Biology 3B Laboratory
The Chordates

Objectives

- Learn and recognize the four major characteristics of chordates
- Learn and identify the major groups within the Phylum Chordata
- Examine and understand the external and internal anatomy of the lamprey and its larval form, the ammocoete

Introduction

The subphylum Vertebrata represents only one of the three subphyla within the phylum Chordata. The other two are the Urochordata and Cephalochordata. Examination of the representative specimens of each of these subphyla available in the laboratory will provide a better understanding of the phylogenetic relationships within the phylum (see Table One). The major characteristics of chordates include the presence of: (1) **notochord** --a flexible rod like structure serving as a skeletal support for the anterior to the posterior region of the body, (2) **dorsal hollow nerve cord** which lies above the notochord, (3) **pharyngeal gill slits**--paired lateral openings through the pharyngeal wall of the gut. All of these characteristics are present in all chordates at least during the embryonic period of development, and (4) the **post-anal tail**.

Examination of The Urochordates

This subphylum consists of the **tunicates**, also called sea squirts. The leathery outer covering of these animals is called a **tunic**. The adult stage demonstrates no evidence of a notochord, a dorsal hollow nerve cord, or a post-anal tail, but it does have pharyngeal gill slits which it uses in filter-feeding. Locate the pharyngeal basket containing the gill slits, the "mouth" (incurrent siphon), and the excurrent siphon. The free-swimming larval stage does possess a notochord and a dorsal hollow nerve cord; in the larval form, the notochord extends into the tail, hence the name Urochordata. Examine a larval tunicate and identify each of the four chordate characteristics.

Examination of The Cephalochordates

The cephalochordates, or lancelets, received their name because in these animals the notochord extends into the head region. Amphioxus is the living example of this subphylum. Amphioxus can swim but they spend more time burrowed into the sand and mud. Amphioxus, like the other two subphyla, is a filter-feeder. Its trunk musculature is segmented into **myomeres**. Examine the chordate features in the specimens of Amphioxus.

Table One. CLASSIFICATION OF THE CHORDATES

Phylum CHORDATA
- **Subphylum UROCHORDATA** (Tunicates)
- **Subphylum CEPHALOCHORDATA** (Lancelets)
- **Subphylum VERTEBRATA** (Vertebrates)
  - **Superclass AGNATHA** (Jawless vertebrates)
    - **Class CEPHALASPIDOMORPHI** (Lampreys)

Class *OSTRACODERMI (Ostracoderms)
Class MYXINI (Hagfishes)
Superclass GNATHOSTOMATA
Class *PLACODERMI (Placoderms)
Class CHONDRICHTHYES (Cartilaginous fishes)
Subclass Elasmobranchii (Sharks and Rays)
Subclass Holocephali (Chimaeras)
Class ACTINISTIA (Lobe-finned fishes)
Subclass Coelacanthimorpha (Coelacanths)
Class DIPNOI (Lungfishes)
Class ACTINOPTERYGII (Ray-finned fishes)
Subclass Chondrostei (Bichirs, Sturgeons, Paddlefishes)
Subclass Neopterygii
Class AMPHIBIA (Amphibians)
Subclass *Labyrinthodontia (Labyrinthodonts
Subclass Lissamphibia (Frogs, Urodeles and Caecilians)
Class TESTUDINES (*Cotylosaurs and Turtles)
Class *SYNAPTOSAURIA (Plesiosaurs)
Class *ICHTHYOPTERYGIA (Ichthyosaurs)
Class *ARCHOSAURIA (Thecodonts, Pterosaurs, Dinosaurs)
Class CROCODILIA (Crocodilians)
Class LEPIDOSAURIA (Snakes, and Lizards)
Class *SYNAPSIDA (Pelycosaurs and Therapsids)
Class AVES (Birds)
Subclass *Archaeornithes (Ancestral birds)
Subclass Neornithes (True birds)
Class MAMMALIA (Mammals)
Subclass Prototheria (Egg-laying mammals)
Subclass Theria (Viviparous mammals)
Infraclass Metatheria (Marsupials)
Infraclass Eutheria (Placentals)

