
mini museum

"Man ska vara snäll."

"One should be kind."

– Dr. Jörgen Fex

mini museum:

a companion guide to the second edition.
billions of years of history as seen from planet earth.

HANS-FILIP J. FEX

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As the physical size of the companion guide is quite small, specific attribution of Wikipedia images has been omitted. A complete list can be found on the website at http://minimuseum.com/book-resources/.

A private donation has also been made to the Wikimedia Foundation.

contents

hello, everyone!

Welcome to the Second Edition of the Mini Museum! My name is Hans Fex, and I am the creator of the Mini Museum.

The Mini Museum is a portable collection of curiosities where every specimen is authentic, iconic, and labelled. The collection is designed to inspire wonder and curiosity.

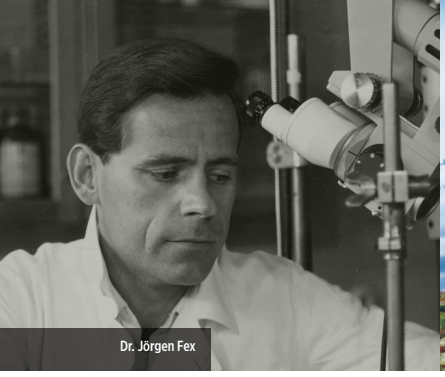
Children studying the Mini Museum in the United Kingdom

"Intellectual curiosity is so insatiable that nothing will discourage it, but in most its edge is easily dulled and blunted. Bacon's saying that we must become as little children in order to enter the kingdom of science is at once a reminder of the open-minded and flexible wonder of childhood and of the ease with which this endowment is lost."

– John Dewey, *How We Think*, 1910

The story of the Mini Museum really begins when I was just seven years old, not much younger than the children in this picture. Growing up in Washington, D.C., I had the opportunity to visit museums nearly every weekend. I also had the benefit of an incredible father, who was really the inspiration for the Mini Museum.

My father was a research scientist with the National Institute of Health. He was fascinated by the world, and he made it a point to share with me his sense of wonder. In 1977, my father cast in resin a small artifact he'd brought home from a trip to Malta.


Dr. Jörgen Fex

Holding this object in my hand, I had a sudden vision for a much larger collection of specimens. Rare and beautiful objects from across the world and time, gathered together into a single manageable collection. It was something I could share with my friends, with everyone.

After many decades of collecting, organizing, and honing my craft, I was finally able to bring the Mini Museum to life and what an incredible response!

And yet, the journey was only beginning.

Over the next few months, our small team prepared hundreds of thousands of individual specimens. This was hard work, always complicated by the fact that each specimen came with its own unique challenges.

We overcame many obstacles during the course of the project.

At each step, we learned something very important about ourselves and the value of hard work, though sometimes I also wonder if we made it through because we were naive to the degree of difficulty.

As I write this, more than a year has passed since the creation of the first edition of the Mini Museum and the fulfillment of my life long dream. I've tried to find the words to express the joy we felt at delivering Mini Museums to thousands of backers spread across 68 different countries, but it is so very difficult. Thankfully, I don't need words because we have pictures.

I owe so much to everyone who helped make this journey possible, from the backers of the first project to all of the scientists, collectors, artists, and craftsmen I met along the way.

"Everybody who went to the moon became more of who they were deep down inside. You'd achieved the dream, the greatest dream really, which unlocked inside another dream."

~ Apollo 12 Astronaut Alan Bean

While finishing the first edition, it was natural for the team to talk about the "next" edition. Even though we covered billions of years of history, there was so much left unexplored. The more we talked about it, the more we wanted to see just how far we could go.

Many times I've talked about the Mini Museum as an adventure, but one of the things I've learned is that there is also a sense of nurturing that comes with understanding one's place in space and time. The second edition of the Mini Museum represents the next step on this continuing journey.

Inside the pages of this Companion Guide, we've tried to capture as much of the project as space will allow. As with the first edition, this Companion Guide is not meant to serve as an all-encompassing reference to the specimens. Rather, you should think of it as a starting point for your own explorations.

Where possible, we've noted interesting books, articles, and scientific research for further study. We've also included a few essays in the back which touch on a few ideas the Mini Museum team found inspiring while working on the second edition.

I truly hope you enjoy the second edition of the Mini Museum. The universe is amazing, and our journey is only just beginning. Thank you so very much for joining us.

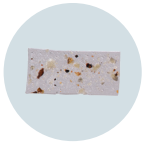
Now, it's back to work!

The custom-milled Japanese Star Sand mold in this image has nine (9) different types of bevels. I tested each one carefully before settling on the final shape.

SPECIMEN TYPE:
METEORITE

SOURCE:
ASTEROID VESTA

ESTIMATED AGE:
C. 4,500,000,000 YEARS OLD



asteroid belt

"They resemble small stars so much as hardly to be distinguished from them. From this, their asteroidal appearance, if I take my name, and call them Asteroids."

– William Herschel, after making observations of Ceres and Pallas in 1802

Between the orbits of Mars and Jupiter lies a ring of rocky objects known as the Asteroid Belt. Early theories about the Asteroid Belt suggested there was once a planet which was destroyed by a massive collision, but more recent calculations indicate that the gravitational influence of Jupiter made this impossible from the very start.

Terrestrial or rocky planets, such as Earth, form through a process of accretion in which small bodies collide and coalesce into increasingly larger forms. At 1km in diameter, the bodies possess enough mass that they begin to attract one another, eventually forming planets.

Astronomers have determined that much of the mass needed to form a planet in the Asteroid Belt was ejected by early interactions with Jupiter. The remaining large bodies then settled into stable orbits, isolated from each other by mutual gravitational perturbations.

While studying Vesta in 2007, NASA's DAWN spacecraft located two large, overlapping impact craters in the southern hemisphere which form a large, deep basin. Surface mineralogy matches the composition of HED meteorites here on Earth.

The specimen in the Mini Museum contains a mixture of several HED meteorites, including: Eucrites "Millbillillie" and NWA 10166; Diogenites "Tatahouine," NWA 7831, and NWA 5784; and Howardites "Johnstown," NWA 1929, and the newly classified NWA 10262.

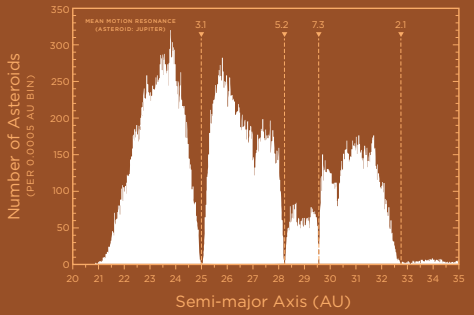
SOURCES:

McSween Jr, Harry Y., et al. "HED meteorites and their relationship to the geology of Vesta and the Dawn mission." The Dawn Mission to Minor Planets 4 Vesta and 1 Ceres. Springer New York, 2012. 141-174.

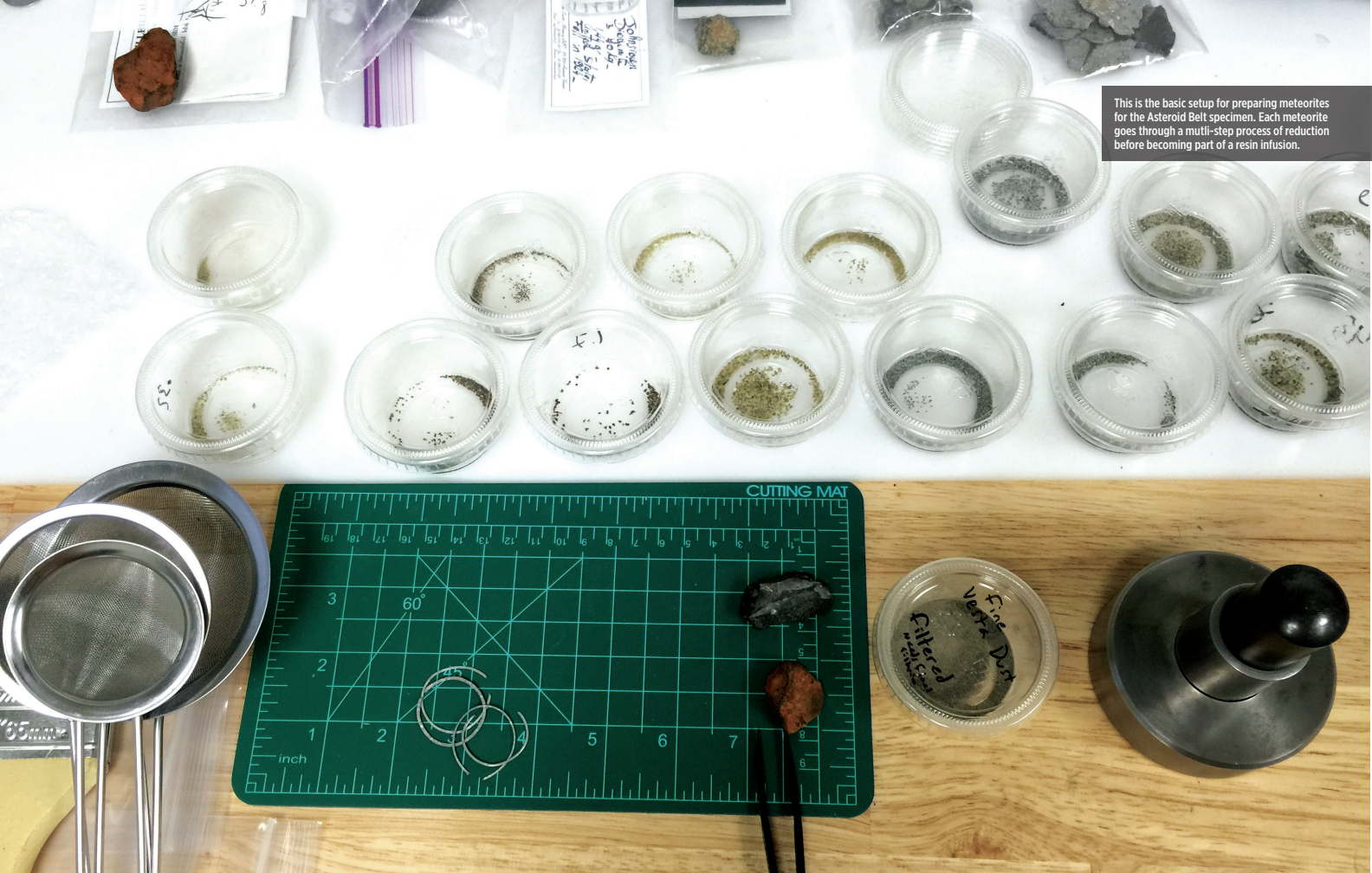
Morbidelli, Alessandro, et al. "The Dynamical Evolution of the Asteroid Belt." arXiv preprint arXiv:1501.06204 (2015).

ASTEROID MAIN-BELT DISTRIBUTION

KIRKWOOD GAPS



In 1866, Daniel Kirkwood noticed gaps in the Asteroid Belt at locations corresponding to specific fractions of Jupiter's orbit around the Sun. Kirkwood correctly postulated that gravitational perturbations from Jupiter nudge asteroids into unstable orbits, ejecting them from the Belt entirely. Similar forces can be seen at work in the gaps and varied densities of the rings of Saturn.



This is the basic setup for preparing meteorites for the Asteroid Belt specimen. Each meteorite goes through a mutli-step process of reduction before becoming part of a resin infusion.

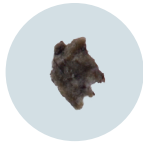
Just how Mars came to lose its atmosphere 4 billion years ago is a subject of intense study. Some theories suggest that the loss of the planet's magnetic field is to blame while others look to the timing of the Late Heavy Bombardment (LHB) during which large numbers of asteroids struck the inner planets of the solar system 4.1-3.8 billion years ago.

NASA's Mars Atmosphere and Volatile EvolutioN (MAVEN) is the first probe to focus exclusively on the the atmosphere of Mars, including the ongoing escape of gases into space and the role this process has played over time.

SPECIMEN TYPE:
METEORITE

BASALTIC ROCK FORMATION:
C. 1,000,000,000 YEARS AGO

ATMOSPHERE CAPTURE:
C. 2,500,000 YEARS AGO



martian atmosphere

"Science is no more than an investigation of a miracle we can never explain, and art is an interpretation of that miracle."

– Ray Bradbury, *The Martian Chronicles*

The thin Martian atmosphere contains a mixture of elements found nowhere else in the solar system, except within tiny glass, "shock-melt" pockets embedded inside a few, special Martian meteorites. The molecules trapped inside these meteorites reveal clues to the warmer and wetter past of our closest solar neighbor.

When a large body, such as an asteroid or comet, strikes a planet it can create enough force to eject pieces of the planet into space. The impact creates tremendous heat which melts the rock, creating glass pockets which can trap molecules from the surrounding atmosphere. The specimen in the Mini Museum comes from a meteorite that was ejected in this manner 2.5 million years ago, preserving the state of the climate at that time.

Known as Zagami, this meteorite fell in rural Nigeria in 1962 and is the largest individual Martian meteorite ever found:

"A farmer was trying to chase the cows out of his corn field when he heard a tremendous explosion and was buffeted by a pressure wave. Seconds later, there was a puff of smoke and a thud, as something buried itself in the soft dirt only ten feet away." – *Meteorite Hunter Robert Haag, who traded an entire collection of meteorites for a portion of the original 18kg/40lb mass.*

Studies of Zagami in the early 1990's provided the first clues to the ratio of Argon isotopes in the Martian atmosphere. NASA's Martian Rover Curiosity confirmed the ratio in 2013, providing strong, direct evidence for the cataclysmic loss of the Martian atmosphere.

SOURCES:

Marti, K., et al. "Signatures of the Martian atmosphere in glass of the Zagami meteorite." Science 267.5206 (1995): 1981-1984.

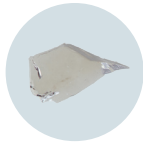
Mahaffy, Paul R., et al. "Abundance and isotopic composition of gases in the martian atmosphere from the Curiosity rover." Science 341.6143 (2013): 263-266.

