PROFILE: LINDA BARTOSHUK

A Taste for Controversy

After discovering "supertasters," Linda Bartoshuk is pushing to change how psychologists evaluate subjective experiences such as taste and pain

GAINESVILLE, FLORIDA—After just a glance at her graduate student's notes, Linda Bartoshuk knows that the results of today's experiment will have to be thrown out. The concentration of quinine—a bitter chemical used in this study of taste perception—is one-tenth of what it should be. The student, Adilia Blandon, suddenly realizes her mistake. Blandon had given the quinine to a team of undergraduate assistants to gauge volunteers' sensitivity to different flavors, but with the wrong standard for bitterness, she can't compare these data with previous results. Blandon turns to Bartoshuk with a cringe and groan. Behind her, the doomed experiment continues.

Moments like these test a busy scientist's patience. But without missing a beat, Bartoshuk nods and says, "Don't worry. This is why we call it a pilot study. Now is the time to catch mistakes." Blandon perks up like a sail catching a fresh breeze and heads back into the lab.

Bartoshuk, a professor here at the University of Florida (UF), Gainesville, wasn't just being nice. "I tell my students that if you're not making mistakes in science, you're not taking enough risk." It was an oversight similar to Blandon's that led to Bartoshuk's most famous discovery: supertasters, people with extreme taste sensitivity. But Bartoshuk's research has illuminated more than the human mouth, says Anthony Jack, a psychologist at Case Western Reserve University in Cleveland, Ohio: "She has helped lead the movement to study subjective experience, considered off-limits for a long time."

That leadership has paid off in many high-profile publications, election to the National Academy of Sciences, and last year, the presidency of the Association for Psychological Science (APS). Her career hasn't come without controversy, however. The concept of supertasters still ignites debate. And Bartoshuk is making waves again. Her latest passion is nothing short of overturning one of the central methods of her entire field, the subjective scales on which generations of psychologists have built their careers.

How not to keep a girl out of science

As a girl born in mostly rural South Dakota in 1938, science was not high on the list of career options for Bartoshuk. But after reading every science-fiction book she could get her hands on, the young Bartoshuk dreamed of astronomy. Her high school had other plans for her. "They forced me to take secretary classes," she recalls with a wry smile. They did accede to Bartoshuk's request to take trigonometry, physics, and chemistry. "I was the only girl in the class, and I was as surprised as anyone when I got the highest grades." It helped her win a scholarship to attend Carleton College in Northfield, Minnesota—her family couldn't afford the tuition otherwise—and it was science ever after.

Bartoshuk says she abandoned astronomy when she learned that "women weren't allowed to use the big telescopes." She switched to the field that would become the scientific love of her life: psychophysics, the study of how physical stimuli from the environment—sugar on your tongue, vibrations in your ear, heat on your skin—lead to the mysterious phenomenon called subjective experience. It may be a branch of psychology, says Bartoshuk, but "psychophysics has a lot in common with astronomy." Like the stars in a distant galaxy, the minds of other people are ultimately "untouchable," she says. The only way to bridge the gap is with rigorous experimental observation and mathematical analysis.

Already as an undergraduate, Bartoshuk decided to study taste. "The tongue was unexplored territory in sensory research," she says. As a first-year graduate student at Brown University, she wanted to work with Carl Pfaffmann, one of the leading taste researchers and the first to identify the nerves that send taste signals from the mouth to the brain. She vividly recalls her first conversation with the man who would become her Ph.D. adviser. "Pfaffmann told me point-blank that he didn't want women in his lab," says Bartoshuk. And why? "They're always crying and washing their hair."

Bartoshuk dresses plainly, but she does wear big, bright emotions. When she laughs, which is often, she shakes with it. And when she recalls the troubles with Pfaffmann, the sting is suddenly visible in her face, 5 decades later. Lewis Lipsitt, a psychologist at Brown University, says that Pfaffmann was not an easy man. "[He] could be

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Taste explorer. After unlocking the mystery of taste sensitivity, Linda Bartoshuk is now hunting for the "perfect tomato."

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blunt and he was by nature not an effusive, congratulating kind of person."

