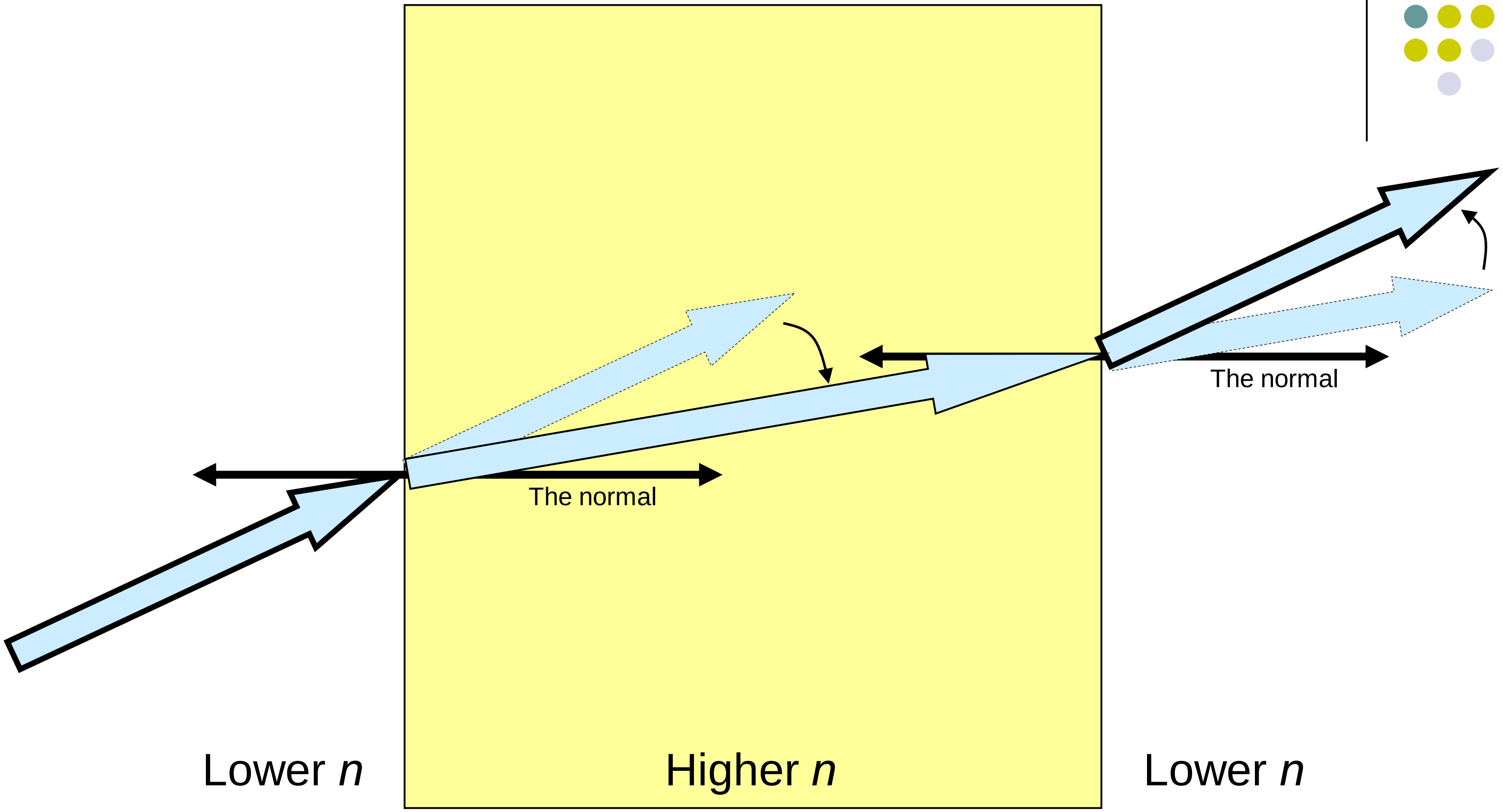

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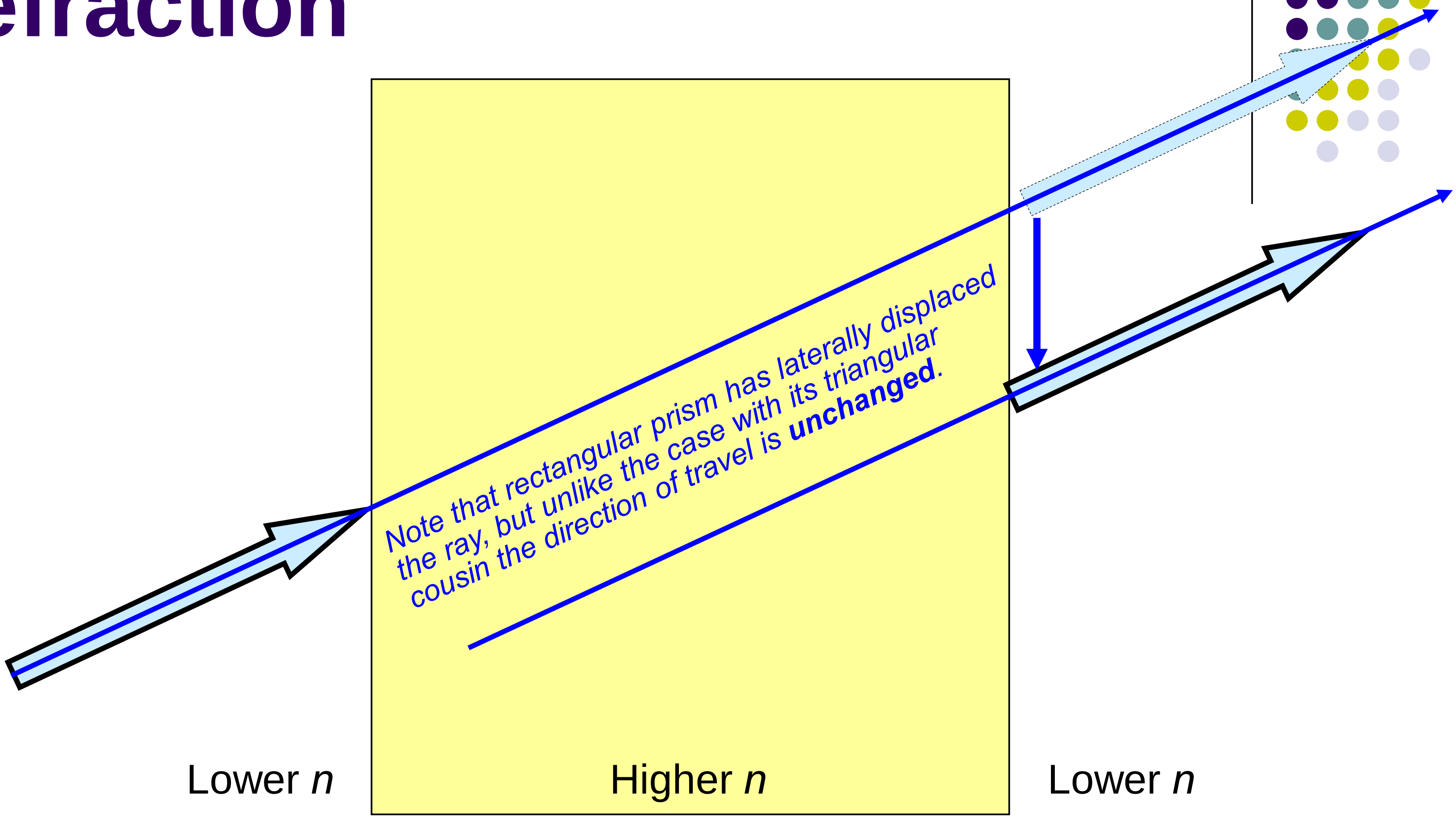