When English archeologist Howard Carter cataloged the tomb of King Tutankhamen in 1922, he identified the scarab at the center of this pectoral as chalcedony, a naturally occurring silica formation. Seventy-five years later, a chance viewing by an Italian mineralogist led to studies which revealed the material to be Libyan Desert Glass.

This 18th Dynasty find is unique among the gems of ancient Egypt, as it is the only know use of Libyan Glass. The scarab is part of a twofold representation of the sun-god, which in Egyptian mythology could be represented by both scarab and falcon.

SPECIMEN TYPE:
IMPACT MELT

ESTIMATED IMPACT AGE:
C. 28,500,000 YEARS AGO



libyan desert glass

"The breakdown of zircon to baddeleyite and silica-glass at temperatures in excess of 1676°C demonstrates that the Libyan Desert Glass is of impact origin."

– Barbara Kleinmann

In the southeastern spur of North Africa's Great Sand Sea, there are several fields of luminous, yellow-green glass known as Libyan Desert Glass. Due to the lack of any visible impact crater, the most likely source is a low-density asteroid or comet airburst explosion leading to the fusion of silica-rich sands.

The distribution of Libyan Desert Glass across several sites leads some scientists to speculate that there may have been multiple explosions, but recent surveys of the surrounding watershed provide strong evidence for erosion.

While the dunes of the Great Sand Sea may seem timeless, during the Early to Middle Paleolithic Era the region was often home to a wetter climate capable of supporting playa wetlands. Further to the south, in what is now one of the least hospitable places on earth, permanent lakes and savanna grasslands supported an even greater abundance of life.

Throughout the region, there is plentiful evidence of multiple periods of early human settlement. Coming and going as the climate changed, our ancestors shaped the glass into tools and decorative items.

The specimen in the Mini Museum comes from several large fragments of Libyan Desert Glass. Studies date the glass to the early formation of the dunes during the Oligocene epoch 28,500,000 years ago.

SOURCES:

Kleinmann, B., Horn, P., and Langenhorst, F.. "Evidence for shock metamorphism in sandstones from the Libyan Desert Glass strewn field." Meteoritics & Planetary Science 36.9 (2001): 1277-1282.

Welland, Michael. Sand: the never-ending story. Univ of California Press, 2009.

Fröhlich, F., et al. "Libyan Desert Glass: New field and Fourier transform infrared data." Meteoritics & Planetary Science 48.12 (2013): 2517-2530.

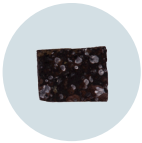
This large and dark fragment of Libyan Desert glass exhibits deep soil inclusions captured during its formation over 28,500,000 years ago.

The shape of a volcano is primarily determined by hydraulic resistance to the flow of magma in a porous medium. Mount Fuji in particular was considered an ideal example of the model.

The Japanese artist, Katsushika Hokusai (1760-1849), was also an admirer of Mount Fuji. His popular series of landscape prints 富嶽三十六景 or Thirty-Six Views of Mount Fuji show the mountain across the range of seasons and from many different views. The included image comes from this collection. The print is known by several names, including Fine Wind, Clear Morning, and 凱風快晴. The slope of the mountain's flank is nearly a perfect fit for the porous flow theory.

SPECIMEN TYPE:
ROCK

CURRENT HEIGHT:
3,776M / 12,389FT



mount fuji
(lava)

"misty rain
a day with Mount Fuji unseen:
so enchanting"

– Matsuo Bashó (1644-1694)

Mount Fuji is the highest mountain in Japan. Yet, the modern Mount Fuji is actually three volcanoes in one: Komitake, Ko-Fuji, and Shin-Fuji. Over the course of the last several hundred thousand years, each volcano formed out of the remains of the last with Shin-Fuji (New Fuji) becoming active just 10,000 years ago.

Shin-Fuji went through several stages of development which included basaltic flows covering large areas to the north, west and southwestern foothills. The stratovolcano's symmetrical cone has served as an inspiration for artists for centuries and more recently for scientists studying the geometrical evolution of volcanoes.

In 864AD, lava from a massive eruption of Mount Fuji filled part of ancient Lake Senoumi, creating Lake Sai, Lake Shōji, and Lake Motosu. The fertile land left behind became the Aokigahara Jukai or "Sea of Trees." This tranquil region also has the unfortunate distinction of being known as the Suicide Forest.

The specimen in the Mini Museum comes from a local stone cutter in this region. For five generations, this family has produced sculptures for Buddhist and Shinto Shrines around Mount Fuji. It was provided by a friend of Hans who owns a cafe and bed and breakfast just outside the Aokigahara with a spectacular view of the mountain.

SOURCES:

Yamamoto, T., et al. "Basaltic pyroclastic flows of Fuji volcano, Japan: characteristics of the deposits and their origin." Bulletin of volcanology 67.7 (2005): 622-633.

Lacey, A., J. R. Ockendon, and D. L. Turcotte. "On the geometrical form of volcanoes." Earth and Planetary Science Letters 54.1 (1981): 139-143.

Fujita, Eisuke, et al. "Stress field change around the Mount Fuji volcano magma system caused by the Tohoku megathrust earthquake, Japan." Bulletin of volcanology 75.1 (2013): 1-14.

Mount Fuji Lava is very dense, but powders easily under pressure so great care must be taken with each specimen.

The islands of Okinawa, Japan are home to several foram sand beaches. A folktale from Taketomi-Jima describes the star-shaped shells as the children of the Polar Star and the Southern Cross, devoured and spat out again by a giant serpent which served the Seven Dragon God of the Sea.

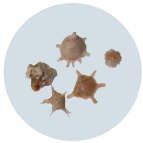
While these natural beaches contain billions of foraminifera remains, the sands also have other debris one is likely to find on many beaches. Therefore, the specimens in the Mini Museum were painstakingly cleaned and each shell placed by hand in custom molds.

Image provided by 663highland: Hoshizuna-no-hama (Star Sand Beach) in Iriomote Island, Taketomi Town, Okinawa Prefecture, Japan.

日本語: 星砂の浜。所在地は
沖縄県竹富町の西表島。

SPECIMEN TYPE:
MICROFOSSIL

TEMPORAL RANGE
550,000,000 YEARS TO PRESENT



japanese star sand
(microfossils)

"Everything in nature which appears insignificant by mere sight not only remains unknown to the mass of the population, but still escapes whole centuries of observation by the precious few who seek to uncover the beauties of creation."

– Alcide d'Orbigny, 1839

Foraminifera are single-celled creatures which produce a diverse range of beautiful and tiny protective shells. These shells appear in the fossil record as far back as 550 million-years, and in some locations, entire beaches are made up of these so-called "foram sands."

Human beings have studied foraminifera since at least the 5th century BC when Herodotus noted their presence in the limestone of Egyptian pyramids. Alcide d'Orbigny [1802-1857], considered the father of modern micro-paleontology, personally classified thousands of species in both France and the Americas.

Today, scientists often use foraminifera as reference points in the study of climate change over long periods of time. Foraminifera often live symbiotically with microalgae, and together they play an important role in coral reef ecosystems via production of carbonate sands and by buffering daily pH changes. The variety of foraminifera species, their physical size, and even their sexual dimorphism are valuable in establishing and confirming the existence of climatic zones in ancient seas.

The specimen in the Mini Museum comes from a private collection obtained many years ago from Hoshizuna-no-Hama ("Star Sand Beach") on the island of Iriomote in Okinawa Prefecture, Japan.

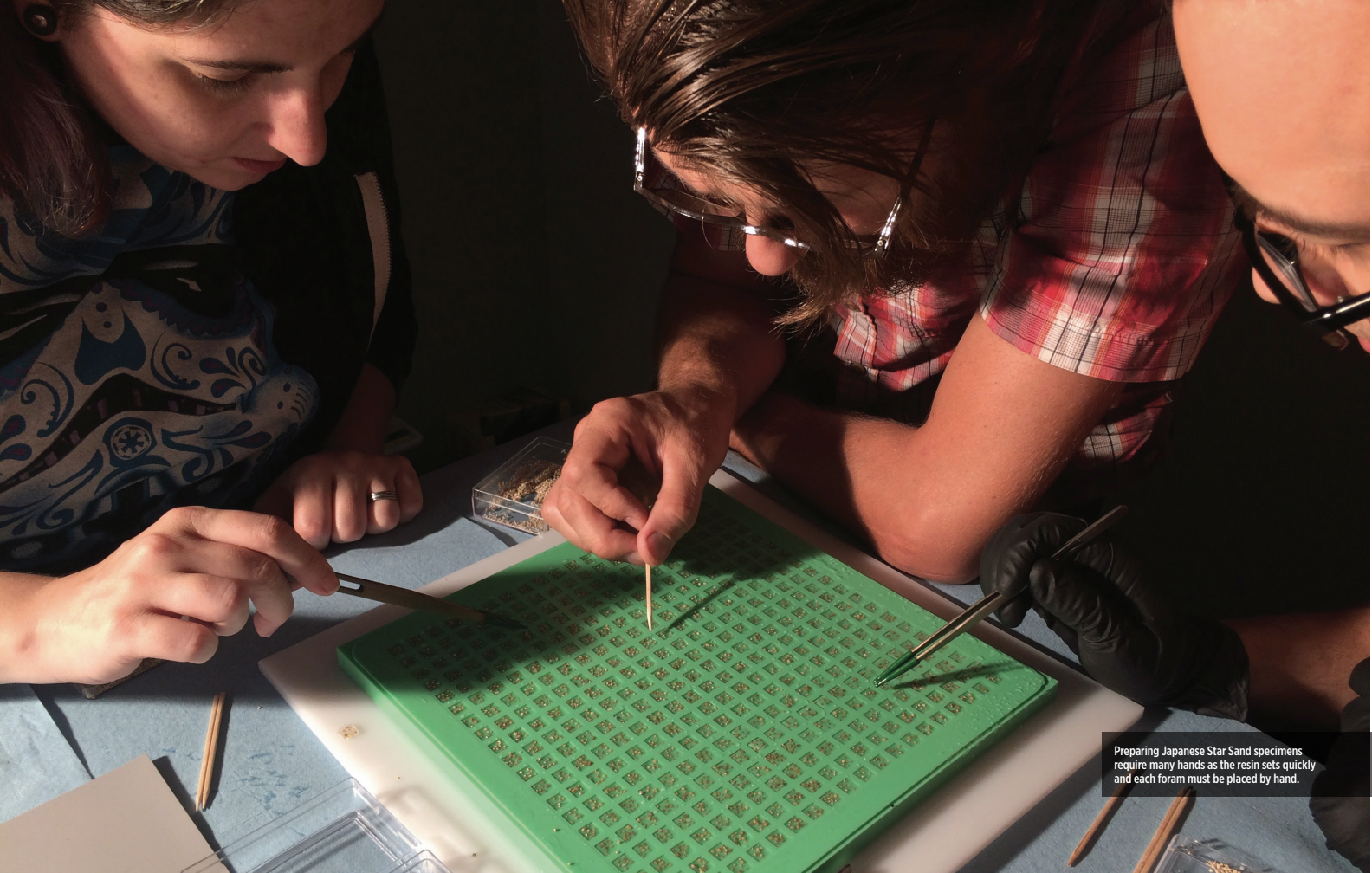
SOURCES:

d'Orbigny, Alcide. Foraminiferes de l'ile de Cuba. 1839.

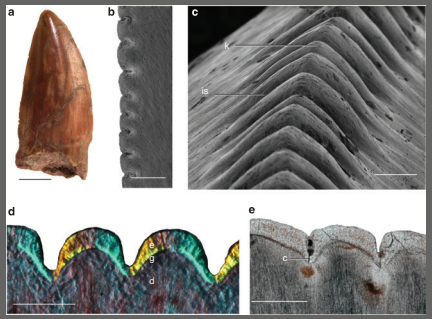
Endo, Shoji. Folktales of Okinawa. Bank Of The Ryukyus International Foundation. 1996.

Doo, Steve S., et al. "Fate of Calcifying Tropical Symbiont-Bearing Large Benthic Foraminifera: Living Sands in a Changing Ocean." The Biological Bulletin 226.3 (2014): 169-186.

Bandy, Orville L. "Planktonic foraminiferal criteria for paleoclimatic zonation." (1960).



Preparing Japanese Star Sand specimens require many hands as the resin sets quickly and each foram must be placed by hand.



Dimetrodon is one of the first terrestrial vertebrates to develop multiple types of teeth, including tightly compressed, recurved teeth with sharp cutting edges. Known as ziphodont teeth, scientists speculate this development was a result of a new, refined feeding style in which flesh is sheared from the bones by pulling instead of direct, bone-crushing force.

Image from doi:10.1038/ncomms4269. Reprinted with permission from Nature Communications.

SPECIMEN TYPE:
FOSSIL

ESTIMATED AGE:
C. 272-295,000,000 YEARS OLD

dimetrodon
(spine sail)

"The apex of the spine in this species is slender, and apparently was flexible. The utility is difficult to imagine."

– Edward Drinker Cope, 1886

The Permian Age represents a radical change to life in response to a more varied climate across the planet. Diversification of plants, the first true bony fish, and on land the evolution of amphibian life gives way to pure terrestrial animals, including Dimetrodon.

With a fearsome jaw and reptilian appearance, Dimetrodon is often mistaken for a dinosaur. However, this apex predator of the Early Permian Age is part of a group of protomammals known as Synapsids.

Over the course of 20 million years, there were many species of Dimetrodon ranging in size and decked with a variety of iconic spine sail shapes. The purpose of this structure has been debated for many decades. Early theories centered on thermoregulation while more recent studies have shown that the spines lacked the necessary channels for carrying blood vessels.

In recent decades, the discussion has moved toward the sail's role in sexual dimorphism, but science is always testing new ideas and methods. As an example, a study in 2012 in conjunction with NASA's Jet Propulsion Laboratory suggests the sail may have served as a spring-like energy storage device for fast locomotion.

