

The Paleontograph

**A newsletter for those interested in all aspects of Paleontology
Volume 4 Issue 5 December, 2015**

From Your Editor

Welcome to our latest issue. This is my first issue from Colorado. I am enjoying my new home state where everything is much calmer and easier going than NY and I don't think it's because everyone is high from smoking grass. I've been busy setting up my prep lab and my fossil storage area and looking forward to getting to work on the hundreds of fossils I've collected and bought and never got to clean up.

As usual, Bob Sheridan has given us a great compliment of articles. But let's not take Bob for granted. What's the chance one of you might write something?

I want to wish you all Happy and Healthy Holidays.



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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Do We Finally Understand Hallucigenia?

Bob Sheridan, July 4, 2015

Many Cambrian animals (most of which we know from the Burgess Shale ~500 Myr) are constantly being reinterpreted. One reason for this is that they are unlike anything alive today, so analogies to living animals are hard to draw. Another reason is that Burgess Shale animals were soft-bodied and were squashed flat in various orientations, under various states of decay, when they were buried. The fossils themselves are just carbonized film on rock, so it is not particularly surprising that we cannot see all the details, and many anatomical interpretations are possible.

One specific animal that has seen many interpretations is Hallucigenia. Just from the name one guess how weird this animal might be. Hallucigenia is a long tube, anywhere from 5 to 15 millimeters, with seven pairs of flexible "tentacles" on one side and seven pairs of somewhat longer rigid "spikes" on the other. Where the spikes are attached to the main body, there are short humps. The ends of the main tube, outside the "appendages," are not well resolved in most specimens, appearing as some kind of blurred blob.

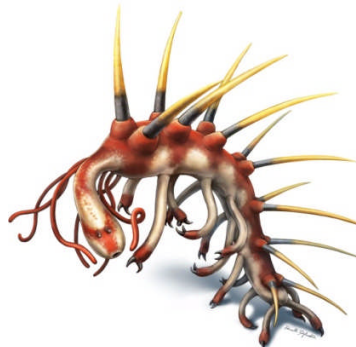


Hallucigenia was first observed in the Burgess Shale by Charles Walcott early in the twentieth century. Similar animals are found in the Chengjiang site in China. Walcott tentatively assigned the animal as a polychaete worm, i.e. a segmented worm with bristles. In 1977 Simon Conway Morris named the fossil *Hallucigenia sparsa* and interpreted it as a really bizarre type of animal. Morris had Hallucigenia walking on the spikes, with the tentacles coming from the back. In 1991 Ramsköld and Xiangyang noticed that if you turned Morris's version of Hallucigenia upside down, the animal would resemble modern (and fossil) velvet worms (onychophorans), with the "tentacles" being the legs.

Hallucigenia would then be an onychophoran, and it is usually reconstructed something like a velvet worm. This makes sense since the dark hooks at the end of the tentacles are clearly interpreted as claws, which velvet worms have. However, modern velvet worms have more than seven pairs of legs, and have antennae. Plus no living or fossil velvet worm has spikes, so the analogy might not be perfect.

Given that the ends of Hallucigenia have not been well resolved, one cannot tell the front from the back. For the same reason, it is plausible to interpret Hallucigenia as a detached portion of a larger animal. This is not unprecedented for Cambrian animals. What appeared to be a specimens of a jellyfish and specimens of shrimp tail turned out to be the mouthparts of *Anomalocaris* once a complete specimen of *Anomalocaris* was discovered.

Recently Smith and Caron (2015) describe several specimens of Hallucigenia from the Burgess Shale with both ends of the body intact. The posterior of the animal ends shortly after the last pair of the legs. On the other hand, there is a slender elongated "neck" (about half as long as the part of the body to which the legs are attached) that extends from the body and ends in a slight swelling that is interpreted as the "head". There are two dark spots at the middle of the head that are interpreted as simple eyes. There are three pairs of long slender tentacles extending from the bottom of the base of the neck. One can clearly see a gut along the entire length of the animal and a wider buccal cavity at the end of the head, which is clearly a mouth. There is a ring at the very front of the mouth, ahead of the eyes, which the authors name "circumoral elements". These are interpreted as some kind of teeth. The authors also interpret a line of dark spots, behind the eyes, aligned with the axis of the foregut, as aciculae, i.e. spikelike teeth. The restoration of Hallucigenia shown in Figure 3 of the paper looks truly bizarre, like something from H.P. Lovecraft or "Barlowe's Guide to Extraterrestrials". (Makers of scifi movies, take note.)



