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II.B.3 Potatoes (White)

This chapter presents the paradoxical history of the potato *(Solanum tuberosum)* in human food systems. It is now the fourth most important world food crop, surpassed only by wheat, rice, and maize. In five centuries, this diverse and adaptable tuber has spread from its original South American heartland in the high Andes to all elevation zones in temperate regions of all the continents, and, lately, its production has been increasing most rapidly in the warm, humid, tropical Asian lowlands during the dry season (Vander Zaag 1984).

In the course of its history, the potato adapted, and was adopted, as a highland subsistence crop on all continents. In Europe, it was originally an antifamine food but then became a staple. In Africa and Asia, it has been a vegetable or costaple crop. The potato has been credited with fueling the Industrial Revolution in eighteenth-century Europe but blamed for the mid–nineteenth-century Irish famine. Over three centuries, it also became a central and distinctive element of European regional, and then national, cuisines. Although "late blight" has continued to plague those dependent on potatoes for sustenance (CIP 1994), the potato's popularity has nevertheless grown since the end of World War II, particularly in its forms of standardized industrially produced potato fries, chips, and other frozen and processed "convenience" foods. Acceptance of standard fries (with burgers) and packaged chips symbolizes the "globalization of diet," as McDonald's, Pepsico, and other transnational food firms move potatoes around the world yet another time in their successful creation and marketing of a universal taste for these products.

White potato

In addition, the 1972 creation of an International Potato Center (CIP) in Lima, Peru, with its regional networks, has greatly accelerated the introduction of improved potato varieties and supporting technologies throughout the developing world.

R. N. Salaman's monumental volume charted *The History and Social Influence of the Potato* (1949) – a book that was edited and reprinted in 1985 by J. G. Hawkes, who updated archaeological and agronomic histories and then subsequently issued his own study (Hawkes 1990). The archaeological evidence for the origins of potato domestication is still fragmentary (for example, Hawkes 1990). However, collections, characterizations, and taxonomies of both wild and cultivated forms (Ochoa 1962; Huaman 1983; Hawkes and Hjerting 1989) continue to progress and are generating conclusions about evolutionary relationships that can now be tested with additional cytoplasmic and molecular data from crossability trials (Grun 1990). Such conclusions can also be tested by complementary ethnohistorical, social historical, and culinary historical data (Coe 1994).

Recent biological and cultural histories are recounted in several volumes by CIP (CIP 1984; Horton and Fano 1985; Horton 1987; Woolfe 1987), which also issues an *Annual Report* and a *Potato Atlas.* Key breeding and agronomic advances are also reported in *The Potato Journal, American Potato Journal, European Potato Journal, Potato Research, Proceedings of the Potato Association of America,* and reports by the potato marketing boards of major producing countries. All are contributing to worldwide understanding and utilization of potatoes, which exhibit perhaps the greatest amount of biodiversity of any major food crop (Hawkes and Hjerting 1989: 3), with matching cultural diversity in food and nonfood uses.

The Potato in South America: Origins and Diffusion

Cultivated potatoes all belong to one botanical species, *Solanum tuberosum,* but it includes thousands of varieties that vary by size, shape, color, and other sensory characteristics. The potato originated in the South American Andes, but its heartland of wild genetic diversity reaches from Venezuela, Colombia, Ecuador, Peru, Bolivia, Argentina, and Chile across the Pampa and Chaco regions of Argentina, Uruguay, Paraguay, and southern Brazil and northward into Central America, Mexico, and the southwestern United States. There are more than 200 wild potato species in this wide habitat that extends from high cold mountains and plateaus into warmer valleys and subtropical forests and drier semiarid intermontane basins and coastal valleys.

The greatest diversity in wild potato species occurs in the Lake Titicaca region of Peru and Bolivia, where the potato probably was domesticated between 10,000 and 7,000 years ago. *Solanum tuberosum* most likely was domesticated from the wild diploid species *S. stenotomum,* which then hybridized with *S. sparsipilum* or other wild species to form the amphidiploid *S. tuberosum* that evolved from the short-day northern Andean subspecies *andigena,* via additional crosses with wild species, into the subspecies *tuberosum,* which had a more southerly, longer-day distribution (Grun 1990; Hawkes 1990). Frost resistance and additional pest and disease resistance were introduced later via hybridizations with additional wild species, which allowed potatoes to be grown at altitudes up to 4,500 meters.

Archaeological Evidence

Fossilized remains of possibly cultivated tubers found on a cave floor in Chilca Canyon suggest that the potato was cultivated at least from about 7,000 years ago, although it is not possible to tell whether these were wild, "dump heap," or already garden acquisitions (Ugent 1970). Potato remains (along with those of sweet potato and manioc) from Ancon-Chillon (to the north of Lima) date from 4,500 years ago; northern coastal remains from the site of Casma date from between 4,000 and 3,500 years ago (Ugent et al. 1982). It is surmised that cultivated varieties were being planted on terraces at intermediate altitudes, extending from the river valleys into the high mountains, by the middle initial period between 4,000 and 3,500 years ago. Coastal remains from the monumental preceramic site of El Paraiso (3,800 to 3,500 years ago) suggest a mixed subsistence strategy, including unspecified *Solanum* plants that might be potatoes (Quilter et al. 1991).

Art provides additional testimony for the potato's centrality and for the antiquity of processed potatoes in pre-Columbian Andean culture. Fresh and freeze-dried potatoes are depicted in ceramics of the Moche people of northern Peru (A.D. 1 to 600), on urns in Huari or Pacheco styles from the Nazca Valley (650 to 700), and later Chimu-Inca pots (Hawkes 1990). Post-contact-period Inca wooden beakers also depict potato plants and tubers.

South American civilizations and states were based on vertically integrated production and consumption systems that included seed crops (especially maize, secondarily quinoa) at lower altitudes, potatoes and other tubers at higher altitudes, and llamas (camelids) to transport goods between zones. Hillside terracing conserved moisture and soils and encouraged the selection of multiple cultivars of a number of species that fit into closely spaced ecological niches. Ridged, raised, or mounded fields (still used for potato cultivation around Lake Titicaca) were a type of specialized field system that saved moisture and also protected against frost. In addition to making use of short-term storage in the ground, Andean peoples stored potatoes in fresh or processed forms. Huanaco Viejo and other Inca sites reveal extensive tuber storage areas, constructed in naturally cool zones, where indigenous farmers (or their rulers) stored whole tubers with carefully managed temperature, moisture, and diffused light to reduce spoilage (Morris 1981). Traditional freeze-drying techniques took advantage of night frosts, sunny days, and running water at high elevation zones and allowed potatoes to provide nourishment over long distances and multiple years, as dehydrated potatoes moved from higher to lower altitudes, where they were traded for grain and cloth.

Biocultural Evolution

As South American cultivators expanded into many closely spaced microenvironmental niches, they selected for thousands of culturally recognized potato varieties of differing sizes, colors, shapes, and textures, with characteristics that provided adequate resistance to pests, frost, and other stressors. At higher altitudes, cultivators selected for bitter varieties of high alkaloid content that were detoxified and rendered edible by freeze-drying (Johns 1990). Culturally directed genetic diversification continues up to the present, as Andean farmers allow wild specimens to grow and hybridize with cultivars, conserving biodiversity while diffusing risk (Ugent 1970; Brush 1992).

