Chromatic Aberration

Basic Optics, Chapter 26

Aberrations

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- Degradation results when light rays from a given object-point fail to form a single sharp image-point
- *It's important to recognize that aberrations are the rule, not the exception*
    - Aberration-free vision essentially never occurs

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    - Spherical error (myopia/hyperopia)
    - Cylinder (astigmatism)
  - Among the others, one of the more important is *Chromatic aberration*

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Aberrations: *Chromatic*

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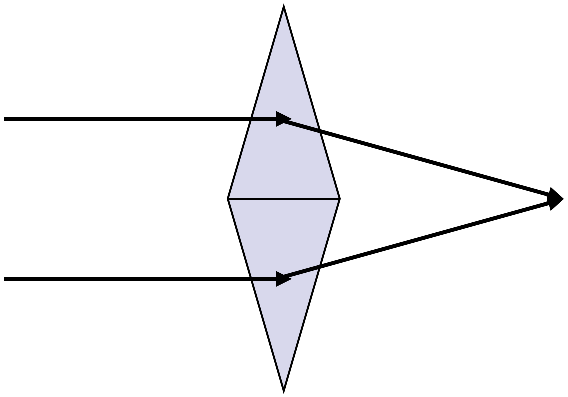
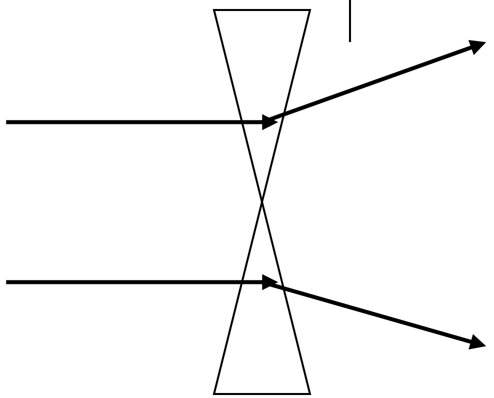


If we placed two prisms base-to-base or apex-to-apex, we could get light to converge and diverge, respectively



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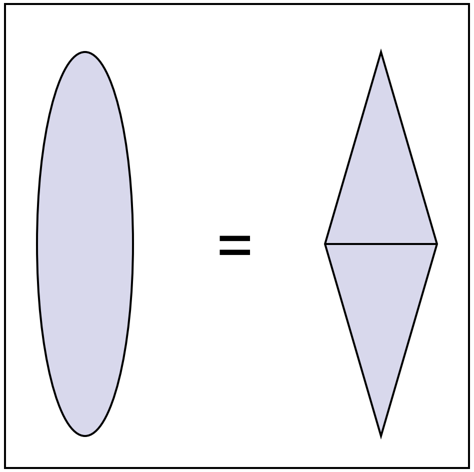

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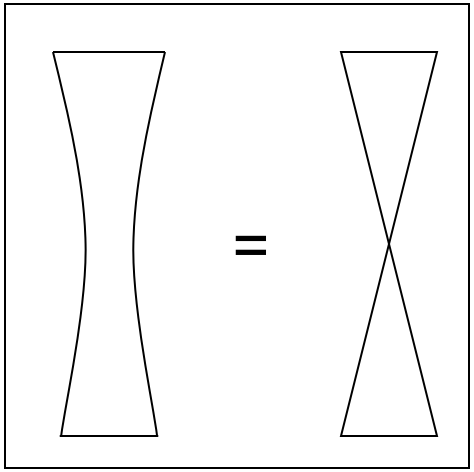

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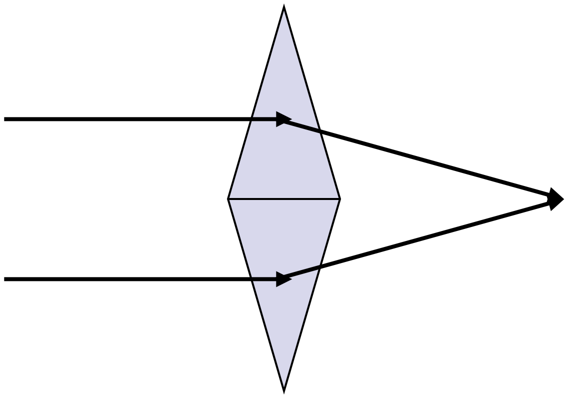

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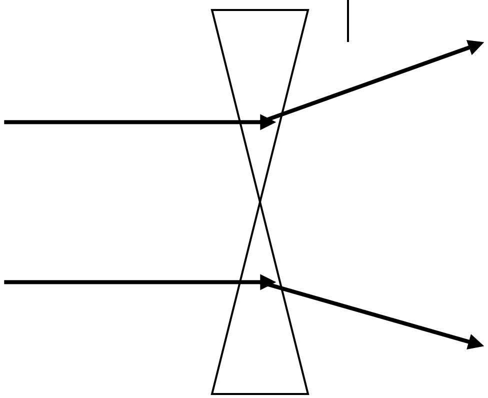

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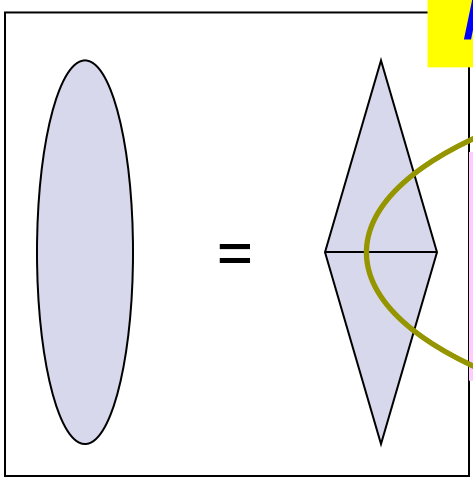

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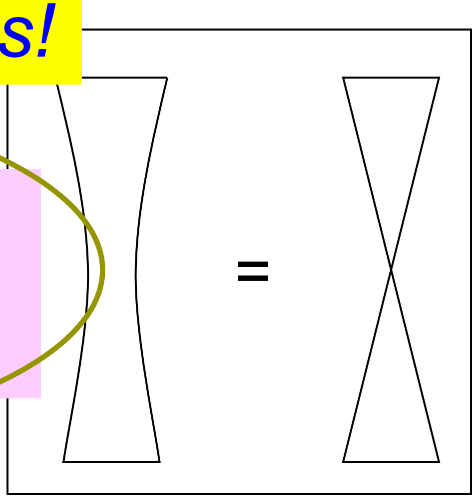

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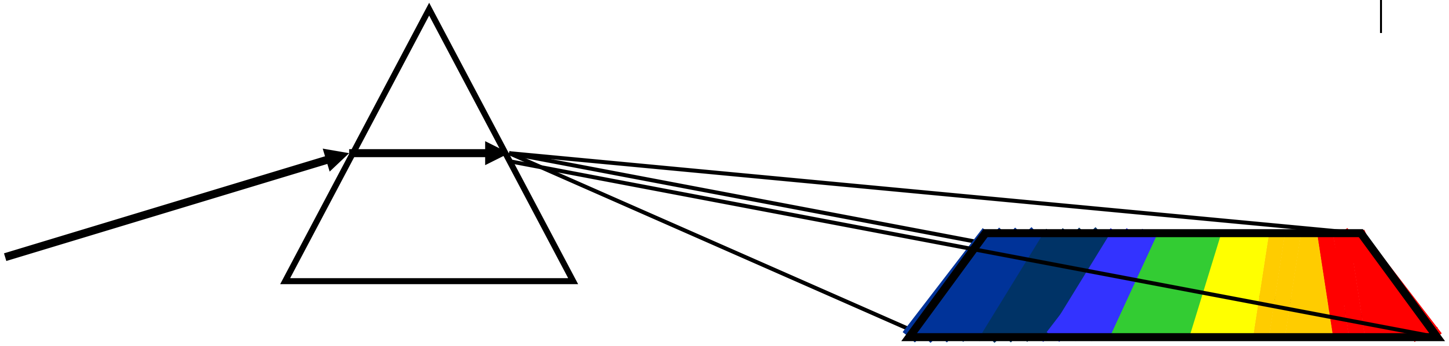

As we noted then, prisms disperse white light into its component colors because different wavelengths are refracted different amounts.

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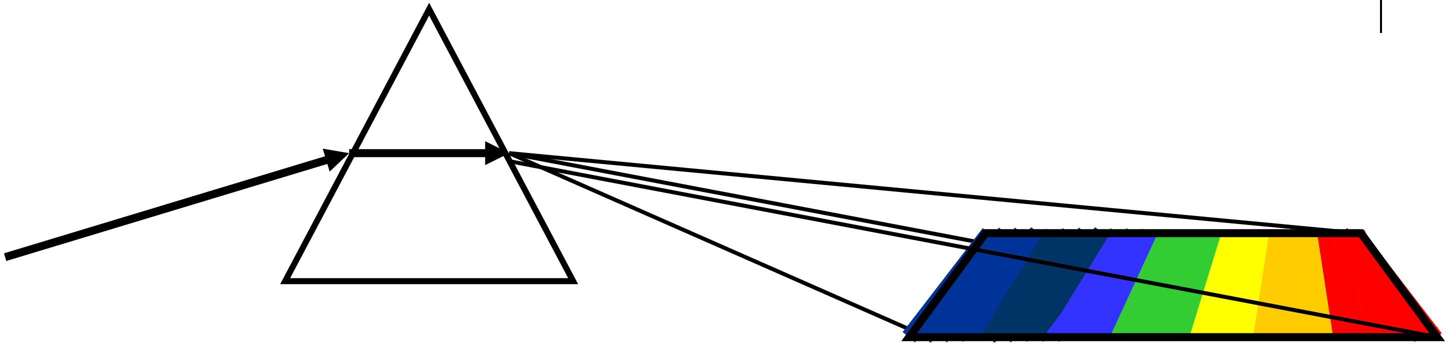

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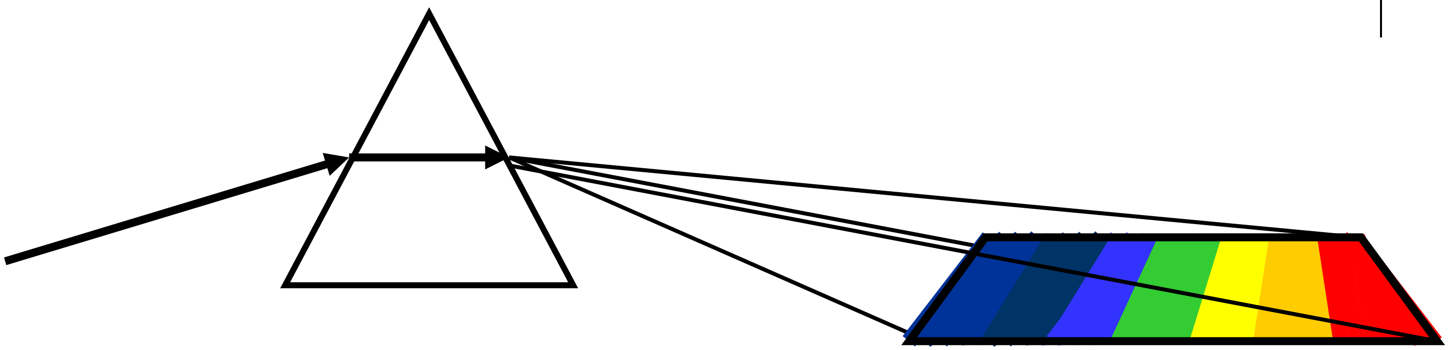

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Simplified

Snell's Law

$$n_i \sin \theta_i = n_t \sin \theta_t$$

Refractive index of the material light is leaving (n_i)

Angle of incidence with respect to the Normal (θ_i)

Refractive index of the material light is entering (n_t)

Angle of transmission with respect to the Normal (θ_t)

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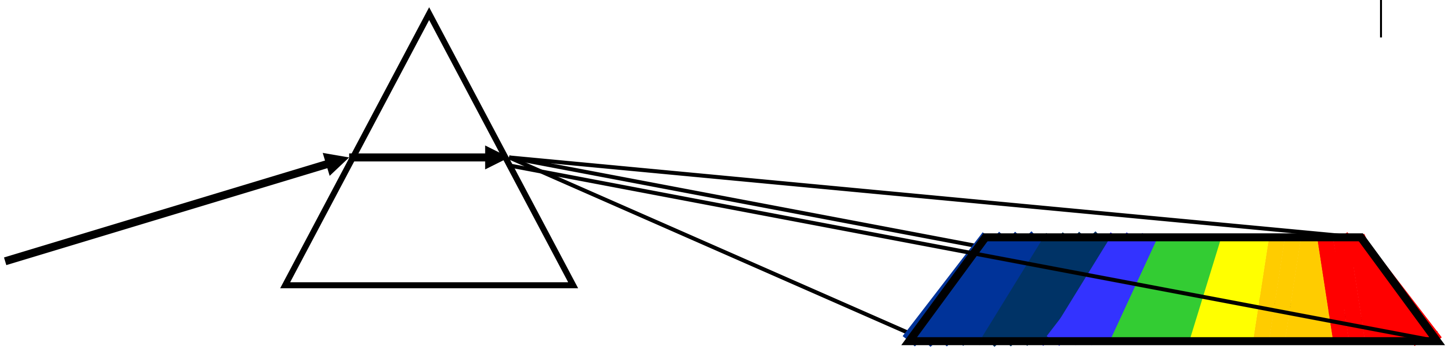

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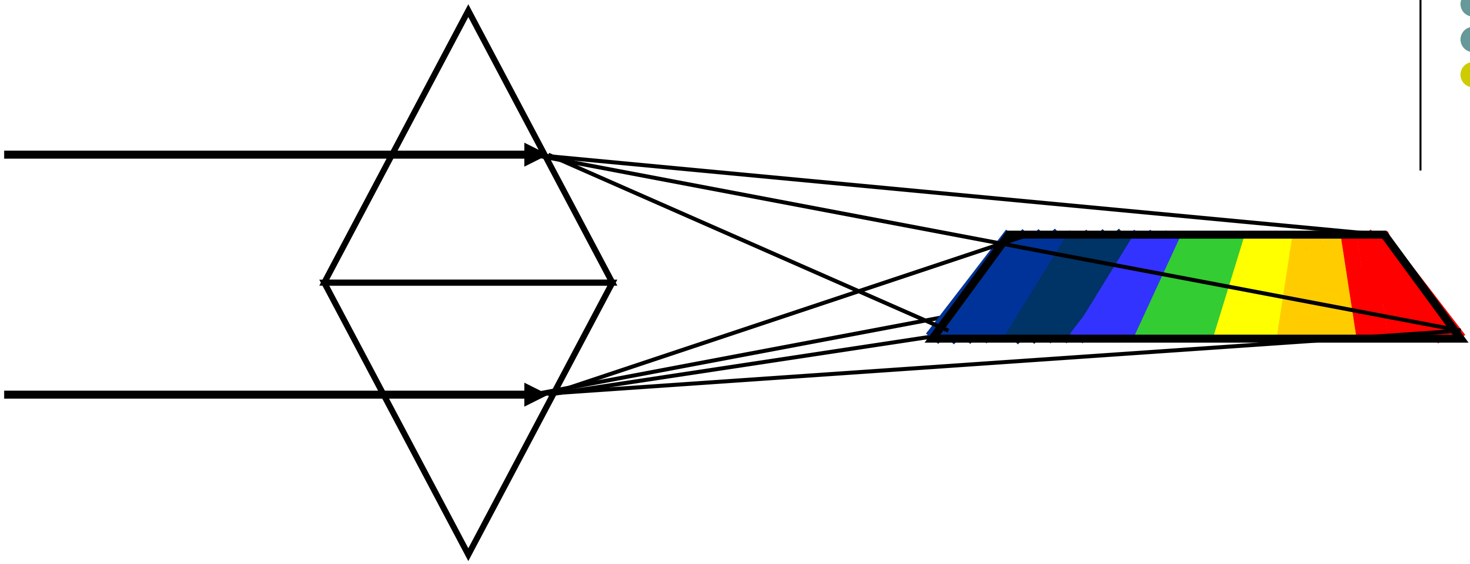
Because of this, for a given angle of incidence θ_i, each wavelength will be refracted a different amount (ie, will have a different angle of transmission, θ_t).

