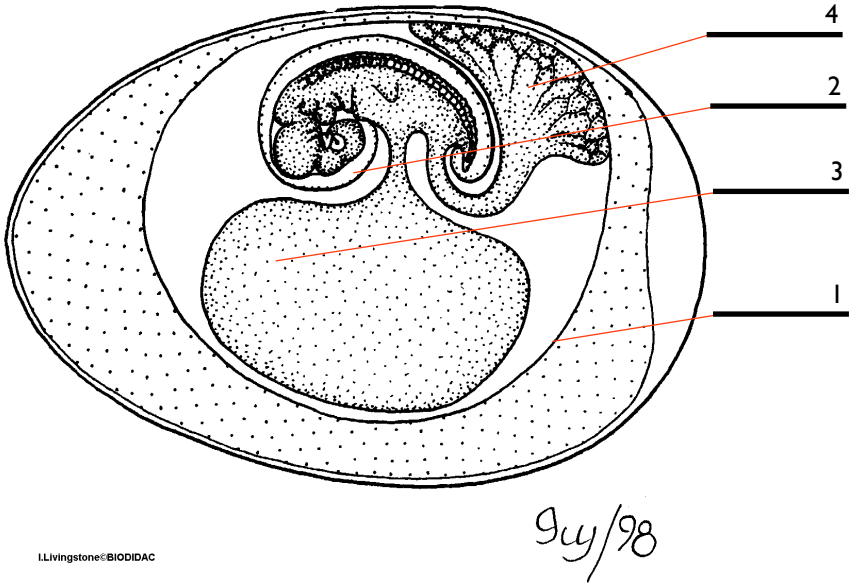
clade Amniota

This taxon represents a monophyletic group including the mammals, reptiles, birds, and their extinct relatives. Specifically, it includes the most recent common ancestor of mammals and reptiles and all descendants of that ancestor (Gauthier et al., 1988). There are many synapomorphies in this group that are noted as characteristics related to a terrestrial lifestyle. The most notable of these features is the amniotic egg, for which the group is named. The various structures associated with the amniotic egg allow the egg to be laid on dry land, and serve to protect and nourish the developing embryo.

The amniotic egg



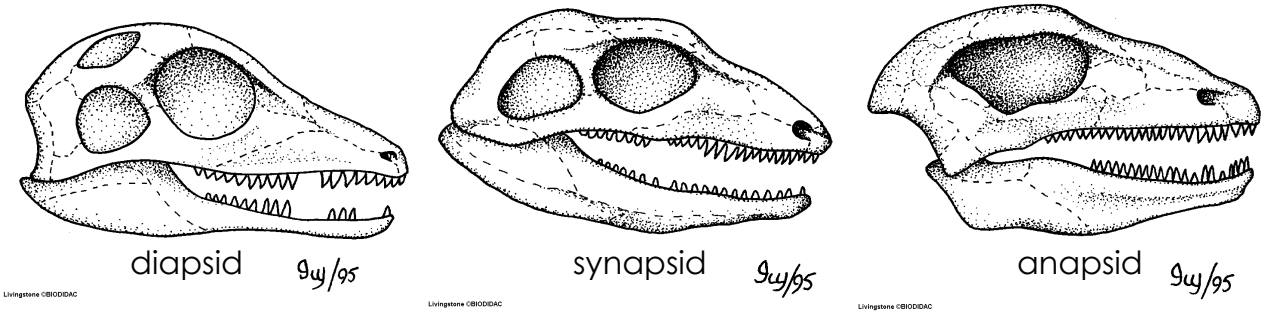
The outermost layer of the egg of amniotes is the shell, which is either soft and leathery or hard and mineralized. The hard egg is a synapomorphy of archosaurs (a group which includes crocodiles and birds) while other reptiles possess a softer, less mineralized, leathery shell (Laurin and Gauthier, 1996). The earliest amniotes most likely had a much less mineralized shell; as a result, these eggs are poorly represented in the fossil record (Laurin, Reisz & Girondot, 2000). The shell is a structure that protects the egg not from desiccation, but from abrasion and friction associated with the pull of gravity coupled with the dry surface on which the egg has been laid. The nutritional, water, and waste removal requirements of the embryo are met by a series of four membranes: the chorion, amnion, yolk sac, and allantois.

The outermost layer (within the shell) is the chorion [1]. The chorionic membrane helps to minimize water loss from the developing embryo. Inside the chorion is the amniotic membrane (amnion [2]). The amniotic membrane originates from the ventral aspect of the embryo. It encloses the embryo which is surrounded by amniotic fluid (also enclosed in the amnion). Also inside the amnion is the yolk sac [3], which contains the yolk, the nutritive substances that will provide for the nutritional requirements of the developing embryo. The allantois [4] develops posterior to the ventral origin of yolk sac. The allantois has two main functions: it stores nitrogenous wastes from the embryo as uric acid and provides for the gas exchange requirements of the embryo. The exchange of O_2 and CO_2 is actually carried out by the highly vascularized chorioallantoic membrane (a fused area of the chorion and the allantois).

