mini museum

"Man ska vara snäll."

"One should be kind."

– Dr. Jörgen Fex

mini museum:

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

HANS-FILIP J. FEX

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

contents

hello, everyone!

My name is Hans Fex. I've spent most of my life collecting rare and fascinating objects. With the help of others, I've been able to assemble an incredible collection which I am sharing with the world through this project we call the Mini Museum.

Over the years, we've worked on so many incredible specimens and overcome incredible challenges. Now, with the release of the Fourth Edition, we've shared over one hundred iconic specimens from across space and time with tens of thousands of people.

Yet, while we've added more friends to the Mini Museum family, the core of the Mini Museum remains the same: together, we are all sharing the universe through our love of science and history. I am, and always will be, so grateful for the opportunity to pursue this life-long dream.

So thank you very, very much for your support! I hope that you will enjoy this collection!

Hans Fex

CREATOR AND CHIEF CURATOR OF THE MINI MUSEUM

Each year nearly 40,000,000 kilograms (88.1 million pounds) of meteoritic material rains down on the Earth from outer space. Less than 1% of these falls holds traces of organic compounds, and within this tiny subset scientists sometimes come across even rarer material... amino acids, including those which form the building blocks of life as we know it.

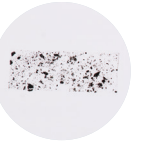
The oldest of these meteorites, known as carbonaceous chondrites (pictured above), date to the formation of the solar system. Recent studies suggest that the amino acids found in some carbonaceous chondrites may have come from the pre-solar nebula.

(Image: Perseid Meteor Shower in Joshua Tree National Park, California)

SPECIMEN TYPE:
METEORITE

AGE:
C. 4,568,200,000 YEARS OLD

AMINO ACIDS:
MORE THAN 70, INCLUDING 8 PROTEINOGENIC



extraterrestrial amino acids

"The nitrogen in our DNA, the calcium in our teeth, the iron in our blood, the carbon in our apple pies were made in the interiors of collapsing stars. We are made of starstuff."

– Carl Sagan, *Cosmos,* 1980

At 10:58 am on September 28th, 1969, a bright fireball appeared in the sky near the small, riverside town of Murchison, Australia. Under tremendous stress, the bolide separated into three main pieces, spreading fragments across 13 square kilometers (5 sq mi), including one lump which crashed through a barn roof and landed in a pile of hay.

As astronomical as the odds might be for this soft landing, the Murchison meteorite would turn out to be literally one of the rarest of all meteorite finds: a remnant formed at the very birth of the solar system, which also happened to carry the building blocks of life.

Known as a carbonaceous chondrite, this type of meteorite is distinguished by calcium–aluminium-rich inclusions (CAI), minerals that are among the first solids to condense in the high temperature gases of a young, protoplanetary disk. In addition to CAIs, Murchison also carries a fantastic array of more than 70 different amino acids, including 8 of the 20 proteinogenic amino acids used to build proteins encoded in our DNA as well as all life here on Earth.

Since the discovery of amino acids in the Murchison meteorite, scientists have discovered that other carbonaceous chondrites also contain amino acids. Recent studies suggest that the amino acids present in these meteorites may even pre-date the formation of the solar system. Further studies have revealed that the diversity of amino acids in a particular meteorite can be used to study the original parent or "host body" and how geological processes (including aqueous alteration) may have enriched these early organic chemicals prior to the emergence

Image Credit: NASA's Goddard Space Flight Center courtesy of NASA/JPL-Caltech

of life in this solar system.

The specimen in the Mini Museum is composed of two special carbonaceous chondrites: Murchison and Jbilet Winselwan. Both of these meteorites are CM2 class carbonaceous chondrites, a class known to contain the highest density of amino acids.

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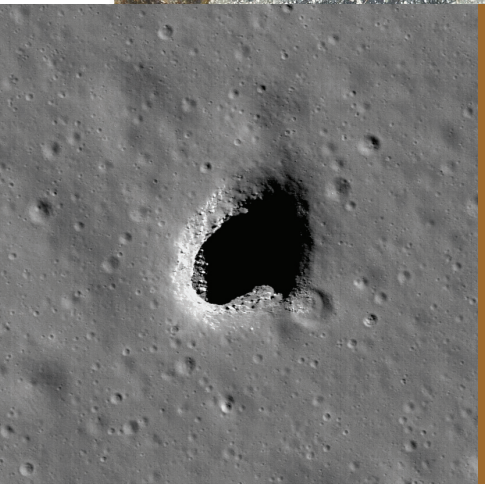


The last major volcanic outflows on the Moon peaked about 3.2 billion years ago, but recent studies show that smaller outflows have taken place as recently as 100 million years ago.

As with volcanoes here on earth, the flood basalts also leave behind lava tubes, natural conduits through which the lava once flowed. Tubes near the surface sometimes collapse as a result of meteor impacts or seismic events. This creates windows or skylights revealing a hidden world within.

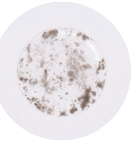
Lunar skylight at Mare Ingenii, roughly 120 m (420 ft) in diameter.

(Image Credit: NASA/Goddard/ Arizona State University)

SPECIMEN TYPE:
METEORITE

ESTIMATED AGE:
C. 3,200,000,000 YEARS OLD

MOST RECENT SURFACE ERUPTION:
C. 18,000,000 YEARS AGO



lunar highlands

"You develop an instant global consciousness, a people orientation, an intense dissatisfaction with the state of the world, and a compulsion to do something about it. From out there on the moon, international politics look so petty. You want to grab a politician by the scruff of the neck and drag him a quarter of a million miles out and say, 'Look at that, you son of a bitch.'"

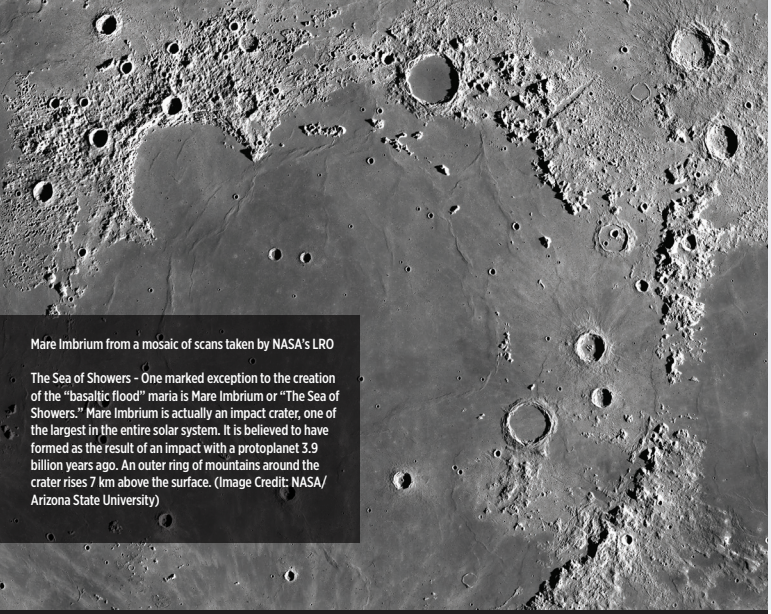
– Edgar D. Mitchell, Apollo 14 Astronaut

It might be hard to imagine volcanoes on the Moon, but evidence of an active volcanic past covers our neighbor's cratered surface, and more recent studies suggest the moon may still have a little life in it yet!

Looking at the moon on a clear night with the naked eye, we are struck by contrasting shades of light and dark. In the autumn of 1609, Galileo Galilei created a series of watercolors based on his observation of the moon through his telescope. Decades later, this landscape inspired astronomer Giovanni Battista Riccioli to give specific names to detailed features in Almagestum Novum (1651) and associating large regions with "Terra" and "Mare" (land and sea in Latin).

The Terra are sometimes referred to today as the "highlands". These bright hills and domes are dominated by ranges of intrusive igneous rocks which formed as large plumes of magma cooled and crystallized within the crust billions of years ago. The dark Maria are basalts created during more recent volcanic floods on the surface.

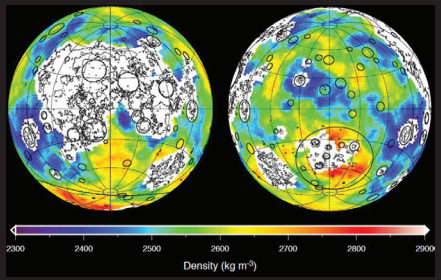
The specimen in the Mini Museum is a handcrafted "moon" composed of fine-grained dust extracted from the NWA 5000 lunar meteorite. One of the largest lunar meteorites, NWA 5000 is a gabbroic rock typical of highlands origin with evidence of impact melt. Argon isotopes indicate the mass crystalized after a large impact 3.2 billion years ago, then experienced a second impact just 500 million years ago which ejected it into space, sending it on a relatively quick trip to Earth.



Mare Imbrium from a mosaic of scans taken by NASA's LRO

The Sea of Showers - One marked exception to the creation of the "basaltic flood" maria is Mare Imbrium or "The Sea of Showers." Mare Imbrium is actually an impact crater, one of the largest in the entire solar system. It is believed to have formed as the result of an impact with a protoplanet 3.9 billion years ago. An outer ring of mountains around the crater rises 7 km above the surface. (Image Credit: NASA/ Arizona State University)

Francesco Grimaldi, map of the Moon Almagestum Novum (1651)



Density of the moon's surface was generated using gravimetric and topographical data from NASA's GRAIL and LRO respectively. The lunar highlands crust averages 2,550 kilograms per meter cubed and is represented by the light green color. (Image Credit: NASA/JPL-Caltech/ IPGP)

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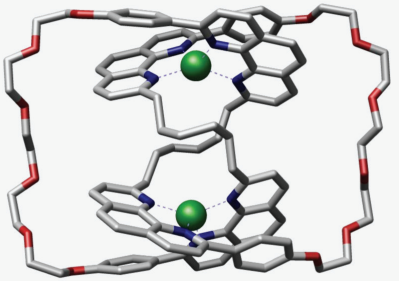
(Image Credit: NWA 5000 Slice Gregory M. Hupé)



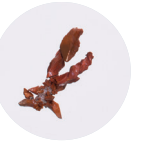
Crystal structure of a molecular trefoil knot with two copper templating ions bound within it reported by Jean-Pierre Sauvage, Journal of the Royal Netherlands Chemical Society 1993, Vol 112

This is a picture generated from crystal structure data reported by Albrechtgary, A. M.; Dietrichbuchecker, C. O.; Guilhem, J.; Meyer, M.; Pascard, C.; Sauvage, J. P. in Recueil des Travaux Chimiques des Pays-Bas. Journal of the Royal Netherlands Chemical Society, Year 1993, Vol 112, Pages 427-428. It shows a molecular knot with two copper(I) templating ions bound within.

SPECIMEN TYPE:
MINERAL

ESTIMATED AGE:
C. 300,000,000 YEARS OLD

LOCATION:
KAZAKHSTAN



copper crystals

"... I will not accept here any copper from you that is not of fine quality."

– Nanni, Babylonian Merchant to Copper Dealer Ea-Nasir, c. 1750 BCE

The intricate lattice of native copper crystals reveals a story of deep geological processes lasting hundreds of millions of years. Stronger than gold, but still soft enough to be shaped easily into tools, weapons, and decorative objects, this form of copper also played an important role in the development of human cultures across the globe as they stepped out of the Stone Age and into the Age of Metals.

Most metallic elements are found in combined states such as ores and alloys. Even iron, which is one of the most abundant metals in the Earth's crust, is typically alloyed with nickel. Pure or "native" metals are relatively rare, with the exception of less reactive elements such as gold, silver, platinum, and copper.

Native copper deposits are found in both igneous and sedimentary rock formations, but the processes involved in their formation are quite different. In the case of igneous rocks, native copper crystalizes in lava flows which have low silicon and low sulfur content. Known as mafic lava, the lack of silicon makes the flow more viscous and the lack of sulfur keeps the copper from forming ores as it cools. Sedimentary-hosted native copper forms through a long process of reduction. Copper is extracted from host rocks soaking in chalky or calcareous brines. These deposits occur in highly permeable sediments in shallow marine basins near the paleoequator where there would have been a high evaporation rate.

The specimen in the Mini Museum comes from native copper deposits located near the city of Zhezqazghan, Kazakhstan. The large copper deposits in this region are

sediment-hosted with mineralization occurring roughly 300,000,000 years ago, and involving brines from late Devonian and early Permian marine sediments. The earliest copper mining in this region dates back to the Bronze Age, crossing numerous cultures, with extensive trade routes into the ancient world.

SOURCES:

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Human Use of Copper

Copper tools and decorative objects date back as far as 10,000 years ago, but for thousands of years, use of copper was limited to the availability of uncombined or "native" metal. Widespread use of copper did not occur until humans learned to extract it from ores through smelting.

Smelting is a process which uses heat and reducing agents to cause a chemical reaction which frees the pure metal from other elements such as sulfur (sulfides) and oxygen (oxides). Tin and lead, which can be smelted in simple hearths, were the first metals extracted using this method. Copper smelting came later, possibly as a side effect of the heat generated in pottery kilns.

Later, tin and copper would be combined to create an alloy known as bronze, a durable material that would shape the ancient world for thousands of years.

Copper remains an indispensable metal in the modern world. It is highly conductive, which makes copper useful for all manner of electrical components. It is also ductile and malleable, two traits which allow copper to be stretched and formed without breaking. This makes copper ideal for wiring and plumbing.

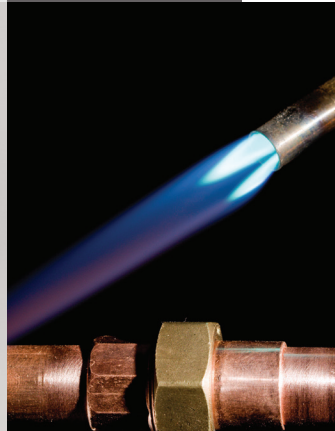
And yet, despite its long history, we're still not quite done with this incredible metal.

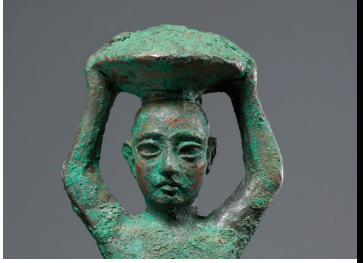
Recent studies have demonstrated that raw copper is a powerful antimicrobial material, highly effective at killing bacteria, viruses, and fungi on contact by disrupting cell membranes. Copper ions are also at the heart of studies in molecular motion, and the construction of tiny, synthetic molecular machines.

Late Bronze Age Copper Ingot from Cyprus c. 1450-1050 BCE

Copper Alloy Bracelet Djenné peoples Mali, Inland Niger Delta region c. 1000-1500 CE

Moche (Loma Negra) Warrior Ornament, Peru, c. 600-700 CE





King Shulgi of Ur, carrying a basket,
c. 2095-2047 BCE

So, I'd like to speak to the manager...

Today we might post a tweet or drop a comment on Facebook, but roughly 3,768 years ago when something went wrong you had to grab a stiff reed, make hundreds of little wedge-shaped marks in clay, and then wait for it to dry.

This particular cuneiform tablet comes from the ancient, coastal city of Ur. It is a complaint letter from the Merchant Nanni to a Copper Dealer named Ea-nasir.

Translated from Akkadian it says:

> ***When you came, you said to me as follows : "I will give Gimil-Sin (when he comes) fine quality copper ingots." You left then but you did not do what you promised me. You put ingots which were not good before my messenger (Sit-Sin) and said: "If you want to take them, take them; if you do not want to take them, go away!"***
>
> ***What do you take me for, that you treat somebody like me with such contempt? I have sent as messengers gentlemen like ourselves to collect the bag with my money (deposited with you) but you have treated me with contempt by sending them back to me empty-handed several times, and that through enemy territory. Is there anyone among the merchants who trade with Telmun who has treated me in this way? You alone treat my messenger with contempt! On account of that one (trifling) mina of silver which I owe(?) you, you feel free to speak in such a way, while I have given to the palace on your behalf 1,080 pounds of copper, and umi-abum has likewise given 1,080 pounds of copper, apart from what we both have had written on a sealed tablet to be kept in the temple of Samas.***
>
> ***How have you treated me for that copper? You have withheld my money bag from me in enemy territory; it is now up to you to restore (my money) to me in full.***
>
> ***Take cognizance that (from now on) I will not accept here any copper from you that is not of fine quality. I shall (from now on) select and take the ingots individually in my own yard, and I shall exercise against you my right of rejection because you have treated me with contempt.***

Translations of 150 different letters like this letter are available in A. Leo Oppenheim's 1967 book, "Letters From Mesopotamia: Official, Business, and Private Letters on Clay Tablets from Two Millennia"

SPECIMEN TYPE:
VOLCANIC ROCK

ESTIMATED AGE:
C. 252,280,000

ESTIMATED RATE OF EXTINCTION:
+95% OF ALL LIFE

ESTIMATED DURATION OF ERUPTION:
1,000,000 YEARS

the great dying

"La vie a souvent été troublée sur cette terre par des événemens effroyables."
[Life has often been disturbed on this earth by frightful events.]

– Georges Cuvier, *Discours sur les révolutions de la surface du globe* (1822)

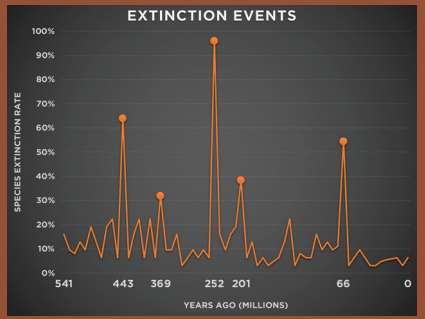
Our planet has gone through many different cycles of life and death over the last 4.5 billion years, from the rise and long-lasting reign of the dinosaurs to the endless variations of tiny cyanobacteria stretching back billions of years. While the fossil record holds a picture of many dramatic events, nothing quite compares to the Permian-Triassic Extinction Event, known as "The Great Dying."

The chief catalyst of this extinction event is a series of massive volcanic eruptions known as the Siberian Traps. Over the course of 1,000,000 years, these flood basalt eruptions covered over 7 million square kilometers (2,700,000 square miles) with as much as 4 million cubic kilometers of lava (~1,000,000 cubic miles).

Nickel released by the Siberian Traps triggered marine bacteria to produce massive amounts of methane. Combined with an injection of carbon dioxide and sulfate aerosols, runaway global warming pushed ocean temperatures over 40C (104F).

Such devastation on land and sea is unequalled in the fossil record. Nearly 95% of all life perished, and most studies indicate life took millions of years to rebound. As life returned, new species rose to the top. The Synapsids (mammal-like reptiles such as Dimetrodon) were replaced by Archosaurs. The Archosaurs descendants included birds, crocodilians, pterosaurs, and of course dinosaurs.

The specimen in the Mini Museum is a basalt slab from the Kuznetsk Basin in southwestern Siberia. The Kuznetsk Basin is also home to one of the largest coal deposits on Earth, a remnant of the global destruction caused by the Siberian Traps.



While there have been numerous extinction events scattered across time, the chart to the left highlights the "Big Five" events as well as a number of smaller events that have occurred in between:

- Ordovician–Silurian extinction events (End Ordovician or O–S): 450–440 Ma
- Late Devonian extinction: 375–360 Ma
- Permian–Triassic extinction event (End Permian): 252 Ma
- Triassic–Jurassic extinction event (End Triassic): 201.3 Ma
- Cretaceous–Paleogene extinction event (End Cretaceous, K–Pg extinction, or formerly K–T extinction): 66 Ma

The rugged terrain of Putorana Plateau on the Taymyr Peninsula in Siberia, Russia is completely formed from the remains of the Siberian Traps. It lies more than 1,000 miles (1,600 km) away from the Kuznetsk Basin giving some sense to the massive scale of this formation.

On an active planet such as ours, change is a constant companion: climates shift, oceans rise and fall, and continents forever churn against each other. Yet life goes on despite all that is thrown at it. It moves and reacts. Over time, life changes; sometimes in radical ways.

But even though life is very resilient, there are times when change is so rapid, widespread, or violently dramatic that it is impossible hold out. During these times, species fall faster than new species can rise to take their place. The cycle triggers even more species to fall in a chain of extinctions. We call these moments Extinction Events, and while they appear to be blips on a chart of time, some can last millions of years and the recovery can take far longer.

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SPECIMEN TYPE:
VOLCANIC ROCK

ESTIMATED AGE:
C. 200,000,000 YEARS OLD

TEMPORAL RANGE:
335,000,000 TO 173,000,000

pangea

"Our planet is a restless home."

– Sean C. Solomon,
Chair NASA Solid Earth Science Working Group, 2002

The hard surface of our planet, the lithosphere, is broken into plates which wander over time. Just over one hundred years ago, in 1912, Alfred Wegener proposed that all the continents once formed a single supercontinent he named Pangea. The basic concepts underlying his continental drift theory were eventually accepted and incorporated into plate tectonics in the 1960s.

However, Pangea is only the most recent supercontinent. Before Pangea there were two supercontinents: Laurasia in the north (North America, Greenland, Europe, and northern Asia) and Gondwana in the south (South America, Africa, Antarctica, Australia and India).

Driven by heat from the core, convection currents churn the solid silicates of the mantle, pushing and pulling the thin plates of crust, bringing continents together and tearing them apart in cycles which can last for hundreds of millions of years. This shifting can also bring several continents into close enough proximity to form a single landmass above sea level. These clusters are known as supercontinents; the most famous of which is Pangea.

Pangea formed roughly 335,000,000 years ago and existed as a single landmass for approximately 160,000,000 years. The breakup came after a series of powerful rifting events in which strong pulses of magma forced continental plates apart at the seams, creating new crust and opening up the basin in which the Atlantic Ocean eventually took shape. Known as the Central Atlantic Magmatic Province (CAMP), the extant remnants of these flood basalts can be found in former rifts located in modern-day Morocco, Southwestern Europe, the Amazon River Basin, and Eastern North America.

