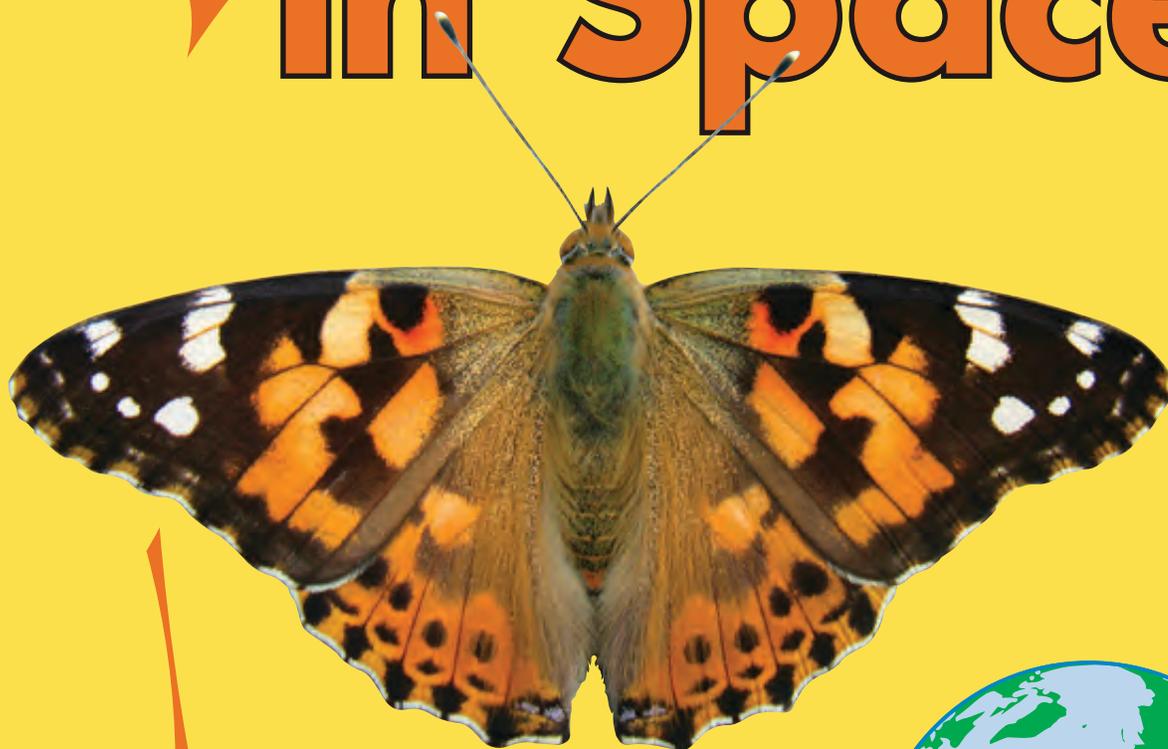


# Butterflies in Space



## TEACHER'S GUIDE

Gregory L. Vogt, Ed.D.  
Nancy P. Moreno, Ph.D.  
Stefanie Countryman, M.B.A.



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**An Experiment Aboard the International Space Station**

*by*

**Gregory L. Vogt, Ed.D.**

**Nancy P. Moreno, Ph.D.**

**Stefanie Countryman, M.B.A.**

## **RESOURCES**

This publication is available in PDF format at  
[www.nsbri.org](http://www.nsbri.org) and at [www.bioedonline.org](http://www.bioedonline.org).

For related resources and professional development, visit  
[www.bioedonline.org](http://www.bioedonline.org) or [www.k8science.org](http://www.k8science.org).

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**BioServe Space Technologies, University of Colorado**

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**Butterfly Pavilion**

Westminster, Colorado  
[www.butterflies.org](http://www.butterflies.org)

**Orion's Quest**

Detroit, Michigan  
[www.orionsquest.org/v3](http://www.orionsquest.org/v3)

**Challenger Learning Center of Colorado**

Colorado Springs, Colorado  
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**National Space Biomedical Research Institute**

Houston, Texas  
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**Office of the Chief Scientist, National Aeronautics and Space Administration**

Washington, D.C.  
[www.nasa.gov](http://www.nasa.gov)

# Teaming with Benefits

by Jeffrey P. Sutton, M.D., Ph.D., Director, National Space Biomedical Research Institute (NSBRI)

Space is a challenging environment for the human body. With long-duration missions, the physical and psychological stresses and risks to astronauts are significant. Finding answers to these health concerns is at the heart of the National Space Biomedical Research Institute's program. In turn, the Institute's research is helping to enhance medical care on Earth.



Dr. Jeffrey P. Sutton

The NSBRI, a unique partnership between NASA and the academic and industrial communities, is advancing biomedical research with the goal of ensuring a safe and productive long-term human presence in space. By developing new approaches and countermeasures to prevent, minimize and reverse critical risks to health, the Institute plays an essential, enabling role for NASA. The NSBRI bridges the research, technological and clinical expertise of the biomedical community with the scientific, engineering and operational expertise of NASA.

With nearly 60 science, technology and education projects, the NSBRI engages investigators at leading institutions across the nation to conduct goal-directed, peer-reviewed research in a team approach. Key working relationships have been established with end users, including astronauts and flight surgeons at Johnson Space Center, NASA scientists and engineers, other federal agencies, industry and international partners. The value of these collaborations and revolutionary research advances that result from them is enormous and

unprecedented, with substantial benefits for both the space program and the American people.

Through our strategic plan, the NSBRI takes a leadership role in countermeasure development and space life sciences education. The results-oriented research and development program is integrated and implemented using focused teams, with scientific and management directives that are innovative and dynamic. An active Board of Directors, External Advisory Council, Board of Scientific Counselors, User Panel, Industry Forum and Academic Consortium help guide the NSBRI in achieving its goals and objectives.

It will become necessary to perform more investigations in the unique environment of space. The vision of using extended exposure to microgravity as a laboratory for discovery and exploration builds upon the legacy of NASA and our quest to push the frontier of human understanding about nature and ourselves.

The NSBRI is maturing in an era of unparalleled scientific and technological advancement and opportunity. We are excited by the challenges confronting us, and by our collective ability to enhance human health and well-being in space, and on Earth.



## NSBRI RESEARCH AREAS

### CARDIOVASCULAR PROBLEMS

The amount of blood in the body is reduced when astronauts are in microgravity. The heart grows smaller and weaker, which makes astronauts feel dizzy and weak when they return to Earth. Heart failure and diabetes, experienced by many people on Earth, lead to similar problems.

### HUMAN FACTORS AND PERFORMANCE

Many factors can impact an astronaut's ability to work well in space or on the lunar surface. NSBRI is studying ways to improve daily living and keep crew members healthy, productive and safe during exploration missions. Efforts focus on reducing performance errors, improving nutrition, examining ways to improve sleep and scheduling of work shifts, and studying how specific types of lighting in the craft and habitat can improve alertness and performance.

### MUSCLE AND BONE LOSS

When muscles and bones do not have to work against gravity, they weaken and begin to waste away. Special exercises and other strategies to help astronauts' bones and muscles stay strong in space also may help older and bedridden people, who experience similar problems on Earth, as well as people whose work requires intense physical exertion, like firefighters and construction workers.

### NEUROBEHAVIORAL AND STRESS FACTORS

To ensure astronaut readiness for space flight, preflight prevention programs are being developed to avoid as many risks as possible to individual and

group behavioral health during flight and post flight. People on Earth can benefit from relevant assessment tests, monitoring and intervention.

### RADIATION EFFECTS AND CANCER

Exploration missions will expose astronauts to greater levels and more varied types of radiation. Radiation exposure can lead to many health problems, including acute effects such as nausea, vomiting, fatigue, skin injury and changes to white blood cell counts and the immune system. Longer-term effects include damage to the eyes, gastrointestinal system, lungs and central nervous system, and increased cancer risk. Learning how to keep astronauts safe from radiation may improve cancer treatments for people on Earth.

### SENSORIMOTOR AND BALANCE ISSUES

During their first days in space, astronauts can become dizzy and nauseous. Eventually they adjust, but once they return to Earth, they have a hard time walking and standing upright. Finding ways to counteract these effects could benefit millions of people with balance disorders.

### SMART MEDICAL SYSTEMS AND TECHNOLOGY

Since astronauts on long-duration missions will not be able to return quickly to Earth, new methods of remote medical diagnosis and treatment are necessary. These systems must be small, low-power, noninvasive and versatile. Portable medical care systems that monitor, diagnose and treat major illness and trauma during flight will have immediate benefits to medical care on Earth.



# 1. Introduction

## How will butterflies react to the environmental conditions of space flight?

The Butterflies in Space mission uses “life in space” as a theme to engage students in conducting their own open-ended scientific investigations. The project combines the excitement of an authentic, real-time experiment on the International Space Station (ISS) with hands-on exploration and data collection by elementary and middle school students in classrooms around the world.

On November 16, 2009 (current launch date), Painted Lady butterfly (*Vanessa cardui*) larvae will be carried into Earth orbit inside a special habitat container on board Space Shuttle Atlantis. Astronauts will transfer the habitat to ISS, where the larvae will complete their life cycles.

Photographs of the live organisms will be transmitted to Earth every 30 minutes during daylight hours. These photographs will be archived and made available to the public on the websites, BioEd Online ([www.bioedonline.org](http://www.bioedonline.org)) and K8 Science ([www.k8science.org](http://www.k8science.org)).

Students will be able to participate in the mission by conducting their own open-ended investigations of the growth, development and behavior of the organisms, which will be growing in microgravity (“weightless”) conditions. Ideally, students will be able to observe and compare similar organisms living under normal gravity conditions in their own classrooms. Students will investigate their own unique

questions—to which no one yet knows the answers!

This guide provides information about the mission and the selected species of butterfly (*Vanessa cardui*), instructions for constructing a butterfly habitat for use in classrooms, and ways in which students may carry out open-ended observational and comparative investigations. Since little is known about how microgravity affects butterflies and most other insects, students will be adding to the body of scientific knowledge about life in space.

Teachers and students may share their questions, experimental designs, and findings in the Discussions sections of BioEd Online and K8 Science.

### SUPPORTING RESOURCES

To introduce students to scientific questions and the process of inquiry, download this free teachers’ guide from the National Institutes of Health.

