Chapter 6
The Cocktail Party of Life

The Chemical Conch Shell

During my morning writing rituals at the bakery where my creativity ebbs and flows, I often find myself totally engrossed in my craft such that the only thing I am consciously aware of outside of my writing is my pumpkin muffin and occasionally the background music. Then there are those moments that my muses leave me and my writing comes to a crashing standstill. During these times, I turn to observe other customers who frequent the bakery each morning. By allowing my mind to wander from the writing at hand, I become captivated by the social interactions of those around me.

As a consequence of my scientific curiosity, I find it fascinating to observe individuals interacting with one another. One of the more interesting aspects of observing humans is social behavior, particularly the subtle, nonverbal ways in which people communicate. I can notice changes in body postures, slight differences in the tone of voices, and even changes in facial expressions. Apart from the actual words spoken during these interactions, these other nonverbal forms of communication can provide a wealth of information about the relationship between the people speaking, their emotions, and maybe hidden meanings behind the words they are using.

Coffee houses and bakery really serve two purposes; the most obvious one is to sell drinks and pastries to waiting customers. Secondary is the atmosphere and community that is built allowing the majority of people at the bakery, the ability to socialize with others. Quite often several individuals from the University gather for a morning meeting over coffee and bagels. A corner of the bakery is occasionally inhabited by a small group of older women that always seem to be having an enjoyable morning. Other people spread papers out covering the entire surface of the table. Once the papers are in place and the coffee is purchased, a conversation ensues that appears to be of a great deal of importance to the participants.

True to my scientific curiosity, I catch bits and pieces of their discussion and study their interactions. I try to reconstruct conversations by studying the subtle body postures and hand gestures of the speakers. I study their facial expressions and where their eyes are gravitating. The tone of their voice is also a continual clue that allows me the opportunity to attempt to piece together the social meaning of these interactions.

P.A. Moore, *The Hidden Power of Smell*, DOI 10.1007/978-3-319-15651-4_6

The real meanings or purposes of these meetings are, of course, beyond my knowledge. I know that, quite independent of the intended purpose of the gathering, there are social interactions occurring at a level that is deeper than just the words that are spoken. At one meeting, a tall gentleman dressed in a dark blue business suit with a red tie is clearly dominating the proceedings. Even from a distance, the person in charge of this meeting can be gleaned from the appearance of his power suit and tie. Although, in terms of physical size he is no different from others, he is establishing the forcefulness of his points by increasing the intensity of his voice. Everyone's eyes are glued to him, and his face is rigid with deep seriousness. The other participants at his table appear to submit to his ideas.

At yet another table, two casually dressed individuals are discussing some papers. As the conversation goes back and forth between them, they shift in their seats and use their hands to stress points or to gesture toward some of the papers. A stark contrast from the previous scenario, a pleasant and constructive conversation is occurring where they appear to give and take equally in the discussion. Every once in a while, a small smile creeps over one of them or a slight laughter emerges.

Over in another corner sits a couple that is enjoying a slow and relaxing morning. Their body postures and facial expressions show that a completely different interaction is occurring here, in sharp contrast to the previous tables. The gentleman reaches across and lightly touches the woman's hand; there is a deep look in her eyes as she glances at him. They both lean into the table in an effort to be nearer to one another.

Each of these social interactions has a very specific purpose. Although I am not privy to the actual conversations during these meetings, I can deduce a little meaning from their interactions through careful observation. The actual words spoken don't matter all that much to me, yet the nonverbal communication and behaviors observed during these interactions are intriguing. If I was not so immersed in biological thought, I would probably be a sociologist in order to study group dynamics and the origin of social behavior in humans. However, since I study some aspects of social behavior in my research life, I can combine both my love of biology and my interest in social interactions. Besides which, I get far fewer stares from people when I closely watch animals interact as opposed to my inquisitive periods in the bakery. Although we are very social, we are hardly unique with respect to the rest of nature in regards to social behavior.

Many various animals exhibit complex social behaviors and, as a consequence, form elaborate animal societies. Probably some of the most well-known social structures occur within mammals. Many primates live within family units or even extended groups. Most marine mammals have some form of social organization, usually forming pods, and even smaller mammals, like mice and rats, have a system of social interactions that form a society. What may not be known is that social behavior is also very prominent outside of mammals. Fish often school or travel in large groups that require some aspect of social behavior, at very least, in coordinated movement. Lobsters and crayfish form hierarchies and that are reinforced with aggressive behavior that dwarfs the typical head-butts seen in mountain goats. What separates human social behavior from other forms found in nature is the unique ability for humans to have multiple social systems with differing hierarchies. Some of my days at the University are a case in point.

6.1 Social Hierarchies

It is a Friday morning as I arrive to the lab and what ensues is a day of meetings. The course of meetings will take me through the different aspects of social interactions with my status fluctuating from being the top dog to runt of the litter in a matter of hours. I start the morning with my weekly lab meeting which a large group of students who themselves are at various stages of their academic career. I currently have 15 people doing some aspect of research under my guidance, which creates an interesting set of social hierarchies. There is a senior research associate that has just joined my lab. Although technically “underneath” me in regards to the administration of the lab, he is my senior in both age and scientific knowledge. Next in line are the graduate students, including a mixture of Ph.D. and Masters students, which I advise. Finally, there are a number of undergraduates some of which have 3 years’ experience working with me while others have been around for 2 weeks. Although I do my best to treat everyone as equals, there is always a series of social interactions that ultimately result in the formation of a hierarchy. Since I run the lab, I am ultimately at the top and all of the final decisions rest with me. My place within this hierarchy is my social status and as we shall see, this status is highly dependent upon the group with which I am surrounded.

Next on my calendar is our periodic faculty meeting. Anyone who really wants to see social dynamics should be a fly on the wall during a faculty meeting in a university department. Our faculty consists of four different levels of appointment. The assistant professors are the youngest appointees and have been in the department less than 7 years. Next on the ladder are the associate professors and the top rung is reserved for full professors. Above us all is the head of the department, our chair. The chair position carries the final authority for all departmental decisions and one could argue that this duty makes the chair an alpha position within our department. Since I am a mid-to-late-career professor at the moment, I leave my lab meeting as the top dog and walk into the faculty meeting where I reside somewhere near the middle on a power rank.

