African Contributions to Science, Technology and Development

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Introduction

Scientific discovery and the application of technology to the natural environment have been essential to the history of Africa and in the development of the African diaspora throughout the world, and especially in the Americas. When Africans migrated, whether under conditions of slavery or as voluntary travelers, they took with them knowledge of agricultural techniques and skills in exploiting the nature environment that were necessary for development. As people have done elsewhere in the world as well, Africans depended for their survival upon the ability to adapt successfully to specific ecological settings and to apply acquired knowledge in a manner that increased production and otherwise enhanced the quality of life.[*]

The African contribution to science and technology can be appreciated with respect to the impact on the development of the Americas, which suffered severe population destruction through disease and European conquest after 1492. Spain, Portugal and then other western European countries took advantage of military superiority and the demographic catastrophe in the Americas to confiscate vast tracts of land, which only needed labor and transferred technology for its development. Europeans empires and the generation of enormous wealth depended upon the combination of these ingredients – virtually free and very fertile land, labor and technology, largely from Africa, and the ability to garner huge profits through the reliance on slavery, in which workers were not paid for their labor or their technology. It is crucial to note that none of the major plantation crops in the Americas and only a few of the foodstuffs consumed by people in the Americas came from western Europe, while virtually all of the newly introduced crops originally came from Africa or were grown there before their introduction to the Americas. Sugar cane was first grown in the Mediterranean and in southern Morocco before spreading to other offshore islands and then to the Americas. Cotton was grown and made into textiles in the western Sudan and in the interior of the Bight of Benin for centuries before being

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introduced to the Americas, along with weaving, indigo dyeing, and the decorative arts associated with textiles. Rice, indigenous to West Africa, was introduced into the sea islands of South Carolina and Georgia, as well as the Mississippi valley, Maranhão in northeastern Brazil, and elsewhere, while numerous foodstuffs and stimulants were transferred from Africa as well. As Judith A. Carney and Richard Nicholas Rosomoff have established that Africans established "botanical gardens of the dispossessed," in which they cultivated many familiar foods, including millet, sorghum, coffee, okra, watermelon, and the "Asian" long bean, for example, all of which were native to Africa. Archaeological records, oral histories, and even documentary evidence of European slave owners and merchants demonstrate that Africans in diaspora planted many of the same crops that were grown in Africa for their own subsistence, and in the course of doing so African farms and gardens became the incubators of African survival in the Americas and Africanized the ways of nourishing the plantation societies of the Americas.

The transfer of knowledge has sometimes been called the "Columbian" exchange to emphasize the transfer of disease and botanical knowledge across the Atlantic, as if ships transferred knowledge and not people. Knowledge was transferred in two ways; what people took with them to the Americas in their heads, from their own experience and training, through efforts at copying what can be observed and involving subsequent experimentation. The reference to this exchange as "Columbian," however privileges European agency, when we know that the exchange of knowledge and the transfer of technology were a much more complicated processes. The exchange of knowledge focused on what was known in Amerindia and Africa, and also indeed Asia and included knowledge from the Islamic sciences as well. We now know that indigenous knowledge of botany and zoology was crucial in the evolution of modern science. Similarly, the application of technology to develop such commercial products as Coca Cola, Worcestershire Sauce, and palm-oil based soap rely on African plants that first came to the notice of Europe and the Americas through the activities of slave ships.

While it may have been possible that these crops and skills would have reached the Americas anyway, the fact is that the transfer of technology and the accumulation of scientific knowledge underlying that technology were done under conditions of slavery. Why it was possible to use slave labor to generate development is still not clear, since all these commodities can be produced otherwise, but nonetheless that is how the technology and science of Africa was harnessed to the benefit largely of western Europe and its colonies, not Africans and their descendants, despite their contributions and involvement in technology transfer and development. It is not clear why crops that were grown under conditions of both family and communal labor in Africa were grown under conditions of slavery in the Americas. Slavery was not the innovation, since slavery also existed in Africa. Indeed many of the same crops, such as rice and cotton, were produced under conditions of slavery in Africa, including plantations in which scores and hundreds of individuals produced crops. The question remains, therefore, as to what was innovative in the production of crops in the Americas. The answer is that it was possible, through conditions of slavery, and in a situation in which land could be "claimed" and moreover fought over in European wars, at no cost, other than the wars, to become productive and benefit a class of individuals from western Europe through two layers of theft – the land and the labor. Some scholars have referred to these developments as a product of entrepreneurship, but this conceptualization neutralizes what later generations would consider crimes against humanity and injustice to indigenous communities and their rights to the land they occupied and should still be theirs.

Any examination of African contributions to science and technology is hampered by the problem arising from racialized views of history and the relegation of Africa to an "underdeveloped" or "undeveloped" stereotype. It might seem that the political history of the post-colonial era in Africa has been unstable, with corresponding economic stagnation and poverty. Hence there is the image that Africa is the poor cousin of the global community, backward, suffering and incapable of intellectual contributions that might contribute to development. Despite this image, the fact is that Africans and the descendants of Africans are gainfully employed as doctors, scientists, engineers, and professors in Europe, North America, Latin America and the Caribbean, as well as in continental Africa, which demonstrates the important contributions of Africans to development.

The legacy of slavery, both in the form of chattel slavery in the Americas and with the domestic slavery within Africa, is seen as undermining and limiting African contributions to development, but especially in terms of the diaspora of enslaved Africans in the Americas and also in the Islamic world. Slavery suggests to many people a victimization that impeded if not prevented the conveyance of knowledge, whether to the Americas or to the Islamic world. The image of African "slaves" as savage, barbaric, primitive and tribal only reinforces the stereotype that Africa had nothing to offer in terms of scientific knowledge or practical technology. If

Africans were involved in development, this stereotype holds, it was only through the forceful application of their brute labour. A more unbiased view of past achievements would establish that the crop development and related technologies largely originated in Africa, not Europe, and the European contribution to development was the forceful transfer of skills and knowledge from Africa across the Atlantic and the accumulation of capital through appropriation.

There are many problems with the stereotypes of African underachievement that have to be addressed. First, it is not true that Africa was a continent of little achievement. We can re-examine the contributions in various areas, especially agriculture, mining, and pharmacology, that will demonstrate that the contributions in these areas alone have been important. Moreover, it is argued here, we must overcome narrow conceptions of science and technology that undermine our understanding of development – how things happen and what it has taken in terms of human intellect to achieve practical goals and improve standards of life. A review of African contributions to science, technology and development asks the crucial question: why was slavery necessary in the "development" of the Americas? Wasn't it possible to have achieved similar or even better results without slavery? Why has it been popular to conceive of development as a product of science and technology, as if slavery has not existed? Would not the scientific and technological development of the modern world have been greater without slavery? These questions frame this discussion of African contributions to development and challenge the stereotype that Africans have made only marginal, if any, contributions to modern science and technology. Rather, it can be shown that slavery stripped Africa of more than just people who might have helped in the development of Africa, but the forced migration also confiscated technological knowledge that was based on previous experience and training that was transformed in the Americas.

Slavery was particularly inefficient in allocating skilled people to where their skills were needed most, but this was the way technology was transferred for purposes of development to benefit the few. The fact that slaves were not paid meant the cost of their labor was the purchase price and the investment in subsistence beyond what the slaves themselves could sustain in their own gardens. While technical skills and scientific knowledge were transferred, slavery nonetheless involved a form of exploitation that required unskilled, brute labor that minimized technology and was exposed to even less science. How is it, one might ask, that one of the ancestors of the modern, scientific world is slavery, whose legacy is the under appreciation of the knowledge of Africans?

The failure to recognize African contributions to science and technology demonstrates that conceptions of scientific knowledge have been racialized, as if knowledge and discovery bear some correlation with the color of skin. The classification of nature and the exploration of the environment for practical application are universal, whether in the Arctic or the tropics and whether in Africa, Asia or Europe. The development of the modern disciplines of botany, zoology, pharmacology, and medicine has occurred because of classification, comparative methodologies that emphasize the discipline of observation, and experimentation that attempts to verify results. To some extent what is often considered to be modern science has developed in isolation from bodies of knowledge that were developed in non-western locations, such as China, the Islamic world, the indigenous Amerindian populations of the Americas, and Africa. Modern science to some extent has been based on a racialized premise: if it is not “discovered” in a European or North American laboratory, there has been no discovery and it is not science. It is only recently, that “scientists” have increasingly turned to bodies of knowledge that derive from alternate systems of classification and analysis.

A botanical vocabulary in Yoruba, based on scientific knowledge collected in Bahia by Pierre Verger, not in Nigeria, is over 700 pages. If the knowledge of botany in Nigeria were added to this compendium, the encyclopedia would be more extensive. This scientific knowledge has considerable pharmacological significance. Similarly, the chemical composition of the numerous salts of the central Sahara and the Lake Chad basin was generally understood in terms of the applications in pharmacology, cuisine, tanning, textile dyeing, and veterinary care. The distinctions between sulfates, carbonates, and chlorides was recognized, and to some extent efforts were made to isolate these various salts in a manner that reveals a level of scientific enquiry that was certainly transferrable to the Americas. Both Yoruba botany and the scientific knowledge underlying Central Sudan salts demonstrate a scientific sophistication that was transferred within West Africa and to the Americas and the African diaspora there.

