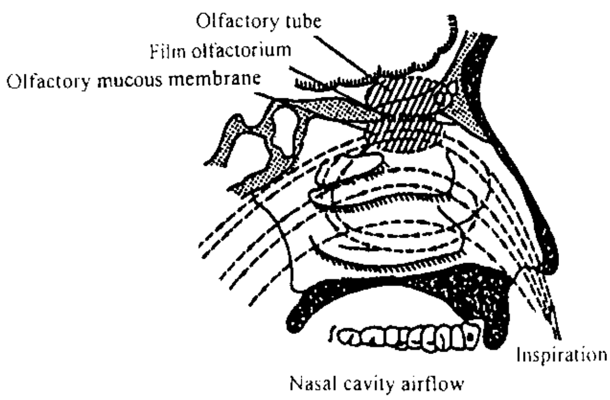
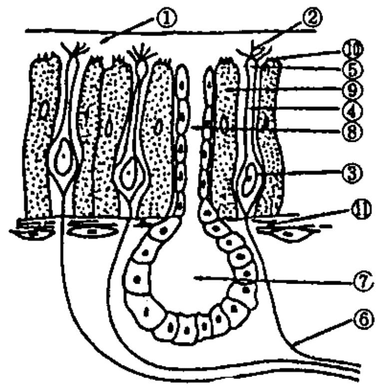
5.5 Effects on senses (sense of smell)

5.5.1 Sense of smell

Humans use their so-called five senses of sight, hearing, smell, touch, and taste as a means of acquiring information from the outside world. Of these five, smell works to identify the nature of odors and, along with taste, may be called a chemical sense. Further, smell possesses functions that only respond to a limited number of chemical substances (those substances with odors). Humans mainly rely on their senses of sight and hearing to live, for which reason, although sight and hearing are well developed, smell is, by comparison, a somewhat primitive sense. Odors such as that of rotting food and of burned substances aim to provide advance warnings of impending danger. On the other hand, on the basis of helping us to lead our individual lifestyles, such fragrances as can be seen in perfume, cosmetics, flavors, and so forth are part of a sense essential for us to lead fulfilled lives, and if we were to consider life without the sense of smell, we immediately begin to realize just how important a sense it is.

Airborne odors enter the nasal cavity along with inhaled air, and arrive at the olfactory membrane in the roof of the cavity by passing along the nasal airway, where they dissolve into the mucous membrane. The olfactory membrane contains olfactory glands (Bowman's gland) centered on olfactory cells, which are sense receptor cells. The olfactory glands hairs extend from the length of the olfactory cells through the mucous, and the tip of the cells (the olfactory small vesicle) also protrudes into the mucous membrane. Odor molecules that enter the mucous collide with both the olfactory glands hairs and the olfactory small vesicle, and excite the cell membrane, thereby transmitting an impulse (an electrical signal) to the olfactory cells. The olfactory nerve, which protrudes from the cells, enters the olfactory tube, which is the primary axis of the direct sense of smell. Moreover, a stimulus is transmitted to the cerebral cortex, where the nature of the odor is identified [1] (see Fig.5.5.1).





① Mucous membrane
② Olfactory glands hair
③ Nasal cells
④ Olfactory dendrite
⑤ Olfactory small vesicle
⑥ Olfactory nerve fiber
⑦ Bowman gland
⑧ Excretory duct of Bowman gland
⑨ Supporting cell
⑩ Cytoplasmic protuberance with small supporting cell surface
⑪ Basement cell layer

Fig.5.5.1 Micro structure of nasal cavity airway and olfactory mucous membrane [1]

5.5.2 Features of the sense of smell

The features of the sense of smell can be cited as being an acute sense. The human sense of smell is considerably inferior when compared with that of a dog, but such detection limit (threshold value) indicates an excellent degree of sensitivity to a multitude of odorous substances, which far exceed the detection limit of modern analytical equipment (see Table 5.5.1[2)]). The difference between the concentration of an odorous substances and the strength of olfactory sense stimulation is known as the Weber-Fechner's law (Weber was a German psycho-physicist, and Fechner was a German psychologist), and is shown in Eq. (1). It shows that the strength of the sense is logarithmically proportional to the strength of the stimulus (concentration of the odorous substances.)

