NIGHT VISION AND DRIVING

Biology

SUMMARY
Students investigate how vision differs in different light levels. They complete a brief reading about the anatomy and physiology of the eye, and explain the findings of their investigation in terms of what they read.

CURRICULAR PLACEMENT
This activity can be used when studying the anatomy of the eye.

NEXT GENERATION SCIENCE STANDARDS
This unit will begin to build the knowledge necessary to meet the following NGSS performance expectations:

- HS-LS1-2

Common Core State Standards: English Language Arts
- RST.9-10.3/11-12.3
- WHST.9-10.2/11-12.2
- WHST.9-10.2.A-F/11-12.2A-E
- WHST.11-12.4
- WHST.11-12.5

OBJECTIVES
- Design and conduct an investigation to compare vision in different light levels
- Learn about the anatomy and physiology of the eye, and use this knowledge to explain the results of their investigation

MATERIALS NEEDED
- Copies of Reproducible Master 1: Learner’s Permit
- Copies of Reproducible Master 2: Investigating Night Vision
Night Vision and Driving

- Copies of Reproducible Master 3: Lab Report Rubric
- Copies of Reproducible Master 4: How the Eye Works
- Tape measures
- Images and objects for testing participants’ vision, such as eye charts, representations of things likely to be seen on roads (e.g., illustrations of road signs, photographs of roadside objects), or materials for making such representations (e.g., colored paper and scissors)
- Optional: Materials to make posters

CLASSROOM ACTIVITY

1. Access students’ prior knowledge about the eye and vision.

   If students have already studied the eye, ask for a volunteer to summarize what the class has learned. If not, prompt students by asking about their experiences with the following:
   - Eye tests
   - Activities demonstrating the presence of a blind spot in the eye
   - Wearing glasses or contact lenses (why they are needed and how they work)
   - Adjusting to a change from light to dark

2. Distribute Reproducible Master 1: Learner’s Permit to students. Point out that many states don’t allow teens with learner’s permits to drive at night. Ask students, “Why might this be the case? What is different about driving at night?”

3. Ask students, “Do you think this rule is fair? Why or why not?”

   Students may think that young people are being singled out as not being capable of driving at night. Discuss why this might be the case.

Teacher Tip

Student teams need to be in environments where they can set the light level as needed for their investigations, and this will be difficult with everyone in the same classroom or laboratory. Are there utility rooms, storage areas, or other rooms available near the classroom so that some student teams can work in different locations? If not, some out-of-class time is likely to be needed for this activity.
4. Tell students that they are going to design and conduct an experiment to investigate how the ability to see varies with the amount of light available. After they have completed their investigations, they’ll read about the eye and try to explain their results in terms of what’s known about how the eye works.

Ask students for their ideas for a possible investigation. Be sure to give them time to think before expecting them to answer. Try to elicit some of the factors listed on RM 1:

- Different light levels
- What types of things you see while driving
- Distance
- Simulated driving conditions


Let students know what resources will be available to them—such as vision test charts, photographs of road signs, or other images and objects to look at under different light levels—and where they will conduct their investigations.

Have students work in teams of three or four to come up with a procedure for investigating a question related to nighttime (or dusk/dawn) vision. Remind them that RM 2 includes suggestions and tips for designing an investigation.

6. If needed, review students’ proposed procedures.

If students have experience with developing their own experimental procedures, they may be able to conduct their investigations without review. If you think some prior review is needed, here are two options:

- Have teams submit their procedures to the teacher for review before they carry out their investigations.
- Have teams pair-share—each team meets with another team to explain its procedure and get feedback. Teams then revise their procedures according to the feedback they received.
7. Have student teams carry out their investigations (whether in or outside of class) and keep thorough records of their results.

8. Distribute *Reproducible Master 3: Lab Report Rubric* to each student. Explain that their lab reports will be assessed using this rubric. Have each student write a lab report that includes the following sections:
   - Hypothesis/research question
   - Procedure
   - Results

9. Distribute *Reproducible Master 4: How the Eye Works* and have students read it. Have students add a discussion section to their lab reports, interpreting their results in light of the information in RM 4.

