

My name is Jack L. Conrad and I published a paper in PLOS ONE about my discovery of a new fossil *Babibasiliscus*, which is the earliest known species of casquehead, also known as “Jesus lizard” – Ask Me Anything!

PLOSScienceWednesday¹ and r/Science AMAs¹

¹Affiliation not available

April 17, 2023

Abstract

Hi Reddit, My name is Jack L. Conrad and I am an Assistant Professor at NYIT College of Osteopathic Medicine and a Research Associate at the American Museum of Natural History (AMNH). My research focuses on the evolution, morphology, and paleontology of modern and living snakes, amphisbaenians, mosasaurs, and other ‘lizards’ (Squamata). Squamates first appeared around 245 million years ago, have a good fossil record for the last 155 million years, and today include more than 9700 living species; that’s alotta Squamata! One of the most difficult problems in understanding squamate evolution is snake origins. We know that many branches of the lizard family tree lost their limbs – there are limbless geckoes, limbless skinks, limbless cousins to the Komodo Dragon, etc. – but we don’t know from which branch of the lizard family tree snakes come. It’s really become quite a headache, but also a fun area for investigation. Studying this problem, and other areas of squamate evolution, leads scientists like myself to understanding other natural science questions and phenomena, including (but certainly not limited to): What was Earth like at various times in the past? Are there physical constraints on how big a lizard can be on land? In the seas? How did lizards move across the planet as they evolved over time? I recently published a study titled “A new Eocene casquehead lizard (*Reptliia*, *Corytophanidae*) from North America” in PLOS ONE. This study described the earliest known species of casquehead, or Jesus lizard, known. Importantly, this animal lived in Wyoming when the planet was much warmer than it is now and because its modern relatives live only in the tropics, it raises questions about what might happen if our planet warmed up a few degrees. I will be answering your questions at 1pm ET. Ask Me Anything! I love everything about reptiles and evolution. I may not have all of your answers, but I will certainly enjoy talking with you about all of your questions! Don’t forget to follow me on Twitter @amoskius.

[REDDIT](#)

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ABSTRACT

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I recently published a study titled "[A new Eocene casquehead lizard \(Reptilia, Corytophanidae\) from North America](#)" in [PLOS ONE](#). This study described the earliest known species of casquehead, or Jesus lizard, known. Importantly, this animal lived in Wyoming when the planet was much warmer than it is now and because its modern relatives live only in the tropics, it raises questions about what might happen if our planet warmed up a few degrees.

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CORRESPONDENCE:

DATE RECEIVED:
December 31, 2015

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Hi!

I babysat a friend's garter snake for a year or so. He seemed to like his chin stroked, and responded with finger cuddles. I didn't think snakes were like that until I read that garter snakes had evolved their cuddly behaviour in cold climates to keep each other warm.

What's the most surprising non-traditional-reptile-behaviour thing you've learned in your work?

[logicalmaniak](#)

Wow! Excellent question... Am I limited to one answer? Can I break it down into categories? Truly most

PLOSScienceWednesday , r/Science , PLOS Science Wednesday: Hi Reddit, my name is Jack L. Conrad and I published a paper in PLOS ONE about my discovery of a new fossil Babibasiliscus, which is the earliest known species of casquehead, al, *The Winnower* 2:e145147.79006 , 2015 , DOI: [10.15200/winn.145147.79006](https://doi.org/10.15200/winn.145147.79006)

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surprising: *Moloch horridus*, the Thorny Devil of Australia, has forelimb, neck, and head scales that are specialized to soak up moisture and draw it over the head to dribble into the mouth. The behavior part of this is that *Moloch horridus* often puts its forelimbs into soggy sand to prime this system. It can get a drink without pool of water!

Most nurturing: Some pythons generate body heat to warm their eggs by "shivering" as they coil around them.

Cutest: Many captive monitor lizards (Varanidae, the Komodo Dragons and their relatives) like to have sponge baths and will nuzzle when they expect one.

Most surprising the I've witnessed myself: I saw an arboreal snake notice a plane at cruising altitude once. It watched it cross the sky.

Hi!

