Paired fins and limbs
-homology between crossopterygian and isthyostegid limbs not due to direct evolution of limbs, but to a common pattern of development

Fin to limb
1. Formation of stylopod and zeugopod (sarcopterygion)
2. Form of autopod region (wrists, fingers)
3. Determination of number of bones/digits (sarcopterygion)
4. Loss of fin rays (tetrapods)

Tetrapods – late activation of hox d 12

-sarcopterygion fish shape some characteristics with early tetrapods
-earlier tetrapods are more fish like than once thought

Why did the fish limbs evolve?
-some environment with fluctuating water levels, decreasing oxygen supply

→Selection pressure favored the evolution of lungs/limbs

- Limbs evolved from fins with axial skeleton
-fin rays allowed the fins to be flexible
-axial skeleton gave support

Selective pressure that favored limbs
1. Exploit unoccupied habitats
-shallow water, more abundant prey, less predators
2. Explot abundant food in shallow water
3. Escape unfavorable environment
-leaves a drying out pond
4. Avoidance of predators in shallow water
5. Improve locomotion; anchor points as body undulates forward
6. Improve locomotion; strut to prevent body from tipping on side

-Ordovician and Silurian
-extensive shallow seas
-ostracoderms, placoderm, acanthodii
-Osteichthyes (Devonian) –radiation of fish

Tetrapods
-First skeletal evidence of tetrapods appear in early Devonian
-continents moving closer together
-losing shallow seas
-fewer epicontinental seas
-formation of large continents
-Laurasia/Gondwanaland separated by the Tethys Sea
-land is productive, moist, vascular plants

Carboniferous
-Pangea present throughout the Permian and Triassic
-160 million years
-covered 36% earth surface
-fewer epicontinental seas
-Pangea colonized by vertebrates

Devonian
-large horsetail/giant club mosses
-First fossil seeds appeared late Devonian

Carboniferous
-increased diversity of terrestrial invertebrates/plants
-cockroach, large dragonflies
→Herbivores and predators
→Land offered novel foods and habitats
→Higher oxygen levels

Class amphibian ←nonamniotic tetrapods
-early tetrapods "labryrinthodont"
-4 groups

1.”stem tetrapods” or labyrinthodontia
-Acanthostega/Icthyostega
2.Batracomorphia
-lepospondyli/temnospondyli →ancestor to modern amphibians
3. Reptiliomorpha –ancestral reptiles
4. Lissamphibia –living amphibians

Origins of tetrapods
-sarcopterygii (lobe finned fish)
1. Osteolepiformes
2. Elpistostegidae (Panderichthyes)
→Tiktaalik rosaea

1. Osteolepiformes
-“the gap between fishes and tetrapods has narrowed”
-cylindrical body
-thick scales
-Variable caudal structures –different tail shape indicates different habitats
-paired crescent shaped vertebrae
    -very similar to earliest tetrapods
-ribs project dorsally from vertebrae
    -probably didn’t spend much time in shallow water, bad bottom support
    -labryrinthodont teeth

-long snout and teeth →stalked or ambushed prey maybe similar to frogfish, ambush predator

-similar behavior to extant frogfish
-can walk and slow gallop on ocean floor

2. Elpistostegidae
-resemble the early tetrapods
-dorsal fins
-reduced tail
-large fish >1m long
-long snout
-Dorsally flattened with eyes on top of head – means spend time on top of water to look for prey items
-lungs
-fins used to prop up body in order to gulp air

Elpistostegidae and tetrapods have
1. Limbs skeletons similar
2. Bones of skull in similar positions
-frontal bone distinct
3. Lungs
4. Ribs project ventrally
5. Labryinthodont teeth
-complex folded tooth

Tiktaalik rosaea
-ancestral characteristics
1. Body scales
2. Fin rays
3. Lower jaw and palette – some bones tetrapod like
4. Well developed gills

-derived characteristics
1. Flattened skull with eyes dorsal
2. Wide spiracular notch
3. Loss of opercular, subopercular and extrascapular
→ Mobile neck
→Move neck independently from body
4. No dorsal fin
5. Pectoral girdle and fin capable of complex movement and support (functional wrist/ankle and digit joints)
6. Overlapping ribs with unicate process
7. Bony connections between vertebrae

New fossil tetrapod tracks
-18 my before first skeletal fossil of tetrapod
-10 my before elpistostegadian fishes
-0.5-2.5 m long
-marine, not stream/forest habitat

Tetrapod group
1. Stem tetrapod
-paraphyletic assemblage of late Devonian genera
-Acanthostega
-Icthyostega

Acanthostega –older of the 2
-Mainly aquatic – gills/lungs
-Forelimb is more fin-like than Icthyostega
-small articulation surface on vertebrae
-neural arches, weakly ossified
-ribs short and strain

Icthyostega
-skeleton had basic structural features of terrestrial vertebrates
-"suspension bridge"
-Vertebral/column must resist collapsing
-girdle and limbs must be firmly attached to the vertebral column

Osteolepidiformes – 2 sets of bones from Centrum (intercentrum and pleurocentrum)

Icthyostega – similar but articulation between neural arches transfer force to adjacent vertebrae

-counters twisting movement of spinal column when moving on land
-broad overlap of ribs

-large interclavicles brace ventral muscles for pectoral girdle
-forelimbs bent at elbows
-pelvic girdle bony plates in the fishes enlarged to form a skid like structure attached to vertebral column by sucrial tip

Stem tetrapods
-Combination of fish-like and terrestrial characteristics
1. Groove in ceratobranchial indicates afferent branchail arteries in gills.
2. Flange on cleithrum (part of pectoral girdle) supports the posterior wall of operculum
3. Sensory canal of lateral line embodied in dermal bone of skull
(Same pattern as sarcopterygii)
4. Caudal fin broadened dorsally/ventral → aquatic
5. Opercular bone lost, but pre opercular bone present

Terrestrial characteristics
1. Scales – v shaped row of ventral armor across abdomen
2. bent forelimbs used as a prop (same as elephant seals)
3. Pelvic limbs used as paddle for steering

-capable of locomotion on land
-we developed limbs etc

-Why did they retain gills which can only function in water?

