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THE ROOTS OF MODERNITY

Cursed is the ground because of you;
through painful toil you will eat of it all the
days of your life.

— GENESIS 3:17

AN AGRICULTURAL MYSTERY

The mechanism by which plants and animals were domesticated may be understood, but that does little to explain the motivations of the people in question. Quite why humans switched from hunting and gathering to farming is one of the oldest, most complex, and most important questions in human history. It is mysterious because the switch made people significantly worse off, from a nutritional perspective and in many other ways. Indeed, one anthropologist has described the adoption of farming as "the worst mistake in the history of the human race."

Compared with farming, being a hunter-

gatherer was much more fun. Modern anthropologists who have spent time with surviving hunter-gatherer groups report that even in the marginal areas where they are now forced to live, gathering food only accounts for a small proportion of their time — far less than would be required to produce the same quantity of food via farming. The !Kung Bushmen of the Kalahari, for example, typically spend twelve to nineteen hours a week collecting food, and the Hazda nomads of Tanzania spend less than fourteen hours. That leaves a lot of time free for leisure activities, socializing, and so on. When asked by an anthropologist why his people had not adopted farming, one Bushman replied, "Why should we plant, when there are so many mongongo nuts in the world?" (Mongongo fruits and nuts, which comprise around half the !Kung diet, are gathered from wild stands of trees and are abundant even when no effort is made to propagate them.) In effect, hunter-gatherers work two days a week and have five-day weekends.

The hunter-gatherer lifestyle in preagricultural times, in less marginal environments, would probably have been even more pleasant. It used to be thought that the switch to farming gave people more time to

devote to artistic pursuits, the development of new crafts and technologies, and so on. Farming, in this view, was a liberation from the anxious hand-to-mouth existence of the hunter-gatherer. But in fact the opposite turns out to be true. Farming is more productive in the sense that it produces more food per unit of land: a group of twenty-five people can subsist by farming on a mere twenty-five acres, a much smaller area than the tens of thousands of acres they would need to subsist by hunting and gathering. But farming is less productive when measured by the amount of food produced per hour of labor. It is, in other words, much harder work.

Surely this effort was worthwhile if it meant that people no longer needed to worry about malnutrition or starvation? So you might think. Yet hunter-gatherers actually seem to have been much healthier than the earliest farmers. According to the archaeological evidence, farmers were more likely than hunter-gatherers to suffer from dental-enamel hypoplasia — a characteristic horizontal striping of the teeth that indicates nutritional stress. Farming results in a less varied and less balanced diet than hunting and gathering does. Bushmen eat around seventy-five different types of wild plants,

rather than relying on a few staple crops. Cereal grains provide reliable calories, but they do not contain the full range of essential nutrients.

So farmers were shorter than hunter-gatherers. This can be determined from skeletal remains by comparing the "dental" age derived from the teeth with the "skeletal" age implied by the lengths of the long bones. A skeletal age that is lower than the dental age is evidence of stunted growth due to malnutrition. Skeletal evidence from Greece and Turkey suggests that at the end of the last ice age, around 14,000 years ago, the average height of hunter-gatherers was five feet nine inches for men and five feet five inches for women. By 3000 B.C., after the adoption of farming, these averages had fallen to five feet three inches for men and five feet for women. It is only in modern times that humans have regained the stature of ancient hunter-gatherers, and only in the richest parts of the world. Modern Greeks and Turks are still shorter than their Stone Age ancestors.

In addition, many diseases damage bones in characteristic ways, and evidence from studies of bones reveals that farmers suffered from various diseases of malnutrition that were rare or absent in hunter-gatherers.

These include rickets (vitamin D deficiency), scurvy (vitamin C deficiency), and anemia (iron deficiency). Farmers were also more susceptible to infectious diseases such as leprosy, tuberculosis, and malaria as a result of their settled lifestyles. And their dependence on cereal grains had other specific consequences: female skeletons often display evidence of arthritic joints and deformities of the toes, knees, and lower back, all of which are associated with the daily use of a saddle quern to grind grain. Dental remains show that farmers suffered from tooth decay, unheard of in hunter-gatherers, because the carbohydrates in the farmers' cereal-heavy diets were reduced to sugars by enzymes in their saliva as they chewed. Life expectancy, which can also be determined from skeletons, also fell: Evidence from the Illinois River Valley shows that average life expectancy at birth fell from twenty-six for hunter-gatherers to nineteen for farmers.

At some archaeological sites it is possible to follow health trends as hunter-gatherers become more sedentary and eventually adopt farming. As the farming groups settle down and grow larger, the incidence of malnutrition, parasitic diseases, and infectious diseases increases. At other sites, it is

possible to compare the condition of hunter-gatherers and farmers living alongside each other. The settled farmers are invariably less healthy than their free-roaming neighbors. Farmers had to work much longer and harder to produce a less varied and less nutritious diet, and they were far more prone to disease. Given all these drawbacks, why on earth did people take up farming?

