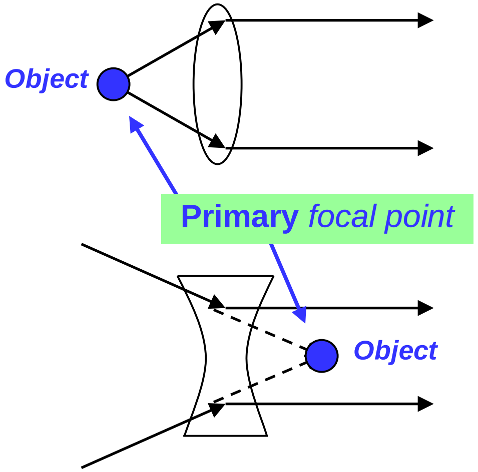
# The Far Point and Refractive Error

*Basic Optics*, Chapter 5

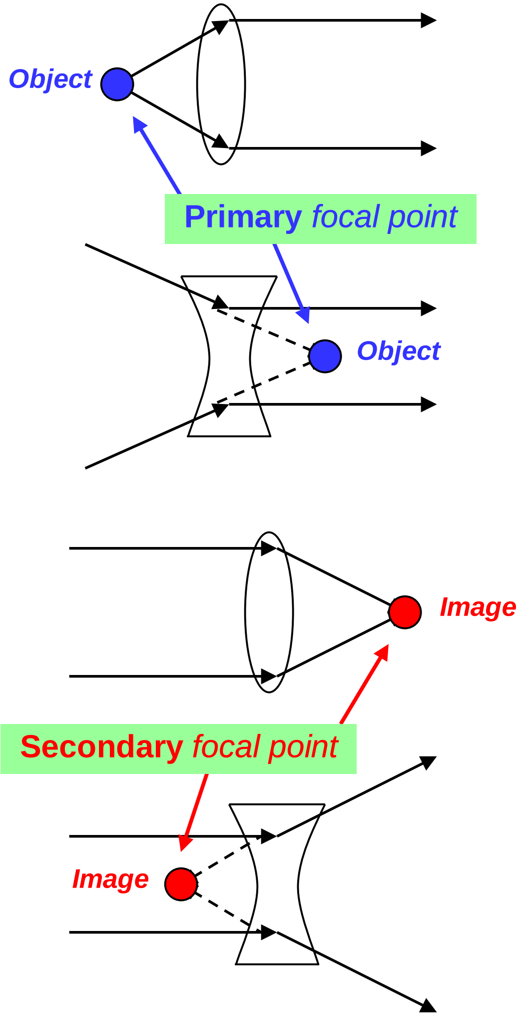
# Focal Points

- Last time, the concepts of the *primary* and *secondary* *focal points* were introduced:
  - Primary focal point: Location at which an **object** could be placed, and light rays associated with the object would exit the lens with zero vergence (i.e., parallel)



# Focal Points

- Last time, the concepts of the *primary* and *secondary* *focal points* were introduced:
  - Primary focal point: Location at which an **object** could be placed, and light rays associated with the object would exit the lens with zero vergence (i.e., parallel)
  - Secondary focal point: Location at which the **image** is formed when light rays with zero vergence (i.e., parallel) encounter a given lens



# Focal Points

- Focal points (especially the secondary focal point) play a central role in clinical optics--specifically, in the correction of refractive error

# Focal Points

- Focal points (especially the secondary focal point) play a central role in clinical optics--specifically, in the correction of refractive error
- To see why, we must first introduce another key concept in clinical optics: *The Far Point*

# The Far Point

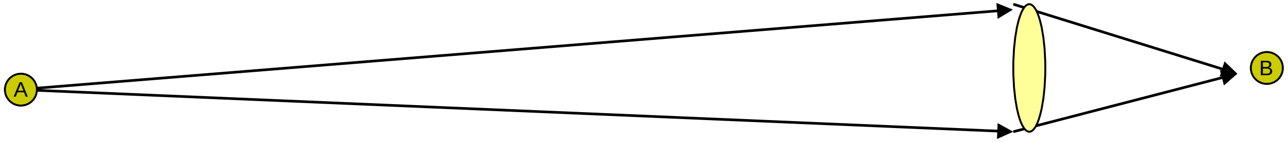
- The far point is a property of an imaging system, NOT a lens

*Lenses do not have far points—eyes do!!!*

# The Far Point

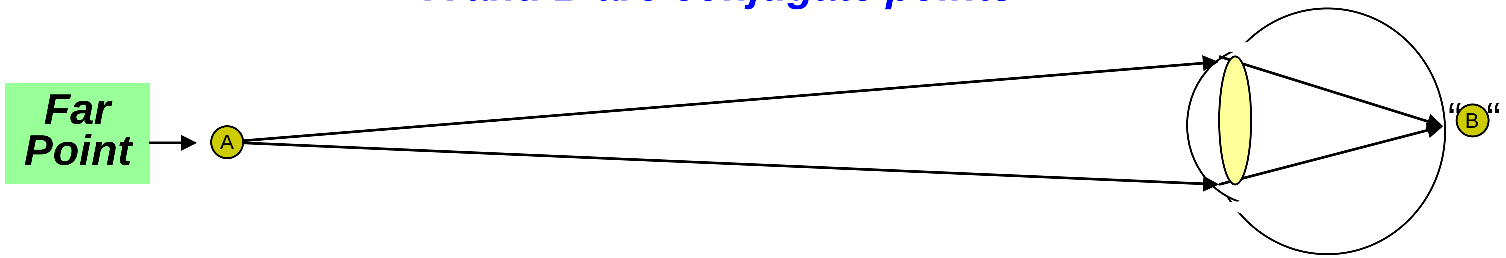
- The far point is a special type of *conjugate point* (recall that conjugate points are locations that are object [*A*] and image [*B*] of one another)

***A and B are conjugate points***



# The Far Point

- Specifically, the far point is *the point in space conjugate to the retina when the eye is not accommodating*



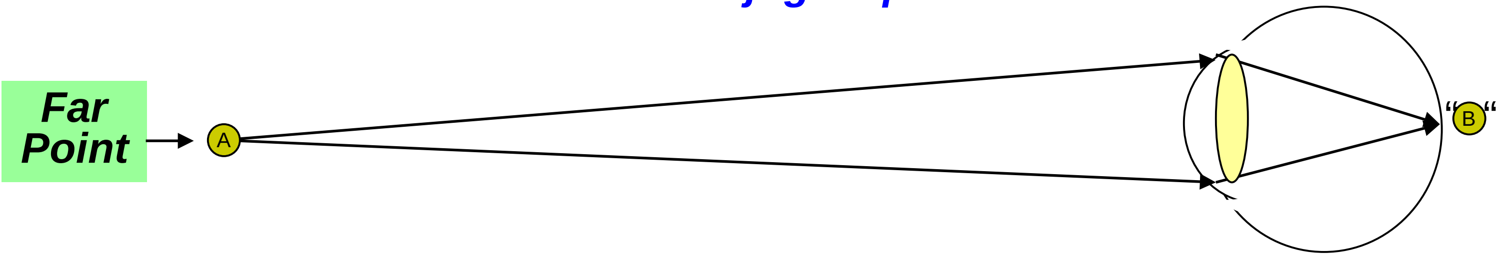
***A and B are conjugate points***

# The Far Point

- Specifically, the far point is *the point in space conjugate to the retina when the eye is not* ***accommodating***

(*Accommodation* refers to conformational changes in the ciliary body/lens to facilitate vision at near. We will have a lot to say about accommodation throughout the *Basic Optics* course!)

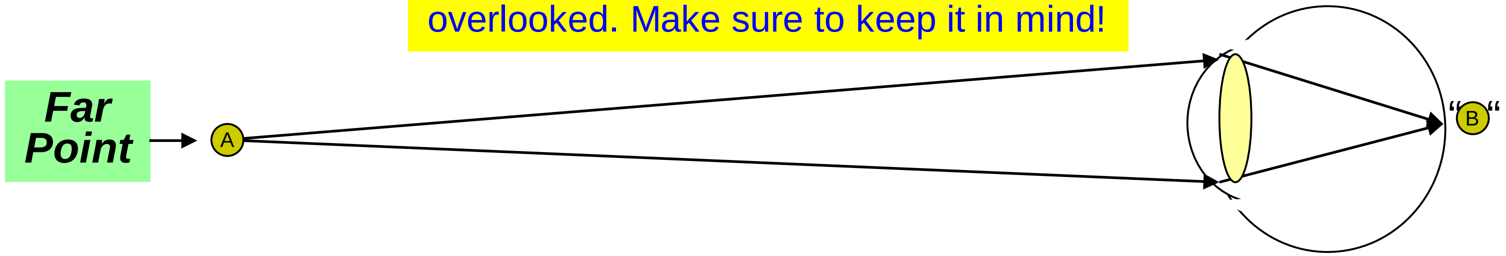
***A and B are conjugate points***



# The Far Point

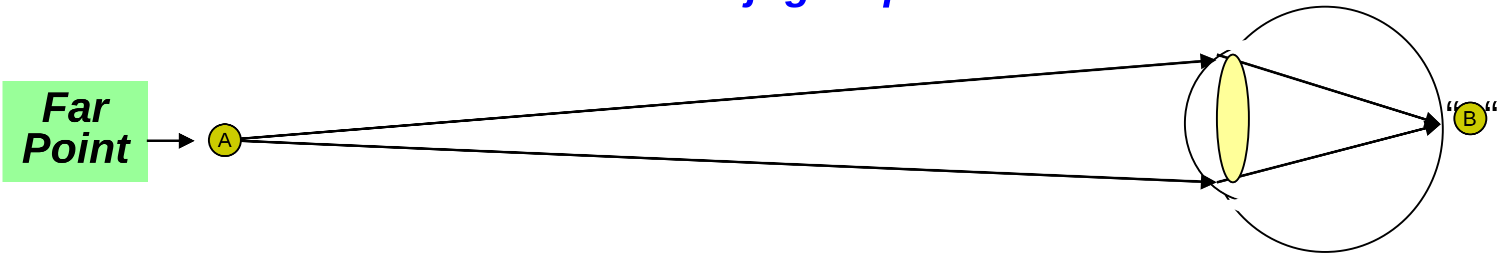
- Specifically, the far point is *the point in space conjugate to the retina <u>when the eye is not accommodating</u>*

**This** aspect of the definition of the far point is **really** important, and often overlooked. Make sure to keep it in mind!



