Chapter 26: Amniote Origins & Reptilian Groups

Phylum: Chordata

Subphylum: Vertebrata

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

Order **Chelonia**: turtles & tortoises

Order **Squamata**: lizards & snakes

Order **Rhynchocephalia** : tuatara

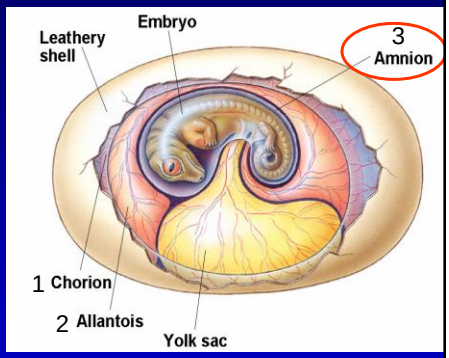
Order **Crocodilia**: crocodiles & alligators

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

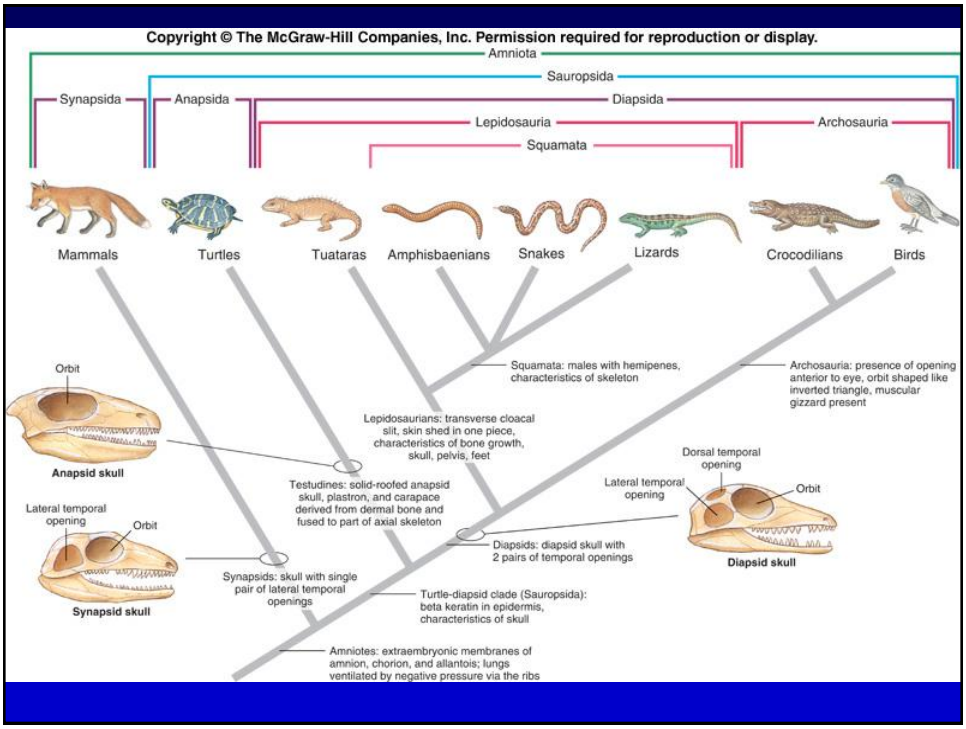
1. **paraphyletic class Reptilia** include first **truly terrestrial vertebrates**
2. Age of Reptiles: >165 million years & included dinosaurs
3. mass extinction at the end of Mesozoic; modern reptiles represent surviving lineages
4. **Tuatara (living fossil)**, sole survivor of a group that disappeared 100 mya: New Zealand broke from Australia 100 mya
   burrowers, nocturnal, eat insects, millipedes, worms
   reasons for its survival??

