CONTENTS

Prologue: Eco-Evolutionary Gastronomy ix

CHAPTER 1. Tongue-Tied 1

CHAPTER 2. The Flavor-Seekers 25

CHAPTER 3. A Nose for Flavor 53

CHAPTER 4. Culinary Extinction 80

CHAPTER 5. Forbidden Fruits 114

CHAPTER 6. On the Origin of Spices 129

CHAPTER 7. Cheesy Horse and Sour Beer 154

CHAPTER 8. The Art of Cheese 182

CHAPTER 9. Dinner Makes Us Human 203

Notes 215

References 245

Illustration Credits 261

Index 263
CHAPTER 1

Tongue-Tied

Tell me what you eat, and I will tell you what you are.

Taste seems to have two chief uses: 1. It invites us by pleasure to repair the losses which result from the use of life. 2. It assists us to select from among the substrates offered by nature, those which are alimentary.

—JEAN ANTHELME BRILHAT-SAVARIN,
THE PHYSIOLOGY OF TASTE

The nature of pleasure and displeasure have preoccupied humans since the first paleolithic philosophers sat around a fire, roasting meat and talking. What questions could be more essential than “Why do we experience pleasure or displeasure?” Or, “When and why should we allow ourselves to enjoy pleasure or subject ourselves to displeasure?” In the first century BCE, the Roman poet Lucretius offered an answer. He argued that the world was material, composed of atoms and atoms alone. Atoms made up the moon, the fence, and the cat on the fence. They also made up the mouse upon which the cat was
about to pounce. In death, the atoms in the mouse might be rearranged into the body of the cat, but they would continue to exist.¹ In such a world, pleasure was the body’s mechanism for fulfilling its material needs. Pleasure led the cat to the mouse. Pleasure was natural; displeasure too. To Lucretius the naturalness of pleasures and displeasures was not a call for hedonism. But it did suggest that a good life could be one in which pleasures were enjoyed and displeasure was avoided. Lucretius recorded his ideas in a moving poem titled *De rerum natura* and typically translated as *On the Nature of Things* or *On the Nature of the Universe*. The poem brought Lucretius’s ideas to a large audience. They weren’t new ideas, not entirely. In part, Lucretius was reiterating and rewriting the ideas of the Greek philosopher Epicurus. But these ideas were nonetheless given a new clarity and beauty. Yet, when the Western Roman Empire collapsed, Lucretius’s words were, bit by bit, lost. By the late Middle Ages, the primary evidence that Lucretius existed was indirect. He could be found in the writings of other scholars, scholars who mentioned and sometimes quoted tantalizingly short excerpts from *On the Nature of the Universe*.

With the fall of the Western Roman Empire, many of the great literary and scholarly works of ancient Romans and Greeks vanished. They were burned, crushed or, more often, simply neglected. Some works were lost permanently. But not all. Many were copied and studied by Muslim scholars in Byzantium; others were preserved in monasteries. Fortunately, Lucretius’s poem was among those manuscripts that were saved. In 1417, *On the Nature of the Universe* was found in a German monastery² by a restless and curious monk named Poggio Bracciolini.

Poggio was struck by the intense beauty of Lucretius’s work. With time, he also became aware that the world Lucretius described, a world full of natural pleasures, seemed to be at odds
with everything he had learned as a medieval Christian. He eventually came to criticize the poem, but not before ordering a scribe to make a copy and then sharing that copy around (and having more copies made). In the coming decades some would come to regard the sentiments embodied in Lucretius’s poem as a defining model for the future, grounded in the past. Meanwhile, to others Lucretius’s ideas were a threat to Western civilization. Our perspectives on pleasure and the materialism of the world remain as divided now as they were then. Such divisions bubble beneath many of our most politicized debates. We won’t resolve such debates here, but we can introduce a missing piece, the answer to the question of why pleasure and displeasure exist. Pleasure is caused by a particular mix of chemicals in the brain. So is deliciousness, the specific pleasure associated with the flavors of food. An animal’s body produces those chemicals in order to reward it for doing those things that will aid its survival and chances at reproduction. As Lucretius recognized, this is as true for mice or fish as it is for humans.\(^3\) Displeasure is the opposite. It penalizes animals for doing things that make survival and reproduction less likely. Together, pleasure and displeasure are nature’s simple way of helping to ensure animals stay alive long enough to make more of themselves and pass on their genes.

One of the things any animal needs is to eat the right food. Just which food a species needs to be guided to, by pleasure, is predicted by a field of science called biological stoichiometry. Biological stoichiometry is perhaps the most boring possible name for a field with enormous consequences for how the world works. It is an obscure field. If you don’t study biological stoichiometry, you have probably never heard of biological stoichiometry.
Biological stoichiometry concerns itself with balancing various versions of a single equation. In the simplest version, the left side of that equation is made up of the bodies of organisms that have been eaten (the prey). Think about all of the animals, plants, fungi, and bacteria you have consumed in your own life. The right side of the equation is the body of the organism doing the eating (the predator), along with all of the waste it has ever produced and all of the energy it has ever used. As Lucretius put it, animals “borrow lives from each other.” They are relay runners that “pass along the torch of life.” Biological stoichiometry deals with the rule by which the baton is passed.

Stoichiometry’s rule is that the equation must balance; the nutrients present in the food and those in the consumer (and its waste and consumed energy) must ultimately match. This is where things get trickier, where the problem begins to resemble an elementary school homework question with a man and two dogs on one side of the river and a woman and a canoe on the other. If the body of a predator, for example, has a high concentration of nitrogen, so too must its prey. This seems so obvious as to not even bear writing down. Brillat-Savarin told us this: you are what you eat and you need to eat what you are. But the tricky part is that the equation linking predator and prey relates not just to, say, nitrogen and carbon; it also relates to any other nutrients that the predator cannot make for itself. As a result, the predator and prey must balance with regard to nitrogen but also magnesium, potassium, phosphorus, and calcium, each of which plays a role inside every animal cell.

We can actually write out the proportional number of molecules of each element present in the bodies of different species of animals (and hence the predator, or more generally, consumer, side of the equation). The average mammal, for example, can be described chemically by the list of elements in its body
and their relative proportions. Here is the ingredient list for making a mammal:

\[
\begin{align*}
H_{375,000,000^0} & \quad O_{132,000,000^0} & \quad C_{85,700,000^0} & \quad N_{64,300,000^0} & \quad Ca_{1,500,000^0} \\
P_{1,020,000^0} & \quad S_{206,000^0} & \quad Na_{183,000^0} & \quad K_{177,000^0} & \quad Cl_{127,000^0} \\
Fe_{2,680^0} & \quad Zn_{2,110^0} & \quad Cu_{76^0} & \quad I_{14^0} & \quad Mn_{13^0} \\
F_{13^0} & \quad Cr_{7^{0}} & \quad Se_{4^0} & \quad Mo_{3^0} & \quad Co_{1^0}
\end{align*}
\]

Mammals, such as humans, have 375,000,000 times more hydrogen (H) atoms in their bodies than cobalt (Co) atoms. Today, scientists can calculate the elemental ingredient lists of humans and other mammals with great precision. But how do wild mammals know how to find all of these elements in nature in order to have what their bodies need and balance their own stoichiometric equations, equations in which the ingredients they consume match those their bodies need? How does any animal know? How, for that matter, do you know?

For predators that eat their prey’s muscles, organs, and bones, hunger (and the pleasure triggered when hunger is sated) might be enough to balance the equation. Dolphins need only hunger and some kind of mental image of what food looks like when compared to non-food (something that tells them not to eat a rock). Things are mostly in balance.

For animals with diets that allow them more choices, things get trickier. For animals that eat plants (herbivores) or animals and plants (omnivores) life is especially challenging. As can be seen in figure 1.1, many elements are found in far higher concentrations in animals than in plants. If an omnivore randomly eats some plants and some animals, it will easily end up with a diet that is deficient in sodium, phosphorus, nitrogen, and calcium. Things are just as tricky for herbivores. How do herbivores and omnivores know how to balance their own stoichiometric equations? To a large extent, they make decisions based on flavor. Flavor is the summation of all of the sensory experiences
that occur inside an animal mouth. Flavor includes aroma, mouthfeel, and also taste. [6] Each of these components of flavor is important in guiding animals toward their needs, but taste plays a special role.

The English word *taste* comes from the vulgar Latin *tastare*, which some dictionaries contend is an alteration of the Latin word *tastare*, “to handle or grasp.” This alteration may be due to the influence of the Latin word *gustāre*, which means to taste. When we taste, we grasp with our tongues. The tongue is covered in taste papillae (the bumps you see in the mirror) in which are found taste buds each of which contains taste receptor cells layered like petals within a flower. [7] These cells are replaced every nine to fifteen days. Even as a vertebrate animal ages, its tongue is always being reborn. Tentacular hairs project from each taste cell. At the tip of these hairs one finds the actual taste receptors, waving in the mouth’s tumultuous sea.

Each type of receptor is a like a lock that can be opened only by a specific key. Open the lock with the right key and a signal is sent from the taste receptor along nearby neurons. From there, the signal splits and travels via separate nerves to each of several parts brain. One of the signal’s paths reaches the primitive, ancient fish part of the brain that controls breathing, heart rate, and other subconscious, necessary, elements of the body’s working. For tastes associated with elements that are needed—such as salt or sugar—one effect of the signal’s arrival in this primitive part of the brain is the release of dopamine. Dopamine triggers a flush of endorphins which you experience as a vaguely conscious sensation of pleasure; it is a pleasure that rewards animals for finding what they need. It also creates cravings: “I love this, I want more.” Another of the signal’s paths reaches the conscious part of the brain, the cortex. Once there,
it triggers the specific sensation associated with what has been tasted, such as “salt,” or “sugar.”

