

GEOL 104 Dinosaurs: A Natural History
Test II Review Sheet

Review Test I, and be sure that you remember:

- The basics of geologic time
- Evolution and evolutionary patterns
- Tree-based thinking: be able to read a cladogram, and think in terms of evolving lineages

Colonization of Land and Life on Land Before the Dinosaurs

Hazards of living on land relative to the water

Features exapted from marine animals for life on land: bony internal skeleton; limbs with wrists/ankles and digits to support weight; lungs to breath air; scales & mucous to prevent desiccation

New features: necks; claws; amniotic egg

Radiations of the **Amniota**:

Late Carboniferous – Early Permian:	Basal synapsids
Middle Permian – Early Triassic:	Therapsid synapsids
Middle Triassic – Late Triassic:	Crurotarsan archosaurs
Jurassic – Cretaceous:	Dinosaurs

Features of each group that made them successful in their time

Permo-Triassic Extinctions

Carrier's Constraint on breathing and locomotion, and how archosaurs (and within archosaurs, dinosauiromorphs) got around it!

Ornithodira :	Elongate tibiae and metatarsi; bird-like necks
Dinosauiromorpha :	Parasagittal stance, digitigrade posture (striding locomotion)
Silesauridae	Dinosauria's sister-taxon; herbivorous quadrupeds

Diversity of the Dinosauria

Be familiar with the lifestyle, major adaptations and their functions, and relationships of the following groups:

The base of **Dinosauria**: Small obligate bipeds of the Late Triassic, with perforated acetabula and hands with semiopposable thumbs and reduced digits IV & V. Divisions into **Ornithischia** and **Saurischia**.

Basal ornithischians: Small obligate bipeds with specializations for herbivory (predeantary bone; leaf-shaped teeth; cheeks; backwards-pointing pubis (after *Pisanosaurus*)); epaxial ossified tendons. Early representatives include **Pisanosaurus**, **Heterodontosauridae** (with ornithopod-like jaws and deep skulls), and *Eocursor*: all of these retained big grasping hands. Later ornithischians divided into Thyreophora and the neornithischians (small obligate bipeds that themselves evolved into Ornithopoda and Marginocephalia)

Thyreophora: Ornithischians with osteoderms as protection; as the dinosaurs became bigger and more heavily armored, shifted to obligate quadrupedality. Advanced thyreophorans split into **Stegosauria** and **Ankylosauria**. Stegosaurus emphasized active defense, with plates, spikes, and the thagomizer: their heyday was the Middle and Late Jurassic. Ankylosaurs emphasized passive defense, with osteoderms fused to the skull, heavy rings of armor on the neck and shoulders, and in general lots of osteoderms over the body. In the **Ankylosauridae** evolution of active defense in the form of tail clubs. Ankylosaurs heyday was the Cretaceous.

Ornithopoda: Evolution of the pleuokinetic hinge and a specialized bite (premaxilla margin below maxillary tooth row and jaw joint below dentary tooth row) to increase chewing ability. Primitive ornithopods relatively small unspecialized bipeds (although at least some burrowed); the more derived **iguanodontians** were typically larger, and many were facultative bipeds. Among Iguanodontia, the **Styracosterna** were the largest, and evolved the Swiss Army Hand (spike thumb; metacarpals II-IV weight bearing supporting hoof-like unguals; opposable pinky). The most advanced styracosternans (and thus most advanced ornithopods) were the **Hadrosauridae** (duckbills), with expanded bills and a grinding dental battery (and no thumb). The diverse hadrosaurids divide into the hollow-crested **Lambeosaurinae** and the broad-billed **Saurolophinae**.

Marginocephalia: Had ridge extending posterior over back of skull. **Pachycephalosauria** were strictly bipedal, with thickened skull roofs eventually evolving into head-banging domes. **Ceratopsia** began as small bipedal

herbivores with a rostral bone; neoceratopsians added the frill to increase the size of their jaw muscles. More advanced **Neoceratopsia** had even larger frill (for display), and became obligate quadrupeds. The most advanced evolved horns: first the postorbital (brow) horns, and then (among the **Ceratopsidae**) the nasal horn. Ceratopsids also evolved the shearing dental battery, and much larger size than all marginocephalians. Among ceratopsids were the deep-snouted **Centrosaurinae** with a pair of spikes sticking out of the frill, and the long-snouted **Chasmosaurinae** with long frills and an enlarged rostral bone.

