Taxonomy & Systematics

... the backbone of biodiversity knowledge

South African Biosystematics Initiative

Acknowledgements

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The following web pages were useful resources:
Convention of Biological Diversity
(http://www.cbd.int/gti/taxonomy.shtml).

The caminacules exercise is a modified lab, taken from Prof RP Gendron, Indiana University of Pennsylvania (nsm1.nsm.iup.edu/rgendron/Evol_lab.doc) and used with his permission.

Case studies are taken from BioNET-INTERNATIONAL®
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/caseStudies/default.jsp) and Systematics Agenda 2000.

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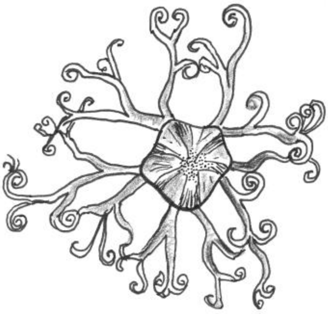


Foreword

Taxonomy / systematics is an exciting, but often neglected field in biology. It is the science of discovering, classifying and naming new species. Classifying and naming plants and animals around us is as old as humankind. It was probably not done very scientifically, but even the stone-age people needed names, for example to communicate which plants are poisonous or edible or have healing powers.

Our knowledge of plants and animals has grown immensely since then, but classifying and naming species of living organisms correctly is still important for communication in a world wide community nowadays. More importantly, taxonomy and systematics is the foundation for most other natural science disciplines.

The world and especially biodiversity-rich countries like South Africa need young people to discover the dynamic world of taxonomy and systematics. This is no longer a profession for crazy old scientists who stare down microscopes all day. Taxonomy and systematics research uses modern technology and involves exploration of different parts of the world, the discovery of new species, some of which may be about to become extinct, or which may be important for human health or agriculture. Without knowing our species, we are not able to identify invasive alien species, crop pests, carriers of disease or threatened species, or know which species can be used for the benefit of human welfare.

The need for names for so many purposes means that taxonomists do important work. Globally there are not enough taxonomists, and specialists in this field are decreasing as the existing scientists get older and retire.

This booklet aims to fill taxonomy / systematics with some life and colour. We hope to give some help with our hands-on exercises and that they may be a useful resource to engage learners with the fascination and importance of this field.

Friederike Voigt & Michelle Hamer

What is Taxonomy?

Taxonomy is a Greek word consisting of two parts:

Taxis = arrange / put in order
Nomos = law

Basically, taxonomy is the law of arranging or dividing “things” and it is used in a wide variety of different contexts. In this booklet we focus on taxonomy in a biological context.

Taxonomy is the science of

- classifying
- describing
- naming

species or groups, according to certain criteria.

The criteria can be based on **morphology** (e.g. all animals with backbones are vertebrates), on **behaviour** (e.g. all animals that give birth to live young are mammals), or on **biochemical** or **genetic** (eg. DNA information).

1. Classifying biodiversity

Classification means organizing all living organisms into groups according to certain characteristics or traits.

In biological sciences, animals, plants, fungi, and microorganisms of the world are classified into the following groups:

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

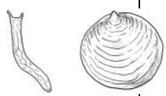
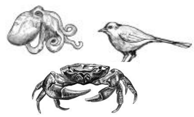
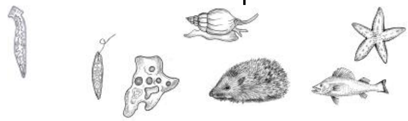
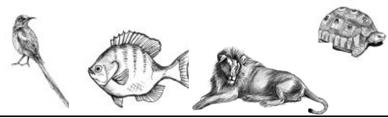
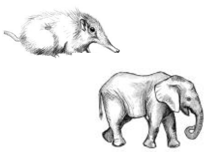
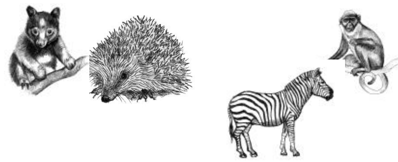
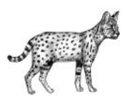
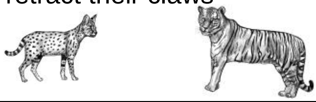
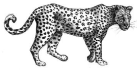
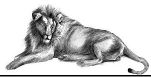
The highest level is the “Kingdom” – this is the biggest group, which includes the largest number of different types of organisms in it, and these organisms are least similar, usually only sharing one or two characteristics or features. For example, all plants belong to the kingdom Plantae, from the biggest trees to the grasses. Plants all share the characteristic of having chloroplasts and being able to make their own food.

The lowest level is the “species” - this is the smallest group, including only those organisms that look the same (share many characteristics or features), and that can breed with each other in nature to produce fertile offspring. For example, all lions belong to the same species. They share some characteristics with other cats, but they cannot mate with leopards or tigers to produce young that themselves are able to breed.

