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Archeological Systems Theory and Early Mesoamerica

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INTRODUCTION

As work on the early periods of Mesoamerican prehistory progresses, and we learn more about the food-collectors and early food-producers of that region, our mental image of these ancient peoples has been greatly modified. We no longer think of the preceramic plant-collectors as a ragged and scruffy band of nomads; instead, they appear as a practiced and ingenious team of lay botanists who know how to wring the most out of a superficially bleak environment. Nor do we still picture the Formative peoples as a happy group of little brown farmers dancing around their cornfields and thatched huts; we see them, rather, as a very complex series of competitive ethnic groups with internal social ranking and great preoccupation with status, iconography, water control, and the accumulation of luxury goods. Hopefully, as careful studies bring these people into sharper focus, they will begin to make more sense in terms of comparable Indian groups surviving in the ethnographic present.

Among other things, the new data from Mesoamerica strain some of the theoretical models we used in the past to view culture and culture change. One of these was the model of a culture adapted to a particular environmental zone: "oak woodland", "mesquite-grassland", "semitropical thorn scrub", "tropical forest", and so on. New data suggest, first, that primitive peoples rarely adapt to whole "environmental zones" (Coe and Flannery 1964: 650). Next, as argued in this article, it appears that sometimes a group's basic "adaptation" may not even be to the "micro-environments" within a zone, but rather to a small series of plant and animal genera whose ranges cross-cut several environments.

Another model badly strained by our new data is that of culture change during the transition from food-collecting to sedentary agriculture. Past workers often attributed this to the "discovery" that planted seeds would sprout (MacNeish 1964 a: 533), or to the results of a long series of "experiments" with plant cultivation. Neither of these explanations is wholly satisfying. We know of no human group on earth so primitive that they are ignorant of the connection between plants and the seeds from which they grow, and this is particularly true of groups dependent (as were the highland Mesoamerican food-collectors) on intensive utilization of seasonal plant resources. Furthermore, I find it hard to believe that "experiments with cultivation" were carried on only with those plants that eventually became cultivars, since during the food-collecting era those plants do not even seem to have been the principal foods used. In fact, they seem to have been less important than many wild plants which never became domesticated. Obviously, something besides "discoveries" and "experiments" is involved.

I believe that this period of transition from food-collecting to sedentary agriculture, which began by 5000 B.C. and ended prior to 1500 B.C., can best be characterized as one of gradual change in a series of procurement systems, regulated by two mechanisms called seasonality and scheduling. I would argue that none of the changes which took place during this period arose *de novo,* but were the result of expansion or contraction of previously-existing systems. I would argue further that the use of an ecosystem model enables us to see aspects of this prehistoric culture change which are not superficially apparent.

In the course of this paper I will attempt to apply, on a prehistoric time level, the kind of ecosystem analysis advocated most recently by Vayda (1964) and Rappaport (1967), with modifications imposed by the nature of the archeological data. Man and the Southern Highlands of Mexico will be viewed as a single complex system, composed of many sub-systems which mutually influenced each other over a period of over seven millenia, between 8000 B.C. and 200 B.C. This systems approach will include the use of both the "first" and "second" cybernetics (Maruyama 1963) as a model for explaining pre-historic culture change.

The first cybernetics involves the study of regulatory mechanisms and "negative feedback" processes which promote equilibrium, and counteract deviation from stable situations over long periods of time. The second cybernetics is the study of "positive feedback" processes which amplify deviations, causing systems to expand and eventually reach stability at higher levels. Because I am as distressed as anyone by the esoteric terminology of systems theory, I have tried to substitute basic English synonyms wherever possible.

PROCUREMENT SYSTEMS IN THE PRECERAMIC (HUNTING AND GATHERING) ERA

Let us begin by considering the subsistence pattern of the food-collectors and "incipient cultivators" who occupied the Southern Highlands of Mexico between 8000 and 2000 B.C.

The sources of our data are plant and animal remains preserved in dry caves in the Valley of Oaxaca (Flannery, Kirkby, Kirkby, and Williams, 1967) and the Valley of Tehuacán (MacNeish 1961, 1962, 1964a). Relevant sites are Guilá Naquitz Cave, Cueva Blanca, and the Martínez Rock Shelter (near Mitla, in the Valley of Oaxaca), and MacNeish's now-famous Coxcatlán, Purrón, Abejas, El Riego, and San Marcos Caves, whose food remains have been partially reported (Callen 1965; Smith 1965a). Tens of thousands of plants and animal bones were recovered from these caves, which vary between 900 and 1900 meters in elevation and occur in environments as diverse as cool-temperate oak woodland, cactus desert, and semi-tropical thorn forest. Because most of the material has not been published in detail as yet, my conclusions must be considered tentative.

