Adapting Data Nuggets for College Introductory Biology Courses

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Introduction:

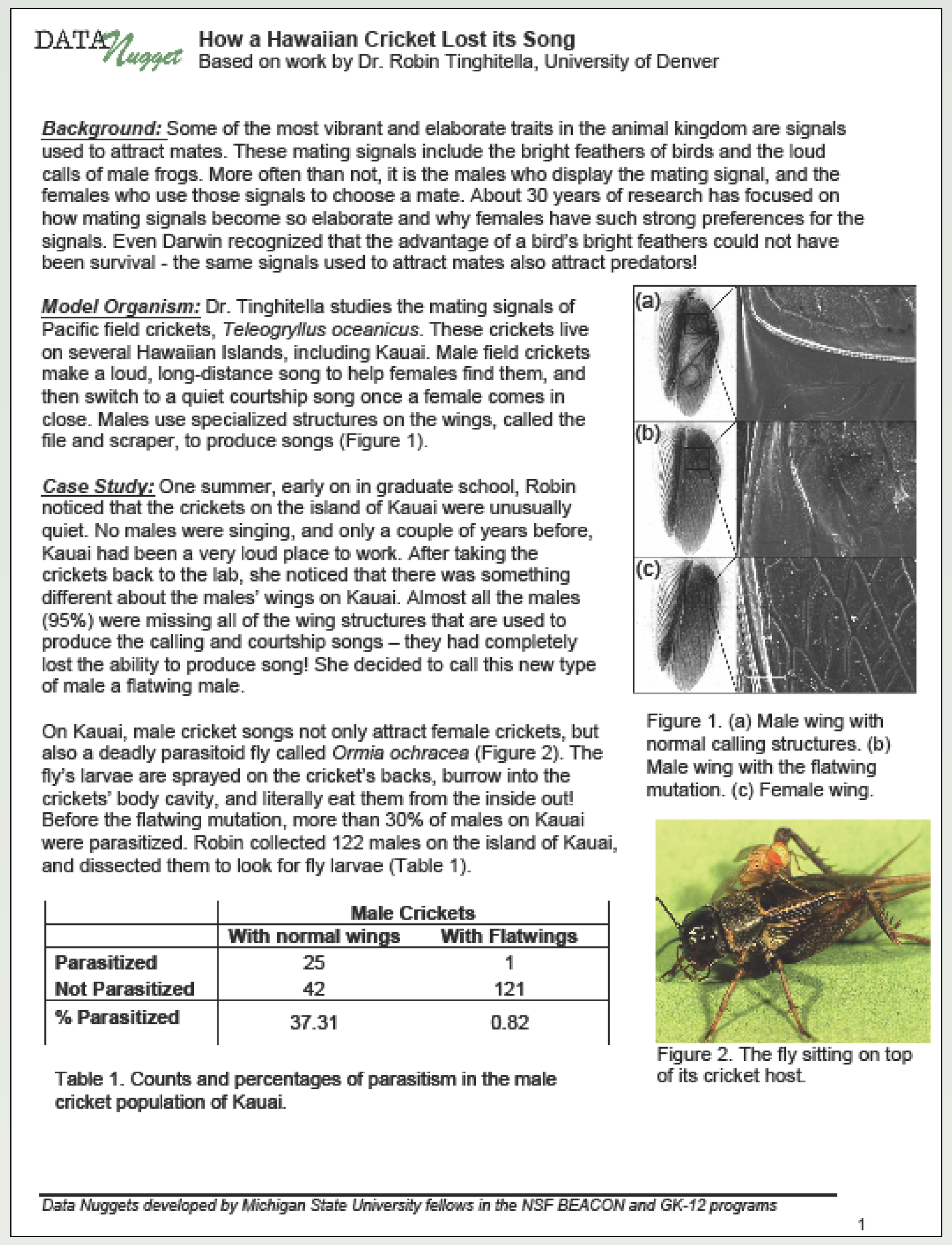
Data Nuggets (DNs) are instructional resources designed to promote the quantitative reasoning and data analysis skills that are foundational for science (Schultheis & Kjelvik, 2015). DNs connect students in classrooms with researchers in the field and their raw data. Students read about a researcher and their research questions and are then presented with a dataset that they graph and reason from. DNs help students learn the scientific practices of data analysis, representation, and interpretation.