- **Doing Science: The Process of Scientific Inquiry**  
<http://science.education.nih.gov/supplements/nih6/inquiry/default.htm>

To learn more about butterflies, visit the following websites.

- **Monarch Lab, University of Minnesota**  
<http://www.monarchlab.org>

*Continued on p. 2.*



**Launch Target Date: November 16, 2009**

Check the NASA website below to find updates regarding the official launch date.

Commander Charles Hobaugh will lead the STS-129 mission to the International Space Station (ISS) aboard Space Shuttle Atlantis. Barry Wilmore will serve as the pilot.

Mission Specialists are Robert Satcher, Michael Foreman, Randy Bresnik and Leland Melvin. Wilmore, Satcher and Bresnik will be making their first trips to space.

The mission will return Nicole Stott, ISS Flight Engineer, to Earth.

STS-129, the 31st space shuttle mission to the ISS, is slated to be the final shuttle crew rotation flight to or from the Space Station.

[http://www.nasa.gov/mission\\_pages/shuttle/shuttlemissions/sts129](http://www.nasa.gov/mission_pages/shuttle/shuttlemissions/sts129)

*Continued from p. 1.*

• **FOSSWEB, Full Option Science System, Butterfly Investigation Videos**

[http://lhsfoss.org/fossweb/schools/teachervideos/1\\_2/Insects\\_Flash.html](http://lhsfoss.org/fossweb/schools/teachervideos/1_2/Insects_Flash.html)

To learn more about gravity, micro-gravity and life in space, visit these free websites.

• **NASA Lesson Plans for Microgravity**

<http://quest.nasa.gov/projects/space/lessons/microgravity.html>

• **National Space Biomedical Research Institute, Teacher Guides on Space Life Science**

<http://www.bioedonline.org/resources/nsbri.cfm>  
[http://www.nsbri.org/Education/Elem\\_Act.html](http://www.nsbri.org/Education/Elem_Act.html)

**NATIONAL SCIENCE EDUCATION STANDARDS**

National Science Education Standards. National Research Council. 1996.

**SCIENCE AS INQUIRY**

*Abilities Necessary to do Scientific Inquiry*

- Ask a question about objects, organisms and events in the environment.
- Plan and conduct a simple investigation.
- Use appropriate tools and techniques to gather data and extend the senses, and analyze and interpret data.
- Use data to construct a reasonable explanation.
- Think critically and logically to make the relationships between evidence and explanations.
- Use mathematics in all aspects of scientific inquiry.
- Communicate investigations and explanations.

*Understandings About Scientific Inquiry*

**K-4**

- Scientific investigations involve

asking and answering a question and comparing the answer with what scientists already know about the world.

- Scientists use different kinds of investigations, depending on the questions they are trying to answer. Types of investigations include describing objects, events, and organisms; classifying them; and doing a fair test (experiment).
- Simple instruments, such as magnifiers, thermometers and rulers, provide more information than scientists obtain using only their senses.
- Scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge).

**5-8**

- Different kinds of investigations call for different kinds of scientific investigations.
- Current scientific knowledge and understanding guide scientific investigations. Different scientific domains employ different methods, core theories, and standards to advance scientific knowledge and thinking.
- Mathematics is important in all aspects of scientific inquiry.
- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles.
- Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. All of these results can lead to new investigations.

**PHYSICAL SCIENCE**

**K-4**

- Objects have many observable properties, including size, weight, shape, color, temperature, and the ability to react with other substances. Those properties can be measured

using tools, such as rulers, balances, and thermometers.

## LIFE SCIENCE

### K–4

- Organisms have basic needs. Organisms can survive only in environments in which their needs can be met.
- Each plant or animal has different structures that serve different functions in growth, survival, and reproduction.
- Plants and animals have life cycles that include being born, developing into adults, reproducing, and eventually dying. The details of this life cycle are different for different organisms.
- Plants and animals closely resemble their parents.
- All organisms cause changes in the environment in which they live.

### 5–8

- Reproduction is a characteristic of all living systems; because no individual organism lives forever, reproduction is essential to the continuation of every species.
- All organisms must be able to obtain and use resources, grow, reproduce, and maintain stable internal conditions while living in a constantly changing external environment.
- Behavior is one kind of response an organism can make to an internal or external stimulus.
- An organism's behavior evolves through adaptation to its environment. How a species moves, obtains food, reproduces, and responds to danger are based in the species' evolutionary history.

## EARTH AND SPACE SCIENCE

### K–4

- The sun, moon, stars, clouds, birds, and airplanes [objects in the sky] all have properties, locations, and movements that can be observed and described.

### 5–8

- Gravity is the force that keeps planets

in orbit around the sun and governs motion in the solar system. Gravity alone holds us to Earth's surface and explains the phenomenon of the tides.

## MATHEMATICS EDUCATION STANDARDS

Principals and Standards for School Mathematics. National Council of Teachers of Mathematics. 2000.

### CONNECTIONS

- Recognize and apply mathematics in contexts outside of mathematics.
- Students will employ mathematics to study and compare Earth-based and flight organisms.

### GEOMETRY

- Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships.
- Specify locations and describe spatial relationships using coordinate geometry and other representational systems.

Students will use geometrical tools to plot the movements of butterflies.

### REPRESENTATIONS

- Use representations to model and interpret physical, social, and mathematical phenomena.
- Students will communicate their results through charts, data tables and other representations.

### MEASUREMENT

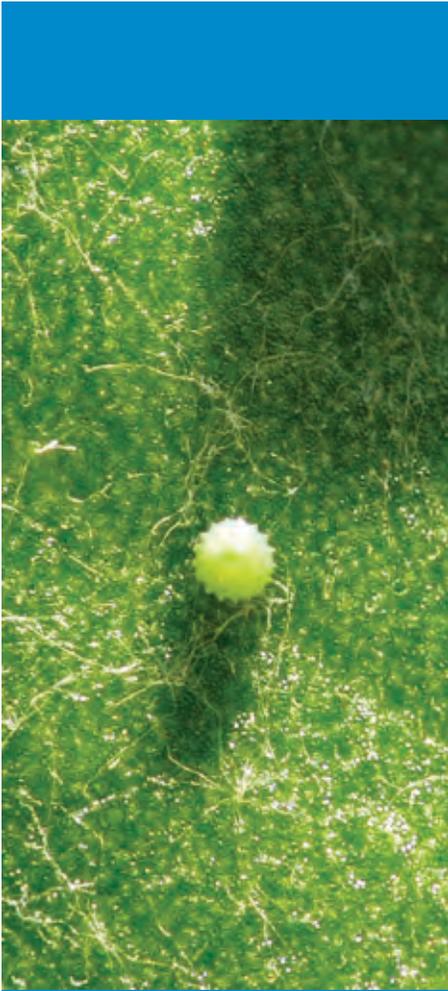
- Apply appropriate techniques, tools, and formulas to determine measurements.
- Students will measure chrysalis sizes and shapes, as well as behavioral patterns.

### DATA ANALYSIS AND PROBABILITY

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.

- Select and use appropriate statistical methods to analyze data. Students will collect and organize data and apply statistical analysis to behavioral patterns exhibited by the organisms.





## 2. *Living Organisms in Space*

Soon, butterflies will be living and adapting to the environment of space inside small habitat boxes on the International Space Station (ISS). At the same time, students in schools and informal educational institutions will be conducting Earth-based comparison experiments. They will construct habitat boxes and raise butterflies under conditions similar to those experienced by the animals in space, but with one important difference. Unlike the ISS-based animals, the Earth-based subjects will feel and sense the direction of gravity. Students will compare their observations of animals in their care to the photographs and videos of the space animals. They will ask and answer questions, write and share research reports, and speculate on how the knowledge they gain might apply to humans traveling further out into the solar system.

### Animal Astronauts

Long before cosmonaut Yuri Gagarin and astronaut Alan Shepard made their historic flights, animal “astronauts” were visiting the new frontier of outer space. These early space explorers allowed scientists to investigate the space environment without risking human life, and to determine if living things could survive the expected space vacuum, wide temperature extremes, and cosmic radiation, all while riding inside egg-like capsules. The first animal experiments, well below the edges of space, were carried on high-

altitude balloons. Starting in 1946, fruit flies, mice, hamsters, cats, dogs, and rhesus monkeys were lofted to altitudes ranging from 27 to 30 kilometers. For periods of up to 28 hours, data were collected on a variety of factors, including potential effects of exposure to cosmic radiation.

From 1948 to 1953, German V2 rockets, captured by American forces at the end of World War II, were launched from White Sands, New Mexico. Monkeys and mice were carried inside life support nose cones in some of these rockets. Their suborbital flights reached altitudes of more than 200 kilometers. As the rockets arced over Earth, a microgravity environment was created inside the spacecraft for as long as several minutes. (See “Investigating Gravity as a Variable,” p. 6.) As more powerful rockets were developed, animals were launched to higher altitudes and microgravity periods were extended.

In 1957, a dog named Laika became the first living thing to orbit Earth. Launched by the Soviet Union, Laika died during the mission, probably due to a malfunction of the capsule’s life support system. Laika was followed by other dogs, and by monkeys and chimpanzees launched by the United States. A Rhesus monkey, Able, and a squirrel monkey, Baker, rode together on a suborbital flight in 1959. In January 1961, the chimpanzee, Ham, made a successful suborbital flight in a test of the Mercury

1.



space capsule that would later be used by Alan Shepard and five other Mercury astronauts. On April 12, 1961, cosmonaut Yuri Gagarin became the first human to orbit Earth.

Manned spaceflight has become almost commonplace, but animal astronauts (including mice, rats, bullfrogs, fish, jellyfish, quail eggs, fruit flies, wasps, beetles, ants, bees, moths, nematodes, cockroaches, monkeys, spiders and butterflies) continue to play an important role in space missions. Animals in space have aided scientists in learning about how living systems adapt to and function in microgravity (the “weightless” condition that occurs during orbital space flight). These missions have amassed important data, and they are leading the way for human astronauts to prepare to return to the Moon, and maybe even reach Mars.

Near the end of 2009, the Space Shuttle Atlantis will carry “butterfly-nauts” to space for an extended stay on the International Space Station. Painted Lady butterflies (*Vanessa cardui*) will live in specially designed habitat boxes during the mission. Each box will provide the food, air, lighting and climate needed by these animals to live in microgravity. Atlantis will dock with the ISS, and astronauts will transfer

2.



the habitat boxes to a support module already on the station.

