Understanding Evolution

Quick evolution leads to quiet crickets

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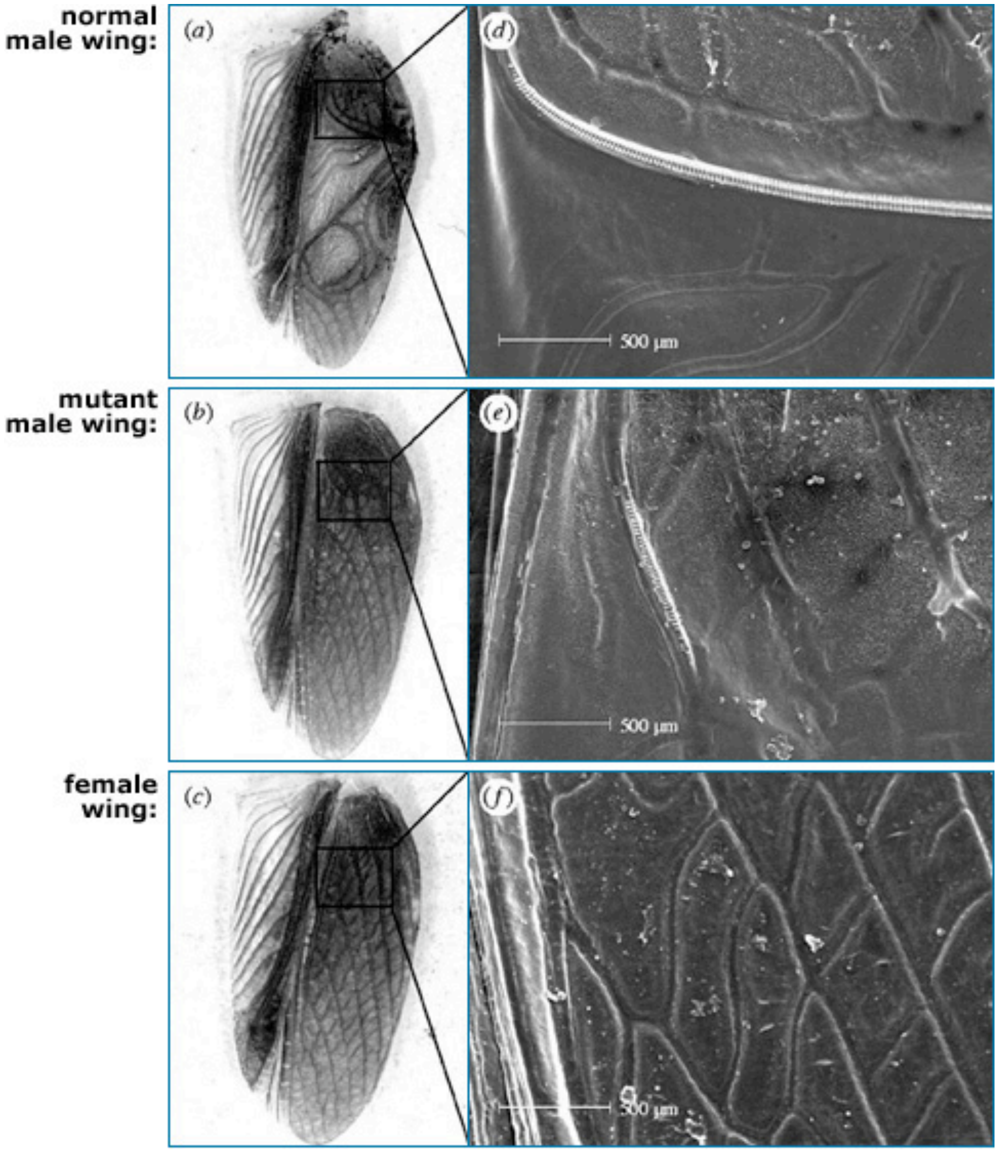
Attack of the flesh-eating parasitoid maggots!! Mutant mute crickets run rampant in tropical paradise!! The headlines may sound like a trailer for a cheap horror flick — but in fact, these sensationalist sound bites accurately describe the situation on the Hawaiian island of Kauai. The "flesh-eating parasitoid maggots" are the offspring of the fly, *Ormia ochracea*, which invaded Hawaii from North America, and the mutant crickets are the flies' would-be victims. The flies follow the chirps of a calling cricket and then deposit a smattering of wriggling maggots onto the cricket's back. The maggots burrow into the cricket, and emerge, much fatter, a week later — killing the cricket in the process. But this fall, biologists Marlene Zuk, John Rotenberry, and Robin Tinghitella announced a breakdown in business-as-usual in this gruesome interaction: in just a few years, the crickets of Kauai have evolved a strategy to avoid becoming a maggot's lunch — but the strategy comes at a cost...

