The Paleontograph

A newsletter for those interested in all aspects of Paleontology
Volume 5 Issue 3 September, 2016

From Your Editor

Welcome to our latest issue. I hope you are all having a good summer/ late summer. I managed to get a week of collecting done in Montana and I'm heading out for a week in South Dakota as soon as I finish up the show in Denver. It is always nice to see and get together with friends from around the country and the world.

I've talked about laws being enacted to protect wildlife such as elephants before. While I am all for protecting endangered species, some of the laws are being written poorly. Instead of properly educating those that enforce the law, they have taken to including extinct species such as Mammoth so that an agent can just look at all tusks for instance and not have to tell the difference between a modern endangered species and one that is extinct. Besides that, using a broad brush stroke, they are including other parts such as teeth. Teeth are made of enamel and dentine, not ivory, so why include them in an ivory ban? They are also using that broad brush and including other species. A recent Colorado law included sharks. So besides trying to save Mammoths, they are also trying to save Megalodon sharks. These broad stroke laws have far reaching, unintended consequences. If someone were to inherit a large collection of fossils they would be unable to sell them and think about how the value of collections in peoples home would plummet if the market dried up for specimens. The commercial fossil dealers trade organization, AAPS (http://www.aaps.net/) keeps track of these laws as they come up and works to bring some common sense into the picture.

TC

The Paleontograph was created in 2012 to continue what was originally the newsletter of The New Jersey Paleontological Society. The Paleontograph publishes articles, book reviews, personal accounts, and anything else that relates to Paleontology and fossils. Feel free to submit both technical and non-technical work. We try to appeal to a wide range of people interested in fossils. Articles about localities, specific types of fossils, fossil preparation, shows or events, museum displays, field trips, websites are all welcome.

This newsletter is meant to be one by and for the readers. Issues will come out when there is enough content to fill an issue. I encourage all to submit contributions. It will be interesting, informative and fun to read. It can become whatever the readers and contributors want it to be, so it will be a work in progress. TC, January 2012

Edited by Tom Caggiano and distributed at no charge

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Eunotosaurus:

the EarlyTriassic Stem Turtle

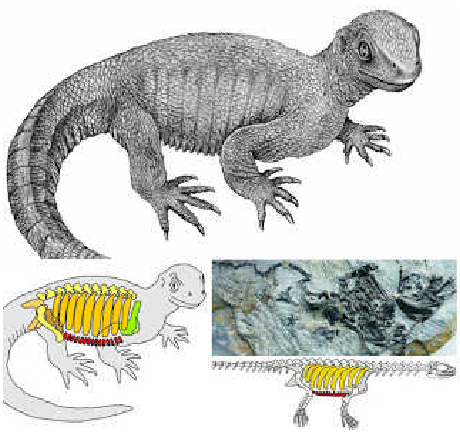
Bob Sheridan October 24, 2015

If you go back a decade or so, a hot topic in paleontology was whether turtles represent “primitive” or “advanced” reptiles. Arguments for the “primitive” side came from the fact that turtles have no openings in their skulls aside from the orbit and nostril, like many early “anapsid” reptiles such as pareiasaurs. Arguments for the “advanced” side point to a genetic resemblance of turtles to later “diapsid” (with two additional holes in the skull) reptiles like lizards and snakes. The latter would argue that the turtle’s skull became convergent on the anapsid condition well after the origin of turtles.

Trying to figure out which type of reptile is ancestral to turtles based on anatomy is very difficult because turtles are very unique among living (and most fossil reptiles). First, they always have a toothless beak. Second, they are covered in a bony box, made of a “carapace” above and a “plastron” below, with the two fused at several points. The shoulder blades of turtles are inside their ribs, which is totally unlike any other tetrapod. Most modern turtles can withdraw their heads, and sometimes their limbs, inside the shell. Turtles also tend to have very short tails for reptiles.

As with many interesting fossil groups, modern-looking turtles seem to appear very suddenly in the fossil record, in this case in the Triassic. For example, Proganochelys (~214Myr.) has a full carapace and plastron and also has a toothless beak. The biggest difference from modern turtles is that it could not withdraw its head, and it had teeth on its palate. Otherwise, it looks like a heavily armored snapping turtle. We now know of two stem-turtles known from earlier in the Triassic and these provide some clues about when turtles developed their characteristic features. These are Odontochelys (~220 Myr.), and Eunotosaurus (~260 Myr.). Odontochelys has a plastron, but not a fused carapace. It also has teeth on upper and lower jaws. Eunotosaurus resembles a lizard, but one with very broad and flat ribs that touch each other and reach far to either side of the body. However, it does have turtle-like vertebrae and details on the ribs look turtle-like. Until recently, it was debatable whether Eunotosaurus was a turtle ancestor, or a reptile that had converged on some turtle characteristics.

