DRAFT DRAFT DRAFT DRAFT DRAFT DRAFT

Biological Exchange and Biological Invasion in World History

J.R. McNeill
Georgetown University
Washington, DC 20057 USA

prepared for the
19th International Congress of the Historical Sciences
Oslo, 6-13 August 2000

For millions of years, most species stayed home. Geographic barriers, such as oceans and mountain chains, inhibited migrations and divided the earth into distinct biogeographical provinces. Only birds, bats, and flying insects bucked the trend consistently. A few other species did so occasionally, thanks to sea-level changes and land bridges, or a chance voyage on driftwood. Natural evolution took place, for most species, in separated biogeographical provinces, in effect in parallel universes.[1]

I. Intra-continental Biological Exchange

This long phase in the earth's history, and the history of life, ended when human beings began their long-distance migrations. Deep in prehistory people, or hominids at any rate, walked throughout Africa and Eurasia, occasionally bringing a plant, seed, insect or microbe to a place it would not easily have gotten on its own. But it was not until plant and animal domestication, some 10-12,000 years ago, that people began to do this on purpose and therefore more frequently. Most of the plants and animals susceptible to domestication were found in Eurasia, and the East-West axis of that continent eased the spread of those plants and animals sensitive to climate conditions, especially to day length. So, it is safe to say, the greatest degree of homogenization in flora and fauna took place within the Eurasian (and North African) land mass. The suites of domesticated plants and animals on which agriculture and herding rest were spread almost instantaneously by the

standards of the past, although in fact it took a few millennia. This process no doubt proved highly disruptive biologically, as local biogeographic provinces were invaded by alien creatures that humanity worked hard to spread. It also proved highly disruptive historically, obliterating peoples who did not adapt to the changing biogeography, the changing disease regimes, and the changed political situations brought on by the spread of farmers, herders, and eventually of civilization and, more specifically, of states.

Out of this turmoil of Afro-Eurasian biological exchange emerged the great civilizations familiar to historians. They all based their societies on a handful of plants and animals, not identical sets, but strongly intersecting sets, from China to the Mediterranean.[2]

This process of biological homogenization within Afro-Eurasia had its limits. The links between North Africa, say, and East Asia before 500 BC were slender indeed. Varying topography and climate also checked the spread of certain species. The process presumably accelerated when inter-regional contacts flourished, and when large states created favorable conditions for the movement of goods and people. The era of the Han and Roman empires, for example, when the trans-Asian silk road was a well-beaten path, unleashed a small flood of biological exchanges. The Mediterranean acquired cherries at this time; sorghum made its way from East Africa to India to China, while grapes, camels and donkeys also arrived in China from southwest Asia and North Africa.[3]

Within Eurasian history there were two other moments of heightened biological exchange. The first of these came during the early Tang dynasty, in the 7th and 8th centuries. The Tang dynasts came from various, ethnic and cultural traditions, and for a century and a half showed a keen interest in foreign trade, technology, culture (e.g. Buddhism) and plants and animals. The court encouraged the import of exotica-curious creatures, aromatic Plants, ornamental flowers. Much of this was inconsequential in social and economic terms, but some of it, such as the cultivation of cotton (imported from India), was not. The Tang were perhaps unusually receptive to strange plants and animals, but there is more to it than that. Their political power on the western

frontier, and the geopolitical situation generally before AD 750, promoted the trade, travel, and transport that make biological exchange likely. For roughly a century and half (600-750) the numerous polities of Central Asia were frequently consolidated into only a few, simplifying travel by lowering protection costs. Tang, Tibetan, Turkic and Abbasid empires exerted powerful sway throughout Central Asia, making the connections between China, India, Persia and southwest Asia safer than usual. This geopolitical arrangement fell apart after 75 1, when Muslims defeated Tang armies near the Talas River, and after 755 when the An Lu-shan rebellion, led by Turkic- Sogdians, shook the Tang to its foundations. Thereafter both the stability of the geopolitical situation and the receptivity of the Tang to things foreign changed, waned more often than waxed, and the opportunities for biological (as well as commercial and cultural) exchange grew scarcer.[4]