$R = k \log S$ (R: strength of the sense, k: constant, S: strength of the stimulus) ············ (1)

In other words, even if the strength of the stimulus were multiplied tenfold, the weight of human senses is revealed to be only doubled in sensitivity. For specifically offensive odorous substances, which are regulated in Japan by the Offensive Odor Control Law, a relationship is reported between the concentration of the substances (strength of stimulus) and six-points odor intensity scale (strength of the sense) (see Table 5.5.2).

When the same odor is smelled for several minutes, the strength of its sense depreciates remarkably, until at last no odor can be detected. The stronger an olfactory stimulus grows, or else the longer that it lasts, the sense of smell becomes extremely fatigued, and the extent of this again depends on the quality of the odor. With such substances as acrolein, the fatigue of the sense of smell is great and, conversely, with such materials as methyl mercaptan, trimethylamine, and isovaleric acid, the sense of smell is not easily fatigued.

Just as with colors, there are color blindness and color weakness, so with odors, both odor blindness and odor weakness can be seen. The phenomenon whereby, while there is a normal sense of smell with regard to other odors, there is no sense with regard to one specific odor, or else the degree of sensitivity is extremely low, is called specific anosmia. For example, 18.2% of Caucasian males, and 4.5% of Caucasian females, cannot sense the odor from hydrogen cyanide.

The function of the sense of smell can be influenced by a variety of illnesses and diseases. The most obvious ones to affect the sense of smell are diseases of the nose such as chronic sinusitis (maxillary empyema), allergic rhinitis, and nasal polyps, and in addition, the sense of smell may also be affected by an external head injury, the side effects of drugs, viral infection, and so forth. A complete loss of the sense of smell is called ageusia, and a reduced capability when compared with the norm is called hyposmia. Such impairments of the sense of smell are caused by damage to the olfactory organs.

Table 5.5.1 Threshold sensitivity values for odorous substances [2)]

