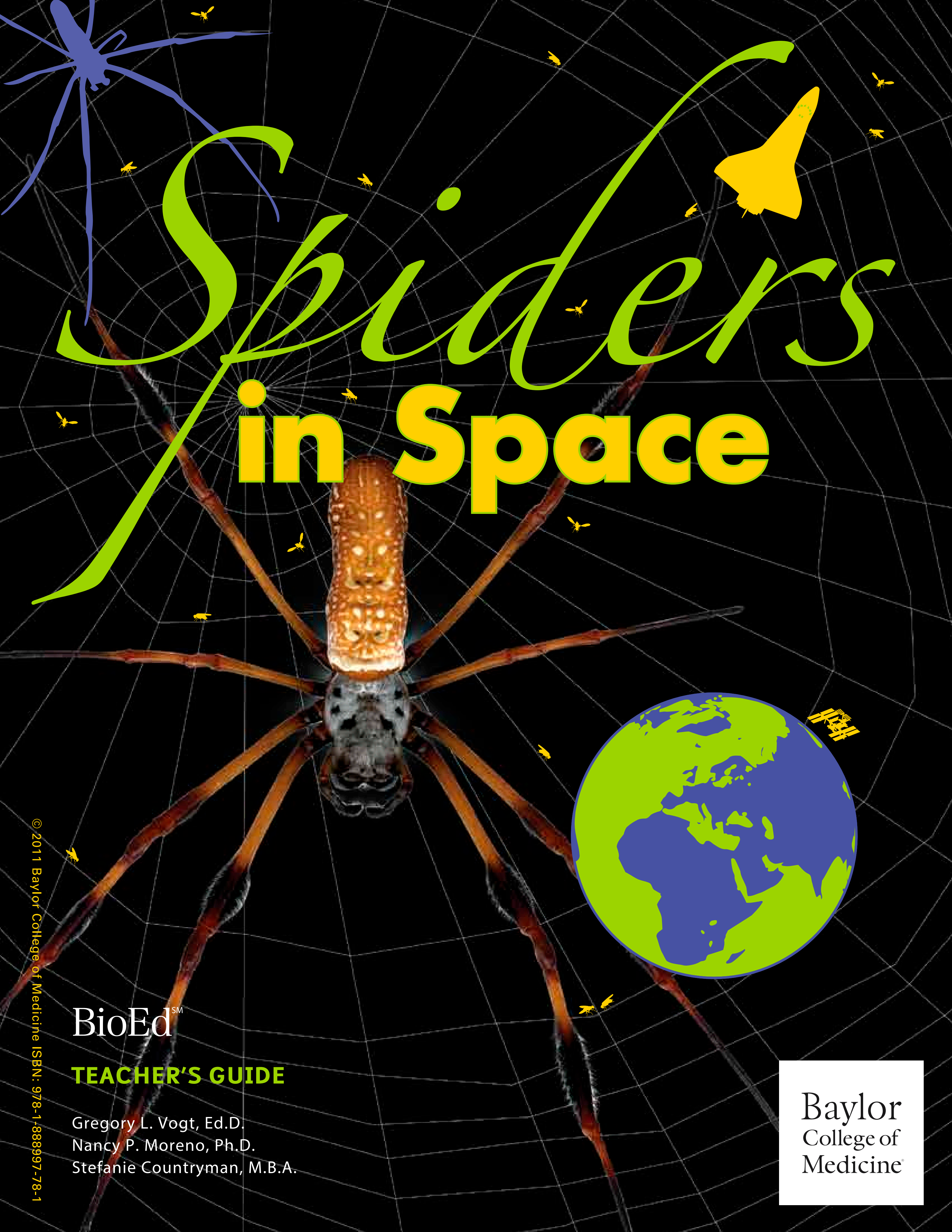
Spiders in Space



BioEd[SM]

TEACHER'S GUIDE

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Baylor College of Medicine

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Spiders in Space

An Experiment Aboard the International Space Station

by

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Most orb weaver spiders build spiral wheel-shaped webs. To begin building the web, an orb weaver first will float a line of silk on the wind to a fixed surface. After securing that line, the spider drops another line of silk and begins weaving the pattern. Photo © DBS Young Photography, http://focusonnature.blogspot.com.

1. Introduction

The penultimate Space Shuttle mission to the International Space Station (ISS) is scheduled for April 2011. In addition to its primary payload, the Shuttle will carry two small investigations appropriate for elementary and middle school students. The first investigation will study the behavior of an orb weaver spider in microgravity; the second will examine plant root growth in space. This investigator's manual describes the spider investigation and provides the necessary details for students and teachers to participate in data collection and analysis.

Students, teachers and the general public around the world are invited to participate in this exciting scientific investigation. To do so, each participant (or group) will set up an Earth-based "ground" chamber and obtain an orb weaver spider to compare with the spider aboard ISS. Once the investigation begins, a stream of images of the "space spider" will be made available for viewing on the BioEd Online website at www.bioedonline.org. The images will offer many opportunities for creative studies that compare a spider in microgravity to one living in normal gravity.

This manual begins with a primer on spiders and web construction, followed by detailed instructions for setting up and conducting an inexpensive ground-based investigation and for spider care and feeding. Other than these instructions, no formal experiment plan has been created. This investigation allows—and requires—participants to ask their own questions regarding the effects of microgravity on spider behavior, and to collect the data needed to answer their questions.

TEACHER RESOURCES

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

PREREQUISITES

Anyone can participate in this activity, but prior to beginning, each investigator should become familiar with basic research techniques and gain a general understanding of the microgravity environment of space. The following modules, which can be found in the Invertebrates in Space sections of BioEd Online (www.bioedonline.org) and K8 Science (www.k8science.org), offer useful background information.

- Microgravity
- Animals and Plants in Space
- Keeping a Naturalist Journal
- Basic Image Processing

2. Spider Primer

Orb weaver spiders come in many shapes, colors and sizes. Some of the most impressive webs are built by members of the species *Nephila clavipes.* Their huge webs appear golden in sunlight, which is why these spiders also are known as Golden Silk Orb Weavers. The larger spider shown above is a female and the smaller one is a male spider. Photo © Josh Hillman, www.floridanature.org.