Preliminary studies of the food debris from these caves indicate that certain plant and animal genera were always more important than others, regardless of local environment. These plants and animals were the focal points of a series of procurement systems, each of which may be considered one component of the total ecosystem of the food collecting era. They were heavily utilized—"exploited" is the term usually employed—but such utilization was not a one-way system. Man was not simply extracting energy from his environment, but participating in it; and his use of each genus was part of a system which allowed the latter to survive, even flourish, in spite of heavy utilization. Many of these patterns have survived to the present day, among Indian groups like the Paiute and Shoshone (Steward 1955: Chapter 6) or the Tarahumara of northern Mexico (Pennington 1963), thus allowing us to postulate some of the mechanisms built into the system, which allowed the wild genera to survive.

Each procurement system required a technology involving both implements (projectiles, fiber shredders, collecting tongs, etc.) and facilities (baskets, net carrying bags, storage pits, roasting pits, etc.). In many cases, these implements and facilities were so similar to those used in the ethnographic present by Utoaztecan speakers of western North America that relatively little difficulty is encountered in reconstructing the outlines of the ancient procurement system.

I. Plants

Literally hundreds of plant species were used by the food-collectors of the Southern Mexican Highlands. There were annual grasses like wild maize (*Zea*) and fox-tail (*Setaria*), fruits like the avocado (*Persea*) and black zapote (*Diospyros*), wild onions (*Allium*), acorns and pinyon nuts, several varieties of pigweed (*Amaranthus*), and many other plants, varying considerably from region to region because of rainfall and altitude differences (Callen 1965; Smith, 1965b, and personal communication). However, three categories of plants seem to have been especially important wherever we have data, regardless of altitude. They are:

(1) The maguey (*Agave* spp.), a member of the Amaryllis family, which is available year-round; (2) a series of succulent cacti, including organ cactus (*Lemaireocereus* spp.) and prickly pear (*Opuntia* spp.), whose fruits are seasonal, but whose young leaves are available year-round; and (3) a number of related genera of tree legumes, known locally as mesquites (*Prosopis* spp.) and guajes (*Lucaena, Mimosa,* and *Acacia*), which bear edible pods in the rainy season only.

System 1: Maguey Procurement. Maguey, the "century plant", is most famous today as the genus from which pulque is fermented and tequila and mezcal are distilled. In prehistoric times, when distillation was unknown, the maguey appears to have been used more as a source of food. Perhaps no single plant element is more common in the dry caves of southern Mexico than the masticated cud or "quid" of maguey (Smith 1965a: 77). It is not always realized, however, that these quids presuppose a kind of technological breakthrough: at some point, far back in preceramic times, the Indians learned how to make the maguey edible.

The maguey, a tough and phylogenetically primitive monocotyledon which thrives on marginal land even on the slopes of high, cold, arid valleys, is unbearably bitter when raw. It cannot be eaten until it has been roasted between 24 and 72 hours, depending on the youth and tenderness of the plant involved.

The method of maguey roasting described by Pennington (1963: 129-130) is not unlike that of the present-day Zapotec of the Valley of Oaxaca. A circular pit, 3 to 4 feet in diameter and of equal depth, is lined with stones and fueled with some slow-burning wood, like oak. When the stones are red-hot, the pit is lined with maguey leaves which have been trimmed off the "heart" of the plant. The maguey hearts are placed in the pit, covered with grass and maguey leaves and finally a layer of earth, which seals the roasting pit and holds in the heat. After one to five days, depending on the age and quantity of

maguey, the baking is terminated and the hearts are edible: all, that is, except the indigestible fiber, which is expectorated in the form of a "quid" after the nourishment is gone. Evidence of the roasting process can be detected in maguey fragments surviving in dessicated human feces from Coxcatlán Cave (Callen 1965: 342).

The Zapotecs of the Valley of Oaxaca, like most Indians of southern Mexico, recognize that the best time to cut and roast the maguey is after it has sent up its inflorescence, or *quiote*. The plant begins to die after this event, which occurs sometime around the sixth or eighth year of growth, and a natural fermentation takes place in the moribund plant which softens it and increases its sugar content. The sending up of this inflorescence is a slow process, which can culminate at any time of the year. The large numbers of *quiote* fragments in our Oaxaca cave sites indicate that the Indians of the preceramic food-collecting era already knew that this was the best point in the plant's life-cycle for roasting.

The discovery that maguey (if properly processed) can be rendered edible was of major importance, for in some regions there is little else available in the way of plant food during the heart of the dry season. And the discovery that maguey was best for roasting *after* sending up its inflorescence and starting its natural fermentation meant that the plants harvested were mostly those that were dying already, and had long since sent out their pollen. Thus the maguey continued to thrive on the hillsides of the southern highlands in spite of the substantial harvests of the preceramic food-collectors: all they did was to weed out the dying plants.

