CHAPTER 4

FARMER POWER

As A TEENAGER, I SPENT THE SUMMER OF 1956 IN MONtana, working for an elderly farmer named Fred Hirschy. Born in Switzerland, Fred had come to southwestern Montana as a teenager in the 1890s and proceeded to develop one of the first farms in the area. At the time of his arrival, much of the original Native American population of hunter-gatherers was still living there.

My fellow farmhands were, for the most part, tough whites whose normal speech featured strings of curses, and who spent their weekdays working so that they could devote their weekends to squandering their week's wages in the local saloon. Among the farmhands, though, was a member of the Blackfoot Indian tribe named Levi, who behaved very differently from the coarse miners—being polite, gentle, responsible, sober, and well spoken. He was the first Indian with whom I had spent much time, and I came to admire him.

It was therefore a shocking disappointment to me when, one Sunday morning, Levi too staggered in drunk and cursing after a Saturday-night binge. Among his curses, one has stood out in my memory: "Damn you, Fred Hirschy, and damn the ship that brought you from Switzerland!" It poignantly brought home to me the Indians' perspective on what I, like other white schoolchildren, had been taught to view as the heroic conquest

of the American West. Fred Hirschy's family was proud of him, as a pioneer farmer who had succeeded under difficult conditions. But Levi's tribe of hunters and famous warriors had been robbed of its lands by the immigrant white farmers. How did the farmers win out over the famous warriors?

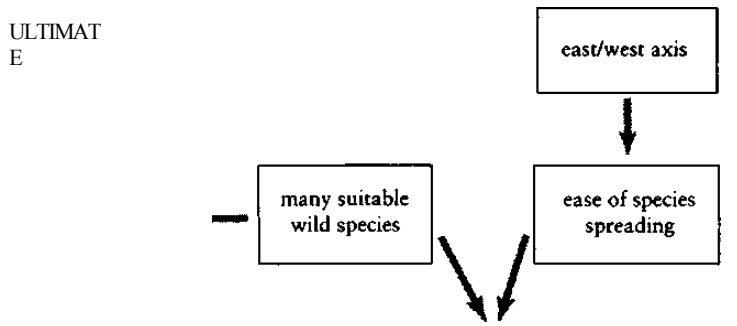
For most of the time since the ancestors of modern humans diverged from the ancestors of the living great apes, around 7 million years ago, all humans on Earth fed themselves exclusively by hunting wild animals and gathering wild plants, as the Blackfeet still did in the 19th century. It was only within the last 11,000 years that some peoples turned to what is termed food production: that is, domesticating wild animals and plants and eating the resulting livestock and crops. Today, most people on Earth consume food that they produced themselves or that someone else produced for them. At current rates of change, within the next decade the few remaining bands of hunter-gatherers will abandon their ways, disintegrate, or die out, thereby ending our millions of years of commitment to the hunter-gatherer lifestyle.

Different peoples acquired food production at different times in prehistory. Some, such as Aboriginal Australians, never acquired it at all. Of those who did, some (for example, the ancient Chinese) developed it independently by themselves, while others (including ancient Egyptians) acquired it from neighbors. But, as we'll see, food production was indirectly a prerequisite for the development of guns, germs, and steel. Hence geographic variation in whether, or when, the peoples of different continents became farmers and herders explains to a large extent their subsequent contrasting fates. Before we devote the next six chapters to understanding how geographic differences in food production arose, this chapter will trace the main connections through which food production led to all the advantages that enabled Pizarro to capture Atahuallpa, and Fred Hirschy's people to dispossess Levi's (Figure 4.1).