This week in Nature, Schoch and Sues (2015) describe a new turtle Pappochelys ("grandfather turtle"). Pappochelys is from the Middle Jurassic Schumann quarry in Germany (~240 Myr.), exactly intermediate in time between Odontochelys and Eunotosaurus. The sediment in which it is found appears to be a lake bottom. Pappochelys has wide ribs above and thick gastralia below, but these are not fused into a carapace or plastron. The tail is long. The skull has teeth in the upper and lower jaw. The authors regard Pappochelys as an anatomical intermediate between Odontochelys and Eunotosaurus, and this is supported by a phylogenetic analysis. One possible anomaly is that Pappochelys appears to have clearly diapsid skull, whereas Odontochelys and Eunotosaurus are generally regarded as having anapsid skulls. However, Eunotosaurus may have had a small upper and lower temporal opening and thus may not be completely anapsid. In any case, Pappochelys does support the idea that turtles came from a diapsid ancestor.



The fact that Pappochelys comes from an aquatic environment suggests a reason for the thick ribs of stem-turtles. Probably it formed ballast to keep the turtle submerged, much as seen in modern manatees.

Sources:

Bever, G.S.; Lyson, T.R.; Field, D.J.; Bhullar, B.-A.,S.
"Evolutionary origin of the turtle skull."
Nature, 2015, 525, 239-242.

Schoch, R.; Sues, H.-D.
"A middle Triassic stem-turtle and the evolution of the turtle body plan."
Nature 2015, 523, 584-587.

Galapagos in Nebraska?

Kenneth Quinn

I graduated from the University of Alabama in January of 1970 with a BS in geology and jobs were scarce. My only edge was that I had found and excavated a mosasaur skeleton out of the Mooreville Chalk on my first wedding anniversary. When I saw an ad in Geotimes that the University of Nebraska State Museum was looking for a Highway Salvage Paleontologist, I applied - and was hired! My job was to visit areas of road construction, look for vertebrate fossils that were uncovered by the road construction, and rescue them. In other words, I was being paid to have fun! I loved being outdoors and traveling, learning new geology, and meeting all sorts of people. My wife was able to travel with me, so the museum got an unpaid assistant!

Due to illness I was on this job only two years but there were several big discoveries during that time. The biggest was near Lodgepole, in Deuel County, where Interstate I-80 was being built. There, in Pliocene sediments, the construction machines uncovered a herd of Galapagos -sized tortoises, about 50 of them! I was sent to reconnoiter. There were that many carapaces visible along a stretch of right-of-way a tenth of a mile long. I called the museum about the scope of the find, and told them it was far beyond my capacity to handle. Luckily it was summer, and the museum had a crew of 5 students working a site about 50 miles away. They were transferred to Lodgepole; our goal was to remove the fossils as quickly as possible so that construction could be interfered with as little as possible.

The tortoises had several things in common. The denticles on the legs were still present - very unusual. In all cases the carapaces were slanted with the head end higher but in only one case were any skull bones present. The characteristics of the sediment were similar to the sediments of modern day streams in the area, such as the South Platte and North Platte Rivers - as the joke goes, "half a mile wide, half an inch deep". The "half an inch" is an exaggeration, the other is not. I surmised the tortoises waded into a river, became mired down, and struggled to keep their heads above water. Scavengers - primitive canids - waded out and claimed the heads; we did find the skeleton of a Borophagus, whose dentition showed it was an elderly individual who may have died of old age or general bad condition at water's edge.

Finally the tortoises were all removed and the extra museum crew left. I stayed on in case of additional discoveries and sure enough a few more things turned up. There was the tusk of a shovel-tusk mastodon, for instance. A few horse bones kept turning up.

Needless to say, it was impossible to keep such a find secret from the public. We had to arrange brief tours of the excavation, from a safe distance, of course, but that created a lot of goodwill.

