Bio Factsheet

Number 91

Taxonomy and Classification

By studying this Factsheet the student should gain:
- **an understanding of the need for classification of organisms and the methods involved in classification.**
- **the ability to use and design dichotomous keys.**

The principles and importance of taxonomy

Classification is the process of sorting a variety of items into manageable groups. The study of biological classification is called **taxonomy** or **systematics**. A universally accepted system of classification is important for scientists if they are to communicate about an organism, confident in the knowledge that they are talking about the same thing. It also enables rapid access to information about a particular type of organism. The aim of classification in biology is that it reflects the evolutionary relationships (phylogeny) between organisms. As evolutionary knowledge has increased over the years it has been necessary to modify and update the classification accordingly.

Methods of classifying organisms

One of the simplest ways of sorting things into groups is to look for differences. Does the organism show a particular feature? If it does put it one group, if it does not put into the other group. Sorting into 'haves' and 'have nots' is the basis for what is described as **artificial classification**. This is a useful approach to identifying organisms through the creation of dichotomous keys (see later).

A **natural classification** system uses similarities between organisms. These similarities can be of two types, homologous and analogous characteristics:

- **Homologous** characteristics have an underlying similarity of origin, structure and position irrespective of function. For example, the flipper of a dolphin, arm of a human, wing of a pigeon and wing of a bat are homologous because they are all modifications of the same structure, the vertebrate pentadactyl (5 fingered) limb.

- **Analogous** characteristics have similarity of function but they are not homologous. For example, the wings of insects and birds have the same function, flight, but their structures are very different. The wing of an insect is not developed from the basic pentadactyl limb.

A modern system of natural classification of organisms uses morphological, anatomical, biochemical, behavioural, chromosomal and genetic fingerprinting characteristics in an attempt to classify organisms according to their evolutionary (phylogenetic) relationships. Species are placed in the same group only on the basis of shared homologous features and shared evolutionary history.

The taxons of the classification

A **taxon** is a grouping of organisms which share some basic features. Every taxon has a status, for example, phylum, class, order and so on which it shares with other taxa, and an individual name, for example, the phylum Arthropoda. There are basically seven levels of taxon; from the largest to the smallest these are:

kingdom, phylum, class, order, family, genus and species.

Exam Hint:- *An easy way to remember this order is by using the saying: King Philip Came Over From Germany Swimming*

A **species** is defined as a group of organisms that shows many marked phenotypic similarities in terms of external morphology, internal anatomy, biochemistry and behaviour. In addition, individuals within a species have the potential to breed with others in the group, producing **viable (fertile) offspring** that are themselves capable of producing viable offspring. The species is usually taken to be the basic taxon (category) for a classification hierarchy.

Sometimes it is possible to recognise sufficient, subtle but consistent variation within members of a species to justify subdividing the group. Such groups are called sub-species.

An internationally accepted system exists to name organisms. **Linnaeus** introduced the **binomial nomenclature system** in the eighteenth century. Each species has two Latin names. The first names the **genus** and always has a capital initial letter. The second names the particular **species** within the genus. This name always has a lower-case initial letter.

Where it is obvious which genus is being referred to, the generic part of the name may be abbreviated to its initial letter (see the prokaryote in table 1 overleaf). If a sub-species is recognised then a third name may be used, once more starting with a small initial letter. It is accepted practice to use *italics* when a binomial is in *print* or underlined when hand-written.

Remember - *A group of related **species** forms a **genus** and related genera form a **family**. Several related families group to form **orders**, orders into **classes**, classes into **phyla** (singular phylum) and phyla into **kingdoms**.*

The classification of living organisms into five kingdoms

It is currently accepted that there are five kingdoms. These are called:

Prokaryotae; **Protoctista**; **Fungi**; **Plantae**; **Animalia**.

The taxonomic divisions are illustrated by the classification of five organisms in Table 1 overleaf. (You do not have to remember all of these names – check on your specification to determine which organisms are listed).

Exam Hint*: - Make sure that you have learnt the characteristic features of each kingdom. Questions about these are asked frequently.*

Table 1. Classification of some organisms in the five kingdoms

Taxon	***E.coli***	**Saw wrack**	**Yeast**	**Horse chestnut**	**Human**
Kingdom	Prokaryotae	Protoctista	Fungi	Plantae	Animalia
Phylum	Gracilicutes	Phaeophyta	Ascomycota	Angiospermophyta	Chordata
Class	Proteobacteria	Phyophyceae	Ascomycetes	Dicotyledoneae	Mammalia
Order	(gamma subdivision)	Fucales	Endomycetales	Sapindales	Primates
Family	Enterobacteriacae	Fucaceae	Endomycetaceae	Hippocastanaceae	Homidae
Genus	*Escherichia*	*Fucus*	*Saccharomyces*	*Aesculus*	*Homo*
Species	*coli*	*serratus*	*cerevisiae*	*hippocastanum*	*sapiens*

The distinguishing characteristics of each kingdom.
Terms marked with * are explained in the glossary.

