

# CASE TEACHING NOTES

## for

# “Conversations with Fireflies: A Case Study of Mimicry and Defense”

by

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## INTRODUCTION / BACKGROUND

This case study, based on an article by J.E. Lloyd (1965), was developed for a special topics entomology seminar for upper-level biology majors; it could also be incorporated into a general biology course as an illustration of aggressive mimicry and a lesson in scientific process and data interpretation. It would also be appropriate for an introductory ecology class or a class on animal behavior.

The case explores the intricacies of behavior in the “femme fatale” firefly—female fireflies in the genus *Photuris* that mimic the flash pattern of females in the genus *Photinus* to lure *Photinus* males and eat them. Students read the case, which incorporates entries in an old field notebook, and answer the questions for homework (although the journal format is fictitious, the recorded observations are genuine, and were originally made by James E. Lloyd—see References below). The instructor presents a series of handouts to students for in-class analysis and discussion in a progressive disclosure format (see: Handout 1, Handout 2, Handout 3, Handout 4, and Handout 5). The case concludes with an assignment in which students write an abstract summarizing the main points of the case (see: Homework Assignment).

## Objectives

- To illustrate aggressive mimicry
- To expose students to the scientific process
- To give students practice interpreting results
- To introduce students to a classic entomological story

Students in my class will already have been exposed to the concept of mimicry from previous coursework and I assign a relevant chapter from Waldbauer (1996) to help them prepare for this case.

## CLASSROOM MANAGEMENT

This case was developed for a 90-minute class period. Students prepare by reading the case story and answering the questions for homework. When the class next meets, the instructor leads the students in a 15- to 20-minute discussion of students’ answers to the homework questions, with student-generated hypotheses written on the board.

The remaining class time is spent evaluating a series of five graphs that are handed out one at a time. Students work in groups of four to answer the questions associated with each handout, which are then discussed as a class before moving on to the next handout. I do not have students turn in answers to the handout questions.

The data presented in the five handouts and the ensuing discussion allow students to further explore the question of how this behavior evolved in female fireflies of this particular species and how the behavior might be adaptive. The graphs are taken from Eisner et al. (1997) and demonstrate that “femmes fatales” acquire not only food from their prey but also defensive compounds that protect them from predation by spiders.

After discussing the second handout, I ask students which of the student-generated hypotheses the data were gathered to test, and we then spend the rest of the class exploring the “defensive chemicals” hypothesis. I allocate about 15 to 20 minutes for the first handout and about 25 to 30 minutes total to cover the remaining four handouts.

Students often have difficulty interpreting the graphs but the group work helps them successfully work through this task. It is important to allow enough time for discussing the graphs as a class to ensure that students feel confident in their understanding of the material.

The case could be modified for a shorter class period by asking students to work through Handout 1 before coming to class and/or giving them the final graph (Handout 5) to interpret and incorporate in the abstract they write as homework (see below).

The take-home assignment, which each student completes, is to incorporate all of the data examined into a written abstract (half-page summary) for a hypothetical paper that would include all of the graphs presented in class. This abstract should emphasize the following points:

- the behavior;
- how the system might have evolved (what pre-existing conditions were the foundation for selection of this behavior?); and
- why the system might have evolved (what advantages are conveyed by predation?).

A sample abstract written by a senior undergraduate is provided in the Answer Key to this case.

## **BLOCKS OF ANALYSIS**

Fireflies are beetles in the family Lampyridae. True to their name, most species use light to attract mates. Interestingly, the fireflies that occur in the Western United States do not have light-producing organs and, thus, most people think that fireflies only occur in the Eastern and Midwestern United States.

Firefly habitat is varied, but fireflies typically are found in grassy fields or along the brushy banks of streams and marshy areas. Fireflies undergo complete metamorphosis, and the larvae are worm-like creatures that prey on snails and scavenge dead insects. The adult diet is not fully known, but it appears that most either do not feed or sustain themselves on plant nectar.

Firefly flashing is an intricate form of communication in which the males advertise their presence to females. The females only flash when responding to the flash of a male, and they do so to indicate their location and willingness to mate. It is the males who fly around flashing their lights; females perch on a blade of grass, a twig, or low-lying branch. This flash-response system is fine-tuned and allows males and females to recognize members of their own species.

