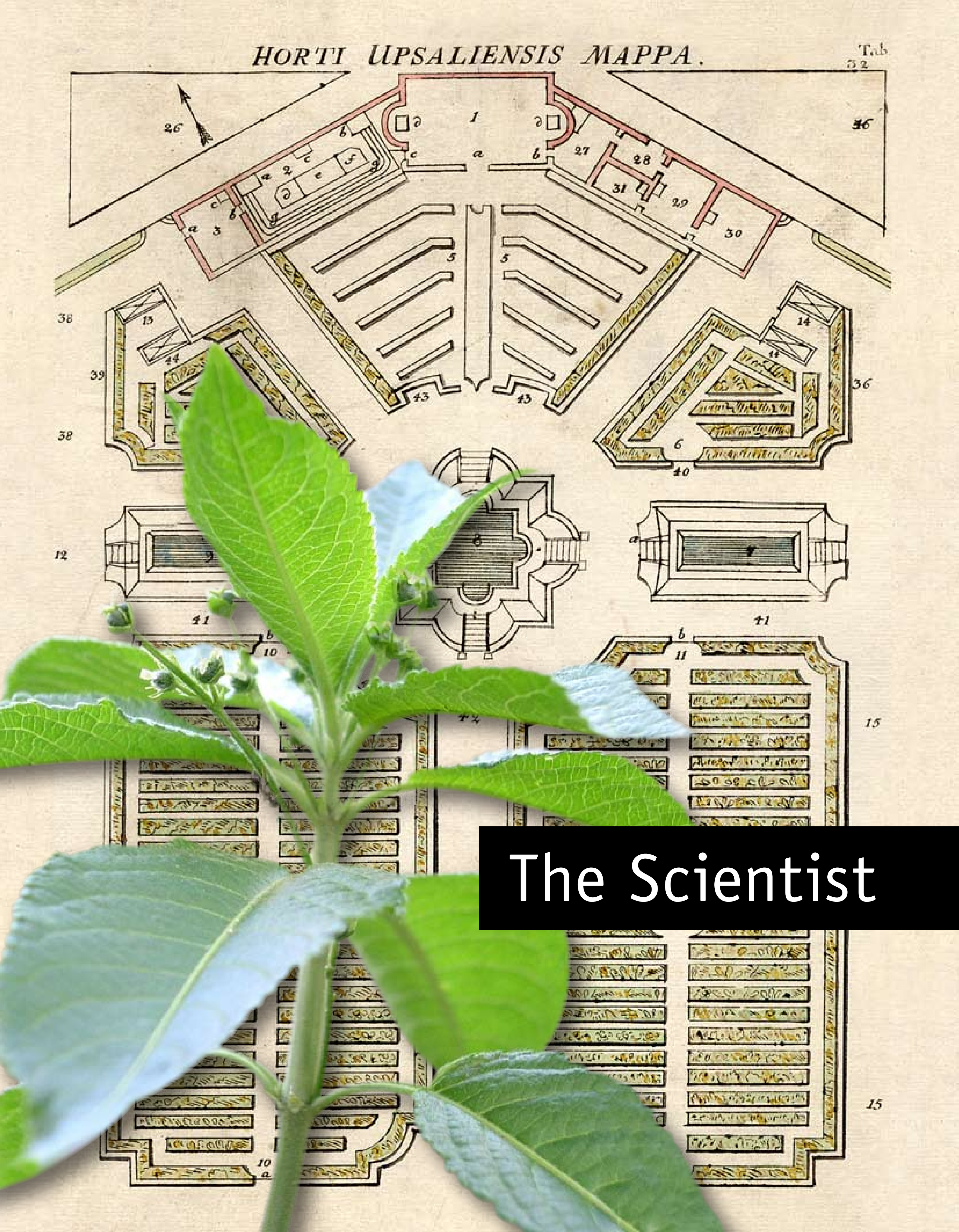
The Scientist

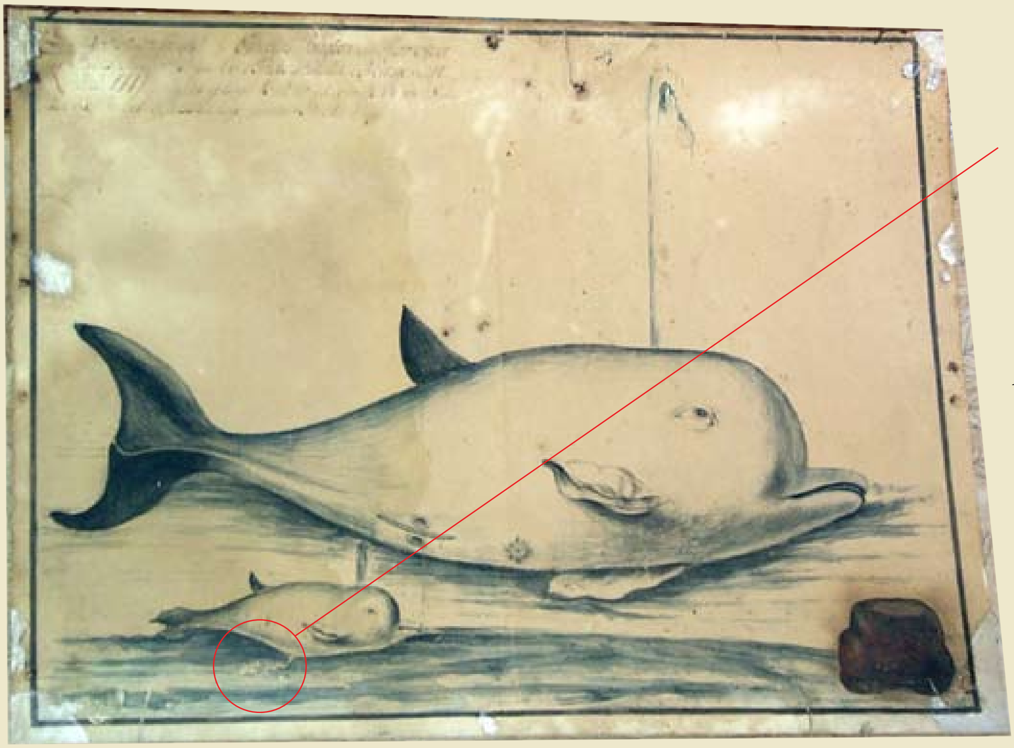


From a Flourishing Sex-life to Modern DNA Technology

Linnaeus the Scientist

All of a sudden you are standing there, in the botanic garden that is to be Linnaeus's base for a whole lifetime of scientific achievements. It is a beautiful spring day in Uppsala, the sun's rays warm your heart as cheerfully as in your own 21st century. The hustle and bustle of the town around you break into the centrally located garden. Carriage wheels rattle over the cobblestones, horses neigh, hens cackle from the house yards. The acrid smell of manure and privies bears witness to a town atmosphere very different from your own.

You cast a glance at what is growing in the garden. The beds do not look particularly well kept. In fact, the whole garden gives a somewhat dilapidated impression. Suddenly, in the distance, you see a young man squatting down by one of the beds. He is looking with great concentration at a small flower, examining it closely through a magnifying glass. When he lifts his head for a moment and ponders, you recognise him at once. It is Carl von Linné, or Carl Linnaeus as he was originally called. He looks very young, just over 20 years old. His pale cheeks tell you that it has been a harsh winter. His first year as a university student at Uppsala has been marked by a lack of money for both food and clothes as well as for wood to warm his rented room.



A painting from Linnaeus's time, now in his study at Hammarby, representing a whale with its young. It contains a small detail that led Linnaeus to transfer the whales to a new class that he called Mammalia. Previously, people had believed that whales were fish. What at first looks like a jet of water is actually the umbilical cord.

