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The Cockroach Connection—Ancient, Seemingly Indestructible Pest. Part 1. Morphology, Behavior, and the Relationship to Allergies and Disease

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This two-part essay provides a brief overview of the cockroach literature. Part 1 looks at the insect's capabilities, distribution, morphology, evolutionary link with humans, and the connection between roaches and allergies and disease.

Anyone growing up in a city, especially in tenements, has encountered cockroaches. From childhood I remember my mother clobbering them with a shoe or a newspaper. Looking back, I marvel at how mothers in slums managed to keep apartments free of them. Even in modern high rises, these insects are indefatigable—often outwitting regular extermination squads. However, what I encountered as a child was nothing compared to my Army experiences. When my outfit transferred from Colorado to Texas, we were installed in barracks so full of cockroaches, gas bombs had to be used to clean them out! I vividly recall a pile of dead roaches that was literally two feet high.

Like many other insects inhabiting the urban environment (like flies and silverfish), cockroaches generally conjure up negative images in the US.¹ But unlike other insects, cockroaches seem to be associated with taboo topics. You don't talk about them in polite company. But this has never deterred us in selecting topics for essays in *Current Contents*®. I was curious to learn more about these ancient, well-adapted creatures.

We've pulled together an interesting review that demonstrates once again that even the most practical and elemental of human problems is closely intertwined with basic research in entomology. Several years ago, in 1984, we reviewed entomology journals,² and that same year I published a tribute to my good friend Miriam Rothschild.³ Her specialty is the flea, but it is not a big jump to talk about cockroaches.

Cockroaches do surface from time to time in the popular consciousness. Two examples that come to mind: the folk song that became popular during the Mexican revolution (1910-1940) that we all fondly know as "La Cucaracha," and the famous scene from the film *Papillon* where a starving Steve McQueen captures a cockroach in his jail cell and eats it on camera! However, for many years, cockroaches escaped such prominence in the popular media—but that all changed in the mid-1980s.

Invasion of the Flying Roaches

It began in late spring 1986. A new immigrant arrived in central Florida by boat. This may not appear to be unusual, but this was a newcomer with a difference—a one-inch fellow known to entomologists as *Blattella asahinai*, or more commonly, the Asian cockroach.

Previously, this insect had been virtually unknown in the New World. Indeed, the Asian roach had been described formally by insect researchers only four years before its appearance in the US. This cockroach's natural range is from southern India through Southeast Asia. Its introduction into central Florida was seemingly inauspicious—in June 1986 the species was limited to sporadic infestations within 60 square miles of Lakeland—and was barely noticed.⁴

But a year later, this changed. A major pandemic infestation was faced by Florida officials. By day, nothing seemed out of the

ordinary; but at dusk, things became quite different. The Asian roaches came out of hiding, and with a vengeance. In 1987 their density was estimated at up to 100,000 per acre—or slightly more than two per square foot—and they infested nearly 500 square miles in three central Florida counties.

Telephone calls from distressed residents began to pour into public offices. The twilight behavior of the insects was like a cheap horror movie come frighteningly alive. The roaches reportedly flew in clouds like locusts. Unlike other cockroach species, they were attracted to illumination—street lights, traffic lights, porch lights, television screens, and lights in houses. Even more disturbing, the insects landed on people without hesitation. As the roaches entered homes, they were attracted to well-lit rooms and landed on the brightest walls. As interior lighting changed in rooms, the roaches moved accordingly. During the day, they acted just like their roach brethren—scurrying into cracks and crevices in the walls and floors, often “hanging out” in kitchens, bathrooms, and potted plants until dusk.⁵

In just three years, the Asian roach expanded its territory from 3 Florida counties to 18. The entomology experts’ fears of the roaches hitchhiking in cars, trucks, and trains to other parts of the country were soon realized—an outbreak of the Asian roach appeared in Michigan in 1988, the insects arriving by way of a travel trailer.⁶ The story at this point became a national media event.

Unlike other insects (such as “killer bees” or ticks carrying Lyme disease⁷), cockroaches have not been proven to be life threatening. Yet roaches seem to be especially—perhaps irrationally—reviled. Last year US consumers spent \$1.5 billion on commercial insecticides to rid their homes of cockroaches—almost twice as much as the Federal government spent on AIDS research (about \$790 million).⁸

In this two-part essay, we’ll briefly review the cockroach literature, as well as focus on research specialties on this insect. Although we may not be able to explain the irrational behavior of many humans in response to these lowly creatures, hopefully we may in-

crease your knowledge about this fascinating insect.