Each species has a characteristic flash pattern defined by the intensity and duration of the flash and the height and shape of the flight pattern of the males as they flash while flying. Evans (1993) includes a reproduction of a wonderful drawing showing the variety of male flash patterns seen in the genus *Photinus* (including the common J-shape, a rhythmic pulsing and a zig-zag pattern). This diversity and specificity of male flash patterns is suggested by the height and duration of the bumps in the graph in Handout 1. Although the females respond

with a flash pattern that is different from that of the males, it is also species-specific and is characterized by the intensity and duration of the flash and the lag time before responding.

Several different species (including species in different genera) typically occur in the same habitat, and it is the distinctiveness of the flash pattern that maintains their reproductive isolation. Femme fatale fireflies are unusual in their ability to mimic the flash pattern of females of other species, and thereby trick the males.

If you have access to David Attenborough's "Trials of Life" video series, you can show the "Finding a Mate" video, which has a segment in which Attenborough "calls" a male firefly by using a small flashlight to mimic the flash and delay of the female. I have used this visual to reinforce students' understanding of the overall system; it's a nice backdrop against which to discuss the unusual natural history of the femme fatale.

Students in my special topics entomology seminar felt that this case was a very useful addition to the course (rating=4.6 on a scale where 1=strongly disagree to 5=strongly agree; N=10), helped them to better understand the scientific process (rating=4), gave them valuable practice with critical thinking (rating=4.9), enhanced their ability to read graphs (rating=4.2), and enhanced their ability to interpret graphs (rating=4.1).

## ANSWER KEY

Answers to the questions posed in the case study are provided in a separate answer key to the case. Those answers are password-protected. To access the answers for this case, go to the [key](#). You will be prompted for a username and password. If you have not yet registered with us, you can see whether you are eligible for an account by reviewing our [password policy](#) and then apply online or write to [answerkey@sciencecases.org](mailto:answerkey@sciencecases.org).

## REFERENCES

- Eisner, T., M.A. Goetz, D.E. Hill, S.R. Smedley, and J. Meinwald. 1997. Firefly "femmes fatales" acquire defensive steroids (lucibufagins) from their firefly prey. *Proceedings of the National Academy of Science USA* 94: 9723-9728. Available online at the website for PNAS (<http://www.pnas.org/>).
- Lloyd, J.E. 1965. Aggressive mimicry in Photuris: Firefly femmes fatales. *Science* 149 (3684): 653-654.
- Lloyd, J.E. 1975. Aggressive mimicry in Photuris fireflies: Signal repertoires by femmes fatales. *Science* 187 (4175): 452-453.
- Waldbauer, G. 1996. *Insects Through the Seasons*. Cambridge, MA: Harvard University Press.

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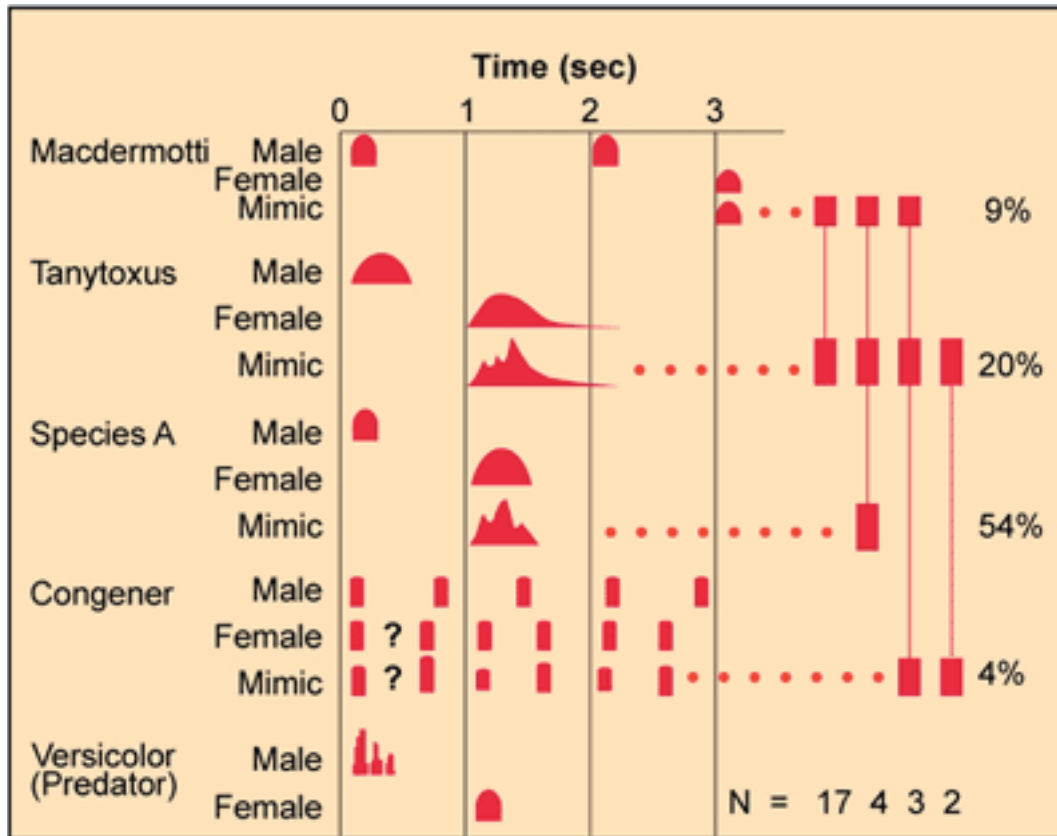
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# Handout 1

