13.3 How Did Agriculture Affect Human Biology?

A misperception shared by the public and anthropologists is that with the appearance of essentially modern *Homo sapiens* in the Late Pleistocene, human biological evolution ground to a halt. That is, many think that humans stopped evolving biologically once they became modern in the Upper Paleolithic. Unlike recent humans' cultural evolution (for example, increasing use of technology and development of the arts), humans' biological evolution since the closing days of the Pleistocene has gone largely unrecognized.

In the remainder of this chapter, we will examine the human biological changes that accompanied the agricultural revolution—changes linked directly or indirectly to the fundamental change, discussed earlier, in how humans have acquired resources, especially food. At the end of the chapter, we will revisit the question of why humans made this remarkable transition. Some very compelling reasons exist to believe that agriculture has contributed to *H. sapiens'* evolutionary success, at least as measured by humankind's remarkable population increase since then.

The Changing Face of Humanity

As discussed at the beginning of this chapter, the foods we eat and the manner in which they are prepared tremendously influence our physical appearance. The relationship between food and morphology is well illustrated by the major anatomical changes throughout human evolution. As discussed in chapter 10, the massiveness of the late australopithecines' face and jaws was clearly linked to the hard foods those hominins ate, such as seeds. Generating the power to chew hard foods required large masticatory muscles (and their bony support). Thus, the well-developed sagittal crests of some later australopithecines—such as *Australopithecus aethiopicus*—are adaptations related to chewing. Over the course of human evolution after the australopithecines, the face and jaws have continually reduced in size and robusticity, reflecting a general decrease in the demand placed on the jaws and teeth as culture became increasingly complex and foodstuffs changed.

The reduction in size of the face and jaws is a general theme throughout human evolution, including during the Holocene and with the dietary adoption of domesticated plants. For example, in studying skulls from England that dated to the past couple of thousand years, Sir Arthur Keith documented a clear reduction in the size of the face and jaws. He believed that this reduction came about from eating soft foods, such as cooked cereal grains. Other biological anthropologists have noted similar changes in many other places of the world. In Sudan's Nile Valley—the region known as Nubia—hunter-gatherers living during the time immediately preceding agriculture had long and narrow skulls, whereas their descendants had short and wide skulls. My own work on the Atlantic coast of the southeastern United States shows similar trends.

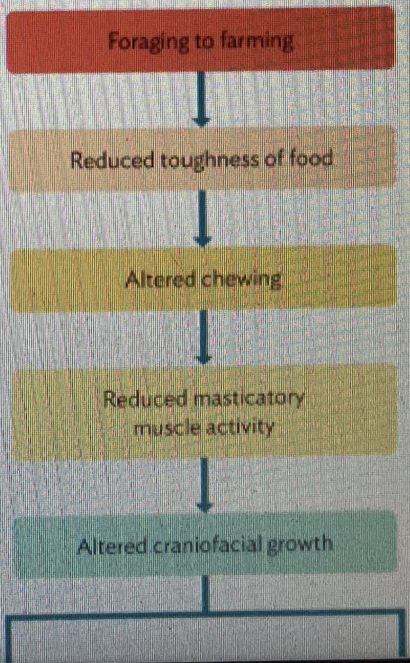
TWO HYPOTHESES To explain why the human skull changed shape in Nubia during the past 10,000 years, anthropologists in the 1800s and most of the 1900s offered an explanation based on old concepts of race (see chapter 5 for discussion of race). In Nubia, for example, they believed that the change occurred because short-headed people invaded territory occupied by long-headed people. These earlier anthropologists viewed head shape as unchanging and essentially a diagnostic racial marker. They were correct that humans living in specific areas of the globe have physical characteristics in common. However, since then, anthropologists have learned that human facial and skull forms are highly plastic, as are other parts of the skeleton.