The third moment of heightened biological exchange within Eurasia came with the *Pax Mongolica* of the 13th and 14th centuries. By this time most of the feasible exchanges of significant Plants and animals had already taken place. But the heightened transport across the desert-steppe corridor of Central Asia apparently allowed the quick diffusion of the bacillus that causes bubonic plague, provoking the famous Black Death, the worst bout of epidemics in the recorded history of western Eurasia and North Africa; plague may also have afflicted China in these centuries, although the evidence is ambiguous. With plague, as with any disease, receptivity to exotic influences was not a conscious matter, but rather one of susceptibility and exposure.[5]

While this process of Eurasian (and North African) biological exchange never truly came to an end, it surely slowed whenever political conditions weakened inter-regional contacts. It also slowed in general after around 200 AD, with the erosion of the *pax romana* and *pax sinica* which had so encouraged long-distance travel and trade within Eurasia. By that time, sugar cane had taken root in India, spreading from its New Guinea home. Wheat had spread widely throughout its feasible range, together with cattle, pigs, horses, sheep and goats. Less and less was left to do even when conditions encouraged biological exchange, as they did during the early Tang and the Mongol imperium.

Meanwhile, on other continents, similar if smaller-scale processes of biological exchange and homogenization were in train. In the Americas, maize spread from its MesoAmerican home both north and south, slowed, it seems, by difficulties in adapting to different day lengths at different latitudes (many plants take their signal to flower from day length). African sorghum and millets, cattle and goats, also migrated wherever cultivators took them and became established wherever local conditions would allow. The Bantu migrations of some 2,000 years ago probably diffused several crops throughout eastern and southern Africa, and possibly brought infectious diseases that ravaged the indigenous, previously isolated, populations of southern Africa. These events in Africa and the Americas, too, must have been biologically and politically tumultuous, although the evidence, almost entirely archeological, is very sparse.

In biological terms, the process of human-promoted biological exchange selected for certain kinds of species, those that co-existed easily with human activity: domesticates, commensals (such as rats), and plants that thrive on disturbed ground, most of which we usually call weeds. These species prospered under the new regimes of expanded human migration and interaction. From their point of view, history had taken a very favorable turn. Indeed, humanity was in a sense working for them, spreading their genetic footprints far and wide within the continents, and into the future.

II. Intercontinental Biological Exchange and Biological Invasion Before 1400 AD

Intercontinental biological exchange also has a long pedigree. Boats seaworthy enough to cross 170km of open ocean existed by around 30,000 BP if not before.[6] The first people to migrate to Australia, which happened at least 40,000 years ago, may have accidentally brought some species with them. Much later, about 3,500 years ago, some migrants to Australia purposely brought the dingo (a large dog), the first domesticate in Australian history. The dingo quickly spread to all Aboriginal groups outside of isolated Tasmania, and also formed feral packs. It proved an effective hunting dog and led to the extinction of some indigenous mammals.[7] The dog (not the dingo) was also the first domesticated animal in the Americas, brought across the Siberian-Alaskan land bridge

with some of the first settlers at the height of the last Ice Age. Here dogs probably played a significant role in reducing the populations of large mammals, many of which became extinct at around the time humans arrived in North and South America. Human settlement, involving a «portmanteau biota» of only a few plants and animals, wrought major ecological changes throughout the southwest Pacific and Polynesia, including numerous extinctions, from about 4,000 years ago through until the colonization of New Zealand roughly a millennium ago. All these instances were cases of invasions of «naive» lands, continents and islands that had no prior exposure to humanity and its fellow travelers, or to the intensified fire regime that human presence normally brought.[9] This helps to explain the dramatic effects, particularly the rash of extinctions, that followed upon human settlement of Australia, New Zealand, and the Americas. Presumably, when hominids first left Africa for Eurasia, they had similar-although less Pronounced-impacts.[10]

Eventually, of course, people began to transport animals, plants and pathogens from one human community to another across the seas. In many cases, the only evidence for such transfers is the existence of the imported species. Consider the sweet potato, a native of South America. It somehow spread throughout Oceania, and was Present in central Polynesia from at least 1000 A.D. The sweet potato is a delicate crop and could not survive a driftwood voyage: no one doubts that people transported it, although no one knows j ust when, how or even who.[11] It eventually became a staple of farmers in the western Pacific, highland New Guinea, and to a lesser extent the East Asian archipelagoes and mainland.

