LIMB DEVELOPMENT

Gene Ties Arthropods Together

From creepy-crawly centipedes to sideways-stepping crabs, legs are arthropods' claim to fame—and keys to disputes over arthropod ancestry. Many crustaceans, for example, feature limbs with two or more branchlike extensions, while insects possess only unbranched limbs. With no clear transitional forms in the fossil record, some paleobiologists assert the two groups must have gone separate ways almost 600 million years ago, a time of odd, poorly fossilized animals, and today they are hardly related at all. Other researchers, however, argue that the groups shared a common ancestor as recently as 400 million years ago, when insects first appeared, and that limb differences arose because insects simply shed their extra branches. Over the years, these arguments have "run themselves into the ground," says Graham Budd, a paleontologist at Uppsala University in Sweden.

Recently, however, geneticists and developmental researchers have joined the debate—on the side of those arguing for a closer insect-crustacean relationship. On page 1363 of this issue, a team led by developmental geneticist Sean Carroll at the University of Wisconsin, Madison, reports that limb branching is a second-order phenomenon, affected by a single gene that initiates development of unbranched limbs in fruit flies and branched limbs in crustaceans such as brine shrimp. Any differences in limb branching correspond with differences in the way this gene, called *Distal-less* (*Dll*), is regulated during development, the group found. The gene's plasticity means "you don't need separate ancestors" to explain the diversity of arthropod limb patterning, Carroll asserts.

Developmental geneticist Michael Akam of Cambridge University in England calls the work "intriguing stuff." He notes that it adds to a growing current of research tying arthropods more closely together. For instance, Jeffrey Boore, Markus Friedrich, and their colleagues recently noted similarities among mitochondrial and ribosomal DNA sequences from insects and crustaceans that also imply the two groups share a close evolutionary history (*Nature*, 13 July, pp. 163 and 165).

Carroll's group—which includes researchers Grace Panganiban, Angela Sebring, and Lisa Nagy—had been studying the role of *Dll* expression in limb development in flies and butterflies. Without the gene, limbs can't grow. Given the insect-crustacean controversy, they decided to explore *Dll* expression among crustaceans as well, hoping it might yield clues about the relationships of the organisms.

Antibody staining of developing limbs of the brine shrimp *Artemia franciscana* and the opossum shrimp *Mysidopsis bahia* showed that each branch of each crustacean limb expresses *Dll*, just as if they were unbranched insect limbs. The exact pattern of expression, however, varied with the body section of the organism. Branches on the head limbs of *Mysidopsis*, for example, grew simultaneously from a single group of *Dll*-expressing cells, while those on thoracic limbs developed sequentially from separate cell groups. "That tells you there is a lot of room to operate within a single class of arthropods ... using the same genes," says Carroll. Branches thus shouldn't be viewed as a distinguishing characteristic of any arthropod group, he argues.

Donald Anderson, an emeritus biologist at the University of Sydney in Australia and a champion of the multiple-lineage theory, admits that "at the moment, the weight of the evidence seems to be pointing" toward a close insect-crustacean relationship. But he notes that because even vertebrates share versions of *Distal-less*—indicating that the gene first arose in some distant progenitor of both the vertebrates and the arthropods—its ubiquity makes it hard to use *Dll* to pinpoint a time for arthropod divergence.


GRACE PANGANIBAN

Leg show. A brine shrimp's branched limbs show activity of the limb-regulating gene *Dll (brown segments)*, as do insect limbs. (Topmost limbs are 0.3 millimeters.)

Carroll's group is taking another tack in tracing that divergence: looking for *Dll* expression in possible arthropod precursors, such as the legless annelids. Finding *Dll* expressed in annelids' leglike body projections—called parapodia—would suggest that the groups are related. And that, in turn, may take researchers another step closer to understanding arthropod relations.

–Wade Roush

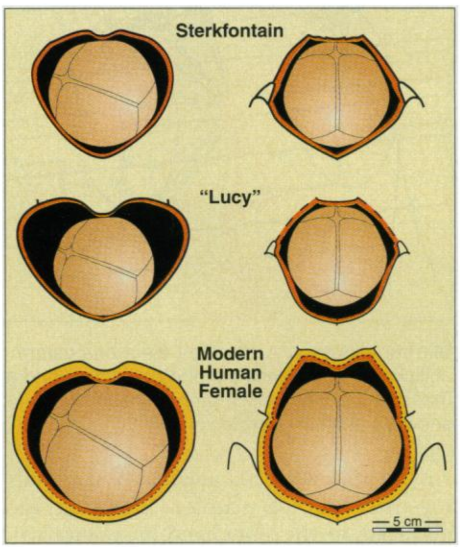
PALEOANTHROPOLOGY

Sexing Fossils: A Boy Named Lucy?

