

1

The Olfactory Nerve



Figure 1.1 Helen Adams Keller (1880–1968) was an American author, political activist, and lecturer. She was the first deaf–blind person to earn a Bachelor of Arts degree. The story of how Keller’s teacher, Anne Sullivan, penetrated the isolation imposed by Keller’s absence of language ability has become widely known through the dramatic depictions of the play and film, *The Miracle Worker*. Here, Keller is shown using one of her remaining senses, olfaction, to smell roses.

ANATOMY/FUNCTION SUMMARY

Figure 1.1 shows Helen Keller enjoying the fragrance of roses. In her 1908 book, *The World I Live In*, Chapter VI is titled, “Smell, The Fallen Angel”, and begins, “For some inexplicable reason the sense of smell does not hold the high position it deserves among its sisters. There is

The Clinical Anatomy of the Cranial Nerves: The Nerves of “On Old Olympus Towering Top”,
First Edition. Joel A. Vilensky, Wendy M. Robertson and Carlos A. Suárez-Quian.
© 2015 John Wiley & Sons, Inc. Published 2015 by John Wiley & Sons, Inc.

something of the fallen angel about it.” Keller then proceeds to describe the importance of smell to her and her own very acute sense of smell (hyperosmia). “The sense of smell has told me of a coming storm hours before there was any signs of it visible.... From inhalations I learn much about people. I often know the work they are engaged in. The odors of wood, iron, paint, and drugs cling to the garments of those who work in them.... When a person passes quickly from one place to another I get a scent of impression of where he has been – in the kitchen, the garden, or the sick-room.”

The olfactory nerve (really a collection of many filaments that are collectively referred to as the olfactory nerve; Figure 1.2) is a purely sensory nerve (special sensory) that conveys the neural impulses that the brain is able to interpret as odors. Our sense of taste is intimately blended with our sense of smell. The olfactory nerve has the simplest anatomy of any of the cranial nerves. There are neurons sensitive to odorous molecules in the upper recesses of the nasal cavity, which send impulses that are interpreted as smells to the brain (Figure 1.2).

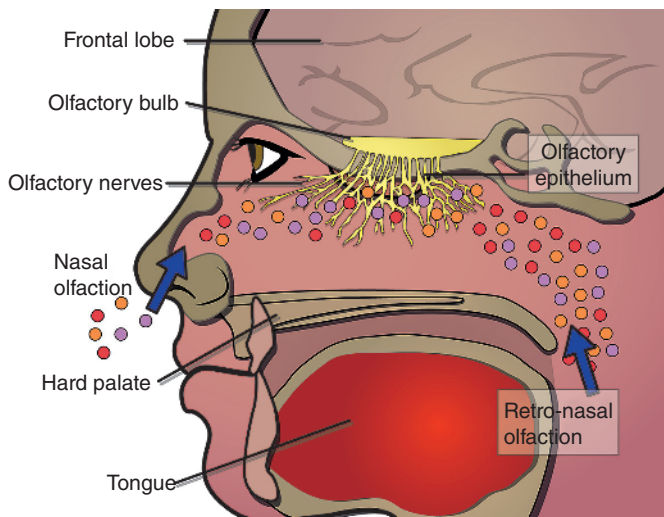


Figure 1.2 Schematic illustration of the olfactory nerve.

Below is an Internet case of anosmia (loss of smell) written by Joan, a 45-year-old woman, who implies that life without a sense of smell is similar to living in a two-dimensional world:

I suffered from allergic symptoms and chronic sinusitis all of my life – plus nasal polyps and a deviated septum. I had three surgeries to repair the septum and remove diseased tissue and polyps that were obstructing

my sinuses and nasal passages. My anosmia developed gradually sometime after the second surgery. It was especially devastating for me because a large part of my life and livelihood relied on my sense of smell – I sold fragrance and aromatherapy products, and had even created several very successful fragrance blends myself. I had very brief periods of partial or total restoration of my sense of smell and taste after an intensive course of oral steroids. The recovery was a week of “glorious 3-D” living – with my smell and taste completely restored. But it disappeared just as quickly as it came. Because the side effects of oral steroids prevent me from being able to take them more than once or twice a year, oral steroids are not a permanent solution – “but I haven’t given up hope for finding one.”

ANATOMY/FUNCTION

Olfaction begins when molecules from an aromatic substance (e.g., Chanel No. 5 as opposed to gold bullion) enter the nasal cavity and ascend with an inhalation (Figure 1.2). These aromatic molecules then interact with a layer of about six million specialized sensory receptor cells that are nestled among the supporting mucosal cells in the roof of the nasal cavity on protuberances called concha.