The specimen in the Mini Museum comes from several fragmentary spine sails found in West Texas. This region, known as the Texas Red Beds, is one of the most complete fossil records of the Early Permian.

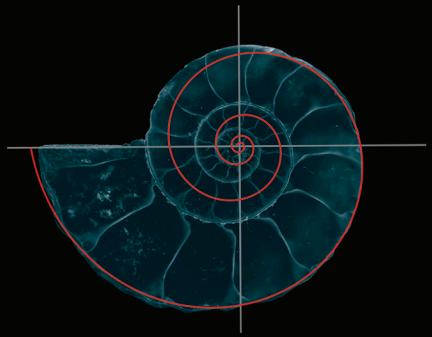
SOURCES:

Cope, Edward Drinker. "Second contribution to the history of the Vertebrata of the Permian formation of Texas." Proceedings of the American Philosophical Society (1880): 38-58.

Rega, Elizabeth A., et al. "Healed fractures in the neural spines of an associated skeleton of Dimetrodon: implications for dorsal sail morphology and function." Fieldiana Life and Earth Sciences (2012): 104-111.

Brink, Kirstin S., and Robert R. Reisz. "Hidden dental diversity in the oldest terrestrial apex predator Dimetrodon." Nature communications 5 (2014).

While every specimen is unique, fossils like Dimetrodon often display surprising variances in color.



The main property of a logarithmic spiral is that the shape of the spiral is unaltered as it increases in size. Each turn is a pure geometrical progression of the last with a common ratio. This form is found in many natural phenomenon, from the shape of galaxies to patterns on sunflower heads.

Many thousands of distinct species make up the long-lived ammonoid clade. Though most ammonite shells are the classic spiral, there are also straight and gastropod-like shells and even some shells that are partially uncoiled. The surface of the shells also vary quite widely from smooth to wildly thorny.

SPECIMEN TYPE:
FOSSIL

ESTIMATED AGE:
C. 110,000,000 YEARS OLD

ammonite

"Three times during their reign of more than 300 million years, ammonites experimented with the most bizarre and startling shell shapes."

– Wolfgang Grulke, author of "Heteromorph: The Rarest Fossil Ammonites"

Ammonites are an extinct group of cephalopods which entered the fossil record 400 million years ago. They survived several mass extinction events, including the Permian–Triassic "Great Dying" which wiped out 96% of all marine species. They finally succumbed during the Cretaceous-Paleogene extinction event 66 million years ago, which also wiped out the dinosaurs.

The size of ammonite shells range from sub-centimeter dwarf species to giants nearly three meters in diameter. Most iconic shells exhibit a nearly perfect logarithmic spiral.

How these creatures lived is of intense interest to science as ammonites likely played a vital role in the food chain in the ancient seas. Evidence exists to suggest that ammonites were a prime food source for Mosasaurs and fishes, while other studies suggest the "bite marks" were created after death by limpets or even by other cephalopods.

Aside from their complex shells, there is little direct evidence regarding the appearance of ammonites due to the absence of soft tissue fossils. However, many scientists believe ammonites had bodies similar to that of the present-day Nautilus.

The specimen in the Mini Museum are Cleoniceras from Madagascar. This species dates to the Albian stage of the lower Cretaceous.

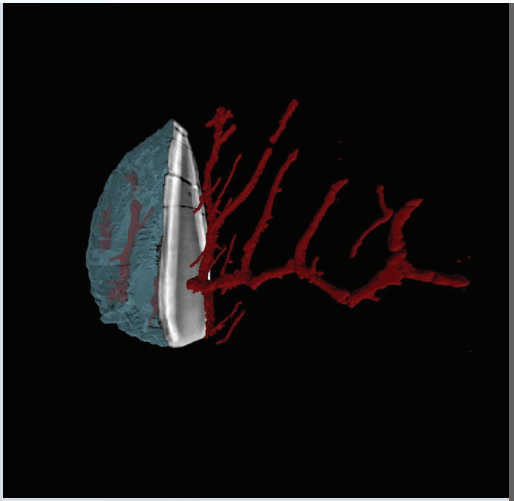
SOURCES:

Tsujita, Cameron J., and Gerd EG Westermann. "Were limpets or mosasaurs responsible for the perforations in the ammonite Placenticeras?." Palaeogeography, Palaeoclimatology, Palaeoecology 169.3 (2001): 245-270.

Moulton, D. E., A. Goriely, and R. Chirat. "The morpho-mechanical basis of ammonite form." Journal of theoretical biology 364 (2015): 220-230.

Lemanis, Robert, et al. "A new approach using high-resolution computed tomography to test the buoyant properties of chambered cephalopod shells." Paleobiology 41.02 (2015): 313-329.

Large fossil Ammonites like these must be trimmed to size before inclusion. They are incredibly delicate and each cut requires great care and consideration.

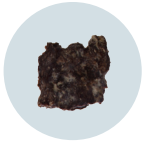


Using volumetric CT scans, researchers have been able to reconstruct 3D models of Stegosaurus plates, highlighting the likely paths of soft tissues and possible vascular pathways. This complex analysis shows promise when compared to similar structures in Alligators. New research also indicates that the thick osteoderms on the backs of Crocodilians store and neutralize the effect of lactic acid during periods of intense anaerobic activity.

Image: Deifenbaugh, Dan; Aeschliman, Benjamin; Barrett, Paul; Brassey, Charlotte; Hayashi, Shoji; and Kim, Beomjin, "3D Reconstruction of the Vascularity of a Stegosaurus Dorsal Plate and an Alligator Scute" (2015).

SPECIMEN TYPE:
FOSSIL

ESTIMATED AGE:
C. 150-155,000,000 YEARS OLD



stegosaurus
(plate)

"Stegosaurus must have been a grand performer under attack — a five-ton ballet dancer with an armor-plated tutu of flipping bony triangles and a swinging war club."

– Robert T. Bakker, *The Dinosaur Heresies*

Armored with twin rows of bony-cored plates and sharp tail spikes, Stegosaurus is one of the best known of all dinosaurs.

The plates and spikes of Stegosaurus are called osteoderms, bony deposits which form in the skin rather than growing as extensions of the skeleton. Lacking an anchor to the skeleton, some scientists believe that Stegosaurus's plates would provide limited mechanical protection. The current scientific thinking leans towards temperature regulation as the primary function.

Osteoderms occur in many animals, from horny scales on the feet of modern birds to the keratin-cored shells of turtles. While often associated with their protective qualities, some osteoderms contain dense networks of blood vessels, which help regulate body temperature.

Substantial evidence exists to support the theory that Stegosaurus used its dermal tail spikes in combat, including pelvic bone punctures in Allosaurus fossils. Yet there appears to be minimal direct confrontation between Stegosaurs. This leads some scientists to speculate that plates could be a marker for sexual dimorphism in the species, playing an important role in distinguishing individuals in a female mate choice process.

The specimen in the Mini Museum comes from a fragmented Stegosaurus plate recovered and reconstructed by paleontologist Gary Olson.

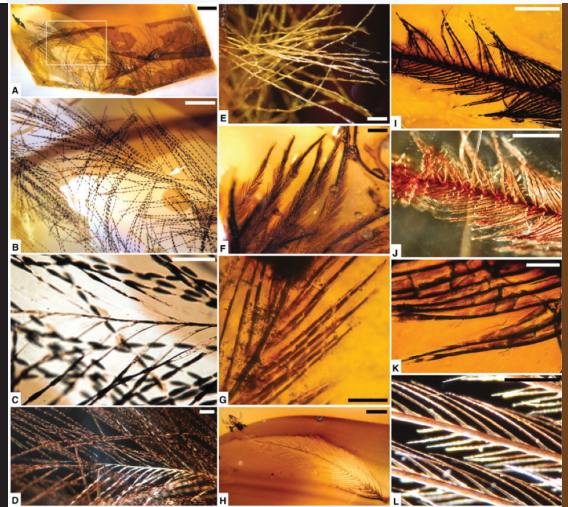
SOURCES:

Farlow, James O., Carl V. Thompson, and Daniel E. Rosner. "Plates of the dinosaur Stegosaurus: forced convection heat loss fins?." Science 192.4244 (1976): 1123-1125.

De Buffrénil, V., J. O. Farlow, and A. De Ricqlès. "Growth and function of Stegosaurus plates: evidence from bone histology." Paleobiology (1986): 459-473.

Saitta, Evan Thomas. "Evidence for Sexual Dimorphism in the Plated Dinosaur Stegosaurus mjosi (Ornithischia, Stegosauria) from the Morrison Formation (Upper Jurassic) of Western USA." (2015): e0123503.

Every fossil goes through a process of stabilization prior to preparation. Dense Stegosaurus plate fragments such as these require multiple treatments.



So how do dinosaurs end up with feathers?

The currently accepted development model for feathers begins with scales, eventually developing into barbs which become follicles for further stages of development. There are also some observations that feathers in dinosaurs were lost and then developed again several times.

Image: Dinosaur Feathers in Amber Image: From [DOI:10.1126/science.1203344]. Reprinted with permission from AAAS.

SPECIMEN TYPE:
FOSSIL

ESTIMATED AGE:
C. 66-73,000,000 YEARS OLD

dinosaur skin

"Most of what is known about the morphology and taphonomy of dinosaur skin comes from several exceptionally preserved hadrosaurid fossils."

– Matt Davis, Department of Geology and Geophysics, Yale University

When we think of dinosaur fossils we usually imagine bones and teeth but fossilized skin and scales have also been discovered along with feathers.

Scales are rigid plates which grow out of the skin and afford protection. They occur in many animals including birds, reptiles, fish, mammals, and even butterflies and moths.

In dinosaurs, scales occur in many different sizes with varied arrangements. The function of scales, aside from what we know from scales in other animals, is still under investigation as is the complex relationship to the development of feathers.

Preservation of dinosaur skin and other soft tissues requires a combination of many factors including sedimentation and the presence of microbial mats. This delicate arrangement creates certain challenges for paleontologists when recovering skin. Early methods of extraction often bypassed these delicate structures entirely, but new methods are yielding surprising discoveries including the extraction of connective tissue and intact cellular structures.

The specimen in the Mini Museum comes from an Edmontosaurus, a species of Hadrosaur common during the Late Cretaceous and purchased directly from paleontologists working in the field on private land.

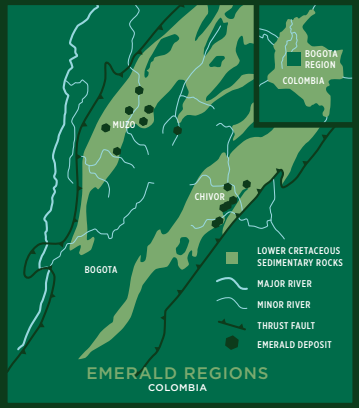
SOURCES:

Chuong, Cheng-Ming, et al. "Evo-Devo of feathers and scales: building complex epithelial appendages: Commentary." Current opinion in genetics & development 10.4 (2000): 449-456.

Herrero, Lucia, and Andrew A. Farke. "Hadrosaurid dinosaur skin impressions from the Upper Cretaceous Kaiparowits Formation of southern Utah, USA." PalArch's Journal of Vertebrate Palaeontology 7.2 (2010): 1-7.

Davis, Matt. "Census of dinosaur skin reveals lithology may not be the most important factor in increased preservation of hadrosaurid skin." Acta Palaeontologica Polonica 59.3 (2012): 601-605.

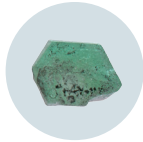
Before extracting a thin layer of Dinosaur Skin it must undergo stabilization. This ensures the scales remain intact.



The rugged and mountainous areas of Muzo and Chivor are comprised of black, carboniferous shale dating to the Lower Cretaceous. This rock was invaded by hydrothermal mixtures which cooled to form white calcite veins. It is here in the calcite veins that Colombian emeralds are most commonly found.

SPECIMEN TYPE:
GEMSTONE

COUNTRY OF ORIGIN:
COLOMBIA



raw emerald

"A casual glance at crystals may lead to the idea that they were pure sports of nature, but this is simply an elegant way of declaring one's ignorance."

– René-Just Haüy, father of modern crystallography who first classified the emerald as a beryl in 1797

We often hold up purity as the chief virtue of the rare and beautiful, but in the world of crystals it is the impurity which often sets the gemstone apart and makes it desirable. For example, the beryl is a colorless crystal, but the addition a chromium impurity causes the beryl to turn green, becoming an emerald - one of the rarest of all gemstones.

Heat, pressure, time, and the influence of water are the primary components in gemstone formation, but there are many possible combinations. In the case of quartz and beryls, the process involves rapid cooling and crystallization of mineral-infused hot water vapor, pushed up through layers of rock by the presence of magma below.

Many gem-producing hydrothermal regions exist around the world, but the emerald producing areas of Muzo and Chivor in the mountains of Colombia are different.

Documented evidence of mining in this region dates back to the Spanish conquest, but archeologists have also discovered evidence that humans have been digging emeralds of unsurpassed quality out of these rugged hills for much longer.

The specimen in the Mini Museum is a rough emerald from Colombia in the Muzo region, acquired from a private seller.

SOURCES:

Keller, Peter C. Gemstones and Their Origins. Springer US, 1990.

Kazmi, Ali H., and Lawrence W. Snee. "Geology of world emerald deposits: a brief review." Emeralds of Pakistan: Geology, Gemology and Genesis (1989): 165-228.

Cheilletz, A., and G. Giuliani. "The genesis of Colombian emeralds: a restatement." Mineralium Deposita 31.5 (1996): 359-364.

Each Raw Emerald is inspected individually for color and size under magnification.

It is not known whether Entelodonts hunted alone or in small social groups, but healed bite marks on Entelodont skulls indicate some level of non-lethal interactions between individuals.

In 2009, scientists revisiting the classification of whales as marine mammals in the broader context of other even-toed mammals uncovered a clear relationship between Entelodonts and Cetaceans. The process is complicated and involves the study of both fossil and molecular data combined with in-depth statistical analysis.

