ECOS
Ecologists Educators and Schools: Partners in GK-12 Education

ECOS Inquiry

1. Contributor's Name: Alison Perkins

2. Name of Inquiry: What in the world do insects see?

3. Goals and Objectives:

a. Inquiry Questions: Do insects see the same way humans see? What do insects see? Why might insect and human eyes see differently?

b. Ecological Theme(s): Our understanding of ecological relationships is affected by our perceptions of the world.

c. General Goal: To help students understand the limits of scientific knowledge.

d. Specific Objectives:

Academic: Different animals have different kinds of eyes; eyes that aren't necessarily like humans' eyes and don't necessarily see what humans see.

Experimental: Students explore insect vision and devise a simple observational experiment to use with a scanning electron microscope.

Procedural/technical: Learning to use magnifying glass and learning about scanning electron microscopes and how they are used in science.

Social: Students work as part of a team to collaborate on hypotheses about variation in insect eyes.

Communication: Students make a formal presentation of their ideas for using the scanning electron microscope to explore eyes of different insects.

e. Grade Level: 1-2

f. Duration/Time Required: 7 parts (4 optional), 10-30 minutes each

→ Preparation requires contacting (http://emtrix.dbs.umt.edu) Dr. Bill Granath or Roy Pescador, Electron Microscopy Technician (roy.pescador@mso.umt.edu) at EMtrix at the University of Montana about preparing scanning electron microscope (SEM) images (currently, the turnaround time for sample processing to results take approximately **1 week** for SEM samples), Jen Marangelo of ECOS to borrow mounts of bees, dragonflies, beetles, and other insects, assembling Powerpoint images of insect eyes and ultra-violet images of flowers the way bees see them (or computer with Internet access)

→ Implementing exercise during class – **Pre-investigation:** eye exploration (30 minutes); **Investigation:** outside observation (20 minutes); insect eye observations (20 minutes); **Building on it – Day 1:** small group work (20 minutes), presentations (30 minutes); **Day 2** (*one week later*): SEM (30 minutes), wrap up (10 minutes)

→ Assessment – in class

4. Ecological and Science Context:

Background (for Teachers):

Human eyes are adaptations that influence our perception of the world. We have binocular vision, which not only provides a larger field of view than a single eye, it allows for a great deal of depth perception. Our eyes are also structured to enhance the images before us. Binocular vision makes seeing faint objects easier, but the structure of our eyes affects how we see, too. For example, we have light receptors and dark receptors, and the arrangement of these receptors *enhances* our image of the edges of objects. Our eyes also are able to detect different wavelengths of light, so we can "see" color. Objects don't give off color, but they do reflect some wavelengths and absorb others. Our eyes can distinguish the wavelengths that are reflected.

The point is not to get too bogged down with the details, but to remember that our eyes are adaptations to our environment. Insects live in very different environments and their evolutionary history is very different from humans. We can only see what we see – we can't see what insects see to boot. We can make indirect observations and inferences about insect sight, however, and these types of evidence are active areas of scientific research. With this inquiry, the idea is to get students to separate themselves and what they see with what they can know about what insects see, to really get them to start thinking about the nature of scientific evidence, and perhaps even how (and why) some of its conclusions are tentative.

Optical Illusions: Scientists are still exploring what causes us to see optical illusions and visual phenomena; many are still without explanation. According to Michael Bach (71 Optical Illusions & Visual Phenomena, http://www.michaelbach.de/ot/) **"***Optical illusion* sounds pejorative, as if exposing a malfunction of the visual system. Rather, I view these phenomena as bringing out particular good adaptations of our visual system to *standard* viewing situations. These adaptations are "hard-wired" in our brains, and thus under some artificial manipulations can cause inappropriate interpretations of the visual scene.**"**

The black and white illusions are caused by the organization and stimulation of light and dark receptors in our eyes. The Hermann grid illusion (Figure 1) is a great example of how scientists are actively investigating how we see – the cause of may not be a result of how light and dark receptors are arranged in our retinas, as originally proposed. So, look to see if you see gray "smudges" where the white lines cross in your peripheral vision (Figure 1). Then see if your brain can determine whether the horizontal lines in Figure 2 are straight lines or curved. The orange bricks look darker with a black background and lighter when the white background is applied. This illusion takes our minds from seeing the colors as contrasting to seeing the colors be assimilated – which are completely opposite effects. Contrast and assimilation are what enable us to see millions of colors in a world with only 400 wavelengths of visible light.

