The Columbian Exchange: A History of Disease, Food, and Ideas*

Nathan Nunn‡
Harvard University, *NBER*, and *BREAD*

Nancy Qian§
Yale University, *NBER* and *BREAD*

First version, September 7th, 2009

ABSTRACT: This paper provides an overview of the long-term impacts of the Columbian Exchange - that is, the exchange of diseases, ideas, food crops, populations, and cultures between the New World and the Old World after the discovery of the Americas by Christopher Columbus in 1492. We focus on the aspects of the Exchange that have been neglected by most economic studies; namely the transfer of diseases, food crops, and knowledge between the two Worlds. We also pay particular attention the effects of the Exchange on the Old World.

Key words: Columbian Exchange, Disease, Food, Technology.
JEL classification: N30, N50.

*Draft prepared for the *Journal of Economic Perspectives*. We thank Eva Ng for excellent research assistance.

‡Department of Economics, Harvard University, Littauer Center M-29, Cambridge, MA 02138, U.S.A. (e-mail: nnunn@fas.harvard.edu; website: http://www.economics.harvard.edu/faculty/nunn).

§Department of Economics, Yale University, 27 Hillhouse Avenue, New Haven, textscct 06520, U.S.A. (e-mail: nancy.qian@yale.edu; website: http://www.econ.yale.edu/faculty1/qian.htm).

1. Introduction

The Columbian Exchange refers to the exchange of diseases, ideas, food crops, populations, and cultures between the New World and the Old World after the discovery of the Americas by Christopher Columbus in 1492.[1] This exchange has drastically altered the global landscape. Enormous benefits and devastations were brought to all parts of the world.[2]

The Exchange greatly enriched the world. Aside from the well known discoveries of metals, the Old World gained new foods that are now consumed as staple crops, such as potatoes, sweet potatoes, maize, and cassava. Foods such as tomatoes, chili peppers, cacao, peanuts, and pineapples are now culinary centerpieces in many Old World countries, namely Italy, Greece, and other Mediterranean countries (tomatoes), India and Korea (chili peppers), Hungary (paprika, made from chili peppers), and Malaysia and Thailand (chili peppers, peanuts, and pineapples). Tobacco, another New World crop, was so universally adopted that it came to be used as a substitute for currency in many parts of the world. The exchange also drastically increased the availability of many Old World crops, such as sugar and coffee, which were particularly well suited for the virgin soils of the New World.

The negative consequences are no less stark than the positive ones. European contact enabled the transmission of diseases to previously isolated communities, which caused devastation far exceeding that of even the Black Death in 14th century Europe. Europeans brought deadly viruses and bacteria, such as smallpox, measles, typhus, and cholera, for which Native Americans had no immunity towards. On their way home, European sailors brought syphilis to Europe. Although less deadly, this disease was known to have caused great social disruption throughout the Old World, and killed several monarchs and at least one Pope.

The effects of the Columbian Exchange were not only isolated to the parts of the world most directly participating in the exchange, i.e. Europe and the Americas. It also had large indirect impacts on Africa and Asia. For example, European exploration (and later colonization) of the vast tropical regions of these continents was aided by the New World discovery of quinine, the first effective treatment for falciparum malaria. More importantly, the cultivation of financially

[1] Throughout the paper we use a broad definition of 'Old World', which includes the entire Eastern Hemisphere. In other words, by 'Old World' we do not mean Europe only. We use the term 'Americas' and 'New World' synonymously.

[2] The controversy surrounding whether Christopher Columbus was the first European to discover the Americas is not important for this paper, which documents the consequences of the large transfer between the Old and New World after his voyages.

lucrative Old and New World crops in the Americas, along with the devastation of Native populations from disease, resulted in a demand for labor that was met with the abduction and forced enslavement of over 12 million Africans during the 16th to 19th centuries. In the 19th and 20th centuries, over one million indentured workers from Asia were brought to the Americas to replace the slave labor after slavery was abolished.

The Columbian Exchange has provided economists interested in the long-term impacts of history and domestic institutions with a rich historical laboratory. However, economic studies thus far have mainly focused on how European institutions, through colonialism, were transplanted to non-European parts of the world.[3] In this paper, we attempt to broaden the scope of this focus by studying the aspects of the exchange that have received relatively less attention. First, we pay particular attention to the effects the exchange had on the Old World, rather than examining outcomes in the New World. Second, rather than concentrating on the effects of the exchange that work through institutional and political structures, we instead focus on the less studied, but no less important channels; namely, the exchange of food crops and disease.

We are aware of only a handful of empirical papers that either focus on the effect of the exchange on the Old World, or focus on channels other than legal institutions. Acemoglu, Johnson, and Robinson (2005) argue that the profits from the Atlantic trade strengthened the merchant class, which resulted in stronger pro-business institutions and increased economic growth in Europe. More recently, two studies have explored the effects from the botanical exchange. Nunn and Qian (2009) find that the introduction of potatoes to the Old World resulted in increased population and urbanization growth rates. Along similar lines, Hersch and Voth (2009) find that the increase in land for cultivating Old World crops such as tea, coffee, and sugar after 1492, caused English welfare to increase by 16–20% by 1850.[4]

The results from these studies suggest that the exchange of food crops, technologies, and disease following Columbus's voyages to the Americas may have had enormous welfare consequences.

[3]The seminal papers by Engerman and Sokoloff (1997), La Porta, Lopez-de-Silanes, Shleifer, and Vishny (1997, 1998), and Acemoglu, Johnson, and Robinson (2001) examine the effects that European contact, taking the form of formal and informal colonial rule, had on other societies. Examples of subsequent research include Mitchener and McLean (2003), Berkowitz and Clay (2005, 2006), Acemoglu, Bautista, Querubin, and Robinson (2008), Dell (2008), and Nunn (2008*a*). Also see the review by Nunn (2009).

[4]The effects from these studies may seem large at first glance, maybe even too large. However, recent estimates find that U.S. consumers have gained welfare equivalent to 2.6% of GDP just from the increase in varieties of goods that has arisen from increased trade between 1971 and 2001 (Broda and Weinstein, 2006). Once one recognizes that the increased access to new goods between 1971 and 2001 pales in comparison to the increase that arose following the discovery of the Americas in 1492, the estimates from Hersch and Voth (2009) seem large, but very reasonable.

However, as with the studies on institutions, each of these investigate a very narrow set of channels. Although this is the usual price for analytical rigor, it also means that even taken together, these existing studies are only able to brush the surface of the vast historic exchange. In this paper, we aim to compliment these studies by taking a much broader, more general approach. We provide the reader with an overview of the neglected aspects of the Columbian Exchange, with the hope that our descriptive analysis will spur further more rigorous studies of the long-term consequences of these understudied aspects of the Exchange.

In the following section, we begin by examining the most devastating and unfortunate impacts of the Columbian Exchange, which arose from the exchange of disease between the Old and New Worlds. In section 3, we examine the effects of the exchange that resulted from the transfer of foods between the New and Old Worlds. In section 4, we turn to the indirect consequences of the Exchange on Africa and Asia. Section 5 concludes.

2. Disease

A. *The Spread of Disease from the Old World to the New*

The list of infectious diseases that spread from the Old World to the New is long, where the major killers include smallpox, measles, whooping cough, chicken pox, bubonic plague, typhus, and malaria (Denevan, 1976, p. 5). Most certainly, this aspect of the Columbian Exchange – the spread of Old World diseases to the Americas – is one of the most significant and the most regrettable. Because Native populations had no previous contact with Old World diseases, they were immunologically defenseless. Dobyns (1983, p. 34) writes that "before the invasion of peoples of the New World by pathogens that evolved among inhabitants of the Old World, Native Americans lived in a relatively disease-free environment... Before Europeans initiated the Columbian Exchange of germs and viruses, the peoples of the Americas suffered no smallpox, no measles, no chickenpox, no influenza, no typhus, no typhoid or parathyroid fever, no diphtheria, no cholera, no bubonic plague, no scarlet fever, no whooping cough, and no malaria."

Although we may never know the exact magnitudes of the depopulation, it is estimated that upwards of 80–95% of the Native American population was decimated within the first 100–150 years following 1492.[5] Within fifty years following the Taino's contact with Columbus and his

[5]See Newson (2001, p. 167) and the references therein.

crew during their 1492 expedition, their population was virtually extinct.[6] Central Mexico's population fell from just under 15 million in 1519 to 1.5 million a century later. Historian and demographer, Nobel David Cook, estimates that in the end, the regions least affected lost 80% of their populations; those most affected lost their full populations; and the typical society lost 90% of its population (Cook, 1998, p. 5).

The uncertainty surrounding the exact magnitude the depopulation of the Americas arises because it is unknown whether depopulation had already occurred, and to what extent, before literate European observers made physical contact and recorded the populations they observed (Dobyns, 1993). If disease traveled faster across the Americas than the explorers, it would have killed a significant portion of native populations before direct contact, thereby causing first-hand accounts of initial population sizes to be downward biased. The uncertainty that arises from these issues is best illustrated by the variation in the 1491 population estimates for the Americas that have been developed by historians. These range wildly from a lower-bound of approximately 8 million (Kroeber, 1939) to an upper-bound of over 110 million people (Dobyns, 1966).

