SOURCE PACKET II: SYSTEMS HISTORY

We will use the following source in our lesson on how problems are often much more complex than you may initially believe them to be once you think of them as part of a large and multifaceted system. As you read the following secondary sources, please jot down your impressions—anything you find striking, interesting, confusing, or otherwise worth your attention—in the margins or in a separate notebook.

Source I: Guns, Germs, and Steel[1]

Plant Domestication: Mastery over Nature or Luck of the Draw? (Adapted from Chapter 7: "How to Make an Almond: The unconscious development of ancient crops")

IF YOU'RE A HIKER WHOSE APPETITE IS JADED BY FARM-grown foods, it's fun to try eating wild foods. You know that some wild plants, such as wild strawberries and blueberries, are both tasty and safe to eat. They're sufficiently similar to familiar crops that you can easily recognize the wild berries, even though they're much smaller than those we grow. Adventurous hikers cautiously eat mushrooms, aware that many species can kill us. But not even **ardent** nut lovers eat wild almonds, of which a few dozen contain enough cyanide (the poison used in Nazi gas chambers) to kill us. The forest is full of many other plants deemed inedible. Yet all crops arose from wild plant species. How did certain wild plants get turned into crops? That question is especially puzzling in regard to the many crops (like almonds) whose wild **progenitors** are lethal or bad-tasting, and to other crops (like corn) that look drastically different from their wild ancestors. What cavewoman or caveman ever got the idea of "domesticating" a plant, and how was it accomplished?

Plant domestication may be defined as growing a plant and thereby, consciously or unconsciously, causing it to change genetically from its wild ancestor in ways making it more useful to human consumers. Crop development is today a conscious, highly specialized effort carried out by professional scientists. They already know about the hundreds of existing crops and set out to develop yet another one. To achieve that goal, they plant many different seeds or roots, select the best **progeny** and plant their seeds, apply knowledge of genetics to develop good varieties that breed true, and perhaps even use the latest techniques of genetic engineering to transfer specific useful genes. At the Davis campus of the University of California, an entire department (the Department of **Pomology**) is devoted to apples and another (the Department of **Viticulture** and **Enology**) to grapes and wine.

But plant domestication goes back over 10,000 years. Early farmers surely didn't use molecular genetic techniques to arrive at their results. The first farmers didn't even have any existing crop as a model to inspire them to develop new ones. Hence they couldn't have known that, whatever they were doing, they would enjoy a tasty treat as a result.

[1] Jared M. Diamond, *Guns, Germs, and Steel: A short history of everybody for the last 13,000 years* (London: Vintage, 1998).

How, then, did early farmers domesticate plants **unwittingly**? For example, how did they turn poisonous almonds into safe ones without knowing what they were doing? What changes did they actually make in wild plants, besides **rendering** some of them bigger or less poisonous? Even for valuable crops, the times of domestication vary greatly: for instance, peas were domesticated by 8000 B.C., olives around 4000 B.C., strawberries not until the Middle Ages, and pecans not until 1846. Many valuable wild plants yielding food prized by millions of people, such as oaks sought for their edible acorns in many parts of the world, remain untamed even today. What made some plants so much easier or more inviting to domesticate than others? Why did olive trees yield to Stone Age farmers, whereas oak trees continue to defeat our brightest **agronomists**?

LET'S BEGIN BY looking at domestication from the plant's point of view. As far as plants are concerned, we're just one of thousands of animal species that unconsciously "domesticate" plants.
Like all animal species (including humans), plants must spread their offspring to areas where they can thrive and pass on their parents' genes. Young animals **disperse** by walking or flying, but plants don't have that option, so they must somehow **hitchhike**. While some plant species have seeds adapted for being carried by the wind or for floating on water, many others trick an animal into carrying their seeds, by wrapping the seed in a tasty fruit and advertising the fruit's ripeness by its color or smell. The hungry animal plucks and swallows the fruit, walks or flies off, and then spits out or **defecates** the seed somewhere far from its parent tree. Seeds can in this manner be carried for thousands of miles.
It may come as a surprise to learn that plant seeds can resist digestion by your gut and nonetheless germinate out of your feces. But any adventurous readers who are not too squeamish can make the test and prove it for themselves. The seeds of many wild plant species actually must pass through an animal's gut before they can **germinate**. For instance, one African melon species is so well adapted to being eaten by a hyena-like animal called the aardvark that most melons of that species grow on the **latrine** sites of aardvarks.

As an example of how would-be plant hitchhikers attract animals, consider wild strawberries. When strawberry seeds are still young and not yet ready to be planted, the surrounding fruit is green, sour, and hard. When the seeds finally mature, the berries turn red, sweet, and tender. The change in the berries' color serves as a signal attracting birds like thrushes to pluck the berries and fly off, eventually to spit out or defecate the seeds. Naturally, strawberry plants didn't set out with a conscious intent of attracting birds when, and only when, their seeds were ready to be dispersed. Neither did **thrushes** set out with the intent of domesticating strawberries. Instead, strawberry plants evolved through natural selection. The greener and more sour the young strawberry, the fewer the birds that destroyed the seeds by eating berries before the seeds were ready; the sweeter and redder the final strawberry, the more numerous the birds that dispersed its ripe seeds.

Countless other plants have fruits adapted to being eaten and dispersed by particular species of animals. Just as strawberries are adapted to birds, so acorns are adapted to squirrels, mangos to bats, and some **sedges** to ants. That fulfills part of our definition of plant domestication, as the genetic modification of an ancestral plant in ways that make it more useful to consumers. But no one would seriously describe this evolutionary process as domestication, because birds and bats and other animal consumers don't fulfill the other part of the definition: they don't consciously grow plants. In the same way, the early unconscious stages of crop evolution from wild plants consisted or plants evolving in ways that attracted humans to eat and disperse their fruit without yet intentionally growing them. Human latrines, like those of aardvarks, may have been a testing ground of the first unconscious crop breeders.