System 2: Cactus Fruit Procurement. Organ cacti of at least four species were eaten at Tehuacán and Oaxaca, and their fruits—which appear late in the dry season—are still very common in Mexican markets. Most are sold under the generic terms *pitahaya* and *tuna*, but the best known "tuna" is really the fruit of the prickly pear (*Opuntia* spp.), the ubiquitous cactus of Mexican plains and rocky slopes. Most cactus fruit appears some time toward the end of the dry season, depending on altitude, but the tender young leaves may be peeled and cooked during any season of the year.

The collecting of cactus fruit had to take place before the summer rains turned the fruit to mush, and had to be carried on in competition with fruit bats, birds, and small rodents, who also find the fruit appetizing. The fruits are spiny, and some of the Tehuacán caves contained wooden sticks which may have been "tongs" for use in picking them off the stem (MacNeish, personal communication). The spines can be singed off and the fruits transported by net bag or basket, but they cannot be stored for long. By sun-drying, the the fruit can be saved for several weeks (Pennington 1963: 117-118), but ventually it begins to rot. It is worth noting, however, that harvest of most f these wild fruits must be done quickly and intensively because of competiion from wild animals, rather than spoilage.

The harvesting and eating of cactus fruits, no matter how intensive it may e, does not appear to diminish the available stands of cactus nor reduce subseuent generations of tuna and pitahaya—for the seeds from which the plant s propagated almost inevitably survive the human digestive tract and escape n the feces, to sprout that very year. It is even possible that such harvests re beneficial for the prickly pear and columnar cacti, in affording them naximum seed dispersal. This is only one example of the self-perpetuating ature of some of the procurement systems operating in preceramic Mexico.

System 3: Tree Legume Procurement. Mesquite is a woody legume which refers the deep alluvial soil of valley floors and river flood plains in the highnds. During the June to August rainy season it bears hundreds of pods hich, while still green and tender, can be chewed, or boiled into a kind of yrup (called "miel" in the Oaxaca and Tehuacán Valleys).

Such use of mesquite extended from at least the Southern Mexican Highnds (where we found it in caves near Mitla) north to the Great American outhwest, where it was evident at Gypsum Cave and related sites (Harringon 1933). *Guajes,* whose edible pods mature in roughly the same season, haracterize hill slopes and canyons, and were abundant in both the Mitla and ehuacán caves (C. Earle Smith, personal communication).

The amount of food available when mesquite and guajes are at the peak of heir pod-bearing season is truly impressive. Botanist James Schoenwetter, tanding outside one of our Mitla caves in 1966 during the optimum mesquiteuaje season, personally communicated to us his suspicion that a family of four ndians could have collected a week's supply of legume pods there "practically ithout moving their feet."

The pod-bearing pattern of mesquite and guaje demands a seasonal, localzed, and fairly intensive period of collecting. The pods can be hand-picked, nd probably were transported in the many types of baskets and net carrying ags recovered in the Oaxaca and Tehuacán caves (MacNeish 1964 a: 533; lannery, unpublished data). Both pods and seeds can be dried and stored for ong periods, but they must be picked at the appropriate time or they will e eaten by animals, like deer, rabbit, and ring-tailed cat.

II. MAMMALS

Mammals were an important year-round resource in ancient Mesoamerica, here winters are so mild that many animals never hibernate, as they do at

more northern latitudes. Deer, peccary, rabbits, raccoons, opossums, skunks, ground squirrels, and large pocket gophers were common in the prehistoric refuse (Flannery, n.d.). However, wherever we have adequate samples of archeological animal bones from the Southern Highlands of Mexico, it appears that the following generalization is valid: white-tailed deer and cottontail rabbits were far and away the most important game mammals in all periods, and most hunting technology in the preceramic (and Formative) eras was designed to recover these two genera. Our discussion of wild animal exploitation will therefore center on these animals.

System 4: White-Tailed Deer Procurement. The white-tailed deer, a major food resource in ancient times, continues to be Mesoamerica's most important single game species. Part of its success is due to the wide range of plant foods it finds acceptable, and its persistence even in the immediate vicinity of human settlement and under extreme hunting pressure. White-tailed deer occur in every habitat in Mesoamerica, but their highest populations are in the pineoak woodlands of the Sierra Madre. The tropical rain forests, such as those of the lowland Maya area, are the least suitable habitats for this deer. Within Mesoamerica proper, highest prehistoric populations would have been in areas like the mountain woodlands of the Valley of Mexico, Puebla, Toluca, Oaxaca, and Guerrero.