As with other major geological events, CAMP was not simply a gentle shifting of landmass. The upheaval correlates with another massive extinction event in the fossil record: the Triassic–Jurassic extinction event. Nearly half of all species on Earth became extinct during this event, and it is considered the final clearing point which allowed the dinosaurs to cement their dominance for the next 135,000,000 years.

The specimen in the Mini Museum is a polished diabase fragment from the Central Atlantic Magmatic Province deposits of Eastern North America. The source rock was donated by the

Luck Stone Quarry adjacent to the Manassas U.S. Civil War battlefield in Northern Virginia. The quarry is a magnificent location where it is possible to clearly see one of the rift valleys which tore through the ancient supercontinent and might once have become the Atlantic Ocean.

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A modern example of our restless home... From the Holuhraun lava field just north of the Vatnajökull ice cap, in Iceland. This 2014 eruption lasted for roughly six months yielding 1.6 km^3 in volume.

With an elongated, non-branching single trunk, cycads resemble today's palm trees. They have evergreen, pinnate leaves and typically either appear compound due to deeply cut leaf margins or have true compound leaves. The seed cones resemble that of conifers, another gymnosperm that has survived to the present day, albeit in much colder climates.

SPECIMEN TYPE:
FOSSIL

TEMPORAL RANGE:
280,000,000 - PRESENT

ESTIMATED AGE:
C. 67,000,000 YEARS OLD

dinosaur food
(cycad)

"Dis-moi ce que tu manges, je te dirai ce que tu es."
[Tell me what you eat and I will tell you what you are.]

– **Anthelme Brillat-Savarin,**
***Physiologie Du Gout, ou, Méditations de Gastronomie Transcendante* (1826)**

The palm-like figure of the Cycad is familiar to fans of classic, paleoart paintings. The extensive presence of these gymnosperms in the fossil record led many early researchers to think of Cycads simply as "dinosaur food," but the current thinking presents a more complex picture of this long-lived family of seed-bearing plants and their relationship with the largest creatures to ever walk the Earth.

The huge bodies of sauropods and herbivorous ornithischians (ceratopsids, ankylosaurids, etc) required a massive amount of energy. To meet these demands, these animals relied on a process of hindgut-fermentation. This digestive model involves rapid cropping and swallowing of plants, which in turn feeds symbiotic bacteria in the gut. This diverse gut flora then processes low-nutrient foods, turning them into products the animal would otherwise be unable to extract on its own.

The fleshy casing of Cycad seeds happen to be one ideal food source to fuel the hindgut-fermentation process. They contain significant amounts of sugar and starch, while the natural toxins found in these seeds limits their consumption by animals without this digestive advantage.

Emerging during the early Permian period, Cycads developed into a diverse and widespread family during the Mesozoic Era, and 300 descendant species can be found in the world today. The specimen in the Mini Museum comes from a fossilized Cycad husk recovered on private land in Wyoming. Part of the Lance formation, this find dates to the Late Cretaceous Period, roughly 67,000,000 years ago.

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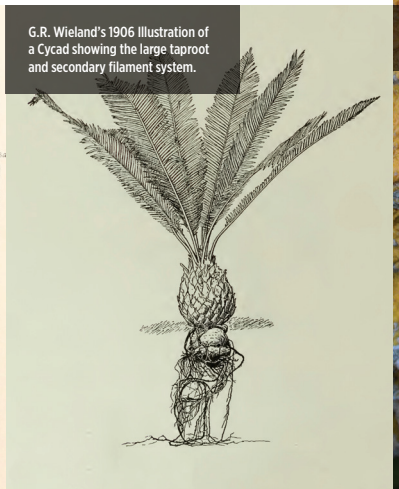
As with many plants of ancient origins, such as ginkgo biloba and conifers, cycads are gymnosperms, or plants which have naked seeds that are directly fertilized through pollination, as compared to flowering angiosperms which enclose their seeds, have a more complex fertilization process, and are more common today. As a dioecious plant, individual plants were either male or female, requiring multiple plants within an area to reproduce, and were typically fertilized by beetles.

During the Mesozoic era, cycads accounted for up to 20% of the world's plant population, with a range stretching from the Arctic to the Antarctic. Combined with other gymnosperms, they dominated the woodlands and forests of the era. They reached a height of approximately five meters, though many of the species had a much shorter, shrub-like appearance.



G.R. Wieland's 1906 Illustration of a Cycad showing the large taproot and secondary filament system.

Bright and beautiful: modern Cycad seed pods

SPECIMEN TYPE:
FOSSIL

TEMPORAL RANGE:
203,600,000-66,000,000
(LATE TRIASSIC THROUGH CRETACEOUS)

MAXIMUM KNOWN LENGTH:
14M (46FT)

plesiosaur
(paddle)

"Like a sea serpent run through a turtle."

– William Buckland,
Oxford University Geology Lectures,
1832

Plesiosaurs, as air-breathing reptiles, lived near the surface in the open seas, and were able to spread around the world. Fossilized skeletons of Plesiosaurs have been found in Europe, North America, and Australia. New paleontological evidence suggests that Plesiosaurs may have given birth to live young instead of laying eggs, adding an interesting twist to a very unique family of reptiles.

Featuring a long, snake-like neck and a stout body equipped with slender paddles, Plesiosaurs are one of the most readily identifiable of all ancient marine reptiles. Biomechanical reconstructions suggest that Plesiosaurs moved through the water in the same way that turtles or penguins do, more like flying than swimming. Scientists have also discovered that Plesiosaurs used their unique bodies to hunt for bottom-dwelling crustaceans.

With global distribution and nearly 140 million years in the fossil record, Plesiosaurs were incredibly successful creatures. To highlight their success, the specimen in the Mini Museum comes from the paddles of two different Plesiosaurs, both recovered on private land but separated by vast distance in both time and location. The first specimen comes from the Lower Oxford Clay in Cambridgeshire, England dating to the Middle Jurassic Period, while the second comes from the Morrison Formation of Utah and dates to the Cretaceous Period.

SOURCES:

Emling, Shelley. The fossil hunter: dinosaurs, evolution, and the woman whose discoveries changed the world. St. Martin's Press, 2009.

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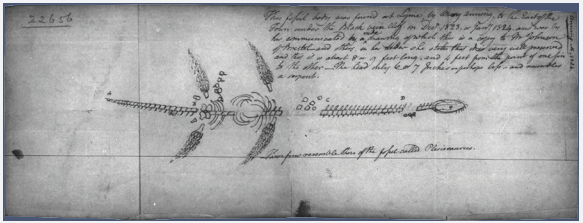

Mary Anning's drawing and letter announcing the discovery of a fossil which would become known as Plesiosaurus dolichodeirus, December 26, 1823

The story of marine reptiles such as the Plesiosaur, not to mention our modern understanding of species extinction, would be incomplete without discussing the contribution of Mary Anning (1799-1847). Ms. Anning was born to a working class family in Lyme Regis, a small town on the Dorset coast of southern England. Like many in the area, Anning's family sold fossils recovered from the cliffs, but for Mary it would become a primary source of revenue and later a connection to the much wider world of science.

Her most notable finds include the first complete Ichthyosaurus and the first two complete Plesiosaurs (the first of which is also credited to her brother Joseph). She is also credited with being the first to recognize the importance of coprolites, and had extensive knowledge of ammonites.

Yet, despite her firsthand experience and deep knowledge of these subjects, Ms. Anning was unable to take part officially in the scientific societies of the day which were only open to men. Her discoveries and observations were instead shared through others, with the one notable exception being her drawing of a complete Plesiosaur. In this instance, the noted French anatomist Georges Cuvier proclaimed the animal a hoax. It would take numerous examinations and debate before Cuvier would reverse his position and admit he'd rushed to judgement.

Ms. Anning died in 1847 of breast cancer. It would take another 163 years for the Royal Society to recognize her influence in the advancement of science.

"The world has used me so unkindly,
I fear it has made me suspicious of everyone."
– Mary Anning

Portrait of Mary Anning by an unknown artist, sometimes referred to as Mr. Grey. In the background is the Golden Cap headland, the highest point on the South Coast of England. Sleeping in the foreground is Tray, Ms. Anning's dog and fossil collecting companion. Tray was trained to sit next to interesting finds while Anning retrieved her equipment from other locations. He perished under a sudden cliff-face collapse in 1833 which nearly took Ms. Anning's life as well.

SPECIMEN TYPE:
FOSSIL

TEMPORAL RANGE:
167,000,000 - 66,700,000

raptor
(dromaeosaurid bone)

"You bred raptors?"

– Dr. Alan Grant, *Jurassic Park*

Fossil discoveries in 1999 confirmed that all dromaeosaurids were probably covered in feathers. This would have included down-like feathers which would have coated the body as well as pennaceous feathers (those with a stalk or quill as illustrated here). Some theropod fossils also include fully developed feathered wings.

Known popularly as "raptors," dromaeosaurids were a diverse family of feathered theropod dinosaurs. Dromaeosaurids first evolved during the mid-Jurassic Period and spread across the globe, where fossils from this family can be found on seven continents.

Within the dromaeosaurid family individual characteristics include a relatively large skull, serrated teeth, a narrow snout, and forward-facing eyes, the latter suggesting some level of binocular vision common to most predators. They had a moderately long S-curved neck and a short body. They were bipedal, walking on their hind legs, their feet bore a large, recurved, scimitar-like claw on the second toe, and their tails were long and slender. Their long arms could be folded next to their body and their large hands had three long fingers ending in sharp claws.

The holotype of Microraptor gui. Preserved feathers indicated by the white arrow and black arrows indicate where they appear to be absent. (Scale bar at 5 cm.)

It has been suggested that at least five dromaeosaurid species had the ability to fly or glide. This possibility is supported by the length of the forelimbs and the evidence of quill knob attachments for long, sturdy flight feathers. The dromaeosaurid, Microraptor gui (pictured above), was equipped with well-developed wings on both hind and forelimbs. Studies have found that Microraptor gui had the physical requirements to sustain level powered flight in addition to gliding.

While this distinctive body plan suggests a link to birds, scientists are still unclear on the exact connection between these two successful evolutionary lines, though there is some evidence that at least five smaller species could glide, if not fly. This possibility is supported by the length of the forelimbs and the evidence of quill knob attachments for long, sturdy, flight feathers.

For many years scientists had hypothesized about group hunting behavior in dromaeosaurids, a natural question given their size in relationship to certain prey. The exciting discovery and analysis of a fossil theropod trackway in 2007 uncovered six parallel and closely spaced trackways.

Elsewhere, theropod fossils have been uncovered in small groups, sometimes near the remains of herbivore dinosaurs. This has been taken as evidence of coordinated packs working together to hunt. However, other interpretations suggest that the theropods were solitary hunters which were drawn to previously killed carcasses; a mobbing behavior.

The specimen used in the Mini Museum was selected from several species recovered in both Morocco and North America. Like birds, dromaeosaurids had a global distribution and varied widely in size, from smaller than a modern day chicken to large, powerful predators measuring more than 18ft (6m) in length from tooth-to-tail.

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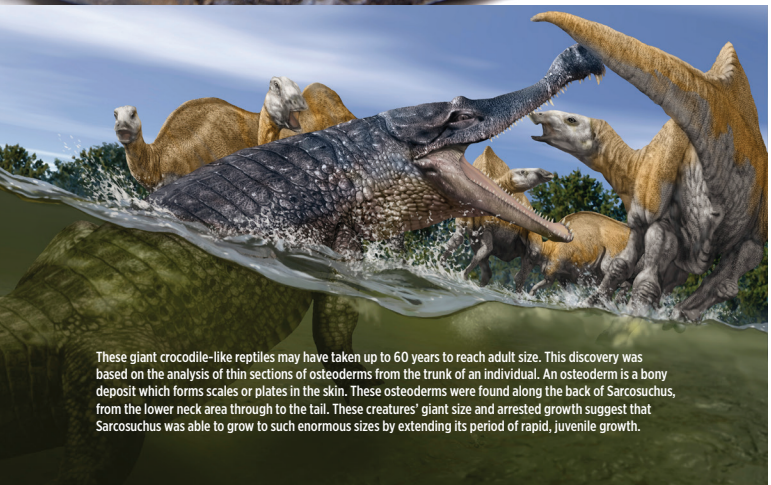
Species in the family ranged in size from smaller than a modern day chicken to large, powerful predators measuring more than 18 ft (6 m) in length from tooth-to-tail. In addition to being feathered, members of Dromaeosauridae had long tails and an elongated "sickle claw" on the second toe. Numerous studies suggest that these adaptations helped these predators quickly subdue their prey.

Size chart of different well known dromaeosaurs: Microraptor gui, Velociraptor mongoliensis, Austroraptor cabazai, Dromaeosaurus albertensis, Utahraptor ostrommaysorum, and Deinonychus antirrhopus. (Image Credit: Fred Wierum)

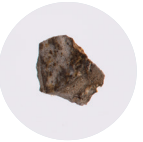


These giant crocodile-like reptiles may have taken up to 60 years to reach adult size. This discovery was based on the analysis of thin sections of osteoderms from the trunk of an individual. An osteoderm is a bony deposit which forms scales or plates in the skin. These osteoderms were found along the back of Sarcosuchus, from the lower neck area through to the tail. These creatures' giant size and arrested growth suggest that Sarcosuchus was able to grow to such enormous sizes by extending its period of rapid, juvenile growth.

SPECIMEN TYPE:
FOSSIL

ESTIMATED AGE:
C. 112,000,000 YEARS OLD

ADULT LENGTH:
11 - 12M



mega croc
(sarcosuchus armor)

"How cheerfully he seems to grin,
How neatly spreads his claws,
And welcomes little fishes in,
With gently smiling jaws!"

– Lewis Carroll (1832-1898)
The Crocodile, 1865

Sarcosuchus was an enormous, crocodile-like, aquatic reptile that dominated freshwater rivers and lakes of the Middle Jurassic Period through the Early Cretaceous Period.

As a predator Sarcosuchus (meaning "flesh crocodile") had a large, elongated head which was dominated by the long snout (75% of its skull length) which contained 35 teeth on each side of the upper jaw and 31 teeth on each side of the lower jaw. These teeth were stout, smooth crowns which did not interlock. The end of the snout was expanded in what is known as a bulla, the purpose of which remains unresolved.

With the largest species reaching nearly 40 feet in length (11-12 meters) and weighing close to 8 metric tons, it should come as no surprise that Sarcosuchus feasted on a wide range of prey. A generalized diet has been proposed to best fit the style of dentition found in Sarcosuchus skulls, including fish and terrestrial dinosaurs which would have been abundant in Sarcosuchus' native habitat. The stratigraphy at the locations of fossil discoveries suggest Sarcosuchus would have lived in an inland fluvial, or shallow lacustrine environment. This was specifically a freshwater habitat and would have had a humid tropical climate.

The specimen in the Mini Museum is a fragment from a Sarcosuchus scute (dermal armor) recovered from the El Rhaz Formation in Niger. As with other crocodyliforms, scientists use the growth rings found in bony scutes, also referred to as osteoderms, to determine the rough age of the animal.

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Skeleton of Sarcosuchus Imperator, exhibition in the National Museum of Natural History in Paris (Image Credit: Sergey Skleznev)

Smilodon fatalis was the middleweight member of the genus, about the size of a lion, but more robust in build. Robustness is an overall Smilodon trait, as are the oversized canines. These characteristics distinguish many of the so-called "dirk-toothed cats," the sabertooth tribe to which Smilodon belongs. The other category of sabertooth felids, the "scimitar-toothed cats," had shorter, broader canines and, in many cases, a somewhat lighter build than Smilodon.

SPECIMEN TYPE:
FOSSIL

TEMPORAL RANGE:
1.6M - 10K

saber-tooth tiger
(smilodon bone)

"If you think about it, Smilodon fatalis likely left their paw prints on what is today Hollywood Boulevard long before Marilyn Monroe left her handprints at the Chinese Theater."

– Z. Jack Tseng, Paleontologist of the American Museum of Natural History

With twin, serrated, canine teeth measuring 8 inches (20 cm) and backed by 600 pounds (275 kg) of muscle, Smilodon fatalis is one of the most iconic animals of the Pleistocene Epoch. While the look of this stocky animal gave rise to its popular name, saber-tooth tigers are only distantly related to modern big cats.

There were three different species of Smilodon. Smilodon gracilis is the earliest-known and smallest member of the genus with the oldest fossils dating to 2,500,000 years ago. It likely descended from the sabertooth Megantereon, which colonized North America from Eurasia. Smilodon gracilis reached South America about 1,000,000 years ago and gave rise to the largest Smilodon of all, Smilodon populator, a massive beast that approached 900 pounds and roamed east of the Andes, from Venezuela south to Patagonia.

The highest-profile species in the genus, Smilodon fatalis, is primarily recorded in North America, where it competed with giant short-faced bears, dire wolves, American lions, and other formidable fellow Pleistocene carnivores. Smilodon fatalis also strayed into western South America, separated by the Andes from its larger cousin, Smilodon populator.

Smilodon's short, muscular legs, a stocky frame, and those enormous sabers lead many paleontologists to suppose these cats were ambush hunters of large mammals such as bison and juvenile mammoths and mastodons. While scientists aren't entirely sure of its exact predatory methods, a leading theory suggests Smilodon reached its quarry with a short burst of explosive speed and seized it with one paw over the shoulder or back and another twisting the victim's head.

Such a grappling move would expose the prey's throat, and a slash by Smilodon's sabers could then efficiently cut the carotid artery and/or jugular. Some biomechanical models suggest that Smilodon might have relied on those powerful neck muscles to sink their long teeth into prey. Both theories are quite different than using bite force to crush the windpipe as cats do today.

The specimen in the Mini Museum comes from a pair of Smilodon fatalis femurs recovered on private land in Florida. This species of Smilodon ranged across North America and into the western half of South America for roughly 1.5 million years, finally succumbing with other megafauna during the Quaternary Extinction Event 10,000 years ago.

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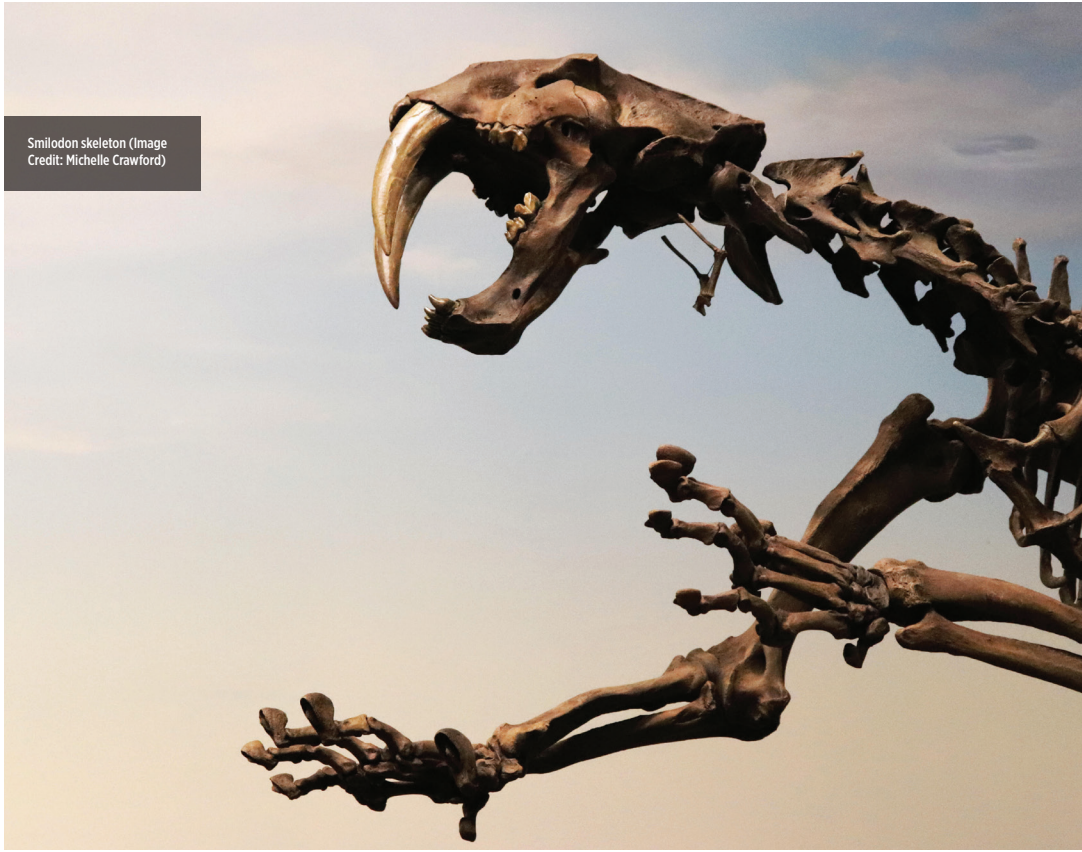


Smilodon skeleton (Image Credit: Michelle Crawford)

SPECIMEN TYPE:
FOSSIL

TEMPORAL RANGE:
3,000,000 - 0.011

SIZE:
6-7 FEET LONG (2M)

INCISOR SIZE:
6IN (15CM)

giant beaver
(castoroides tooth)

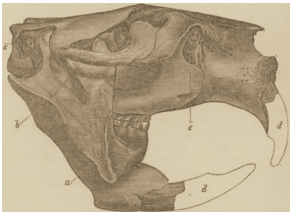
"The rodents of unusual size? I don't think they exist."

– **Westley, aka The Dread Pirate Roberts,** ***The Princess Bride,*** **1987**

Important morphological differences exist between Castoroides and its modern cousin, Castor. The Giant Beaver's incisors, which reached six inches (15cm) in length, were blunt-tipped as opposed to Castor's chisel teeth. This suggests Castoroides didn't gnaw through trees and construct dams as the modern American beaver does. The giant beaver's proportionately smaller, smoother brain also hints that it may not have exhibited complex social behavior.

