# BLOSSOMS - What's in an Eye?

Hello and welcome. My name is Ishara Mills-Henry, and I am the director of a program called Science of the Eye: Bringing Vision into the Classroom. This program is based in Professor Jonathan King's laboratory at MIT. The eye is a fascinating organ that has several components working together to allow for us to see. However, the eye can have some imperfections, leading to eye disease and eye issues. Today we're going to dissect a mammalian eye and identify structures in the eye that allow for us to see.

Before we get started, I would like to ask you a few questions. First of all, why do you think it's important for us to have eyes at all? And have you ever thought about what animals see in animal vision? Do they see the same things that we do? I want you to take a few moments, and think about these questions with your classmates. And also, for the challenge segment of this portion, I'd like for you to try and match the animals in the right hand column to what you think they can see in the left hand column.

Welcome back. I hope you enjoyed that challenge. And in a few moments, we'll discuss the answers to the activity. However, before we do that, I want to talk a little bit more about animal eyes. You may be wondering why am I wearing these funny goggles? In these goggles, the one image that we normally see, I actually see multiple of these images. This is how some people thought animals with compound eyes would see. However, biologists now believe that this is a misconception, and that animals with compound eyes actually see more of a mosaic, pixelated vision. However, it's still fun to think about what are animals actually seeing.

Many invertebrates, such as bees, flies, and ants, have compound eyes. But invertebrates also have other types of eyes, from pit eyes to pinhole eyes to eyes with lenses. An example of an animal with pit eyes are snails. Pit eyes have eyes spots set into a hole, which allows the organism to deduce the angle of incoming light. Animals with pit eyes should be able to see the direction of light.

Nautiluses have a slightly more complex version of a pit eye called a pinhole eye, which evolved from a pit to a cup, and then a chamber. With a small opening, this type of eye allows the organism to sense direction and some shapes. Scallops have 40 to 60 iridescent blue eyes that are arranged in a row along a scallop's mantle edge. These allow the scallop to detect motion, light, and dark. Scallops can also regrow lost or injured eyes.

The compound eye has many facets, or repeating units, called ommatidia. This picture is the example of a compound drosophila, or fruit fly, eye. It is at very high magnification. Each single facet, or ommatidium, has eight photoreceptor cells, support cells, pigment cells, and a cornea. And here's a picture of the drosophila eye at even higher magnification. This is why many people imagined they would see multiple pictures, like the goggles that I mentioned earlier. The octopus eye is amazing and very similar to mammalian eyes, even though they are related to clams. Like the human eye, they have pupils, except theirs are horizontal slits instead of being rounded like ours.

But now let's turn back to our eyes. Our eye is an example of vertebrate eyes. And later we will do an exploration of a vertebrate eye. Do you wear glasses or contacts, or maybe know family members who have glaucoma or cataract? What we're going to talk about now is the different parts of our eyes, and how these diseases can affect those portions of the eye. Our eyes are very important in how we sense the environment around us. Approximately 1/3 of our brain is devoted to visual processing.

So now we're going to go into how do you think we see? So you want to take a look at your worksheets and predict, using the diagram, how you think light would reflect off an object and come into your eye.

So how do our eyes work? Using a model human eye, I'll demonstrate what happens. First light bounces off of objects. For example, you see this image here--into the cornea, which refracts light or bends light, through the lens, which also refracts light, and then onto the photosensitive portion of the retina. In the retina, it sends electrical chemical signals on through the optic nerve, and then into the brain. The image that's formed on the retina is actually upside down. And then our brains, as great as they are, flip this image right side up.

We detect a narrow region of the electromagnetic radiation spectrum called the visible light region. These are the wavelengths that are visible to the human eye. Photosensitive cells in the retina can detect the visible light region of the spectrum, ranging from short wavelengths, starting at about 390 nanometers, to longer wavelengths, ending at about 750 nanometers.

Animals can respond to different wavelengths of light. Some animals can actually perceive wavelengths outside of the visible light region of the electromagnetic spectrum. For example, insects, such as bees, can see in the ultraviolet region of the electromagnetic spectrum, as well as the visible light region. Other animals can perceive longer wavelengths of light, such as snakes--which have an infrared detector organ separate from their eyes--called pit vipers.