-living amphibious fish have retained their gills
-excrete CO_2 and nitrogenous wastes

Origins of tetrapods
-origins of tetrapods and that of terrestrial lifestyle must have been two separate events
-Late Devonian to early carboniferous – stem tetrapods
("Labryrinthodont") radiated into 2 lineages (clades)
→Batracomorpha
→Reptilomorpha

2. Batrachomorpha
-broad flat skull
-more aquatic than anthraosaurus
-Includes temnospondyles –largest and longest lasting group of primitive non-amniotes tetrapods
-some living amphibians (frogs) are derived from the group

3. Reptilomorph
-diverse array of animals
-dome shaped skulls
-anthracosaur predominant group
-largely terrestrial
-ancestor of amniotes appear in the late carboniferous

4. Lissamphibia (modern species)
-amphibian
-modern species
1.urodela –tailed amphibians –salamanders
2. Anura – tailless amphibians – frogs and toads
3. Gymnophionans – legless amphibian

First vertebrate on land
-advantages
-new food sources virtually competitor free
-disadvantageous
1. Respiration
2. Gravity
3. Desiccation

1. Respiration
-lung used to acquire oxygen from air
-crossopterygii and dipnoi
-tetrapod lungs greatly increased in complexity especially when associated with endothermy

Problem
-how do you get the air into your lungs
1. Limbs to assist in raising the body off the ground
2. Long stout ribs for muscle attachment
-contraction and relaxation of muscle changes volume of thoracic cavity
3. Head becomes flatter/longer
-possibly related to development of stronger buccal pump
4. Cutaneous respiration

2. Gravity
-fish body supported by water
→Need strong support fore and aft to prevent buckling of body
-on land gravity pulls body down
→ Weight on ventral surface
→ Spine must support limbs and resist bending in some places and have increased mobility in others

-requirements on land are:
1. Vertebrates with firm centra
2. Interveterbral joint that could move or resist motion
3. Vertebral column and girdles closely associated

-pectoral and pelvic girdle
-large and stronger
<u>-fish</u>
→Girdles don't support body; act as pivot or anchor points
→Pelvic girdle is not attached to vertebral girdle
<u>Amphibian</u>
→Appendages attached to girdle
-limbs and girdle attachment to vertebral column

-limbs and girdle attached to vertebral column
-pectoral girdle fused to sternum in later tetrapods and all modern amphibians
-orientation of the limbs
→Reduces contact with ground

-head movement
-osteichthyes
-pectoral girdle attached indirectly to vertebral column
→Head and body move as one unit
-articular surface at back of the skull is a single flattened surface

-tetrapods
-occipital condyles divided into a rounded pair
-One articular surface at back of skull is a single flattened surface

-tetrapods
-occipital condyles divided into a rounded pair
-One articular surface on each side
-allows the head to move up and down
-independently of the body

-simple discs and rings
-interlocking vertebrae
-more efficient
-maintains flexibility
-enhance strength

Structure of vertebrae
-Centrum – principle component
→Below spinal cord
-consists of one or two elements
-If two – intercentrum and pleurocentrum
-if one
-it may be the intercentrum (some extinct tetrapods)
-or the pleurocentrum (amniotes)

Evolution of vertebrae structure
-sarcopterygion, Elpistostegidae and some stem tetrapods
-2 sets of ossification in centra region
-posterior end below neural arch
=pleurocentrum
→Icthyostega and other early tetrapods

-later "labryrinthodont"
→Trend toward expulsion of either
1. The pleurocentrum or
2. The intercentrum
→ More solid Centrum

-stem reptiles, modern reptiles, birds, mammals
→ Enlargement of pleurocentrum
→Eventual loss of the intercentrum

-3 conditions evolved
1. Intercentrum develops – extinct line
2. Intercentrum and pleurocentrum develops
→two centra formed – extinct line
3. Pleurocentrum expanded and fused to form a complete ring – reptiles, birds, mammals

-Lissamphibia
-no clear story
-Centrum – no evidence of intercentrum and pleurocentrum
-no cartilaginous preformation
-adjacent vertebrae articulate by their centra
-some may also articulate by process carried on the neural arch
-zygapohyses

Types of centra articulation
-shape of the articulatory surfaces at the end of the centra is important both functionally and evolutionarily

-5 conditions
1. Amphicoelus – both surfaces are concave
→ Limited movements in many directions
2. Procoelus – centra concave anteriorly and convex posteriorly
3. Opistocoelus – centra concave posteriorly and convex anteriorly
→Procoelus and opishocoelus permit motion in any direction and resist dislocation

4. Acoelus – centra has flat end →withstand compression and limit motion

5. Heterocoelus – saddle shaped ends
→Allowed vertical and lateral flexing
→Prevent rotation around the axis of the spine

Non-amniotic tetrapods
-opishocoelus
-procoelus
-amphicoelus

-stronger centra + processes (that interlocked adjacent vertebrae) →flexibility and prevent twisting of the vertebrae column

-adaptation of the girdle and vertebral column, amphibians were able to lift their bodies and use their limbs to move about

3. Desiccation
-moisture lost from lungs and skin
-adaptation
1. Can tolerate high conc. of salt tissue in tissue x3 body
2. Behavioral adaptations
3. Permeable skin – reabsorb water from bladder

-restrictions to reproduce
→Water needed to reproduce
→ Lay eggs in moist environment

→Tetrapods and their adaptations overview
1. Terresterial →streamline not as important as in fish
2. neck advantageous – improve feeding an division without reducing streamlining
3. Loss of median fins; paired fins →limbs
4. Stronger limbs, firmer attachment to girdle increase strength to vertebral column
5. gills → lungs and pulmonary circulation
6. Increasing cornification of the skin

LECTURE 11
Amniotes
Classification in amniotes
Adaptations
-modification to skull, vertebral joint, limbs, girdle, scales, amniotic egg

Amniotes – evolved in response to terrestrial arthropods / becline in non-amniotes
-Evolved probably from a reptilomorpha – 340 mya (carboniferous Permian early)
-4 changes in the evolution of amniotes
1. Evolution of stronger more efficient jaw muscles
2. Evolution of more effective locomotion on land
3. Development of amniotic egg
4. Development of scales (reptile and birds)

