# Chapter 9
# Smells Like Teen Spirit

## Growing Up in a World of Flavors and Fragrances

My parents are very active in their church and have an intense love of music and singing. These two areas are married in their long-term involvement in their church choir. My mother is a soprano and my father sings as a tenor. Their choir is a small handful of dutiful parishioners that lead the congregation through the hymns. I do not know if this is common among church choirs in the Midwest, but this little choir always seemed to be lacking male participants. The altos and sopranos outnumbered the male voices almost two to one during the years that I grew up. Compounded on top of this disparity, the number of men singing bass was always fewer than those that sung tenor. As a result of these mismatches, my older brother was drafted to sing as soon as his voiced changed. His singing voice ended up being a tad lower than my father's voice. Really a baritone in voice, he was close enough to augment the meager amount of basses present.

I am close to 2 years the junior of my brother and since the male voices in the choir were not multiplying rapidly, I knew that my fate was also sealed when puberty caused my voice to change. This was really not as bad as I make it sound here. Looking backward, I appreciate the family togetherness that this brought about. The choir was full of friendly people and there was a good sense of belonging to a real community. Yet, at that time, I did not have the pleasure of an adult brain, but that of a redheaded awkward teenager trying to fit in at school. In my mind at the time, singing in the choir was not really building my social status.

Roughly a year and a half after my brother's voice changed, that magical time of physiological adulthood hit and my body changed as a result of puberty. My voice began to alter and drop as most adolescent's boy voices do. During this change, my voice became a little lower than my father's tenor or brother's baritone voice. So my place with the one other bass was secured and we doubled the power of that choir section. My brother, having been freed from forcing his voice lower, left the basses and joined the tenors. I believe that my voice ended up somewhere in between a baritone and bass which is probably not possible. I found myself able to sing the low baritone notes and high bass notes. In addition to the ambiguous nature of my voice, I did not inherit my mother's, father's, or brother's singing ability; I am not sure that



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I helped the cause of my fellow bass. I remember many choir practices where I spent my singing time constantly jumping between the upper bass notes and the lower tenor notes. We had a very kind choir director that tended to overlook my musical transgressions, possibly because I was at least singing some of the bass notes (albeit somewhat off key).

Voice wasn't the only thing changing during this time. The kids around me were at all stages of puberty. The males were starting to grow facial hair and voices were cracking during classes. This time period was the late seventies and the cheesy moustache was a popular addition to the faces of young men. A review of the class photos of that period of time would show different amounts of facial hair and yet, every one of us was quite proud of any little bit of hair that would adorn our upper lips. I think we were all unaware of how truly horrible sparse moustaches or beards would look. These were badges of adulthood proudly displayed like a groups of peacocks with their tails advertising their sexual virility.

For the girls, the most obvious changes centered on the blossoming of their chests. Being a male, I can't imagine that a very public measure of your state of puberty is a socially pleasant thing for young girls to experience. Unlike shaving and facial growth, the girls' experience is not controllable and visible for most all to observe especially around young men with raging hormones. The final experience of puberty that attacks both sexes is the dreaded battle with acne. Just like facial hair, secondary sexual characteristics (breasts), and voice changes, the severity of acne would range greatly across individuals.

The timing of puberty also seemed to have a very wide range across this age group. I seemed to be on the leading edge puberty as I was able to grow a full moustache by the age 11. I do seem to remember a larger young boy named George who seemed to have a full beard by the age of 10. The same spectrum appeared with the opposite sex where some girls had "filled out" far earlier than other girls. Puberty, in humans, can start as early as 8 years old and as late as 13 years old, and some of this variation in the age at which puberty starts is due to the genetics of the parents. Outside of parental genetics, environmental factors such as dietary quality and physical activity also influence when puberty starts. Of course, another very important factor for nonhuman mammals is their odor environment.

Many nonhuman mammals live in varying sizes and structures of social groups and, with social groups, comes differing social odors. Unlike the sexual pheromones described in Chap. 8, these odors are the "everyday" variety that are present because these mammals live in close quarters. The common house mouse (*Mus musculus*) is an excellent example of this case. These animals have quite a flexible social behavior structure that is highly dependent upon the environmental conditions. If found in rich habitats (such as human apartment buildings), mouse populations tend to be hierarchical in nature. This means that there are clear social roles with dominant and subordinate animals. In poor habitats, those with not many shelters or food resources, these mice tend to be territorial and both male and female aggression tends to be heightened. The relatedness of groups also changes across different habitats. Within crowded and resource rich human dwellings, social groups can include both related and non-related individuals, whereas in natural settings, social groups tend to include

only related individuals. The significance of the relatedness of the social groups plays a role in the way that chemical cues influence sexual development and maturity.

Unlike civilized human environments where we have isolated environments to deal with our urine and feces, social mammals use their reproductive waste to mark territory, identify individuals, and determine the sex and reproductive status of those individuals around them. Mice are no different and use urine cues to mark territories. Urine also plays a different role in the physical development of those younger animals in social groups. Female mice reach puberty faster in the presence of unrelated male urine then in the absence of male urine. The chemical signal, called the major urinary protein complex, is detected in the vomernasal organ. Named the Vandenbergh effect after J.H. Vandenbergh, who discovered the effect in 1975, the presence of the urinary pheromones causes an increase in the gonadotropin releasing hormone in the young female mouse. This hormone is directly responsible for the onset of puberty in mammals. The accelerated puberty enhances the ability of the young female mouse to mate with a close and presumably dominant male.