Now an elderly man is walking along the garden path. His fine clothes and way of walking tells you that he is a prosperous man of high rank. He stops alongside the young Linnaeus and starts a conversation, asking what the young student is doing in the garden. Linnaeus talks enthusiastically about his studies, his botanical interests and that he has already collected more than 600 plants in his own herbarium. He names a number of the plants in the bed without hesitation. The elderly man is deeply impressed and invites the student to his house.

Suddenly, you hear a cheerful voice just behind your shoulder. You turn round and stand face to face with a smiling Linnaeus, but not the young man you recently saw at a distance. It is the same Linnaeus who took you on an excursion across fields and meadows in the countryside not so long ago "How opportune that you could witness this important event in my life!" he exclaims, without any further greeting. He explains that the chance meeting in the botanic garden with the wealthy dean and amateur botanist Olof Celsius was extremely valuable for him as a student. Celsius offered the young Linnaeus free board and accommodation as well as access to his extensive library.

You study the sturdy figure before you inquisitively and wonder how old he really is, here and now. It seems to be impossible to find the answer in his features. His lively face reflects a young man's eagerness and playfulness but at the same time reveals in some remarkable way a discerning and established scientist with many years of research behind him. The bright, brown eyes return your look intensely. "Does it really matter?" Linnaeus laughs, in answer to the question you have never actually asked. "I am as young as I am old, as new-born as I am dead, perhaps I am even timeless. An impossible condition, don't you think?" he asks with a gleeful smile.

