Notes for the Natural History of Dinosaurs 3

A word of warning... these notes are to give you the basic structural backbone for concepts in the course. This should help you study for the exam, but you should not study from it by itself. Make sure that you read the required chapters in the book, and study both your notes and the slides of the course that have been posted online. Exam 3 is in-class on Wednesday, April 11. Happy studying!

Exam: Wednesday, April 11

Saurischians

- Two major subgroups: Sauropodomorpha and Theropoda
- Shared, derived characteristics
  - Subnarial foramen
  - Twisted thumb
- Earliest forms are small, bipedal, and carnivorous
  - *Herrerosaurus*
  - *Eoraptor*

Sauropodomorpha

- Two major subgroups: Prosauropoda and Sauropoda
- Shared derived characteristics
  - Relatively small skull
  - Long necks
  - Deflected 'lip' of mandible
  - Elongate peg-like teeth
  - Large thumb
- Prosauropoda
  - Late Triassic to Early Jurassic
  - Large thumb claw
  - Front limbs shorter than hind limbs
  - Not chewers - though jaw joint positioned below the tooth row
  - Leaf shaped teeth with little wear
  - Mostly herbivorous (some may have been omnivorous)
  - Many gastroliths
  - Gymnosperms were large part of diet
  - Prosauropod diversity increases with increasing gymnosperm diversity
  - Facultative bipeds
- Sauropoda
  - *Cetiosaurus*: first Saurpod discovered - had spngy bone like a whale. Was throught to be aquatic

    - All early sauropods have shortened head, rounded snout, lower temporal fenestrae ***below*** orbit, nares moved to top of skull
    - triangulate, spatulate, or pencil-like teeth; the number of teeth is limited in some clades
    - A few have a dental battery (*Nigersaurus*)
    - 12+ neck vertebrae, massive solid limb bones
    - ***Pleurocels***: what are these for?
    - Understand uni-directional breathing
    - Two major subgroups: Camarasaurs and Diplodocids
- Camarasaurs
    - Large nares
    - Relatively shorter neck
    - Relatively longer limbs
    - U-shaped neck vertebrae for nuchal ligament to hold up head
    - Bull-dog shaped face
    - Brachiosaurids
        * 13 elongate vertebrae
        * held head vertically over body (37-40 foot-long neck)
        * vaulted skull
        * Large heart to pump blood up to head
    - Titanosaurids
        * Very small heads
        * Osteoderms that become spaced out and hollow with age
        * Robust lower forelimbs
        * Primarily in Cretaceous and some of the largest terrestrial animals ever
- Diplodocidae
    - 12 vertebrae + bifurcate neural spines
    - Veerrrrryyy long tail (80+ tail vertebrae)
    - neck joint is horizontal so neck is parallel to ground
    - Large blade-like chevrons directly behind tail for muscle attachment, and flatter chevrons farther down the tail. What was the likely use of these?
    - Largest known Sauropod: *Amphicaelias*
    - What are the advantages and disadvantages to large body size?
    - Cope's Rule
- Sauropods as ecosystem engineers: modern analogues include elephants, whos presence changes woodlands to grasslands

Dinosaur Metabolism - basics

- Original ideas about dinosaur metabolism
- Dinosaurs were slow and sluggish
- Costs and benefits of being cold-blooded vs. warm-blooded (energy cost vs. activity time)

- Endothermic poikilotherm
- Endothermic homeotherm
- Ectothermic poikilotherm
- Ectothermic homeotherm
- Activity expenditure for endotherms vs. ectotherms

Dinosaur Metabolism - the evidence

- Anatomy
  - All modern erect animals are endotherms and the problems with a sprawling stance
  - Limb vs. muscle proportions to estimate aerobic power (endotherms have more)
- Diet
  - Endothermy requires more food (chewing dinosaurs processed a lot of food... who were the chewing dinosaurs?)
  - How might secondary palates play a role here?
- Hearts
  - All endotherms have 4-chambered heart; allows lower blood pressure in lungs & higher blood pressure in body to diffuse oxygen
  - Stone heart??
- Brains
  - Dinos with big brains vs. body size could be inferred to be ectothermic... high activity levels
  - Upright stance: All living species with upright stance are endotherms
- Bone Histology
  - What does Dense Haversian Bone tell us?
  - What do LAGs (Lines of Arrested Bone Growth) tell us?
  - Do modern endotherms have LAGs? Does this help or hurt the argument?
- Plumage
  - Plumage is a bad idea for ectotherms... why?
- The ratio of predators to prey could tell us about whether the community is endothermic or ectothermic... because endothermic predators need more energy than ectothermic predators, one should expect less endothermic predator biomass vs. prey biomass. What do we see in the fossil record?
- Oxygen isotopes record temperature. We can look at the oxygen isotopes of internal bones vs. bones closer to the extremities (fingers/toes). What would an endotherm look like? What would an ectotherm look like?
- Endotherms need a lot of oxygen, so they will need to breathe more. As they do this, they loose more water. Many endotherms have nasal turbinates, however dinosaurs do not have these.