The first connection is the most direct one: availability of more consum-

Figure 4.1. Schematic overview of the chains of causation leading up to proximate factors (such as guns, horses, and diseases) enabling some peoples to conquer other peoples, from ultimate factors (such as the orientation of continental axes). For example, diverse epidemic diseases of humans evolved in areas with many wild plant and animal species suitable for domestication, partly because the resulting crops and livestock

Factors Underlying the Broadest Pattern of History



helped feed dense societies in which epidemics could maintain themselves, and partly because the diseases evolved from germs of the domestic animals themselves.

able calories means more people. Among wild plant and animal species, only a small minority are edible to humans or worth hunting or gathering. Most species are useless to us as food, for one or more of the following reasons: they are indigestible (like bark), poisonous (monarch butterflies and death-cap mushrooms), low in nutritional value (jellyfish), tedious to prepare (very small nuts), difficult to gather (larvae of most insects), or dangerous to hunt (rhinoceroses). Most biomass (living biological matter) on land is in the form of wood and leaves, most of which we cannot digest.

By selecting and growing those few species of plants and animals that we can eat, so that they constitute 90 percent rather than 0.1 percent of the biomass on an acre of land, we obtain far more edible calories per acre. As a result, one acre can feed many more herders and farmers—typically, 10 to 100 times more—than hunter-gatherers. That strength of brute numbers was the first of many military advantages that food-producing tribes gained over hunter-gatherer tribes.

In human societies possessing domestic animals, livestock fed more people in four distinct ways: by furnishing meat, milk, and fertilizer and by pulling plows. First and most directly, domestic animals became the societies' major source of animal protein, replacing wild game. Today, for instance, Americans tend to get most of their animal protein from cows, pigs, sheep, and chickens, with game such as venison just a rare delicacy. In addition, some big domestic mammals served as sources of milk and of milk products such as butter, cheese, and yogurt. Milked mammals include the cow, sheep, goat, horse, reindeer, water buffalo, yak, and Arabian and Bactrian camels. Those mammals thereby yield several times more calories over their lifetime than if they were just slaughtered and consumed as meat.

Big domestic mammals also interacted with domestic plants in two ways to increase crop production. First, as any modern gardener or farmer still knows by experience, crop yields can be greatly increased by manure applied as fertilizer. Even with the modern availability of synthetic fertilizers produced by chemical factories, the major source of crop fertilizer today in most societies is still animal manure—especially of cows, but also of yaks and sheep. Manure has been valuable, too, as a source of fuel for fires in traditional societies.

In addition, the largest domestic mammals interacted with domestic plants to increase food production by pulling plows and thereby making it possible for people to till land that had previously been uneconomical for farming. Those plow animals were the cow, horse, water buffalo, Bali

cattle, and yak / cow hybrids. Here is one example of their value: the first prehistoric farmers of central Europe, the so-called Linearbandkeramik culture that arose slightly before 5000 B.C., were initially confined to soils light enough to be tilled by means of hand-held digging sticks. Only over a thousand years later, with the introduction of the ox-drawn plow, were those farmers able to extend cultivation to a much wider range of heavy soils and tough sods. Similarly, Native American farmers of the North American Great Plains grew crops in the river valleys, but farming of the tough sods on the extensive uplands had to await 19th-century Europeans and their animal-drawn plows.

All those are direct ways in which plant and animal domestication led to denser human populations by yielding more food than did the hunter-gatherer lifestyle. A more indirect way involved the consequences of the sedentary lifestyle enforced by food production. People of many hunter-gatherer societies move frequently in search of wild foods, but farmers must remain near their fields and orchards. The resulting fixed abode contributes to denser human populations by permitting a shortened birth interval. A hunter-gatherer mother who is shifting camp can carry only one child, along with her few possessions. She cannot afford to bear her next child until the previous toddler can walk fast enough to keep up with the tribe and not hold it back. In practice, nomadic hunter-gatherers space their children about four years apart by means of lactational amenorrhea, sexual abstinence, infanticide, and abortion. By contrast, sedentary people, unconstrained by problems of carrying young children on treks, can bear and raise as many children as they can feed. The birth interval for many farm peoples is around two years, half that of hunter-gatherers. That higher birthrate of food producers, together with their ability to feed more people per acre, lets them achieve much higher population densities than hunter-gatherers.