This specialized mucosal area (often referred to as the olfactory epithelium) can be distinguished by a faint yellowish color from the adjacent more reddish respiratory mucosa (Figure 1.3). With every breath, air is forced over 10–50 very fine hairs called cilia ($0.3\mu\text{m}$ in diameter) arising from each of the olfactory receptor cells that are sensitive to aromatic compounds in the air. The incredibly thin unmyelinated axons from the olfactory receptor cells (about $0.2\mu\text{m}$ in diameter) coalesce into about 20 bundles, collectively referred to as the olfactory nerve, and ascend about 30mm from the nasal cavity through the cribriform plate and enter the cranial cavity. As discussed in the introductory chapter, the cribriform (sieve-like) plate is characterized by foramina that allow the passage of the axons from the sensory cells to the brain. The actual space in the nasal cavity in which the olfactory epithelium is located, the olfactory cleft, is only about 1–2mm wide and thus can be easily blocked by disease.

Once through the cribriform plate, the olfactory nerve axons synapse in an ovoid extrusion of the cerebral cortex that rests on the cribriform plate called the olfactory bulb, which is about 8mm^2 in size (Figure 1.4).

The olfactory sensory cells are unique among human sensory receptors because they can regenerate if damaged, but only if their supporting layer of cells is preserved. This is possibly an evolutionary adaptation to their

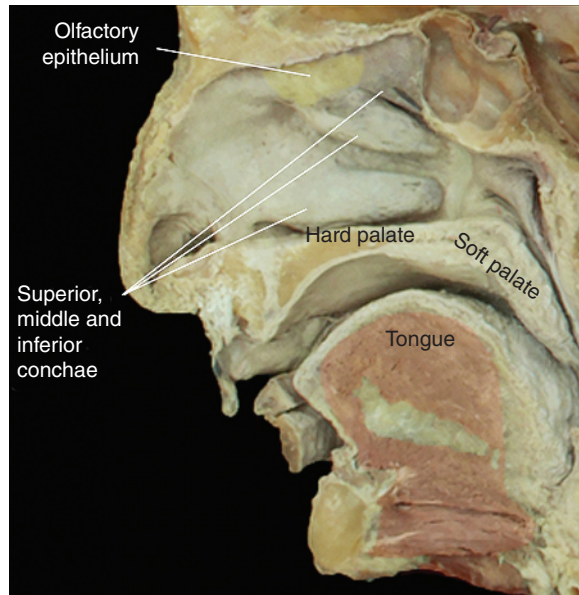


Figure 1.3 Bisected view of the head of a cadaver showing the interior of the nasal cavity and the location of the olfactory epithelium (yellow shading).

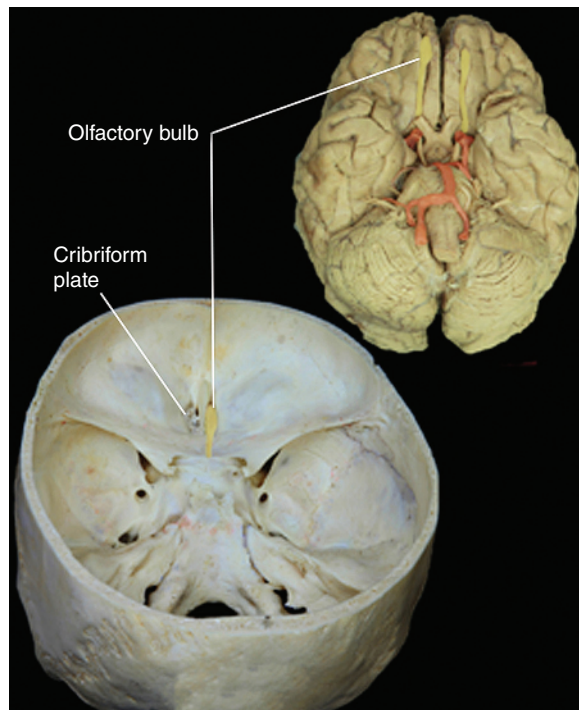


Figure 1.4 Paired images showing the location of the olfactory bulb in the skull and on the brain. The inside surface of the base of the skull is shown on the lower left of the image. The surface of the brain that rests on the skull is shown on the upper right side of the image. An olfactory bulb was digitally inserted into the skull to demonstrate how it rests on the cribriform plate.

relatively high susceptibility to damage. These cells are even capable of repenetrating the cribriform plate and forming new connections with the olfactory bulb when damaged. Furthermore, they uniquely project directly to the brain (olfactory bulb) without an intervening synapse. Although this allows a very precise relationship to exist between odorants and cognition of them, it also unfortunately forms a primary route for exposure of the brain to viruses, bacteria, prions, and airborne toxins. Both Alzheimer and Parkinson diseases have been hypothesized to be caused by organisms and toxins that enter the brain via the olfactory route, although proof of this hypothesis has been elusive.

