The Art of Fermentation

What’s in it for me? Learn how fermentation shapes life on Earth

Fermentation is everywhere. It’s what transforms grapes into wine and wine into vinegar. It’s how chocolate, vanilla, coffee, cheese, and charcuterie are made. Then there are the more obvious ferments like sauerkraut, kimchi, and kombucha. Without it, our diets would be unrecognizable. But there’s more to fermentation than what we eat. As you’ll learn in these blinks, it also shapes every facet of life on Earth. Without fermenting bacteria, our planet’s atmosphere wouldn’t contain enough oxygen for us to exist. Nor would we be able to process vital vitamins that keep our bodies functioning. In these blinks, you’ll learn

why bacteria-rich foods are good for our guts; what heavy-drinking treeshrews can teach us about evolution; and how to start making your own fermented food.

Fermentation transformed our planet.

Fermentation. It’s a word you've probably heard, and if you’ve ever eaten bread or cheese or drunk beer, you're familiar with the products of this vital process. But what does fermentation actually mean? To answer that question, we need to go all the way back to the origins of life on our planet. All of Earth’s life forms need energy for their cells to create macromolecules, their building blocks. The way a cell obtains this energy is through its metabolism. The very first living organisms, certain kinds of bacteria, had anaerobic metabolisms – that is, they didn’t need oxygen to convert nutrients into energy. Another word for this process? Fermentation. As time went on, new kinds of metabolism would develop from these fermenting bacteria, leading to life on Earth as we know it today. The key message in this blink is: Fermentation transformed our planet. As biologists Lynn Margulis and Dorion Sagan put it in their study of microbial evolution, Microcosmos, bacteria actually invented all of life’s essential chemical systems. Take our oxygen-rich atmosphere – the precondition for the existence of complex life-forms like animals, plants, and fungi. This was created by fermenting bacteria. How did they do it? Well, during the first couple of billion years of life on Earth, these bacteria interacted with one another. It could be a struggle to the death, with one bacterium destroying another. But it could also be a complex, two-way relationship that transformed both bacteria. One product of this second type of interaction was a new kind of metabolism. Over time, certain microbes evolved to produce, or photosynthesize, energy from sunlight. The byproduct of this nutritional strategy was oxygen. As the number of these microbes grew, the planet’s atmosphere was oxygenated – and transformed forever. At this point, the first aerobic – or oxygen-dependent – cells entered the evolutionary fray. It appears that their relationship with older, anaerobic cells was initially that of predator and prey. Over time, though, these former foes learned to coexist. Aerobic cells took up residence inside anaerobic cells without destroying them – an arrangement that allowed both parties to profit from each other’s metabolisms. It was this relationship that paved the way for the emergence of eukaryotes – the complex organisms which, at a cellular level, make up the building blocks of all human, animal, and plant life.

Humans coevolved with bacteria and we can’t live without them.

Seen through a biologist’s microscope, the human body is a vast world home to trillions of inhabitants. There are eukaryotes – complex cells containing our unique DNA. But these are a minority in the human body. Bacteria – simpler, single-celled organisms called prokaryotes – outnumber them ten to one. All in all, our bodies are home to around 100 trillion prokaryotes. These bacteria aren’t simply hitching a free ride with their hosts, though – they’re essential to human life. The key message in this blink is: Humans coevolved with bacteria and we can’t live without them. At a microscopic level, our bodies are like landscapes. Between our scalps and our toes, there are thousands of distinct environmental niches. Each is home to unique bacterial communities. Consider arms. It’s only a short hop from hairy, moist underarms to smooth, dry forearms, but these two landscapes are as ecologically dissimilar as rainforests and deserts. Bacteria that thrive in one niche can’t survive in the other. Like all species, they’ve adapted to their environments. There are bacteria on every surface of the human body, including our eyes. They’re also inside our respiratory tracts and orifices. A healthy mouth alone supports around 700 species of bacteria. All of these organisms play a vital role in maintaining our health. Take the vagina. Inside the body, it secretes glycogen – a carbohydrate the body uses to store energy. This glycogen supports bacteria called lactobacilli, which are also found in foods like yogurt. When lactobacilli ferment glycogen – that is, break it down in order to create energy for themselves – they produce lactic acid. This process creates an acidic environment that repels disease-causing bacteria, thus protecting the vagina and supporting reproductive health. Something similar happens in the gut, which is where most of those 100 trillion bacteria live. Intestinal bacteria occupy ecological niches which would otherwise be inhabited by harmful pathogens. They also break down hard-to-digest nutrients into useful substances. Vitamins B and K are great examples of this process. These chemical compounds foster cellular metabolism, proper nerve and muscle function, and blood health, but we wouldn’t be able to access them without bacteria. From an evolutionary perspective, these bacteria enable our cells to do things they couldn’t do on their own. Put differently, it’s the bacteria that we coexist with that enable us to exist at all!