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Refraction

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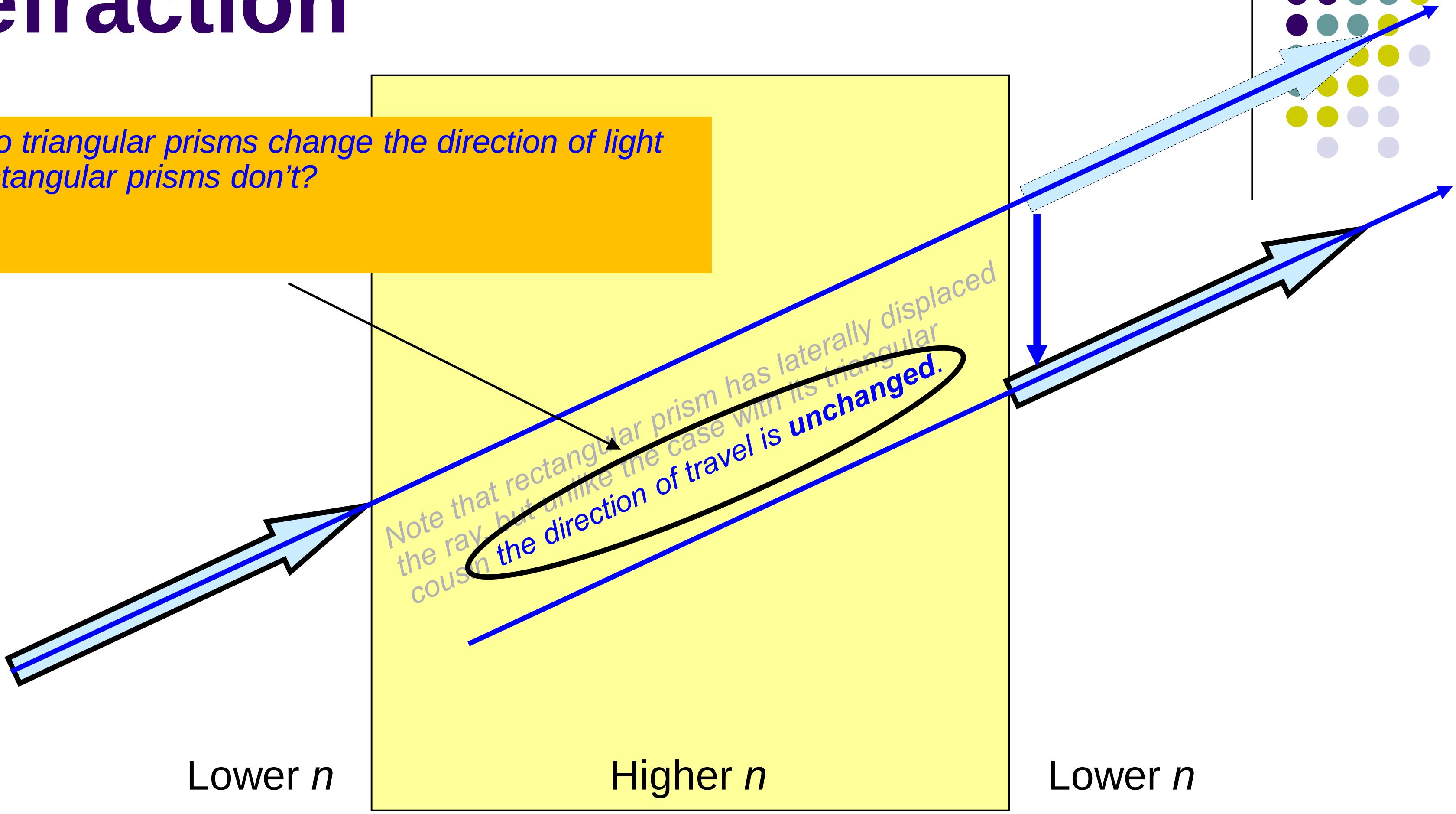

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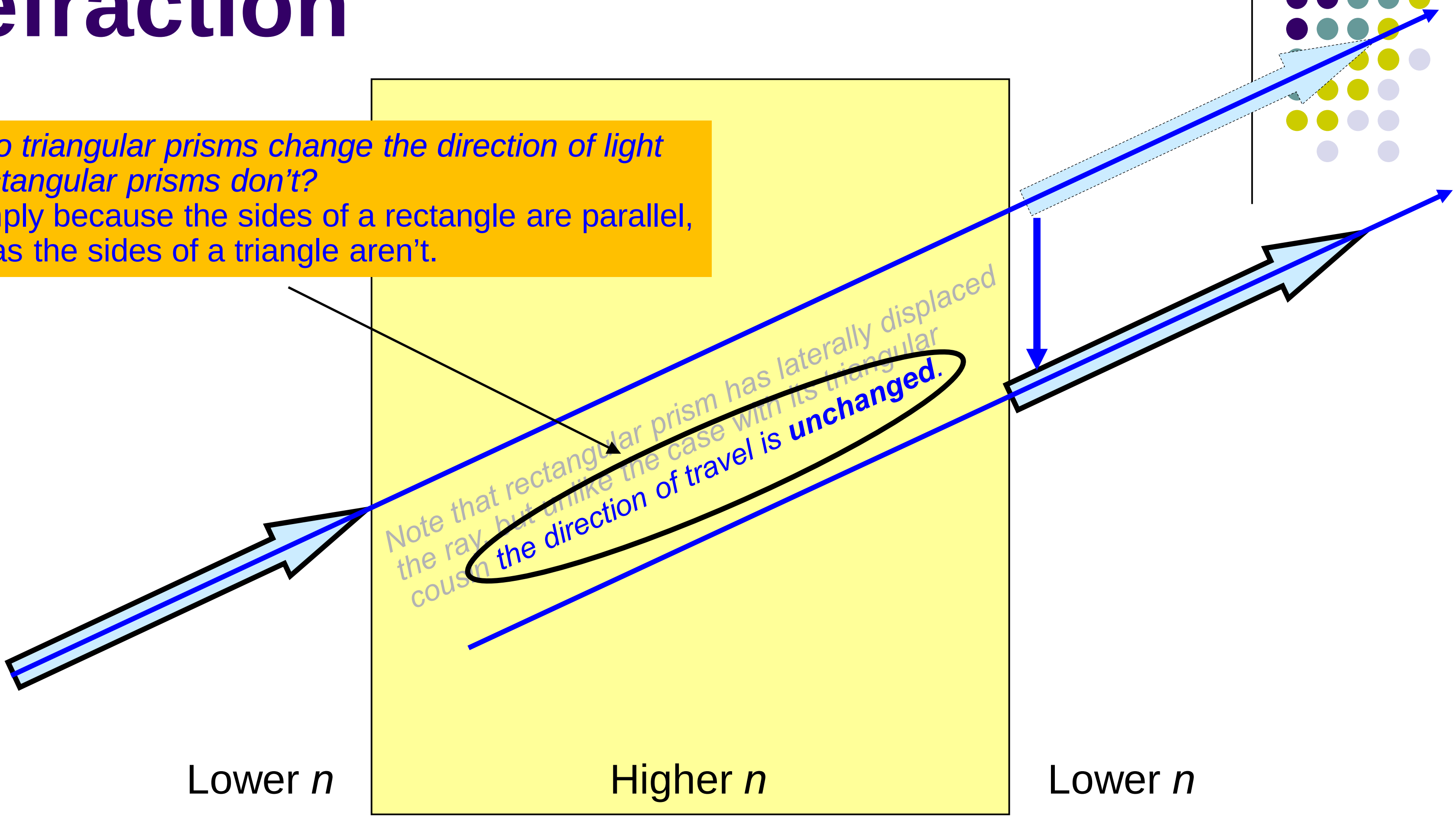
It's simply because the sides of a rectangle are parallel, whereas the sides of a triangle aren't.



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