Teacher Guide:

Caterpillars and Climate: How Temperature Affects Feeding Rate In Insects

Age Group: Grades 6-8

Learning Objectives:

- To understand how temperature can drive the daily activities and impact the evolutionary fitness of cold-blooded organisms**.**
- To understand how scientists use experiments to measure the natural world and draw conclusions from data

Materials

- *Manduca sexta* caterpillars (can often be obtained from local universities, or purchased through biological supply companies – see resources)
- Magnifying glass
- Infra-red thermometer
- Petri dishes
- Caterpillar diet (you can also use tomato leaves if they are available)
- Hot packs
- Ice Packs
- Pens
- Timers
- Red and blue stickers

Time Required: About one hour

Vocabulary:
Ectotherm: a cold-blooded organism, changes temperature with the surrounding environment

Endotherm: a warm-blooded organism, generates its own body heat and regulates its own temperature

Teacher Background: Cold-blooded and warm-blooded animals derive energy from different sources. Ectotherms (cold-blooded animals) change temperature with their surroundings and cannot generate their own body heat. Endotherms (warm-blooded animals) generate their own body heat through a faster metabolism and have many processes to thermoregulate (manage their body temperature). Because of their ability to regulate temperature, endotherms can cope more easily with changes in climate, while endotherms, are at the mercy of their environment. Their basic processes, such as feeding, digestion, reproduction, and respiration are dependent on the temperature of their surroundings. In this study, students will observe how a common endotherm, a

tobacco hornworm caterpillar, responds to temperature. This activity works well as a compliment to lessons on climate change, the differenes between ectotherms and endotherms, and with lessons on insect behavior and physiology.

Preparation: Download and print the full size posters available online (http://sarahseiter.wordpress.com/education/) and display them in the classroom. If you aren't able to print large posters, there are smaller versions included in the teacher guide that can be used as individual hand outs. Students can use the poster with directions for reference as they complete the experiment, and the graph will be used to display and analyze data. The life cycle graph can also be used to engage students in a discussion of insect needs and life cycles.

Obtain caterpillars from a local research laboratory or through a biological supplier (see resources). This activity works well when students work in pairs, and you will need two caterpillars for each pair of students. For each group, place one caterpillar with some caterpillar food (or tomato leaves) in each petri dish and place one petri dish on a hot pack and another on a cold pack. It is best to prepare the caterpillars about 10 minutes before students begin the activity.

Begin by talking with students about what they know about insects to access prior knowledge. The poster with the insect life cycle can be helpful in facilitating this discussion. You can ask them if they can list some ways that insects are different from mammals or birds. You might also offer a brief explanation of climate change, and ask them to make some predictions about different groups of animals might respond to changes in temperature.

Next review the steps of the scientific method with students and explain that they will do an experiment to see how temperature affects a basic process (feeding) in a common North Carolina insect, the tobacco hornworm. You might also ask students to think about how they would design an experiment on how temperature affects feeding rate in caterpillars before introducing the worksheet.

Orient the students to the worksheet and help them break into groups to complete the experiment. It may be helpful to take brief breaks to check in with the students about their understanding. Questions 1-3 are designed to familiarize students with the equipment and caterpillars, questions 4-5 guide students through data collection and graphing, and questions 6-12 are designed to help students interpret their data, link their findings to larger ideas, and metacognate about the process of designing and interpreting science experiments.

Wrap up and Extension:
Ask students to speculate about how climate change might affect species, contrasting endotherms and ectotherms. You might ask them to think about what might happen to food webs if insect populations were diminished. You can also ask them how they might measure how climate change was affecting animals in the wild, and show them

examples of large scale monitoring projects such as the National Ecological Observatory Network: (http://www.neoninc.org/about/overview).

There are also additional activities available from Dr. Arthur Shapiro's research group at the University of California Davis, that use real field data on temperature, precipitation, and butterfly sightings to show how climate can cause changes in insect populations: (http://butterfly.ucdavis.edu/education/stat2). These involve doing some simple statistics and may be more appropriate for advanced learners.

