AUSTRALIAN ALMANAC Vol.2 No 24

The Extended Sensorium

A Touching Subject

by Jason Ross

The weight of this sad time we must obey,
Speak what we feel, not what we ought to say.[1]

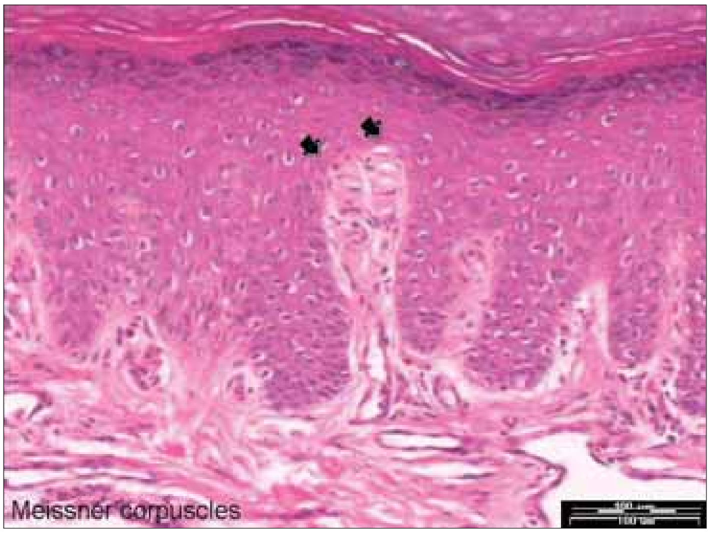
The possibility of differentiating our senses comes from our ability to determine the means by which they are aroused. The game of peek-a-boo teaches babies that although their eyes may be covered, the world they see does not disappear. The connection between one aspect of understanding one's surroundings, and the eyes, is developed: vision is not reality. The different perception of an object when it is placed in the mouth shows the mouth to be a location of particular sensibility. Objects not in the mouth do not have the same richness of perception as when they are in contact with the tongue. This can be a fun game for a baby, separating an object's taste from its other qualities, and learning that their fingers cannot taste. A childhood cold teaches the differences and connections between taste and smell: foods *taste* different, although the tongue itself is unimpaired. Similarly, playing with the ears teaches of their function. Touch functions only when one's body is in contact with an object. Thus, the body, the world beyond, and our means of learning about it, become consciously differentiated.

Although the sensory organs can be differentiated, the perceptual distinctions between the senses may be blurred.[2] The strong connection between smell and taste is possibly the clearest example. The McGurk effect reveals a connection between hearing and vision, and experiments with artificial colors and tastes indicate that even vision has a huge impact on our sense of taste.[3] Synesthetes have more pervasive connections between sensory functions, often involving color and letters. For them, the shape and color-aspects of vision are not separable as they are in other people, and some shapes are connected with characteristic colors. Although we have knowledge of the different sensory organs, their connection in the mind, developed through habituation, can be difficult to then separate.

Touch

Although touch is considered a single sense, it is itself a blurred combination of a variety of entirely different receptor modalities. Just as our single sense of vision actually makes use of four different light-receptor cells, our sense of touch involves no less than *eleven* different receptors![4] Compare the perceptual categories – viewed objects may be described as *red*, *globular*, *smooth*, or *large*, descriptions which to some degree represent the differentiated aspects of visual construction: shape and color, for example. The language of touch includes such descriptions as *rough*, *smooth*, *sharp*, *hot*, *cold*, *vibrating*, *heavy*, which more directly reflect the varied nature of touch: there are more distinct categories of perception.

Totally different receptors inform us of maintained pressure as opposed to initiated or released pressure. The pressure receptors in the lips and tongue (Krause corpuscles) differ from those in the fingertips. Low-frequency vibrations have two receptors dedicated to them, located deeper within the limbs and body. The Meissner corpuscle is found only in hairless skin, and is most sensitive to very low frequencies (20-40Hz). The Pacinian corpuscle is found throughout the skin, and responds to



Meissner corpuscles are mechanoreceptors present in the dermal papilla.

higher frequencies (150-300Hz). Pain and damage (and itching!) have their own receptors, whose nerve impulses travel an order of magnitude slower than the others, along non-myeleinated nerve cells.[5] Heat receptors are active at temperatures above 86°F, and cold receptors are activated below 95°F. Although their distribution varies over the body, cold-receptors are more numerous. These senses can be fooled with the familiar warm-water experiment: the subject starts with one hand in cold water and the other in hot water, and then places them both in the same container of warm water. A difference-based perception arises – the formerly hot hand feels the water as colder than the hand that was previously in cold water. At very high or low temperatures, these receptors are inactive, and pain is the only indication of extreme temperatures. A person born without pain receptors may be able to feel normal warmth, but be oblivious that his hand is burning. Anesthetics can serve to separate the different sensations: one can feel the pressure of a scalpel cutting the skin, but neither its sharpness nor the usually attendant pain.

