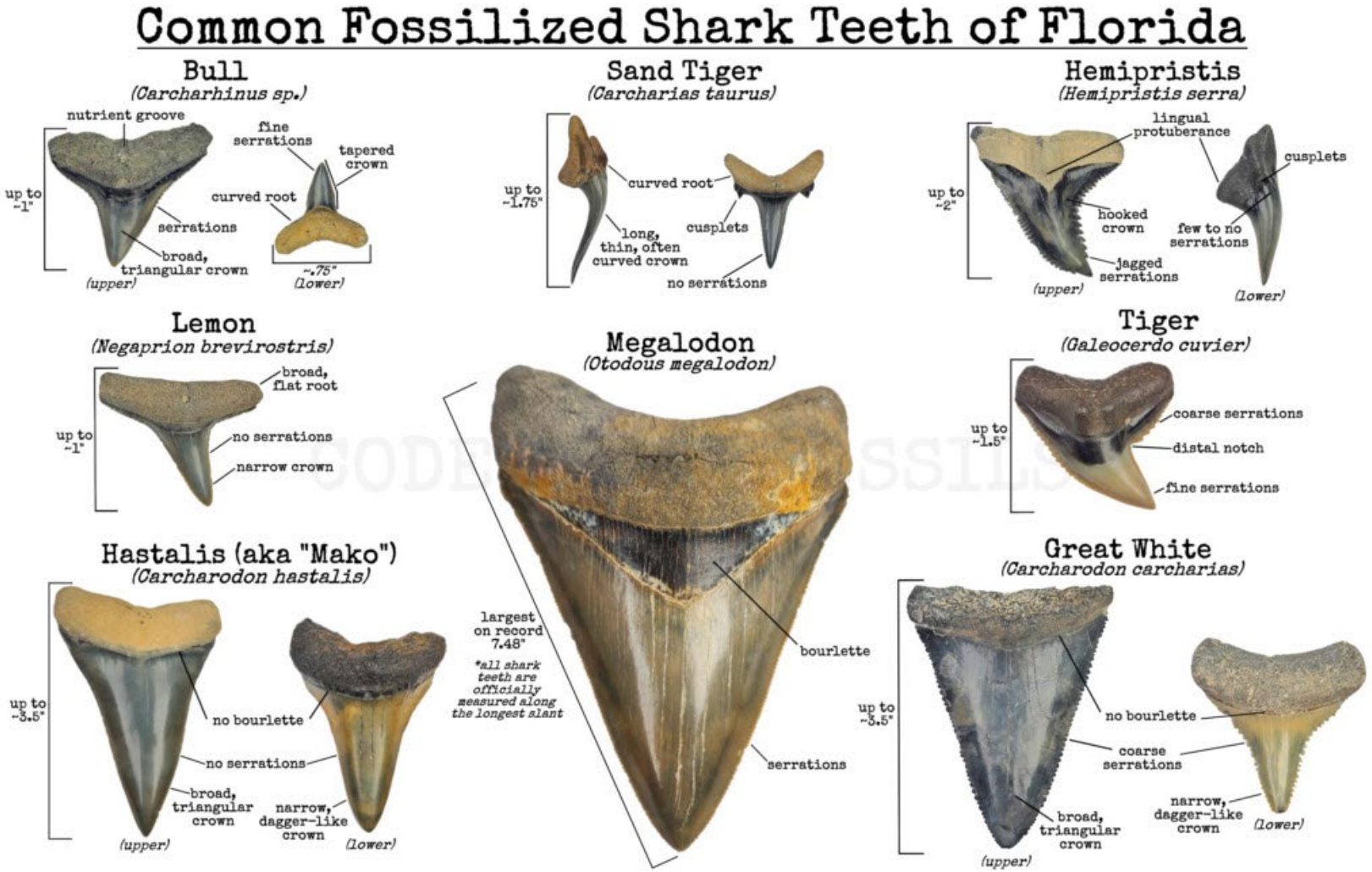
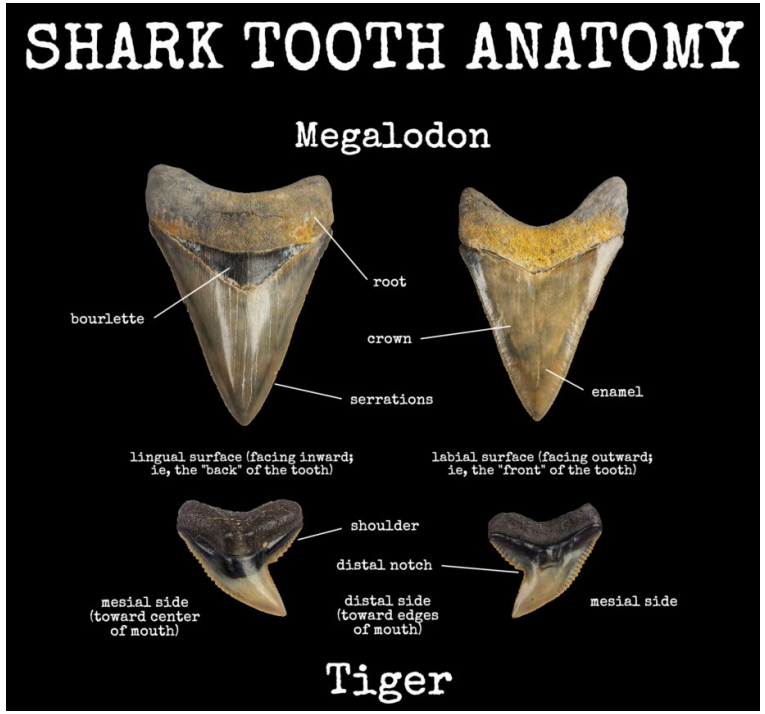
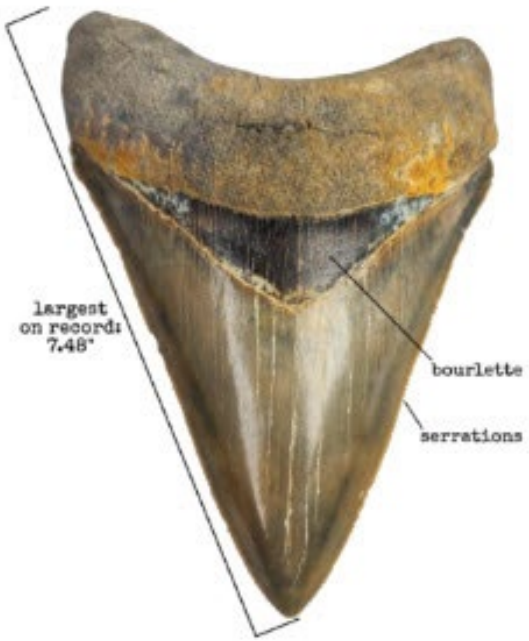
Fossil Details