The module, called the Commercial Generic Bioprocessing Apparatus (CGBA), and the butterfly habitat box were developed by BioServe Space Technologies of the University of Colorado. The CGBA features a self-contained camera system that will begin collecting images of the animals after the unit is transferred from the Space Shuttle to the ISS.

Images will be collected daily, for two to four weeks. Also, videos of significant life cycle events (e.g., feeding, pupation, emergence, etc.) will be taken. Images and video will be transmitted to Earth and made available on the Internet ([www.bioedonline.org](http://www.bioedonline.org)) so students can study the life cycles of butterflies freed from the limits of gravity.

While the flight portion of the experiment will be completed by early 2010, the ground research can continue indefinitely. Future classes of “space scientist” students can conduct their own ground-based experiments and visit the web-based archives to review the flight data for comparison. 🦋

3.



**1. Arabella, a common cross spider, spun this web on the 1973 Skylab 3 mission. The experiment was designed by Massachusetts high school student, Judy Miles.**

**2. Astronaut Jack Lousma examining velvet bean caterpillar moths and honey bee drones during the STS-3 mission in 1982. The experiment was designed by Minnesota high school student, Todd Nelson.**

**3. Astronaut Donald Thomas in the spacelab science module observing a newt. Smaller organisms, such as newts, are able to develop from embryos and hatch during a mission. Information gathered helps to advance a program to determine if development occurs normally in the space environment.**



### 3. Investigating Gravity as a Variable

Scientific investigations can take many forms. Depending on the question, scientists might observe and describe objects, organisms or events; carry out experiments; work with existing data and observations; develop models of how a system works or interacts with other systems; or discover new objects, organisms or phenomena. The methods chosen depend on the question being asked.

Many important scientific questions are open-ended and exploratory. For example, when Anton van Leeuwenhoek (1632–1723) used a simple microscope to examine the world of microorganisms, he was not conducting a formal experiment. He aimed to observe and describe the previously unknown organisms he called “animalcules.” His work, along with that of other scientists, laid the foundation of modern microbiology.

When conducting investigations, scientists sometimes use control groups to examine the effects of one or more conditions. A condition that is allowed to change is called a “variable.” An experimental group of plants, for example, might receive a new type of soil nutrient, while a second group (“control”) would not. The control group does not. The

nutrient is the variable. All other conditions (light, water, temperature, etc.) are maintained, or controlled, to remain as similar as possible for both groups. That way, the growth of the two plant groups can be compared to learn about the effect of the nutrient on stem height, flowering or other aspects of growth and development.

Traditionally, scientists have been able to control experiments for temperature, chemical composition, light and other radiation, magnetic fields, pressure, and so on. One variable they could not manipulate was the magnitude of gravity. In Earth-based laboratories, the force exerted by gravity is always “on.” Therefore, researchers could not investigate questions regarding the effects of reduced gravitational attraction on the formation, physiology, or behavior of living things.

The limitation on investigating the effects of gravity changed with the advent of space flight and orbital spacecraft. Space flight creates an environment that simulates the near absence of gravity. The proper name for this environment is microgravity. It is often called “zero gravity” or “weightlessness,” but both of these terms are misleading because they imply that gravity disappears when orbiting Earth. Gravity does not go away; it actually keeps space shuttles and the International Space Station (ISS) in orbit. Without gravity, both vehicles would fly off into space

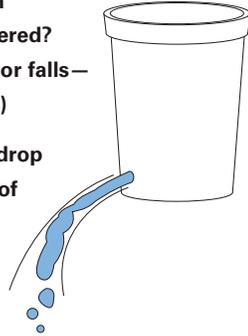
**MICROGRAVITY**  
An environment created by free fall in which gravity's effects are greatly reduced.

## Simple Microgravity Experiment

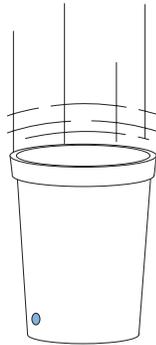


Punch a hole in the side of a Styrofoam cup, near the bottom. Fill the cup with water and cover the hole with your thumb. What will happen when the hole is uncovered? (Water streams—or falls—through the hole.)

Next, prepare to drop the cup a couple of meters into a basket or basin. Ask students to



predict what will happen to the water stream. (The water stream will stop because the cup and water are falling together.)

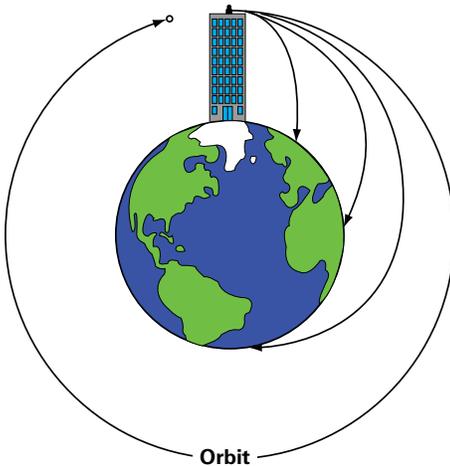


For a moment, the cup and water experience microgravity. The water stops streaming because microgravity greatly reduces the relative forces between the cup and the water.

in a straight line. (Newton's first law of motion at work.)

Why then, do astronauts float inside their spacecraft? The answer only adds to the mystery: astronauts do not float. Instead, they fall.

Imagine standing on the roof of a tall building and tossing a baseball straight outward. Gravity immediately will cause the ball to fall toward Earth as it moves outward, away from the building. Thus, the ball's path is curved.



Now imagine throwing a second ball, this one harder than the first. This ball's path also curves, but because it is moving faster, it travels farther from the base of the building than the first ball did. The curve is less steep. Throw a third

ball even harder and it lands still further away. If you could throw a ball hard enough, it would pass beyond the horizon. If you threw one final ball so fast that the curve of its falling path matched the curvature of Earth, the ball would travel completely around Earth and come back to its starting point. In other words, the ball would orbit the Earth! (Because this is imaginary, we can imagine that air friction doesn't slow the ball.)

Of course, NASA uses rockets to launch spacecraft and satellites into orbit. Climbing vertically at first, rockets gradually nose over and accelerate forward while rising even higher. When they reach their desired altitude, they are going fast enough to remain in orbit. Engines shut down and the satellite or spacecraft begins falling in a broad curved path that matches the curved shape of Earth. The ISS, for example, orbits about 360 kilometers above Earth. To remain in orbit, it must travel forward at 7.7 kilometers per second while it falls toward Earth.

Let's go back to our imaginary building. After you've finished throwing baseballs, you board the elevator to return to the ground floor. Unfortunately, the elevator cables break and the car begins falling. At that moment, something



A water drop spun off during a microgravity crystallization experiment takes on a spherical shape. Without buoyancy, gas bubbles do not rise, but remain inside the drop.



View of surface tension demonstration in microgravity using water being held in place by a metal loop. Drops of food coloring are for demonstration only.

The concept of artificial satellites was developed by Sir Isaac Newton (1642-1727) in his seminal work, *Philosophiæ Naturalis Principia Mathematica*. Rather than tossing a ball from a building roof, Newton described a cannon firing from a very tall mountain.

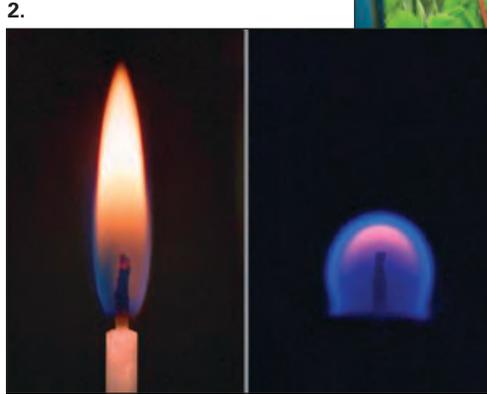


1. Collage of protein and virus crystals grown on the Space Shuttle and the Russian Mir Space Station. Shown under polarized light, the nearly perfect crystals were submitted to X-ray diffraction analysis.

2. A candle flame on Earth is stretched by rising air currents that bring in a fresh supply of oxygen. In microgravity, convection currents are greatly diminished, and oxygen is slowly supplied to the flame by diffusion. In the absence of gravity's effects, the flame becomes spherical.

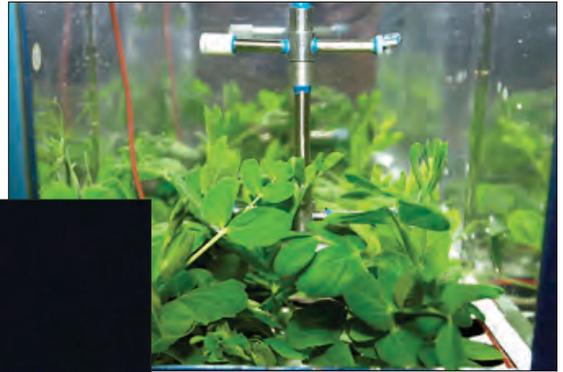
3. A view of a plant growth experiment conducted on the ISS.

1.

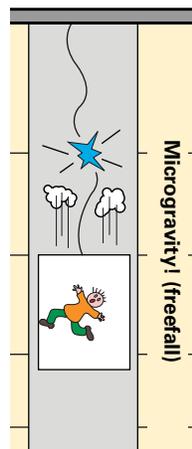


2.

3.



interesting happens. You fall with the car, and it feels like gravity has disappeared. If you were carrying a cup of water and shook the water loose, it would momentarily form a beautiful liquid sphere. The flame of a candle would become round. A handful of candies would drift randomly about like a swarm of flies. Falling produces a microgravity environment that simulates the absence of gravity. This unique environment would last until the elevator's



Assuming no air drag, the occupants and things inside a falling elevator car will experience microgravity for a brief period, until the car reaches the bottom.

emergency brakes engaged to stop the fall. At that point, you would remember that gravity still is present!

