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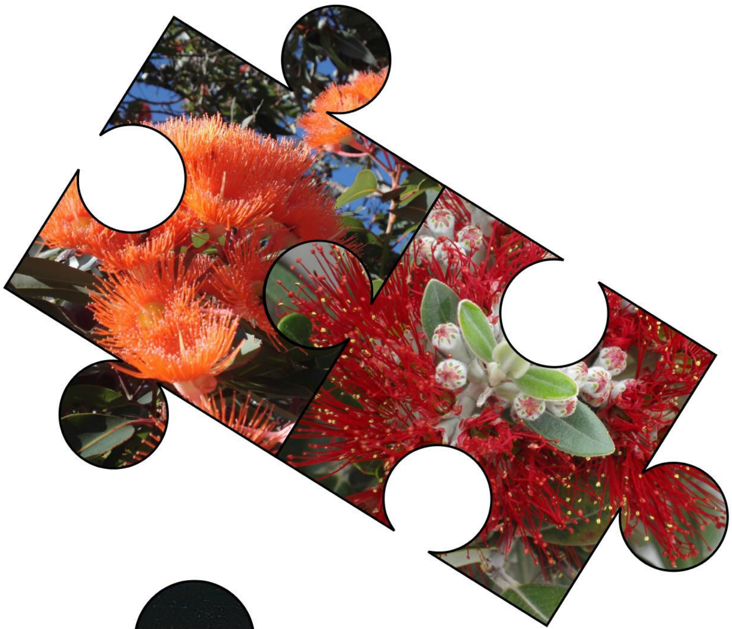

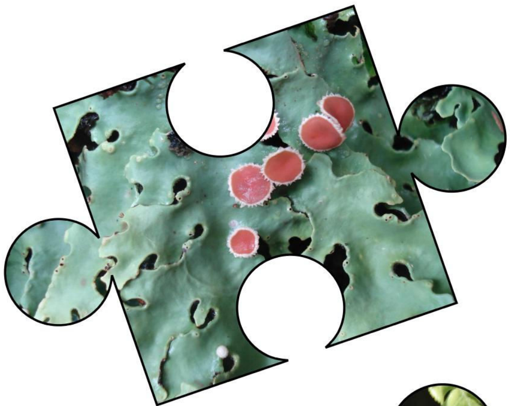

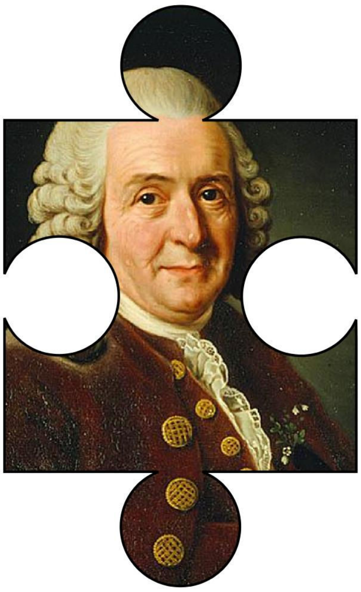

Carl Linnaeus and biological classification

Dr Anna Meyer

the ROYAL SOCIETY of NEW ZEALAND
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Why do we need to classify living things?

Imagine yourself at the beach, in the bush, or diving in the ocean – how many different types of life can you see? Life comes in all shapes and sizes, and is found in many different places. There are over a million different forms of life on Earth, from humans and other animals, to seaweed, flowering plants, mould, bacteria and other things too small to see. Some forms of life are very similar to each other (like a dog and a wolf, or a rat and a mouse), and some are very different (like a daffodil and an elephant).

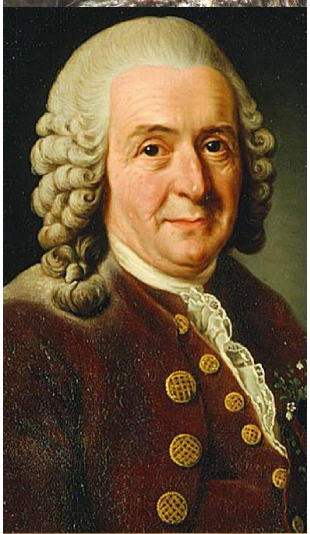
How can we make sense of all of the living things that exist in the world? The answer that biologists have come up with is to use a classification system – a way of grouping all of life in an orderly, logical way that makes it easier to study and understand.

