The lives of Native Americans changed in dramatic ways after Christopher Columbus landed in the Caribbean islands in 1492. Written records paint a vivid picture of conquest and epidemics causing death and disease among the indigenous peoples of the Americas, quickly decimating them. Until recently, in fact, almost all that was known about the biological consequences of contact with the Europeans was based on these old documents, which emphasize epidemics and population collapse. Although these texts offer an important perspective, they are not the only source of information.

Bioarchaeology, an emerging field that focuses on the study of archaeological remains, is supplementing our view of the health and daily life of Native Americans, particularly those who lived in the Spanish missions of the Southeast, in an area once known as La Florida. Sustained encounters between Indians and Europeans in La Florida began in 1565, when Pedro Menéndez de Avilés established the town of St. Augustine on the Atlantic coast in northeastern Florida. From there Roman Catholic priests set up a chain of missions among the Timucua and Apalachee Indians of northern Florida and the Guale Indians of the Georgia coast. At some of those places—including Santa Catalina de Guale on St. Catherines Island, San Martin de Timucua and San Luis de Apalachee—archaeologists have uncovered the ruins of large churches that served the converts. As the nucleus of each community, the church carried out important religious functions for the living, for the dead, it provided a burial ground.

Skeletons found beneath the floor of these churches have provided scholars with a surprisingly complete record of the diet and work habits of the mission Indians. Bioarchaeology is beginning to fill in the details of the historical record, offering specifics about how food sources changed and raising unexpected questions about the merits of a purely agricultural way of life—at least for the Indians who inhabited La Florida.

Food, obviously, is fundamental to human well-being, as it provides nutrients for growth, development and other physiological processes. Before our research, the diets of La Florida Indians were reconstructed from two sources: accounts by priests and other Europeans, and food remains at archaeological sites. The written records are often contradictory. Some depict little farming at the time. Others, including those examined by Grant D. Jones of Davidson College, say that indigenous peoples relied heavily on agriculture, particularly on corn.

The archaeological record is inconclusive as well. Plant remains do not always survive well, and in coastal regions they are particularly vulnerable to the destructive effects of moisture and acidic soils. Nevertheless, analysis of such evidence by C. Margaret Scarry of the University of North Carolina at Chapel Hill and Donna Ruhl of the University of Florida has revealed that native peoples ate numerous plant species, both wild and domesticated, before and after the arrival of the Europeans. But their use of corn is unclear. Excavations have revealed some kernels and cobs from late prehistoric and contact-era sites; however, the relative importance of this grain in the Indians' diet is not known.

**RECONSTRUCTING DIET**

To resolve some of these questions, we turned to the many bones found at these sites. Because the tissues of all living things contain stable isotopes of such elements as carbon and nitrogen, we can measure the amounts of these elements in bones and then use this information to reconstruct ancient diets. Differences in the ratios of two carbon isotopes, carbon 12 and carbon 13, contain a record of which plants an individual ate. Most plants are divided into two types: carbon 3 plants break down a three-carbon molecule during photosynthesis; carbon 4 plants synthesize a four-carbon molecule. The distinctive chemical signature of the C3 and C4 plants that a
person consumes shows up in his or her bones. Virtually all plants eaten in the La Florida region were of the C₃ variety—including fruits, wheat, acorns and hickory nuts. The only major C₄ plant eaten by native peoples was corn.

Nitrogen isotopes provide a different set of clues. Fish bones and oyster shells in archaeological sites indicate that the Guale and other native peoples of the region ate seafood regularly—before and after the Europeans arrived. Because marine plants, such as algae, and terrestrial plants use the two stable isotopes of nitrogen—nitrogen 14 and nitrogen 15—differently, the ratios of these isotopes are different in the bones of a person who ate mostly marine foods as opposed to one who ate mostly terrestrial foods.

Examining the differences between carbon and nitrogen ratios in bones before and after the Europeans arrived pointed to enormous changes in the Native Americans' diets. Margaret J. Schoeninger of the University of Wisconsin-Madison, Nikolaus J. van der Merve of Harvard University, Dale L. Hutchinson of East Carolina University, Lynette Noor of the University of Florida and I found that the variations were geographically and chronologically patterned. As would be expected, coastal people ate more seafood than inland people did, regardless of the era. The Guale Indians on St. Catherine's and Amelia Islands ate corn before and after the missionaries arrived. But during the mission period, they ate more than their ancestors had. Similarly, the Apalachee, who had eaten some corn before contact, seemed to eat it more after the Europeans arrived; and the Timucua, who had eaten little or no corn before contact, also adopted it after the establishment of the missions.