As well as being important in and of themselves, correctly identifying the pre-Columbian populations of the Americas is also important for our understanding of the direct impact that European contact had on New World civilizations, as well as for correctly understanding the level of sophistication and development that existed in the pre-Columbian Americas.

B. *Syphilis: A New World Disease?*

There are very few examples of disease being spread from the New World to the Old. The most notable, and by far the most controversial, is venereal syphilis. Biologist Irwin Sherman (2007) lists venereal syphilis as one of the 12 diseases that changed the world. This may seem surprising given that today venereal syphilis is a non-fatal disease that is effectively treated with penicillin. However, this was not always the case. Early on, in the late 15th and early 16th centuries, the disease was frequently fatal, and its symptoms were much more severe. They included genital ulcers, rashes, large tumors, severe pain, and eventual death. Over time as the disease evolved, its symptoms changed, becoming more benign and less fatal. By the 17th century syphilis had developed into the disease that we know today (Crosby, 2003, pp. 151–153).

[6] Estimates of the original population of the Taino of the island of Hispaniola ranges from 60,000 to 8 million (see Cook, 1993).

Two theories of the origins of syphilis exist. The first, referred to as the "Columbian hypothesis", asserts that the disease causing agent *Treponema pallidum*, originated in the New World and was spread in 1493 by Christopher Columbus and his crew, who acquired it from the Natives of Hispaniola through sexual contact. Upon return to Spain, some of these men joined the military campaign of Charles VIII of France and laid siege to Naples in 1495. Encamped soldiers exposed the local populations of prostitutes, which amplified disease transmission. Infected and disbanding mercenaries then spread the disease throughout Europe when they returned home. Within five years of its arrival, the disease was epidemic in Europe. Syphilis reached Hungary and Russia by 1497; Africa, the Middle East and India by 1498; China by 1505; Australia by 1515; and Japan by 1569 (Snodgrass, 2003, Sherman, 2007). The second theory, the "pre-Columbian hypothesis", asserts that the disease had always existed in the Old World, and the fact that there are no documented cases prior to the 1490s is explained by the conjecture that prior to this date, it had not been differentiated from other diseases with similar symptoms like leprosy.

For decades, the only existing evidence was based on bone scars from lesions on pre-Columbian skeletal remains. While there are many remains providing evidence for pre-Columbian syphilis in the New World, very few examples exist for the Old World. The few cases that do exist remain uncertain, controversial, and inconclusive. The uncertainty arises because it is difficult to determine the age of skeletal remains and to distinguish venereal syphilis from other diseases that also leave similar scars.

Recently, findings from phylogenetics (the evolutionary study of genetic relatedness of different populations) have added valuable evidence to the mystery of the origins of venereal syphilis. The evidence supports the Columbian hypothesis that venereal syphilis is in fact a New World disease. Harper, Ocampo, Steiner, George, Silverman, Bolotin, Pillay, Saunders, and Armelagos (2008) found that bacterium causing venereal syphilis arose relatively recently in humans and is most closely related to a variation of the tropical disease yaws found in a remote region of Guyana, South America. This relationship is most consistent with venereal syphilis, or some early ancestor, originating in the New World.

3. New Foods and Increased Agricultural Productivity

The transfer of foods between the Old and New Worlds during the Columbian Exchange had important consequences for world history. Historian Alfred Crosby describes the significance of

the transfer of food crops between the continents, writing: "The coming together of the continents was a prerequisite for the population explosion of the past two centuries, and certainly played an important role in the Industrial Revolution. The transfer across the ocean of the staple food crops of the Old and New Worlds made possible the former." (Crosby, 1989, p. 666)

There are two channels through which the Columbian Exchange expanded the global supply of agricultural goods. First, it introduced previously unknown species to the Old World. Many of these species such as potatoes, sweet potatoes, maize, and cassava, resulted in caloric and nutritional improvements over existing staples grown in a region. Other crops such as tomatoes, cacao, and chili peppers were not by themselves especially rich in calories, but complimented existing foods by increasing vitamin intake and improving taste. In many instances, the New World foods had an important effect on the evolution of local cuisines. Chili peppers gave rise to spicy curries in India, to paprika in Hungary, and to spicy kimchee in Korea. Tomatoes significantly altered the cuisine of Italy and other Mediterranean countries. Second, the discovery of the Americas provided the Old World with vast quantities of relatively unpopulated land that was particularly well-suited for the cultivation of certain crops that were in high demand in Old World markets. For example, crops such as sugar, coffee, soybeans, and bananas were all introduced to the New World, and the Americas quickly became the main suppliers of these crops to the world.

A. *New Foods from the Americas*

Table 1 provides statistics showing the world's most popular foods.[7] The first column reports foods with popularity measured by the average consumption of calories per person per day. Because this metric may overstate the popularity of high calorie food crops, we also provide a ranking by tons of production per year, and by hectares of land under cultivation, both measured in 2000. These are reported in the second and third columns of the table. Foods that are indigenous to the New World are indicated by a double asterisk. Examining all three rankings, the following pattern emerges: the most consumed and produced crops are rice, wheat, and sugar, all Old World crops. However, five of the top fifteen crops are from the New World: maize, potatoes, cassava, sweet potatoes, and tomatoes. Also high on the list are a number of additional New World foods such as chili peppers and cacao, which, despite not being consumed in large quantities, are of central importance to the cuisines of many countries.

[7] Data are from the FAO's ProdSTAT and Consumption Databases. See `http://faostat.fao.org/`.

Table 1: The World's Most Important Foods.

Average Calories Consumed Daily		Production in Tonnes		Hectares of Land Harvested	
Rice	567	Sugar cane++	1,252,547,301	Wheat	215,479,110
Wheat	527	Rice	598,822,502	Rice	154,062,815
Sugar++	196	Maize**	592,477,760	Maize**	136,999,375
Maize**	147	Wheat	585,869,919	Soybeans++	74,367,896
Potatoes**	60	Potatoes**	328,743,067	Barley++	54,520,195
Cassava**	42	Sugar beet	247,077,236	Sorghum++	40,954,844
Sorghum++	32	Cassava**	176,532,832	Millet++	37,081,458
Sweet Potatoes**	29	Soybeans++	161,291,464	Rapeseed	25,835,280
Millet++	29	Sweet potatoes**	138,661,547	Sunflower seed**	21,120,631
Soyabeans++	17	Barley++	133,131,846	Potatoes**	20,127,983
Bananas++	14	Oil palm fruit	120,440,185	Sugar cane++	19,516,427
Coconuts	12	Tomatoes**	108,919,763	Cassava**	17,004,330
Apples	9	Watermelons	76,535,082	Oats	12,682,536
Tomatoes**	8	Bananas++	64,888,468	Coffee, green++	10,767,066
Oranges++	8	Grapes	64,790,291	Coconuts	10,594,814
Rye	7	Oranges++	63,812,015	Chick peas	10,120,870
Yams	7	Apples	59,056,783	Oil palm fruit	9,962,994
Onions	7	Sorghum++	55,773,347	Rye	9,822,485
Plantains++	7	Coconuts	52,893,570	Sweet potatoes**	9,721,340
Barley++	7	Onions, dry	49,838,803	Olives	8,327,399
Other Notable New World Foods:					
Cacao Beans**	3	Eggplants**	27,239,222	Cacao beans**	7,602,980
Pineapples**	2	Sunflower seed**	26,454,517	Natural rubber**	7,563,460
		Chillies/peppers, green**	20,852,764	Tobacco**	4,169,891
		Pineapples**	15,097,558	Tomatoes**	4,020,150

Notes: All figures are for the year 2000. Consumption is measured in calories per capita per day. Production is measured in tonnes, and area harvested in measured in hectares of land. An ** indicates a New World food crop. ++ indicates Old World crops for which more than 26% of world production is from New World countries. (26% is the fraction of arable land that is located in thenNew World.) The table does not report the consumption of oils.

Overall, table 1 provides a sense of the full extent to which foods indigenous to the New World comprise an important portion of the world's diet today.[8]

Staple Crops

The Columbian Exchange introduced a wide range of new calorically rich staple crops to the Old World – namely potatoes, sweet potatoes, maize, and cassava (also known as manioc). The primary benefit of the New World staples was that they could be grown on land and in climates that were unsuitable or less suitable for the cultivation of Old World staples. Crosby (2003, p. 177) writes: "The great advantage of the American food plants is that they make different demands of soils, weather and cultivation than Old World crops, and are different in the growing seasons in which they make these demands. In many cases the American crops do not compete with Old World crops but complement them. The American plants enable the farmer to produce food from soils that prior to 1492, were rated as useless because of their sandiness, altitude, aridity, and other factors."

[8]We have omitted oils from the list. Among oils, the fourth most consumed oil, sunflower oil, is derived from sunflowers, a New World crop.

Table 2: Top Consumers of New World Foods.

