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Behavioral Priming in Jumping Spiders

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Laboratory exercises in behavior are relatively uncommon, and this is in part due to the difficulty of working with most model organisms. Here I propose a novel model organism for teaching behavior, and exemplify its tractability and accessibility with a laboratory exercise in behavioral priming. In this inquiry-focused exercise, students will design behavioral experiments and investigate the concept of behavioral priming in the context of jumping spider communication. The basics of obtaining, maintaining, and manipulating jumping spiders are also described.

Keywords: Salticidae, jumping spiders, behavior, behavioral priming, ethology

Introduction

There has long been a need for a new model organism suited for teaching principles of animal behavior in a laboratory setting. Current models work well within a limited range of ethological concepts, but most of these models are narrow in their range of flexibility or impractical for a teaching laboratory (such as most vertebrate models). It is the author's opinion that spiders in the family *Salticidae* possess such a flexibility for teaching ethological concepts. It has been demonstrated that these spiders are capable of everything from simple routine grooming behavior to learning and problem solving. Furthermore, these spiders possess a commonality that offers to students a degree of familiarity as well as a great opportunity to refute myths surrounding spiders. In this laboratory exercise, students will learn about behavioral priming, designing behavioral experiments, quantifying behavior, and interpreting results from their own experiments. This exercise is a guided inquiry based on the definition given by Colburn (2000), and is flexible enough for the degree of student responsibility to be varied to include more or less background knowledge. The specific exercise given here is aimed at students in a majors introductory organismal biology course; however, it could be easily be adapted to a non-majors student audience. This lab is designed to be conducted in a single two-hour lab period, with a brief follow-up session at the beginning of a subsequent lab period. The preparation time will vary, but should not take more than two hours if supplies are already available.

Student Outline

Introduction

In this laboratory exercise, you will be testing for the effects of priming on behavior. Behavior can be defined simply as stimulus and response. A sudden loud noise (stimulus) results in a startling behavior (response) in many birds. Most behaviors are influenced by many stimuli. A famous example, though not typically thought of in this light, is Pavlov's dog. Pavlov trained a dog to respond to a secondary stimulus (the ringing of a bell) in preparation for a primary stimulus (food). In this case, the trained dog used the secondary stimulus to anticipate the primary stimulus as indicated by a change in its behavior (drooling). This phenomenon of stimulus A (the secondary stimulus) preparing the animal for stimulus B (the primary stimulus) is known as behavioral priming. You will be using the change in behavior of jumping spiders to identify the effects of a secondary stimulus. Your interpretation of the secondary stimulus will be based on the change in effectiveness or strength of a primary stimulus.

Before you can begin to work with jumping spiders, you should know a little about their biology. Jumping spiders are true spiders, whose members make up the family *Salticidae*. This is the largest family of spiders, represented by over 5300 species worldwide. These spiders are known among the terrestrial invertebrates for their exceptional vision and their dramatic courtship displays. Male spiders do most of the courting, which involves waving of legs, dancing in patterns, and visual displays. Most male jumping spiders will engage in showy courtship-like activities with other male spiders in a male-to-male showdown. The competition determines who the dominant male is while avoiding cannibalism. This behavioral tendency, coupled with the spiders' excellent vision, will allow us to test the effects of secondary stimuli on the primary stimulus of responding to another male. As a jumping spider travels, it leaves behind a continuous string of silk, often referred to as a dragline or safety line, since the spider will dangle from the silk if it is knocked off its perch or misses a jump. Male spiders can locate potential mates by the chemical traces left on the silk wherever it is attached. The male spider can detect the silk strand with sensory structures on its palpi (short, fuzzy, leg-like structures near the mouth) and follow the strand to its source, thus locating a mate. The silk provides us with a secondary stimulus to work with.

Putting it all together, you will be using the spider's vision and its propensity to interact with other male spiders of its species using showy displays as a primary behavior. To elicit this behavior, you will be using small mirrors. The spiders will perceive their reflection as another male spider, and thus their own reflection will serve as a primary stimulus. The secondary stimulus will be the silk threads left by a different spider. In summary, the goal of this experiment is to determine if the presence of spider silk has a priming effect on the spider's response to its own reflection (simulating another male spider).

Objectives

You will meet the following objectives while answering this key question: Does foreign spider silk operate as a priming stimulus for display behavior?

- Determine a means of quantifying jumping spider behavior.
- Identify the effects of behavioral priming, if any, in jumping spiders.
- Describe the experiment conducted, and explain the conclusions reached.

Equipment and Materials

You are restricted to using the following equipment listed below:

Scissors	White paper
Pins	Transparencies
Tape	Mirror apparatus
Plastic tubes with foam stoppers	Stopwatches
Jumping spiders	

In general, you will be placing spiders in plastic tubes and allowing the spiders to see their reflections using a mirror chamber.

Experimental design

While designing your experiments you should keep the following facts in mind:

- A jumping spider's most prominent sense is vision, but they are also good at detecting vibrations.
- Be careful to establish a clear start and stop point in your experiment, as these are essential to getting reliable data.

The basic approach of this experiment will involve watching the behavior of a jumping spider as it responds to its own reflection in a mirror. You will be placing spiders in plastic tubes and allowing the spiders to see their reflections using a mirror chamber. One of your objectives is to figure out how to quantify the behavior in such a way that you can detect the effects of behavioral priming. Remember that you can only use the equipment provided.

Answer the following questions in one or two sentences using the space provided. These questions will help you focus the development of your experiment.

1. In your own words, what is the goal of your experiment?

2. In light of the previous question, what then would be a possible hypothesis you could test?

3. How will you go about testing this hypothesis? Outline the steps of your experiment in the space below. Indicate what data will be collected, and during which step(s). Check this design with your lab instructor before proceeding.

4. What do you expect the results to look like?

Experimentation

Transferring jumping spiders

You will need to transfer spiders from one tube to another. This is not difficult, but does require a steady hand. First, remove the stopper from the empty tube. Next, tilt the tube containing the spider so that the stopper is facing down at an angle. The spider should crawl up to the closed end of the tube. If it does not, you can turn the tube stopper-end up and try gently tapping the tube on the counter to knock the spider down to the bottom of the tube. If the spider does not budge from its spot, see the alternative method below. Once the spider is in the opposite end of the tube, remove the stopper from the spider tube, and place the open end of the spider tube against the open end of the empty tube. Hold the tubes together and gently invert the tubes. The spider should now crawl up into the previously empty tube. Again, if the spider does not crawl into the desired tube, you can try inverting the tubes again and gently tapping the tubes on the counter to get the spider to fall into the lower tube. Remove the old spider tube and insert the stopper. You have now transferred your spider.