Fermented food is vital to good health.

How did the gut come to host so many life-supporting prokaryotes? The simple answer is that our ancestors consumed lots of bacteria. Before refrigeration and other technologies to prevent contamination, the food humans ate was never sterile. Eventually, the microbes in that food moved into our intestines. Scientists are only just starting to figure out how exactly intestinal bacteria regulate our overall health, but it’s clear that they play a vital role in everything from vitamin absorption to immune response. The key message in this blink is: Fermented food is vital to good health. Humans have intuitively understood the connection between health and bacteria-rich foods throughout history. Take the ancient Chinese philosopher Confucius. He refused to eat any meal unless there was also an accompanying jiang – a fermented condiment similar to miso – on the table. Then there are the Sudanese Fur people, who have long praised the disease-preventing qualities of a fermented paste of green leaves called kawal. Yogurt, kefir, and other fermented milk products have enjoyed a similar reputation across much of Eurasia for thousands of years. In the early twentieth

century, the pioneering Russian microbiologist Elie Metchnikoff even argued that it was the lactic bacteria in yogurt which explained the remarkable longevity of Bulgarian peasants. Recent research confirms this intuitive connection. Consider just two health benefits of fermented foods: First off, pre-digestion. This term refers to the way fermenting bacteria alter the composition of the substances they metabolize. Some bacteria make hard-to-access compounds in foods available to human cells. Soybeans, for example, are loaded with essential amino acids, one of the building blocks of proteins. We can't access those acids, however – unless the beans are fermented. That's why fermented soy products like miso and tempeh are such a great source of protein. Other bacteria create unique and healthful nutrients that weren't present in the raw ingredients. If you introduce the bacterium Bacillus subtilis to soaked and steamed soybeans and let this mixture ferment for a week, you'll end up with a Japanese breakfast dish called natto. This process creates a new enzyme called nattokinase. It's responsible for the dish's pungent taste, but it also has other uses – uses like treating hypertension, coronary artery disease, and peripheral vascular disease. Fermenting bacteria can also detoxify foods. Bitter cassava tubers, for example, contain enough cyanide to kill most things that eat them. And yet it's a staple crop consumed by millions of people around the world. How is this possible? Easy! Fermentation removes the cyanide.

If you want to preserve food, ferment it.

Trees only produce nuts once a year. For a short while, usually in the fall, there's a bonanza. Then comes winter. Suddenly, they're impossible to find. That's a problem if these hard-shelled fruits are your primary source of calories, which is why squirrels instinctively collect and hide nuts for future use. Humans also store food. As the anthropologist Sidney Mintz notes, however, this isn't so much instinct as an "invented, constructed, symbolically transmitted technology." In other words, human solutions to the problem of storing food for later use can be handed down and refined. While squirrels continue hiding their nuts in the same old way from one generation to the next, humans work on new food-preservation technologies like pottery vessels – or fermentation. The key message in this blink is: If you want to preserve food, ferment it. You don't have to ferment food to preserve it. You could keep it cool and dry in a dark cave, or follow squirrels' lead and bury it. If you pack it in sand, there's a good chance it'll make it through the winter – unless it gets wet. If your cave leaks, or your hole floods, seeds will germinate, grains will mold, and vegetables, fruits, meats, and fish will rot. Fermentation doesn't eliminate the risk of spoilage entirely, but it does significantly reduce it. How? Well, there are a couple of different things going on here. First off, fermenting bacteria tend to dominate in the food they're metabolizing. In simple terms, they crowd out other, potentially harmful bacteria. One of the ways they do this is by producing bacteriocins – proteins that are antibacterial against pathogenic types of bacteria. Secondly, when these bacteria break down sugars, they produce several byproducts, including carbon dioxide, lactic acid, and acetic acid. All three substances inhibit the growth of pathogenic bacteria, but the two acids also transform the flavor of food. It's their work that creates the delicious tang we associate with fermented foods like cheese, yogurt, salami, kimchi, and sauerkraut. Best of all, fermentation works anywhere. In cold climates, where there's little to eat in winter, it's essential to preserve what you gather, harvest, or hunt in the summer. This is how you end up with fermented fish in Iceland and pickled tomatoes in Russia. In hotter, tropical climates, food is available year-round but spoils quickly. Fermentation also solves this problem, which explains why a country like Sudan boasts over 80 unique fermented

