

HAWAIIAN FLIES: Song & Dance Success

We may think only humans are sexy, but tell that to a Hawaiian fly when he's wagging his bottom, whirring his wings, and trying his hardest to attract a mate. Like most animals, Hawaiian flies spend a lot of their energy engaged in the mating game. Their sex lives are hidden from us only because of their tiny size.

Fly sex is no secret to Ken Kaneshiro, a biologist at the University of Hawaii. With the aid of a microphone, a video camera, and a device that records sound vibrations, Ken studies the mating behavior of Hawaiian *Drosophila* (dro-SOFF-ih-lah), a group of flies found only on the Hawaiian Islands. These flies are related to *Drosophila* flies worldwide, including the flies that hover over ripe bananas in your fruit bowl. But Hawaiian *Drosophila* aren't ordinary flies. They're famous for having some of the most diverse and bizarre courtship behaviors in the world.

There's *Drosophila silvestris* (sil-VEST-ris), a flashy fly with spotted wings. To attract a female he performs a kind of solo tango, sliding back and forth and circling her in a series of intricate steps while vibrating muscles in his abdomen to serenade her with purring sounds. If he gets tired, she chases after him and hits him with her legs until he starts dancing and singing again. Then there's *Drosophila heteroneura* (heh-ter-OH-noora), a fly with a big head shaped like a double hammer. To impress a mate he uses his head to fight other males who enter the lek (an arena where males go to strut their stuff). And then there's *Drosophila glabriapex* (gla-BREAH-pex), a fly who romances his mate by rubbing his hairy legs on her abdomen.



This Hawaiian *Drosophila* (*Drosophila differens*) is perched on a decaying Clermontia shrub. Female *D. differens* flies lay their eggs on Clermontia branches. When the eggs hatch, the larvae feed on the shrub as they develop into adults.

Photo courtesy Kevin T. Kaneshiro

Ken Kaneshiro and other fly researchers have identified at least 800 species of *Drosophila* in Hawaii, each of them strikingly different. No other place in the world has so many diverse fly species in so small a space. And what is more astonishing, it probably started with just one pregnant fly that blew ashore several million years ago. Biologists call the explosive evolution of one or two species into hundreds “adaptive radiation.” The Hawaiian *Drosophila* are one of the world’s foremost examples. “What is it about the Hawaiian Islands,” Ken wonders, “that has contributed to so many species?”

To understand what is special about Hawaii, start by imagining the immense Pacific Ocean. Then imagine a small chain of volcanic islands in the middle of it, more than two thousand miles from the nearest continent. For a tiny fly to make it from North America or Asia all the way to one of these islands (long before ship or plane travel) is remarkable in itself. Ken and other scientists speculate that she was blown there by a storm several million years ago.

Hawaii is remote, but it is also a tropical paradise rich in diverse habitats. A fly that managed to survive the journey was a lucky fly. Her new surroundings offered opportunities she didn’t have back on the continent, where the environment was already crowded with competing insects and voracious predators. Hawaii is so isolated that only some kinds of organisms can make it there. The first fly and her small brood were safe from most competitors and predators. Some of her offspring thrived in the new environment and mated, and the tiny population built up.

Because of their size, *Drosophila* flies don’t usually travel far. They tend to live generation after generation in the same neighborhood. But a few flies from the first tiny population, or their descendants, traveled on hurricane winds to other islands, or to different habitats on the same island.

To a fly, even a tiny Hawaiian island has many small, isolated habitats, ranging in extremes from lush mountain forests to barren lava fields. Not all the flies that landed in these strange new habitats were able to survive and reproduce. Some of them had features or behaviors better suited to finding food or laying eggs in their new surroundings. These flies were more likely to survive and produce more offspring. The more suitable characteristics passed to the next generation, and gradually throughout the population. This process is called evolution through natural selection. Hawaiian *Drosophila* populations evolved unique adaptations to the different places they landed in. Today, for example, there are species of flies that hunt prey such as spider eggs, others that sip flower nectar, and still others that eat only rotten food. And there are different species that lay their eggs in rotting leaves, bark, fruit, and fungi.

But how did different fly populations become new species? Over thousands of generations, as the flies in isolated new habitats became more and more different from populations in older habitats, they eventually became unable to recognize or breed with the ancestral populations. They had evolved into a new species.

This is where fly sex comes into the picture. Having the ability to survive is only half the story. Mating is the other half. And attracting a mate is a big part of