The American biological anthropologists David Carlson and Dennis Van Gerven have offered an alternative hypothesis, which explains differences in head shape in Nubia but can also be applied globally. Their masticatory-functional hypothesis states that change in skull form represents a response to decreased demands on the chewing muscles—temporalis and masseter—as people shifted from eating hard-textured wild foods to eating soft-textured agricultural foods, such as millet. (Figure 13.12 lays out the hypothetical steps of this process.) To be sure, the millet grains eaten by ancient Nubians were not especially soft in their uncooked form. However, during the very late Pleistocene and beginning of the Holocene, early farmers used pottery vessels to cook grains (**Figure 13.13**). By *cooking*, I mean not a simple warm-up but cooking for hours until grains turned into soft mushes, rather easily chewed. The chewing of these mushes would have required far less powerful masticatory muscles. Because light use of muscle produces limited bone growth, the later Nubians, eating soft foods, had reduced faces.

Carlson and Van Gerven's explanation for much of the change in human head shape during the Holocene is strongly supported by evidence from living species, including nonhumans. For example, experimental research shows that primates fed soft foods have a relatively shorter skull with a smaller face and jaws than those of primates fed hard foods.

IMPLICATIONS FOR TEETH These changes in skull size and skull shape had enormous implications for our teeth. Today, the high numbers of people with orthodontic problems—malocclusions ranging from simple overbite to very poorly aligned teeth—contrast sharply with the few such problems found in ancient hominins and throughout much of prehistory. The American biological anthropologist James Calcagno has noted a number of exceptions, which may have influenced the size of our teeth, but malocclusions are rare prior to the modern era.

Why, then, do so many people around the globe have dental malocclusions? As with general skull shape, food plays an especially important role. Animals fed soft-textured foods develop far more occlusal abnormalities, such as crooked teeth, misaligned jaws, and chewing problems, than do animals fed hard-textured foods. The study of many thousands of skulls has shown that tooth size and jaw size have reduced in the past 10,000 years but at different paces. Bone is greatly subject to environmental factors, so a child fed softer foods than his or her parents ate will have appreciably reduced jaws. By contrast, teeth are controlled much more by genes, so over the course of evolution, teeth have reduced far less than jaws have. Simply, the greater reduction of the bones supporting the teeth has led to greater crowding of teeth. This disharmony underscores the complex nature of our biology, which involves an interplay between intrinsic (genetic) factors and extrinsic (environmental) factors.