A distinction clearly has to be made between the ability of transferring knowledge and whether or not knowledge that arose from discovery in Africa was actually transferred. Besides its brutality and arbitrariness, slavery was not an efficient method of transferring actual knowledge that could be applied, although as in the case of rice cultivation and perhaps in tending livestock and growing cotton and indigo there was some direct transfer. Individuals who were enslaved in Africa were not enslaved because of their skills or knowledge, but rather for political, opportunistic and occasionally religious and legal reasons. There was no thought about reallocating knowledge or harnessing brain power for purposes of technology and development. That was not the purpose of slavery, but individuals who were enslaved had skills and specialized knowledge that could be and often were transferred.

To some extent an actual transfer of scientific and technological knowledge was coincidental, not intentional, therefore. Hence the enforced migration of Africans to the Americas was based solely on the desire for brute labor, not specific skills, although the realization that some individuals were literate, or had been blacksmiths, or knew how to grow rice or tend cattle were benefits that almost entirely accrued to the slave owner. The movement of enslaved Africans within the Islamic world also was not focused on skills or knowledge. Specialization in "skills" was a factor, as in the market for eunuchs and the demand for concubines, but neither specialization was related to science or technology. Eunuchs and concubines might well find themselves close to those in power and therefore could acquire knowledge and even affect decisions relating to development. However, their background knowledge of science and technology was not essential and often was unimportant. Hence slavery almost always intercepted the transfer of knowledge and undermined the maximization of technology. Ironically, therefore, the "European" and "western" worlds have often received credit for the advancement of science and the application of technology for development. Yet if one looks in the laboratories and colleges of the world today, there is no racialized environment. It is as if the world is finally catching up with the realization that science and technology rose from the collective knowledge of the human experience. The fact that laboratories and universities today are staffed by individuals from all parts of the world has to be taken into consideration in evaluating the African contribution to science and technology. In doing so, it is important to recognize that one of the consequences of slavery has been that African contributions to science and technology have not been recognized. This denial of contribution and the misappropriation of the knowledge of Africans are further reasons why slavery has been defined as a crime against humanity. The type of development that occurred in the colonial context with slavery, dominated by European and American regimes, was distorted in several important ways, including who benefited from the application of technology and who has received credit for scientific discovery. The failure to recognize African contributions therefore explicates the extent of the criminality.

This introduction to the African contributions to science, technology and development begins with the dawn of civilization and the domestication of agriculture, which introduced crops that have long continued to be important in food production. The African contribution in agriculture alone shaped the Americas, as the underlying technologies of production were applied in new settings, albeit under conditions of slavery. This included specialization in livestock production. Without these agricultural skills, there would have been little point in relying on African labor for the development of the Americas. Considering that many crops were indigenous to Africa or relied on technologies originating in Africa, it is essential to understand the history of agricultural change in Africa and to appreciate that the development of the Americas through the transfer of knowledge from Africa paralleled the continued development of agriculture through applied technologies in Africa, as elsewhere in the world. Africa imported new crops, such as tobacco, cassava, and maize from the Americas, and new strains of crops, such as Asian rice, bananas and plantains, to increase production and improve outputs. Similarly, an examination of manufacturing and industry demonstrates African contributions in textile and leather manufacturing, salt and mineral production and industrial development. Also Africans made important contributions in architecture, such as in mosque construction and in the churches of Coptic Ethiopia.

Once the African contributions to science and technology are examined, it is possible to counter the ignorance and racialized interpretations that have been extended to people of Africa and the African diaspora today. The contributions of African peoples through innovation in science and technology have helped shape the modern world. In Africa these achievements related to environment and society, and the desire to overcome the limitations of ecologies and maximize the ability to exploit natural resources for human needs and wants. In the African diaspora, some of these achievements were forcibly transferred across the Atlantic through the use of the labor, talents and knowledge of enslaved Africans, who were not only enslaved for their labor but also deprived of their dignity through the denial of their intellectual achievements. African contributions not only influenced the development of the continent of Africa but also the broader Atlantic, Islamic and Indian Ocean worlds.

Although racial stereotypes and xenophobia that deny or minimize the extent of African contributions have sometimes been accepted, the historical record demonstrates the opposite – as in other parts of the world, people adjusted to their environment, sought ways to improve output, increase production and raise living standards. Technology was harnessed in accordance to the extent of local skills and knowledge. The African continent was not isolated from other parts of the world, and the movement of people and ideas were crucial to the development of Africa but also wherever Africans were found in diaspora. An understanding of the African contributions to science, technology and development must also account for the enterprise and activities of Africans in diaspora. The purpose of this essay is to provide examples of African achievements as a means to provide a factual basis to counter racial and ethnic stereotypes and otherwise disseminate the new knowledge about African enterprise to a global audience.

The Dawn of Civilization

African contributions to the ancient world are well known. The pyramids of Egypt attest to the skills of engineering and architecture. Classical Egypt crossed all the frontiers of northeastern Africa and southwestern Asia. The populations of this area were mixed. Those who built the pyramids included Africans from the middle and upper Nile River valley, as well as people from the Mediterranean and elsewhere. The technology and the science behind the technology were not racialized but crossed many cultures. Similarly, the Nok culture of what is now central Nigeria displays an antiquity in art forms that reveal knowledge of metallurgy and stone sculpture that has similarities to other parts of the world. This is important to recognize; technological and scientific breakthroughs occurred independently in many parts of the world. The spread of iron technology is a case in point. Africans could transfer the skills of blacksmithing to the Americas because these skills were ancient in Africa. If anything, some African skills were not transferred into diaspora, such as the ability to work in other metals, including bronze and silver. Generally, there was no need for these skills in plantation America, while there was a need for skills in working iron. This is but one example of the types of technological knowledge that were common in Africa but were not transferred into diaspora but rather the skills were lost, retarding development. Once again we see the inefficiency of slavery as a system; the exploitation of people as slaves tended to undermine the transfer of skills.

The construction of ancient monuments, palaces and temples in the Nile valley demonstrates an architectural tradition that was continued in the construction of mosques in West Africa and along the East African coast, as well as churches in Ethiopia. The knowledge of mathematics and engineering is ancient and was closely tied to the availability of building materials. In the Americas, architectural contributions can be seen in the construction of forts and churches, especially in Cuba and mainland Latin America, where Africans and people of African descent were involved in both construction and maintenance. Many of the palaces, mosques, temples, churches, and fortifications have been designated UNESCO Heritage sites from medieval times onward. The ancient pyramids of the Nile valley demonstrate that the issue of what was "African" and what was not is a question of definition. Certainly the pyramids are unique and as much a part of the history of African contributions to technology and development. Also to be highlighted will be Zimbabwe, the Ethiopian Coptic churches, the Islamic architecture of the East African coast. The spread of adobe mosque and palace construction associated with the tradition of al-Sahili can be highlighted. In addition, African skills in architecture and construction spread to the diaspora. Some of the cathedrals of Hispanic America, dating from the 16th to the 18th centuries, as well as fortifications, were built by architects who were of African descent. Similarly, Africans, many from what is now Ghana, constructed all the buildings in the colonial town of Newport, Rhode Island, as they did in Kingston, Jamaica, and elsewhere.

The Domestication of Agriculture

It is clear that African contributions to agriculture have underpinned the development of the African continent and to a great extent the Americas as well. This can be seen with respect to several agricultural innovations, including the domestication of millet/sorghum, rice, yams, kola, and coffee. The base line for understanding the contribution of Africans to agricultural development, both in Africa and then in the Americas, is the emergence of civilizations that are reflected in the sculpture of the Nok complex in Nigeria and the enclosures of Zimbabwe in southern Africa. Agriculture, including animal husbandry, evolved independently in Africa, which in a real sense was not only the origin of all people but also the cradle of food production, crop specialization, and experimentation in systems of agriculture and transhumance livestock management. These great advances in the technology of agricultural production demonstrate the contribution of Africa in the evolution of the ancient world into the modern world. A focus on technological and agricultural innovations establishes that skills acquired in Africa could be transferred to the Americas and therefore could affect development. One of the questions to be asked, therefore, is what was the nature of African knowledge of agriculture, and to what extent was this knowledge transferred and furthered in the Americas under slavery? It is contended here that extensive knowledge was transferred, especially with respect to certain crops, such as rice, indigo and cotton, whether or not there was any intention on the part of slave owners in the Americas to harness that expertise. Rather, it seems, Africans were foremost seen as brute workers with no transferrable skills or any previous knowledge that might prove useful. Any benefits arising from the transfer of knowledge for purposes of development was purely coincidental and seldom recognized.

An examination of the indigenous development of agriculture in different parts of Africa demonstrates that agriculture was developed in several parts of the world, independently of each other. Such is the case for West Africa and Ethiopia, at least, where various crops are known to be indigenous, including rice and millets, and in forested tropics, yams and other root and tree crops, including the oil palm. The various millets were particularly important and have formed a staple of food production in many parts of Africa to this day. Production techniques show great variation from swidden ("slash and burn") systems and to methods of inter-cropping. Similarly the domestication of the yam has enabled the demographic expansion of people into forested regions of Africa. In the Americas, the cultivation of root crops in plantation settings was often done on the side, not as part of the work load for the slave owners but for the subsistence strategies of the African population. In time of food shortage or natural disasters, such as hurricanes, survival depended upon access to root crops. Agricultural innovation does not just involve the development of new crops but also the adoption and adaptation of imported species of foodstuffs, including bananas, maize, and manioc, and their significance in terms of agricultural production and sustainability. Similarly, farmers inevitably experimented with different strategies of agricultural cultivation, from swidden systems to irrigation, tree and root crops, grains, fruit, vegetables, condiments and spices.