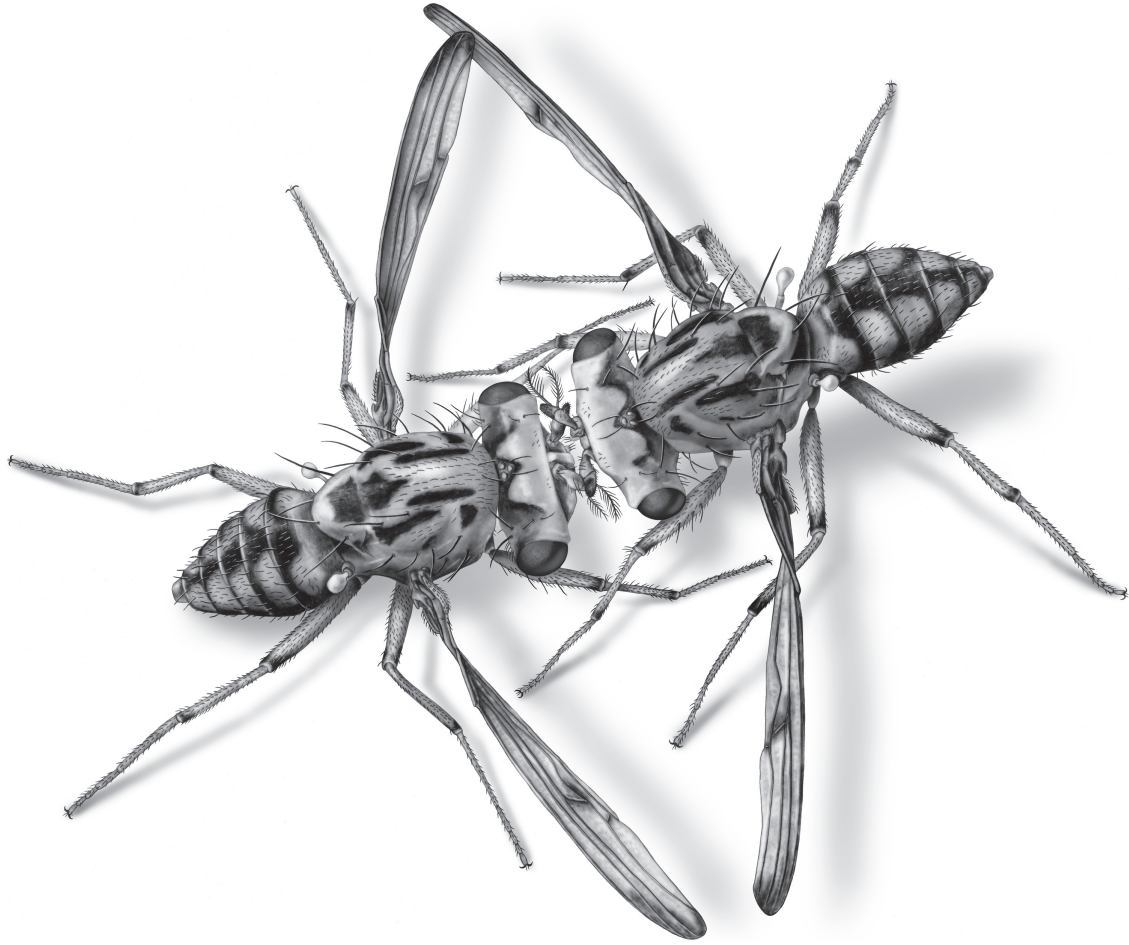
that story. Scientists call this principle of evolution sexual selection. Many organisms have characteristics and behaviors that serve no other purpose than to attract a mate. Male peacocks, for example, have large colorful tails that they display to catch the eye of females. The larger and more colorful the tail, the more likely the peacock is to mate and produce offspring. The offspring with the largest, most beautiful tails are also most likely to mate and reproduce, ensuring that future generations of peacocks evolve even larger and more colorful tails—at least up to a point. If a tail is too large and heavy it could be a hazard rather than an asset, making it difficult for the peacock to escape from predators and reducing his chances of surviving and reproducing.

Ken Kaneshiro and other researchers have observed the principle of sexual selection at work in Hawaiian *Drosophila*. Body features such as bold wing markings and the amount of hair on the legs, as well as behaviors such as intricate songs and dances, often lead to mating success. These sexual characteristics and behaviors are tightly controlled by genes, which means that “sexiness” is inherited. A female fly that is attracted to a hairy-legged male and mates with him will tend to have hairy-legged, and therefore sexy, sons. Like their hairy dad, the sexy sons will attract females that share



Ken Kaneshiro from the University of Hawaii studies the evolution of Hawaiian *Drosophila*. Ken smears rotten bananas on trees and shrubs to attract his research subjects.

Photo courtesy Robert Chin, University of Hawaii



Two male Hawaiian flies (*Drosophila heteroneura*) in the head-to-head posture of their territorial defense display.

UNSM Angie Fox illustration

their mother's tastes.

Ken studies sexual selection in Hawaiian *Drosophila* by tracking different species in the wild, trapping them with bait, and raising them in the lab. He takes males and females, puts them together in a mating chamber, and observes and records their behavior. He keeps track of which males and females will mate and pass on their genes.

Ken has discovered that in any population of flies, some males are great performers and some are lousy. He also observed two types of females—picky and passionate. The picky females only mated with a male if they recognized and liked his performance. The passionate ones would take any fly that came along, whether he performed well or not. Ken was one of the first fly researchers to study female mating

preferences and the difference their choosing makes to future generations of flies.

From his observations, Ken has developed a theory. He believes that female choosiness has driven the rapid evolution of fly species in Hawaii—and some very bizarre body shapes and courting behaviors. The picky females play an important role in sexual selection when fly populations are large and there are lots of males to choose from. But passionate females play an even more important role, especially in small populations when mate choice is slim. In those conditions picky females may not mate at all, and passionate females are likely to choose “whatever comes along,” including flies with bizarre new features and behaviors.