Humans have approximately 350 functional types of olfactory receptors, that is, receptors that will respond to a few specific odorants. This allows great specificity to olfactory sensations. Furthermore, not all sensations that we associate with smell are in fact truly conveyed by the olfactory nerve. The trigeminal nerve (Chapter 5) has sensory branches in the mouth and nose that respond to sensations such as warmth, coolness, pungency, and irritation. For example, ammonia not only smells awful but also results in a pungent, burning feeling in the nose resulting from trigeminal stimulation. Thus, our cognition of smell is complex, based not only on odors but also taste and these trigeminal sensations. Because of this interaction, it is sometimes not possible to truly say that a patient has complete anosmia because in high concentrations some substances may be perceived via trigeminal stimulation.

The olfactory bulb has cells arranged in six concentric layers. Each particular olfactory neuron only synapses with one or two olfactory bulb cells so that the receptor-specific odorant response is preserved. The primary output neurons of the olfactory bulb project via the olfactory tract to brain structures that are referred to as the primary olfactory cortex.

CLINICAL ASPECTS

Loss of smell

Although the consequences of the total absence of a sense of smell, anosmia, would intuitively seem small compared to loss of one of the more prominent senses such as vision, the effect on quality of life and on one's safety is substantial. If asked about how anosmia has affected their lives, patients often begin by narrating humorous anecdotes about how they no longer react to offensive or nauseating odors. However, when these patients get more serious they talk about how sad they feel when they look closely at a strawberry before eating it and smell nothing. Some patients describe how they have lost their libido because smell is so important to sex. One mother related how she had a very difficult time bonding with her newborn child because she could not smell the child.

People with anosmia can be self-conscious about personal hygiene, often taking several showers a day because they do not know whether or not their body odors are offensive. Cooking becomes difficult and eating becomes monotonous with little associated pleasure. Because eating is typically social,

people with anosmia can lose interest in being with friends and can become depressed and socially isolated.

The French author, Marcel Proust, described in *Remembrance of Things Past* (also known as *In Search of Lost Time*) how the sense of (smell and) taste of a small cake (a madeleine) caused an intensely pleasurable memory to take hold of his body related to complex feelings from childhood.

Importantly, the loss of smell also results in danger to the patient who cannot smell smoke or gas leaks. Such patients cannot tell whether fish has been out of water for 3 hours or 3 days, or whether milk is sour. Because people with anosmia cannot taste well, they may tend to eat excessively in an attempt to get some satisfaction from food.

In 2004, Drs. Richard Axel and Linda Buck were awarded the Nobel Prize in Medicine for the discovery of odorant receptor mechanisms and the organization of the olfactory system. Dr. Axel said in his Nobel acceptance speech:

In humans, smell is often viewed as an aesthetic sense, as a sense capable of eliciting enduring thoughts and memories. Smell however is the primal sense. It is the sense that affords most organisms the ability to detect food, predators, and mates. Smell is the central sensory modality by which most organisms communicate with their environment.

Accordingly, humans who lose their sense of smell are often seriously disabled and depressed. Part of the explanation for the unexpected seriousness associated with anosmia is that along with the loss in smell is a similar loss in taste. Much of what we think of as taste actually results from a complex interaction of taste, smell, and touch. When we eat, aromatic compounds in the food enter the nose from the mouth during swallowing (Figure 1.2). This is why taste is also often distorted during an upper respiratory infection when inflammation of the nasal passages interferes with this process.

Olfactory testing

Prior to the mid-1980s, only rudimentary methods of testing the ability of patients to smell were available. Typically, the clinician would have an assortment of commercially available odors (e.g., menthol oil, lavender oil, coffee, ammonia, clove, vinegar, pepper, and turpentine) and observe if and how the patient responded to each. However, the strengths of the odorants varied and it was not possible to quantify patient response or whether there was much clinical interest in doing so.

The Smell Identification Test™, which was developed in the mid-1980s, consists of four booklets, each containing 10 “scratch & sniff” odorants. The odorants are embedded on brown strips at the bottom of each of the test booklets (Figure 1.5). The stimuli are released by scratching the strips. Written above each odorant strip is a multiple-choice question with four possible responses. A percentile score for the patient is determined relative to normal individuals.