5. lizards & snakes radiated into diverse & abundant groups
6. 300 my 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 descended 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** sister groups belonging to a monophyletic group apart from other reptiles, the **Archosauria**
7. Some taxonomists defined **Reptilia** as **Archosauria** + **lepidosaurs**, thus including birds
8. Evolutionary taxonomists argue birds represent a novel adaptive zone & grade of organization; **class Aves** based morphological & ecological novelty of birds
9. "Reptilian group" refers to members of four monophyletic groups formerly considered class **Reptilia**



Dentures

1. Acrodont teeth

1) lower teeth fit into a groove between two rows of upper teeth
2) teeth made of bone & fastened to outer surface of jaw bone
3) tuatara & snakes teeth
4) old tuataras often **edentulous**: eat with 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 loss teeth & cannot
kill their faster, normal prey
old tuataras survive very well - eating slugs, teeth not essential

2. Plurodont teeth

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

3. Thecodont teeth

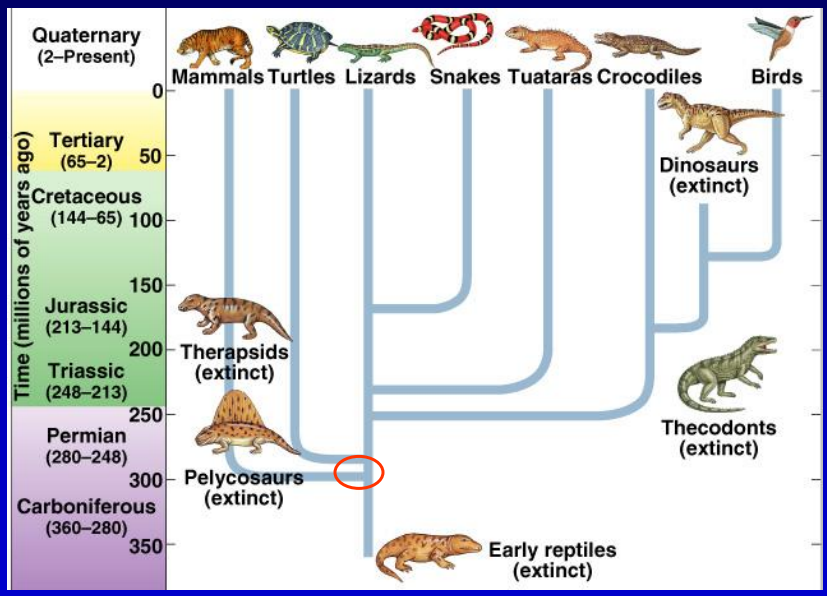
1) teeth set in bone
2) crocodiles

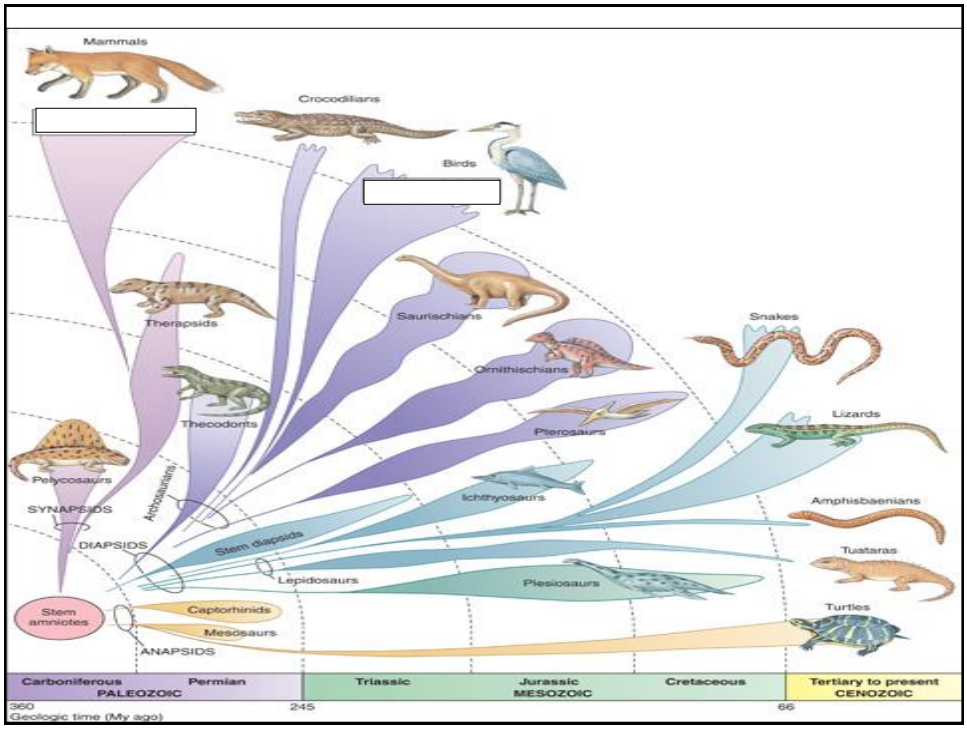
Humans? thecodont teeth sitting in sockets