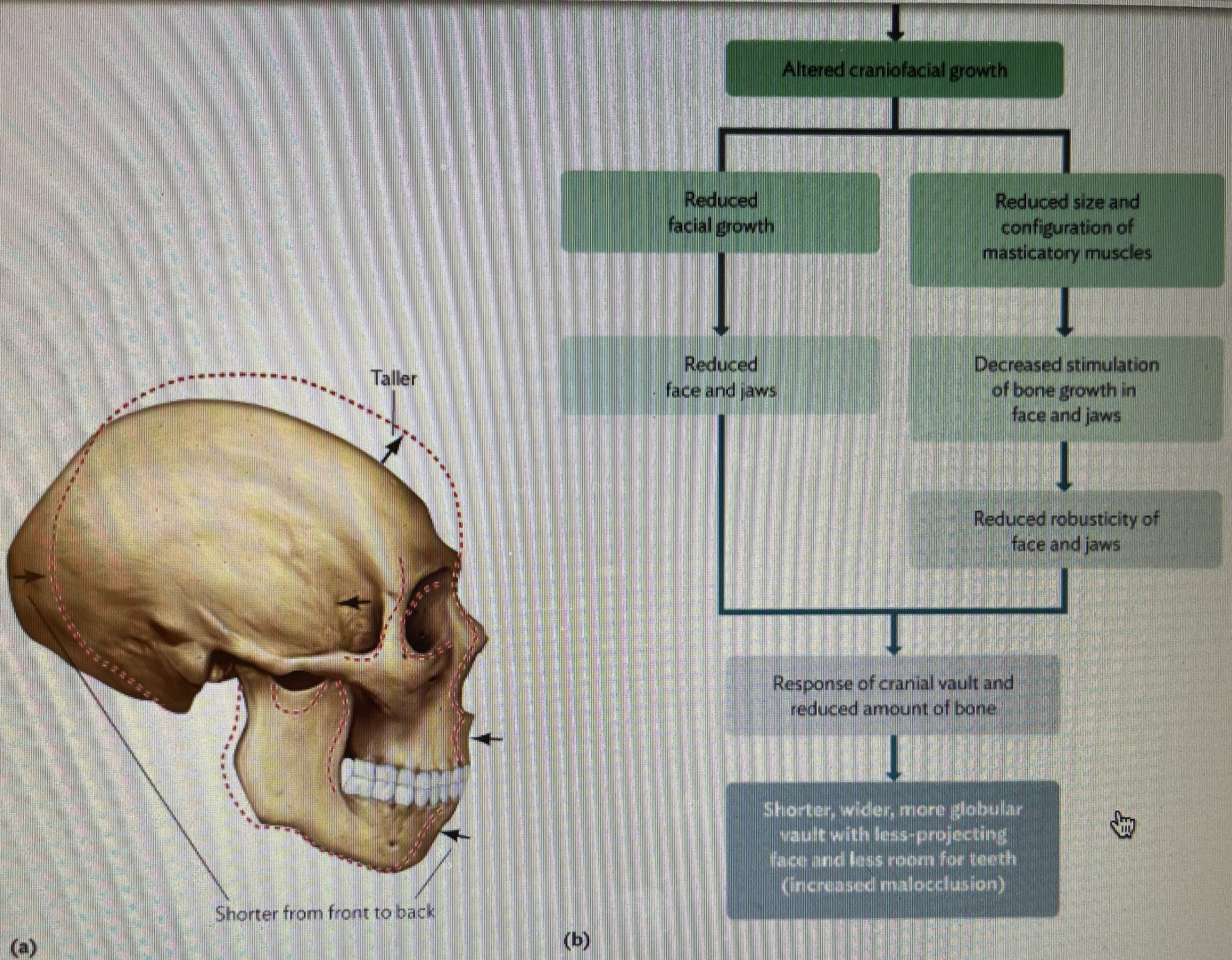


FIGURE 13.12

***Craniofacial Changes* (a)** The overall reduction in cranial size over the course of human evolution can be seen in Nubians' skeletal remains. Here, the dashed line indicates the craniofacial changes that have occurred between the Mesolithic foragers and the later agriculturalists. The skull has become shorter from front to back and, simultaneously, has gotten taller. **(b)** As presented in this flowchart, the Nubians' craniofacial changes resulted from alteration in diet associated with eating softer foods. In changing their diet, the Nubians were placing less demand on their chewing muscles. As a result, the associated bones diet, the Nubians were placing less demand on their chewing muscles. As a result, the associated bones changed; facial bones and jaws became smaller, and the cranial vault became rounder. The reduction in jaw size left less room for teeth, and the increased crowding resulted in malocclusion.

Malocclusion is a clearly negative result of humans' eating soft foods. A positive result is that our teeth have very little wear because eating soft foods places less stress on the chewing surfaces.

370

CONCEPT CHECK

Soft Food and Biological Change

The shift to agriculture and the eating of softer foods resulted in biological changes to the face, jaws, and teeth of modern people. Although not universal, some tendencies characterized the skulls and teeth of hunter-gatherers and of agriculturalists.

Hunter-Gatherers	Agriculturalists
Long cranial vault	Short skull
Large, robust mandible	Small, gracile mandible
Large teeth	Small teeth
Few malocclusions	Many malocclusions

Few malocclusions	Many malocclusions
Much tooth wear	Little tooth wear

Building a New Physique: Agriculture's Changes to Workload and Activity

One major debate in anthropology concerns the extent to which the agricultural revolution improved the quality of human life, including workload. Did people have to work more or work less to acquire food through agriculture rather than through hunting and gathering? The eminent American archaeologist Robert Braidwood characterized the lifestyle of a typical hunter-gatherer as "a savage's existence, and a very tough one...following animals just to kill them to eat, or moving from one berry patch to another." About the time Braidwood was writing this in the 1960s, the Canadian cultural anthropologist Richard Lee and the American biological anthropologist Irven DeVore organized what turned out to be one of the most important conferences in the modern era of