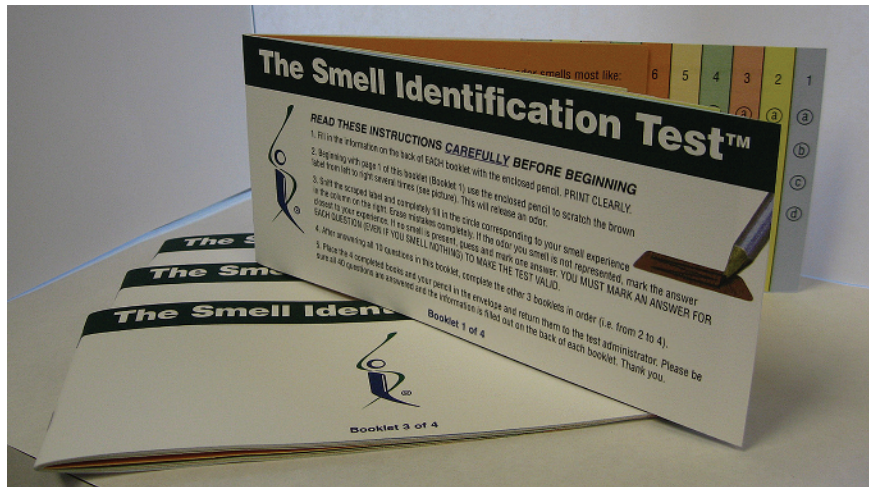


Figure 1.5 The four booklets of the Smell Identification Test™.

More sophisticated testing is possible using electrophysiological apparatus, which are only available in specialized centers. The electrophysiological tests evaluate either electrical activity at the surface of the olfactory epithelium (electro-olfactogram) or integrated electrical activity on the scalp in response to odors (i.e., odor-event recorded potentials).

Olfactory disorders

There are several types of olfactory dysfunction. Anosmia is the complete loss of the ability to detect odors. Partial anosmia is the loss of the ability to detect some, but not all, odors. Hyposmia or microsmia refers to decreased sensitivity to olfactory stimuli. Increased sensitivity to olfactory stimuli is referred to as hyperosmia. Dysosmia or parosmia is distortion of olfactory perception, referred to as cacosmia when the odor is perceived as fetid. Phantosmia is the perception of an odor when no true olfactory stimulus is present, such as olfactory hallucinations. The inability to recognize an odor that can be perceived is olfactory agnosia.

The causes of olfactory disorders may also be divided into three classes: (1) conductive or transport impairments, which result from mechanical obstruction of the nasal passage as in chronic nasal inflammation; (2) sensorineural impairments, which result from damage to the olfactory epithelium as might occur after a viral infection; and (3) central olfactory neural impairment, which results from central nervous system damage as when tumors compress the olfactory tract, and neurodegenerative disorders. These causes are not mutually exclusive. It is possible, for example, for a virus to damage the olfactory epithelium and cause an upper respiratory infection that might also cause conductive impairment.

Growths in the nasal and cranial cavities

Hyposmia (anosmia) may be caused by nasal polyps, which are soft, painless, benign growths on the lining of the nasal passages or sinuses. They can result from chronic inflammation, recurrent infections, or allergies. Larger polyps can obstruct nasal passages, leading to anosmia. Nasal polyps affect up to 4% of the general population.

A wide variety of cancers can arise in the nasal cavity. By obstructing airflow and/or cellular destruction these tumors can cause olfactory dysfunction. Some of these tumors arise from accessory salivary glands that are scattered around the throat and nasal cavity.

A rare aggressive tumor, called an olfactory neuroblastoma (esthesioneuroblastoma), actually originates directly from the olfactory nerves. An olfactory neuroblastoma can occur at any age, although it tends to peak in young adults and in the elderly. There are no known risk factors. Olfactory neuroblastomas tend to be large tumors that invade the cribriform plate and virtually always affect olfaction, both neurologically and mechanically. These tumors can become very large and disfiguring (Figure 1.6). They may cause complete anosmia.

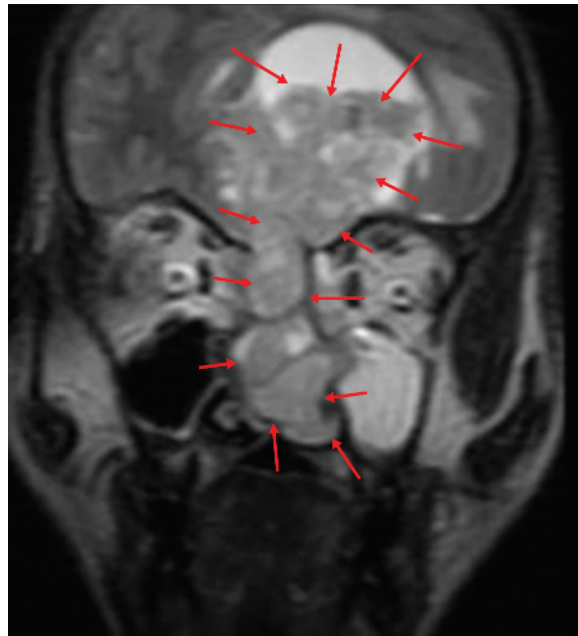


Figure 1.6 Coronal view of a CT scan of a patient with a massive neuroesthesioblastoma. The arrows outline the tumor, which has greatly distorted the normal nasal anatomy in this patient.