My final meeting of the day is that of a University-wide committee that is made up of undergraduate and graduate students, professors, and high ranking University administrators. In some ways, since the faculty do not pay tuition to the University and ultimately serve as financial drains on the system, faculty members are on the bottom rung with this group. Being the only non-administrator/faculty member on the committee, I have finally sunk to my lowest social standing of the day.

The development and the maintenance of these many hierarchies is one of the most important aspects of studying social behavior in humans and other animals. In fact, one could almost say that without hierarchies there would be no social behavior. Whether that being is the queen in insect societies or the queen in human royalty, the main concepts underlying social interactions, social standing, and status, are the same. Any level in the hierarchy carries with that position certain privileges or advantages that other positions do not. The higher up a position is within the hierarchy, the better these privileges or advantages become. Being on top of the hierarchy means more mates, better shelters or territories, or more food. For example, the queen bee or queen ant is the only individual that reproduces for the colony or hive. All of the workers and guards are there to serve the needs of the queen, whether they are supplying the queen food or caring for her eggs. A frequently used quote on the benefits of a high social status comes from the movie, *History of the World, Part I*. Mel Brooks, portraying a lecherous French monarch, repeatedly states "It is good to be da King" as he orders around servants and wenches. Just as the "top dog" gets all of the privileges in animal societies, one need not look too far to see the benefits of being higher-up in human hierarchies, whether they are business or royalty hierarchies.

6.2 Do the Clothes Make the Man or Does the Man Make the Clothes?

Growing up in a middle class household, my parents often impressed upon me that the clothes make the man. I would hear this idea in many different forms ranging from "dressing for success" to "you can tell the cut of his jib by the clothes that he wears," which can be understood by the nautically inclined. All of these statements reflect the sentiment that one can gather some meaningful information about the social standing of an individual simply by how he or she chooses to dress. Underlying this thought was the idea that those individuals that were to be respected within society, the doctors, lawyers, politicians, and business individuals, would surely choose to dress in professional clothes.

Evolving from these ideas were the business principles behind the idea of power suits and ties. The color red would send one message, whereas the color yellow would send a different message. When attending that all important business meeting, the red tie with dark blue business suit would exude confidence and power. Instant social standing is assured just by having the right combination of colors and clothing. This raises a subtle but interesting point: Do the clothes make the man or does the man make the clothes? Or in social (and non-sexist) terms, do the clothes reflect the social status of the wearer or do they determine the social status of the wearer?

As humans, we often want to think of ourselves as a highly evolved species that would certainly see beyond the simple coverings of clothes and be able to judge the true nature of an individual regardless of what they are wearing or how they smell to us. Subscribing to the contradictory, yet equally pervasive adage "Don't judge a book by its cover," we would think that putting a crown on a vagabond does not make her or him a queen or king. This person would still be a vagabond. This social standing has to be earned or inherited. Certainly the abilities of an individual are a manifestation of who they are or what training they have had and have little to do with their appearance. Thus, the clothes merely reflect the status of the individual, right?

If this were true, then certainly if we went to a new doctor, our level of comfort or trust in their abilities would not matter if they were wearing nice clothes or ripped jeans and a ratty old t-shirt. Imagine walking into a business meeting where the

CEO had not showered in days or wore clothes that we would call "inappropriate" for such an important meeting. Our perceptions about people, especially those initial perceptions, are colored by the signals that clothes and even perfume or cologne send to us. But how big of a role do these nonverbal signals play in our impressions of individuals? Are these the conch shells of The *Lord of the Flies*, where whoever has the shell is currently the leader and, thus, the shell determines the social status rather than reflecting it? In reality, the answer is whoever has the right chemical perfume rules the roost.

Allen Moore, at the University of Georgia, has discovered nature's version of *The Lord of the Flies'* conch shell by studying the development and maintenance of social hierarchies in cockroaches. Apart from our human bias concerning our perception of the cockroach, they are exquisite research animals. This is especially true if you disdain the ordinary American variety of cockroach and chose to study the forest cockroaches of Tanzania. These cockroaches engage in very intense social interactions, which include fighting and ritualized courtship. A fight (termed an agonistic encounter by scientists) between cockroaches hardly follows the gentlemanly rules of boxing (called the Marquess of Queensbury rules). The agonistic encounters include butting, lunging, biting, kicking, grappling, and chasing. Simply putting two cockroaches together in an arena will result in all-out war. Within seconds, one animal will ram, bite, and kick the other animal. All of this occurs rather quickly and ends with one animal, the dominant, chasing the other, called the subordinate, around the tank. This hierarchy, and other more complex ones that form among groups with multiple animals, can have profound consequences for the mating behavior of the cockroach. Often, a specific animal in the hierarchy (and probably not the obvious one to the human observer) is the most attractive to the female cockroaches. Even for the lowly cockroach, reproductive and social success is tied to the proper place within your society. But before we can reveal the secret of the female's choice, a little more background information about cockroach agonistic interactions and insect behavior is needed.

Anyone who has watched a nature show will eventually come across the typical video footage of intense social interactions. These often take the form of the most violent, making spectacular scenes. These images tend to be the loud and powerful head-butts of mountain goats, the impressive antler crashing of male deer, or the loud roars and sometimes lethal consequences of elephant seal fights. One common feature that is seen in the fights from this diverse group of animals is that fights are relatively long. Determining the alpha male or dominant animal can take an incredible amount of time and energy. Yet, Dr. Moore realized that his cockroaches fought intensely, but only for a relatively short period of time. In fact, he began to think that these fights were not the typical fights seen in other animals. The fights look as if the outcome was predetermined before the cockroaches began to fight, similar to a match between a heavy weight boxing champion fighting the proverbial 98-pound weakling. Yet the cockroaches in Dr. Moore's studies were always the same size. This begs the question as to which cockroach is the 98-pound weakling and how the contestants could know the difference. To answer this question, the role of chemical communication in insects needs to be reviewed.

