# Phototaxis in Pillbugs: Working with Circular Data

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# Goals for today

By the end of today you will:

1. Be able to identify circular data and articulate why it must be treated differently than linear data
2. Implement your own experiment and test a hypothesis
3. Analyze and plot your own circular data

# Photokinesis and Phototaxis

- Photokinesis: a change in the velocity of an organism in response to a change in light levels
- Phototaxis: orientation or movement towards or away from a light source

Photokinesis

Discodoris boholiensis

Moves fast in daylight, slow in darkness

# Phototaxis

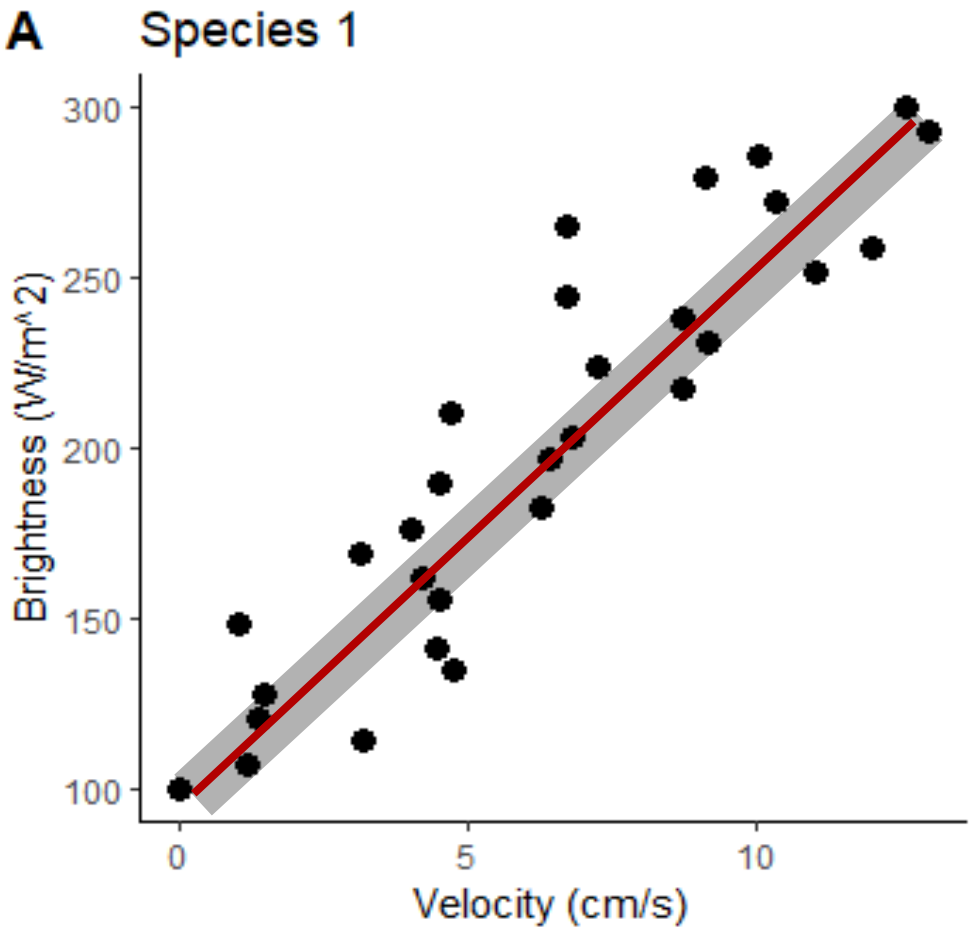

Positive


Negative

# Experiment from the Pre-Class Reading

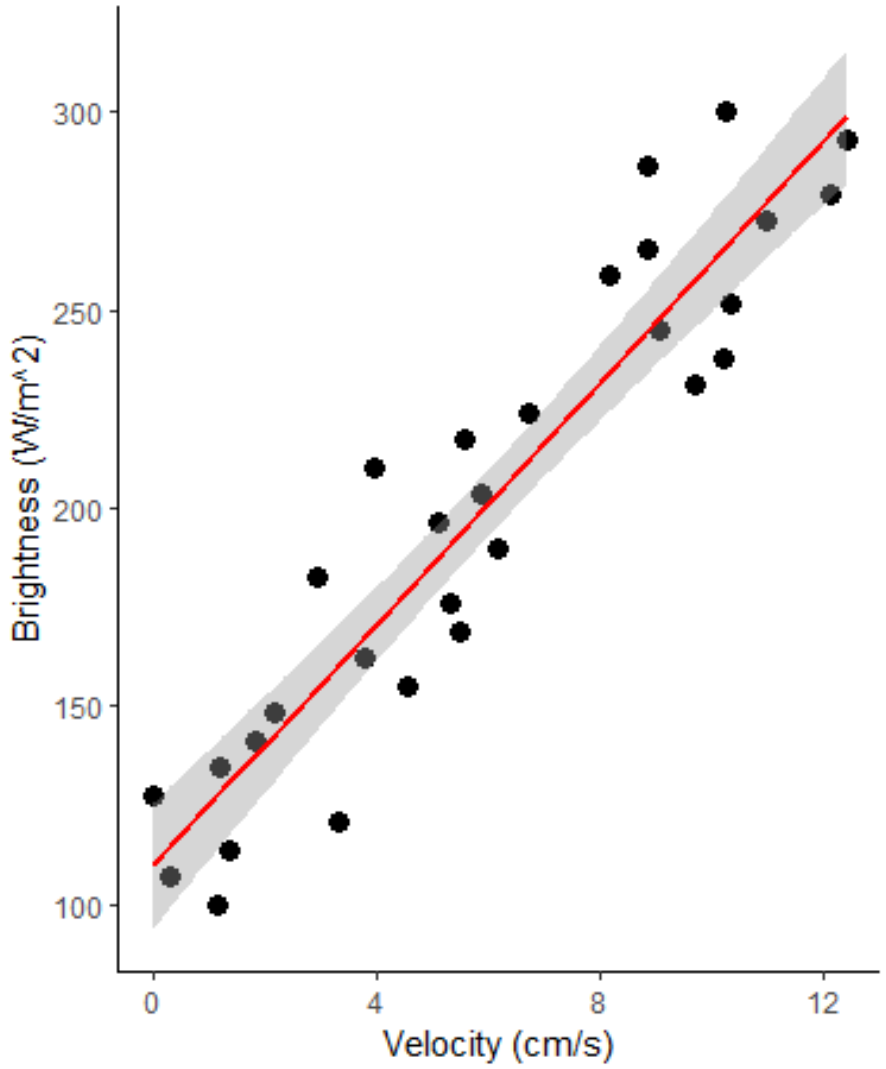
- What was the main question of the study you read before class
- What methods did they use?
- How did they measure their results?