Modern American and Eurasian beavers are both impressively hefty rodents, outsized only by the South American capybara. Yet the 70 or so pounds (~32 kg) these industrious aquatic mammals attain make them relatively tiny compared to a Pleistocene Epoch counterpart: Castoroides. Popularly known as the Giant Beaver, Castoroides was about the size of a modern black bear, weighing roughly 220 pounds (100 kg) and measuring more than 7 feet (2.5 m) without their long, flat tails.

Two species of Castoroides inhabited North America: C. leiseyorum, found only in Florida, and the much more widespread C. ohioensis, whose fossils have been recovered from a broad range of places in Alaska, Canada, and the continental United States, though they're most abundant along the southern edge of the Great Lakes in present-day Illinois and Indiana.



Castoroides appears to have favored marshes and swamp-edged lakes. One 2001 study reconstructed the paleo-environment of a female C. ohioensis that died some 10,000 years ago in northeastern Indiana; this giant beaver apparently inhabited a bulrush marsh/wet meadow ringed by boreal-style conifer forest.

The specimen in the Mini Museum is a fragment of a Giant Beaver incisor recovered on private

land. While we might imagine Castoroides using these mighty teeth to fell enormous trees, their blunt ends suggest the Giant Beaver lived as muskrats do today, feasting on softer, leafy plants rather than building dams and lodges.

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Both elephants and mammoths cycle through several sets of molars throughout a lifetime as their diet of coarse plant matter wears old teeth down, replaced by new teeth erupting behind.

The high-crowned molars of woolly mammoths are pleated with ridges of enamel: somewhat similar to the dentition of the modern Asian elephant, but distinct from the fewer, diamond-shaped, enamel plates of the African elephant. The morphology of mammoth teeth and the distribution of mammoth remains suggests mammoths were predominantly grazers subsisting mainly upon grasses and sedges, a diverse biomass that the modern Arctic tundra doesn't approach.

SPECIMEN TYPE:
FOSSIL

EXTINCTION OF WOOLLY MAMMOTH:
C. 10,000 BCE

DISAPPEARANCE OF DOGGERLAND:
C. 6,500 BCE

doggerland mammoth (tooth)

"Doggerland was the real heartland of Europe until sea levels rose to give us the coastline of today."

– Dr. Richard Bates, Geochemist,
St. Andrews University

Great Britain was not always an island. During the Pleistocene, it was the northwest peninsula of the European continent. Bounded to the north by steep walls of ice, the land between was home to a steppe ecosystem full of life. Now lost beneath the waves of the North Sea, this phantom countryside is known as Doggerland.

From recovered artifacts and core samples, scientists have managed to piece together a widespread prehistoric ecosystem in Doggerland referred to as a "mammoth steppe," a cold grassland quite distinct from the tundra that today dominates the ice-free reaches of the Arctic. The steppe existed as the result of an intricate, self-perpetuating interplay between native grasses and their grazers, which included woolly mammoths as well as horses, bison, saiga antelope, reindeer, and woolly rhinoceroses. Lions and cave hyenas were among the dominant carnivores, along with Doggerland's various human residents (Neanderthals and modern humans).

Given rising sea levels in our current age, the ultimate destruction of Doggerland is a topic of intense interest. Recent studies suggest that Doggerland lost ground slowly at first as seas rose, then a series of more dramatic events forced an exodus. Lake Agassiz, a prehistoric glacial lake in North America equal in size to all the modern Great Lakes, emptied into the ocean causing a massive rise in global sea levels. This was followed by an undersea collapse in Norway, known as Storegga Slide, which displaced 3,500 cubic kilometers (840 cu mi) of debris and produced an enormous tsunami. By 7,000 to 6,000 BCE, the land bridge was no more and the North Sea cut Great Britain off from Europe.

Submerged Forests: The first conceptual maps of Doggerland created by British Geologist and Paleobotanist, Clement Reid in 1913. The boundaries are still considered accurate today.

The specimen in the Mini Museum is a fragment of a woolly mammoth tooth recovered from the lost world of Doggerland. Like other Pleistocene megafauna, the Woolly mammoth vanished from most continental regions roughly 10,000 years ago. A few mammoth refuges persisted awhile longer, including small, isolated populations on Alaska's St. Paul Island and on Russia's Wrangel Island, until perhaps 4,000 years ago.

Doggerland is named after the "Dogger Bank," a large sandbank which rises 20 meters (66 ft) from the seafloor and extends over 17,600 square kilometers (6,800 square miles), which in turn was named for the medieval dutch cod fishing vessels, known as "doggers," which once plied these waters just as modern fishing trawlers do today. The region is now a fertile fishing ground which occasionally yields remains from a long vanished world of Neanderthals and megafauna like the woolly mammoth.

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The interior of a mammoth tooth, taken while preparing specimens

Coastal concentrations of Elephant Bird eggs raise the possibility that Aepyornis nested communally. Eggs and juvenile elephant birds may have been vulnerable to now extinct predators, such as giant fossa or the Malagasy crowned eagle. Yet given their size, adults likely had little to worry about from other creatures—except, perhaps, human beings.

(Image: Nesting Aepyornis illustration, Scientific American Supplement No. 1308, January 26th, 1901)

SPECIMEN TYPE:
EGGSHELL

ESTIMATED EGG WEIGHT:
22 POUNDS (10 KG)

elephant bird
(aepyornis eggshell)

"So why did the Elephant Bird disappear? I suspect it was these.... its eggs. People may not have been able to tackle an adult bird but they could take its eggs which were a huge source of nourishment."

– Sir David Attenborough, *Attenborough and The Giant Egg,* 2011

Aepyornis, popularly known as the Elephant Bird, was the largest member of an extinct family of flightless birds native to the island of Madagascar. Some individuals stood nearly 10 feet tall (3m) and weighed upwards of 1,100 pounds (500 kg).

Elephant-bird eggs outsize any other bird eggs known, with volumes approaching 1.9 gallons (7L). At 160 times that of an average chicken, these are the heftiest eggs of any vertebrate, including dinosaurs.

Such imposing figures may conjure ideas of an enormous ostrich or even the savage "terror bird" of the late Paleocene, but researchers believe that these giants were more like their distant (and much, much smaller) cousins, the kiwi. Given their physical bulk, scientists believe they moved slowly through the forests of Madagascar, browsing and splitting tough fruits with their heavy, pointed bills, until their extinction approximately 1200 years ago.

One common theory for the disappearance of elephant birds is the arrival of humans in Madagascar some 2,000 years ago. Fragments of elephant-bird eggs have been found in archaeological sites; some elephant-bird bones show the scoring of knives. Some scientists question this hypothesis, suggesting such evidence for human hunting of elephant birds is sparse, but it would be difficult to question the nutritional value of such an enormous egg.

The agent or agents of extinction for the elephant bird aren't entirely known; neither is the exact period of their disappearance. In 1658,

a French colonial governor of Madagascar, Etienne de Flacourt, made an intriguing reference to an enormous bird, the *vouropatra*, inhabiting remote portions of southern Madagascar, which suggests that at least one species of Aepyornis may have survived a bit longer.

Aepyornis Egg Comparison, Scientific American Supplement No. 1308, January 26th, 1901

"A large bird, called the 'vouropatra' haunts the Ampatres. It lays eggs like the ostriches; but in the loneliest places so that the people of these places may not take them."

The specimen in the Mini Museum is a fragment of an Elephant Bird eggshell generously donated from the personal collection of renowned Australian art dealer and long-time supporter of Mini Museum, Hank Ebes.

SOURCES:

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Examining Elephant Bird Eggshell fragments

Encompassing 592,000 square kilometers (228,000 sq mi), Madagascar is the fourth largest island on Earth. From mangrove swamps and tropical shores, to grassy plains and high plateaus, this diverse ecosystem evolved in isolation for 88,000,000 years. As a result, most of the plants and animals found on Madagascar are unique to the island.

SPECIMEN TYPE:
LIQUID WATER

TOTAL LENGTH:
4,300 MILES (6,900 KM)

ESTIMATED FORMATION:
C. 55,000,000 YEARS AGO

amazon river

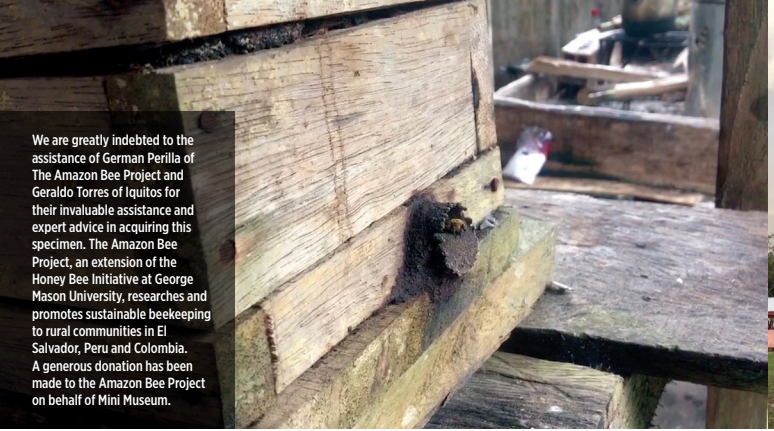
"Have I forgotten the Amazon, Earth's greatest river? Never, never, never. It has been burning in me for half a century, and will burn forever."

– Naturalist John Muir (1838-1914)

With headwaters located high in the Peruvian Andes, just 100 miles from the Pacific Ocean, the Amazon river gathers strength from over 1000 tributaries as it flows for more than 4,300 miles (6,900 km) across the South American continent. On meeting the Atlantic Ocean, this mighty river discharges 7.7 million cubic feet of water per second, drowning its nearest competitor, the Congo, by a factor of five. The river's massive, 2.7 million square mile basin (7 million square km) is home to the Amazon rainforest, the largest collection of living species on the planet.

Bound by the ancient Guiana Highlands to the north, and its unique tepuis or "table-top" mountains which rise from the jungle below, and the rolling hills of the Brazilian Plateau to the south, the Amazon basin may seem timeless. Yet like much of the Earth's surface, the region has undergone many changes. Mountains have risen and fallen. Water has crossed the continent in both directions. Unique forms of life have taken shape here, and newcomers have been nurtured by the landscape.

During the Cretaceous Period, the Eastern Highlands rose during the separation of the South American and African continents, sending water westward toward the Pacific. During the Miocene Epoch, water actually flowed both ways from a low ridge in the center of the continent known as the Purus Arch. Later, as the Andes began their rise, a significant portion of the western continent was a massive, enclosed wetland encompassing 1,000,000 sq km (390,000 sq mi). The Purus Arch later succumbed to millions of years of pounding water, and the river broke free carrying Andes



We are greatly indebted to the assistance of German Perilla of The Amazon Bee Project and Geraldo Torres of Iquitos for their invaluable assistance and expert advice in acquiring this specimen. The Amazon Bee Project, an extension of the Honey Bee Initiative at George Mason University, researches and promotes sustainable beekeeping to rural communities in El Salvador, Peru and Colombia. A generous donation has been made to the Amazon Bee Project on behalf of Mini Museum.

sediment to the Atlantic 11,000,000 years ago.

The silt-heavy Andean tributaries of the Amazon are called "whitewater" rivers; tributaries sourced in the Guiana Highlands and the Brazilian Plateau, meanwhile, are either "blackwater" rivers, stained dark by humic acids, or clearwater rivers that carry little suspended sediment.

The Amazon's largest tributary, the Rio Negro, is a blackwater river, and at Manaus, Brazil it empties into the mainstem in the famous "Meeting of the Waters," its warmer, darker outflow clearly demarked against the whitewater current for several miles before mixing. Similar "meetings" occur in many places, but few are quite as dramatic.

As the river approaches the sea, the Amazon splits into many distributaries forming a great estuary that approaches 200 miles across and encompasses the gigantic island of Marajo. Strong Atlantic tides and currents discourage the formation of a delta at the Amazon's mouth, but its plume of freshwater reduces the ocean's salinity as far as 200 miles offshore.

Most studies suggest that humans first entered the Amazon Basin 10,000 years ago. Until very recently, researchers assumed that the people were few in number, living nomadic lives which had very little impact on the natural landscape. New botanical studies have shown that humans living in the Amazon were far more numerous than expected, and likely had a tremendous impact on plant diversity going back thousands of years. In a paper published in March of 2018, archeologists revealed 81 sites using LiDAR surveying systems which show a complex culture of earthwork building existed in the southern Amazon. Population estimates for this region alone have exceeded more than 1,000,000 people.

These new discoveries suggest that we have much more to learn about the history of this incredibly diverse resource, but we may be running out of time. Nearly 20% of the rainforest in the Amazon basin has been lost, as deforestation and development during the latter decades of the 20th century have stripped away 750,000 sq km (290,000 sq mi). Vast and rapid migration of indigenous people to urban areas have left even more of the landscape vulnerable to destruction.

It will be a difficult road ahead, but there are signs that conditions may improve. While deforestation is ongoing, the volume of land lost each year has declined as governments have put new policies into place. Numerous programs, such as the Amazon Bee Project, are working to enable indigenous people to stay connected to their lands and improve their quality of life without relocation. These are positive steps, but maintaining the progress and reversing the damage will take decades of focus and attention. This might seem like a long time in human terms, but in the scope of a landscape like the Amazon it is a drop in the bucket.

The specimen in the Mini Museum is a small vial of Amazon river water personally collected by Hans near Iquitos, Peru. Iquitos is known as the "Peruvian capital of the Amazon." The Amazon mainstem's broad and deep channel allows oceangoing ships to travel more than 2,000 miles upriver to Iquitos, which has the distinction of being the largest city on Earth which is only accessible by air or water.

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Identifying its ultimate source in the Andes has fueled exploration well into the 21st century: For decades geographers pinpointed either Carruhasanta or Apacheta creeks in the Rio Apurimac drainage, running off the slopes of Nevado Mismi, but a 2014 study suggests that the true source may lay at the head of the Rio Mantaro—an Apurimac tributary—in the Cordillera Rumi Cruz.

NASA image created by Jesse Allen, using SRTM data provided courtesy of the University of Maryland’s Global Land Cover Facility, and river data provided courtesy of the World Wildlife Fund HydroSHEDS Project

Geological studies suggest that the land around Stonehenge might have been somewhat barren of trees, as it sits on a bed of Late Cretaceous chalk. Whether this had an impact on the selection of Stonehenge as a ritual site is still a matter for debate, but this discovery has enlivened the current debate about the possibility of a tunnel under the site to alleviate modern traffic on the A303 (estimated cost of £1.6 billion). Tunneling through the chalk is a straightforward process, but the length of the tunnel could require ventilation shafts which would pass up and through layers of history set down over thousands of years.

SPECIMEN TYPE:
ROCK

ESTIMATED INSTALLATION AT STONEHENGE:
2500 BCE

stonehenge
(bluestone quarry)

"The stones are great, and virtue they have."

– Laȝamonn, Brut 1190

Of the numerous megalithic stone structures found throughout the British Isles and Continental Europe, Stonehenge is arguably the most famous. Yet despite the timeless familiarity of its iconic image, the site is still yielding new discoveries about the history of people throughout the region and their place in the landscape.

The purpose of Stonehenge has inspired numerous hypotheses over the centuries. Is it a celestial calendar? Maybe a burial ground or a place of healing? Perhaps all of these things are true, or at least were true at one point or another, but it is difficult to say. What we do know is that new technologies have presented a complex picture of continual change as new people and new cultures passed through the region, and each would likely have different reasons for using the site.

The concentric rings of local Sarsen stone and Welsh bluestone that we identify today as Stonehenge were erected between 2400 and 2200 BCE, and replaced earlier wooden structures, but Stonehenge is actually part of a massive complex of monuments, burial grounds, and ritual sites.

The oldest of these early structures are more than 10,000 years old, and many are quite fantastic in their own right. For example, the Greater Cursus is a massive earthwork enclosure 2.7 kilometers long (1.7 miles). Radiocarbon dating of found artifacts inside suggests it was constructed between 3630 and 3375 BCE.

The specimen in the Mini Museum is a fragment of dolerite bluestone recovered downstream from the quarry at Craig Rhos-y-Felin on the banks of Afon Brynberian. Located on the

Plan of the central Stone Structure at Stonehenge as it survives today. Stone numbers are those conventionally used in the recent literature and following Petrie, F. 1880. (Image Credit: Anthony Johnson, 2008)

The quarry at Craig Rhos-y-Felin with archaeological excavations exposing thousands of years of human activity layer by layer. (Image Credit: Mike Parker Pearson)

northern flank of the Preseli Mountains near Pembrokeshire, the Craig Rhos-y-Felin quarry was an active site for thousands of years, with the earliest known human encampments dating to 8,500 BCE. Research suggests that stones extracted from this quarry migrated from site to site, "borrowed" for different uses, and radiated outward over time until being used at Stonehenge some 140 miles away.

This practice of "borrowing" of stones has been a question of some debate for decades. Numerous studies of other megalithic sites have shown clear evidence that ritual stones were moved as populations migrated to new regions. As further confirmation of this hypothesis, a 2018 study of genetic material from remains found at Stonehenge indicates that the people who erected the stones were indeed from the same part of Wales before they themselves were replaced by a new wave of migrants from Europe as part of the expansion of the "Beaker Culture."

SOURCES:

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A very special thank you to Tom Kapitany of Crystal World for his invaluable assistance in acquiring this unique specimen. Tom is a world-class adventurer who uses his in-depth knowledge of the natural world to enrich museums around the globe. He is also an amazing human being who occasionally can be found in volcanoes!

James Ferguson's 1872 drawings of the structures in the vicinity of Stonehenge.

SPECIMEN TYPE:
HUMAN ARTIFACT

ESTIMATED AGE:
1ST MILLENIUM BCE

ESTIMATED FIRING TEMPERATURE:
+800 °C (1472 °F)

mummy beads
(1st millenium BCE)

"If people can write to each other across space, why can they not write across time too?"

- Ahdaf Soueif, *The Map of Love*

Jewelry, clothing, and other forms of adornment, including beads, were powerful markers of culture and social standing. Faience beads in ancient Egypt were luxury items valued as semi-precious objects, and wearing them was a sign of wealth. Foreign kings and queens searching for ways to legitimize their rule to the masses frequently adopted visible elements of what they perceived to be Egyptian culture. Wearing jewelry and clothing featuring faience beads became a way for non-native rulers to tell a story emphasizing their ties to Egypt.

In the largely pre-literate ancient world, colors had intense cultural, social, and communicative value. The vibrant blues and blue-greens of Egyptian faience were no exception. For Egyptians, the bright shimmery blue of these objects spoke of the heavens, water, life, and rebirth. The color was imbued with spiritual significance and a sense of magic.

Faience first emerged in Mesopotamia during the 5th millennium BCE. Egyptian artisans began working with it the following millennium. During the Predynastic Era, production techniques were relatively simple. Craftsmen shaped objects by hand, then carved and abraded them to create detail after the drying process was complete. A copper-infused glaze applied before firing gave Egyptian faience its characteristic shine and color. The Egyptian word for this material speaks volumes. They called it "tjehenet" which roughly translates to dazzling or brilliant.

The middle of the 2nd millennium BCE witnessed an explosion of faience production in Egypt. Artisans began using clay molds to work with the material, and a new method of glazing, efflorescence, became popular. Instead of applying glaze after the shaping of an object, craftsmen began including glazing materials in the paste itself. The use of molds and the innovation of adding glaze directly to the paste led to the mass production of faience products, including rings, amulets, and tiles.

The history of faience is tightly linked to the importance of visual symbols in a world in which most people could neither read nor write. Elites relied on visual imagery to communicate their wealth and legitimize their

power. Ancient Mesopotamians were fond of using gold for this purpose. The scarcity of gold in Mesopotamia led to the development of trade routes designed to obtain the precious metal. Egypt had the gold the elites of Babylon and other Mesopotamian city-states wanted. Artisans familiar with faience production and faience objects themselves flowed along trade routes and eventually made their way to Egypt.

The specimen in the Mini Museum is a selection of mummy beads spanning several eras from the 1st millennium BCE. The beads were acquired from the former collection of Simon Ohan Simonian, an antiquities dealer in Alexandria, Egypt throughout the 20th century.

SOURCES:

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Shaw, Ian, ed. The Oxford History of Ancient Egypt. Oxford University Press, 2000.

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Egyptian faience is made of silica, ash, and lime. The silica came from sand or quartz pebbles, natron or ash provided the alkali, and limestone contributed the lime. Craftsmen would pulverize the materials, combining them with copper, cobalt, magnesium, and other metals to create a powder which they then made into a malleable paste. When fired, metallic oxides migrated through the porous material, cooling at the surface, and leaving behind the rich colors and glass-like surface.

While there are no records concerning the efficiency of the hypocaust, modern masonry heaters work on a similar principle and are quite efficient. Fired once or twice per day, the heat warms the tiles and concrete which is then slowly released into the home.

In practice, hypocausts were very expensive to build and maintain. As such, most Roman homes only heated one or two rooms. However, in northern parts of the empire, such as Britain and Germany, radiant heat was considered indispensable and entire homes would be constructed to take advantage of the hypocaust.

The collapse of the Roman empire also brought the end of the hypocaust. By the 5th century CE, heating reverted to inefficient open fireplaces for roughly a thousand years.

SPECIMEN TYPE:
HUMAN ARTIFACT

ESTIMATED DATE OF HYPOCAUST INVENTION:
1ST CENTURY BCE

roman bath
(hypocaust flue)

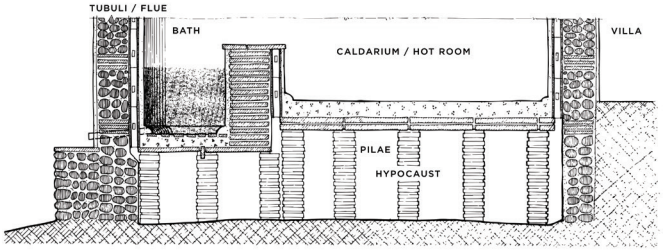
"Our ancestors did not think that one could have a hot bath except in darkness."

