For the statements below, write the letter of the type of evidence above this best matches. Five types of evidence for evolution are comparative embryology, homologous morphological structures, fossils, vestigial organs, and biochemical homologies. Label fossil layers by age. Number the oldest layer 1. Write a 2 on the next oldest layer and so on. What layer would contain the most recent animal and plant remains? Why? Pieces of rock broke off of the ledge below. Within the pieces of rock various fossils were found. Match the key to what you have found. Name the fossil. This fossil was the youngest than the dinosaur Skull. Which was the oldest and youngest based on their layered position. We can also compare this to the fish skeleton. Cut out all the fossils from page 1. Paste the in order of age below. Getting children interested in science can be a challenge. However, there are some topics that are reliable crowd-pleasers, including space, volcanoes, and dinosaurs. Along with dinosaurs, most of us have been fascinated by the fossils that are part and parcel of palaeontology – often without understanding how they were formed in the first place. They form when living organisms (such as plants and animals) die and are covered in sediment. This is followed by anaerobic decomposition, which breaks down the organism's soft tissue. The hard bones are left behind, and the sediment hardens into rock, forming fossils. However, this is only one way in which fossils can be formed. This article will look at this method in further detail and also explore other fossilization methods, answering any questions you may have about their formation. Most Common Type of Fossilization The most common type of fossilization is known as permineralization. As mentioned above, it involves the anaerobic decomposition of the soft tissues of a living organism after it is buried under sediment. Once the soft tissue decays away, groundwater seeps into the remains, and the minerals in the groundwater fill the empty spaces in the remains. Over time, these minerals fully replace any remaining organic materials and harden, along with the sediment in which the hard bones or shells are encased, forming rocks that we recognize as fossils. This process is also known as petrification. Other Types of Fossilization Permineralization is the most common type of fossilization – but it isn't the only one. Some other types include: Replacements or Impressions These fossils follow the same formation path as permineralized ones. That is, until groundwater seeps into the picture. Unlike permineralization fossils, in these cases, the water dissolves away the hard bones, leaving an empty space in the rock shaped like the organism. These are known as molds. In some situations, minerals fill the mold after the organism dissolves completely. These mineralized fossils are known as casts. Compression As the name suggests, compression fossils are formed when a three-dimensional organism is flattened by the weight of sediment or water to form two-dimensional remains. These forms are most commonly plant fossils. In some cases, the rock holding the fossil may split naturally, with sections of the remains either attached to both halves or creating a mold on one half. These are known as a slab and counter slabs. Trace While fossils most commonly form around the remains of living organisms, they can also form around the activity of an organism. This includes the footprints and burrows of organisms. Several footprint fossils grouped together, showing the movement of an animal, are known as trackways. Trackways may also include other evidence of the organism's movement, such as tail and wing impressions. Coprolites are another important type of trace fossil. These are essential fossilized feces of animals and are used to examine the diet of the animal they came from. Soft Tissue Preservation In rare instances, not only is the hard bone and shell matter of an organism preserved, but their soft tissues can also be preserved too. This happens in very rare cases when the body of an organism is quickly buried in a low oxygen environment very soon after death. The best-known examples of this happening are when an organism is encased in another material soon after death, such as ice, tar, or tree resin. The resulting fossils are exceptionally well-preserved and provide scientists with a wealth of important information. Final Thoughts Fossils are an essential window into the Earth's past. They help us better understand where we came from and the history of our planet. They are formed following the death of a living organism, including ones as small as pollen. However, in some cases, they may be formed around organism activity. , the free encyclopedia that anyone can edit. 117,937 active editors 7,001,078 articles in English The English-language Wikipedia thanks its contributors for creating more than seven million articles! Learn how you can take part in the encyclopedia's continued improvement. GL Mk. II transmitter van Radar, Gun Laying, Mark I, or GL Mk. I for short, was an early World War II radar system developed by the British Army to provide information for anti-aircraft artillery. There were two upgrades, GL/EF (elevation finder) and GL Mk. II (pictured), both improving the ability to determine a target's bearing and elevation. GL refers to the radar's ability to direct the guns onto a target, known as gun laying. The first GL sets were developed in 1936 using separate transmitters and receivers mounted on gun carriages. Several were captured in 1940, leading the Germans to believe falsely that British radar was much less advanced than theirs. The GL/EF attachment provided bearing and elevation measurements accurate to about a degree: this caused the number of rounds needed to destroy an aircraft to fall to 4,100, a tenfold improvement over early-war results. The Mk. II, which was able to directly guide the guns, lowered the rounds-per-kill to 2,750. About 410 Mk. Is and 1,679 Mk. IIs were produced. (Full article...) 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Archive Start a new article Nominate an article Ngũgĩ wa Thiong'o Kenyan writer and activist Ngũgĩ wa Thiong'o (pictured) dies at the age of 87. In snooker, Zhao Xintong wins the World Championship. Ōnosato Daiki is promoted to yokozuna. In association football, Liverpool win the Premier League title. In motor racing, Álex Palou wins the Indianapolis 500. Ongoing: Gaza war M23 campaign Russian invasion of Ukraine timeline Sudanese civil war timeline Recent deaths: Phil Robertson Mary K. Gaillard Peter David Alan Yentob Gerry Connolly Sebastião Salgado Nominate an article May 30: Statehood Day in Croatia (1990) Johann Sebastian Bach 1431 – Hundred Years' War: After being convicted of heresy, Joan of Arc was burned at the stake in Rouen, France. 1723 – Johann Sebastian Bach (pictured) assumed the office of Thomaskantor in Leipzig, presenting the cantata Die Elenden sollen essen in St. Nicholas Church. 1922 – The Lincoln Memorial in Washington, D.C., featuring a sculpture of the sixteenth U.S. president Abraham Lincoln by Daniel Chester French, opened. 1963 – Buddhist crisis: A protest against pro-Catholic discrimination was held outside the National Assembly of South Vietnam in Saigon, the first open demonstration against President Ngô Đình Diệm. 2008 – The Convention on Cluster Munitions, prohibiting the use, transfer, and stockpiling of cluster bombs, was adopted. Ma Xifan (d. 947)Colin Blythe (b. 1879)Norris Bradbury (b. 1909)Wynonna Judd (b. 1964) More anniversaries: May 29 May 30 May 31 Archive By email List of days of the year About Seventeen performing "Oh My!" in 2018 South Korean boy band Seventeen made their debut in 2015, when they performed a showcase for their debut EP 17 Carat in front of a crowd of 1,000 people. Since then, the group have held 9 concert tours, 13 fan meetings, and have performed at a number of music festivals and awards shows. Their concert tours include the Right Here World Tour, which sold over one million tickets, and the Follow Tour, which was noted by Billboard as being the top grossing K-pop tour of 2023. In 2024, Seventeen made their first appearances at festivals in Europe, when they were the first South Korean act to perform at Glastonbury Festival's Pyramid Stage and as headliners for Lollapalooza Berlin. Seventeen's live performances are well regarded by fans and critics alike, and garnered them the award for Top K-pop Touring Artist at the 2024 Billboard Music Awards. (Full list...) Recently featured: Accolades received by Top Gun: Maverick National preserve 76th Primetime Emmy Awards Archive More featured lists Ignace Tonené (1840 or 1841 – 15 March 1916), also known as Nias or by his Ojibwe name Maiagizis ('right/correct sun'), was a Teme-Augama Anishnabai chief, fur trader, and gold prospector in Upper Canada. He was a prominent employee of the Hudson's Bay Company. Tonené was the elected deputy chief before being the lead chief and later the life chief of his community. In this role as deputy, he negotiated with the Canadian federal government and the Ontario provincial government, advocating for his community to receive an annual financial support from both. His attempts to secure land reserves for his community were thwarted by the Ontario premier Oliver Mowat. Tonené's prospecting triggered a 1906 gold rush and the creation of Kerr Addison Mines Ltd., although one of his claims was stolen from him by white Canadian prospectors. This photograph shows Tonené in 1909. Photograph credit: William John Winter; restored by Adam Cuerden Recently featured: Australian white ibis Hell Gate Bridge Anemonoides blanda Archive More featured pictures Community portal – The central hub for editors, with resources, links, tasks, and announcements. Village pump – Forum for discussions about Wikipedia itself, including policies and technical issues. Site news – Sources of news about Wikipedia and the broader Wikimedia movement. Teahouse – Ask basic questions about using or editing Wikipedia. Help desk – Ask questions about using or editing Wikipedia. Reference desk – Ask research questions about encyclopedic topics. Content portals – A unique way to navigate the encyclopedia. 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Many other Wikipedias are available; some of the largest are listed below. 