Two steps forward: Interpreting results reported with scientific figures

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Abstract

Biological Question

This module can be adapted easily for any biological content. Several figures included in the exercise as potential examples could be replaced by other examples.

Statistical Content

The focus of the module is on interpreting figures from the scientific literature. To do this, students must differentiate between categorical and continuous variables, identify the dependent and independent variable, understand treatments, interpret visual presentation of variation and draw and evaluate conclusions from the data presented.

What students do

Students are introduced to a two-step process for describing and interpreting a figure and are given two acronyms to help them remember the key parts of each step. They are given graphs to practice on in groups of two. After practicing with a partner, students are directed to find their own scientific paper and apply the two-step process to at least one of the figures within the paper. The module can be adapted for any size class – see Faculty Notes for suggestions.

Skills

interpreting graphs, finding and reading scientific literature

Student-active approaches

Working in pairs.

Assessable outcomes

Individual answers to Practice 3 may be handed-in for assessment. Several example methods for assessment are provided in the Faculty Notes section.

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The 'steps for reading a graph' in Part 1 was modified from: Picone et al. (2007) http://tiee.ecoed.net/vol/v5/research/picone/abstract.html.

Background
Scientists in a variety of fields perform experiments when they do empirical research, *i.e.,* they collect tangible data on variables that can be manipulated and measured. Experimental methods for data collection are not the only way to "know" things, but they have particular utility for testing cause and effect explanations.

Ways to collect data
Observational study: observes individuals and measures variables of interest but does not attempt to influence the responses. *(Stand back and watch.)*
Experiment: deliberately imposes some treatment in order to observe the responses.
Anecdotal Evidence: based on haphazardly selected individual cases. These cases need not be representative of any larger group of cases. Anecdotal evidence is NOT science!

- Experiments allow us to study the effects of treatments.
- Experiments are better than observational studies at providing causal evidence.
- Experiments allow us to study the specific treatments we are interested in, while controlling the effects of lurking variables.

Parts of an experiment
Factors: the specific treatments or experimental conditions (the **independent variables**).
Levels: the specific values of the factors that will be used
Experimental units or subjects: the individuals to which the factor is applied.
Response variable: what is being measured on each unit/subject (**dependent variables**).

The simplest experiment is to apply a single **factor** and observe the **response**. Sometimes, however, we are interested in the combined effects of two or more factors. By applying two (or more) treatments in an experiment, we can test for an **interaction**. An interaction occurs when the response to one treatment changes in the presence of the other treatment.

Graphs
A common way to report the factors and response variables for an experiment is with graphs. Generally, the **independent variable** goes on the x-axis of a graph and the **response variable** goes on the y-axis. Experimental units or subjects are identified in a title or the legend. Learn the appropriate graph type for two kinds of variables:

A quantitative or continuous variable answers a "how many?" type question. "How old are you?" and "What is your GPA?" are both questions that would yield quantitative responses. It makes sense to find an average for an answer to a quantitative question.

A categorical variable answers a question with a word response, such as "yes", "no", "blue", "biology". "What is your major?" and "What color are your eyes?" are both questions that would yield categorical responses. It would NOT make any sense to find an average for an answer to a categorical question.

The appropriate graph is related to the types of variables:

Histogram: One quantitative variable
Scatterplot: Two quantitative variables – to show association
Bar chart or *side by side plots*: One quantitative variable with categorical groups
Time course graph: Sequence of events over time

Student Instructions, Part 1: Reading a graph in two steps

When faced with a new graph, following a *two-step process* will allow you to determine what results are communicated with the graph and to evaluate the findings.

Step 1: Describe First focus on getting 'the lay of the land.' To do this, use EASULT.

Experimental units or subjects – What are the individuals to which the experimental treatment is applied and what do they represent?

Axes – What is shown on the x-axis and y-axis? Which variables are quantitative or **continuous** and which are **categorical**?

The x-axis runs horizontally and usually displays the **independent variable.** The independent variable is the treatment.

The y-axis displays the **dependent variable**. The dependent variable **"**depends" upon the independent variable. The dependent variable is the response to the treatment.

Scale - What is the **scale** on each axis (if it's a continuous variable)?

Units - Understanding the units allows you to quantify relationships between variables. For example, if one response is greater than another, ask, "By how much?"

Legend – What is being compared in the graph: different levels of a treatment? different groups? different times?

Treatments – What are the treatments? The Axis and Legend should reveal the treatments.

Step 2: Interpret. Now that you are familiar with the structure of the graph, its time to find its 'take home message(s).' To interpret the graph, use PVC.

Pattern – What is the pattern?

