EARLY ANDEAN EXPERIMENTAL AGRICULTURE

Jack Weatherford

There is only one Machu Picchu, but it guards many mysteries. The ruins of this ancient Peruvian city sit perched eight thousand feet above sea level on a mountain overlooking the Urubamba River. Even though in size Machu Picchu barely surpasses a village, the ruins show a complexity indicative of a much more important place. The stone houses with trapezoidal doorways and simple lintel construction do not resemble the houses of the *puric,* the common peasants, and the public buildings surpass any administrative or religious building one might expect to see in a town of comparable size. The ruins show precision-crafted buildings with the neat regular lines, beveled edges, and mortarless seams that characterize the best of Inca architecture.

The spectacular setting combined with the exquisitely wrought buildings evoked much speculation and much romantic rubbish about the purpose of the city. The North American discoverer Hiram Bingham erroneously assumed that he had found Vilcabamba, the holdout capital of the Inca Empire after the fall of Cuzco. Lacking an explanation, many people assume that the purpose must have been religious and thus have dubbed the place "the sacred city of the Incas." Others claim that it was built as a city to protect the noble women from the Spanish, or that it served as a monastery associated with the sacred coca plant, or as a cult center.

None of this agrees with what we know about the Incas. Unlike the superstitious Aztecs, the Incas did not build large pyramids to perform massive blood sacrifices or pursue long wars to please their gods. Unlike the mystical Mayas, they did not build observatories to watch the endless patterns of the stars or write long, philosophical poems on the creation of the world. They displayed an austere practicality in every aspect of their lives, and they show little hint of religious fervor, no penchant for meditation, no tendency toward either the sentimental or the superstitious.

The supposedly practical peoples of ancient Rome, traditional Germany, and the contemporary United States seem almost like mystics compared to the Incas, and ancient Sparta seems like the home of the frivolous. The Incas' practicality shows in the precise and very angular style they used to construct buildings, in

contrast to the more haphazard and rounder style of their predecessors. This same practicality and passion for organization shows in their economic system, which lacked money, markets, or merchants and yet managed to avoid the famine that stalks so many great empires.

In light of this practicality the very existence of Machu Picchu seems all the more puzzling. Why would the Incas build a city and line the mountain with terraces even though there was very little soil there? The builders used the best techniques known to them to make terraces that would last for eternity. Then the workers added layers of rock and clay as subsoil, and from the river below them they hauled up rich dirt over steep embankments half a mile deep. This task would be the equivalent of hauling dirt from the Colorado River to plant fields on top of the Grand Canyon.

The Incas built hundreds of the terraces, all of them quite small for any kind of extensive agriculture. Some of them narrow to as little as six inches in width. Yet these terraces climb up and down the mountain to great distances, and the Incas even built small terraces high up on the facing peak of Huayna Picchu, an hour's steep climb from the city. Such an arrangement makes no more sense than if Americans today decided to start farming the face of Mount Rushmore with plots the size of large flower boxes.

A hint of the possible function of Machu Picchu came to me while hiking around the area for two days with Charles Laughlin, a plant scientist from the University of Georgia. On one of our excursions, we returned to the ruined city by way of the Inca trail from the south. This trail enters the city through Inti Punuc, the stone gate of the sun, perched high up in the saddle of the mountain dividing the Machu Picchu side of the mountain from a dry inland valley. Standing in the gateway one sees two worlds, the brown and lifeless valley to one side and on the other side the lush, emerald-green valley watered by the thick fogs and mists of the Urubamba River far below the city ruins.

As we descended toward the city from this high pass, I stared out at the spectacular landscape. Why had the Incas built the city here at this point? Was it to guard the river? But what was there to guard? Perhaps it was a place to trade coca. But why would they need a monumental city for that? Why had they built the city up so far from the water of the river?

All the while I searched up and down the long vistas of the Urubamba and the surrounding mountains, Chuck was looking at the vegetation and naming everything growing along the path. I found this distracting from the big picture, but as we descended the mountain and passed from one terrace to another, the plants that he named changed. We were passing through a series of ecological layers, as one does on many mountains in the Andes. The mountainside is laid out in strips of vegetation and microzones. The place is a scientist's dream—the perfect place for all kinds of controlled experiments. Viewed in that context, the small terraces took on new meaning as experimental patches at a range of altitudes and built at so many different angles facing the morning sun, the evening sun, constant sun, or no sun. They are like a scientist's set of experiments all laid out in a field.