1,000,000+ articles العربية Deutsch Español فارسی Français Italiano Nederlands 日本語 Polski Português Русский Svenska Українська Tiếng Việt 中文 250,000+ articles Bahasa Indonesia Bahasa Melayu Bân-lâm-gú Български Català Čeština Dansk Eesti Ελληνικά Esperanto Euskara עברית Հայերեն Magyar Norsk bokmål Română Simple English Slovenčina Srpski Srpskohrvatski Suomi Türkçe Oʻzbekcha 50,000+ articles Asturianu Azərbaycanca [?] Bosanski کوردی Frysk Gaeilge Galego Hrvatski ქართული Kurdî Latviešu Lietuvių [?] Македонски [?] Norsk nynorsk [?] Shqip Slovenščina ไทย [?] اردو Retrieved from "2EP by Seventeen 17 CaratEP by SeventeenReleasedMay 29, 2015 (2015-05-29)GenreK-popdance-popHip hopLength16:48LanguageKoreanLabelPledis EntertainmentLOEN EntertainmentSeventeen chronology 17 Carat(2015) Boys Be(2015) Singles from 17 Carat "Adore U"Released: May 29, 2015 17 Carat is the debut extended play (EP) by South Korean boy group Seventeen. It was released on May 29, 2015, by Pledis Entertainment and distributed by LOEN Entertainment. "Adore U" serves as the lead single for the EP. 17 Carat features five tracks written, co-written, and co-produced by Seventeen's group members. "Adore U" was chosen as the lead single for the EP and was performed on multiple music shows by the group. "Shining Diamond" was used as a pre-single on the group's reality debut show. The group stated that the tracklist was chosen to reflect Seventeen's core concept of "boys' passion".[1] The album has two physical versions: one with a "black" themed photo card set, and the other with a "white" themed photo card set. All copies include a CD containing the songs and a fold-up poster/lyric sheet. "Adore U" is the lead single of the extended play. It was written by Woozi, S.Coups, and Yeon Dong-geon.[2] The Korea Herald states "Adore U" is a funky pop song about a teenage boy trying to navigate through puppy love."[3] It marks the beginning of the group's trilogy composed of the singles Adore U, Mansae, and Pretty U about a boy meeting, falling in love and asking out a girl. The track was released on May 29, 2015, and was directed by Dee Shin. The dance choreography was choreographed by Hoshi and focuses on "storytelling, and on highlighting each member's strengths onstage".[4] The single has sold more than 38,000 digital copies and peaked at number 13 on the Billboard US World Chart. The EP has sold over 82,972 copies in South Korea.[5] It peaked at number 4 on the Korean Gaon Album Chart[6] and number 8 on the US World Billboard Chart.[7] Year-end lists Critic/publication List Rank Ref. Billboard The 10 Best K-pop Album of 2015 Placed [8] Hoshi participated in the choreography of "Adore U" and "Shining Diamond", Dino choreographed "Jam Jam".[9] Official track list[10]No.TitleLyricsMusicArrangementsLength1."Shining Diamond"WooziVernonS.CoupsKim Min-jeongWooziMasterKeyRishiMasterKeyRishi3:42."Adore U" (; Akinda)WooziVernonS.CoupsBumzuWooziBumzuYeon Dong-geonWooziBumzuYeon Dong-geon3:073."Ah Yeah" (Hip-Hop unit)S. CoupsVernonWonwooMingyuCream DoughnutRishiCream DoughnutRishi3:294."Jam Jam" (Performance unit + Vernon)WooziHoshiDinoVernonWooziCream DoughnutCream DoughnutRishiCream DoughnutRishi3:255."20" (Vocal unit)WooziWooziWon Yeong-heonWon Yeong-heonWon Yeong-heon2:23 Weekly chart performance for 17 Carat Chart (2015-2023) Peakposition Japanese Albums (Oricon)[11] 46 South Korean Albums (Gaon)[12] 4 US World Albums (Billboard)[13] 8 Year-end chart performance for 17 Carat Chart (2015) Peakposition South Korean Albums (Gaon)[14] 47 ^ "Seventeen hopes to shine like diamonds with '17 Carat'". The Korea Herald. 26 May 2015. Retrieved 30 November 2016. ^ "Adore U". Color Coded Lyrics. 29 May 2015. Retrieved 29 November 2016. ^ "Seventeen hopes to shine like diamonds with '17 Carat'". The Korea Herald. 26 May 2015. Retrieved 30 November 2016. ^ "Seventeen hopes to shine like diamonds with '17 Carat'". The Korea Herald. 26 May 2015. 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View (previous 50 | next 50) (20 | 50 | 100 | 250 | 500)Main Page (links | edit) Pledis Entertainment discography (links | edit) List of 2015 albums (links | edit) 2015 in South Korean music (links | edit) Seventeen (South Korean band) (links | edit) S.Coups (links | edit) Vernon (rapper) (links | edit) Wonwoo (links | edit) List of awards and nominations received by Seventeen (links | edit) Seventeen discography (links | edit) Love & Letter (links | edit) Joshua (singer) (links | edit) Seventeen TV (links | edit) 17 Carat (redirect page) (links | edit) List of Seventeen live performances (links | edit) Teen, Age (links | edit) Al1 (links | edit) Bumzu (links | edit) You Make My Day (links | edit) You Made My Dawn (links | edit) Jun (Chinese entertainer) (links | edit) List of Stray Kids live performances (links | edit) The8 (links | edit) An Ode (links | edit) Seungkwan (links | edit) Fallin' Flower (links | edit) Heng:garæ (links | edit) Semicolon (EP) (links | edit) Your Choice (links | edit) Going Seventeen (web series) (links | edit) Not Alone (Seventeen song) (links | edit) Attacca (EP) (links | edit) Rock with You (Seventeen song) (links | edit) Woozi (links | edit) Hoshi (South Korean singer) (links | edit) Don't Wanna Cry (Seventeen song) (links | edit) Darl+ing (links | edit) Face the Sun (links | edit) Left & Right (Seventeen song) (links | edit) 24H (EP) (links | edit) We Make You (links | edit) Hot (Seventeen song) (links | edit) Dream (Seventeen EP) (links | edit) BSS (band) (links | edit) FML (EP) (links | edit) Super (Seventeen song) (links | edit) Always Yours (album) (links | edit) Seventeenth Heaven (links | edit) View (previous 50 | next 50) (20 | 50 | 100 | 250 | 500) Retrieved from " WhatLinksHere/17 Carat" No front page content has been created yet. These fossils worksheets introduce fossils and cover their identification and uses in science. Dinosaur bones are fun to learn about! The free worksheets are PDF, PNG, and Google Slides formats. Download, print, or use them online for personal or classroom use Related Posts From giant parrots and feathered dinosaurs to really old poop and the Bone Wars to the difference between body fossils and trace fossils, here are some fun facts about fossils, adapted from an episode of The List Show on YouTube. 1. A FOSSIL SHOWED THAT PARROTS USED TO BE 3 FEET TALL. In 2019, a paper published in the journal Biology Letters described the fossil of a parrot that lived somewhere around 16 to 19 million years ago. The bones were originally found in 2008, but they were misidentified as an eagle because no one assumed there would be a parrot that big. The bird, believed to be about 15 pounds, is now affectionately referred to as "squakzilla." 2. THERE ARE REQUIREMENTS THAT NEED TO BE MET FOR SOMETHING TO BE CONSIDERED A FOSSIL. Fossils are generally defined as the preserved remains, traces, or imprints from an organism. The common definition also requires that it be 10,000 years or older. 3. THERE ARE A FEW TYPES OF FOSSILS. When we think of fossils, most of us probably picture animal bones or teeth. These are known as body fossils. But there are also trace fossils, which are evidence of an animal's activity: things like footprints, nests, eggs, and even poop. 4. THE MEANING OF THE WORD FOSSIL HAS CHANGED. The word fossil can be traced to the Latin term fossus, which means "dug up." That was also fossil's original meaning when it emerged around the 1600s. It began to mean "preserved remains" in 1736. 5. THERE'S SUCH A THING AS "MICROFOSSILS." It's not always easy to determine what a fossil used to be. Microfossils are fossils of bacteria or pollen, or other things that you can't study with the naked eye. In 2017, paleobiologist J. William Schopf and a team published a paper about the microfossil microbes he found in the early '90s. Schopf claimed these rocks showed evidence of microbes from 3.46 billion years ago, which would have made them, at that time, some of the oldest fossils ever found. Not everyone was convinced; some said the so-called fossils were just minerals that happened to look like biological specimens. Schopf and his collaborators worked for almost 25 years to prove that the rocks contained the right carbon isotopes to have once been microbes, and their 2017 paper provided what some in the field felt was compelling evidence, using raman spectroscopy to analyze the specimens in question. Skeptics remain, though, including scientist David Wacey, who had issues with both the accuracy of the methods Schopf used and with the peer review process which led to the paper's publication. Wacey, for his part, was part of the team that discovered evidence for a different microfossil that once contained the title of oldest discovered fossil. 6. IT CAN TAKE A LONG TIME TO DIG UP FOSSILS. Procuring the fossils can feel endless. For example, in 1989, William Zinsmeister found the fossil of an estimated 15-ton, 40-foot-long elasmosaur, which is a Plesiosaur that basically looks like a sea monster. But he found it on Seymour Island in the Antarctic, where excavating isn't easy. Teams could only work for a few weeks out of the year and only when they had the financial resources. Excavation wasn't complete until 2017. 7. WE'VE BEEN FINDING FOSSILS FOR A LONG TIME. Humans have been discovering fossils—and even using them—since very early in our history. At least one member of the Homo heidelbergensis species (one of our ancestors from hundreds of thousands of years ago) created an axe that prominently featured a fossilized sea urchin. 8. FOSSILS MIGHT HELP EXPLAIN ANCIENT MYTHOLOGY. People found fossils throughout history and didn't really know what they were, which might help explain some ancient mythology. The Ancient Greeks believed in Cyclopes. One popular explanation why? Ancient elephants once roamed the area. The empty space in their skull where the trunk would go, when found by an ancient person, might have looked like the perfect spot for a single eye. 9. WE ONCE BELIEVED MAMMOTH AND MASTODON FOSSILS WERE THE BONES OF GIANTS. There are many stories of people finding the large bones from creatures like mammoths and interpreting them as having once belonged to giant humans. In 1712, Puritan minister Cotton Mather of Salem Witch Trial fame] professed in a letter to the Royal Society of London that parts of mastodon skeleton were evidence that there were giants in the Americas, and that those giants were then taken out by the flood described in the Bible. 10. THE FIRST DINOSAUR FOSSIL WAS FOUND AROUND 1815. The first identified dino fossil belonged to a Megalosaurus. An array of its bones, including a large lower jawbone, were found around 1815, but it wasn't until 1824 that William Buckland published an article describing their previous owner as a reptile or "great fossil lizard." 