

## **Lecture 8: Ornithischia - Stegosaurus and Ankylosaurs**

### **Stegosaurus**

#### -main features

- pelvis(bird pevis)
- pubis parallel to ishium

#### \*remember:

- Saurichian: pubis not parallel to ishium
- Ornithischian: pubis parallel to ishium
- middle opening of both called hip socket (acetabulum)

#### -other shared features:

- narrow bone called palpebral
  - crosses outside of eye socket - possibly connects eye lid
- additional bone called predeantary
- toothless and rough front top of snout - ex. turtles
- ossified (bony) tendons above sacral region
  - stiffens backbone at pelvis

### **-Basal Ornithischia**

- Triassic ornithischian fossils are rare compared to triassic Saurichians  
ex:pisanosaurus (argentina) / Eocurar (South Africa)
- no record (definite) of Triassic ornithischian in North America
- heterodontosauridae
  - most basal major radiation of Ornithischian
  - late triassic or early jurassic to early Cretaceous - lived on most contin.
  - small bodied, bipedal, canine like front teeth and chewing back teeth
  - could be omnivores/ herbivores
  - some had (Tianyulong): long filamentous structures growing from skin
    - homologous with feathers?
- lesothosaurus
  - close to base clade Genasuria - majority ornithischians
  - long limbed small herbivores
  - from Lesotho, South Africa
  - early Jurassic

### **-Thyreophora** (thyreo - shield / phora - bearer)

- jugal (cheek bone) with broad process behind eye
- parallel row of dermal armour scutes on back
  - possibly bad evolution

### **-Basal Thyreophora**

- scutellosaurus: early Jurassic Arizona
- emausaurus: early Jurassic Germany
- scelidosaurus: early Jurassic England (basal ankylosaurs)
- first appear in early Jurassic in North America, Europe, Asia
  - replaced by ancestors: Stegosaurus and ankylosaurs in middle Jurassic

### **-Stegosaurus (stego - rood / saurus - lizard)**

- osteoderms - rows of bones that can develop into spines and plates along back tail
- parascapular spines - over shoulder blade in some species

- other features: \*no flowery plants at this time
  - quadrupedal limb posture
  - long thin small heads (small brains)
  - simple teeth - herbivores
  - short and massive forelimbs
  - long and columnar hindlimbs
  - broad hooves
  - 3-9 m in length and weighted 300-1500 kg
  
- small head = small brain?
  - capability to survive
  - did achieve world wide distribution
  - origin in middle jurassic
    - by late - 10 plus species = fossils not complete though
    - down to two or so by early Cretaceous
  - evolves over span of 60 ma
    - no in Antarctica/ Australia
  
- history of discovery
  - early in England 1870's
  - great dino. rush at Como bluff by Marsh and Cope
    - upper jurassic Morrison Formation: stegosaurus
  - spiny kentrosaurus (kentro - prickly)
    - discovered in eastern Africa 1910
  - recent in China (jiangosaurus) and Portugal (Miragaia)
  
- Paleobiological observation
  - foot prints uncommon
  - gait - not built for great speed
  - large and strong hind legs - stride
  - cadence - hindlegs and forelimbs work at same rate
    - causes:
      - slow walk
      - can be temporarily bipedal by lifting hindlegs (weight allow?)
      - speed 6-7 km/h
  
- food
  - jaws covered with ramphotheca ex: like turtles
    - it is shape edge allow stripping from plants
  - small chewing teeth
    - weak chewing muscles
  - use of gastroliths? - stones to break down food
  
- level of feeding
  - body position suggest low feeding in underbrush
  - centre of gravity more back due to hindlimbs
  - Bakkar suggested standing on hindlegs
    - long tail acted as a third leg ex: kangaroo
  
- brain
  - brain smaller than brain case

- to measure use latex through foram magnum
  - fill with water and see
- normally brain size grows with body size
- stegasaurus - uncomplicated range of behaviour due to brain size

#### -behaviour

- no known nest/eggs
- sexual dimorphism - difference btw male and female?
  - number of sacral ribs
  - shape of femur maybe?
- solitary or gregarious (group living)

#### -role of spines and plates

- just defence?
- not attached to underlying spine of vertebrae
  - embedded in skin - skin cover (maybe change colour)
- put down/ raise for defence?
- allows thermoregulation (endo/ecto thermic)
- evenly grooved with lines and honey comb structure
  - surrounded by blood vessels (cool down/ absorb heat)
- plates in double row and staggered

#### -phylogeny (evolutionary relationships)

- early had spines
  - serving for defence
- later for plates
- vascular system for thermoregulation
- tail spikes
  - cluster along called thagomizer
  - defence weapon?
- migration - began in asia - early spiny
  - due to landbridge

#### **Ankylosaurs** = fortress (armour and spines)

- fully protected ex: armadillo/ turtle/ some bugs

#### -evolution

- first definitive in middle jurassic - rare fossils
- some from late jurassic/ early cretaceous form clade
  - anklyosaurs -> polacanthidae
- rise in diversity by end of cretaceous
  - derived families: anklyosauridae and nodosauridae
- lasted until cretaceous

#### -size

- moderate in size ex: Edmontonia
  - mostly 5 m in length
- short stubby legs

- history of research
  - hylaeosaurus - in England
    - one of first named (Owens Dinosauria)
  - nodosaurus from Wyoming named by Marsh in 1880's
    - not recognized as own group from Stegosaurus until 1920's
  - localities
    - alberta badlands
    - mongolia
    - also in south Gondwana
  
- incomplete fossil record
  - plate arrangement of neck, back, tail, etc...
    - based on a few species
  - asian fossils ground upright
    - due to rapid burial/ sandstorms
  
- habitat
  - skeleton in North America found in marine setting
    - liked water/by sea
  - are terrestrial animals
  
- position of fossil
  - in north america found upside due
    - due to heavy armour?
  
- distinct features
  - the terminal club(tail club)
    - distal tail vertebrae fused to form handle
    - osteoderms fused to vertebrae form knob
  - nodosauridae - no tail club
  
- food
  - head close to ground
  - herbivore due to teeth/beak
  - long tongue
    - hinted by bones in throat supporting tongue
  - secondary plate - chew and breath at same time
  - deep cheek pouches - teeth deeply inset
  
- mouth
  - beak shaped varies
  - scooped shaped selective plants
  - round -indiscriminate feeding
  - teeth not closely packed
    - wear and tear can be seen in fossil teeth
  
- digestion
  - deep rib cage
    - hosting abdominal region
    - possibly fomentation compartments like horses/ cattle/ rhino
  
- movement

- large weight
- slow movement
  - trackway suggest 3 km/h
  - also by limbs and body posture
- brain (behaviour)
  - small brain
    - but well protected from predators
  - plates over eyes
  - usually solitary specimens
    - group of juvenile Pinacosaurus found
  - fortress in mesozoic landscape
  - worldwide distribution