An examination of rice cultivation demonstrates how African technology was transferred to the Americas and how knowledge that derived from Africa was exploited through slavery. Rice was domesticated in the savanna region of West Africa and along the upper Guinea coast and spread from there to South Carolina, Louisiana, the Amazon region of Brazil and elsewhere. An examination of the different techniques of production and how these spread to the Americas demonstrates the important role of Africans in the development of the Americas. The Bambara, Fula, Malinke, and Songhay had long experience in growing rice along the Niger River, while Serer, Mende, Temne, Kissi, Papel, and Baga utilized their own special techniques of rice production from Senegal to the Ivory Coast. There are extensive scholarly studies of rice-producing societies on the upper Guinea coast, including the Doala, Bran, and others.

Of the more than twenty species of rice found on the planet, only two were domesticated, one in Asia (*Oryza sativa*), the other in West Africa (*Oryza glaberrima*). It is believed that *O. glaberrima* was originally domesticated in the freshwater wetlands of the inland delta of the middle Niger River in Mali some two thousand years ago. Genetic diversity also suggests two secondary centers of African rice innovation and development: north and south of the Gambia River and the Guinean highlands between Sierra Leone, Guinea Conakry, and Liberia.

Several contrasts are evident between African and Asian rice. African rice is better adapted to soil nutrient deficiencies, such as acidity, salinity, excessive flooding, iron toxicity, and phosphorus deficiency. It grows quickly, which makes *glaberrima* more competitive with weeds in its early growth cycle than *sativa*. But under optimum soil and water conditions, the Asian specie typically provides higher yields. One factor limiting the extension of *glaberrima* cultivation over a broad area of the world is the notorious difficulty of milling African rice for consumption. The indigestible hunks of African rice must be removed through a processing method that keeps the grains whole; the African mortar and pestle (Portuguese: *pilao*) serve this purpose of milling.

Some studies attribute the early presence of rice in West Africa to Portuguese navigators who brought it from Asia to the upper Guinea coast. However, rather than introducing rice, Portuguese caravels depended upon the purchase of locally produced foodstuffs, especially rice, that were marketed in Africa. Europeans referred to the coast where rice was grown as the Rice Coast, as distinct from the Grain Coast, where millet and sorghum could be purchased. By the sixteenth and seventeenth, West Africans were selling rice to slave traders to provision their ships, including feeding the Africans who were taken to the Americas.

The species of rice reported by early European accounts was *Oryza glaberrima*, which has erect, compact flower clusters and red grains, and was grown as early as 1500 B.C. along the

Casamance River in Senegambia and in the inland delta where the Niger River flows northeast toward Timbuktu. Much later, the adaptable Asian species, *O. Sativa*, which has leaning clusters and white grains, and has a greater yield, was introduced into the western Sudan and the upper Guinea coast. The Asian species and hybrids tended to replace the indigenous species. However, the successful introduction of Asian varieties occurred because a system of irrigated rice culture and methods to mill the rice already existed.

The region where rice is grown in West Africa is divided into a northern and southern portion, depending upon amount of rainfall. The result is two distinctive land-use systems for rice cultivation. In the northern zone, in areas that receive less than 35 inches of annual precipitation, rice cultivation unfolds on wetlands in conjunction with cattle grazing. To the south, in areas receiving more than about 35 inches of rain, animals figure less centrally as land use shifts from an agro pastoral to a mostly agricultural system. Three principal water regimes influence West African rice planting: rainfall, groundwater, and tides. The resultant rice systems are respectively known as upland, inland swamp, and tidal production.

The upland system, which may actually be only a hundred feet above sea level, where rainfall reaches at least 1,000 mm, is characterized by clearing forest for the planting of well-drained soils. Seed is planted in furrows, either by broadcasting or by dropping rice grains into a hole made by puncturing the soil with a special hoe. Then the shallow hole is covered with the heel of the foot. Because the upland rice system is regulated by the length of the wet season, West African farmers usually plant seed varieties of short duration, grown over a three- to four-month period. Generally, upland rice cultivation occurs under favorable climatic, soil, and land-use systems in Sierra Leone and Liberia.

The second principal rice system encountered along a West African landscape gradient is cultivation in *inland swamps*, where groundwater reaches the root zone for most of growing period. The broad range of inland swamps sown with rice reflects a sophisticated knowledge of soils and their moisture-retention properties as well as methods to facilitate water impoundment for supplemental irrigation. As Judith A. Carney observes, planting rice in inland swamps requires careful observance of topography and water flow. Farmers often construct bunds, small earthen embankments, around plots to form a reservoir for capturing rainfall or stream runoff. The practice keeps soils saturated through dry cycles of short duration during the cropping season. If excess flooding threatens the rice crop, the plot can be quickly drained by puncturing the bund. Farmers sometimes improve drainage and aeration in inland swamp plots by ridging the soil. Rice grains either are sown directly atop the ridges or seedlings are then transplanted, the latter method often being favored when water-logging poses a risk to seedling development.

Tidal rice cultivation occurs in three distinct floodplain environments: along freshwater rivers, seasonally saline rivers, and coastal estuaries with permanent marine water influence. Mangrove rice is the highest-yielding crop in the West African rice region, characterized by farming in saline estuaries. From Cape Verde to Sierra Leone the topography determine the development of mangrove technology in rice cultivation. In the estuaries of numerous silt-laden rivers mangrove roots clutch the earth and hold the alluvium, producing the richest soil ideally suited to rice culture. Natives clear the mangrove swamp of underbrush and construct a dike to keep out the salt water of the Atlantic Ocean. A levee is closed with sluice gates of wood at high tide and opened again at low tide so that the saline soil may be washed by fresh waters of rain and rivers. The field is subdivided by series of canals and causeways that aid in irrigation. Repeated for a long period of time that may take years this drains the alluvium of salt. Farmers, using a log shovel, prepare ridges closest to the sea. Meanwhile, the women, using a small hoe, prepare other fields on higher ground and sow it with rice seeds to be later transplanted to the fields. After the harvest, the manure of cattle provides further nourishment throughout the entire trypanosome-free zone of the rice region. Rice farmers south of the trypanosome belt do not have these advantages: in absence of the cattle they must rely upon other techniques to maintain soil fertility, such rotating fields with nitrogen-fixing legumes and intercropping plants that add crucial nutrients to the soil.

The labor of women proved crucial to the rice-cropping system in West Africa in ways that were not the case with other cereals such as sorghum and millet. Their activities included selecting the seeds, hoeing and harvesting the rice, milling, and carrying in baskets, processing, cooking, and selling rice in markets. The role of female labor varied in relationship to the significance of rice in the farming system, with male participation in cultivation being greater in places where rice was the dietary staple. When rice was a secondary crop in the regional food system, the crop was often farmed solely by women.

One of the chief contributions of enslaved Africans to the Americas was the transmission of the West African rice knowledge systems – land-use principles, gendered division of labor, and processing techniques. In at least two important areas of New World slavery, South Carolina and the eastern Amazon in Brazil, European planters drew on African expertise in rice farming to develop plantations based on the crop. In both landscapes, the techniques of rice cultivation were very close to those practiced in West Africa. Many enslaved Africans were experienced rice producers, and as a result British colonists in South Carolina had some difficulty in cultivating the crop successfully. Otherwise, the period in which rice became an important export commodity coincided with that in which Africans were imported in significant numbers, this fact suggest that English colonists possessed an early awareness about Africans knowledge of rice cultivation. On the other hand, many of the practices of early production in South Carolina paralleled those in Africa. Thus enslaved Africans were active rather than passive participants in the founding of American civilization.

Africans played an important role in the development of the commercial rice industry in colonial South Carolina and Georgia. Enslaved laborers on South Carolina rice plantations were skilled. Throughout the eighteenth century, planters placed a positive value on slaves brought from rice-growing regions, which is revealed in newspaper advertisements by South Carolina planters searching for runaway slaves. Colonists preferred captives from the Rice Coast, despite the predominance of Congo-Angola slaves. Merchants in Charleston and Savannah maintained a close relationship with the owners of the Bance Island in the Sierra Leone River, whose captives often were destined for rice plantations in South Carolina and Georgia. Planters using enslaved Africans subsequently transmitted rice-growing technology to Texas, Louisiana, and Brazil.

Maranhão began to export rice in the late 1760s and remained the principal source of exports from Brazil during the colonial period. Between 1760 and 1810, two out of every three Africans who arrived in the rice-growing region of Maranhão came from the upper Guinea coast; indeed almost all embarked at Cacheu and Bissau. Elsewhere in Brazil, there were virtually no Africans from the upper Guinea coast. Rice cultivation in northeastern Brazil depended upon a predominance of Africans from rice-producing regions of West Africa.

Africans planted rice in the spring by pressing a hole with the heel and covering the seeds with the foot, the motion used was similar to that employed in West Africa. In summer, Carolina blacks moved through the rice fields in a row, hoeing in unison to work songs that followed the pattern of cultivation in West Africa, and not one that was imposed by Europeans. In October when the threshed grain was “fanned” in the wind, the wide, flat winnowing baskets were made by black hands after an African design. Also the process of removing rice kernels from their husks was made with the use of the mortar-and-pestle technique from Africa. Based on this technological evidence and the presence of enslaved Africans from the upper Guinea coast and the rice producing interior, it is clear that African technology and knowledge on rice production was transferred to the Americas.