11. ONE FOSSIL WAS BELIEVED TO BE A HOAX. A few decades later, an Archaeopteryx fossil was found, which contained both feathers and teeth—an unusual combination. Thomas Henry Huxley, certainly inspired by Charles Darwin's recently published On the Origin of Species, was the first to claim that dinosaurs and birds were relatives. In 1985, this fossil made headlines again when British astronomer Sir Fred Hoyle and five other scientists claimed that the fossil, then sitting in the British Museum of Natural History, was a fake—that the feathers were pressed into stone in modern times. But the museum has since proven those accusations false. Because the fossil was preserved inside of limestone, there are two matching halves to it. Technology can help show that the halves are identical, which wouldn't be possible if it were a modern-made. 12. A FOSSIL OF A NON-AVIAN DINOSAUR WITH FEATHERS WAS FOUND IN 1996. The dino was Sinosauropteryx. The feather impressions—also called dinosaur fuzz—contain preserved melanosomes, which helps determine what colors certain dinosaurs were. Experts believe that Sinosauropteryx had a red and white tail. 13. SOME FOSSIL COLORS ARE HARD TO IDENTIFY. We've also discovered that the Anchiornis had black and white feathers with some red on its head, and the Ichthyosaur had dark skin. Unfortunately, this method can't be used for all dinosaurs. Some colors, like yellow, are produced through different pathways, and they're harder to identify. 14. IN 2019, SOME PALEONTOLOGISTS PUBLISHED A PAPER ABOUT THE DAY THE DINOSAURS WENT EXTINCT. Working in Hell Creek Formation in North Dakota, they discovered fossils of fish, who were part of the 75 percent of the earth's plant and animal species wiped out that day. Hell Creek is about 2000 miles from where the asteroid struck that caused this destruction. And yet the researchers claimed that it led to big enough waves in this particular river valley that many fish became buried under sediment. Some even had rock, which they said had supposedly rained down from the sky, in their gills. This research isn't a sure thing, though, and some geologists argue that Hell Creek could have experienced these geological changes without it necessarily having to do with that asteroid. 15. FOSSILIZED POOP CAN BE PRICEY. Trace fossils are a great way to learn about how extinct animals behaved. Studying fossilized feces, also known as coprolite, is an important part of paleontology. And some people are just fascinated by it. For instance in 2014, a collector bought a 40-inch coprolite at an auction for over $10,000. That may have been a mistake: It came from a formation in Washington State where similar items have been studied and were actually just the mineral siderite. 16. SOME FOSSIL-FINDERS HAVE FUN NAMING THEIR DISCOVERIES. In 1985, Australian scientists discovered the fossil of an ancient python in Riversleigh, Queensland, Australia, which they named Montypythonoides riversleighensis. Despite the apparent connection to the British comedy legends, the official explanation for the name claimed that it was because "it was found on a small hill or monti" and was broadly like present-day pythons. Sadly for us comedy fans, it was later renamed Morelia riversleighensis. 17. ONE ANCIENT MAMMAL WAS NAMED FOR A ROCKER. In 2014, a species from 19 million years ago was discovered. It was a mammal, related to the hippopotamus we know today, and it had large lips—so one of its discoverers, Ellen Miller, named it the Jaggermeryx naida, or "Jagger's water nymph," after none other than Mick Jagger. 18. LUCY WAS NAMED AFTER A BEATLES SONG. Lucy lived 3.2 million years ago and was found in 1974. At the time of her discovery she was the earliest and most complete skeleton of an ancient hominin. Donald Johanson was the first to see her bones in Ethiopia and that night, his team was listening to a Beatles cassette when one of them suggested her name, inspired by the song "Lucy in the Sky with Diamonds." (For the record, we now have remains of much older hominins than Lucy.) 19. ONE FOSSIL WAS DISCOVERED WITH 38 OFFSPRING. In 2018, we learned about an exciting mammalian relative that reproduced more like a reptile than a modern mammal. Researchers Eva Hoffman and Timothy Rowe found the skeleton of a K. wellesi that was found with at least 38 offspring, which is considerably more than modern mammals have in a litter. 20. A FOSSIL SKULL BELONGING TO A BIG CAT WAS DISCOVERED IN 2010. Another exciting fill-in-the-gap discovery was the Panthera blytheae in 2010. This was the skull of a big cat, a relative of the snow leopard, which showed that big cats actually lived around 6 million years ago, earlier than previous fossil evidence had indicated. It also showed that big cats evolved in Asia when it had been thought that they evolved exclusively in Africa. 21. WE KNOW ABOUT ANCIENT TICKS THANKS TO FOSSILIZED RESIN. Another interesting type of fossil is fossilized resin or amber. Many trees contain resin, which can turn into fossils, and when there are critters inside, we can learn about their ancient lives too. For instance, in 2017, a paper was published showing that ticks used to suck the blood of dinosaurs. Scientists already knew that ticks existed back then, but figured they went after other animals. But fossilized amber was found containing a tick from 99 million years ago holding onto a dinosaur feather. 22. THANKS TO FOSSILS, WE KNOW THAT SOME ANCIENT CROCODILE RELATIVES WERE HERBIVORES. Fossil records can demonstrate the incredible diversity of life on our planet, like the fact that some crocodile relatives were actually herbivores. A different crocodilian was only 20 inches long, and so mammal-like that it was named "cat crocodile." 23. A CONSTRUCTION WORKER FOUND A 110-MILLION-YEAR-OLD FOSSIL AT A WORK SITE. In 2011, construction worker Shawn Funk found the skeleton of a 110-million-year-old dinosaur at a work site in Alberta, Canada. This Borealopelta was a "nodosaur," which in the words of experts call "bloat and float." The animal dies, which causes it to bloat with gases, then it floats through water until it loses that gas and sinks. But 1.5 tons of dinosaur sinking causes quite the disturbance, so this Borealopelta got covered in sediment, preserving it amazingly. 24. FOSSILS LAUNCHED WHAT CAME TO BE KNOWN AS THE BONE WARS. The Bone Wars took place in the late 19th century. Many paleontologists were rushing to identify and name a bunch of dinosaur species, including notably Edward Cope and Othniel Marsh. Marsh named the Apatosaurus in 1877 and the Brontosaurus in 1879. Then in 1903, paleontologist Elmer Riggs officially stated that this was the same genus, so the Brontosaurus was an Apatosaurus (because the first to be named keeps its name). But then, in 2015, a 300-page study was published that examined 81 sauropods. Though it wasn't the original intention of the study, it concluded that the Apatosaurus and Brontosaurus are indeed different enough to be considered separate animals. It claimed, amongst other differences, that the Brontosaurus has a higher, thinner neck. Not every paleontologist subscribes to this distinction, though. 25. ONE ANCIENT PENGUIN PREDECESSOR WAS OVER 5 FEET TALL. In 2018, a fossil of the Crossvallia waiparensis was discovered in New Zealand. This prehistoric penguin lived between around 56 and 66 million years ago, and based on the skeleton, researchers determined that it was about 5 foot 3 inches tall. It's one big bird, but it's not the tallest penguin predecessor in history: Palaeeudyptes klekowskii could have been 6 foot 5. Source: www.mentalfloss.com/ In need of engaging and educational activities for teaching about fossils? Look no further! Our Fossils Activities Worksheets offer a range of captivating exercises and hands-on tasks to captivate your students. These worksheets provide a systematic approach to learning about fossils, covering topics such as the formation process, types of fossils, and their significance in understanding Earth's history. 11 Images of Fossils Activities Worksheets Fossil Activity Worksheet Printable Dinosaur Fossil Worksheet Fossil Crossword Puzzle Answers Fossil Word Search Printable How Are Fossils Made Worksheet Fossil Worksheets Printables Index Fossils Worksheet Fossil Record Worksheets Fossil Fuels Non Renewable Energy Science Fossils Worksheets for 3rd Grade Fossil Activity Worksheet Answers Enhance your students' understanding of paleontology with our Fossils Activities Worksheets, a valuable resource for hands-on learning. Designed for elementary and middle school students, these Fossils Activities worksheets are the perfect tool for educators seeking to inspire and engage young minds in the fascinating world of paleontology. What is Fossil? You are familiar with the term fossil, aren't you? Most people perceive fossils as stuff that gets buried in the deep ground for thousands of years. According to National Geographic, it takes 10.000 years for remains to turn into fossils. Fossil is the conserved remains of plants and animals buried in sediments, such as sand and mud. Paleontologists (people who study fossils) usually find fossils under seas, lakes, and rivers. The soft parts of the body will decay immediately after death, but the solid parts (bones, shells, and teeth) get replaced with minerals that harden into rock. Some soft elements, such as feathers, fern plants, and footprints, can also be preserved by nature. Remains may include microscopic fossils such as unicellular foraminifera and pollen grains. Some also take the form of more familiar ones, such as ammonites and trilobites. Preserved proof of the body pieces of ancient animals, plants, and other life states are called body fossils. Meanwhile, trace fossils are the proof left by organisms in sediment, such as footprints, burrows, and plant roots. How did Fossils Form? The experts found fossils in sedimentary rocks and sometimes in fine-grained, low-grade metamorphic rocks. Fossilization requires rapid burial by previously waterborne sediments. The burial process isolates the remains from biological and physical processes that would otherwise decompose or dissolve body material. For example, fossils have more possibility to exist in marine environments where rapid burial by sediment is possible. Less favorable environments include rocky peaks where the carcass collapses and lets some sediment elements bury the body remains. There are four methods of preservation: Petrification: After a shell, bone, or tooth is buried in sediment, it can be exposed to mineral-rich liquids that travel through porous rock material, filling it with antiseptic minerals such as calcium carbonate and silica. Eventually, the minerals replace the organic matter, and the remains become stone or "petrified Compression: The compression process occurred in-depth, which makes the results look like a pressed imprint. Mold and Cast: When the original shell or bone is removed, it may leave a void in the shape of the original material called the mold. The sediment may fill the space and form a suitable cast. Preserved Animals: The rarest form of fossilization is the original skeleton and soft body parts preservation. For example, insects captured and preserved in amber (petrified tree sap) are examples of preserved relics. How Many Types of Fossils Are There? According to Oxford University, there are two types of fossils (body and trace). Body fossils are the remains of ancient plants and animals that have been preserved in rock or sediment. These fossils could include bones, teeth, shells, and soft tissues, such as skin or feathers. Body