* *indicates extinct groups*

Examination of The Vertebrates

1. A "Primitive" Vertebrate, The Lamprey

The first vertebrates show many of the characteristics of the higher vertebrates, but differ from the latter in the absence of true jaws (**Superclass Agnatha**) and are recognized taxonomically as the **Class Cephalaspidomorpha**. The only surviving agnathan vertebrates are the lampreys and hag-fishes. These forms are of particular interest, therefore, in that they provide living examples of the general structure of the earliest of vertebrates. The adults are parasitic or scavengers, while the larval stages (ammocoetes) are filter feeders in much the same manner as Amphioxus. In addition to their primitive characteristics, they exhibit both specializations, particularly for feeding in the adult stage, and degenerate features (e.g. the loss of bone).

a. External anatomy of the Lamprey

Place an adult lamprey (*Petromyzon*) in a pan with about 1/2 inch of water to prevent the specimen from drying out. Note the cylindrical body divisible into head and trunk regions. The trunk musculature exhibits the **segmental** arrangement previously noted in Amphioxus and the **myomeres** are visible through the skin, particularly in the tail region. Observe the myomeres of the lamprey are more complex than those of the lancelet. **Median fins** only are present, a plesiomorphic feature already seen in Amphioxus. Two dorsal fins and a **caudal fin** are present and are supported by paired, cartilaginous fin rays .

The anterior part of the head forms a **buccal funnel** directed ventrally. The buccal funnel is fringed with lip tentacles, and its inner surface is beset with **horny teeth** (not homologous to the teeth of higher vertebrates). The arrangement of the teeth varies with the species and its feeding habits. An armed piston-like tongue is visible deep in the center of the buccal funnel. The mouth is situated just above the tongue.

On top of the head is the single nasal opening leading to the single **olfactory sac** and the **nasohypophysial sac** . The single nasal opening is another diagnostic feature; two laterally-placed nostrils are characteristic of all other vertebrates. The light area directly posterior to the nasohypophysial opening represents the well-developed third or pineal eye. The true eyes lack eyelids and are situated on the upper sides of the head. A series of seven gill slits is situated behind the eyes. The gill slits open into gill pouches lined with gill lamellae. Examination of the head will reveal lines of small papillae with a tiny pore at their apex. These are lateral line organs found also in higher fishes and certain amphibians. A continuation of the lateral line system will be found to extend above the gill slits toward the posterior end of the body. Trace the lateral line system on the head and body of your specimen. What is the function of the lateral line system?

At the rear of the trunk, below the second dorsal, is located the **cloacal pit** . It contains the **anus** in front and the **urogenital** papilla behind.

b. Internal anatomy of the Lamprey

The gross features of the internal anatomy may be studied in the mid-saggital sections of adult lampreys that have already been prepared. Note the buccal funnel, tongue, and large muscle masses that operate the tongue. The mouth leads into an **esophagus** running above the gills and a **ventral pharynx** or respiratory tube into which the gill pouches open. The **velum** guards the entrance to the pharynx. The **esophagus** leads into the remainder of the digestive tract, which is essentially a straight tube terminating in the anus. A stomach is not developed. The large **liver** is visible as an elongate greenish structure. A **gall bladder** is present. The **paired kidneys** are suspended from the dorsal wall of the **coelom** in the posterior part of the body.

The **notochord** appears as a conspicuous, stiff rod lying in the dorsal part of the body. The **brain** lies above the beginning of the notochord, and the spinal cord can be traced from the rear part of the brain posteriorly above the notochord. The **nasohypophysial tube**, **olfactory sac**, and **nasohypophysial sac** are clearly evident in the section. Determine their relationships. The nasohypophysial sac is a

muscular bulb that pumps water in and out over the sensory epithelium lining the olfactory sac.
Both sexes possess a single **gonad** that lies in the body cavity and is suspended by a mesentery from the dorsal body wall. The ovary is more granular in appearance than the testis. When released from the gonad, the germ cells lie free in the coelom, a unique feature among vertebrates.