Table 1. Example of the classification of some living organisms

Kingdom	Animalia			Plantae
Phylum	Chordata		Arthropoda	Angiospermaphyta
Class	Mammalia		Insecta	Monocotyledoneae
Order	Primate	Carnivora	Hymenoptera	Liliales
Family	Hominidae	Felidae	Apidae	Liliaceae
Genus	*Homo*	*Panthera*	*Apis*	*Aloe*
Species	*H. sapiens*	*P. leo*	*A. mellifera*	*A. ferox*
Common name	Human 	Lion 	Honey bee 	Ferox aloe 

Table 2: Example of classifying the lion

Group Level	Name	Some Criteria
Kingdom 	Animalia 	cells have no chloroplasts 
Phylum	Chordata 	have backbones 
Class	Mammalia 	breastfeed their young 
Order	Carnivora 	meat eaters 
Family	Felidae 	can retract their claws 
Genus	Panthera 	can roar 
Species	*P. leo*	social cats 

Hands-on Taxonomy I

An example of how a classification system works:

A school is organizing their learners according to different characteristics:

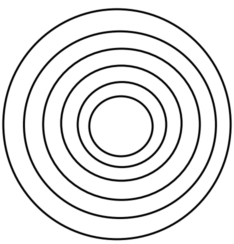
- Kingdom = all learners at the school
- Phylum = all learners in Grade 11
- Class = all Grade 11 learners that live in Durban
- Order = all Grade 11 learners that live in Durban and have a brother or a sister at the school
- Family = all Grade 11 learners that live in Durban, have a brother or a sister at the same school, and are 16 years old
- Genus = all Grade 11 learners that live in Durban, have a brother or a sister at the same school, are 16 years old, and are studying biology
- Species = all Grade 11 learners that live in Durban, have a brother or a sister at the same school, are 16 years old, and are studying biology and maths

What happens to the number of characteristics used to classify the learners as you move from Kingdom to Species?

What happens to the number of learners in each group as you move from Kingdom to Species?

Could you illustrate these groupings of learners in the form of a diagram?

A clue ...



The trend is the same when we classify living organisms.

2. Describing species

There are approximately 1.78 million species that we know of today (number given on the homepage of the Convention of Biological Diversity) but scientists estimate that there are still between 5 and 30 million species that have not yet been discovered and described. Each of these 1.78 million species was described very carefully and in great detail by a taxonomist when it was first discovered.

How does a scientist know that he or she has discovered a new species?

Taxonomists are often given samples of plants or animals by other scientists, or members of the public, or they go on expeditions to explore important areas and collect many plants or animals themselves.

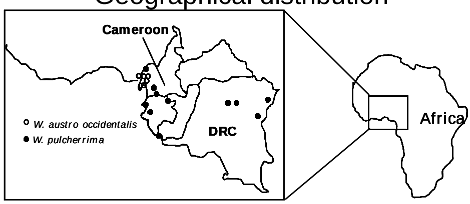
In the laboratory, the scientist will first have to decide what family and then which genus the specimens belong to, and then the specimen will have to be checked against all known species in that genus. The scientist will use scientific journals and books on the particular group of organisms to do this. If the specimen does not match the characteristics of any known species, it is probably a new species.

Once the scientist is sure, the new species will be described, and this description will be published in a scientific journal.
The description of a new species usually includes external and internal features, the place it was found (e.g. Kruger National Park, South Africa), the habitat/ecosystem where it was found (e.g. savannah), when it was collected and who collected it. In modern descriptions of new species, differences in the **DNA** are also sometimes given, especially when the species looks similar to others. The DNA make-up of a species will separate it from other similar species (see page 10).

New species based on DNA

Douglas Stone, lecturer for Molecular Systematics at the University of KwaZulu Natal is sure, *Warneckea austro-occidentalis,* is a new species. *Warneckea austro-occidentals* is a tree species from the western region of Cameroon.
Based on the morphology, it was assumed it was a variation of *Wanreckea pulcherrima* which occurs in the same region.

Geographical distribution



It was noticed that there are some slight differences such as differences at the leave-base (see drawing). But was this variation within a species or a new species?

Morphological differences

Leaf of *W. austro-occidentalis*

Leaf of *W. pulcherrima*

Prof Stone sequenced two different DNA regions and found enough differences between them to declare it a new species.

Small section of the nuclear ribosomal DNA (ETS region) sequence

W. pulcherrima TTGCTTCGACTTGTCTT-GC**T**-GTT
W. austro-occidentals TTGCTTCGACTTGTCTT-GC**C** -GTT

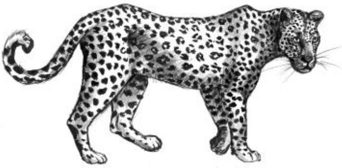
non-variable region variable region

The sequence was 669 characters long and differed at 7 different places.

