DEFINING COMPARATIVE ANATOMY

The title of this course might be more adequately be called "Comparative Vertebrate Functional Anatomy".

Why emphasis on function? Integration of form and function is a fundamental necessity in studying an organism. We need to realize that anatomy of an animal is a certain way because an organism needs to function. The most successful structures are those that are going to be able to persist in the population; less successful structures will die out with their owners.

Example - Activity of wing muscles of the bird and the bat. Dissection of these animals can give an idea of what the muscular and skeletal structures look like, but you still need to correspond the structures to what actually goes on during flight.

What we will see this semester are variations on themes - all organisms must be able to perform certain functions to survive. They all must perform locomotion (or not, in the case of sessile organisms), respiration, circulation, excretion, digestion, and reproduction. The diversity of life that we see is a product of animals finding different ways of performing these functions.

A BRIEF HISTORY OF ANATOMY

Anatomy comes from the Greek word that means "to cut up" or "dissect"

Much of the early work in anatomy was based mostly on descriptions of organ systems, muscle systems, and usually was conducted on domestic animals such as livestock and chickens.

Aristotle - 4th century BC

Made detailed observations of animal anatomy. For example, he described watching the heart of a chick develop from the liquid mass of an egg.

Also established groupings of animals based on their structural form, which is now known as the field of taxonomy

Galen - 2nd century AD

� Greek physician known for his comparative study of animals

� Carried out experiments to understand kidney function, movement of blood through arteries.

� Book on Anatomical Preparations was accepted for nearly 1400 years as the Western World�s most authoritative reference on medical anatomy

� Downside to Galen�s work - he had little concern for pain and suffering of his animal subjects and often dissected and examined animals while they were still alive.

Very few advancements in anatomical study during the Middle Ages, primarily because advancements in biological thought were also relatively infrequent during this time.

After the Middle Ages, work moved to include the study of functional anatomy, or the study of how structures within organisms, such as cells, tissues, organs, organ systems, and other complex functional units, perform specific functions.

Leonardo da Vinci (15th century AD)

� His studies of anatomy, design and mechanics are well-known, as are his sketches and work on the anatomy of flight.

William Harvey (17th century)

� Studied circulation of blood in the body, including the function of valves in the veins from the limbs.

Giovanni Borelli (17th century)

� Applied the concept of levers (originally studied by Archimedes) to the locomotion of animals

Carl von Linne (Carolus Linnaeus; 1707 - 1778)

� Devised the binomial system for naming plants and animal which forms the basis of modern taxonomy

� Philosophically argued that species were unchangeable, created originally as we find them today (based on creation as described in Genesis)

Jean-Baptiste de Lamarck (19th century)

� Philosophie Zoologique (1809) spoke to three issues of evolution:

1) fact: species change through time - the simplest arise through spontaneous generation from inanimate matter but thereafter evolved onward and upward into higher forms

2) course: progressive changes in species along an ascending scale, from the lowest/simplest to most complex/"perfect" (humans)

3) mechanism: need itself produces heritable evolutionary changes - when environments or behaviors changed, an animal developed new needs to meet the demands the environment placed on it

\* Summarized as: "Evolution by means of the inheritance of acquired characteristics"

Georges Cuvier (19th century)

� Compared organs of various vertebrates and studied functional relationships among the organs

� Extremely knowledgeable in the skeletal structure of animals, and could infer the shapes of bones that would connect to neighboring bones.

Karl Ernst von Baer, Ernst Haeckel

� Both studied comparative developmental anatomy

� von Baer noted that all early vertebrate embryos look "fishlike" and diverge anatomically as development proceeds

� Haeckel proposed the "biogenetic law", or "ontogeny recapitulates phylogeny", which implied that during the embryonic stages (ontogeny) all higher animals progressively change morphologically and resemble the evolutionary stages that preceded (phylogeny). The theory has since been re-evaluated and given less emphasis in comparative studies.