# The Far Point

- Specifically, the far point is *the point in space conjugate to the retina when the eye is not accommodating*



***A and B are conjugate points***

- As we shall see, *an eye’s refractive status—that is, whether it is* emmetropic, myopic *or* hyperopic*—is a function of the location of its far point*

# The Far Point

*Remember:*

1) The far point is the point in space conjugate to the retina when the eye is not accommodating

2) An eye’s refractive status is a function of the location of its far point

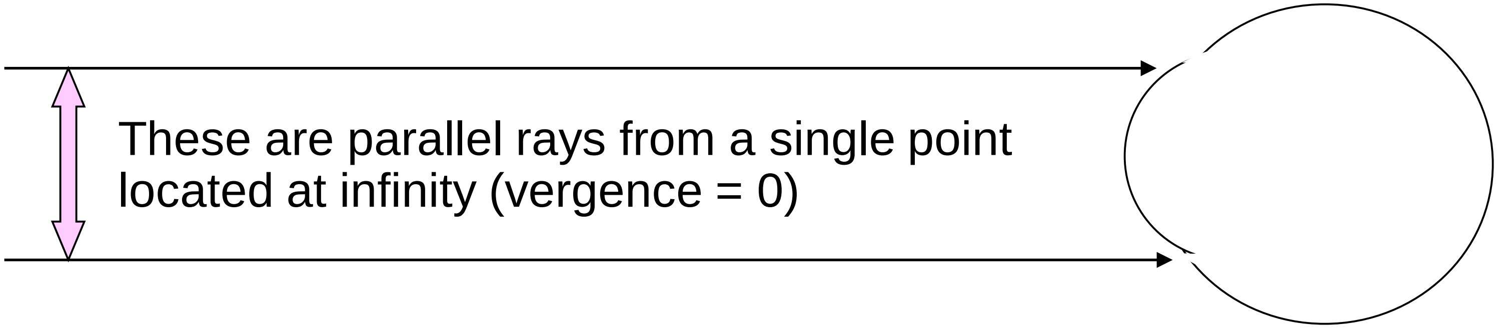
# The Far Point

*Remember:*

1) The far point is the point in space conjugate to the retina when the eye is not accommodating

2) An eye's refractive status is a function of the location of its far point

## The Emmetropic Eye

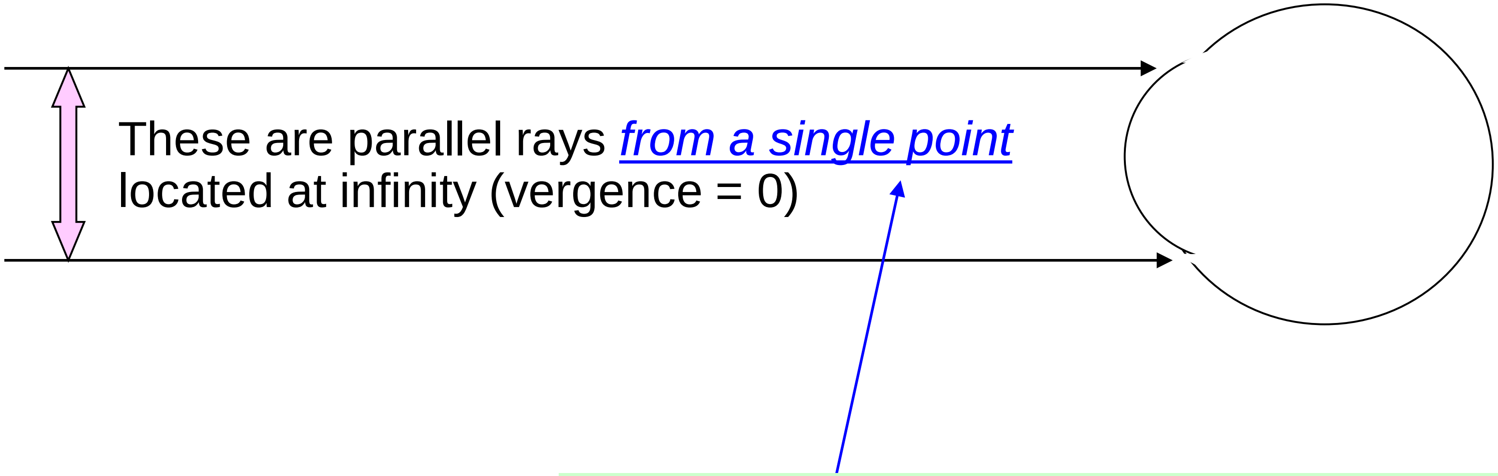


These are parallel rays from a single point located at infinity (vergence = 0)

# The Far Point

*Remember:*
1) The far point is the point in space conjugate to the retina when the eye is not accommodating
2) An eye’s refractive status is a function of the location of its far point

## The Emmetropic Eye



These are parallel rays *from a single point* located at infinity (vergence = 0)

*This is important!* The separateness of the rays in the drawing seems to indicate that they originate at different locations on the source of origin. *They do not!* They originated from a **single point**, but are so far removed from that point that their relative vergence is now zero.

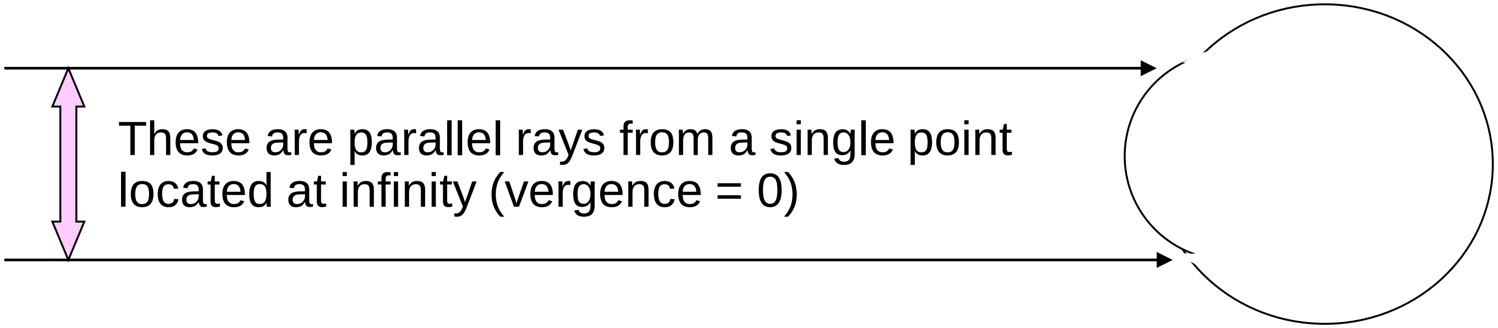
# The Far Point

*Remember:*

1) The far point is the point in space conjugate to the retina when the eye is not accommodating

2) An eye’s refractive status is a function of the location of its far point

## The Emmetropic Eye



These are parallel rays from a single point located at infinity (vergence = 0)

So how does the far point relate to refractive status? To answer this, consider what happens when an eye attempts to focus on a point located at infinity. We’ll start with an emmetropic eye, and then consider myopic/hyperopic eyes.

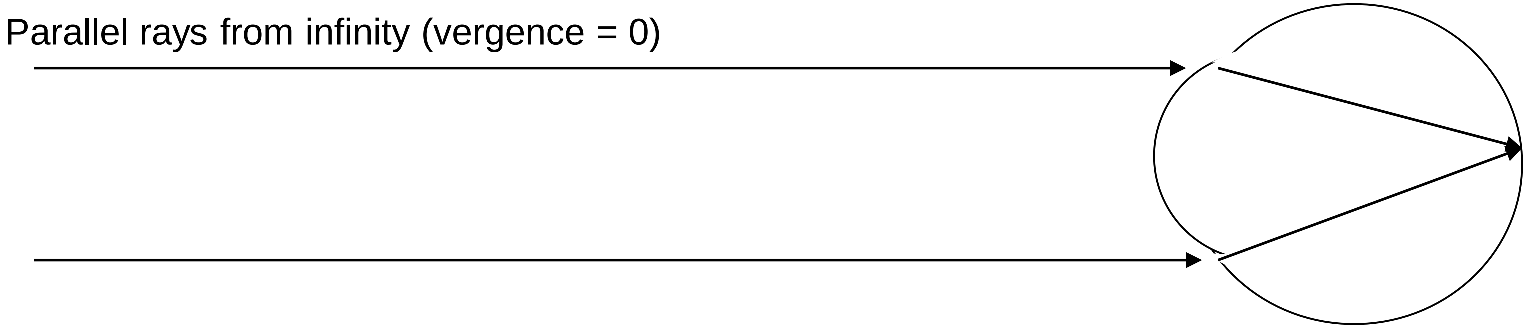
# The Far Point

*Remember:*

1) The far point is the point in space conjugate to the retina when the eye is not accommodating

2) An eye's refractive status is a function of the location of its far point

## The Emmetropic Eye



In the emmetropic eye, the parallel rays from a point at infinity are focused to a point located precisely on the retina.

# The Far Point

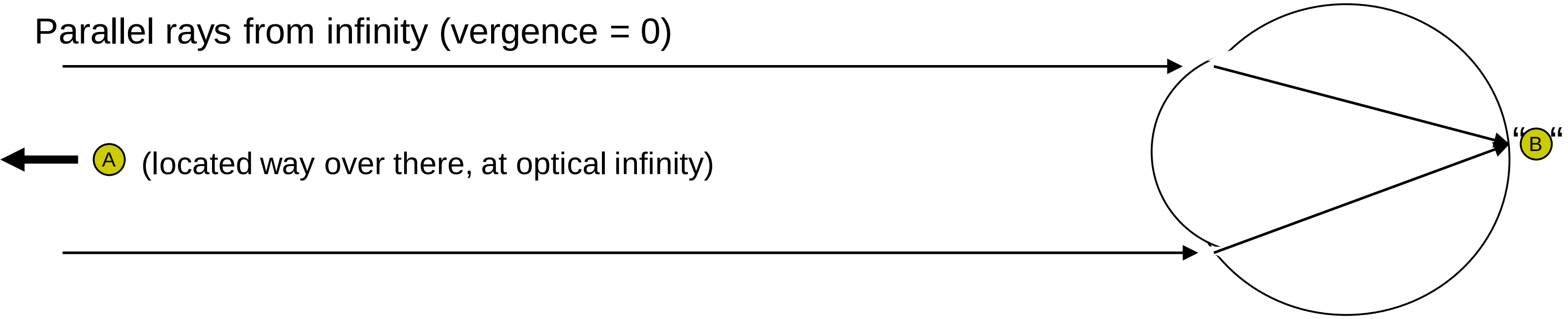
*Remember:*

1) The far point is the point in space conjugate to the retina when the eye is not accommodating

2) An eye's refractive status is a function of the location of its far point

## The Emmetropic Eye

***A and B are conjugate points***



In the emmetropic eye, the parallel rays from a point at infinity are focused to a point located precisely on the retina. In other words, *the far point of the emmetropic eye is located at infinity.*

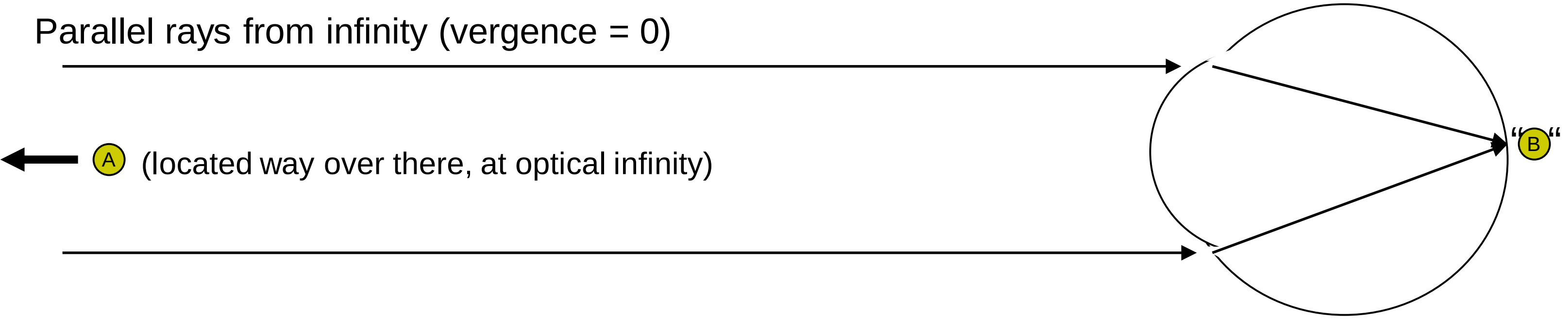
*Far point of the emmetropic eye:* ***Infinity***