Maize		Cassava		Sweet Potatoes	
Country	**Consumption**	**Country**	**Consumption**	**Country**	**Consumption**
Lesotho	1508	Congo, Dem. Rep.	925	Solomon Islands	457
Malawi	1151	Congo	688	Rwanda	330
Mexico	1093	Angola	668	Burundi	293
Zambia	1058	Mozambique	650	Uganda	228
South Africa	924	Ghana	639	China	106
Zimbabwe	903	Benin	470	Timor-Leste	64
Guatemala	835	Liberia	451	Madagascar	59
Timor-Leste	808	Togo	393	Cuba	57
El Salvador	772	Madagascar	382	Tanzania	57
Kenya	766	Central African Rep.	374	Haiti	45
Potatoes		**Tomatoes**		**Pineapples**	
Country	**Consumption**	**Country**	**Consumption**	**Country**	**Consumption**
Belarus	320	Greece	68	Costa Rica	84
Latvia	258	Libya	47	Thailand	26
Estonia	255	United Arab Emirates	45	Kenya	20
Lithuania	248	Egypt	44	Philippines	14
Ukraine	248	Turkey	42	Samoa	11
Poland	242	Italy	38	Venezuela	10
Portugal	221	Lebanon	33	Antigua and Barbuda	8
United Kingdom	221	Tunisia	32	Australia	8
Russian Federation	217	Israel	29	Malaysia	8
Ireland	209	Cuba	26	Swaziland	8

Notes : Consumption figures are measured in average calories consumed per capita per day. The data are from the FAO and are for the year 2000.

This benefit of New World crops has resulted in their adoption in all parts of the world. As shown by table 2, maize has been widely adopted by a number of countries. The New World countries that today consume the greatest amounts of maize are the southern African countries of Lesotho, Malawi, and Zambia. The average person in Lesotho consumes an astonishing 1,500 calories per day from maize. Cassava has also been extensively adopted by many countries in sub-Saharan Africa. Although both foods do have their imperfections - for example, a diet of too much maize causes pellagra and consumption of insufficiently processed cassava results in konzo - today they provide sustenance for millions around the globe. The table also shows that sweet potatoes have also been widely adopted in the Old World and today are most heavily consumed in Rwanda, Burundi, Uganda and China.

The New World crop that provides abundant calories and can sustain life better than any other food when consumed as the sole article of diet is the potato (Nunn and Qian, 2009). Table 2 shows that today, this nutritious crop is most widely consumed in Eastern European, and that it has been so widely embraced by Old World populations that today the top 12 consumers of potatoes are Old World countries. Two studies have attempted to empirically estimate the effects of the introduction

of the potato. Mokyr (1981) examines variation across counties in England and estimates that the cultivation and consumption of the potato did spur population growth. Nunn and Qian (2009) also examine the impacts of the potato on population growth, but do so for the entire Old World. They find that the potato had a significant positive impact on population growth, contributing to 12% of the increase in average population between the pre- and post-introduction periods, which they take to be 1700. They also estimate the effect the potato had on urbanization rates, and find that 47% of the increase in urbanization between the pre- and post-adoption periods is explained by the potato.

We now turn to a discussion of crops that provide fewer calories, but are no less important to Old World cuisines: capsicum peppers, tomatoes, cacao, and vanilla. Then, we also discuss two less healthy additions to the Old World diet: coca and tobacco.

Capsicum Peppers

The capsicum pepper originated in the areas that today are Bolivia and southern Brazil. By the time of the arrival of the Europeans, the plant had migrated to Mesoamerica and the Caribbean. Capsicum annuum, which was domesticated in Mesoamerica, is the ancestor of the most commonly consumed varieties today: the Cayenne pepper, Bell peppers, and the Jalapeño pepper. A second variety, Capsicum frutescens, first cultivated in the Amazon basin, gives us the Tabasco pepper (Andrews, 1992, 82–83).

By 1493, capsicum peppers had arrived in Spain and Africa. They then reached the East Indies by 1540 and India by 1542 (Andrews, 1992). In Hungary, *paprika*, the spice made from grinding dried fruits of the capsicum pepper, is first mentioned in 1569. Paprika has since been widely adopted in a variety of Hungarian dishes, including goulash, and today is the country's national spice (Halasz, 1963). The capsicum has had a significant impact on the cuisine of many other countries. In South and South East Asia, some form of pepper is used in the base of almost every dish (e.g. curries). In China, cuisine in the Southwest (e.g. Sichuan, Guizhou, Hunan) are defined by uses of certain chili peppers. In Korea, a side dish of spicy kimchi is consumed with every meal. Hot chili peppers, in the form of a paste and powder, are central ingredients to nearly all dishes. Today, even parts of Africa have begun to use chili peppers as a main flavoring ingredient. For example, in Rwanda, the most common flavoring besides salt is a spicy, red colored sauce called piri-piri. It is added to enhance the flavor of most dishes.

Tomatoes

Tomatoes are a fruit that originated in South America. Botanists believe that approximately one thousand years before the Spanish arrived in the Americas, an unidentified wild ancestor of the tomato made its way north and came to be cultivated in South and Central America (Smith, 1994, p. 17). The tomato is first mentioned in European texts in 1544. Mathiolus described how tomatoes, *pomi d'oro* (golden apple) were eaten in Italy with oil, salt and pepper, suggesting that the first tomatoes in Europe were yellow and not red (Gould, 1983, pp. 30–53). European cultivation became widespread in the ensuing decades in Spain, Italy, and in France.[9] Cookbooks mentioned tomatoes as early as 1692 in Naples and 1752 in England.

One of the difficulties in consuming tomatoes was that they did not preserve well. Ripe tomatoes can become putrid within days in hot climates. The canning process helped increase the shelf life of the tomato to several months, but prior to 1890, it was a costly manual process. The mechanization of canning at the turn of the 20th century significantly lowered the cost of this process, and resulted in a significant increase in tomato consumption (Gould, 1983, pp. 30–53).

Today, tomatoes have become a truly global food. As shown in table 2, nine of the top ten tomato consuming countries are Old World countries. Greece consumes the most tomatoes per capita, followed by other Mediterranean and Middle Eastern countries. Italy, known for it use of tomato sauces with pasta and on pizza, ranks sixth on the list. The top producers of tomatoes are listed in table 3. As shown, eight of the top ten producers are Old World countries, with only two New World countries, Brazil and Mexico, breaking the list of top tomato producers.

Although it is not particularly rich in calories, tomatoes are an important source of vitamins, particularly vitamins A and C. The tomato has been so thoroughly adopted and integrated into Western diets, that today the tomato provides more nutrients and vitamins than any other fruit or vegetable (Sokolov, 1993, p. 108).

The importance of tomatoes will probably increase as recent medical researchers discover a growing number of health benefits from tomato consumption. Recent research has also found that lycopene, a powerful anti-oxidant contained in cooked or canned tomatoes, has properties that may help reduce cancer (e.g., Basu and Imrhan, 2007). Although research is still in progress, the

[9] In France it was called *pomme d'amour* (love apple), probably the result of a corruption of the early Spanish name, *pome dei Moro*.

Table 3: Top Producers of New World Crops.

Potatoes		Chili Peppers, Dry		Chili Peppers, Green	
Country	**Production**	**Country**	**Production**	**Country**	**Production**
China	66,318,167	India	983,700	China	9,436,452
Russian Federation	33,979,460	China	212,000	Mexico	1,734,630
India	24,713,200	Pakistan	174,571	Turkey	1,480,000
Poland	24,232,376	Bangladesh	143,000	Spain	946,762
USA	23,297,460	Ethiopia	115,000	USA	912,990
Ukraine	19,838,100	Viet Nam	76,500	Indonesia	727,747
Germany	13,694,283	Peru	62,000	Nigeria	715,000
Belarus	8,717,800	Mexico	55,000	Egypt	428,066
Netherlands	8,227,000	Myanmar	49,100	Korea, Republic of	391,298
United Kingdom	6,636,000	Nigeria	47,500	Italy	364,963
Tomatoes		**Cacao Beans**		**Tobacco**	
Country	**Production**	**Country**	**Production**	**Country**	**Production**
China	22,324,767	Côte d'Ivoire	1,401,101	China	2,563,854
USA	11,558,800	Ghana	436,600	Brazil	578,451
Turkey	8,890,000	Indonesia	421,142	India	520,000
Italy	7,538,100	Nigeria	338,000	USA	477,632
India	7,430,000	Brazil	196,788	Zimbabwe	227,726
Egypt	6,785,640	Cameroon	122,600	Turkey	200,280
Spain	3,766,328	Ecuador	99,875	Indonesia	146,100
Iran	3,190,999	Malaysia	70,200	Greece	136,593
Brazil	2,982,840	Papua New Guinea	46,800	Italy	129,937
Mexico	2,666,280	Colombia	44,544	Argentina	114,509
Vanilla		**Natural Rubber**		**Quinoa**	
Country	**Production**	**Country**	**Production**	**Country**	**Production**
Indonesia	1,681	Thailand	2,378,000	Peru	28,191
Madagascar	880	Indonesia	1,501,430	Bolivia	23,785
China	650	Malaysia	928,000	Ecuador	650
Mexico	255	India	630,000	Other countries	0
Comoros	140	China	481,571		
Tonga	130	Viet Nam	290,800		
Turkey	100	Côte d'Ivoire	123,398		
Uganda	40	Nigeria	107,000		
French Polynesia	35	Liberia	105,000		
Réunion	25	Brazil	87,800		

Notes: Data are from the FAO's ProdSTAT Database. All production figures are in tons for the year 2000.

