Norway Rat Behavior Repertoire

An informal description of rat behavior

THE ACTORS

The rats who have performed most of these behaviors for me are my three male rats, Cricket, Widget and Snip. Here they are at 7 months old:

To tell them apart in the following photographs:

- **Snip** is the black hooded rat (white with a black head and broken dorsal stripe).
- **Cricket** is a black berkshire (black with a white belly), with a white stripe on his forehead and smooth fur.
- **Widget** is a black berkshire too, but he has wavy rex fur. His head markings are also different from Cricket's, for Widget has an all-black forehead and a white spot on the left side of his nose. Widget also has a mild head tilt, which does not bother him but causes his head to tilt slightly to his right.

SOCIAL BEHAVIOR

Agonistic Behavior

A quick note: "agonistic behavior" refers to the complex of aggression, appeasement and avoidance behavior that occurs between members of the same species. Agonistic behavior is a much broader term than "aggression," which refers to behavior patterns which serve to intimidate or damage another (for more, see McFarland, 1982).

For a more detailed article on this topic, see Aggression in Norway rats.

Social agonistic behavior

Rats are social animals, and they establish and maintain simple dominance hierarchies through social agonistic behavior. Such hierarchies generally consist of one dominant individual and several subordinates.

Most social agonistic behavior in pet rats is seen between males, but it may also occur between females. In males, social aggression increases around age 6 months.

• Agonistic behavior sequences

Agonistic behaviors are strung together into sequences that vary in their intensity and duration. The lowest intensity encouters are chases. As the intensity increases, you may see stand-offs and physical contact like boxing and sidling. These physical encounters may escalate in rare instances into a fight.

The immediate "goal" of much offensive behavior is for one rat to deliver a bite to the subordinate rat's rump, while the "goal" of the defending rat is to prevent such a bite.

Aggressive neck grooming is a form of agonistic behavior. Grooming consists of rapid little nibbles in which the groomer seizes folds of neck skin between his teeth (Miczek and Boer 2004). The groomed rat remains immoble and may peep or squeak softly. Any sudden movement by the groomed rat may trigger a bite and kick from the groomer.

Many agonistic interactions consist of one rat chasing another for a few seconds. The chased rat flees and either outruns or hides from the pursuer, or sometimes the pursuer desists. If the pursuer catches up, he may nip or bite the rump of the fleeing rat and may attempt to engage him in an encounter. Sometimes, the pursuer may mount the fleeing rat. The aggressing rat may also engage in aggressive neck grooming.

If the chased rat holds his ground, chaser and chasee may have an encounter. A pursued rat may turn to face the pursuer, initiating a nose-off. The defending rat may show an open-mouth tooth display, with long squeaks and sometimes hisses. Sometimes the tails of both rats writhe on the ground, and both rats' fur may be piloerect. Frequently the encounter goes no further, and one of the rats (usually the pursued one) flees.

If neither rat flees, the encounter may escalate with physical contact. The rats may box and/or sidle, and if the sidling rat gets very close he may push or kick out with a hind foot. The subordinate rat, especially if he is young or the rats are confined in a cage, may roll over into a belly-up roll. I've found among my rats that most of the few encounters that get this far end here, with the flight of the pursued rat. After the flight another sequence may occur, and on a few occasions combinations of chases, sidling, and flight have lasted for tens of minutes or even an hour or more (these tense times are known as "Widget rampages").

A variation on the sidle sequence is seen on ledges such as shelves and hammocks. On ledges, the sidling rat crowds the other toward the edge. This may be a very slow process, with the sidling rat maneuvering a fraction of an inch at a time, with long pauses when nobody moves. If the second rat does not jump off the ledge himself, he will be pushed off. Sometimes the pursuer will follow the second rat around the cage, pushing him off ledge after ledge. If the second rat resists, the encounter may escalate.

Rarely, physical contact may escalate into a fight. On a handful of occasions the encounter escalates beyond the sidle-and-kick stage, and the two rats close into a fighting ball, in which the attacking rat may bite the other's flank or rump. These fights are usually brief (lasting just a few seconds) and end with one rat fleeing, hiding and staying staying quiet and subdued for a while -- an hour or more.

For more on rat aggression, see Blanchard *et al.* 1975, Blanchard and Blanchard 1977, Blanchard *et al.* 1977.

• Observations of agonistic behavior in my own rats

Their first year: Widget emerged as the dominant rat in the cage. Widget directed most of his aggression toward Snip and chases were common. During a chase Snip typically retreated to the cage, which has a single door in the roof. Widget usually stopped his pursuit before climbing the cage wall (with his head tilt, Widget is not as agile a climber as Snip). If Widget chased him out of the cage, Snip had favorite hiding places in the room. His first hiding place was on top of a computer that rested on the floor. One day, Widget managed to climb the computer and forcibly pushed Snip off the computer. Both rats fell, fighting, to the floor. They separated on impact and neither was hurt, but Snip never retreated to the computer again, his safe spot had been violated. He chose my office chair as a new hiding place and and rested high up there where Widget couldn't reach him.