# The Far Point

*Remember:*
1) The far point is the point in space conjugate to the retina when the eye is not accommodating
2) An eye's refractive status is a function of the location of its far point

## The Emmetropic Eye

***A and B are conjugate points***



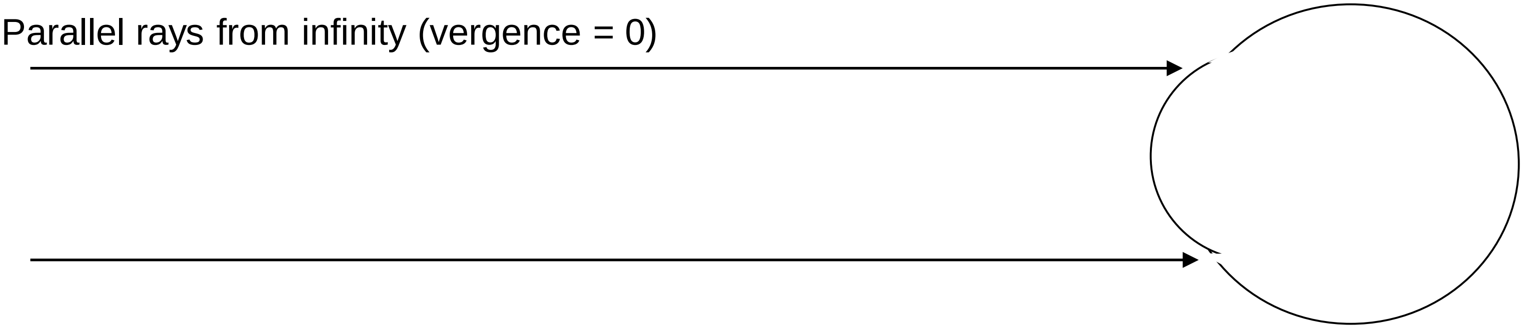
In the emmetropic eye, the parallel rays from a point at infinity are focused to a point located precisely on the retina. In other words, *the far point of the emmetropic eye is located at infinity.* Thus, emmetropes can see 20/20 (or better) at distance without correction.

*Far point of the emmetropic eye:* ***Infinity***

# The Far Point

*Remember:*
1) The far point is the point in space conjugate to the retina when the eye is not accommodating
2) An eye's refractive status is a function of the location of its far point

## The Myopic Eye

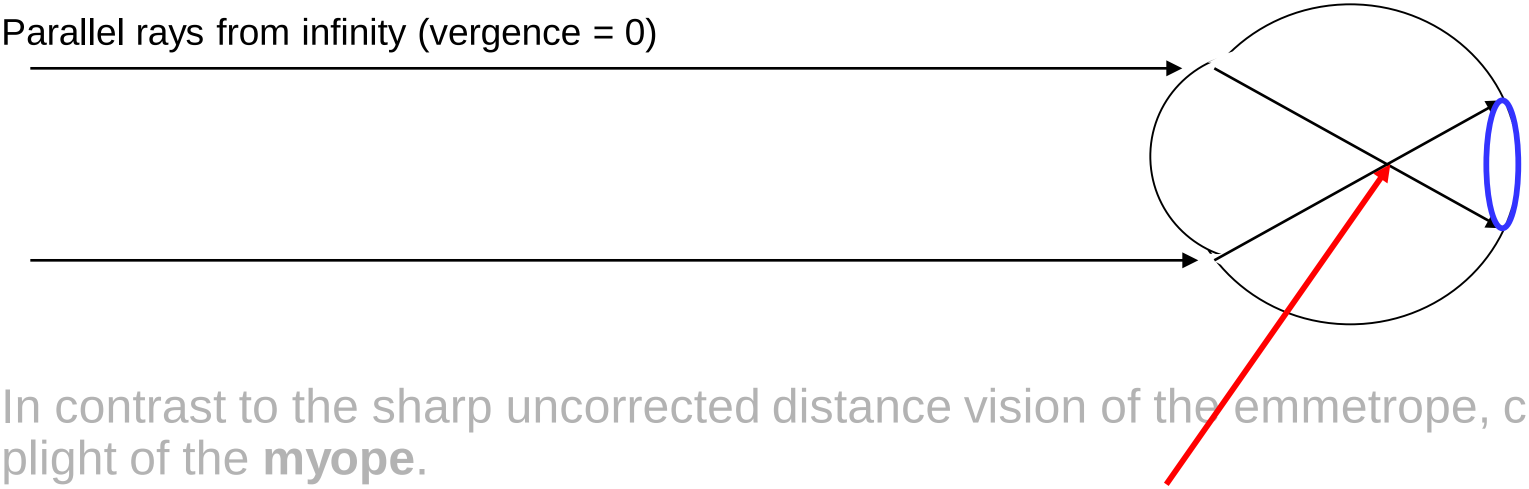


In contrast to the sharp uncorrected distance vision of the emmetrope, consider the plight of the **myope**.

# The Far Point

*Remember:*
1) The far point is the point in space conjugate to the retina when the eye is not accommodating
2) An eye's refractive status is a function of the location of its far point

## The Myopic Eye



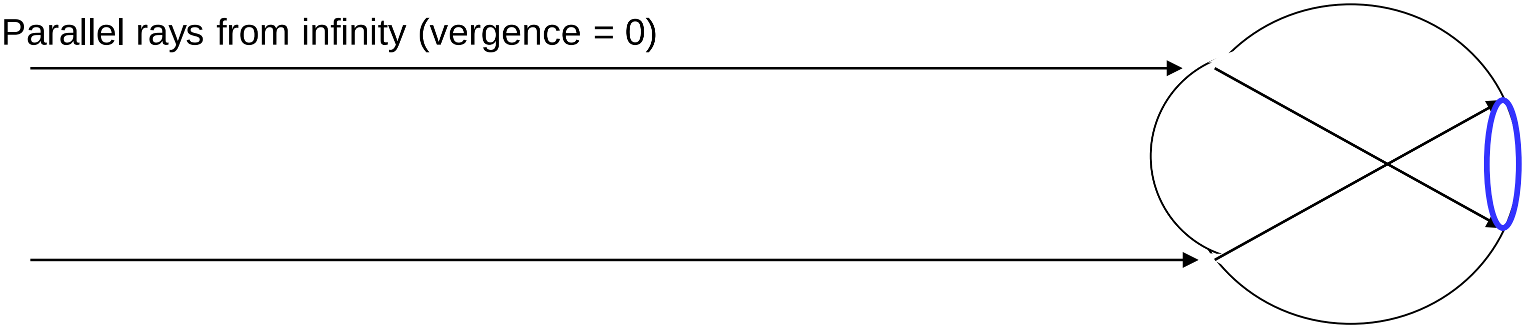
In contrast to the sharp uncorrected distance vision of the emmetrope, consider the plight of the **myope**.
In the myopic eye, rays from infinity meet in the vitreous. By the time they reach the retina, the rays have diverged to form a **blur circle**--not a focal point.

# The Far Point

*Remember:*
1) The far point is the point in space conjugate to the retina when the eye is not accommodating
2) An eye's refractive status is a function of the location of its far point

## The Myopic Eye

*The myopic eye has too much converging power for its length*



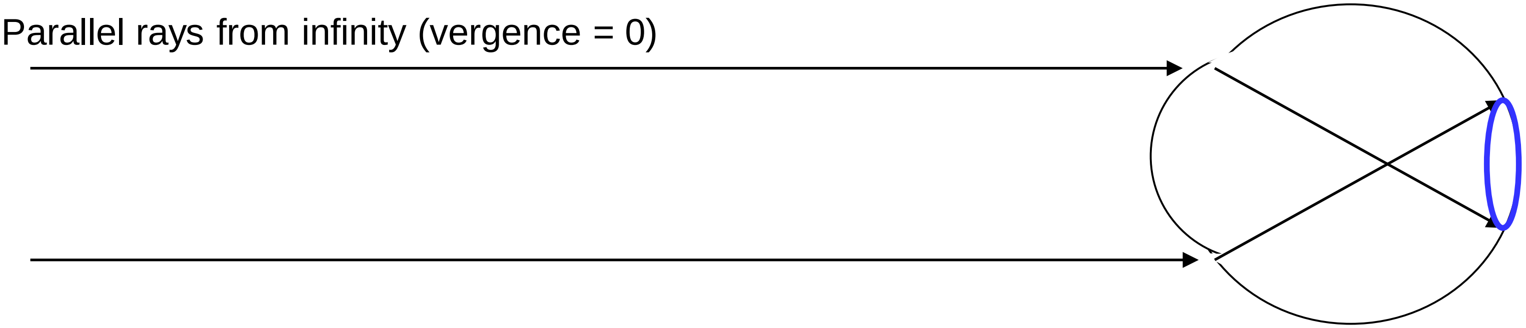
In contrast to the sharp uncorrected distance vision of the emmetrope, consider the plight of the **myope**.
In the myopic eye, rays from infinity meet in the vitreous. By the time they reach the retina, the rays have diverged to form a blur circle--not a focal point.
You could say the myopic eye has too much converging power for its length.

# The Far Point

*Remember:*
1) The far point is the point in space conjugate to the retina when the eye is not accommodating
2) An eye's refractive status is a function of the location of its far point

## The Myopic Eye

is too long
v
*The myopic eye ~~has too much~~*
*~~converging power~~ for its ~~length~~*
^
converging power



In contrast to the sharp uncorrected distance vision of the emmetrope, consider the plight of the **myope**.
In the myopic eye, rays from infinity meet in the vitreous. By the time they reach the retina, the rays have diverged to form a blur circle--not a focal point.
~~You could say the myopic eye has too much converging power for its length.~~

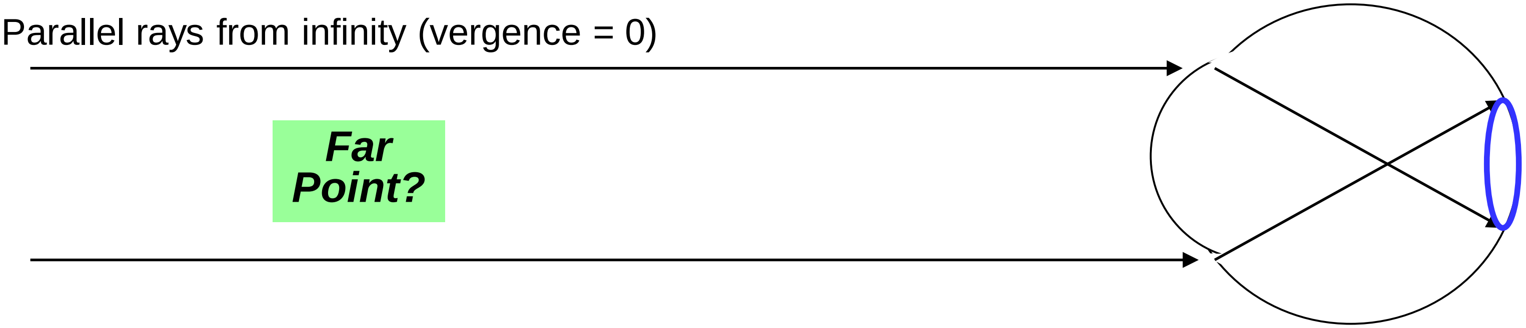
Of course, you could also say the myopic eye is **too long for its converging power**. Truth be told, garden-variety myopia is far more likely to be the result of excess eyeball length (so-called *axial myopia*) than the result of excessive built-in refractive power. However, there's an important conceptual reason for thinking of myopia as resulting from excess converging power, as we shall soon see.