### **Pachycephalosauria - late cretaceous - chapter 5 lesson 9\*\*\***

- pachy-thick, cephalo - head, saurus - lizard
- brain endocast is small compared to dome (means brain not in dome)
- discovery
  - rudimentary fossil record (limited)
  - 1850 stenopelix found in Germany
  - first cranial fragment found in USA by Leidy and Marsh in late 1800's
    - not properly identified though
  - first pachycephalosaurus dome by Lawrence Lambe in Alberta
    - named stegoceras in 1902
  - first full described by C.M Gilmore in 1924
    - skull and partial skeleton 2 m length
    - short forelimbs
    - long hindlimbs - walks on bipedal
    - ornamented skull
  - 1943 spectacular skull of pachycephalosaurus
    - 65 m in length
    - solid dome 20 cm thick
    - snout studded with large densely packed bumps
    - estimated 8 m long
  - pachycephalosauridae formed from pachycephalosaurus and stegosaurids in 1945
  - in 70's and 80's large amount of specimens came from:
    - china and mongolia
  - named whole genera based on skull
    - homalocephale
    - prenocephale
    - tylocephale
    - wannanosaurus
    - goyocephale
- Homalocephale** - flat skulls - thick headed
  - possibly a juvenile characteristic?
- recent discoveries
  - 2006 Dracorex
    - late cretaceous - south Dakota

- spikey but dome less skull that resembles dragon
- controversial taxon: Juvenile?
- 2013 Acrotholus
  - late cretaceous, Alberta
  - known only from a dome
  - oldest definitive pachycephalosaurid in North America and possibly world
- preservation
  - overrepresentation of skulls in this group
    - due to sturdiness
    - over dozen based on skulls
  - all in northern hemisphere
  - late cretaceous - long gap between evolutionary divergence not filled
- characteristic features
  - mainly from cranial region
  - thickened skull roof
  - modified cheeks
  - shortening floor of brain case
    - but expansion back of skull
  - strongly ornamented external skull surface
  - short forelimbs
  - reduced pubis bone (not contribute to hip joint size)
  - special features of back and tail vertebrae
- division based on skull roof
  - pachycephalosauridae - rounded skull roof
  - homalocephalidae - flattened skull roof
  - their phylogenetic relationship is debated
    - flat skull roof of homalocephale can indicate immaturity
- ontogenetic series - development of organism/ animal
  - stegoceras
    - transition from flat-head to domed during growth?
- diversity
  - left lateral view of the skull
    - i. stegoceras
    - ii. homalocephale
    - iii. prenocephale
    - iv. pachycephalosaurus
    - v. tylocephale
  - \*all domed
- distribution
  - found exclusively in Northern Hemisphere (Laurasia)
  - origin might be central/east asia
    - arctic migration to North America
    - found in alaska (alastacephale)

- preservation in North America
  - mainly skull caps
  - river and lake sediments
  - skeletons widely missing
  - no suitable habitat with fossilization potential?
  - transportation over long distance hypothesized
    - recently analysis rejected based on wear on skull caps
  
- preservation in Asia
  - more complete
    - due to desert conditions
    - smaller streams
    - faster sediment rate
    - little evidence for transport
  
- food
  - herbivores
  - browsing not from home grounds
  - front jaw carries simple peg like gripping teeth
  - further back are cheek teeth with small triangular crowns with coarse serration
  - cutting and puncturing plant leaves and fruit
  - ribcage very broad
    - room for large gut
  
- behaviour
  - head structure - head butting ex: rams
    - look for scars on smooth outer surface of skull
  - inner structure - network of bony columns perpendicular to surface
    - support against stress
  - head on pushing and butting
    - i-homalocephale (more flat)
    - ii-stegoceras (more dome)
  
- features support behaviour
  - strong neck muscles
  - dampening hurtful rotation or dislocation
    - deals good with impact
  - vertebrae spliced together in tongue and groove fashion
  - rigidity to back preventing lateral rotation

\*look at skull injury between fully domed and partially
  
- sexual dimorphism
  - specimen in same area at same time - sympatric specimens
  - comparison btw dome size and brain case size
  - accelerated growth of dome size and thickness: male/female?
    - smaller dome = female?
  - dimorphism of dome has been suggested for pachephalosaurus
    - latest unable to confirm
  - modern example: deer, bird, crocks, coloration and size
  
- stygimoloch
  - microscopic opening in skull cap for blood vessels

- possibly for colour change and such
- for display rather than fighting

- sexual selection (rams/ other)
  - preferred access to females
  - establish dominance
  - big horn sheep (curl on horns)
  - lizards colourful skin under chin

**Ceratopsia:** The horned dinos. - **chapter 6 lesson 10\*\*\***

- well studied
- first appeared in Late Jurassic of Asia
- mostly in cretaceous of North America/ Asia, are in Europe
  - great herds in Alberta, Montana and Wyoming
  - distribution is North America and Asia (more eastern)
- define by presence of a rostral bone forming the upper beak
- 3 types of Ceratopsia
  - i-psittacosauridae
  - ii-basal neoceratopsians (incl. protoceratopsids/ leptoceratopsids)
  - iii-ceratopsidae
    - 2 & 3 make up Neoceratopsia

**-Bipedal vs. quadrupedal**

- psittacosaurus - biped
- neoceratopsia - quadrupeds
- secondary evolutionary step back to quadrupedality

**-Ceratopsian Skulls**

- psittacosaurus - no frills
- protoceratopsid - frill
- centrosaurine - have spikes
- chasmosaurine - more thinning of frills
- any genetic features associated with all of them? (problem)

**-Characteristic features**

- rostral bone: unique bone at top of snout leading to a parrot like beak
- skull that is narrow at the beak and flaring
- deep in the cheek region

**-skull**

- frill composed principally of paired parietal bones (on top of skull)
- strongly vaulted palate beneath the beak
- separating nasal from oral cavity

**-Ceratopsid skull characteristics cont.**

- folding of bones on top of the head to form secondary skull roof
- dental batteries
- and others
  - teeth were stacked on top

### **-ceratopsid diagnostic characters**

- shape and number of horns
  - shape and size and frills (ontogenetic?)
  - hooks on back of frill
  - long spikes extending from frill margin
  - neck vertebrae fused to support heavy head
- Pachyrostra: derieved centrosaurines with thick bosses replacing horns

### **-Ceratopsian Discovery**

- 1870s-1880s: cope and Marsh
  - parts of pelvis, some vertebrae and teeth
  - horn cores from Colorado misidentified by Mash as belonging to a prehistoric bison
  - 1880s skull of triceratops (tro-three, cera-horn, tops-face) in Wyoming
- Tricepratops-tucked legs vs. sprawling ?
- somewhat like rhinos - can they charge as well?