An Adaptable, Successful Living Fossil

Cockroaches are among the most primitive living winged insects—they have remained essentially unchanged for more than 300 million years. Cockroach fossils found in coal and amber deposits show virtually no morphological differences in size or shape from those inhabiting our cupboards today. The oldest known cockroach fossil is *Paleoblatta douvillei*, found in Carboniferous deposits of the Devonian period. Its preferred habitat was among ferns in low, moist areas along banks of rivers and marshes.⁴

But today, roaches can be found just about anywhere. With more than 3,500 identified cockroach species (ranging in size from 8 millimeters [3/10 of an inch] to nearly 70 [3 inches]), these insects are distributed fairly generally throughout most continents, with perhaps the most species residing in tropical America and western Africa. Of the total number of species, only 50 are regarded as “pests”—that is, an insect viewed as detrimental or annoying to human beings. As a general rule, cockroaches have been found to survive comfortably at temperatures between 19 and 116 degrees Fahrenheit, making the insects adaptable to most areas that humans inhabit.⁹ (p. 10)

The three widest spread species are the American cockroach (*Periplaneta americana*); the German cockroach (*B. germanica*), the most common insect pest worldwide; and the Oriental cockroach (*Blatta orientalis*), also known as the “water bug,” considered one of the filthiest of household pests.¹⁰

Cockroaches are very adaptable and virtually indestructible. Some species can swim rapidly underwater for up to 2 minutes and remain submerged for as long as 15 minutes; the Asian roach has been collected in mountainous regions and even in areas of intermittent snow.⁴ Roaches inhabit TVs, microwave ovens, and even submarines.¹¹ They have been found in hospital laundry baskets, incubators for premature babies,

and beauty salons in department stores.⁹ (p. 11) Some 20 species have been found on aircraft. These were recovered from airplanes at airports in the US, Kenya, and New Zealand, suggesting that this may be a significant method of species migration. German and American roaches are the most "frequent flyers."⁹ (p. 12)

Speaking of transportation, some of the earliest records of cockroaches as pests can be found in ship logs. These insects are found in the reports of Sir Francis Drake (sixteenth century) and William Bligh (eighteenth century). Drake reported one captured Spanish ship to be overrun with cockroaches. Bligh recorded in the *Bounty's* logs a description of a successful method of killing the cockroach population—using boiling water. Centuries later, the insects are still a nuisance to shipping—the German roach appears to be the most successful species, especially associated with galleys, cabins, and mess rooms.⁹ (p. 12)

Cockroach Morphology and Behavior: Like Roach, Like Human?

For every cockroach one sees in the average home in the eastern US, there are—*on average*—1,000 not seen. Five fertile German roach females could theoretically produce 45 million descendants in one year, but usually a pair of roaches produces 100,000 offspring annually.¹¹⁻¹³

Until recently, cockroaches were classified as members of the insect order Orthoptera, which includes praying mantises, katydids, walking sticks, grasshoppers, and crickets. However, in 1989 entomologists moved the insects to an exclusive order just for roaches—Blattodea.¹⁴ According to the *Encyclopaedia Britannica*,

The cockroach is characterized by a flattened, oval body; long, threadlike antennae; and a shining, black or brown, leathery integument. The head is bent downward, and the mouthparts point backward instead of forward or downward as is the case in most other insects. The male usually has two pairs of wings; the female, often wingless or with vestigial wings, carries eggs in egg cases (called ootheca) that protrude from her body.¹⁰

Cockroaches have a well-defined courtship prior to actual mating. The mating ritual itself can take up to an hour. Male roaches are attracted to virgin females in a receptive condition. Such females frequently secrete pheromones, chemical substances that influence the behavior of other individuals of the same species. In American roaches, on detection of the odor, the male initiates searching movements, first with antennae, then with wings fluttering, actively searching the female out. (Scientists have been vigorously pursuing the artificial creation of the cockroach pheromone, but more about this later.)