Thanks for your time here. I have always been fascinated with how snakes stemmed off the evolutionary backbone to become who they are today. What is the specific advantage a loss of limbs provides to a species over time? It seems like the adaptation doesn't provide them any habitat advantage since lizards and the like can be found in almost the same environments. Also, is there any conjecture on where their fangs were derived from? To my knowledge, there aren't any other reptiles alive today with fangs. Is their presence the pivot that allowed for so many snakes to be venomous but so few (one?) lizards?

Thanks!

[shaqpak238](#)

Great questions! Thank you! Becoming limbless or limb-reduced is excellent for moving through a small burrow or tunnel. It also allows an animal to use "head-first burrowing." One of the major ideas about how snakes became limbless is that they went through a "fossorial" (burrowing) or semi-fossorial stage. In this scenario, the ancestral snake was a head-first burrower that braced its body and then pushed its head through the substrate (soil, mud, leaf-litter, or something similar). Unlike mammalian burrowers such as moles, the animal used its head rather than its limbs to push its way forward. This allowed the animal to make a smaller burrow for its size. Many squamates (snakes, amphisbaenians, and other 'lizards') are head-first burrowers, and most of these are very limb-reduced (see, for example, https://en.wikipedia.org/wiki/Western_three-toed_skink and https://en.wikipedia.org/wiki/Mexican_mole_lizard) or limbless (see <https://en.wikipedia.org/wiki/Acontias>, https://en.wikipedia.org/wiki/Common_scaly-foot, <https://en.wikipedia.org/wiki/Anelytropsis>). As you may know, there are many branches on the squamate family tree that have produced limbless members--snakes are just the most conspicuous (and most successful) group of limbless squamates. Of course, not all modern snakes are burrowing, but the loss of limbs has not prevented them from living on the ground, in the ocean, in trees, or even gliding (<https://www.youtube.com/user/SochaLab/playlists>).

A competing hypothesis suggests that fossil marine lizards like *Dolichosaurus* may have been close to the ancestor of snakes. *Dolichosaurus*, *Adriosaurus*, and some related forms were very long, slender, lizards with small limbs that may have used small crevices in reefs or rocky shores as hunting or hiding places (see Caldwell, M.W. 2000. *Journal of Vertebrate Paleontology* 20: 720-735.).

Snake fangs are highly modified back teeth that are used to deliver venom. The ancestral fang may have looked a little like the tooth of a modern Gila Monster or Beaded Lizard (*Heloderma* (<https://en.wikipedia.org/wiki/Heloderma>)). *Heloderma* use tooth grooves to channel modified, toxic, saliva into wounds cut by their sharp teeth. Venomous snakes typically have a set of back teeth in the upper jaw (the maxilla) that are longer than the teeth around them. In some cases these teeth have

grooves similar to those of *Heloderma*, but in other cases the tooth has completely grown around the groove to form a closed tubular fang. This is common in cobras and their relatives (Elapidae) and in rattlesnakes and their relatives (Viperidae). Viperids, or vipers, have greatly increased the size of the fang and greatly reduced the size of the maxilla. This means that the maxilla has few contacts and can rotate. The maxilla rotates so that the fang is erect when the snake opens its mouth, but folds back into the mouth when the mouth is closed (see http://digimorph.org/specimens/Bothrops_asper/). Thanks for your questions!

Has there been a render of what the lizard might have looked like? And can you share it with us please.

[No sexy times for me](#)

Unfortunately, no, there's not been a full artistic representation of this animal. I'm sorry. However, I can say this: It is actually closer to *Laemanctus* (<https://en.wikipedia.org/wiki/Laemanctus>) than *Laemanctus* is to *Basiliscus* ([https://en.wikipedia.org/wiki/Basiliscus_\(genus\)](https://en.wikipedia.org/wiki/Basiliscus_(genus))) or *Corytophanes* (<https://en.wikipedia.org/wiki/Corytophanes>)... So when you look at one of those critters, you get a pretty good idea of how *Babibasiliscus* looked.

What made you get into this specific field of science? And how did you first gain an interest in science?

