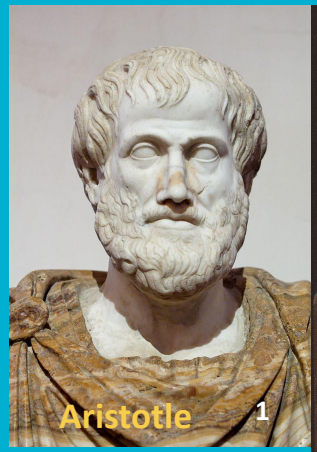
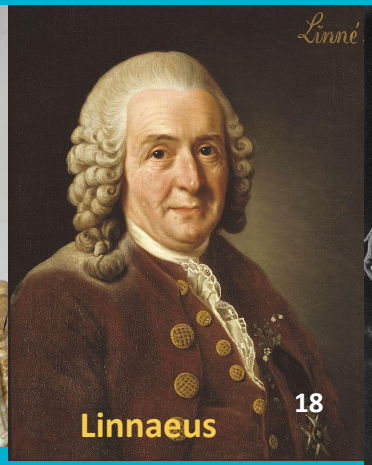
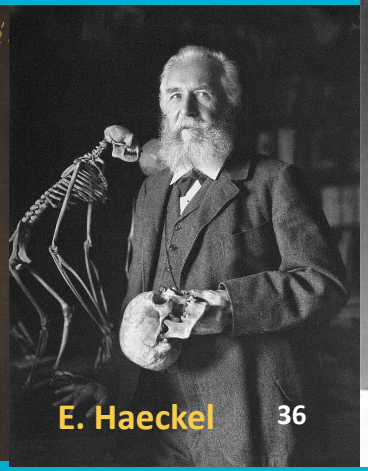
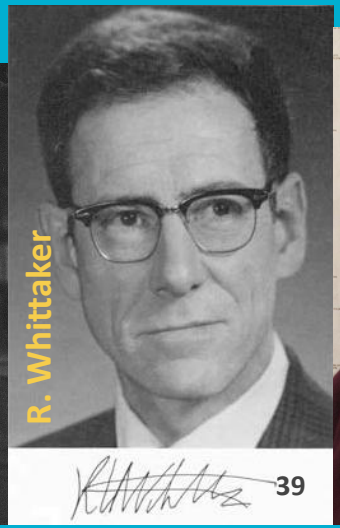
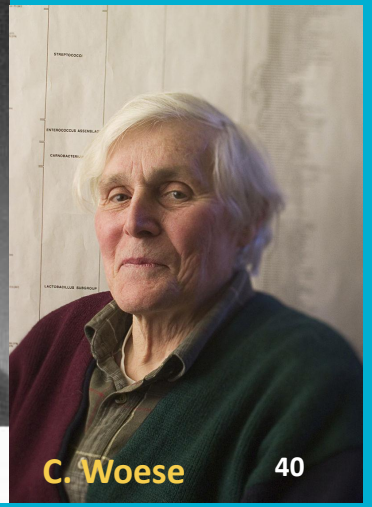
CLASSIFICATION OF LIVING BEINGS











FROM ARISTOTLE TO KEELING

Last revision July 31, 2024

CLASSIFICATION OF LIVING BEINGS

INDEX

INTRODUCTION

INTRODUCTION

Classifying living beings has roots in ancient times.

The first attempts date back to Aristotle (384 or 383 BC - 322 BC) who was an intelligent and methodical observer.

Nowadays, there are a lot of scientists in the world working on it, a clear sign that this adventure is not over. And it's not over because more and more new forms of cellular life are being discovered.

INTRODUCTION

In fact, we must keep in mind that the methods of investigation that reveal unexpected aspects, that have never been analyzed until now, are increasingly sophisticated.

Just think of these technologies: DNA sequencing, bioinformatics, databases, imaging ...

ARISTOTLE

ARISTOTLE

Aristotle (384 BC - 322 BC.)
Ancient Greek philosopher and scientist.
He dealt with many aspects of human knowledge; among them the studies of biology and cosmology are very important for this topic.

Aristotle: Roman copy of his bust created by Lysippos (Palazzo Altemps)

ARISTOTLE

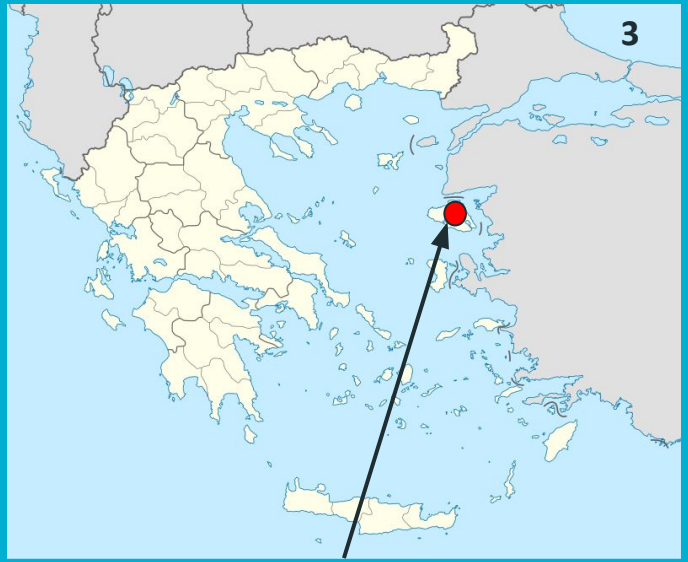
In the book Historia animalium he describes individuals and groups (set of individuals with the same characteristics) to evaluate their differences. For example, the birds group is characterized by specimens with feathers, beaks and wings.

Historia animalium
Constantinople, 12th century
Laurentian Library

ARISTOTLE

Most of his observations date back to the time he lived on Lesbos, an island off the Anatolian coast, and are based on marine biology.

The work is divided into 10 books.



Lesbo isle

ARISTOTLE

In the first 4 books Aristotle deals with the differences in animals in particular parts of their body.
In books V, VI, VII and IX the philosopher deals with various activities including reproduction in humans and in many animals marine invertebrates included.
The ninth book is instead dedicated to many topics (nutrition, migration, disease and climate influences).
For the tenth book the attribution is controversial but it does not appear to be by Aristotle.

ARISTOTLE

His studies were so accurate that he discovered that the octopus changes color when disturbed. In fact it camouflages itself among the stones. He also observed that cuttlefish and squid emit ink to escape predators and for general defensive purposes.

Octopus

ARISTOTLE

Another of his observations: the dogfish is viviparous and the baby grows inside the mother's body attached with a rope to something similar to a placenta (a yolk sac). This was confirmed only in 1842 by the German zoologist Johannes Peter Müller.

Above: the dogfish is a shark that is not dangerous to humans.
On the right: the baby attached to a sort of placenta.

ARISTOTLE

Another Aristotelian discovery confirmed only in 1890 by the zoologist Louis Agassiz. The male of a freshwater fish known as the Aristotle's catfish, very similar to the one in the adjacent image, worries about his offspring.

Silurus glanis
or
wels catfish

ARISTOTLE

Since the female moves away after spawning, it is the male who watches over the eggs for forty or fifty days and chases away all the small fish that threaten them, emitting a continuous murmur..

Specimen of Silurus glanis caught in the Ebro river in Spain

ARISTOTLE

The other text by Aristotle that testifies to his interest in biology is De generatione animalium which deals with the reproduction of animals.
The concept that the philosopher conveys about this essential function for life is extremely interesting. The form, according to him, is transferred from the male seed while the matter is linked to the female menstrual blood.
Aristotle's belief is that the species is immutable.

ARISTOTLE

Other reproduction studies to remember are linked to embryos. Aristotle practiced dissection as early as the 4th century BC, but his studies on the embryo were carried out on fertilized chicken eggs that he broke at different times. His book highlights how he had already understood that all the organs are not present from the beginning of development but that they are added at different times.

ARISTOTLE

Obviously, given the basic means at his disposal, not everything he conveyed in his books was later confirmed. For example, the role of the brain to which he attributes only the function of cooling the blood.

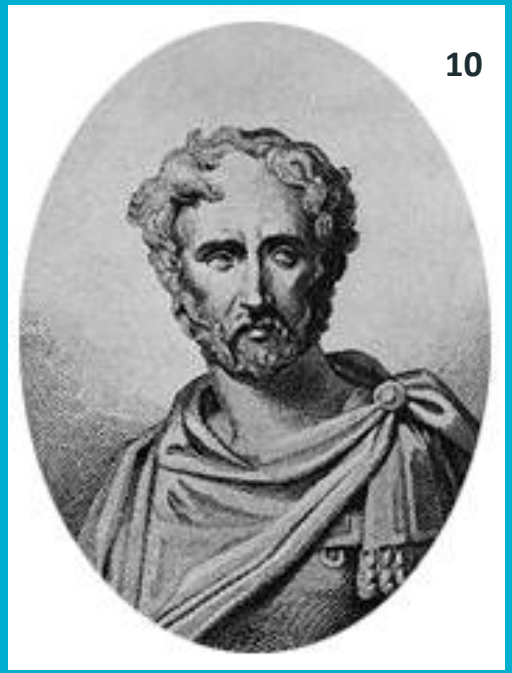
9

Human brain

PLINY THE ELDER

PLINY THE ELDER

Before proceeding with other scholars it is worth focusing on Pliny the Elder.
Admiral, writer but above all naturalist, who lived in the 1st century AD.
His books were a point of reference for scientific knowledge until the Renaissance period.