Groups within the Amniota

There are three main skull types found within the Amniota. These skull types reflect some of the phylogenetic relationships within the group. The synapsids represent a group which diverged from the rest of the Amniota, probably in the middle Pennsylvanian (around 310 mya)(Lee, 2004). The synapsids include the mammals and their extinct ancestors and relatives. A synapsid skull has a single opening behind the eye. The rest of the amniotes, the Saurapsids, are represented by two skull types, anapsid and diapsid. The saurapsids include all

living reptiles, birds, and dinosaurs. Birds and most modern reptiles are diapsid. The diapsid skull has two openings in the skull behind the eye. The remaining reptiles are anapsid. The only remaining anapsid reptiles are the turtles. However, recent molecular evidence places the Testudines as sister to the Crocodilia. This evidence points to a convergence between the anapsid skull of turtles and the anapsid skulls of other extinct reptilia.



class Mammalia

The most basal group of extant amniotes is the mammals. The mammals are descendants of a cynodont ancestor (also a synapsid). Members of the class Mammalia are noted as possessing plesiomorphic characters such as hair, sebaceous glands, a synapsid skull, diphyodont teeth, and endothermy. These characteristics were most likely present in the cynodont ancestor of the Mammalia. It should be noted, however, that endothermy in this group evolved independent of the endothermy found in the dinosaurs and birds. Similarly, hair evolved as a new epidermal structure, not homologous with scales or hair. Autapomorphies in this group include the presence of mammary glands and the production of milk to nourish offspring. Most mammals are viviparous, with the notable exception of the extant (and extinct) monotremes. There are five extant species of monotremes, including one species of platypus (*Ornithorynchus anatinus*), and four species of echidna (*Tachyglossus aculeata* and *Zaglossus spp.*).

The clade Mammalia is divided into two subgroups (subclasses): Prototheria and Theria. These groups represent two sister groups, although the monophyly of the prototherians is questionable with inclusive of the extinct groups.

Subclass Prototheria

Order Monotremata

The prototherians include a single extant order, which are the monotremes (Monotremata). These are the egg-laying mammals. Monotremes possess no nipples, but feed their young using milk that pools on the skin, produced by small milk producing glands embedded in the skin inside the pouch.

Subclass Theria

Infraclass Metatheria: Order Marsupialia

The therians include two infraclasses, the Metatheria and the Eutheria. The Metatheria comprises a single extant order, Marsupialia. The kangaroos, opossums, koalas and others are in this group. The marsupials give live birth, but to an underdeveloped embryo, which completes its development in the mother's pouch. The placenta, if present, is underdeveloped in this group. Metatherians generally have a female reproductive organs which remain unfused, resulting in two vaginas and two uteri. In addition the males have a bifurcated penis. The

scrotum of males is located anterior to the penes, a feature found in only one group of eutherians, the lagomorphs.


John Gould, 1845

Subclass Theria

Infraclass Eutheria

The rest of the therian mammals are the "placental mammals," in the infraclass Eutheria. These mammals possess a well developed placenta that provides for the exchange of gases, nutrients, and nitrogenous wastes, via diffusion between the maternal and embryonic capillary beds associated with the placenta. The umbilical cord carries embryonic blood from the embryo to the placenta, and back. The bellybutton or umbilicus is the point of attachment for the umbilical cord, and therefore is not present in monotremes and many marsupials.

Human torso model

- Note the following structures: pharynx, epiglottis, larynx, esophagus, vocal cords, trachea, bronchi, bronchioles, lungs, heart, liver, stomach, gall bladder, pancreas, small intestine, appendix, cecum, ascending colon, transverse colon, descending colon, rectum, kidneys, ureters, bladder.

Cat dissection

- Draw and label the following structures: liver, gallbladder, stomach, large intestine, spleen, small intestine.

Human skeleton

- Find and label the following bones: cervical vertebrae, thoracic vertebrae, lumbar vertebrae, coccyx, clavicle, scapula, ribs, humerus, radius, ulna, carpals, metacarpals, phalanges, ilium, ischium, pubis, femur, tibia, fibula, tarsals, metatarsals.

Cat skeleton.

- Find the same structures listed above.

class Reptilia

The Amniota are represented by two lines, the synapsids and the sauropsids. The sauropsids include a group referred to as the parareptiles and the Reptilia. The reptiles are described as the most recent common ancestor of the saurians and the turtles, and its descendants (Gauthier et al., 1988). The modern reptiles are represented by five groups: squamates (snakes and lizards), tuataras, turtles, crocodilians, and birds. Historically, the birds have been placed in their own class, but molecular and morphological evidence places them squarely within the reptiles.

