Much of Givaudan's business—which generates nearly four billion dollars a year—is built on deceiving our senses when we eat. The

ANNALS OF SCIENCE

THE TASTE MAKERS

The secret world of the flavor factory.

BY RAFFI KHATCHADOURIAN

consumption of food flavorings is one of the modern era's most profound collective acts of submission to illusion. Photographs by Hans Gissinger.

Growing up, Michelle Hagen lived near a large factory in Cincinnati that produced what she and her sisters called The Smell. The aroma was dynamic and unpredictable, almost like a living thing. On some hot summer days, it was thick and sweet, and when it drifted over Hagen's neighborhood—a series of row houses by the interstate—it was as if molasses had been poured through the streets. At other times, the smell was protein-rich and savory. Many of the odors triggered specific associations—birthday cake, popcorn, chicken-noodle soup—and they stayed with her. In 1992, Hagen went to the University of Cincinnati to study art, but she soon turned to science, majoring in biology. She never imagined that she would end up working in the factory that made The Smell. The factory belongs to a Swiss company called Givaudan, the largest manufacturer of flavors and fragrances in the world, and upon graduating Hagen got a temporary job there that soon grew into something permanent. After three years of gruelling apprenticeship, she became a flavorist, a job that admitted her into a kind of secret society. There are fewer than five hundred flavorists in the United States, and they almost never speak about their work outside their laboratories.

Hagen is thirty-five. She is a brunette, with straight hair that falls just below her shoulders. She is not thin, but her face is, and it lights up easily. She prefers things that are vivid. Beneath her lab coat, Hagen is sure to be wearing some bright-hued article of clothing—a scarf, a sweater. She holds her hair back with sunglasses, in summer and in winter. After spending even a short time with her, one can't help but think of Roald Dahl's Willy Wonka, who believed that the manufacture of flavors—particularly the sweet and flashy ones that go into candy, chewing gum, and marshmallow—demands a childlike openness. At the end of "Charlie and the Chocolate Factory," Wonka tells Charlie Bucket that an adult could never run his factory. "Mind you, there are thousands of clever men who would give anything for the chance to come in and take over from me, but I don't *want* that sort of person," he says. "I don't want a grown-up person at all." But Wonka surely would have hired Hagen. Her office resembles a walk-in high-school locker, if such a thing existed. The walls are covered with magazine clippings, photographs, and Post-its; a clock-size Swatch with a blue kangaroo painted on it; and a dry-erase board with lists of words meant to inspire flavor creation ("baobab," "jujube," "mamoncillo"). Tacked here and there are paint chips from Benjamin Moore, which she once used as aides to memorize the aromas of approximately a thousand chemicals. California Lilac was ethyl isovalerate; Mellow Yellow was gamma octalactone.

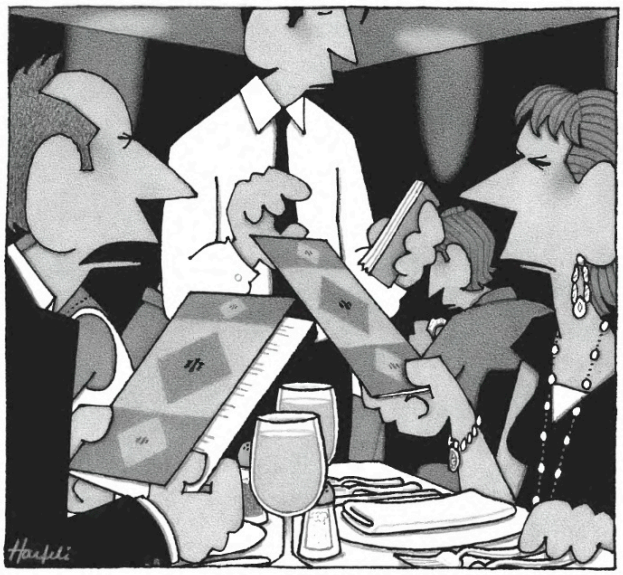
"We have ways of making you talk."

If you like sports drinks, or something with açaí or pomegranate or huckleberry on its label, you may well have tasted one of Hagen's creations. Naming the products that contain her flavors, however, would undermine the confidentiality agreements that Givaudan keeps with its clients, and elicit a severe reprimand. Several years ago, a Givaudan employee attending a convention accidentally let slip to a reporter for *Beverage World* that the company had made a vanilla flavor for Coca-Cola. After the comment was published, Givaudan executives acted as if a state secret had been breached: they investigated the leak, restricted all information about their business with Coke to employees working directly for the company, and flew to Atlanta to visit the Coca-Cola headquarters and apologize in person. In the world of flavor, it is not enough to keep secret a chemical formula. (Typically, these formulas are not patented; hence the obscuring use of "natural flavoring" as an ingredient—and an omnipresent riddle—on food labels.) The Givaudan employee who attended the convention had broken a more fundamental rule. Few of the companies that sell processed foods or drinks want the public to know that outside laboratories supply them with flavors. Even after Snapple's founders admitted to me that, more than twenty years ago, a Brooklyn-based company named Virginia Dare had designed the flavors for a line of sodas that Snapple has long since discontinued, people at

Virginia Dare refused to discuss the matter.

Such secrecy helps shape the story of our food. It encourages consumers to think of processed foods as fully formed objects, rather than as assemblages of disparate components. It treats a brand as sacrosanct. (This is not the case in all industries: Dell openly acknowledges that the processors for its computers come from Intel.) Perhaps this kind of deception is necessary because eating and drinking are such elemental experiences. Our evolutionary forebears did not have to wonder about the supply chain of, say, an apple, and many of us today seem unwilling to register the complexity of industrial foods.

More than half of Givaudan's business—which generates nearly four billion dollars in revenue a year—is built on deceiving our senses when we eat. The consumption of food flavorings may stand as one of the modern era's most profound collective acts of submission to illusion. When you watch a movie or look at photographs or listen to an iPod, you tend not to forget that what you are taking in has been recorded and re-created for you in some fashion. Flavor additives are no less a contrivance; in fact, flavor re-creations typically have less fidelity than digital photography or MP3s. They more closely resemble paintings: subjective creations, made by people who work in competing styles. There are the hyperrealists, who strive for molecular-level precision; the neo-primitivists, who use centuries-old palettes of extracts and essential oils; the Fauvist types, who embrace a sensually heightened sensibility. Placed in the context of art history, the flavor industry today would be in its modernist phase, somewhere in the waning days of Cubism, for even the most outlandish flavor concoctions take direct inspiration from the real world. Whereas a perfumer can invent commercially successful aromas that are totally nonrepresentational—a Pollock in a crystal bottle—the flavorist must still respect the deeply held conservatism that people tend to hold when it comes to putting food in their mouths. Snapple's use of kiwi-strawberry flavoring in a juice drink may seem unusual (and the sum flavor of it may barely approximate real strawberry combined with real kiwi), but we can imagine that the flavor is authentic—that it captures some platonic gastronomic truth.