On the ISS, microgravity continues as long as the station orbits Earth. This condition allows scientists to conduct

new studies in basic science. Processes that depend on gravity, such as buoyancy and sedimentation, do not take place in microgravity. Materials mix differently in space, crystals of protein form more perfect structures, fluids form spheres, plant roots can grow in different directions, and animal and plant cells grow and develop differently. Microgravity also affects animal behavior. For example, adult fish carried to space tend to swim in circles, while fish born in space swim more normally.

The STS-129 butterfly investigation will seek to answer a number of questions. How successfully do butterfly larvae feed while in microgravity? Do they go through their metamorphosis stages normally? In microgravity, do butterflies pump their wings to normal shapes, or do the wings remain wrinkled? Will the butterflies try to fly or just drift about? Will they lay eggs? Investigating physical and biological processes with gravity as a variable provides scientists with a whole universe of new questions to answer. 🦋



## 4. Butterfly Primer

**W**ith approximately 20,000 species on Earth, butterflies are among the world's most recognizable and popular insects. Colorful and delicate, butterflies undergo a fascinating life cycle that begins with an egg, advances through larva (plural: larvae) and pupa (plural: pupae) stages, and ends with an adult laying eggs that will become the next generation.

All butterflies are herbivores. They serve as prey for other insects, lizards, frogs, toads, birds, and small mammals.

As insects, butterflies belong to the order Lepidoptera (scale wing) in the class Insecta of the phylum Arthropoda. Adult butterflies have three body parts: head, thorax, and abdomen. The head has one pair of compound eyes, one pair of antennae and a straw-like mouth, called a proboscis, that uncurls to suck up nectar and rolls up when at rest. The thorax has three pairs of jointed legs and two pairs of wings. The abdomen houses all of the butterfly's important organs.

Painted Lady butterflies (*Vanessa cardui*) will be flown on the International Space Station. This species was chosen because its members are widely distributed, and because artificial foods have been created to keep them alive and well inside various enclosures. Live specimens of *V. cardui* can be obtained from science education supply companies and are used frequently for teaching students. Further, as noted by educators with the Lawrence Hall of Science, if a Painted Lady butterfly escapes, it

will not be an environmental concern, because these butterflies are already well established throughout the United States and most of the world.<sup>1</sup>

### **Mission Specialist: Butterflynaut (*Vanessa cardui*)**

The Painted Lady, also known as the cosmopolitan or thistle butterfly, is the world's most widely distributed butterfly. Members of this species live in all temperate and tropical regions, except Australia and New Zealand. Where the weather turns cold, Painted Ladies migrate to warmer climates.

Farmers consider the Painted Lady a pest because its voracious larvae can devastate crops, such as beans. On the other hand, the Painted Lady has become a popular classroom insect for study because it is easy to cultivate.

The Painted Lady's life cycle lasts approximately one month, or sometimes a little longer in cooler temperatures. After the adults emerge from the chrysalis (butterfly pupa), they live from two to four weeks. During this short time, the butterflies mate, lay eggs, and die.

The life cycle begins with an egg that is the size of a pinhead. Painted Lady eggs are pale green and are covered with 12 to 14 longitudinal ridges (see image, p. 10). A butterfly may lay as many as 500 eggs on the underside of thistle, mallow, or hollyhock leaves, where they will be hidden from predators. Painted

1. <http://lawrencehallofscience.org/foss/fossweb/teachers/materials/plantanimal/ladybutterfly.html>



Lady eggs (image 1, left) incubate for three to five days, sometimes longer in cooler temperatures.

When the larvae hatch, they eat the remains of the egg cases, which contain valuable nutrients. Afterward, the larva, or caterpillar, (image 2) dines on leaves. Over several days, it grows in size and bulk. During molting, the caterpillar’s skin becomes tight and splits open, thus enabling the caterpillar to continue growing. This molting process occurs five times.

The phases between skin sheddings (molts) are called instar stages. The caterpillar will have a slightly different color—ranging from purple to black, crossed with yellow-green stripes—at each instar stage (image 3). It will have three pairs of true legs, near the head. Strong leg-like muscles on the abdomen, called prolegs, serve as the caterpillar’s primary source of locomotion.

When the caterpillar grows to about three centimeters long, it is ready for its next stage of development. At this point, the caterpillar selects a safe place beneath a leaf or twig and attaches itself with a strand of silk. The silk comes from a finger-like projection called a spinnerette. The caterpillar hangs upside down from the tip of its abdomen and sheds its final skin, revealing the pupa, or chrysalis. The skin of the pupa hardens to protect the butterfly during its most remarkable growth stage: metamorphosis (image 4). For further protection, butterflies have adapted their chrysalises to resemble curled leaves of the plants to which they cling.

During its seven to ten days inside the pupa, the larva completely breaks down into a kind of “caterpillar soup,” and then reconstructs itself. The three body parts form, and legs, antenna and wings are created. Large, color sensing eyes and a proboscis form on the head. Near the end of the process, the chrysalis begins to turn transparent. Colors on the butterfly wings become visible through the chrysalis walls (image 5).

Then, the new butterfly excretes a reddish waste product, called meconium, and begins to emerge from the chrysalis. While emerging, the butterfly hangs upside down. Gravity helps it to unfurl its wings, and fluid pumps into the veins to straighten the wings. The butterfly remains hanging for several hours until the wings dry out and become rigid. The butterfly’s wingspan ranges from five to six centimeters. Finally, the adult Painted Lady takes flight and begins to search for nectar-producing flowers on which to feed.

During their short adult lifespan, male and female butterflies seek reproductive partners with which to mate. Once reproduction has taken place, eggs are laid on an appropriate species of host plant, which the female butterfly identifies through smell. Not long after the adults reproduce and lay eggs, they die.

**Note:** Students may observe that the Painted Lady appears to have only four legs. The butterfly has six legs, but the front pair is difficult to see, because the legs are hairy and kept folded close to the thorax. Painted Lady butterflies use only the middle and back legs for walking.





## 5. Butterfly Habitats

In preparation for the flight experiment, butterfly eggs will be placed into the space habitat. To closely match the experiment protocol, obtain Painted Lady eggs from one of the suppliers listed below. In addition, larvae food will have to be obtained as a separate item. Painted Ladies also can be purchased as larvae, which are shipped from suppliers, usually with adequate food supplies. Larvae will be received in one of the early instar stages, perhaps as small as one centimeter in length. Whether you obtain eggs or larvae, your animals may be a few days ahead of or behind the flight experiment. Your students will need to determine the variation to accurately compare their butterflies to those on the ISS.

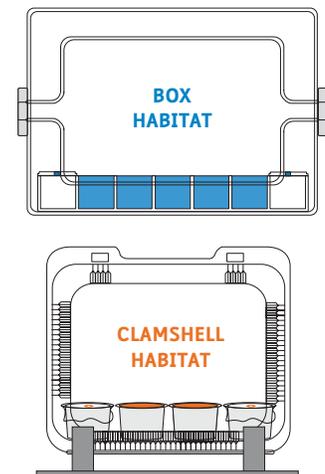
Painted Lady butterfly eggs, larvae and food are available from a number of companies, including the following suppliers.

- Insect Lore, [www.insectlore.com](http://www.insectlore.com)
- Carolina Biological Supply Company, [www.carolina.com](http://www.carolina.com)
- Ward's Natural Science, [wardsci.com](http://wardsci.com)
- Simply Butterflies, [www.simplybutterflies.com](http://www.simplybutterflies.com)

### TYPES OF HABITATS

We provide instructions for two different classroom habitats. The “Box Habitat” is a clear plastic box that closely models the dimensions and conditions of the habitat on the ISS. Use this design if you wish to maintain conditions that are similar to those experienced by the space butterflies.

The “Clamshell Habitat” is a clear plastic food container (hinged to allow the box to be sealed shut), about 8 in. x 8 in. in size. Use this habitat for an easy-to-assemble, low cost approach. For details, see pages 14–15.



### MAINTAINING CULTURES

#### Butterfly Larvae Food

When you prepare the habitats, distribute the larvae food evenly among the food containers. If you obtain eggs, do not place them directly on the food or the eggs will not hatch. Follow the instructions that come with the eggs. If you obtain larvae, use caution not to harm them while transferring food to the compartments. Place the feeding tray and the larvae inside the habitat.

#### Inserting the Larvae

Carefully place the larvae on the food compartments inside the butterfly

## ADDITIONAL TIPS

**CLEAN HABITAT:** Keeping the outside of your habitat clean and free of fingerprints is important for clear visibility of your butterflies/larvae.

**HUMIDITY:** The environment in which the habitats will be kept on board the International Space station will have a humidity level of approximately 50%. However, the humidity level inside the butterfly habitat will be closer to 80–90%. Your classroom habitat probably will not be in an environment with such high humidity. This difference should not affect your larvae much. The food may dry out more quickly, but it should maintain its moisture content long enough for your larvae to develop and form chrysalises.

**LIGHTING:** For the space flight habitats, a 12-hour light/dark cycle is provided. Six LEDs (bright whites) are used in the butterfly habitat for daytime lighting. For classroom purposes, a standard fluorescent bulb in a “shop” light fixture or desk lamp would work sufficiently. A simple plug-in timer can be used for the 12-hour on/off cycle of the lamp. Incandescent light can be used, but should not be placed too closely to the habitat, since this type of lighting can become very warm.

**TEMPERATURE:** The ISS habitats will be kept at approximately 25 degrees Celsius. However, temperatures between 21–26 degrees Celsius will work fine in your classroom. The caterpillars will develop more slowly in cooler temperatures. Monitoring the temperature of your habitat will be useful when comparing the space flight and ground control specimens.

**VENTILATION:** Even without modification, your habitat should have sufficient ventilation through the lid seams. If desired, use a hot nail to melt vent holes, and then cover the holes with fine mesh.

**BUTTERFLY LARVAE HEALTH:** Once the butterfly larvae are hanging in the “J” formation, it is important to not disturb them. Your organism is very susceptible to damage during this stage of metamorphosis. A few hours after the full chrysalis is formed, you should be able to move the habitat gently without risk to your organisms.

habitat. A small paintbrush can be used to gently push the larvae on to the food. Begin daily observations.

### Adult Butterfly Nectar

Three or four days after the larvae have pupated, prepare artificial nectar for the adult butterflies using the following formula.

- 1 ounce of sugar
- 4 ounces of water
- 2 pinches of salt

Boil the water, and then add the sugar and salt. Stir to dissolve sugar and salt. Allow to cool completely. Moisten cotton balls with this mixture and place them in the two outer food compartments. Replace compartment lids.