A separate consequence of a settled existence is that it permits one to store food surpluses, since storage would be pointless if one didn't remain nearby to guard the stored food. While some nomadic hunter-gatherers may occasionally bag more food than they can consume in a few days, such a bonanza is of little use to them because they cannot protect it. But stored food is essential for feeding non-food-producing specialists, and certainly for supporting whole towns of them. Hence nomadic hunter-gatherer societies have few or no such full-time specialists, who instead first appear in sedentary societies.

Two types of such specialists are kings and bureaucrats. Hunter-gath-

erer societies tend to be relatively egalitarian, to lack full-time bureaucrats and hereditary chiefs, and to have small-scale political organization at the level of the band or tribe. That's because all able-bodied hunter-gatherers are obliged to devote much of their time to acquiring food. In contrast, once food can be stockpiled, a political elite can gain control of food produced by others, assert the right of taxation, escape the need to feed itself, and engage full-time in political activities. Hence moderate-sized agricultural societies are often organized in chiefdoms, and kingdoms are confined to large agricultural societies. Those complex political units are much better able to mount a sustained war of conquest than is an egalitarian band of hunters. Some hunter-gatherers in especially rich environments, such as the Pacific Northwest coast of North America and the coast of Ecuador, also developed sedentary societies, food storage, and nascent chiefdoms, but they did not go farther on the road to kingdoms.

A stored food surplus built up by taxation can support other full-time specialists besides kings and bureaucrats. Of most direct relevance to wars of conquest, it can be used to feed professional soldiers. That was the decisive factor in the British Empire's eventual defeat of New Zealand's well-armed indigenous Maori population. While the Maori achieved some stunning temporary victories, they could not maintain an army constantly in the field and were in the end worn down by 18,000 full-time British troops. Stored food can also feed priests, who provide religious justification for wars of conquest; artisans such as metalworkers, who develop swords, guns, and other technologies; and scribes, who preserve far more information than can be remembered accurately.

So far, I've emphasized direct and indirect values of crops and livestock as food. However, they have other uses, such as keeping us warm and providing us with valuable materials. Crops and livestock yield natural fibers for making clothing, blankets, nets, and rope. Most of the major centers of plant domestication evolved not only food crops but also fiber crops—notably cotton, flax (the source of linen), and hemp. Several domestic animals yielded animal fibers—especially wool from sheep, goats, llamas, and alpacas, and silk from silkworms. Bones of domestic animals were important raw materials for artifacts of Neolithic peoples before the development of metallurgy. Cow hides were used to make leather. One of the earliest cultivated plants in many parts of the Americas was grown for nonfood purposes: the bottle gourd, used as a container.

Big domestic mammals further revolutionized human society by becom-

ing our main means of land transport until the development of railroads in the 19th century. Before animal domestication, the sole means of transporting goods and people by land was on the backs of humans. Large mammals changed that: for the first time in human history, it became possible to move heavy goods in large quantities, as well as people, rapidly overland for long distances. The domestic animals that were ridden were the horse, donkey, yak, reindeer, and Arabian and Bactrian camels. Animals of those same five species, as well as the llama, were used to bear packsCows and horses were hitched to wagons, while reindeer and dogs pulled sleds in the Arctic. The horse became the chief means of long-distance transport over most of Eurasia. The three domestic camel species (Arabian camel, Bactrian camel, and llama) played a similar role in areas of North Africa and Arabia, Central Asia, and the Andes, respectively.

The most direct contribution of plant and animal domestication to wars of conquest was from Eurasia's horses, whose military role made them the jeeps and Sherman tanks of ancient warfare on that continent. As I mentioned in Chapter 3, they enabled Cortes and Pizarro, leading only small bands of adventurers, to overthrow the Aztec and Inca Empires. Even much earlier (around 4000 B.C.), at a time when horses were still ridden bareback, they may have been the essential military ingredient behind the westward expansion of speakers of Indo-European languages from the Ukraine. Those languages eventually replaced all earlier western European languages except Basque. When horses later were yoked to wagons and other vehicles, horse-drawn battle chariots (invented around 1800 B.C.) proceeded to revolutionize warfare in the Near East, the Mediterranean region, and China. For example, in 1674 B.C., horses even enabled a foreign people, the Hyksos, to conquer then horseless Egypt and to establish themselves temporarily as pharaohs.