What is a species?

Taxonomists work with species. A species includes individuals of plants or animals that look similar to one another, and that can breed with one another to produce fertile offspring.
Some species are easy to distinguish, e.g.:

Lion
Panthera leo



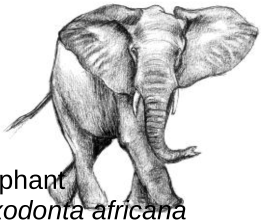
Leopard
Panthera pardus

Some species look very similar but are from different genera or even different families:

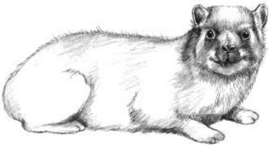
Square lipped or white rhino
Ceratotherium simum

Hook-lipped or black rhino
Diceros bicornis

and some species look very different, but are still closely related:



Elephant
Loxodonta africana



Rock dassie
Procavia capensis

? Find out Why do you think scientists believe **?**

Are there still new species to be found?

Yes, yes, yes – every year thousands of new species are discovered and described by taxonomists, ranging from new bacteria and viruses, to new species of birds and even mammals. These new species are discovered by scientists who embark on expeditions to poorly studied areas of the world to sample plants and animals, or by restudying species already described, but using new techniques.

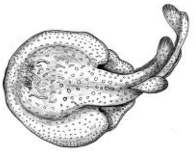
In 2005 an exploration of the Foja Mountains in the hard-to-reach parts of New Guinea, Indonesia, found new mammals such as golden-mantled tree kangaroos, new birds such as the honeyeater, 20 new frogs and reptiles and many new invertebrate species.

Even in Europe where intensive research has covered the continent for hundreds of years, a new mouse species (*Mus cypris*) was discovered in 2006 on the island of Cypris.

In Africa, the discovery of a giant elephant shrew (*Rhynchocyon udzungwensis*) in Tanzania made big waves in 2007. Scientists believe that these mouse-like mammals are more closely related to elephants than to shrews.

One of the new species recently discovered in South Africa is *Clivia mirabilis.* It is a very unusual new species as it was found in the Northern Cape, in a semi-arid climate, far away from other *Clivia* species which are all found in shady habitats in summer rainfall areas. The new species was described in 2002 by Dr. Rourke from the Kirstenbosch Research Centre. “This name, which means ‘astonishing’ or ‘miraculous’, was chosen to reflect our amazement at the apparently endless surprises nature still has in store for us in this part of South Africa," said Dr Rourke.

Another recent discovery off the east coast of South Africa is *Electrolux addisoni*, an electric ray whose vigorous sucking power gave reason to name the new genus after a vacuum cleaner; the species name (*addisoni*) reflects the name of the person who collected it.



Each year the International Institute for Species Exploration (IISE) at Arizona State University announces a list of the Top 10 New Species for the preceding calendar year. (http://www.getwonder.com/2008/06/iise-the-top-10-new-species-of-2007/)

3. Naming species

The different species on the previous pages have Latin names. After a species is described and classified, taxonomists give it a unique, Latin or Greek name. Each one of the 1.78 million species has its own name that is not shared with any other species.

The person who started the system of naming species was Carl Linnaeus in 1758 (see 'Faces of a changing Profession' on page 26). People have named animals and plants and classified them since Aristotle's time in ancient Greece. But Linnaeus simplified the system in giving each species a two-parted name (binomial): a genus name and a species name (e.g. *Panthera leo* for the lion).

The name of a species very often carries additional information, like the name of the person who found it, the location where it occurs, or some of the characteristic features of it.

Linnaeus borealis is a little Swedish forest plant. The genus name *Linnaeus* honours Carl Linnaeus because it was his favourite plant.
The species names *borealis* refers to its distribution: borealis = from the northern parts (in Europe).

L. borealis

Diospyros rotundifolia is a tree from southern Africa. The genus name *Diospyros* is derived from the Greek words *dios* = God and *pyros* = grain/wheat, so *Diospyros* means “food for the Gods”, which refers to the edible fruits in some species of *Diospyros*.

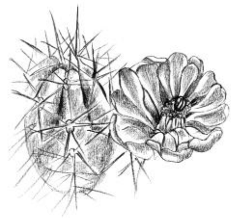
D. rotundifolia

The species name *rotundifolia* refers to the round leaves (*rotundi* = round, *folia* = leaves)

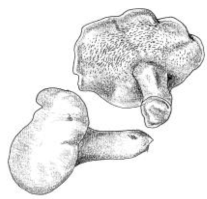
Many species from South Africa are named “capensis”, which means they were first collected from the Cape region.