American Cancer Society has already begun to promote increased consumption of tomatoes as a potential method for cancer prevention.

Cacao

The Codex Mendoza records that by the time Cortes arrived, chocolate was being cultivated by farmers in the Yucatan and traded in large quantities through out the Empire (West, 1992, p. 108). Historical records indicate that Columbus first brought back specimens of cacao pods to King Ferdinand I after his second voyage to the New World. Outside of the Americas, cacao was first cultivated in 1590 by the Spanish off the coast of Africa on the island of Fernando Po (West, 1992, pp. 110–111).

The Spanish held a monopoly on production and trade of cacao up until the 17th century when the French began cacao production in Martinique and Saint Lucia. The Dutch also began production of cacao in Indonesia, which was the Dutch East Indies at the time. Even today, as shown by table 3, Indonesia remains one of the largest producers of cacao beans. Cacao cultivation came late to mainland Africa, with Cameroon and Ghana being the first cultivators in the late 1870s and 1880s (West, 1992, pp. 116–118). But today, the West African countries of Cameroon, Cote d'Ivoire, Ghana and Nigeria are among the world's largest producer of cacao beans, with Cote d'Ivoire being the largest producing nation in the world (see table 3).[10]

While chocolate is most popularly consumed as a condiment, candy or dessert, cacao is also a high energy food known for lifting psychological effects. Pure chocolate, which is more than half cocoa-butter, has a higher energy output per unit of weight than most other carbohydrate- or protein-rich foods. This has made it an important food for physically taxing expeditions where travelers needed to minimize the food carried. For example, in Roald Amundsen's trek to the South Pole, his men were allocated 4,560 calories per day, where over 1,000 came from cacao (West, 1992, pp. 117–118).

Plain Vanilla

We now turn to vanilla, a crop that, despite being completely unknown to the Old World prior to 1492 and despite having little nutritional importance, has become so widespread and so common

[10]Cacao production has been an enormously important part of the economy for West African countries. For example, in Ghana since independence cacao exports have accounted for approximately 50–70% of total exports (Oduro, 2000, p. 173).

that in English its name is used as an adjective to refer to anything that is "plain, ordinary, or conventional".[11]

Vanilla comes from the tropical forests of eastern and southern Mexico, Central America, and northern South America. Vanilla is from the fruit of *Vanilla planifolia*, a species of the vanilla orchid, which is the only species of the orchid family that produces edible fruit. Neither the vanilla flower nor its fruit, which takes the shape of a long pod, naturally has any conspicuous scent or flavor. Vanilla pods must be fermented to produce the chemical compound vanillin, which gives the pods a distinctive vanilla scent and flavor.

It is unclear whether vanilla was first brought back to Spain by Cortes or another Spanish traveler. In any case, it achieved popularity quickly in Spain, where factories were using it to flavor chocolate by the second half of the 16th century. Like chocolate, it was considered a luxury for the wealthy. King Phillip II was known to have drank vanilla flavored chocolate as a nightcap. It was also quickly adopted by aristocratic circles in other parts of Europe. Queen Elizabeth I of England was also known to have been a frequent user of vanilla products.

In the 18th century, the French began to use it widely as a flavoring for foods such as confectionaries and ice, and also as a scent for perfumes and tobacco. French colonial islands began to attempt to systematically cultivate cuttings of the plant taken from the Americas. However, because of a lack of proper insects for pollination initial attempts ended in failure (Bruman, 1948, pp. 371–372). It was not until after 1836, when Belgian botanist Charles Morren was able to hand-pollinate vanilla orchids, that the French were able successfully cultivate plants that flowered (Morren, 1838). As shown by table 3 the French colonial islands (and former colonial islands) such as Comoros, Réunion, and French Polynesia continue to be large suppliers of vanilla. Mexico also continues to be a large producers of vanilla, although it producers far less than Madagascar, Indonesia or China.

Tobacco

It is believed that Native Americans began to use tobacco around the first century BC. Although there is no evidence that Native Americans ever consumed tobacco recreationally, it was used as a entheogen during religious ceremonies, where it was consumed in large quantities to produce hallucinogenic effects. Tobacco was also commonly used as a painkiller.

[11] See for example the Merriam-Webster definition for "vanilla".

Ramon Pane, a monk who accompanied Columbus on his second voyage, gave lengthy descriptions about the custom of smoking tobacco. He described how Natives inhaled smoke through a Y-shaped tube. The two ends were placed in the nostrils and the third end over a pastille of burning leaves. Although the exact manner of smoking differed between regions within the Americas, the practice of smoking tobacco appears to have been universal (Penn, 1901, pp. 5–11).

Tobacco was quickly adopted by Europeans. Pane is usually credited with being the first man to introduce tobacco to Europe (Brooks, 1952, p. 16). At first tobacco was regarded and consumed only as a medicine. In 1560, the French ambassador to Portugal, Jean Nicot de Villemain (from whom the term 'nicotine' originates), proclaimed that tobacco had a panacea of medicinal properties. In 1561, Nicot sent tobacco leaves to Catherine de Medici, the Queen of France. She was so impressed with the plant that she decreed that tobacco be called *Herba Regina* (the Queen's Herb). In England, tobacco was first introduced by Sir John Hawkins and his crew in the 1580s. It was chiefly used by sailors, including those employed by Sir Francis Drake. By the beginning of the 17th century, tobacco had spread to all parts of Europe.

Besides being consumed, tobacco was also used as currency by Native American tribes, Europeans explorers, and colonialists during the 17th and 18th centuries. It was used as a monetary standard for approximately two centuries, longer than the use of the gold standard in America. In 1776, during the American Revolutionary War, the Revolutionary Government of America used tobacco as collateral for part of its loans from France. Tobacco's use as currency was not isolated to the American colonies. In Japan, where tobacco was introduced by Dutch and Portuguese trading vessels in the ports of Nagasaki and Kagoshima in the 16th century, it spread through the country within decades, often by Buddhist monks who use tobacco seeds as a method of payment along their long pilgrimages (Brooks, 1952, p. 34).

In the 20th century, tobacco consumption began to increase dramatically around the time of World War I, when cigarettes were commonly called "soldier's smoke". Beginning in the 1950s, medical researchers began to discover negative health effects from smoking. These results were publicized starting in the 1960s. In 1964, the U.S. Surgeon General published a report on the health consequences of smoking titled *Smoking and Health* (see Cochran, Farber, Frieser, Furth, Hickman, Le Maistre, Schuman, Seevers, Bayne-Jones, and Burdette, 1964). This was an important stimulus for the extensive anti-smoking campaigns that developed over the next four decades. Although smoking rates have declined in developed countries, tobacco consumption continues to rise in

most less-developed countries (Jha, 1999, pp. 13–20). As an example, in China between 1992 and 1996 alone, per capita cigarette consumption increased by 50%, from 10 to 15 cigarettes per day. According to the World Health Organization, today tobacco is the leading cause of preventable death (Mackay, Eriksen, and Shafey, 2006). It is estimated that 1 in every 10 adult deaths is due to tobacco consumption. Driven by the rising rates of smoking in developing countries, this figure is expected to worsen to 1 in every 6 adults within the next two decades (Jha, 1999, p. 22).

Coca

Coca leaves are grown from bushes native to the Andes. These leaves contain alkaloids that can be extracted to produce commercial cocaine. The use of coca leaves has a long history. During the Incan Empire, they were chewed during religious rituals. Early Spanish settlers adopted this practice and brought it back to Europe. Beginning in the 19th century, Europeans began to refine coca leaves. Many notable figures, such as Sigmund Freud, became regular users and active proponents of its ability to increase creativity, stamina, and decrease hunger. Freud supposedly began using it after hearing of the Belgian army's experiments in giving coca extracts to its soldiers, who performed better on less food over longer periods of time. The most famous legal use of coca is undoubtedly the soft drink Coca-Cola, which was invented by a pharmacist in Atlanta, Georgia, as a substitute for alcohol during American Prohibition (Hobhouse, 2006, pp. 310–313).

Today, cocaine is one of the most highly traded illegal substances in the world. Although the consumption of cocaine has spread to all corners of the globe, only three New World countries – Colombia, Peru, and Bolivia – produce the world's supply of coca leaves. In 2008, Colombia produced 62%, Peru produced 28%, and Bolivia produced 10% of the world's supply (U.N. Office on Drugs and Crime, 2008, p. 70). The coca industry accounts for a significant portion of income in these countries. It is estimated that the coca leaf by itself accounts for 2.3% of Bolivia's GDP, and 16% of its total agricultural production (U.N. Office on Drugs and Crime, 2008, p. 233). In Colombia, a country with a much larger economy, the analogous numbers are smaller, but still significant: 0.5% and 5% (U.N. Office on Drugs and Crime, 2009, p. 6).

B. *Improved Cultivation of Old World Foods in the New World*

After Columbus' voyage to the Americas, it was soon discovered that certain Old World crops were very well suited to New World climates. In many cases the Old World crops were grown

much more productively in the New World soils and climates than they were grown back home.

