Reopening Old Wounds

By RICHARD MONASTERSKY

Physicians and paleontologists learn new lessons from ancient ailments

Bruce M. Rothschild spends his time studying an unusual assortment of joints. As a physician specializing in arthritis, he sees men, women and children. In recent years, he has also started examining dinosaurs, American camels and other long-dead oddities. His aim: to diagnose the afflictions of ancient animals and trace the antecedents of some modern diseases.

Rothschild, who practices in Youngstown, Ohio, has become a leading figure in a burgeoning field called paleopathology – the study of disease and injury in fossils. Researchers who study ancient animals are beginning to view old bones in a new light, looking for abnormalities that might indicate, for instance, that dinosaurs were accident prone or extinct sea turtles developed the bends. In some cases, paleopathologists are turning to modern medical techniques such as CAT scans and immunologic tests to diagnose ancient diseases.

Why should such maladies matter? Researchers involved in paleopathology say both physicians and paleontologists stand to benefit from their work. "We're contributing to the understanding of disease today by studying ancient animals. But we're also learning about their lifestyles," Rothschild says.

While anthropologists and medical doctors have long examined the pathologies of early human remains, paleontologists studying animal fossils have been less active in this field. Now, their interest is growing – a fact made clear at November's meeting of the Society of Vertebrate Paleontology in Austin, Tex., when a session devoted entirely to paleopathology drew a standing-room-only crowd.

Some of the packed session's most intriguing presentations involved pathologies found in dinosaur bones. Darren H. Tanke, who prepares fossils at the Tyrrell Museum of Palaeontology in Drumheller, Alberta, described evidence of frequent injuries suffered by certain dinosaurs.

While examining the museum's fossil collections, Tanke was surprised to find a large number of damaged bones belonging to one family in particular, the hadrosaurs. In the last decade, paleontologists have discovered much about the lifestyle of these duck-billed herbivores, which lived during the last half of the Cretaceous period, dying out around 66 million years ago.

In the large collection of hadrosaur bones at the Tyrrell Museum, Tanke found several body parts that frequently displayed pathologies. A number of ribs showed healed breaks, leading him to suspect it was not uncommon for hadrosaurs to experience rib-cracking blows. Evidence from other museums appears to support this theory, he says. Two hadrosaur skeletons mounted in the Royal Ontario Museum in Toronto, for example, show evidence of injuries that broke several ribs at once.

Tanke speculates the rib wounds may have been the painful legacy of combat between hadrosaur males. In an attempt to win favor among females or to establish dominance in a herd, males could have kicked at each other with their hind feet, he suggests.

Other parts of the hadrosaur skeleton also displayed numerous injuries. Tanke found many broken vertebrae at the base of the tail, where it attaches to the hindquarters. The tops of the vertebrae are compressed and cracked as if a great weight had pressed down on them. The vertebrae often healed in their broken position.

During his presentation, at the risk of offending modest colleagues, Tanke displayed an artist's rendition showing how females might have incurred this type of injury while mating. A 4-ton male hadrosaur could easily have caused the cracks if it rested part of its weight on the back of a mate, Tanke says.

