Lecture 10

Modifications for Life on Land

- Terrestrial vertebrates can't use _____
  - Gills clump together in the air, reducing surface area
  - Functions of gills must be taken over by _____ and kidneys
    - Lungs are required for exchange of respiratory gases
    - _____ exchange sodium and chloride ions and excrete nitrogen
- Terrestrial vertebrates store fat differently
  - In fishes, fats are stored as lipid droplets in the _____ and muscles
  - In tetrapods, fats are stored as adipose tissue
    - Reptiles and amphibians store fat in discrete abdominal fat bodies, and around the base of the _____
    - Mammals and birds store fat in _____ layers and in association with the muscles, and organs

Craniodental System

- Skull of early tetrapods is similar to that of primitive bony fishes
  - Extensive _____ is present even in living tetrapods
  - The main difference is that the gill skeleton, operculum, and bones connecting the operculum to the pectoral girdle are _____
  - Compared to fish skulls, tetrapod skulls are _____ and flatter and/or longer
    - Wider flatter skulls are associated with _____ pumping for lung ventilation
    - Longer skulls allow the jaws to surround prey, since _____ feeding is ineffective on land
- Tongue
  - Larger and less bony in tetrapods
  - Tetrapod tongue works in concert with the hyoid apparatus
    - _____ apparatus is the lower part of the hyoid arch that was integrated with the gill arches in fishes
  - Tetrapod tongue is used to manipulate food in the mouth
  - Some tetrapods can project their _____ to capture prey
    - Frogs, salamanders, true chameleon lizards
- Salivary Glands
  - _____ is required to swallow food on land
  - Saliva contains _____ that begin the chemical digestion of food while it is still in the mouth
  - These secretions have sometimes evolved into _____ that kill prey

        - Some insectivorous mammals, two species of lizards, several lineages of snakes
- _____ musculature
    - Gill levators of fish were not lost when gills were lost
    - Cucullaris (gill levators) became the _____
        - Runs from top of neck and shoulders to the shoulder girdle
        - Helps rotate and stabilize the scapula in locomotion
    - _____ mandibularis remains the major jaw-closing muscle and becomes increasingly complex
    - _____ mandibulae runs from the back of the jaw to the skull and helps the hypobranchials open the mouth
    - Constrictor _____ surrounds the neck and acts primarily in swallowing food

Axial Skeleton

- Terrestrial vertebrates must deal with demands of _____
    - Bodies of vertebrates have the same density of water and are given support when in water
    - Out of water, vertebrate bodies require additional _____ support
- Vertebrae
    - The vertebral column suspends the weight of the body underneath it
    - Vertebrae of tetrapods interlock by means of _____
        - Zygapophyses transform the vertebral column into a stiff rod that withstands twisting and _____ and allows the spine to act like a suspension bridge to support the weight of the viscera on land
        - Tetrapod that have permanently returned to the _____ have secondarily lost the zygapophyses
    - Vertebrae are differentiated into multiple regions from anterior to posterior
        - Cervical vertebrae (neck region) enhance mobility of the head
            - 2 most anterior vertebrae are _____ and _____
        - Trunk vertebra are in the middle region of the body
            - Differentiated into thoracic and lumbar in mammals
                - Only _____ bear ribs
        - Sacral vertebrae fuse with pelvic girdle
        - Caudal vertebrae are found in the tail
- Ribs
    - Ribs of early tetrapods were fairly stout and more prominently developed than in fishes
    - They stiffen the _____
    - They protect the _____ and prevent them from sagging
- Axial muscles

- Muscles are more important on land because the body is not supported by _____
- Muscles are important on land for _____ of lungs
- Muscles are important in locomotion of primitive tetrapods
  - Appendicular skeleton is more important for that in modern ones
  - Epaxial and _____ muscles contribute to the bending motions of the trunk while walking on land
- In tetrapods the hypaxial muscles of all tetrapods show a more complex pattern of differentiation into layers than is seen in fishes
  - Hypaxials of bony fish form two layers
    - _____ obliques
    - _____ obliques
  - In tetrapods a third layer is added, the transverse _____
    - Responsible for exhalation of air from the lungs of modern amphibians
  - _____ abdominus- another new hypaxial muscle in tetrapods
    - Runs along the ventral surface from the pectoral girdle to the pelvic girdle
    - Role is primarily _____
  - _____ muscles in rib cage are formed by all three layers of the hypaxial muscles
    - Responsible for both inhalation and exhalation
- Epaxial muscles
  - Differentiated into three major components
  - Primary role is postural, not locomotory

- Axial skeleton and muscles assume different roles in tetrapods
  - Skeleton participates in:
    - _____ support
    - ventilation of lungs
    - _____
  - Some functions are incompatible
    - Bending of the trunk of a lizard when it runs creates conflict between locomotory and respiration
    - Mammals and birds address this conflict with limbs held more directly _____ the body
      - Propelled by limb movements rather than trunk bending

Appendicular Skeleton

- Pelvic Girdle
  - Consists of ilium, pubis, ischium
  - _____ on each side connect the pelvic limbs to the vertebral column