A second crop transfer, almost equally mysterious, took place across the Indian Ocean some time before AD 500. Somebody brought bananas, Asian yams, and taro to East Africa. These crops had much to recommend them, as they do well in moist circumstances, whereas the millets and sorghum that Bantu expansion brought into central and southeastern Africa were adapted to dry conditions. Plantains, of which bananas are one variety, existed in the wild in a broad band from India to New Guinea. New linguistic and genetic evidence suggests they arrived on the East African coast as early as 3,000 years ago, and penetrated the forest to the west of the great lakes around

2,000 years ago, just about the time of the Bantu migrations. Quite possibly the success of Bantu speakers, often attributed to their use of iron, owed something to their successful adoption of exotic crops. As relative newcomers to East and southern Africa, they had less invested in prevailing ecological patterns and fewer disincentives to experiment. Bananas, taro and yams were probably introduced to East Africa more than once, and almost surely were brought again in the Austronesian settlement of Madagascar that took place some time before AD 500. These Asian crops assisted crucially in the epic (but unrecorded) colonization of Central Africa’s moist tropical forests by farmers, as well as in the settlement of Madagascar.[12]

A few other significant intercontinental biological transfers took place before AD 1400, mainly between Africa and Asia, a route that posed minimal obstacles to sailors. Africa’s pearl millet, derived from a West African savanna grass, is the world’s sixth most important cereal today. It was introduced into India some 3,000 years ago, and became an important food source, especially in dry parts of Gujarat, Maharashtra, and Uttar Pradesh. Today pearl millet accounts for about 10% of India’s cereal acreage. East African sorghum entered India at about the same time, and eventually became India’s second most important grain after rice. Sorghum stalks were especially useful as fodder for India’s cattle. Finger millet, also from Africa, made it to India only around 1,000 years ago. It became the staple in Himalayan foothill communities and in India’s far south.[13] The main effect of the transfer of African crops to South Asia was to provide India with drought-resistant dryland crops, opening new areas to settlement and providing a more reliable harvest where water supplies were uncertain. These examples suggest a very lively world of crop exchange-and probably weeds, diseases, and animals too-around the Indian Ocean Rim from c. 3000 to 1500 years ago. The regular monsoon winds of the Indian Ocean helped make this region of the world precocious in its maritime development and hence biological exchange. We can imagine it as a longer, slower, earlier version of Crosby’s Columbian Exchange across the Atlantic.[14] Call it the Monsoon Exchange. Most of its consequences are now invisible, but we can assume that it, like better documented, more recent flurries of biological exchange, brought epidemics and weed

infestations, as well as useful crops, to new locations.

While African finger millet was helping Indians colonize and consolidate settlements in South Asia, a suite of south and southeast Asian food crops was transforming the Middle East and the Mediterranean. Between the tenth and thirteenth centuries, Arab trading networks, facilitated by the relative peace supervised by the Abbasid caliphate (750-1258) brought sugar, cotton, rice and citrus fruits from India to Egypt and the Mediterranean.[15] These plants, and the cultivation technique that came with them, worked a small revolution on the hot and often malarial coastlands of North Africa, Anatolia, and southern Europe. They caused many coastal plains to be brought under cultivation on a regular basis, often for the first time since the Roman Empire. Sugar and cotton could flourish with unskilled and unmotivated slave labor; their introduction may have quickened the slave-raiding that kept Mediterranean and Black Sea populations anxious for centuries, and kept Muslim-Christian relations fractious. Keeping an army of laborers at work on malarial coasts-in the Levant, Egypt, Cyprus, Crete, Sicily, Tunisia and Andalusia to mention a few centers of sugar production-required constant re-supply from poorly defended peasantries. Sometimes this quest took slave raiders to the Black Sea coasts, but it also took slave merchants across the Sahara and along Atlantic coasts. Saadian Morocco, a state originally based on plantations in the Sous and Draa river valleys, brought sugar and African slaves together in a profitable mix that would soon be transplanted to Atlantic Islands such as the Canaries and Madeira, and then to the Americas.