Timurlengia-

-The Middle Tyrannosaur

Bob Sheridan April 9, 2016

The family of known tyrannosaurs is now getting fairly large. At first we knew about the giant Late Cretaceous tyrannosaurs (>30 ft) from western North America (Tyrannosaurus, Albertosaurus, Daspletosaurus, etc.) and Asia (Tarbosaurus). Also notable are the middle-sized (~25 ft) Late Cretaceous tyrannosaurs from eastern North America like Appalachiosaurus and Dryptosaurus (the latter is from New Jersey). In the past 20 years a number of small (~10 ft) ancestral tyrannosaurs were discovered from the Late Jurassic and Early Cretaceous (mostly from Asia): Sinotyrannus, Guanlong, Dilong, Eotyrannus, for example.

Bits of information relevant to today’s story:

1. Somewhere between the Early and Late Cretaceous some tyrannosaurs grew in size, got shorter arms, and deeper skulls with more robust jaws.
2. Somewhere between the Early and Late Cretaceous tyrannosaurs attained characteristic detailed structures in the skull. Many of these are “brain and sensory” features that have to do with the shape of the brain case and inner ear. Some have to do with “pneumaticity,” i.e. the position and complexity of air sacs.

Cont'd

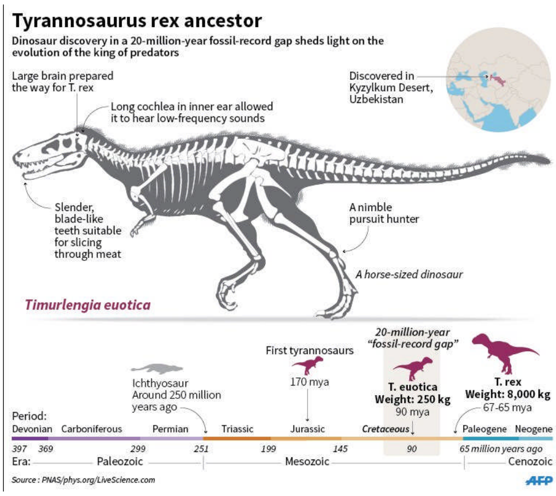
Timurlengia Cont'd

3. There is a gap in the mid-Cretaceous where no tyrannosaur specimens have been previously found so we do not know when these changes took place.

Brusatte et al. (2016) describe a tyrannosaur specimen from Uzbekistan, which they name *Timurlengia euotica* (after the fourteenth-century ruler Tamerlane and "well-eared"). This specimen was surface-collected from the same horizon of the Bissekty Formation which is thought to be ~90 Myr., i.e. mid-Cretaceous. The specimen is very fragmentary and probably is from more than one individual (but assumed to represent the same species): a few vertebrae, part of the maxilla, hand and foot claws, parts of the mandible, but importantly, part of the braincase. Timurlengia would have been about 10 ft. long, about the same size as Early Cretaceous tyrannosaurs.

The most relevant piece is the right side of the braincase, which includes a very well-preserved inner ear. The detailed anatomy was elucidated by CT-scanning. The major point is that some of the anatomical details (for instance the inner ear structures) are similar to those in Late Cretaceous tyrannosaurs, but some (for instance the sinuses) are similar to those in Early Cretaceous Tyrannosaurs. Timurlengia is too fragmentary to say anything about the length of the arms or the depth of the skull.

Two phylogenetic analyses were done, one on the braincase alone, and one on the other fragments, including some collected by others. In both cases, Timurlengia comes out as an intermediate between Early and Late Cretaceous tyrannosaurs. The authors feel this supports the idea that the braincase and other parts are from the same species.



Timurlengia supports the idea that tyrannosaurs developed their characteristic brain structures and ear structures before they got larger and developed complex sinuses. Of course, many lineages of animals contain multiple genera, all living at the same time, with different combinations of primitive and advanced characteristics. (Early birds are a good example.) If this is true of tyrannosaurs, one genus may not tell the whole story, and the picture could change as more mid-Cretaceous tyrannosaurs are found.

Sources:
Brusatte, S.L.; Averlanov, A.; Sues, H.-D.; Muir, A.; Butler, I.B.
"New tyrannosaur from the mid-Cretaceous of Uzbekistan clarifies evolution of giant body sizes and advanced senses in tyrant dinosaurs."
Proc. Natl. Acad. Sci. 2016, 113, 3447-3452.

