# The Scars of Human Evolution

*Although man stands on two legs, his skeleton was originally designed for four. The result is some ingenious adaptations, not all of them successful*

by Wilton M. Krogman

IT has been said that man is "fearfully and wonderfully made." I am inclined to agree with that statement —especially the "fearfully" part of it. As a piece of machinery we humans are such a hodgepodge and makeshift that the real wonder resides in the fact that we get along as well as we do. Part for part our bodies, particularly our skeletons, show many scars of Nature's operations as she tried to perfect us.

I am not referring to our so-called vestiges—those tag-ends of structures which once were functional, such as the remnant of a tail at the base of the spine, the appendix, the pineal or "third" eye, the misplaced heart openings of "blue babies," or the like. Nor do I mean the freak variations that crop up in individuals. I am discussing the imperfect adaptations the human race has made in getting up from all fours.

We have inherited our "basic patents," as W. K. Gregory of the American Museum of Natural History calls them, from a long line of vertebrate (backboned) ancestors: from fish to amphibian to reptile to mammal and finally from monkey to ape to anthropoid to *Homo sapiens*. In all this evolution the most profound skeletal changes occurred when we went from a four-legged to a two-legged mode of locomotion.

Gregory has very aptly called a four-legged animal "the bridge that walks." Its skeleton is built like a cantilever bridge: the backbone is the arched cantilever; the vertebrae of the forward part of the backbone are slanted backward and those of the rear forward, so that the "thrust" is all to the apex of the arch; the four limbs are the piers or supports; the trunk and abdomen are the load suspended from the weight-balanced arch; in front the main bridge has a drawbridge or jointed crane (the neck) and with it a grappling device (the jaws).

When all this was up-ended on the hind limbs in man, the result was a terrific mechanical imbalance. Most of the advantages of the cantilever system were lost, and the backbone had to accommodate itself somehow to the new vertical weight-bearing stresses. It did so by breaking up the single-curved arch into an S-curve. We are born, interestingly enough, with a backbone in the form of the simple ancestral arch, but during infancy it bends into the human shape. When we begin to hold our head erect, at about the age of four months, we get a forward curve in the backbone's neck region; when we stand up, at about a year, we get a forward curve in the lower trunk; in the upper trunk and pelvic regions the backbone keeps its old backward curve.

BUT we achieve this at a price. To permit all this twisting and bending, Nature changed the shape of the vertebrae to that of a wedge, with the thicker edge in front and the thinner in back. This allows the vertebrae to pivot on their front ends as on hinges, like the segments of a toy snake. On the other hand, it also weakens the backbone, particularly in the lower back region, where the wedge shape is most pronounced. Heavy lifting or any other sudden stress may cause the lowermost lumbar vertebra to slip backward along the slope of the next vertebra. The phrase "Oh, my aching back" has an evolutionary significance!

There are other ways in which the backbone may literally let us down. The human backbone usually has 32 to 34 vertebrae, each separated from its neighbor by a disk of cartilage which acts as a cushion. Of these vertebrae 7 are cervical (in the neck), 12 thoracic (upper trunk), 5 lumbar (lower trunk), 5 sacral (at the pelvis) and 3 to 5 caudal (the tail). Every once in a while the seventh cervical vertebra may have an unusually long lateral process; if long enough, this protruding piece of bone may so interfere with the big nerves going down to the arm that it has to be sawed off by a surgeon. Most people have 12 pairs of ribs, borne by the 12 thoracic vertebrae, but occasionally the transverse processes of the next lower segment, the first lumbar vertebra, are so exaggerated that they form a 13th pair of ribs. In some people the lowest (fifth) lumbar vertebra is fused with the sacral vertebrae. The latter are usually united into one bone, called the sacrum, but sometimes the first sacral vertebra fails to join with its mates. All these idiosyncrasies can cause trouble.