During the courtship ritual, the male backs up into the female, depositing a sperm packet that the female retains for four to five months while continually producing egg sacks, each holding 16 to 35 tiny roaches. When the eggs are ready to hatch, the female deposits the ootheca. Soft white nymphs emerge, hardening and turning brown in color on exposure to the air. Before becoming mature adults, the nymphs go through several immature stages with molts in-between before a sexually mature adult is produced. German cockroaches mature in about 6 to 10 weeks and begin mating within just four to seven days of molting to the adult stage, starting the next generation.¹⁵

The cockroach diet is varied—ranging from pet food to shoe polish. Cockroaches have a gourmand's taste for the exotic, eating wire insulation, cardboard, Styrofoam, soap, paint chips, leaf litter, textiles, leather, human hair... (I think you get the picture.) Entomologists have found that 12 roaches can live on the glue of a postage stamp for a week, while the American cockroach can survive on just water for a month, and nothing at all for three weeks. The German cockroach can fast for two weeks.¹²

Cannibalism has been observed frequently in cockroach behavior, with recently molted nymphs and copulating or injured adults especially susceptible to predation. Overcrowding, food shortages, and high temperatures are factors that increase cannibalism.

Although roaches like to eat almost everything, there are some animals that like to eat these insects in return (thank goodness!)—

however, most live in tropical climates. They include arachnids (such as theraphosid spiders and scorpions), ants, parasitic wasps, amphibians (such as *Bufo marinus*, the giant toad of the West Indies, the Pacific islands, and Central America), lizards, birds (a Peruvian bird named *Troglodytes audax* is called locally the *cucarachero*), and mammals (such as marsupials, monkeys, and rats).⁹ (p. 364-6)

Human Link

Despite our abhorrence of cockroaches, these insects and we humans are related—if somewhat distantly. Neuropeptide hormones that control the way humans digest food may have a strong evolutionary link to a recently discovered natural hormone affecting the cockroach's own digestive system. A neuropeptide delivers messages from the nervous system to other parts of the body and, in this case, stimulates muscle contraction of the digestive tract and blood circulation.¹⁶

Ronald J. Nachman and William F. Haddon, US Department of Agriculture, Albany, California, and colleagues discovered the hormone leucosulfakinin (LSK) while analyzing the mashed heads of 3,000 roaches of the species *Leucophaea maderae*. They published a paper entitled "Leucosulfakinin, a sulfated insect neuropeptide with homology to gastrin and cholecystokinin," which reported that the LSK in cockroaches is strikingly similar to the human neuropeptides gastrin II and cholecystokinin.¹⁷

LSK has the highest biochemical correlation yet reported between a neuropeptide in a vertebrate and that in an insect—55 percent of the amino acid residues of LSK are identical with those of human gastrin. This finding led scientists to speculate that both roaches and humans had the same ancestor about 500 million years ago. It also is an indicator that species evolution occurs at the molecular level as well.¹⁶

Cockroaches long have been the favorite experimental animals for biologists and entomologists because of their large size, ease of culture, prodigious fecundity, and rela-

tively generalized structure. Ever since the first monograph on the Oriental cockroach was published in 1886, research on various aspects of cockroach biology has continued.⁹ (p. v) Today, the emphasis of biological research on these insects is with a view toward possible uses in extermination. Looking at papers in the 1988-1989 ISI® databases with the word "cockroach" in their titles, we found that 170 are devoted to the biology of the insect, 48 to methods of extermination, 16 to allergenic effects of roaches on humans, and 6 to cockroaches as possible vectors of disease. In Part 2 of this essay, we will take a look at these topics.

Cockroaches: The Allergy and Disease Connection

Compared to the locust (which prodigiously destroys crops) or the mosquito *Anopheles quadrimaculatus* (which transmits malaria to humans), cockroaches have not been considered injurious insects to man. However, a growing body of evidence may change this view. For example, a 1988 courtroom decision (during a "wrongful death" lawsuit) ruled that an asthmatic died from a fatal asthma attack initiated by arthropod allergy, and not from pesticides used in the home as was claimed by the spouse.¹⁸ Furthermore, cockroaches are associated with four strains of poliomyelitis virus, 40 species of pathogenic bacteria, and 12 helminth species with primary vertebrate hosts. But in no case has it been proved that cockroaches have transmitted infectious diseases to man.⁹ (p. 15) Indeed, in the middle of the nineteenth century, a powder made from dried cockroaches was recommended as a diuretic!¹⁹ Research continues on the cockroach/disease-vector link, however.