The biological classification system that is used today was invented nearly 300 years ago, by a Swedish doctor named Carl Linnaeus.

> The science of classification is called taxonomy, and someone who carries it out is a taxonomist.

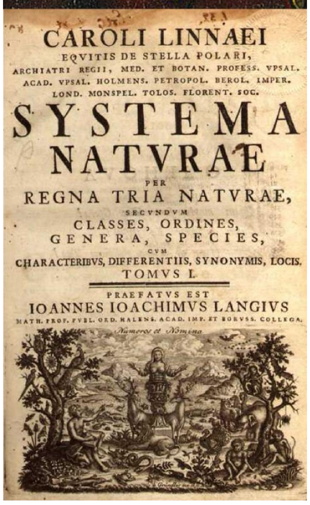
Carl Linnaeus

Carl Linnaeus was born in 1707, and was interested in plants and their names from an early age. He studied medicine at university, and in those days botany was a key part of medical studies. In 1735 he published the first edition of his most famous work, *Systema Naturae*, which outlined a system he had developed for classifying plants. He published several later editions of this, and expanded into classifying animals too.



Linnaeus' works helped to establish and standardise, for the first time, a method for naming species, and for organising and grouping living things. Other scientists soon began to use his classification system, until it became the standard system for classifying life.

For the rest of his life, Linnaeus continued to revise his scheme, and gathered a huge collection of plant and animal specimens. He became a professor at Uppsala University in 1741, and in 1761 he was knighted, becoming Carl von Linné.



CAROLI LINNAEI
EQVITIS DE STELLA POLARI,
ARCHIATRI REGII, MED. ET BOTAN. PROFESS. VPSAL.
ACAD. VPSAL. HOLMENS. PETROPOL. BEROL. IMPER.
LOND. MONSPEL. TOLOS. FLORENT. SOC.
SYSTEMA
NATVRAE
PER
REGNA TRIA NATVRAE,
SECVNDVM
CLASSES, ORDINES,
GENERA, SPECIES,
CVM
CHARACTERIBVS, DIFFERENTIIS, SYNONYMIS, LOCIS.
TOMVS I.
PRAEFATVS EST
IOANNES IOACHIMVS LANGIVS

> Linnaeus gave living things standard names – before him, scientists used whatever name suited them, which could be confusing. His binomial (two name) system is still used today.
>
> Every species has a scientific name in two parts, based on the Latin language. The first word, written with a capital, is the genus and the second word, without a capital, is the species. These names are normally written in italics or are underlined.
>
> For example, humans have the scientific name *Homo sapiens. Homo* is our genus, *sapiens* is our species.

Classification today

Biologists still use a classification system based on the one devised by Linnaeus, although there have been a number of changes. Many details of classification are still being debated by scientists – there is no one system accepted by all. Modern systems contribute to biosystematics, in which scientists work out the relationships between organisms, their roles in ecosystems, and their evolutionary development.

All forms of life are placed into their own unique **species**. A species is a group of individuals that can interbreed with each other and produce fertile offspring. However, a taxonomist also uses physical characteristics to determine species.

Many closely related plants can hybridise (interbreed) however, and botanists generally accept a small amount of hybridisation between plant species. Linnaeus was actually one of the first to recognise and study plant hybrids.

In the next level up in the Linnaean system closely related species are grouped into a **genus**. For example, lions (species name *Panthera leo*) and tigers (*Panthera tigris*) are different species, but are similar enough to be members of the same genus (*Panthera*).

Following on from this, closely related genera (the plural word for genus) are grouped into a **family**. For example, African elephants (*Loxodonta africana*) and Asian elephants (*Elephas maximus*), although different species and genera, are members of the same family, Elephantidae.