LATRINES ARE MERELY one of the many places where we accidentally sow the seeds of wild plants that we eat. When we gather edible wild plants and bring them home, some spill en route or at our houses. Some fruit rots while still containing perfectly good seeds, and gets thrown out uneaten into the garbage. As parts of the fruit that we actually take into our mouths, strawberry seeds are tiny and inevitably swallowed and defecated, but other seeds are large enough to be spat out. Thus, our **spittoons** and garbage dumps joined our latrines to form the first agricultural research laboratories.
At whichever such “lab” the seeds ended up, they tended to come from only certain individuals of edible plants—namely, those that we preferred to eat for one reason or another. From your berry-picking days, you know that you select particular berries or berry bushes. Eventually, when the first farmers began to sow seeds deliberately, they would inevitably sow those from the plants they had chosen to gather, even though they didn’t understand the genetic principle that big berries have seeds likely to grow into bushes yielding more big berries.

So, when you wade into a thorny thicket amid the mosquitoes on a hot, humid day, you don’t do it for just any strawberry bush. Even if unconsciously, you decide which bush looks most promising, and whether it’s worth it at all. What are your unconscious criteria?

One criterion, of course, is size. You prefer large berries, because it’s not worth your while to get sunburned and mosquito bitten for some lousy little berries. That provides part of the explanation why many crop plants have much bigger fruits than their wild ancestors do. It’s especially familiar to us that supermarket strawberries and blueberries are gigantic compared with wild ones; those differences arose only in recent centuries. Such size differences in other plants go back to the very beginnings of agriculture, when cultivated peas evolved through human selection to be 10 times heavier than wild peas. The little wild peas had been collected by hunter-gatherers for thousands of years, just as we collect little wild blueberries today, before the preferential harvesting and planting of the most appealing largest wild peas—that is, what we call farming—began automatically to contribute to increases in average pea size from generation to generation. Similarly, supermarket apples are typically around three inches in diameter, wild apples only one inch. The oldest corn cobs are barely more than half an inch long, but Mexican Indian farmers of A.D. 1500 already had developed six-inch cobs, and some modern cobs are one and a half feet long.

Another obvious difference between seeds that we grow and many of their wild ancestors is in bitterness. Many wild seeds evolved to be bitter, bad-tasting, or actually poisonous, in order to deter animals from eating them. Thus, natural selection acts oppositely on seeds and on fruits. Plants whose fruits are tasty get their seeds dispersed by animals, but the seed itself within the fruit has to be bad-tasting. Otherwise, the animal would also chew up the seed, and it couldn’t sprout.

Almonds provide a striking example of bitter seeds and their change under domestication. Most wild almond seeds contain an intensely bitter chemical called amygdalin, which (as was already mentioned) breaks down to yield the poison cyanide. A snack of wild almonds can kill a person foolish enough to ignore the warning of the bitter taste. Since the first stage in unconscious domestication involves gathering seeds to eat, how on earth did domestication of wild almonds ever reach that first stage?
The explanation is that occasional individual almond trees have a mutation in a single gene that prevents them from synthesizing the bitter-tasting amygdalin. Such trees die out in the wild without leaving any progeny, because birds discover and eat all their seeds. But curious or hungry children of

early farmers, nibbling wild plants around them, would eventually have sampled and noticed those nonbitter almond trees. (In the same way, European peasants today still recognize and appreciate occasional individual oak trees whose acorns are sweet rather than bitter.) Those nonbitter almond seeds are the only ones that ancient farmers would have planted, at first unintentionally in their garbage heaps and later intentionally in their orchards.

Already by 8000 B.C. wild almonds show up in **excavated** archaeological sites in Greece. By 3000 B.C. they were being domesticated in lands of the eastern Mediterranean. When the Egyptian king Tutankhamen died, around 1325 B.C., almonds were one of the foods left in his famous tomb to nourish him in the afterlife. Lima beans, watermelons, potatoes, eggplants, and cabbages are among the many other familiar crops whose wild ancestors were bitter or poisonous, and of which occasional sweet individuals must have sprouted around the latrines of ancient hikers. While size and tastiness are the most obvious criteria by which human hunter-gatherers select wild plants, other criteria include fleshy or seedless fruits, oily seeds, and long fibers. Wild squashes and pumpkins have little or no fruit around their seeds, but the preferences of early farmers selected for squashes and pumpkins consisting of far more flesh than seeds. Cultivated bananas were selected long ago to be all flesh and no seed, thereby inspiring modern agricultural scientists to develop seedless oranges, grapes, and watermelons as well. Seedlessness provides a good example of how human selection can completely reverse the original evolved function of a wild fruit, which in nature serves as a vehicle for dispersing seeds. In ancient times many plants were similarly selected for oily fruits or seeds. Among the earliest fruit trees domesticated in the Mediterranean world were olives, cultivated since around 4000 B.C. for their oil. Crop olives are not only bigger but also oilier than wild ones. Ancient farmers selected sesame, mustard, poppies, and flax as well for oily seeds, while modern plant scientists have done the same for sunflower, safflower, and cotton.

Before that recent development of cotton for oil, it was of course selected for its fibers, used to weave **textiles**. The fibers (termed lint) are hairs on the cotton seeds, and early farmers of both the Americas and the Old World independently selected different species of cotton for long lint. In flax and hemp, two other plants grown to supply the textiles of antiquity, the fibers come instead from the stem, and plants were selected for long, straight stems. While we think of most crops as being grown for food, flax is one of our oldest crops (domesticated by around 7000 B.C.). It furnished linen, which remained the chief textile of Europe until it became supplanted by cotton and synthetics after the Industrial Revolution.