Still later, after the invention of saddles and stirrups, horses allowed the Huns and successive waves of other peoples from the Asian steppes to terrorize the Roman Empire and its successor states, culminating in the Mongol conquests of much of Asia and Russia in the 13th and 14th centuries A.D. Only with the introduction of trucks and tanks in World War I did horses finally become supplanted as the main assault vehicle and means of fast transport in war. Arabian and Bactrian camels played a similar military role within their geographic range. In all these examples, peoples with domestic horses (or camels), or with improved means of using them, enjoyed an enormous military advantage over those without them.

Of equal importance in wars of conquest were the germs that evolved in human societies with domestic animals. Infectious diseases like smallpox, measles, and flu arose as specialized germs of humans, derived by mutations of very similar ancestral germs that had infected animals (Chapter 11). The humans who domesticated animals were the first to fall victim to the newly evolved germs, but those humans then evolved substantial resistance to the new diseases. When such partly immune people came into contact with others who had had no previous exposure to the germs, epidemics resulted in which up to 99 percent of the previously unexposed population was killed. Germs thus acquired ultimately from domestic animals played decisive roles in the European conquests of Native Americans, Australians, South Africans, and Pacific islanders.

In short, plant and animal domestication meant much more food and hence much denser human populations. The resulting food surpluses, and (in some areas) the animal-based means of transporting those surpluses, were a prerequisite for the development of settled, politically centralized, socially stratified, economically complex, technologically innovative societies. Hence the availability of domestic plants and animals ultimately explains why empires, literacy, and steel weapons developed earliest in Eurasia and later, or not at all, on other continents. The military uses of horses and camels, and the killing power of animal-derived germs, complete the list of major links between food production and conquest that we shall be exploring.

CHAPTER 6

TO FARM OR NOT TO FARM

FORMERLY, ALL PEOPLE ON EARTH WERE HUNTER-GATHERers. Why did any of them adopt food production at all? Given that they must have had some reason, why did they do so around 8500 B.C. in Mediterranean habitats of the Fertile Crescent, only 3,000 years later in the climatically and structurally similar Mediterranean habitats of southwestern Europe, and never indigenously in the similar Mediterranean habitats of California, southwestern Australia, and the Cape of South Africa? Why did even people of the Fertile Crescent wait until 8500 B.C., instead of becoming food producers already around 18,500 or 28,500 B.C.?

From our modern perspective, all these questions at first seem silly, because the drawbacks of being a hunter-gatherer appear so obvious. Scientists used to quote a phrase of Thomas Hobbes's in order to characterize the lifestyle of hunter-gatherers as "nasty, brutish, and short." They seemed to have to work hard, to be driven by the daily quest for food, often to be close to starvation, to lack such elementary material comforts as soft beds and adequate clothing, and to die young.

In reality, only for today's affluent First World citizens, who don't actually do the work of raising food themselves, does food production (by remote agribusinesses) mean less physical work, more comfort, freedom from starvation, and a longer expected lifetime. Most peasant farmers and

herders, who constitute the great majority of the world's actual food producers, aren't necessarily better off than hunter-gatherers. Time budget studies show that they may spend more rather than fewer hours per day at work than hunter-gatherers do. Archaeologists have demonstrated that the first farmers in many areas were smaller and less well nourished, suffered from more serious diseases, and died on the average at a younger age than the hunter-gatherers they replaced. If those first farmers could have foreseen the consequences of adopting food production, they might not have opted to do so. Why, unable to foresee the result, did they nevertheless make that choice?