Bartoshuk's emotions and hair care didn't prevent her from winning over Pfaffmann. One day, Bartoshuk says, she finally became "one of the boys." An experiment was going badly, with nerve fibers drying out. "I had an idea for a solution, but Pfaffmann was completely dismissive," she says. So she stormed out and returned with a contraption she'd made out of wire to keep the fibers suspended in mineral oil. It worked. "He told me, 'I guess you're pretty good at this.' "

Five years later, when Bartoshuk was settled as a scientist at Yale University, the phone rang. It was Pfaffmann. "I was still mad at him," she recalls, but he had an astonishing proposal. Calling her from a hospital bed, he wanted Bartoshuk to study him; a viral infection had damaged Pfaffmann's nervous system, knocking out taste sensation from one side of his tongue.

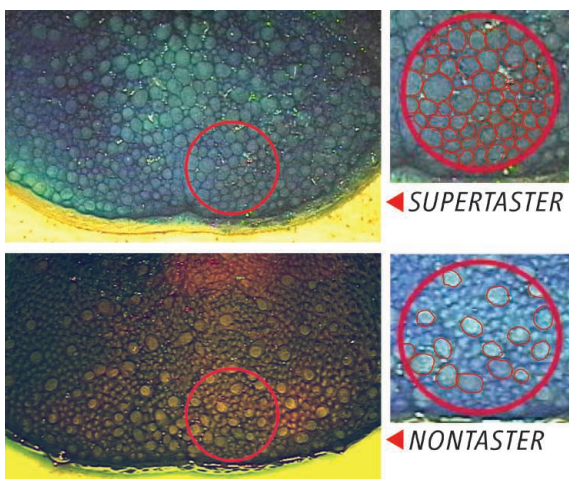
Intrigued by this rare opportunity, for months Bartoshuk conducted experiments on her former mentor. By "painting" taste solutions across his tongue in different directions—either from the "dead" side to the "live" side or vice versa—she was able to test conflicting theories for taste perception. "We proved that the taste-transmitting nerves do not poach across the midline of the tongue," says Bartoshuk. "We confirmed that taste follows touch paths on the tongue, which wasn't known." And by tracking the intensity of tastes as Pfaffmann's nerves healed, they discovered "unexpected" aspects of how the nerve signals add up to subjective taste perception. "He turned into one of the best data sets at the time," says Bartoshuk.

Then, Pfaffmann suffered a stroke and slowly died. Bartoshuk published a short abstract version of the results and put the data away. "I was too sad to work on it," she says. But all these years later, some of the work is still new to science. Bartoshuk intends to publish it, with Pfaffmann as lead author, "if people agree that it's ethical."

Supertasters

In 1990, Bartoshuk noticed something strange in her latest study of people's sensitivity to bitterness. Like researchers before her, she observed that people differ in sensitivity to identical solutions of a bitter chemical called PTC. The underlying genetics were well understood. The expression in taste buds of a protein receptor for PTC was required, and you either had it or you didn't. Over the years, she had been using the same test subjects for other taste experiments, and she suddenly realized that "some of the same people who were the most sensitive to bitterness were also the most sensitive to sweetness and sourness."

For the most part, sensitivity to what was known as the "basic tastes"—bitter, sweet, sour, salty—were thought to be independent. But what if they weren't? Bartoshuk's subjects were judging the intensity of bitter solutions in relation to a control solution of saline. "I realized that if some people are more sensitive to every taste, salt included, then that is no control at all."



Rosetta stone. Supertasters have far more fungiform papillae, bumps on the tongue that house the taste buds.

To try to get around the problem, Bartoshuk asked her subjects to put the intensity of tastes they experienced on a scale based on a totally different sense. "I used sound," she says. At the bottom of the scale was silence; at the top was "the loudest sound you have ever heard." Because people's sensitivity to taste and sound should be independent, this could be a way to identify people with highly tuned tongues.

A striking pattern emerged from the data. About 25% of people she studied were highly sensitive—as high as triple the average—to every taste. "These are people who live in a different taste world," says Bartoshuk. "If our tastes are painted in pastel colors, theirs are painted in neon." She dubbed them "supertasters."

The term soon became a household name, and Bartoshuk was inundated with requests for interviews. Bartoshuk didn't mind the attention, but she quickly regretted the term, especially as confusion about the phenomenon spread. "It's not actually true that their taste is super," she acknowledges. "It's just different." She says that, for example, vegetables from the Brassicaceae family of plants—cabbage, broccoli, kale—taste bitter to supertasters so they tend to avoid them. On the other hand, they also tend to eat fatty and salty foods sparingly, "so they are less likely to be obese."