Table 1 shows Old World crops that today have more than 26% of their total production in the New World. These crops are marked with double-pluses. We choose a 26% cut-off because this is the fraction of arable land located in the Americas. Therefore, the table highlights Old World crops for which a disproportionate share of output (normalized by arable land) is produced in the New World.[12]

The fact that Old World crops flourished in the New World, and New World crops flourished in the Old, is not just coincidence. It is, in part, the result of two aspects of the Columbian Exchange. First, both the New World and the Old World contain continents that lie on a North-South orientation and span nearly all degrees latitude. Because climates change most drastically as one moves North-South, rather than East-West, this helped to ensure that New World plants could find an Old World climate similar to their native climate and vice versa.[13] Second, there was also a benefit that arose from the two regions being isolated for thousands of years prior to contact. The isolation caused separate evolutions of plants, parasites and pests. Therefore, transplanted crops tended to flourish because they were able to escape the pests and parasites that had co-evolved with them in their native habitat.[14] Because of the greater prevalence of pests and parasites in tropical regions, tropical plants benefited most from being transplanted (Dean, 1987, pp. 59–60). This benefit explains why today 57% of the production of coffee (which originated in the Old World) is produced in the New World, and why 98% of natural rubber is produced in the Old World from transplanted rubber trees originally from the New World. Numerous other examples of transplanted crops exist. For example, the Americas currently produces 84% of the world's soybeans, 65% of its oranges, 35% of its bananas.[15]

Sugar Cane

The most striking example of an Old World crop that could be much more effectively cultivated in the New World is sugar cane. This can be seen visually in figure 1, which shows the global distribution of climates suitable for sugar cane cultivation. The underlying data, which are from

[12]The Americas has 16% of the World's population. Therefore, on a per capita basis as well, these Old World foods are disproportionately produced in the Americas.

[13]A similar point has been made by Diamond (1997) explaining the diffusion of crops, within the Old and New Worlds, prior to the Columbian Exchange.

[14]This also led to some transplantation disasters, which we do not discuss in this paper.

[15]All figures are for production measured in tons for the year 2000. Data are from the FAO.

the FAO's GAEZ 2002 database, are based on finely detailed information on the global distribution of climate and soil characteristics.[16] Much of the most suitable land lies in the Americas, particularly in Latin America and the Caribbean. In addition to land, the low population densities and abundance of forests in the Americas ensured an ample supply of fuel necessary for the processing of the sugar cane (Galloway, 2000, p. 443).

Sugar cane was first carried to the New World (from the Spanish Canary Islands) on Columbus' second voyage in 1493 and was first cultivated in Spanish Santo Domingo (Dominican Republic). By 1509, enslaved Africans we being imported to the Island, and by 1516 sugar was being exported to Europe. Soon after, the Portuguese also brought sugar cane across the Atlantic. By 1526, sugar was being exported from Brazil to Lisbon (Mintz, 1985, pp. 32–33). Beginning in the last two decades of the sixteenth century, the interests of the Dutch, English and French also turned to sugar production. Between 1630–1660, the Dutch, English and French began to found their own sugar colonies. The climate in the Americas provided such an advantage to New World sugar producers that by 1680, sugar cane production was dominated by the New World (Galloway, 2005, pp. 78–83).

One consequence of the large-scale production of sugar in the Americas was that, for the first time in human history, there was a large enough supply of the commodity that it could be consumed by the commoner in Europe. In England, the annual per capita consumption of sugar increase by twenty fold between 1663 and 1775, and it increased a further five fold between 1835 and 1935 (Sheridan, 1974, p. 21, Burnett, 1966, p. 274).

Sugar, providing a cheap and easy source of calories for the growing urban working class in Europe, was first consumed in tea and other hot drinks. During the 19th century, sugar consumption further increased as processed foods – such as jams, cakes and biscuits, canned vegetables and fruits, relishes, and white bread – became more common (Galloway, 2005, pp. 6–9).

It is hard to overstate the importance of sugar for the European masses. Hersch and Voth (2009) estimate that the increase in sugar availability between 1600 and 1850 increased European welfare by an amazing 8%. Anthropologist Sidney Mintz (1985, p. 180) even goes so far as to put forth a hypothesis about the importance of sugar for creating a industrial working class in the United Kingdom. He writes that sugar, "by provisioning, sating – and, indeed, drugging – farm and factory workers, sharply reduced the overall cost of creating and reproducing the metropolitan

[16]The data are publicly available and can be accessed from `http://www.iiasa.ac.at/Research/LUC/SAEZ/index.html`.

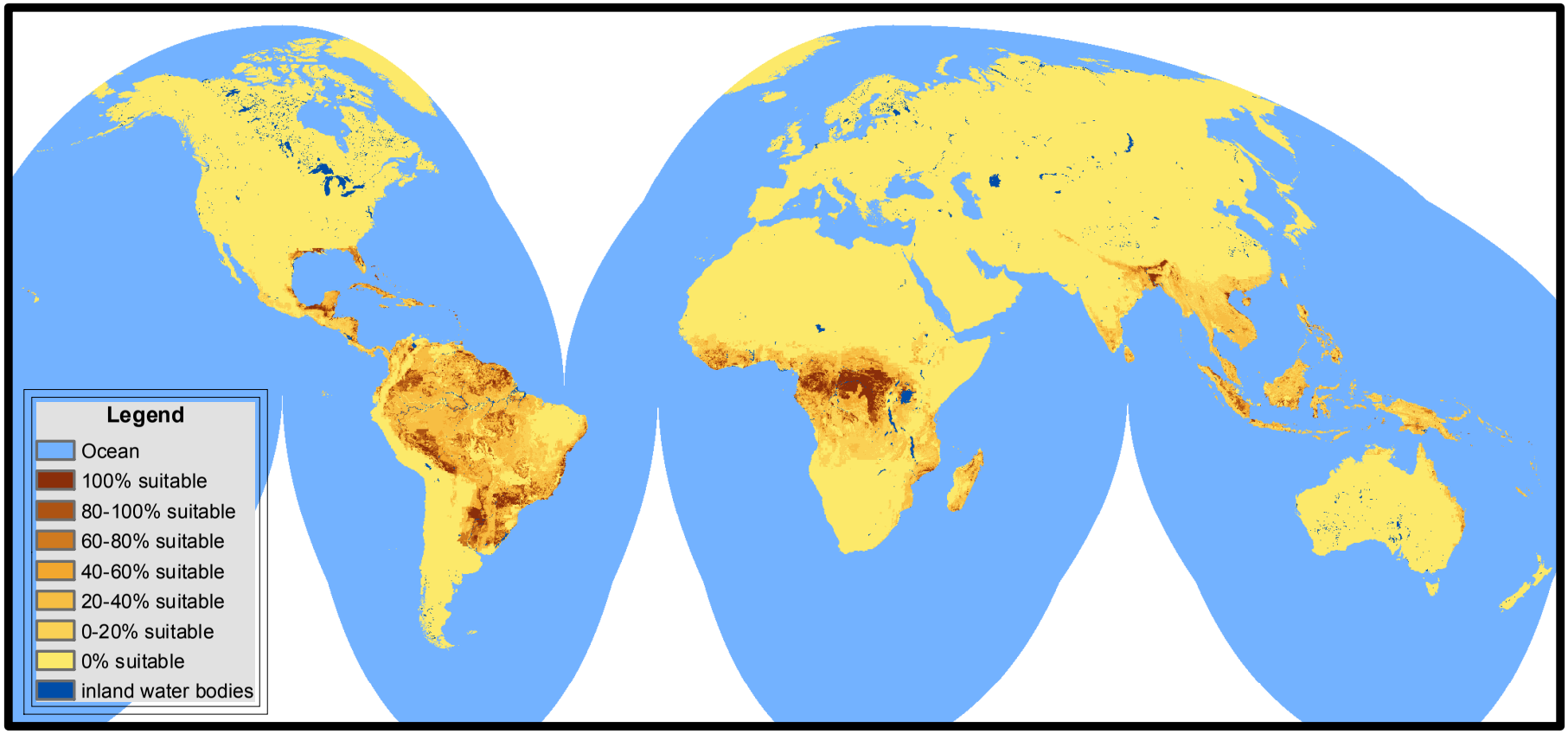

Figure 1: Global Distribution of the Suitability for the Cultivation of Sugar Cane.

Table 4: Top Producers of Old World Foods.

