The Science of Smell Part 1:
Odor perception and physiological response

Olfaction, the sense of smell, is the least understood of the five senses. This, among other factors, makes the task of reducing livestock odors a considerable challenge.

Odor terminology and perception

An *odorant* is a substance capable of eliciting an olfactory response whereas *odor* is the sensation resulting from stimulation of the olfactory organs. Odors play an important part in our everyday life, from appetite stimulation to serving as warning signals for disease detection. A number of diseases have characteristic odors including gangrene, diabetes, leukemia, and schizophrenia. Odors have been implicated in depression and nausea as well.

Detectable odors can have a significant impact on people by affecting moods as well as having physiological impacts on the olfactory system. People associate odors with past experiences and, from those experiences, involuntarily assess the odor as likable, dislikable or indifferent. Effects on individuals, however, vary from one person to another.

Odor threshold is a term used to identify the concentration at which animals respond 50 percent of the time to repeated presentations of an odorant. This term is reserved, primarily, for use in research with animals. Most often, however, *odor threshold* is used to mean *detection threshold*, which identifies the concentration at which 50 percent of a human panel can identify the presence of an odor or odorant without characterizing the stimulus. *Detection threshold* is the term most frequently used when discussing odor research results associated with livestock operations. The *recognition threshold* is the concentration at which 50 percent of the human panel can identify the odorant or odor, such as the smell of ammonia or peppermint.

Although the detection threshold concentrations of substances that evoke a smell are slight (table 1), a concentration only 10 to 50 times above the detection threshold value often is the maximum intensity that can be detected by humans. This, however, is in contrast to other sensory systems where maximum intensities are many more multiples of threshold intensities.The maximum intensity of sight, for instance, is about 500,000 times that of the threshold intensity and a factor of 1 trillion is observed for hearing. For this reason, smell often identifies the presence or absence of odor rather than quantifies its intensity or concentration.

The ability to perceive an odor varies widely among individuals. More than a thousand-fold difference between the least and the most sensitive individuals in acuity have been observed. Differences between individuals are, in part, attributable to age, smoking habits, gender, nasal allergies, or head colds. Nonsmokers over the age of 15 show greater acuity than smokers in general. Furthermore, females tend to have a keener sense of smell than males, a finding that has been substantiated in recent work at Iowa State University. Generally, the olfactory sensory nerves atrophy from the time of birth to the extent that only 82 percent of the acuity remains at the age of 20; 38 percent at the age of 60 and 28 percent at the age of 80. Consequently, olfactory acuity and like or dislike of an odor decrease with age.

Infants appear to like all classes of odorous materials, perhaps because the lack previous experience and because of their innate curiosity. Children younger than five years old rated sweat and feces as pleasant but above that age, as unpleasant. Like and dislike of a particular odor can change with odor concentration or intensity. Generally, humans can distinguish between more

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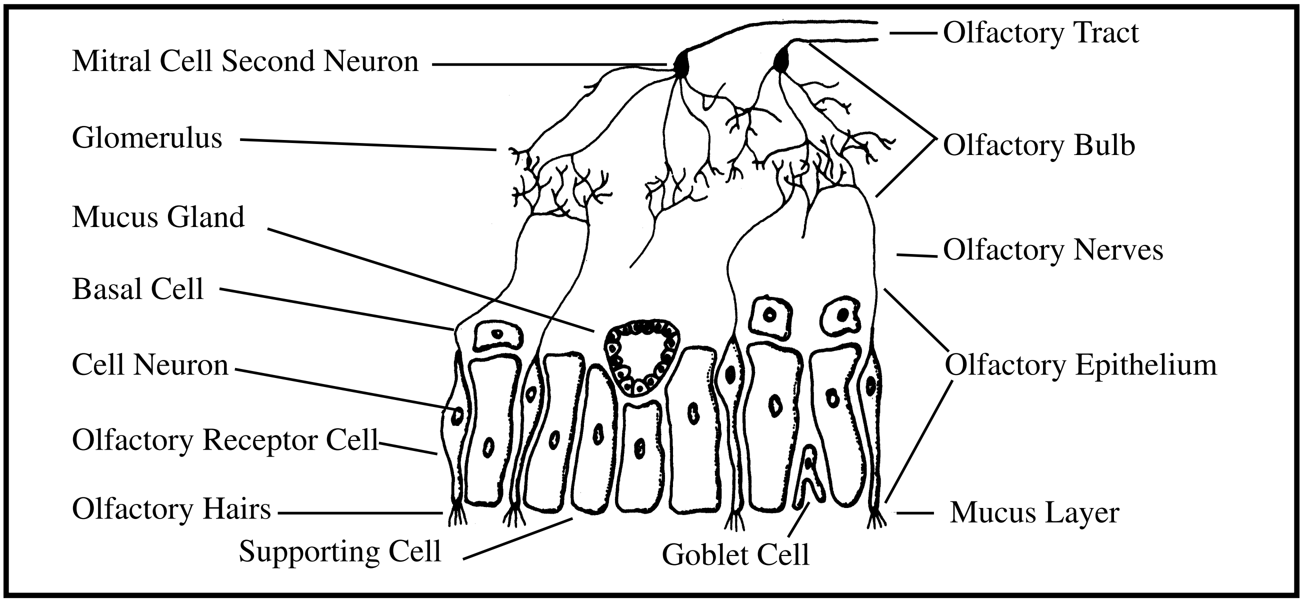
Table 1. Examples of varying threshold measurements of odorous substances (odorants).