Resources for purchasing caterpillars:
Carolina Biological Supply: http://www.carolina.com/hornworm/hornworm-larvae-manduca-sexta-living-pack-of-50/143886.pr
Backwater Reptiles: http://www.backwaterreptiles.com/feeders/hornworms-for-sale.html
Educational Science: http://educationalscience.com/hawkmothlarvae.htm

Standards Addressed:

North Carolina Essential Science Standards (Middle School):

Structures and Functions of Living Organisms	
6.L.2 : Understand the flow of energy through ecosystems and the responses of populations to the biotic and ***abiotic*** factors in their environment.	**6.L.2.3:** Summarize how the abiotic factors (such as ***temperature***, water, sunlight, and soil quality) of biomes (freshwater, marine, forest, grasslands, desert, Tundra) affect the ability of organisms to grow, survive and/or create their own food through photosynthesis.
7.L.1 Understand the processes, structures and functions of living organisms that enable them to survive, reproduce and carry out the basic functions of life.	**7.L.1.4** Summarize the general functions of the major systems of the human body (***digestion***, respiration, reproduction, circulation, and excretion) and ways that these systems interact with each other to sustain life.
Ecosystems	
8.L.3 Understand how organisms interact with and respond to the biotic and ***abiotic*** components of their environment.	**8.L.3.1** Explain how factors such as food, water, shelter and space affect populations in an ecosystem.

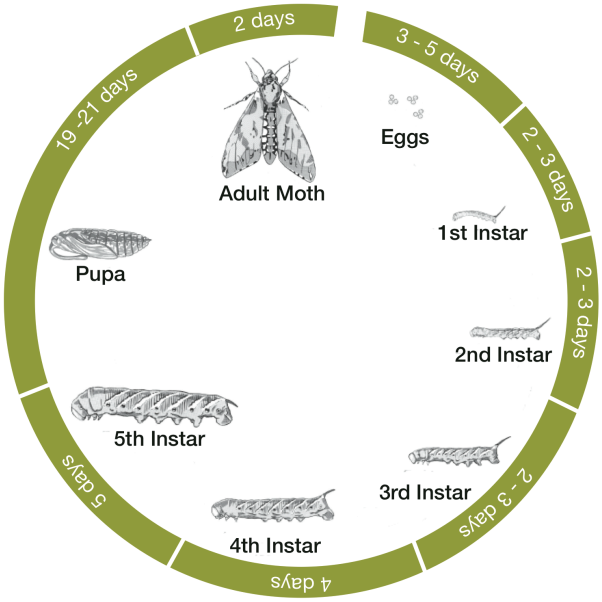
Common Core Standards:
English Language Arts Standards - Science & Technical Subjects - Grade 6-8

Key Ideas and Details	
CCSS.ELA-Literacy.RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks
Integration of Knowledge and Ideas	
CCSS.ELA-Literacy.RST.6-8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
CCSS.ELA-Literacy.RST.6-8.9	Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

MEET THE CATERPILLARS!

The Tobacco Hornworm

These caterpillars are tobacco hornworms (scientific name: ***Manduca sexta***). They have evolved to live in warm climates like **North Carolina**. They feed on **tomato** and **tobacco** plants. Have you seen them in your garden?

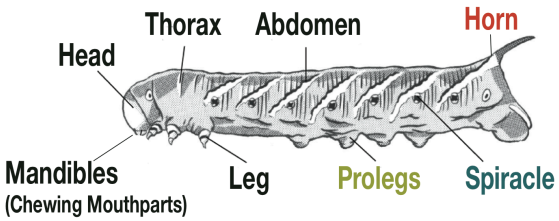


Manduca Life Cycle:

Manduca are **holometabolic** insects. This means that they completely transform 3 times in their lives. First from an egg to a larva or caterpillar, then from a caterpillar to a pupa, and finally from a pupa to an adult moth. While they are caterpillars, they **molt** (shed their skin) 4 times. What proportion of its life does a *Manduca* spend as a caterpillar? A pupa? An adult? Is this different than what you expected?