A cranial cavity tumor that can affect olfaction is an olfactory groove meningioma (Figure 1.7). These tumors arise in the midline from the arachnoid layer of the brain covering (meninges) that lies over the cribriform plate. These benign slow-growing tumors cause olfactory impairment in a majority

of patients, presumably because of mechanical impingement on the olfactory nerves, bulbs, and tracts, as exemplified in the Internet case below:

Dave said this about his meningioma. “The tumor stretched and then snapped my olfactory nerve. The tumor was benign and it is gone, but the anosmia will be with me the rest of my life. It has been about nine years since I woke up and smelled the coffee.”

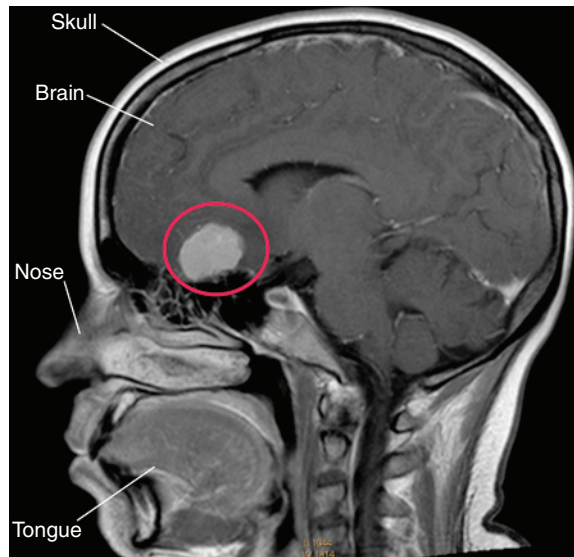


Figure 1.7 MRI of the brain of a patient with a meningioma (tumor of meninges). Note how the tumor (circled in red) is located immediately above the cribriform plate and is therefore in a perfect location to compress the olfactory bulb and thereby interfere with olfaction. Reproduced with permission and courtesy of Health@SarahRamsden.com.

Upper respiratory infections

Upper respiratory infections (colds), usually viral, are the most common cause of chronic hyposmia or anosmia. Even the common cold may cause permanent damage to olfaction, as Judy indicated in her Internet forum posting.

I’ve had a cold that started last Friday. Last night I noticed I couldn’t smell anything – perfumes, coffee, etc. On Monday I was still unable to smell so I went to the doctor, who said that I am “completely blocked up”, nose-wise. I used nasal decongestant spray for a few days, but have stopped. I still can’t smell much. How long do you think these symptoms will last? Usually I can smell more than this when I’m sick. It’s been a bad year cold-wise!

Colds cause inflammation and swelling of the mucosal lining of the nasal cavity. This swelling and mucous secretion can physically block odorants

from reaching the cilia on the receptor cells and thus prevent the cells from responding to odorants. Olfactory function has been found to be decreased in patients during a cold, even when the patient does not have signs of nasal congestion. However, strangely enough, mild or moderate nasal congestion in the absence of disease does not necessarily cause impairment of smell function and may actually enhance it, perhaps forcing more air into the olfactory cleft. Olfactory disorders associated with colds are typically not serious and regress as the cold regresses and/or can be successfully treated with medications. Sometimes, however, the cold virus can have lasting effects.

The British columnist and author Diana Appleyard wrote a column in the *Daily Mail* on January 28, 2012: *A cold left me unable to smell or taste for two years... Would I ever enjoy the aroma of roast chicken or flowers again?*

“Two years ago, I suffered from a very heavy cold. With a runny nose, itchy eyes, persistent cough and sore chest, my symptoms were nothing out of the ordinary. Yet when they disappeared, I was left with one that has had a profound and dispiriting effect on my life. I seemed to have permanently lost my sense of taste and smell.

After my cold, I kept thinking these senses would return, but as weeks turned into months, I was in despair. Would they ever come back?

Until you lose them, you have no idea how much pleasure they bring to everyday life. A stressful day is soon forgotten by the aroma of a dinner of roast chicken and a glass of rioja. A walk in the woods is heightened by pine and wild garlic.”

Diana saw her physician who examined her nasal passages with a nasal endoscope and found swelling and inflammation. He told her that her condition was treatable using a salt-water nasal wash, a steroid spray to reduce the inflammation in the lining of her nose and anti-histamines.

A month after she began treatment her sense of smell and taste began to return. “It’s as if the world is gradually being restored to color around me. I am still taken by surprise occasionally.” Diana’s sense of smell fully recovered.