The body even feels itself internally. A blindfolded test subject, allowing her arm to hang loosely, can tell the orientation of her arm when it is moved around her, even if quite gently. The knowledge does not come from pressure on the skin, since this experiment can be performed even with an anesthetic. Receptors inside the muscles, tendons, and joints allow the mind to make such determinations. This sense is called *proprioception*, meaning *self-perception*. When the head is moved in different directions, structures within the inner ear respond, allowing us to maintain a sense of which way is up. Spinning in circles can confuse these structures, causing dizziness and disorientation. Proprioception lets us determine how heavy an object is: both the pressure against the hand and the effort needed to hold it become one sensation of weight.

In his book *The Man Who Mistook His Wife for a Hat*, neurologist Oliver Sacks relates the story of a woman who lost her sense of proprioception due to a viral infection in her spinal cord. Without the ability to know the orientation of her feet, legs, and body, she was unable to walk. After lengthy physical therapy, and learning to walk with a mirror, using her eyes to tell her what her proprioception used to, she was able to walk, although only with total concentration and great difficulty. Speech, too, was quite difficult, as she could no longer feel her vocal apparatus, and had to learn to use her hearing as the primary feedback mechanism. She also had difficulty understanding how firmly she held objects, since the tension of the muscles (proprioception) was no longer available to her.

The case of amputees provides further insight into the sense of touch. Many of those who lose a limb continue to *feel* its presence, and, unfortunately, this perception may be one of great discomfort or pain. Without an actual limb to treat or sooth, the condition can be maddening, and analgesics are not always effective. One treatment involves using a mirror box to give the patient the visual impression of once again having both limbs. Therapy applied to the existent limb can provide relief for the phantom limb. Even simply moving the real hand can give a surrogate sense of proprioceptive motion for the phantom one, which can be helpful.

Other Uses of Touch

Touch can be used as a form of mechanical communication. In technological situations, this is usually referred to as *haptic feedback*. One application is the development of prosthetic limbs. An artificial arm, for example, may use muscle motions in the chest to activate its motions, and may provide pressure and other feedback to the skin of the chest.[6] Additional applications have been tested for pilot feedback via a tactile harness, providing such information as altitude or bearing, and for the replacement of eyes for vision. Blind people have successfully used tongue-vision, a technology by which a camera transmits an image to the tongue via electrical impulses. The shape of the impulses on the tongue provides a replacement for the non-functioning optical system.[7] Therapeutic effects may be evoked by touch. Premature babies, often confined to incubators, receive little emotional touch, but studies show that gentle touching and skin contact can be beneficial for their health and development. Touch and hearing are two senses from among those they will develop later that are available to the embryo in the womb. Simple non-intimate physical contact with another human being has significant effects on mood and well-being. Tests show that simple touch, such as "accidentally" brushing a subject's hand in an encounter, lead to greater enjoyment of the situation, even if the subject did not particularly note the event. A server who gently touches the patrons' shoulders in an informal dining environment can typically expect slightly larger tips. A massage therapist can report that part of the beneficial effects of massage are not the effect of *pressure* on muscles and tissues: it is the simple fact that it is *human touch*. For this reason, mechanical massage devices do not provide the same benefits.

Hardly a single sense, touch operates as a microcosm of our sensory apparatus as a whole: different types of biological receptors are used by the mind to piece together an overall conception of the surrounding world. Discovery of the ironies between the reports provided by different receptor modalities provides the opportunity for new insights into the processes that act upon the parts of our bodies that are particularly sensitive to them, and thus we learn more of the world that lies beyond our senses. The human mind need not express knowledge as correlated patterns of stimulation of sensory tissues: our reflection upon the cause of these stimulations finds answers in the intentions that we use to compose the way we act on the world around us. Statistical modeling is akin to studying patterns of activity in sensory organs, rather than the actual world revealed by true science. Although the universe is not sensible, it does make sense.

