Lab 8: Functional Morphology

Objectives:

1. Interpretation of functional morphology from isolated and associated limb bones
2. Application of basic physical mechanics to the evolutionary construction of vertebrate limbs
3. Basic statistical analysis and interpretation of quantitative morphological data

Limbs and locomotion: some background

Vertebrate limbs are essentially just levers that act to transfer muscular energy into motion. Muscles pull on the bones, which pivot around their fulcra (joints) to produce motion. There are three basic types of lever systems, all of which are represented in the skeletal system:

1st class levers: First class levers have the fulcrum between the load and the force moving it. The extension of the elbow joint by the triceps is a fine example of a first class lever system.

2nd class levers: Second class levers have the load between the force and the fulcrum. Your calf muscles work a second class lever system when you rise up on the balls of your feet. This type of lever system is quite rare in the vertebrate skeleton

3rd class levers: Third class levers place the force between the load and the fulcrum. These are the most common type of levers in your body. An example is the flexion of the elbow joint by the biceps.

In all these types of levers, the ratio of the force exerted on the load (Fout) to the force exerted by the muscle (Fin) is equal to the ratio of the length of the lever from the fulcrum to the load (Lout) to the length of the lever from the fulcrum to the point where the force is exerted (Lin). Or, in mathematical terms:

$$\frac{F\_{in}}{F\_{out}}= \frac{L\_{in}}{L\_{out}}$$

On the other hand, the same proportion applies to the ratio of the distance traveled by the motion of the muscle (Xin) to the distance traveled at the point where the force is exerted (Xout). That is:

$$\frac{L\_{in}}{L\_{out}}= \frac{X\_{in}}{X\_{out}}$$

With this in mind, develop a prediction for the relative sizes of the in and out levers in a part of the skeleton where POWER is important. Write your prediction down somewhere; it will be part of the work you hand in. Now think about EFFICIENCY. This means that a given amount of muscular effort gives you a large return in terms of motion. How might the need for efficiency affect the structure of the in and out levers in a joint system? Hint: think about the high gears on a bicycle. How do they work to help you travel long distances? Write your prediction in your handout. Now, let’s test those predictions.

Procedure:

Stuff you need:

* A partner. We’re doing the lab by the buddy system, although you’ll each do your own lab writeup.
* A measuring device. I’ll provide rulers, string, and other measuring devices as available; different devices will work better for different animals.
* Your datasheet (see the back of this lab handout)

Locomotor types:

We’re going to look at how different locomotor modes affect the morphology and lever systems of the limbs. To do this, you’re going to measure and describe proportions of the limbs and feet of a number of mammals and compare them to the demands of their ecology. Here are the locomotor categories you’ll be examining:

1. Terrestrial – these are relatively generalized mammals that spend most of their time on land, not specializing in any particular form of locomotion.
	1. Porcupine - *Erethizon*
	2. Ground squirrel - *Spermophilus*
	3. Hyrax - *Procavia*
	4. Bear - *Ursus*
	5. Cat – *Felis*
	6. Dog - *Canis*
2. Cursorial – these are running specialists, generally species that can run long distances very efficiently. Some definitions of cursorial include sprinters like cheetahs, but that’s different from what we’re looking at today, and imposes a very different set of physical demands on the skeleton.
	1. Goat - *Capra*
	2. Horse - *Equus*
	3. Camel - *Camelus*
3. Fossorial – these animals are burrowers, specializing in using the forelimbs to excavate their burrows. (note: there are a number of fossorial animals that use other parts of their anatomy, like their teeth, to dig, but we aren’t looking at them today)
	1. Mole - *Scalopus*
	2. Gopher - *Thomomys*
	3. Armadillo - *Dasypus*
	4. Sewellel - *Aplodontia*
4. Arboreal – these are climbers and tree-dwellers.
	1. Opossum - *Didelphis*
	2. Monkey
	3. Lemur
	4. Squirrel - *Sciurus*
5. Ricochettal – these are jumping mammals that get around by bouncing on their hind feet.
	1. Wallaby
	2. Kangaroo rat – *Dipodomys*
	3. Gerbil – *Gerbillus*
	4. Rabbit - *Sylvilagus*
6. Semiaquatic – these mammals spend a substantial amount of their time in water and have adaptations for swimming, although we haven’t included any fully aquatic animals, because their limbs often play only a minor role in locomotion.
	1. Muskrat - *Ondatra*
	2. Beaver - *Castor*
	3. Platypus - *Ornithorhynchus*
	4. Sea lion - *Zalophus*

You’ll be taking a series of measurements on mammals from different locomotor categories, and comparing your results statistically. Choose 4 of the 6 categories to compare, one of which MUST be Terrestrial; this is the basic category to which you’ll be comparing everything else. With your partner, measure all the available members of your chosen categories, as well as the human, for the following dimensions:

1. Length of humerus
2. Length of femur
3. Length of radius
4. Length of ulna
5. Length of tibia
6. Length of metacarpal III
7. Length of metatarsal III
8. Length of deltopectoral crest from head of humerus
9. Length of olecranon process of ulna

Enter your data on the datasheet provided with the lab. Now, input your data into a computer for a little data exploration. For each species, figure the following ratios:

1. Femur / tibia
2. Humerus / radius
3. Femur / (tibia + metatarsal III)
4. Humerus / (radius + metacarpal III)
5. Length of ulna / length of olecranon process
6. Length of humerus / length of deltopectoral crest

How do these ratios relate to the lever systems at the knee and elbow joints? Explain how these dimensions relate to the in and out levers for the movements involved in locomotion in the groups you’re studying.

Using the graphing utility in Excel (or any other program you prefer that performs the same function), generate a plot of ratio 1 (see above) against ratio 2. Can you tell the difference between your different locomotor types? What about ratio 3 vs. ratio 4? Experiment with plotting your data against one another until your find a “morphospace” (or more than one, if you need it) that separates out each of the locomotor types from one another. Add humans to your plots. Hmmm…why might they be falling out where they are? Now, answer the questions on the last page of this handout.

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| Species | Locomotor type | Humerus length | Femur length | Tibia length | Radius length | Ulna length | MC length | MT length | DPC length | OP length |
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Lab assignment Lab 8: Functional Morphology

Type up the answers to these questions and turn them in for your grade on the lab.

1. Explain your prediction for the relationship between the lengths of the in and out levers for a joint system where POWER is important.
2. Explain your prediction for the relationship between the lengths of the in and out levers for a joint system where EFFICIENCY OF MOVEMENT is important.
3. List the 4 categories you’re comparing here. What are the major demands each locomotor habit places on the limb system of the mammal using this type of motion?
4. How do the measurements you took relate to the lever systems that allow locomotion?
5. Attach a few plots (no more than 3) that best show the differences among your categories in terms of limb structure.
6. Explain WHY these dimensions best distinguish the categories the way they do. This will require that you explain the difference in the demands of these lifestyles. Spend some time thinking, and maybe even reading, about the challenges of different mammalian lifestyles, and come to an understanding of what’s different and what’s the same about the demands these styles of locomotion make on the limbs. This explanation should take you a page or two.
7. Where are humans in your plots? Why?
8. How does size affect the proportions of the limbs independent of locomotor habit? This is a discussion that might be helped by another graph or two.