Olfactory Sense in Different Animals

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Abstract

The sense of olfaction in all the living things of world is unique and special. Through this sense animal can not only recognized the smell of food but also they communicate, interact, navigate, recognize and role are many more. Perception of odour can be separated of two system – olfactory system and trigeminal system. Chemoreceptors are located in the nasal cavity as well as in the oral cavity which can differentiate the flavor of the different food. Recently some amazing facts about the olfaction in marine animals and plants are studied. Due to this sense the importance of dog breeds are characterized and used for different purposed.

Keywords: Animals, Chemoreceptor, Olfaction, Sense, Taste

Introduction

Animals receive information about the environment and communicate with each other through the sense of Olfaction. The odours (or pheromones) emitted by the animal play an important role in insect and animal reproduction behaviour (Rekwot *et al.*, 2001), neonate–mother interactions (Distel and Hudson, 1985) and in the detection of predators. In this review, we consider the role of odours in assisting animals to find, recognize and discriminate between foods. Olfaction plays a major role in general animal awareness. Sommerville and Broom (1998), defined it as 'a state in which complex brain analysis is used to process stimuli or constructs based on memory'. Size of the nasal epithelium is a good indicator of the degree of an animal's sense of smell because the number of olfactory receptor cells per unit surface area is a constant. Long–nosed mammals such as horses, cattle and sheep, olfactory senses are likely to be well developed. Olfaction when linked to memory allows the animal to recollect the sensory characteristics of the feed and also whether the metabolism of that feed is favourable to it. Thus animals exhibit 'nutritional wisdom'.

Voluminous literature is available on the olfaction and food preferences of insects. For example, moths (Masante–Roca *et al.,* 2002), mites (De Boer *et al.*, 2005) and lacewing (Reddy, 2002) are known to discriminate between volatile odors of various plants. Moths detect plant volatiles by projection neurons on the antennal lobe (Anton and Hansson, 1995; Greiner *et al.*, 2002; Masante–Roca *et al.*, 2002). Insects locate plant through their odor and a strong interaction exists between specific plants and particular insect species. Plant odours also play an important role in the location and selection of feedstuffs in mammals.

Anatomy of odor detection

The conscious perception of odor involves two separate systems i.e. The *Olfactory system* (consist of paired nares, nasal cavity, respiratory epithelium, olfactory epithelium, olfactory nerves, olfactory bulb, olfactory centre in the cerebrum) and *Trigeminal system* (consist of chemosensory trigeminal nerve receptors which is spread in the nasal cavity and intranasal trigeminal nerve branches). The third structure involved is the Vomeronasal organ (primarily concerned with pheromones). In mammals, it consists of palatine duct located posterior to the 2nd incisor and connects nasal cavity to oral cavity. It is located in hard palate between nasal and oral cavities and their neurons which travel to the lateral olfactory bulb and to the limbic system structures and cortical centres also. The anatomy and location of the three structures help in easy perception and sensation of variety of smell.

The physiology of odour detection

Odorants are volatile chemical compounds that are carried into the nasal cavity with inhaled air, dissolve in the mucus membrane and come into contact with the olfactory epithelium. In some cases they are aided by odorant binding proteins. The receptors are highly sensitive and act through a standard G–protein cascade, causing cation channels to open and action potentials to be fired. Olfactory neurones in the olfactory epithelium project upwards through the cribriform plate to the ipsilateral olfactory bulb. This region is one of the few places where new neurones are regenerated in the adult. The perception of gas–phase molecules involves the olfactory and trigeminal systems. The trigeminal system is responsible for the perception of sensations such as irritation, stinging, burning, tickling, warm, cool and pain (Doty *et al.*, 1978; Doty and Commetto–Muiz, 2003). Trigeminal perception occurs via free nerve endings found in the nasal and oral cavities, with the nasal cavity being the more sensitive of the two (Silver and Finger, 1991).

Olfactory receptors

It is commonly believed that each neurone expresses one olfactory G–protein coupled receptor (Mombaerts, 2004). Odorant receptor (OR) genes comprise the largest gene family in the mammalian genome. Mammalian ORs are disposed in clusters on virtually all chromosomes. They are encoded by the largest multigene family (~1000 members) in the genome of mammals. Odor detection plays a significant role in feed preferences of livestock.