Gaius Plinius Secundus
(23/24 -79 AD)

PLINY THE ELDER

Pliny the Elder died following the sulfur fumes released by Vesuvius during the eruption of 79 AD.

His behavior on that occasion is an indication of his great curiosity.

Pompeii: plaster casts of the victims surprised by the eruption of Vesuvius

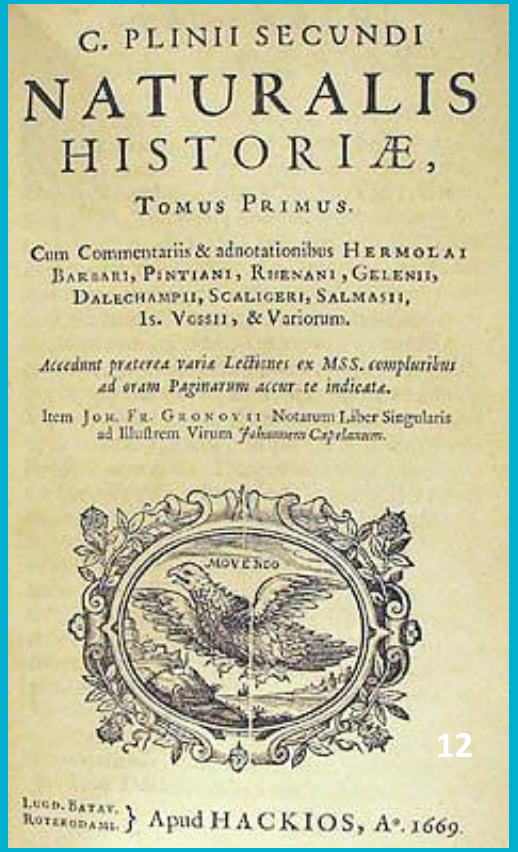
PLINY THE ELDER

In fact, at that moment he was in Miseno with the role of prefect. When he realized what was happening he set sail his galleys and got as close as possible to the area. Not only to observe the eruption but also to help some friends. 27 years later it was his nephew, Pliny the Younger, who told Tacitus about the episode and described the eruption in detail. It is no coincidence that we talk about a Plinian eruption when referring to Vesuvius and other volcanoes of the same type.

PLINY THE ELDER

Pliny the Elder wrote many books but the only intact one is the Naturalis historia which is considered a real encyclopedia.

37 volumes in which he included the most varied topics. The human knowledge of that historical moment.

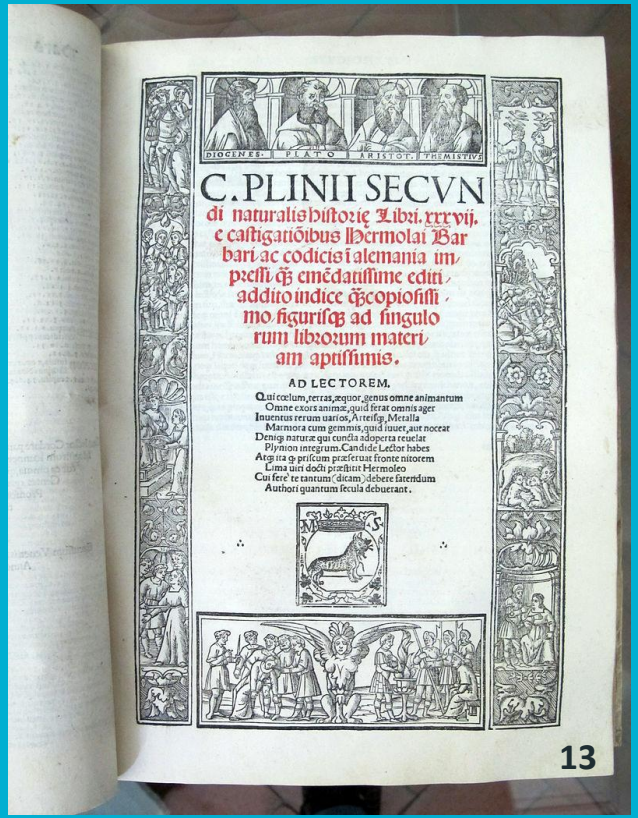


Frontispiece of Naturalis historia

PLINY THE ELDER

The volumes are divided by astronomy, geography, anthropology, psychology, zoology, botany, medicine, mineralogy and metallurgy.

4 volumes are dedicated to zoology and 12 to botany including techniques for having a beautiful garden, growing fruit plants and keeping a farm.



Frontispiece of an edition of Naturalis historia dated 1525

PLINY THE ELDER

Pliny the Elder was a keen observer but also an excellent collector of sources and tireless in his work. He knew how to organize himself and make full use of the time available. For these reasons his work is so vast and detailed at the same time.
He left written that his subject was the world of nature, in other words the life.

PLINY THE ELDER

Among the many descriptions relating to zoology we can mention the production of the color purple red or Tyrian purple, a pigment obtained from a sea snail (Murex) already described and classified by Aristotle and to which we also owe the name.

Two shells of Bolinus brandaris (Muricidae family)

PLINY THE ELDER

It seems that the pigment was already used in the Phoenician era.

To color an entire dress, thousands of specimens were needed and therefore it was only used by the wealthiest classes.

Fresco dating back to the 1st century BC, from the Roman era, which portrays men with togas. There are purple-red colored stripes in togas.

PLINY THE ELDER

Pliny also tells the origin of the pearl or how fish and oyster farming was practiced.

Extraction of a pearl from an oyster

PLINY THE ELDER

Pliny the Elder also described animals such as the hippo or elephant.

Hippopotamus amphibius

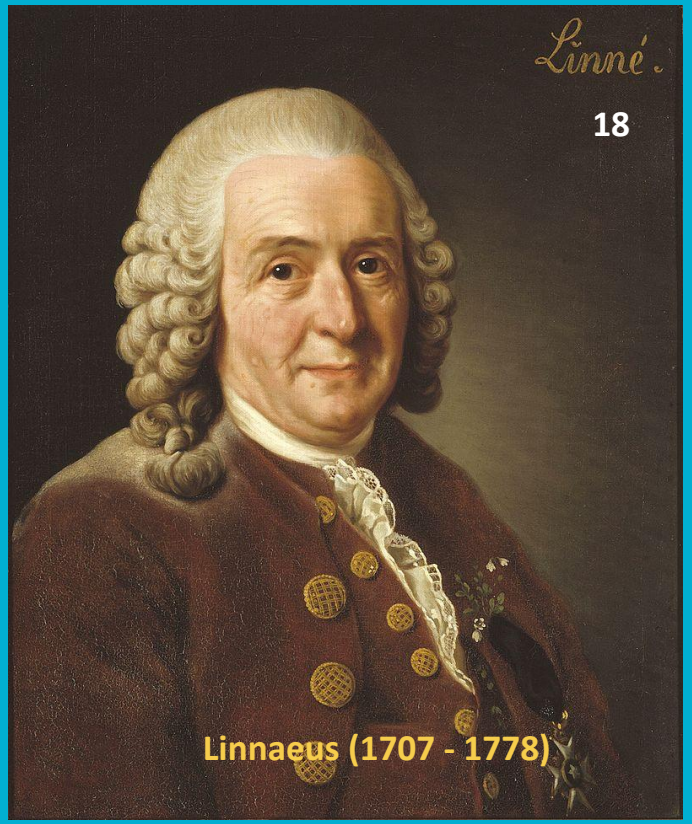
PLINY THE ELDER

However, we cannot say that Pliny the Elder had the same role as Aristotle. Indeed, his primary source for zoology was Aristotle himself. Followed by Juba II, king of Mauretania, very erudite on the subject. Juba is also the source of him for botany. Obviously, Pliny the Elder added his experiences to these sources. He can be defined as a true reporter and an attentive observer. Probably without his encyclopedic work the scientific knowledge of the previous period would never have reached us.

LINNAEUS (Part 1)

LINNAEUS (Part 1)

His real name is Carl Nilsson Linnaeus but he is known in Italy with the Italianized form of Linneo. He was a Swedish doctor, botanist and naturalist. He linked his name to the first modern scientific classification of living beings.



LINNAEUS (Part 1)

From an early age he showed a notable interest in botany and managed to attend university. So he could begin to develop a system of classification of plants based on petals, stamens and pistils. Later in life, this interest cost him a complaint from the Swedish state for immorality.
He had dared to talk about sexual organs!

Linnaeus' signature

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LINNAEUS (Part 1)

In his professional life he was always divided between botany and medicine. The two passions ran parallel because the treatment of diseases was based on the use of plant substances. Linnaeus, among other things, worked extensively on syphilis.

These two passions did not limit his ability to adopt a rigorous classification system also valid for the animals that he studied equally well.

LINNAEUS (Part 1)

Before his method was made explicit, each species was classified with a diagnostic designation, that is, a phrase that more or less corresponded to its description and which required around 15 words including nouns and adjectives.

Linnaeus' binomial nomenclature was born as an alternative proposal to this method which required real memory exercises.

