Chapter 18: Amniote Origins & Reptilian Groups

Phylum: Chordata

Subphylum: Vertebrata

Class **Reptilia** (~8000 spp.)

Order **Chelonia**: turtles & tortoises

Order **Squamata**: lizards & snakes

Order **Rhynchocephalia** : tuatara

Order **Crocodilia**: crocodiles & alligators

Reptiles

- **Characteristics**
  - **amniotic egg**
    - chorion - outermost membrane
    - allantois - surrounds waste cavity
    - **amnion** - encases embryo
    - yolk sac - surrounds yolk (food)
  - **dry skin**
  - **thoracic breathing**

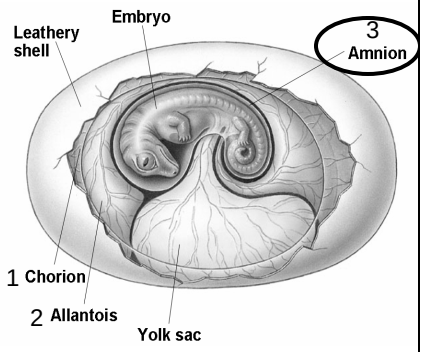
Amniote Origins

amphibians tied to water
- a) lack shelled eggs
- b) often have gill-breathing larvae

monophyletic assemblage called Amniota
named after innermost of three
extraembryonic membranes, **amnion**

before the end of the Paleozoic
amniotes **truly terrestrial**
developed an egg
lungs

Amniotes led to the three vertebrate groups
- a) reptiles
- b) birds
- c) mammals



Diversity

1. **paraphyletic class Reptilia** include the first **truly terrestrial vertebrates**
2. Age of Reptiles lasted over 165 million years & included dinosaurs
3. mass extinction at the end of Mesozoic; modern reptiles represent surviving lineages
4. **Tuatara (living fossil)**, sole survivor of a group that otherwise disappeared 100 mya

New Zealand broke off from Australia 100 mya

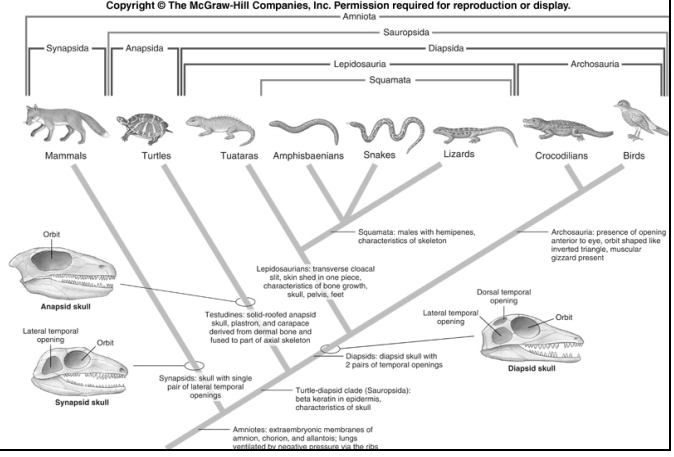
burrowers, nocturnal, eat insects, millipedes, worms
reasons for its survival??

5. lizards & snakes radiated into diverse & abundant groups
6. 300-million-year-old history of reptile life on earth complicated by widespread convergent & parallel evolution among many lineages

Changes in Traditional Classification of Reptilian Groups

1. **Cladistic methodology** insists on hierarchical arrangement of **monophyletic groups**
2. disqualifies traditional **class Reptilia** as a valid taxon because **not monophyletic**
3. **Class Reptilia** excludes birds, which descend from most recent common ancestor of reptiles
4. makes **class Reptilia a paraphyletic group** because does not include all descendants & their most recent common ancestor

5. Reptiles therefore identified as amniotes that are not birds
6. Based solely on shared derived characteristics, crocodilians & birds are sister groups belonging to a monophyletic group apart from other reptiles , the Archosauria
7. Some taxonomists defined Reptilia as the Archosauria plus the lepidosaurs , thus including birds
8. Evolutionary taxonomists argue birds represent a novel adaptive zone & grade of organization; **class Aves** based on morphological & ecological novelty of birds
9. "Reptilian group" refers to members of four monophyletic groups formerly considered class Reptilia



Dentures

Acrodont teeth

1) lower teeth fit into a groove between two rows of upper teeth
2) teeth actually made of bone & fastened to outer surface of jaw bone
3) tuatara & snakes teeth
4) old tuataras often **edentulous** & just eat with their jaw bones,
   like old people: lost their false teeth
   loss of teeth very serious for carnivores, like lions &often a death sentence
   man-eating tigers in India often lost teeth & cannot kill their faster, normal prey
   eating slugs, teeth not essential; so old tuataras survive very well