The "Achilles' heel" of our backbone is the unstable lower end of the vertebral column. This is where we reap most of the evil consequences of standing up on our hind legs. It is a crucial zone of the body—the pathway for reproduction and the junction point where the backbone, the hind end of the trunk and the legs come together. The skeletal Grand Central Station where all this happens is a rather complicated structure consisting of the sacrum and the pelvis. The pelvis is not only a part of the general skeletal framework of the body but also a channel for the digestive and urogenital systems and the coupling to which the muscles of the hind legs are attached. When we stood up on our hind legs, we burdened the pelvis with still another function, namely, bearing the weight of the upper part of the body. How have we changed our pelvis to adapt it to its new position and burdens?

The pelvic structure is made up of three sets of paired bones, the ilium, the ischium and the pubis. The three bones meet at each side in the hip socket, where the head of the thighbone articulates. In standing erect man tilted the whole structure upward, so that the pelvis is at an angle to the backbone instead of parallel to it. The relative position of the three pelvic bones changed, with the pubis now in front instead of below.



© 1951 SCIENTIFIC AMERICAN, INC

The bones also were altered in shape. The iliac bones, formerly elongate and bladelike (in the anthropoids), are now shortened and broadened. They form the crests of our hips, and they help support the sagging viscera, especially the large intestine. The pubic bones help to form the subpubic arch—that "arch of triumph" beneath which we must all emerge to life and to the world. The ischial bones retreat to the rear; they are the bones that bear the brunt of sitting through a double feature or before a television screen.

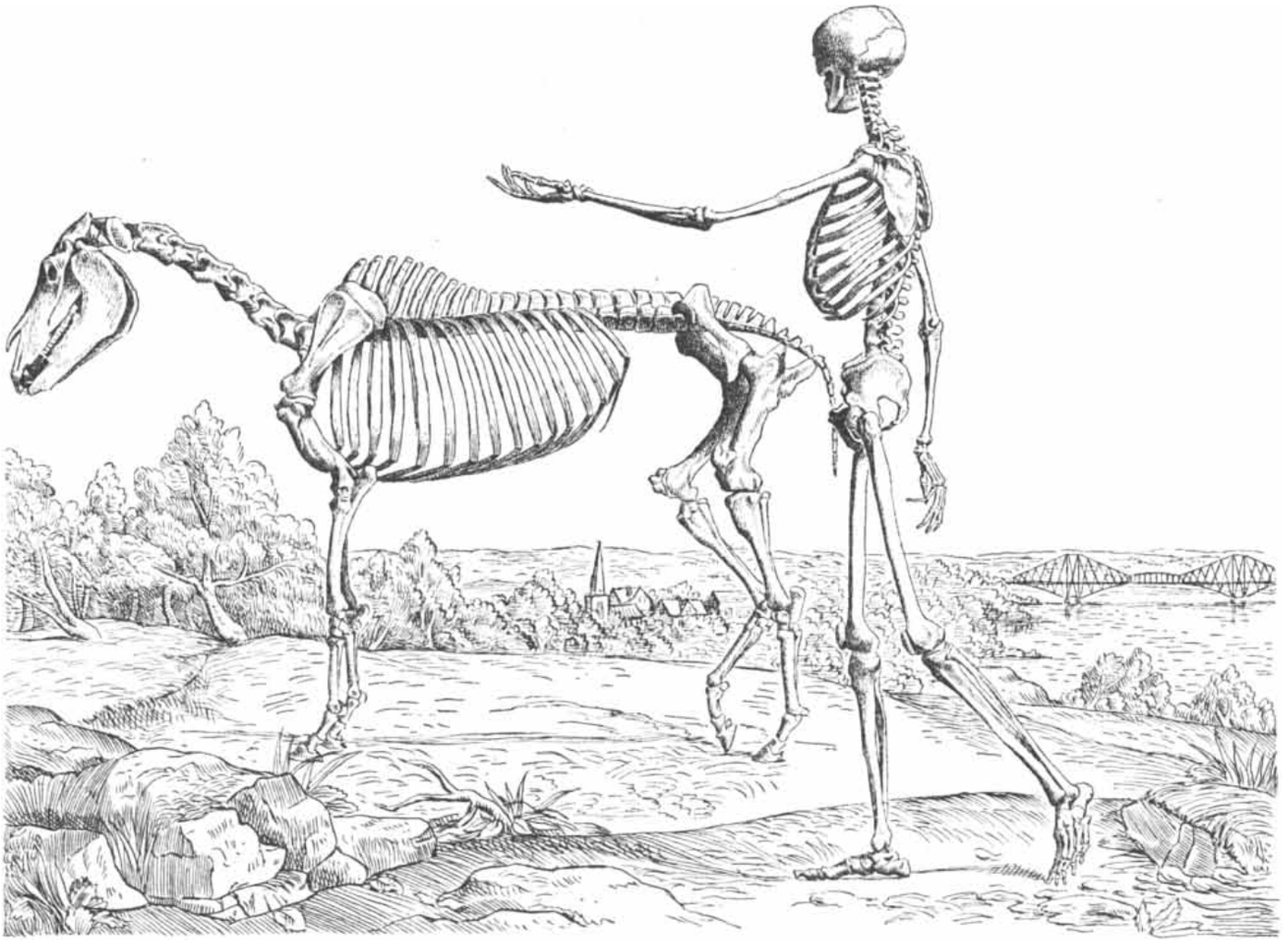
THE greatest change is in the zone of contact between the iliac bones and the wedgelike sacrum—the so-called sacroiliac articulation. Here are focused the weight-bearing stresses set up by the erect posture. Two things have happened to adapt the pelvic structure for "thrusting" the weight of the trunk to the legs. The area of contact between the sacrum and the iliac bones has increased, strengthening the articulation. In the process the sacrum has been pushed down, so that its lower end is now well below the hip socket and also below the upper level of the pubic articulation. This has brought trouble, for the sacrum now encroaches upon the pelvic cavity and narrows the birth canal that must pass the fetus along to life. Furthermore, the changes have created an area of instability which far too often results in obscure "low back pain" and in "slipped sacroiliacs."