Sugar Cane		Coffee (Green)		Soybeans	
Country	**Production**	**Country**	**Production**	**Country**	**Production**
Brazil	327,704,992	Brazil	1,903,562	USA	75,055,288
India	299,230,016	Viet Nam	802,500	Brazil	32,734,958
China	69,298,730	Colombia	637,140	Argentina	20,135,800
Thailand	54,052,124	Indonesia	554,574	China	15,411,495
Pakistan	46,332,600	Côte d'Ivoire	380,000	India	5,275,800
Mexico	44,100,000	Mexico	338,170	Paraguay	2,980,060
Australia	38,164,688	Guatemala	312,060	Canada	2,703,000
Cuba	36,400,000	India	292,000	Bolivia	1,197,251
Colombia	33,400,000	Ethiopia	229,980	Indonesia	1,017,634
USA	32,762,070	Honduras	193,309	Italy	903,490

Oranges		Bananas		Sorghum	
Country	**Production**	**Country**	**Production**	**Country**	**Production**
Brazil	21,330,258	India	14,137,300	United States of America	11,951,910
USA	11,790,680	Ecuador	6,477,039	Nigeria	7,711,000
Mexico	3,812,683	Brazil	5,663,360	India	7,529,400
India	2,674,700	China	5,139,909	Mexico	5,842,308
Spain	2,616,220	Philippines	4,929,570	Argentina	3,344,493
Italy	1,876,182	Indonesia	3,746,962	China	2,608,456
Iran	1,843,564	Costa Rica	2,181,000	Sudan	2,488,000
Egypt	1,610,520	Mexico	1,863,252	Australia	2,115,912
Pakistan	1,328,000	Thailand	1,750,000	Ethiopia	1,188,080
China	1,180,631	Colombia	1,613,000	Burkina Faso	1,016,275

Notes : Data are from the FAO's ProdSTAT Database. All production figures are in tons for the year 2000.

proletariat."

Today, as shown in table 4, Brazil is the world's largest supplier of sugar cane. Other New World countries that are also top producers include Mexico, Cuba, Colombia, and the United States. Global production of sugar cane in 2000 was 1,252 million tons. Of this, 45% was produced in the Americas, with Latin America and the Caribbean accounting for 94% of the New World production.

4. Indirect Consequences of the Columbian Exchange

A. *Quinine: The New World's "Gift" to Europe's Old World Colonies*

Quinine, an important medicinal "gift" from the New World, had important consequences for the relationship between Europe and its tropical Old World colonies, particularly its African colonies. Quinine and related anti-malarial alkaloids (quinidine, cinchonine, cinchonidine) are derived from the bark of cinchona trees native to the Andes. The trees grow in scattered clumps in the eastern mountainous forests of Colombia, Ecuador, Peru and Bolivia betweens 10N and 20S at elevations between 800 to 3400 meters (Brockway, 1979, p. 108). Quinine was the first effective treatment of malaria caused by *Plasmodium falciparum*, the protozoan parasite that is transmitted

between mammals by the female Anopheles mosquito. Quinine works by inhibiting Plasmodium reproduction.

The use of quinine as a prophylactic was first discovered in 1841 by Dr. Thomas R. H. Thomson; the findings were later published in *The Lancet* (see Thomson, 1846). The British government, amidst the expansion of its empire into many malaria ridden regions, and seeing the potential benefits of quinine, encouraged the Royal Society to research the properties of quinine and explore the possibilities of farming it outside of the Andes. In 1858, recognizing the benefits of the cinchona tree, the British Botanical Gardens (headed by Kew Gardens, London) began the "cinchona transfer project" that aimed to ensure a stable, adequate, and cost-effective quinine supply to the colonizers of the British Empire.[17] The British were successful in transferring plants to Kew Gardens in London, Calcutta, and the Nilgiri Hills of India. Within decades, production was also expanded to Singapore and Dutch Java. Estimates suggest that by 1880, enough was produced to supply 10 million people with a daily dose (Hobhouse, 2006, p. 28).

The exact importance of quinine's use as an anti-malarial alkaloid is still being established by historians, but the evidence suggests that it was an important 'tool of empire' and significantly enhanced Europe's ability to colonize the tropical regions of the globe. Although debated (see e.g., Etemad, 2007), the traditional historiography recognizes quinine as having facilitated European survival in malaria ridden regions during the age of exploration and colonial expansion (Headrick, 1981). The standard view is that Europe's colonization of Africa would have been virtually impossible without quinine. Curtin (1961, p. 110) notes that "between 1819 to 1836 the average annual death rate per thousand mean strength of European troops on the West African coast was 483 for enlisted men, and 209 for officers. Between 1881 and 1897 the annual average death rate for officials was 76 in the Gold Coast and 53 in Lagos…since there were no further medical reforms between the 1850's and the 1880's comparable to quinine prophylaxis or the abolition of dangerous treatments, it is fair to assume that the medical reforms of the 1840's reduced European mortality on shore by at least half and perhaps more." Curtin concludes that "the history of tropical Africa would certainly have been very different if European mortality had continued at the old rate".

[17] This was an organized effort to buy, steal, bribe, and smuggle cinchona plants and seeds out of the Andes to London and colonial gardens in Ceylon and India (Brockway, 1979, pp. 115–117).

B. ***Rubber and the Heart of Darkness***

Rubber is made from latex, which is produced when the plants are cut or punctured. Although rubber can be made from many different plants around the world, the only commercially viable rubber plants are the *Hevea* rubber tree from Central and South America, and a wild vine that grows in West-Central Africa.

Historically, Africans made little use of rubber, except as an adhesive to fasten spearheads and arrowheads to their shafts (Loadman, 2005, p. 139). Native Americans, on the other hand, had developed methods to prevent the latex from decaying, which was accomplished by smoking the latex over fires to form spools of usable crude rubber. The rubber was used to create a wide range of items that were of central importance in their daily lives: hoods, boots, tents, balls, torches, jars, containers, syringes, toys, breastplates, rubber headed drum sticks, and adhesives.

Europeans did not recognize the benefits of rubber until 1770, when French naturalist Charles Marie de La Condamine noticed its use by Amazon Natives. The first commercial use of rubber was in the production of shoes, primarily from New England, in the early 19th century. However, the real boom for the rubber industry did not occur until the process of 'vulcanization' was discovered. This process includes heating the rubber and combining it with other chemicals to produce a more stable product with a wider range of uses.

Between 1851 and 1881 the world production of rubber increased from 2,500 to 20,000 tons annually (Hobhouse, 2003, p. 129). This boom, although significant, was modest compared to what was to come. The following three decades witnessed an explosion in the demand for rubber. Hobhouse (2003, p. 130) describes the rubber boom, which lasted from 1880 to 1910, writing that "rubber became the most important, most market-sensitive, most sought-after new commodity in the world." The rising demand for rubber was first driven by the rise of electricity, since rubber was used as an insulator. As well, the demand was also fed by the need for rubber to produce rubber tires for bicycles, and later for motorcycles and cars.

During this period rubber production was able to keep up with the rising demand, doubling every 3–5 years (Hobhouse, 2003, pp. 130–137). This was accomplished, in part, by an increase in supply from tropical regions outside of the Americas. In 1876, 70,000 *Hevea* rubber tree seeds were taken from Amazonia to Kew Botanical Gardens in Ceylon and Singapore by Sir Henry Wickham (Loadman, 2005, pp. 81–107). This was the genesis of the rubber industry that now exists in all

of Asia.[18] A second supplier of rubber during the period, one which became the most notorious example of European exploitation in sub-Saharan Africa, was the Congo region of West Central Africa. Here grew the only other indigenous plants that were able to provide commercially viable sources of natural rubber. Between 1900 and 1908, during the height of the boom, between 4,500 and 6,000 tons of rubber were exported each year from the Congo Free State.

The atrocities and human costs that were suffered in the production of rubber are well known and have been well documented (e.g., Hothschild, 1998). In an attempt to force natives to gather rubber, villages were burnt, groups were massacred, hostages were taken and often starved, and bodies were severely disfigured.[19] The population of the Congo is estimated to have been about 25 million prior the rubber boom, in the 1880s. In 1911, after the peak of the boom, the population was 8.5 million, and in 1923 after the completion of the boom, it was 7.7 million. If one compares the lives lost relative to the production of rubber, an astonishing conclusion is reached: one human life was lost for every 10 kilograms of rubber exported (Loadman, 2005, pp. 140–141).

C. *Forced and Voluntary Migrations to the Americas*

During the 16th–19th centuries, over 12 million Africans were shipped to the Americas during the trans-Atlantic slave trade, the largest involuntary migration in human history (Lovejoy, 2000, Manning, 1990, Nunn, 2008*b*). The trade was fueled by the high demand for labor in the Americas, which was driven, at least in part, by two aspects of the Columbian Exchange. The first was the spread of Old World diseases to Native Americans, which resulted in extremely low population densities in the New World. The second was the cultivation of highly prized Old World crops, such as sugar and coffee, that were particularly suitable for New World soils and climates.

The forced movement of African slaves to the Americas reached its height in the 18th century before slowing significantly in the 19th century. The trans-Atlantic slave trade slowed, first as a result of the British Slave Trade Act of 1807, that banned imports of slaves into British Colonies,

[18]The current domination of the rubber industry by Asian countries is shown in table 3. The top 6 producers of natural rubber are all Asian countries.

[19]This was also the beginning of the practice of cutting off the hands of men in this part of Africa. The exact motivation for the beginning of this practice is unknown. One possibility is that soldiers did this in response to a Belgian policy to save bullets. To make sure that the soldiers did not waste the bullets in hunting animals, their officers demanded to see the amputated right hand of every person they killed. Hothschild (1998, p. 165) writes that "the standard proof was the right hand from a corpse. Or occasionally not from a corpse. 'Sometimes', said one officer to a missionary, 'soldiers shot a cartridge at an animal in hunting; they then cut off a hand from a living man'."

and later the British Slavery Abolition Act of 1837, which abolished any use of slave labor within the British colonies.