However, sometimes Snip actually seemed to seek Widget out to trigger an encounter. On at least two occasions, Widget's "rampage" was dying down, and Snip appeared to prolong the conflict. Snip blocked Widget's exit from the nestbox, confronted him elsewhere in the cage, and then followed Widget closely. Snip did not employ dominant tactics, however. No sidling or lateral pushing or biting Widget's rump. Intstead, Snip's actions triggered close nose-offs and boxing encounters, during which Snip repeatedly nipped Widget's nose. Sometimes Snip pushed Widget over with his front feet while boxing, and groomed and nipped Widget's belly, while Widget squeaked short squeaks. After fifteen minutes of this, Widget went seriously on the offensive again, chased Snip around the cage and cornered him. Snip emitted long squeaks and 20 kHz ultrasound squeaks (barely audible) and hissed and both rats chattered their teeth, then Widget attacked and bit Snip. Snip's use of defensive

tactics in these encounters with Widget is not because Snip does not know offensive tactics. I have seen Snip use offensive tactics against Cricket several times. Snip chases, sidles, and kicks at Cricket... he just never does this to Widget.

During this first year, Widget bit Snip twice: at age 4.5 months he bit Snip on the rump, and at age 7 months he bit Snip on the side of the belly. Both wounds healed uneventfully. I noticed that these bites tended to occur when Snip was cornered and could not escape Widget (e.g. inside a nestbox, corner of a high shelf). I responded by eliminating places where a rat could get cornered: I cut four holes in each nestbox so a rat inside could escape from any angle, and I slung a hammock below the high shelf so a cornered rat could always jump down to safety. Widget continued to chase Snip, but Snip was rarely cornered again.

Age one year and beyond: As the rats approached one year of age, these aggressive encounters escalated, especially between Widget and Snip. I heard distressed squeaking and saw boxing and sidling almost every day. During free-range time, Widget chased Snip and Cricket so much that they spent all their time hiding in the cage while Widget had the run of the entire floor.

At 11.5 months, things came to a head. Widget bit Cricket on the scrotum, opening an inch long gash. While Cricket was recovering in another cage, Widget bit Snip twice on the hind legs (on the knee and lower leg), drawing blood, and in self defense Snip bit Widget on the face just under the eye. After these bites I separated Widget permanently from the other two rats. He now lives in a separate cage next door to theirs. Snip and Cricket get along well, displaying only mild aggression, and have never bitten each other.

Widget now has free range time at a different time from the two other rats. Snip and Cricket, instead of hiding in the cage, now spend their free range time exploring and running about.

Interestingly, during free range times in the months after Widget's separation, Widget and Snip still engaged in nose-offs through the bars of the cage (Widget sought out Snip, Snip sought out Widget). Snip would squeak piteously, and frequently hissed. They sometimes lunged at each other as well, but could not make contact due to the cage bars (for pictures of these between-the-bars altercations, see the photos under hiss)

Snip, the omega rat in the original threesome (Cricket was a beta) became the dominant rat in the little Snip-Cricket twosome. Snip chases Cricket and sometimes sidles and kicks him, but these encounters are uncommon, brief, and not very intense. Cricket emits a few squeaks sometimes but rarely seems perturbed.

Snip and Cricket have fought only once since Widget's separation, when Widget had a nose-off with Snip through the cage bars. Snip became distressed, displaying piloerect fur and prolonged squeaking for several minutes. Snip then turned and attacked Cricket. Nobody was hurt, but after incident I put both rat cages on stands, raising them about a foot off the ground, making such between-the-bars encounters impossible. There have been no encounters and no fights since then.

Maternal aggression

A different category of rat aggression is maternal aggression, in which a pregnant or lactating mother rat attacks intruders (other rats, humans, or other animals).

Maternal aggression can include a lunging attack, typically directed at the neck or back of an intruding rat. The mother rat may also bite, sidle, and kick (thrust of one hind leg toward intruder during a sidle). Intruders usually respond with nose-offs or belly-up postures (Erskine *et al.* 1978) . Mother rats may also attempt to drag the intruder by the neck or side (Price and Belanger 1977).

Maternal aggression is present but occurs relatively infrequently at the end of pregnancy, and starts to increase after the birth of the litter. Maternal aggression peaks during the 9th day of lactation. On the ninth day, the highest percentage of females attacks and bites intruders, with the lowest hesitation before doing so. After the ninth day, maternal aggression declines (Erskine *et al.* 1978).

The presence of the litter is an important in triggering maternal aggression: if the litter is removed the mother rat's aggression subsequently decreases. Four hours after the litter's removal, the mother rat's aggression is down to nearly normal levels (Erskine *et al.* 1978).

Maternal aggression may discourage other animals from approaching and possibly harming her offpsring (e.g. predators, unfamiliar rats who could commit infanticide).

Play fighting

To me, as a rat owner, young rat play involved a lot of chasing, fleeing, rolling over, jumping on each other and, as they grew a bit older, boxing and sidling. There didn't appear to be too much pattern to it to me as a casual observer, with the three rats playing with each other in all combinations. Over time, however, one rat (Widget) appeared to come out on top more often. As the rats grew older, they started fighting seriously, using some of the same behaviors, as well as boxing, sidling, nipping and biting.

