Pheromones and the Vomeronasal System
In Humans
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Evolution

Figure 1 - This figure is a cartoon drawing of the vomeronasal organ and the vomeronasal receptor neurons. (Hughes, 1999)
Controversy

In ancient Roman times when gladiator fights were common so was the knowledge that human sweat can be a powerful substance. If a king were to want to have a child his best athlete was instructed to run a marathon and then collect his sweat in a jar to give to the king’s wife. The queen then drank the sweat which was believed to increase her fertility. Whether or not this actually produced the intended results has not been studied, but since those same ancient Romans believed that one should be drained of their blood whenever they got sick one would be wise to be skeptical.

In modern times there are many pheromone manufacturers that still believe in the power of pheromones. For years perfume makers have been putting secretions of musk deer and civet cats which almost surely contain pheromones in their perfumes and the public has been paying high prices for them. Despite public opinion of the effectiveness of pheromones much controversy has remained in the scientific community until recent years.

Much of the controversy was the result of an inability to detect pheromones in humans and the largely accepted view that humans lacked a functional vomeronasal system, (VNS) (Johns, 1978 in Grosser, 2000) which is the neurosensory system which almost all other terrestrial mammals use to detect pheromones. A landmark study by McKlintock in 1971 provided the first well accepted scientific study that described a human phenomena to be the result of pheromones. In this study McKlintock showed that female college students living together in a dorm could develop synchronized menstrual cycles when a pheromone containing substance was placed regularly under their nose. (McClintock, 1971 in Grosser, 2000) McKlintock however was unable to identify a specific pheromone or a means of reception in the women so skepticism continued. A 1994 invention by Monti-Bloch et al was used in a study by Grossner to silence some skepticism when it successfully delivered 100 picograms of a particular pheromone directly to the vomeronasal organ, (VNO) the receptor of pheromones in the VNS. This device has been used in numerous studies and has shown that pheromones applied directly to the VNO can produce a significant physiological effect in the receiver. (Grosser, 2000)

Pheromones first evolved as a means of communication, communication that was necessary for males and females to coordinate reproductive functions in order to maximize fertility. (Moore, 2003) It is plausible to suggest that when chemical signaling first appeared those males and females that were able to use it had an evolutionary advantage over others, because it would have been much easier for them to find each and communicate simply that they were ready to reproduce. This type of communication would be selected for because it gives both males and females an evolutionary advantage. This means of communication has also been shown to be very successful since almost all terrestrial animals use it. It has been shown to be less successful in marine vertebrates like dolphins, whales seals, crocodiles and sea turtles as well as avian vertebrates including birds and many species of bats, for none of these animals display it. What is particularly troublesome for those who believe that humans still use pheromones as a means of communicating is the fact that the trait has been lost in Old World Primates. (Brennan, 2001) It is believed that the reason for this is that it simply was not advantageous in their complex social system based on increased vocal and auditory capabilities that rendered pheromonal communication useless. Of course humans evolved from the Old World Primates so to suggest that humans still use pheromonal signaling is to suggest that the trait was lost and then re-evolved. Phylogenists would believe that this explanation lacks parsimony and would therefore search for another phylogeny. However an interesting study by Bhatnagar in 1998 mapped the path of the VNS through many bat species and has shown that it has been lost and then re-evolved many times in their evolutionary history. (Bhatnagar, 1998) These results suggest that it is at least possible for humans to have re-evolved or at least regained the use of their VNO, perhaps the most critical structure in pheromonal communication.

This study hopes to compile the best evidence for human’s use of pheromones into a convincing argument for their existence as a necessary component of sexual selection. First we will look at exactly what pheromones are and what they do. Then we will look at the new evidence that makes it impossible to deny that pheromones can produce a sexually specific physiological response in humans. Then we will look at the VNS, the system that receives and processes pheromonal input, and we will settle
the argument as to whether or not humans have a functional VNS. Lastly we will summarize the evolutionary advantage that pheromonal communication and pheromonal communication facilitators provide humans in that never ending mating game that we call life.