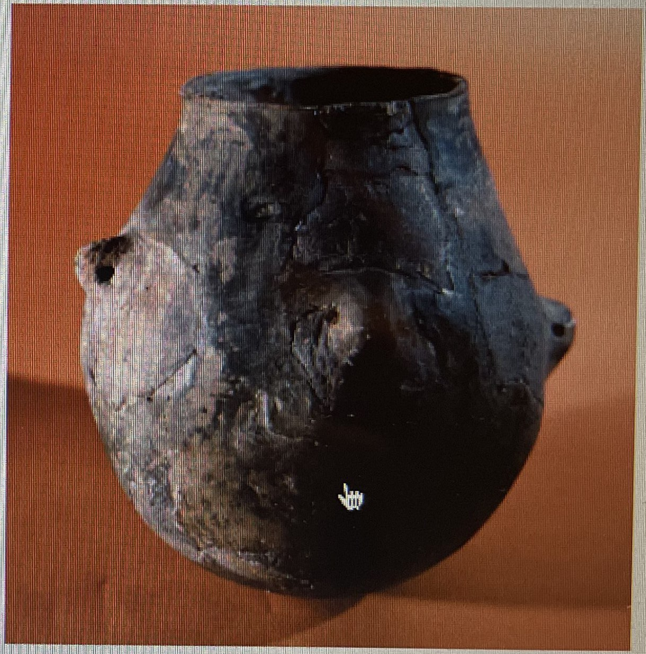


FIGURE 13.13
Pottery Vessels, such as this terra-cotta pot, were an important invention. Such containers made possible both the storage of food for periods of time and the cooking of food into softer forms.

softer forms.

conferences in the modern era of anthropology. They invited experts in different areas of anthropology from around the globe to determine the quality of life of hunter-gatherers, ancient and modern. A key component in assessing the quality of life was workload. If Braidwood was correct, hunter-gatherers had to work very hard, basically spending all waking hours in the food quest, getting food wherever and whenever possible. However, Lee and others reported that hunter-gatherers might not have had it all that bad when it came to workload. In fact, in his research on the Ju/'hoansi (!Kung) of southern Africa, Lee found that these hunter-gatherers had a great deal of leisure time (**Figure 13.14**).

Lee's work in the 1960s set in motion the work of a whole generation of anthropologists, who addressed both his observations and his hypotheses. Science works this way, of course—old hypotheses are often rejected as new observations are made, and new observations generate new hypotheses. Indeed, the subsequent work showed that hunter-gatherers have quite diverse workloads. Anthropologists realized that workload depended highly on the local ecology and the kinds of foods being eaten. For example, in how they acquire plants and animals, people living in the tropics differ greatly from people living in the Arctic.

How do scientists know how hard or how easy a lifestyle was? Obviously, they cannot observe the behavior of dead people. But biological anthropology offers a way to

biological anthropology offers a way to reconstruct past behavior. Biomechanics, an area of great interest to biological anthropologists, provides enormous insight into the evolution of the body below the neck in relation to workload and to other activity. As with the bones of the face and of the jaws, the bones of the postcranial skeleton are highly plastic during the years of growth and of development, all the way through adulthood. The general shape and size of bones—the femur, in the leg, for example, or the humerus, in the arm—are determined by a person's genes. However, the finer details are subject to work and activity. Highly physically active people's bones tend to be larger and more developed than those of not so physically active people.

FIGURE 13.14
Leisure Time While foragers, such as this band of !Kung, must spend many hours searching for and hunting for food, their work does not preclude them from relaxing for periods of time. However, studies of numerous foraging groups have shown a great deal of variation in the workloads and amounts of leisure time of hunter-gatherers.