The figure below portrays the luminescent signals of selected fireflies. The response used by the predator is shown beneath the female it mimics. Vertical bars at right indicate observed individual repertoires; N is the number of females exhibiting the repertoire. Capture rates (percentages) are adjacent to prey species. The flash rate of the congener female is variable, and the specific nature of the coding is unknown.



## Prey species:

*Photinus macdermotti*  
*Photinus tanytoxus*  
*Photuris sp. A*  
*Photuris congener*

## Predator/mimic:

*Photuris versicolor*  
 (i.e., femme fatale)

## Questions

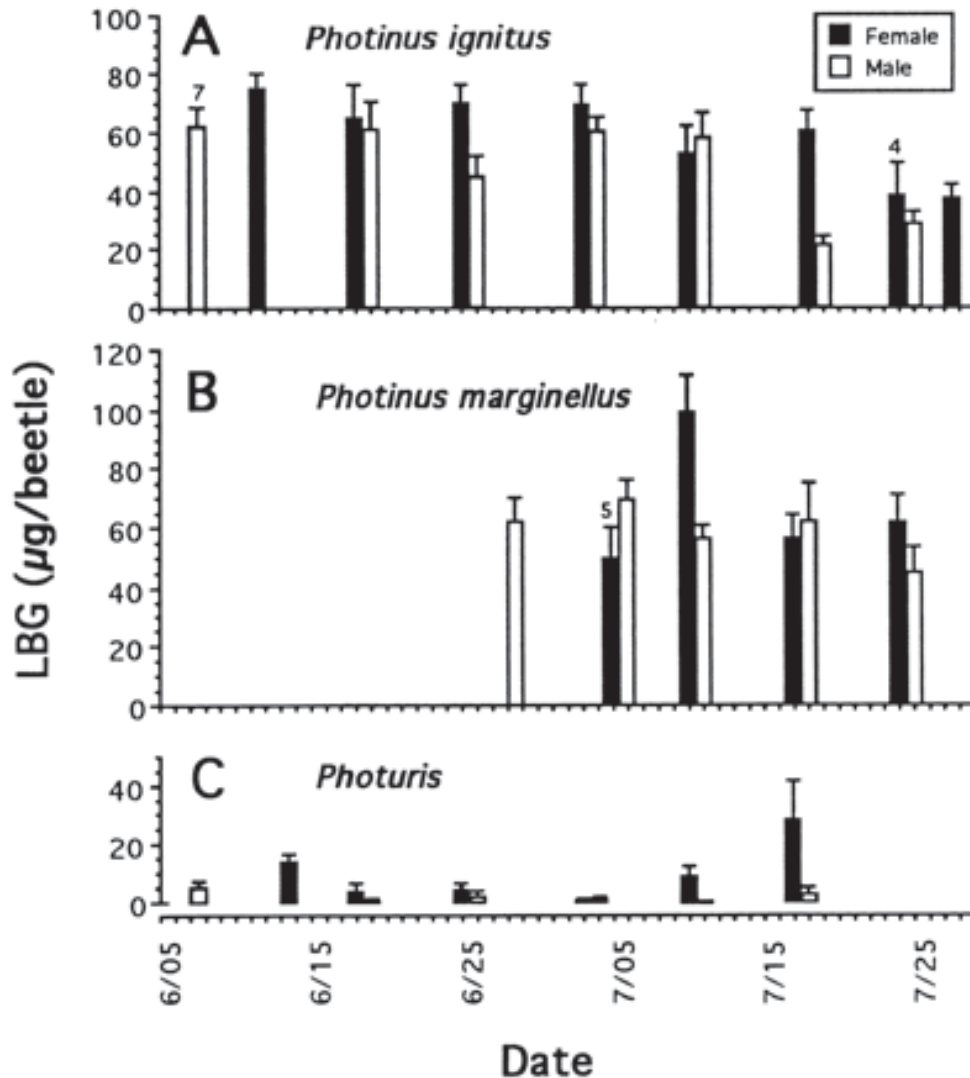
1. What do the black horizontal humps represent in the body of the graph?
2. In general, what information does this graph convey?
3. Compare the normal mating flash-response pattern of the femme fatale with that of the mating signals used by her prey species.
4. How perfect does the mimic have to be?
5. What are the potential benefits of this predation strategy?