Classification of amniotic
-Traditionally based upon the features of the skull –temporal fenestration
-Anapsid – without opening
-Synapsid – with one opening
-Diapsid – with 2 openings

5 subclasses were used in this system
-anapsid, synapsid, arcinosauria (class), lepidosauria (lizard, snake)

Split between synapsida and anapsida, diapsid much later on, more heavily modified

Amniotes

Cotylosauria = Amniota + Diadectomorphs

Synapsida	sauropsida
Mammal's mammal-like	reptiles/birds

Sauropsida divides
Parareptiles – contains many lineages that are not related to modern amniotes except for turtles

Eureptiles splits
→ Lepidosauromorpha –lizards and snakes shed in one big place
→Archosauromorpha – dino, bird, gizzard upright stance

Adaptation of amniotes
1. modified skull, cranial vertebrate joints, limbs, girdle, scales, and egg

We have glandular skin and can't excrete uric acid

1. mod/evolution of skull
-skeletal structure found in head region
-Chondrichthyes – chrondocranium and upper jaw
-osteichthyes → mammals
-skull a fused units – braincase is added to and welded together by a series of dermal bones

-skull of early tetrapods
-labrinthodont
-3 major units. Neurocranium, splandocranium, dermal elements

1) Chrondocranium –braincase, splandocranium, dermal elements

1. Chrondocranium – braincase, formed originally as cartilage, if ossified – Neurocranium

2. Palatal complex –ossification of palatoquadrate cartilage (upper jaw) and some dermally, derived membrane bone – forming the roof of the mouth

Separated from edge of shield by subteryporal fossa

3. Dermal skull roof or dermatocranium
Shield of membrane or dermal bone
-covers top and sides of the head
-extends down to jaw rims

-in non-amniotes and stem reptile the dermal skull is unbroken
-temporal muscles are inside the solid dermal roof of the cheek or temporal region

-When jaw close – muscles shorten and expand in breadth
-little room for expansion under shield

Early tetrapods
Amniotes – changes in jaw muscle attachment to the skull
→ Stronger and more efficient
Several lineages developed openings in the dermal skull roof
→Muscle exits skull and attaches to outer surface of cranium
Evolved independently several times

Cranial Vertebral Joing
Fish – amphicoelus
Amphibians – occipital condyle, ball socket joint between skull and first vertebrae only move head up and down

Amniotes – atlas, axis joints allow a lot of flexibility. Side to side and up and down movements

Cranial vertebrae joint
-joint between vertebrae
-some vertebral elements get incorp to the back of the skull
-pro atlas very small on tip of atlas

Atlas (1st vertebrae)
-neural arch of vertebrae 1 = atlas
-intercentrum of vertebrae 1 ← only found in atlas

Axis – composite bone
-neural arch of vertebrae 2 = axis
-pleurocentrum of vertebrae 2
-pleurocentrum of vertebrae 1
Obontoid process

Vertebrae 3,4,5
-pleurocentrum, neural arch

→strength to C.V joint
→flexibility
→rotation in neck area

Advantages
1. increase feeding opportunity
2. reposition head which improves the sense organs and locomotion

Girdles and limbs
-stem reptiles
Structure of girdles and limbs very similar to non-amniotic tetrapaods
-short legs
-legs came out at right angles to body
-move legs in horizontal planes
-thrust of limbs and body undulation

-amniotes ←giirdles/limbs
Appendicular skeleton more suitable for terrestrial environment
1. reduction in the number of bones in the pectoral girdle

Anura (frogs/toads) – 6 bones
Labryinodonts (early non-amn tetrap) – 6 bones
Stem reptiles – 5 bones
Synapsida – 5 bones
Monotremes – 5 bones
Birds – 3 bones
Mammals -2 bones (scapula and clavical)
➔strength, fewer bones, fewer suture lines

Pelvic girdle
Fish – pelvic girdle doesn't attach to vertebral column (no bone-bone contact between girdle/spine)
Labryinodonts – pelvic girdle articulates 1 vertebrae

Pubis/ilium/ischeum all verts with bones have 3 bones in pelvic girdle

-elongation of bone to increase SA for muscle attachment

Birds pelvic girdle fuse to many vertebrae + bones in lower back (synsacrum)

Reptiles – 2 vertebrae attatched to girdle
Mammals –sacrum (4-5 vertebrae)
Pelvic girdle attached to 4-5 girdle

➔more vertebrae attatched → stronger

Girdles and limbs
-limbs move directly beneath the body
→more effective support and locomotion
-therapsid (ancestors to mammals)
-archosaurs (dinosaurs, ancestors to birds)
-in advanced amniotes the elbows rotate backwards, knees forward
→feet now point forward
→faster, more efficient locomotion →increase length of stride, facilitates fast running

-in modern reptiles (snakes excluded) locomotion very similar to early amniotic tetrapods

4) scales
Cornified scales increase amniotic tetrapods ability to live in terrestrial environment

Generalized skin of vertebrates
Has 2 principle layers
1)epidermis –superficial stratified into several layers: derived from ectoderm
2)dermis – deeper derived

Epidermis
-strantum germinatium – living inner layer
-stranum cornium – dead outer layer of cells filled with a protein called keratin

Fish skin
Epidermis
Thickness varies , dermis, a cellular "bony scales" embedded in this layer
-derived from bony plates of ostracoderms

Amphibian skin
-lack bony plates
-epidermis is very thin
-strantum cornium is very thin, with little keratin
-large mucus glands – retain moisture

Reptile skin
-epidermis forms a complete body covering of keratilized scales
-epidermis consists of strantum germination and outer straum cocneum (VERY THICK)
-Molting
-several times per year the epidermis is replaced by molting
1)strantum germinaum proliferates to form a new set of inner epidermal layer
2)outer epidermal layer seperates at the separation zone
3)outer skin is shed
4)upper-cell die, dry out and form new scales

Formation of scales
-scales form by folus in the integument
-each bump consists of epidermis and underlying dermis papilis

Papilli have different growth (cells on anterior outer surface grows faster than cells on posterior inner surface)