I got interested in rat play after my rats had stopped play-fighting so much, and so I did a search in the library to see what I could find. There is a wealth of information out there on rat play! Here's what I found:

Young rats play intensely with each other: they chase and flee, roll over and box, jump on each other and bounce around the cage. In fact, they use many of the same behavioral sequences we see later in agonistic encounters.

Play fighting in rats is different from adult fighting, however, in that it targets a different area of the body and may involve different tactics. Play fighting involves attack and defense of the *nape*, while serious fighting involves attack -- with intent to bite -- and defense of the *rump*.

Fig 1. Play fighting in young rats: attack on nape

Fig 2: Sequence of play fighting in young rats, with attempts to attack & defend the nape

Fig 3: Breaking free of nape hold with lateral movement.

Fig 4. Serious fighting sequence in adult rats: sidling attack on flank

Pellis and Pellis. 1987. ref

Juveniles and subordinate adults defend against nape attacks by (among other tactics) rolling over into the supine position (belly-up roll) which hides the nape and rump from the attacker. The attacker may stand over the supine rat and may nibble at the sides of the belly (belly grooming), attempting to reach the nape. The pinned rat may peep and squeak.

Adult dominance hierarchies can be predicted from this juvenile play fighting: oddly enough, the most frequent juvenile play-attacker becomes the *subordinate* rat after sexual maturity. This reversal is due to the least-frequent-attackers' emerging proficiency at defense and successful counterattack, namely, switching from the belly-up roll to the forequarter pivot when attacked.

Play fighting serves a social maintenance function in both juveniles and adults. Subordinates direct more playful contacts at dominant rat than at each other. Directing such playful attacks on the dominant rat may lead the dominant rat to tolerate the subordinate's presence. As adults, the dominant rat tends to evade these encounters with adult defense tactics (forequarter pivot).

Subordinate rats, when playfully attacked by the dominant rat, roll over into the juvenile defense position. (the supine rat is usually a subordinate, but I have occasionally seen the dominant on his back before a subordinate too). The recumbent rat may make a few efforts to get up and may be pushed back again. These encounters usually end when the top rat desists and the supine rat rolls onto his feet. Usually the encounter goes no further and the pinned rat does not flee once he gets to his feet. On one occasion, however, I observed a belly-groom escalate into a fight, when both rats were confined in a small travel cage.

Not all subordinates are the same. Some initiate many playful contacts with the dominant, and in turn tend to be tolerated by him. Others avoid the dominant and are more frequently attacked by him when he encounters them. These avoiders are more likely to rise to the dominant position if the dominant rat is removed.

For those who are interested, here's a more detailed description of play in rats. And, for more on animal play in general, see Burghardt 1999.

- Barnett 1975
- Blanchard and Blanchard 1977, 1990
- Panksepp, Jaak 1981
- Pellis and Pellis 1987, 1991, 1992
- Pellis, Pellis, and McKenna 1993

Allogrooming

(Allogrooming means grooming another individual, as opposed to autogrooming, or grooming oneself.)

Rats groom each other in a number of contexts. Nibbling and snout-touching directed at the nape may be the consumatory phase of play fighting, and the nibbled rat may submit to the grooming or may protest with peeps and squeaks and may pull away. Sometimes, to protect his nape and rump, one rat may roll over, leaving his belly exposed to belly-grooming.

Head and body grooming, especially directed at the eyes and mouth, may serve a health function, as the groomed rat cannot reach these areas with his tongue and teeth. Head and body grooming may be an amicable social behavior that maintains ties between members of a group (which is also a function of play fighting), and may help to spread a common scent. It may function as olfactory investigation of the sebum from the dorsal surface of the rat. Sometimes the groomed rat protests with peeps and squeaks.

In my own rats, I see most head and body grooming between my two subordinate rats, Snip and Cricket. Less frequently, I see head and body grooming between one of them and the dominant rat, Widget.

Communication

Vocal Communication

Audible rat sounds: Rats produce a variety of audible vocalizations, from soft peeps and squeaks to loud shrieks. Many of the vocalizations, such as peeps and short squeaks and their variants, occur during mild social interactions such as play fighting or head grooming. Most audible squeaks and peeps indicate protest. Long squeaks tend to indicate stronger protest, and hissing occurs during escalated conflict. Rats shriek during fights, when they are in pain, or to indicate very strong protest.

Rats also grind their incisors together in a soft, rhythmic fashion, called bruxing. The movement is caused by the the jaw muscles pulling the jaw rapidly and repeatedly upward so that the incisors grind against each other. During high intensity bruxing, the masseter muscle, which runs through the rat's eye socket, may vibrate the eyeball in and out in time with the jaw, a phenomenon known as "eye boggling." The muscular activity involved in bruxing is quite different from that seen in chewing, and may involve a separate neural pattern generator (Byrd 1997).

Rats may brux to sharpen their incisors, called *thegosis* (Murray and Sanson 1998). Rat incisors grow the rat's entire life, and are ground down through gnawing and bruxing. Anecdotally, rats brux during times of relaxation, while rat is alone or sometimes while being gently stroked. Rats

also brux during stress and uncertainty (Rosales *et al.* 2002, Pohto 1979). Bruxing during stressful situations, such as tense social interactions, is often called chattering. Chattering may be louder than bruxing and may contain more sharp cracking sounds. However, it is unclear whether bruxing and chattering are distinct sounds, or whether they are the same sound given in different contexts. A spectral analysis would help answer this question.