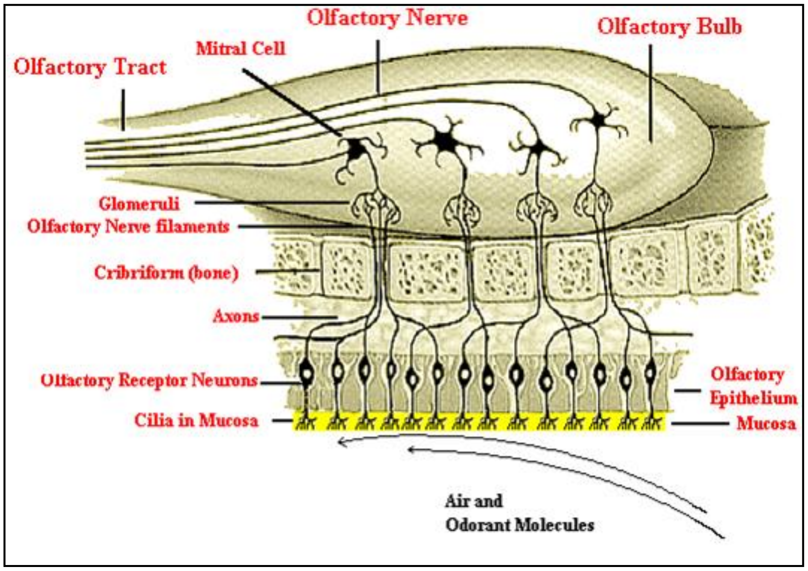

Figure 1: Microscopic view nasal cavity of mammals.

Species	OR genes	Reference
Humans	350 (560 pseudogenes)	
Mice	1000 – 1300	Glusman *et al.* (2001)
Other Mammals	4000	
Cow	2129	
Dog	1100	
Macaque	606	Niimura and Nei (2007)
Rat	1767	
Mice	1391	

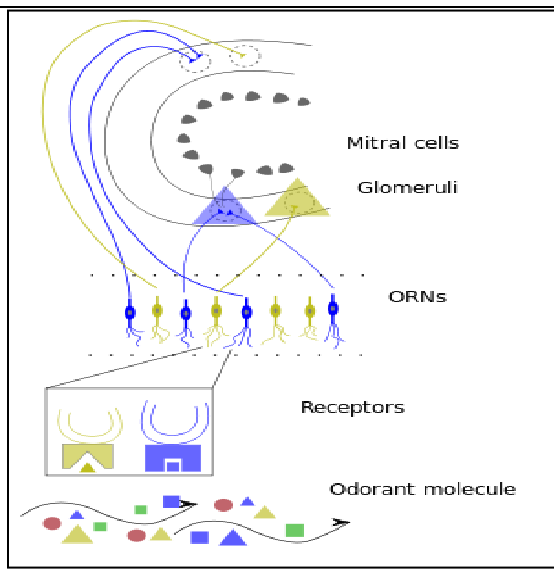

Figure 2: Action pathway of odorant molecules

Different sensations of smell

There may exist more than 50 different primary sensation of smell. The main among them are musky, floral, camphoraceous, ethereal, pepperminty, pungent and putrid. In humans, it has been found that they may be odor blind to one or more type of smell. However, odor blindness in animal is not known.

Table No 1: Humans have seven primary odors that help them determine objects.

Odor	Example
Camphoric	Mothballs
Musky	Perfume/Aftershave
Floral	Rose
Pepperminty	Mint Gum
Etheral	Dry Cleaning Fluid
Pungent	Vinegar
Putrid	Rotten Eggs