Some animals can perceive some of the same colors that we do, and they also can perceive some colors that we cannot. Also, we can perceive colors that some animals cannot perceive. For example, some primates can see a mixture of reds, blues, and greens, or what we call trichromatic vision, like us. Other primates can see a mixture of blues and greens, but not reds. They are considered dichromatic. And others, like the nocturnal owl monkey, are monochromatic, seeing only blacks, whites, and grays.

Dogs and cats, for example, can see very pale shades of colors. But they can see a lot better at night, better than we can. They have better peripheral vision, and also they can see movement a lot better than humans can. Because of these reasons, they probably were very good hunters when they had to be. Now, we just feed them dog food and cat food.

This may look like a volleyball, but this represents the size of the largest eye in the animal kingdom. Can you guess what animal this eye belongs to? Well, if you guessed the giant squid, you would be right. Can you imagine this eye looking at you? Well, now I have discussed some of the animal eyes, look at your worksheets and if you have some changes to make, I'm going to give you some time to do that. And I'll see you soon.

Welcome back. So what did you think? Did you make any changes? If we look at the first picture, it looks like this animal perceives the infrared region of the electromagnetic spectrum. Which animal does that? That's right, snakes. Remember snakes have pit organs that can sense infrared radiation, or in other words heat, and allow the snake to process this image.

The second picture is an example of what some primates may see. So we match it to the squirrel monkey. Remember, some primates have dichromatic vision and probably can see very similar to what a person with red-green color blindness sees.

The third picture is an example of what nocturnal animals see, animals that are active at night Which animals do we know can see well at night? That's right. Cats see well in the dark and at night. Cats and other nocturnal animals have a tissue in their eyes called the tapetum lucidum that assists in helping animals see in low light environments. Light reflecting off of this structure is why animal eyes glow at night. We will see this tissue later in the lesson.

What about the fourth picture? This is a picture of an animal that has a blind spot in the middle of its field of view. Horses have eyes on either side of their heads, which is good for the range in their field of view, but makes it difficult to see right in front of them, especially when their heads are parallel to the ground. Research has shown that this blind spot is probably the width of the body of the horse. You may have noticed that horses raise their head slightly if they are approaching an item head on, for example, a gate that it has to jump over. This allows the horse to see the item in front of them better, and gives them better depth perception.

For example, if you covered one eye and tried to reach out for something, it's more difficult than if you had two eyes. With one eye covered, that is the case of monocular vision. And with two eyes, that's the case of binocular vision. You should try this at home, but don't break anything. By lifting its head, the horse is switching from monocular vision to binocular vision, thereby giving it a better depth perception.

In the fifth picture, you see a pixelated mosaic view of a flower. As mentioned before, biologists predict that many animals with compound eyes can see pixelated images. So you probably picked the fly. Learning more about the compound eye will help researchers develop lenses for cameras that will allow the camera to see in dark areas and light areas of the field of view.

In the last photo, there is a clear view of two best friends. This is a representation of what we see as humans. Scientists are constantly adding new knowledge about what we see, and about what animals see.

Now that you've thought a little bit about how you see, I have a challenge question for you. How long does a mirror have to be in order for you to see your entire body? Do you see that if you're closer to the mirror, you see less of your body, and if you're further away from the mirror, you see more of your body? Do you think distance would play a role in how much you see in the mirror?

Well, we're going to test this out right now to see if distance does play a role. And I'm going to use my handy assistant here, Lisa. So with the mirror at eye level and held in a flat position, I will ask Lisa to move forward and back from the mirror. Lisa, did you see more of your body or less of your body?

“No. Distance did not play a role in how much of my body I could see in the mirror, whether I came forward or backward.”

So distance does not play a role. This may seem counter-intuitive, but let's think about it in terms of vision. What's happening? What will happen is that light will actually bounce off of our foot and into to the mirror, and then from the mirror into our eyes. So the mirror would have to be 1/2 of a body length in order for us to see our entire body. And you can try this out at home.

Today, we are going to dissect a mammalian eye. And this is actually a cow's eye. So as you can see, the cow's eye looks fairly big. It is a little bit bigger than our eyes. The cow eye has a lot of surrounding tissue around the eye. Can you guess what the surrounding tissue is? You see some tissue that's actually yellow and white in nature, and some tissue that's actually pink in nature.

So this tissue surrounding the eye is fat and muscles that are important. The fat is important for cushioning the eye in the bone orbital that surrounds the eye. So you can imagine that if, for some reason, we had a head injury, the fat is sort of used as the shock absorber, and prevents the eye from being damaged.