The Tully Monster Reinterpreted

Bob Sheridan April 14, 2016

The Burgess Shale, noted for the exceptional preservation of soft-bodied animals from the Cambrian, has been under study for just over 100 years. Many of the animals remain "problematica," i.e. they cannot be unambiguously affiliated with familiar groups of animals. One may remember the debates from the 80's and 90's whether the problematica represent phyla that went extinct after the Cambrian (as often argued by Stephen Jay Gould), or just extreme versions of modern phyla, e.g. sponges, molluscs, or arthropods (as counter-argued by Simon Conway Morris). Generally we see that with additional fossil finds, aided by phylogenetic analysis, we can recognize commonality between the problematica and modern phyla. For example, Hallucinogenia is reinterpreted as a velvet worm, conodonts are shown to be chordates, etc.

There are problematica from times later than the Cambrian. Today's story concerns the 'Tully monster', which is from the Mazon Creek fauna from Illinois. Mazon Creek is believed to be Carboniferous in age (~310 Myr.). The Tully monster, first described by Francis Tully in 1969, is given the genus name Tullimonstrum, and is the state fossil of Illinois.

As with many fossils preserved in two dimensions, interpretation of the Tully monster is not necessarily straightforward. It appears to be a torpedo-shaped animal 3-14 inches long, with horizontal fins and a dorsal fin toward the back of the "tail." Then two very weird features that make it the "monster" it is:

1. A thin rigid bar extends from the top of the animal laterally, extending slightly past the sides of the animal. There appear to be round, dark eye-like structures at the end of the bar. Stalked eyes would be expected in an arthropod, but unexpected in something so "fish-like."
2. At the front is a long, relatively thin, proboscis ending in a set of long jaws with sharp teeth. To me it looks like a tiny human arm with an alligator sock puppet.

Within a month I came across two articles in the journal Nature that take another look at the Tully monster and independently make the same (surprising) suggestion as to its affinity, based on completely different lines of reasoning.

McCoy et al. (2016) reexamined ~1200 specimens of Tullimonstrum and reinterpreted earlier findings. First what was formerly interpreted as the "gut" in Tullimonstrum is equivalenced to the "notochord" in Gilpichthys, another animal from the Mazon Creek, which is interpreted as a primitive hagfish. Also, the eyebar seems to extend from the middle of a trilobed "brain." Chordates possess a trilobed brain and the optic nerve extends from the middle lobe. Transverse "segments" in the body of Tullimonstrum resemble the muscle blocks characteristic of chordates. The teeth in the jaws appear to be backward-pointing hollow cones, much like those seen in lampreys and hagfish. The proboscis is not a flexible "hose," but appears to be jointed in at least three places. There might be a tongue-like structure just to the rear of the jaws, and gill pouches on the side of the body.

To the authors, the characteristics of Tullimonstrum are not consistent with the "free-swimming mollusc," "conodont," or "extinct phylum" interpretations, but more consistent with a "lamprey or hagfish" model. These are stem jawless vertebrates, so Tullimonstrum could be a vertebrate also. Phylogenetic analysis based on the anatomy of these animals seems to support this.

Clements et al. (2016) use high-tech methods to examine the eye of Tullimonstrum. The first method is electron microscopy. One can see two kinds of micrometer-sized bodies in the eye region, one cylindrical and one ovoid. These two types of bodies occur in separate layers. The bodies are likely melanosomes, bodies that contain melanin pigment. That the putative melanosomes really contain pigment is shown by x-ray spectroscopy.

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Tully Cont'd

The spectrum gathered from the Tullimonstrum eye resembles melanin from extant animals, although it more closely resembles artificially aged melanin (usually via heating). While some invertebrate groups contain melanin in their eyes, the same type of layered structure of melanosomes is found almost exclusively in vertebrate eyes. Phylogenetic analysis based only on eye microstructure places Tullimonstrum among the chordates and probably the primitive vertebrates like the lamprey or hagfish. It is plausible that Tullimonstrum had sophisticated image-forming eyes, despite their small size relative to the body.

One can question the hagfish/lamprey interpretation by noting that Tullimonstrum would be a very unusual hagfish; the body of Tullimonstrum seems to be rigid and probably moved by undulating fins, while hagfish have eel-like bodies that move by wriggling. Also, very few other vertebrates have have jaws at the end of a proboscis, separated from the head. Eyes on stalks are also very unusual for vertebrates, although Clements et al. note that some fish larvae have them. The adult hammerhead shark is a much less extreme example.

If the vertebrate affinity of Tullimonstrum holds up, it does show that the diversity of early vertebrates is a lot larger than formerly thought, and the Tully monster is even more monstrous compared to its relatives.