These signals can accelerate the onset of puberty even in the absence of the male mouse. Its signature urine is all that is necessary to cause this hastening of puberty in the female mice. Along with the Bruce effect (Chap. 8), the functioning of the female mouse reproductive system is sensitive to a number of different odors in their environment. Pregnancies can be terminated, sexual maturity can be accelerated, and estrous cycles can be synchronized all due to the chemical environment that surrounds the female mouse. All of these signals act through a very sensitive vomernasal organ that ultimately sends signals on to the hormonal centers within the mouse's body. Within humans, there is little evidence for fully functional vomernasal organ, so it is unlikely that similar effects will be found within humans. Thus, unfortunately, all those youngsters going through the various stages of puberty at different rates will have to let nature take its course.

## 9.1 The Smelly School Bully

Seemingly linked to the physiological development that occurs at the awkward ages of 8–13 is the social development. I, not so fondly, remember the formation, destruction, and reformation of different social clichés, groups, and gangs in the socially volatile times of these ages. Brought together by commonalities that range from the purely physical (size or beauty) to the purely social (sports or academic activities), these groups often had social standings that were created through peer pressure or other psychological means. Just as there were ranges in the physiological development of puberty, there were quite a wide variety of social or moral development phases. A common factor that seems apparent across a number of social situations is the classic school bully. Portrayed in various forms in movies and TV shows for both males and females, the male version of the bully tends to be the physically superior individual whereas the female version of the bully tends to be the one

controlling different groups of individuals. Although not entirely true to real life, these individuals often resorted to force for the males or peer pressure for the females to extract lunch money, food, or some other payment in exchange for less harassment. This differentiation of modes of actions across males and females that is a product of popular culture is interestingly reflected in nature also.

Nature is not without its bullies especially during this developmental phase of an organism's life. While lunch money is not at play among animals, accesses to critical resources such as food and shelter are nature's equivalent. Many studies with a disparate group of animals have shown the physiological and psychological effects of physical bullying on animals particularly for the runts of litters. If these animals manage to live to sexual maturity, their reproductive output is significantly lower than animals that were not bullied. Olfactory cues can also play a role in the bullying of animals particularly with mammals.

The lesser mouse lemur is an interesting creature with quite an oxymoronic name. The lesser mouse lemur is not a mouse and is not lesser in size. It is the largest member of the mouse lemurs and to add to the curiosity of the name, it is the largest member of the smallest group of primates. Nocturnal in nature, the lesser mouse lemur has rather large eyes to aid in its nighttime lifestyle. Found only on the island of Madagascar, this lemur can be found in multisex groups during day sleeping in the holes in trees. Males and females both have multiple sex partners during reproduction with the females giving birth to typically two offspring after a 60 day gestational period.

The key to this reproductive system is that both males and females have multiple partners. This simple aspect sets up an interesting sexual dynamic in that males would have a reproductive advantage if other males could not be reproductive. By suppressing the sexual development and reproductive potential of surrounding males, the dominant or bully male has an increased chance of siring more of the offspring in the surrounding females. Conversely, females, needing multiple sexual partners, would have an advantage by promoting the sexual development of as many males as possible. These females are acting in a nurturing fashion by enhancing the sexual activity of the poor bullied males.

As with many social mammals, these lesser mouse lemurs have social hierarchies where there is a single dominant male with multiple submissive or subordinate males. These status distinctions are established and reinforced through aggressive interactions. The fights often occur before the breeding season such that the dominance hierarchies are fully established by the time that females become sexually receptive. At this point in time, the males act as school yard bullies and fight to fully determine who is king of the reproductive hill. As the mating season approaches, which is around September and October, overt physical aggression is reduced among the males, but the aroma of dominant males still functions to bully the subordinate males. Males leave urine cues around nests and territories and as the breeding season approaches, scent marking with urine increases. The presence of the urine delays sexual maturity in subordinate males. The male urine pheromones, as yet to be identified, actually decrease the production of testosterone in subordinate males which inhibits their sexual activity.

Testosterone in the males increases the size and mass of the testes which increases the sperm production in sexually active males. Sperm production is important because the females have multiple matings with different males. Multiple matings lead to what is called sperm competition which is a relatively new aspect of sexual selection theory originated by Darwin mentioned in the previous chapter. Sperm competition occurs when females have multiple mating partners, and the fertilization of her eggs is done by sperm from different males. In the race for the most offspring, the evolutionary advantage goes to the male who manages to fertilize the most eggs. If, within the female reproductive organs, sperms from multiple partners are simultaneously present, then there can be competition among the different sperm or sperm packets for reproductive success. This competition can result in a number of different evolutionary solutions. Animals can use behavioral mechanisms such as the active removal of sperm in subsequent mates that occurs in some insects. Many species have mechanical advantages such as sperm precedence where the mating order biases egg fertilization or even biochemical mechanisms like natural spermicide. Thus, when sperm competition exists, having a larger number of robust sperm can increase a male's reproductive success and when dominant male lemurs suppress the production of male sperm in subordinates, they are chemically bullying submissive lemurs in order to reduce the number of potential offspring.

From the female's perspective, this chemical reproductive bullying is counterproductive. If females have multiple sexual partners (up to seven or so), they want each and every mating event to be with robust and hearty males who are up to their highest reproductive potential. Having one mating with a fully functioning male and six matings with less than vigorous males is essentially wasting her time with the sexually inferior males. So, while the dominant males have a selective advantage using their chemicals to suppress any subordinate males around them, the females want to enhance the fertility of all the males in their area. Just as the males use their urine to reproductively bully males, sexually receptive females use urine to increase the fertility of males in the territory. As the female lesser mouse lemurs become sexually receptive, they increase their scent marking using urine as their source of marks. In the sexually mature urine are pheromones that not only attract males to mate but also increase the production of testosterone and spermatogenesis in males that smell her urine. Thus, there exists an evolutionary arms race between the sexes or at least between dominant males and sexually receptive females in the lesser mouse lemurs. The dominant males are producing bullying urine that serves to reduce sperm production in subordinate males while at the same time, females are producing sexually nurturing urine that has the opposite effect on males.