To read more about bruxing and hear bruxing samples, go to the Norway Rat Vocalizations Page.

Ultrasonic vocalizations: Rats also emit a number of vocalizations in the ultrasonic range, above our level of hearing (>20 kHz). Ultrasonic vocalizations include infant distress calls (around 30-50 kHz), long distress calls (around 20 kHz), and short, positive high pitched chirps (around 50 kHz). These high-pitched chirps have generated a lot of interest: here's an article on "laughing in rats" as well as a summary article written by the researchers. We cannot hear these sounds, but they can be recorded and replayed at our level of hearing using a bat detector. For more, see Bclee's Rat Detector Project.

Twenty kHz is at the very upper limits of our range of hearing. During a tense nose-off between Widget and Snip, I bent down close to them and heard a series of barely audible, high-pitched squeaks which might have been long distress USVs. I was amazed -- the rats were perfectly still and it looked like nothing was happening, but in reality a whole barrage of communication was going on that I could barely detect!

A month later, I was recording squeaks while Widget and Snip boxed and nosed-off in the cage. The encounter got more intense, Snip emitted long squeaks and hisses, and both rats chattered their teeth. Widget attacked and I immediately broke it up. Later, looking at sonograms of the recordings, I saw a whole series of long, high pitched squeaks just above 20 kHz, right at the top of what my microphone could detect. Snip had been squeaking in ultrasound.

For descriptions, recordings, and sonograms of rat sounds, visit my Norway Rat Vocalizations page.

Olfactory Communication

Sexually mature rats, especially males, deposit tiny droplets of urine on surfaces and objects they walk on, known as urine marking. Rats prefer to mark surfaces and objects they can readily walk on, and their marking behavior increases dramatically when they encounter an unfamiliar odor (Hopp and Timberlake 1983). Male rats prefer to urine mark over the odors of other adult rats, and neutered animals mark very little (Brown 1975, 1977).

In general, urine marking is considered a form of advertisement of one's presence and a sex attractant. Doty (1974) hypothesizes that male rats advertise and the female selects her mate from among the advertisers. Female rats advertise themselves through urine marking as well, though at much lower rates than males. Females urine mark the most on the night before estrus (Birke, 1978; Calhoun 1962, p. 151). Male rats find the urine and sebaceous odors of females to be highly attractive (Sachs 1997; Pfaff *et al.* 1973) so the female may be advertising her availability and receptivity to potential mates.

Urine marking isn't the only kind of chemical communication between rats. Rats have scent glands on their flanks, and they rub this scent on objects in their environment (known as flank marking). Males flank mark more than females, and rats flank mark more when they can smell other rats (Peden and Timberlake 1990).

For more, see the rat's world of smell, and urine marking in Norway rats.

REPRODUCTIVE BEHAVIOR

Female rats

Female rat ovarian cycle: The female rat's cycle is divided into several phases: **proestrus**, which lasts 12 hours, corresponds to the onset of mating behavior, known as *behavioral estrus*, or *heat.* The female *ovulates* at the end of proestrus and thus enters **estrus**, which lasts 36 hours. After estrus she enters **diestrus**, a 48 hour period that is subdivided into *diestrus I* (first 24 hours) and *diestrus II* (second 24 hours). After diestrus, she enters proestrus again.

Proestrus	--> ovulation	--> estrus	--> diestrus
12 hours		36 hrs	48 hrs

Female rat mating behavior: During **proestrus**, or behavioral estrus, the female solicits the male to prompt him into mounting her. She darts toward him and runs or hops away. She may repeat this approach-retreat sequence several times, sometimes wiggling her ears. She may also pause near him or run by him, and may intercept him in his pursuit of another female. The male finds these solicitation behaviors very attractive, and follows the female. He mounts her, and the pressure he exerts on her flanks, lower back, and anogenital area triggers lordosis in the female rat (Nelson 1995).

Lordosis is the female mating posture, in which she stands stiff and immobile, her back arched downward, her rump elevated, her tail deflected to one side, and her vulva facing backwards. Without lordosis copulation is not possible. After copulation, the female leaves the mating posture. She may groom herself or the male, she may walk about, or rest (Nelson 1995).

Male rats

Male hormones and reproductive behavior: Male sex drive is expressed after puberty, when the testes become active and start to secrete a hormone called *testosterone*. Testosterone does not cause reproductive behavior outright so much as it increases the liklihood of reproductive behavior occuring in a particular context, such as in the presence of a receptive female. A male with high testosterone levels is more likely to copulate with a receptive female than a male with low testosterone levels. Castration, which removes the testes and thus the source of testosterone, greatly reduces sexual responsiveness.

Male rat mating behavior: Prior to mounting, the male engages in *precopulatory behavior*: he investigates the female, sniffs her mouth and anogenital region. Then he *mounts* her, and if she is in heat, she will exhibit the lordosis posture, which makes intromission possible. *Intromission*, when the male reproductive organ enters that of the female, is accompanied by thrusting motions of the hindquarters. The male's spine may arch and his forepaws may lift off the female's back. Intromission is followed by *ejaculation*, the foreceful expulsion of seminal fluid from the male's body through the urethra. A *sperm plug* may be deposited in the vagina, which serves to block intromission by other males for a while, thus giving the current male's sperm more time to fertilize the female. After mating, the male may emit ultrasonic vocalizations, and he becomes sexually inactive and lethargic. He may groom himself, then lie down and sleep (Nelson 1995).