Have anthropologists been engaged in a 20-year affair with a gender-bending hominid? Two Swiss anthropologists think so. They've examined the bones of one of the most famous female figures of all time—a 3-million-year-old skeleton known as "Lucy," discovered in 1974—and when their gaze moved below the waist, they got a shock: She was not a she.

This is not the script for a sequel to the movie *The Crying Game*, but an argument made in the October issue of the *Journal of Human Evolution* by Martin Häusler and Peter Schmid of the University of Zurich in Switzerland. Judging from Lucy's pelvis, they say, this little representative of the species *Australopithecus afarensis*, long posed near the base of the human family tree, was more likely a male. Their study does more than challenge Lucy's gender. If correct, it threatens to reignite one of the hottest controversies in anthropology: whether *A. afarensis* was one species—or two.

Opinion on this species-splitting gender switch is, well, divided. Häusler and Schmid argue that Lucy was a male because the skeleton's pelvis was too narrow to accommodate an australopithecine baby. The contention, says anthropologist Robert Taugue of Louisiana State University, "will certainly challenge people to evaluate this specimen again." But many other anthropologists think the pelvic data are being stretched. "This analysis is so tortuous and labyrinthine I don't know where to start," says Owen Lovejoy of Kent State University, who undertook the original reconstruction of Lucy's pelvis.



M. HÄUSLER AND P. SCHMID

Male delivery? A reconstruction of the inlet *(left)* and midplane *(right)* of Lucy's pelvis shows the shape, compared to another fossil pelvis and a modern one, is the wrong one for giving birth.

Lucy was discovered at Hadar in Ethiopia by paleoanthropologist Donald Johanson. Standing barely a meter high, and with a tiny mandible and canine tooth sockets, its body proportions were considered far too petite to be male. (Male primates are generally larger than females.) This assumption seemed confirmed when a host of additional—but larger—specimens were found at Hadar. Johanson, now at the Institute of Human Origins in Berkeley, California, and Tim White of the University of California, Berkeley, concluded that all the material represented a single, sexually dimorphic species: The small individuals like Lucy were females, and the large specimens were males. *A. afarensis*, they further claimed, was the single root giving rise to all subsequent hominids, including our own genus, *Homo*.

Other investigators protested that the disparity in size was too great and implied two separate species, with only the larger one ancestral to *Homo*. The debate sizzled for over a decade, until most experts were persuaded that Johanson and White had been right (*Science*, 1 April 1994, p. 34).

Häusler and Schmid are not persuaded. They compared two different reconstructions of Lucy's pelvis with that of another from the South African site of Sterkfontain, usually attributed to the species *Australopithecus africanus*. They looked at a standard suite of traits used to ascertain sex in modern humans, such as a ridge on the pubic bones called the ventral arc, found in 95% of modern females pelves, and the promontorium, a protrusion at the rear of the pelvis that juts forward in males, giving the pelvic inlet a heart shape. The Sterkfontain pelvis appears to be female, while Lucy, with a ridgeless, heart-shaped pelvis, seems to be a male.

Häusler and Schmid concede that modern male features on Lucy's decidedly unmodern pelvis are only partly convincing; they may have had nothing to do with gender in australopithecines. But could such a pelvis give birth to an australopithecine infant? Using standard regression equations, they scaled down estimates for the average size of an adult australopithecine skull to neonatal proportions. They did this calculation two ways: by including the larger specimens from Hadar (which should be done if *A. afarensis* is indeed one species), and by excluding them (as if they belonged to another species). In the first case, birth through Lucy's pelvis was impossible; their calculations indicated that there was simply not enough room to allow the infant's head to pass through. In the second instance, starting with smaller fossils and scaling down to a smaller neonate head, Häusler and Schmid conclude that birth would have been possible, but with great difficulty. So Lucy could be female—but only if the larger fossils were another species. "I cannot say for certain that Lucy was male," says Häusler. "What I *can* say is that she did not belong to a species with great sexual dimorphism in body size."

