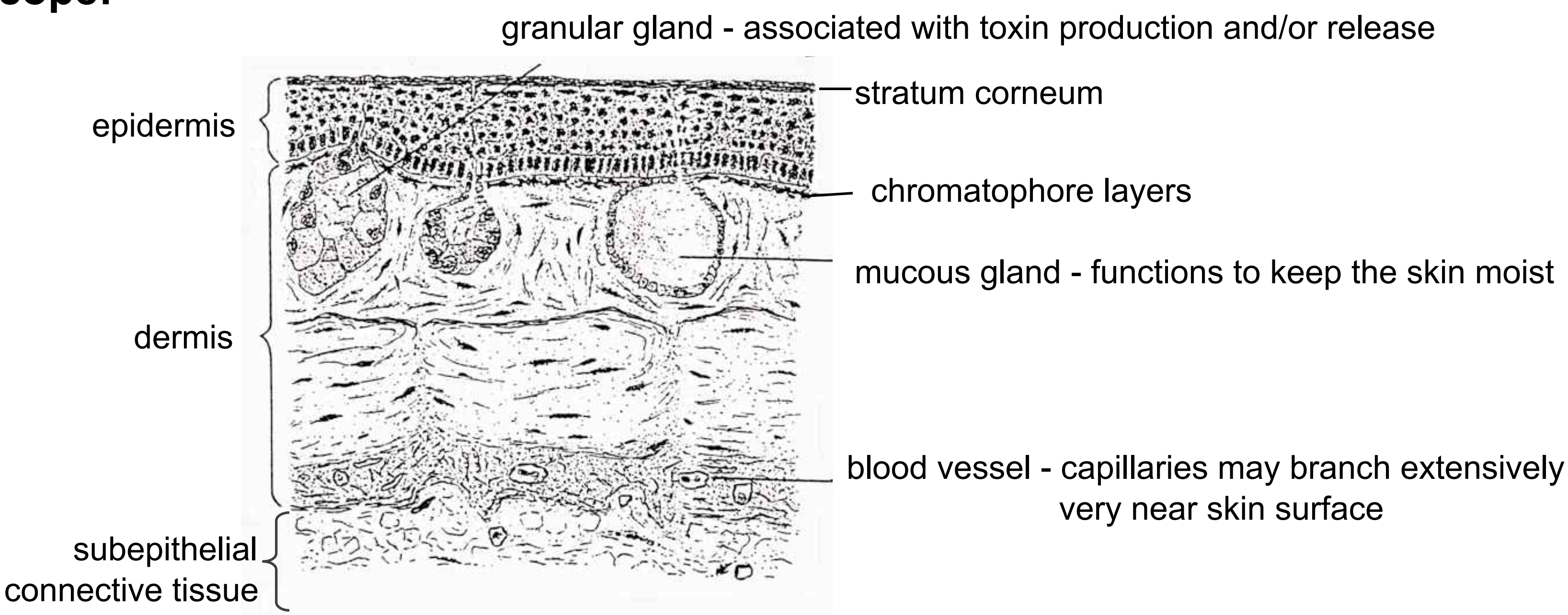
Classification of the Major Taxa of Amphibia and Reptilia

	examples
Phylum Chordata	
Subphylum Vertebrata	
Class Amphibia	
Subclass Labyrinthodontia	extinct earliest land vertebrates
Subclass Lepospondyli	extinct forms of the late Paleozoic
Subclass Lissamphibia	modern amphibians
Order Urodela	newts and salamanders
Order Anura	frogs and toads
Order Gymnophiona	caecilians
Class Reptilia	
Subclass Anapsida	
Order Captorhinomorpha	extinct stem reptiles
Order Testudina (Chelonia)	turtles
Subclass Synapsida	
Order Pelycosauria	primitive mammal-like reptiles
Order Therapsida	advanced mammal-like reptiles
Subclass Lepidosaura	
Order Eosuchia	early lepidosaurs
Order Squamata	lizards, snakes, amphisbaenians, and the tuatara
Subclass Archosauria	
Order Thecodontia	extinct ancestors of dinosaurs, birds, etc
Order Pterosauria	extinct flying reptiles
Order Saurischia	dinosaurs with pubis extending anteriorly
Order Ornithischia	dinosaurs with pubis rotated posteriorly
Order Crocodilia	crocodiles and alligators
Subclass Euryapsida	extinct marine reptiles

AMPHIBIAN SKIN

Most amphibians (*amphi* = double, *bios* = life) have a complex life history that often includes aquatic and terrestrial forms. All amphibians have bare skin - lacking scales, feathers, or hair -that is used for exchange of water, ions and gases. Both water and gases pass readily through amphibian skin. Cutaneous respiration depends on moisture, so most frogs and salamanders are restricted to moderately moist micro-habitats. However, there are several frog species that have successfully invaded arid habitats. Cutaneous respiration is made more efficient by thinning of the epidermis over the superficial cutaneous capillaries.

Many amphibians have glands on the skin that release toxins. There are some local newts (a kind of salamander) that produce tetrodototoxin in sufficient strengths to kill 25,000 white mice per newt! The toxins released from the tropical frogs of the genus *Phyllobates* are used for poison darts. **Look at the slide of a cross-section of amphibian skin under the microscope!**