PARENTAL BEHAVIOR

Maternal behavior

Pregnant female rats choose a nest site and build a nest before the young are born. Once the young are born, mother rats must perform three parental behaviors if the young are to survive:

- lick their pups to clean them of amniotic fluid and to stimulate the elimination of wastes.
- adopt the nursing posture, crouching over the pups to facilitate nursing, and protect and warm them
- retrieve the pups if they leave the nest (e.g. Smith and Berkson 1973)

To facilitate the first nursing by newborn pups, the mother rat licks her vulva and and belly during birth, spreading amniotic fluid onto her belly. The odor of the amniotic fluid attracts the newborn rats to her nipples. As the pups age, the odor of their own saliva and that of their littermates and mother keeps attracting them back to the nipples.

A mother of young pups may also exhibit maternal aggression, characterized by attacks directed at any animal who approaches her nest and young. Such attacks may discourage other animals from approaching and possibly harming her offspring.

The **onset** of maternal behavior is influenced by hormones and by experience with pups.

Hormones play an important role in influencing maternal behavior, but the exact relationship between the many hormones involved and maternal behavior is not yet fully understood. Prolactin, a hormone closely associated with lactation, is known to be important, but many other hormones are also involved (see Nelson 1995 for more).

Exposure to pups also plays a role. Maternal behavior may be triggered in non-mother female rats through repeated daily exposure to foster pups (a process called *concaveation*). In females who have never had litters, this process takes 5-6 days. Females who have had litters in the previous weeks have much lower latencies, however, and behave maternally toward foster pups after a day (Bridges 1990).

Maternal behavior is **maintained** by tactile stimulation. Many maternal behaviors involve the mouth (licking, pup retrieval, nest building), and are drastically reduced if the mother's muzzle is anesthetized (Stern 1989). The nursing posture is maintained through the stimulation of the young rooting against the nipples, if the mother's nipples are anesthetized she will not adopt the nursing posture (Stern *et al.* 1992). If the pups' mouths are anesthetized so that they do not root up against the mother, then an unanesthetized mother will not adopt the nursing posture either (Stern and Johnson 1990).

As the pups grow older, there is more mutually initiated contact between them and their mother. Around 14-16 days of age, the pups begin to explore the world outside the nest. The pups return to the nest guided by a chemical signal produced by the mother from days 15-27 of lactation (Leon and Moltz 1972).

Over time, mother-offspring contact declines, and maternal care **wanes**. The waning of maternal care is in part regulated by the mother's body temperature and her need to dissipate heat. A mother crouching over a litter cannot dissipate heat. As the pups grow older, they retain heat more efficiently, so the mother spends shorter and shorter bouts of time in the nest with them and avoids overheating herself (Woodside and Leon 1980).

Further reading: Nelson 1995.

Wild vs. domestic maternal behavior: Domestication has had relatively little impact on maternal behavior: maternal behavior of domestic rats is qualitiatively similar to that of wild rats. Both wild and domestic mothers nurse, retrieve pups, build nests, and display maternal aggression. There are some quantitative differences, however: wild rats are more efficient at pup retrieval (wild mothers retreive more pups after they are scattered, and retrieve them more quickly). Domestic mothers spend more time building their nest and build bigger nests in a short period of time. Wild rats end up building equally large nests, but it takes them longer.

Communal nesting: Two or more mother rats may also pool their litters in a single nest and raise them together. My own rats were the product of a communal nesting situation: three females and two males were relinquished to the local humane society and were accidentally combined in a single cage. All three females became pregnant and all five rats were taken in by a local rat rescue organization. One of the females didn't lactate,

so the remaining two mothers raised the three litters together. It was impossible to tell which litter was which, and impossible to know whether the parents were related to each other. My three male rats are therefore some combination of full siblings, half siblings, and unrelated.

For more on communal nesting, see separate article entitled Communal nesting and nursing in the Norway rat.

Paternal behavior

Before weaning: Schultz and Lore (1993) studied nesting in groups of three adult rats: two females and one male. The females gave birth to two litters sired by the male. The male did not kill or harm the baby rats, but he did not care for them either: the male never attended to them or provided parental care. In fact, he rarely approached them at all. If he did so, he was severely attacked by the mothers. Most of the males spent spent their time alone in a corner of the cage, and by the time the pups were weaned all the males had been wounded.

The presence of the father had no effect on the success of the litters: mothers with and without the fathers present gave birth to the same number of pups, and raised the same percentage of pups to weaning, and spent similar amounts of time with their pups.

After weaning: Almost all studies of parental behavior in rats focus on the mother. Usually, the father isn't even present. The few studies that consider the father examine his behavior during his pups' infancy, when he is marginalized by the mother. Almost no studies examine the interactions between adult males and their juvenile offspring after weaning, even though it is highly unlikely that juvenile rats are socialized in the absence of adult males in the wild.

