Notes for the Natural History of Dinosaurs 4

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 4 is on Monday, May 9 @ 3:00, CLSSRM 110. Happy studying!

> **Final Exam**: Monday May 9 from 3:00 to 6:00pm in CLSSRM 110. Be sure to show up on time, as it will only take ca. 50 minutes, and no one will be there if you show up an hour late, FYI

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?

Flying Reptiles

- Pterosaurs are Ornithodirans, which Dinosaurs are as well... they are the sister clade to Dinosauria. Orithodirans are also derived Archosaurs, a namesake that they also share with Crurotarsans (which include Crocodylomorphans)
- Characteristics of Pterosaurs
  - Cranial crests, large brains, stiff torso (similar to birds), hollow limbs, a unique *pteroid* bone, elongate 4th fingers, skin membranes making up the wing, and a breastbone with a keel
  - Cranial crests are keratinous, species-specific, and sometimes sexually dimorphic
- Early pterosaurs are smaller with short, teeth-laden jaws: the *Ramphorynchids*
  - Late Triassic
  - Long teeth and nails, generally lacked boney crests
  - Many ramphorynchids also had tail vains, which would have stabilized flight
- Many more derived forms such as *Pteranodon* had scoop-shaped bills, are large-bodied, have heavily-fused pectoral girdles, are more glider-like, and likely piscivorous

- Pterosaurs not covered in hair, but in **pycnofibres**, a convergently evolved filamentous covering that is similar in some respects to the central shafts of feathers
  - why this is evidence that these animals were endothermic?
- What are the flight advantages of high aspect ratio wings vs. low aspect ratio wings?
- Pterosaurs have a pectoral girdle that is very similar to a bird's. Is this a case of a homologous or analogous set of traits?
- The pteroid bone is unique to pterosaurs and is similar to what bone that is unique to birds? What function do these bones serve for flight?
- Pterosaur wings are uniquely supported by **actinofibrils**, which are 3-distinct layers of criss-crossing fibers of unknown material and oxygenated by looping blood vessels - makes for a very strong and resiliant wing
- There has been evolving thought in how pterosaurs (particularly the big ones) moved while on land. The prevailing theory is that they had a sprawling gait supported by their massive fore-limbs with their wings folded.
- The largest pterosaur (*Quetzalcoatlus* from the latest Cretaceous) was much larger than the largest bird in evolutionary history

Swimming Reptiles

- *Mosasaurus* was one of the first prehistoric reptile bones found - predating even the discovery of dinosaurs
- Major groups of aquatic reptiles include:
  - Sauropterygians: Nothosaurs & placodonts, plesiosaurs & pliosaurs
  - Icthyosaurs
  - Mosasaurs
  - Turtles
  - Marine, freshwater, and even terrestrial crocodylimorphs
- Placodonts: "tablet teeth"
  - Mid to late Triassic
  - Shallow, coastal environments
  - Small: 1-3 feet long with a turtle shape
  - Boxy skulls with large table-like teeth: mollusk-strainer?
  - 2 groups: Placodontoids (unarmoured) and the Cyamodontoids (armoured)
- Nothosaurs: Triassic seals
  - mid-Triassic in Eurasia
  - Coastal environments: not fully-formed flippers - likely relied on coastal environments

  - 12 feet long as adults, small pointed teeth
  - Fish/squid specialists

- Plesiosaurs
  - Early Jurassic to late Cretaceous
  - Front and hind limbs evolved into flippers
  - Stiff trunk, strong pelvic and pectoral girdles allow efficient swimming motion
  - Long necks, short tails, small head, sharp teeth (fish/squid eaters)
  - Fully marine-adapted
  - Slow but very maneuverable

- Pliosaurs: Apex predators
  - Early Jurassic to end Cretaceous
  - Whale-sized, about 40-50 feeet long
  - Huge head: Skull was about 1/3 of its length
  - Large and fast - large conical teeth for crushing