fossils give us insight into the morphology, anatomy, and behavior of extinct organisms. Meanwhile, trace fossils are the marks and impressions left behind by ancient life. These fossils can include footprints, burrows, and even feces. Trace fossils provide evidence of the activities of organisms, including their locomotion, feeding behavior, and social interactions. Trace fossils also give us insight into the environments in which these organisms lived, as well as the relationships between different species. What is the Importance of Learning Fossil? Some might think that learning about a fossil is a waste of time since it is about the last moment. However, studying it has many benefits for human life. Fossils provide various and beneficial insights into the history of life on the Earth's surface. They tell humans where life and people came from, how the environment has changed over geological time, and how the now widely separated continents once were. Paleontologists also use fossils to determine the age of a rock. They did various evolutionary processes on different types of fossils that occur in rocks of different ages. This complicated process is crucial for understanding the geological history of this planet. For geologists, fossils are one of the most crucial tools for the age correlation process. Ammonites, for example, are excellent index fossils for stratigraphy. These fossils are useful to determine the relative ages of two or more rock formations or formations at different locations within the same country or elsewhere. How to Introduce Fossil Learning to Students? Introducing fossil learning to kids can be an exciting and engaging experience that ignites their curiosity about the natural world. Here are some tips on how to do it effectively: Begin by explaining what fossils are and how they are formed. Use visual aids. Take kids on a nature walk or to a museum with a fossil exhibit. Create activities such as fossil coloring pages and fossil digs, or even make your own fossils with Play-Doh. Explain how fossils are valuable for scientific research and can help us better understand the history of life on Earth. From fossil identification to learning geology, understanding the Earth's history, and various science experiments, these worksheets prepare everything. The hands-on learning that these Fossil Activities worksheets offer will help the young learners study fossils in a fun and engaging manner, which will boost and strengthen their knowledge. Mastering the paleontology field will be beneficial as it can help young learners pave the way for their future careers. Some of informations, names, images and video detail mentioned are the property of their respective owners & source. My student loved using this resource. I will recommend this resource to my science team.Strongly disagreeStrongly agreeConstruct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history. Emphasis is on how analyses of rock formations and the fossils they contain are used to establish relative ages of major events in Earth's history. Examples of Earth's major events could range from being very recent (such as the last Ice Age or the earliest fossils of homo sapiens) to very old (such as the formation of Earth or the earliest evidence of life). Examples can include the formation of mountain chains and ocean basins, the evolution or extinction of particular living organisms, or significant volcanic eruptions. Assessment does not include recalling the names of specific periods or epochs and events within them. Preserved remains or traces of organisms from a past geological age "Dinosaur bones" redirects here. For the band, see Dinosaur Bones. For other uses, see Fossil (disambiguation). "Fossilization" redirects here. For the linguistics term, see Fossilization (linguistics). Montage of animal fossils. Clockwise from top left: Onychocrinus and Palaeosinopa; bottom row: Gryphaea and Harpactocarcinus A fossil (from Classical Latin fossilis, lit. 'obtained by digging')[1] is any preserved remains, impression, or trace of any once-living thing from a past geological age. Examples include bones, shells, exoskeletons, stone imprints of animals or microbes, objects preserved in amber, hair, petrified wood and DNA remnants. The totality of fossils is known as the fossil record. Though the fossil record is incomplete, numerous studies have demonstrated that there is enough information available to give a good understanding of the pattern of diversification of life on Earth.[2][3][4] In addition, the record can predict and fill gaps such as the discovery of Tiktaalik in the arctic of Canada.[5] Paleontology includes the study of fossils: their age, method of formation, and evolutionary significance. Specimens are sometimes considered to be fossils if they are over 10,000 years old.[6][7][8] The oldest fossils are around 3.48 billion years [9][10][11] to 4.1 billion years old.[12][13] The observation in the 19th century that certain fossils were associated with certain rock strata led to the recognition of a geological timescale and the relative ages of different fossils. The development of radiometric dating techniques in the early 20th century allowed scientists to quantitatively measure the absolute ages of rocks and the fossils they host. There are many processes that lead to fossilization, including permineralization, casts and molds, authigenic mineralization, replacement and recrystallization, adpression, carbonization, and bioimmuration. Fossils vary in size from one-micrometre (1 µm) bacteria[14] to dinosaurs and trees, many meters long and weighing many tons. The largest presently known is a Sequoia sp. measuring 295 feet (88 meters) in length at Coaldale, Nevada.[15] A fossil normally preserves only a portion of the deceased organism, usually that portion that was partially mineralized during life, such as the bones and teeth of vertebrates, or the chitinous or calcareous exoskeletons of invertebrates. Fossils may also consist of the marks left behind by the organism while it was alive, such as animal tracks or feces (coprolites). These types of fossil are called trace fossils or ichnofossils, as opposed to body fossils. Some fossils are biochemical and are called chemofossils or biosignatures. Part of a series onPaleontology Fossils Fossil Fossil preparation Fossil collecting Index fossil Microfossil Trace fossil Transitional fossil Geology Geology Absolute dating Relative dating Biochronology Geochronology Geologic formation Geologic record Geologic time scale Geological map Lagerstätte Stratigraphy Extinction Extinction Extinction event Lazarus taxon Living fossil Pseudoextinction Mass extinction Evolution Evolution Cladistics Convergent evolution Natural selection Phyletic gradualism Punctuated equilibrium Phylogenetic tree Speciation History History of paleontology List of years in paleontology Applications Age of Earth Origin of life History of life Cambrian explosion Ediacaran biota Biogeography Biochronology Biostratigraphy Ecological succession Anagenesis Evolutionary taxonomy Macroevolution Microevolution Cultural impact Cultural depictions of dinosaurs List of films featuring dinosaurs Dinosaur renaissance Paleoart Paleontology portal Categoryvte Main article: History of paleontology For a chronological guide, see Timeline of paleontology. Gathering fossils dates at least to the beginning of recorded history. The fossils themselves are referred to as the fossil record. The fossil record was one of the early sources of data underlying the study of evolution and continues to be relevant to the history of life on Earth. Paleontologists examine the fossil record to understand the process of evolution and the way particular species have evolved. Ceratopsian skulls are common in the Dzungarian Gate mountain pass in Asia, an area once famous for gold mines, as well as its endlessly cold winds. This has been attributed to legends of both gryphons and the land of Hyperborea. Fossils have been visible and common throughout most of natural history, and so documented human interaction with them goes back as far as recorded history, or earlier. There are many examples of Paleolithic stone knives in Europe, with fossil echinoderms set precisely at the hand grip, dating back to Homo heidelbergensis and Neanderthals.[16] These ancient peoples also drilled holes through the center of those round fossil shells, apparently using them as beads for necklaces. The ancient Egyptians gathered fossils of species that resembled the bones of modern species they worshipped. The god Set was associated with the hippopotamus, therefore fossilized bones of hippo-like species were kept in that deity's temples.[17] Five-rayed fossil sea urchin shells were associated with the deity Sopdu, the Morning Star, equivalent of Venus in Roman mythology.[16] Fossil shells from the cretaceous era sea urchin, Micraster, were used in medieval times as both shepherd's crowns to protect houses, and as painted fairy loaves by bakers to bring luck to their bread-making. Fossils appear to have directly contributed to the mythology of many civilizations, including the ancient Greeks. Classical Greek historian Herodotos wrote of an area near Hyperborea where gryphons protected golden treasure. There was indeed gold mining in that approximate region, where beaked Protoceratops skulls were common as fossils. A later Greek scholar, Aristotle, eventually realized that fossil seashells from rocks were similar to those found on the beach, indicating the fossils were once living animals. He had previously explained them in terms of vaporous exhalations,[18] which Persian polymath Avicenna modified into the theory of petrifying fluids (succus lapidificatus). Recognition of fossil seashells as originating in the sea was built upon in the 14th century by Albert of Saxony, and accepted in some form by most naturalists by the 16th century.[19] Roman naturalist Pliny the Elder wrote of "tongue stones", which he called glossopetra. These were fossil shark teeth, thought by some classical cultures to look like the tongues of people or snakes.[20] He also wrote about the horns of Ammon, which are fossil ammonites, whence the group of shelled octopus-cousins ultimately draws its modern name. Pliny also makes one of the earlier known references to toadstones, thought until the 18th century to be a magical cure for poison originating in the heads of toads, but which are fossil teeth from Lepidotes, a Cretaceous ray-finned fish.[21] The Plains tribes of North America are thought to have similarly associated fossils, such as the many intact pterosaur fossils naturally exposed in the region, with their own mythology of the thunderbird.[22] There is no such direct mythological connection known from prehistoric Africa, but there is considerable evidence of tribes there excavating and moving fossils to ceremonial sites, apparently treating them with some reverence.