Forbidden Flavors

Scientists consider how disgusting tastes can linger surreptitiously in memory

By BRUCE BOWER

John Garcia relishes the story he heard as a child about how his mother came to detest that most vaunted of sweets, chocolate. Just before taking a boat voyage at age 3, she contentedly ate several chocolate candies. While on board later that day, she became terribly seasick and vomited. From then on, she found the taste of chocolate abhorrent, even though the grown-up Mrs. Garcia knew that chocolate treats do not cause seasickness.

Working on farms and ranches in Northern California as a youth, Garcia heard more stories of food aversions caused by illness—these occurring in a different corner of the animal world. If a coyote or other wild creature eats poisoned bait and survives, the budding scientist was told, it never again picks up bait. As a result, older predators prove nearly impossible to kill with standard baits.

It seems fitting, therefore, that Garcia's more than 40-year career in psychology has revolved around the study of such taste retreats. He refers to the behavior as conditioned taste aversion, but many animal investigators call it simply the Garcia effect.

In brief, creatures up and down the food chain readily associate nausea or other bodily signs of illness with the taste of what they have most recently consumed. That flavor is then shunned, often after only the initial bad experience. What's more, the effect ensues with equal force whether nausea strikes a few minutes or many hours after a tainted snack or slurp.

Garcia's research sparked intense controversy in the 1960s and 1970s because it contradicted the basic tenets of psychologist B.F. Skinner's then-dominant radical behaviorism. Skinner held that general laws of learning shape the behavior of all animals, regardless of a particular creature's evolutionary history or biological makeup. In contrast, Garcia argues that an animal is a "biased learning machine" designed by evolutionary forces to forge meaningful links between some stimuli but not others.

According to Skinner's theory, food or any other reinforcing stimulus consistently made available after a random behavior—any act fancied by the experimenter—renders that behavior inevitable whenever the stimulus reappears. Pigeons trained to obtain food pellets by pecking at keys whenever a light above the keys was turned on came to symbolize the power of Skinnerian reinforcement.

Garcia, now 79 and a professor emeritus at the University of California, Los Angeles, presented an alternative view that has moved from the fringes to the mainstream of animal research. The confection rejection exhibited by Garcia's mother derived not from random learning but from evolutionary influences that yielded gut-level mechanisms for expelling poisons from the body. Skinner's pigeon experiments did not produce key pecking from scratch, Garcia contends. In hitting the keys with their beaks, the pigeons employed their natural feeding behavior—pecking at bits of grain or other goodies.

Russian physiologist Ivan Pavlov laid the foundation for current strains of taste aversion research. Getting hungry dogs to drool at the sound of a bell is one type of biologically based learning; taste aversion is another.

"I originally got into a lot of trouble in psychology for studying conditioned taste aversions, but this has become a broad and very exciting area of research," Garcia remarks.

The exploration of taste aversions has expanded to include efforts to ward off wild predators from livestock without killing the carnivores, to chart animals' social communication about food aversions, to explore hormonal sensitivities that may push some teenage girls toward self-starvation and anorexia, and to identify brain structures essential for tagging selected flavors as forbidden.

Garcia's research also inspires psychologists now investigating central realms of human knowledge and learning, such as categorizing local animals and plants (SN: 11/16/96, p. 308) and detecting people who cheat on mutually beneficial agreements (SN: 1/29/94, p. 72).

A pair of studies the UCLA scientist published in 1966, 11 years after his first experiments on conditioned taste aversion, provide a vivid demonstration that animals are biologically prepared to learn about taste in a way that differs from how they learn about other sensations. Rats readily associated nausea caused by lithium chloride injections with earlier intake of sweetened water but not with brightly illuminated water made available after the sound of a tone, he and his coworkers reported. As a result, the animals declined any further opportunities to drink the sweet stuff but continued to drink the "bright and noisy" water.

In contrast, repeated electric shocks to their feet did not diminish rats' taste for sweetened water. Animals regularly shocked after drinking either sweet or illuminated water acted aggressively when offered those fluids in the laboratory but calmly drank both back in their home cages. Away from the threat of shocks, jolted rodents still enjoyed the beverages' flavors, in Garcia's view.

Buoyed by such findings, one of Garcia's former graduate students saw an opportunity to deploy taste aversion techniques in predator control. In 1974, psychologist Carl R. Gustavson attempted to keep coyotes from killing sheep while preserving their vital ecological role (SN: 11/30/96, p. 344). A meal of mutton laced with a nonlethal dose of nausea-inducing lithium chloride could convert sheep into artificially toxic prey for even the hungriest coyote, Gustavson theorized.

He and psychologist Joan C. Gustavson of Arizona State University in Tempe conducted pilot tests on zoo animals. As they suspected, coyotes and wolves fed the flesh of sheep and then given lithium chloride injections turned away from live lambs and sheep after a few sniffs. Similarly, a cougar refused to eat deer meat, which it had consumed prior to being nauseated, but continued to enjoy cow and horse meat.