Plurodont teeth

1) teeth supported by a shelf of bone
2) lizards

Thecodont teeth

1) teeth set in bone
2) crocodiles

Humans? thecodont teeth sitting in sockets

History

1. Amniotes arose from amphibian-like tetrapods (**anthracosaurs)** during Carboniferous

2. By late Carboniferous (~300-280 mya), amniotes had separated into three lineages:

   a. **Anaspids** have skull with no temporal opening behind orbits;
   modern turtles (anaspids)

   b. **Diapsids** gave rise to all other reptilian groups & to birds

      1) diapsid skull two temporal openings; one pair below cheeks & another above

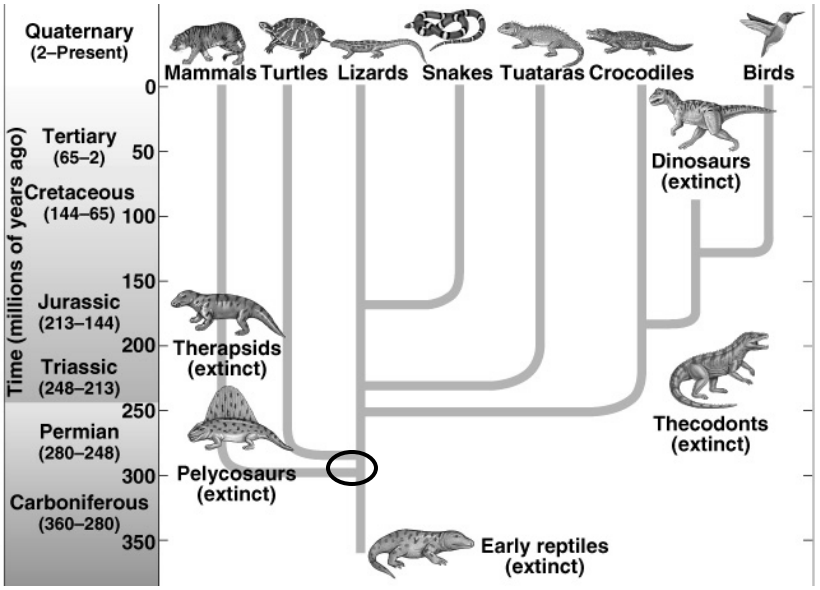
      2) **Lepidosaurs** include ichthyosaurs & modern reptiles
      except for turtles & crocodilians

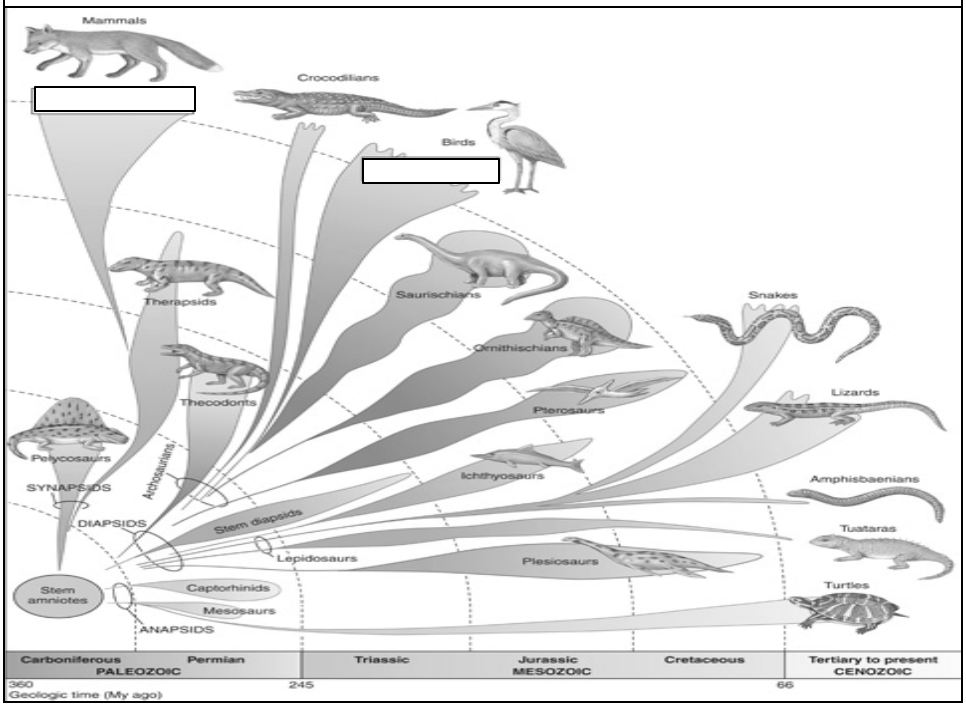
      3) more derived archosaurs included dinosaurs, living crocodilians &birds