Aberrations: *Chromatic*



Prisms working in tandem would do the same thing.

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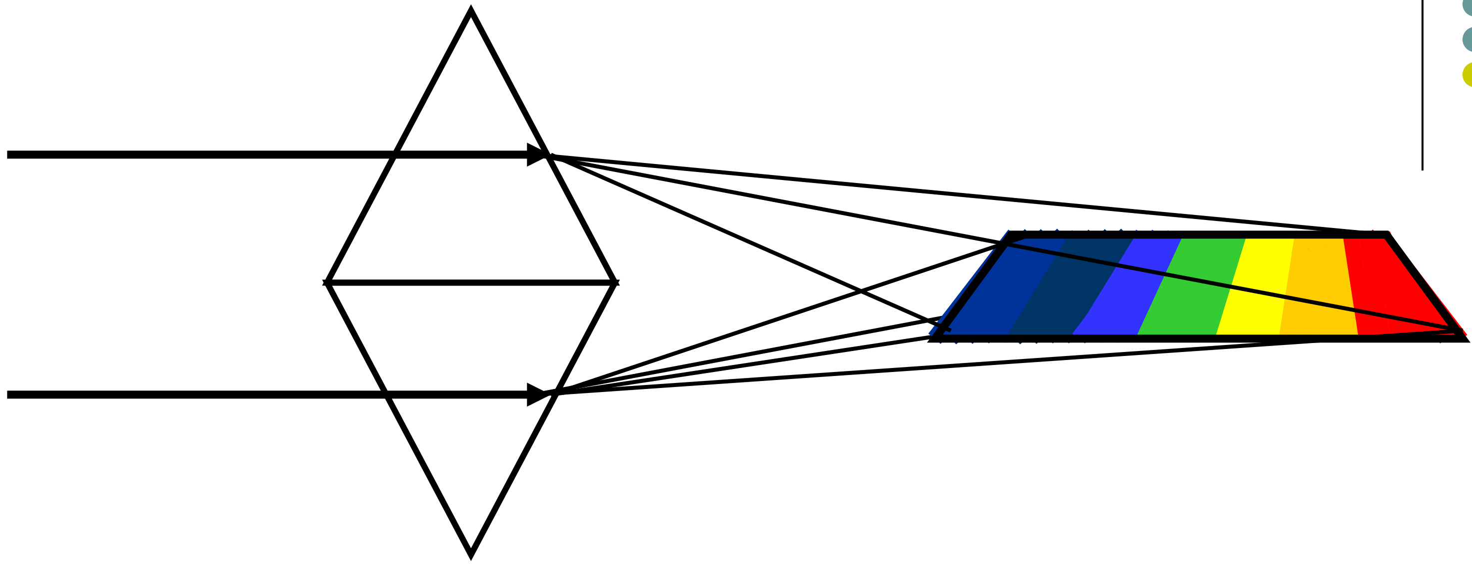
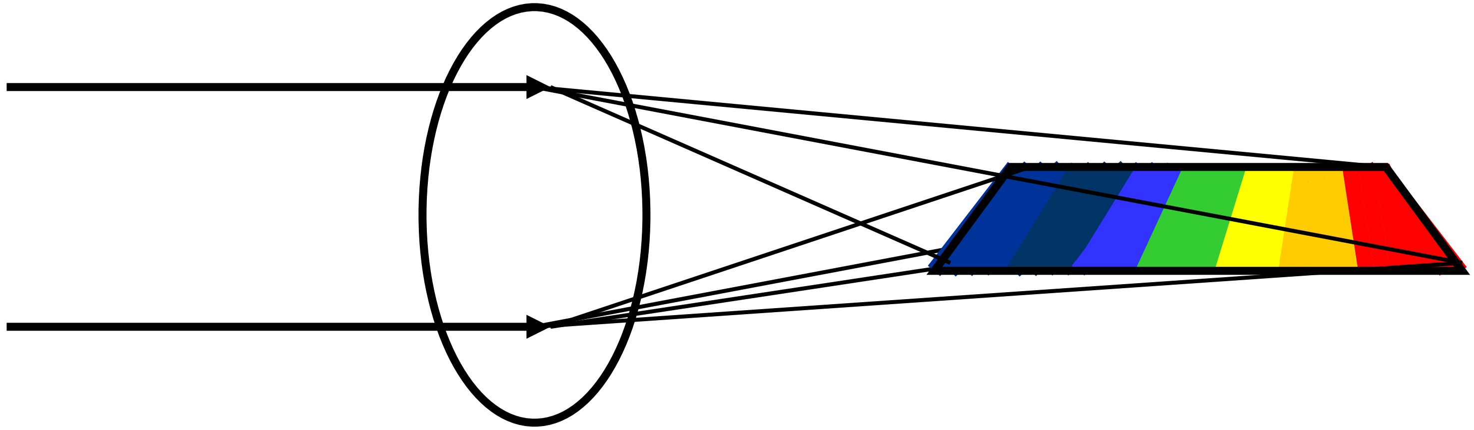


And because lenses are essentially prisms working in tandem, they do the same as well.



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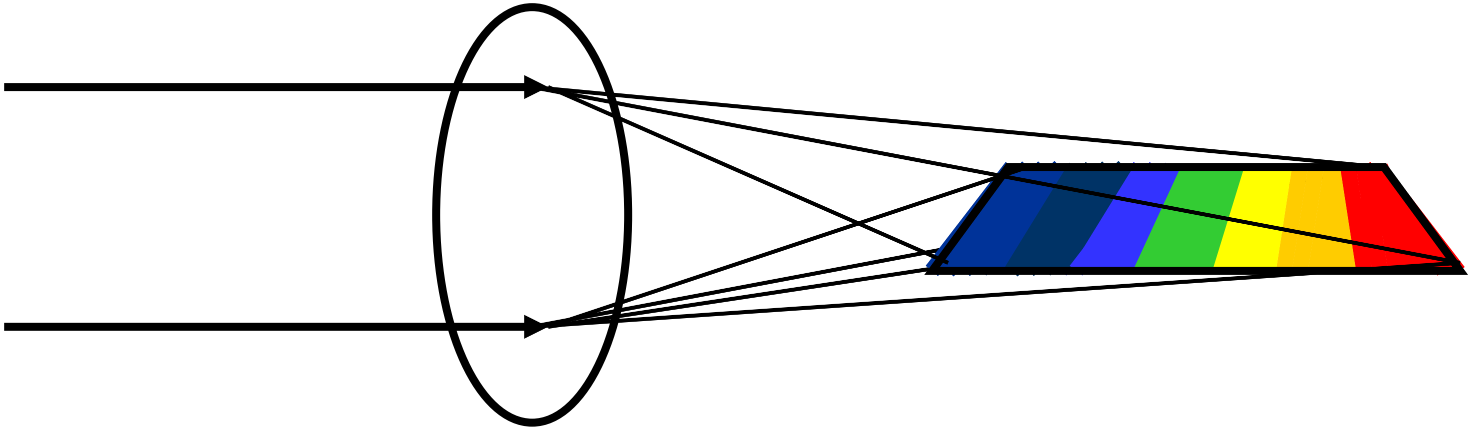

And finally, because the cornea/lens of the eye act like one big lens…

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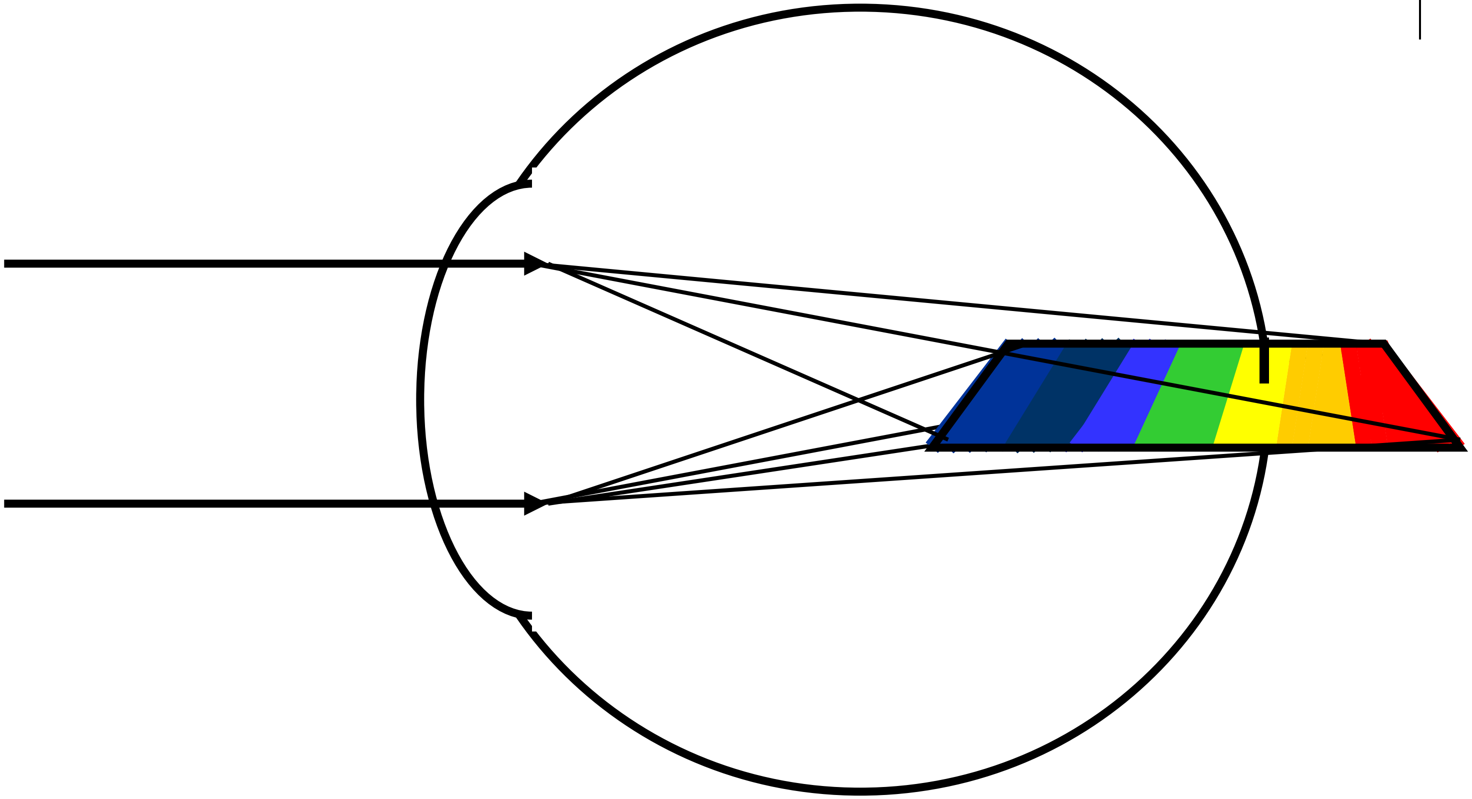

And finally, because the cornea/lens of the eye act like one big lens…***the eye does it as well***.