The muscles that surround the eyeball are important for eye movement. Cows have four muscles, one at the top of the eye, one at the bottom, and two on the sides. This allows for the cow to move its eye up and down and side to side.

For one of our challenge questions, I want to ask you do you think we have more muscles than the cow eye or less muscles? In the challenge question, we're actually going to do an exercise that indicates how our eyes move, even if we think we're staring. So I want you to take a look at this optical illusion and describe what you see in the optical illusion.

Welcome back. So we actually have six muscles. We have two additional muscles around our eyes. This allows us to roll our eyes when we're upset at our parents, and this allows us to have more movement in our eyes, compared to the cow. What did you see when you saw the optical illusion? Well, you probably saw that there were some slight movements of the particular boxes in the frame of reference. This indicates that our eye has voluntary eye moments, like the rolling of eyes, and also our eye has involuntary eye movements.

The reason why we have involuntary eye movements is that it prevents our cells in the back of our eye, the cells of the retina, from becoming too overly stimulated. So the slight movement of the eye will prevent them from becoming dull or overly stimulated, and allows us to continue to see an image around us.

If you look closely, you start to see some liquid seeping out of where I'm cutting. This liquid is called the aqueous humor. And the aqueous humor is important for providing nutrients to all the structures in the anterior portion of the eye-- so for the cornea. And as we'll see once I cut the cornea out, we'll see the iris and the other portions of the eye.

If you have issues with the cornea is what causes some of our refractive errors. If the cornea is too thick, it can cause nearsightedness, or myopia. Or if it's too thin, it can cause farsightedness, or hyperopia. The cornea is a transparent tissue that refracts most of the light that enters our eyes. Refractive errors, such as nearsightedness and farsightedness, are caused because of abnormalities within the cornea.

If the cornea bulges too much, or if the eyeball is slightly longer than normal, what happens is that light will actually refract, or bend, in front of the retina, causing what's called nearsightedness, or myopia. On the other hand, if the cornea is too thin, or if your eyeball is too short, what happens is light will refract, or bend, behind the retina, causing hyperopia, or farsightedness. These refractive errors can be corrected by using either contact lenses or glasses.

How many of you have heard of LASIK surgery? LASIK uses a UV laser to change the overall shape of the cornea. The process involves creating a corneal flap by using a small knife called a micro knife. The flap is folded back, and the laser beam then reshapes the cornea. Then the corneal flap is folded back in place. The laser can remove tenths of millimeters of corneal tissue, and is extremely precise. By reshaping the cornea, light can be refracted directly onto the retina, thereby improving vision.

The cornea is important for refraction, and also the lens is important for refraction. The cornea performs most of the refraction, because if you think about it, as light travels from an air medium to an aqueous environment, which is our eye, light will actually bend.

Think about the straw in the glass and how light bends the straw. This is exactly what's happening in our cornea. The light is being bending mostly in the cornea, and then the lens, which we'll see in a moment, is actually fine focusing the light onto the retina.

Using the light box, I will demonstrate how light is refracted onto the retina. When light strikes the cornea, it bends and converges on the back of the eye. The lens fine focuses the light onto the retina. We will see the lens in a few moments. The cornea of the eye is usually transparent.

Looking at the pictures--is this person nearsighted or farsighted? And how would you correct their vision with a corrective lens? Think about those questions, and work on this problem with your classmates.

So what did you think? If you have myopia, or nearsightedness, what happens is light focuses before the retina. And to correct for this issue, you would need a concave lens like this one. A concave lens has a thinner middle, and is wider on the edges. If you have hyperopia, or farsightedness, light rays would focus after the retina. In order to correct for this, you would need a convex lens, which is thicker in the middle and thinner on the edges. I hope you enjoyed that challenge.

Have you ever had the dreaded pink eye? Conjunctivitis, or pink eye, is the inflammation or infection of the conjunctiva, a transparent membrane that covers part of the eyelid and the interior part of the sclera, the white portion of our eyes. This membrane is important for providing blood supply to the outer surface of the eye.

Exposure to viruses, bacteria, allergens, or chemicals, can cause inflammation of the small blood vessels in the conjunctiva. The dilation of the small blood vessels in a conjunctiva causes these vessels to become more visible, and the eye appears to be pink or red. Hemorrhaging of the blood vessels can also cause the eye to appear red.

So now we've opened up the cornea. What you can see underneath is the iris and the pupil. So the iris is actually what gives our eyes their color. We have different color irises, like green, blue, brown. Mostly for cows, they have brown or black irises. And the pupil is actually the hole in which the light goes through.