This taste system works because the elements any particular animal needs are relatively predictable. They are predictable based on the past: what an animal’s ancestors needed is likely to be what that animal also needs. Taste preferences, therefore, can be hardwired. Consider sodium (Na). The bodies of terrestrial vertebrates, including those of mammals, tend to have a concentration of sodium nearly fifty times that of the primary producers on land, plants (figure 1.1). This is, in part, because vertebrates evolved in the sea and so evolved cells dependent upon the ingredients that were common in the sea, including sodium. To remedy the difference between their needs for sodium and that available in plants, herbivores can eat fifty times more plant material than they otherwise need (and excrete the excess). Or they can seek out other sources of sodium. The salt taste receptor rewards animals for doing the latter, seeking out salt in order to reconcile their great need and balance their life’s stoichiometric equation.

Most mammals appear to have two kinds of receptors that respond to the sodium (Na) in salt (NaCl). One of the taste receptors responds to sodium above a certain minimum threshold concentration. If sodium is present above that concentration, it sends a signal to the brain. Pleasure ensues, as does the conscious perception of “salt.” Think of biting into a big soft laugenbrezel at the little shop between the airport and the train station in Berlin (or at least that is what we thought of while writing this). This first receptor leads mammals toward salt. For example, elephants walk hundreds of miles to muddy patches of salty soil. In doing so, they wear game trails deep into the ground, trails that trace the geography of their needs.
But as much as not eating enough salt (and hence sodium) is bad, eating too much salt can also be bad. The ingestion of too much salt can easily occur in mammals that live by the sea if they slake their thirst with salt water. To cope with this potential problem, mammals have a second salt taste receptor that detects high concentrations of sodium and, having done so, sends a signal of displeasure and a conscious perception of “too much!” to the brain. If you get a particularly salty bite of your laugenbrezel and feel compelled to brush off some of the salt, it is this second receptor at work. Salt taste receptors lead terrestrial mammals, whether they be mice, squirrels, or humans, toward the concentrations of salt that, on average, they and other terrestrial vertebrates have tended to need over the last tens of millions of years. They lead them toward those concentrations and, simultaneously, away from excess.

Lucretius imagined that fatty foods might be made up of smooth atoms and bitter or sour foods crooked, rough, and barbed ones. They aren’t. Instead, the experience any animal has of a particular food reflects how its taste receptors are connected to its brains. The sensation we experience associated with salt, the sense of the taste “salt,” is entirely arbitrary. We can know that other animals have salt taste receptors just like our own and we can know that those receptors trigger cravings and pleasure (thanks to detailed studies in mice and rats) and even at what concentrations, but we cannot know what “salt” tastes like in those other species. We don’t know exactly what the pleasure of encountering such a taste feels like in those other species. We don’t know anything about the experiences of tastes or pleasures in humans other than ourselves. We just assume they are always the same.

As you can see in figure 1.1, sodium (Na) isn’t the only element that is more common in vertebrate bodies, such as those of mammals, than in plants. So too is nitrogen (N). In plants
Tongue-Tied 9

and animals, nitrogen tends to be found in the amino acids and in nucleotides. Amino acids are the Lego bricks out of which proteins are made, and nucleotides are the bricks from which DNA and RNA are built.

Animals that eat some plants, be they pigs, humans, or bears, can easily end up with diets deficient in nitrogen. On average, animals have about two times as much nitrogen as plants, as a proportion of their body mass. How do omnivores and

Figure 1.1. The percent by mass of the elements most abundant and biologically “essential” in animals (horizontal axis), and how these compare with their abundance in plants (vertical axis). Elements with a positive values are more concentrated in animal than plant tissues. For example, sodium (Na) is nearly 50 times (or 5000 percent) more concentrated in the bodies of mammals than in the tissue of plants. Conversely, silica (Si) is slightly more concentrated in plants than in animals.
herbivores deal with this shortage? Some species just consume two (or more) times as much food as they need and void the excess. Like aphids, scale insects, for example, drink from the sugary phloem flowing through plant veins. In doing so, they gather the small amounts of nitrogen in what they have imbibed and as much sugar as they need, then excrete sugar water. That excess falls from them and is gathered by ants and some humans as a delicacy. (It is thought the manna of the Bible may have been the excess falling from the tamarisk manna scale insects, *Trabutina mannipara*, feeding on tamarisk trees.) But for mammals, this approach to balancing isn’t a great solution. Instead, a taste receptor for nitrogen, or one or another compound that is indicative of foods with nitrogen, seems like a better approach. But until 1907 no taste in humans was known to correspond to the presence of nitrogen, or the amino acids and proteins in which nitrogen is found, in food.

In 1907 Kikunae Ikeda, a chemistry professor at Tokyo Imperial University, was eating a bowl of broth that changed his life. The broth was dashi. Ikeda had consumed dashi before, but on this particular occasion he was struck by its deliciousness. It was salty, a tiny bit sweet and, well, there was a hint of something else, something very good. Ikeda decided he wanted to identify the origin of this extra taste, the very good taste that he would come to call “umami.” The word “umami” is rooted in the Japanese words for savory (*umai*) and essence (*mi*). It also means “a delicious taste and its level of deliciousness,” as well as “a skillful thing to relish, especially in relation to techniques in art.”

The recipe for dashi is superficially simple. It includes fermented fish flakes (katsuobushi),
9 water, and, in some cases, a special kelp (kombu). Ikeda knew the taste did not come from the water. It must then have come from either the fish flakes or the kombu. All Ikeda had to do was identify which compound
in the fish flakes or kombu triggered the taste he believed himself to have perceived, the taste of umami. This was easier said than done. A “simple” dashi broth can contain thousands of chemical compounds potentially able to produce tastes or aromas. Ikeda had to identify these compounds and test them one by one. According to the tally of Jonathan Silvertown in his book *Dinner with Darwin*, it took thirty-eight separate steps to finally extract some gritty crystals from the kombu kelp in the broth that appeared both to be relatively pure (a single compound) and to taste of umami. The crystals were glutamic acid. Glutamic acid is an amino acid; it is a building block of protein and so a reliable indicator of the presence of nitrogen in a food. The taste of umami is a taste that rewards us for finding nitrogen. Umami taste, triggered by glutamic acid, leads us toward our necessary amino acids. But umami taste is not triggered by glutamic acid alone.

Subsequent studies by other Japanese researchers would show that in addition to glutamic acid, inosinate and guanylate, two ribonucleotides, can also trigger umami taste. These two ribonucleotides are not found in the dashi’s kombu, but instead in the fish flakes. When inosinate or guanylate and glutamic acid are experienced together, they produce a kind of super umami. Glutamic acid and inosinate are experienced together in dashi. Dashi is rich with super umami, a flavor that is both deeply pleasing and indicative of the presence of nitrogen.

For decades, few scientists outside of Japan believed Ikeda’s result (nor, for that matter, the subsequent results related to inosinate and guanylate). But don’t feel too bad for Ikeda; he patented the method used to produce MSG in 1908. MSG results from the combination of glutamic acid and sodium. Thanks to that patent, Ikeda did just fine for himself. People were willing to pay for umami taste even before they believed it
to exist. As for why Ikeda’s work was neglected outside of Japan, it was partly because the first paper was written in Japanese and so not widely read by scientists in Europe and the United States. But it wasn’t just language, it was also a problem of mechanism. Although Ikeda could show that when his glutamic acid crystals were added to a food that they improved its taste, he hadn’t identified how the mouth tasted them. The taste receptor for umami would not be discovered for ninety years. The separate receptor that responds to inosinate and guanylate would take even longer to resolve. It was only once they were discovered that umami taste was widely accepted by most sensory scientists as a human taste.

If you return to figure 1.1, you will see that another element that is much more common in animals than in plants is phosphorus (P). Phosphorus is more than twenty times as concentrated in the bodies of animals as in the tissues of plants. A lack of phosphorus is a key challenge faced by many animal species. Why then isn’t there a taste receptor that detects phosphorus in food and rewards animals for finding it? One possibility is that foods, particularly foods in the form of whole animals with lots of nitrogen, typically also have sufficient phosphorus. Perhaps having a receptor for one of the two nutrients was sufficient. Nature often packages nitrogen and phosphorus together. Yet, this wouldn’t explain how herbivores or even most omnivores find phosphorus. Another possibility is that some animals do have a phosphorus taste receptor.

Michael Tordoff is a scientist at the Monell Chemical Senses Center (in the world of taste, all roads lead to Monell). He has specialized in laboratory studies of poorly charted tastes, including the taste of phosphorus. Since the 1970s, studies have shown that mice are able to somehow taste phosphorus salts. More recently, Tordoff was able to show that mice appear to be
able to distinguish between low concentrations of such salts (which please them) and high concentrations (which displease them).\[10\] Tordoff suspects that most mammals, including humans, have the ability to taste phosphorus salts and to distinguish pleasing concentrations of such salts from displeasing ones.\[11\] With the discovery of umami, the broad acceptance that umami was a taste required the discovery of the taste receptor for umami and its functioning. Tordoff is on his way to that step with phosphorus. Recently he even discovered what appears to be the receptor that alerts mice that they have found too high of a concentration of the phosphorus (in the form of phosphates).\[12\] No one has yet discovered the receptor that tells them when they have found just the right amount. It is possible that someday soon phosphorus may be accepted as an additional human taste.

You might imagine that the discovery of a new taste, a taste that you might be experiencing each time you eat, would trigger hundreds of follow-up studies. An award of some sort. Television interviews. It hasn’t yet. The world is full of mysteries. Even mouths are full of mysteries. As a result, Tordoff’s studies of the taste of phosphorus are cited by relatively few other papers. One of those papers demonstrates that cats, like mice, prefer foods that contain more phosphorus. Phosphorus is now added (as phosphate) to most cat foods to encourage cats to eat the food. Cats don’t need to believe or not believe Tordoff’s results in order to experience the pleasures, it seems, of phosphorus taste. Meanwhile, the other element that is scarce in animal diets relative to animal bodies is calcium. Tordoff thinks he has discovered evidence of a calcium taste receptor too.