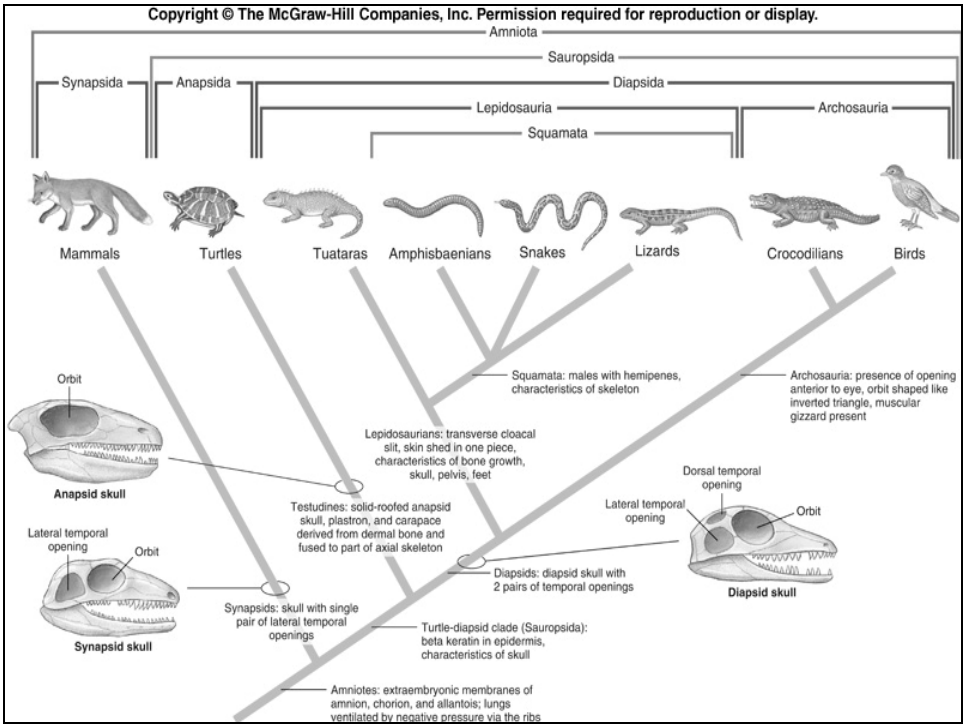
      4) **Sauropterygians** included extinct aquatic groups
      including long-necked plesiosaurs

   c. **Synapsids** mammal-like reptiles with a single pair of temporal openings

Evolutionary Relationships







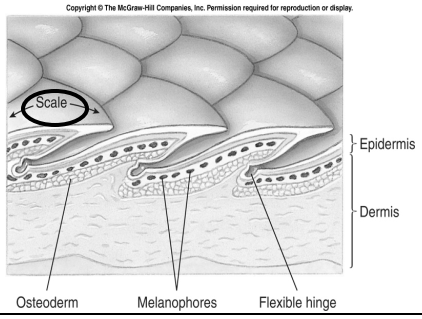
Differences between Reptiles & Amphibians

1. Skin
2. Shelled egg
3. Reptilian jaws
4. Internal fertilization
5. Circulatory system modifications
6. Lungs
7. Water conservation
8. Support of limbs for locomotion
9. Nervous systems

Characteristics Distinguishing Reptiles from Amphibians

A. Skin

1. reptiles have a **tough, dry, scaly skin** that offers protection against desiccation & injury
2. thin epidermis shed periodically
3. thicker, well-developed dermis underneath has **chromatophores** that provide color
4. dermis converted to snakeskin leather for shoes & pocketbooks
5. reptilian scales primarily of keratin, formed from epidermis & not homologous with fish scales **(collagen, salts, enamel)**
6. scales may grow gradually to replace wear, as in alligators
7. snakes & lizards replace old scales with new & "shed their skins"
8. turtles add new layers underneath old layers of platelike scutes