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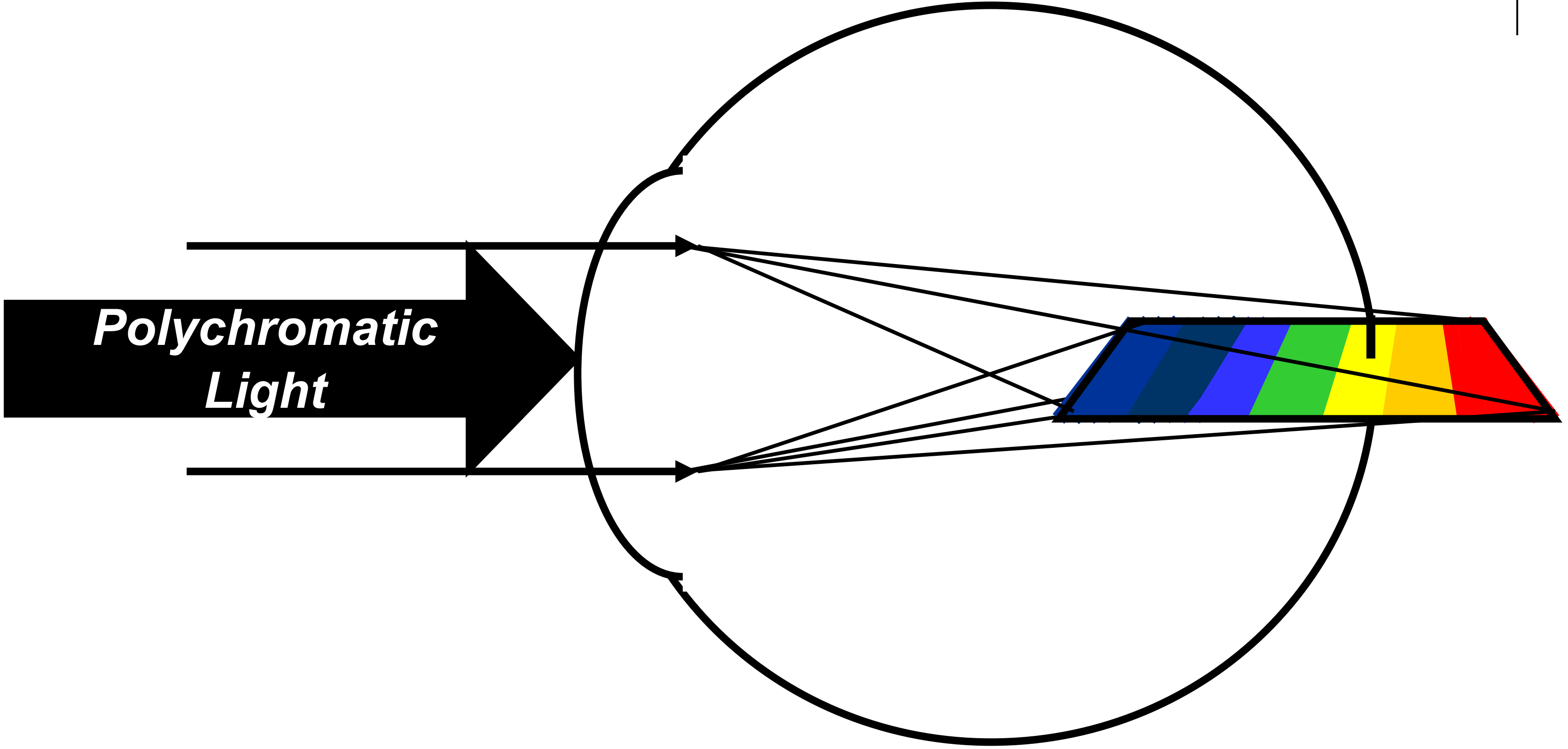
Thus, when ***polychromatic light*** strikes the eye, it is refracted into a ***chromatic interval***



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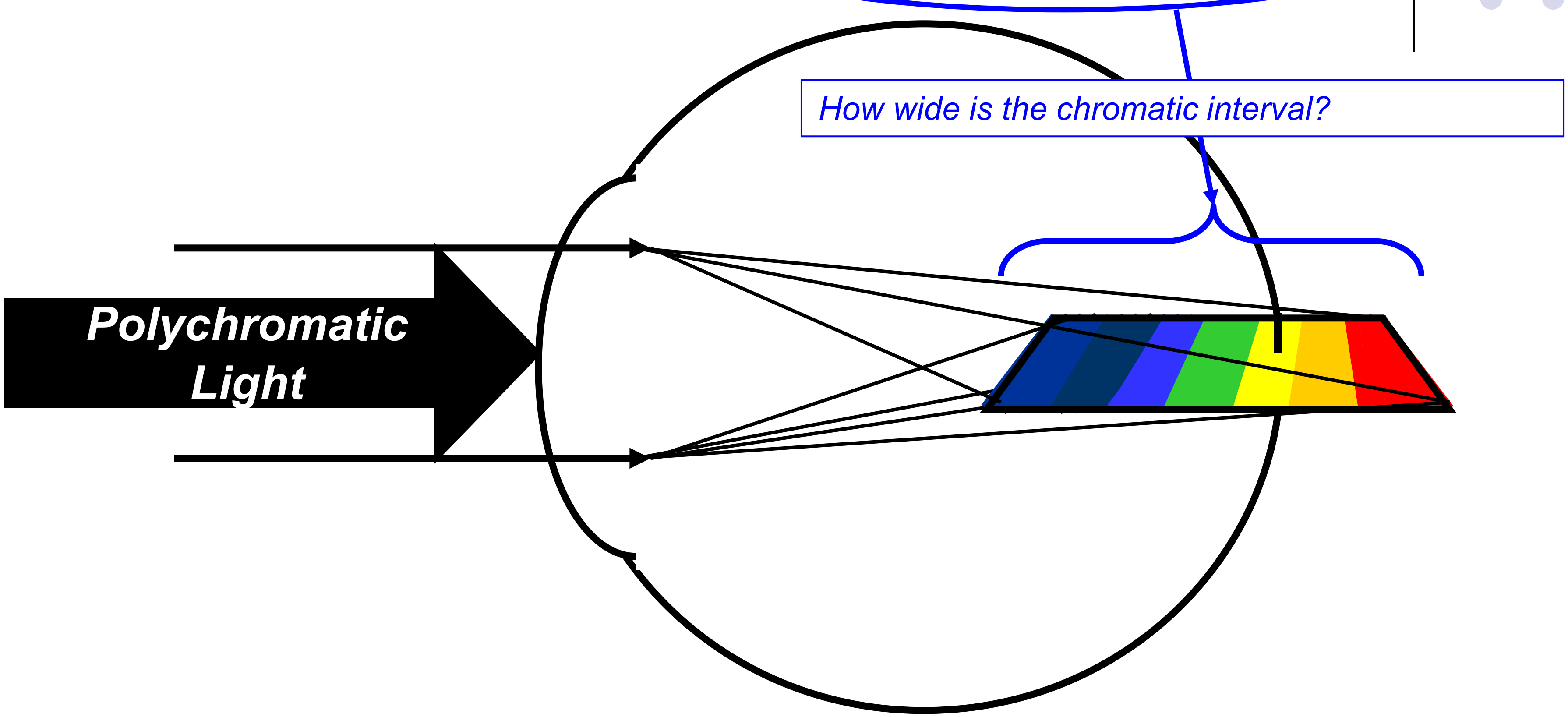

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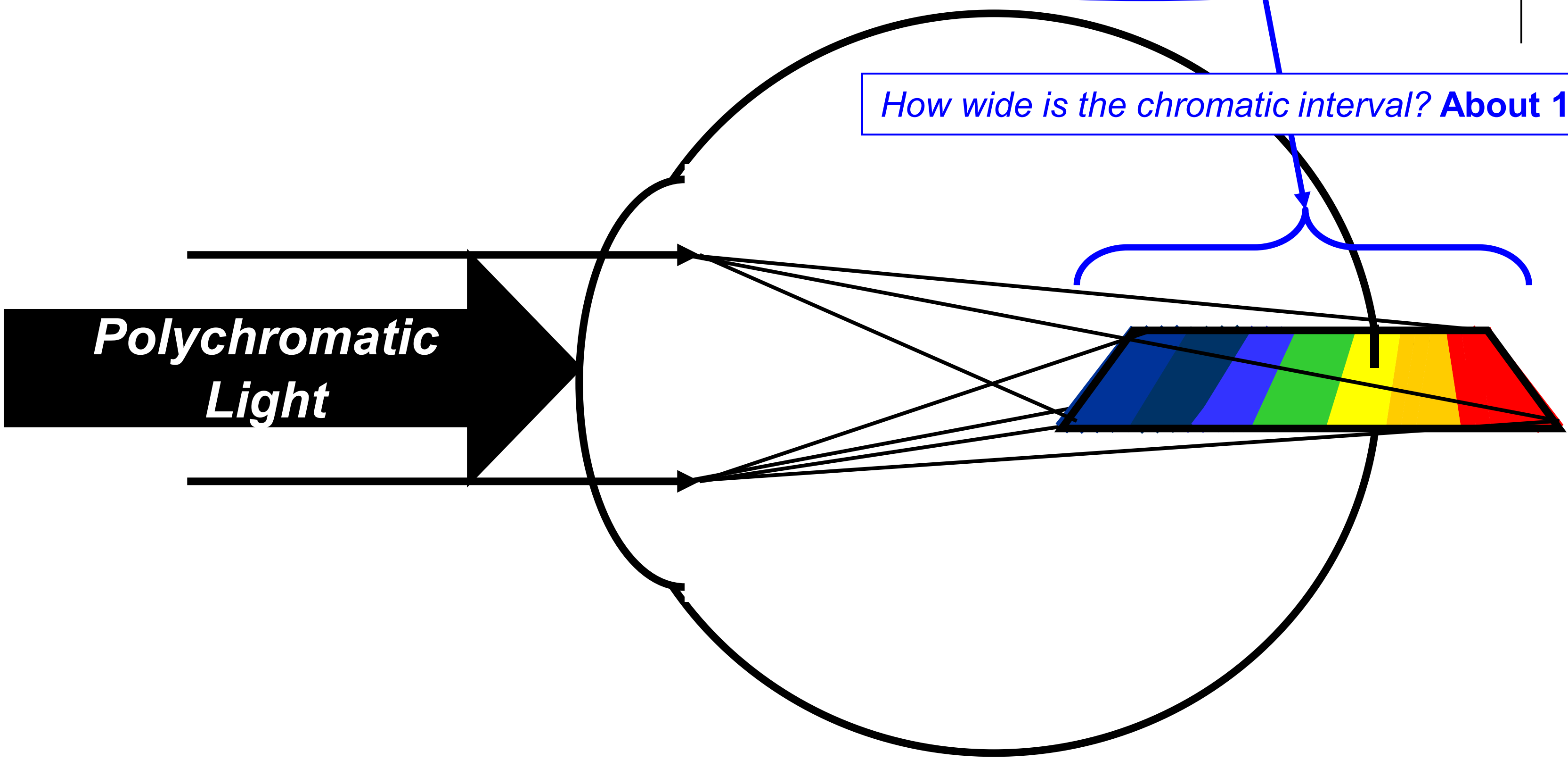
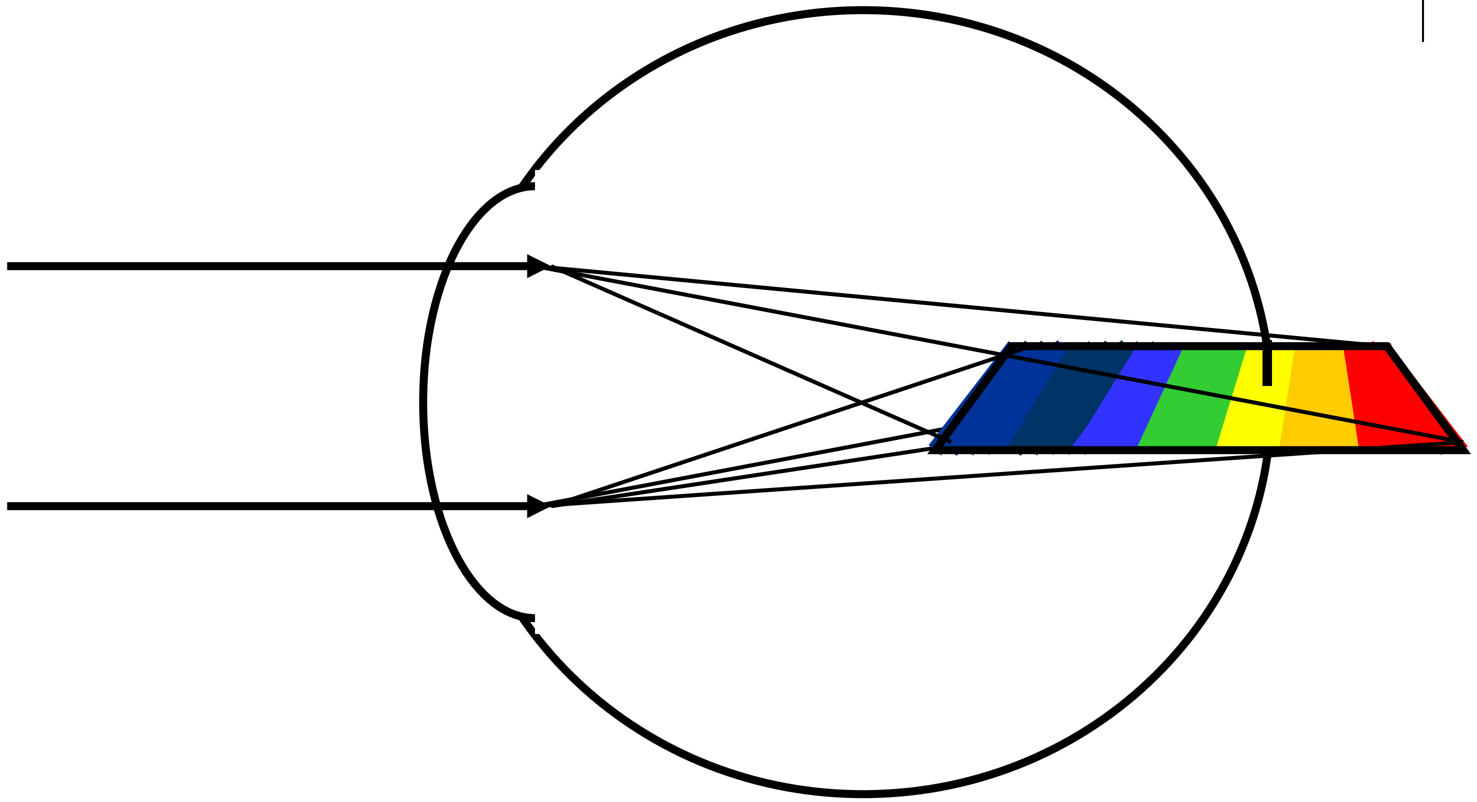
How wide is the chromatic interval? **About 1.25D!**



Aberrations: *Chromatic*

Chromatic aberration contributes to a phenomenon called ***night myopia***.