### Butterfly Care and Feeding

It is simple to care for Painted Lady butterfly larvae, pupae and adults. Allow larvae to live on the commercial food until they create their pupae. The pupae (also called chrysalises) will be dormant for seven to ten days, during which time they should not be disturbed. When a butterfly is ready to emerge from its pupa, the pupal casing will become transparent and the wings will be visible. The butterfly then will begin to push on the pupal casing, causing it to break open along seams. Within two to five minutes, the butterfly should be free from its pupa. With hemolymph (circulatory fluid, or “blood” of arthropods) pumping through its veins, the butterfly will stretch out and straighten the wings. The wings will be sufficiently hard and ready for flight in two to eight hours. The butterfly also will cleanse its body by releasing a large amount of reddish waste, called meconium.

Adult Painted Lady butterflies usually feed 12–24 hours after emergence. They will require a liquid diet of artificial nectar. Use the formula above to create nectar for your habitat. Butterflies also

will do well with juicy fruits, such as orange slices and sports drinks. However, these are not being flown in the space experiment and should not be used with your specimens. Adult Painted Lady butterflies have a relatively short lifespan of one month or less.

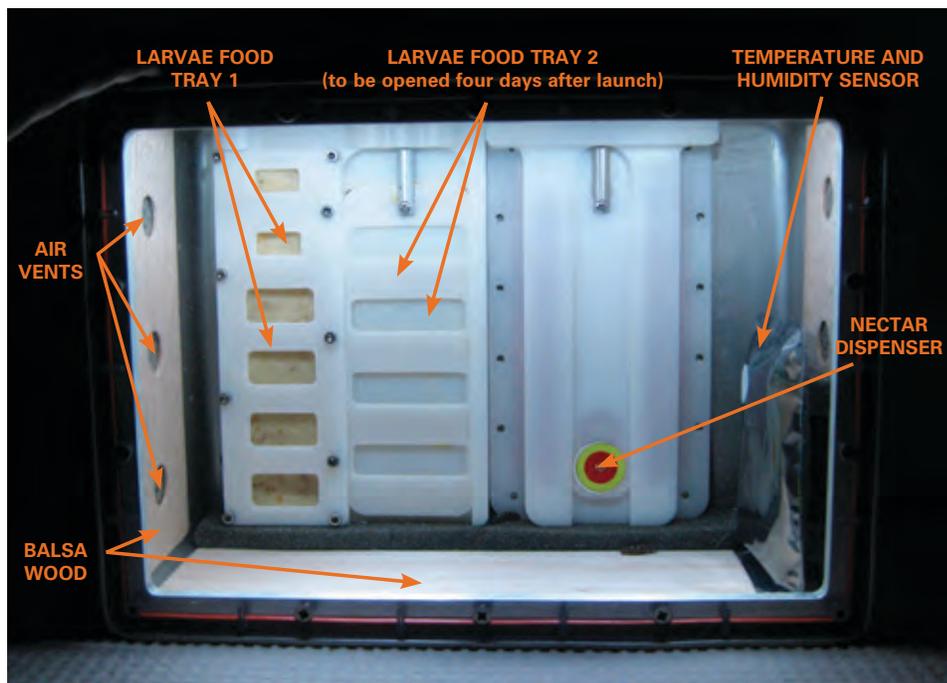
### SAFETY

Always follow all district and school laboratory safety procedures. It is a good idea for students to wash their hands with soap and water before and after any science activity.

For guidance on the proper care of animals in the classroom, consult the NSTA Position Statement, *Responsible Use of Live Animals and Dissection in the Science Classroom*, <http://www.nsta.org/aboutpositions/animals.aspx>. 

# STS-129 Protocol for Painted Lady Butterflies

1. Four, 6-day-old Painted Lady butterfly larvae, larvae food and butterfly nectar will be loaded into the butterfly space flight habitat approximately 30 hours before launch. A second experimental habitat also will be loaded at that time. Photos from the second habitat will not be available.
2. At 28 hours before launch, the butterfly habitats and one associated camera module will be handed over to NASA for loading into the space shuttle. Each habitat and camera module will be placed in a gallon-sized Ziplock® bag (not closed), and packed into a suitcase-like container, surrounded by foam, which will be securely stowed in the nose section of the space shuttle, where it will remain until the habitats and camera module are transferred to the ISS. This container will provide no lighting and will hold the habitats at ambient temperature, approximately 21 degrees Celsius. The habitats will remain in this environment for approximately 90 hours, from loading of the habitat to transfer to the ISS.
3. At approximately MET (mission elapsed time—measured from the moment the shuttle launches) 2 days, 12 hours, a crew member will unpack the habitats and camera module and transfer them from the space shuttle to the BioServe Commercial Generic Bioprocessing Apparatus (CGBA) onboard the ISS. The crew member will install the two habitats and camera module into CGBA, which will provide the power source to run the habitat lighting and camera module systems. It also will maintain the correct temperature for the habitats. The temperature inside CGBA, and thus, the habitats, will remain approximately 25 degrees Celsius.
4. When the crew member transfers the



Two sets of food dispensers are used in the flight habitat. One set will be sealed and opened later in the flight to provide additional food for the animals. The rectangular openings expose the initial food supply. Notice the aluminum rods near the top of the picture. When pulled upward from the outside of the box, the attached sliding panel exposes new feeding slots. (Note: Your habitat will not look exactly like the CGBA.)

- habitats from stowage to CGBA, he or she will expose the second set of food for the larvae in each habitat.
5. A 12-hour on/off lighting cycle will be provided to both habitats, and will run between 8 a.m. and 8 p.m., Mountain Standard Time. The butterfly habitats have six bright white LEDs to simulate daytime lighting.
6. Within 24 hours of installation, project personnel on Earth should begin to receive images from the habitats. Color images will be taken every 30 minutes during the “day-time” 12-hour cycle. Images from the Painted Lady habitat will be uploaded to the teacher/student websites once each day ([www.bioedonline.org](http://www.bioedonline.org) and [www.k8science.org](http://www.k8science.org)).
7. If possible, significant events (for example, eating, chrysalis formation, butterfly emergence) will be captured as video. If meaningful video

is obtained, it will be posted on the same websites as the images.

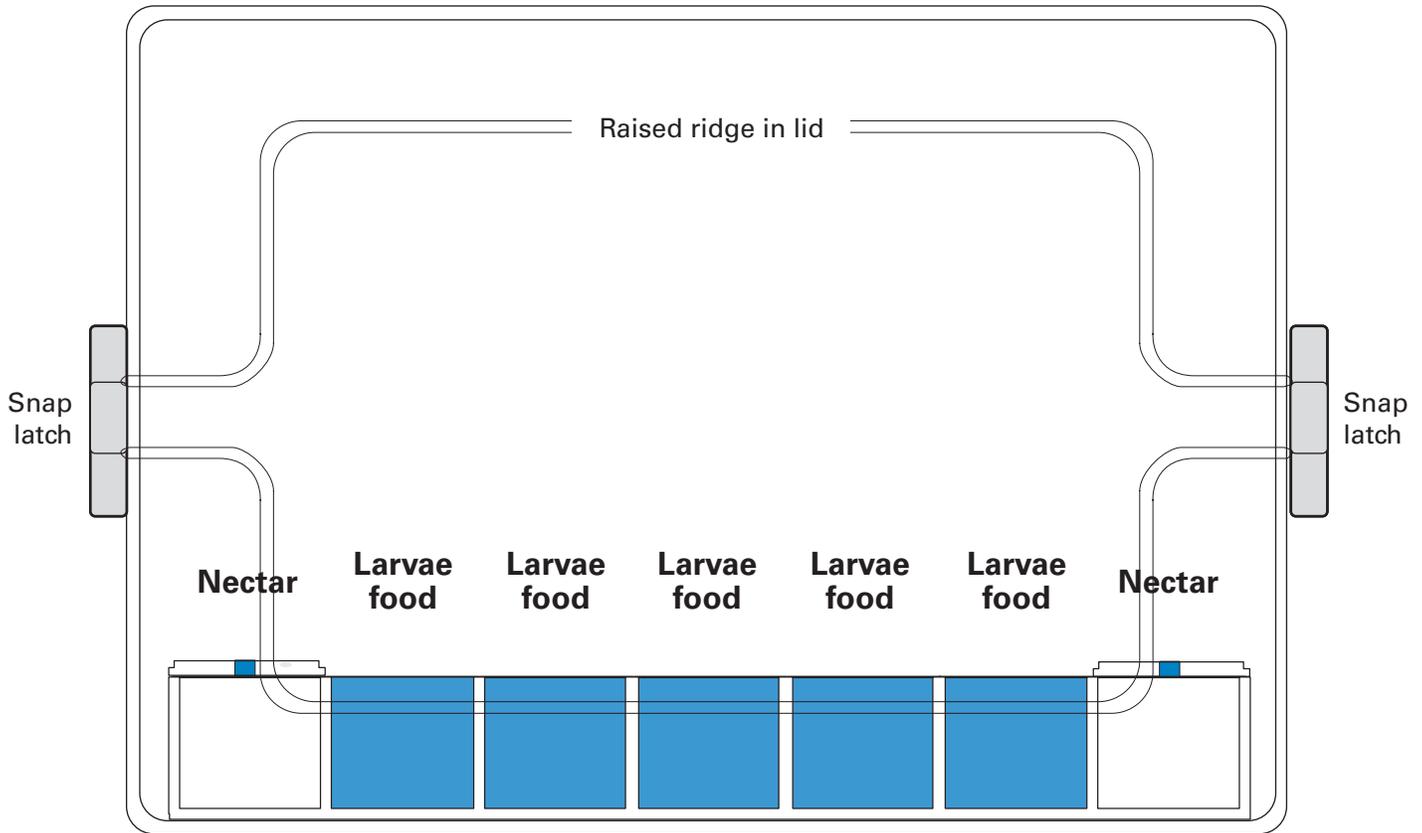
8. At approximately MET 11 days, a crew member will access the habitats and expose nectar for the soon-to-emerge butterflies.
9. Both habitats will return to Earth on the space flight mission 20A (STS-130), currently scheduled to launch in February 2010. Because butterflies have relatively short life spans, they are not expected to be alive at this time.