The group that includes the traditional reptiles is paraphyletic (or polyphyletic, depending on perspective). Reptiles are often described as possessing the following characteristics: ovipary; dry, scaly skin; ectothermy. However, these characters are hardly unique to reptiles, and they do not adequately describe all reptiles. With regard to reproductive mode, we see a variety of paradigms in the Reptilia. Some reptiles are oviparous, and produce amniotic eggs with varying degrees of mineralization in the shell. Many reptiles however, are ovoviviparous, retaining nutritionally independent eggs within the body until they are ready to hatch, giving birth to live young. There are also some reptiles that give true live birth, with a placenta-like structure to nourish

the developing embryo inside the mother. In practice, the line between ovovivipary and true vivipary is a blurry one; most ovoviviparous reptiles produce a yolk and a chorioallantoic placenta (Stewart, 1992). The size of the yolk and the degree of development of the placenta are generally negatively correlated. At one end of this spectrum lies true vivipary and on the other ovovivipary. Most reptiles giving "live birth" lie somewhere in the middle. Vivipary has likely evolved multiple times within the reptiles, and is found in many unrelated groups.

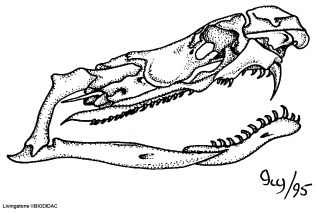
Most reptiles do possess relatively dry scaly skin. However, scales have been modified for different purposes in some groups, such as the feathers found in the dinosaurs and birds. The scales of reptiles are epidermal in origin, and thus differ from the dermal scales of fish. The scales of reptiles are keratinized and serve as a barrier for protection and prevention of water loss.

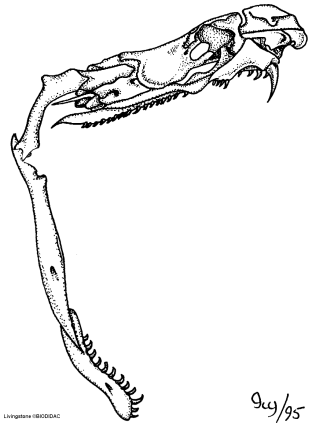
With regard to body temperature, most reptiles are ectothermic, with the notable exception of birds, some dinosaurs, and possibly the ancestors of crocodilians (Summers, 2005). Endothermy may have evolved more than once in this group, and at least once in the synapsids. As ectothermic animals, most reptiles do not produce enough metabolic heat to maintain a constant body temperature. Instead, their body temperature is subject to changes in ambient temperature. However, some reptiles are somewhat homeothermic, maintaining a body temperature within an narrow range during active periods (Pough et al, 1989).

The main nitrogenous waste excreted by reptiles is uric acid. Uric acid most likely evolved as a autapomorphy of the Amniota, due to the cleidoic nature of amniotic eggs. Being closed off from the environment, nitrogenous wastes of the developing embryo must be stored in a relatively non-toxic form. Since uric acid is relatively non-toxic, even when concentrated, it does not need to be diluted with water for storage. (It is also of relatively low solubility in water.) Although uric acid takes more energy to produce than urine, the lower toxicity and reduced water requirements make it a better choice for animals with a cleidoic (amniotic) egg.

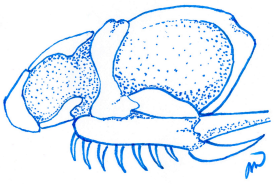
Infraclass Lepidosauromorpha

Order Sphenodonta (Rhynchocephalia)

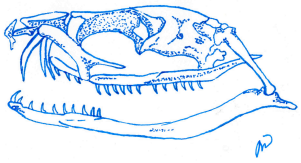




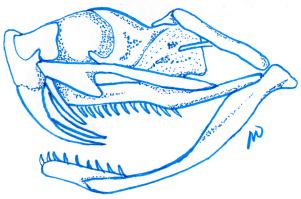
The lepidosaurs include two sister groups, the rhyncocephalians and the squamates. The rhynchocephalians include only two extant species of tuataras. Although similar in body form to lizards, the tuataras are not lizards, and are no more closely related to lizards than they are to snakes or amphisbaenians. The tuatara is found in New Zealand and the surrounding islands. They possess a well developed **parapineal**, also referred to as a pineal or parietal eye. This "third eye" is located on the top of the head. Tuataras have lower body temperatures than most reptiles and can remain active even at very low temperatures (around 45° F).



opisthoglyphous



proteroglyphous



solenoglyphous

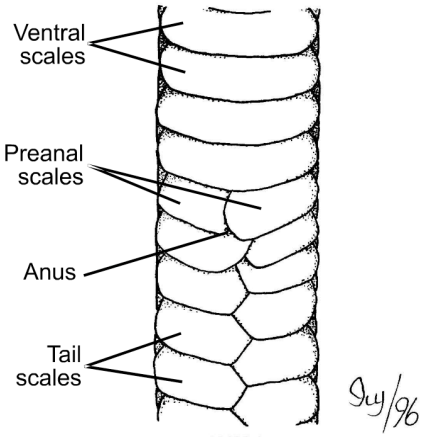
Order Squamata

The squamates include the lizards, snakes, and amphisbaenians (worm lizards). One of the characteristics common to the squamates is a moveable lower jaw. The position of the **quadrate** bone at the back of the skull creates a double-hinge that allows the jaw to be moved forward and backward, and in snakes, opened to 150°.