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Hallucigenia Cont'd

The authors argue that the circumoral and pharyngeal teeth of *Hallucigenia* are primitive characteristics that link various animals in the group known as ecdysozoa, which includes the ancestor of arthropods, tardigrades (water bears), lobopodians (which includes the velvet worms), and priapid worms. This conclusion might be premature because the details of *Hallucigenia*'s teeth are not resolved (assuming they are teeth) and cannot be easily compared with the teeth of those other groups. Also, convergence among these groups is also plausible. Most soft-bodied animals would need some type of hard "teeth", and these teeth, even if evolved independently, would certainly be near the mouth.

Sources:

Ma, X.
"Hallucigenia's head."
Nature 2015, 523, 38-39.

Smith, M.R.; Caron, J.-B.
"Hallucigenia's head and the pharyngeal armature of early ecdysozoans."
Nature 2015, 523, 75-79.

Collinsium: Hallucigenia's Spikier Cousin

Bob Sheridan, July 25, 2015

A few weeks ago I wrote story about a new description of *Hallucigenia*. *Hallucigenia* is a small (up to 15 mm long) soft-bodied animal from the Burgess Shale (~500 Myr). Its body appears to be a long tube with seven pairs of flexible "tentacles" on one side and seven pairs of somewhat longer rigid "spikes" on the other. *Hallucigenia* has undergone several reinterpretations. The latest is that it is an early version of today's velvet worm (onychophorans). Given that model, the tentacles are "feet" and that the spikes point up. Very recently Smith and Caron (2015) described more complete specimens, so we now know what the "head" and "tail" of *Hallucigenia* look like.

I was not aware that there were many fossils in the same family as *Hallucigenia* until I came across the recent article by Yang et al. (2015) describing *Collinsium cilosium* ("hairy [monster] of [Desmond] Collins"). Specimens are from the Early Cambrian Xiaoshiba Lagerstätte, which is the Chinese equivalent to the Burgess Shale. There are enough specimens that *Collinsium* is known completely.

As with *Hallucigenia*, the body of *Collinsium* is a long tube (but much larger--up to 85 mm). The tube is somewhat thicker overall and it tapers toward the front. There are 15 pairs of appendages below, i.e. "feet". Unlike in *Hallucigenia*, the appendages seem to vary in shape. The 9 rearmost pairs appear to be walking legs with a terminal claw. The front most pairs are long, tendril-like, and are covered in some kind of long bristles (hence "hairy" in the name). The head seems to have some kind of short antennae (like modern velvet worms). Having bristles might imply a lifestyle of filter-feeding. Whereas *Hallucigenia* has 7 pairs of spines, *Collinsium* has 15 sets of three spines each, with the center spine being the longest. This gives *Collinsium* a very spiky appearance. It is not clear what kind of predator *Collinsium* was trying to ward off, but the function of the spikes seems to be protection.



The authors do a phylogenetic analysis that includes several dozen paleozoic lobopodians. These are worm-like animals with stubby legs, of which the onychophorans are a member. Other members are tardigrades (which include modern "waterbears") proto-arthropods. *Collinsium* groups with other "monster" specimens named by Desmond Collins and two other partially known fossil lobopodians, and of course, *Hallucigenia*.



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Spiky Cont'd

Looking more closely at the anatomy of about a dozen fossil onychophorans (most of which are incompletely known), we see that there are three groups. One called the "stem-group Onychophora", includes *Hallucigenia* and many other species. What groups these together is that all feet are similar. The second group, which is called the *Luolishaniidae*, includes *Collinsium*. Their major characteristic is having different types of feet, and having many more spikes. The third group consists of "crown-group Onychophorans", which include all the extant velvet worms. These have uniform feet and no armor whatever. Clearly, the Cambrian onychophorans were much more diverse than the modern ones.

Sources:

Smith, M.R.; Caron, J.-B.
"Hallucigenia's head and the pharyngeal armature of early ecdysozoans."
Nature 2015, 523, 75-79.