Most of the elements and compounds we need in our diets are necessary for building new cells and other components of our bodies. Because of this, we need them in proportion to their
relative rarity or abundance within our bodies (that equation again). In addition, however, our bodies also need energy for daily activity; even once the building is built you have to keep the lights on. The more active a species is, the more such energy it needs. This is as true for insects as it is for mammals. The most active, aggressive, ants, for example, require the highest calorie diets.[13] Most of that caloric energy, whether for ant or elephant, comes from breaking apart carbon compounds.

Simple sugars, all of which are small carbon compounds, are easy for animals to convert into energy. Simple sugars include glucose, fructose, and the result of their biochemical marriage, sucrose. Sweet taste receptors reward animals for finding these sugars.10 They reward us with sweetness for eating mangos, honey, figs, or nectar. Complex carbohydrates, such as starches, are also sweet to many mammals. Old world monkeys, apes, and humans are unusual in that their sweet taste receptors do not respond to starch. However, these species produce an enzyme called amylase in their mouths. This amylase does not aid in the digestion of starch (which happens later) but has been hypothesized to break down some of the starch in the mouth so that it can be detected by the sweet taste receptor. Ancient humans, like modern gorillas or chimpanzees, produced some amylase in their mouths but not much. However, with shifts to more starchy diets, some groups of humans evolved the ability to produce more amylase in their mouths, perhaps to more quickly perceive starch to be sweet. Evolution can make bland foods sweet and vice versa, simply by changing how they are perceived.

The other source of energy for working cells is fat (protein can also be converted to energy, but is the body's last choice). Fats contain twice as much energy per gram as do simple sugars. Not surprisingly, many mammals appear to experience pleasure
in eating fat. For example, Danielle Reed (yet another scientist at the Monell Chemical Senses Center) used to give her laboratory mice a high fat diet. When she did they would, as she put it, go on a “Friday night binge. They would just eat all their fat and groom their hair with it and they’d just get in the middle of their fat. They love fat.” Surprisingly, it is not clear what it is about fat that mice or other animals enjoy. The answer may be mouthfeel. Fats have a pleasing mouthfeel (a gastronomic term for the sensation of touch as it is manifest inside the mouth). Put a piece of avocado in your mouth. It will be pleasing, but the pleasure is not the taste (it is not very sweet, nor sour, nor salty, nor really umami). Nor is the pleasure of the avocado its aroma, which is simple, often described simply as “green.” The pleasure is, instead, the feel, the smooth touch of the fruit, the same smoothness we experience when enjoying butter or cream. This touch is part of the story. But mysteries remain.

Salty, umami, and sweet taste receptors (and maybe also phosphorus and calcium taste receptors) evolved to point animals, through deliciousness, to what might otherwise be missing from their diet, whether in order to make new cells or, in the special case of simple sugars, to make new cells and to run them. But taste receptors can also serve the opposite purpose; they can point animals away from danger. They do so through feelings of displeasure. In some contexts, sour taste, which detects acidity in food, is displeasing. We will return to why this might be in chapter 7 (sour taste is mysterious and yet potentially very important to our human story). The more clear-cut case is that of bitter taste receptors. Bitter taste receptors allow animals to identify plants, animals, fungi, and anything else in nature that might be dangerous to ingest. For nearly all taste receptor types, animals have one or two (salt) basic classes of receptors. With bitter taste receptors, animals have many kinds.
Each kind of bitter taste receptor is triggered by one or more chemicals or classes of chemicals. Lucretius wrote of “nauseous wormwood,” a key ingredient in absinthe, whose “foul flavor set the lips awry.” We now know that it is the absinthin in wormwood that triggers one of our bitter taste receptors. And we even know which receptor (hTAS2R46, if you are curious). A different receptor responds to strychnine in plants; another responds to the noscapine found in poppies and their relatives. Yet another responds to the salicin in willow bark (and aspirin). Because being able to avoid toxic chemicals is very important (and failing to do so often results in having no offspring and so not passing on your genes) bitter taste receptors tend to evolve relatively rapidly. Species tend to have bitter taste receptors that reflect the dangerous kinds of compounds they are most likely to find in their environments. Humans and mice, for example, have about 25 and 33 kinds of bitter taste receptors, respectively, but the overlap between ours and theirs is modest. Some compounds that mice evolved to avoid (and hence taste as bitter) have no taste in our mouths and vice versa. Variation even exists among humans within populations. As Lucretius put it, “what is sweet to some, to others proves bitter.” As a result, a group of people might be able to detect more kinds of compounds as bitter than any individual. The combined knowledge of a community contains three types of bitter compounds then, those that everyone tastes as bitter (dangerous), those that some people think are bitter (maybe dangerous) and those that no one tastes as bitter (safe).

But, although most vertebrate species can detect many kinds of potentially toxic compounds via many types of taste receptor, and different individuals are able to taste different compounds as bitter, individual vertebrates perceive only one kind of bitter. All the bitter taste receptors are wired to a single nerve
and only register a single conscious perception BITTER. If a bitter compound is ingested in a high concentration, it can trigger nausea. If it is ingested at a high concentration twice (for example, via two gulps) the stomach muscles of the consumer stop contracting in rhythm. They begin to twitch out of sync which ultimately, if the dance of indigestion is sufficiently strong, triggers vomiting. Bitter taste receptors tell us things are bad and then, with vomiting, trigger both a reminder that they were serious and, with that reminder, expel some of the offending compound.

The displeasing sensation a species experiences in association with bitter compounds is just as arbitrary as that of saltiness or sweetness. Its key message is simply displeasure, displeasure that, like a stick, is meant to lead animals from things they are too stupid to avoid otherwise. As humans we have learned to sometimes ignore the bitter taste warning these receptors offer us, such as when we drink coffee, hoppy beers, or bitter melons. We do so even as our tongues cry out, “Bitter. Danger. Bitter. Danger.” “Hush now,” we say to our tongues as we enjoy coffee, tea, or hoppy beer. “Hush, I know how much of this toxin I can consume without danger. Hush, I know what I am doing. I have learned.”

What we’ve just described of the taste system is representative of the average terrestrial vertebrate. But as terrestrial vertebrates have evolved, their lifestyles have changed. Such changes have led to (or in some cases been caused by) evolutionary changes in taste receptors, such that each species perceives, with its mouth, a different world. Or, as Lucretius put it, “there are different senses in living creatures, each of which perceives in itself the object proper to it.” Some of the changes are subtle and relate to the thresholds at which particular compounds are detected. Others of the changes are more extreme and include the losses of entire tastes.
Perhaps the fastest of the slow ways taste receptors evolve is by breaking. Taste receptor genes tend to be large and so are prone to collect mutations that break them so they can no longer function. Over millions of years the genes for particular taste receptors have broken again and again when the desires (or avoidances) of an animal and its needs are mismatched. Cats, be they pumas, jaguars, or house cats, are strict carnivores (though see, in chapter 4, the special case of cats and avocados). Cats have evolved specialized forms of hunting so as to be extraordinarily good at killing their prey. If you look again at figure 1.1, you will see that an animal that only eats other animals will tend to have in its diet about the right concentration of nitrogen and phosphorus. It also ends up with enough energy, in the form of fat and sugars in its prey’s cells, to carry out its daily activity. Cats with sweet taste receptors are no more likely than those without to survive and flourish; if they spent too

<table>
<thead>
<tr>
<th>Taste</th>
<th>Substance</th>
<th>Necessary concentration to trigger response (parts per million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salty</td>
<td>Sodium chloride (NaCl)</td>
<td>2000 ppm</td>
</tr>
<tr>
<td>Sweet</td>
<td>Sucrose</td>
<td>5000 ppm</td>
</tr>
<tr>
<td>Umami</td>
<td>Glutamate</td>
<td>200 ppm</td>
</tr>
<tr>
<td>Sour</td>
<td>Citric acid</td>
<td>40 ppm</td>
</tr>
<tr>
<td>Bitter</td>
<td>Quinine</td>
<td>2 ppm</td>
</tr>
</tbody>
</table>

The minimum concentration of a substance needed to trigger a taste receptor varies greatly from receptor to receptor. Bitter taste receptors tend to be triggered by even very low concentrations of the chemicals to which they respond, such as quinine, a toxin produced by plants. These receptors evolved in order to warn us away, and that works best if it happens before we ingest a lot of whatever it is that has touched our tongue. Sugar, on the other hand, is most useful if it is in high concentrations. Below such concentrations our tongues don’t even know they’ve encountered something sweet. The other taste receptors fall in between. Sour is the most unusual of the taste receptors. It deserves special treatment so we’ll return to it in chapter 7. The data shown here are for a subset of studied humans. These thresholds, however, differ among species as well as among individual humans.
much time sipping nectar and too little time eating prey they might have even been less likely to survive. As a result, when the sweet taste receptor of an ancient cat broke, that cat survived nonetheless. It did more than survive, as Xia Li (at the time also a researcher at the Monell Chemical Senses Center) recently showed. It begat all modern species of cats. No modern cat species have functioning sweet taste receptors.\[15\] Forests of sweet fruits and nectar are not delicious to cats, not even a little. If you give a cat a sugar cookie, well, it really doesn’t care. It does not experience any pleasure in the cookie’s sweetness; the cookie, to the cat, is not sweet.