As an alternative method for uncooperative spiders that hide in their silk nests, you can gently herd the spider into the correct tube using a cotton swab. Any time a jumping spider jumps or falls from a surface it leaves a silk safety line, and you can use this to your advantage by lowering the hanging spider into the correct tube.

Observing jumping spiders

Since these spiders have relatively good vision, it is important to reduce movement around the test chamber as much as possible. These spiders are also covered with many sensory setae (hence the fuzzy appearance) and can detect vibrations easily. Therefore, it is also important not to talk loudly while making your observations. Be patient; some spiders may take as much as five minutes to respond to the mirror. Generally, no spider should take longer than five minutes, but if this happens, try transferring the spider to another tube and starting the experiment over with the new tube.

Loading the mirror chambers

Begin by placing the tube containing a spider halfway into the slot with the stopper facing the mirror. Be sure that the spider is not clinging to the stopper before proceeding to the next step. Remove the stopper, and then slide the tube up against the mirror. Insert a straight pin into the cardboard behind the tube to hold it into place. Always check to make sure there is not a gap between the mirror and the tube through which the spider could crawl.

5. Once your experimental design is approved, conduct your experiments using the spiders following that design. Record your data in the space below:

Results and Report

6. Once you have completed your experiments and collected your results, you should answer the questions, "What do your results tell you?" and "What is your initial conclusion?" in the space below. Limit your response to no more than three sentences.

Write up a brief lab report using standard format. It is due next week.

Recommended format:

- Use 12-pt. Times New Roman font, double-spaced, with major headings for each section.
- There should be four main sections to this report: introduction, methods, results, and discussion.
- Use in-text references (e.g., McKinney 2011) of scholarly publications to support your introduction. Include a literature cited section at the end of your lab report. Use **http://peckhamia.com/pubs.html** as a starting place when looking for references.
- Your discussion should address at least the following two items: is there a difference between the experimental group and the control group? Is that difference statistically significant?
- Do not write more than 4 pages.

Materials

For each group of students (for a lab of 20 students with 4 per group) conducting the lab, you will need the following:

Quantity	Item	Type
1 (5)	Scissors	Reusable
1 (5)	Stopwatch	Reusable
5 (25)	Sheets plain white printer paper	Disposable
1 (5)	Roll of tape	Disposable
1 (5)	Box of straight pins	Reusable
3 (15)	Mirror chambers (cardboard + mirrors)	Reusable
6 (30)	Plastic vials with foam stopper	Reusable*
3 (15)	Adult jumping spiders	Reusable**

* Vials will have to be washed between uses, though this could be left unstated as a part of testing student reasoning.

** Spiders can be reused between and within lab sections; however, there is ample evidence that they may learn that the priming signals or mirror are not rewarding. Therefore, a decreased level of responsiveness is expected if they are used for successive weeks. Potentially, individual spiders can be maintained for up to one year.

Other materials

Cardboard, adhesive tape, and mirrors for constructing the mirror chambers. You will need one mirror, one piece of cardboard (6.75 inches x 3.75 inches), and two pieces of tape about 2 inches long. Petri dishes are recommended for maintaining the spiders outside of class, and mealworms or small crickets are suggested for feeding the spiders. More details can be found in the appendices.

Notes for the Instructor

Important information to note

Biology

Jumping spiders (*Araneae, Salticidae*) are diurnal predators that actively hunt insects. This family of spiders makes up more than 10% of the true spiders. Very few of these spiders build webs to trap insects, though many of them use silk to build nests to hide in at night. These spiders have remarkable vision and can distinguish prey types visually. Reproduction begins with an elaborate courtship display put on by the male. This display varies from species to species. Male jumping spiders typically have a different type of display for use on other males of the same species. There is some evidence that females observing male-to-male contests prefer to mate with the winning male spider.

Jumping spiders have stunning and overt behaviors that should be easily observed by most students. Most specimens will perform their behaviors clearly when left to themselves. Impatient students who make exaggerated motions in close proximity to the spider test chambers may disrupt the behaviors they are to observe.

It is thought that cannibalism within species is rare in nature, and that male-to-male signaling is one cause for the reduction in cannibalism. This is important to remember if using jumping spiders other than members of the genus *Phidippus*. The author has noted that members of the genus *Hentzia* begin signaling upon finding silk strands of conspecifics (member of the same species) even in the absence of visual cues. Thus, there is an obvious change in behavior without the necessity of a mirror. Students recording only behaviors associated with the mirror could then come to the wrong conclusion about the silk-induced behavior.

Jumping spiders typically respond strongly to their own reflections. This phenomenon is so pervasive that attempting to photograph them at close range can be challenging as they jump at the "other spider" in the lens. The same is true if an observer is wearing sunglasses and leans too close to the spider, so students should have no trouble observing behaviors. The problem they will have is in quantifying these behaviors. Therefore, it is best to direct students to use a consistent framework (say a 5-minute time span) and count the number of times, or the length of time, key behaviors occur.

Catching spiders

This laboratory exercise is easily expanded into two successive weeks of lab. This is highly recommended if you are going to collect local spiders. The first lab would entail introducing the spider and its biology. A number of excellent resources exist on the Internet for showing images and videos of the spiders and their behavior (**www.peckhamia.com, www.youtube.com**, Google image search). After a brief introduction, the students can be taken outside to collect the spiders. These spiders are ubiquitous and can be found even in urban environment; thus, students need not go far from their classroom. Collecting can be accomplished as follows: a large white sheet of cloth (a single sized bed sheet works well) is spread on the ground under a large tree (magnolia, oak, or maple work the best) with low hanging branches. The low hanging branches are shaken vigorously over the sheet. A variety of arthropods will fall onto the sheet, and some of them will be jumping spiders. Students should capture as many spiders as they can; identification of jumping spiders vs. other spiders (using appendix E) can be done back in the classroom.

Quantification of behavior

Measuring behavior can be done through a number of different methods. For these experiments, the easiest ways to quantify behavior are either by frequency of an activity over a set period of time (such as number of leg waves in three minutes), or length of duration of a single activity (such as the length of time that the spider stares at its reflection). Of these two examples, it is easier to record the time the spider spends focused on its reflection than it is to count the number of times the spider responds to its image. This is because it can be hard to count some behaviors that occur quickly (e.g., leg waving), and harder yet to determine what behaviors should be counted (does the front legs raised and held count as leg waving vs. when the legs are raised and lowered?).