# The Far Point

*Remember:*
1) The far point is the point in space conjugate to the retina when the eye is not accommodating
2) An eye's refractive status is a function of the location of its far point

## The Myopic Eye

*The myopic eye has too much converging power for its length*



In contrast to the sharp uncorrected distance vision of the emmetrope, consider the plight of the **myope**.

In the myopic eye, rays from infinity meet in the vitreous. By the time they reach the retina, the rays have diverged to form a blur circle--not a focal point.

You could say the myopic eye has too much converging power for its length.

To be conjugate with the retina, the far point of a myopic eye will have to offset its excess convergence with an equivalent amount of divergence. **To accomplish this…**

# The Far Point

*Remember:*

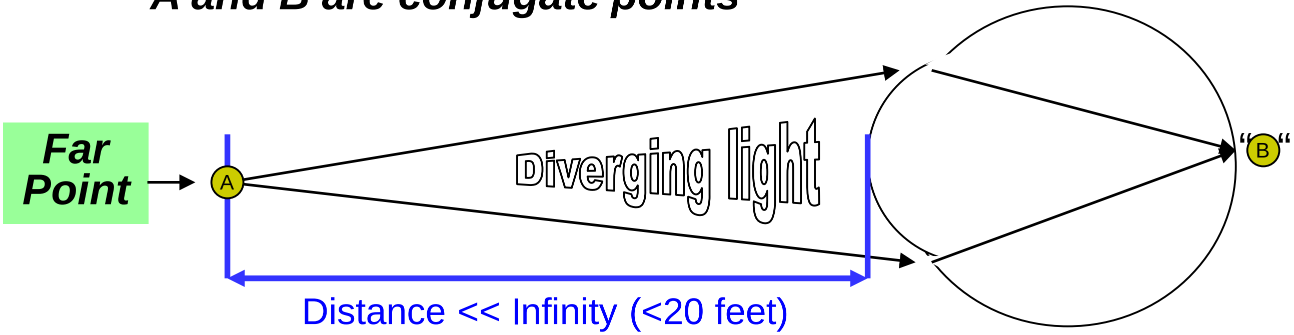
1) The far point is the point in space conjugate to the retina when the eye is not accommodating

2) An eye’s refractive status is a function of the location of its far point

## The Myopic Eye

*The myopic eye has too much converging power for its length*

***A and B are conjugate points***



***Far Point***

Diverging light

Distance << Infinity (<20 feet)

**…the far point of a myopic eye is just anterior to the corneal plane.** Rays from this location are still quite divergent when they reach the eye.

# The Far Point

*Remember:*

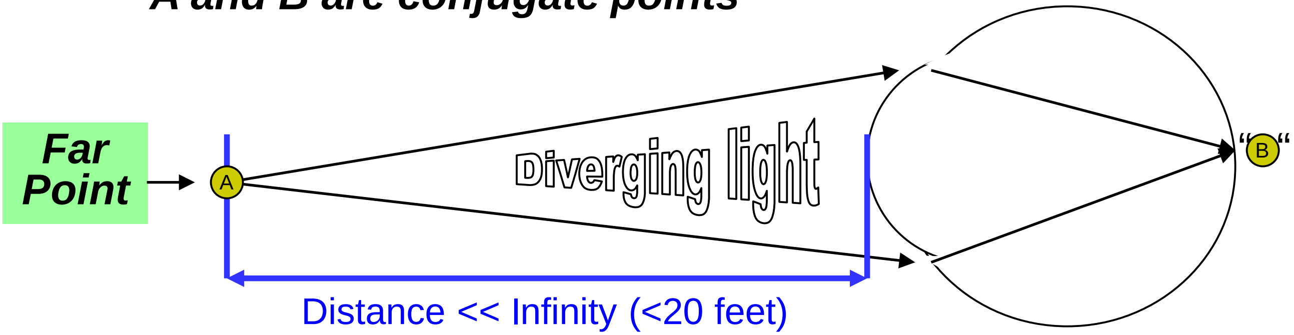
1) The far point is the point in space conjugate to the retina when the eye is not accommodating

2) An eye's refractive status is a function of the location of its far point

## The Myopic Eye

*The myopic eye has too much converging power for its length*

***A and B are conjugate points***



**…the far point of a myopic eye is just anterior to the corneal plane.** Rays from this location are still quite divergent when they reach the eye. This divergence offsets the excess convergence that is built into the myopic eye, so rays originating from the far point end up sharply focused at the retina.

# The Far Point

*Remember:*

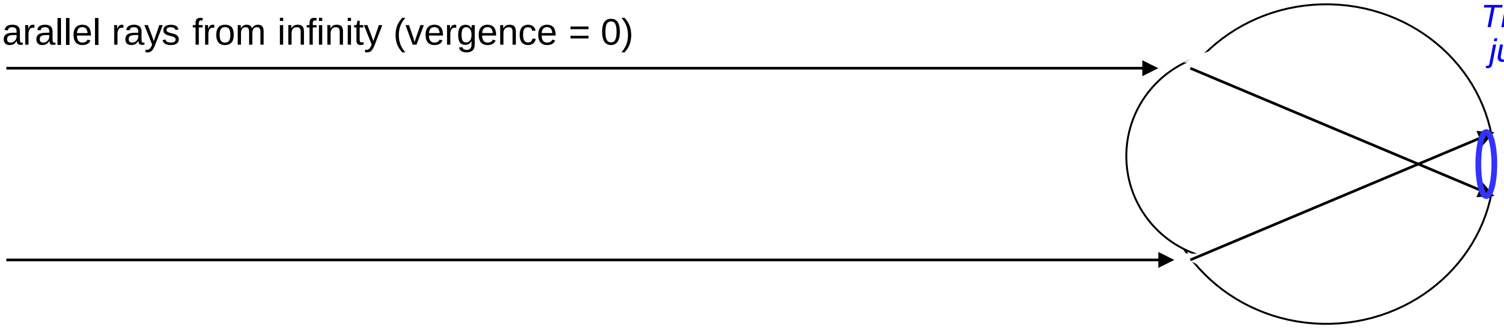
1) The far point is the point in space conjugate to the retina when the eye is not accommodating

2) An eye's refractive status is a function of the location of its far point

## The Myopic Eye

***Low*** **myopia**

Parallel rays from infinity (vergence = 0)

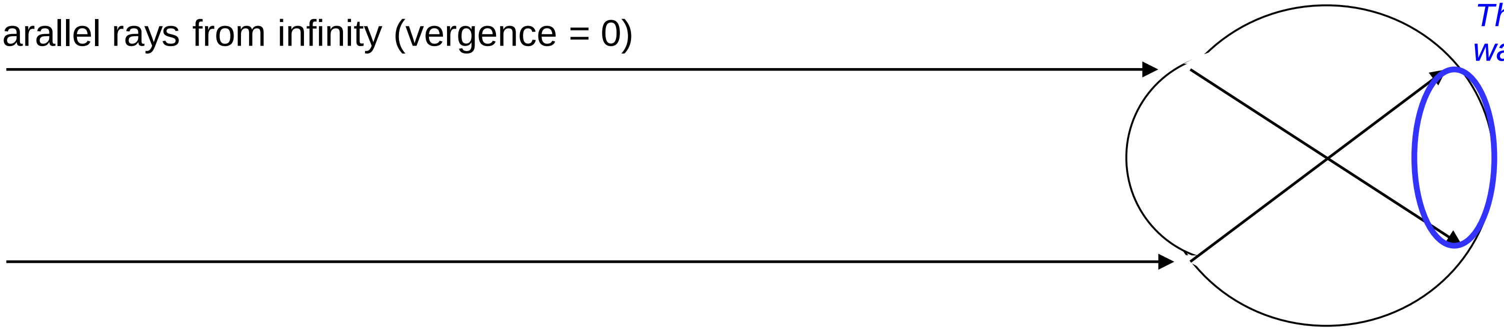


*The low-myopia eye has just a smidge too much converging power for its length*

Differences in the amount of myopia are reflected in the distance between the retina and the far point:

***High*** **myopia**

Parallel rays from infinity (vergence = 0)



*The high-myopia eye has way too much converging power for its length*

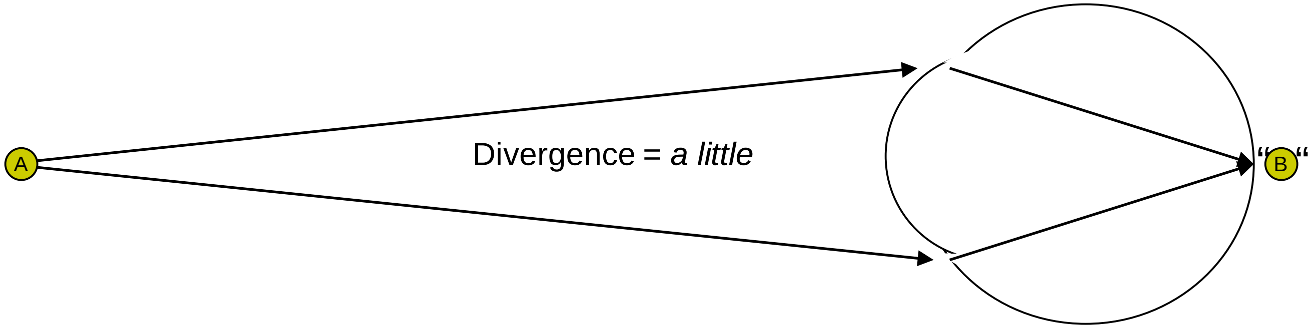
# The Far Point

*Remember:*
1) The far point is the point in space conjugate to the retina when the eye is not accommodating
2) An eye's refractive status is a function of the location of its far point

## The Myopic Eye

***A and B are conjugate points***

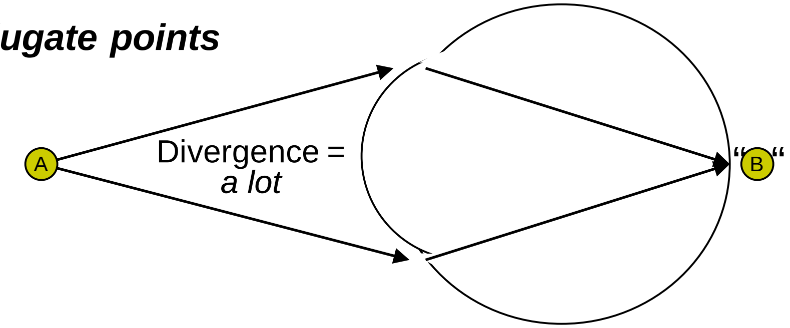
***Low*** myopia



Differences in the amount of myopia are reflected in the distance between the retina and the far point:
**Higher myopia→more excess convergence→more compensatory divergence→*closer* far point**