A second avenue of exchange involving the Mediterranean basin linked it to sudanic Africa. While this was not genuinely an intercontinental exchange, the Sahara for several millennia functioned somewhat liked a sea, as the use of the Arabic term for shore (sahel) for the West African desert edge implies. A thousand years before Columbus crossed the Atlantic, some unknown soul crossed the Sahara, re-uniting the Mediterranean and the sahel, which the arid Sahara had divided since about 3000 BC. Trans-Saharan trade developed, flourished even, in salt, slaves, and gold. But no doubt this re-unification included a biological dimension. The earliest written records come much too late to illuminate such matters and what follows is admittedly speculative.

But it seems possible, given analogous events elsewhere, that with trans-Saharan trade after AD 800 new diseases, common in Eurasia for centuries or millennia, ravaged previously unexposed West African populations. If so, perhaps this catastrophe prepared the way for conversions to Islam, as similar events in the Americas and Oceania after Columbus and Cook paved the way for conversions to Christianity. Few things can make minds as receptive to new religions as inexplicable and unprecedented disasters, especially if they seem only to befall people who do not practice the new religion.

Less speculatively, large horses seem to have made their debut in West Africa via transSaharan trade. Linguistic evidence suggests they came from the Maghreb to the north. These animals eventually became a decisive element in a military revolution on the sahel, creating a mounted aristocracy that by the 14th century built imperial states. The Jolof, Mali, and Songhai empires depended on horse cavalry, which undergirded their military power and, via slave-raiding, their economies. When ecological conditions permitted, these empires bred their own war horses, and when they did not, they had to import them, usually from Morocco. In any case, the social, economic, and political history of West Africa took a new direction with the arrival of big horses.[16]

These instances show that long before the great age of oceanic navigation, the links of trade and colonization in the Pacific, in the Indian Ocean, and across the Sahara brought biological exchange, and, on occasion, exchanges that powerfully influenced the course of history. The further exchanges attendant upon the voyages of Columbus, Magellan, Cook and others extended this process, wrenchingly, to lands formerly quite separate in biological (as in other) terms.

III. Biological Globalization after AD 1400

By AD 1400 most of the historically significant biological exchange of Afro-Eurasia had already taken place. In the next 400 years, mariners would unite almost every nook and cranny of the humanly habitable earth into a biologically interactive unit. This process is now familiar to many historians, thanks chiefly to the work of Alfred Crosby. The world’s seas and deserts no

longer served to isolate biogeographical provinces, thanks to purposeful and accidental human intervention. It became a world without biological borders, as plants, animals and diseases migrated wherever ecological conditions permitted their spread, although how soon and how thoroughly they did so often depended on patterns of trade, production, and politics.

Crosby noted two grand patterns in all this. First was the exchange across the Atlantic, whereby the Americas acquired a large suite of new Plants and animals, as well as devastating diseases that severely depopulated the Western hemisphere between 1500 and 1650. In the same process, Africa and Eurasia acquired some very useful crops from the Americas, most notably potatoes, maize, and cassava (or manioc). Ecosystems and societies in the Americas were remade, with new biologies and new cultures. But the same was true, if less catastrophically, in Africa and Eurasia. The new food crops fueled population explosions in Europe and China, and quite likely in Africa too. Maize and potatoes changed agriculture in Europe, and maize and sweet potatoes did similar things in China, allowing more intensive production, and allowing new lands not suited to wheat, barley, rye or rice, to come into production. In Africa, cassava and peanuts became important crops, encouraging denser settlement of the moist tropical forests in the first case, and a cash crop economy in Senegambia in the second. Some 200 million Africans today rely on cassava as their staple food. Many of the rest, mainly in the south and east, rely on maize. One indication of the impact of American foods on Africa is the list of crops raised in the Handeni District of northeastern Tanzania published by James Giblin.[17]