The Structure of Insect Eyes: Insect eyes look very different than human eyes. This structural difference is obvious when looking at a dragonfly's eyes. Insect eyes have many facets. Each facet represents the end of an ommatidium. Each ommatidium is an independent unit. Evidence suggests that these compound eyes do not provide high image resolution compared with our eyes. They do give a much larger view angle, however, and the eyes can detect fast movement (try to sneak up a fly!). Some insects have to be able to see with high resolution, if they are predators for example, and scientists have found that some portions of their eyes may yield particularly acute vision. The coolest part is that as scientists gain greater access to the world of insect vision through technology such as Scanning Electron Microscopes (SEM), they are discovering new information and modifying and developing their theories about how insects see.

Pollination: Technically, pollination is the transfer of male gametes (pollen grains) to female gametes (ovules). Pollination is important to humans, and especially agricultural crops, because many of our foods (fruits, nuts, seeds) will not develop if they are not pollinated. Bees and butterflies are the most well-known pollinators, but plants can be pollinated by many other types of insects (beetles, wasps, and flies), and also birds and even bats! Flowers and pollinators have a tight-nit co-evolutionary history; the nectar in flowers attracts pollinators which then can serve to move the pollen grains to other flowers, but the nectar and pollen also are important foods for the pollinators.

So, scientists believe that insects may have some adaptations related to how they find that find flowers and food. They have done some interesting work with light wavelengths and found that flowers look very different under ultraviolet light than they do under visible light (the wavelengths humans can perceive). They have evidence that insects can perceive the ultraviolet light patterns reflected from the flowers, and that the flowers' patterns somehow provide a cue to the location of the nectar. Again, the specifics are less important than the understanding that knowing what another animal sees (or for that matter what another person sees) is very difficult given our limitations (both physical and technological). Scientists have to use indirect evidence, and they are actively developing ideas and testing them; some may be valid, supported by more and more evidence, and others may be discarded. Students can develop their own ideas about how insects find their nectar and pollen foods and make predictions about the kinds of eyes they would expect a pollinator to have.

5. Motivation and Incentive for Learning:

Students get to go outside and explore the world of insects. In addition, they get to virtually use technology (a scanning electron microscope) to enhance their powers of observation.

6. Vocabulary:

binocular vision – vision in which both eyes are used together. Our brains process images causing binocular *fusion*, in which a single image is seen despite each eye's having its own image of any object.

ommatidium – one unit of the compound eye of insects, each providing an image. Insect eyes may have many thousands of ommatidia (plural); the image they ultimately see comes from all those different inputs.

7. Safety Information:

Children should not approach bees, wasps, and other stinging insects.

8. Materials List (including any handouts or transparency masters):

toilet paper tubes or thick white paper rolled into tubes (2 per team)
3”x3” cutouts of magazine pictures (2 per team)
handouts of optical illusions
transparencies / Powerpoint presentation

- flower images in regular and ultraviolet light from the Internet (one source may be http://www.naturfotograf.com/UV_flowers_list.html, but these pictures are copyright protected and cannot be reproduced here)
- SEM images of fly eyes from EMtrix (http://emtrix.dbs.umt.edu/Main.htm – some images available at the end of this inquiry)

magnifying jars (or magnifying glasses and containers)
sweep nets/butterfly nets
insect mounts
computer with Internet access (for Building on it with the SEM – optional)

9. Methods/Procedure for students:

a. Pre-investigation work: The inside investigation can be set up in workstations instead of progressing through each exercise individually.

First, talk to the students about the way humans see. We use our binocular vision extensively. For playing sports to driving cars to appreciating art, we rely on the fusion of the images our two eyes receive. Give each team two cardboard (or paper) tubes and two pictures. Have each student hold one tube up to their own eye and cover their other eye with their hand. Students should find an object on the wall to focus on, then slowly move their hand away from their covered eye. Have them stop when they can see the object on the wall “through” their hand. Then have them move their hand away from their face far enough that both eyes see the hand.