One of the most prominent themes in insect biology is their reliance on chemical signals for making a host of ecological decisions. Insects have been shown to use pheromones for mating, individual recognition for social hierarchies, to control reproduction, and a variety of other behaviors essential to survival, such as the nest mate recognition exploited by the thieving ants described in Chap. 1. In fact, it would be possible to center every nature story in this book on insects. Cockroaches, just like any other insect, use chemical signals in their daily lives and have prominent antennae on their head that are sensitive to a host of different chemicals. Thus, Dr. Moore thought that, instead of a series of vocalizations used in many different mammalian fights, the cockroaches may be using a language of smell to communicate who the winner and loser will be in the fights.

It turns out that these Tanzanian cockroaches produce a pheromone that communicates clearly to other cockroaches who is the boxing champion and who is the 98-pound weakling. As with most other insect pheromones, the signal is not a single omnipotent compound, but a mixture of three different chemicals that is analogous to a sentence constructed of various words conveying specific information such as social status. Each of three different components conveys a different meaning for the cockroaches. Moore took each of the chemicals in the pheromone blend and placed them on tiny pieces of paper (almost like the clothes analogy above). He placed these pieces of pheromone paper on cockroaches as either a single chemical, or in the many combinations of two, or all three components. The mere presence of one of the chemicals makes a particular male cockroach act like a subordinate: that cockroach cowers and runs for cover. If one of the other two chemicals is placed on the same cockroach, the opposite happens. The cockroach now struts around the arena as if it was king of the world. If both of the latter two compounds are attached to the cockroach, the effect is magnified. This signal is an essential component of these social interactions. Cockroaches produce all three components of the signal; therefore, the presence of the signal does not make one cockroach dominant and the other one subordinate. The relative concentrations of the three components is the critical aspect that makes the difference in the individual's social standing.

In the English language, sentences are constructed from three simple building blocks: the subject, the verb, and the object. Basically, these three concepts are: who is doing something (subject), what they are doing (verb), and to whom are they directing the action (object). The meaning of some sentences can change dramatically by emphasizing one of these components over the other two. For example, let us examine a simple phrase like "I am King." If the "I" is emphasized, we are trying to differentiate between the fact that "I" am the ruler as opposed to any other possible usurpers. If the "am" is accented, the sentence takes on the connotation of elation as if reveling in achieving the highest stature. Finally, by emphasizing the "King" and raising our voice a little, the sentence may become a statement of surprise or even a question. This last example certainly carries less forcefulness than the previous two versions of the sentence. In our running analogy, the three words are different articles of clothing with the word "King" being the powersuit.

Like the analogy "I am King," the cockroach pheromone system acts in a similar manner. By emphasizing (having a higher concentration of) the "I" and "am" portions of the pheromone, the cockroach strongly convinces his opponents that he is indeed the king and that they should cower at his 6 feet. Conversely, by accenting the "King" (having a higher concentration of this component), the cockroach is asking the question "I am King?" and is thus relegated to a submissive role within the population. For the cockroaches, the relative concentration of these components makes an animal dominant, and these signals are just as clear as grabbing the conch shell as in *Lord of the Flies* or putting on the one ring in *Lord of the Rings*.

If being on the top of the social ladder confers advantages in regard to mates, shelter, and food, why would the cockroaches produce the third component that relays a message of submission? Why not just produce the two dominant components of the pheromone and become super dominant? This approach should get the male cockroach all of the matings he could ever want, right?

Just as there are stereotyped agonistic interactions between males, there is also aggression between males and females during the courtship that precedes mating. The super dominant males will win all of the fights, but the problem is that they get too aggressive for the females. During fights between males or between males and females, one of the animals may lose one or both of their antennae. For humans losing our sense of smell is not as critical to our survival as losing our sight or hearing, but for the cockroach, the loss of an antenna is the loss of their whole sensory world. Without the sense of smell, they cannot mate, locate food, or find places to lay eggs. Thus, females choose males that are dominant, not super dominant so as not to get injured during the intense courtship ritual. The third pheromone component serves to temper the social effects of the first two pheromone components. Just as the clothes make the man, in the example above, the smell makes the cockroach. Without this perfume, the cockroach is nothing, but with it, the cockroach is king.

6.3 The Secret (Smell) of My Success

The cockroach use of a pheromone in determining the status of the individual is somewhat unique within nature. The more common situation is when an animal becomes dominant and consequently the dominant animal produces a pheromone that reflects that status. We can think of this situation as a perfume that reflects the social history of the animal. Dominant animals would wear Chanel No. 5 whereas subordinate animals would maybe choose a knock off brand bought in a gas station. There is a good reason the preceding sentence was phrased as a conscious choice on the part of the animal. It is as if one could choose to either wear the upscale perfume as opposed to the garden variety smell. If this is the case, why would any animal choose the subordinate smell and, as a consequence, gain access to only the sub-par habitats, food, and mates?

Crayfish, as described in the previous chapter, are one of the many crustacean models for animal behavior and chemical communication. They are nocturnal animals often found in murky or muddy environments. In these environments, particularly at night, visual signals are of no consequence. Crayfish are also gregarious, living in large groups, and often in very high densities. They have a bladder system (as described in the previous chapter) and two enlarged claws used for fighting and social behavior. All of these characteristics make them ideal for studying social behavior and chemical signals.

As with cockroaches, crayfish will often fight and establish hierarchies but, unlike the cockroaches, the agonistic interactions between crayfish can last for several minutes. These fights can put to shame the brutal nature of mountain goat headbutts or elephant seal fights. The enlarged claws are used to grasp and tear; while some of the fights between crayfish can even turn lethal, more often than not the fights usually end before this occurs. The outcome of these fights is used to establish a hierarchy within the population and, as with most animals, the larger the animal, the more dominant that animal becomes. The smaller animals tend to be at the bottom of the hierarchy and are thus relegated to less than ideal habitats and have fewer opportunities to mate. Social signals in crayfish are closely tied to the neurochemistry of the animals' brain.

The crayfish nervous system is an elegant model to study the neurochemical basis of hierarchies and dominance, which all revolves around a simple organic molecule known as serotonin. Serotonin is a very interesting molecule and is associated with a host of behavioral and neurological problems in humans, such as schizophrenia and Parkinson's disease. However, what is interesting is that serotonin is linked to social behaviors in both humans and crayfish. Here is where I would like to introduce Don Edwards, who has been leading the research into the role that serotonin plays in the social behavior of crayfish at Georgia State University.