For a **bar graph**, which treatments are higher or lower? If there are two treatments, does the graph show an interaction?

For a **scatter plot** or **line graph**, does the response variable increase or decrease with the treatment variable? Is the relationship linear, 'hump-shaped,' or 'U-shaped'? Does the graph show **causation** or **correlation**?

Variation - How does variation affect the results? What could be the cause of that variation?

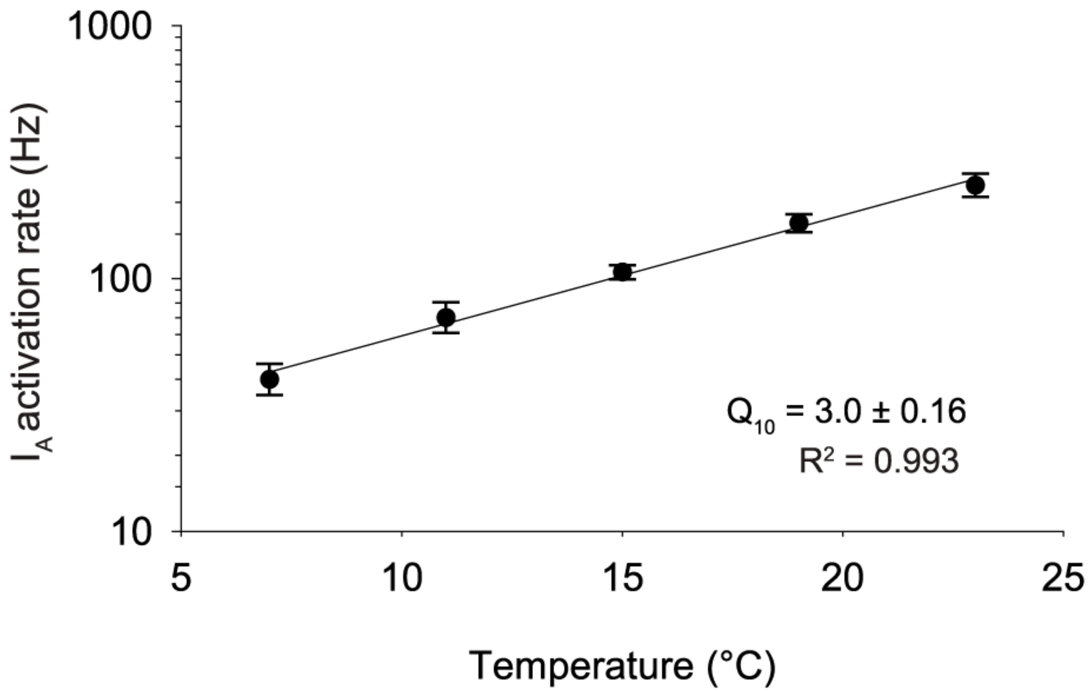
Conclusions – Write 1 or 2 bullet points that are the main conclusions of the figure.
From those bullet points, answer these questions:

Does the graph support or reject the study's hypothesis?
Do you agree or disagree with the author's conclusions from the graph?
What are alternative explanations for the pattern?

Practice for Part 1

Practice 1A. In groups of two, use the two-step process to interpret the graphs below. Each person works on a different graph. Use the space below the graphs to Describe and Interpret the figures.

Figure 1. From Tang et al. (2010) PLoS Biology 8(8): e1000469. Effect of changing temperature on the activation rate of crab neurons.