These deer have relatively small home ranges, and although they often spend part of the daylight hours hiding in thickets, they can be hunted in the morning and evening when they come out to forage. Deer have known trails along which they travel within their home ranges, and where ambush hunters can wait for them. In other words, they are susceptible to daylight hunts, on foot, by men armed with nothing more sophisticated than an atlatl or even a fire-hardened spear, such as used by the Chiapanecs of the Grijalva Depression (Lowe 1959: 7). On top of this, they can stand an annual harvest of 30 to 40 per cent of the deer population without diminishing in numbers (Leopold 1959: 513). Archeological data (Flannery, n.d.) suggest that the hunters of the Tehuacán and Oaxaca Valleys did not practice any kind of conservation, but killed males, females, fawns and even pregnant does (as indicated by skeletal remains of late-term foetuses). This does not seem to have depleted local deer populations in any way. In fact, by thinning the herds during times of optimum plant resource availability, it may even have prevented the starvation of deer during the heart of the dry season.

System 5: Cottontail Procurement. I have already discussed the ecology of Mexican cottontails in a previous paper (Flannery 1966) and will only recapitulate briefly here: cottontails are available year round (though most abundant in the rainy season) and can best be taken by means of traps or tern of exploitation one might think, for the Great Basin Indians had a rough idea that acorns and pinyon nuts would be available in the autumn, wild legumes and grasses in the rainy season, and so on. The outlines of a schedule, albeit with conflicts, were present; the "scouting reports" helped resolve conflicts and gave precision to the dates of each kind of resource exploitation, depending on individual variations in growing season from year to year.

These individual variations, which are a common feature of arid environments, combined with the scheduling pattern to make it unlikely that specialization in any one resource would develop. This prevented over-utilization of key plants or animals, and maintained a more even balance between varied resources. Because scheduling is an opportunistic mechanism, it promoted survival in spite of annual variation, but at the same time it supported the *status quo*: unspecialized utilization of a whole range of plants and animals whose availability is erratic over the long run. In this sense, scheduling acted to counteract deviations which might have resulted in either (1) starvation, or (2) a more effective adaptation.

EVIDENCE FOR SCHEDULING IN THE FOOD-COLLECTING AND "INCIPIENT CULTIVATION" ERAS (8000-2000 B.C.)

Thanks to the plants and animal bones preserved in the dry caves of Oaxaca and Tehuacán, we can often tell which season a given occupation floor was laid down in. Because of the work of botanists like Earle Smith, Lawrence Kaplan, and James Schoenwetter, we know the season during which each plant is available, and hence when its harvest must have taken place. Even the use of animal resources can often be dated seasonally; for example, in the Tehuacán Valley, we studied the seasonality of deer hunting by the condition of the antlers, which indicates the time of year when the animal was killed.

Assuming that each occupation floor in a given cave represents the debris of a single encampment, usually dating to a single season (an assumption that seems to be borne out by the quantity and nature of the refuse), the combinations of plant and animal remains observed in a given level tell us something about prehistoric scheduling decisions. Analyses of our Oaxaca caves and MacNeish's Tehuacán Caves, by roughly the same group of specialists (MacNeish 1962, 1964a; Flannery, n.d.), suggest the following tentative generalizations:

(1) *Dry season camps* (October-March), depending on their elevation above sea level, may have great caches of fall and winter plants—for example, acorns in the Mitla area, or Ceiba pods in the Coxcatlán area—but in general they lack the variety seen in rainy season levels. And perhaps most significantly, they have a high percentage of those plants which, although not particularly tasty, are available year-round: maguey, prickly pear leaf, *Ceiba* root, and so on. These are the so-called "starvation" plants, which can be eaten in the heart of the dry season when little else is available. These same levels also tend to have high percentages of deer bone. Some, in fact, have little refuse beyond maguey quids and white-tailed deer.

(2) *Rainy season camps* (May-September), as might be expected, show great quantities of the plants available at that time of the year: mesquite, guajes, amaranth, wild avocado, zapotes, and so on. They also tend to be rich in small fauna like cottontail, opposum, skunk, raccoon, gopher, and black iguana. Although deer are often present in these camps, they frequently represent only a small percentage of the minimum individual animals in the debris. Nor are the "starvation" plants particularly plentiful in these rainy-season levels.