Borrowing from how engineers measure the strength of building materials—such as the I-beam used in the construction of a bridge or of a building—biological anthropologists have developed a means for assessing the robusticity of bone cross sections. Based on the simple premise that material placed farther away from an axis running down the center of the bone is stronger than material placed closer to the axis (**Figure 13.15**), it has become possible to look at the degree of bone development and determine by empirical means how bone strength has changed over the course of human evolution to the present. Bone comparisons—from hunter-gatherers' to later agriculturalists' to comparisons—from hunter-gatherers' to later agriculturalists' to modern peoples'—show a remarkable decline in size.

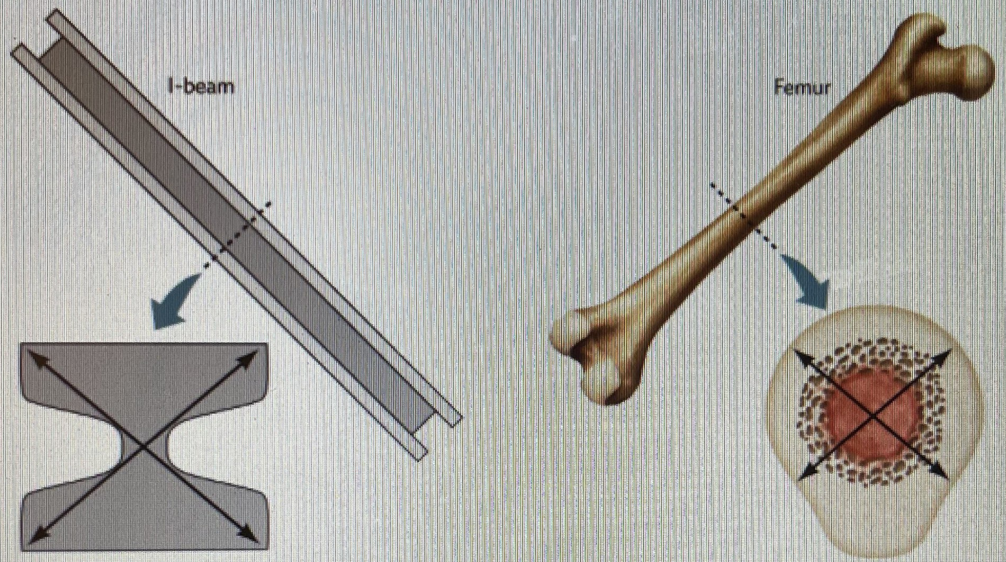


FIGURE 13.15
Cross-Sectional Geometry Using engineering principles, biological anthropologists can gain insight into activity patterns by examining the cross sections of long bones, such as the femur and the humerus. The shapes of long bones, like those of I-beams (building materials used for structural support), maximize both strength and ability to resist bending by distributing mass away from the center of the section.