Stimulants

Africa was the origin of three important pharmacological substances, known as alkaloids (kola, coffee, khat). The principal characteristic of these agricultural commodities is that they have pharmacological properties that stimulate the brain and the central nervous system. Like other alkaloids (tea, cacao, betel, coca, tobacco, opium, etc.), they have virtually no food value but rather provide the sensation of reducing hunger and fatigue. The active ingredients in the various alkaloids vary, caffeine (kola, coffee) and theobromine (tea, kola) being two of the most important. Moreover, all alkaloids are addictive to varying degrees, with nicotine (tobacco) being the most addictive. The extent to which alkaloids lose their properties after harvest determines the distribution of these commodities, which have often been considered luxury goods, depending how perishable they were. How alkaloids are activated varies as well; some have to be taken as a beverage (coffee, tea), others ingested through smoking (tobacco), or eaten (kola, and to some extent, tobacco). Several alkaloids are indigenous to Africa, including kola, coffee, and khat, a stimulant developed in Ethiopia, but which has not spread extensively beyond northeast Africa because it cannot be transported easily and loses its properties once dried. Here the focus is on kola and coffee because of the implications of these two commodities in the transfer of knowledge from Africa to the rest of the world and hence influence the spread of science and determine particular kinds of development.

Kola nut production, particularly *Cola nitida*, is indigenous to western Africa and is the basis of the popular cola drinks, which were developed in the United States and Europe in the 1880s and 1890s. This section examines the pharmacology of kola as a medicine, stimulant and item of consumption. The basis of "kola" drinks, kola nut consumption was largely confined to West Africa for reasons relating to the nature of the commodity. Only *C. nitida* can be transported relatively easily. The nuts perish and lose their properties quickly unless handled with care. Other varieties of kola perish more quickly.

Kola nuts, which are eaten because they contain caffeine, theobromine and kolatin, are a popular stimulant in many parts of West Africa. Like other mild stimulants, including coffee, tea and cocoa, kola nuts are moderately addictive. Of the two most common varieties, *Cola nitida* contains from 1.0 to 4.0 percent caffeine by weight and traces of theobromine, while *C. acuminata* has from 1.5 to 3.6 percent caffeine and from 0.02 to 0.09 percent theobromine. Both caffeine and theobromine are alkaloids which stimulate the nervous system and the skeletal muscles. Both varieties contain small amounts of kolatin, a glucoside heart stimulant, and tannin. In combination, these properties make kola as effective as other, mild stimulants, including coffee, tea and cocoa (Table 1). Although kola nuts were not reduced to a drink, the nuts have sometimes been compared with coffee, even being called the "coffee of the Sudan."

Caffeine and Theobromine in Mild Stimulants (percent)

Stimulant	Caffeine	Theobromine
Kola	1.0-4.0	0.02-0.09
Coffee	0.7-3.0	None
Tea	1.0-4.7	Traces
Cocoa	0.07-0.36	0.8-4.0

Kola is indigenous to the West African forest, but is found as far east as Gabon and the Congo River basin. Of its more than forty varieties, four – *C. nitida, C. acuminata, C. verticillata,* and *C. anomala* – are the most common of the edible species, and have been important in the commerce of West Africa. These four types are similar in their chemical composition and use. They contain, together with other compounds, large amounts of caffeine, and smaller quantities of theobromine, kolatin, and glucose. All these are stimulants: caffeine affects the central nervous system, theobromine activates the skeletal muscles, kolatin acts on the heart, and glucose provides energy to the body as a whole. Because of these properties, kola had various medicinal uses, which demonstrates that there was knowledge of the pharmacologic importance of kola, particularly *C. nitida*, as a medicine and stimulant. When chewed, and it appears that kola was not cooked or made into drinks anywhere in Africa, the nuts have an effect similar to that of coffee, tea or cocoa, and consequently kola, being an excellent refreshment, can be used to relieve hunger, thirst, and fatigue, lending itself well to social situations.

The fruit of the kola grows in pods that contain from three to twelve nuts. *C. nitida* nuts are divided into two cotyledons, are can be easily separated at the time of consumption, while *C. acuminata* has from two to five cotyledons. Each nut is about the size of chestnut, approximately one to two inches in diameter. The nuts spoil easily and must be kept damp and protected from the air. If cared for properly *C. nitida* nuts can last for many months, even a year or more, subject to constant inspection to remove insect-infested nuts, moldy nuts and others that have been spoiled or withered. To protect the nuts in transit and during storage, they were wrapped in leaves. Although there are at least forty-two varieties of kola, *C. nitida* and *C. acuminata* have been particularly important historically. Red, white, or shades in between, the *C. nitida* nuts in particular were valued because they cleansed the mouth, provided a spurt of energy, and were credited with numerous medicinal and other properties. Kola is also mildly addictive, which was an important, if not always recognized, reason why thousands of common folk chewed it, at naming ceremonies, weddings and other occasions, although it constituted a luxury. For the wealthy, they were a necessary sign of their hospitality and affluence. Other varieties of kola, less widely distributed and less prestigious, had similar physiological effects.

The taste for kola is acquired because the nuts are bitter. Consumption of only a small piece of the nut affects the body, and hence consumers often break a nut into pieces; as a result there are terms for the size of a piece. Once a nut is broken open, moreover, it quickly oxidizes, turning dark red and then black as it dries, and losing virtually all of its effect. Consequently, nuts were shared, which reinforced the social dimension of consumption. The taste of the nut lingers for some time after chewing and has the effect of making water taste sweet and refreshing, no matter how tainted the water might be from natron or other common minerals found in well water. When consumed in sufficient quantities, kola stains the teeth and lips slightly red, which was considered pleasing and a sign of good health, if not prosperity.

Kola had a ready market almost everywhere in West Africa: in the savanna, where demand was high in the absence of tea, coffee or other preparations filling such roles, and tended to increase with the spread of Islam and its prohibitions on alcoholic beverages. Kola was also consumed in the forest areas, where alcohol was also consumed, and there kola was often associated with rituals and ceremonies.

The distinct taste of kola provided the inspiration for numerous cola drinks. Such wondrous potions as kola-wine, kola-cocoa, and kola-chocolate were experimented with in Great Britain in the 1890's, although Wellcome's "Forced March Tabloid" was a unique preparation that retained the original taste of the bitter nut. Of course, in carbonated form, Pepsi Cola and Coca Cola are now the most popular. These carbonated beverages are heavily sweetened and hence are not bitter, as the nuts that have been traditionally chewed in West Africa are.

The kola producing zone of West Africa was divided into two parts, one in the forests to the west of the Volta River where *C. nitida* was grown and the other to the east of the Volta River, where *C. acuminata, C. verticillata* and *C. anomala* were grown and where that was no *C. nitida*. This division is significant because *C. nitida* was by far the most important variety in terms of trade between forest and savanna, and because its zone of cultivation was geographically separated from that of the other varieties. There does not appear to be any difference in the techniques of cultivation that would account for this. The explanation as to why one variety assumed such importance commercially while the others did not also remains unclear; one can only note that a market had to be developed, since taste for the nuts is acquired, and that, whatever the reasons, demand for the other varieties has always remained small by comparison. An important factor probably was the relative ease of preserving the nuts, and *C. nitida* can be stored for up to a year if inspected carefully and regularly.

Before the last decade of the nineteenth century, the production of *C. nitida* was confined to the forests west of the Volta River, except for a very limited output in Nupe, near the confluence of the Niger and Benue rivers; this variety of kola was in particular demand among Muslims, and since areas of production were far away, it had to be transported considerable distances in order to reach the most eastern markets in the Central Sudan. *C. acuminata* was the primary variety grown in Yorubaland, the Igbo country, and areas further east; some was sold outside the forest zone, but it figured more prominently in local trade. *C. Verticillata* also was grown in the forests of Yorubaland, and perhaps further east too; some was exported north into the Central Sudan, where it was known to Hausa consumers as *hannunruwa;* it was also used in Borno, although demand there appears to have been far less than for *C. nitida. C. verticillata* was considered slimy, and women used it as much for cosmetic purposes as for its caffeine. *C. anomala* was grown only in Bamenda, in Cameroons, and was exported north, at least by the middle of the nineteenth century, and unlike *C. verticillata,* it was an acceptable substitute for *C.*

nitida in the markets of the Central Sudan. The production area was limited, however, and possibly little *C. anomala* was cultivated before the expansion of Hausa trade into southern Fombina (Adamawa) in the nineteenth century.

Although kola was indigenous to the whole forest region of West Africa, only certain areas have been important historically in the production of *C. nitida.* Kola trees can grow in the forest region south of approximately 10^{o} N latitude, but the main area for *C. nitida*, which is the variety discussed in the rest of this article unless otherwise indicated, has been between 60^{o} and 80^{o} N, from the Volta to the rivers of the Upper Guinea coast. Proximity to the savanna was significant in determining potential output, the most productive region beginning from 125 to 150 kilometers inland and ending approximately 300 kilometers from the coast. This belt was subdivided into four parts. In the east, the Akan forests were the principal source: in the nineteenth century kola was found in Asante, from Mampong in the east through Tekyiman and the Tano River valley, and it also grew in the Ano region along the Comoé River, 200 to 300 kilometers from the coast. The second area, straddling the Bandama River, was the Guro country, but also included the Bete area to a lesser extent. The third area was further west astride the present Sierra Leone-Liberia-Guinea boundary near the source of the Niger River: a variety of people exported kola from this zone, including, from east to west, the Dan, Gerze (Kpelle), Toma, Kisi, and Kono. The fourth area was the coast between the Scarcies and Nunez rivers in Sierra Leone and Guinea, where the Temne and Bullom collected kola for export along the coast and through the Futa Jallon highland. Kola was also cultivated north of this broad belt, but then only in small groves near villages where conditions were favorable; usually these nuts were smaller, and were consumed locally. Trees had to be tended carefully, and their presence in Futa Jallon, Kuranko country, and even near Kankan indicates their commercial importance.

