Morian Hall of Paleontology

Welcome to your Prehistoric Safari!

Here you will meet the heroic microbes that battled acidic seas and poisonous air, and won.

You will greet multitudes of trilobites, each one a jewel of evolution. Ferocious fish will guide you through the conquest of land and a Texas fin-back will introduce you to your own ancient reptilian ancestors.

Dinosaurs carry the story through the age of “T. rex,” but the journey will not be smooth. Sudden mass extinctions will punctuate your progress. Wave after wave of new and marvelous beasts will seize control of the ecosystem, only to suffer disaster from mysterious causes.

In the final stages of your Prehistoric Safari you will see an invention that changed the rules of nature – the atlatl – and learn where we humans fit in the flow of history.

Stromatolite

Nearly 3.5 billion years ago, the air on Earth lacked the oxygen to support most modern-day plants and animals. The oceans were entirely acidic, and the Sun's ultraviolet light was powerful enough to kill most of today's living organisms.

Despite these dismal conditions, life appeared, survived and evolved.

How did Earth's earliest life forms succeed?

Earth's earliest life forms were tiny one-celled creatures, much like today's simplest bacteria. Some of these microbes began building multi-layer mounds called "stromatolites," structures that still exist today and resemble giant, upside-down egg cartons.

Each stromatolite layer was formed by living microbial mats. New layers trapped particles of silt and minerals until the structure had dozens or even hundreds of layers. Stromatolite layers filtered out most of the sun's deadly UV rays and allowed the microbes that comprised them to flourish.

How did the earliest life forms get energy and food?

Earth's early life forms couldn't operate like most modern bacteria or higher animals, because there wasn't enough oxygen.

Some based their metabolism on sulfur, instead. Modern sulfur-based bacteria thrives in dark habitats where oxygen and UV light are scarce, like swamps and even inside our own intestines.

Trilobites

Trilobites, also affectionately called mudbugs by many paleontologists, are hard, segmented arthropods that existed more than 500 million years ago in the Earth's ancient oceans. They ruled the Paleozoic Era, going extinct before the first dinosaurs ever appeared. They're incredibly important to the fossil record for a number of reasons. They existed on all continents, and they were some of the first creatures to exhibit the kind of complexity that is the foundation for life today. Trilobites were incredibly diverse, with the smallest-known species measuring under a millimeter and the largest being over two feet long. More than 20,000 different species have been described, and we are lucky to have one of the most complete collections of these fascinating creatures in the country.

Trilobites

Enrollment

Trilobite had another tendency that might remind you of a modern insect - the pill bug. As a mode of defense, trilobites were able to roll themselves into a hard, impenetrable ball using their flexible thoracic segments. This shielded the trilobite’s soft appendages and vulnerable ventral, or bottom, surface. Then, a trilobite could watch and wait for conditions to improve. When enrolled, many more elaborate trilobites displayed discouraging spines to would-be predators.

Trilobites

Lifestyles/Movement

Burrowing

Although most trilobites dwelled at the sea-bottom, crawling over sand and mud, some burrowed using shovel-shaped growths on their heads. Burrowing trilobites were usually scavengers, ingesting the mud and silt itself to feed off of the organic material contained within, much like an earthworm. Others burrowed to hide, intercepting passing prey at the mud’s surface.

Swimming

Although trilobites' chunky little bodies don't resemble the streamlined bodies of swimming Olympians, some trilobites did manage to traverse via water. Swimming trilobites had narrower bodies and likely fed either by filter-feeding or as predatory hunters. Many of the smallest trilobites were swimmers, living close to the water surface and floating about like plankton.

Scuttling

Most trilobites scuttled around the sand on the sea bottom, leaving distinctive and important trace fossils in their wakes that have helped scientists track their movement, speed and even feeding habits.

Devonian Disaster

Massive Extinction Among Reefs, Shallow Water

Trilobites, and Giant Armored Fish

Reef-Builders Hit Hard

Early Devonian reefs flourished wherever there was shallow sea water. Tabulate and rough-horn corals helped build the reefs, assisted by the stromatoporoid sponges. Trilobites lived in the reefs as cephalopods swam above, and brachiopods attached themselves to the reef and to the bottom mud.

Devonian reefs were so large and widespread that they controlled ocean currents in many shallow water habitats. Today, oil-geologists search for buried reefs with exploratory drilling,

and their remains continue to pour out millions of barrels of fossil fuels.

How did these reefs die? Tabulate and horn corals suffered deep fall in diversity, as did the stromatoporoids sponges.

Trilobite Catastrophe

In the Late Devonian, trilobites suffered the greatest die-off in their history.

Since the Cambrian, the trilobite family tree had developed a dozen main orders (major evolutionary units containing a multitude of families), each one with a distinctive style of eyes, spines, bodies and tails. Despite some Ordovician extinctions, Devonian trilobites were rich in variety. But the End-Devonian Extinction cut down every single trilobite order except one.

Brachiopods suffered extinction at the same time, and so did cephalopods.