In my mind, Machu Picchu suddenly became an agricultural station. In that

sense it was a sacred spot, because agriculture was a sacred activity for the Incas, who worshiped the life-giving Pachamama, the earth mother, and Inti, the sun, who together made the plants grow.

The ancient Peruvians had been among the world's greatest experimenters with agriculture, and they built numerous experimental areas where crops could be grown in different ways. It would not be surprising if they devoted a place such as Machu Picchu to just such activity. Whether this site actually functioned as an ancient experimental agricultural station or not, the Indians of the Andes probably did more plant experiments than any other people anywhere in the world.

Starting thousands of years before the Incas, the natives ascertained how to produce extremely high yields of potatoes from small plots of land. In the modern world, producing high yields has come about primarily through developing plants that can grow in different types of environments and, when necessary, through the manipulation of the immediate environment of the plant to ensure that it has just the right amount of moisture, nitrogen, and other requirements for maximum growth. Peruvians seem to have approached the problem in the opposite way. They sought to develop a different kind of plant for every type of soil, sun, and moisture condition. They prized diversity. They wanted potatoes in a variety of sizes, textures, and colors, from whites and yellows through purples, reds, oranges, and browns. Some tasted sweet and others too bitter for humans to eat, but the latter were useful as animal fodder.

They did not seek this diversity merely for the aesthetic pleasure of having so many shapes, colors, and textures, but rather for the practical reason that such variations in appearance also meant variation in other, less noticeable properties. Some potatoes matured fast and some slowly, an important consideration in a country where the growing season varies with the altitude. Some potatoes required a lot of water and some required very little, which made one variety or another more adaptable to the highly variable rainfalls of different valleys. Some potatoes stored easily for long periods of time, others made excellent food for livestock.

In addition to the potato, the Incas produced other tuber and root crops, such as *oca, añu, achira, papa liza, luki,* and *maca,* none of which even have names in English. The Peruvians grew corn in just as many varieties and diverse habitats, and they cultivated the native American grain crops that in Quechua they called *kiwacha* (or amaranth, *Amaranthus caudatus*) and *quinua* (or quinoa, *Chenopodium quinoa*).

The success of these early experimenters remains visible today, not only in the variety of food crops but in the extensive agricultural ruins of the Urubamba Valley stretching from Machu Picchu to the Inca capital city of Cuzco. As one goes along the valley, one is constantly in sight of Indian ruins remaining from the Spanish conquest. Crumbling watchtowers dot the high ridges like a row of decaying teeth, and empty citadels loom over nearly deserted villages. Irrigation canals once brought water down from the melting snows high in the mountains

to the terraces. But the terraces now lie broken, and rock or mud long ago filled in the canals. It taxes the mind to imagine how magnificent this valley must have been before the conquest. Green terraced fields continued for miles, punctuated by filled warehouses; now, parched parcels of land, crumbling terraces, and destroyed bridges are all that remain to be seen.

As the Spanish armies, clergy, and diseases swept through the river valley, whole villages died or were taken away to work the mines of Potosí, and the rich valley soon gave way to decay and dim memories. This valley of the Urubamba River, which may have supported millions, now has only a fraction of its former population. While these fields lie neglected, the government of Peru, the land of the potato, imports potatoes from the Netherlands to feed the people.

Indians of the Andes have cultivated the potato on their mountain slopes and in their valleys for at least the last four thousand years. Apparently the potato descended from a tuberous *Solanum* that grew wild throughout the Americas and was used by Indian groups as far north as the southwestern United States, where the Navajos made it a major part of their diet. The Indians of the United States and of Mexico apparently were in the process of domesticating their own varieties of this potato when the Spanish arrived in the sixteenth century (Salaman, p. 1).

At the time of the Spanish conquest, Andean farmers already were producing about three thousand different types of potatoes in the Andes. This contrasts with the mere 250 varieties now grown in North America, and of those no more than twenty varieties constitute three-quarters of the total potato harvest in the contemporary United States. Under the guidance of the Indian farmers of the Andes, the potato became the basis for several great Andean empires, the last of which was that of the Incas whose empire fell to Francisco Pizarro in 1531.