### **-finds in Alberta**

- 1890s-1910: Lawrence Lambe (ottawa)
  - centrosaurus
  - chasmosaurus - thin frill
  - styracosaurus
- Barnum Brown (new york)
  - anchieratops
  - leptoceratops

### **-finds in Asia (maybe original)**

- in 1923 ceratopsian dinos. discovered in Gobi Desert
- psittacosaurus
- protoceratops - late cretaceous, asia

### **-psittacosaurus - early cretaceous**

- means "parrot reptile"
  - parrot-like beak with rostral bone
  - discovered in the Gobi in 1920s
  - hundreds of specimens
  - no skull frill
  - bipedal
- they has gastroliths - help with digestion (stones)
- brooding (birds) sitting on eggs

### **-Ceratopsid diversity**

- one of the fastest-growing dino families
- over a dozen new species recognized in the past 5 years
  - first asian ceratopsid
  - oldest North American ceratopsids
- lumpers vs splitters

-new dino? (lumpers put everything together)

-over 50 complete and partial skulls of Triceratops

### **-torosaurus**

-one of the largest ceratopsians

-7-8 metric tons

-one skull was measured 2.8 m from snout to end of frill

-frill is made of thin bony struts and skin, not solid bone

-some think this is the fully mature ontogenetic stage of triceratops, not a different genus

-triceratops -

-torosaurus - more developed frill

### **-evolution**

-from small (1-2 m) bipeds to large (5-10 m) massive quadrupeds

-only small and very basal ceratopsians in the Late Jurassic

-basal neoceratopsians common in Asia through Cretaceous

-ceratopsids first appear and are only in Late Cretaceous, mostly in North America (rare exception in Asia)

### **-geographic range**

-sternberg discovered pachyrhinosaurus in Alberta

-late discovered on North slope of Alaska

-70 mill years ago up to 5 degrees of the late Cretaceous North pole

-migratory? different populations?

-was norther pop. different or migratory dino

-paleobiogeography - making out

-Laramidia (rockys?) and appalachia (east of north america)

### **-abundance in North America**

-make up about 25% of late cretaceous Canadian fauna

-in comparison to:

-hadrosaurs about 50% - most abundant

-theropods about 10%

-all other dino about 15%

### **-feeding**

-herbivores

-dense cluster of teeth in checks

-teeth were replaced when worn

-dental battery -(stacked)

-sturdy coronoid process - membrane bone on upper side of lower jaw to the back, lacking teeth

-evidence for fleshy cheeks

-good food processing within mouth

-gastroliths found with psittacosaurus

### **-chewing muscles -frills also allow attachment for strong chewing muscles**

-strong muscles for high-efficiency mastication

-attached through the upper temporal opening to base of the frill

-attached to a sturdy, large coronoid process on the mandible

### **-feeding position**

- low browsing
- no standing on hindlimbs
- knocking down trees?
- diet: shrubs, angiosperms, ferns, small conifers

### **-locomotion**

- comparable to rhinoceros?
  - usually slow, but able to charge
- tracks are uncommon
- 2-4 km/hour
- max running speed of 30-35 km/h
- debate on stance: under vs sprawling (modern reptiles)

### **-integument - soft parts**

- quills and bristles on the tail of psittacosaurus
- scale impressions from the rest of body

### **-social behavior**

- interspecific: among different species
  - role of horns, protection against predator
- intraspecific: within the same species - sex and such
  - role in display
  - ritualized combat (punctured wounds in frills and skulls)
  - establishment of dominance
  - defense of territories
  - sexual selection

### **-role of frills**

- attachment for jaw muscles
- protoceratops: frills increase with sexual maturity and larger in males
- sexual selection

### **-herb living**

- bonebeds
- several thousand specimen
- intraspecific behaviour related to gregarious lifestyle

### **-brain size**

- small compared to body
- larger than sauropods and stegosaurus
- slow uncomplicated lifestyle
- keep predators away with display of horns and frills

### **Ornithopoda -bird foot - Chapter 7 lesson 11\*\*\***

- means bird foot
- ornithischian dinos
- middle jurassic to late cretaceous (not made at beginning)
- extensive fossil record, worldwide distribution

## History of discovery

- 1820's-30s, Gideon Mantell discovers Iguanodon teeth & bone in England
  - body form not well understood in early decades
- 1850's Joseph Leidy discovers Hadrosaurus in New Jersey
  - hadrosaurus becomes first dino. mounted on display in museum
- 1878 discovery at Bernissart, Belgium
  - over 30 skeletons of iguanodon in a coal seam, anatomy becomes completely known
  - continuous discoveries
  - over 100 ornithopod species now described
- cerapoda: ceratopsians + ornithopods

## Ornithopoda

- characteristic features
  - cranial kinesis
  - lower position of jaw joint and ventral margin of premaxilla with respect to maxilla
  - obturator process (obp) on ishium (is)

## Basal Ornithopoda (hypsilophodontidae)

- traditionally paraphyletic grade of non-iguanodont ornithopods
  - consist of descendants of last common ancestor
- some jurassic ornithischians usually include in this group (ex. Othnielosaurus) may be just outside Cerapoda and this not true ornithopods
- small, bipedal herbivores
- fleet-footed
- possibly splittable into some monophyletic families
  - jeholosauridae, thescelosauridae
- some lived in burrows
  - oryctodromeus

## Iguanodontia

- monophyletic
- middle jurassic to late cretaceous
- characteristic features (not all appear simultaneously in this clade)
  - generally larger and more heavily built than basal ornithopods (up to 15 m)
  - expanded premaxilla lacking teeth (at jaw)
  - hoof like unguals, reductions in number of phalanges/ digits
  - other
- ex: camptosaurus

## Hadrosauridae - duckbills

- late cretaceous
  - north and south america, europe, asia, antarctica
- ex: hypacrosaurus, lambeosaurus, prosaurolophus

-basal genasauria and ornithopoda mainly western north americas, south africa and australia, Antarctica

-iguanodontia distributed america, europe, asia, africa, south america, antarctica

## Geographic distribution

- from paleoequator to polar attitudes
- notable high paleolatitude discoveries
  - spitsbergen, norway: big iguanodont tracks
  - north slope of alaska: edmontosaurus bonebed, thescelosaurid teeth
  - dino cover, SE Australi and James Ross island, Antarctic: new genera of basal ornithopods

### **Paleoenvironments**

- coastal plain deposits
- fluvial deposits
- marine deposits

### **Locomotion**

- bipedal terrestrial animals
- quadrupedal stance when standing still or feeding
- inguanodon - quadrupedal locomotion?
- strong hindlimb support weight

### **Inguanodon**

- capable of both bipedal and quadrupedal locomotion?
- strong front and hind limbs would support weight
- tail strengthened by ossified tendons and served as counterbalance

### **ouranosaurus**

- ossified tendons - things on the back (mowak lo)

### **Speed and brains**

- faster - 15-20 km/h with max of 60 for smaller ornithopods
- relatively large brains
- intelligence helps alertness
- no other means of protection present
  - no spikes, armour

### **Hands**

- some non-hadrosaurid iguanodons (iguanodon, ouranosaurus, camptosaurus)
  - first digit (thumb) was conical and sharply pointed
  - used for breaking apart vegetation?
  - weapons?
  - fifth digit opposite to thumb
  - three middle digits were hoofed

#### **-hadrosaurus:**

- thumb spike absent
- hooves on inner gingers
- digits joint in a thickened pad

### **Feeding habits - have bill (no beak)**

- extraordinary fossils such as edmontosaurus
- fossilized stomach contents
  - twigs, berries and coarse plant matter
- beak for cropping vegetation

### **Teeth:**

- block of cheek teeth
- dental batteries for grinding coarse material
- strong muscles
- teeth deeply set indicating large fleshy cheeks

-John ostrom suggested in 1961:

- chew mech. in hadrosaurs had propalinal jaw movement (back to front)
- others side to side

### **Bilateral occlusion**

- both teeth meet on both sides of jaws
- pleurokinese
  - lateral mobility of the upper jaw
  - opposing rotation of both jaws
    - impossible in humans
  - very flexible joints of the skull bones
  - dental batteries chewing vegetation with large amount of fiber

### **Behaviour and head structure**

#### **-hadrosaurs:**

- cranial features with nasal cavity
- solid and hollow crests
- for visual and vocal display
- important in mating behaviour

#### **-lambeosaurines:**

- hoow crest on top of head
- served as resonating chambers within crest

\*parasaurolophus - late cretaceous, north america

- nasal cavities in lambeosaurine hadrosaurids
  - lambeosaurus, parasaurolphus, corythosaurus

-display features

- good hearing and vision
- large eye sockets
- preserved middle and inner ear structure
- hearing of a wide range of frequencies
- elaborate outer shapes of crests point toward display
- species specific
- dimorphic? - diff. between male and female
- less developed in juveniles?