# Linear Regression



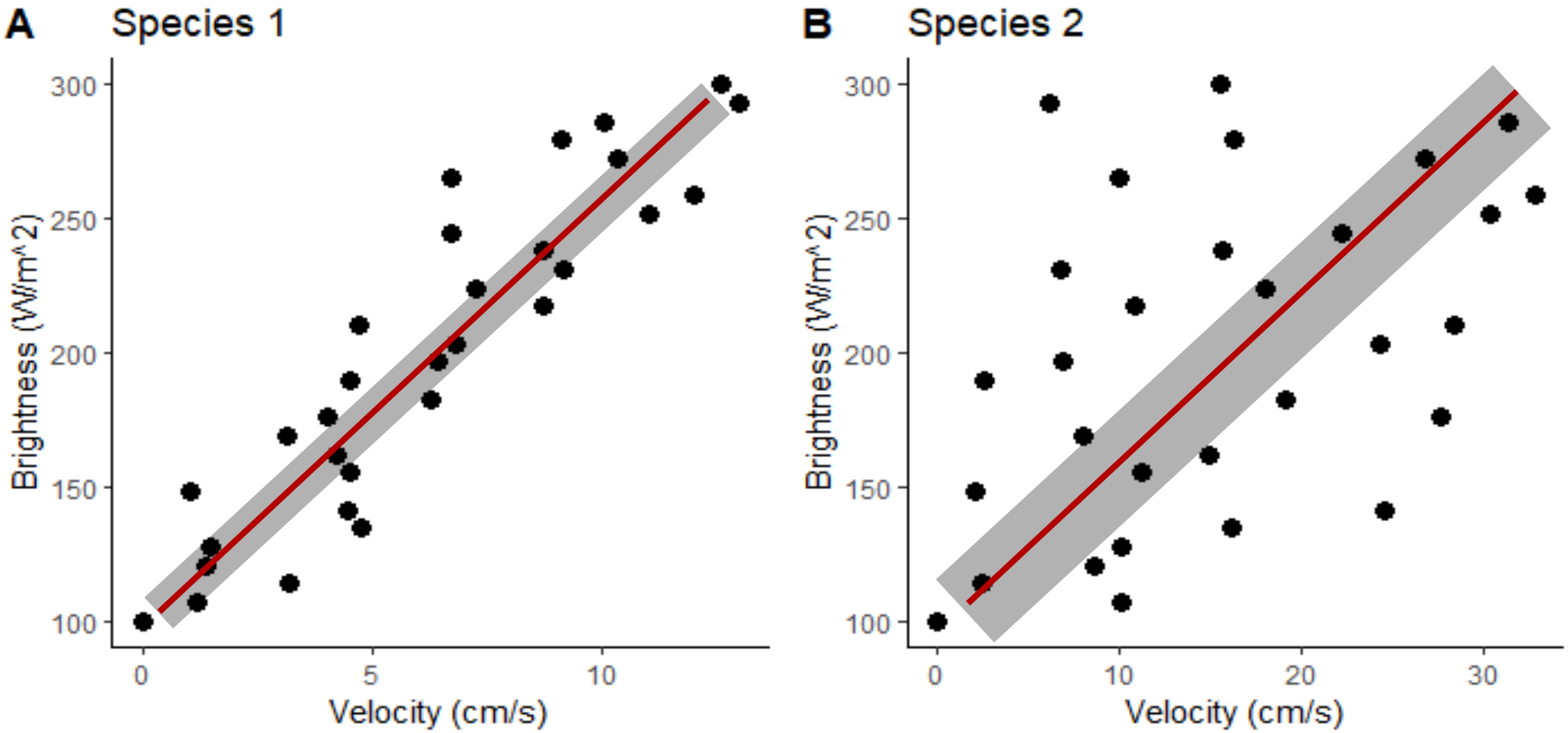

- What is slope
- What is $R^2$
- How do you determine significance?