Fossil Details

Megalodon (*Otodus megalodon*)



The megalodon is the largest shark to ever live. It terrorized seas worldwide from ~20 - 3.6 million years ago, growing to an estimated 60+' long and 60+ tons, with jaws nearly 10' wide and teeth over 7" long, with the largest tooth on record measuring 7.48" from tip to corner (which is how shark teeth are typically measured). Possessing the strongest bite force of any animal in history at an estimated 40,000 lbs/sq inch, it feasted on large marine mammals such as dugongs, manatees, sea lions, seals, dolphins, and even whales, in addition to sea turtles, large fish, and other sharks. It's thought to have primarily hunted in warm, shallow seas across the globe, as evidenced by its fossilized teeth being found from Australia to Indonesia, Morocco, Peru, the entire southeastern coast of the US (from Florida to Maryland) and beyond (indeed, its teeth have been found on every continent except Antarctica). While scientists once believed that the megalodon was an ancestor of the modern great white, recent evidence points to them evolving from different lineages and the two species not being closely related at all. Megalodon teeth are differentiated by their sheer size and the fact that they possess both serrations and a *bourlette* (a triangular or V-shaped band between the root and crown), with uppers being broad and triangular, lowers being somewhat narrower, and posteriors having short, squat crowns with wide, thick roots.

SHARK FACT

The side most people think of as the "front" of a shark tooth is actually the back side! The *labial*, or outward facing side of shark teeth is actually flat and relatively featureless, whereas the *lingual*, or inward facing side is the one that gets all the attention.

Great White (*Carcharodon carcharias*)

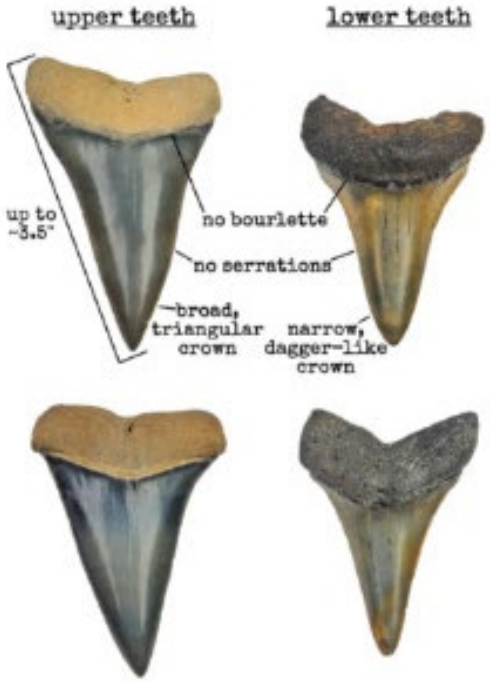
The great white is unquestionably the most [in]famous shark alive today. A *sexually dimorphic* species, females are larger than males, with the largest ever tagged (named Deep Blue) clocking in at 20' long and ~4,500 lbs (though the average female is ~16' and the average male is ~13'). With a top speed of 35 mph, a diving capacity of nearly 4,000', an estimated bite force of 4,000 psi, and a life span of 70+ years, the great white is among the most dominant apex predators in all of history. Their teeth tell this tale: a coarsely serrated crown seemingly custom built for slicing through flesh, with uppers being broad and triangular and lowers narrowing sharply from root to tip.

SHARK FACT

While great whites are often thought of as the "top dogs" of the sea, they do have one natural predator: *Orcinus orca*, the killer whale. Orcas have been observed ramming into great whites (and other large sharks) at high speeds, momentarily stunning them. They then flip the stunned shark over to induce *tonic immobility*, a reflex in sharks in which they become catatonic and effectively paralyzed, and hold them in that position until they drown. Their reward? Shark liver (which can comprise over 25% of a great white's total body weight): a meal not only loaded with vital nutrients, but one that is more calorically dense than even whale blubber, and which is excised with almost surgical precision, as typically the rest of the now dead shark is left intact.

Fossil Details

Hastalis (aka "Mako")
(*Carcharodon hastalis*)



The extinct hastalis, or lesser white, is among the most sought after shark teeth in Florida. While there has been a great deal of debate about the ancestral lineage of the hastalis throughout the years (you'll often see them classified as either *Isurus* or *Cosmopolitodus hastalis*, or referred to by their still common nickname of "makos"), recent studies indicate that they're actually ancestral to modern great whites. Indeed, the two species' teeth share a great deal in common in terms of size and overall shape, with the hastalis simply lacking the serrations of their great white counterparts. Hastalis uppers are broad and triangular, while lowers are narrower with more sharply angled roots.

