What adaptations were needed for terrestrial locomotion?

- **Fossil Tetrapodomorph:** Tiktaalik
- **Lissamphibia:** Rough-skinned Newt
- **Squamata:** Komodo Dragon
- **Sprawling vs. Upright Posture**
  - Kardong Fig. 9.33, 9.34, 9.35 & 9.36
- **Mammalia:** Cheetah

Describe the development of appendicular muscle tissue:

- **Development**
  - Neural tube
  - Epaxial trunk muscles
  - Myotome
  - Notochord
  - Horizontal skeletogenous septum
  - Myotomic buds entering limb bud
  - Cells from somatic layer of lateral plate contribute to somatic muscles of flank and appendages
  - Splanchnic layer of lateral plate
  - Visceral muscles from splanchnic layer of lateral plate

- **Adult**
  - Dorsal and ventral appendicular muscles
  - Skeleton of appendage and girdle
  - Hypaxial trunk muscles

How does use of axial muscles differ in water vs. on land?

- **Summaries of mean values for the timing of epaxial EMGs**
  - (thick horizontal bars) among different types of locomotion.
  - Dark shading (Tail)
  - Light shading (Trunk)
  - White (Anterior to pectoral girdle – head excluded).

- **African lungfish**
  - A – swimming
  - B – swimming in viscous fluid
  - C – moving on land
  - https://www.youtube.com/watch?v=O9qG5QbFNM - in water

- **Salamander**
  - D - Walking
  - https://www.youtube.com/watch?v=xyMbfRl7xbo

- **Diogo & Molnar, 2014**

How are the major groups of appendicular muscles?

- **Pectoral girdle**
  - **Dorsal**: extend, elevate, abduct
  - **Pectoral Fin of Sturgeon**
  - Simple, small sheets of **extrinsic** muscles in shark
  - **Axial muscles of aquatic salamander**
  - **Diogo & Simons, 2000**

- **Ventral**: flex, depress, adduct
  - **Limb muscles (new → intrinsic) of terr. salamander**
  - **Brainerd & Simons, 2000**

- **Axial muscles of aquatic salamander**
  - **Horner & Jayne, 2014**
How are skeletal muscles modified with upright posture?

- **Trapezius**: Hypomere mesoderm
- **Rhomboideus**: Hypaxial
- **Serratus ventralis**: Hypaxial
- **Pectoralis**: Ventral Appendicular muscles.

Tetrapods: extrinsic & intrinsic appendicular muscles.

Compare with Kardong Fig. 10.28

What are the benefits of these modified ankle joints?

- **Crurotarsal**
- **Mesotarsal**

Compare with Kardong Fig. 9.26 & 9.27

Human Scaling size (body mass) has an effect on limb design

- Change in size, constant shape
  - Less Massive
    - Less Resistance
    - Lower Cost to Swing
  - More Massive
    - More Resistance
    - Higher Cost to Swing

- Change in shape, constant size
  - Distally Light
    - Less Resistance
    - Lower Cost to Swing
  - Distally Heavy
    - More Resistance
    - Higher Cost to Swing

Kilbourne & Hoffman, 2013

Why & how do Cheetah’s “fly”?

© Photo by Ken Gali\nat National Geographic Magazine
What skeletal features give cheetahs great speed?

Digitigrade + longer limbs $\rightarrow$ increase stride length.
Movement of spine adds ~75 cm to total stride of 6.6m.

How is the pectoral girdle modified for running?

Lumbar: Small neural spines & zygapophyses allow bending.

What makes American Pharoah so fast?

How does a horse skeleton combine speed & “safety”?

Unguligrade $\rightarrow$ increases stride length; but it is the same as cheetah!
Large metatarsal/femur & metacarpal/humerus ratios

How & why is their lumbar region so stiff?

Compare the gait patterns of a horse & a cheetah

Bertram & Gutmann, 2009
Compare with Kardong Fig. 9.42

http://www.youtube.com/watch?v=OcD1_jvhc_g
http://www.youtube.com/watch?v=scZbaTTAbCM
**Describe the embryonic origin of appendicular muscles. What are the functions of the dorsal & ventral divisions of the appendicular muscles in fishes?**

**Diagram a transverse section through the abdominal region of a salamander. Label the epaxial & hypaxial regions. Describe the changes in function of the epaxial & hypaxial muscles from fish to amphibians. Compare the axial muscle activity in a lungfish in water vs. on land and with a terrestrial salamander’s axial muscle action on land.**

**Describe the general changes in functions & locations of appendicular muscles in the transition from fish → salamander → mammal. What is the advantage of a muscular “sling” to hold shoulders & reduced/lost clavicle in cursorial species?**

**Diagram the relationship between tibia, fibula & astragalus (talus) & calcaneus in the ankles: tibio-tarsal & mesotarsal. What are the advantages of the ankle designs? Are analogs or homologs?**

**Compare these 2 designs for efficiency of locomotion: changes in size, constant shapes vs. changes in shape, constant size in the figure by Kilbourne & Hoffman. Explain the relative changes in length of the femur compared to the metatarsals, in mammals with plantigrade, digitigrade & unguligrade posture. (See Kardong Fig. 9.37) How does foot posture affect stride length & cost of locomotion?**

**Compare these running adaptations of the cheetah and the horse: degree of spinal flexion & extension, aerial phase(s) when running. How do their lumbar vertebrae differ? What are the advantages of a rotary vs. a transverse gallow?**

**Describe the design & functions of long spring ligaments & tendons and short shock absorber digital flexor muscles in large ungulates. Which part of a horse’s limb produces most of the force of locomotion? Which part of a horse’s limb “saves” the most energy with these springs? Why don’t all mammals have to similar springs?**