Pheromones

The term pheromone was first introduced to the scientific community by Karlson in 1959. His definition of a pheromone as “a substance excreted by an animal, to the outside of that individual, which is then received by another individual classically of the same species, which then elicits some behavioral or developmental response related to the survival of the species,” (Karlson, 1959 in McCoy, 2002) is still largely accepted. Now most would add the word “stereotypical” before “behavioral”. The reason that most scientists now believe that pheromones should be said to elicit stereotyped responses comes in part from new evidence from hamsters. When allowed to sniff a pheromone from hamster vaginal fluid called aphrodisia the male hamster almost immediately begins to perform the “mounting behavior” a stereotypical response. (Linman, 1999) A lack of evidence for stereotyped behaviors similar to the male hamster in humans has lead McKlintock to propose that pheromones should be simply said to simply modulate human behavior. (Jacob, 2000)

In 1999, Cutler concluded that there are four types of behavioral effects of pheromones, these are: opposite-sex attractants as seen when a dog is in heat, same-sex repellant with cats marking their territory, mother-infant bonding, and the modulation of the timing of the fertile cycle in women as seen in McKlintock’s famous 1971 study. (Cutler, 1999 in McCoy, 2002). Others would append the first type to say that pheromones are also involved in eliciting and maintaining masculine and feminine sexual behavior. (Guillamón, 1997)

Chemically, pheromones are considered to be volatile and sometimes non-volatile substances. (Rothardt, 2001) (Cruz, 1998) Each pheromone can be divided into two groups: releasing pheromones, those that elicit an immediate reaction like mating and priming pheromones which produce long-term changes in behavioral or endocrine state, an example of this is seen when the presence of the male rat around pre-pubertal females causes menarche. (Linman, 1999)

Because of the money-making opportunity that researchers find themselves in when they are able to identify a pheromone, they tend to keep the chemical formula a secret. Nevertheless a few chemical formulas are known to the public. Androsta-4,16-dien-3-one (Grosser, 2000) , 16-androstenes, 5alpha-androst-16-en-3beta-ol, 5alpha-androst-16-en-11-one and 5alpha-androst-16-en-3-one are all volatile steroid molecules found to be released from the apocrine sweat glands of men (Rothardt, 2001) While pregna-4,20-diene-3,6-dione (Monti-Bloch, 1998) and 1,3,5(10)16-estratetraen-3-ol (Jacob, 2000) are pheromones released from the apocrine sweat glands in women. Apocrine sweat glands are the main producers of pheromones in humans and are located mainly in the axilla, mammary areola, labia majora, circumanal region, the forehead in between the eyes, the sides of the nose nearest the lips, the ear lobes and the belly button. Many of these areas the only places where humans have retained hair and these hairs promote diffusion of any chemicals on them. These areas are also conveniently located in areas associated with intimate interpersonal and sexual contact. (Hughes, 1999) This fact alone may be some of the most convincing evidence for the importance of pheromones in human reproduction. The apocrine sweat glands in humans are also the only sweat glands that contain peroxisomes which are the organelles in which cholesterol, the building block of any steroid molecule, is synthesized. It has also been shown that apocrine sweat glands can take up certain steroids circulating in the blood and excrete them as pheromones. (Rothardt, 2001)

Pheromones: Proof of Existence in Humans

One of the most intriguing aspects of pheromones is the fact that most of them are completely undetectable by the five senses. Unfortunately this fact has made them particularly elusive to scientific investigation. Two studies, one by Cutler the other by McCoy have shed light on the mystery of pheromones and legitimized their role in human’s reproduction.

In an interesting study published by Cutler in 1998, 38 heterosexual males agreed to wear a specially made aftershave that contained a male pheromone characteristic of heterosexual men in their most sexually active years or a placebo three to four times a week. The chemical formula of this pheromone is secret and will only be released once the patent is approved. In order to make sure that there was no
detectable difference between the two aftershaves each subject was asked if they could smell a difference and all said no. Each subject was then to record the number of times they engaged in six sociosexual behaviors: petting/affection/kissing, formal dates, informal dates, sleeping next to a romantic partner, sexual intercourse and masturbation. They were also asked at the end of each week whether or not they thought they noticed a difference since before they started using the aftershave. After six weeks of data collecting, the numbers were compiled and it was found that the two most intimate sociosexual behaviors, sexual intercourse and sleeping next to a romantic partner showed a significant increase in frequency. Also significantly more men that received the pheromone reported that they noticed its affects. Petting/affection/kissing and informal dates showed a tendency to increase, while informal dates and masturbation did not show a significant increase. The results of the last two sociosexual behaviors were explained by the fact that women did not play a significant role in them, assuming that it is the male who would initiate a formal date. From these results, Cutler et al concluded that the pheromone under examination increased the sexual attractiveness of men to women. While assuming that frequency of masturbation would be an indicator of sexual motivation they concluded that the pheromone did not increase the sexual motivation of men. (Cutler, 1998) Wearing this pheromone obviously increased the reproductive potential of the male, so a male producing this pheromone naturally would have an evolutionary advantage over those who do not.