First the genus and then the species, just two terms.

LINNAEUS (Part 1)

It was a real revolution that allowed the natural sciences to have the same rigor that was the prerogative only of the physical sciences.

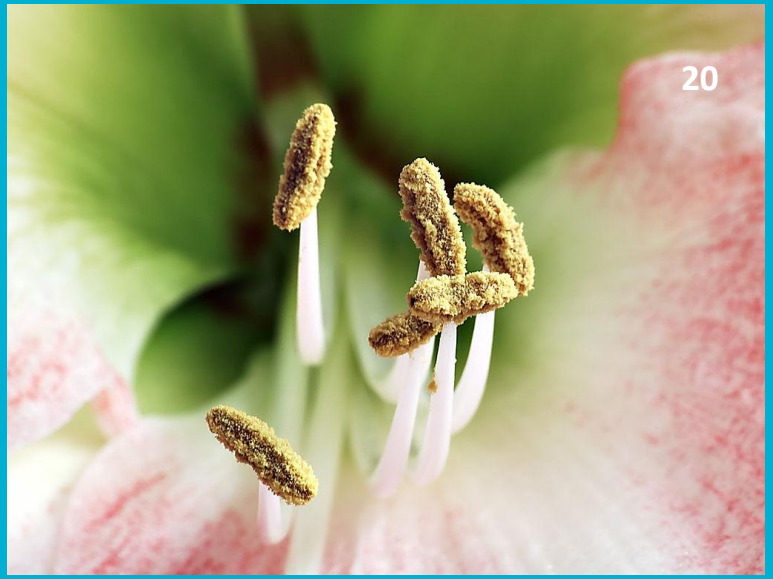
Aristotle was also an essential reference point for Linnaeus.

We can talk about a real method adopted by Linnaeus which was based on some rules. First of all, the characters were divided into primary (only a few morphological aspects) and secondary (physiological, environmental and behavioral).

LINNAEUS (Part 1)

Let's start with botany.

Number, shape, size and proportion of the stamens (fertile male part of the plant = androecium) contribute to determining the class.



Hippeastrum stamens
In the foreground, the anthers loaded with pollen

LINNAEUS (Part 1)

The analysis of the pistil (female part of the flower = gynoecium) with its three portions (ovary which contains the ovules, style and stigma) leads instead to the definition of the order.

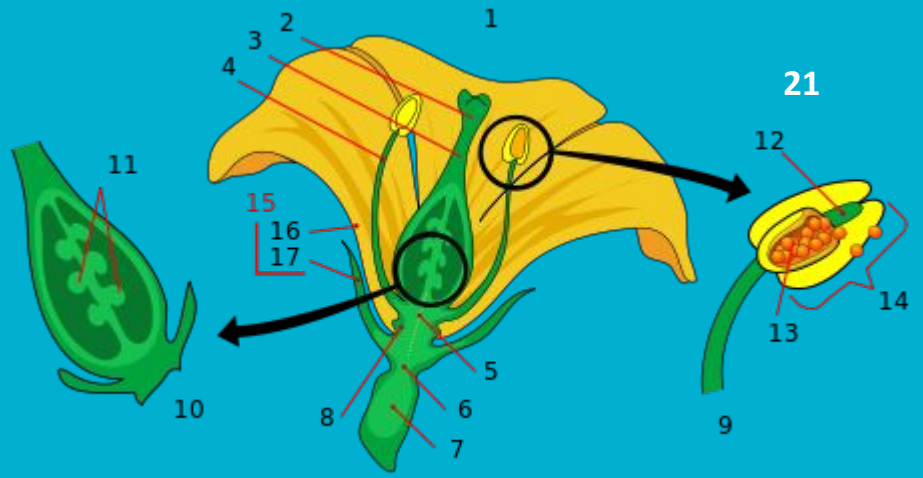


Diagram of an Angiosperm flower:
gynoecium formed by ovary (10) with ovules (11), style (3) and stigma (2)
androecium formed by stamens (9) with terminal anthers (14)

LINNAEUS (Part 1)

But what are class and order?

Let's call them containers. Containers in which to include living beings for some similar characteristics. At the time of Linnaeus, variety, species, genus, order, class, family, tribe were used. But these containers were not articulated with each other.

The Linnaean novelty also lies in this. He gave a specific hierarchy to these containers with a method that was always applicable.

LINNAEUS (Part 1)

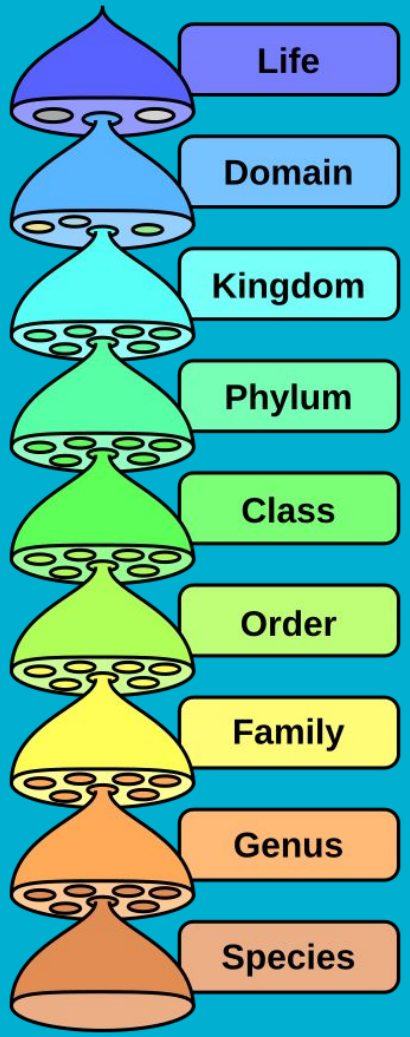
Having identified a specific hierarchy means that Linnaeus considered each of these containers included other smaller ones and the same container in turn was subordinate to a larger one. This principle is still valid today even if the name and characteristics of some containers have changed over time. For example, Linnaeus used the containers variety, species, genus, order, class but not tribe or even family. While today the family has its own very specific position.

LINNAEUS AND THE CURRENT TAXA

LINNAEUS AND THE CURRENT TAXA

On the side, the containers that was discussed in the previous slides are highlighted according to the hierarchical scale as they are currently used.

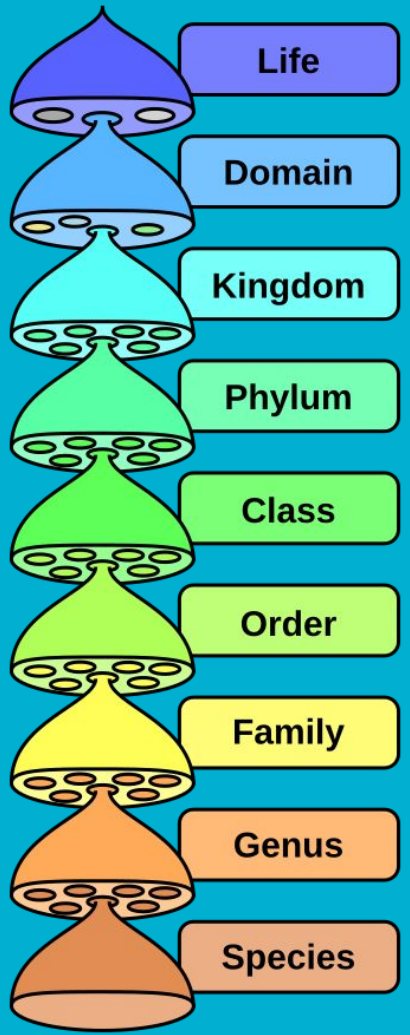
The containers are the taxa. Every living being belongs to a species that is part of a genus. Genus and species are the two terms of the binomial nomenclature introduced by Linnaeus.



LINNAEUS AND THE CURRENT TAXA

Among the species classified by Linnaeus we have the pineapple or ananas.
Ananas comosus is its binomial nomenclature.

Ananas is the **genus**
comosus is the **species**.
The first letter must be capitalized in the genus and always lowercase in the species.