***High*** myopia

***A and B are conjugate points***



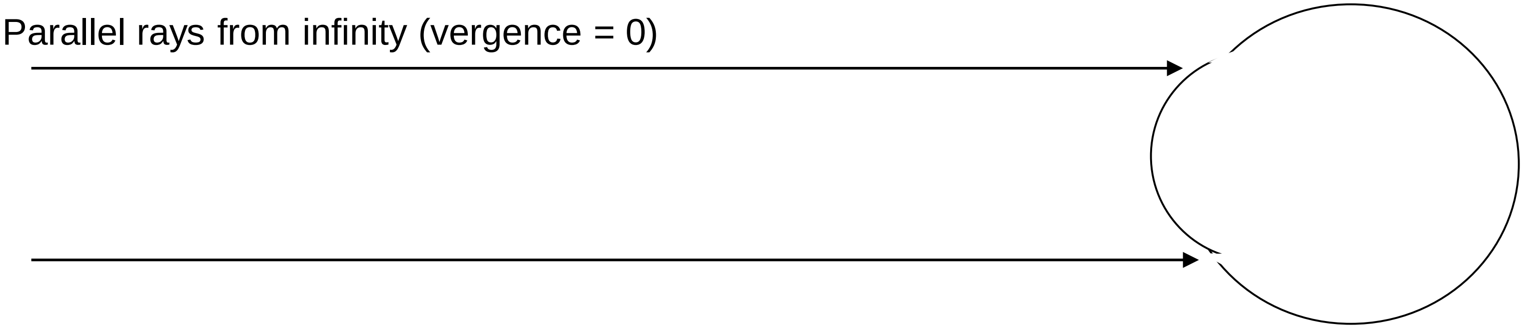
# The Far Point

*Remember:*

1) The far point is the point in space conjugate to the retina when the eye is not accommodating

2) An eye's refractive status is a function of the location of its far point

## The Hyperopic Eye

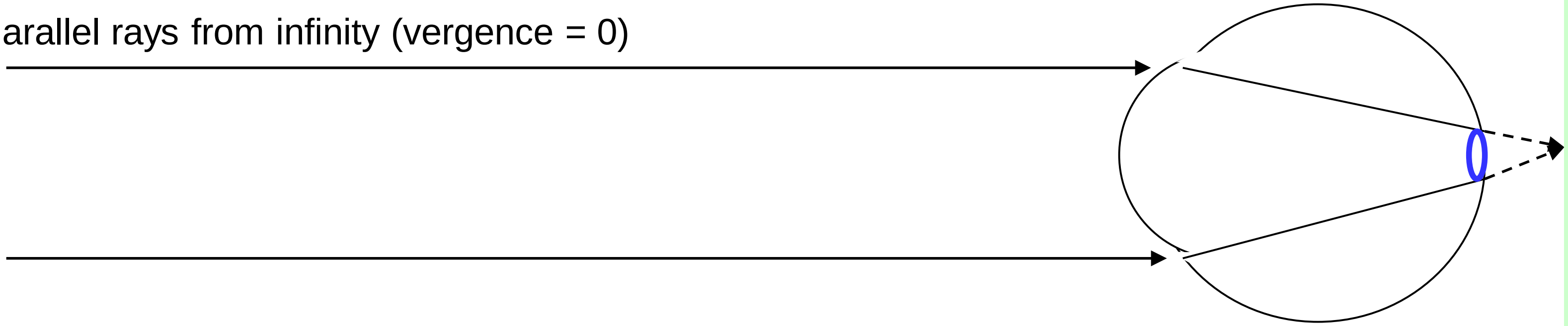


Now consider the **hyperope**.

# The Far Point

*Remember:*
1) The far point is the point in space conjugate to the retina when the eye is not accommodating
2) An eye's refractive status is a function of the location of its far point

## The Hyperopic Eye



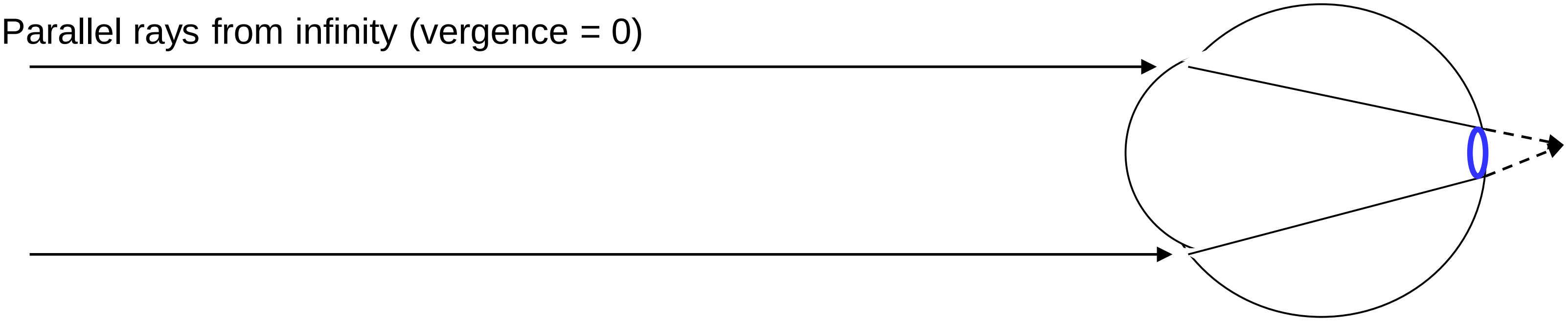
Note: This is where the rays would meet if they hadn't run into the retina. ***It is NOT the far point!*** (We'll christen this location shortly.)

Now consider the **hyperope**.
In the hyperopic eye, rays from infinity never meet—they run out of eyeball first.
Thus, like the myopic eye, the rays form a blur circle, not a focal point, at the retina.

# The Far Point

*Remember:*
1) The far point is the point in space conjugate to the retina when the eye is not accommodating
2) An eye's refractive status is a function of the location of its far point

## The Hyperopic Eye



*The hyperopic eye has too little converging power for its length*

Now consider the **hyperope**.
In the hyperopic eye, rays from infinity never meet—they run out of eyeball first.
Thus, like the myopic eye, the rays form a blur circle, not a focal point, at the retina.
You could say the hyperopic eye has too *little* converging power for its length.

# The Far Point

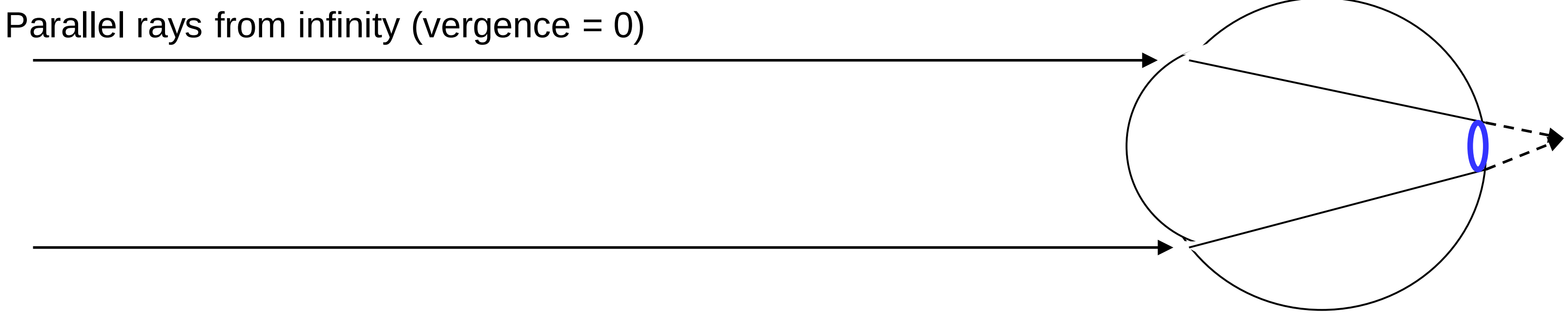
*Remember:*

1) The far point is the point in space conjugate to the retina when the eye is not accommodating

2) An eye's refractive status is a function of the location of its far point

## The Hyperopic Eye

*The hyperopic eye* is too short *~~has too little converging power~~ for its ~~length~~* converging power



Now consider the **hyperope**.
In the hyperopic eye, rays from infinity never meet—they run out of eyeball first.
Thus, like the myopic eye, the rays form a blur circle, not a focal point, at the retina.
~~You could say the hyperopic eye has too *little* converging power for its length~~.

As was the case with myopia, hyperopia is interpretable as a problem of axial length; ie, one could say **the hyperopic eye is too short for its converging power**. And as with myopia, clinical hyperopia is more likely to result from a short eye (*axial hyperopia)* than a dearth of refractive power. However, we're still building toward that important conceptual payoff. Bear with me.

# The Far Point

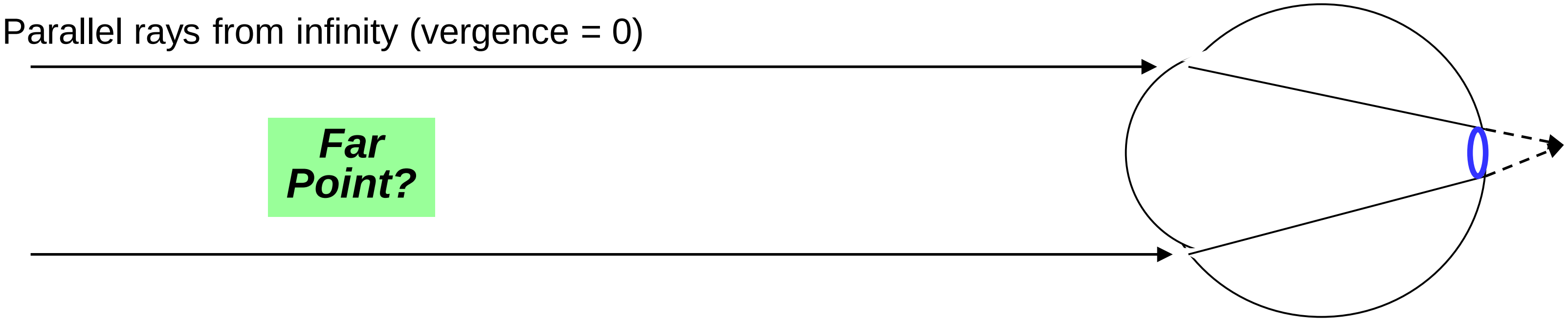
*Remember:*

1) The far point is the point in space conjugate to the retina when the eye is not accommodating

2) An eye’s refractive status is a function of the location of its far point

## The Hyperopic Eye

*The hyperopic eye has too little converging power for its length*



Parallel rays from infinity (vergence = 0)

***Far Point?***

Now consider the **hyperope**.
In the hyperopic eye, rays from infinity never meet—they run out of eyeball first.
Thus, like the myopic eye, the rays form a blur circle, not a focal point, at the retina.
You could say the hyperopic eye has too *little* converging power for its length.