Olfaction in Cattle

Smell complements visual information and is responsible for social organisation in the group, recognition of individual animals and helps to create a bond between the dam and the offspring. Olfactory communication between animals and reproduction is mainly based on scents / pheromones released, but has to be supported by other senses. Odours are detected by sensory cells (chemo-receptors) located in the epithelium of the nostrils. However, cattle also possess a second olfactory organ: the Jacobson organ or *organum vomeronasale* (vomeronasal organ), which is located in the mouth in the upper palate and is more sensitive to pheromones than the mucus membrane of nose. Olfactory communication between individuals is made via pheromones which are chemical molecules emitted by an animal that engender a specific response in the animal that detects (perceives) them (Cheal, 1975). These molecules, present in all animal secretions (perspiration, urine, faeces, oestrus and vaginal secretions), are of a varied chemical nature but are mainly composed of aromatic alkenes (Phillips, 1993). Its use is closely linked to the characteristic behaviour known as the 'Flehmen behaviour' whereby the animal lifts its nose with the mouth slightly open, the upper lip curled up and the tongue lying flat to enable the air to pass into the Jacobson organ. The two olfactory systems (mucous membrane of the nose and sinus and *organum vomeronasale*) very likely have complementary functions but their chemical characterisation has not been proven (Phillips, 1993). The sensitivity of these two organs varies according to the natural concentration of the odour and its biological significance (Boissy *et al.*, 1998). The fact that cattle have numerous odoriferous glands confirms the use of odours in communication between individuals (Bouissou *et al.*, 2001). Cattle perception of odour is, therefore, more acute than human perception (Albright and Arave, 1997).

Olfactory communication between cattle is made and recognised essentially via pheromones (Schloeth, 1956, Signoret *et al.*, 1997). Thus, the presence of a stressed cattle or the odour of its urine will modify the behavioural reactions of its fellow creatures (Boissy *et al.*, 1998). One can also observe a slower learning capacity in heifers when they are exposed to the odour of a stressed fellow animal. (Bouissou *et al.*, 2001). Thus, pheromones constitute a warning signal from the animal in danger to its fellows.

Smell also plays a role in the reproduction of cattle (Signoret *et al.*, 1997). Vaginal secretions transmit odorous molecules. The bull detects the scent of the female's vaginal secretions (Klemm *et al.*, 1987) and sexual behaviour has been successfully stimulated by using the vaginal mucus of females in heat (Albright and Arave, 1997).

The role of urine in stimulating sexual behaviour is recognised and corroborated by its chemical composition: specific composites can be detected in the urine of cows that are in heat (Kurma *et al.*, 2000). The cow's urine acts as a chemical signal to entice the male via pheromones, but its exact role is not defined (Rekvot *et al.*, 2001).

Similarly, perception of olfactory molecules influences sexual development. Thus, the presence of a male accelerates puberty in heifers (Izard and Vandenbergh, 1982) and conversely, the presence of cows stimulates testicular development and the production of testosterone in bulls (Katongole *et al.*, 1971). The Jacobson organ is essential for sexual behaviour stimulation (Klemm *et al.*, 1987) and is often associated with the Flehmen behaviour (Albright and Arave, 1997). In addition, removal of the olfactory bulb does not impede the reproductive behaviour of cattle (Mansard and Bouissou, 1980).

Finally, cattle use odours along with colours and taste to identify and choose their food (Bailey *et al.*, 1996). The characteristics of food, odour included, condition the animal's appetite (Baumont, 1996). Thus, adding aromas to grass ensilage may increase the quantity consumed. Moreover, the odour of manure has a lasting dissuasive effect on pasture; the animals refuse to graze in contaminated zones for a month after (Dohi *et al.*, 1991). The roles of maternal vision and olfaction in regulating the suckling-mediated inhibition of LH secretion, expression of maternal selectivity, and lactational performance was examined in anestrous beef cows by Griffith and Williams (1996).

Cattle perception of human scent

Cattle handlers observe that a stock breeder who regularly lets his animals sniff him gives the impression of being 'recognised' by them. Conversely, they affirm that an outsider will be recognised by his 'strange' or even by his 'parasitic' scent, such as that of medication in the case of a veterinarian. However

Rybarczyk *et al*. (2001, 2003), failed to prove that cows discriminate through smell. In their studies, only one calf succeeded in identifying the 'right' handler if the human-stimuli presented for tests wore overalls of the same colour. That is why they concluded that cattle principally use visual keys to differentiate humans but that nevertheless, they can use other determining factors.

Olfaction in Dog

Olfaction, the act or process of smelling, is a dog's primary special sense. A dog's sense of smell is said to be a thousand times more sensitive than that of humans. While the human brain is dominated by a large visual cortex, the dog brain is dominated by an olfactory cortex. In fact, a dog has more than 220 million olfactory receptors in its nose, while humans have only 5 million.