Dinosaur Metabolism - what does this tell us overall?

- Dinosaurs are a mixed bag
- Large ornithopods and theropods were likely homeothermic endotherms as juveniles, and more like homeothermic ectotherms as adults
- Sauropods were likely gigantotherms ~ their large size retained core heat (small SA:V); homeothermic without the cost of endothermy
- Small ornithopods and theropods were likely homeothermic endotherms throughout lives
- Some large slow-moving ornithischians were likely more ectothermic, and perhaps poikilothermic

Body Size

- Volumetric measures of body size vs. other techniques
- Cross sections of limb bones allows us to predict dinosaur mass based on known measurements of modern animals
- More refined cross-section approaches can result in better measurements
- Metabolic rate scales with body size by the 3/4 power law
- How do we estimate growth rates from dinosaurs?
- Dinosaur growth rates vs. body size shows that they are not generally easily classified as ectotherms or endotherms; they are *mesotherms*
- Allometric scaling: body size tells us a lot about life history, mortality, population size, population growth, and even predator-prey relationships
- Know the nested relationship between African carnivores and their prey
- The biggest animals (sauropods) might have needed to communicate across large distances… how?

Theropods

- Theropods are the other big clade of Saurischian dinos. Remember that Saurischians are united by: subnarial foramen, an extra articulation on the dorsal vertebrae, a twisted thumb, and a forward-pointed pubis
- What does *theropod* mean?
- Shared characteristics of Theropods
  - Clawed and bipedal
  - Sharp, serrated teeth
  - Hollow vertebrae and limb bones
  - Stiff tail
- Theropods had loosely jointed, kinetic skulls. Why?
- Know the cladograms and specifically the following groups:
  - Basal: Ceratosaurs, Spinosaurs
  - Intermediate: Carnosaurs, Tyrannosaurs, Ornithomimids, Oviraptor & Therizinosaurs

  - Derived: Troodontids, Dromaeosaurs
- In particular, familiarize yourself with the *Theropods Simplified* cladogram from the slides

- **Ceratosaurs**
  - Robust hip joints
  - Fusion of upper ankle bones for support
  - Late Jurassic to Early Cretaceous
  - *Coelophysis* Bone beds!
  - *Dracoraptor* Earliest Jurassic
- **Spinosaurs**
  - Strong shoulders, long arms
  - Long, narrow snout
  - Piscivory (fish-eating) & semi-aquatic lifestyle
  - The largest carnivorous dinosaurs
  - Some have large sails on back
- **Carnosaurs**
  - Big heads
  - Big nostrils + elaborate sinuses
  - Large bodied (>5 meters long)
  - *Giganotosaurus* and *Carcharadontosaurus* are two of the largest theropods outside of the Spinosaur group
  - *Giganotosaurus* may have been a group hunter & had a larger brain
- Arcto-metatarsal ankle among Coelurosaurs. Fast runners! Understand the horse analogy
- **Tyrannosaurs**
  - Large bodies & short arms
  - A range of body sizes: from horse-sized to the largest (*T. rex*)
- **Ornithomimosaurs**
  - Small, lightly built skulls with tiny orbits
  - Very ostrich-like
  - No upper-teeth, some lower teeth
  - Long arms
  - Thought they had baleen-like strainers, but now scientists think these are teeth for crushing vegetation… herbivorous theropods
- Maniraptorans all share a semi-lunate carpal wrist bone, increasing manual dexterity
- *Oviraptor*: Known for a skull full of opening and a central boney protrusion sticking down from the upper palate that was likely used to break open shellfish
- Therozinosaurs: backward pointed pubis (like the ornithischians), 3 ft long claws. Most similar animal might have been the giant ground sloth. They were herbivores, but are pretty mysterious.
- **Troodontids** Small, big brained, big eyed. Likely hunted mammals at night.
- **Dromaeosaurs**: Includes *Velociraptor* and *Deinonychus*. They had a re-

tractable claw on their foot used to slice and dice. Some were chicken-sized. Others were about 15 feet tall. *Boreonykus* was a dog-sized dromaeosaur recently found in a *Pachyrhinosaurus* bonebed dating to 73 million years old

