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Biology as a Source for Algebra Equations: Insects

The integration of mathematics and other content areas has long been advocated by mathematics educators and sought after by teachers of mathematics, from kindergarten through high school and beyond. Science is one area that provides context and content for many valuable and useful connections with mathematics. When attempts are made to integrate mathematics and science, it seems that all too often mathematics is thought of as a "computational tool" for the sciences. For example, students need to have these computational tools for data analysis, so they can work with the data they collect in their science experiments. This use is not bad. However, it does not help students see the full power, usefulness, and beauty of mathematics. Beyond computation, mathematics can be used to determine and model science relationships, explain complex applications and, of course, solve problems.

What follows is an activity that was developed in an integrated high school course that was team-taught by both mathematics and science teachers. The course integrated first-year algebra with introductory environmental biology/anatomy and physiology and was taught in a two-hour block. Students were able to deepen their understanding and appreciation of both subjects through inquiry-oriented lessons developed by identifying areas where mathematics and biology content intersect.

The activity examines linear equations developed from relationships in biology. These equations provide students with opportunities to see how mathematics (algebra) can be used to describe biological relationships and then applied to solve problems based on these relationships. The selected equations are basic and thus can be used early in students' study of algebra.

INSECTS

One of the simplest algebraic equations is $y = x$, an equation representing a direct variation $y = kx$, where the constant of variation is 1. One aspect of biology looks at the impact the environment has on living things, either plants or animals. Many such impacts can be studied. Our students were interested to learn that the ambient temperature, as one environmental condition, has a profound impact on insects. Insects cannot control their body temperatures; their rate of metabolism and activity depend upon the temperature around them. Thus for most insects, their body temperature (dependent variable) depends directly upon the temperature of the air (independent variable) that surrounds them. The first investigation in the "Insects and Their Ambient Temperature" activity (**sheet 1A**) provided opportunities for our students to represent this relationship graphically and with an algebraic equation.

By plotting these ordered pairs on a coordinate plane, students noticed that, despite small deviations, the insect body temperatures generally vary directly with air temperature. These deviations

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might be attributable to factors such as errors in measuring the temperatures or variations among individual insects. Students are asked to determine a line that best fits these data points by approximating the line with a piece of spaghetti or other thin rod. However, they could use a graphing calculator if they are familiar with this function of the calculator. Students soon find that the line $i = a$ gives the best representation of this relationship between an insect's temperature (i) and its surrounding ambient temperature (a). This relationship is a direct variation and the simplest of linear equations.

Another insect application of linear equations is the relationship between the ambient temperature and the rate at which crickets chirp. The second part of the "Insects and Their Ambient Temperature" activity (**sheet 1B**) provides students with data to examine this relationship. In this activity, temperature is measured in Fahrenheit degrees and chirping rate is the number of chirps per minute. To discover a relationship, students use the data to plot the ordered pairs (F, n), or (temperature, number of chirps). They then approximate an equation for the relationship, in which the ambient temperature is the independent variable and number of chirps per minute is the dependent variable. The equation for this line should be close to $n = 4F - 156$.

This setting provides a rich mathematical context for students to explore an inverse function. Because the above relationship is a linear function, the inverse function $F = (n/4) + 39$ exists, is also linear, and can be used to determine F given n. People who spend time in the out-of-doors use the chirps of a cricket such as the male snowy tree cricket to give them an approximation of the ambient temperature (*Field and Stream* 1993, p. 21). One way to think about this equation is to realize that the temperature is the number of chirps in 15 seconds plus 39.