Effects of Ecology on Agricultural Development (Adapted from Chapter 8: "Apples or Indians: Why did peoples of some regions fail to domesticate plants??")

WE HAVE JUST SEEN HOW PEOPLES OF SOME REGIONS began to cultivate wild plant species, a step with momentous unforeseen consequences for their lifestyle and their descendants' place in history. Let us now return to our questions: Why did agriculture never arise independently in some fertile and highly suitable areas, such as California, Europe, temperate Australia, and subequatorial Africa? Why, among the areas where agriculture did arise independently, did it develop much earlier in some than in others? Two contrasting explanations suggest themselves: problems with the local people, or problems with the locally available wild plants. On the one hand, perhaps almost any well-watered temperate or tropical area of the globe offers enough species of wild plants suitable for domestication. In that case, the explanation for agriculture's failure to develop in some of those areas would lie with cultural characteristics of their peoples. On the other hand, perhaps at least some humans in any large area of the globe would have been receptive to the experimentation that led to domestication. Only the lack of suitable wild plants might then explain why food production did not evolve in some areas.

WHEN ONE HEARS that there are so many species of flowering plants, one's first reaction might be as follows: surely, with all those wild plant species on Earth, any area with a sufficiently benign climate must have had more than enough species to provide plenty of candidates for crop development.
But then reflect that the vast majority of wild plants are unsuitable for obvious reasons: They are woody, they produce no edible fruit, and their leaves and roots are also inedible. Of the 200,000 wild plant species, only a few thousand are eaten by humans, and just a few hundred of these have been more or less domesticated. Even of these several hundred crops, most provide minor supplements to our diet and would not by themselves have sufficed to support the rise of civilizations. A mere dozen species account for over 80 percent of the modern world's annual tonnage of all crops. Those dozen blockbusters are the cereals wheat, corn, rice, barley, and sorghum; the pulse soybean; the roots or tubers potato, manioc, and sweet potato; the sugar sources sugarcane and sugar beet; and the fruit banana. Cereal crops alone now account for more than half of the calories consumed by the world's human populations. With so few major crops in the world, all of them domesticated thousands of years ago, it's less surprising that many areas of the world had no wild native plants at all of outstanding potential. Our failure to domesticate even a single major new food plant in modern times suggests that ancient peoples really may have explored virtually all useful wild plants and domesticated all the ones worth domesticating.

Yet some of the world's failures to domesticate wild plants remain hard to explain. The most flagrant cases concern plants that were domesticated in one area but not in another. We can thus be sure that it was indeed possible to develop the wild plant into a useful crop, and we have to ask why that wild species was not domesticated in certain areas.

A typical puzzling example comes from Africa. The important cereal sorghum was domesticated in Africa's Sahel zone, just south of the Sahara. It also occurs as a wild plant as far south as southern Africa, yet neither it nor any other plant was cultivated in southern Africa until the arrival of the whole crop package that Bantu farmers brought from Africa north of the equator 2,000 years ago. Why did the native peoples of southern Africa not domesticate sorghum for themselves?

Equally puzzling is the failure of people to domesticate flax in its wild range in western Europe and North Africa, or einkorn wheat in its wild range in the southern Balkans. Since these two plants were among the first eight crops of the Fertile Crescent, they were presumably among the most readily domesticated of all wild plants. They were adopted for cultivation in those areas of their wild range outside the Fertile Crescent as soon as they arrived with the whole package of food production from the Fertile Crescent. Why, then, had peoples of those outlying areas not already begun to grow them **of their own accord**? Similarly, the four earliest domesticated fruits of the Fertile Crescent all had wild ranges stretching far beyond the eastern Mediterranean, where they appear to have been first domesticated: the olive, grape, and fig occurred west to Italy and Spain and Northwest Africa, while the date palm extended to all of North Africa and Arabia. These four were evidently among the easiest to domesticate of all wild fruits. Why did peoples outside the Fertile Crescent fail to domesticate them, and begin to grow them only when they had already been domesticated in the eastern Mediterranean and arrived thence as crops? Other striking examples involve wild species that were not domesticated in areas where food production never arose spontaneously, even though those wild species had close relatives domesticated elsewhere.

For example, the olive *Olea europea* was domesticated in the eastern Mediterranean. There are about 40 other species of olives in tropical and Southern Africa, southern Asia, and eastern Australia, some of them closely related to *Olea europea,* but none of them was ever domesticated. Similarly, while a wild apple species and a wild grape species were domesticated in Eurasia, there are many related wild apple and grape species in North America, some of which have in modern times been **hybridized** with the crops derived from their wild Eurasian counterparts in order to improve those crops. Why, then, didn't Native Americans domesticate those apparently useful apples and grapes themselves?

One can go on and on with such examples. But there is a fatal flaw in this reasoning: plant domestication is not a matter of hunter-gatherers' domesticating a single plant and otherwise carrying on unchanged with their nomadic lifestyle. Suppose that North American wild apples really would have evolved into a terrific crop if only Indian hunter-gatherers had settled down and cultivated them. But nomadic hunter-gatherers would not throw over their traditional way of life, settle in villages, and start tending apple orchards unless many other domesticable wild plants and animals were available to make a **sedentary** food-producing existence competitive with a hunting-gathering existence.

How, in short, do we assess the potential of an entire local flora for domestication? For those Native Americans who failed to domesticate North American apples, did the problem really lie with the Indians or with the apples?