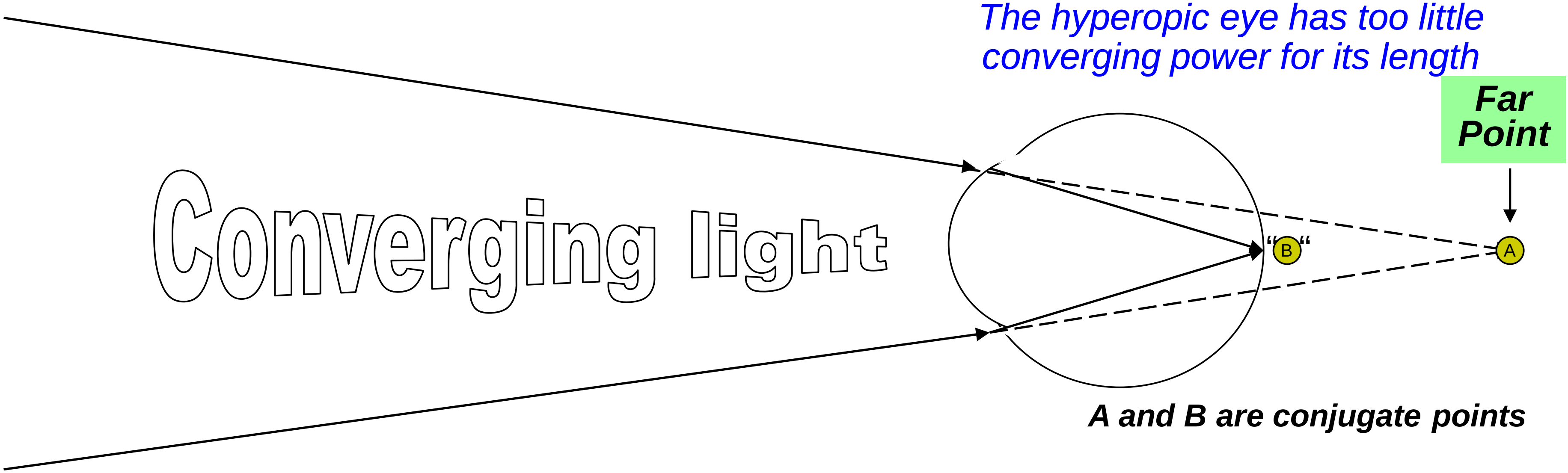
In order to be conjugate to the retina, the Far Point of a hyperopic eye must contribute convergence to compensate for this lack of converging power.
To accomplish this…

# The Far Point

*Remember:*
1) The far point is the point in space conjugate to the retina when the eye is not accommodating
2) An eye's refractive status is a function of the location of its far point

## The Hyperopic Eye

*The hyperopic eye has too little converging power for its length*



***A and B are conjugate points***

**…the far point of a hyperopic eye is *behind* the corneal plane**. It contributes **convergence** to make up for the inadequate native convergence of the hyperopic eye. Thus, rays associated with the far point end up sharply focused at the retina.

## *As an aside:*

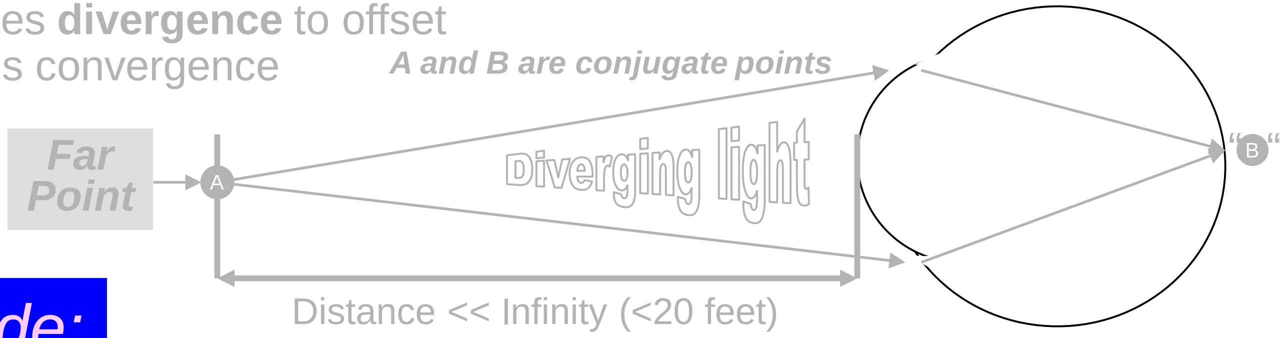
You can now see why the terms ***nearsighted*** and ***farsighted*** cause confusion for laypersons.

# The Myopic Eye

## (*aka* 'nearsighted')

*The myopic eye has too much converging power for its length*

The far point of a myopic eye contributes **divergence** to offset its excess convergence



***A and B are conjugate points***

Distance << Infinity (<20 feet)

## *As an aside:*

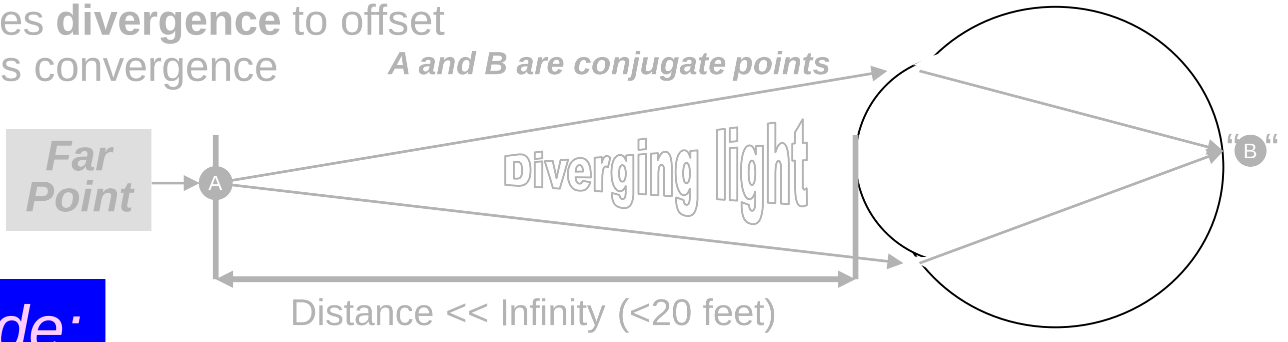
You can now see why the terms ***nearsighted*** and ***farsighted*** cause confusion for laypersons. On the one hand, nearsighted persons can see clearly at near (specifically, at their far point) but not at distance. Given this, one would think that a farsighted person faces the reverse situation—clear at far, blurry at near.

# The Myopic Eye

**(*aka* ‘nearsighted’)**

*The myopic eye has too much converging power for its length*

The far point of a myopic eye contributes **divergence** to offset its excess convergence



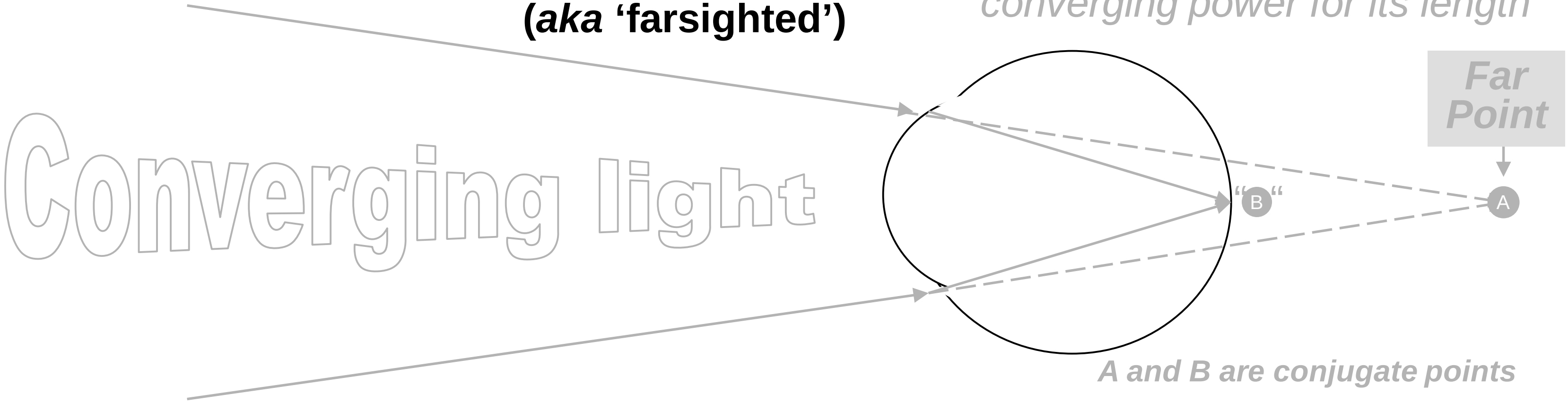
## As an aside:

You can now see why the terms ***nearsighted*** and ***farsighted*** cause confusion for laypersons. On the one hand, nearsighted persons can see clearly at near (specifically, at their far point) but not at distance. Given this, one would think that a farsighted person faces the reverse situation—clear at far, blurry at near. This is not the case, however—the hyperope’s far point is *behind* the eye, and thus not within her line of light. This is why, in the absence of refractive correction and/or accommodation, farsighted persons are out of focus at **every** distance.

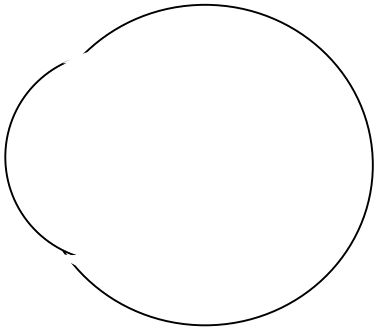
# The Hyperopic Eye

**(*aka* ‘farsighted’)**

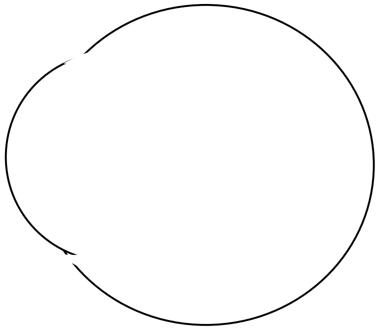
*The hyperopic eye has too little converging power for its length*



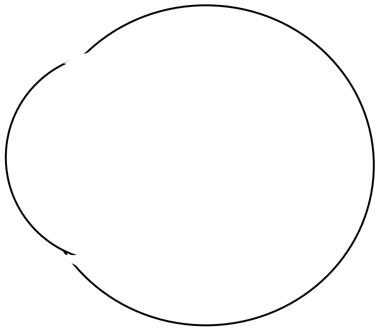
## The Hyperopic Eye



## The Emmetropic Eye

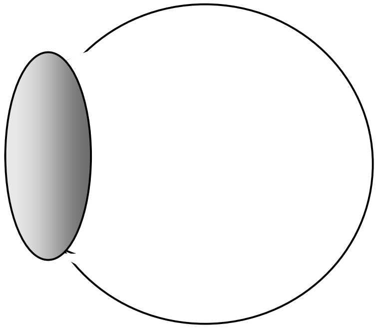


## The Myopic Eye

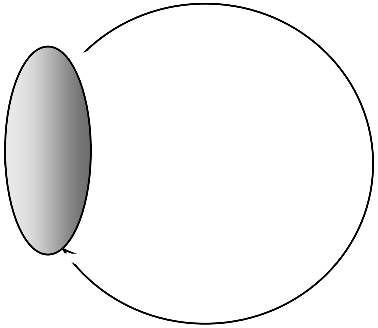


*We stressed earlier that lenses have focal points but not far points—only eyes have far points. But* ***do eyes have focal points****?*