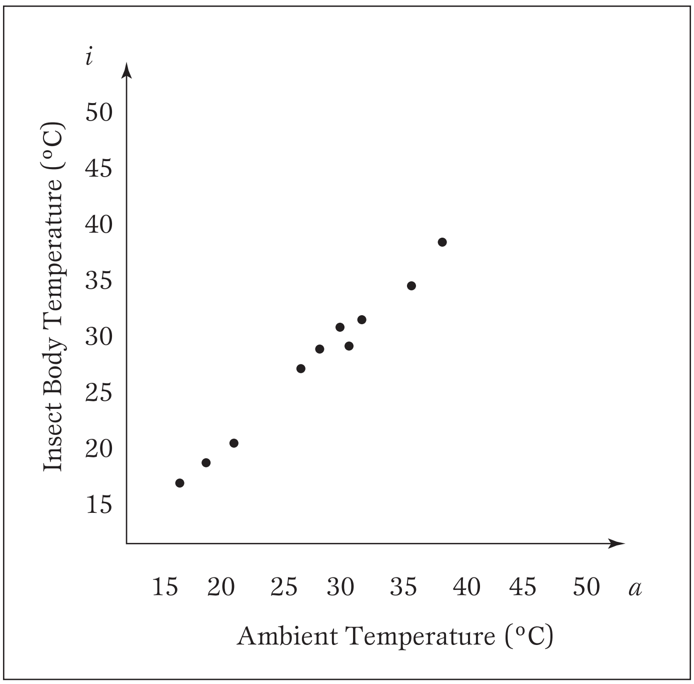

Fig. 1 Answer to question 3

Another mathematical understanding from this cricket chirp activity involves the Fahrenheit and Celsius systems. Changing to the Celsius temperature system allows students to think mathematically about graphs of linear functions under linear transformations. Using the conversion $C = (5/9) \cdot (F - 32)$, the equation $F = (n/4) + 39$ becomes $C = (5/9)((n/4) + 7)$, which can be approximated by $C = (n/7) + 4$. This, too, is a linear equation and can be used to determine ambient Celsius temperature (C) from the number of cricket chirps per minute (n).

CONCLUSION

This activity provided an opportunity for the algebra and biology teachers together to examine the domains of these functions, as they related to both areas. For example, students considered the question "Are there minimum or maximum temperatures for which these relationships hold?" (i.e., "What is the domain of each of these linear functions?"). In this discussion, students talked not only about what the domains of the functions could be mathematically, but also about what the domains really could be, given the biology situations. In discussing the cricket chirp activity, students considered independent and dependent variables when using the inverse function to determine the temperature given the number of cricket chirps.

There are other instances that mathematics and biology teachers can use to explore jointly the effects of ambient temperature on cold-blooded animals. Although procedurally these are usually more time consuming, they provide starting points for developing integrated mathematics and biology projects for students. Two examples easily accessed on the Internet are "The Effects of Water Temperature Change on Goldfish Physiology and Behavior" (Pittis 1999) and "Body Temperature of Cold-Blooded Animals and Liquid Crystals" (Mastromatteo, Mazzer, and Wise 1994).

SOLUTIONS

1. The metric system

2. The independent variable should be a, the ambient temperature. The dependent variable should be i, the insect temperature. The horizontal axis should be a, and the vertical axis should be i.

3. See **figure 1.**

4. When the ambient temperature gets higher an insect's body temperature gets higher. The insect body temperature often seems to be a little higher than the ambient temperature. The insect temperatures are very close to the ambient temperature for each insect.

5. Yes, the ordered pairs seem to lie close to a line. The equation for this line is $i = a$.

6. There might have been errors in measuring the ambient temperature and the body temperatures of the insects. Using different insects for each measurement might cause variation because of differences among insects.

7. The English system

8. The variable t = ambient temperature should be the independent variable. The variable n = number of chirps per minute should be the dependent variable. The horizontal axis should be t, and the vertical axis should be n.

9. See **figure 2.**

10. The points almost seem to lie in a line. When the ambient temperature rises, the number of chirps per minute gets larger also.

11. Yes, the ordered pairs seem to lie close to a line. The line of best fit is close to $n = 4F - 156$.

12. Errors in measuring the temperature and in counting the number of chirps per minute could occur. The temperature might change slightly just as the person is counting the number of chirps. There might be variations among the crickets whose chirps are being counted.

REFERENCES

"Cricket Thermometers." *Field and Stream* 98, no. 3 (July 1993).

