the brain) to make people less aggressive and impulsive cast a cloud over clinical research on aggression as well, despite having won the Nobel Prize in medicine for its inventor, Portuguese neurosurgeon António Egas Moniz, in 1949.

In part because of this tainted legacy, modern-day violence researchers take pains to emphasize that one's genetic heritage isn't everything—rather, behavior is shaped by a subtle interplay among genes, environmental conditions, and life experiences. "That's the beauty of this work," says Dee Higley, who studies aggression in rhesus macaques at the National Institute on Alcohol Abuse and Alcoholism in Poolesville, Maryland. "It shows you that genes matter, but they're not destiny."

Teasing apart the contributions of nature versus nurture, however, is a daunting task. One problem is finding animal models that mimic human violence yet are ethically acceptable. Popular techniques in the '60s and '70s included giving rats electrical shocks or applying heat to their footpads to elicit aggressive behavior—a model that many researchers now concede was cruel and, because it was so unnatural, hardly meaningful.

The Snarls and Sneers That Keep Violence at Bay

A bull elephant gores a rival in a duel over a female. A rat attacks and eats his mate's pups. In a fight for supremacy, one chimpanzee mauls another to death. Scenes like these may suggest that the ability to mete out violence is linked to survival in the animal kingdom. But a handful of researchers is now making a persuasive case that scores are settled far more often by subtle, nonviolent signals—a curled lip, a snarl, a swivel toward an opponent. Their provocative idea is that inflicting violence on a member of one's own species is a pathological condition that arises when these signals are missed or misinterpreted.

Scientists are now unearthing clues to the behaviors that keep violent impulses at bay. Their findings suggest that personality, social status, life experience, and anxiety levels all factor into whether chance encounters end in peace or, more rarely, in carnage. "For many animals, a lot of social behavior is probing or testing a relationship, always testing with a little aggression and a little friendliness," says Sergio Pellis, an ethologist at the University of Lethbridge in Alberta, Canada.

"Humans also have a tendency to restore relationships and resolve conflict," says Frans de Waal, a primatologist at the Yerkes Regional Primate Research Center in Atlanta, Georgia. Laying bare the roots of violence in people, says Jaap Koolhaas, a behavioral physiologist at the University of Groningen in the Netherlands, may lie in understanding how we—like many other animals—rely on instinctual behaviors that keep violence in check.

A bully in the cage. A male rat strikes an offensive sideways position while two others rear up to defend themselves.

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Coping strategies

In the 1960s, the great German ethologist, Konrad Lorenz, made a case, extrapolating from his studies of birds and fish, that humans are an aggressive species and that a penchant for violence leads to clan and tribal warfare. But that dogma is beginning to fade, largely thanks to studies suggesting that aggressiveness is part of a repertoire of behaviors that has arisen to balance the need of the individual to look out for himself and still maintain good standing within the group.

By the time Koolhaas delved into this area about a decade ago, researchers had shown that in many species, individuals are mainly polarized into aggressive or passive personality types. "There's a bimodal distribution," he notes. Searching for cognitive differences that set these two personality profiles apart, Koolhaas's team found in 1993 that highly aggressive rodents are more likely than calmer peers to act quickly when thrust into a potentially life-threatening situation. He proposed the existence of an inborn tendency toward either a "proactive" or "reactive" coping strategy, which has since been discerned in organisms as diverse as birds, cattle, pigs, fish, and octopi. A typically reactive rat, for example, will sniff an electric probe introduced into its cage and get zapped just once, thereafter steering clear of the pain-giving intruder. A proactive rat, on the other hand, will actively try to cover it with the bedding of its cage. That type of reaction may seem wasteful, but proactive coping strategies can boost the odds of survival: Put in a chilly cage, proactive rats build nests to stay warm, while reactive rats sit in a corner and shiver.

Proactive animals also tend to be less easily deflected once they learn a behavior, Koolhaas and his colleagues have found. "The highly aggressive animal tends to develop routines," he says. "With repeated experience, these animals don't pay any attention to environmental stimuli." At the XIV World Meeting of the International Society for Research on Aggression in Valencia, Spain, earlier this month, Koolhaas detailed experiments on rodents in mazes and in social situations. His group has found that proactive mice and rats that have learned to navigate a maze to get to a food reward are unperturbed when the maze is slightly altered—such as when tape is placed at a spot on the floor. They keep going as if the tape weren't there. Reactive individuals, on the other hand, stop and check out the new landmark. Then, as if confused by the tape, they often lose their way to the food, even though the course is otherwise the same.

This tendency shows up in social interactions, too. Even rodents that have never seen a member of the opposite sex can quickly tell a male from a female. Males tend to be nasty toward other males when first introduced, whereas they usually nuzzle new females. But if a solitary, proactive male is presented with another male several times in a row, then is introduced to a female, he will fail to notice the gender switch and will attack the female. "It first does and then thinks," says Koolhaas, whereas a reactive individual "first thinks and then does. It's a crucial difference, and it leads ultimately to violence."