Manduca Anatomy:

Manduca caterpillars have 6 legs like all insects, but they have 8 special **prolegs** to support their long bodies. They also have special breathing holes called **spiracles** along their sides. What do you think their spiny **horn** is for?



supported by the nsf

Join the

CATERPILLAR EXPERIMENT

Test whether caterpillars eat faster when hot or cold

1 Form a hypothesis

A **hypothesis** is an educated guess about what will happen in your experiment. Which caterpillar do you think will be the fastest eater?

2 Take the caterpillar's temperature

Use the thermometer to take the caterpillar's temperature. Just shine the light on the caterpillar and check the screen!

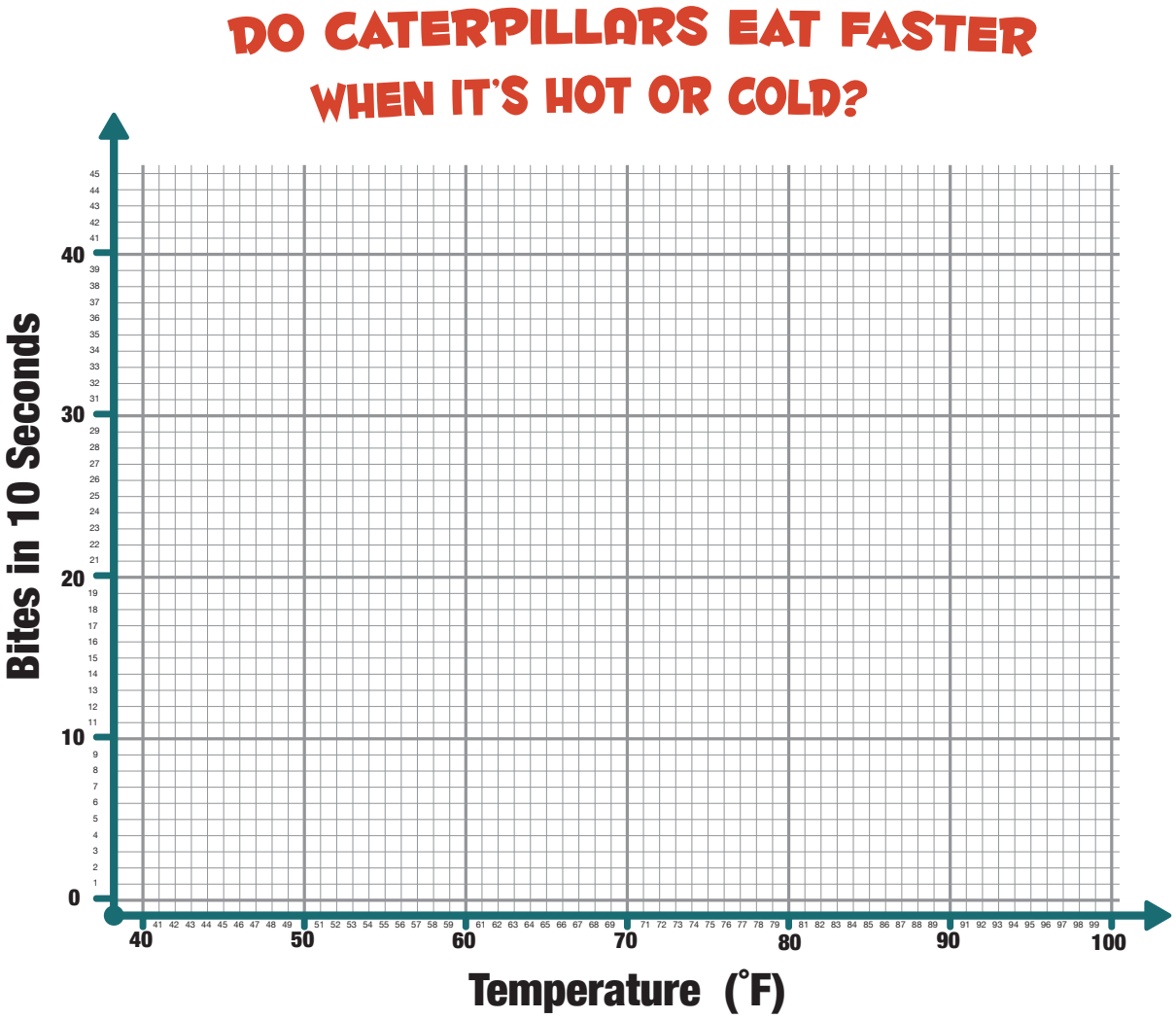
3 Collect Data on Caterpillar Feeding

Pick a caterpillar and set the timer. Count how many bites it takes using the clicker. How much did your caterpillar eat? Was this what you guessed?

