

The
Science
of

Bad **B**reath

The age-old condition of bad breath is coming under new scientific scrutiny, leading to insights into diagnostic approaches and possible solutions

BY MEL ROSENBERG • ILLUSTRATIONS BY JOSEPH DANIEL FIEDLER



Consider the case of Dr. John Floss.

A dedicated dentist, Dr. Floss works long hours, often so focused on his patients that he neglects to eat or drink. His own teeth and gums are, of course, exemplary. Nevertheless, Dr. Floss is unaware of a problem emanating from his mouth. His patients know, as does his hygienist. But they are too embarrassed to inform Dr. Floss: he has exceedingly bad breath.

In this bad-breath scenario, as in many, the foul odor is the result of the metabolic activity of oral bacteria that are happily feeding on a small pool of postnasal drip that regularly collects on the back of the dentist's tongue. The bacteria leave behind a collection of rank compounds. Gargling with an effective mouthwash and cleaning the tongue would most likely alleviate the problem. Even chewing a few bites of food would help. For now, though, the dentist's patients are protected only by his surgical mask.

Obviously, people have always been aware of the phenomenon of bad breath, or halitosis (from the Latin *halitus*, breath,

and the Greek *-osis*, meaning abnormal condition). But halitosis is now emerging as a fascinating scientific subject, involving an intimate human condition of widespread concern and traversing a wide range of scientific fields, including bacteriology, chemistry, physiology and psychology.

Millions have bad breath and, like Dr. Floss, probably don't know it, which makes it difficult to generate accurate statistics about the frequency of halitosis. One recent study, a survey of Brazilian college students by Paulo Nadanovsky of the Institute of Social Medicine at the University of the State of Rio de Janeiro, revealed that 31 percent of the students had at least one family member with habitual bad breath, with serious implications: 24 percent reported that they had trouble enjoying the company of the family member with halitosis, and 62 percent said that they were affected in some way by their relative's breath problem.

My own interest in this area began almost 20 years ago, when my group embarked on the development of a two-phase mouthwash designed to trap oral bacteria and debris on the surface of small oil droplets. At that time, only a handful of academic researchers, led by the late Joseph Tonzetich of the University of British Columbia, were investigating halitosis. Now hundreds of scientists in universities and industry study the problem. Last July the fledgling International Society for Breath Odor Research (ISBOR) drew about 350 attendees to its fifth international meeting in Tokyo.

The growth in the science reflects a general public concern (or in some cases obsession) with sweet-smelling breath. According to a market research firm's findings, Americans spent \$1.8 billion on toothpaste in 2000, around \$715 million on oral-care gum, almost \$740 million on mouthwash and other dental rinses, and almost \$950 million on toothbrushes and dental floss. Although many of those products are primarily for maintenance of oral health, people are certainly buying them to ensure that their breath is pleasant as well. And the \$625 million spent on breath fresheners other than gum and mouthwash—for example, breath mints—is directly for that purpose.

Overview/*Halitosis*

- Halitosis, or bad breath, is a common condition that affects personal relationships. In addition to cases of actual halitosis, a pervasive fear of bad breath, known as halitophobia, severely interferes with some people's quality of life.
- Researchers have recently begun to analyze halitosis qualitatively and quantitatively, leading to new insights concerning the causes and possible treatments of the condition. Entire new species of oral bacteria have been discovered in the process, and the fact that the vast majority of halitosis cases originate in the mouth has been confirmed.
- Breath freshening and oral hygiene is big business, with billions of dollars spent annually in the U.S. on toothpaste, toothbrushes, floss, mouthwashes, mints and other breath fresheners.

The Source of the Smell

THE BASIC CAUSES of most cases of halitosis are now fairly well understood. According to research conducted by ISBOR co-founder Daniel van Steenberghe and his co-workers at Catholic University–Leuven in Belgium and our group at Tel Aviv University in Israel, about 85 to 90 percent of cases originate in the mouth. As with other odors emanating from the moist microbial jungles of the body—such as underarms and shod feet—bad breath is primarily the result of microbial metabolism.

The mouth is home to hundreds of bacterial species with various nutritional preferences. These tiny organisms particularly enjoy proteins, and the chemical compounds that result from the digestion of these proteins include some truly fetid substances. At any given time, oral bacteria, usually anaerobic, may be producing hydrogen sulfide, with its distinctive rotten-egg smell; methyl mercaptan and skatole, also present in feces; indole, used in small amounts in perfume but foul in large quantities; cadaverine, associated with rotting corpses; putrescine, found in decaying meat; and isovaleric acid, which smells like sweaty feet. No wonder human breath can at times be so offensive.