(3) What these generalizations suggest, for the most part, is that scheduling gave preference to the seasonality of the *plant* species collected; and when conflict situations arose, it was the *animal* exploitation that was curtailed. I would reconstruct the pattern as follows:

> A. In the late dry season and early rainy season, there is a period of peak abundance of wild plant foods. These localized resources were intensively harvested, and eaten or cached as they came to maturity; this appears to have been a "macroband" activity. Because "all hands" participated in these harvests, little deer hunting was done; instead the Indians set traps in the vicinity of the plant-collecting camp, an activity which does not conflict with intensive plant harvests the way deer-hunting would.
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> B. In the late fall and winter, most plants have ceased to bear fruit, but deer hunting is at its best. Since this is the mating season, male deer (who normally forage by themselves) fall in with the does and fawns, making the average herd larger; and since this is also the season when the deciduous vegetation of the highlands sheds its leaves, the deer can be more easily followed by hunters. As the dry season wears on, however, the deer grow warier and range farther and farther back into the mountains. This is the leanest time of the year in terms of plant resources, and it was evidently in this season that man turned most heavily to plants available year round, like the root of the Ceiba (which can be baked like sweet manioc) or the heart of the maguey plant (which can be roasted). These appear to have been "microband" activities.
>
> C. By chewing roots and maguey hearts, the preceramic forager managed to last until the late spring growing season, at which point he could wallow in cactus fruit again. Essentially, his "schedule" was keyed to the seasonal availability of certain wild plants, which climaxed at those times

of the year which were best suited for small-game-trapping. He scheduled his most intensive deer hunting for the seasons when big plant harvests were not a conflicting factor.

D. Climatic fluctuations, delays in the rainy season, or periodic increases in the deer herds at given localities probably kept the picture more complex than we have painted it, but this cannot be detected in the archeological record. The constant evolution of new bags, nets, baskets, projectile points, scrapers, carrying loops, and other artifacts from the caves of the Southern Highlands suggests slow but continual innovation. To what extent these innovations increased the productivity of the system is not clear.

Because the major adaptation was to a series of wild genera which crosscut several environmental boundaries, the geographic extent of the ecosystem described above was very great. This adaptation is clearly reflected in the technological sphere. Implements and facilities of striking similarity can be found in regions which differ significantly in altitude and rainfall, so long as the five basic categories of plants and animals are present. This can be illustrated by an examination of the Coxcatlán Phase (5000-3000 B.C.) as it is represented at Coxcatlán Cave, Puebla (MacNeish 1962) and at Cueva Blanca, Oaxaca (Flannery, Kirkby, Kirkby, and Williams, 1967).

Coxcatlán Cave, type site for the phase, occurs at 975 meters in an arid tropical forest characterized by dense stands of columnar cacti; kapok trees (*Ceiba parvifolia*); chupandilla (*Cyrtocarpa* sp.); cozahuico (*Sideroxylon* sp.); and abundant Leguminosae, Burseraceae, and Anacardiaceae (Smith 1965 b: Fig. 31). Cueva Blanca occurs at 1900 meters in a temperate woodland zone with scattered oaks; *Dodonaea;* ocotillo (*Fouquieria*); wild zapote (*Diospyros*); and other trees which (judging by archeological remains) may originally have included hackberry (*Celtis*) and pinyon pine.

In spite of environmental differences, implements at the two sites are nearly identical; even the seasonal deer hunting pattern and the size of the encamped group are the same. In the past, such identity would have inspired the traditional explanation: "a similar adaptation to a similar arid environment." But as seen above, the two environments are not that similar. The important point is that the basic adaptation was not to a zone or even a biotope within a zone, but to five critical categories—white-tail deer, cottontail, maguey, tree legumes, prickly pear and organ cactus. These genera range through many zones, as did the Indians who hunted them, ate them, propagated their seeds, and weeded out their dying members. This is not to say that biotopes were unimportant; they played a role, but they were also crosscut by a very important system.

Seasonality and scheduling, as examined here, were part of a "deviation-counteracting" feedback system. They prevented intensification of any one procurement system to the point where the wild genus was threatened; at the same time, they maintained a sufficiently high level of procurement efficiency so there was little pressure for change. Under the ecosystem operating in the Southern Mexican Highlands during the later part of the food-collecting era, there was little likelihood that man would exhaust his own food resources or that his population would grow beyond what the wild vegetation and fauna would support. Maintaining such near-equilibrium conditions is the purpose of deviation-counteracting processes.

POSITIVE FEEDBACK AND CULTURE CHANGE

Under conditions of fully-achieved and permanently-maintained equilibrium, prehistoric cultures might never have changed. That they did change was due at least in part to the existence of positive feedback or "deviation-amplifying" processes. These Maruyama (1963: 164) describes as "all processes of mutual causal relationships that amplify an insignificant or accidental initial kick, build up deviation and diverge from the initial condition."