SHARK FACT

Sharks, along with their close cousins rays, skates, and sawfish (and distant cousins chimeras) comprise a *class* of fish called *Chondrichthyes* (kahn-DRIK-thee-eez): those with *cartilaginous (car-tuh-LADGE-in-iss)* skeletons rather than ones made of bone. Cartilage is both lighter and more flexible than bone, reducing a shark's overall weight and allowing for quicker movements and improved agility underwater. However, without a bony rib cage to protect their internal organs, sharks can literally be crushed by their own weight out of the water.

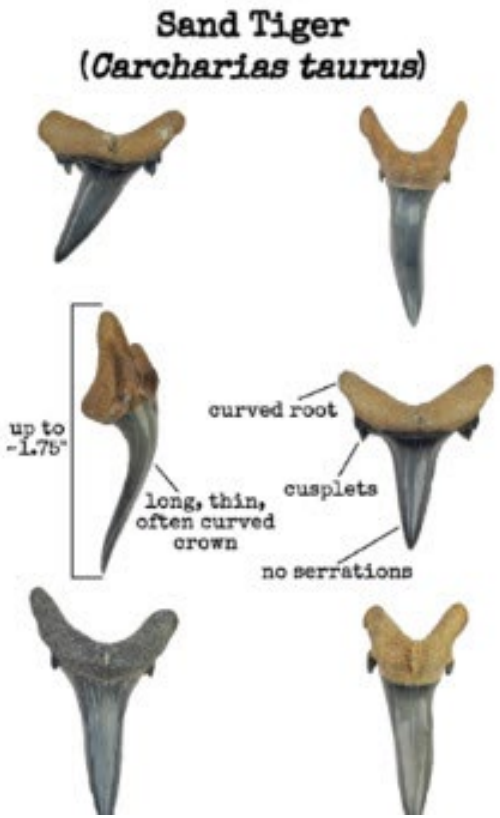
Tiger Shark
(*Galeocerdo cuvier*)

Tiger sharks derive their name from the spots and stripes that dot their backsides, though these typically fade with age. Legendary for their diverse diets, common prey includes fish, birds, seals, dolphins, whales, crustaceans, squid, sea snakes, other sharks, and, notably, sea turtles. Edible items aren't the only ones on the menu, however, as they've been found with everything from license plates to fur coats in their stomachs. Though their large size and dietary ambivalence make them dangerous to humans, attacks are still rare and fatalities even more-so. Among the most iconic shark teeth, they're easily identified by their unique shape: a broad, plunging root and telltale notched, complexly serrated crown (their serrations have serrations of their own!)

SHARK FACT

The size and shape of each species' teeth can tell you about their diet: long, needle-like teeth are ideal for gripping slippery fish and squid; large, triangular, serrated teeth for slicing through larger fish and especially marine mammals; and broad, flat teeth for crushing shelled and armored prey. Then there are non-functional *vestigial* teeth, as in the case of filter-feeders like basking, megamouth, and whale sharks, which are merely evolutionary remnants from earlier ancestors and no longer serve any practical use.

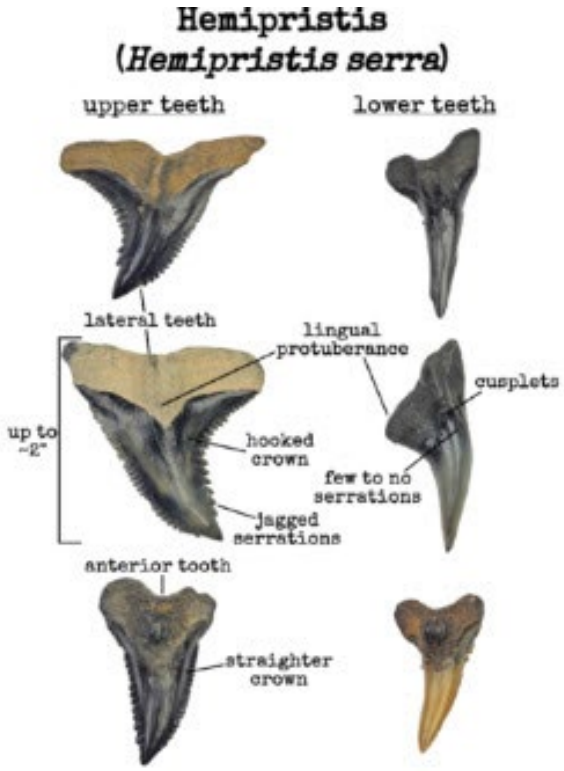
Fossil Details



Sand tiger sharks have been around for tens of millions of years. They inhabit temperate and sub-tropical coastal waters worldwide, with adults growing up to 11' long and 350 lbs. Despite their fearsome appearance, they pose minimal threat to humans, instead using these long, needle-like teeth to grip their desired prey: slippery fish, smaller sharks, rays, and squid. Interestingly, they're the only sharks known to "gulp" air at the surface. They store this air in their stomachs in order to achieve *neutral buoyancy*, which allows them to hover motionlessly just above the seafloor in wait of prey. A collectors' favorite, sand tiger teeth are long and needle-like with tiny cusplets on either side of a markedly curved root.

SHARK FACT

You may have heard that if a shark stops moving it will no longer be able to breathe and eventually die. But is this actually true? For some sharks, like the great white and whale – yes! As *obligate ram ventilators*, the moment they stop moving, oxygen-rich water stops flowing through their gills. But many sharks, like the sand tiger, have special adaptations to combat this problem, such as *buccal pumping*, in which muscles in the cheeks are used to draw water in through the mouth and back out through the gills, ensuring a constant supply of oxygen-rich water to their motionless host.