On the left is a typical field cricket like those on Kauai, and on the right are the parasitic maggots of *Ormia ochracea* inside such a cricket.

Where's the evolution?

The evolution in this story hinges on what is probably a single mutation affecting wing shape in male crickets. Normal males have specially-equipped wings with a scraper and teeth that produce a chirp when rubbed together. Mutant males, on the other hand, have wings more like those of a female, without the noise-making features, turning them into something of an auditory cross-dresser: mutant males are silent like females and cannot chirp to attract a mate.



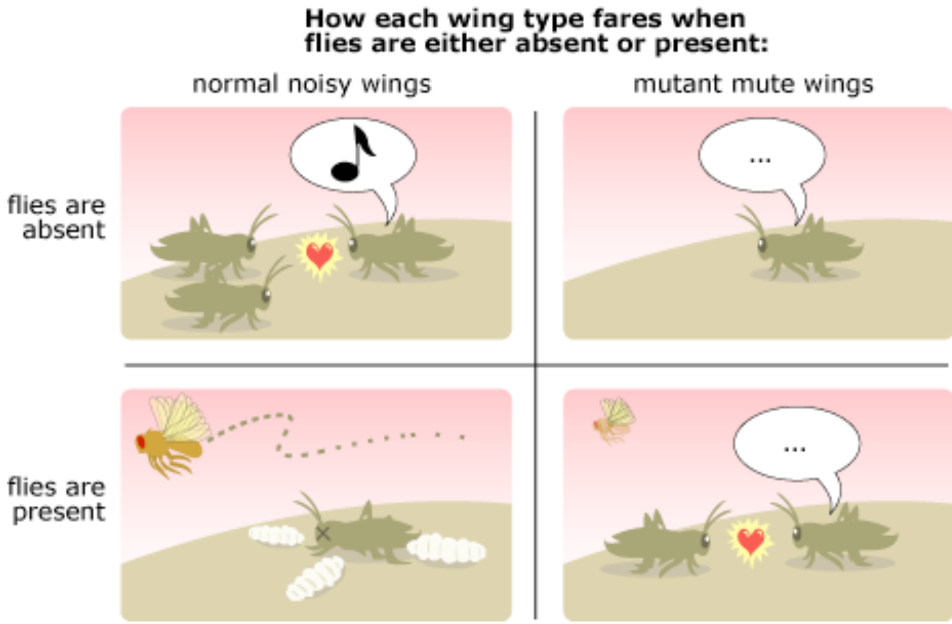
Undersides of the right forewings from normal male, mutant male, and female crickets. The corresponding SEM micrographs show the part of the wings where noise is generated. Normal male wings have a toothy vein that is scraped to make sound. In mutant males, that vein is smaller and repositioned. Females don't have this toothed vein at all.

Which is more advantageous for a male cricket: normal noisy wings or mutant mute wings? Well, it depends. As shown in the diagram below, on islands without the parasitic fly, noisy-winged crickets have the advantage since they can attract mates with their calls — unlike the mutant crickets. On those fly-free islands, we'd expect natural selection to favor the normal crickets and weed out the mutant silent crickets — who would be less attractive to females, would get fewer chances to mate, and hence would leave behind fewer offspring. However, on fly-infested islands, mutants have the advantage; calling males get attacked by flies and eaten by maggots, while the

Mutation on the X chromosome

Based on mating experiments, the cricket wing mutation appears to be sex-linked. In humans, sex is determined by the X and Y chromosomes: XX individuals are female and XY individuals are male. However, crickets have no Y chromosomes: XX crickets are female and crickets with a single X (X- individuals) are male. The mutant wing gene is located on the cricket's X chromosome, represented by the symbol X_m. All females silent males evade the flies and survive to mate another day. In that situation, natural selection favors the mutant crickets — though some calling males are likely to remain in the population because of their strong advantage when it comes to attracting a mate, as is the case on Kauai.

(XX, XX_m, and X_mX_m) have the normal mute female wings, X- males have the normal noisy male wings, but X_m- males have the mutant mute wings.



The island of Kauai is testimony to how quickly natural selection can operate under the right conditions. Between 1991 (when they started monitoring the situation on Kauai) and 2001, Marlene Zuk and her colleagues documented major declines in the island's cricket population. The crickets seemed to be no match for the parasitic flies. In one study, 30% of calling males were infested with the parasite, and in 2001, the island was virtually silent: the team heard only one cricket call! Such intense parasitism represents strong selective pressure favoring any genetic change that helps the crickets evade the flies. And in 2003, the team discovered the result of that selection: the cricket population had bounced back! The island was again crawling with crickets — but of the silent sort. When the team investigated further, they discovered the wing mutation. Between the late 1990s and 2003, in just 20 or so cricket generations, Kauai's cricket population had evolved into an almost entirely silent one!