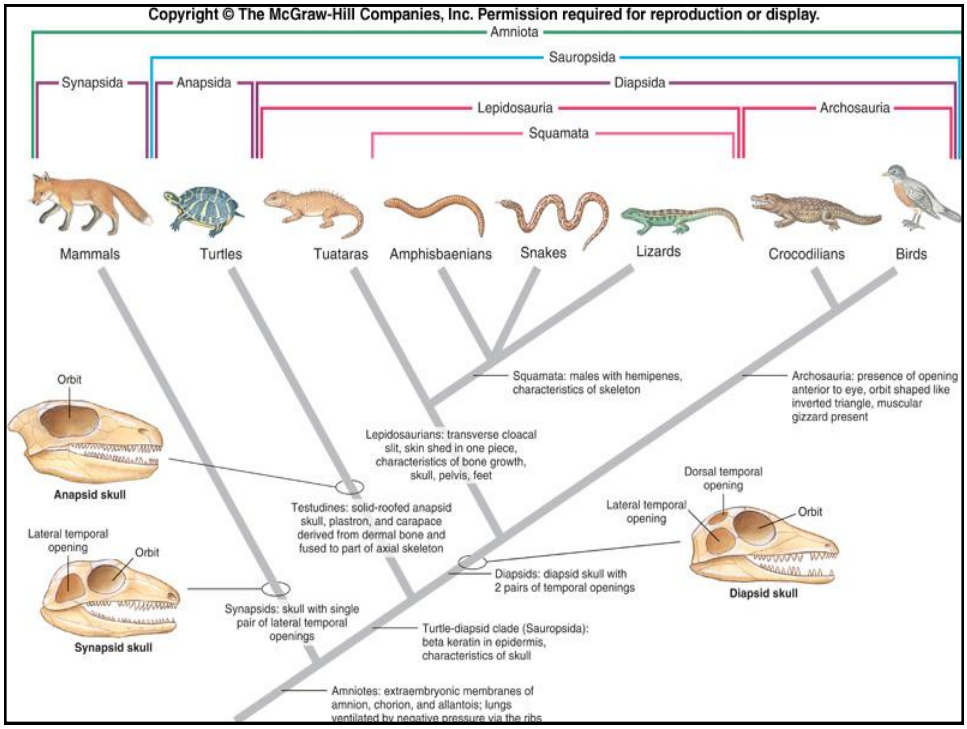
History

1. Amniotes arose from amphibian-like tetrapods (**anthracosaurs**) during Carboniferous
2. Late Carboniferous (~300-280 mya), amniotes: separated into 3 lineages:
   a. **Anaspids**: skull with **no temporal opening** behind orbits; modern turtles (anaspids)
   b. **Diapsids** skull with **two temporal openings** one pair below cheeks & another above
      1) diapsids gave rise to all other reptilian groups & to birds
      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 **single pair of temporal openings**

Evolutionary Relationships







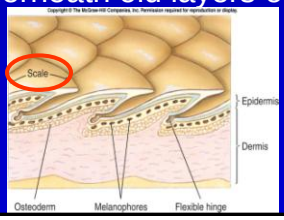
Differences between Reptiles & Amphibians