Apex-Predators—Panzer-Sharks Gone!

The End-Devonian crisis came in waves spaced out over about 10 million years. The first blows came against the reefs and the invertebrates. Then, late in the period, the biggest, most advanced predators died out completely.

Panzer-sharks like "Dunkleosteus" achieved their greatest size and ferocity and then disappeared. All the armor-plated placoderm fish died out.

"Titanichthys" had evolved from a "Dunkleosteus" relative to become the first giant swimming plankton-eater.

"Titanichthys" disappeared at the same time "Dunkleosteus" went extinct. The ocean

ecosystem had lost two of the most important feeding categories: Huge filter-feeders and apex predators.

The Search for the End-Devonian Killers

Was it ice?

Glaciers were appearing in Gondwanaland, and the southern ice age was getting more severe. Perhaps cool ocean water killed some ocean systems?

Pollution From the Land?

Woodlands evolved rapidly at the end of the period, and rivers and streams became clogged with vegetable debris during the rainy season.

Plant roots also helped break down rocks and change hard minerals into soft clays. In heavy rains, runoff carried tons of mud and silt into the

watercourses and could have suffocated the reefs with organic detritus.

Pangaea

Carboniferous-Permian 300-200 Million Years Ago

In the Carboniferous and Permian Periods, the globe was spectacularly different. Instead of having continents spread all over with wide oceans separating them, there was just one single supercontinent: Pangaea.

Fossil Plants and Glacial Deposits Map out Two Great Subcontinents

Laurasia-North America and Eurasia Combined

The cool swamps were full of seed-ferns. The fossilized wood has a few growth rings,

indicating that the climate was warm all year round and the tree trunks grew without interruption by cold winters. A great variety of reptiles and amphibians swarmed over the forests and swamps.

Gondwanaland- South America, Africa, India, Australia and Antarctica combined

Dropstones from floating ice bergs and other glacial sediments prove that a major ice age was in full force.

Fossil Compasses

A great mass of evidence comes from geophysics, as well. Paleo-magnetism is the fossil record of where ancient continents fit along a north-south gradient. During the Carboniferous and Permian Periods, Gondwanaland continents extended far into the cold southern latitudes.

Putting the Pieces Together

In the Carboniferous and Permian, North America was joined to Eurasia and Africa collided into the east coast of North America. South America rammed our Gulf Coast. South America and Africa were united and joined to Australia, India and Antarctica. Wherever these collisions occurred, mountain ranges were pushed up.

Result: Pangaea

On a fine vacation in the Carboniferous or in the Permian, you could walk from Houston to Rio de Janeiro, then over to Nairobi, farther east to New Delhi, and on down to Sydney.

Fabulous Fins for Slow Dancing

We call “Dimetrodon” a “fin-back” for obvious reasons. The tops of the vertebrae grew into tall rods of bone, held together in life by a sheet of tough skin.

Growing a tall fin requires a lot of extra bone, and bone is “expensive” in that it requires calcium and phosphate that the animal has to get from its food. Plus, the fin limits mobility. A “Dimetrodon” couldn’t hide from the hot sun in a burrow, because the fin would get in the way.

Some scientists have hypothesized that the “Dimetrodon” fin may have been a solar panel. In the cool morning, the fin-back could turn sideways to the sun and let the rays heat up its body. If “Dimetrodon” got over-heated at noon, it could turn its fin again so the breeze went over the fin surface.

Evolution is fastest in body parts used to attract mates or to scare away rivals. Many modern-day creatures intimidate each other by trying to look as tall as possible. American bison have massive humps of hair and fat over their shoulders to look bigger and scarier. Under the hump is a type of fin made from tall bone spines.

Modern finned lizards do “broadside displays,” standing sideways next to each other and arching their backs.

The main reason “Dimetrodon” evolved a fin was likely to give the animal a taller, more impressive silhouette.

Cobble-Stone Lizard with Fancy Fins

The Redbeds ecosystem encouraged fin evolution. Besides “Dimetrodon”, there was a fin-backed land amphibian, “Platyhystrix.” And

one of the biggest, most common plant-eaters was the finny “Edaphosaurus.”

The “Edapho” part of their name means “cobble-stone.” Their jaws had hundreds of small teeth crowded together, like cobblestone pavement. But rather than saying, “Cobble-Stone-Lizard,” most Redbeds bone-diggers - including the HMNS Paleo Team - use the nickname “Daffy.”

Daffys grew fin bones almost as tall as those of “Dimetrodon.” But edaphosaurs made their fin rods far fancier. Instead of a simple rod, the edaphosaur fin bone was more like the mast of a full-rigged ship, with yardarms coming out both sides. The paleontologist who found the first “Edaphosaurus,” Professor Edward Cape, had a vision of the animal hanging sails on its cross-bars.

Edaphosaur fins were probably also used for courtship and intimidation.