Strantum conerum becomes thicker, one scale overlaps the next

Function of scales
1) thick layers of keratin reduces water loss
→ less dependent on moisture in environment
2 protection from abrasion

Amniotic egg
Cotylosaruia → amniotia + Diadectomorphs
→several special extra –embryonic membranes
-allow development independent of H20
AS SIGNIFICANT AS JAWS TO THE EVOLUTION OF VERTEBRATES

Strucutre of an egg
Reptiles have a **telolecithal** egg
→large amount of yolk, unevenly distributed
→small amount of protoplasm in germinal disk
Cleavage only occurs in germinal disc (meroblastic cleave)

Development of the egg
Periphery of disc spreads out over yolk
Eventually covers entire yolk
YOLK SAC
Yolk sac is infiltrated by blood vessels
NutRIENT FROM YOLK TO EMBRYO

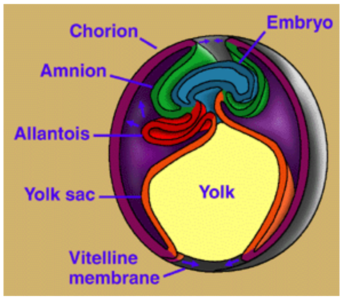
Other extra-embryonic membranes expand up over the embryos to form coelom between the two layers

Extra – embryonic membranes
4 membranes
1) yolk sac
2) amnion – envelops the embryo
3) chorion –outer membrane
4) allantois –
We get amniotic cavity – umbilical cord

Advantages of the layers
Provides the embryos with a fluid medium for development
-embryo floats
→no compression from gravity
-protects the embryo from dessication
-fluid acts as a shock absorber
→even pressure on all sides of the embryo

Disadvantages
-isolate the embryo from environment
→chorion and amnion prevent embryo from being near surface – little access to O2
→ problem with gas exchange
-no means of disposing of nitrogenous waste

Allantois
-storage of waste
-develops from hind gut of embryo
-from the allantois sac
-expands very rapidly to fuse with chorion
-develops blood vessels on the surface which are connected to umbilical cord
-also the respiratory organ for the embryo



Success
1. amniotic eggs ended the dependence on h20 for reproduction
2. keratinized epidermis
3. better jaw operation
4. better modes of locomotion
5. changes to head articulation

Dominant vertebrate life on land during the Mesozoic era!

Paleozoic 375 mya
-mesozoic lasted 180 million years
-end of Mesozoic – massive extinction of reptiles
-cenozoic era covers the last 65 million years
-age of mammals
→first originated in Triassic
→ birds originated in Jurassic

Pangea started to break up during early Jurassic
→laurasia and Gondwanaland
→creates epicontinental seas and oceans

-late Jurassic, Gondwanaland breaks up to form asia, Africa, Australia, antartica and S.A)
-mesozoic –diversification of vertebrates

Triassic –dinosaurs and first mammals, sphenodontids, turtles, crocodiles, ancestor of frog

Jurassic – birds (archaeopteryx)

Cretaceous
→S.A seperates from Africa, antartica and Australia
→evolution of snakes, modern types of croc, monotremes, marsupials, placental mammals

-land connections between N.A and sibera (early Eocene another with Greenland)
-loss of land bridge results in isolation of populations and prevent gene flow
-massive rearrangement of land masses
-modified water bodies
-changes in climate –cooling trend
-period of glaciations

-Archosauria gave rise to birds
-two independent radiation of flying vertebrates
1.pterasauria
2.dinosauria

-diapsids
-legs were held close to body
-many were bipedal
→saurschia
-theropoda –carniverous, bipedal
-sauropodomorpha + quadraped/herbivores

Pterasaurs
-late Triassic to cretaceous
-great range in size
-some sparrow sized
-some larger had wing spands of 13 meters
-membrane forms the surface of the wing
-not precursors to birds
-different in the structure of the wing
-4th digit is elongated –supported membrane, skin of wing
-digits 1,2,3 present as claws
-birds – remaining digits are fused together
-tip of wing supported 3rd digit
-2nd and 4th digit were reduced
-covered in feathers

-Thomas Huxley
-birds are nothing but glorified reptiles
-class sauropsida

-Traditional systematic
-class aves and class reptilian

-Sauriscian dinosaurs
1.sauropodomorpha
2. theropsida

-birds + all saurischian dinosaurs which more closely resemble birds than to the sauropodomorph dinosaurs

Theropsida
-these general types of animals
1. large predators –jaws used as weapons
-certosaurs, allosaurs, tyrannosaurs
2. fast moving predators –forelimbs to capture prey –ornithomids
3. fast moving predators – huge claw on hind foot used to attach pray
-dromeasaurs

Birds evolved form small mini raptorian coelusaurian dinosaurs

-sinosauropteryx –fringe of hair like or down –like structure along neck, backbone and flanks
-closely related to basal coelusaurs

-caudipteryx and protoarcaeopteryx
-long feathers with central rachis (shaft)
-possibly interlocking –barbs

Birds now viewed as the most derived form of therapod dinosaurs
-similarities of birds and therapods
1. elongate, mobile S-shaped necks
2. tridactly fod with a digigrade posture
3. intertarsal ankle joint
4. hollow, pneumatic bones

-differences

1. features associated with flight and endothermy

Characteristics of basal coelusaurs and birds
-feathers
-furcula
-enlarged sternum
-long arm and hands
-sideways flexing wrist
-nesting behavior
-rapid growth rates

Archaeopteryx
-oldest known birds are form the late Jurassic
-more dinosaur-like than living birds
-only one fossilized impression of a feather
-seven fossilized skeleton, some with very distinct impressions of feathers
-crow size

Characteristics of archaeopteryx
1. feathers, in places where modern birds have feathers
2. vertebrate possibly amphicoelus
3. forelimbs wing-like, but ended with 3 clawed digit
4. 5 trunk vertebrae fused to form synsacrum
5. long tail
→vertebrae form central axis of tail
→extant birds- feathers attached to pygostyle
6.forelimbs relatively short and rounded
-capable of short flights