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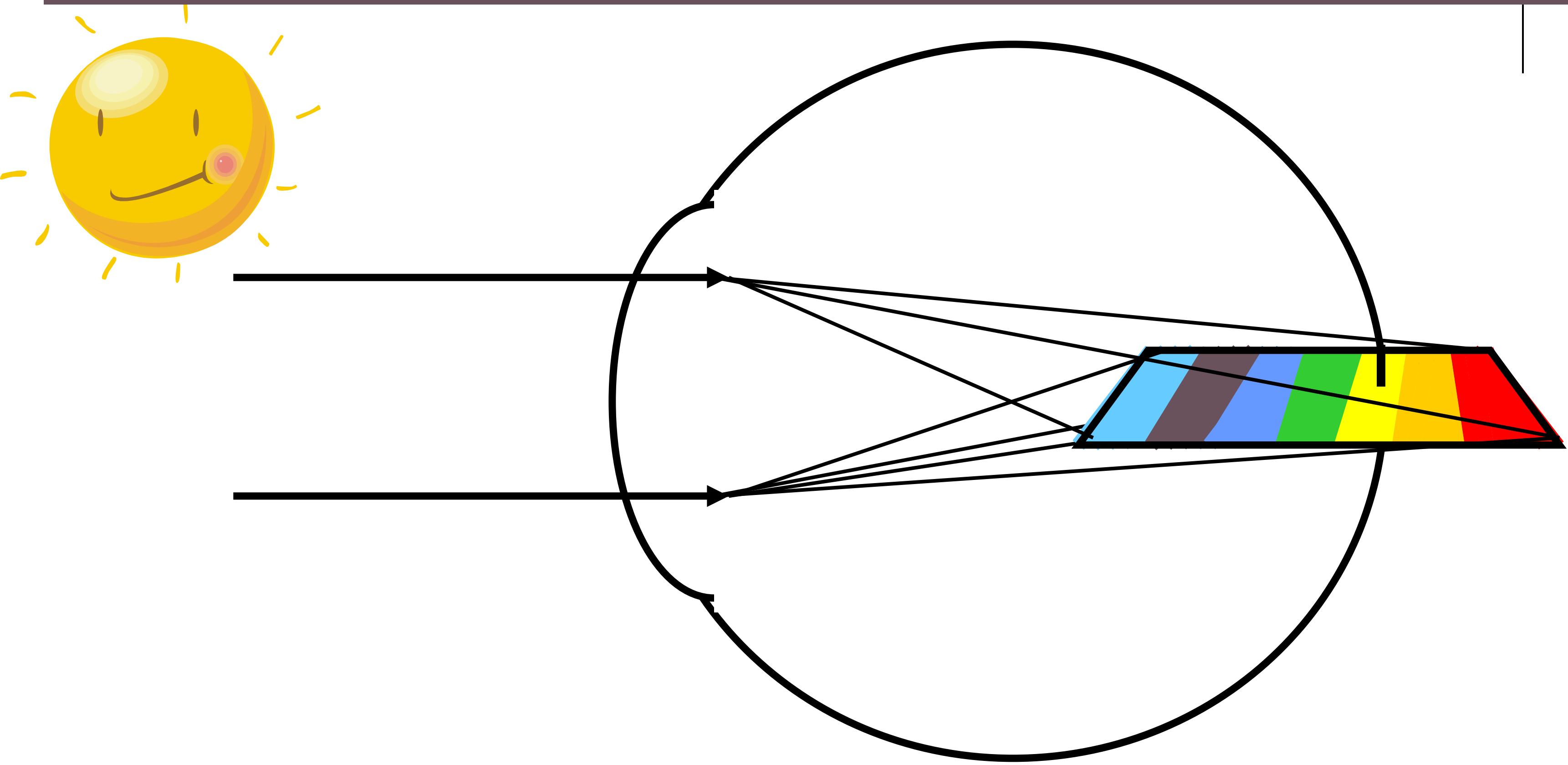

Under bright illumination conditions, wavelengths from the yellow portion of the spectrum predominate.

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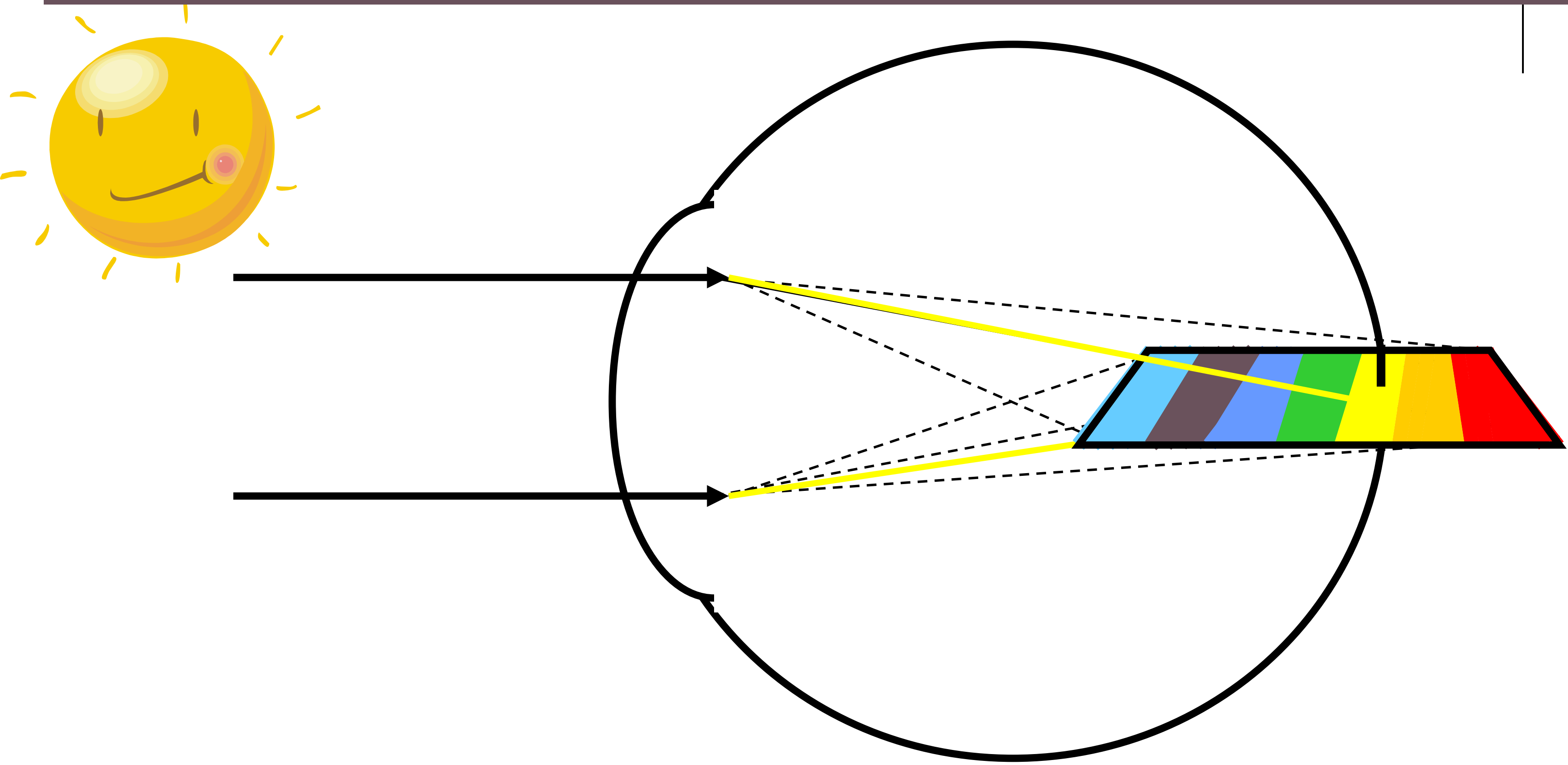

Under bright illumination conditions, wavelengths from the yellow portion of the spectrum predominate. (It is likely not a coincidence that this is the portion of the chromatic interval that falls on the retina in an emmetropic eye.)

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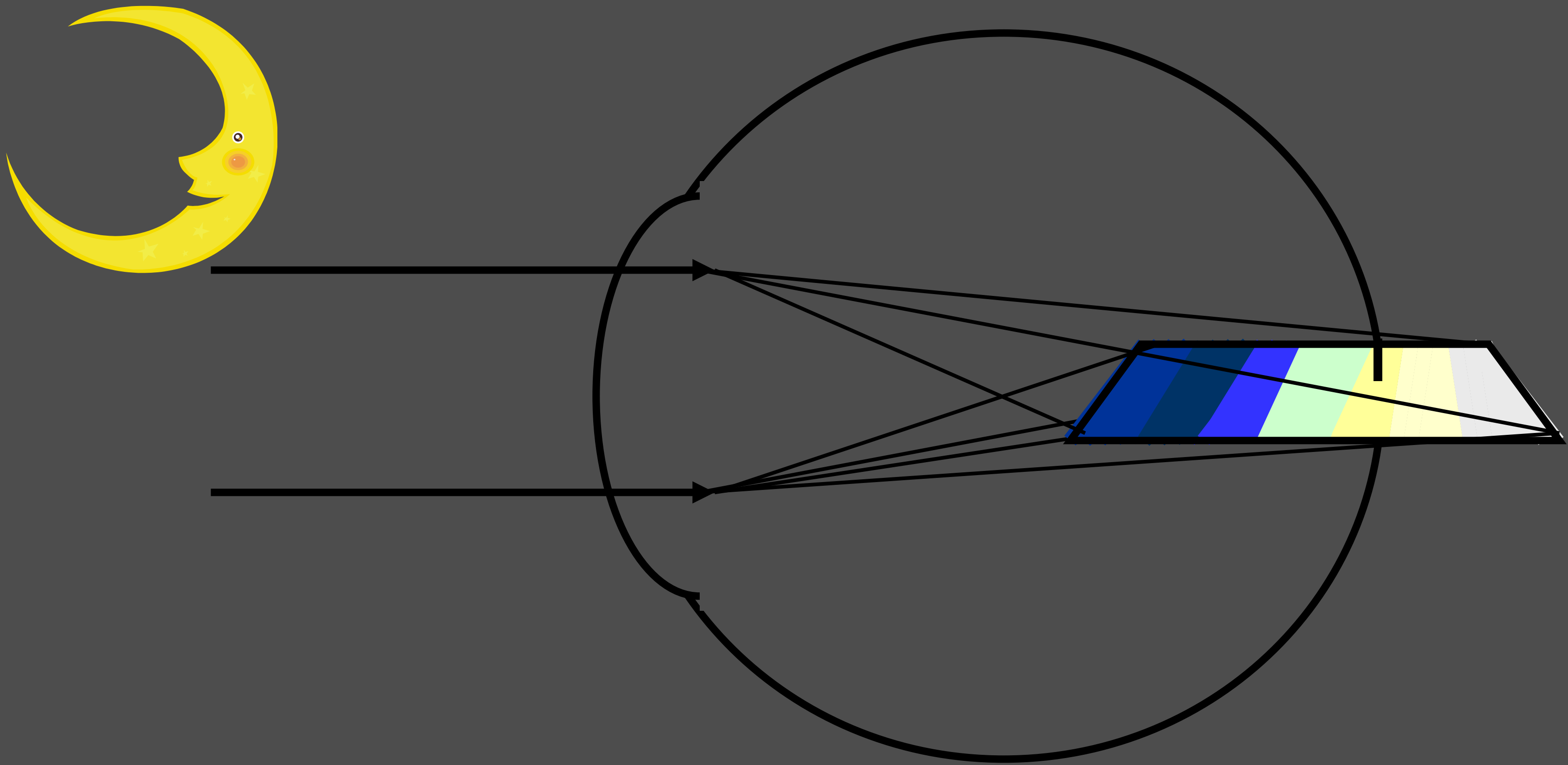

However, under low-illumination conditions, the majority of wavelengths present are from the blue-violet end of the spectrum. (Go out-of-doors at dusk and you'll see what I mean.)

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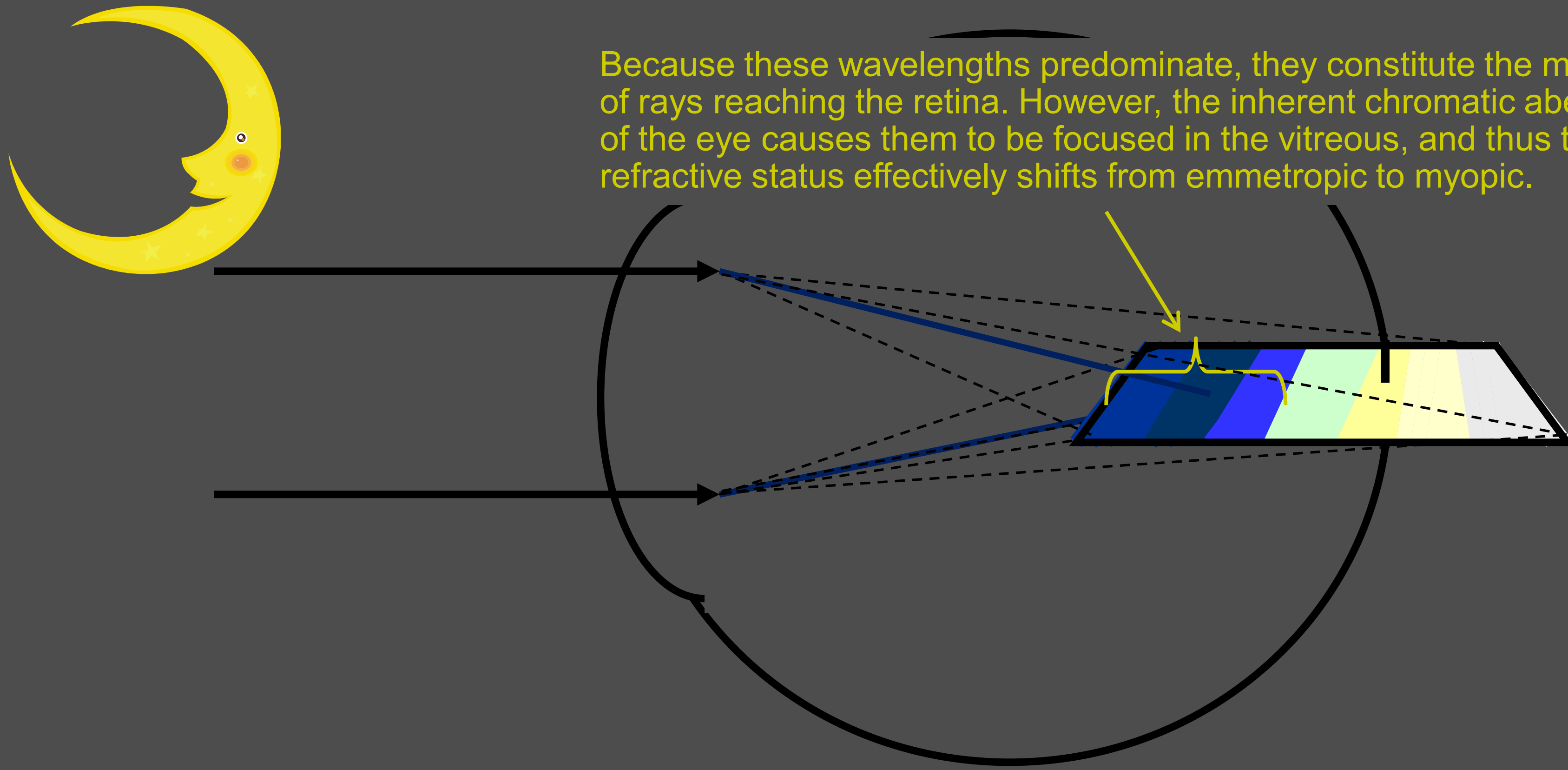