Drews et al. (1982) examines social behavior in family groups consisting of adult females, adult males, and their post-weaning young. The authors recorded the behavior of all the rats in the family groups during three 8 days observation cycles starting when the rats were 25, 60, and 79 days old.

Rat families were quite amicable. There was no wounding or biting between any of the rats. Threat displays were extremely rare, and tended to be given by young males toward other young males. Juvenile behavior graded seamlessly into adult behavior without any qualitative change: the forms of the behaviors didn't change, only their frequencies.

On the whole, all the rats wrestled, boxed, pinned chased and mounted each other. However, the frequencies of these behaviors changed over time in the different age-sex groups.

Juveniles **wrestled** together a great deal. To a lesser extent, adults wrestled with juveniles. Only half the wrestling bouts had a discernable winner. Of these, adult males usually won. Juvenile males won next most often, followed by juvenile females. Adult females usually lost. **Boxing** was relatively rare, and winners were hard to discern, but once again when winners could be discerned adult males consistently won. Juvenile males won less over time, while juvenile females won more as they grew older. **Chasing** increased over time too. Young females chased more than adult females, but overall chasing was a male activity. By the end of the study adult males were doing most of the chasing. **Mounting** increased over time, and by the end of the study adult males were doing most of the mounting. Juveniles were more likely to **initiate interactions** than adults, and males more than females.

In all, juvenile males are slower to make the transition from juvenile to adult behavior when their fathers are present. When fathers are absent, at about age 40 days juveniles start to wrestle less and box more, mount others, threaten each other, and begin to establish stable dominance hierarchies (Meany and Stewart 1981). When fathers are present, however, these changes are delayed: juvenile males continue to wrestle, they mount more but not as much as young rats without fathers, and stable dominance hierarchies haven't emerged even by 87 days. The presence of fathers may be responsible: fathers engage in wrestling and boxing with their offspring (and consistently win these encounters), and by the end fathers are doing most of the chasing and mounting (Drews *et al.* 1982). Therefore, juvenile dominance and sexual behaviors may emerge more slowly when adult males are present and account for most of the dominance and sexual behaviors. Adult males also interact more with the juveniles than the adult females do, and may therefore play an important role in the socialization of young rats.

FEEDING and DRINKING

How do rats choose what to eat?

How rats choose what to eat is a large, well-studied area in animal behavior. Rats are omnivores, and can potentially eat just about anything. This ability to eat anything makes them very flexible (unlike, say, the panda which eats mostly bamboo) and able to live in a huge variety of enviroments. Rats aren't "pre-programmed" to eat certain foods; each rat needs to figure out what to eat in its own environment.

However, one major danger of being able to eat anything is that there are a lot of poisonous foods out there, and a mistake can be fatal. How does a young rat decide which foods are good, and which are dangerous? Well, choosing the foods that other rats have eaten is a pretty good rule of thumb. Amazingly, this learning process happens at many different stages:

* *Fetal rats* detect odor-bearing chemicals that come from the mother's diet and cross the placental barrier. Shortly after birth, newborn rats will respond positively to those foods.

* *Nursing rats* receive information through their mother's milk about what their mother is eating, and prefer those foods.

* Later, when *young rats* are weaning and finding their own meals for the first time, they use adults of their colony as guides and forage where adults are eating, or at sites where adults have previously scent-marked.

* In *adolescence and adulthood*, when rats forage independently, their food choices can be influenced by social factors that occur in the home burrow far from feeding sites. The scent of foods recently eaten, carried on fur, whiskers, and breath of a forager can profoundly influence food choices in the rats that forager interacts with.

(Galef 1996)

In addition, rats can learn what foods to avoid by experience. When a rat encounters a new food, he may sample just a small piece of it. If he becomes ill, he will associate the food with the illness and will avoid that food in the future (Garcia and Keolling 1966).

Fore more, see expanded article "How do rats choose what to eat?"

Eating and drinking

Many rats cache their food. Caching makes a lot of adaptive sense, because food sources for the rats' wild ancestors may not have been constant, so securing and hiding food for later would be an important survival strategy. It is only in the captive environment that rats are fed an abundance of food regularly in the same location as the day before.

Rats eat by holding small items of food in their forepaws, and by eating large items straight from the ground.

Most domestic rats drink from water bottles, licking the water off the metal ball at the end of the waterspout. As they lick they briefly press the ball back into the spout with their tongue, which releases another drop of water that coats the metal ball. Rats may also lap standing water from a dish.

Pica: eating of non-nutritive substances

Rats cannot vomit; they respond to nausea by eating non-nutritive substances (an activity called *pica*) like clay, dirt, and sometimes even bedding (Mitchell 1976, Mitchell *et al.* 1977a, b, c, Morita *et al.* 1988b, Clark *et al.* 1997)). Pica may be an adaptive response to nausea because nausea is frequently caused by a toxin: the non-nutritive substances (especially clay) may help dilute the toxin's effect on the body (e.g. Philips *et al.* 1995, Philips 1999, Sarr *et al.* 1995).