The University of Michigan's Walter J. Loesche, a past president of ISBOR, recently discovered that the microbiota on the tongue differ from those species living in plaque on teeth. Loesche, who received a grant from the National Institutes of Health to study halitosis, has uncovered previously undescribed bacterial species making their home in our mouths. He is currently cataloguing the microbiota in people with and without



Oral bacteria may be producing hydrogen sulfide, with its **ROTTEN-EGG** smell, as well as the aptly named **CADAVERINE** and **PUTRESCINE**.

halitosis, work that should be completed this summer.

In otherwise healthy people, the very back of the tongue, rather than teeth or gums, is the main source of bad breath. This region is poorly cleansed by saliva and contains numerous tiny invaginations in which bacteria can hide. These bacteria have a field day putrefying postnasal drip—common in perhaps one quarter of the urbanites studied—and other oral debris that can collect there.

Additional oral sources of bad breath include poor oral hygiene (especially if it leaves proteinaceous particles between teeth), gum inflammation, faulty dental work, unclean dentures, and abscesses. Because a steady flow of saliva washes away bacteria and their smelly chemical products, anything that promotes dryness—mouth breathing, fasting, prolonged talking, stress and hundreds of medications—can exacerbate the situation. Tobacco smoking is a notable enemy of fresh breath. Although smoke may reduce bacterial activity, this potentially positive effect is drowned out by negatives: smoke dries out the mouth, worsens gum conditions and postnasal drip, and leaves a residue whose aroma mixes with the preexisting oral bouquet.

Some bad breath seems to be associated with actual periodontal disease, the destruction of the gums, and is therefore useful as a clue to physicians and dentists. Hydrogen sulfide and methyl mercaptan are toxic as well as malodorous; they can damage cells and thus may be a factor in gum disease. In addition, some bacterial species implicated in gum disease work up quite a stink when grown anaerobically on amino acids in the laboratory, according to research by Israel Kleinberg of the State University of New York at Stony Brook. The presence of several of these key bacteria—such as *Treponema denticola*,

THE AUTHOR

MEL ROSENBERG grew up in Canada and moved to Israel in 1969. He is professor of microbiology at the Maurice and Gabriela Goldschleger School of Dental Medicine at Tel Aviv University. He has received several awards for his research as well as honorary academic appointments in the U.S., the U.K. and Canada. In 1996, together with Karl Laden and university support, he founded InnoScent, a company that develops products for fighting body odors. He has published a children's book on bacteria and enjoys expelling air through his saxophone.

OLFACTORY OBSESSIONS

RUBY (a composite of patients) dresses impeccably and is particularly well groomed. She runs a successful small business and seems to have everything under control. There is only one problem. A schoolmate told her once, 30 years ago, that she had bad breath. Since that time, she has lived in constant fear that people can smell her breath. She addresses customers at a distance and chews gum incessantly. Ruby visits her dentist regularly and brushes her teeth four or five times a day; she cleans her tongue, flosses, and gargles with antiseptic mouthwash. She avoids kissing her husband on the mouth and refrains from being physically close to people at parties. Outside, Ruby tries to stand downwind when talking to people. She was so embarrassed about her bad breath that she had never before talked to

anyone about it. When Ruby finally came to our clinic, she broke down in tears. "I feel that I have succeeded in my life despite this debilitating problem," she confided. But when we smelled her breath, we detected no odor at all. Subsequent visits did not turn up any telltale odors either. Ruby's breath was pristine.

Ruby and millions of others suffer from halitophobia, the exaggerated fear of having halitosis. In 1997 Murray B. Stein, a social-phobia expert now at the University of California at San Diego, found in a study of 1,206 people in Alberta, Canada, that 15.8 percent worried "a lot" about how their breath smelled, 2.8 percent had seen a professional about their breath, and 2.7 percent said that breath concerns interfered with their lives a moderate or severe amount. One percent revealed that they had avoided going to a party because they were worried about their breath. Clearly, halitophobics may shun social activities and live in a state of self-enforced solitude.

Halitophobics I have interviewed include lawyers, teachers, judges,

performers, a physician, a high-ranking politician and even someone who became a dentist, hoping that his studies would help him deal with his "problem."