SPECIMEN TYPE:
FOSSIL

ESTIMATED AGE:
C. 24-33,000,000 YEARS OLD

hell pig

(entelodont jaw)

"Over the past 155 years, Entelodontidae have undergone revision at every taxonomic level."

– Paleontologist Scott E. Foss, *The Evolution of the Artiodactyls*

During the Late Eocene era, a new apex predator arose on the plains of Eurasia and North America. Popularly referred to as "Hell Pigs," Entelodonts (en-TE-lo-don-ts) had enormous jaws which could open nearly 90 degrees.

Though not true pigs, Entelodonts likely shared a common ancestor with pigs and peccaries. Still, given that some species stood nearly 2 meters at the shoulder, it's not hard to imagine how Entelodonts came by their nickname.

Entelodontidae means "perfect teeth" and the name has more to do with the functional range of Entelodonts' dentition rather than their intimidating appearance. Their fearsome jaws actually held four different types of teeth, including molars for grinding plants. This suggests Entelodonts were omnivores, eating whatever was available. This would also be the ideal diet for their preferred floodplain habitat.

It's unclear what might have caused the disappearance of the Entelodonts, but it was likely related to the end of the Miocene Climatic Optimum. The Miocene Climatic Optimum was a period of extreme global warmth, with averages 4-5 °C higher than today. The period ended with a dramatic and permanent cooling step.

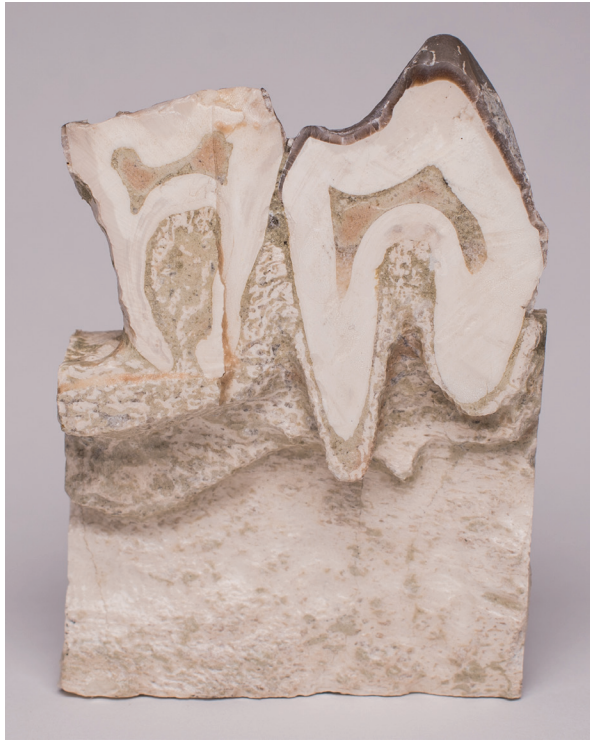
The specimen in the Mini Museum comes from the lower jaw of an Archaeotherium, a cow-sized species of Entelodont which dominated the plains of North America. The specimen was acquired from a private collector.

SOURCES:

Prothero, Donald R., and Scott E. Foss. The evolution of artiodactyls. JHU Press, 2007.

Spaulding, Michelle, Maureen A. O'Leary, and John Gatesy. "Relationships of Cetacea (Artiodactyla) among mammals: increased taxon sampling alters interpretations of key fossils and character evolution." PLoS One 4.9 (2009): e7062.

Close inspection of the enormous teeth of the Hell Pig compared with a cross-section of both teeth and jaw, led to more than a few vivid dreams!

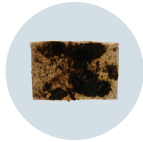


This confrontation between a dire wolf and a saber-toothed cat was mainly the product of the illustrator's imagination, but it may not be far from the truth. Increased breakage rates among Pleistocene carnivore teeth recovered from Rancho La Brea suggest large predators made greater use of carcasses than their modern counterparts by crushing bones from scavenged remains.

*Image: From **A History of Land Mammals in the Western Hemisphere**, published in 1914.*

SPECIMEN TYPE:
TAR / FOSSILS

ESTIMATED AGE:
C. 38,000 YEARS OLD



la brea tar pits

"We weren't looking for stuff living in it."

– John Harris, Paleontologist and Chief Curator at The Page Museum

The Rancho La Brea Tar Pits in Los Angeles, California are one of the most well-known petroleum seeps in the world. Excavated animal remains at La Brea comprise nearly 700 different species and date back 40,000 years to the Late Pleistocene.

Petroleum seeps are places where hydrocarbons stored in oil and gas reservoirs leak out of folded layers of sedimentary rock and bubble to the surface. Over many thousands of years, seeps can grow into large lakes.

Dirt, leaves, or even water can cover the seep, turning the surface into a sticky trap. Once caught in the viscous tar, the animals die, though perhaps not without attracting other animals who prey on the remains and often become trapped as well.

The remains from the La Brea Tar Pits speak to an ancient cycle of life and death. Yet, there are always surprises in science and in 2007 scientists discovered living microbial communities deep within the hardened layers of tar. This unexpected find is leading to new ways of thinking about life here on Earth and elsewhere.

The specimen in the Mini Museum comes from a selection of mined La Brea Tar Pit material which contained the remains of coyotes, dung beetles, rabbits, and even a bald eagle.

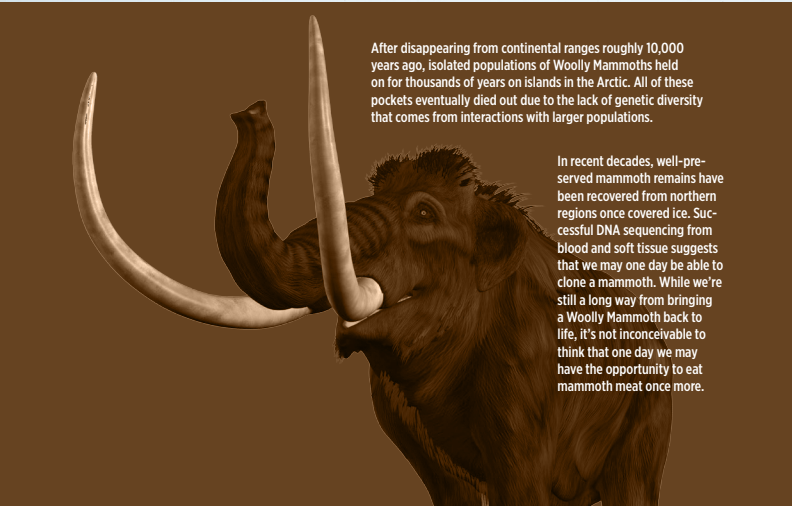
SOURCES:

VanValkenburgh, Blaire, and Fritz Hertel. "Tough times at La Brea: tooth breakage in large carnivores of the late Pleistocene." Science 261.5120 (1993): 456-459.

Kim, Jong-Shik, and David E. Crowley. "Microbial diversity in natural asphalts of the Rancho La Brea Tar Pits." Applied and environmental microbiology 73.14 (2007): 4579-4591.

Gold, David A., et al. "Attempted DNA extraction from a Rancho La Brea Columbian mammoth (Mammuthus columbi): prospects for ancient DNA from asphalt deposits." Ecology and evolution 4.4 (2014): 329-336.

Each sheet of completed La Brea Tar Pit is reviewed before final preparation to ensure the best distribution of material across finished specimens.



After disappearing from continental ranges roughly 10,000 years ago, isolated populations of Woolly Mammoths held on for thousands of years on islands in the Arctic. All of these pockets eventually died out due to the lack of genetic diversity that comes from interactions with larger populations.

In recent decades, well-preserved mammoth remains have been recovered from northern regions once covered ice. Successful DNA sequencing from blood and soft tissue suggests that we may one day be able to clone a mammoth. While we're still a long way from bringing a Woolly Mammoth back to life, it's not inconceivable to think that one day we may have the opportunity to eat mammoth meat once more.

SPECIMEN TYPE:
PRESERVED MEAT

C14 AGE:
19,551 YEARS OLD

mammoth meat

"Various legends exist about frozen mammoths. It has been said that the scientists who excavated the Beresovka mammoth, discovered in the year 1900, enjoyed a banquet on mammoth steak. What really appears to have happened is that one of them made a heroic attempt to take a bite out of the 40,000 year old meat but was unable to keep it down, in spite of a generous use of spices."

- Björn Kurtén in "How to Deep Freeze a Mammoth"

For thousands of years, the Woolly Mammoth was a dietary staple of many early humans across Europe, Asia, and later in North America.

While human expansion and predation is often thought to be the main cause of the Woolly Mammoth's disappearance (along with other megafaunal species), there is also evidence that changes in climate during the Late Pleistocene compounded the human impact.

Climate change is not the same thing as shifts in day-to-day weather; it takes place over many years, stretching across decades, centuries, and even millennia. As a result, the effects of such long-running transitions are complex and often complicated to unravel. The staggered extinction of the Woolly Mammoth is a good example of this phenomenon.

The specimen in the Mini Museum comes from a well-preserved wooly mammoth discovered near the Indigkra River in Siberia, Russia and radiocarbon dated to 19,551 years old.

SOURCES:

Kurtén, Björn. How to deep-freeze a mammoth. Columbia University Press, 1986.

Bocherens, Hervé, et al. "Isotopic evidence for diet and subsistence pattern of the Saint-Césaire I Neanderthal: review and use of a multi-source mixing model." Journal of human evolution 49.1 (2005): 71-87.

Sherkow, Jacob S., and Henry T. Greely. "What if extinction is not forever?." Science 340.6128 (2013): 32-33.

Cooper, Alan, et al. "Abrupt warming events drove Late Pleistocene Holarctic megafaunal turnover." Science (2015): aac4315.

The Mammoth Meat specimen comes from the leg of this Woolly Mammoth. The leg was nearly 7 feet long.

Once thought to be nothing more than hair-covered brutes, our understanding of Neanderthals has changed much over the last 150 years. Perhaps the greatest advance comes from the recent discovery that many of us have Neanderthal DNA embedded in our own modern genetic code. Neanderthals are not just a divergent species; they are part of us.

Image: Reconstruction of a Neanderthal woman dubbed "Wilma" due to genetic evidence of red hair and freckles

SPECIMEN TYPE:
HUMAN ARTIFACT

ESTIMATED AGE:
C. 140,000 AND 70,000 YEARS OLD

neanderthal hand axe

"One day, we may be able to understand why, of all the primates, modern humans spread to all corners of the world and reshaped, both intentionally and unintentionally, the environment on a global scale. I am convinced that part of the answer to this question lies hidden in the ancient genomes we have sequenced."

– Svante Pääbo, Director of Genetics, the Max Planck Institute for Evolutionary Anthropology

The first recognized Neanderthal remains were discovered in 1856, but claims that a specimen from an ancient human race had been found were immediately discounted. Just a few years later the publication of Charles Darwin's Origin of the Species, and the realization that earlier finds of similar remains had occurred in other countries, made it clear that our past was not what we had long thought it to be.

With each passing decade more curious finds would emerge, changing our notions of human history in radical ways:

Stone tools discovered in a Neanderthal site above the French village of Le Moustier opened our eyes to an advanced, tool-making culture. Additional finds extended this culture across Europe and Central Asia, reaching back well over one hundred thousand years. Later, careful archeological studies would uncover complex social relationships, including care of the injured and burial rituals.

The specimen in the Mini Museum comes from the collection of a retired French postman. He spent decades traversing rural France, collecting and cataloging Mousterian stone tools. The tools have been validated by experts in the field, with estimated ages between 140,000 and 70,000 years old.

SOURCES:

Drell, Julia RR. "Neanderthals: a history of interpretation." Oxford Journal of Archaeology 19.1 (2000): 1-24.

Pääbo, Svante. Neanderthal man: In search of lost genomes. 2014.

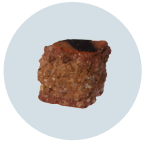
We used traditional flint-knapping tools in the early stages of preparing the Neanderthal Hand Axe specimen. Bone and stone produced the most consistent results without marring the surface of the material.

Aridamerica was comprised of bands of nomadic people who ranged north of Mesoamerica, abutting several superareas in North America including the hunters on the Great Plains and the fishing cultures of the Pacific Northwest, and at the heart lay the agrarian communities of Oasisamerica.

Image: Three Cultural Superareas of Pre-Contact Mexico

SPECIMEN TYPE:
HUMAN ARTIFACT

ESTIMATED TEMPORAL RANGE:
100 BCE TO 1500 CE



oasisamerica

"Ancient Native history is a chain of successive scenes and simultaneous happenings."

– Alfredo López and Leonardo López Luján

The history of the First People of the Americas is a complex web of unique societies and civilizations stretching across two continents and many thousands of years. Our modern understanding of this history has moved from ignorance to awe, and later to an awakening of the subtle connections between distinct cultures that still exist today.

Stretching across the American Southwest and Northern Mexico, Oasisamerica is just one of three cultural superareas in a region known as "Pre-Contact Mexico" stretching from California and the Southwestern United States through Mexico and much of Central America.

For over one thousand years, several complex agricultural societies flourished in Oasisamerica. In addition to beautiful ceramics, they built large and complex irrigation systems, multi-story dwellings, and conducted extensive trade with the Mayans of Mesoamerica and other societies thousands of kilometers away.

The specimen in the Mini Museum comes from a range of ceramics associated with three of the ancient societies within Oasisamerica: Ancestral Puebloans (also known as Anasazi), the Mogollon, and the Hohokam. The world over, the invention of ceramics has marked the end of pure hunter-gather societies and a shift towards more sedentary forms of living.

SOURCES:

Kirchoff, Paul. "Mesoamerica: Its geographic limits, ethnic composition and cultural characteristics." Heritage of Conquest (1952): 17-30.

Austin, Alfredo López, and Leonardo López Luján. Mexico's indigenous past. Vol. 240. University of Oklahoma Press, 2005.