4 Add Your Data to the Graph

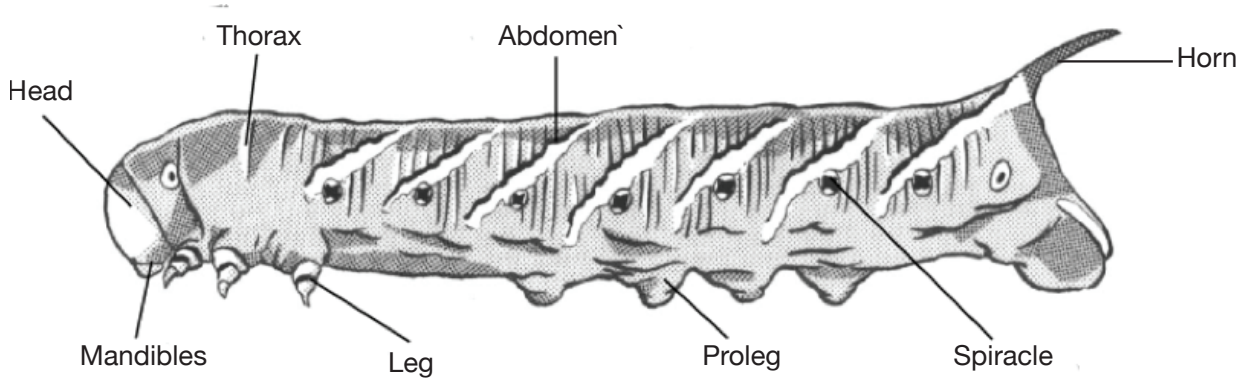
Share your data with other scientists! Mark the temperature on the x axis (horizontal), the number of bites on the y axis (vertical). In general, **do hot or cold caterpillars eat faster?**

Supported by the nsf


DO CATERPILLARS EAT FASTER WHEN IT'S HOT OR COLD?
Bites in 10 Seconds
0
10
20
30
40
Temperature (˚F)
40
50
60
70
80
90
100

Answers:
Part 1: Getting to know the caterpillars

Use your magnifying glass to find all the parts of your caterpillar. When you find a body part, read about what the caterpillar uses it for.



Mandibles : Mandibles are chewing mouth parts that caterpillars use to grind up their food

Spiracles : Spiracles are breathing tubes that caterpillars use to let air into their bodies.

Legs : Caterpillars have six legs, like all insects

Prolegs : Because they have such long bodies, caterpillars have some extra limbs called pro-legs to support their bodies. The prolegs are not real legs and they don't have joints.

Part 2: The caterpillar experiment

1. Make a hypothesis
Before starting an experiment, scientists always make a hypothesis. A hypothesis is an educated guess about what the results of your experiment will show. Based on what you know about temperature and cold-blooded organisms, do you think caterpillars will eat faster when they are hot or cold?

A. Write your hypothesis here:

Students can form the hypothesis that caterpillars will either eat faster when it is hot or cold.

B. What information did you use to make your hypothesis? What made you guess this?

Students might provide different reasoning depending on their hypothesis. Some examples from students are below:

Cold	*Hot*
"Caterpillars eat faster when it is cold because they are cold and need to eat to gain energy and get warm"	*"Caterpillars will eat faster when it is hot because they can chew faster when they are warm"*
"Caterpillars eat faster in the cold because I eat faster when I am cold"	*"Caterpillars will eat faster when it is hot because they are cold-blooded and depend on heat to get the energy to eat"*

2. Begin observing your caterpillars

Take the magnifying glass and get a close look at your caterpillars. Can you see its mandibles (mouth parts)? Is it taking bites of its food? Do you think it is eating fast or slow?