Our current work extends the reach of DNs as an assessment for college biology and expands their scope by incorporating core scientific competencies. Specifically, our adaptation of DNs guides students through a series of practices that mirror authentic scientific practice: graphing data to visualize trends, using scientific arguments to explain the data, and using models to represent and reason about system interactions.

Methods:

Students (n = 184) in a second semester introductory biology course were provided with DN (Fig. 1), that was amended to include the following prompts:

1. Construct/draw a model (picture, box-and-arrow, etc) that describes the interactions in the system.
2. On your model, circle the first structure that you drew or wrote. Briefly describe your strategy or approach for assembling the model for this problem.
3. Predict how you expect the populations of crickets and parasitoid flies to change after several generations. Consider both population size and morphological characteristics in your response.



DATA Nugget **How a Hawaiian Cricket Lost its Song**
Based on work by Dr. Robin Tinghitella, University of Denver

Background: Some of the most vibrant and elaborate traits in the animal kingdom are signals used to attract mates. These mating signals include the bright feathers of birds and the loud calls of male frogs. More often than not, it is the males who display the mating signal, and the females who use those signals to choose a mate. About 30 years of research has focused on how mating signals become so elaborate and why females have such strong preferences for the signals. Even Darwin recognized that the advantage of a bird's bright feathers could not have been survival - the same signals used to attract mates also attract predators!

Model Organism: Dr. Tinghitella studies the mating signals of Pacific field crickets, *Teleogryllus oceanicus*. These crickets live on several Hawaiian Islands, including Kauai. Male field crickets make a loud, long-distance song to help females find them, and then switch to a quiet courtship song once a female comes in close. Males use specialized structures on the wings, called the file and scraper, to produce songs (Figure 1).

Case Study: One summer, early on in graduate school, Robin noticed that the crickets on the island of Kauai were unusually quiet. No males were singing, and only a couple of years before, Kauai had been a very loud place to work. After taking the crickets back to the lab, she noticed that there was something different about the males' wings on Kauai. Almost all the males (95%) were missing all of the wing structures that are used to produce the calling and courtship songs – they had completely lost the ability to produce song! She decided to call this new type of male a flatwing male.

On Kauai, male cricket songs not only attract female crickets, but also a deadly parasitoid fly called *Ormia ochracea* (Figure 2). The fly's larvae are sprayed on the cricket's backs, burrow into the crickets' body cavity, and literally eat them from the inside out! Before the flatwing mutation, more than 30% of males on Kauai were parasitized. Robin collected 122 males on the island of Kauai, and dissected them to look for fly larvae (Table 1).

Figure 1. (a) Male wing with normal calling structures. (b) Male wing with the flatwing mutation. (c) Female wing.

	Male Crickets	
	With normal wings	With Flatwings
Parasitized	25	1
Not Parasitized	42	121
% Parasitized	37.31	0.82

Table 1. Counts and percentages of parasitism in the male cricket population of Kauai.

Figure 2. The fly sitting on top of its cricket host.

Data Nuggets developed by Michigan State University fellows in the NSF BEACON and GK-12 programs