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: **tough, dry, scaly skin**:
   offers protection against desiccation & injury
2. thin epidermis shed periodically
3. thicker, well-developed dermis underneath has **chromatophores** providing color
4. dermis: snakeskin leather for shoes & pocketbooks
5. Reptile scales primarily of keratin, formed from epidermis & not homologous with fish **scales**
6. Scales grow gradually to replace wear, as in alligators
7. Snakes/lizards replace old with new scales & "shed skins"
8. Turtles: new layers underneath old layers of platelike scutes

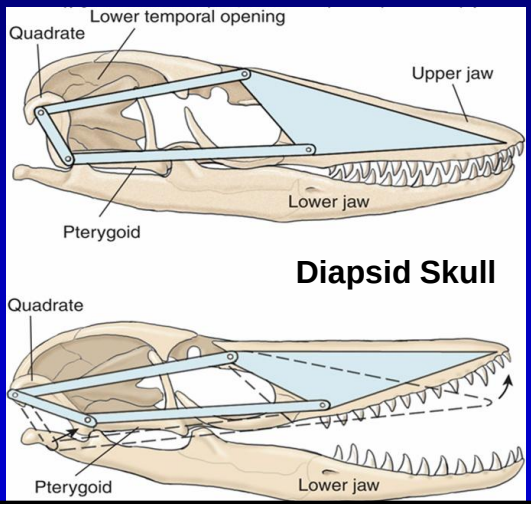


B. Shelled Egg

1. shelled egg **contains food & protective membranes:**
   support embryonic development on land
2. chorion & allantois exchange CO_2 & O_2 with environment
3. amnion & shell support growing embryo & ↓ H_2O loss
4. shelled egg widened 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

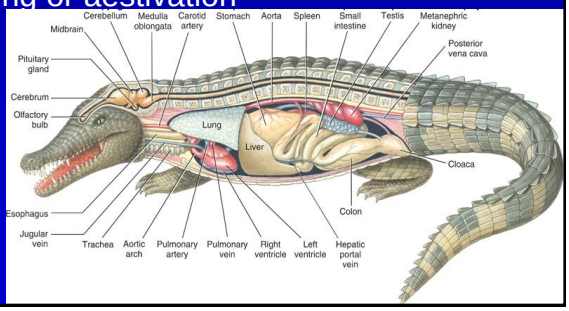
3. paired testes produce sperm carried by **vasa deferentia** to copulatory organ

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

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

E. Circulatory System Modifications

1. reptiles 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: incompletely separated ventricle but little mixture of blood occurs; two functionally separate circulations
5. incomplete separation between heart sides permits blood to bypass lungs during diving or aestivation



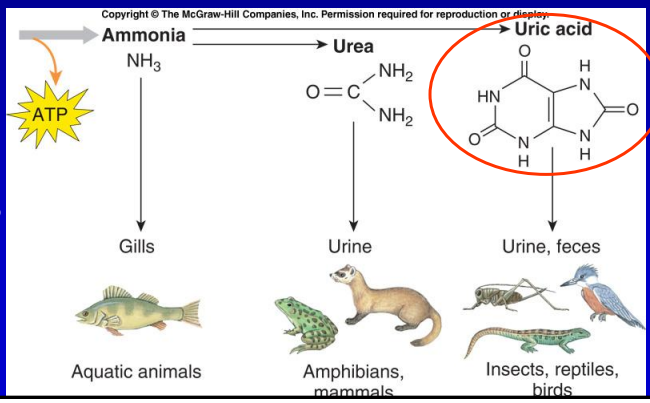
F. Lungs

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: **salt glands** near nose or eyes to secrete salty fluid **hyperosmotic** to body fluids
4. nitrogenous excreted as **uric acid** rather than urea or NH_3
5. uric acid: **low solubility &** precipitates readily; H_2O conserved

Nitrogen Endproducts

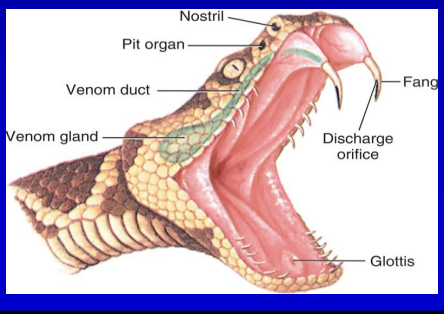


H. Support of Limbs for Locomotion

1. except for limbless members, all reptiles 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 >efficient legs directed beneath body
4. **bipedal locomotion:** superior to quadrupedal locomotion if speed & better support of body required