## Handout 2

Firefly femmes fatales acquire defensive steroids (lucibufagins) from their firefly prey.

Body LBG\* content of field-collected male and female fireflies, plotted as a function of date of collection (Ithaca, NY); n = 10 per column, except where otherwise indicated. Note: *P. marginellus* appears later in the season than the other two fireflies, accounting for the absence of samples of this species for most of June.

\* LBG = a chemical class of cardiotonic steroids known as “lucibufagins.” These compounds are structurally similar to steroids produced by Chinese toads (*Bufo* spp.), which are known to be toxic to many vertebrates. The name “lucibufagin” is a combination of the name of the chemical that produces the light in fireflies (luciferin) and the toad’s name (bufo).



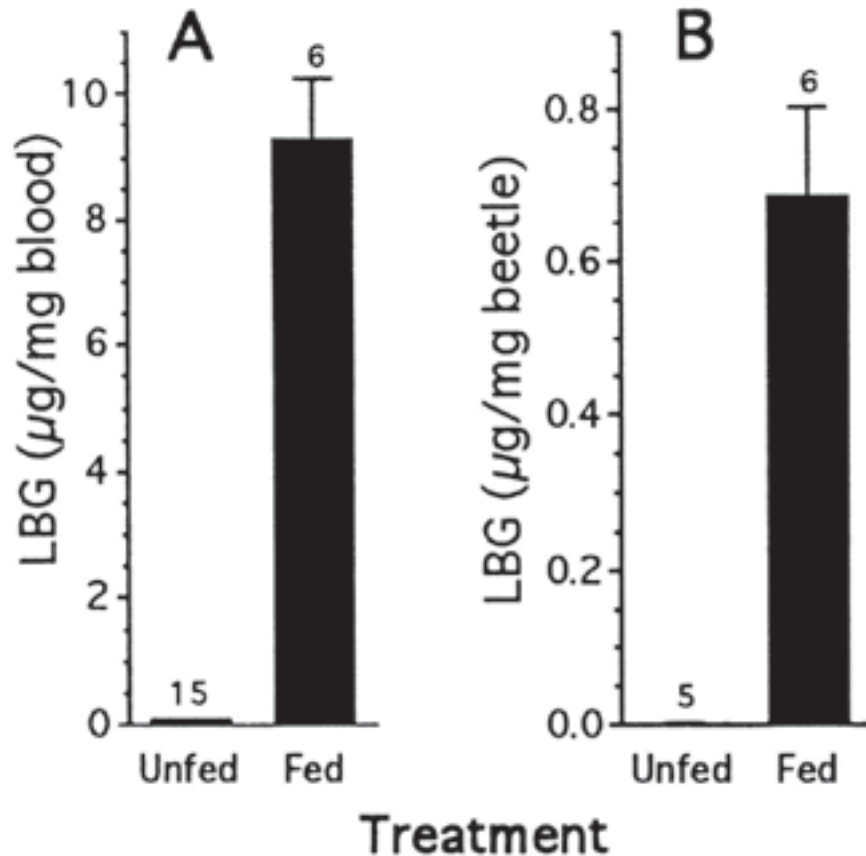
## Questions

1. How do *Photinus* spp. compare to *Photuris* spp.?
2. How do males compare to females (*Photinus* spp.)?
3. How do males compare to females (*Photuris* spp.)?

## Handout 3

LBG content of *Photuris* females that ate two *P. ignites* males (n=6) or were kept unfed (controls; n=15).

LBG values are expressed as concentration (in blood [Graph A] and body [Graph B]). In both cases, differences were significant (t tests,  $p < 0.01$ ).