There exist many actual cases of hunter-gatherers who did see food production practiced by their neighbors, and who nevertheless refused to accept its supposed blessings and instead remained hunter-gatherers. For instance, Aboriginal hunter-gatherers of northeastern Australia traded for thousands of years with farmers of the Torres Strait Islands, between Australia and New Guinea. California Native American hunter-gatherers traded with Native American farmers in the Colorado River valley. In addition, Khoi herders west of the Fish River of South Africa traded with Bantu farmers east of the Fish River, and continued to dispense with farming themselves. Why?

Still other hunter-gatherers in contact with farmers did eventually become farmers, but only after what may seem to us like an inordinately long delay. For example, the coastal peoples of northern Germany did not adopt food production until 1,300 years after peoples of the Linearband-keramik culture introduced it to inland parts of Germany only 125 miles to the south. Why did those coastal Germans wait so long, and what led them finally to change their minds?

BEFORE WE CAN answer these questions, we must dispel some misconceptions about the origins of food production and then reformulate the question. What actually happened was not a *discovery* of food production, nor an *invention,* as we might first assume. There was often not even a conscious choice between food production and hunting-gathering. Specifically, in each area of the globe the first people who adopted food production could obviously not have been making a conscious choice or consciously striving toward farming as a goal, because they had never seen farming and had no way of knowing what it would be like. Instead, as we

shall see, food production *evolved* as a by-product of decisions made without awareness of their consequences. Hence the question that we have to ask is why food production did evolve, why it evolved in some places but not others, why at different times in different places, and why not instead at some earlier or later date.

Another misconception is that there is necessarily a sharp divide between nomadic hunter-gatherers and sedentary food producers. In reality, although we frequently draw such a contrast, hunter-gatherers in some productive areas, including North America's Pacific Northwest coast and possibly southeastern Australia, became sedentary but never became food producers. Other hunter-gatherers, in Palestine, coastal Peru, and Japan, became sedentary first and adopted food production much later. Sedentary groups probably made up a much higher fraction of hunter-gatherers 15,000 years ago, when all inhabited parts of the world (including the most productive areas) were still occupied by hunter-gatherers, than they do today, when the few remaining hunter-gatherers survive only in unproductive areas where nomadism is the sole option.

Conversely, there are mobile groups of food producers. Some modern nomads of New Guinea's Lakes Plains make clearings in the jungle, plant bananas and papayas, go off for a few months to live again as hunter-gatherers, return to check on their crops, weed the garden if they find the crops growing, set off again to hunt, return months later to check again, and settle down for a while to harvest and eat if their garden has produced. Apache Indians of the southwestern United States settled down to farm in the summer at higher elevations and toward the north, then withdrew to the south and to lower elevations to wander in search of wild foods during the winter. Many herding peoples of Africa and Asia shift camp along regular seasonal routes to take advantage of predictable seasonal changes in pasturage. Thus, the shift from hunting-gathering to food production did not always coincide with a shift from nomadism to sedentary living.

Another supposed dichotomy that becomes blurred in reality is a distinction between food producers as active managers of their land and hunter-gatherers as mere collectors of the land's wild produce. In reality, some hunter-gatherers intensively manage their land. For example, New Guinea peoples who never domesticated sago palms or mountain pandanus nevertheless increase production of these wild edible plants by clearing away encroaching competing trees, keeping channels in sago swamps clear, and promoting growth of new sago shoots by cutting down mature

sago trees. Aboriginal Australians who never reached the stage of farming yams and seed plants nonetheless anticipated several elements of farming. They managed the landscape by burning it, to encourage the growth of edible seed plants that sprout after fires. In gathering wild yams, they cut off most of the edible tuber but replaced the stems and tops of the tubers in the ground so that the tubers would regrow. Their digging to extract the tuber loosened and aerated the soil and fostered regrowth. All that they would have had to do to meet the definition of farmers was to carry the stems and remaining attached tubers home and similarly replace them in soil at their camp.