[marinewannabee97](#)

Hi! Thank you for your question. Like many kids, I was interested in paleontology from a very young age. I had exceptional parents (Terry and Sue Conrad) who read to me all the time and nurtured my interest in science. Unlike some people, I never grew out of science. This was also probably helped by the fact that we lived in Hurley, MO (population of about 125 people when I was growing up) and there was lots of nature around, as well as an excellent zoo (Dickerson Park Zoo) about an hour away. I went to grad school thinking I would study dinosaurs, but I found that the modern squamate (snake and 'lizard') diversity was much broader and that the fossil record was great. It allowed me to ask really exciting paleontological questions and questions about evolutionary biology and morphology. I had an excellent advisor in Chicago (Olivier Rieppel) and had a great mentor at the American Museum of Natural History (Mark Norell). I've been hooked on this stuff all my life. Thank you for your question! All the best.

How fascinating that the fossil record may give us insight into how ecologies may shift based on projected climate change! Can you tell us more about how your findings regarding the casquehead lizard can inform us about the implications of increased greenhouse conditions? Resulting insight into biodiversity? Medicine and human health? Many thanks for taking the time to do this AMA!

[p1percub](#)

Hi! Great question! There are many pieces of evidence that have to be viewed together to get a handle on this and I only have some basic ideas right now. Modern diversity is greatest in areas of warm, damp, climates. This is true for all major groups of organisms--from vertebrates, to leeches, to plants, to microparasites. That's one thing. Earth has a long history of warming and cooling trends. When it's really warm, like in the Eocene and Paleocene (66-40 million years ago), we find different distributions of things than when it's really cool (e.g., during the Pleistocene--2.6-0.01 million years ago). Eocene rocks show crocodylians in the Arctic; Eocene rocks see woolly elephantids in Nebraska. That's another thing. Biologists sometimes use ectothermic animals (animals which don't use internal bodily processes to regulate their body temperatures--sometimes they're called "cold-blooded") like amphibians, lizards, snakes, turtles, and crocodylians to detect environmental change. This is because

ectotherms are often more sensitive to such changes than mammals or birds may be. That's another thing.

In the case of our little casquehead group (Corytophanidae, or corytophanids), we see a group that is restricted to the tropics. Now, a Brown Basilisk really doesn't care where the Tropic of Cancer is drawn on the map, she just knows that if it's the right amount of warm and there's plenty of resources, she's happy living there. If Earth heats up a little and it's nice north of the Tropic of Cancer, she might move there. Pretty simple, right?

Now, here's where it gets a little bit interested (scary). Corytophanidae have a range that pretty closely matches some strains of malaria and dengue fever in the Americas. This may mean that the microscopic organisms that cause those diseases in humans may have similar environmental requirements as the corytophanids. When we find a corytophanid (a real one, not a cousin of corytophanids, but a nested member of the group) as far north as Wyoming in the Eocene, when global temperatures were just a few degrees (between 6 and 9 degrees C) warmer than they are today, we must start asking questions about whether that might indicate conditions favorable to dengue (etc.) might expand if our planet experiences a warming trend.

We need more data, but this is something worth our attention. Thanks again!!

Hi Jack! Thanks for doing this AMA! You have mentioned something that I have thought about for a long time: how big can crocs and anacondas get? Everytime I see a new image of a croc it seems to be bigger than the last (probably just my morbid fear of them, but ya know I'd rather be in the loop if they're undergoing some generational growth spurt haha). Is it possible that because of environmental changes caused by humans (such as human caused climate change, ocean acidification) these animals are getting bigger?

Also, how do you identify a limbless lizard? Do they have remnants of limb bones kind of like whales? Is there any way I could tell them apart from a snake by just looking at them? Cheers and a preemptive Happy New Year!

[DERP TURKEY](#)