Now the pupil, if you've noticed, can change shape depending on how much light it's exposed to. In environments of low levels of light, usually the pupil expands. And in environments of high intensity light, the pupil will actually contract and get smaller.

If you take a flashlight and you shine it into one eye but not the other eye, both pupils should contract. So I'm going to demonstrate this on Lisa. So again, if we take a flashlight and we shine it into one eye, both pupils will actually contract and get smaller, because of the brightness of the light. Doctors use this as a diagnostic tool to check to see if there's damage in your optic nerve, your brain stem, or also for the use of certain drugs. Try this with your partner in the classroom.

Now what we'll do is we'll cut around the iris to expose the lens. The lens is the white portion that you see behind the pupil. So the pupil is actually just the hole that's letting the light through, even though it looks black in our eyes. So as I cut around, you can see the lens sits in the middle of the eye.

And surrounding the lens-- I will show you later-- is actually the ciliary body. So for now, just pop the lens out. Now, usually, once again, our lenses are transparent and clear. But because of the preservatives that are used to prevent the eye from rotting, the lens is now cloudy.

I'm actually going to take out the vitreous humor. So the vitreous humor sits below the lens. And the vitreous humor helps maintain the eyeball shape. So if you can see, if I squeeze on the eyeball, it's usually pretty stable, and not flexible, and rigid.

But if we were to take out the vitreous humor, which is this jelly substance that's coming out, we now see that the eyeball is actually quite flexible. So the vitreous humor really helps to maintain the eyeball shape.

Now I'm going to cut into the eye so we can see that ciliary body that's surrounding the lens. So this black portion here is the ciliary body that helps the lens during accommodation. So the lens sits right in the middle of the ciliary body. And these muscles will contract in order to make the lens fatter to see things close up. And it's expanded when you need to see things that are far way.

Let's try this exercise. Close one eye. And now stare at an object about 20 feet away. Now it should be in focus. Now take your hand and place your finger right in front of your field of view, and focus on your finger. What's going on here? So you should see that now your eye is focused on your finger instead of the object that's 20 feet away.

This is what is called lens accommodation. The lens can accommodate depending on if you're focusing on an object that's close or an object that is far away. How does it do this? Well, surrounding the lens is something called the ciliary body. And this body of muscles, when they contract, actually causes the lens to get fatter, allowing for you to see up close, and changing the focal length of the eye. When the lens is actually elongated, it causes the eye to focus on things that are far away.

Often athletes, like baseball players and cricket players, perform these exercises to improve their reaction times to help adjust their eyes when a ball is traveling fast towards them. As the lens ages, and as we age, the lens becomes more rigid, and the muscles become more difficult to contract. This is why people usually require reading glasses or bifocals in order to see things up close.

Have you ever noticed that people have to actually hold the paper out in front of them in order to see the words on the page? This is a condition called presbyopia, and it usually happens to us after the age of 40, when the lens muscles and the lens itself starts to age. And it becomes more difficult for the lens to accommodate.

What if the lens was not transparent and it was opaque? What do you think would happen in this case? Take a few moments to discuss with your classmates what you think would happen. And we'll be back in a moment.

Welcome back. And now I'm going to introduce you to a professor of biology here at MIT, Professor Johnathan King. He studies proteins called crystallins that are in our eye lens. And he's going to explain what happens when our eye lens goes from being transparent to opaque.

The lens is actually one of the very few transparent tissues in the human body. The rest of the body absorbs light. The lens has to be transparent, because, of course, the lens transmits light to the retina. And if your brain is going to recognize the image, know what you're seeing, it has to receive light from the environment.

The lens has to stay clear all your life, from the time you're born until older age, until my age. It's packed full of proteins. It's a little bit like the white of an egg. Just like when you cook an egg, the proteins unfold and they stick together, and they stop transmitting light. You can get damage to the proteins in your lens, and they stick together and form big aggregates, we call them. And those scatter light. And you no longer can see clearly.

In older people, this is a very, very serious problems. In fact, cataracts are the leading cause of blindness in the world population. So we are spending our time-- we study these proteins in the test tube often, sometimes in animals, to try to understand why do they go wrong.

You should be aware of the fact that your lens is somewhat more delicate than you might otherwise think. And make sure when you're out in the bright sun, you're wearing sunglasses. Watch out when you're in the laboratory for lasers and other forms of intense light. Don't stare at the sun. And be good to your lens, and you'll be able to see all your life.