Next, working in teams, have students place the two pictures side by side in front of them. Taking turns with both tubes, students should hold one tube up to each eye moving the distant ends apart and then together slowly. They should look at the pictures and describe what they see. Are they seeing two images? If they look long enough through the tubes when they are far apart, does one image seem to dominate? How close do the tubes need to be to see only one image? Get them to think about what their brains are seeing versus what is really there.

Still working in teams, have one student be the “fly” and the other the “cheese”. The “fly” needs to close their eyes while the “cheese” goes and stands somewhere in the room. The “fly” needs to put the tubes up to his/her eyes before opening them – making sure the tubes are spread apart the way an insect might see, not close together like a human sees. Each “fly” must then go find their partner by using their insect eyes, turning their head back and forth to navigate. The point of the exercise is less about “chasing” the cheese and more about having to deal with their brains’ ways of processing the visual images. After all the students have tried to deal with navigating in this manner, get them to think about how hard it was to move around. Did they have to constantly look around? How long would it take them to find real food? What about other individuals? How hard was it to maneuver around other people in the room? What if there had been any predators around? Would the flies have been able to see them?

Second, give each student the optical illusions. Each of these illusions exploits how our brains process the images our eyes receive. Some of the optical illusions might be difficult to see for young children, but the point is that our eyes don’t necessarily see what is truly there; sometimes we see more, sometimes we see less. The idea is to get students to understand that humans see the world in a specific way because of our biology; ours is not the only perspective, however. Have each student experiment with each optical illusion to see what happens; they can also work in small groups to help each other. Some of the illusions are most obvious when you don’t look directly at them; slowly changing your focal point (for example, start by focusing on a square on the left side, move one square to the right, another square, etc.) may also help visualize the illusion. Have the students discuss what they saw. Did they see the gray shadows in the white space between the black boxes in Figure 1? Did they think the lines were bent or straight in Figure 2? Have them get out a ruler to find out. Which orange boxes were darker in Figure 3, those on the left or those on the right? (They are exactly the same color.)

Third, introduce them to plants and pollinators (bees make honey from the nectar provided in many flowers, and as bees harvest the nectar, they pollinate the flowers). Show students some of the transparencies (or Powerpoint presentation) of flowers. Start with a flower as we see it. Have the students describe the color pattern. Is there any indication on the flower where the sweet, sugary nectar that insects eat might be? If they are looking at it from far away, is there any color pattern that might make the nectary (the place on a flower where nectar is produced) more visible? Next, introduce the UV photographs. Let the students describe the color pattern the way scientists think a bee sees the flower. Make sure they understand that we aren’t seeing what a bee sees; we can only see what we see – true or not. Remind them of the optical illusions –that what they see has to do with how their eyes and brains work. Use several different shaped flowers (such as daisy-like flowers, bell-shaped flowers, tubular flowers); you can have the children predict what the UV pattern might be based on the flower shape.

b. Investigation work: Have students go outside and look at insects. They should take their journals. Have them focus specifically on the eyes. Students should write their thoughts about the insects’ eyes, what they look like, what they think seeing with those eyes would be like. In addition, they should write about the plant (or other substrate) on which the insect was found, for example on the flower, stem, or leaves, the color of the flower, whether it is in the sun or in shade. Working in teams, they could even try to investigate how close they can get to the insect before the insect flies away. The point is to try to get them to think about whether insect eyes are the same or different from human eyes, and perhaps, why.

Using the sweep nets or butterfly nets, capture several kinds of insects and put them into the magnifying jars (alternatively, they can use magnifying glasses if they have something to hold the insect in, like a jelly jar, plastic cup, or tuna fish can). With their magnifying jars, have students draw and/or describe the eyes of the insects in their journals. Bring out the mounted insects, so they can see a variety of insects that may have the same kinds of eyes or different eyes. Have them think about the types of places these insects might live and what they might need to see. Can they imagine any eyes or eye adaptations for some of the different insects?