Halitophobics conceal their concern. A colleague of mine once tried to persuade me that halitophobics are practically nonexistent. "What are you talking about?" his wife of more than 30 years suddenly blurted out, "I'm one myself!"

Halitophobics usually think that they have logical reasons for believing that their breath smells. They may interpret bad taste as a sign of bad breath, although taste and breath are not necessarily connected. A family member who has bad breath may lead some to conclude that they have inherited the problem. And some halitophobics are sure that they have foul breath because they

misinterpret others' behavior—for example, opening a window or simply rubbing their noses—as a reaction to the halitophobic's breath. The few halitophobics who are ready to entertain the possibility that their fears have a psychological basis can often be helped by psychotherapy. Indeed, in collaboration with Ilana Eli of Tel Aviv University in Israel, we noted that halitophobics have tendencies toward hypersensitivity in interpersonal interactions and toward obsession-compulsion, according to psychological profiles [see "Patient, Smell Thyself," by Steve Mirsky; *Anti Gravity*, *SCIENTIFIC AMERICAN*, August 1996]. Most halitophobics, however, continue to search for the cure to a problem that doesn't exist. —M.R.



Porphyromonas gingivalis and *Bacteroides forsythus*—in plaque or the tongue coating can be determined in minutes in the dental clinic using a color assay, the BANA test (for benzoyl-DL-arginine-naphthylamide), devised by Loesche. These bacteria produce an enzyme that degrades BANA, forming a new, colored compound. Not surprisingly, positive BANA tests are statistically associated with halitosis.

The various oral bacteria that prefer feeding on sugars instead of on proteins have traditionally been considered irrelevant to bad breath. Research by Nir Sterer in my laboratory, however, suggests otherwise. Much of the available protein in the mouth is actually in the form of glycoproteins, in which sugar residues are linked to the protein core. The sugar-feeding organisms can clip the residues from the glycoproteins, leaving naked proteins to be digested by bacteria that favor them. Sterer and co-workers have recently shown, using a simple color test, that the amount of enzymatic sugar cleavage in saliva correlates with bad breath levels. In the future, scientists may be able to attack bad breath by preventing the initial sugar cleavage.

One might be tempted to conclude that the eradication of all microorganisms on the tongue would be a potential treatment for halitosis. These bacteria, however, also play a protective role. Ordinarily our tongues harbor the yeastlike *Candida* fungus in small numbers, the population kept in check by the presence of bacteria. When tongue bacteria are wiped out by antibiotics, *Candida* can run rampant. And candidal diseases are more severe and difficult to control than halitosis. The idea, then, is to keep bacterial populations present but under control.

More Halitosis Diagnosis

THE MOST COMMON SOURCE of bad breath, after the mouth, is the nose and nasal passages. In these 5 to 10 percent

BILLIONS OF DOLLARS of breath-freshening products may be bought by individuals who only fear they have **A PROBLEM.**

of cases, the odor comes mainly out of the nose, not the mouth, and has a very different quality, which once again can be a diagnostic tool to the physician or dentist. Nasal odor may result from sinusitis or conditions that impede or block mucus flow. In one odd case, an uncharacteristic breath odor in a 28-year-old woman led us to discover an embedded bead that she had apparently stuck up her nostril as a young child. Indeed, children are notorious for sticking objects up their nose, sometimes generating a foul nasal discharge that they may smear all over themselves; a foreign body in a nasal passage is something to check for when a child suddenly develops an overall offensive odor.

Putrid tonsils may cause about 3 percent of halitosis cases. Hundreds of other diseases and conditions together cause less than 1 percent of the halitosis generally encountered. One interesting but rare instance is so-called fish-odor syndrome. Sub-

Most Unwanted List

Compounds commonly produced by mouth bacteria and their odors

Hydrogen sulfide	Rotten eggs
Methyl mercaptan	Feces
Skatole	Feces
Cadaverine	Corpses
Putrescine	Decaying meat
Isovaleric acid	Sweaty feet

jects with this condition sense that their saliva and sweat sometimes have a fishy quality, although others may have trouble verifying the smell. A physician unaware of this condition may even refer these patients for psychotherapy. In fact, fish-odor syndrome, or trimethylaminuria, results from an insufficiency of an enzyme that normally breaks down trimethylamine, a fishy-smelling molecule.