Spiders are the most abundant terrestrial predators on Earth. In fact, spiders are so common that you rarely are more than two meters away from one.

Spiders belong to the class Arachnida of the animal phylum Arthropoda. Arthropods (meaning "jointed foot") are animals with segmented bodies, jointed legs and a hard exoskeleton (external support structure). Crabs, centipedes, millipedes, insects, shrimp, ticks, spiders and scorpions are arthropods.

Spiders have four pairs of legs and a pair of front appendages, called pedipalps. The four pairs of legs differentiate spiders from members of the Insecta class of the arthropod phylum. (Insects have only three pairs of legs.) Spiders are further distinguished from insects in that they have no antennae or wings, and have two main body parts, instead of three. Scorpions, mites and ticks are close relatives of spiders. Of these animals, however, only spiders produce silk.

Spiders have two main body regions: 1) the head and thorax, fused together into a cephalothorax; and 2) the abdomen. Spiders also have a pair of jaw-like structures that end in hollow-pointed fangs, through which they eject venom. Spinnerets, small finger-like projections on the abdomen, secrete chains of protein that harden into very strong, elastic silk after being released from the body.

The venom of some spiders is toxic, but most is not dangerous or of medical importance to humans. In fact, most spiders are beneficial predators that hunt pests, such as flies, aphids and other insects. More than 40,000 species of spiders have been identified worldwide.

The spider life cycle begins with eggs being laid within a silken egg sac. The sac, which often is spherical, can contain anywhere from a few eggs to several hundred. A female spider may produce several egg sacs and usually dies after laying the eggs.

Upon hatching, new spiders emit strands of silk that are caught and distributed by wind currents. Via a process called "ballooning," these currents sometimes deposit spiders miles away from their point of origin. Spider babies grow through a molting process, shedding their hard "skin" four to 12 times before achieving maturity. Different species of spiders have different life spans. After mating, females lay new eggs and the process begins again.

Spiders are crafty predators that typically feed on living prey they have trapped in a web or caught by active hunting. Spiders use venom to immobilize captured prey and to initiate the digestive process. Because spiders consume only liquid food, they must "prepare" their meals before eating. They deposit digestive fluids onto the surface of their prey and create holes in the prey's exoskeleton, through which the fluids can enter the body. After enzymes in the digestive fluids have broken down the prey's tissue, the spider sucks in the predigested, liquefied food.

Continued

Orb Weaver Spider in the Family Araneidae

Orb weaver spiders—the classic web spinners—construct flat, circular, sometimes very elaborate webs. Each type of orb weaver spider spins a web with a distinctive design. These spiders have poor vision and depend on their webs to capture prey. Vibrations produced by a struggling fly or other small creature cause tension changes in the silken web and lead the spider to its prey. The spider then immobilizes the insect with venom and quickly wraps it in silk for later consumption.

Orb weaver spiders are found throughout the United States. They often build their round, vertical webs in nooks and corners around houses, particularly on porches near lights that attract insects. Orb weaver spiders usually build a new web every evening, just around sunset. By the next evening, the spider takes the web down, by literally eating the silk from which the web is constructed. The spider then rests and reemerges in the evening to start web building all over again.

Orb weavers hatch and crawl out of their egg sacs on warm spring days. Each spiderling crawls up a blade of grass or other high point, releases a strand of silk to catch a breeze, and "balloons" to a new home. After landing, spiderlings build their own small orb webs. By late summer, they have molted into adulthood. Adult female orb weavers are much larger than adult males, which rarely build webs. Instead, they wander around in search of a mate.

Web Spinning

Orb weaver spiders are noted for their ability to spin beautiful and complex orb webs. To begin building its web, a spider releases a strand of silk into the breeze, where air currents carry the strand to a branch, wall, or other structure. Once the initial thread is secured, the spider walks along that "bridge," reinforcing it with additional strands of silk. The spider then moves to the approximate center of the bridge and drops down on a line of silk. This line is attached to the bridge strand, which pulls the bridge strand down into a triangle. The spider then attaches the strand on which it is resting to another branch or substrate below. The center of the triangle becomes the hub of the web.