The botanical history of the cultivated potato is slowly being assembled by considering together the findings from plant scientists' genetic and taxonomic studies, archaeologists' interpretations of archaeological and paleobotanical remains, and ethnographers' observations and analogies from contemporary farming, food processing, and storage. Plant scientists continue to explore wild and cultivated habitats in the potato's heartland, where they find wild potato species that offer a tantalizing range of useful characteristics to protect against frost; against fungal, viral, and bacterial infections; and against nematodes and insects (for example, Ochoa 1962; Ochoa and Schmiediche 1983). Carnivorous, sticky-haired species, such as *Solanum berthaultii,* devour their prey; others repel them pheronomically by mimicking the scent of insects under stress (Hawkes and Hjerting 1989).

Added into the botanical and archaeological data mix are culinary historians' insights from agricultural, botanical, lexical, and food texts. Guaman Poma de Ayala, shortly after Spanish penetration, depicted and described plow-hoe potato and maize cultivation in his chronicle of the Incas (1583–1613) (Guaman Poma de Ayala 1936). Dictionaries that record concepts of the sixteenth-century Aymara peoples from Peru describe time intervals in terms of the time it took to cook a potato (Coe 1994)!

Indigenous peoples also developed detailed vocabularies to describe and classify potatoes, as well as myths and rituals to celebrate the tubers' importance. Even after conversion to Catholicism, they continued to use potatoes in their religious festivals; for example, garlands of potatoes are used to decorate the image of the Virgin Mary at the festival of the Immaculate Conception in Juli, Peru (Heather Lechtman, personal communication).

Indigenous Potato Products

Indigenous use of potatoes has included the development of processing methods to extend their nutritional availability and portability. In high altitude zones, selected varieties undergo freezing, soaking, and drying into a product called *chuño* that is without unhealthful bitter glycoalkaloids, is light and easily transported, and can be stored for several years. To render *chuño* (freeze-dried potato), tubers are frozen at night, then warmed in the sun (but shielded from direct rays). Next, they are trampled to slough off skins and to squeeze out any residual water, and then they are soaked in cold running water.

After soaking for 1 to 3 weeks, the product is removed to fields and sun-dried for 5 to 10 days, depending on the cloud cover and type of potato. As these tubers dry, they form a white crust, for which the product is labelled "white *chuño*" (in contrast to "black *chuño,*" which eliminates the soaking step). Another processing method involves soaking the tubers without prior freezing for up to a month, then boiling them in this advanced stage of decay. R. Werge (1979) has commented that the odor of this ripening process is "distinctive and strong" and has noted that, as a rule, this product is consumed where it is produced.

Chuño has a long history of provisioning both highland and lowland Andean populations; it was described by early Spanish chroniclers (for example, José de Acosta 1590) and also mentioned in accounts of sixteenth-century mine rations, in which Spanish mine managers complained about its high price. It is curious that one seventeenth-century source mentioned *chuño* as a source of fine white flour for cakes and other delicacies, although it was usually considered to be a lower-class native food (Cobo 1653). Ordinarily, *chuño* is rehydrated in soups and stews.

Another native product is *papa seca* ("dehydrated potato"), for which tubers are boiled, peeled, cut into chunks, sun-dried, and then ground into a starchy staple that is eaten with pork, tomatoes, and onions. *Papa seca* is consumed more widely than *chuño* in urban and coastal areas and can now be purchased in supermarkets.

In areas of frost, potatoes traditionally were also rendered into starch. Traditional products, however, are in decline, as household labor to produce them is now redirected toward higher-value cash employment or schooling. In addition, such traditional products tend to be thought of as inferior, "poor peasant" foods, so that those with cash income and access to store-bought pasta or rice consume these starches instead.

Biodiversity

Declining potato diversity, a byproduct of the insertion of higher-yielding "improved" varieties into South American field systems, is another reason for the fading of traditional potatoes and potato products. Traditional Andean potato farmers sow together in a single hole as many as 5 small tubers from different varieties and even species, and keep up to 2 dozen named varieties from 3 or 4 species (Quiros et al. 1990; Brush 1992). A particular concern has been whether genetic diversity erodes with the introduction of modern varieties and greater integration of local farmers into regional and national markets. Traditional varieties adapted to lower altitudes (where 75 percent of modern varieties are planted) are at greater risk than those of more mountainous terrains, which are less suited to the cultivation of irrigated, marketable, new varieties. So far, ethnographic investigations do not confirm the conventional wisdom that modern varieties generally compete successfully and eliminate traditional races. Although changes in cropping strategies allocate more land to new, improved varieties, thus reducing the amount of land allocated to traditional varieties, the midaltitude regions that grow modern varieties intensively tend also to devote small areas to older varieties that farmers maintain to meet ritual, symbolic, or preferential local food needs (Rhoades 1984; Brush 1992). In these commercial production zones, the land area allocated to traditional varieties appears to vary with income, with better-off households more likely to maintain larger plots.

Greater production of certain native varieties is actually encouraged by market opportunities. On-farm conservation of potato biodiversity has therefore been favored by the economics of particular native as well as introduced potato varieties, by vertical biogeography, and by persistent cultural customs calling for multiple traditional varieties (Brush, Taylor, and Bellon 1992), and there remains a large amount of as-yet unexploited population variability encoded in folk taxonomies (Quiros et al. 1990). Uniform sowings of improved varieties tend to replace older varieties only in the best-irrigated, midaltitude areas, where farmers harvest and sell an early crop and thus enjoy higher returns for the "new" potatoes. Traditional varietal mixes, however, continue to be grown in higher elevation zones where more extreme and risky environments encourage farmers to propagate a larger variety of them. But unless on-farm conservation programs are encouraged, it may only be a matter of time before erosion occurs.

Andean farmers' ethnotaxonomies ("folk classifications") continue to be studied by anthropologists and plant scientists to learn more about the ways in which traditional peoples recognize and organize plant information. These folk classifications, in most instances, recognize more distinctions than those captured by modern botanical taxonomies, and they also indicate the high value traditional peoples put on maintaining crop species biodiversity as a strategy to reduce risk of total crop failures. The more plant scientists improve their ability to understand the molecular biology, cytology, biochemistry, and genetics of the potato, the more they return to this traditional, natural, and cultural heartland to collect ancient wild and cultivated types and cultural knowledge about how to use potatoes.

In addition, traditional peoples developed ways to store and process potatoes, so that their availability could be extended greatly in time and over space. Agricultural and food scientists, in studying archaeological evidence of cold storage bins (Morris 1981) and contemporary practices (Rhoades 1984), have adopted and disseminated techniques, such as diffused lighting for storage areas and freeze-drying, as ways to increase the potato's food value in other parts of the world. This return to indigenous knowledge at a time of international diffusion of modern molecular technologies is one paradoxical dimension of the potato's history.