## STS-129 MISSION DETAILS

For details on the space shuttle mission timeline, crew and activities, please go to [http://www.nasa.gov/mission\\_pages/shuttle/shuttlemissions/sts129/index.html](http://www.nasa.gov/mission_pages/shuttle/shuttlemissions/sts129/index.html).



# Box Habitat



## MATERIALS FOR ONE HABITAT

- Clear plastic box, item number 079-C (7-7/16" x 5-5/16" x 3-3/4"). Order from Pioneer Plastics (sold by case, 18 per case) at 800-951-1551 or [www.pioneerplastics.com](http://www.pioneerplastics.com).
- Clear or white 7-day medicine organizer, 6" x 1.25" x 1" (available at most pharmacies)
- Drill (or nail and pair of pliers, see Item 3 below)
- Prepared larvae food and nectar (see "Maintaining Cultures," p. 11)
- Red permanent marker

## PROCEDURE

1. No modification of the box is necessary.
2. Cut off the Monday–Friday lids of the medicine organizer.
3. Drill 1/8-inch holes through the Sunday and Saturday slots of the organizer (to hold nectar). OR, hold the nail with a pair of pliers and heat the nail with a candle flame. Push the heated nail through the center of the Sunday and Saturday lids. The plastic will melt around the nail and cool to form a hole. Using the marker, draw a red circle around each hole.

4. Place the modified medicine organizer with food on the bottom edge of the box (see "Maintaining Cultures," p. 11) and stand the box on its side, as shown above.
5. Place the habitat in an area where it will not be disturbed. It may occasionally be necessary to move or open the box, so it should not be fixed permanently to a shelf or counter top.

## HUMIDITY

If the air in your classroom is dry during the experiment, add an additional portion cup with a moistened cotton ball to the habitat. Remoisten the cotton ball as it dries out.

## SPACE HABITAT

Providing food twice will more closely duplicate the flight habitat conditions. One dispenser will suffice and can be removed and refilled with larvae food or nectar, if necessary (see "STS-129 Protocol for Painted Lady Butterflies," p. 13).



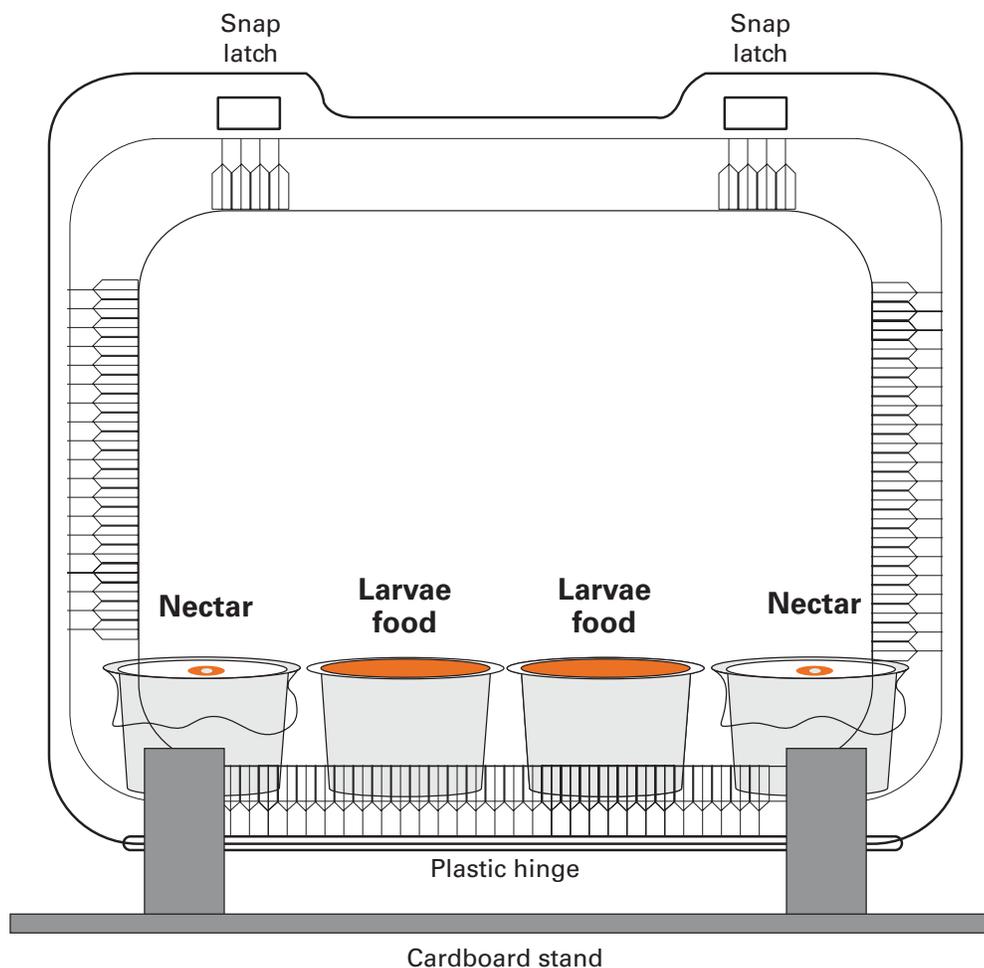
# Clamshell Habitat

## MATERIALS FOR ONE HABITAT

- Clear, hinged “clamshell” take-out food container, 8” x 8” x 3” (approximate), available from most grocery stores with salad bars or bakeries. If you wish to make more than one habitat, clamshell food containers are available to purchase in larger quantities (such as Reynolds Easy-Lock Hingeware, item number REY2647) from online vendors.
- 4 clean individual portion cups (such as those used to hold ketchup in restaurants) and 2 lids
- Distilled water
- Prepared larvae food and nectar (see “Maintaining Cultures,” p. 11)
- Hot glue gun and glue
- Pair of scissors
- Plastic report cover
- Red permanent marker
- Sheet of cardboard (see Item 2, below)

## PROCEDURE

1. No modification of the box is necessary.
2. Make a simple base out of cardboard to hold the box upright on its hinged side. OR, allow students to invent a support for the habitat using cardboard, wood blocks, clay, etc., held together with hot glue or tape, as appropriate.
3. Cut a 1” x 6.5” strip of plastic from the report cover. It will serve as the base for the portion cups.
4. Use a hot glue gun at a low temperature to attach the portion cups to the base.
5. Punch small holes (about 1/8-inch diameter) in the center of the two portion cup lids. Draw a ring around



the holes using the red marker. (Adult butterflies will be attracted to the red color for feeding.) Place the lids on the two “end” portion cups after each is filled with nectar (see “Maintaining Cultures,” p. 11).

## HUMIDITY

If the air in your classroom is dry during the experiment, add an additional portion cup with a moistened cotton ball to the habitat.





## 6. Designing the Investigations

It is important for students to design their experiments before your butterfly larvae arrive. The principle experimental variable will be gravity. Unlike butterflies in the microgravity environment of the International Space Station (ISS), butterflies in your classroom will experience gravity and have a distinct sense of up and down. However, all other conditions within the “space butterfly” habitat (air composition, atmospheric pressure, 12-hour cycles of light and darkness, temperature, etc.) will match those experienced by the Earth butterflies as closely as possible. The “Potential Investigations” table on page 17 provides ideas for student investigations.

Several days after the Space Shuttle is launched, the butterfly habitat will be transferred to the Commercial Generic Bioprocessing Apparatus on the ISS. Shortly thereafter, photographs of the interior of the butterfly habitat, taken at 30-minute intervals, will be made available on the BioEd Online ([www.biodeonline.org](http://www.biodeonline.org)) and K8 Science ([www.sk8science.org](http://www.sk8science.org)) websites. (Check one of these sites periodically for updates on the Shuttle launch and approximate dates for the transfer of the butterfly habitat to ISS.) Students should base their research questions on behaviors or physical features that can be observed and recorded via time-sequenced photographs. Ideally, student investigations will call for similar

observations and measurements on the organisms both in space and in their classrooms. For example, students may choose to observe specific behaviors or developments of their “Earth butterflies” at a certain time each day, and then collect data from a single photograph of the “space butterflies” taken at the same time. Photographs will be archived by date on BioEd Online and K8 Science, so students will be able to access earlier photographs as needed.

Once students have prepared their research questions and identified the observations they will be making, they can immediately begin collecting data on their classroom organisms. They will be able to study their Earth-based butterflies through all stages. However, remind students that the space-based larvae will be at least seven days old when they arrive on ISS. Therefore, the classroom organisms may be “behind” or “ahead” of the development of the space butterflies in real time. Students will have to calibrate data collected from their classroom butterflies with data gathered on the “butterflyonauts,” based on the number of days each specimen has advanced into the life cycle.

### PROCEDURE

1. Divide your class into research teams of three or four students each.
2. Provide opportunities for the teams to learn as much as possible about the Painted Lady butterflies before

## POTENTIAL INVESTIGATIONS

Behavior/Variable	Data/Categories	Notes
Average temperature	Temperature	Temperature can affect an animal's behavior. If the temperature is too high or too low, an animal may act unnaturally, and even perish.
Relative humidity	Humidity	Humidity can affect animals. If the humidity is too low, larvae food may dry out, larvae may not be able to molt, and butterflies may not be able to exit their pupae. If humidity is too high, food may mold.
Activity levels	Activity	Compare the types and frequency of activities carried out by animals on Earth with those of animals in microgravity.
Growth of larvae	Size	Measure the initial size and growth rate of the larvae.
Larval feeding	Feeding	Are the animals feeding? Do animals on Earth feed more or less frequently, or at different times than the animals in space?
Larval survival	Success	What percentage of the larvae survived to pupate?
Pupating	Ability to pupate	Are the animals in microgravity molting and pupating correctly?
Emergence	Ability to emerge	Do the butterflies in microgravity emerge from their pupae? What is the success rate?
Locomotion	Flight ability/ walking behavior	Do the butterflies in microgravity fly, or do they only walk? If they fly, how does their flight compare to the flight of butterflies on Earth?
Adult feeding	Feeding	Are the adults able to find and eat their food?
Mating	Ability to mate	Do the adults exhibit mating behavior? (This question applies only if a male and female are present.)
Egg laying	Ability to lay eggs	Did the butterflies lay eggs? If so, how many? Where did they lay their eggs?
Larval emergence	Eggs hatching	Was fertilization of the eggs successful? (In other words, how many eggs hatched?)

the investigation begins. The background information and references in this guide can serve as a starting point. The student sheets on pages 20 through 22 will introduce students to the life cycle and anatomy of Painted Lady butterflies.