Thanks so much for your questions! Happy New Year (early). Although, I do not share your fear of our scaly cousins, I think I understand why they might make you nervous... They are so foreign and often move in ways that are strange to us... And some are deadly! There are three major lineages of modern Crocodylia... Each produces at least one species that grows to be about a metric ton (1000kg, 2204lbs). The Saltwater Crocodile (a crocodylid) averages about 4.5 meters (nearly 15ft); the Black Caiman (an alligatorid) averages about 4 meters (nearly 12ft), and the Gharial (a gavialid) averages around 4.5 meters (but it's a lightweight at only around 975 kg, or 2150lbs). Green Anacondas (*Eunectes murinus*) average 5 meters (about 16.5ft) and are the heaviest snakes, with larger specimens reaching over 100kg (220lbs). Reticulated Pythons (which often have a nasty disposition) grow longer and regularly exceed 6 meters (about 20 feet), but are more slender. Global climate change very well may change what is normal for these big reptiles. A few years ago, some of my friends published a paper on the biggest known fossil snake, *Titanoboa* (Head, J.J., J.I. Bloch, A.K. Hastings, J.R. Bourque, E.A. Cadena, F.A. Herrera, P.D. Polly and C.A. Jaramillo. 2009. *Nature* 457: 715-718.), which is now estimated to have exceeded 14.5 meters (more than 47.5 feet--longer than a school bus--it would have been able to eat a cow whole). The main reason it got so big: It lived at a time when the world was warmer. That being said, there's a long-standing 'contest' for anyone who can prove the existence of a living snake over 30ft long. The cash prize has never been claimed. When that (rather sizeable) reward is cashed in, THEN you should start worrying about the snakes. Until then, though, we can continue to worry about shrinking ice caps and rising sea levels. Yay. Thank you for your message!!

Hello Jack! Do you believe that anthropological climate change will impact squamates with thermally-regulated sex determination? *Intelligama Lesueurri* is the species I am most interested in.

[Regis_the_puss](#)

If anthropological climate change is real (and it looks like it is), I think it has great potential to all organisms on the planet. With many species (including your Water Dragon), there may be a tipping point where we don't see any change for awhile, and then suddenly it becomes "too much" and we see a drastic shift. When I say "tipping point," I mean some sort of threshold is crossed. For example, ice is ice at -30 degrees Celsius and -2 degrees Celsius. Heating up the ice by 28 degrees doesn't change much. But, if your ice is -2C and you warm it by 5 degrees, you get water. The same thing may be true of environmental changes. Your Australian Water Dragons may have normal clutches despite some observed environmental changes, but the more things change the more you can expect any organism will be affected. Great question! Thank you!

Why is it called "Jesus Lizard"?

[vtjohnhurt](#)

fum45 is right... I'll elaborate just a touch. Some modern squamates with very long legs (e.g., *Basiliscus*) can use a combination of speed and modified toe scales to run across the surface of the water--thus, Jesus Lizards. There are some accounts of *Laemanctus* and even the more distantly related *Anolis* doing this, but they are less well documented. Note that I don't really know if *Babibasiliscus* could do the whole "walk-on-water" thing, but its close relatives could and that gives us room to speculate. What's really fun, though, is that if you found a complete *Basiliscus* skeleton in the fossil record and there were no living Jesus Lizards today (nor any other lizard that can run on water), it's likely that the idea would never cross our minds. Same with flying fish. And... If there were no modern elephants, what would a paleontologist make of an elephant's skull? :D

Hello and thanks for doing this AMA. I have a simple question for you: how did you find yourself in this specific line of paleontology? Surely there are so many, I always wonder how people find themselves in any niche!

Thank you again!

[DragonFive](#)

Hi DragonFive! Thanks for asking. Please see my answer to marinewannabee97 :D Have a great day!

How did you create those HRXCT images of *Babibasiliscus*? What is the exposure time for something like that? Was the X-ray source an Xray tube or a synchrotron?

[Uncle_Charnia](#)

Great question... With only an "Okay" answer. The American Museum of Natural History has an excellent micro-CT scanner and some really smart people running it. Ana Balcarcel actually helped with the scan along with Morgan Hill and Henry Tobin. As far as I can tell, they're all geniuses. You can learn more about the scanner here: <http://www.amnh.org/our-research/microscopy-and-imaging-facility>
Sorry I cannot help more...

Did snakes evolve from lizards, or has that not been determined?

[Meatchris](#)

Hi! Great question. Snakes are lizards just like whales are mammals and birds are dinosaurs. Snakes, amphisbaenians, mosasaurs, and "lizards" are all part of the Squamata. So, that's the easy part of the question. The more difficult (and possibly not implied question) is: From which group of "lizards" did snakes evolve? That's an easy question. Just about everyone who works on squamates know which group of lizards gave rise to snakes. The problem is that nobody agrees. There are five major groups of "lizards": Iguanomorpha (iguanas, casquehead lizards, anoles, agamas, chameleons, and others), Gekkonomorpha (geckos and snake lizards), Lacertoidea (wall lizards, tegus, and micro-teiids), Scincoidea (skinks), and Anguimorpha (Komodo Dragons, glass-lizards, crocodile lizards, knobby lizards, and relatives). Every group except for Lacertoidea has been suggested as being closely related to snakes. Someone should post a reply and say that snakes are lacertoids. Thank you for your question!