Sources:
Clements, T.; Dolocan, A.; Martin, P.; Purnell, M.A.; Vinther, J.; Gabbot, S.E.
“The eyes of Tullimonstrum reveal a vertebrate affinity.”
Nature 2016 doi:10.1038/nature17647

Kuratani, S.; Hirasawa, T.
“Getting the measure of a monster.”
Nature 2016 doi:10.1038/nature17885.

McCoy, V.; Saupe, E.E.; Lamsdell, J.C.; Tarhan, L.G.; McMahon, S.; Lidgard, S.; Mayer, P.; Whalen, C.D.; Soriano, C.; Finney, L.; Vogt, S.; Clark, E.G.; Anderson, R.P.; Petermann, H.; Locatelli, E.R.; Briggs, D.E.G.
“The ‘Tully monster’ is a vertebrate.”
Nature 2016 doi:10.1038/nature16992

The Bare Bones--A Review

Bob Sheridan April 22, 2016

The “Life of the Past” series from Indiana University (editor James Farlow) seldom disappoints. The latest entry is “The Bare Bones” by Matthew Bonnan, which I finished reading a few days ago. Bonnan is a vertebrate paleontologist and Associate Professor of Biology at Stockton University (in New Jersey). TBB is his first book. You should check out his blog “The Evolving Paleontologist” at https://matthewbonnan.wordpress.com/

TBB is a massive book at over 500 pages, and it covers what might be called “functional skeletal anatomy,” that is, why bones have the shapes they do to get their job done. According to the author’s blog, the idea was to update and expand on a classic book by Leonard Radinsky “The Evolution of Vertebrate Design”. The book covers the first vertebrates to modern mammals, pretty much in chronological order in 21 chapters. While the text is written in an informal style, it is basically a scientific review article with embedded references. There are copious illustrations, about one per page; these are mostly simple diagrams or simplified skeletons drawn by the author. For those of you who like to look at pictures of actual fossils, some photos are found in the center color section.

This is pretty dense material, even if it does not use a lot of anatomical jargon and has an informal style, so you should expect to expend as much effort on TBB as you would reading an undergraduate college textbook. It took me a month or two to get through it, reading a quarter of a chapter at a time. I do feel it was worth it.

This is a pretty pricey book at the nominal cost of $75, but it is available cheaper at Amazon.

Sources:

Bonnan, M.F.
“The Bare Bones. A Unconventional Evolutionary History of the Skeleton.”
Indiana University Press, Bloomington and Indianapolis, 2016, 508 pages $75.

Tiny Titanosaur

Bob Sheridan April 23, 2016

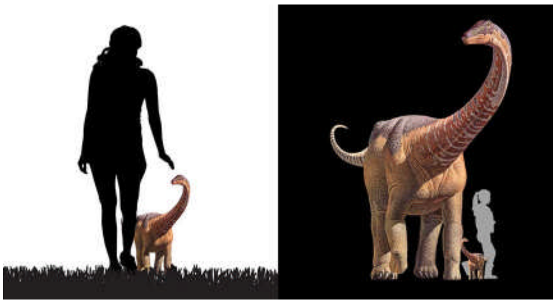
Titanosaurs are the branch of sauropod dinosaurs that lived in the southern hemisphere and Europe during the Cretaceous. Among them are some of the largest sauropods known. For example Argentinosaurus is estimated to be over 100 ft long and weigh 90 metric tons. They are not as completely known as some of the Late Jurassic sauropods from North America, especially in regards to skull anatomy. However, we have many complete examples of titanosaur eggs and their embryos. Given the size of the eggs, soccer ball sized or smaller, it is obvious that titanosaurs increased their weight over their lifetime by ten-thousand-fold.

Growth series are known for several dinosaurs, but we have very few examples of anything between hatchling and adult titanosaurs. A new publication in Science by Rogers et al. (2016) describes a few limb bones of a baby titanosaur. This specimen, called UA 9998, consists of a femur, a tibia, a fibula, a humerus, and few scattered phalanges. It was excavated from the Maevarano Formation in Madagascar, which is Late Cretaceous in age. The bones resemble those of a previously known titanosaur Rapetosaurus. The femur is about eight inches long, which would make UA 9998 about 14 inches at the hip. An adult Rapetosaurus would have a femur about 60 inches long and be 12 ft high at the hip. (Rapetosaurus is smallish for a sauropod, especially a titanosaur.)