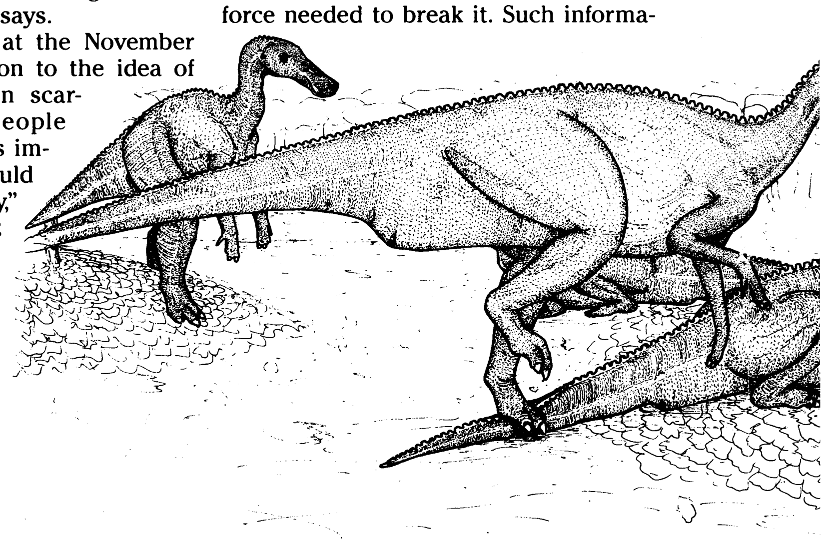
A few researchers at the November meeting took exception to the idea of dinosaurs engaging in scarring sex. "Some people thought that an act as important as mating would not have caused injury," Tanke told SCIENCE NEWS. But the vertebral cracks probably were not life-threatening, he says, since their healing clearly indicates the animals survived the encounter. Whether the injured parties were male or female remains unknown.

Other pathologies common in hadrosaurs appeared toward the end of the tail. Tanke found more than a dozen tail vertebrae with cracks, which he thinks resulted when one hadrosaur stepped on another's tail. "These guys traveled in herds, and I think it [stepping on tails] was a fairly frequent occurrence. Most of [these] injuries seem to be related to having a great weight pressing down on them," he says.

In all, Tanke reports, 85 percent of the pathologic bones in Tyrrell's dinosaur collection come from hadrosaurs. "I find that quite surprising. Hadrosaurs are traditionally portrayed as rather peaceful, placid animals," he says. The injuries instead suggest they were aggressive toward each other or accident prone – or perhaps both.

Tanke's highly speculative theories concerning the cause of the injuries need testing. As a start, he plans to examine other hadrosaur collections to see whether a larger population shows the same distribution of injuries. For instance, he says, if rib breaks do represent combat injuries, they should appear mostly in adults, as they did in the Tyrrell collection.

Engineering studies can also help, says arthritis specialist Rothschild. By studying the shape of a rib, researchers can estimate the amount and direction of force needed to break it. Such informa-



tion should help reveal, for instance, whether a crack resulted from a fall instead of a kick.

Rothschild's own interest in paleopathology was piqued 20 years ago when he learned of reports that many dinosaur skeletons showed evidence of osteoarthritis. In humans, this disease damages joints by causing cartilage to fray and overgrowths to form on bone surfaces. It often affects very heavy people, so it seemed reasonable that the largest land animals in Earth's history developed similar problems.

As a professor of medicine constantly looking for ways to arouse students' curiosity, Rothschild thought arthritic dinosaurs seemed a perfect candidate. But when he scrutinized dinosaur bones for signs of osteoarthritis, he couldn't detect any. "I found out that what people had been referring to was spurs on the spine, which have nothing to do with osteoarthritis," he says. In fact, osteoarthritis is rare among the 10,000 dinosaur specimens Rothschild has since examined. He is now preparing to publish the results of that study.

Whether or not dinosaurs developed osteoarthritis may seem inconsequential to humans suffering from the disease. But Rothschild thinks otherwise. "Look at these massive animals weighing 80 tons and not developing osteoarthritis," he says. "There had to be something that protected them. Looking at that, I think there are some lessons for humans."

His work in other areas of paleopathology took off after a chance encounter during his search for arthritic dinosaur bones. While Rothschild was visiting the University of Kansas at Lawrence, paleontologist Larry D. Martin showed him a spine from a mosasaur – a huge aquatic lizard that lived during the age of the dinosaurs. Seven of the vertebrae had fused together in a manner suggesting the animal had suffered an infection.

"When that was shown to me, I said the diagnosis was interesting, but to confirm it you really had to section it," Rothschild recalls.

Because slicing through a fossil is tantamount to destroying it, he was surprised by Martin's response. "I turned around to leave, and Martin said, 'Well, let's go downstairs and section it.' That was my first realization that someone might consider any type of destructive analysis," Rothschild says.