For example:
Impatiens capensis - a little flowering plant
Parabuthus capensis - a scorpion
Procavia capensis - the rock dassie

Both the genus and the species name make up the full name for a species. There are many trees with round leaves (*rotundifolia*) or plants that occur in the northern parts of Europe (the borealis belt), but there is only one *Diospyros rotundifolia* and only one *Linnaeus borealis*.



Erinaceus europae
Echinocerus sp.



Hydnum repandum

Scientific names are in Latin or Greek and are valid all over the world. As they are “foreign” words, they are written in italics. Each language has common names for some animals and plants, but they can be confusing. For example, the common English name hedgehog is used for the little insect-eating mammal (*Erinaceus europaeus*), a cactus of the genus *Echinocerus* and an orange fungus (*Hydnum repandum*). It would be very confusing if a scientist wrote about his research on a hedgehog, meaning the spiny animal, but people reading about the research thought he was talking about a fungus.

Think about all the names in different languages that we have for lion in South Africa. The only way we can be sure that all scientists, no matter what language they speak, are referring to the same species, is by using the scientific genus and species name.

Hands-on Taxonomy II

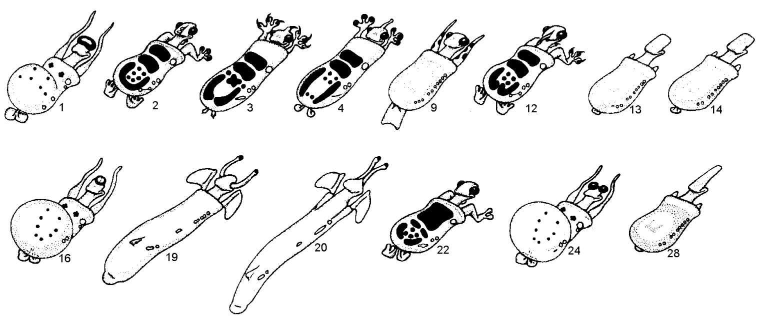
Exercise 1:
To give some life to the abstract concept of taxonomy, try this exercise:

Hand out the following objects:

- different office tools (coloured paperclips, ruler, staples, glue, puncher) or
- pictures from a magazine of different cars (colour, size, brands) or
- a pack of ordinary playing cards

The learners can group the objects e.g. according to shape, colour, weight, size, material into species, genera, families, orders, classes and kingdoms.

Exercise 2:
Another possible exercise are the “Caminacules”.



These are artificial organisms invented by Joseph Camin, and they can be used as a fun exercise to demonstrate several concepts. Each picture above represents a species. The number for each species can be used as the species name. The learners can identify which characters they will use to classify the species, and then group them, using the hierarchal classification (as in Table 1 on page 6). There is no correct answer, but the answer must be logical (e.g. numbers 19 and 20 are in the same genus because they are more like each other than any of the other species).

Hands-on identification keys

Identification keys are developed and used by taxonomists and other scientists to identify species.

The important characters of a group that are used to identify and distinguish it from other groups can be used to develop an identification key. Keys are basically questions about an object, leading to the name of the species or group. You can make an identification key with your class, using your example with the office tools, or any of the other objects.

Example 1: How to key out a paperclip:

1
a. The object is heavier than 20g ……………………….go to 2
b. The object is lighter than 20g..…………………..........…go to 4

2
a. It is less than twice as long as it is broad (makes holes in paper)……………………………………………paper punch
b. It is more than twice as long as it is broad……..…….go to 3
3
a. It is made out of two metal parts, linked at a join
......…………………………………………………………stapler
b. It is made out of plastic with a sticky filling
………...glue stick

4
a. It is more than 5 times as long as it is broad..……….go to 5
b. It is less than 5 times as long as it is broad and made of metal? ………………………………………........go to 6

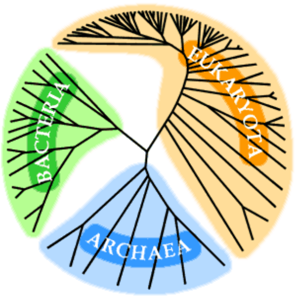
5
a. The shape is round in cross section………………………..pen
b. The shape is flat in cross section………………………….ruler

6
a. It is a long, thin, bent wire ....paperclip
b. It is short, straight and with a sharp point at one end, with a broad, flat, round part at the other end ....drawing pins

You can also develop a key for the Caminacules.

What is Systematics?

Systematics is the science of investigating the evolutionary history of species and their relatedness based on them sharing a common ancestor, e.g. species within a genus are more closely related to each other than species from a different genus. All the species in one genus share a common ancestor.