- Two ways to be a dinosaur predator: You can be a slicer/Dicer or a Crush-and-Destroy predator
  - Slice/Dice: teeth are recurved with larger serrations and are thinner and narrower
  - Crush-and-Destroy: teeth are rounder, conical, bulky, with smaller serrations with a more circular cross-section
  - All predators have a jaw hinge in line with the tooth row for scissor-like cutting power
- Evolutionary Trends among the Theropods
  - More robust skulls among the earlier species (brute force), to thinner, more gracile forms (slashing/tearing) in the derived species
  - An increase in the number of air sacs in front of the eye… a general pneumatization of the snout => increased respiratory efficiency
  - Stereoscopic vision… particularly in the Tyrannosaurids
  - Relative brain size increases… particularly the olfactory lobe and visual cortex
  - Finger elongation: implies increasing dexterity (+ semi-lunate carpal in derived theropods) - using hands/claws to take down prey in addition to toe claw and teeth… earlier theropods just used jaws
  - Limb elongation: faster running speeds
- Adaptations for speed (particularly for derived and some intermediate theropods)
  - Near horizontal vertebral column
  - Center of gravity positioned at hips
  - Tails stiffened by elongate boney processes; Tail flexible at base for balance (like a cheetah)
- *Persistence hunting*: Wearing a prey down over long distances until it can be safely killed. Could only be done by a bipedal, energetically efficient predator. Humans are only known persistence hunter… some theropod dinosaurs… maybe?
- Trackways indicate intermediate running speeds for smaller theropods; slow speeds for larger theropods. Some, like the ornithomimids likely approached cheetah speed (80 mph)
- Cranial ornamentation
  - Many theropods had nasal horns, eye horns, and rugosities on head
  - *Dilophosaurus* had two crests on its snout
  - *Monolophosaurus* might even have had a resonating chamber for vocalization
  - These attributes suggest some form of sociality… if they lived in groups, though, we might expect sexual dimorphism
  - Sexual dimorphism is only seen in *Coelophysis* and *Syntarsus*
- Venom: Hollow teeth found for a Dromaeosaur, suggesting potential venom

usage

- Parental Care
  - Tyrannosaurs were likely altricial (vs. precocial)
  - Review the differences between these ways of bringing up young
  - What advantage would there be for a predatory dinosaur to raise its young? It has to do with competition among smaller predatory dinosaurs...
- Predators vs. Scavengers
  - Evidence for active hunting: efficient running ability, stereoscopic vision, disproportionately long teeth (to kill), healed bitemarks on potential prey
  - Evidence for scavenging: Rounded teeth (for crushing bone), small arms, large olfactory lobes in the brain
  - The large theropods were likely a mix... even hyenas only scavenge 30% of the time
  - The smaller derived theropods were almost certainly primarily active hunters... they were designed for killing rather than scavenging
- Where do you find theropods and why?
  - Herbivores follow the environment; predators follow herbivores
  - Theropods are more habitat-generalists because all they need is an ample supply of herbivore prey
  - Larger theropods associate with larger herbivore species; smaller theropods associate with smaller herbivore species
  - Dinosaur provincial park vs. Devil's Coulee: 2 sites with very different environmental attributes. What are the attributes, and what is the main difference between the herbivore and predator groups that we find in both sites?

Evolution of Birds

- Bird traits: feathers, no teeth, large brains, *carpometacarpus*, bipedality, pygostyle, pneumatic bones, rigid skeleton
  - Which traits are ancestral vs. derived?
- Details on feathers
  - Central shaft, barbs linked by barbules forming a vane
- Flight stroke
  - Downward stroke: Pectoralis muscle attached to the sternal keel
  - Recovery stroke: Suprocoracoides muscle *also* attached to keel. It pulls up on the wing via the supracoracoides tendon looped through the *Trioseal foramen* and onto the arm bone
  - Unique to animal kingdom
- The evidence for birds being derived theropod dinosaurs: know details of each line of evidence
  - Oology: single layered vs. multi-layered, *autochronous ovideposition*
  - Behavior: sleeping

  - Osteology: furculum (wish bone), fused sternum, ventral ribs, uncinate processes, semilunate carpal
  - Integument: feathers, quill knobs
  - Molecular: Amino acid sequence (i.e. protein) similarities between chickens and *T. rex*
- Feathers before flight:
  - Know the 4 stages of feather formation and developement. Their evolution is also thought to follow this pathway
  - Earliest feathers: barbed filaments (coloration, signalling, insulation)
  - Asymmetric feathers (indicators of flight) arise just before the Maniraptors
- Power stroke & flight stroke evolutionary steps all arise before *Paraves* (non-avian theropods). What is the advantage of the power stroke if not for flight?
- Pneumatic bones are old within the Theropod linneage... what are the advantages of this if not for flight?
- Adaptations for low-velocity flight: Alula (what does this do?), pygostyle (what does this do?), + perching adaptations
- What bone - also shared by other maniraptorans - allows birds to fold their wings against their bodies?
- Low-speed flight adaptations evolve after *Paraves* (stem-group birds)
- How does body size inform our understanding of the evolution of flight?
- Key: *Paraves* could likely fly. Birds continued to fly. The other group of dinosaurs that evolved from *Paraves* (Troodontids and Dromaeosaurids) lost the ability, many of which evolved much larger, terrestrially-bound body sizes.
- Cursorial Hypothesis vs. Arboreal Hypothesis... what is the difference?