Clavical fused; rectangular sternum
-modern birds have a very large sternum
Pelvic girdle and hind limbs resemble some of the archosaurians –elonged ilium to pubis

Teeth in sockets on both upper and lower jaw
-modern birds lack teeth, parrots have teeth buds
-bipedal terrestrial cursorial (adapted to run)
-running, flapping to capture prey
-short flights to escape predators

-class AVES
1. subclass archeorniths –all extinct by end of Jurassic
-archaeopteryx
2.subclass neorinthes
-28 extant orders
-157 families, 8700 species
-two major radiations
1. Eocene (mainly water fowl and non-pusserine forest dwelling birds)
2. Miocene (passerine birds)(perching birds)

1.modified diapsids
2. single occipital condyle –mammals have 2
3. lower jaw composed of several elements – quadrate and articular
4. single ear ossicle (middle ear) –columella
5. unicate process
6. ankle joint is between two rows of tarsal bones
7. pubis extends backwards
8.epidermal scales on legs and feet
9. few glands in skin
10.respiratory air sacs associated with lungs , air sacs increase volume of air in body X9
11. amniotic egg with shell

Nonreptilian characteristics
1. high metabolic ratel high body +temp – endothermic
2.wings
3. large sternum with keel
4. synsacrum
5.pygostyle
6.4 chambered heart
7.retained right aortic archl circulatory system
8. kertinized bill

Integument of birds
-skin of reptiles have thick kerinitized cuticle
-birds have thin slightly keratinized skin with feathers
-only legs and feet have scales

Feathers
-kerinitized outgrowths of the skin

Functions
1. provide insulation
2. provide streamline, controlling of the body during flight –reduces drag
3. provide large S.A

Strucutre of feather
1. contour feather
-rachis (vein in middle of feather)
-calamus (quill)
-vane (feathers)

2. barb
-ramus
-barbule
-barbicel
-hamuli

Types of feathers
1.contour feathers
Flight feathers, forms outline of body
→reduces drag
-shed water/oils
-airfoil for wing and tail
-produces drag for breaking and steering
-coloration
-camoflague
-mating

2.Down
-short fluffy under countour feathers
-relatively short rachis
-has barbs and barbules, but no hamuli

Function
1. insulation
2. bouncy
3. water proofing –powder down
-granules of keratin released among the feathers

3. semiplume
-intermediate between down and contour
-found on side of abdomen, neck and along mid-back
Function
1. insulation
2. some contouring

4. filoplume
-very finely structured feathers
-very slender rachis with a small tuff of barbs on the end
-no hamuli
-well innervated – sensory device
-allignment of feathers
-grooming

5. bristles
-stif rachis
-no barbs
-located at the base of bill and around the eyes
Function
Protection
Enhances the size of mouth
-swallows feeding on flying insects

Development of feathers
-feathers start as a dermal papillae
-depression around papillae deepens to form the feather follicle
-feathers only formed from ectoderm
-mesoderm extends the length of shaft
-nourishes the developing feather
-shaft lengthens and the barbs form along edge
-regulating pattern regulated by 2 genes

-alternating on/off
-sheath protects developing feather

-when growth complete
1. mesoderm reabsorbed
2.sheath is shed
3. feather unfurls and hardens

Origin of feathers
-evo-devo
-5 stages

Stage 1
-elongation of feather follicle → hollow unbranched filament

Stage 2
-differentiation of tissue to form inner (barb ridges) and outer layer (sheath)
-inner layer forms a tuft of barbs fused at the base (calamus)

Stage 3
-tufts of barbs with branched barbules
-open pennaceous vane with rachis and barbs

Stage 4
-differentiation of barbules and hamuli

Stage 5
-specialization of feathers – asymmetrical flight feathers

Flight
-archaeopteryx – full plumage
-feathers evolved earlier in non-flying ancestors
1.display
2.foraging
3. insulation
-nest
-young
-endothermy

Origin of flight
-two main theories
1. arboreal theory
2. cursorial theory

1. arboreal theory
-archaeropteryx were tree climbers
-jumped from branch to branch
-selection against animals that couldn't jump long distances or break their fall
→strong selection for gliding and steering
→gliding led to flapping (forward propulsion)

2. cursorial theory or ground up theory
-wings used as insect nets
-extended forelimbs provided lift
→some gliding
→forward propulsion, if combined with fast running (chickens flap wings to run faster)

Wing assited incline running (WAIR)
-treadmills test on ground based birds
-flap wings to increase traction on steep inclines and vertical surfaces
-"spoiler" effect
-climbs cliffs or trees to escape predators
-increase control during descent
-clipped/plucked feathers, they can't do it anymore
-even newborn chicks can do it

Requirement for flight
1.upward force to overcome gravity –lift
2. streamline body – reduce drag/turbulence
3. some means of propulsion
4. stabilizer and steering
5. light weight and strong framework
6. efficient method of production and utilization of power

-enzyme efficient – endotherm
-90% food digestible – not bulk feeders

Avian adaptation for flight
A-Feathers
B-Powerful wings and associated muscles
C-weight reduction
D-efficient respiratory and circulation systems

Advantages of flight
1. improve access to food sources – migrate long distances to take advantages of seasonal availability of food
2. greater mobility
3. escape from predators
4. exploit refugia for nests (canyons/mountains)
5. can easily cross barriers – migration to exploit seasonal abundances
6. dispersal

Disadvantages of flight
1. very energy expensive
2. restricts body size and shape –maximum size for flight limited body shape
3. niches filled by mammals cannot be occupied by birds
→ no birds that prey on large prey –limits size of prey
→ birds are not bulk feeder

Lecture 14
Development of the heart
Comparative anatomy of vertebrate hearts, aortic arches, abdominal vein, kidney

Development of the heart
-amniotes
-blood cells and vessels arise from mesoderm to form clusters called blood islands
-outer layer differentiates into endothial cells which form tubes
-cells in the center differentiate into blood cells
-the cells form a maze of channels

-fusion of the two aorta on the ventral side start the formation of the heart
-posterior portion forms the sinus venosus (SV)
-anterior portion forms the atrium , ventricle and conus arteriosus
-heart forms very early in development (29 hours)