"Don't try to distance yourself from my choice of entrée."

• •

For Hagen, the boundaries of realism are something to be pushed. She spoke to me with admiration of Miró's "Prades, the Village"—"I love the electric colors, the contrast of abstract to real, and the beautiful indigo sky in that painting"—but she could just as easily have been talking about her own artistic creations. Her flavors are charged, odd, playful, personal. One day, she plans to try slipping a touch of menthol into a butterscotch flavor, or something similarly unexpected into blueberry—something "interesting, that makes you think." Not long ago, I asked her about the sorts of flavors that she mulled over at the edges of her imagination. She responded by e-mail: "Every year, my old high-school friends and their spouses and I take a long weekend in the fall to hang out in Gatlinburg, Tennessee. There are no kids and lots of beer. We stay up late playing cards or games. I usually get up really early one morning to see the sunrise over Great Smoky Mountains National Park. I like to make coffee, sit out on the deck, and listen to the silence. The forest is majestic and usually blanketed by a thin, rolling fog over its beautiful autumnal colors. On our last trip, while I was awaiting the sun, I remember thinking what a cool flavor this moment would make. I would use a zesty lemon base to represent the sun; I would add notes of cedar and pine to include the essence of the forest, and just a hint of phenolic vanilla, which would symbolize the smoky, white fog."

In January, Hagen flew to Riverside, California, and took a cab to the Mission Inn, where Givaudan had reserved rooms for thirteen members of its staff. The hotel was to serve as a staging ground for a commercial flavor-hunting expedition—what the company calls a Taste Trek—which had been organized to study exotic citrus varietals in the area. Citrus flavors, particularly those in the orange family, are among the most popular in the world, and in 2005 Givaudan conducted a yearlong, world-

wide study to map consumer preferences in citrus and identify "white spaces"—combinations of different flavor attributes, such as nuttiness and floralness, that people enjoy but that are unavailable in an existing product. Fewer and fewer beverage companies develop new flavors on their own, even as they are fiercely engaged in what can only be called the Great Flavor Rush. The fight over white spaces in the supermarket aisles has grown so furious that grocery shelves are lined with bottles promising baroque exoticism: energy drinks and waters laced with kiwi-dragonfruit, or hibiscus-orange, or jackfruit-guava, or agave-melon, or clove-cardamom-cinnamon. This is fine by Hagen. "The flavors that I create are white-space flavors—out there," she said.

The citrus trek had already generated interest from key clients, among them some of the largest beverage companies in the world. What Givaudan's team was hoping to find in Riverside was a flavor that told a story. Studies have shown that when a flavor is marketed to consumers as a specific botanical type—evocative of a place or a culture, or complete with some peculiar tale of discovery—people are more likely to enjoy it. For instance, "Georgia peach" is preferable to "peach," even if there is no real difference. Givaudan was not looking to create a juice, although many juices contain natural flavoring—even ones that would not seem to, such as Ocean Spray's 100% Juice Cranberry & Blueberry. Rather, the company was looking for something more abstract: botanical inspiration. Its discoveries would lead to the creation of nutritionally vacant additives that could be deployed in all manner of processed food, from soft drinks to ice cream. With few exceptions, even the most artificial-seeming flavored products (Tang) are based on things that are natural (orange juice). Hagen told me, "I try not to have any preconceived notions of what to expect. There aren't a lot of things that haven't already been discovered, but Mother Nature is a great flavorist."

In Riverside, oranges have long been a grand romantic calling. The city took root in 1870, when a group of Midwestern abolitionists settled at the foot of a sand-colored pile of stone they later named Mt. Rubidoux. Two years later, Luther Tibbets and his wife, Eliza, arrived from Washington, D.C. They were odd: Luther wandered about in a hat trimmed with a woman's veil, to cover his face; Eliza followed a Swedish mystic and entered trances. The Tibbetses ordered a few Brazilian navel-orange trees and planted them on their land. According to legend, one was trampled by a cow; Eliza nourished the others with dishwater. They bore fruit, and that is how the California citrus industry began.

In 1907, the University of California established the Citrus Experiment Station in Riverside, on a plot of land in the foothills of Mt. Rubidoux. Scientists working with the university collected samples of oranges, and also lemons, limes, pomelos, mandarins, and their botanical cousins, to see what would thrive in Southern California's sun-baked soil. A hundred years later, the collection's groves have more than a thousand plant varieties, including oddities from the Far East, such as the Buddha's Hand, a citron that looks like it has been crossbred with a squid. The groves—now named the Citrus Variety Collection—are one of the largest and most diverse of their kind, and serve as a national repository for citrus germplasm. Many of the fruits there are legendary, such as the Meyer lemon, which was collected in China by Frank Meyer, who travelled as far as Turkestan and Manchuria in search of plants. A compulsive wanderer, he mysteriously drowned in the Yangtze in 1918, while travelling with specimens.

Meyer would have appreciated Givaudan's Taste Treks. Since 1999, the company has conducted them in Africa, Latin America, and the Far East. The first expedition began at a large open-air market in Libreville, Gabon, and ended in a remote logging camp deep inside a rain forest known as the Forest of the Bees. The team spent weeks exploring the jungle floor, and combed the canopy in a hot-air balloon. Givaudan's researchers sampled hundreds of species with the intention of translating their taste or fragrance into flavors, and even attempted to record the ambient aroma of the rain forest itself before sunset. (Givaudan's equipment proved incapable of registering it.) The team identified a dozen plants as having commercial potential. *Landolphia owariensis* has been used for rubber, arrow poison, and drugs for treating epilepsy and dizziness; it bears an aromatic red-spotted fruit, and led to the invention of a Givaudan flavor called "jungle fruit." The team also created "Gabonese pineapple" from the bristly orange berries of *Diospyros mannii*, a species akin to ebony. The researchers discovered varieties of tree bark that, when crushed into powder, tasted either like onion or like garlic, and they took samples of wild ginger containing aframodial and labda-8(17),12-diene-15,16-dial—molecules that were later analyzed in Givaudan's laboratories and patented for their ability to intensify both the pungency of spicy foods and the cooling sensation that spearmint and peppermint create in your mouth. The compounds also enhance the taste of alcohol, making low-proof spirits seem stronger; recently, Givaudan put them to use in a well-known liqueur.