Look closely at these spine bones from an edaphosaur and from “Dimetrodon.” “Edaphosaurus’s” fin bones were thicker than “Dimetrodon’s” and had grooves all over for blood vessels. All this blood flow meant that the skin here grew fast and built up thick, and perhaps even complex layers.

Soggy Bottom Boys: Bottom-Hugging Amphibians

The Largest Fossil Sample Ever Dug from the Texas Redbeds!

What you're looking at is the "Judy Block," named for north Texas native and ranch owner Judith Whitley. Dozens of fossil skulls and chest armor are mingled together in this flood-deposit. All are from a new species, a close relative of "Trimerorhachis." We call these flat-headed amphibians "panzer mudpuppies," because their chunky limbs and stout bodies look like those of today's mudpuppy salamanders. But, like most Permo-Carboniferous amphibians, they had bone scales embedded in their skin.

The world's largest find of Redbeds amphibians was made by bulldozer operator James

Smajstrla of Baylor County, Texas. Smajstrla was excavating a water tank for cattle on the Carddock Ranch in Seymour, Texas, but first needed a detailed survey of the site. Dr. Robert Bakker, curator of vertebrate paleontology at HMNS, combed the outcrop for three days searching for fossils, but found none.

There were no fossils on the surface, but when Smajstrla dug 10 feet he spotted some odd-looking rocks. At 12 feet, Smajstrla hit a layer of red rock jammed full of petrified heads, shoulders, and chests. The bones were so delicate that the crew had to soak them in super glue before they crumbled into dust. Museum curator David Temple led a team of volunteers who chipped out the 6-ton block. The combined efforts of cowboys, farmers, ranchers and museum volunteers rescued the giant slab of previously petrified relics—bringing them to light for countless future generations to see.

Redbeds CSI—Two-Stage Burial

How did all these skeletons get buried together?

A major clue is that all the bones are from adults or young adults.

What event would bring adult amphibians together but keep babies and juveniles away?

Frogs and salamanders today often crowd together to court their mates. It's usually adults-only. Youngsters stay away so they don't get trampled.

Somehow, a multitude of mating mudpuppies died near their mating grounds. Their bodies rotted away, but snouts, foreheads and chest armor became fossilized.

Here’s a puzzle:

We found very few thin, light bones—hardly any ribs, vertebrae, legs or toes. Why are there only big bones in the deposit?

The clue is in the sediment.

Sand and gravel covered the bones, which would have been carried by a strong current. Lighter bones, like ribs leg-bones, and toes, got washed away along with the lighter sediments.

Thanks to a little flood, the “Judy Block” captures the joy, excitement and tragedy of ancient amphibian love.

Crinoid

“Seirocrinus subangulrais”

Crinoid fossils are frequently referred to as “Sea Lilies” because of their resemblance to flowers. The name crinoid is derived from the Greek word krinon, meaning “lily form;” however, they are actually animals.

The crinoid is an ancient animal that experienced its greatest diversity in the Paleozoic. Some species survived into the Mesozoic, and a few live in the deep ocean depths today. The universally accepted, earliest crinoid is from the Mid-Ordovician around 460 million years ago.

Jurassic Motherhood

We nicknamed this skeleton "Jurassic Mom." She was carrying seven unborn babies when she died and became fossilized. Can you find all seven? It's a bit of a trick question: one baby was caught in the birth canal.

Mother ichthyosaurs with late-term babies are common of Holzmaden. Something caused high mortality in the birthing season.

Big-Headed Babies

Most vertebrate babies seem big-headed compared to their moms, but fish-lizards go to extremes. The newborn “Stenopterygius” had a head that was as long as its body. When “Stenopterygius” grew up, the head would be only a third of its body length. Why?

The babies probably had to find food for themselves right away. A proportionately huge head and jaws would have permitted the youngsters to capture full-sized squid.

Reptilian Shark

The Icthyosaur “Stenopterygius”

One of the most magnificent sea-reptiles was the “fish-lizard” ichthyosaur. Advanced fish-lizards like this “Stenopterygius” achieved the highest level of adaptation to life in the open ocean. They spent their entire lives in the ocean and never came on land, even to lay eggs.

We can tell from the tail shape that “Stenopterygius” was as fast as the fastest shark alive today. The tail fin was made of two narrow curved blades, one pointed up, the other pointed down. Great white sharks have tails of the same shape, and so do mako sharks and other speedy shark species. One difference: ichthyosaurs were upside-down sharks. The shark vertebral column bends up into the tail, which fish-lizard vertebrae bent down.

The ichthyosaur forelimbs were steering flippers - long, tapered and backswept. Since the hind limbs weren't needed for walking or for digging nests, they were greatly reduced.

Super Night-Vision

Advanced fish-lizards had huge eyes. Thin wedges of bone, arranged like a camera lens, reinforced the eyeball. Owls, eagles and many lizards today have similar eyeball-bones (known as sclerotic rings). Equipped with hyper-vision, fish-lizards could hunt in the dim depths or at night.