Use the transparencies (or Powerpoint presentation) of pictures from the scanning electron microscope (SEM) to show some of the extreme detail of fly eyes. Explain that scientists believe each facet of the insect's eye provides an image. As a result, the insect is processing many images at once; human brains process only two images (one from each eye). Have them guess at how many images each eye receives. What do they think would be the value of that many images? What would they be able to see if they had to think about that many images to deal with?

c. Building on it: The students can get their own pictures of insect eyes from the SEM, but they should have a good hypothesis (a sound reason based on the information they've obtained so far) for looking at different insect eyes. Have students work in small groups. They should brainstorm reasons to have up to three different insects scanned. Each group should draw pictures and make a presentation of their reasoning, and the class should decide which three insects should be scanned and why.

Once the class has decided, contact Roy Pescador at EMtrix and make arrangements for the scan and recording of the process. EMtrix will contact you with instructions for dealing with the images.

One Week Later: Before exploring the EMtrix website, remind students of their ideas about the insect eyes they are about to view. Explain that the scanning electron microscope is a powerful microscope that uses a system of vacuums with the electron beam to create an image. The electron beam scans the surface of the sample, and electrons that emanate from the sample are collected. It records at a level of detail that we cannot see. Look carefully at the pictures and return to the original question the class posed. Are there any conclusions you can draw? What ideas do students have about technology helping make observations? What would they like to invent to help see what an insect sees?

10. Assessment: The group presentations can serve as assessment for this inquiry. Students should indicate some understanding of the limitations of human eyes in determining what insects see, but they should also have a natural curiosity about different insects' eyes and how they may vary depending on habitat or even body type. Presentations should include conceptual drawings and the question they are interested in asking about insect eyes.

11. Extension Ideas:

Building an insect eye: Students can try to come up with the architecture that would provide a glimpse of what insect eyes may see. Most craft stores have thick, shiny craft paper that can be used to create small cones that when fitted together might simulate the different images coming into the insect eye. Silver paint lining the insides of four or so small paper cups may also work. Be creative!

Explore the world of vision with the pictures of flowers taken in ultraviolet light: Many flowers have patterns designed to attract pollinators. Are there any patterns that can be detected among flower types? What about different pollinators? Generalist pollinators versus specialists?

12. Scalability: This exercise easily scales to higher grade bands than 1-2 depending on the amount of exploration. For example, optical illusions are plentiful on the web, as are discussion of the physics of light and color and the biological structure of the human eye. Students could conduct more rigorous experiments to explore the ecological function of insect eyes.

13. Science Standards Accomplished:

From the *National Science Education Standards* (http://www.nap.edu/readingroom/books/nses/)

UNIFYING CONCEPTS AND PROCESSES STANDARD:

- *Systems, Order, and Organization*: The natural and designed world is complex; it is too large and complicated to investigate and comprehend all at once. Scientists and students learn to define small portions for the convenience of investigation.
- *Evidence, models, and explanation*: Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems.
- *Form and function*: Form and function are complementary aspects of objects, organisms, and systems in the natural and designed world. The form or shape of an object or system is frequently related to use, operation, or function. Function frequently relies on form.

CONTENT STANDARD A (Science as Inquiry):

- *Abilities necessary to do scientific inquiry*
- *Understanding about scientific inquiry*

CONTENT STANDARD C (Life Sciences):

- *The characteristics of organisms*
- *Organisms and environments*

MISSOULA COUNTY PUBLIC SCHOOLS SCIENCE CURRICULUM:

- *Standard #1 – Science as Inquiry*
    - Ask questions, find answers, and compare the known and unknown involved in scientific investigations
    - Use different methods to investigate
    - Demonstrate use of instruments and other devices for measuring and observing
- *Standard #2 – Unifying Concepts of Science*
    - Use grade-level appropriate strategies to apply scientific concepts, processes, and vocabulary which include the following:
        - Models, evidence, and explanation.
        - Form and function
        - Design innovation.
- *Standard #3 – Humans and Science*
    - Investigate natural resources and environments
- *Standard #5 – Life Science*
    - Observe insects and develop a growing curiosity and respect for them as living things.
    - Acquire the vocabulary associated with insect life.
    - Distinguish between living and non-living things.

14. References:

http://www.pbase.com/dorff/uvflowers
http://www.srs.fs.fed.us/4505/hanula/pollinator_studies/uv_photography.htm
Also see:
http://www.naturfotograf.com/UV_flowers_list.html - this website has spectacular photographs of flowers under UV light. The pictures are copyright protected.