And what makes someone a supertaster? "It turns out to be simple," says Bartoshuk, who regrets that she is not one of them. "Supertasters have far more taste buds than the rest of us." Bartoshuk has administered the test for taste-bud density—counting those bumps in a fixed area of a blue-dyed tongue—to thousands of people. Realizing that taste-bud density determined the intensity range of taste "was like discovering a Rosetta stone for the senses," she says.

Not everyone agrees with Bartoshuk that people are born with fixed food preferences, and it seems that most who disagree do so sharply. "People learn to like or dislike bitter foods," says Tom Baranowski, a psychologist at Baylor College of Medicine in Houston, Texas. "There's no relationship between those preferences and whether or not you're a supertaster." Baranowski says he had hoped supertaster status would be "a lever" for improving public health. But now he calls it "a waste of time." Several other researchers have also failed to reproduce correlations between supertaster status and behavioral or health trends.

Partly because of the media blitz, a scientific "feud" over supertasters may have been inevitable, says Beverly Tepper, a psychologist at Rutgers University in New Brunswick, New Jersey. "Some of [Bartoshuk's] colleagues have felt that she oversold supertasters." Tepper says that further research has supported the supertaster effects—that Bartoshuk was right after all, she believes—but that "a lot of people have gotten soured to this field because there are a lot of confusing results." There is even disagreement over how to diagnose someone as a supertaster. The most widespread diagnostic method continues to be high sensitivity to bitterness, frustrating Bartoshuk. "Initially, lots of people accepted that definition," she says, although taste-bud density turned out to be a more reliable marker. "I think we were sloppy about it."

Regardless of the disputes, says Tepper, Bartoshuk "really launched this whole area, and it has helped psychophysics to see individual differences" between people.

You taste tomato, I taste ...

Bartoshuk pops a bright red wedge into her mouth. "Oh! These are delicious," she says, munching on one of the different varieties

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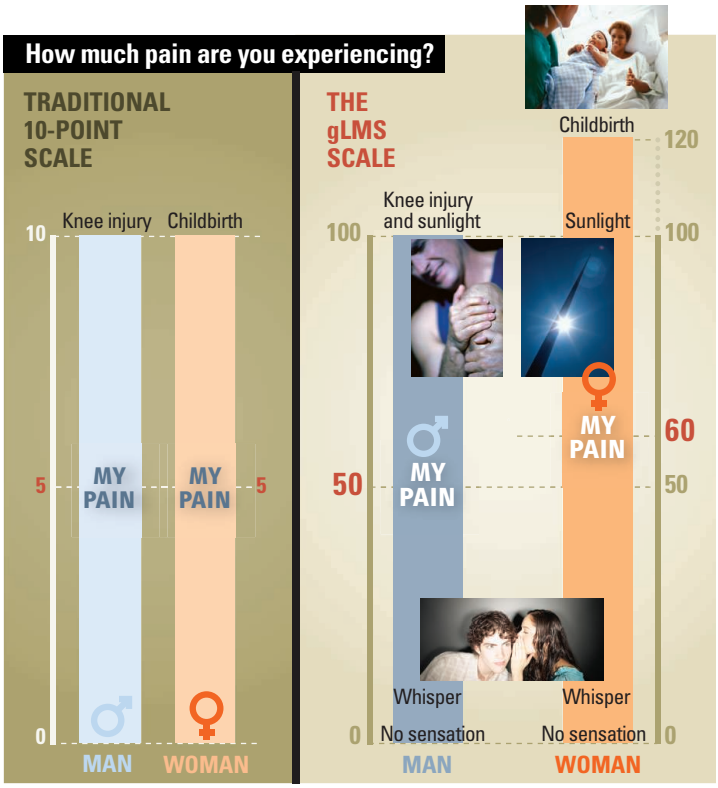
of tomatoes that have just been sliced and distributed into plastic sample cups. In the coming weeks, hundreds of people will eat similar tomato wedges, scoring various aspects of the taste experience. "The goal is to find the perfect tomato," she says.

Improving people's diet is the aim of this interdisciplinary study. The taste of tomatoes and other fruits "have degraded because of the pressures of the market," says Harry Klee, a plant biologist at UF who collaborates on the project. As supermarkets have demanded fruit that can withstand shipping and rapidly ripen, taste has been unintentionally bred out of tomatoes. Klee believes that the genes for tastiness, most of which is determined by the dozens of aroma molecules that tomatoes produce, can be put back into supermarket varieties. But the challenge is to nail down what exactly people like about "good" tomatoes.