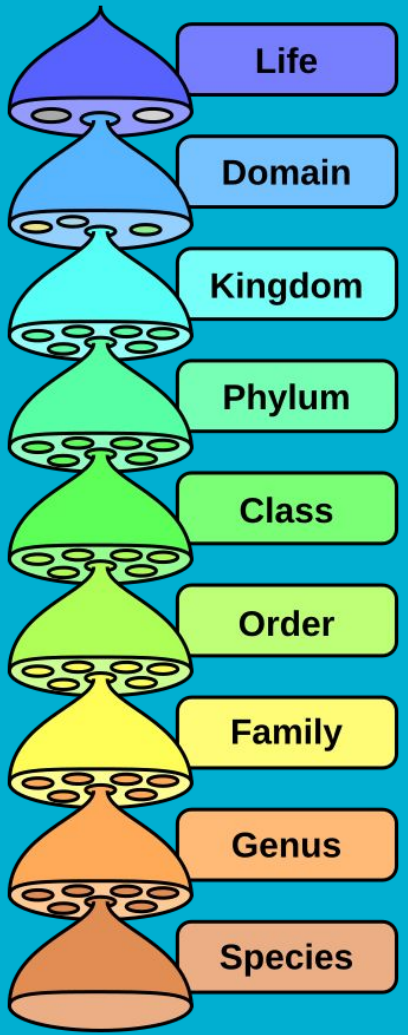


LINNAEUS AND THE CURRENT TAXA

Currently, we must add the following taxa to the binomial nomenclature, according to the modern classification of angiosperm plants:

Family: Bromeliaceae

Order: Poales



LINNAEUS AND THE CURRENT TAXA

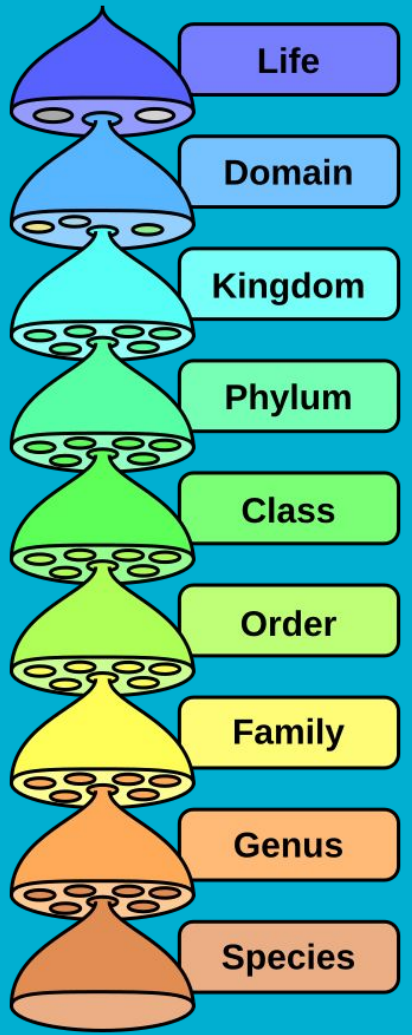
So an order includes several families.

A family includes several genera.

A genus includes several species.

In turn, the order is a subgroup of the class.

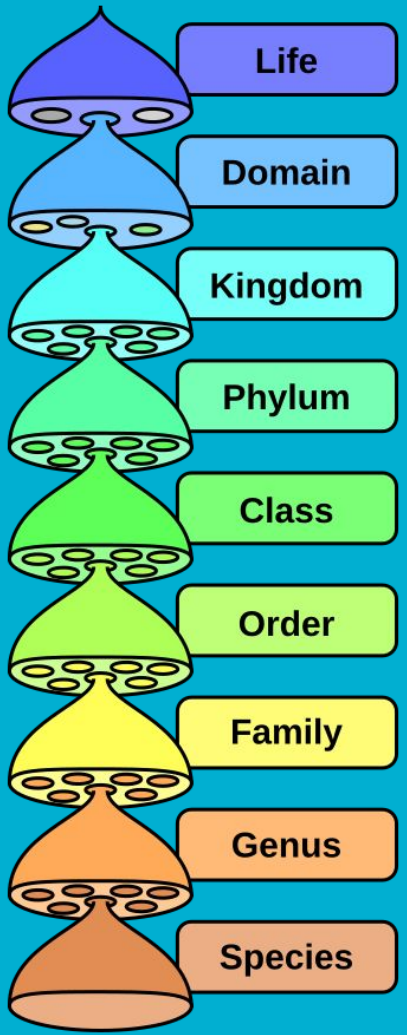
The hierarchy continues up to the maximum taxonomic group which is the domain



LINNAEUS AND THE CURRENT TAXA

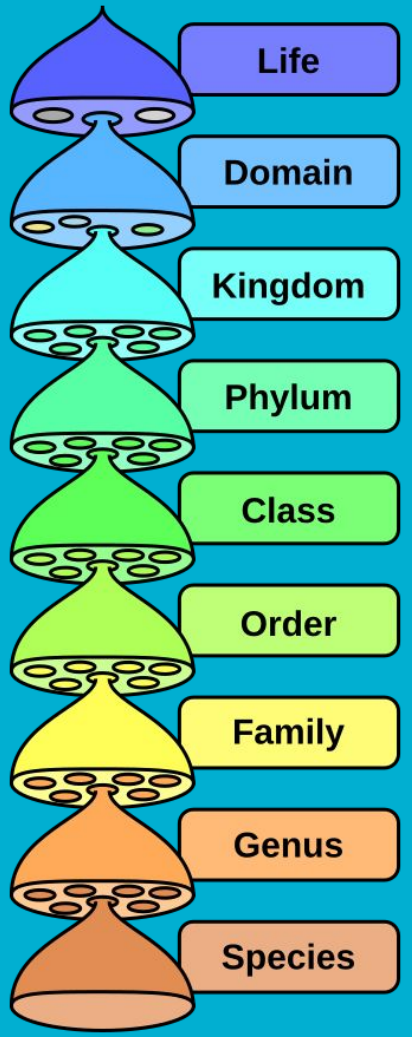
Another example, always starting from taxa classified by Linnaeus. Let's talk about the European honeybee. **Apis mellifera** is the binomial nomenclature to which we must add

Family: *Apidae*
Order: *Hymenoptera*
Class: *Insecta*
Phylum: *Arthropoda*
Kingdom: *Animalia*
Domain: *Eukaryota*



LINNAEUS AND THE CURRENT TAXA

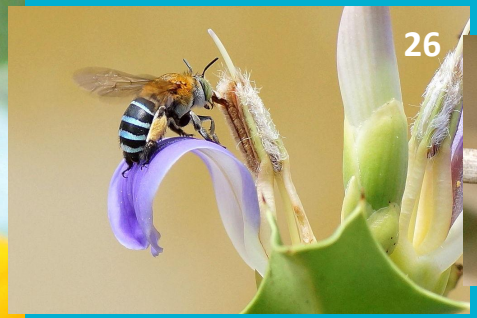
Before continuing with Linnaeus it is good to give more details in the given examples. Let's stay in the Apidae family. If everything is clear it will be easy to understand that they are a large family of hymenopteran insects. But what do they have in common in the family they belong to?



LINNAEUS AND THE CURRENT TAXA

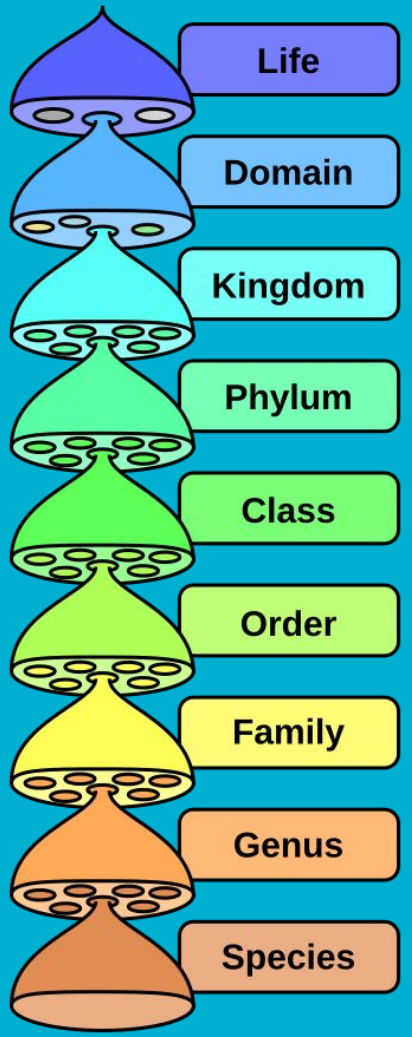
The **Apidae family** includes eusocial bees (genera Apis and Bombus), solitary bees, and kleptoparasitic bees. They all collect nectar and pollen.

Bombus (bumblebee)
Eusocial bee



Amegilla cingulata
Solitary bee

Nomada flava
Kleptoparasitic bee that has the habit of laying eggs in the nests of other insects



LINNAEUS AND THE CURRENT TAXA

And what does the **Hymenoptera order** have in common? The specimens are very different and have different behaviors but they all have two pairs of membranous wings.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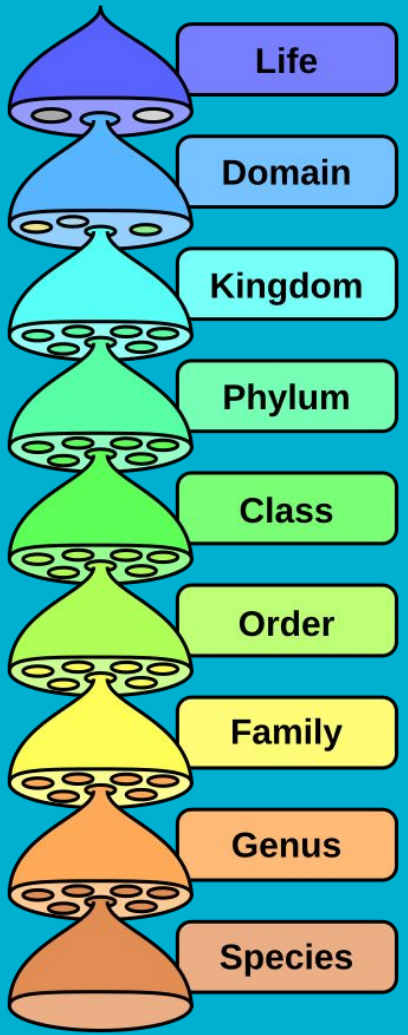
Aleiodes indiscretus