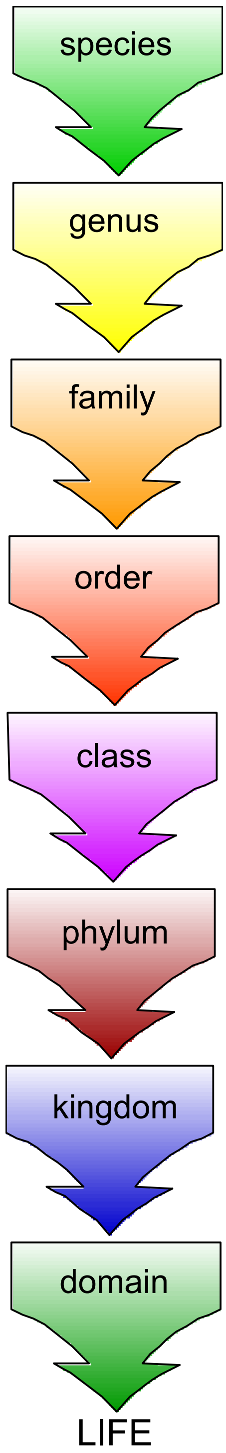
There are several more levels of organisation in the modern Linnaean system:

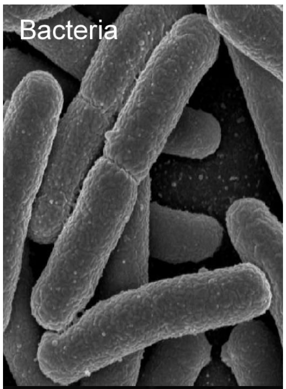
- closely related families are grouped into an **order**
- closely related orders are grouped into a **class**
- closely related classes are grouped into a **phylum**
- closely related phyla (plural of phylum) are grouped into a **kingdom**
- closely related kingdoms are grouped into a **domain**

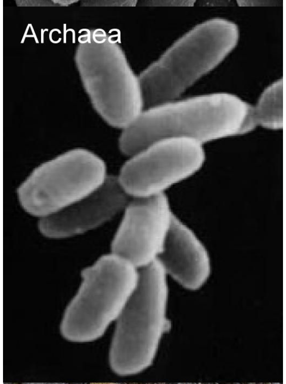
Each type of living thing belongs to a particular group at each of these levels of classification. For example, as a human you are a member of the

species	*Homo sapiens*
genus	*Homo*
family	Hominidae (hominids)
order	Primates
class	Mammalia (mammals)
phylum	Chordata (vertebrates)
kingdom	Animalia (animals)
domain	Eukaryota (eukaryotes)

You might find it useful, and fun, to use a mnemonic (a phrase using the first letter of each word) to help remember the order of levels. So D,K,P,C,O,F,G,S. could be "Daring Kites Played Craftily Over Forested Green Spaces." Try making up your own, or in the other direction: S,G,F,O,C,P,K,D.







Classification in detail

In the next few pages we'll look at some of the groups of living things that exist at each level in the Linnaean classification system. We will start our exploration at the top level of the classification system – domain – and work our way down, all the way to the bottom level - species.

Domain

The highest level in the Linnaean classification system is known as the domain. Since 1990 it has gradually become accepted that there are three domains at the top of the classification. These are:

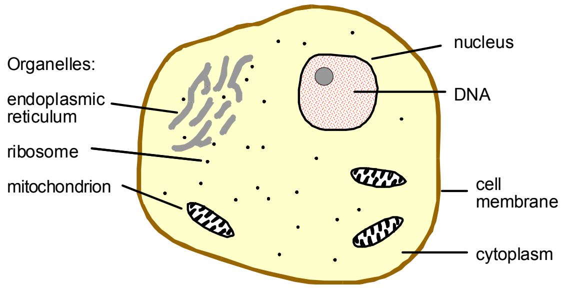
1. Bacteria
2. Archaea
3. Eukaryota

Bacteria are small, single-celled forms of life, and they live almost anywhere on Earth you can imagine. Some cause disease, but most do not, and many are actually essential for our survival. They can replicate very quickly by simply dividing in two. Bacteria have a cell wall made of a substance known as peptidoglycan, which is not found in cells of organisms in the domain Eukaryota. Bacteria come in many shapes and sizes, including rods, spheres, and even spirals.

