Subsistence Economy of El Paraíso, an Early Peruvian Site

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Studies of food remains from the Preceramic monumental site of El Paraíso, Peru (1800 to 1500 B.C.), have shed new light on a debate regarding the relative importance of seafood versus terrestrial resources and the role of cultigens in subsistence economies during the early development of Peruvian civilization. Fish was the primary animal food at the site whereas plant foods consisted of a mixture of cultivated resources (squashes, beans, peppers, and *jicama*) with an additional reliance on fruits (guava, *lucuma*, and *pacae*). Wild plants, especially the roots of sedges and cat-tail, also may have accounted for a substantial part of the diet. Cotton was a chief crop, used in making fishing tackle and the textiles that served as clothing and items of high value and status. As an example of the beginnings of civilization, El Paraíso is a case in which impressive architecture was built on a relatively simple subsistence economy and energy was expended in the production of resources useful in local and regional exchange systems.

THE RELATION OF THE ORIGINS OF FOOD PRODUCTION TO the development of civilization is one of the central issues of anthropological archeology. All early state societies relied on food surpluses, commonly in the form of storable grains, such as wheat in many places in the Old World and maize in the Americas. The nature of the food economies that sustained the first large populations organized on more than kin-based political systems has thus been of great interest to students of cultural evolution.

Peru is commonly cited as one of the few areas in the world where state societies developed independent of outside influences. Although the region was always thought to be precocious in social developments, new evidence (*1*) suggests that large architectural complexes on the Peruvian coast may be the earliest in the New World. Immense constructions of stone and adobe, often covering scores of acres of land, were erected during the Late Preceramic and early Initial periods, from about 2000 to 1400 B.C. (*2*). These sites commonly are found in the lower portions of river valleys, which provide water and resources in the otherwise barren coastal desert. Detailed studies of these complexes have only recently been undertaken, however, and a chief question in their investigation is the nature of the resource bases that sustained the people who constructed and used the flat-topped pyramids, sunken courts, and numerous rooms of these sites.

The clearest statement regarding the subsistence economy of early Peru was voiced by Moseley (*3*) who drew on the work of Lanning (*4*), Patterson (*5*), and Fung P. (*6*) in suggesting that early civilization in Peru was not founded upon domesticated plants and animals but on the rich seafood resources of the Pacific coastal waters. This argument was based on the fact that the earliest widely used cultigens in Peru were cotton and gourds used for fishing nets and floats by about 2500 B.C. or earlier, while the intensive cultivation of food plants occurred later. The adoption of plant cultivation was relatively slow because the rich maritime subsistence base was sufficient to support the construction of large architectural complexes in the Late Preceramic and early Initial periods, which are thought to represent the beginnings of hierarchical social organizations (*7*).

Moseley's argument fueled a debate on the subsistence economy of early Peru that had started somewhat earlier (*8*). The ensuing discussion raised a number of issues such as the nutritional importance of specific foods, subsistence technologies, the impact of El Niño on Preceramic subsistence, and the temporal parameters of the period under discussion (*9–11*). But scant data were available because no early monumental site had been excavated with the specific goal of investigating subsistence. To rectify this problem, our program of archeological investigations at El Paraíso was undertaken with the primary goal of retrieving such data.

First Steps Toward Civilization

Dramatic cultural changes occurred in Peru during the Late Preceramic and early Initial periods. Pottery made its first appearance, the heddle loom was introduced, large-scale architecture was constructed (Fig. 1), and there were shifts in where human populations were concentrated in the landscape. The most readily observable signs of the changes are the large architectural complexes that are found in almost every valley from just south of Lima, northward along the Peruvian coast. Due to the massive scale of these sites, few of them have been excavated with any degree of thoroughness. Work that has been done has concentrated on the uppermost terraces and platforms of the complexes which were commonly built in a rough U shape. The summits yield evidence of chambers

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devoted to religious rituals while the relative paucity of more extensive excavations elsewhere leaves open the question of other activities at these sites, the size of resident populations, the means by which they provided themselves with the necessities of life, and their relationships with other populations locally and beyond.

El Paraíso (Fig. 2) is one of the most impressive of the early architectural complexes and was occupied between 1800 and 1500 B.C. (*12*). It consists of eight or nine stone buildings, ranging in size from three or four rooms (unit XI) to massive room complexes (units II and VI) 300 m long and 100 m wide. The site covers well over 50 ha in area, near the mouth of the Chillón Valley, a few miles north of Lima on the central Peruvian coast. Engel (*13*) excavated and restored a single building at the site (unit I) in the mid-1960s, providing general indications that beans and other cultigens may have been grown at the site. Moseley (*2*, p. 97) suspected that El Paraíso may have had a relatively small resident population partly because little evidence of trash piles was visible. Quilter, however, suggested that subsurface deposits of refuse were present, and excavations were carried out in 1983 to retrieve a sample sufficient for study of the site's subsistence economy.