The shortening of the iliac bones has increased the distance between the 12th (lowest) rib and the top or crest of the ilium. This has given us our waist, but it has also materially weakened the abdominal wall, which now, for about a palm's breadth, has only muscle to support it. The greatest weakness of the upright posture is the lower abdominal wall. In four-legged animals the gut is suspended by a broad ligament from the mechanically efficient convex vertebral arch. The burden of carrying the weight of the viscera is distributed evenly along the backbone. Up-end all this and what happens? First of all, the gut no longer hangs straight down from the backbone but sags parallel to it. Secondly, the supporting ligament has a smaller and less secure hold on the backbone. One result of the shift in the weight-bearing thrust of the abdominal viscera is that we are prone to hernia.

Nature has made a valiant effort to protect our lower belly wall. She invented the first "plywood," and made it of muscle. Three sheets of muscle make up the wall, and their fibers crisscross at right and oblique angles. This is all right as far as it goes, but it has not gone far enough: there is a triangular area in the wall which was left virtually without muscular support—a major scar of our imperfect evolution.

The upright posture required a major shift in the body's center of gravity, but here Nature seems to have done a pretty good job. The hip sockets have turned to face slightly forward instead of straight to the sides; the sockets and the heads of the thighbones have increased in size, and the neck of the thighbone is angled a bit upward. As a result of this complex of adjustments the bodily center of gravity is just about on a level with a transverse line through the middle of the hip sockets, and the weight of the trunk upon the pelvis is efficiently distributed on the two legs.