In order to answer this question, we shall now compare three regions that lie at opposite extremes among centers of independent domestication. As we have seen, one of them, the Fertile Crescent, was perhaps the earliest center of food production in the world, and the site of origin of several of the modern world's major crops and almost all of its major domesticated animals. The other two regions, New Guinea and the eastern United States, did domesticate local crops, but these crops were very few in variety, only one of them gained worldwide importance, and the resulting food package failed to support extensive development of human technology and political organization as in the Fertile Crescent. In the light of this comparison, we shall ask: Did the flora and environment of the Fertile Crescent have clear advantages over those of New Guinea and the eastern United States?

ONE OF THE central facts of human history is the early importance of the part of Southwest Asia known as the Fertile Crescent (because of the crescent-like shape of its uplands on a map). That area appears to have been the earliest site for a whole string of developments, including cities, writing, empires, and what we term (for better or worse) civilization. All those developments sprang, in turn, from the dense human populations, stored food surpluses, and feeding of nonfarming specialists made possible by the rise of food production in the form of crop cultivation and animal husbandry. Food production was the first of those major **innovations** to appear in the Fertile Crescent. Hence any attempt to understand the origins of the modern world must come to grips with the question why the Fertile Crescent's domesticated plants and animals gave it such a potent head start.

Fortunately, the Fertile Crescent is by far the most intensively studied and best understood part of the globe as regards the rise of agriculture. For most crops domesticated in or near the Fertile Crescent, the wild plant ancestor has been identified; its close relationship to the crop has been proven by genetic and chromosomal studies; its wild geographic range is known; its changes under domestication have been identified and are often understood at the level of single genes; those changes can be observed in **successive** layers of the archaeological record; and the approximate place and time of domestication are known. I don't deny that other areas, notably China, also had advantages as early sites of domestication, but those advantages and the resulting development of crops can be specified in much more detail for the Fertile Crescent. The Mediterranean climate zone of the Fertile Crescent extends westward through much of southern Europe and northwestern Africa. There are also zones of similar Mediterranean climates in four other parts of the world: California, Chile, southwestern Australia, and South Africa. Yet those other Mediterranean zones not only failed to rival the Fertile Crescent as early sites of food production; they never gave rise to indigenous agriculture at all. What advantage did that particular Mediterranean zone of western Eurasia enjoy?

It turns out that it, and especially its Fertile Crescent portion, possessed at least five advantages over other Mediterranean zones. First, western Eurasia has by far the world's largest zone of Mediterranean climate. As a result, it has a high diversity of wild plant and animal species, higher than in the comparatively tiny Mediterranean zones of southwestern Australia and Chile. Second, among Mediterranean zones, western Eurasia's experiences the greatest climatic variation from season to season and year to year.

That variation favored the evolution, among the **flora**, of an especially high percentage of annual plants. The combination of these two factors—a high diversity of species and a high percentage of annuals—means that western Eurasia's Mediterranean zone is the one with by far the highest diversity of annuals. The significance of that **botanical** wealth for humans is illustrated by the geographer Mark Blunder's studies of wild grass distributions. Among the world's thousands of wild grass species, Blumler tabulated the 56 with the largest seeds, the cream of nature's crop: the grass species with seeds at least 10 times heavier than the median grass species (see Table 8.1). Virtually all of them are native to Mediterranean zones or other seasonally dry environments. Furthermore, they are overwhelmingly concentrated in the Fertile Crescent or other parts of western Eurasia's Mediterranean zone, which offered a huge selection to incipient farmers: about 32 of the world's 56 prize wild grasses! Specifically, barley and emmer wheat, the two earliest important crops of the Fertile Crescent, rank respectively 3rd and 13th in seed size among those top 56. In contrast, the Mediterranean zone of Chile offered only two of those species, California and southern Africa just one each, and southwestern Australia none at all. That fact alone goes a long way toward explaining the course of human history.

A third advantage of the Fertile Crescent's Mediterranean zone is that it provides a wide range of altitudes and topographies within a short distance. Its range of elevations, from the lowest spot on Earth {the Dead Sea} to mountains of 18,000 feet {near Teheran}, ensures a corresponding variety of environments, hence a high diversity of the wild plants serving as potential ancestors of crops. Those mountains are in proximity to gentle lowlands with rivers, flood plains, and deserts suitable for irrigation agriculture. In contrast, the Mediterranean zones of southwestern Australia and, to a lesser degree, of South Africa and western Europe offer a narrower range of altitudes, habitats, and topographies.

The range of altitudes in the Fertile Crescent meant staggered harvest seasons: plants at higher elevations produced seeds somewhat later than plants at lower elevations. As a result, hunter-gatherers could move up a mountainside harvesting grain seeds as they matured, instead of being overwhelmed by a concentrated harvest season at a single altitude, where all grains matured simultaneously. When cultivation began, it was a simple matter for the first farmers to take the seeds of wild cereals growing on hillsides and dependent on unpredictable rains, and to plant those seeds in the damp valley bottoms, where they would grow reliably and be less dependent on rain.

The Fertile Crescent's biological diversity over small distances contributed to a fourth advantage—its wealth in ancestors not only of valuable crops but also of domesticated big mammals. As we shall see, there were few or no wild mammal species suitable for domestication in the other Mediterranean zones of California, Chile, southwestern Australia, and South Africa. In contrast, four species of big mammals—the goat, sheep, pig and cow—were domesticated very early in the Fertile Crescent, possibly earlier than any other animal except the dog anywhere else in the world. Those species remain today four of the world's five most important domesticated mammals (Chapter 9). But their wild ancestors were commonest in slightly different parts of the Fertile Crescent, with the result that the four species were domesticated in different places: sheep possibly in the central part, goats either in the eastern part at higher elevations (the Zagros Mountains of Iran) or in the southwestern part (the Levant), pigs in the north-central part, and cows in the western part, including Anatolia. Nevertheless, even though the areas of abundance of these four wild progenitors thus differed, all four lived in sufficiently close proximity that they were readily transferred after domestication from one part of the Fertile Crescent to another, and the whole region ended up with all four species.