Once a highly proactive animal for the first time wins a series of aggressive encounters and repels an intruder, it acquires a fighting habit, and "its behavior does not depend anymore on what the opponent is doing," Koolhaas says. It ignores peace overtures, such as baring the belly. But such highly proactive animals are rare: Most aggressive encounters between a solitary rodent and a newcomer end up

"That was nutty stuff," says Craig Ferris of the University of Massachusetts (UMass), Worcester. Instead, most researchers now use so-called ethological models in which they draw out more natural forms of aggression displayed by animals defending territory or establishing a dominance hierarchy. Ferris, for instance, pairs up male Syrian golden hamsters and monitors their aggressive confrontations. In monkey models, researchers are limited to studying "display behavior" where animals snarl and growl, but very rarely actually hurt each other (see sidebar below); eliciting more injurious forms of aggression is considered by most to be unethical. Although such dustups may seem only a distant echo of, say, a wife-beater or a bloodthirsty psychopath, researchers think some of the same neural pathways may be involved.

Clinical researchers face formidable hurdles, too. For one, many studies involve unpleasant or time-consuming experimental procedures, such as spinal taps or brain scans. In addition, it's notoriously difficult to quantify a person's aggressiveness. "You could have a confederate frustrate a subject and see how they respond," says University with the guest showing the proper deference followed by détente or even playfulness. In observing the highly proactive animal's failure to take into account what the opponent is doing, Koolhaas says, "we have hit upon one of the causes of the development of violence."

Personality and rank

"Type A" behavior is not limited to rodents, says Robert Sapolsky, a neuroendocrinologist at Stanford University in California. He has observed several troops of baboons in their native habitats for almost 20 years. "Personality can be at least as important as social rank" in determining how well an individual fits in, and consequently, the likelihood of getting into fights, he says. Like Type A humans, who tend to perceive a hostile world around them, Type A baboons have higher levels of stress hormones. And if a male Type A baboon can't tell the difference between a minor provocation and a major power struggle—inferring a threat, for instance, from a subordinate that happens to be napping too close to his turf—he's "less likely to remain dominant," Sapolsky says.

Although baboons are considered quite aggressive primates by nature, violence tends to be much more prevalent when the troop's structure is unstable, such as when baboons are kept in captivity. If the troop members don't know one another, or if the hierarchy is disturbed, say, by the loss of the top male, the rush to establish rank results in scuffles that only subside when everyone knows his or her place. "Aggression has something to do with attaining a high rank, but far less to do with retaining it," Sapolsky says. Once dominance is established, violent actions subside, replaced by subtle signals—a sideways glance, for example, or a slight but perceptible tensing of the body.

Should a squabble occur, animals know how to make amends. In a new book, *Natural Conflict Resolution*, de Waal and Filippo Aurelli chronicle peacemaking in animals and in people: After an aggressive encounter over food, for example, animal combatants often offer each other friendly overtures, such as grooming or licking one another. Children, too, kiss and make up. Such conciliatory gestures are "extremely widespread," de Waal reports, as they help preserve relationships that may be necessary to survival and can be particularly key when animals (or people) live in crowded conditions. (See de Waal's Review on p. 586.)

These gestures acquire meaning, it seems, during critical developmental windows. By play fighting, young rats, for example, learn how to interact with one another. Both proactive and reactive coping strategies are moderated by these experiences. As Koolhaas's team reported in the March 1999 issue of *Developmental Psychology*, depriving adolescent rats of just 2 weeks of contact—and, consequently, play fighting—transformed them into maladapted individuals who had serious problems dealing with their peers. Isolation, he argues, prevents an individual from "learning to play the game according to the rules."

Those results are in line with what Pellis has found in 20 years of observing play fighting among rats. His team has gleaned the subtle changes in posture and movements that distinguish "play" from something more serious. A rat lacking play experiences is likely to be overly friendly when he first encounters another animal, sniffing it with gusto. "But when the other animal reciprocates, it exhibits hyperdefensiveness," backing off or trying to nip the face, Pellis says. Such behavior seems odd to a rat that has had a normal rough-and-tumble youth, and the miscommunication can result in escalated aggression as both animals get excited and drawn into a fight. This, says Pellis, suggests that "social skills are especially sensitive to what happens in juveniles."

Studies on nonhuman primates support the idea that play fighting is not so much a way to learn combat skills as a way to develop social intuition. According to Pellis, adults in species with irregular contact are more playful than adults of species that live in close-knit groups. Play fighting involves a lot of sniffing and touching, and animals that spend much time together have substituted more sophisticated signals that are often visual or vocal.

Even so, Pellis says, grooming among nonhuman primates suggests that touching still plays an important role in defusing tensions. For example, when primates are fed on a regular schedule, they develop a habit of grooming one another before the food arrives, possibly to ease tensions that might escalate over access to the upcoming meal.

Chacma tai chi. By grooming each other, these chacma baboons and other nonhuman primates may diffuse tension over daily tribulations such as getting enough to eat.

The thought of schoolchildren combing each other's hair to calm down before lunch may seem odd. But animal studies are relevant to people, says Pellis. Children have a biological need to play, he points out, and perhaps even to get into minor scuffles with their peers. That may be how they learn subtle social cues. "Preventing kids from doing it may be causing them harm," he says. "They may be less able to deal with subtle interactions."

Neither Pellis nor others studying aggression in animals think their work will fully explain why people on occasion turn violent. Nevertheless, "the distance between us and animals may be smaller than we like," says Menno Kruk, a behavioral neurobiologist at Leiden University in the Netherlands. "Actually too close for comfort sometimes."

—ELIZABETH PENNISI

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