The second pattern Crosby saw was one in which European imperialism, in the Americas, Australia, and New Zealand, simultaneously promoted, and was Promoted by, the spread of European (or more usually Eurasian) animals, plants and diseases. Europeans brought a «portmanteau biota» that unconsciously worked together to favor the spread of European settlers, European power, and European species, and thereby to create what Crosby called neo-Europes (which category includes Australia., New Zealand, most of North America, southern Brazil, Uruguay, and Argentina.) He shied away from considering South Africa, where after 1652 Dutch

settlement brought new diseases that provoked epidemics among the local populations; brought new crops, which the locals soon adopted; and brought horses, which they did not adopt, and which formed part of the political power of the Boers. South Africa is a fascinating case for the history of biological exchange and biological invasion, one which deserves far more scrutiny than it has received.

So does the history of the biological expansion of Africa into the Americas. More than 10 million Africans arrived in the Americas in slave ships. In those same ships came yellow fever and malaria, which profoundly influenced settlement patterns and probably imperial history in the Americas.[18] They also brought West African rice, which became the foundation of the coastal economy in South Carolina and Georgia in the 18’h century. Much later African honeybees imported into Brazil crossbred to create a dangerous «Africanized» bee that since the 1950s has colonized much of the Americas. But what else in the American biota is of African origin and how did it get there? That subject too awaits its historian.

The age of sail brought the continents together as never before. But sailing ships did not prove hospitable carriers to every form of life. They filtered out a few, those that could not for one reason or another survive a long journey, or required conditions that sailing vessels could not provide. The age of steam, and then of air travel broke down yet further barriers to biological exchange, adding new creatures to the roster of alien intruders, and accelerating the dispersal of old and new migratory species alike. The advent of iron ships toward the end of the 19th century, for example, opened a new era in biological exchange involving species of the world’s harbors and estuaries.

After the 1880s iron ships began to carry water as ballast, whereas wooden ships had usually carried rock to help stay upright in rough seas. Soon special water ballast tanks became standard, and a ship from Yokahama bound for Vancouver would scoop up a tankful of water and marine species from Japanese waters, carry it across the wide Pacific, then release it in Puget Sound before taking on cargo. In the 1930s Japanese clams hitched such a ride and upon arrival began to colonize the seabeds of Puget Sound, creating a multi-million dollar clam fishery in British Columbia and

Washington State. A jellyfish that devastated Black Sea fisheries arrived from the East Coast of the USA in about 1980. The zebra mussel, a Black and Caspian Sea native, colonized the North American Great Lakes and river system from a beachhead established near Detroit in 1985 or 1986. It has cost the USA and Canada billions of dollars by blocking water intakes on city water systems, factories, and nuclear power plants. The failures of Soviet agriculture, the expanded grain trade from North America in the 1970s and 1980s, created a new pattern of ship traffic that eventually brought disruptive biological exchanges to both superpowers.[19]

Like all biological exchange, this too had its social and political dimensions. Ballast water traveled in particular to ports that exported bulk goods, such as timber, oil, or copper. So the general pattern, not without several exceptions, was to export harbor species from cities that imported the bulk goods. In this way, Japan, the USA, and western Europe-all of which imported vast quantities of bulk goods in the 20th century-exported more than their shares of marine species.

This is but a single example of the swirl of biological exchange going on in modern times. Transport, travel, and trade take place on such a scale now, and with such rapidity that a vast homogenization of the planet’s flora and fauna is underway. What it may eventually mean is quite impossible to say. But I’ll try anyway.

IV. Conclusion

This paper may appear a swirl too, a chaotic series of quick sketches of species going this way and that. While the historical reality of biological exchange has indeed been marked by chaos, I will nonetheless try to offer some perspective on the whole affair.