Prokaryotae*
- Cells have no nucleus.
- Cells have no membrane-bound organelles.
- Cells lack organelles based on a 9 + 2 arrangement of microtubules.*
- Cells have circular DNA.

Examples: all bacteria, including blue-green bacteria.

Protoctista
- Organisms found in this kingdom are eukaryotes* that have characteristics that exclude them from any of the other kingdoms. If an organism is eukaryotic, but is not a member of the Fungi, Plantae or Animalia then it is a member of the Protoctista.

Examples: all protozoa such as *Amoeba*, all nucleated algae and slime moulds.

Fungi
- Eukaryotes.
- Possess outer walls made from polysaccharides. The walls contain chitin but no cellulose.
- Heterotrophic nutrition, either saprophytic or parasitic. Not photosynthetic.
- Store carbohydrate as glycogen.
- Vegetative part of most fungi involves coenocytic* hyphae* that form a mycelium.*
- Reproduce by spore production. The spores have no flagella.

Examples: *Mucor* (pin mould), *Penicillium* and *Agaricus* (mushroom)

Plantae
- Multicellular eukaryotes.
- Cells have cellulose walls.
- Majority possess chloroplasts and are photosynthetic autotrophs.

Examples: mosses, ferns and flowering plants.

Animalia
- Multicellular eukaryotes.
- Heterotrophic nutrition.
- Simpler animals are diploblastic* and show radial symmetry*.
- More complex animals are triploblastic* and show bilateral symmetry*.
- Some triploblastic animals have a coelom*.

Examples: jellyfish, tape worms, earthworms, insects, fish, birds, mammals.

Glossary of terms

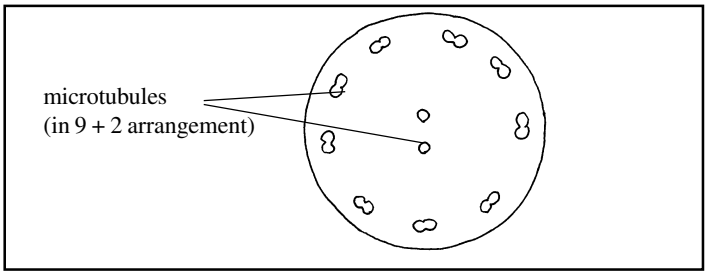
Prokaryotic: This refers to minute cells which lack a membrane-bound nucleus, lack membrane-bound organelles, and lack any organelles based on a 9 + 2 arrangement of microtubules. They have a single circular chromosome (DNA) and may also contain small ringlets of DNA known as plasmids.

Eukaryotic: This refers to cells which have a membrane-bound nucleus with chromosomes, membrane-bound organelles, such as mitochondria, and organelles with a 9 + 2 arrangement of microtubules, such as centrioles.

Microtubules: These are long, hollow, cylindrical structures made of a protein called tubulin. They run in all directions through the cytoplasm, making up the cytoskeleton.

They also are arranged into a 9 + 2 arrangement of parallel running tubules, making up the structure of centrioles, cilia and flagella. A transverse section through a flagellum is shown in Fig 1.

Fig 1. Electron micrograph of a flagellum in transverse section.



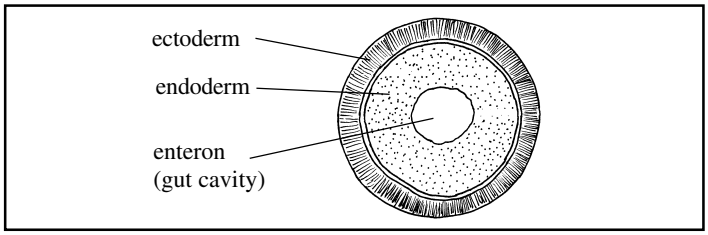
Hyphae: These are the white thread-like structures that form a network making up the body of a fungus.

Mycelium: This is the whole body of the fungus, made up of hyphae.

Coenocytic: This refers to a structure consisting of a mass of cytoplasm and nuclei but not divided into cells. ('Syncytial' is often used as an alternative word for coenocytic).

Diploblastic: This refers to an animal that has two basic germ layers in its body, the ectoderm and the endoderm. Germ layers consist of cells that can differentiate into particular tissues. For instance, ectoderm cells can differentiate into nervous tissue, endoderm cells differentiate into the lining cells of the digestive tract. Fig 2 shows a transverse section through a diploblastic animal (sea anemone).

