McPherson Eye Research Institute
UNIVERSITY OF WISCONSIN–MADISON

Instructor's Guide to Comparative Ocular Anatomy: **In the Dark and in the Light**
March 2025

Slide 1. Title page. Personalize with speaker's name and date. Introduce yourself.

Slide 2. Our learning goal
Today we are going to talk about the differences in eyeball anatomy between animals that are mostly awake during the day, and those that are awake at night. I know you've been studying the human and bovine eye, so this will also review some information you've already learned. As we go through the material, you'll fill out your worksheets, and I'll also ask you lots of questions.

Slide 3. Comparative Ocular Pathology Lab of Wisconsin
When veterinarians see a patient-- a dog, or a cat, or a horse, or cow-- with an eye problem, if they don't know what it is, they will remove the eyeball and send it to the Comparative Ocular Pathology Lab of Wisconsin. Can you guess what kind of animal's eye this one is? [**It's a horse**!] In the lab, the eyeball is trimmed of fat and muscle. Then the eyeball is "fixed" in a preservative, stained and sliced very thinly, so we can look at a section of the eyeball that's only one cell thick. How many of you have viewed a slide through a microscope? The pink stain allows us to see structures we otherwise would not be able to see.

Slide 4. Picture of a dog head
All vertebrates, or animals with backbones, (particularly mammals, birds, amphibians, fish) have the same basic structures in their eyes.
And these structures work together to achieve the same objective – to capture light and provide the animal with information about its environment.
The slides that follow are of eyes from animals that died from disease, not related to the eye, and whose body was donated to science. These are normal eyes.

Slide 5. The Normal Dog Eye
Using this cross-section of The Normal Dog Eye, let's review some of the structures you have studied: Cornea, Sclera, Iris, Lens, Vitreous, Retina, Optic Nerve.

Now that we've reviewed the anatomy, let's talk about the function of each of these parts of the eye.

Cornea – an outer covering that protects the front of the eye, lets light in, is responsible for ~70% of refraction (bending) of light, as light goes from air into the curved corneal tissue.
Sclera: protection, holds the eye together, keeps it rigid
Iris: regulates the amount of light entering the eye
Lens: focuses light onto the retina; about 1/3 of the refraction occurs in the lens
Vitreous: allows light to pass through, keeps eye shape, holds retina in place
Retina: converts light energy into electrical energy which can be analyzed by the brain
Optic Nerve: formed from axons from ganglion cells, transmits signals from the retina to the brain. This is where the blind spot is.

Slide 6. Now let's look at diagrams of eyes from animals that are active at night (nocturnal), in bright daylight (diurnal), and those that are irregular in their waking and sleeping periods (arhythmic). [The behavior of animals awake at dawn and dusk is *crepuscular*.] In fact, most mammals are arhythmic. When we look at eyes from different species, they all have the same components -- lens, cornea, retina, sclera, etc.

Slide 7. Why these Differences? Given that all of the eyes have the same objective – to capture light images -- what differences do you see?

Complete the table with the differences you see in the diagrams of eyes from animals with these three types of eyes (Figure 71):

	Nocturnal	Arhythmic	Diurnal
Relative size of cornea			
Lens shape (all are convex)			
Lens size			
Location of the center of the lens			

Key:

	Nocturnal	Arhythmic	Diurnal
Relative size of cornea	Large	Medium	Small
Lens shape (all are convex)	Rounder	Oval/almond	Flatter
Lens size	Larger	Medium	Smaller
Location of the center of the lens	Toward the retina	More toward the center of the eye	Closer to the cornea

With its large cornea and round lens, the **nocturnal** eye collects all available light for a **small, low-resolution image** on the retina.

The **diurnal eye's smaller cornea and smaller, forward-placed lens** limits the amount of bright light entering the eye and focuses a **large, sharp, detailed image** onto the retina. The arhythmic eye is in-between, allowing activity in a mixture of light environments. The monkey shown is a *Rhesus macaque*.

Slide 8. Let's take a closer look at the retina. Looking at higher magnification of cross-sections of the retina, we can see that it is composed of many layers.

Slide 9. Remember that we saw that the retina is composed of several layers of cells. Here are diagrams of the retinas of nocturnal and diurnal animals. The ganglion layer is at the top (towards the front of the eye). **Ganglion Cells** are nerve cells that transmit electrical information in the form of impulses to the brain.
The photoreceptor layer contains the cells that respond to light and send the signal to the ganglion cells. There are two types of photoreceptors. Rods are long and thin. Cones are shorter and wider. Each photoreceptor has a nucleus.

In addition to differences in the lens and cornea, nocturnal and diurnal animals also have differences in their retinas. In particular, we see differences in the relative numbers of photoreceptors and their nuclei between nocturnal and diurnal eyes.