THE CONSEQUENCES OF CORN

The bone chemistry findings thus show that the Indians' diets changed after the Europeans came—but not for the better. Their relatively heterogeneous diet, rich in seafood and a variety of plants and animals was replaced by a more homogeneous and less nutritious diet focused on the cultivation of a single crop: corn.

Corn-dominated diets are very poor ones. Corn contains a great deal of sugar, which promotes cavities and poor oral health in general. It also contains phytate, a chemical that binds with iron, inhibiting absorption of the mineral by the body. As a result, people whose diets are heavy in corn are predisposed to anemia and the many other consequences of low iron [see "Iron Deficiency," by Nevin S. Scrimshaw; SCIENTIFIC AMERICAN, October 1991]. To make matters worse for corn-dependent populations, growth and development are hampered because corn is a poor source of calcium and of niacin, or vitamin B₃ which is necessary for metabolism. Corn is also an inadequate source of protein because, depending on the strain, it is deficient in or entirely lacking three of the eight essential amino acids: lysine, isoleucine and tryptophan.

For these reasons, some mission Indians have more, and larger, cavities than their ancestors did. Tooth decay was probably exacerbated by the consis-
Signs of Stress in a Skeleton

Hypoplasias
These lines on the teeth of pre-contact Indians are the mildest signs of disease and malnutrition.

Tooth Microwear
The teeth of mission Indians are smoother (left) than those of their ancestors (right), suggesting that the latter diet centered on soft foods, such as corn gruel, which promote the buildup of plaque and cavity-causing bacteria.

Osteoarthritis: Joint Polish
Excessive wear and tear on a skeleton can be detected in several places, including the joints. Polishing of the joints indicates that cartilage was worn down, and that the joint surface had deteriorated.

Osteoarthritis: Lipping
The vertebrae of the lower back in many mission Indians show evidence of lipping—that is, of distortion from heavy lifting. The incidence of lipping and the joint polish suggest that many adults suffered from osteoarthritis.

Anemia and Porotic Hyperostosis
Corrosive rickets, which inhibits the absorption of iron and results in many mission Indians suffering from anemia and their bones have telltale lesions that can be seen on the skull and in a microscopic close-up. In non-native individuals the dark bands would be much thicker than those shown here (right). These lesions may also be the result of parasitic infections.

Dental Cavities
Cavities were common in Indians who ate a lot of nuts—a grain that contributes to tooth decay.

Retzius Lines
These growth lines can be seen in teeth enamel. In many of the mission Indians they are abnormally dark, indicating that poor diet and disease were common.

Infection
The lower leg bones, or shins, and fibulae, of many of the Indians living in the missions have visible lesions. These can be caused by toothed infections.

KEROZO QIST (dentures, dental cavities, antlers showing hypoplasias); MARK TEMPLI (bone microwear); BARRY STARK (osteosarcoma, joint polish and osteoarthritis, lipping); MARK C. CRIPPEN (lesions); MICHAEL SCHULTZ (skull, photograph); SCOTT W. SIMPSON (retzius lines)
DISEASES of the precontact Indians differ from those of their ancestors, particularly when viewed in cross section. The bones of the upper arm and the thigh of Indians working in the main shaft of the mine indicate that they were stronger and had adapted to a more demanding life.

In the absence of good, clean running water, the Indians drank well water, and anyone living in the region today knows the dangers of drinking water from shallow wells: it is easily contaminated and can cause parasite infection and other problems.

The probability of rampant infection is strengthened by the fact that most of the defective tooth enamel we studied appears to have been formed during the first two years of life. This is a period when dehydration from infantile diarrhea is a primary health threat. Acute dehydration can inhibit the function of all forms of cells, including ameloblasts—the cells responsible for enamel formation. As in many underdeveloped nations today, bacteria and viruses in contaminated food and water cause infantile diarrhea. Certainly the mission would have created the kind of living circumstances that promote infantile diarrhea and the pattern of growth stress we have seen in teeth.