By the first decade of the twentieth century, *C. nitida* trees were planted, as was probably done for many centuries. Cultivation was common among the Temne, Baga, Kisi, Toma, Gerze, Dan, Mano, Ge, Guro, Gan and perhaps the Asante. Groves of thirty to sixty trees were common near Ge villages, while the Kisi planted trees in the forests by their villages. Among the Gerze and Toma, groves were located along the Diani River, in Kabaradougou, and in Simandougou. In the Ano region, which supplied Kong, kola was planted in groves of 250 to 300 trees. Trees were elsewhere planted in smaller numbers. The Guro planted individual trees when girls were aged six or seven in preparation for puberty rites, but there were no plantations. The Mano planted a tree or two on gravesites, this sometimes resulting in the formation of small groves.

Even when trees were wild, they were often claimed and marked. The Toma, Gerze and their neighbors, after clearing the land around newly discovered trees, used bundles of straw, old machete handles with small stones tied to them, pieces of calabash stuffed with bombax "cotton," and other devices to establish a claim. In Gerze country, abandoned villages were visible because of the number of kola trees at their locations. The Guro acted differently: except for a few trees, most nuts were gathered in forests, where access was a lineage right. In the area between Kumasi and Nkoranza in Asante, kola trees were so thick in the 1980s that they formed a gigantic kola forest. Some of the trees there may even have been planted, and certainly underbrush was cleared away to protect seedlings, which must have been a regular practice for a long time. As with the Guro, however, the gathering of kola seems to have been possible for any member of a lineage, which maintained collective rights to the trees.

It is difficult to know how long there has been an active trade in kola and therefore a concern with kola cultivation. Customs associated with planting trees on gravesites and as a preliminary stage in puberty rites are very old. The question is how old, and how significant such practices have been in spreading *C. nitida:* one text from the sixteenth century indeed states that "plantations of kola" existed then, but this being the only reference, it remains theoretically possible that, as the market for kola developed, commercialization at first only involved nuts tapped from trees in their natural state. Nonetheless, *C. nitida* spread throughout the area from the Scarcies and Nunez rivers eastward to the Volta. As a result of the movement of villages, the opening of new lands, and local trade, kola trees were planted and those found in the wild were protected and cleared of brush.

Linguistic data indicate that the likely origin of *C. nitida* cultivation was in the Guinea-Liberia-Sierra Leone border area. Although there is no evidence for ascertaining a date of initial development, kola is by origin common to languages that are classified as West Atlantic, as distinct from Mande languages and other languages in West Africa. Moreover, Mande-speaking groups moved into the kola forests in the sixteenth century, which resulted in the expansion of kola production for commercial purposes. Kola was certainly traded to the savanna by the thirteenth century, and possibly much earlier. Kola production in the Akan forests, which developed later than in areas to the west, was important by the fifteenth and perhaps the fourteenth century. This corroborates the thesis that kola cultivation was initiated well before this time in the original area of production. Furthermore, the evidence of kola imports in the Central Sudan demonstrates that demand was quite large in the savanna by the fifteenth century, since the Central Sudan was at a considerable distance from areas of production. Finally, information on trade along the upper Guinea coast gives some indication of the scale of production at the time when the movement of Mande groups into the forest initiated major changes in the original production zone. The coastal trade must have represented only a fraction of the interior trade, but it was, nonetheless, on the order of several hundred tons per year for a relatively restricted geographical area of the savanna. It seems likely that other parts of West Africa of comparable population density imported at least as much by the same time. The total trade, therefore, probably involved the distribution of thousands of tons of kola annually by the late sixteenth century.

Coffee was developed as a consumable drink in Ethiopia and subsequently spread to Arabia and from there throughout the world. Coffee contains several compounds, particularly caffeine, but also theophylline and theobromine, each of which has different biochemical effects on the human body. The major compound in coffee is caffeine, which is a mild stimulant that can enhance alertness, concentration and mental and physical performance. Because caffeine influences the central nervous system in a number of ways and because a small number of people may be particularly sensitive to these effects, sometimes individuals have bad reactions to coffee consumption. Coffee has become one of the most important consumables in the world today. Unlike kola, coffee can be transported easily, once the beans have been roasted.

The coffee plant is a woody perennial evergreen dicotyledon that belongs to the *Rubiaceae* family. The plant can grow to a relatively large height, but when pruned it more accurately resembles a bush. It has a main vertical trunk (orthotropic) and primary, secondary, and tertiary horizontal branches (plagiotropic).Other members of the family include the gardenias and plants which yield quinine and other useful substances, but coffee is by far the most important member of the family economically. There are several different coffee species, but the two main species that have been cultivated *Coffea Arabica*, or Arabica, and *Coffea canephora*, or Robusta. Arabica coffee is indigenous to the highlands of Ethiopia, while Robusta is indigenous to the forests of West and Central Africa.

The origins of coffee consumption can be traced to Ethiopia, specifically the forests of the Kaffa region, where *Coffea arabica* grew wild. The region of Kaffa gave coffee its name, although in Amharic "bun" or "buna" is the word for coffee, which was also found in the Harar region. The popular theory about the origin of coffee in Kaffa attributes the discovery to a sheep herder known as Kaldi, who noticed that his sheep became hyperactive after eating the red “cherries” of the coffee plant. Kaldi is credited with trying the beans himself, where upon he discovered the effects of caffeine, the active ingredient in coffee. Whether or not this legend has any historical accuracy, the story emphasizes the act of observation and discovery. Certainly coffee has been consumed in Ethiopia for a very long time. Among the Galla, coffee beans were ground and mixed with animal fat for consumption on long hunting and military expeditions, and the “energy bars” are still consumed in Kaffa and Sidamo in Ethiopia today. In Ethiopia, coffee has always been regarded as a medicine, a food and a beverage. Sometimes, coffee was eaten with grain, and coffee cherries can be mixed with butter, pepper and other spices as a snack. As a food, the coffee cherries had to be fresh, which limited their area of consumption, but the roasted beans can be preserved for a long time without losing their stimulating properties. As a drink, fresh coffee cherries can be boiled to produce a greenish liquid that is known as “white coffee.” While consumed locally in Ethiopia, the far more popular of preparing coffee is starts with roasting the coffee, grinding it, and then brewing it with water.

Manufacturing and Industry

An examination of the technological development of particular manufacturing items includes a number of items. This section focuses on the early spread of cotton cultivation, since at least 1,000 CE, and in some places there was also local production of raffia cloth and the use of skins and leather as clothing. Most significant development, however, was the manufacture of cotton textiles. An examination of the textile industry in West Africa demonstrates indigenous innovation and development. This can be seen clearly in the development of indigo dyeing, including the development of dye pits using locally produced cement. It should be noted that the production of indigo for industrial purposes spread to the Americas via the African diaspora. Similarly, cotton production was also developed in the Americas, and especially in the United States in the nineteenth century.

Cotton had been cultivated, harvested, cleaned, spun into yarn, and woven into cloth for centuries in West Africa, long before direct trade with Europeans. Cotton was being grown in the region of Senegambia and probably across the whole of the savanna by 1000 A.D. Consumer markets for certain types of textiles were already in place when Portuguese mariners began exploring the coastline in the fifteenth century. Early centers of textile production arose in at least two areas of West African Interior. A western centre was located around the upper Niger, Gambia and Senegal watersheds, and contiguous areas on the desert edge. An eastern centre was located around Lake Chad, and the area of the early Hausa kingdoms.

Cloth is made by fiber, but no all fibers are spun into thread, and not all threads are woven into textiles. In many parts of Africa's rainforest, for example fibers from young leaves of the raphia palm (*raphia viniferera*) were selected and carefully processed (but not spun) and woven into textiles that served many uses, including that of form of currency. Then there is bark cloth, a category nonwoven fabrics that can have structures ranging from very sturdy to thin and delicate. Such cloths were made in West and central Africa b carefully removing sections of the inner bark of certain selected trees and then pounding those sections with a mallet to make them wider, softer and more flexible. In other cases, various types of fiber were spun and then twisted together into heavier threads or cordage that would then be knotted, twined or plaited by hand into clothing and other useful articles. Spining direction is another important feature of thread. Spinners learn to spin by turning the spindle in one direction or the other, clockwise or counterclockwise, and this spinning direction can be clearly seen in the thread itself. In one direction there is an 'S' while in the other a 'Z' [Fig. 6].