It was a little past eight in the morning when Hagen and the rest of the Givaudan team entered the Citrus Variety Collection. The sun had not yet become intense, and the air was crisp, laced with the aroma of desert flora. (The exhaust from I-91, which runs between the groves and Mt. Rubidoux, had not yet thickened into smog.) Hagen wore a broad-brimmed hat and held a spiral notebook. With her were members of Givaudan's marketing staff, Ph.D.s in organic chemistry, and a research scientist who had brought a device—consisting of tubes, filters, and a small bell jar—designed to capture the aroma, or "headspace," of unpicked fruit. This device can make molecular-level recordings of just about any fragrance, but the results require labor-intensive analysis, so it is used sparingly. There was a Givaudan flavorist from Amsterdam, a man of precision in comportment and in language, who told me that he was a "supertaster" capable of registering bitterness with unusual acuity. And there was Jim Hassel, a chemical engineer from New York—tall with graying hair and a Brooklyn accent—who had designed a blockbuster flavor called CitraFresh Lime, and whom Hagen regarded as a kind of guru. "Jim goes very, very, very deep in citrus," she told me. Not long ago, he created a flavor for an American

"I know where the bodies are buried. I buried them."

• •

beer which has generated tens of millions of dollars in sales.

Everyone walked over to a tree bearing Allspice tangelos—a hybrid of a tangerine and a grapefruit—which had lumpy exteriors, like lizard skin, and spongy rinds. Hassel described what to look for when evaluating a specimen. "You've got the essential oils in the peel," he said. "I always like to scrape the peel first, just to see what the essential oil is like. That is one aspect of the fruit. The second thing, obviously, is the juice. They can be very similar and very different, and in citrus processing we always separate the oil from the peel, and then the juice from the fruit. You never want the two to meet, because the acid in the juice will chew up the peel oil." Essential oils have been distilled from spices and other botanicals since at least the Middle Ages, later gaining wide use as natural flavorings. Hassel told me that the reason for this was stability. It doesn't take long for juice to rot, but oils, especially when refined, have a longer shelf life. (It takes a ton of lemons to press about six pounds of lemon oil.) Slices of tangelo were passed around, and Hassel dug his nail into the rind, which yielded droplets of citrus oil. He then brought the rind to his nose and inhaled. The oil, he said, wasn't especially aromatic.

Hagen was holding a slice to her nose, too. "To me, it is sweet mandarin," she said. "Light lemon."

"Not too much anthranilate, right?" Hassel said, referring to a family of chemicals commonly found in grapes and strawberries.

"No," Hagen said. "Sweet orange. Light lemon."

Hassel inhaled again. "Not too tart," he said.

"Certainly no allspice in there," Hagen said. "It's a misnomer."

Hassel said that he had expected the fruit to contain compounds that have malty, yeasty flavors, some of which are found in Gouda cheese, but they weren't there. Unimpressed, he tossed the slice away.

Hagen was still sniffing. "Just clove," she said. "That's all."

Flavor is a cognitive figment. The brain fuses into a single experience the results of different stimuli registered by the tongue, nose, eyes, and ears, in addition to memories of previously consumed meals. For reasons that are not fully understood, we perceive flavor as occurring in our mouths, and that illusion is nearly unshakable, as is made clear by our difficulty identifying, with any reasonable specificity, the way each of our various senses contributes to the experience. In 2006, Jelly Belly, the candy manufacturer, produced a jelly-bean that mimicked the flavor of an ice-cream sandwich. When the company manufactured a prototype with a brown exterior and a white interior, people identified the flavor accurately during a trial, and said that it was a good representation of an ice-cream sandwich. Jelly Belly then made an all-white prototype; many trial respondents found it confusing, misidentifying its flavor as vanilla or marshmallow. As Hagen told me, "Color can play tricks on your mind, for sure."

Hagen hoped to sample more than fifty of the collection's citrus specimens, but she was interested primarily in the aromas. Our sense of smell plays a much larger role in defining flavor than our sense of taste does. Taste receptors on the tongue are primarily limited to the detection of saltiness, sweetness, bitterness, sourness, and umami—a Japanese term for the brothiness that one encounters when tasting MSG. These receptors may also perceive fattiness, though this sensation is so poorly understood that it is hard to say for sure. Scientists have identified the function of fewer than thirty taste receptors, and still do not know which ones are responsible for the perception of saltiness and sourness. Jay Slack, one of Givaudan's chief research scientists, told me, "We are just beginning to scratch the surface of what happens when a molecule binds with the tongue, and then all of the biochemical events that happen after that to get a perception. If you imagine a domino trail, we've knocked off maybe four or five dominoes, and have a thousand more." Taste receptors are blunt instruments. With taste alone, one cannot distinguish a grape lollipop from a watermelon one; coffee is like hot water with a bitter aftertaste, and Coke a bland sugary solution. The limitations of taste are unsurprising when one considers its evolutionary purpose. Our biological progenitors, living in the wilderness, needed to know only what

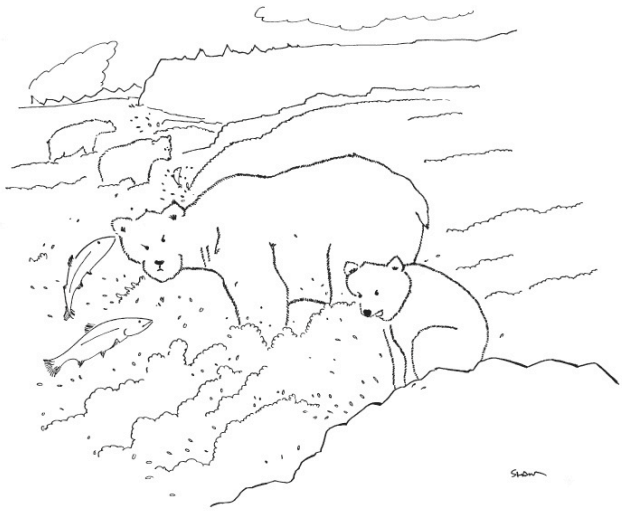
was worth eating and what wasn't. If something tasted sweet, there was a good chance that it provided energy; saltiness suggested the presence of minerals; sourness indicated the level of ripeness, and bitterness the presence of poison.

Smell is a more supple and primordial sense, and its centrality is evident in the way the human brain is arranged. Our forebrains evolved from tissues that once focussed on processing smells, and there are three hundred or so olfactory receptors in the nose. When we taste or see or hear something, the information must pass through the thalamus, a kind of relay station in the brain that allows us to attend to different aspects of perception. (If you suddenly notice a stop sign on the road, for instance, the thalamus has most likely directed your attention to it.) Smells, for the most part, are fed directly from the nose to a "presemantic" part of the brain where cognition does not occur, and where emotions are processed. The bypassing of the thalamus may be one reason why smells can be so hard to describe in detail, and also why aromas stimulate such powerful feelings. The smell of rotten meat can trigger sudden revulsion in a way that merely looking at it cannot.