Although you may think flies are an unusual case, the evolution of elaborate sexual characteristics is really very common. Investigate the fascinating realm of sexual selection for yourself, and consider the effects of what happens when females call the shots. In this activity you’ll meet some interesting flies, learn how to sing their songs, and create a model to test the theory that passionate rather than picky females have the advantage in reproducing.

PART ONE

Meet the flies

You probably have already met a *Drosophila*. These little flies are the ones you find lazily buzzing around a fruit bowl especially when it is warm. You have probably never given them a second thought... other than “what are those weird little bugs doing on my bananas?” There are people, however, who spend most of their time thinking only about flies. *Drosophila* are perhaps the most studied of all animals. People know more about fly genetics and development than they know about humans. But why would anyone care about flies? Lots of reasons. Shuffle through the fly fact cards and find out.

Work with a partner

Each team will need:

- Fly Fact Cards 1–3 (cut, fold, and tape the 12 fly cards)
- paper
- tape or glue
- scissors

1 Fly Fact Cards: What Sort?

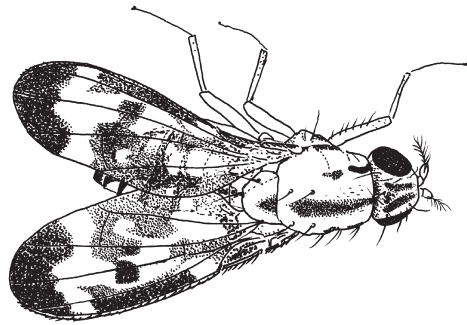
- a Cut the fly cards apart along the dotted lines so the text and the image are connected. Fold the cards along the center line. Tape or glue them closed so they make a two-sided card.
- b Sort the fly card pictures into groups or families in a way that makes sense to you. What feature or features did your group use to sort?
- c Share your sorting with the other groups. Did everyone sort the same?

2 Consider This

Read the fly facts on the other side of the cards (the facts don't necessarily match to the fly picture). Choose your favorite fly fact. Each person writes his or her fact as a question on a slip of paper. Wad the slip up and throw it into the middle of the table. Draw a question (one you didn't write). See if you can remember the answer.

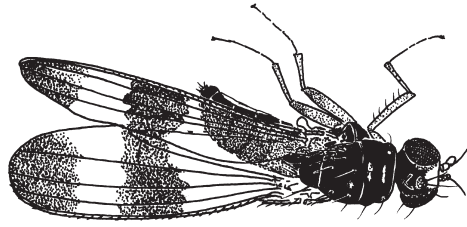
Fly Fact Cards 1

Cut on dashed lines, fold on solid line.



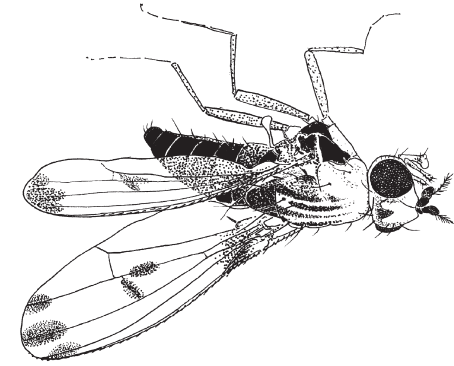
Drosophila bostrycha

Some Hawaiian *Drosophila* are called the "Birds of Paradise" of the insect world because of their spectacular courting displays.



Drosophila cilifemorata

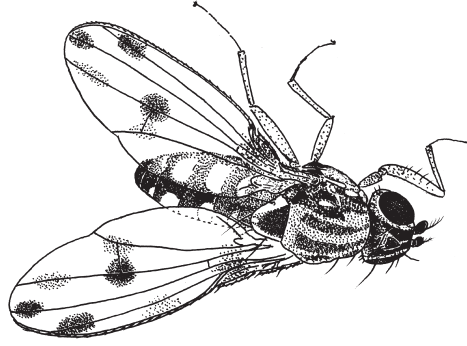
Tail wagging, big antennae, extra hairy legs, songs and dances are features that female Hawaiian *Drosophila* find sexy. Females of each species are attracted to only some features and not others.



Drosophila silvestris

Some Hawaiian flies "sing" with more than one body part. The male *Drosophila silvestris* creates a "purr" sound by vibrating his abdomen. He can also hum by vibrating his wings.

Some females prefer a male who sings while holding his head under her wings.



Drosophila fasciculisetae

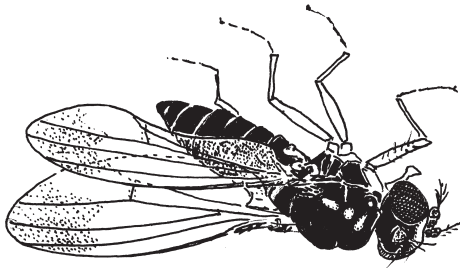
Some *Drosophila* are highly studied little animals. Their hardiness and talent for fast reproduction makes the fly, *Drosophila melanogaster*, a favorite lab animal for genetic scientists.

Many Hawaiian *Drosophila* are still mysterious creatures, yet to be studied and named.

Francisca C. do Val illustration.