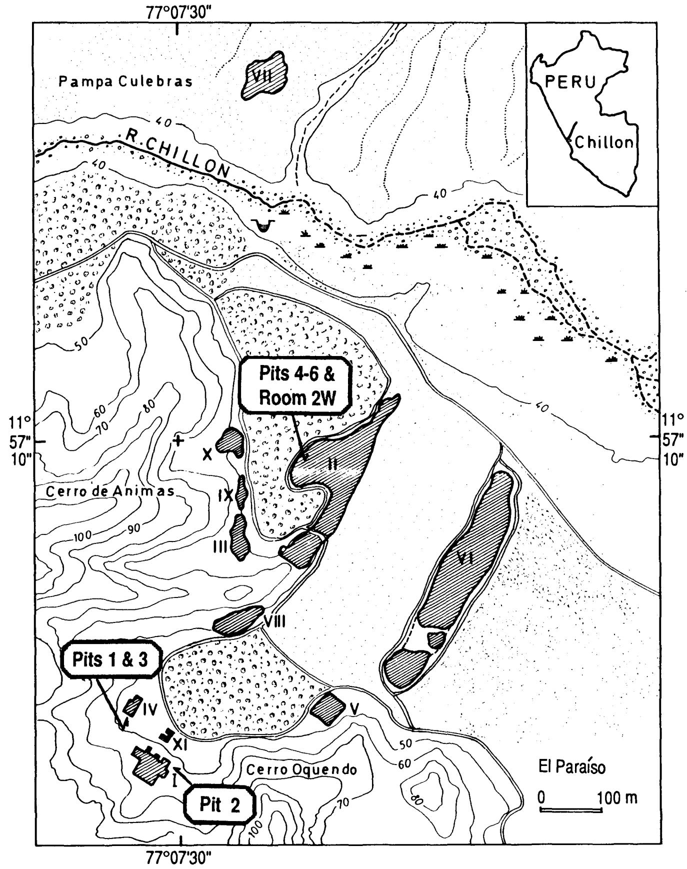

Fig. 2. Excavations in different buildings (indicated by hatched lines) provided a representative sample of food remains and confirmed that the structures were built and used in the Late Preceramic Period.

Refuse Was Buried at El Paraíso

In 1983, six pits, usually measuring 1 m by 2 m, were specifically excavated to retrieve food remains. Three of these were in midden deposits (pits 1, 2, and 4); the rest were in architecture, which yielded light and sporadic subsistence remains. Pits 1 and 2 were directly associated with architecture, units IV and I respectively. Pit 4 was placed in the western sector of unit II where no architectural remains were visible on the surface. Pits 3, 5, and 6 were excavated in architecture, but also yielded food and other refuse. All of the excavations in middens were carried out following natural stratigraphy. Thick natural strata were commonly encountered and were internally subdivided in 10 cm units to allow for comparisons of possible temporal or other changes within the larger deposits. The excavated soils were sifted through quarter-inch hardware cloth with materials picked through by hand and saved. The screening through the quarter-inch mesh was done above screens of one-sixteenth–inch mesh. A "grab" sample was made from the materials in the one-sixteenth–inch screen and saved. In addition, a 20 cm by 20 cm block of unsifted midden was reserved from each pit for detailed analysis in the laboratory. Pollen samples were saved from floors in architecture and other appropriate locales although subsequent analyses suggest that pollen is not well preserved at the site. In this article, we discuss the analysis of materials from the quarter-inch screens and column samples, including coprolites, which are the chief sources of information for investigating subsistence economy at El Paraíso.

The placement of excavation units reflected our attempt to control for different architectural features that could be observed on the surface of the site. Pit 1 was thus placed at the southern end of a small building (7 m by 14 m), unit IV, where nonprofessional digging had exposed trash deposits, and pit 3 was placed inside the structure (Fig. 3). Pit 2 was placed in an unrestored section of unit I, the southernmost building at the site, of medium size (50 m by 50 m) but relatively close to unit IV. Pits 4 and 5, however, were placed at a considerable distance from the first three, in unit II, one of the massive arms of El Paraíso, 300 m long and 113 m in maximum width. Pit 4 was placed in a flat area devoid of observable architecture, where midden might be encountered because all the known midden locations were outside of architecture. Pits 5 and 6 were placed inside unit II in order to see whether food remains could be found in rooms, and additional excavations were carried out in small rooms adjoining the 5 m by 5 m chamber initially excavated.