UA 9998 was studied in two ways in this paper. One is by bone histology and CT-scanning and the other is comparing the shape of the bones, in particular the femur. I do not understand the histology enough to comment. However, these are the main points made by the authors:

1. Young reptiles generally show a “hatching line” in their bones that indicates when they left the egg. The authors use this to estimate how old UA 9998 was when it died: between 39 and 77 days, and also to estimate its size at hatching, about half of the length of UA 9998 at death. This would imply an almost ten-fold weight gain in a month or two.
2. The bones seem “remodeled”, which to the authors implies that the legs were being used for walking.
3. Cartilage at the end of the bones appears to have stopped growing. The authors feel this implies UA 9998 was starving, and this caused its death.

Interestingly, the three or four known Rapetosaurus femurs (including that of UA 9998), which vary 8-fold in length, are nearly identical in shape. To the authors, this implies that baby titanosaurs were miniatures of their parents. This bears some discussion. We mammals are used to our youngest juveniles being very different from adults in shape: rounder, larger head, shorter limbs, etc. compared to the overall body size (i.e. they look “cute”). These young juveniles need lots of parental care, not to mention stronger bones, before they can get around on their own. Some dinosaurs, for which we have growth series, e.g. Protoceratops, Maiasaura, etc., show the same sort of differences in proportion and have insufficiently ossified limbs. This apparently is not the case for sauropods.



It is generally thought that the baby animals with a different juvenile shape are “altricial”, i.e. they cannot get around on their own and require parental care, while the animals that appear to be miniature adults are “precocial” and can immediately take care of themselves. (Another recent example of this thinking has to do with the discovery that the wing proportion of embryo pterosaurs is the same as in adults, and therefore it is inferred that newly hatched pterosaurs could fly right away.) Therefore, the authors propose that baby titanosaurs were precocial, looked similar to adults, and did not require parental care. This makes intuitive sense, because it is hard for us to imagine how sauropods, with their rigid bodies, extremely long necks, and weights in the range of tens of metric tons could care for cat-sized hatchlings.

It seems fair to conclude UA 9998 could walk a few months after hatching. However, I would add some cautions about drawing broader conclusions about parental care. **Cont'd**

Tiny Cont'd

Precocity in the sense of being able to immediately walk immediately after birth or hatching, the lack of juvenile proportions, and the lack of parental care are not always correlated or absolute. Sea turtles swim immediately after hatching, and get absolutely no parental care, but still have juvenile proportions. Birds like chickens are "precocial" in the sense that they can walk and eat on their own immediately after hatching, but do not resemble their parents, and receive some parental care.

Then there is the issue of what we can extrapolate from one body part. Just because the femur has the same shape as hatchling and adult, that does not mean the relative size of the femur to the body is the same throughout life. Also, the femur alone may not say anything about the proportions of other body parts like the neck. We already know that embryo titanosaurs have shortish necks compared to adults, and this would likely persist some time after hatching.

Sources:
Monahan, P.
"The tiniest titan"
Science 352, pg. 395.

Rogers, K.C.; Whitney, M.; D'Emie, M.; Bagley, B.
"Precocity in a tiny titanosaur from the Cretaceous of Madagascar"
Science 2016, 352, 450-453.

Aquilonifer, the Spiny Kite Bearer

Bob Sheridan April 30, 2016

Briggs et al. (2016) describe a new arthropod from the Silurian Herefordshire Lagerstatte in the United Kingdom. Fossils in this formation are preserved in three dimensions as calcite precipitation within carbon nodules of volcanic ash. In this case these fossils were studied by serial sectioning. That is, the surface of a fossil-containing is ground flat and a photograph is taken. Then the surface is ground down by 30 micrometers, and another photograph is taken, etc. Once one has ground down through the entire thickness of the rock, all the photographs are assembled into a stack and virtual models of individual animals can be generated.

The new animal described in this paper is named *Aquilonifer spinosus* ("spiny kite bearer"), and the reasons for the name will be obvious shortly. Aquilonifer would be about a half inch long. To me Aquilonifer resembles an elongated spiky "pillbug." There is a triangular head with a forward pointing "rostrum". There is one pair of large antennae from the underside of the head. There are 11 body segments of roughly equal size, each with a pair of legs and pair of laterally pointing thin spines. The last segment bears a pair of rearward very long filamentous cerci. Some of the legs are "biramous," i.e. have gills branching from the upper surface. No eyes are evident. Phylogenetic analysis suggests Aquilonifer is a very basal member of the mandibulata, the group of arthropods that contains crustaceans, insects, and myriopods.

