13.1 The Agricultural Revolution: New Foods and New Adaptations

Up until this point—to around 10,000 yBP or so—humans had acquired *all* their food through hunting and gathering. They hunted, trapped, fished, and otherwise collected animals big and small, terrestrial and aquatic, and they collected a huge variety of plants. During the later Pleistocene, they began to intensively exploit fish and shellfish in oceans, lakes, and streams. In the final centuries of that epoch, at the key environmental transition from the Pleistocene's cold and dry climate to the Holocene's warm and wet climate, people began to control animals' and plants' growth cycles through a process anthropologists call domestication. Eventually, humans replaced nearly all the wild animals and wild plants in their diets with domesticated animals and domesticated plants. This dramatic change in lifeway—where people at the end of the Pleistocene and in the Early Holocene raised the animals and grew the plants they ate—is associated with the period called the Neolithic.

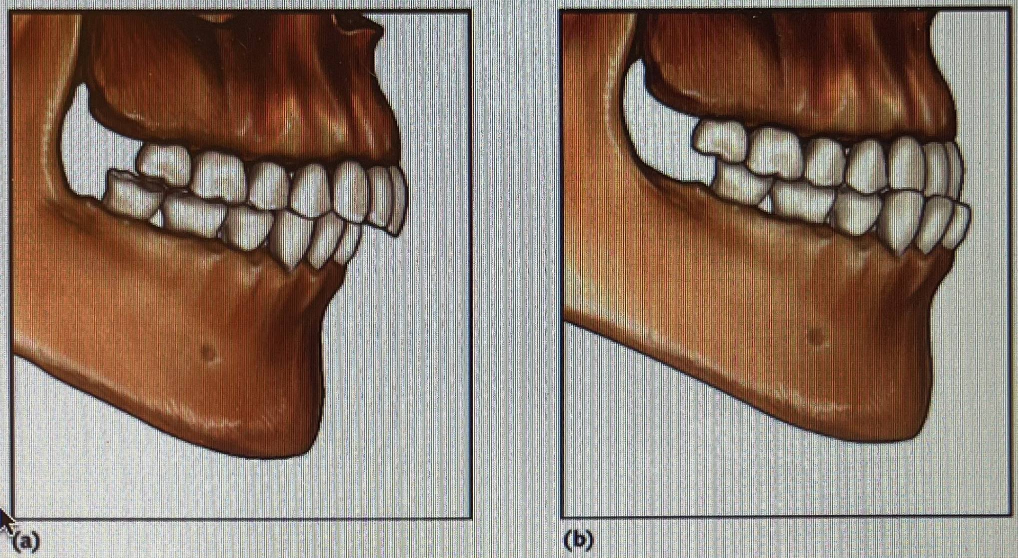


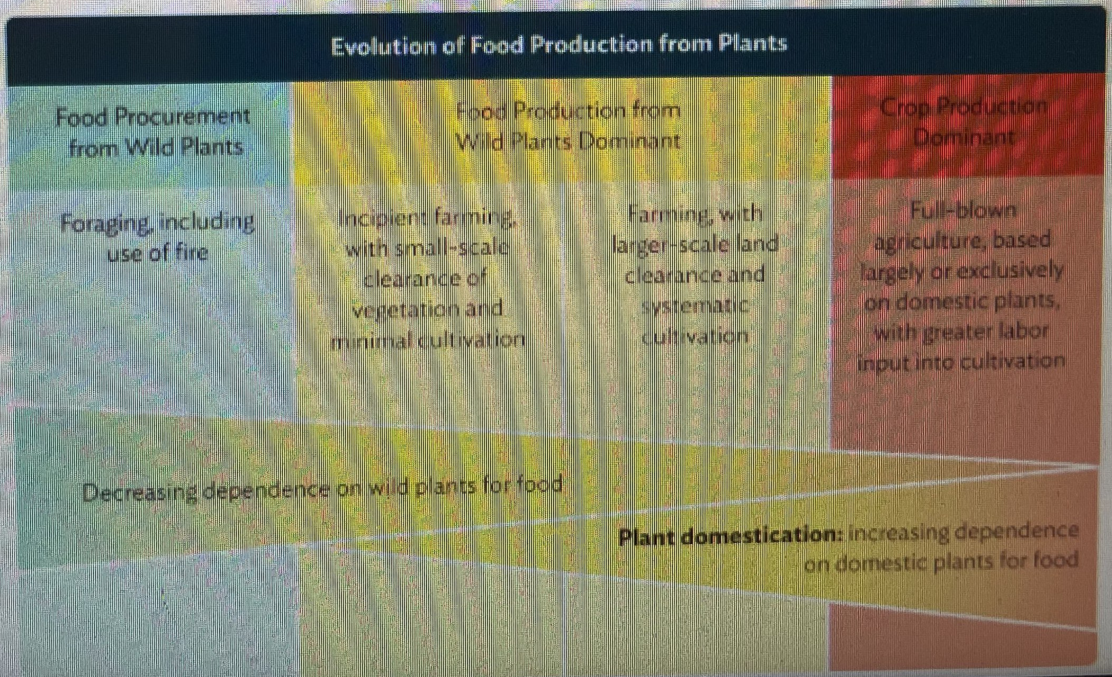
FIGURE 13.2

Malocclusion Two major forms of malocclusion can be corrected with orthodontic treatments, including braces. **(a)** An overbite occurs when the maxillary teeth extend farther forward than the mandibular teeth. **(b)** An underbite occurs when the mandibular teeth extend farther forward than the maxillary teeth. While malocclusion appears in some archaeological skeletal remains, it became common only after humans adopted agriculture.