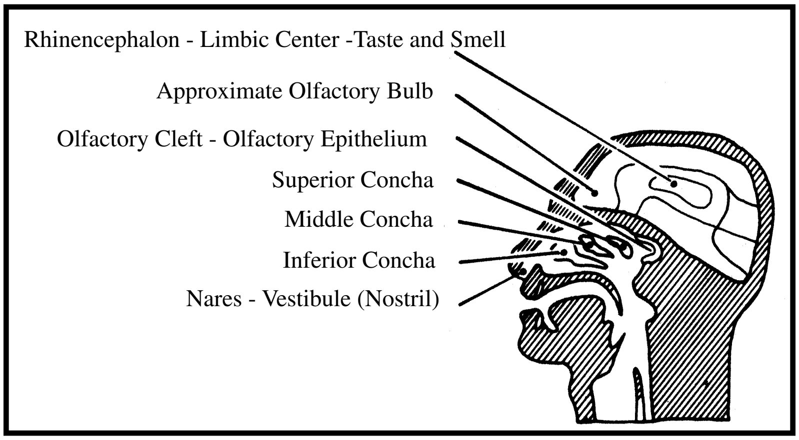
Odorant	Formula	Characteristic Odor	Odor Threshold (ppm)	Detection Threshold (ppm)	Recognition Threshold (ppm)
Acetaldehyde	$CH_3 \bullet CHO$	Pungent, fruity	.004	--	.21
Allyl mercaptan	$CH_2 \bullet CH \bullet CH_2 \bullet SH$	Strong garlic, coffee	.00005	.016	--
Ammonia	NH_3	Sharp, pungent	.037	--	46.8
Amyl mercaptan	$CH_3 \bullet (CH_2)_3 \bullet CH_2 \bullet SH$	Unpleasant, putrid	.0003	--	--
Benzyl mercaptan	$C_6H_5 \bullet CH_2 \bullet SH$	Unpleasant, strong	.00019	--	--
Butylamine	$C_2H5 \bullet CH_2 \bullet CH_2 \bullet NH$	Sour, ammnia-like	--	--	.24
Cadaverine	$H_2N \bullet (CH_2)_5 \bullet NH_2$	Putrid, decaying flesh	--	--	--
Chlorine	Cl_2	Pungent, suffocating	.01	.01	.314
Chlorophenol	ClC_6H_5O	Medicinal, phenolic	.00018	--	--
Crotyl mercaptan	$CH_3 \bullet CH:CH \bullet CH_2 \bullet SH$	Skunk-like	.000029	.0077	--
Dibutylamine	$(C_4H_9)_2NH$	Fishy	.016	--	--
Disopropylamine	$(C_3H_7)_2NH$	Fishy	.0035	--	.085
Dimethylamine	$(CH_3)_2NH$	Putrid, fishy	.047	--	.047
Dimethylsulfide	$(CH_3)_2S$	Decayed vegetables	.001	--	.001
Diphenylsulfide	$(C_6H_5)_2S$	Unpleasant	.000048	--	.0021
Ethylamine	$C_2H_5NH_2$	Ammoniacal	.83	--	.83
Ethyl mercaptan	$C_2H_5 \bullet SH$	Decayed cabbage	.00019	.0026	.001
Hydrogen sulfide	H_2S	Rotten eggs	.00047	--	.0047
Indole	C_2H_6NH	Fecal nauseating	--	--	--
Methylamine	CH_3NH_2	Putrid, fishy	.021	--	.021
Methyl mercaptan	CH_3SH	Decayed cabbage	.0011	--	.0021
Ozone	O_3	Irritating above 2 ppm	.001	.5	--
Proply mercaptan	$CH_3 \bullet CH_2 \bullet CH_2 \bullet SH$	Unpleasant	.001	.5	--
Putrescine	$NH_2(CH_2)_4NH_2$	Putrid, nauseating	--	--	--
Pyridine	C_6H_5N	Disagreeable, irritating	.0037	--	--
Skatole	C_9H_9N	Fecal, nauseating	.0012	.223	.47
Sulfur dioxide	SO_2	Pungent, irritating	.009	--	--
Tert-butyl mercaptan	$(CH_3)_3C \bullet SH$	Skunk, unpleasant	.00008	--	--
Thiocresol	$CH_3 \bullet C_6H_4 \bullet SH$	Skunk, rancid	.0001	.019	--
Thiophenol	C_6H_5SH	Putrid, garlic-like	.000062	.014	.28
Triethylamine	$(C_2H_5)_3N$	Ammoniacal, fishy	.08	--	--

Figure 1. Nasal cavity and detail of nerve fibers from olfactory cells.



than 5,000 odors but some individuals experience anosmia (smell blindness) for one or more odors. In this situation, the individual apparently has a normal sense of smell, but is unable to detect one particular odor regardless of its intensity. For example, because methyl mercaptan has an odor recognition threshold of only 0.0021 ppm (Table 1), it is often mixed with natural gas as an indicator of leaks; however, approximately one in one thousand persons is unable to detect the strong odor of this mercaptan. An estimated 30 percent of the elderly have lost the ability to perceive the minute amount of this mercaptan used in natural gas.