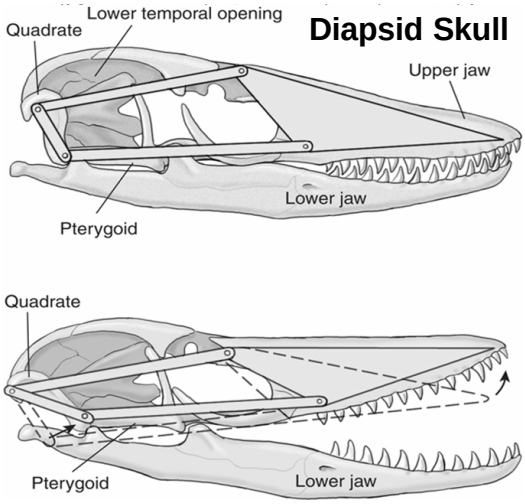
B. Shelled Egg

1. shelled egg **contains food & protective membranes** to support embryonic development on land
2. chorion & allantois exchange CO_2 & O_2 with environment
3. amnion & shell support growing embryo & reduce water loss
4. shelled egg widened the division between evolving amphibians & reptiles

C. Reptilian Jaws

1. jaws of fish allowed fast jaw closure to seize food but little force for chewing

2. reptiles, jaw muscles became larger & **arranged for mechanics of chewing**



D. Internal Fertilization

1. shelled egg requires internal fertilization; sperm must reach egg before it's enclosed

2. reptiles have some form of **copulatory organ,** permitting internal fertilization

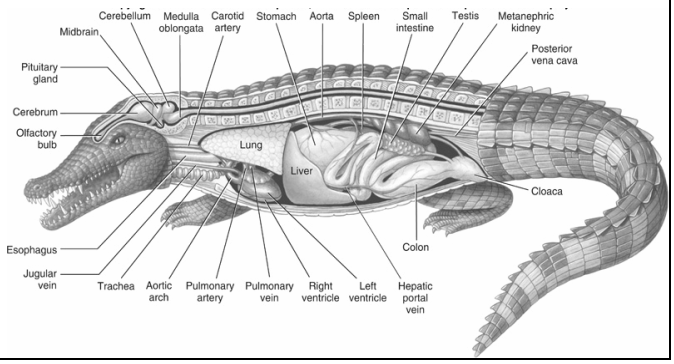
3. paired testes produce sperm carried by **vasa deferentia** to copulatory organ

4. female has **paired ovaries** & oviducts

5. glandular walls of **oviducts secrete albumin & shells** for the relatively large eggs

E. Circulatory System Modifications

1. reptiles have efficient circulatory system & higher blood pressure than amphibians
2. right atrium receives unoxygenated blood completely partitioned from left atrium
3. Crocodilians: **separated ventricles** dividing **pulmonary & systemic circulation**
4. other reptiles: an incompletely separated ventricle but little mixture of blood occurs; two functionally separate circulations
5. incomplete separation between heart sides permits blood to bypass the lungs during diving or aestivation



F. Lungs

1. Reptile lungs better developed than those of amphibians
2. Reptiles depend almost exclusively on lungs for respiration, supplemented by pharyngeal membranes
3. inspiration by enlarging the **thoracic cavity;** some aquatic species use pharynx, cloaca & skin
4. Snakes & lizards: expansion of rib cage; turtles & crocodilians use movement of internal organs to create negative pressure to inhale (i.e., reptiles "**suck**" air into lungs, unlike amphibians, which "**force**" air into lungs)
5. Reptiles **lack diaphragms**

G. Water Conservation

1. all amniotes have **metanephric kidneys** drained by ureter

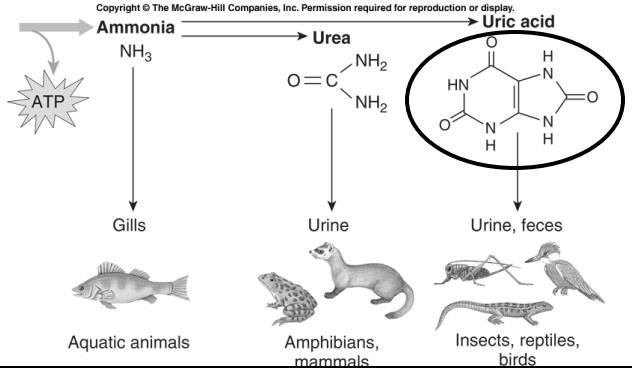
2. nephrons of reptilian metanephros **lack loop of Henle** that allows conc. of solutes

3. many reptiles have **salt glands** near nose or eyes to secrete salty fluid hyperosmotic to body fluids

4. nitrogenous wastes are excreted as **uric acid** rather than urea or ammonia

5. uric acid: **low solubility &** precipitates readily; this allows water to be conserved

Nitrogen Endproducts



H. Support of Limbs for Locomotion

1. except for limbless members, all reptiles have better body support than amphibians

