looked at the development of the vulva, a female sexual organ. She found that even there, where consistency would seem to be paramount to ensure proper mating, cell lineages that build the vulva varied quite a bit even within a species. As might be expected, such variation becomes even more pronounced between species.

Felix has since tracked down several genes that underlie this variation. "Variation is there," Baird says, "not necessarily hidden, but underutilized." The variation doesn't seem to interfere with the worms' development and doesn't seem to lead to speciation, at least not at this point in time. But that might not always be the case, says Jeffery: "Variations in a reproductive organ could in principle be a cause of reproductive isolation and subsequent speciation."

Baird unearthed variation of a different sort in his studies of sex determination in worms. He hybridized two *C. elegans* cousins, breeding different strains of the hermaphroditic *C. briggsae* with different strains of *C. remanei*, which has male and female members. To his surprise, the reproductive system in the offspring varied depending on the strains used. One mating might yield males and hermaphrodites; another, all hermaphrodites.

It seems that the sequences of the genes involved vary slightly, Baird has determined. That difference doesn't seem to matter when it comes to intraspecies matings. But it can cause havoc during hybridization. Baird observed that slight incompatibilities between the two species' genomes disrupted the normal determination of the sex of the offspring. "We are currently trying to map the genes responsible for that variation, and then [we] want to look at [base changes] to try to see what differences are affecting the interactions," Baird explains. Studying hybrids, he is uncovering variation in the sex-determining pathways that might otherwise go undetected. That hidden reservoir of individual differences might allow the species to adjust to environmental changes, he speculates.

Eyes at a price

Even as Baird and others track down the genes that make nematodes vary, Maryland's Jeffery has a gene in hand from his microevolutionary studies of a cavefish species found in Mexico. He has been looking at two populations of *Astyanax mexicanus*. One group lives underground and lacks functional eyes; the other lives at the surface and sees quite well. In exploring the genetic and developmental basis of this difference, he found a tradeoff: The blind cavefish had bigger jaws and more teeth than the surface ones. These traits, it turns out, are tied to the set of genes that also determine the development of eyes.

This led Jeffery to think that eyes disappeared only because the bigger teeth and jaws proved so advantageous in this new environment. When he began looking for how this evolution occurred, he discovered that it didn't take major genetic changes to tip development in favor of one phenotype or the other. Instead, he and his colleagues found that a slight alteration in where a gene called *sonic hedgehog* was active in the developing head caused eyes to form or not form (*Science*, 23 June 2000, p. 2119). "A fairly small change was able to give a fairly large phenotypic result," he points out.

These efforts exemplify the power of studying evolution on an ever finer scale. Evolutionary researchers such as Lynch hope their developmental colleagues will be inspired to go a step further in incorporating microevolutionary ideas into their thinking. "Often what is compared is just the end [physical and physiological appearance] rather than the actual developmental pathway that led to its production," he laments. He would like to see a more sophisticated approach in which researchers figure out the interplay between genetics and development, keeping in mind that changing either one too much or too fast will lead to organisms incapable of procreating. He also points out that factors such as the size of the population in which the variation develops and the number of genes that influence a changing trait need to be considered. Nonetheless, recent efforts signal that "people are starting to get on the same page about what needs to be done," he says. That should help make sense of the interplay between the micro and macro sides of evolution.

–ELIZABETH PENNISI

MEETING SOCIETY OF VERTEBRATE PALEONTOLOGY

A Bonanza of Bones

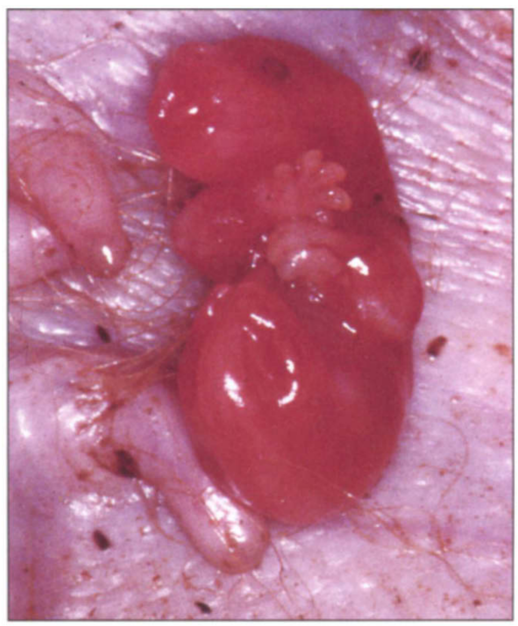
NORMAN, OKLAHOMA—Paleontologists came sweepin' down the plain to the 62nd annual meeting of the Society for Vertebrate Paleontology. From 9 to 12 October, some 1000 attendees heard about new ideas and specimens that spanned the taxonomic gamut.