This excavation strategy was successful in producing a considerable amount of food refuse. Although there was a thin layer of later materials in some areas of the site, dating to the Early Intermediate

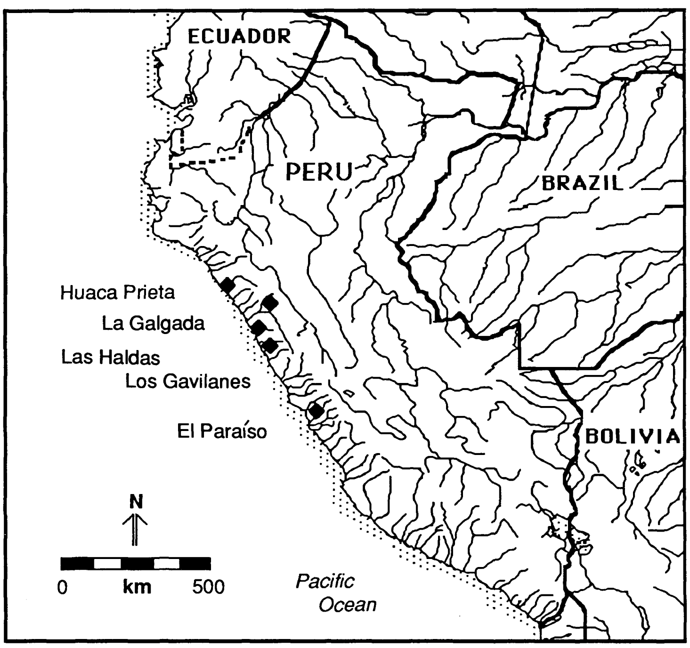

Fig. 1. The sites shown on this map, discussed in the text, represent only a few of scores of impressive remains dating to the Late Preceramic and early Initial periods.

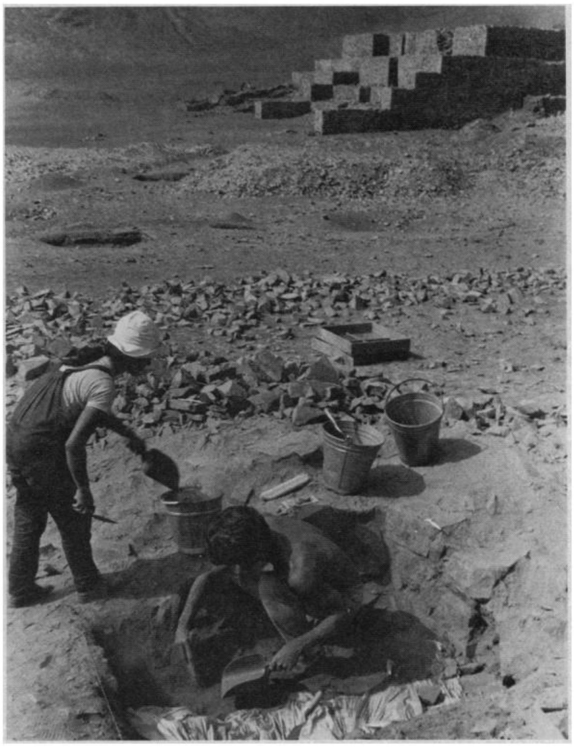

Fig. 3. Excavations in pit 3, in the interior of unit IV, by Peruvian and U.S. archeologists. Partially restored unit I, where pit 2 was located, can be seen in the background.

Period, (about 200 B.C. to A.D. 550), these materials clearly represented a temporary, short-term use of an abandoned ruin, and most were easily separated from the Preceramic materials below as they usually were found only on the surface of the site or in windblown fill above Preceramic plaster floors.

Both pits 1 and 2 were composed of distinct, layer cake–like strata of midden, much of which was burnt. In pit 1, there was clear evidence that refuse had been placed in a deliberately dug trash pit whereas in pit 2, layers of midden were interspersed with deposits of disintegrated plaster and stone rubble fill. Organic refuse at El Paraíso was burned and then either thrown into trash pits or incorporated into building activities, thus providing an explanation as to why no large midden piles were visible on the surface of the site.

Pit 4, in an area resembling a patio or small plaza, revealed a complex set of thin layers of trash and the presence of a hearth. It appears that small amounts of food were consumed here and the residues were simply covered up with layers of soil tamped down to restore the area to its original appearance. Excavations inside other architecture also yielded small amounts of food remains in construction fill, suggesting that work crews threw their lunch trash into the sites in which they were working. These commonly consisted of the valves of several molluscs and the rinds and seeds of fruits and vegetables. Another excavation in architecture yielded surprising results. Room 2W, adjacent to the main chamber of room 1 (pit 5) was excavated to a depth of 3.09 m. This work consisted of the discovery and removal of a series of plaster floors separated by layers of rock fill or adobes. At the bottom of these materials, however, a stone wall was found that was the outer wall of an early building at the site. Next to it, in a space restricted by later walls built above, was a tiny area of soil rich in midden, below which sterile soil was encountered. Given the space limitations, however, no more than a small, relatively uncontrolled sample of materials could be removed from the earliest level of occupation of this part of the site.