Agriculture was launched in the Fertile Crescent by the early domestication of eight crops, termed "founder crops" (because they founded agriculture in the region and possibly in the world). Those eight founders were the cereals emmer wheat, einkorn wheat, and barley; the pulses lentil, pea, chickpea, and bitter vetch; and the fiber crop flax. Of these eight, only two, flax and barley, range in the wild at all widely outside the Fertile Crescent and Anatolia. Two of the founders had very small ranges in the wild, chickpea being confined to southeastern Turkey and emmer wheat to the Fertile Crescent itself. Thus, agriculture could arise in the Fertile Crescent from domestication of locally available wild plants, without having to wait for the arrival of crops derived from wild plants domesticated elsewhere. Conversely, two of the eight founder crops could not have been domesticated anywhere in the world except in the Fertile Crescent, since they did not occur wild elsewhere.

Thanks to this availability of suitable wild mammals and plants, early peoples of the Fertile Crescent could quickly assemble a potent and balanced biological package for intensive food production. That package comprised three cereals, as the main carbohydrate sources; four **pulses,** with 20-25 percent protein, and four domestic animals, as the main protein sources, supplemented by the generous protein content of wheat; and flax as a source of fiber and oil (termed linseed oil: flax seeds are about 40 percent oil). Eventually, thousands of years after the beginnings of animal domestication and food production, the animals also began to be used for milk, wool, plowing, and transport. Thus, the crops and animals of the Fertile Crescent's first farmers came to meet humanity's basic economic needs: carbohydrate, protein, fat, clothing, traction, and transport. A final advantage of early food production in the Fertile Crescent is that it may have faced less competition from the hunter-gatherer lifestyle than that in some other areas, including the western Mediterranean. Southwest Asia has few large rivers and only a short coastline, providing relatively meager aquatic resources (in the form of river and coastal fish and shellfish). One of the important mammal species hunted for meat, the gazelle, originally lived in huge herds but was overexploited by the growing human population and reduced to low numbers. Thus, the food production package quickly became superior to the hunter-gatherer package. Sedentary villages based on cereals were already in existence before the rise of food production and predisposed those hunter-gatherers to agriculture and herding. In the Fertile Crescent the transition from hunting-gathering to food production took place relatively fast: as late as 9000 B.C. people still had no crops and domestic animals and were entirely dependent on wild foods, but by 6000 B.C. some societies were almost completely dependent on crops and domestic animals.

The situation in Mesoamerica contrasts strongly: that area provided only two domesticable animals (the turkey and the dog), whose meat yield was far lower than that of cows, sheep, goats, and pigs; and corn, Mesoamerica's staple grain, was, as I've already explained, difficult to domesticate and perhaps slow to develop. As a result, domestication may not have begun in Mesoamerica until around 3500 B.C. (the date remains very uncertain); those first developments were undertaken by people who were still nomadic hunter-gatherers; and settled villages did not arise there until around 1500 B.C.

In all this discussion of the Fertile Crescent's advantages for the early rise of food production, we have not had to invoke any supposed advantages of Fertile Crescent peoples themselves. Indeed, I am unaware of anyone's even seriously suggesting any supposed distinctive biological features of the region's peoples that might have contributed to the potency of its food production package. Instead, we have seen that the many distinctive features of the Fertile Crescent's climate, environment, wild plants, and animals together provide a convincing explanation for the independent development of agriculture in the region.

Effects of Geography on the Diffusion of Knowledge (Adapted from Chapter 10: "Spacious Skies and Tilted Axes: Why did food production spread at different rates on different continents?")

ON A MAP OF THE WORLD, compare the shapes and orientations of the continents. You'll be struck by an obvious difference. The Americas span a much greater distance north-south (9,000 miles) than east-west: only 3,000 miles at widest, narrowing to a mere 40 miles at the Isthmus of Panama. The major **axis** of the Americas is north-south. The same is also though to a less extreme degree, for Africa. In contrast, the major axis of Eurasia is east-west. What effect, if any, did those differences in the orientation of the continents' axes have on human history? This chapter will be about what I see as their enormous, son tragic, consequences. Axis orientations affected the rate of spread of and livestock, and possibly also of writing, wheels, and other inventions. That basic feature of geography thereby contributed heavily to the different experiences of Native Americans, Africans, and Eurasians in the last 500 years.

For example, was the spread of crops from the Fertile Crescent so rapid? The answer depends partly on that east-west axis of Eurasia with which I opened this chapter. Localities distributed east and west of each other at the same latitude share exactly the same day length and its seasonal variations. To a lesser degree, they also tend to share similar diseases, regimes of temperature and rainfall, and habitats or biomes (types of vegetation). For example, southern Italy, northern Iran, and Japan, all located at about the same latitude but lying successively 4,000 miles east or west of each other, are more similar to each other in climate than each is to a location lying even a mere 1,000 miles due south. On all the continents the habitat type known as tropical rain forest is confined to within about 10 degrees latitude of the equator, while Mediterranean scrub habitats (such as California's chaparral and Europe's maquis) lie between about 30 and 40 degrees of latitude. But the germination, growth, and disease resistance of plants are adapted to precisely those features of climate. Seasonal changes of day length, temperature, and rainfall constitute signals that stimulate seeds to germinate, seedlings to grow, and mature plants to develop flowers, seeds, and fruit. Each plant population becomes genetically programmed, through natural selection, to respond appropriately to signals of the seasonal regime under which it has evolved. Those regimes vary greatly with latitude. For example, day length is constant throughout the year at the equator, but at temperate latitudes it increases as the months advance from the winter solstice to the summer solstice, and it then declines again through the next half of the year. The growing season—that is, the months with temperatures and day lengths suitable for plant growth—is shortest at high latitudes and longest toward the equator. Plants are also adapted to the diseases prevalent at their latitude.