Comparative anatomy of the heart
Fish
-Single circulatory system
-large SV
-common cardinal, hepatic vein
-SV➔A➔V➔CA
-S shaped loop
-completely deO2 blood

Lungfish
-beginning s of the double circulatory system
-heart is partially divided
-A, V, CA
-SV opens into right side of atrium
-O2 blood from lung enters the left side of atrium
-some mixing of 02 and de02 in partially divided V and CA
-pretty good at separating at the atrium
-spiral valve
-CA connects to 2 blood vessels
1. ventral vessel → O2 blood to body (2,3,4)
2. dorsal vessel → de02 blood to gills and lungs (5,6)

Amphibians
-SV shifts to right; empties into RA
-LA is completely separated from RA
-only 1 V
-CA contains spiral valve
-blood on right side goes to lung
-returning pulmonary blood enters the LA
➔venticle ➔hits spirval valve in different regions than the returning systemic blood ➔ vessels leading to rest of the body
-V have (traberculae) which assists in separation of 02 and de02 blood

Reptiles
-more separation of L and R sides of heart
-V is almost completely separated
-CA splits into the pulmonary trunk and 2 aortic trunks

Birds and mammals
-four chamber heart, double circ system
-no SV
→incorperated into wall of right atrium
-LA receives blood from lungs
-completely separated LV and RV

Comparative anatomy of the heart
Birds
-RA→RV→pulmonary artery → lungs → pulmonary vein → LA → LV → body
-single aortic arch (right side retained)

Mammals very similar to birds but left aortic arch is retained instead of right

Modifications to aortic arches
-aorta-continuous vessel in embryo
-blood vessels connect ventral aorta to dorsal aorta
-first bend = first aortic arch
-almost all vertebrates embryos have 6 aortic arches
-more primitive vertebrates may have more

-modification due to
-adults that lack gills
-gills to lungs
-single to double circ system

Evolution of aortic arch
-primitive condition
-6 aortic arches
-elasmobranch
-heart →gills via afferent branchail arteries → capillary bed in gills → efferent branchial arties → dorsal aorta
-1st aortic arch lost, 2nd arch present in elasmobranchii but lost in many other fish

Lungfish
-gills and lungs present
-arch 3 and 4 have no cap beds
-5th and 6th still have gill capillary networks
-1st is lost
-2nd arch is modified
→carotids = extension of the arteries
-pulmonary artery arises form arch 6
→to lung
-pulmonary vein returns blood to heart
-lung not very efficient, but sufficient ot get them through
- some ability to shunt blood (arch ¾)
→when in water using gills, shunt ¾
→ on land shunt everywhere except 6, straight to lung then straight to body

Amphibian
-anurian – frog
-1st and 2nd lost
-5th lost in most –present in salamanders
-arch 3 and 4 unchanged
-3 = carotid
-4 = left and right systemic aorta
-6th goes to lung (pulmonary)

Reptiles
-1st, 2nd ,5th are lost
-3rd and 4th are present
-some reptiles have a carotid duct joining 3 to 4
-carotids formed from 3rd
-6th goes to lung
-ventricle → pulmonary trunk → 2 pulmonary arteries
-associated with the right side of the ventricle
-caries mostly de02 blood (right side)
-R and L systemic arches
→join to form the dorsal aorta
-L systemic arch = L aorta
(L side of arch 4) + curved section of dorsal aorta
-right more dominant
-forms carotid/subclavian

Birds and mammals
-1st, 2nd, 5th lost
-6th arch →lung
-3rd arch → carotid
-4th arch birds – L lost ; R remains as aortic arch
Mammals –R lost; L remains as dorsal aorta

Aortic arch trends
1. arch changes association of heart
2. loss of arches 1,2 5
3. modifications of arches 3 and 6
4. 6 associated with lung (pulmonary artery)
5. retention of both sides of arch 4 in reptiles
6. Arch 4 – L side lost in birds; R side in mammals

Abdominal veins
-cyclostomates
-posterior cardinal veins
-originally a pair of simple dorsal vessels, draining posterior of body

Jawed fish
-renal portal system originates
-blood flow now goes through kidney

Sarcopterygii (lungfish)
-development of posterior vena cava –kidney ot heart

-lungfish and urodels
-some blood still passes through the posterior cardinal

Frogs and higher vertebrates
-posterior cardinal separated from their posterior trunk
-one portion remains as azygous vein

Reptiles and some amphiabians the renal portal system is declining in importance
→ much of blood by passes depending on stress

Mammals
-no renal portal system
-posterior vena cava is composed of many parts of other veins

Kidney
-ammonotelism →excretion of ammonia
-ureotelism →excretion of urea
-uricotelism →excrete uric acid
-salt glands
Marine too much salt in body

Lecture 15
Origin of mammals
Characteristics of mammals
Classification of mammals
Teeth
Hair
Reproduction in mammals

-mammals evolved from the reptile lineage of synapsida
-order therapsida had basic features of mammals
-carboniferous
-therapsids had a marginal existence until the Cenozoic
-first mammals appear at the end of the Triassic

-Morphological trends in therapsid-mammalian line
-simplification at the skeletal system
-skull and jaw
-reduction in number of bones
-skull extended
-limbs and girdle simplified
-down to 2 bones at pectoral girdle
-mammals are not radically different from therapsids
→osteological characteristics

Features distinguishing mammals from reptiles
1. jaw articulation with skull
Reptile –articular to quadrate
→ 6-7 bones in lower jaw

Mammals –dentary to squasmosal
→lower jaw = dentary

2.articular and quadrate highly modified in mammals
-articular ➔malleus (AM)
Quadrate ➔incus (IQ)
-hyomandibular ➔columella ➔stapes (HS)

3. angular bone
→tympanic bone
-surrounds and protects the middle/inner ear

4. occipital condyle
-reptiles -1 amphibians 2 condyles
Mammals -2 condyles – heads heavier more support

5. single external nareal opening
-nostril separated by cartiledge

6. secondary palate
-extensions of premaxilla, maxilla, sometimes palatine (bones extend to shut mouth to muscle cavity)