# Linear regressions




| Linear |
| --- |
| Test if slope is = 0 |
| Assess the spread $R^2$ |

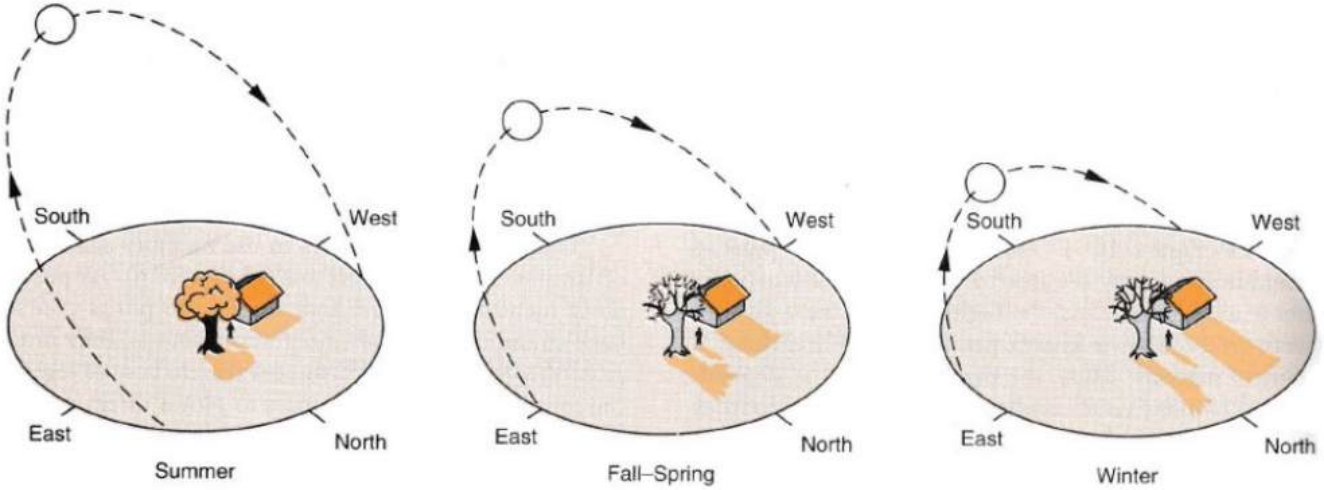
# From the Readings—Linear Regression

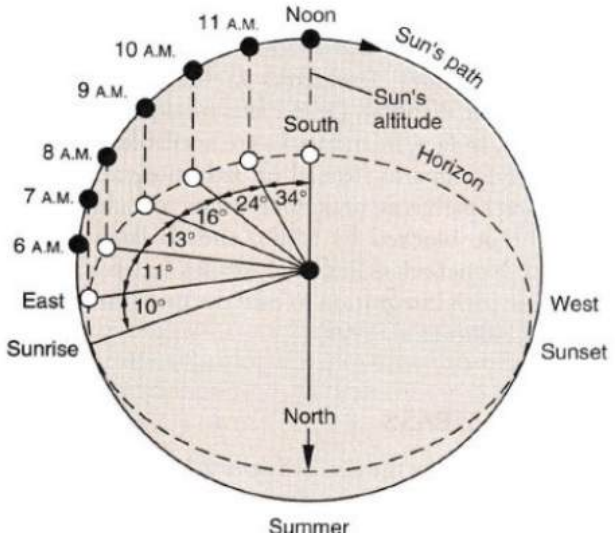


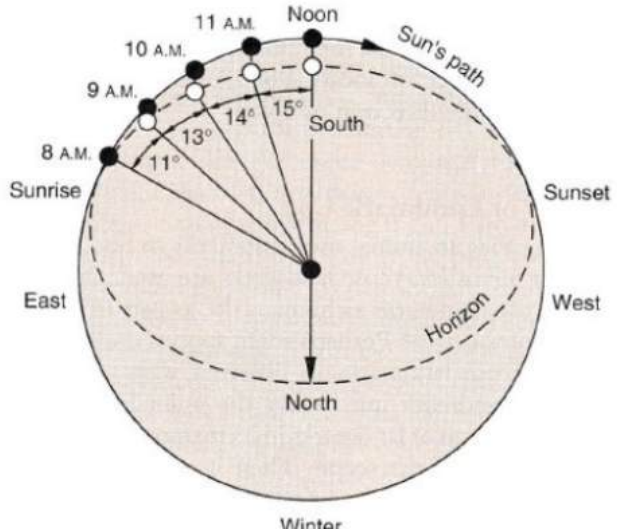
# Thinking about the experiment

- Based on the graphs, were the roly polys exhibiting photokinesis?
  - What are some differences between species 1 and 2 (behaviorally)?
- How would you test for phototaxis?