Archaea are also single-celled, but some features of their metabolism make them more similar to the eukaryotes than bacteria are. Most Archaea live in extreme environments, such as geysers, oil wells, cows' stomachs, and even sewage.

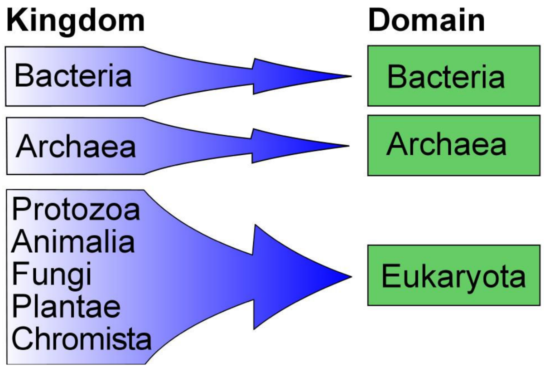
Bacteria and Archaea are collectively known as ***prokaryotes***. Their most distinguishing feature is that they do not have a cell nucleus – their DNA just sits inside the cell itself.

Eukaryotes are mostly larger, more complex forms of life. The most important feature that separates them from prokaryotes is that they have a cell nucleus – their DNA is partitioned away from the rest of the cell. Some eukaryotes are microscopic and single-celled, but most are multicellular (made up of many cells). All forms of life that are large enough to see are eukaryotes – including ourselves.



Basic structure of a eukaryotic animal cell

Kingdom
All living things are classified into one of seven kingdoms – though some biologists recognise more.



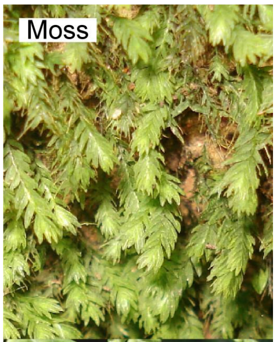
Protozoa are single-celled eukaryotes, and include groups such as amoeba and paramecium. They are much larger than most bacteria, and can appear almost animal-like, with structures such as bristles, hairs, mouth and foot-like extensions, and flagella (small propellers). Some cause disease, for example *Giardia* and *Cryptosporidium*.

Animals are usually large and multicellular. They rely on eating other organisms for their food, as they cannot make their own. Most can move around, usually quite rapidly, and are good at responding to their environment. Animal bodies have specialised tissues and organs, which perform different functions. The animal kingdom includes mammals, birds, reptiles, insects, fish, crustaceans, worms, sponges, starfish and corals.

Fungi, like animals, cannot make their own food, so they break down dead organic material and absorb it. They are often made up of networks of branched, tubular structures, and they reproduce using spores. Fungi include useful organisms such as mushrooms (used for food), yeast (used in bread making and brewing) and *Penicillium* (used in producing the antibiotic penicillin).

Plants are the fourth kingdom in the eukaryote domain. As well as familiar plants such as mosses, ferns, and flowering plants, the kingdom also includes several types of algae. Plants are almost all green, because they contain a pigment called chlorophyll. Plants use this to capture energy from light, which they then use to make sugar from carbon dioxide and water. Plants are essential for the survival of life on Earth, as almost all other forms of life rely on eating either them, or other plant-eating animals.

Chromista vary from very small, such as diatoms (tiny aquatic organisms with beautiful silica shells), to very large, such as kelp. Some used to be classified as fungi, like some mildews that cause plant diseases. Most chromists carry out photosynthesis, but they use a different form of chlorophyll to plants, and don’t store their energy as starch. Several unique features of their cells and DNA show they are related to each other and separate from other kingdoms.