Systematists produce “trees” with branches called phylogenies that show the relationships between species or other levels of classification. The phylogeny shown in the picture tells us that the three major groups of organisms on earth all go back to one common ancestor, because all life shares some basic characteristics (image taken from: www.ucmp.berkeley.edu/education/explorations/tours/Trex/index.html)

If we look at the lion as a simple example, the lion (*Panthera leo*) is more closely related to the leopard (*Panthera pardus*) than to the cheetah (*Acinonyx jubatus*). But why did systematists group leopards and lions in the same genus, if leopards and cheetahs both have spots and lions don’t?

Answering this type of question is the work of systematists. Systematists would look not only at the spots, but also at a whole lot of other characteristics. They could also investigate the DNA structure. By putting all the characteristics together, systematists are able to get a good idea of which species are most closely related and the pattern of relatedness through a family. Systematists can also work with fossils of extinct species to see what characteristics more ancient members of a family had and how these have changed.

Modern systematists use complex technology to analyse DNA, and to analyse very large sets of data or information on the characters found in different species. Some analyses can take a powerful computer several days to give an answer.

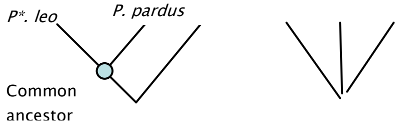
An example for a phylogeny is printed on the cover of this booklet.

Hands-on Systematics

How to make a tree:

You can make your own tree based on your classification example: e.g. all cars from Ford are more closely related than cars from Isuzu or Landrover. Four-wheel drive vehicles made by different companies have some characters in common, but that is because they are built to serve the same purpose (like having similar adaptations to the environment in animals that are not related, e.g. the spots of leopard and cheetah).

Example 1:
Another exercise that will show how the construction of systematic trees shows relatedness would be to get learners to develop their own family tree going back as far as possible, or for them to do a family tree of a well known person such as Nelson Mandela, or some other person in history. On this diagram they should be able to identify common ancestors, most closely related, and most distantly or least related people.
Pay special attention to how you draw the lines of your tree:



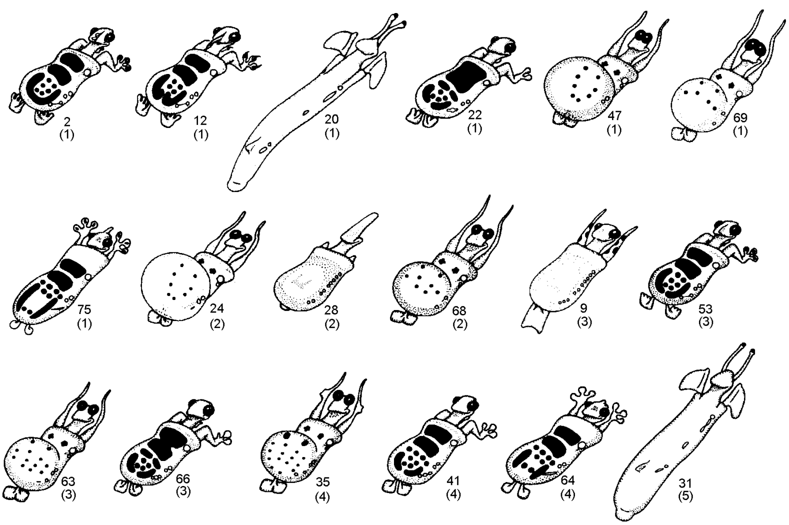
* once the genus is named, it is common to shorten the genus name to the first letter, thus *Panthera leo* becomes *P. leo*, in the ongoing text

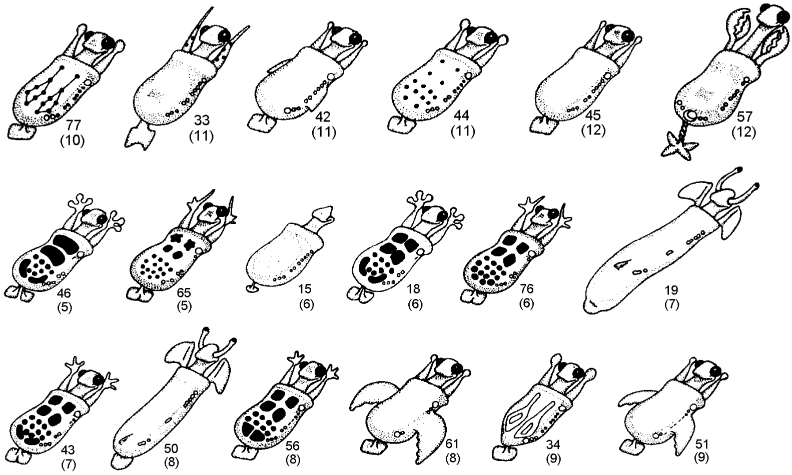
Example 2:

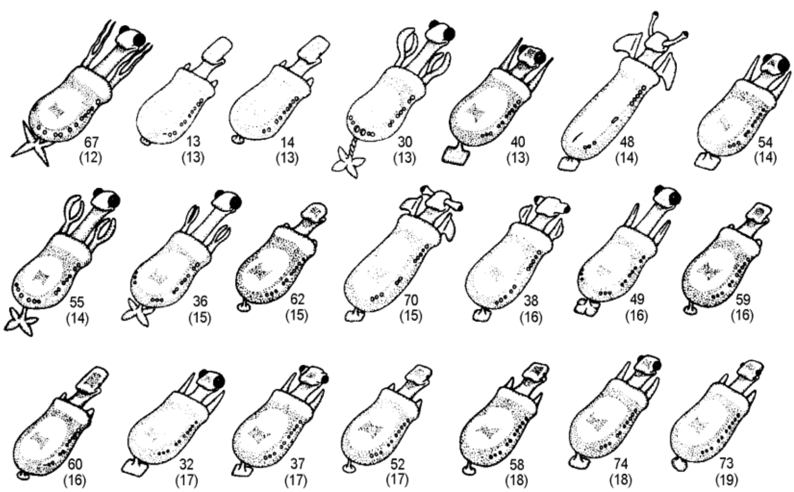
You can use the fossils of the Caminacules below to reconstruct a phylogeny. The easiest way to do this is to take a big piece of paper (A3) and draw 20 lines at regular distances. Cut the Caminacules out and lay the oldest fossil at the base of the paper. Going through time, you can see how they evolved, how they become more diverse and some went extinct, whereas others did not change over time. This exercise links nicely with evolution and lends itself to discuss topics, such as radiation and living fossils. There is only one logical phylogenetic tree possible.

Fossil Caminacules:

NOTE: the number in brackets indicates their age in millions of years

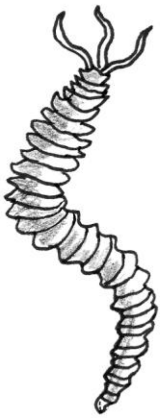






SOLUTION at the end of the booklet on page 32

Why taxonomy and systematics matters



What difference does it make to people if we know the names of all the different species or not and why do we need classifications?

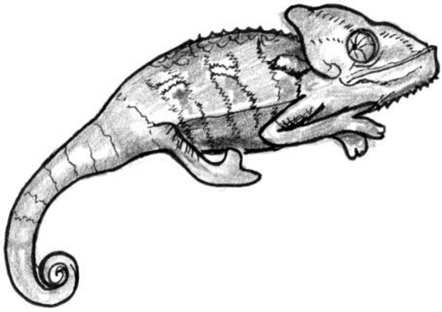
- We can't protect or use species if we don't even know they exist – so discovering them is important.
- We need to have a formal, scientific name for each species, with the characteristics of each species so that we can communicate about each species clearly, without confusion.
- We also need to organise information about species into a system – a classification, and the classification must be scientific and understood by everyone. Classifications must be based on evolution, relatedness, and ancestry, so systematics is important for organising all the information about species. If we didn't have a system for organising information, it would take a long time to find the information we are looking for. For example, in a library, all the books dealing with mammals will be in the same section. In a text book, the information about plants will be in one section. If you look for information on the internet, you can put the name of a species or genus or family into 'Google' to find information. What would happen if we had no classification systems or names for anything?

We said that we need to discover and name species so that we can protect species. But why is this important? Does it really matter if a few thousand species become extinct if we have got millions more?

Besides a moral and ethical responsibility to leave a rich and varied biodiversity on earth for future generations, each society relies tremendously on nature and on the ecological services nature provides. Ecosystems, made up of many different species, provide clean water, fresh air, and fertile soils. Some species remove waste like dung, while others pollinate flowers, and control pests in houses and on crops. Species interact, forming complex ecosystems that have evolved over millions of years with their environment. Nobody knows how many species can be lost before ecosystems collapse and are no longer able to provide services to us.

In addition, species have enormous potential to provide us with new medicines, foods, clothing materials, and even fuels. If we do not study and protect species, they may become extinct because of habitat destruction through building of houses and factories, roads, agriculture, or pollution.

Without identifying, organising and classifying our biodiversity, we cannot use it or protect it. This means that **taxonomy and systematics are the backbone of all biological and related sciences.**



Cases from around the world

The following cases are some examples to demonstrate the importance systematics plays in our daily lives and its economic contribution.

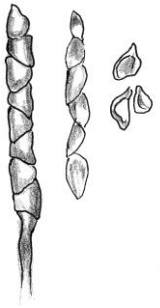
The Malagasy periwinkle

Catharanthus roseus

The Malagasy periwinkle is an endemic flower from Madagascar. It is called a blessing for humanity because it contains chemicals that reduce white blood cell/bone marrow activity.

The drug developed, based on the chemical extract from this species, has helped to increase the survival of children with leukaemia.