The Potato in Europe

Sixteenth-century Spanish explorers, who first observed the potato in Peru, Bolivia, Colombia, and Ecuador, compared the unfamiliar tuber food crop to truffles and adopted the Quechua name, *papa.* The first specimens, arguably short-day *S. tuberosum* ssp. *andigena* forms from Colombia, probably reached Spain around 1570. From there, the potato spread via herbalists and farmers to Italy, the Low Countries, and England, and there was likely a second introduction sometime in the following twenty years. Sir Francis Drake, on his round-the-world voyage (1577 to 1580), recorded an encounter with potatoes off the Chilean coast in 1578, for which British and Irish folklore credits him with having introduced the potato to Great Britain. But this could not have been the case because the tubers would not have survived the additional two years at sea. All European potato varieties in the first 250 years were derived from the original introductions, which constituted a very narrow gene pool that left almost all potatoes vulnerable to devastating viruses and fungal blights by the mid–nineteenth century. *S. tuberosum* ssp. *tuberosum* varieties, introduced from Chile into Europe and North America in the 1800s, represented an ill-fated attempt to widen disease resistance and may actually have introduced the fungus *Phytophthora infestans,* or heightened vulnerability to it. This was the microbe underlying the notorious nineteenth-century Irish crop failures and famine.

Herbal Sources

The potato's initial spread across Europe seems to have involved a combination of Renaissance scientific curiosity and lingering medieval medical superstition. Charles de l'Ecluse or Clusius of Antwerp, who received two tubers and a fruit in 1588 from Philippe de Sivry of Belgium, is credited with introducing the plant to fellow gardeners in Germany, Austria, France, and the Low Countries (Arber 1938). The Swiss botanist Caspar Bauhin first described the potato in his *Phytopinax* (1596) and named it *Solanum tuberosum* esculentum. He correctly assigned the potato to the nightshade family (Solanum) but otherwise provided a highly stylized, rather than scientific, drawing (1598) and gossiped that potatoes caused wind and leprosy (probably because they looked like leprous organs) and "incited Venus" (that is, aroused sexual desire), a characterization that led to folkloric names such as "Eve's apple" or "earth's testicles." Such unhealthful or undesirable characteristics probably contributed to potatoes being avoided in Burgundy (reported in John Gerard's *The Herball,* 1597) and in other parts of Europe. As a result of such persistent negative folklore, the introduction of the potato, a crop recognized by European leaders to have productive and nutritive capacities superior to those of cereal grains (particularly in cold and dry regions), was stymied for years in Germany and Russia.

Gerard – whose printed illustration in his *Herball* of 1597 provided the first lifelike picture of the potato plant, depicting leaves, flowers, and tubers (the plate was revised with careful observation in the later edition of 1633) – appears to have been fascinated by the plant, even wearing a potato flower as his boutonniere in the book's frontispiece illustration. But he also obscured the true origins of *Solanum tuberosum* by claiming to have received the tubers from "Virginia, otherwise called Norembega," and therefore naming them "potatoes of Virginia." The inaccurate name served to distinguish this potato from the "common potato," *Batata hispanorum* ("Spanish potato") or *Ipomoea batatas* ("sweet potato"). Additionally, "Virginia" at the time served the English as a generic label for plants of New World (as opposed to European) origin. *The Oxford English Dictionary* contains an entry labeling maize as "Virginia wheat," although it makes no reference to Gerard's "potato from Virginia."

Alternatively, Gerard may have confused a tuber truly indigenous to Virginia, *Glycine apios* or *Apios tuberosa,* with the *Solanum* potato after sowing both tubers together and then attributing an English origin to the tuber of greater significance in order to please his sovereign, Queen Elizabeth (Salaman 1985; Coe 1994). In any case, the false designation and folklore persisted into the next century, by which time potatoes had entered the agricultural economy of Ireland. A legend of Ireland credits the potato's introduction to the wreck of the Spanish Armada (1588), which washed some tubers ashore (Davidson 1992). Whatever its origins, William Salmon, in his herbal of 1710, distinguished this "Irish" (or "English") potato from the sweet potato, and "Irish potato" became the name by which "white" (as opposed to "sweet") potatoes were known in British colonies.

Eighteenth- and Nineteenth-Century Diffusions

The original short-day, late-yielding varieties illustrated in Gerard's and other herbals had by the eighteenth century been replaced by farmers' selections for early-maturing varieties that were better suited to the summer day length and climate of the British Isles. The new varieties' superior yield of calories per unit of land made subsistence possible for small farmers who had lost land and gleaning rights with the rise of scientific agriculture and the practice of enclosure. Potatoes also provided a new, cheap food source for industrial workers; Salaman (1949), William McNeill (1974), and Henry Hobhouse (1986) were among the historians who saw the potato as having encouraged the rapid rise of population that brought with it the Industrial Revolution.

Potatoes also spread across Italy and Spain. The Hospital de la Sangre in Seville recorded purchases of potatoes among its provisions as early as 1573 (Hawkes and Francisco-Ortega 1992). By 1650, potatoes were a field crop in Flanders, and they had spread northward to Zeeland by 1697, to Utrecht by 1731, to Overijssel by 1746, and to Friesland by 1765. In some high-altitude areas, they were originally adopted as an antifamine food, but the harsh winter of 1740, which caused damage to other crops, hastened potato planting everywhere. By 1794, the tubers had been accepted as an element of the Dutch national dish, a hot pot of root vegetables (Davidson 1992). Toward the end of the eighteenth century, potatoes had become a field crop in Germany, which saw especially large quantities produced after famine years, such as those from 1770 to 1772 and again in 1816 and 1817. Their popularity was increased not only by natural disasters (especially prolonged periods of cold weather) but also by the disasters of wars, because the tubers could be kept in the ground, where stores were less subject to looting and burning by marauding armies.

Such advantages were not lost on such European leaders as Frederick the Great, who, in 1774, commanded that potatoes be grown as a hedge against famine. Very soon afterward, however, potatoes proved to be not so safe in time of war. The War of the Bavarian Succession (1778 to 1779), nicknamed the *Kartoffelkrieg* ("potato war"), found soldiers living off the land, digging potatoes from the fields as they ravaged the countryside. The war ceased once the tuber supply had been exhausted (Nef 1950).

This war in Germany unintentionally provided the catalyst for popularization of the potato in France. A French pharmacist, A. A. Parmentier, had been a German prisoner of war and forced to subsist on potatoes. He survived and returned to Paris, where he championed the tuber as an antifamine food. His promotional campaign saw Marie Antoinette with potato flowers in her hair and King Louis XVI wearing them as boutonnieres. But widespread potato consumption in France still had to wait another century because, at a time when bread and soup were the French dietary staples, potato starch added to wheat flour produced an unacceptably soggy bread that was too moist to sop up the soup (Wheaton 1983). Widespread utilization of the whole potato in soup or as fries did not occur until well into the following century; even at the time of Jean François Millet's famous "Potato Planters" painting (1861), many French people still considered potatoes unfit for humans or even animals to eat (Murphy 1984).

From the middle eighteenth through nineteenth centuries, potatoes finally spread across central and eastern Europe into Russia. At the end of the seventeenth century, Tsar Peter the Great had sent a sack of potatoes home, where their production and consumption were promoted first by the Free Economic Society and, a century later, by government land grants. But "Old Believers" continued to reject potatoes as "Devil's apples" or "forbidden fruit of Eden," so that as late as 1840, potatoes were still resisted. When, in that year, the government ordered peasants to grow potatoes on common land, they responded with "potato riots" that continued through 1843, when the coercive policy ceased. But, in the next half-century, the potato's obvious superiority to most grain crops and other tubers encouraged its wider growth, first as a garden vegetable and then, as it became a dietary staple, as a field crop (Toomre 1992).