General problem areas

It is possible to use a wide variety of containers for the spiders, or even none at all, but it must be remembered that a clear container also provides some level of reflectance. This can potentially confuse the experimenter, as the spider runs around its enclosure signaling at every reflection it sees. Eventually the spider will ignore its reflection, but this may also negatively impact the strength of the behavior. Therefore it is important to use the same type of containers consistently; to not use square containers (flat surfaces are better at reflecting); and to not use highly polished containers, such as most glass vials.

Another factor that should be considered is the lighting of the room. If the room is poorly lit, the spiders may not respond as readily to their reflections. Furthermore, most jumping spiders retreat to their nests in the evening before the sun sets. The lack of sufficient lighting can be resolved by using dissection microscope light sources, if available. The caution here is that the light be kept at least an arm's length away from the container housing the spider to prevent overheating problems.

In the case of an evening lab, the spiders may be reluctant to move around. This minor problem can be generally overcome by keeping them in a location that is well lit through the part of the day when they will be used. Their biological clocks should readjust to the timeframe when you will be using them.

Some students may exhibit undue anxiety over working with spiders. In the author's experience, this is a surprisingly rare complication. As long as the instructor demonstrates confidence about the low level of danger involved, and firmness about the necessity of all students participating, there should be few problems, though it may be best if those students that actually transfer spiders be willing volunteers. These spiders are not aggressive, and the only bites that the author is aware of are those involving carelessness or accident (e.g., setting one's arm on a spider).

If spiders are caught from the wild for use in the classroom, it is important to know the sex and genus of the spiders that are to be used. Male spiders consistently perform well in the mirror chambers, while females tend to be more cryptic in their behaviors. Females may stalk their own image slowly by creeping towards the mirror, and they may simply stare at their own image for a prolonged period before running away. Gender can be determined by looking at the pedipalps of the spider. Male spiders have enlarged bulb-like palpi that look distinctly darkened at the tip. Females' palpi are regular in shape and lack the aforementioned darkening. It is important to use at least the same genus of spider, if not the same species, as most jumping spider displays are species-specific.

Escaped spiders pose no threat to students, and neither are they a danger to the ecosystem. If the recommended purchased spiders are used, there is little issue. Since these spiders are all male, they will not become established. If locally caught spiders are used, they will only re-inhabit where they already belong. The author has found that a plastic Petri dish bottom works well for preventing escaped spiders from getting away by simply placing it over the retreating spider.

Anticipated conclusions

In some respects it could be said that your students are operating on the cutting edge of behavioral science concerning jumping spiders. Three research articles serve as the basis for this laboratory exercise. Jackson (1986) demonstrated that jumping spiders are capable of using pheromones attached to spider silk to find potential mates. Clark and Jackson (1994) demonstrated that at least one species of jumping spider could distinguish between its dragline (silk) and the dragline of a conspecific (another spider of the same species). Lastly Clark, Harland, and Jackson (2000) demonstrated that the same species of spider could distinguish between the dragline of conspecifics and the dragline of other species of jumping spiders. From the work of these authors comes a picture of the capacities of these spiders. The following seem to be true facts, but the assumption does exist that the aforementioned observations are true of jumping spiders in general:

- Jumping spiders can detect individual draglines.
- Jumping spiders can distinguish between their own and another spider's dragline.
- Jumping spiders alter their behavior in response to foreign draglines.
- The alteration of behavior in response to another spider's dragline is immediate.
- The alteration of behavior in response to another spider's dragline is substantial.

Additional reading

Further information about jumping spiders can be found through the Peckham Society webpage, **http://peckhamia.com/** (accessed September 29, 2012). This web page contains or links directly to videos of jumping spider behavior, images of jumping spider behavior, numerous freely available journal articles, and many other resources.

Addressing health concerns

At this time, there are few verifiable, medically recorded cases of jumping spider bites. The few that do exist indicate that the bites from these spiders are not a cause for any concern medically. Though it is undocumented, there is always a possibility of a reaction from an arthropod bite or sting. In the unlikely event of a bite, the affected individual should be watched closely for any symptoms of allergic reaction (tightness in the throat, difficulty breathing, sudden headache). However, these facts are well established:

- These spiders are some of the most common spiders encountered by humans.
- Bites are very rare, even among those individuals that regularly handle these spiders.
- The author has worked with these spiders for years and has never been bitten by one.
- There is no evidence in the current medical knowledge that anyone has ever suffered serious symptoms from bites delivered by these spiders.

Timeline

What follows is a basic timeline for preparing for this lab exercise and completing it within standard time constraints. This serves to highlight the sequence of important preparation steps, but it does not mandate the actual time spacing, as individual teaching situations will vary.

Two weeks before lab

Order your supplies no less than two full weeks before the day you intend to teach the lab. If you are collecting your own spiders, then you can do so at this time also. Make sure you have enough materials for your students. If you collect spiders, be sure to supply them with water. Refer to the next section for tips on maintaining spiders. If you are ordering spiders, make sure there is someone available to unpack them once they arrive. Remember that in captivity spiders are cannibalistic, so each spider should have its own cage.

The week of lab

It is important to feed the spiders 24 or 48 hours before lab to minimize the effects of hunger on their behavior. All of the spiders should be fed 1 mealworm in the same hour. If it is not possible to feed the spiders in advance, you will need to take this into account when looking at student results (expect greater variation in data).

The day of lab

Set up 3 to 5 group locations (depending on the number of students) in the lab. Each location should have the following materials:

Quantity	Item
1	Scissors
1	Box of pins
5	Sheets of plain white printer paper
1	Roll of tape
3	Mirror chambers (cardboard + mirrors)
3	Empty plastic vials with foam stoppers
3	Plastic vials with 1 jumping spider per vial
1	Stopwatch

When placing the vials on the counter, lay them down stopper-end to clear-end so that the spiders inside are unable to see each other.

The beginning of lab

Evenly distribute students among the group locations to create the groups. Present a basic introduction about behavior, the study of behavior, and jumping spiders in this context. The level of detail needed to prepare students for this lab exercise will depend on what they already know and what your expectations are. It is assumed that they know some basic components of experiments in biology. The following table lists some of the major ideas that they need to know, as well as some of the things this exercise presumes that they know.