# Circular Data

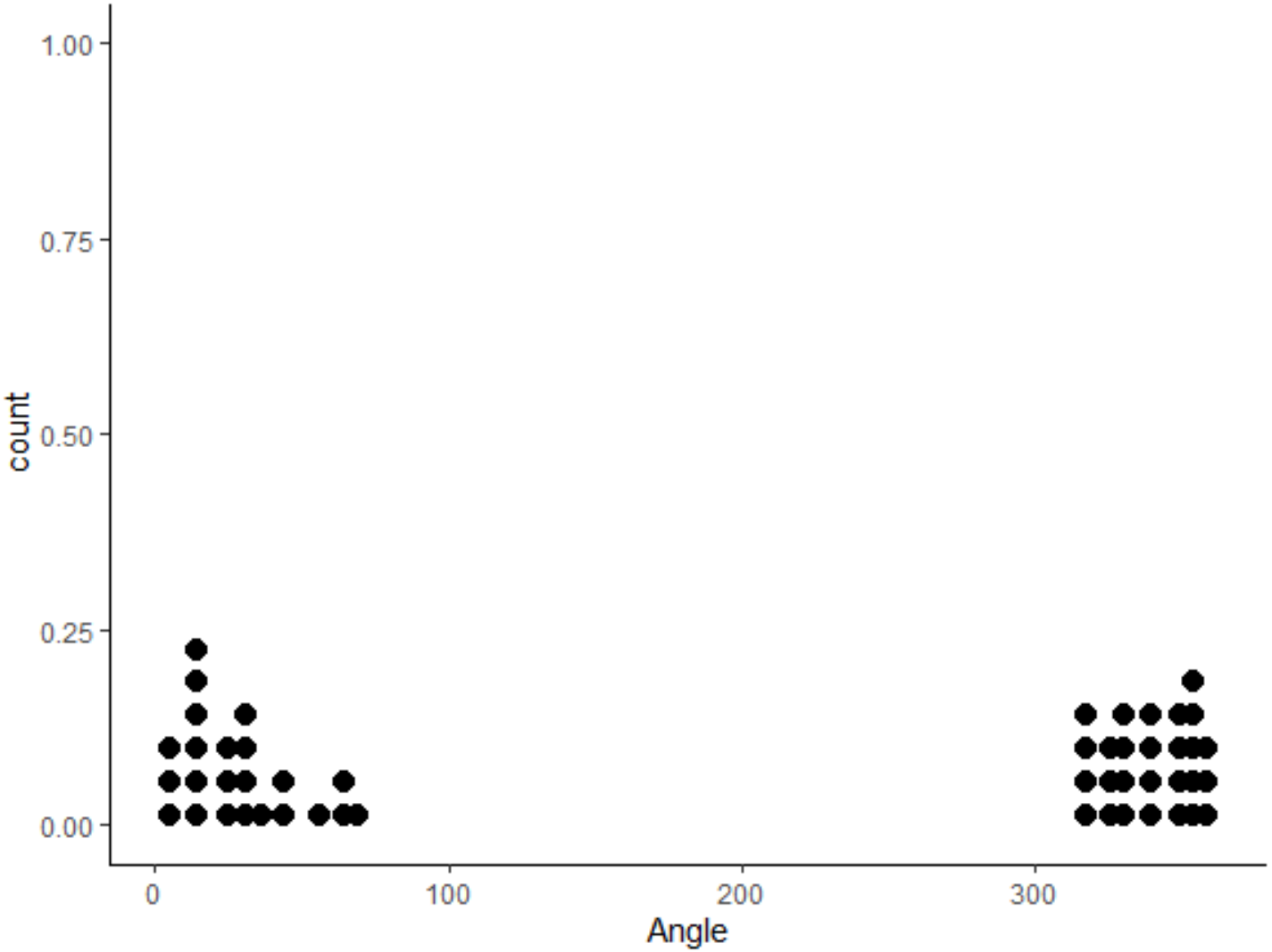



- Is predominately used in navigation
- Used when there is directionality in a relationship
- Used for measurements like:
  - Compass Bearings
  - 24 hr clock
  - Angles
  - Phases of a cycle (e.g. lunar)

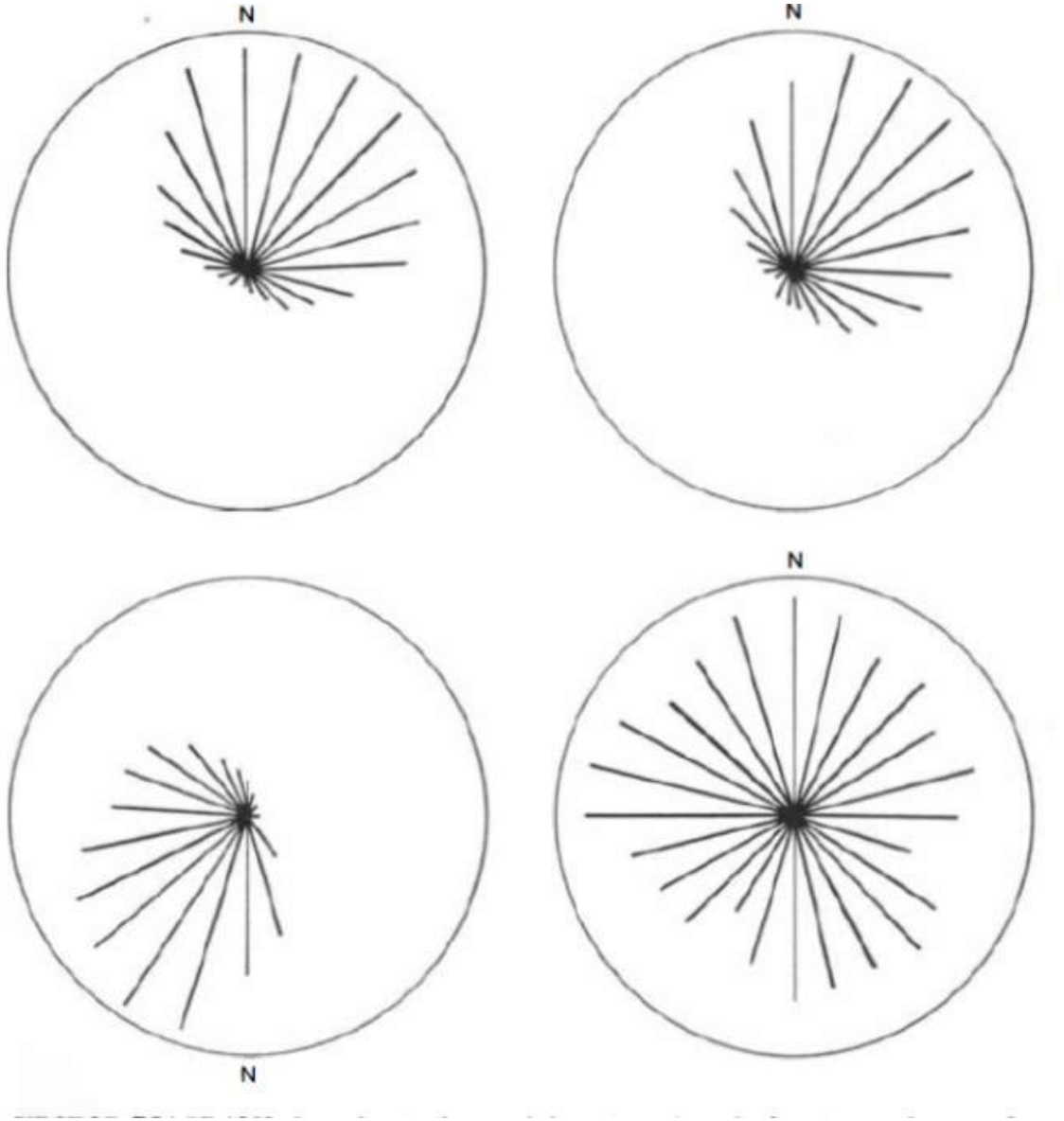
# Circular Data




- How is this graph misrepresentative of the data?
- What is an appropriate way to represent circular data visually?