Evolution of Amphibians and Reptiles

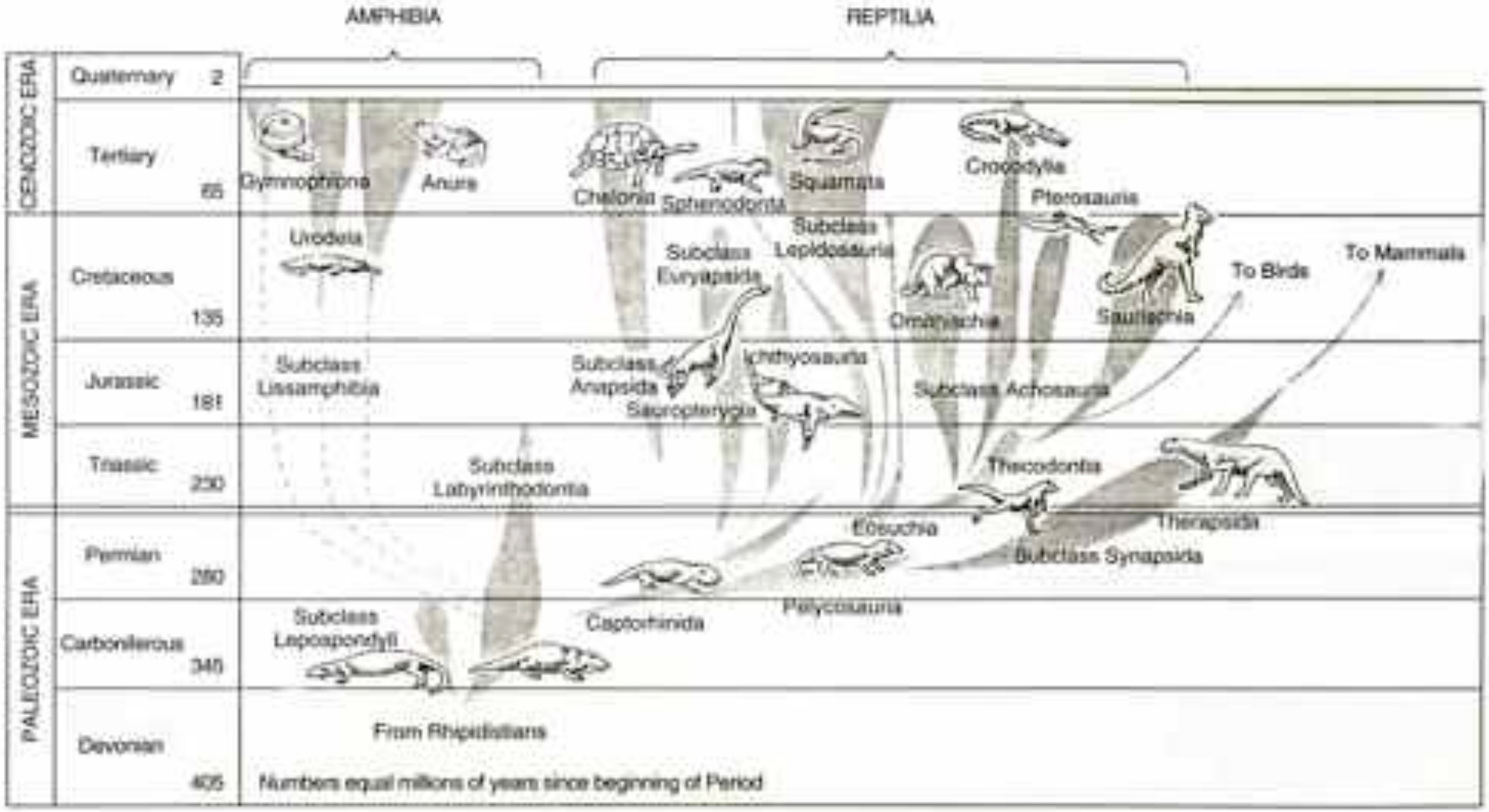
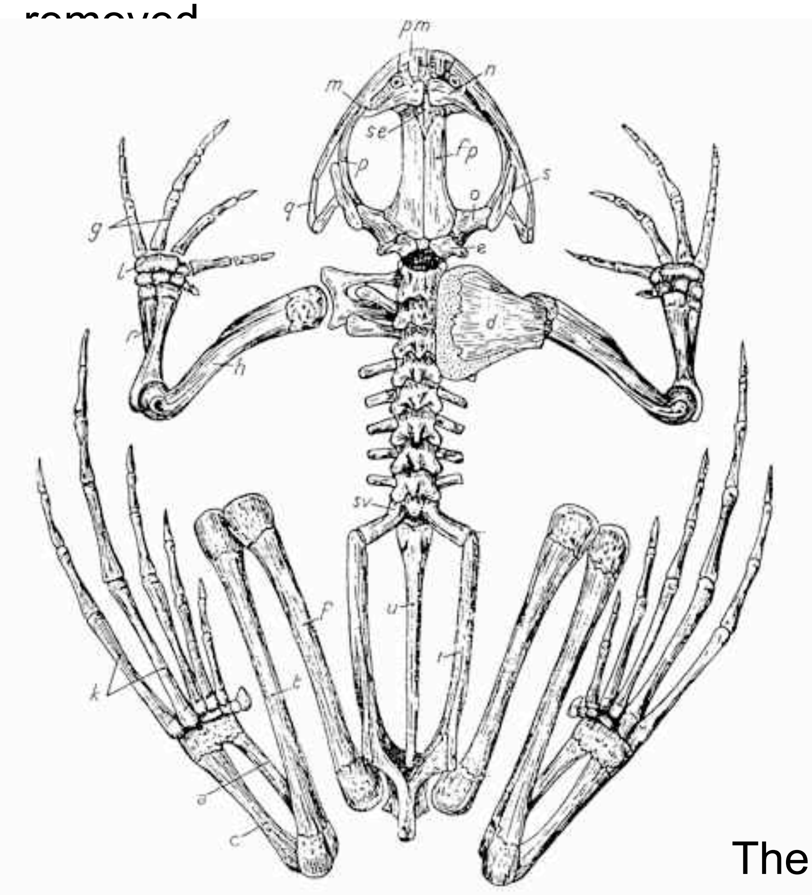


FIGURE 3-17 The evolutionary history of amphibians and reptiles, their distribution in time, and relative abundance.

AMPHIBIAN SKELETONS

Skeleton of a frog, seen from the dorsal surface with the left suprascapular and scapular removed

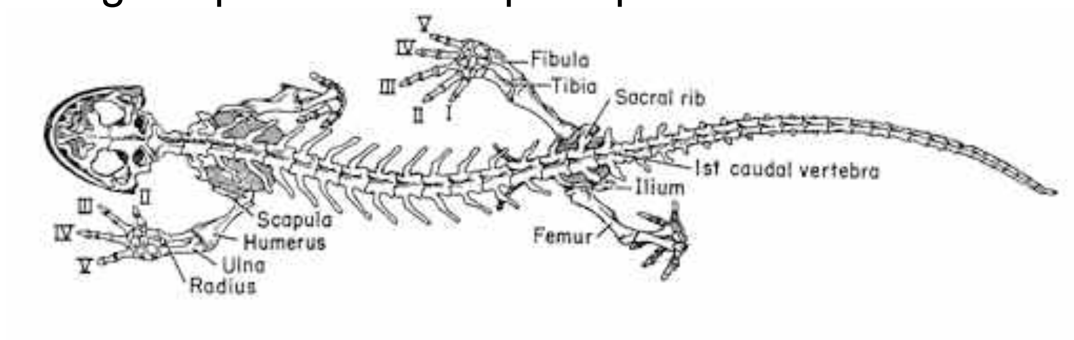


a astragalus
c calcaneum
d suprascapular
e exoccipital
f femur
fp frontoparietal
g metacarpals
h humerus