Have you ever wondered how someone with an eye disease views the world? Well let's mimic cataract, for example. And it's very simple to do. All you have to do is take a set of goggles, and wrap wax paper around those goggles. Then place them on your head.

How has that changed your vision? Glaucoma is a name for a set of diseases that can cause damage to the optic nerve. Some types of glaucoma are caused because of an increase in pressure in your eye, called intraocular pressure. This can cause parts of the optic nerve to pinch and lead to damage of those cells in the optic nerve. It can become so severe that it can lead to blindness.

For your last challenge, you will observe your blind spot. And then we'll do a set of exercise to see why it's so difficult for you to even find your blind spot.

Did you find your blind spot? It should have been about 20 centimeters from your face. So why is it so difficult to find our blind spot? Did you notice that when you looked at the blue line, it looked continuous, instead of segmented? Well, what a brain does is it uses the surrounding information to fill in our blind spot. And that's why we saw the line was actually continuous, and also the reason why we saw that the red circle was actually a blue circle.

Well, remember to take care of your eyes, you must protect them from injury, get regular eye exams, and definitely wear your sunglasses when you go out. Thank you.

Well I hope that you enjoyed the lesson that I've created to talk about eye function and eye disease. I basically put a little twist on the traditional eye dissection, because I've found that a lot of classes dissect the eye. And they talk about the structures and functions. But they don't talk often enough about eye diseases that affect those structures.

So I thought that by putting the eye diseases and the function together, this would help students to remember more about why it's important to have particular components of the eye. I hope you enjoyed the different types of the eye in the animal kingdom section.

That's something new that we added to the lesson to hopefully engage students, and to start them thinking about the evolution of the eye. We don't specifically talk about the evolution of the eye in this lesson. But that's something you could definitely add on if you're interested in doing so. And you can often talk about why animals would have needed particular parts of the eye in order to adapt to their environments.

So this lesson can be used-- if you have eyes available to dissect, it would be very useful to do it along with the lesson. But if you don't have eyes available to you, I think also it still would be useful for students to see the different parts the eye. You can obtain eyes from possibly a local butcher. But if you do not have a local butcher to obtain the eyes, you can also order them online through Carolina and other biological supply companies.

In thinking about the challenge questions, I thought about what would engage students? What would make them think a little bit more about the eye? So the first question was sort of a fun activity to think about what animals see. And that can be done by splitting up students into pairs, or in groups of four. And then have them match according to their prior knowledge first. And then hopefully, by going through the lesson, they can make a more educated guess on what animals see.

For the second challenge, I really wanted to tap into the misconceptions that some students have about vision. We often find that, in asking students how vision works, they think that something actually shoots out from your eyes, or what we like to call the Superman effect. And so the mirror exercise hopefully helps them think about how light is actually bouncing off of objects, and then going into our eyes, and going through an entire process in order for us to see.

The other challenge questions can be done in groups of two or four, or can be done alone. For example, the optical illusion could be done just individually. And that exercise is really trying to show that we have these involuntary eye movements that we’re not always aware of.

The involuntary eye movements are important because we do not we want our photoreceptors to become over-adapted or over-stimulated. If it were to do that then our image would actually go blank. So our eyes just slightly move around in order to allow the photoreceptors to continue to be slightly turned on and respond.

The fourth challenge, hopefully, got students to think about eye diseases, and what someone with an eye disease would see, and how they would view their world. So in that example, I used the cataract goggles. But there's lots of other different goggles that you can make: glaucoma goggles, age-related macular degeneration goggles, retinitis pigmentosa goggles. There's lots of different things that, just by looking online, and seeing how scientists predict a person like that sees, and then kind of modeling it in any way that you feel is helpful.

The last challenge is probably my favorite one. It really goes to seeing a structure in the eye, the blind spot, and where the optic nerve is coming out, and then looking it. Being able to find it visually, I think, is very interesting. And those exercises are lots of fun to do. It is basically showing where your blind spot is located.

What we found for most teachers and students is that it's really fascinating to see that, to actually recognize that you have a blind spot. And then the other exercises in that challenge question just really show that the brain is filling in a lot of the information to help us not be able to recognize that we have a blind spot. So the brain is very, very powerful in this visual processing that we have.

And I hope you enjoyed the lesson. Feel free to give comments and feedback on anything that you've seen. And enjoy.