Figure 2. Olfactory system.



Odor physiology

Olfaction depends upon the interaction between the odor stimulus and the olfactory epithelium. The olfactory membrane is a sensitive area, covering 4 to 6 square cm in each nostril (Fig. 1). Beneath the membrane is a mucous layer. The nerve cells or peripheral receptor cells that primarily sense odors and fragrances are located in the epithelium. Cilia extend from the nerve cells into the mucous layer, which greatly increases the potential receptor area. The cilia are thought to contain the ultimate olfactory receptors, which are specialized protein molecules. Specific anosmia may result from the inability to synthesize the appropriate protein. The receptor cells transmit impulses to the olfactory bulb located at the base of the front brain (Fig. 2). At the bulb, fibers from the nose contact with other nerves, which travel on to various parts of the brain.

An estimated 100 million receptor cells are present in humans. For a substance to be detected as an odor by the receptor cells, several criteria must be met:

1) the substance must be volatile enough to permeate the air near the sensory area;
2) the substance must be at least slightly water-soluble to pass through the mucous layer and to the olfactory cells;
3) the substance must be lipid-soluble because olfactory cilia are composed primarily of lipid material; and finally,
4) a minimum number of odorous particles must be in contact with the receptors for a minimum length of time.

Many theories have been proposed to describe the mechanism of smelling odors. Most can be classified into one of two groups: a physical theory or a chemical theory. The physical theory proposes that the shape of the odorant molecule determines which olfactory cells will be stimulated and, therefore, what kind of odor will be perceived. Each receptor cell has several different types of molecular receptor sites, and selection and proportion of the various sites differ from cell to cell.

The chemical theory, which is more widely accepted, assumes that the odorant molecules bind chemically to protein receptors in the membranes of the olfactory cilia. The type of receptor in each olfactory cell determines the type of stimulant that will excite the cell. Binding to the receptor indirectly creates a receptor potential in the olfactory cell that generates impulses in the olfactory nerve fibers. Receptor sensitivity may explain some of the variation in detection thresholds exhibited by different compounds. For example, ammonia has an odor threshold of 0.037 ppm whereas the corresponding values for hydrogen sulfide and sulfur dioxide are 0.00047 and 0.009 ppm, respectively (Table 1).

Odor responses

Odor adaptation is the process by which one becomes accustomed to an odor. The adaptation time needed is greater when more than one odor is present. When adaptation occurs, the detection threshold increases. The detection threshold limits change faster when an odor of high, rather than low, intensity is presented. Besides, adaptation occurs differently for each odor. Odor fatigue occurs when total adaptation to a particular odor has occurred through prolonged exposure. This situation would apply to milkers or dairy managers who are exposed to the smell of dairy manure on a daily basis and appear virtually unaware of the odor.

While ammonia and hydrogen sulfide are odorants, and not odors per se, they are produced through processes often associated with odor, including municipal sewage treatment systems, coal burning, industries and factories, and livestock operations.

Both ammonia and hydrogen sulfide can cause olfactory losses as a result of chronic or prolonged exposure. Ammonia also can affect the central nervous system. A number of other chemical pollutants, including some insecticides result in losses in olfaction by damaging olfactory receptors. The use of medications may exacerbate chemosensory disorders.

On average, olfactory receptors renew themselves every thirty days. Pollutants may alter this turnover rate or disrupt the integrity of the lipid membranes of olfactory receptors. Threshold levels have been identified for a number of pollutants, above which odor or irritation occur. Unfortunately, however, knowledge of the exact mechanisms by which pollutants alter olfaction is limited.

Resources

This publication along with PM 1963b, Science of Smell Part 2: Odor chemistry;
PM 1963c, Science of Smell Part 3: Odor detection and measurement (after 9/1/04)
PM 1963d, Science of Smell Part 4: Principles of odor control (after 9/1/04) can be found on the Air Quality and Animal Agriculture Web page at: http://www.extension. iastate.edu/airquality.

References

Powers-Schilling, W.J. 1995. Olfaction: chemical and psychological considerations. *Proc. of Nuisance Concerns in Animal Management: Odor and Flies Conference*, Gainesville, Florida, March 21-22.

Table and figures from Water Environment Federation. 1978. Odor Control for Wastewater Facilities. Manual of Practice No. 22. Water Pollution Control Federation, Washington D.C.

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