-difference btw species

- if they live in same time and area:
  - display features have to be different to avoid attracting the wrong mate
  - thus, diff. headdresses

### **-saurolophinae**

- accentuated nasal arches and stout cranial crest possibly used for head pushing during male to male combat
- nostrils covered by skin flaps which were blown out to impress enemy or make noise?

\*circumnarial depression supported inflatable flap of skin ex: Gryposaurus / Lambeosaurus

-ex: telmatosaurus, maisaura, gryposaurus, brachylophosaurus, prosaurolophus, saurolophus, edmontosaurus

-herd living

- boneheads suggested living in herds up to 10 000 individuals
- complex social behaviour
- safety in numbers?

-use of crests

- species recognition
- intraspecific combat
- ritualized display
- courtship
- parent-offspring communication
- social ranking?

**-hadrosaur nesting colonies**

- maisaura and hypacrosaurus
  - nests with up to 17 eggs
  - soft sediment
  - nest spacing as large as body of parent
  - shells are damaged from trampling
  - hatchling remained in nest
  - estimated nesting time: 8-9 months
  - quick growth

**-integument** - skin impressions well-known for hadrosauridae

- comparison of scale pattern in species of saurolophus
- mottled tail in *S. osborni*
- banded tail in *S. angustirostris*, tabular scales along midlines (9b)

**Sauropodomorpha** - Chpt. 8 lesson 12 \*\*

-off of Saurischian

- lizard hipped (pubis projects forward and downward (primitive reptiles))
- named by H.G. Seeley in 1887
- includes the smallest and largest dinos.
- all of carnivorous dinos, plus more herbivores
- derived features of saurischia
  - subnasal foramen - opening beneath the nostril area
  - elongation of the rearward back vertebrae (longer neck)
  - increased articulations btw vertebrae
  - robust thumb supported by a broad metacarpal bone
  - digit II of hand longer than digit III

**-eoraptor**

- small (1.3 m long) bipedal early saurischian from the late triassic of argentina
- initially described in the 90s as an early theropod
- reinterpreted in the 2010 as a sauropodomorph
- shares with other sauropodomorphs skull features related to herbivory, thumb claw rotated forward

**-sauropodomorpha** - sauro(lizard), pod (foot), morpha(form) - retained all five digits (lizards)

- includes all the biggest dinos.
- weight: up to 75 000 kg
- length: 40 m
- height up to 6 m at the shoulder
- ex: prosauropod and sauropod
- diverse late triassic record\* - lack of fossils from late triassic of North America
  - prest in South America, Africa, Europe, India, Thailand
  - very basal sauropodomorphs**: Chromogisaurus, Eoraptor, Papadromaeus, Panphagia, Saturnalia
  - traditional "prosauropods"**: Efraasia, Jaklapallisaurus, Plateosaurus, Riojasaurus, Unaysaurus...
  - early sauropods**: Antetonitrus, Isanosaurus
- survival (over 160 mil years)
  - animal that big test processes such as:
    - weight support
    - neural circuitry
    - respiration
    - digestion
- \*global distribution of sauropodomorpha

- prosauropods** - Plateosaurids, Massospondylids, Riojasaurids, Yunnanosaurids
  - evolutionary radiation in the late triassic
  - thriving with worldwide distribution in early Jurassic (Canada - Nova Scotia) and Antarctica
  - extinct in middle Jurassic
  - prolly not monophyletic (one descendent) group; some more closely related to sauropods
  - small heads, long necks, bulky bodies, but most bipedal
  - first tall browsing herbivores in earth's history

ex: Plateosaurus (prosauropod) - well developed thumb claw (herbivore or omnivore)  
 other ex: Anchisaurus, Coloradisaurus, Lufengosaurus, Yunnanosaurus

\*other to note feeding on gymnosperms gastroliths have been identified stomach fermentation

### -sauropoda

- monophyletic (common descendent)
- shortening of rear portion of skull
- lower temporal opening situated partly beneath eye socket
- 12 to 19 neck vertebrae
- 4 to 7 sacral vertebrae
- quadrupedal**
- massive and vertical limbs and solid long bones
- broad snout with spoon-shaped or pencil-like teeth at front jaw, loss of overbite
- long tail (modified in some to end in a small club or very long whip)
- cont.
  - evolved from prosauropods in the late triassic
  - increasing size and diversity in the Jurassic
  - absent in northern America in the late Cretaceous - but successful until end of Cretaceous in most world

ex: patagosaurus

**-history of discovery:**

- first sauropodomorpha species were named from european discoveries in the 1830s and 1840s: thecodontosaurus, plateosaurus, cetiosaurus
- not among the reptiles included by richard owen in his original concept of dinosaur
- sauropods and prosauropods not formally classified together as sauropodomorpha until 1930s

**-cont. North america**

- new chpt. in sauropod research began in 1870 by Cope (camarasaurus) and Marsh (apatosaurus, diplodocus)
- most prolific source is the Morrison formation, late triassic, western USA
- continues with sauropods from this formation still recently being named:
  - suuwassea (2004), kaatedocus (2013)
- no sauropod body fossil yet from Canada, but footprints recently found in BC

**-camarasaurus** - late jurassic

- most common sauropod in North America
- 18 m long body
- head high, short and powerful
- teeth not restricted to front of jaws

**-diplodocus** - late jurassic

- 27 m long
- nostril opening far back on skull
- elongate snout
- pencil like teeth at front of jaws only
- long drawn out tail acting as whip
- neck vertebrae in Diplodocus with Y-shaped neural arches
  - hold ligament called nuchal ligament in place for neck support
- other of Morrison formation: Apatosaurus, Barosaurus, Supersaurus
- seismosaurus named in early 90s - may be very large individual of diplodocus

**-worldwide**

- tendaguru hills in Tanzania
- major expedition by E. Fraas and Werner Janensch
  - 225000 man days
  - over 100 articulated skeletons
  - hundreds of isolated bones
  - 4300 jackets to be carried to port city
  - 5400 walks, each one four days
  - specimens shipped to berlin
- 1907
- 500 local workers
- new late jurassic sauropods: Dicraeosaurus, Giraffatitan (related to Brachiosaurus), Janenschia, tornieria
- amargasaurus (early cretaceous)
- diplodocoid related to tendaguru's dicraeosaurus - late jurassic
  - double row of long spines on neck: defines? supporting a pair of sails?