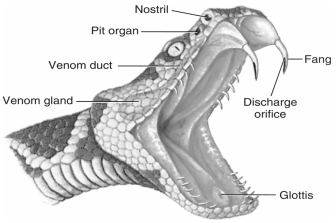
2. many modern reptiles still walk with legs splayed outward & belly close to ground

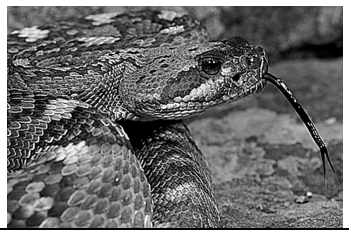
3. most dinosaurs & some modern lizards have >efficient legs directed beneath body

4. **bipedal locomotion:** superior to quadrupedal locomotion if speed & better support of body is required

I. Nervous System

1. reptilian nervous system considerably **more complex** than amphibian
2. reptile brain: still small but **cerebrum** relatively larger
3. sense organs generally well-developed, except for hearing
4. **Jacobson's organ**: highly developed in lizards & snakes to detect odors carried by tongue

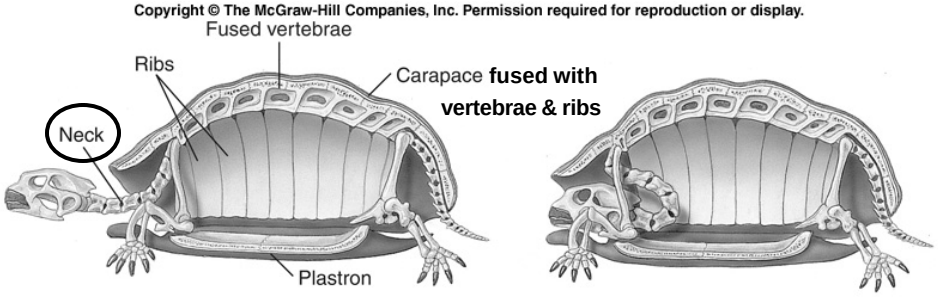




Anapsid Reptiles: Subclass Anapsida

Order Chelonia (Testudines): turtles

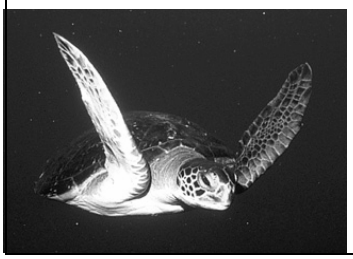
1. descended from one of earliest anapsid lineages: probably late Permian (248 mya)
2. fossils appear in Upper Triassic, 200 mya & have occurred ever since
3. shells consist of **dorsal carapace** & **ventral plastron**
4. bony layer: fusion of ribs, vertebrae & **dermally-ossified** elements –> the shell
5. shell offers protection for head & appendages
6. **lack teeth** & have tough, horny plates for gripping food



7. **Breathing**
   a. rigid shell prohibits turtle from **expanding its chest** to breathe
   b. use abdominal & pectoral muscles as a "**diaphragm**"
   c. air drawn in by contraction of limb flank muscles, increasing abdominal cavity volume
   d. exhalation accomplished by drawing back shoulder girdle to compress viscera

8. **Nervous System & Senses**
   a. middle & an inner ear but **sound perception poor**; make few sounds aside from during mating
   b. good sense of **smell**, **acute vision** & **color perception** about equal to humans

9. **Giant Turtles**
   a. buoyed by water, marine turtles may reach 2 m long & weigh 725 kg
   b. giant land tortoises, (Galápagos Islands), weigh several hundred kg
   c. low metabolic activity may explain their longevity >150 years



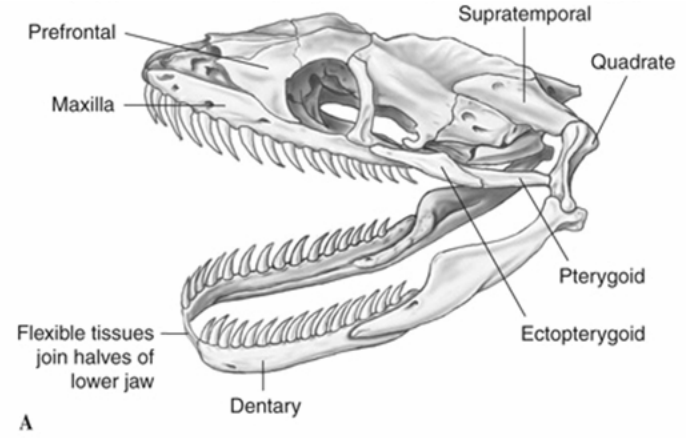
10. **Reproduction & Development**
    a. **oviparous**; **fertilization internal** & all turtles bury their eggs in ground
    b. some turtle families, as in crocodilians & some lizards, nest temperature determines sex of hatchlings
       low temperatures: male offspring
       high temperatures: female offspring