- Depending on the ages and prior knowledge of your students, and the time available, carry out one or more of the following steps to further prepare your class for the project ahead.

- Use the student sheet, "Naturalist Journal Practice Sheet," (p. 23) to teach students how to make detailed observations of butterflies.
- Have teams write and present research reports or essays, computer presentations, or posters that summarize what they have learned about butterfly anatomy, feeding, growth, reproduction, behavior, etc.
- Discuss or conduct one or more

inquiry activities on gravity or microgravity. NASA Lesson Plans for Microgravity (<http://quest.nasa.gov/projects/space/lessons/microgravity.html>) provide a variety of approaches for covering this topic.

- Based on their background studies, ask each team to develop a research question to guide its investigation. It is not certain that the larvae in space will progress completely to the butterfly stage, so students may

want to plan their questions and investigations with that in mind.

5. Provide each team a copy of the “Research Proposal” sheet (p. 24) to guide the development of their experimental designs. Review team proposals and offer advice, if needed, on how to improve each team’s central question and proposed measurements or observations.
6. During the investigation, students will track the behavior of the classroom animals and compare their data to observations of the flight animals. Basic information (about the length of the larvae stages, for example) can be maintained in tabular form. Of course, additional useful data also will be available. Not all of the data will be conducive to reporting in tables. Students should devise their own strategies for collecting and reporting data. These strategies might include taking digital photos and making measurements from these images (the larvae are very fragile, so students should devise strategies that do not involve removing the larvae from the chamber); making sketches; observing and documenting behaviors, etc.
7. At the conclusion of the butterfly investigation, student teams should wrap up their work. Have teams review their data, decide if their data support their hypotheses (predicted answers to research questions), and discuss what they learned from their research. Each team should submit a final investigation report for assessment. Possible reporting strategies include a classroom scientific journal that combines the reports and illustration from all teams; or individual team posters/presentations (in PowerPoint® or hard copy) that summarize their findings. Consider sharing students’ projects and conclusions in the Discussion Forums on BioEd Online and K8 Science.

## ADDITIONAL CONSIDERATIONS

### Naturalist Journals

One of the oldest methods of recording observations of the natural world is the naturalist’s journal. Scientists and explorers throughout history have kept journals of their explorations and experiences. Leonardo DaVinci, John Audubon, Lewis and Clark, Charles Darwin, and many others recorded their discoveries in notes and illustrations. Both techniques are still valid, and in some ways, sketching is more beneficial to the observer than is photography or digital imaging. To sketch a butterfly, for instance, students must study the subject very closely. They must look for shapes and structures, both small and large, as well as textures and colors. A photograph or digital image contains far more detail, but these media often encourage the observer to see the whole instead of the details. Sketching and recording observations force students to see both the parts of a subject and the relationship of these parts to the whole. Further, comparative observations of similar species will lead to student insights on how living things adapt to their environments.

To help your students sharpen their observation skills before the investigation, provide them with copies of the “Naturalist Journal Practice Sheet,” (p. 23) featuring two photographs of butterflies. Or download the “Butterflies in Space” slide set from the BioEd Online website or provide a live specimen for the students to observe. Students will sketch one butterfly and record their observations about it. They will need pencils of varying hardness, and erasers. Colored pencils are beneficial but not essential, since students can add captions to their illustrations to identify different colors. During the actual investigation, students will write their observations on the borders of their sketches, describing the behaviors they observed. Many new questions may arise from their careful observations.

### Data from Space

Images and relevant data for the space-based specimens will be archived on the websites listed below. This archive will allow student teams to coordinate the “space data” with data collected from their Earth-based investigations. (See “STS-129 Butterfly Protocol for Painted Lady Butterflies” on page 13.) Depending upon communication schedules for the ISS crew and Mission Control in Houston, Texas, data will be routinely downloaded.

Still and video images of the butterflies will be downloaded from the ISS. Average temperatures and humidity within the habitat also will be downloaded to the BioEd Online and K8 Science websites. Students will have to use known dimensions within the habitats to compare the sizes of their Earth-based specimens at various stages to those of the “space specimens” at the same stages, as seen in photographs. Use the size of the feeding slots to make accurate measurements. The centermost feeding slot is 3.3 cm by 1.0 cm.

To save time, you may want to bookmark the website you will be using to retrieve flight data. You also may want to create and display in the classroom a table or chart on which you record humidity and temperature data. Although your students will be able to download images, video, and data at any time, including from home, it is suggested that you save the images in dated files on a classroom computer for all to share. This will eliminate the need to spend class time repeatedly downloading large image files for individual teams.

### Web Sites

BioEd Online ([www.biodeonline.org](http://www.biodeonline.org))  
K8 Science ([www.k8science.org](http://www.k8science.org))

### Data Analysis

It is appropriate for students to calculate means (averages) of daily measurements for the Earth- and space-based butterflies. Line graphs can be helpful for interpreting changes in measured

variables over time. For a detailed overview of how to represent and interpret students' data, see "Science of Research and the Process of Science" from Intel Science Talent Search ([http://www.societyforscience.org/isef/primer/scientific\\_method.asp](http://www.societyforscience.org/isef/primer/scientific_method.asp)).

### Collecting Images

In space, digital images will be taken daily after the animal enclosures are transferred to the ISS, and will be made available online as soon as possible. If your students plan to sketch their Earth-based animals, they should make sketches from the space images as well. It will be easier and more accurate for them to compare space- and ground-based data if they use the same techniques to collect data from both specimens. If photographs are to be taken of the Earth-based animals, have students practice and become familiar with the camera(s) to be used prior to the experiment. Also, address the following important imaging considerations.

Because the boxes are clear plastic, reflections may cause a problem for cameras, so care should be taken when composing photos. Also, it will be necessary to get very close to your subjects to make good photos, so be sure to use a camera with macro focus. Begin by determining the optimal distance for the camera you will be using. Take several practice photos of each habitat, framing the entire interior space. Place objects inside the enclosures and focus on them instead of the surface of the enclosures.

Adjust the angle of the enclosure or camera slightly to eliminate as much reflection as possible. Black poster board can help to block stray reflections. Another technique for reducing reflections is to cut a camera lens-sized hole in the middle of a sheet of black poster board. Shoot pictures through the hole in the poster board.

Avoid touching the front or back surfaces of the boxes. When possible, handle the boxes by the sides. Fingerprints and dust collected on the surfaces should

be cleaned before daily imaging.

It also is imperative for sufficient light to expose the inside of the habitats. Room light or small flashlights, pointed through the sides or top of the enclosures, will brighten the subjects. It is far better to have a light that seems too bright than to have insufficient lighting. Do not illuminate from the front of the habitat or use the flash on the camera, as this will cause a strong reflection.

The background in each habitat can impact the quality of photos. A plain, light gray-colored background in the butterfly habitat will permit sharp images, and help the butterflies to stand out. Be sure to focus directly on the butterflies, and set the camera for "spot" or "center-weighted" metering. Otherwise, the brighter background may cause the butterflies to appear dark.

Even if photos will be the main source of data, have students take notes and make sketches to help them analyze the images. Be sure to have students label photos and sketches, so they can match them later. Periodic videos will be taken of the space animals, and students will be able to view these videos on their computers. With video controls, they will be able to stop action. Students then can sketch and plot the location of the butterflies (both space- and Earth-based) over time, and can create diagrams illustrating the animals' movement (like footprints in snow). Students then can compare behaviors of the space- and Earth-based specimens. Encourage students to use computer drawing software for their diagrams. 

## BUTTERFLY RESOURCES

- ***The Family Butterfly Book***, by Rick Mikula. Projects, activities and a field guide to 40 North American butterfly species.
- ***Meet the Arthropods***, by Ellen Doris. This book introduces the six classes of arthropods, and provides numerous facts and 200 color photos for students in grades 4-7.
- ***Painted Lady Butterflies***, by Donna Schaffer. Picture book for younger readers.
- ***Practical Entomologist***, by Rick Imes. This book is a valuable reference for beginners looking for more information about insects and their life cycles.
- ***Waiting for Wings***, by Lois Ehlert. A rhyming picture book for younger students that focuses on butterfly metamorphosis.
- ***Butterflies Through Binoculars: A Field Guide to the Butterflies of Eastern (Western) North America***, by Jeffrey Glassberg. Published by Oxford University Press, these two field guides provide comparison pictures and information for butterfly watchers.
- ***Butterflies of North America***, by Kenn Kaufman. A vinyl-bound pocket guide containing more than 2,000 images of North American butterflies.

## TEACHER RESOURCES

Downloadable activities in PDF format, annotated slide sets for classroom use, and other resources are available free at <http://www.bioedonline.org> or <http://www.k8science.org>.