– Seneca the Younger, Moral Letters to Lucilius Epistulae Morales ad Lucilium, 65 CE

Baths and the culture of public bathing stood at the center of social life throughout the Roman Empire. By the end of the Republic, most Roman citizens' lives included a daily trip to the baths. Men, women, and children spent their afternoons relaxing at these institutions. They were social gathering spaces-places to come together with others for rest, relaxation, entertainment, medical treatments, and good old gossip. The grandest structures included libraries, art displays, and areas for lectures. Cities had small local *balinea* and grand breathtaking *thermae*. By the last decades of the 4th century C.E., bathers could choose between at least 10 monumental bathing complexes in the city of Rome.

The baths were open for business every day, except on the rare occasions when they required regular maintenance. Bathing usually took place during the afternoon. Most Romans, except for children, paid for the privilege of visiting the baths. Supporting local establishments, either through paying for fuel, or subsidizing entrance fees, was a popular patronage activity for wealthy Romans. Emperors funded free bathing for all when politically expedient. Food stalls and massage specialists paid for space in large urban complexes, and their rental payments helped support the running of these large public gathering spaces.

Roman bathing was a leisurely activity with a variety of relaxation options. Visitors removed their clothing and left them in *apodyteria*. *Frigidaria* welcomed those interested in taking a dip in a pool of cool water, and *caldaria* invited those craving the exact opposite.



Outdoor *palaestrae* beckoned avid fitness enthusiasts, while *laconica* and *sudatoria* provided sauna-like experiences. Practitioners offered massages with fragrant oils in *unctoria,* and activities involving the scraping off of oil with strigils took place in *destrictaria*.

Hypocaust systems warmed most monumental urban baths by delivering heat to the floors and walls of these structures. Warm air circulated freely under the floors and rose through the walls to create a warm feeling of radiant, enveloping heat. Hot air from fires burning in *praefurnia,* or heating rooms, passed through spaces under bathhouse floors and rose through tubes in the walls to create one of the earliest forms of indoor heating. Heated floors and walls meant Roman baths could have windows—an innovation which decreased the development of condensation. *Praefurnium* fires also heated the water of the *caldarium.*

The specimen in the Mini Museum comes from a section of Roman Hypocaust box flue *(tubuli)* purchased from a private dealer of antiquities. Developed during the first century CE, the box flue was formed from a single piece of thick clay which was wrapped around a solid mold. Once fired, stacks of these hollow, rectangular ceramics formed the core of Roman bathhouse walls.

SOURCES:

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Bernan, Walter. "On the History and Art of Warming and Ventilating Rooms and Buildings, 2 vols." London 11 (1845): 95.

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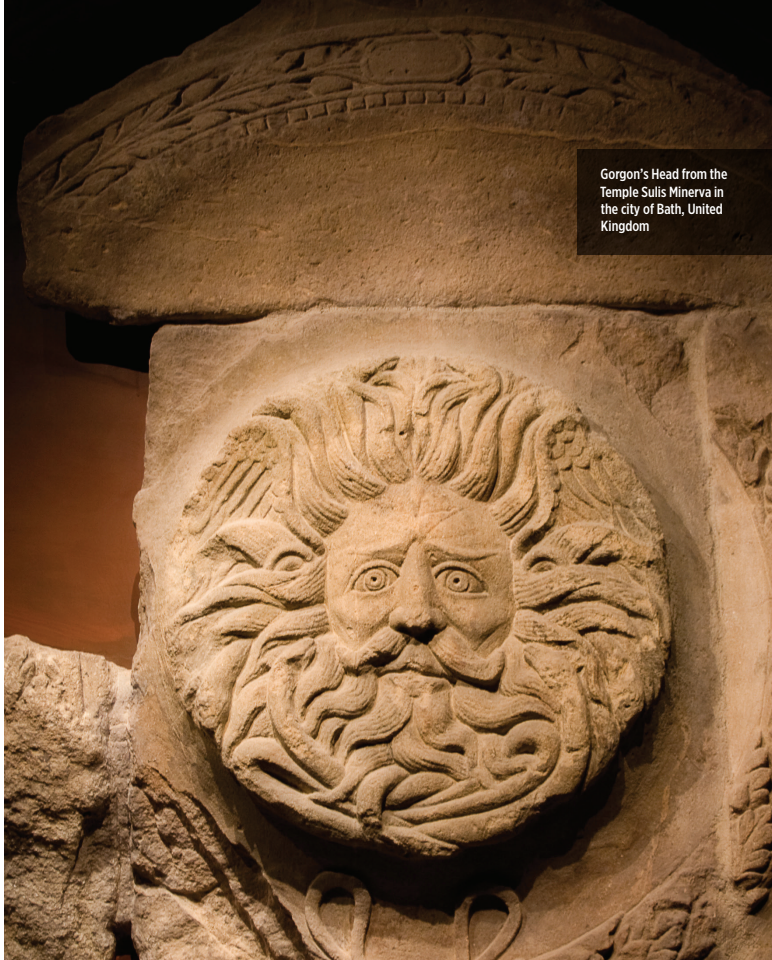

Gorgon's Head from the Temple Sulis Minerva in the city of Bath, United Kingdom

Our modern knowledge of medieval swords is indebted to the work of Ewart Oakeshott (1916–2002). As is the case today, fashions and technology changed often in the middle ages. Oakeshott spent much of the mid-twentieth century identifying different sword typologies and building a detailed system which is the standard by which swords are assessed, classified, and dated. Under the Oakeshott system, this sword is classified as Type XIIIa. This style of sword is typically of German origin and sometimes described as Grans espeès d'Allemagne or "Big Swords of Germany."

SPECIMEN TYPE:
HUMAN ARTIFACT

ESTIMATED AGE:
LATE 13TH CENTURY CE / EARLY 14TH CENTURY

SWORD TYPE:
OAKESHOTT XIIIA

knight's sword
(14th century BCE)

"Conquest I saw, enthroned in majesty,
But with sharpened sword above his head
Suspended by a single thread."

– **Geoffrey Chaucer, The Knight's Tale from *Tales of Canterbury,* 1387 CE**

Though many battles raged throughout the "long thirteenth century" of the High Middle Ages, scholars often refer to this century as a time of relative peace. This did not mean knights could retire on their estates. Eager kings looking to extend their authority, continued military campaigns to the Holy Land, and a growing professionalization of warfare all combined to keep the European knight reliant on the tools of their trade: horse, armor, and sword.

Between 1000 and 1300, fourteen different types of sword were in use, all of them consisting of a straight, two-edged blade with blunt tips, designed for cutting and hacking rather than thrusting. By the thirteenth century, the knightly (or arming) sword became the standard, with a blade between 30 and 32 inches long (~80 cm), and weighing about 2.5 to 3.5 pounds (~1.5 kg) in total.

Contrary to depictions in popular movies and television shows today, these swords were very maneuverable, owing to their light weight and the emphasis placed on balance during the manufacturing. Because the sword was meant to be wielded with one hand, sword smiths weighted the blade toward the hilt, where the knight gripped the sword. Additionally, heavy pommels, often shaped as discs and perhaps containing a relic or precious stone in very luxurious examples, helped to counteract the weight of the long blade. A crosspiece, either straight or curved, separated the hilt from the blade, placed there to protect the knight's hand from an opponent's blade that might slide along his sword in the heat of combat. The grip normally consisted of two pieces of wood glued

together and perhaps wrapped with leather.

Each sword was individually crafted by a smith who had developed the tricky art of sword making over time through apprenticeship, trial, and error. Because a sword had to be strong to make an effective cut, yet remain flexible so as not to shatter on impact, smiths experimented with forging blades from steel, created by adding carbon (usually from charcoal) with iron. During the forging process, the smith had to shape the metal, ensuring a softer, more flexible core, while the edges and point needed the harder steel. After the sword was forged, it needed tempering, a process of hardening the blade by slowly heating and then rapidly cooling it in a bucket of water or oil. Without the benefit of standardized measuring instruments or even precise timing implements, smiths often developed their own techniques, making each sword unique.

Sword makers and owners recognized and promoted the unique aspect of a sword through inscriptions chiseled along the fuller (the middle section running the length of the blade) or by naming the sword. Inscriptions fall into three main categories: the maker's name, a religious or spiritual message (such as in nomini domini, in the name of the Lord), or an as-yet indecipherable grouping of letters.

The great expense and time needed to make a sword meant that it became a family treasure, often passed down for generations, though new swords were obviously made throughout the period. A young boy might receive a sword at various points in his life, such as at birth or during his knighting ceremony.

The specimen in the Mini Museum is a fragment of a knight's sword dating to the late 13th / early 14th century CE. For the last 200 years the sword was held in a private family collection in France until recently acquired by a private dealer of antique arms in the United Kingdom.

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Folio 23 from the Maciejowski or Morgan Bible, c. 1290 CE

Pictured here is the Aztec calendar stone, also known as "the Sun Stone," one of the most famous artifacts of post-classical Mexicà culture. Currently housed in the National Anthropology Museum in Mexico City, the piece was buried shortly after the Spanish conquest in the Zócalo (the main square of Mexico City). It was rediscovered in 1790 and is now housed in the Museo Nacional de Antropología (National Anthropology Museum) in Mexico City, Mexico.

The term "Aztec" is sometimes credited to the 17th century scientist and adventurer, Alexander Von Humboldt (1769-1859), but this term and similar words are mentioned in numerous early histories of the region, both in Spanish and in the native Náhuatl language. Of these, the Crónica Mexicayotl produced in the 16th century by Chimalpahin is perhaps the earliest account of the Mexicà people (Mëxihcah) who would come to dominate the Triple Alliance.

SPECIMEN TYPE:
HUMAN ARTIFACT

ESTIMATED AGE:
15TH CENTURY CE

FOUNDATION OF THE AZTEC EMPIRE:
1427

END OF THE EMPIRE:
1521

FINEST OBSIDIAN CUTTING EDGE:
30 ANGSTROMS (0.000003 MM)

aztec empire
(obsidian tool)

"Y dije asimesmo que tenia noticia do un gran señor que se llamaba Muteczuma... y que contando en la grandeza de Dios, y con esfucrzo pensaba irle á ver do quiera que estuviese."
[And I also said that I had news of a great lord named Montezuma ... and that, counting on the greatness of God, I thought I would go see him wherever he was.]

– Hernán Cortés, from the Second Letter to King Charles V c. 1519 CE

The history of human civilization in Mesoamerica spans thousands of years; numerous cultures connected by shared traditions in architecture, science, politics, religion, and warfare. Among the last in a long line, the Aztec Empire rose from an alliance of three city-states during a violent civil war at the beginning of the 15th century CE. Also known as the Triple Alliance, the cities of Tlacopan, Taxacoco, and México-Tenochtitlán came together to defeat the ruling Azcapotzalco. Over the course of the next century, the empire grew to encompass 80,000 square miles (207,000 sq km) and more than 10,000,000 people.

To maintain and rule this complex empire, the Aztecs relied on a system of taxation and tribute. Subjugated and allied city-states would provide material resources and labor on a strict schedule, and all young men were required to enter military service. The Aztecs used these resources to create massive public works, and the Mexicà city of México-Tenochtitlán became a vast capital on par with some of the largest cities in the world.

Aztec rule of the region came to an abrupt end in 1521 when the forces of Spanish conquistador Hernán Cortés took control of Tenochtitlán. There is still great debate about the underlying causes of their fall: disease, superior technology, and even internal collusion with the Aztec Emperor Moctezuma II himself. Cortés attributed the victory to a strategy which involved

supplementing his small Spanish force with large numbers of disgruntled Aztec tributaries. If accurate, this reversal of fortunes was not unlike that which brought the Aztecs to power. However, the result would have more far-reaching effects, as the Spanish not only gained a powerful foothold but also developed the tactics required to conquer the rest of Mesoamerica.

The specimen in the Mini Museum is a fragment of an Aztec obsidian tool acquired from a private collection. While incredibly sharp, obsidian blades are brittle and break easily, so new stone was always needed. This was common among many Mesoamerican societies, but research of Aztec tool-works suggests that their consumption for military use was unusually high. Among the weapons used by Aztec warriors, the fearsome *macuahuitl* (broad sword) and the *tepoztopilli* (thrusting-spear) were lined with rows of prismatic blades. The macuahuitl in particular was said to be capable of decapitating a horse.

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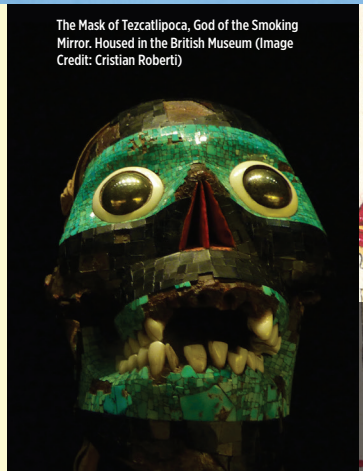
Obsidian is a natural volcanic glass which can be polished to create a mirror-like finish. It forms when lava rich in feldspar and quartz cools quickly, resulting in a material that is harder than steel yet so brittle that it can be easily fractured to create clean, sharp edges ten times finer than modern scalpels. Obsidian is particularly abundant in the highland plateaus of Central Mexico which lie within the Trans-Mexican Volcanic Belt. This highland plateau where the Aztecs once thrived is called The Valley of Mexico but is also known as Anahuac in the Náhuatl language, or The Land Between the Waters.

Cities and settlements of the Valley of Mexico c. 1519

The Mask of Tezcatlipoca, God of the Smoking Mirror. Housed in the British Museum (Image Credit: Cristian Roberti)



Tezcatlipoca from the first page of the Codex Yoalli Ehēcatl, a ritual and divinatory record created after the Spanish conquest. Also known as the Codex Borgia, the manuscript was discovered by Alexander von Humboldt in 1805 among the personal effects of Cardinal Stefano Borgia.

Built from 1904 to 1906, the RMS Lusitania was briefly the world's largest ship, until it was overtaken by its sister ship, the Mauretania. The ship was named after the ancient Roman province of Lusitania, which included all of modern Portugal. While Lusitania was considered a civilian vessel, its construction was financed by the British government with the understanding that the ship could be converted to an "armed merchant cruiser."

(Image: *Lusitania (1907)*, by Norman Wilkinson)

SPECIMEN TYPE: HUMAN ARTIFACT

DATE OF SINKING: MAY 7TH, 1915

lusitania
(deck chair)

"The best joke I've heard in many days, this talk of torpedoing."

– William Turner, Captain of the Lusitania

Briefly the world's largest ship, the luxurious R.M.S. Lusitania was also one of the fastest vessels of its era, able to cross the Atlantic in five days.

When the First World War erupted in 1914, the Lusitania became caught up in naval warfare between the British and German empires. The British Royal Navy blockaded the German coastline, preventing its adversary from shipping in key supplies. Not only did this make it harder for the German military to obtain arms, but it threatened the German people with starvation. In response, German submarines, or U-boats, began torpedoing British ships. While they initially only attacked naval vessels, the U-boats began targeting merchant ships in 1915. They argued that because Britain used such ships to transport weapons and munitions, they were not truly civilian targets, making them fair game for naval attacks.

Despite this threat, the Lusitania continued to operate across the Atlantic Ocean. In the spring of 1915, Germany's embassy in the United States published warnings in several American newspapers, advising Americans against traveling to Europe.

On May 1st, 1915, the Lusitania departed from New York on a voyage to Liverpool with 1,959 passengers aboard. The cargo hold of the Lusitania held passengers as well: 4.2 million rifle rounds, 1,250 shrapnel shell cases, and 18 fuse cases, all destined for the battlefields of the Great War. Though the Royal Navy had promised to escort the Lusitania for part of the journey, the escort never appeared.

The Lusitania entered Irish waters on May 7th, slowing so it could navigate the foggy weather. A nearby German U-boat took advantage of this situation, torpedoing the ship twice and causing the hull to explode. 1,198 passengers drowned, including 128 American citizens, a fact which enraged the American public and later served as a catalyst for U.S. President Woodrow Wilson's push to enter the war.

The specimen in the Mini Museum comes from an oak deck chair which once graced the decks of the R.M.S. Lusitania. The chair was among the untold tonnes of flotsam and hundreds of bodies which washed ashore in Cobh, Ireland (known as Queenstown at the time) and was held on public display for decades. It was acquired at auction from Christie's London office in late 2016.

SOURCES:

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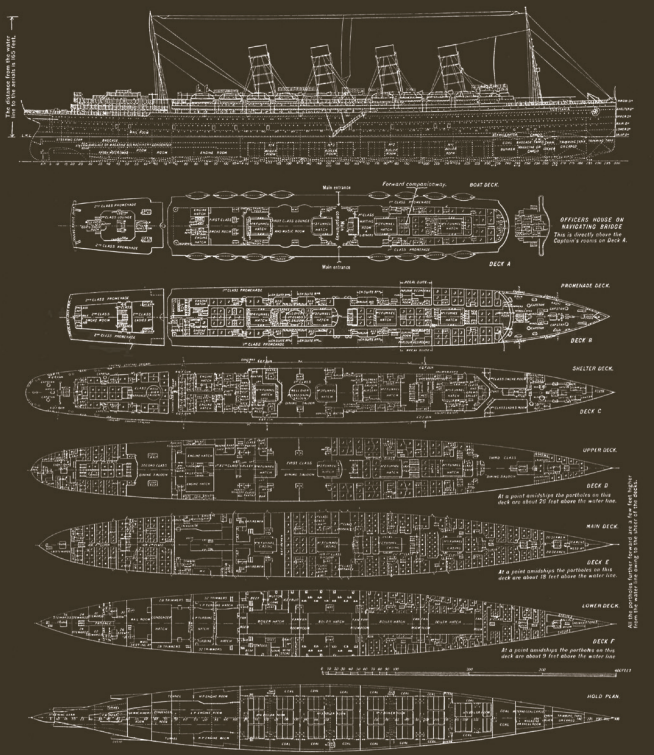
Lusitania Deck Plans



SPECIMEN TYPE:
HUMAN ARTIFACT

BORN:
NOVEMBER 30, 1874

DIED:
JANUARY 24, 1965

winston churchill
(fur muff)

"Victory will never be found by taking the line of least resistance."

– Winston Churchill

"The Roaring Lion" This portrait was taken during a visit to the Canadian Parliament on December 30, 1941 by renowned photographer Yousuf Karsh. Churchill was not informed that a portrait session would take place after his speech and he was not pleased. He was even less pleased when Karsh, very quickly but respectfully stepped forward and plucked Churchill's ever-present cigar from his mouth. "By the time I got back to my camera, he looked so belligerent he could have devoured me. It was at that instant that I took the photograph."

A soldier, a gifted writer, and a politician who seemed equally talented in inspiring awe and anger in both allies and enemies alike, Sir Winston Leonard Spencer-Churchill did not move quietly through the world. His long life straddled two very different centuries. It was a tumultuous period in which maps were redrawn and the world hovered several times on the brink of total annihilation.

Born in 1874, Churchill came of age at the height of the British Empire. Churchill's early life was one of rank and privilege. Yet despite the advantages, he struggled in his education and did not find firm footing until he qualified as a cavalry officer. He saw action in locations across the world: Cuba, Afghanistan, the Sudan, and the Second Boer War in South Africa. As a journalist, his dispatches from the battlefield made his name with the public and eased his entry into politics.

Churchill was first elected to Parliament in 1900. He began as a member of the Conservative Party before joining the Liberal Party in 1904. In 1908, he married Clementine Hozier, with whom he would have five children. The same year, he took his first Ministerial position as President of the Board of Trade.

By the end of his life in 1965, Churchill had served nearly 64 years in Parliament across five different constituencies, swinging from one side of the aisle to the other and then back again. He held numerous positions within government including Home Secretary, First Lord of the Admiralty (twice), Colonial Secretary, Chancellor of the

British Prime Minister Winston Churchill, U.S. President Franklin Roosevelt, and Soviet leader Joseph Stalin met at Yalta in February 1945 to discuss their joint occupation of Germany and plans for postwar Europe in February of 1945

Exchequer, and Prime Minister (also twice).

At his core, Churchill held an ardent belief in the pre-eminence of Great Britain. This belief would often guide his decisions and fuel his seemingly bottomless need for action. Together, these two aspects of his person often led Churchill to take positions which are difficult to reconcile favorably. Yet, it is precisely such qualities which made Sir Winston the resolute leader the United Kingdom required during the dark years of the Second World War. Today, the "Bulldog of Britain" is considered by many to be one of the greatest Britons in history.

As you might imagine, a brief sketch of such a life is difficult at best. Churchill himself seemed to realize this as he quipped, "History will be kind to me, for I intend to write it myself."

And write it he did..

In 1953, Churchill was awarded the Nobel Prize for Literature "for his mastery of historical and biographical description as well as for brilliant oratory in defending exalted human values." From journalistic reports and biographical sketches, to multi-volume historical studies and, of course, the archives of his voluminous oratory, Sir Winston's body of work encompasses some 11,000,000 words.

The specimen in the Mini Museum is a section of a faux leopard-skin hand muff used for many years by Winston Churchill. Despite a life of near constant action and travel, Churchill was known to suffer from poor circulation in his later years, and often made use of a muff to keep his hands warm. This muff was purchased at auction in 2016 from Christie's of London, and included a signed letter from Lady Soames, Churchill's youngest daughter.

SOURCES:

Howells, Roy. Churchill's last years. D. McKay Company, 1965.

Jenkins, Roy. Churchill: A biography. Pan Macmillan, 2012.

Churchill, Winston. "My Early Life: 1874-1904." T. Butterworth, London (1930).

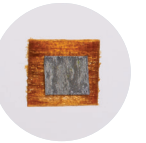
Clarke, Peter. "Hope and Glory: Britain 1900-2000." Penguin Books, London (1996, 2004).