When they split the vertebrae, the researchers spotted a shark tooth buried in the gnarled bone. This suggested a dramatic scenario: The wounded mosasaur must have barely escaped the jaws of a hungry shark, later developing an infection that fused its vertebrae.

While it seemed a tight story, Rothschild wanted to check a normal mosasaur vertebra for comparison. So he tested his welcome further by proposing they split another bone, this time a "healthy" one.

Martin recalls picking up the most normal-looking vertebra he could find. But cutting open the bone revealed something strange: a band of dead cells running through the center. This phenomenon, called avascular necrosis, occurs when a blockage of blood supply causes portions of the bone to die.

In humans, avascular necrosis results primarily from three factors: radiation exposure, bismuth poisoning and decompression syndrome. In the mosasaur vertebra, various pieces of evidence ruled out the first two causes, leaving Martin and Rothschild with the intriguing possibility that mosasaurs suffered from decompression syndrome, known to deep-sea divers as the bends.

By checking X-rays of most of the available mosasaur vertebrae in museums worldwide, the researchers went on to confirm that avascular necrosis struck mosasaurs around the globe. What's more, its distribution dovetails with paleontologists' suspicions about the diving habits of different types of mosasaurs. Avascular necrosis appeared most often in *Platecarpus*, already thought to be a deep diver, but did not show up in mosasaurs believed to be surface swimmers.

Since these initial discoveries, Rothschild and Martin have found evidence of the bends in sea turtles, both ancient and modern. In one case, they identified avascular necrosis in a turtle that also had mosasaur bite marks on its shell, Rothschild says.

The recognition that mosasaurs and other ancient animals suffered from decompression syndrome provides important clues to their behavior. Paleontologists treasure such details because fossilized bones, while providing significant information about an animal's structure, seldom reveal as much about the animal's lifestyle. "Behavior is the first thing to go when you're dead," notes Martin.


Tanke

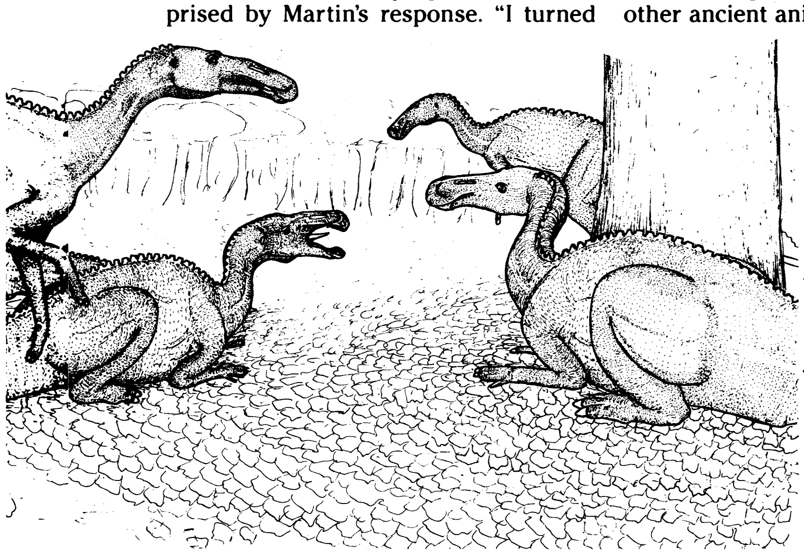
A kick during male combat may have been the blow that broke six of this hadrosaur's ribs, which later healed.

Human divers develop the bends when ascending too quickly from the deep, causing dissolved nitrogen in the bloodstream to form bubbles that can block blood vessels. The condition causes immediate pain and sometimes even death, but its necrotic aftermath in survivors often goes unnoticed until years later, when joints may collapse.

Avascular necrosis in mosasaurs provides strong evidence that certain types did dive deeply, as researchers had suspected. But it also suggests these lizards ascended too quickly at times. Rothschild and Martin hypothesize that mosasaurs could have developed the bends while fleeing sharks or chasing turtles.

