pigments from green plants, and maybe from bugs, that battery hens don’t. But feeds for battery hens routinely include ingredients for coloring their yolks that are rich in the same or similar vitamin-related pigments (mainly lutein and zeaxanthin, both important for keeping our eyes healthy). Among those ingredients are yellow maize, meals made from marigold petals, alfalfa, grass, algae, paprika extract, and (in Europe, not the United States) synthetic pigments.

Egg producers in different regions formulate their feeds to match consumer preferences, which are measured on scales like the Roche Yolk Color Fan. (There are similar color scales for salmon flesh). According to a recent European review, Ireland and Sweden prefer light yellow yolks of Roche 8–9, France and England a deeper 11–12, and northern Europe and Spain an orange 13–14.

A number of other factors also affect yolk color, including the hen’s breed, age, and other feed components. So the only way to know where a beautiful yolk got its color is to know the hen’s owner, and to ask what it eats.

The best way to highlight yolk color is to avoid cooking the egg fully. Just as happens in the white, the heated proteins form microscopic aggregates that scatter light rays and eventually turn the liquid into a cloudy solid. The more moist you leave the yolk, the clearer and deeper its color will remain. ◆

MICROBES IN FOOD are all the rage these days. I’m not talking about Listeria-laden cantaloupes or salmonella-infused peanut butter. I’m talking about “good” bacteria—yeasts and molds that have the molecular machinery to transform relatively bland food substrates into delicious fermented foods. You might even say that a fermentation revolution is sweeping across the country, with Americans from Brooklyn to Oakland dedicating entire sections of their homes to the odoriferous and often unpredictable world of fermented foodstuffs. If you don’t have a crock of rotting cabbage in the corner of your kitchen, you just aren’t cool anymore.

In the Momofuku test kitchen, we’ve been helping David Chang and his lab chefs develop microbial recipes to beautifully ren rice into kōji, grains into miso, and pork into katsuobushi. We’re teaching these chefs how to use invisible ingredients—native New York yeasts and molds isolated in their kitchen—to ferment foods that are usually made with commercial microbial strains. Chang is so excited about microbes that he’s traveling around the world giving lectures in which he declares that microbes are the future of American cuisine. To a microbiologist, hearing a chef get excited about Aspergillus oryzae and Neurospora sitophila is mind-blowing.

One of the reasons people are so intrigued by fermentation is that these microbes in the air, soil, and water in our own backyards can actually contribute to regional flavors. Just as the soil and climate of a particular region create the terroir of a wine, regional microbes can create signature flavors, too. This notion is something that Chang and others have called microbial terroir. Different species of microbes have different ways to make flavor molecules as they break down raw ingredients into smaller pieces. If two producers in two different locations use almost identical raw ingredients, but one has ten different microbes growing on his or her product while the other has only five, you can expect different flavors to result.

Microbial terroir is currently just a buzz phrase in the artisanal food movement; there is no scientific data to back it up. In America, we know almost nothing about the microbial biodiversity of our fermented artisanal foods, so it’s impossible to know how microbes vary from one place to another. Even for American artisanal cheese or sourdough bread, in which microbial terroir is implied, we have absolutely no data on what microbes

American Microbial Terroir by Ben Wolfe
play a part in these foods. As with all things food, the microbiophiliac Europeans are way ahead of us, and have done hundreds of studies documenting how bacteria and fungi vary from one food-production region to another. They’ve even gone as far as suggesting that they need to protect regional food microbes just as regional foods are protected.

As a card-carrying microbiologist, I can tell you that the idea of American microbial terroir is not at all crazy. It rests on two basic assumptions: 1) microbial diversity is different in different regions of America; and 2) microbes that colonize food play as much of a role in producing foods as do the raw ingredients that go into that food. We know both of these things to be true. Scientists have recently shown that the microbial diversity of the air, soil, and water is extremely different from one part of the United States to another, even in places just a few miles from each other. This diversity also changes throughout the seasons, and different combinations of microbial producers have popped up around the country, making salami that are truly American, but that also reflect the microbial terroir in American salami, I asked a bunch of my food-loving friends in Boston (my chef husband, his chef friends, and other food-science nerds) to eat the salami with me, and to describe the type and intensity of different flavors (sweet, sour, salty, porky, rancid) they perceived. Food scientists call this sensory analysis. I also isolated the bacteria and fungi from the outside of each salami, and sequenced the DNA of these isolates to identify their microbial-species diversity.