The Social Influence of the Potato

European writers credited the potato with the virtual elimination of famine by the early nineteenth century, without necessarily giving the credit to state political and economic organization and distribution systems (Crossgrove et al. 1990; Coe 1994). Larger-scale potato production subsequently provided surpluses that supported a rise of population in both rural agricultural and urban industrial areas. Potatoes were adopted widely because they grew well in most climates, altitudes, and soils and were more highly productive than grains in both good years and bad. During the seventeenth and eighteenth centuries, selection for earliness and yield gave rise to clones that were better adapted to European temperate, longer-summer-day growing conditions and could be harvested earlier. By the end of the eighteenth century, many varieties were in existence, some specified for human consumption, others as food for animals (Jellis and Richardson 1987). Agricultural workers across Europe increasingly grew potatoes on small allotments to provide food that was cheaper than wheat bread and also inexpensive fodder in the form of substandard tubers. Grains and potatoes, together with the flesh and other products of a few farm animals, provided an economically feasible and nutritionally adequate diet.

No less an authority than Adam Smith, in *An Inquiry into the Nature and Causes of the Wealth of Nations* (1776), estimated that agricultural land allocated to potatoes yielded three times the food/nutrient value of land planted with wheat, so that more people could be maintained on a given quantity of land. Even after workers were fed and the stock replaced, more surplus was left for the landlord. Favorably contrasting the nourishment and healthfulness of potatoes with that of wheat, Smith noted:

> The chairmen, porters, and coalheavers in London, and those unfortunate women who live by prostitution, the strongest men and the most beautiful women perhaps in the British dominions, are said to be, the greatest part of them, from the lowest rank of people in Ireland, who are generally fed with the root.

The single outstanding disadvantage of the potato was that stocks could not be stored or carried over from year to year because the tubers rotted (Smith 1776, Volume 1, Book 1, Chapter 11, Part 1: 161–2).

By this time, potatoes were also providing cheap food for growing industrial populations. Low-cost provisions enabled industrialists to keep wages low (Salaman 1985). Indeed, in both rural and urban areas, more than three centuries of resistance to potatoes was overcome. The tuber had been variously regarded as poisonous, tasteless, hard to digest, and an aphrodisiac; some thought of it as pig food, others as famine food or food for the poor, but such prejudices gradually faded as potatoes became the most affordable food staple. Yet, at the same time, the growth of a potato-dependent population in Ireland elicited dire predictions of calamity (by Thomas Malthus, for one), for potatoes were already proving vulnerable to various diseases. Dependent populations were especially at risk because potatoes could neither be stored for more than a few months nor be easily transported into areas of famine, and because those within such populations tended to be politically powerless and economically exploited. For all these reasons, although Ireland suffered a devastating blight that ruined the potato crop from 1845 to 1848, it might accurately be said that the Irish famine was a man-made disaster that could have been prevented or mitigated by timely British emergency relief and greater noblesse oblige on the part of better-off Irish countrymen.

The Potato and Ireland

The history of the potato in Ireland has been summarized by C. Woodham-Smith (1962), A. Bourke (1993), and C. Kinealy (1995), among others. Such accounts trace the way in which the potato, along with the "conacre" system of land and labor allocation and the "lazy-bed" system of potato cultivation, came to dominate Irish agriculture as British landlords made less and less land and time available for their Irish workers' self-provisioning. The advent of more scientifically based agriculture and the enclosure of common lands had left many landless by the end of the eighteenth century. The "conacre" custom (or economy) allowed landless peasants to rent small plots for 11-month periods in return for agricultural services to the landlord. Peasants managed to feed themselves on such minuscule holdings by setting up raised "lazy" beds in which they placed tubers, then covered them with manure, seaweed, and additional soil to protect them from moisture.

Average yields of potatoes were 6 tons per acre, in contrast with less than 1 ton per acre for wheat or oats. In 1845, the potato crop occupied 2 million acres, and a 13.6 million ton harvest was anticipated, of which slightly less than half would have gone to humans. But grains were higher-value crops, and expansion of roads into the hinterlands during the early decades of the nineteenth century meant that grains could be more easily transported than they previously had been. Thus, values for (grain) export agriculture rose and competed more fiercely with subsistence crops for land. Conacres shrank, and many workers migrated seasonally to Scotland for the harvest, thereby reducing consumption at home and earning additional money for food. This was yet another route by which the potato and its associated social institutions "fed" the industrial economy (Vincent 1995).

"Late blight" *(Phytophthora infestans),* having ravaged potato crops in North America, disrupted this highly vulnerable agroeconomic and social context in the 1840s. The blight first appeared in late July 1845 in the Low Countries, spreading from there to England and finally to Ireland, where the poor farming population had no alternative foods to fall back on. It is ironic that late blight probably was introduced into Europe via new potato varieties that had been imported from the Western Hemisphere to counter epidemics of fungal "dry rot" and viral "curl" that had plagued previous decades. Although some scientists had observed that copper sulfate (as a dip for seed or an application for foliage) offered plants protection against what later came to be understood as fungal diseases, the science of plant pathology and pesticides was not yet far advanced, and no preventive or ameliorative steps were taken. "Bordeaux mixture," an antifungal application suitable for grape vines and potatoes, was not tried until the 1880s.

The blight of 1845 savaged 40 (not 100) percent of the crop, but infected tubers were allowed to rot in the fields, where they incubated the spores of the following years' disasters. In 1846, ideal weather conditions for late blight aided the rapid infection of early tubers, so that barely 10 percent of the crop was salvaged. But in the aftermath of the less-than-total disaster of 1845, the 1846 emergency was largely ignored by the British government, which failed to suspend the Corn Laws and continued both to export Irish grain and to forbid emergency grain imports. Taxes continued to be enforced, evictions soared, and relief measures, which included food-for-work and soup kitchens, were too few and too late. Bourke (1993), among others, blamed the English as well as the Irish landlords, a well-off greedy few who benefited from the political and economic policies that impoverished the masses.

Sickness accompanied hunger through 1848, with the result that more than a million and a half Irish people either died or emigrated in search of sustenance. Neither the population nor its potato production ever recovered, although to this day, Ireland's per capita potato consumption (143 kilograms [kg] per year) surpasses that of rival high consumers in Europe (the Portuguese consume 107 kg per year and Spaniards 106 kg) (Lysaght 1994).

The potato also remains an enduring "polysemous symbol," celebrated in Irish literature and culinary arts. In the writings of James Joyce, the potato serves as talisman, as signifier of heroic continuity, but also as a symbol of deterioration and decadence (Merritt 1990). Joyce's references to typical Irish national dishes have been collected, with recipes, into a cookbook entitled *The Joyce of Cooking* (Armstrong 1986).

Later European Developments

European descendants of the original *S. tuberosum* ssp. *andigena* clones were virtually wiped out with the arrival of late blight in the mid-nineteenth century. They were replaced by ssp. *tuberosum* varieties that also – like their predecessors – hybridized readily across subspecies. A single clone, named "Chilean Rough Purple Chili," has accounted for a large proportion of subsequent European and North American potatoes, including the "Early Rose" and "Russet Burbank" varieties, the latter of which was introduced into the United States in 1876. In addition to Russet Burbank, several very old varieties still predominate in the United States and Europe, notably "Bintje," introduced into the Netherlands in 1910, and "King Edward," introduced into the United Kingdom in 1902 (Hermsen and Swiezynski 1987). Attempts to broaden the genetic base for breeding accelerated in the 1920s and 1930s, with N. I. Vavilov's Russian expedition that collected frost- and blight-resistant varieties from South America and, subsequently, with the British Empire (later Commonwealth) Potato Collecting Expedition (Hawkes 1990).