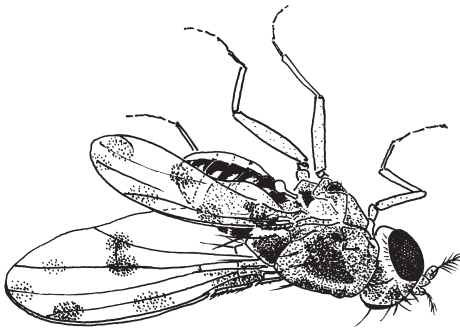
Fly Fact Cards 2

Cut on dashed lines, fold on solid line.



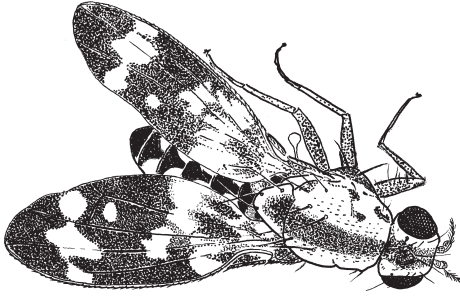
Drosophila fungiperda

There are over 800 species of *Drosophila* in Hawaii. Ninety percent of Hawaii's species are endemic (found nowhere else in the world).



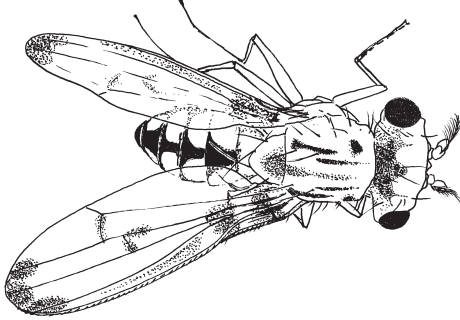
Drosophila glabripes

Drosophila are found all over the world. Hawaii is home to a quarter of the world's species in an area no bigger than the state of Connecticut.



Drosophila grimshawi

The Hawaiian islands are the world's most isolated landmass. Two thousand miles of ocean on all sides surround them. It is amazing for any insect to have arrived here.



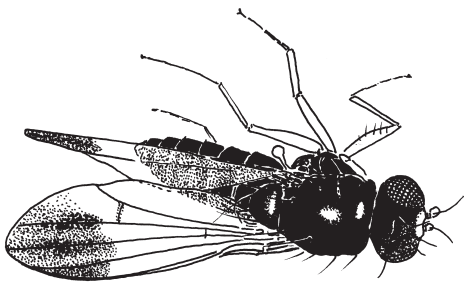
Drosophila heteroneura

The youngest Hawaiian island, the Big Island, is only half a million years old. The 26 species of picture winged *Drosophila* on the Big Island evolved within that time span.

Francisca C. do Val Illustration.

Cut on dashed lines, fold on solid line.

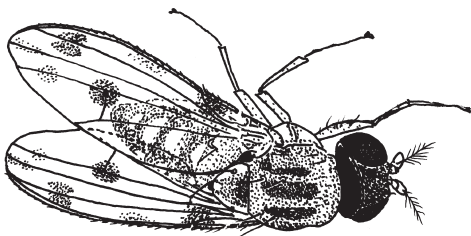
Fly Fact Cards 3



Drosophila longipedis

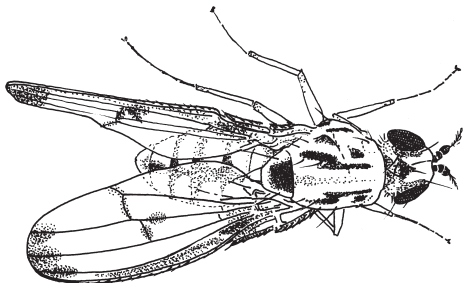
Many *Drosophila* have orange-brown bodies and measure from 1/16 to 1/8 inches in length. These flies have clear, unmarked wings.

Over 100 species of Hawaiian *Drosophila* are larger, up to 3/4 inches in length with bold black wing markings.



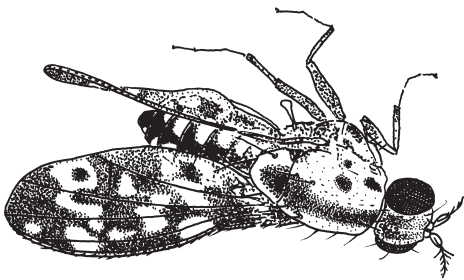
Drosophila pilimana

All Hawaiian *Drosophila* may be descended from a single pregnant female. Scientists think she may have blown ashore about eight million years ago.



Drosophila planitibia

Compared to *Drosophila* on the U.S. mainland, those on Hawaii have low reproductive rates. Some Hawaiian *Drosophila* species lay only a few eggs in their lifetime, while others may lay up to 200 eggs.



Drosophila crucigera

A male of one species of Hawaiian *Drosophila* sings and dances with a series of virtuosic steps, circling, gliding back and forth, whirring his wings, wagging his body.

A male may repeat a dance for an hour or more to please a female. If the male finally gives up, the female may rush after him and rear back, hitting him with her front legs. That makes him come back and start all over again.

Francisca C. do Val illustration.

PART TWO

Rate-a-mate

Simply surviving is only part of being successful. Getting your genes into the future population is also a necessary part of survival. Finding a receptive mate of your own species is key to reproductive success. In Hawaiian *Drosophila* signature songs and dances help males and females of the same species find each other. Female flies choose mates only when they recognize their species' special song and if they like the male's performance. In the fly world, it's ladies' choice.