What is unusual about Aquilonifer is that there are ten elongated-lemon shaped small bodies hanging by "threads" from the lateral spines. Each small body is about one-fifth the length of Aquilonifer, and each thread is about the same length. The resemblance of these bodies to kites is the source of the genus name. There is not enough resolution in the virtual models to say anything further about these bodies.

The authors consider whether these small bodies represent parasites, epizoans, or eggs/juveniles. They tend to discount parasites because the small bodies are not in a position to bite or otherwise get nutrients from the host. Epizoans would be animals that "hitch a ride" on another animal perhaps to gain access to a food source. The authors feel Aquilonifer could clean off the epizoans, which would impair its swimming, and thus is less likely. This leaves eggs/juveniles. While arthropods have a number of strategies of attaching eggs or hatchlings close to themselves, trailing them like kites is not one previously seen, hence "unique mode of brood care" in the title of the paper.

My feeling is that explanations other than "eggs/juveniles" are not really given a fair shake and probably should be explored further. Since the authors do not mention other specimens of Aquilonifer, there is no other example of this animal, and we cannot eliminate the possibility that the small bodies are on all specimens, and perhaps represent some kind of camouflage or decoration. This can settled only by finding more examples.

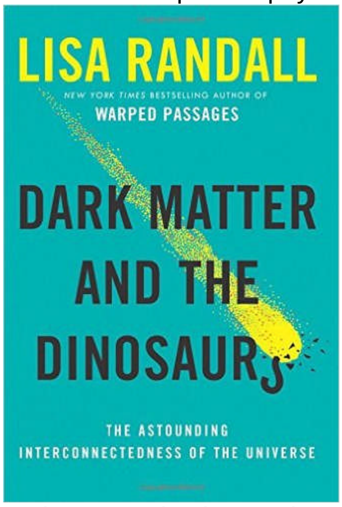
Sources:
Briggs, D.E.G.; Siveter, D.J.; Siveter, D.J.; Sutton, M.D.; Legg, D.
"Tiny individuals attached to a new Silurian arthropod suggests a unique mode of brood care."
Proc. Natl. Acad. Sci. USA, 2016, 113, 4410-4415.

Proc. Natl. Acad. Sci. USA, 2016, 113, 4410-4415.

Dark Matter and the Dinosaurs--A Review

Bob Sheridan July 6, 2016

Today I am reviewing "Dark Matter and the Dinosaurs" by Lisa Randall, who is a professor of theoretical and particle physics at Harvard.



It takes some background to appreciate the arguments in this book. The stars, planets, and everything we can see are made of "baryonic matter" (or "ordinary matter" if you prefer). Astronomers and physicists have postulated for some decades now that there is another type of matter called "dark matter" that interacts with ordinary matter only through gravity. (As the author points out "dark matter," is a misleading name. It should have been called "transparent matter" in that it does not absorb or emit light or any other kind of electromagnetic radiation, i.e. there is nothing particularly "dark" about it.) The postulate is based on observations that there seems to be much more gravity around individual galaxies than can be accounted for by all the visible stars. As a matter of fact, there would have to be over five times as much dark matter than ordinary matter in the Universe.

As strange as the above description sounds, dark matter almost certainly exists. Cosmological models seem to require some kind of dark matter to reproduce the observed large-scale structure of the universe. Alternative models that try to explain astronomical observations without invoking some type of dark matter, for instance the idea that the inverse-square law of gravity is not quite right, seem to be ruled out. At present, physicists do not know what dark matter is made of. It cannot be accounted for by the currently accepted Standard Model of particle physics. Various attempts have been made to directly test for dark matter assuming it has a very small but non-zero interaction with ordinary matter. So far no definitive results.

It is not really known whether dark matter interacts with itself by anything but gravity, and this is an important point in this book. Most galaxies, including our galaxy The Milky Way, are flat spirals of hundreds of billions of stars. Conventional thought is that there is a thick diffuse halo of dark matter surrounding each galaxy. However, one speculative theory from the author is that if we allow the possibility of dark matter interacting with itself, by say, allowing it to emit energy of some kind, the dark matter in a galaxy could settle into a very thin disk, even thinner than the disk formed by the stars. This hypothetical structure is called the "dark disk." Remember it would not be detectable except by gravity.

More astronomical background is needed to follow the argument further. Our solar system is surrounded by a hollow shell of icy bodies called the Oort Cloud, which is 30-50 times as far from the Sun as the Earth is. (There is a closer shell of icy bodies called the Kuiper belt outside the orbit of Neptune. Pluto is now regarded as a Kuiper Belt object.) The Oort Cloud is thought to be the source of long-period comets. Any influence gravitationally perturbing the Oort Cloud can send some comets toward the sun, where they might once in a while collide with a planet.