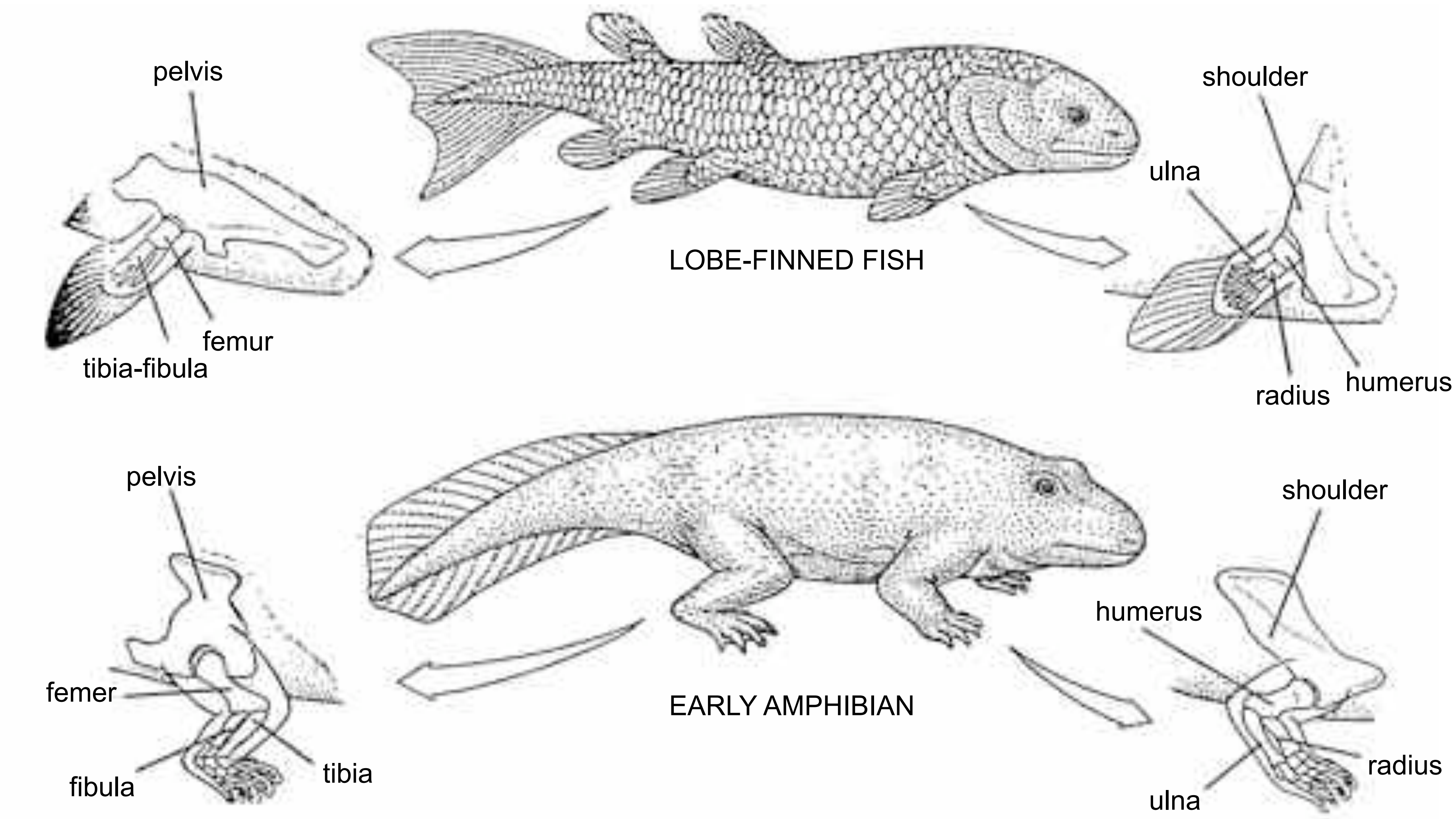
i ilium
k metatarsals
l carpus
m maxilla
n nasal
o prootic
p pterygoid
pm premaxilla

q quadratojugal
r radio-ulna
s squamosal
se sphenethmoid
sv sacral vertebrae
t tibio-fibula
u urostyle (coccyx)

The skeleton of a salamander, seen from the dorsal surface, emphasizing adaptations for a quadripedal locomotion.



AMPHIBIAN EVOLUTION



Reconstruction of *Ichthyostega*, one of the first amphibians with efficient limbs for crawling on land, an improved olfactory sense associated with a lengthened snout, and a relatively advanced ear structure for picking up airborne sounds. Despite these features, *Ichthyostega*, which lived about 350 million years ago, was still quite fishlike in overall appearance and represents a very early amphibian.

CLASS: REPTILIA

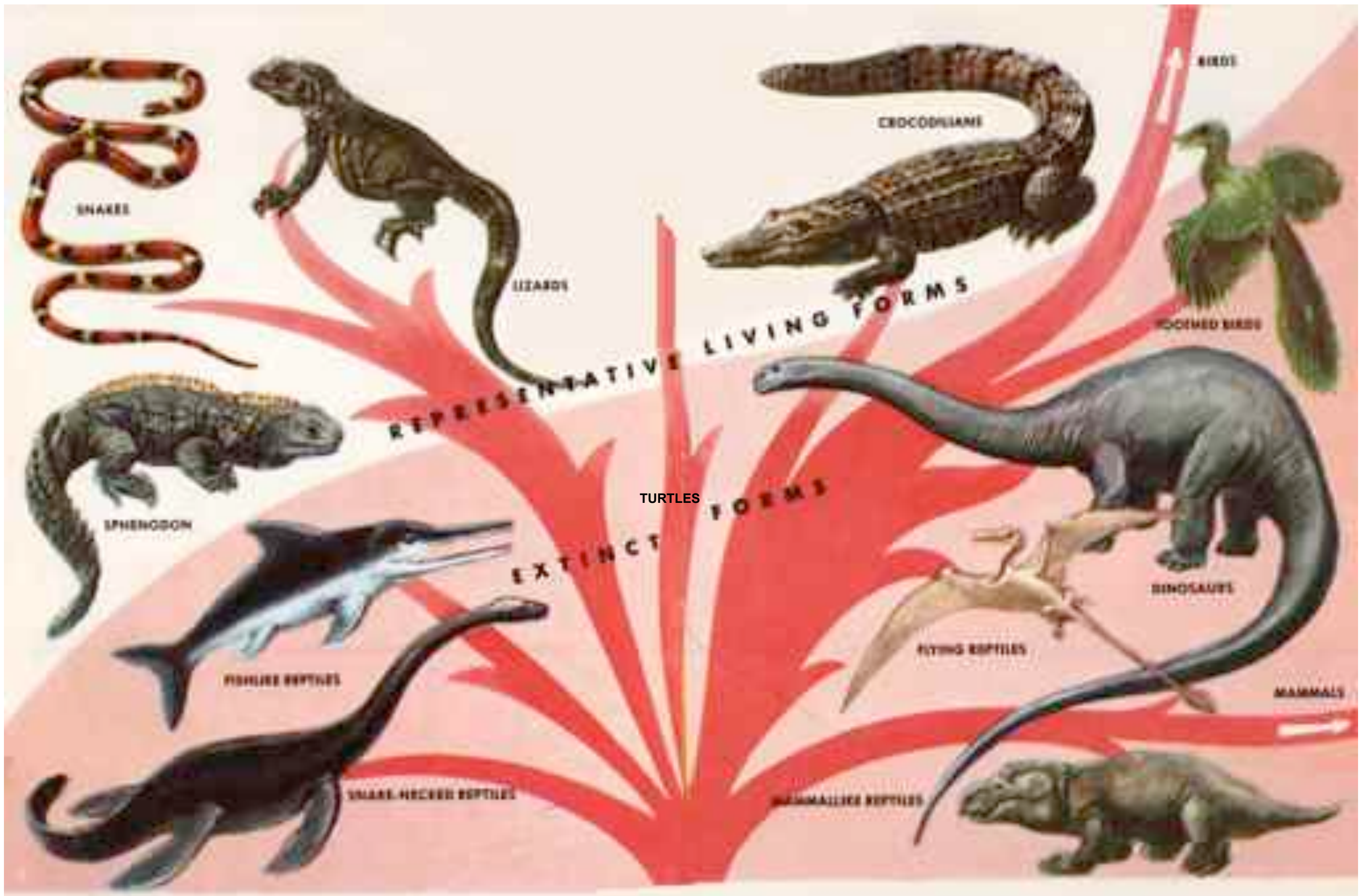
Includes 4 orders (3 represented here in lab)