Woe betide the plant whose genetic program is mismatched to the latitude of the field in which it is planted! Imagine a Canadian farmer foolish enough to plant a race of corn adapted to growing farther south, in Mexico. The unfortunate corn plant, following its Mexico-adapted genetic program, would prepare to thrust up its shoots in March, only to find itself still buried under 10 feet of snow. Should the plant become genetically reprogrammed so as to germinate at a time more appropriate to Canada—say, late June—the plant would still be in trouble for other reasons. Its genes would be telling it to grow at a leisurely rate, sufficient only to bring it to maturity in five months. That's a perfectly safe strategy in Mexico's mild climate, but in Canada a disastrous one that would guarantee the plant's being killed by autumn frosts before it had produced any mature corn cobs. The plant would also lack genes for resistance to diseases of northern climates, while uselessly carrying genes for resistance to diseases of southern climates. All those features make low-latitude plants poorly adapted to high-latitude conditions, and vice versa. As a consequence, most Fertile Crescent crops grow well in France and Japan but poorly at the equator.

Animals too are adapted to latitude-related features of climate. In that respect we are typical animals, as we know by introspection. Some of us can't stand cold northern winters with their short days and characteristic germs, while others of us can't stand hot tropical climates with their own characteristic diseases. In recent centuries overseas colonists from cool northern Europe have preferred to emigrate to the similarly cool climates of North America, Australia, and South Africa, and to settle in the cool highlands within equatorial Kenya and New Guinea. Northern Europeans who were sent out to hot tropical lowland areas used to die in droves of diseases such as malaria, to which tropical peoples had evolved some genetic resistance. That's part of the reason why Fertile Crescent domesticates spread west and east so rapidly: they were already well adapted to the climates of the regions to which they were spreading. For instance, once farming crossed from the plains of Hungary into central Europe around 5400 B.C., it spread so quickly that the sites of the first farmers in the vast area from Poland west to Holland (marked by their characteristic pottery with linear decorations) were nearly contemporaneous. By the time of Christ, cereals of Fertile Crescent origin were growing over the 10,000-mile expanse from the Atlantic coast of Ireland to the Pacific coast of Japan. That west-east expanse of Eurasia is the largest land distance on Earth.

Thus, Eurasia's west-east axis allowed Fertile Crescent crops quickly to launch agriculture over the band of temperate latitudes from Ireland to the Indus Valley, and to enrich the agriculture that arose independently in eastern Asia. Conversely, Eurasian crops that were first domesticated far from the Fertile Crescent but at the same latitudes were able to **diffuse** back to the Fertile Crescent. Today, when seeds are transported over the whole globe by ship and plane, we take it for granted that our meals are a geographic **mishmash**. A typical American fast-food restaurant meal would include chicken (first domesticated in China) and potatoes (from the Andes) or corn (from Mexico), seasoned with black pepper (from India) and washed down with a cup of coffee (of Ethiopian origin). Already, though, by 2,000 years ago, Romans were also nourishing themselves with their own hodgepodge of foods that mostly originated elsewhere. Of Roman crops, only oats and poppies were native to Italy. Roman staples were the Fertile Crescent founder package, supplemented by quince (originating in the Caucasus); millet and cumin (domesticated in Central Asia); cucumber, sesame, and citrus fruit (from India); and chicken, rice, apricots, peaches, and foxtail millet (originally from China). Even though Rome's apples were at least native to western Eurasia, they were grown by means of grafting techniques that had developed in China and spread westward from there.

While Eurasia provides the world's widest band of land at the same latitude, and hence the most dramatic example of rapid spread of domesticates, there are other examples as well. Rivaling in speed the spread of the Fertile Crescent package was the eastward spread of a subtropical package that was initially assembled in South China and that received additions on reaching tropical Southeast Asia, the Philippines, Indonesia, and New Guinea. Within 1,600 years that resulting package of crops (including bananas, taro, and yams) and domestic animals (chickens, pigs, and dogs) had spread more than 5,000 miles eastward into the tropical Pacific to reach the islands of Polynesia. A further likely example is the east-west spread of crops within Africa's wide Sahel zone, but paleobotanists have yet to work out the details.

CONTRAST THE EASE of east-west diffusion in Eurasia with the difficulties of diffusion along Africa's north-south axis. Most of the Fertile Crescent founder crops reached Egypt very quickly and then spread as far south as the cool highlands of Ethiopia, beyond which they didn't spread. South Africa's Mediterranean climate would have been ideal for them, but the 2,000 miles of tropical conditions between Ethiopia and South Africa posed an insuperable barrier. Instead, African agriculture south of the Sahara was launched by the domestication of wild plants (such as sorghum and African yams) indigenous to the Sahel zone and to tropical West Africa, and adapted to the warm temperatures, summer rains, and relatively constant day lengths of those low latitudes.

Similarly, the spread southward of Fertile Crescent domestic animals through Africa was stopped or slowed by climate and disease, especially by trypanosome diseases carried by tsetse flies. The horse never became established farther south than West Africa's kingdoms north of the equator.
The advance of cattle, sheep, and goats halted for 2,000 years at the northern edge of the Serengeti Plains, while new types of human economies and livestock breeds were being developed. Not until the period A.D. 1-200, some 8,000 years after livestock were domesticated in the Fertile Crescent, did cattle, sheep, and goats finally reach South Africa. Tropical African crops had their own difficulties spreading south in Africa, arriving in South Africa with black African farmers (the Bantu) just after those Fertile Crescent livestock did. However, those tropical African crops could never be transmitted across South Africa's Fish River, beyond which they were stopped by Mediterranean conditions to which they were not adapted.