[23] In Japan, fossil shark teeth were associated with the mythical tengu, thought to be the razor-sharp claws of the creature, documented some time after the 8th century AD.[20] In medieval China, the fossil bones of ancient mammals including Homo erectus were often mistaken for "dragon bones" and used as medicine and aphrodisiacs. In addition, some of these fossil bones are collected as "art" by scholars, who left scripts on various artifacts, indicating the time they were added to a collection. One good example is the famous scholar Huang Tingjian of the Song dynasty during the 11th century, who kept a specific seashell fossil with his own poem engraved on it.[24] In his Dream Pool Essays published in 1088, Song dynasty Chinese scholar-official Shen Kuo hypothesized that marine fossils found in a geological stratum of mountains located hundreds of miles from the Pacific Ocean was evidence that a prehistoric seashore had once existed there and shifted over centuries of time.[25][26] His observation of petrified bamboos in the dry northern climate zone of what is now Yan'an, Shaanxi province, China, led him to advance early ideas of gradual climate change due to bamboo naturally growing in wetter climate areas.[26][27][28] In medieval Christendom, fossilized sea creatures on mountainsides were seen as proof of the biblical deluge of Noah's Ark. After observing the existence of seashells in mountains, the ancient Greek philosopher Xenophanes (c. 570 – 478 BC) speculated that the world was once inundated in a great flood that buried living creatures in drying mud.[29][30] In 1027, the Persian Avicenna explained fossils' stoniness in The Book of Healing: If what is said concerning the petrifaction of animals and plants is true, the cause of this (phenomenon) is a powerful mineralizing and petrifying virtue which arises in certain stony spots, or emanates suddenly from the earth during earthquake and subsidences, and petrifies whatever comes into contact with it. As a matter of fact, the petrifaction of the bodies of plants and animals is not more extraordinary than the transformation of waters.[31] From the 13th century to the present day, scholars pointed out that the fossil skulls of Deinotherium giganteum, found in Crete and Greece, might have been interpreted as being the skulls of the Cyclopes of Greek mythology, and are possibly the origin of that Greek myth.[32][33] Their skulls appear to have a single eye-hole in the front, just like their modern elephant cousins, though in fact it's actually the opening for their trunk. In Norse mythology, echinoderm shells (the round five-part button left over from a sea urchin) were associated with the god Thor, not only being incorporated in thunderstones, representations of Thor's hammer and subsequent hammer-shaped crosses as Christianity was adopted, but also kept in houses to garner Thor's protection.[16] These grew into the shepherd's crowns of English folklore, used for decoration and as good luck charms, placed by the doorway of homes and churches.[34] In Suffolk, a different species was used as a good-luck charm by bakers, who referred to them as fairy loaves, associating them with the similarly shaped loaves of bread they baked.[35][36] Georges Cuvier's 1812 skeletal reconstruction of Anoplotherium commune based on fossil remains of the extinct artiodactyl from Montmartre in Paris, France More scientific views of fossils emerged during the Renaissance. Leonardo da Vinci concurred with Aristotle's view that fossils were the remains of ancient life.[37]: 361 For example, Leonardo noticed discrepancies with the biblical flood narrative as an explanation for fossil origins: If the Deluge had carried the shells for distances of three and four hundred miles from the sea it would have carried them mixed with various other natural objects all heaped up together; but even at such distances from the sea we see the oysters all together and also the shellfish and the cuttlefish and all the other shells which congregate together, found all together dead; and the solitary shells are found apart from one another as we see them every day on the sea-shores. And we find oysters together in very large families, among which some may be seen with their shells still joined together, indicating that they were left there by the sea and that they were still living when the strait of Gibraltar was cut through. In the mountains of Parma and Piacenza multitudes of shells and corals with holes may be seen still sticking to the rocks....[38] Ichthyosaurus and Plesiosaurus from the 1834 Czech edition of Cuvier's Discours sur les revolutions de la surface du globe In 1666, Nicholas Steno examined a shark, and made the association of its teeth with the "tongue stones" of ancient Greco-Roman mythology, concluding that those were not in fact the tongues of venomous snakes, but the teeth of some long-extinct species of shark.[20] Robert Hooke (1635–1703) included micrographs of fossils in his Micrographia and was among the first to observe fossil forams. His observations on fossils, which he stated to be the petrified remains of creatures some of which no longer existed, were published posthumously in 1705.[39] William Smith (1769–1839), an English canal engineer, observed that rocks of different ages (based on the law of superposition) preserved different assemblages of fossils, and that these assemblages succeeded one another in a regular and determinable order. He observed that rocks from distant locations could be correlated based on the fossils they contained. He termed this the principle of faunal succession. This principle became one of Darwin's chief pieces of evidence that biological evolution was real. Georges Cuvier came to believe that most if not all the animal fossils he examined were remains of extinct species. This led Cuvier to become an active proponent of the geological school of thought called catastrophism. Near the end of his 1796 paper on living and fossil elephants he said: All of these facts, consistent among themselves, and not opposed by any report, seem to me to prove the existence of a world previous to ours, destroyed by some kind of catastrophe.[40] Interest in fossils, and geology more generally, expanded during the early nineteenth century. In Britain, Mary Anning's discoveries of fossils, including the first complete ichthyosaur and a complete plesiosaurus skeleton, sparked both public and scholarly interest.[41] Early naturalists well understood the similarities and differences of living species leading Linnaeus to develop a hierarchical classification system still in use today. Darwin and his contemporaries first linked the hierarchical structure of the tree of life with the then very sparse fossil record. Darwin eloquently described a process of descent with modification, or evolution, whereby organisms either adapt to natural and changing environmental pressures, or they perish. When Darwin wrote On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life, the oldest animal fossils were those from the Cambrian Period, now known to be about 540 million years old. He worried about the absence of older fossils because of the implications on the validity of his theories, but he expressed hope that such fossils would be found, noting that: "only a small portion of the world is known with accuracy." Darwin also pondered the sudden appearance of many groups (i.e. phyla) in the oldest known Cambrian fossiliferous strata.[42] Since Darwin's time, the fossil record has been extended to between 2.3 and 3.5 billion years.[43] Most of these Precambrian fossils are microscopic bacteria or microfossils. However, macroscopic fossils are now known from the late Proterozoic. The Ediacara biota (also called Vendian biota) dating from 575 million years ago collectively constitutes a richly diverse assembly of early multicellular eukaryotes. The fossil record and faunal succession form the basis of the science of biostratigraphy or determining the age of rocks based on embedded fossils. For the first 150 years of geology, biostratigraphy and superposition were the only means for determining the relative age of rocks. The geologic time scale was developed based on the relative ages of rock strata as determined by the early paleontologists and stratigraphers. Since the early years of the twentieth century, absolute dating methods, such as radiometric dating (including potassium/argon, argon/argon, uranium series, and, for very recent fossils, radiocarbon dating) have been used to verify the relative ages obtained by fossils and to provide absolute ages for many fossils. Radiometric dating has shown that the earliest known stromatolites are over 3.4 billion years old. The fossil record is life's evolutionary epic that unfolded over four billion years as environmental conditions and genetic potential interacted in accordance with natural selection. The Virtual Fossil Museum[44] Paleontology has joined with evolutionary biology to share the interdisciplinary task of outlining the tree of life, which inevitably leads backwards in time to Precambrian microscopic life when cell structure and functions evolved. Earth's deep time in the Proterozoic and deeper still in the Archean is only "recounted by microscopic fossils and subtle chemical signals."[45] Molecular biologists, using phylogenetics, can compare protein amino acid or nucleotide sequence homology (i.e., similarity) to evaluate taxonomy and evolutionary distances among organisms, with limited statistical confidence. The study of fossils, on the other hand, can more specifically pinpoint when and in what organism a mutation first appeared. Phylogenetics and paleontology work together in the clarification of science's still dim view of the appearance of life and its evolution.[46] Phacopid trilobite Eldredgeops rana crassituberculata. The genus is named after Niles Eldredge Niles Eldredge's study of the Phacops trilobite genus supported the hypothesis that modifications to the arrangement of the trilobite's eye lenses proceeded by fits and starts over millions of years during the Devonian.[47] Eldredge's interpretation of the Phacops fossil record was that the aftermaths of the lens changes, but not the rapidly occurring evolutionary process, were fossilized. This and other data led Stephen Jay Gould and Niles Eldredge to publish their seminal paper on punctuated equilibrium in 1971. Synchrotron X-ray tomographic analysis of early Cambrian bilaterian embryonic microfossils yielded new insights of metazoan evolution at its earliest stages. The tomography technique provides previously unattainable three-dimensional resolution at the limits of fossilization. Fossils of two enigmatic bilaterians, the worm-like Markuelia and a putative, primitive protostome, Pseudooides, provide a peek at germ layer embryonic development. These 543-million-year-old embryos support the emergence of some aspects of arthropod development earlier than previously thought in the late Proterozoic. The preserved embryos from China and Siberia underwent rapid diagenetic phosphatization resulting in exquisite preservation, including cell structures.