c. Structure of the Ammocoete larvae of the Lamprey
As noted above, the larval lamprey serves as a better example of the primitive vertebrate than does the adult. Examine a preserved specimen of an ammocoetes. The myomeres of the trunk musculature are more apparent and an oral hood is developed instead of the sucking-type of mouth parts found in the adult. The inner surface of the dorsal area of the oral hood and the membrane surrounding the mouth are covered with **oral papillae** utilized in straining out food organisms. The nasal opening and the pineal eye area are prominent. The true eyes are sunken beneath the skin and are nonfunctional. Photo receptors are present in the tail, however. What is the significance of their location in this area? The gill slits are prominent, and the branchial region is somewhat expanded. The cloacal pit is found in the same position as in the adult.
For further details of the internal structure of the ammocoetes study stained whole mounts. Identify the oral hood and oral papillae. The mouth leads into a buccal cavity which is bounded behind by a pair of flaps, the velum. What is the function of this structure? The large pharynx begins at the velum, and the gill slits, gill pouches, and gill lamellae can be distinguished in this region. Below the anterior half of the pharynx is a large mass, the endostyle. What is the apparent homolog of this structure in the adult lamprey and in higher vertebrates?
The pharynx leads posteriorly into the **esophagus** which continues into the **intestine**. The intestine can be traced to the anus. Food items may be visible within the gut. Just below the juncture of esophagus and pharynx is the **heart**. Lying between the heart and esophagus is the **pronephros**, the excretory organ.

2. Classification of Recent Vertebrates
These exercises provide a general introduction to the major classification of the living fish-like vertebrates. Using these work sheets, learn the scientific classification and general characteristics of each taxonomic division. Look for the adaptive trends exhibited by the animals in each group, and for the evolutionary trends implied by the classification.

PLEASE HANDLE ALL SPECIMENS WITH EXTREME CARE

A. CLASSIFICATION OF RECENT FISHES

Superclass AGNATHA (Jawless vertebrates)
Jaws absent. Paired fins lacking (in recent forms).
Notochord persistent. Two semicircular canals in inner ear. Myotomes not divided into dorsal and ventral portions with horizontal septum.
Class CEPHALASPIDOMORPHA (Lampreys)

Body naked and eel-like. Mouth suctorial, with tongue transformed into a rasping organ. Single nasohypophysial opening; naso-hypophysial sac not communicating with oral cavity. Gills contained in gill pouches. Seven external gill openings on each side of body. Skeleton cartilaginous; skull well developed, rudimentary neural arches present. A paired "salivary" gland present.

Class MYXINI (Hagfishes)

Body naked, eel-like. Mouth with tentacles; tongue transformed into rasping organ. Single nasohypophysial and opening nasohypophysial sac communicating with pharynx. Five to 15 gills located in pouches. Skeleton cartilaginous; skull weakly developed; branchial skeleton rudimentary; no evidence of vertebrae. No "salivary" gland developed.

Superclass GNATHOSTOMATA

Class CHONDRICHTHYES (Cartilagenous fishes)

Jawed fishes with cartilaginous skeletons. No swim bladder. Pelvic fins usually modified to form claspers in the male. Spiral valve present in the intestine.

Subclass ELASMOBRANCHII (Sharks and rays)

Skin bearing placoid scales or naked. Five to seven gill arches and gill openings on each side; first opening, the spiracle, small. No gill cover developed. Hyoid arch contributing to support of jaws (hyostylic or amphistylic). Cloaca present.

Subclass HOLOCEPHALI (Chimaeras)

Skin naked. Upper jaw (palatoquadrate) indistinguishably fused to neurocranium, the hyoid arch not participating in the suspension of the jaws (holostylic condition). Teeth usually in form of grinding plates. No cloaca. Tail symmetrical. Frontal claspers on head.

- OSTEICHTHYES Bony fishes

Skeleton at least partly ossified. Jaws present. Swim bladder usually present. Gills covered by a single bony operculum. Pelvic fins of male not developed into claspers. Spiral valve usually not present in intestine.

Class DIPNOI (Lungfishes)

Tendency toward reduction of skeletal ossification in some species. Scales originally cosmoid, reduced in modern forms. Paired fins with jointed medial axis. Upper jaw (palatoquadrate) fused to neurocranium (autostylic). Grinding teeth present. Internal nares. An air bladder with ventral connecting to gut has special pulmonary circulation and serves as lung (air-breathing organ). Cloaca present. Diphycercal tail.

Class ACTINISTIA (Lobe-finned fishes)

Cosmoid scales. Paired fins with scale-covered lobe containing radials arranged biserially. Autostylic jaw. Internal nares. Air bladder with ventral connection to gut. Two dorsal fins.