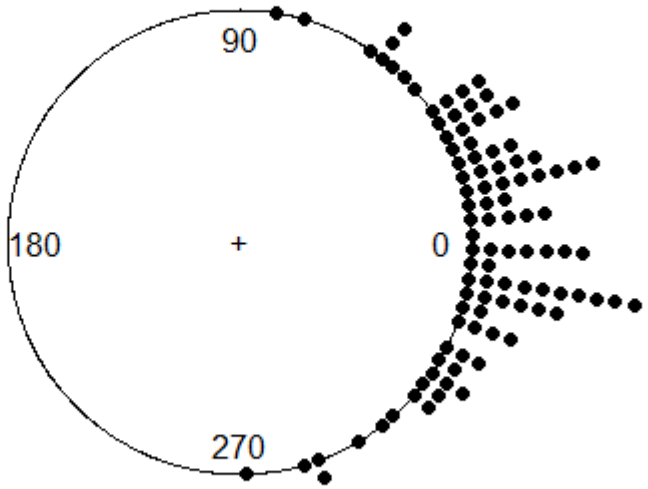
# Thinking about Circular Data

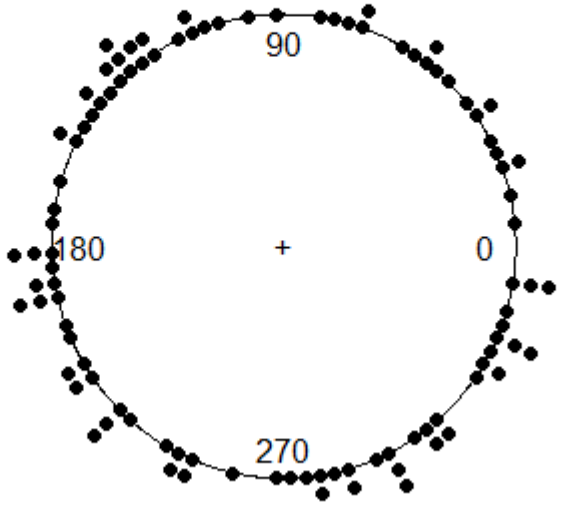
- Explain what circular data is in your own words.




| Linear | Circular |
|---|---|
| Test if slope is = 0 | Test if points are oriented uniformly |
| Spread$R^2$ | Mean resultant vector |

# Circular Data—Test of Uniformity



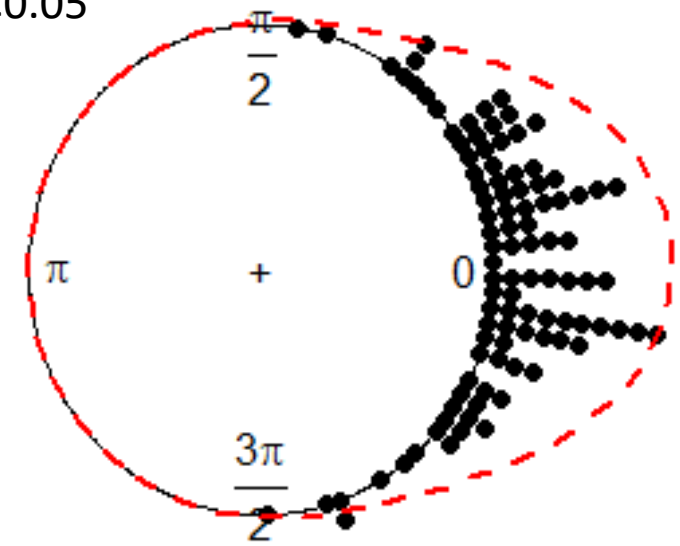




Ho: The points are oriented uniformly around the circle

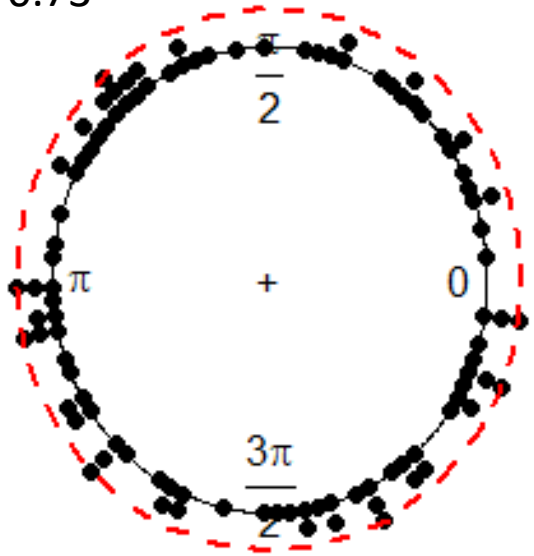
Ha: The points are not oriented uniformly around the circle