10. Conclude the activity by having some or all student teams report their results to the class or by having them prepare posters for a poster session or display at school.
Did You Know . . .
If you are going to drive at night, here are some tips for helping you improve your night vision and drive safely:

- **Wait a minute.** Or two. It takes a few minutes for your pupils to dilate and let in the maximum amount of light. Give your eyes a chance to adjust to the darkness before you start driving.
- **Keep it dark inside.** Having lights on inside the car will make it more difficult to see. Turn off the interior lights, and focus on keeping your eyes on the road.
- **Know where to look.** When an oncoming vehicle shines light directly into your eyes, look down and to the right until the vehicle goes by. You'll still be able to see the vehicles around you with your peripheral vision, but the glare won’t bother you as much.
- **Adjust your mirror.** Use your mirror’s “night” setting to reduce reflected glare. Usually this means flipping a small lever at the bottom of the mirror.
- **Use your lights courteously.** Avoid using your high beams when you see oncoming vehicles. This will make the roads safer for everyone!
- **Slow down.** Give yourself more time to react if something happens on the road in front of you.
- **Take breaks.** If you are driving at night, make sure to take frequent breaks and give your eyes a chance to recover.
- **Clean it up.** Debris on your windshield, mirrors, or headlights can make it difficult to see, especially at night. Make cleaning the glass and mirrors inside and outside of your vehicle part of your regular routine.

RESOURCES

Discovery Fit & Health. (January 21, 2009). *At Night, Why Does It Take My Eyes Several Minutes to Get Used to Darkness?* Available at health.howstuffworks.com/human-body/systems/eye/eyes-adjust-darkness.htm

Teens in the Driver Seat. (2016). *Nighttime and Drowsy Driving.* Available at www.t-driver.com/know-the-risks/high-school/driving-at-night/
Learner’s Permit

Why do so many states (49 out of 50!) restrict nighttime driving for teens?
Because driving at night is more dangerous, especially for teens!

- The fatal crash rate (crashes per mile driven) for 16-year-olds is almost twice as high at night as it is during the day.¹
- The rate of nighttime fatal passenger vehicle crash involvements per 100 million miles traveled in 2008 was almost 4 times higher for male drivers ages 16–19 than for male drivers ages 30–59. The corresponding comparison for females yields almost 3 times the rate.²
- In 2002, 41 percent of teenagers who died in crashes died between 9 p.m. and 6 a.m., even though night driving accounted for only about 15 percent of the miles driven by teens.³
- Teenage motor vehicle crash deaths in 2012 occurred most frequently from 9:00 p.m. to midnight (17 percent)⁴

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FOCUS ON SAFE NIGHTTIME DRIVING


At night your eyes are set up for light gathering and movement detection, as opposed to looking for fine details and colors during the day. . . . The pupils get larger and, like a camera set on a large aperture, you don’t have a very good depth of field . . . Reactions are much slower at night, and we don’t see things as quickly because of the way our eyes process images.

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FOR SOME, DAYLIGHT SAVINGS MEANS ANOTHER HOUR OF TREACHEROUS NIGHT DRIVING

Connecticut Post, ctpost.com, November 4, 2011

Because drivers can’t see as well at night, even with the aid of headlights they’re more apt to make dangerous mistakes, such as entering a highway via the exit ramp. Darkness may compromise or limit depth perception, color recognition, peripheral vision, and visual acuity. Twilight, as the dusk is first falling, is the most difficult time to drive because the driver’s eyes are adapting to light changes.

Deer make night driving on suburban roads dangerous

Investigating Night Vision

To better understand how driving at night can be challenging, you’re going to design and report on an investigation of how your vision changes in different light levels.

BACKGROUND INFORMATION: VISION IN DIFFERENT LIGHT LEVELS

In your investigation, you should compare vision in at least two of the following light levels:

- **Photopic**: Vision in well-lit conditions, such as daylight or bright artificial light.
- **Scotopic**: Vision in dim light, such as a moonless night without any artificial light source.
- **Mesopic**: Vision in light levels between scotopic and photopic. In most nighttime driving situations, there is enough light for mesopic vision rather than photopic vision.

Your ability to see color, shape, and movement are different at each light level. How well you see objects directly in front of you as compared to those off to the side (peripheral vision) also changes in different light levels.

DESIGNING THE INVESTIGATION: FACTORS TO CONSIDER

How to vary light levels

There’s a good chance that you won’t be able to conduct your investigation while driving in a car on a road in different light levels. (In fact, that’s probably not very safe!) So, how will you simulate the different conditions? You might do all of it in the same indoor location, with lamps to change the amount of light. Another option is to do your investigation outdoors, some of it during the day and some at night.

Distance

If an object is close enough, it’s usually recognizable even in very low lighting. Consider starting with your objects at a great distance away, and then bringing them closer until they are recognized. You can then compare recognition distance under different light levels.
Types of things you see while driving
The eye has the ability to recognize colors, shapes (including letters, numbers, and physical objects), movement, distance/depth perception, and more. Think about this in terms of the things you need to see while driving:

- Different categories of road signs and the text on them
- The shapes, sizes, and distances of cars
- People
- Moving and stationary obstacles

For example, you might investigate how reading street signs differs in different light levels. (This is important because if you are peering at street signs, trying to decipher them, rather than focusing on the road, that’s going to affect your ability to drive safely.)