The result was the all-too-familiar course of the last two millennia of South African history. Some of South Africa's indigenous Khoisan peoples (otherwise known as Hottentots and Bushmen) acquired livestock but remained without agriculture. They became outnumbered and were replaced northeast of the Fish River by black African farmers, whose southward spread halted at that river. Only when European settlers arrived by sea in 1652, bringing with them their Fertile Crescent crop package, could agriculture thrive in South Africa's Mediterranean zone. The collisions of all those peoples produced the tragedies of modern South Africa: the quick decimation of the Khoisan by European germs and guns; a century of wars between Europeans and blacks; another century of racial oppression; and now, efforts by Europeans and blacks to seek a new mode of coexistence in the former Khoisan lands.

CONTRAST ALSO THE ease of diffusion in Eurasia with its difficulties along the Americas' north-south axis. The distance between Mesoamerica and South America—say, between Mexico's highlands and Ecuador's—is only 1,200 miles, approximately the same as the distance in Eurasia separating the Balkans from Mesopotamia. The Balkans provided ideal growing conditions for most Mesopotamian crops and livestock, and received those domesticates as a package within 2,000 years of its assembly in the Fertile Crescent. That rapid spread preempted opportunities for domesticating those and related species in the Balkans. Highland Mexico and the Andes would similarly have been suitable for many of each other's crops and domestic animals. A few crops, notably Mexican corn, did indeed spread to the other region in the pre-Columbian era.

But other crops and domestic animals failed to spread between Mesoamerica and South America. The cool highlands of Mexico would have provided ideal conditions for raising llamas, guinea pigs, and potatoes, all domesticated in the cool highlands of the South American Andes. Yet the northward spread of those Andean specialties was stopped completely by the hot intervening lowlands of Central America. Five thousand years after lamas had been domesticated in the Andes, the Olmecs, Maya, Aztecs, and all other native societies of Mexico remained without pack animals and without any edible domestic mammals except for dogs. Conversely, domestic turkeys of Mexico and domestic sunflowers of the eastern United States might have thrived in the Andes, but their southward spread was stopped by the intervening tropical climates. The mere 700 miles of north-south distance prevented Mexican corn, squash, and beans from reaching the U.S. Southwest for several thousand years after their domestication in Mexico, and Mexican chili peppers and chenopods never did reach it in prehistoric times. For thousands of years after corn was domesticated in Mexico, it failed to spread northward into eastern North America, because of the cooler climates and shorter growing season prevailing there. At some time between A.D. 1 and A.D. 200, corn finally appeared in the eastern United States but only as a very minor crop. Not until around A.D. 900, after hardy varieties of corn adapted to northern climates had been developed, could corn-based agriculture contribute to the flowering of the most complex Native American society of North America, the Mississippian culture—a brief flowering ended by European introduced germs arriving with and after Columbus.

Recall that most Fertile Crescent crops prove, upon genetic study, to derive from only a single domestication process, whose resulting crop spread so quickly that it preempted any other incipient domestications of the same or related species. In contrast, many apparently widespread Native American crops prove to consist of related species or even of genetically distinct varieties of the same species, independently domesticated in Mesoamerica, South America, and the eastern United States. Closely related species replace each other geographically among the amaranths, beans, chenopods, chili peppers, cottons, squashes, and tobaccos. Different varieties of the same species replace each other among the kidney beans, lima beans, the chili pepper *Capsicum annuum I chinense,* and the squash *Cucurbita pepo.* Those **legacies** of multiple independent domestications may provide further testimony to the slow diffusion of crops along the Americas' north-south axis.

Africa and the Americas are thus the two largest landmasses with a predominantly north-south axis and resulting slow diffusion. In certain other parts of the world, slow north-south diffusion was important on a smaller scale. These other examples include the snail's pace of crop exchange between Pakistan's Indus Valley and South India, the slow spread of South Chinese food production into Peninsular Malaysia, and the failure of tropical Indonesian and New Guinean food production to arrive in prehistoric times in the modern farmlands of southwestern and southeastern Australia, respectively. Those two corners of Australia are now the continent's breadbaskets, but they lie more than 2,000 miles south of the equator.

Farming there had to await the arrival from faraway Europe, on European ships, of crops adapted to Europe's cool climate and short growing season.

I HAVE BEEN **dwelling** on latitude, readily assessed by a glance at a map, because it is a major determinant of climate, growing conditions, and ease of spread of food production. However, latitude is of course not the only such determinant, and it is not always true that adjacent places at the same latitude have the same climate (though they do necessarily have the same day length). Topographic and ecological barriers, much more pronounced on some continents than on others, were locally important obstacles to diffusion.