Step 1: Describe

Experimental subjects -

Axes –

Scale –

Units –

Legend –

Treatments –

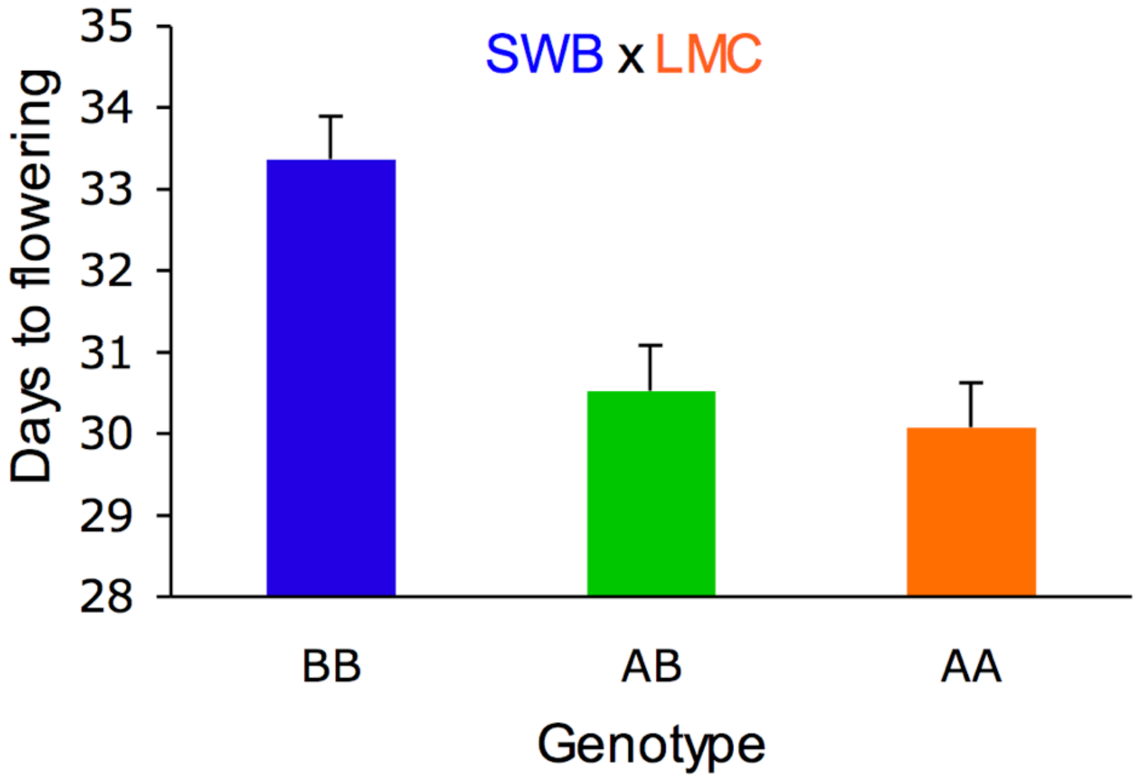
Step 2: Interpret

Pattern –

Variation –

Conclusions –

Figure 2. From Lowry & Willis (2010) PLoS Biology 8(9): e1000500. SWB x LMC is the cross that produced the three genotypes shown.