Subclass COELACANTHIMORPHA (Coelacanths)

Class ACTINOPTERYGII (Ray-finned fishes)

Scales not cosmoid (usually ganoid, cycloid, or ctenoid, may be lacking). Paired fins usually without fleshy base. Jaws hyostylic. No internal nares.

Subclass CHONDROSTEI

Order POLYPTERIFORMES (Bichirs)

Medium sized (up to 1 m), elongate, ray-finned fishes. Caudal fin symmetrical, pectoral fins with fleshy base, dorsal fin divided into numerous finlets. No internal nares. Ganoid scales. Air bladder functions as lung, and connects to ventral side of gut. Spiral valve present in intestine.

Order ACIPENSERIFORMES (Sturgeons and paddlefishes)

Large ray-finned fishes with heterocercal tails. Skeleton secondarily cartilaginous; vertebra lack centra. Body naked or partially covered with bony scutes. Snout elongate, mouth inferior. Premaxillary fused with maxillary. Pelvic fins abdominal. Air bladder smooth internally and connected to gut dorsally, does not function in respiration. Spiral valve present in intestine.

Subclass NEOPTERYGII

Order SEMIONOTIFORMES (Gars)

Caudal fin abbreviate-heterocercal. Pelvics abdominal, dorsal fin posterior. Elongate snout with many sharp, conical teeth; nasal openings at end of snout. No gular plate. Ganoid scales. Vertebrae opisthocoelous.

Order AMIIFORMES (Bowfin)

Caudal fin abbreviate-heterocercal. Pelvics abdominal. Premaxillary firmly articulated with cranium. Lower jaw with three dermal bones on inner side, each bearing teeth. Teeth conical, a band of rasp-like teeth on rear of lower jaw. Large gular plate between lower jaws. Scales cycloid.

- TELEOSTEI Modern bony fishes

Very small to large ray-finned fishes with well developed vertebral centra and considerable cranial ossification. Scales lacking ganoin in living species, usually cycloid or ctenoid. Tail usually homocercal. Air bladder arising from dorsal wall of gut, although sometimes connection disappears by maturity. Intestine lacking a spiral valve, but generally elongate and coiled.

Superorder OSTARIOPHYSI

Order CYPRINIFORMES

Minnows, suckers, and their allies. Weberian apparatus present (3 modified anterior vertebrae connecting air bladder and inner ear). Air bladder typically physostomous. Pelvic fins usually abdominal. Fins without spines. Head scaleless. Scales cycloid.

Superorder ACANTHOPTERYGII (Spiny-rayed fishes)

Order PERCIFORMES

Perch-like fishes. Air bladder physoclistous. Pelvic fins usually thoracic, but sometimes jugular or slightly behind pectorals. Fins usually with spines in addition to soft rays. Often 2 dorsal fins, with anterior one spinous. If dorsal single,

anterior portion with spines. Scales usually centoid.

Other teleosts that you should be familiar with:

Superorder ACANTHOPTERYGII

Order CYPRINODONTIFORMES (Top minnows)

Superorder PROTACANTHOPTERYGII

Order SALMONIFORMES (Salmon, trout, pikes)

B. CLASSIFICATION OF RECENT AMPHIBIANS

Class AMPHIBIA (Amphibians)

Tetrapods with naked and usually moist skin. External scales absent, although some forms with small mesodermal scales embedded in skin. Both pairs of limbs usually developed, although hind limbs or both pairs sometimes lacking. Digits usually lacking claws. Toes in recent forms do not exceed 4-5. Skull with two occipital condyles. Ribs, if present, do not articulate with sternum. Respiration by means of gills, lungs, skin, or mouth cavity or some combination of these; gills always present at some stage of the life cycle. Eggs lack embryonic membranes of any sort, usually encased in jelly coats. There is typically an aquatic larval stage which undergoes metamorphosis into the adult. Poikilothermous or ectothermous.

Subclass LISSAMPHIBIA (Frogs, salamanders and caecilians)

Order ANURA (Frogs and toads)

Tail absent, head and trunk continuous, with no definite neck. Hind limbs elongated, with four segments. Vertebrae number 10 or less. Free ribs rarely present. Terminal portion of vertebral axis consisting of urostyle. Fertilization usually external. Larvae of tadpole type, usually aquatic. No true teeth in larval stage. Metamorphosis pronounced.