# Circular Data—Test of Uniformity

Rayleigh Test of Uniformity:
P<0.05



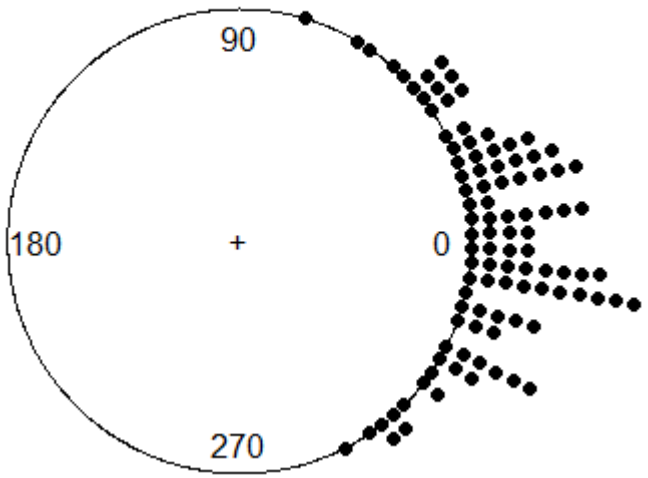

Rayleigh Test of Uniformity:
P=0.73

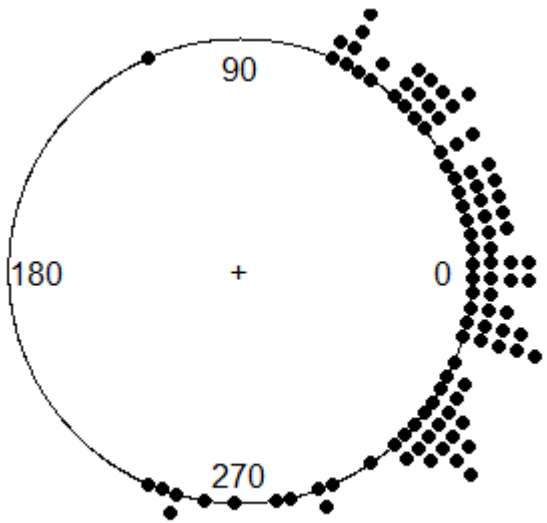


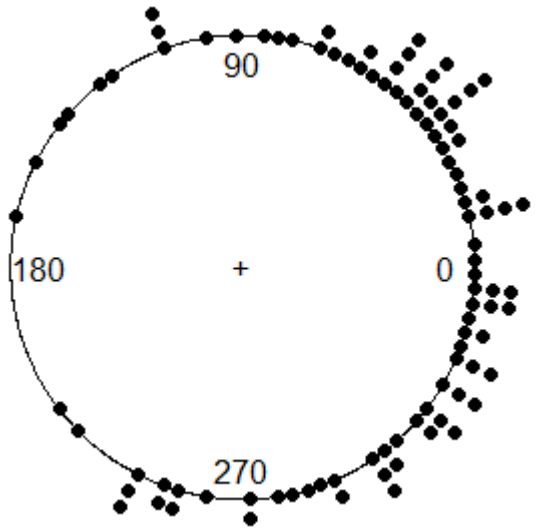

Ho: The points are oriented uniformly around the circle

Ha: The points are not oriented uniformly around the circle

# Circular Data—Mean Resultant Vector

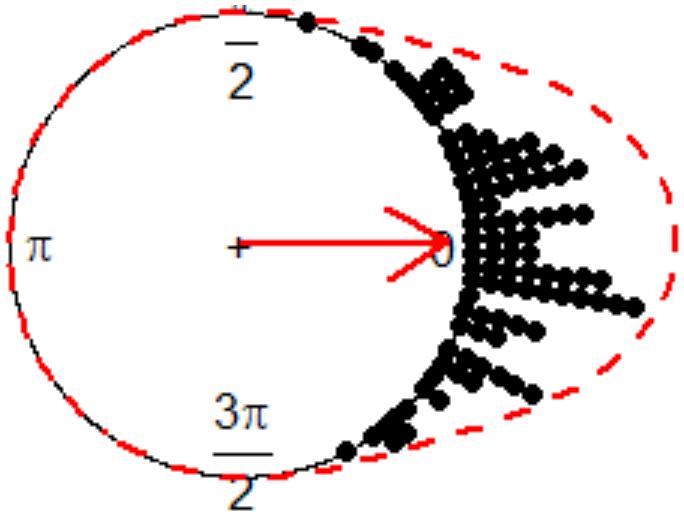


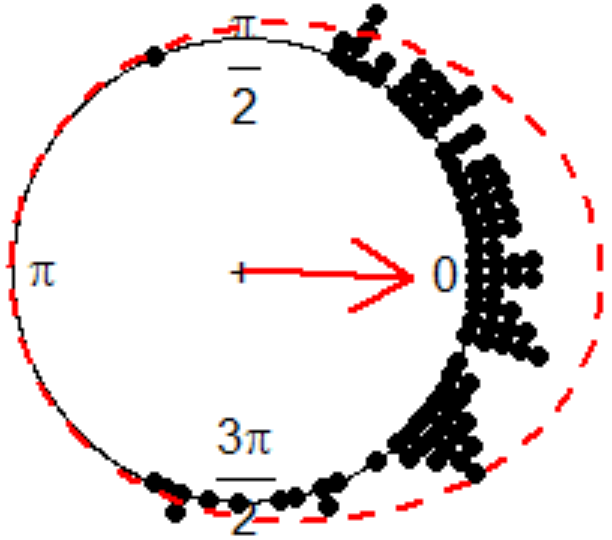
# Circular Data—Mean Resultant Vector

Rayleigh Test of Uniformity:
P<0.05



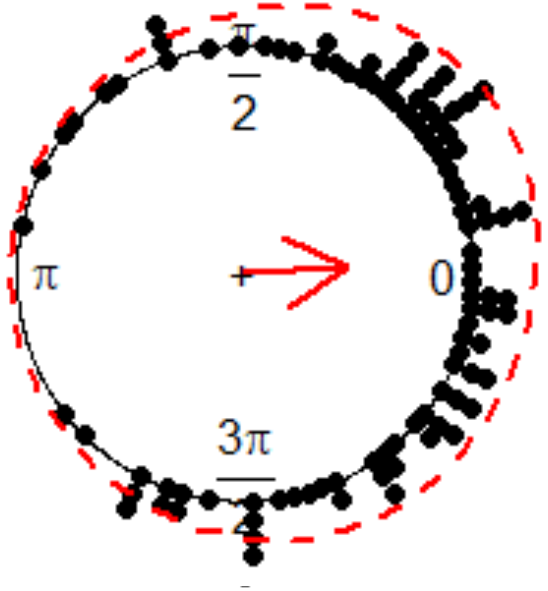

Mean Angle: ~0
Resultant Vector Length: 0.89

Rayleigh Test of Uniformity:
P<0.05



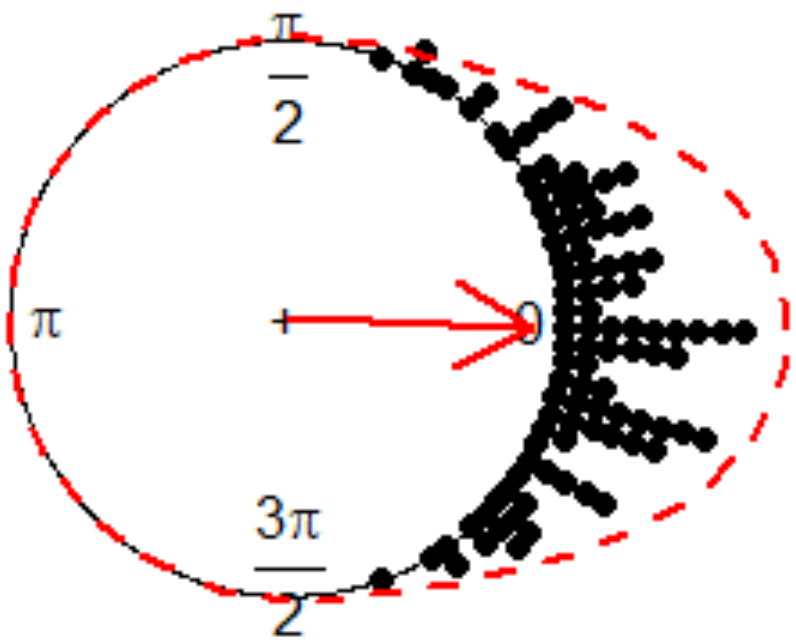

Mean Angle: ~0
Resultant Vector Length: 0.72

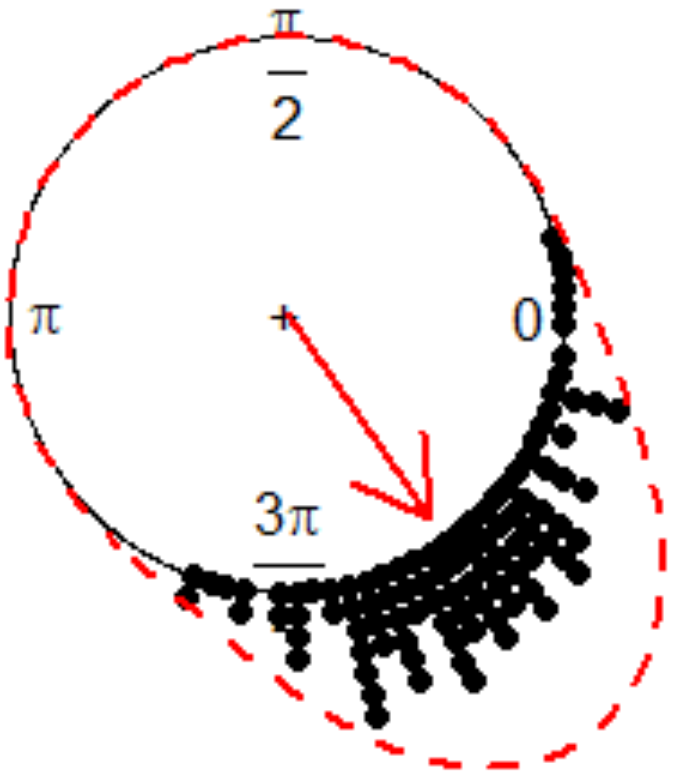
Rayleigh Test of Uniformity:
P<0.05



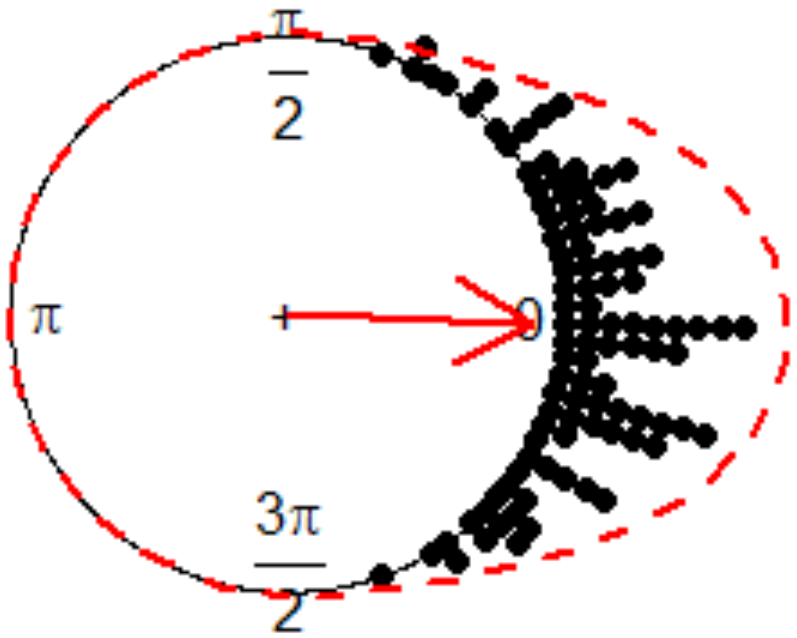

Mean Angle: ~0
Resultant Vector Length: 0.44

# Comparing two distributions

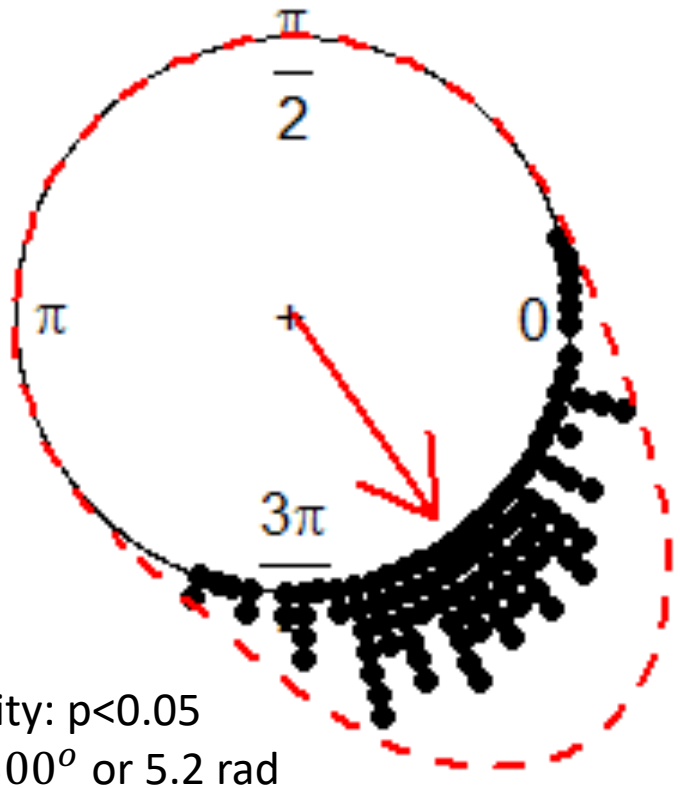


# Comparing two distributions

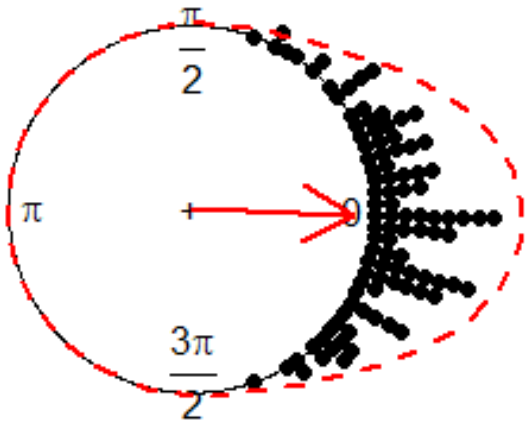



Test of Uniformity: p<0.05
Mean Angle: ~0
Resultant Vector Length: 0.89

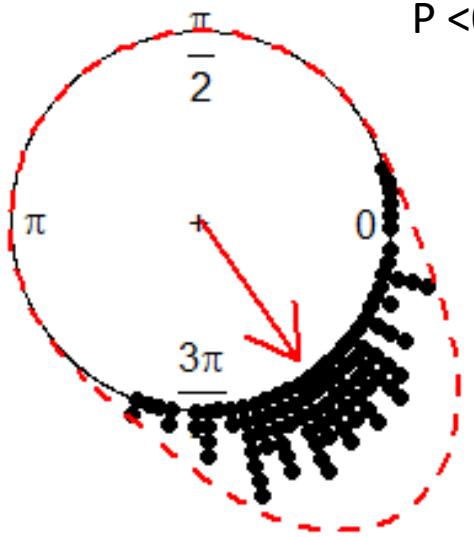



Test of Uniformity: p<0.05
Mean Angle: ~$300^o$ or 5.2 rad
Resultant Vector Length: 0.89

# Comparing two distributions: Watson two-sample test




P <0.001