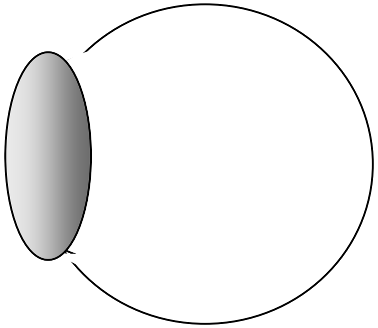
**The Hyperopic Eye**



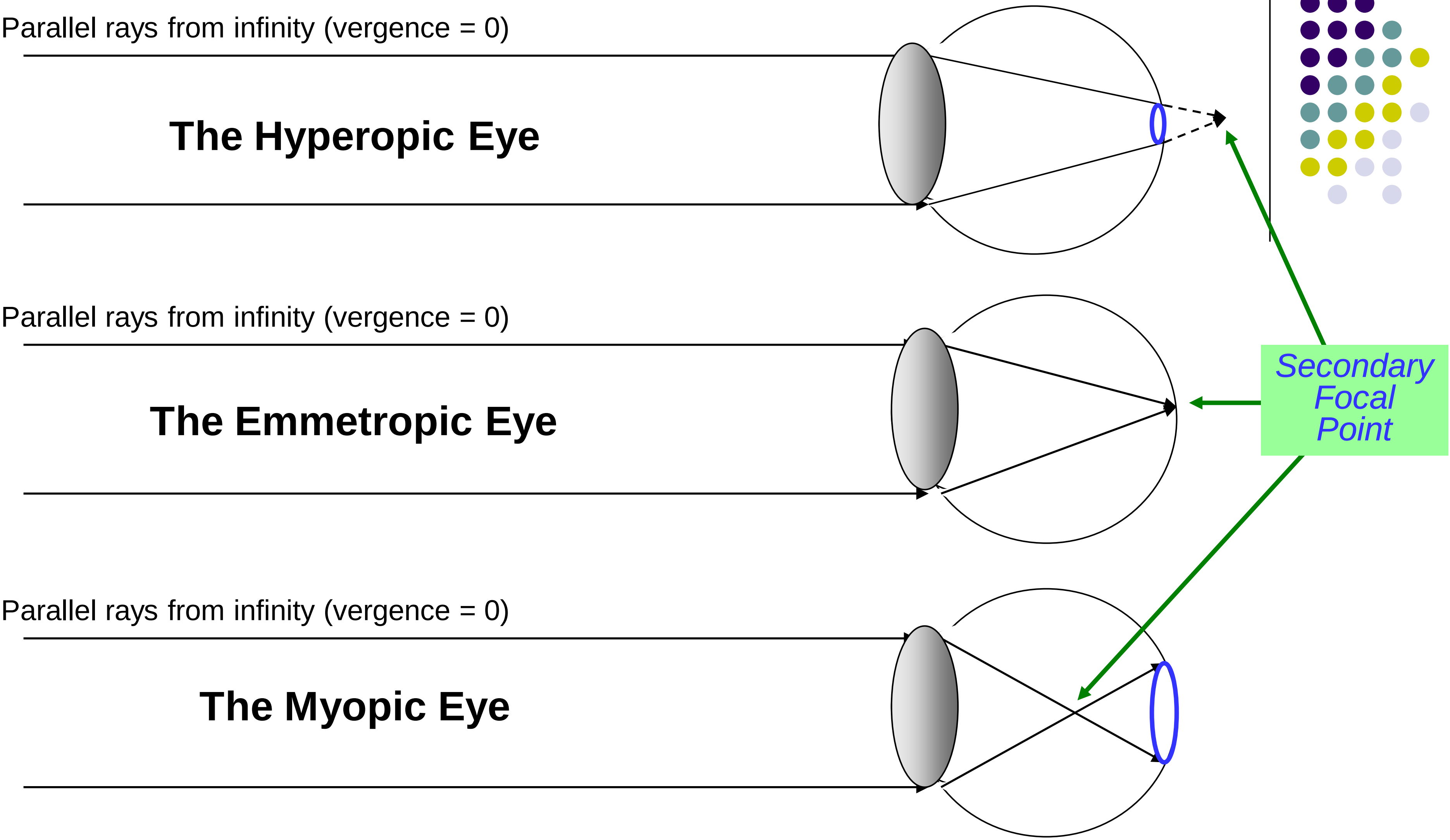
**The Emmetropic Eye**



**The Myopic Eye**



*We stressed earlier that lenses have focal points but not far points—only eyes have far points. But **do eyes have focal points**?*
**Yes!** With respect to its ability to refract light, think of the front of the eye (specifically, the cornea and native lens) as being one big ‘plus’ lens. Like any lens, this ‘big lens’ has both a primary and a secondary focal point.



Parallel rays from infinity (vergence = 0)

**The Hyperopic Eye**

Parallel rays from infinity (vergence = 0)

**The Emmetropic Eye**

Parallel rays from infinity (vergence = 0)

**The Myopic Eye**

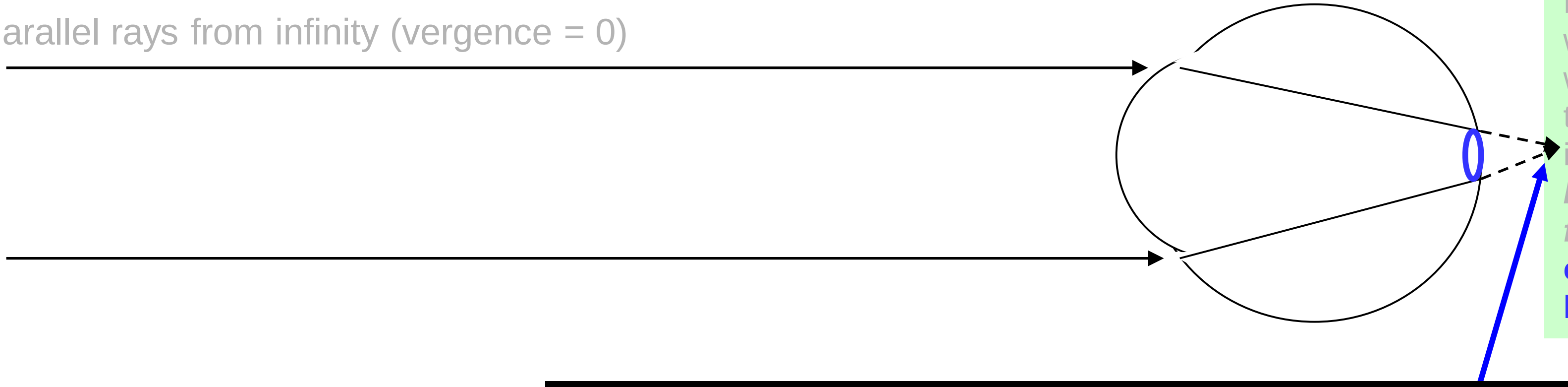
*Secondary Focal Point*

The **secondary focal point** is the image location where parallel rays meet.

# The Far Point

*Remember:*
1) The far point is the point in space conjugate to the retina when the eye is not accommodating
2) An eye's refractive status is a function of the location of its far point

## The Hyperopic Eye



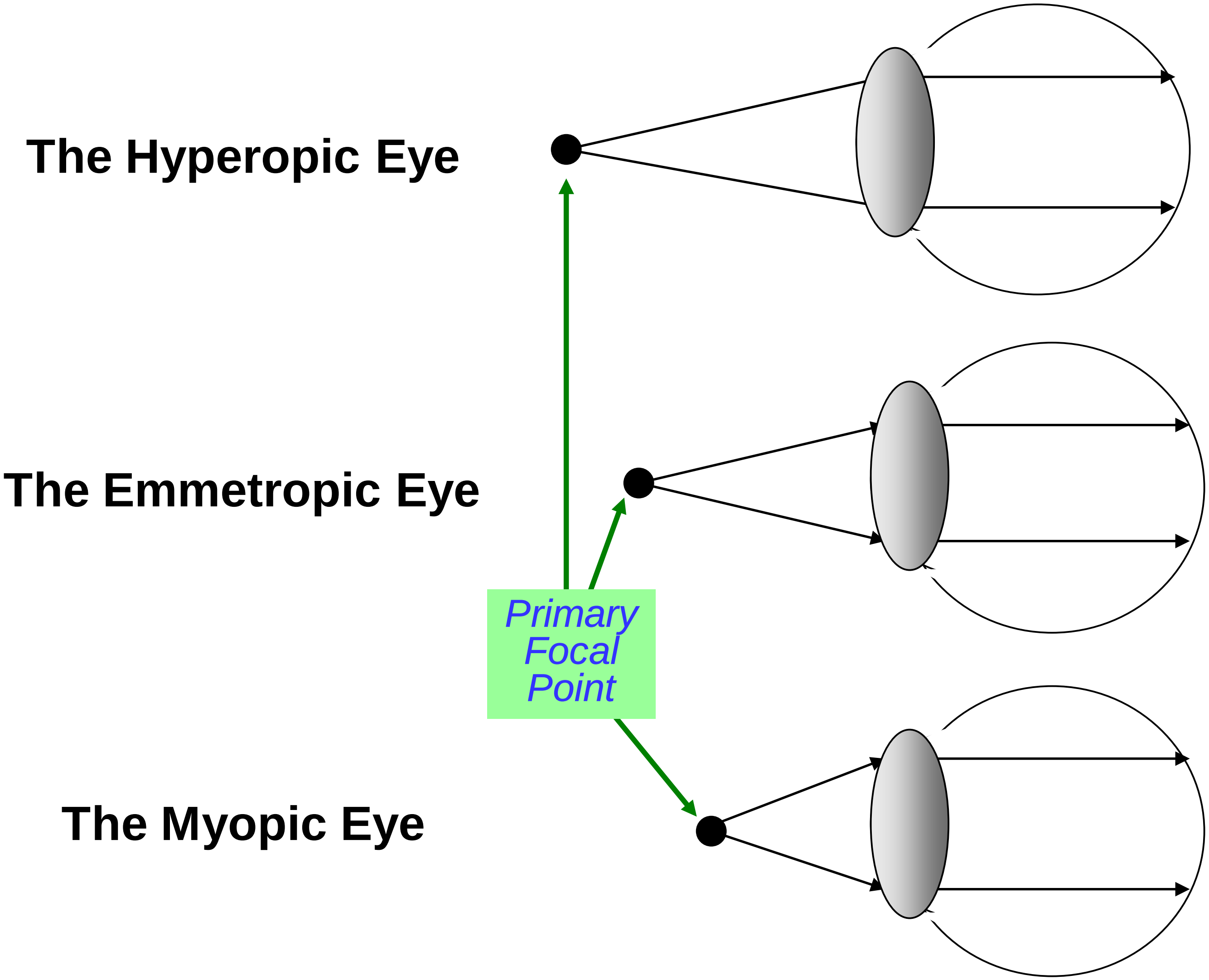
Parallel rays from infinity (vergence = 0)

Note: This is where the rays would meet if they hadn't run into the retina. ***It is NOT the far point!*** (**We'll christen this location shortly.**)

Recall this slide—we now recognize that this is the ***secondary focal point*** of the hyperopic eye

Now consider the **hyper**

In the hyperopic eye, rays from infinity never meet—they run out of eyeball first.
Thus, like the myopic eye, the rays form a blur circle, not a focal point, at the retina.



