Vertebrate Taxonomy and Diversity

Aim

Distinguish between major groups of vertebrates through a demonstrated understanding of their taxonomic classification and diversity.

TAXONOMY: GROUPING BIOLOGICAL ORGANISMS

In the scientific system, living organisms are classified by dividing them into groups, which have similar characteristics. These groups are then divided into smaller groups with similar characteristics. These are divided again and so the division of group to sub group and sub group to further sub groups goes on, until you finally have only one type of organism in each group.

There are many different levels of division, although the main ones which we use are at the bottom end of the scale (i.e. family, genus, species and variety).

The main levels of division are as follows:

All animals are divided into PHYLA (singular: Phylum)

Phyla are divided into DIVISIONS

Divisions are divided into CLASSES

Classes are divided into ORDERS

Orders are divided into FAMILIES

Families are divided into GENERA (singular: Genus)

Genera are divided into SPECIES

Species are sometimes divided into VARIETIES or other more specific categories such as SUBSPECIES

In addition to these levels of division new divisions have been introduced. For example, infraclass and super order (among others). Due to new species being discovered everyday there are increasing numbers of new species belonging to the same number of divisions. The increase in the number of described species has led to the growth of the divisions of classification.

Also, as the techniques for identification have advanced species which may have once belonged to one division may have been reclassified into another division. In addition to this, whilst sharks and rays are known as Elasmobranchs, the class they belong to is Chondrichthyes. There are always exceptions and the classifications shown in one text book or resource may differ slightly to another. Lastly, statistics given may also change over time. For example, there may be 25 000 – 30 000 fish species but not all are described and it is not always easy to create an exact figure.

THE CLASSIFICATION OF HIGHER ANIMALS

Although the term “Higher Animals” is well established in both common and scientific language as a synonym for vertebrates, we should bear in mind that there are other groups of animals that are highly developed, namely insects and cephalopods.

Phylum Chordata

The subphylum Vertebrata is placed within the phylum Chordata. Most chordates are bilaterally symmetrical animals with differentiation into head, trunk, and tail.

As a rule, chordates are active animals. The most distinctive anatomical features of chordates are a notochord and nerve cord. The notochord is an exceptionally important characteristic of chordates. It is like a stiffened rod that does not compress. This allows the body muscles to act against the notochord and thus allows the animal to move.

The phylum Chordata includes three subphyla:

1. Subphylum Acrania includes about 30-35 contemporary species placed in one class and three families. All are marine animals. Look like small (~10 cm or smaller) semi-transparent fish.

2. Subphylum Urochordata (Tunicata) consists of three classes of exclusively marine animals.

    2.1 Class Ascidia includes about 1,000 contemporary sessile filter-feeding animals also called Sea Squirts. Order Synacidiae includes species dwelling in colonies, while order Monoscidiae includes solitary animals.

    2.2 Class Thaliacea (Salpae) includes about 70 contemporary pelagic filter-feeder species shaped like a barrel, and is divided into three orders. Order Pyrosomidae consists of species dwelling in colonies: orders Salpidae and Doliolidae consist of solitary species.

    2.3 Class Appendiculariae includes about 60 small (several millimeters) pelagic species.

3. Subphyla Vertebrata includes animals with a distinct internal skeleton. They are multicellular animals derived from embryos that have three cellular layers: endoderm (endo- internal), mesoderm (meso- medium) and ectoderm (ecto- external). They have bilateral symmetric bodies, and internal gut with two openings, mouth and anus. Only Vertebrates have a true brain with several different areas and a skeletal structure that protects the brain, the cranium. They have developed sensory organs (eyes, ears, olfactory organs). They possess a more complex digestive system, with several accessory digestive glands. The heart is chambered. They have developed more complex respiratory and muscular systems as well.

Classes within Vertebrata include:

- Cyclostomata (Lampreys and Hagfish)
- Chondrichthyes (Sharks, Skates and Rays, Elephant Fishes)
- Osteichthyes (Bony Fishes) (Choanichthyes (Lungfish) separated from this class by some researchers)
- Amphibia (Amphibians – Frogs and Toads, Newts and Salamanders, Caecilians)
- Reptilia (Crocodiles, Lizards and Snakes, Turtles and Tortoises, Marine Iguanas)
- Aves (Birds)
- Mammalia (Mammals)

MORPHOLOGY AND EVOLUTION

Morphology is the study (-logy) of forms (morpho-). Animal morphology studies not only animal form, but also why animals develop in a certain way.

To understand why an animal part or structure is as we know them today, we have to study what pushes evolution in a certain path and not in another direction.

There are two major factors that determine evolution:

- Environment
- Genetics

Environment determines animal form by providing opportunities for better survival and reproduction. Environment provides for unoccupied habitats or ecological spaces (niches) where it is advantageous to develop structures or to use existing ones differently, to make the animal better suited to their environment, that is, to survive better as an individual or as a species. Thus, environment puts limitations to animal evolution, and encourages certain evolutionary paths.