FROM THOSE PRECURSORS of food production already practiced by hunter-gatherers, it developed stepwise. Not all the necessary techniques were developed within a short time, and not all the wild plants and animals that were eventually domesticated in a given area were domesticated simultaneously. Even in the cases of the most rapid independent development of food production from a hunting-gathering lifestyle, it took thousands of years to shift from complete dependence on wild foods to a diet with very few wild foods. In early stages of food production, people simultaneously collected wild foods *and* raised cultivated ones, and diverse types of collecting activities diminished in importance at different times as reliance on crops increased.

The underlying reason why this transition was piecemeal is that food production systems evolved as a result of the accumulation of many separate decisions about allocating time and effort. Foraging humans, like foraging animals, have only finite time and energy, which they can spend in various ways. We can picture an incipient farmer waking up and asking: Shall I spend today hoeing my garden (predictably yielding a lot of vegetables several months from now), gathering shellfish (predictably yielding a little meat today), or hunting deer (yielding possibly a lot of meat today, but more likely nothing)? Human and animal foragers are constantly prioritizing and making effort-allocation decisions, even if only unconsciously. They concentrate first on favorite foods, or ones that yield the highest payoff. If these are unavailable, they shift to less and less preferred foods.

Many considerations enter into these decisions. People seek food in order to satisfy their hunger and fill their bellies. They also crave specific foods, such as protein-rich foods, fat, salt, sweet fruits, and foods that

simply taste good. All other things being equal, people seek to maximize their return of calories, protein, or other specific food categories by foraging in a way that yields the most return with the greatest certainty in the least time for the least effort. Simultaneously, they seek to minimize their risk of starving: moderate but reliable returns are preferable to a fluctuating lifestyle with a high time-averaged rate of return but a substantial likelihood of starving to death. One suggested function of the first gardens of nearly 11,000 years ago was to provide a reliable reserve larder as insurance in case wild food supplies failed.

Conversely, men hunters tend to guide themselves by considerations of prestige: for example, they might rather go giraffe hunting every day, bag a giraffe once a month, and thereby gain the status of great hunter, than bring home twice a giraffe's weight of food in a month by humbling themselves and reliably gathering nuts every day. People are also guided by seemingly arbitrary cultural preferences, such as considering fish either delicacies or taboo. Finally, their priorities are heavily influenced by the relative values they attach to different lifestyles—just as we can see today. For instance, in the 19th-century U.S. West, the cattlemen, sheepmen, and farmers all despised each other. Similarly, throughout human history farmers have tended to despise hunter-gatherers as primitive, hunter-gatherers have despised farmers as ignorant, and herders have despised both. All these elements come into play in people's separate decisions about how to obtain their food.

As WE ALREADY noted, the first farmers on each continent could not have chosen farming consciously, because there were no other nearby farmers for them to observe. However, once food production had arisen in one part of a continent, neighboring hunter-gatherers could see the result and make conscious decisions. In some cases the hunter-gatherers adopted the neighboring system of food production virtually as a complete package; in others they chose only certain elements of it; and in still others they rejected food production entirely and remained hunter-gatherers.

For example, hunter-gatherers in parts of southeastern Europe had quickly adopted Southwest Asian cereal crops, pulse crops, and livestock simultaneously as a complete package by around 6000 B.C. All three of these elements also spread rapidly through central Europe in the centuries before 5000 B.C. Adoption of food production may have been rapid and

wholesale in southeastern and central Europe because the hunter-gatherer lifestyle there was less productive and less competitive. In contrast, food production was adopted piecemeal in southwestern Europe (southern France, Spain, and Italy), where sheep arrived first and cereals later. The adoption of intensive food production from the Asian mainland was also very slow and piecemeal in Japan, probably because the hunter-gatherer lifestyle based on seafood and local plants was so productive there.