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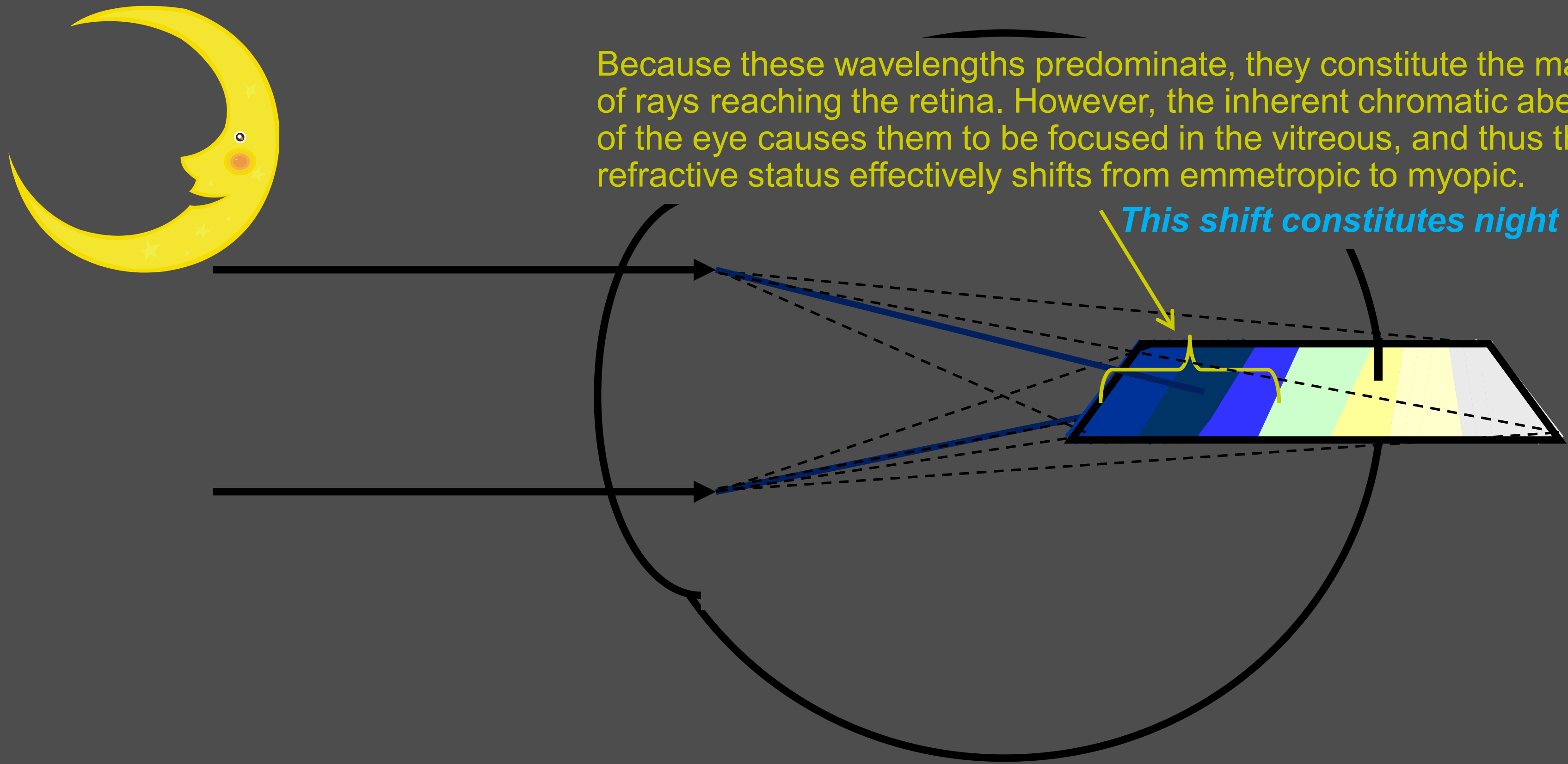

Because these wavelengths predominate, they constitute the majority of rays reaching the retina. However, the inherent chromatic aberration of the eye causes them to be focused in the vitreous, and thus the eye's refractive status effectively shifts from emmetropic to myopic.

This shift constitutes night myopia.

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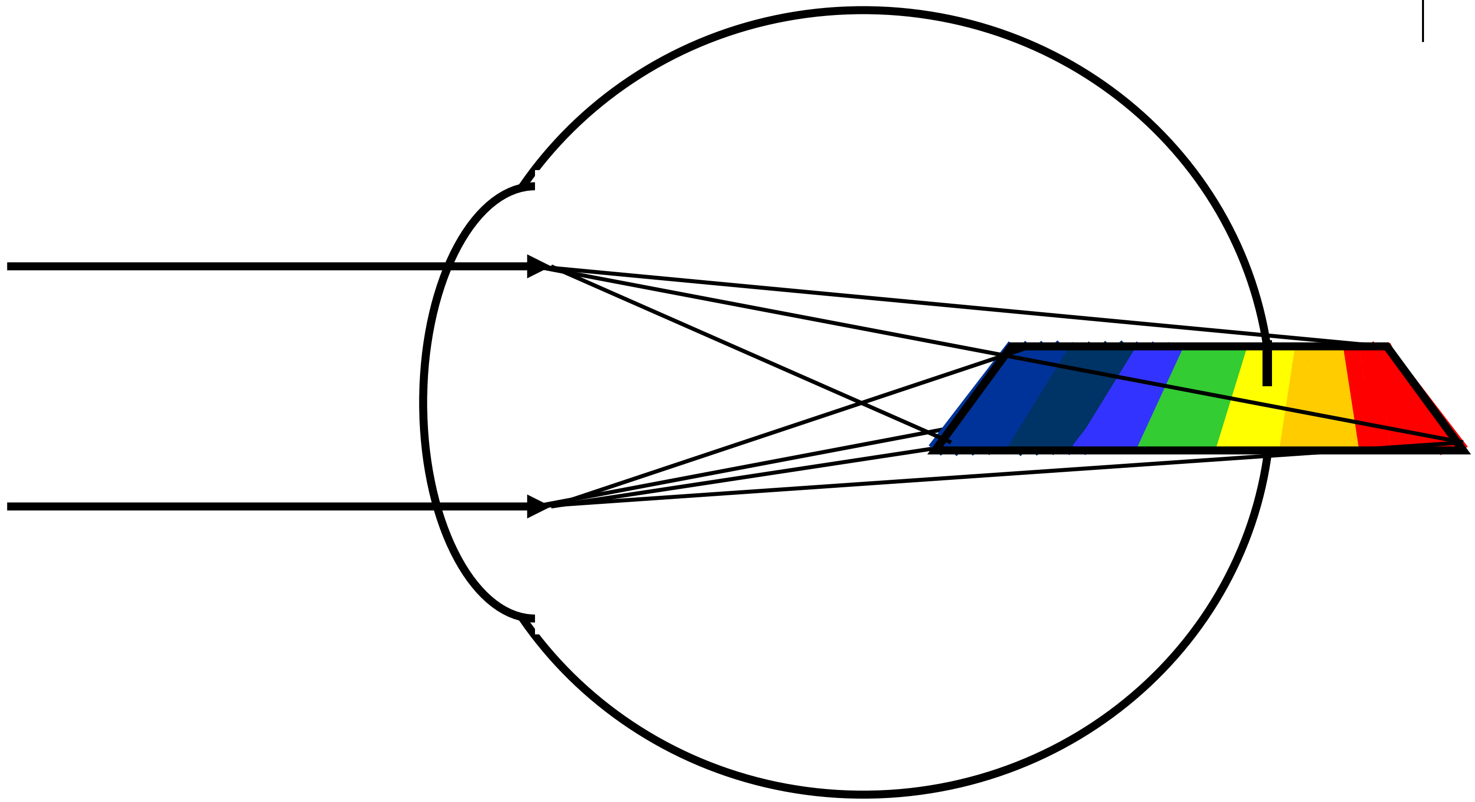

As mentioned previously, in emmetropia the **yellow portion** of the chromatic interval falls on the retina. A good refraction will do the same for an ametrope. However, the fact that a pt can read the 20/20 line doesn't prove it is so.

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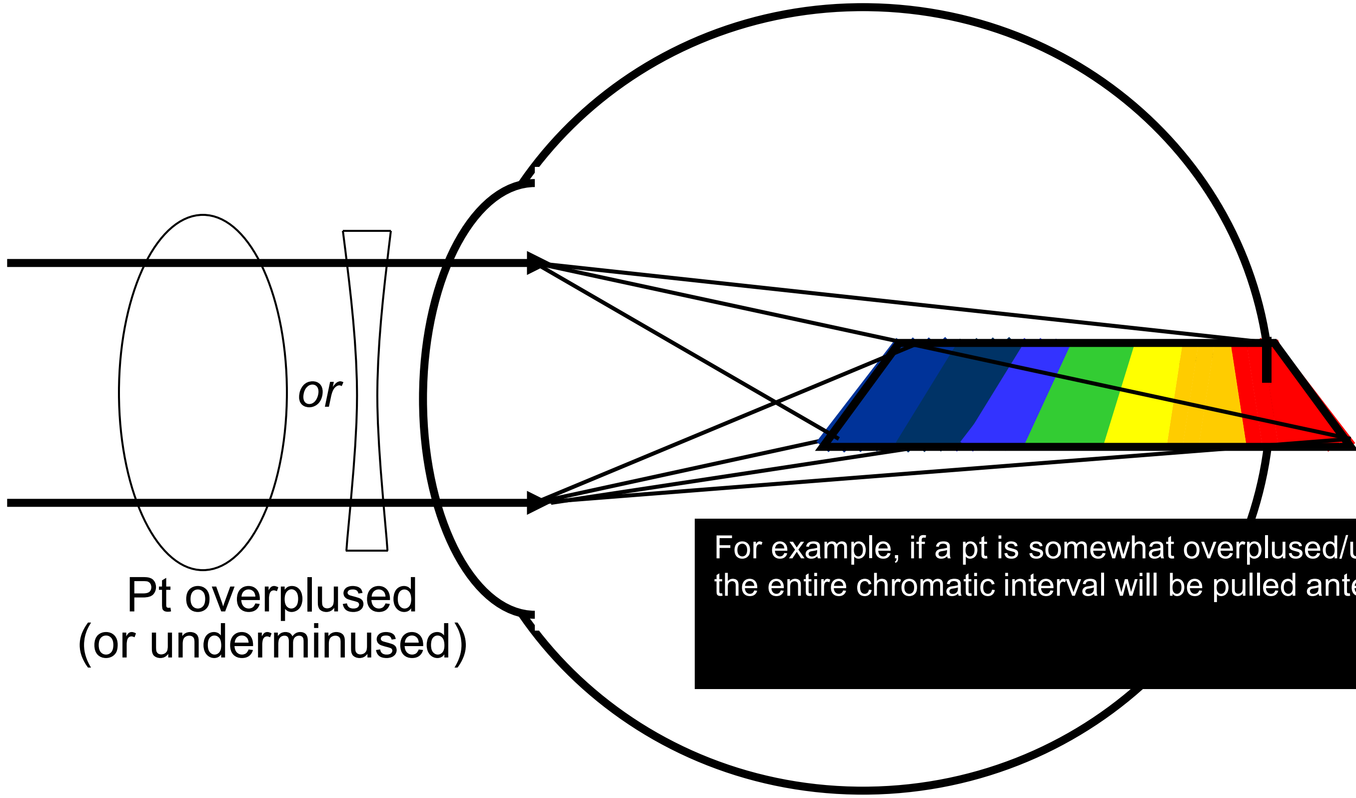

For example, if a pt is somewhat overplused/underminused, the entire chromatic interval will be pulled anteriorly.

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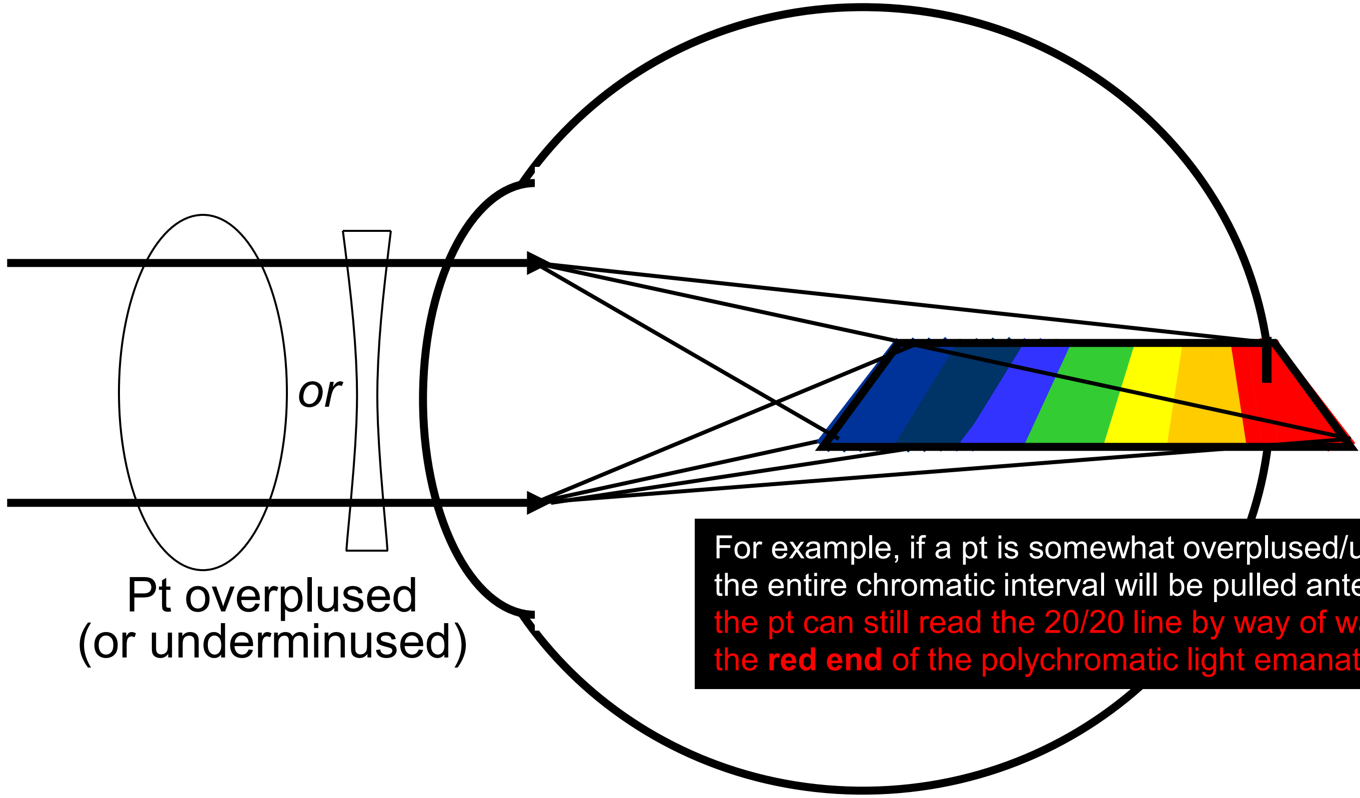

For example, if a pt is somewhat overplused/underminused, the entire chromatic interval will be pulled anteriorly. However, the pt can still read the 20/20 line by way of wavelengths from the **red end** of the polychromatic light emanating from the chart.