Morphological changes are also determined by genetics. A certain structure may change in a certain way, because there is a genetic possibility that allows for that change. But an animal cannot develop a structure when there are no genes that could be modified to develop the new structure. There must be a genetic predisposition. A primate cannot develop feathered wings because the feathered wing genes were not in primitive mammals' evolution.

Genes are changing constantly, although the rate of change may be very slow. Genetic change is accelerated though when environmental changes are quicker. Evolution has been faster in geological times where environmental instability has been the highest.

Environment determines animal behaviour, and behaviour determines evolution as well. Animal behaviour is determined by basic survival needs:

- Feeding
- Reproducing
- Surviving predation

Any structural change that reinforces or facilitates the three functions above will be promoted if there is genetic seed for it.

The effects of evolution in animal morphology can be classified in two main types:

- Speciation
- Diversification

Speciation happens when an animal population expands geographically. In every location, the population will encounter different environments, even if differences are slight. A one degree average annual temperature variation may be a significant difference for some species.

With time, there will be genetic variation in the population due to adaptations to the different environmental factors encountered across the population living grounds. Individuals may be able to breed with other individuals living nearby. But if genetic changes become too big, for instances in populations that were separated geographically long time ago, interbreeding cannot occur, and species become more and more distinct. Eventually they will develop as separate species.

There are several diversification processes by which evolution proceeds.

- Successive adaptive radiation is the process by which a common ancestor gives rise to several different phyla, classes or families.
- Convergence is seen when two or more different animal groups show the same characteristic or feature. For instances, birds and bats have wings. Fishes and dolphins have fins. Even if the structure seems similar and serves the same purpose, that is to fly or to swim, their origin is different, they are not derived from the same structure. They developed from different primitive structures to improve the animal or its progeny's survival.

Environmental factors and shape

Animal shapes have evolved to adapt to environment and thus be able to colonise new habitats, or just survive as a species in a slowly (geologically speaking) changing environment.

Environmental factors that affect animal shapes are:

- Temperature

- Food types and distribution

Temperature

In cooler climates, endothermic animals have developed adaptations that allow them to maintain their body temperatures within the limits needed to be alive, which for most of the eutherians is around 38°C. Internal temperature needs to be kept within a very small range otherwise animals cannot survive.

Heat is lost through the body surfaces of the body, be it external like the skin, or internal like the mouth and lungs surfaces. There are several mechanisms that animals use to maintain their bodies temperatures:

- Modifying body shape and size
- Having insulation
- Changing peripheral blood flow
- Modifying behaviour

Here we will review the first three factors, which affect animal morphology directly.

Animals with a large skin and small weight have a ratio area/volume large, that is they have large areas through which they can exchange heat with the surrounding air, and small internal volume where heat is being produced though metabolic processes. On the contrary, animals that have round shapes, and that are larger, have a ratio area/volume smaller. That means that they conserve heat better. Thus, one of the adaptations we can see in endo-thermic animals from colder climates is that they are larger and rounder than species living in warmer climates. This is general rule named Bergmann's rule. There are observations though for mammals that point out that a larger body size may not be the best solution at latitudes higher than 63°N, which could be related to the increased food quantity needed to maintain that body size.

Animals in colder climates have better insulation than animals in warmer climates. They have thicker skins, furs or plumage than their counterparts in temperate or tropical areas.

An example very well known to us is sheep and other mammals raised by their wool. Examples of wild animals are the arctic foxes and wolves. They may also accumulate more body fats, such as Arctic and Antarctic mammals and birds: penguins, seals, sea lions, whales and bears. Insulating materials under the skin may be fat, as in terrestrial mammals, or blubber as in aquatic mammals like whales, seals and walruses. Blubber acts as well as a buoyancy element and gives a streamlined shape to the animal.

Some animals change their area/volume ratio and their insulation layers throughout the year, so that in colder seasons they are rounder and show thicker layers of fat under the skin and thicker furs, than in summer. Arctic bears and penguins are examples of that.

Animals that live constantly in colder weather may also have shorter appendages, i.e shorter ears, in comparison to the same species from warmer locations. This is known as Allen's rule. They may also be covered by fur and have smaller thicker limbs. Foxes living in the Arctic have small ears and noses and shorter legs, in comparison with desert foxes that show longer and thinner legs and longer unfurred ears.

Peripheral blood flow helps animals to lose heat, when it is increased. Conversely, in cold weather, many animals reduce the blood circulation near the skin or to body appendages, such as ears, noses, limbs and tails. Arctic land mammals decrease their limbs temperatures nearly to freezing point in winter, nonetheless maintaining blood circulation active but avoiding heat loss with a mechanism called countercurrent heat exchange. This mechanism is similar to fridge and air conditioning heat exchangers in its conception. Countercurrent heat exchange also happens in beavers' tails.

