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

<u>Colonization of Land and Life on Land Before the Dinosaurs</u>

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, dinosauromorphs) got around it!

Ornithodira: Elongate tibiae and metatarsi; bird-like necks

Dinosauromorpha: Parasaggital stance, digitigrade posture (striding locomotion)

<u>Diversity of the Dinosauria</u>

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 (predentary bone; leaf-shaped teeth; cheeks; backwards-pointing pubis (after *Pisanosaurus*). Early representatives include *Pisanosaurus*, heterodontosaurs (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 themselved 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. Stegosaurs 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 Hadrosauriformes 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 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 Hadrosaurinae.

Marginocephalia: Had ridge extending posterior over back of skull. Pachycephalosaurs 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 Ceratopsinae with long frills and an enlarged rostral bone.

Basal saurischians: Specialized joints between vertebrae. Early saurischians such as herrerasaurs and *Eoraptor* were bipedal carnivores. The more advanced eusaurischians had pleurocoels (hollow air sac chambers in their vertebrae), elongate necks, and modified hands with large thumb claws and long index fingers. Eusaurischians 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 also had highly complex airsac chambers. Among the eusauropods the most specialized forms were the diverse neosauropods. Neosauropods include the long-skulled pencil-toothed Diplodocoidea and the big-nosed Macronaria. The diplodocoids included the Rebbachisauridae (with their 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 build uphill) and the diverse wide-bodied Titanosauria (which included the largest of all dinosaurs, as well as armored sauropods).

Theropoda: Early theropods were long and slender. Neotheropods evolved the intramandibular joint (for dealing with struggling prey in the jaws), the furcula (as a brace for stresses on the forelimb) and a functionally tridactyl (three-toed) foot. Early neotheropods included coelophysoids and dilophosaurids. Later groups included the short-armed Ceratosauria (which in particular included the stump-armed Abelisauridae, top predators of Late Cretaceous Gondwana) and the stiff-tailed big-handed Tetanurae. Basal tetanurine groups included long-faced Spinosauroidea (most especially the conical-toothed gigantic fish-eating Spinosauridae) and the Carnosauria (which combined deep skulls with blade-like teeth and powerful gripping arms). 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:

- Tyrannosauroidea: 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 and arctometatarsus)
- 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 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. 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)
    - Boxy-skulled Oviraptorosauria (all but the most primitive being toothless)
    - Small, fast ant-eating Alvarezsauridae with their essentially thumbs-only hands
    - And the diversity of Eumaniraptora
        - 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. More derived birds 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
Phases of bird flight origin:

- Phase I: Basal coelurosaurs: Terrestrial runners with protofeathers
- Phase II: Basal maniraptorans: Primarily terrestrial, but with WAIR
- Phase III: Basal eumaniraptorans: Arboreal/scansorial, gliding/parachuting/some limited flight
- Phase IV: Basal ornithothoracines: Powered flight, but still used long leg feathers for steering
- Phase V: Basal euornithines: Tail fan replaces long leg feathers
- Phase VI: Modern bird flight: Powerful pectoral muscles

Dinosaur History and Plate Tectonics

- Phase I: Late Triassic: Primitive dinosaurs share world with crurotarsan archosaurs and therapsid synapsids; sauropodomorphs only successful dinosaurs; Pangaea all connected
- Triassic-Jurassic Extinction: Central Atlantic Magmatic Province eruption; all crurotarsan except for crocodilian-ancestors and all therapsids except for mammal-ancestors wiped out
- Phase II: Early Jurassic: dinosaur diversification
- Phase III: Middle and Late Jurassic: 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
- 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-titanosaur faunas; Asiamerica by tyrannosaur-hadrosaurid-marginocephalian-ankylosaurid fauna; Europe and other regions inherit primitive faunas or migrants from other regions