Dr. Edwards has been examining the levels of serotonin in animals with different social histories and altering the serotonin levels in other animals in order to understand the linkage between serotonin and dominance. Dominant crayfish tend to have more serotonin in their nervous system than subordinate crayfish. To state that serotonin levels directly correlate with dominance status is not the complete story but a simplified version for the purposes of a book on chemical communication. Basically, Dr. Edwards has shown that as serotonin increases in concentration within the nervous system, the subsequent dominance status also increases. A number of factors such as past social experience, size, and sex of the individual also play a role in dominance establishment and can influence the effect serotonin has on the nervous system.

Crayfish have a semi-open circulatory system. When serotonin is produced by the nervous system, the molecule is released into its circulatory system and delivered to appropriate places within the crayfish. This is in contrast to the closed circulatory system of mammals. In a closed system, the body's blood is enclosed in a system of pipes, which we call blood vessels. The blood is forced through these vessels by the repeated contractions and expansions of the chambers of our heart. In a "true" open circulatory system, there is no system of pipes and no pump serving to push the blood around. Crayfish have a semi-open circulatory system because they have a small set of open-ended blood vessels that are connected to a rudimentary heart. This type of circulatory system is critical to the development of our story on crayfish, social signals, and serotonin.

Now that we have established a base of knowledge for the biology of crayfish and serotonin, let us return to the idea of chemical signals. If you were to place two crayfish in a fish tank, you can guarantee that they will fight. A casual glance at the fight with untrained eyes probably would not reveal anything unusual. One would see two clawed animals pushing each other around with the claws closed. If one of the crayfish does not back down from this "boxing match," the fight will begin to escalate. The crayfish will then open their claws and actively grab hold of each other in an effort to turn over and pin their opponent. Professional wrestlers have nothing on these animals as they push, grab, and use leverage to try to influence the outcome of the fight. Again, if one of the crayfish does not submit, they both take the next step in fighting: an all-out unrestrained, no-holds barred fight with the lethal claws. At this point, any fighting rules go out the window and each crayfish will literally attempt to dismember their opponent. During these increasingly aggressive stages of fighting, one of the animals usually realizes that winning the fight is not in the cards for the day and retreats from the other animal.

Notice that I used the words "untrained eye" when describing the observation of these fights. There is far more to these crayfish fights than the obvious pushing, grabbing, and tearing by the lethal claws. The trained observer will notice subtle but key elements of the fights are missing from the description above. During the fights, crayfish will often "flick" their lateral antennules. The lateral antennules are a pair of small, hairy appendages that stick out from the top of their head. The "hairiness" of the appendage is due to the thousands of chemoreceptors that are located on the appendage, which is often described as the nose of the animal. (Although a more appropriate description would be one of the noses since the crayfish carries 12 different appendages, each of which functions as a "nose"). The "flick" of the crayfish antennule is a rapid downward movement of the appendage and is the equivalent of our sniffing to gain more information about a particular smell. Thus, the crayfish are actively sniffing some chemical in the environment, perhaps assessing the smell of their opponents during their fights. But what do they smell?

Back in Chap. 1, I mentioned the story about "the smell of fear"; as you may recall, crayfish have a bladder in which they store "urine." In addition to a bladder, the crayfish have a pair of nephropores, one directly beneath each of their eyes. The nephropores are the outlets of the bladder and can be opened and closed to release their contents into the surrounding water. When opened, a stream of water is expelled directly forward and away from the animal. It may seem awfully strange and unsanitary to us to have your nephropores right beneath your eyes, but this location serves a very useful purpose to the crayfish during social interactions.

During a fight, two crayfish face each other and carefully approach with claws raised and open in a threatening gesture (Fig. 6.1). What is obscured from view by the presence and use of such lethal weapons is the exchange of a wealth of information about the opponent through the use of urine and the chemicals contained within it. Instead of solely relying on the visual information about the size and strength of their opponent, these crayfish begin a literal "pissing match" and release relatively copious quantities of urine in the direction of their opponent. With the open circulatory system, any change in serotonin will also have a concomitant change in the

Fig. 6.1 Crayfish flicking antennule

amount of serotonin and metabolites of serotonin in the blood of the winning crayfish. Eventually, this serotonin or its metabolites will find its way into the bladder system of the crayfish to be used in its next match giving the winner of the fight an added boost.

The subsequent role of these stored hormones (in crayfish or other social animals) can cause what are known as “winner” effects. This “winner effect” is the phenomenon where a crayfish that has had a recent winning fight is more likely to win the next fight. Winners keep on winning and losers keep on losing (because of a “loser effect”). This is analogous to confidence, ego, or momentum in the human world. Think of all the times that we have heard about a sports team believing that they are invincible. If two crayfish are placed in a tank and one of them has just won a fight, the winner will invariably win the next match. If this experiment is repeated, but this time the urine release of the winning crayfish is blocked, the “winner effect” disappears and the two crayfish act as if there never was a previous fight. So, the momentum or ego of the crayfish appears to be tied-up in the chemicals being released in the urine. The urine “announces” the win–loss record of crayfish just as surely as a ring announcer does in a heavyweight championship fight. But the urine has a more far-reaching consequence for the crayfish.

Imagine a situation with the classic schoolyard bully. Everyday the bully enters the schoolyard and eyes all of the potential marks. Seeing a smaller kid over by the swings, the bully approaches and begins to flex his muscles or starts to make some threats. Quickly, the smaller individual will succumb to this level of intimidation and will hand over his lunch money. If this scene is continued day in and day out, two types of phenomena will manifest themselves. First, the smaller kid will recognize the bully at a distance and will either hide or relinquish his money to the bully without the show of muscles or verbal threats. A certain relationship has been established, and this relationship needs very little reinforcement to remain in place.

Second, the smaller kid will begin to exhibit subordinate behavior all of the time, not just to the bully. The pattern of bullying will result in a lack of ego or low self-esteem in the kid being bullied.