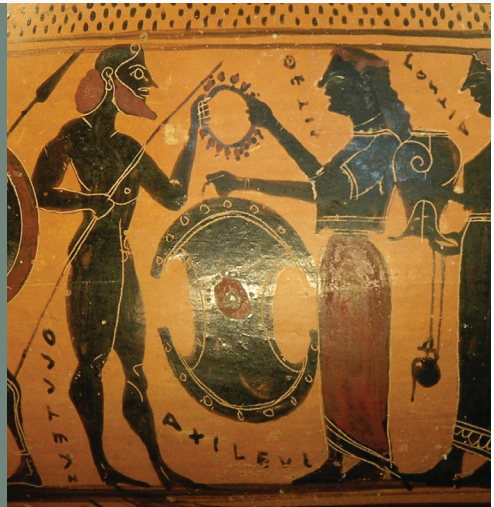
Galván, Francisco Mendiola. "Imaginary Border, Profound Border." Jon C. Lohse and Nancy Gonl n (2008): 291.

Roberts, David. "The Lost World Of the Old Ones: Discoveries in the Ancient Southwest. Norton." (2015): 100-100.

We cataloged each fragment of Oasisamerican ceramics prior to preparation.

In the songs of the Iliad, Homer paints a portrait of war between the Mycenaeans and the Trojans. The scene here depicts the sea nymph Thetis giving her son Achilles weapons forged by the god Hephaestus. The urn, which is housed in the Louvre, dates to 550-575 BCE, or roughly 600-700 years after the supposed timeline for the Trojan War.

Whether the Trojan War took place as written is still some matter of debate among scholars. What is clear is that the mysterious and rapid Late Bronze Age Collapse speaks to the fragility of human relations and civilization itself.



SPECIMEN TYPE:
HUMAN ARTIFACT

ESTIMATED AGE:
12TH CENTURY BCE

bronze age dagger

"Let me not then die ingloriously and without a struggle, but let me first do some great thing that shall be told among men hereafter."

– Homer, *the Illiad*

For 2000 years, the Eastern Mediterranean was home to a series of increasingly sophisticated cultures bound by complex trade routes. Then, in the late 12th century BC, empires and kingdoms from Greece and Anatolia to Egypt and Babylon collapsed in a rapid wave of famine, political upheaval, and war. Known today as the Late Bronze Age Collapse, the cause of this catastrophic event remains a matter of debate.

By many accounts, these nations suffered from repeated attacks by "Sea Peoples," a loosely affiliated group of outside invaders. Some studies have questioned the violent perception of these sea peoples, suggesting that they were in fact migrants leaving areas effected by famine induced by dramatic climate change and war.

There is also a more nuanced version of events in which a large, interconnected group of nations suffered multiple calamities. While any of these issues might have been managed individually, the simultaneous occurrence of disasters and chaotic change resulted in a complete system collapse, casting the region into a dark age of isolation and rebuilding.

The specimen in the Mini Museum comes from a pair of daggers dated to the late 12th century BC after the style of the Mycenaean culture. They were acquired from a private dealer of ancient armaments.

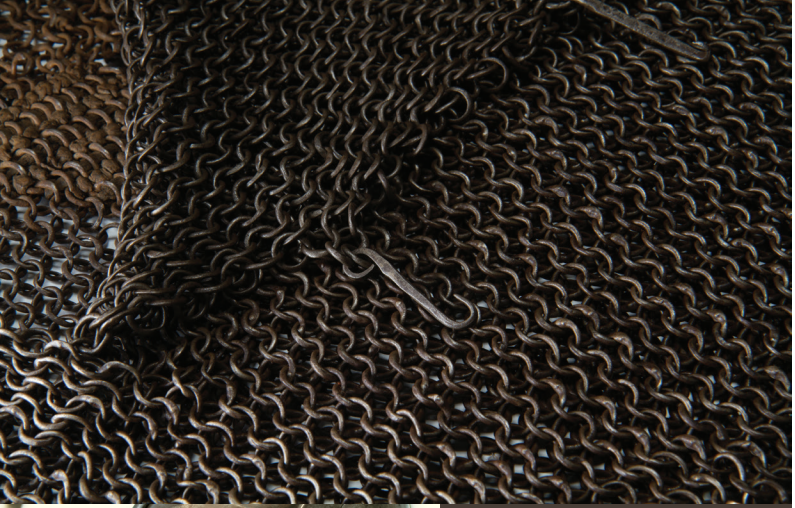
SOURCES:

Allen, Susan Heuck. Finding the Walls of Troy: Frank Calvert and Heinrich Schliemann at Hisarlik. Univ of California Press, 1999.

Drake, Brandon L. "The influence of climatic change on the Late Bronze Age Collapse and the Greek Dark Ages." Journal of Archaeological Science 39.6 (2012): 1862-1870.

Cline, Eric H. 1177 BC: The Year Civilization Collapsed. Princeton University Press, 2014.

The first step to preparing the Bronze Age Dagger for inclusion was to remove the green oxidized patina known as verdigris. This revealed the brilliant surface captured here.



Chain mail garments were heavy. A coif, such as the hood pictured here, could weigh as as much as 11kg (25lbs) and mailshirts in excess of 27kg (60lbs).

While the design of chain mail provided good protection from edged blades, it did little to ease the force of the blow. For this reason, knights would also wear quilted jackets beneath and over the mail.

In European armor there are two main types of mailshirts: the hauberk and the haburgeon (the latter being a sleeveless garment). Quilted jackets worn beneath the mail are referred to as a *gambesons.*

SPECIMEN TYPE: HUMAN ARTIFACT

ESTIMATED AGE: 15TH CENTURY CE

medieval chain mail

"When we made the film *Monty Python and the Holy Grail*, most of us wore imitation chain-mail made out of knitted wool, which was uncomfortable enough, but Graham Chapman, as King Arthur, wore a genuine metal chain mail coif and found the weight of it unbearable for more than short periods."

– Terry Jones

Valued for flexibility in combat, chain mail was the primary defensive armor in Europe for more than one thousand years.

To create a chain mail garment, thousands of rings would be punched out whole or riveted from strands of wire. A blacksmith would weave the rings into sheets using a pattern of interlocking rings. Patterns varied by region, dictated by armaments and fighting styles. Given the labor intensive process of weaving, chain mail garments were very costly to purchase but relatively simple to repair.

The earliest chain mail dates to the Etruscans, but the Celts are usually credited with creating the industry of chain mail in the 5th century with their 4-in-1 pattern. This relatively simple pattern was the standard in Europe for hundreds of years.

The specimen in the Mini Museum is a complete ring from a 15th century hauberk acquired in private auction. This period is considered the sunset of chain mail in Europe, as advanced plate armor completely supplanted mail.

SOURCES:

Arthur, Harold, and Viscount Dillon. "III.—On a MS. Collection of Ordinances of Chivalry of the fifteenth century, belonging to Lord Hastings." Archaeologia (Second Series) 57.01 (1900): 29-70.

Jones, Terry. Chaucer's Knight: : The Portrait of a Medieval Mercenary. Weidenfeld & Nicolson, 1980.

Gorsline, Douglas W. What People Wore: 1,800 Illustrations from Ancient Times to the Early Twentieth Century. Courier Corporation, 1994.

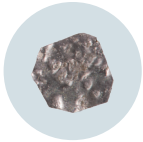
Each Mini Museum contains a full and complete riveted ring of Medieval Chain Mail. Cleanly separating punched from riveted rings required patient effort.

The *real de a ocho*, or Spanish "piece of eight," was created in 1497 and went on to become the world's first global currency. Spanish Galleons carried the coins to all corners of the Spanish Empire. Pieces of eight were even considered legal tender in the USA until the passage of the Coinage Act of 1857.

Image: Panorama of Havana, *Gabriel Bodenehr, 1671*

SPECIMEN TYPE: HUMAN ARTIFACT

DATE OF THE WRECK: NOVEMBER 2ND, 1641



shipwrecked pieces of eight

"The worst dreams that ever I have are when I hear the surf booming about its coasts or start upright in bed with the sharp voice of Captain Flint still ringing in my ears: 'Pieces of eight! Pieces of eight!'"

– **Robert Louis Stevenson, *Treasure Island***

Tales of pirates looting Spanish Galleons have entertained us for centuries, but the Spanish lost far more vessels to storms.

One of the largest and most powerful financial enterprises in the history of the world, the Spanish Empire's wealth stemmed from early conquests on the Gold Coast of West Africa, but this paled in comparison to the discovery New World.

Spanish convoys operated for more than two centuries, carrying raw materials, finished goods, and slaves to all corners of their Empire, transferring over $1.5 trillion in wealth.

In the New World, gold, silver, jewels and other resources would pool in the port of Veracruz then ships would carry them along the coast to Havana in Cuba. From here, fleets of twenty or more ships would make their way across the Atlantic.

One of those ships, the Concepción, left Havana in September of 1641 at the head of a 21-ship fleet and carrying 100 tons of silver and gold. A hurricane struck almost immediately, hobbling the ship, which then drifted into the reefs and shoals along the Florida coast.

The specimen in the Mini Museum comes from the wreck of the Concepción, recovered in 1978 by Burt Webber, Jr. protege of the great treasure hunter Mel Fisher.

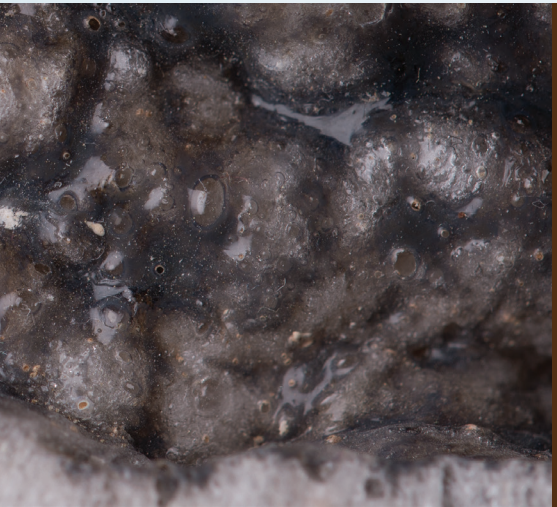
SOURCES:

Earle, Peter. The Treasure of the Concepción. Viking Adult, 1980.

Fine, John Christopher. Treasures of the Spanish Main: Shipwrecked Galleons in the New World. Globe Pequot, 2006.

Harpster, Matthew. "Shipwreck Identity, Methodology, and Nautical Archaeology." Journal of Archaeological Method and Theory 20.4 (2013): 588-622.

Producing minature coins from original the real de a ocho involved rolling the silver into thin strips and then reverse engineering texture and patina before cutting just the right shapes by hand.



Modern scientists use fulgurites as natural time capsules. Scientists extract these fulgurites from fossil dunes which preserve the delicate structure of fulgurites as well as ancient soil deposits known as paleosols.

Microspectroscopic analysis of trapped gasses within the fulgurites provide a view to climates thousands of years old in regions where weather patterns have changed dramatically.

SPECIMEN TYPE:
MINERAL

MINIMUM FORMATION TEMPERATURE:
1,800°C / 3,270°F

petrified lightning

(fulgurite)

"The tube is sometimes thick as a finger or thumb sometimes as a feather quill... Sometimes if one knows them and is on the lookout they can be seen shining forth out of the earth."

– Pastor David Hermann, first recorded observation of fulgurites in 1706

To most of us, lightning is a "bolt from the blue" - a flash of light breaking out of the clouds. It strikes the ground then fades to black against the crash of thunder. Dramatic as this sounds, the mechanics of lightning are very complicated.

A lightning strike is like two fingers coming together. An ionized column of air known as a leader works its way down from the clouds, meeting up with a similar column rising from the ground. As these two columns connect, a return stroke moves from the ground to the clouds creating the bright light we know as lightning. The amount of current moving through this connection is enormous and superheated air around the bolt explodes; this is what we call thunder.

When ground is composed of dry sand, the intense heat melts and fuses the silica creating tubes of rough glass called fulgurites. The process happens quickly, often trapping molecules from the surrounding atmosphere inside the walls of the impact tube. These complex, branching structures sometimes reach over 40' in length.

The specimen in the Mini Museum comes from fulgurites collected in the Sahara Desert. Analysis of saharan fulgurites provides additional evidence that the region was once more hospitable to life.

SOURCES:

Navarro-González, Rafael, et al. "Paleoecology reconstruction from trapped gases in a fulgurite from the late Pleistocene of the Libyan Desert." Geology 35.2 (2007): 171-174.

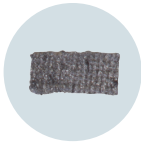
Carter, Elizabeth A., et al. "A Raman spectroscopic study of a fulgurite." Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences 368.1922 (2010): 3087-3097.

After preparing fulgurite specimens, we reviewed batches for structural integrity under a digital microscope.

Spanning 245 meters (803.8 ft), the Hindenburg and its twin the Graf Zeppelin II were the largest airships ever flown. Due to the highly flammable nature of Hydrogen, the airship was engulfed in flame in less than 30 seconds.

SPECIMEN TYPE:
HUMAN ARTIFACT

GAS CAPACITY:
200,000 CUBIC METERS, 7,062,000 CUBIC FEET



hindenburg
(airship skin)

"Oh the humanity!"

– Herbert Morrison, radio reporter recording live at the scene

At precisely 7:25 PM on May 6th, 1937, the Hindenburg burst into flames above the skies of Lakehurst Naval Air Station in New Jersey. The Hindenburg disaster claimed the lives of 35 on-board and one member of the ground crew.

Though the Zeppelin Company originally planned to use Helium as the lifting agent, a ban on Helium exports by the United States forced the Hindenburg to fly as a Hydrogen-filled craft.

Certainly there were concerns, but the Hindenburg line's rigid-frame design was based on engineering principles which had governed over a long, unbroken passenger safety record. Covering nearly 1,000,000 miles and the circumnavigation of the globe, Graf Zeppelins had experienced every possible combination of bad weather, including being struck by lightning.

Official reports blamed the explosion on the combination of St. Elmo's Fire and an undetected hydrogen leak. The surviving crew strongly disputed this claim and many felt that sabotage was to blame. To this day, most evidence to support such claims have proven circumstantial at best.