Teensy-teeth, Tweezer-jaws, Stomach Contents

Fossil stomach contents leave no doubt about fish-lizard diets. Many ribcages are stuffed with squid hooks and squid shells. The jaws were quick snapping but delicate, and the teeth were small - ideal for capturing quick, squirmy prey.

“Big Al”

“Allosaurus”

Blunt Steak Knives

During the Triassic-Jurassic transition, the land ecosystem was revolutionized as giant crocodile relatives made way for a new apex predator: dinosaur carnivores.

Dinosaur predators used thick fangs shaped like steak knives. The tooth tip was bent backward, and the front and back edges were serrated.

“Allosaurus” was the most common giant meat-eater in the Late Jurassic. Its teeth were too short to kill its prey with one bite, but it could open its jaws wide to rip long, jagged wounds.

Darwininan Head Gear

Allosaurs grew low, sharp-edged horns over their eyes, making the allosaur look more formidable - a useful trait for attracting mates and scaring away rivals.

Pack Hunting

Allosaurs fed in family groups. We know this because we find the shed teeth of babies, half-grown juveniles and adults together with the chewed-up skeletons of giant plant-eaters. On average, late Jurassic plant-eaters were much bigger than the allosaurs. Perhaps the allosaurs also hunted in packs.

Jurassic Veggie-Saurs

"Stegosaurus"

By the Late Jurassic, the plant-eating dinosaur clans had expanded into a dozen families.

Stegosaurs are famous for their tiny brains – one thirtieth the size of an elephant's of the same weight and ten times smaller than the meat-eating allosaur's.

However, what stegosaurs lacked in brains they made up for in brawn. The muscular tail carried four sharp bone spikes, covered in life with an outer layer of horny skin. Tail joints let the stegosaur twist and curl its tail in almost any direction, and it could curve its torso and neck with ease.

Stegosaurs also had a tighter turning circle than any other large plant-eater. On hard ground, they

were skilled swordsmen, lunging and thrashing with their four-pointed lances.

Five-Ton Ballerinas

Although they were as heavy as elephants, stegosaurs had tiny feet with just three tiny toes. The foot area was only a third as big as that of other big herbivores like “Triceratops” and “Denversaurus”- an adaptation to suit hard, firm ground.

Whip-Tail Tripods

“Diplodocus”

The Jurassic was the Golden Age of vegetarian giants. “Long-necks,” formally known as sauropods, grew larger and larger until they reached 30 tons or more - as heavy as five normal-sized elephants.

No clan of land animals ever matched the bulk of the long-necks.

What was their secret?

Sauropod necks were hollow and filled with air, like bird necks, so the beasts could swing their neck side-to-side quickly. To reach high in the tree-tops, long-necks went tripodal. Hind legs were much stronger than the fore legs, and the tail served as a third limb for balancing when the body tilted up.

“Diplodocus” was the ultimate tripod. Its tail was immensely strong, and its torso was lightened by hollowed-out vertebrae. When tipped up, the head could reach 25 feet. Its close cousin “Barosaurus” could reach 36 feet.

With heads that high, the heart couldn’t pump blood to the brain. No problem. The brain was tiny and could function without fresh blood for 10 minutes at a time.

Long-necks didn’t chew. Instead, they plucked branches off trees and passed the food down to their muscular gizzards, where hard rocks crushed and split the vegetable bits. Fossilized gizzard stones have been dug inside the ribcages of long-necks and their kin.

For defense, “Diplodocus” had a giant bull whip. The last 30 feet of the tail were made from tin bone rods jointed together and encased in tough

connective tissue. The powerful muscles at the front of the tail could swing the whip-end with tremendous speed. A direct hit on a meat-eater's face would cause dreadful pain.

By the Late Jurassic, the dinosaur clans had expanded into a dozen families of plant-eaters, mostly long-necks.

The Two-Fingered Tyrannosaur

“Gorgosaurus”

“Tyrannosaurus rex” is inarguably the world’s number one favorite dinosaur. It came late in its family history, in the Lancian Age. The earliest members of the tyrannosaur family were smaller; the species called “Gorgosaurus” ruled the Judithian Age, growing to 2 tons - 10 times heavier than a big male lion, but less than half the size of a “T. rex.”

“Gorgosaurus” had the distinctive hands of the tyrannosaur family. Instead of the three-fingered hands of allosaurs or acrocanthosaurs, gorgosaurs had hands with two small, weak fingers. The shoulder blade and upper arm were much thinner and less muscular than those of earlier carnivores.

Why did Tyrannosaurs evolve such weak arms and hands?

Professor Henry Fairfield Osborn, who named "Tyrannosaurus" and the tyrannosaur family in 1905, had an answer: tyrannosaurs were ticklers!

Osborn knew that big, scary apex predators might need a way to express soft, family-friend emotions. A tyrannosaur male might reach out to a female and delicately massage her shoulders. A mother tyrannosaur might stroke her sisters when they helped in raising the tyrannosaur kids.

Swift Ankles, Speedy Shins

The best way to compare speed in meat-eating dinosaurs is by comparing ankles and shins. Faster speed requires longer legs below the knee.