Fig 2. Transverse section through a diploblastic animal



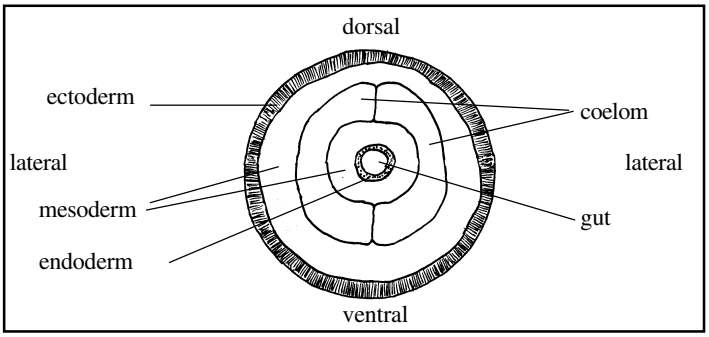
Radial symmetry: Refers to an animal (or flower) that can be cut in any vertical plane to produce two mirror image halves. This has the advantage that stimuli can be received equally well from all directions and responses made in all directions. The sea anemone in Fig 2 illustrates radial symmetry.

Triploblastic: This refers to an animal that has three basic germ layers in the body, the ectoderm, mesoderm and endoderm. The mesoderm can differentiate into blood, muscle tissues and skeletal tissues. Fig 3 shows a section through a triploblastic animal, of earthworm type.

Bilateral symmetry: This refers to an animal (or flower) that can only be cut down one vertical axis to produce two mirror image halves. This symmetry allows development of specialisation into anterior, posterior, dorsal, ventral and lateral parts of the body (Fig 3).

Coelom: This is a body cavity which develops inside the mesoderm. It gives room to enable the organs to move. A coelom can be seen in Fig 3.

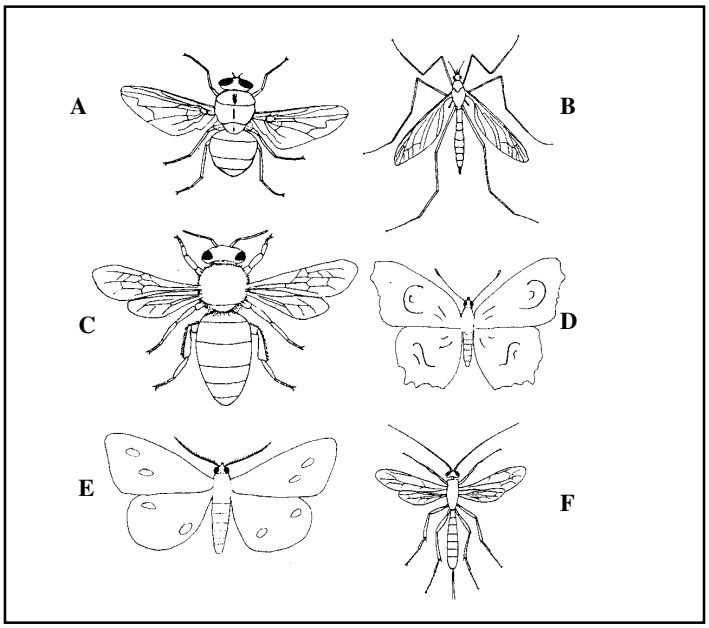
Fig 3. Transverse section through a triploblastic coelomate animal



Dichotomous keys

Keys are used for categorising and identifying organisms. In a dichotomous key, the defined group of organisms is divided into <u>two</u> subgroups on the basis of one easily observed characteristic. The procedure is repeated with each of the subgroups, using a different characteristic in each case, until all the types of organism have been separated into their own subgroup. Each stage of the key must have no more than two alternatives. The key below illustrates how the six insects shown in Fig 4 may be separated.

Fig 4. Drawings illustrating features of six types of insect.



There are numerous ways of doing the key. The following is an example only.

1.	insect has 1 pair of wings	go to 3
2.	insect has 2 pairs of wings	go to 5
3.	abdomen has 4 segments	Species A
4.	abdomen has 7 segments	Species B
5.	antennae clubbed	Species D
6.	antennae not clubbed	go to 7
7.	wings small in area relative to body	go to 9
8.	wings much larger than body	Species E
9.	abdomen/body is thin	Species F
10	abdomen/body is thick	Species C

Exam Hint: *– A common error made by students is to have more than two alternatives in one or more steps of their key. Only truly dichotomous keys are acceptable to the examiners. Only a single characteristic should be used at each step.*