Temperature may also determine animal shapes during a natural year. Weight shifts and changes in density and colour in plumage and fur are common in birds and mammals. Voles and shrews decrease their body mass during winter.

Food types and distribution

The food types and its availability have determined animal evolution strongly.

Birds' beaks have evolved to be able to eat more types of food. A classic study is that of Darwin in the Galapagos Islands. Thus, we can observe long beaks in insectivorous birds that gather insects from trees bark, and especially long beaks in wading birds that search for worms and other invertebrates in mud. Birds that show long beaks may also gather flowers nectar, like in the hummingbird. Hummingbirds (Fam. Trochilidae) have also other adaptations that allow them to reach flowers' nectar while flying, like high metabolism that supports high rate wing flapping. To maintain this high metabolism, hummingbirds need to access high energy easily digested foods like simple sugars, and that is what they ingest in nectar. Thus, they are highly specialized. Their high metabolic rate and food distribution restrict their habitat to tropical and warm temperate locations.

Mammals' teeth and jaws have evolved to be able to eat a wide range of foods too. Insectivorous and carnivorous have developed sharp pointed or blades-like teeth for piercing, shearing and tearing insects and other animals. In contrast, herbivorous have flat teeth and molars that allow them to crush, shred and grind fibrous materials.

More specialized adaptations are barbs in whales and other aquatic mammals that feed in plankton. Similarly, Flamingoes (Aves, O. Phoenicopteriformes) feed filtering plankton from mud and water, and for that they have developed hairy structures called lamellae which line the mandibles, and a large rough-surfaced tongue.

Bats can be classified in two main groups according to their ears size and complexity: Microchiropterans comprise 70% of them, and Macrochiropterans the remaining 30%. Bats are the most abundant mammals, together with rodents. Both groups feed on plants and insects, which are the most abundant foods on Earth. Microchiropteran bats have long complex ears and can also produce ultrasounds. Their ears can detect ultrasounds echoing back to them and thus they can locate insect preys. In contrast, Macrochiropterans are frugivorous (fruit eating) bats and they have simpler shorter ears and no ultrasound hearing abilities, because they don't need them. They are exploiting another niche.

Giraffes have elongated necks that allow them to reach leaves that are not available for grazers with shorter necks, like zebras and antelopes. Elephants have evolved another solution, their long proboscis that allows them to grasp plants parts that are otherwise unreachable.

Animal internal morphologies are also well matched to their feeding type and behaviour. Digestive systems are short and simple in insectivorous mammals, and very long and with several stomachs in herbivores.

When body shape is determined by other considerations, such as quick movements to capture prey or slender body to fit into crevices for the same reason, as in the weasels (Mustela spp) then other body features have to compensate for the energy loss in cold weather. One of those mechanisms is a higher metabolism. That means though that more food is needed, in comparison with animals of the same body mass but better insulated, in order to maintain body temperature stable.

Certain animals lower their body temperature, metabolic rates, respiration and heart rate when food is most scarce, as in winter in temperate and high latitudes, or in other periods of inactivity. They may lower their body temperatures as much as to 2 -5°C when becoming dormant or hibernating. Examples of hibernation are ground squirrels, marmots and hedgehogs. Several birds (swifts, hummingbirds, sunbirds), bats, rodents and bears depict periods of dormancy, where their metabolic rate and body temperature is lowered, although not as much as hibernating species.

TERMINOLOGY

- Vertebrates - Animals that have vertebrae (note: a vertebra or several vertebrae) (backbone) throughout their life.
- Chordates - Animals that have a notochord (A dorsal stiffening rod) at some stage of their life.
- Circadian - Circadian rhythms or cycles are periods lasting about 24 hours.
- Cloaca - An opening in the body that is used for both reproduction and excretory functions.
- Physiological -Those characteristics that relate to processes occurring within an animal, such as digestion, breathing, and metabolism. (are not breathing (respiration) and digestion functions of metabolism?)

SET TASK

Visit a zoo, wildlife park or even a pet shop. Observe the range of animals present. If your mobility is restricted, look at the web site of a zoo or similar organisation, and see what diversity of animals is to be seen on that web site.

Write down the scientific names (if available - otherwise common names/breeds) of at least ten animals that you find. Try to find representatives from at least four different classes.

Observe these animals (and/or anything written about them) for at least 5 minutes, taking note of what characteristics differentiate them from other animals.

Assignment 1

Question 1

List the names of the animals you saw in your set task; and indicate the class which each animal belongs to.

Question 2

Describe five different animals which you have observed (their external appearance and behaviours), applying points that you have learned from your set task. (Write one paragraph for each)

Question 3

Select 2 classes of vertebrates. Compare and describe their similarities and differences with one another. Write approximately half a page or compare their characteristics using a table.

Question 4

Define the following in your own words:

- Tetrapod
- Anatomy
- Biology
- Morphology
- Palaeontology

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