The squamates have **homodont** dentition, although in snakes, there is some variation among species with respect to size and structure of fangs. There are four main fang morphologies found in modern snakes. These categories are not phylogenetically informative. Nonvenomous snakes kill their prey using

constriction. Constrictors do not have specialized fangs, and are referred to as **aglyphous**. Venomous snakes with moveable fangs are referred to as **solenoglyph**. Solenoglyph snakes include the Old World vipers and the New World pit vipers (e.g. rattlesnakes, moccasins, copperheads). These snakes have a very effective and controllable method of delivering venom through their hollow fangs. **Opisthoglyph** snakes are sometimes referred to as rear-fanged snakes. These snakes have a moveable maxilla with an anteriorly directed solid fang that has to be pivoted forward to deliver venom. This method is not quite as effective, but can still result in a deadly envenomation in some cases, even for a large animal such as a human. The **proteroglyph** snakes have hollow fangs, but they are fixed in position at the front of the mouth. Coral snakes, mambas, and cobras are in this group.

Squamates have no eyelids. Instead, the eye is covered with a clear scale called a **spectacle** that protects the eye from desiccation. When a snake is near molting, the ocular scale becomes noticeably cloudy (or "blue"). Snakes generally molt their entire skin at once. Lizard skin usually molts in sections (except in the legless glass lizards, which molt like snakes).



Most lizards have legs, but snakes do not. If you look on the belly of the snake, there are wide ventral scales. The vent of the snake serves as an opening for the genitals and cloaca. The vent is preceded by the preanal scale or scales. In some cases the preanal scale divided. The tail is posterior to the vent. Some snakes have long tails, and some have shorter tails. Faster snakes tend to have longer tails.

Another notable difference between lizards and snakes is the presence of external ear openings. Lizards have ear canals with external openings, while snakes do not. Snakes can sense vibrations through their jaw bones and inner ear, but have no outer ear openings or tympanic membrane.

Preserved snakes

- note the following structures: hemipenes, ventral scales, fangs (if present), vent, tail, head, thermal pits (if present), nares.

Preserved lizards

- note the following structures: legs, tail, tympanic membrane, nostrils, pineal eye (if present), eyes, homodont teeth, vent (cloacal opening), nares.

Infraclass Archosauromorpha: Superorder Archosauria

The archosaurs are a diverse group that includes, among others, the crocodiles, the turtles, the dinosaurs, and the birds. This diapsid group is distinguished from the rest of the diapsids by the presence of a single fenestra in front of the eye. The archosaurs also differ from the rest of the diapsids in terms of dentition. The lepidosaurs generally have acrodont or sometimes pleurodont dentition, but the archosaurs possess thecodont dentition. Thecodont teeth possess a root that is embedded in the jawbone.

Order Chelonia

The turtles are a distinct monophyletic group within the Reptilia, but pose a phylogenetic problem. Morphologically, they are distinct from the other reptiles, especially with respect to their hard shell and anapsid skull. Historically, they have been assumed to be basal to the rest of the extant reptiles, diverging prior to the squamates and the archosaurs. However, recent molecular evidence places the turtles in a clade sister to the lepidosaurs. Other studies place the turtles as sister to the crocodilians (within the archosaurs)(Hedges and Poling, 1999).

Turtles possess an anapsid skull, a bony external shell (covered with scales), and a keratinized beak instead of teeth. The bony shell characteristic of turtles is composed of bony extensions of vertebrae and ribs, fused with **osteoderms** (dermal bone). This upper portion of the shell is referred to as the carapace. The ventral shell is referred to as the plastron.

Preserved turtles

- note the following structures: carapace, plastron, head, tail, eyes, nares, limbs.

Turtle skeleton

- label the following: scapula, procoracoid, coracoid, humerus, radius, ulna, vertebrae, ribs, pubis, ischium, caudal vertebrae, femur, tibia, fibula, phalanges.

Order Crocodilia

The crocodiles are a group that has changed little in over 200 million years. Crocodilians are well adapted to their aquatic lifestyle. Crocodilians possess a double palate that allows them to breath through their nostrils while their mouth is full of water or food. This allows them to remain submerged with just their nostrils above the water for extended periods of time. Like the turtles, they have dorsal osteoderms that act like armor plating for protection. In the fish eating species (e.g. gharials), the snout is quite narrow, to allow quick side-to-side movement underwater. The tail is used mainly for swimming, and is laterally flattened to allow it to generate thrust through sinusoidal movement. Like the birds and dinosaurs they possess a pneumatic skull, with air spaces to reduce mass.