29

Pelecinus polyturator


30

Vespula germanica



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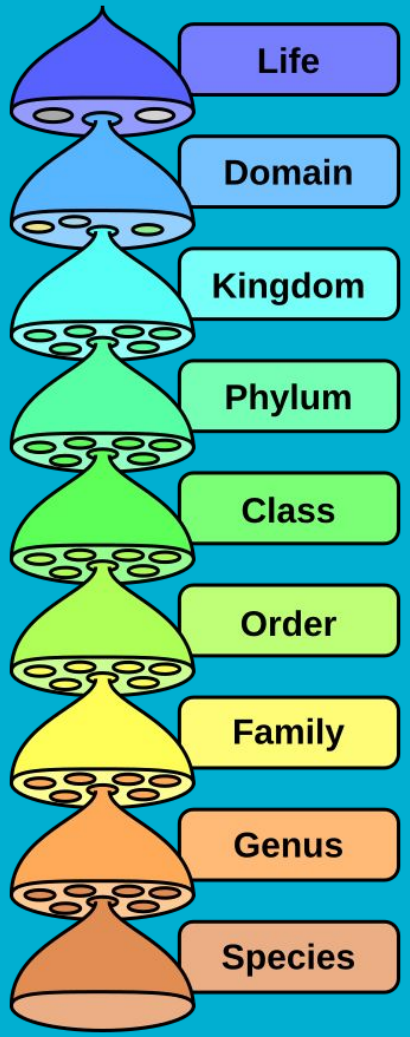
LINNAEUS AND THE CURRENT TAXA

And what unites all members of the insect class (Insecta)? Insecta was attributed by Linnaeus in 1758.

The body is divided into head, thorax and abdomen. And then there are 6 legs; all these are important features.



LINNAEUS AND THE CURRENT TAXA

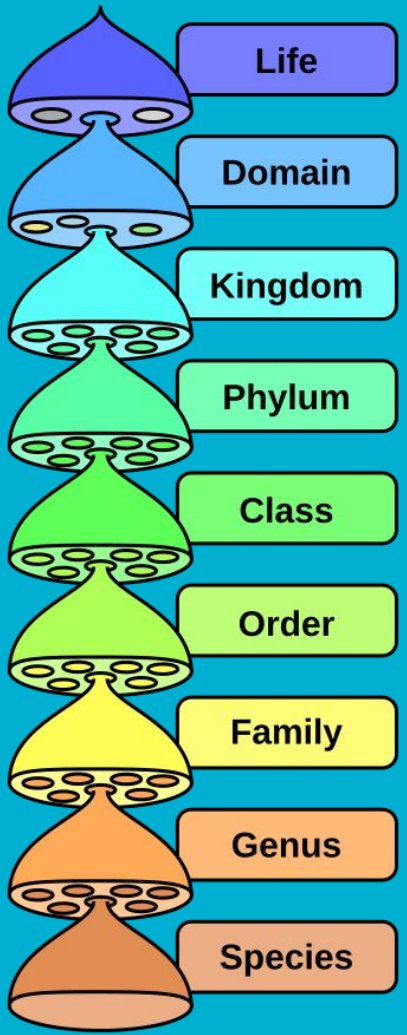
In fact, the number of legs and the body structure are some of the characteristics that allows us to classify the Arthropoda phylum into different subphyla and classes. Below some examples.

Apis mellifera
Insect (Insecta)

Araneus diadematus
Arachnida

Centipede
Myriapoda

Squilla mantis
Crustacean



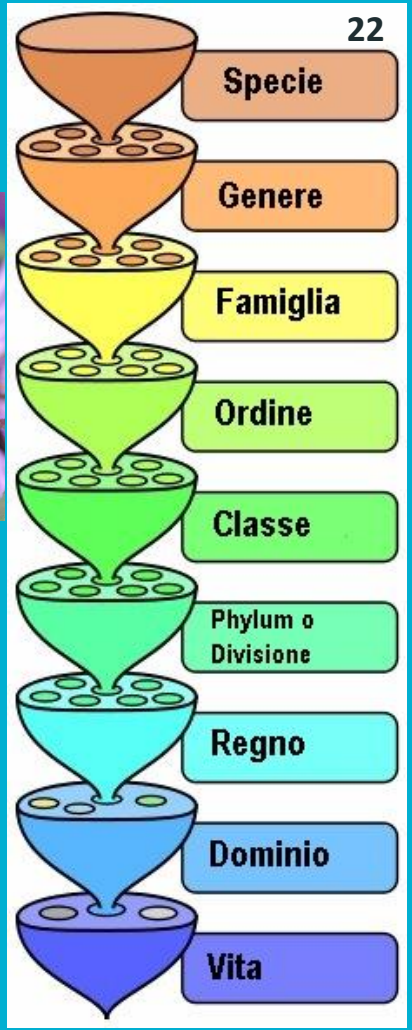
LINNAEUS AND THE CURRENT TAXA

Apis mellifera

It is part of the phylum **Arthropoda** like the other examples but the subphylum and class are different.

Apis mellifera
Insecta

Subphylum **Hexapoda**.
Body: divided into head, thorax and abdomen
Legs: 3 pairs associated with the thorax
Class **Insecta** In addition to the characteristics already mentioned, they have appendages such as antennae and wings.



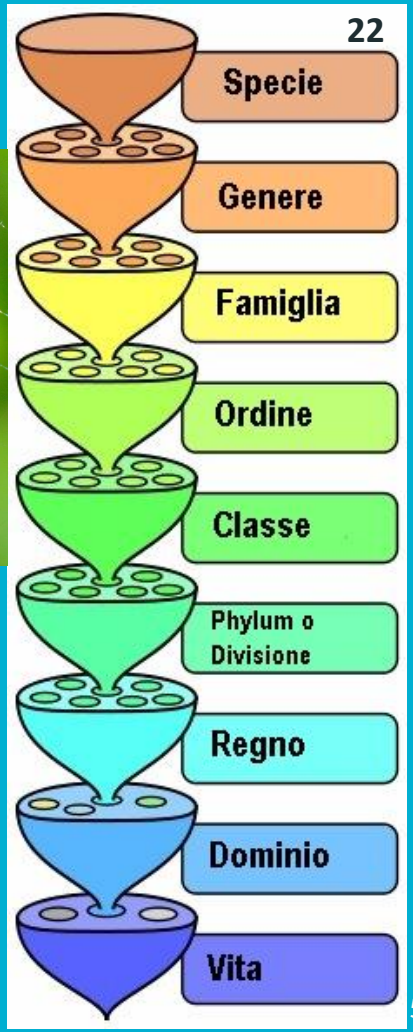
LINNAEUS AND THE CURRENT TAXA

Araneus diadematus
Arachnida

Araneus diadematus

Still phylum Arthropoda but let's see the rest of the classification.
Subphylum **Chelicerata**.

Body: divided into prosoma and opisthosoma
Legs: 4 pairs connected to the prosoma.
Other articulated appendages: chelicerae, pedipalps.
Class Arachnida. They do not have wings and antennae like insects.



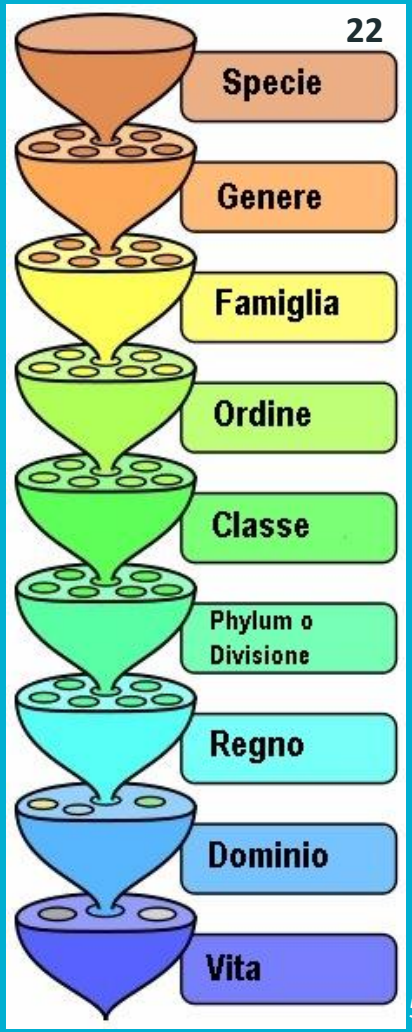
LINNAEUS AND THE CURRENT TAXA

Millipede

Phylum Arthropoda but very different characteristics from the previous subgroups.

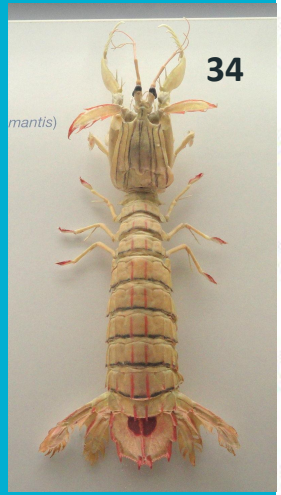
Millipede
Diplopoda

Subphylum **Myriapoda**.
Body: divided into several segments.
Legs: 1 or 2 pairs articulated to each segment.
Class Diplopoda. 2 pairs of legs associated with each segment.