This situation is not uncommon in nature and is just an extension of the winner or loser effect described in the previous paragraph. Another example, albeit a little unpleasant, occurs when a dog has been mistreated for a period of time by abusive owners. If one is in the presence of a dog that has been treated poorly, the dog will exhibit classical subordinate behavior to everyone (not just the previous owner). This is seen when the dog approaches a human and often keeps its body close to the ground, its tail is tucked underneath the body, and the dog often refuses to make long-term eye contact with the human. This is a series of conditioned subordinate behaviors and usually occurs with long-term exposure to an overpowering physical presence, such as a schoolyard bully or abusive owner. This behavior is also seen in crayfish. What is unique about crayfish and our story on urine is the ability of only the smell of urine to produce the same low self-esteem effect seen in dogs and bullied school children.

Here, with great pleasure, I can count on my own work. This work was performed with Dr. Dan Bergman, a former graduate student of mine. If you subject a crayfish to a week-long series of repeated fights with larger crayfish, the original crayfish will perceive itself a loser and will begin acting like our dog or bullied child described above. The "loser" crayfish will lose fights, run away from opponents, and generally act as a thoroughly subordinate crayfish. This seems to be a fairly straightforward concept. Now, if you subject a naïve crayfish (naïve means no social history) to a week-long exposure of only the urine from a bully crayfish, the naïve crayfish will become a subordinate crayfish and act identical to the crayfish that has been beaten up for a week. Just the mere smell of a bully crayfish is enough of a stimulus to alter the behavior of the second crayfish. This phenomenon exhibits itself without any physical interaction and without any visual contact with the bully crayfish. Given what we currently know about the role of serotonin and crayfish social behavior, a specific chemical signal in the urine of the crayfish appears to be powerful enough to alter the inherent social status of the crayfish.

This is similar to the "power tie" mentioned at the beginning of this chapter. This tie not only reflects dominance in the wearer but also forces those individuals around the wearer to become subordinate without consciously realizing it. Imagine attending a potentially hostile business meeting where critical contracts or key business decisions are at stake. Furthermore imagine that you have the human clothing equivalent of the crayfish dominance signal. Simply slip this "super" power coat" on and by the end of the meeting all eyes are on you and ready to follow your lead.

6.4 What's the Password?

Around the age of 10, a few of my neighborhood friends and I formed one of those typical childhood clubs. A club is nothing without a clubhouse, or at least we thought at that age. So we embarked upon that great childhood journey of building a clubhouse. Gathering bits and pieces of old lumber, nails, and screws, we began the task of building our dream clubhouse. If I remember correctly, this was going to be the palace of tree houses with a secret trap door, rope ladder, lighting, and several booby traps for those unwanted visitors. As with many other youths at this age, the mind projects images and ideas that our bodies often cannot see through to the end. Our fabulous tree house ended up as a group of boards slapped together that barely kept out the rain, but to us that tree house was our own private little kingdom.

Another key aspect of a club is having a membership; some belong and some do not. Being young enough that I still had disdain for girls, our club was quite exclusive and stereotypical in that "no girls were allowed." To ensure that only the privileged ones entered the clubhouse, we had a series of top-secret passwords and handshakes. Without performing the correct ritual in the correct order, there was no admittance into our hallowed haven. Looking back however, I am not too sure that any of the neighborhood's opposite sex really wanted to join our club, anyway.

The point, however, is that without the ability to identify those that belong to the guild and those that do not, there is no opportunity for group behavior to arise. Even though I am a fair bit older and hopefully wiser now, I belong to a number of different groups that require a modern type of "password" in order to identify those that are in and those that are out. As a faculty member of the University, I have a special parking pass that allows me to park near my laboratory. My research interests and research papers identify me as a member of the behavioral group within my department.

Outside of my work, I root for a number of different sports teams and during their games I wear the respective team jersey. I used to go to a conference in Florida during the Stanley Cup playoffs, and several years ago my favorite Red Wings were heavily favored to win the Cup again. When I sat at a bar watching the game in my red jersey, I was immediately identified as part of an impromptu gathering of fellow fans. We rooted, cheered, and celebrated the various victories of my beloved Wings and their captain Steve Yzerman. During this time period, the Colorado Avalanche had been their dreaded rivals. Every once in a while, a fellow bar patron would wear their team jersey and some friendly banter was traded between us during a Wings/Avalanche game. These group gatherings and the resulting behaviors were never planned, but arose out of our ability to identify those individuals that belonged in our circle (Wings fans) and those individuals who belonged in a different circle (Avalanche fans). Whether we possessed an ID card, wore a team jersey, or put a lab group on a research paper, these signals sent a clear message of where I belong and do not belong (Fig. 6.2).

Humans, in many ways, are the quintessential social animals. For many of us, we need or even crave to be in a cohort and are unhappy unless there is some association with others of the like mind. In addition to the positive social interactions that come from being in a group, we like being identified as part of a specific group of people. A badge of belonging that many of us wear with a deep sense of pride. Our badge could be a Shriner's hat, military uniform, or a bindi, but all of these are symbols of an exclusive group membership that communicate that fact to everyone that recognizes the symbols.

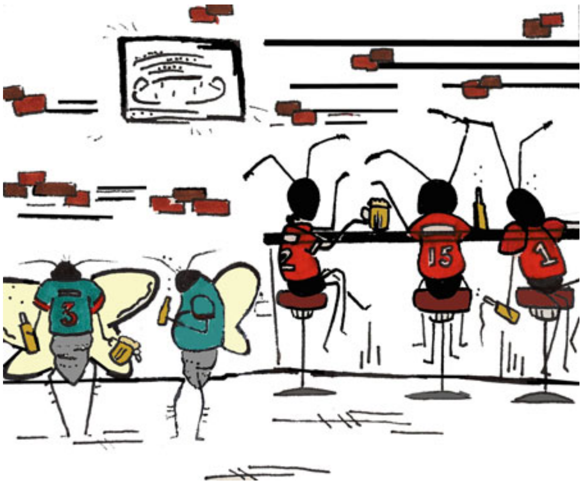

Fig. 6.2 Ants and insects in jersey

Nature, too, has its group membership and symbols of group membership that can best be seen within the social insects, particularly the social honeybees. Social honeybees have a strong hierarchical relationship and an interesting division of labor. Bees are separated into groups with varying numbers. At the top of the whole hive is the queen. The queen, true to her human counterpart, has numerous workers that busy themselves taking care of her every need. Workers clean her, bring her food, and perform all of the daily needs for the queen. Her only job for the hive is to produce eggs that will grow into future young. The young bees work solely on nest activities, taking care of the larvae, building and repairing the nest, and other housekeeping duties. After a month, they graduate to guard duty. Standing sentry at the door, they make sure that only those bees that belong in the nest are granted entry. Usually after 2 weeks of guard duty, they take the final step and graduate to foraging responsibilities. These bees are the ones we see flying from flower to flower gathering the essential goods for the hive. Our story of passwords and special admission returns to the second stage of duties for social bees: guard duty.