THE ORIGINS OF FARMING

The short answer is that they did not realize what was happening until it was too late. The switch from hunting and gathering to farming was a gradual one from the perspective of individual farmers, despite being very rapid within the grand scheme of human history. For just as wild crops and domesticated crops occupy a continuum, there is a range from pure hunter-gatherer to relying entirely on farmed foods.

Hunter-gatherers sometimes manipulate ecosystems to increase the availability of food, though such behavior falls far short of the deliberate large-scale cultivation we call farming. Using fire to clear land and prompt new growth, for example, is a practice that goes back at least 35,000 years. Australian aborigines, one of the few remaining groups of hunter-gatherers to have survived into

modern times, plant seeds on occasion to increase the availability of food when they return to a particular site a few months later. It would be an exaggeration to call this farming, since such food makes up only a tiny fraction of their diet. But the deliberate manipulation of the ecosystem means they are not exclusively hunter-gatherers either.

The adoption of farming seems to have happened as people moved gradually along the spectrum from being pure hunter-gatherers to being ever more reliant on (and eventually dependent on) farmed food. Theories to explain this shift abound, but there was probably no single cause. Instead a combination of factors were probably involved, each of which played a greater or lesser role in each of the homelands where agriculture arose independently.

One of the most important factors appears to have been climate change. Studies of the ancient climate, based on the analysis of ice cores, deep-sea cores, and pollen profiles, have found that between 18,000 B.C. and 9500 B.C. the climate was cold, dry, and highly variable, so any attempt to cultivate or domesticate plants would have failed. Intriguingly there is evidence of at least one such attempt, at a site called Abu Hureyra

in northern Syria. Around 10,700 B.C. the inhabitants of this site seem to have begun to domesticate rye. But their attempt fell victim to a sudden cold phase known as the Younger Dryas, which began around 10,700 B.C. and lasted for around 1,200 years. Then, around 9500 B.C., the climate suddenly became warmer, wetter, and more stable. This provided a necessary but not sufficient condition for agriculture. After all, if the newly stable climate was the only factor that prompted the adoption of farming, then people would have adopted it simultaneously all around the world. But they did not, so there must have been other forces at work as well.

One such factor was greater sedentism, as hunter-gatherers in some parts of the world became less mobile and began to spend most of the year at a single camp, or even took up permanent residence. There are many examples of sedentary village communities that predate the adoption of farming, such as those of the Natufian culture of the Near East, which flourished in the millennium before the Younger Dryas, and others on the north coast of Peru and in North America's Pacific Northwest. In each case these settlements were made possible by abundant local wild food, often in the form

of fish or shellfish. Normally, hunter-gatherers move their camps to prevent the food supply in a particular area from becoming depleted, or to take advantage of the seasonal availability of different foods. But there is no need to move around if you settle next to a river and the food comes to you. Improvements in food-gathering techniques in the late Stone Age, such as better arrows, nets, and fish hooks, may also have promoted sedentism. Once a hunter-gatherer band could extract more food (such as fish, small rodents, or shellfish) from its surroundings, it did not need to move around so much.

Sedentism does not always lead to farming, and some settled hunter-gatherer groups survived into modern times without ever adopting agriculture. But sedentism does make the switch to farming more likely. Settled hunter-gatherers who gather wild grains, for example, might be inclined to start planting a few seeds in order to maintain the supply. Planting might also have provided a form of insurance against variations in the supply of other foods. And since grains are processed using grinding stones which are inconvenient for hunter-gatherers to carry from one camp to another, greater sedentism would have made

grains a more attractive foodstuff. The fact that grains are energy-rich, and could be dried and stored for long periods, also counted in their favor. They were not a terribly exciting foodstuff, but they could be relied upon in extremis.

It is not hard to imagine how sedentary hunter-gatherers might have started to rely more heavily on cereal grains as part of their diet. What was initially a relatively unimportant food gradually became more important, for the simple reason that proto-farmers could ensure its availability (by planting and subsequent storage) in ways they could not for other foods. Archaeological evidence from the Near East suggests that proto-farmers initially cultivated whatever wild cereals were at hand, such as einkorn wheat. But as they became more reliant on cereals they switched to more productive crops, such as emmer wheat, which produce more food for a given amount of labor.

Population growth as a result of sedentism has also been suggested as a contributory factor in the adoption of farming. Nomadic hunter-gatherers have to carry everything with them when they move camp, including infants. Only when a child can walk unaided over long distances, at the age of three or four, can its mother contem-

plate having another baby. Women in settled communities, however, do not face this problem and can therefore have more children. This would have placed greater demands on the local food supply and might have encouraged supplemental planting and, eventually, agriculture. One drawback with this line of argument, however, is that in some parts of the world the population density appears to have increased significantly only after the adoption of farming, not beforehand.