Compare "Gorgosaurus" to the Early Cretaceous "Acrocanthosaurus." The gorgosaur clearly has an advantage in limb proportions, and thus could outrun the earlier Cretaceous predator.

Why did big meat-eaters get faster? Was there a co-evolutionary arms race between predator and prey? Were herbivorous dinosaurs getting faster in the Late Cretaceous?

No—the common plant-eaters of the Late Cretaceous, the duck-bills, were about as fast as their Early Cretaceous relatives, the iguanodons.

This is yet another dinosaur puzzle. The faster tyrannosaurs replaced the slower acrocanthosaurs and their relatives, even though prey speed stayed the same.

“Stan”

“Tyrannosaurus rex”

Tyrant Lizard King

“Stan,” nicknamed after his discoverer Stan Sacrison, was a vicious predator that lived 65 million years ago at the end of the Cretaceous Period. One of the largest land predators to ever live, Stan feasted on dinosaurs such as “Triceratops” and duckbilled Hadrosaurs. Excavated from a cliff face 100 feet high and prepared by paleontologists from the Black Hills Institute of Geologic Research, the original specimen required more than 30,000 hours to complete. Details of Stan’s life experiences were preserved on his skeleton. Broken and healed ribs and a bite at the base of his skull match the teeth from another “Tyrannosaurus.” The bite,

which missed his spinal cord by an inch, was not the cause of death; it had begun to heal when Stan died.

Dining with a Dinosaur

A carnivore's teeth are usually sharp for cutting meat from bone or tearing a skeleton into smaller pieces.

Stan's teeth show him to be a carnivore, but his teeth are not "meat-slicing sharp." They are strong, with a thick D-shaped cross-section.

The tooth sticking out of a "T. rex" jawbone is only the tip of the iceberg. The root of the tooth is two or three times larger than the crown and securely anchored in the jaw. Blunt teeth are not intended to remove meat from bone, but rather to tear flesh from prey in manageable chunks. As a "Tyrannosaurus rex" bit its prey, its powerful

jaw muscles would push its teeth into skin and muscle until they struck bone. With a few swift jerks and a headshake, the "T. rex" would tear off the flesh. Then, the "Tyrannosaurus" would point its massive head skyward and, with the help of gravity, move the lump of chewed muscle down its throat.

What's for Dinner?

"Triceratops" and Duck-billed Hadrosaurs.

Lane

“Triceratops” Mummy

The Only One in the World

“Triceratops” is the world’s number one favorite veggie-saur, and it is one of the most dangerous land herbivores to have ever evolved.

Paleontologists thought we knew all there was to know about “Triceratops,” but this particular specimen, known as “Lane,” made us reevaluate everything.

“Lane” is named for a member of the family that owns the ranch where this mummy was dug. Lane is an excellent skeleton with some of the best “Triceratops” feet ever discovered. The giant hind paw spread its four toes widely to give maximum traction on soft, gooey ground. The forepaw was five-toed and wide, too. No doubt

about it - “Triceratops” was a “mudder,” a beast designed to tromp across swamps and bogs.

Lane’s torso was ultra-compact and short front-to-back. The barrel-shaped ribcage expanded sideways in the abdomen to hold a capacious gut.

Tiny-Tailed Wonder

For a dinosaur, “Triceratops” carried a tiny tail that curled down from the hips; no other clan of dinosaurs had reduced their rear appendage to such an extreme. That posed a locomotive challenge. In most dinosaurs, the biggest muscle that attached to the thigh came from the tail, so a wide, long tail was necessary for powerful movement.

A “Triceratops” would be at a disadvantage—unless an alternative muscle developed. Look at

the lower-rear hipbone (the ischium). It is unusually strong and curves down. There is a muscle attached here that runs to the thigh (the adductor). Perhaps "Triceratops" developed an especially thick muscle here.

Wide-Snouted Duck-Billed Dinosaur

“Edmontosaurus”

Two centuries ago, great herds of American bison grazed the High Plains of Nebraska, South Dakota, and Wyoming. Sixty-five million years ago, massive herds of wide-snouted “Edmontosaurus” moved across hot, humid river deltas that covered this same part of North America. Edmontosaurs are the most common dinosaur dug on our continent. At a half dozen quarries, there are thousands of specimens - adults, adolescents and babies - all buried together.

The three skeletons here were all excavated from one edmontosaur bone bed, the Ruth Mason Quarry.

Drowned Multitudes?

What happened to preserve entire herds? The sediments these duck-bills are found in were once river sandbars. Perhaps a hurricane drowned the herd and piled up blankets of sand over the carcasses, or an epidemic killed thousands and then a spring blood buried the skeletons.

Low Mowers

All duck-bills were low-croppers. Their backbone curved down at the shoulders, so the head was held close to the ground. With their wide, squared-off beaks, edmontosaurs could crop low-growing vegetation like dinosaurian lawn-mowers.