Smell probably became wrapped up with eating because of its ability to predict. Each whiff is a harmless sample of a potentially risky food. To apprehend something by smell, it must be evaporating, even if only minutely. Chemical compounds that evaporate are said to be "volatile." Chocolate has many volatile compounds. So does lemon sorbet. A hot cup of coffee contains roughly five hundred volatile chemicals. When we eat, volatile chemicals in our food flow through a cavity at the back of the mouth into the nose. Some of them are extremely potent. The smell of roast lamb comes from minute quantities of sulfur compounds. Volatile chemicals can be mysterious. For many decades, we have known that a compound called vanillin plays a large role in determining our sense of vanilla, but the beany aroma that often makes high-quality vanilla seem full-flavored had long eluded science. People in the industry call the search for a complete mapping of a substance's volatile chemistry "chasing zero," and I met with a scientist working for Givaudan who had spent a great deal of time chasing this beaniness to zero. Doing so required multidimensional chromatography—a process for separating trace molecules out of a mixture—and expensive equipment. Last year, after evaluating hundreds of chemicals, he hit upon the three relevant molecules. "We found the beany contributors!" he told me. "We were very excited." The molecules were present at the level of parts per billion.

I asked Hagen how many chemicals she thought she could identify in a single bite of food. "I want to say twenty," she said. "If I am tasting a citrus fruit in the field, I could probably pick out ten chemicals for sure, and I could probably speculate about twenty-five more." Other flavorists said they could do about the same, and hearing them speak about the bouquet of Mountain Dew or Sprite—evaluating its arc, from top notes to bottom notes—you might think they were discussing a 1980 Montrachet. (Hagen told me that she thought Dr Pepper was "amazing," with a floral note that was unique and high. She spoke with awe of orange Gatorade: "I mean, that is *beautiful*.") During a meeting with several flavor professionals in New Jersey, I compared a flavor chemist's ability to break down the structure of a soft drink to the skills of Robert Parker, the wine critic. I was quickly corrected. "That's kind of like hocus-pocus," one of them said. "Parker may say that a wine has a nutty note or is oaky, but a lot of things can be behind that, and I don't think he's matching aspects of the flavor to a chemical compound and going, 'O.K., this note here, it comes from methyl isobutyrate.' " And yet controlled experiments show that, no matter what a person's professional vocabulary or expertise, aromas remain a blur: the average person, with minimal training, can perceive about three or four distinct components in a given aroma; professional flavorists—without leaning on their chemical knowledge of particular types of food—can do no better.

Even the most familiar products can bewilder us. Coca-Cola, for instance, is primarily a citrus beverage, its flavor derived from lemon, orange, and lime oils, combined with vanilla, cinnamon, other spices, and corn syrup. Its flavor has little in common with the astringent-tasting kola nut, from which it takes its name, and its caramel coloring is largely imposed. For many people, describing Coke's flavor as a combination of different parts is nearly impossible. (In one study, two-thirds of the subjects could not tell the difference between Classic Coke and Diet Coke.) If you close your



"I want a bagel!"

eyes, inhale deeply, and try to pay close attention to the volatile chemistry of Coke, it is possible to pick out a few basic elements, but for the average consumer the flavor is "cognitively impenetrable." That is, if you ask someone "What does Coke taste like?" the answer will be tautological: "It tastes like Coke." This presents a conundrum that many flavorists try not to think about. If consumers are cognitively unable to regard a flavor meaningfully, is there any point to what flavorists do? Hagen once told me, "My husband loves football, and so when I am watching the players on the sidelines drink Gatorade I'm thinking that they have no idea how complex that lemon-lime is. All they know is that it is quenching their thirst and it tastes good." Still, she was hoping to discover the next big drink. Coke's success is, in part, a testament to the sophistication of its formula, its exquisite balance, even if it does confound our senses.

By late morning, Hagen, Hassel, and the rest of the Givaudan team had begun eating salted crackers, trying to calm their palates after tasting so many citrons, oranges, and pomelos. The team had worked its way through half a dozen clementines. The Marisol clementine was a touch overripe, and its oil was oddly insectile. "It smells like crushed lightning bugs," Hagen said approvingly, as she held a Marisol rind to her nose. "Kind of like formates. When you crush an ant, there is formic acid, so formates belong to a family of molecules that are, to me, all buggy." The Nour clementine, from Morocco, was sweet. "There is something here that reminds me of bubble gum," Hagen said. "Very kid-friendly. Isoamyl acetate, which is the chemical that reminds people of Circus Peanuts." Hagen loved Hubba Bubba bubble gum as a child, and she thought that the Nour might have commercial potential. "It has a little bit of an edge," she said. "A friendly edge."

Exotic flavors rarely have immediate commercial appeal. Often, they must ease their way into the market, usually in combination with an old and well-loved companion. When, in the early nineties, Snapple paired kiwi with strawberry flavoring for its juice drink, the notion was considered highly innovative. Snapple had been working with the oldest American flavor house, Fritzsche Dodge & Olcott, which was acquired by Givaudan in 1991. Leonard Marsh, one of Snapple's founders, told me that the flavorists made a variety of fruit flavors for him, including kiwi, which he initially rejected. "It didn't taste good on its own," he told me. "I said, 'Can you mix this with something like strawberry?' " The result was wildly popular—and highly profitable for Givaudan. A former Givaudan executive told me, "We were selling Snapple fifty-five-gallon drums of kiwi-strawberry drink. At one point, we had purchased all the kiwi juice that was available globally."

Hagen told me that her favorite white-space flavor—the one she wished she had created—was Red Bull, because it succeeded in getting consumers to embrace the surreal. The co-founder of Red Bull, Dietrich Mateschitz, acknowledges that the company went out of its way to develop a flavor that was unorthodox. ("Some people say medicine never tastes good," he told me. "You can translate this into our taste philosophy.") Other flavorists were perplexed by Red Bull, which was created in 1987. "Have you ever tasted such a crazy flavor?" Hagen said. "What is it? There is nothing like it, and every once in a while you come across a flavor that is not especially balanced but for some reason it takes off." Today, it is virtually impossible to market an energy drink that does not have the same unbalanced characteristics that Red Bull has. "It scores terribly when you put it in front of consumers who don't think it is an energy drink," a salesman for one of the top flavor houses told me. "But the spiky note in there now defines 'energy.' So when I build energy flavors with our client it has got to taste bad. If you give the consumer a great-tasting orange flavor for an energy drink, their liking drops way down, because it doesn't have that 'energy note' they expect."

Midway through the trek, it became evident that the fruits of greatest interest to the flavorists had off notes that, in combination with more palatable natural chemicals, added enough aromatic discordance to make the flavors unique. The Jamaican Ugli fruit, a large tangelo with rough greenish-yellowish skin, which has slowly been gaining a commercial following, had a sulfuric undertone that Hagen suspected was caused by prenyl mercaptan—which is often found in skunky beer. "With Corona, because it is in a clear bottle, when light hits it, it oxidizes, so that's why you put a lime in Corona—to kill this mercaptan," Hagen said. "It is this yucky bad note that people like. And you're, like, O.K., whatever." When I tasted the

"Can I get you anything from the meat bar?"