Dr. Ken Kaneshiro and his team at the University of Hawaii have made a study of fly songs. This is not easy since the fly tunes are not really audible to human ears. A special microphone is placed close to a pair of courting flies to record the songs. The recordings are graphed as pulse patterns on an oscilloscope.

What have the researchers found? *Drosophila* males sing by fanning or vibrating their wings. The vibrations are very fast (measured in thousands of beats per second). If you were to listen you wouldn't call it music because there is no tune. It is more like pulses or beats. However, each pulse pattern is unique to a species of fly. How well a male scores in the mating game depends on what kind of pulses he puts out. Now it's your turn to investigate some fly songs.

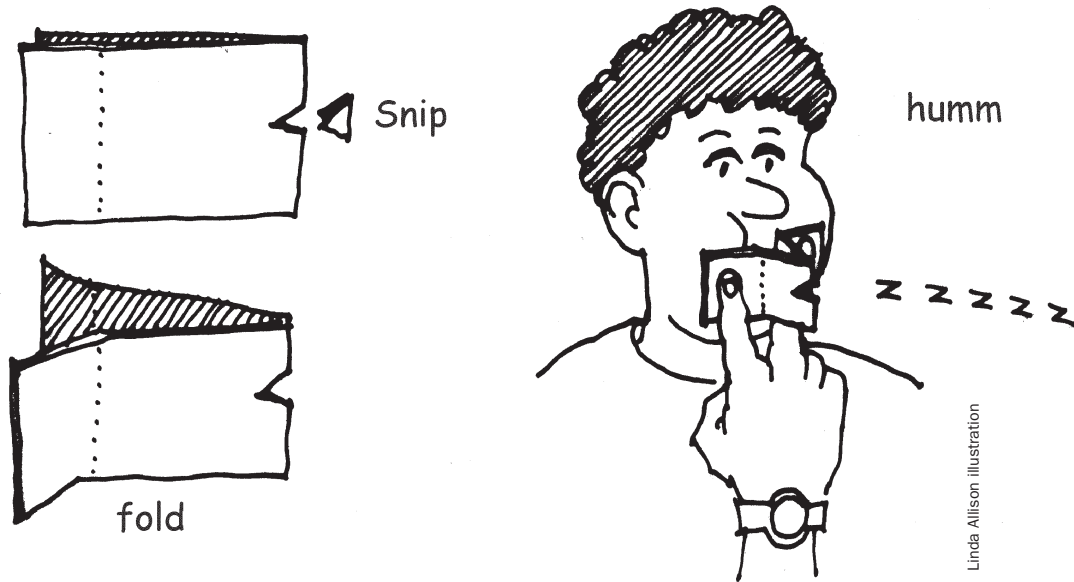
Divide the players into two groups. Each group should have the same number of players. One group will be female flies and the other will be male flies.

Each player will need:

- Fly Song Simulator
- Songs of Hawaiian *Drosophila* card, either a male or a female, depending on your group.
- chair
- scissors

1 Make a Fly Song Simulator

- a Cut the song simulator out along the dotted lines.
- b Fold it in half on the dotted line. Cut the diamond shape out of the center.
- c Fold the flaps back to make handles.