PREDATORY BEHAVIOR

While the majority of a rat's diet consists of plant materials, rats also prey on other animals, which they hunt, chase, kill and consume. Rats are quite adaptable in their food preferences and are known to kill and eat a wide variety of small animals, including **invertebrates** (Strecker *et al.* 1962), **other rodents** (Hsuchou *et al.* 2002), **bats** (Villa 1982), **birds** (Atkinson 1985, Austin 1948, Drever and Harestad 1998, Harfenist 1994, Heather *et al.* 2002, Johnstone 1985, Moira *et al.* 1999, Moors 1985), **amphibians** and **reptiles** (Newman 1986, Whitaker 1978).

A common sequence of predatory behavior includes:

detection of prey --> chase --> bite --> kill --> manipulate --> eat

While the overall behavioral sequence stays relatively constant, it may be modified depending on the kind of prey. When a rat hunts and kills a cricket or other similar insect, the rat pursues the cricket, and may pin it down, bite it, pick it up with its forepaws, bite the head, remove the legs and wings, and eat the head and body (Ivanco 1996). When a rat hunts and kills a mouse, the rat pursues the mouse and, penetrating the mouse's behavioral defenses, bites the mouse on the head, neck or upper back until it delivers a fatal bite. The first bite is frequently fatal (Hsuchou *et al.* 2002; more on muricide).

The adaptability and effectiveness of the rat's predatory behavior are some of the reasons rats are a major conservation concern: when rats invade and establish themselves in a new habitat, they prey on indigenous wildlife. Rats may drastically reduce the numbers and reproductive success of local species, and may drive some species to extinction.

LOCOMOTION

Newborn rats cannot walk -- they "air-step" and "swim" with their paws. They don't have the balance (vestibular system), neural connections, or postural reflexes that are required for walking, and cannot lift their trunk from the ground. They can only lift their head. In just a few days, however, they start to crawl. Between days 3 and 10 their nervous system starts to develop the ability to walk quadrupedally. During this phase they take longer "steps," they start to coordinate their legs such that the front left left and hind right leg (and vice versa) advance together, and their foot position starts to change (Jamon and Clarac 1998). They can also groom and rear up, but they need to support themselves with a foreleg (Geisler *et al.* 1993). By two weeks of age, the baby rat's vestibular system, and neural connections between the brain stem and lower back are completed (Clarac *et al.* 1998). By day 16, baby rats can walk like adults, and can groom and rear on their hind legs without support (Geisler *et al.* 1993).

Juvenile and adult rats walk, trot, gallop, and when particularly exuberant, bound to get from place to place. Rats increase their speed by taking longer, faster strides (Clarke 1991, Cohen and Gans 1975).

As rats age, they hold their legs farther apart, take smaller strides and their gait becomes asymmetrical. Exercise can counteract some of these effects of age, however, lengthening the stride and increasing symmetry in elderly rats (Dorner *et al.* 1996).

Rats are also avid climbers, advancing up just about any vertical or slanted surface with a sufficient handhold. Rats climb up more easily then they descend. They descend head first, and appear to have some difficulty controlling their weight and speed on descent. A rat may start a descent and may then jump or fall the rest of the way.

GROOMING

Rats engage in a number of self-grooming activities, which keep the fur and skin clean. The most extensive is the cephalocaudal groom, a grooming sequence that covers the face, flanks and tail and is found in some form or another in all rodents. A less extensive grooming sequence is the nibble. In rare circumstances nibbling may become excessive and turn into self-barbering. Lastly, rats scratch themselves, usually with a hind foot.

GNAWING, CHEWING AND DIGGING

Rats enjoy gnawing. Most hard or soft objects (from wood door frames to pieces of paper to electrical wire) are good for at least a nibble, and possibly much more.

Gnawing and chewing involve all three jaw muscles: the masseter, temporal, and pterygoid muscles. These muscles move the lower jaw up and down and forward and backward.

But gnawing is actually quite different from chewing!

When a rat *gnaws*, its lower jaw shifts forward. This brings the incisors into contact with each other, and the molars out of contact with each other. The upper incisors hold the object, and the lower insisors cut against it. The jaw can move forward like this because:

- The socket in the skull where the lower jaw articulates is elongated and does not have a limiting bony projection (process) that stops the jaw from moving forward.
- Over evolutionary time, the attachment points on the skull of the muscles that move the lower jaw have moved forward toward the nose. This arrangement enables the rat to gnaw very effectively and powerfully. In fact, part of the masseter jaw muscle runs *through* the infraorbital canal, right next to the eyeball. This muscle running through the eye socket is why a rat's eyes vibrate in and out ("eye-boggling") when he bruxes enthusiastically (grinds his incisors up and down rapidly): the masseter muscle pushes against the eyeball (Figure 1).

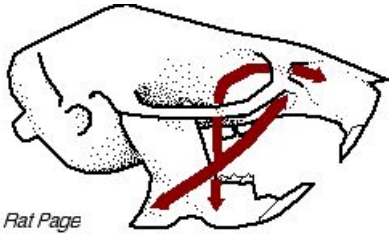

Figure 1. Rat skull, showing the anterior placement of portions of the masseter muscle. The medial masseter muscle passes through the eye socket, right next to the eye, and attaches on the muzzle. This is the muscle that "boggles" the eye when the rat bruxes. The lateral masseter muscle attaches just below and in front of the zygomatic arch. This muscle arrangement enables the rat to pull its lower jaw forward during gnawing, and makes the jaw very powerful.