They pulverized leaves and branches with hundreds of curved “molars” packed in together in the rear of the mouth, like a carrot-grater.

Each “molar” had one side coated in hard enamel. The rest of the tooth was softer dentine. As the entire chewing surface wore away, the enamel sides stuck up, making sharp edges. New crowns were growing in all the time.

The Only Thumbless Dinosaurs

Look closely at the forepaws. Duck-bills are the only thumbless dinosaurs. Scientists use this symbol for duck-billed dinosaurs. Can you decipher it?

Why did duck-bills lose their thumb in evolution? Duck-bill ancestors were probably iguanodon dinosaurs—herbivores with a spike-shaped thumb useful for stabbing.

If duck-bills evolved a different defense, then perhaps they discarded the thumb-spike.

Wyrex

The Bobtailed "T. rex"

Number One in Pedal Paleontology

"Tyrannosaurus rex" did two things especially well: bite and run. To understand the running part, we need fine feet, and the "Wyrex" in front of you has some of the best-preserved feet ever found.

Bird Toes

Both hind paws are nearly perfect. Though "T. rex" grew to be as heavy as an elephant, the toes look like standard bird toes—three main digits, the middle one longest, with a little inner toe facing inward. This toe design is excellent for running on all sorts of ground—soft and hard. It is also top notch for grabbing prey, and for kicking.

Best “T. rex” Hands

Our Wyrex skeleton has the best hands of any “T. rex” ever discovered. Count the fingers. There are just two—thumb and forefinger—and a tiny vestige of the middle finger.

What Good Were the “T. rex” Fingers?

Best theory: the weak claws were good for gentle stroking and tickling during courtship or for family bonding.

Bobtail

Check out Wyrex’s tail. Something bit off the rear half. Dinosaur tails housed thick muscles that attached to the thigh, making the tail part of the running apparatus. If Wyrex survived its tail-ectomy, it would have had to learn how to walk and run again. Look closely. The bitten tail bone

shows little or no sign of healing, so the bite must have happened after death, or not long before.

Can You Outrun an Angry "T. rex"?

Some scientists speculated that because an adult "T. rex" was as heavy as an elephant, it would also be as slow.

But "Tyrannosaurus rex" was not built like an elephant. Tyrannosaurs of all species had the essential design features for high-speed running: huge pelvic and hind leg muscles, long slender ankles and long shins.

A sure sign of slow runners is a short ankle. Elephant ankles are stubby and wide. Tyrannosaur ankles are twice as long, and the three main ankle bones are tightly wrapped around each other.

A “T. rex” could have run rings around an elephant. (Of course elephants didn’t excited when “T. rex” was alive, but tyrannosaurs could run circles around all the big place eaters of their time.)

Giganto-Dactyl

"Quetzalcoatlus"

"Quetzalcoatlus" and its close kin were the greatest flying creatures to ever evolve. Thirty-five feet from wing-tip to wing-tip, "Quetzals" were far wider than the California condor and many times heavier. Aeronautical engineers were stymied by "Quetzals" when they were first discovered; their body mass simply seemed too big to fly.

But fly they did. The upper arm had huge bony flanges for the flapping muscles. Hind legs added power. Like a pat, the wing was attached the hind leg. "Quetzalcoatlus" was not a mere passive glider; it could and did engage in active flight.

They were quick on the ground, as well. "Quetzal" legs were exceptionally tall, and they likely moved like giant versions of bats. They could gallop along the ground to catch prey, or get a running start for takeoff.

The evolutionary fat of giant 'dactyls was tied to the dinosaurs and the great sea-reptiles. When the Cretaceous Period ended, they all died out. Many birds survived, but not one bird would ever achieve the magnitude of the great "Quetzalcoatlus."

Ammonites

The Real Winners of the Darwinian Race

Evolutionary High Score

When it comes to evolution, what matters is how many new species you produce, how fast you produce them, how widespread they become, and how long you can keep it up.

Ammonites made high marks in all categories. From the Devonian Period to the end of the Cretaceous, ammonites generated tens of thousands of species that invaded nearly every saltwater habitat in the world.

Ammonites as Geological Time-Keepers

Ammonite species came so fast and furiously that the average species only lasted a million

years or less. This quick turnover means that ammonites are near-perfect paleo-clocks.

Squiggle-Sutures

Ammonites are close kin of cuttlefish, squid and octopus and distant kin of the “Nautilus.” Like nautiloids, ammonites had hard shells that usually curled up in a tight spiral. As they grew, ammonites and nautiloids sealed off old parts of the shell with internal walls called septa.

Where nautiloids made simple partitions, ammonites’ inner shell walls were bent and folded. In advanced ammonites, each species had its own way of squiggling, giving us a quick method of identification.

But these squiggles served a greater purpose. The ammonite’s body, head and tentacles were connected to the inner shell wall by muscles,

which could be strained when it grabbed prey or wrestled with another ammonite. A folded inner shell wall gave the muscles more surface area, allowing them to attach much more firmly.