Keegan, John. "Winston Churchill: A Life." Viking/Penguin, New York (2002).

SPECIMEN TYPE:
HUMAN ARTIFACT

YEAR COMPLETED:
1923

ORIGINAL LETTERS:
H-O-L-L-Y-W-O-O-D-L-A-N-D



hollywood sign

"Hollywood is a place you can't geographically define. We don't really know where it is."

– John Ford, American Film Director (1964)

For nearly a century, the Hollywood sign has stood on the southern slope of Mount Lee overlooking the city of Los Angeles. First constructed in 1923 to advertise the exclusive real estate development known as "Hollywoodland", the sign used 4,000 light bulbs to illuminate different sections in succession; the word "Holly" would light up first, followed by "Wood," then "Land," and finally the whole sign.

As the film industry's cultural importance grew, the sign quickly became a bright beacon for those seeking stardom and a symbol for the entertainment industry. By 1949, the Hollywood Chamber of Commerce entered an agreement to oversee and repair the sign. The word "LAND" was removed and the sign was given a fresh coat of paint. Yet, over the next few decades, the sign gradually slipped into disrepair as time, neglect, and vandalism took their toll.

By the late-1970s, a complete replacement was required. The reconstruction was financed primarily by private fundraising efforts led by Playboy Magazine founder Hugh Hefner. Hefner brought together an unlikely group of entertainers, from silver screen legend Gene Autry to theatrical shock rocker Alice Cooper, who each sponsored a letter in the new sign.

"It's become something iconic and represents not only the town but represents Hollywood dreams, and I think that's something worth preserving." - Hugh Hefner

The specimen in the Mini Museum is a two-piece fragment of the original Hollywood sign, salvaged during the 1978 reconstruction. It was acquired from the private collection of a retired Los Angeles sound engineer.

Mount Lee, home to the Hollywood Sign, is a small peak in Santa Monica Mountains. This small coastal range runs parallel to the Pacific Ocean for 40 miles (64 km) north of the densely populated Los Angeles Basin. Archeological studies of Native American sites found throughout the range suggest that ancestors of the Tongva and Chumash people inhabited this region for more than eight thousand years prior to Spanish conquest in the late 18th century.

During the silent, "Tinseltown" years of Hollywood, the peak was purchased by comedy film producer Mack Sennett. Sennett flattened the top of the mountain with the intent of building a palatial home for himself with views of the entire city. The stock market crash of 1929 and the advent of the talking film ended those plans as Sennett's funds dried up and his career faded. The prepared land was later sold to the Don Lee Broadcasting System which built the original radio and television transmitting station. Today, the transmitting station is owned by the City of Los Angeles, and much of the surrounding land is part of Griffith Park, one of the largest urban parks in the United States.

SOURCES:

Mallory, Mary. "Hollywoodland." Arcadia Publishing, (2011)

Brook, Vincent. "Land of Smoke and Mirrors: A Cultural History of Los Angeles." Rutgers University Press, New Brunswick (2013).

Braudy, Leo. "The Hollywood Sign: Fantasy and Reality of an American Icon." Yale University Press, New Haven (2011).

Schatz, Thomas. The genius of the system: Hollywood filmmaking in the studio era. Macmillan, 1996.

Atomic bombing of Nagasaki on August 9, 1945, taken by Charles Levy

SPECIMEN TYPE:
HUMAN ARTIFACT

TOTAL COST OF THE PROJECT:
$1.89 BILLION
(APPROXIMATELY $24 BILLION IN 2018)

manhattan project

(shield window)

"Man's understanding of nature is usually a cumulative and gradual process. Certainly this has been the case throughout the growth of atomic physics. No single stroke of genius delivered up the finished product. Rather, its present state of development derives from the labors of many individuals from many countries, operating in many fields of endeavor, over a span of many years."

– General Leslie Groves, "Now it can be told" (1962)

The Manhattan Project was the codename for the research and development effort which allowed the United States to rapidly develop a series of atomic breakthroughs during World War II, including the first industrial-scale plutonium production reactor and the first atomic bombs. This enormous project involved over one hundred thousand scientists, engineers, technicians, and construction workers at more than 30 sites across the United States, including well-known locations such as Oak Ridge, Los Alamos, Trinity, and Hanford.

Located in the high desert region of Washington State, the former town of Hanford is the site of the world's first full-scale plutonium production complex. The creation of the site was authorized on January 16, 1943 under the authority of General Leslie Groves. Residents and Native American tribes in the region were relocated and furious construction began. Less than two years later, on Christmas Day 1944, the first irradiated slugs were removed from the B Reactor and sent to the T Plant (221-T) for chemical separation. On February 2, 1945, Los Alamos received its first Plutonium shipment from Hanford. Plutonium processed at Hanford was used in both the Trinity test on July 16, 1945 and in the "Fat Man" atomic bomb used over Nagasaki, Japan on August 9, 1945.

The specimen in the Mini Museum comes from a leaded glass window installed in the T Plant (221-T) Plutonium Recovery Building, the first and largest of two production bismuth-phosphate chemical separations

plants used to extract plutonium from fuel rods irradiated in the Hanford Site's reactors.

The glass was acquired from the window's current owner, Dan Dunn. Mr. Dunn owns several windows from the site which were sold during a government surplus auction in the late 1980s as part of the long (and continuing) decommissioning process. The yellow color of the glass is due to a high concentration of lead-oxide (up to 70%), which blocks blue and near-UV spectral frequencies, and also gives the glass its protective qualities.

The Hanford, WA facilities encompass 586 square miles of high desert. The Columbia River constitutes about 50 miles of the site's north and east borders.

Hanford's facilities originally had 554 buildings, including several production reactors and the unique chemical processing buildings where Plutonium was extracted from Uranium. These buildings were 800 feet long, 65 feet wide, and about 80 feet high. Standing in one reminded workers of standing in the bottom of a canyon, so the buildings were known as "the canyons."

For decades, the Hanford facilities produced plutonium for America's nuclear weapons programs. The last reactor at Hanford ceased operation in 1987. Soon after, the U.S. Department of Energy, the EPA, and Washington State University's Department of Ecology signed an agreement to clean up the hundreds of billions of gallons of liquid and millions of tons of solid waste stored there.

Today, there are 8,000 employees involved in the deactivation, decommissioning, decontaminating, and demolishing of the site's facilities and structures, except those designated as part of the Manhattan Project National Historical Park. Tours of the site are available to the public, government officials, the media, and other interested parties. The tours for the public focus on efforts to decommission and decontaminate buildings and building sites, and the disposal of radioactive and industrial chemical waste.

SOURCES:

Groves, General Leslie R. Now it can be told: The story of the Manhattan Project. Harper and Row, 1962

Howes, Ruth H., and Caroline L. Herzenberg. Their day in the sun: women of the Manhattan Project. Vol. 71. Temple University Press, 2003.

Hughes, Jeff A. The Manhattan Project: big science and the atom bomb. Columbia University Press, 2002.

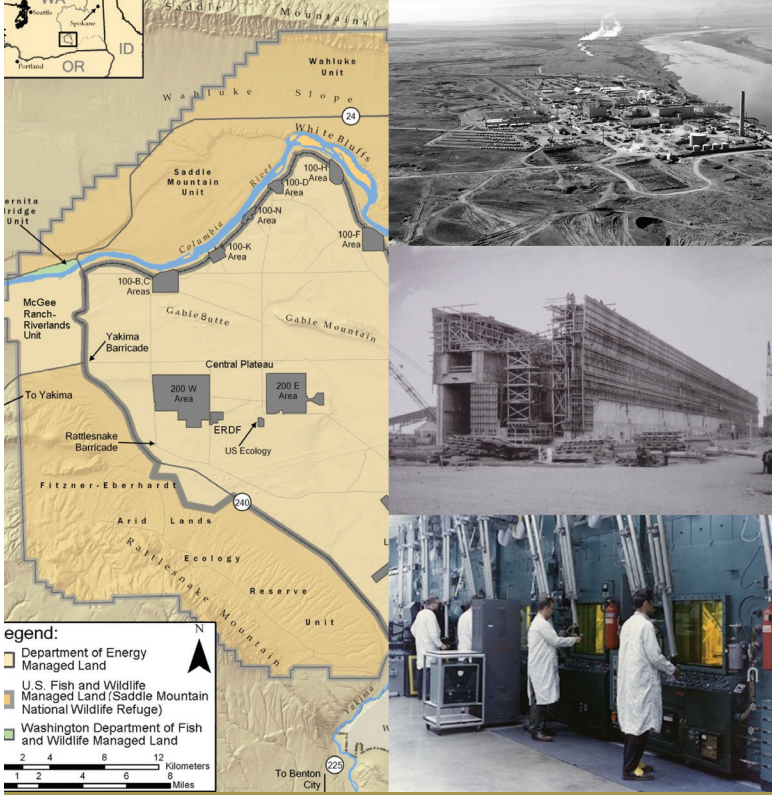
Selden, Kyoko Iriye, and Mark Selden. The Atomic Bomb: Voices from Hiroshima and Nagasaki: Voices from Hiroshima and Nagasaki. Routledge, 2015.

Gerber, M. S. "A Brief History of the T Plant Facility at the Hanford Site." Richland, WA: Westinghouse Hanford Company (1994).

Libby, Leona Marshall (1979). Uranium People. New York: Charles Scribner's Sons.

Nichols, Kenneth David (1987). The Road to Trinity: A Personal Account of How America's Nuclear Policies Were Made. New York: William Morrow and Company.

Bethe, Hans A. (1991). The Road from Los Alamos. New York: Simon and Schuster.



Clockwise from the left: a map of the Hanford site, an aerial photo taken from the eastern edge of the complex, the 221-T "Canyon" Plant under construction, technicians working behind shield windows.

Nothing After Would Ever Be the Same:

TWO INDIVIDUAL STORIES OF THE MANHATTAN PROJECT

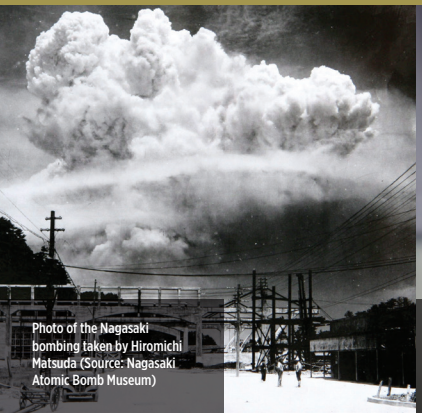
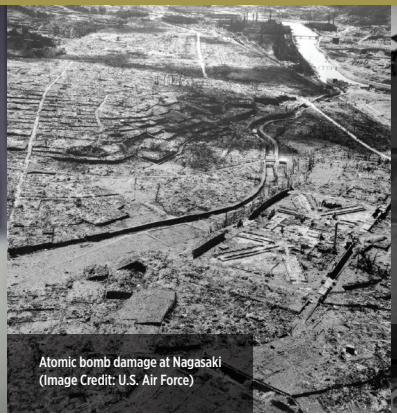


Photo of the Nagasaki bombing taken by Hiromichi Matsuda (Source: Nagasaki Atomic Bomb Museum)

Sumiteru Taniguchi (1929-2017) in 2013 with a photo of himself taken six months after the bombing of Nagasaki. (Image Credit: Lucas Vallecillos)



Atomic bomb damage at Nagasaki (Image Credit: U.S. Air Force)

Luis Alvarez (1911-1988) on Tinian Island holding the Plutonium core of the "Fat Man" bomb.

There are so many personal stories to tell about the Manhattan Project, from the people of the Wanapum tribe and the townspeople of Hanford, White Bluffs, and Richland who were all displaced by the construction, to the thousands upon thousands of people who worked to make it a reality. To bring the human story closer we selected just two: Nagasaki bombing survivor, Sumiteru Taniguchi, and an American physicist named Luis Alvarez.

Over 200,000 people perished in the atomic attacks on Hiroshima and Nagasaki. Roughly half died on the first day, while others struggled on (sometimes for months) with burns and radiation sickness before succumbing to death. Surviving victims of the atomic attacks on Hiroshima and Nagasaki are referred to as *hibakusha* (被爆者) or "explosion-affected people."

One of the most active members of this community, Sumiteru Taniguchi, was just 16 years old on August 9th, 1945 when the fat man bomb exploded over Nagasaki. Color photographs and film of his back, stripped of flesh as he was riding his mail delivery bicycle, were so shocking that they were kept from public view for twenty-five years.

In 2010, Taniguchi took the stage at the United Nations Headquarters in New York during the Review Conference for the Treaty on the Non-Proliferation of Nuclear Weapons. He showed the pictures taken during his hospital stay to the delegates:

"When the bomb exploded, I was burned on my entire back by the heat rays of 3,000 to 4,000 degrees Celsius, which could have melted rocks and iron, and exposed to invisible radiation. The next moment I was blown away together with the bike for about 4 meters and smashed to the ground by the bomb blast. I am not a guinea pig. I am not an exhibit. But please look at this again without averting your gaze."

Taniguchi passed away in 2017 at the age of 88 as a result of pancreatic cancer. Shortly after his death, the International Campaign to Abolish Nuclear Weapons (ICAN) won the Nobel Peace Prize. As a part of the Fourth Edition project, a donation has be made to ICAN to help further their mission.

Luis Alvarez was one of the most prolific physicists of his day, winning the Nobel Prize in Physics in 1968 for his work on elementary particle states. Later in life, he worked with his son Walter, a noted geologist in his own right, to author the Alvarez hypothesis. The Alvarez hypothesis was the first theory to suggest that the Cretaceous-Paleogene extinction event was the direct result of a massive asteroid impact.

During World War II, Alvarez was attached to the Manhattan Project, working first with Enrico Fermi at the University of Chicago before moving to Los Alamos to work with Robert Oppenheimer. On August 9th, 1945, Alvarez was aboard the B-29 bomber, The Great Artiste, which was assigned to monitor the blast over Nagasaki. On the return flight home he wrote the following letter to his son, who was just five years old at the time.

August 6th
10 miles off the Jap
Coast at 28,000 feet

Dear Walter:

This is the first grown-up letter I have ever written to you, and it is really for you to read when you are older. During the last few hours I have been thinking of you and your mother and our little sister Jean. It was tough to take off on this flight, not knowing whether I would ever see any of you again. But lots of other fathers have been in the same spot many times before in this war, and I had a job to do, so I can't claim to be any sort of hero.

I wonder if you will remember the time in Albuquerque, when you climbed all through a B-29 Superfortress. Probably you will remember climbing thru the tunnel over the bombbay, as that really impressed you at the time. Well, I have been in this B-29 for eight hours so far, and we won't be back for another five or six.

The story of our mission will probably be well known to everyone by the time you read this, but at the moment only the crews of our three B-29s, and the unfortunate residents of the Hiroshima district in Japan are aware of what has happened to aerial warfare. Last week at the 20th Air Force, stationed in the Marianas Islands, put over the biggest bombing raid in history, with 6000 tons of bombs (about 3000 tons of high explosive). That means that the days of large bombing raids, with several hundred planes, are finished. A single plane disguised as a friendly transport can now wipe out a city. That means to me that nations will have to get along together in a friendly fashion, or suffer the consequences of sudden sneak attacks which can cripple them overnight.

What regrets I have about being a party to killing and maiming thousands of Japanese civilians this morning are tempered with the hope that this terrible weapon we have created may bring the countries of the world together and prevent further wars. Alfred Nobel thought that his invention of high explosives would have that effect, by making wars too terrible, but unfortunately it had just the opposite reaction. Our new destructive force is so many thousands of times worse that it may realize Nobel's dream.

After that little sermon, I'll try to describe what it is like to go into combat for the first time. I had not made up my mind to go on the mission before I left the states, but I was pretty well convinced that I would end up by going. I thought the thing through on at least a dozen nights, while I was trying to go to sleep. I think these mental trips were the worst part of the deal.

When I arrived in the Marianas, I told the commanding officer that I thought I should go. I got cleared after a lot of radio messages to and from Washington. The mission was held up for several days by weather, and this was tough. We would get keyed up and read to go, and then the weather experts would call it off. Finally we got the go-ahead sign and then worked most of the day checking instruments. We had several briefings which were quite exciting. I had attended bombing briefings in England for the RAF, but it is quite different when you are to go on the mission yourself. Data on anti-aircraft batteries and enemy fighters becomes of great personal concern. One of the planes of our squadron had come home with large flack holes in its wings two days before, so we felt some concern in that score. We were told a lot about landing the plane in the ocean. The big worry, of course, was landing on the Empire and being captured by the Japs. They have been particularly savage with ordinary pilots, and I am sure they would have a special reason for disliking us immensely.

We were to take off at 2:45 A.M., and this last waiting was the worst part. We saw a movie until 9:30, and then packed up last minute supplies for the plane. Then we got equipped with our combat flying suits, which weight about seventy or eighty pounds. First comes a survival vest, with fish hooks, drinking water kits, first aid packages, food, and a host of other things useful to a man forced down on the ocean. Over that was our parachute harness, to which could be clipped a chest chute pack, and a one-man liferaft. With this equipment, it is possible to go into the water from a plane, some distance from anyone else, and survive. Over this already bulging mess, we wore our flack suits, to protect our bodies from flying shell fragments. This is a very heavy and clumsy thing, like a suit of armor, but we were glad to put up with the discomfort during our 65 minutes over the Empire. Finally, we wore a cloth helmet with an oxygen mask attached, and over that a flack helmet to protect our heads.

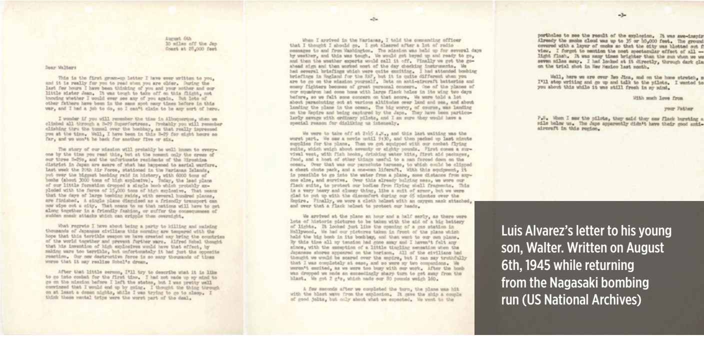
We arrived at the plane an hour and a half early, as there were lots of historic pictures to be taken with the aid of a big batter of lights. It looked just like the opening of a gas station in Hollywood. We had our pictures taken in front of the place which held the big bomb in its bombbay, and then went to our own plane. By this time all my tension had gone away and I haven't felt any since, with the exception of a little tingling sensation when the Japanese shores appeared on the horizon. All of the civilians had thought we would be scared over the empire, but I can say truthfully that I was completely at ease, and so were my two companions. We weren't excited, as we were too busy with our work. After the bomb was dropped we made an accordingly sharp turn to get away from the blast. We got 2 g's, which made our 80 pounds weigh 160.

A few moments after we completed the turn, the plane was hit with the blast wave from the explosion. It gave the ship a couple of good jolts, but only about what we expected. We went to the portholes to see the results of the explosion. It was awe-inspiring. Already the smoke cloud was up to 35 or 50,000 feet. The ground was covered with a layer of smoke so that the city was blotted out from view. I forgot to mention the most spectacular effect of all—the light flash. It was many times brighter than the sun when we were seven miles away. I had looked at it directly, through dark glasses, on the trial shot in New Mexico last month.

Well, here we are over Iwo Jima, and on the home stretch, so I'll stop writing and go up and talk to the pilots. I wanted to tell you about this while it was still fresh in my mind.

With much love from
your Father

P.S. When I saw the pilots, they said they saw flack bursting a mile below us. The Japs apparently didn't have their good anti-aircraft in this region.



Luis Alvarez's letter to his young son, Walter. Written on August 6th, 1945 while returning from the Nagasaki bombing run (US National Archives)

SPECIMEN TYPE:
HUMAN ARTIFACT

CORNERSTONE LAID:
OCTOBER 13, 1792 (BY GEORGE WASHINGTON)

ADDRESS:
1600 PENNSYLVANIA AVENUE

the white house
(brick)

"For the President's House I would design a building which should also look forward but execute no more of it at present than might suit the circumstances of this country, when it shall first be wanted. A plan comprehending more may be executed at a future period when the wealth, population, and importance of it shall stand upon much higher ground than they do at present."

– George Washington, March 8th, 1792

In September 1961, Congress passed a law to officially label the White House as a museum, and no significant architectural changes have been made to the building since Truman's renovation. However, every new president does add their own touches to the building, such as Barack Obama's installation of solar panels on the White House roof.

The history of the White House is one of constant change and conflict. Still, no matter who the occupant might be at any given time, or the changes they've made, the White House itself endures as a powerful symbol for the United States and the office of the Presidency, proof that the "American Experiment" continues.

In 1791, President George Washington chose the site for the future executive residence and offices. A year later Irish architect James Hoban won the competition to design the building. Hoban's designs were highly influenced by Washington himself, who had recently dismissed city planner Major Pierre Charles L'Enfant.

Construction lasted from 1792 until 1800, when John Adams became the first President to take up residence in the executive mansion.

Following Adams, Thomas Jefferson moved in to what he called a "pleasant country residence" but noted that it was "big enough for two emperors, one pope, and the grand lama in the bargain." Nevertheless, Jefferson added low colonnades to each wing.

Decades later, First lady Mary Todd Lincoln undertook a massive redecorating project to restore what she saw as a building with "the air of a run-down, unsuccessful, third-rate hotel." The project ran so far over budget, it caused President Abraham Lincoln to declare that he would "never approve the bills for flub dubs for that damned old house."

In 1901. the White House received its formal name, when Theodore Roosevelt officially dubbed it the White House after years of being

called the "President's House" or the "Executive Mansion." In the following years, additions were made to the core structure. The West Wing was added in 1902 and the East Wing in 1942.