Footnotes

[1] William Shakespeare, *King Lear*

[2] See Oyang Teng's report.

[3] The McGurk Effect is seen in the creation of a film in which the video is a person enunciating *fa* while the audio is the same person saying *ba*. Amazingly (and somewhat infuriatingly), even when he knows the trick, an auditor cannot help hearing *fa*. Taste-tests with food colorings and flavors demonstrate that when tastes are combined with unexpected colors, they are misperceived. For example, a yellow glass of sweet fluid that is strawberry-flavored may be perceived as tasting like lemonade!

[4] *Known receptors include: hair follicles, Ruffini endings, Krause corpuscle, Pacinian corpuscle, Meissner corpuscle, free nerve endings, Merkel cells, proprioceptors, heat receptors, cold receptors, and the otoliths.*

[5] This is why, if you stub your toe, you feel the event first, and then the pain follows a measurable (short) time afterwards.

[6] Pearson, Aria. "Woman with bionic arm regains sense of touch." New Scientist, Feb, 2007. www.newscientist.com/article/dn11094

[7] As an interesting display of plasticity, the portion of the brain primarily involved in processing visual information is active in blind people when reading in Braille.

The Ironies of Smell

by Jason Ross

The sense of smell is absolutely unique in its evolutionary primacy, its emotional power, and the heterogeneity of the impressions it provides. At its inception, what was to become the sense of smell was simply the ability of life to respond to its surrounding environment. Bacteria moving towards higher concentrations of food sources are using what can be considered a sense of smell, just as a dog following a trail is smelling its path. The simple sense of smell of the bacteria still exists in complex life in a new form: the internal regulation of bodily processes by means of chemical messengers. Just as river-spawning ocean fish recognize their birth stream by smell, so may people be brought back to memories of childhood by the smell of a familiar house, town, or food. The rich variety of smells, not simply of different shades, but of wholly distinct types and characters, makes the field of smell one that is uniquely difficult to categorize, quantify, and describe, and one that is singularly rich.

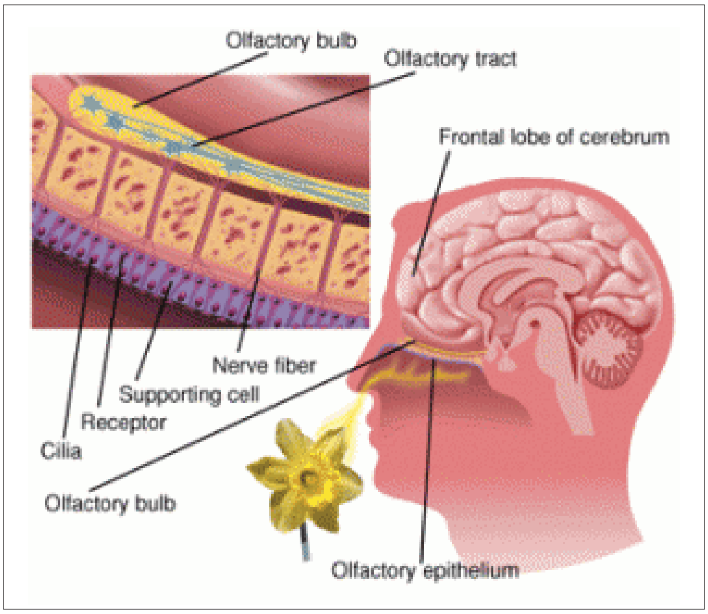
Internal communication

Bodily functions and processes are regulated in a number of ways. Voluntary activities and conscious sense perceptions involve the central and somatic nervous systems. However, most of the involuntary activities of the body are controlled by the separate autonomic nervous system, including: retinal dilation, urine production, heart rate, saliva production, digestive gland activity, the opening and closing of gastrointestinal valves (sphincters), and sweating. These behaviors are controlled by nerves, but not by the brain. In addition to control via nerve impulses, there is also a hormonal chemical regulatory system, known as the endocrine system.