Blights and viruses notwithstanding, the potato played an ever-expanding role in European food economies. Epitomized in Vincent Van Gogh's "Potato Eaters" of 1885, but more nobly so in Millet's "Potato Planters" of 1861, potatoes on the European mainland came to symbolize the rugged, honest peasant, wresting life and livelihood from the soil. In England, eastern Europe, and Russia, potatoes played significant nutritional roles during ordinary times and assumed extraordinary nutritional roles in war years (Salaman 1985). Even today they remain the fallback crop in times of turmoil, as was seen in Russia in the severe months of 1992, following glasnost and the reorganization of the economy. An article the same year in the *New Scientist* reported that Russian citizens were planting potatoes everywhere, even illegally in the Losinskii Ostrove National Park, and attempting to steal potatoes from farms!

Europeans were directly responsible for the introduction of potatoes into North America, where they were well established by the eighteenth century. In addition, potatoes accompanied colonists to India, to French Indochina (CIP 1984), to China (Anderson 1988), and to New Zealand where, in the nineteenth century, the Maoris adopted them on the model of other tuber crops (Yen 1961/2). Potatoes also entered Africa with Belgian, British, French, and German colonists, who consumed them as a vegetable rather than as a staple starch. The largest recent expansion of potato cultivation has been in former European colonies, where people in the nineteenth century regarded the tuber as a high-value garden crop and prestigious European vegetable but since then (perhaps in conjunction with the end of colonialism) have come to view it as a staple or costaple garnish and snack (Woolfe 1987).

Potatoes in Developing Countries

In Asia and Africa, the potato has filled a number of production and consumption niches, and its history on these continents has been similar to that in Europe. Once again, despite its advantages as an antifamine, high-elevation alternative to grain, with particular virtues during conflicts, the potato was at first resisted by local farmers, who believed it to be poisonous. In the highest elevation zones, such as the Nepalese Himalayas (Fürer-Haimendorf 1964) and the upper reaches of Rwanda (Scott 1988), potatoes took root as a new staple food crop and contributed to subsistence, surplus, and population expansion. The plants were promoted by savvy rulers, who used demonstration, economic incentives, or coercion to overcome farmers' superstitions and resistance (CIP 1984). In Africa, as in Europe, the popularity of the tubers increased in wartime because they could be stored in the ground.

With the 1972 creation of the International Potato Center (CIP) and its mission to increase potato production and consumption in developing countries while protecting biodiversity, the introduction of improved potato varieties has accelerated around the world. CIP's activities, along with the operation of diverse market forces, have resulted in some African and Asian countries rapidly becoming areas of high potato consumption. Prior to its most recent civil conflict, Rwanda in some localities witnessed per capita consumption as high as 153 to 200 kg per year (Scott 1988) – higher than that in any Western European country, including Ireland. If Rwanda can reattain peace, and agronomic and credit constraints on production and infrastructural limits on marketing could be removed, production could expand much farther and faster from the "grassroots," as it has in neighboring Tanzania. There, local farmers in recent years have developed the potato as a cash crop – the result of the introduction of several new varieties brought back by migrant laborers from Uganda, the diffusion of other varieties from Kenya, and the comparative advantage of raising potatoes relative to other cash or subsistence crops (Andersson 1996).

The potato offers excellent advantages as a subsistence crop because of its high yields, low input costs, and favorable response to intensive gardening techniques (for example, Nganga 1984). But potato promotions in Africa ominously echo the terms in which eighteenth- and nineteenth-century British observers praised the tuber. Scientists and political economists should be ever vigilant in ensuring that the potato is not again employed as a stopgap measure in contexts of great social inequality and food/nutritional insecurity, where vulnerability to late blight (or any other stressor) might lead to a repetition of the Great (nineteenth-century Irish) Hunger. Techniques of "clean" seed dissemination and mixed cropping strategies that "clean" the soil are designed to help prevent such calamities now and in the future. But all highlight the need to monitor pests and improve breeding materials so that resistant varieties of the potato are easily available to farmers who have become increasingly reliant on it for food and income.

The same cautions hold for Asia, where production and consumption of potatoes is expanding because of the market as well as international agricultural interests. Since the 1970s, the greatest rate of increase has been in the warm, humid, subtropical lowlands of Asia, where potatoes are planted as a dry-season intercrop with rice or wheat (Vander Zaag 1984), providing income and relief from seasonal hunger (Chakrabarti 1986). The surge in potato production has been spurred in some cases by new seeding materials and techniques. In Vietnam in the 1970s and 1980s, the Vietnamese and CIP introduced superior, blight-resistant clones that could be multiplied by tissue culture and micropropagation methods. Some enterprising farming families then took over the labor-intensive rapid multiplication, so that by 1985, three household "cottage industries" were supplying 600,000 cuttings for some 12,000 farmers (CIP 1984). Production in other Asian nations has also accelerated (for example, in Sri Lanka) as a result of government promotions and policies that have banned imports of all (including seed) potatoes since the 1960s (CIP 1984).

In Central America and the Caribbean, financial incentives and media promotion have been used to increase production and consumption of potatoes in places unaccustomed to them, such as the Dominican Republic, where the state offered credit and guaranteed purchase to potato farmers after the country experienced a rice deficit (CIP 1984). Similarly, during post-hurricane disaster conditions of 1987, Nicaraguans were encouraged to eat more potatoes – these shipped from friendly donors in the Soviet bloc. In South American countries, campaigns are underway to encourage farmers to grow more potatoes for sale as well as for home consumption, as in Bolivia, where economists hope that as part of diversified employment strategies, an increased production and sale of improved potato varieties can have a multiplier effect, reducing unemployment and increasing access to food (Franco and Godoy 1993). But all of these programs highlight the need to reconcile production and income concerns with the protection of biodiversity and reduction of risks.

Maintaining and Utilizing Biodiversity

Modern scientific attempts to broaden the genetic base for potato breeding began with European scientific expeditions in the 1920s and 1930s, including the already-mentioned Russian (Vavilov 1951) and British collections. Today, major gene banks and study collections are maintained at the Potato Introduction Center, Sturgeon Bay, Wisconsin; the Braunschweig-Volkenrode Genetic Resources Center (Joint German-Netherlands Potato Gene Bank); the N. I. Vavilov Institute of Plant Industry in Leningrad; and the International Potato Center (CIP) in Lima. Major potato-producing countries publish annual lists of registered varieties, standardized to report on agronomic characteristics (disease and pest resistances, seasonality, and environmental tolerances) and cooking and processing qualities (industrial-processing suitability for fries, chips, or dehydration; or home-processing aspects, such as requisite cooking times for boiling, baking, roasting, or frying). Additional consumer descriptors include color, texture, flavor, and the extent of any postcooking tendency to blacken or disintegrate.

Acceptably low alkaloid content is the main chemical toxicity concern, especially because glycoalkaloids are often involved in pest-resistance characteristics introduced during plant breeding. In one historical example, U.S. and Canadian agricultural officials were obliged to remove a promising new multiresistant variety (named "Lenape") from production because a scientist discovered its sickeningly high alkaloid content (Woolfe 1987).