Two big patterns emerged from this exercise. First, while there is a core set of microbes found across all salami (if you build it, they will come), there are also specific microbes that are unique to specific producers (hello, microbial terroir!). The relative amounts of the different species and types of microbes (bacteria versus mold versus yeast) also varied from sausage to sausage. You can easily see this by scanning the circles in the figure showing the bacteria and fungi that I isolated (see page 107). Some microbial colonies are common across the five salami, while some are clearly unique.

For example, all salami included the yeast species Candida, which is the most commonly found yeast on European salami, which is also often found on North American cheeses. They also all had the mold Penicillium nalgiovense, probably because they were all inoculated with this mold from the sausage-making industry. But the salami from Berkeley, California, was super yeasty due to the presence of Candida deformans, which produces rustic, barnyard volatile compounds when grown in isolation. The salami from Utah was the only sausage to have the yeast Candida zeylanodona, a species seen on some European salami and raw cheeses.

Another interesting pattern was the relationship between flavor complexity and microbial diversity. The least microbiologically interesting salami was the salami from Oakland, California. That thing was packed full of the mold Penicillium and a few yeasts, but had almost no bacteria growing on the casing. It was by far the mildest-flavored salami. It was fine—it tasted like salami—but it didn’t have intense flavors that really set it apart from the rest. It’s likely that the lack of bacteria leads to a loss of the distinct flavor molecules that can increase the complexity of the flavor.

If the salami from Oakland was the microbial equivalent of a well-manicured golf course, then the salami from Oregon was a freaking jungle. This salami had four different species of Staphylococcus—more than any other salami I looked at—and had its own unique mold (a species of Scopulariopsis) that was present only on the Oregon salami. Looking under the microscope, the Oakland salami looked like a homogenous snowy field, while the Oregon salami looked like a scene from Where the Wild Things Are. The Oregon had the funkiest flavor profile of all the salami we tasted. Some tasters noticed hints of barnyardy-umami-mushroom, while others were talking about burnt chocolate and butter.

There was also obvious variation in flavor production among different strains of the same species. The bacteria Staphylococcus nasicornus in addition to nitrates/nitrites that are added to the meat, prevents bad bacteria from growing and adds a lactic tang to the flavor of the finished sausage. Generally, this process is highly controlled to ensure that the food is safe. There are only a few microbe cultures available for this stage (mostly Lactobacillus, Pediococcus, and some Staphylococcus species), so flavor profiles don’t vary too much from one producer to the next. Consider the boring stage of salami microbiology. But after this first one- or two-day fermentation, salami are hung in a cool, humid environment where they slowly lose moisture. This is where it gets really interesting. Over a period of weeks or months, a fuzzy and sometimes bumpy rind will develop on the casing. Much of the fuzziness comes from molds that are either added (Penicillium nalgiovense is generally the mold of choice) or that naturally colonize the salami from the air. The molds help modify the meat surface, and can also add a level of mushroomy earthiness to the salami. Nested within this mold forest are much tinier cells of yeasts and bacteria that also colonize the casing from the air. Based on studies in Europe, we now know these bacteria are a completely different species of Staphylococcus. (Don’t worry, they have no relation to the Staphylococcus or “Staph” species known as MRSA, which is often in the headlines for killing people. A few species of Staphylococcus can make people really sick, many are benign.)

The yeasts are typically Candida and Debaryomyces species. All of these microbes release enzymes that break down the meat under the casing. This process of intestinal rot leads to the production of compounds that we perceive as flavors in the meat, such as acetoin (creamy butteriness), various esters (fruity yeastiness), and branched-chain aldehydes (typical aged-meat/cheese flavors). As the salami loses moisture, these microbial flavors become more concentrated.

Not all microbes break down meat in the same way. Some species are better at breaking down fats, while others have the machinery to efficiently break down proteins. And even within each of these categories, there are many ways to rot a piece of meat. So the presence of a particular microbe on your salami can have a strong influence on the overall appearance and flavor of the salami.

This is where it gets really interesting. But it actually gets more interesting when grown in isolation. While a few species of Staphylococcus can make people really sick, many are benign. So if we were going to attempt to track down and exploit the elusive microbial terroir in our pubescent culinary landscape, where would we look and how would we try to define it? We’d want to start with a fermented food that’s made in different places throughout the country. We’d want a food that isn’t heavily seasoned or manipulated, so that the microbial transformation of the food is the primary source of flavors. And we’d want something where microbes from the environment could freely colonize the surface of the food and contribute substantially to the flavor. What we want is American artisanal salami.