Dogs also possess vomeronasal organ (Jacobson's organ) that also contains olfactory epithelium. It is located above the roof of the mouth and behind the upper incisors. A dog's nose which is normally cool and moist helps in olfaction. Today, people use a dog's keen sense of smell in many ways. Dogs are trained for search and rescue missions, in the detection of narcotics and contraband agriculture products, to respond to disasters worldwide, to detect drugs and to search for lost individuals, homicide victims and forensic cadaver materials. They are trained to detect bombs so as to combat terrorist threats, stop the illegal flow of narcotics, detect unreported currency and concealed humans. The most commonly used breeds for the above purposes are Labrador retrievers, Golden retrievers, German shepherds, Belgian Malinois, and many mixed breeds.

Beagles are used to detect agriculture contraband. They are also trained to detect prohibited fruits, plants, and meats in baggage and vehicles of international travelers.

Medical tests have recently shown that specially trained dogs are capable of detecting certain types of tumors, the beginning of a heart seizure and terminal stages of cancer in humans.

Table No 2: Scent-Detecting Cells in Humans and Dog Breeds (Stanley and Sarah, 2013)

Species	Number of Scent Receptors
Humans	5 million
Dachshund	125 million
Fox Terrier	147 million
Beagle	225 million
German Shepherd	225 million
Bloodhound	300 million

Scent hounds as a group can smell one- to ten-million times more acutely than a human, and Bloodhounds, which have the keenest sense of smell of any dogs, have noses ten- to one-hundred-million times more sensitive than a human's. They were bred for the specific purpose of tracking humans, and can detect a scent trail a few days old. The second-most-sensitive nose is possessed by the Basset Hound, which was bred to track and hunt rabbits and other small animals.

Olfaction in Cat

A domestic cat's sense of smell is about fourteen times stronger than human beings. Cats have twice as many receptors in the olfactory epithelium (i.e. smell-sensitive cells in their noses) than humans and hence have a more acute sense of smell than humans. Cats also have a scent organ in the roof of their mouths called the vomeronasal (or Jacobson's) organ. When a cat wrinkles its muzzle, lowers its chin, and lets its tongue hang a bit, it is opening the passage to the vomeronasal. This is called *gaping*, "sneering", "snake mouth", or "Flemming". Gaping is the equivalent of the Flehmen response in other animals, such as dogs, horses and big cats.

Olfaction in Bear

Bears, such as the Silvertip Grizzly found in parts of North America, have a sense of smell seven times stronger than that of the bloodhound. This is needed for locating food underground by using their elongated claws, bears dig deep trenches in search of burrowing animals, nests, roots, bulbs and insects. Bears can detect the scent of food from up to 18 miles away. Their immense size helps them to scavenge new kills, driving away the predators (including packs of wolves and human hunters) in the process.

Olfaction in Primates

The sense of smell is poorly developed in the catarrhine primates (Catarrhini), and nonexistent in cetaceans. This is compensated with a well-developed sense of taste. Some prosimians, such as the Red-bellied Lemur have scent glands atop the head.

Olfaction in Fish

Most aquatic organisms have the olfactory cells mounted in a position where they will be exposed to moving water, presumably to limit time lags imposed by diffusion of the chemical through the boundary layer surrounding the sensory cell (remember that the boundary layer is smaller as water speed increases). For the same reason, perhaps, the olfactory organs are usually anterior on the organism, where the boundary layer is thinner, although many might argue that the anterior position simply allows the organism a better chance to smell what it's getting into. Vertebrates bear the olfactory cells in the nostrils, usually with arrangements for moving water over them; the taste cells are located on the tongue. Fish, the original aquatic vertebrates, have chemoreceptors scattered all over their bodies, but with particular attention to sensory structures such as the lips or barbels. Invertebrates bear the olfactory structures on various parts of the body, often tentacles or antennae near the head, but also on mouthparts, feeding structures, legs, feet, tails, and so on.