I'm really excited about this! Squamates are awesome, and there's about thirty questions that I can think of, but I'll just ask about Geckos because they're my favorite, and I've never been able to study them.

Have we done any research into the *evolution* of the gecko's claws and climbing ability? Where can I read about gecko evolution specifically?

As far as Hemidactyls are concerned, when did our relationship with them begin? When did they become "House Geckos?"

Is there anything interesting about the evolution of Geckos in particular that you can share? I have about thirty other questions but not knowing really anything about Gecko evolution, I don't even know what to ask.

Thank you, Professor!

[OllieGarkey](#)

Thanks for your enthusiasm! There's a genius of a biologist named Aaron Bauer who has forgotten more about modern geckos than I will ever know. Anything you can get your hands on by him about geckos will be great. I can tell you a couple of things: Geckos are tremendously derived and specialized animals. Many have reduced the bones in their heads to increase the mobility of the skull. Some of the skull bones are so thin that you can read through them. Some geckos (I think Eyelash Geckos) have more teeth than any other reptiles. Most geckos have a single eyelid (the lower) that is fused closed and completely clear and immovable. This year we named a very basal (early, primitive) gekkonomorph from the Gobi Desert (Conrad, J.L. and J.D. Daza. 2015. *Journal of Vertebrate Paleontology* 35: e980891.). You can see a ct scan of its skull here (http://digimorph.org/specimens/AMNH_21444/). The animal shows that geckos became "gecko-like" in their braincases long before they did in their faces (Conrad, J.L. and M.A. Norell. 2006. *Historical Biology* 18: 405-431.). Gecko feet have received a lot of attention, and rightly so. The toe pads have millions of tiny, hair-like protuberances that are muscularly controlled. The geckos control these small extensions in such a way that they can use van der Waals forces (https://en.wikipedia.org/wiki/Van_der_Waals_force) to stick to something as smooth as glass. The toes pads themselves are not "sticky" in that dirt doesn't cling to them and the animal can release at will. I'm sorry, but I don't know how House Geckos became "house geckos." Some organisms (e.g., House Centipedes, Cellar Spiders) are just able to co-exist easily with big, bald, bipedal primates. I

suspect that House Geckos were able to do that long before there were proper houses... Thanks for your question! Sorry if I didn't give you a satisfactory answer...

A quick mosasaurus moment: holes in ammonites being caused by a mosasaurus jaws always seemed far fetched. Would not their jaw be super powerful and perhaps nearly unable to gently grip with its mouth? A shell boring baculite type rasp-tounge dude seems more likely. I did a short st in at the Royal Tyrell Museum and always disliked telling folks this.

[the_cheeky_monkey](#)

Nice! Yes, I agree with you about the mosasaur "bite holes" in the ammonites. Some of them are probably legitimate mosasaur bites, but I think if, say, *Prognathodon* wanted to crush an ammonite, it could. On the other hand, ammonites probably WERE on the menu. Look at the crushing teeth of *Globidens*! <https://en.wikipedia.org/wiki/Globidens> Thanks for your question!

Hello what is your favorite fact or maybe particular trait of the snakes, amphisbaenians, mosasaurs, or Squamata?

[tdexor](#)

Wow! Thanks for asking! Can I have a couple? Please? I am fascinated by the size range... *Sphaerodactylus ariasae*, *Sphaerodactylus parthenopion*, and *Brookesia micra* are the smallest amniotes (Amniota = Reptilia including birds, and Mammalia) and could sit on an American dime, but the largest known squamate (*Mosasaurus hoffmanni*) was larger than a school bus (topping out at around 15m or 50ft) and weight about 100 million times as much as *Sphaerodactylus ariasae*.