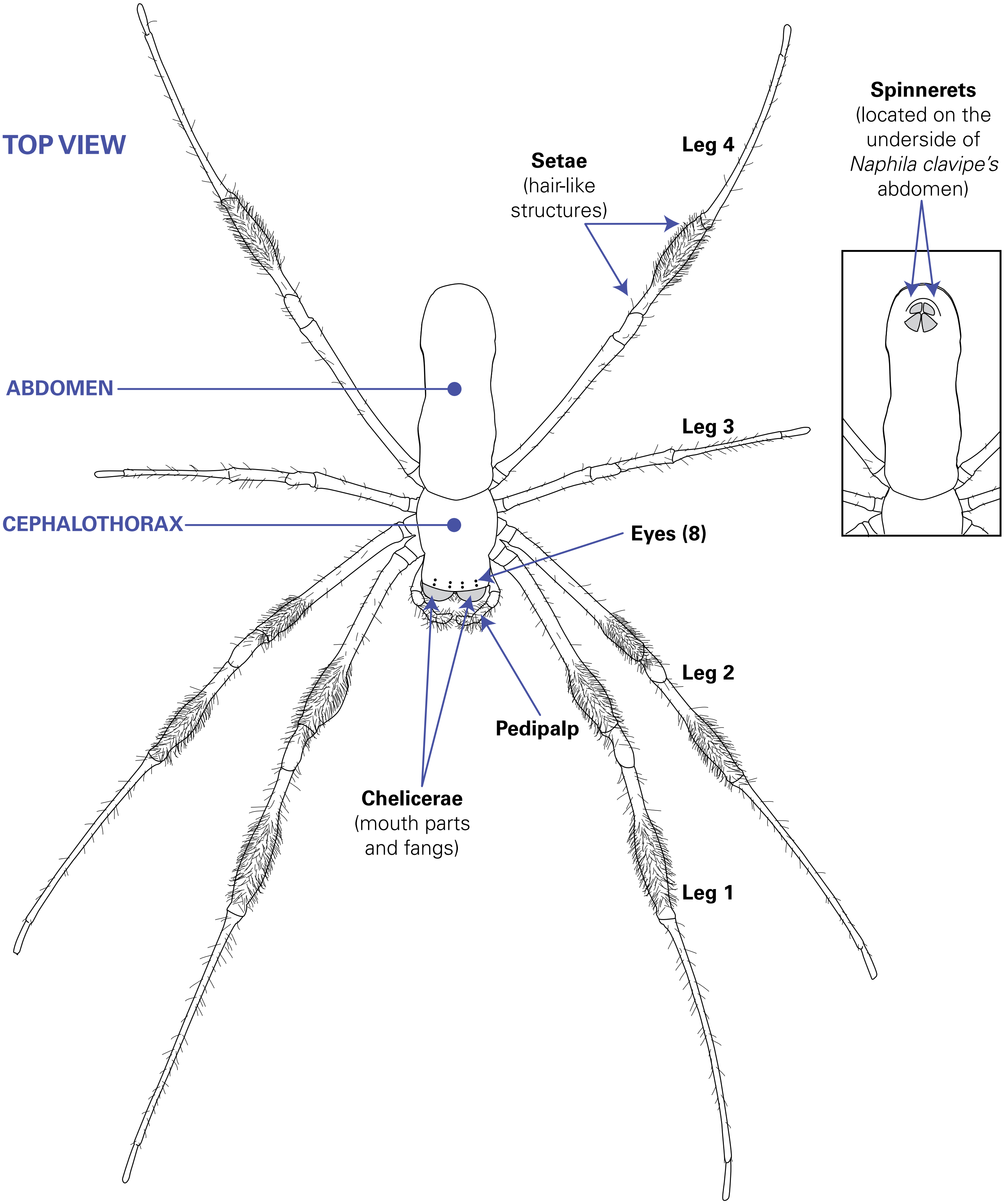
At this point in the web-building process, the spider has created three radial strands—the two arms of the triangle and the silk line released by the spider as it dropped down. The spider then climbs back up to the center (hub) of the web and crawls along one of the radii to the bridge thread, releasing silk as it goes. It carries this new silk strand down along another branch or object and attaches a new radial line there. This process is continued until many radii are formed. The spider uses these radii as supports to walk along as it spirals around, filling in the rest of the web. Many, but not all, of the radii are constructed of "sticky silk," which helps trap insect prey.

Once its web is completed, the spider either retreats to the margins and waits for an insect to become trapped, or it monitors the web from the hub. When an insect is captured and begins to struggle in the web, the spider feels vibrations in the web strands and moves in to secure the prey. Orb webs are very effective at trapping flying insects.

Most orb weavers build round, vertical webs. Photo © Mischa L. Rieser, Wikimedia Commons, http://commons.wikimedia.org.

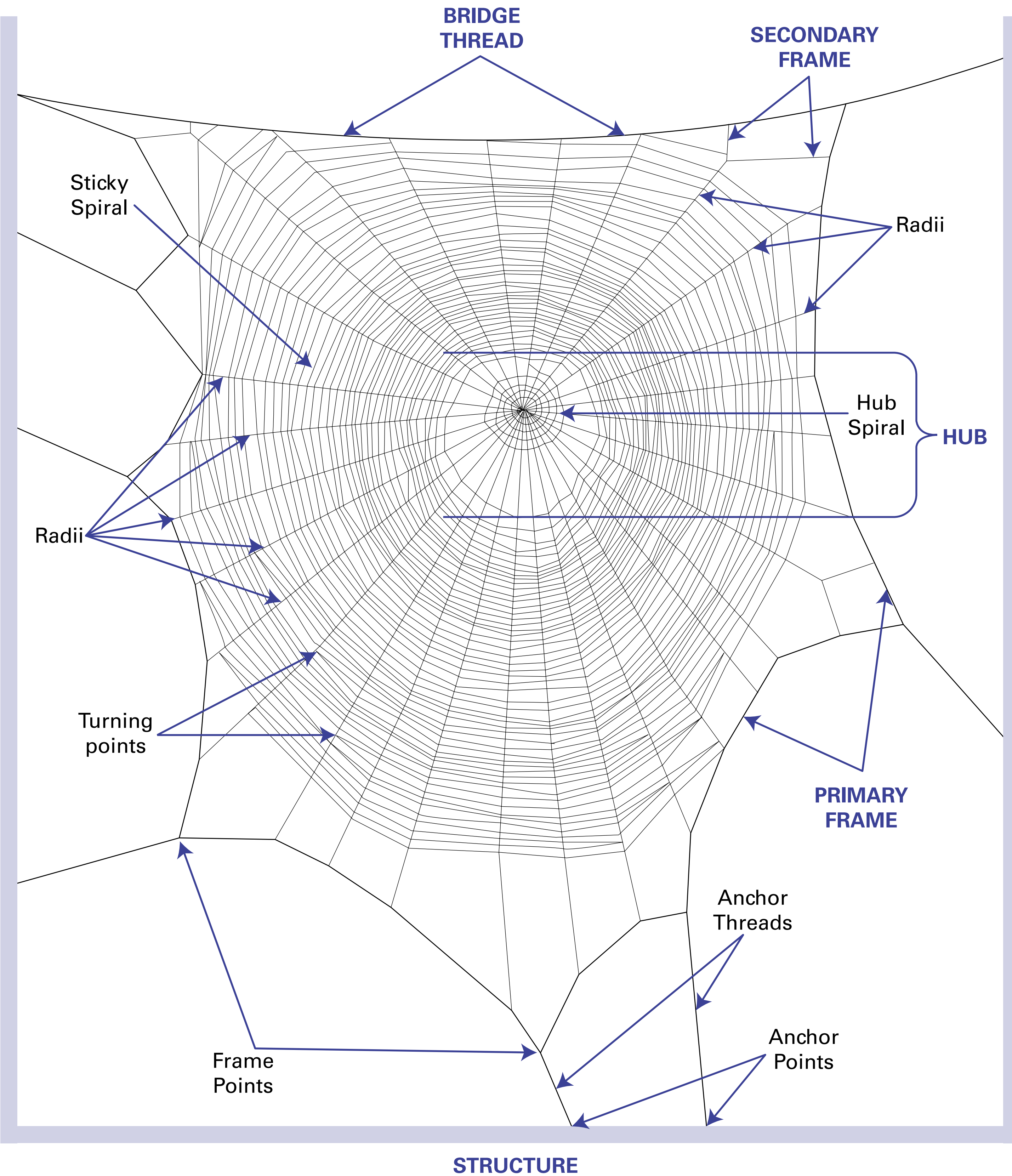
An *Argiope aurantia* orb spider wraps its next meal—a redlegged grasshopper—in silk. Photo © Hubert Pan, Animal Diversity Web, University of Michigan Museum of Zoology, http://animaldiversity.ummz.umich.edu.