The sun orbits the galactic center more or less in the galactic plane, taking ~250 million years to go around. However, there is motion perpendicular to the plane; the sun should periodically pass through the plane of the galaxy several times per orbit.

Finally, we know the Earth and Moon have been bombarded with asteroids and comets all through their history, the most frequent collisions happening near the beginning of the solar system. At least one asteroid/comiet collision has caused a mass extinction: the K-T. Some scientists claim, based on the age of known craters and the spacing of mass extinctions, that asteroid/comet strikes have a periodicity, i.e. they are more frequent at regular intervals.

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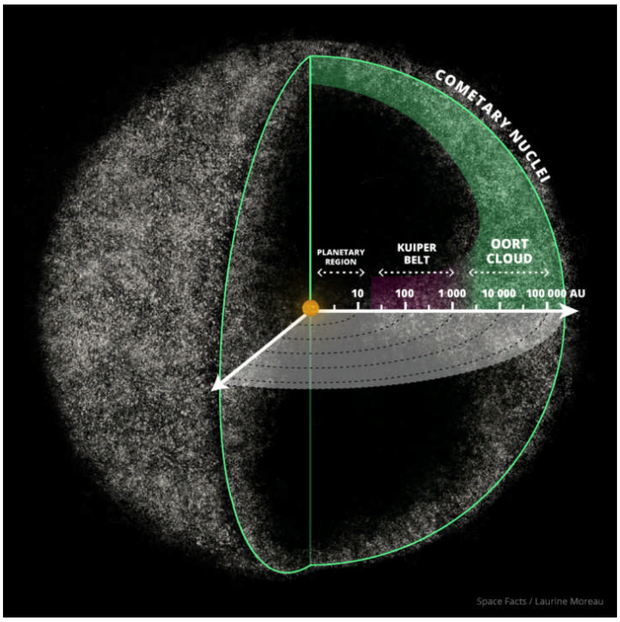

Estimates range from 20-60 Myr., but it is far from certain that the periodicity is real and not a statistical artifact. In the 1980's it was proposed that the sun had a companion brown dwarf star (called Nemesis) with an extremely elongated orbit that could periodically approach the sun and perturb the Oort Cloud, thus explaining the supposed periodicity in comet strikes. Nemesis should have been visible in later surveys of nearby stars, but it was not seen. This is not surprising since it was invented only to explain one iffy observation.

This is the ladder of thought by which the author takes to link dark matter to the dinosaurs:

1. There is a periodicity of ~35 million years to crater impacts on Earth.

2. The sun crosses the galactic plane at about the same period.

3. Whereas the stars in the galaxy would not have enough density to perturb the Oort Cloud through gravitational tidal forces, a dark disk would have enough density to do so.

4. Therefore, the periodicity of crater impacts is explained by the dark disk model.

Randall and coauthor Matthew Reese published this line of reasoning in 2014 in Physical Review Letters as an article "Dark Matter as a Trigger for Periodic Comet Impacts." This article can be considered the starting point of "Dark Matter and the Dinosaurs". The additional point added in the book is:

5. The extinction of the dinosaurs was caused by a comet strike due to the periodic perturbation of the Oort Cloud, which was in turn caused by a dark matter disk.

This is a big stretch. First, we cannot necessarily assign the specific K-T strike to a particular wave of comet strikes, similarly to the way we cannot assign Hurricane Sandy to global warming. We do not know that the K-T impactor was a comet and not, say, a near Earth asteroid. It is not clear whether there is a real periodicity in crater impacts and we do know with precision how often the sun would cross the galactic plane. The dark disk idea depends on a particular set of assumptions about dark matter made by the author, and these assumptions are speculative at best. The author admits that this chain of reasoning is tenuous and discusses all these uncertainties in detail.

On the one hand, the book is an easy read and I learned a lot about dark matter, galaxy formation, and near-earth asteroids. So thumbs up for it as a semi-popular book about new areas of astronomy and physics. On the other hand, I feel sort of cheated because the link to dinosaurs was largely "smoke and mirrors." If you are looking for a book on paleontology, or even mass extinction, look elsewhere.

Sources:
Randall, L.
"Dark Matter and the Dinosaurs. The astounding connectedness of the universe."
Harpercollins 2015, 412 pages. $30 hardcover.