So is that it? Problem solved by evolutionary ingenuity? Well, not quite... Natural selection is not a magic bullet; it simply selects the variants that work at a given time, in a particular environment, from what's available in the population. Silent wings may be the key to avoiding parasitic flies — but they are also a serious liability when it comes to the local singles scene, since females locate mates by following their chirps. Currently, mutant mute males are dealing with their dating woes by hanging out near their literal "wingmen" — the few calling males remaining in the population. Female crickets are attracted to these callers but may get distracted by a mutant mute male *en route*.

A silent male that intercepts a female has made it over one hurdle, but even then, his mute wings are a major handicap in terms of reproductive success. Typically, a male cricket that has attracted a female would then perform a courtship song to seal the deal, but mutant males have no voice for that sweet-talking. For most female crickets, the lack of a courtship song would be a serious turn-off. However, Kauai's females seem to be a bit less choosy and are willing to accept a silent male as a mate. Marlene Zuk and colleagues hypothesize that the Kauai population has evolved to be less choosy than other populations because of the high frequency of mute males on that island.

So far, the mute males' bait-and-switch strategy for finding a mate seems to be working — after all, the frequency of the mutation has skyrocketed, and all those males carrying the mutation must have been fathered by mute males who had some mating success. Will this strategy succeed in the long run? It's hard to say. The mute wings mutation is a trade-off — a brokered deal between selection for survival (avoiding parasitism) and sexual selection (attracting a mate). At the moment, because of the intensity of parasitism, selection for survival seems to have gained the upper hand, increasing the frequency of the mute wings mutation. But as calling males become rarer, calling might become more valuable in terms of reproductive success, shifting the balance of power towards sexual selection and increasing the frequency of normal wings in the population. Or because of the difficulty of locating their now nearly silent hosts, the fly population could crash, again changing the way that natural selection acts on the crickets. But whatever the ultimate fate of the Kauaian cricket population, their potential for rapid evolution is well-documented. These crickets have undergone major evolution in the past few years, and we should expect further evolutionary changes in their future.

Read more about it

News and journal articles:

- A complete description of the research from the UC Riverside newsroom
- A kid-friendly article on the topic from *Science News for Kids*
- *National Geographic*'s summary of the discovery

Understanding Evolution resources:

- A brief review of sexual selection
- Clarification of common misunderstandings related to natural selection, including the misconception that natural selection is a magic bullet, which provides organisms with exactly what they need
- An advanced tutorial on DNA and mutations

For teachers

Discussion and extension questions:

- In what situations would you expect the silent wing mutation to be favored by natural selection? In what situations would you expect the normal wing version to be favored by natural selection? List at least two ideas for each.
- Read the comic strip Survival of the Sneakiest, which discusses the concept of evolutionary fitness. Explain what fitness means in terms of the Kauai crickets. What traits contribute to fitness in these crickets?
- Read about the concept of sexual selection. How has sexual selection affected male crickets on Kauai? How might sexual selection have affected female crickets on Kauai?
- This news brief describes traits which have been affected by sexual selection. Research and describe traits in other three other organisms that have been affected by sexual selection.
- Imagine that the parasitic fly goes completely extinct on the island of Kauai. Over the next five years how would you expect the cricket population on Kauai to evolve? Explain your reasoning.

Related lessons and teaching resources:

- Teach about sexual selection and fitness: This comic strip for grades 6-12 follows the efforts of a male cricket as he tries to attract a mate, and in the process, debunks common myths about what it means to be evolutionarily "fit."
- Teach about how natural selection acts on mutations: In this classroom activity for grades 9-12, students build, evolve, and modify paper-and-straw "birds" to simulate natural selection acting on random mutations.

References

- Mesa, A., Garcia-Novo, P., and dos Santos, D. (2002). X_1X_20(male) - $X_1X_1X_2X_2$ (female) chromosomal sex determining mechanism in the cricket *Cicloptyloides americanus* (Orthoptera, Grylloidea, Mogoplistidae). *Journal of Orthoptera Research*. 11: 97-90.
- Zuk, M., Rotenberry, J. T., and Tinghitella, R. M. (2006). Silent night: adaptive disappearance of a sexual signal in a parasitized population of field crickets. *Biology Letters*. DOI:10.1098/rsbl.2006.0539

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Cricket photo provided by Cook Islands Biodiversity & Natural Heritage; parasitized cricket photo provided by UC Riverside; the cricket wing images are provided by The Royal Society, Marlene Zuk, John Rotenberry, and Robin Tinghitella, from the *Biology Letters* paper referenced above