Unfortunately, there is no direct diagnostic test to demonstrate viral anosmia. If no other cause of anosmia can be found and the patient has had a recent upper respiratory infection, then a diagnosis of viral anosmia is made.

Mick O’Hare described his presumptive viral anosmia in the September 24, 2005 issue of *New Scientist*. He noted that although he had a cold he knew immediately that this was different. He had a total loss of any sense of taste or smell. He said it was initially terrifying and his doctors generally told him that “he had to live with it.”

Chronic bacterial infection is also believed to be associated with destruction of the nasal receptor cells, but because hundreds of species of bacteria normally inhabit the nasal cavity, it is almost impossible to determine which of these can cause such destruction.

Drug-induced hyposmia (anosmia)

Many drugs interfere with the ability to smell, although taste is affected more frequently. Unfortunately, most of the data supporting this relationship are case reports that lack quantitative olfactory testing. Drugs known to affect smell and/or taste based on olfactory measurement rather than anecdotal reporting include calcium channel blockers, antibiotics, antithyroid drugs, opiates, antidepressants, and sympathomimetics (drugs that mimic the action of the sympathetic nervous system). Recreational drugs that are snorted, for example, cocaine, are sometimes associated with anosmia because of destruction of the olfactory epithelium. This happened to Jim:

I lost my sense of smell due to cocaine use over 30 years ago. I only used it recreationally for about five years in the early 80's but it did enough damage that I lost a lot of my sense of smell and some of my sense of taste. Over the years I have regained some of that, but certain flavors are just outside the range that I can taste...in the same way that some smells are outside the range that I can smell. It seems similar to being color blind but pertaining to sense of smell instead.

Nonbiologic airborne toxins

Airborne toxins, including herbicides, pesticides, solvents, and heavy metals can damage the olfactory primary cells, especially with chronic exposure. One of the heavy metals that can do this is zinc, as described in Bonnie Blodgett's book, *Remembering Smell: A Memoir of Losing and Discovering – The Primal Sense*. In the fall of 2005, she developed anosmia. Based on the recommendation of her husband, she had used a zinc-based "homeopathic" gel called Zicam™ to relieve her cold symptoms. She had thought, "What did I have to lose?"

Zicam is actually the name for a series of products marketed for cold and allergy relief. The only active ingredient is zinc. On June 16, 2009, the Food and Drug Administration (FDA) advised consumers to stop using three of Zicam's products including the nasal gel because of the risk of anosmia. The FDA advisory panel indicated that the FDA had received reports of anosmia from approximately 130 Zicam users since 1999. The FDA also issued a Warning Letter to Matrixx Initiatives, Inc., which owns Zicam LLC, that eventually led to the recall of all affected products. In 2006, Matrixx settled 340 lawsuits for \$12 million from patients who said the product eliminated their sense of smell. By 2009, hundreds more suits had been filed. Blodgett noted that from the original lawsuit each of the plaintiffs received about \$12,000, which was a paltry sum to many of them. Blodgett associated this small sum to the perception that smell is a relatively unimportant sense.

After using Zicam Blodgett's cold was unfazed and she spent a week congested and miserable. A week later she noticed very vile odors. She didn't realize it but she had cacosmia (phantosmia).

Rather, she questioned her sanity. An ear, nose and throat specialist (ENT) prescribed an antidepressant that he hoped would relieve her from the "odiferous onslaught of burning flesh, rotting fish, feces, and the like."

The antidepressant was effective but upon losing the olfactory hallucinations, Blodgett also lost all sense of smell. The specialist had actually told her that this was likely to happen because such hallucinations often precede anosmia.

When the specialist had asked her how much Zicam she had used, Blodgett told him that she had figured "the more the better." She stated that immediately after using the product her "sinuses were suddenly on fire, and so were the tissues far in my throat where the gel had apparently started to drip. *So this is how cattle feel under a branding iron, I thought as tears filled my eyes.*"

The ENT specialist told Blodgett that he suspected that the active ingredient in the Zicam, zinc gluconate, is toxic to the smell receptors. He explained that all of her olfactory receptors were likely destroyed. When Blodgett asked why he thought it was the gel rather than the cold virus that destroyed her nasal cells, he said that the immediate acute pain suggested to him that it was the Zicam.

For much of her 240 page book, Blodgett describes her ordeal with anosmia. Her profession as a gardener made her malady even more devastating. She of course also lost taste. She stated that physical intimacy with her husband become "oddly arid" because she couldn't smell her husband. Depression followed.

After about six months of anosmia, on a walk with her dog, Blodgett passed a popcorn shop and all of a sudden smelled popcorn. She thought she was hallucinating. Next she sniffed her dog's poop and her upper lip curled. A few weeks later she started smelling the flowers in her garden. She finishes her book with: "My journey was done. I was home again, and whole. The world was more intoxicating than ever before. I could really smell it."

