Champs, Chirps and Twerps: What Do We Choose in Mates?

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Overview:
Students learn that natural variations exist among species and among individuals, that these differences may be inherited, and if so, female choice for these traits can lead to evolutionary change. The lesson starts out with an introduction to heritable song variations among cricket families and leads into why these variations could be important components of the Darwinian fitness (generally referred to simply as "fitness") of the individuals. The idea of female mate choice for these song variations is then used to emphasize that reproductive success is the bottom line of natural selection. Students design an experiment testing which components of the cricket song the females prefer and test their hypotheses by measuring the song components using provided songs and analyzing a dataset from a working laboratory.

Lesson Concepts:

- Traits can be defined as any aspect of the phenotype (= physical form, such as body mass, height, song frequency, etc.) that can be measured with a reasonable degree of reliability (repeatability).
- Individuals within families are more similar than individuals from different families, which can be used to infer that there may be heritable differences among families.
- Many traits vary from individual to individual and can contribute to how attractive an individual is to the opposite sex.
- When there is genetic variation in the population, traits can change in response to selection pressures, such as mate choice.
- Variation in a population can be measured and used to predict future trends in populations

Grade Span: 7-12, college lower- or upper-division evolutionary biology class

Materials:

- A computer with internet connection and either Google Forms or Excel (recommended but not mandatory). If no computers are available, rulers can be used to acquire measurements.
- Each student should be able to fill out the digital spreadsheet (can be from a computer or smart phone) or a printed out spreadsheet. Otherwise, teacher can manually input data for them.
- Audacity program (Audacity) downloaded on computers enables precise measurement of song characteristics.

Advance Preparation:

Read Teacher Background (below)
Follow instructions in Teacher Packet (http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/Cricket_Teacher_Packet_1.pdf) to create a Google Form.
Also in Teacher Packet: instructions for analyzing data using Excel

Time: Two to three hours

Grouping: Collaborative groups for discussion and measurements

Teacher Background:

The fitness of an individual is generally comprised of two measures: survival to reproductive age and how many offspring the individual contributes to the next generation. If the individual survives to reproductive age but then does not mate, its fitness will be zero because it failed to pass on any genes to the following generation. If the individual dies before reproductive age, it never has the opportunity to mate and its fitness is also zero. If we compare two individuals that survived to reproductive age and then mated, the one that has the most offspring has the higher fitness because it was able to pass on more copies of its genes. This is natural selection. Sexual selection is a type of natural selection but in this case the fitness of one sex is contingent on the preferences, or performance, of the other sex.

Suppose we compare Male 1 and Male 2. All of their traits are the same, except that Male 1 has a short tail and Male 2 has a long tail and this trait is genetically determined. In this population long tails are rare but females tend to prefer them over short tails. Both of the males survive to reproductive age but because of female preference Male 2 obtains three mates and produced six offspring while Male 1 was favored by only a single female and produced two offspring. The next generation has more copies of the genes producing long-tails than genes that produce short-tails. Therefore, the fitness of Male 2 was higher than that of Male 1 and over time the frequency of long tails will increase in the population.

The phenotypes (or outward appearances) of many traits, such as height and weight, are determined by many genes rather than just one gene: such traits are termed “polygenic traits”. This produces continuous variation of the trait in the population, so that instead of having simply two classes of males, those with short tails and those with long tails, there are males with tail lengths ranging over the whole spectrum from short to long. If males that have, on average, longer tails get more mates, then after several generations the average tail length of males in the population will increase. Because the same genes generally operate in females the tail length of females will also increase. This is evolution by sexual selection, or the selection of traits that increase the mating success of individuals. The mating advantage may be enough to overcome pressure from natural selection, such as the metabolic cost of growing a longer tail.

Biologists can study sexual selection in the field or in the laboratory by bringing in individuals from the field. The benefit of field studies is that it is a more natural setting with all the stressors and environmental components that come with natural habitats. The benefit of the lab is that you can control for different components of the environment and be able to disentangle the effects of these components. Here we are introducing a lab study that was done on the mating system of sand crickets.

In most crickets and grasshoppers males attract females by means of a song (in a few species both sexes are silent and in all species females are silent). Females use the male song to firstly identify that the male is of the correct species and secondly to measure the “attractiveness” of the male relative to other males of the same species. Research on the sand cricket has shown that females judge the attractiveness of males by the amount of time the males spend calling and by particular components of the calling song. These song traits have been shown to be heritable in this species.

Also, read:

- Adaptation
- Natural Selection
- Sexual Selection and Sexual Selection 2

Vocabulary: fitness, mate choice, natural selection, sexual selection, behavior, evolution, population, trait, amplitude, frequency, rate, hypothesis

Procedure:

1. Start by asking students to think of an animal that they are familiar with (humans, dogs, cats, etc.). Ask them to write down 5 characteristics that all individuals of that species share. Note that these traits can be morphological (e.g., height), physiological (e.g., blood pressure) or behavioral (e.g., barking, aggressiveness, tail wagging). Then ask them to think of ways in which these traits differ from individual to individual. [think-pair-share]
2. Ask students to share their list of traits and differences within those traits with their partner(s). Try to lead students to think about auditory signals and songs.
3. Ask: Could traits like this be found for any species? Would individuals within a species be able to identify differences in these traits? Why would these traits vary from individual to individual?
4. Ask: Would these traits be more similar in related individuals versus unrelated individuals? Why or why not? Get them to think about both genetic and environmental factors that could make individuals more or less similar.
5. Introduce the life history of sand crickets by reading the last paragraph of the **Teacher Background** (see above) background information and by going over the online lecture with them. [http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/story.htm]