Watson Two-Sample Test
Ho: The mean of the two distributions are the same
Ha: the means of the two distributions are different


Experiment Time

# Experimental Subjects

- Pillbugs are terrestrial crustaceans
- They live in dark, cool places like under stones and leaf litter.
- They are best-known for their defensive behavior of rolling into a ball (aka roly poly)


- Why would a pillbug be sensitive to light?
- Would you hypothesize positive or negative phototaxis?
- If you had the opportunity to design an experiment to test phototaxis in pillbugs, what would you do?

# Experiment Details

- Items needed: Box, lamp, paper cup, orientation arena, 6 roly polys
- 3 Experimental Trials (light on), 3 control trials (light off)
- For each trial, place 1 roly poly in the center of the arena under a paper cup, allow the roly poly 30 seconds to adjust, then remove the cup
- Allow the roly poly to reach the edge of the arena and mark with pencil where it exited the arena
- Repeat (more detailed instructions in your handout!)
- Add your group's results to the class data on the board!

# R-Shiny

- https://rfitak.shinyapps.io/circbio/

**Group 1: Enter a set of angles in degrees, one per line**

**Group 2: Enter a set of angles in degrees, one per line**

**Save plot as file type**

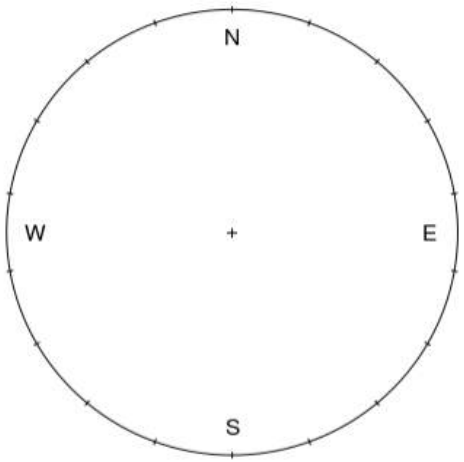
- (•) png
- ( ) pdf

Download the plots