For a variety of optical illusions see: http://www.michaelbach.de/ot/

15. List of Experts and Consultants:

Jen Marangelo, University of Montana – insects, insect education
Doug Emlen, University of Montana – insects, insect development, behavior

16. Evaluation/Reflection by Fellows and Teachers of how it went:

This activity has not been tested.

Figure 1: Do you see the gray ghosts?

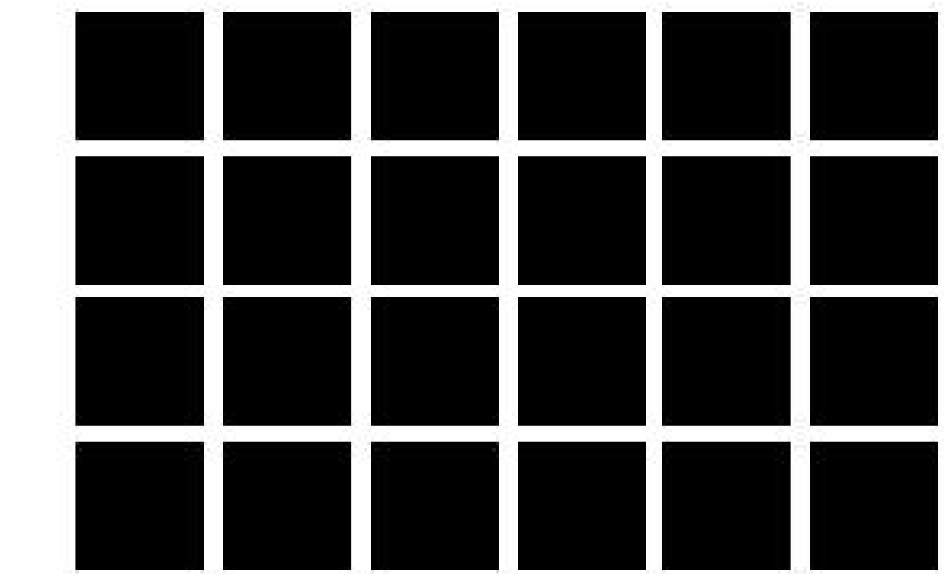

Figure 2: Are the horizontal lines straight or bent?

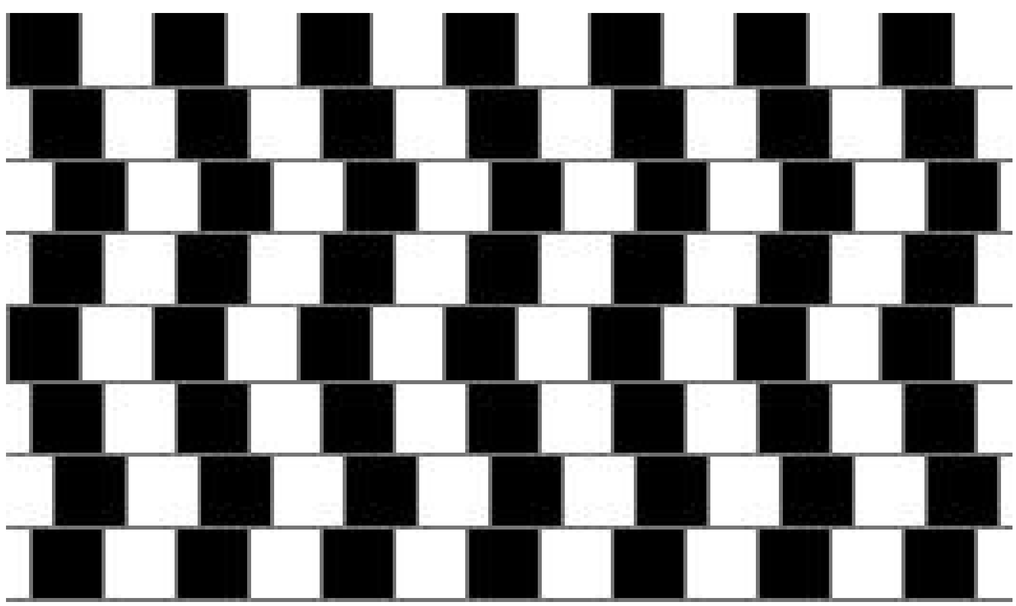

Figure 3: Which orange boxes are brighter?