-rebbachisaurids: bizarre early-late cretaceous diplodocoids of south america, Africa and Europe: most are recently discovered  
-specialized for low feeding with **dental battery** at front of snout - not typical sauropods but skull lightly built  
-highest rate of tooth replacement for dinos: individual teeth lasted as short as two weeks

ex: Nigersaurus - early cretaceous (africa)

-**titanosauria**: very successful clade, only sauropods at the end of late cretaceous  
-wide heavy bodies, more flexible vertebral articulations, some had osteoderms (bone plates and other in skin later)  
ex: futalognkosaurus - late cretaceous  
-huge range of body size: some titanosaurs were relatively small sauropods, other were among the largest that ever lived  
-titanosaur - super giants - more examples:  
-argentinosauros, puertasaurus, futalognkosaurus, ruyangosauros, alamosaurus  
-most are incompletely known - some estimated about 35 m long and 75 tonnes  
-more ex: Yongjinglong - early cretaceous in China  
-publishes early in 2014 one of many recent sauropod discoveries

-taphonomy

-most skeletons are incomplete: bodies too big to be rapidly buried?  
-most skulls of sauropods are missing  
-some late cretaceous mongolian sauropods known only for skulls  
-Nemegtosaurus, quaesitosaurus

-habitats

-wide geographic distribution  
-diff. habitats  
-fine-grained floodplains  
-channels  
-eolian sandstones  
-lakes  
-rivers  
-many represented in Morrison formation, jurassic of western USA

-migration

-western interior was seasonally dry during jurassic  
-sauropods responded with migration to lush areas  
-trackways

-live in deep water? - argument for

-early hypothesis: too big to live on land?  
-body too heavy to be supported thus needing buoyancy of water?  
-breathing like whales?  
-long tails used for swimming?  
-nostrils acted as snorkel?

-argument against:

-air pressure: animals breath air at 1 atmosphere of pressure  
-in water pressure increase by 1 atmosphere every 9.8 m  
-lung of sauropods would have collapsed

-air sacs in bones would make sauropods float

-closer look at:

-diplodocidae

-shorter forelimbs, most weight supported by hindlimb

-brachiosauridae

-note long forelimbs would a tripod posture be possible?

-blood pressure

-distance btw heart and brain is huge

-thus pump high to prevent fainting

-pressure of humans (120/70)

-brachiosaurus 8.5 m long neck

-thus 620 pressure, giraffe has about 320

-ex: apatosaurus - late jurassic - north america

-heart size?

-very large muscular

-estimated 400 kg

-other anatomical features

-one way valve to prevent backflow

-unidirectional avian style respiration where air sacs support lungs to pump air

-posture

-head up in the air requires high blood pressure

-tripodal posture: lifting up forelimbs

-using the tail for third leg

-oxygen exchange

-oxygen has to be transported to lungs through the wind pipe (trachea) for exchange with carbon dioxide

**-mammals**

-mammals: not very efficient only 20 percent of air makes it to lungs for exchange

-bidirectional airflow

-air remains within the trachea

-birds: about 40 percent exchanged

-unidirectional airflow

-oxygen exchange in sauropods

-giraffes have narrow tracheas to limit dead air space

-giraffes are at the limit with length of neck... for mammals

-sauropods surpassed them

-food

-triassic: ferns, seed plants, cycads, ginkgoes

-jurassic: conifers, less ginkgoes, ferns and horsefalls

-cretaceous: conifers or angiosperms

-fossil plants found with sauropods remains

-diversity of skull and tooth types suggests diversity of feeding strategy

-social behaviour:

-trackways and large bonebeds

-found in North and South America, europe, asia and africa

-narrow and huge

-horseshoe shaped with no imprint of massive claw on thumb

- foot ovoid with toe claws and heel pad
- rare tail drag marks
- gregarious
- large impact on environment
- migration in search of food
- give birth to young?
- titanosaur nesting ground found in patagonia
- a square km large with thousands of unhatched eggs
- 4 layers of eggs with clusters of 15-34 eggs
- behaviour and growth
  - no adult bones found at nest site
    - parents leave nest?
  - long if take to reach maturity?
  - life span?

### **Theropoda: Chapter 9 and 10 - lesson 12**

- they are saurischian
- late triassic to end of late cretaceous, worldwide distribution
- all were obligate bipeds, derived features in forelimbs and hindlimb
- includes practically all the carnivores dins, but not all theropods were carnivores
- only group of dinos with living descendants are **birds!**
  
- early discoveries (megalosaurus - middle jurassic, europe)
  - megalosaurus**: first dino to be named (by William Buckland), was reconstructed as a quadruped (no very complete)
  - compsognathus(1859)**: - solnhofen limestone, Germany
    - first complete skeleton of small theropod
    - T.H Huxley speculated on bird connection
  
- the bone wars
  - 1866-cope named "Laelaps" from new jersey, marsh renamed it **Dyptosaurus**
  - 1870-90 - marsh names **allosaurus, coelurus, ceratosaurus, ornithomimus** from west USA
  - 1881 - marsh named group **Theropoda**: thero- beast & poda- foot
  - ex: allosaurus - late jurassic - north america and europe
  
- late discoveries
  - many familiar theropods were named in early decades of the 20th century
    - albertosaurus (1905)
    - tyrannosaurus (1905)
    - spinosaurus (1915)
    - struthiomimus (1917)
    - oviraptor (1924)
    - velociraptor (1924)
  - present understanding of theropod phylogeny and relationship to birds not until late 20th C
  - some new families discovered since 1990 (in Gondwana)
    - alvarezsauridae
    - neovenatoridae
    - scansoriopterygidae
  - first **feathered** non-avian theropods discovered in late 1990s

### **-triassic theropods**

- oldest known theropods are late triassic
- widespread and modestly diverse, but generally not biggest predators
  - ex: herrerasaurus - late triassic
- coexisted with large carnivorous pseudosuchians
  - ex: postosuchus
- herrerasauridae
  - most basal family of theropods - not universally agreed to be theropod (could be own group of carnivorous basal dins)
  - surprising mix of primitive and derived characters
  - lived exclusively in late triassic
- coelophsoidea
  - unambiguous early theropod, sharing with later theropod more birdlike foot
  - late triassic to early jurassic
  - well known from boneheads, trackways
  - best known: coelophysis - 3m long, agile, early theropod

### **-jurassic theropods**

- emerge from Tr-j extinction as dominant carnivores on land, diversity and body size increases
- commonly sported ornamental crest of bone on the skull
  - ex: -dilophosaurus - early jurassic, north america
  - ceratosauria - early jurassic to late cretaceous - small and large forms - strange skull
- other ex: cryolophosaurus - early jurassic, antarctica
- masiakasaurus - late cretaceous - madagascar
- jurassic ceratosaurs lived practically worldwide
  - absent in north america and asia in cretaceous but very successful in south hemisphere
- abelisauridae: large, short snouted ceratosaurs
  - carnivores
  - forearms and hand extremely reduced
- other examples: carnotaurus - late cretaceous, south america
- tetanurae - tetanus: stiff & uro: tail
  - back half of tail is stiff
  - elongation of the interlocking fore- and aft projections from the neural arches, called **zygopophyses**
  - early jurassic to late cretaceous (non avian) or recent (birds)
  - evidence of filamentous integument
  - miniaturized tetanuran lineage led to bird by the late jurassic
  - also group containing the biggest theropod:
    - spinosaurus, giganotosaurus, tyrannosaurus, etc. (suchomimus - early Cret. africa)
- spinosauridae
  - large hand closed, specialized jaws and teeth - fish eaters
- allosauroidae, carcharodontosauria
  - deep hatched-like snout
  - sauropod hunters?