## 9.2 The Mean Girls Club

For the lesser mouse lemur, the males are the reproductive bullies, but the status of bully is not limited to only one sex. In the 2004 comedy "*Mean Girls*," the bullies of the school is a small clique of girls called "The Plastics." The movie is,

unfortunately, a fairly accurate representation minus the comedy of many different high school situations where clichés form and those outside of that cliché are targeted for retribution or mockery. In "*Mean Girls*," those individuals, particularly the other girls, that are deemed unworthy in either beauty or social standing, are ostracized by the plastics. As often with the formation of groups and group dynamics, those inside the group are offered opportunities or treated better than those outside of the group. In-group members receive special benefits like money, access, and information whereas out-group individuals are bereft of any benefits. It pays to be on the inside.

In high school comedy movies as well as nature, the concept of bullying isn't limited to just one sex. Female animals are just as adept at the control of other females as males are controlling the reproductive output of other males. The evolutionary advantage for females is relatively clear. If other female's reproductive output and even sexual receptivity is inhibited then all or most of the offspring are sired by that singular female. This type of situation can be found commonly amongst social insects where a singular queen is the only female capable of reproduction. For social insects like bees, the reproductive situation is different than in social mammals. In social bees, the queen bee and drones (males) are almost genetically identical. Almost because the males only have one set of chromosomes and genes, whereas the female queen has two sets of chromosomes. The set of chromosomes that the males do have is identical to that of one set of the queen's chromosome. The workers are sexually undeveloped females, and their state of continual "prepubescence" is controlled chemically by the presence of the queen and her pheromones. For most social mammals, all of the members of the group, male and female, have two sets of chromosomes and, thus, vary genetically from each other.

Among the primates, marmosets are a group of 22 different new world monkey species that are generally small and live within cooperative groups. Within the primate community, new world monkeys refer to those primates found in Central and South America (whereas old world primates refer to those primates found in Asia, Africa, and the Middle East). These groups of new world monkeys can consist of 15 individuals, but in most species of marmosets only a singular female breeds. As with most primates, the marmosets have a social hierarchy and the dominant females exert considerable control over group dynamics. Just like the plastics in the movie "*Mean Girls*," dominant females often exhibit aggressive behaviors toward other females to either establish or reinforce that dominant–subordinate relationship. The privilege to breed is a benefit of being the dominant female amongst the marmosets. Yet, the restrictive breeding isn't buttressed by the aggressive displays and actions towards subordinates; a pheromone from the dominant marmoset suppresses the ovulation of the other marmosets.

Among mammals including humans, luteinizing hormone (LH) is produced by the pituitary gland and is necessary for ovulation in females. An increase in LH production induces ovulation whereas a decrease in LH production results in a delayed or suppressed ovulation. Without ovulating, females cannot conceive and, thus, are infertile. If juvenile marmosets are exposed to the odors of dominant female marmosets, their LH production is decreased and they do not produce eggs.

Still, the aroma of dominant females does more than act on the physiology of the other marmosets; the subordinate marmosets do not even exhibit adult sexual behavior. This pheromone then stunts both the reproductive physiology of the marmosets as well as the sexual behavior of the subordinates. If the dominant female is removed from the groups, the subordinates begin to produce more LH and exhibit sexual behaviors, at least until another dominant female arises from the ranks of former subordinates. Among the marmosets, the mean girls get all of the guys and it definitely pays (evolutionarily) to be part of that mean group.

## 9.3 The Unbreakable Bond

During my school days, I was active enough to be a part of different school groups. I played sports through three different seasons (fall, winter, and spring), was part of the music program, and was smart enough to participate in some academic groups. Each of these groups and their leaders had different rituals or events designed to forge a close knit community among its members. One could argue how "effective" these programs were, but being naïve and wanting to be a part of these groups, I blindly followed along just like a sheep.

The fall season for band meant marching practice which includes a week-long marching band camp at some off site location. We stayed 6–8 students per cabin and were grouped by our different instruments. Playing tuba in the band, I stayed with a fairly rambunctious group of boys. Maybe this is my bias, but for me, two groups (drums and tubas) in the marching band stick out as either a tad more theatrical or crazier than other band sections. Certainly, the drum section is unique because they lead the band on and off the field and are the center piece of rhythm for the entire band. This group often seemed a very close group because if one of them is off rhythmically, it is fairly obvious to the audience and band alike. The drum section always seemed to have some special movements, twirls with drum sticks, or shouts that were unique to them. Carrying a rather large tuba or Sousaphone, even in a large band, makes one quite obvious while marching. In addition, the tuba section often had distinctive movements with the instrument and like the drums, being out of sync is an ultimate sin for a marching band. So, while the rest of the band had down time, the drum line and tuba section had their own self-generated practices that resulted in group bonding.

Within athletics and academic groups, similar self-generated events also lead to a group bond that was designed to create a community with a common goal whether that goal was winning a football game, putting on a great show, or winning a debate. These bonds, one could argue, are necessary to focus groups of individuals toward a common vision or mission. They also created a set of in-group and out-group behaviors where those people inside the group (say tuba section) had privileges or received more magnanimous behaviors that those outside the group. I am not trying to equate the differential behavior actions to the mean girl syndrome discussed above, but simply that those members that are part of the "in-group" receive preferential

support or attention. Now, some 30 years later, I attempt to create that same in-group bonding with my laboratory. Having potluck dinners, cookouts, game nights, or celebrating each other's accomplishments is designed to create a supportive atmosphere. For anyone going through undergraduate or graduate school knows that this support is almost a requirement. My laboratory group is small enough that there is no need for additional mechanisms for recognizing group members beyond facial features, but we do have numerous lab t-shirts that bear the initials "LSE" for the Laboratory for Sensory Ecology.