Order URODELA (Salamanders)

Body elongate, with head, trunk, and tail distinct, and suggestion of neck. Limbs if present subequal. Reduction of cranial and pectoral girdle elements from primitive condition. Larvae, if present, resemble adults in general body form and possess teeth in both jaws. Metamorphosis not pronounced. Fertilization often internal.

Order APODA (Caecilians)

Worm-like amphibians with burrowing habits. Limbs absent. Skulls compact, roofed with bone. Eyes lidless and often hidden beneath the bones of the skull. A protrusible tentacle on the side of the face between nostril and eye. Tail very short, anus nearly terminal. Males with a protrusible copulatory organ. Fertilization internal. Caecilians occur throughout the world in tropical regions with the exception of Madagascar. Their structure combines a number of primitive and highly specialized characteristics, the latter being chiefly correlated with burrowing habits.

C. CLASSIFICATION OF RECENT “REPTILES”

“Reptiles” are not a natural group, however, the taxon does have utility in when observing living tetrapods. The member of this taxon have a dry skin usually covered with epidermal scales or horny plates. Limbs are usually present, but may be reduced or absent. Digits when present typically 5 and tipped with claws. Respiration is by means of lungs. Skeleton is well ossified. There is one occipital condyle. Middle ear is often present, with a single bone. Fertilization is internal, an amniote egg is present; embryonic membranes are (amnion, chorion, allantois, and yolk sac) present during development. In oviparous species eggs have a brittle or leathery shell.

Class TESTUDINES (CHELONIA) (Turtles)

Body broad and encased in a variously developed upper shell (carapace) and lower shell (plastron) composed of bony plates covered with leathery skin or bony shields (laminae). Thoracic vertebrae and ribs usually fused to shell. Skull with immovable quadrate bone. Jaws lacking teeth and provided with horny sheaths. Penis single, located in ventral floor of cloaca. Anal opening a longitudinal slit.

Class CROCODILIA (Crocodilians)

Body long. Head large and long. Tail well developed and strongly compressed. Limbs short, feet partially webbed, digits 5-4. Skin thick and leathery, with bony plates (osteoderms) usually underlying horny scales on dorsum and venter. Ear opening small, covered by a flap. Skull retaining 2 complete temporal fossae. Teeth numerous, conical, thecodont. Abdominal ribs present. Copulatory organ single. Anal opening a longitudinal slit.

Class LEPIDOSAURIA (Lizards, snakes and tuatara)

Skull with 2 temporal openings separated by the postorbital and squamosal bones. Ventral border of lower temporal fossa absent in some forms.

Order RHYNCHOCEPHALIA (Tuatara)

This primitive order of reptiles is represented by a sole surviving form, *Sphenodon* . *Sphenodon* is a "living fossil", exhibiting the essential characteristics of the diapsid stocks in the late Permian. Formerly widespread through out New Zealand, the tuatara is now confined to several small islands off the coast. It reaches a length of 2 feet and inhabits burrows, which are sometimes shared with petrels (marine birds). Its diet consists of insects, earthworms, snails, fishes, and the eggs and occasionally the young of petrels.

Scales granular; a middorsal row of low spines. Skull with 2 complete temporal fossae, in contrast to snakes and lizards in which the lower opening has no border of bone. Tip of upper jaw beak-like and separated from remainder of jaw by a notch. Quadrate immovable. Mandibles joined by ligament.

Order SQUAMATA (Lizards and snakes)

Lower temporal fossa open below. Quadratojugal lacking, squamosal much reduced, quadrate movable. Copulatory organ (hemipenes) double and eversible. Anus a transverse slit.

Suborder LACERTILIA (Lizards)

Limbs usually 4 but sometimes reduced or absent. Eyelids usually movable. Ear opening present or absent. Tongue variously developed, usually entire but occasionally bifid. Lungs usually equally developed. Urinary bladder typically present. Mandibles joined anteriorly in a bony symphysis. Pineal opening often present. Tail often capable of regeneration. Usually several rows of ventral scales. Anterior braincase usually open.

Suborder SERPENTES (Snakes)

Body elongate. Limbs absent except as vestiges of pelvic girdle in some forms. No external ear opening. No sternum. No bladder. Eyes immobile, no free eyelids. Tongue slender, bifid. Teeth acrodont. Left lung reduced. Mandibles usually joined anteriorly by a ligament rather than a bony symphysis. Tail not capable of regeneration. Ventral scales usually in single row. Anterior braincase closed.