- giganotosaurus - meaning: giant southern reptile
  - mid cretaceous
  - argentina
  - discovered 1994
  - 14 m long, 8 metric tons
  - larger than T. Rex
  - 25 million years older than T. Rex
- tyrannosauridae
  - front teeth are D-shaped in cross sections
  - reduced forelimbs with loss of digit III
  - a large "boot" on the end of pubis
  - and many more
  - (gorgosaurus - late cretaceous, north america)
  - (daspletosaurus - late cretaceous, north america)
- tyrannosaurus rex
  - very large and heavy head
  - very short forelimbs which could not reach mouth
  - were forelimbs reduced to lessen weight for counterbalance of heavy head
  - able to lift 200 kg
- ornithomimosaur
  - lightly build skull
  - long and low snout
  - reduction or loss of teeth
  - long and low mandible
  - long forelimbs
  - flat claws on the foot
- oviraptorids - late cretaceous
  - deep skull with shortened snout
  - short and deep lower jaw with short, concave and thickened from rim
  - palate with a pair of median, tooth-like projections
  - ex: caudipteryx: feathered oviraptorosaurs from early cretaceous - asia
  - non avian dino or flightless bird?
- troodontidae
  - sickle-claws
  - enlarged ear cavity
  - sinus system in the base and sides of branches
  - modifications of angle and foot
  - ex: saurornithoides - late cretaceous, asia
- dromaeosauridae - ex: velociraptor - late cretaceous
  - sickle clawed
  - active predator
  - close relation to troodontids and birds
  - wing feathers on forelimbs and hindlimb - in some species (gliders)
  - larger forms were flightless
- paleoecology** (fossils)
  - wide range of paleoenvironments
  - fluvial channels (river stuff)
  - overbank deposits
  - lacustrine environments

- eolian dunes
- many are disarticulated
- isolated finds - shed teeth are common
- ex: dromaeosaur teeth - late cretaceous of alberta
- bonebeds:
  - ghost ranch new mexico
  - several hundred individuals of coelophysis
  - mapusaurus in patagonia
  - cleveland-lloyd quarry utah
  - excavation of over 40 allosaurus since 1927
- living organism
  - large range in size
  - small ones: 1 m long, 5 kg
  - large ones: nearly 15 m long, 5 -8k kg
    - ex: albertosaurus (late cretaceous) and deinonychus - small (early cretaceous)
- why theropoda reach such large size:
  - large herds or hadrosaurs and ceratopsian dinos
  - modern carnivorous mammals are smaller
  - cretaceous food sources more plentiful?
  - physiological differences between giant theropods and living endotherms?
- locomotion:**
  - bipedal, unable to run on all 4 limbs
  - body was balanced over pelvis
  - vertebrate column held horizontally
  - feet were placed close to body
  - one foot in front of the other
  - ex: mononykus - late cretaceous
- balance:
  - great balance due to a horizontal vertebral column
  - centre of gravity over hips
  - smaller theropod exceptionally smile
  - able to leap
- digitigrade stance:
  - foot was placed on toes
  - ankle held well off the ground
  - digit usually have sharp claws
  - relatively short femora (plural of femur) in smaller theropods
  - long strides
  - running speeds of 40-60 km / hour
- diet:
  - most lineages were carnivores
  - predators or scavengers?
  - terrestrial hunting or fishing
  - omnivory or herbivory common in coelurosauria (tetanurae)
    - ornithomimosaur
    - therizinosaur
    - oviraptorosaur
    - birds
- loss of teeth

- multi branches have lost some of all teeth
  - ornithomimosaur
  - oviraptorosaurs
  - limusaurus (Ceratosaur)
  - various birds
- beak of cornified skin or scales on jaws
- quick jaw closing action
- weaponry
  - feet: large claws
  - deinonychosaurs:
    - huge one on 2nd digit, retracted during running to avoid abrasions
    - slicing open prey?
    - holding onto prey
  - forelimbs equipped to catch prey
  - enlarge hand
  - digit 2, 3 and 4 or 1, 2, and 3?
  - largest claws on inner digit esp basal tetanurans
  - changes in wrist for better grasping ability
- senses
  - keen sense of vision for prey tracking
  - large eyes (especially in ornithomimosaur)
  - binocular vision, eye moved forward: troodon and tyrannosaurus
  - large middle ear cavities - low frequency sounds
  - communication btw both ears
- behaviour
  - troodontids and other maniraptors have biggest brain size
  - most sophisticated intra and interspecific behaviour
  - deinonychus - packing hunting?
  - 3 skeletons were found with remains of a large ornithomimid, tenontosaurus
- single hunting?
  - hit and run attack
  - one big bite killing prey or bleeding prey to death
  - suffocation of victim by grabbing it by the snout - large skulls and jaws
  - shaking their victims to death
  - scavenges ?
- prey
  - fossilized stomach content
    - in compsognathus: fast running lizard
    - indicates speed
  - velociraptor caught fighting with protoceratops
  - predator and prey have to be within same fossil assemblage  
ex: tarbosaurus and saurolophus - late cretaceous
- social behaviour: display
  - visible cranial crests made of bone common in large theropods
  - some were follow being part of cranial air sinus system
  - elevated margins on snout and over eyes
  - some smaller theropods used feathers for display
- reproduction
  - relatively few records of fossil eggs

- brooding on nests like birds
- ex: oviraptorid nest
- growth and sexual dimorphism
  - are certain features more expressive in adult specimens - male vs female
  - little is known about growth stages in most dinos
  - bonebeds offer best study grounds

#### **-coelophysids**

- bodies from hatching to adult stage are found
- 10-15 fold increase in size
- over 8 years??

#### **-tyrannosauridae**

- nanotyrannus or juvenile t. rex?

### **Feathered Dinosaurs: - lesson 14**

- what early tells us about evolution of feathers?
- Archaeopteryx
  - fossil feather known since 1861 but...
  - archaeopteryx feathers are essentially already developed as modern birds
  - did feathers evolve before flight or for flight?
- less than 20 years ago no feathered dinos were known
- velociraptor as depicted in Jurassic Park (1993)
- discoveries/ localities
  - most feathered dino are known from early cretaceous Jehol group of Liaoning Province, northeastern china
  - more recently the middle-late jurassic rocks in the region also produced feathered dinos
- sinosauropteryx
  - discovered in 1996 - first non-avian dino with feathers preserved
  - Yixian formation, early cretaceous (124 mil years old)
  - small theropod with very long tail and short arms related to compsognathus
  - short, downy feathers are preserved along the neck and back tail
- protarchaeopteryx
  - 1997 - first non-avian dino with rectrices (tail fan feathers); symmetrical vaned feathered not capable of flight
  - Yixian formation, early cretaceous (124 mil years ago)
  - actually lived later than archaeopteryx probably related to oviraptorosaurs
- caudipteryx
  - 1998 - first non-avian dino with half a wing of symmetrical feathers on hand - tail fan also present
  - Yixian formation
  - an oviraptorosaur with long hindlimb, teeth in premaxilla only, gastroliths in stomach region
- beipiaosaurus
  - 1999 first feathered therizinosauroid
  - Yixian formation, early cretaceous (124 mil years ago)
  - greater body size than previously known feathered dino (over 2 metres long)
  - 2009 second skeleton found
  - elongated broad filamentous feathers (EBFFs) may have had a display role
- feathered dromaeosaurids
  - important group for establishing dino- bird link (recall Ostrom's work on Deinonychus)