In a recent review on health implications of cockroach infestations, Richard J. Brenner, Philip G. Koehler, and Richard S. Patterson, University of Florida, Gainesville, point out that there are numerous references to the isolation of pathogens from cockroaches in proximity to epidemics. These included an outbreak of dysentery in Northern Ireland, the isolation of *Salmo-*

nella bacteria from cockroaches captured in a hospital ward where gastroenteritis was common, and a study in New York City where 89 percent of the cockroaches sampled (from a variety of human habitations, including restaurants, apartments, and hospitals) harbored at least three species of pathogenic bacteria.²⁰ Other recent publications on this subject have linked American roaches with bacterial diarrhea in Accra, Ghana,²¹ and have examined the distribution and associated bacteria carried by the cockroach species *Supella supellectilium* in a hospital in Rennes, France.²²

Although at present there is no definite connection between cockroaches and disease epidemics, there is a serious link between cockroaches and allergies. In a previous series of essays, I discussed the behavioral manifestations, epidemiology and etiology, and diagnosis and treatment of allergies.²³

On the topic of cockroach-related allergies, the items that humans are hypersensitive to include bodily remains, cast skin, feces, and ootheca egg cases. The actual allergen-causing agents in cockroach materials are proteins. Unfortunately, some cockroach proteins persist in their allergenic capability for many years. Indeed, some are virtually indestructible—even boiling them for hours doesn't destroy the proteins' allergenicity. Of the more than 50 identifiable cockroach proteins, only 10 to 15 actually cause allergic reactions.²⁴

The most common symptoms of cockroach allergies are sneezing, fits of asthma, and inflammation of the skin (including itching eruptions on the hands), which caused the coining of the phrase "cockroach dermatitis."²⁵ Cockroaches were not implicated in allergic conditions until generalized skin rashes on people (following exposure to the insects) were first reported in 1943.²⁶

Statistics indicate that about 7 to 8 percent of Americans have an allergy to roaches. Among those who have grown up in roach-infested homes, the allergy rate can be as high as 70 percent.¹² Indeed, allergy to cockroaches is the second most common hypersensitivity among asthmatics (house-dust mites are ranked first) with a 51 percent positive reaction in standard skin scratch

tests (compared with 84 percent for house-dust mites).¹⁸ There have been a handful of studies over the years published on cockroach sensitization in hospitalized patients and laboratory workers.²⁷⁻³⁰ Earlier this year, at the 46th annual meeting of the American Academy of Allergy and Immunology, there were further presentations on the allergenic relationship of cockroaches to humans. These indicate activity in skin reactivity tests to cockroach allergens and examinations of cockroach dust extracts for assays.

The Most-Hated Pest

The major objections to cockroaches are psychological ones. Roaches generally arouse more hostility in us than bedbugs or fleas. A cockroach in one's home is usually equated with poor hygiene, and roaches do spoil food by depositing saliva and feces on it and leave unpleasant odors (derived from the abdominal glands).

Our negative reaction to these insects may be connected with characteristics that help the insects avoid capture. These include great running speed (up to three miles per hour) and the ability to squeeze their bodies into inaccessible cracks due to the softness and flexibility of their exoskeleton.⁹ (p. 16)

Unlike other household pests, such as ants, cockroaches are not seasonal pests. Rather, cockroaches are perennial and, when discovered, come not singly or even in scores, but in the tens of thousands. Many species, unlike their Asian brethren, avoid brightly lit areas (called photophobia) and run when exposed. These insects appear in places that cause much consternation and dismay, such as bread boxes, cupboards, bathrooms, dishwashers, clocks, televisions, bed linens, and so on. But keep in mind that while we may cringe at the thought of roaches cavorting in our kitchens, not all of us think similarly; these ancient creatures and their eggs are used as a high protein food source in Australia, Thailand, China, Japan, and other parts of Asia.⁹ (p. 366) Indeed, for many years there has been a restaurant in Los Angeles, California, specializing in cockroach fare.

In Part 2 we will look at what science is doing to control this pest—via pesticides, biochemical analogs of the insects' own hormones and pheromones, and even "birth control pills." We also will highlight some entomological *Citation Classics*® that are

related to cockroach investigations by scientists.

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