Many people believe—and some businesses through advertising have attempted to foster that belief—that bad breath comes from the stomach rather than from the mouth. The infrequency of the stomach's being such a source was central to a recent court case in which I participated as an expert witness [see box on page 79]. Bad breath originating outside the mouth or nasal passages is, in fact, quite uncommon. The esophagus is a closed tube, and continuous flow (as opposed to a simple



SMALL STONES called tonsilloliths grow in the crypts of the tonsils and consist of partially calcified bacteria and debris. Tonsilloliths smell foul themselves but don't always cause bad breath. They are relatively uncommon (perhaps 2 to 3 percent of the adolescent and adult population have or have had them). Because they do not usually cause any medical problems, many physicians and dentists have never heard of them. The samples at the left were collected from a single individual.

the U.S., is quite effective against halitosis. Unfortunately, it can also discolor teeth, impair taste and generate oral ulcerations. These effects, though reversible, preclude the use of chlorhexidine for more than a few days at a time.

Other cures date back thousands of years. Tongue cleaning is an ancient oral hygiene practice from the Far East that is still popular there and that is catching on in the West. One early antidote mentioned in the Babylonian Talmud is gum mastic, which may be the same ladanum referred to in Genesis. Gum mastic is the resin of the *Pistacia lentiscus* shrub, which is still cultivated for this purpose on the Mediterranean island of Chios, although modern synthetic chewing gums have largely supplanted mastic. Interestingly, this resin was once used extensively for treating wounds and is now known to have potent antibacterial properties. Chewing the gum, therefore, might both increase saliva flow and kill some bad-breath microbes.

Other natural products chewed around the world for breath freshening include guava peels (Thailand), anise seeds (Far East), parsley (Italy), clove (Iraq) and cinnamon (Brazil). Some of the molecules responsible for the flavor in these plants have antibacterial properties that give scientific credibility to these folk practices. Many popular mouthwashes contain flavor oils, including menthol, eucalyptol and methyl salicylate (wintergreen oil).

The American Dental Association currently has guidelines whereby a product can get ADA approval as being efficacious against plaque, gingivitis or cavities. The ADA is now reviewing guidelines that would allow products to receive similar approval for their breath-freshening powers. Seemingly paradoxically, some companies that manufacture breath fresheners are against the ADA effort. A closer look reveals that the approval would require the companies to create better products: most available breath products work only briefly, on the order of 20 to 120 minutes, and the ADA will most likely demand a significantly longer effect for official recognition. For example, mint is widely accepted as a primary example of a good ingredient in a breath treatment. But mint is actually relatively weak and its effect short-lived compared with other essential oils.

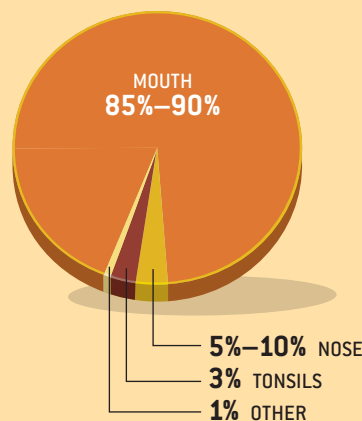
Over the past 15 years I have had the opportunity to smell the mouths of thousands of individuals in clinics and in research studies, not to mention the hundreds I have smelled surreptitiously in supermarkets, in airplanes and in synagogue during the fast day of Yom Kippur. Just as Camembert cheese smells quite different than Edam does, bad breath is not one odor but a constellation of them, depending on the microorganisms involved, where they come from and what they have been up to. Whereas researchers continue to argue about the best ways to quantify offensive breath, future electronic noses [see “Plenty to Sniff At,” by Mia Schmiedeskamp; News and Analysis, SCIENTIFIC AMERICAN, March 2001] may provide not only halitosis levels but also an indication of the types of odors detected, which would give clues about their origins.

The ability to identify the probable origin is of considerable importance in halitosis research and in counseling individuals, and it requires extensive “nose-on” experience. There remains

Odor in the Court

IN 1999 I was an expert witness for Warner-Lambert (it has since merged with Pfizer), which made Listerine, Certs and other breath products, in its suit against BreathAssure. The latter company marketed BreathAssure capsules, which allegedly combated bad breath internally. Warner-Lambert claimed that the trade names of BreathAssure’s products “constituted false and misleading claims that the products alleviated bad breath and gave the defendant an unfair advantage over the plaintiff.” In part because BreathAssure’s claims of an internal source for halitosis were not supported by credible scientific evidence, the U.S. Court of Appeals for the Third Circuit eventually found for Warner-Lambert. —M.R.