Weaving is a particular process by which two independent sets of threads are interlaced together: the lengthwise, or warp, threads are held under tension in the loom, and the crosswise, or weft, thread is passed between sets of raised and lowered warp threads. When the weft is beaten into place, it intersects each warp thread at a right angle. Then the orientation of the warp threads is reversed – the ones that had been raised are now lowered, and the ones that have been lowered are raised. The weft thread is passed back through this opening in the threads and is beaten in against the previous weft. And so on. A continuous weft thread passed back and forth will result in a firm bound edge at each side of the warp – self-edge, or selvage. This feature confirms that a fabric has been woven on a loom and that it is indeed a textile.

Weaving is a craft based on calculation and counting. In order to set up a loom, the weaver must estimate how much thread is needed for the warp, which depends on the type of thread, its thickness or fineness, and the intended dimensions and density of the fabric. Then the warp threads have to be measured out to the correct length, placed in sequential order, and arranged on the loom. How the warps are arranged and manipulated creates different types of fabric structures. The most common, elementary textile structure is a *plain weave*, with single alternating warp threads raised or lowered and single weft threads passed through and beaten in. Using pairs of thread rather than single threads for the warp and weft creates what is then called a *basket weave*.

Other types of structures are made by changing the proportion of warps to wefts. Many more warp than weft threads per square inch, such that the wefts can hardly be seen in the fabric, create a *warp-face weave*. Having more weft than warp threads per square inch creates a *weft-face weave*. Tapestries are weft-face textiles, their imagery made with different colors of weft threads completely covering the warps. Figures 8 and 9 give examples of different combinations of warps and wefts.

Weavers working with the vertical loom have employed a variety of fibers either gathered in the wild or cultivated, processed locally or imported from elsewhere, and some of them were spun into thread and others not. The earliest forest textiles were most likely woven of unspun fibers, such as young palms leaflets, which required soaking, beating, and combing before being dressed and woven on the loom. Of the various different palm trees that have been used to make textiles in Africa, the most important ones in the lower Niger region were several species of *Raphia vinifera*, which was valuable also as a source of palm wine. So far no evidence has come to light that raphia palms were deliberately cultivated for the specific purpose of producing textiles on a large scale, as they were in parts of Central Africa, west of the Niger for wine tapping. These locales could easily have become sources of supply for raphia fiber as well, since the gathering of it does not endanger the life of the tree.

Raphia cloth continued to be made alongside cotton and in the face of centuries of textile imports from overseas, which suggest that consumers in the region continued to prefer it for certain purposes and considered it necessary for special ceremonial occasions. Indeed cloths woven entirely of raphia fiber were deemed significant enough in Yorubaland to be designated by their own specific vernacular name: *odun*, meaning a grass cloth made from bamboo fibers, and *odon*, or *odun* meaning a cloth of palm leaf fibers.

Textile manufacture in the Sokoto Caliphate was impressive not only because of the quantity of cloth produced but especially because of its recognizably superior quality. From the specialized yarns and densely woven for certain that the renown of caliphate products was indeed well earned. They were certainly higher in quality than the *tellem* cloths, and equal or finer than the best of the Indian cottons that were traded before industrialized cotton manufacture in Europe and North America. Furthermore, it also appears that the finest cloth was selected to make garments and wrappers strictly for Muslim consumers, both male and female. For these consumers, dress was an indicator of character, taste, acumen and worldly achievement. Prominent Muslim men wore tailored clothing –as long as it was made of acceptable fabrics and in an appropriate style- as an outward sign of their inner qualities and public position. An in the Sokoto Caliphate, *sak'i* cloth in particular was reserved for the tailored robes and trousers that were most esteemed the ones destined to be embellished with embroidered imagery.

Indigo has played an important role in local, regional, and international economic histories. Indigo is native to native tropical areas of south Asia, the Americas and Africa. Various parts of the plant yield medicines and dyestuff that came to be known and highly valued in the ancient Mediterranean world and were imported by the Greeks and Romans by a least the last few centuries BC. *Indigofera tinctoria*, was native to eastern and southern Africa, though it has been widely cultivated in West Africa as well, and it was vigorously promoted in Nigeria after 1905 as a richer source of dye than *I. tinctoria*. Another species, from a different genus, *Lonchocarpus cyanescens*, has been harvested in the wild and also cultivated by farmers in the rainforest and moister savannah areas of much of West Africa. Its presumed antiquity and ubiquity in Yourubaland have earned for it the alternative vernacular term "Yoruba wild indigo". Another *Indigora* species, *I. suffruticosa*, was originally native to tropical America and the West Indies before being introduced into certain parts of Africa during the Atlantic trade. It has been a important indigo dyestuff of international commerce.

The making of indigo-dyed cloth has a long history in the lower Niger region, and the making of *adire eleko* is firmly rooted in that history. At the same time, the *adire eleko* tradition owes much to the Atlantic trade along the Guinea Coast, which brought new types of patterns, techniques and materials that transformed the way dyed wrappers were made and how they looked. A number of discoveries were made about particular varieties of indigo that could be used as a dyestuff, and differences were noted among them. The efficacy of indigo as a coloring agent varies with the species, growing conditions, and timing of harvest, and the resulting differences can be easily recognized in textile products by an experienced and discerning customer. Dyers would be especially conscious of these differences in visual qualities and so could be expected to work hard to achieve the deeper shades.

The efficacy of the indigo dye also varied according to the composition of the dye vat and the particular qualities of the other ingredients. Additional ingredients especially are the key to generating a deep blue color and making sure it adheres well to the fiber of the cloth. Much of the dyer processes which involve preliminary treatments of the fiber with a mordant to fix the color, indigo dyeing is based on an entirely different set of chemical principles and procedures. The process has two separate stages. Indigo dye is insoluble in water; hence it must first undergo reduction to dissolve it, a procedure that also changes the dye bath into a clear liquid called “indigo white.” Fabric dipped into this bath and taken out again has a yellowish color that soon changes to green and then to blue. The second stage, the oxidation of the dye, thus completes the dye process. Creating a strong indigo blue was not a simple or easing task, especially when using natural ingredients with all their attendant irregularities and impurities. African dyers, many of them women, discovered various ways of creating effective dye vat solutions for reducing indigo. Furthermore, West African dyers used particular kinds of salts for making an alkaline vat.

As more of West Africa’s urban elites and political leaders converted to Islam after the eleventh century, tailored garments became the preferred clothing for prominent men. Garments of all sorts, especially–shirts, robes, veils and turbans made their way across the Sahara into markets along sub-Saharan Sahel and savannah belt to clothe growing numbers of Muslim notables. Textile manufacturing in West Africa was supplemented by imports across the Sahara. Woolen cloth was imported from the Maghreb and was especially associated with the Berbers groups. Even so, sturdy woolen blankets and other textiles were also produced south of the Sahara from camel hair and sheep’s wool. Silks were the most exotic and luxurious of the imports.

After 1500 textile manufacturing in West Africa was supplemented and stimulated by of imports on the coast. The Bight of Benin and its hinterland was one of several regions where cloth was imported and where West African weavers produced cotton cloth for export. The large numbers of Benin cloths in the seventeenth century that European merchants began trading were classified according to the number of pieces per wrapper. It exist two main types of these textiles: a wrapper made from three pieces of cloth and one made from four pieces of cotton dyed indigo blue or patterned with indigo stripes. There where another types of "Benin cloth" as well, but their precise features and vernacular names have not been identified. The popular three pieces served as an accounting term that the Dutch used to calculate their purchases. Textiles coming from the hinterland into the ports of Arbo and Lagos in the eighteenth century were bulked and sorted to be shipped to markets on the Gold Coast, the Gabon estuary, Angola, the island of São Tomé, and as far away as the West Indies and Brazil. Allada was another entrepot along the Bight of Benin from were cotton textiles where exported. There, too many cloths were produced in hinterland communities, some has far inland as the northern Yoruba kingdom of Oyo. On the Ivory Coast, cotton textile exports were called "*quaqua* cloth" by European merchants. Other cotton were exported from the Grain Coast around Cape Mount and Cape Mesurado but it is not clear whether these were *quaqua* cloths. Here cotton textile production was carried out primarily in the interior, and the finished goods were brought to the coast where they were exchanged for salt and overseas goods. *Quaqua* cloths were not as varied structurally and visually as Allada and Benin cloths and they were made up of alternating white and blue strips or loom-patterned stripes. The simplest structures and patterns of *quaqua* cloth may explain why it was less expensive than certain types of cloth from Benin.

Cotton textile exports from upper Guinea coast were also made of narrow strips woven on a treadle loom. Some may have been produced as far inland as the Niger bend, while many others were made in a broad region defined by the watersheds of the Senegal and Gambia Rivers. These textiles served as the models for cloth manufacturers in the Cape Verde Islands and their importance in regional trade is remembered in the oral traditions of prominent Juula trading families. They continued to be made in the West African interior throughout the Atlantic slave trade era and remained important commodities for English, Dutch, Portuguese, and, especially Euro-Africans merchants well into the eighteenth century. Available in large numbers especially along the upper Gambia and Senegal Rivers, thousands of cotton cloths were purchased in the seventeenth century to be used either as currencies for buying provisions or as export goods for trade elsewhere on the coast.

