Pill bug Magnetoreception Lab: Handout **NAME**___________________________

Additional materials and procedures can be found through the link below:
https://github.com/rfitak/Circular_Biology/blob/master/README.md

Magnetoreception: Potential Mechanisms and Uses of the Magnetic Sense

Numerous behavioral experiments have shown that a variety of organisms, from bacteria to mammals, can sense Earth's magnetic field. This ability, called magnetoreception, is similar to how humans use a compass to figure out the direction they are moving. In addition to identifying a direction, some animals, like sea turtles, can actually sense changes in the magnetic field strength and angle relative to the Earth's surface to navigate to specific locations. This is like having a natural, built-in GPS sensor! So, how to these animals sense the magnetic field? Unfortunately, the mechanism is not well known, but scientists have come up with a few ideas that are supported by their data: 1) a magnetic particle-based mechanism and 2) a chemical mechanism.

The magnetic particle mechanism predicts that animals have tiny crystals of magnetite, a naturally occurring mineral, in contact with various cells. These magnetite crystals act like little compass needles, so when they attempt to turn or rotate in response to Earth's magnetic field, they mechanically stress sensory cells, like hair cells or stretch receptors, or open and close ion channels in neurons to initiate a signal. The chemical mechanism is a bit more complicated. Certain proteins, like the visual pigment cryptochrome, have a free pair of electrons, or radical pair, after exposure to light. Each electron in this pair is spinning in a particular direction, so taken together the two electrons can be spinning the same direction (parallel) or different directions (antiparallel) – with different chemical reactivity in each state. Because the amount of time spent spinning either parallel or antiparallel depends on the angle of the ambient magnetic field, different chemical reactions can occur as the magnetic field changes. These reactions are thought to occur in the eyes of many migrating bird species.

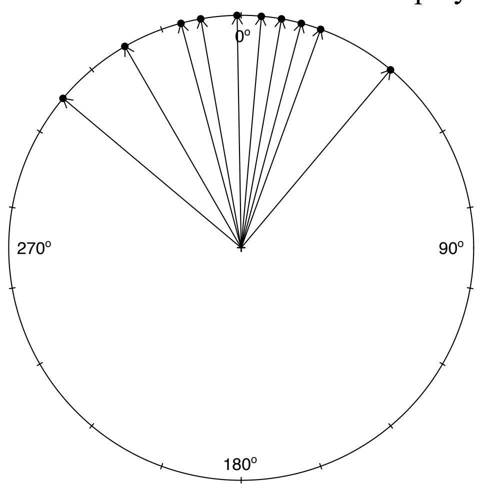
How do scientists study magnetoreception in animals? The most common method used is an orientation experiment. The goal of an orientation experiment is to identify the direction an individual wants to move. Hopefully by controlling all the possible cues an animal can use to move and manipulating only the magnetic field, scientists can determine the role of the magnetic field. Scientists often compare the directions of control individuals with individuals exposed to some kind of magnetic field treatment. In today's laboratory, we are going to expose pill bugs to a magnetic pulse to see if the pulse affects their movement. You can read more about pill bugs, the experimental procedure, and data analysis at the link above. The worksheet below should help guide your thinking along the way and includes space for recording your data. After completing the lab, please submit your answers to the questions below. Have fun!

1. Briefly describe each of the two proposed mechanisms of magnetoreception:

2. Describe two ways in which animals might use their magnetic sense:

Circular vs. Canonical Statistics

Examine the orientation data displayed below, along with the angles of orientation:



Angles:
5°
10°
15°
20°
40°
310°
330°
345°
350°
359°

1. Draw an arrow that you think approximates the average angle of orientation.

2. Using canonical (arithmetic) statistics, calculate the average value of the angles, and draw an arrow that represents that value.

   Average Value: ___________

3. How do the arrows you drew in questions 1 and 2 compare with one another? Why might they be different?

4. Now use circular statistics in R to calculate the average angle from the above data. Draw a third arrow that represents this value. How does this arrow compare to the arrow you drew in question 1?

Constructing the Pulse Magnetizer

1. Once you have built your pulse magnetizer, use the multimeter to record the maximum current it produces, in Amps. Repeat the measurement three times; record each measure here and then calculate the average current.

   a. Measurement 1__________

   b. Measurement 2__________

   c. Measurement 3__________

   d. Average current__________

2. Now use the numbers you recorded above to estimate the strength of the magnetic field inside the coil using the equation

$$B = u_0 \frac{N}{L} I$$

B is the field strength in Tesla (T)
u_0 is the permeability of free space ($4\pi \times 10^{-7}\ T \cdot m \cdot A^{-1}$)
N is the number of turns (wraps) in the coil
L is the length of the coil in meters (measure with a ruler)
I is the current measured in Amperes (A; average of the three measurements taken)

B = _______________

Orientation Experiments

One of the key skills in the study of animal behavior is the ability to take detailed notes about what you observe. Practicing on simple behaviors like the orientation of your pill bug is a great way to develop this skill. Practice below by making at least three observations about the "control" behaviors you observe, and three observations about the "pulsed" behaviors you observe. These observations can be anything you think is important—be creative and observant!

1. Control Behaviors:
   a. Observation 1:

   b. Observation 2:

   c. Observation 3:

2. Pulsed Behaviors:
   a. Observation 1:

   b. Observation 2:

   c. Observation 3:

Statistical Data Analysis

Here is a table you can use to record your data and results.

Trial	Control Angles	Pulsed Angles
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
Mean Angle		
Rayleigh Test P-value		

Watson Two-sample Test P-value: ____________________

1. What can you conclude about orientation from the results of your Rayleigh test?

2. What can you conclude about orientation from the results of your Watson test?

Conclusion and Comprehension

1. Once you have finished your orientation trials and statistical analyses, find at least two other groups and compare your results with theirs. Are your results similar or different? How?

2. What are some external factors that you think might contribute to variation between groups? Why might some bugs in some groups act differently than other bugs in other groups?

3. Describe three ways that you might make this experiment more controlled, meaning reduce the variation between groups. (Hint: you can use the external factors you outlined in Question 2 for inspiration!)

4. Propose at least two follow-up experiments that you might do to learn more about magnetoreception in pill bugs, or another animal.

5. Brainstorm and describe one way that you think an increased understanding of the magnetic sense might be useful to human society.