There are many other theories. In some parts of the world hunter-gatherers may have turned to farming as the big-game species that were their preferred prey declined in number. Farming may have been prompted by social competition, as rival groups competed to host the most lavish feasts; this might explain why, in some parts of the world, luxury foods appear to have been domesticated before staples. Or perhaps the inspiration was religious, and people planted seeds as a fertility rite, or to appease the gods after harvesting wild grains. It has even been suggested that the accidental fermentation of cereal grains, and the resulting discovery of beer, provided the incentive for the adoption of farming, in order to guarantee a regular supply.

The important thing is that at no point did anyone make a conscious decision to adopt an entirely new lifestyle. At every step along the way, people simply did what made the most sense at the time: Why be a nomad when you can settle down near a good supply of fish? If wild food sources cannot be relied upon, why not plant a few seeds to increase the supply? The proto-farmers' slowly increasing dependence on cultivated food took the form of a gradual shift, not a sudden change. But at some point an imperceptible line was crossed, and people began to become dependent on farming. The line is crossed when the wild food resources in the surrounding area, were they to be fully exploited, are no longer enough to sustain the population. The deliberate production of supplementary food through farming is then no longer optional, but has become compulsory. At this point there is no going back to a nomadic, hunter-gatherer lifestyle — or not, at least, without significant loss of life.

DID FARMERS SPREAD, OR DID FARMING SPREAD?

Farming then poses a second puzzle. Once agriculture had taken root in a few parts of the world, the question then becomes: Why

did it spread almost everywhere else? One possibility is that farmers spread out, displacing or exterminating hunter-gatherers as they went. Alternatively, hunter-gatherers on the fringes of farming areas might have decided to follow suit and become farmers themselves, adopting the methods and the domesticated crops and animals of their farming neighbors. These two possibilities are known as "demic diffusion" and "cultural diffusion" respectively. So was it the actual farmers or merely the idea of farming that spread?

The idea that farmers spread out from the agricultural homelands, taking domesticated crops and knowledge of farming techniques with them as they went, is supported by evidence from many parts of the world. As farmers set out to establish new communities on unfarmed land, the result was a "wave of advance" centered on the areas where domestication first occurred. Greece appears to have been colonized by farmers who arrived by sea from the Near East between 7000 B.C. and 6500 B.C., for example. Archaeologists have found very few hunter-gatherer sites, but hundreds of early farming sites, in the country. Similarly, farmers arriving via the Korean peninsula from China seem to have introduced rice

agriculture to Japan starting in around 300 B.C. Linguistic evidence also supports the idea of a migration from agricultural homelands in which languages, as well as farming practices, were dispersed. The distribution of language families in Europe, East Asia, and Austronesia is broadly consistent with the archaeological evidence for the diffusion of agriculture. Today, nearly 90 percent of the world's population speaks a language belonging to one of seven language families that had their origins in two agricultural homelands: the Fertile Crescent and parts of China. The languages we speak today, like the foods we eat, are descended from those used by the first farmers.

Yet there is also evidence to suggest that hunter-gatherers were not always pushed aside or exterminated by incoming farmers, but lived alongside them and in some cases became farmers too. The clearest example is found in southern Africa, where Khoisan hunter-gatherers adopted Eurasian cattle from the north and became herders. Several European sites provide archaeological evidence of farmers and hunter-gatherers living side by side and trading goods. The two types of community had very different ideas about what sort of sites were desirable for settlement, so there is no reason why they

could not have coexisted, as long as suitable ecological niches remained for hunter-gatherers. Things would have become progressively more difficult for hunter-gatherers living near farmers, however. Farmers would not have worried so much about overexploiting wild food resources near their settlements, given that they had farmed foods to fall back on. Eventually the hunter-gatherers either joined farming communities, or adopted farming themselves, or were forced to move to new areas.

So which mechanism predominated? In Europe, where the advent of farming has been most intensely studied, researchers have used genetic analysis to determine whether modern Europeans' ancestors were predominantly indigenous hunter-gatherers who took up farming or immigrant farmers who arrived from the Near East. In such studies, people from the Anatolian peninsula (western Turkey), which lies within the Fertile Crescent, are taken to be genetically representative of the earliest farmers. Similarly, Basques are assumed to be the most direct descendants of hunter-gatherers, for two reasons. First, the Basque language bears no resemblance to European languages descended from proto-Indo-European, the language family imported

into Europe along with farming, and instead appears to date back to the Stone Age. (Several Basque words for tools begin with "aitz," the word for stone, which suggests that the words date from a time when stone tools were in use.) Second, there are several Basque-specific genetic variations that are not found in other Europeans.