- feathers predicted by artists since the 70s and 80s
- 1999 first feathered dromaeosaurid fossil, sinornithosaurus (Yixian formation)
- 2000 microraptor (Jiufotang formation - 120 mya.)
- 2002 first dromaeosaur with modern pinnaces feathers
  - named cryptovolans by clerks et al, but may be same as Microraptor
- 2003 - microraptor with 4 wings
- dromaeosaurids
  - 2001 "Dave" a sinornithosaurus - like dromaeosaur (Yixian Formation)
  - complete skeleton, but species could not be identified due to crushed, flattened bones possibly immature age
- dilong, a feathered tyrannosauroid
  - 2004 from the Yixian formation
  - primitive features such as small size (2 m) and 3 fingers
- juravenator
  - 2006 from solnhofen area of germany (late cretaceous)
  - scaly skin on tail initially suggested that this was a featherless theropod
  - further studying using UV light revealed that feathers were present but mainly preserved
- epidexipteryx
  - 2008 from the Daohugou Beds (middle or late jurassic)
  - along with scansoriopteryx (named in 2003) belong to scansoriopterygidae - closely related to birds
  - very small with extremely short tail and long display feathers
- anchiornis
  - 2009 from the tiaojishan formation (middle to late jurassic)
  - 4 wings as in microraptor but wing feathers are shorter and not as aerodynamic
  - a troodontid (theropod feather bird)
- late discovery: Xiaotingia
  - announced july 27, 2011
  - probably from the Tiaojishan formation
  - very similar to both anchoring and archaeopteryx, called into question whether or not archaeopteryx was a bird
- other fossil evidence
  - quill knobs (ular papillae) on arm bones of velociraptor (turner et al 2007)
  - preserved in amber (mckellar et al 2011)
  - protein immunohistochemistry of fibres associated with the alvarezsaurid Shuvuuia (schweitzer 2001)
- feathered ornithischians
  - one specimen of the ceratopsian psittacosaurus has bristles on its tail
  - heterodontosaurid tianyulong sporting very long filaments
  - distribution of feather like structure in dinosaurs and their relatives is complex, involving convergences or losses
  - homology of non coelurosaur structure with true feathers is still controversial
- what evolutionary stages did feathers pass through?
  - current model of feathers evolution based on developmental and fossil evidence
  - feathers begin as single hollow filaments (stage 1) then tufts of filaments (stage 2) and then branching structures (stage 3)
  - interlocking barbules are a hallmark of advanced birdlike feathers (stage 3 and 4)
  - xu et al (2010) recognized up to 9 types of fossil feathers

- but foth (2011 in press) has studied the feathers of an experimentally flattened modern bird and believes some of these feather type to be taphonomic artifacts
- was the function of dino feathers?
  - most basal known feathered dino had down like feathers, likely function was insulation
  - no remiges or recites origin of feathers unconnected to origin of flight
  - broad elongated feathers may have had an important display function in dino like beipiaosaurus and epidexipteryx
  - oviraptorosaurs had specialized flexible tails with short vertebrae and a fused pygostyle courtship display likely involved wagging the tail feathers (persons et al, 2011)
  - wing feathers could also help a flightless oviraptorosaur shield its eggs and young
  - first reconstruction had all 4 wings extending out in almost the same plane
  - model favoured by aerodynamic tests of alexander et al (2010)
  - other researchers doubt if this pose was possible without dislocation the legs
  - alternative model by chatterjee and temple (2007) of micro raptor as a dino biplane
- colour of feathers - yes to some extent
  - dark organic imprints in many fossil feather were found to be fossilized melanosomes, organelles responsible for a feathers melanin pigment
  - diff shapes of melanosomes correspond to different colours in modern feathers
  - phaeomelanosomes indicate that sinosauropteryx reddish brown or orange
    - tail had a striped pattern
  - eumelanosomes indicate that anchoring was dark grey or black

## **Pterosaurs: Chapter 12 - lesson 15 - flyers**

### **-flyers**

- started relatively late
- requires significant modifications:
  - skeleton
  - muscles
  - motor control/brain
- three levels of flight
  - gliding/parachuting: body surface increases to provide resistance to air
  - flying: powered
  - soaring: take advantage of air movement
- air spaced conquered
  - devonian - 195 mil yeahs ago
  - animals and plants moved on land
  - first spores used air space for distribution
  - insects
- why fly?
  - advantages:
    - larger distance in shorter time
    - arctic tern with an annual migration route of 3000 km
    - discovery of new areas, inaccessible over land - colonization by air
    - flyers can escape predators
    - predators can capture their prey
    - almost every group of vertebrate has members with the ability to:
      - fly, glide, soar

### **-flying animals**

- insects

- flying fish
  - capable of flying 200 m with speeds of up to 50 km/h
- flying frogs
  - indonesia
  - membrane between toes
- lizards and geckos
  - membrances along the side of body
  - draco volans, a flying lizard from southeast asia
  - ribs extend beyond body
  - air born for about 15 m
- flying snakes
  - from southeastt asia, india and sri lanka
  - flatterns its body to increase air resistance

### **-mammals**

- bats, flyinf squirrels, gliding possums and flyinf lemurs
- fossil record goes back 60 mya.
- bats
  - flying mammals
  - fossil records of 60 may
  - four greatly elongated fingers
  - flying reptiles have on finger
  - birds have feathers instead
- birds
  - since late jurassic
  - archaeopteryx lithographica
  - solnhofen limestone
  - recent finds in texas place origin of birds back to time of pterosaurs
- pterosaurs
  - flying reptiles
  - appeared at the end of triassic
  - 213 mya.
- what flyers have in common
  - wings
  - hollow bones for body weight reduction
  - some fused joints reduce flexibility for controlled movement
  - warm bloodedness for constant high levels of energy
- bones
  - hollow
- poor fossil record of flyers**
  - hollow and fragile bones
  - poor fossilization potential
  - lithographic limestones of solnhofen offers preservation potential
  - chalks of kansas
- solnhofen - germany**
  - 140 mil. years central europe was covered by a tropical sea
  - tethyan sea
  - quiet lagoon sheltered by barrier reef
- solngofen limestone:**

- quarried for 2000 years
- used by romans as building rock
- lithography
- splitting of rocks into thin slabs reveals fossil content
- why ideal for fossilization
  - lagoon - hypersaline
  - carcasses fall in and settle down to the seafloor
  - lack of scavengers destroying carcasses
  - cover of very fine sediment
  - forming sedimentary rock

### **-pterosaur?**

- word means winged lizard
- survived over 140 mil. years
- extinction at 65 mil years
- cretaceous/ tertiary boundary
- not a dino!
- world wide distribution
- early discovery in 18th C
- white cliffs of dover
- solnhofen limestone
- chalk deposits of kansas
- prior to dinosauria - split off ornithodira

### **-systematics**

- kingdom: animalia
- phylum: vertebrata
- class: reptilia
- sub-class: rarchosauria
- order: pterosauria
- sub order: rhamphorhynchoidea
  - Pterosactyloidea
- genus: >60 genera

### **-origin**

- first ones already highly specialized flyers
- missing link to more primitive forms
- no fossil record of ancestors
- scleromochlus
- described 1907 from upper triassic of scotland
- 20 cm long, large head, long tail
- locomotion: jumping like kangaroo rat

### **-ancestor**

- scleromochlus
- 220 mil years old: scotland
- skeletal modifications
- similar clavicle to pterosaurs
- ankle modification
- large skull compared to body
- light skeleton

-2 groups of pterosaurs

- rhamphorhynchoidea

  - triassic to jurassic

  - primitive

  - retain tail, teeth

  - smaller

- pterodactyloidea

  - more advanced

  - longer skulls and necks

  - fused backbones in should region

  - longer wrist bones

  - shorter tail and 5 toe.