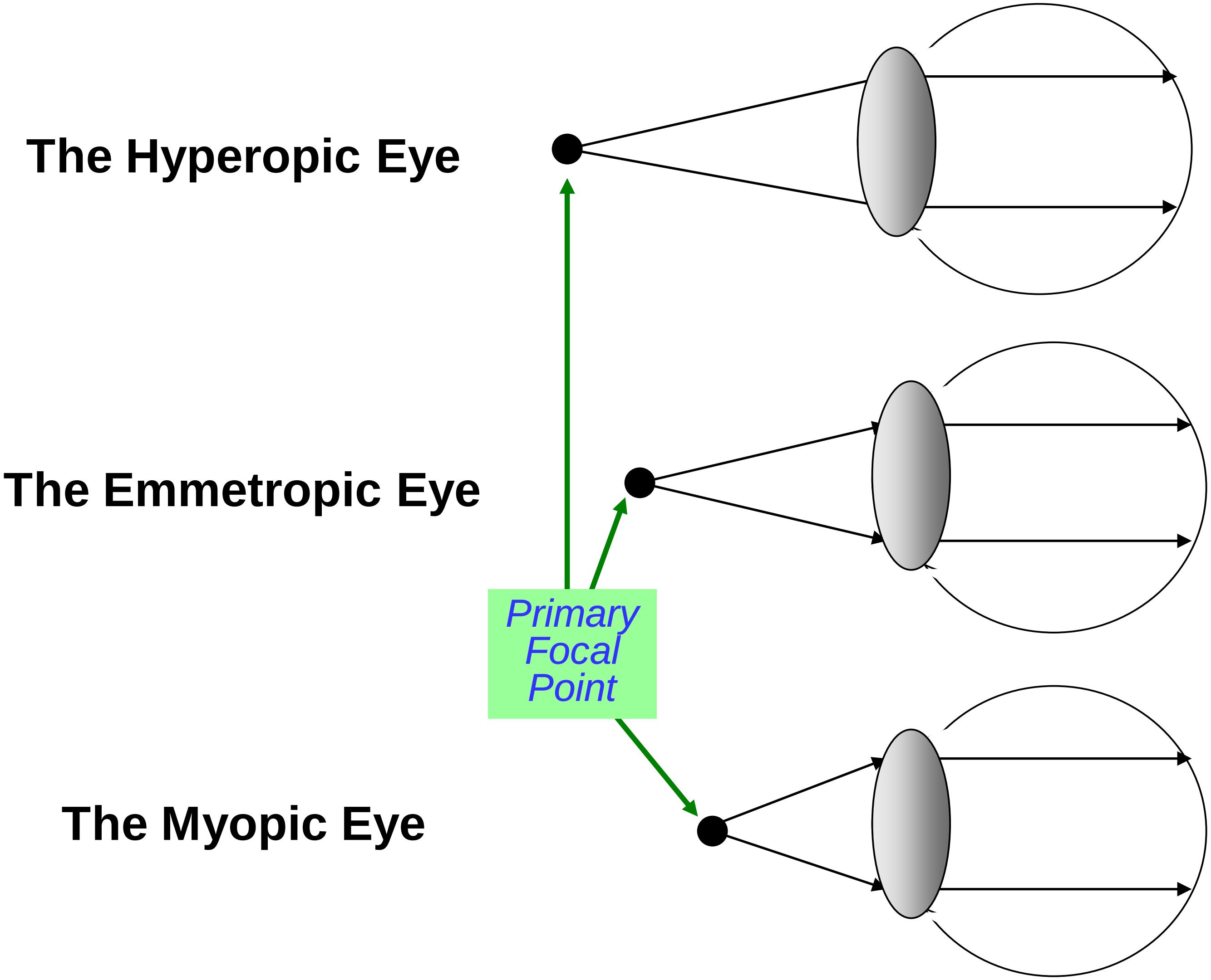
**The Hyperopic Eye**

**The Emmetropic Eye**

**The Myopic Eye**

*Primary Focal Point*

Likewise, the **primary focal point** is the object location from which associated rays would end up parallel within the eye.



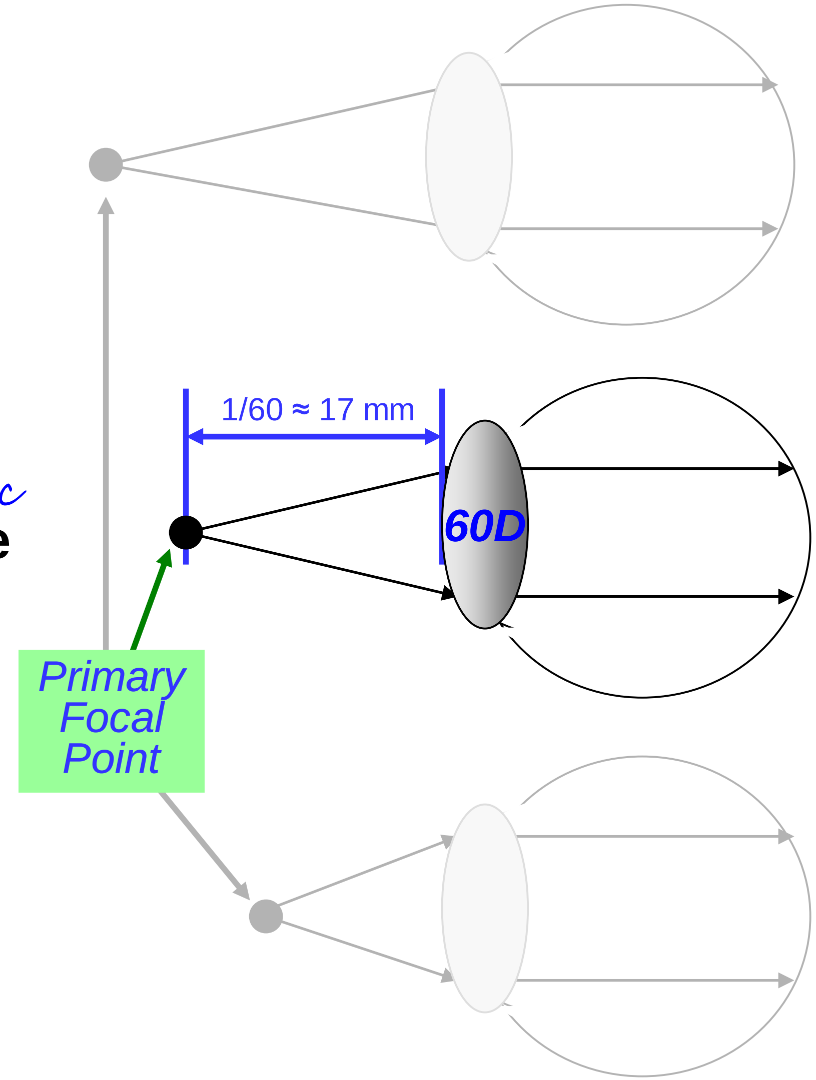
**The Hyperopic Eye**

**The Emmetropic Eye**

**The Myopic Eye**

*Primary Focal Point*

*How far from the eye is the primary focal point?*



The Hyperopic Eye

Güllstrand reduced schematic
The ^~~Emmetropic~~ Eye

*Primary Focal Point*

The Myopic Eye

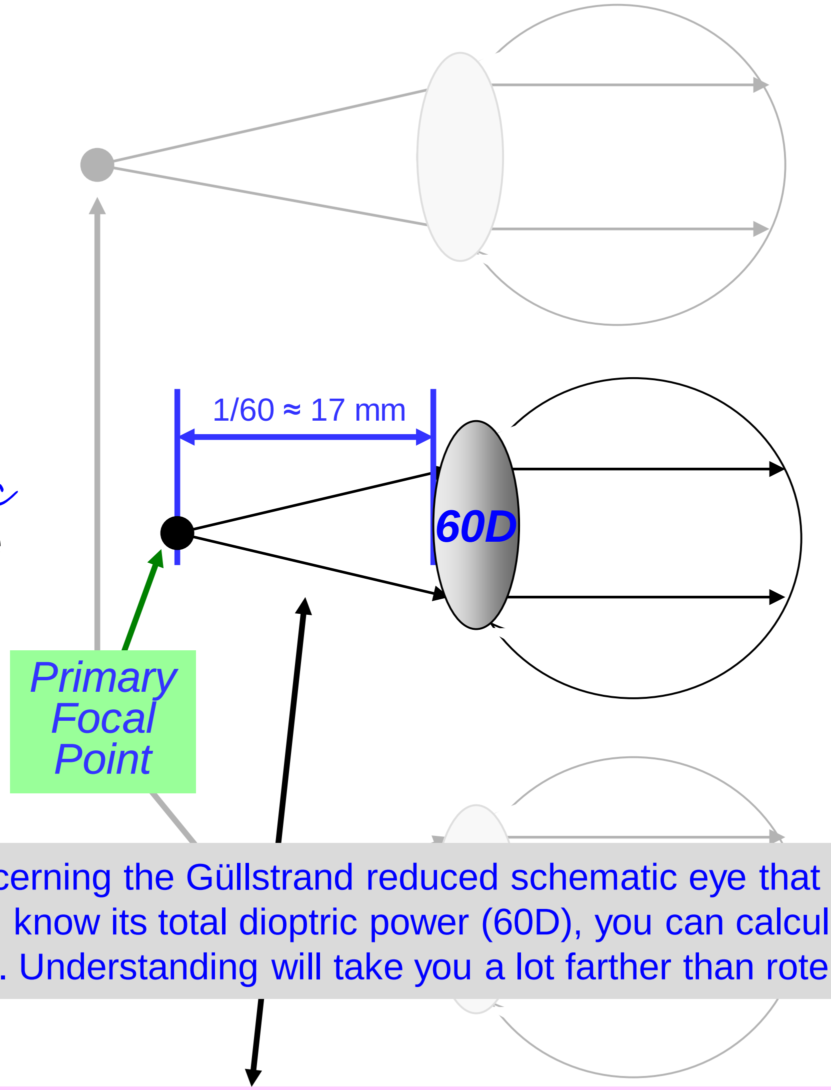
*How far from the eye is the primary focal point?*

The distance depends upon the total dioptric power of the ‘big lens.’ The *Güllstrand reduced schematic eye* is the model to which ophthalmologists refer most frequently when addressing questions of this sort. In this model, the ‘big lens’ of an emmetropic eye has a total of 60D of power, all of which is located at the corneal plane. Therefore, the primary focal point is 1/60 ≈ 0.017 m (17 mm) anterior to the cornea. (We will have more to say about the Güllstrand model eye in future chapters.)

## The Hyperopic Eye

Güllstrand reduced schematic

## The ~~Emmetropic~~ Eye



These are but two of a number of facts concerning the Güllstrand reduced schematic eye that you are expected to know for the OKAPs. But note that, if you know its total dioptric power (60D), you can calculate its primary focal length—you don't have to memorize it. Understanding will take you a lot farther than rote memorization.

*How far from the eye is the primary focal point?*

The distance depends upon the total dioptric power of the 'big lens.' The *Güllstrand reduced schematic eye* is the model to which ophthalmologists refer most frequently when addressing questions of this sort. **In this model,** the 'big lens' of an emmetropic eye has a total of 60D of power, all of which is located at the corneal plane. Therefore, the primary focal point is 1/60 ≈ 0.017 m (17 mm) anterior to the cornea. (We will have **much** more to say about the Güllstrand model eye in future chapters.)