From the sixteenth to the eighteenth centuries the textiles manufactured in Cape Verde Islands were very famous. Supplies of cotton many of which were distinguished by elaborate loom produced patterns, gave Portuguese and Luso-African merchants a much needed advantage during the pivotal early period in Atlantic trade. Exploiting the textile technology of the West African mainland, cotton and indigo plantations were established on the islands of Sao Tiago and Fogo and by the last decades of the fifteenth century, raw cotton was being exported to the Gambia, Casamance, and Cacheu Rivers. After the 1500s cotton textiles were being woven on the islands, imitating the mainland products and relying on the skills of slaves who grew, harvested, processed, spun, wove and dyed cotton under merchant supervision. The Cape Verde Island cloths competed with the textiles that were made in the hinterlands of the upper Guinea Coast and, as a result, plain cottons from workshops in the interior were traded to entrepots such as Cacheu, where they were dyed with indigo imported from the Senegambia region farther north.

West African patterns of consumptions shaped much trade on the Guinea Coast. At same time, however, imported cloth was also a vehicle for creating new local textile products. Asante, an Akan Kingdom that expanded into a powerful federation in the Gold Coast hinterland, provides two examples of this process: the textiles known as kente and adinkra. Before international trade in the coast, peoples of rainforest in this region produced cloth from processed bark and bast fibre and this cloth continued to be made into the twentieth century in rural areas for the poor and for ceremonial purposes.

Production and trade are, of course, a two way street. By weaving, dyeing, sewing and embellishment such a rich variety of cloth and clothing, African artisans helped to facilitate the workings of local regional and international commerce over time. And along the way, they were able to gain access to new fibers, techniques and imagery which opened up possibilities for the invention of new products and the alteration of standard ones. In other words, the phrase “local craft production” is something of an oxymoron, for textile manufactures were neither insulated from external change nor impervious to it. One factor that contributed much to this dynamism was an especially high cultural value placed on cloth. Peoples in West Africa, and in many others parts of the continent, shared an avid appreciation of the powerful sensual qualities of woven fabric and the serious matters of proper and stylish dress and public display.

Textile technology was labor-intensive, but that did not mean that was static, outmoded, or unprofitable. The various occupations involved with textile technology proved to be remarkably adaptable and flexible and continued to attract new trainees over centuries of competition with products imported from overseas. African textile producers and consumers were linked to international trading systems long before the colonial era. During the heyday of Muslim commerce, robes, trousers, shirts, turbans, caps, and other garments made of narrow hand-woven strip cloth were manufactured in workshops all over West Africa, even as a steady flow of foreign textiles came into Sub-Saharan markets by caravan. The well-known Guinea cloth of Atlantic commerce, exported from India and then imitated by manufacturers in Europe, had to be made in the manner of plain hand-woven African cottons in order to satisfy the tastes of choosy consumers along the Guinea Coast.

Salt Production and Pharmacology

An examination of salt production and pharmacology in the central Sudan of West Africa demonstrates the impact of technological developments in West Africa. As the chemistry of various salts that were exploited suggests, there was considerable knowledge of NaCl (sodium chloride), sodium sulfates, potassium chlorides and sulfates. Different types of salt, including natron, trona, vegetable salts, and sea salt, had significance for use as medicines, culinary purposes, tanning of leather, and other uses.

This section discusses salt production and pharmacology, including the chemistry and uses of various salts. The types of salt ranged from pure NaCl (sodium chloride), to sodium sulfates, potassium chlorides and sulfates, natron, trona, vegetable salts, and sea salt. The different salts were used for cooking, as medicines, for tanning leather, to fix dyes in textile production, as well as mixed with tobacco for chewing or snuff. It should be noted that tobacco was grown in West Africa, after being introduced across the Atlantic from the Americas. Because of Muslim prohibitions on smoking, tobacco was more often chewed or taken up the nose, which also released the nicotine, the active ingredient and also an alkaloid with stimulating effects similar to coffee and kola.

Salt was scarce in Africa before the twentieth century. Salt was found in scattered deposits, mostly in the Sahara and in the desert area near the Red Sea but also released through brine springs in widely scattered locations. Salt was also extracted from sea water through evaporation. The residue in pots was also used as a salt substitute in areas deficient in salt. In many places, salt earth was scraped from the ground after rain water had evaporated, and in places where there was considerable natural evaporation, the deposits of salt could be used as salt licks for animals and the salt earth could be marketed for animals.

The most sophisticated production of salt developed in the Central Sudan, and particularly in the area dominated by the state of Borno, and its predecessor, Kanem, in the basin of Lake Chad. Borno, a Muslim country since at least the eleventh century, controlled the oases of Fachi and Kawar, on the caravan route to North Africa and crucial not only for trans-Saharan trade but also as the sites of major salt deposits. The types of salt from these sites included red natron (Dirkou), white natron (Djado, Sequidine), *kantu* salt (Bilma, Fachi), and small quantities of purer, higher priced salt (*beza*, *bilma*). These sources are the best known of the production sites in the Central Sudan, Their position on the route to North Africa meant that medieval Arabic writers were familiar with their locations, although there is no mention of salt production, except for alum. Because of the importance of Kawar in trans-Saharan communication, they have loomed large in Borno history. It seems likely that the salt resources were exploited from an early date. Because Borno had firm control of Kawar and Fachi in the sixteenth century, at least, the state dominated the trade with North Africa and hence benefited from the salt industry of the desert. The northern side of the Komodugu Yo in effect consisted of a broad belt, which stretched from the Sosebaki states in the west to the shores of Lake Chad. The region subdivided into Muniyo, Mangari, Kadzell, and the islands and eastern shore of the lake. Only the lake itself was not under the political control of Borno, but even so the state was able to influence trade across the lake and hence salt distribution. The types of salt included several kinds of natron, *baboul* or *kige*, which was derived from the ashes of bushes, and many varieties of *manda*, which was a mixture of natron and sodium chloride, and from the eastern shores of Lake Chad, *ungurnu*, or trona.

Borno salts consist of sodium chloride, sodium sulfate, sodium carbonate, potassium chloride, calcium carbonate, sodium phosphate, potassium sulphate, and calcium sulphate in various concentrations. Those referred to as natron (*kanwa*) have low concentrations of sodium chloride (less than 4 per cent) and are high in sodium carbonate (20-75 per cent) but can include high concentrations of sodium sulfate and/or calcium carbonate. Mangari salt has even a greater variation in composition but generally has a higher concentration of sodium chloride (12-68 per cent), usually with significant amounts of sodium carbonate (many samples range from 11-31 per cent, but some are as low as 0.18 percent) and sodium sulfate (15-56 per cent). Small amounts (less than 5 per cent) of potassium chloride are often found in these samples and occasionally traces of other salts (sodium phosphate and potassium sulfate) are present. *Baboul* or *kige* salt contains virtually no sodium carbonate or sodium sulfate and consists primarily of sodium chloride and potassium chloride, with smaller amounts of calcium carbonate, potassium sulfate, and calcium sulfate. *Gwangwarasa* is different from the other types of natron in that it consists almost completely of sodium sulfate, and hence cannot be consumed by humans. The greatest variation in chemical composition is found in the natron and salt from the regions of Muniyo, Mangari, and Kadzell. Geological conditions differed greatly throughout this wide area, so that the output from different places was unique. Indeed the salt and natron of Mangari and Muniyo can be thought of as falling on a continuum based on the amount of sodium chloride present. The desert sites were fewer and while variations existed among locations there were in effect only five or six types, compared to the hundred or more found in the sahel.

Borno salt was used for a variety of industrial purposes. By far the greatest industrial use was as a salt and medicine for livestock. White natron in powdered form (*gari*) was used for this purpose throughout the Central Sudan and beyond. Natron was used as a mordant in dyeing textiles, although this function was replaced to a great extent in the Hausa centers of the nineteenth century by using the residue from dye pits. In earlier times, however, when the Borno textile industry was more important, its use may have been greater. White natron was also used in making soap and it was mixed with ink. *Gwangwarasa*, found in only a few locations in Mangari, was used in tanning hides and skins. Since the leather industry was second only to textile production in the Central Sudan, the demand for *gwangwarasa* was very great.

The medicinal uses of the different salts were numerous: *ungurnu*, or trona, from the eastern shores of Lake Chad, white natron from Mangari and Kawar, and red natron from Mangari and Kawar contained high concentrations of sodium carbonates and hence were excellent for stomach ailments. Local medicinal knowledge credited the different types of natron with specific properties: some were milder and better for children and elders, while others were useful in pregnancy. Because Mangari salt was so similar to natron, it, too, could be used as medicine. In addition, natron and varieties of Mangari salt were used in various mixtures to treat dandruff, problems related to pregnancy, eye disorders, infertility, and as an ingredient in curative potions and mixtures.

Culinary uses were equally specialized. Specific recipes required their own salt or natron. The standard Hausa millet porridge, for example, could be made with various grades of white natron, *ungurnu*, red natron, or Mangari salt; each recipe had a different name. Special meals were prepared for new mothers, in which the hooves of cattle were cooked in brine made from Mangari salt. Most salts could be used as substitutes, and consumption depended to a great extent on price and availability. Nonetheless, it is clear that market demand influenced output. Since the tastes of the various salts differed, it is in the culinary uses especially that Borno salts faced competition from other sources. While Mangari salt was in great demand in rural Kano and Zaria, *baboul* was seldom exported that far west. Its consumption was confined largely to Borno, which suggests that production was never great enough to satisfy western demand. Similarly, the highest quality Kawar salt, *beza*, never filled the demand, and consequently good quality salt from Teguidda and other desert locations further west was found in the Central Sudan markets. Salt from the Benue River valley, especially from Awe and probably Keana and other sites, was also shipped north, since it was relatively pure in sodium chloride when compared with the Borno types. Salt and natron were also mixed with tobacco, which was commonly chewed or taken as snuff. Salt, whether from Kawar, Mangari, or Lake Chad, was used widely for this purpose in the Central Sudan, Asante, the Yoruba states, and elsewhere. *Ungurnu* from Lake Chad was especially popular in Asante, but white natron from Muniyo was also common. Any salt could be added to bring out a pungent taste to the tobacco, and preference appears to have varied with the consumer and availability.