foods, condiments, and sauces.

“If we are to enjoy surpluses of food, then we must have strategies for preserving them in the presence of our microbial ecology.”

Humans aren’t the only animals that enjoy alcohol.

To make alcohol, you need two things: carbohydrates that can be broken down into sugar and yeast. You can either add yeast or use the natural yeasts found on the surface of foods. Give this yeast plenty of sugar to ferment or metabolize, and you’ll end up with the chemical compound we call alcohol. Grapes, apples, barley, and potatoes – the main ingredients in wine, cider, beer, and vodka – can be fermented into mind-altering brews. So too can rice, agave, pineapples, and beets. Fermented drinks have played an important role in just about every human culture for thousands of years. Even cultures that reject alcohol partially define themselves against it. Alcohol isn’t a human invention, though – it’s the product of an intimate relationship between yeast, plants, and animals that’s been around since prehistoric times. The key message in this blink is: Humans aren’t the only animals that enjoy alcohol. Neolithic pottery shards discovered in China show that humans were deliberately producing alcohol around 9,000 years ago. The favored tipple of these prehistoric ancestors combined rice, honey, and fruits. Archaeological sites in the Middle East suggest that barley was being fermented around the same time. Alcohol consumption is much older than the intentional production of alcohol. In fact, it predates human cultural practices altogether. Every vertebrate species possesses liver enzymes capable of metabolizing alcohol, and many animals consume alcohol in their natural habitats. Take pen-tailed treeshrews, a native of Malaysia’s jungles. Biologists regard these mammals as living models of the animals from which all primates are ultimately descended. Fascinatingly, these shrews are habitual drinkers. The alcohol they consume occurs naturally in the flowers of the bertram palm. Wild yeast communities ferment the sugars in the flowers’ nectar. The result is a sweet-smelling and heady brew that attracts the shrews, who spend their days climbing palms and pollinating their flowers. The trees, pollinating shrews, and fermenting yeasts all coevolved this arrangement together. Shrews aren’t the only animals that consume alcohol, either. Migrating elephants have been observed swaying lethargically after gorging themselves on fermented fruit underneath trees. Then there are flying foxes, the world’s largest bats. Their diet consists of an intoxicating mix of rotten and fermented fruit. Once they’re done feeding, they fall from the sky and spend the rest of the night waddling around in a drunken stupor.

“Alcohol forms part of an intricate web of interrelationships between yeasts, plants, and animals for their mutual benefit and propagation.”

Fermenting vegetables is easier than you might think.

Fermentation is at the heart of our evolutionary story. Seen through a microscope, it’s part of what makes our bodies tick. It’s no less important on the larger canvas of our species’ history. It was fermentation that allowed our ancestors to preserve food for