The Andean farmers also devised and perfected the first freeze-dried method of preserving the potato. At night, farmers put their potatoes out in the freezing air of the high mountains. During the day the sun thawed the potatoes, and the farm family walked over them to press out the melting moisture. After several repetitions of this process, the potato dried into a white chunk which very much resembled modern plastic foam. In this very light form the Incas easily transported great numbers of potatoes to distant storehouses, where they could be preserved for five or six years without harm. When needed, the potato could be reconstituted by soaking it in water, and then it could be cooked. Cooks also ground it into meal for making soups and other dishes. Today this entire procedure continues exactly as before in thousands of hamlets scattered throughout the Andes. The resulting *ch'uño,* as the dried potatoes are called in Quechua, still serves as a staple of Andean cuisine throughout the year.

The Incas also used drying techniques on a variety of other vegetable crops and even on meat. The dried meat, or *charqui* as it was called in Quechua, also found favor among the Europeans as a convenient and light way to preserve and transport meat. The name *charqui* was taken over and corrupted into *"jerky,"* one of the few English words derived from Quechua.

Just as the silver of Potosí spread to Europe and then on to the Ottoman Empire, Timbuktu, and China to cause a major change in the world's economy, the humble potato spread to the rest of the world. The potato spread far more slowly than the silver, but in the end the potato and the other native crops of America have produced a far greater impact than the mountain of silver.

It is difficult to imagine what Ireland would be today without the potato. What would the Russians, the Germans, the Poles, and the Scandinavians eat? Without the potato the Soviet Union might never have become a world power, Germany would not have fought two world wars, and northern Europe and the Benelux countries would not have one of the world's highest standards of living.

Before the discovery of America, the Old World depended primarily on grain crops of domesticated grasses such as wheat, rye, barley, and oats in Europe and the Near East, rice in the Far East, and millet and sorghum in Africa. All of these plants, however, face numerous problems in their growing cycle. Because they grow on high stalks above the ground, they are easy prey to the destructive elements of wind, hail, heavy rain, and snow as well as to birds, insects, and animals.

For centuries the northern countries such as Russia and Germany suffered periodic famines when the grain crop failed because of unsuitable weather. For as long as the Old World depended on grain crops, the great population and power centers remained in the warmer southern nations around the Mediterranean, where the grains flourished. Greece, Rome, Persia, and Egypt all had successful empires primarily because of their control of grain production. Even a nation as far north as France was able to become a world power and a reasonably good producer of grain. But the unpredictable weather and food supply sat as a permanent burden on the German states, England, and Scandinavia, and on Russia, which sometimes exported grain and then sometimes imported it. These were all societies waiting for their chance to act on the cultural and political stage of world, but first they needed a consistent supply of nutritious and cheap food to sustain them.

This food finally arrived in the somewhat ugly form of the Andean potato. Together with maize corn from Mexico, potatoes were what French historian Fernand Braudel called "the miracle crops" (Braudel, vol. I, p. 74). The Europeans by no means greeted this new plant with general enthusiasm. The peasants of Europe despised the new plant. Aside from the occasional side dish of parsnips, turnips, and carrots, Europeans did not eat root crops. They certainly did not want to adopt one as a staple of their daily diet. For them the staples were the grains that they could mill and then bake into bread or more commonly could eat as a porridge, such as the oatmeal of the Scots and Irish or the gruel of the English. This was real food to the European peasant, not a knotty tuber grown by American savages.

European legends claimed potatoes caused leprosy because the potato grew in such a misshapen and ugly form. Some Orthodox sects in Russia called it the devil's plant and decreed it a sin to eat the potato, the tomato, and sugar, because they were not mentioned in the Bible. Even as authoritative a source as Denis

Diderot's *Encyclopédie* of 1765 accused the potato of being tasteless and of causing excess flatulence in the peasants who eat it (Braudel, vol. I, p. 170).

Adam Smith wrote one of the first defenses of the potato and theorized about the tremendous importance that its adoption portended for Europe. He accurately predicted that increased cultivation of potatoes would cause an increase in production, an increase in population, and an increase in the value of land. Based on his observation of Ireland, which was at that time the only country where the potato was already widely cultivated, Smith judged the tuber to be an excellent food, especially for the lower classes. In his opinion, the potato made men stronger and women more beautiful, and he based this opinion on his observations of the prostitutes and laborers imported from Ireland to London. Despite Smith's strong advocacy of potato cultivation, he doubted that potatoes would become very widespread because of the difficulty of preserving them for longer than a season (Smith, pp. 160–61).