One of the researches from the previous study decided to run a second experiment reversing the sexes. Norma McCoy published the study in 2002 testing the effects of a different secret pheromone, this time one found on sexually active, fertile, heterosexual women, on sociosexual behavior. She asked 36 women to bring in their favorite perfume and she added either the pheromone or a placebo to it and told the women to apply it every other day to certain areas. The experiment lasted for three menstrual cycles and the data from the first eight days of each menstrual cycle was excluded. It was found that there was no significant difference in perception of the effects of the pheromones between those that used the pheromone and those that did not. But a significantly larger percentage of pheromone users showed an increase in frequency of petting/affection/kissing, sleeping next to a romantic partner, sexual intercourse and formal dates. No significant difference was found in informal dates, masturbation and an added sociosexual behavior, male approaches. These results show that the pheromone acted as a sexual attractant to males and did not increase the sexual motivation of the women. (McCoy, 2002) The author did not speculate as to why the males in Cutler’s study were able to perceive the difference in sociosexual behavior resulting from the pheromone while the females in her study could not, the difference is likely to be social rather than genetic though. Similar to Cutler’s study this shows that a female who is able to produce these pheromones naturally would have an evolutionary advantage. Both studies also show that the reviever would also have an evolutionary advantage.

Other studies have even produced physiological responses in humans by using nonhuman pheromones, this hints at the ancestral nature of pheromonal communication. When adrostenone, a boar pheromone also found in males was applied to a seat in a dentists waiting room significantly more women than men sat in that seat. (Kirk-Smith, 1980 in Pause, 1999) Androstenone also has a distinguishable unpleasant smell for some women, but interestingly the same women report the scent to be neutral around ovulation. (Hummel, 1991 in Pause, 1999) Another study has shown that human neurotensin receptor type 1, a receptor associated with pituitary hormone secretion and muscle relaxation can successfully replace the endogenous pheromone receptor in some yeast. When the endogenous yeast receptor is removed completely without being replaced by the human equivalent the yeast’s ability to receive pheromones ceases. (Leplatois, 2001) Based on how long ago yeast cells diverged from the branch of life that lead to humans this study shows how little the mechanisms for pheromone reception have changed over the years.

Vomeronasal System

The vomeronasal system is a complex organization of different sensory and neocortical structures that are used to detect and process pheromones. While the VNS is related to the main olfactory system in function and location it is very different in pathway, organization and electrical composition.

Showing that humans respond to pheromonal signals is only half the battle, we must also describe the mechanism of reception. In mammals the receiving end is located in the
vomeronasal organ, a dense organization of vomeronasal receptor neurons (VRN). Information going to the VNO can be first collected in the nasal or oral cavity and is then transferred to a small opening at the top of the nasal cavity. (Linman, 1999) From there the VRNs transfer information directly to the accessory olfactory bulb, a sub neocortical brain structure in the VNS. The information is then passed directly to the amygdala and hypothalamus, bypassing any neocortical processing. The receiving neurons for our olfaction system transfer information to the main olfactory bulb (MOB) which then transfers information to the cortex where the organism then becomes aware of the stimuli. This is different from the pathway of the VNS where cognitive perception of the stimuli is not available when the information is transferred directly to the amygdala, which controls emotions, and the hypothalamus which can control specific behavioral and hormonal responses.

Vomeronasal receptor neurons are much more complexly organized and sensitive than regular olfactory neurons. (Brennan, 2001) This complexity is thought to allow the organism to more easily identify specific blends of pheromones. The complexity of the VRNs is reflected in the AOB which is organized much more variably than the MOB and is also very plastic. The complexity in the AOB is necessary to recognize all of the different blends of information that the VRNs report and the plasticity of the AOB increases its ability to learn or remember certain blends. (Linman, 1999) This could be particularly advantageous when mothers need to identify their young and when mates need to identify their partner.