What students need to know	What students should already know
Challenges involved in behavioral experiments	Basic concepts in experimental design
General behavior of jumping spiders	Basic concepts of behavior
Concept of behavioral priming	General format of lab reports
Goal of the lab exercise	
Example set-up of the mirror chamber	

During lab

Make sure students are on task developing their experiments. Provide direction for students who are uncertain where to begin, and answer questions as they arise. Once students are well under way with their experimental designs, it may be helpful to demonstrate how to use the mirror chambers and how to transfer the spiders from one tube to another.

As students request that you check their experimental designs, specifically check to see that they have an appropriate control group, experimental group, and a correct means of quantifying the behavior they are about to observe (see the example work section below for more details). Groups that have poor experimental designs should be given some guid-

ance as to what needs further work and allowed to restructure their experimental design to correct for their error.

Example work

What follows are good, and some bad, answers to the questions asked of the students in the student handout above. These are in no way the only possible answers. However, notes at the end of each section indicate key things that the students must figure out before proceeding.

1. In your own words, what is the goal of your experiment?

(good) The goal of my experiment is to determine the effect silk has on the behavioral response of jumping spiders to visual stimuli.

(bad) The goal of my experiment is to test jumping spiders in tubes. (Answer not specific enough)

(bad) The goal of my experiment is to test the effects of behavioral priming, if any, on jumping spiders in tubes with silk. (Answer not really in the student's own words, as the middle portion is the second objective.)

Students need to recognize that their goal is to test the effects of one stimulus on the behavioral response to another. Therefore, they need to include the silk and the display behavior.

2. In light of the previous question, what then would be a possible hypothesis you could test?

(good) Jumping spider display behavior is affected by foreign silk

(good) Jumping spider display behavior is not affected by foreign silk

(bad) Jumping spiders are affected by silk (Not specific enough)

(bad) Jumping spiders choose to display more often when exposed to silk (Identifying choice is not the goal of this experiment)

The hypothesis needs to be a specific statement that they can test for validity. It is not so important that they choose to state their hypothesis as a positive or negative, so long as their hypothesis is testable within what they are doing in lab.

3. How will you go about testing this hypothesis? Outline the steps of your experiment in the space below. Indicate what data will be collected, and during which step(s).

There is a wide variety of answers for this question, but the following components are necessary for student success. Students must:

A. Indicate preparation of materials for the experiment.

Mirror chambers need to be set up, sliding paper covers need to be made for the mirrors, stopwatches need to be zeroed and ready, empty tubes should be washed if necessary, and tasks need to be assigned to different group members (typically one data recorder, one time caller, and one timekeeper), though all will be observing the spiders.

B. Identify control group, its set up, and its operation.

One spider transferred to a new/clean tube. Tube placed into mirror chamber. Stopper removed, tube slid up against mirror, and pinned in place. Paper cover over mirror removed, stopwatch started. Experiment will be repeated twice using the same spider.

C. Identify experimental group, its set up, and its operation.

One spider transferred to a tube that was previously occupied by another spider. Tube placed into mirror chamber. Stopper removed, and tube slid up against mirror, and pinned in place. Paper cover over mirror removed, stopwatch started. Experiment will be repeated twice using the same spider.

Students need to realize that there is an experimental group and a control group. This will likely come automatically to majors students who have had at least one biology lab course since high school. Freshman students may need a little more instruction in this area. Some students might suggest that putting two male spiders into one tube will work as a control. That idea will not work for this experiment, as one spider will be entering a tube where another spider has already laid down silk line. Furthermore, it does not account for the effects of the mirror (thus not correcting for an obvious variable). The best control is one where a spider is transferred to a new, clean tube and then exposed to a mirror. The experimental group should be identical except for using a tube containing the silk of another spider. The best source for a tube that already contains silk is to use one of the tubes provided that has already contained a jumping spider.

D. Identify time as a means of quantifying display behavior.

There are several ways of doing this, and all the ones listed here are functional.

- Record the time between the start of the experiment and the beginning of display behavior.
- Record the time duration of one (or each) individual display behavior.
- Record the total time of all display behaviors within a set length of time.

E. Identify frequency as a component of quantifying display behavior (though by itself quantity is not enough).

Number of displays by the spiders is important, so no mention of it in the proposed experiment may result in student consternation down the road. However, this omission may also work as a great learning opportunity for the students about the need to modify procedures as new developments arise.

4. What do you expect the results to look like?

(good) I expect to see a greater degree of display behavior from the experimental group than the control group.

(bad) I think the spiders will display to the mirrors. (This is already presented as a fact and does not reflect any informative results.)

The goal here is to get the students to anticipate a result, so that they are actively looking for something to record. What they are looking for is not as important as the fact that they are looking for something. However, they should be looking for something that is related to their experiment.

5. Once approved, conduct your experiments using the spiders following that design. Record your data in the space below:

Data should be recorded into table form, which should be intuitive to science majors; it is not expected that there will be problems with this aspect. What is important is that students record data clearly and consistently. The following are two different examples of good formats for recorded data (the data itself is not real):

Example 1

	Control	Experiment
Trial 1	1:30	0:30
Trial 2	2:12	0:25
Trial 3	1:45	0:50

This table shows the time (min:secs) between the uncovering of the mirror and the spider's first display to its reflection.

Example 2

	Trial 1 displays (sec)	Trial 2 displays (sec)	Trial 3 displays (sec)
Control	20, 15, 18	19, 12, 17	12, 20
Experiment	32, 23, 25, 14	20, 19, 25	24, 22, 18, 18

Each number represents the duration of an individual display event within a given trial.

6. Once you have completed your experiments and collected your results, you should answer the question "What do your results tell you?" and, "What is your initial conclusion?" in the space below. Limit your response to no more than three sentences.

Answers will depend upon the results that the students obtained. What you are looking for is an accurate interpretation of their data based on a cursory examination. What follows is a good answer for the second example data table (above):

My results indicate that the silk increased the number of display events by the jumping spiders. Also, it appears that the duration of those events was slightly affected. Therefore, my initial conclusions are that silk has a priming effect on jumping spider display behavior.

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Appendix A

Preparation of Materials

The easiest method of testing visual responses of spiders to a mirror image is to contain the spider in a *Drosophila* culture vial and place the open end of the vial against a mirror. A mirror segment large enough to cover the opening is necessary; a one-inch square mirror tile works well. Recommended vial size for working with adult spiders is 25 mm in diameter by 95 mm in height. Any similar size should be fine. Foam, paper, or cotton plugs can, and should, also be obtained along with vials. A 172-mm by 96-mm piece of cardboard (single-ply, roughly 3 mm thick) can be used to make the stand for the mirror. A slot should be cut for the mirror, and two-thirds of the length of the sides should be folded up to prevent the test vial from rolling from side to side. To ease folding, a sharp knife should be used to cut the outer layer of cardboard on the side opposite the fold. Exact dimensions and cut sites are given in the following image (Fig. 1). This diagram can be cut out and taped to pieces of cardboard as a cutting guide as the diagram is actual scale.