Endocrine regulation does not involve direct nervous connections to the affected tissues. Rather, chemicals known as hormones are secreted into the bloodstream, where they come in contact with all organs, and can cause their activity to change. This form of internal communication is similar to the types of communication available to simpler creatures. Absolutely all organisms respond to their chemical surroundings. With the development of multi-cellular life, a distinction between *inside* and *surface* cells of the organism could be made. Thus in addition to environmental chemical detection and communication between organisms, it was now possible for life to have an internal environment, both from a stable nutritive standpoint, but also an internal regulatory environment. By changing the internal environment, cycles in the organism can be regulated. The human endocrine system has major glands in the brain, but also in the thyroid, kidneys, pancreas, and gonads. Familiar hormones released by these glands include growth hormone, melatonin (sleep regulation), thyroxine and triiodothyronine (overall metabolic rate), insulin (glucose uptake from the blood), adrenaline, androgen and estrogen.

The Physiology of Smell

While it is said that we smell with our noses, the actual detection of scents occurs about three inches beyond our nostrils, deep in the nasal cavity. There, a small structure known as the *olfactory epithelium*, containing 10 to 40 million olfactory receptors, does the work of smelling.[1.] Each olfactory receptor is a neuron with a dozen ciliate tips that extend into a patch of mucus lining the nasal cavity. These neurons do not live long: after one to two months, they die and are replaced by a new receptor grown from a stem



cell.[2] The way that the ciliate tips respond to odorants is not totally clear, although the most pursued hypothesis is that chemical receptors respond directly to particular odorant molecules. Hundreds of different receptor proteins have been identified in mice, and each neuron may have several, thus determining its sensitivity. The olfactory neurons pass through the skull and congregate in the olfactory bulb, part of the brain. They then pass directly to the olfactory cortex, without passing through the thalamus, as the other senses do. This makes smell anatomically unique among the senses, in its connection to the cortex.[3]

In trying to determine how these individual receptors make the tens of thousands of distinct smells we can recognize, HHMI investigators discovered a structure not in the distribution of receptors in the olfactory epithelium itself, but rather in the olfactory bulb. It appears that similar receptor neurons converge to the same portion of the olfactory bulb.[4]

In addition to the main olfactory epithelium, many animals have separate organs in the nasal cavity that perform a second function like smell. Known as the vomeronasal organs (VNOs), these structures have a different connection to the brain, connecting to auxiliary olfactory bulbs rather than the cortex, and may indeed cause changes unconsciously. Some animals must make an effort to cause air to enter the VNOs, such as the behavior known as *flehmen* performed by deer: this involves raising the head and curling the upper lip. Experiments with animals have revealed molecules known as *pheromones*, picked up by the VNOs, often involved in mating behavior and social identification. For example, one study with hamsters revealed that the VNOs are required for the animals to first become sexually active.[5] It seems that VNOs may function analogously to an inter-organismic endocrine system, regulating the social cycles of populations of animals.

The question of human VNOs, although interesting, is not yet settled. Small pits with what appear to be VNOs can be found in most humans, but a nervous connection to the brain has not yet been clearly identified. Unfortunately, much of the research done is funded by companies that market human pheromones in perfumes and colognes, making it difficult to gauge the reliability of the studies. The reported synchronization and entrainment of human menstrual cycles may involve VNO sensitivity.

Describing the Power of Smell

Smells are notoriously difficult to describe, and almost impossible to convey to someone who has not experienced the same smell in the past. This is very much unlike vision, where, although different objects may appear totally different and distinguishable, the domain of their possible appearances can be ordered. The different shades and tints of colors can all be described, and understood as a continuum, allowing them to be used as a verbal palette for painting an image. Sounds, although more difficult, can also be described, at least in terms of intensity, duration, and pitch. Similarly, although touch is itself a multifaceted sense, there is a continuum in each of its identifiable aspects.[6] But, when it comes to smells, we find that besides indicating intensity, we simply lack a language to describe the domain of our perceptions; we have to describe either the effect of the smell upon us (stinky, pleasant, refreshing), or refer it to our experientially developed smell-vocabulary (citrus, rose, fetid, sweet). Although continuous variations may appear for certain similar smells and tastes, as Helen Keller has noted, no conceptual space for *all* smells has been developed, at least not in popular understanding or discourse. Indeed, since different odors are so unique, smell has been an important part of chemistry, as a tool capable of distinguishing different substances, particularly organic ones. Enantiomorphic pairs of molecules may be difficult to distinguish chemically, but the nose has no trouble distinguishing many such pairs.[7]