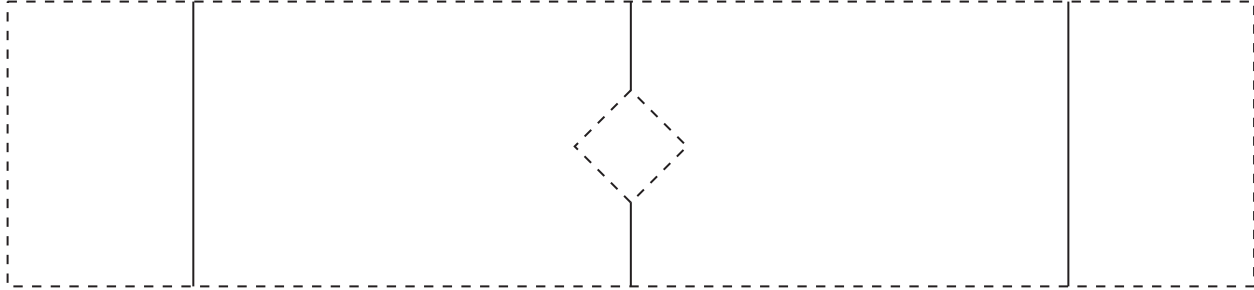
Linda Allison illustration


2 Make Your Simulator Sing

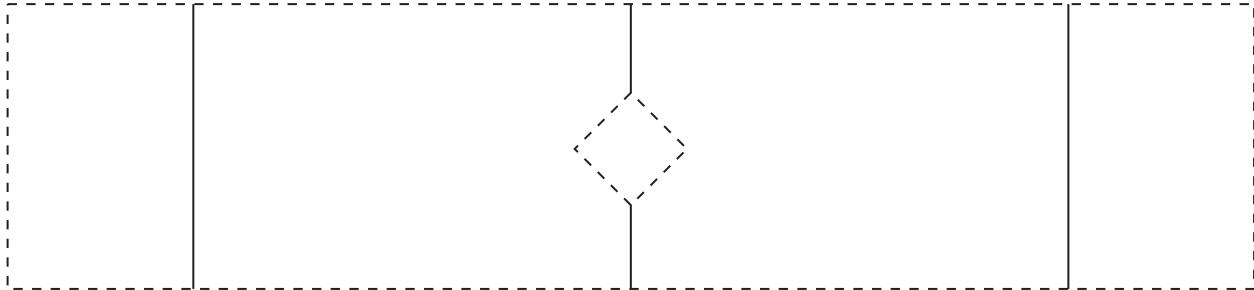
- a Hold the flaps between two fingers about 1/8 inch apart and press them to your lips. Blow through your mouth so that air blows out through the hole. The paper will vibrate. What does it sound like? (If this doesn't work, try blowing and humming a tone at the same time.)
- b Use your song simulator to play some of the songs from the Songs of Hawaiian *Drosophila* Cards.
 - Use one tone.
 - Vary the vibration or buzz by changing the loudness (tall lines) or softness (short lines). Try blowing harder and softer or pinching the flaps closer or farther. Experiment!
 - Vary the length of time that you hold a tone.


FLY SONG SIMULATORS

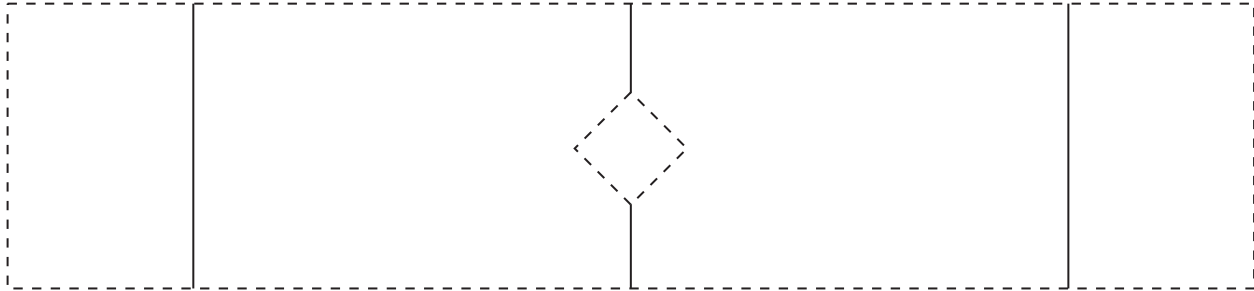
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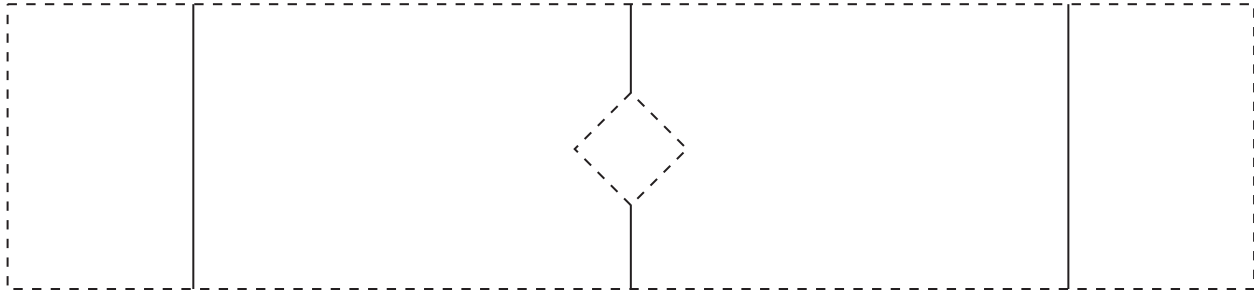
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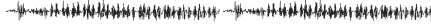
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Linda Allison








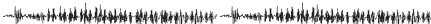
SONGS of HAWAIIAN DROSOPHILA - Female Cards

 Cut on dashed lines.

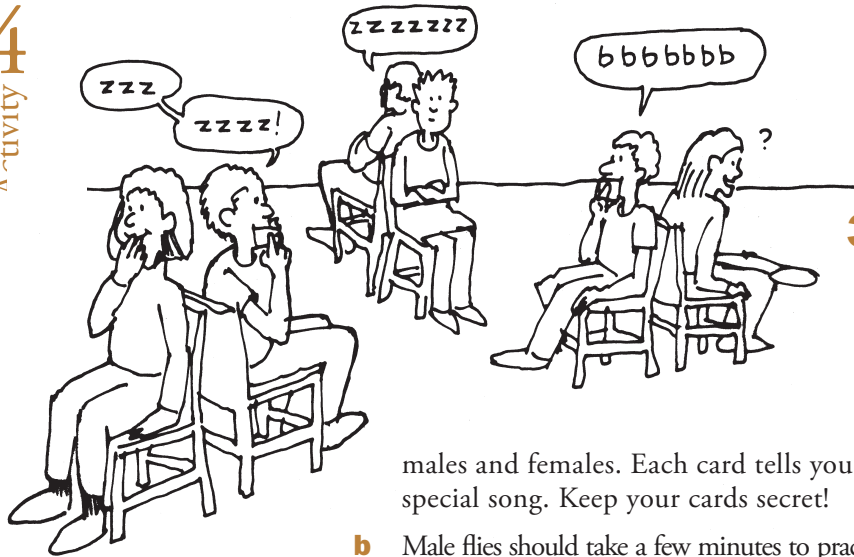
<p>Song of <i>Drosophila ingens</i></p> <p>one cycle: </p> <p>several cycles: </p>	<p>Song of <i>Drosophila silvestris</i></p> <p>one cycle: </p> <p>several cycles: </p>
<p>Song of <i>Drosophila neoperkinsi</i></p> <p>one cycle: </p> <p>several cycles: </p>	<p>Song of <i>Drosophila hemipeza</i></p> <p>one cycle: </p> <p>several cycles: </p>

SONGS of HAWAIIAN DROSOPHILA - Male Cards

 Cut on dashed lines.