Mastromatteo, Maria, Pat Mazzer, and Martha Wise. "Body Temperature of Cold-Blooded Animals and Liquid Crystals." Available at olbers.kent.edu/alcomed/Sam_Net/August94/Brown.html. 1994.

Pittis, Melinda. "The Effects of Water Temperature Change on Goldfish Physiology and Behavior." Available at www.the-aps.org/education/k12curric/activites/pdfs/pittis-fish.PDF. 1999. ∞

Activity sheets follow.

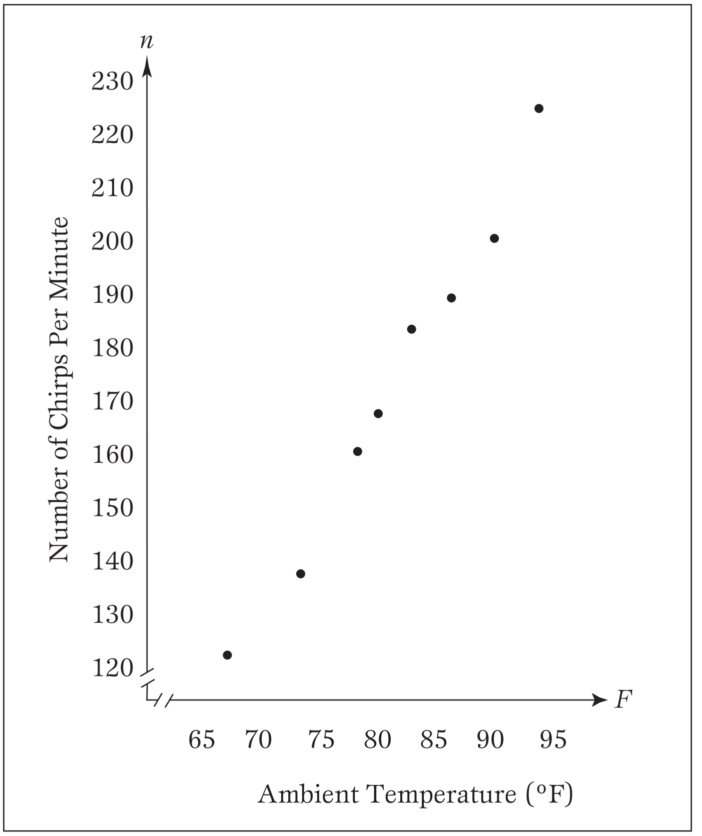

Fig. 2 Answer to question 9

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Insects and Their Ambient Temperature Sheet 1A

The table gives pairs of numbers: an insect's body temperature and the temperature around it (the ambient emperature) measured in a controlled laboratory setting.

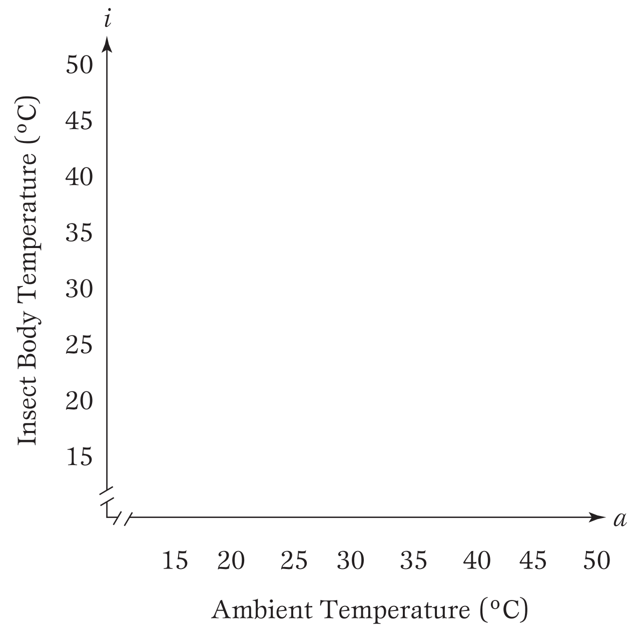
Ambient Temperature (°C)	Insect Body Temperature (°C)
30.3	28.6
18.7	18.5
16.4	16.7
29.6	30.4
37.8	37.7
32.0	31.1
35.3	34.1
27.7	28.8
26.1	27.0
21.3	20.8