Students might provide different answers based on which caterpillar they are observing. The critical thing is to help the students to identify and observe the mandibles so that they can count the bites taken by the caterpillars during the experiment.

3. Using the thermometer

Shine the infrared thermometer on the caterpillar's back. Make sure you're shining the light on the caterpillar and not on the food or the table. What temperature is your caterpillar? Just for fun, carefully take the temperature of your hand. What temperature is your hand? What temperature is your lab partner's shoe?

This portion of the activity is to help students get comfortable using the infrared thermometer.

Caterpillar: *The caterpillar temperature will depend on whether the caterpillar is on the hot pack or cold pack.*
Hand: *Hands should be around 98 ° F or slightly colder*

Shoe: *Shoes are typically room temperature (60 – 70 ° F)*

4. Collect data

Pick a caterpillar and take its temperature using the infrared thermometer. Write it down on the data sheet so you don't forget! Get a close look at your caterpillar's mandibles and ask your lab partner to set the timer for 10 seconds. Count how many bites your caterpillar takes before the timer beeps. You and your lab partner will do 6 trials in your experiment. That means that you will count the caterpillar's bites and take their temperature 6 times. Make sure to record all your data on the data sheet.

Data Sheet

Trial	Hot / Cold	Temperature (°F)	Bites in 10 Seconds
1	Hot	*Temperature and feeding rates will vary, but it is helpful to make sure that students take measurements of the caterpillars after they have adjusted to their temperature. A difference of 10 ° F usually produces noticeable differences in caterpillar behavior. You may want to collect additional data if you do not see a difference*	
2	Hot		
3	Hot		
4	Cold		
5	Cold		
6	Cold		

5. Put your data on the graph

Take your data sheet to the graph and add your data points using the stickers you were provided. To add your data, find the temperature on the x-axis (the horizontal line). Then slide your finger up the line until you reach the number of bites your caterpillar took. Use red dots for the caterpillars on the hot pack and blue for the caterpillars on the ice pack.

Conclusions

6. Now that everyone's data is on the graph, do you think that caterpillars eat faster when they are hot or cold? Was your hypothesis right?

There should be a noticeable difference between caterpillars in the hot treatment and the cold treatment groups, with caterpillars in the hot treatment group taking more bites on average. Students should refer back to their hypotheses to see if they guessed correctly.

7. Are caterpillars (and all insects) cold-blooded or warm-blooded? How does temperature affect cold-blooded animals?

Caterpillars are cold-blooded, and they get energy from heat in their environment. They cannot move quickly if they are at a cold temperature

8. What is the scientific word for cold-blooded animals? What about for warm-blooded animals?

Endotherms are warm-blooded animals, and ectotherms are cold-blooded

9. How would being cold-blooded affect the ability of caterpillars to eat in hot and cold temperatures?

Cold-blooded animals need energy from their environment to move around. Caterpillars might eat slowly in the cold because they do not have enough energy to feed.

10. Based on the conclusions you made from data you and your classmates collected, how do you think that climate change might affect insects?

Climate change might make insects eat faster if the weather becomes hotter, and they might run out of food. If the climate became colder, then insects might not be able to eat enough to stay alive.

11. Did all of the data that you and your classmates collected follow the same pattern? Are there any data points that are far away from the others?

Students should notice any outliers or any instances in which caterpillars ate faster in the cold treatment group.

12. If you had measured the caterpillars only once, do you think you would have reached the same conclusion about how temperature affects caterpillar feeding? Why do you think scientists might want to do many experiments before making conclusions about their data?

If you did only one set of measurements and one of your caterpillars did not eat for some reason, or suddenly ate a lot, you might reach the wrong conclusion. Scientists do many experiments so that they can be sure that the patterns they observe are very common. By doing many tests, they can be sure that they have reached the right conclusion and are not basing their answers on one observation that might be a coincidence.