Song Heritability

6. Pass out Student Handout 1. This is in one of three versions:
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/Cricket_Student_Handout_Middle_School_1.pdf
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/Cricket_Student_Handout_High_School_1.pdf
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/Cricket_Student_Handout_High_School_manual_1.pdf

Tell them that females use these songs to choose between males but ask students which of the song characteristics they learned about in the online lecture might be particularly attractive to a female cricket. Have the students indicate their choice of song characteristic on their handout. Split students into groups and each group must identify one song characteristic that they will measure to determine which song characteristics the females are using for mate choice. Make sure that each group has a different characteristic to measure so that many are covered.

7. Provide students with waveforms for each individual in the two families (A1 and A10). Go over how Audacity can be used to measure their chosen characteristics or how the measurements can be made on printed out waveforms (frequency and decibels measurements have to be done on Audacity; instructions are in the Student Handouts HS and MS).
8. Have each group measure the characteristic they chose for each of the individual males and record their measurements on a spreadsheet. Pool the data from the different groups (either on Google Forms or manually by the teacher).
9. Then have them look at similarities between individuals within a family and then differences between families. Having averages of the measurements for the families will help in finding differences. Ask students why it might be that some traits are more similar within families than between families.

Sexual Selection

10. Share with the students that the individuals in Family A1 are more attractive to the females than the individuals in Family A10. Ask which characteristics the females are likely using to distinguish between the families. Students should be able to arrive at the fact that the characteristics that are most similar between individuals within families but are most different between the two families are the most likely candidates for mate choice. The family data cannot be used to determine which traits are important to female choice because we don't know who the males were paired up with, so ask how they would go about testing which characteristics are important.
11. Have a class discussion about how one would go about testing whether females use these characteristics in mate choice. Have the students construct hypotheses as to how the females are choosing between different males. Have them state the hypotheses in "if…then" statements. How would they measure the female preference? ("If _____[I do this] _____, then _____[this]_____ will happen.") Have them devise an apparatus to do this.
12. Tell the students that experiments like the ones they devised have been done in labs and show them the paired male data from these experiments (http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/Paired_Male_Data_HS_AP_Version_1.docx or http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/Paired_Male_Graphs_MS_1.docx). Refer to online lecture.
    a. For Middle school - have students match the given graphs of the song characteristics to the sample graphs for directional and stabilizing preference (selection) and identify the type of preference (selection) for each song characteristic. Then have the students proceed to the conclusion section.

b. For high school classes - have students follow the directions to use a spreadsheet to analyze and graph the lab data. Then have students proceed to the conclusion section. Song pdfs and wave files are listed below.
c. For high school AP (and maybe Honors) classes- In addition to what the students did in part "b", you can choose to have students identify their chosen song characteristic and complete a chi square analysis of the paired data. For example, when analyzing whether frequency is directionally preferred in mate choice, the null hypothesis is that frequency has no effect, so the expected value would be that half the chosen males would have a higher frequency than the other male and half would have a lower frequency. If your observed values show a significant difference upon chi square analysis, the conclusion would be that frequency is a factor and the one more chosen is the desired frequency (higher or lower). Then have students proceed to the conclusion section.

13. Ask thought question: Ask how this mating system can lead to evolutionary change of this species: How would the next generation be affected, how would the phenotype of this trait change in the population over time, how can small changes like this lead to bigger phenotypic shifts over time, etc. [think-pair-share]

Cricket Song Graphs (Right-click to save):
Family A1:
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_graphs/**LW1_A1-2a_song_graph.pdf**
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_graphs/**LW1_A1-3a_song_graph.pdf**
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_graphs/**LW2_A1-3a_song_graph.pdf**
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_graphs/**SW1_A1-3b_song_graph.pdf**
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_graphs/**SW2_A1-1_song_graph.pdf**

Family A10:
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_graphs/**LW1_A10-1a_song_graph.pdf**
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_graphs/**LW2_A10-1a_song_graph.pdf**
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_graphs/**SW12_A10-1a_song_graph.pdf**

http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_graphs/**SW12_A10-1b_song_graph.pdf**
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_graphs/**SW13_A10-1b_song_graph.pdf**

Cricket Song Wave Files:
Family A1:
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_wav_files**/LW1_A1-2a.wav**
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_wav_files**/LW1_A1-3a.wav**
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_wav_files**/LW2_A1-3a.wav**
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_wav_files**/SW1_A1-3b.wav**
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_wav_files**/SW2_A1-1.wav**

Family A10:
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_wav_files**/LW1_A10-1a.wav**
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_wav_files**/LW2_A10-1a.wav**
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_wav_files**/SW12_A10-1a.wav**
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_wav_files**/SW12_A10-1b.wav**
http://idea.ucr.edu/documents/flash/champs_chirps_and_twerps/cricket_song_wav_files**/SW13_A10-1b.wav**