By any measure, agriculture ranks as one of the most transformative developments in the record of hominin evolution. It was the foundation for the profoundly important adaptive transition from foraging to farming. I rank agriculture up there with bipedalism and speech as being fundamental to who humans are as an organism. As will be discussed in this chapter, this shift had important and long-lasting implications for *Homo sapiens* as an evolving species. For lasting implications for *Homo sapiens* as an evolving species. For example, many diseases we have today are linked in one way or another to this remarkable change in lifeway. And the transition from foraging to farming laid the foundation for population size to increase to its current level in an increasingly crowded world.

For 99.8% of the 7 million years of human evolution, hominins had eaten plants of all kinds, but not until very recently had they *grown* them. Domesticated plants quickly became an integral part of food production across much of the globe, but that quickness is relative to the geologic timescale. Rather than happening overnight, in other words, the shift from foraging to farming took place over centuries and likely involved many successes and failures as the process unfolded for different human populations around the world (**Figure 13.3**). But compared with evolutionary changes that took place over thousands or hundreds of thousands of years, the transitional process of domestication—the dietary changes, biological adaptations, and resulting health changes—was quite rapid.

Authorities agree on where and when domestication took place, based on the study of plant and animal remains found in archaeological sites. In addition, breakthroughs in plant and animal genetics provide new windows on the origins of domesticated species. That is, the domesticated descendants of formerly wild plants and formerly wild animals have undergone genetic changes compared with the ancestral forms. These genetic changes have been documented via breeding experiments and by the extraction and study of DNA. The changes were brought about by humans' selecting study of DNA. The changes were brought about by humans' selecting food products that were beneficial to them. For example, they probably selected many plants with soft outer coatings and large seed yields. In a very real sense, humans practiced artificial selection, as opposed to natural selection. The resulting changes proved very deleterious for some of the species being domesticated. In wheat, the part holding all the edible sections is called the *rachis*, and at some point humans selected wheat with a hard rachis for storage and later consumption. This selection, in turn, selected for plants with a hard rachis. After many generations, the wheat was unable to reproduce itself because humans had selected for plants that could not do so without human intervention (annual planting manually).



Past Time (yBP) Present

FIGURE 13.3

Adoption of Agriculture As this chart illustrates, humans did not simply abandon foraging and adopt agriculture. Initially, they foraged for wild plants to supplement their farming of cultivated plants. Over time, they depended less on wild plants and more on domesticated plants.

The American archaeologist and paleobotanist Melinda Zeder regards one important outcome for humans to be the increased security and predictability of food access. This was a mutualistic relationship with their plant and animal "partners" in that plants and animals experienced increased reproductive fitness and range expansion.

Authorities disagree on the *cause* for this dramatic, worldwide change in food acquisition. They are learning, however, that the change likely did not have only one cause. At least two factors probably brought about this agricultural revolution. First, the environment changed radically, going from cooler, drier, and highly variable during the later Pleistocene to warmer, wetter, and more stable during the Holocene (Figure 13.4). This abrupt environmental change brought about new conditions—local climates and local ecologies—suited to the domestication of plants and of animals. Second, almost everywhere agriculture was developing, human population was increasing.

Population Pressure

Population Pressure

Changes in climate and in ecology would not have resulted in plant and animal domestication, of course, without people. Almost everywhere agriculture developed, abundant archaeological evidence indicates that the number and size of living sites had increased. For example, on the Georgia coast of eastern North America (see the opening discussion in chapter 1), the beginning of agriculture coincided with an increase in the number and especially the sizes of villages. As human population sizes grew all over the world, people likely needed greater quantities of food than hunting and gathering could provide. This population pressure model suggests that humans *had* to develop a new strategy; that is, domestications in order to feed the ever-growing world population. Thus, agriculture came into being as a response to population pressure and the need to have another, more productive way of acquiring food. Domestication, especially of plants, produced more food per unit area of land than had hunting and gathering—more people could be fed from the same amount of land. In addition, agriculture provided food that could be stored for long periods. As an adaptive solution to population increase, domestication shows yet another example of humans' remarkable flexibility in new and challenging circumstances.

(a)