Lovejoy, Johanson, and others strongly disagree. Lovejoy points out that the Swiss study depends on estimates of neonatal head sizes in australopithecines that are themselves based on controversial estimates of adult brain sizes—all to determine whether a hypothetical infant of a vanished species could fit through a pelvis that was itself recovered in a badly crushed condition.

Given these stacked assumptions, says Karen Rosenberg of the University of Delaware, Lucy's small stature may still be the most telling feature. "Lucy is not absolutely the smallest specimen at Hadar in every feature, but she's pretty close," says Rosenberg. "By that standard, it's hard to imagine how she could be male."

–James Shreeve

James Shreeve is a science writer in Takoma Park, Maryland.

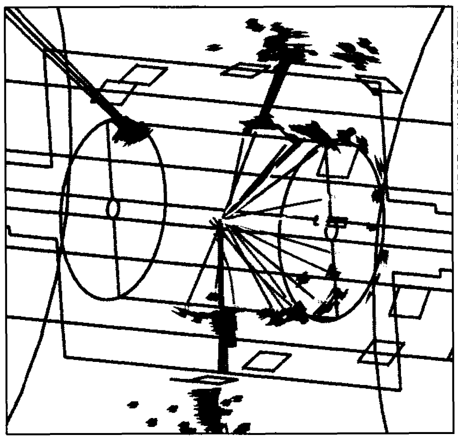
PHYSICS

LEPing Up to Higher Energies

The unwritten rule of particle physics has always been build a better accelerator, and you'll discover something new. That expectation has been seriously dampened by the success of the "Standard Model" of particles and forces, which predicts no new particles beyond those already discovered. It has not been quenched entirely, however. Proposed "supersymmetric" theories—efforts to transcend the Standard Model by linking all of the fundamental forces except gravity in a single framework—suggest that an abundance of new particles is waiting to be discovered. And physicists have always had an optimistic streak, in any case.

That optimism is amply evident these days at the European Laboratory for Particle Physics (CERN), where physicists are enjoying a new look at some of the highest energies ever. On 31 October, CERN's Large Electron-Positron Collider (LEP) began a month-long run at 130 billion electron volts (GeV), nearly twice its previous energy and the highest ever reached in an electron-positron machine. With physicists at four detectors analyzing particle collisions online, the result, says LEP physics coordinator Tiziano Camporesi, "is incredible hysteria. ... People are manning shifts, 24 hours a day, on all four experiments."

Since the run began, operators have cranked up the energy another notch, to 140 GeV. That still falls well short of the energy of the Tevatron Accelerator at the Fermi National Accelerator Laboratory, which collides protons at a trillion electron volts. But because each proton is made of three quarks and many gluons, proton-proton collisions



SOURCE: V. INNOCENTE/CERN

Minute alchemy. A 131-GeV electron-positron collision at LEP spawns a photon *(green)* and a massive Z boson, which promptly annihilates in showers of other particles.

are the microscopic equivalent of slamming together bags of marbles. Electrons and positrons, on the other hand, are point particles, which makes LEP "a much cleaner environment" for detecting new particles that might materialize at high energies, says University of Geneva physicist Maurice Bourquin, a LEP experimentalist.

LEP owes its new potency to 16 new superconducting radio-frequency cavities, which CERN engineers added to the 44 superconducting RF cavities already accelerating particles in the 6-year-old machine. The upgrade, completed last month, is the first in a series that will eventually take LEP to 196 GeV by the summer of 1998. "This run was a so-called pilot run at high energy," says Camporesi, "but it turns out we already have some discovery power in the supersymmetric energy range." Among other things, he says, the beam's luminosity—its density of particles—is unexpectedly high. Now CERN physicists are hoping the run will nail down the lightest predicted supersymmetric particle, the so-called chargino.

For those who want to follow the quest, results from the new LEP run can be seen on the home pages of the various LEP experiments. That of L3, an experiment led by Nobel laureate Sam Ting, can be found at **http://hpl3sn02.cern.ch/130GeV.html**. The page offers images of collisions and their debris. So far, none of the events violates the Standard Model. But the experimenters are undaunted. The page concludes: "The largest excitement from this higher energy run comes from the search of events due to new physics processes." Click on "events," and at press time the display read, "We are very sorry but there are no candidate New Physics events (YET) ..."

–Gary Taubes