From the Olympian height that allows a view of all life on earth over its entire history, the last 10,000 years appear as an instantaneous homogenization of ecosystems, a new era in earth history, the «homogeocene.» Humankind has connected formerly distinct spheres of life, through trade and travel, reprising in the blink of an eye what formerly happened through continental drift. Some 300 to 250 million years ago, the world’s continents fused to form a single supercontinent, called Pangaea. Creatures formerly kept apart from one another now rubbed shoulders, and large numbers

of them went extinct by about 220 million years ago .20 Reptiles inherited the earth, spreading throughout the globe. In the last few millennia, our species has once again fused the continents, and to some extent the seas, and is probably provoking (through this and other means) the sixth great extinction spasm in the history of earth.

From less Olympian heights, other vistas Present themselves. The process of biological exchange, as I have noted time and again, is much influenced by the technology of transportation. The invention of ships, of ocean-going ships, of ballast tanks, of railroads and airplanes, all led to changes and surges in the pattern of biological exchange. This provides one rhythm. Another is political.

Some states and societies showed great eagerness to import exotic species. Monarchs of ancient Egypt and Mesopotamia buttressed their prestige by maintaining gardens and zoos filled with exotic plants and animals.[21] The Tang, as noted, showed a similar enthusiasm. Thomas Jefferson once opined that “The greatest service which can be rendered to any country is to add a useful plant to its culture.”[22] He tried his best to establish silkworms in Virginia. Later, the US government employed an army of plant prospectors in the Bureau of Plant Introductions, who scoured the globe for potentially useful species, and brought tens of thousands to the US. In the 19th century, Australia and New Zealand featured «acclimatization societies» which made it their business to import species that met with their approval (usually from Britain). Nowadays the US, Australia, New Zealand, and many other countries spend vast sums trying to prevent the importation of unwanted species, hoping to forestall biological invasions rather than foment them.

Beyond the disposition any society might have toward exotic species, the changing nature of intersocietal relations and geopolitical regimes also affected biological exchange. Trade and travel- and presumably biological exchange- flourished in peacetime and contracted in times of war, brigandage and piracy. Probably eras of imperial power provided the best Political environment for biological exchange, when a single power enforced a general peace. Anarchic systems of competing states probably checked biological exchange by slowing trade and travel. Furthermore, imperialism

also seems to have inspired, as well as eased, the process of collection: botanical gardens and the like. Kew Gardens outside of London proved a crucial link in exporting rubber seeds from Brazil to Malaya at the end of the 19th century, which started a new plantation economy in southeast Asia. The swings between moments of consolidated imperialism and anarchic struggle established another rhythm governing the history of biological exchange.[23] This, of course, was influenced in turn by biological exchanges, as in the case of horses on the African savanna.

One can only postulate such patterns in the history of biological exchange. Demonstrating their validity would require quantitative evidence beyond what one can reasonably hope to find. In the absence of decisive data supporting (or refuting) these views on the rhythms of biological exchange, and their connections to political and technological history, I fall back on the more obvious, but often ignored conclusion, that time and time again in the past 10 millennia biological exchange has altered the course of economic, political, and social history.

The next 10 millennia will probably be no different.

Notes

[1]David Burney, «Historical Perspectives on Human-Assisted Biological Invasions,» Evolutionary Anthropolgy 4(1996), 216-221.

[2]Jared Diamond, Guns, Germs, and Steel (New York: Norton, 1997) reviews early domestication and dispersal of plants and animals.

[3]National Research Council (USA), Lost Crops of Africa. I. Grains (Washington: National Academy Press, 1996), 140; Edward H. Schafer, The Golden Peaches of Samarkand (Berkeley: University of California Press, 1963), 76, 142.

[4]My grasp of these matters depends on Christopher Beckwith, The Tibetan Empire in Central Asia (Princeton: Princeton University Press, 1987), especially pp. 178-9; Denis Sinor, Inner Asia (Bloomington: Indiana University Press, 1969); and Edward H. Schafer, The Golden Peaches of Samarkand, *passim*; and on conversation with my Georgetown colleague Jim Millward.

[5]On the Mongol moment and the interaction it brought, Janet Abu-Lughod, Before European Hegemony (New York: Oxford University Press, 1989); on the spread of bubonic plague, William McNeill, Plagues and Peoples (New York: Doubleday, 1976). Some China historians are skeptical of the notion that bubonic plague struck China in the 13th and 14th centuries.