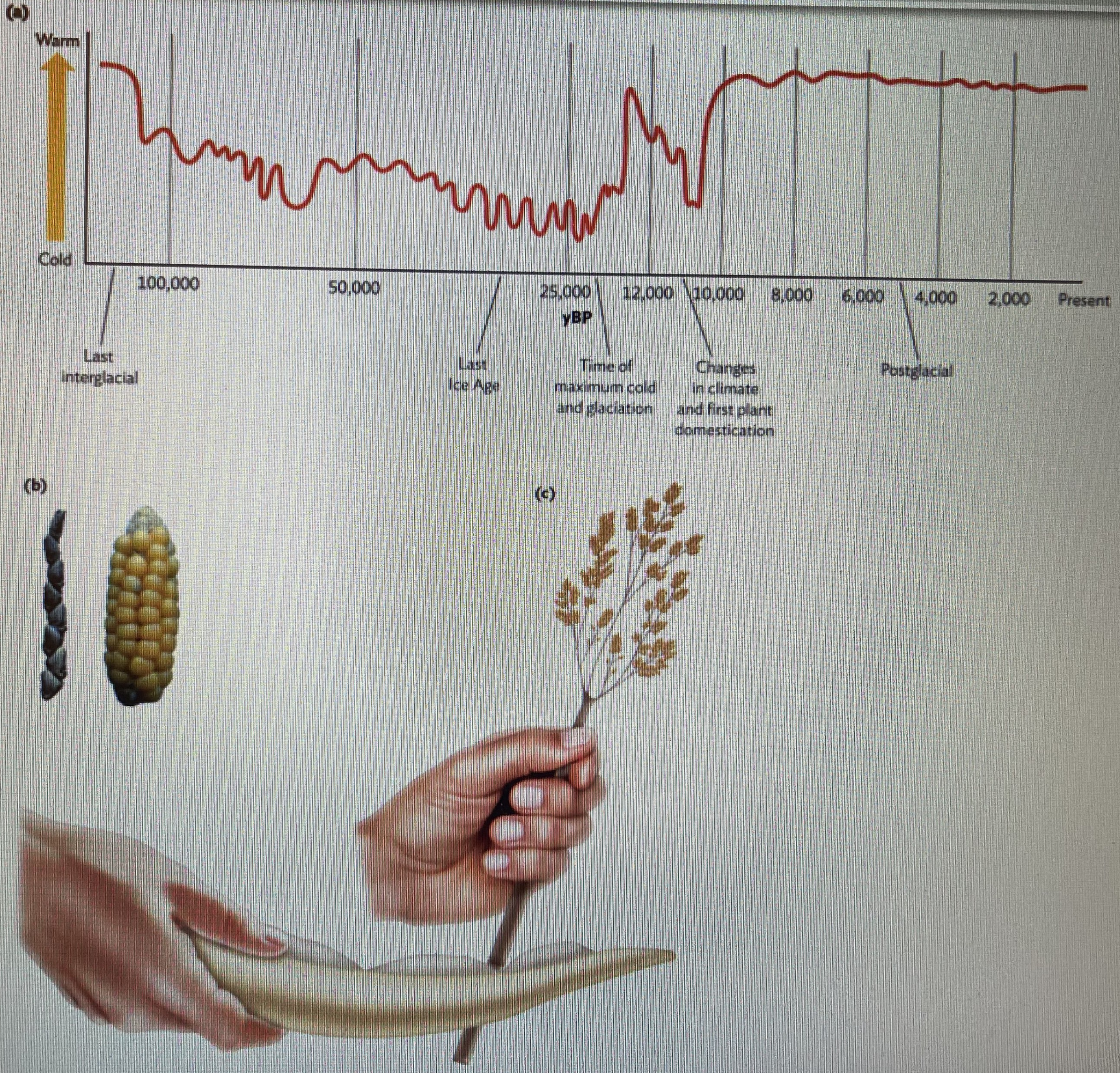

(a)
Warm
Cold
100,000
50,000
25,000
12,000
10,000
8,000
6,000
4,000
2,000
Present
yBP
Last interglacial
Last Ice Age
Time of maximum cold and glaciation
Changes in climate and first plant domestication
Postglacial
(b)
(c)

FIGURE 13.4

FIGURE 13.4
Temperature Changes and Plant Domestication **(a)** Over the past 120,000 years, as this timeline shows, Earth's temperature has fluctuated substantially. Around 11,000 yBP, a rapid warming trend created new habitats favorable for plant domestication. **(b)** The first grains were the wild ancestors of the domesticated varieties we know today. The wild ancestor of maize (right) is teosinte (left). **(c)** Domestication began with humans' harvesting of wild plants using Late Paleolithic technology, such as this tool, an antler handle with stone microblades inserted into it.