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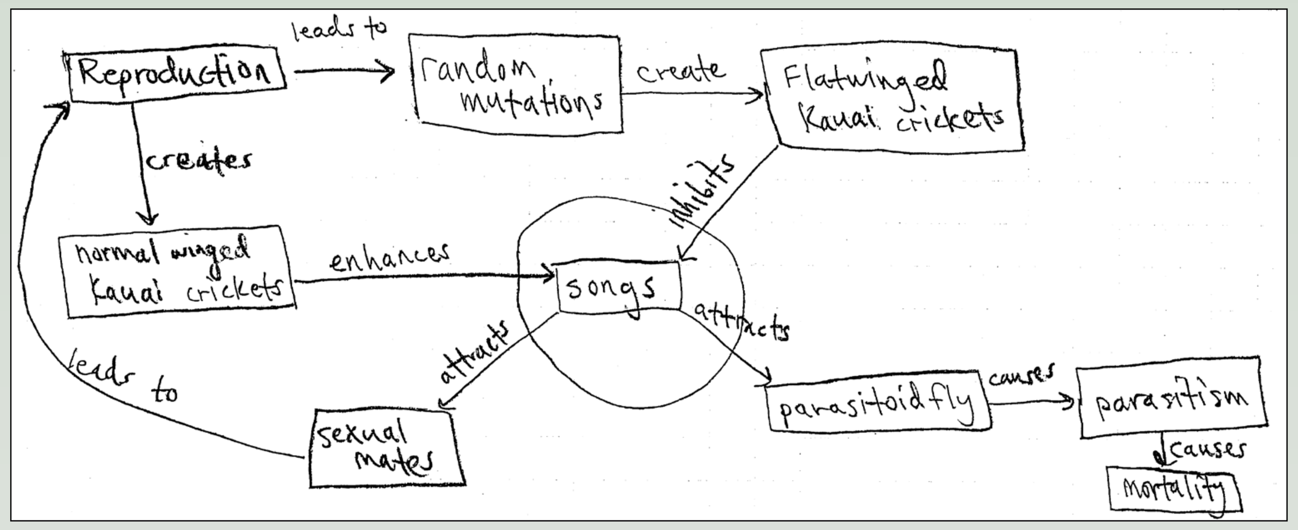
Figure 1. Data Nuggets (datanuggets.org) are assessments that use real researchers and their data to assess students' competencies in data analysis and argumentation. We adapted the Hawaiian Cricket Data Nugget ("How the Cricket," 2015) to incorporate the additional scientific practice of modeling.

Student models were then coded and analysed for :

- presence/absence of relevant structures (e.g. normal male cricket, parasitoid fly).
- presence/absence of a mechanism to attract females (i.e., song).
- web-like causality index (WCI; Plate, 2010), an indicator of model complexity.

Analysis and Results:



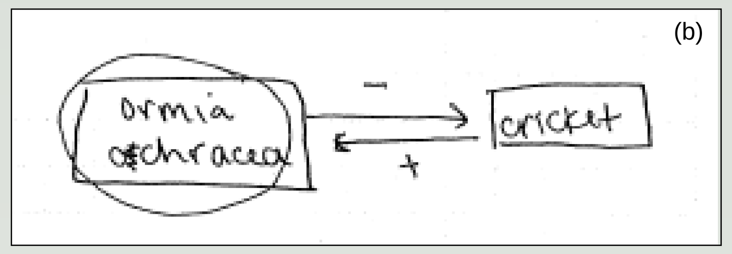


Figure 2 (a) and (b): Students' models varied widely in terms of complexity, numbers of structures used, and approaches for explaining relationships among model components.

Of the 184 responses, 164 box and arrow models were considered for further analysis; 20 were excluded on account of significant departure from format that made coding impractical.