Since the 1960s, new varieties have been protected by plant breeders' rights and, internationally, by the *Union Pour la Protection des Obtentions Végétales* (UPOV), which uses a standard set of 107 taxonomic characters to describe individual potato cultivars. UPOV is designed to facilitate exchanges among member countries and so accelerate the breeding process. Collection, conservation, documentation, evaluation, exchange, and use of germ plasm are also regulated by descriptor lists produced in cooperation with the International Bank for Plant Genetic Resources (IBPGR).

The pace of new varietal introductions is accelerating as more wild species of potential utility for potato improvement are identified and genetically tapped for useful traits that are transferred with the assistance of biotechnology. Wild potatoes with resistance to one pathogen or pest tend to be susceptible to others and may have undesirable growth, tuber, or quality (especially high alkaloid) characteristics. Conventional breeding still requires 12 to 15 years to develop new varieties that include desirable – and exclude undesirable – genes. Protoplast fusion, selection from somaclonal variation, and genetic engineering via *Agrobacterium tumefaciens* are some "unconventional" techniques that promise to widen the scope and quicken the pace of varietal improvement, especially once the genes that control important traits have been characterized. The latter process is facilitated by advances in genetic linkage mapping (Tanksley, Ganal, and Prince 1992) and in practical communication among conventional breeding and agronomic programs (Thomson 1987) that set objectives.

European countries (such as the Netherlands, which has a highly successful seed-potato export business) have been contributing to the development of varieties with superior tolerance for environmental stressors, especially heat and drought, as potato production grows in subtropical countries of Asia and Africa (Levy 1987). Innovative breeding programs also include social components that respond to economic concerns, such as that growing potatoes for market contributes to women's household income. A Dutch-sponsored program in Asia built up a potato network of women social scientists, nutritionists, and marketing experts along these lines. CIP, in consultation with professionals from national programs, coordinates research and varietal development as well as collection and characterization of germ plasm (seed material) from wild resources.

The Significance of CIP

The International Potato Center (CIP) which grew out of the Mexican national potato program funded by the Rockefeller Foundation, is part of the Consultative Group on International Agricultural Research. It provides a major resource and impetus for strategic studies that tap the genetic and phenotypic diversity of the potato and accelerate the introduction of useful characteristics into new cultivars. Since 1972, CIP has built and maintained the World Potato Collection of some 13,000 accessions, characterized as 5,000 cultivars and 1,500 wild types. In addition to South American programs, CIP potato campaigns extend from the plains of India, Pakistan, and Bangladesh to the oases of North Africa and the highlands and valleys of Central Africa.

CIP's major technical activities include an effective population breeding strategy, "clean" (pest- and disease-free) germ-plasm distribution, virus and viroid detection and elimination, agronomy, integrated pest management, tissue culture and rapid multiplication of seed materials, advancement of true potato seed as an alternative to tubers or microtubers, and improvement of storage practices. In the 1990s, a principal thrust of research has been to generate seed materials resistant to late blight, which has reemerged in a more virulent, sexually reproducing form (Niederhauser 1992; Daly 1996).

Strategies involve breeding for multi-gene ("horizontal") rather than single-gene resistance, development and dissemination of true potato seed (which does not disseminate the fungus), and integrated pest management that relies on cost-effective applications of fungicides (CIP 1994). Training, regional networks, and participatory research with farmers are additional dimensions of CIP programs. Collaborative networks offer courses that allow potato specialists to interact and address common problems. In addition, CIP also pioneered "farmer-back-to-farmer" research, whereby effective techniques developed by farmers in one part of the world are shared with farmers in other geographic areas. For example, as already mentioned, reduction of postharvest losses through diffused-light storage is a technique that CIP researchers learned from Peruvian farmers and then brokered to farmers in Asia and Africa (CIP 1984; Rhoades 1984).

CIP also extends its networking to international food purveyors, such as McDonald's and Pepsico – transnational corporations interested in developing improved, pest-resistant, uniformly shaped, high-solid-content potato varieties to be used in making standardized fries. One goal of such enterprises is to develop local sources of supply of raw potatoes for the firms' international franchises, an accomplishment that would improve potato production and income for developing-country farmers and also reduce transportation costs (Walsh 1990). Although principally engaged in agricultural research and extension, CIP also studies consumption patterns, which can improve the potato's dietary and nutritional contributions while eliminating waste (Woolfe 1987; Bouis and Scott 1996).

Dietary and Nutritional Dimensions

Potatoes – simply boiled, baked, or roasted – are an inexpensive, nutritious, and ordinarily harmless source of carbohydrate calories and good-quality protein, and potato skins are an excellent source of vitamin C. Because a small tuber (100 grams [g]) boiled in its skin provides 16 mg of ascorbic acid – 80 percent of a child's or 50 percent of an adult's daily requirement – the potato is an excellent preventive against scurvy. Potatoes are also a good source of the B vitamins (thiamine, pyridoxine, and niacin) and are rich in potassium, phosphorus, and other trace elements. Nutritive value by weight is low because potatoes are mostly water, but consumed in sufficient quantity to meet caloric needs, the dry matter (about 20 percent) provides the micronutrients just mentioned, an easily digestible starch, and nitrogen (protein), which is comparable on a dry-weight basis to the protein content of cereals and, on a cooked basis, to that of boiled cereals, such as rice- or grain-based gruels (Woolfe 1987).

Potato protein, like that of legumes, is high in lysine and low in sulfur-containing amino acids, making potatoes a good nutritional staple for adults, especially if consumed with cereals as a protein complement. Prepared in fresh form, however, tubers are too bulky to provide a staple for infants or children without an energy-rich supplement. Food technologists are hopeful that novel processing measures may manage to convert the naturally damp, starchy tuber (which molds easily) into a light, nutritious powder that can be reconstituted as a healthful snack or baby food. They also hope to make use of potato protein concentrate, derived either directly by protein recovery or from single-cell protein grown on potato-processing waste (Woolfe 1987). Both advances would minimize waste as well as deliver new sources of nutrients for humans and animals, rendering potato processing more economical. Containing contaminants in industrial potato processing is still very expensive, but sun-drying, a cottage or village industry in India and other Asian countries, holds promise as an inexpensive way to preserve the potato and smooth out seasonal market gluts.

Preservation looms as a large issue because fungus-infected, improperly stored, and undercooked potatoes are toxic for both humans and livestock. Storage and preparation also can diminish the tuber's sensory and nutritional qualities. Sweetening (enzyme conversion of starch), lipid degradation, and discoloration or blackening are signs of deterioration that reduces palatability and protein value. Storage in direct sunlight raises glycoalkaloid content. Other antinutritional factors, such as proteinase inhibitors and lectins, which play a role in insect resistance in some varieties, are ordinarily destroyed by heat, but undercooking, especially when fuel is limited, can leave potatoes indigestible and even poisonous.