ge 456

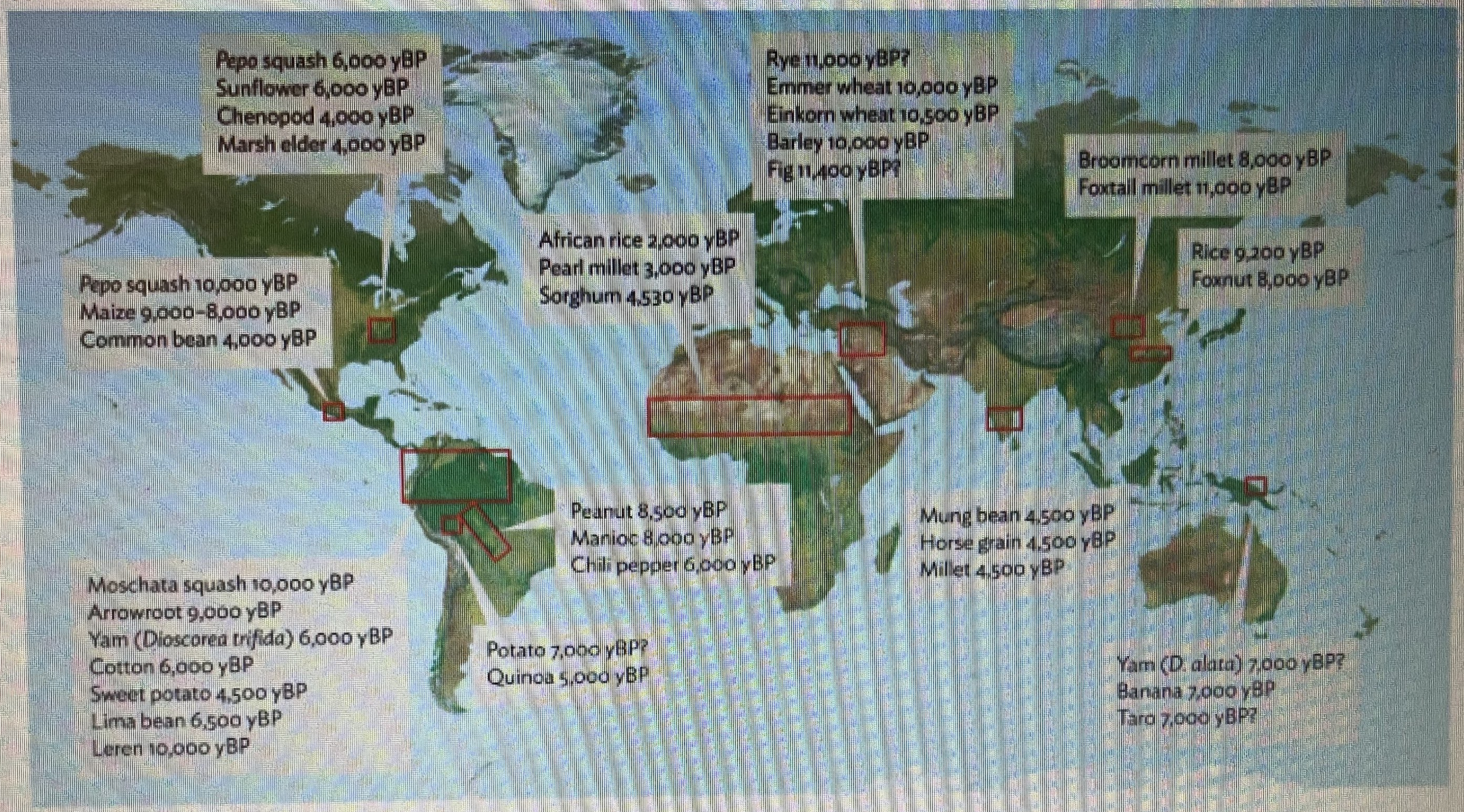
Regional Variation

Plant and animal domestication was not just a one-time event, first occurring in one place and then spreading globally. Rather, domestication—in particular, plant domestication—started in at least 11 independent regions around the world (**Figure 13.5**). Out of these primary centers, the idea spread through a process of diffusion in some areas and through the movement of agricultural people in others. The process evolved slowly in some areas and quickly in others. Eventually, every inhabitable continent except Australia saw the change. In some regions, newly domesticated plants replaced earlier ones. For example, in the American Midwest, native seed crops—goosefoot, sumpweed, and sunflowers—were farmed about 6,000–1,000 yBP. Later, corn replaced these crops, probably owing to its greater productivity and potential for feeding more people than before.

(a)

ncia.wwnorton.com/75342/r/goto/cfi/188!/4

(a)



(b)

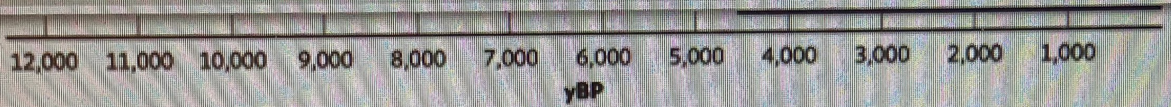


FIGURE 13.5
Worldwide Plant Domestication **(a)** This map shows the 11 separate centers of plant domestication. At each location, different types of domesticated plants were cultivated, including maize in Central America, sunflowers in eastern North America, cotton in South America, millet and sorghum in Africa, wheat in the Middle East, and banana trees in New Guinea. **(b)** This chart illustrates the approximate times of plant and animal domestication in the major regions of the world.

Archaeological evidence and genetic studies of domesticated plants indicate that prior to becoming agricultural at the end of the Pleistocene, people living in southwestern Asia began to intensively harvest the grains of wheat's and barley's wild ancestors. These grains provided food for the growing populations that were beginning to live in small, settled communities for at least part of the year. For the other part of the year, people were likely out and about, hunting and gathering. Within 1,000 or so years after this combined practice of exploiting wild grains and foraging, sometime around 11,500 yBP, people began to manipulate the growth cycles of plants. This manipulation was probably based on the simple observation that some

seeds falling to the ground grew into new plants. People figured out what circumstances were conducive to the plants' growth, such as adequate water and protection from animals that might eat the plants. It would have been important for the people harvesting these plants to realize that if the seeds were placed in the ground, they would sprout new plants that could grow to full maturity. These mature plants could then be harvested, just as the plants' wild ancestors were harvested generations before.

FIGURE 13.6

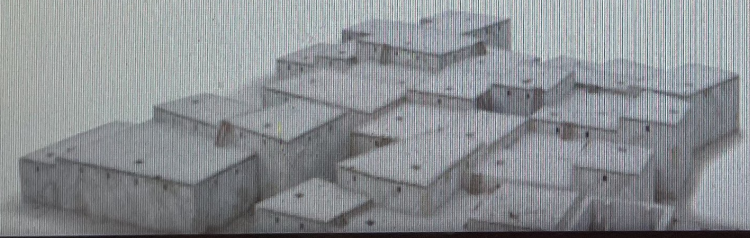
Southwestern Asia and the Fertile Crescent Southwestern Asia, especially the region known by anthropologists as the Fertile Crescent, has numerous

FIGURE 13.6

Southwestern Asia and the Fertile Crescent Southwestern Asia, especially the region known by anthropologists as the Fertile Crescent, has numerous archaeological sites that date between 11,500 and 8,000 yBP and contain evidence of early agriculture.

