Hormone of Monogamy

The prairie vole and the biology of mating

By KATHY A. FACKELMANN

What makes some males stay with one female while others play the field?

Researchers believe that a chemical produced in the brain may turn on monogamous behavior. But alas for those who would like to package the stuff, scientists have only been able to tie this love potion to a mouse-like mammal known as the prairie vole — not to humans. Scientists just don't know whether this chemical, or any other like it, mediates human behavior.

Field biologists have noted that the male prairie vole pairs off with a single female, probably for life. Neuroscientists have long wondered what keeps these males content with one mate while their close cousins, the montane voles, exhibit a more, shall we say, promiscuous dating style. While the stay-at-home prairie voles cuddle in their burrows, montane males mate indiscriminately with one female after another.

This vast difference in lifestyle may come down to a single brain hormone, vasopressin, which in the human body is more commonly associated with regulation of water content. Research indicates that vasopressin induces the male prairie vole to stay with and protect his mate.

At the same time, vasopressin may trigger another characteristic behavior — that of the father prairie vole caring for his pups, another group of investigators finds.

What makes the monogamous prairie voles so radically different from their polygamous cousins?

To answer that question, neuroscientist Thomas R. Insel of the National Institute of Mental Health (NIMH) neurophysiology lab in Poolesville, Md., turned to a discovery his team made last year (SN: 7/4/92, p.6). The researchers found that compared to polygamous voles, prairie voles' brains had different distributions of certain receptors, proteins that sit on the surface of nerve cells. That finding led the team to the chemicals that fit with those receptors — namely, vasopressin and the reproductive hormone oxytocin.

In their most recent research, "We asked a very simple question," says Insel "[Does] either of these hormones induce or affect pair-bonding in the monogamous animal?" Insel and his colleagues, including C. Sue Carter of the University of Maryland at College Park, provide some answers in a report published in the Oct. 7 NATURE.

Before delving into the specifics of the team's investigation, it may be helpful to define monogamy. The average person probably thinks of monogamy as a sexually exclusive relationship. Biologists, however, define the word a little differently. The monogamous animal is one that spends most of its time with one mate but is not entirely faithful, points out Insel. Most monogamous animals will, on occasion, mate with a stranger, he says. In addition, the monogamous male vole often takes a fiercely protective stance when a stranger threatens the nest. Finally, such males often help their mates with child-rearing tasks.

Insel and his colleagues began by observing mate-guarding behavior, the dramatic change that overcomes a male prairie vole when an intruder enters his family's burrow.

Previous research had shown that, after mating, the normally timid male prairie vole will attack any strange male that happens by the nest, explains report coauthor James T. Winslow, who worked with Insel at the NIMH laboratory and is now a researcher at Hoechst-Roussel Pharmaceuticals, Inc. in Somerville, N.J.

The team confirmed that response, showing that males who had mated with a female would indeed show this Jekyll-to-Hyde transformation when confronted with a strange male vole. In contrast, virgin male prairie voles remained timid when a new male was placed in their cage.

Something happened during the sexual experience, the team theorized, to transform the normally shy male prairie vole into an aggressor. To test the theory, the researchers tried to prevent that behavioral change with a chemical blockade, something that would stop the action of vasopressin or oxytocin.

Both vasopressin and oxytocin consist of short chains of amino acids. In their role as traditional mammalian hormones, they are secreted by the pea-sized pituitary gland and can take minutes to exert their effects. Vasopressin stimulates absorption of water by the kidneys and thus decreases urine flow. Oxytocin plays a role in many reproductive functions, such as the contraction of the uterus during labor.

However, these chemicals are also synthesized by specialized nerve cells in the hypothalamus and other parts of the brain. In their role as brain hormones, they transmit messages between nerve cells in the brain, a process that takes only a fraction of a second. As fast-acting chemical messengers, oxytocin and vasopressin must each approach and dock with its own protein receptor on a target nerve cell. Once the docking is complete, each chemical triggers a cellular response.

The NIMH-Maryland team wanted to interrupt those messages. To do so, it injected into the brains of male prairie voles a chemical that fits into the vasopressin receptor, thus blocking the real McCoy's docking site on the neuron. Other male voles got an injection of a substance that blocks oxytocin. Voles in a third group received a shot of a fluid that did not contain a hormone.

Next, the team allowed the voles 24 hours in which to mate. The voles, it turns out, mated every hour. Scientists believe that the long honeymoon is essential for spurring the brain to produce the hormone that mediates monogamy.

Voles that received no hormones showed the expected "jealous husband" response when a strange male vole was placed in their home cage. So did the males that got the injections of the oxytocin blocker, a finding that suggests oxytocin isn't involved in this behavior.

However, the voles given the vasopressin blocker remained timid, even when confronted by a stranger. This finding strongly indicates that it is vasopressin that triggers aggression in male prairie voles, Winslow says.

Indeed, the prairie voles given the vasopressin blocker appeared similar in their after-sex behavior to the polygamous montane voles. Males of this species don't have the same interest in securing the female's undivided attention, notes Carter. Polygamous male voles don't need to guard the females — indeed, their reproductive strategy involves getting a number of females pregnant, she adds.