For its first two centuries in Europe, the potato was little more than a curiosity grown in herbal gardens around monasteries and universities and eaten by the upper and middle classes as a novelty food; the masses steadfastly ignored the interloper. Not until the second half of the eighteenth century did the potato finally take root in fields of northern Europe. The peasants grudgingly accepted it only after their rulers forced them to plant it. Frederick the Great in Prussia, Catherine the Great in Russia, and similarly enlightened monarchs forced the peasants to grow potatoes or starve following a series of eighteenth-century famines, epidemics, and wars.

The archbishop of Mainz broke the dependence of the villagers of Kahl on grains through a number of strenuous laws. In Kahl and other villages, he outlawed construction of new home ovens and provided each village with only a single communal oven that the village women used in shifts. The large beehive-shaped oven still stands in the oldest part of Kahl near the church as a historical talisman uniting the contemporary villagers with the ancient community of their ancestors. The building of the communal oven markedly reduced the bread and baked goods available, because each housewife had only one turn per week at the oven, and she had to pay tax on each tray of foods she baked. Taxes on mills further reduced dependence on flour, and additional taxes on bakers and ovens raised the cost of bread. The peasants had to grow potatoes or face severe financial strain and possible hunger.

The monarchs and Adam Smith knew what the peasants would soon learn: a field of potatoes produces more food and more nutrition more reliably and with less labor than the same field planted in any grain. Even today, a hectare of land planted in potatoes produces 7.5 million calories. The same land planted in wheat produces only 4.2 million calories. The cultivation of potatoes also consumes far less calories or energy than does that of wheat. This means that each farmer could produce more hectares of food per worker, or that some of the workers could be freed for other tasks. The potato needed only three or four months to grow compared to almost double that for grains. The potato also needed far less attention and care while growing, and it grew in a variety of soils

that were not otherwise productive (Farb and Armelagos, p. 76). Farmers found that the potato required none of the extensive milling and processing of grains, which necessitated a large capital investment in equipment and transportation. By contrast, potatoes could be pulled from the fields for immediate consumption or stored in the basement for nearly a year before being cooked.

The potato could be used for bread, although that was usually not necessary, since enough grain existed for the making of bread. Instead, cooks could make the potato into many new dishes to replace the limited breads, noodles, gruels, and porridges that could be made from grains. The potato could be served baked, boiled, roasted, or fried or could be made into soups, pancakes, dumplings, soufflés, and pies.

Once introduced into the fields of the European farmers, the potato thrived. Accustomed to the cool and often damp highland valleys of the Andes, the potato adapted easily to the cool and damp climates of Ireland, Germany, Poland, Russian, Scotland, England, the Netherlands, Belgium, and Scandinavia. Of the approximately three thousand varieties of potato grown in America, comparatively few were transplanted to Europe, but there were enough varieties to ensure that whatever region of Europe wanted a potato, at least one type possessed the traits that made it ideal for that climate and soil conditions. In Europe only the warmer areas of the Mediterranean proved inhospitable to the potato; there the natives continued with their traditional grains.

In the northern climates, where long winters without fresh vegetables were the rule, the potato offered a new source of vitamin C that greatly improved the health of the population. For a reason still not adequately understood, potatoes do not produce tooth cavities nearly as much as grains. When eaten as processed flour, the finely ground starches from grains stick to the teeth and rot them. On the other hand, when eaten as tough grains, they are very abrasive and wear out the teeth. By eating more potatoes, the northern Europeans retained strong teeth until an older age, and this improved their general health. Nutritional diseases declined steadily, and by early in the eighteenth century, they virtually disappeared as causes of death in Europe except during war (Petersen, p. 442).