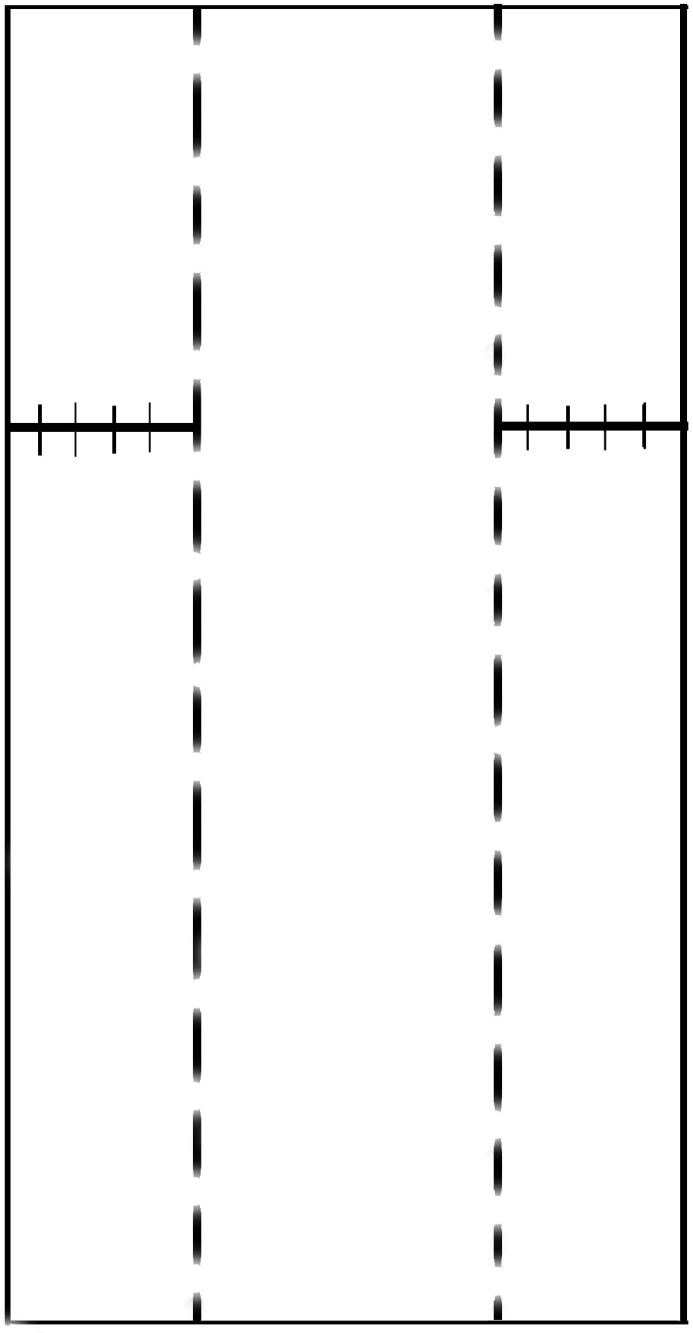


Figure 1. This diagram represents (1:1 scale) where cuts should be made on a cardboard rectangle that will become a mirror chamber. Vertical dashed lines indicate where the cardboard should be scored half-way through, and horizontal lines with hatch marks indicate places where the piece of cardboard should be cut all the way through. Sequence of cuts is un-important.

The cut piece of cardboard should be folded away from the cuts (into the plane of the page). This will create a drawbridge-like structure. The mirror is held in place between the folded edges of cardboard from the longer two-thirds portion and the middle of the shorter one-third. The final product should look like the diagram below (Fig. 2).

