COMPARATIVE VERTEBRATE ANATOMY

An Outline Text

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Des Moines, Iowa

This condensed yet comprehensive text is designed to guide students rapidly and efficiently through the vast amount of information encompassed by comparative vertebrate anatomy. Emphasis is placed upon facts and concepts that relate to more advanced studies in embryology and human anatomy. Early chapters cover general aspects of vertebrate structure, present an evolutionary survey of vertebrate groups dealing with the phylogeny and characteristics of each class, and describe the processes of early development. A short discussion of major types of tissue is included as a basis for understanding the differentiation of organ systems. The text then examines each organ system individually. Each discussion encompasses phylogenetic relationships, manifestations in different vertebrate groups, embryology, and adult structure. A summary of the development of aortic arches and an explanation of the development of venous channels are provided. Such topics as the anatomical basis for naming peripheral nerve fibers and differences in describing muscle action in quadrupeds and bipeds receive special attention. The numerous illustrations in the text focus on basic principles. Many word roots and their translations are included, and a self-quiz is provided on structures formed during early stages of vertebrate development.

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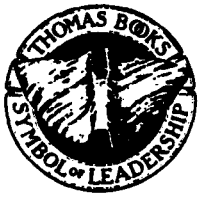

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COMPARATIVE
VERTEBRATE ANATOMY

To my family

PREFACE

THIS Outline-Text has been written to put the concepts and information presented in traditional Comparative Vertebrate Anatomy courses into an easily handled and useful framework. The amount of material typically included in Comparative Anatomy courses is so overwhelming that even excellent students profit from an outline such as this, which offers direction and perspectives. An added dimension of this text that appeals to modern students is its emphasis upon embryology and human morphology. It is the purpose of this book to present basic concepts of comparative anatomy in a streamlined form that is easily used as a supplement to classroom work in comparative anatomy, as an aid in other undergraduate courses that lean heavily upon morphology, and as a means of rapid review during professional study.

The outline approach has been used because it presents a large amount of information in a form that is easy to assimilate and, by its very nature, organizes material so that appropriate grouping of ideas and facts is accomplished. Generalizations are presented that form a brief but accurate framework upon which many details rest in an orderly and predictable pattern. The drawings have been executed with the utmost simplicity, to represent the most basic concepts underlying the development of vertebrate structure. Many word roots and their translations have been included in order to make mastery of professional vocabulary less difficult.

It is always appropriate to acknowledge contributions of persons who have been helpful to the author. Deep appreciation is expressed to all my colleagues and friends who have assisted in a variety of significant ways. My greatest thanks go to my students for their careful scrutiny of the text and their constructive criticisms. These students have been of great help in identifying difficult areas and in working with me to make necessary clarifications. Former students have returned, bringing insights from their continued studies, which have helped to shape this book to have maximum utility in relating comparative anatomy to advanced professional study.

CONTENTS

COMPARATIVE
VERTEBRATE ANATOMY

Chapter One

INTRODUCTION TO THE VERTEBRATE BODY

I. General structure of the vertebrate body

A. Components
   1. Head: cephalization correlated with bilateral symmetry
   2. Trunk: contains coelom lined with peritoneum
   3. Postanal tail: contains vertebrae and associated structures which extend posterior to the trunk
   4. Appendages: no more than two sets of paired appendages

B. Body plan described as being a tube within a tube
   1. Outer tube designated as somatic; comprises the body wall
   2. Inner tube designated as visceral; composed of gut and derivatives

II. Vertebrate characteristics

A. Characteristics common to all vertebrates as members of the phylum Chordata
   1. Notochord
   2. Dorsal hollow nerve cord
   3. Pharyngeal modifications: pouches, slits, and arches
      a. Pouches: segmentally arranged outpocketings of pharyngeal tube, which grow toward outside of organism
      b. Slits: formed if pouch is met by an ingrowing groove and the separating wall (closing plate) breaks down. Gill slits of fish are formed in this way
      c. Arches: the tissue separating consecutive pouches from each other