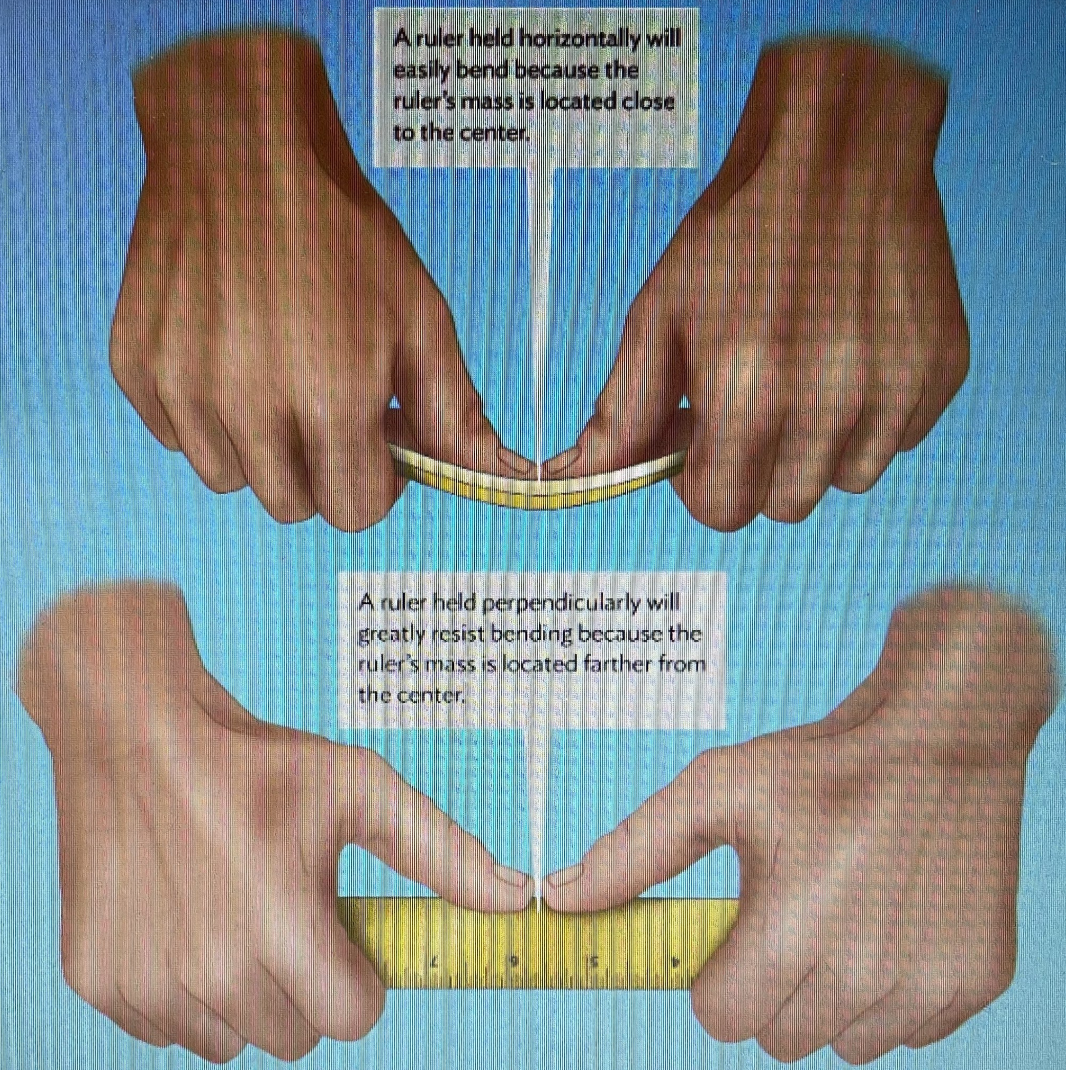
Measurement involves first getting a good image of the bone's cross section. Doing so might mean cutting the bone to physically expose the cross section, usually in the mid-diaphysis. If cutting is impossible, a cross section can be created by taking a CAT (computed axial a cross section can be created by taking a CAT (computed axial tomography) scan of the bone, just as a radiologist would as part of a medical examination. On the section, the biological anthropologist traces the bone's outer perimeter, or periosteal surface, and inner perimeter, or endosteal surface, with an electronic stylus hooked up to a computer loaded with engineering software that automatically calculates the second moments of area.

HOW DO WE KNOW

BONES AND BEHAVIOR

The shapes and sizes of bones are determined largely by each species' genetic plan. However, because individual bones have a significant amount of plasticity, their shapes can be reconfigured, especially those of arm and leg bones.

These reconfigurations are determined by environmental factors, in particular the stresses from muscles and from body weight. By studying these reconfigurations in skeletons, biological anthropologists learn a great deal about past peoples' lifestyles.