In Fish, both olfaction and taste serve different ecological roles. The *lateral olfactory system* (dorsolateral olfactory bulb glomeruli and lateral olfactory tract) and the external taste buds are probably specialized for food search and amino acid discrimination. The *medial olfactory system* (basomedial olfactory bulb glomeruli and medial olfactory tract) and the solitary chemosensory taste cells, however, may have their roles in intra- and interspecific interactions (discriminating pheromones by olfaction, bile components by both olfaction and taste). Whereas stimulation of the taste systems alone triggers reflexes, complex, conditional or conditioned behaviours are only released when the olfactory system is intact. This points at the importance of telencephalic and diencephalic integration of olfactory and taste inputs (Kotrschal, 2000).

Different fishes use their sense of smell for different purposes.

Salmon, to identify and return to their home stream waters; Catfish, to identify other individual catfish and to maintain a social hierarchy; Many fishes, to identify mating partners or to alert to the presence of food; Smooth dogfish (*Mustelus canis*), a species of Shark to maintain directional response (Parker, 1914). He provided a plausible explanation of how this was accomplished; he postulated that the two separated nostrils have the ability to detect small differences in the concentration of odorous materials enabling the shark to orient in the direction of equal stimulation and to head "upstream" to the source. This tracking ability is well recognized by skin divers and fishermen who have involuntarily attracted sharks by retaining speared fish or by discarding trash fish and offal from their boats.

It was believed that whales and dolphins lack the ability to smell. However, the finding of olfactory hardware linking the brain and nose, and functional protein receptors required to smell showed that whales have the ability to smell. Bowhead whales have a relatively large, developed olfactory bulb similar to that in other animals with a developed sense of smell. Unlike most whales, bowheads have separate nostrils, which suggest they may be able to sense the direction from where a particular smell is coming (Walker, 2010).

Avian Olfaction

The relatively small and simple avian olfactory bulb gave rise to the belief that birds had poor sense of smell (Waldvogel, 1989). Recent research has emphasized the complexity and depth of the avian sense of smell. Bang (1960), suggested that the sense of smell could be more developed in birds in certain ecological niches. Birds with high olfactory ratios were typically ground-dweling carnivores, small New-World Vultures, or marine birds like the kiwis, Turkey Vulture, tubenoses (Procellariiformes) (Bang and Wenzel, 1985; Evans and Heiser, 2001). Bang's research initiated olfaction research in birds and broadened the horizons of the understanding of how birds smell. Though birds seemingly would have little use for smell; in the airy treetops odors disperse quickly and would be of minimal help in locating obstacles, prey, enemies, or mates, yet the apparatus for detecting odors is present in the nasal passages of all birds. Based on the relative size of the brain center used to process information on odors, physiologists expect the sense of smell to be well developed in rails, cranes, grebes, and nightjars and less developed in passerines, woodpeckers, pelicans, and parrots. By recording the electrical impulses transmitted through the bird's olfactory nerves, physiologists have documented some of the substances that birds as diverse as sparrows, chickens, pigeons, ducks, shearwaters, albatrosses, and vultures are able to smell.

Kiwis

Possibly have the best avian sense of smell. They are small, ancestral, flightless, nocturnal carnivores found in the forests of New Zeland. Their olfactory lobe is ten times the size of other birds and nostrils are located at the bill tip, rather than at the base of the bill (where they are found on all other birds). Kiwis use their bill to probe for worms and bugs in the soil and are capable of locating food by smell alone, although they also have a well-developed sense of hearing (Evans and Heiser, 2001; Gill, 1995 and Wenzel, 1968)

Procellariformes

Tubenoses- albatrosses and petrels - pelagic (0pen ocean) birds have well-developed, tubular nostrils. Tubenoses use olfactory cues to forage and also to return to their burrows over many kilometers. They are attracted to fish oil and dimethyl sulfide which is volatile compounds released by dead fish and the plankton that feed upon them. Smaller species, those that feed upon plankton, arrive first at most odor sources, and appear to have the best-developed sense of smell. Procelliformes also are capable of using smells to locate their burrows at night, locating individual nests by smell (Bonadonna *et al.*, 2001; Evans and Heiser, 2001; Verheyden and Jouventin, 1994).