VRNs also have very different electrical properties than regular olfactory neurons. They have potassium ion channels which activate and deactivate slowly. This is expected because of the nature of the chemicals the VNO is detecting. All the VNO has to do is detect a few pheromones and then send the signal to initiate a stereotypical response or modify the organism’s behavior. Once this response is initiated it is not necessary for the VRNs to quickly deactivate to get ready to detect another pheromone, their job is already done. (Linman, 1999)

The human VNO is a bilateral tubular organ located underneath the lining of the anterior nasal septum. (Takami, 2002) The VNO is connected to the nasal cavity through a hole about 1.2 mm in diameter. (Monti-Bloch, 1998) There has been considerable debate as to whether the VNO is functional in adult humans. It is agreed that the VNO develops in early fetal life because it is essential to guide the migration of developing lutenizing hormone releasing hormone neurons to hypothalamic areas. This is known because when the VNO does not develop a disorder called Kallman’s syndrome develops which causes neuroendocrine deficits. (Brennan, 2001) The debate comes from the apparent loss of AOB in adult life, though not all researchers have agreed on this. (Brennan, 2001) (Linman, 1999) and more research is likely to be needed until a conclusion is made. A loss of the AOB could mean one of two things, either that the VNO becomes cut off from the brain and is rendered useless or that new neural pathways develop and the VNO retains its function. Recent studies by Monti-Bloch and Grosser suggest the latter.

The VNS in humans as well as many other mammals is sexually dimorphic. This makes perfect sense because it responds to pheromones that are specifically male or female in origin and initiates different responses depending on the sex of the individual. In cats a male responding to another male’s pheromone marker of territory would be an entirely different response than a female responding to the same pheromone. This is necessary because it would not be evolutionarily advantageous for a male cat to respond to another male cat in a sexual manner for there would be no opportunity to pass on his genes. If the male cat were to respond to the female pheromones by eliciting some sort of sexual behavior that increases his chances of reproducing then that response would be evolutionarily advantageous. In rats it has been shown that neonatal androgens increase the size of the VNS. While a similar mechanism has not been identified in humans it has been observed that like rats the human male VNS is significantly larger than the female. (Guillamón, 1997) The evolutionary advantage behind the larger VNS in males is still unclear. It is likely that it is a vestigial trait that came from females first evolving the ability to make pheromones and then males responding by evolving the ability to identify those pheromones. Therefore the evolution of pheromone glands in females and the VNS in males might be more advanced because it has been around for a long period of time. An interesting study by Zhou et al in 1995 found that male-to-female transsexuals had a size difference in a subsection of the VNS called the BSTc. Those male-to-female transsexuals had a
BSTc much smaller than normal males and was actually the same size as a female’s BSTc. (Zhou, 1995 in Guillamón, 1997) Further research in this direction could have interesting implications in the biology of sexual orientation.

In rats parental behavior differs greatly depending on sex and has been shown to be correlated with the sexual dimorphism of the VNS. A sexually dimorphic subsection of the VNS called the BOAT could be the reasoning for this. The size of this structure has been negatively correlated with the amount of parental behavior. The BOAT in female rats is much smaller than the BOAT in male rats who have a higher chance of committing infanticide. However when the BOAT of male rats is removed that chance is greatly reduced to equal the probability females have in committing infanticide. (Cruz, 1998) While no direct evidence of a relationship between differential parental behavior and a subsection of the VNS has been found in humans a study by Corter and Fleming in 1995 has shown that significantly more new mothers than new fathers can recognize their own infants clothing based on olfactory cues alone. (Corter, 1995 in Cruz, 1998) This finding suggests that the mother is detecting the unique pheromone blend of her newborn child. This same pheromone blend could initiate an advantageous emotional response that causes the mother to care for the infant more, giving the infant a greater opportunity to pass on his/her genes, and the mother a better opportunity to see her genes passed on.

**Vomeronasal System: Proof of Existence in Humans**

Perhaps the two most convincing studies of a functional VNO have come from Monti-Bloch and Grosser. A vomeropherin is a pheromone that has previously been proven to only by received in the vomeronasal organ. In 1998, Louis Monti-Bloch et al studied the effect of pregna-4,20-diene-3,6-dione (PDD), a vomeropherin released from the apocrine sweat glands of women on males and females and found that it significantly affected males only. PDD significantly decreased male’s respiration, cardiac frequency, augmented alpha waves, decreased serum lutenizing hormone, follicle stimulating hormone and testosterone levels. (Monti-Bloch, 1998) The overall effect on the males was a calming one and it could be advantageous for females to secrete PDD in order to calm the “inherent male instinct” to go and mate with more females. Or among other explanations it could simply give the male a good feeling therefore positively reinforcing his close proximity to the female releasing PDD, leading to a greater probability of passing on genetic material. The study by Grosser et al in 2000 tested the effect of androsta-4,16-dien-3-one (androstenione), the most common androstene found in the male axilla and semen. This study showed that not only was androstenione a powerful pheromone but that it is detected specifically in the VNO and does not have to be cognitively processed. Grosser et al delivered 100 picograms of androstenione directly to the VNO using a special device developed by Monti-Bloch. They then measured the physiological and behavioral response produced by the pheromone. After administering the androstenione, respiratory frequency, cardiac frequency, and galvanic skin response significantly decreased and body temperature, cortical activity and parasympathetic tone significantly increased all with P values under .01. Behaviorally androstenione significantly decreased negative affect: emotions like nervousness, tension, irritability and anger as well as negative character: qualities like sensitivity, guilt, remorsefulness, sadness and timidity. They found a marginally significant difference in arousal/excitement/aggression emotions and as well as a difference in qualities regarding social warmth and friendliness. (Grosser, 2000) The evolutionary implication for this study is that androstenione makes women feel better and that therefore they would be positively reinforced when around men. This would be evolutionarily advantageous for the pheromone receiver and giver because it would lead to more male-female interaction that would increase the likelihood of reproduction.