Perennial maize



Zea diploperennis

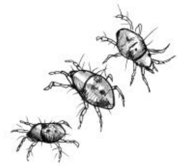
In the 1970s a Mexican botanist, was exploring the cloud forest of Jalico. He discovered a wild form of corn which could be hybridized with commercial corn. It made the corn live longer than one season (perennial) and increased its resistance to viruses. Can you imagine the huge economic impact of that discovery?

Rooibos tea

Aspalathus linearis

Rooibos tea was used by the Khoisan people of the Western Cape for a long time, before it became a popular health tea drink all over the world. It was first reported by the botanist Carl Thunberg in 1772. South Africa is the only country growing rooibos tea and it is restricted to the Cedarberg area in the Western Cape.

Spider mites on African tomatoes



T. urticae

Spider mites are a common plant pest. The tiny invertebrates can cause up to 90% of crop loss in tomatoes, which is a serious problem especially in small-scale farming in southern Africa. Assuming the pest was a species called *Tetranychus urticae* a US$ 800,000 program was initiated to develop an integrated pest management strategy. A closer look at the actual pest species by the South African Agricultural Plant Research Council – Plant Protection Research Institute (ARC-PPRI) held a big surprise. The actual pest was *T. evansi.* A whole new strategy needed to be developed as *T. evansi* is an invasive alien species, which is not attacked by indigenous predators. A predatory mite was introduced as a biocontrol agent. Without the taxonomists of the ARC-PPRI, huge amounts of money and time would have been spent on an unsuccessful project (M. Knapp & F. Haas, see web address on page 2).

Symbiotic fungus warns of invasive wasp and forestry loss

Sirex noctilio

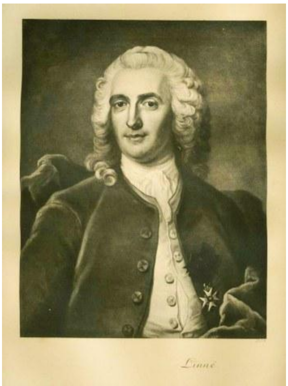
In 1994 a pine tree was felled in a plantation outside Cape Town and the wood was rejected. Parts of a dead bluish wasp and exit holes on the stem were found under the bark. These were signs of the wood wasp *Sirex noctilio* which attacks stressed conifer trees and can kill up to 70 % of trees in plantations worldwide.

To confirm that this pest was present, the wood was cultured and tested for a symbiotic fungus (*Amylostereum areolatum*) by the mycology division of the ARC-PPRI in Pretoria. The fungus was found in the wood. Female wood wasps inject the fungus, just before laying their eggs. Thus, the presence of the fungus confirmed the presence of the wasp. Due to the early warning, a successful biocontrol agent (a parasitic nematode) could be established and this minimalised the economic loss for South African forestry. (GD Tribe see web address on page 2)

Faces of a changing profession

Taxonomy is an ancient profession. As early as 350BC Aristotle was describing and classifying animals and plants. People have always tried to classify the world around them according to their knowledge. As travel increased and people began to explore more continents, the world seemed to expand, and new plants and animals were discovered. This resulted in scientists from museums leading expeditions all over the world, bringing back animals and plants that few people had seen before. Times have changed and new methods are used, but finding new species and understanding their evolutionary histories is still the core motivation for taxonomists and systematists today.

Carl Linnaeus



Carl Linnaeus was born in 1707 in Sweden. He studied medicine and had a chair of medicine at the Uppsala University. He was a royal physician and was even ennobled by the King of Sweden in 1761 and became Carl von Linné. However his famous legacy was to classify and name plants and animals consistently with the binomial Latin name, which is still the international standard used today. His famous book “Systema Natura” (1735-70) entailed the classification of 15,000 plants and his book “Species Plantarum” (1753) included a detailed description and identification of all plants known at the time. The classification system today is based on his classification system. Linné classified animals and plants mainly based on their morphological features.

This is still an important approach used by taxonomists. However, as methods of studying genes and DNA become easier and more readily available, genetic differences and similarities on certain gene sequences have provided additional characteristics for separating and identifying species and understanding relationships.

Famous taxonomists in South Africa

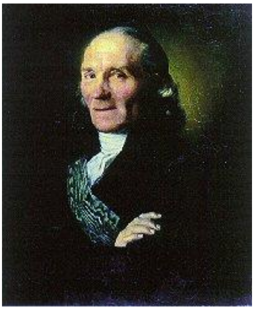
Austin Roberts

Austin Roberts was born in 1883, the son of a church minister in Pretoria. He is one of South Africa's most famous zoologists. His Book "Birds of South Africa" is a standard book to identify birds and is now in its 7th edition. He worked at the Transvaal Museum from 1910 – 1946 and in his lifetime he collected over 30,000 birds and 13,000 mammals from South Africa.