**-features: pterosaurs**

- leathery bat-like wing

- one greatly elongated finger

- a joint at the base of finger so that the wing can be folded in when not flying

- 4 joint in the finger

- 3 more short fingers for grasping prey, branches - bearing claws

- wing membrane

  - superbly preserved specimens of Germany and Brazil

  - preservation of wing membrane

    - consisting of several layers

    - outer layer is reinforced by thin fibers

    - why?

- larger opening between nostril and eye, maybe to lighten skull

- brains were large and bird-like

- sharp bill, some with teeth on the jaw

- teeth were sharp without serration suitable for capturing and killing

- breastbone is a large plate for bracing the wings and anchoring the massive flight muscles

- no wishbone

- hollow vertebrae at the front of body and connected to the lungs by pneumatic tubes

- found also in birds and saurischian dinos.

- pneumatic tubes allow air into bones

  - weight reduction

  - cooling system

  - oxygen reserve in warm-blooded animals

- long legs with a foot of five toes

-skull ornamentation

- pterodactyloid: complex and large

- rhamphorhynchoids

  - small, no ornamentation

-food

- either insect or fish eating

- evidence from stomach content

- impressions of throat sacs (pelicans)
- later taxa without teeth - scavengers
- scooping over water
- some had webbed feet
  
- on the ground
  - bipeds or quadrupeds?
  - membrane attachment - we have no clue
  
- in the air
  - smaller forms likely active flyers
  - large forms - mixture of active flight and soaring
  - take-off of an animal the size of a small plane?
- lifting into the air?
  - arboreal hypothesis:
    - maybe tweet climbers, but fossils found in desert conditions
    - sharp claws only found on hands, not feet
  - cursorial hypothesis:
    - running on the ground and lifting up
    - long legs
    - walking on end of toes
    - similar hips, knees, foot joints than upright animals such as birds
  
- pteranodon**
  - 17 kg
  - 7 m wingspan
  - good flyer
  - slow but able to maneuver and land softly
  - long, bony headcrest
  - no teeth, long beak
  - late cretaceous
- lifestyle
  - triassic - dry
  - cretaceous - lush
  - on land, along ancient coastlines
  - hunting several 100 km out to sea
  - egg lying, maybe in colonies
  
- fossil record
  - over 90 species of pterosaurs
  - birds have 8000 species
  - poor fossil record
  - 20 percent alone found in solnofen

## **Marine Reptiles - Lecture 16**

### **-Turtles**

- anapsids
- most primitive group of living reptiles
- ancestry is poorly known

- odontochelys from china, 10 mil years older than:
  - proganochelys - late triassic - europe
- common during jurassic and cretaceous
- seas and estuaries
- modern sea turtles
  - limb are modified into hydrofoils
  - using all 4 limbs as wings under water
  - precise migration over 1000 km
  - warm blooded

**-archelon - the Giant**

- cretaceous
- 3 m long
- 4 m in flipper span
- no complete bony carapace due to weight
- bony framework

**-crocodiles**

- archosaurs
- ancestors were terrestrial
- late triassic
- since early jurassic living at the water edge

-postosuchus - late triassic crurotarsi 4-5 m long - fast hunter

**-phobosuchus**

- late cretaceous, texas
- largest crocodile
- 11 m in length, possibly 15 m
- 6 tons, possibly 18
- duckbill dino as prey?

\*in Holzmaden during Jurassic time

**-Jurassic in southern Germany**

- over 60 mil years europe partly covered by water forming smaller basins
- stagnant - reduced oxygen exchange
- posidonienschiefer
- lower jurassic
- rich in well preserved fossils

**-ex: Ichthyosaurs - Leptopterygius - 7.8 m long**

- diapsids
- similarity to dolphins
- but tail flukes are vertical, no horizontal
- spine is running into lower tail fin
- allowing steep vertical diving
- limbs are small stiff fins

-cont

- good vision - large eyes

- long and thin jaw in advanced species
- piercing conical teeth for catching fish
- early species had blunt shell-crushing teeth
- hunting cephalopods

### **-shonisaurus**

- late triassic, Nevada
  - up to 20 m long, largest found in Canada
  - strong, deep body
  - 37 specimens were found fossilized together with all facing in same direction
  - mass stranding such as observed with whales?
- ex: ammonite with teeth marks of marine reptiles = eat it

### **-Sauropterygia (order)**

- nothosaurs
- plesiosaurs
  - small heads, long necks
  - preying on small fish

#### **-nothosaurs**

- triassic
- alps and china
- lots of material, but only few well preserved specimens
- powerful tail for propulsion
- hind limbs acted as rudders
- strong limbs, possibly allowing moving on land for egg laying

#### **-plesiosaurs**

- replaced nothosaurs in early jurassic
- strong limbs, highly modified for swimming
- true plesiosaurs:
  - elamosaurus - cretaceous, Kansas
  - 12 m, 76 neck vertebrae
- pliosaurs: large
  - kronosaurus: 12 m, 4m skull, Australia
- powerful 4 limbs
- powerful ligaments to move limbs
- up and down stroke
- comparable to flying through water such as penguins
- prey: small fish due to their small heads

### **-mosasurs**

- late cretaceous
- more than 40 species
- up to 10m in length
- main propulsion through flexing of body
- skulling with tail
- large heads with powerful jaws
- some had staying teeth, some had blunt teeth to crush sea shells

-cont

- ex: platecarpus and mosasurus
- carnivores
- limbs were hydrofoils
- rigid elbow joint
- should joint designed for up and down movement

### **-air-breathers**

- such as modern marine mammals
- dangerous process at time of birth
- turtles lay eggs on land
- dolphins: young are born tail first, then pushed by adults to surface to breath
- immediate need to suckle
- what did ichthyosaurs do?

### **-ichthyosaurs behaviour**

- fetuses of ichthyosaurs have long jaws
- born tail-first
- requirements of parental care

### **-mosasaur behaviour**

- no juveniles were found
- unusual pelvis possibly giving birth to large live offspring
- 1996 mosasaur with two juveniles inside found in South Dakota

### **-egg laying?**

- placodonts, nothosaurs and plesiosaurs have limbs allowing entering the beach
- did they lay eggs along the shoreline?
- all marine reptiles became extinct except turtles and crocodiles

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