Yang, J.; Ortega-Henrandez; Gerber, S.; Butterfield, N.J.; Hou, J.-B.; Lan, T.; Zhang, X.-G.
"A superarmored lobopodian from the Cambrian of China and early disparity in the evolution of onychophora."
Proc. Natl. Acad. Sci. USA. 2015, 112, 8678-8683.

Color Patterns of Fossil Shells, Part 2

Bob Sheridan, June 27, 2015

In April I wrote a story concerning the work of Hendricks et al. (2015). These workers used UV light to bring out the color patterns of fossil cone shells from the Dominican Republic. It has been known for some time that, although fossil shells appear white in visible light, residual pigments in the shells fluoresce under UV light. One can get a good approximation of the color pattern in the living shell by "inverting" (dark becomes light, green becomes red, etc.) a photograph of the fluorescing shell with a photo editor. It is usually necessary to soak the shells in bleach beforehand to get the maximum fluorescence. Based on the color patterns in the fossils, one can assign some of the fossil cone

shells to known modern species. However, a dozen or so species appeared to be previously unknown.

The shells studied by Hendricks et al. were 4-6 million years old. Caze et al. extend this work by examining fossil shells from the Cordebugle Konservat Lagerstätte in France. These are dated from the Jurassic (157 Myr.) This is the first attempt to apply this technique to fossil shells from the Mesozoic. Previously, the oldest studied specimens were from the Paleocene.

This study looked at 575 specimens from 28 species of gastropods and 18 species of bivalves. The specimens were in a collection at the Natural History Museum at Paris and at Sorbonne University. Certain specimens were excluded from the study because they were preserved with glue to keep them from falling apart, and bleaching them would hurt their preservation.

Of the 46 species, 14 out of 28 of the gastropods and 11 out of 18 of the bivalves showed color patterns. Most of the paper is a technical description of the color patterns in each species. There are basically 6 different color patterns in the gastropods and 3 in the bivalves. Many of these are common among living molluscs. The authors note that some species fluoresce in red, and some in yellow. In this collection the red fluorescent shells tend to belong to the Vetigastropoda, which is a subclass of marine snails. The Neritimorpha, another class of gastropods display no fluorescence, but commonly preserve pigment under visible light. Thus these characteristics might be used to diagnose new gastropod species whose class membership might be hard to assign.

Sources:

Caze, B.; Merle, D.; Schneider, S.
"UV light reveals the diversity of Jurassic shell color patterns: Examples from the Cordebugle Lagerstätte (Calvados France)."
PLoS ONE, 2015, OI:10.1371/journal.pone.0126745.

Hendricks, J.R.
"Glowing seashells: diversity of fossilized coloration patterns on coral reef-associated cone snail (gastropoda: conidae) shells from the Neogene of the Dominican Republic."
PLoS ONE, 2015, 10, e0120924

Wendiceratops

Bob Sheridan, July 18, 2015

A month ago I wrote an article about the description of *Regaliceratops* by Brown et al. (2015). *Regaliceratops* is claimed to be a chasmosaurine ceratopsian dinosaur that converged on the horn ornamentation of a centrosaurine ceratopsian. Let me repeat a little of the background information from my previous article to make that statement meaningful. Ceratopsians are quadrupedal ornithiscian horned dinosaurs that lived in the Late Cretaceous. Except for the very primitive types like the sheep-size *Protoceratops*, ceratopsians vary from rhinoceros-size to elephant-size. Most of their specialized characteristics are in their very large heads, which have a sharp beaks, frills, and multiple horns. Ceratopsians overall come in two major groups: chasmosaurines and centrosaurines. Chasmosaurines (named for *Chasmosaurus*, but *Triceratops* is a more popular example) have long forward-pointing brow horns (also called "postorbital horns") and short nose ("nasal") horns. Centrosaurines (named for *Centrosaurus*) have a long nose horn and short or nonexistent brow horns. All ceratopsians also have half a dozen or so bony processes at the edge of the frill (called "episossifications") on each side. Individual episossifications can range from being a tiny knob to being a long spike, depending on the species, and depending on the location on the frill. In chasmosaurines, all the episossifications tend to be small. In centrosaurines, the episossifications toward the top of the frill tend to be large.