Practice Questions

1. The table below refers to four of the five taxonomic kingdoms.

Kingdom	Features	Examples
Fungi		
Protoctista		
Plantae		
Animalia		

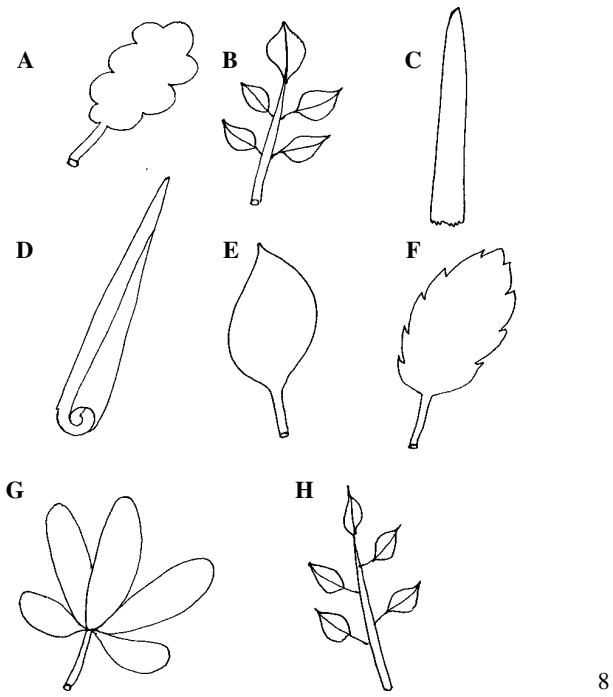
(a) Select features from the following list and write them in the appropriate features box on the table. Some features may be used more than once, or may not be relevant. You should write <u>three</u> features in each box.

has eukaryotic cells, has prokaryotic cells, has cellulosic cell walls, has chitinous cell walls, autotrophic, heterotrophic, consists of hyphae, often unicellular or groups of similar cells, always multicellular, have nervous coordination. 4

(b) Select organisms from the following list and complete the table by placing them in the appropriate examples box. Give <u>two</u> examples in each box.

Green algae, *Penicillium*, Ferns, Mushrooms, Bacteria, *Amoeba*, Malarial parasite, Dicotyledons, *Mucor*, Frog, Moss, Viruses, Tapeworm, Spider. 4

2. Devise a dichotomous key which would distinguish the following leaves. Only use features that are visible in the drawings.



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3. The full classification of the tiger is as follows:

Kingdom:	**Animalia**
Phylum:	**Chordata**
Class:	**Mammalia**
Order:	**Carnivora**
Family:	**Felidae**
Genus:	***Panthera***
Species:	***P. tigris***

(a) (i) Suggest two features of tigers that place them into the animal kingdom. 2

(ii) Suggest two features of tigers that place them in the class Mammalia. 2

(iii) Suggest one feature of a tiger that places it in the order Carnivora. 1

(b) (i) The family Felidae is the cat family. Suggest another family of animals which is classified in the Carnivora. 1

(ii) The genus Panthera includes the tigers and panthers. Name another genus of the family Felidae. 1

(c) The classification of a group of organisms is supposed to represent their phylogeny. What does this mean? 2

Answers

1.

Kingdom	Features	Examples
Fungi	eukaryotic, heterotrophic, consists of hyphae chitinous cell walls;	mushrooms *Penicillium* *Mucor*;
Protoctista	eukaryotic, heterotrophic (some), autotrophic (some), unicellular or groups of similar cells;	*Amoeba* green algae malarial parasite;
Plantae	eukaryotic, autotrophic, multicellular, cellulosic cell walls;	moss ferns dicotyledons;
Animalia	eukaryotic, heterotrophic, multicellular, have nervous coordination;	tape worm spider frog;

(a) 1 mark per box with three correct features and no incorrect features. 4
(b) 1 mark per box with two correct examples and no incorrect examples. 4

2.

1.	leaves simple/not divided	go to 3
2.	leaves compound/divided into leaflets	go to 11
3.	leaves spear/lance-shaped/isobilateral.	go to 5
4.	leaves with broad lamina/dorsi-ventral	go to 7
5.	leaf rolled/curled	leaf D
6.	leaf flat	leaf C
7.	leaf with smooth margin	leaf E
8.	leaf with shaped margin	go to 9
9.	margin lobed	leaf A
10.	margin serrated	leaf F
11.	leaflets all arise from tip of petiole	leaf G
12.	leaflets arise along side of petiole	go to 13
13.	leaflets arise opposite to each other	leaf B
14.	leaflets arise alternately/not opposite	leaf H

Allow 1 mark for each leaf correctly separated. 8
Allow 1 mark for a correct dichotomous key. 1
Accept alternative keys if correct and clear.

3. (a) (i) has nervous coordination;
is non-photosynthetic/heterotrophic; 2

(ii) has skin with hair in follicles;
viviparous/has gestation periods/young born from uterus;
has mammary glands/young fed on milk; 2

(iii) only eats meat/ref. to dentition; 1

(b) (i) dog family/Canidae/bear family/Ursidae/any other correct example; 1

(ii) *Leo*/lion genus/*Felis*/domestic cat genus/any other correct example; 1

(c) the classification represents the evolutionary history/evolutionary affinities of organisms;
the closer two types of organisms are in the classification, the closer their evolutionary relationship; 2

Acknowledgements:
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