Order Squamata: Lizards, snakes

Order Testudina/Chelonia: Turtles

Order Crocodilia: Crocodiles, alligators

Order Rhynchocephalia: 2 species of Tuatara



REPTILES appeared nearly 250 million years ago. The group slowly spread, and about 60 million years later took over the land. Dinosaurs included the largest land animals. Other reptiles took to the air and to the seas. As the climate changed, nearly all the great reptiles died off. Reptiles of today are resourceful descendants of magnificent but adaptively limited ancestors.

ORDER: SQUAMATA

Features distinguishing the order Squamata (snakes and lizards) include:

- a cleidoic egg
- ectothermy
- skin that bears horny scales or shields
- movable quadrate bones, allowing the upper jaw to move relative to the braincase
- males with a hemipenis (paired copulatory organs)

Carolina anole

Green tree monitor lizard

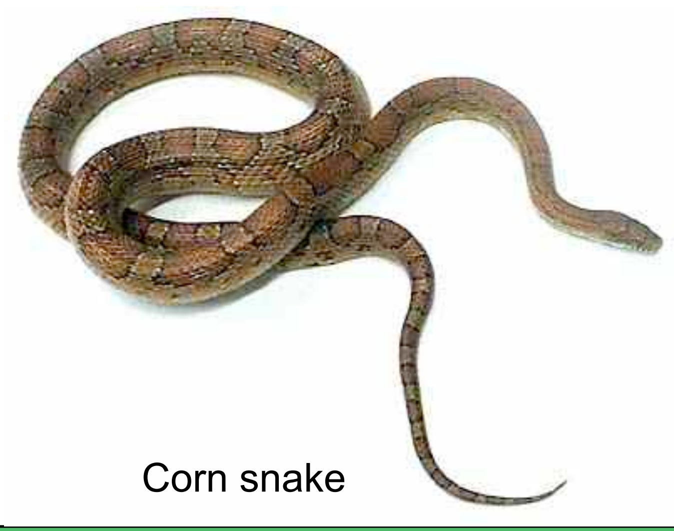
Plumed basilisk (the species name made famous by the Harry Potter books)

ORDER: SQUAMATA

Major differences between snakes and lizards include:

- Lizards and snakes differ drastically in skull morphology. The skull bones of lizards tend to be tightly joined and stocky. Those of snakes tend to be elongated and mobile. This reflects their type of prey. Most lizards are insect eaters and eat small prey, whereas snakes tend to eat vertebrate prey (lizards, small birds, mice) and they eat less frequently.
- Snakes have one row of scales on the ventral surface, whereas lizards have many rows.
- Lizards have external ear openings, which snakes lack.
- Snakes focus by moving the lens relative to the retina of the eye. Whereas lizards have closing eyelids, snakes have a transparent eyelid that is fused closed.
- Unlike lizards, the tails of snakes are short relative to their body.
- Snakes have only one lung, one kidney, and the ovaries are packaged sequentially
- Snakes have 160-400 vertebrae

Functionally, and probably phylogenetically, snakes are extremely specialized legless lizards. They may have been specialized for a fossorial (underground) life, that allowed for different eyes to evolve, but snakes have so many features in common with lizards that they probably evolved from a lizard lineage.



Corn snake

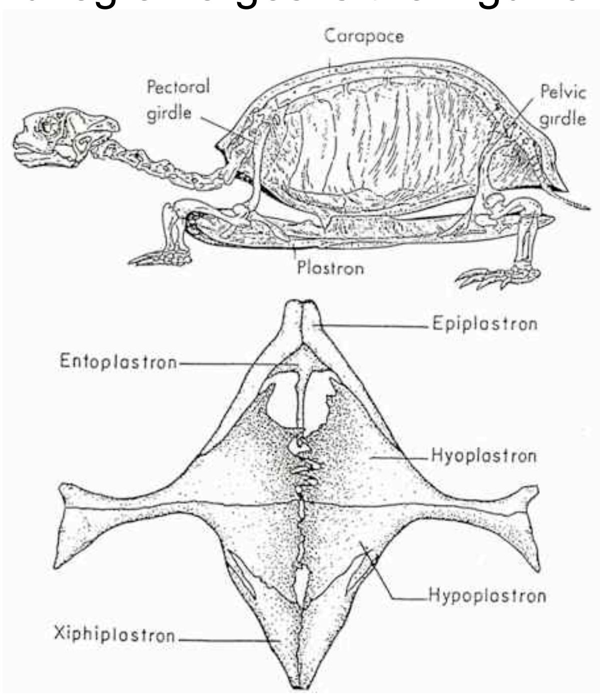
Sheltopusik - a legless lizard

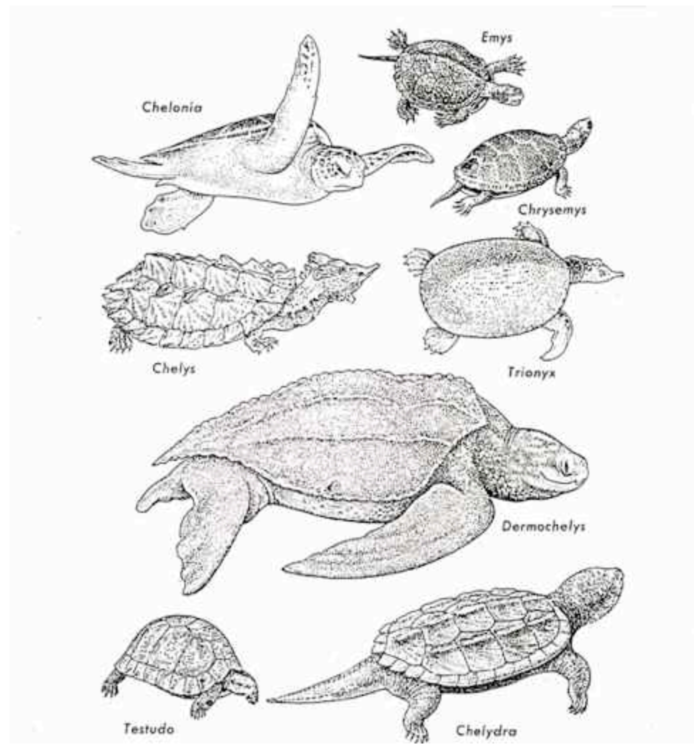
ORDER: TESTUDINA/CHELONIA

Both turtles and crocodiles diverged from the rest of the reptiles long ago. The skeleton of turtles has become extremely specialized. The shell of the turtle consists of two parts: the upper *carapace* and the lower *plastron*. On each side between the fore and the hind leg the two parts are joined by a bridge.