Further studies conducted by Carl Gustavson and Joan Gustavson and others indicated that lithium-generated taste aversions can protect mice from rats, ferrets, and hawks; chickens from raccoons; vegetable gardens from baboons; and sandhill crane eggs from ravens and crows.

Just as Garcia's studies generated a dispute over how animals learn, the work of Carl Gustavson and Joan Gustavson ignited a battle over whether lithium baits truly keep wild coyotes from attacking sheep.

Working with researchers at ranches in Washington and in Saskatchewan, Canada, Carl Gustavson found that baits of mutton wrapped in sheep hide and laced with lithium—which were scattered over wide areas—yielded significant drops in lamb kills over as many as 3 years. A program of spreading baits and injecting sheep carcasses with lithium, conducted in Southern California's Antelope Valley by psychologist Stuart R. Ellins of California State University, San Bernardino, achieved similar success.

A different story emerged from several other field studies, some conducted by biologists at a research outpost of the U.S. Fish and Wildlife Service in Denver. Lithium baiting failed to reduce coyote predation in those projects.

The two groups of scientists accused each other of using flawed methods and statistics. By the mid-1980s, they had apparently reached a standoff.

In an unpublished manuscript completed shortly before his death from a heart attack last year at age 49, Carl Gustavson—then director of a private research company in Tucson—wrote that lithium-baiting tactics "have undergone more stringent field testing than other methods of animal damage control" and "show the greatest promise for successful application." Interest in taste aversion techniques is now on the rise, even among federal wildlife biologists, says Ellins.

Animals that have eaten tainted food appear to communicate their aversion, according to preliminary data on groups of rats and coyotes, notes Ellins. If one animal in a group of five or six residing together refuses to eat a particular food after having consumed it with a dose of lithium, the rest soon follow suit, he and his coworkers have found. Coyotes may alert others to food deemed unfit with behaviors such as urinating on the offensive material or covering it with dirt. However, social communication in coyotes and rats about dangerous foods remains poorly understood, Ellins says.

Taste aversions exert an iron grip on individual behavior because they provoke the body's gut defenses, such as regurgitation or diarrhea, Garcia contends. Because of their importance for survival, these reactions typically take root without necessarily being remembered explicitly. For example, if rats drink sweetened water and then experience nausea-inducing drugs while anesthetized, they refuse to consume sweetened water several days later; humans show comparable taste aversions if nauseating injections are delivered during sleep. Garcia describes this research in the July 1990 JOURNAL OF COGNITIVE NEUROSCIENCE.

Carl Gustavson and Joan Gustavson suspected that taste aversions caused by hormonal changes underlie anorexia nervosa in some girls. In experiments conducted over the past decade, they found that male rats frequently get nauseated and develop taste aversions following injections of the female sex hormone, estrogen. The same reactions occurred in estrogen-depleted female rats whose ovaries had been removed shortly after birth.

Girls who produce low amounts of estrogen—perhaps because of prenatal exposure to toxic substances—acquire a malelike estrogen sensitivity, the researchers propose. When estrogen concentrations shoot up at puberty, these girls become anxious and develop taste aversions to available foods. A vicious pattern begins, in which dramatic weight loss reduces the nauseating estrogen concentrations, and weight gain from eating leads to increased estrogen concentrations, with a return of anxiety and food aversions.

Whether this bold theory pans out or not, evidence suggests that specific parts of the brain orchestrate taste aversions. The insular cortex, a structure that monitors the state of the heart and other internal organs, assumes primary responsibility for branding certain tastes as off-limits, according to research directed by neuropsychologist Federico Bermúdez-Rattoni of the National Independent University of Mexico in Mexico City.

In a series of experiments, Bermúdez-Rattoni's group has found that a damaged or destroyed insular cortex renders rats incapable of forming taste aversions. Fetal brain tissue grafted into a rat's damaged insular cortex restores this capacity in about 1 month; taste aversions assume their former power in 2 weeks if grafts are accompanied by injections of nerve growth factor. Both grafts and nerve growth factor stimulate production of a chemical messenger, acetylcholine, involved in memory formation, the investigators report.

The lasting impact of taste aversions probably depends on communication between the insular cortex and several other brain areas, Bermúdez-Rattoni wrote in a chapter of *Plasticity in the Central Nervous System* (1995, Mahwah, N.J.: Lawrence Erlbaum).

Garcia's work has had its own lasting impact, states psychologist Bruce R. Moore of Dalhousie University in Halifax, Nova Scotia. Conditioned taste aversion research "has helped to bring the study of animal learning back into contact with biology," remarks Moore, a longtime critic of Skinner's views.

Bennett G. Galef, a psychologist at McMaster University in Ontario, also ranks Garcia as a trailblazing researcher, although he calls the evidence of innate taste aversions to poisonous substances "okay, but not great, especially for humans."

For his part, Garcia classifies the effect that he has championed as simply one of many "instincts for learning" that coordinate animal behavior.

"Some researchers have treated this effect as if it's something special," he states. "That's kind of ridiculous." □

Ellins

Clockwise from upper left: An unsuspecting coyote approaches a lithium-tainted bait, tastes it, gets nauseated, and finally urinates on the sickening snack.