I. Nervous System

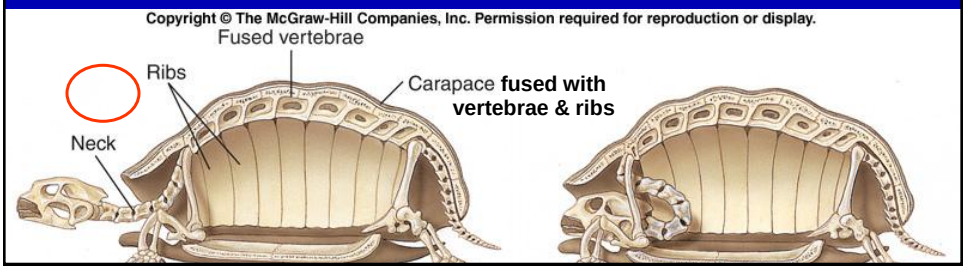
1. reptilian nervous system **more complex** than amphibian
2. reptile brain: still small but **cerebrum** relatively larger
3. sense organs generally well developed, except for hearing
4. **Jacobson's organ**: highly developed in lizards & snakes to detect odors carried by tongue



Anapsid Reptiles: Subclass Anapsida

Order Chelonia (Testudines): turtles

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



7. **Breathing**
   a. rigid shell prohibits turtle **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: 2 m long & weigh 725 kg
   b. giant land tortoises, (Galápagos Islands), several 100 kg
   c. low metabolic activity: their longevity >150 years



10. **Reproduction & Development**
    a. **oviparous**; **fertilization internal**
        & all turtles bury 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

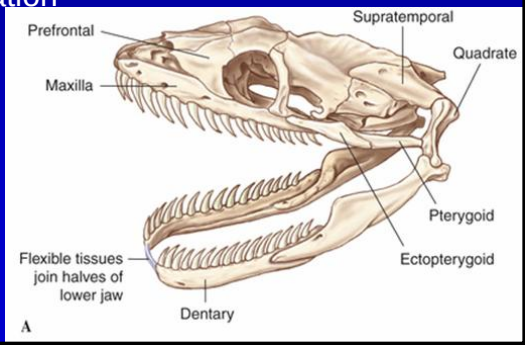
Diapsid Reptiles: Subclass Diapsida

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, joint at dorsal end & articulates with lower jaw
3) joints in palate & across roof of skull permit tilted up snout
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: terrestrial, burrowing, aquatic, arboreal, & aerial

1) **geckos** small, agile, nocturnal forms;
adhesive toe pads with fine filaments walk on ceilings

2) **iguanids:** New World lizards & Galápagos marine iguana

3) **chameleons** arboreal lizards of Africa & Madagascar;
extendible tongue

4) **skinks**: elongate bodies & reduced limbs

5) **glass lizards** nearly limbless (degenerate limbs)


gecko


chameleon


Galápagos marine iguana


glass lizard


skink

b. lizards: movable eyelids; snakes: transparent covering

c. **nocturnal** geckos: retinas with only rods;
day-active lizards: both rods & cones

d. lizards: an external ear: snakes lack

e. geckos: vocal signals for territoriality & drive away males

f. some lizards survive well in hot & dry regions

1) conserve water: produce crystalline **uric acid**

2) water loss minimized with lipids in thick skin

3) store fat in tails: energy & metabolic H_2O during drought

g. gila monster & beaded lizard 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
         e.g. (tropical deserts & grasslands)
   2) **ectotherm** not an inferior characteristic;
         but successful environmental coping strategy
   3) **behavioral thermoregulation:** constant body temp


gila monster

4. worm lizards: Suborder Amphisbaenia
   a. highly specialized burrowing forms, not true lizards
   b. generally lack any trace of external limbs;
      eyes & ears hidden under 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 neural spine → musculature more leverage

b. feeding apparatus →ingestion prey several X their own diam
1) two halves lower jaw loosely joined, allowing them to spread apart
2) skull bones loosely articulated so mouth can accommodate large prey