Just as a hunting-gathering lifestyle can be traded piecemeal for a food-producing lifestyle, one system of food production can also be traded piecemeal for another. For example, Indians of the eastern United States were domesticating local plants by about 2500 B.C. but had trade connections with Mexican Indians who developed a more productive crop system based on the trinity of corn, squash, and beans. Eastern U.S. Indians adopted Mexican crops, and many of them discarded many of their local domesticates, piecemeal; squash was domesticated independently, corn arrived from Mexico around A.D. 200 but remained a minor crop until around A.D. 900, and beans arrived a century or two later. It even happened that food-production systems were abandoned in favor of hunting-gathering. For instance, around 3000 B.C. the hunter-gatherers of southern Sweden adopted farming based on Southwest Asian crops, but abandoned it around 2700 B.C. and reverted to hunting-gathering for 400 years before resuming farming.

ALL THESE CONSIDERATIONS make it clear that we should not suppose that the decision to adopt farming was made in a vacuum, as if the people had previously had no means to feed themselves. Instead, we must consider food production and hunting-gathering as *alternative strategies* competing with each other. Mixed economies that added certain crops or livestock to hunting-gathering also competed against both types of "pure" economies, and against mixed economies with higher or lower proportions of food production. Nevertheless, over the last 10,000 years, the predominant result has been a shift from hunting-gathering to food production. Hence we must ask: What were the factors that tipped the competitive advantage away from the former and toward the latter?

That question continues to be debated by archaeologists and anthropologists. One reason for its remaining unsettled is that different factors may have been decisive in different parts of the world. Another has been the

problem of disentangling cause and effect in the rise of food production. However, five main contributing factors can still be identified; the controversies revolve mainly around their relative importance.

One factor is the decline in the availability of wild foods. The lifestyle of hunter-gatherers has become increasingly less rewarding over the past 13,000 years, as resources on which they depended (especially animal resources) have become less abundant or even disappeared. As we saw in Chapter 1, most large mammal species became extinct in North and South America at the end of the Pleistocene, and some became extinct in Eurasia and Africa, either because of climate changes or because of the rise in skill and numbers of human hunters. While the role of animal extinctions in eventually (after a long lag) nudging ancient Native Americans, Eurasians, and Africans toward food production can be debated, there are numerous incontrovertible cases on islands in more recent times. Only after the first Polynesian settlers had exterminated moas and decimated seal populations on New Zealand, and exterminated or decimated seabirds and land birds on other Polynesian islands, did they intensify their food production. For instance, although the Polynesians who colonized Easter Island around A.D. 500 brought chickens with them, chicken did not become a major food until wild birds and porpoises were no longer readily available as food. Similarly, a suggested contributing factor to the rise of animal domestication in the Fertile Crescent was the decline in abundance of the wild gazelles that had previously been a major source of meat for hunter-gatherers in that area.

A second factor is that, just as the depletion of wild game tended to make hunting-gathering less rewarding, an increased availability of domesticable wild plants made steps leading to plant domestication more rewarding. For instance, climate changes at the end of the Pleistocene in the Fertile Crescent greatly expanded the area of habitats with wild cereals, of which huge crops could be harvested in a short time. Those wild cereal harvests were precursors to the domestication of the earliest crops, the cereals wheat and barley, in the Fertile Crescent.

Still another factor tipping the balance away from hunting-gathering was the cumulative development of technologies on which food production would eventually depend—technologies for collecting, processing, and storing wild foods. What use can would-be farmers make of a ton of wheat grains on the stalk, if they have not first figured out how to harvest, husk, and store them? The necessary methods, implements, and facilities

appeared rapidly in the Fertile Crescent after 11,000 B.C., having been invented for dealing with the newly available abundance of wild cereals.

Those inventions included sickles of flint blades cemented into wooden or bone handles, for harvesting wild grains; baskets in which to carry the grains home from the hillsides where they grew; mortars and pestles, or grinding slabs, to remove the husks; the technique of roasting grains so that they could be stored without sprouting; and underground storage pits, some of them plastered to make them waterproof. Evidence for all of these techniques becomes abundant at sites of hunter-gatherers in the Fertile Crescent after 11,000 B.C. All these techniques, though developed for the exploitation of wild cereals, were prerequisites to the planting of cereals as crops. These cumulative developments constituted the unconscious first steps of plant domestication.