- Icthyosaurs
  - Early forms are long, thin; later forms are short, squat (dolphin-like)
  - Understand the ideas about convergent evolution in body shape between Icthyosaurs (reptiles), dolphins (mammals), and tuna or sharks (fish)
  - Up to 50 feet in length! Most species were smaller
  - Forelimbs as fins; hindlimbs shorten; small floating pelvis like whales
  - Forelimbs used for directional control & stability; tail used for propulsion
  - Similar ecological niche as dolphins
  - The largest eyes (relative to body size) of any animal in Earth's history. What would be the advantages of this?
  - Known to be viviporous (live-birth animals)

- Mosasaurs
  - 5-45 feet long
  - Blunt snouts, smaller heads than Pliosaurs
  - Large eyes, stout teeth, apex predators
  - Early forms may have been mollusk-eating animals
  - Later forms are long and slender
  - Likely stalking predators, attacking with short burts of speed (similar to great white sharks perhaps)
  - Later forms have double-hinged jaws allowing them to swallow prey larger than their heads
  - Covered in overlapping scales, which likely promoted efficient swimming and speed

- Turtles
  - Eary forms had teeth and did not yet have solid carapaces
  - First fully-shelled turtles known from late Triassic
  - Largest known turtle is *Archelon* from the late Cretaceous; likely mollusk and squid specialists
- Crocodylomorphs
  - Evolved in the early-mid Triassic
  - Two important marine forms: Teleosaurids and Metriorynchids
  - Teleosaurids
    - Early Jurassic to Early Cretaceous
    - Long snouts (indicating piscivory)
    - Very crocodile-lie with limbs that could be useful on the land
  - Metriorynchids
    - Mid Jurassic to Early Cretaceous
    - Fully aquatic with limbs evolved into flippers
    - Lost osteoderms
    - High swimming efficiency
    - Some (*Dakosaurus*) had teeth analogous to killer whales and salt glands in snout
  - Freshwater Crocs
    - *Sarcosuchus*: Uncovered in the Sahara; early - mid Cretaceous
    - 40 feet long, 6 ft long skull
    - Somewhat thinner skull, but likely ate large fish, turtles and small dinos
    - *Deinosuchus*: early - mid Cretaceous
    - 35-40 feet long, much larger, more robust skull
    - Likely preyed on larger dinosaurs such as hadrosaurs drinking from the riverbank (tooth marks from *Deinosuchus* found on hadrosaur tail vertebrae)

Bringing it home: The Mesozoic World

- Recall the early archosauts of the Triassic: Rhyncosaurs, Rauisuchians, basal archosaurs like *Proterosuchus*
- Recall the **cladistic relationships** and general characteristics of ALL of the dinosuar groups that we have covered so far
  - Thyreophorans: Stegosaurs and Ankylosaurs
  - Ceropods: Marchinocephalians: Ceratopsians & Pachycephalosaurs
  - Ceropods: Ornithopods
  - Sauropodamorpha: Prosauropods & Sauropods

  - Non-avian Theropods
  - Bird-like non-avian theropods
  - The avian theropods

- How and when did Dinosaurs originate? Know the general timeframe
- The 2 hypotheses concerning Dinosaur takeover
  - 1) Competitive replacement scenario
  - 2) Opportunistic mass extinction scenario
- Know the general global changes associated with the Triassic, Jurassic, and Cretaceous
- Triassic
  - Supercontinent (Pangea)
  - Warm climate, no ice caps, very dry (deserts)
  - Lycophytes, ferns, confiers and tree ferns
  - Prosauropods, early bipedal carnivorous dinosaurs
  - Archaic archosaurs, therapsids, first small mammals, turtles
  - Long-form icthyosaurs, Ramphorynchids, nothosaurs & placodonts
  - Understand how endemism alters diversity... does Pangea promote endemism? How/why?
- Jurassic
  - Continents routinely flooded, extensive rifting and volcanism
  - North Atlantic begins to form
  - Sea levels high
  - Lush coniferous jungles, cycads, ginkgoes, ferns
  - Diversification of Dinosaur groups in mid-late Jurassic
  - Stegosaurs, sauropods,
  - Large carnivorous theropods in mid Jurassic
  - *Archaeopteryx* the first bird in the late Jurassic
  - Mammals (nocturnal insectivores), pterosaurs, plesiosaurs
  - Mid-Jurassic gap in the fossil record... why? what caused it
  - End-Jurassic increase in diversity as continents move apart. What does this have to do with endemism?
- Cretaceous
  - Continued rifting, inland seas
  - Increased CO2, greenhouse environment
  - Development of Southern Atlantic
  - Continents isolated completely
  - Cycads, ginkgoes, ferns decline as Angiosperms diversify
  - Chewing dinosaurs do VERY WELL... ornithopods & ceratopsians, as well as some non-chewing groups such as ankylosaurs & pachycephalosaurs