He died in a car accident in the Transkei in 1948. Pretoria named a bird sanctuary after him: the Austin Roberts Bird Sanctuary.

Carl Peter Thunberg

Carl Peter Thunberg was born in 1743 in Joenkoeping, Sweden and became a naturalist and doctor. In 1771 he was offered the opportunity to go to Japan to collect plants for the Botanical



Garden in Amsterdam. As only Dutch protestants were allowed to visit Japan at the time, he spent three years in the Cape Region to learn the language. During that time, he did several long and dangerous voyages, collecting large numbers of plants in the Cape Colony. He published the first Flora Capensis in 1807. On his way to Japan, he stopped in Java, collecting plants wherever he went. As travelling in Japan was very restricted, he traded medical knowledge for plants from the interior of the country. He arrived back in Sweden in 1779. He is called the father of South African Botany and the "Japanese Linnaeus". His most important publications were Flora Japonica (1784) and Flora Capensis (1807). He was the successor of Linnaeus, after he had died. Thunberg died in 1828. His vast herbarium collection is still used today.

Taxonomy today in South Africa

Savel Daniel

Savel Daniel was born in 1974 in South Africa. He is a Senior Lecturer at Stellenbosch University. Sometimes species can be very similar based on their morphology and it is hard to tell whether they are one or two species. Savel Daniel's research focuses on separating species that are difficult to tell apart using only morphological characteristics. He has worked on crabs, shrimps, lizards and velvet worms and he is using genetic markers to examine them. Genetic markers prove to be a useful tool, showing that there are far more species than we thought before we investigated DNA.

Nicola Bergh

Nicola Bergh was born in 1972 in South Africa. She works as a taxonomist for the South African National Biodiversity Institute (SANBI) at the Kirstenbosch Herbarium in Cape Town. Her own research focuses on the relationship, evolution and identification of *Gnaphalieae* (a tribe in the daisy family), involving molecular, anatomical and morphological (microscope) work. Her job is varied and she also looks after a large number of plant specimens in the herbarium by keeping the information about the specimens up-to-date and going on expeditions to add to the collection. She also identifies daisy plants sent in by the public, and works with conservationists and other scientists to promote the importance of taxonomy and systematics.

The workplace of Systematists

Where do Systematists work?

Systematists work in many different institutions such as:

- South African National Biodiversity Institute (www.sanbi.org)

- Museums (Albany Museum, Port Elizabeth Museum, East London Museum, Durban Natural Science Museum, Natal Museum, Northern Flagship Institute / Transvaal Museum, Iziko Museum, National Museum)

- Universities

- Agricultural Research Council

- Research organisations such as the South African Institute for Aquatic Biodiversity (SAIAB)

Who do they work with?

They collaborate with a variety of different fields such as:

- Veterinary and medical laboratories

- Conservation organisations

- Members of the public

- University students

- Other researchers such as ecologists

- Environmental impact assessment consultants

New fields of research in taxonomy

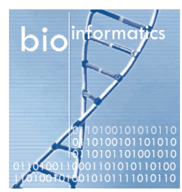
There are new fields emerging in taxonomy, such as:

Forensic entomology: Investigators can solve crimes by studying

the insects that have invaded a corpse. The species of insects found on a body can tell them how long a person has been dead, whether they were killed inside or outside, whether the body has been moved, and whether the victim was taking drugs. Correct identification of the insects needs taxonomic expertise.

Climate change impacts on plants and animals: We can study the effects of climate change on biodiversity by studying changes in animal or plant communities over time. Correct identification of these plants and animals requires taxonomists' assistance.

Bioinformatics: The process of managing the information on millions of species and where they live, what they look like and their gene sequences requires massive databases. There is a great shortage of people with a combination of biology and information technology who can develop software to manage and use this kind of information.



Natural science museums and herbaria:

- Natural science museums have large collections of preserved animals that are used for research. The collections are not on display, but are kept in special collection rooms. They are studied by taxonomists all over the world. Some of the specimens were collected more than 100 years ago, and so they are a record of past biodiversity. Visit the websites of the South African museums to find out about the different collections these institutions hold.
- Herbaria are similar to museums, but they house large collections of plant specimens. There

are national collections of plants at Kirstenbosch in Cape Town, and in Pretoria. Some universities also have large herbaria.

In many of these institutions there are opportunities for teachers to take classes to see the collections. Contact a local institution to find out about visits. Information is online available as well, e.g. electronic plant information (www.epic.kew.org)

Some exciting international projects on collections and taxonomy:

Internationally, politicians and scientists have recognised the need to collect and co-ordinate taxonomic information about the world's biodiversity. Visit the following websites to find out about these projects:

- Encyclopaedia of Life (www.eol.org)
- Tree of Life (www.tolweb.org)
- International Barcode of Life (www.dnabarcoding.org)

Solution for Caminacules Phylogeny