One aspect of *Regaliceratops* ("royal reptile"), unusual for a chasmosaurine, is that all the episossifications around the frill are large and triangular, making the frill resemble a crown, hence the name. Today's story also involves unusual frill ornamentation in a ceratopsian, this time in new dinosaur *Wendiceratops pinhornensis*. Evans et al. (2015) describe *Wendiceratops* based on 200 bones from a monospecific bonebed in the Oldman Formation of Alberta. The formation is from a time (78-79 Myr.) when ceratopsians were just beginning to appear in North America; not many species are known from that era. *Wendiceratops* is named after Wendy Sloboda, who discovered the bonebed.



Wendy Sloboda said she's been looking for dinosaur fossils since she was a child.

Wendiceratops is still incompletely known. There are miscellaneous ribs, vertebrae, and parts of the arms, and hip. From the skull we have the complete frill, the cheeks, part of the nose, and the beak. Even so, there is enough to tell that *Wendiceratops* is a chasmosaurine. Interestingly, the most similar previous known ceratopsian is *Sinoceratops*, which is from China and lived later. The nasal horn of *Wendiceratops* is broken off and what is left is short, but the authors infer a "large upright" nasal horn as would be expected for a centrosaurine (and as seen in *Sinoceratops*), although the restoration of *Wendiceratops* in Evans et al. shows a nasal horn much shorter than in *Sinoceratops*. If one accepts that *Wendiceratops* has a substantial nasal horn, the fact that *Wendiceratops* and *Sinoceratops* are not in the same sub-group as other long-nose-horned centrosaurines like *Centrosaurus*, and the fact that some ceratopsians related to *Wendiceratops* do not have nasal horns, this would mean that long nose horns evolved independently in different centrosaurines. Also, given its age, *Wendiceratops* would be the first ceratopsian to show a nasal horn. The restoration of *Wendiceratops* also shows long brow horns. This seems unexpected; there is no evidence for such, since that portion of the skull is not preserved.

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Wendy Cont'd



However, the entire outside of the frill of *Wendiceratops* is preserved and we can say something definite about the ossifications. The three pairs of ossifications at the top of the frill are large and point forward, much like those in *Centrosaurus*. Those further to the side are shorter and point more backward. This is an arrangement seen in no other ceratopsid.

Sources:

Brown, C.M.; Henderson, D.M.

"A new horned dinosaur reveals convergent evolution in cranial ornamentation in ceratopsidae." *Current Biology* 2015, 25, 1-8.

Evans, D.C.; Ryan, M.J.

"Cranial anatomy of *Wendiceratops pinhornensis* gen. et sp. nov., a centrosaurine ceratopsid (Dinosauria: Ornithischia) from the Oldman Formation (Campanian), Alberta Canada, and the evolution of ceratopsid nasal ornamentation." *PLoS ONE* DOI:10.1371/journal.pone.0130007.

Pappochelys: the Middle Triassic Stem Turtle

Bob Sheridan July 29, 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.

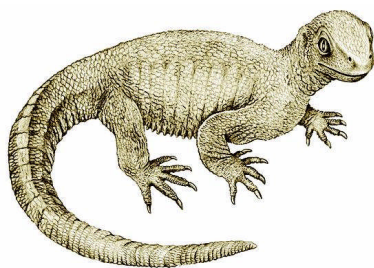
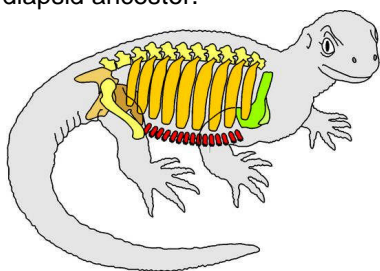
Trying to figure out which type of reptile is ancestral to turtles based on anatomy is very difficult because turtles are very unique among living (and most fossil reptiles). First, they always have a toothless beak. Second, they are covered in a bony box, made of a "carapace" above and a "plastron" 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.

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Stem Turtle Cont'd

This week in Nature Schoch and Sues (2015) describe a new turtle *Pappochelys* ("grandfather turtle"). *Pappochelys* is from the Middle Triassic 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:

Schoch, R.; Sues, H.-D.

"A middle Triassic stem-turtle and the evolution of the turtle body plan."

Nature 2015, 523, 584-587.