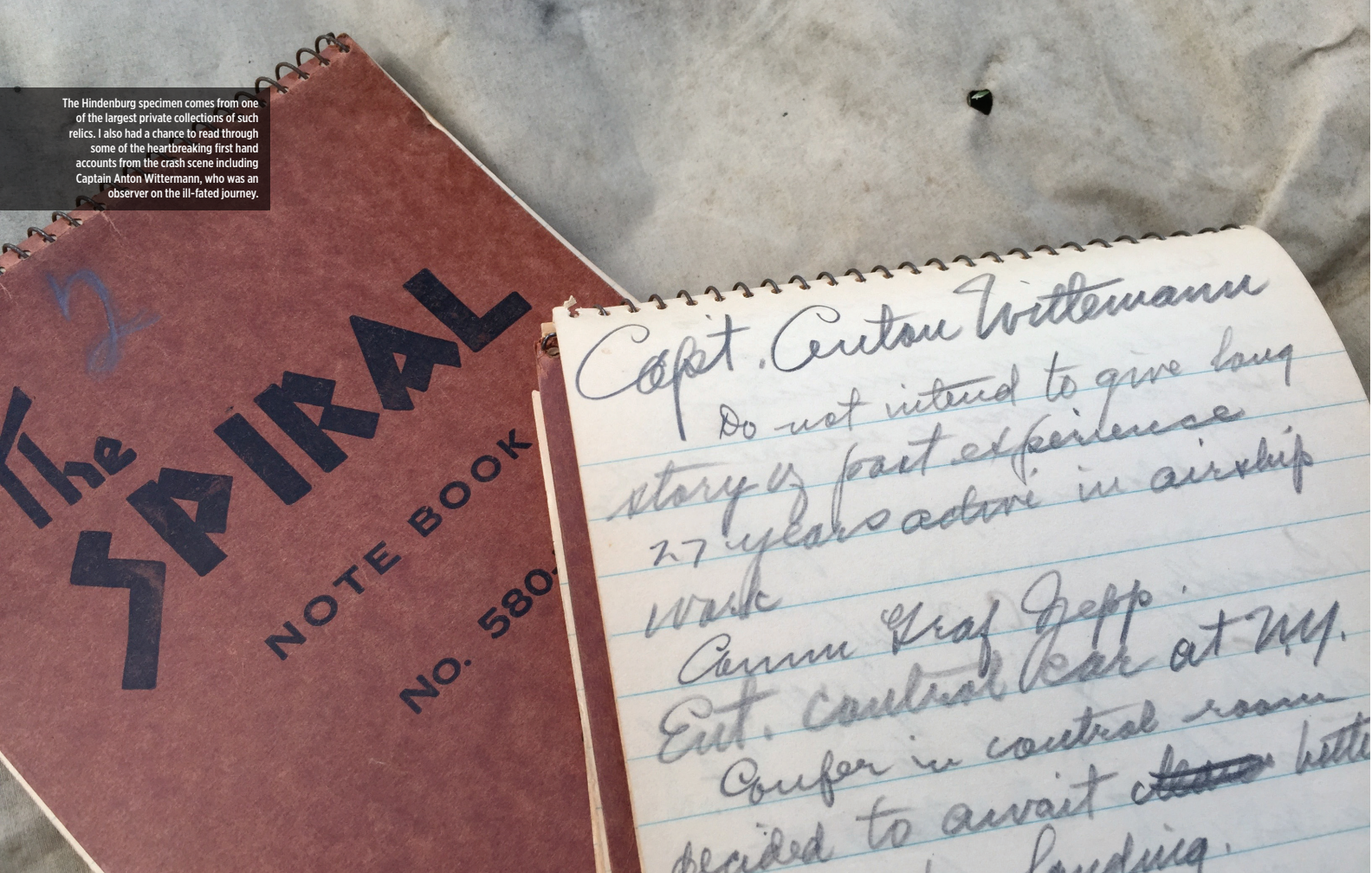
The specimen in the Mini Museum is from a piece of cloth retrieved at the scene by journalist Harry Kroh. Kroh was a local reporter dispatched to cover what was expected to be a routine landing, but turned into one the most well-covered disasters in history.

SOURCES:

Archbold, Rick, and Ken Marschall. Hindenburg: an illustrated history. Warner Books, 1994.

Dessler, A. J. "The Hindenburg Hydrogen Fire: Fatal Flaws in the Addison Bain Incendiary Paint Theory." Lunar and Planetary Laboratory, University of Arizona, Tucson AZ (2004).

Dick, Harold, and Douglas Robinson. The golden age of the great passenger airships: Graf Zeppelin and Hindenburg. Smithsonian Institution, 2014.

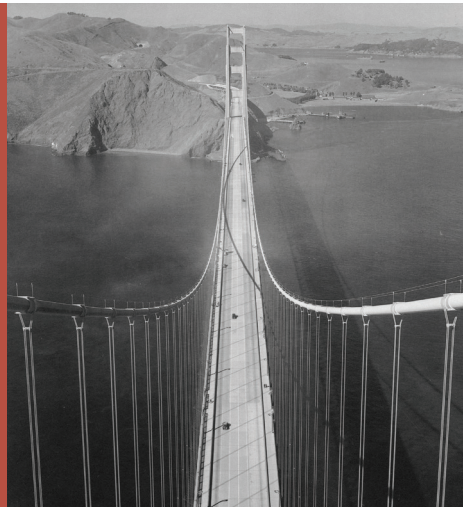


The Hindenburg specimen comes from one of the largest private collections of such relics. I also had a chance to read through some of the heartbreaking first hand accounts from the crash scene including Captain Anton Wittermann, who was an observer on the ill-fated journey.

The main support cables of the Golden Gate Bridge consist of 27,572 galvanized wires, bundled by custom cable bands. Across the entire structure, the cable wires have an average tensile strength of 235,600lbs per square inch.

From time to time, the main cables are tightened but unlike the suspender ropes they can never be replaced.

Image: Looking north from the top of the Golden Gate Bridge in 1938.



SPECIMEN TYPE:
HUMAN ARTIFACT

WEIGHT OF WIRE USED IN CABLES:
23,185 TONS

golden gate bridge

"At last, the mighty task is done."

– Joseph B. Strauss

On May 27th, 1937, the Golden Gate Bridge opened to the public, fulfilling a decades long dream of "Bridging the Gate." Spanning 1,280 meters (4,200 ft), the Golden Gate Bridge was the longest suspension bridge in the world for nearly thirty years, and at nearly 80 years old it is still in the top 12.

Developing the political support necessary to build such a monumental structure, fell to Chief Engineer Joseph B. Strauss. For nearly a decade, Strauss worked to promote the bridge. He wrangled financing, fought lawsuits, and oversaw the execution of the project.

When it came time to build, Strauss put just as much hard work into the construction, delivering just five months beyond the promise date and $1.3M under budget. Less than a year after the Golden Gate Bridge opened to the public, Strauss passed away, suffering a massive stroke while recuperating in Arizona.

While Strauss is rightly credited with giving so much to the Golden Gate Bridge, this structure is also the work of many thousands of men, including designer Charles Alton Ellis. Ellis and Strauss had a difficult falling out during the early stages of construction, which led to Ellis' expulsion from the project. The State of California recognized his contribution in 2007.

The specimen in the Mini Museum comes from the original 250 pairs of vertical suspender ropes attached to the main cables. The ropes were replaced in the mid-70s, and the State of California sold some of the material to help pay for the work. The process took four years and was itself considered a major engineering feat.

SOURCES:

Strauss, Joseph Baermann, and Clifford E. Paine. The Golden Gate bridge: report of the chief engineer to the Board of directors of the Golden Gate Bridge and Highway District, California, September, 1937. Golden Gate Bridge, Highway and Transportation District, 1938.

Starr, Kevin. Golden Gate: The Life and Times of America's Greatest Bridge. Bloomsbury Publishing USA, 2010.

How do you break what was never meant to be broken? In the case of the Golden Gate Bridge specimen, we used a commercial hydraulic chain cutter. It was slow work, but nothing else could cut it cleanly.

The Torch Relay itself represents both the Olympic flame and the journey from the ancient world to the modern.

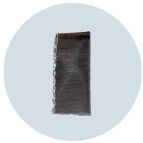
Germany introduced the modern concept of the Olympic Torch Relay during the 1936 Games in Berlin. Since then, the Relay has been a feature of every Summer Games.

The 2004 Olympic Torch Relay covered 78,000km and was the first relay to travel to Africa, South America, and India. In 2008, the International Olympic Committee repeated the global relay but the event also sparked protests in a number of countries.

The attention the Torch Relay receives speaks to the challenges faced by the entire world to live up to the ideals of behind Coubertin's original vision.

SPECIMEN TYPE:
HUMAN ARTIFACT

DISTANCE COVERED IN 2004 OLYMPIC RELAY:
78,000 KM / 48,467 MI



olympic torch

"We shall not have peace until the prejudices which now separate the different races shall have been outlived. To attain this end, what better means than to bring the youth of all countries periodically together for amicable trials of muscular strength and agility?"

– Pierre de Coubertin, founder of the modern Olympic Games

The modern Olympic Games are the manifestation of the ideals of Pierre de Coubertin, who in 1894 revived the 3,000 year old concept of the Greek Olympiad as a practical, hands-on extension to the peace education movement of his day. Coubertin's goal was nothing less than peace among all nations, which he hoped to bring about through a program of sport emphasizing the unique value of each human body.

Over the last century, the sheer scale of the modern Olympic Games has come to mirror of the complexity inherent in global human relations. Yet, Coubertin's Olympic motto, "Citius, Altius, Fortius" (Faster, Higher, Stronger), has served well as a reminder of the indomitable human spirit at the heart of the Games.

The specimen in the Mini Museum comes from one a relay torch used in the 2004 Olympic Torch Relay. The shape of the torch itself was design to evoke the image of an olive leaf.

"In the torch, I have tried to include as many elements as possible of Greek civilization and culture for the purpose of promoting through it dialogue between people, which is the fundamental aim of the Olympic Games." – *Andreas Varotsos, designer of the 2004 Athens torch*

SOURCES:

De Coubertin, Pierre. Olympism. Comité Internationnal Olympique, 2000.

MacAloon, John J. This great symbol: Pierre de Coubertin and the origins of the modern Olympic Games. Routledge, 2013.

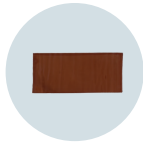
The interior of the 2004 Olympic Relay Torch with the Magnesium case removed.

During their down time the Skylab mission astronauts listened to music and read paperback books. Of the three, it's fair to say Paul Weitz had the most eclectic taste mixing Sons of the Pioneers, Johnny Cash, the Mormon Tabernacle Choir, Beethoven, Henry Mancini, Andy Williams, Wayne Newton, and Pat Boone among his recordings.

Today, astronauts aboard the International Space Station do much the same. They also take pictures and keep in touch via the Internet.

SPECIMEN TYPE:
HUMAN ARTIFACT

MISSION DURATION:
28 DAYS, 49 MINUTES, 49 SECONDS



astronaut mix tape
(skylab, 1973)

"And Houston, Skylab Two with you. We fix anything."
– Pete Conrad, Mission Commander

An unmanned SkyLab launched on May 14, 1973. Unfortunately, just sixty seconds after takeoff, the Micrometeoroid Shield deployed early and crushed two of SkyLab's solar panels.

Mission Control put the space station into a barrel roll to turn its remaining solar panels towards the sun and generate as much electricity as possible. As temperatures inside the space station soared, there were concerns that the entire project might need to be scrapped.

With the fate of Skylab in jeopardy, the follow-up mission to activate the space station quickly became an emergency repair mission.

Spending nearly a month in space, the crew survived dangerous repair challenges, including a failed attempt to free the Micrometeoroid Shield with a ten foot pole while hanging out of the airlock. Inside the super-heated space station, temperatures reached 130F. Working in five hour blocks, the crew not only stabilized SkyLab they also completed all of the scientific objectives of the mission and set an endurance record for the longest human spaceflight.

Skylab was abandoned in 1974 as NASA focused resources on the Space Shuttle program. In 1978, intense solar activity heated the upper atmosphere and increased drag on Skylab. As a result, the space station fell back to Earth, ultimately crashing south of Perth, Australia in July of 1979

The specimen in the Mini Museum comes from one of four mission-flown mix tapes belong to Pilot Paul Weitz. The cassette was acquired at auction and has been digitally preserved.

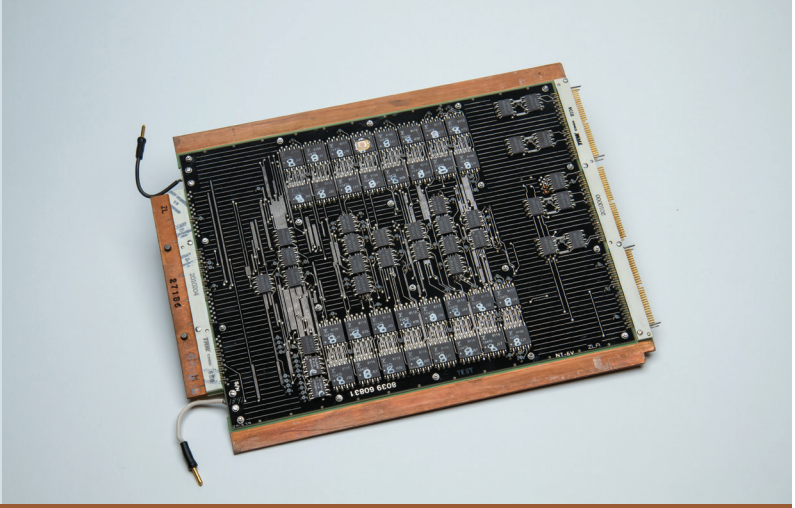
SOURCES:

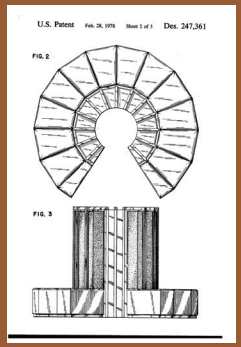
Weitz, P. J. "The role of man in conducting earth resources observations from space." (1974).