Anatomy of an Orb Weaver Spider: Naphila clavipes *(female)*



M.S. Young from photos © Josh Hillman.

Orb Web Nomenclature



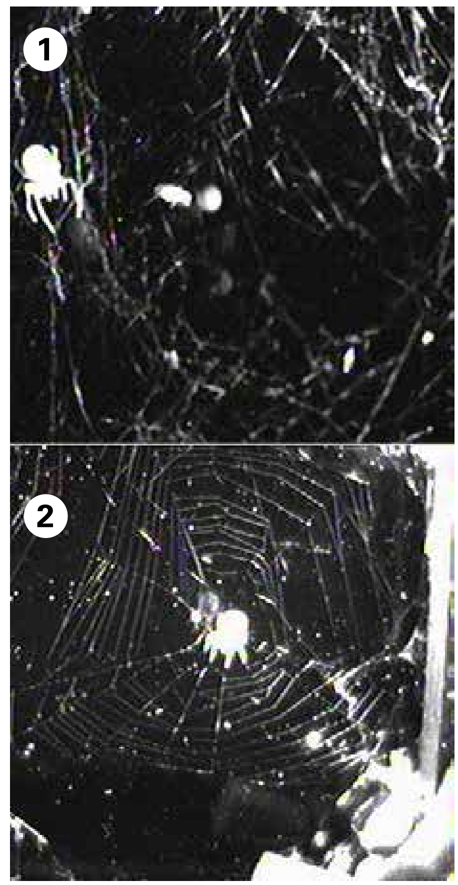
G.L. Vogt after Zsohokke, S., Nomenclature of the Orb Web, *Journal of Archnology*, v27, No. 2 (1999).

The strange shape of *Gasteracantha cancriformis* orb spiders (also known as crab spiders or spiny-backed orb weavers), resembles that of an alien spacecraft. Photo © Arthur D. Forman, www.pbase.com/artichoke/fauna.

3. Spidernauts

Orb weaver spiders have flown in space several times. The first spider investigation, flown on the Skylab space station (1973), involved two garden cross spiders (a common kind of orb weaver). A high school student proposed the experiment as part of a nationwide competition. More recently, two orb weaver spiders were carried to the International Space Station (ISS) by Space Shuttle Endeavour on Mission STS-126 (2008).

In both experiments, the spiders initially built distorted webs (see image 1, upper right). However, within a few days, the spiders seemed to adapt to microgravity and began to spin more symmetrical webs (image 2, lower right). During the 2008 experiment, the spiders were flown with fruit flies, which were intended to reproduce slowly and provide a steady food supply. Instead, the fruit fly population grew rapidly; crawling fruit fly larvae "slimed" the interior of the spider chamber and images became blurred. Results of this investigation can be found at BioEd Online and K8 Science.



Successful spider adaptation to a microgravity environment was achieved in 2008 with NASA mission STS-126. Photo courtesy of NASA.

SPIDERS IN SPACE

On the Space Shuttle mission scheduled for April 2011 (STS-134), one or more orb weaver spiders will once again take up residence in the microgravity environment of the ISS. With lessons learned during the 2008 ISS spider investigation, the new experiment chamber will keep the spiders and fruit flies separated until feeding times. (The chamber has small ports at the back that can be opened for fruit fly entry.) It is hoped that this new design will allow more thorough study of the spiders, while also making it possible to conduct a separate investigation on fruit fly behavior. A small framework within the habitat provides "corners" in which the spider(s) can build webs. The

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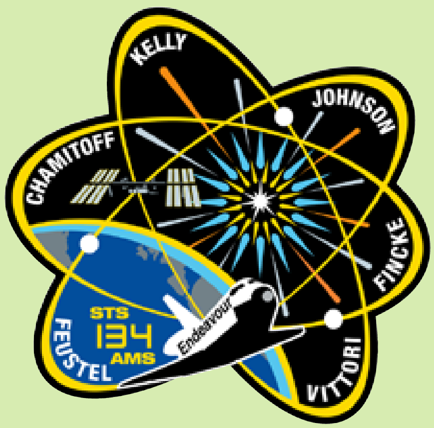


Illustration courtesy of NASA.

Launch Target Date: April 19, 2011

Check the NASA website below for updates regarding the official launch date.

Mark Kelly serves as Commander of STS-134 mission to the International Space Station (ISS) aboard Space Shuttle Endeavour. Gregory H. Johnson serves as the pilot.

Mission Specialists are Greg Chamitoff, Andrew Feustal, Michael Finke and the European Space Agency's Roberto Vitorri.

During the 14-day mission, Endeavour will deliver the Alpha Magnetic Spectrometer (AMS, partical physics detector) and spare parts including two S-band communications antennas, a high-pressure gas tank, additional spare parts for Dextre (two-armed station robot), micrometeoroid debris shields, and several life science experiments. Four spacewalks are planned.