What will you look at?
You may not be able to use real road features in your investigation. So, think about what you might use to test someone’s ability to read a sign at different distances (and remember that once they’ve read it under one set of conditions and they know what it says, you’ll need to use something slightly different under the other set of experimental conditions). You might use paper cutouts of different shapes as a model to test a person’s ability to tell the difference between a car and a large shrub at different distances and light levels. You could also use toy cars to test how easily a person can recognize an object’s direction and speed of movement in different light levels.

WRITING YOUR LAB REPORT
Your report should include the following sections:

- Hypothesis/research question
- Procedure
- Results
- Discussion

Note: In the discussion section, you will explain your results based on the information you read in Reproducible Master 4: How the Eye Works, which you will receive after completing your investigation.
## Lab Report Rubric

<table>
<thead>
<tr>
<th>Expectations</th>
<th>4 Exceeds</th>
<th>3 Meets</th>
<th>2 Approaches</th>
<th>1 Below</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduces the topic clearly</td>
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<tr>
<td>Introduces the topic and organizes ideas, concepts, and information to make important connections and distinctions; includes formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aid in comprehension</td>
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<tr>
<td>Develops the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, or other information and examples appropriate to the audience's knowledge of the topic</td>
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<tr>
<td>Uses varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among ideas and concepts</td>
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<tr>
<td>Uses precise language and domain-specific vocabulary to explain the topic</td>
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<tr>
<td>Establishes and maintains a formal style and objective tone while attending to the norms and conventions of the discipline in which the student is writing</td>
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<tr>
<td>Provides a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic)</td>
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<tr>
<td>Produces clear and coherent writing; the development, organization, and style are appropriate to the task, purpose, and audience</td>
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<td>Demonstrates a very good command of the conventions of standard written English</td>
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</table>
How the Eye Works

To understand some of the challenges of driving at night, you need to know how the eye works—especially how the light-sensitive cells in the retina function.

PARTS OF THE EYE

- **Cornea**: A transparent covering on the front of the eye.
- **Pupil**: The opening in the center of the iris, through which light passes into the eye.
- **Iris**: A ring of muscle that contracts and expands to control the size of the pupil.
- **Lens**: The part of the eye behind the pupil that focuses light on the retina.
- **Retina**: A thin layer on the inside of the eye that contains several types of nerve cells.
- **Optic nerve**: A bundle of axons transmitting impulses from the retina to the brain.

**Photoreceptor**: A nerve cell that is sensitive to light. The human retina has two types of photoreceptors, called rods and cones, described in more detail on the next page. Cones are more concentrated toward the center of the retina, while rods are more concentrated at the periphery.

**Fovea centralis**: An area of the retina where cones are highly concentrated and there are no rods.

**Blind spot**: A place on the retina that is not sensitive to light, because there are no rods or cones there. The blind spot (also called the optic disk) is where the optic nerve leaves the retina. Most of the time, we are not aware of the blind spot, because the brain fills in an image based on what it expects to see.

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PHOTORECEPTORS OF THE RETINA: RODS AND CONES

The differences between nighttime vision and daytime vision are mostly due to the differences between the two types of photoreceptors in the eye: rods and cones.

<table>
<thead>
<tr>
<th>Night Vision Notes</th>
<th>Rods</th>
<th>Cones</th>
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<tbody>
<tr>
<td>You see objects in shades of gray, making it harder to recognize these objects and to distinguish them from the background.</td>
<td>Can respond to very low light levels</td>
<td>Respond best in daylight or other high-light levels</td>
</tr>
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<td>It is harder for you to recognize that objects are moving and to estimate their speed.</td>
<td>Respond more slowly than cones, making motion detection less accurate.</td>
<td>Respond more quickly than rods, enabling more accurate motion detection.</td>
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<td>Objects are blurrier, making it harder for you to recognize their shape and to distinguish them from the background.</td>
<td>Low</td>
<td>High</td>
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<td>In very low light, your peripheral vision may be better than your central vision. When there is almost no light, you may not be able to see a small object that is almost directly in front of you, because the light from this object falls on your fovea, where there are no rods.</td>
<td>Toward the periphery (front) of the retina; there are no rods in the fovea.</td>
<td>Concentrated at the fovea (center of the retina).</td>
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<th>Image sharpness (visual acuity)</th>
<th>Distribution</th>
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<td>Black-and-white vision</td>
<td>About 120 million in each eye</td>
<td>Can respond to very low light levels</td>
<td>Respond more slowly than cones, making motion detection less accurate</td>
<td>Low</td>
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<td>Cones</td>
<td>Color vision, contrast</td>
<td>About 6 million in each eye</td>
<td>Respond best in daylight or other high-light levels</td>
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