A fourth factor was the two-way link between the rise in human population density and the rise in food production. In all parts of the world where adequate evidence is available, archaeologists find evidence of rising densities associated with the appearance of food production. Which was the cause and which the result? This is a long-debated chicken-or-egg problem: did a rise in human population density force people to turn to food production, or did food production permit a rise in human population density?

In principle, one expects the chain of causation to operate in both directions. As I've already discussed, food production tends to lead to increased population densities because it yields more edible calories per acre than does hunting-gathering. On the other hand, human population densities were gradually rising throughout the late Pleistocene anyway, thanks to improvements in human technology for collecting and processing wild foods. As population densities rose, food production became increasingly favored because it provided the increased food outputs needed to feed all those people.

That is, the adoption of food production exemplifies what is termed an autocatalytic process—one that catalyzes itself in a positive feedback cycle, going faster and faster once it has started. A gradual rise in population densities impelled people to obtain more food, by rewarding those who unconsciously took steps toward producing it. Once people began to produce food and become sedentary, they could shorten the birth spacing and produce still more people, requiring still more food. This bidirectional link between food production and population density explains the paradox

that food production, while increasing the quantity of edible calories per acre, left the food producers less well nourished than the hunter-gatherers whom they succeeded. That paradox developed because human population densities rose slightly more steeply than did the availability of food.

Taken together, these four factors help us understand why the transition to food production in the Fertile Crescent began around 8500 B.C., not around 18,500 or 28,500 B.C. At the latter two dates hunting-gathering was still much more rewarding than incipient food production, because wild mammals were still abundant; wild cereals were not yet abundant; people had not yet developed the inventions necessary for collecting, processing, and storing cereals efficiently; and human population densities were not yet high enough for a large premium to be placed on extracting more calories per acre.

A final factor in the transition became decisive at geographic boundaries between hunter-gatherers and food producers. The much denser populations of food producers enabled them to displace or kill hunter-gatherers by their sheer numbers, not to mention the other advantages associated with food production (including technology, germs, and professional soldiers). In areas where there were only hunter-gatherers to begin with, those groups of hunter-gatherers who adopted food production outbred those who didn't.

As a result, in most areas of the globe suitable for food production, hunter-gatherers met one of two fates: either they were displaced by neighboring food producers, or else they survived only by adopting food production themselves. In places where they were already numerous or where geography retarded immigration by food producers, local hunter-gatherers did have time to adopt farming in prehistoric times and thus to survive as farmers. This may have happened in the U.S. Southwest, in the western Mediterranean, on the Atlantic coast of Europe, and in parts of Japan. However, in Indonesia, tropical Southeast Asia, most of subequatorial Africa, and probably in parts of Europe, the hunter-gatherers were replaced by farmers in the prehistoric era, whereas a similar replacement took place in modern times in Australia and much of the western United States.

Only where especially potent geographic or ecological barriers made immigration of food producers or diffusion of locally appropriate food-producing techniques very difficult were hunter-gatherers able to persist until modern times in areas suitable for food production. The three out-

standing examples are the persistence of Native American hunter-gatherers in California, separated by deserts from the Native American farmers of Arizona; that of Khoisan hunter-gatherers at the Cape of South Africa, in a Mediterranean climate zone unsuitable for the equatorial crops of nearby Bantu farmers; and that of hunter-gatherers throughout the Australian continent, separated by narrow seas from the food producers of Indonesia and New Guinea. Those few peoples who remained hunter-gatherers into the 20th century escaped replacement by food producers because they were confined to areas not fit for food production, especially deserts and Arctic regions. Within the present decade, even they will have been seduced by the attractions of civilization, settled down under pressure from bureaucrats or missionaries, or succumbed to germs.