A Mixed Subsistence Economy for Inhabitants of Monumental Architecture

Once excavated, materials were studied in laboratories in Lima and various institutions in the United States. Portions of 27 separate column samples representing the range of levels and pits were sorted and analyzed, usually consisting of 1000 g of material per 10-cm level. In addition, nine entire 10-cm levels were studied from pits 1 and 2 as well as all of the material recovered from the quarter-inch screens. This resulted in the identification of 30 animal taxa at the family level (Tables 1 and 2) and 19 plant families (Table 3) including 31 definite or probable species.

The results of analyses support the contention that fish were the primary protein source for the inhabitants of El Paraíso. More than 90% of the animals identified are bony fishes and molluscs (Tables 1 and 2) with 10 to 15 taxa most commonly represented. The most common bony fishes are the anchovies (Engraulidae) and the most common shellfish are mussels (Mytilidae), based on calculations of minimum numbers of individuals (MNI). But although mussels dominate the collection in terms of MNI, the *Mesodesma* clam represents more edible food and is also the dominant mollusc species in terms of shell weight, based upon a 100% sample of shells removed from quarter-inch screens and the "grab" sample from the sixteenth-inch materials.

The role of molluscs was once a central issue in estimating the importance of seafood in Preceramic diets (*14*). In comparison with the other food remains at El Paraíso, however, they do not appear to have been significant in the subsistence economy. Small schooling varieties of fish such as anchovies (*Engraulis ringens*) were the chief source of protein drawn from the sea, although other fishes probably contributed a substantial amount of food as well.

Representatives of land mammals, both wild and domesticated, were scarce to absent. Only two cervid bones were encountered, suggesting that deer meat was an insignificant part of the diet.

Table 1. Identified vertebrates from El Paraíso.

Families	Species	Common name
	Mammals	
Hominidae	*Homo sapiens**	Human
Muridae	*Oryzomys* sp.	New World rodents
	Akodon sp.	
	Phyllotis sp.	
Canidae*	*Dusicyon* sp.	Fox
Camelidae*		New World camels
Cervidae*	*Odocoileus*	Deer
	Birds	
Anatidae*		Duck
Columbidae*		Dove
Mimidae*		Mockingbird
Strigiformes*†		Owl
	Amphibian	
Anuran*†		Frog or toad
	Cartilagenous fishes	
Carcharhinidae*		Requiem shark
Mylobatidae*		Ray
	Bony fishes	
Ariidae*		Sea catfishes
Clupeidae		Herring
Engraulidae		Anchovies
Muilidae	*Mugil cephalus*	Mullet
Sciaenidae	*Cynoscion* sp.	Weakfish
	Sciaena deliceosa	Corvina

*Not found in column samples. †Level of identification to order.

Table 2. Molluscan taxa at El Paraíso (*26*).

Families	Species	Common name
	Molluscs, bivalves	
Mactridae	*Mulinia edulia* (King)	Sweet surf clam
Mesodesmatidae	*Mesodesma donacium* (Lamarck)	Wedge clam
Mytilidae	*Choromytilus chorus* (Molina)	Large blue mussel
	Aulacomya ater (Molina)	Mussel
	Perumytilus pupuratus (Lamarck) (= *Brachidontes purpuratus*)	Small mussel
	Semimytilus algosus (Gould)	Small mussel
Pectinidae	*Argopecten purpuratus* (Lamarck)	Scallop
Veneridae	*Eurhomalea rufa* (Lamarck)	Large clam
	Prototheca (Prototheca) theca (Molina)	Clam
	Molluscs, snails	
Acmaeidae	*Acmaea* spp.	Limpets
Bulimulidae	*Scutalus* spp.	Land snails
Calyptraeidae	*Crepipatella* spp.	Slipper shells
Chitonidae	*Chiton* spp.	Chitons
Fissurelidae	*Fissurella* spp.	Keyhole limpets
Muricidae	*Concholepas concholepas* (Bruguiere)	Sea snail
Nassiariidae	*Nassarius gayi* (Kiener)	Small snail
Naticidae	*Polinices (Polinices) uber* Valenciennes	Snail
Thaididae	*Thais (Stromonita) chocolata* (Duclos)	Snail
	Thais sp.	Snail
Trochidae	*Tegula (Chlorostoma) atra* (Lesson)	Small snail
Turbinidae	*Prisogaster niger* (Wood)	Small snail
	Crustacea, barnacles	
Balanidae	*Balanus* spp.	Barnacles
	Crustacea, crabs	
Decapoda*		Unidentified crabs
	Echinoderms	
Echinoidea†		Unidentified sea urchins
Stelleroidea†		Unidentified starfish

*Also found in column samples. †Identification to order or class level.