The fronts of the incisors (the side closest to the lips) are coated with hard enamel, while the backs (the sides closest to the tongue) don't have enamel and are covered in soft dentine. So the incisor wears at an angle, with the back wearing off before the front. This guarantees a sharp cutting edge at the top of the tooth. In some rodents, an iron compound strengthens the enamel even more, which gives the teeth a yellow color.

Rat incisors are rootless and grow continuously, which reflects the rat's adaptation for gnawing: the rat has a constant source of new tooth and does not risk wearing its teeth down to the gum. As a corollary, incisors of rats who cannot gnaw, or whose incisors do not meet, may grow too long. Here's more on rat teeth.

Rats have a small flap of tissue that closes behind the incisors, keeping unwanted debris from entering the mouth. Beavers and naked mole-rats have this flap too, which lets them gnaw with their lips closed underground and underwater.

When a rat *chews*, the jaw is moved back into the chewing position. In this position, the molars are in contact with each other, but the incisors are not. During chewing, food is ground to a pulp between the molars prior to ingestion. For more on the movements of the mandible during chewing, see Weijs 1975.

- More on rodent gnawing morphology and rodent jaws.

DIGGING

Rats can and do dig. Pet rats placed in a dirt box will happily dig. Rats dig holes (typically in corners) by pulling handfulls of dirt backwards with their front paws, making a pile under their stomach. Sometimes the rat's back will arch with the effort, as the rat uses its whole forebody to pull a load backwards. Periodically they clear the accumulated pile by kicking it backwards with their hind feet.

However, most dirt in a "digging box" is too loose to permit real burrow digging. Domestic rats can, however, dig real burrows if given the right environment and opportunity.

Burrowing outdoors: Boice (1977) placed domestic albino rats in an outoor pen. These rats dug burrows successfully, raised young, and founded a population that lived in the pen for two several years. These burrows were indistinguishable from burrows constructed by wild rats. They started with an entrance hold with dirt scattered around half of it, they constructed a nest chamber at the end of the first tunnel, they always constructed a bolt hole, dug from within, from the second tunnel. The diameter, depth, and length of the tunnels and the number of nest chambers were very similar to those of wild rats. Therefore, domestic rats have not lost the ability to burrow even after hundreds of generations in captivity.

Burrowing indoors: Boice also placed domestic and wild rats in glass-sided observation chambers filled with dirt to observe their digging (specifications of Boice's digging boxes). The burrows they dug were largely similar to those dug outdoors (same diameter etc.), but were constrained by the size of the box. The digging-box tunnels were shorter in length, and were placed deeper in the soil. Some burrow systems were elaborate: they might be dug on multiple descending levels or in a circle. Digging behavior improves with experience: rats who had experience in the digging box began digging more quickly, accomplished more complex burrow systems, and were more coordinated (they moved dirt out of the tunnel with a combined action of forefeet and head.)

SLEEPING

Rats sleep about 13-15 hours per day. They tend to be active during twilight hours (crepuscular) or at night (nocturnal).

Rats tend to sleep in sheltered, hidden locations like nestboxes or pockets, in moderately exposed locations like suspended hammocks, or more rarely on hard, exposed places like cage shelves. They may line their nest with bedding material (see separate section under nesting). They may sleep with other rats in a "ratpile", or alone.

Rats sleep in many positions, depending on temperature, location, and hardness of their sleeping spot. Generally, they sleep stretched out (on their stomach, side, or sometimes their back) in warm temperatures, and curled up in cooler temperatures.

Like humans and other mammals, rats have two different kinds of sleep. They have Slow Wave sleep (SV) and Rapid Eye Movement sleep (REM), which is the deepest kind. Rats probably use their REM sleep to make new connections in their brains, consolidating memories - rats that play in a stimulating environment before bedtime show evidence of modifying synaptic connections the next time they go to sleep (see research done at Rockerfeller). Also, rats that run a maze before bedtime appear to replay the maze in their brains, footstep by footstep in approximately real time, when they enter REM sleep. During Slow Wave sleep, they replay segments of the maze in fast-forward. Hence, REM sleep and SW sleep appear to help rats organize and cement what they've learned (see Wilson's work at MIT).

Rats yawn and stretch like we do. For some wonderful photos of rat yawns, check out the Dapper Rat Gallery of Yawns page.

NESTING

Rats drag or carry desirable nesting material in their mouths to their chosen sleeping spot, such as a nestbox or burrow, to build a nest. Domestic rats may use fabric, tissue paper, or shredded cardboard, while wild rats may use leaves and grass. Rats may shred the nest material into smaller sizes, and line the bottom of their nest with it.

Rats produce several types of nest. The *pad* is the simplest kind of nest, and consists of just a few flat objects like leaves or paper. This is the most typical nest built by male rats. A *cup shaped nest* is larger and has low walls, lined with flat, somewhat interwoven objects. A *hooded nest* is the largest, most organized nest. Its walls grow so high they form a ceiling and the nest becomes a hollow sphere with one opening. These nests are sometimes built by mothers for litters.