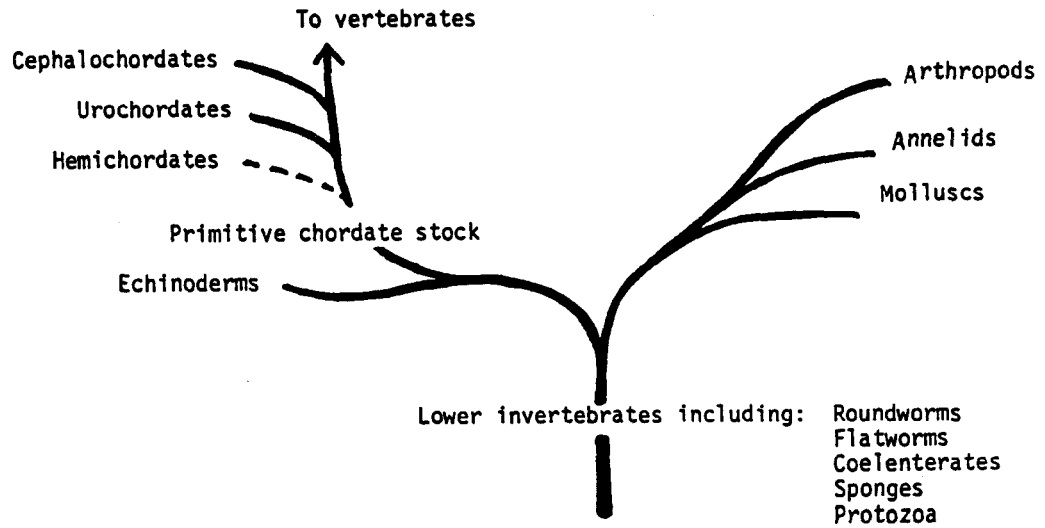
B. Characteristics which separate vertebrates from most invertebrates
   1. Skeletal system
      a. Vertebrae and cranium
      b. Living endoskeleton
      c. Mouth closed by raising lower jaw
   2. Circulatory system
      a. Ventral heart
      b. Closed blood system, i.e. capillaries as opposed to open sinuses
      c. Erythrocytes present
   3. Urinary and reproductive systems closely related
   4. Two layered skin
   5. Complex endocrine gland system
   6. Neural crest cells

III. Place of vertebrates in the animal kingdom

A. Summary of essential terms
   1. Notochord: dorsally located supporting rod present in all chordates
   2. Chordate: any organism which possesses a notochord at some stage in its life history
      a. Protochordates: simple chordates which do not develop vertebrae
      b. Vertebrates: chordates in which additional supporting structures (vertebrae) develop around the notochord

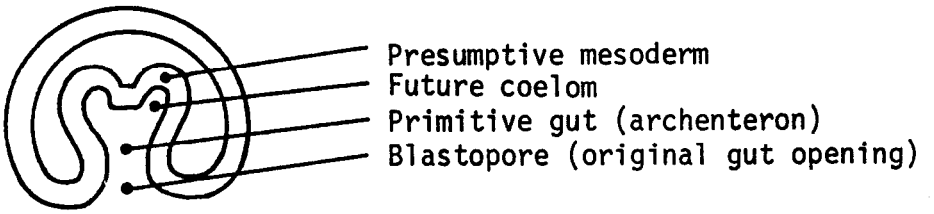
B. Major groups of protochordates
   1. Urochordates (tunicates)
      a. Have notochord in tail region only
      b. Possess tough leathery tunic
      c. Best known representatives are the sea squirts
         (1) Adult
            (a) Sessile filter feeders with prominent pharyngeal gills
            (b) Notochord and nerve cord absent
         (2) Larva
            (a) Free swimming
            (b) Has notochord in tail; also possesses dorsal, partially hollow nerve cord
            (c) Possesses pharyngeal gill slits
      d. Members of *one* group, the larvaceans, remain larval (in the sense that they are free swimming) throughout life
   2. Cephalochordates
      a. Frequently grouped under the general name amphioxus, which means pointed at both ends
      b. Adult displays all three basic chordate characteristics
         (1) Notochord: extends into head region, hence the name cephalochordate
         (2) Dorsal, hollow nerve cord
         (3) Pharyngeal gill slits and arches
      c. Examples of vertebrate-like characteristics
         (1) Segmental arrangement of muscles
         (2) Pattern of circulatory system similar to that of simple vertebrates
         (3) Two layered skin
         (4) Filter feeders; cilia on gill arches important in obtaining food as was true of the most primitive vertebrates
      d. Excretory and reproductive systems invertebrate-like
   3. Hemichordates
      a. Named for a questionable "half notochord" in region of proboscis
      b. Sometimes listed as protochordates; sometimes listed separately from chordate groups
      c. Closely related to echinoderms
      d. Characteristics
         (1) Questionable notochord (as indicated above)
         (2) Dorsal *and* ventral nerve cord; dorsal cord hollow anteriorly
         (3) Pharyngeal gill slits