Basal saurischians: Specialized joints between vertebrae; had pleurocoels (hollow air sac chambers in their vertebrae), elongate necks, and modified hands with large thumb claws and long index fingers. Saurischians split into the herbivorous sauropodomorphs and the carnivorous theropods.

Sauropodomorpha; Characterized ancestrally by small skull size and leaf-shaped teeth with large denticles. The “**core prosauropods**” evolved larger size, proportionately even smaller heads and longer necks, and possibly cheeks. These in turn evolved into the “near-sauropods”: larger still, and quadrupedal. Actual **Sauropoda** had rounder snouts, and the **Eusauropoda** had even larger size and tooth-to-tooth occlusion. Eusauropod had hands that formed a horse-shoe curve and feet supported by large fleshy pads. Eusauropods lose the cheeks and gain a wider gape, allowing for “bulk-browsing”. Eusauropods also had highly complex airsac chambers. Among the eusauropods the most specialized forms were the diverse **Neosauropoda**. Neosauropods include the long-skulled pencil-toothed **Diplodocoidea** and the big-nosed **Macronaria**. The diplodocoids included the **Rebbachisauridae** (with their grazing/gnawing dental battery), the short-necked **Dicraeosauridae**, and the enormous long-necked whip-tailed **Diplodocidae** (which, because their forelimbs were much shorter than their hindlimbs, could probably rear up to feed very high in the trees). Among the more specialized macronarians were the enormous **Brachiosauridae** (with very long forelimbs, so that they were built uphill) and the diverse wide-bodied **Titanosauria** (which included the largest of all dinosaurs, as well as the armored but smaller **Lithostrotia**).

Theropoda: Early theropods were long and slender, and evolved the promaxillary fenestra, grasping claws, and the intramandibular joint (for dealing with struggling prey in the jaws). Basal theropods of the Triassic include the **Herrerasauria**, **Eoraptor**, and **Tawa**. The later theropods form **Neotheropoda**, and are characterized by the furcula (as a brace for stresses on the forelimb), an elongate ilium, loss of manual digit V, and a functionally tridactyl (three-toed) foot. Early theropods included **Coelophysidae** and **Dilophosauridae**. After the Triassic/Jurassic extinction, theropod size and relative tooth size increases. Derived theropods (Averostra) included the short-armed **Ceratosauria** (which in particular included the long-legged toothless “**elaphrosaurs**”, small digging **Noosauridae**, and powerful skulled, stump-armed **Abelisauridae** (the top predators of Late Cretaceous Gondwana)) and the stiff-tailed big-handed **Tetanurae**. Basal tetanurine groups included long-faced **Megalosauroidae** (most especially the conical-toothed gigantic fish-eating **Spinosauridae**) and the **Carnosauria** (which combined deep skulls with blade-like teeth and powerful gripping arms). Basal theropods up through Carnosauria used a “slice-and-bite” feeding mode. More advanced were the fuzzy agile **Coelurosauria** with their bigger brains and their long slender hands, feet, and tails. Early coelurosaurs were typically small predators. Among the more important coelurosaur groups were:

- **Tyrannosauroidae**: Initially small agile predators with stronger bites and U-shaped premaxillary teeth; over the Cretaceous they emphasized the skull over the forelimbs, eventually evolving into the gigantic two-fingered **Tyrannosauridae** (with their powerful skulls with a suite of adaptations for “puncture-and-pull” feeding, two-fingered hands, and arctometatarsi)
- More advanced coelurosaurs with even larger brains. Most of these have reduced skull size, long necks, and non-predatory snouts (tiny leaf-shaped teeth with no serrations or with big denticles), showing a shift away from flesh eating
 - **Ornithomimosauria**: Small headed, long necked omnivores or herbivores, with modified hands in which all three metacarpals were the same length. The advanced Late **Cretaceous** **Ornithomimidae** were toothless and had an arctometatarsus
 - **Maniraptora**: Coelurosaurs with enlarged forelimbs and strap-like feathers. Among the maniraptorans were:
 - Long-necked plant-eating **Therizinosauria** (with leaf-shaped teeth and (in advanced forms) a backwards pointing pubis and exceptionally short metatarsi
 - Small, fast ant-eating **Alvarezsauroidae**, with their enlarged thumb. In the derived **Alvarezsauridae** there are very short powerful arms ending with their essentially

thumbs-only hands (and, in the advanced forms, backwards-pointing pubes and an arctometatarsi). Alvarezsauroids share with the remaining maniraptorans an enlarged bony sternum.