Camelids were also represented by only two bones and were found in contexts that were rare cases of uncertainty as to their dates. They may well represent residues from the Early Intermediate presence at the site. Guinea pigs, which provided an important source of protein in later prehistory, are absent at El Paraíso.

Study of the plant remains (Table 3) yielded both expected and surprising results. A number of domesticates already in use, probably for 100 years or more, at the beginning of El Paraíso's occupation were found. These include gourd (*Lagenaria siceraria*), squash (*Cucurbita ficifolia*, *C. maxima*, and *C. moschata*), chili pepper (*Capsicum* sp), and cotton (*Gossypium barbadense*). Other cultivated plants include *achira* (*Canna edulis*) and *jicama* (*Pachyrrhizus tuberosus*), which provide large edible tubers, and common and lima beans (*Phaseolus vulgaris* and *P. lunatus*). One of the surprises was the abundance of tree fruits, especially guava (*Psidium Guajava*), *lucuma* (*Lucuma bifera*), and *pacae* (*Inga Feuillei*). These were likely also cultivated, although lack of comparative data on seed size and other diagnostic characteristics leave open the possibility that native trees could have been harvested or "managed" under less than full domestication. These treës also were the chief sources of wood for construction and manufacturing purposes at the site.

Since grasses (*Gramineae*) and sedges (*Cyperaceae*) were a chief source of fiber for the construction of mats, roofing, and coarse textiles, their ubiquity among the plant remains was not surprising. But the likelihood that some of these plants, such as cat-tail (*Typha angustifolia*), were a source of food was a new insight into Preceramic diets which was somewhat unexpected (*15*). Not only were cat-tail roots and seeds found in our samples, but the relative paucity of significant sources of carbohydrates in the remains, with only squash and *jicama* as the outstanding examples, suggests that the people of El Paraíso made use of them for food. Use of wild plants is also in evidence in the use of groundcherry (*Physalis* sp.) and unidentified members of *Solanum* spp., which include plants ranging from night shade to potatoes.

Analysis of the contents of coprolites augmented the information obtained from the other samples. Ten human coprolites revealed high amounts of *Cucurbita*, *Solanum*, and *Physalis* abundant in two coprolites each; fish bone or scales were common in five coprolites; and indeterminant plant fibers, fruits, and seeds made up most of the rest of the materials. Crawfish carapace fragments were found in three coprolites and mammal meat residue occurred in four samples, in one of which it was a major component. The relative abundance of crawfish and meat stands in marked contrast to the contents of coprolites at other Preceramic sites, but since a coprolite represents only part of one or more meals eaten in a 24- to 36-hour period before deposition, the El Paraíso samples must be viewed as augmenting rather than reorienting the view of subsistence gained from the overall study. The identification of a canine coprolite also provides the only evidence for dog at the site.

Table 3. Identified Preceramic plants of El Paraíso.

Families	Species	Common name
Amaranthaceae	*Amaranthus* sp.	Amaranth
Amaryllidaceae	*Furcraea* sp.	*Pacpa*
Bromeliaceae	*Tillandsia latifolia* Meyen*	*Achupalla*
Cannaceae	*Canna edulis* Ker-Gawl*	*Achira*
Cactaceae	*Cereus* sp.	Cactus
Compositae	*Baccharis* sp.	*Chillca*
	Tessaria intergrifolia R. & P.*	*Pájaro bobo*
Cucurbitaceae	*Cucurbita ficifolia* Bouche	Squash
	Cucurbita maxima Duch.	Squash
	Cucurbita moschata Duch.	Squash
	Lagenaria siceraria (Mol.) Standl.	Gourd
Cyperaceae	*Cyperus* sp.* or *Scirpus* sp.	Sedge
Equisetaceae	*Equisetum* sp.	Horse-tail
Gramineae	*Gynerium sagittatum* (Aubl.) Beauv.	*Caña brava*
	Pennisetum sp.	Grass
	Phragmites communis Trin.	Grass
Leguiminosae	*Inga Feuillei* D.C.	*Pacae*
	Pachyrrhizus tuberosus (Lam.) Spreng.*	*Jicama*
	Phaseolus lunatus L.	Lima bean
	Phaseolus vulgaris L.	Common bean
	Prosopis sp.	*Algarroba*
Malvaceae	*Gossypium barbadense* L.*	Cotton
Myrsinaceae	*Rapanea* sp.	*Manglillo*
Myrtaceae	*Psidium Guajava* L.	Guava
Salicaceae	*Salix chilensis* Mol.*	Willow
Sapinaceae	*Sapindus Saponaria* L.	Soapberry
Sapotaceae	*Lucuma bifera* Mol.	*Lucuma*
Solanaceae	*Capsicum* sp.	Pepper (*aji*)
	Physalis sp.	*Tomatillo*
	Solanum spp.	Night shade, potato
Typhaceae	*Typha angustifolia* L.*	Cat-tail

*Likely species identification.