Like cats, other carnivores such as fur seals, Asian small-clawed otters, spotted hyenas, fossa, and bottlenose dolphins also have broken sweet taste receptors. All of these breaks in the sweet taste receptor gene occurred independent of each other; they are convergent forms of falling apart. One question one might ask about these carnivores is why others of their taste receptors haven’t also broken. Cats are unlikely to need more salt than their prey contain. That the cats’ salt taste receptors, as well as those of other carnivores, haven’t also broken may just be a matter of time. Sea lions have broken sweet taste receptors and broken umami taste receptors. Dolphins have taken this trend further. They no longer taste sweet, salty, or even umami.\[16\] They thrive on the basis of hunger and satisfaction alone, hunger, satisfaction, and the belief that anything that moves like a fish is dinner. This raises the question of just what it is about a prey item that pleases a dolphin. We don’t know. The pleasures of dolphins, whatever they are, are beyond the understanding of science, at least for now.

The loss of particular taste receptors is not the unique purview of predators. Losses have also occurred in animals with diets that are specialized in other ways. The ancestors of giant
pandas were bears. As bears, they were omnivores, drawn to living prey but also sweet berries and sour ants. But giant pandas evolved to take advantage of a new diet, one dependent on bamboo. On bamboo alone, they thrive. Initially, as they shifted to bamboo they enjoyed both the bamboo and meat. But with time, giant pandas that were still drawn to meat were either no more likely to survive and mate, or, even less likely, their wants and needs mismatched, their attention distracted. With time the umami taste receptors of giant pandas, like the sweet taste receptors of cats, broke.\footnote{17} Now, even if offered meat, giant pandas decline.\footnote{18}\footnote{16}

It is unlikely that the descendants of cats, sea lions, or dolphins will enjoy sweetness even long into the future, nor will giant pandas enjoy savory tastes, even though their preference for bamboo has led their populations to decline, in lock step, with declines in size of bamboo forests.\footnote{19} It is harder to make something from scratch when it is needed than to break it, a
lesson from evolution for daily life. Harder, but not impossible.

Sweet taste receptors, for example, have been lost, but they have also been regained. The ancestor of all modern birds, mammals, and reptiles lived about three hundred million years ago. That ancestor appears to have been able to taste salty foods, savory foods, and sweet foods. However, the ancestor of all modern birds lost its sweet taste receptor. For reasons that cannot yet be discerned, the sweet taste receptor was no longer useful. As a result, birds cannot detect sweetness. Or at least most birds can’t.

Hummingbirds descend from ancient swifts. Like modern swifts, these ancient swifts were exclusively insect eating. The ancient swifts were pleased by umami tastes, such as those associated with the bodies of insects or worms, but disinterested in sugars. However, roughly forty million years ago, one population of swifts began to feed on nectar and other sugar sources, perhaps simply to slake their thirst. The nectar was not sweet to the birds. To the extent to which it tasted like anything, it tasted like water. But unlike water, the nectar provided sugars. It has been hypothesized that individuals that drank more nectar were more likely to get energy and pass along their genes, so much so that their umami taste receptor evolved so as to be able to detect sugars in addition to the compounds that ordinarily trigger umami taste (amino acids such as glutamic acid as well as some nucleotides). This swift lineage would become the first hummingbird. Hummingbirds, unlike most birds, can taste sugars and amino acids. However, because they do so using a single receptor it is likely that they experience the two substances as the same, pleasurable sensation, sweet-umami.\[^{20}\]

These examples of the ways in which an animal species can come to find new things delicious and, in doing so, remedy its
deficiencies, are beautiful. They are the fine tuning of the ability of organisms to satisfy their needs through pleasure. The more we study the evolution of taste receptors, the more these stories seem to emerge. We can even predict where they might occur. Hummingbirds are not the only birds that feed on nectar. Sunbirds, flower-piercers, and honey-eaters are unrelated to hummingbirds, but they also feed on nectar and other sweet foods. It seems likely that they too have evolved the ability to detect sugary foods and be pleased by them. Three different desert mammals, in different deserts, have evolved the ability to feed primarily on plants that exude salt. Doing so required them to evolve extraordinary traits that make this lifestyle possible, such as hairs in their mouths that help to scrape salt from the plants. These salty-plant-eating mammals have no need to seek out extra salt and so it seems likely that they have lost their salt taste receptors. But all this fine tuning raises an interesting question when we consider our own lineage.

We are primates, which is to say we are related to lemurs, monkeys, and apes. Within the primates, our narrower branch is that of the hominids, which includes us as well as gorillas, chimpanzees, bonobos, orangutans, and an entire zoo of extinct relatives. Within the hominids, we are the sole surviving member of the tribe Hominini, the hominins. If we look across the entirety of the primates, species differ greatly in their taste receptors. They differ both in what their receptors detect and the thresholds at which they detect them. Some plants that are bitter to us (and deadly) are not bitter (nor dangerous) to some of the monkeys, for instance. Additionally, while we appreciate foods with a relatively low concentration of sugar to be sweet, marmosets only perceive foods to be sweet if the sugars are highly concentrated. In other words, comparing species across the entirety of the primates we see differences, some of them
quite big. But then here is the curious thing. If we compare ourselves to our closest living relatives, the chimpanzees, our taste receptors are actually very similar to their taste receptors. What is delicious to a human is, for the most part, delicious to a chimpanzee. This is surprising since, in the time since our shared ancestor, we and chimpanzees have embarked on radically different culinary paths. Chimpanzees live in the forest and, to a lesser extent, grasslands, and eat fruit, insects, and the occasional leg of monkey. We colonized nearly all of terrestrial Earth. As we did, we came to eat something different in each new habitat. Why hasn’t the difference between our diet and that of chimpanzees precipitated some kind of major change in taste receptors? In part, the answer is that there have been some subtle changes, if we look closely enough. But there is something else.

When our ancestors began to develop culinary traditions and tools, they found ways to take the foods of any habitat and alter them so as to make them more delicious. In doing so, they dulled natural selection’s effects on their taste receptor genes. They dulled nature’s effects on which versions of such genes were passed one generation to the next. Our ancestors did not have to wait for natural selection to solve dietary deficiencies through the differential survival and reproduction of individuals with more locally relevant taste receptor genes. They compensated for bland diets by using tools to seek out flavor. Those flavors were often (though not always) indicators of what they needed. This is what Lucretius might have called a “swerve.” Through a modicum of consciousness and a pinch of free will our ancestors altered their situation. In doing so they changed the world. In seeking deliciousness, they caused a swerve in the story of their kind, of our kind. This swerve, as we’ll argue in the next chapter, was a key step in the evolution of our ancestors.
They figured out how to make tools to find foods that were tastier than those that were otherwise available. They used tools to make their habitats more delicious, then they used tools to help make the landscapes wherever they traveled more delicious. In this way, the pleasure of deliciousness was central to human evolution.
### INDEX

A page number in *italics* refers to a figure or table.

- absinthe, 16
- acetic acid (vinegar): aroma of fermented herring and, 179; sour taste of, 164
- acetic acid bacteria, 156, 162, 165, 166
- acidic foods, free of pathogens, 162, 166
- adrostenol, 58, 59
- adrostenone, 229n21
- agouti meat, 102
- alcohol: favoring some bacteria over others, 166, 202; in fermented foods and drinks, 156–57; intoxication by, 166–67; metabolism in liver of hominids and, 166–67; pleasure induced by, 167, 169, 180
- alcohol dehydrogenase, 166, 180
- algae, eaten by chimpanzees, 30, 34
- allicin, 141–42
- alliin, 141, 234n8
- alliinase, 141, 235n8
- alliums, 141–43. See also garlic
- almendro fruits, 159–60, 161
- *America’s First Cuisines* (Coe), 105
- amino acids: nitrogen in, 9, 10, 11; produced by bacteria, 35; tasted by hummingbirds, 21
- ammonia aroma, of fermented shark, 239n12
- amylase, 14
- ancient humans: atrophied food-processing body parts of, 49–50; defined, 32; with different diets in different regions, 50–51; experience of flavor in, 69; fermentation of fruits by, 167–69, 180; fueling a larger brain with new food ways, 32–33, 36; honeybees and, 32–33; hunting animals of Europe and Asia, 83; learning new aromas and flavors, 75–76, 77–78; processing foods, 32, 34–37; shellfish in diets of, 33–34, 48, 51; with smaller teeth than chimpanzees, 32, 33, 49–50; tools of, 34–35, 77–78. See also *Homo erectus*
- Ancient Mesopotamia Speaks (Lassen, Frahm, and Wagensonner), 142
- anise, 130; eaten in pregnancy, 135, 140
- ants: eaten by primates, 41, 43; fruits appealing to, 116
- Apicius, spiced meat recipe of, 144–45
- apple cider, 168
- Arandjelovic, Mimi, 164, 223n25
armadillos: bear-sized (glyptodonts), 122, 123; meat of, 102

aromas: of alcoholic fruits, 169; of animal’s food appearing in their meat, 99, 102; of cheeses, 193, 197, 199–200, 240n3; complex, 48, 70–72, 168, 199–201; as component of flavor, 6, 53–54, 67; differences among species in perception of, 54; evolution of sense of smell and, 63–64, 66–67; of fermented foods, 167, 168, 172, 173, 179–80; of fish, 136; of fruits attractive to mammals, 116; of greenness, 136; hardwired in mammalian brains, 57–58; individualized categorization of, 74–75, 226n13–14; innate human predispositions toward, 69–70; learning to identify, 73, 74, 199–200; loss of transverse lamina and, 66–67; path of exhalation in humans and, 68; prenatal and neonatal experiences of, 134–37, 139–40, 233n4–5, 234n6; ranked in memory, 75; of toxic plants, 133–34; of truffles, 62–63. See also olfactory bulb; olfactory receptors; orthonasal aromas; retronasal aromas

The Art of Natural Cheesemaking (Asher), 196
Asher, David, 196
Asiago, 192
aspirin, 16