The researchers wanted more direct proof of vasopressin's effects, however, so

they devised another experiment. This time, they injected the hormone into the brains of virgin male prairie voles. Again, they confronted each of the test animals with a strange male vole. The researchers discovered that a one-time bolus of this hormone didn't have any observable effect: The test animals remained retiring despite the intruder's challenge.

Perhaps a long period of mating, during which vasopressin is released frequently in small amounts, is necessary to transform a mild-mannered vole into one that is ready to pick a fight, the team speculated. So in the next phase of the study, the researchers used a pump to infuse tiny amounts of vasopressin into the brains of virgin male prairie voles during a 24-hour period.

After the infusion, the researchers placed another male in the cage with the test rodents. This time, the team did see the characteristic change in behavior – the vasopressin-infused voles threatened, and in some cases bit, the intruders.

Getz/Lisa Davis

A male prairie vole threatens an intruding male vole. The intruder continues his advance toward the burrow entrance. A brief but fierce battle ensues as the prairie vole defends his home.

Another key component of monogamy, prairie vole style, involves bonding with a particular sex partner. That's quite a feat in the mammalian world: Most mammals are polygamous by nature.

Lowell L. Getz of the University of Illinois at Urbana-Champaign was the first to document the prairie vole's rather surprising family values. Getz, who for years tracked voles in the grassy fields of Illinois, noticed that he would repeatedly catch a pair of prairie voles in the same trap. He began to suspect that the prairie voles formed strong social bonds with a partner of the opposite sex. In contrast, the Illinois researcher rarely trapped pairs of meadow voles, another cousin of the prairie vole. The philandering meadow voles meet briefly for flings but normally lead very solitary lives, he notes.

In a series of field studies, Getz and his graduate students dusted prairie voles with a material that glows under ultraviolet light, thus enabling them to track these secretive rodents. The glowing trail led them to the voles' burrows – hollow, underground chambers packed with shredded grass. Inside each nest, the researchers often found a male and a female and, if they discovered the burrow in the spring, a litter of newborns.

Getz discovered that 75 percent of these pairs broke up only when a mate died. Rarely did a male prairie vole abandon his mate, he says.

With that picture of harmonious home life as a backdrop, Winslow's team wondered whether vasopressin alone, in the absence of mating, would cause male prairie voles to exhibit monogamous behavior.

To find out, the researchers again turned to the infusion pump. They gave male prairie voles a 24-hour infusion of vasopressin, oxytocin, or a hormone-free fluid. Each male was housed with a female vole whose ovaries had been removed and therefore would not mate. Nonetheless, the pair groomed each other and cuddled during the infusion.

After the infusion, the researchers moved the pair to a cage designed to give the male prairie vole a choice of partners. The male's female partner was tethered in one section of the cage, while a different female was tied in another. Males were allowed to visit either female. The team then observed how much time each male spent with each female vole.

Males that had received the oxytocin or the hormone-free fluid split their time between the new female and the familiar partner. In the absence of vasopressin or mating, these males failed to form a strong attachment to their female cage-mate, Winslow says.

However, male voles that had received the vasopressin appeared much pickier. These voles spent 75 percent of their time with the familiar female, which suggests that vasopressin leads to the formation of a social attachment. As happens in nature, these males also visited, and sometimes mated with, the novel female.

Nobody really understands the mechanism by which vasopressin leads males to pick a familiar female. Some scientists believe this brain chemical underlies a mammal's ability to remember certain events. For example, studies in rats suggest that vasopressin may play a role in the recognition of a cage-mate.

In the vole experiment, vasopressin may help males recall the time they spent with their partner, thus triggering a preference. "In this case, it may be involved in the formation of the memory or imprint of the attachment," Winslow says.

The same stuff that inspires male prairie voles to be devoted hubbies may also make them good daddies.

Biologists know that monogamous males share parenting tasks with their partners, a characteristic almost never seen among polygamous creatures. Indeed, mother and father prairie voles both spend a lot of time grooming and huddling close to their newborns, notes

Continued on p.365

Continued from p.361

Geert J. De Vries of the University of Massachusetts at Amherst. Furthermore, incest appears to be rare among prairie vole families, Getz notes. In general, male and female young do not enter puberty as long as they remain at home.

De Vries knew that female voles, like human females, experience dramatic hormonal fluctuations during pregnancy. Such changes probably prime the mother-to-be for her parenting duties. In fact, oxytocin is known as the "hormone of mother love" because it stimulates milk secretion in mammals, including humans. Some scientists speculate that oxytocin may also influence social attachments, including a human mother's bonding with her newborn.

A father-to-be never experiences pregnancy firsthand and thus isn't exposed to this hormonal surge. What causes a father prairie vole's interest in his young pups then? De Vries has published and unpublished data suggesting that vasopressin may also be the hormone of father love.

To study the biology of parenting behavior, De Vries and his colleagues decided to compare the prairie vole and the meadow vole. Like the montane vole, the meadow vole leads a polygamous life in which child-rearing duties are left to the female.