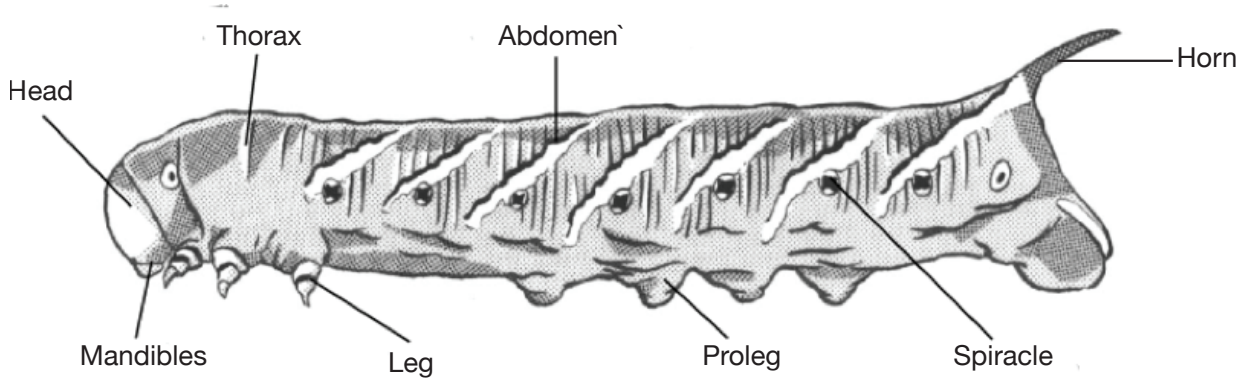
Caterpillars and Climate: How Temperature Affects Feeding Rate In Insects

Materials

Manduca sexta caterpillars (2)
Magnifying glass
Infra-red thermometer
Petri dishes
Caterpillar diet (you can also use tomato leaves if they are available)
Hot pack
Ice Pack
Pen
Timer
Red and blue stickers

Part 1: Getting to know the caterpillars

Use your magnifying glass to find all the parts of your caterpillar. When you find a body part, read about what the caterpillar uses it for.



Mandibles : Mandibles are chewing mouth parts that caterpillars use to grind up their food

Spiracles : Spiracles are breathing tubes that caterpillars use to let air into their bodies.

Legs : Caterpillars have six legs, like all insects

Prolegs : Because they have such long bodies, caterpillars have some extra limbs called pro-legs to support their bodies. The

prolegs are not real legs and they don't have joints.

Part 2: The caterpillar experiment

1. Make a hypothesis

Before starting an experiment, scientists always make a hypothesis. A hypothesis is an educated guess about what the results of your experiment will show. Based on what you know about temperature and cold-blooded organisms, do you think caterpillars will eat faster when they are hot or cold?

A. Write your hypothesis here:

_____

_____

_____

B. What information did you use to make your hypothesis? What made you guess this?

_____

_____

_____

2. Begin observing your caterpillars

Take the magnifying glass and get a close look at your caterpillars. Can you see its mandibles (mouth parts)? Is it taking bites of its food? Do you think it is eating fast or slow?

_____

_____

_____

3. Using the thermometer

Shine the infrared thermometer on the caterpillar's back. Make sure you're shining the light on the caterpillar and not on the food or the table. What temperature is your caterpillar? Just for fun, carefully take the temperature of your hand. What temperature is your hand? What temperature is your lab partner's shoe?

Caterpillar: _____

Hand: _____

Shoe: _____

4. Collect data

Pick a caterpillar and take its temperature using the infrared thermometer. Write it down on the data sheet so you don't forget! Get a close look at your caterpillar's mandibles and ask your lab partner to set the timer for 10 seconds. Count how many bites your caterpillar takes before the timer beeps. You and your lab partner will do 6 trials in your experiment. That means that you will count the caterpillar's bites and take their temperature 6 times. Make sure to record all your data on the data sheet.

Data Sheet

Trial	Hot / Cold	Temperature (°F)	Bites in 10 Seconds
1	Hot		
2	Hot		
3	Hot		
4	Cold		
5	Cold		
6	Cold		

5. Put your data on the graph

Take your data sheet to the graph and add your data points using the stickers you were provided. To add your data, find the temperature on the x-axis (the horizontal line). Then slide your finger up the line until you reach the number of bites your caterpillar took. Use red dots for the caterpillars on the hot pack and blue for the caterpillars on the ice pack.

Conclusions:

6. Now that everyone's data is on the graph, do you think that caterpillars eat faster when they are hot or cold? Was your hypothesis right?