In response to the abolition of the slave trade, many employers resorted to bonded labor contracts for cheap labor. Most of the migration occurred between Europe's Old and New World colonies. Caribbean plantations provided the main demand for laborers from French Indochina and the British colonies in Asia. For example, over half a million indentured laborers were moved from the Indian subcontinent to the British Caribbean during the 19th century and the beginning of the 20th century (Williams, 1962, p. 100).[20] China, after its forced opening to the West upon losing the Opium Wars (in 1842 and 1860), provided another important source of indentured labor. Employers of these "coolies" included guano pits, cotton and sugar industries in Peru, sugar cane fields in Cuba (following the abolition of slavery in 1886), and railways in the United States and British Columbia.

Although most indentured laborers entered servitude voluntarily, many parallels can be drawn between the harsh conditions of slavery and those faced by the indentured laborers.[21] For example, many would die on the voyage to the Americas, where crowded conditions and malnutrition made the laborers vulnerable to disease. In 1865, on a transportation from Macao to Tahiti, only 162 the 550 Chinese on board survived (Castro de Mendoza, 1989, p. 45). And like slaves who were denied the rights of ordinary citizens, indentured laborers were often denied the right to naturalize and obtain citizenship after their contracts were over.

The 19th and 20th centuries also witnessed a dramatic increase in voluntary migrations from the Old World. Between 1851 and 1924 alone, 45 million people migrated from the Old World to the Americas, with the majority, 34 million, choosing to migrate to the United States. Those that migrated to Latin America primarily went to Argentina and Brazil. Between 1850 and 1940, 7 million went to Argentina and 4.5 million to Brazil (Crosby, 2003, pp. 214–215).

A recent data construction effort by Putterman and Weil (2009) provides complete estimates of the extent of post-1492 population flows from the Old World to the New World. The authors construct a matrix showing the share of a country's current population (in 2000) whose ancestors were originally from other countries of the world. Using this matrix, we are able to calculate, for

[20]Over 238,000 Indians were introduced to British Guiana, 145,000 to Trinidad, 21,500 to Jamaica, 39,000 to Guadeloupe, 34,000 into Surinam, 1,500 into St. Lucia, 1,820 into St. Vincent, 2,570 into Grenada, and over 6,000 into Martinique (Williams, 1962, p. 100).

[21]See Northrop (1995, pp. 4–10) for a detailed discussion.

Table 5: Historic migrations from the Old World to the New.

	Share of population in 2000 that is of:		
Country	Old World origin	African origin	European origin
Haiti	1.00	0.98	0.03
Dominican Republic	1.00	0.48	0.52
Trinidad and Tobago	1.00	0.46	0.07
Puerto Rico	1.00	0.16	0.84
Canada	0.97	0.02	0.76
Uruguay	0.96	0.04	0.91
Guyana	0.95	0.39	0.00
Brazil	0.95	0.20	0.19
Argentina	0.95	0.02	0.84
United States	0.91	0.12	0.67
Costa Rica	0.91	0.03	0.87
Colombia	0.69	0.13	0.56
Chile	0.67	0.00	0.65
Panama	0.64	0.13	0.45
Venezuela	0.64	0.10	0.54
Belize	0.62	0.16	0.41
Nicaragua	0.60	0.09	0.51
Paraguay	0.54	0.01	0.52
El Salvador	0.50	0.00	0.50
Honduras	0.48	0.02	0.46
Ecuador	0.42	0.04	0.38
Peru	0.37	0.01	0.34
Mexico	0.31	0.01	0.29
Bolivia	0.30	0.00	0.30
Guatemala	0.27	0.01	0.26

Notes: Data are from Louis Putterman and David Weil's *World Migration Matrix, 1500-2000* . The table shows the proportion of the population of New World countries in 2000 that are descended from individuals living in the Old World, Africa, and Europe in 1500. See Putterman and Weil (2008) for full details.

the 25 New World countries in their sample, the share our their current populations originally from the Old World. These figures are reported in the first column of table 5. The share ranges from 27% for Guatemala to 100% for the New World Island economies of Dominican Republic, Haiti, Puerto Rico, and Trinidad and Tobago. In the second and third columns of the table, we further disaggregate the population share from the Old World into the share from Europe and the share from Africa.[22] For many countries, a significant portion of their population is from either Africa (e.g., 98% for Haiti) or from Europe (e.g., 91% for Uruguay or 87% for Costa Rica).

5. Concluding Thoughts

Our aim has been to provide a historical overview of the effects of the Columbian Exchange with a particular emphasis on aspects of the Exchange that have generally been ignored by economists. At this point, we can only speculate about the magnitude of the full welfare consequences of the Columbian Exchange. Certainly, for many parts of the world, like Europe, there were clear gains from the trade. The New World provided virgin soils that were very suitable for the cultivation of a variety of products, like sugar and coffee. The increased supply lowered the prices of these products significantly, making them affordable to the general population for the first time in history. The production of these products also resulted in large inflows of profits back to Europe, which some have argued, fueled in the industrial revolution and the rise of Europe (Inikori, 2002, Acemoglu *et al.*, 2005).

Europe, and the rest of the Old World, also gained access to new crops that were widely adopted. Potatoes were embraced by the Irish and the Eastern European societies, chili peppers by the cultures of South and Southeast Asia, tomatoes by Italy and other Mediterranean societies, and tobacco by all nations of the world. The welfare gains from the exchange of food crops during the Columbian Exchange may be the most easily quantifiable. Recent studies, like Mokyr (1981), Nunn and Qian (2009), and Hersch and Voth (2009) have taken initial steps in this direction.

Although it is clear that certain parts of the world gained from certain aspects of the Exchange, it is also clear that certain groups were devastated. Native American populations were completely decimated by Old World diseases.[23] The Exchange also had indirect negative effects for other parts of the world. The movement of Old World crops like sugar cane and coffee, along with the

[22] We do not reported the share from all other parts of the Old World.

[23] Although we have not focused on it, this was also true for flora and fauna native to the Americas. See Crosby (2003) for a discussion.

depopulation of Native Americans that resulted from the spread of Old World diseases, fueled the demand for labor during the trans-Atlantic slave trade. The result was the forced movement of over 12 million slaves from Africa to the Americas, and devastating political, social, and economic consequences for the African continent. Beyond the slave trade, Africa was also affected by European colonial rule, which was facilitated by the discovery of quinine, from the New World. As well, the knowledge of how to harvest and process rubber, learned from Natives of the Andes, had particularly regrettable consequences for those in Africa's Congo region.

A vast literature has emerged focusing on an important aspect of the Columbian Exchange. How transplanted European institutions affected the political and economic development of the New World. However, as we have shown the exchange had much broader consequences that affect both the New and Old Worlds. We are aware of only a handful of empirical papers that investigate the broader effects of the Exchange. Our hope is that our descriptive overview will spur further research examining broader aspects of the Columbian Exchange, particularly its effect on the Old World, and the impacts arising from the exchange of disease, foods, and ideas between the two Worlds.

References

Acemoglu, Daron, María Angélica Bautista, Pablo Querubin, and James A. Robinson. 2008. Economic and political inequality in development: The case of Cundinamarca, Colombia. In Elhanan Helpman (ed.) *Institutions and Economic Performance*. Cambridge, MA: Harvard University Press.

Acemoglu, Daron, Simon Johnson, and James A. Robinson. 2001. The colonial origins of comparative development: An empirical investigation. *American Economic Review* 91:1369–1401.

Acemoglu, Daron, Simon Johnson, and James A. Robinson. 2005. The rise of Europe: Atlantic trade, institutional change and economic growth. *American Economic Review* 95:546–579.

Andrews, Jean. 1992. The peripatetic chili pepper: Diffusion of the domesticated capsicums since columbus. In Nelson Foster and Linda S. Cordell (eds.) *Chilies to Chocolate: Food the Americas Gave the World*. Tucson: University of Arizona Press, 81–93.

Basu, A. and V. Imrhan. 2007. Tomatoes versus lycopene in oxidative stress and carcinogenesis: Conclusions from clinical trials. *European Journal of Clinical Nutrition* 61(3):295–303.

Berkowitz, Daniel and Karen Clay. 2005. American civil law origins: Implications for state constitutions. *American Law and Economics Review* 7(1):62–84.

Berkowitz, Daniel and Karen Clay. 2006. The effect of judicial independence on courts: Evidence from the American states. *Journal of Legal Studies* 35:399–400.

Brockway, Lucile H. 1979. *Science and Colonial Expansion: The Role of the British Royal Botanical Gardens*. New York: Academic Press.

Broda, Christian and David Weinstein. 2006. Globalization and the gains from variety. *Quarterly Journal of Economics* 121(2):541–585.

Brooks, Jerome Edmund. 1952. *The Mighty Leaf: Tobacco through the Centuries*. Boston: Little, Brown and Company.

Bruman, Henry. 1948. The culture history of Mexican vanilla. *Hispanic American Historical Review* 28(3):360–376.