- Pectoral Girdle
  - Main endochondral bones are the _____ and the coracoid
  - The _____ (upper arm bone) articulates at the scapula
  - _____- runs along anterior border of the scapula in extinct primitive tetrapods
  - Clavicle connects the scapula to the sternum
  - Interclavicle lies ventral to the _____
    - Lost in birds and most mammals
  - Pectoral girdle does not articulate directly with the _____ _____
    - The connection between the pectoral girdle and vertebral column is indirect via the sternum and the ribs
    - Sternum is a midventral structure that links the lower ends of the right and left thoracic ribs in vertebrates
- Tetrapod limb
  - Made up of limb girdle and _____ segments articulating end to end
  - All tetrapods have:
    - Jointed limbs
    - Wrist/ankle joints
    - Hands and feet with digits
  - In primitive tetrapods
    - Feet are mainly used for _____ contact with ground
    - Propulsion is mainly generated by body _____ musculature
  - In modern tetrapods
    - Feet of amniotes are used as levers to propel the animal and the ankle forms a distinct hinge joint
    - Appendicular muscles have become increasingly complicated and _____
      - _____ in humans correspond to levator in fish
      - Pectoralis corresponds to _____ in fish
      - Many additional muscles move elbow, wrist, and fingers

Locomotion

- Basic form of tetrapod limb movement consists of moving _____ pairs of legs together
  - Left front and right hind leg move together as a unit, then right front and left hind
- Initial mode probably combined axial flexing of the body with limbs outstretched and feet acting primarily as holdfasts (trunk muscles, not limb muscles, providing force)
- New specialization of amniotes is the walk

    - In walking each leg moves _____ in succession, usually with three feet being down on the ground at any one time
    -
- Faster walk is called an _____
    - Only one foot or two feet may be on the ground at one time
    - Seen in elephants and some horses
- _____
    - Moving of diagonal pairs of limbs together, as in the primitive tetrapod condition
- Derived amniotes
    - Have upright posture and hold limbs more directly underneath the body
    - Mammals devised some new modes of locomotion with the evolution of the dorsoventral flexion of the ventral column
    - _____ involves jumping off the hind legs and landing on forelegs with flexion of the back contributing to the length of the stride
    - _____ is used by larger animals
        - Period of suspension in the air is not with legs stretched out in midleap, but in the bunched-up recovery phase where the hind legs move forward for the next stride
    - _____ – bipedal hopping
        - Used by kangaroos, jerboas, spring hares

Respiratory System

- Lungs were not evolved for the express purpose of breathing on land
    - Fish in oxygen depleted water gulped air to supplement oxygen uptake by the _____
    - Breathing could have evolved in well-aerated water if additional oxygen was needed primarily to supply the _____ muscle
- _____ pumping – positive pressure system
    - Use hyoid apparatus to ventilate the lungs
    - Oral cavity is expanded _____ air into the mouth
    - Floor of the mouth is raised, _____ the air into the lungs
- Negative pressure mechanism – used by amniotes
    - Expansion of the rib cage by _____ hypaxial muscle creates a _____ pressure in the abdominal cavity and sucks air into the lungs
    - Air is exhaled by-
        - _____ the abdominal cavity through elastic return of the rib cage to a resting position
        - _____ of the elastic lungs
        - Contraction of the _____ abdominus muscle
- Lungs
    - In amphibians, they're simple sacs with few internal divisions
    - In amniotes:
        - Subdivided in complex ways

        - Have long _____ (windpipe) that branch into bronchii
        - Have larynx
            - At junction of pharynx and trachea
            - Used for _____ production

Cardiovascular System

- Includes presence of _____ system
    - One-way system of vessel that parallel the pathways of the veins and allow fluid in the tissues to drain into the venous system at the base of the neck
    - Lymph is kept moving through _____ of muscles and tissues
    - Backflow is prevented by _____
    - Lymphatic tissue is involved in the immune system
        - White blood cells travel along this route
        - Lymph tissue can intercept foreign materials
- Includes the _____
    - Sinus venosus and conus arteriosu are reduced or absent in the hearts of tetrapods
    - Lungfish and tetrapods have a heart that is at least partially divided
        - _____ is always completely subdivided
        - Ventricle is at least partially subdivided
        - Right side receives _____ blood returning from the body
        - Left side receives oxygenated blood returning from the _____
        - Coronary arteries supply oxygenated blood to the ventricles
            - Especially where the ventricles are completely divided and returning from the lung

Excretory System

- Gills of fish regulate uptake and excretion of _____ ions, and nitrogenous wastes diffuse across the gills and skin
- In tetrapods, _____ assume a major role
    - Amniotes have a _____ kidney
        - Tubules become highly compacted and numerous and achieve the capacity to _____ urine
        - Ureter – duct draining the _____
        - Urinary bladder- for storage of _____

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Reproductive System

- Amniotes have an amniotic egg
    - Egg has a shell and a characteristic series of extraembryonic membranes
    - The gilled larval form is lost in amniotes
    - Amniotic eggs are not usually laid in the _____