Such "insignificant or accidental initial kicks" were a series of genetic changes which took place in one or two species of Mesoamerican plants which were of use to man. The exploitation of these plants had been a relatively minor procurement system compared with that of maguey, cactus fruits, deer, or tree legumes, but positive feedback following these initial genetic changes caused one minor system to grow all out of proportion to the others, and eventually to change the whole ecosystem of the Southern Mexican Highlands. Let us now examine that system.

System 6: Wild Grass Procurement. One common activity of the food-collecting era in the Southern Highlands was the harvesting of annual grasses. Perhaps the most useful in pre-agricultural times was fox-tail grass (*Setaria*) (Callen 1965: 343), followed by minor grasses like wild maize (*Zea mays*), which may have been adapted to moist barrancas within the arid highland zone (Smith 1965a: 95).

We know very little about the nature of the early "experiments" with plant cultivation, but they probably began simply as an effort to increase the area over which useful plants would grow. For example, Smith (1965a: 77-78) has suggested that the preceramic food-collectors may have attempted to increase the density of prickly pear and organ cactus stands by planting cuttings of these plants. For the most part, judging by the archeological record, these efforts led to little increase in food supply and no change in emphasis on one genus or another, until—sometime between 5000 and 2000 B.C.—a series of genetic changes took place in a few key genera. It was these genetic changes, acting as a "kick", which allowed a deviation-amplifying system to begin.

As implied by Maruyama, many of these initial deviations may have been accidental and relatively minor. For example, beans (1) became more permeable in water, making it easier to render them edible; and (2) developed limp pods which do not shatter when ripe, thus enabling the Indians to harvest them more successfully (Kaplan 1965). Equally helpful were the changes in maize, whose genetic plasticity has fascinated botanists for years. While *Setaria* and the other grasses remained unchanged, maize underwent a series of alterations which made it increasingly more profitable to harvest (and plant over wider areas) than any other plant. Its cob increased in size; and, carried around the highlands by Indians intent on increasing its range, it met and crossed with its nearest relative, *Zea tripsacum,* to produce a hybrid named *teocentli.* From here on its back-crosses and subsequent evolution, loss of glumes, increase in cob number and kernel row number, have been well documented by MacNeish, Mangelsdorf, and Galinat (1964).

Another important process, though somewhat less publicized, was the interaction between corn and beans recently emphasized by Kaplan (1965). Maize alone, although a reasonably good starch source, does not in itself constitute a major protein because it lacks an important amino acid—lysine—which must therefore be made up from another source. Beans happen to be rich in lysine. Thus the mere combining of maize and beans in the diet of the southern highlands, apart from any favorable genetic changes in either plant, was a significant nutritional breakthrough.

Starting with what may have been (initially) accidental deviations in the system, a positive feedback network was established which eventually made maize cultivation the most profitable single subsistence activity in Mesoamerica. The more widespread maize cultivation, the more opportunities for favorable crosses and back-crosses; the more favorable genetic changes, the greater the yield; the greater the yield, the higher the population, and hence the more intensive cultivation. There can be little doubt that pressures for more intensive cultivation were instrumental in perfecting early water-control systems, like well-irrigation and canal-irrigation (Neely 1967; Flannery, Kirkby, Kirkby, and Williams, 1967). This positive feedback system, therefore, was still increasing at the time of the Spanish Conquest.

What this meant initially was that System 6, Wild Grass Procurement, grew steadily at the expense of, and in competition with, all other procurement systems in the arid highlands. Moreover, the system increased in complexity

by necessitating a *planting* period (in the spring) as well as the usual *harvesting* season (early fall). It therefore competed with both the spring-ripening wild plants (prickly pear, organ cactus) and the fall-ripening crops (acorns, fruits, some guajes). It competed with rainy-season hunting of deer and peccary. And it was a nicely self-perpetuating system, for the evolution of cultivated maize indicates that no matter how much the Indians harvested, they saved the best seed for next year's planting; and they saved it under storage conditions which furthered the survival of every seed. Moreover, they greatly increased the area in which maize would grow by removing competing plants.

As mentioned earlier, (1) procurement of "starvation" plants like *Ceiba* and maguey seems to have been undertaken by small, scattered "microbands", while (2) harvests of seasonally-limited plants, abundant only for a short time —like cactus fruits, mesquite and guajes, and so on—seem to have been undertaken by large "macrobands", formed by the coalescence of several related microbands. Because of this functional association between band size and resource, human demography was changed by the positive feedback of early maize-bean cultivation: an amplification of the rainy-season planting and harvesting also meant an amplification of the time of macroband coalescence. MacNeish (1964b: 425) anticipated this when he asked:

> "Is it not possible as the number of new agricultural plants increased that the length of time that the microbands stayed in a single planting area also increased? In time could not perhaps one or more microbands have been able to stay at such a spot the year around? Then with further agricultural production is it not possible that the total macroband became sedentary? Such would, of course, be a village."