Boom and Bust and Boom and Bust

Ammonites demonstrate a rhythm of success and failure over 300 million years—exploding in diverse new species, and then, tens of millions of years later, going totally bust.

Most species would die out, and the few surviving species would proliferate again and then go bust once more.

The final boom happened as “T. rex” and “Triceratops” ruled the land. Just as the last big dinosaurs died out, the ammonite hordes died, too. This time, there were no survivors.

Jurassic Park

The Zuhl Collection

These sections of fossilized tree trunks are from trees that lived millions of years ago. When these trees died, rather than rotting away, they were petrified.

In order for a tree trunk to petrify instead of rotting, the wood must be rapidly buried to exclude oxygen. Without oxygen, the chemical reactions that cause the wood to decay cannot take place.

The volcanic sediments covering the trees are rich in soluble silica, a combination of atoms of the elements silicon and oxygen. The silica dissolved in the water and the buried wood soaked up the silica-rich solution like a sponge. The dissolved silica fills the spaces in the lacey

network of cells that make up the wood. Over time the water evaporates and leaves behind the silica, which solidifies.

Within spaces such as a crack or a rotten spot in the wood, the silica may form large quartz crystals with visible natural facets. In most of the wood, the rapidly solidifying silica forms milky opal, or layer upon layer of colorful agate. The different appearances of these forms of silica result from the way the atoms are arranged as the silica hardens. The colorful stone record preserves the tree's structure and reveals details about the environment of millions of years ago, as well as the distinct history of each particular tree.

“King of the Sharks”

“Megalodon”

Here is the largest jaw ever assembled of the stupendous “C. megalodon” shark—a fish twice as long as the largest known great white shark. “Meg” teeth were whole-choppers. Each tooth carried a fine, saw-toothed edge and a thick central zone. Whale bones from deposits full of Meg teeth show deep cuts and gouges that match the “C. megalodon’s” dental anatomy.

Elephant tribes were on the menu, too. All members of the elephant clan are expert swimmers; mastodons and mammoths spread across the Pacific. Mastodons dog-paddling in the surf were occasional victims of Meg attacks, as proven by bite-marks on mastodon ribs and vertebrae.

“C. megalodon” Jaw.

Gift of Charles T. Jeremiah and Family

Mastodon with a Built-in Shovel

“Platybelodon”

About 17 million years ago came the strangest tusks of all. “Normal” Mastodon tusks, like “Gomphotherium’s,” were long and straight with pointed tips. “Platybelodon,” the shovel-tusked mastodon, carried lower tusks that were unbelievably wide. Together the right and left tusks made a sort of shovel.

What did shovel-tuskers do with their shovel? Perhaps they scooped up water plants. Maybe they cut through thick bushes. Or, maybe they carried their babies when the babies grew tired of walking behind their moms.

We don’t know the answer yet. What do you think?

Hippo-Rhino

“Chilotherium”

The zebra-like “Hipparion” was long-legged and fast. And in most places, its companion was the short-legged, tubby hippo-rhino.

From Texas to China to East Africa, hippo-rhinos like “Chilotherium” moved in great herds that left behind bone beds with tens of thousands of bones. They were true rhinos, close kin of today’s “Rhinoceros,” the Asiatic one-horned rhino. Short legs go with water-loving habitats. Most modern-day rhinos love to wade and wallow in muddy pools or stream edges. Early rhinos had low molars fit for chomping soft fodder. Tall molars gave hippo-rhinos grass-eating potential, though gritty bushes were a favorite food, too.

Fang-Fighters

When we think “rhino,” we tend to think “horns.” But that’s wrong: most extinct rhinos had small horns or no horns at all. Instead, their weapon was a lower incisor tooth which developed into a sharp-tipped spear that could rip open a saber-tooth cat or even a mastodon. Modern Indian and Sumatran rhinos still carry the lower fang of their ancestors.

A hundred years ago, when European big-game hunters rode in howdahs on their elephants, Indian rhinos occasionally attacked and killed the elephants. "Chilotherium" evolved just about the largest fighting fangs of any rhino ever. Bulls carried longer fangs than cows, suggesting that bull-on-bull violence was common. Angry "Chilotherium" bulls probably attacked mastodons when those pachyderms got too close.

“Slothzilla”

“Eremotherium”

Greatest of the Ground Sloths

Sloths today are strictly tree-climbers of modest size, hanging upside down, eating leaves, moving slowly, and coming down to the ground only to defecate.

A few thousand years ago, the sloth clan was rich in gigantic ground-dwelling species as big as oxen or even elephants. The sloth families were one branch of a vast old South American complex that included armadillos and anteaters.

But as long as oceans separated South American from North America, the sloth empire could not expand. When the Isthmus of Panama emerged from the sea about 5 million years ago, sloths moved north, occupying Texas and other

southern states. One sloth family made it all the way to Alaska.

North America was a dangerous place to invade. Sloths were greeted by giant bears, lions and three types of saber-toothed cats. How did they defend themselves?