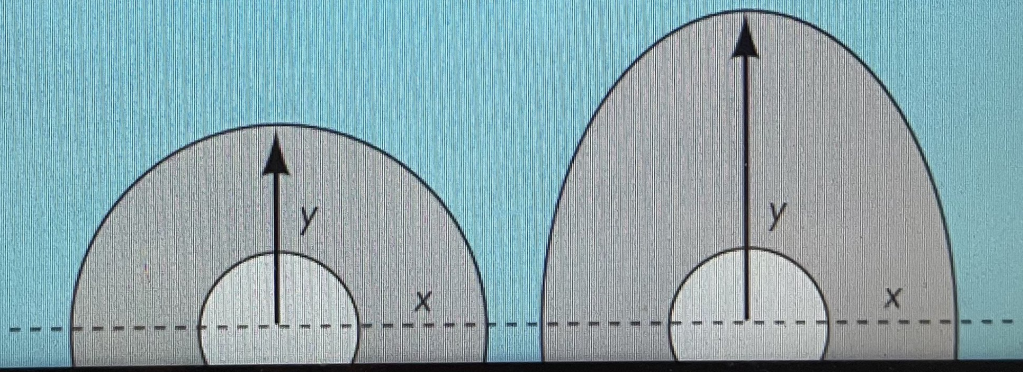


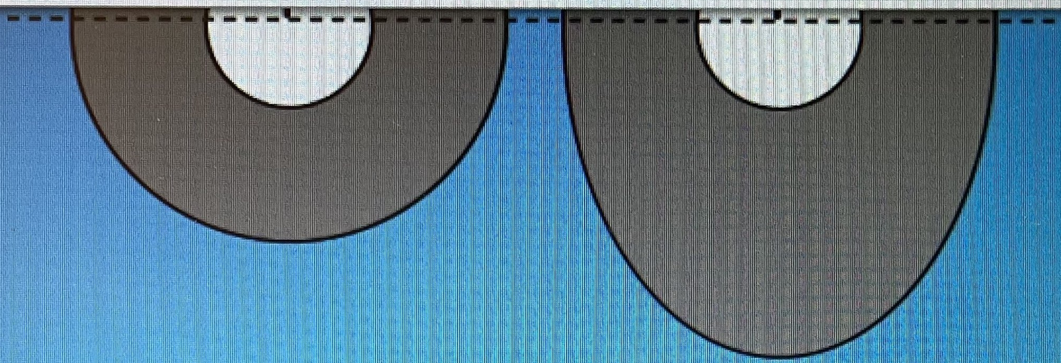
A Bending a ruler helps illustrate the principles of biomechanics.

One breakthrough in biological anthropologists' understanding of earlier humans' physical activity has been the application of biomechanics to bones. (See the text and Figures 13.15 and 13.16.) To visualize these

One breakthrough in biological anthropologists' understanding of earlier humans' physical activity has been the application of biomechanics to bones. (See the text and Figures 13.15 and 13.16.) To visualize these biomechanical principles, hold a plastic ruler flat, with one hand at each end, and bend it. Now rotate the ruler so that its edge is facing up, again with one hand at each end, and try to bend it. On the flat plane, the ruler bends easily because its mass is distributed close to the central axis, so its bending "strength"—actually, resistance to bending—is low. With its edge up, the ruler is almost impossible to bend because its mass is distributed farther from the central axis, so its bending strength is high. In this plane, it resists bending forces you have applied to the ruler with your hands.

Now imagine a perfectly circular hollow tube, seen in cross section. In the different planes across the section, the bending strength is equal. However, if the tube is a little flattened, the elongated section has greater resistance to bending because the tube's mass is placed farther from the central axis than it is in the narrow section. Now replace that hollow tube with a femur or humerus.





B Because it is perfectly round, the cross section on the left has equal strength, or equal resistance to bending, in all directions. The slightly flattened cross section on the right, however, has greater strength in the y-axis than in the x-axis because the material is distributed farther from the central point.

To assess the bending and torsional (or twisting) strength of that limb bone, biological anthropologists measure biomechanical properties called *second moments of area*. Engineers call these properties *I*, which denotes bending strength, and *J*, which denotes twisting strength. Biological anthropologists measure these properties in relation to two primary axes in a bone cross section, the *x*-axis and the *y*-axis, or I_x and I_y. The I_x values measure the strength or resistance of bone to front-to-back bending, and the I_y values measure the strength or resistance of bone to side-to-side bending. *J* is the sum of these two values. The larger the *I* or *J* values, the greater the bone's ability to resist bending forces and ultimately breaking from the forces placed on the bones during walking, running, or lifting heavy objects.