Step 1: Describe

Experimental subjects -

Axes –

Scale –

Units –

Legend –

Treatments –

Step 2: Interpret

Pattern –

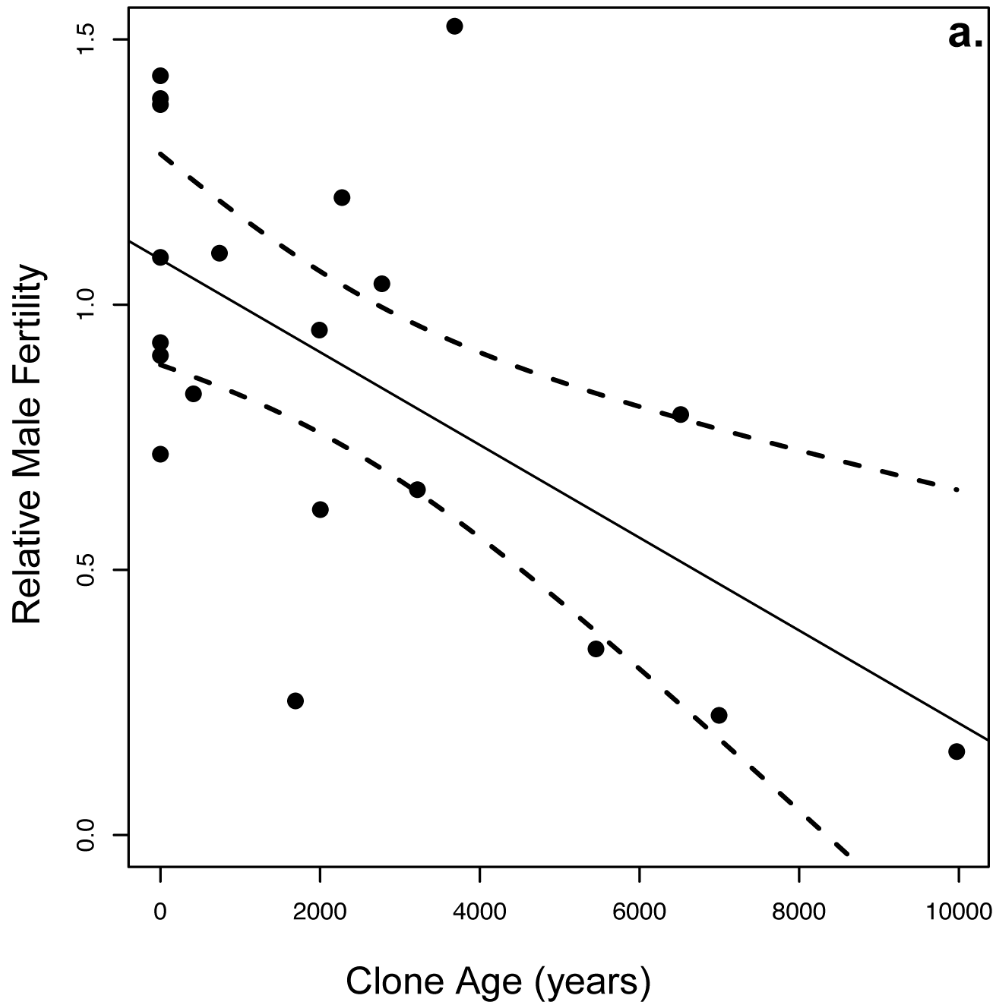
Variation –

Conclusions –

Practice 1B. Teach your partner about the graph you described and interpreted. Make sure you both agree on the key parts of each step and on the 'take home message' of each graph.

Practice 2A. With your partner, describe and interpret the two graphs below. Work on different graphs individually and then teach each other about your graph.

Figure 3. From Ally et al. (2010). PLoS Biology 8(8): e1000454.



Step 1: Describe
Experimental subjects -

Axes –

Scale –

Units –

Legend –

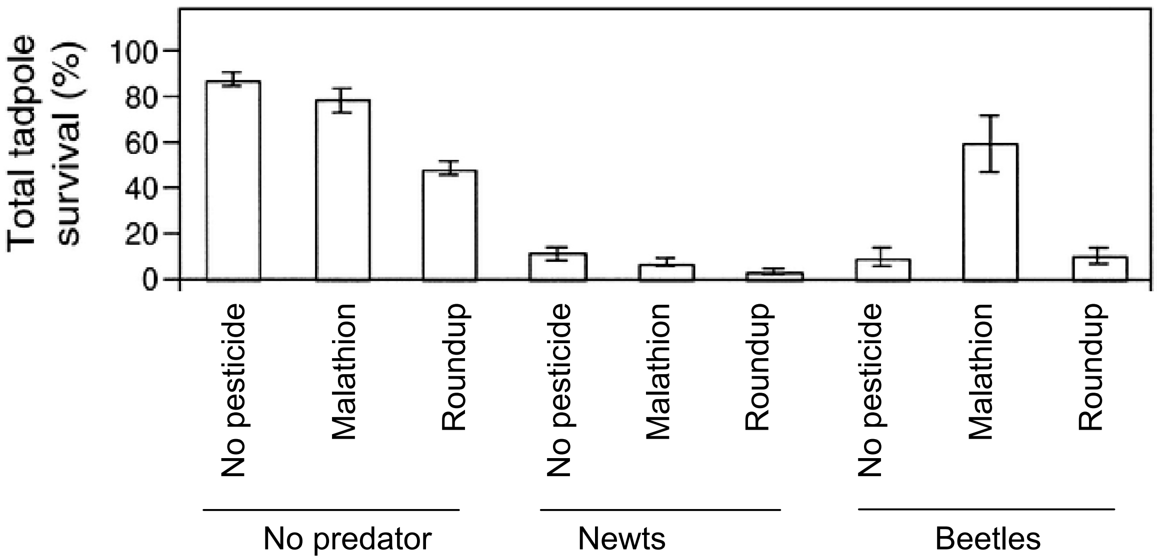
Treatments –

Step 2: Interpret
Pattern –

Variation –

Conclusions –

Figure 4. From Relyea at al. 2005, *Ecol. Appl.* **15**: 1125-1134. Total survival of tadpoles living in experimental ponds with different pesticides and predators present. Data are means ± SE.



Step 1: Describe
Experimental subjects -

Axes –

Scale –

Units –

Legend –

Treatments –

Step 2: Interpret
Pattern –

Variation –

Conclusions –

Practice 2B. Answer the following questions concerning all four figures.

2B.1. Which figure(s) demonstrate(s) causation and which correlation? Why?

2B.2. Which figure(s) show an interaction? Why?

Practice 3A. Individually, find a paper from the scientific literature on a topic that interests you. Read the abstract and locate one figure from the paper that illustrates one of the authors' main conclusions.

Practice 3B. Apply the two-step process to the graph you have chosen.

Step 1: Describe

Experimental subjects -

Axes –

Scale –

Units –

Legend –

Treatments –

Step 2: Interpret

Pattern –

Variation –

Conclusions –

Practice 3C. Answer the following questions about the graph you have described and interpreted using information from the abstract.
Does the graph support or reject the study's hypothesis? Why?