Dietary Roles

Although peeling, boiling, and other handling of potatoes decrease micronutrient values, they remove dirt, roughage, and toxins, as well as render potatoes edible. In their Andean heartland, potatoes have always been consumed fresh (boiled or roasted) or reconstituted in stews from freeze-dried or sun-dried forms. They have been the most important root-crop starchy staple, although other cultivated and wild tubers are consumed along with cereals, both indigenous (maize and quinoa) and nonindigenous (barley and wheat). Despite the importance of the potato, cereals were often preferred. For example, Inca ruling elites, just prior to conquest, were said to have favored maize over potatoes, perhaps because the cereal provided denser carbohydrate-protein-fat calories and also was superior for brewing. For these reasons, the Inca may have moved highland peasant populations to lowland irrigated valley sites, where they produced maize instead of potatoes (Earle et al. 1987; Coe 1994). In South America today, potatoes are consumed as a staple or costaple with noodles, barley, rice, and/or legumes and are not used for the manufacture of alcohol. In Central America and Mexico, they are consumed as a costaple main dish or vegetable, in substitution for beans.

In Europe, potatoes historically were added to stews, much like other root vegetables, or boiled, baked, roasted, or fried with the addition of fat, salt, and spices. Boiled potatoes became the staple for eighteenth- and nineteenth-century Irish adults, who consumed up to 16 pounds per person per day in the absence of oatmeal, bread, milk, or pork. These potatoes were served in forms that included pies and cakes (Armstrong 1986). In eastern Europe and Russia, potatoes were eaten boiled or roasted, or were prepared as a costaple with wheat flour in pasta or pastries. In France, by the nineteenth century, fried potatoes were popular, and potatoes were also consumed in soup. In France, Germany, and northern and eastern Europe, potatoes were used for the manufacture of alcohol, which was drunk as a distinct beverage or was put into fortified wines (Bourke 1993). In Great Britain and North America, there developed "fish and chips" and "meat and potatoes" diets. In both locations, potatoes comprised the major starchy component of meals that usually included meat and additional components of green leafy or yellow vegetables.

In former European colonies of Asia and Africa, potatoes were initially consumed only occasionally, like asparagus or other relatively high-cost vegetables, but increased production made them a staple in certain areas. In central African regions of relatively high production, potatoes are beaten with grains and legumes into a stiff porridge, or boiled or roasted and eaten whole. Alternatively, in many Asian cuisines they provide a small garnish, one of a number of side dishes that go with a main staple, or they serve as a snack food consumed whole or in a flour-based pastry. Woolfe (1987: 207, Figure 6.7) has diagrammed these possible dietary roles and has described a four-part "typology of potato consumption" that ranges from (1) potato as staple or costaple, a main source of food energy eaten almost every day for a total consumption of 60 to 200 kg per year; to (2) potato as a complementary vegetable served one or more times per week; to (3) potato as a luxury or special food consumed with 1 to 12 meals per year; to (4) potato as a nonfood because it is either unknown or tabooed. For each of these culinary ends, cultural consumers recognize and rank multiple varieties of potatoes.

Culinary Classifications

In the United States, potato varieties are sometimes classified, named, and marketed according to their geographical location of production (for example, "Idaho" potatoes for baking). They are also classified by varietal name (for example, Russet Burbank, which comes from Idaho but also from other places and is good for baking) and by color and size (for example, small, red, "White Rose," "Gold Rose," "Yukon Gold," or "Yellow Finn," which are designated tasty and used for boiling or mashing). Varieties are also characterized according to cooking qualities that describe their relative starch and moisture content. High-starch, "floury" potatoes are supposed to be better for baking, frying, and mashing; lower-starch, "waxy" potatoes are better for boiling, roasting, and salads (because they hold their shape); and medium-starch, "all-purpose" potatoes are deemed good for pan-frying, scalloping, and pancakes.

Cookbooks (for example, McGee 1984) suggest that relative starch content and function can be determined by a saltwater test (waxy potatoes float, floury varieties sink) or by observation (oval-shaped, thick-skinned potatoes prove better for baking, whereas large, round, thin-skinned potatoes suit many purposes). Specialized cookbooks devoted entirely to the potato help consumers and home cooks make sense of this great diversity (Marshall 1992; see also O'Neill 1992), offering a wide range of recipes, from simple to elegant, for potato appetizers (crepes, puff pastries, fritters, pies, and tarts); potato ingredients, thickeners, or binders in soups; and potato salads, breads, and main courses. They detail dishes that use potatoes baked, mashed, sauteed, braised, or roasted; as fries and puffs (*pommes soufflés* is folklorically dated to 1837 and King Louis Philippe), and in gratinées (baked with a crust); as well as potato dumplings, gnocchi, pancakes, and even desserts. Potato cookbooks, along with elegant presentations of the tubers in fine restaurants, have helped transform the image of the potato from a fattening and undesirable starch into a desirable and healthful gourmet food item.

Mass production over the years has produced larger but more insipid potatoes that are baked, boiled, and mashed, mixed with fats and spices, fried, or mixed with oil and vinegar in salads. Running counter to this trend, however, has been a demand in the 1990s for "heirloom" (traditional) varieties, which increasingly are protected by patent to ensure greater income for their developers and marketers. In the United States, heirloom varieties are disseminated through fine-food stores, as well as seed catalogues that distribute eyes, cuttings, and mini-tubers for home gardens. There is even a Maine-based "Potato of the Month Club," which markets "old-fashioned" or organically grown varieties (O'Neill 1992) to people unable to grow their own.

Breeders are also scrambling to design new gold or purple varieties that can be sold at a premium. In

1989, Michigan State University breeders completed designing a "perfect" potato ("MICHIGOLD") for Michigan farmers: Distinctive and yellow-fleshed, this variety was tasty, nutritious, high yielding, and disease resistant, and (its breeders joked), it would not grow well outside of Michigan's borders (from the author's interviews with Michigan State University scientists). Also of current importance is a search for exotic potatoes, such as the small, elongated, densely golden-fleshed "La Ratte" or "La Reine," which boasts "a flavor that hints richly of hazelnuts and chestnuts" (Fabricant 1996). These return the modern, North American consumer to what were perhaps the "truffle-like" flavors reported by sixteenth-century Spaniards encountering potatoes for the first time. Such special varieties also may help to counter the trend of ever more industrially processed potato foods that has been underway since the 1940s.

Industrially Processed Potato Foods

Since the end of World War II, processed products have come to dominate 75 percent of the potato market, especially as frozen or snack foods. Seventy percent of Idaho-grown and 80 percent of Washington-grown potatoes are processed, and the proportion is also growing in Europe and Asia (Talburt 1975). Freeze-dried potatoes received a boost during the war years, when U.S. technologists are reported to have visited South America to explore the ancient art of potato freeze-drying and adapt it for military rations (Werge 1979). Since World War II, the development of the frozen food industry and other food-industry processes and packaging, combined with a surging demand for snack and "fast" (convenience) foods, have contributed to the increasing expansion of industrially processed potato products in civilian markets. By the 1970s, 50 percent of potatoes consumed in the United States were dehydrated, fried, canned, or frozen, with close to 50 percent of this amount in the frozen food category. The glossy reports of mammoth food purveyors, such as Heinz, which controls Ore-Ida, proudly boast new and growing markets for processed potatoes (and their standby, ketchup) in the former Soviet Union and Asia.