Australopithecus: bipedalism changing olfaction in, 67–68; evolutionary changes in, 31; experience of flavor in, 69; forest diet of A. sediba, 219n7; honeybees and, 33
avocados: enjoyed by cats, 96; mouthfeel of fats in, 15, 96; undispersed seeds in wild relatives of, 118–19
awamori, 201
Axel, Richard, 73
Aynaud, Carole, 60
Aynaud, Edouard, 60–61, 62

bacteria, fermenting. See acetic acid bacteria; lactic acid bacteria
bacteria, pathogenic: killed by acid, 162, 166; killed by alcohol, 166
Baker, Samuel White, 109
Barkai, Ran, 108–9, 110, 184, 230n28
barley beer, 157, 158, 236n2
Bates, Henry, 102
bats, aromas of fruits appealing to, 116
bears: meat of, 229n17; in megafauna, 88
beer: brewing process for, 236n2; cheeses washed in, 199, 201; preceding onset of agriculture, 157–58; sour, 156, 157, 162. See also hops
bees. See honeybees
Benedictine monks: cheeses made by, 189–90, 197; diet of, 189, 195, 201, 241n4; rule book for, 188, 191, 241n4. See also monasteries
Berbesque, Colette, 44–46, 229n19
big mammals: in cave paintings, 60, 112–13; Clovis people’s killing and eating of, 84–88; encountered by first Americans, 83–84. See also megafaunal extinctions
Billing, Jennifer, 143
biological stoichiometry, 3–5; salt and, 7
bipedalism: energy saving derived from, 218n3; evolution of, 30, 31; olfaction changed by, 67–68
birds: able to taste sugars, 21, 22; attracted to colorful fruits, 116;
capsaicin in chilies and, 149, 235n13; eaten into extinction, 89; fat in some seabirds, 229n15; meat of, 101, 229n18
A Bite-Sized History of France (Hénaut and Mitchell), 199
bitter leaf, as medicine and spice, 139, 234n7
bitter taste: added to dangerous products, 217n13; of hops in beer, 17, 133, 146; of leaves eaten by howler monkeys, 102–3; newborn baby’s response to, 234n15; not detected by some monkeys, 22; reduced by fermentation, 168; sometimes ignored for coffee or beer, 17; stronger in children, 217n14; of toxic seeds spit out by monkeys, 231n2; of toxins intentionally used, 134
bitter taste receptors, 15–17; differing among animal species, 96, 133; differing between humans and chimpanzees, 39, 220n14; differing between individual people, 16; differing between recent human lineages, 51, 224n27; nausea and vomiting associated with, 17; phenylthiocarbamide and, 224n27; toxic plants and, 133–34
black pepper, 131, 147–48, 235n13
Blake, Michael, 158
bloomy-rind cheeses, 194, 198
blue cheeses, 195–96. See also Cabrales cheese
Boesch, Christophe, 27, 164
Boethius, Adam, 177–78
bones: DNA extracted from, 51, 223n26; eating marrow and grease of, 51
bone tools, of first people in the Americas, 84
Booth, Alvin, 203, 204, 208
Boswell, James, 25, 80
Braccioli, Poggio, 2–3
brain: aromas that are hardwired in, 57–58; cataloging aromas, 72, 73–75, 78, 225n10, 226n11; evolving larger size in ancient humans, 31, 32, 33, 36, 50; receiving signals from taste receptors, 6–7. See also learning; olfactory bulb
Breslin, Paul, 155
Brevibacterium linens, 196, 197, 198
Brie de Meaux, 194, 202
Brillat-Savarin, Jean Anthelme, xi–xii; on cooking, 220n11; on distinguishing flavors, 80; on eating oysters, 34, 47–48; on eating slowly, 223n24; on foods disliked by French, 223n22; on happiness from eating new dish, 83; on human experience of flavor, 68–69; on infinite number of flavors, 129; on needed nutrients, 4; on sense of smell, 53; on sociability of meals, 209–10; on things of no importance, 41; on uses of taste, 1
browning of cooked food, 71, 225n7
Bruno-Bárcena, Jose, 182–83, 186, 188
Buck, Linda, 73
buffalo milk cheese, 191
bulbs: defined, 219n4; giving flavor to peccary meat, 101; as spices, 131
Bunyard, Edward, 182, 193, 240n1
butterflies and moths, sex pheromone of, 225n3
Byron, Lord, 114
cadaverine, 57, 58, 225n2
caffeine, 133
calcium, possible taste receptor for, 13
Camembert, 135, 194
capsaicin, 148, 149
capuchin monkeys, 159–60, 161, 168
carbohydrates: broken down in rumen, 100; complex, 14; as energy source, 14, 98
carbon compounds, metabolized for energy, 14
 carnivores: broken sweet taste receptors of, 18–19; storing and fermenting meat, 238n9; taboo against eating meat of, 228n10
carrion-feeding animals, 58, 106, 163, 171, 228n10
Catching Fire (Wrangham), 36
Cato the Elder, on salting ham, 176–77
cats: broken bitter taste receptors of, 96; broken sweet taste receptors of, 18–19, 96; enjoying avocados, 96
cave paintings: of Cantabria, 183–84; of the Dordogne, 60, 111–13
Chapman, Ben, 147
Cheese and Culture (Kindstedt), 199
cheeses: aromas of, 193, 197, 199–200, 240n3; easier to make hard than soft, 186; fresh, 190–91; influenced by animal’s diet, 190–91, 240n3; learning to discriminate between, 200; made by monasteries, 189–90, 193–94, 196–201, 241n8; as means for storing milk, 186; shipping and storing, 186, 191; sulfurous, eaten during pregnancy, 135–36. See also hard cheeses, aged; soft cheeses, aged
chemesthesis, 147–52
chemical elements: in animals vs. plants, 5, 8–10, 9; in mammals, 4–5
tasting: to experience full flavors, 223n24; food softened by fermentation and, 46–47, 168, 180; made easier by processing, 47; of shellfish, 47–48
chili peppers, 149–52, 235n12–13, 236n14; attracting birds, 149, 235n13; as fruits, 130–31
Chimay cheese, 199, 201
chimpanzees: alcohol metabolism in, 166–67; calls of, 207–8; crabs eaten by, 34; culinary traditions of, 28–29, 37, 218n1; eating colobus monkeys, 90, 205, 209, 242n4; eating figs, 44, 221n15; enjoying sour taste, 38, 164–65; experience of flavor in, 67; as gourmets, 41, 43; Goodall’s studies of, 25–27; human body’s differences from, 37–38; human researchers eating foods of, 39–40; learning to enjoy new fruits, 76–77; meat in diet of, 48–49, 222n20, 223n25 (see also colobus monkeys); not mixing multiple ingredients, 130; oxytocin in, 206, 243n5; plants eaten by, 39–40, 220n13–14, 221n15; preferring cooked vegetables and meat, 48–49, 223n25; prenatal learning of beneficial foods and, 136; seeking flavors, not necessarily nutrients, 41, 42–43, 222n18; sharing food, 205–6, 209, 242n4; sour taste and, 38, 164–65; taste receptors similar to human ones, 23, 37–38; tools of, xiv, 26–29, 29, 30, 32, 35, 37, 41; using plants as medicine, 234n7. See also common ancestor of humans and chimpanzees
Chinese Gastronomy (Lin and Lin), 46, 70
cider, 168
cinnamon, 148, 235n12

citric acid, 18, 164

climate change, and megafaunal extinctions, 90, 228nn7–8

*Clostridium botulinum*, 171

*Clostridium perfringens*, 171

Clovis people, 82; changed after megafaunal extinctions, 90; eating large quantities of meat, 84, 86–88; Fisher’s speculations on fermentation by, 169–75; hunting megafauna, 84–88, 91, 119; killing predators not eaten, 95; likely food preferences of, 105–8; limits of our information about, 103–5; pursuing pleasures of food, 110–11

Clovis points, 82, 84, 85, 90

Coe, Sophie, 105

collagen, in meat, 98

colobus monkeys, eaten by chimpanzees, 90, 205, 209, 242n4

common ancestor of humans and chimpanzees: enjoying honey, 44; as gastronomes, 41, 43; prenatal learning of beneficial foods and, 136; seeking flavorful foods, 40–41; using newer kinds of tools, 43–44, 46–47; using plants as medicine, 234n7

complex aromas, 48, 70–72, 168, 199–201

complex carbohydrates, 14

complex flavors, 200–201

cooked meat: aromas of, 48, 70–72; Brillat-Savarin on, 220n11; of Clovis people, 82, 86, 87, 104–5; compared to raw meat, 47–48; of Fisher’s fermented horse, 173; in Homer’s *Iliad*, 86–87; increased glutamate in, 48; Neanderthals and, 78–79, 87; from older animals, 104–5; of peoples descended from Clovis, 87, 227n4; preferred to raw by chimpanzees, 48–49, 223n25; sources of flavor in, 97–98; spices used with, 143–45, 144. See also stews

cooking: earliest history of, 86; at high temperatures, 71; improving flavor, 36–37, 48–49, 72; Maillard reaction and, 71, 177; reducing chewing time, 46–47. See also cooked meat; fire cooking pots, 139

corn: fermented by ancient Native Americans, 158; spices used with, 147, 153

Craig, Oliver, 137–39

Crittenden, Alyssa, 220n12

Croatia, stone pen in, ix–x, xviii

Cro-Magnon humans, 111

cuisine: of chimpanzees, xiv, 28–29, 37; defined, 28

culinary endangerment, 103

culinary extinctions, 79, 89–90

culinary traditions: of chimpanzees, 28–29, 37, 218n1; defined, 28

culture and diet, 28

cutting foods, 46–47, 78

dandelions, 134

Darwin, Charles, 25, 26, 102, 210–11

dashi, 10–11, 217n9

deer meat, 100

deliciousness, xii; beginning of cooking and, 36–37; of cheese that’s hard to make, 186; improved by togetherness, 210; of proboscideans, 108–10; tool use by our ancestors and, 23–24. See also flavor; pleasure