As outlined in Chap. 6 in the social dynamics of life, animals have different groups that result in differential support or efforts exhibited toward those inside of the group definition over those outside. The most fundamental distinction for in- and out-group recognition is that of kin. Within kin recognition, the genetic bond connecting groups is permanent as opposed to the participation in a band, team, or graduate lab. The ability to recognize and provide differential support to those that are related and unrelated is central to any concept of social behavior. Narrowing this view even further, the recognition of offspring (and the genetic relationship) can be critical to providing parental care. There are animals that have evolved mechanisms to exploit this differential care, such as the cuckoo bird covered earlier. The cuckoo bird lays its eggs in other birds' nests and without the lack of the genetic relationship between parent and offspring, the other bird raises the cuckoo chick as its own.

Thus, the recognition of one's own offspring and the ability to give support to this offspring and no other can lead to success growth for that offspring. Unlike lab t-shirts or team uniforms, the odors of identity can provide a lifelong connection from mother to infant, and sheep have shown researchers how this connection can be made. As with a number of scientific discoveries, people, and in this case shepherds, were performing this bonding trick for years without even realizing what was happening at the biological level. Shepherds recognized that the bond between mother and lamb is so strong that the mother will not allow any other lamb to suckle from them. This bond happens in the first few hours after birth of the lamb. Thus, any lamb, whose mother died during birth, would also be a lost cause because of this critical bond. Conversely, any dam who has lost her lamb would have an udder of good milk but no lamb to suckle with. To create an artificial bond between foster lamb and mother, the shepherd would take the amniotic fluid from the lamb who passed away and rub the foster lamb in this fluid. Next, the shepherd would present the foster lamb now covered in the other lamb's fluid to the original dam. Once the dam cleaned off the lamb, she would accept this offspring as her own and raise it to adulthood. Shepherds would call this practice rubbing the lamb in "the waters" (amniotic fluid) and "cleanings" (placenta) and would have considerable success using this technique.

Dr. Federic Lévy from France has discovered an intricate series of neurological and behavior events that eventually lead to the dam–lamb bonding. This bond leads from birth canal to the brain and ultimately to the behavior of the mother. During birth of the lamb, the vagina and cervix of the mother sheep gets stretched. The stretching, which can be painful, excites nerve endings and sends these pain messages to the brain of the dam. The brain, upon receiving these messages, triggers the

hormonal centers of the body to produce oxytocin which is a hormone that functions during childbirth. The oxytocin finds its way into the olfactory bulb of the mother. The olfactory bulb is the "mini-brain" of the olfactory system and is responsible for the processing and decision-making on olfactory signals. When oxytocin floods the olfactory bulb, the sheep experiences a switch in behavior. Without oxytocin in the olfactory bulb, female sheep are repulsed by the smell of amniotic fluid, whereas with oxytocin causes the mother to be attracted to the smell of amniotic fluid. This is not unlike the strange olfactory and gustatory cravings that human mothers have before childbirth. In addition, the oxytocin increases the dam's ability to learn individual odors. So, the physical act of childbirth sets in motion the ability of the dam to be attracted to and learn her offspring's odor.

Yet, all of the neurological changes are not finished yet. Since the dam is attracted to the smell and taste of the amniotic fluid, she cleans the young lamb and by doing so begins to imprint her recognition of the lamb on those tastes and odors she is receiving. While she is cleaning off her lamb, the stimulation of these chemicals causes neurogenesis in the olfactory bulb. So, these chemicals cause new neurons to grow inside of the olfactory bulb, and the neurons that grow are selectively tuned to those unique odors that are her lamb's chemical signature. Almost the entire olfactory part of her brain is rewired to be attracted to and recognize her lamb by giving birth. The shepherds, unknowingly, took advantage of this entire neurological sequence by rubbing foster lambs in the single most important stimulus to trigger this sequence of events. These odors and the rewiring of the brain forge an unbreakable bond between mother and lamb in sheep and without these chemical connections, the lamb would not receive the parental care necessary to grow to adulthood. Although the exact neurological events in humans are not known in this detail, a similar mechanism is most likely important for that mother–baby bonding that occurs in humans (Chap. 4).

## 9.4 Waiting for Superman

It is probably not too far of a stretch to say that aromas are the ninjas of the sensory world. As the title of this book seems to indicate, the natural perfumes of the world are hidden, at least consciously, and work their magic on our brains just like ninja's pulling off a secret attack in the middle of the night. The mother sheep example above demonstrates that odors are capable of rewiring the brain and altering the behavior of mother sheep. Even beyond mammals, odors can alter the physiology and neurochemistry of the receivers. In crayfish, just the body odor of a dominant crayfish can turn the crayfish exposed to that odor into a subordinate animal. Dominant and subordinate behaviors in crayfish are controlled by the neurochemical serotonin which is also associated with similar behaviors in humans. Although the exact mechanism that drives this behavioral phenomenon is still unknown, the most likely answer is that the dominant odors influence the production of serotonin in the receiver and by altering brain chemistry, turns a crayfish into a submissive

animal. Since the subordinate animal is at a competitive disadvantage to the dominant animal, these odors are altering brain chemistry in the receiver in a detrimental and uncontrollable way.

Crayfish aren't alone in how odors can alter important physiological factors. Maine lobsters, close cousins of the crayfish, are also quite sensitive to environmental odors. Lobsters, like all crustaceans, carry around a hard exoskeleton that serves as armored protection against other lobsters and predators. While this shell works well to protect these animals, the down side for these animals is they need to molt these shells in order to grow and reproduce. As mentioned in Chap. 4, during the process of molting, the animals grow a new shell underneath the older hard shell. This new shell is soft and pliable and doesn't harden until it is exposed to seawater. In order to grow, the lobster creates a slit in the outer hard shell right at the juncture between the main body and the tail. Once the slit is created, the lobster performs an escape maneuver that would make the great Harry Houdini proud. The lobster pulls its entire body, including the soft and smaller new shell right through this slit. Once free from its old body, the lobster draws in water to "inflate" its soft new shell to provide room for growth. The lobster remains soft and vulnerable for the next 30 minutes or so. During this and only during this very short time period, the female lobsters can be impregnated because the males now have access to transfer sperm packets. When not in the reproductive period of the summer months, female lobsters tend to synchronize their molting where all of the animals shed their old exoskeletons in a relatively close period of time. This synchronization is very reminiscent of the McClintock effect in humans where the famous psychologist Martha McClintock found that human females living in close proximity began to synchronize their reproductive cycles.