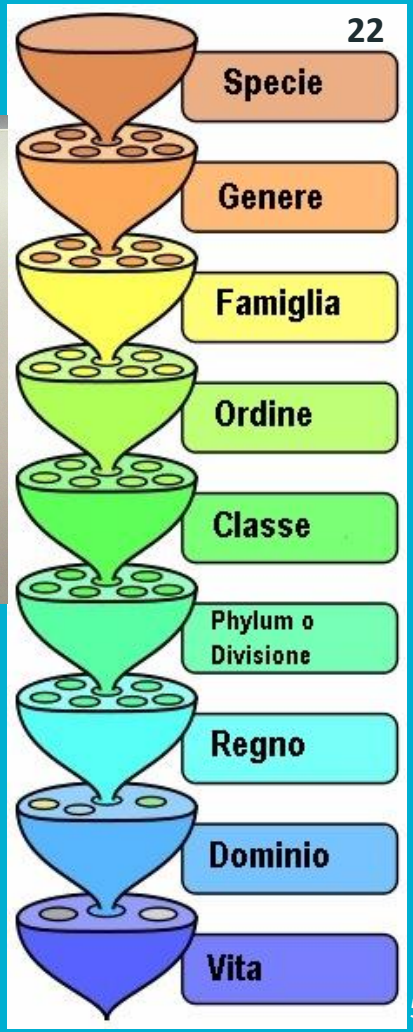
LINNAEUS AND THE CURRENT TAXA

Squilla mantis
Malacostraca



Squilla mantis Another example of Arthropoda phylum but with some typical characteristics. Subphylum **Crustacea**.

Body: divided into head, thorax and abdomen. Head and thorax are often fused. Each segment may have jointed appendages. Class Malacostraca. Body: divided into head, thorax and abdomen. Legs: 3 pairs jointed on the thorax plus various types of jointed appendages.



LINNAEUS AND THE CURRENT TAXA

Before continuing to examine the historical path of the classification of living beings, I want to point out an aspect that I always come across in my research on this subject.
Regarding the classification of arthropods as well as many other living beings, there may be differences between different linguistic versions of Wikipedia and even within the same scientific communities.
The following slides are dedicated to the reasons why this happens.

LINNAEUS AND THE CURRENT TAXA

Evolving science: the field of arthropod taxonomy is constantly evolving as new species are discovered and their genetic relationships are better understood. This can lead to changes in the way scientists classify and organize them. Different language versions of Wikipedia may be updated at different rates, reflecting the latest scientific consensus at various levels.
So it is worth checking the dates of external footnotes and links; but these checks are not always reassuring. Sometimes the links consulted are the same but the differences remain. We can only look at other reasons.

LINNAEUS AND THE CURRENT TAXA

Regional perspectives: distinct regions of the world have their own levels of research and expertise in certain arthropod groups. This could lead to regional biases in classification schemes, which could be reflected in different language editions of Wikipedia. Not only Wikipedia is involved, but several other scientific sources.

Language and cultural differences: slight differences in the classification schemes used in different language versions of Wikipedia may depend on the way scientific terms and concepts are translated.

LINNAEUS AND THE CURRENT TAXA

Alternative classification systems: so there is not always a single universally accepted classification system for arthropods and also for other living beings. Sometimes, different scientists or institutions might use classification systems based more on their research focus or preferred methodologies. Well, that's really the point.

An interesting read is provided by this site

Global taxonomy initiative

LINNAEUS AND THE CURRENT TAXA

For my slides I have essentially relied on the paper "A Higher Level Classification of All Living Organisms" by Michael A. Ruggiero and others (April 29, 2015) and relative correction (June 11, 2015) which I will also refer to at another point in this presentation.

However, one thing is certain,

THE UNIVERSALLY ACCEPTED CLASSIFICATION IS STILL BASED ON GENUS AND SPECIES BY LINNAEUS.

With this certainty we can continue our historical journey.

LINNAEUS (Part 2)

LINNAEUS (Part 2)

The **kingdom** for all the specimens considered starting from Apis mellifera is that of animals (**Animalia**).

At this point we can return to Linnaeus.

The basic rules adopted for the classification of plants (**Plantae**) were explained in part 1.

We must now see what criteria accompanied him in the classification of animals.

LINNAEUS (Part 2)

First of all he took into consideration the circulatory system, thus classifying animals based on its complexity. But Linnaeus did not limit himself only to circulatory system. He also evaluated the other systems, even if he attributed them an increasingly lesser importance. In order we have the reproductive and respiratory systems. Then the joints, the masticatory system, the sense organs, the integuments.

LINNAEUS (Part 2)

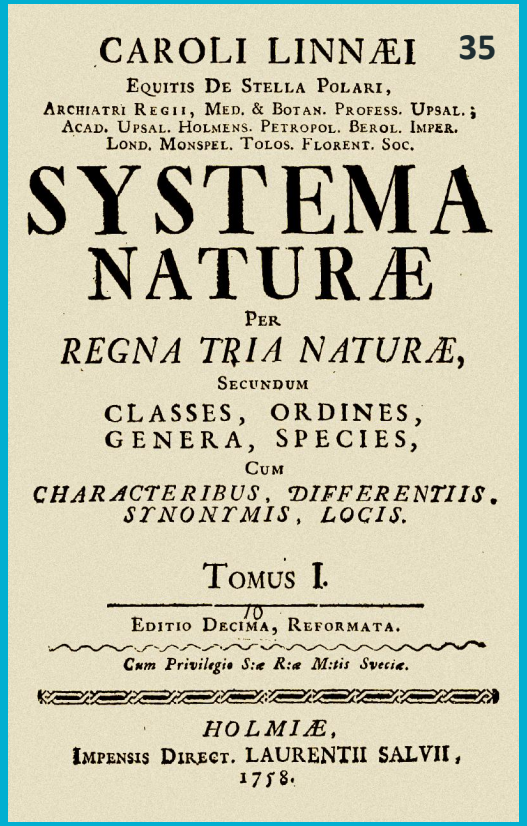
In this way he catalogued Cetaceans among Mammals.

Another important step to be attributed to him was to include man and monkeys among Primates.

Many of the terms still in use in the scientific environment and in the systematics relating to Biology and Botany were coined by him.

LINNAEUS (Part 2)

All this cataloguing work absorbed more than thirty years of his life and was the fruit of numerous scientific expeditions in Lapland, Sweden and then in various parts of the world. All his studies, his conclusions and his classifications are reported in the Systema naturae


CAROLI LINNÆI 35

EQUITIS DE STELLA POLARI,
ARCHIATRI REGII, MED. & BOTAN. PROFESS. UPSAL.;
ACAD. UPSAL. HOLMENS. PETROPOL. BEROL. IMPER.
LOND. MONSPEL. TOLOS. FLORENT. SOC.

SYSTEMA NATURÆ

PER
REGNA TRIA NATURÆ,
SECUNDUM
CLASSES, ORDINES,
GENERA, SPECIES,
CUM
CHARACTERIBUS, DIFFERENTIIS.
SYNONYMIS, LOCIS.

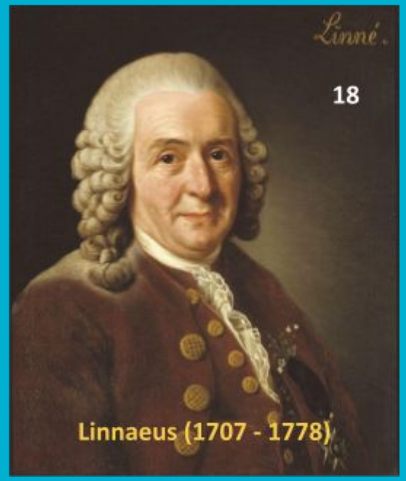
TOMUS I.

10
EDITIO DECIMA, REFORMATA.

Cum Privilegio S:æ R:æ M:tis Sveciæ.

HOLMIÆ,
IMPENSIS DIRECT. LAURENTII SALVII,
1758.