Ugli fruit, I didn't initially catch the prenyl mercaptan, but Hagen steered me. "Once you are past the floralness, the citrusness, then there is the sulfur note," she said—and there it was.

The team found that a rare specimen—the *Oxanthera neo-caledonica* hybrid—had even more divergent characteristics. The fruit's peel was smooth and yellow-green, and its oil had an aroma that was sugary, floral, and reminiscent of Juicy Fruit gum. After inhaling it, Hagen wrote in her notebook, "girlie-pink bubble gum notes, powdery fruit punch, sweet, tropical punch, very candy, reminds me of a Skittles or Starburst-type flavor, possible peach citrus notes, complex and unusual." But the fruit's taste was harshly bitter, even slightly fishy, and the juice caused a tingly, numbing sensation on the tongue—"a good example of how the peel is completely different from the taste," she told me. She found the specimen exciting.

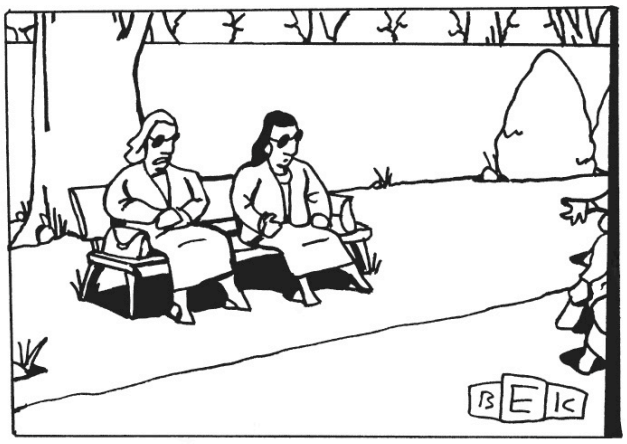
Hassel agreed. Very few edible fruits have a numbing quality, and he thought that the tingling sensation could work in an alcoholic drink. "Even if you don't like the whole package, go in there and analyze what's giving it those unique notes," he said. Later, a Givaudan scientist tried to capture the headspace of a fruit that was still on the tree: he scraped a section of the peel, covered the exposed area with the bell jar, and activated a small pump that sent a stream of air over the fruit's surface, forcing molecules into the jar, where they collected in a filter.

Before the team moved on to the next grove, the flavorist from Amsterdam wondered if, in the laboratory, the numbing element could be extracted from the fruit's awful-tasting juice and then recombined with a flavor inspired by the peel oil. "You might add the numbing, but you wouldn't add the bitterness," he said. "Maybe just a hint. You would want something pleasant in the end."

Once you begin to consider the natural world at a molecular level, the boundaries that separate one fruit from another begin to seem like artifice. Givaudan's many scientists often refer to food as "the application," as if it were composed of malleable lines of computer code; from this perspective, adding a flavor is as simple as updating software. A garden strawberry turns out to be a very complicated application, made up of hundreds of differing molecules—some of them highly volatile, some of them inert to our senses—but among the ones that seem to matter most very few are exclusive to the strawberry. If you combine gamma-decalactone from a peach, ethyl butyrate from an apple, methyl cinnamate from a guava, and Furaneol from a pineapple, you can construct a very rudimentary strawberry flavor. As John Wright, a former vice-president for International Flavors & Fragrance, a New York-based company and a Givaudan rival, told me, "Flavors are a little bit like jigsaw puzzles." The interchangeability of nature made possible Givaudan's search for inspiration in Riverside. No matter how much the team liked the *Oxanthera neo-caledonica's* peel aroma, everyone on the trek knew that growing enough of the fruit to extract commercially significant quantities of its essential oil would be prohibitively expensive. An approximation of the oil would have to be constructed from more readily available materials.

In this respect, the *Oxanthera neo-caledonica* is just like the pomegranate or the açaí berry, both of which are expensive to harvest, or even the common lemon. Unusually cold weather in California and in Argentina, along with a hot Saharan wind pushing into the Mediterranean region, destroyed roughly thirty per cent of the world's lemon crop in 2008. So Givaudan, the world's largest purchaser of citrus oil, announced that it would create a "replacement" from the many lemon-oil molecules found in other botanicals and from whatever it could derive from natural sources in the lab. Citral, a dominant chemical in most lemon oils, is also found in lemon myrtle, a leafy plant native to a subtropical rain forest in Australia, and in *Litsea cubeba*, a small deciduous tree. In China, *Litsea cubeba*, known as mountain pepper, is used as a spice, but it also contains an oil that is made up largely of citral. Every year, the Chinese harvest hundreds of tons of the oil. For many years, *Litsea cubeba* and lemongrass have been the world's biggest natural sources of citral. If you drink or eat something with lemon flavoring today, one of its key ingredients probably does not come from a lemon.

A little before noon, the Givaudan team made an exciting discovery when David Karp—a writer and a part-time botanical explorer who is a research



"She's one of those bad mothers who say they're bad mothers but think they're good mothers."

• •

associate at the Citrus Variety Collection—ran over with a large pomelo and announced that he had something to share. "Most of the pomelos I really don't care for, at least as grown here in California," he said. "To me, they have a soapy flavor, in addition to the bitterness of the membrane. Even when you fillet them, I don't care for them, but Tahitian pomelos are very different. They tend to have a much thinner skin, and sort of a greenish flesh, and a very distinctive lemon-lime flavor." He cut into the fruit, carefully holding it away from his body. Juice sprayed all around him. "Never, ever open a pomelo near your computer or camera equipment," he said. "O.K., who wants to go first?"

"Me, me, me!" Hagen said.

Karp handed her a slice, which she held to her nose. He distributed more slices. "Usually, it is at its best when we are here in February," he said. On first impression, the Tahitian pomelo was unappealing: the rind oil gave off a bitterly unpleasant scent, and the fruit was densely seedy. But the taste and aroma of the juice was candylike, with hints of rice, peppercorn, and freshly cut grass, and it had a clean fruitiness: an uplifting wash of citrus. It had aspects of strawberry in it, and other aromatic layers hard to identify. If you closed your eyes and tasted it, it would be difficult to know what kind of fruit it was.

"Ah," Hagen said, throwing her head back. "That's wonderful."

Karp, passing around more slices, declared the fruit to be one of the most promising underexplored varieties of citrus on earth. He has occasionally sold exotic specimens to grocery stores, and told me that, a number of years ago, he had shipped a pallet of Tahitian pomelos to a wholesale affiliate of Gourmet Garage, in New York: "They said, 'What the hell are you sending us this horrible, green, seedy, nasty stuff for?' And I said, 'I'm sorry.' They said, 'We're going to put it in the Dumpster right now, you idiot.' They called me back the next day and said, 'How many more pallets can you get?' The chef tasted it, and he went wild."