C. Diagram summarizing place of chordates in animal kingdom:



D. Characteristics linking echinoderms and chordates on same side of two branched phylogenetic "tree"
   1. Cleavage patterns
      a. Cleavage defined: successive divisions of zygote until normal cell size for the species is reached
      b. Indeterminate cleavage displayed by echinoderms and chordates
         (1) Fate of material in newly divided zygote is *not* rigidly predetermined and is therefore called indeterminate. If the cells of the two cell stage of a developing echinoderm or chordate are separated from each other, each of the separated cells is capable of developing into an entire organism, as in the case of human identical twins
         (2) If the cells of the two cell stage of an annelid, arthropod or mollusc are separated from each other, each cell will start to develop into a nonviable half embryo
      c. Radial cleavage characteristic of echinoderms and chordates
         (1) In radial cleavage, each cell lies directly over the one below, resulting in radial or spoke-like symmetry of the developing organism
         (2) Major invertebrate phyla other than echinoderms show spiral cleavage in which each tier of cells is aligned with other tiers in such a way that a spiral pattern results
         (3) Diagram comparing radial and spiral cleavage:

   2. Final position of mouth: echinoderms and chordates are deuterostomes because the final mouth of the organism is located at a distance from the first mouth or blastopore (see diagram below)
   3. Mesoderm and coelom formation similar in echinoderms and primitive chordates
      a. Mesoderm formed from cells pinched off from gut wall
      b. Coelom pinched off with outpocketing mesoderm
      c. Diagram showing mesoderm and coelom formation in amphioxus:



   4. Larval forms similar in primitive chordates, echinoderms, and other closely allied organisms
   5. Biochemical similarities (e.g., similarity of protoplasmic proteins)

Chapter Two

SURVEY OF THE VERTEBRATES

I. Classification of organisms

A. Natural system of classification recognizes evolutionary relationships
B. Difficulties in classification
   1. Absence of important specimens
      a. Soft parts tend to be poorly preserved
      b. Bodies may have been destroyed by natural phenomena (e.g. fire, predation)
   2. Gradual and continuous nature of evolutionary changes (e.g. duckbill platypus shows distinct reptilian characteristics as well as distinct mammalian characteristics)
   3. Confusion caused by popular names (e.g. *Amia*, a primitive bony fish, is referred to as a choupique, cypress trout, mudfish, grindle, blackfish, beavertail and fresh water dogfish)
C. Mechanics of correct classification
   1. Major taxonomic groups
      a. Phylum
      b. Class
      c. Order
      d. Family
      e. Genus
      f. Species
   2. Binomial system of nomenclature
      a. Scientific name of an organism consists of genus and species (e.g., *Felis domesticus*)
      b. Scientific name should be written in italics or underlined
      c. First letter of genus name (but not that of species) should be capitalized
D. Living vertebrates placed into seven classes
   1. Superclass Pisces (fish)
      a. Class Agnatha
      b. Class Chondrichthyes
      c. Class Osteichthyes
   2. Superclass Tetrapoda
      a. Class Amphibia
      b. Class Reptilia
      c. Class Aves
      d. Class Mammalia
E. Extinct placoderms not included in above classification

II. Fish

A. Class Agnatha ("without jaws")
   1. Ostracoderms ("shell skin")
      a. Earliest vertebrates preserved in fossil record
      b. Characteristics
         (1) Extinct
         (2) Jawless

(3) Filter feeders
(4) Possessed no paired fins
(5) Armored
(6) Usually less than one foot long
(7) Lived in fresh water