7. teeth
-reptiles – most single cusped pleurodont teeth
Mammals – complex shape to teeth (heterodont)
-specialization to aquire and process food reduce competition wide diet
-thecodont

8. Post cranial feature
-marked distinction among types of vertebrate
-legs are rotated in and under the body
→rotation of knee and elbow

9. soft anatomy
-features nto found readily in fossil reacord
A) hair – present at some stage in life cycle
→some aquatic forms only have a few stiff bristles
→some reptiles – hair like structures
→ some mammals have keratinized scales (armadillos)

B)external ear opening (pimae)
-flesh structure that surrounds the external opening of the ear

C) mammary glands
→provides nutritious milk for young during initial period of post natal growth

D) sweat glands
-promotes evaporatative cooling
-eliminates some forms at nitrogenous waste
-pheromones
-various patterns of distribution

E) muscular diaphragm – seperates thoracic and abdominal cavity
-helps ventilate lungs
- only in lungs
→ birds – wing muscle pull sternum up and odwn which expands/contracts the thoracic cavity
Costal breathing →reptiles – move liver to epand and collapse the body cavity

F) divided ventricle (4 chambered heart)
G) most mammals are viviparous
→embryo received nutrients through placenta'
→some oviparious – monotremes

H) endothermic →homeostasis maintenance
→active throughout
→nerve muscle optimal temp

Endothermy ← insulation
-birds, mammals, some evidence that some reptiles may have been endothermic, need some sort of insulation to keep warm but cant get solar radiation
Eventually develop endothermy some way to regulate internal body

Advantageous
-homeostasis –active enzymes optimal
-independent form environment
-exploit new habitats & niches both in space and time

Disadvantages
1. ectotherms have fairly low metabolic rates
-devote 30-90% of food energy into growth/repair

Endotherms 1-10%
-must eat more for same output
-more efficient in gathering food

2. endotherms can't coast over lean periods
-ectotherms decrease metabolic rate till improvement
-endotherms rely on stored body fats or hibernation

On avg and situations ectotherms < endotherms

Origin of mammals
-Triassic to cretaceous – great extinction of terrestrial vertebrates
-many herbivores therapsids die out
-carnivor therapsids survive
→these reptiles were acquiring more and more mammal like characteristics

First mammals were
1) very small
2) dentary –squasmosal articulation
3) derived features of skull
→ changes to inner/middle ear
→ cheek teeth with divided roots
4) oviparious
5) insectivores
6) nocturnal
7) solitary
8) large olfactory lobes 3 cerebral hemispheres

2 major radiation of mammals
1) Triassic – cretaceous
-margonucdont, docodonts, triconadonts, symmetridonts, drydestid
- most did not survive the end of the Mesozoic
2)radiation
-jurassic
-first true therian mammal with tribosphemic molars
-marsupian + true placentals
→ mid Jurassic
-first monotremes fossils in early cretaceous deposits
-separate from other lineages since beginning of Jurassic
Multtuberculate – Jurassic

3 lineages survive the Mesozoic
1) monotremes
2) multituberculates (extinct)
3)therians

Extant orders of mammals
Monotremes
Marsupials and eutherians ← therians

Mammalian teeth
1) most ancesteral
-3 cusps arranged in a row
-triconodont
→ may have been carnivores
Size mouse→cat (large)

2)revesred triangle
-holotherians
-insectivores
-upper tooth points inward
-lower tooth points outwards
→creates large SA for shearing action

3)tribosphenic molar
-tribosphenida
-includes theria
-new cusps added – protocone
-grinding and punching as well as shearing and cutting
-greater diversity in diet

4) multituberculates
-late Jurassic to late Eocene
-"rodent of Mesozoic"
-broad multicusp teeth
-specialized for grinding

Classification of mammals
1) subclass prototheria – monotremes
2)subclass theria
→infraclass metatheria – marsupials
→infraclass eutheria – true placentals

-4500 species of extant mammals ←# varies but around 4500 due to extinctions and splitting of species

1) subclass prototheria
-most ancesteral
-oviparious, no placenta
-no pinnae and inner ear is simple

Living order – monotremata
-echnidas, platypus
-retain reptilian features
1. lay eggs which are incubated
2. pectoral girdle similar to theraspid reptiles – more bones in shoulder girdle than other living mammals
They have coracoids bar in which other mammals lost
3. retains a number of bones in the skull that are lost in theria
-they have post orbital

Prototheria –mammalian features
-true hair

-suckle their young
-endothermic
-dentary – squasmosal jaw articulation

2. subclass theria
-viviparious
-placental
-17 living orders
Infraclasses metatheria, eutheria

A. Infraclass metatheria
-marsupialia
-only living order
→choriovitelline placenta
→ very short gestation period (## in days not weeks)
→small underdeveloped newborns crawl to marsupium from urogenital opening to complete development
→ southern hemisphere animal

B. Infraclass eutheria
- 16-17 living orders
-chorioallantoic placenta
-"placental mammals"
-primarily N hemisphere
-long gestation period
-more advanced state of development at birth

Reproduction in mammals
-all have internal fertilization
-all females nourish their young with secretions from mammary glands
-all show various degree of parental care

1. Subclass prototheria
-order monotremata
→large ovaries and ova
-large amount of yolk
Uterus (egg coated with leathery mineralized shell) →urogenital sinus → cloaca (single opening)

-platypus – 2 eggs laid into a nest
-lactate hatchlings

-Echnidas hold their egg and young in 'pouch'
-until stiff hairs start to develop
-suckle for 10 months

2. subclass theria
A. metatherians (order marsupialia)
-ovum has more yolk than eutharians, but a lot less than monotremes
-zygote → uterus
-blastocyst implants into the wall of uterus
-uterine wall thickens and becomes highly vascularized
-endometrium

-short gestation period
-born at very early stage of development
-young moves to marsupium
-young attatches to nipple
-nipple swells to firmly attatch the young
-completes development in marsupium
-short gestation period because embryo is very close to mothers tissue, reduce chance of rejection of embryo
-survival strategy, sacrifice young to get away