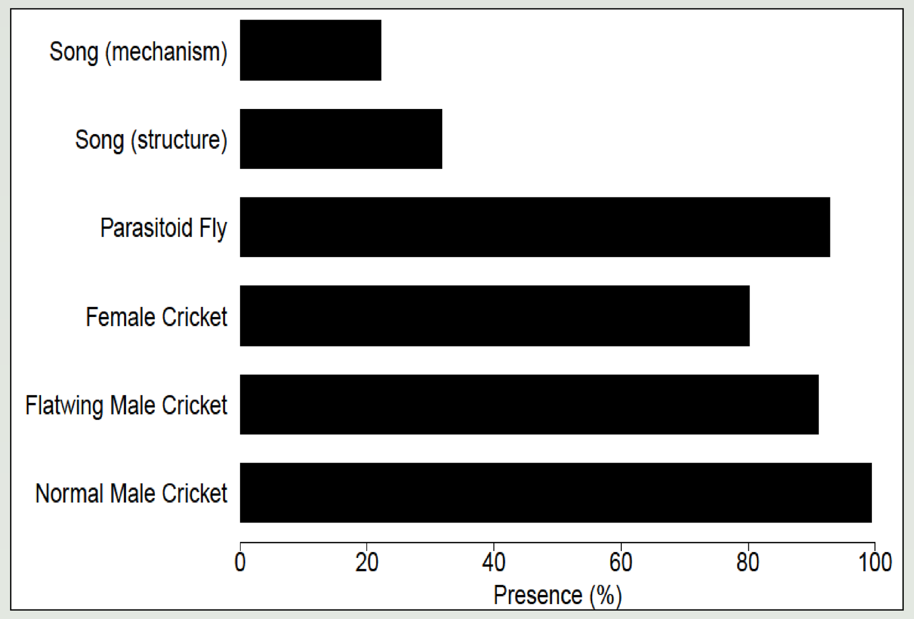


Figure 3. Percentage of student models that contained expected system elements. A majority of students were able to identify relevant system structures (e.g., normal and flatwing crickets, parasitoid flies, and females) but only a minority inferred a role for cricket song.