[jargon] This research is a notable example of how knowledge encoded by the fossil record continues to contribute otherwise unattainable information on the emergence and development of life on Earth. For example, the research suggests Markuelia has closest affinity to priapulid worms, and is adjacent to the evolutionary branching of Priapulida, Nematoda and Arthropoda.[48][jargon] Despite significant advances in uncovering and identifying paleontological specimens, it is generally accepted that the fossil record is vastly incomplete.[49][50] Approaches for measuring the completeness of the fossil record have been developed for numerous subsets of species, including those grouped taxonomically,[51][52] temporally,[53] environmentally/geographically,[54] or in sum.[55][56] This encompasses the subfield of taphonomy and the study of biases in the paleontological record.[57][58][59] Main articles: Geochronology and Relative dating Stratigraphy of the Montañita-Olón locality of the Dos Bocas Formation. Stratigraphy is a useful branch when it comes to the understanding of the successive layers of rock and their fossiliferous content, giving insight into the relative age of fossils Paleontology seeks to map out how life evolved across geologic time. A substantial hurdle is the difficulty of working out fossil ages. Beds that preserve fossils typically lack the radioactive elements needed for radiometric dating. This technique is our only means of giving rocks greater than about 50 million years old an absolute age, and can be accurate to within 0.5% or better.[60] Although radiometric dating requires careful laboratory work, its basic principle is simple: the rates at which various radioactive elements decay are known, and so the ratio of the radioactive element to its decay products shows how long ago the radioactive element was incorporated into the rock. Radioactive elements are common only in rocks with a volcanic origin, and so the only fossil-bearing rocks that can be dated radiometrically are volcanic ash layers, which may provide termini for the intervening sediments.[60] Consequently, palaeontologists rely on stratigraphy to date fossils. Stratigraphy is the science of deciphering the "layer-cake" that is the sedimentary record.[61] Rocks normally form relatively horizontal layers, with each layer younger than the one underneath it. If a fossil is found between two layers whose ages are known, the fossil's age is claimed to lie between the two known ages.[62] Because rock sequences are not continuous, but may be broken up by faults or periods of erosion, it is very difficult to match up rock beds that are not directly adjacent. However, fossils of species that survived for a relatively short time can be used to match isolated rocks: this technique is called biostratigraphy. For instance, the conodont Eoplacognathus pseudoplanus has a short range in the Middle Ordovician period.[63] If rocks of unknown age have traces of E. pseudoplanus, they have a mid-Ordovician age. Such index fossils must be distinctive, be globally distributed and occupy a short time range to be useful. Misleading results are produced if the index fossils are incorrectly dated.[64] Stratigraphy and biostratigraphy can in general provide only relative dating (A was before B), which is often sufficient for studying evolution. However, this is difficult for some time periods, because of the problems involved in matching rocks of the same age across continents.[64] Family-tree relationships also help to narrow down the date when lineages first appeared. For instance, if fossils of B or C date to X million years ago and the calculated "family tree" says A was an ancestor of B and C, then A must have evolved earlier. It is also possible to estimate how long ago two living clades diverged (i.e., the age of their last common ancestor) by assuming that mutations accumulate at a constant rate for a given gene. These "molecular clocks", however, are fallible, and provide only approximate timing: for example, they are not sufficiently precise and reliable for estimating when the groups that feature in the Cambrian explosion first evolved,[65] and estimates produced by different techniques may vary by a factor of two.[66] Further information: Ghost lineage, Signor–Lipps effect, and Biostratigraphy Organisms are only rarely preserved as fossils in the best of circumstances, and only a fraction of such fossils have been discovered. This is illustrated by the fact that the number of species known through the fossil record is less than 5% of the number of known living species, suggesting that the number of species known through fossils must be far less than 1% of all the species that have ever lived.[67] Because of the specialized and rare circumstances required for a biological structure to fossilize, only a small percentage of life-forms can be expected to be represented in discoveries, and each discovery represents only a snapshot of the process of evolution. The transition itself can only be illustrated and corroborated by transitional fossils, which are never guaranteed to demonstrate a convenient half-way point.[68] The fossil record is strongly biased toward organisms with hard parts, leaving most groups of soft-bodied organisms with little to no presence.[67] It is replete with mollusks, vertebrates, echinoderms, brachiopods, and some groups of arthropods.[69] Main article: Lagerstätte Further information: List of fossil sites Fossil sites with exceptional preservation—sometimes including preserved soft tissues—are known as Lagerstätten (German for "storage places"). These formations may have resulted from carcass burial in an anoxic environment with minimal bacteria, thus slowing decomposition. Lagerstätten span geological time from the Cambrian period to the present. Worldwide, some of the best examples of near-perfect fossilization are the Cambrian Maotianshan Shales and Burgess Shale, the Devonian Hunsrück Slates, the Jurassic Solnhofen Limestone, and the Carboniferous Mazon Creek localities. A fossil is said to be recrystallized when the original skeletal compounds are still present but in a different crystal form, such as from aragonite to calcite.[70] Calcite-recrystallized fossil shell of Mercenaria permagna from Fort Drum, Florida Calcite-recrystallized fossil shell of Busycon sp. from Indrio Pit Recrystallized scleractinian coral (aragonite to calcite) from the Jurassic of southern Israel Calcite-recrystallized fossil shell of pentamerid brachiopods from Indiana Recrystallized bivalve shell with sparry calcite from Bird Spring Formation Permineralized bryozoan from the Devonian of Wisconsin Replacement occurs when the shell, bone, or other tissue is replaced with another mineral. In some cases mineral replacement of the original shell occurs so gradually and at such fine scales that microstructural features are preserved despite the total loss of original material. Scientists can use such fossils when researching the anatomical structure of ancient species.[71] Several species of saurids have been identified from mineralized dinosaur fossils.[72][73] Permineralization is a process of fossilization that occurs when an organism is buried. The empty spaces within an organism (spaces filled with liquid or gas during life) become filled with mineral-rich groundwater. Minerals precipitate from the groundwater, occupying the empty spaces. This process can occur in very small spaces, such as within the cell wall of a plant cell, and can produce very detailed fossils at small scales.[74] For permineralization to occur, the organism must become covered by sediment soon after death, otherwise the remains are destroyed by scavengers or decomposition.[75] The degree to which the remains are decayed when covered determines the later details of the fossil. Some fossils consist only of skeletal remains or teeth; other fossils contain traces of skin, feathers or even soft tissues.[76] This is a form of diagenesis. Phosphatization refers to a process of fossilization where organic matter is replaced by abundant calcium-phosphate minerals. The produced fossils tend to be particularly dense and have a dark coloration that ranges from dark orange to black.[77] This fossil preservation involves the elements sulfur and iron. Organisms may become pyritized when they are in marine sediments saturated with iron sulfides. As organic matter decays, it releases sulfide which reacts with dissolved iron in the surrounding waters, forming pyrite. Pyrite replaces carbonate shell material due to an undersaturation of carbonate in the surrounding waters. Some plants become pyritized when they are in a clay terrain, but to a lesser extent than in a marine environment. Some pyritized fossils include Precambrian microfossils, marine arthropods, and plants.[78][79] Pyritized ammonoid Pleuroceras solare fossil specimen Pyritized specimen of the brachiopod Paraspirifer bownockeri Pyritized Triarthrus eatoni from Whetstone Gulf Formation Pyritized Furcaster paleozoicus from Hunsrück Slate Pyritized Tornoceras uniangulare from Ludlowville Formation In silicification, the precipitation of silica from saturated water bodies is responsible for the fossil's formation and preservation. The mineral-laden water permeates the pores and cells of some dead organism, where it becomes a gel. Over time, the gel will dehydrate, forming a silica-rich crystal structure, which can be expressed in the form of quartz, chalcedony, agate, opal, among others, with the shape of the original remain.[80][81] Chalcedony replaced fossil shells of Elimia tenera with inclusions of ostracods Chalcedonized gastropods internal molds Agatized internal molds of gastropods from Deccan Traps Agatized fossil coral from Florida Fossil bivalves replaced by opal, from Queensland Rear view of an opalized Addyman Plesiosaur fossil at the South Australian Museum In some cases, the original remains of the organism completely dissolve or are otherwise destroyed. The remaining organism-shaped hole in the rock is called an external mold. If this void is later filled with sediment, the resulting cast resembles what the organism looked like. An endocast, or internal mold, is the result of sediments filling an organism's interior, such as the inside of a bivalve or snail or the hollow of a skull.[82] Endocasts are sometimes termed Steinkerns, especially when bivalves are preserved this way.