Despite the lawsuits and FDA action, in the book, *The Neurology of Olfaction*, the authors suggest that the putative relationship between Zicam and hyposmia is dubious because it is unclear whether the underlying infection or the medication is the cause of the disorder.

A study in *Occupational Medicine* in 2005 described a more classic case of a patient losing his sense of smell due to chemical exposure.

A 31-year-old worker in Finland did not use any personal respiratory protection while applying a waterproofing compound in bathrooms. The patient had noted that the chemical's odor was very strong. After four weeks of using the chemical the patient felt irritation in his eyes and

mucous membranes. The patient was unable to smell any tested odor. The chemical waterproofing compound was found to emit a variety of toxic chemicals including butanol, acetone, acrylates, and carbon disulfide, all of which have been reported to induce hyposmia or anosmia. The patient remained anosmic after one year (Hannu *et al.*, 2005).

Trauma

In 1870, Dr. William Ogle said in a presentation to the London Medical Society, "I wish to bring to the Society some cases in which the sense of smell was either entirely lost, or greatly impaired. ... I will begin with three cases which have fallen under my notice in which smell, and smell alone, was completely lost."

CASE 1.- Mr. A. fell from a horse twenty-seven years ago, and struck his head heavily against the ground, on the left side and in the posterior part. Ever since the accident he has been liable to headache, and his "nerves are not so strong as they were." He has also ever since completely lost the sense of smell. The very strongest odors brought under his nose produce no sensation whatsoever. The tactile sensibility of his nostrils is with this quite unaffected. The slightest touch of the mucous membrane is felt perfectly, and snuff produces tickling and sneezing. He states that he has lost not only the sense of smell, but also that of taste: for he cannot in the least distinguish one meat from another. Boiled onions, boiled apples, boiled turnips, all appear the same to his palate. He cannot at all recognize the aroma or flavor of wines; though he can distinguish wines from each other to a certain extent by their different degrees of roughness and of sweetness. Port, for instance, he can tell from claret by its being sweeter and less rough. Besides sweetness he can distinctly recognize saltiness, bitterness, and acidity. Excluding these qualities, one substance is exactly like another to his palate, excepting so far as they are more or less hard and rough.

Notwithstanding all this he is not absolutely indifferent as to his food. He has preferences, derived apparently from memory; and he especially dislikes any new article of diet. There is no muscular palsy, no loss of sensibility, nor other symptom than those mentioned.

CASE 2.- Mr. B. was knocked down by a cab some two years ago, and fell backwards, striking his occiput heavily against the road. For a minute he was stunned, but recovered, and managed to get home, where he was laid up for a time suffering from the local injuries, and from severe headache. All this, however, passed off, and he was left with no other permanent symptom than total loss of smell. This has remained without change ever since the accident. He cannot perceive the very strongest odors, that for instance of asafetida [a herb with a pungent odor]. The tactile sensibility of the nostrils is perfectly normal. Ammonia salts and snuff tickle his nostrils, and cause lachrymation or sneezing as in other men.

He states that he has lost not only smell but taste. Cinnamon appears to his palate utterly without flavor. He cannot tell one meat from another when his eyes are shut, though he can in some degree distinguish various articles of diet by their tactile qualities. He cannot recognize the aroma of wine. Port, he says, tastes like sugar, claret like weak vinegar. The former also seems thicker than the latter. He cannot only recognize sweetness and acidity, but also bitterness and saltiness. This, however, is the limit of his gustatory perceptions.

He is not quite indifferent as to his food, but still has fancies and preferences, dependent perhaps on habit; so also he still smokes.

CASE 3.- Mr. C. was admitted into hospital in February, 1869. He had been knocked about the head in a drunken row the preceding Christmas, and ever since had suffered from strange sensations in the head, and from occasional attacks of nose-bleeding. He was somewhat deaf since the injury to his head, and had completely lost his sense of smell. He could neither smell asafetida nor buchu [a fragrant herb]. He stated that he had also lost his taste; but he could perfectly distinguish quinine, table salt, and sugar, from each other, and pronounced each correctly to be bitter, salt, or sweet. After a short stay in the hospital, serious head symptoms declared themselves, and the man became so noisy and violent that he had to be removed; and eventually he became, I was informed, insane.

There can, I think, be little doubt that the loss was due to rupture of the olfactory nerves as they pass from the bulb through the holes in the ethmoid bone [cribriform plate].

It is easy to understand how a blow, which is not sufficiently violent to do serious mischief to the anterior brain generally, may still suffice to tear the olfactory nerves, owing to their very small size, and, still more, owing to their excessive softness. In only one recorded case of loss of smell from a blow on the head, have I found mention of the exact part struck. There also, as in these cases, the blow was on the occiput (Ogle, 1870).