Complete the table with the differences you note between the nocturnal and diurnal retinas (Figure 72).
Ganglion Cells: nerve cells that transmit electrical information in the form of impulses to the brain.
Rods: very light sensitive photoreceptors, are used in situations with very small amounts of light; these don't decode color. They are narrow, so many more fit an area of the retina than the cones will.
Cones: decode color, need more light to "fire", are larger and take up more space.

	Nocturnal	Diurnal
Main kind of photoreceptors		
Number of photoreceptor nuclei		
Number of ganglion cells		

Key:

	Nocturnal	Diurnal
Main kind of photoreceptors	Rods	Cones
Number of photoreceptor nuclei	More numerous	Relatively decreased
Number of ganglion cells	Fewer	Many more

Slides 10 - 12. Now let's look at the cross sections of two squirrel retinas that were viewed through a microscope. Pay attention to the prevalent photoreceptors, the number of photoreceptor nuclei and the number of ganglion cells.
Which animal has more ganglion cells? Which animal has more photoreceptor nuclei? If it has more photoreceptor nuclei, then it must have more rods and cones, too. So, which animal is nocturnal, and which is diurnal?

Key:

Flying squirrel	Nocturnal
Ground squirrel	Diurnal

Answer: Flying squirrel is nocturnal, and ground squirrel is diurnal. In this lesson, we're focusing on the two ends of the behavioral spectrum, nocturnal and diurnal.

Slide 13. The Nocturnal Mammal (Springhaas): Review relatively large cornea, large lens, few ganglion cells, and many photoreceptor nuclei. One species lives in South Africa. The other lives in East Africa.

Slide 14. The Diurnal Mammal (Orangutan) – Note the Fovea, which is the portion of the retina of most acute vision. It is full of cones. Review smaller cornea, forward positioned and smaller lens. Microscopic images of the retina show the pit at the fovea with many cones. Ganglion cells are on either side of the pit. The fovea is a feature in primate eyes, as well as some raptors and some hummingbirds.

Slide 15. A comparison of nocturnal (Fruit Bat), arhythmic (Pet Dog) & diurnal (Horse) eyes. Review characteristics of each.
Which is the nocturnal eye? Which is the diurnal eye? The arhythmic?

Slides 16, 18, 20. Unknowns – Identify whether the eye is from a nocturnal animal or a diurnal animal. Record the evidence for your identification:

	Nocturnal or diurnal?	Evidence
Slide 16		
Slide 18		
Slide 20		

Key:

	Nocturnal or diurnal?	Evidence
Slide 16 Cheetah	Diurnal	Flattened lens placed more toward the cornea. The black, umbrella-like lines are the ciliary processes, which hold the lens in place.
Slide 18 Red-tailed Hawk	Diurnal	Flattened lens positioned toward cornea, relatively small cornea. The corrugated structure that emerges from the retina is the pecten. It provides nutrients and oxygen for the retina. The black stripes at the top of the vitreous are ciliary processes, which hold the lens in place.
Slide 20 Leopard cat	Nocturnal	Relatively large cornea, large round lens positioned more toward retina

Slide 22. Here are Anna Shen's examples of what humans (diurnal) and cats (nocturnal) see in daylight. What differences are there?
Slide 23. Cat Vison night simulation by Anna Shen. Note the differences.

Slide 24. Concluding Question [which is on the student worksheet. Every other student should answer this question for the human eye. The other half will answer it for the bovine eye. As students have this question on the worksheet, advance to the next slide (#24) to project images of the eyes.]: You have recently completed the study of the human eye and dissection of the bovine eye. Using what you've learned in today's presentation,

a) Identify whether the human (or bovine) eye is nocturnal, arhythmic or diurnal.
b) Give at least 3 pieces of evidence for your identification.
c) What advantages (or disadvantages) does this structure have for human (or bovine) vision?
[Display Slide "25".]

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Slide 25. Human eye and Bovine eye images.
If time permits, students should share their answers with an adjacent student who answered the Concluding Question for the other eye.

Answers to Concluding Question (Slide "24"): The human eye is a diurnal eye. It has a relatively small cornea, and a flatter lens, with the center of the lens positioned more toward the cornea. These adaptations maximize the size of the image falling onto the center of the retina (and they work best in abundant light). It also has a well-developed fovea that perceives fine detail, with a high concentration of cone cells. The human eye is not very good at gathering light in low light situations.

The bovine eye is an arhythmic eye (as are most mammals). It has a relatively larger cornea and a somewhat rounder lens, positioned further toward the retina. We don't see a foveal pit in the bovine retina. In the dissection, we observed the shiny blue tapetum lucidum, which enhances vision in low light.

Slide 26. References.
Please make sure your name is on your sheet, that your entries are complete and legible, and hand it in on your way out. Thank you for your attention and your participation.

Slide 27. Image acknowledgements
Slide 27. Questions?

EXIT SLIP: Ask students to complete the
3 (things I learned today),
2 (things to improve) and
1 (question I still have) before they leave.
Dr. Dick Dubielzig will read their questions and send the answers to their teacher.