The results of our studies thus indicate that the diet of the inhabitants of El Paraíso was a mix of domesticated and gathered resources. The general impression of the subsistence economy is that it may have been maintained with relatively low labor costs, or at least very different strategies for food procurement than might be expected at a large architectural complex which took tremendous amounts of energy to build. The apparent importance of nondomesticated resources suggests that there was sufficient food which could be expropriated directly from nature rather than from intentional cultivation. The gathered portion of the diet is not necessarily surprising since most societies, except for urban populations in agro-industrial states, rely on gathered and hunted resources to greater or lesser degrees. However, the virtual absence of terrestrial fauna in the food remains supports the contention that seafood was the chief source of animal protein. There is no evidence for changes in the El Paraíso food economy through time. The radiocarbon dates which potentially might serve for comparisons within and between pits are so close in age (*12*, p. 281) that the subsistence data must be treated as representing a single period of occupation and single subsistence economy. Since the material culture and architectural canons used at the site remained constant throughout its occupation, there is good evidence to argue that subsistence practices remained the same as well.

The plant foods consumed at El Paraíso generally are not significantly different than those found at contemporary nonmonumental sites nor from those that were occupied well before the beginnings of monumental architecture. The few studies available on subsistence at other Late Preceramic sites show variations on a general theme with an emphasis on beans, cucurbits, and fruits. The common bean (*P. vulgaris*) is found at El Paraíso and La Galgada (*16*), whereas jack bean (*Canavalia* sp.) is present at the latter but not at the former. No avocado (*Persea americana*) was found at El Paraíso but was present at La Galgada, Las Haldas (*17*), and Los Gavilanes (*18*). All of these sites and others (*19*) where such variability exists are relatively contemporary, so that the differences suggest a period of relatively rapid introduction of new cultigens within a few centuries of one another. Chronological controls are not yet precise enough to allow us to say more than that different plants were grown in different parts of Peru during the same general time period. Comparisons between sites are hampered by a less than complete understanding of their temporal relationships beyond the fact that they were built and used within a few centuries of one another. Although this is usually adequate for most discussions in archeology, the apparent rapidity of culture change now observable requires that finer chronological controls be established before the history of such changes can be documented and discussed.

Thus, the significance of and reasons why some foods are found at certain sites and not others remains to be explored and is an important topic for understanding the intensification of agriculture in early Peru. Although maize (*20*), peanuts (*21*), and other plants generally not considered Preceramic may have been grown in some parts of Peru, they were not significant sources of food at El Paraíso nor have they been reported as significant at other contemporary large monumental complexes. The subsistence economy that supported the construction of monumental architecture was not based on grain agriculture as may have been the case for other world regions.

More Than Subsistence Revealed

Besides lack of refuse piles, Moseley (*3*, p. 97) noted that the wall and room sizes of El Paraíso were beyond the range of ordinary dwellings and that El Paraíso seemed exceptionally large for a society based only on fishing and farming. These observations prompted him to suggest that the site was some sort of administrative center, implying that socio-political hierarchization was under way. But a number of lines of evidence suggest that the concept of the site as an administrative center, supervising activities in outlying, smaller communities, may be inappropriate.

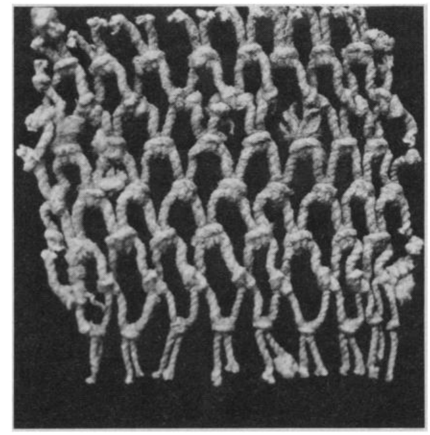

Fig. 4. A variety of cotton products, such as this net fragment found in pit 1, were recovered during excavations and attest to the importance of cotton in the economy of El Paraíso. Fragment width, 5.5 cm.

First there is evidence that the exploitation range of the site may have been relatively small. There is a clear pattern of the dominance of sand dwellers, such as *Mesodesma*, as the primary source of shellfish meat at El Paraíso. If the molluscan assemblage directly reflects the area of exploitation of resource areas, then El Paraíso's exploitation range extended only as far as the northern end of Ventanilla Bay. Most molluscs were probably collected from the sandy beaches close to the site by the inhabitants of El Paraíso, rather than brought in by people living in outlying communities. This seems rather surprising given the fact that the site is so large and impressive and would be expected to draw resources from a wide area, especially if it were an administrative center engaged in controlling economic activities of smaller communities under its sway.