In one recent study, genetic samples were taken from both these groups and were then compared with samples from populations in different parts of Europe. The researchers found that the genetic contributions from Basques and Anatolians varied significantly across Europe: The Anatolian (that is, Near Eastern farmer) contribution was 79 percent in the Balkans, 45 percent in northern Italy, 63 percent in southern Italy, 35 percent in southern Spain, and 21 percent in England. In short, the contribution from farmers was highest in the east and lowest in the west. And this provides the answer to the puzzle. It suggests that farming spread as a result of a hybrid process in which a migrant farming population spread into Europe from the east and was gradually diluted by intermarriage, so that the resulting population ended up being descended from both groups. The same thing probably happened in other parts of the world, too.

The spread of farming from its agricultural homelands, followed by the population growth of farming communities, meant that farmers outnumbered hunter-gatherers within a few thousand years. By 2000 B.C., the majority of humanity had taken up farming. This was such a fundamental change that even today, many thousands of years later, the distribution of human languages and genes continues to reflect the advent of farming. During domestication, plants were genetically reconfigured by humans; and as agriculture was adopted, humans were genetically reconfigured by plants.

MAN, AN AGRICULTURAL ANIMAL

Human farmers and their domesticated plants and animals struck a grand bargain, though the farmers did not realize it at the time, and their fates became intertwined. Consider maize. Domestication made it dependent on man, but its alliance with humans also carried maize far beyond its origins as an obscure Mexican grass, so that it is now one of the most widely planted crops on earth. From mankind's point of view, meanwhile, the domestication of maize made available an abundant new source of food; but its cultivation (like that of other

plants) prompted people to adopt a new, sedentary lifestyle based on farming. Is man exploiting maize for his own purposes, or is maize exploiting man? Domestication, it seems, is a two-way street.

Even today, thousands of years after the first farmers began the process of domesticating plants and animals, mankind is still a farming species, and food production remains humanity's primary occupation. Agriculture employs 41 percent of the human race, more than any other activity, and accounts for 40 percent of the world's land area. (About a third of this land is used for crop production, and about two thirds provide pasture for livestock.) And the same three foods that underpinned the world's earliest civilizations are still the foundations of human existence: Wheat, rice, and maize continue to provide the bulk of the calories consumed by the human race. The vast majority of the remaining calories are derived from domesticated plants and animals. Only a small proportion of the food consumed by humans today comes from wild food sources: fish, shellfish, and a sprinkling of wild berries, nuts, mushrooms, and so on.

Accordingly, almost none of the food we eat today can truly be described as natural.

Nearly all of it is the result of selective breeding — unwitting at first, but then more deliberate and careful as farmers propagated the most valuable characteristics found in the wild to create new, domesticated mutants better suited to human needs. Corn, cows, and chickens as we know them do not occur in nature, and they would not exist today without human intervention. Even orange carrots are man-made. Carrots were originally white and purple, and the sweeter orange variety was created by Dutch horticulturalists in the sixteenth century as a tribute to William I, Prince of Orange. An attempt by a British supermarket to reintroduce the traditional purple variety in 2002 failed, because shoppers preferred the selectively bred orange sort.

All domesticated plants and animals are man-made technologies. What is more, almost all of the domesticated plants and animals on which we now rely date back to ancient times. Most of them had been domesticated by 2000 B.C., and very few have been added since. Of the fourteen large animals to have been domesticated only one, the reindeer, was domesticated in the past thousand years; and it is of marginal value (tasty though it is). The same goes for plants: Blueberries, strawberries, cranber-

ries, kiwis, macadamia nuts, pecans, and cashews have all been domesticated relatively recently, but none is a significant foodstuff.

Only aquatic species have been domesticated in significant quantities in the past century. In short, early farmers managed to domesticate most of the plants and animals worth bothering with many thousands of years ago. That may explain why domesticated plants and animals are so widely assumed to be natural, and why contemporary efforts to refine them further using modern genetic-engineering techniques attract such criticism and provoke such fear. Yet such genetic engineering is arguably just the latest twist in a field of technology that dates back more than ten thousand years. Herbicide-tolerant maize does not occur in nature, it is true — but nor does any other kind of maize.

The simple truth is that farming is profoundly unnatural. It has done more to change the world, and has had a greater impact on the environment, than any other human activity. It has led to widespread deforestation, environmental destruction, the displacement of "natural" wildlife, and the transplanting of plants and animals thousands of miles from their original

habitats. It involves the genetic modification of plants and animals to create monstrous mutants that do not exist in nature and often cannot survive without human intervention. It overturned the hunter-gatherer way of life that had defined human existence for tens of thousands of years, prompting humans to exchange a varied, leisurely existence of hunting-and-gathering for lives of drudgery and toil. Agriculture would surely not be allowed if it were invented today. And yet, for all its faults, it is the basis of civilization as we know it. Domesticated plants and animals form the very foundations of the modern world.