**Pheromonal Communication Facilitators**

Due to the recent evidence from Cutler, McCoy, Grosser and others the scientific community can no longer say that it is undecided when it comes to the issue of pheromonal communication in humans. In light of this fact human behavior can be observed in a new light.

Many children giggle at the odd behavior of the Eskimos when they hear about Eskimo kisses. But now the Eskimo kiss makes perfect sense. When they touch noses the apocrine sweat glands on the sides of the nose perfectly line up with the nose of the other. They are simply collecting the pheromonal signals that
the other is giving off! If one of these pheromones is androstadienone then the female feels a calming effect from the Eskimo kiss and is positively reinforced to stay around the male. And who knew that the second part of the Eskimo kiss is to lick one’s own hands and then rub their hands on the other’s face. This is certainly one of the most direct ways for another to receive the pheromones that have been shown to be present in saliva. (Hughes, 1999) A less well-known example of a cultural tradition that has revolved unknowingly around communication via pheromones comes from some ethnic groups in India. The tradition there is to kiss on the nose and then on the cheek. This is interesting because the most tactically sensitive part of the face is the lips and to maximize tactile pleasure one would think that the kiss on the lips would be preferred. But these ethnic groups must be maximizing pheromonal pleasure by this behavior. This may even keep the couple coming back for more, more easily than the kiss on the lips, though this has yet to be experimented upon. One would not be finished without also mentioning the European custom of a kiss on the cheeks and forehead as a greeting. This simply is another example of a culturally universal behavior that facilitates pheromonal communication and has persisted for many generations. Since this type of behavior or more specifically the ability to invent variations of this behavior has persisted for so long it could be that, not only are the pheromones that one secretes under selection, but it could also be the ability to facilitate pheromonal communication by a genetically determined pattern of behaviors that is under selection. If this were true then maybe only the many cultural variations of this pheromonal communication behavior are learned. More research would have to be conducted to come to a conclusion on this matter.

It would be smart to ask that if the ability to perform behavior that facilitates pheromonal communication is under selection then why don’t Americans display some of these previously mentioned behavior patterns? This is because even though Americans don’t kiss in greeting there are many other behaviors that can be easily classified as pheromonal communication facilitators. For example one of the most common characteristics of any dance is the raising of the arms, presumably to expose the apocrine sweat glands in the axilla. From ballroom dancing where the woman’s arms are on the man’s shoulders, to the dancing at hip-hop concerts, where the DJ indiscrately yells “Throw your hands in the air and wave them like you just don’t care,” every dance craze has involved some sort of axillary apocrine sweat gland exposure. That isn’t even to mention the fact that dancing always increases sweat production which would increase diffusion of pheromones into the air. This isn’t even to mention that classic dating move where the man suddenly has a huge uncontrollable yawn where his arms fly up and somehow land on the shoulders of his date. If that isn’t obvious axillary apocrine sweat gland exposure, then there isn’t such a thing.

**Conclusion**

In order to maximize fertility, a large component of evolutionary success, males and females must coordinate reproductive functions. In order to maximize coordination all forms of communication should be utilized. New studies confirm that pheromonal communication plays a role in that coordination. No studies have yet identified a genetic component that shows variation and is selected for in humans that is related to pheromone production. Because of this they have not been able to identify how pheromonal communication is selected for in humans. Presumably the more pheromone production and the better pheromone detection one individual has the more evolutionary fitness that individual will possess. In modern times though chemically synthesized pheromones can be easily obtained and those who are not fit because they have less pheromone producers and detectors will be able to artificially reverse or hide their evolutionary unfitness. This could lead to more refined mechanisms of pheromonal production where only those that are truly fit are able to respond to and produce pheromones. Or it may even cause pheromonal communication’s usefulness to vanish leading to the loss of the trait.

**References**


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