Diapsid Reptiles: Subclass Diapsida

1. Superorders:
   a. Lepidosauria – lizards, snakes, worm lizards & *Sphenodon*
   b. Archosauria – crocodilians (& birds in classic taxonomy)

2. **Order Squamata**: 3 lineages: lizards, snakes & worm lizards
   a. **squamates** most recent & diverse of diapsids; **95% of living reptiles**
   b. lizards in fossil record Permian (248 mya) but did not radiate until Cretaceous (144-65 mya)
   c. snakes Jurassic (213-144 mya) from descendants include monitor lizards
   d. snakes gained specializations for losing legs & engulfing large prey
   e. **amphisbaenians** probably evolved from lizards & specialized for burrowing

   f. **diapsid** skulls lost dermal bone ventral & posterior to lower temporal opening
      1) evolution in lizards of a mobile skull with movable joints, a **kinetic skull**
      2) quadrate, fused to skull in other reptiles, has a joint at the dorsal end & articulates with lower jaw
      3) joints in palate & across roof of skull permit snout to be tilted up
      4) squamates seize & manipulate prey; close jaw with force
      5) exceptional skull mobility of snakes considered major factor in their diversification



g. **Viviparity**
1) limited to squamates
2) evolved at least 100 separate times
3) associated with cold climates
4) involves increasing length of time eggs kept in oviduct
5) developing young respire through extraembryonic membranes
6) young obtain nutrition from yolk sacs or via mother, or a combination of both

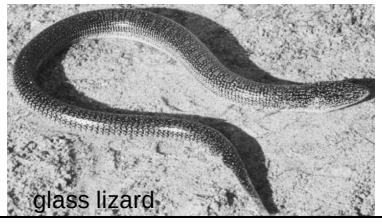
3. **Lizards: Suborder Sauria**
a. diverse group with terrestrial, burrowing, aquatic, arboreal, & some aerial
1) **geckos** small, agile, nocturnal forms; adhesive toe pads with extremely fine filaments that allow them to walk on ceilings
2) iguanids include many New World lizards & Galápagos marine iguana
3) chameleons arboreal lizards of Africa & Madagascar; many have an extendible tongue
4) **skinks**: elongate bodies & reduced limbs
5) **glass lizards** nearly limbless (degenerate limbs)


gecko

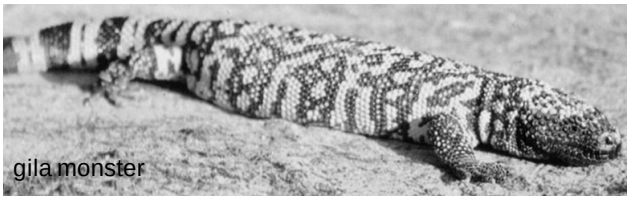

chameleon


skink


Galápagos marine iguana


glass lizard

b. lizards: movable eyelids; whereas snakes have a transparent covering
c. nocturnal geckos: retinas with only rods; day-active lizards: both rods & cones
d. lizards have an external ear that snakes lack
e. geckos use vocal signals to announce territory & drive away males
f. some lizards survive well in hot & dry regions
   1) conserve water by producing crystalline **uric acid**
   2) water loss minimized with lipids in thick skin
   3) store fat in their tails to provide energy & metabolic water during drought
g. gila monster & beaded lizard the only capable of a venomous bite
h. **ectothermic**, few live in cold climates
   1) **ectotherms** use less energy than **endotherms**; survive in habitats with low productivity & warm climates such as tropical deserts & grasslands
   2) **ectotherm** not an inferior characteristic but a successful environmental coping strategy
   3) keep body temperature relatively constant by behavioral thermoregulation


gila monster

4. **worm lizards : Suborder Amphisbaenia**
   a. highly specialized burrowing forms that are not true lizards
   b. generally lack any trace of external limbs; eyes & ears hidden under the skin
   c. skin divided into numerous rings resembling earthworms
   d. one species occurs in Florida but most live in South America & tropical Africa