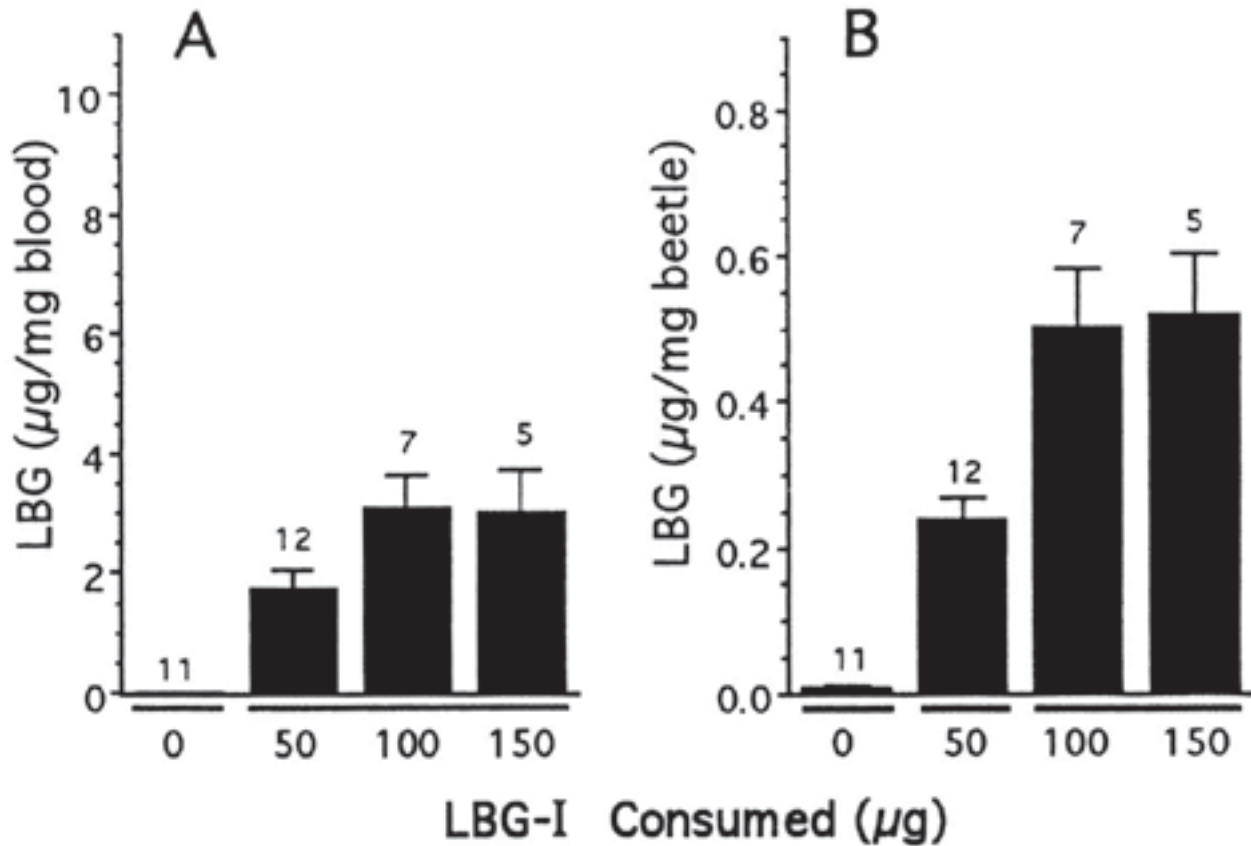
## Questions

1. What can you conclude about the presence of LBG in *Photuris* spp. females?
2. Given that Graph B represents the concentration of LBG in a whole beetle that was ground up (so it includes both blood and other tissues) and that Graph A represents the concentration found in the blood alone, what can you conclude about how the LBG is distributed in the tissues of the fed females?

## Handout 4

LBG content of *Photuris* females, plotted as a function of LBG-I consumed.

Data are presented as concentrations as in the previous Handout 3. In both cases, significant differences were detected [ANOVAs of  $\log(x + 1)$  transformed data,  $P < 0.0001$ ]. Within a plot, columns not sharing underlining are significantly different (experiment-wide  $\alpha = 0.05$ ).