New-World Vultures

Different from Old-World Vultures (which are closely related to eagles), New-World Vultures (*Cathartidae*) are more closely related to storks. Old-World Vultures have very little sense of smell and rely mainly on their keen sense of sight to find carrion. Likewise, the larger New-World species are primarily visual foragers. Smaller species (Turkey, Greater and Lesser Yellow-headed Vulture) are capable of using olfactory cues to locate food and have the enlarged olfactory bulb to go with that ability. Black Vultures and other larger species often use Turkey Vultures as cues to the location of a carrrion source, clouding the issue of which species use olfactory cues. Pipeline engineers have used this ability as well, injecting ethyl mercaptan (an odorant found in carrion) into pipes and following vultures to the leak (Evans and Heiser, 2001; Gill, 1994; Kirk and Mossman, 1998; Smith and Paselk, 1986)

Orientation & Navigation in birds

Aside from the previous examples, many other species have been shown to use olfactory cues to forage, to home and to migrate. Many of these species appear to be using small-scale olfactory cues for local piloting, but homing pigeons and some migratory birds may be using olfaction for true navigation. While it does not seem to be a primary navigational cue, odors are proving to be important cues in orientation and migration. (Clark and Mason, 2000; Walraff and Andreae, 2000; Waldvogel, 1989).

Olfaction in Insects

In insects smells are sensed by olfactory sensory neurons in the chemosensory sensilla, which are present in insect antenna, palps and tarsa, but also on other parts of the insect body. Odorants penetrate into the cuticle pores of chemosensory sensilla and get in contact with insect Odorant-binding proteins (OBPs) or chemosensory proteins (CSPs), before activating the sensory neurons.

Insects have been used as a model system to study olfaction. Insects use primarily their antennae for detecting odors. Sensory neurons in the antenna generate odor-specific electrical signals called spikes in response to binding of odors. The sensory neurons send this information via their axons to the antennal lobe, where they synapse with other neurons in semidelineated (with membrane boundaries) structures called glomeruli. The antennal lobes have two kinds of neurons, projection neurons (mostly excitatory) and local neurons (inhibitory, and some excitatory). The projection neurons send their axon terminals to mushroom bodies and the lateral horn (both of which are part of the protocerebrum of the insects). Recordings from projection neurons show in some insects' strong specialization and discrimination for the odors presented (especially for the projection neurons of the macroglomeruli, a specialized complex of glomeruli responsible for the pheromones detection).

Interactions of Olfaction with other Senses

Olfaction and taste

Olfaction, taste and trigeminal receptors (also called Chemesthesis) together contribute to flavor. The human tongue can distinguish only among five distinct qualities of taste, while the nose can distinguish among hundreds of substances, even in minute quantities. It is during exhalation that the olfaction contribution to flavor occurs, in contrast to that of proper smell, which occurs during the inhalation phase. The neurons of the olfactory system are the only one of the human senses that bypasses the thalamus and connects directly to the forebrain.

Toxic substances are noted for their taste and smell. Alkaloids which are poisonous are extremely bitter. Its nature's way of protecting an animal from eating poisonous plants. Cyanide gas gives an almond smell. The presence of almond like smell in the stomach contents indicates cyanide poisoning. Bacteria rich food emits noxious odors and has an unpleasant taste. The palatability of feed is determined by the smell and taste. Unpalatable food makes the animal anorexic.

Olfaction and audition

Olfaction and sound information has been shown to converge in the olfactory tubercles of rodents. This neural convergence is proposed to give rise to a percept termed smound. Whereas a flavor results from interactions between smell and taste, a smound may result from interactions between smell and sound.

Olfcation in Plants

The tendrils of plants are especially sensitive to airborne volatile organic compounds. Parasites such as dodder make use of this in locating their preferred hosts and locking on to them. The emission of volatile compounds is detected when foliage is browsed by animals. Threatened plants are then able to take defensive chemical measures, such as moving tannin compounds to their foliage.

Terms and conditions associated with olfaction

Loss of sense of smell is termed Anosmia, whereas Hyposmia indicate partial loss of sense of smell. Anosmia induces anorexia in the cat, whereas Hyposmia induces hyperrexia (increased food intake) in the same species. In dogs conditions like canine paarainfluenza, cushing's disease, hypothyroidism, canine distemper, nasal tumours and even diabetes mellitus can diminish the sense of smell.

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