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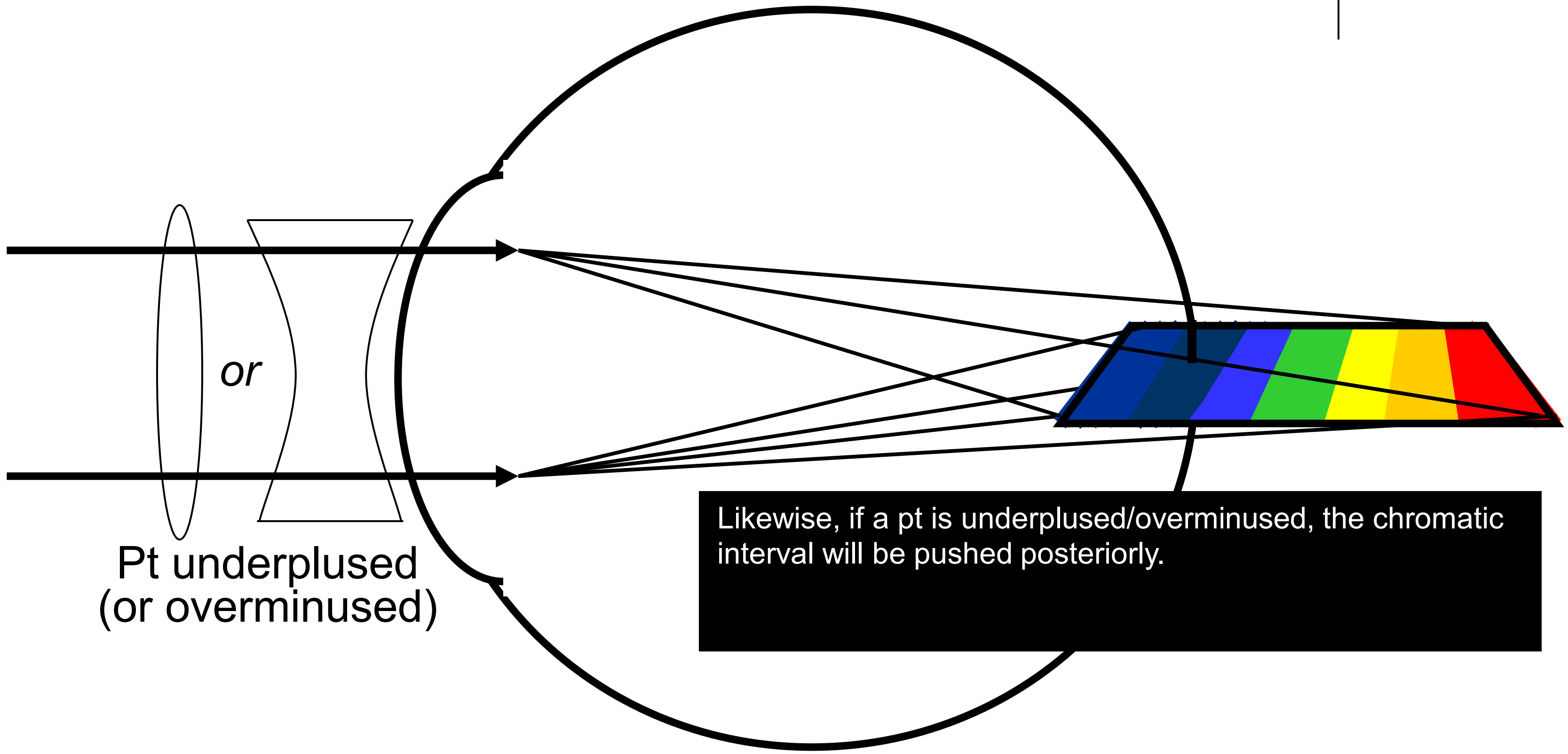

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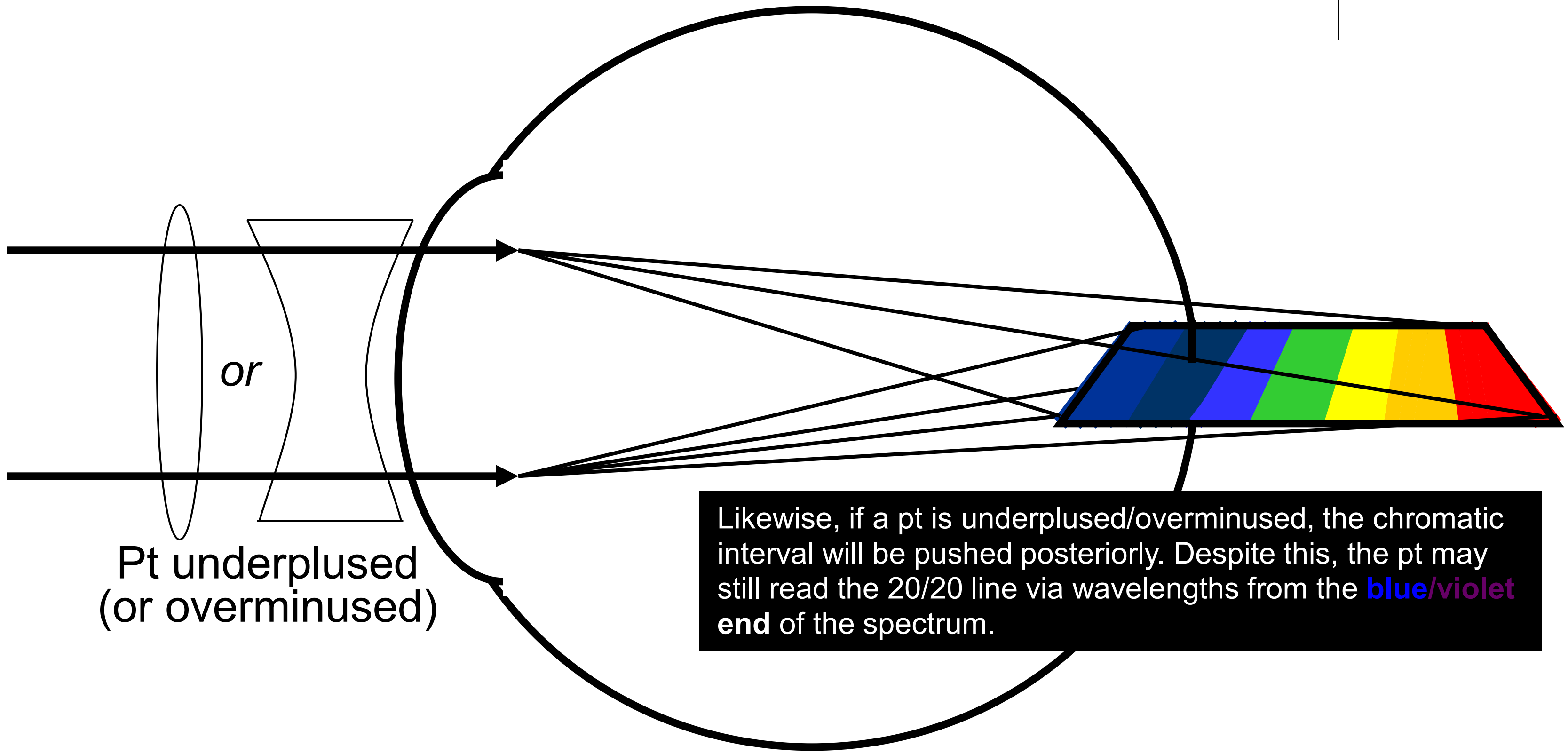

Likewise, if a pt is underplused/overminused, the chromatic interval will be pushed posteriorly. Despite this, the pt may still read the 20/20 line via wavelengths from the **blue/violet end** of the spectrum.

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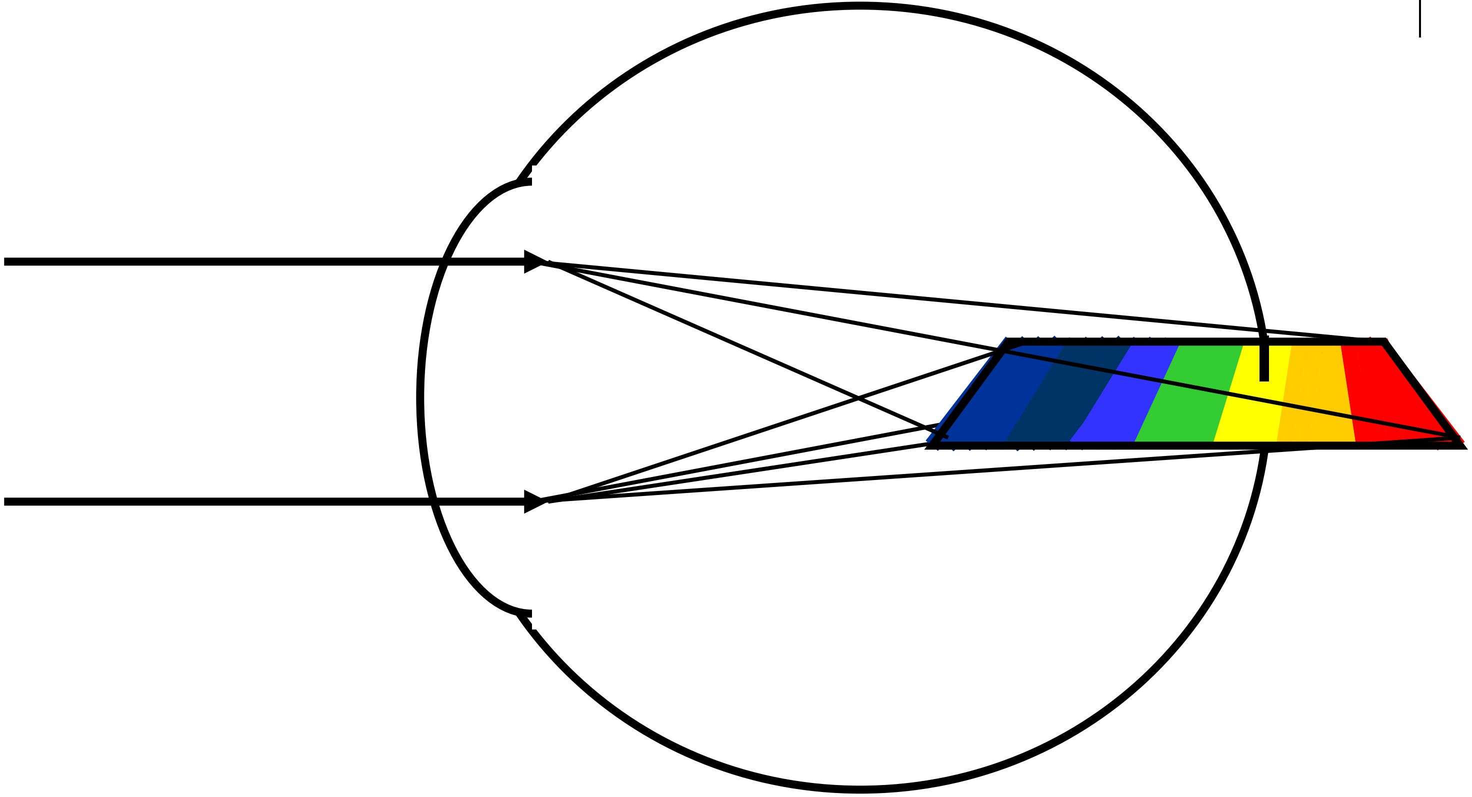

The duochrome test works by pitting the two ends of the chromatic interval against one another.

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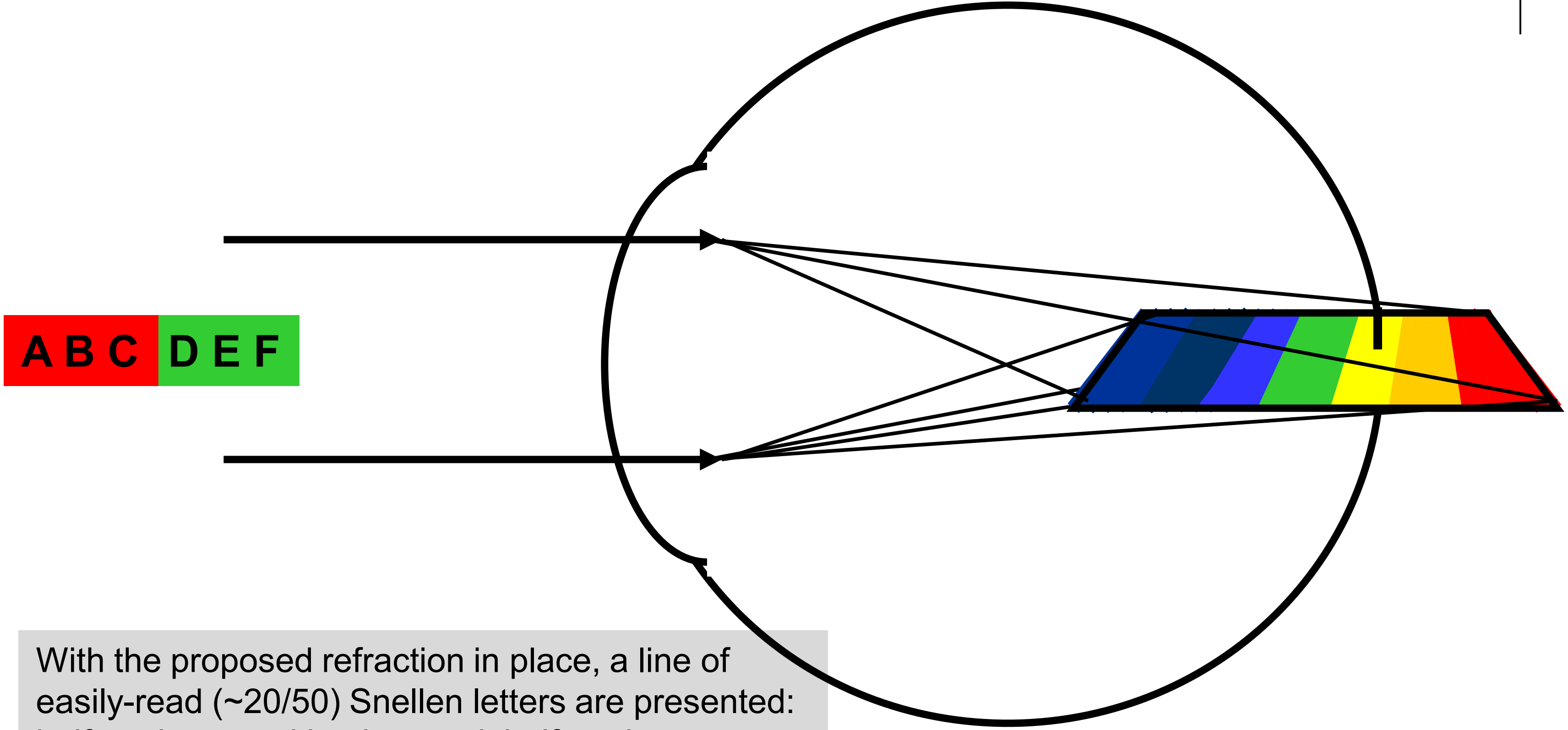

With the proposed refraction in place, a line of easily-read (~20/50) Snellen letters are presented: half against a red background, half against green. (The test is done monocularly.) The pt is asked if one group of letters appears clearer than the other.