Lobsters, as with other crustaceans, are a weird combination of social/antisocial animals. When the term social animals is used, images of large charismatic mammals traveling in family groups or herds are often brought to mind. Yet, nature is decidedly not mammalian or vertebrate in reality. At present time, there are roughly 5500 known species of mammals which pale in comparison to the 40,000 known species of crustaceans. At a broader level, there are approximately 60,000 species of vertebrates and over 1.2 million species of invertebrates. These numbers provide some justification for extending definitions of sociality or social behavior to more than just one half of a percent of the animal kingdom. Lobsters exhibit social behavior in that they form dominance hierarchies through ritualized fights. The dominant lobster then exerts and re-exerts its dominance on a daily basis by walking around its territory and temporarily kicking all of the male subordinate animals out of their shelters. Essentially, the big lobster on campus is acting like a bully. Still, it pays to be the Superman of the lobster world because all of the females want to mate with the dominant male. Yet, if all the females are molting at the same time and they can only mate during that precious 30 minutes between molting and hardening of the exoskeleton, there exists a conundrum.

Female lobsters can sense the dominant lobster by its body odors and probably through some specialized chemical signals in the urine. Lobsters love to live in shelters which amount to small dens or holes dug in soft sediments typically located underneath rocks. The females within a territory will roam smelling the water in

order to determine which local male is the superman and worthy of her attention. As the summer waters warm and the females begin to move into a molting status, the drive to mate with the dominant lobster increases. So, the females increase their periodic olfactory forays into the male lobster's shelters just to be present when they molt. If the females are ready to molt, they'll actually move into the male's shelter and temporarily live with the dominant lobster. When she molts, the lobsters have sex and she'll stay another 7 days in which the male provides some protection against predation. The conundrum with this system arises if another female wants to mate with the dominant lobster, but he is still cohabitating with his previous partner. As noted above, most of the females molt at the same time of the year.

Molting is a physiological phenomenon controlled by hormone levels in the lobsters, yet it turns out that the timing of the molting is somewhat controllable. If a dominant male is currently tied up with another female, the other females, all ready to molt and mate, will continually come by the Superlobster's fortress of solitude for a good smell of the aromas. If she senses that the mating has ended and the previous female is ready to move out, she begins the molting sequence. If there is no chemical hint that the cohabitation is ending soon, the female lobster has the ability to delay her molting until superman is no longer busy. This has been called "serial monogamy" in that the females have the ability to literally line themselves up in week-long intervals just in order to mate with the dominant lobster. In absence of those dominant male odors, the females all molt at the same time in the summer. When a fertile and dominant male is present with all his aromas, the female lobsters alter their reproductive physiology just to mate with him. Occasionally, if the lineup is too long and one female just can't hold it any longer, she'll rush over to the Jimmy Olsen (Superman's weak sidekick) of the lobster world to mate because mating with a subordinate lobster is better than no mating at all. Waiting for superman is the preferable route for lobsters, but alas, sometimes, superman is just not available (Fig. 9.1).


**Fig. 9.1** Lobster deli line waiting for superman

## 9.5 Fear and Loathing in Odors

The presence of a real superman, not a lobster version of a superman, would provide a sense of security and safety akin to what the females lobsters need during their molting process. In lobsters, the father is essentially gone right after insemination and while the mother provides some parental care and protection after the larva are born, the juvenile lobsters are on their own to find food and avoid predation. While humans aren't under attack from wolffish, cod, or flounders like lobsters, having an excellent sense of what to fear and what not to fear is essential to navigating the often perilous world of the young teen years. Mammalian offspring are altricial offspring which means that they are essentially helpless after birth. Extended parental care is standard for most mammals and the roughly 15–16 years that humans provide care and support is long even among mammals. During these juvenile and teen years, the transfer of knowledge about how the world works can be critical to the survival of the offspring.

During my younger years, my family would often spend our summer vacation camping among the more undeveloped and rustic areas of the midwest and as I got older, we began to explore some of the western states. During these years, I was quite the precocious youngster with little fear of exploring deep woods, streams, or the lakes surrounding our campsite. I am not sure whether my lack of fear of these areas resulted from naiveté or stupidity, but I sure did get into some adventures. I am sure that these adventures are what prompted me to become a biologist as I had this innate curiosity for watching nature and wondering why animals did what they did. Walking through the woods, I would often find holes or burrows in the ground and being curious, I would poke around near the burrow or occasionally stick something down the burrow hole in hopes of coaxing the owner out into the open. Not a particularly bright maneuver for a young budding biologist, but sometimes curiosity gets the better of our logical judgments.