B. eutherians
-ovum has very little yolk
-embryo nourished from secretions and fusion with the wall of uterus
-zygote ➔uterus (wall thickens) ➔blastocyst implants very deeply in uterus
-very close association between fetal and maternal blood supply
-extended gestation period – produces highly developed young
-variable female reproductive tract

Eutheria

-placenta-like structures appear in toehr groups (some fish, some reptiles) but refined in mammals
-nutirent transfer, respiratory gases, metabolic wastes
-consists of embryonic and maternal tissue
-animals in womb
-types of placenta
-two major types
-choriovitelline (chorio ← placental layer / vitelline ← yolk sac
-chorioallantoic

1.choriovitelline placenta
-marsupial – except family peramelidae (bandicoot)
-yolk sac enlarged –yolk sac touches chorion
-yolk sac + chorion forms fetal tissue

-blastocyst sinks into shallow depression in wall of uterus
-slight wrinkling of surface of chorion and yolk as it ____ to endometrium
-wall of uterus secrets "uterine milk"
-nourishes embryo till blood vessels established to give nutrients

2. chorioallantoic placenta
-eutheria and bandicoot
-yolk sac relatively small
-chorion + allantois
-allantois greatly enlarged
-improved design
-provides nutrients for long periods of time
-provide large quantity of nutrients
-fusion of chorion and allantois allows better transfer of nutrient and wastes

-blastocyst sinks into the endometrium → attaches deeply into wall of uterus
-chorion extends from fetal side to form chorionic villi
-initial nourishment is supplied by breaking down uterine tissue
-uterus becomes highly vascularized
-great surface area for rapid exchange of nutrients and gases
-total length of human chorionic villi = 50 km

Lactation and mammary glands
-unique feature to mammals

Monotremata
-lack nipples
-mammary glands resemble modified sweat glands
-2 mammary gland region on abdomen secrests milk and the young laps it up suckle hairs

Eutheria
-glands are concentrated into specific areas
-nipples
-numerous ducts that release milk during suckling
-teats
-one common duct – common chamber
-cows, deers, horses – udders

Lactation and mammary glands
-evolved from sweat glands or scent glands
-therapsids or early mammals incubated their nest
-sweat glands may have moistened the nest and young
→prevent dessication
→nutrient secretion → increased survival of young

Advantages of lactation
1) smooth out feeding pattern of young
2)young don't need to forage
3)females free to leave to forage –leave young in safe cryptic space- can leave young in protected areas

Hair
-birds, insect, plants have hair like structures but not true hair
-true epidermal hair found only in mammals
-keritinized structure

Development of hair
-thickening of the epidermis that pushes down into the mesoderm
-depressions form the hair follicle
-tiny cup under hair is a papillae
-matrix cells (epidermal) initiate keritinization to produce hair within follicle
-keritinization within the follicle is localized and intermittent

Strucutre of hair
1) medulla – central core
-keratinized remnant of cells; may contain a pigment
-absent in some species (ungulates) hollow hole to trap air
2) cortex
3)cuticle (outer layer)

Types of hair
1) vibrissae –whiskers
-long, very stiff
-well innervated
-function –tactical sensors
-mostly on rostrum, but could be on legs or other parts of body

2) guard hairs
-overhairs in pelage
-functions – protection from solar radiation, abrasion, - coloration –highly pigmented, - communication of behavior states
-modified guard hairs
-bristles horse main, spines porcupines

3) underfurs
-fine, uniformly soft hairs on underside of mammals
-function – insulation

Function of hair
1) tactile devices
-may have been original function of hair
-rod-like projection off innervated cells
-reptilian scales have sensory pits – similar distribution as hairs in mammals
-vibrassae –hair on moles

2) coloration
-concealing the animal
-warning
→striped skunks
-communication
→ rump patches on white tail deer

3) bouncy
-air trapped under the fur increases buoncy
→ beaver, muskrat

4) protection
-quills of porcupine

5)locomotion
-pacific water shrew- hind feet and tal have long stiff hairs that increases SA, act as paddles
-snowshoe hair – long hair on feet- help spread weight load on snow

6) insulation
-fair conductor of heat, but a good insulator
-air trapped between hair
-reduces energy requirements → reduces food requirements

Keys to success of mammals
1) development and enhancement of viviparity
2)development of mammary glands
3)endothermy
4)increased locomotion
5) stronger jaw -1 bone in lower jaw, make it stronger, teeth in sockets
6) few, strong specialized teeth – cheek teeth allow process of plant material

Characteristics of teeth in vertebrate class
-Agnatha – no jaw, no teeth
-conodont elements
-placodermi – modified dermal bones on the jaws – no enamel/dentine subject to wear
→ may have functioned like teeth
-Acanthodii – teeth present , no enamel

Chondrithyes
-numerous teeth at margin of jaw
-similar to placoid scales in structure
-several large cusps in ancient groups
-single blade like tooth in modern forms
-skates and rays have blunt, crushing teeth
-all homodont
-skin attatchment to jaws

Osteitchyes
A. acinopterygii (ray finned fish)
-numberous teeth- hundreds and on margin of jaw, mouth, gill arch
-conical shape teeth
-99% homodont, acrodont

B. sarcopterygii (lobe finned fish) – lung/coelacanth
-resemble ray finned, but labrythadont type tooth
-stronger, more resistant to wear- folded teeth

Characteristic of teeth in vertebrate class
Amphibian
-labrythodontia – labryinthodont dentition
-lissamophibia – relatively few teeth; homodont, pleurodont

Reptilian
-all types – acrodont, thecodont, pleurodont, ligamentatous, edentate
-in general homodont
-therapsids – heterodont

Aves
-modern forms edentate
-embryo of ducks, parrots have dental lamina on their jaws
-ancient birds had homodont, thecodont teeth

Mammals
-very few teeth on margin of jaw
-usually heterodont, some homodont, few edentate
-thecodont withstand shearing force

Trends in teeth
Ancesteral – large number of teeth, scattered throughout mouth, homodont, ligamentaous

Advanced – fewer teeth, only on jaw margin, heterodont, thecodont

Differentiation of teeth
- increasingly strength and anchoring of teeth + temporal fossae → increase diversity of food types
-increase efficiency in processing food → lower competition and opened up new niches
Herbivores