<p>Song of <i>Drosophila ingens</i></p> <p>one cycle: </p> <p>several cycles: </p>	<p>Song of <i>Drosophila silvestris</i></p> <p>one cycle: </p> <p>several cycles: </p>
<p>Song of <i>Drosophila neoperkinsi</i></p> <p>one cycle: </p> <p>several cycles: </p>	<p>Song of <i>Drosophila hemipeza</i></p> <p>one cycle: </p> <p>several cycles: </p>

Courtesy Animal Behaviour 1994, 47, 1363-1374.



3 Play Rate-a-Mate

- a** Cut out the song cards. Create a deck of four male cards and four corresponding female cards. Pass out the cards to the

males and females. Each card tells you what kind of fly you are and your special song. Keep your cards secret!

- b** Male flies should take a few minutes to practice performing the song on their card using their simulators. Meanwhile female flies should be setting up pairs of chairs around the room; each pair should be back-to-back facing opposite directions.
- c** When you are ready to begin, each male fly picks one of the empty chairs in the pairs. This will be their “lek” or territory. Male flies defend their territories or leks from other males.
- d** Female flies migrate around the room and pick an empty chair next to a male fly. When she settles down, the male fly performs the song on his card. Be sure you are back-to-back and you can’t see each other’s cards, but you are close enough to hear the song.
- e** Male flies perform the song and the female fly listens. When she has heard enough, it is up to her to choose if she likes the performance, and if the song matches her species (the song on her card).
- f** Play enough rounds so all the players have a chance to pair up. If there is time you may want to switch roles and play another round. Make new simulators if someone new is going to use them.

4 Consider This

- a** Did you find a mate of your species?

If not, do you think failing to find a mate was because the females were too choosy? Or was it because the male songs were performed badly?

- b** Would you say that easy-to-please females or choosy females have a better chance of finding a mate?

Would you think that males that are poor performers or good performers have a better chance of finding a mate? Why?

PART THREE

Song-and-dance success

Do you think choosy female flies or non-choosy females are going to have better reproductive success over several generations? Experiment with a model of sexual selection and test your prediction.





Work with a partner

Each team will need:

- Fly Paper sheet
- Tracking Fly Population Chart
- scissors

1 Create a Population

Cut out all the squares on the fly paper. Clear a tabletop space. Sort the different flies into piles. Start by counting out a population of the following: three Picky Females, three Passionate Females, three Cool Males, three Klutz Males.

<p>Picky Females These choosy females mate only with cool males . . . good singers and dancers.</p> 	<p>Cool Males These males are good singers and dancers.</p> 
<p>Passionate Females These non-choosy females mate with any male.</p> 	<p>Klutz Males These males are poor singers and dancers.</p> 