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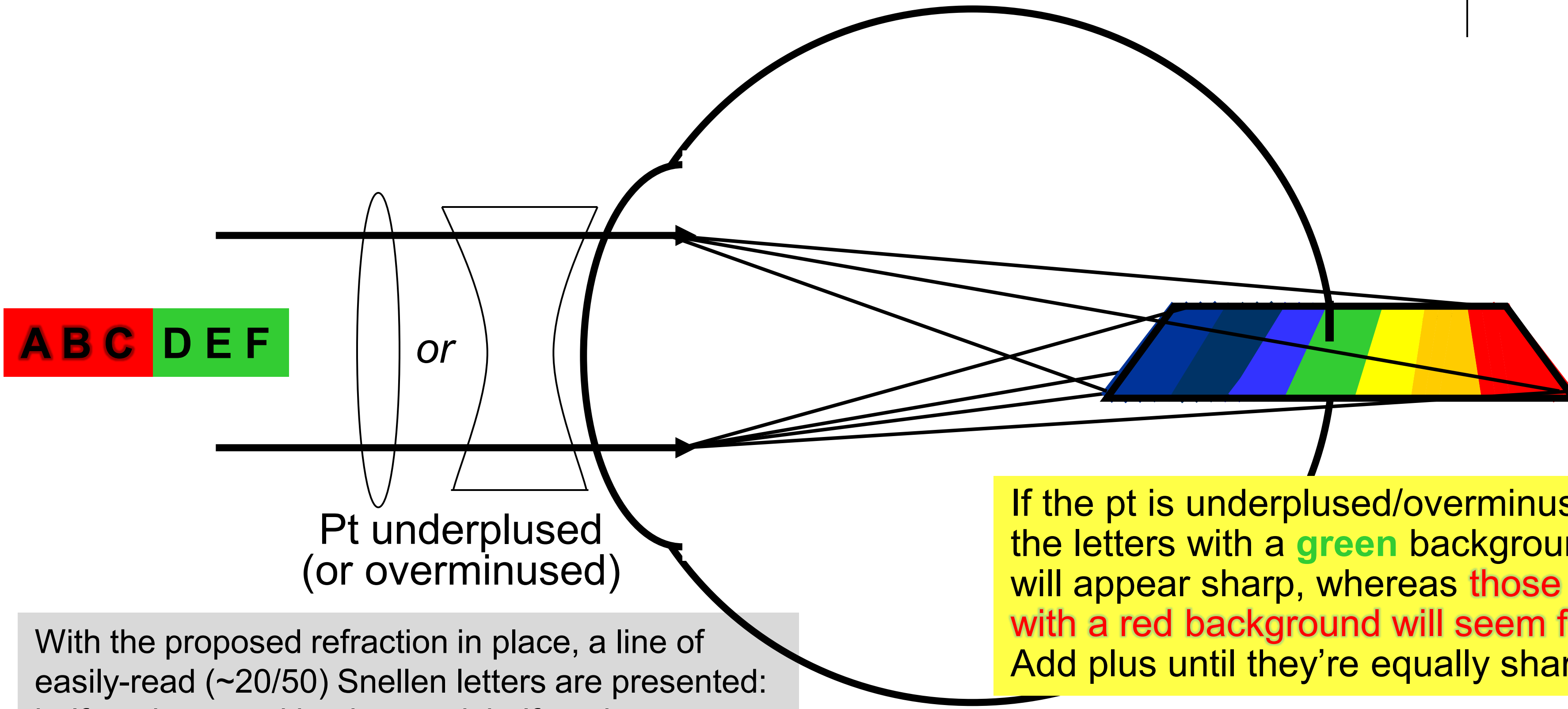

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If the pt is underplused/overminused, the letters with a **green** background will appear sharp, whereas those with a red background will seem fuzzy. Add plus until they're equally sharp.

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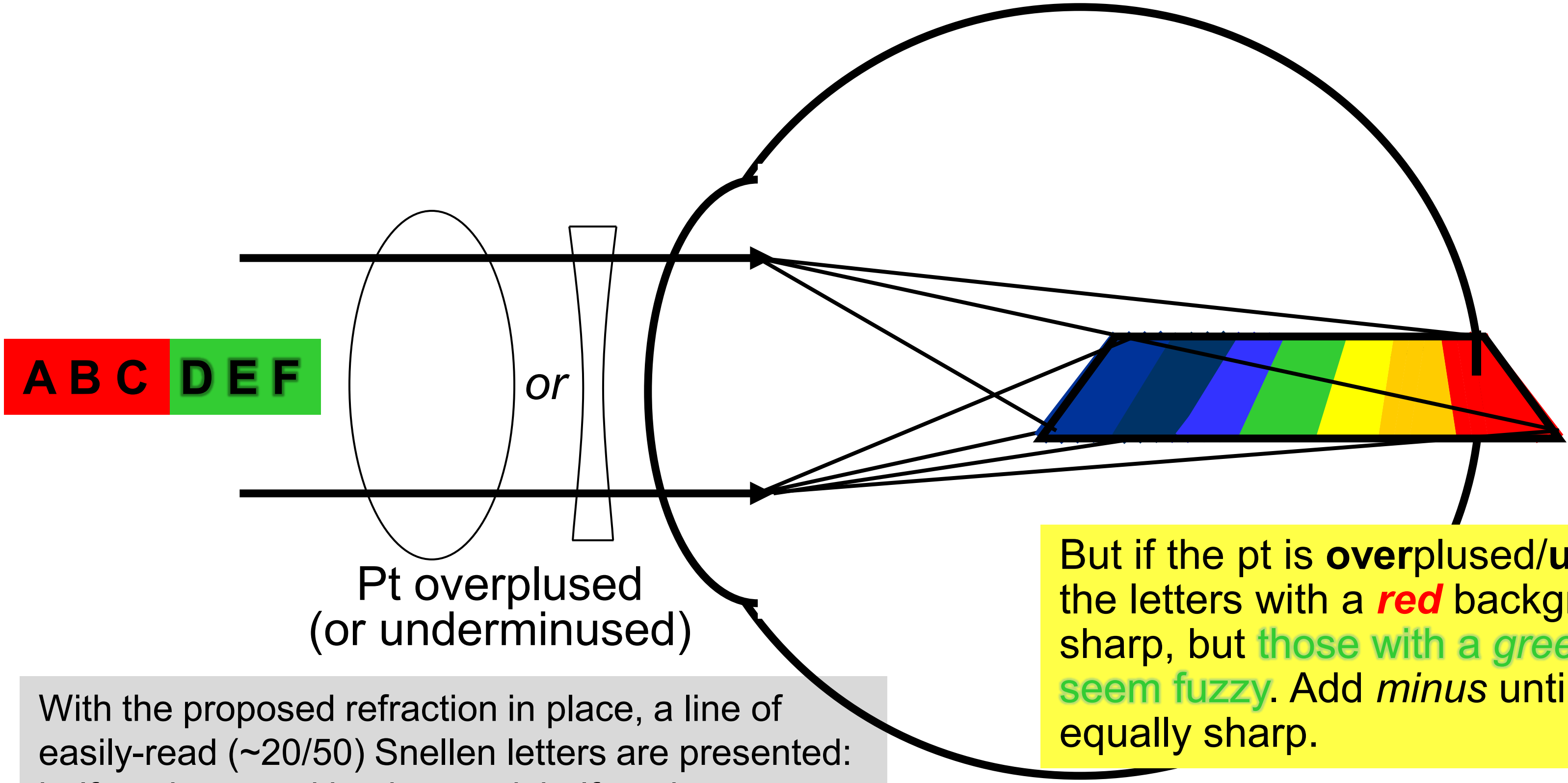

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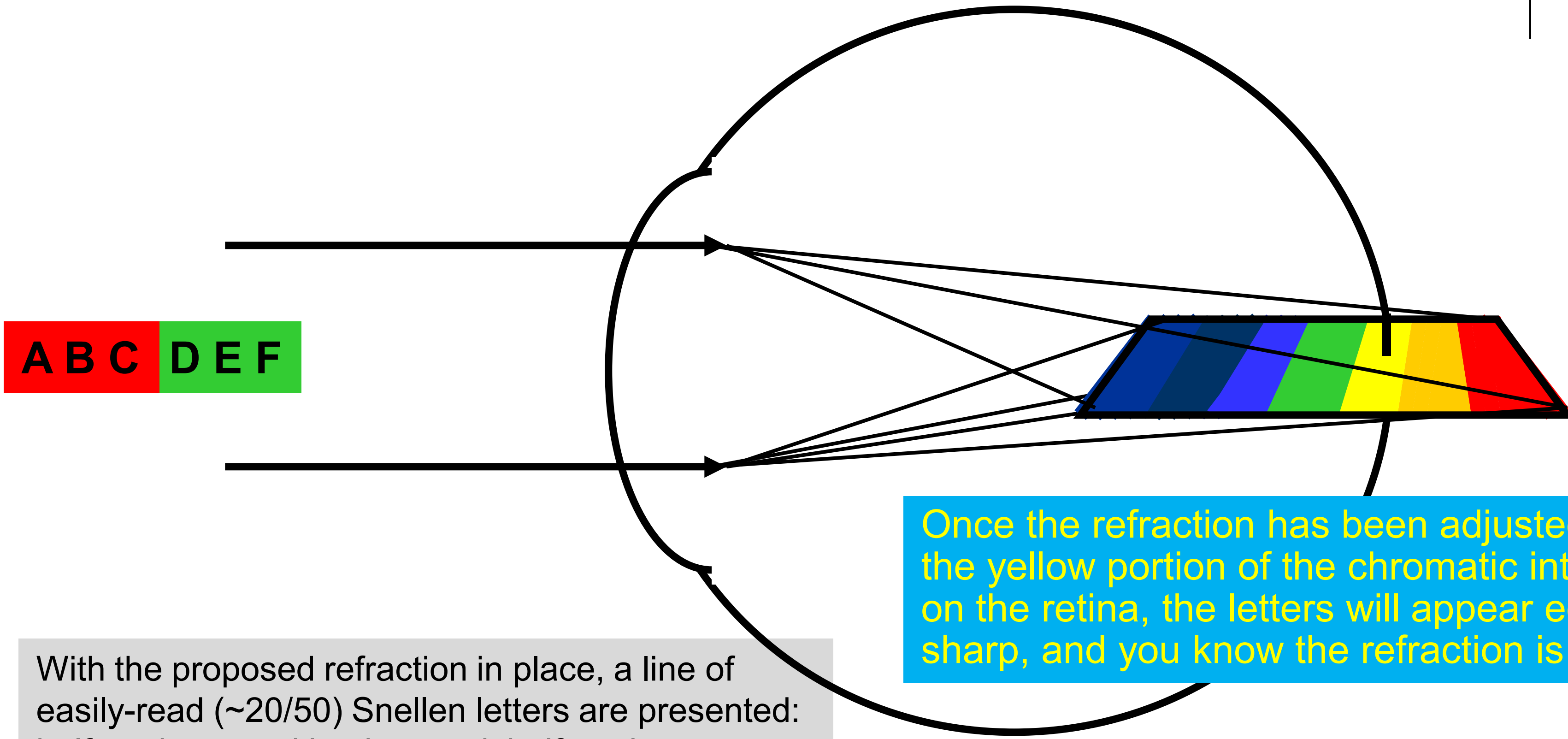

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Once the refraction has been adjusted so that the yellow portion of the chromatic interval is on the retina, the letters will appear equally sharp, and you know the refraction is good!*

**For that eye; don't forget to test the other one!*

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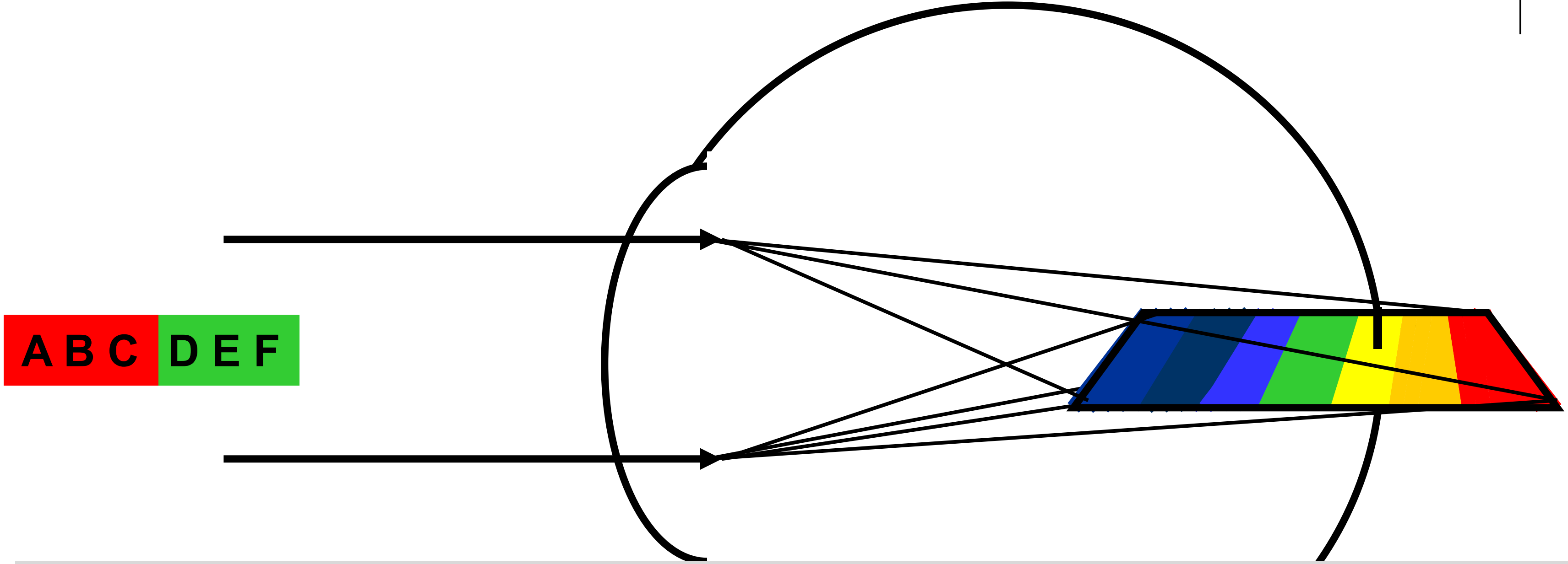