[6]Clive Gamble, Timewalkers: The Prehistory of Global Colonization (Cambridge: Harvard University Press, 1994), 228. The 170km in question were from New Ireland to Buka in the Solomons (southwest Pacific).

[7]Tim Flannery, The Future Eaters (Chatswood, NSW: Reed, 1994), 275-7 on the dingo.

[8]«Portmanteau biota» is Alfred Crosby’s phrase, taken from Ecoloaical Imperialism (New York: Cambridge University Press, 1986). The Polynesian impact is treated in P.V. Kirch, «Man’s Role in Modifying Tropical and Subtropical Polynesian Ecosystems,» Archaeology in Oceania 18(1983), 26-31.

[9]The phrase is borrowed from John Dodson, ed., The Naive Lands: Prehistory and Environmental Change in Australia and the Southwest Pacific (Melbourne: Longman Cheshire, 1992).

[10]Less pronounced because they had no domesticated dogs with them, because they had a less formidable arsenal of hunting weapons, and perhaps because their numbers were small relative to the size of populations of others species. No one knows the size of the migrant groups, nor just when they moved out of Africa, but in might have been around 700,000 BP.

[11]Jon Hather and P.V. Kirch, «Prehistoric Sweet Potato (*Ipomea batatas*) from Mangaia Island, Central Polynesia,» Antiquity 65(1991), 887-889.

[12]E. De Langhe, R. Swennen and D. Vuylsteke, «Plantain in the Early Bantu World,» Azania 29-30(1994-1995), 147-60; Gerda Rossel, «Musa and Ensete in Africa: Taxonomy, Nomenclature and Uses,» Azania 29-30(1994-1995). 130-46; J. Berchem, «Sprachbeziehungen im Bereich des Kulturwortschatzes zwischen den Bantusprachen und dem Malagasy,» Sprache und Geschichte in Afrika 10- 11(1989-90), 9-169.

[13]National Research Council, Lost Crops of Africa, *passim*

[14]Alfred Crosby, The Columbian Exchange: Biological and Cultural Consequences of 1492 (Westport, CT: Greenwood Press, 1972).

[15]Details in Andrew Watson, Agricultural Innovation in the Early Islamic World: The Diffusion of Crops and Farming Techniques (Cambridge: Cambridge University Press 1983).

[16]Jack Goody, Technology, Tradition and the State in Africa (London, 1971), 35, 68-9; N. Levtzion, Ancient Ghana and Mali (London, 1973), 177-78. For a summary of the early history of the horse and camel in the Sahara, R. Mauny, “Trans-Saharan Contacts and the Iron Age in West Africa,” in The Cambridge History of Africa. Vol. II (London, 1978), 277-290. See also Donald Wright, The World and A Very Small Place in Africa (Armonk: M.E. Sharpe, 1997), 75-77; James Webb, Desert Frontier (Madison: University of Wisconsin Press, 1995), 69-72; Robin Law, The Horse in West Africa (Oxford: Oxford University Press, 1980)

[17]The Politics of Environmental Control in Northeastern Tanzania, 1840-1940 (Philadelphia: University of Pennsylvania Press, 1992).

[18]J.R. McNeill, «Ecology, Epidemics, and Empires: Environmental Change and the Geopolitics of Tropical America, 1600-1825,» Environment and History 5(1999), 175-84.

[19]J.T. Carlton, «Marine Bioinvasions: The Alteration of Marine Ecosystems by Nonindigenous Species,» Oceanography 9(1996), 36-43.

[20]The Permian extinction probably derived from additional events as well as the fusion of the continents; scientific opinion is divided on the subject.

[21]Karen Polinger Foster, «Gardens of Eden: Exotic Flora and Fauna in the Ancient Near East» In: Jeff Albert et al, eds., Transformations of Middle Eastern Natural Environments (New Haven: Yale School of Forestry and Environmental Studies, Bulletn No. 103, 1998), 320-9.

[22]Lawrence Busch et al 1995:68.

[23]For this view of international history, see Adam Watson, The Evolution of International Society (London: Routledge, 1992).