(Number of materials: 223) Units: ppm

No	Material	Threshold
	Sulfur compounds	
1	sulfur dioxide	0.87
2	carbonyl sulfide	0.055
3	hydrogen sulfide	0.00041
4	methyl sulfide	0.0030
5	methyl allyl sulfid	0.00014
6	ethyl sulfide	0.000033
7	acrylic sulfide	0.00022
8	carbon dioxide	0.21
9	methyl disulfide	0.0022
10	ethyl disulfide	0.0020
11	allyl disulfide	0.00022
12	methyl mercaptane	0.000070
13	ethyl mercaptane	0.0000087
14	n-propyl mercaptane	0.000013
15	isopropyl mercaptane	0.0000060
16	n-butyl mercaptane	0.0000028
17	isobutyl mercaptane	0.0000068
18	sec-butyl mercaptane	0.000030
19	tert butylmercaptan	0.000030
20	n-amylmercaptane	0.00000078
21	isoamylmercaptane	0.00000077
22	n-hexylmercaptane	0.000015
23	thiophene	0.00056
24	tetrahydrothiofene	0.00062
	Alcohols	
1	methyl alcohol	33
2	ethyl alcohol	0.52
3	n-propyl alcohol	0.094
4	isopropyl alcohol	26
5	n-butyl alcohol	0.038
6	isobutyl alcohol	0.011
7	sec-butyl alcohol	0.22
8	tert-butyl alcohol	4.5
9	n-amyl alcohol	0.10
10	isoamyl alcohol	0.0017
11	sec-amyl alcohol	0.29
12	tert-amyl alcohol	0.088
13	n-hexyl alcohol	0.0060
14	n-heptyl alcohol	0.0048
15	n-octyl alcohol	0.0027
16	isooctyl alcohol	0.0093
17	n-nonyl alcohol	0.00090
18	n-decyle alcohol	0.00077
	Aldehydes	
1	formaldehyde	0.50
2	acetaldehyde	0.0015
3	propionaldehyde	0.0010
4	n-butylaldehyde	0.00067
5	isobutylaldehyle	0.00035
6	n-valeraldehyde	0.00041
7	isovaleraldelyde	0.00010
8	n-Hexylaldehyde	0.00028
9	n-heptylaldehyde	0.00018
10	n-octylaldehyde	0.000010
11	n-nonylaldehyde	0.00034
12	n-decylaldehyde	0.00040
13	acrolein	0.0036
14	metacrolein	0.0085
15	crotonaldehyde	0.023
	Ketones	
1	Acetone	42
2	methyl ethyl ketone	0.44
3	methyl n-propyl ketone	0.028
4	methyl isopropyl ketone	0.50
5	methyl n-butyl ketone	0.024
6	methyl isobutyl ketone	0.17
7	methyl sec-butyl ketone	0.024
8	methyl tert-butyl ketone	0.043
9	methyl n-amyl ketone	0.0068
10	methyl isoamyl ketone	0.0021
11	diacetyl	0.000050
	Fatty acids	
1	acetic acid	0.0060
2	proprionic acid	0.0057
3	n-butyric acid	0.00019
4	Isobutyric acid	0.0015
5	n-valeric acid	0.000037
6	isovaleric acid	0.000078
7	n-caproic acid	0.00060
8	isocaproic acid	0.00040
	Esters	
1	methyl formate	1.30
2	ethyl formate	2.7
3	propyl formate	0.96
4	isopropyl formate	0.29
5	n-butyl formate	0.087
6	isobutyl formate	0.49
7	methyl acetate	1.7
8	ethyl acetate	0.87
9	n-propyl acetate	0.24
10	isopropyl acetate	0.16
11	n-butyl acetate	0.016
12	isobutyl acetate	0.0080
13	sec-butyl acetate	0.0024
14	ter-butyl acetate	0.071
15	n-hexyl acetate	0.0018
16	methyl propionate	0.098
17	ethyl propionate	0.0070
18	n-propyl propionate	0.058
19	isopropyl propionate	0.0041
20	n-butyl propionate	0.036
21	isobutyl propionate	0.020
22	methl n-butylate	0.0071
23	methyl isobutylate	0.0019
24	ethyl n-butylate	0.000040
25	ethyl isobutylate	0.000022
26	n-propyl n-butylate	0.011
27	isopropyl n-butylate	0.0062
28	n-propyl isobutyrate	0.0020
29	isopropyl isobutyrate	0.035
30	n-butyl n-butylate	0.0048
31	isobutyl n-butylate	0.0016
32	n-butyl isobutyrate	0.022
33	isobutyl isobutylate	0.075
34	methyl n-valerate	0.0022
35	methyl isovalerate	0.0022
36	methyl n-valerate	0.00011
37	ethyl Isovalerate	0.000013
38	n-propyl n-valerate	0.0033
39	n-propyl isovalerate	0.000056
40	n-butyl isovalerate	0.012
41	isobutyl isovalerate	0.0052
43	ethyl acrylate	0.00026
44	n-butylAcrylate	0.00055
45	isobutyl Acrylate	0.00090
46	metacrylate	0.21
	Phenol cresol	
1	phenol	0.0058
2	o-cresol	0.00028
3	m-cresol	0.00010
4	p-cresol	0.000054
	Other oxides	
1	2-ethoxyethanol	0.58
2	2-n-butoxyethanol	0.043
3	1-butoxy 2-propanol	0.16
4	2-ethoxyethyl acetate	0.049
5	diosmine	0.0000065
6	Ozone	0.0032
7	furan	9.9
8	2.5-dihydrofuran	0.093
	Amines	
1	Methylamine	0.035
2	ethylamine	0.046
3	n-propylamine	0.061
4	isopropylamine	0.025
5	n-butylamine	0.17
6	isobutylamine	0.0015
7	sec-butylamine	0.17
8	tert-butylamine	0.17
9	dimethylamine	0.033
10	diethylamine	0.048
11	trimethylamine	0.000032
12	triethylamine	0.0054
	Other nitrogen oxides	
13	nitrogen dioxide	0.12
14	ammonia	1.5
15	acetonitrile	13
16	acrylonitrile	8.8
17	meta-acrylonitrile	3.0
18	pyridine	0.063
19	Indole	0.00030
20	skatole	0.0000056
21	ethyl-o-totuidine	0.026
	Saturated normal hydrocarbons	
1	propane	1500
2	n-butane	1200
3	n-pentane	1.4
4	isopentane	1.3
5	n-hexane	1.5
6	isohexane (2-MPen)	7.0
7	3-methylpentane	8.9
8	2,2-dimethyl butane	20
9	2,3-dimethyl butane	0.42
10	n-heptane	0.67
11	isoheptane (2-MHex)	0.42
12	3-methyl hexane	0.84
13	3-ethyl pentane	0.37
14	2.2 dimethyl pentane	38
15	2,3 dimethyl pentane	4.5
16	2,4-dimethyl pentane	0.94
17	n-octane	1.7
18	isooctane (2MHep)	0.11
19	3-methyl heptane	1.5
20	4-methyl heptane	1.7
21	2,2,4-trimethyl heptane	0.67
22	n-nonane	2.2
23	2,2,5-trimethyl hexane	0.90
24	n-decane	0.87
25	n-undecane	0.62
26	n-dodecane	0.11
	Unsaturated normal hydrocarbons	
1	propylene	13
2	1-butene	0.36
3	isobutene	10
4	1-pentane	0.10
5	1-hexane	0.14
6	1-heptane	0.37
7	1-octene	0.0010
8	1-nonene	0.00054
9	1,3-butadiene	0.23
10	isoprene	0.048
	Aromatic hydrocarbons	
1	benzene	2.7
2	toluene	0.33
3	styrene	0.035
4	ethyl benzene	0.17
5	o-xylene	0.38
6	m-xylene	0.041
7	p-xylene	0.058
8	n-propyl benzene	0.0038
9	isopropyl benzene	0.0084
10	1,2,4-trimethyl benzene	0.12
11	1,3,5-trimethyl benzene	0.17
12	o-ethyl toluene	0.074
13	m-ethyl toluene	0.018
14	p-ethyl toluene	0.0083
15	o-diethyl benzene	0.0094
16	m-diethyl benzene	0.070
17	p-diethyl benzene	0.00039
18	n-butyl benzene	0.0085
19	1,2,3,4,-tetramethyl benzene	0.011
20	1,2,3,4-tetrahydronaphthalene	0.0093
	Monoterpene	
1	α-pinene	0.018
2	β-pinene	0.033
3	limonene	0.038
	Alicyclic hydrocarbons	
1	methylcyclopentane	1.7
2	cyclohexane	2.5
3	methyl cyclohexane	0.15
	Chlorine and chlorides	
1	chlorine	0.049
2	dichloromethane	160
3	chloroform	3.8
4	trichloroethylene	3.9
5	carbon tetrachloride	4.6
6	tetrachloroethylene	0.77