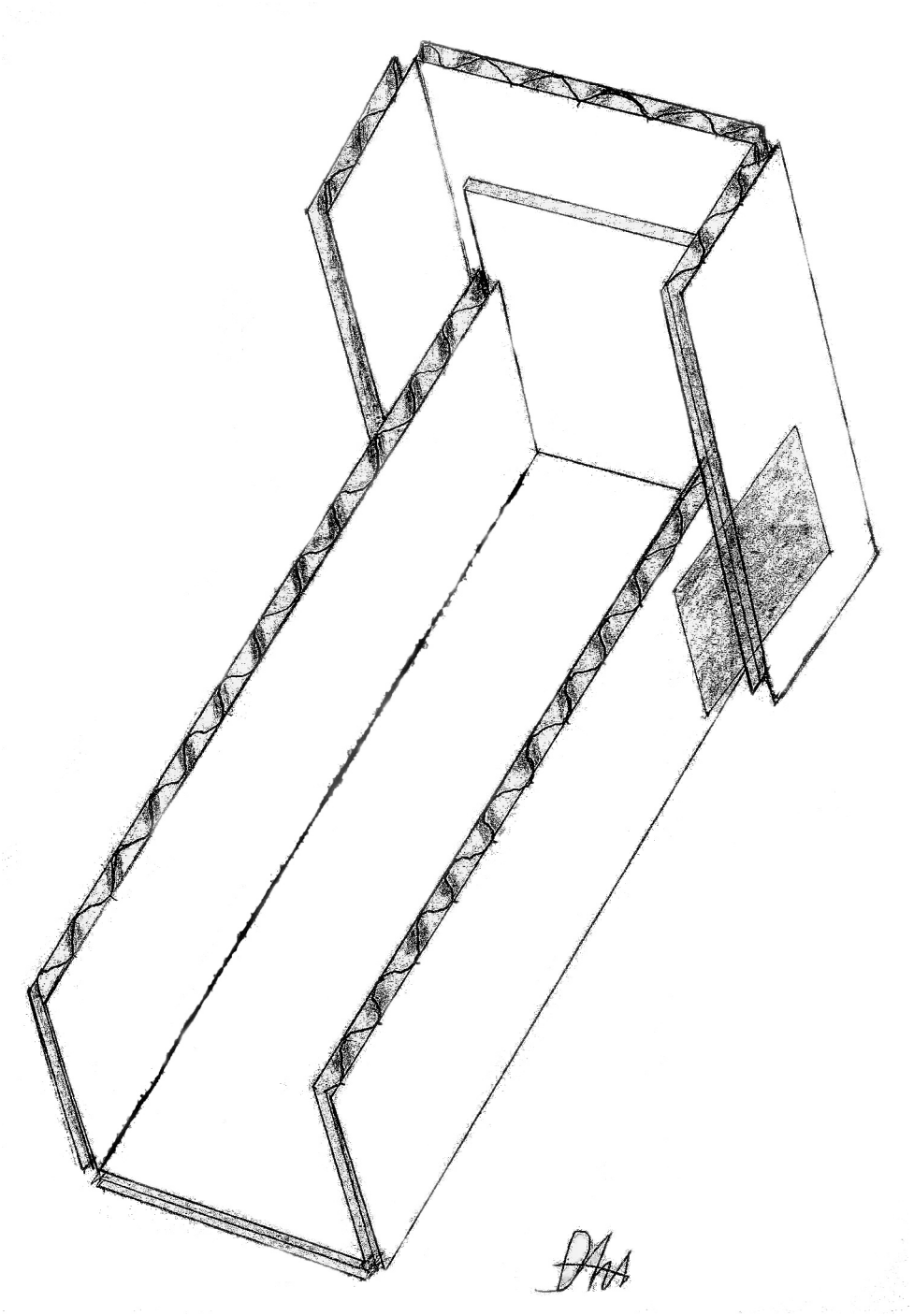


Figure 2. This is what the completed mirror chamber should look like.

Appendix B

Suppliers and Supplies

These are suggested suppliers of these items, though prices may be better locally and a wide variety of similar items will make acceptable substitutes.

Supplier: Carolina Biological Supply Company
Web address: **http://www.carolina.com**

Drosophila Culture Vials, Pack of 12
Catalog #: 173120, Price: $8.25 US
This is enough for 10 students; you will need to order two sets if you have more students.

Electronic Alarm Stopwatch
Catalog #: 696911, Price: $13.25 US
The important feature here is that the stopwatch keeps time to 1/100 of a second.

Petri Dishes, Polystyrene, Disposable, Sterile, 100 x 15 mm, Pk 20
Catalog #: 741250, Price: $5.65 US
These are for long-term maintenance of jumping spiders and are optional.

Mealworms (*Tenebrio*), Living, Larvae, Pack of 50
Catalog #: 144272, Price: $7.95 US
These are for feeding the spiders the day before the experiment to enhance the consistency of the results. They can also be used in long-term maintenance of jumping spiders.

Supplier: Mister Art
Web address: **http://www.misterart.com**

Mirrors, 1 1/2 in. square 10 tiles/bag
Catalog #: 6710125, Price: $3.36 US
This will make 10 mirror chambers.

36 in. x 48 in. x 1/8 in. sheet corrugated cardboard
Catalog #: 6241000, Price: $2.21 US ea.
This is enough cardboard to make more than 90 mirror chambers. Cardboard can also be obtained by cutting up old boxes.

Transparency Film, pack of 25
Catalog #: 4490350, Price: $17.92 US
These will last for a long time. They may be cheaper at a local office supply store.

Aluminum Pins
Catalog #: 7232370, Price: $3.20 US
These are listed here for convenience. Almost any kind of straight pin over 1 inch long will work.

Tape, 3/4 in. x 650 in. dispenser roll
Catalog #: 6200922, Price: $2.35 US
A wide variety of tapes will work so long as they are ½- to ¾-inch wide. These are available locally in department stores, and listed here mainly for convenience.

Supplier: Spider Pharm Inc.
Web address: **http://www.spiderpharm.com**

Phidippus octopunctatus live, adult male, dozen Jumping spiders (Phidippus octopunctatus, Salticidae)
Catalog #: 379L:5AM012, Price: $49.50 US

Adult male spiders have the most dramatic responses to their own reflection. Females also work, though their actions may be far more subtle. Email in advance to be sure spiders are actually available for shipping.

Note:

Spiders can be purchased from suppliers (e.g. **http://www.spiderpharm.com**), but having students collect them as a class exercise is more reliable for lab timing, and a good lead-in to the subject of jumping spiders. It is therefore the author's recommendation that catching jumping spiders be incorporated as an introductory lab to the one presented here.

Other materials

- Scissors - Any basic kind should work fine.
- White printer paper - Available from any department store or office supply store.
- Clear adhesive tape - Masking tape should also work. Available from any department store or office supply store.

Appendix C

Maintaining Spiders

Housing

Almost any container will work. Many researchers have had success with plastic Petri dishes, and the author would recommend them to anyone who has access to them. Plastic Petri dishes are flattened so that they can easily be stacked; they are clear, allowing observation of the specimen; they do not seal air-tight, allowing the specimen to breathe; and they are disposable when the experiment is finished. Because they are plastic, extra holes can easily be added with a hot nail or pin (held with pliers or forceps). Petri dishes are not the only functional housing for jumping spiders. Beverage bottles, old food containers, even plastic bags and small finely screened boxes can work as housing for jumping spiders. It is recommended that spiders be housed individually as they will eat each other. The following illustration (by the author) is what the author recommends as a simple yet efficient house for keeping jumping spiders.