Standing in the grove, the Givaudan team was going wild, too. People called out their first impressions. Except for someone who picked up "a shoe-polish note at the end," everyone was smitten. One of the flavorists declared that the Tahitian pomelo was "very different from anything I have tasted before." I turned to Hagen, and she grinned before announcing her verdict: "A good soda." It recalled, for her, the freshness of Sprite, but it had a childlike quality, too. "This is awesome," she told me. "Kind of like a lime—like the lime Life Savers, a little bit of lemon, a little bit of sweet pink grapefruit. Pink lemonade. It is really nice."

For much of human history, flavor additives were simple and direct. Spices and sauces added richness to food, and often preserved it. The pharaohs had a taste for cumin, as did the ancient Greeks, who kept it on the dinner table. But the diet of ancient Western civilization lacked many flavors that we now consider fundamental. For centuries, Rome's subjects did not know the lemon, which originated in Asia, and they never tasted a tomato, or chocolate or vanilla—derived from plants native to the New World. The ancients did not have coffee or tea. According to Andrew Dalby, the author of "Food in the Ancient World from A to Z," the Homeric epics offer the earliest record in Western civilization of a beverage infused with flavor: *kykeon*, a mixture of wine, herbs, and barley. ("One such drink is served to a soldier as a restorative after a hard day's work at the siege of Troy," Dalby says.) The Romans used grape syrup and spices in cooking, but perhaps the most popular additive was a fermented fish sauce called liquamen, or garum, distinguished by its saltiness. Liquamen was made throughout the Roman Empire; the earliest known manufacturer was a man from Pompeii. We know this from an advertisement that he had inscribed on his jars: "Best strained liquamen. From the factory of Umbricus Agathopus." For more than a millennium, flavor technology did not advance appreciably beyond the Agathopus workshop.

Essential oils have been used in fragrances for hundreds of years, and since at least the eighteenth century people have also consumed them. The first flavorists were typically pharmacists, who added flavors to medicines. As John Wright, the former International Flavors & Fragrance executive, has noted, their flavors were "often not very close to the character of the real food." Flavor creation did not take its present form until the development of organic chemistry, in the early nineteenth century, when scientists began to identify volatile chemical compounds with distinct aromas. In many instances, the discoveries were accidental. Benzaldehyde was among the first known molecules to be identified with a flavor, in 1832, and it is still widely used today. "It is my favorite chemical," Hagen told me. "Bitter almond was the source, and it is in there at a low level, but benzaldehyde really shines when it is in fruit flavors, where it can be used at a much higher level: cherry, grape, fruit punch—childhood bliss. My dad played softball, and we always would go to games and get a Cherry Icee. When I was first exposed to benzaldehyde in the industry, it reminded me of that. It's now one of my signature compounds."

At first, most flavors were natural. (Some of the earliest volatile chemicals to be identified were for strawberry, garlic, and roasted barley.) But during the ensuing decades chemists began to find ways to create these molecules entirely in the laboratory. Vanillin was synthesized in 1874 by two German scientists, Ferdinand Tiemann and Wilhelm Haarmann, from a molecule found in coniferous trees. Today, vanilla is the world's most popular flavor, and thousands of tons of vanillin are synthesized from industrial petrochemicals and waste from the production of wood pulp. (It is possible to extract it even from cow dung, as Japanese chemists demonstrated in 2006.) There is no molecular distinction between synthesized vanillin or vanillin extracted from vanilla beans, but the way the molecule is made determines whether it will be advertised as "natural" or "artificial." Flavor chemicals often make up less than one per cent of the ingredients in processed foods, and many flavorists regard the terms "natural" and "artificial" as largely meaningless—an indulgence for consumers who happen to believe that one is more likely to be toxic than another, even if the perception is not necessarily true. (After all, snake venom is natural.) The flavor industry has long resisted the public disclosure of its for-

mulas, and so monitoring the safety of the chemicals in them is complex. After extended negotiations, the Food and Drug Administration and the industry agreed to maintain a list of compounds "generally recognized as safe," the use of which companies are not obligated to reveal.

In 1895, Xavier and Leon Givaudan, two brothers from Lyons, opened their company, in Zurich. They expanded to America in 1924. The fragrance-and-flavor industry was small, secretive, and rapidly changing. Most of the companies were clustered in lower Manhattan, near the dockyards on the East River, where drums of raw materials arrived from overseas. As the industry grew, it crept uptown. The factory owners were clubby: one of them conducted so much business at the Little Venice, a restaurant on Twelfth Street, that his Rolls-Royce became a fixture out front.

In the thirties and forties, many European flavor houses opened offices in New York, though not all of them brought their formulas. Jim Broderick, a retired flavorist, told me that he once interviewed for a job at the New York office of Firmenich, a European flavor-and-fragrance house: "When I asked them 'What's my job?' it was 'You take the flavors that we make over there and re-create them over here,' and I said, 'Well, can I see the formulas?' And they said no." At the time, flavor chemists kept formulas locked in a safe, or hid them in a drawer if someone walked into their office. "A company's soul is kept in formulas," Bill Downey, a former flavorist at Fritzsche, told me. (He created the flavoring for Snapple's original lemon iced tea one afternoon with a friend.) Flavorists can spend months trying to match a competitor's creation. When the Society of Flavor Chemists was founded, at the Little Venice in 1954, some members attended in secret because their companies did not want them there. One longtime flavor scientist called the industry "paranoid."

Today, flavor and fragrance houses bring in annual revenues of twenty billion dollars. About ninety per cent of the money that Americans spend in the supermarket goes toward processed food, much of which could not be made without companies like Givaudan. "Most of the food-and-beverage companies have become marketing-and-distribution companies," a flavor-company executive told me, only somewhat in jest. I understood what he meant when, in one of his laboratories, I saw a number of his colleagues working on a tasteless "slurry," consisting largely of starch, oil, and salt, which a client was hoping to transform into a marketable product. The client had asked the flavor company's in-house chef to develop various dips, such as guacamole, using fresh ingredients; after settling on the best recipes, the company's flavorists mimicked them chemically, with an eye toward injecting the flavor compounds into the slurry in the most stable and cost-effective way.

Given that flavor additives are generally safe, and make up a tiny percentage of any given product's ingredients, companies like Givaudan are in an unusual position when one considers how their work affects our health. A couple of older flavorists told me that the essence of their work is to bring greater enjoyment to life, which is not necessarily the same as providing food that is good for you. Eric Schlosser, in "Fast Food Nation," argues that the fast-food industry could not exist without the flavor industry: he points out that even McDonald's French fries are laced with natural flavoring to make them tastier.