Phylum

The level below kingdom is the phylum – each kingdom has its own unique set. For example, although ideas about plant phyla vary between different groups of researchers, most recognise about 10 or 12 different ones. These include:

1. Bryophyta (mosses)
2. Pteridophyta (ferns)
3. Coniferophyta (conifers)
4. Magnoliophyta (flowering plants)
5. Rhodophyta (red algae)
6. Chlorophyta (most green algae)

Mosses are small and inconspicuous plants that are low growing because they do not have any wood to give them support and transport water. They have very small leaves, and do not produce flowers. Instead, they produce sperm and eggs, and after fertilisation a spore capsule on a stalk grows to disperse thousands of tiny spores. New Zealand has about 500 mosses, including the 'giant' *Dawsonia superba*, which is up to 50 cm tall.

Ferns do not have flowers or seeds, but disperse spores from special structures on leaves. The often showy leaves are above ground, but stems are often hidden below ground. New Zealand has about 120 species of ferns, including the tall tree ferns and tiny filmy ferns that grow in damp shady forests.

Conifers reproduce by seeds but don't have flowers. Some of New Zealand's tallest and most important trees are conifers, like kauri, rimu, kahikatea and matai. Altogether, we have 20 species of conifer.

Flowering plants are the largest phylum, with about 250,000 species worldwide. Flowering plants reproduce with seeds, and they all produce some variety of flower as the basis of their reproductive system. Different types of flowers are suited for different pollinators, including insects, birds, wind and water, that carry the pollen from flower to flower. New Zealand has over 4000 flowering plants. Over half of these are native and most are only found here.

Red algae is a large group of marine algae. The phylum contains many different types of seaweeds, which can be single-celled or multicellular. Some red algae float around in the water, others are attached to surfaces. Certain types of red algae are used to make products such as agar and food products.

Green algae is the most diverse group of algae – there are thousands of species of them, growing in a variety of different habitats. They almost all live in water, either marine or fresh, and can be single celled or multicellular. Some live in other environments, such as attached to rocks or trees. Interestingly, lichens are formed by a symbiotic relationship between a fungus and a green alga, though some use photosynthetic bacteria instead.

Class
Each phylum is made up of a unique set of classes. For example, all plants that fall within the flowering plant phylum (Magnoliophyta, often known as angiosperms) are traditionally classified into one of two classes. These are:

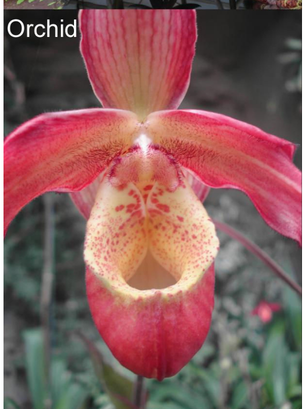
1. Magnololiopsida (also called dicotyledons, or just dicots)
2. Liliopsida (also called monocotyledons, or just monocots)

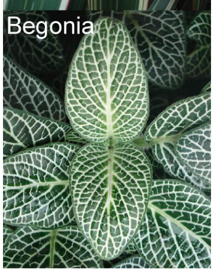
However, recent research has shown that this simple division into two classes does not reflect evolutionary history very well, and so a new, informal structure has been developed that divides the flowering plant phylum into three groups that might one day be formalised as classes:

1. Basal Angiosperms
2. Moncotyledons
3. Eudicots

Basal Angiosperms are a small group made up of several early offshoots from the flowering plant evolutionary tree. These include water lilies, magnolias, and several tropical species like cinnamon and camphor. They have two seed leaves (cotyledons) and pollen with one pore.

Monocotyledons have just one seed leaf and pollen with one pore. Usually, their leaves are slender with parallel veins, and their flower parts are in multiples of three. They include grasses, sedges, orchids, New Zealand flax and palms.