Preserved alligator

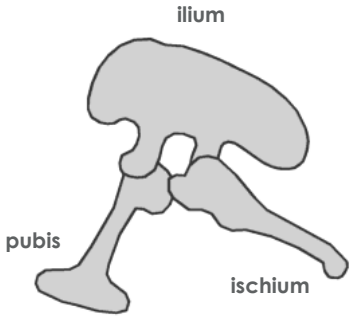
- note the following structures: dorsal scutes, homodont teeth, head, tail, eyes, nares, limbs.

Alligator skeleton

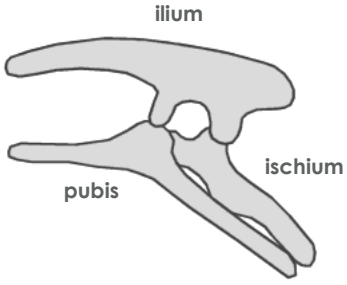
- note the following structures: pneumatic skull, pectoral girdle, pelvic girdle, vertebrae, humerus, radius, ulna, carpals, metacarpals, ribs, femur, tibia, fibula, tarsals, metatarsals, phalanges, caudal vertebrae.

Order Saurischia/Ornithischia

The dinosaurs fall into two orders: Ornithischia (bird-hipped dinosaurs) and Saurischia (lizard-hipped). The Ornithischia are the so-called bird-hipped dinosaurs. This term originates from the similarities between the pelvis of birds and the pelvic arrangement found in this group. As it turns out, this similarity is a matter of convergence. The birds actually fall within the Saurischia. The saurischians include the therapod dinosaurs such as *Velociraptor* and *Tyrranosaurus rex* (and the birds), and the sauropods (i.e. *Apatosaurus, Brachiosaurus,* etc.) These dinosaurs possess the primitive pelvic structure for the archosaurs.



Saurischian pelvis



Ornithischian pelvis

The Ornithischia possess a derived pelvic structure similar to that found in birds, with the pubis bone directed posteriorly ventral to the ischium. The ornithischian dinosaurs included the hadrosaurs (duck-billed dinosaurs), *Stegosaurus*, and *Triceratops*.

- Examine the model dinosaurs and note whether they are ornithischian or saurischian. (You can play with them if you like.)

Class (clade) Aves

The birds are, most likely, a monophyletic group. The members of this clade possess feathers, and usually fly. However, it should be noted that the presence of feathers is actually a plesiomorphic character in birds. Feathers appear in therapod lineages sister to the birds (e.g. dromaeosaurs like *Velociraptor*).

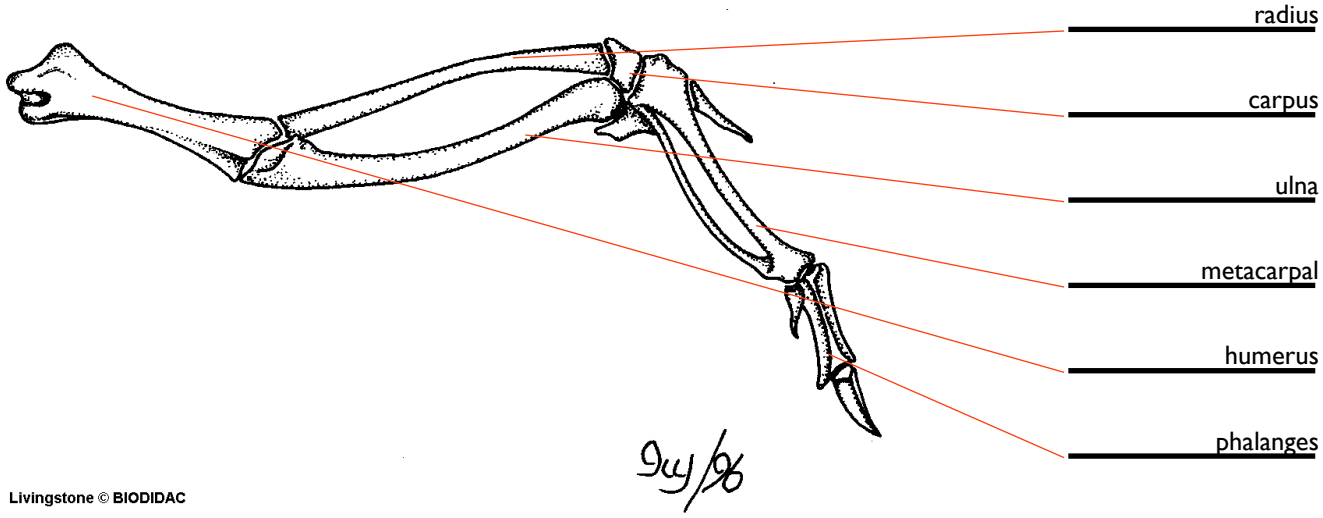
There are many derived characters found in the birds that are related to flight. In the modern birds (Neorthithes), the teeth have been lost and replaced with a keratinous beak, to reduce anterior distribution of weight. The earliest birds still had teeth. The birds are all oviparous, also a plesiomorphic condition. The birds possess a unique lung, with constant unidirectional airflow. Auxiliary air sacs contract and expand alternately