Table 5.5.2 Relation between concentration of offensive odorous substances and strength of odor

Odorous substance	1	2	2.5	3	3.5	4	5
ammonia	0.1	0.6	1	2	5	10	40
methylmercaptane	0.0001	0.0007	0.002	0.004	0.01	0.03	0.2
hydrogen sulfide	0.0005	0.006	0.02	0.06	0.2	0.7	8
methyl sulfide	0.0001	0.002	0.01	0.05	0.2	0.8	2
methyl disulfide	0.0003	0.003	0.009	0.03	0.1	0.3	3
trimethyl amine	0.0001	0.001	0.005	0.02	0.07	0.2	3
styrene	0.03	0.2	0.4	0.8	2	4	20
propionic acid	0.002	0.01	0.03	0.07	0.2	0.4	2
n-butyric acid	0.00007	0.0004	0.001	0.002	0.006	0.02	0.09
n-valeric acid	0.0001	0.0005	0.0009	0.002	0.004	0.008	0.04
isovaleric acid	0.00005	0.0004	0.001	0.004	0.01	0.03	0.3
tolene	0.9	5	10	30	60	1×10^2	7×10^2
xylene	0.1	0.5	1	2	5	10	50
ethyl acetate	0.3	1	3	7	20	40	2×10^2
methyl isobutyl ketone	0.2	0.7	1	3	6	10	50
isobutanol	0.01	0.2	0.9	4	20	70	1×10^3
acetaldehyde	0.002	0.01	0.05	0.1	0.5	1	10
propionaldehyde	0.002	0.02	0.05	0.1	0.5	1	10
n-butylaldehyde	0.0003	0.003	0.009	0.03	0.08	0.3	2
isobutylaldehyde	0.0009	0.008	0.02	0.07	0.2	0.6	5
n-valeraldehyde	0.0007	0.004	0.009	0.02	0.05	0.1	0.6
isovaleraldehyde	0.0002	0.001	0.003	0.006	0.01	0.03	0.2