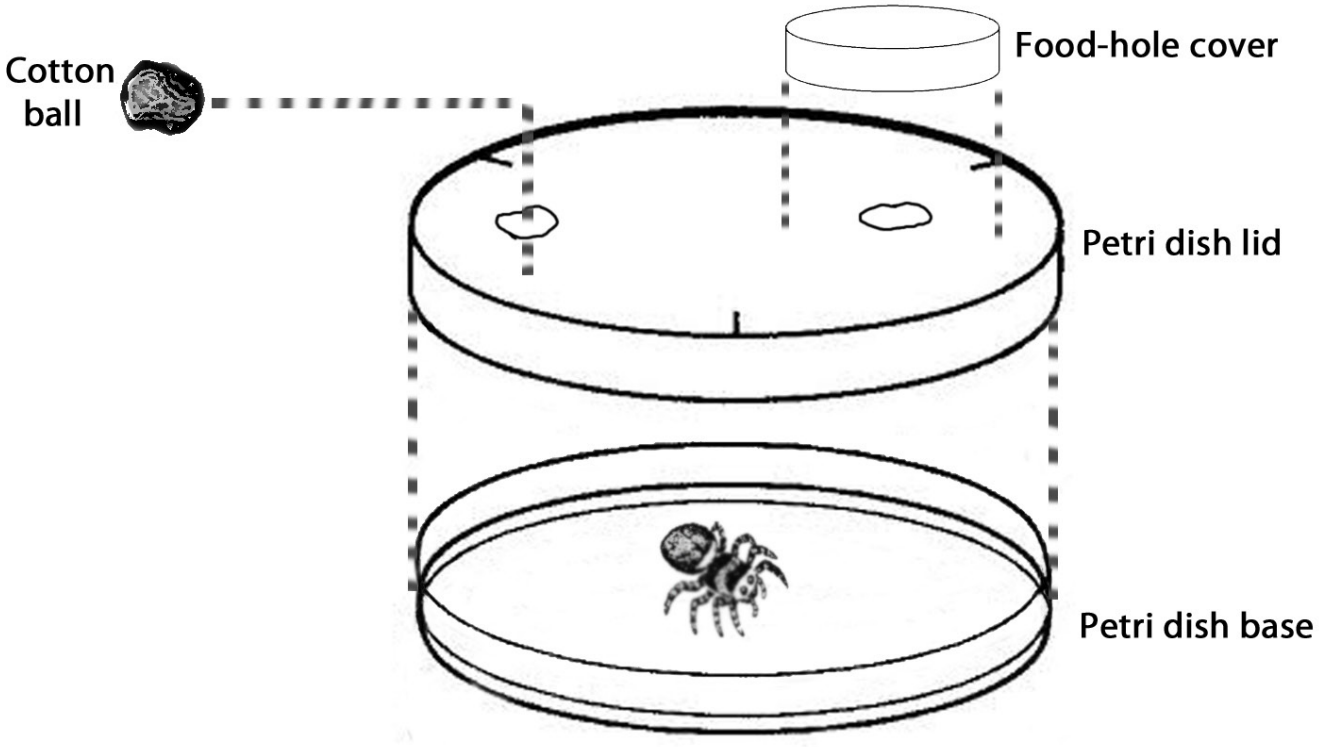


Figure 3. Author's rendering of a spider house made from a Petri dish

Feeding

Jumping spiders, in general, should be fed once or twice a week. Single food items should be introduced at each feeding if the prey is large (1/2 the size of the spider or larger). If the food item is small, two or three items should be given a week. Food items should not be larger than the spider's body. It is possible to build an "automatic" feeding enclosure for jumping spiders but may be more work than warrants the time it saves. However, interested individuals can consult Jackson (1974). The food provided can be almost any kind of insect. For most small jumping spiders, fruit flies (genus *Drosophila*) serve as an acceptable and recommended food source. Most biological supply companies sell both flies and fly-rearing media. Fruit flies can also be captured locally by leaving a container of fly food (e.g., prepared media or a banana) outside for a day. Mealworms and houseflies are good food sources for larger jumping spiders, and both are available from biological supply companies.

Watering

Water can be provided regularly on a wad of cotton or, preferably, the cut-off end of a cotton swab. With this type of watering system, the wad will need dampened once a week, depending on relative humidity. If the room is very dry, it may need to be moistened daily.

Appendix D

Collecting Spiders

Catching

Jumping spiders can be found in almost every habitable terrestrial location in the world. Because they are diurnal, they are most easily seen during the day. A brief discussion of modes of life will be followed by a guide that is separated by seasons to make it easier for the reader to look for jumping spiders in each season.

It is necessary to interject a caution at this point. Any time a person goes into the outdoors looking for a particular creature, there is a twofold danger. First, there is the danger of finding something that the person does not want to find (skunk, beehive, snakes, etc.), so be careful, and do not bother something that is dangerous, or something that you are unable to identify as dangerous or harmless. Second, there is the danger of the person who is searching becoming overly zealous and damaging delicate ecosystems, and it is not the author's intention to encourage destructive behavior. Use caution, try to be as noninvasive as possible, and avoid significant alteration of the habitats into which you are searching. Furthermore, some places are protected by law (such as national parks), and you should always obtain permission from the proper authorities before spider-collecting.

Modes of life

There are some general categories of habitat that may make it easier to find spiders. It must be remembered that these categories are generalizations from dozens of literature articles and do not reflect an absolute principle. Some jumping spiders only live at the ground level. These jumping spiders are found in leaf litter and roaming over rocks and sand looking for prey. Their nests can be found under rocks, fallen leaves, and small sticks. A fair number of jumping spiders can be found in weedy locations, whether living there or simply hunting in that location. These species can be found searching for food on the stems and leaves of brush, weeds, grass, and annual plants. Their nests can be found in the crown or apex of these types of plants. A number of them inhabit the heads of dry grasses, and their nests are easily located by the webbing in the tops of such plants. The last category of habitat that is readily apparent is that of tree dwelling. Within this category there are two subgroups—those spiders that live on the bark and those spiders that live in the periphery of the tree. Periphery spiders can be seen looking for a meal on the upper and lower limbs of trees. Typically these spiders are on the tips of branches, but they can be found further in toward the trunk. They nest in the leaves and crooks of the branches. Bark-dwelling species can be found hunting and nesting in, on, and under the bark of trees. Rock-dwelling species can be found under, on, or near rocks. The author has found established populations of such types of jumping spiders in landscaped areas in urban settings.

Everywhere

For the most part these spiders can be found in a wide variety of habitats. The author has found four specimens of three different species within ten minutes less than twenty feet from his door. Places they can be found include, but are not limited to, urban yards and gardens, city parks, along roadways, wooded areas, fields and fence rows, drainage ditches, shorelines, rocky outcroppings, on buildings, and even on automobiles (especially when the spiders are ballooning). It should be noted that these spiders are generally inactive at night and during periods of inclement weather such as rainy days, cold days (<5°C), and so forth.

Spring

Depending on the latitude of the region, early spring may require the same kinds of searching techniques as those in winter. Jumping spiders become active on warm spring days, and can be found several weeks before the general bud burst ("leafing-out") of many deciduous trees. Before bud burst, jumping spiders can be found under objects on the ground, in the dry woody stems left behind by last year's annual weeds, and under bark. After deciduous trees leaf out, jumping spiders can be found at the periphery of the tree, hunting on leaves and branches. Hatchling spiders from overwintering eggs may also be ballooning during breezy days.

Summer

This season is the time when jumping spiders are most active. Jumping spiders can readily be collected using a sweep net in weedy or brushy areas such as field borders or roadsides in rural places (Gardner, 1965). Early and late in the day, jumping spiders can be found in their nests, so at this time they are more likely to be found under stones, bark, or leaves. Spiders can also be collected by systematically searching individual leaves on trees. This method seems especially effective for finding *Lyssomanes* on magnolia (Richman and Whitcomb, 1981).