Tetrapodophis: The Snake with Four Legs

Bob Sheridan August 8, 2015

It has been a while since I saw an article on the origin of snakes. Snakes have a number of unique features relative to most reptiles. They have a very large number of vertebrae (>150), no limbs, no external ears, and a jaw (with hooked teeth) that is essentially unhinged from the rest of the skull. It is very likely that the ancestor of modern snakes was a lizard, but which lizard is not clear. It should also be noted that long-bodied legless lizards, which are distinct from snakes in having eyelids and hinged jaws, evolved several times.

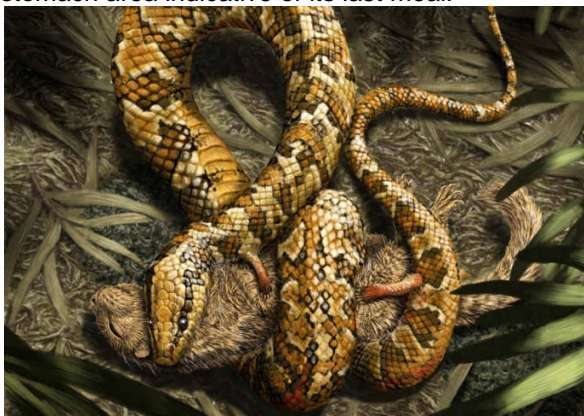
Many fossils snakes have been identified, the oldest of which is from the Middle Cretaceous. Some have vestigial hindlimbs. One classical idea about the origin of snakes (specifically about how they ended up limbless) is that their ancestors were marine reptiles, similar to mosasaurs, if not mosasaurs themselves. They supposedly lost their limbs to become better swimmers. Another idea is that snakes are limbless because their ancestors were borrowing land-dwelling lizards, and it is better not to have limbs when crawling through tunnels. Fossil snakes with vestigial hindlimbs have been found in both marine and lake deposits, so we cannot use the "primitive" characteristic of having partial limbs as a way of guessing snake origins. Even assuming a marine origin, we can probably eliminate mosasaurs themselves as snake ancestors since snakes are not genetically related to today's varanid lizards, of which mosasaurs are members.

If the ancestors of snakes are lizards, we would expect to eventually find a snake with all four limbs, and such an animal is recently described by Martill et al. (2015). The species *Tetrapodophis amplexus* ("four-footed snake") is based on a single, very well preserved specimen presumably from the Crato Formation in Brazil, which is Early Cretaceous in age. The matrix in which it is found is limestone, probably from a lake bottom since it contains the coprolites of a specific fish. This specimen would have been less than a foot long in life. The specimen is disposed with a tightly curled neck and tail, and a gently curved body; obviously it would have been flexible in life.

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4 Legs Cont'd

Tetrapodophis is an extremely modern looking snake in many aspects. First it is extremely elongated with 250+ vertebrae. It has a curved lower jaw with small hooked teeth, and an intramandibular joint, allowing each side of the jaw to move independently. This is indicative of carnivory. Indeed it seems to have some bones in its stomach area indicative of its last meal.



Tetrapodophis has features expected for borrowing (as opposed to swimming snakes), including a long head but a short face, plus a cylindrical (as opposed to a flat) tail. On the other hand, in Tetrapodophis one can distinguish the cervical, dorsal, and caudal vertebrae, based on the presence and length of ribs, whereas those regions are hard to tell apart in modern snakes. The positions of the fore and hindlimbs in Tetrapodophis are consistent with where those regions begin and end, as we would expect.

The most interesting aspect of Tetrapodophis is its limbs. Each is complete from humerus/femur to toes. To me the bones look not at all like those of a lizard limb, but a creepy shortened caricature of the human arm, with parallel fingers and toes. The limbs are very tiny compared to the length of the body, only a few millimeters long, so it is unlikely they were used for locomotion. The authors feel the limbs could have been used for hooking or grasping prey or mates, or perhaps climbing.



The authors point out that since Tetrapodophis is from Brazil, this reinforces the idea that snakes originated in Gondwanaland (the southern continent in Cretaceous times), plus being from a lake deposit suggests a terrestrial origin.

After the paper was published in *Science*, Tetrapodophis became a matter of controversy. The specimen is now on permanent loan to the Museum Solnhofen museum in Germany, but before that it was in a private collection for several decades. There are no records about where or when it was collected. The authors assign it to the Crato Formation based on the characters of the rock in which it was found. However, it is possible that the true origin is not the Crato Formation, so conclusions based on its presumed age and location could be wrong. Also, it has been illegal to export fossil or archaeological material from Brazil since 1942, so it is possible that Tetrapodophis was exported illegally. At present that is not known.