Perhaps it is the uniqueness of smells, in addition to their direct connection to the cortex, that allows them to evoke memories with such power. A long-forgotten scent, once experienced anew, can bring back a flood of memories of people, places, and events in the past, in a way that no other sense can: or at least, not in so unexpected and surprising a manner. An oft-cited example of this is by author Marcel Proust, who wrote in *The Remembrance of Things Past*:

No sooner had the warm liquid mixed with the crumbs touched my palate than a shudder ran through my whole body, and I stopped, intent upon the extraordinary thing that was happening to me. An exquisite pleasure had invaded my senses, something isolated, detached, with no suggestion of its origin... Suddenly the memory revealed itself. The taste was of a little piece of madeleine which on Sunday mornings... my Aunt Léonie used to give me, dipping it first in her own cup of tea... Immediately the old gray house on the street, where her room was, rose up like a stage set... and the entire town, with its people and houses, gardens, church, and surroundings, taking shape and solidity, sprang into being from my cup of tea.[8]

Human Experimentation

Interesting aspects of human smell have been explored in small variety of experiments, covering subjects such as the smell of infants, emotional smells, and the courtship aspects of smell. Studies show a familial identification ability: adults given the scent of a recently born nephew, niece, or grandchild along with the scents of other infants born at the same time, are able to identify their relatives, despite not having met them before.[9] Some studies of the kinds of scents that people find to be attractive, reveal that there is a correlation between the nature of an individual's immune system and the attractiveness of his or her scent.[10] The major histocompatibility complex (MHC) is involved in marking body cells as belonging to the body, making it easier to detect intruder cells. The scents of people with different MHCs are found to be more attractive, while those with similar MHCs reminded women of their brothers or other male relatives. These are not just preferences in choosing a spouse: MHC-similar couples are more likely to suffer miscarriages.[11] Apocrine glands produce both scents and a substrate that bacteria consume, creating smells. Those of men are larger than those of women, and are particularly active when emotional, such as at times of nervousness. Smell really can be a guide to emotional states.

Because of the intense power of smell, it is also studied for crowd-control applications. Rather than studying gases that actually cause pain in the nose (experienced via the trigeminal nerve), the Monell Institute has been developing a ill-smelling brew they call "stench soup," which is so foul that absolutely no one would want to be anywhere near it.[12]

Conclusion

The great variety of distinct smells, and the olfactory epithelium's direct connection to the cortex, make this sense powerful emotionally, in ways that are both conscious and unconscious. Compositions of smells and tastes (the knack of cooking) have their own harmonic aesthetics, that can be recognized even in food cultures unfamiliar with them, but these harmonic compositions have not been successfully used to communicate concepts or a quality of mind in anything more than a symbolic way. If this were possible, and developed, then cooking could truly be said to have become an art. Until then, smell serves us in many hidden ways, strengthening our memories, communicating our states of mind to others, and, possibly, altering our social dispositions.

Footnotes

[1]Sources vary in the number of receptors.

[2]Although this is presented as an anomaly for nerve cells, which are said not to reproduce, this phenomenon is increasingly found to be more common in the body than once thought.

[3]Additionally, the olfactory bulb itself has connections with the hippocampus, amygdala, and hypothalamus.

[4]See the excellent HHMI report at: www.hhmi.org/senses/

[5]Triggers of Innate Behavior. www.hhmi.org/senses/d220.html

[6]That is, although temperature and texture are independent components of what is called *touch*, each of its components has its own reasonably complete lexicon.

[7]For examples, see "Chirality and Odour Perception" at www.leffingwell.com/chirality/cyclic_terpenoid.htm

[8] Proust, Marcel. *À la recherche du temps perdu*, 1913. English translation by C. K. Scott Moncrieff, 1922.

[9] Peter K. Brennan and Keith M. Kendrick, "Mammalian Social Odors: Attraction and Individual Recognition." Philosophical Transactions: Biological Sciences, Vol 361, 2009, pp. 2061-2078. http://jstor.org/stable/20209801

[10]The performance of these experiments also reveals a social preoccupation with sex.

[11]See Brennan and Kendrick, footnote 7, and F. Bryant Furlow, "The Smell of Love." First published Mar 1, 1996, last updated Aug 13, 2010. Accessed at: www.psychologytoday.com/articles/200910/the-smell-love

[12]This differs from current gases, which actually cause pain to the nasal cavities.