Just as some cities are richer than other cities, some beehives are better off than other beehives. The richer hives have more larvae and more food supplies. Whenever there is an inequity of resources, bees may steal what is needed as opposed to earning a good day's pay by foraging. In harsh times and sparse food supplies, bees will often seek out richer hives and attempt to steal some food or larvae. Thus, the role of the guard bees is to ensure only those bees that belong to the nest are allowed access to the inner sanctum.

Similar to my childhood clubhouse, bees also have a password that signifies those that belong and those that do not. Dr. Michael Breed at the University of Colorado is an expert on social bees and their chemical passwords. In addition to studying the tropical thieving ants introduced in Chap. 1, Dr. Breed has spent a lifetime investigating the chemical language of bees and has noticed some fascinating behavior among bees upon return from their foraging trips.

Foraging bees, as most of us are probably familiar, often visit many flowers in the hope of gathering as many resources as possible for the hive. Laden down with nectar and pollen, they return to the hive only to be stopped at the entrance of their home. Guard bees step forward and perform a thorough inspection of the incoming bee. Tapping them with their antennae, the guard bees chemically inspect the returning forager for their chemical password. If the forager has the right password, they are granted admittance to the hive. However, if they have the wrong password, the guard then summons other guards and a vicious attack is launched on the would-be intruder. (In some cases, the intruder is allowed to pass through without the proper chemical if the intruder offers a valuable bribe in the form of sweet nectar). Dr. Breed noticed that most of the guards would inspect the returning foragers with their antennae, repeatedly tapping and touching various parts of the forager's body. He suspected that the bee was sniffing for a specific signal and proceeded to delve further into this story.

There are a number of different explanations or possible scenarios for the specificity of the chemical password. The passwords could be unique for the individual bees or could be unique for the hive. If the password is unique to the individual, this would be akin to the social security number for Americans. Imagine if you were suddenly placed in the bee's world and are sitting at the entrance of the hive. A forager hovers over to the nest, heavy with pollen and nectar. A guard bee steps forward and asks for their password. In the individual password scenario, the guard bee would have to remember each of the tens of thousands of foraging bee passwords. "Is this Jen, Christy, Sarah, or Patty?" the guard would ask herself. Since bees are only guard bees for 2 weeks, they would have to learn and remember each individual foraging bee within that brief period. Without the help of a computer system for tracking individual records, a specific chemical signature for each individual bee is highly unlikely. If a chemical password for the nest as a whole is used then it could be comparable to the passport system that signifies one's country of origin. This would mean that the guard would only need to learn one password. Therefore, Dr. Breed turned his attention to the usage of a global password that all the bees from a single hive would have.

Like many of nature's products that human industry attempts to copy, bee's wax remains far superior to the wax that we can synthesize. The wax has some interesting properties of strength and pliability, but more importantly for our story is that each hive's wax is unique. Bee's wax is a mixture of the specific genetic make-up of the bees (each hive has a slightly different wax) and the raw materials available for producing wax, which come from the diversity of flowers in the bee's local neighborhood. The key waxy components of a beehive tend to be fairly constant across different hives, but what varies among hives are the minor components that add distinctive odors. A hive located in a field of clover will have a different smell than those hives located in a field of mixed wild flowers. Thus, each hive has an exclusive hive odor that is caused by the local flora and the individual genetics of the colony.

This hive odor is readily transferable to any bee simply by spending time in the hive. To demonstrate this, Dr. Breed performed a series of elegant experiments in which he placed a piece of hive in a small cup with a bee from a different hive. After 5 minutes, he then returned the bee to its original home colony where that "altered" bee was promptly attacked by the guard bees and summarily dismissed as an intruder. If he placed this bee in the colony from which he obtained the piece of the hive, the bee was welcomed in as a loyal citizen. Interestingly, he did similar experiments with the guard bees. He found that a guard bee performs their duties not by memorizing the hive's chemical password, but by simply comparing an odor template of what they smell like to what the intruder smells like. So when a bee returns from working in the fields, the guard greets the worker and takes a good whiff of the incoming bee. The guard then compares this sample to its' own smell and if the chemical passwords match, admittance is granted. Dr. Breed also tested this hypothesis by changing the guard bee's reference smell by placing the guard bees on a bit of bee's wax from another hive for 15 minutes. After this exposure, he then presented the guard with two potential intruders, one of its' own hive and one from the hive that kindly donated the hive wax. The guard bee treated its' own hive member as an intruder and the intruder as an exclusive member of the hive. This password system works well because all of the bees start their lives inside the hive and are constantly exposed to the odors of the home colony. Once a bee leaves that individual will still have the hive's chemical signature upon its return. The chemical password signifies that the bee was already on the inside and deserves admittance. This system seems far more effective than our series of complicated handshakes needed to gain admittance to our exclusive clubhouse. In this manner, the chemical password of the beehive maintains a much better regime of those that belong in and those that need to be kept outside.

As expected, whenever there is an exclusive club, there are those who want in but are not allowed in. If this exclusivity is taken to the extreme and there are differences in resources for those animals in the club as opposed to those outside the club, the exclusivity can lead to potential conflict. In nature, this conflict can escalate to hive, troop, or intergroup warfare. Whether the conflict is over admission to private territories, conflict over mates, food resources, or shelters, or over the life and death struggle of predator–prey interactions, chemical signals are playing a role in some of the most intense struggles found in nature.

6.5 With a Little Help from My Friends

Despite being somewhat of an introvert, I have spent a good portion of my life as parts of different teams or groups. As mentioned above, all of these teams have different badges or symbols that acknowledge some type of group association. Many years ago, I played numerous sports in high school. Each team had a style of clothing, coloration, and mascot that would serve as some sort of rallying focal point. Academic and band groups also had points of focus that would bring people together for a common cause. Now as an adult, I find myself in many similar group or team situations where individuals have come together to achieve certain outcomes.