Same pain? On the traditional scale (*left*), the pain reported by a man and woman may end up equal. Bartoshuk's method uses a personalized scale built of each person's experiences from various senses. In this case, the calibrated scale indicates the woman's injury is more painful than the man's.

Bartoshuk is drawing on a lesson from her supertaster research by reconceiving how to use sensory scales. She has decided that to make sure the subjective taste data from different people can be compared, each subject must build a personalized scale. It is a complex process, beginning with a strange task: "Please identify the strongest sensation of any kind that you have ever experienced." For most people, says Bartoshuk, the strongest is some kind of pain. Among women, for example, it is usually childbirth. That defines the top of a sensory ladder, and the intensity of various nontaste sensations—loud sounds, bright lights—define the intermediate rungs.

Bartoshuk says that this method, called the general labeled magnitude scale (above), helps her avoid a serious mistake. "If I want to compare the taste experiences of different people, how do I know they're using the scale the same way?" she says. On a 10-point scale of sweetness, "if you say this tomato is 6, and I also say it's a 6, how do we know it's the same sensation? Your 6 might actually be equivalent to a 3 for me."

She first noticed the scaling problem in taste research, but Bartoshuk says that it goes far deeper: "Anytime you want to compare subjective experience across different subjects, you run into the scaling problem." She says the error casts doubt on decades of psychophysics research, as well as studies in other fields that have misused subjective scales, such as in neuroscience in which subjects report experiences as their brains are mapped. Nor does it end with academia. The same scaling methods are still used to compare subjective experience between potential customers—billions of dollars are spent on market research—and by physicians, particularly for assessing pain.

It's not just that the traditional subjective scales produce noisy data, says Bartoshuk: "They can produce misleading results." The worst of these are "reversal artifacts." Bartoshuk says she encountered one of those with supertasters. "If you use the old 10-point scale, you can make it seem as if supertasters are less sensitive to salt than normal people, which of course is the opposite of reality."

One convert is Ann Berger, a clinical pain researcher at the National Institutes of Health Clinical Center in Bethesda, Maryland, who worked with Bartoshuk in the 1990s on oral pain. "I use [Bartoshuk's] scale and it works," says Berger. "It's most important for assessing chronic pain." Berger says that data collected from traditional 10-point scales "are meaningless," and as a result "patients are incorrectly medicated." The tradeoff with the new scaling method is that "it does take longer to do," she says, "but it's crucial." Berger would like to see Bartoshuk's scale adopted as the standard method for pain assessment. The problem, she says, is that "these bad scales were made mandatory by the Joint Commission," the organization responsible for accrediting health care organizations in the United States. "Now we're stuck with them."

In recent years, Bartoshuk has pushed to get the word out on the problem of subjective scaling; it was the sole focus of her plenary lecture at last year's annual APS conference. She has discovered that the issue has a history. R. Duncan Luce, a psychologist at the University of California, Irvine, had described problems with subjective scaling in a 1983 paper in the economic journal *Theory and Decision*. "The [traditional] 10-point scale is really easy to use, but it's also useless," says Luce. "A lot of people dismiss this problem as the concern of a few theoreticians. But it is serious."

One veteran researcher who dismisses it is Adam Drewnowski, director of the Nutritional Sciences Program at the University of Washington, Seattle. "There is no reversal artifact," the epidemiologist says. "All these scales work in a similar way and get you approximately similar results." Nonetheless, Drewnowski says that new computer-aided techniques allow him to avoid numbered scales altogether. "We now use visual analog scales" on which subjects "point and click" relative positions. "It's much faster," he says, but "you can use any scale."

Some agree with Bartoshuk but have varying degrees of optimism that her alternative scaling method will catch on. "There is huge inertia involved in changing a system that seems to work," says John Prescott, a psychologist at the University of Newcastle in Ourimbah, Australia. "In fact, this success is illusory, based on the fact that scale results are consistent with previous scale results, without any consideration of whether the scale measures what it is supposed to measure."

Of course, it could be that Bartoshuk's concern about the subjective scaling error is itself an error. After thinking it over, she lays down a verdict. "It would be wonderful," she says. "Making conceptual mistakes can be an incredible window into new insights."

–JOHN BOHANNON

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