to keep air flowing across the lungs during inhalation and exhalation. This increases the efficiency of the lung, allowing birds to maintain the high metabolic rates necessary for flight. The bones of the vertebrae of birds are reduced to provide stability in flight. The sacral vertebrae are fused to form the synsacrum. The sternum of birds possesses a large process called a keel. This provides a larger area of attachment for the enlarged pectoral muscles associated with flight.

* Examine the bird specimens representing different orders of extant birds.

bird skeleton

* Label the following: skull, atlas, axis, cervical vertebrae, thoracic vertebrae, lumbar vertebrae, synsacrum, pygostyle, clavicle, coracoid, scapula, humerus, radius, ulna, carpus, ilium, ischium, pubis, femur, patella, fibula, tibiotarsus, tarsometatarsus.



questions

amniota

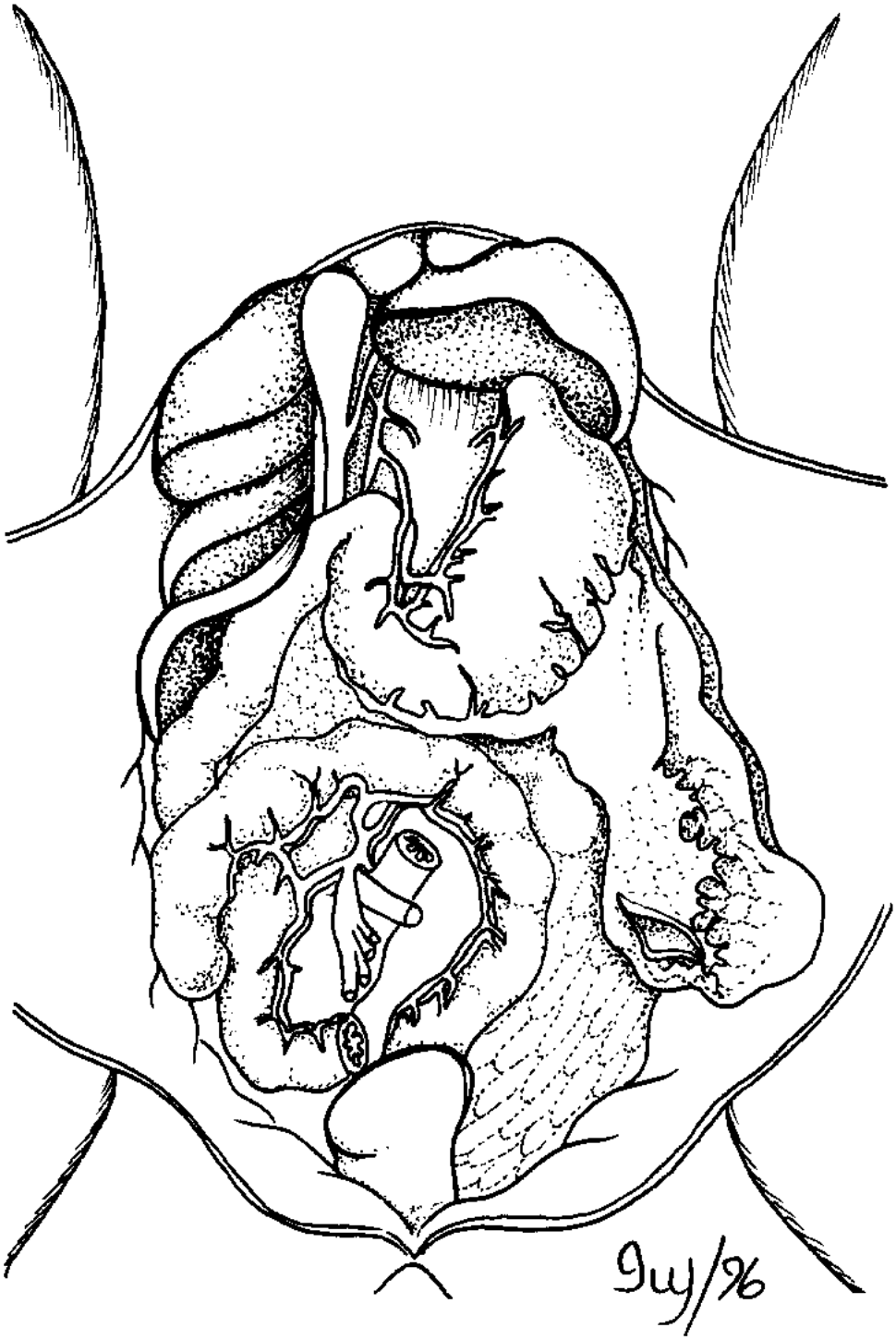
1. How does the amniotic egg allow for a truly terrestrial existence?