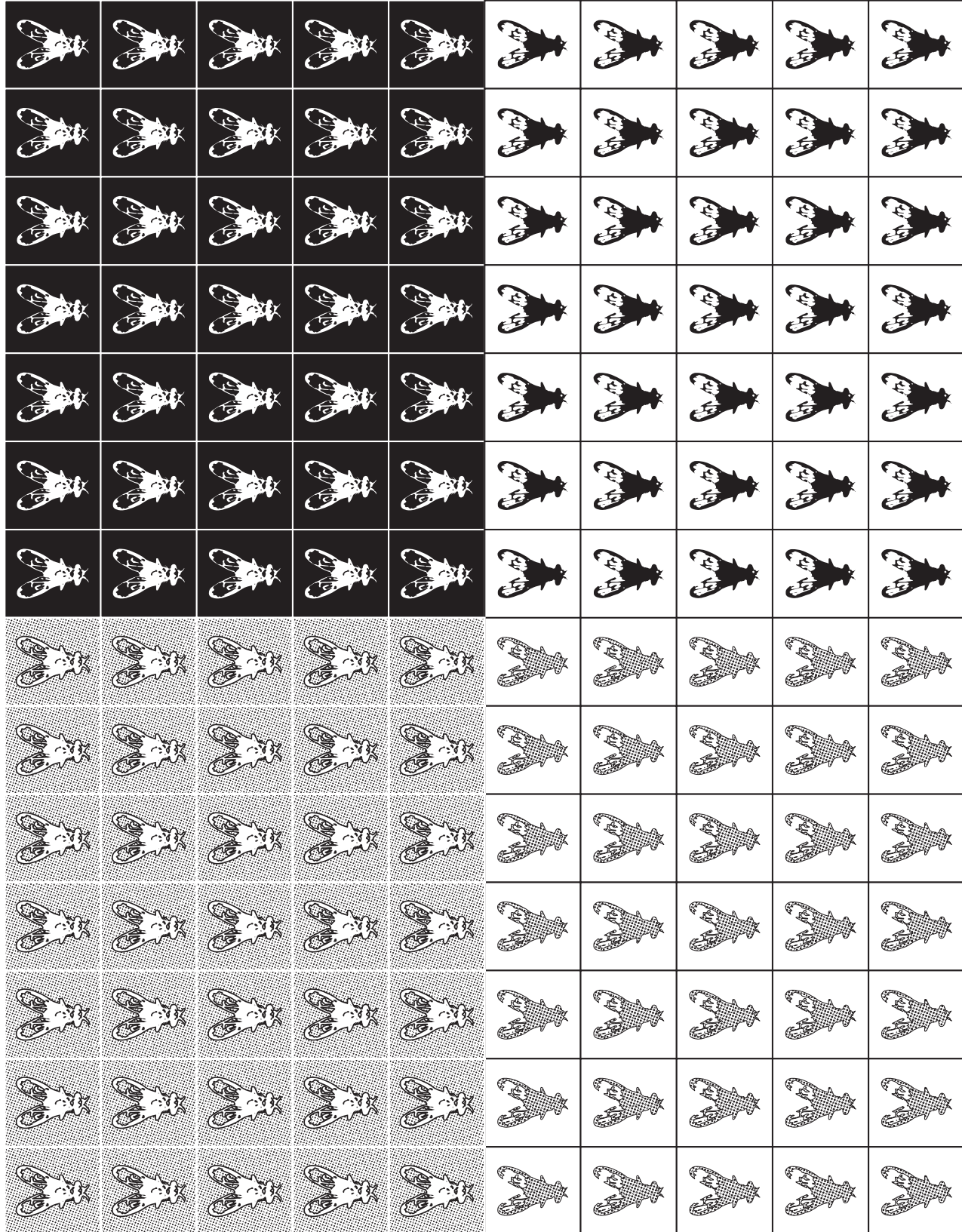
2 Make a Prediction

Picky or Passionate? Will Picky (choosy) or Passionate (non-choosy) females have better chances of mating?

FLY PAPER

COOL MALES: good singers and dancers

PICKY FEMALES: only mate with cool males



KLUTZ MALES: poor singers and dancers

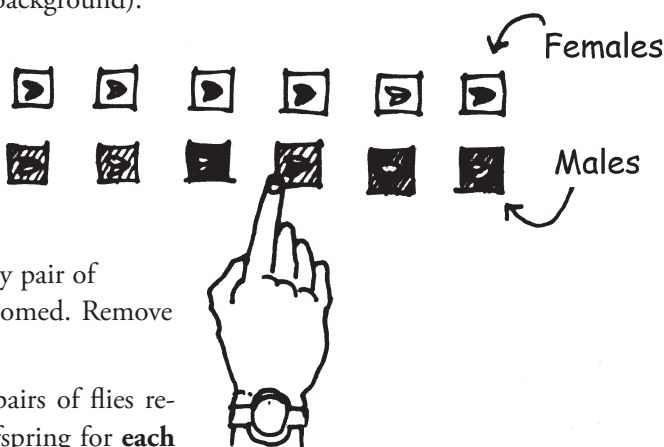
PASSIONATE FEMALES: mate with any male

Linda Allison illustration

3 Ready, Set, Experiment!

a Scramble: Line up the six female flies in a random order (Female flies are on a white background). Line up the six male flies at random, opposite the females (Male flies are on a toned background).

b Mate: Bring the two lines together to make pairs of males and females. In the real world, now is when the male flies begin their courtship songs and dances. Picky females will not mate with a male that can't sing or dance. Any pair of picky female and klutz male is doomed. Remove them both.







c Reproduce: All the remaining pairs of flies reproduce. To do this, add a like offspring for **each remaining fly**.

d Count: Tally the fly population by type. Record your findings on the Tracking Fly Population Chart.

e Repeat the mating cycle using only the remaining flies. Do this for generation 2, 3, and 4. Go through **all** the steps for each generation: Scramble, Mate, Reproduce, Count. After each mating, count the flies by type and record the results for each generation on the Tracking Fly Population Chart.



Tracking Fly Population Chart

FLY TYPE	Generation 1	Generation 2	Generation 3	Generation 4
PICKY FEMALE 	3			
PASSIONATE FEMALE 	3			
COOL MALE 	3			
KLUTZ MALE 	3			
TOTAL POPULATION (add all Males and Females)	12			

NOTE: Pairs of picky females & klutz males do not produce offspring.

4 Check It Out

- a Which male flies were the most successful reproducers in your experiment?

- b Which female flies were the most successful reproducers?

- b Check your results with another team. Did their results agree or disagree with yours?

5 Consider This

Based on your results, which males and which females are more likely to pass their genes into the future? How would this affect a fly population over time?

PART FOUR

Be a science reporter

Write a short news story about Hawaiian flies. Tell your readers about how eight million years ago, there were no *Drosophila* flies on Hawaii. Now there are more than 800 species found only on the islands. Based on what you have learned, explain how you think so many new species came to be on the islands.

P.S. Don't forget the headline.