The archaeological record suggests that farming began in southeastern Turkey by 10,500 yBP or so. By 8,000 yBP, early agricultural communities had sprung up along a vast swath extending from the eastern side of the Mediterranean across an arch-shaped zone of grasslands and open woodlands known as the *Fertile Crescent* (**Figure 13.6**). Once domestication developed, within a short time villages sprang up; some of these villages developed into cities. For example, the early agriculture-based settlements of Jericho and Çatalhöyük, in Israel and Turkey, respectively, grew from tiny villages consisting of a few huts to the first cities, containing several or more thousands of people living in close, cramped settings (**Figure 13.7**).

page 458



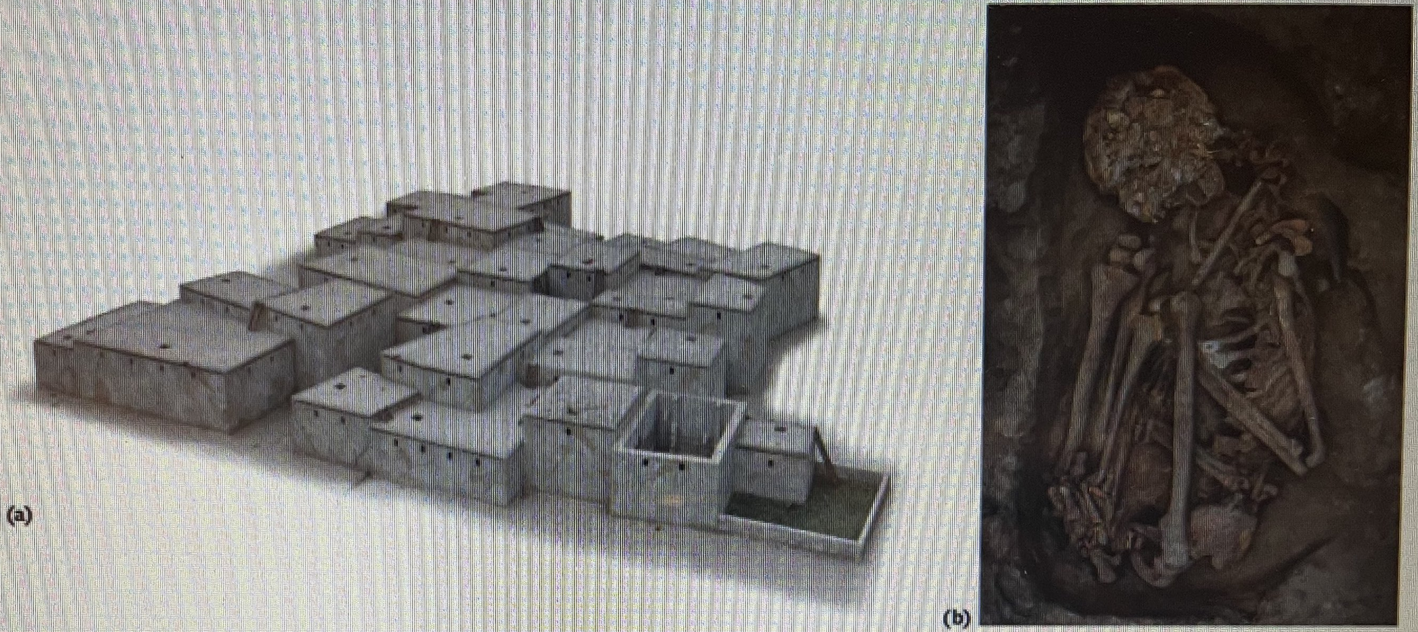


FIGURE 13.7

Çatalhöyük One of the earliest agricultural communities in Southwest Asia, Çatalhöyük eventually grew into a city with a large sedentary population. **(a)** This reconstruction shows how closely spaced the houses and other buildings were in the burgeoning city. **(b)** Skeletal remains have been discovered at the Çatalhöyük site, such as this Neolithic adult male. An obsidian knife can be seen on his left shoulder. Skeletons such as these provide an immense amount of information about life in this early city. (Photo courtesy of Scott Haddow).

Plant domestication was nearly as early in China (millet at 11,000 yBP and rice at 9,200 yBP) as in southwestern Asia (**Figure 13.8**). By this time, the form of agriculture identified by archaeologists was well along in its development, so agriculture likely developed in China earlier than that, perhaps by several thousand years. Other early domesticated plants are from Mexico (bottle gourds, 10,000 yBP, earlier than that, perhaps by several thousand years. Other early domesticated plants are from Mexico (bottle gourds, 10,000 yBP; corn, 9,000 yBP), New Guinea (taro and banana trees, 7,000 yBP), eastern North America (squash, sunflowers, and goosefoot, 6,000 yBP), South America (e.g., yams, 6,000 yBP; sweet potato, 4,500 yBP; potato, 7,000 yBP), and Africa south of the Sahara Desert (sorghum and yams, 4,500 yBP).

Like most other technological innovations, agriculture spread by diffusion out of the primary centers, usually for very long distances. Corn, for example, spread from its primary center in Mexico (probably in the lowland tropics) to the American Southwest. Eventually, corn agriculture reached North America's Atlantic coast about 1,000 yBP. The spread occurred not through people carrying corn but through people describing their agricultural successes to neighbors, those neighbors telling their neighbors, and so forth, until the idea spread for thousands of miles over a series of generations. For some areas of North America, the adoption and intensive use of corn occurred very rapidly, perhaps within a few generations.