The condition apparently did not affect the animals too seriously, however. Almost all *Platecarpus* skeletons show signs of avascular necrosis, Martin says, yet this genus was the most successful of the mosasaurs.

Evidence of the bends may also reveal something about the evolution of mosasaurs. Other diving reptiles that shared the seas with mosasaurs – such as ichthyosaurs and plesiosaurs – developed over a stretch of hundreds of millions of years in the Triassic and Cretaceous periods, and their remains show no evidence of decompression syndrome. Mosasaurs, in contrast, existed only during the last 25 million years of the Cretaceous. Although this represents a long time, Rothschild and Martin say it may not have given mosasaurs sufficient opportunity to evolve the decompression resistance that apparently emerged in ichthyosaurs and plesiosaurs.


Tracey Ford, Poway, Calif.

Tanke has found numerous cracks in hadrosaur tail vertebrae. Because paleontologists think hadrosaurs traveled in herds, he suggests the cracks developed when one hadrosaur stepped on another's tail.

Since the mosasaur study, the Rothschild-Martin collaboration has blossomed into other paleopathological pursuits. At the November meeting, the two described their examination of thousands of specimens from a fossil site known as Natural Trap Cave, near northern Wyoming's Bighorn mountains. The cave is a large pit carved out of the limestone rock by water. A 65-foot drop separates the cave floor from the narrow opening at the top.

For more than 110,000 years, the underground vault has accumulated the bones of unsuspecting animals that wandered too close to that opening. A list of the victims reads like a who's who for ice-age mammals, many of them long extinct on this continent. In this natural burial mound, the excavation crew has uncovered the remains of the woolly mammoth, American cheetah, American camel, short-faced bear, American lion, pronghorn antelope, bison, various wolves, five species of horses and many others. In all, the team has excavated only about 5 percent of the cave's deposits and has identified some 40,000 bones so far.

To paleopathologists, the fossils from Natural Trap Cave represent a rare opportunity to study the incidence of different diseases in a large population of animals. The cave's special quality is that it provides a random selection of animals. "This was an unusual sample," says Martin. "Animals essentially fell into the hole by accident."

In contrast, other fossil-loaded sites may have attracted animals with particular traits, skewing impressions of the species as a whole. At the famous La Brea Tar Pits in Los Angeles, for example, live animals stuck in the tar probably drew the attention of sick or otherwise disabled predators unable to catch free-running prey, Rothschild says. Thus, La Brea fossils may reflect a disease or injury incidence higher than that of the actual population.

Using the numerous fossils from Natural Trap Cave, Martin and Rothschild tested the hypothesis that osteoarthritis affected mainly the largest and fastest animals, whose joints presumably took the hardest pounding.

"I think the interesting result from the study is that there was really very little evidence to suggest that either of those things was a factor," Martin says. "The fastest animal in the trap was the American cheetah, and it had very little incidence of joint disease. The second-fastest animal in the trap was the American pronghorn, and it had even less."

Size, too, seemed to make little difference. Bison, among the largest animals, did show a high rate of joint disease, but other animals of similar size, such as the American camel and the woodland musk-ox, did not. "Somehow the bison are special in that regard, and we haven't quite decided what the reason is," Martin says.

He and Rothschild also examined Natural Trap fossils for evidence of erosive arthritis, which can result from infections or from diseases such as rheumatoid arthritis that destroy bone near the joints. They found signs of erosive arthritis in only three species — bison, bighorn sheep and woodland musk-ox — all of them extinct bovids. The shape of the bone erosions suggests an infectious organism caused the arthritis, Rothschild says.

The researchers have no reliable method for identifying this organism, but educated guesswork points toward tuberculosis or brucellosis, both bacterial infections. In modern animals, these are among the few infectious diseases that principally affect bovids, showing up less frequently in other mammals. What's more, in modern animals they cause the same pathologies seen in the fossils from Natural Trap Cave.