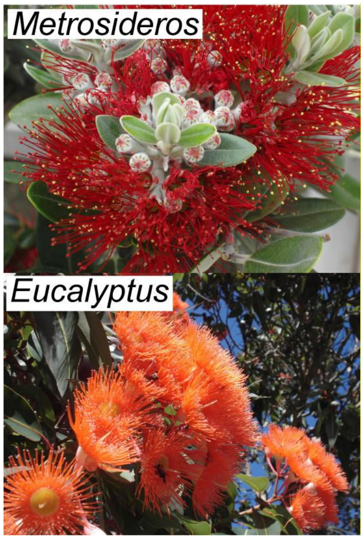




Eudicots are the largest flowering plant grouping and include many familiar plants. They have two seed leaves and pollen with three or more pores. Usually they have net-veined leaves and flower parts in multiples of four or five. Daisies, harebells, roses, begonias, beech and many others are eudicots.

Order and family
The next two levels down in the Linnaean classification system are known as the order and family. Each class has its own unique set of orders, and each order has its own set of families. Familiar large plant families include daisies, orchids, beans and grasses.

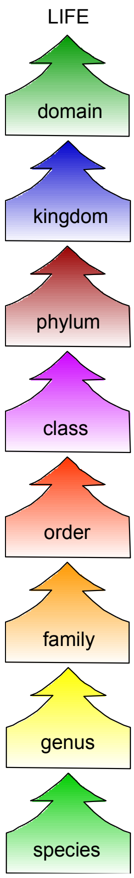
Genus and species
The final levels in the Linnaean classification system are the genus and species. Each family has its own unique set of genera, and each genus has its own set of species.



For example, the *Metrosideros* genus contains about 50 trees, shrubs and vines native to the Pacific region. Some are small, and others are very large. New Zealand has 12 species of *Metrosideros,* one of which is the 'New Zealand Christmas tree', the pohutukawa (*Metrosideros excelsa*).

Two New Zealand relatives of pohutukawa are *Metrosideros robusta* (northern rata), and *Metrosideros umbellata* (southern rata). From their scientific names, you can see they are members of the same genus, but are different species.

An Australian relative of pohutukawa is the *Eucalyptus* genus – it is part of the same family as the *Metrosideros* genus. There are more than 700 species of *Eucalyptus*, and most of these are native to Australia. They are found in all parts of the country, and most are known as gum trees because they produce a lot of sap.



The end of the journey
Now we have travelled from the top to the bottom of the Linnaean classification system, starting with the domain, and working all the way down to the level of the species. We can also follow this thread back up in the other direction, from species to domain, just like we did with humans earlier on. For example, the species pohutukawa (*Metrosideros excelsa*) is in

Genus	*Metrosideros*
Family	Myrtaceae
Order	Myrtales
Class	Eudicots (currently an informal group)
Phylum	Magnoliophyta (flowering plants)
Kingdom	Plantae
Domain	Eukaryota

By taking this tour of the Linnaean classification system, and learning more about just some of the forms of life that exist within it, you can get an idea of why it is so useful – life is just so complicated and comes in so many forms that there really has to be a way of keeping track of it all.

How is classification carried out?
Each different type of living thing that we know about today has been given a place in the Linnaean classification system – it has been given a species name, and also put into a genus, family, order, class, phylum, kingdom and domain. Sometimes, however, a new variety of life is discovered that has not been classified before – such as when new parts of the ocean floor are explored. How do biologists decide where to put it in the classification scheme?

The first step is to examine closely what it looks like, and compare it to other similar forms of life. If it is different enough, it will be given its own new species, genus, and maybe even higher levels such as family and order. This process requires expert biological knowledge.

Genetic techniques (the use of DNA) can also help, and are especially useful in deciding if two similar-looking living things should be classed as separate species or not, or placing an unusual species among its relatives, which can often look very different. In fact, the use of DNA has revolutionised classification.

Classification is often an ongoing process – as more is learned about a particular living thing or group of living things, the way in which it is classified may need to be adjusted.

Working in biological classification

Do you like the idea of helping to make sense of the natural world? Then perhaps you might like to think about having a career that involves biological classification. There are lots of people working in this area in New Zealand, in universities, Crown Research Institutes, and in government departments such as the Department of Conservation, as well as museums such as Te Papa.

To find out more about careers in biological classification, see Alpha 136.

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