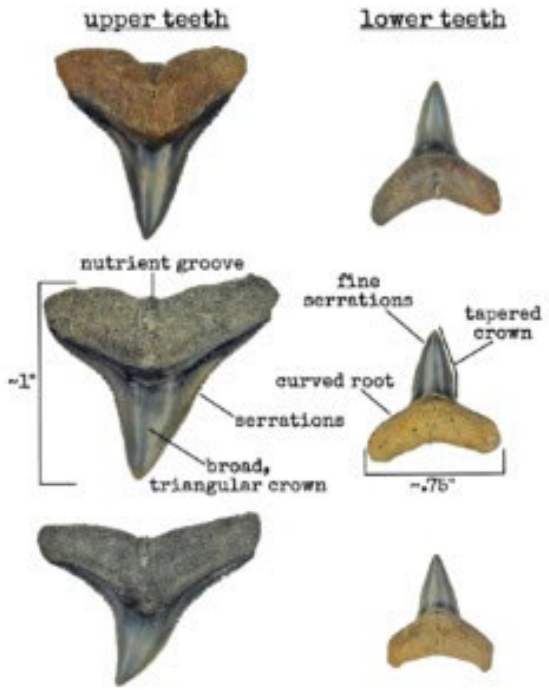
Hemipristis serra, aka the snaggletooth shark, is an extinct weasel shark that was widespread during the *Miocene* (~23 to ~5.3 mya, or million years ago). It was significantly larger than its 8' long *extant* (still in existence) cousin, clocking in at 20' in length. Upper and lower hemi teeth look quite different (and until recently were believed to be from two completely different species) and had opposing functions, with the broad, heavily serrated uppers acting as knives, cutting and tearing flesh, while the pointy, lightly or un-serrated lowers acted as forks, spearing prey and holding it in place. Note that upper *lateral* teeth (those toward the sides of the jaw) have a significant curve while upper *anterior* teeth (those toward the center of the jaw) are straighter and narrower. Lowers, which are often confused with sand tiger teeth, can be distinguished by the significant *lingual protuberance*, or hump, in the center of the root.

SHARK FACT

When an animal has upper and lower teeth that differ in size and shape it is said to have *dignathic heterodonty (die-NATH-ick HET-err-oh-don-tee)*. Many sharks exhibit this trait, but few as markedly as the Hemipristis.

Fossil Details

Bull Shark
(*Carcharhinus sp.*)

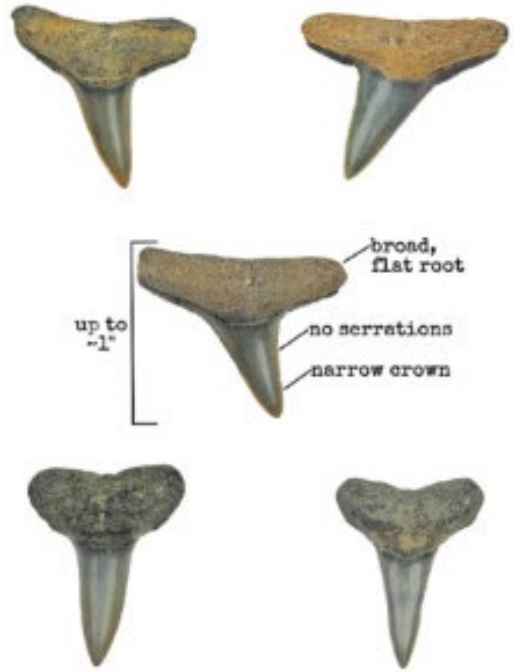


Bull sharks are one of many species in the broad genus *Carcharhinus*, which also includes the dusky and silky. Teeth from within this genus often look very similar, making them difficult to tell apart. As such, they're typically grouped together by collectors and simply referred to as "bulls." Highly freshwater tolerant, bull sharks have been found in rivers over 1,000 miles upstream. Aggressive and unpredictable, they account for multiple attacks on humans every year, though luckily most aren't fatal. Their upper teeth are broad and triangular with well-defined serrations, a plunging root, and a prominent nutrient groove while lowers, which are often confused with lemon shark teeth, are narrower, smaller, very finely serrated, taper inward about halfway down the crown, and have a curved root.

SHARK FACT

While the teeth of most other animals are firmly rooted directly into the jaw, shark teeth are held in place by special connective tissue in the "gums" and are lost continuously throughout a shark's life. Most sharks have around 50 tooth positions, with 5-15 rows of teeth growing in each one. These rows operate like a conveyor belt: as one tooth is lost or damaged, a new one moves forward to take its place. Some sharks can go through 35,000 or more teeth in a lifetime. That's part of the reason you find so many of them while fossil hunting!

Lemon Shark
(*Negaprion brevirostris*)



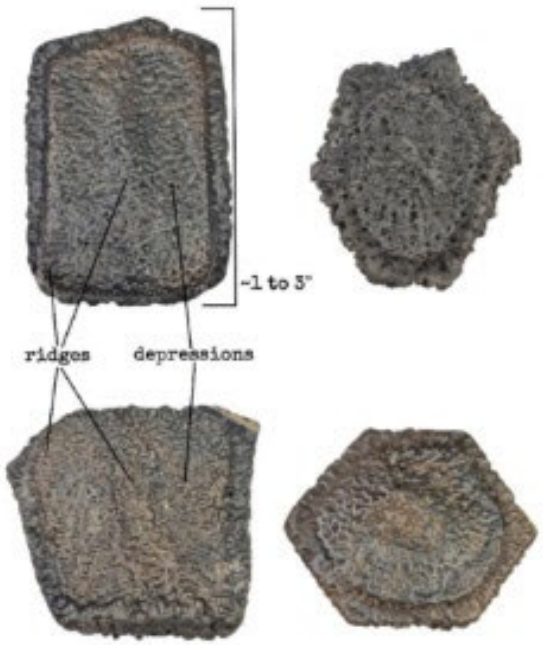
Modern lemon sharks primarily inhabit shallow, coastal waters of the eastern hemisphere. They're thought to have evolved during the late *Cretaceous period*, some 75-95 mya (million years ago), meaning they co-existed with dinosaurs. Though relatively large (growing up to 11' and 300+ lbs), they are a docile species and pose very little threat to humans. They're named after the yellow hue of their skin, which offers excellent camouflage in their preferred shallow, sandy hunting grounds. Their teeth lack serrations, have narrow crowns with broad, flat roots, and resemble the letter "T".

