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| find this information, links and an explanatory video: <http://evolution.berkeley.edu/evolibrary/news/100901_bedbugs>   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | |  | | --- | |  | | [en Espanol](http://evolution.berkeley.edu/evolibrary/news/100901_bedbugs_sp) [en Español](http://evolution.berkeley.edu/evolibrary/news/100901_bedbugs_sp)     [print](http://evolution.berkeley.edu/evolibrary/print/printable_template.php?article_id=100901_bedbugs&context=) [print](http://evolution.berkeley.edu/evolibrary/print/printable_template.php?article_id=100901_bedbugs&context=) |   [Resource library](http://evolution.berkeley.edu/evolibrary/resourcelibrary.php) : [Evo in the news](http://evolution.berkeley.edu/evolibrary/news/newsarchive_01) :  **Bed bugs bite back thanks to evolution** *September 2010*   |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | |  |  | | --- | --- | | bedbug | http://evolution.berkeley.edu/evolibrary/images/dot_clear.gif | | http://evolution.berkeley.edu/evolibrary/images/dot_clear.gif | | | *Cimex lectularius*, the bed bug | http://evolution.berkeley.edu/evolibrary/images/dot_clear.gif | | http://evolution.berkeley.edu/evolibrary/images/dot_clear.gif | |   Bed bugs might sound like an old-fashioned problem, but now they are back — and with a vengeance. Fifty years ago, the blood-sucking pests were nearly eradicated in the United States thanks in part to the use of pesticides like DDT. Today, they are creeping over sheets — and tormenting hapless sleepers — across the country. New York was recently declared America's most bed-bug-infested city: Times Square movie theatre, the Empire State Building, and the offices of a major fashion magazine — not to mention the homes of 11,000 New Yorkers who filed official complaints about the vermin last year — have all housed these itchiest of bedfellows. And the Big Apple is not alone in its disturbed slumber. This summer, the Centers for Disease Control and Prevention (CDC) and the Environmental Protection Agency (EPA) issued a joint statement on the resurgence of bed bugs throughout the country. Wherever you live — whether that's Los Angeles or Louisville — bed bugs may soon be coming to a mattress near you! |   **Where's the evolution?** What's to be done if you wind up the unhappy bunkmate to a nest of these pests? In the past, the answer was simply to spray with a pesticide. Unfortunately, that response is less effective than it used to be — not because the pesticides used today are weak — but because bed bugs have [evolved](http://evolution.berkeley.edu/evolibrary/glossary/glossary_popup.php?word=evolution" \t "gpop)resistance to the most commonly used chemicals. The top choice for bed bug infestations are two related groups of chemicals that are both toxic and repellent to the bugs: pyrethrins, which are extracted from chrysanthemum plants, and pyrethroids, the synthetic versions of those chemicals. The evolution of pyrethrin in plants in the first place probably resulted from [natural selection](http://evolution.berkeley.edu/evolibrary/glossary/glossary_popup.php?word=natural+selection) for plants better able to avoid being eaten by insects. We humans have simply co-opted the plants' chemicals defenses to deal with our own insect problems. Pyrethrins and pyrethroids are especially useful to us because they generally have a stronger effect on bugs than on mammals, making them relatively safe for use in homes.  These compounds work by attacking the nervous system. Insects (and humans) have tiny pores in the membranes of their nerve cells that can be opened to allow sodium into the cells, triggering a nerve impulse. Pyrethrins and pyrethroids muck up the nervous system by binding to the sodium pores, locking them in the open position. This allows sodium to pour into the cell continuously, causing the nerve to fire repeatedly and eventually leading to paralysis. Mammals and insects inherited similar nerve cells from our [common ancestor](http://evolution.berkeley.edu/evolibrary/glossary/glossary_popup.php?word=common+ancestor) — meaning that the human nervous system is also vulnerable to these pesticides. However, the compounds are relatively safe for us because, in comparison to insects, our bodies have more effective ways to break the compounds down before they can do major damage.  