One of these times that I was wandering in the woods looking for burrows, I was accompanied by one of my uncles. This uncle spent a considerable amount of time in the military and was, to the younger me, a rather brawny and gruff individual. A hunter and outdoorsman, there wasn't much that would scare him or even cause him to raise an eyebrow. I did not have a close relationship with him, being 1 of 12 uncles, still I felt quite safe walking through the woods and poking sticks in small and large burrows. The purpose of the journey was not for me to find nature to play with, we were on the hunt for the elusive and delicious morel mushroom to augment our dinner that night. So, while my uncle was examining trees and looking under leaves, I was becoming quite bored and started investigating burrows. I came upon one that was clearly freshly dug and my excitement was heightened. I thought maybe I could discover something interesting inside. I grabbed a living branch covered with leaves off of a young sapling and stuck the branch and leaves into the hole. After a couple of attempts, the branch started to move on its own. In a buzz of emotion, I called out to my uncle that I had found something. He turned and his face was a mixture of intrigue and annoyance. I backed away from the burrow entrance, and this small black creature began to emerge appearing quite put off by antics. As the

head of the creature emerged, I saw a tuft of white fur on top of its head and suddenly my uncle yelled, "Run boy!" I was shocked into action, turned on my heels, and followed my uncle for a good 100 meters sprint away from the burrow. As I was running, I wondered what dangerous animals could scare my uncle because certainly the size of this vicious predator wasn't intimidating. As we slowed to a stop, my uncle explained that I had found the burrow of the infamous skunk and his fear wasn't based on any potential injury. His response was based on previous experiences of getting sprayed by a skunk and having to deal with the odorous consequences of provoking it.

Without my uncle's help, I certainly would have learned about skunk and their defensive weaponry, but the transfer of knowledge from his experiences to my mind certainly made my juvenile and now adult years much easier. Although my pet dogs don't seem to have learned lessons about skunks, luckily I have not had a close enough encounter to a skunk to be sprayed. The juvenile years of our lives are full of examples where adults and mentors are preparing us for the good and bad of adulthood. During the younger years of their children, parents are often saying "No" or "don't" as kids begin to explore the world around them. Whether the admonishment is aimed at the danger of streets, unfamiliar dogs or campfires, the goal is to transfer that knowledge of potential danger before a first-hand learning experience happens.

For humans, this knowledge can be transmitted through parental commands or through images such as stop signs or warning notices. Other mammals do not have the benefit of stories, books, or communal knowledge, so learning takes place through other sensory channels. The smell of fear is not a phrase invented for movie titles and funny lines; mammals exude a different type of aroma when placed in situations that evoke fearful responses as opposed to neutral situations. What is interesting about the smell of fear that mammals produce is that juveniles can learn to avoid or fear those same situations just by smelling the fear of their parents. Instead of shouting "Run boy!" with words, other mammals shout this emotion with their pheromones.

At the University of Michigan, Dr. Jacek Debiec led a team of researchers that discovered this pheromonal learning in rats. The researchers constructed an experiment where female rats learned to associate the smell of peppermint with mild unpleasant shocks. After this associated learning occurred, the rat mothers would show a fear response just to the smell of peppermint even without the mild shocks. After this learning, the rat mothers were impregnated and allowed to deliver her pups.

After the pups were born, they were exposed to only peppermint odors under various conditions. The pups were presented peppermint odors in the presence of their mother and without the mother near them. The researchers used a special brain imaging technique that allowed them to monitor neural activity in the brain of the rat pups under all of the various experimental conditions. They used this technique to quantify activity in the amygdala, which is a part of the mammalian brain associated with fear responses. They discovered that rat pups could learn what their mother's feared even without the mother being present during the experiment. Yet, the pups only learned to fear peppermint if the mother's fearful odor was piped into the test chamber.

**Fig. 9.2** Fear and ancestry

Peppermint is something that does not normally evoke a fearful response in rats; thus, the rat pups learned to fear something that their mother feared even before she was pregnant and that this learned fear was solely based on the odors given off by the mother. As a follow up to this experiment, Dr. Debiec and his team blocked the activity in the offspring's amygdala and the rats failed to learn this response.

The mother's fearful aroma has the ability to reprogram the pup rat's brain in order to evoke the same emotional response. The transmission of information from mother to offspring about what to fear and what not to fear is done through the pheromones released by the mother. This would be similar to asking my uncle about what a skunk is and learning to fear the skunk based on changes in the smell of my uncle's sweat. While this finding alone is quite alarming, the fact that the rats are fearing an unnatural stimulus (peppermint odor) instead of a more natural odor like a predatory mountain lion adds a level of complexity. Mothers, or at least rat mothers, can learn to fear situations that might be dangerous in their environment before the pups are born and provide that information to their offspring simply by producing the right body odors. The transmission of learned fear and the ability to alter what is feared by learning through chemical signals is approaching the definition of a social language. At the very least, a knowledge of environmental dangers encoded through chemical signals. Whether that danger is wolffish (for lobsters), hawks (for rats), or skunks (for humans), parental fear and loathing is imparted by parents, probably unwittingly through the biochemistry of their bodies (Fig. 9.2).

## 9.6 Your Ancestor's Taste

Having spent the first 20 some odd years of my life in the Midwest of the United States, I grew up in a household full of Midwestern culture imported from Europe. My parent's ethnic heritage includes some Scottish ancestors via Nova Scotia with a good dash of Welsh thrown in. In addition, family gatherings usually centered on some type of holiday and definitely included large doses of traditional food found in a largely farming family culture. Most meals included some derivation of meat and

potatoes and most of that meat didn't deviate far from beef or pork unless deer season was successful or Thanksgiving was at hand.

I am not sure if this is unique to my version of the Midwestern family, but an interesting thing that was missing from most of our meals was a diversity of spices. Salt was definitely used during cooking, and pepper was used sparingly. The use of anything beyond these two basic cooking ingredients seemed to be discouraged, and most certainly any spice that originated outside of Europe was unheard of in my family. As a child and young adult exposed to very little outside of these cooking methods, I was essentially clueless to the large diverse world of tastes and spices.