Within the ranks of faculty at a modern university, faculty committees are formed, given a name, and charged with accomplishing certain tasks around campus. I am a member of a martial arts club, and our symbols and rituals are designed to foster an atmosphere of cooperation and support. Communities can be built around symbols and rituals.

Certainly, within the sciences, individuals can accomplish their goals of performing good science, but science is inherently a social endeavor. Papers and presentations are reviewed in a social manner, graduate students pass through different public or social hoops in order to signify their level of readiness to be a scientist, and in fieldwork, cooperation and help are critical. In many ways, scientific survival is dependent upon cooperation and teamwork. Probably the group that I am most proud to be a part of is my group of graduate and undergraduate students that comprise my lab. This group, called "The Laboratory for Sensory Ecology," is a large, boisterous group full of strong personalities. Every year we produce t-shirts with the lab logo or some other drawing/saying that is key to that year. In addition, when students have significant accomplishments, we gather and celebrate them as a group. For paper acceptances, grants, and graduation, the students get their own bottle of champagne. As the group gathers, the celebrator globs some paint on the top of the champagne cork (the color of the paint symbolizes the event), pops the cork, and marks the ceiling. Finally, the student climbs a table and signs their name on the ceiling next to the paint mark. We all cheer and congratulate them on their accomplishment. These badges (t-shirts) and ceremonies (popping champagne) of belonging serve to draw the social group together and foster an environment of collaboration.

While completing his work "In Memoriam" in 1849, Alfred Lord Tennyson created the phrase "…Nature, red in tooth and claw" to symbolize the often violent nature of competition and natural selection as opposed to the collaboration described above. Some of the stories about hierarchies described above might also give rise to the notion that nature is often full of conflict and warfare. Cooperation also exists within nature and that cooperation occurs across different levels of groups. In birds, there are cases where the previous generation of siblings will stay to help raise the next generation of brothers and sisters. The Australian mudnestors are obligatory cooperative breeders meaning that without helpers the parents cannot fledge their offspring. Cooperative breeding also occurs within mammals such as Meerkats and some primate species.

Beyond breeding, cooperation is seen among many different groups for predator protection. Among Canada geese, individuals will take turns being vigilant for predators while other geese are foraging. Two to three geese in a large flock will voluntarily stop eating in order to stretch their necks looking for potential predators. After some period of time, these geese will begin foraging and a couple others will start their turn watching for predators. This rotating set of eyes (rotating turns for guard duty) allows the flock to increase their overall efficiency for foraging, while maintaining a safe level of detection for predators. There isn't any active communication about coordinating this behavior among the flock, but the group behavior arises from the periodic turns that animals take being vigilant. The same type of vigilant behavior is commonly seen for prairie dogs, zebras, and other savanna herbivores.

In some instances, the coordination of group behavior is performed through communication, chemical, or otherwise (as seen with Dictyostelium aggregation outlined in Chap. 1). In primate communities, vocalizations are used to signal the presence of predators, and different sounds are used to signal danger from above (raptors), in the trees (snakes), or from the ground (jaguars). Communication to coordinate group behavior is seen throughout nature and not just in animals or bacteria. Even plants will exhibit a rudimentary form of communication between members of a "group." The term group here is used quite loosely because there isn't any active behavior on the part of the plant to group themselves. For the most part, grouping is done through the varied processes of reproduction and seed dispersal.

Plants are not the first group that are commonly thought of for examples of behavior and communication, yet this group of organisms provide excellent examples of chemical communication. As mentioned in Chap. 1, plants can produce a number of chemicals that are sequestered in the leaves and other tender parts of the plant that are of particular interest to herbivores. In a previous example, oak trees would release a chemical signal through their roots that served to increase the anti-herbivory chemicals in the leaves of surrounding oak trees. Given that roots are designed to release and take in chemicals from the soil, this example may not be too surprising. What may be more surprising is that plants also send signals through the air to other plants to communicate predatory events. Acacia trees in Africa are a source of nutrition for the numerous herbivores on the African savanna. These trees, once attacked by an herbivore, can produce chemicals and sequester them in their leaves. The chemicals, a class of compounds called tannins, are aimed at reducing leaf herbivory and are so toxic at high enough concentration that kudus have been known to die from an overdose of toxic leaves. Another prominent African herbivore, the giraffe, has been observed consuming the leaves only on upwind trees and avoiding the luscious leaves of downwind trees. In addition to producing more tannins in their own leaves, the attacked tree also sends airborne chemical signals (pheromones) to the surrounding group trees. As the downwind trees detect the pheromone, they start producing more toxins and these leaves become, at a high enough concentration, lethal to the kudu.

Some acacia trees don't stop with these simple chemical defenses though. In a true sense of calling on friends for help in times of need, the acacia trees are master alchemists. Now, the concept of chemical communication in plants was not an easy one for the scientific community to accept. Early pioneers in this field, such as Dr. David Rhoades at the University of Washington, continued work on a wide variety of plants and their chemical reactions to insect attacks. The concept of chemical communication between plants of the same species has become fairly common and even some evidence on communication across different species of plants. The bullhorn acacia, found in Central and South America, has a unique relationship with ants that helps protect the plant against the relentless attacks of grazing herbivores.

Acacia trees in general have thorns that grow on the branches that are part of their deterrents to grazers such as antelopes, but on the bullhorn acacia, the thorn has expanded and been enlarged through natural selection. The thorn still functions as an anti-herbivory defense, but is also a home to an ant (*Pseudomyrmex ferruginea*) that has a symbiotic relationship to this particular acacia. In symbiotic relationships, both organisms benefit from their close relationship. In some instances, the organisms involved in the symbiotic relationship cannot survive without the other organism. With acacia trees and this species of ants, the tree provides the ants with precious food produced at the tips of the thorns. The ants, in turn, provide the trees with protection against those organisms that would like to consume the tree's leaves. Unlike the acacia trees in Africa, this particular species of acacia doesn't produce the tannins in response to grazing on its leaves. Work performed by Dr. Anurag Agrawal (Cornell University) found these trees have the ability to "call" for help from the ants that live within the thorns. Upon a disturbance (break of leaves or branches or grazing), the acacia tree emits a special pheromone that attracts the ants to any spot of damage. In one set of trials, Dr. Agrawal punched a hole in a leaf with a common paper hole punch. Within 4 minutes the number of ants patrolling the damage site had increased by 400 %. The ants, riled up and gathered in one spot by the chemical distress call, will attack any herbivore in the area and protect the tree from any further damage. Having the right friends in the right places at the right time definitely pays off; of course, having the right pheromone is necessary to place that call for help.