So, how do resistant bed bugs survive pyrethroid spraying? Biologists have actually figured out exactly which [mutations](http://evolution.berkeley.edu/evolibrary/glossary/glossary_popup.php?word=mutation) are responsible for many cases of resistance. For example, changing just two of the 2000 [amino acids](http://evolution.berkeley.edu/evolibrary/glossary/glossary_popup.php?word=amino+acid) that make up part of the sodium pore is enough to make an insect 250 times more resistant to a commonly used pyrethroid. These mutations may change the pore so that the insecticide can no longer bind to it effectively and/or may change the way the pore responds when the insecticide binds.   |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | http://evolution.berkeley.edu/evolibrary/images/dot_clear.gif | |  |  |  | | --- | --- | --- | | http://evolution.berkeley.edu/evolibrary/images/dot_clear.gif | | | | http://evolution.berkeley.edu/evolibrary/images/dot_clear.gif | | | | NESCent | http://evolution.berkeley.edu/evolibrary/images/dot_clear.gif | Video podcast provided by the National Evolutionary Synthesis Center (NESCent). To learn more, visit the[NESCent website](http://www.nescent.org/news/evo_news_podcasts.php). | | http://evolution.berkeley.edu/evolibrary/images/dot_clear.gif | | | | | http://evolution.berkeley.edu/evolibrary/images/dot_clear.gif | |   Such mutations arise [randomly](http://evolution.berkeley.edu/evolibrary/glossary/glossary_popup.php?word=random) and are favored when a [population](http://evolution.berkeley.edu/evolibrary/glossary/glossary_popup.php?word=population) of organisms winds up in an environment in which the mutations happen to be useful — in this case a bed sprayed with a pyrethroid. In that situation, if some (or even just one) of the insects carry the resistance mutations, those insects will be better able to survive and reproduce and will wind up passing the mutation on to their offspring. As this process continues through several generations, the population may evolve such that every individual carries the resistance mutations — an outcome which is great for the bugs but immensely frustrating for the human occupants of the bed!  The key to this process of natural selection is having the right [genetic variation](http://evolution.berkeley.edu/evolibrary/glossary/glossary_popup.php?word=genetic+variation) in the insect population. If the population doesn't happen to carry any of the advantageous resistance mutations, the pyrethroid treatment will wipe out the bed bug population. It might seem then, that resistant populations should be rare — after all, how many bed bug populations are likely to be lucky enough to carry just the right mutations to survive pyrethroid spraying? A lot, it turns out. Here's why. Bed bug populations have been primed with the right sort of genetic variation by their evolutionary history — a history which includes extensive exposure to a different insecticide, DDT. Like pyrethroids, DDT kills insects by acting on the sodium pores in their nerve cells — and it just so happens that many of the same mutations that protect an insect against DDT also happen to protect it from pyrethroids. When DDT was first introduced, such mutations were probably extremely rare. However, with the widespread use of DDT in the 1950s and 60s, such mutations became much more common among bed bugs through the process of natural selection. Though DDT is rarely used today because of its environmental effects, these mutations have stuck around and are still present in modern bed bug populations. Because of the action of natural selection in the past (favoring resistance to DDT), many bed bug populations today are primed with the right sort of genetic variation to evolve resistance to pyrethroids rapidly.  And evolve rapidly they have! In the last decade, resistance to pyrethroids among bed bugs has become a major problem in the U.S. and may help explain why the pests are crawling into bed next to more and more of us. The map below shows how prevalent just two of the mutations conferring resistance have become. The pace at which widespread resistance has evolved suggests that relying on chemicals alone to control bed bug infestations is not enough — and may even encourage the evolution of more resistant populations. Instead, the CDC and the EPA recommend a more integrated approach, one that incorporates pesticides, along with other techniques to which resistance is unlikely to evolve: heat treatment (temperatures between 113 and 120°F can kill the bugs), vacuuming, removing clutter, and sealing cracks and crevices. The rapid evolution of insecticide resistance in these pests has made it harder — but not impossible — to kick them out of bed for good!  