STS-134 will be the 36th Space Shuttle mission to the ISS.

www.nasa.gov/mission_pages/shuttle/shuttlemissions/sts134

front of the chamber is clear, making it easy to capture photos and video of the spider(s). Small, white light-emitting diodes (LEDs) will provide illumination. They will be turned on and off to simulate day and night.

Several days after the launch of the Space Shuttle, the carrier unit holding the spiders and fruit flies will be transferred into an experiment rack on the ISS, and the investigation will begin. Matching the photos of the spider(s) in microgravity with images or sketches of spiders on Earth provides an excellent opportunity for a comparative developmental or behavioral study.

In addition to the "Spiders in Space" and fruit fly investigations, the STS-134 carrier unit will hold a plant growth experiment, which will be activated during fall 2011. The "Plants in Space" investigation will provide another opportunity for student research. Please refer to the BioEd Online website for full details of the investigation and how to participate.

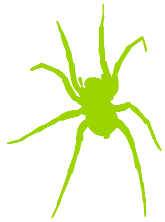
TEACHER RESOURCES

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

SPIDER IMAGES

There are many online sources of images and information about different species of spiders. The following are good places to find spider images, and most are free for educational use. However, please contact individual copyright holders.

- **Animal Diversity Web,** University of Michigan Museum of Zoology: http://animaldiversity.ummz.umich.edu
- **Arachno Web,** International Society of Arachnology: www.arachnology.org
- **BugGuide.Net,** Iowa State University Entomology: http://bugguide.net
- **Dennis Kunkel Microscopy, Inc., Education Website:** http://education.denniskunkel.com
- **Florida Nature:** www.floridanature.org
- **North American Insects and Spiders,** Red Planet, Inc.: www.cirrusimage.com
- **PBase.com** (searchable image galleries): www.pbase.com
- **Tree of Life** (Araneidae images): http://tolweb.org/images/Araneidae/2788



Many orb weavers, such as this ***Leucauge venusta,*** **or Venusta Orchard spider, have beautiful, multicolor markings on their legs and bodies.** Photo © Arthur D. Forman, www.pbase.com/artichoke/fauna.

4. Habitat and Food

It is simple to build a habitat for ground-based spiders that approximates the size and conditions of the the chamber to be flown on the International Space Station (ISS). A spider chamber can be constructed from a shallow clear plastic "take-out" salad box with an attached hinged lid (approximately 20 x 20 x 8 centimeters in size). With a small amount of preparation, the box can provide a suitable environment for an orb weaver spider and allow an Earth-based investigation that parallels the one being conducted on the ISS.

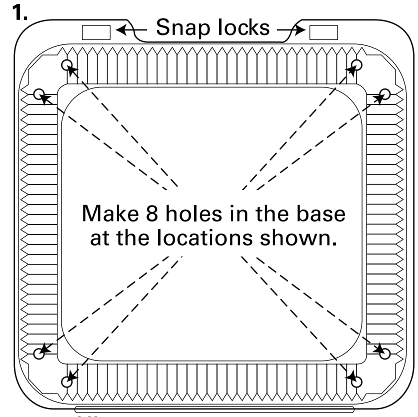
To modify the take-out salad box into a home for your spider, use a heated ice pick or small nail (held with pliers), to melt eight holes through the lid of the container (see illustration 1, right). Use a candle flame or a butane fireplace lighter to heat the ice pick or nail. Keep the holes small, about 3 millimeters in diameter.

Thread a piece of knitting yarn through the holes. When the yarn is tied off, it will form a rectangular frame, which the spider can use for web construction (see illustration 2, right).

Using the ice pick or nail again, melt one more hole, about 5 millimeters across, through the base of the container on the opposite side (see illustration 3, right). On the inside of the container, circle the hole with a small bead of low-temperature hot glue. Press a cotton ball to the glue. This opening will be used for adding water to the chamber.

Create a stand from cardboard or other sufficiently sturdy material to hold the chamber upright on its side (see illustration 4, page 9). Place the chamber in an area where it will not be disturbed or tipped over. It will be necessary to move and open the box occasionally,

1.



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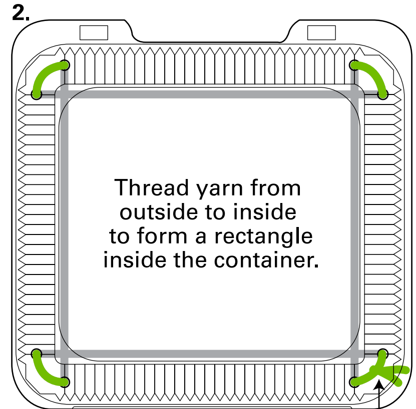

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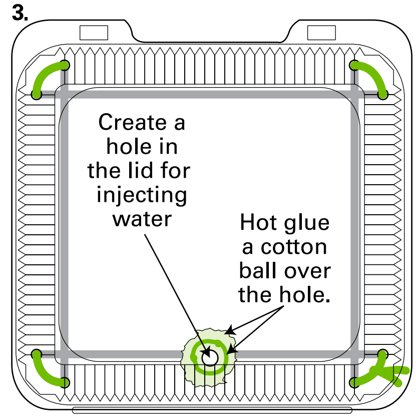
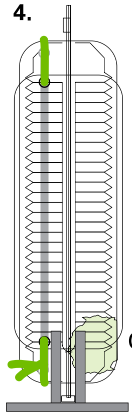


Illustrations by M.S. Young © Baylor College of Medicine.

so it should not be permanently fixed to a shelf or a countertop.



Obtaining Spiders

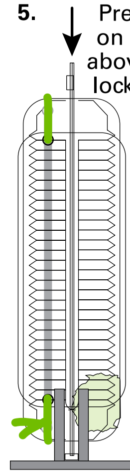
Orb weaver spiders can be collected at night, when their webs are most easily seen (as noted, most species take their webs down during the day). Webs can be found at forest edges, on porches, in grassy fields, or anywhere insects fly. Most orb weavers monitor their webs from the hub at night (they often rest in difficult-to-find retreats during the day). To capture an orb weaver, hold a dry vial (empty pill canister, small canning jar, etc.) just behind the spider as it rests on the web. Be very careful not to touch any web strands when you position the jar, as this will alert the spider. When the container is in position, gently poke the "belly" side of the spider through the web with the eraser end of a pencil. The startled spider often will drop off the web right into the container. If not, you can poke a little harder to knock the spider into the container. Orb weavers are very clumsy off the web and cannot crawl out of a glass or plastic container. After capture, transfer the spider into the living chamber you have prepared.