2. Cyclostomes ("round mouth")
   a. Modern agnatha which have lost ability to form bone
   b. Represented by two living suborders
      (1) Lampreys
         (a) Display certain primitive characteristics as well as some which are highly specialized
         (b) Life cycle includes larval and adult states: typically involves both fresh and salt water
         (c) Larval stage (ammocoetes): resembles amphioxus in many respects (e.g., filter feeding): also displays all the basic vertebrate characteristics (e.g., notochord does not extend forward into head region, nerve cord expanded anteriorly to form primitive brain, pronephric kidney present)
      (2) Hagfish
         (a) Exclusively marine
         (b) Feed mainly upon dead fish

B. Class Placodermi
   1. Completely extinct
   2. "Experimented" with jaws and appendages
   3. Characteristics of more advanced placoderms
      a. Mouth closed by lower jaws
      b. No more than two pairs of appendages
      c. Possessed air bladder

C. Class Chondrichthyes
   1. Possess cartilaginous skeleton
      a. Believed to be a specialization, not a primitive character
      b. Some fossil forms contained a limited amount of bone
   2. Representative living examples
      a. Elasmobranchs (naked gill slits)
         1. Selachians or sharks
         2. Batoidea (flattened forms)
            (a) Skates
            (b) Rays
            (c) Sawfish
      b. Holocephalians: chimera or ratfish

D. Class Osteichthyes
   1. General characteristics
      a. Skeleton contains bone
      b. Gills covered by bony operculum
      c. Typically have air (swim) bladder
      d. Divided into two groups on basis of fin structure
         (1) Actinopterygii (ray finned fishes)
         (2) Sarcopterygii (fleshy or lobe finned fishes)
   2. Actinopterygii
      a. Characteristics
         (1) Fins supported entirely by dermal rays
         (2) No internal nares
         (3) Abundance of cartilage in certain forms represents loss of ability to form bone
      b. Major groups
         (1) Chondrosteans ("cartilage-bone") represented in North America by sturgeon and spoon-bill
         (2) Holosteans ("complete-bone") represented today by *Amia* and *Lepidosteus* (Alligator gar)
         (3) Teleosts ("end-bone"); the ultimate or "end" in bony development

(a) Includes 90% or more of all living fish
(b) Show extensive adaptive radiation
(c) Examples: perch, eel, blind fish of caves, sea horse

c. An evolutionary dead end

3. Sarcopterygii (fleshy or lobe finned fishes)
   a. Characteristics which "preadapt" them to land living
      (1) Extensive skeletal elements extending into fleshy fins
      (2) Internal nares present; therefore, these fishes are sometimes called choanichthyes or "nostril fishes"
      (3) Air bladder connected with nostrils
   b. Major groups
      (1) Crossopterygians (fringe finned)
         (a) One highly modified form still alive: *Latimeria* (a coelocanth)
         (b) Ancient crossopterygians ancestral to primitive amphibians
      (2) Dipnoi ("double breathing")
         (a) Are true lungfish
         (b) More specialized than typical crossopterygians, e.g., farther away from primitive vertebrate stem
         (c) Three surviving genera: found in Africa, Australia, and Brazil

III. Tetrapods

A. Class Amphibia
   1. Skeletal evidence supports belief that Amphibia arose from crossopterygians
      a. Similarity of skull bones
      b. Labyrinthine or maze-like pattern found on teeth of both
      c. Homologous major bones appear to be present in paired appendages
   2. Primitive amphibians
      a. Heavily armored
      b. Many were probably completely aquatic
      c. Labyrinthodonts (primitive amphibians with maze-like patterns on their teeth) gave rise to modern amphibians
   3. Modern amphibians
      a. Typically have both aquatic and terrestrial stages in life history
      b. Grouped into three orders
         (1) Caudata ("tailed"): amphibians such as salamanders
         (2) Anura ("without tail"): frogs and toads
         (3) Apoda ("without feet"): burrowing amphibians