Sources:

Evans, S.
"Four legs too many?"
Science 2015, 349, 374-375.

Martill, D.M.; Tischlinger, H.; Longrich, N.R.
"A four-legged snake from the Early Cretaceous of Gondwana."
Science 2015, 349, 416-419.

The Gut Contents of Rhamphorhynchus

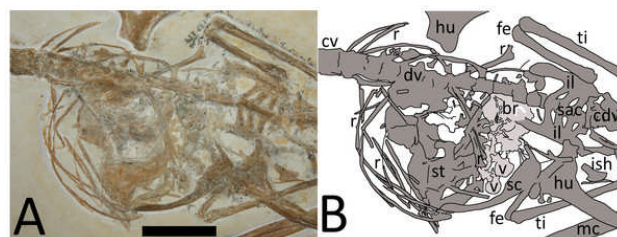
Bob Sheridan September 18, 2015

The Jurassic pterosaur Rhamphorhynchus was first described in 1825. It is the genus for which the rhamphorhynchoid pterosaurs are named: these generally have large toothed heads, short necks, and a long tail with a diamond-shaped vane at the end. Although Rhamphorhynchus has been found in other European countries and Africa, the best specimens are from Solnhofen limestone; these often show impressions of the wing membrane. Over the years time a large number of species of Rhamphorhynchus of various sizes had been named based on over 100 specimens. However, it was suggested in 1995 that these were all the growth stages of a single species Rhamphorhynchus musteri. An adult Rhamphorhynchus would have a wingspan of 1.2-1.5 meters.

One might suspect from the forward-facing spike-like teeth of Rhamphorhynchus that fish were the likely prey. However, despite having been studied for over 100 years, the diet of most pterosaurs has not been definitively established. The major reason for this is that preserved gut contents in pterosaurs is extremely rare. However, a few specimens of Rhamphorhynchus with gut contents consistent with a fish diet have been described. There is a spectacular specimen from 2012 where a Rhamphorhynchus appears caught in the jaws of the fish *Aspidorhynchus*, and another fish *Leptolepides* is visible in the throat of the Rhamphorhynchus. If nothing else, this indicates Rhamphorhynchus spent time over water and did eat fish at least part of the time.



A recent paper by Hone et al. (2015) describes an additional specimen of Rhamphorhynchus where there are well-preserved soft tissue and gut contents. This particular specimen TMP 2008.41.001 was collected in 1965 and was in private hands until 2008, when it was bought by the Royal Tyrrell Museum. The specimen is complete and articulated. It would have had a wingspan of about a meter. Based on the size and the state of fusion of its bones, it represents a young adult. One can see the outline of the wings and tail vane, see fibrils in some parts of the membrane, and can see the keratin sheaths of a few of the foot and hand claws. The important findings in this specimen involve gut contents. There is accumulation of material in the abdomen where the stomach would be expected to be. The authors note that some of this material is made of "squat cylinders", although not much more can be discerned since calcite deposited in the specimen during fossilization disturbed the original material. Additionally there is a "coprolite" a few centimeters long posterior to the sacrum, the first coprolite observed in a pterosaur. Again, calcite has disrupted some of the original material, but the coprolite consists of small (<0.5 mm) hooks and spikes.



The gut contents of this specimen appear hard to identify. The authors suggest a few possibilities for the stomach contents: fish vertebrae, frog vertebrae, or ankle bones of baby crocodiles. One possibility for the coprolite is that it is made of hooks from the tentacles of small squid, but the authors also suggest spines of sea urchins or spicules from sponges as possibilities. One optimistic interpretation is that, since the gut contents cannot be definitively assigned as parts of fish, this indicates that Rhamphorhynchus had a wider diet than had originally been suspected.

Sources:

Hone, D.; Henderson, D.M.; Therrien, F.; Habib, M.B.

"A specimen of Rhamphorhynchus with soft tissue preservation, stomach contents, and a putative coprolite."

[PeerJ 2015, DOI 10.7717/perj.1191](https://doi.org/10.7717/perj.1191)