In the case of junk food, flavor additives mask an absence, making cheap, nutritionally negligible ingredients seem delicious (or, at least, edible). But in many other cases, flavor additives mask a reduction in sugar or salt or trans fats—things that, in excess, are harmful. It may be too much to expect an American menu stripped of all processed food items, and such a world may not even be desirable. "Think about unflavored rice cakes," Hagen told me, when I raised the issue with her. "They would sit on the shelves, because they taste like ceiling tiles. Now, add a maple-syrup flavor or a cheddar-cheese flavor to those rice cakes. People would choose them as a snack. It's not practical or economical to use 'real' foods to add flavor. There are lots of problems with this: the availability, the stability, the over-all intensity of such things."

Taking unhealthy ingredients out of a well-loved brand—for instance, removing trans fats from Oreos—while trying to retain its flavor requires complex chemistry. Since the nineteen-seventies, flavor houses have been relying on gas chromatography and mass spec-

EXERCISE

Because the Greeks didn't bother much about plagiarism
Poems by Anacreon, born in Teos around 500 B.C.,

Appear among the Anacreontea,
Imitations made by poets who loved him.

In a dream I saw Anacreon, who called to me.
As he stumbled, drunk, he lifted a crown of flowers from his head.

Stephanus translated the poems into Latin in 1554.
In Taintignies, using a dictionary

Small enough to carry on active service,
Richard Aldington made the prose translation I adapt here.

I bound the garland around my forehead;
When I sang about Cadmus, my lyre spoke of love.

In my copy of "The Manner of Anacreon," Egoist Press, 1919,
Hamilton Collier of Scarsdale, New York, has written on the flyleaf

My first real understanding of the Greeks.
I regret I am unable to agree with them.

Hephaestus, carve me a hollow cup!
The dark earth drinks, and the trees drink the earth.

The sea drinks the wind,
The sun drinks the sea.

I was a child in the hills of Phrygia.
The swallow of Pandion was once a girl.

—James Longenbach

trometry to decode the secrets of natural chemistry, and their expertise has deepened considerably. (In 1948, only nine components in orange-peel oil were known; since then, nearly two hundred more have been identified.) But, as the technology has changed, the notion of what a flavor company is has changed, too—from the simple mixing of ingredients that nature provides to a highly sophisticated sensory legerdemain. As a flavor-research scientist told me, "We are almost getting to pharmaceutical-grade science."

Givaudan emerged as the world's largest flavor company over the past few decades, following the acquisition of many competitors. In the past ten years, the flavor industry has undergone rapid consolidation. Nearly every flavorist I met had fallen into the profession by chance, and only after working as a journeyman apprentice in one of the smaller firms. Givaudan's head of flavor strategy, Bob Pellegrino, told me that several years ago, when he thought about his company's future, he noticed there was virtually no one new to hire: "It was like, Oh my God, we are going to have a bunch of flavorists in retirement in the next ten years, and then what?" He announced that any Givaudan technician or scientist could apply for a training program—three years of full-time study.

Hagen was among two dozen applicants. "By that point, I had fallen in love with what I was doing," she told me. She had been working as a lab technician, assembling formulas for a flavorist. "I had made a raspberry as a technician, and I was carrying it upstairs in an elevator in a little bottle, and I was just waiting in the elevator, and then I smelled it and I was like, God, how did that happen? It was this magical moment. I had brought all these chemicals together. The result smelled just like the raspberries that I used to pick with my grandmother." Hagen was one of only six applicants who made it through rigorous testing and interviews—she turned out to have an acute sense of smell. She completed the training in 2006, and joined the Society of Flavor Chemists the following year. Her first flavor to make it into a product was a blackberry.

By May, Hagen had developed several flavors based on the fruits that she had sampled in Riverside. I flew to Givaudan's headquarters in Cincinnati to follow her progress. The company's buildings occupy dual campuses on either side of Interstate 75—the factory on one side, and laboratories, kitchens, and offices on the other. When I pulled up to the building containing the laboratories, I was hit by an intoxicating odor, a blend of savory, earthy fragrances: cumin and cinnamon, perhaps, combined with a heavy sweetness. The intense aroma was somewhat chemical, but not immediately unpleasant (though locals occasionally complain). I walked past gardeners mowing the lawn. The fragrance of cut grass was absorbed by the building's ambient aroma, and as I entered I thought of something that Hagen had told me in Riverside. "The company has a murky brown smell," she had said. "It's like when you were a kid and you mixed all your paint up."

Most of the people I met at Givaudan went about their work with detached amusement. "We have a software specialist who has spent his whole career, thirty-five years, coming up with different coefficients for chemicals in chewing gum," Hagen told me. "He is able to predict when you experience certain chemicals throughout the chew." Later, during tours of the facilities—I had to promise not to reveal the names of any products—I met with researchers who had developed an experimental gum that changed flavors three times when chewed, and a "sequential release" cereal bar that went from blueberry to orange in my mouth. Much of their work was geared toward figuring out ways to maintain the tastiness of food that had been stripped of key ingredients. They experimented with molecules that make reduced-fat foods taste creamy and full-bodied, or that fool the mouth into thinking that low-sodium chicken soup tastes good.

For more than a century, Givaudan focussed on tinkering with volatile chemicals that register mainly in the nose. In the past decade, it has been investing heavily in taste research—a significant shift. After substantial sections of the human genome were decoded, in 2000, Givaudan hired a team of scientists to experiment with its application to food. Jay Slack, the research scientist, was one of them. He is now working with a chemical called hydroxy-alpha sanshool. "It is a 'tingle compound,'" he said. "If you ever put your tongue on a nine-volt battery—that buzz. So there is a chemical that evokes that sensation in your tongue. It is found in the Szechuan chili, and that is a unique sensation. It's not cooling, it's not burning, it's not warming. It is truly tingling, and so we are really interested to understand what is the receptor, or

receptors, that give you that sensation in the oral cavity." Slack, along with several colleagues, is free to submit scientific papers—he recently published an article on how genetic differences shape the perception of sweetness around the world. His research on taste receptors (including some recently discovered in the intestine) has focussed on a question of tremendous commercial importance: how to dampen the experience of bitterness, a persistent side effect of many sugar alternatives. "Our goal is to develop flavor molecules that will tweak the sensitivity of the sweet system but not be sweeteners, because if they become sweeteners they are no longer flavors," he told me. "It's a regulatory line that's drawn in the sand."

Later, I was shown a building that was devoted to savory flavors, which tend to be complex, because of the vast number of chemicals involved and the time-sensitive nature of their aromas. (Fresh out of the kitchen, grilled fish or roasted beef may smell wonderful, but it can become unappealing an hour later.) In 2008, Givaudan conducted a yearlong study of chicken; using the device with the bell jar, researchers attempted to capture the headspace of dishes from around the world. A molecule-for-molecule re-creation of a recipe from China—roast duck with pickled radish—was stored in a little brown jar. A scientist dipped a paper blotter into it and handed it to me for a sniff. The smell was remarkably evocative.