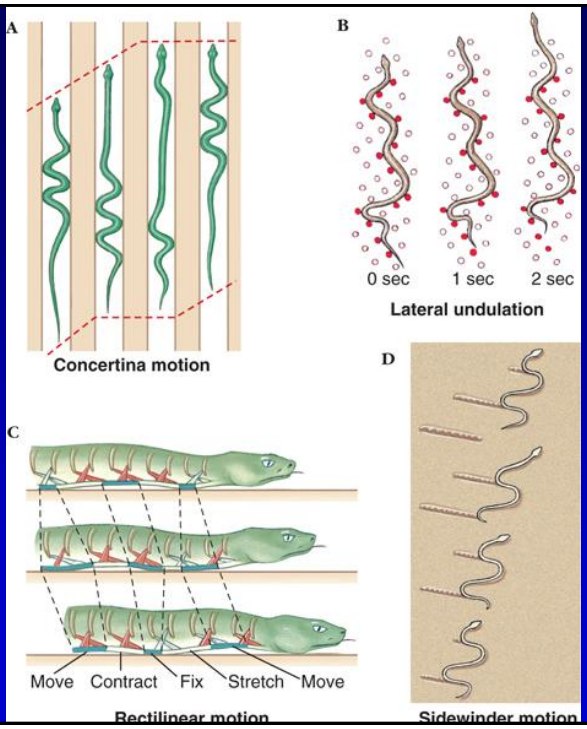
c. eyeballs reduced mobility with permanent corneal membrane for protection

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

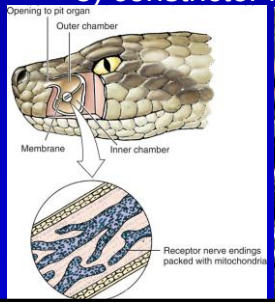
e. lack external ears but respond to low frequency vibrations & ground vibrations

kinetic skull

parrot snake Central America



f. **chemical senses** not vision/hearing, to hunt prey
g. **Jacobson's organs**: pair of pits in 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 by ambushing
  5) constrictor muscle arrangements reduce travel speeds

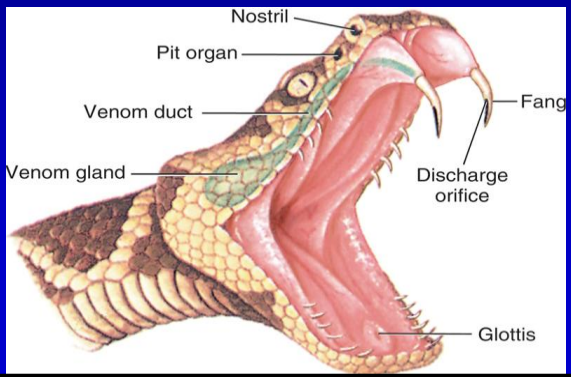


i. **Venomous Snakes**

1) < 20% venomous except in Australia
2) divided into five families
   a) family Viperidae: New/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 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 inject venom striking prey
2) average 8,000 bites/yr in U.S.: ~5-10 deaths/yr
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/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:** destroy blood vessels & red blood cells; much blood leaked into tissue spaces
5) sea snakes & Australian tiger snake: most deadly venom/unit
6) large venomous spp. deliver > venom; king cobra may be most dangerous
7) India, Pakistan & nearby countries:dense human populations with poor footwear & medical care→ snakebite deaths
8) worldwide, ~50,000-60,000 deaths/yr 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. Tuatara: Order Sphenodonta

a. only 2 living species in New Zealand represent this ancient lineage

b. sphenodontids radiated modestly in 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 mya

g. well-developed **median parietal eye** buried beneath skin, function unknown

h. *Sphenodon:* slowest rate of evolution among vertebrates

8. **Order Crocodilia: Crocodiles & Alligators**

a. modern crocodilians only surviving reptiles of **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) **crocodiles:** 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 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