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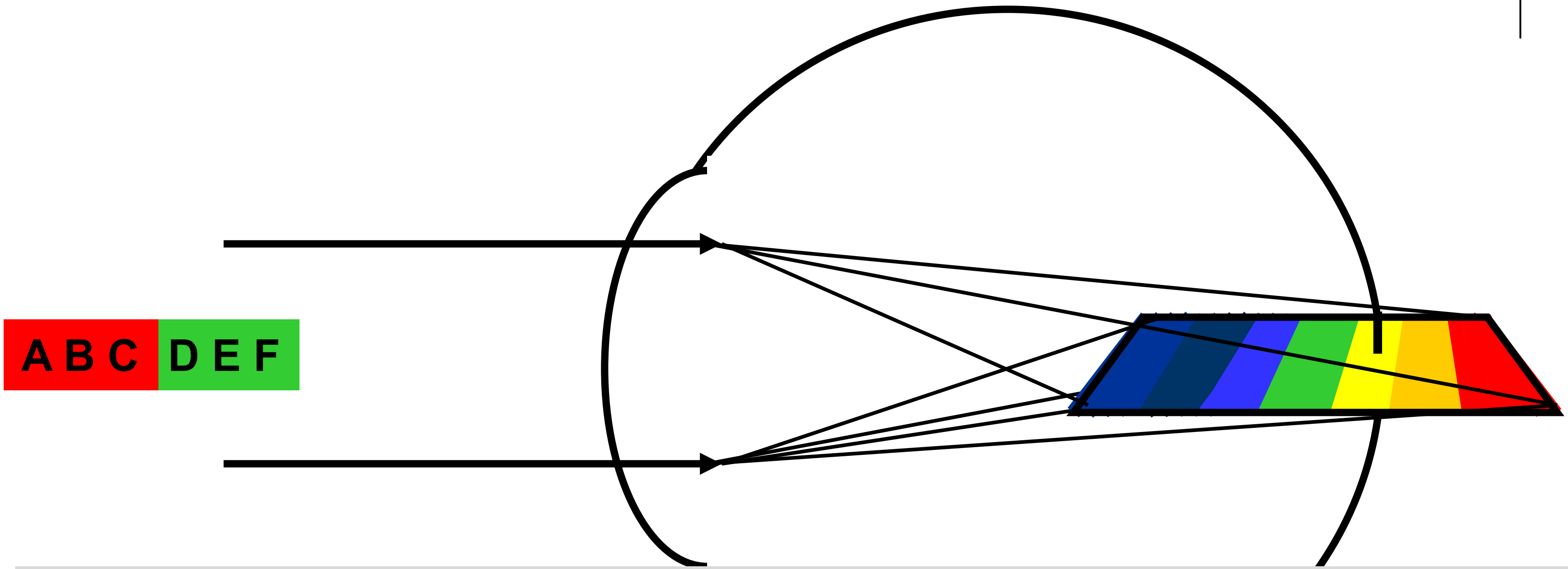

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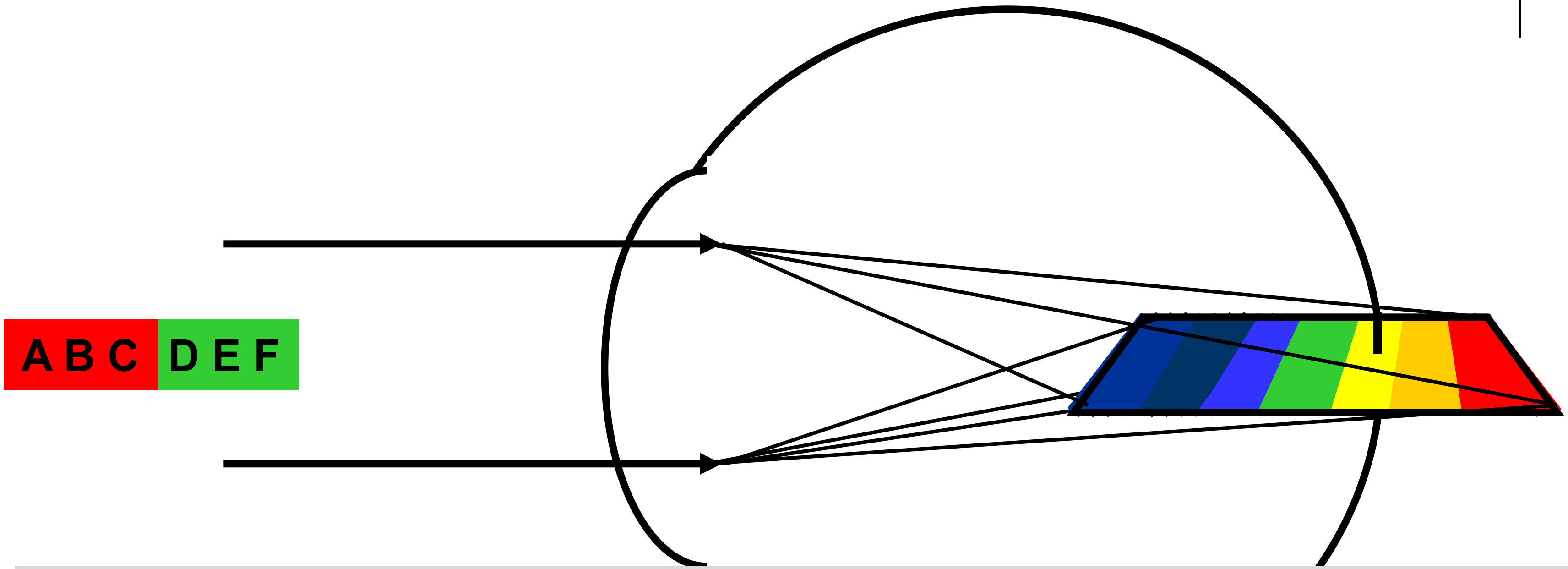

*Why use **red** and **green** as the test colors? Why not **red** and **violet**, which would cover the whole interval?*

There are two reasons **green** is used as the anterior color in the duochrome test:

1) The wavelength corresponding to **yellow** (ie, the one we want to put on the retina) is dioptrically halfway between those of **green** and **red** (don't let the figure mislead you); and

2)

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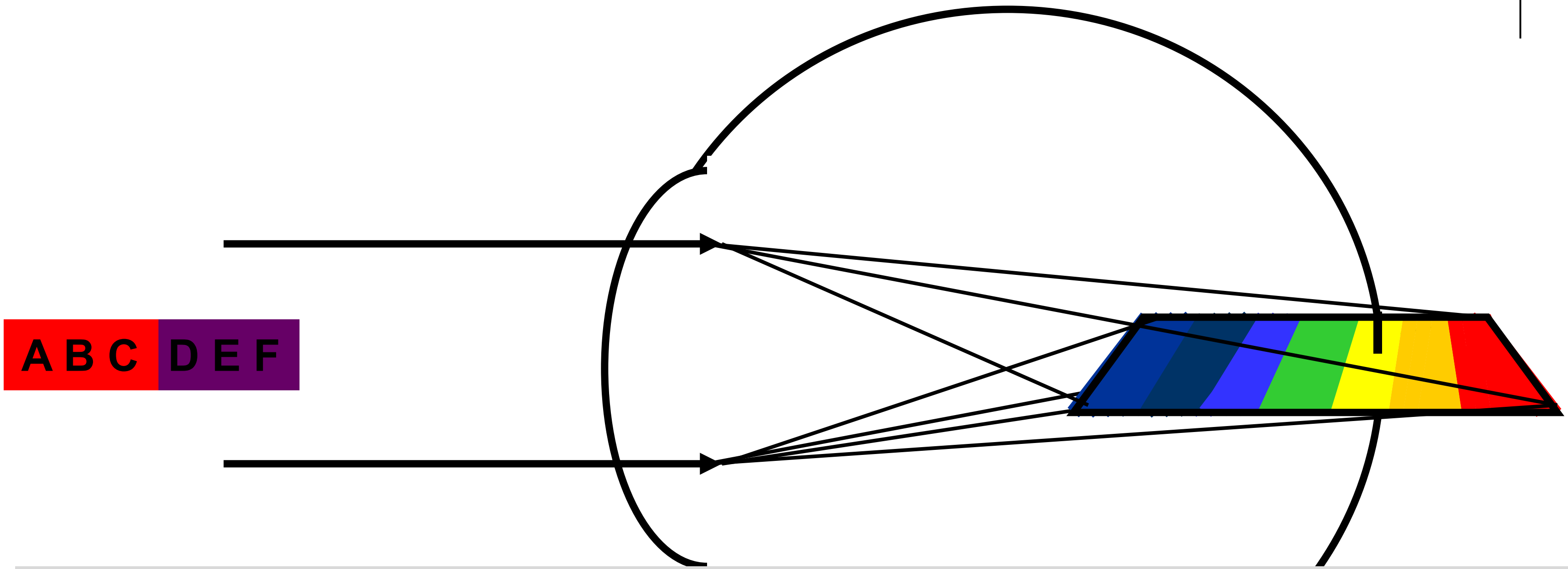
Aberrations: *Chromatic*

Chromatic aberration is not all bad, however. It forms the basis for a useful clinical maneuver called the ***duochrome test***.



*Why use **red** and **green** as the test colors? Why not **red** and **violet**, which would cover the whole interval?*

There are two reasons **green** is used as the anterior color in the duochrome test:

1) The wavelength corresponding to **yellow** (ie, the one we want to put on the retina) is dioptrically halfway between those of **green** and **red** (don't let the figure mislead you); and
2) If **violet** were used, the contrast with the black letters would be poor, and might influence the test.

The duochrome test works by pitting the two ends of the chromatic interval against one another.

Aberrations

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  3) Irregular astigmatism
     - *Irregular* meaning 'that which **can't** be corrected with cylindrical lenses'

Essentially, *irregular astigmatism* was a wastebasket term for aberrations that:
1) could not be measured in the clinic; and
2) could not be corrected (by glasses) even if they had been measureable

Aberrations

Old Lingo

Sphere

Myopia

Hyperopia

'Regular Astigmatism' — Cylinder

'Irregular Astigmatism' — Any component of refractive error that could not be remediated with spherical and/or cylindrical lenses

This is how we thought of aberrations back in the day

Aberrations

- *Wavefront analysis* did away with the first problem
  - Allows clinicians to identify/quantify many of the refractive problems previously consigned to the irregular-astigmatism wastebasket

Essentially, *irregular astigmatism* was a wastebasket term for aberrations that:

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Aberrations

Old Lingo		***New Lingo*** (from wavefront analysis)
Sphere Myopia Hyperopia	← = →	Defocus

‘Regular Astigmatism’ { Cylinder

‘Irregular Astigmatism’ { Any component of refractive error that could not be remediated with spherical and/or cylindrical lenses

Aberrations

Old Lingo		***New Lingo*** (from wavefront analysis)
Sphere	=	Defocus
Myopia	=	*Positive* defocus
Hyperopia	=	*Negative* defocus

'Regular Astigmatism' — Cylinder

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Aberrations

Old Lingo		***New Lingo*** (from wavefront analysis)
Sphere	=	Defocus
Myopia	=	*Positive* defocus
Hyperopia	=	*Negative* defocus
'Regular Astigmatism': Cylinder	=	Cylinder

'Irregular Astigmatism': Any component of refractive error that could not be remediated with spherical and/or cylindrical lenses

Aberrations

Old Lingo		***New Lingo*** (from wavefront analysis)	
Sphere	=	Defocus	'Lower-order Aberrations'
Myopia	=	*Positive* defocus	
Hyperopia	=	*Negative* defocus	
'Regular Astigmatism': Cylinder	=	Cylinder	

'Irregular Astigmatism': Any component of refractive error that could not be remediated with spherical and/or cylindrical lenses

Aberrations

Old Lingo		**_New Lingo_** (from wavefront analysis)	
Sphere	=	Defocus	'Lower-order Aberrations'
Myopia	=	*Positive* defocus	
Hyperopia	=	*Negative* defocus	
'Regular Astigmatism': Cylinder	=	Cylinder	
'Irregular Astigmatism': Any component of refractive error that could not be remediated with spherical and/or cylindrical lenses	=	Spherical aberration Coma Trefoil (Others, less clinically relevant)	

Aberrations

Old Lingo		New Lingo (from wavefront analysis)	
	Sphere ⟷ = ⟷	Defocus	‘Lower-order Aberrations’
	Myopia ⟷ = ⟷	*Positive* defocus	
	Hyperopia ⟷ = ⟷	*Negative* defocus	
‘Regular Astigmatism’	Cylinder ⟷ = ⟷	Cylinder	
‘Irregular Astigmatism’	Any component of refractive error that could not be remediated with spherical and/or cylindrical lenses ← = →	Spherical aberration; Coma; Trefoil; (Others, less clinically relevant)	‘Higher-order Aberrations’

Aberrations

- *Wavefront-guided keratorefractive surgery* did away with the second problem

Essentially, *irregular astigmatism* was a wastebasket term for aberrations that:

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Aberrations

- ***Wavefront-guided keratorefractive surgery*** did away with the second problem
  - Allows surgeons to correct many of the higher-order aberrations identified via wavefront analysis

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  - Allows surgeons to correct many of the higher-order aberrations identified via wavefront analysis
  - Precisely *which* higher-order aberrations should be corrected (and to what degree) is an unsettled issue at this time
  - We will address higher-order aberrations in detail in the *Refractive Surgery* subsection (slide-set *RS6*)

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2) ~~could not be corrected even if they had been measureable~~

*That's it! At this juncture, you should assess your Optics knowledge by taking the final quiz (*6*; slide-set* BO32*). After that, consider reviewing the tutorial every few months to keep it fresh.*