_____

_____

_____

_____

7. Are caterpillars (and all insects) cold-blooded or warm-blooded? How does temperature affect cold-blooded animals?

_____

_____

_____

8. What is the scientific word for cold-blooded animals? What about warm-blooded animals?

_____

_____

9. How would being cold-blooded affect the ability of caterpillars to eat in hot and cold temperatures?

_____

_____

_____

10. Based on the conclusions you made from the data you and your classmates collected, how do you think that climate change might affect insects?

_____

_____

_____

11. Did all of the data that you and your classmates collected follow the same pattern? Are there any data points that are far away from the others?

_____

_____

_____

12. If you had measured the caterpillars only once, do you think you would have reached the same conclusion about how temperature affects caterpillar feeding? Why do you think scientists might want to do many experiments before making conclusions about their data?

_____

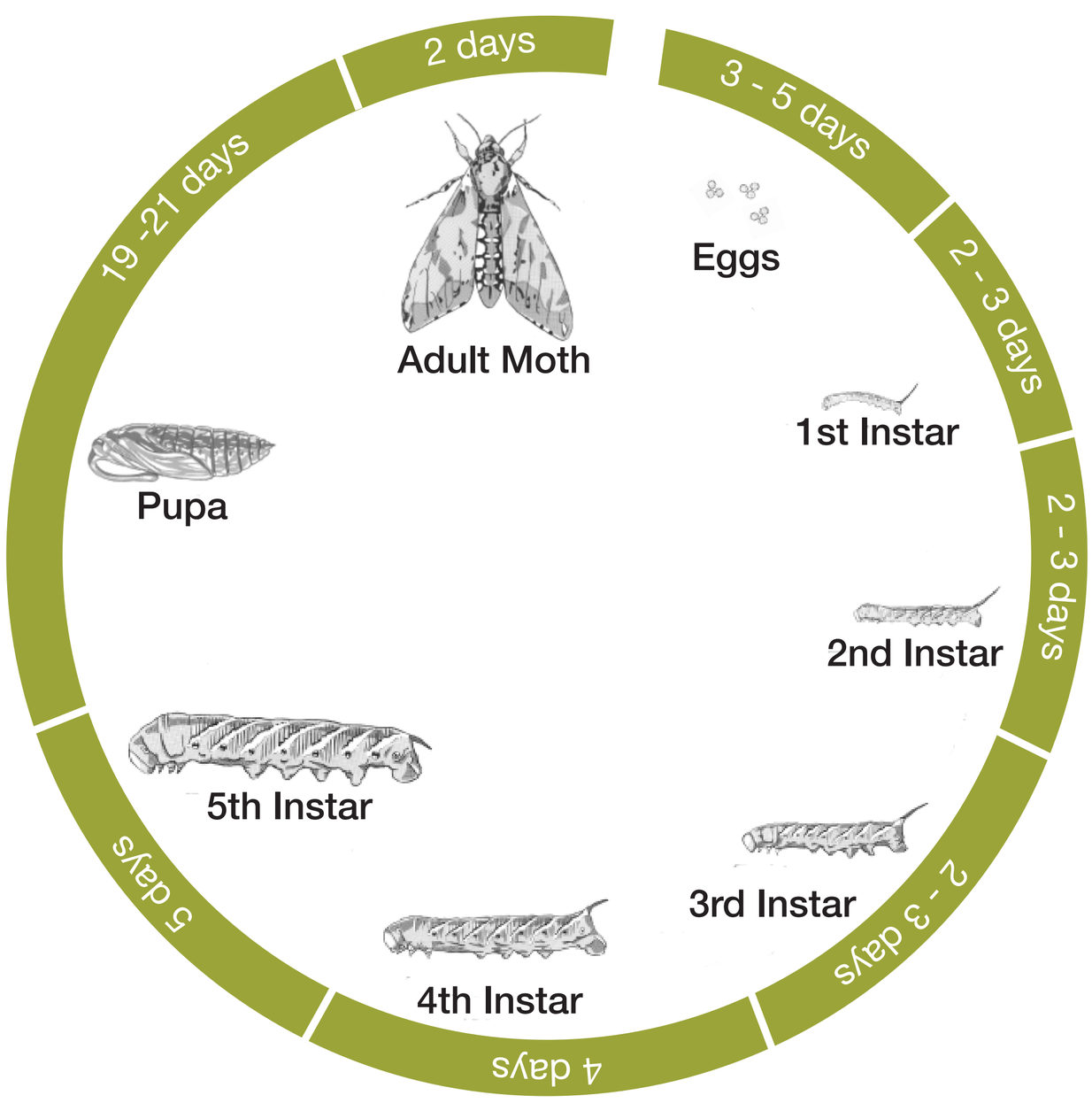
_____

_____

MEET THE CATERPILLARS!

The Tobacco Hornworm

These caterpillars are tobacco hornworms (scientific name: ***Manduca sexta***). They have evolved to live in warm climates like **North Carolina**. They feed on **tomato** and **tobacco** plants. Have you seen them in your garden?

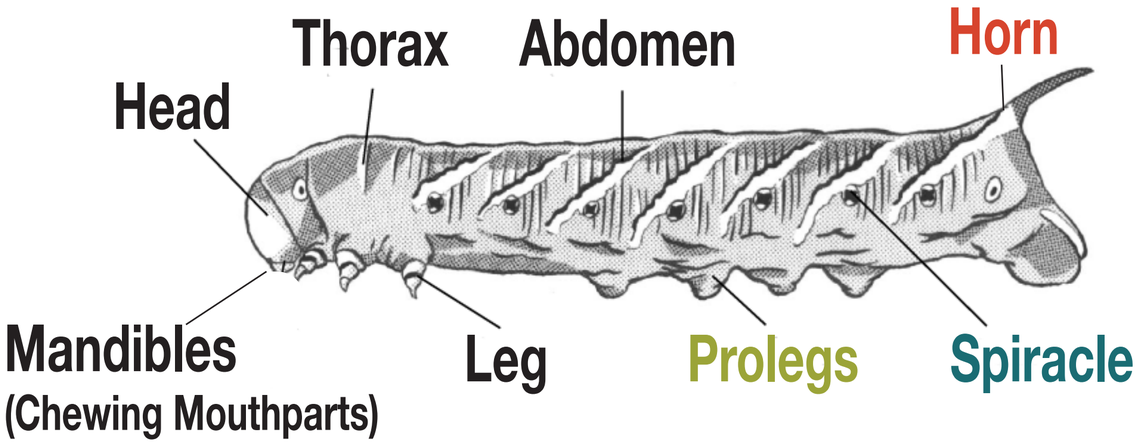


Manduca Life Cycle:

Manduca are **holometabolic** insects. This means that they completely transform 3 times in their lives. First from an egg to a larva or caterpillar, then from a caterpillar to a pupa, and finally from a pupa to an adult moth. While they are caterpillars, they **molt** (shed their skin) 4 times. What proportion of its life does a *Manduca* spend as a caterpillar? A pupa? An adult? Is this different than what you expected?

Manduca Anatomy:

Manduca caterpillars have 6 legs like all insects, but they have 8 special **prolegs** to support their long bodies. They also have special breathing holes called **spiracles** along their sides. What do you think their spiny **horn** is for?



supported by the nsf

Join the

CATERPILLAR EXPERIMENT

Test whether caterpillars eat faster when hot or cold

1 Form a hypothesis

A **hypothesis** is an educated guess about what will happen in your experiment. Which caterpillar do you think will be the fastest eater?

2 Take the caterpillar's temperature

Use the thermometer to take the caterpillar's temperature. Just shine the light on the caterpillar and check the screen!

3 Collect Data on Caterpillar Feeding

Pick a caterpillar and set the timer. Count how many bites it takes using the clicker. How much did your caterpillar eat? Was this what you guessed?

4 Add Your Data to the Graph

Share your data with other scientists! Mark the temperature on the x axis (horizontal), the number of bites on the y axis (vertical). In general, **do hot or cold caterpillars eat faster?**

Supported by the nsf

DO CATERPILLARS EAT FASTER WHEN IT'S HOT OR COLD?