In a recently published study, De Vries and his colleagues found evidence suggesting that soon after mating, certain nerve cells that manufacture vasopressin become hyperactive. He suspects the cells dump a load of this hormone into the limbic system, part of the brain responsible for primitive emotions. This may ready the male for his upcoming parenting duties, De Vries adds.

To test this hypothesis, the Massachusetts team first decided to study a single virgin male prairie vole. They injected vasopressin into this rodent's lateral septum, a part of the limbic system. Normally, such virgin animals show little or no parental behavior if placed in a cage with a vole youngster. But this test vole immediately went right up to the pup and started cuddling.

"It was quite amazing," De Vries recalls. "We thought we might be on to something."

They decided to run the same test on a group of male prairie voles, all of whom were sexually naive. Each male in the experimental group received a shot of vasopressin delivered to the lateral septum. A second group of rodents got injections of a chemical that blocks vasopressin's action, and a third group received a shot of saline solution.

Immediately after giving the injections, the team placed each male rodent in a clean, dry cage with a very young vole pup. The male voles that got the vasopressin spent significantly more time in fatherly pursuits than their peers. Specifically, they groomed or cuddled with the young pups more often than those that had received injections of saline solution or the vasopressin blocker.

In contrast, the voles that received the saline or blocker acted like bachelors: They paid little attention to the pups and in several cases actually attacked them.

The team will detail those findings in an upcoming PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES.

There's a lot of uncertainty about the implications of these findings. De Vries speculates that vasopressin may act as a master switch in the brain. Researchers know that vasopressin released by the pituitary fine-tunes the body's water content and blood pressure. And recent work by Insel, De Vries, and others suggests that prairie voles, and perhaps other mammals, have co-opted this brain hormone to govern a host of complex behaviors.

Take the vole's penchant for protecting its mate. When the male prairie vole spies an intruder, nerve cells may begin to churn out vasopressin, which in a fraction of a second docks with neurons in the limbic system. That chemical message somehow triggers the unusual mate-guarding action.

"And that behavior has some of the properties that some more primitive functions do," Carter points out, noting that the target cells are located in the limbic system, a very old region of the brain involved with instinctual behaviors.

Vasopressin may not work alone to trigger such complex actions. De Vries speculates that it works in concert with other brain hormones to yield vastly different behaviors.

It's tempting to view vasopressin as a hormone that could transform men into the kind of guys who protect their families fiercely yet are gentle caretakers when it comes to their kids. However, scientists caution that what works for voles may not apply to humans.

"Making the jump from vole to human is dangerous at best," Winslow says, noting that voles are virtually slaves to their brain chemistry. Humans, on the other hand, experience environmental and cultural influences that appear to play a large role in their sexual and parenting behaviors.

Nevertheless, the research may lead to a human payoff. Insel speculates that brain hormones may play a part in certain bonding disorders, such as autism and schizophrenia. In the future, drug designers may develop synthetic hormones to promote bonding in the autistic child, who has extreme difficulty forming social attachments, he adds. And such an approach might also work for schizophrenics, who can be socially isolated, Insel says.

To the layperson, the study of vole society may seem like a frivolous occupation. Such studies undoubtedly reveal the fascinating details of a vole's sex life, but so what?

According to Carter and other neuroscientists in the field, research on voles is uncovering important clues to how brain hormones influence complex social attachments. "By studying animal behavior, we are beginning to see the emergence of patterns of hormone usage," she says. Furthermore, by charting the course of such brain hormones in the rodent world, scientists hope to find additional pieces to the puzzle of what makes humans tick. □

Continued from p.363

women report having masturbated at some time in their lives, at least in the United States and Canada. Mary Beth Oliver of Virginia Polytechnic Institute and State University in Blacksburg and Janet Shibley Hyde of the University of Wisconsin-Madison present these findings in the July PSYCHOLOGICAL BULLETIN.

Sociologists proposed 20 years ago that masturbation lies at the root of many gender differences in sexuality. They held that adolescent boys first focus their sexuality on masturbation and thus learn to associate sexuality with individual pleasure; adolescent girls' earliest experiences with sexuality usually involve a male partner, which promotes a focus on the quality of relationships.

Evolutionary theorists do not usually address sex differences in masturbation. However, Robin Baker and Mark Bellis, both biologists at the University of Manchester in England, propose that ejaculation through any means removes old sperm and allows younger, more active sperm to accumulate. In the absence of sex with a partner, masturbation makes sense after a few days as a way to maintain a potent store of sperm, Baker and Bellis contend. The capacity to masturbate fairly frequently may have evolved in prehistoric males, who faced many uncertainties about whether a female partner had recently mated with someone else, they note.

Cher: I'm losing my appetite.

Me: Seeing as how I've done most of the talking, maybe you could do me a favor. How about singing a chorus of that classic love song "I Got You, Babe"?

Cher: Dream on, buster.

At that point I woke up, my stomach grumbling. I craved a pizza. Love and sex stoke a hunger deep inside. Even if you just dream them up. □