The carapace is composed of a large number of bones, each of which is articulated with the adjoining bones by jagged sutures. Looking at the carapace from a ventral view one can see the various bones that comprise the carapace. Along the margins one can find an outer ring of bones known as the peripherals. In the midline there are at least twelve bones.

The plastron comprises a median bone and four paired bones. On each side, between the fore and hind legs, two bones of the plastron articulate with peripherals three to seven to form the bridge. The notch from which the front leg protrudes is the auxillary notch and that from which the hind leg emerges is the inguinal notch.

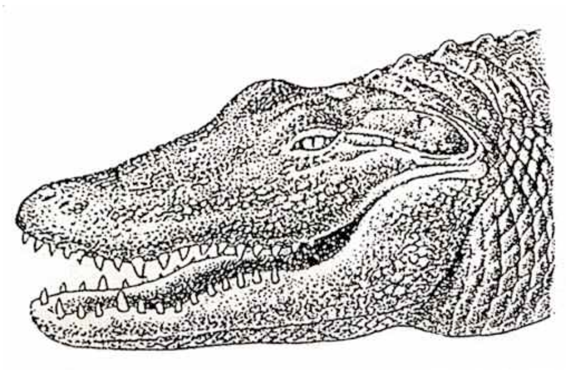




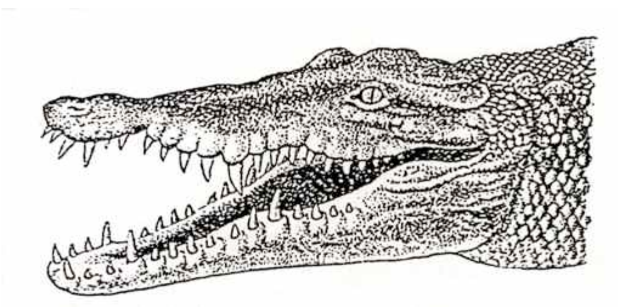
ORDER: CROCODILIA

Alligators and Crocodiles form a distinct group of reptiles of ancient lineage. The best way to distinguish an alligator from a crocodile is to look at its head. Crocodiles tend to have heads that taper to a point whereas alligators (and caimans) tend to have broader, more rounded snouts, although considerable variation can occur. These differences in head shape reflect the diets of the animals, with the more broad-snouted species having more varied diets including turtles, fish, and terrestrial animals, whereas the species with narrower snouts are primarily fish eaters. More definitive identification can be made by examining the fourth tooth in the lower jaw, which is enlarged in both groups. In crocodiles these enlarged teeth are visible even when the jaw is shut because the teeth do not align with grooves in the upper jaw.

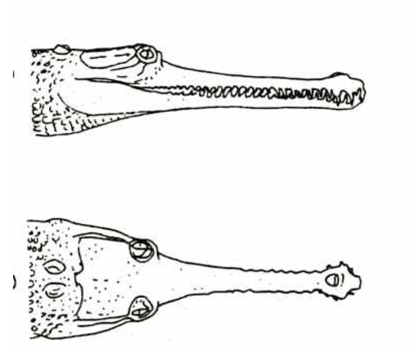
Both turtles and crocodiles diverged from the rest of the reptiles long ago. Each has developed a type of armor: in turtles the armor is derived from the skeleton and in crocodiles it is derived from the skin in the form of bony epidermal plates. The crocodiles, along with the birds, are the closing living relatives of dinosaurs. Most crocodiles have extended parental care, a behavior commonly seen in birds. Young crocs stay near their mother for up to 2 years.



Alligator



Crocodile



a fish-eating Gharial

How a Snake Captures and Swallows its Prey

Although some snakes specialize in eating small insects and worms, most eat prey that are large in proportion to their own size. Large prey and a slow metabolism gives them the advantage of not having to eat often. Few eat more than once a week, many eat only 8-10 times per year, and a large python can go for 12 months or more without eating. There are several adaptations that allow snakes to eat such large prey. They include the following:

1) Versatile jaws allow snakes to swallow food headfirst and whole, even when the victim is larger than the snake's body, and may even be alive and kicking. If the prey animal is dangerous (e.g. a rat) it is usually killed by venom, constriction, or a hard bite. If it is relatively harmless (e.g. a frog) it may be swallowed live. The jaw bones are attached to the skull only by muscles and ligaments, so that each bone can be moved individually-up and down, back and forth, or from side to side. The two halves of the lower jaw are not fused at the front. Thus, each half of the lower jaw as well as each of the six toothed bones of the upper jaw and palate is independently movable.

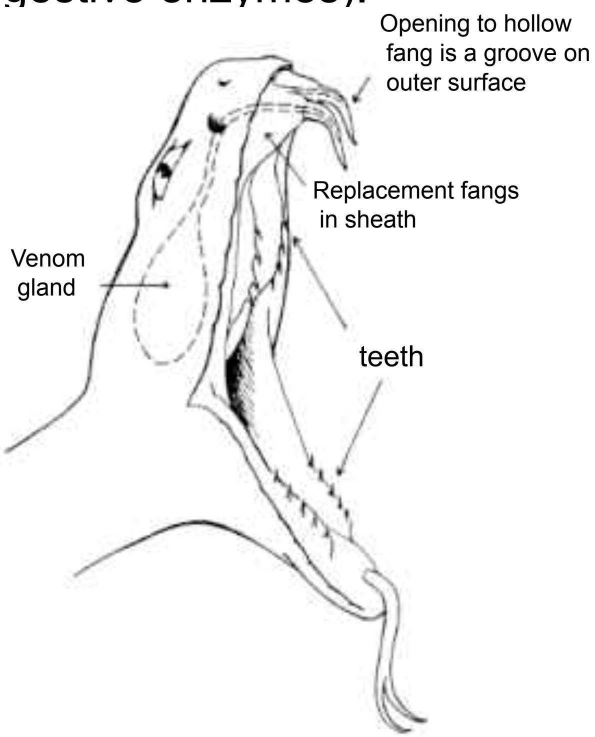
2) Snakes' teeth are sharply pointed, inwardly curving cones used to hold a prey animal and drag it back into the esophagus. The snake generally turns prey to go down the gullet headfirst. The toothed bones of the jaw work alternately, "walking" the prey into the esophagus. The snake then forms a sharp curve in its neck behind the prey animal and pushes it down into the stomach.