Suborder AMPHISBAENIA (Worm lizards)

Body elongate, wormlike. Limbs, external ears, and usually eyes absent. Body covered with scales, appears segmented. In U.S. restricted to Florida. Strictly fossorial.

d. CLASSIFICATION OF RECENT BIRDS

Observe the great amount of adaptive radiation in the beaks and feet. Try to correlate the bill and foot structure of each species with its feeding and other habits.

These specimens have been prepared by skinning the bird, then stuffing the very delicate skin with cotton. They are extremely fragile. Handle them with extreme care. Pick them up only by grasping them gently around the breast; never grasp them by the bill, head, neck, legs, feet, or tail. Do not spread the wing or tail feathers.

Class AVES

The recent birds form a coherent and well-characterized class of vertebrates, which may adequately be defined by a single feature -- the presence of feathers. The forelimbs are modified into wings, while the hind limbs are variously adapted to walking, perching, or swimming. The general skeleton is highly ossified and combines strength and lightness in its structure. The skull has a single occipital condyle and teeth are absent in all recent forms. The sternum is enlarged and usually keeled. Birds have a relatively high metabolic rate and are homeothermic or endothermic. Fertilization is internal and the eggs are of the amniote type, large, rich in yolk, and covered with a hard calcareous shell.

Subclass ARCHAEORNITHES

This group includes the fossil birds known from the Jurassic. In these forms, the tail is elongate, consisting of more than 13 vertebrae each with a pair of rectrices; the metacarpals and digits are separate, the latter with claws; and the jaws contain teeth.

Subclass NEORNITHES The remainder of the birds are placed in this subclass. In this group the tail is reduced, being composed of fewer than 13 caudal vertebrae which are also compressed, rectrices attach in a fan-like manner, the metacarpals are fused and the digits reduced, claws not being present on all. The Neornithes includes 28 extant orders and several extinct orders dating back as far as the Cretaceous.

Order SPHENISCIFORMES Penguins

Bill short and stout to relatively long and decurved. Neck short, body stout. Wings are paddle like. Tail very short. Legs short and stout, set far back; feet webbed. Plumage consists of a dense coat of very small feathers. No apteria. Found only in the Southern hemisphere (one species inhabits the Galapagos Islands on the equator).

Order PODICIPEDIFORMES Grebes

Water birds, form duck-like, tail rudimentary and soft; legs inserted far back on body; tarsus compressed; serrate behind; toes 3 in front, 1 behind, lobed nails broad and flat; bill generally long and straight although tip sometimes decurved.

Order PELECANIFORMES Totipalmate Swimmers (Tropic-Birds, Pelicans, Boobies, Cormorant, Anhingas, Frigatebirds)

Wings large; legs short; all 4 toes included in web (totipalmate); nostrils tiny or lacking external openings; epidermal covering of bill compound; gular pouch present, small in some instances.

Order ANSERIFORMES Waterfowl (Ducks, Geese, Swans)

Duck-like form; legs and tail short; front toes webbed; bill broadened.

Order FALCONIFORMES Diurnal Birds of Prey, Vultures, Secretary birds, Hawks, Eagles, Ospreys, and Falcons (but not the New World vultures)

Feet raptorial, toes 3 in front, 1 behind, outer more or less opposable; claws generally strongly curved and sharp for grasping prey; beak strong and hooked, with sharp cutting edges. Eyes directed more or less laterally.

Order GALLIFORMES Fowl (Turkeys, Grouse, Pheasants, Curassows, Quail, Prairie Chickens, etc.)

Stout-bodies; wings short and rounded, primaries stiff and curved; feet large, not webbed, toes 3 in front, 1 behind; bill short, culmen decurved, upper mandible vaulted.

Order CHARADRIIFORMES (Shore-birds, Gulls, and Auks)

Wings pointed, outer primaries usually longer than secondaries; front toes webbed to varying degree; hind toe rudimentary or absent; lores feathered.

Order COLUMBIFORMES Pigeon-like Birds

Wings long and pointed; short legs; feet rather small, 3 toes in front, 1 behind, latter elevated; bill slender, constricted in middle, swollen at base, with a fleshy operculum.

Order PSITTACIFORMES Parrots

Plumage coarse and dense; tarsus bare; feet zygodactyl, outer toe (5-jointed) reversible (outer hind toe longer than inner hind toe); bill with cere, short, powerful, strongly hooked, and not toothed.