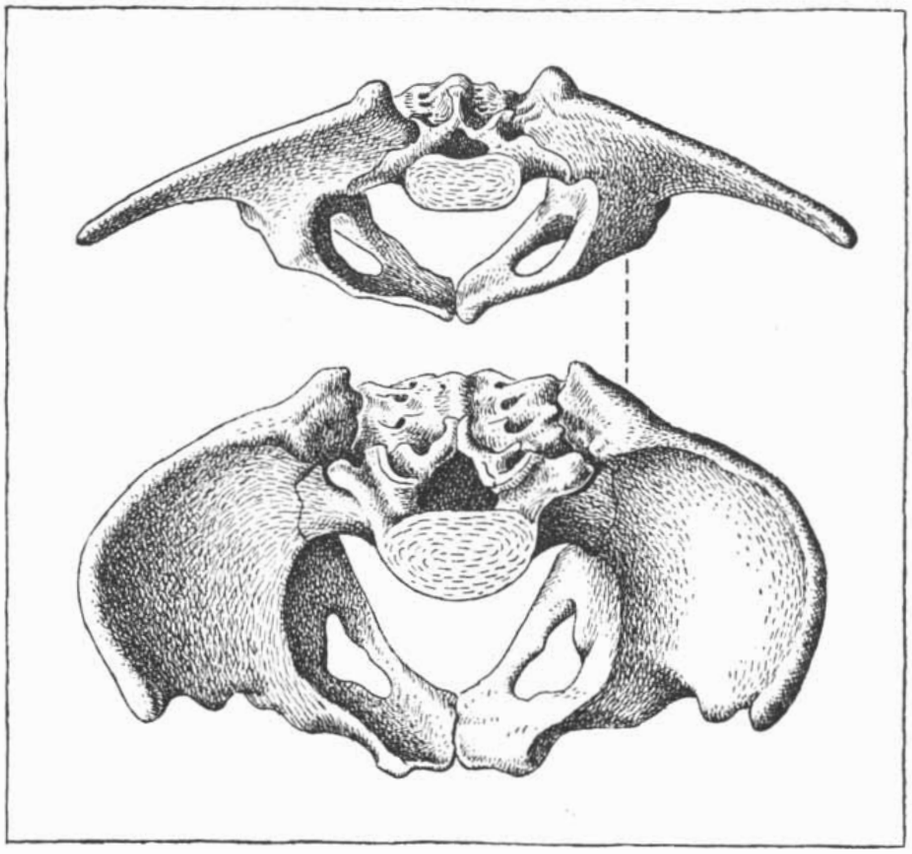
Though it does not directly involve the skeleton, I might mention here that the blood circulation is another factor that is not helped by our upright position. Since the heart is now about four feet above the ground, the blood re-