Denisovans, 51

*De rerum natura*. See Lucretius

*The Descent of Man* (Darwin), 25

desert mammals, eating salty plants, 22
dill, 134
dimethyl sulfide: babies preferring aroma of, 136; from truffles, 59
*Dinner with Darwin* (Silvertown), 11
displeasure: bitter taste receptors and, 15–17; excess of salt and, 8; Lucretius on, 1–2, 3; of medium-length fatty acids, 217n12; memory of an aroma and, 75
disulfide bonds, aroma associated with, 225n4
dodo, eaten into extinction, 89
dogs: ancient relationship to kitchen and, 225n5; chemicals deposited in fat eaten by, 99; human experience of flavor compared to, 69; hunting truffles, 54, 59, 60–62, 65, 69; noses of, 64–65
dolphins, broken taste receptors of, 19
dopamine: sensation of pleasure and, 6; social bonds and, 206
*Dordogne*: cave art in, 60, 111–13; hunting truffles in, 60–62; Neanderthals in, 59–60, 78–79, 111, 231n31
drying meat, 175–76
duiker meat, 102

**Entangled Life** (Sheldrake), 56
Epicurus, 2
Époisses, 135, 198–99
Ertebølle hunter-gatherers, 138–39
Estienne, Vittoria, 222n18
ethanol. See alcohol
Evans, Josh, 230n22
extinct animals. See megafaunal extinctions
extinct flavors, 88
extinct plants, 227n6

fat: chemicals held in, 98, 99, 100; cultural differences in liking of, 105; energy from, 14, 98; factors affecting an animal’s amount of, 98, 228n14; fermented, 105; of fruits attractive to mammals or ants, 116; in meat, 98–99, 105, 107; in meat of elephant feet, 109, 110; in meat of some seabirds, 229n15; mouthfeel of, 15, 98, 105; pleasurable to mammals, 14–15; as triglycerides, 217n12
fatty acids: adding flavor to meat of ruminants, 100; in goat cheese and buffalo cheese, 191; tastes of, 98, 217n12
fear, aromas hardwired for, 57–58
*Feast* (Jones), 211
fermentation: acidic foods and drinks made by, 156–57; acidity as indicator of safety and, 161–62; before agriculture, 158; alcoholic foods and drinks made by, 156–57; aromas of foods and, 167, 168, 172, 173, 179–80; benefits of, 35–36, 168; of fish, 177–81; of fish flakes (katsuobushi), 10–11, 216n9; of fruits, 156, 158, 160–62, 167–69, 180, 237n6; improving flavor, 168; making food soft for
chewing, 46–47, 168, 180; of meat, 35, 48, 169–75, 177–81, 238n9; microbiological definition of, 156; nutrition enhanced by, 168; in ruminants’ digestive tract, 100; for storing fruits and vegetables, 168; of tofu, 201–2. See also beer; cheeses

fire, 36–37, 78, 220n11–12; communication at gatherings around, 210. See also cooking

first people in the Americas, 82–83

fish: eaten while breast-feeding, 136; fermentation of, 177–81, 239nn11–12

Fisher, Daniel, 169–75, 177

fish flakes (katsuobushi), 10–11, 216n9

fish sauces, 179, 239n13

Fjeldså, Jon, 100, 101, 102, 229n15, 229n18

flavor: of aged soft cheeses, 193; aromas as component of, 6, 53–54, 67; complex, 200–201; components of, 6; food preferences of chimpanzees and, 40–41; guiding animals to their needs, 5–6; improved by cooking, 36–37, 48–49, 72; loss of transverse lamina and, 67; more available with processing, 34; prenatal and neonatal experiences of, 134–37, 139–40, 233nn4–5, 234n6. See also deliciousness

flavor of meat: bearing flavors of animal’s diet, 100–103, 229n18; eaten by hunter-gatherers, 91–97, 97, 113; fat and, 99, 228n14; fermentation and, 168; fruits eaten by animal and, 100, 101, 102, 106, 113; of herbivores, 99–103; muscle and, 97–98, 106–7; of omnivores, 99–103, 229n17; of predators, 99; of ruminants, 100, 102, 105; sources of, 97–98; of white meat vs. red meat, 106–7. See also cooked meat

flavor-seeker hypothesis, 37

food-borne illness: antimicrobial compounds in spices and, 140–41, 141, 143, 145, 146, 153; aromas associated with, 140; black pepper as source of, 147; studied by specialists, 212

Frank, Hannah, 163, 164

fresh cheeses, 190–91

fructose, 14; in honey, 45

fruits: complex aromas of, 72; evolved for dispersion of seeds, 115–17; fats in, 116; fermentation of, 156, 158, 160–62, 167–69, 180, 237n6; giving flavor to meat, 100, 101, 102, 106, 113; qualities appealing to different animal groups, 116; spices in form of, 130–31 (see also chili peppers); undispersed, 118–19. See also megafauna fruits

fungi. See Penicillium fungi; truffles

Garcia effect, 140

garlic, 134, 141–43, 234n8; in amniotic fluid, 135, 233n4; antimicrobial properties of, 141, 142, 145–46

garlic mustard, 138–39

garum, 239n13

gastronomy, xi–xiii, 41

gastrophy, 107

Gastrophysics (Spence), xiii

giant mammals. See big mammals; megafaunal extinctions

giant pandas, 19–20, 20, 218n16

giant sloths: of Costa Rica, 121, 123; killed by Clovis people, 84, 88; questionable flavor of, 230n24. See also sloths
glucose, 14; in honey, 45
glutamate: freed by cooking or fermenting meat, 48; taste threshold of, 18
 glutamic acid, 11, 12; formed in fermentation, 168
glyptodonts, 122, 123
goat milk and cheese, 191
gomphotheres, 88, 106, 108, 122, 123
Goodall, Jane, 25–27
gorillas: alcohol metabolism in, 166–67; experience of flavor in, 67; food preferences of, 38, 221n15–17; mutation in sweet taste receptors, 41–42, 221n17; preferring cooked vegetables, 48–49; sour taste enjoyed by, 165; using plants as medicine, 234n7
Gotelli, Nick, 211
Gouda, 192, 241n6
grains: domesticated in order to ferment, 158; spices to flavor simple dishes of, 147, 153
grapes, fermentation of, 237n6
grasses: giving flavor to cheeses, 190–91; in mammoth diet, 106, 108
grassland plants, silica in, 131
grinding, 46–47, 78
grizzly bear meat, 229n17
grouse, 101, 102
Gruyère monastery, 198
guanulate, 11, 12
Guénard, Benoit, 201
Guevara, Elaine, 42, 221n17
Guthrie, Dale, 230n23
hackberries, 137
Hadza hunter-gatherers, 44, 101, 220n12, 223n22, 229n19
Halwachs, Winnie, 117
ham, salting of, 176–77
haplorhine primates, evolutionary changes in, 65–69
hard cheeses, aged, 190, 191–92, 199
Harrison, Jim, 80–81, 227n1
Haynes, Gary, 84, 109, 229n17, 230n28
Haynes, Vance, 82
heat receptors: of birds or rodents, 149; in mouth and nose, 148
Hénaut, Stéphane, 199
Henry, Amanda, 219n7
herbivores: balance of chemical elements in, 5, 9–10; chemical defenses of plants and, 131–34; flavor of meat of, 99–103; phosphorus and, 12; seeking out salt, 7
herbs, 130; meat of animals feeding on, 101
herring, fermented, 178–79, 180, 239n11
Holmberg, Allen, 130
Homer’s Iliad, sacrifice of cattle in, 86–87
Homo erectus, 31–32; fermentation and, 167; olfactory libraries of, 75–76; protein from fossil teeth of, 223n26
Homo sapiens, 51, 213
honeybees: calmed by smoke or plant exudates, 32–33, 44, 220n9; chimpanzees accessing honey of, 32, 42–43, 222n18; chimpanzees eating bee brood, 42, 222n18; Hadza hunter-gatherers and, 44–46; honey-making process of, 45
honey locust trees, 126–27, 127
hops, 17, 133, 146
horse meat: fermented in Fisher’s experiment, 172–75; flavor of, 100–101
horseradish, 148
horses: in cave paintings, 60, 112; giant, 88; Janzen’s fruit experiments with, 122–24; preferring sweet to sour or salty taste, 232n5
howler monkeys, disliked meat of, 95, 96, 102–3
human ancestors, 30–31. See also ancient humans; common ancestor of humans and chimpanzees; recent humans
hummingbirds, 21
hunter-gatherers: Efe people, 33; Ertebølle people, 138–39; fires of, 220n12; first people in the Americas, 83; flavors of meat eaten by, 91–97, 97, 113; Hadza people, 44, 101, 220n12, 223n22, 229n19; Mayangna and Miskito in Nicaragua, 93–97, 94, 97; pounding food, 35; spices and, 130, 137–39. See also Clovis people
hunters: choosing prey with preferred flavor, 95, 101; of Europe and Asia for a million years, 83; first people in the Americas, 83–84; optimal foraging and, 91, 93, 94, 95. See also megafaunal extinctions
Hutson, Jarod, 84
Ikeda, Kikunae, 10–12
inosinate, 11, 12
insects as food: ants eaten by primates, 41, 43; concentrating flavors of their diet, 230n22
jamón ibérico, 177
Jänig, Susann, 67
Janzén, Daniel, 116–24, 232n6
Japanese monks, 201
jicaro fruits, 122–24
Jones, Martin, 211
Kalan, Ammie, 207
katsuobushi, 10–11, 216n9
Kays, Roland, 230n24
KCNK receptors, 148–49
Kindstedt, Paul, 193
Koko the gorilla, 49
kombucha, 157, 160, 161
Koster, Jeremy, 92–96, 98–99, 228nn10–11, 228n14
Kuehl, Hjalmar, 46, 223n25
Kurlansky, Mark, 177
lacrimators, 142
lactase, 38
lactic acid: consumed by fungi on cheese, 196, 241n9; sour taste of, 164
lactic acid bacteria, 156, 162, 165, 166; cheeses and, 196, 241n9; in Fisher’s fermenting meat, 173, 174, 175
Lactobacillus: in Fisher’s fermenting meat, 174, 175; fruits made sour by, 167
Lambert, Joanna, 106
Lanning, Nike, 204, 208
learning: chimpanzees enjoying new fruits and, 76–77; by Clovis people, 86; of cooking methods by our ancestors, 227n13; to enjoy repulsive aromas, 180; to enjoy spicy food, 151, 152; to identify aromas, 73, 74, 199–200; to like hops in beer, 146; to like or dislike aromas, 139–40, 145; to love flavors, 72; of new aromas and flavors by ancient humans, 75–76, 77–78; of reaction to sour taste, 155
leaves: spheres of chemicals on, 130, 132, 233n12; of trees, and flavor of meat, 102–3, 106
leftovers, plant parts used for preservation of, 139
lemons, 77, 131, 162, 164
Lévi-Strauss, Claude, 227n4
Li, Xia, 19
Lieberman, Daniel, 39, 66, 68
Lin, Hsiang Ju, 46, 70
Lin, Tsuifeng, 46, 70
Liu, Li, 157
Lost Feast (Newman), 89
Lucretius, 1–3, 4; on atoms of foods, 8; bitter tastes and, 16; on different senses in different creatures, 17; on odors, 53; on a swerve, 23
Madden, Anne, xvii
Maillard, Louis Camille, 71
Maillard reaction, 71, 177
Mallot, Liz, 159–60, 161, 237n3
mammals: chemical elements in, 4–5; fruit qualities with attraction for, 116. See also big mammals
mammoth meat, 80, 230n28; of delicious feet, xv, 110, 129–30; imagined cuts of, 92; of red muscle, 107
mammoths: in cave paintings, 60, 112; climate change and, 228n7–8; killed by Clovis people, 84, 88, 90, 106, 110, 238n7; stone tools found with bones of, 82; surviving until 2000 BCE, 89; woolly, 89, 108, 228n8
Manchego, 192
manna of the Bible, 10
Maroilles, 198
Martin, Paul S, 88–89, 95, 119, 121–22
Martinez del Rio, Carlos, 105