In its gradual conquest of Europe the potato moved primarily from west to east. Ireland was the first nation to make an enthusiastic conversion to potato farming. As is often the case when reliable historical information is scarce, various legends arise to account for the origin or introduction of the potato. According to one such legend, Sir Walter Raleigh introduced the potato to Ireland in the sixteenth century on his way back to England from the Caribbean. Another legend claims that the Irish peasants discovered the potato in galleys of the ships of the Spanish Armada washed up on Irish beaches in 1588 after the Armada was attacked by the English navy and dispersed by a great storm. The timing for both legends seems more or less accurate; the latter half of the sixteenth century is usually accepted as the date of introduction. But another century passed before the plant took hold and won the widespread and fanatic devotion which the Irish have had for it ever since. By the end of the seventeenth century, it was the staple food of Ireland (Salaman, p. 222).

From Ireland, the potato as a staple crop of the field, rather than as a mere curiosity of the garden, spread through England, Scotland, and Wales, across the low countries and France, and through Germany and eastern Europe. The Russians did not adopt it very widely until the 1830s and 1840s, but then became no less devoted converts than the original Irish.

Despite the difficulties of introducing the potato to Europe, once the peasants became accustomed to it they loved it. In Flanders, between 1693 and 1791, grain consumption fell from 758 grams per person per day to 475 because of the introduction of potatoes. This means that potatoes replaced about 40 percent of the cereal consumption of Flanders (Braudel, vol. I, p. 170). The nutrition of the people improved markedly and the population grew accordingly.

One major problem encountered when tracing the history of the potato derives from its being misnamed from very early in the English-speaking areas. The Indians of the Andes have called it and still call it the *papa*. The word "potato" first came into English as the name of a very different plant imported from the Caribbean islands. The word *batata* came from the Taino Indians of what is now the Dominican Republic and Haiti; the Spanish made it *patata,* whence came the English "potato." This plant has since been called the "sweet potato" in English, but at the time of its introduction it was known simply as the potato. When the *papa* arrived from the Andes the English mistook it for the Caribbean sweet potato and consequently have called it "potato" ever since. To distinguish between the two unrelated tubers, one is often called the "sweet potato" now and the other is the "common potato" or sometimes the "white potato." In reading the early chronicles of plants and agriculture, it is often impossible to ascertain which of these plants is designated by the name "potato."

With the new calorie source and the new source of nutrition, the potato-fed armies of Frederick of Prussia and Catherine of Russia began pushing against their southern neighbors. During the Age of the Enlightenment these northern cultures wrestled free from the economic, cultural, and political domination of the south. Power shifted toward Germany and Britain and away from Spain and France, and finally all were eclipsed by Russia. Russia quickly became and remains the world's greatest producer of potatoes, and the Russians are among the world's greatest consumers of the potato. Their adoption of the potato as their staple food preceded their rise as a world power.

American foods brought about the miracle that centuries of prayer, work, and medicine had been unable to do: they cured Europe of the episodic famines that had been one of the major restraints on the population for millennia. Even France, the richest country of Europe, suffered acutely from numerous general famines and even more regional ones. The number of general famines in France varied from as few as two in the twelfth century to as many as twenty-six in the eleventh century. Even as recently as the eighteenth century, France succumbed to sixteen general famines, bringing the total number of famines to 111 for the years between 1371 and 1791 (Braudel, vol. I, p. 74).

As little as an acre and a half sufficed to nourish the average family if they planted the land in potatoes and supplemented these with milk, butter, or cheese.

With the revolutionary crop, the population of Ireland expanded from 3.2 million in 1754 to 8.2 million less than a century later in 1845. During this same century an additional 1.75 million Irish left Ireland for the New World. Thus in the first century after the introduction of the potato, the population of Ireland effectively tripled (Crosby, p. 183). Then when the potato blight hit, thousands of Irish starved or emigrated, because without the potato Ireland could not support such a massive population. Had the Irish followed the Indian technique of planting many different types of potatoes rather than just a few, the effect of the blight probably would have been considerably lessened.

Despite the Irish famine, the population of each country boomed as it adopted the potato. Possibly it was because of this effect of the potato on population that so many people accepted the notion that the potato was an aphrodisiac. The reputed aphrodisiac powers of the plant may also have been due to the tuber's somewhat phallic shape. Its erotic reputation further grew because of its similarity to the truffle, an extravagantly expensive delicacy associated with the rowdy and gluttonous life of the rich and aristocratic.