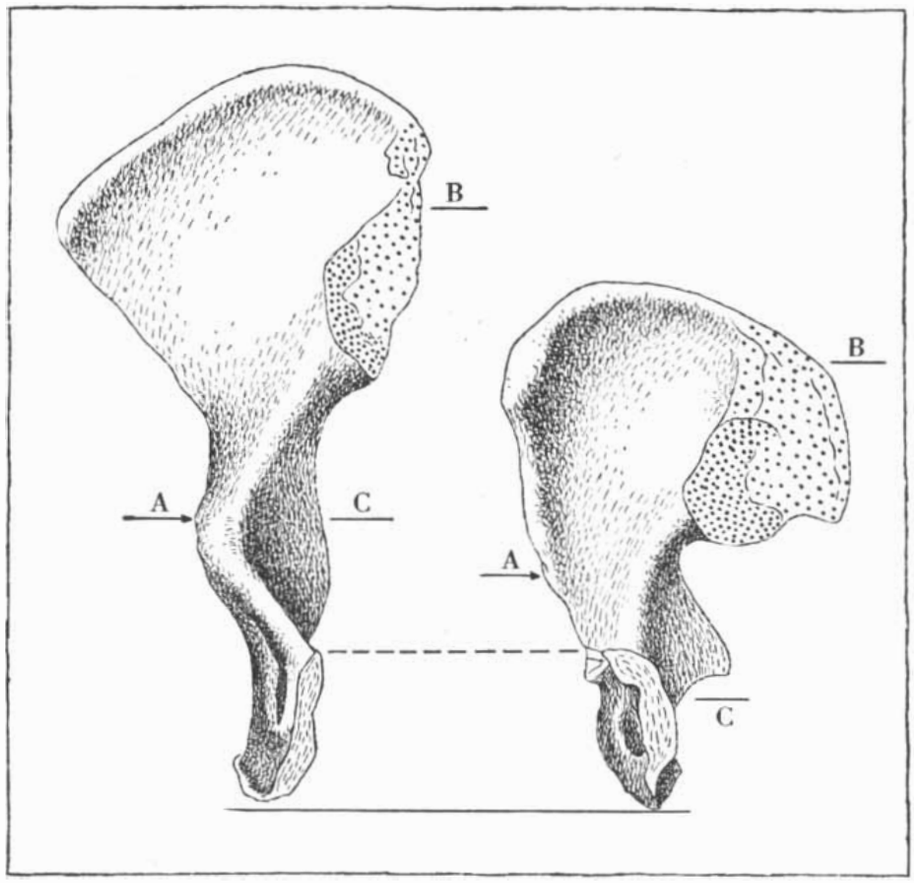
**BACKBONES** of the horse and man illustrate the principal problem of adapting the quadruped skeleton to biped purposes. The horizontal backbone of the horse is gently arched between two supports, rather like the cantilever bridge in the right background. The vertical backbone of man, in contrast, is curved like an S.



© 1951 SCIENTIFIC AMERICAN, INC



**TOP VIEW OF THE PELVIS** of the gorilla (*top*) and man (*bottom*) show how the latter has developed to support the weight of the abdominal organs. The dotted line indicates the width of the sacrum in man.




**INSIDE VIEW OF THE HIP BONE** of the gorilla (*left*) and man (*right*) show how the latter has become shorter. The dotted line and the letters A, B and C indicate similar anatomical features in both structures.

turned to the heart from the veins of the legs must overcome about four feet of gravitational pull. Often our pumping system and veins find the job too much, and the result is varicose veins. The lower end of the large intestine also is affected, for its veins, when up-ended in a vertical position, become congested more easily, so we get hemorrhoids.

Even more serious is the danger to the circulation along the vertebral column. Two great vessels, an artery and a vein, run down this column. At the level where these vessels divide into two branches, one for each leg, the right-sided artery crosses over the left-sided vein. In a quadruped this presents no problems, but in the erect position the two vessels must cross a sharp promontory of bone at the junction of two vertebrae, and the viscera piled up in the pelvis press down on them. During pregnancy the pressure may increase so much that the vein is nearly pressed shut, making for very poor venous drainage of the left leg. This is the so-called "milk leg" of pregnancy.