harsh winters and prevent it from spoiling during hot summers. But there's more to fermentation. As we've seen, fermented foods are packed with the bacteria our guts crave. In other words, they're just as important for our health today as they were for our survival in the past. Which brings us to a practical question: How can you start making your own fermented foods? The key message in this blink is: Fermenting vegetables is easier than you might think. If you've never fermented anything before, there's no better place to start than kraut chi – a fermented cabbage recipe developed by the author which draws on Korean kimchi and German sauerkraut. Making kraut chi requires four steps – chopping, salting, packing, and waiting. Well, five. You'll also need to buy a cabbage. This is a freeform recipe, so you can use whichever kind you like best. To ferment vegetables, you have to submerge them beneath a salted brine, which can be made from their own juices. That's why chopping is so important. When you cut your cabbage into smaller pieces, you're exposing more surface area, which allows you to pull more water out of it. The finer you chop it, the more juice you'll get. The next step is salting the chopped cabbage. This does a couple of things. First, it draws water out through osmosis. Second, it hardens plant cell compounds called pectins, which helps keep the cabbage crisp. Finally, it aids fermentation by creating an environment in which many pathogenic bacteria struggle, thus giving salt-tolerant lactic acid bacteria a competitive advantage. How much salt? A good rule of thumb is to use between 1.5 and 2 teaspoons per pound of cabbage. Scatter the salt over the cabbage and squeeze with clean hands to release even more juice. Next, pack your cabbage and any additional spices you feel like in clean jars. Remember, it should be fully submerged, so pack it down tightly. If there isn't enough juice, add a little dechlorinated water. Finally, seal the jar with a close-fitting lid. The last step is waiting. Here, you'll have to trust your taste buds. Give the cabbage at least three days and then try it regularly. Some people prefer fresher-tasting young ferments; others swear fermented cabbage only tastes right after half a year. Only you can tell where you fall on that spectrum!

When it comes to fermenting, there's no reason to fear mold.

Fermentation is a form of anaerobic, or oxygenless, metabolism. That's why you have to submerge fermenting vegetables in a brine. Submersion encourages the growth of anaerobic lactic acid bacteria and protects vegetables from oxygen-loving fungi like yeasts and molds. But even fully submerged ferments can have issues with these organisms. Blame it on the edge – the point at which the surface of the nutritious vegetable juices meets oxygen-rich air. Together, these two environments create a rich biodiversity that fungi love. That's the bad news. The good news? Mostly, it doesn't matter! As long as these organisms can't penetrate beneath the liquid's surface, they can't harm your vegetables. The key message in this blink is: When it comes to fermenting, there's no reason to fear mold. Yeasts and molds are distinctive organisms, but a layer of yeast usually becomes a layer of mold. Kahm yeast is one of the most common fungi that grows on the surface of fermenting vegetables. That's down to the nature of lactic acid fermentation, which produces a distinctive yeast flora on the surface of the vegetable's liquid. This is beige in color and has a dramatic, wavy texture. Luckily, it's pretty easy to deal with Kahm yeast. If you spot it growing on your fermenting cabbage, just remove it with a clean stainless steel spoon. The same goes for any other white-colored growth. As long as these organisms remain on the surface, they can't do anything to your vegetables. This is why it's important to remove them quickly. The longer a mold grows, the deeper its mycelia – the rooting part of fungal organisms –

penetrate beneath the surface. Leave it too long and the mycelia will begin digesting lactic acid and pectins, sinking the pH level and leaving you with moldy-tasting, mushy vegetables. There's one important caveat to what we've said about yeasts and molds. If your fermented vegetables start developing green, black, or reddish-orange molds, you should toss them out. Unlike Kahm yeast and white molds, these aren't harmless organisms that coexist with the fermentation process – they're a sign that harmful bacteria have undermined the process. If that happens, don't worry – you can always start again. That's the beauty of fermentation. From the first bacteria billions of years ago to the neolithic humans who figured out how to alter their minds with nothing more than honey, rice, and fruit, fermentation has always been about trial and error.

Final summary

The key message in these blinks is that: For the first billion years of life on Earth, the atmosphere contained little oxygen and single-celled bacteria were the planet's only inhabitants. They produced energy through fermentation, and that drove their evolution. Eventually, they oxygenated the atmosphere and started interacting with aerobic cells. This was the foundation of eukaryotes – more complex cells which comprise all animal and plant life. Fermentation played a vital role in these organisms' development. Fermenting bacteria made the human gut what it is, allowing our species to absorb life-giving nutrients, and helped our ancestors preserve precious calories when food was in short supply. And here's some more actionable advice: "Burp" your fermented vegetables Fermentation produces carbon dioxide. This gas can cause a considerable buildup of pressure inside your jar, leading to buckled lids or even explosions. To prevent this, you'll need to "burp" your vegetables during the first week of fermentation. All that means is loosening the lid once a day and allowing excess gas to escape. After the first few days, carbon dioxide production will slow down, meaning you only need to check in on them every couple of weeks. Got feedback? We'd love to hear what you think about our content! Just drop an email to with The Art of Fermentation as the subject line and share your thoughts!