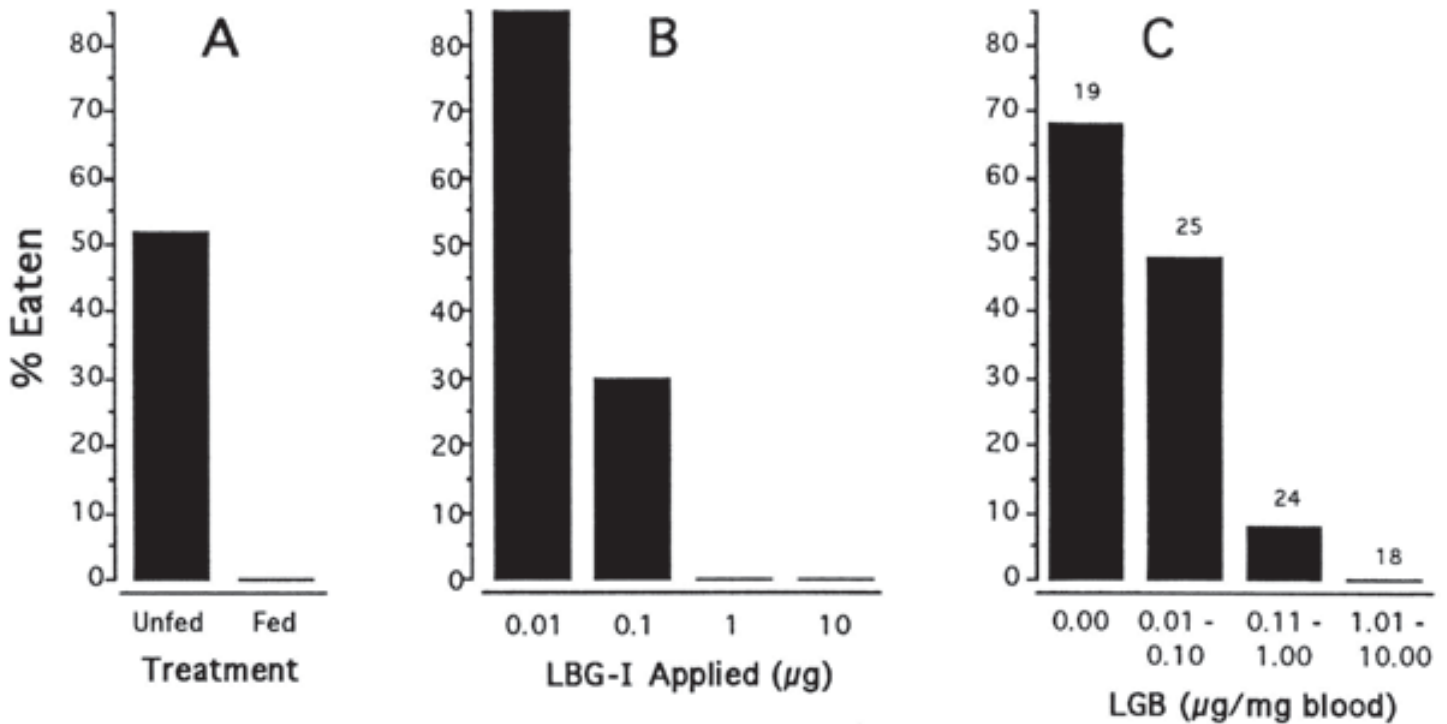


## Questions

1. What conclusions can you draw based on these data?
2. In this experiment the scientists fed *Photuris* spp. different LBG concentrations. Why was this a necessary experiment?

# Handout 5

Predation tests with *Phidippus* spiders (Graph A and Graph C, *P. audax*; Graph B, *P. regius*).



Graph A—Acceptability of *Photuris* females, plotted as a function of whether or not they had eaten two *P. ignitus* males (n=29 per category) [i.e., unfed are *Photuris* females who have not eaten the *P. ignitus* males, and fed are those who did eat them].

Graph B—Acceptability of the fruitfly *Drosophila melanogaster*, plotted as a function of quantity of LBG-I added topically (n=20 per category). Note: *D. melanogaster* are small flies that are readily available for purchase and are easily reared in the laboratory. By using them as a stand-in for the fireflies, the scientists ensure that the results can be attributed to the LBG and not something else in the fireflies.

Graph C—Acceptability of field-collected female *Photuris*, plotted as a function of LBG concentration in blood. Acceptability was dependent upon treatment (A and B) or blood LBG content (C) (G-tests, in each case,  $P < 0.00001$ ).

## Questions

1. Given the fact that *Phidippus* spiders are common predators of fireflies, interpret these graphs.
2. What result would you predict if you offered male *Photuris* to the spiders?

## **Homework Assignment—Putting it all together**

Write an abstract for a paper based on this case. Emphasize the following points:

- the behavior;
- how the system might have evolved (what pre-existing conditions were the foundation for selection of this behavior?); and
- why the system might have evolved (what advantages are conveyed by predation?).