3) The snake's body skin is flexible enough to let a large animal stretch it without tearing. Snakes have dispensed with the pectoral girdle and the sternum associated with front limbs in other vertebrates, so it does not obstruct the passage of food through the esophagus.

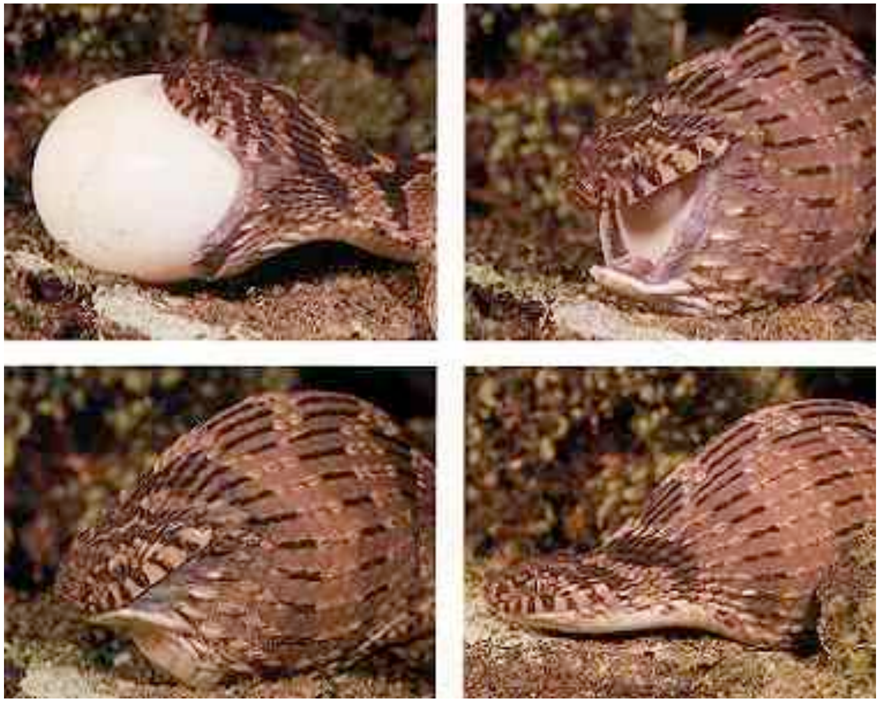
The long, forked tongue of snakes are harmless. As it flickers in the air, it collects odorous particles and brings them into the mouth to the smell-sensitive organ there.

SNAKE SKELETON

Look at the snake skeleton display to identify features that allow the swallowing of large prey. Note the absence of a pectoral girdle (associated with the front limbs in other vertebrates) and the sternum (fused ribs in other vertebrates). The figure of the rattlesnake jaw below illustrates some of the specialized jaw features. Of some 120 snake species found in the U.S., 17 produce venom that can seriously harm humans. An extreme example of feeding in snakes is the rattlesnake, which can eat prey up to 80% of their body weight. Venom not only immobilizes the prey, but also aids in digestion so that the food won't rot in the snake's stomach (most venoms are digestive enzymes).



Head of a rattlesnake in striking position. Supplementary fangs are covered by a sheath of tissue. Each fang is located in a double socket. Replacement fangs appear in what are currently empty sockets.



An African egg-eating snake swallowing an egg more than twice the width of its body. The pleated lining inside the mouth and flexible tissues between the jawbones allow the jaw to stretch wide. Saliva flows freely to help the egg slide into the mouth. Once inside, the egg passes through the elastic throat, where it is cracked open by contact with sharp internal spines.

MORPOLOGY, HABITAT and CONVERGENT EVOLUTION

The shape and color of lizards and snakes varies greatly. Some of this diversity can be explained by how the animal functions in its environment. For example, lizards and snakes that are arboreal tend to be green, have long limbs and tails, and have vertically flattened bodies. Animals that live on the ground, on the other hand, tend to be brown and have short stocky legs, stocky or horizontally flattened bodies.

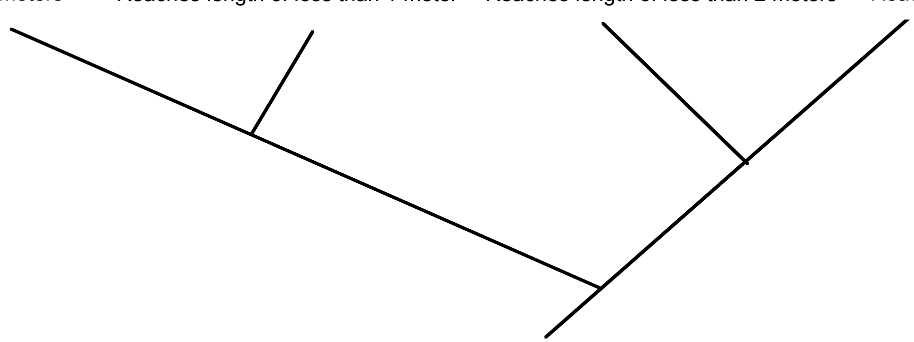
Of the four snakes in the Boidae family displayed here, one set of two is closely related, and the other two are closely related. What do you think they are? Two large groups of snakes are the pythons, which are all old world snakes, and the boas, which are all new world snakes. Therefore the Emerald Tree Boa and the Rosy Boa are in the same subfamily (Boinae), whereas the Ball Python and the Green Tree Python are in the same subfamily (Pythoninae). The similarity in color, patterning, morphology, and resting behavior of the two green tree-dwelling snakes and of the two ground-dwelling brown snakes is called convergence. Convergent evolution often comes about due to similar environmental conditions.