When my wife and I left home to travel out to Woods Hole for graduate school, little did we know that the trek would take us across the globe in regard to food and spices. During the 4 years between my bachelors and Ph.D. degrees, the lab environment would include a Spaniard from Barcelona, a very stereotypical New Englander from Maine, two students from the Philippines, a German, an Italian, an Argentinian professor, a southerner from Georgia, and a Swiss German. My best friend and mentor turned out to be the German who loved to eat and cook, and my wife and I would spend every Thanksgiving eating a German feast at his small apartment. One summer we lived with the Spaniard and learned the joys of eating potato pancakes at 10:00 pm while dancing the night away. Through this inculcation of different tastes, smells, and foods, my Midwestern taste buds slowly gave way to a palate that included such things as wasabi, cumin, ginger, curry, Weiner schnitzel and, of course, fresh seafood. It was nearly impossible to remain true to the meat and potatoes with no spices diet that I had grown up with and I am quite thankful to that time period that exploded my gustatory world.

Certainly, the parental influence on our taste preferences is well established, and numerous studies have shown that the diversity of food to which we are exposed to early in our childhood establishes the norm for our dietary choices. What if those influences go beyond the normal plate of food placed before our children? What if dietary preferences or taste per se is influenced almost like the smell of fear in the example in the previous section? These are the types of questions answered by Dr. Julie Menella who also resides at the Monell Chemical Senses Center in Philadelphia.

For years, Dr. Menella has been asking questions on how flavors and fragrances influence the youngest members of our society. She is particularly interested in the role that flavors in breast milk can influence taste preferences of babies and later on as those babies mature into children. In an early study, Dr. Menella performed an experiment with two groups of mothers and their breast-feeding children. She asked one group of mothers to consume a garlic pill before breast feeding and in the other group, the mothers consumed a control placebo pill. After this, the research team tracked the amount of time the babies spent attached to the breast and how long they fed. Turns out that the garlic flavor in the breast milk hits maximum concentration in about 1–3 hours after consuming the pill and that the babies could detect the change in flavor of the breast milk. The babies feeding on "flavored" breast milk spent longer feeding than those babies whose mother did not consume the garlic. The second hand flavors in the milk could influence how much the babies preferred the milk and consequently how much nutrition they would receive from each feeding session.

Dr. Menella ran a similar study using carrot juice and found that baby's preferences could be extended beyond just breast milk. In this study, breastfeeding mothers were separated into two groups again. In the first group, the mothers were asked to drink carrot juice while the control group was asked to consume only water. Now, instead of studying the breastfeeding behavior of the babies, the researchers wait until the children were ready for solid food. At this point in the child's life, they were offered two different choices for snacks. One snack was carrot flavored cereal, and the other was just normal cereal. Carrot flavored cereal doesn't sound too appealing, and certainly, the babies whose mothers drank only water, and not carrot juice, thought that the cereal was just a horrible taste. These babies made the appropriate facial expressions showing disgust. Conversely, the babies whose mothers drank the carrot juice showed significantly less distaste in their facial expressions. So, here is another example of how the mother's preferences for food can be transmitted to their children through breast milk.

Still, this just wasn't enough for Dr. Menella, so she extended her study even farther. In an ingenious twist on these experimental designs, she asked pregnant women to drink carrot juice while she asked another group to avoid carrot juice and carrot flavored items. This is called an experiment in prenatal learning. These experiments are the gustatory equivalent of the products that make the claim that playing Mozart through speakers into a pregnant women's womb will stimulate the early brain activity of children and produce the next Einstein or Mozart. The evidence that playing music to children in the womb will produce smarter children is rather suspect, but the opposite is true of the evidence for the transfer of taste preferences during prenatal times. Babies born to mothers who drank carrot juice while they were pregnant showed an increased preference for carrot flavored cereal as opposed to those babies whose mothers avoided carrot food and drink items. Cultural preferences for food is certainly a learned phenomenon. Even now, despite the my current love affair with Cajun food or sushi, I still have craving for that old time steak and potatoes meal of my ancestors that I spent so many years consuming when I was younger. While this craving may have been learned, there is certainly an aspect of my ancestor's palate that was passed down to me during my prenatal time. Just like my red hair and stocky stature harken to my Scottish ancestry, my taste is my ancestor's taste mixed with a dab of my cultural environment and a dollop from the environment of the womb during those critical prenatal months.

## 9.7 Jonesing for That Smell of Junior

While many different studies, including the one described previously in this chapter, have shown that parents communicate with their offspring with words, actions, and aromas, one wonders if that communication pathway is bidirectional. While parental care is virtually absent among many different species including the lobsters described earlier, parental attachment and affection can be important for the survival of some offspring. For species with altricial offspring, nurturing during the

young and adolescent years can determine the likelihood of survival to adulthood. Certainly, nature's parents have a vested interest in keeping their offspring alive and raising them to an age where they are self-sufficient. Despite this interest, the offspring have a bigger interest in staying alive until they get to reproduce. Without sounding too callous, the parents often have other reproductive opportunities as larger bodied animals have multiple mating seasons. Offspring, on the other hand, are a unique combination of genes from their mother and father and have only this one chance to survive to reproduce. Thus, junior definitely wants to ensure that mom and dad stay around to help raise them.

In Chap. 4, I highlighted research that showed how the smell of a newborn baby can excite the pleasure centers of the brain to promote bonding between the parent and child. The bonding ultimately ensures that the child is properly cared for because the parents have an emotional investment in the welfare of their progeny. This explanation certainly makes sense within an evolutionary framework because the offspring carries at least half of the genetic makeup of the parents. From this perspective, the parents certainly benefit genetically and therefore, should want to care for their children as best as possible. What if we flip our thought process on this research and instead of thinking about what benefits the parents received, we focus on the needs and benefits of the child?