If we look at the larger population picture since the spread of American crops around the world, we see much the same process. In the three centuries between 1650 and 1950, the population of Europe (including the Soviet Union) climbed from just over 100 million to almost 600 million, a sixfold increase. In 1650 the population of Africa was probably about the same as that of Europe, but Africa's population only doubled, from 100 million to about 198 million in 1950. This comparatively slow growth reflects the slower incorporation of American food crops as well as the depopulation caused by the slave trade and colonization. Asia's population did not increase as rapidly as Europe's but did grow faster than Africa's. Asia went from 327 million to 1.3 billion in the same three centuries. In all, the Old World of Europe, Asia, and Africa increased in population from about half a billion people in 1650 to over two billion by 1950. In addition, tens of millions of people left Asia, Africa, and Europe to live in the New World as colonists or slaves (Crosby, p. 166).

On the world scene, the total population in 1750 has been estimated at 750 million. It reached a billion in 1830, two billion in 1930, and four billion in 1975 (Farb and Armelagos, p. 75). In recent decades, medical advances have accounted for some of the increase in population, but most of the population growth preceded the medical innovations. Improved nutrition accounts for most of the growth prior to this century. Only later did improvements in public health and sanitation have an impact, and only in the past century have any real gains in medicine affected the population.

The potato alone cannot claim full responsibility for the great population and health boom of the Old World. The American Indians cultivated over three hundred food crops, and many of these had dozens of variations. The people of the Old World gradually transplanted many of these crops from America, and each in turn contributed in various ways to improving the world diet in both quantity and quality of foods. The Indians gave the world three-fifths of the crops now in

cultivation. Many of these grew in environments that had formerly been inaccessible to agriculture because of temperature, moisture, type of soil, or altitude.

Some of these plants spread through the world by way of Europe, but most of the tropical plants crossed directly to Africa and Asia. The African slave trade sent hundreds of ships laden with humans across the middle Atlantic to Brazil, the Caribbean, Virginia, and the Carolinas, but they had less cargo with which to return. In carrying food and supplies with them on the return voyage to Africa, the crews also carried American Indian foods and spices, many of which quickly took root in the similar soil and climate of Africa. At a slightly slower pace the tropical American foods spread to Asia aboard Spanish ships sailing from Acapulco, Mexico, to Spain's major Asian port at Manila in the Philippines. Other products were brought to Asia from the opposite direction by the Portuguese, who carried products from their Brazilian colony to their scattered holdings in Africa, around to Goa in India, and on to their easternmost colony of Macao in southern China.

The protein supply of the Old World also increased with the great variety of beans brought in from America, principally from Mexico, where beans, corn, and squashes had been the mainstay of the Indian diet. Different parts of the Old World eagerly adopted one or more of the American beans, including kidney beans, string beans, snap beans, the Mexican frijole, the common bean, butter bean, lima bean, navy bean, and pole bean. In addition, American Indian beans included many which took on very un-American names, such as the French bean, Rangoon bean, Burma bean, and Madagascar bean (Crosby, p. 172).

In Africa the American peanut or groundnut also helped to increase the protein intake. The peanut found a large following in Asia as well as in Africa, but in Europe it never became anything more than a novelty snack, a source of oil, and animal fodder. Even a food as common in the diet of the United States as peanut butter never found a European following, but it became common in West Africa, where peanut butter is mixed with hot peppers and sold in the streets as a tasty and nutritious snack.

Farther north in Europe where the cold hampers peanut cultivation, large amounts of oil and animal feed are made from another American staple, the sunflower, which is native to the United States plains and was domesticated by the Indians of North America. Next to the potato the sunflower is probably the most important plant that America gave to Russia. Neither olives nor oil-producing grains grew very well in Russia, and thus the sunflower finally gave the Russians a reliable source of edible oil. As with the potato, the Soviet Union is today the world's largest producer and consumer of sunflowers.

Of the many types of American grains, only maize corn found a use among the Europeans. The European farmers learned to grow corn, but most of them never learned to eat it. Only in a few areas of southern Europe, such as Italy, Greece, Yugoslavia, and Romania, is it sometimes used as a substitute for grains in making soupy porridges. Otherwise, the Europeans have largely ignored it. But corn did have a role to play. Many important products such as oil can be made

from it, and it makes a nutritious food for most domesticated animals. Potatoes may be eaten by some animals, such as pigs, but not by others, such as cows or chickens. Corn, however, could be fed to all of these animals. Corn did for the animal population of Europe what the potato did for the human population. The new animal food not only increased the supply of meat and lard but also increased the supply of eggs, milk, butter, cheese, and all the animal products that constitute so important a part of the European diet. These foods substantially increased the European intake of protein.