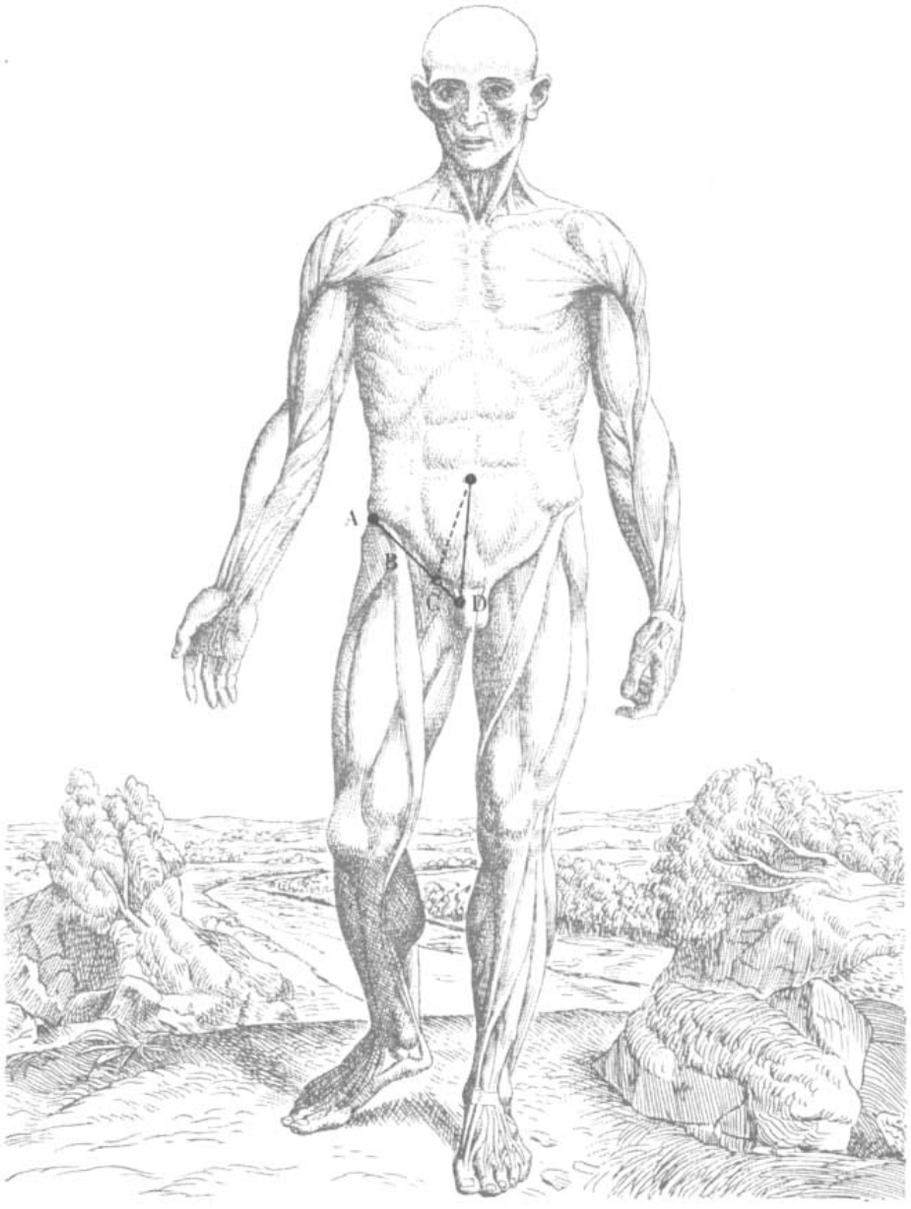
GOING back to the skeleton, it is clear that the two-legged posture places a much bigger burden on our feet. They have adapted themselves to this by becoming less of a grasping tool (as in the monkeys) and more of a load-distributing mechanism. We have lost the opposability of the big toe, shortened the other toes and increased the length of the rest of the foot. The main tarsal bones, which form the heel, ankle joint and most of the instep, now account for half the total length of the foot, instead of only a fifth as in the chimpanzee. We have also achieved a more solid footing by developing two crosswise axes, one through the tarsals and the other through the main bones of the toes. The little-toe side of our foot is relatively neglected—the toe is little because it is not so useful. Our fallen-arch troubles, our bunions, our calluses and our foot miseries generally hark back to the fact that our feet are not yet healed by adaptation and evolutionary selection into really efficient units.

Now let us go to the other extreme—to the head. A lot has gone on there, too. We have expanded our brain case tremendously, and there can be no doubt that many of the obstetrical problems of Mrs. H. Sapiens are due to the combination of a narrower pelvis and a bigger head in the species. How long it will take to balance that ratio we have no idea. It seems reasonable to assume that the human head will not materially shrink in size, so the adjustment will have to be in the pelvis; *i.e.*, evolution should favor women with a broad, roomy pelvis.