1. In what system are these temperatures measured?

2. If the insect's body temperature depends upon the temperature of the air around it, which of the variables, a = ambient temperature or i = insect temperature, should be the independent variable? Which should be the dependent variable? If you were to graph these ordered pairs, which variable should be the horizontal axis (the usual x-axis) and which one should be the vertical axis (the usual y-axis)?

3. Plot the ordered pairs (a, i), or (ambient temperature, insect body temperature), from the table on this coordinate plane.

4. What observation(s) can you make about the graph?



5. Do the ordered pairs seem to lie close to a line? Use a piece of spaghetti or other thin rod to estimate what this line could be. Draw this line on your graph. Write an equation (using a and i) for this line. This line is called the "line of best fit" for these data points.

6. Why do you think the ordered pairs do not lie *exactly* on this line? What might cause the insect body temperatures to vary as they do?

Insects and Their Ambient Temperature Sheet 1B

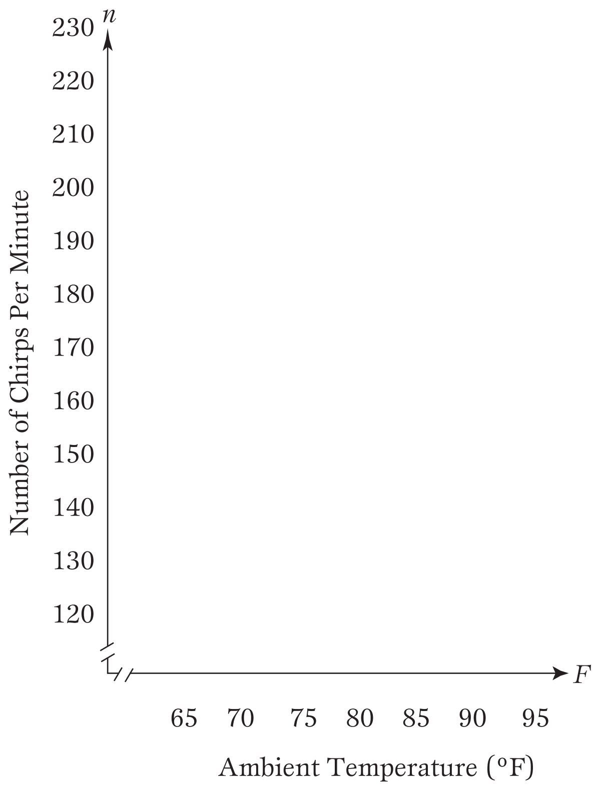
This table gives you pairs of numbers having to do with the number of times a cricket chirps in a minute and the ambient temperature where the cricket is chirping.

Ambient Temperature (°F)	Cricket Chirps Per Minute
80	160
84	181
68	121
81	166
91	200
94	227
75	140
88	189

7. In what system are these temperatures measured?

8. If the number of times a cricket chirps in a minute depends upon the temperature of the air around it, which of the variables t = ambient temperature or n = number of chirps should be the independent variable? Which should be the dependent variable? If you were to graph these ordered pairs, which variable should be the horizontal axis (the usual x-axis) and which one should be the vertical axis (the usual y-axis)?

9. Plot the ordered pairs (F, n), or (ambient temperature, chirps per minute), from the table on this coordinate plane.



10. What observation(s) can you make about the graph?

11. Do the ordered pairs seem to lie close to a line? Use a piece of spaghetti or other thin rod to estimate what this line could be. Draw this line on your graph. Write an equation (using F and n) for this line. This line is called the "line of best fit" for these data points.

12. Why do you think the ordered pairs do not lie *exactly* on this line? What might cause the number of chirps to vary as they do?

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