Depending upon season and availability, spiders also can be obtained from the following commercial sources.

- http://www.bugsofamerica.com
- http://www.carolina.com
- http://www.kenthebugguy.com

Adding the Spider to the Habitat

Open your prepared chamber and deposit the spider. Snap the lid closed and position the chamber upright in the stand constructed to hold it. Using an eyedropper or a pipette, squeeze several drops of water through the hole leading to the cotton ball. Evaporation from the cotton ball will maintain humidity in the chamber. After the spider has built a web, feed it by inserting live food into the chamber. Gently press down on one of the lid's two snap locks, as shown (illustration 5, right). This will spread the sides slightly and open a temporary gap, through which food can be inserted.



Spider Food

Orb weaver spiders prefer live food. Pinhead crickets can be obtained from a pet store. Insert one or two crickets at a time. Fruit flies also are a good food source. Fruit fly larvae can be obtained from science supply companies, such as Carolina Biological Supply Company.

You also can raise your own fruit fly larvae. Place some banana or apple slices inside a large, clean, clear plastic bottle with a small-neck (e.g., a washed ketchup bottle or a soft drink bottle). Place the bottle on a counter several days before you set up the chamber. When fruit flies enter the bottle, put the cap on to capture them. For a time (usually several weeks), until the bottle is fouled, the fruit flies will reproduce and provide a steady supply of spider food. To transfer the fruit flies, open the cap. Press down on the top edge of the habitat over one of the snap locks. Place the bottleneck next to the gap of the spider chamber. Tap the bottle with a pencil to agitate the flies. When one or two enter the chamber, close the bottle and let the gap in the lid close.

Orb weaver spiders typically eat only insects caught in their webs. Thus, if your spider does not spin a web, it will may be difficult to get it to feed. Spiders can live a long time without food, but not without moisture. Remember to keep the cotton ball moist.

ADDITIONAL RESOURCES

The Biology of Spiders by Rainer Foelix is an excellent general biology classroom reference on spiders, but it is not geared to children.

The Book of the Spider: From Arachnophobia to the Love of Spiders, by Paul Hillyard. Great stories about spiders in folklore and myths as well as solid information about spider biology.

Golden Guide to Spiders and Their Kin by Herb and Lorna Levi is an excellent and inexpensive field guide for the classroom.

Insects & Spiders by George Else, Nature Company Discoveries Libraries, contains excellent information about spider biology.

The Life of the Spider by J. Henri Fabre. The engaging and informative text is available electronically at http://www.worldwideschool.org/library/books/youth/howandwhy/TheLifeoftheSpider/toc.html.

The Private Life of Spiders by Paul Hillyard. A beautifully illustrated book about spider biology.

Spiders of North America: An Identification Manual, edited by D. Ubick, P. Paquin, P.E. Cushing, and V. Roth, provides good general information about the biology of spiders and how to collect them. Available online at at Amazon, www.americanarachnology.org, or www.bioquip.com.

Spiders of the World by Rod and Ken Preston-Mafham contains good information, drawings and photos of spiders.

The Tarantula Scientist by Sy Montgomery is about a real-life arachnologist, Dr. Sam Marshall, who studies tarantulas. Full of great information regarding the study of spiders and why one would do such a thing. This is an excellent book for children interested in science as a career.

MIssion Specialist Heidemarie Stefanyshyn-Piper (STS-126) works with a customized, temperature controlled experiment insert, part of the Commercial Generic Bioprocessing Apparatus (CGBA) on the middeck of Space Shuttle Endeavour, while docked with the International Space Station. Photo courtesy of NASA.

Top view, inside a CGBA insert housing small spider habitats (upper left and lower right) and cameras, part of Mission STS-134. Photo courtesy of BioServe Space Technologies.

5. Spider Investigation

Life science investigations conducted within the microgravity environment of the International Space Station can provide powerful motivation for students to achieve excellence in their studies. Students will follow the same procedures for their investigations as professional scientists follow in their work, including observations, questions, controls, variables, data collection and analysis.

Students participating in a space-based experiment must design their procedures before the investigation actually begins. For example, if organisms are involved, it may be necessary to obtain seeds or live plants/animals, and to create a habitat before the study can start. The principal experimental variable will be gravity. Organisms in orbit around Earth will not sense gravity, but organisms in your classroom will. Usually, students' investigations involve some aspect of the question, "How does the absence of gravity's effects impact the growth or behavior of living things?"

Typically, habitat chambers containing space research organisms will be transferred from the launch spacecraft to the Commercial Generic Bioprocessing Apparatus (CGBA) on the International Space Station (see image, upper left). The CGBA is an experiment support module developed by BioServe Space Technologies at the University of Colorado in Boulder. After transfer is completed, the investigation is initiated and cameras built into the CGBA begin collecting images on a regular schedule. Artificial lighting provides a day/night cycle, with infrared imaging taking place at night.

Images are downloaded daily and made available for viewing and research on the mission page of Baylor College of Medicine's BioEd Online website. You and your students can access the site at www.bioedonline.org.

Students must be ready to begin collecting appropriate data from their ground-based organisms and the space organisms as soon as the experiment begins. The website page listed below, offering current information related to NASA's launch schedule, can help you to plan your class activities.

http://www.nasa.gov/missions/highlights/schedule.html

Suggested Classroom Research Framework

1. Divide your class into research teams of two to four students.
2. Instruct teams to learn as much as they can about the research organism (including care and feeding, watering, etc.) before the investigation begins.
3. Have teams prepare and present research reports or essays, computer presentations, or posters about the study organism, summarizing what they have learned about its anatomy, feeding, growth, reproduction, behavior, etc.
4. Ask each team to develop a research question to guide its investigation. You also may want older students to devise a hypothesis, which states a possible answer (or set of alternative answers) to their research questions.
5. Ask each team to write a proposal

REVISITING THE INVESTIGATION

BioEd Online and K8 science archives data from each space investigation. Future students can repeat these investigations by building new habitats and formulating their own research questions or hypotheses. Archived results from each flight can be downloaded and compared, day-by-day, with observations of classroom habitats, permitting students to experience the excitement of space-based life science research.

detailing its research question or hypothesis, its plans for answering the question, the types of evidence to be collected, and ways the team will use evidence to support—or not support—its hypothesis.