5.5.3 Effects on the physiological functions of odors [1) 3)]

The mutual relationship between the sense of smell and psychology is considerably large, and varies greatly from person to person. Many animals besides humans also react to take evasive action to avoid offensive odors they experience. This is an instinctive danger warning system, and is a means of avoiding danger. As a defensive posture against danger, humans have developed autonomic sympathetic nerve functions subconsciously. Although we experience considerable alarm when encountering offensive odors, including stimulant odors, when we continue to receive unpleasant odors, a state similar to the following is created. Namely, we feel deeply disturbed when we sense offensive odors. This sense of unpleasantness leads subconsciously to a tension in the sympathetic nerves. This state of tension in the sympathetic nerves has a variety of effects on various organs throughout the body, such as an increased pulse rate, and a rise in blood pressure. If the stimulus due to the offensive odor lasts only a short period of time, the state of tension in the sympathetic nerves returns to normal along with the disappearance of the stimulus, but if the duration of the stimulus is a long one, or else of the duration is short but reoccurs frequently, the state of tension in the sympathetic nerves is sustained, and ataxia of the autonomic nerves results.

When a pleasant odor is scented, the respiration deepens, but when an even stronger odor is scented, the respiration reacts by stopping. When the concentration of an odor gradually grows from weak to stronger, the breath count initially increases, but if the concentration rises even further, it is then detected as if it were an offensive odor, and both the breath count and the depth of respiration are reduced. These changes in respiration are due to the use of information pivotal in respiration. When a pleasant odor is detected and the respiration deepens, there are simultaneously changes in the blood pressure, and we feel relaxed. It has also been reported that in addition to both apple and spicy floral odors, nutmeg, mace, neroli, and Valerian root are useful in reducing stress. Further, in animal experiments, with stimulant odors such as ammonia and chloroform, although blood pressure drops initially with a weak dose, a phenomenon whereby it subsequently rises can be seen.

In the case of eating food, appetite increases for food which gives off good odors, there is no appetite for foods with bad odors, and on occasion, we feel nauseous and also vomit. In animal experiments, feed with pleasing smells increase the quantity of feed consumed remarkably. That is to say, the quantity of feed consumed is increased due to a heightening in digestive capabilities through the adding of odors to the foodstuff.

In addition, an effect can also be seen on the reproductive system of animals. The mating season for animals is greatly influenced by odors. Other effects of odors are thought to be effects on sleep and on psychology. It has been reported that unpleasant odors can cause prevention of sleep.

5.5.4 Effects of odors and their uses

Since olden times, people have pacified the spirit through the scent of blooming flowers, soothed their emotions with herbal baths, and have experienced improvements in their mood through odors. Humans have used odors since prehistoric times, and in ancient Egypt, scented materials were being used in the creation of mummies and, in addition, the mixing of medicinal scents is recorded in the Old Testament. Further, the traditional incense-smelling games of "kaori awase" (fragrance identification) and "kado" (fragrance arrangement) were devised in Japan, and also, the customs of impregnating clothing with incense, and burning incense within a room when greeting a guest arose.

At present, fragrances are used in a wide variety of fields such as foodstuffs, cosmetics, animal feed, household goods an, besides these, industrial applications, where their functions are used as anti-bacterials, antioxidants, air fresheners and for masking unpleasant smells, as well as in both physiological and psychological uses. Further, recently, such products as scented handkerchiefs, scented neckties, and other perfumed goods have gone on sale, besides which, the tendency to perfume one's living environment has manifested itself, and involvement in both domestic air fresheners and air conditioning systems has also appeared. A concept known as aromachology is behind this introduction of scents into the living environment.

Experiments to evaluate the usefulness the various physiological and psychological effects possessed by fragrances in both daily living and the treatment of disease have long been conducted in Europe, and the French comparative pathologist Gattefosse has suggested aromatherapy using refined oils that contain both scented medicines and herbs. This is not the traditional treatment methods of taking medicine internally, ointments, injections, or so forth, but a psychological treatment through scents using treatment by inhalation and direct atomization into the nasal cavity. Not only a pharmaceutical reaction incited by olfactory stimuli, but also psychological effects such as feelings of pleasantness, unpleasantness, excitement, calm, and so forth, are expected, leading to the recognition that it is an effective treatment for both mental and physical ailments.

On the other hand, the previously-cited word "aromachology" is employed when using odors to stimulate not physiological, but psychological changes, employing odors and scents in the daily lives of ordinary, healthy people, and in research aiming to create a more pleasant lifestyle [4].

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