Charles Darwin (19th century)

� In his books On the Origin of Species (1859) and The Descent of Man (1871) he helped to establish the evolutionary basis of our modern synthesis of comparative, functional and adaptive morphology and anatomy

� Proposed three conditions for and mechanisms of evolutionary change:

1) If left unchecked, members of any species will increase naturally in number because all species posess a high reproductive potential.

2) Competition for resources.

3) Survival of the few - natural selection - nature weeding out the less fit. Superior adaptations would, on average, fare better and survive to pass on their successful adaptations.

Alfred Wallace (19th century)

� Idependently developed the concept of "survival of the fittest" from the observation that the human population increases faster than food to correspond with Darwin�s "survival of the few"

Comparative anatomy as an interdisciplinary field: As with many fields, comparative anatomy must be interdisciplinary to incorporate the full range of factors influencing animal morphology. We now find people from all fields involved in the study, including the following fields:

Zoology - study of animals

Physiology - study of function

Histology - study of cell and tissue structure

Genetics - study of our genetic blueprint and its effects

Ecology - study of the relationship between organisms and their environment

Developmental Biology - study of the ontogeny of individuals from fertilization to parturition

Evolutionary biology - study of natural selection and adaptation of organisms to their environment

Phylogeny - comparative study of evolutionary relationships between organisms

Research focuses on a seemingly simple question - evolution of animal body plans, and how long ago different body plans diverged. Still, two centuries of comparative anatomy have not yielded a consensus about the separation of different phyla.

Although we know that a swordfish, a fly, and Marilyn Monroe all have different body plans (representative of their phyla), we still do not know how the characteristics unique to each arose.

Several different fields have been involved in this study to resolve the phylogenetic tree:

Paleontologists - look at the fossil record to come up with possible relationships based on morphology

Paleoecologists - try to imagine how each organism may have functioned in the environment, either as a filter feeder, predator or grazer

Developmental biologists, molecular biologists and geneticists - have looked at homeobox genes (which regulate the expression of other genes and determine the features characteristic of each body segment) to see how they are different, and may give some indication of where each body plan diverged.

Without the cooperative efforts between these diverse fields, the exact relationships between the different body plans might be more speculative.

This example should give you some idea of the different directions that the field of comparative anatomy can take you.

Using comparative anatomy in the real world - medicine and beyond

At this point, you may begin thinking about how you will use this course in the future, to get you thinking about how the concepts can be applied - most limit their thinking of the medical applications of this class!

As a small sample of what you can potentially do:

Medicine - the techniques you learn in this class, including memorization and integration of concepts, as well as the terminology, will certainly help in a medical career.

Athletics and physical therapy - requires knowing how bones and muscles interact as lever systems for maximum benefit of training exercises as well as to minimize possibility of stress or injury to body tissues.

Physical anthropology - understanding how stature, body shape and limb proportions relate to environment, and apply to human origin, distribution and ecology.

Animal behavior - how anatomical structures are used in behavior. Examples: horns and antlers used in combat displays are related to acquiring mating opportunities.

Evolutionary biology - anatomy helps us to understand organismal phylogenetic relationships

Forensic anthropology - analysis of physical remains of humans to determine identity and circumstances of death

Biological and medical illustration

Any other areas?

MORPHOLOGICAL CONCEPTS

To analyze design, concepts of form, function, and evolution have developed which address similarity, symmetry, and segmentation.