Burnett, John. 1966. *Plenty and Want*. London: Thomas Nelson.

Castro de Mendoza, Mario. 1989. *El transporte marítimo en la inmigración China, 1849–1874*. Lima, Peru: Consejo Nacional de Ciencia y Tecnología.

Cochran, William G., Emanuel Farber, Louis F. Frieser, Jacob Furth, John B. Hickman, Charles Le Maistre, Leonard Schuman, Maurice H. Seevers, Stanhope Bayne-Jones, and Walter J. Burdette. 1964. *Smoking and Health: Report of the Advisory Committee to the Surgeon General of the Public Health Service*. Washington, D.C.: US Department of Health, Education, and Welfare.

Cook, Noble David. 1993. Disease and depopulation of Hispaniola, 1492–1518. *Colonial Latin American Review* 2:213–245.

Cook, Noble David. 1998. *Born to Die: Disease and New World Conquest, 1492–1650*. Cambridge: Cambridge University Press.

Crosby, Alfred W. 1989. Reassessing 1492. *American Quarterly* 41(4):661–669.

Crosby, Alfred W. 2003. *The Columbian Exchange: Biological and Cultural Consequences of 1492*. Westport, CT: Praeger Publishers.

Curtin, Philip D. 1961. The white man's grave: Image and reality, 1780-1850. *Journal of British Studies* 14:95–110.

Dean, Warren. 1987. *Brazil and the Struggle for Rubber: A Study in Environmental History*. New York: Cambridge University Press.

Dell, Melissa. 2008. The mining mita: Explaining institutional persistence. Mimeo, MIT.

Denevan, William M. 1976. Introduction. In William M. Denevan (ed.) *The Native Population of the Americas*. Madison, Wisconsin: University of Wisconsin Press, 1–12.

Diamond, Jared. 1997. *Guns, Germs, and Steel*. New York: W.W. Norton & Company.

Dobyns, Henry F. 1966. Estimating aboriginal American population: An appraisal of techniques with a new hemispheric estimate. *Current Anthropology* 7:395–416.

Dobyns, Henry F. 1983. *Their Number Become Thinned*. Knoxville: Univeristy of Tennessee Press.

Dobyns, Henry F. 1993. Disease transfer at contact. *Annual Review of Anthropology* 22:273–291.

Engerman, Stanley L. and Kenneth L. Sokoloff. 1997. Factor endowments, institutions, and differential paths of growth among New World economies: A view from economic historians of the United States. In Stephen Harber (ed.) *How Latin America Fell Behind*. Stanford: Stanford University Press, 260–304.

Etemad, Bouda. 2007. *Possessing the World: Taking the Measurements of Colonisation from the Eighteenth Century to the Twentieth Century*. New York: Berghahn Books.

Galloway, J.H. 2000. Sugar. In Kenneth F. Kiple and Kriemhild Coneè Ornelas (eds.) *Cambridge World History of Food*. Cambridge: Cambridge University Press, 437–449.

Galloway, J.H. 2005. *The Sugar Cane Industry: An Historical Geography from its Origins to 1914*. Cambridge: Cambridge University Press.

Gould, Wilbour A. 1983. *Tomato Production, Processing and Quality Evaluation*. Westport, CT: AVI Publishing Co.

Halasz, Zoltan. 1963. *Hungarian Paprika Through the Ages*. Budapest: Corvina Press.

Harper, Kristin N., Paolo S. Ocampo, Bret M. Steiner, Robert W. George, Michael S. Silverman, Shelly Bolotin, Allan Pillay, Nigel J. Saunders, and George J. Armelagos. 2008. On the origin of the treponematoses: A phylogenetic approach. *Public Libary of Science: Neglected Tropical Diseases* 2(1):1–13.

Headrick, Daniel R. 1981. *Tools of Empire: Technology and European Imperialism in the Nineteenth Century*. Oxford: Oxford University Press.

Hersch, Jonathan and Hans-Joachim Voth. 2009. Sweet diversity: Colonial goods and the rise of European living standards after 1492. Mimeo, University of Pennsylvania.

Hobhouse, Henry. 2003. *Seeds of Wealth: Four Plants that Made Men Rich*. Oxford: MacMillan.

Hobhouse, Henry. 2006. *Seeds of Change: Six Plants That Transformed Mankind*. New York: Counterpoint.

Hothschild, Adam. 1998. *King Leopold's Ghost*. New York: McMillan.

Inikori, Joseph E. 2002. *Africans and the Industrial Revolution in England: A Study in International Trade and Economic Development*. Cambridge: Cambridge University Press.

Jha, Prabhat. 1999. *Curbing the Epidemic: Governments and the Economics of Tobacco Control*. Washington, D.C.: World Bank.

Kroeber, Alfred L. 1939. Cultural and natural areas of native North America. *University of California Publications in American Archaeology and Ethnology* 38.

La Porta, Rafael, Florencio Lopez-de-Silanes, Andrei Shleifer, and Robert Vishny. 1997. Legal determinants of external finance. *Journal of Finance* 52:1131–1150.

La Porta, Rafael, Florencio Lopez-de-Silanes, Andrei Shleifer, and Robert Vishny. 1998. Law and finance. *Journal of Political Economy* 106:1113–1155.

Loadman, John. 2005. *Tears of the Tree*. Oxford: Oxford University Press.

Lovejoy, Paul E. 2000. *Transformations in Slavery: A History of Slavery in Africa, Second Edition*. Cambridge, UK: Cambridge University Press.

Mackay, Judith, Michael Eriksen, and Omar Shafey. 2006. *The Tobacco Atlas*. Brighton, UK: Myriad Editions Ltd.

Manning, Patrick. 1990. *Slavery and African Life*. Cambridge, UK: Cambridge University Press.

Mintz, Sidney W. 1985. *Sweetness and Power: The Place of Sugar in Modern History*. New York: Penguin Books.

Mitchener, Kris James and Ian W. McLean. 2003. The productivity of U.S. states since 1880. *Journal of Economic Growth* 8:73–114.

Mokyr, Joel. 1981. Irish history with the potato. *Irish Economic and Social History* 8:8–29.

Morren, Charles. 1838. On the production of vanilla in Europe. *Annals of Natural History* 1(3):1–9.

Newson, Linda. 2001. Pathogens, places and peoples. In George Raudzens (ed.) *Technology, Disease and Colonial Conquest, Sixteenth to Eighteenth Centuries*. Boston: Brill, 167–210.

Northrop, David. 1995. *Indentured Labor in the Age of Imperialism, 1834–1922*. New York: Cambridge University Press.

Nunn, Nathan. 2008*a*. Slavery, inequality, and economic development in the Americas: An examination of the Engerman-Sokoloff hypothesis. In Elhanan Helpman (ed.) *Institutions and Economic Performance*. Cambridge, MA: Harvard University Press, 148–180.

Nunn, Nathan. 2008*b*. The long-term effects of Africa's slave trades. *Quarterly Journal of Economics* 123(1):139–176.

Nunn, Nathan. 2009. The importance of history for economic development. *Annual Review of Economics* 1(1):65–92.

Nunn, Nathan and Nancy Qian. 2009. The potato's contribution to population and urbanization: Evidence from an historical experiment. NBER Working Paper 15157.

Oduro, Abena D. 2000. Performance of the external trade sector since 1970. In Ernest Aryeetey, Jane Harrigan, and Machiko Nissanke (eds.) *Economic Reforms in Ghana: The Miracle and the Mirage*. Asmara, Ethiopia: Africa World Press, Inc., 168–184.

Penn, W.A. 1901. *The Soverane Herbe: A History of Tobacco*. New York: E.P. Dutton & Co.

Putterman, Louis and David Weil. 2009. Post-1500 population flows and the long run determinants of economic growth and inequality. Mimeo, Brown University.

Sheridan, Richard B. 1974. *Sugar and Slavery*. Barbados: Caribbean University Press.

Sherman, Irwin W. 2007. *Twelve Diseases that Changed our World*. Washington, DC: ASM Press.

Smith, Andrew F. 1994. *The Tomato in America: Early History, Culture, and Cookery*. Columbia, South Carolina: University of South Carolina Press.

Snodgrass, Mary Ellen. 2003. *World Epidemics: A Cultural Chronology of Disease from Prehistory to the Era of SARS*. Jefferson, North Carolina: McFarland & Company, Inc.

Sokolov, Raymond. 1993. *Why We Eat What We Eat? How Columbus Changed the Way the World Eats*. New York: Simon & Schuster.

Thomson, Thomas R.H. 1846. The value of quinine in African remittant fever. *The Lancet* 47(1174):244–245.

U.N. Office on Drugs and Crime. 2008. *World Drug Report 2008*. New York: United Nations Publications.

U.N. Office on Drugs and Crime. 2009. *Columbia Coca Survey 2008*. New York: United Nations Publications.

West, John A. 1992. A brief history and botany of cacao. In Nelson Foster and Linda S. Cornell (eds.) *Chilies to Chocolate: Food the Americas Gave the World*. Tucson: University of Arizona Press, 105–121.

Williams, Eric. 1962. *History of the People of Trinidad and Tobago*. London: Andre Deutsch.