  - Derived theropod dinosaurs expand - particularly the raptors (Troodontids & Dromaeosaurs)
  - Dolphin-like icthyosaurs, large pterosaurs, plesiosaurs, a diversity of birds
  - Difference in Southern vs. Northern continent dinosaur communities - what were these differences?

Assessing diversity through time

- Compare changes in diversity among a well-represented group (marine shelled invertebrates) in different areas over time
- Different areas are compared to avoid issues caused by biases in rock formation affecting different places
- What is "the pull of the recent"?
- What is the Sepkoski curve, and what was thought to cause the 62 million year cycle in extinctions and speciations in the fossil record? Hint: The Milky Way
- Diversification of angiosperms tracks diversification of many dinosaur groups - particularly the chewers
- Plants certainly impacted dinosaurs, but did diversification of dinosaurs impact the diversification of plants? How did scientists test this assertion?

From Crocoducks to mammals

- Diversification of terrestrial crocodylomorphs in the Mesozoic shows invation of many different ecological niches: from the small (Rat Croc) to mid-size (Dog Croc, which was a plant and grub eater, & Duck Croc which is thought to have a keen sense of smell), to the large (Boar Croc, which had 3 sets of canine teeth, stereoscopic vision, and likely predated on dinosaur prey)
- Know the evolutionary relationships between
  - Early/Late therapsids
  - Morganucodon
    - Late Triassic
    - Small insectivore
    - True mammal ear but still attached to jaw rather than skull
  - Monotremes
    - Cretaceous to now (*Echidna* & *Platypus*)
    - Hair, but no breasts; milk oozes from skin
    - Ear bone shift from lower jaw to skull during development
    - Electroreception

    - Modern forms are insectivores. *Platypus* is semi-aquatic and the only poisonous mammal
  - Mult-tuberculates
    - Jurrasic to Eocene (100 Million year linneage)
    - Important small herbivore in Cretaceous and Cenozoic
    - Single bone in lower jaw
    - Many types of teeth! Incisors, premolars, molars
    - Evidence of hair and live birth in the fossil record
  - Marsupials
    - Cretaceous to now
    - Live young (embryos) crawl into pouch to develop
    - Complex molar tooth shape
    - Cretaceous forms opposum-like
    - Modern forms are diverse in Australia and South America - fill all ecological niches until recently (Tasmanian Tiger went extinct in the 1930s)
  - Placentals
    - Cretaceous to now
    - Give birth to fully developed young
    - Fetus nourished by placenta
    - Cretaceous forms very shrew-like
    - Modern forms are the dominant group in most ecosystems
  - (which are you?)
- Major evolutionary innovations among mammals
  - Diverse, occluding teeth
  - A single jaw bone (dentary), which auxillary jaw bones moved towards the inner ear. These extra bones give mammals increased hearing abilities relative to the "simpler" ears of reptiles
  - Secondary palate
  - Shifting breathing musculature to the diaphragm
  - Large brain size (what is the primary cost of large brains?)