6.6 The Life of the Party

In Chap. 2, I described the neural connections for our sense of smell and compared them to the neural pathways for our vision and hearing. To summarize again, the information from the eyes and ears go to specific areas in our cortex and as such, we think about these stimuli before responding to them. The thought process might be exceptionally quick or a slow deliberate process. In contrast, the information from our nose is sent to the limbic system which evokes a powerful emotional response. The delight of the smell of food, the sensual nature of a sinful perfume, or the refreshing aroma of air after a morning thunderstorm all provide strong sensations. Within a social context of the human existence, I would define our olfactory senses as rather judgmental. The immediate emotional response, rather than some cognitively developed response, evoked by chemical signals colors our perception of people in social settings.

Another thought experiment might provide some illumination on this concept of judgmental olfactory responses. Imagine you are off to a meeting; say, a fairly important meeting. Definitely not a business casual meeting, as there is an unwritten expectation that everyone should look "presentable." The meeting occurs in some high rise building that requires an elevator ride. Maybe the elevator is slow or the building is tall, but there will be a substantial period of time riding in the relatively small and closed space inside of the lift. As you enter, a rather well-dressed middle aged man follows you onto the elevator. Perhaps, he is going to the same meeting that you are attending. As the doors close, you perceive a subtle hint of body odor. There are only two of you in the elevator and you showered thoroughly in the morning, so clearly this aroma is arising from your companion. As the ride gets longer and longer, the odor increases in intensity. Without much thought, what are your conclusions about this gentleman? What would change about those judgments had the gentleman smelled pleasantly?

The scientific work in the use of smells in judging others is still relatively sparse, but Drs. Chuck Wysocki and George Preti at the Monell Chemical Senses Center in Philadelphia have spent years collecting, analyzing, and testing different bodily odors that are produced under different conditions. Humans have a tremendous ability to produce odors and these odors appear to be different given the condition or mood of the odor donor. Human sweat will have a variety of smells depending on whether the donor is scared, excited, or sexually aroused. Although most of the work has focused on the axillary glands located in the armpit, there are other sources of human odors such as the mouth, feet, and genitals. Drs. Wysocki and Preti have categorized some of these odors as either primer pheromones (those that impact the endocrine or nervous system), releaser pheromones (those that evoke a behavior), modulator pheromones (those that impact the moods of other people), or signal pheromones (those signals that supply specific information such as reproductive status or sex of the sender). Within a social context, the modulator pheromones may be the most interesting because these chemical signals may influence the mood of the social environment without the other people actively noticing or being aware of those signals.

The work by the famous psychologist Martha McClintock has shown that the odors emanating from lactating women have the ability to increase the sexual motivation in other women. Interestingly, this effect was different for women with a regular sexual partner as opposed to those women that were single (the key to being single is not related to sexual activity but connected to companionship). The increased sexual motivation was higher in those women with partners. Dr. Preti and Wysocki have shown that women's sexual moods were increased if they were presented with odors from the armpits of male participants. These are just two examples of how chemical signals can alter or modulate the moods of people without any cognitive recognition of those odors. I would like to refer back to the definition of pheromone covered in Chap. 2 and to note that pheromones and, in particular, these modulator pheromones alter or enhance moods of people on the receiving end of the odor. The search for a human pheromone that evokes uncontrollable behavior as depicted in popular culture is probably a fruitless search.

These studies show that social judgment based on odors is possible within humans. In the scenario above, the body odors produced by the elevator companion may tell us a lot about the emotional state of the gentleman. Work by Drs. Denise Chen and Jeannette Haviland-Jones has demonstrated that humans are capable of detecting different moods of people based on their body odor. In this study, participants were asked to watch either short clips of a happy or comedic movie and other participants were asked to watch a short clip on bugs, spiders, and snakes. Collecting human body odors doesn't sound like a fun job, but there is a standard technique that is relatively straight forward. Those people watching the movie wear cotton pads underneath their arms and then the cotton pad is used to produce odors. At some later point, both the donor and naïve people are asked to come in, smell vials of body odor, and asked to identify whether the odor came from a happy person or fearful person. The participants could accurately assess the mood of the donor person. A more recent study, led by Dr. Gün Semin, showed that people who are exposed to context specific body odors tend to have the same emotional response as the donor person. For example, Dr. Semin showed male participants one of two different movie clips to evoke specific emotional responses. They were shown either horror clips (*The Shining* with a wonderful performance by Jack Nicholson) or disgusting clips (scenes from MTV's *Jackass* show). As in the studies above, cotton pads were placed underneath the armpits of the donor males. Females were invited in to take a whiff of the odor, and the researchers tracked eye movements and facial muscle contractions in order to capture their initial emotional responses to the chemical stimulation. (Males were selected as donors because they produce stronger chemical signals, and females were selected as tester because, on average, females are more sensitive to chemical signals.) The researcher found that the female participants reacted in an identical fashion as the emotional context of the odor. In other words, if the participant smelled a "fear" odor, they reacted with a fearful expression and those participants that smelled a "disgusting" odor reacted with disgust.

The authors have labeled this phenomenon an "emotional contagion" where the emotional state of one individual may spread to others via chemical signals. To extend this analogy farther, scary movies may be even scarier in crowded theaters where some individuals may be (unintentionally) sending fearful signals across the theater through body odors. If the gentleman that entered the elevator with you is in a state of fear, perhaps because of the impending big meeting, you may also begin to feel a heightened sense of fear after "receiving" his chemical signal. Similar to the bullhorn acacia trees, maybe this is our response to potential danger and that chemical signals (as modulators of our moods and behaviors) could be a powerful and hidden part of human society. In the next chapter, I'll explore how these social signals could evolve into something a little more sinister as animals have developed the ability to lie, cheat, and deceive through their odors.