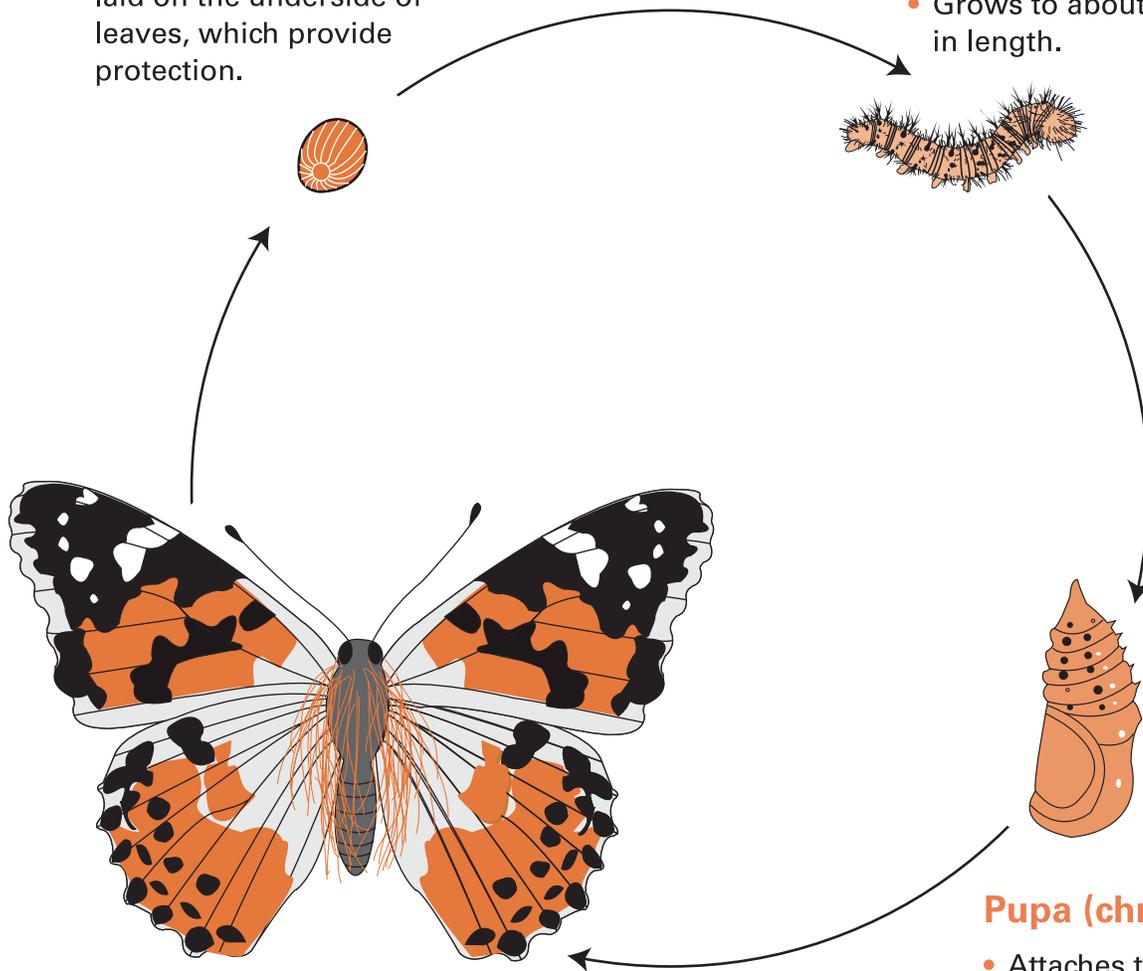
# Life Cycle of *Vanessa cardui*

## Egg

- The size of a pinhead, with 12 to 14 longitudinal ridges.
- As many as 500 eggs are laid on the underside of leaves, which provide protection.

## Larva (caterpillar)

- Brownish-green, to purple, or even black.
- Develops long fuzzy spines.
- Grows to about 3 centimeters in length.



## Adult (butterfly)

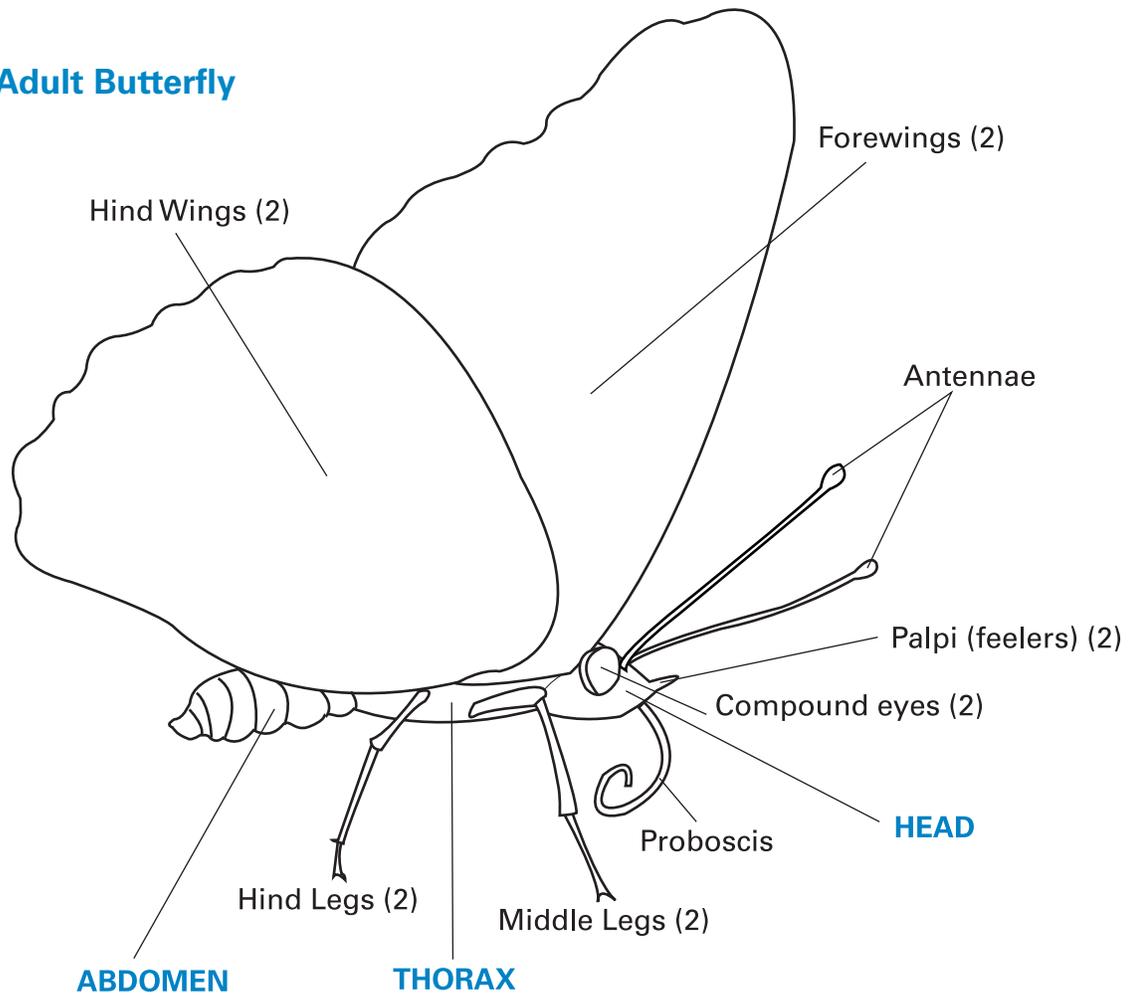
- “Unzips” pupa and spreads wings.
- Feeds through proboscis, mates, reproduces, and then dies.
- Average wingspan: 5 to 5.5 cm.
- Thorax is very hairy.

## Pupa (chrysalis)

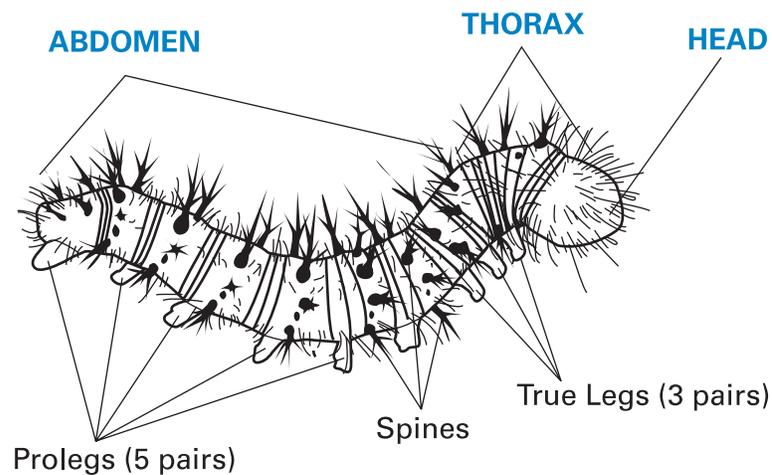
- Attaches to a leaf or branch.
- Resembles a dried, curled-up leaf.
- Becomes transparent as the larva metamorphoses into a butterfly.
- Wing colors become visible.

# Anatomy of *Vanessa cardui*

## Adult Butterfly



## Larva (caterpillar)



# Instar Stages



One egg of a Painted Lady butterfly is about the size of a pin head. When a caterpillar hatches, it eats continuously for about five to seven days. As it grows, the caterpillar’s skin becomes tight, splits open and sheds off of its body. This shedding, or molting process, enables the caterpillar to continue growing. The phases between skin sheddings (molts) are called “instar stages.” After a caterpillar has molted once, it is referred to as a “second instar caterpillar,” and so on.

A caterpillar will have a slightly different color—ranging from purple to black, crossed with yellow-green stripes—at each instar stage (see images, enlarged for detail, above).

When a fifth instar caterpillar reaches about three to four centimeters in length, it attaches

itself with a strand of silk to the bottom side of a leaf or twig. It hangs upside down from the tip of its abdomen and sheds its final skin, revealing the pupa, or chrysalis. The skin of its pupa hardens to protect the butterfly during its most remarkable growth stage: metamorphosis.

While emerging, a butterfly hangs upside down. Gravity helps it to unfurl its wings, and fluid pumps into the veins to straighten the wings. The butterfly remains hanging for several hours until the wings dry out and become rigid. The butterfly’s wingspan ranges from about five to six centimeters. Finally, the adult Painted Lady takes flight and begins to search for nectar-producing flowers on which to feed. 🦋

# Naturalist Journal Practice Sheet

Name: \_\_\_\_\_

## Materials Needed

- Pencils of varying heaviness (colored preferred)
- Eraser
- Metric ruler

## Procedure

This practice activity will help you to prepare to collect data for your Butterflies in Space investigation. Pretend that you have come across a butterfly while on a nature walk. Make a detailed sketch of the butterfly. Write down all of your observations, including measurements.

## Your Sketch

## Observations

Would you be able to recognize this butterfly species if you came across it again? What makes it distinctive?

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Photo of *Vanessa cardui* on rocks courtesy of Michael Hanselmann. Photo of *Vanessa cardui* on flowers courtesy of John R. Desjarlais. Wikimedia Creative Commons Share Alike 3.0.

# Research Proposal

Team Member Names:

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1. What is your research question?

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2. Why did you select this question?

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## Research Plan

1. What variable or variables will you investigate?

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2. What data or observations will you collect?

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3. How often will you collect data or observations?

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4. How will you record your data or observations?

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5. What do you predict might happen? (hypothesis)

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