Marsupial Shoulder Restraint

Placental mammals have evolved shoulder girdles capable of such diverse activities as powered flight, deep-water diving, and playing racquetball. Their marsupial cousins, on the other hand, never came up with forelimbs with these kinds of exotic shapes. Why? The standard answer is that the evolution of their shoulders has been hamstrung by a unique demand of marsupial reproduction: After birth, marsupials must make a life-or-death crawl to a teat in their mother's pouch, where they continue to develop.

Now Karen Sears, a graduate student at the University of Chicago, has tested this long-standing hypothesis for the first time and confirmed it. The results are "insightful and so extremely important for understanding the pattern of marsupial evolution," says Farish Jenkins, a vertebrate paleontologist at Harvard University.

In preparation for their crawl, fetal marsupials develop the bones of the shoulders and forelimbs much faster than the rest of their skeleton. They even temporarily fuse the shoulder blade and collarbone to get more power for the climb. Because important muscles attach to the shoulder blade, or scapula, its shape could have a large influence on how the shoulder girdle and forelimb develop. To check whether adults really are limited in their anatomy, Sears first measured the shape of these bones in 97 families of placental mammals and 21 families of marsupials.



All thumbs. Marsupial diversity is limited because newborns like this wallaby must develop large arms to crawl to a teat.

CREDIT: GEOFF SHAW/UNIVERSITY OF MELBOURNE, AUSTRALIA

She included 15 taxa of extinct marsupials, such as *Diprotodon*, a giant wombat relative from Australia, to get as full a range as possible. A battery of statistical tests showed that marsupials indeed had significantly less variety in the shape of their shoulder bones.

Two lines of evidence suggest that this is due to constraints imposed by the crawl. First, marsupial species that crawl to the teat tend to develop their scapula in much the same way, whereas many placentals showed greater variation during their development. (Interestingly, bandicoots differed slightly from other marsupials. These small, pointy-headed marsupials fall onto the teat, rather than crawl to it, which might allow more flexibility in how their scapula develops, Sears says.) Second, the shape of the marsupial pelvis—which is not needed during the crawl and doesn't develop until afterward—has more variation than the scapula. "It's really a very clear difference," says Marcelo Sanchez-Villagra of the University of Tübingen, Germany.

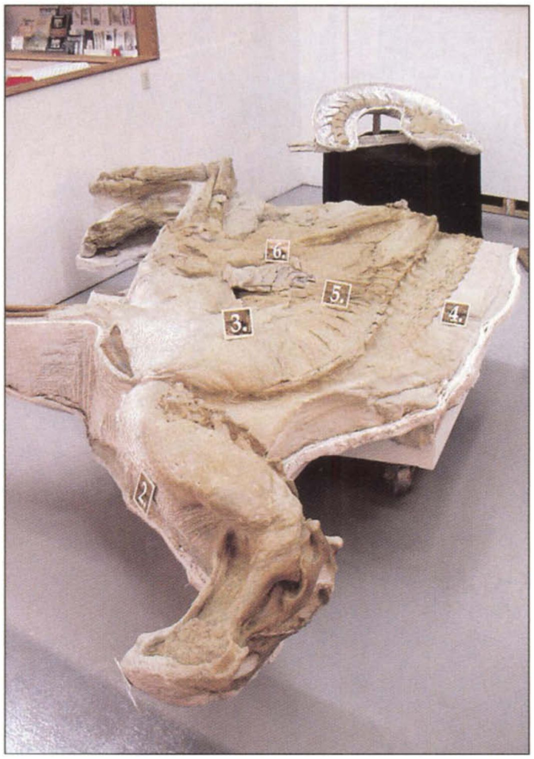
Now that the role of the shoulder blade has been pinned down, Sanchez-Villagra says it would be interesting to look at other parts of the anatomy that are used in the neonatal crawl, such as the hands, to see if their morphological diversity is also constrained. But Jay Lillegraven of the University of Wyoming, Laramie, hopes that Sears will next compare morphological features of the brain, which he thinks will turn out to be the most important factor that helped placentals diversify.