6. Have each team write a set of guidelines regarding proper care of its research organism.
7. Review team proposals and offer advice, if needed, on how to improve them.
8. Follow the instructions in "Habitat and Food," for details of the construction of the ground chamber and care instructions.
9. Designate an area of the classroom where teams can safely store their research organism habitat chambers.

During the investigation, students will track the behavior or growth properties of their research organisms and compare their data to that from the flight organisms. Basic data can be maintained in tabular form. Graphs and illustrations are useful for collecting data and reporting results.

Research Question or Hypothesis

A guiding research question is an open-ended approach to the investigation. Almost all scientific investigations begin with a question. Students should use what they have learned about the research organism to devise a question to investigate. Students will observe and record growth or behavior related specifically to their question. Provided below are sample questions from Experiments in Space guides.

- Will the web spun by a spider in space be similar or equivalent to a web spun on Earth?
- How long does it take to spin a web in microgravity, compared to the time it takes on Earth?
- Will the space plant form the same number of leaves as Earth-based plants do?
- Can a butterfly use its wings to fly in microgravity?

A hypothesis is a kind of research question that leads to a "yes" or "no" answer. It also can be thought of as a possible answer (or set of alternative answers) to a research question. Data collected will support the hypothesis, or provide evidence for rejecting it. Some sample hypothesis statements include the following.

- Webs spun by spiders in space will be indistinguishable from webs spun on Earth.
- It takes more time for a spider to spin a web in microgravity than on Earth.
- The plant in space will form more leaves than the plant on Earth does.
- The butterfly in space will use its wings to fly in the habitat.

Reporting the Results

When the investigation concludes, student teams should wrap up their work. Have teams review their data, determine whether or not their research questions were answered and why, or whether their hypotheses were supported by the evidence gathered. Then, each team should produce a final investigation report, to be submitted for assessment. Possible reporting formats include posters that display teams' results, PowerPoint® or podcast presentations, or written documents.

Planning the Investigations

It is important for students to design their investigations before they obtain spiders. In all cases, the principle experimental variable will be gravity. The spider(s) on the International Space Station will be living in a microgravity environment, but classroom spiders will

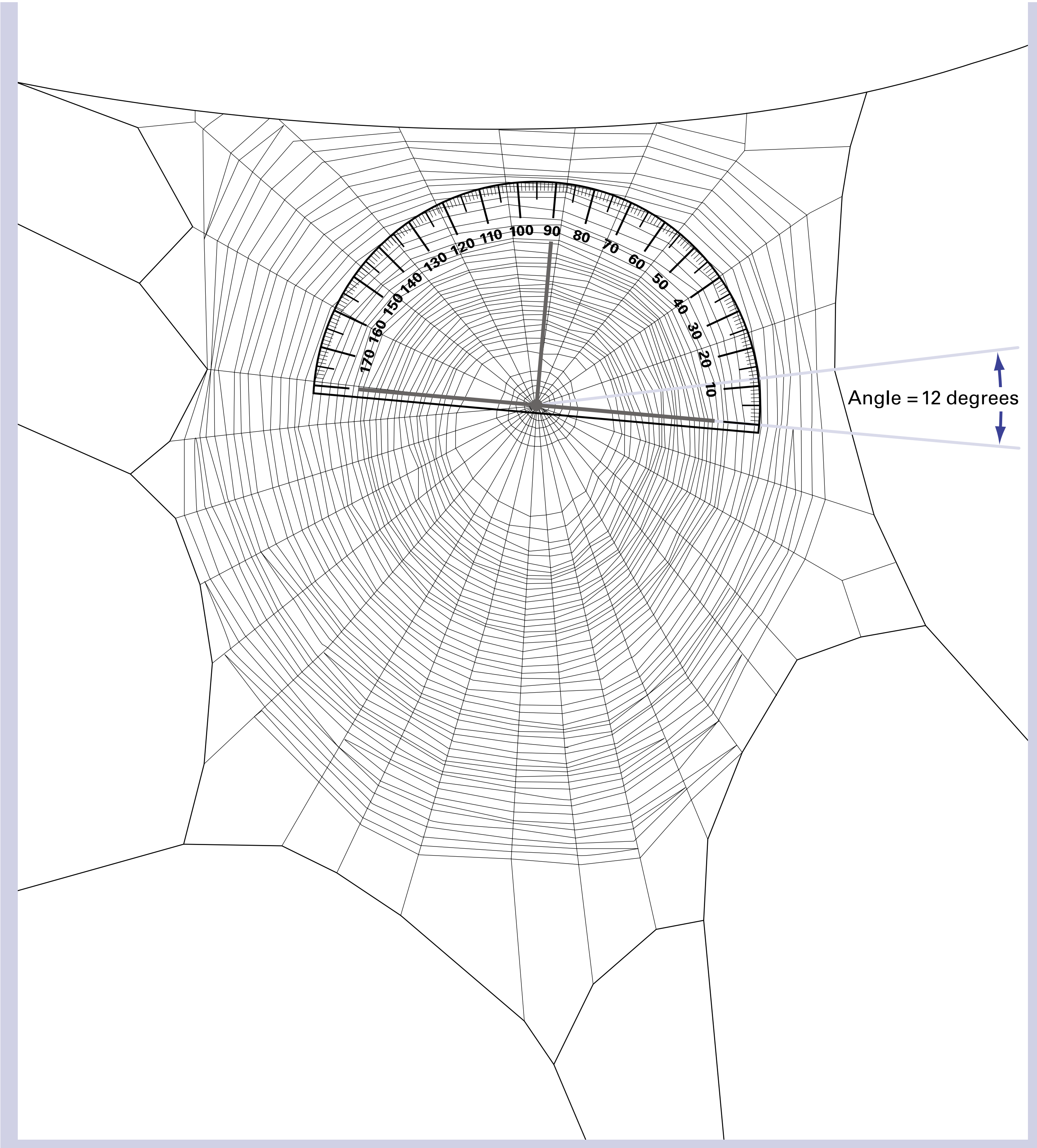
POTENTIAL INVESTIGATIONS		
Behavior/Variable	**Data/Categories**	**Notes**
Feeding	Feeding	Does the spider feed? How often? How much? What does the spider do to trapped prey?
Spider position	Web present, spider on web	Note location of spider on the web.
	Web present, spider not on web	Note location of spider in the chamber.
	No web present	Note location of spider in the chamber.
Old web or new web	Web remains from previous day	If the web is old, all other variables from previous observations should be the same.
	Newly-built web	
Hub placement	In center of web	On Earth, most hubs are located in the upper hemisphere.
	Near upper hemisphere	
	Near lower hemisphere	
Number of strands	—	Count number of radii. Are they the same in each web?
Radial angles, upper hemisphere	Record angles between several radii and determine the average angle.	Are the angles approximately equal, or do they vary widely?
Radial angles, lower hemisphere	Record angles between several radii and determine the average angle.	Are the angles approximately equal, or do they vary widely?
Turning points in upper hemisphere	Number of turning points	Turning points are places where the spider changes direction in stringing the spiral threads. (There may be fewer turning points in the webs built in microgravity.)
Turning points in lower hemisphere	Number of turning points	
Average distance between adjacent spirals	Select one hemisphere or side of the web and measure the distance between adjacent spirals.	The spider may change the diameter of the silk. This may be difficult to observe, but there could be a relationship between thread diameter and the distance between spirals.