Other diseases, such as smallpox and measles, may have easily spread as well because the Indians were clustered together in crowded communities around the missions. Although many acute infectious diseases kill people long before their bones are affected, some infections—such as those caused by the bacterium Staphylococcus aureus—can travel from a soft-tissue wound to nearby bone, leaving observable lesions. Numerous lower-leg bones, or tibiae, of contact-era Indians have lesions that suggest just this kind of infection.

Infection can also cause anemia because some types of parasites, such as hookworm, bleed their human hosts. Observations of mission bones indicate that such infection was common. The surfaces of many of these bones have siewelike lesions—called porotic hyperostosis—that can be caused by iron deficiency, scurvy or infection. Few precontact Indians seemed to have these lesions, probably because their diet of fish...
and maize together provided enough iron to stave off anemia. But the abundance of porotisch hyperostosis in the mission Indians was most likely the result of the anemia brought on not simply by an increasingly corn-rich diet but also by intestinal infection.

Food and living conditions were not the only aspects of culture that were drastically altered for the Indians who lived in the missions. The Spanish practiced repartimiento—draft labor in La Florida, which meant that able-bodied Indian men were required to work on farms, in public works, and government building projects, and for the military. Indians were also required to carry heavy loads over long distances, because draft animals were not available in the region until after 1680 or thereabouts.

In our studies of skeletons, we noticed that contact-era Indians had a higher rate of osteoarthritis than their predecessors did—a phenomenon we believed had been caused by the increased workload, because wear and tear on the joints can lead to osteoarthritis. But the condition is related to other factors as well. So we decided to investigate further, looking to the skeletons for more answers.

**WORKING BONES**

The skeleton of a living person is highly responsive to physical activity. Throughout life a person's bones change shape and structure in response to mechanical forces acting on them. Basically, bone tissue is placed where the skeleton needs it. When a person walks, for example, or stands, forces deriving from the pull of muscles or from body weight trigger cellular activity in the bone that results in skeletal remodeling. Without the proper amount or distribution of bone in key places, the force of bending or twisting could break the thigh bone, or femur.

Drawing from methods developed by civil and mechanical engineers for measuring the strength of building materials, Christopher B. Ruff of the Johns Hopkins University School of Medicine and I have analyzed the strength of femur and humerus (upper-arm) bones from both precontact and mission sites in La Florida. This approach entails measuring cross-sectional geometric properties of the bones called second moments of area. Second moments of area reflect how the bone is distributed in cross section and indicate the strength or ability of the bone to resist breaking during bending or twisting. The analysis entails tracing the profile of the outer (subperiosteal) and inner (endosteal) parameters of the bones in cross section and then calculating the biomechanical properties of the bone [see illustration on previous page].

We discovered that the mission Indians had stronger bones than their predecessors did: the later bones had greater second moments of area than the earlier bones. This is not to say that the bones of the mission Indians were better than those of their ancestors. Rather, the bones had just adapted to new mechanical demands. Given the well-known circumstance of exploitation and the heavy workloads of the Indians laboring under the Europeans, we believe that the increases in bone strength and osteoarthritics were caused by fundamental alterations in their way of life that involved increased physical activity.

The insights afforded us by bioarchaeology confirm much of what is found in historical texts—including the forced labor of the Indians and the diseases that plagued them—but they also give us a much more comprehensive and precise picture of the past. European contact introduced hardships for the Indians on many fronts. Pestilence, poor nutrition, iron deficiency, growth disruption, infection and hard labor all took their toll. Yet despite the unfavorable state of affairs, native peoples accommodated new demands and new challenges, a story that is repeated time and again in the history of our species.

**THE AUTHOR**

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**FURTHER INFORMATION**

**THE ARCHAEOLOGY OF MISSION SANTA CATALINA DE OUALE, VOL. 1: SEARCH AND DISCOVERY**


**THE ARCHAEOLOGY OF MISSION SANTA CATALINA DE OUALE, VOL. 2: BIOCULTURAL INTERPRETATIONS OF A POPULATION IN TRANSITION**


**THE WARPATH CONFLICT, ECOLOGICAL RESPONSES TO CONQUEST**


**THE APACHE INDIANS AND MISSION SAN LUIS**


**REGIONAL VARIATION IN THE PATTERN OF MAIZE ADOPTION AND USE IN FLORIDA AND GEORGIA**


**SKELETONS IN OUR CLOSET: REVEALING OUR PAST THROUGH BIOARCHAEOLOGY**