Green Tree Python
Morelia viridis
Rainforest trees of New Guinea and tip of Cape York Peninsula of Australia
Eats mammals and birds
Reaches length of less than 2 meters

Ball Python
Python regius
Savannah habitats of equatorial Africa
Eats mammals
Reaches length of less than 1 meter

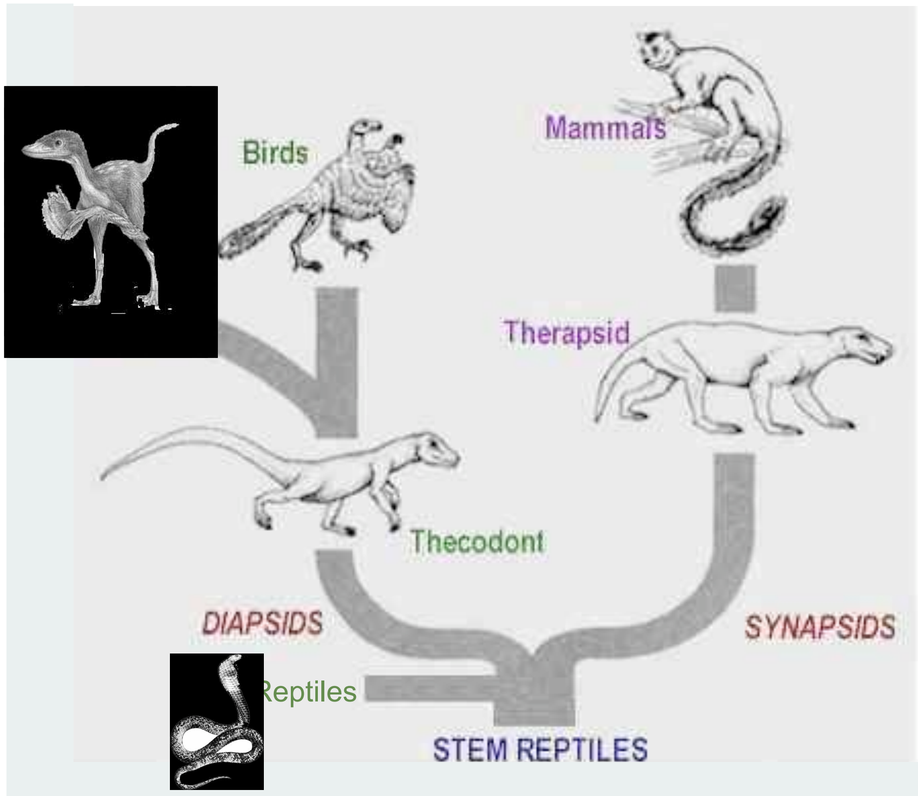
Emerald Tree Boa
Corallus caninus
Amazon basin rainforest trees
Eats lizards, mammals and birds
Reaches length of less than 2 meters

Rosy Boa
Charina trivirgata
Rocky desert habitats of Southwestern US and Northwest Mexico
Eats rodents
Reaches length of less than 1 meter



LINK BETWEEN BIRDS AND REPTILES

Testudina, crocodiles, Rhyncocephalians, Squamates (lizards and snakes) comprise the four orders of the extant Reptilia. Unquestionably birds evolved from dinosaurs (perhaps questioned by the group of non-scientists known as creationists) and are very closely related to crocodiles. Some biologists unite birds and crocodiles together in a group called archosaurs. One extinct genus that is thought to be the link between birds and dinosaurs is *Archaeopteryx*. Some paleontologists place Archaeopteryx with the dinosaurs and some ornithologists place them with the birds. This is because *Archaeopteryx* has features of both. Bird-like features include feathers, wings, and hollow bones. Reptile like features include the lack of a wish-bone, presence of a reptilian like beak, teeth and the presence of scales. Except for their powers of flight, birds may be regarded as little dinosaurs descended from the coelurosaurs.



LINK BETWEEN BIRDS AND REPTILES

(1) *PTEROSAUR*:

Although no reptiles alive today can fly, some did in the past. This long-tailed Rhamphorhynchus was one of these reptiles that took to the air some 180 million years ago. A big-jawed, toothy creature, it had an extremely elongated finger on each forelimb, providing a frame for its featherless wing. The other clawed fingers protruded for climbing. The tail ended in a rudder, aiding stability in fight. It had weak legs, probably walked little and cruised low over the water in search of its prey.

(2) *ARCHAEOPTERYX*

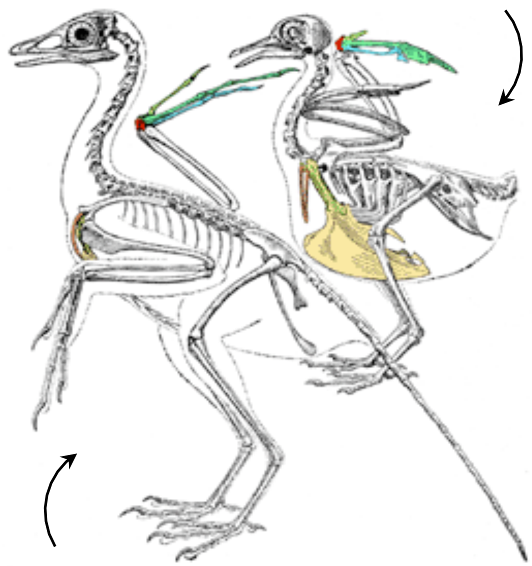
The crow-sized *Archaeopteryx*, an ancient bird that lived toward the end of the era of flying reptiles, possessed many characteristics of the reptiles from which it sprang. Like the birds, *Archaeopteryx* was feathered and had strong hind limbs with claws adapted for perching. But it had a toothed, reptilian beak, claws on its forelimbs and a reptilian tail. Fossil remains indicate that the animal had a weak jaw and small teeth and, unlike the pterosaurs, probably fed on plants, insects and grubs.

(3) Skeletal comparison of *Archaeopteryx* and a pigeon.

How many skeletal changes can you find?

(from Colbert: Evolution of the vertebrates, ed. 2, New York, 1969, John Wiley & Sons, Inc.)

A pigeon, for comparison.



Archaeopteryx, the earliest known bird of the Jurassic period

Archaeopteryx: Early Bird Catches a Can of Worms

Call it the feathered Sphinx of the Jurassic. The name is apt because this fossil, *Archaeopteryx*, is the source of riddles as impenetrable as the ones that issued from the Greek original. Since the first *Archaeopteryx* specimen was discovered in Germany in 1861, scientists have been pecking at each other like bantam roosters in an attempt to sort out the creature's true place in evolution. The latest phase of the controversy pits ornithologists, who consider the 150 million-year-old creature a bird, adapted to life in the trees and capable of powered flight, against paleontologists, who claim *Archaeopteryx* was dinosaur that spent most of its life on the ground.

More than a century after the dispute began, the squawks keep rising in volume. In this issue of Science, ornithologist Alan Feduccia of the University of North Carolina at Chapel Hill argues that the claws on *Archaeopteryx* indicate that it did live in the trees and was unquestionably a bird (see page 790). "Paleontologists have tried to turn *Archaeopteryx* into an earth-bound, feathered dinosaur," Feduccia says. "But it's not. It is a bird, a perching bird. And no amount of 'paleobabble' is going to change that." Paleontologists remain far from convinced.

Partly obscured by the flying feathers are two opposing views of avian evolution. The first stems from Darwin's contemporary, Thomas Henry Huxley, who argued in the late 1860s that birds are directly descended from dinosaurs. The other view holds that both birds and dinosaurs share an earlier, crocodile-like ancestor. For much of this century, ornithologists and paleontologist were almost unanimous in accepting the second hypothesis. According to that view, rather than resulting from a single line of descent, the features shared by birds and the small running dinosaurs known as coelurosaurian theropods (including hollow bones, long hind limbs, long tails, and long necks) arose from parallel evolution.