The first modern scientific classification of living beings



Linnaeus

2 kingdoms

1735

PLANTAE

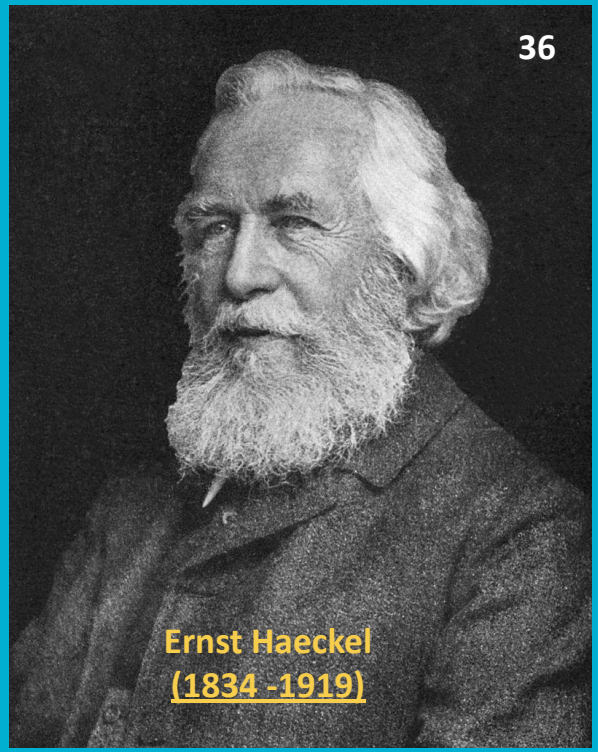
ANIMALIA

unique living forms known

ERNST HAECKEL

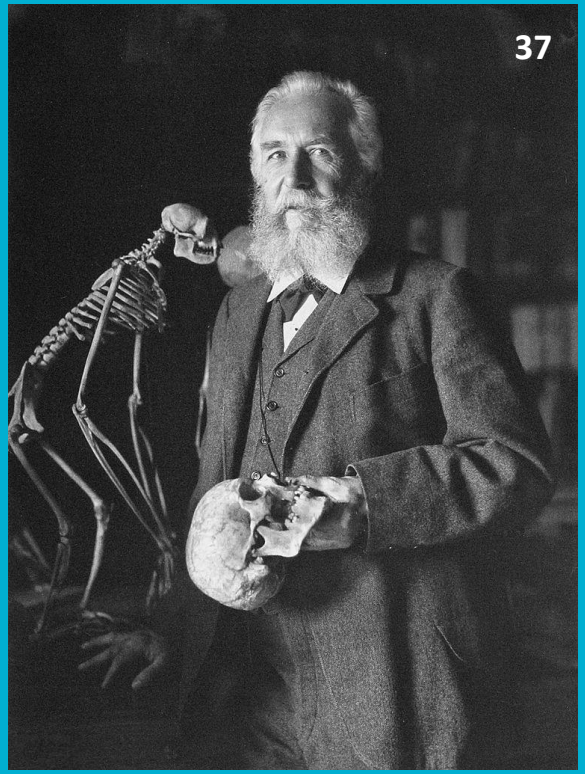
ERNST HAECKEL

For Linnaeus there were only two **kingdoms**: **Plantae** and Animalia. The introduction of the **third kingdom of Protists** (**Protista**) is due to Haeckel in 1866. He was a biologist specialized in marine biology, naturalist, professor of comparative anatomy, physician, philosopher and artist.



ERNST HAECKEL

This scholar is responsible for some terms that are still important in the scientific field such as phylum, ecology, stem cell ...
He described and classified numerous new species.
He was a supporter of Darwin's theory.



Ernst Haeckel

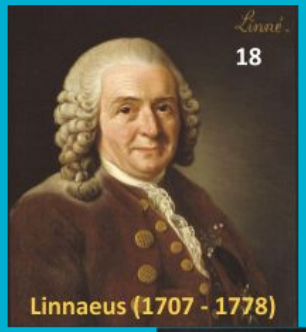
ERNST HAECKEL

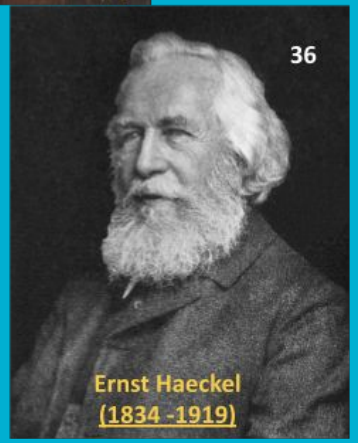
Being an artist he was also able to illustrate his scientific books independently. There are 100 of his detailed illustrations.

He is also remembered for many other theories that put him in conflict with important scientists of his time.

Sea Anemones by Ernst Haeckel

Haeckel's Three Kingdoms





Linnaeus	Haeckel
2 kingdoms	3 kingdoms
	PROTISTA
PLANTAE	PLANTAE
ANIMALIA	ANIMALIA

1866

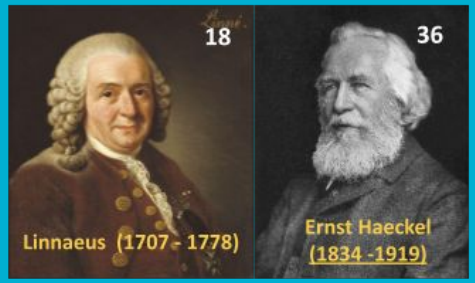
ÉDOUARD CHATTON

Édouard Chatton

Edouard Chatton (1883 - 1947), French biologist, specialist in marine biology and zoology, was the first to highlight the differences between **prokaryotic** and **eukaryotic** cell structure and to use these terms in 1925 in a scientific article.

His contribution to the study of protozoa, especially marine ones, was fundamental in the development of scientific knowledge.

THE TWO EMPIRES OF CHATTON



1925

Linnaeus	Haeckel	Chatton
2 kingdoms	3 kingdoms	2 empires
		PROKARYOTA
	PROTISTA	EUKARYOTA
PLANTAE	PLANTAE	
ANIMALIA	ANIMALIA	

HERBERT COPELAND

HERBERT COPELAND

Herbert Copeland (1902 - 1968), American biologist, was the first to introduce the **kingdom** of **Monera** (1966) which included bacteria and primitive algae both with a prokaryotic cell.

The taxonomic group of Monera had already been proposed by Ernst Haeckel but as a phylum. Chatton raised it to the rank of kingdom.

Copeland's Four Kingdoms

1938

Linnaeus	Haeckel	Chatton	Copeland
2 kingdoms	3 kingdoms	2 empires	4 kingdoms
	PROTISTA	PROKARYOTA	MONERA
		EUKARYOTA	PROTISTA
PLANTAE	PLANTAE		PLANTAE
ANIMALIA	ANIMALIA		ANIMALIA

ROBERT WHITTAKER

ROBERT WHITTAKER

Robert Whittaker (1920 - 1980). American biologist proposed (1969) his own classification, that was followed for decades, based on **five** **kingdoms**: **Monera**, **Protista**, **Fungi**, **Plantae** and **Animalia**. His system held up until investigations on living beings were done directly on RNA and DNA.

Whittaker's Five Kingdoms

Whittaker

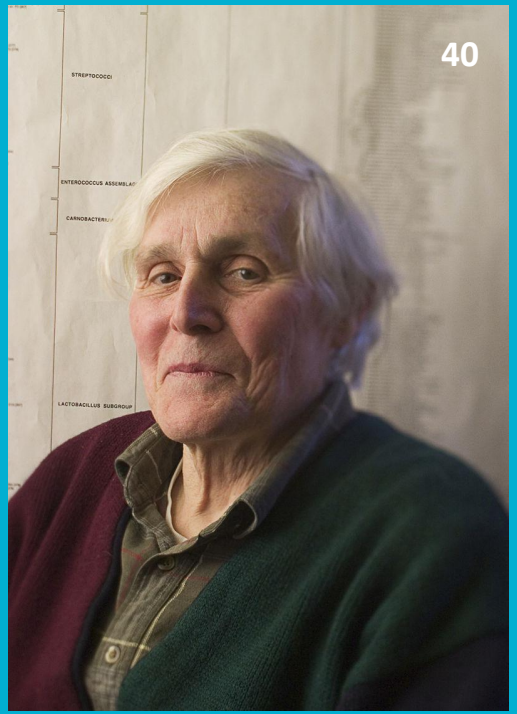
1969

Linnaeus	Haeckel	Chatton	Copeland	Whittaker
2 kingdoms	3 kingdoms	2 empires	4 kingdoms	5 kingdoms
	PROTISTA	PROKARYOTA	MONERA	MONERA
		EUKARYOTA	PROTISTA	PROTISTA
PLANTAE	PLANTAE		PLANTAE	FUNGI
				PLANTAE
ANIMALIA	ANIMALIA		ANIMALIA	ANIMALIA

CARL WOESE

CARL WOESE

Carl Woese (1928 - 2012). American microbiologist and biophysicist. His fame is mainly due to the fact that he divided Whittaker's kingdom **Monera** into the two kingdoms of Archaebacteria and Eubacteria. Archaebacteria had always been considered part of Bacteria.