Another important area of the world where anthropologists have studied the origins and diffusion of agriculture consists of both far western Asia and Europe. From southwestern Asia, the domestication of wheat

Asia and Europe. From southwestern Asia, the domestication of wheat and barley spread to Greece by 8,000 to 7,000 yBP, and then throughout Europe. The idea of agriculture spread through cultural contact and the exchange of knowledge. New analysis by Ayça Omrak and her paleogenetics team of the ancient DNA of Neolithic skeletons in western Anatolia (modern Turkey) and in Europe, however, reveals sharing of significant elements of the genome. These genetic similarities in Neolithic Anatolians and Europeans signal significant gene flow. This indicates that the movement of early farmers from western Asia to Europe was widespread enough to result in the patterns of genetic diversity seen today in Europe and European-descent populations.

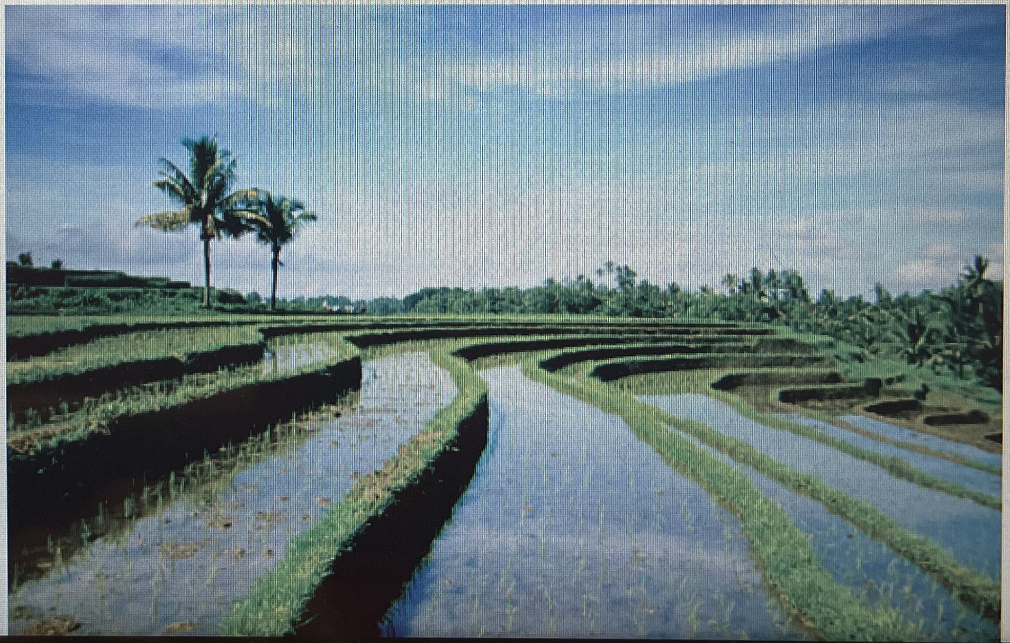


FIGURE 13.8
Rice There are more than 20 varieties of wild rice and two types of domesticated rice. The first variety of domesticated rice was established in southern Asia approximately 9,200 yBP. The second variety of domesticated rice was established in western Africa approximately 2,000 yBP.

Animals were also domesticated around the world, beginning with dogs between 30,000 and 15,000 or so years ago. By 8,000 yBP, goats, sheep, cattle, and pigs were domesticated. These animals were important in Asia and later Europe, but domesticated plants likely provided the majority of calories and were far more fundamental to the growing human populations' survival at the regional and the global scales. For Neolithic Southwest Asia, American archaeologist Benjamin Arbuckle suggests that not only is animal husbandry highly labor-intensive and resource-expensive, but also prior to domestication, hunting as a social act was a central element of community life and not easily abandoned. Regardless of the reasons for considerably greater focus on the role of domesticated plants than domesticated animals in diet, the record reveals human adaptation and change that is largely explained by the central importance of domesticated plants.

Survival and Growth

The importance of domestication for human evolutionary history cannot be overestimated. Domestication fueled humans' remarkable

Survival and Growth

The importance of domestication for human evolutionary history cannot be overestimated. Domestication fueled humans' remarkable population growth in the Holocene, and it formed the foundation for the rise of complex societies, cities, and increasingly sophisticated technology. Archaeologists are learning that domesticated plants served as both a food staple and a source of drink, especially alcoholic drink. In China, for example, chemical analysis of residue inside ceramic vessels shows that perhaps as early as 8,000 yBP, grapes and rice were fermented for wine.

HOW DO WE KNOW

BIOARCHAEOCHEMISTRY

RECONSTRUCTING PAST DIETS AND INFERRING NUTRITION

The foods we eat say a lot about who we are. Perhaps of most importance, our foods determine our nutrition and therefore influence our health and well-being. Nutrition also affects our ability to be productive, to undergo

RECONSTRUCTING PAST DIETS AND INFERRING NUTRITION

The foods we eat say a lot about who we are. Perhaps of most importance, our foods determine our nutrition and therefore influence our health and well-being. Nutrition also affects our ability to be productive, to undergo normal growth and development, to survive to adulthood, and to produce healthy offspring. Darwin recognized that nutrition is the bread and butter of evolution.

It comes as no surprise, then, that biological anthropologists are so keenly interested in diet in both past and living populations. An understanding of diet is at the top of the list for knowing why some human populations are successful and others are not. For much of the history of anthropology, the diets of past populations were reconstructed solely by identifying the remains of plants and animals that were discovered in places where people once lived. Unfortunately, in many instances, plant and animal remains either do not preserve well or do not preserve at all. Even under the best of circumstances when these remains are preserved, their identification really only tells us *what* the human groups were eating. They often do not provide a picture of what foods were particularly important or the quantity eaten. We need to know how important specific foods were in the diets of past people in order to infer the nutrition that these foods provided.