The other large growth area for fried potatoes and chips has been in the transnational restaurant chains, where fries (with burgers) symbolize modernization or diet globalization. Unfortunately, the "value added" in calories and cost compounds the nutritional problems of consumers struggling to subsist on marginal food budgets, as well as those of people who are otherwise poorly nourished. For less affluent consumers, consumption of fries and other relatively expensive, fat-laden potato products means significant losses (of 50 percent or more) in the nutrients available in freshly prepared potatoes – a result of the many steps involved in storage, processing, and final preparation. Although processed potato foods are not "bad" in themselves, the marginal nutritional contexts in which some people choose to eat them means a diversion of critical monetary and food resources from more nutritious and cost-effective food purchases. The health risks associated with high amounts of fat and obesity are additional factors.

Potato: Present and Future

Potato consumption is on the rise in most parts of the world. In 1994, China led other nations by producing 40,039,000 metric tons, followed by the Russian Federation (33,780,000), Poland (23,058,000), the United States (20,835,000), Ukraine (16,102,000), and India (15,000,000) (FAO 1995). Average annual per capita consumption is reported to be highest in certain highland regions of Rwanda (153 kg), Peru (100 to 200 kg), and highland Asia (no figures available) (Woolfe 1987), with the largest rate of increase in lowland Asia.

Expansion of potato production and consumption has resulted from the inherent plasticity of the crop; the international training, technical programs, and technology transfer offered by CIP and European purveyors; the ecological opportunities fostered by the "Green Revolution" in other kinds of farming, especially Asian cereal-based systems; and overarching political-economic transformations in income and trade that have influenced local potato production and consumption, especially via the fast-food industry. The use of potatoes has grown because of the ease with which they can be genetically manipulated and because of their smooth fit into multivarietal or multispecies agronomic systems, not to mention the expanding number of uses for the potato as a food and as a raw industrial material.

Genetic Engineering

The potato already has a well-developed, high-density molecular linkage map that promises to facilitate marker-assisted breeding (Tanksley 1992). Coupled with its ease of transformation by cellular (protoplast fusion) or molecular (*Agrobacterium*-assisted) methods, and useful somaclone variants, the potato is developing into a model food crop for genetic engineering. By 1995, there was a genetically engineered variety, containing bt-toxin as a defense against the potato beetle, in commercial trials (Holmes 1995). Where the potato is intercropped rather than monocropped, it also encourages scientists to rethink the agricultural engineering enterprise as a multicropping system or cycle, within which agronomists must seek to optimize production with more efficient uses of moisture, fertilizer, and antipest applications (Messer 1996). Resurgent – and more virulent – forms of late blight, as well as coevolving virus and beetle pests, are the targets of integrated pest management that combines new biotechnological tools with more conventional chemical and biological ones.

Potatoes continue to serve as a raw material for starch, alcohol, and livestock fodder (especially in Europe). In addition, they may soon provide a safe and reliable source of genetically engineered pharmaceuticals, such as insulin, or of chemical polymers for plastics and synthetic rubbers. Inserting genes for polymer-making enzymes has been the easy step; regulating production of those enzymes relative to natural processes already in the plant is the next, more difficult, one (Pool 1989). A cartoonist (Pool 1989) captured the irony of saving the family farm – whereby small farmers, on contract, grow raw materials for plastics – by portraying the classic Midwestern "American Gothic" farmer husband and wife standing pitchforks in hand, before a field of plastic bottles!

Potato Philanthropy

With less irony, potatoes have come to serve as a model crop for philanthropy. The Virginia-based Society of St. Andrew, through its potato project, has salvaged more than 200 million pounds of fresh produce, especially potatoes, which has been redirected to feed the hungry. Perhaps the memory of Ireland's potato famine continues to inspire acts of relief and development assistance through such organizations as Irish Concern and Action from Ireland, which, along with Irish political leaders (for example, Robinson 1992), reach out to prevent famine deaths, especially as the people of Ireland mark the 150th anniversary of the Great Hunger.

Concluding Paradoxes

In the foregoing history are at least four paradoxes. The first is the potato's transformation in Europe from an antifamine food crop to a catalyst of famine. Ominously, the principal reliance on this species, which makes possible survival, subsistence, and surplus production in high-elevation zones all over the world, and which yields more calories per unit area than cereals, "caused" the Irish famine of 1845–8 and continues to make other poor rural populations vulnerable to famine.

Paradoxical, too, has been the transformation of this simple, naturally nutritious, inexpensive source of carbohydrate, protein, and vitamins into a relatively expensive processed food and less-healthy carrier of fat in the globalization of french fries and hamburgers.

A third paradox is the enduring or even revitalized importance of Andean source materials for the global proliferation of potatoes. Advances in agronomy and varietal improvement have made the potato an increasingly important and diverse crop for all scales and levels of production and consumption across the globe. But in the face of such geographic and culinary developments, the traditional South American potato cultures continue to present what to some scientists is a surprising wealth of biological, ecological, storage, and processing knowledge (Werge 1979; Rhoades 1984; Brush 1992). The management of biological diversity, ecology of production, and storage and processing methods are three areas in which indigenous agriculture has continued to inform contemporary potato research. Thus, despite dispersal all over the globe, scientists still return to the potato's heartland to learn how to improve and protect the crop.

A fourth paradox is that potatoes may yet experience their greatest contribution to nutrition and help put an end to hunger, not directly as food but as a component of diversified agro-ecosystems and an industrial cash crop. Since their beginnings, potatoes have always formed a component of diversified agro-livestock food systems. Historically, they achieved their most significant dietary role when grown in rotation with cereals (as in Ireland). Today, they are once again being seasonally rotated within cereal-based cropping systems. Because potatoes are intercropped, they stimulate questions about how biotechnology-assisted agriculture can be implemented more sustainably. So far, plant biotechnologists have considered mainly the host-resistance to individual microbes or insects, and never with more than one crop at a time. But adding potatoes to cereal crop rotations encourages scientists, as it does farmers, to look more closely at the efficiency with which cropping systems use moisture and chemicals, and to ask how subsequent crops can utilize effectively the field residues of previous plantings in order to save water and minimize pollution.

Efforts to integrate potatoes into tropical cropping systems, particularly those in the tropical and subtropical lowlands of southern and southeastern Asia, are stimulating such inquiries. Thus, potatoes, perhaps the first crop cultivated in the Western Hemisphere, are now contributing to a revolution of their own in the newest agricultural revolution: the bio- or gene revolution in Asia. In addition, potatoes may also help to save family farms in the United States and Europe by providing income to those growing the crop for plastic.

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II.B.4 Sago

Sago is an edible starch derived from the pith of a variety of sago palms, but mostly from two species of the genus *Metroxylon* – *M. sagu* and *M. rumphii.* The sago palms flower only once (hapaxantic) and are found in tropical lowland swamps. Other genera of palms that yield sago starch include *Arecastrum, Arenga, Caryota, Corypha, Eugeissona, Mauritia,* and *Roystonea.* In all, there are about 15 species of sago palms distributed in both the Old World and the New, with the most significant of these, *M. sagu,* located mainly on the islands of the Malay Archipelago and New Guinea. As a staple foodstuff, only the *Metroxylon* genus appears to be in regular use, generally among populations located in coastal, lacustrine, or riverine areas. Worldwide, sago provides only about 1.5 percent of the total production of starch and, consequently, is fairly insignificant as a global food source (Flach 1983). It is processed into flour, meal, and pearl sago, and is often used for thickening soups, puddings, and other desserts.

Prickly Sago palm