SHARK FACT

Sharks evolved into their modern forms during the *Jurassic period* some 200 mya, though the direct lineage of shark-like fishes (which some scientists lump into the broader "shark" family) goes back to at least the *Silurian period*, 440+ mya. Here's a list of things "sharks" are older than: trees; amphibians; dinosaurs; reptiles; birds; Pangea; the Atlantic Ocean; the Rockies, Alps, Himalayas, and Andes; Saturn's rings; and Polaris (the star itself, not just its run as the "North Star," which is a super interesting astronomy tangent – Google "north star precession" to

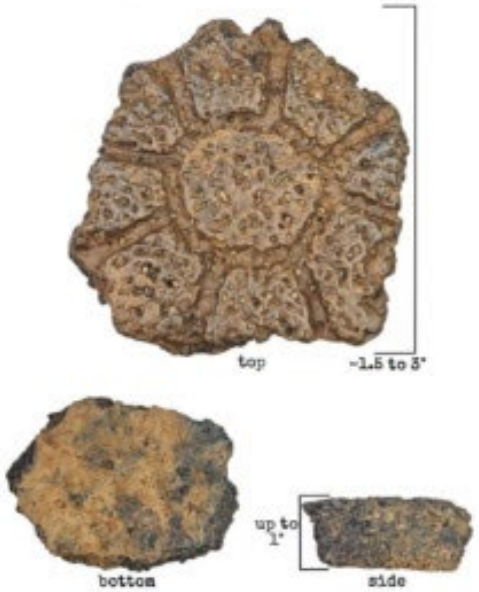
Fossil Details

Giant Armadillo scutes
(Holmesina sp.)



Though commonly called giant armadillos, these animals were actually *pampatheres*, an extinct line of armadillo-like creatures. Originally evolving in South America, they dispersed northward after the Isthmus of Panama was formed roughly 2.7 mya in an event known as the *Great American Biotic Interchange*, in which tremendous migrations of animal species took place between the Americas via this newly formed land bridge. Unlike modern armadillos, which are *insectivorous* (insect eaters) or *omnivorous* (eating a mixed diet of plants and animals), giant armadillos were strictly *herbivorous* (plant eaters). They were much larger than the giant armadillos of today (found in South America), with the larger of the two species (*septentrionalis*) growing to 3' tall, 6.5' long, and weighing 600 lbs. Their shells were covered by hundreds of individual *scutes* (also called *osteoderms*), or bony, scale-like structures in the skin, of many shapes, sizes, and functions, with some even overlapping one another (called *imbricating scutes*), forming bands similar to those of modern armadillos. These bands afforded flexibility while still offering protection from predators.

Glyptodont scutes
(Glyptotherium sp.)



Glyptodonts are an extinct relative of armadillos, anteaters, and sloths (together forming the *clade* - a grouping of animals that all evolved from a common ancestor - *Xenarthra (zen-ARTH-ruh)*, latin for "strange joints") that initially evolved in South America before migrating northward after the Isthmus of Panama was formed some 2.7 million year ago. They dwarfed their giant armadillo cousins, growing to 5' tall, 11' long, and weighing over 4,000 lbs: about the size (and roughly the shape) of a Volkswagen Beetle. Their heavily armored heads, tails, and dome-shaped shells were equipped with over a thousand individual *scutes* (also called *osteoderms*), or bony, scale-like structures in the skin, and they bore a slight resemblance to the unrelated and much older – but similarly armored – *Ankylosaurid* dinosaurs in a case of what paleontologists call *convergent evolution*, in which ecological pressures lead two or more different species to evolve similar traits, features, or characteristics.

Fossil Details

The evolutionary lineage of horses is perhaps the best attested in all of paleontology, starting in North America 50+ mya with a 20" tall hoofed mammal called *Eohippus*. Unlike modern horses, which are *grazers* (grass-eaters) and have one, unpadded, hoof per leg, this diminutive ancestor was a *browser* (meaning it ate leaves, soft shoots, and/or shrubs) and had four padded hooves per front leg with three in the rear. Over the course of horse evolution, which is a complex web that illustrates how diverse evolutionary mechanisms can truly be, the following trends ultimately won out: increase in overall size; reduction in number of hooves and loss of footpads; lengthening of legs and a fusion of the lower leg bones; increase in head and brain size; and a transition to crested, high-crowned teeth ideal for grazing (called *hypsodont dentition*).