In the late 1970s, two scientists—J. C. Vogel, a geochemist, and Nikolaas van der Merwe, an archaeologist—applied a revolutionary new method of reconstructing diet by measuring the relative amounts of the two stable isotopes of carbon (^{13}C and ^{12}C) in human bones from archaeological contexts and comparing this ratio to a standard that was based on the ^{13}C

In the late 1970s, two scientists—J. C. Vogel, a geochemist, and Nikolaas van der Merwe, an archaeologist—applied a revolutionary new method of reconstructing diet by measuring the relative amounts of the two stable isotopes of carbon (^{13}C and ^{12}C) in human bones from archaeological contexts and comparing this ratio to a standard that was based on the ^{13}C and ^{12}C found in *Belemnitella*, a fossil marine organism from coastal South Carolina. These ratios, expressed as $\delta^{13}C$ values, are relatively high in corn, and Vogel and van der Merwe hypothesized that the bones of humans who ate corn during their lifetimes should show higher $\delta^{13}C$ values than those of the bones of humans who ate no corn. This is simply because the human body metabolizes the foods eaten and incorporates the chemistry of the foods into body tissues, including bones.

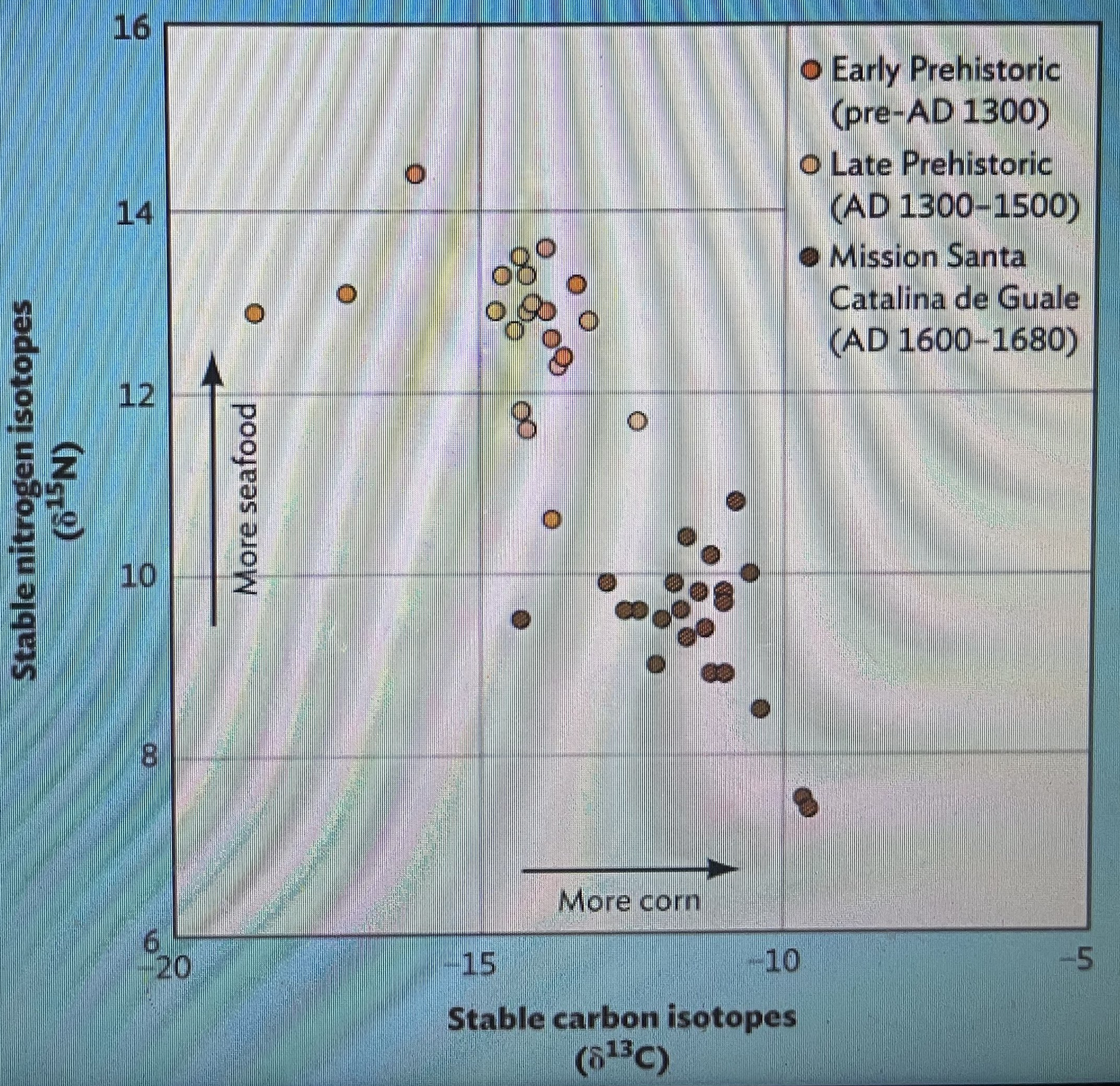
Indeed, as shown by Vogel and van der Merwe's pioneering study of archaeological human remains from New York State, their hypothesis that predicted higher $\delta^{13}C$ values for later prehistoric corn consumers than for earlier prehistoric non–corn consumers proved to be absolutely true. That is, Vogel and van der Merwe found that the corn consumers had higher $\delta^{13}C$ ratios than those of the non–corn consumers. This preliminary analysis of corn farmers compared to earlier hunter-gatherers revolutionized how we document dietary patterns for many past populations globally, especially where there are shifts in the underlying chemistry of bones and teeth from archaeological sites.