mastodons: apparently stored by Clovis people, 169–70, 174–75; with bone point in rib, 84; climate change and, 228n7; delicious meat of, 108; fruit-eating, 121–22; killed by Clovis people, 84, 88, 106, 169–70, 238n7
Mattes, Richard D, 217n12
Maupassant, Guy de, 100–101
Mauritius red rail, eaten into extinction, 89
Mayangna people, 92–93; food preferences of Waorani and, 103, 104; tastiness of different animals and, 97, 100, 101–3
McGee, Harold, 46, 70, 72
meat: with aromas from animal’s food, 99, 102; in chimpanzee diet, 48–49, 222n20, 223n25 (See also colobus monkeys); connective tissue in, 33; cut to facilitate digestion, 35; dangerous bacteria in decay of, 171; eaten by Clovis people, 84, 86–88; eaten by Neanderthals, 78–79, 84, 86; fat in, 98–99, 105, 107, 109, 110, 229n15; fermentation of, 35, 48, 169–75, 177–81, 238n9; with flavors from animal’s food, 102–3, 229n17; of organs, 107; processing of, 47; raw, 34, 46, 223n23; red vs. white, 106–7. See also cooked meat; flavor of meat
megafauna fruits, 113, 114, 118–24, 232n6; of almendro tree, 159–60; dispersed after megafaunal extinction, 124–28; human contribution to survival of, 125–28; stinking toe tree, 118–20, 120, 128
megafaunal extinctions, xv; causes of, 90–91; climate change and, 90,
228nn7–8; as culinary extinctions, 89; ecosystem changes caused by, 90; in Europe, 89, 112–13; hunting by Clovis people and, 88, 90–91, 119; of non-ruminants vs. ruminants, 230n23; undispersed fruits and, 119–26. See also big mammals

menthol, 72, 73, 148

milk: flavors from cooking at high temperatures and, 225n8; lactase in adults and, 38; microbes from udders and skin contained in, 240n3; plant compounds contained in, 240n3; stored by making cheese, 186

mint, 73, 75, 132, 134, 148

Miskito people, 92–93, 94; food preferences of Waorani and, 103, 104; tastiness of different animals and, 97, 100, 101–3

Mitchell, Jeni, 199

moas, eaten into extinction, 89

monasteries: cheeses made by, 189–90, 193–94, 196–201, 241n8; origin of, 188. See also Benedictine monks

monkey meat: of colobus eaten by chimpanzees, 90, 205, 209, 242n4; of disliked howler monkeys, 95, 96, 102–3; of fruit eating species, 100, 102, 103

monkeys and sour tastes, 163–64

Mouritsen, Ole, xiii

mouthfeel: of aged soft cheeses, 193; as component of flavor, 6, 46, 68; defined, 15; diverse experiences of, 46; of fat, 15, 96, 98, 105; improved by processing, 46, 47; of muscle in cooked meat, 97

Mouthfeel (Mouritsen and Styrbak), xiii

MSG, 11–12

Munster, 135, 198, 241n12

muscle, flavor of, 97–98, 106–7

mustard, 148

Nabhan, Gary, 81, 101

Navajo, eating meat of animals feeding on sage, 101

Neanderthals: coexisting with Homo sapiens, 231n31; cooking meat, 78–79; diet in a Gibraltar cave, 226n15; in the Dordogne, 59–60, 78–79, 111, 231n31; eating meat, 84, 86; elephants butchered by, 109–10; experience of flavor in, 69; hackberries found on hearth of, 137; hunting animals of Europe, xv, 83; taste receptors of, 51; tasting of phenylthiocarbamide and, 224n27

Neuroenology (Shepherd), xiii, 75, 199–200

Neurogastronomy (Shepherd), xiii, 64

Newman, Lenore, 89

night monkeys, liking sour taste, 164

Nishida, Toshisada, 39–40, 76, 164–65, 220n14, 221n15

nitrogen: added to food by fermentation, 168; in animals vs. plants, 8–10; in carnivore diet, 18; in panda’s bamboo diet, 218n16; phosphorus found with, 12; umami taste and, 10–11

non-ruminants: extinction of, 230n23; likely preferred by Clovis people, 105–6, 230n23. See also megafaunal extinctions; proboscideans

Norbrook, David, 215n3

noscapine, 16
nose: of dog, 64–65; of human, 52, 65–67; of pig, 55, 57. See also olfactory receptors; orthonasal aromas; retronasal aromas nucleotides, 9, 11

odors. See aromas

okapi meat, 243n6

oleogustus, 217n12

olfactory bulb, 57, 64, 72–73, 226n11

olfactory receptor codes, 73, 74, 226n12

olfactory receptors, 57, 72–73; of dog, 65; evolution of, 63–64, 66; of humans, 66, 225n10. See also nose

omnivores: balance of chemical elements in, 5, 9–10; flavor of meat of, 99–103, 229n17; phosphorus and, 12

On Food and Cooking (McGee), 46, 70

onions, 141–42

On the Nature of Things. See Lucretius

optimal foraging, 91, 93, 94, 95; by predatory mammals, 96

opuntia cactus fruit, 232n6

orthonasal aromas: decreased human sense of, 66; defined, 62–63; dog’s nose specialized for, 65; of fermented meats and fish, 179

oxytocin, 206–7, 243n5

pacas, 94, 95, 102, 103, 228n11

pandas, giant, 19–20, 20, 218n16

Parmigiano-Reggiano (parmesan), 192, 198

pastoralists, planning to find a preferred flavor, 101

Patagonia, Arizona, 80–81, 91–92, 95, 110

Patterson, Penny, 206

Patterson, Penny, 49

pawpaw fruit, 232n7

peccaries: flavorful to hunters, 95, 96, 101, 103; giant, 88, 122; as omnivores, 99

Penicillium fungi: on bloomy-rind cheeses, 194, 198; of Cabrales cheese, 195–96; metabolizing lactic acid, 241n9; P. camemberti, 194; P. roqueforti, 195

Pentadiplandra brazzeana, 41–42, 115–16

pepper. See black pepper; chili peppers; sichuan peppers

phenylthiocarbamide, 224n27

pheromones, 58–59, 225n3, 229n21

phosphorus, 12–13, 18

Physiologie du goût. See Brillat-Savarin, Jean Anthelme

pig knuckles, Cantonese black vinegar, 109

pigs: human experience of flavor compared to, 69; with meat having aroma from male pheromone, 229n21; noses of, 55, 57; sour tastes and, 163–64; truffles and, 54, 57, 59, 62, 69; wild, flavor of meat from, 100, 101

pigtail monkeys, 164

pine grosbeak, 229n18

piperine, 148, 235n13

plants: defensive chemicals of, 102–3, 106, 131–34, 153; eaten by chimpanzees, 39–40, 220n13–14, 221n15; as medicine, 139, 234n7; with seeds storing energy in fat, 228n13; sometimes giving unpleasant flavor to meat, 102–3; spheres of chemicals on leaves of, 130, 132, 233n12; storing energy in carbohydrates, 98

pleasure: alcohol from fermentation and, 167, 169, 180; ancient human
questions about, 1–3; aromas hard-wired for, 57, 58–59; brain chemicals and, 3, 6; Brillat-Savarin and, xii; central to human evolution, 24; of companionship when dining, 210; divided perspectives on, 3; food sharing and, 206–7, 208; memory of an aroma and, 75; pursued by ancient hunter-gatherers, 110; of spices, 153. See also displeasure poisons. See toxic chemicals

predators: biological stoichiometry and, 4, 5; hunted but not always eaten, 95; musk glands of, 229n16; simple guts of, 229n17; tasting like low-fat beef, 99

primates: differences in taste receptors, 22–23; haplorhine, evolutionary changes in, 65–69. See also chimpanzees; gorillas; monkey meat; monkeys and sour tastes

proboscideans, 108, 110, 121–22. See also elephants; gomphotheres; mammoths; mastodons

processing of foods: by ancestors of humans and chimpanzees, 43–44, 46–47; by ancient humans, 32, 34–37; complex aromas and, 70–72; freeing time and energy for other pleasures, 47

pronghorn meat, 105

proteins: aromas from sulfur compounds in, 97; in muscle of cooked meat, 97; nitrogen in, 9, 10, 11; in panda’s bamboo diet, 218n16