Salt production in Muniyo and Mangari was far more scattered than the desert industry. First, natron was processed throughout Muniyo and Mangari, sometimes at large sites, sometimes simply by scraping natron from the ground wherever it appeared. Second, manda salt was made at perhaps one hundred sites from western Muniyo to an area that was only a few kilometers from Birni Gazargamu. This salt required filtering devices and furnaces and hence production centers gained a degree of permanence. Some sites were quite large, but there were also many small ones. Third, *baboul* salt, which also needed filters and ovens, was even more dispersed; there were no large sites. Salt camps consisted of only one or two furnaces, and workers shifted location from year to year. Their camps were found primarily in Kadzell, but some were located in northern and eastern Mangari, again within a few kilometers of Birni Gazargamu. There were also sites south of the Komodugu Yo along the western shore of Lake Chad.

The production of natron in Muniyo and Mangari differed from the manufacture of *manda*. No furnaces were used and no filtering was necessary. The natron was simply scraped from the ground or from the edges of the ponds and lakes, which filled the many depressions between the sand dunes of the countryside. Red natron was only worked in bogs, because the crystals, which formed in a completely dry bed were too difficult to extract. Red natron was found at Yamia, Saouarni, between Guidjigaoua and Adebour, and at other places. White natron was best mined in completely dry conditions, if loose, producing the impure variety (*gari*), which was packaged in mats. Pieces of white natron came primarily from the edges of retreating lakes and ponds. Because of the impurities in the natron, "white" natron (Hausa: *farar kanwa*) was in fact classified into three types: white, grey, and black. Finally, *gwangwarasa*, used in tanning, was only found at a few sites, and was worked in the same fashion as white natron.

The production of *manda* involved boiling filtered brine in ovens, which contained from forty to one hundred and seventy small pots. The product, often referred to as cones of salt, weighed three to six kg and varied greatly in purity and chemical composition. The techniques of manufacture were the same, however, and the organization and number of workers at each furnace appear to have been very similar, at least for the first few decades of the twentieth century when information is available on production. Work units consisted of ten to twenty people, mostly men, who carried brine, scraped salt earth for the filters, made the filters and furnaces, fetched firewood, and packaged the finished salt cones for transport. A headman was in charge of the furnace, other workers (*kandine*) made the molds for the salt boiling, while male and female workers (*bagazao*) did the rest. At Ari Koumbomiram, a major location near Cheri, for example, there were ten furnaces in operation in the early 1940s, and these were organized into work units of approximately ten people each. At one furnace there were five *kandine*, including the furnace master, and five *bagazao*. This unit included eight men and two women, who were the wives of the furnace master and one of the workers. The salt season lasted from five to eight months, depending upon the year and the site. In a seven-month season, a work unit could stage twenty-seven boilings, which produced fifty cones each time, for a total of 1,350-1,400 cones.

Production of salt in Kadzell involved a different process than in Mangari and Muniyo. The salt, *baboul* or *kige*, was made primarily from the ashes of a bush, *Salvadorapersica* (Kanuri: *babul*, *kaligu*; Arabic: *arak*, *siwark*). The bush grew throughout Kadzell, eastern Mangari, the area south of the Komodugu Yo near Lake Chad and also to the east of the lake. Other plants were also burned to produce salt, including three varieties of grass (Kanuri: *pagam*, *kalaslim*, and *kanido*), which were found near Lake Chad, and the bush, *Capparis aphylla* (Kanuri: *tundub*), which was found as far south of the Komodugu Yo as Kukawa. The equipment used in making *baboul* was similar to that used in Mangari and Muniyo, but first the bushes and clumps of grass were burned, and the ashes placed in a filter similar to the ones used in the production of *manda*. The brine was then boiled in ovens or in single pots over a fire.

The salt to the east of Lake Chad, *ungurnu*, was relatively pure trona, which was found in the valleys east of the lake. Although these areas of production were not part of Borno in the nineteenth century, much of the production was exported across the lake to Borno, while the rest passed through tributary states to the south of the lake. The Yedina, who lived on the islands and manned large fleets of canoes, controlled much of this production and transported the *ungurnu* across Lake Chad. While the Yedina never submitted to the Borno government, commercial relations were so important that an informal dependency was in fact established. Without the Borno commercial infrastructure and its connections with the wider Central Sudan market, there would have been no commercial outlet.

The processing of *ungurnu* was simple. Since the lake was subject to constant evaporation, the salt (trona) was forced to the surface on the neighboring valleys to the east and northeast of the lake in the region known as Foli, and all that was required was to break the deposited trona into chunks for transport to Borno. The Yedina appear to have used slaves for this task. Sometimes, they travelled east of the lake, particularly to the region of Kelbouram in Kanem, where deposits were to be found at Kelbouram, Betra, Liga, Tergouna, and Anjia. The *ungurnu* was cut into flat cone-shaped blocks weighing about thirteen kg each.

Conclusion: African Contributions to Science and Technology

This exploration of technological innovation demonstrates the dimensions of African contributions to scientific discovery. A full historical analysis must await further research. The extensive writings of West African scholars at Timbuktu and other places in the Sahel and savanna undoubtedly contain important information of past discoveries, especially in mathematics. Moreover, the achievements of the Dogon in astronomy and the contributions to navigation in the Indian Ocean and Red Sea, and Atlantic are further examples, just as the knowledge of the chemistry of salt, iron, copper, tin and gold were well understood in Africa, long before any direct trade with Europe.

It has been argued by some that the transfer of rice technology to the Americas had little if anything to do with African production of rice or the knowledge of labor organization required to produce rice in varying ecological and environmental conditions. In fact, rice production in West Africa was extensively developed, and ranged in production techniques based on a gendered division of labor to the exploitation of plantation slaves along the Gambia River. The technology employed to create conditions for maximal rice production had involved extensive experimentation in drainage, construction of polders, desalination, and irrigation that was copied and amplified in the Americas. Even the initial variety of rice cultivated in the Americas was the black rice of West Africa.

Some would discount the importance of these contributions to introduction and development of risiculture in the Americas, laying emphasis instead on European entrepreneurship and capital. These claims ignore certain key historical facts, first that rice was not grown in Europe, and as with all other crops that were exploited using slave labor, there was no knowledge of the crop in scientific, military, or entrepreneurial circles. Second, rice was purchased early in the coastal trade of West Africa, first opened by the Portuguese and later expanding as other European countries pushed into the Atlantic world. Rice was bought to feed slaves because it could be stored easily and because many Africans were accustomed to rice as a mainstay of diet. Third, Europeans did indeed bring innovation and entrepreneurship to the Atlantic world. The principal innovations were naval technology that permitted control of the Atlantic and ultimately global sea lanes, which meant the ability to transport goods and people and otherwise reorganize the intercontinental division of labor and factors of production. Entrepreneurship, however, was confined to two forms of theft, first through the use of slave labor to intensify production and secondly by arbitrarily confiscating land in the Americas that had previously belonged to other people. In both cases, appropriation was achieved through forms of theft. The same also applied to the theft of the technology of the production of rice and other crops. The resulting profits were based on the transfer of technology, and admittedly its further enhancement. That transfer was based on labor that was subjected to slavery and exploited to the advantage of individuals who today would be charged with crimes against humanity. Not only was labor not paid and land taken without payment, but those who benefited most paid no taxes either. Some scholars have argued that this larceny represented an expression of agency on the part of enterprising people, but for those who were enslaved and those who lost not only their resources but often their lives as well, slavery and the exploitation that benefited British, French, Dutch, Spanish, Portuguese, some other Europeans, and their descendants in the Americas, inflicted lost income, denied investment opportunities, undermined dignity, and plagiarized legitimate claims to technological innovation.

The failure to recognize African contributions to science and technology and the transfer of expertise to the Americas minimizes the role of enslaved Africans in the development of the Americas, despite the often inefficient use of the skills and talents of individuals. Africans and their descendants were primarily responsible for the production of staple export crops and the mining of gold and silver. They also had to feed themselves, which to a great extent relied on food crops and recipes brought from Africa. African labor was important in maritime commerce and in the activities of port towns throughout the Atlantic world. Even where technology was known in Europe, such as blacksmithing, many smiths in the Americas were from Africa, where they brought similar technological expertise and skill in metallurgy. European technology excelled in weaponry and naval wares. Otherwise, whether in textile and leather production, agriculture, and mining, there was little technological contribution from Europe that superseded that brought from Africa, at least before the nineteenth century. Was it necessary, therefore, to secure the development of the Americas through the confiscation of land, the appropriation of labor and technology through slavery, and the use of military and naval superiority to subjugate people? The violent concentration of wealth through the gains from the exploitation of tropical production was based on enslaved labor, mostly from Africa. The gains were instrumental in the emergence of banking, insurance, joint stock companies, and other capitalist institutions in the financial centres of Europe and America. This concentration of wealth was based on the appropriation of the technological advances, whatever their origins, in the interests of entrepreneurs who found ways to reap undue profits through activities that relied on theft and slavery.

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