6. Snakes: Suborder Serpentes

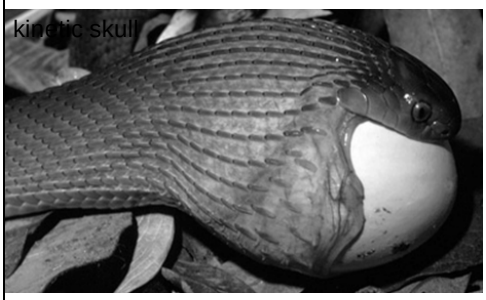
a. **limbless** & lost pectoral & pelvic girdles (except vestigial structures in pythons)
   1) many vertebrae shorter & wider than in other tetrapods, allowing undulation
   2) ribs increase vertebral column rigidity improving resistance to lateral stress
   3) elevation of the neural spine gives the musculature more leverage

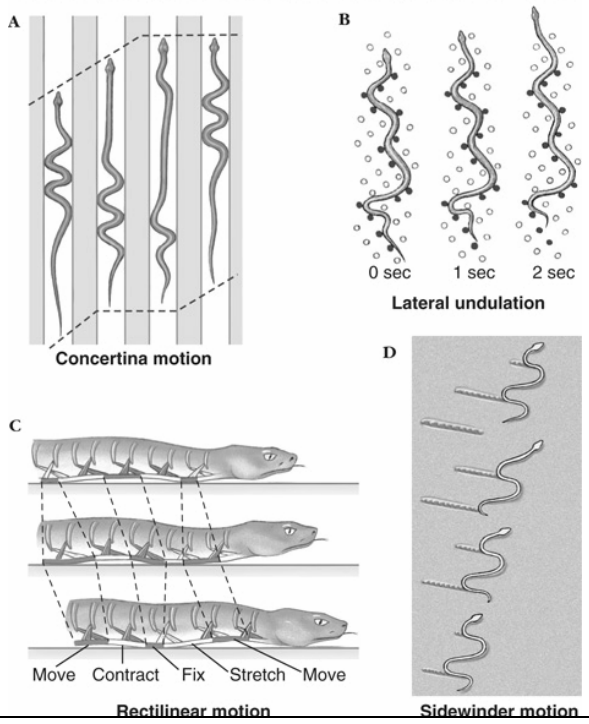
b. feeding apparatus allows them to eat prey several times their own diameter
   1) two halves of the lower jaw are loosely joined, allowing them to spread apart
   2) skull bones loosely articulated so the mouth can accommodate large prey

c. eyeballs reduced mobility & a permanent corneal membrane for protection

d. most snakes: **poor vision;** tropical arboreal snakes have highly developed vision

e. lack external ears but respond to low frequency vibrations & ground vibrations

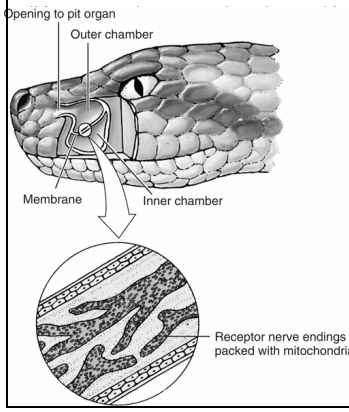




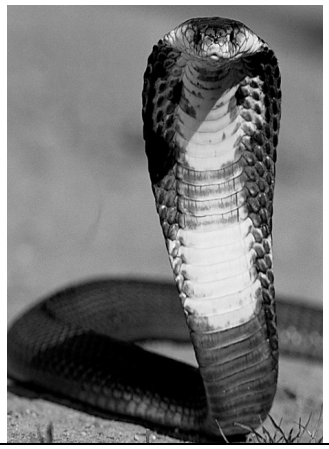
f. chemical senses rather than vision or hearing, main senses to hunt prey

g. **Jacobson's organs**: pair of pits in the roof of mouth
   1) lined with olfactory epithelium
   2) **forked tongue** picks up scent particles & conveys them past this organ

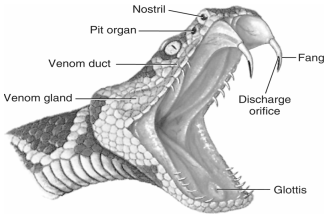
h. Many snakes swallow prey alive
   1) smaller prey may cause less injury due to struggles
   2) prey include worms, insects, frogs & small mammals
   3) some locate prey by actively foraging
   4) constrictors often feed on larger mammals using ambush tactics
   5) muscle arrangements in constrictors reduce their travel speeds



i. V**enomous Snakes**
   1) < 20% venomous except in Australia
   2) divided into five families
      a) family Viperidae: New World & Old World vipers with & without pits
      b) family Elapidae: cobras, mambas, coral snakes & kraits
      c) family Hydrophiidae: highly venomous sea snakes
      d) family Atractaspididae: fossorial mole vipers
      e) family Colubridae: non-venomous; several including the African twig & African boomslang: rear-fanged & bite can be fatal to humans



k. **Pit vipers,** e.g. rattlesnakes, **"pits"** with nerve endings sensitive to heat emitted by warm-bodied birds & mammals
1) viper fangs: hollow & hinged to inject venom when snake striking prey
2) average 8,000 bites/yr in U.S.: only 5-10 deaths
3) pair of modified teeth on maxillary bones serves as fangs
4) fangs become erect during a strike; venom injected through their canals
5) prey paralyzed or die after bite then swallowed whole by viper