Instead of a potentially loving and bonding experience, what if the child could produce an aroma that actually manipulates the parents into taking care of it? Instead of viewing that new baby smell as a source of pleasure for parents, it is possible to view the perfume of a new child as something stronger than pleasure: addiction. Dr. Johannes Frasnelli, Montreal University, has investigated the neural substrates for the olfactory bonding of child and parent. In an all-too-familiar experimental design, the research team presented clothing that has been recently worn by infants to two groups of women: one group of women that recently gave birth (6 months) and another group that had never given birth. The babies, that wore the pajamas provided to the both group of women, were unrelated to either of the two test groups. The researchers were measuring the reaction of the women and any potential changes in brain activity to completely unrelated and unfamiliar infant odors. The caudate nucleus is that part of the brain that is central to pleasure, but is also a critical component of the brain that plays a role in addiction. Addiction can be viewed as a much more intense version of reward learning. For example, as I train my canine companion, Cedric, to perform appropriate behaviors like relieving himself outside or chewing on his toys instead of shoes or clothes, I provide him simple dog treats when he performs positive behaviors. The taste of the treat activates his taste buds which send signals to his brain that eventually reach his caudate nucleus. Once there, the release of certain neurotransmitters signal creates a state of happiness which serves to reinforce those positive behaviors. So, I actively stimulate these neural pathways through the use of dog treats in order to manipulate (or the more pleasant word of train) his behavior to what I want.

If this reward learning systems goes into overdrive, that pleasure seeking system shifts from seeking to craving. The person (or dog) changes their behavior from wanting those treats to needing or desiring those treats in order to continually activate


**Fig. 9.3** First smell is free

that pleasure system. The same neural circuits involved in happiness and reward are also involved in craving or addiction. This is the neural circuit involved in seeking alcohol, tobacco, or even our obsession with certain drugs.

Newborn odors sneak their way into these pleasure centers of mothers, but not women who have not had children. These aromas activate the same neural circuits that are out of control for compulsive coffee drinkers, chain smokers, and other addicts. Given that this part of the brain is not turned on in women, who have not had children, probably indicates that the act of childbirth with all of the hormonal changes that accompany the birthing process either alters the pathways within the brain or at least makes certain pathways more susceptible to increased learning. If mothers become "addicted" to the smell of babies, this craving has the potential to ensure that the mother does everything possible to take care of the baby. This olfactory yearning may also explain why mothers with grown child still love to hold and take care of their children's babies or even just love the smell of newborns. They could be jonesing for a jolt of an aroma-mediated happiness that hasn't happened in a while (Fig. 9.3).

## 9.8 The Odor of Maturity

As described at the beginning of the chapter, many aspects of our bodies change during that magical time of sexual maturity or puberty. Having completed this pathway many years ago, I watched as a spectator as my own son went through many of those same changes that I highlighted previously. The increase in body and facial

hair is probably the most visually noticeable, but as virtually any parent of a teenage boy would attest to, the most noticeable change is the olfactory aroma of the bedroom. The unique, and hardly attractive, perfume of the pubescent boy is an interesting mixture of suspect hygiene and body odors being shaped and altered by the hormones associated with maturing.

Most of that unique eau de boy is caused by a toxic mixture of sweat glands fueling a particularly pungent microbial flora in the underarms. Human have sweat glands called eccrine glands. The glands are actually located all over the body, but have a high density in the underarm area. These glands produce a slightly salty solution (that we call sweat) that is used to cool the body as the sweat evaporates. The sweat itself is odorless and is uninteresting when describing the inside of a teenage boy's room. The actual odor is produced by the bacteria that use the sweat as a food source. At the age of puberty, the eccrine glands are joined in the job of sweat production by the apocrine glands. Apocrine glands are located near hair follicles and as hair growth increases during puberty, apocrine glands are activated. In animals, these glands can be associated with pheromone production that was outlined in other chapters. In humans, these glands secrete an oily or waxy substance that is diluted by the sweat produced by the eccrine glands. Again, just like the salty sweat of the eccrine glands, the waxy substance produced by the apocrine glands is not that smelly itself. The real culprits of that teenage boy smell are the bacteria that consume this new type of sweat and as a byproduct of having meals of the apocrine sweat, the bacteria produce that all too familiar stench of the pubescent teenage boy.

Having a teenage boy in my house transported me through an olfactory portal to my teenage years which were spent, in large part, playing some form of sports. Whether the sport was cross country, football, wrestling, baseball, or track, all of these sports required two things that seemed to deal a death blow for fresh air. First, they required large amounts of teenage boys and second, these teenage boys were producing copious quantities of apocrine sweat for all of the bacterial colonies around a locker room. This odiferous production seemed to peak during our wrestling season. Our practices were often performed in rooms with elevated temperatures, and wrestling teammates most certainly increased our wrestling skills as well as spreading around all of that sweat. To be honest, we did attempt to keep the mats and towels as clean as possible, but the diligence of high school wrestlers is probably not as good as it should be. The locker room, our gym bags, and uniforms were certainly washed at regular intervals, but there always seems to be some sort of olfactory signal that could guide visitors either toward our practice, or if the visitor was smart, a direct bee line away from the offending source of that pheromone. Although I had a decent set of wrestling skills, intense competition required using all of the weapons in our training arsenal, and one of those weapons was teenage chemical warfare. If I had an exceptionally difficult match in an upcoming tournament, I would conveniently "forget" to wash my uniform for a couple of days and conveniently leave that uniform zipped up in a gym bag in the trunk of my car. After having ripened, I would gladly wear the uniform as it seemed as if I quickly adapted to the presence of the unique odor. At the start of my next match, I would literally lock up with my opponent which means that one of my hands would be wrapped around his neck and

I would draw his head in close to my uniform. Once he inhaled the rather foul aroma, there would be a slight hesitation in my opponents thinking (or even more obvious response that was often demonstrated by my mother as she opened my bag to wash my uniform). I would take advantage of this olfactory distraction to take him down to the mat to the pin. The trick was certainly successful and would lead to a couple of good wins for my career. Now that I am older and perhaps a bit wiser, I don't quite have that teenage odor anymore, although given the age of my son, the smell of teen spirit is certainly alive and well within the house.