Distribution of resistance mutations in bed bug populations  **Read more about it**  Primary literature:   * Yoon, K. S., Kwon, D. H., Strycharz, J. P., Hollingsworth, C. S., Lee, S. H., and Clark, J. M. (2008). Biochemical and molecular analysis of deltamethrin resistance in the common bed bug (Hemiptera: Cimicidae). *Journal of Medical Entomology*. 45: 1092-1101. [read it](http://www.bioone.org/doi/pdf/10.1603/0022-2585(2008)45%5b1092:BAMAOD%5d2.0.CO;2) * Zhu, F., Wigginton, J., Romero, A., Moore, A., Ferguson, K., Palli, R. ... Palli, S. R. (2010). Widespread distribution of knockdown resistance mutations in the bed bug, *Cimex lectularius* (Hemiptera: Cimicidae), populations in the United States. *Archives of Insect Biochemistry and Physiology*. 73: 245-257. [read it](http://onlinelibrary.wiley.com/doi/10.1002/arch.20355/abstract)   News articles:   * [A report on the bed bug resurgence](http://www.pittsburghlive.com/x/pittsburghtrib/news/s_697060.html) from *The Pittsburgh Tribune-Review* * [An evolutionary perspective on bed bug resistance](http://nymag.com/daily/intel/2010/08/in_1913_the_department_of.html) from *New York Magazine Services* * [An official statement on the bed bug resurgence](http://www.cdc.gov/nceh/ehs/publications/Bed_Bugs_CDC-EPA_Statement.htm) from the CDC   Understanding Evolution resources:   * [A tutorial on the process of natural selection](http://evolution.berkeley.edu/evolibrary/article/evo_25) * [A review of the role of genetic variation in evolution](http://evolution.berkeley.edu/evolibrary/article/4_0_0/evo_17) * [An advanced tutorial on DNA and mutations](http://evolution.berkeley.edu/evolibrary/article/mutations_01)   **Discussion and extension questions**   1. [Review some background information on natural selection.](http://evolution.berkeley.edu/evolibrary/article/evo_25) Explain how a mutation causing resistance to pyrethroids would spread through a population of bed bugs that are being treated with the pesticide. Make sure to include the concepts of variation, selection, and inheritance in your explanation. 2. Which of the steps described in the item above (variation, selection, and/or inheritance) are affected by the prior exposure of bed bug populations to DDT? How are those steps or step affected? 3. If bed bugs had never been exposed to DDT in the 1950s and 1960s, how would you expect that to affect bed bugs' evolution of resistance to pyrethroids in the last decade? Would it affect the rate of this evolution, the timing of this evolution, and/or the geographic origins of this evolutionary process? Explain your reasoning. 4. [Read this article about the evolution of malaria strains that are resistant to our drugs.](http://evolution.berkeley.edu/evolibrary/news/091201_malaria) That article describes how medical professionals are using "combination therapies" to slow the evolution of resistance in malaria. Apply the same reasoning to the case of the bed bug resurgence. Describe what a combination therapy approach to tackling the bed bug problem might be like. What are the pros and cons of such an approach? 5. [Read this brief article on bed bugs](http://www.popsci.com/scitech/article/2009-01/don%E2%80%99t-let-bedbugs-bite) from *Popular Science*. The article concludes with the recommendation that we stockpile insecticides to deal with the bed bug resurgence. What do you think of this advice? If that advice were put into practice, how would it likely affect the evolution of resistance among bed bugs? Explain your reasoning. 6. [Read this brief article on bed bugs](http://www.physorg.com/news150651765.html) from Physorg. The article says that "resistance means mutations are acquired over time by selection with pyrethroids." Is this an accurate way to describe the evolution of resistance? Explain your reasoning, and be sure to address whether or not selection causes mutations to be acquired. | |