experience the effects of Earth's gravity. ("Microgravity" is the term scientists use to describe the sensation of weightlessness that occurs in an orbiting space vehicle. For details on this effect, please refer to the "Microgravity" article at www.bioedonline.org.)

When the investigation begins onboard the ISS, spidernaut images and photographs of web-building behavior will be transmitted to Earth and made available online for anyone to use. What will your students study? What questions will they seek to answer? What behaviors or characteristics will they compare between spiders in the normal gravity of the Earth-based chambers and the spider(s) in space?

Sometimes, students must spend a couple days observing several variables to devise an interesting question or pattern to investigate. The table above provides a sample of possible ideas. "Measuring Radii," shows how web strands can be measured.

Measuring Radii



G.L. Vogt after Zsohokke, S., Nomenclature of the Orb Web, *Journal of Archnology*, v27, No. 2 (1999).

STS-134 Protocol for Nephila clavipes

1. Four identical spider habitats (two for space flight, two for ground control) will be prepared for Mission STS-134 to the International Space Station (ISS). The top of each habitat has four plungers, which, when pulled up or pushed down, open or close internal chambers. The plunger release openings of Chambers 1–3 are covered by a small screen, which allows movement of fruit flies in and out of the chambers, but keeps the spider out.
   - Chambers 1–2 are fruit fly chambers that will contain only food at launch.
   - Chamber 3 will contain the initial supply of fruit flies and fruit fly food.
   - Chamber 4 will contain water and serve as a temporary holding chamber for the spider.

   The habitat will be sealed with a glass window to keep the spider and fruit flies from escaping into the Shuttle or ISS.
2. At about 30 hours prior to the launch of Space Shuttle Endeavour, fruit fly food and water will be loaded into the habitat chambers, along with one juvenile *Nephila clavipes* orb weaver spider and 30–40 fruit flies (half male, half female).

   The fruit flies will mate, lay eggs and repopulate Chamber 3 for about 30 days. (Once the habitats are onboard the ISS, Chambers 1–2 will be opened and closed at scheduled times, for repopulation of the fruit flies.)
3. At about 28 hours before launch, the two space habitats will be packed within a stow bag and loaded into a middeck locker in the nose section of the Shuttle. While on the Shuttle, the habitats will receive no light and remain at a steady ambient temperature of about 21°C.
4. About four days after launch, a crewmember will unpack both habitats and transfer them to the BioServe Commercial Generic Bioprocessing Apparatus (CGBA) on the ISS. The CGBA will power the habitat lights and cameras, and will maintain the correct temperature (25°C) for the habitats.

   During habitat installation, a crewmember will pull up Plunger 4 to release the spider into the primary spider habitat. He or she also will pull up Plunger 3 to release 10–30 fruit flies into the spider habitat. Once the fruit flies have been released, the crewmember will push down Plunger 3 to close Chamber 3.
5. Each habitat will be illuminated by six white LED lights to simulate daytime and six infrared lights for imaging at night (some spiders are more active then).

   A 12-hour on/off lighting cycle will be maintained between 7 am and 7 pm, and 8 am and 8 pm, MST. Lighting will be offset by one hour to provide "dawn" for one habitat and "dusk" for the other.
6. Within 24 hours of installation on the ISS, black and white images of the habitats will be taken every five minutes during the day/night cycle and downloaded to BioServe personnel on Earth. The images will be uploaded once daily to Baylor College of Medicine's BioEd Online and K8 Science websites (www.bioedonline.org, www.k8science.org). Videos (web spinning, capturing prey, eating, molting, etc.) may also be posted.
7. About four days after installation, a crewmember will release another 15–30 fruit flies from Chamber 3. He or she also will open Chamber 2 to give the fruit flies fresh food and allow them "seed" the new chamber for reproduction.
8. Every four days thereafter, a crewmember will release 15–30 fruit flies into the primary spider habitat, and open or close chambers for the repopulation of fruit flies.
9. The experiment will conclude approximately 45 days after launch. If the spiders and/or fruit flies are still thriving, they will live the remainder of their lives in the habitats on the ISS.