Eremotheres' hide had a layer of tightly packed bone nuggets that worked like the chain-mail of a medieval knight. Active defense was performed by swipes of their forepaws. A 10-ton eremothere could fling a saber-toothed cat a dozen yards.

"Eremotherium" displays the advanced ground-sloth body design: thick, powerful hind-legs, stubby tail and long arms. Few tubers and edible roots were safe from determined eremothere. These multi-ton sloths could harvest leaves, fruit and branches by reaching up and dragging tree limbs down.

Eremotheres walked on the outside of their hind-feet, curling their large claws inward. When they dug with their forelimbs, ground-sloths braced themselves with their tails and dug into the ground with their rear claws.

Despite their prodigious success, all ground sloths abruptly became extinct around 10,000 years ago. Their extermination was part of the terminal Ice Age extinction—a die-off of nearly all the giant mammals across North and South America.

Giant Bull

“Mammut americanum”

Enormous mammoths and mastodons roamed North America in the Ice Age, and humans hunted both. The “American Mastodon,” “Mammut americanum” was the last species of “Mammut” and kept the same simple chopping molars that had evolved in the Miocene 12 million years earlier.

Different dietary preferences keep mastodons and mammoths apart in most places. Mammoths preferred grass and dry leaves in open plains and woodlands while mastodons went for softer, wider branches in wetter forests and swamps. Many mastodon bones turned up in bogs being drained by American farmers in the 1700s.

Thomas Jefferson’s Order to Lewis and Clark: “Find a Live Mastodon!”

Colonial naturalists were fascinated with “Mammut.” Thomas Jefferson had mastodon bones on display in the White House when he was president, along with ground sloth specimens and parts of mammoths.

Jefferson was sure that such a magnificent creature must have been alive, somewhere in the unknown American West. He instructed explorers Lewis and Clark to find a herd of live mastodons in the Rocky Mountain region.

Lewis and Clark didn’t bag a mastodon, or a mammoth, or a ground sloth.

Ice Age fossils proved that nature was unpredictable and prone to worldwide catastrophe. Our present-day ecosystem is missing most of the giant mammals that once ruled, and Jefferson never got his prize alive.

Cast of Mastodon Skeleton, “Priscilla.”

Gift of Charles T. Jeremiah and Marla Moore

Atlatl Overkill?

The Great Ice Age Extinctions

Mammoths, mastodons, giant sloths, saber-toothed cats and many other mega-fauna species died out about 10,000 years ago in North America. It was the fast monumental extinction of land life in the fossil record. What happened?

One popular theory is that skilled atlatlists were so effective that they slaughtered all the giant herbivores. The carnivores, deprived of food, then died of starvation. There is circumstantial evidence for this theory: humans entered the New World about 15,000 years ago. Clovis-style atlatl points become common and widespread about 13,000 years ago. Most of the giant mammals disappeared between 11,000 and 10,000 years ago.

Think of it as a trial. Human hunters had the opportunity—they were here at the right time. They had motive—mammoth meat was delicious (or at least nutritious). They had the means—the atlatl, equipped with a Clovis point, could kill a giant.

Case closed? Not quite. There is a problem with the theory: very few mammoth skeletons show cut marks from human butchering. Most mammoth, mastodon and giant sloths seem to have died from other causes. If humans did cause the extinction, it must have happened so fast that fossilization couldn't capture the evidence.

We may have overestimated how effective stone-age weaponry, atlatls or even bows and arrows are. Native African hunters, armed with poison arrows and deadly bows, did not exterminate all

the giant mammals in Africa; Africa today still has two elephant species, two giraffes, three rhinos and a hippo species, in addition to water buffalo.

On islands, the situation is different. Native fauna does seem especially vulnerable to human hunting. The giant flightless birds of New Zealand, the moas, disappeared shortly after the arrival of humans around 1,000 AD, and the same fate awaited the elephant bird of Madagascar when our species invaded in about 1,400 AD.

In Australia, the circumstantial evidence again points to humans as agents of extinction, at least in part. The first atlatl-wielding humans became common around 40,000 years ago. Shortly afterwards, giant kangaroos and huge wombat-relatives go extinct.

Alternative Suspect: Climate Change

The climate worldwide suffered savage perturbations through the Ice Age. Glaciers advanced over the land and then retreated a dozen times. Winters got dry, then wet. Forests spread north, then retreated south. The very last glacial melt-back was followed by hot weather.

Could these weather shifts have killed the mammoths and their neighbors? Elephants today are hardy creatures, capable of dealing with all sorts of habitats. They can migrate hundreds of miles to escape local adverse conditions. An important consideration is that there were dozens of big mammals, each species adapted to a different habitat. It’s hard to imagine a climate shift that would kill off the woolly mammoths and all the Columbian mammoths, plus the desert ground-sloths and

the woodland ground-sloths, and the swamp-loving mastodons as well.

The Great Ice Age die-offs continue to provide debate, and there is no consensus about what part humans played in exterminating the dozens of multi-ton mammals in the New World.