Because the olfactory receptors are located very high in the nasal cavity, blows to the nose, even those that cause a "broken nose," typically have only transient effects on olfaction. The major association of trauma with olfactory dysfunction results, as exemplified by Dr. Ogle's cases, from head trauma, injuries that are colloquially referred to as "head-bangers." In head trauma, anosmia or hyposmia, as surmised by Ogle, is usually attributed to a shearing of the olfactory nerve fibers as they exit from the cribriform plate to enter the olfactory bulb (Fig. 1.2). There does not need to be a skull fracture for anosmia to be present, which is important from a medicolegal standpoint. Back and side impact injuries cause smell damage more frequently than front impact injuries. The incidence of olfactory dysfunction related to head trauma is thought to lie between 4 and 15%. The probability of loss of the sense of smell

from head injury correlates to the severity of the injury and the degree of rapid acceleration and deceleration of the head.

The recovery of smell in patients with head trauma is a function of many factors including age, severity, and elapsed time. Initially, there is often a relatively rapid recovery because the anosmia may simply be due to nasal swelling.

Previously, we mentioned that the olfactory receptor cells can regenerate. So why don't they in typical head trauma cases? Although the olfactory neurons probably do regrow, it is likely that trauma-induced scar tissue overlying the cribriform plate prevents the axons from penetrating the plate and reaching the olfactory bulb.

Ogle did not mention whether any of his three patients suffered from olfactory hallucinations, which are common in head trauma cases, as shown by Becky's case from the Internet.

Becky fell and suffered a concussion in 2006. She lost her senses of taste and smell that day. Her doctors told her that 1/3 of head injury patients suffer with anosmia and 1/3 of them never recover. Her primary physician said that if she didn't recover her smell within a year then she probably never would. "Well it is after a year and so far I'm still anosmic! The first year was the worst, I had horrible phantom smells (odors that were horrible and wouldn't go away!). I lost weight and was depressed." Becky's "phantom odors" lessened after the first year.

Treatment

A patient with an olfactory deficit needs to be evaluated to determine whether the cause is conductive, sensorineural, or both, or if it is due to CNS dysfunction. Growths causing conductive loss can typically be evaluated by nasal endoscopy. Further analysis may involve a CT scan of the nose and paranasal sinuses or an MRI scan, which is better than CT for delineating soft tissue abnormalities (e.g., inflammation). CT, however, is better than MRI for discerning bony abnormalities such as a fracture of the cribriform plate from a traumatic event. If the patient has a mechanical obstruction that reduces the exposure of the olfactory cells to inhaled air, then surgery, steroids, or anti-inflammatory sprays may be helpful.

Steroids are also often prescribed in high doses after a suspected traumatic injury to the olfactory nerves with the aim of reducing scar-tissue formation, but the value of this treatment is questionable.

Aging and olfaction

Reduction in smell ability is a normal consequence of aging in humans. Generally, the age-related decline in the sense of smell is more severe in men than in women. In contrast to reductions in hearing and vision, age-related decline in smell often is unappreciated by the patient or their clinician. Above the age of 65, between 50 and 75% of the population shows significant

decreases in the ability to smell. The causes of this decline in the sense of smell relate both to neurodegenerative changes within the CNS and also to factors that directly affect the olfactory nerves. The olfactory receptors undergo damage because of repeated infections, viral and others, that occur throughout life. Surprisingly, smell likely declines with age because some of the foramina of the cribriform plate close with age. This presumably reduces the number of olfactory nerve filaments that can reach the olfactory bulb. Why this occurs is not known.

At least 90% of patients with Alzheimer disease demonstrate an abnormal sense of smell if tested, often unrecognized by the patient. Similar findings have been found in patients with Parkinson disease. In fact, the American Academy of Neurology's guidelines for the diagnosis of Parkinson disease conclude that, if a patient with suspected Parkinson disease has normal results on a smell test, the clinician should suspect a Parkinsonian-type disorder other than idiopathic Parkinson disease. The ramifications of the loss of sense of smell with these neurodegenerative diseases are significant. Patients often have a loss of appetite and weight loss related to their decreased sense of smell and taste. Safety is a concern because of the inability to smell smoke or recognize spoiled food.

This chapter discussed the cranial nerve of the most primitive "special sense," smell. The next chapter discusses the cranial nerve of the most advanced special sense, vision.

REFERENCES

- Hannu T, Toskala E, Tuomi T, Sainio M (2005) Anosmia in association with occupational use of a waterproof coating chemical. *Occupational Medicine (London)* 55: 142–4.
- Ogle W (1870) Anosmia, or cases illustrating the physiology and pathology of the sense of smell. *Medico-Chirurgical Transactions* 53: 263–90.