B. Class Reptilia
   1. Stem reptiles (cotylosaurs) believed to have arisen, as did modern amphibians, from labyrinthodonts
   2. Became true land animals with land egg containing amnion and other membranes; therefore were the first *amniotes*
   3. Groups of reptiles
      a. Subclass Anapsida (without arches)
         (1) Possess no fossae or arches in cheek region to accommodate muscles
         (2) Absence of arches and fossae believed to be a primitive trait
         (3) Includes cotylosaurs, turtles, and tortoises
      b. Euryapsida
         (1) Possessed one temporal fossa high on each side of skull
         (2) Includes large extinct aquatic forms
      c. Diapsid reptiles
         (1) Two arches and associated fossae on each side of skull
         (2) Includes widely divergent groups
            (a) Extinct forms: dinosaurs and pteryosaurs

(b) Living forms: Sphenodon (a "living fossil"), crocodiles, snakes, and modern lizards

d. Subclass Synapsida
   (1) Possessed one arch and fossa on each side for muscle attachment
   (2) All are extinct
   (3) One group gave rise to mammals

C. Class Aves (birds)
1. Probably arose from a group of ruling reptiles
2. Primitive birds
   a. Possessed teeth, conspicuous claws on wings, and vertebrae in tail region
   b. Thought to be weak fliers; feathers may have served primarily for insulation
3. Modern birds
   a. Described by some workers as "glorified reptiles"
   b. Homeothermic (sometimes referred to as endothermic)
   c. Divided into two groups
      (1) Ratites: running, flightless birds such as the ostrich
      (2) Carinates: flying birds; sternum deeply keeled (carinate) for muscle attachment
   d. Behavior patterns are area of current research

D. Class Mammalia
1. Arose from synapsid reptiles
2. Important characteristics include the following:
   a. Hair
   b. Mammary glands
   c. Sweat glands
   d. Three bones in middle ear cavity
   e. Muscular diaphragm
   f. Homeothermic (endothermic)
3. Major groups of mammals
   a. Monotremes
      (1) Name refers to "one hole." The digestive, urinary, and reproductive systems share a common opening (cloaca) to the outside
      (2) Sometimes referred to as prototheria or first beasts
      (3) Includes only the duckbill platypus and the spiny anteater
   b. Theria: all mammals except monotremes have some type of placenta and are grouped together as theria (beasts)
      (1) Marsupials (pouched mammals)
         (a) Sometimes referred to as metatheria or "between" beasts to distinguish them from eutheria, which are "true" beasts with a well-developed placenta
         (b) Possess simple placenta in which yolk sac is prominent
         (c) Young born alive in immature condition
         (d) Found almost entirely in Australia; opossum only representative in North America
      (2) Insectivores
         (a) Closely related to primitive stock from which other true mammals arose
         (b) Examples: moles and shrews
      (3) Chiroptera (bats) are the only true flying mammals
      (4) Primates
         (a) Mostly arboreal mammals
         (b) Characterized by opposable thumb (and usually, also great toe)
         (c) Examples: lemurs, tarsoids, and anthropoids
      (5) Edentates
         (a) Teeth absent or reduced
         (b) Two major groups: Hairy forms (such as sloths) and armored forms (armadillo)
      (6) Pholidota: represented by pangolin (scaly anteater)
      (7) Rodentia

(a) Gnawing animals with single pair of upper and lower incisors which grow throughout life
(b) Examples: rats, guinea pigs, and squirrels

(8) Lagomorpha
(a) Similar to rodents except for two pairs of upper incisors (one pair directly back of the other)
(b) Represented by rabbits and hares

(9) Cetacea: whales, dolphins, and porpoises

(10) Carnivora
(a) Fissipedes ("cleft feet") are land animals such as bears, dogs and cats
(b) Pinnipedes ("wing feet") are aquatic carnivores such as seals, walruses, and sea lions

(11) Perissodactyls: hooved animals (ungulates) with odd number of toes, e.g., horse

(12) Artiodactyls: hooved animals (ungulates) with even number of toes, e.g., cow and pig

(13) Proboscidea: subungulates with elongated upper lip, e.g., elephants

(14) Sirenia: aquatic subungulates, e.g., sea cow

(15) Hyracoidea
(a) Commonly known as conies or rock badgers
(b) Found in Africa and neighboring countries
(c) Possess hoof like nails (except one digit which has a claw)