This is interesting, say Martin and Rothschild, because it might help scientists trace the history of these diseases. Physicians long ago noted that Native Americans suffered a higher incidence of tuberculosis than did immigrants from Europe. Many have postulated that the disease came to the New World with early settlers from Europe, then ran rampant through native populations that lacked natural immunity. Similarly, researchers have suggested that the brucellosis endemic in American bison stems from a bacterium brought over in European cattle.

But Martin and Rothschild question those scenarios. The work with ice-age fossils from Natural Trap Cave leads them to suspect instead that tuberculosis and brucellosis may have existed in North America for tens of thousands of years before people arrived from Europe. This could help explain why the disease permeated Native American and bison populations, they say.

Identifying the diseases that caused the erosive arthritis in the ice-age bones from Natural Trap Cave would provide a test of this hypothesis. Traces of the microbes may still remain in the bones if the joint disorders did indeed result from an infectious organism.

A decade ago, no one would have dreamed of detecting such organisms. But in 1987, Rothschild showed it was possible to identify ancient disease-causing microbes. Applying the same immunologic tests used to identify syphilis in living humans, he detected remnants of syphilis-causing organisms on an 11,000-year-old bear bone that bore lesions characteristic of that disease (SN: 9/26/87, p.205). While others have disputed his interpretation of that finding (SN: 6/18/88, p.390), Rothschild maintains the assay offers clear evidence that a syphilis-like infection caused the lesions.

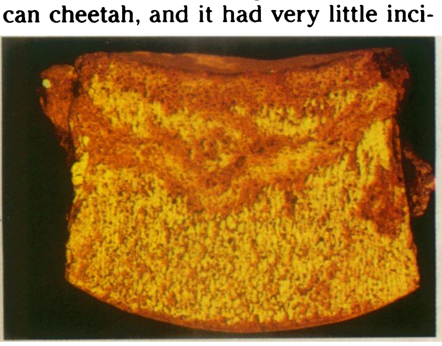
As a paleontologist accustomed to working with indirect evidence, Martin says such direct tests will prove immensely useful. He hopes immunologic assays can determine whether tuberculosis and brucellosis caused the pathologies in the Natural Trap bovids.

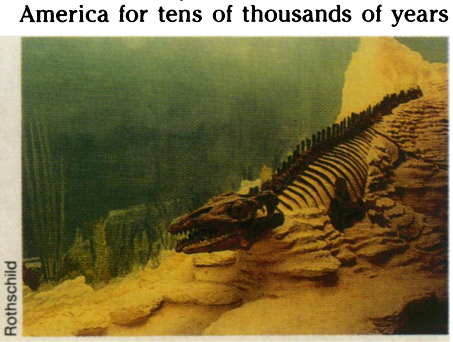
That proof will have to wait, however. Currently, Rothschild knows of no immunological or genetic test that can specifically identify traces of these diseases, and it may be some time before such tests emerge.

Curiosity about abnormal fossils is nothing new. Many museum curators over the years have kept special drawers for bones deformed by some disease or injury. But only recently have paleontologists begun actively studying such collections in an attempt to test their cursory diagnoses, Martin notes.

He and Rothschild will continue their investigations at Natural Trap Cave as workers excavate more bones from even deeper layers of the ice-age past.

Though the research crew at the cave had hoped to find human remains, none has yet turned up. Martin recounts one close call, however. The hole acts as a natural trap because its opening is practically invisible from more than a few feet away. Years ago, several spelunkers in a Volkswagen Bug were driving toward the hole and did not see it until very late. "They stopped only about three or four feet from going in," he says. "Had they not [done so], we would have had humans in the cave. The very top of the pile of bones would have had a Volkswagen Bug on it." To prevent such disasters, safety-minded authorities have since placed a grate over the cave entrance. □


D.W. Baccadutre/Univ. of Kansas


Rothschild

A band of dead cells exposed in this vertebral cross section (left) reveals that mosasaurs (right) developed decompression syndrome from deep dives.