Dinosaur 'Mummy' Unveiled

A duck-billed dinosaur from Montana is wowing paleontologists with its remarkably well-preserved state. The 77-million-year-old hadrosaur, described at the meeting, retains traces of 80% of its skin, as well as other tissues and its last meal.

The 6.7-meter-long member of the hadrosaur family, called *Brachylophosaurus canadensis*, was excavated in the summer of 2000 by Nate Murphy, an amateur paleontologist at the Phillips County Museum in Malta, Montana, with help from Timescale Adventures of Bynum, Montana, a nonprofit organization that organizes fieldwork tourism. The group discovered the fully articulated skeleton—with 90% of its bones—and excavated it in a single 6.5-ton block. "When we get a specimen with so much soft-tissue preservation, it's a real opportunity," Murphy says.

Highlights of the find start with skin impressions covering most of the body. The creature's throat seems to be intact, as does what appears to be a shoulder muscle. And exposed in the chest and pelvic areas are fossilized plant remains. Dennis Braman, a palynologist at the Royal Tyrrell Museum in Drumheller, Canada, identified more than 40 kinds of plants, including freshwater algae, ferns, liverwort, and angiosperms, among the contents of the digestive system.



Intact. Much of the skin, and some other tissue, is preserved on this duck-billed dinosaur.

CREDIT: MARK THOMPSON/JUDITH RIVER DINOSAUR INSTITUTE (WWW.MONTANADINODIGS.COM)

Dinosaur fossils with preserved soft tissue are extremely rare, and this one might contain more information than two famous mummies discovered early in the 20th century by famed fossil hunter Charles Sternberg. "It's a beautiful specimen," says Lawrence Witmer of Ohio University in Athens. "There's a lot you could learn from it."

Weighing Dinos by Bones Alone

Almost anyone who has stared at the hulking skeleton of a sauropod or woolly mammoth has wondered how much the beast weighed. Paleontologists are even more curious, because body mass influences heart rate, temperature, population size, and many other important aspects of ancient life. At the meeting, Ryosuke Motani of the University of Oregon, Eugene, presented a new method for estimating the body mass of extinct animals from the dimensions of their limb bones. "It clarifies, simplifies, and makes things much more specific," says Matt Carrano of Stony Brook University in New York.

There are a variety of ways to get a rough handle on how much an extinct animal weighed. Some researchers have made plastic models, dunked them in water, and measured the displacement. Others use computer reconstructions to estimate volume. Either way, these methods require some speculation about the animal's shape. Alternatively, one can try to infer mass from the shape of bones, say, or the length of the skeleton. In 1973, biologist Thomas McMahon of Harvard University proposed that body mass could be calculated solely from the dimensions of limb bones (*Science*, 23 March 1973, 1201), because all limbs must bear weight without buckling. But when examined in living animals, the relation didn't hold up.

Looking back, Motani realized the reason for the failure: McMahon's equations took into account only the weight of the limb itself, whereas in fact, limbs bear the weight of the entire body. After rewriting the equations, Motani checked them with limb measurements from 94 mammals of known body mass belonging to 12 orders and ranging in size from shrews to an elephant. The limb dimensions correlated extremely well with body mass. "That means limb bones may be used to infer body mass," Motani says.

Applying his equations to the long extinct, Motani tried to estimate the mass of the colossal dinosaur *Brachiosaurus*. This sauropod is unusual because of its long upper arm. Motani's method yielded an upper limit of 36 metric tons. That's about 30% less than usual back-of-the-envelope estimates, which typically rely just on bone circumference. One reason for the difference is that the new equations take into account the fact that longer bones break more easily than shorter bones of the same circumference.

The method will work for any animal that held its limbs erect rather than sprawling like lizards. "I think it's really good," says Don Henderson of the University of Calgary, Canada, who constructs computer models of dinosaur locomotion. He says the method could be a useful independent check of other methods. And although no one approach is perfect, Motani has come up with a definite improvement. "It gives a truer picture of the real situation," Henderson says.

—ERIK STOKSTAD