But in 1973, John Ostrom, a paleontologist at Yale University, upset the consensus in a letter to *Nature* in which he asserted that the skeleton of *Archaeopteryx* was "that of a coelurosaurian dinosaur." Ostrom was, in effect backing Huxley's view that birds are descended from dinosaurs, and he went on to argue in subsequent studies that dinosaurs such as *Velociraptor* and *Segisaurus* even possessed the antecedent of the most bird-like structure of all: the wishbone. By the mid-1980s, it appeared Ostrom had won; at an international conference on *Archaeopteryx*, most researchers agreed that it was directly linked to dinosaurs.

Ostrom wasn't content to crow over his apparent victory. He kept piling up data that undermined the image of *Archaeopteryx* as the earliest bird. Since *Archaeopteryx* apparently lacked breastbones for anchoring flight muscles, he questioned whether it could fly at all and suggested that it claws resembled not those of high fliers but the feet of lowly ground dwellers such as quail and roadrunners. By the time Ostrom was finished, *Archaeopteryx* had been pushed out of the treetops and was reduced to running through the shrubs--a well-feathered but thoroughly grounded dinosaur. What is more, Ostrom claimed, if *Archaeopteryx* ran on the ground, then avian flight probably originated when creatures like *Archaeopteryx* began leaping up (after insects, say) rather than swooping down from the treetops.

Although stunned by Ostrom's apparently successful claims, the ornithologists began clawing their way back, attempting to reclaim *Archaeopteryx*, which, after all, was replete with feathers, wings, hollow bones, and a broad tail. "The paleontologists would like it to be a done deal," says Storrs Olson, curator of birds at the Smithsonian Institution. "But their terrestrial idea is almost certainly wrong, and Feduccia's paper will keep them aware that the issue has not been resolved."

Feduccia was one of the leaders in ornithologists' reclamation effort. In previous, highly regarded papers (Science, 9 March

1979, p.1021), he argued that *Archaeopteryx's* feathers and wings are identical to those of modern birds. There, at least, he's scored success since by now even paleontologists concede *Archaeopteryx* was capable of limited flight. "Okay, in the vernacular sense, it is a bird," grouses Jacques Gauthier, a herpetologist at the California Academy of Sciences in San Francisco and a supporter of *Archaeopteryx's* dinosaur ancestry. "If by that you mean something with feathers that sort of flies."

Those concessions don't satisfy Feduccia. In his current article, he lends additional touches to his portrait of *Archaeopteryx* as a full-fledged bird by arguing that its claws resemble those of birds that spend most of their time in the trees. To substantiate his claim, Feduccia measured the curvature of the foot claws (*Archaeopteryx* also had claws on its wings) of the three best *Archaeopteryx* specimens, then compared this arc with 500 species of modern birds. The fossils' arc fell comfortably in the range of definitive perching birds such as the South American motmots and the cuckoo-rollers of Madagascar. A further clue comes from the fossils' curved claw on the reversed first toe (the hallux), which Feduccia says is "strictly a perching adaptation; it would be a tremendous obstacle to running on the ground."

Feduccia even turns *Archaeopteryx's* curious wing claws (or manus claws) to advantage. Other researchers, puzzled by the long claws, have suggested they were used for everything from gripping branches to aiding flight to trapping insects. To Feduccia, though, they are simply another adaptation for life in the treetops. ":The claws are extremely similar" to the foot claws of modern trunk-climbing birds, he insists. "In fact, if you compared the claws of a wood creeper with the manus claws of *Archaeopteryx*, you would be hard pressed to tell them apart. They are virtually identical."

To other ornithologists, Feduccia's gripping tale clinches the case. "Feduccia's paper establishes conclusively that the claws of *Archaeopteryx* have the morphology of a perching, climbing animal," says Larry Martin, a paleo-ornithologists at the University of Kansas in Lawrence. "It was not running on the ground."

Some paleontologists, however, think Feduccia is, well, out of his tree. Paul Sereno, an evolutionary biologist at the University of Chicago, disputes whether one can use a bird's claw to draw definitive conclusions about its overall behavior. "Many so called ground birds, for example chickens, still spend some tine in the trees," he says. Sereno also questions Feduccia's claims for the wing, or hand, claws. "I think the hand claws are particularly irrelevant because he makes no comparisons to dinosaurs. In fact, *Archaeopteryx's* hand claws are very, very similar to those of theropods." Gauthier adds, "If *Archaeopteryx* used it hand claws for climbing trees, then all the related dinosaurs -- theropods *Velociraptor. T. rex* -- all climbed in trees." And if that's the case says Gauthier, "You've got a problem," since *T. rex* was clearly a terrestrial creature.

But not all the clucks from paleontologists are those of disapproval. Ostrom, whom one might expect to be outraged, is preening instead. "I'm just having a ball," he said with a chuckle. "It sounds to be as if Alan [Feduccia] has presented a very good argument; I'm not sure he's absolutely right, but I'm sure he's on solid ground." Even though Ostrom acknowledge that Feduccia may be right about the shape of the claws, Ostrom is far from giving up his own, hard-won ground. Like Sereno and Gauthier, he doesn't think the case can be closed before the claws of *Archaeopteryx* have been compared with those of therapods.

In any case, says Ostrom, his ideas have been constructive in stimulating scholars to examine assumptions. "In the early 1970s, it was a given that birds learned to fly from the trees down," Ostrom says. "I thought people hadn't looked closely enough at the evidence, so I deliberately wrote my paper to provoke people. And I'm laughing now because it has provoked people out of their hides, it's great big controversy--which is what it should be." And a controversy in which the world hasn't heard the final peep.

-- **Virginia Morell** *Science*, Feb. 5, 1993, pp. 764-765

Station 6. Relationships Among Reptiles

Green Iguana

Flap-necked chameleon

Twilight of the Reptiles

Of the 16 orders of reptiles known from fossils, only four have managed to survive until modern times, and three are widely recognized. The Squamata include both lizards and snakes, with a grand total of about 5,700 living species (3,000 lizards and 2,700 snakes). By contrast, there are only 200 species of turtles, 23 species of crocodilians throughout the world, and only two species of tuatara living on remote islands near New Zealand. Fossils of at least 108 species of extinct crocodilians are known. The Rhynchocephalian order, to which the tuatara belongs, once numbered at least 23 species.

It has taken some 150 million years of paleontological disasters to reduce the immense diversity of reptilian life to a meager four orders. But it has taken man only a few hundred years of indiscriminate slaughtering to bring many survivors to the brink of extinction. Belatedly, in some areas of the world, conservationists are now studying ways to save these relics of the distant past.