Few small outlying communities are known for the lower Chillón and surrounding region during the time of El Paraíso's occupation (*22*). If such sites exist they may be buried under later occupations or the floodplain and thus not observable today. Floodplain occupation seems unlikely, however, because human habitation would have robbed the economic system of valuable agricultural land, and such locations have almost never been occupied throughout the history of Peru. Without satellite communities in evidence, however, it is hard to argue that El Paraíso was an administrative center since there is no evidence that there was anyone to administer or manage who did not live at El Paraíso itself.

The fact that some of the rooms at El Paraíso are beyond the range of ordinary dwellings known in general for the Late Preceramic does not discount the likelihood that there was a large resident population. Our investigations have shown that the sizes of rooms vary, indicating that a wide range of activities was carried out at the site. The evidence suggests that the site's inhabitants were engaged in new activities that had not been practiced previously. As for the problem of a fishing-farming subsistence base supporting large numbers of people, Moseley has revised his estimates upwards about the potential of a maritime subsistence economy, due to the nutritional value of schooling fish (*23*); evidence from our study of food remains suggests a more varied diet than previously presumed, as evidenced by the role of fruits.

The new activity engaged in by the people of El Paraíso was the intensive production of cotton which dominates our collection of plant remains. Part of the ubiquity of cotton may be due to the nature of the plant and the techniques for processing it for use in textile manufacturing; in other words, perhaps there are more cotton plant parts at the site because it was not consumed and only a small part of it was used. But even if the total amount of cotton, measured in weight or in plant parts, was halved, it would still rank in the top five plants found at the site.

Cotton's role in Preceramic life was twofold. It was the major industrial product that supported fishing, in the form of nets and lines (Fig. 4). Second, it was manufactured into textiles and used as clothing for both everyday use and as a form of wealth or high status. Cloth has a long tradition in the Andes as a prestige good, and its origins in this role can be traced to the Preceramic Period, exemplified by the elaborately decorated textiles of Huaca Prieta (*19*) and other sites. The ubiquity and importance of cotton are so great that some scholars refer to the Late Preceramic Period as the "Cotton Preceramic" (*3*, p. 21), although the times of the first use of the plant in different parts of Peru have not been fully established. Smith (*16*, p. 136) has cited evidence that cotton seed may have been processed for oil, which could have been consumed, thus providing an additional source of food.

The only areas of the Peruvian littoral region where cotton can be grown in large quantities are the river valleys, such as the Chillón, and the determinants of the production levels of different valleys certainly varied, including amounts of cultivable land and water. The Chillón-Rimac region appears to have had the potential for high productivity due to the large floodplain near the site, and an even greater area of fields could have been put in production if irrigation technology was known, as has been suggested for the contemporary site of La Galgada (*16*, p. 144).

It thus seems quite probable that at least a partial explanation for the establishment and growth of El Paraíso is its control and development of cotton production. Sites such as El Paraíso in the Late Preceramic represent a shift in population to concentrated locales where the right combination of land and water could be found for farming. This occurred on the central and north coasts. On the south coast, where there are fewer large river valleys with wide floodplains, Late Preceramic settlement patterns tend to be similar to earlier ones of relatively small, scattered hamlets (*24*). If the impetus for the construction of large architectural complexes was due to subsistence concerns, such as corn agriculture or environmental effects due to a severe El Niño (*9*), then a uniform change should be in evidence throughout the Peruvian coastal region.

A chief cause for the concentration of populations in large sites may thus have been due to the desire for increased cotton production that could only be achieved in the valley bottoms, rather than to increase food supplies. It is also likely that the implementation of irrigation technology, if it occurred in the Late Preceramic (*16*, p. 144), also was associated with increasing the area for cotton fields. At La Galgada, the same ubiquity of cotton and the role of the site as a place for its production have also been noted (*16*, p. 138). The eventual increased use of agriculture for food production in ancient Peru may be a result of greater distances of sites from maritime protein sources as ancillary factors in the attempt to better control cotton production rather than an adoption of more intensive food agriculture for its own sake.

El Paraíso offers important lessons for those attempting to delineate the ways in which hierarchical societies came into being because the site exhibits varying degrees of elaboration of some aspects of culture and not others. Although the site is a stone architectural complex of monumental proportions it has not yielded evidence of complex political organization. No elaborate burials of a ruling group have been found. Large-scale religious artworks associated with theocratic political systems, if present, should be apparent given the work conducted so far and yet remain absent. At the same time, analysis of plant and animal remains suggests a society that was knowledgeable and capable of intensive subsistence agriculture and yet chose not to conduct it, because a substantial component of the El Paraíso diet consisted of collected resources. Human energy and agricultural technology were devoted to an industrial crop, cotton, suggesting that regional economic considerations were the motivating forces that directed the growth and maintenance of the site and the activities that occurred there rather than local subsistence needs. Surplus cotton or products made from it were probably exchanged for other goods both with coastal peoples who could not produce a surplus as well as highland communities.