Order STRIGIFORMES Owls

Nocturnal birds of prey; plumage fluffy, prominent facial disc; eyes directed forward; feet zygodactyl , outer toe reversible, bill with cere, strongly hooked.

Order APODIFORMES Swifts, hummingbirds

Bill very small, slightly decurved; gape large. Wings very long and pointed. Tail short and truncate (with feathers in some species spin-tipped) to long and forked. Legs extremely short; tarsi or even toes) feathered in many species.

Order PICIFORMES Woodpeckers and allies

Tail shorter than wing; rectrices often stiff and sharp pointed; feet zygodactyl -outer toes reversed outer hind toe longer than inner hind toe); bill long, straight, sharp-pointed, chisel-like.

Order PASSERIFORMES Passerine Birds (Flycatchers, Larks, Swallows, Orioles, Crows, Titmice, Nuthatches, Creepers, Wrens, Shrikes, Warblers, Finches, etc.)

Feet adapted to perching, with three toes in front, 1 behind; rear toe incumbent (inserted at same level as front toes) and about equal to or longer than lateral toes; rectrices usually 12; bills various; lores feathered.

e. CLASSIFICATION OF RECENT MAMMALS

Look for the adaptive trends exhibited by the mammals in each group, and for the evolutionary trends implied by the classification. Note especially the skulls and dentition; you should be able to identify each Order from the skull alone.

These specimens have been prepared by skinning the mammal, then stuffing the skin with cotton. They are extremely fragile. Handle them with extreme care. Pick them up by grasping around the body. Never hold them by the head, neck, legs or tail.

Class MAMMALIA

Homeothermic. Hair at some stage of development. Mammary glands. Lower jaw composed solely of dentary and articulating with squamosal bone of skull. Two occipital condyles. Secondary palate developed. Three ossicles in middle ear. Scapula usually with spine. Four-chambered heart with completely double circulation. Left aortic arch present. Erythrocytes non-nucleated. Muscular diaphragm.

Subclass PROTOTHERIA (Egg-laying mammals)

Teeth lacking in adults. Cervical vertebrae bearing separate ribs. Cloaca present. Genital system of female completely double, oviducts opening separately into cloaca. Penis of male lies in ventral wall of cloaca and transmits only sperm. Oviparous. Mammary glands lack nipples. Brain

essentially mammalian but lacking corpus callosum.

Order MONOTREMATA (Monotremes)

This is the only order within the subclass Prototheria. Its characteristics are those of the subclass. The members of this primitive yet specialized mammalian group include the spiny anteaters or echidnas and the duck-billed platypus. Monotremes are confined to Australia, Tasmania, and New Guinea.

Subclass THERIA Mammals giving birth to living young (viviparous)

Mammary glands with teats. Female tubal genitalia differentiated into oviduct (Fallopian tube), uterus, and vaginal portions. Sperm and urine transported through penis. Cloaca usually absent.

Infraclass METATHERIA

Order MARSUPIALIA (Marsupials)

Young larvaceous at birth. Marsupial pouch usually present, though variously developed. Total number of teeth often exceeding 44, full complement of cheek teeth consisting of 3 premolars and 4 molars. Median and lateral vaginae often developed in females. Intrauterine nourishment by taking up of "uterine milk" by yolk sac, actual contact of yolk sac with uterine wall, or, in one genus, by means of a true allantoic placenta. Testes located in prepenial scrotum. Brain lacking corpus callosum. Now found only in North America (one species), South America, and Australia and nearby islands.

Infraclass EUTHERIA (Placentals)

Young retained for considerable time in uterus, nourished by allantoic placenta. No pouch. Corpus callosum present. No cloaca. 44 or fewer teeth.

Order INSECTIVORA Insectivores (moles, shrews, hedgehogs)

Small to medium sized mammals. Plantigrade or semi-plantigrade. Full dentition often preserved or little reduced; incisors, canines, anterior premolars often little differentiated. Brain with large olfactory bulbs, small cerebral hemispheres. Corpus callosum small.

Order CHIROPTERA (Bats)

Flying mammals, with wing membrane (patagium) supported by last 4 digits which are greatly elongated; thumb free, short, and bearing claw. Pectoral girdle robust, clavicle large, sternum with keel. Radius strongly developed, ulna reduced. Teats thoracic or pectoral in position. Penis pendant.