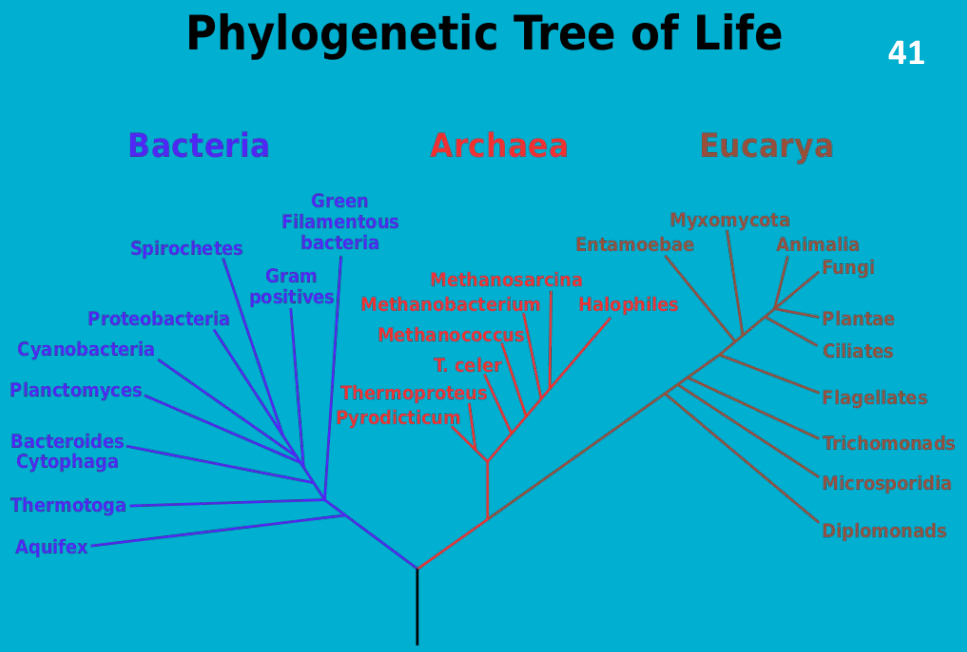


Woese's Six Kingdoms (1977)

Linnaeus	Haeckel	Chatton	Copeland	Whittaker	Woese
2 kingdoms	3 kingdoms	2 empires	4 kingdoms	5 kingdoms	6 kingdoms
		PROKARYOTA	MONERA	MONERA	ARCHAEBACTERIA
					EUBACTERIA
	PROTISTA	EUKARYOTA	PROTISTA	PROTISTA	PROTISTA
PLANTAE	PLANTAE		PLANTAE	FUNGI	FUNGI
				PLANTAE	PLANTAE
ANIMALIA	ANIMALIA		ANIMALIA	ANIMALIA	ANIMALIA

CARL WOESE

This happened in 1977, so a few years after Whittaker's proposal.
In 1990 he revolutionized everything with the phylogenetic tree of life (here on the side) in which all living beings had to be divided into **three domains**



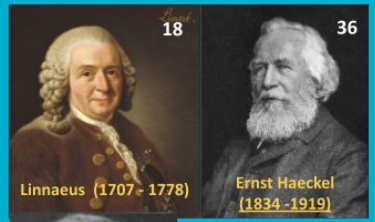
CARL WOESE

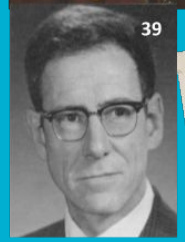
The real revolution of his proposal lies in the fact that his classification is not based on morphological similarities between organisms but on their genetic relationships.

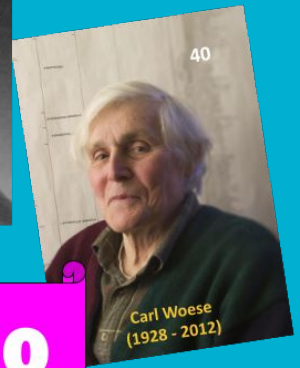
Woese arrived at these conclusions because he was a pioneer of molecular phylogenetic techniques applied to 16S ribosomal RNA. This technique is now a routine procedure in laboratories that deal with taxonomic research.

Woese was also a firm believer in the theory that the first nucleic acid to appear on Earth was RNA and not DNA

Woese's Three Domains (1990)







1990

Linnaeus	Haeckel	Chatton	Copeland	Whittaker	Woese	Woese
2 kingdoms	3 kingdoms	2 empires	4 kingdoms	5 kingdoms	6 kingdoms	3 domains
	PROTISTA	PROKARYOTA	MONERA	MONERA	ARCHAEBACTERIA	ARCHAEA
					EUBACTERIA	BACTERIA
		EUKARYOTA	PROTISTA	PROTISTA	PROTISTA	EUCARYA
PLANTAE	PLANTAE		PLANTAE	FUNGI	FUNGI	
				PLANTAE	PLANTAE	
ANIMALIA	ANIMALIA		ANIMALIA	ANIMALIA	ANIMALIA	

THOMAS CAVALIER-SMITH

THOMAS CAVALIER-SMITH

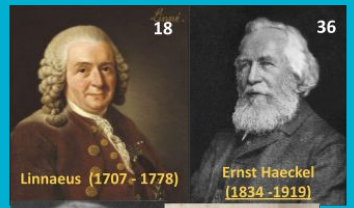
Thomas Cavalier-Smith (1942-2021) was a professor of evolutionary biology.
His studies have led to the identification of a new **kingdom**, **Chromista**. It includes unicellular and multicellular organisms with eukaryotic cells, mostly photosynthetic but some of them heterotrophs.

Organism belonging to the order Chromista

THOMAS CAVALIER-SMITH

This biologist is responsible for several classification proposals. The first dates back to 1993. He initially decided to divide the **kingdom** of Protista into **Protozoa** with mitochondria and **Archeozoa** without mitochondria. His in-depth studies on these unicellular organisms had led him to consider that protists without mitochondria could be archaic forms that had not yet been able to include mitochondria as endosymbionts.

Cavalier-Smith's Eight Kingdoms (1993)

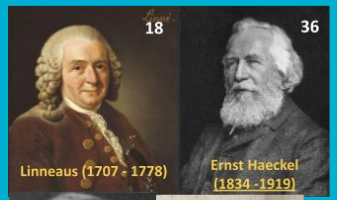


Linnaeus	Haeckel	Chatton	Copeland	Whittaker	Woese	Woese	Cavalier Smith
2 kingdoms	3 kingdoms	2 empires	4 kingdoms	5 kingdoms	6 kingdoms	3 domains	8 kingdoms
	PROTISTA	PROKARYOTA	MONERA	MONERA	ARCHAEBACTERIA	ARCHAEA	ARCHAEBACTERIA
					EUBACTERIA	BACTERIA	EUBACTERIA
		EUKARYOTA	PROTISTA	PROTISTA	PROTISTA	EUCARYA	ARCHEZOA
							PROTOZOA
							CHROMISTA
PLANTAE	PLANTAE		PLANTAE	FUNGI	FUNGI		FUNGI
				PLANTAE	PLANTAE		PLANTAE
ANIMALIA	ANIMALIA		ANIMALIA	ANIMALIA	ANIMALIA		ANIMALIA

THOMAS CAVALIER-SMITH

After only 5 years he proposed a second classification going from 8 to 6 **kingdoms**. The changed numbers derive from the fact that the scholar, after further investigation, decided to unify **Bacteria** and **Archaebacteria** under the single kingdom of **Bacteria**. The same operation for **Protozoa** and **Archaezoa** reunited in the single group of **Protozoa**.

Cavalier-Smith's Six Kingdoms (1998)



1998

Linnaeus	Haeckel	Chatton	Copeland	Whittaker	Woese	Woese	Cavalier Smith	Cavalier Smith
2 kingdoms	3 kingdoms	2 empires	4 kingdoms	5 kingdoms	6 kingdoms	3 domains	8 kingdoms	6 kingdoms
	PROTISTA	PROKARYOTA	MONERA	MONERA	ARCHAEBACTERIA	ARCHAEA	ARCHAEBACTERIA	BACTERIA
					EUBACTERIA	BACTERIA	EUBACTERIA	
		EUKARYOTA	PROTISTA	PROTISTA	PROTISTA	EUCARYA	ARCHEZOA	PROTOZOA
							PROTOZOA	
							CHROMISTA	CHROMISTA
PLANTAE	PLANTAE		PLANTAE	FUNGI	FUNGI		FUNGI	FUNGI
				PLANTAE	PLANTAE		PLANTAE	PLANTAE
ANIMALIA	ANIMALIA		ANIMALIA	ANIMALIA	ANIMALIA		ANIMALIA	ANIMALIA

THOMAS CAVALIER-SMITH

In 2015, however, he partially retraced his steps, reintroducing the initial subdivision of bacteria.

Ruggiero's classification, in the next slide, refers to this last phase of his studies. Ruggiero was one of his collaborators.

Ruggiero's Seven Kingdoms (2015)

Linnaeus	Haeckel	Chatton	Copeland	Whittaker	Woese	Woese	Cavalier Smith	Cavalier Smith	Ruggiero
2 kingdoms	3 kingdoms	2 empires	4 kingdoms	5 kingdoms	6 kingdoms	3 domains	8 kingdoms	6 kingdoms	7 kingdoms
		PROKARYOTA	MONERA	MONERA	ARCHAEBACTERIA	ARCHAEA	ARCHAEBACTERIA	BACTERIA	ARCHAEBACTERIA
					EUBACTERIA	BACTERIA	EUBACTERIA		EUBACTERIA
	PROTISTA	EUKARYOTA	PROTISTA	PROTISTA	PROTISTA	EUCARYA	ARCHEZOA	PROTOZOA	PROTOZOA
							PROTOZOA		
							CHROMISTA	CHROMISTA	CHROMISTA
PLANTAE	PLANTAE		PLANTAE	FUNGI	FUNGI		FUNGI	FUNGI	FUNGI
				PLANTAE	PLANTAE		PLANTAE	PLANTAE	PLANTAE
ANIMALIA	ANIMALIA		ANIMALIA	ANIMALIA	ANIMALIA		ANIMALIA	ANIMALIA	ANIMALIA

PATRICK J. KEELING

PATRICK J. KEELING

Patrick J. Keeling (born in 1969) is a biologist, expert in protists.
His studies, based on genomics and molecular evolution, could change the most accredited proposals for the classification of living beings.
We'll see.

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