The Psychology of Flavour (Stevenson), xii–xiii

ptarmigan, 101, 102

puhadi, 142–43

putrescine, 57–58, 225n2

rancid butter aroma, of fermented herring, 179

raw, unprocessed foods, 34, 46, 48, 220n10

recent humans: Cro-Magnon, 111; culinary traditions and cuisines of, 51; defined, 32; lineages of, 51; similar taste receptors in lineages of, 51. See also Neanderthals

Reed, Danielle, 15

Reshef, Hager, 108–9, 110

retronasal aromas: of chemicals in fat, 99; in chimpanzees and gorillas, 67; as component of flavor, 68; of fermented meats and fish, 179, 180; increased human sense of, 66, 68, 69; loss of transverse lamina and, 66; path of exhaled breath and, 65; of truffles, 63

ribonucleotides, 11

roots: benefits from cooking of, 46, 48; defined, 219n4; fermentation of, 35, 47, 167–68, 180; giving flavor to meat, 100, 101, 102, 106, 229n17; processed to facilitate chewing, 46–47, 48; processed to release nutrients, 34

Roquefort, 195

rotten egg aroma, of fermented herring, 179

Rozin, Paul, 150–52

ruminants: flavor of meat from, 100, 102, 105; megafaunal extinction and, 230n23

Sabater Pi, Jordi, 165, 221n16

Saint Benedict, 188–89, 191, 197. See also Benedictine monks

salicin, 16
salt: animals’ needs for, 7–8; ashes of plants used as, 130; chimpanzees’ attraction to, 38; dolphins’ inability to taste, 19; favoring some bacteria over others, 202; in Roman fish sauce, 239n13; washed-rind cheeses and, 196, 197, 241n10

Salt (Kurlansky), 177

salt curing of meat, 176–77

salt taste receptors, 7–8; desert mammals and, 22

Samuni, Liran, 205, 206, 243nn4–5

Sauer, Jonathan, 157

sauerkraut, 156, 164

Saul, Hayley, 137–39

savory taste. See umami taste

scale insects, 10

Schaal, Benoist, 135

sex, aromas hardwired for, 58–59, 225n3, 229n21

sharing food: by chimpanzees, 205–8, 209, 242n4; with human conversation, 207, 209–11

shark meat, fermented, 239n12

Sheldrake, Merlin, 56, 168

shellfish eating, 33–34, 47–48, 51

Shepherd, Gordon, xiii, 64, 68, 72, 75, 199–200, 203

Sherman, Paul, 139–41, 143

sichuan peppers, 148–49

sickness: aromas associated with, 140.
See also food-borne illness

silica, in grassland plants, 131

silphium, 227n6

Silvertown, Jonathan, 11

sloths: holding out on islands, 89; terrible flavors of, 230n24. See also giant sloths

Smalley, John, 158

smeared-rind cheeses, 196

See also aromas; nose; olfactory bulb; olfactory receptors

smoking meat, 176

sniff: bipedalism and, 67; of dog, 64–65, 67

sodium. See salt

soft cheeses, aged, 190, 192–99, 241n8; bloomy-rind, 194, 198; blue, 195–96 (see also Cabrales cheese); washed-rind, 74, 196–99, 198, 241n8

sour beers, 156, 157, 162

sourdough bread, 157, 162

sour taste: acidity detected by, 15; animals that enjoy, 163–65; aversion of many animals for, 163; chimpanzees’ attraction to, 38, 164–65; of fermented fruits, 160, 167, 169, 180, 237n6; fermented meat or fish and, 169, 172, 173, 175, 179, 180, 181, 238n9; human enjoyment of, 164; as a mystery, 15, 154–56; newborn baby’s response to, 155, 234n5; safe fermentation indicated by, 162, 181; of very short fatty acids, 217n12

sour taste receptors, 155, 163, 236n1

Spence, Charles, xiii

Speth, John, 174

sphagnum bogs, 171, 238n9

spices: almendro seed, 160; ancient Roman meat recipe with, 144–45; antimicrobial activity of, 140–41, 141, 142, 143, 145, 146, 147, 152–53; archaeological record and, 137–39; black pepper, 131, 147–48, 235n13; chemesthesis and, 147–52; culinary danger added by, 149–51; defined, 130; fetal experience of, 134–37, 233n4; in 4000-year-old proto-
curry, 235n11; hunter-gatherers’ use of garlic mustard, 138–39; intentionally using toxic plants, 134; as medicines, 139, 234n7; not universally used by humans, 130; parts of plants used as, 130–31; pleasure of food and, 147, 153; used more in hotter regions, 143–44, 144

sugars, 14
sulfurous cheeses, eaten during pregnancy, 135–36
surface ripened cheeses, 194, 198
Surovell, Todd, 229n17
sweetness: chimpanzees’ choice of fruits and, 40; energy to fuel a larger brain and, 32–33; newborn baby’s response to, 234n5
sweet taste receptors, 14; body size of animal and, 217n10; fruit protein that short-circuits, 41–42; gorilla mutation in, 41–42, 221n17; lost in birds, 21; lost in carnivores, 18–19; of marmosets, 22; similar between humans and chimpanzees, 38; similar between recent human lineages, 51
sweet-umami receptors, in hummingbirds, 21
swifts, evolving sweet-umami receptors, 21

Takahata, Yukio, 76
tannins, 106
tapir meat, 95
taste: as component of flavor, 6, 68; Latin word origin, 6; preferences of newborn babies, 233n5. See also Brillat-Savarin, Jean Anthelme
taste buds, 6, 216n8
taste receptors: calcium and, 13; evolutionary changes in, 17–23; human efforts dulling natural selection on, 23–24; locations of, 6, 216n7–8; losses of, 17; phosphorus and, 12–13; pointing animals away from danger, 15–17; pointing animals to needed foods, 15, 41; signals sent to brain from, 6–7;
taste receptors (continued)
similar between humans and chimpanzees, 23, 37–38; similar between recent human lineages, 51; thresholds of detection, 18, 22. See also bitter taste receptors; salt taste receptors; sour taste receptors; sweet taste receptors; umami taste receptors
“tastes like chicken,” 97
teeth: DNA from fossils of, 51, 223n26; smaller in humans than chimpanzees, 32, 33, 49–50; stones serving in place of, 35
temperature receptors, 148, 235n13
termites, eaten by our ancestors, 43
terroir of meat, 101
thyme, 132–33, 134, 233n2
thyme basil, 133, 233n3
tofuyou, 201–2
tools: of ancient humans, 34–35, 77–78; of chimpanzees, xiv, 26–29, 29, 30, 32, 35, 37, 41; of common ancestor of humans and chimpanzees, 43–44, 46–47; hunting and, xiv–xv; used by our ancestors to seek flavor, 23–24. See also stone tools
Tordoff, Michael, 12–13, 215n1
toxic chemicals: of bacteria in decaying meat, 171; bitter, 16–17, 133–34, 217n13–14; in plants, 100, 131, 133–34
transverse lamina, 66–67
tree leaves, and flavor of meat, 102–3, 106
tree shrews, broken TRPV1 gene of, 235n13
trimethylamine, 136
TRPA1 receptor, causing tingling, 148–49
TRPM8 cold receptor, 148
TRPV1 heat receptor, 148, 235n13
truffles, 52, 54–57, 60–62, 70
Tuber, 55, 224n1
tubers, 46, 219n4, 223n22
Tyone, Mary, 179
umami taste, 10–12; of aged soft cheeses, 193; of avocados, 96; of fermented foods, 168, 179, 180; newborn baby’s response to, 234n5; of salted meat, 177; of shellfish, 47
umami taste receptors, 12; broken in giant pandas, 20; broken in sea lions and dolphins, 19; evolved to detect sugars, 21; similar between humans and chimpanzees, 38; similar between recent human lineages, 51
Ungar, Peter, 50
Vaillant, François Le, 109
van Zonneveld, Maarten, 126, 127–28
vinegar: aroma of fermented herring and, 179; sour taste of, 164
vitamin B12, added by fermentation, 35, 168
vitamin C: not synthesized by humans, 216n5; sour taste of, 155
vomiting: aroma associated with, 140; triggered by bitter compound, 17
Waorani people of Ecuador, 103, 104
Warren, Robert, 126–27
warthog, delicious, 101, 229n19
wasabi, 148
washed-rind cheeses, 74, 196–99, 198, 241n8
Wejendorp, Kim, 104
wet fermentation of meat and fish, 177–79
wild boars, meat of, 101, 229n21
Williams, William Carlos, 77
wine: fermentation of grapes and,
   237n6; learning to discriminate,
   200
wine experts, 74, 75, 226n13
Wittig, Roman, 205–6, 242nn3–4
woolly mammoths: causes of extinction,
   228n8; in Europe, 89; meat of, 108.
See also mammoths
Wrangham, Richard, 36–37, 49, 220n11,
   221n15
yeasts: alcohol produced by, 156, 166,
   167; bacteria competing with, 166;
carried to sugar sources by insects,
   237n4; fermentation by, 156–57, 160,
   167, 237n6; metabolism of, 166
Zimmerman, Andrew, 118