When a horse eats, it inadvertently yanks up grit and soil in addition to grass. Grass requires a lot of hard, grinding chewing to make it digestible and is itself full of microscopic, abrasive silica granules called *phytoliths*. The chewing of this *exogenous* (originating from outside an organism) grit in addition to the abrasive phytoliths naturally present in grass causes horse teeth to literally erode away over time. As a result, their teeth evolved to slowly erupt out of the gum line as they're worn down. Each tooth tells a story: a long tooth (adult molars start at ~5") indicates that the horse it belonged to died at a young age, while a severely worn tooth, sometimes hardly more than just the roots, relays that its owner lived a long life before ultimately succumbing to starvation or, no longer able to eat and in a weakened state, predation.

barbs

There are around 220 known living species of stingrays worldwide, with countless extinct ones. Closely related to sharks, they've been around since at least the *Jurassic period* (~150 million years), meaning they co-existed with dinosaurs. Their venomous, serrated tail barbs are only used as a last line of defense, as rays would rather flee than fight. When deployed, they're whipped to the side or over the stingray's head like a scorpion.

dermal denticles

Also known as *placoid scales* (and commonly called "mermaid nipples"), denticles are essentially modified teeth (not actual scales) that cover the skin of sharks, rays, and skates. They act not only as armor, offering protection from predators and parasites alike, but also increase the animal's *hydrodynamics* by reducing drag and turbulence as it swims. If you've ever "pet" a ray, you'll remember how smooth it felt when you went with the grain from head to tail but the second you went against the grain it felt like sandpaper. Those were the dermal denticles at work!

mouth plates

Stingray teeth grow in rows, fusing together to form broad crushing plates on the tops and bottoms of their mouths which they use to squash the shells of their armored prey. These plates typically break apart into individual teeth after rays die, but can occasionally be found still fused together.

Fossil Details

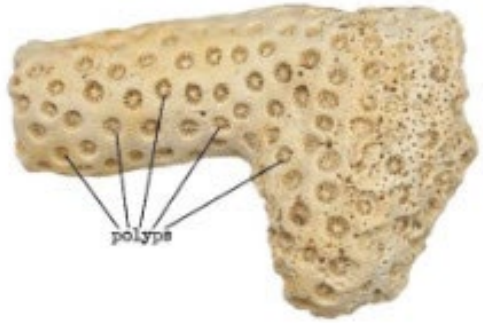
Whale inner ear bone (*tympanic bulla*)

Cetaceans (seh-TAY-shenz) are a group of mammals that initially evolved on land before "re-entering" the water 50 some odd million years ago. Their immediate ancestors were amphibious and bred on land (similar to seals) and their closest modern relative is the hippopotamus. There are two modern groups of Cetaceans: the toothed whales, or *Odontocetes (oh-DON-tuh-seats)*, which include sperm whales, orcas (killer whales), dolphins, and porpoises and which use high pitched clicks and pops to *echolocate* and communicate; and baleen whales, or *Mysticetes (MISS-tuh-seats)*, which include blue, humpback, and right whales and which hear and communicate at much lower frequencies that can occasionally be heard by other whales up to an astonishing 1,000 miles away. As whales transitioned from amphibious creatures to purely aquatic ones, their ears had to adapt as well: from an early compromise of hearing just ok both above and below water, to the hyper-specialized, underwater eyes that they function as today. Few other animals are as reliant on hearing as whales.

Burr/Pufferfish mouth plates

Burr, puffer, and porcupinefish belong to the broader "blowfish" family (taxonomically, *order*). Many of the fish in this order possess sharp, spiny armor (where the "burr" in burrfish comes from), some are highly venomous, and all have the ability to inflate when threatened by predators. Their fused teeth, or "mouth plates," form a beak of sorts which they use to crush their armored prey. On the menu? Crabs, clams, sea snails, shrimp, urchins, and more.

Coral



Despite their plant-like appearance, corals are actually animals, often forming colonies consisting of thousands of individual *polyps* - each one being a different animal! Finger coral, a species of stony coral, is one of the most abundant corals in the Caribbean and western Atlantic. They thrive in waters up to 65' deep, so it's no surprise they're found so commonly - fossilized or otherwise - in Florida's shallow seas.

Fossil Details

Dugong rib

Dugongs, which are closely related to manatees, once roamed Florida's seas in huge numbers but are now found exclusively in the eastern hemisphere – the east coast of Africa, western India, southeast Asia, and northern Australia. Their ribs, which are extremely dense and therefore heavy, act as *ballast* (similar to a scuba diver's weight belt), allowing them to achieve neutral buoyancy instead of merely bobbing around at the surface of the water. The more dense a bone is, the more readily it will fossilize (all other things being equal), and these certainly live up to the billing, being one of the most common fossil finds in Florida. A general rule of thumb is that wherever dugong ribs are present, megalodon teeth are *potentially* close by, as dugongs were one of their favorite snacks (as evidenced by the predation marks megalodon teeth often left on these ribs).

Alligator teeth

Mature alligators have 80 conical teeth, which they lose and replace by the thousands over the course of their lifetimes. Replacements grow in from below the existing tooth at about the same rate as human fingernails. A rootless, hollow-bottomed tooth was lost by a living animal, whereas a rooted tooth came from a deceased one. The largest (modern) American alligator on record was captured in 2014 and was nearly 16' and weighed over 1000 lbs. While this seems (and is!) enormous, it paled in comparison to its Miocene contemporary, the marine (saltwater dwelling) American crocodile, which is thought to have reached 30' long and over 8,000 lbs.