- Either lay eggs on land or give birth to live young, even if adults live in water
- Requires _____ fertilization
  - Penis is secondarily lost in many birds

Nervous System

- Vomeronasal Ogan / Jacobson's Organ is an organ of _____ unique to tetrapod
  - When snakes flick their tongues, they transfer molecules from air to this organ
  - Male hoofed mammals often sniff the _____ of females to determine the stage of the reproductive cycle
  - Male hoofed mammals often curl the upper lip and raise their heads to inhale _____ into the vomeronasal organs
- Tetrapod Eyes
  - Light is transferred easily through the _____
  - Cornea of the eye is important
    - Formation of an image is easier due to _____ of light at the surface between the air and the cornea
    - Lens needs to do less to _____ the image on the retina
      - Lens focuses by changing _____, rather than moving forward and backward
  - Eye's surface must be protected and kept moist
    - Eyelids
    - Tear glands- _____ gland and Harderian glands
    - Nasolacrimal _____- drain tears from eyes and into nose

- Inner ear assumes function of hearing airborne sounds
  - Transmission of sound waves through a bone (or bones) in a middle ear
  - Middle ear is a sound _____
    - Receives relatively low energy of sound waves on the tympanic membrane
    - These are transmitted by the bones of the middle ear to the oval window
    - Movement of the oval window produces wave of compression of fluids in the inner ear
    - These compressions stimulate hair cells in the _____ (or cochlea)
- Proprioception
  - Provides information about _____ limbs are relative to the body
    - Include:

- muscle _____ which detect the amount of stretch in the muscle
- tendon _____ which convey information about the position of the joints

Tetrapod Origins

- Earliest are from the late Devonian (about 360 million years ago)
  - Acanthostega and _____
  - Gap between fishes and tetrapods is narrowing
- Tetrapods radiated into different lineages during the late Paleozoic and Mesozoic
- Tetrapods has split into two lineages by the early Carboniferous
  - Distinguished by the way the roof of the skull is fastened to the posterior portion of the braincase
    - Batrachomorphs –
      - Includes the temnospondyls - largest, longest-lasting group of primitive, extinct, nonamniote tetrapods
      - Some lineages extended into the Cretaceous
    - Reptilomorphs –
      - Contains both nonamniotes and amniotes
      - Immediate ancestor of the major amniote groups
      - _____ have been the dominant tetrapods since the late Paleozoic

Fish-Tetrapod Relationships

- Tetrapods are related to _____ fishes
- Scientists now consider that _____ are more closely related to tetrapods than is the coelocanth
  - There was some debate, because lungfishes are highly specialized

Earliest Tetrapods

- New fossils have shed light on the characteristics of early tetrapods
- More _____ than once thought
- Have groove on the ventral surface of the _____ (part of gill support)
  - In derived fishes, the groove accommodate the afferent branchial aortic arches, which carry blood to the gills
  - This suggests that the tetrapods had _____ fish-like gills (not external gills like those found in larval amphibians or adult salamanders)
- Cleithrum has a flange called a postbranchial _____, on its anterior margin.
  - This suggests that the early tetrapod had fish-like internal gills and an open opercular chamber

Evolution of Tetrapod Characters in an Aquatic Habitat

- How does a land animal evolve in water?
  - Tetrapod characteristics evolved because they were advantageous for animals that were _____ _____ _____ _____
  - Elpistostegids
    - were large, heavy fish that could gulp air
      - Could swim to surface in deep water
      - Could prop themselves up on pectoral _____ in shallow water
    - Probably stalked prey or _____ prey
      - _____- used fins to prowl through dense growth of plants on bottom of pond
      - Ambush- fins support body while waiting for prey
  - Living frogfishes
    - Provide a model for usefulness of a tetrapod-like limb in water
    - Pectoral fins are modified into structures that look like the limbs of tetrapods
    - They use these fins to _____ over the substrate
    - An analysis of frogfish locomotion reveals that they have both a walk and a slow gallop

- What were the advantages of terrestrial activity?
  - Classic Theory: Devonian was a time of droughts and fish that could move from a _____ _____ could survive and reproduce
    - Criticism:
      - Fish is evolving a means of going on to lead the life of a _____, not a terrestrial animal
  - Alternative theories
    - New niches available
      - In water, _____ and _____ were widespread
      - Any sarcopterygian that could occupy a terrestrial environment could escape competition and predation
    - Moved towards new niches in stages
      - Juvenile Ichthyostega and Acanthostega might have congregated in shallow water
        - Juveniles of living fishes and amphibians escape _____ by escaping the attention of larger predatory fishes in this manner
        - Shallow water is warm during the day, and warm water holds little _____, thus lungs are important
        - In very shallow water, legs would have provided _____ for the body

    - Such an animal could have lifted its head above water, and changes in the shape of the _____ could have started to occur
- Gradual progression of forms cable of exploiting terrestrial habitat
    - Start with aquatic _____ snapping up terrestrial invertebrates that fell into the water
    - Terrestrial _____ might have developed to the stage where tetrapods moved overland from one pond to another
    - Smaller size of _____ bodies could simplify the difficulties of support, locomotion, and respiration during transition