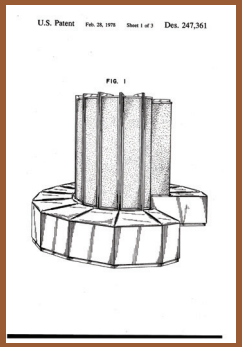
Shayler, David. Skylab: America's space station. Springer Science & Business Media, 2001.

Moye, J. Todd. SKYLAB: THE HUMAN SIDE OF A SCIENTIFIC MISSION. Diss. UNIVERSITY OF NORTH TEXAS, 2007.

After trimming each specimen of Astronaut Mix Tape, the specimens are cleaned and packaged in special, static resistant bags.







The iconic look of the Cray-1 is more than just 1970's aesthetics at play. Everything was thought through to provide advantages in performance.

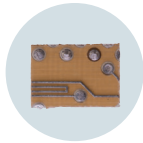
The columnar design of the cabinet allowed Cray to minimize the amount of wiring between processing stacks, while the cushions ringing the unit covered the enormous power supplies at the base of each tower.

Image: Cray-1 cabinet design from Seymour Cray's 1978 Patent

SPECIMEN TYPE:
HUMAN ARTIFACT

ORIGINAL PRICE (1978):
$8,800,000 USD

INFLATION ADJUSTED (2015):
$32,208,809 USD



first super computer
(cray-1)

"There's something about the speed of light;
It's just hard to get around."

– Seymour Cray

Seymour Cray was a legend in the world of early digital computers. He was also a veteran of past attempts to create large supercomputers:

"If you work in a large corporation it is very hard to keep on one track for 4-5 years. So, I think that building large computers should be done with the fewest possible people. One is perfect, but it can't quite work with one. The next best thing is about 12."

Eschewing the methods of the past, Cray created a new kind of supercomputer company using just four main principles: simplicity, size, discipline, and cooling.

Earlier attempts to create a viable supercomputer involved the use of incredibly complex integrated circuits. The Cray-1 used just three different types of integrated circuits across the entire machine, vastly simplifying the architecture. For cooling, freon circulated through stainless steel tubing bonded between vertical wedges of aluminum fitted between the stacks of circuit boards.

Cray's innovations yielded a machine was so advanced that a bidding war ensued for the first machine off the line. This made the Cray-1 was the first commercially successful supercomputer and launched the legend that became Cray Research.

The specimen in the Mini Museum comes from the Cray-1 originally installed at Lawrence Berkeley Labs.

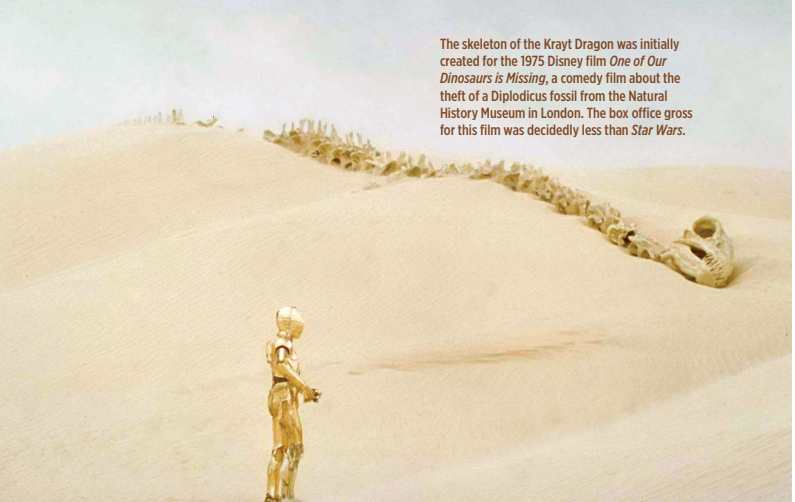
SOURCES:

Cray, Seymour. Live presentation at Los Alamos National Lab (LANL), 1976. https://www.youtube.com/watch?v=vtOA1vuoDgQ

Murray, Charles J., and Arthur L. Norberg. The supermen: the story of Seymour Cray and the technical wizards behind the supercomputer. Wiley, 1997.

Igarashi, Yoshihide, et al. Computing: A historical and technical perspective. CRC Press, 2014.

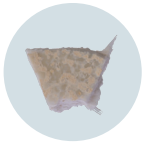
Each Cray-1 Supercomputer memory consists of three layers. Each had to be disassembled by hand.



The skeleton of the Krayt Dragon was initially created for the 1975 Disney film *One of Our Dinosaurs is Missing*, a comedy film about the theft of a Diplodicus fossil from the Natural History Museum in London. The box office gross for this film was decidedly less than *Star Wars*.

SPECIMEN TYPE:
HUMAN ARTIFACT

WHO SHOT FIRST:
HAN SOLO



star wars IV

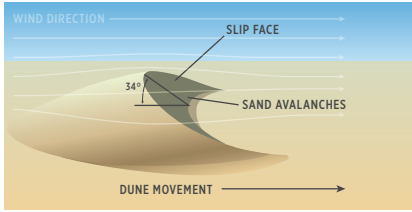
"A long time ago in a galaxy far, far away..."

On May 25th 1977, George Lucas' *Star Wars* premiered in theaters. The film was an instant success. Fans saw the movie multiple times, sometimes on the same day. Star Wars went on to become a global phenomenon and still remains the third highest grossing film of all time (inflation adjusted).

The specimen in the mini museum comes from a vertebra of the "Krayt Dragon" the long serpentine skeleton C-3PO encounters soon after separating from R2-D2 on Tatooine.

After the original filming in Tunisia, the production team abandoned the Krayt Dragon as well as several sets in the desert. The entire area is considered a significant tourist attraction, bringing in thousands of visitors per year. Locals take advantage of the traffic by conducting tours of the ruins and salvaging wreckage for sale.

Science is also benefitting from the remains. NASA uses the position of the sets to track the progress of large, crescent-shaped sand dunes called "barchans" which sweep through the area at 15 meters per year.



The largest barchans in the solar system are on Mars. Known as megabarchans, these massive dunes reach over 500 meters high and 6-7 kilometers in length. Perhaps someday film crews will leave behind props there as well!

SOURCES:

Lorenz, Ralph D., et al. "Dunes on planet Tatooine: Observation of barchan migration at the Star Wars film set in Tunisia." Geomorphology 201 (2013): 264-271.

Roesch, Stefan. The experiences of film location tourists. Vol. 42. Channel View Publications, 2009.

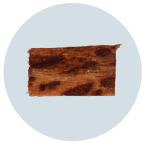
The fiberglass vertebra of the Krayt Dragon was incredibly hard, with sand embedded in every conceivable crevice.

Apollo 14 capped an incredible career in space for Alan Shepard. The only member of the Mercury Seven to reach the moon, Shepard battled through Ménière's disease, which affects hearing and balance, to return to flight status.

*Alan Shepard holds the distinction of being the first man to "play" golf on the moon. He brought along a number 6 golf club head which he attached to his excavator, hitting a ball that went "for miles and miles" (though really just a few hundred yards).

SPECIMEN TYPE:
TREE

DISTANCE TRAVELED:
1,851,262 KM / 1,150,321 MI



moon tree
(apollo 14)

"We sure picked a clear day to arrive - you can see all the way to the horizon."

– Stuart Roosa, Apollo 14 Command Module Pilot, upon entering lunar orbit

In 1971, Apollo 14 carried astronauts Alan Shepard, Edgar Mitchell, and Stuart Roosa to the moon along with hundreds of tree seeds. The seeds were stored in Roosa's personal kit as part of an experiment, but on return the seed canisters burst open during the decontamination process. The U.S. Forest Service assumed the seeds would no longer be viable, but surprisingly, most of the seeds survived. Saplings from those surviving seeds were dispersed as part of the nation's bicentennial celebration in 1975 and 1976.

Before becoming a test pilot and astronaut, Stuart Roosa worked for the Forest Service in the 1950s as a smoke jumper. After going to the moon, Roosa continued on with the space program. He was a backup pilot for Apollo 16 and 17, then worked on the Space Shuttle program until his retirement from the Air Force. Roosa passed away in 1994, and a second-generation moon sycamore was planted at Arlington National Cemetery to honor his service.

The specimen in the Mini Museum comes from the downed limb of a first-generation moon sycamore living between the Kuiper Space Sciences Building and the Flandrau Science Center and Planetarium on the University of Arizona campus in Tucson, Arizona. The limb was damaged in a storm and recovered by Senior Research Specialist and White House Champion for Change, Dolores Hill. We are incredibly grateful for her kind donation of this rare and unusual specimen.

SOURCES:

Reynolds, David West, Wally Schirra, and Von Hardesty. Apollo: The epic journey to the Moon. New York: Harcourt, 2002.

Watkins, Billy. Apollo moon missions: the unsung heroes. Greenwood Publishing Group, 2006.

Mitchell, Edgar D. Earthrise: My Adventures as an Apollo 14 Astronaut. Chicago Review Press. 2010.

Finished specimens of Moon Tree are inspected to ensure the grain will show up well after inclusion.

Dimetrodon Spine Sail vertebra

Measuring the depth of Stegosaurus plate fragments.

bizarre structures

"Extinction is the fate of most species, usually because they fail to adapt rapidly enough to changing conditions of climate or competition. Darwinian evolution decrees that no animal shall actively develop a harmful structure, but it offers no guarantee that useful structures will continue to be adaptive in changed circumstances."

– Stephen Jay Gould

We humans have a deep attraction to things which are different, even bizarre. There's something in us that strives to make rational explanations, even in the absence of evidence. Take for instance the spine sail of Dimetrodon and dorsal plates of Stegosaurus (left).

Historically, the purpose of these strange structures have proven irresistible for outright speculation by both amateurs and scientists alike. Some of the theories are fanciful, such as the gliding Stegosaurus of dinosaur enthusiast W.H. Ballou (pictured right).

In Ballou's opinion, the plates of Stegosaurus were so flexible that the animal might use them to fly, or at least glide. While we might laugh at this assertion today (and certainly some did in the 1920s when the article appeared), Ballou does make one real and important point:

"For nearly half a century every paleontologist in the world has attempted to explain the reason for these plates and there have been more harsh words passed over the remains of Stegosaurus than over any animal past or present."

– W.H Ballou

Certainly the same is true of Dimetrodon. Since the first descriptions of Dimetrodon in the 1870s, scientists have advanced many theories about the tall spine sails of Dimetrodon and their herbivorous cousins in the Permian Age. For many years, thermoregulation was the favorite. Facing the sail towards the rising sun, Dimetrodon would be able to raise its body temperature. Alternatively, facing into the wind, the sail would provide a cooling surface. In recent years, improved techniques and numerous studies of modern sail-backed reptiles suggest that the sails are inefficient for raising and lowering body temperature.

Another interesting example of changing techniques can be found in the scientific history of the Irish Elk.

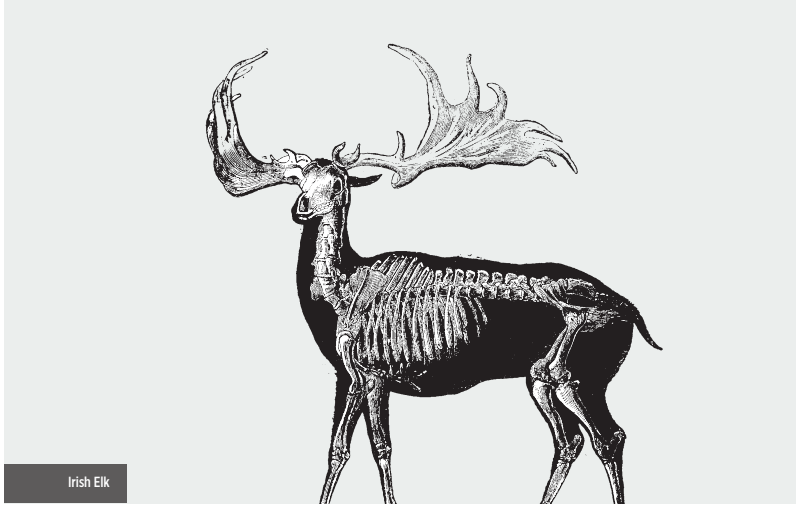
The Irish Elk, also known as *Megaloceros giganteus* is not an actual elk, but rather an extinct species of Pleistocene deer. Most specimens have been recovered from Irish peat bogs, but relatives of the species have been found as far away as Siberia. Many specimens of the Irish Elk exhibit an antler span of 3.5m (12ft). The antlers were shed and regrown each year, and this incredible span has proven to be a tempting subject for many scientists.

In the early 19th century, the Father of Paleontology himself, the French naturalist Georges Cuvier, used *Megaloceros* to argue for his theory of species extinction. Charles Darwin also studied *Megaloceros*, and softly advanced the idea that antler size might have evolved for ritualized fighting among males, much like modern deer do today.

Alternate theories about *Megaloceros*'s antlers include general defense and thermoregulation, which should sound familiar after studying Dimetrodon and Stegosaurus. Some scientists have gone as far as using the antlers to attack evolution itself, arguing that such a useless structure could not provide a fruitful advantage.

It isn't until 1974, that we see a scientific study of *Megaloceros* using modern statistical techniques. By surveying the remains of 79 different individuals from museums across the world, scientist and author Stephen Jay Gould demonstrated that while the antlers of *Megaloceros* were statistically in line across the species in relationship to body size. Furthermore, he went on to cross reference big game studies of modern deer and again found a strong allometric relationships to support his findings.

In his popular version of the technical paper, "The Misnamed, Mistreated, and Misunderstood Irish Elk," Gould avoids too much direct criticism of those who came before, instead focusing on the methods he used to illuminate the subject. His conclusion is that *Megaloceros*, as spectacular as those antlers might be, can be explained through careful observation, calculation, and cross-checking of data points.



Irish Elk

It is fun to think about the way strange creatures might have lived and how their bodies adapted over time to the environment they encountered. I think scientists have the same sort of fun.