The population impact of maize corn was much stronger in southern Europe than in the north. During the eighteenth century, when corn and other American crops were being widely cultivated in southern Europe, the population of Italy grew from eleven million to eighteen million, and the population of Spain doubled (Farb and Armelagos, p. 76). The impact on Africa is more difficult to measure, but corn grew more reliably than did the traditional African staples of millet and sorghum.

Corn grows easily in soils that receive too much or too little moisture for wheat or rice. While rice grows best in semitropical zones and wheat flourishes primarily in temperate zones, maize corn thrives in both. Indians cultivated rapid-growing varieties in areas as cold as Canada and Chile, while other types of corn flourished in the heat of the Amazon. Inca farmers cultivated it on the terraced sides of Andean mountains, and Hopi farmers irrigated it and made it grow in the hottest and driest deserts of the United States.

Even though the whites adopted corn slowly in comparison with the Chinese and Africans, they have not stopped finding new uses for it. The many varieties can be eaten directly or made into flour, starch, or syrup for cooking in other products. Particularly in its use as dextrose or as corn syrup it has steadily replaced cane sugar in processed foods. Unlike cane sugar, corn syrup can hold its moisture and thereby prevent crystallization of itself as well as any other sugars with which it is mixed. This unique resistance to drying out and crystallizing creates unusual uses for corn syrup, as in motion-picture studios, where special-effects artists dye it red and use it for blood in their films, since it will retain the appearance of fresh blood for hours of rehearsals and film shootings. This same quality has more practical applications, making corn syrup the ideal ingredient for sweetened drinks from baby formulas and chocolate milk to colas as well as for ice creams, catsup, syrups, candies, salad dressings, pies, and any dish for which moisture is desirable. Corn syrup can also do all of this much more cheaply than other sugars.

In Africa, maize corn and cassava together underlie the great population explosion which started in the last century and has continued throughout the twentieth century. Cassava assumed a particularly important role in Africa because it grows in poor soils that will not produce any other food crop; thus it does not compete with corn or the grains for land. Cassava has the added advantage that its roots can be harvested at any time within a two-year period after becoming mature. Thus they make an excellent food bank that can be preserved in the ground for times of scarcity. The climate and the numerous animal and insect

pests of tropical Africa make food storage precarious. Cassava has one major drawback in that unlike the potato and corn it lacks substantial nutrition. Since the cassava root is almost pure starch, one hectare of land planted in cassava produces almost ten million calories, compared with less than half that for grains and three-fourths that for rice and potatoes. Cassava became a major source of calories and an important crop in preventing famine, but it did not improve the nutrition of the African diet.

Asians adopted the sweet potato with the same eagerness that Africans adopted cassava, and it had much the same impact on their diets as the common potato had on the Europeans'. Even though rice offers more nutrition than most grains, it still suffers from many of the shortcomings of the grains. It also showed high susceptibility to both droughts and floods, which caused frequent famines in China. The sweet potato enabled the Chinese to ameliorate the cycle of feast and famine that their dependence on rice had so long made inevitable. The sweet potato yields three to four times as much food as would rice planted on the same area of land, and the sweet potato thrives in weather and soils that kill rice (Crosby, p. 172).

Even though the stereotype of Oriental food is that it is all rice-based, the common people depend heavily on the sweet potato as well. China is the world's largest producer of sweet potatoes; the Chinese enjoy them plain or ground into flour to make noodles, dumplings, and other dishes. Rice is the prestige food of the Orient, but the sweet potato is the daily food for many of the peasants.