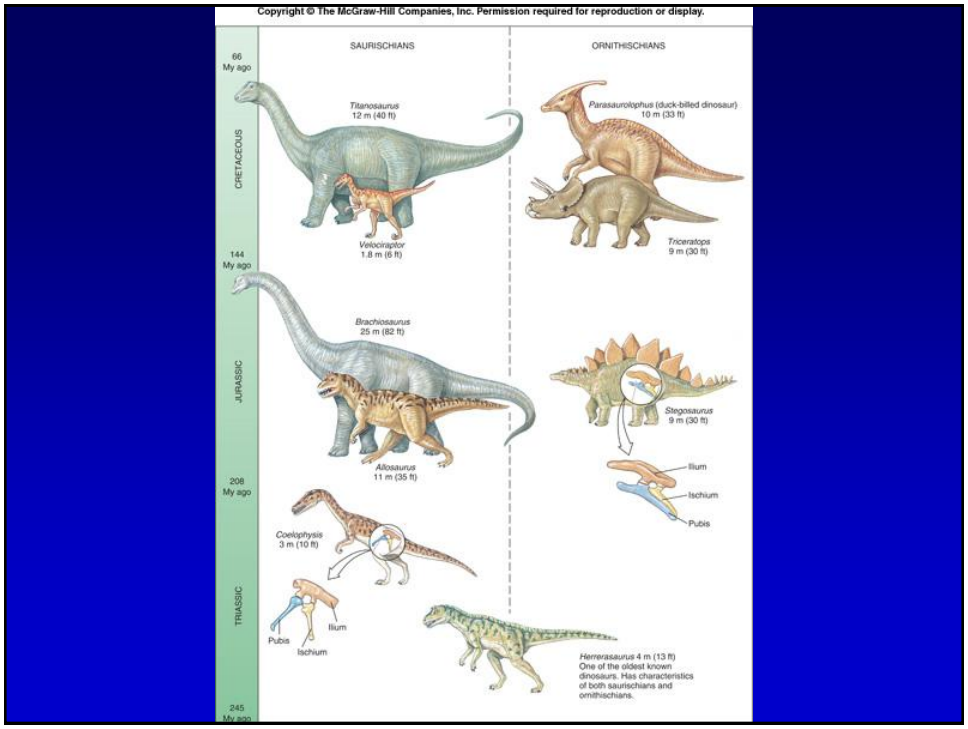

crocodile


alligator

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
- are more aggressive	- are more docile
- have pointed snout	- have rounded snout
- show more teeth when the mouth is closed live in brackish, salty water	- show fewer teeth when the mouth is closed
- adults are light tan to brown	- live in fresh water
- the belly button scars heal	- adults are grayish black
- have ISOs all over (including belly skin)	- have belly button scars
- have functioning salt glands on their tongues	- have ISOs* around mouth only
- lay nests in mud or sand in brackish (salt) water	- do not secrete salt from their tongues
	- make nests out of vegetation in fresh water

***ISOs integumentary sense organs**
Both crocodiles and alligators have small, sensory pits around the upper and lower jaws
ISO capable of detecting small pressure changes in H_2O, &assist in locating & capturing prey
Crocodiles have similar organs covering virtually every scale on their body,
but alligators & caimans have none except those around the jaws.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SAURISCHIANS
ORNITHISCHIANS
66 My ago
144 My ago
208 My ago
245 My ago
CRETACEOUS
JURASSIC
TRIASSIC
Titanosaurus 12 m (40 ft)
Velociraptor 1.8 m (6 ft)
Parasaurolophus (duck-billed dinosaur) 10 m (33 ft)
Triceratops 9 m (30 ft)
Brachiosaurus 25 m (82 ft)
Allosaurus 11 m (35 ft)
Stegosaurus 9 m (30 ft)
Ilium
Ischium
Pubis
Coelophysis 3 m (10 ft)
Pubis
Ilium
Ischium
Herrerasaurus 4 m (13 ft) One of the oldest known dinosaurs. Has characteristics of both saurischians and ornithischians.