

# Rad Roaches

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Nuclear weapons and missile defense systems have been in the news of late, as the Bush administration struggles to shepherd the enormous U.S. arsenal of weapons: >5,400 warheads on intercontinental ballistic missiles, 1,750 cruise missiles and nuclear bombs capable of being fired from bomber planes, almost 1,700 tactical nuclear weapons and about 10,000 nuclear warheads ensconced in bunkers around the country. Such firepower has profound and troubling implications for insects—namely, has escalation in the arms race produced enough atomic weaponry that if a nuclear war were to break out, a cockroach maybe couldn't survive?

It's one of those entomological truisms, a fact that everyone who knows nothing else about insects can recite, that "If there's a nuclear war, cockroaches will be the only survivors." Cultural references to the radiation-resistance and durability of cockroaches abound. According to an interview with band member Coby Dick, the metal/punk group Papa Roach picked the name because "a cockroach can survive anything: earthquake, nuclear holocaust. They come in small numbers, and then they infest. We want to infest the world" (S. Quelland 1999, <http://www.metroactive.com/papers/metro/10.07.99/paparoach-9940.html>). When officials in New Zealand wanted to alert the public about Y2K preparedness, they chose as their symbol a cockroach because its ability to survive any kind of disaster, including a nuclear one, is so well known (<http://www.jsonline.com/news/intl/ap/jul99/ap-new-zealand-mil072299.asp>). There's even a website advertising a "giant deluxe cockroach," a five-inch rubber roach, "which like most cockroaches could probably survive a nuclear war" (<http://www.insectarium.com/NewCatalog/toys/09525.htm>). So, people can take comfort in the thought that the fortunate few human survivors of a nuclear Armageddon can play post-Apocalyptic practical jokes on one another.



Harry left you?  
Never mind that honey.

We survived the ice age, the H-bomb, DDT!  
Believe me, you'll survive what's his face!

It's not easy to figure out where this idea of cockroach radiation resilience originated. It doesn't seem to have been the result of an empirical test. Atomic bomb blasts have been (mercifully) few and far between and, after an exhaustive search, I couldn't find any obvious references to postblast investigators noting the presence of unperturbed roaches at ground zero. There are, though, dozens of references on the Internet and elsewhere to the solitary ginkgo tree that apparently remained standing after the bomb blast in Hiroshima; vendors of herbal medicines unfailingly mention that fact when touting the virtues of ginkgo in maintaining mental acuity, preventing asthma attacks, speeding poststroke recovery, and increasing blood flow to the penis (e.g., <http://www.nutraceutical.com/educate/pdf/ginkgo.pdf>).

So, most likely, the idea that cockroaches would be the sole survivors of a nuclear holocaust must have come from laboratory studies on radiation resistance. But what laboratory data exist aren't exactly consistent with cockroach supremacy. Among other things, cockroaches are relative newcomers to the ranks of the radiation-resistant. Probably the first study done to deter-

mine the effects of radiation on insects dates back to 1919 when W. P. Davey tested the effects of small doses of X-rays on the longevity of *Tribolium confusum*; surprisingly, Davey found that chronic exposure to X-rays at a dose of about 60 rads actually prolonged the life of this flour beetle. This finding evidently languished in the literature for about 37 years until a dubious J. M. Cork (1957) repeated the study under more controlled conditions and to his dismay obtained essentially the same result (concluding his paper with the remark, "It is hoped that the results reported on a simple structure of this kind will not be construed as a license for X-ray practitioners to become less critical of recognized safety factors in dealing with the human organism").

Perhaps the most widely cited study documenting effects of radiation on insects was H. J. Muller's (1927) demonstration of artificial transmutation of genes in *Drosophila melanogaster*; Muller essentially was the first person to induce mutations, an accomplishment that revolutionized the science of genetics. Hanson and Heys (1928) heralded the accomplishment as "one of the most notable events in the field of pure biology in this century" and extolled the virtues of the new mutagenic agent; "on one Sunday afternoon, 40 mutations were found. Prior to the use of the X-ray, if one mutation were found in 40 Sunday afternoons the time would have been considered well spent." Exposure to X-rays, radium, and other sources of radiation thus replaced the multifarious harmful agents that had been tested and found wanting as mutagens, including, among others, continuous and intermittent rotation, very high temperatures, very low temperatures, and, in one failed attempt to mutagenize white rats, 10 successive generations of daily exposure to alcohol fumes ("the young of 10 generations of alcoholic ancestors were both physically and mentally the equals of the controls and in some cases slightly superior"). Muller's finding inspired

a generation of biologists to expose all kinds of insects to radiation in order to induce mutation, including haplodiploid parasitic wasps (the thinking being that because males are haploid, recessive visible mutations should be easily visualized) (Whiting 1929). (Many of these studies, by the way, were funded by a grant from the Committee for Investigation of Problems of Sex of the National Research Council; the fact that this committee no longer exists at the NRC suggests that this august body eventually did work out its problems of sex, whatever they may have been).