Order PRIMATES Primates (Prosimians, monkeys, apes, humans).

Primarily arboreal animals; usually vegetarians or omnivorous, but a few are insectivorous. Limbs plantigrade, usually with 5 digits, one opposable. Orbits usually surrounded by bone and directed forward. Brain typically with well developed cerebral hemispheres. One pair of thoracic mammae. Tail present or absent.

Order LAGOMORPHA. Lagomorphs (Rabbits, hares, and pikas).

Gnawing mammals with 2 pairs of upper incisors, the second small and peg like, and one pair of lower incisors. Canines absent. Cheek teeth separated from incisors by distinct gap (diastema). Bony palate narrow and short. Tibia and fibula joined distally. Tail abbreviate. Ears and hind feet often large.

Order RODENTIA Rodents (Mice, rates, squirrels, beaver, etc.).
Gnawing mammals with single pair of chisel-like incisors in upper jaw and a single pair in lower jaw. Enamel on front surface of incisors not extending to posterior part, resulting in uneven wear. Incisors growing from persistent pulps. No canines, cheek teeth separated from incisors by a large gap (diastema). Body form and habits highly variable.

Order CETACEA Cetaceans (Whales, dolphins, porpoises).
Fully aquatic. External form fish-like. Tail provided with lateral outgrowths termed flukes. Forelimbs modified into flippers. Hind limbs reduced to internal vestiges. Hair covering reduced to scattered bristles or lacking in adult. Nostrils opening at vertex of head. Cervical vertebrae often compressed and fused into single mass.

Suborder ODONTOCETI (Toothed whales)
Calcified teeth present after birth. Nostrils form single external opening.

Suborder MYSTICETI (Baleen whales)
Functional teeth absent in adult, baleen plates present. Nostrils open separately.

Order CARNIVORA Carnivores (Cats, bears, dogs, weasels, etc.).
Mammals of variable size and habits, but primarily terrestrial. Strong sharp claws usually present. Canines usually well developed. Cheek teeth show tendency toward development of cutting edges, last premolar of upper jaw and first molar of lower often showing greatest modification for this purpose and termed the carnassial or sectorial teeth.

Order PINNIPEDIA Pinnipeds (Walruses, seals, and sea lions).
Medium to large (to 6.5 m) aquatic mammals. Digits not separate, connected by thick web forming flipper for swimming. Facial region of skull relatively small, pinnae very small or lacking. Vibrissae well developed. Molariform teeth mostly homodont, canines well developed. Tail very short or absent. Body usually covered with hair.

Order PROBOSCIDEA Elephants
Large mammals (to 7.5 m, 6 tons) with graviportal (pillar-like) legs, and a long, prehensile proboscis or trunk for harvesting leaves and branches. Skull massive, shortened, and increased in height for wielding the heavy trunk. Single upper incisor on each side elongated to form tusk. A single large molar on each side functional at any one time, replaced from the rear. Found in

Sub-Saharan Africa and Southern Asia.

Order SIRENIA Manatees and dugongs

Thick body up to 4 m long, little hair except for bristles around mouth. Tail with horizontal fluke. Nostrils on upper surface of snout. Forelimbs modified as paddles, hind limbs represented only by internal vestiges. Skeleton heavy and dense. Pinnae lacking. Teats pectoral, testes abdominal. Teeth reduced in number and modified for grinding aquatic vegetation. Found in tropical and subtropical seas and coastal rivers of America, Africa, and Asia.

Order PERISSODACTYLA Odd-toed ungulates (Horses, tapirs, rhino)

Axis of fore and hind feet passing through third or middle digit, which is always largest and in some cases the only functional toe. Digits bearing symmetrical hoofs. Incisors present, canines reduced or absent, premolars and molars forming continuous series and generally similar in shape. Nasal bones expanded posteriorly. Stomach simple.

Order ARTIODACTYLA Even-toed ungulates (Antelope, cows)

Axis of fore and hind feet passing between third and fourth digits, which are nearly equally developed and asymmetrical. Upper incisors and canines absent in more advanced forms. Premolars and molars usually dissimilar in appearance. Nasal bones not expanded posteriorly. Stomach generally complex, four-chambered in more advanced groups.