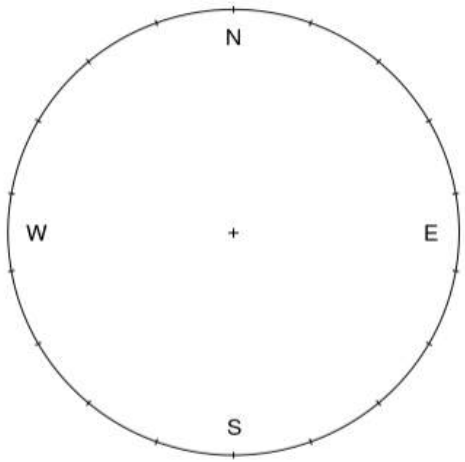
# Plots

(data points shown in black, mean vector in red)

**Group 1**




**Group 2**



# Let's think back

- How do you know if there is a significant difference in uniformity?
- What does the mean vector length r mean?
- What does the mean angle tell us?

Results:

Group 1

```
Mean angle:  NA
Mean vector length (r):  NaN
Rayleigh test p-value:
```

Group 2

```
Mean angle:  NA
Mean vector length (r):  NaN
Rayleigh test p-value:
```

Watson's test to compare two groups

```
NULL
```

# Exit Ticket

Email danae.diaz@duke.edu, lyv.martinez@duke.edu, and snowicki@duke.edu the following in one document:

- Of your team's data:
  - A picture of the circular plot of both the light on and light off group.
  - The mean angle, Rayleigh test p-value, and mean resultant vector for both the light on and light off group
- For both the team and class data:
  - A results statement that includes the above values as well as a sentence or two that explains (1) why results between groups might have differed and (2) given the restrictions of the class, how would you adjust the methodology to correct for potential extraneous or uncontrolled variables that might have influences on results?

In total: 2 plots, 2 Rayleigh tests, 2 mean angles, 2 mean resultant vectors and approximately two sentences explaining the results.