[83] Internal mold (steinkern) of Hormotoma sp. from Galena Formation Gastropod internal mold (steinkern) from Ventana Formation Shell external mold of Anomalodonta gigantea from Waynesville Formation Internal mold (steinkern) of Glycymeris alpinus, Austria External mold of Aviculopecten subcardiformis from the Logan Formation, Lower Carboniferous, Ohio This is a special form of cast and mold formation. If the chemistry is right, the organism (or fragment of organism) can act as a nucleus for the precipitation of minerals such as siderite, resulting in a nodule forming around it. If this happens rapidly before significant decay to the organic tissue, very fine three-dimensional morphological detail can be preserved. Nodules from the Carboniferous Mazon Creek fossil beds of Illinois, US, are among the best documented examples of such mineralization.[84] Compression fossils, such as those of fossil ferns, are the result of chemical reduction of the complex organic molecules composing the organism's tissues. In this case, the fossil consists of original material, albeit in a geochemically altered state. This chemical change is an example of diagenesis. What remains is often a carbonaceous film known as a phytoleim, in which case the fossil is known as a compression. Often, however, the phytoleim is lost and all that remains is an impression of the organism in the rock—an impression fossil. In many cases, however, compressions and impressions occur together. For instance, when the rock is broken open, the phytoleim will often be attached to one part (compression), whereas the counterpart will just be an impression. For this reason, one term covers the two modes of preservation: adpression.[85] Fossils that are carbonized or coalified consist of the organic remains which have been reduced primarily to the chemical element carbon. Carbonized fossils consist of a thin film which forms a silhouette of the original organism, and the original organic remains were typically soft tissues. Coalified fossils consist primarily of coal, and the original organic remains were typically woody in composition. Carbonized fossil of a cycloneuralian worm that was once misidentified as a leech[86] from the Silurian Waukesha Biota of Wisconsin. Partially coalified axis (branch) of a lycopod from the Devonian of Wisconsin. Because of their antiquity, an unexpected exception to the alteration of an organism's tissues by chemical reduction of the complex organic molecules during fossilization has been the discovery of soft tissue in dinosaur fossils, including blood vessels, and the isolation of proteins and evidence for DNA fragments.[87][88][89][90] In 2014, Mary Schweitzer and her colleagues reported the presence of iron particles (goethite-aFeO(OH)) associated with soft tissues recovered from dinosaur fossils. Based on various experiments that studied the interaction of iron in haemoglobin with blood vessel tissue they proposed that solution hypoxia coupled with iron chelation enhances the stability and preservation of soft tissue and provides the basis for an explanation for the unforeseen preservation of fossil soft tissues.[91] However, a slightly older study based on eight taxa ranging in time from the Devonian to the Jurassic found that reasonably well-preserved fibrils that probably represent collagen were preserved in all these fossils and that the quality of preservation depended mostly on the arrangement of the collagen fibers, with tight packing favoring good preservation.[92] There seemed to be no correlation between geological age and quality of preservation, within that timeframe. The star-shaped holes (Catellocaula vallata) in this Upper Ordovician bryozoan represent a soft-bodied organism preserved by bioimmuration in the bryozoan skeleton.[93] Bioimmuration occurs when a skeletal organism overgrows or otherwise subsumes another organism, preserving the latter, or an impression of it, within the skeleton.[94] Usually it is a sessile skeletal organism, such as a bryozoan or an oyster, which grows along a substrate, covering other sessile sclerobionts. Sometimes the bioimmured organism is soft-bodied and is then preserved in negative relief as a kind of external mold. There are also cases where an organism settles on top of a living skeletal organism that grows upwards, preserving the settler in its skeleton. Bioimmuration is known in the fossil record from the Ordovician[95] to the Recent.[94] Examples of index fossils Main article: Index fossil Index fossils (also known as guide fossils, indicator fossils or zone fossils) are fossils used to define and identify geologic periods (or faunal stages). They work on the premise that, although different sediments may look different depending on the conditions under which they were deposited, they may include the remains of the same species of fossil. The shorter the species' time range, the more precisely different sediments can be correlated, and so rapidly evolving species' fossils are particularly useful as index fossils. The best index fossils are common, easy to identify at species level and have a broad distribution—otherwise the likelihood of finding and recognizing one in the two sediments is poor. Main article: Trace fossil Trace fossils are fossil records of biological activity by lifeforms but not the preserved remains of the organism itself. They consist mainly of tracks and burrows, but also include coprolites (fossil feces) and marks left by feeding.[96][97] Trace fossils are particularly significant because they represent a data source that is not limited to animals with easily fossilized hard parts, and they reflect animal behaviours. Many traces date from significantly earlier than the body fossils of animals that are thought to have been capable of making them.[98] Whilst exact assignment of trace fossils to their makers is generally impossible, traces may for example provide the earliest physical evidence of the appearance of moderately complex animals (comparable to earthworms).[97] Coprolites are classified as trace fossils as opposed to body fossils, as they give evidence for the animal's behaviour (in this case, diet) rather than morphology. They were first described by William Buckland in 1829. Prior to this they were known as "fossil fir cones" and "bezoar stones." They serve a valuable purpose in paleontology because they provide direct evidence of the predation and diet of extinct organisms.[99] Coprolites may range in size from a few millimetres to over 60 centimetres. Cambrian trace fossils including Rusophycus, made by a trilobite A coprolite of a carnivorous dinosaur found in southwestern Saskatchewan Densely packed, subaerial or nearshore trackways (Climactichnites wilsoni) made by a putative, slug-like mollusk on a Cambrian tidal flat Main article: Transitional fossil Further information: List of transitional fossils A transitional fossil is any fossilized remains of a life form that exhibits traits common to both an ancestral group and its derived descendant group.[100] This is especially important where the descendant group is sharply differentiated by gross anatomy and mode of living from the ancestral group. Because of the incompleteness of the fossil record, there is usually no way to know exactly how close a transitional fossil is to the point of divergence. These fossils serve as a reminder that taxonomic divisions are human constructs that have been imposed in hindsight on a continuum of variation. Microfossils about 1 mm Main article: Microfossil See also: Micropaleontology and Protists in the fossil record Microfossil is a descriptive term applied to fossilized plants and animals whose size is just at or below the level at which the fossil can be analyzed by the naked eye. A commonly applied cutoff point between "micro" and "macro" fossils is 1 mm. Microfossils may either be complete (or near-complete) organisms (such as the marine plankters foraminifera and coccolithophores) or component parts (such as small teeth or spores) of larger animals or plants. Microfossils are of critical importance as a reservoir of paleoclimate information, and are also commonly used by biostratigraphers to assist in the correlation of rock units. Main article: Amber The wasp Leptofoenus pittfieldae trapped in Dominican amber, from 20 to 16 million years ago. It is known only from this specimen. Fossil resin (colloquially called amber) is a natural polymer found in many types of strata throughout the world, even the Arctic. The oldest fossil resin dates to the Triassic, though most dates to the Cenozoic. The excretion of resin by certain plants is thought to be an evolutionary adaptation for protection from insects and to seal wounds. Fossil resin often contains other fossils, called inclusions, that were captured by the sticky resin. These include bacteria, fungi, other plants, and animals. Animal inclusions are usually small invertebrates, predominantly arthropods such as insects and spiders, and only extremely rarely a vertebrate such as a small lizard. Preservation of inclusions can be exquisite, including small fragments of DNA. See also: Zombie taxon Eroded Jurassic plesiosaur vertebral centrum found in the Lower Cretaceous Faringdon Sponge Gravels in Faringdon, England. An example of a remanié fossil. A derived, reworked or remanié fossil is a fossil found in rock that accumulated significantly later than when the fossilized animal or plant died.[101] Reworked fossils are created by erosion exhuming (freeing) fossils from the rock formation in which they were originally deposited and redepositing them in a younger sedimentary deposit. Main article: Fossil wood Petrified wood. The internal structure of the tree and bark are maintained in the permineralization process.Polished section of petrified wood showing annual rings Fossil wood is wood that is preserved in the fossil record. Wood is usually the part of a plant that is best preserved (and most easily found). Fossil wood may or may not be petrified. The fossil wood may be the only part of the plant that has been preserved;[102] therefore such wood may get a special kind of botanical name. This will usually include "xylon" and a term indicating its presumed affinity, such as Araucarioxylon (wood of Araucaria or some related genus), Palmoxylon (wood of an indeterminate palm), or Castanoxylon (wood of an indeterminate chinkapin).[103] A subfossil dodo skeleton The term subfossil can be used to refer to remains, such as bones, nests, or fecal deposits, whose fossilization process is not complete, either because the length of time since the animal involved was living is too short or because the conditions in which the remains were buried were not optimal for fossilization.[104] Subfossils are often found in caves or other shelters where they can be preserved for thousands of years.