The specimen in the Mini Museum is a fragment from a brick recovered during the 1948-1952 renovation and expansion of the White House. The project is sometimes referred to as a reconstruction rather than a renovation as the venerable structure was gutted from within and refitted with a steel superstructure. This process generated an enormous amount of salvage material, some of which was used as landfill, but more attractive items became part of a popular public souvenir program designated by the Commission on the Renovation of the Executive Mansion.

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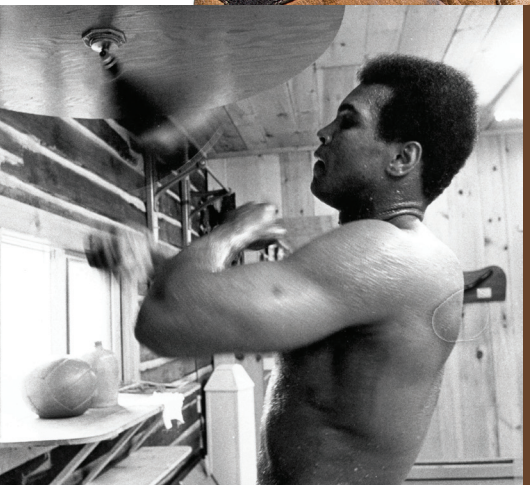
Elder, William P. "Geology of the Golden Gate headlands." Geology and Natural History of the San Francisco Bay Area: A Field-trip Guidebook. US Geological Survey Bulletin 2188 (2001).

The last major renovation to the White House came under Harry S. Truman's presidency. Years of poor maintenance had left the structure unstable and on the verge of collapse, leading Truman to vacate the residence in 1948 to allow for a complete reconstruction. The interior rooms were entirely dismantled. Care was taken to mostly preserve the interior layout, though two new sub-basements and central air conditioning were added.



In 1964, a loud, handsome boxer from Louisville, Kentucky shocked the sporting world by beating the reigning heavyweight champion of the world. The new champion's name was Cassius Marcellus Clay, Jr. and he was just 22 years old. The day after the fight, Clay announced to the press that he was a Muslim and confirmed rumors that he had joined the Nation of Islam. Ten days later, the champion was introduced to the world by a new name: Muhammad Ali.

(Image: Cassius Clay Jr. in 1962. Age 20)

SPECIMEN TYPE:
HUMAN ARTIFACT

BORN:
JANUARY 17, 1942
(CASSIUS MARCELLUS CLAY JR.)

DIED:
JUNE 3, 2016

FIRST HEAVYWEIGHT CHAMPIONSHIP:
FEBRUARY 25, 1964
(7TH ROUND TKO OVER SONNY LISTON)

muhammad ali
(punching bag)

"I don't have to be what you want me to be. I'm free to be who I want."
– Muhammad Ali, 1964

During his illustrious professional boxing career, Muhammad Ali compiled a record of 56-5 with 37 wins by knockout. His victories include wins over what some consider the finest opposition in history: Sonny Liston (twice), Joe Frazier (twice), Floyd Patterson, Ken Norton (twice), and a knockout victory against George Foreman, one of the hardest punching boxers of all time. Ali also held the title three different times, each time defeating a reigning champion. This feat has never been equalled, nor is it likely to be.

But Muhammad Ali was far more than just a boxing legend. His conversion to Islam and association with the Nation of Islam became a lightning rod for opinion across the United States. Later, his opposition to the war in Vietnam and direct engagement with civil rights issues catapulted him into a world far beyond the ring. He became an ambassador for peace, addressing the UN Special Committee Against Apartheid in 1978. Twenty years later he became one of the first United Nations Messengers of Peace, one of his many messages being "Service to others is the rent you pay for your room here on earth."

Muhammad Ali passed away on June 3rd, 2016 after a thirty year battle with Parkinson's. Throughout his struggle, Ali never complained. He simply referred to the disease as his trial, yet one more challenge in a life of challenges.

The specimen in the Mini Museum comes from a punching bag formerly used by Muhammad Ali. Known as a double-end or "crazy" bag, this particular type of punching bag is used to improve accuracy, speed, and endurance. The double-end bag is attached at two ends

with floor-to-ceiling elastic straps. This makes the bag highly reactive to punches, which is useful in developing defensive skills, as the bag is prone to "hit back". This particular bag was used by Muhammad Ali during training sessions in the 1970's. The bag was gifted to long-time Louisville sports radio personality and friend of Muhammad Ali, John Ramsey, and later purchased at auction by Mini Museum.

SOURCES:

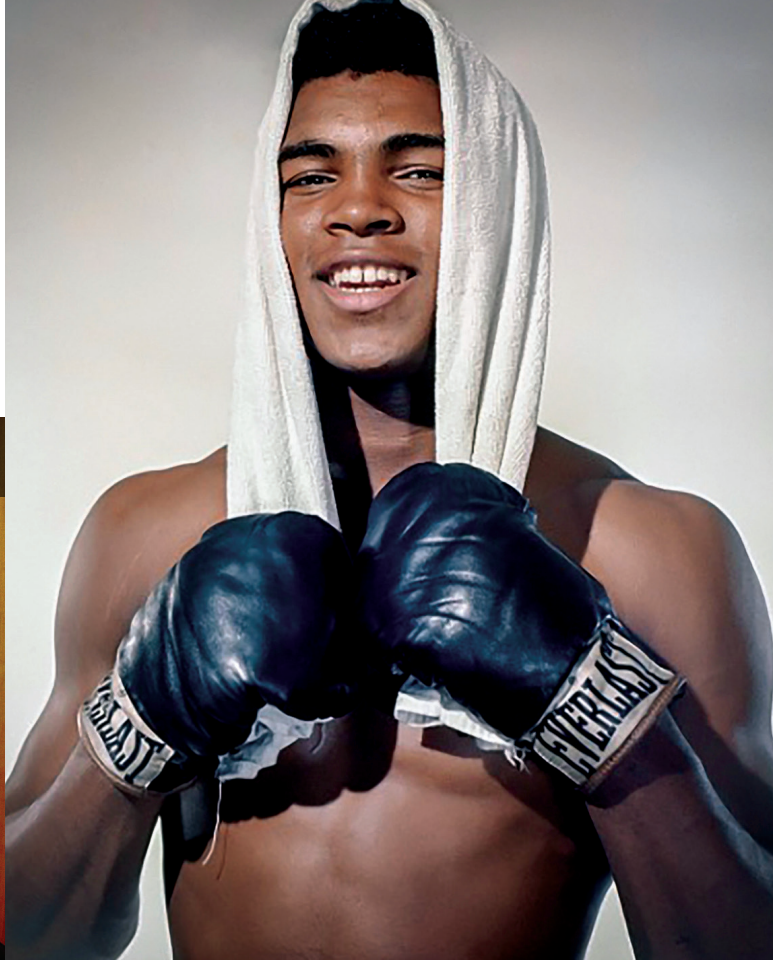
Eig, Johnathan. "Ali: A Life." (2017).

Remnick, David. King of the World. Picador, 1999.

Ali, Muhammad, and Richard Durham. The Greatest: My Own Story. New York: Ballantine Books, 1976.

Ali, Muhammad, and Hana Yasmeen Ali. The Soul of a Butterfly: Reflections on Life's Journey. New York, Simon and Schuster, 1974.

Muhammad Ali named as a UN Messenger of Peace in 1998 by UN Secretary-General Kofi Annan



How fast was the Concorde? At a maximum speed of Mach 2.04 — more than twice the speed of sound — it was fast enough to make the New York to Paris flight in less than 3.5 hours.

The Soviets developed their own version of the Concorde: the Tupolev Tu-144. The Soviet supersonic jet reportedly was developed after spy efforts recovered blueprints of the Concorde. While it was never a serious rival to the Concorde, new aircraft developed on more advanced technology may soon bring the dream of commercial supersonic flight back to the skies.

SPECIMEN TYPE:
HUMAN ARTIFACT

FIRST FLIGHT:
MARCH 2ND, 1969

PUBLIC INTRODUCTION:
JANUARY 21ST, 1976

LAST FLIGHT:
OCTOBER 24TH, 2003

TOP SPEED:
MACH 2.04 (1,354 MPH OR 2,180 KMH POAT CRUISE ALTITUDE)

MAXIMUM ALTITUDE:
18,300 METRES (60,039 FT)

concorde (jet rotor)

"I've always thought of the Concorde as a magical object, a symbol, a miracle."

– Andrée Putman, French Designer responsible for the 1994 revamp of the Air France Concorde interior (1925-2013)

On January 1, 1976, the Concorde became the first supersonic commercial aircraft in history. With a Space Age design that signaled the arrival of the future, the joint project between British and French engineers fulfilled a decades-old dream of faster-than-sound passenger travel.

For nearly thirty years, these magnificent aircraft cruised at altitudes twice as high as their subsonic counterparts, twice the speed of sound, and with ticket prices twice the price of their most expensive luxury rivals. While the program operated above cost, the profits were not enough to save the Concorde as it reached the end of its technical lifespan. Waning passenger numbers stemming from a 2000 Concorde crash and fewer overall airline passengers after September 11, 2001, terrorist attacks set the program on track for closure. The last Concorde flight occurred on October 24, 2003.

Today, the remaining Concordes are in storage or on display around the world, but they could soon be returning to the skies. In 2015, Club Concorde said it had enough funding to return the aircraft to operation. Tentatively, the Club hopes to achieve this by 2019.

The specimen in the Mini Museum is a fragment from a flown, high-pressure compressor vane, an integral part of the four turbojet engines that allowed the Concorde to cruise above Mach 2. Produced by Britain's Rolls Royce and Snecma Moteurs of France, the Olympus 593 Mk 610 were the most powerful transport certified engines in the world at the time of their introduction.

SOURCES:

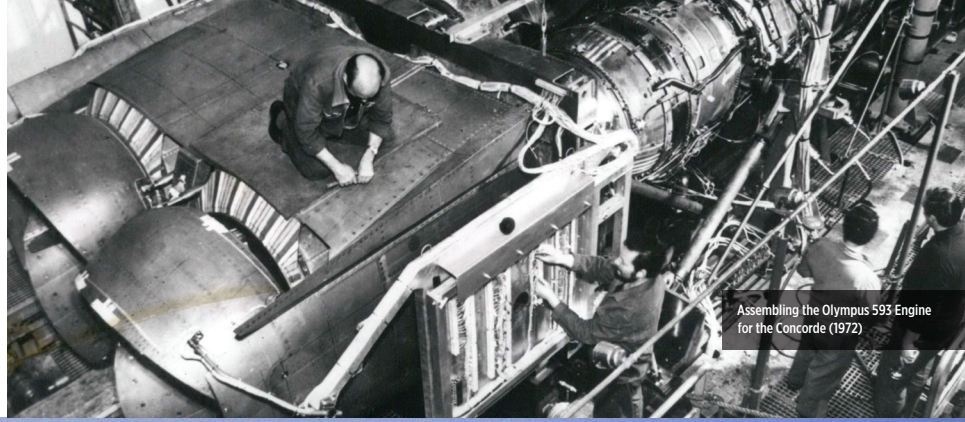
"Concorde: The Rise and Fall of the Supersonic Airliner" Jonathan Glancey (no citation in Google Scholar so make your own)

Calder, P. H., and P. C. Gupta. "Future SST engines with particular reference to Olympus 593 evolution and Concorde experience." The Aeronautical Journal 80.786 (1976): 235-252.

Costello, John, and Terry Hughes. The Concorde Conspiracy. New York: Scribner, 1976. Print.

Owen, Kenneth. Concorde and the Americans: International Politics of the Supersonic Transport. Washington, D.C: Smithsonian Institution Press, 1997. Print.

Owen, Kenneth. Concorde: Story of a supersonic pioneer. London: Science Museum, 2001.



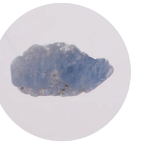
Assembling the Olympus 593 Engine for the Concorde (1972)

A British Airways Concorde on a Christmas flight to Finland, December 24, 1987. (Image Credit: Mohamed LOUNES/Gamma-Rapho via Getty Images)

SPECIMEN TYPE:
GEMSTONE

TOTAL PERFORMANCES:
3713° FAHRENHEIT (2045° CELSIUS)

HARDNESS:
9.0 (MOHS SCALE)



rough sapphire
(myanmar)

"Beauty is meaningless until it is shared."

– George Orwell, *Burmese Days,* 1934

Sapphires can command some of the highest prices paid for any gem. In 2009 a 16.65-carat Kashmir sapphire was sold for $2,396,000. The market to obtain a quality sapphire is complex. From the time a rough and first generation cut gem is sold it will travel through many buyers and dealers at different levels depending on its quality. A sapphire's value will also be related to a ceiling dictated by comparable gems (size, color, clarity).

(Image: Sorting gemstones from sand in Mogok, Myanmar)

Dazzling and durable, sapphires are among the most popular gemstones in the world. Sapphires form very slowly inside cooling igneous and metamorphic rocks as metals seep into aluminum oxide crystals. Also known as corundum, the crystals are transparent on their own, but the presence of different metals lends unique colors to the final stone. Traces of titanium result in a blue hue while the presence of iron results in the color yellow. Any color except red is considered a sapphire, while red, indicating the presence of Chromium, is considered a ruby.

Most sapphire is recovered from placer deposits. This occurs where the softer host rock is weathered or eroded to the extent that these crystals are separated. They have a high density of 4.0 (specific gravity) and can be recovered from alluvial materials derived from their original host rock, in a similar manner to gold placers.

Natural sapphire can exhibit asterism or "stars" on surfaces of stones with round-cut surfaces, known as cabochons. The "stars" are caused by light reflecting off tiny inclusions of the mineral rutile, or other iron or iron-titanium oxide minerals, which have grown within the crystal and are aligned parallel to the hexagonal faces at 60 degrees. The light reflects along these crystallographic planes.

The Star of India is perhaps one of the most celebrated star sapphires in the world. It is considered almost flawless, and displays stars on both sides. The Star of India was found in Sri Lanka and first exhibited to the public at the Paris Exposition of 1900. During the 1960's it was stolen and subsequently found and returned to

the American Museum of Natural History where it presently resides. The largest star sapphire in the world is the Star of Adam. It weighs 1,404.49 carats and is valued at over $300,000,000 USD.

The specimen in the Mini Museum is a rough sapphire from Myanmar's Mogok Metamorphic Belt, also known as the "Valley of Gems." Stretching over 930 miles (1500 km), this region has yielded some of the world's greatest rubies, jade, and sapphires.

SOURCES:

Giuliani, Gaston, et al. "Oxygen isotope composition as a tracer for the origins of rubies and sapphires." Geology 33.4 (2005): 249-252.

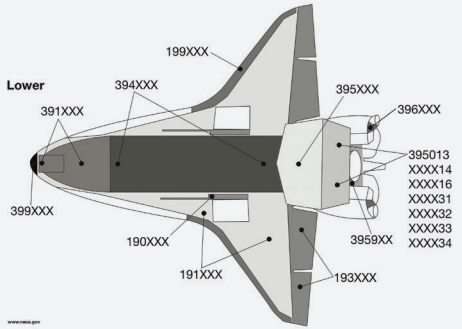
Groat, Lee A. "Gemstones". American Scientist. 100 (2012): 128-137.

Chatterjee, Kaulir Kisor. Uses of Industrial Minerals, Rocks and Freshwater. New York: Nova Science Publishers, Inc. 2009.

Mason, Brian and L.G. Berry. Elements of Mineralogy. San Francisco: W.H. Freeman and Company, 1968.

Themelis, Ted. Mogôk: Valley of Rubies & Sapphires. 2000.

Mining in Mogok. Extraction methods include a combination of alluvial mining, open pit mining, and carving caves and tunnels in solid rock. (Image Credit: Olivier Goujon / Le Pictorium)



While the Space Shuttle orbiter's structural skin consisted of a graphite epoxy over aluminum, the spacecraft would require a Thermal Protection System (TPS) capable of withstanding temperatures in excess of 2,300 °F (1,260 °C) during reentry into the Earth's atmosphere. Over 20,000 HRSI tiles were specifically designed to meet the exact shape, weight, and possible temperature resistance required at its specific location. The map to the left indicates the location of the tile in the Mini Museum when it was attached (section 3959XX).

SPECIMEN TYPE:
HUMAN ARTIFACT

FIRST FLIGHT:
APRIL 12, 1981

LAST FLIGHT:
JANUARY 16, 2003 (SHUTTLE DESTROYED DURING RE-ENTRY ON FEBRUARY 1, 2003 AND ALL SEVEN ASTRONAUTS ON BOARD KILLED.)

DISTANCE TRAVELLED:
201,497,772 KM (125,204,911 MILES)

first space shuttle
(columbia flown tile)

"The Shuttle is to space flight what Lindbergh was to commercial aviation."

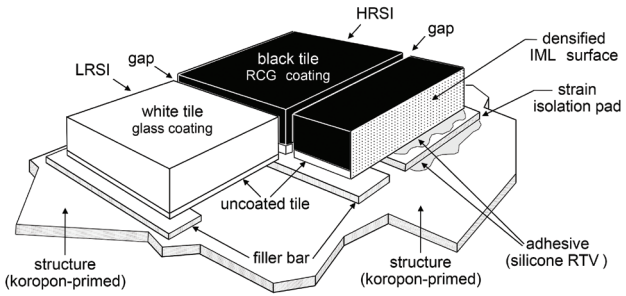
– Arthur C. Clarke

On April 12, 1981, the Space Shuttle Columbia roared to life on the pad at the Kennedy Space Center's historic Launch Complex 39A. Solid rocket boosters and Columbia's own engines delivered more than 6,600,000 pounds of thrust, lifting the crew of two and 4,500,000 pounds (2,000,000 kg) of dreams into orbit at more than 17,500 miles per hour (28,163 kmh).

The successful launch and return of Columbia heralded a new age in space exploration. Envisioned in the 1950's as a fleet of reusable spacecraft, Columbia was joined by Challenger, Discovery, Endeavor, and Atlantis. Over the course of 135 missions, the fleet delivered hundreds of astronauts and thousands of tons of materials into orbit. They also deployed satellites and served as a platform for the advancement of science while traveling more than half a billion miles during three decades of operation.

Despite a tremendous record of success, two tragedies also struck the program. On January 28, 1986, the Space Shuttle Challenger exploded 73 seconds into flight as the result of a failed O-ring seal on the right solid rocket booster. Seventeen years later, the Space Shuttle Columbia was lost when the craft disintegrated due to an undetected puncture in the wing which occurred during liftoff but did not present a problem until re-entering the atmosphere on February 1, 2003. Both tragedies claimed the lives of their respective crews, fourteen brave women and men in total, a powerful reminder of the dangers humanity faces as they move boldly toward the stars.

The specimen in the Mini Museum is a fragment of a mission flown High-Temperature Reusable



Shuttle Tile Assembly and Parts from "Coatings and Surface Treatments for Reusable Entry Systems" (Image Credit: Sylvia M. Johnson, NASA Ames Research Center)

Space Shuttle Columbia seen in flight moments before touchdown at Edwards Air Force Base on April 14, 1981. (Image Credit: NASA Image number: S-81-30455)

Surface Insulation Tile (HRSI) that was once attached to the space shuttle Columbia (OV-102). HRSI tiles are made of low-density silica, but 90% of the volume is actually air. This design allowed the tiles to protect parts of the orbiter exposed to re-entry temperatures exceeding 2,300 °F (1,260 °C). NASA disposition paperwork accompanying the tile indicates it was removed after Columbia's 7th mission, STS-61-C, which flew on January 12, 1986.

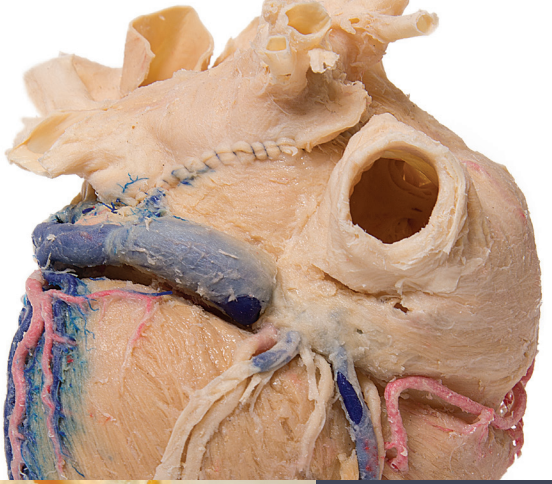
SOURCES:

Ward, Jonathan H. Leinbach, Michael D. "Bringing Columbia Home: The Untold Story of a Lost Space Shuttle and Her Crew." Arcade Publishing (2018)

Harland, David M. The space shuttle: roles, missions, and accomplishments. Vol. 2. John Wiley & Sons, 1998.

White, Rowland. Into the Black: The Extraordinary Untold Story of the First Flight of the Space Shuttle Columbia and the Astronauts Who Flew Her. Simon and Schuster, 2017.

Faget, Maxime A. "Space shuttle vehicle and system." U.S. Patent No. 3,702,688. 14 Nov. 1972.



The rhythmic pulse of a beating heart is a powerful reminder of the essence of life. It can even reach out to us across time...

Here, in the Epic of Gilgamesh which details events said to have taken place in 2600 BCE, the namesake king of Mesopotamia laments on the death of his friend Enkidu:

"Enkidu lifted not his head, and when Gilgamesh felt for his heart, there was no heartbeat. He covered the face of his friend as thou he were a bride. He circled him like an eagle, pacing like a lioness worried for her lost cubs. He tore out his curly hair and stripped off his fine garments as though they had become an abomination." - From Tablet VII (William Muss-Arnolt 1901 translation)

This tragic moment, now separated from us by more than 4,600 years, is a palpable example of why so many cultures have considered the heart the seat of the self.

SPECIMEN TYPE:
HUMAN ARTIFACT

AVERAGE BEATS PER DAY:
100,000

AVERAGE BEATS IN A LIFETIME:
2,500,000,000

human heart

"The heart is of such density that fire can scarcely damage it."