Although our research has clarified some aspects of the Peruvian Preceramic, particularly the subsistence economy of El Paraíso, it has also focused attention on new areas. For example, while cotton production may have played a crucial role in culture change during the Late Preceramic, it is likely that other factors were at work. Theoretically, at least, cotton production could have been intensified with an increase in lower valley populations but without necessarily requiring them to inhabit a single, large monumental building complex. Clearly, culture changes were taking place in which new social, political, and ideological systems were interacting with economic ones, and the investigation of how such different aspects of culture were interrelated remains to be documented and discussed.

Moseley suggested that agriculture was not a prime mover in culture change during the Preceramic and that the rich seafood base of Peru provided a different means for social developments similar to those based on agriculture elsewhere; an example of convergent development (*23*, p. 3). Although agriculture may not have been important in the food economy, it was the only means by which the major nonfood resource of coastal peoples could be produced in quantity. Rather than agriculture providing a food base upon which arts and industry could flourish, in the classic, 19th century view of cultural evolution, the evidence from El Paraíso suggests that a rather simple subsistence economy supported the growth of a nonfood agricultural system supplying industrial and social needs in the form of fishing line and cloth. The funneling of human energies into large agricultural fields and use of new agricultural techniques for the growth of food may have occurred somewhat later than their service in cotton production. So too, clear evidence of political hierarchization is not in evidence until after the Late Preceramic.

This pattern of uneven development is not unknown in history. The growth of the wool industry in 13th century England and the 19th century employment of steam technology to pump water out of coal mines were both attempts to maintain socio-economic systems by modifying only slightly current conditions from the perspectives of the people who made them (*25*). The consequences of these actions, however, were great, leading to completely new social and economic orders. This same general pattern appears to apply to Late Preceramic Peru in which change came about less as the result of the creation of entirely new technologies but due to a shift in emphasis on what was already known. The presence of certain cultigens at some sites and not at others, monumental architecture of varying styles, lacking signs of hierarchical social organization, are not anomalous but rather evidence that people were in the process of culture change.

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Chemistry and Biology of the Immunophilins and Their Immunosuppressive Ligands

Stuart L. Schreiber

Cyclosporin A, FK506, and rapamycin are inhibitors of specific signal transduction pathways that lead to T lymphocyte activation. These immunosuppressive agents bind with high affinity to cytoplasmic receptors termed immunophilins (immunosuppressant binding proteins). Studies in this area have focused on the structural basis for the molecular recognition of immunosuppressants by immunophilins and the biological consequences of their interactions. Defining the biological roles of this emerging family of receptors and their ligands may illuminate the process of protein trafficking in cells and the mechanisms of signal transmission through the cytoplasm.

Research during the past decade has contributed significantly to our knowledge of T lymphocyte function. The identification and functional analysis of T cell surface receptors (*1*) and nuclear transcription factors (*2*) have made these components of the signal transduction apparatus among the best understood in biology. This understanding is largely due to the use of probe reagents, such as monoclonal antibodies and radiolabeled nucleic acids, that have been developed for the study of surface and nuclear phenomena, respectively. However, the mechanisms for the transduction of signals through the cytoplasm, the "black box" of the signal transduction pathway, remain mysterious.

A family of natural products has emerged as probe reagents for cytoplasmic signaling mechanisms in the T lymphocyte. These small molecules are immunosuppressants that appear to exert their inhibitory actions distal to early membrane-associated events and proximal to nuclear processes. Studies on a family of immunosuppressant binding proteins, the immunophilins, have attempted to identify the structural requirements for high-affinity interactions between immunophilins and their immunosuppressive ligands and the biological consequences of the formation of immunophilin-ligand complexes. Although there is much to explore in this avenue of research, some general principles associated with the intermediary events of signal processing are emerging.

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The Immunosuppressants

Cyclosporin A (CsA), an inhibitor of T cell activation, is currently the favored therapeutic agent for prevention of graft rejection after organ and bone marrow transplantation, and it has been credited with initiating a revolution in clinical transplantation (*3–5*). The recently discovered compound FK506 inhibits T cell activation by mechanisms that are similar to those of CsA, but FK506 is 10 to 100 times as potent (*6*). FK506 has performed remarkably well in initial human clinical transplantation trials (*7, 8*), despite reports of toxic effects in animals (*6*). Rapamycin inhibits T cell activation at concentrations comparable to those of the structurally related FK506, yet with mechanisms that are strikingly different from those mediated by FK506, and thus CsA (*9*). Only CsA, FK506, and rapamycin have been used for the identification of members of the immunophilin class. A nonnatural ligand, 506BD (*10*), and analogs of CsA (*11–13*) have also provided insights into the inhibitory mechanisms of immunosuppressants. Many recently discovered immunosuppressive agents (*14*) with undefined mechanisms, such as