[105] The main importance of subfossil vs. fossil remains is that the former contain organic material, which can be used for radiocarbon dating or extraction and sequencing of DNA, protein, or other biomolecules. Additionally, isotope ratios can provide much more information about the ecological conditions under which extinct animals lived. Subfossils are useful for studying the evolutionary history of an environment and can be important to studies in paleoclimatology. Subfossils are often found in depositionary environments, such as lake sediments, oceanic sediments, and soils. Once deposited, physical and chemical weathering can alter the state of preservation, and small subfossils can also be ingested by living organisms. Subfossil remains that date from the Mesozoic are exceptionally rare, are usually in an advanced state of decay, and are consequently much disputed.[106] The vast bulk of subfossil material comes from Quaternary sediments, including many subfossilized chironomid head capsules, ostracod carapaces, diatoms, and foraminifera. Subfossil Theba geminata For remains such as molluscan seashells, which frequently do not change their chemical composition over geological time, and may occasionally even retain such features as the original color markings for millions of years, the label 'subfossil' is applied to shells that are understood to be thousands of years old, but are of Holocene age, and therefore are not old enough to be from the Pleistocene epoch.[107] See also: Biosignature Chemical fossils, or chemofossils, are chemicals found in rocks and fossil fuels (petroleum, coal, and natural gas) that provide an organic signature for ancient life. Molecular fossils and isotope ratios represent two types of chemical fossils.[108] The oldest traces of life on Earth are fossils of this type, including carbon isotope anomalies found in zircons that imply the existence of life as early as 4.1 billion years ago.[12][13] Main article: Stromatolite Further information: Earliest known life forms Lower Proterozoic stromatolites from Bolivia, South America Stromatolites are layered accretionary structures formed in shallow water by the trapping, binding and cementation of sedimentary grains by biofilms of microorganisms, especially cyanobacteria.[109] Stromatolites provide some of the most ancient fossil records of life on Earth, dating back more than 3.5 billion years ago.[110] Stromatolites were much more abundant in Precambrian times. While older, Archean fossil remains are presumed to be colonies of cyanobacteria, younger (that is, Proterozoic) fossils may be primordial forms of the eukaryote chlorophytes (that is, green algae). One genus of stromatolite very common in the geologic record is Collenia. The earliest stromatolite of confirmed microbial origin dates to 2.724 billion years ago.[111] A 2009 discovery provides strong evidence of microbial stromatolites extending as far back as 3.45 billion years ago.[112][113] Stromatolites are a major constituent of the fossil record for life's first 3.5 billion years, peaking about 1.25 billion years ago.[112] They subsequently declined in abundance and diversity,[114] which by the start of the Cambrian had fallen to 20% of their peak. The most widely supported explanation is that stromatolite builders fell victims to grazing creatures (the Cambrian substrate revolution), implying that sufficiently complex organisms were common over 1 billion years ago.[115][116][117] The connection between grazer and stromatolite abundance is well documented in the younger Ordovician evolutionary radiation; stromatolite abundance also increased after the end-Ordovician and end-Permian extinctions decimated marine animals, falling back to earlier levels as marine animals recovered.[118] Fluctuations in metazoan population and diversity may not have been the only factor in the reduction in stromatolite abundance. Factors such as the chemistry of the environment may have been responsible for changes.[119] While prokaryotic cyanobacteria themselves reproduce asexually through cell division, they were instrumental in priming the environment for the evolutionary development of more complex eukaryotic organisms. Cyanobacteria (as well as extremophile Gammaproteobacteria) are thought to be largely responsible for increasing the amount of oxygen in the primeval Earth's atmosphere through their continuing photosynthesis. Cyanobacteria use water, carbon dioxide and sunlight to create their food. A layer of mucus often forms over mats of cyanobacterial cells. In modern microbial mats, debris from the surrounding habitat can become trapped within the mucus, which can be cemented by the calcium carbonate to grow thin laminations of limestone. These laminations can accrete over time, resulting in the banded pattern common to stromatolites. The domal morphology of biological stromatolites is the result of the vertical growth necessary for the continued infiltration of sunlight to the organisms for photosynthesis. Layered spherical growth structures termed oncolites are similar to stromatolites and are also known from the fossil record. Thrombolites are poorly laminated or non-laminated clotted structures formed by cyanobacteria common in the fossil record and in modern sediments.[111] The Zebra River Canyon area of the Kubis platform in the deeply dissected Zaris Mountains of southwestern Namibia provides an extremely well exposed example of the thrombolite-stromatolite-metazoan reefs that developed during the Proterozoic period, the stromatolites here being better developed in updip locations under conditions of higher current velocities and greater sediment influx.[120] An example of a pseudofossil: Manganese dendrites on a limestone bedding plane from Solnhofen, Germany; scale in mm Main article: Pseudofossils Pseudofossils are visual patterns in rocks that imitate fossils but are produced by geologic processes rather than biologic processes. Some pseudofossils, such as geological dendrite crystals, are formed by naturally occurring fissures in the rock that get filled up by percolating minerals. Other types of pseudofossils are kidney ore (round shapes in iron ore) and moss agates, which look like moss or plant leaves. Concretions, spherical or ovoid-shaped nodules found in some sedimentary strata, were once thought to be dinosaur eggs and are often mistaken for fossils as well. It has been suggested that biominerals could be important indicators of extraterrestrial life and thus could play an important role in the search for past or present life on the planet Mars. Furthermore, organic components (biosignatures) that are often associated with biominerals are believed to play crucial roles in both pre-biotic and biotic reactions.[121] On 24 January 2014, NASA reported that current studies by the Curiosity and Opportunity rovers on Mars would begin searching for evidence of ancient life, including a biosphere based on autotrophic, chemotrophic and/or chemolithoautotrophic microorganisms, as well as ancient water, including fluvio-lacustrine environments (plains related to ancient rivers or lakes) that may have been habitable.[122][123][124][125] The search for evidence of habitability, taphonomy (related to fossils), and organic carbon on the planet Mars is now a primary NASA objective.[122][123] According to one hypothesis, a Corinthian vase from the 6th century BCE (Boston 63.420) is the oldest artistic record of a vertebrate fossil, perhaps a Miocene giraffe combined with elements from other species.[126] However, a later study by Julián Monge-Nájera using expert evaluations rejects this idea, because mammals do not have the eye bones shown on the painted monster. Monge-Nájera believes the morphology shown in the vase painting corresponds best to an extant varanid that would have been known to the Ancient Greeks.[127] Main articles: Fossil trading and Fossil collecting Fossil trading is the practice of buying and selling fossils. This is often done illegally with artifacts stolen from research sites, costing many important scientific specimens each year.[128] The problem is quite pronounced in China, where many specimens have been stolen.[129] Fossil collecting (sometimes, in a non-scientific sense, fossil hunting) is the collection of fossils for scientific study, leisure, or profit. Amateur fossil collecting is the predecessor of modern paleontology and remains a practiced hobby to date. Professionals and amateurs alike collect fossils for their scientific value. The use of fossils to address health issues is rooted in traditional medicine and include the use of fossils as talismans. The specific fossil to use to alleviate or cure an illness is often based on its resemblance to the symptoms or affected organ (see sympathetic magic). The usefulness of fossils as medicine is almost entirely a placebo effect, though fossil material might conceivably have some antacid activity or supply some essential minerals.[130] The use of dinosaur bones as "dragon bones" has persisted in Traditional Chinese medicine into modern times, with mid-Cretaceous dinosaur bones being consumed in Ruyang County during the early 21st century.[131] Marine fossils found high in the Himalayas. Collection of the Abbot of Dhankar Gompa, HP, India Three small ammonite fossils, each approximately 1.5 cm across Eocene fossil fish Priscacara liops from the Green River Formation of Wyoming A permineralized trilobite, Asaphus kowalewskii Megalodon and Carcharodontosaurus teeth. The latter was found in the Sahara Desert. Fossil shrimp (Cretaceous) Petrified wood in Petrified Forest National Park, Arizona Petrified cone of Araucaria mirabilis from Patagonia, Argentina dating from the Jurassic Period (approx. 210 Ma) A fossil gastropod from the Pliocene of Cyprus. A serpulid worm is attached. Silurian Orthoceras fossil Eocene fossil flower from Florissant, Colorado Micraster echinoid fossil from England Productid brachiopod ventral valve; Roadian, Guadalupian (Middle Permian); Glass Mountains, Texas. Agatized coral from the Hawthorn Group (Oligocene–Miocene), Florida. An example of preservation by replacement. Fossils from beaches of the Baltic Sea island of Gotland, placed on paper with 7 mm (0.28 inch) squares Dinosaur footprints from Torotoro National Park in Bolivia. Paleontology portalGeology portal Bioerosion – Erosion of hard substrates by living organisms Cryptospore – Fossilised primitive plant spore Endolith – Organism living inside a rock List of fossil parks Living fossil – Organism resembling a form long shown in the fossil records Paleobiology – Study of organic evolution using fossils Paleobotany – Study of organic evolution of plants based on fossils Schultz's rule – Relationship between tooth wear and lifespan of fossil organisms Shark tooth – Teeth of a shark Signor–Lipps effect – Sampling bias in the fossil record raising difficulties to characterize extinctions ^ Oxford English Dictionary. Oxford University Press. Archived from the original on 11 January 2008. Retrieved 17 June 2013. ^ Jablonski, David; Roy, Kaustuv; Valentine, James W.; Price, Rebecca M.; Anderson, Philip S. (16 May 2003). "The impact of the pull of the recent on the history of marine diversity". Science. 300 (5622): 1133–1135. 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