SITES OF ORIGIN OF BAD BREATH



ORAL MALODOR is indeed an oral phenomenon for the most part. Research suggests that the vast majority of cases of bad breath start in the mouth, with almost no cases originating below the tonsils.

much that we do not know. For example, we must match individual bacterial species to the odors with which they are associated. The details of the contributions of the nasal passages and the tonsils to bad breath are still incompletely understood. And few psychologists actively study halitophobics. Although the recognition and treatment of halitosis may seem insignificant in the pantheon of medical conditions, it can have a profound effect on a person’s life and relationships. SA

MORE TO EXPLORE

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Bad Breath: Research Perspectives. Second edition. Edited by M. Rosenberg. Ramot Publishing, Tel Aviv University, 1997.

Tel Aviv University’s Web site on bad breath: www.tau.ac.il/~melros/
Possible causes of halitosis: www.tau.ac.il/~melros/bda/index.html

Bacterial species that inhabit the mouth:
www.tau.ac.il/~melros/faq/5.html

TIPS FOR GOOD BREATH



- Gently clean the very back of your tongue with a plastic tongue cleaner. Take care not to damage your tongue; just sweep the mucus layer away. Practice helps to overcome the gag reflex.
- Eat a good breakfast; it cleanses the mouth and gets the saliva flowing.
- Prevent your mouth from drying out. Chewing gum for just a few minutes can reduce bad breath. Drink sufficient quantities of liquids.
- Use a mouthwash. The most effective method is to rinse and gargle just before sleep. This prevents the buildup of microorganisms and odor during the night.
- Clean your mouth after eating odorous foods or drinks such as garlic, onions, curry and coffee. Make sure to clean between your teeth, especially after eating food or beverages rich in proteins.
- Brush and floss (or otherwise clean between your teeth) according to your dentist's instructions.
- Ask an adult family member or close friend about your breath. This is the most reliable (and cheapest) way to find out if you have halitosis.

burp) of gas or putrid matter from the stomach indicates a health problem, such as a fistula between the stomach and intestine or reflux serious enough to be bringing up stomach contents. Even after garlic is eaten, it is the mouth that retains a substantial part of the sharp odor.

A lingering mystery is why people tend to be exquisitely sensitive to the breath quality of their fellows and notoriously bad at smelling their own. One previous theory, that we become somehow inured to our own bad breath, seems lacking. Research conducted with Ilana Eli, Ronit Bar-Ness Greenstein and others in our laboratory revealed that people such as the blithely unaware Dr. Floss are able to assess samples of their own oral malodors more objectively when the source is removed from the mouth—for example, when they smell debris sampled from between their teeth with a toothpick.

The answer may be simply that because we expel air from our mouths horizontally and only subsequently breathe vertically through our nose, the chance of getting a representative whiff is low. Whatever the reason, it is difficult for someone to know if he or she has bad breath without being told. And given the embarrassment involved, being told is unlikely. Ironically, the billions of dollars that buy breath-freshening products annually may be spent in large part by individuals who do not in fact have a problem but merely fear they do. An extreme version of this common belief is the phenomenon of halitophobia—a conviction, usually unsupported by objective analysis, that one has bad breath [see box on page 76].

A Fresh Approach

THOUGH BY NO MEANS the only factors in halitosis, the volatile sulfur compounds produced by bacterial metabolism are a prime suspect. In the late 1980s, with Jacob H. Gabbay of the Israeli Ministry of the Environment and later with Christopher A. G. McCulloch of the University of Toronto, our research group determined that the sulfides that contribute to bad breath could be assessed using a portable sulfide monitor. The monitor's manufacturer, Manny Shaw of Interscan in Chatsworth, Calif., was initially skeptical that there would be a market for Halimeters, but he has since sold his device to thousands of dentists and researchers. In 1999 Alfredo Sanz-Medel, a chemist at the University of Oviedo in Spain, reported a different technique, one that indirectly quantifies sulfide concentration by optically measuring the fluorescence induced by the reaction of sulfides with a mercury compound.

Such technologies might someday lead to the development of an effective, pocket-size sulfide meter. Existing Halimeter scores do correlate statistically with more complex chromatographic analyses and with the gradings of human odor judges, who personally smell the breath of study subjects and rate it for research purposes.

Once the presence of halitosis is established, the affected individual ordinarily wishes to be rid of the condition. Of course, basic oral hygiene—regular flossing and brushing—cannot be underestimated as a preventive. The gingivitis medication chlorhexidine, an antimicrobial agent sold by prescription in