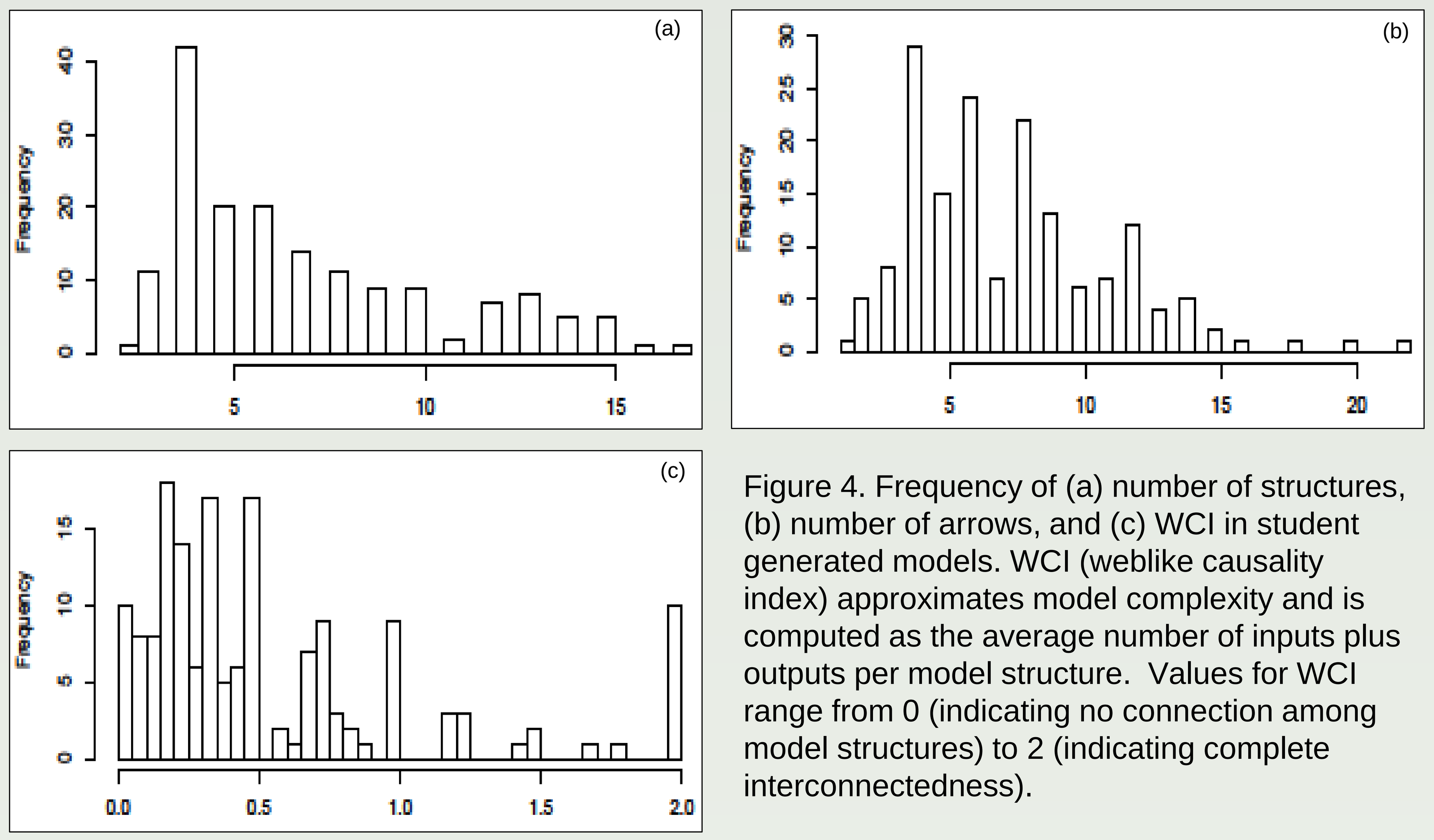


Figure 4. Frequency of (a) number of structures, (b) number of arrows, and (c) WCI in student generated models. WCI (weblike causality index) approximates model complexity and is computed as the average number of inputs plus outputs per model structure. Values for WCI range from 0 (indicating no connection among model structures) to 2 (indicating complete interconnectedness).

The number of structures per model ranged from 2 to 17, whereas the number of arrows ranged from 1 to 22. Virtually all the models (99%) included the structure 'Normal Male Fly', but only 32% considered 'song' as a mechanism for attracting mates (Figs. 3, 4). Values for WCI ran the full spectrum from 0 to 2, and decreases as a function of increasing number of structures (Fig. 5). For most students WCI was below 0.5 indicating low interconnection among structures.

References:

How the cricket lost its song, Part I. (2015, June 22). Retrieved June 06, 2016, from http://datanuggets.org/2015/06/how-the-cricket-lost-its-song/

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Discussion:

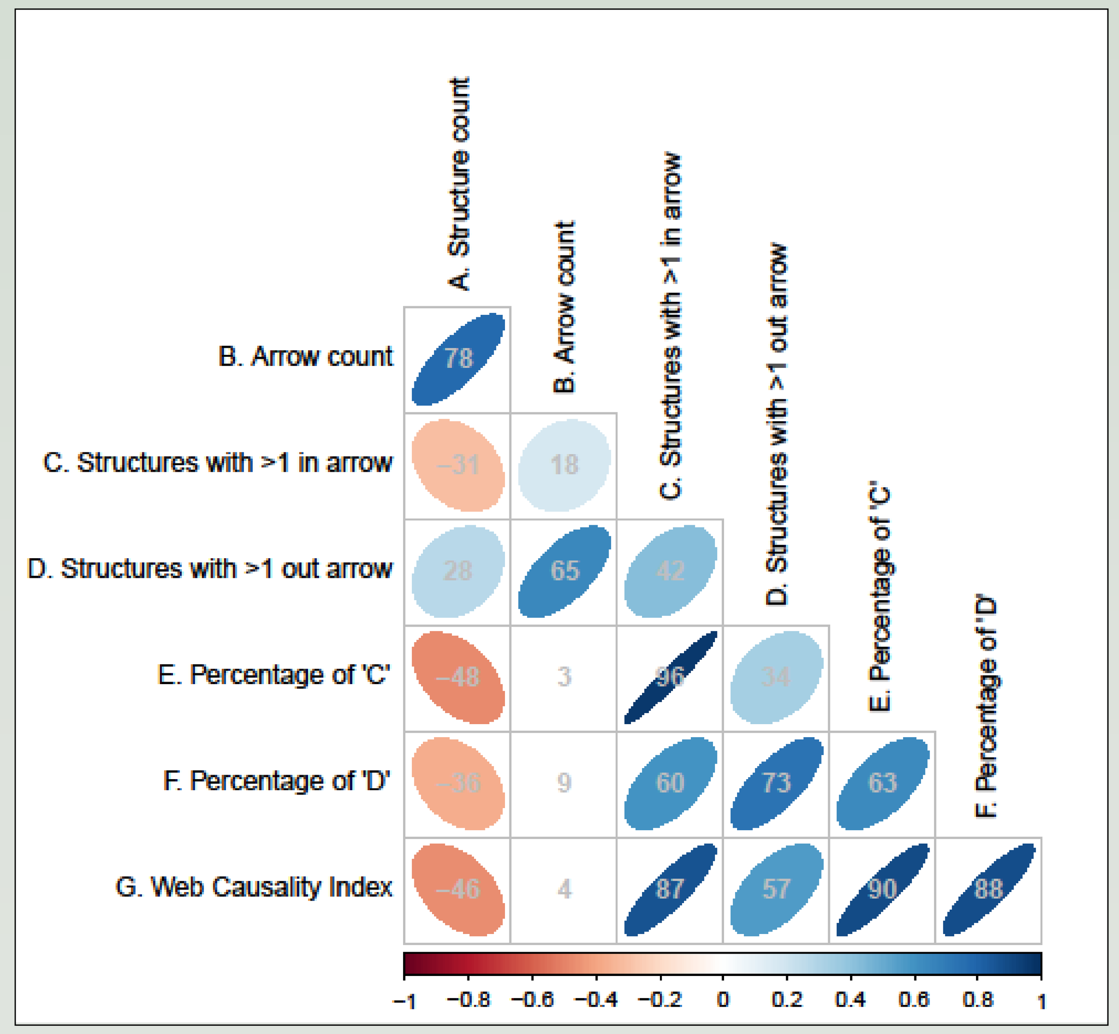
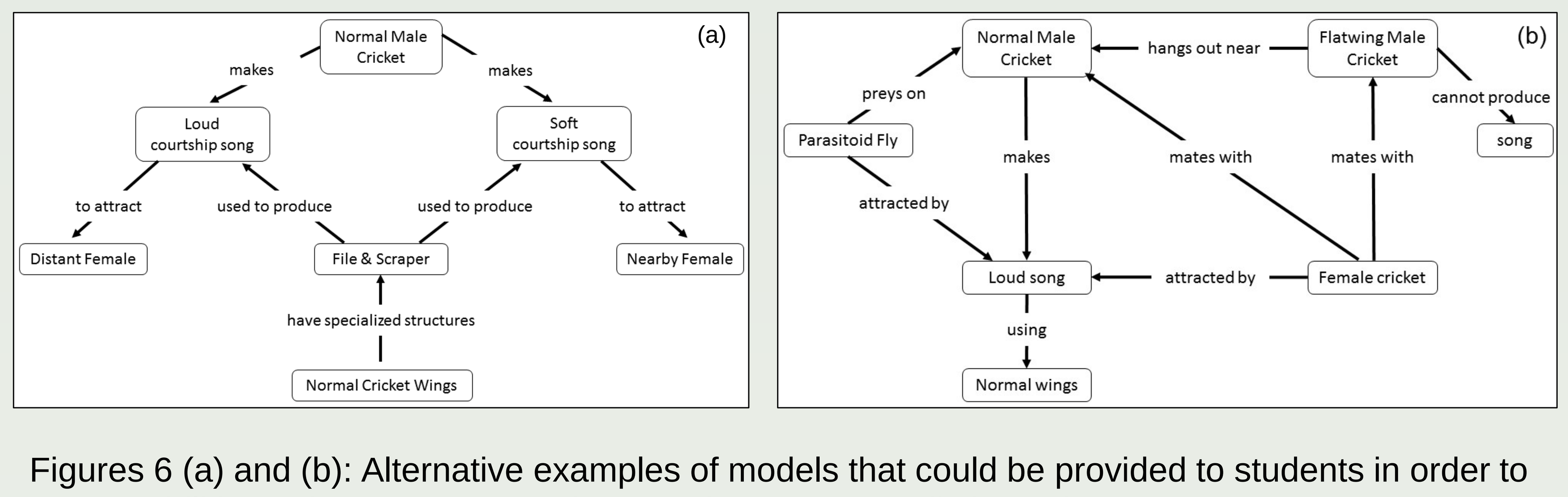


Figure 5: Correlation matrix among model components.

Models are foundational to biological science and should be represented in biology curricula. As instructional tools, models can help students visualize complex systems, develop and test hypotheses about system functions, and predict consequences of system perturbations. However, diversity among students' representations can pose challenges for instructors in terms of practical issues, such as scoring and feedback.

One strategy could be to ask students to interpret, analyse, and make predictions using quantitative data and the provided models (e.g., Figs. 6 (a) and (b)). Alternatively, students could be asked to construct models using provided structures, such that the assessment focus is on the relationships and mechanisms that describe the interrelationship among model structures.



Figures 6 (a) and (b): Alternative examples of models that could be provided to students in order to assess abilities to interpret, reason from, and generate predictions about systems.

Future analyses will compare relative advantages and disadvantages of having students construct vs. use provided models to reason about systems.

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