It really wasn't until the 1950s, when peacetime uses for atomic radiation (particularly for by-products of the nuclear power industry) were at a premium, that radiation resistance in insects became a focus for research. In 1957, two reports appeared in the same issue of *Nature*, documenting the use of gamma radiation for control of wood-boring insects as well as stored product pests; thus, among the irradiated woodborers were *Anobium punctatum*, *Xestobium rufovillosum*, and *Lyctus brunneus*, and among the irradiated pantry pests were *Calandra oryzae*, *C. granaria*, *Rhizopertha dominica*, *Tribolium castaneum*, *T. confusum*, *Oryzaephilus surinamensis*, *O. mercator*, *Trogoderma granarium*, *Callosobruchus chinensis*, *Ephestia elutella*, *E. kubniella*, and *Sitotroga cerealella*. Their durability was, on the whole, daunting. *Lyctus* adults exposed to dosages of 48,000 rads continued to lay eggs, and mature eggs of *Anobium* withstood exposures between 48,000 and 68,000 rads (Bletchly and Fisher 1957); exposure to 20,000 rep failed to kill adults of *Rhizopertha dominica* or *T. castaneum* (Cornwell et al. 1957)

No one, though, thought to aim his/her cathode ray tubes, cobalt 60 sources, or Van de Graaf generators at cockroaches until Wharton and Wharton (1957) directed 1,000 rads against the American cockroach, *Periplaneta americana*; they found that this sublethal dose interfered with pheromone production. In a subsequent study (Wharton and Wharton 1959), these same authors conclusively demonstrated that the American cockroach was, compared with the rest of the known irradiated insect world, a wimp; *P. americana* died at doses of 20,000 rads. In comparison, it was noted that *D. melanogaster* had an LD<sub>100</sub> of 64,000 rads and the parasitoid wasp *Habrobracon* an LD<sub>100</sub> of 180,000 rads.

In retrospect, it could be argued that *Periplaneta americana* might have been atypically sensitive to radiation as far as cockroaches go, but it's hard to find any sub-

sequent studies that might have created the reputation of roaches as tops among the ranks of the radiation-resistant. Ross and Cochran (1963) examined the effects of ionizing radiation on the German cockroach, *Blattella germanica*, and found that doses as low as 6,400 rads killed 93% of nymphs after 35 days, and effects on reproductive capacity could be detected at doses as low as 400 rads. Granted, German cockroaches proved capable of surviving 10 times the dosages over the same time period that would be lethal to humans, but, in point of fact, they ultimately succumbed to dosages that don't even disturb many other insect species. So, why is it that Americans came out of the atomic era with the image of a survivor cockroach rather than a survivor fruit fly or survivor lesser grain borer?

Probably because lesser grain borers and fruit flies don't fit the image of the ultimate survivor. People will continue to believe that cockroaches will survive nuclear war no matter how powerful nuclear weapons become or how large arsenals grow. As David George Gordon (1996) pointed out in his book *The Compleat Cockroach*, today's run-of-the-mill 1-megaton thermonuclear devices are at least 70 times more powerful than the 15-kiloton bomb dropped on Hiroshima (and even these pale in comparison with the 58-megaton nuclear device tested by the former Soviet Union in 1961); therefore, even if a cockroach could have survived Hiroshima's bombing, it wouldn't have had much hope today of surviving even a nuclear skirmish between rogue states, much less a battle between nuclear superpowers. And cockroaches likely will remain in the public conscience as the most radiation-resistant of all creatures, all data to the contrary. *Deinococcus radiodurans* recently enjoyed quite a bit of favorable publicity (for a bacterium at least) when its genome was sequenced completely. *D. radiodurans* (as the specific epithet suggests) is without doubt the most radiation-resistant organism known on the planet. A pinkish bacterium that smells vaguely of rotten cabbage, it was isolated originally from canned meat that had spoiled despite being irradiated (it has turned up in irradiated fish and duck meat, as well as in the dung of elephants and llamas and in granite from Antarctica) (Travis 1998). It grows happily in radioactive waste sites in the presence of levels as high as 1.5 million rads (keep in mind that's over 1,000 times the 1,000 rads that kill humans and sterilizes American cockroaches). In a frozen state it may even be able to withstand 3 million rads.

Notwithstanding its astonishing biological abilities, I don't see a stinky pink bacterium ever displacing the venerable cockroach in the public imagination as the sole survivor of whatever havoc humans wreak on the planet. For that matter, I don't even see any metal/punk bands anytime in the near future called *Deinococcus radiodurans* either (although "The Lesser Grain Borers" or "The Confused Flour Beetles" definitely have rock band name potential). 

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