I visited a kitchen where celebrity chefs, among them Wylie Dufresne, of New York's wd-50, had worked on dishes that Givaudan's researchers then studied. For the chef Todd English, Givaudan had created a line of "melting powders"—chemical approximations of the sum flavor of his recipes, based upon a molecular breakdown of his entrées. The powders, which are sold on the Home Shopping Network, liquefy when they are sprinkled on cooked food, creating instant versions of English's recipes.

At one point, Hagen and I were walking through a hallway. "Hey," she called out to a flavorist hunched over a pristine lab bench, mixing chemicals in a beaker. "What are you up to?"

"Oh, making butter," the flavorist said.

Hagen's laboratory is on the second floor. Large windows overlook a metallic sculpture inspired by machinery that sprays flavor powders onto things like tortilla chips. Her shelves are lined with thousands of sepia-tinted bottles that could be artifacts from a nineteenth-century apothecary. The range of the bottles' contents is huge, and very few of the flavors are artificial. Hagen had an entire cabinet devoted to strawberry flavors, some of them combined with other fruit, some of them designed for specific applications, such as yogurt or hard candies. She directed me to some of her favorite molecules. One smelled "like fresh rain." Another smelled like carrots, and another like a mojito. She handed me a bottle and said, "Smells earthy, kind of like root, raw vegetable." Then she said, "Here is another flavor that I love. I made this and said, 'God, this smells like a Gummi worm!' " There were flavors that Hagen had created without ever sampling an original specimen. For a recent assignment, she had been given an analytical rundown of a jackfruit—a list of more than ninety of its volatile chemicals, identified by a gas chromatograph—and built a flavor solely on that information. Afterward, during a trip to San Francisco, she found a jackfruit in Chinatown, and tried it. Her version was slightly different, as she had expected it to be. "You are trying to sell a flavor," she said. "It's not like you are getting judged on how close you are to the real fruit. At the end of the day, you are getting judged on how good the flavor tastes. And you kind of have to take some artistic liberties."

In Riverside, Hagen had made initial sketches of the flavors from the citrus collection on a proprietary device that Givaudan calls the Mini Virtual Aroma Synthesizer, or the Mini-VAS. The machine—a complex network of valves and motors housed inside a shock-resistant stainless-steel suitcase—resembles the portable nuclear-missile launching systems that Dan Aykroyd and Chevy Chase lugged around in "Spies Like Us." When plugged into a laptop computer, the Mini-VAS can re-create just about any aroma. Each suitcase has room for twenty-nine removable plastic cylinders, called "keys," and each key contains a solid filter with an aroma embedded in it, such as spicy cinnamon or sweet orange or Citra-Fresh Lime. By forcing air through the keys at different intensities, flavorists can combine notes, like an organist playing a chord, until they get an aroma that closely matches the smell of a food that they want to simulate in the lab. The result is emitted through a small glass cone. Once the flavorist has "re-

corded" his subjective impressions of a fragrance, an algorithm produces an approximate molecular formula for the corresponding flavor. Increasingly, Givaudan has been inviting representatives from food and beverage manufacturers to use the machine so that they can more easily describe what they want the flavorists to do.

The company's citrus team had decided to develop a dozen flavors from the trek in Riverside, based mostly on limes and lemons (including the Meyer lemon) but also on more exotic items, such as the Tahitian pomelo and the Jamaican Ugli fruit, both of which had attracted the attention of one of America's largest beverage manufacturers. Hagen had taken several company executives to the Riverside groves, where they sampled the fruits and refined their impressions, using the Mini-VAS. The executives were enthusiastic and said that the company might rush the flavors to market in a series of drinks by the end of the year. But they wanted Hagen to make some adjustments first.

Hagen invited me to observe while she revised a flavor that she had based on the Mency tangor—a hybrid of a Mediterranean sweet orange and a Dancy mandarin. The Mency tangor was bred at the Riverside citrus collection in 1915 and exists in a limited supply. The collection's catalogue notes that it is an "early ripening fruit of sprightly, acid flavor," and during Hagen's return visit to the collection, in February, the tangor was overripe. Hagen had eliminated that aspect of it in her re-creation, but the beverage company had said that it wanted it back. Hagen found herself, as she put it, in "an interesting predicament." She had to add to the sample a note that was typically unappealing, but in a way that would improve the over-all flavor. "This is not something I initially know how to do," she said, and then began thinking aloud. "What happens when a fruit becomes overripe? It becomes sweeter and sweeter. The acid drops, so it becomes brown and sugary. I will have to add some brown notes."

She began at her desk, scrolling through a comprehensive spreadsheet that she had made during her training; it contained her descriptions of hundreds of chemicals. When fruits ripen, they not only become sweeter; they also become more sulfuric. Hagen began looking for sulfur compounds that she had previously associated with overripe aromas. There was dimethyl disulfide, which she called "garbacious." It can be found in garlic, leeks, and human feces. "That is not necessarily something I want to put into my citrus," she said. After considering a variety of chemicals, she settled on a few options: two sulfurous compounds—one found in grapefruit, another in black currant—and a molecule, common to many berries, that had "a sweet brown note and gives the impression of sugar." The latter was one of the most widely used Givaudan flavor compounds.

Because Hagen works with minute quantities of liquids—often with ingredients measured in parts per million—her instrumentation is highly precise. Using small clear plastic cups, an electronic scale, a beaker, a pipette, and a magnetic device that stirs chemicals evenly, she began trying out different recipes. With each attempt, she sampled the flavor in a solution of water, sugar, and citric acid. The first sulfuric compound made the drink taste dull; the second made the tangor flavor seem heavy and eggy; in the third, the brown note was hard to detect.

"I have one other idea—just hang with me," she said, and began to hunt through the many bottles. "There is a note that adds overripe to strawberries." She pulled down a bottle labelled "2-OCTEN-4-ONE"—a recently "discovered" compound in strawberry. Less than a decade ago, the molecule was considered artificial, but it was chased down in the natural world, and its status changed. It is now natural. "It is just the ripest note in the world to me," Hagen said, with growing excitement. Using the pipette, she carefully added a few drops to the existing flavor solution and, after diluting it with water, served it up. The change was pleasant, and, if anything, made her version of the tangor more conventional. Perhaps this was what the people at the beverage company had wanted all along. Hagen told me that she would make a few minor adjustments, but she felt that the job was done.

A few weeks later, I called her to see how the tangor revision had been received. She hadn't heard yet. There was always a period of uncertainty after she sent out a flavor, she told me. "I could sell a flavor as a strawberry, and at the end of the day it could be marketed as a mixed berry," she said. Sometimes, after a flavor leaves her lab, months, even years elapse before it is used in a product. Hagen told me that fewer than five per cent of her creations actually find their way to market. She didn't sound particularly dismayed. "It's in a bottle with a label," she said of her latest creation. "It is just waiting for an opportunity. I love it." ♦

"Chef, the salads are ready, the meat is seasoned, and you're washing your hands in the soup."

• •