Actually, it may not be strictly accurate to say that sedentary village life was "allowed" or "made possible" by agricultural production; in fact, increased permanence of the macroband may have been *required* by the amplified planting and harvesting pattern.

"RE-SCHEDULING" IN THE EARLY AND MIDDLE FORMATIVE PERIODS (1500—200 B.C.)

An aspect of early village agriculture in Mexico not usually dealt with in the literature is the extent to which increased concentration on maize production made it necessary to "re-schedule" other procurement systems. It is not possible in a paper of this length to discuss all the subtleties of Formative agricultural systems. The basic distinction I would like to make is this: given the technology of the Early Formative as we understand it at present, there were regions where maize could be grown only during the rainy season, and regions where maize could be grown year-round. All differences in scheduling to be considered in this paper ultimately rest on this dichotomy.

Regions where we postulate that agriculture was practiced only during the rainy season include areas with an extremely arid climate like the Tehuacán Valley, or higher valleys where frosts occur in October and continue until April, as is the case in the Valley of Mexico (Sanders 1965: 23). Regions where we postulate that agriculture was practiced year-round include very humid areas in the frost-free coastal lowlands (such as the southern Gulf Coast or the Pacific coasts of Chiapas and Guatemala), and areas in the frost-free parts of the interior where one of two techniques was possible: (1) intensive cropping of permanently humid river bottomlands, such as in the Central Depression of Chiapas (Sanders 1961: 2) or (2) very primitive water control techniques like "pot-irrigation", such as in the western Valley of Oaxaca (Flannery, Kirkby, Kirkby and Williams, 1967).

What did this mean, region by region, in terms of "scheduling"? It meant that, in regions of year-round agriculture, certain seasonal activities were curtailed or even abandoned, and emphasis was placed on those year-round resources that did not conflict with farming schedules. In regions where farming was conducted only in the rainy season, the dry season was left open for intensive seasonal collecting activities. Even exploitation of permanent wild resources might be deferred to that time of year. Let me give a few examples:

The Re-Scheduling of Deer Hunting. Deer hunting in the Formative differed greatly from region to region, depending on whether agriculture could be practiced year-round, or only seasonally. In the Valleys of Mexico and Tehuacán, remains of white-tailed deer are abundant in Formative sites (Vaillant 1930, 1935; Flannery, n.d.), but wherever we have accurate counts on these fragments it is clear that by far the most intensive deer hunting was done in the late fall and winter. Projectile points and obsidian scrapers of many types are plentiful in these sites (MacNeish 1962, Vaillant, op. cit.). On the Guatemalan coast, at Pánuco, or in the western Valley of Oaxaca, deer remains are absent or rare, and projectile points nonexistent (Coe and Flannery 1967, MacNeish 1954). It has occasionally been suggested that the lowland areas had such intensive agriculture that hunting was "unnecessary", whereas the highland areas needed deer "as a supplement to their diet". I do not believe this is the case; it is more likely a matter of scheduling. It so happens that the best season for deer hunting in the oak woodlands of highland Mesoamerica is late fall, after the maize crop has been harvested and the frosts are beginning. This made intensive fall and winter deer hunts a logical activity.

By contrast, lowland peoples concentrated on those wild resources that were available year-round in the vicinity of the village. Exploitation of these resources could be scheduled so as not to siphon off manpower from agricultural activities. On the Guatemalan Coast, for example, the very rich perennial fish resources of the lagoon and estuary system were relied upon. Some villages, located near mangrove forests, collected land crabs; others, located at some distance from the mangroves, ignored them (Coe 1961, Coe and Flannery 1967). None of these resources conflicted with the farming pattern.

Similar "re-scheduling" of wild plant collecting took place in the highlands. The plants that dwindled in importance were the ones that ripened during the seasons when corn would have to be planted or harvested. Plants like maguey, whose exploitation could be deferred until the winter, were still exploited intensively, and in fact eventually came to be cultivated widely in areas where a winter maize crop is impossible. In the arid Mitla region of the Valley of Oaxaca today, maguey is as important a crop as maize, and some years it is the only crop that does not fail (personal communication, Aubrey W. Williams, Jr.).

System 7: Procurement of Wild Water Fowl. Until now, we have not mentioned Mesoamerica's great water fowl resources, since we still have no good archeological evidence from the food-collecting and "incipient cultivation" periods in any of the lake and marsh areas where those fowl congregate. But beginning with the Formative period, we do have data on wild fowl exploitation from the lakes of highland Mexico and the swamps and lagoons of the coast.