For instance, crop diffusion between the U.S. Southeast and Southwest was very slow and selective although these two regions are at the same latitude. That's because much of the intervening area of Texas and the southern Great Plains was dry and unsuitable for agriculture. A corresponding example within Eurasia involved the eastern limit of Fertile Crescent crops, which spread rapidly westward to the Atlantic Ocean and eastward to the Indus Valley without encountering a major barrier. However, farther eastward in India the shift from predominantly winter rainfall to **predominantly** summer rainfall contributed to a much more delayed extension of agriculture, involving different crops and farming techniques, into the Ganges plain of northeastern India. Still farther east, **temperate** areas of China were isolated from western Eurasian areas with similar climates by the combination of the Central Asian desert, Tibetan plateau, and Himalayas. The initial development of food production in China was therefore independent of that at the same latitude in the Fertile Crescent, and gave rise to entirely different crops. However, even those barriers between China and western Eurasia were at least partly overcome during the second millennium B.C., when West Asian wheat, barley, and horses reached China. By the same token, the potency of a 2,000-mile north-south shift as a barrier also varies with local conditions. Fertile Crescent food production spread southward over that distance to Ethiopia, and Bantu food production spread quickly from Africa's Great Lakes region south to Natal, because in both cases the intervening areas had similar rainfall regimes and were suitable for agriculture. In contrast, crop diffusion from Indonesia south to southwestern Australia was completely impossible, and diffusion over the much shorter distance from Mexico to the U.S. Southwest and Southeast was slow, because the intervening areas were deserts hostile to agriculture. The lack of a high-elevation plateau in Mesoamerica south of Guatemala, and Mesoamerica's extreme narrowness south of Mexico and especially in Panama, were at least as important as the latitudinal gradient in throttling crop and livestock exchanges between the highlands of Mexico and the Andes.

Continental differences in axis orientation affected the diffusion not only of food production but also of other technologies and inventions. For example, around 3,000 B.C. the invention of the wheel in or near Southwest Asia spread rapidly west and east across much of Eurasia within a few centuries, whereas the wheels invented independently in prehistoric Mexico never spread south to the Andes. Similarly, the principle of alphabetic writing, developed in the western part of the Fertile Crescent by 1500 B.C., spread west to Carthage and east to the Indian subcontinent within about a thousand years, but the Mesoamerican writing systems that flourished in prehistoric times for at least 2,000 years never reached the Andes. Naturally, wheels and writing aren't directly linked to latitude and day length in the way crops are. Instead, the links are indirect, especially via food production systems and their consequences. The earliest wheels were parts of ox-drawn carts used to transport agricultural produce. Early writing was restricted to elites supported by food-producing peasants, and it served purposes of economically and socially complex food-producing societies (such as royal propaganda, goods inventories, and bureaucratic record keeping). In general, societies that engaged in intense exchanges of crops, livestock, and technologies related to food production were more likely to become involved in other exchanges as well.

America's patriotic song "America the Beautiful" invokes our spacious skies, our amber waves of grain, from sea to shining sea. Actually, that song reverses geographic realities. As in Africa, in the Americas the spread of native crops and domestic animals was slowed by constricted skies and environmental barriers. No waves of native grain ever stretched from the Atlantic to the Pacific coast of North America, from Canada to Patagonia, or from Egypt to South Africa, while amber waves of wheat and barley came to stretch from the Atlantic to the Pacific across the spacious skies of Eurasia. That faster spread of Eurasian agriculture, compared with that of Native American and sub-Saharan African agriculture, played a role (as the next part of this book will show) in the more rapid diffusion of Eurasian writing, metallurgy, technology, and empires.

To bring up all those differences isn't to claim that widely distributed crops are admirable, or that they testify to the superior ingenuity of early Eurasian farmers. They reflect, instead, the orientation of Eurasia's axis compared with that of the Americas or Africa. Around those axes turned the fortunes of history.

II. Vocabulary

From Text[2]

Agronomist: One who studies the science of farming crops
Ardent: Passionate, intense
Axis: A central line that bisects a two-dimensional body or figure
Botanical: Of, pertaining to, made from, or containing plants
Defecates: To excrete feces
Diffuse: To spread or scatter widely or thinly; disseminate
Disperse: To spread widely; disseminate
Dwell: To linger over, emphasize, or ponder in thought, speech, or writing
Enology: The study of wine and the making of wine
Excavate: To expose or lay bare by or as if by digging; unearth
Flax: A widely cultivated plant, *Linum usitatissimum,* from which a textile fiber is obtained
Flora: Plants (as distinguished from fauna, or animals)
Hitchhike: To travel by standing on the side of the road and soliciting rides from passing vehicles
Hybridized: Interbred, combined
Innovation: Introduction of new things or methods
Latrine: Toilet (British)
Legacies: Anything handed down from the past, as from an ancestor or predecessor
Lentil: A leguminous plant *(Lens culinaris)* native to southwest Asia, having flat pods containing lens-shaped, edible seeds
Mishmash: A confused mess; hodgepodge; jumble
Of one's own accord: By one's own choice, without coercion
Pomology: The science that deals with fruits and fruit growing.

[2] "Dictionary.com," Dictionary.com, LLC, http://dictionary.reference.com/.

Poppy: A red flower whose seeds are the source of many narcotics, including opium
Predominantly: Mostly
Progenitor: A predecessor or precursor
Progeny: A descendant or offspring
Pulse: A plant that produces edible seeds, such as peas, beans, or lentils
Render: To cause to be or to become; to make
Sedentary: Accustomed to sit or rest a great deal or to take little exercise
Sedge: A type of rushlike or grasslike plant that grows in wet places
Spittoon: A bowl-shaped, usually metal vessel, often with a funnel-shaped cover, into which people spit
Successive: Following one another in a regular sequence
Temperate: Moderate in respect to temperature; not subject to prolonged extremes of hot or cold weather
Textiles: Any cloth or goods produced by weaving, knitting, or felting
Thrush: A kind of songbird
Unwittingly: Inadvertently; unintentionally; accidentally
Viticulture: he culture or cultivation of grapevines; grape-growing

GRE Words[3]

Abstruse: Hard to understand
Exegesis: Explanation of a literary work
Inchoate: Not fully developed or formulated
Lugubrious: Mournful, exaggeratively sad, doleful
Protean: Readily assuming different forms; changing

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[3] Michael Chapman, *The Historian's Companion* (Reading, MA: Trebarwyth Press, 2008).