CODE BLACK FOSSILS

Fossil Geologic Time Scale v6.0

Cenozoic Era: 66 mya to today
(~1.5% of Earth's history)

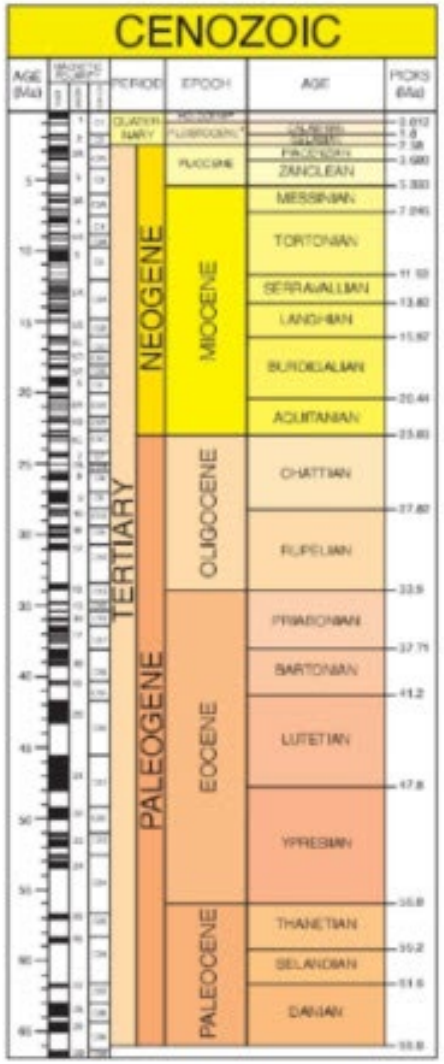
From the Greek words for new (*kainos*) and life (*zoe*), our modern era, the Cenozoic (*sen-uh-ZOH-ick* or *see-nuh-ZOH-ick*), started with a bang: the K-T or K-Pg (Cretaceous-Tertiary/Paleogene) extinction event, in which 70-80% of all plant and animal species disappeared from the fossil record (including the big one: non-avian dinosaurs).

The Cenozoic marked the flourishing of flowering plants (including, importantly, grasses), birds, and especially mammals (including humans), which thrived in the new ecological niches created by such a massive and sudden extinction event. Mammals in particular rapidly diversified from a few small, rudimentary forms hardly recognizable by today's standards into a vibrant collection of marine, terrestrial, and flying animals, setting in motion what would eventually lead to the evolution of genetically "modern" humans some 200,000 years ago.

Major geological changes also took place during the Cenozoic. As the tectonic plates drifted into their present locations, *Gondwana* experienced its final break up (as Antarctica split from South America and Australia); India slammed into Asia (forming the Himalayas); Arabia collided with Eurasia, closing the *Tethys Ocean* (vestiges of which still exist in the form of the Mediterranean, Caspian, and Black Seas); the Atlantic continued to widen; and the *Isthmus of Panama* was formed, connecting North and South America and shifting oceanic currents worldwide, hastening the coming Ice Ages of the Pleistocene epoch.

Climatically, the beginning of the Cenozoic was much warmer than today with ice free poles and sea levels ~300 meters (close to 1000') higher than current levels. Then, ~50 mya, Earth entered a general long term cooling trend (with occasional warm periods mixed in), eventually leading to the extreme glaciations of the Pleistocene, the last of which ended only ~14,000 years ago.

The oldest fossils you'll find in Florida are from the *Eocene epoch* and are around 50 million years old. The vast majority, however, are far younger, from the *Miocene* onward, topping out at 23 million years old. This sliver of time represents just .05% of Earth's history, a mere blip on the radar.



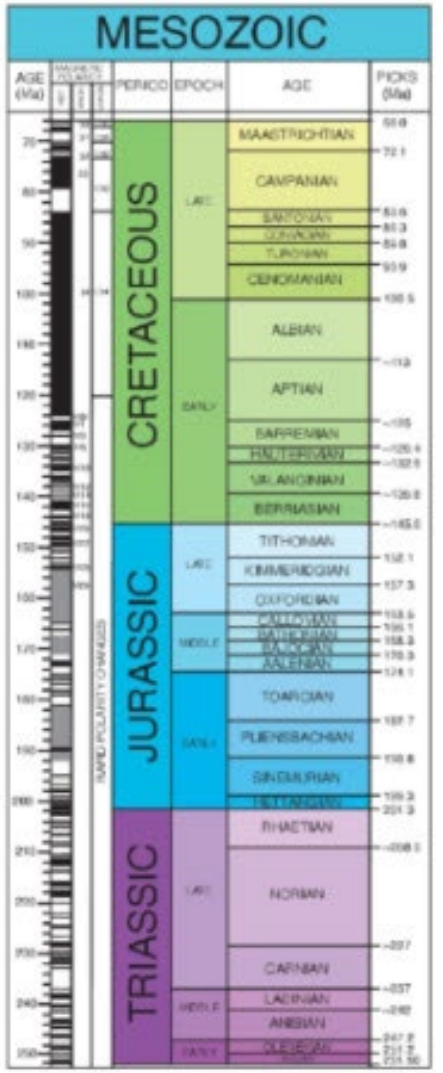
Mesozoic Era: 252 – 66 mya
(~3% of Earth's history)

The Mesozoic era (*mess-uh-ZOH-ick* or *mez-uh-ZOH-ick*), from Greek middle (*meso*) and life (*zoe*), and comprising three periods - the Triassic, Jurassic, and Cretaceous - began with an even bigger bang than the Cenozoic: the P-Tr (Permian-Triassic) extinction event (also called the *Great Dying*). The most devastating mass extinction in Earth's history, this cataclysm resulted in ~90% of all plant and animal species disappearing (including ~95% of marine species and ~70% of terrestrial species).

Out of the ashes of the Great Dying, reptiles came to dominate the earth. Plesiosaurs, ichthyosaurs, and later on mosasaurs flourished in the oceans while crocodilians out-competed the giant amphibians that had previously ruled the freshwater seas. Dinosaurs grew to terrifying sizes (though many species remained quite small) and became the preeminent terrestrial animals. Birds (avian dinosaurs) eventually evolved and would be the only dinosaurs to survive the coming K-T mass extinction. Mammals also evolved during this time, but remained small and limited in diversity until the Cenozoic. Modern forms of sharks evolved and insects first attained full metamorphosis. Conifers and ferns dominated lush, coastal forests (especially near the equator), with vast, highly seasonal deserts occupying much of the interior of the Pangean supercontinent. Another mass extinction took place, this time at the Triassic/Jurassic boundary, resulting in the disappearance of 70-75% of all species.