Water fowl in Mesoamerica are as restricted in availability as the seasonal plant resources mentioned above. Only four species breed in Mexico. All the others (perhaps some two dozen species or more of ducks and geese) spend the summer in the prairie marshes of western Canada, principally in Alberta, Saskatchewan and Manitoba. Before the formation of winter ice in November, these ducks and geese head south down a series of four well defined routes, of which only two will be considered here: the Pacific and Central Flyways. Ducks coming down the Central Flyway, terminating at the lakes of the Central Mexican Plateau (Texcoco, Patzcuaro, Cuitzeo, Chapala), include the pintail (*Anas acuta*), the shoveler (*Spatula clypeata*), and the green-winged teal (*Anas carolinensis*). The coot (*Fulica americana*) is resident year round in Lake Texcoco, but constitutes only three percent of the water fowl. Ducks coming down the Pacific Flyway reach the extensive lagoon-estuary system of the Chiapas and Guatemala coasts. Among the most numerous ducks taking this route are the pintail (*Anas acuta*), blue-winged teal (*Anas cyanoptera*), and baldpate (*Mareca americana*). There are also a few resident species like the black-bellied tree duck (*Dendrocygna autumnalis*), but they constitute less than one percent of the waterfowl. In other words, between 97 and 99 per cent of the duck population of Mesoamerica is available only between November and March; by March or April most of these species are either back in Canada or on their way. This necessitated an intense seasonal exploitation pattern similar to that required by perishable seasonal fruits.

It is difficult to compare the relative abundance of waterfowl on the Pacific coast lagoons with Lake Texcoco, because the lake system of the Valley of Mexico was drained by the Spanish, and is now a pale shadow of what it was in the Formative. In 1952, an estimated 33,540 migratory ducks spent the winter in Lake Texcoco (Leopold 1959: Table 4), while the totals for the Chiapas Coast during the same period were over 300,000; some 27,000 of these were in the area between Pijijiapan and the Guatemalan Coast alone, a stretch of only 100 miles of coastline.

The Early Formative villagers responded quite differently to these populations of winter waterfowl. Every Formative site report from the Lake Texcoco area stresses the abundance of duck bones in the refuse. Vaillant (1930:38) claimed that the animal bones from Zacatenco indicated "considerable consumption of the flesh of birds and deer," and his illustrations of bone tools suggest that bones of waterfowl were well represented. Worked bird bone also appears at El Arbolillo (Vaillant 1935:246-7). Piña Chán (1958:17) likewise lists "bones of deer and aquatic birds" from Tlatilco. At Ticomán, bird bones were also common, and the larger ones apparently were ducks (Vaillant 1931). Recently, I have had a chance to examine faunal remains from Tolstoy's new excavations at El Arbolillo, Tlatilco, and Tlapacoya, as well as the Late Formative site of Temesco near Lake Texcoco (Dixon 1966), and ducks of the genera *Anas* and *Spatula* are abundant, confirming Vaillant's impressions.

On the Guatemalan Pacific Coast, as suggested by Coe and Flannery (1967) the extensive duck populations were virtually ignored. Although rich in fish and mollusks, the Formative middens have yielded not a single bone of the ducks that flew over our heads as we traveled upriver to the site each day. Since other birds, like the brown pelican, were sometimes killed and eaten, we assume that ducks must occasionally have been consumed. But the paucity of their remains is in striking contrast to the Lake Texcoco sites.

I suggest that in areas where agriculture was practiced year-round, heavy exploitation of winter duck resources would have conflicted with farming, and hence was not practiced. In areas like the Valley of Mexico, where winter frosts prevent agriculture, ducks arrive during the very time of the year when

farming activity was at its lowest ebb, and hence they could be heavily exploited. This may be one further example of the kind of "scheduling" that characterized the Formative.

CONCLUSIONS

The use of a cybernetics model to explain prehistoric cultural change, while terminologically cumbersome, has certain advantages. For one thing, it does not attribute cultural evolution to "discoveries", "inventions", "experiments", or "genius", but instead enables us to treat prehistoric cultures as systems. It stimulates inquiry into the mechanisms that counteract change or amplify it, which ultimately tells us something about the nature of adaptation. Most importantly, it allows us to view change not as something arising *de novo*, but in terms of quite minor deviations in one small part of a previously existing system, which, once set in motion, can expand greatly because of positive feedback.

The implications of this approach for the prehistorian are clear: it is vain to hope for the discovery of the first domestic corn cob, the first pottery vessel, the first hieroglyphic, or the first site where some other major breakthrough occurred. Such deviations from the pre-existing pattern almost certainly took place in such a minor and accidental way that their traces are not recoverable. More worthwhile would be an investigation of the mutual causal processes that amplify these tiny deviations into major changes in prehistoric culture.

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