– Leonardo da Vinci, c. 1490

In medical science, numerous cultures have sought to unravel the role of the heart. The Egyptians discuss the heart in great detail in papyri dating back as far as 1550 BCE, while traditional medical practices in both China and India have used the pulse as a diagnostic tool even longer.

The Greek philosopher Aristotle (384–322 BCE) considered the heart the central physiological mechanism of the human body, an intelligent organ directing operations of all others. Among the first to separate these functions was another Greek, Aelius Galenus (129-200 CE). Galenus, also known as Galen of Pergamon, was a physician working in the Roman Empire. His detailed observations of the nervous system led him to divide the role of the heart, creating a three-part system of the self with the "rational" (logistikon) residing in the brain, the "spirit" (thumoeides) in the heart, and "desire" (epithumētikon) emanating from the liver. Galenus' theory also held that the liver was the source of blood and that production was continuous, flowing between the chambers of the heart by means of minuscule pores, and pumped to the brain and other organs only to be consumed.

By the Renaissance, researchers such as the 16th century Spanish physician and humanist philosopher, Andrés Laguna de Segovia (1499–1559) had a more contemporary view of the structure of the heart, but the mechanism of circulation was still stuck in the theories of Galenus:

"The heart has only two ventricles, a right and a left. I do not know what is the

meaning of the riddle proposed by the people who add a third ventricle to the heart unless perhaps they intend by it those pores which are found in the septum." – From Anatomica methodus, seu De sectione humani corporis contemplatio (1535)

And such would remain the case for another century until English physician William Harvey (1578-1657) calculated that Galen's theory would require the liver to produce a minimum of 498 pounds of blood per day. Harvey also demonstrated the flow of blood through the heart, entering the right ventricle, forced out via the pulmonary artery to the lungs, then returning to the heart via the pulmonary vein to the left ventricle. His findings, published in 1628 as "Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus" resulted in a powerful rebuke that he himself had predicted prior to publication:

> ***"But what remains to be said about the quantity and source of the blood which thus passes, is of so novel and unheard-of character that I not only fear injury to myself from the envy of a few, but I tremble lest I have mankind at large for my enemies, so much doth want and custom, that become as another nature, and doctrine once sown and that hath struck deep root, and respect for antiquity, influence all men: still the die is cast, and my trust is in my love of truth, and the candour that inheres in cultivated minds."***

It would be more than 20 years before Harvey's observations met general acceptance in the scientific community.

Today, physicians have a better sense of the heart and its role in the circulatory system. The human heart is the first organ to develop in vitro, already beating at just three weeks into embryogenesis. It is made of muscle tissue that works twice as hard as the muscles that support movement and posture. The heart is also one of the last organs to stop functioning at death.

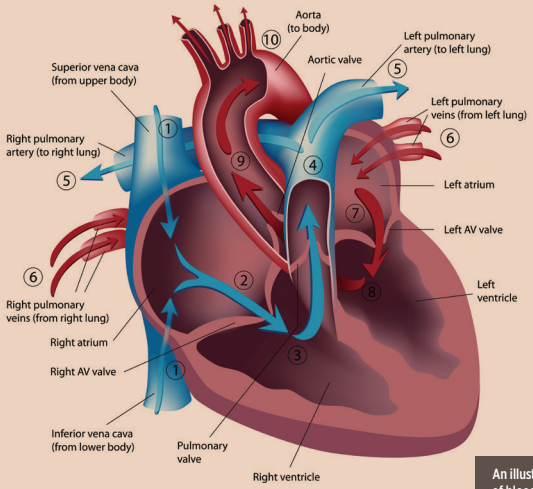
The specimen in the Mini Museum is a human heart recovered from a 74 year-old woman who passed away due to non-cardiac related natural causes. The heart was prepared by a laboratory which uses plastination techniques to preserve human tissues for various exhibits and medical research purposes worldwide. The heart was considered unusable for most technical purposes due to a mishap during preparation which caused a long tear along the surface of the left atrium.

SOURCES:

Amindon, Stephen. "The Sublime Engine: A Biography of the Human Heart." Rodale, 2011.

Mackay, Judith. The atlas of heart disease and stroke. Vol. 5. World Health Organization, 2004.

Morris, Thomas. The matter of the heart: a history of the heart in eleven operations. St. Martin's Press, 2018.

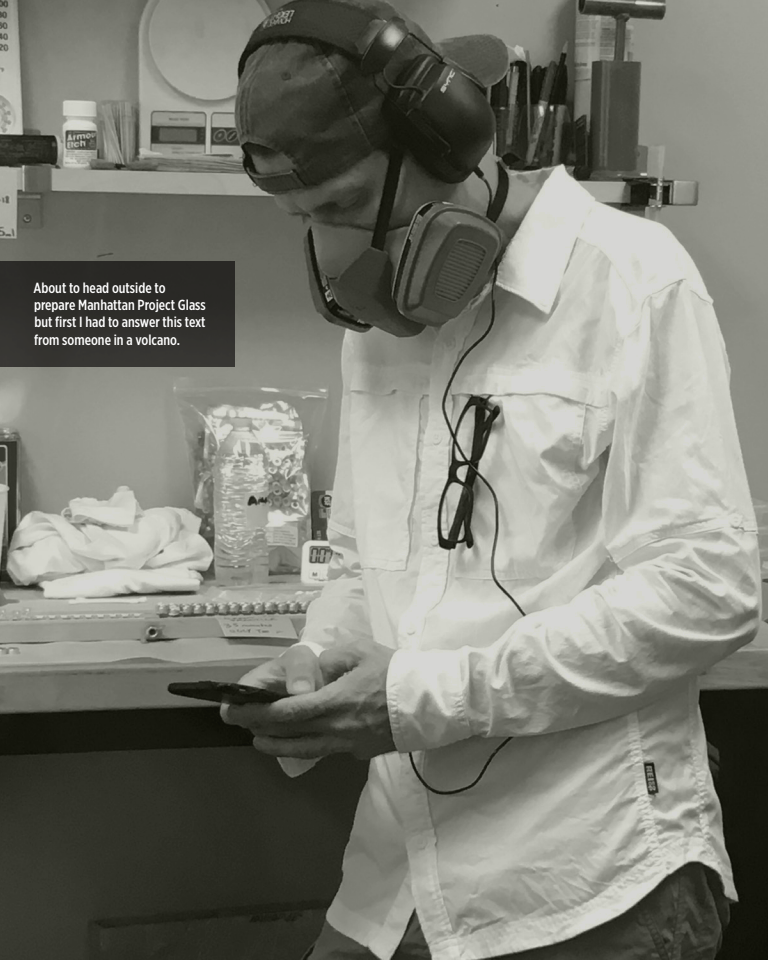


An illustration of the pathway of blood flow through the heart.

The heart is segmented into four distinctive chambers, two atriums that are responsible for receiving blood and two ventricles that discharge it. A cardiac cycle begins when the atria contract and ends when the ventricles relax. Separating the chambers are valves that trap the blood within the designated compartment during that cycle. A heart beating 80 times a minute will move around 360 L of blood, or between 60 to 90 mL per contraction.

Blood in need of oxygenation enters the right atrium via the superior and inferior vena cava and is held there by the tricuspid valve. When the atria contracts, the valve opens and the blood moves downward to the right ventricle. As the heart muscle relaxes, the valve closes to keep the blood from flowing upward back into the atrium. The pulmonary valve prevents the blood resting in the right ventricle from advancing into the pulmonary artery until the next contraction. When the heart muscle squeezes the ventricles, the valve opens forcing the blood into the pulmonary artery where it will travel to the lungs for oxygenation.

On the left side of the heart, there is a similar process with each cardiac cycle. The left atrium receives oxygenated blood traveling from the lungs in one of four pulmonary veins. The mitral valve closes after a contraction to prevent the blood from flowing down into the left ventricle. When the heart pumps, the valve opens and the oxygenated blood moves on to its next station. The left ventricle pumps blood rich with oxygen into the aorta for transportation to the body via the arteries.



About to head outside to prepare Manhattan Project Glass but first I had to answer this text from someone in a volcano.

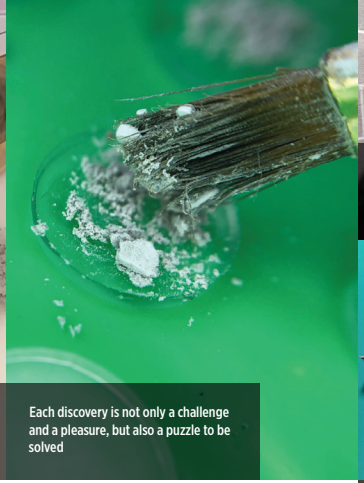
crafting the fourth edition

When you think about the work that goes into crafting thousands upon thousands of specimens, it might seem as if each individual item could easily get lost in the process. Over the years, we've learned that nothing could be further from the truth.

Each specimen, whether nipped or assembled from constituent parts, is a unique experience. The experience may only last a moment, or it may go on for minutes, days, or even weeks at a time. The process of bringing the specimens of the Fourth Edition together highlights this feeling in dramatic fashion.

Willie sorting thousands of Mummy Beads by size, then color. This is a time-consuming process which takes weeks of slow and methodical work.

Applying fine meteorite dust to a working sheet of Extraterrestrial Amino Acids by gently tapping a toothpick



Each discovery is not only a challenge and a pleasure, but also a puzzle to be solved

Chris carefully prepares the acid solution for Copper Crystals. Copper Crystals before, during and after their bath

Preparing Dinosaur Food for inclusion. Even with the stabilizer, dust and loss is a reality so extra care is taken when working on the final specimens.

Specimens like Extraterrestrial Amino Acids, an amalgam of two different meteorites forged during the birth of the solar system, undergo a lengthy process of reducing the source material to varying grades ranging from fine particulates to mini meteorites under 0.2mm in diameter.

From here, we create small sheets of material, carefully adding bit by bit and balancing the density and grain.

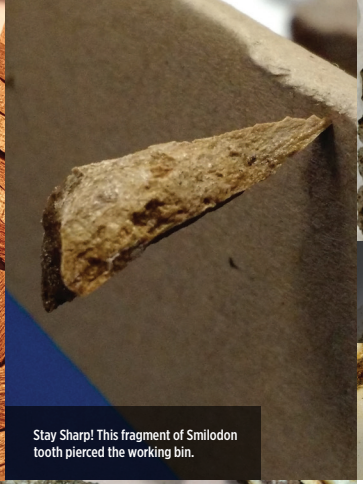
A similar process was involved with creating the Lunar Highlands specimen.

We wanted to create a different look here, something that would evoke the image of the bright highlands of the moon. The piece gets its shape from a custom aluminum mold into which we pour silicon to create a reusable mold. Resin is placed into the mold, drop by drop, and then finely ground lunar dust from meteorite NWA 5000 is applied to each resin dot with a brush.

Some specimens are naturally delicate and seem like they would be very simple to prepare. However, there is always some unexpected surprise waiting to be discovered. Copper Crystals provides a great example.

The dendritic structure adds great texture to the top line of the Mini Museum, as well as an interesting geological tale, but preparing the specimen revealed the bright inner shine so we decided to chemically remove the patina to highlight the beauty of the metal.

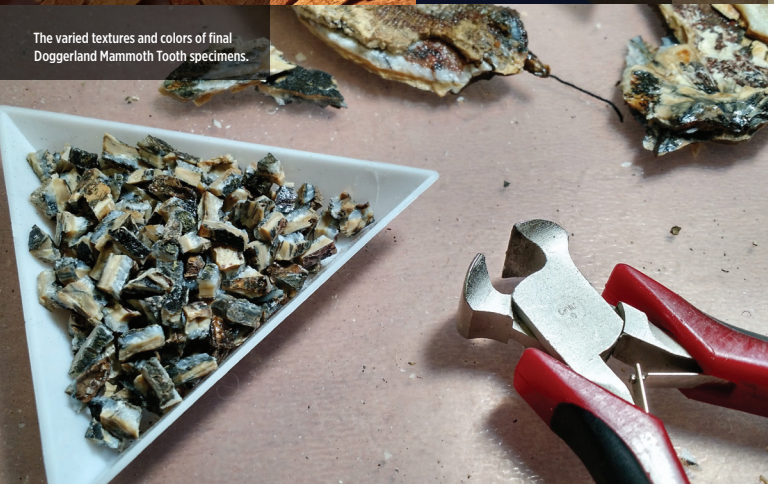
Bill captures the beautiful texture of the Lusitania Deck Chair.



Stay Sharp! This fragment of Smilodon tooth pierced the working bin.

Bright strips of rolled steel undergoing chemical treatment to create a more aged look. Each of these strips will be sanded by hand before the next step.

Early prototype Knight's Sword specimens. Each is just 2mm wide.



The varied textures and colors of final Doggerland Mammoth Tooth specimens.

Fossil specimens, such as Dinosaur Food, are typically stabilized with penetrating adhesives and then shaped into individual pieces.

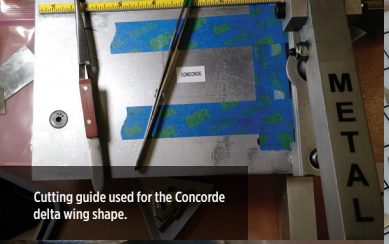
This delicate work requires attention to form as well as the natural crevices and fractures within the material to minimize waste and avoid the sharp and tiny projectiles which are known to poke and pierce.

In particular, the Doggerland Mammoth Tooth ranks among some of the hardest organic material we've ever worked with. The edges of these layered teeth could be ragged, tearing through gloves and rapidly dulling steel shears.

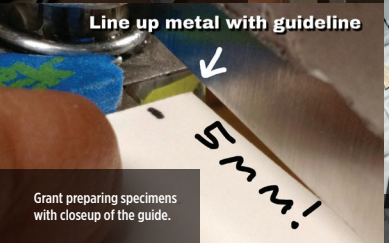
But, as with many things, tough material like this often yields the most interesting shapes and colors.

Artifacts from human civilization are always an interesting puzzle. The goal is to create a shape which evokes an image of the whole piece, or perhaps captures some unique feature of the material. At times, we make choices as to whether we want to capture the original look or perhaps recapture the essence of the discovered item.

The deck chair from the Lusitania is one such item in which the original physical characteristics of the material took center stage. Worn by the cold and violent waters of the Atlantic Ocean and tempered by time, the surface of the wood was gray and coarse. But inside, the wood was still alive



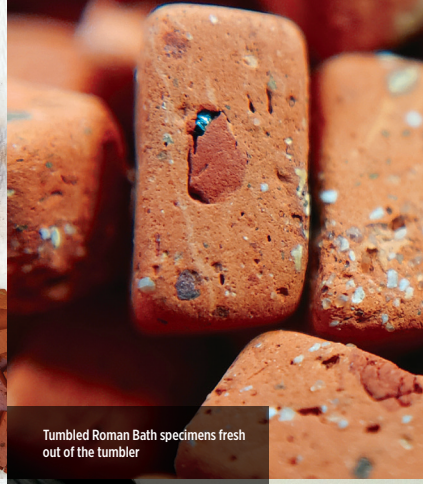
Cutting guide used for the Concorde delta wing shape.



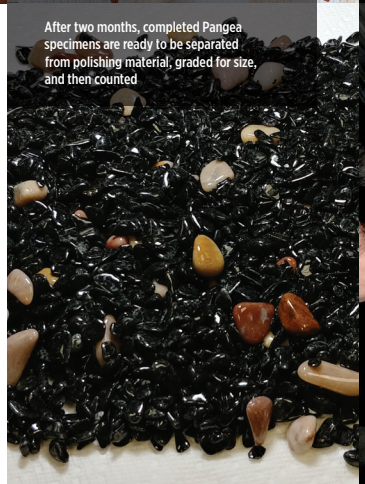
Grant preparing specimens with closeup of the guide.

Final specimens ready for QA.

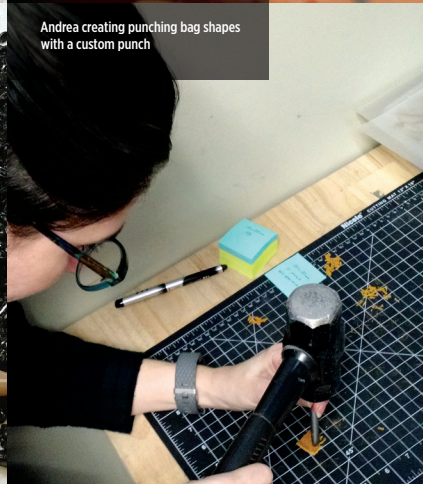
Early stages of preparing Roman Bath specimens, reducing material step by step



Tumbled Roman Bath specimens fresh out of the tumbler



After two months, completed Pangea specimens are ready to be separated from polishing material, graded for size, and then counted



Andrea creating punching bag shapes with a custom punch

with rich and vibrant color. Now exposed, you are seeing the wood as it would have appeared on deck more than 100 years ago.

On the opposite end of the spectrum we have the Knight's Sword, a 14th century CE blade which lay in a stream for several hundred years before joining a family collection in France. The black coating suggests the blade was stabilized in the 1960s or perhaps earlier.

Yet, when we cut into the blade, the bright flash of steel was revealed. Rolling the material thin, which is very difficult to do with ferrous metals, polished the metal further. After careful consideration, we decided to recapture the original patina by chemically treating the thin strips of metal prior to carefully cutting them into tiny blade shapes.

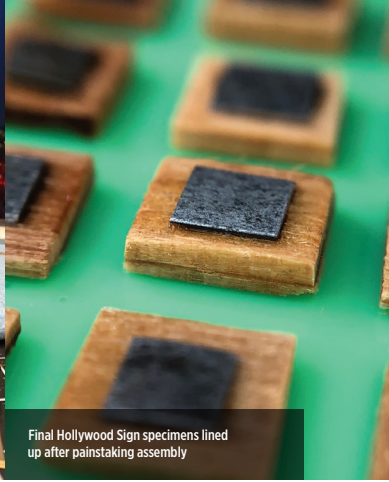
The cutting of the blades itself is more complicated that it seems. Getting the point just right is a challenge, because at this size even a tenth of a millimeter off can result in an odd shape.

Guides which are useful for cutting shapes like the delta wing of the Concorde are less useful at this scale because the material is still quite durable. So more often than not, the trimming is done by hand time and time again.

Simple shapes such as the rounded miniature monoliths of Stonehenge and the stackable Roman Bath Hypocaust Flue belie the numerous steps required to emulate their original shapes. Material is cut down to a

Zooming in on Muhammad Ali Punching Bag specimens with a 20X loupe

Jen's workstation while working on Hollywood Sign prototypes



Final Hollywood Sign specimens lined up after painstaking assembly

very specific size and then tumbled.

In the case of the "fluffy" Hypocaust Flue above, the tumbling only goes on for a few hours.

The hard bluestone of Stonehenge must be tumbled for days, and includes multiple steps to achieve the polished shine.

Pangea is comprised of an even more durable stone, and so it tumbles much longer and with more steps to achieve the high-gloss shine. The process takes more than two months, but without it, the specimens would be gray and flat.

Complex shapes, such as the Muhammad Ali Punching Bag and the Hollywood Sign are the result of hours of work. For the Punching Bag, we used a teardrop-shaped punch to get just the right shape.

The leather used to make this bag was very tough, so we used a combination of specialty razor blades to turn each little punched shape into four to six specimens.

The Hollywood Sign was built a little like a sandwich. First, the paint was removed from the surface of the metal, then the metal was rolled thin and cut into tiny squares. The original wooden post was shaved into thin strips and cut into slightly larger squares. These two pieces were brought together to create the tiny signs we've placed into thousands of museums.

Testing plays a big role in the process, and the Hollywood Sign is a perfect example. We originally wanted to use the paint as well as the metal and the wood, but when subjected to temperatures over 300F the color of the paint shifted from white to brilliant, almost fluorescent yellow. We went through dozens of tests to stabilize the paint, and each failed, but in the end I think the final specimens capture the heart of the sign quite well.

Perhaps our most tested specimen in the Fourth Edition is something we've never done before: liquid water. Capturing the Amazon River in the Mini Museum was a dream of mine, but the tremendous forces of heat and pressure at work in the autoclave required a very special solution.

Each tiny vial is a handmade bottle, filled using a pipette with roughly 0.4ml of water from the Amazon. The water is shaken before the sample is pulled so that sediment will be present in each specimen.

In order to fit inside the Mini Museum, we couldn't use a standard 11mm vial. They are all too tall. So, we used tiny, handmade, glass bottles and married them to the aluminum caps using a small dollop of marine putty to create the look of a classic liquid specimen.

Without question, this specimen is our most complicated and time consuming. The amount of putty must be perfectly matched to the size of the vial (which all vary slightly since they are handmade). The putty also has a short working time, so that also plays a role in how much is used.

I originally created several custom jigs to hold the water bottles. While the solution worked well, we were surprised to find that our results were more consistent when working completely by hand. This is all part of the process of making things. Each step is a lesson and valuable in its own right.

Filled Amazon Water Vials waiting for the sealing stage

Bill, Andrea, and Grant during one of many Amazon River water vial sessions

Jamie inspecting Amazon River vials with his magic 5X science goggles

Attempt to place the cap too early in the curing process and the putty rises, too late and the cap will not bond properly. The cap is also slightly larger than the top of the vial, so each one is not only placed by hand but seated and adjusted while the putty cures. When complete, each vial is carefully studied to make sure that cap and bottle align in a pleasing way.

And yet, while the Amazon River was the most time-consuming specimen, it was not the most technical specimen. That prize belongs to the Space Shuttle Tile.

Space Shuttle tiles are almost 90% air, and the rest is silicon. This makes the tile incredibly light and heat resistant, but it also makes it susceptible to flaking and powdering when using mechanical cutting instruments. While researching the best method of preparation, we turned to a NASA study on working with the tiles. It was disheartening to read, as they also had trouble working with the material. In our case, the problem was enhanced by an order of magnitude, as we only have one tile and our target size is thousands of times smaller than the average tile.