While science does not always have all the answers, the conclusion to be drawn here is that science is always changing. Additional methodologies and techniques should be not be seen as stifling human creativity, but rather as a clear way to validate modes of inquiry.

SOURCES:

The Ogden standard-examiner. (Ogden, Utah), 15 Aug. 1920. Chronicling America: Historic American Newspapers. Lib. of Congress.

Gould, Stephen Jay. "The origin and function of 'bizarre' structures: antler size and skull size in the 'Irish Elk,' Megaloceros giganteus." Evolution (1974): 191-220.

Gould, Stephen Jay. Ever since Darwin: Reflections in natural history. WW Norton & Company, 1992.

At the Second Edition photoshoot with a cast replica of the Feldhofer Neanderthal skull, the first recognized remains of H. neanderthalensis.

the adventure of science

"In the lab, Matthias Krings and Ralf Schmitz could hardly control their delight as they showed me the string of A's, C's, G's, and T's coming out of the sequencers. That afternoon, Matthias had started our DNA sequencing machines, feeding them fragments of a Neanderthal arm bone held at the Rhienisches Landesmuseum in Bonn for the last 140 years. Years of mostly disappointing results had taught me to keep my expectations low, but neither they nor I had ever seen anything like it before."

– Svante Pääbo, director of Genetics at the Max Planck Institute of Evolutionary Anthropology writing about the first discovery of Neanderthal DNA

This sense of joy is the heart of all scientific discovery. You can find traces of it in nearly every major event, going all the way back to Archimedes' shout of "Eureka!" This is the urge, the drive to uncover the secrets of the universe and share them with the world.

We share the love of discovery, the adventure of the yet to be known.

The story of science is a tale of adventure. Epic in scope, the domain of science is the entire universe and all of time, from the smallest particles to the greatest superstructures of the cosmos.

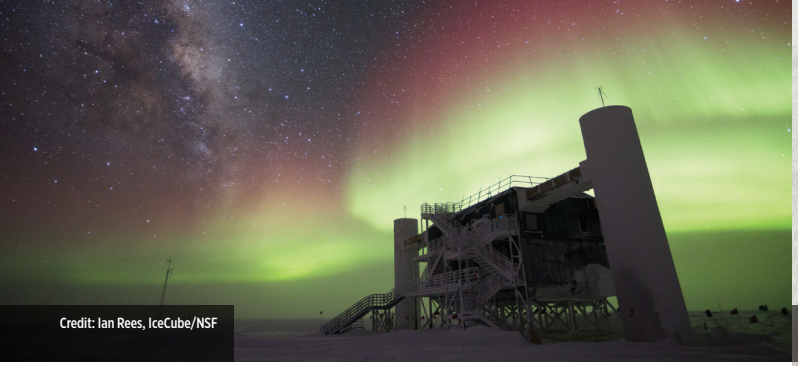
Yet, at the same time, science is also a story of people.

In their quest to understand our universe, scientists face many challenges. Sometimes they risk their lives, and sometimes they do not return. By studying their journeys and their results, we are peering through a window.

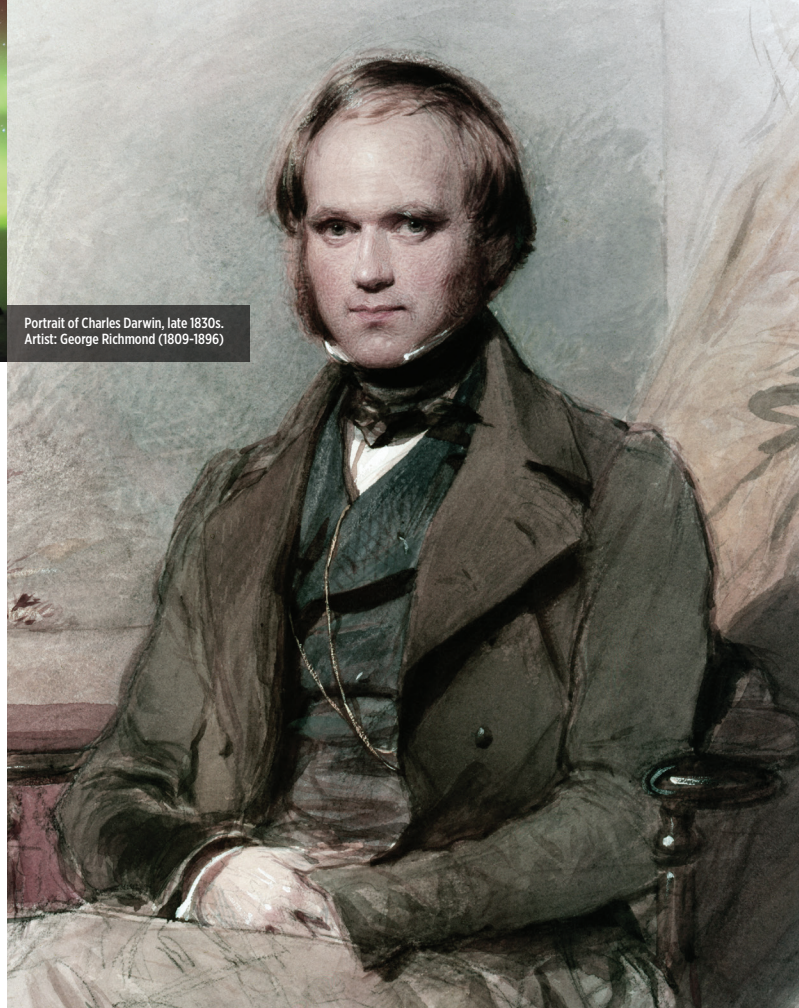
And what do we see when we look through that window? I think that in many ways what we see is some measure of our own place, a view so personal as to be nurturing.

So where do we look for these tales? They are everywhere.

In Charles Darwin's portion of *The Voyage of the Beagle*, a young naturalist recounts his adventures at sea and in many ways his coming



Credit: Ian Rees, IceCube/NSF



Portrait of Charles Darwin, late 1830s.
Artist: George Richmond (1809-1896)

of age. While gathering specimens in Patagonia, Darwin fell ill with Typhoid fever near Valparaiso, Chile. The episode is treated somewhat lightly in the written account, but Darwin nearly died. But from this journey and all he had learned, Darwin's fevered mind made the first connections which would blossom into his vision of evolution.

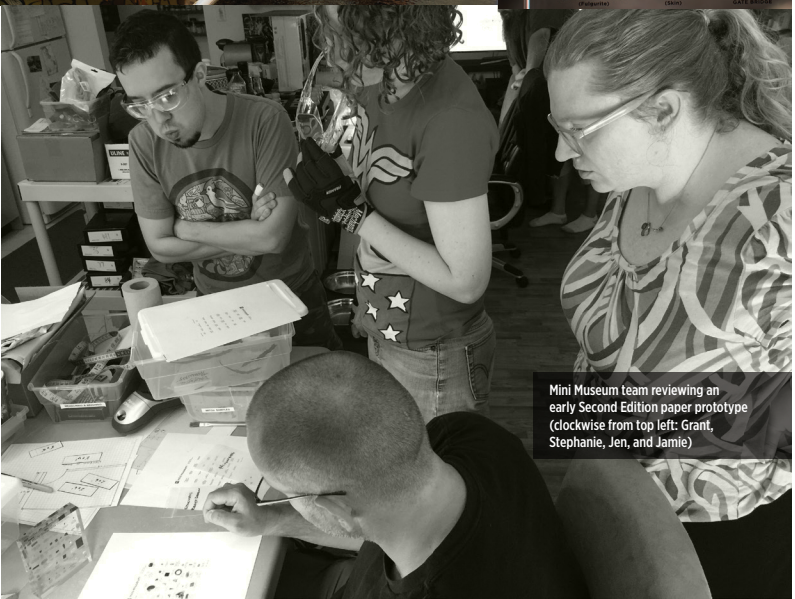
There are many other tales of scientific adventure to be found across history. People go forth. People like you and I and everyone you know. Something pushes them forward into places they have never been. Deep within the most challenging moments, there are often bright spots, illumination of ideas, and the bruising hard work of gathering data.

Today, as in days gone by, there are scientists all over the world engaged in adventure as part of the pursuit of science. In Antarctica, scientists are stationed around the continent, including the South Pole. They study the climate on Earth but also look towards the skies.

The Ice Cube Neutrino Observatory is a special kind of telescope, a cubic kilometer particle detector made directly from the Antarctic ice and thousands of digital optic modules frozen in the ice. Scientists and support staff man the facility year round, including in the depths of the Antarctic winter when temperatures drop to as low as -83 °C (-117 °F).

While the day-to-day work is very hard, these scientists also sift through vast quantities of data. It is estimated that 10,000,000,000 neutrinos pass through every square centimeter of our bodies each and every second. These particles provide astronomers with information about the stars that no other source can provide.

I'm dwelling on this subject because I think it is so important that we connect the work of science into our daily lives. It's there whether we look at it or not, so why not look? Why not ask questions? One never knows where such questions may lead. You may go to the South Pole or even to Mars!



Mini Museum team reviewing an early Second Edition paper prototype (clockwise from top left: Grant, Stephanie, Jen, and Jamie)

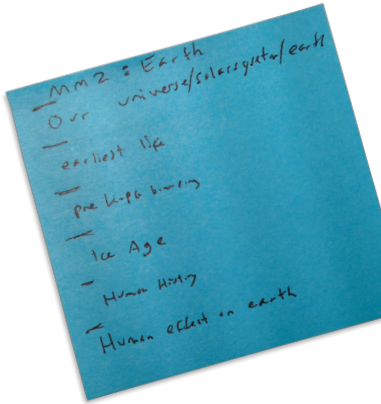
creating a mini museum

"A living museum must surely see itself as a locus of argument. A breathing art institution is not a lockup but a moveable feast."

– Andrew O'Hagan, Novelist

It should come as no surprise that creating a Mini Museum itself is a very complicated process. Each specimen presents unique challenges and we've had to consult with craftspeople from around the world. I can't tell you the number of times that we've been told that we're trying to do something that can't be done... Yet, our team finds a way.

Given the variety of techniques involved, I thought it would be interesting to share some of our thoughts about the nature of creating a Mini Museum. I've supplemented the text with pictures from the making of the second edition.



An early paper prototype of the second edition

SELECTING SPECIMENS

Selecting specimens for a Mini Museum collection is a strange process. There's no formula, but much like the final collection the process is part art and part science.

The post-it note on the previous page is a very early note I made about the Second Edition. I make notes like this constantly, jotting down ideas for specific specimens or just general themes like this example. I even create large wall-sized grids of paper specimens, moving items in and out of the collection.

How do the specimens look next to each other? How does the order feel when viewing individual lines (both vertical and horizontal)? So many things need to be considered. The process takes time.

As the collection begins to take shape, certain curiosities creep into the process. Patterns emerge. Relationships become apparent. Even though there are often more that two specimens involved in these connections, we often refer to these relationships as "pairings."

In the second edition of the Mini Museum there are many such pairings. Some objects are connected by time, some by geology or geography, and some only by human perception. On occasion, there are pairings that do not become apparent until later. Perhaps you have discovered these pairings for yourself or even many I did not imagine.

ACQUIRING SPECIMENS

Specimens for the Mini Museum come from all over the world and often from places far, far beyond.

There are many ways to acquire a specimen. Some specimens are acquired by auction, some directly from researchers working in the field.

Of course, at times, getting on a plane bound for another part of the world is the only way to get something unique.

There's often a lot of waiting involved, sometimes for years. Still, it's always an exciting process.

I also think often about the specimens that I've acquired by chance or through personal connections. These specimens often come with unexpected stories and lead to wonderful friendships.

With Wolfgang Grulke, author of *Heteromorph.*

Exactly how does one prepare that which was meant to be unbreakable?

Bonding stegosaurus

SPECIMEN PREPARATION

Specimen preparation is hard, and every specimen comes with unique challenges. Often we find ourselves doing something that no one has ever thought about doing.

Understanding the specimen is just the first step in the process. Trial and error are common, especially when trying to scale a technique which works well for producing a single individual specimen to many thousands.

To prepare a Mini Museum requires millions of unique decisions. This is not an exaggeration. Each cut must be approached with care and consideration. Many hours are spent sifting, cleaning, and counting.

There are many difficult moments just as there are many joyful moments too. It's a balance of sorts, the drive to share a beautiful project with the world and the idea that each individual specimen will be held by a unique human being.

TOOLS

"Good workmen never quarrel with their tools."

- Lord Byron, Canto I of *Don Juan*

I arrived early one morning and found this little fellow (above) resting on a table.

This fan was part of one of our pop-up spray booths. The spray booth is used for indoor tasks which involve dust or chemical fumes. The fans often run for many hours at a time, so it is inevitable that parts will fail. This is true of all tools.

Of course, we do our best to care for our tools, but we also know that while the objects we create will last for generations our tools will not. Nippers dull. Rollers scratch. Blades break. Crucibles shatter...

Sometimes we know we're going to fatigue a piece of equipment, even take it all the way to the point of failure on purpose, and sometimes we don't. It just happens.

This is the way it has always been with tools. Even ancient tools.

THE SURPRISE OF THE UNIQUE

It may sound strange, but it's always a surprise when I see a completed Mini Museum for the first time.

I find myself drawn into different aspects of the collection each time I look at one. Sometimes I think about the history of the specimens. Sometimes I recall what it was like to solve the riddle of one particular specimen's preparation. I often recall specific specimens, which is perhaps the biggest surprise of all.

One would think that with hundreds of thousands of specimens, it would be impossible to remember a specific item but it happens. I'm not sure how or why, though it could be that I think about how a specimen will look when someone sees it for the first time.

I suppose that if one were to think about the core lesson in creating a Mini Museum it would be the idea that each cut, each specimen, each collection is just as unique as the person who will ultimately receive it and share it with their friends and family.

The Mini Museum was designed to inspire wonder. I hope that we've managed to capture some of that in this guide and that you've enjoyed learning about the Second Edition. Thank you so very much! Now, it's back to work! - Hans