Fall

Like the spring season, jumping spider collection in the fall can be highly variable with latitude. Generally, the first significant frost will herald a cessation of jumping spider activity, and spiders will have to be found in their winter locations. The fall is also a time of prevalent ballooning of jumping spiders on windy days. This makes it easy to find them on hand railings of almost any kind, which act as a catch for ballooning spiders. It can be difficult to find adults of some annual species in the fall (Gardner, 1965).

Winter

Because they are ectothermic (so-called "coldblooded"), jumping spiders are only active during warmer months. However, with practice, they can easily be obtained during the cooler months of temperate regions. Frequently, adults overwinter under the bark of dead standing or fallen trees during the winter months. Standing dead trees should be left alone if they are unstable, since they could fall onto would-be spider searchers. Loose bark is easily pulled away from dead trees, and spiders can be seen hibernating in silk enclosures under the bark. They can also be found hibernating under stones and other objects on the ground.

Appendix E

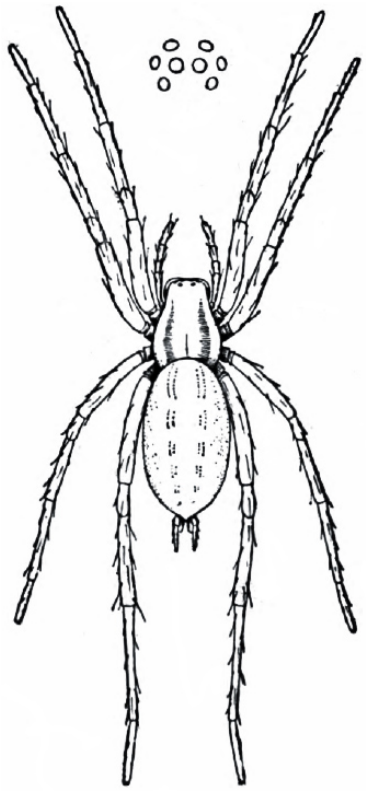
Identifying Jumping Spiders

Identifying jumping spiders is not hard, but may seem daunting to the newcomer. As a general rule, any spider that is active during the day, not found in a web, and runs or jumps readily is in one of two spider families. It is either a salticid or a lycosid (or related family). A great aid to spider hunting is starting out with a fair idea of what jumping spiders look like rather than catching spiders and bringing them back to the classroom only to discover that what was found was something other than what was desired. A great aid to this would be the identification web page known as BugGuide (**http://bugguide.net**). Though the majority of contributors are not taxonomists, those images that are identified are accurate at least to family, based on the author's experience.

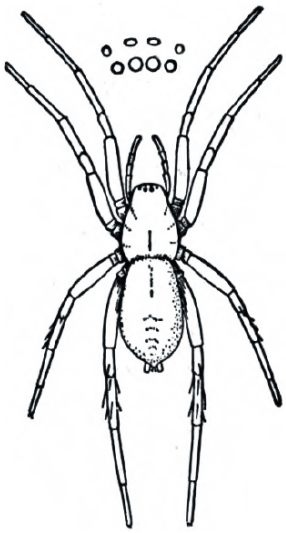
Jumping spiders are readily distinguished from other spiders by the position of the central forward-facing pair of eyes. Using the following diagrams will allow most people to clearly distinguish jumping spiders from several other spiders that look similar superficially. If the spider in question has a body longer than one-and-a-half inches (38mm) it is not a jumping spider –they do not get that big. Generally speaking, jumping spiders have eight eyes (only six of which are easily visible in some jumping spiders) that encircle the head (giving them nearly 360° vision). Any spider that has all the eyes on its face is not a jumping spider. Any spider in which the central eyes are the same size as the surrounding eyes is not a jumping spider, and any spider with eyes directly under the central forward facing eyes is not a jumping spider.

The following diagrams (from J. H. Emerton 1878. *The Structure and Habits of Spiders*. S. E. Cassino Pub., Salem, 118 pages.) are for distinguishing between jumping spiders and similar spiders they could be confused with. Each diagram represents a dorsal view, and is accompanied by a set of circles intended to reflect the relative position and size of the eyes from a frontal (face forward) view of the respective spider. Please keep in mind that these are generalizations, and do not reflect every species that might be encountered. Additional information on identifying types of spiders can be found at **http://www.spiders.us/articles/identification/.**

Diagrams by J. H. Emerton (1878)

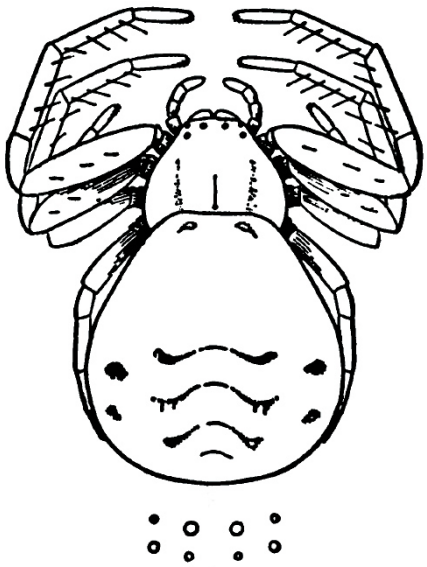


Agelenidae – Funnel-web spider

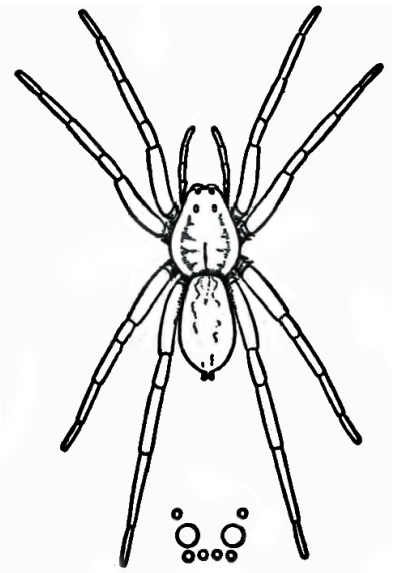


Gnaphosidae – Ground spider

Salticidae – Jumping Spider



Thomisidae – Crab spider



Lycosidae - Wolf spider

About the Author

Mr. McKinney received his B.S. in biology and a M.S. in counseling from Bob Jones University. In 2011 he received a M.S. in entomology from University of Nebraska-Lincoln. He is currently a doctoral student in entomology at the University of Georgia, working with mosquito reproductive endocrinology. Mr. McKinney is also interested in curriculum development in biology. He especially enjoys working with introductory-level students using insects and spiders to teach biology concepts.

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