Building on their work, American biological anthropologist Margaret Schoeninger and I undertook a comprehensive regional study of the Georgia coast and the coast and inland of northern Florida—the region of eastern North America colonized by Spain in the sixteenth and seventeenth centuries (see chapter 1, pp. 3–4). In this setting, archaeological evidence (plant remains) and historical documents (diaries, travel accounts, and early descriptions of native activities) are contradictory about what people did or did not eat in the region. Such that it was, the archaeological record suggested little or no consumption of corn prior to arrival of the Spaniards. Indeed, archaeologists working in the region made the case for many years that Georgia coastal native people became farmers only after Europeans arrived in the region. This seemed contrary to most other regions of the eastern United States where corn farming in late prehistory was a crucial part of diet, fueling the rise of complex societies. Moreover, ethnohistoric accounts of native people in the sixteenth century noted a considerable focus on corn farming. Schoeninger and I believed that a more compelling record of diet could be constructed via the analysis of stable isotope ratios, testing the hypothesis that late prehistoric people employed corn as a key part of their diet—they were farming at least several centuries before the arrival of Europeans in the sixteenth century. As discussed in this chapter, a dominance of domesticated plants in the diet, especially corn, signals relatively poor-quality nutrition owing to the fact that they are protein-poor foods (see pp. 477–479). Overly narrow diets based on corn should predict negative impact on health, including relatively poor growth and higher prevalence of dental caries, infection, and iron deficiency.

We took bone samples from several hundred skeletons from the region and measured their ratios of stable isotopes of carbon and other elements. Our results were clear: We found a very pronounced and a near-continuous increase in the $\delta^{13}C$ ratios with time prior to European contact, reflecting the adoption of a corn-based diet in the last several centuries of prehistory before the arrival of Europeans, followed by a highly significant increase in corn consumption during the Spanish colonial period.

There is a caveat, however. We also knew that these coastal populations ate various seafoods on the basis of the abundant shellfish and fish remains found where these populations were living. It turns out that marine foods can mimic the $\delta^{13}C$ ratios of corn because of the manner in which marine foods metabolize carbon. So we used yet another set of stable isotopes—^{15}N and ^{14}N—and their ratios ($\delta^{15}N$) in order to distinguish marine foods (fish and shellfish) from corn in the diet. Populations eating a lot of seafood tend to have higher $\delta^{15}N$ values than those of populations not eating seafood. By plotting the values for each individual using both $\delta^{15}N$ and $\delta^{13}C$ values in a bivariate graph, we were able to distinguish the relative contributions of seafood and corn in diet over time.

Our analysis revealed a dramatic change in diet for the inhabitants of the region. Using St. Catherines Island, Georgia, as a microcosm of dietary change, we compared the stable isotope ratios for the early prehistoric period, late prehistoric period, and Santa Catalina de Guale colonial mission period. This record shows a clear shift in diet from high seafood consumption and no corn in the early prehistoric people, to still high seafood consumption but with corn in the late Prehistoric people, to limited seafood consumption and even more corn in the Mission people. From this seafood consumption but with corn in the late Prehistoric people, to limited seafood consumption and even more corn in the Mission people. From this record, we can infer an increasingly decreased access to iron and an increasing focus on a food that causes dental caries. Moreover, the region as a whole shows the same trend of reduced access to protein and increased focus on iron–poor, cariogenic corn.



This graph shows the temporal change in stable carbon and stable nitrogen isotope ratios in bone samples from St. Catherines Island, Georgia, including those of the early Prehistoric hunter-gatherers, the late prehistoric farmers, and the Mission farmers of Santa Catalina de Guale. Each dot represents a person. These ratios measure the relative reliance on corn and seafood, respectively. Notice the dramatic drop in seafood consumption and increase in corn consumption peaking during the Mission period.

Our earlier research on St. Catherines Island and the region generally showed an increase in dental caries and other indicators of increasingly poor health, especially during the contact period after arrival of the Spaniards and the establishment of missions in the region. Our application of chemistry to bones of the long deceased helped us to understand why—it is explained by poor nutrition and increasing focus on plant carbohydrates. Increased accuracy in dietary reconstruction from the study of bone chemistry helped us to know with more certainty the diets of past people.

The arrival of European explorers and colonists in the Americas had an enormous impact on the kinds of domesticated plants consumed by world populations. That is, beginning with Columbus's voyages, different plants were transported and grown throughout the world. Corn, for example, was taken back to Europe by early explorers. By the middle of the 1500s, its use as a food had spread widely, and it had explained by poor nutrition and increasing focus on plant carbohydrates. Increased accuracy in dietary reconstruction from the study of bone chemistry helped us to know with more certainty the diets of past people.

The arrival of European explorers and colonists in the Americas had an enormous impact on the kinds of domesticated plants consumed by world populations. That is, beginning with Columbus's voyages, different plants were transported and grown throughout the world. Corn, for example, was taken back to Europe by early explorers. By the middle of the 1500s, its use as a food had spread widely, and it had become an important part of diets, especially in Africa.

Today, domesticated plants are crucial for sustaining human populations. Two-thirds of calorie and protein intake comes from the key cereal grains domesticated in the earlier Holocene, especially wheat, barley, corn, and rice. Rice has fed more people since its domestication than any other plant. It now accounts for *half* the food consumed by the 1.7 billion people in the world whose diets include rice and for more than 20% of all calories consumed by humans today. Rice and these other cereal grains are now aptly called superfoods.