Our mechanical cutting tests, from sawing to shearing, proved just as difficult as the NASA study suggested. We tried densifying the material using special silicate solutions as well as penetrating stabilizers. These worked to a certain degree, but chemical reactions triggered by the heat of inclusion caused the material to deform or change colors in ways that were not reflective of the original tile.

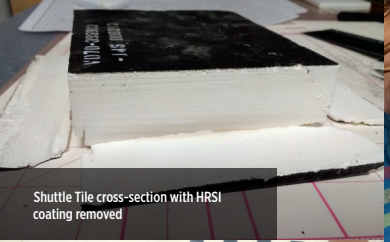
In the end, we found a combination of freezing and a very unique resin allowed us to stabilize the material for fine cutting without causing the deformations under heat, so bit by bit, with runs to the deep freeze, the specimens for the Mini Museum are produced one at a time.

And here, I think it is important to talk about the emotional effect of creating these specimens for each and every Mini Museum. I've said many times that each specimen has its own challenges, and while I've discussed the technical aspects of creating these specimens, there is a powerful emotional component to sharing the Mini Museum with all of you.

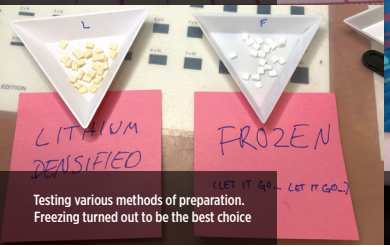
We think about how each specimen will look when you (and I mean you personally) receive the Mini Museum or give it as a gift. We wonder what you will think. Will you like this specimen? Might it look more interesting with a small edit?

How will it look when set in place with other specimens? These considerations drive our deep attention to details, but they also spark other thoughts. We think about the history of the object, some of which have traveled billions of miles over millions and millions of years. Others which are deeply personal or have an emotional impact far beyond their humble form.

Of all the specimens in the Fourth Edition, the Manhattan Project Glass and the Human Heart are perhaps the most complex from



Shuttle Tile cross-section with HRSI coating removed



Testing various methods of preparation. Freezing turned out to be the best choice

Stephanie working with HRSI tile coating

Max preparing thousands of Roman Bath specimens on the wet saw

The dynamic range of specimens in Plesiosaur

Slabs from the remains of the Great Dying, the largest extinction event in the fossil record

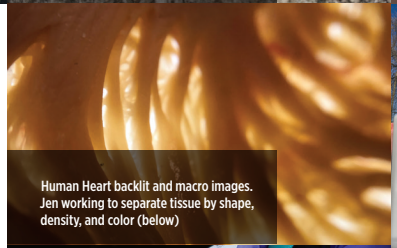
an emotional perspective. The Manhattan Project Glass was a very complex substance to work with from a technical perspective.

In the image here, I was very lucky to get a clean break as the high lead oxide content causes the glass to crumble rather than fracture. The sound it makes is also very sharp like the ticking of a clock. Multiplied over many weeks, the two factors combine to make for a nerve wracking experience, but also one in which you are very conscious of the fact that the material represents the creation of the most destructive force in human history.

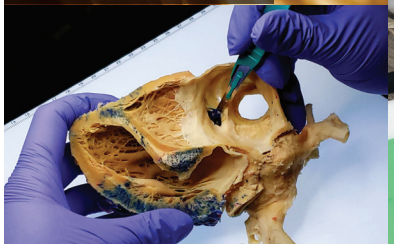
Now, contrast this with the Human Heart.

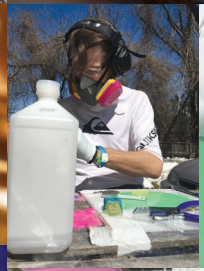
Preparing this specimen for inclusion was very much like unraveling a life. However, as this is a life which is impossible to know, it is only natural that your thoughts may drift towards details of your own life or perhaps those you love. The effect is a range of emotions from sadness to overwhelming joy, the prospect of one's own mortality, and the beauty in the constant renewal of life.

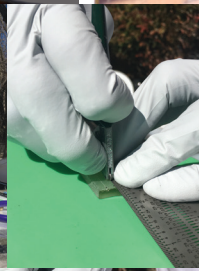
And then of course, there is everything else I've discussed... Thoughts of you and what you will think about these specimens when you see them juxtaposed against each other and with the rest of the collection. It's an intense experience for all of us, and one of the reasons we are all so very grateful for the opportunity to create and share the Mini Museum with all of you.

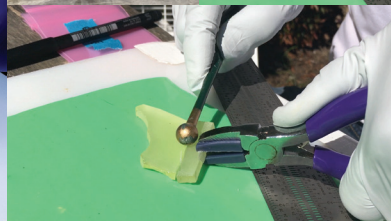


Human Heart backlit and macro images. Jen working to separate tissue by shape, density, and color (below)









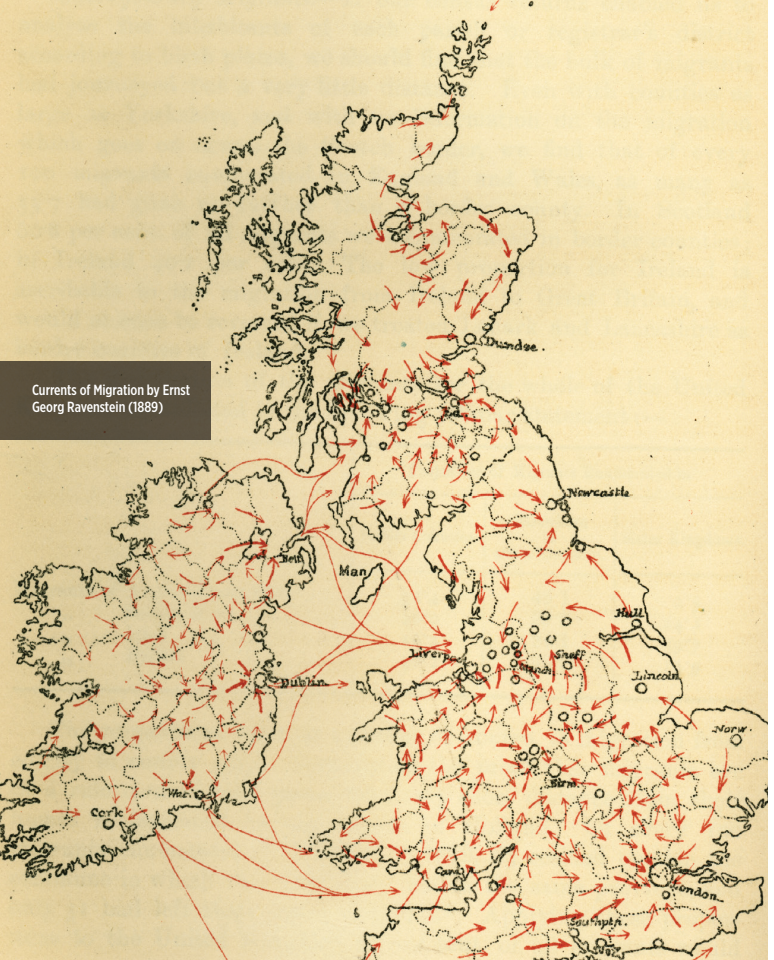
To illustrate how beautiful it can be, I'd like to end this section of the Companion Guide by sharing one of the many small treasures we've discovered while preparing specimens:

I came across this scene one morning in our workshop before anyone else arrived. Grant had been sorting Pangea specimens the day before and found this perfect little heart-shaped stone. He set it aside for Stephanie with the note you see here.

Of course, I had to take a picture.

I found this so touching, and not just because Grant is a wonderful person who loves his wife and thinks of brightening her day (though I have to admit it is beautiful). No, the really striking thought I had is that we've been doing this work for five years now. We've created over 750,000 specimens, each one unique and personal just like this little heart-shaped Pangea. They are all out there in the world with you, and each of you has a story to tell.

How incredible is that?!



Currents of Migration by Ernst Georg Ravenstein (1889)

CURRENT GLOBAL MIGRANT POPULATION:
258,000,000 PEOPLE

currents of migration

"Everything is related to everything else, but near things are more related than distant things."

– Waldo Tobler, American-Swiss Geographer (1970) First Law of Geography

As we've followed the progression of life across billions of years of history, we've come across many examples of the importance of migration and its central role in the diversity of life on Earth. From the Woolly Mammoth's vast metropolitan population spread across the steppe, to the rise and fall of thousands of species of tiny foraminifera in the ocean, each of these stories plays out on a grand scale that often encompasses hundreds of thousands of years. On this scale, small changes to these patterns of movement can have dramatic effects resulting in the emergence of new species and the extinction of the old.

We, as human beings, are not immune. On the contrary, our own story is a vibrant example of how powerful the effect of migration can be on a single species and the environment of an entire planet.

This map (left) was published in 1889 in the Journal of the statistical society of London. It was accompanied by a paper titled The Laws of Migration. Created by geographer, Ernst Georg Ravenstein, the Laws of Migration established a working framework for the statistical study of human migration as it relates to economic and population development.

A view from the deep past... The Denisova Cave and the surrounding countryside of the Altai mountains in Siberia, Russia (Image Credit: Ruslan Olinchuk)

The study is breathtaking in its scope, covering data from Great Britain, Europe, Canada, and the United States. Though published nearly 130 years ago, Ravenstein's findings are still considered valid today:

1. **Most migrations occur over short distances.**
2. **Migration often happens in stages, moving from one center to another, steadily rising from rural to large urban centers.**
3. **Most migrants are adults.**
4. **Within a country, females are more migratory, though males are more likely to travel long distances.**
5. **Long-distance migration typically involves a move to urban areas.**
6. **Urban areas grow more by migration than natural increases.**
7. **Urban dwellers are less migratory than rural populations.**
8. **Economic factors drive most migration.**
9. **Each migration produces measurable, though not necessarily equal, movement in the opposite direction.**

When we look back into the deep past, it's interesting to consider how these findings might apply to the movement of our close relatives. There is ample evidence to suggest that small migrations were common, moving with the seasons as nomadic peoples do today. But what of larger moves? Crossing continental divides and entering forbidden lands?

While finishing this edition of the Mini Museum, Paleogeneticist Viviane Slon of the Max Planck Institute in Leipzig published a groundbreaking study of the remains of a girl born to Neanderthal and Denisovan parents 90,000 years ago. The discovery is part of a large cache of ancient human remains discovered in the "Denisova Cave" located in the Altai mountains of Siberia, Russia.

Neanderthals and Denisovans separated genetically roughly 400,000 years ago (200,000 years after separating from us). Yet, genetic studies of this unique individual's parents indicate that migrations between Eastern and Western Eurasia were frequent enough to suggest that mixing between these different hominin populations was not unusual.

We know nothing of the Denisovans physical appearance, aside from a few fragmentary remains. However, the DNA extracted from these tiny samples and compared with modern descendants (i.e. us) show they made their way down to the islands of Southeast Asia, New Guinea, and Australia. There are also suggestions that a third — and still undiscovered — hominin may also play a role in the diverse genetic makeup of the modern human species. While it's still impossible to say where this story will lead us in the future, it is clear from even these early findings that migration has played an enormous role in our journey to the present.

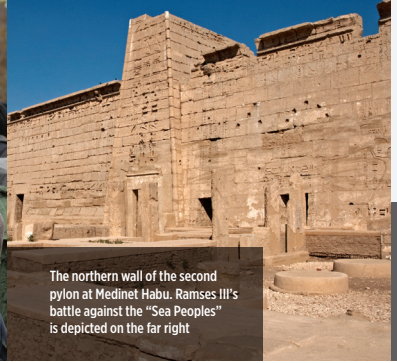
Today the currents of migration are as powerful as ever and show no signs of slowing. Rather, the pace is escalating and the scale is exponential. Countrysides around the world are emptying as rural populations move to urban centers. As these locations become increasingly dense, the waves of people move on, crossing borders and oceans, and entering new countries or entirely new continents.

According to the United Nations' 2017 International Migration Report, 258,000,000 people now live in a country other than their birth. This is a 17% increase from the year before and a 49% increase since the year 2000.

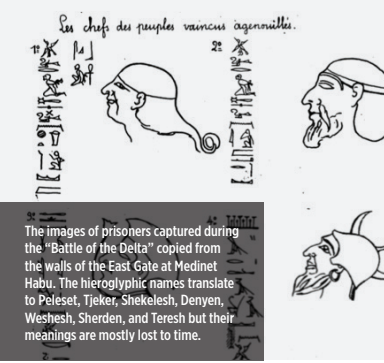
The UN report also indicates that 42% of the net positive population gain in North America during the period of 2000-2015 can be attributed to migration. In Oceana, the figure is 31%. Reflecting on this data, Ravenstein's observation about migration in the "New World" vs the "Old World" is particularly instructive:

> ***Another difference is this: whilst with us in Europe the "foreign element" constitute as mere fraction of the population, it assumes vast proportions in the new world.***
>
> ***Here in Europe every inflow of foreign elements is largely compensated by an outflow of natives, but in the new world the inflowing currents are overpoweringly strong, whilst the compensatory countercurrents are of the feeblest proportions.***

Hundreds of refugees make their way to Macedonia from a makeshift camp at the Greek-Macedonian border, near the Greek village of Idomeni (Image Credit: Orhan Tsolak Alamy Live News Idomeni, March 14, 2016)



The northern wall of the second pylon at Medinet Habu. Ramses III's battle against the "Sea Peoples" is depicted on the far right



The images of prisoners captured during the "Battle of the Delta" copied from the walls of the East Gate at Medinet Habu. The hieroglyphic names translate to Peleset, Tjeker, Shekelesh, Denyen, Weshesh, Sherden, and Teresh but their meanings are mostly lost to time.

These differences should constantly be borne in mind when discussing the statistics of American migration. They have been most marked in the past, and are very striking still. In course of time, however, they will become less glaring, until at last the new world shall have become assimilated to the old in its migratory currents no less than in other respects depending upon the population having attained a density commensurate with the natural resources of the country. ~ Ravenstein p. 278

In response, natives of a region move to erect borders and barriers that are both physical and conceptual. They try to restrict the inflow, but if history is any guide it is not truly possible.

"Speaking broadly, persons of foreign birth are most numerous in the frontier departments and in certain maritime towns. Their nationality in these localities corresponds with that of the nearest foreign country, in fact, as concerns migration, political boundaries do not appear to exist: Germans, notwithstanding the hostile feeling supposed to be entertained towards them, have nevertheless crossed the frontiers in considerable numbers, whilst natives of France have not allowed themselves to be deterred by rigorous passport regulations from crossing the French boundary into neighbouring parts of Germany." ~ Ravenstein p. 271

The people will still come regardless of all obstacles placed in their path.

They will enter forbidden lands. They will come regardless of hostile attitudes, disregarding the threat of physical harm and even the possibility of death. Perhaps it is because the way back is worse than the way forward, or perhaps it is simply the momentum of the current that carries them onward.

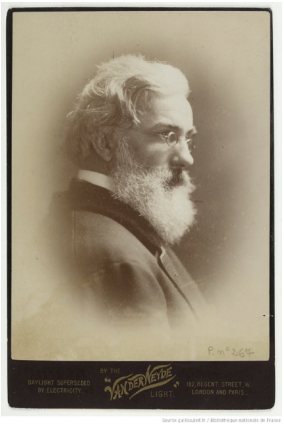
In the Second Edition of the Mini Museum, I touched on the fall of Bronze Age civilizations in the Eastern Mediterranean over 3,000 years ago. During this period, there were massive movements of people coming to population centers from many directions. Usually referred to as the "Sea People", this diverse group is said to be responsible for the destruction of numerous cities and regions.

The Egyptians recorded their resistance on the walls of the mortuary temple of Ramesses III at Medinet Habu. All around the temple there are great murals depicting the effort expended in repelling waves of people.

"Those who reached my boundary, their seed is not; their hearts and their souls are finished forever and ever. As for those who had assembled before them on the sea, the full flame was their front before the harbour mouths, and a wall of metal upon the shore surrounded them. They were dragged, overturned, and laid low upon the beach; slain and made heaps from stern to bow of their galleys, while all their things were cast upon the water." ~ Attributed to Ramses III from the inscriptions at Medinet Habu

But who were these people? What were they seeking? The records are sparse, but a complex picture of migration is slowly emerging; people forced to move by changes in climate, warfare, mercenary desire, and no doubt dire need to face such forces.

I imagine that their stories are at heart no different from those who make similar perilous journeys today, or perhaps even that of Ernst Georg Ravenstein himself.



Ernst Georg Ravenstein (1834-1913)

From the old to the new world - German emigrants for New York embarking on a Hamburg steamer. Harper's Weekly, November 7, 1874 via the United States Library of Congress

Ravenstein was born on December 20, 1834 in Frankfurt am Main, Germany. His father was a noted cartographer, and young Ernst trained in the discipline until the age of 18 when he immigrated to Great Britain. Upon arrival, he was apprenticed to another young German expatriate named August Heinrich Petermann. Petermann had arrived just a few years before and set up his own cartography business.

The connection between the journey of these two men may seem conveniently matched, but in reality they were both part of an enormous wave of immigrants who left Germany over the course of the 19th century. During this time, Germany suffered numerous setbacks and upheavals from the aftermath of the Napoleonic Wars, and environmental havoc caused by the eruption of Mount Tambora in 1815, to the failed Spring of Nations Revolutions of 1848, and ongoing struggles throughout the rest of the century.

Most German immigrants during this period headed to North America, and the United States in particular. In the United States, Germans settled in large coastal cities such as New York and Baltimore, but many more settled in midwestern cities such as Milwaukee, Cincinnati, St. Louis, Chicago, and others. By 1900, numerous cities throughout midwestern part of the country had dominant populations of now German-Americans.

In Great Britain, the destination of choice was London with smaller communities in Manchester and elsewhere. As with communities in the United States, the Germans relocating to Great Britain developed a vibrant community

Art of the Erdapfel (or "Earth Apple") the oldest surviving globe, created by Martin von Behaim (1459-1507) and reproduced by Ravenstein in 1908 for his final book *Martin Behaim: His Life and his Globe*

based on their own cultural traditions, but over time they became business owners and deeply integrated into all levels of society.

Like other German immigrants, Ravenstein worked hard to contribute. Three years after he immigrated, Ravenstein joined the Topographical Department of the British War Office where he served for 20 years before embarking on a remarkable 35 year career as one of the preeminent cartographers in Europe. He produced the first detailed maps and studies of equatorial East Africa, and learned Portuguese so that he could research and write a detailed account of Vasco da Gama's first voyage of 1497-1499 from Portugal to India. The culmination of his life's work led to his receipt in 1902 of the first Victoria gold medal of the Royal Geographical Society which recognized "his efforts during 40 years to introduce scientific methods into the cartography of the United Kingdom."

After nearly 60 years abroad, Ravenstein returned to Germany. He passed away on March 13, 1913 in Hofheim, just outside his native Frankfurt. Only a little more than a year after his death, the outbreak of World War I would result in one of the largest displacements of human beings in history, and the aftermath would change immigration policies and controls around the world.

Yet where one avenue of migration ends another begins, and looking back to the UN report we can see that the currents of migration press onward. And why might that be? For Ravenstein the answer would be clear:

> ***"Bad or oppressive laws, heavy taxation, an unattractive climate, uncongenial social surroundings, and even compulsion (slave trade,transportation), all have produced and are still producing currents of migration, but none of these currents can compare in volume with that which arises from the desire inherent in most men to "better" themselves in material respects." - From the Conclusion of* The Laws of Migration**

I'll close this essay with Emma Lazarus' (1849–1887) sonnet, "The New Colossus" which was written in 1883 to raise funds for the construction of the Statue of Liberty's pedestal. The text of the sonnet was cast onto a bronze plaque in 1903 and appears on the inner wall of the pedestal:

Not like the brazen giant of Greek fame,
With conquering limbs astride from land to land;
Here at our sea-washed, sunset gates shall stand
A mighty woman with a torch, whose flame
Is the imprisoned lightning, and her name
MOTHER OF EXILES. From her beacon-hand
Glows world-wide welcome; her mild eyes command
The air-bridged harbor that twin cities frame.

"Keep, ancient lands, your storied pomp!" cries she
With silent lips. "Give me your tired, your poor,
Your huddled masses yearning to breathe free,
The wretched refuse of your teeming shore.
Send these, the homeless, tempest-tost to me,
I lift my lamp beside the golden door!"

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Unveiling of the Statue of Liberty Enlightening the World by Edward Moran (1886)

thank you

"We but mirror the world. All the tendencies present in the outer world are to be found in the world of our body. If we could change ourselves, the tendencies in the world would also change. As a man changes his own nature, so does the attitude of the world change towards him. This is the divine mystery supreme. A wonderful thing it is and the source of our happiness. We need not wait to see what others do."

– Mohandas K. Gandhi, August 9, 1913

Each Mini Museum collection is a like a large story covering billions of years of history. I have occasionally described it as a poem or a song, and I hope it sparks a sense of serendipity. I also hope that it makes you think about your place in the wider world, not just here in the moment while you are reading these words, but in the wider expanse of time and space. If I've learned anything while working on the Mini Museum all these years it is that life is about transition. It is an ever-changing story filled with delights and surprises as well as challenges and struggle.

If you count the preparation work we put into getting the First Edition ready to launch, the core team here has been hard at work sharing a love of science and history with the world for five years. Just thinking about all the things we've done during that time sets my head spinning.

Yet life is also very much about those you meet along the way. I have been very fortunate to meet so many incredible people all over the world and to receive support for the Mini Museum from all of you.

As I said at the beginning of the Companion Guide, you have made it possible for all of us to share the Mini Museum. So here at the end of of the Fourth Edition, I'd like to take a moment to thank you all so very much once more. Your support has made this journey possible for all of us, and I can't wait to see where we will all go together next!