In the past five years, a handful of producers have popped up around the country, making salami that are truly American, but that also reflect traditional European styles. While the composition of the meat, spices, wine, and herbs provide body to the salami, the microbial degradation of the meat through the production of enzymes is the key to creating signature flavors. To the average person, the outside of salami is just a dusty white jacket. But it actually comprises millions of microbial cells that have accumulated over time, as the salami has aged. This microbial ecosystem transforms an intestine full of raw meat into a perfectly petriified expression of porkiness. When food scientists try to age salami with different species of raw meat, they get a raisin intestine full of raw meat.

In the first stage of salami production (usually just a day or two), lactic-acid bacteria (similar to those found in yogurt and cheese) rapidly acidify the raw meat that has been stuffed into the sausage casing. This acidic environment rapidly acidify the raw meat that has been stuffed into the sausage casing. This acidic environment
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In the past five years, a handful of producers have popped up around the country, making salamis that are truly American, but that also reflect traditional European styles. While the composition of the meat, spices, wine, and herbs provide the base, the salami’s microbial degradation of the meat through the production of enzymes is the key to creating signature flavors. To the average person, the outside of salami is just a dusty white jacket. But it actually conceals millions of microbial cells that have accumulated over time, as the salami has aged. This microbial ecosystem transforms an intestine full of raw meat into a perfectly petri-tipped expression of porkiness. When food scientists try to age salami with the same environment from which the meat comes, they can also add a level of mushroom earthiness to the salami. Nestled within this mold forest are much tinier cells of yeasts and bacteria that also colonize the casing from the air. Based on studies in Europe, we know these bacteria are a particularly diverse set of Staphylococcus. (Don’t worry, they have no relation to the Staphylococcus or “Staph” species known as MRSA, which is often in the headlines for killing people. A few species of Staphylococcus can make people really sick, many are benign.)

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To search for microbial terroir in American salami, I purchased samples from five different producers in North America. (To make sure the sampling was representative, I bought three to four separate salamis from each producer.) I wanted to be able to detect differences in flavors due to the presence of microbes, so I tried to get those salamis with the least amount of spices or other flavors added. I asked a bunch of my food-loving friends in Boston (my chef husband, his chef friends, and other food-science nerds) to eat the salami with me, and to describe the type and intensity of different flavors (sweet, sour, salty, porky, rancid) they perceived. Food scientists call this sensory analysis. I also isolated the bacteria and fungi from the outside of each salami, and sequenced the DNA of these isolates to identify their microbial species diversity.

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1. While the FDA does routine inspections of some fermented foods for pathogens, the good microbes are never isolated. It’s sort of shocking, considering that the good microbes might help get rid of the bad microbes.
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But wait, you may be saying. This guy has a Ph.D from Harvard and he wants me to believe that the patterns he observes from just five different salami prove this crazy idea of American microbial terroir? Fair enough. This isn’t a perfect scientific study (as if that wasn’t obvious by the fact that it is being published in Lucky Peach). But it does provide some much-needed data to more clearly develop the notion of microbial terroir in America.

There are two perfect experiments to conduct that would really settle this whole microbial-terroir thing. First, I could make a ton of salami in Boston, using my own recipe, and then send them off to all five producers I studied and have them age the salami using the exact same techniques they normally use. (Salami producers: I would love to come check out your salami microbes. Call me?)

The second-best approach would be to take the unique microbial ecosystems from each of these salami and inoculate them into my basic salami recipe. Call it a microbial transplant. This would tell me if the variations in the microbes from place to place are really driving the flavor differences that I observe. Every other variable—environment and length of aging—would be held constant.

I tried this experiment in my amateur salami-aging cave (closed). The quick, and perhaps not surprising, answer is that the flavor differences we noticed in the original salami carried over to the experimental salamis. The yeasty/Staphy salami (like the Utah salami) were more well-rounded and earthy in their flavor profiles. The salami that had more mold growth (like the Oregon salami) had a sharper, almost metallic, blue-cheese pungency. So even when the meat ingredients are the same, the different microbial communities on the outside of the salami created noticeable differences in flavors. Fun stuff!
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