Do you agree or disagree with the author's conclusions from the graphs based upon the information in the abstract? Why?

What are alternative explanations for any patterns presented in the figures?

Practice 4. To connect what you're learning to historical research endeavors, notice that there are no graphs in Darwin's book, *'The Power of Movement in Plants'* published in 1880 to explain his investigations of plant movement. A "secondary source" is a summary article written by a writer but not by the researchers. Many textbooks are a secondary source about Darwin's research. A secondary source can be easier to read and give you a good overview of the research but you generally need to find the primary source to get enough details to understand an investigation. Find the "primary source" written by Darwin who conducted a study of plant responses to light with the Online book by Darwin (1880) The power of movement in plants, London http://darwin-online.org.uk/content/frameset?itemID=F1325&viewtype=text&pageseq=1

4A. Graph results from one of Darwin's experiments. Darwin performed a series of controlled experiments on flowering plants to quantify the effects of light, gravity and temperature on movement and growth patterns. In one experiment. Darwin observed that the upper half of the hypocotyl of the cabbage (*Brassica oleracea)* seedling was light sensitive, and would influence the curving movement of the lower half in response to a light stimulus. As an experimental treatment, Darwin tested this with an experiment by wrapping the upper halves of 20 seedling hypocotyls in an opaque material, thus removing the light stimulus. As a control he applied transparent material to the upper halves of 12 hypocotyls. All seedlings were placed in a box with black inner walls and open in the front, so that light stimulus entered the box from a single direction. The box was placed in front of an artificial light source for 7-8 hours. All unwrapped and control (wrapped with transparent material) hypocotyls responded to the light treatment with "strongly-marked" heliotropism (one control responded moderately). Of the 20 treated (covered) hypocotyls, 14 showed no response to light and 6 showed a "slight" heliotropic response (4 of these 6 were imperfectly wrapped). If you were Darwin, what would you measure and how would you graph those results?

4B. Darwin then went on to test which conditions were necessary and sufficient to transmit the heliotropic effect from the upper hypocotyls to the lower plant. His results suggest that the effect is real, because a transparent covering was used as an appropriate control to show that tropism does not occur when a response to light stimuli is blocked. Darwin described his experiment clearly, neglecting only a few details. Even modern scientists could easily replicate his work. Replication by other scientists could produce accurate quantitative measures for more powerful modern statistical methods. However, despite these failings, Darwin's findings did persuade people that tropism is caused by a response to light stimuli, though his results did not explain the reason for the movement of the plant. This was something that still needed to be determined. What possibility would you suggest should be investigated today to identify the mechanism involved? Design and illustrate with a graph how you would report results in a comprehensive manner for your own modern experiment to answer this question.

Faculty Notes

Objectives and audience

This exercise is aimed at the beginning undergraduate student. The goal is to develop students' proficiency with graphs. This module can be adapted to any size course. Practices 1 and 2 can be done in pairs, even in a large lecture class. Practice 3 can be assigned for homework for any size class. Practice 3 and 4 could also be adapted into a Calibrated Peer Review (CPR) exercise, which may be particularly effective for very large classes.

Suggestions for using the exercise

- While all Practices can be completed in class or lab, we suggest that Practices 1 and 2 be done in class with Practice 3 assigned as homework. Alternatively, faculty may wish to only do Practice 1 in class. Practice 2 and 3 could both be assigned as homework. However, the interaction and correlation vs. causation questions are often difficult concepts, which is why we suggest completing Practice 2 in class so that students can teach each other and so that faculty can make sure students understand these concepts before diving into finding their own papers/figures.
- The module can easily be split over two classes with Practice 1 done during one day of class and Practice 2 on a separate day. Practice 3 could then still be assigned as homework.
- This module can be adapted for any biological content; simply replace the example figures to teach the statistical concepts using biological content relevant to your course.

Assessment and evaluation

We have several suggestions for assessment and evaluation.

- This material lends itself well to iClicker questions that could be sprinkled throughout the semester. The early questions could focus on Step 1: Describe while the later ones focus on Step 2: Interpret. One could easily make several iClicker questions for a given graph – it may even be ideal to use the Step 1 questions on a graph earlier in the semester and then return to the same graph later in the semester for Step 2 questions. Using the same graphs presented in the exercise may test for retention and understanding at a class-level scale.
- Students can hand-in their answers to Practice 3 for assessment.
- Practice 3 and 4 could easily be adapted into a Calibrated Peer Review (CPR) exercise. Some examples of CPR assignments have been particularly effective for a large class. To adapt Practice 3 for CPR, faculty may wish to expand the number of questions posed to students, perhaps even adding an objective of having students read the entire paper, or interpret more figures.