2. The reptiles are a paraphyletic group unless the birds are included. What are some characteristics that are shared among birds and the rest of the reptiles?

Drawings

Cat dissection

Kingdom: _____
Phylum: _____
Class: _____
Order: _____

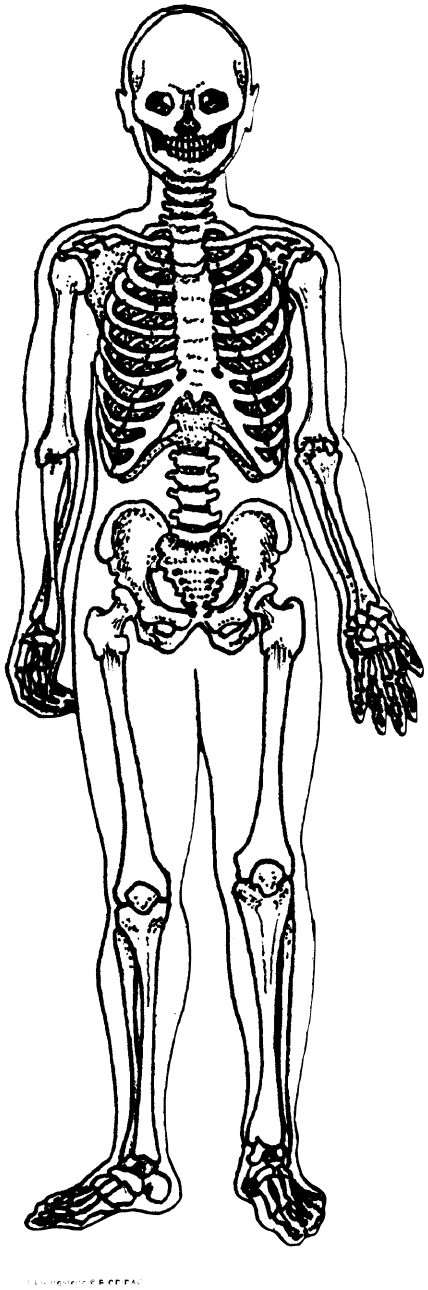


Livingstone, © BIODIDAC

Drawings

Human skeleton

Kingdom: _____
Phylum: _____
Class: _____
Order: _____



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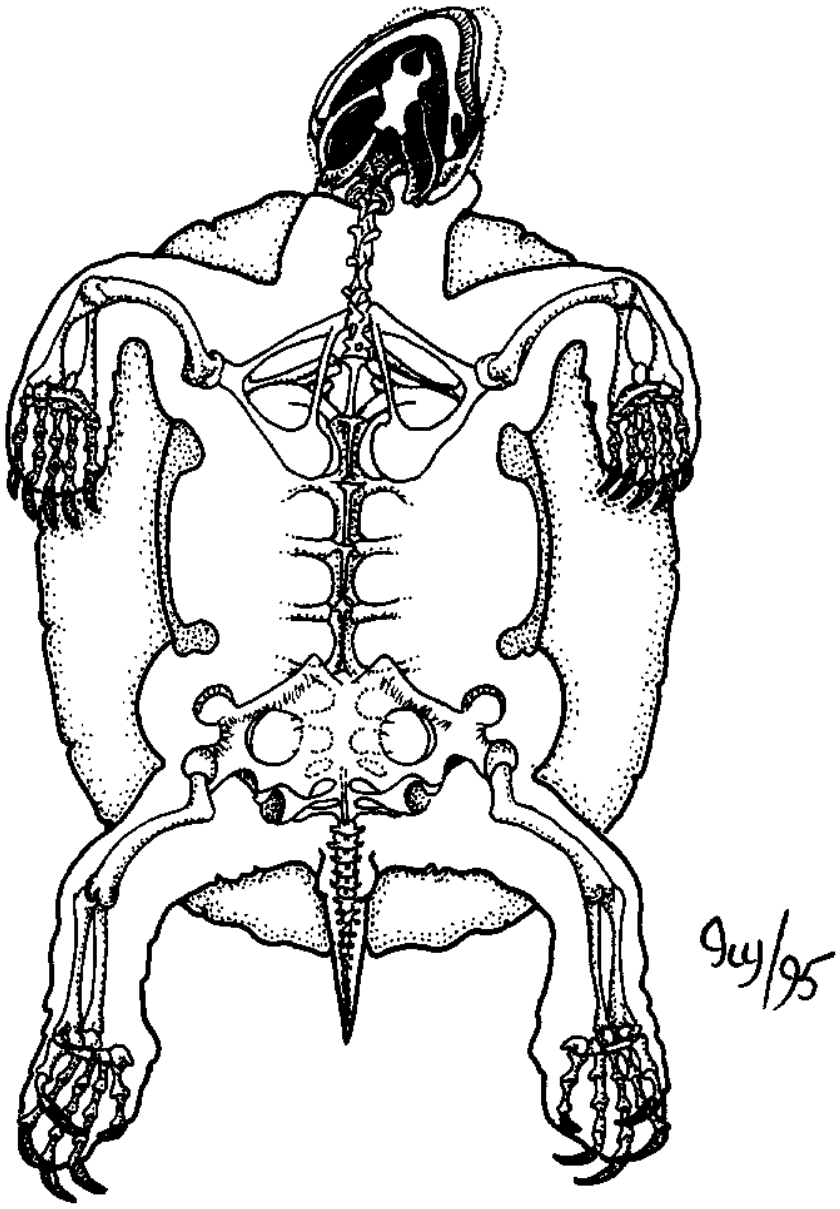
Drawings