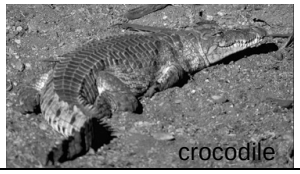


l. **Snakebite & Toxicity**
1) saliva of harmless spp. limited toxins → basis for natural selection of venom
2) most **venoms** a complex combination of venom types
3) n**eurotoxins:** act on nervous system → blindness or stopping respiration
4) **hemorrhagin:** breaks down blood vessels &red blood cells; much blood is leaked into tissue spaces
5) sea snakes & Australian tiger snake: most deadly venom per unit
6) large venomous spp. deliver > venom; king cobra may be most dangerous
7) India, Pakistan & nearby countries, dense human populations with poor footwear & delayed medical care contributes to most snakebite deaths
8) worldwide, ~50,000-60,000 persons die annually from snakebites

m. **Reproduction**
1) most **oviparous** & lay shelled eggs under logs, rocks or in ground holes
2) others, including pit vipers: **ovoviviparous** (egg hatches internally to facilitate a live birth)
3) few: **viviparous**, a primitive "placenta" exchange nutrients with young

7. T**uatara: Order Sphenodonta**
   a. only 2 living species in New Zealand represent this ancient lineage
   b. sphenodontids radiated modestly in the early Mesozoic but then declined
   c. once widespread across New Zealand, 2 species restricted to small islands
   d. lizard-like & live in burrows often shared with petrels
   e. slow growing & may live to 77 years of age
   f. skull nearly identical to diapsid skulls of 200 million years ago
   g. well-developed median parietal eye buried beneath skin, function unknown
   h. *Sphenodon:* one of the slowest rates of evolution known among vertebrates

8. **Order Crocodilia: Crocodiles & Alligators**
   a. modern crocodilians only surviving reptiles of the **archosaurian lineage**
   b. lineage gave rise to Mesozoic radiation of dinosaurs & to birds
   c. modern crocodilians differ little from primitive crocs of early Mesozoic
   d. modern crocodilians classified in three families
      1) **alligators & caimans**: primarily in New World; a broader snout
      2) c**rocodiles:** widely distributed & include huge saltwater crocodile
      3) **gavials: 1** sp in India & Burma; very narrow snout
   e. all have a long, well-reinforced skull & jaw musculature for powerful bite
   f. teeth set in sockets typical of archosaurs & earliest birds
   g. complete secondary palate, a feature only shared with mammals
   h. share a **four-chambered heart** with birds & mammals
   i. estuarine crocodile in southern Asia & Nile crocodile: both very large
   j. crocodiles may attack cattle, deer, & people; alligators less aggressive
   k. alligators & crocodiles: **oviparous**; usually 20-50 eggs laid in a vegetation
      1) alligators emit loud bellows during mating season
      2) females of guard their eggs then open nest sites when young hatch
      3) nests left unguarded easily discovered & raided by predators
      4) high nest temperatures →males; low temperatures → females



MAIN DIFFERENCES BETWEEN CROCODILES AND ALLIGATORS

CROCODILES	ALLIGATORS
- tropical	- subtropical
- do not hibernate	- hibernate
- males grow to 19 feet or more	- males grow to 14 feet
- more aggressive	- more docile
- have pointed snout	- have rounded snout
- show more teeth when mouth is closed	- show fewer teeth when the mouth closed
- live in brackish, salty water	- live in fresh water
- adults: light tan to brown	- adults: grayish black
- belly button scars heal	- have belly button scars
- have ISOs* all over (including belly skin)	- have ISOs* around mouth only
- have functioning salt glands on tongues	- do not secrete salt from tongues
- nests in mud/sand in brackish (salt) water	- nests out of vegetation in fresh water

*ISOs integumentary sense organs
- both crocodiles & alligators have small, sensory pits around upper & lower jaws
- ISO capable of detecting small pressure changes in H_2O, & assist in locating/capturing prey