The K-T (K-Pg) Extinction

- Separated the Mesozoic (Cretaceous) from the Cenozoic (Paleogene)
- Bolides
  - Asteroid: rocky or metallic minor planet or planetoid
  - Comet: an asteroid that sublimates (gas, water vapor)
  - **Meteorite**: a natural object from outer space that survives an impact with the Earth

  - Most bolides come from the asteroid belt, which has been around since the origin of the solar system

- Gradualist vs. Catastrophic scenarios:
  - Know the difference between these lines of thought and as well as the people known for supporting and spreading these views (Charles Lyell and Georges Cuvier)
- Gradualist thought (uniformitarianism) won and pervaded most of 20th century science
- Team Alvarez in the late 1970s
  - Noticed that beds below KT contained Cretaceous-only organisms
  - Beds above the KT contained Teriary marine organisms
  - No mixing of the two - suggested a catastrophic event (large change in a short period of time)
  - A Clay layer separated these two time periods
  - Found 1000x times expected Iridium abundance in clay layer - much higher than that found in Earth's crust, but matching what you find in objects from outer space
  - Why is there so little Iridium in Earth's crust?
  - Team Alvarez used 1) estimated energy from Krakatoa, 2) known surface area of Earth's crust, 3) Abundance of Iridium found in asteroids... to calculate the mass of the asteroid that hit at the KT boundary. mass estimated to be 34 billion tonnes, or a rock 7-10 Km in diameter producing an crater 100-150 Km wide
  - Other evidence of an impact
    * Shocked Quartz
    * Melt spherules (microtektites)
    * Graphite
- Chicxulub Crater at the Northern tip of the Yucatan peninsula
  - 180 Km wide
  - Lots of microtektites
  - Dated to 65.5 Million years ago
- Planetoid Baptistina broke into fragments during the Jurassic: one fragment hit the moon (Tycho Crater), and one hit the Earth (Chicxulub)
- Consequences
  - Debris forms microtektites
  - Blast wave knocked down trees, tidal wives, shock-heated the rock, circled Earth with stratospheric dust
  - Extinguishes life near impact, dust blocks out sun, photosynthesis shuts down for a year
  - Acid rain forms, nitrous oxides form in ocean (which dissolves shells), water in atmosphere destroys the Ozone layer

  - After the short-term cooling, a longer-term greenhouse effect occurs from the CO2 released into the atmosphere at impact

- What happened to different organismal groups at the KT?
  - In the ocean
    * Fish and Sharks: hard to say
    * Plesiosaurs/Pliosaurs: disappeared around the KT but also not clear
    * Mosasaurs: Abrupt extinction at KT
    * Ichtyosaurs: Disappeared well before KT
    * Ammonites: Abrupt extinction at KT
    * Bivalves: 65% went extinct within last 10 Million Years (MA)
    * Foraminifera & Calcareous nanofossils: Abrupt extinction at the KT
  - Plants
    * 79% of angiosperms go extinct
    * A fungus spike follows (taking advantage of decaying plant matter)
    * Global fern spike follows this
  - Animals
    * Aquatic animals have a higher survivorship than terrestrial animals
    * Ecothermic animals have a higher survivorship than endotherms
    * Small animals have a higher survivorship than large animals
  - In general, after
    * 1) the massive extinction of species, there follows
    * 2) A successive bloom of opportunistic species
    * 3) Followed by the radiation of new species into emptied niches

- Other possible explanation for the extinction events
  - Volcanism: Does not explain shocked quartz, but could explain Iridium spread. Still, you'd expect to see Iridium in higher concentrations near the volcanic activity, which you don't
  - The Deccan traps are the result of massive volcanic activity, but this occurs before, during, and after the KT, so there is no detectable effect of this on biota

- The impact is the most likely explanation for the dinosaur extinctions, **however** we now know that dinosaur species had an extinction rate greater than their speciation rate for 24 million years before the KT. We don't know why, but dinosaur species were dwindling long before the mass extinction, which put the final nail in the coffin
- We can understand impact events from observing those on other planets: comet Shoemaker-Levy 9 impacted Jupiter in 1994

- Enormous impacts (one of which formed the moon) occurred early in Earth's history, and life didn't emerge until after these 'bombardments' stopped
- Extinctions for catastrophic events reset the clock... the extinction at the KT boundary made it possible for mammals to diversify and occupy niches otherwise held by dinosaurs. We owe a lot to that asteroid.

Thanks for a great class!
Good luck studying for the final exam, and enjoy the summer!