The coolest morphological thing about squamates is that one of the characteristics that separates them from tuataras (their nearest living relatives--<https://en.wikipedia.org/wiki/Tuatara>) is that the males have two intromittent organs (hemipenes--that word is intentionally jargon for those of you reading this with kids) and the females have to complimentary structures (hemiclitores).

The coolest behavior for me (in this moment) is that many snakes eat things bigger than their heads and swallow them whole. That's pretty basic, but you try to do it!

Thanks!

I have always had a mental concept in my head regarding the cognitive abilities of various organisms. Insects being more like organic machines, simple if-then reactions to outside stimuli and such, no ability to learn, and mammals having all that + what reptiles have with a higher layer of thought and emotion running on top, with the ability to modify behavior as needed, and reptiles somewhere in the middle, with very basic behavior that is largely reactions to stimuli, with a layer of more complex innate behaviors, but incapable of emotion or self-modification of behavior as mammals are.

In your opinion is this highly simplified notion applicable? Or is it seriously flawed ?

[Duliticolaparadoxa](#)

This is a really great question and I don't know if there's a definitive answer. Ten years ago, I would have said that they are like organic machines, but now I think you have to look at it on a case-by-case basis for different species. I don't really think any of them are as simplistic as the far end of the spectrum you described. A few years ago, I became aware of the fact that some Komodo Dragons (*Varanus komodoensis*) can learn their names and respond to simple commands (in captivity, of

course). That really surprised me. Komodo Dragons are pretty intelligent as far as lizards go, though, and I thought this might be exceptional. I also kind of chalked it up to the fact that macro-predators (e.g., lions, wolves, hawks, etc.) are usually 'smarter' than many other animals (e.g., cows, turkeys). Recently, though, I met a captive Rhino Iguana (*Cyclura*) that comes when called, recognizes people, and likes to have his chin rubbed. Reptiles lack a part of the brain present in mammals called the neocortex. The neocortex is closely associated with complicated, learned, behaviors in mammals. One might suggest, based on that absence, that reptiles would be incapable of similar behaviors, but we know that African Grey Parrots and Ravens have significant ability to learn and remember contextually. This is not a great answer to your question... I am still surprised by reptile behavior, especially when reptiles do something complex and learned, but I'm no longer incredulous. I don't see the reptile brain as a control center in a simple machine... Does that help? Thanks for the question!

Do you have a picture of the lizard?

[doubleapowpow](#)

Yes! You should download the paper for free from *PLOS ONE*! :)

<http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0127900>

that's alotta Squamata

You couldnt resist could you?

[SeniorSaggyScrotum](#)

I never have before...

Well, I'm not much of a paleontologist, so how do you do your work and go about announcing your findings. Lets do this in a case example: You have found a post-atomic age human finger bone wedged in between the teeth of a predatory dinosaur. Your tests are conclusive that the dinosaur is prehistoric and the human is 'modern'. What are those tests and how do you go about telling the planet of this crazy finding?

Also, what is your favorite beer?

[UCLANeedAProgrammer](#)

I'm the only paleontologist I know who doesn't drink alcohol... It's all sodas and water for me.

Your question is a good one... I have no answer and I'm out of time.

"We know that many branches of the lizard family tree lost their limbs -- there are limbless geckoes, limbless skinks, limbless cousins to the Komodo Dragon, etc. -- but we don't know from which branch of the lizard family tree snakes come. "

Has anyone used DNA analysis to try to provide some useful information here?

[ZuluCharlieRider](#)

Yes. The best hypothesis right now (based on DNA and morphology) is that snakes are related to Anguimorpha (incl. Komodo Dragons) and Iguanomorpha (including casquehead lizards and

chameleons). See: Reeder, T.W., T.M. Townsend, D.G. Mulcahy, B.P. Noonan, P.L. Wood, Jr., J.W. Sites, Jr. and J.J. Wiens. 2015. Integrated analyses resolve conflicts over squamate reptile phylogeny and reveal unexpected placements of fossil taxa. Public Library of Science [PLoS] One 2015: 1-22. Or (for a morphology-only counter argument, see this old chestnut Conrad, J.L. 2008. Phylogeny and systematics of Squamata (Reptilia) based on morphology. Bulletin of the American Museum of Natural History. 310: 1-182.)