America also gave the world some new grains that offered more nutritional value than any of the Old World grains. For the most part the Europeans ignored the amaranth from Mexico and quinoa from the Andes. In the last years before the conquest of Mexico, the Aztec capital of Tenochtitlán received an annual tribute of twenty thousand tons of amaranth grain from its seventeen provinces (mostly in native Mexican varieties of *Amaranthus hypochondriacus* and *A. cruentus*). Because of its high protein content of 16 percent, compared with 7 percent for rice and 13 percent for wheat, amaranth is considerably more nutritious than most grains. It also has twice the lysine found in wheat and as much as is in milk, making it far more balanced in proteins than most plant foods. The Aztecs respected the grain so highly that each year they publicly celebrated it by eating amaranth cakes made with honey or human blood shaped into the forms of the gods. The Spanish interpreted this as a black mockery of the holy communion of the Christian church and consequently forbade the cultivation, sale, or consumption of amaranth under penalty of death (National Academy of Sciences, pp. 1–4). No matter how nutritious it might be, they already had enough grain crops and did not want more.

In the twentieth century, scientists discovered that Indian farmers in the high valleys of the Andes and in remote parts of Mexico still cultivate amaranth. Now international research organizations such as the National Academy of Sciences of the United States and UNICEF encourage its dissemination to help feed the Third World nations. Amaranth went on sale in health-food stores in the United States

in the 1970s, and quinoa followed in 1986, but the great potentials of these two miracle grains of the Indians have not yet been tapped.

Amaranth has become one of the most important cereals in the diets of highland peoples in India, China, Pakistan, Tibet, and Nepal. Cultivation has spread so widely in the past century that Asia now cultivates and consumes more amaranth than do the Americas.

In the marshy ponds that dot the terrain of Minnesota and Wisconsin, the Indians for centuries gathered a water-grown grain which the whites later called "wild rice," even though it is not an Old World rice. Despite the emphasis on "wild," the plant grew under human care, for during the harvesting the Ojibwa farmers dispersed the seed for the next year's crop. The Ojibwas also introduced wild rice into ponds where it had not grown: In this way they spread the plant into new areas, but they also controlled the type of plant grown in ponds by selecting for particular characteristics preferred by various groups of Ojibwas. Thus lakes and ponds became associated with particular types of wild rice.

Unlike regular rice, which grows in semitropical areas, wild rice thrives in the coldest parts of the northern great plains. It grows after passing the winter in lakes that freeze for four or more months each year. This unusual crop has become popular as a luxury food, and cooks often mix it with white rices to accompany gourmet dishes. The full food potential of the plant is yet to be explored. Just as the potato was eaten only by the rich for the first two hundred years after its introduction to Europe and only later became a staple for common people, perhaps one day wild rice may find its role in the feeding of large populations in cold swampy areas such as the Siberian tundra which have shown little agricultural potential thus far.

Today the agricultural experimentation that began many centuries ago in the Andes continues at the International Potato Institute, located in the suburbs of Lima. The modern buildings of the institute spread out over the countryside like the new campus of a community college. Immaculate beds of potatoes in small, neat rows surround and run between the buildings. The site looks almost as though the beautiful mountain terraces of Machu Picchu had been flattened out and arranged in military formations across the plain. Funded by various international agencies, the institute serves as a bank of germ plasm for the approximately ten thousand varieties of domesticated and wild potatoes found in the Andes. In addition to the beds at this lowland center, the institute maintains a highland center and one in the jungle as well. In the bins of the institute one sees yellow, red, and purple potatoes as well as white, blue, green, black, and brown ones. Some are round or oval, others horn-shaped or squash-shaped. Some have smooth skins and others have gnarled skins. No matter how beautiful or ugly a potato may be, each one is carefully protected and nourished for the future treasure it may give the world.

The full array of scientists from agronomists and anthropologists through botanists, cartographers, demographers, economists, and on through the alphabet to zoologists all work together to study every aspect of the potato and its place in the environment and in human society. They study the way it grows, how the peasants prepare the soil, how it is harvested, and the ways of storing it in diverse climates. Looking at so many scientists puttering around the potato beds, working in the lab, conferring around coffee pots, and experimenting with diagrams on computers, I could not help but think of what it must have been like at Machu Picchu five hundred years earlier. I have no special knowledge of exactly what went on at Machu Picchu then, but perhaps the work done there now continues at this institute.

Like their predecessors, these scientists work to expand the range of the potato into new environments such as the tropics, to find ways of growing potatoes from seed rather than from the root, and to develop ways to preserve its nutrition longer. They hope that one day the potato might feed the peoples of Brazil, Botswana, or Bangladesh as it already feeds the peoples of Germany, Ireland, and Russia.

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