Turtle skeleton

Kingdom: _____
Phylum: _____
Class: _____
Order: _____

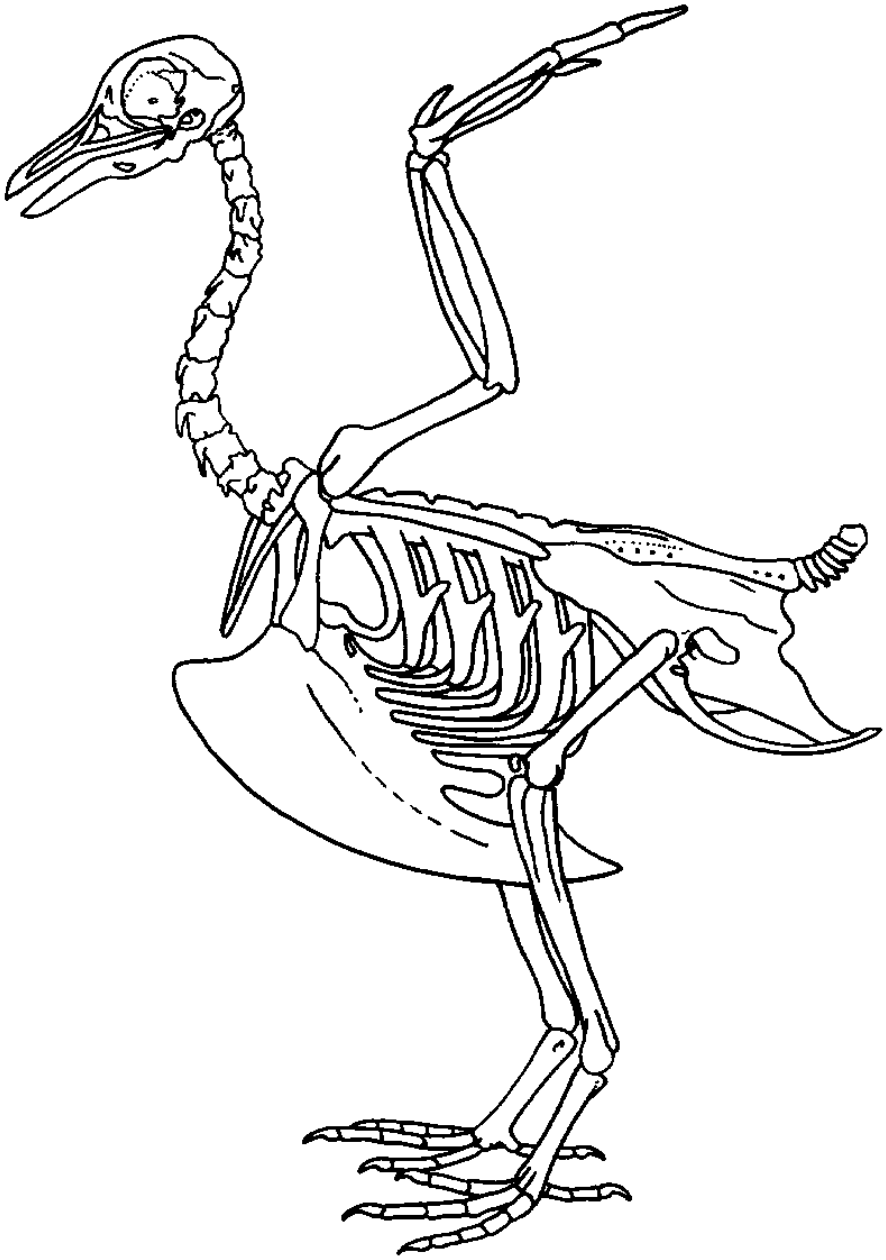


Livingstone, © BIODIDAC

Drawings

Bird skeleton

Kingdom: _____
Phylum: _____
Class: _____
Order: _____



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