- And the two advanced groups, which share true feathers on the arms and tail. From their sideways-oriented shoulders came very long arms which could fold up tight because of the semilunate carpal; these arms could be pulled in quickly because of the large bony breastbone
 - Boxy-skulled **Oviraptorosauria** (all but the most primitive being toothless; some advanced forms with an arctometatarsus)
 - **Eumaniraptora**: Long arms, tails which were mobile at the base but stiff distally, long leg feathers, and a distally-placed metatarsal I. Early eumaniraptorans were crow-sized, and likely tree-dwellers. The two main branches are **Deinonychosauria** and **Avialae**. Deinonychosaurs had a retractable pedal digit II ending in a sickle claw: they are divided into the diverse strictly-carnivorous **Dromaeosauridae** and the swift-running small-toothed **Troodontidae**. Avialae had even longer arms and shortened tails: in all but the most primitive the distal caudals are fused together into a short pygostyle. Basal avialians were not any better fliers than were basal deinonychosaurs. **Ornithothoraces**, however, evolved the alula (thumb-feathers) and a very broad sternum to become better fliers. One of the ornithothoracine branches—**Enantiornithes**—were primary upland dwellers, and very diverse. The other branch—**Euornithes**—were often associated with water-based feeding. These latter lost the long leg feathers and evolved the tail fan. The **Hesperornithes** became flightless swimming fisheaters: the only ocean-going dinosaurs of the Mesozoic. **Carinatae**: more derived birds which evolved a keeled sternum (becoming fully-modern fliers): among these are **Aves** (the modern birds). Nearly all Late Cretaceous avians were water-feeders.

Evolution of Flight

Know key terms: arboreal, cursorial, scansorial; integument; powered flight vs. gliding/parachuting

Arguments for and against the arboreal and cursorial flight origin models

Examples of powered fliers: insects, pterosaurs, birds, bats

Feather origins

WAIR & CFD

Phases of bird flight origin:

- Phase I: Protofeathered cursors (basal coelurosaurs)
- Phase II: WAIR (basal maniraptorans)
- Phase III: Tree-dwelling gliders (basal eumaniraptorans)
- Phase IV: Flapping flight (basal ornithothoracines)
- Phase V: Specialized tail steering (basal euornithines)
- Phase VI: Modern bird flight (basal carinates)

Dinosaur History and Plate Tectonics

- Phase I: Late Triassic: Primitive dinosaurs share world with crurotarsan archosaurs and therapsid synapsids; sauropodomorphs only successful dinosaurs (probably because they are the only high-feeding large herbivores); Pangaea all connected
- Triassic-Jurassic Extinction: Central Atlantic Magmatic Province eruption; all crurotarsans except for crocodilian-ancestors and all therapsids except for mammal-ancestors wiped out
- Phase II: Early Jurassic: dinosaur diversification. Major groups include dilophosaurids as apex predators, “core prosauropods” and near-sauropods as major herbivores, with primitive thyreophorans, heterodontosaurids, and sauropods present as well
- Phase III: Middle and Late Jurassic: major diversification of dinosaurs continues. Carnosaur-sauropod-stegosaur communities worldwide

- Phase IV: early Early Cretaceous: iguanodontians and ankylosaurs replace sauropods and stegosaurs as more common herbivores; beginning of distinction between Laurasian and Gondwanan communities; flowering plants (angiosperms) evolve
- Phase V: late Early Cretaceous and early Late Cretaceous: highest sea levels and high temperatures result in high productivity of plants and gigantic dinosaurs in equatorial regions; origin of advanced tyrannosaur-hadrosaurid-marginocephalian-ankylosaurid fauna in Asia → migrating to western North America
- Phase VI: Gondwana dominated by abelisaurid-megaraptoran-titanosaur faunas; Asiamerica by tyrannosaur-hadrosaurid-marginocephalian-ankylosaurid fauna; Europe and other regions inherit primitive faunas or migrants from other regions