Pangea began rifting apart during the early Jurassic (~200 mya), breaking into Laurasia (North America, Europe, and Asia) and Gondwana (South America, Africa, Australia, New Zealand, India, Madagascar, and Antarctica) before fracturing further, with many land masses beginning to take on their modern shapes.

Global temperatures were generally much warmer, with a "greenhouse climate" in effect for much of the era. There was also far less variance in temperatures between the poles and equator than we see today.



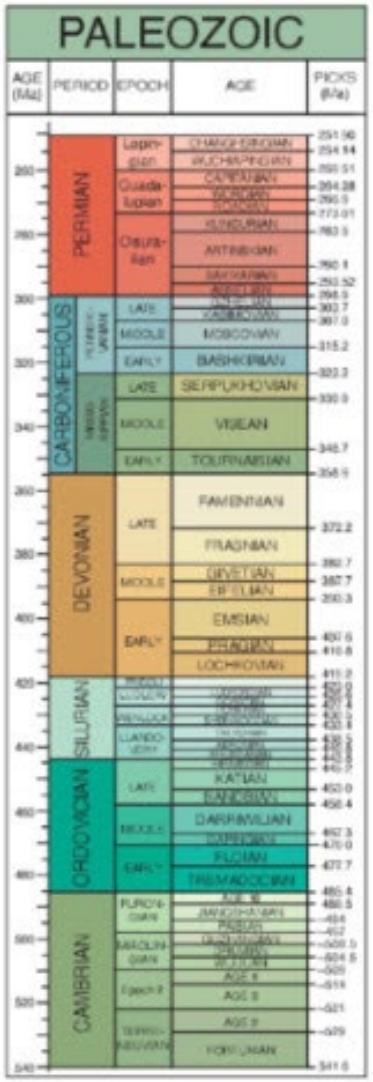
Fossil Geologic Time Scale v6.0

Paleozoic Era: 541 – 252 mya
(~8% of Earth's history)

The Paleozoic era (*PAY-lee-oh-ZOH-ick*), from Greek *palaios* (old) and *zoe* (life), is the oldest era of the *Phanerozoic eon*, and consists of six periods: the *Cambrian*, *Ordovician*, *Silurian*, *Devonian*, *Carboniferous* (further split into the *Mississippian* and *Pennsylvanian*), and *Permian*. It started with the greatest and most widespread diversification of life in Earth's history: the *Cambrian explosion*. It was during this time that *vertebrates* (animals with spinal columns, or backbones) first evolved, eventually branching off into fish, amphibians, reptiles, birds, and mammals over the ensuing millions to hundreds of millions of years.

The seas of the early Cambrian were teeming with life. Proto-fishes, arthropods (such as trilobites), worms, and algae flourished in shallow, coastal seas. Meanwhile, life on land was non-existent, save for small colonies of bacteria. It's generally thought that rudimentary plants and animals first began colonizing land around 500 mya, although recent discoveries are pushing these numbers back even further. By the Silurian, leafless plants and centipede-like arthropods were widespread on the coasts. Meanwhile, the first proto-sharks evolved in the seas. In the Devonian, vertebrates managed to colonize land in the form of proto-amphibians, which evolved from air-breathing fish. 30' tall fungi towered over the landscape, as trees had yet to evolve. In the Carboniferous, plants and animals became widespread on land, having evolved mechanisms which allowed them to overcome their reliance on moist environments for reproduction. Giant insects took to the air as the first flying animals (some with wingspans of over 3'). Lush forests that would ultimately become rich coal deposits formed across the globe. By the Permian, reptiles were becoming dominant and Pangea was fully formed.

Lasting for nearly 300 million years, the Paleozoic was a time of massive fluctuations in climate, as landmasses coalesced, broke apart, and drifted between the poles and equator. There were times of extreme warmth and high levels of atmospheric CO_2, times of near-global glaciation, and everything in between.



Precambrian Super-eon: 4.6 bya – 541 mya
(~88% of Earth's history)

The Precambrian Super-eon covers the *Proterozoic*, *Archean*, and *Hadean eons*, a period of over 4 billion years and accounting for a whopping 88% of Earth's history.

Fossils from this time are incredibly sparse (as animals didn't form hard parts that fossilize well until after the Cambrian explosion) and most Precambrian rock is either deeply buried beneath younger strata, eroded away, or heavily metamorphosed and therefore of limited scientific value. We think the earth coalesced from space detritus orbiting the sun some 4.6 bya, possibly smashing into another proto-planet and forming the moon early on in its existence. Zircon crystals in Australia have been dated to ~4.4 billion years, indicating that liquid water, an atmosphere, and a stable crust must have been in place by that point. These early years of Earth's history were chaotic: the solar system was still forming and collisions with other celestial bodies was common; the atmosphere was an inhospitable mix of hydrogen, CO_2, and methane with a surface temp of 230°C (nearly 450°F); and the air pressure at sea level was 27 times that of today - heavy enough to keep water liquid well past its boiling point.

Life is thought to have first started ~3.8 bya, in the form of *anaerobic* microbes. Eventually, ~2.7 bya, *cyanobacteria* came onto the scene. These microscopic, single-celled organisms (which still exist today) obtain energy through photosynthesis, releasing oxygen - something the atmosphere was devoid of at the time - in the process. Paradoxically, as oxygen gradually built up in the atmosphere over the ensuing hundreds of millions of years, it became toxic to most life on the planet. This set in motion a massive shift in the metabolism of early life forms from anaerobic to aerobic, and in their composition from unicellular to multicellular, which ultimately culminated in the explosion of life forms we saw as the Precambrian gave way to the Paleozoic.