Similarities - corresponding parts may be considered similar to each other by:

� Homology - two or more features that share a common ancestry: bird�s wing and mole�s arm may be traced back to common ancestral reptile

- serial homology - special case with similarities between successively repreated elements in the same organism: vertebral collumn, muscle segments

� Analogy - features with a similar function: wings of bats and bees similar in function but of different ancestral structural origin

� Homoplasy - features that simply look alike; may or may not be homologous or analogous: turtle and dolphin flippers; insect wings which look like leaves but cannot photosynthesize

Symmetry - how the body meets the surrounding environment:

� radial symmetry - the body is laid out equally from a central axis; any of several planes passing through the center divids the animal into equal halves

� bilateral symmetry - only the midsagittal section divides the body into two equal halves

� body regions are described by basic terms of:

- anterior = head end (cranial/superior)

- posterior = tail (caudal/inferior)

- dorsal = back

- ventral = front

- the midline is medial; the sides lateral

- attached appendages have a distal (farther away) and proximal (closer) portion

- the pectoral region or chest supports the forelimbs

- the pelvis region refers to the hips which support the hindlimbs

- a frontal plane divides the body into dorsal and ventral sections, sagittal plane into left and right, and transverse plane into anterior and posterior portions

Segmentation - a body built of repeated or duplicated segments (metameres) separated by a series of septa.

In addition to these three, Cephalization is the pronounced tendency for the anterior end of the body to become more and more distinctly separated and differentiated from the rest of the body as a head.

During cephalization, the brain and sense organs become centralized at the head, and there forms a greater elaboration of the feeding apparatus, which includes jaws, musculature, teeth, beaks, tongues and glands.

EVOLUTIONARY MORPHOLOGY

Evolution and morphology have not always been happy companions - cooperation between disciplines has led to concepts of design and change in design.

The concept of function covers both how a part works and how it serves adaptively in the environment - cheek muscles of a mouse function both within an organism (chewing) and by meeting environmental demands (resource processing), which are defined by:

� function: the action or property of a part as it works in an organism

� biological role: how the part is used in the environment during the course of the organism�s life history

Preadaptation: a structure or behavior posesses the necessary form and function before the biological role arises that it eventually serves - feathers in birds probably served as insulation to conserve body heat prior to development of flight (thermoregulation now a secondary function)

Evolutionary change involves continuous renovations - old parts are altered but new parts rarely added

Comparisons among characters require careful use of terminology defining relationships - traits may be Primitive/Generalized/Derived/Specialized

An important distinction to make is among the terms. They are not necessarily interchangeable, and should be used carefully when describing morphology.

Primitive and derived are antonyms -

� Primitive - structures that are similar to that of the ancestors or shared by all living groups

� Derived - structures that are different from that of the ancestors

as are generalized and specialized

� Generalized - modified to perform a variety of functions

� Specialized - modified to perform restricted functions

As an example:

In mammals, the pentadactyl (five phalanges) condition is primitive, in that it is found in all living groups. However, there is a derived condition in some mammals, such as the bat wing, in which the first digit is elongated, or in the horse foot, which is reduced completely to a single digit.

In contrast, our anterior phalanges (fingers) are generalized, in that they can perform a number of different functions, from playing the piano to carving a sculpture. However, our posterior phalanges (toes) are specialized, and can usually only perform the function of balance and walking.

PHYLOGENY

The course of evolution (phylogeny) is often summarized in dendrograms (schematic diagrams) that depict treelike branched connections between groups

Phylogenies serve as a graphical representation of the evolutionary relationships of organisms. They may show:

� which organisms branched off first from a common ancestor; i.e. the major stages of evolution of fishes

� may also give information on the relative abundance of these taxa;

Each branch in the dichotomous branching pattern signifies a point at which two taxa diverge based on some morphological or other character trait.

All extant species usually listed in a line at the top. Extinct species lines do not meet up with those of extant species.

PALEONTOLOGY

Vertebrate evolution was once referred to as the "Vertebrate Story" by paleontologist Alfred Romer - unfolds across 590 million years with roughly 99.9% of all species which ever to have evolved now extinct

All that survives are their remnants, the fossils and scetchy vignettes they tell of the structure and early history of vertebrates

Fossil remnants may include bones, teeth, eggs, small boney elements (embryos, diet?), feces, DNA traces - fossil dating, restoration, and reconstruction lead to an improved understanding of the past