If the head has increased in size, the reverse is true of the facial skeleton. Bone for bone the face has decreased in size as we proceed from anthropoid



© 1951 SCIENTIFIC AMERICAN, INC




**TRIANGLE OF WEAKNESS** in the abdominal wall lies between the epigastric artery (C) and the central abdominal muscles. A is the hip; D, the pubic bone. B on the line between A and D is the inguinal ligament.

to man. To put it succinctly, we have a face instead of a snout.

What about the teeth in that face of ours? All mammals have four kinds of teeth: incisors in front, canines at the corner, premolars and molars along the sides. With but few exceptions the mammals have both a milk set and a permanent set of teeth. About 100 million years ago, or maybe a bit more, the first mammals had 66 permanent teeth, of which 44 were molars or premolars. Most mammals today have 44 teeth, including 28 molars and premolars. But man, and the anthropoid, has only 32 teeth—8 incisors (upper and lower), 4 canines, 8 premolars and 12 molars. The loss has been greatest in molars, next in incisors, then in premolars, with the canine a veritable Rock of Gibraltar.

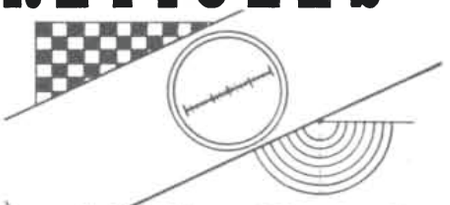
While the face bones have decreased in size, our teeth have remained relatively large. Many orthodontists believe that this uneven evolutionary development may be partly responsible for the malocclusion of teeth in children. Certain it is that some human teeth are apparently on the way out: the third molars ("wisdom teeth") are likely to be impacted or come in at a bad angle, and many people never have them at all. Perhaps in another million years or so we shall be reduced to no more than 20 teeth.

It is mayhap a form of human conceit—the egotism born of a highly evolved brain—to worry about our bodily imperfections or inadequacies. As the philosopher said:

*The world is old and thou art young;*
*The world is large and thou art small;*
*Cease, atom of a moment's span*
*To hold thyself an All-in-All!*

*Wilton M. Krogman is professor of physical anthropology at the University of Pennsylvania.*

RETICLES



for the Finest in Precision

Reticles with lines one micron in thickness with spacing between lines as fine as 5 microns. Their fineness of line, accuracy, assure perfect operating efficiency.

Available in custom or any one of several standard designs. U.S. Testing reticles meet the exacting needs of industry.

Write for our brochure today.

The New
INSTRUMENTS DIVISION
UNITED STATES TESTING COMPANY, INC.
Established 1880
1660 Park Avenue,
HOBOKEN, NEW JERSEY
PHILADELPHIA • BOSTON • PROVIDENCE
CHICAGO • NEW YORK • LOS ANGELES
DENVER • MEMPHIS
Member of American Council of Commercial Laboratories

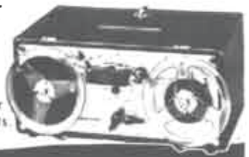
MAGNECORD
Sound Research*



* TROUBLE-SHOOTS A POWER LINE

Giant transmission lines require constant maintenance and replacement. Magnecord Tape Recorders help in this full-time job by checking the hum of high voltage transformers. Magnecord sound analysis of this hum pin-points trouble spots along miles of power lines . . . cuts maintenance costs and assures safe delivery of needed power.

Whatever your recording problem — in the laboratory or in your field tests — Magnecorders offer greater fidelity and precision. Available for subsonic, audio and supersonic research, Magnecord can fill your most exacting requirements.



Magnecord, INC.

HIGH FIDELITY TAPE RECORDERS FOR INDUSTRY
Write for New Catalog. Dept. SA-12
Magnecord, Inc., 360 N. Michigan Ave., Chicago 1, Ill.



© 1951 SCIENTIFIC AMERICAN, INC