Without waiting for your reply, he changes the subject, saying that he wants to talk to you about some important scientific contributions he has made. Suddenly, you realise that the garden has changed around you and that you are now standing in the most organised of all worlds. You have both moved on from that day in 1719 to the 1740s. When Linnaeus was made a professor in 1741, he began a real improvement of the unkempt garden. You note that it is now well-kept and stylish, full of symmetry. The straight paths form right-angled patterns of neat beds in which a great variety of different species are carefully placed in groups in order to reflect the classes in Linnaeus's sexual system.

You both squat down in front of a flowerbed. Linnaeus eagerly explains how his sexual system makes it possible in a simple way to find out what kind of plant you have in your hand. This system brings order to the chaos of many new species that 18th-century scientists were faced with when both the home environment and distant countries were being explored with inexhaustible energy. Earlier systems used to determine species were not as simple and reliable, with the result that it was not possible to know whether different scientists were describing different species or in actual fact the same species. Linnaeus points to a beautiful plant in the bed at your feet, a wild tulip with a bright yellow flower.

"Look at this. You can clearly see that this wild tulip has six stamens. So it belongs to Class VI. Simple, isn't it? By the way, you write the classes with Roman numerals," says Linnaeus. "And over there, for example, is the wood anemone species. That species belongs to Class XIII. Now, you'd think it must have 13 stamens, but it's not as easy as that. The straightforward logic of the number of stamens works up to Class X, but after that the classification is a little different," Linnaeus explains.

He points out with almost childish enthusiasm that his system has gained a great many supporters among prominent scientists in many countries. But he is not so willing to mention his critics. This system divides the whole plant world into 24 classes. The flowering plants comprise 23 classes and the starting point for their classification is the number of stamens a plant has and how the stamens are placed round the pistil. The 24th class consists of plants that have no flowers, for example, mosses. The classes can in turn be divided into categories, principally on the basis of the flowers' pistils.

Then he explains that, as the system is based on stamens and pistils, that is, the plants' reproductive organs, it seemed natural to him to call his invention the sexual system. Maybe this term also amused him to the same degree that it shocked some of his contemporaries, you think to yourself.

A young man with an appetite for life is probably quite interested in sex. Linnaeus smiles broadly. "Do you know what I call the various classes, so as to sort of clarify the whole system? he asks. "Well, for example, Class V is called Five men in the same marriage, and Class VI Six men in the same marriage. And my first university paper was called *Praeludia Sponsaliorum Plantarum*, which means "On the Foreplay to the Wedding of Plants".

He looks at you elatedly, to note your reaction. But in the next breath, he explains that terms like wedding, wedding bed and foreplay were not so revolutionary in botanic contexts as it might seem. There were other scientists before him who were thinking along the same lines, that is, drawing parallels between human sex life and plant reproduction. What Linnaeus did that was unique was to invent an easily manageable system for determining species and to tirelessly drive it through in a consistent manner for several thousand species. And the fact that the terms he used alluded to sex can hardly have reduced the publicity value of the new system.

Linnaeus stretches his legs, straightens his back and looks contentedly at the whole garden: annuals, perennials, medicinal plants, other useful plants, ponds full of wetland plants. And at the back, the beautiful orangery, housing plants from tropical countries. Perhaps there are as many as 3,000 species collected together in this garden. It is not strange that, under Linnaeus's management, it is one of the foremost botanic gardens in Europe.

You stroll a while along the broad central path and stop at the bed where the wood anemone grows. Linnaeus asks you if you know its scientific name. Before you can open your mouth, he chants *Anemone seminibus acutis foliolis incises caule unifloro,* and tells you at once that it means Anemone with pointed seeds, indented leaves and a solitary flower. He shakes his head at the complicated name and says that there are even worse examples of long scientific names. Then he smiles a little secretively and lowers his voice. His eyes shine as he reveals his plans to introduce a much simpler way of naming species. Instead of being obliged to learn long, descriptive names, it is possible to build up a system on a two-name principle. Each species would have a family name and a species name. "More or less like a surname and a Christian name!" you add. "Exactly, and this idea can be applied to all plants and the whole animal kingdom too," Linnaeus continues enthusiastically.

You lay your hand on his shoulder and tell him that the binomial principle has been a long-term success used all over the world even in your own 21st century. However, the sexual system of plants is no longer so valid, as it is an artificial system that does not attempt to reflect the relationship of species to each other. Instead, the modern system is based on dividing species into groups according to how closely related they are, you explain. Linnaeus does not seem to be all that disappointed to hear this. He himself was aware at an early stage that his sexual system was artificial, but what was important for him was to create a system that made it simple to identify species. "All research is a continuous process of development," you point out, at the same time as you emphasise that Linnaeus's work has to be seen in the light of the stage of scientific advance in the 18th century and what the practical conditions were.

Suddenly, you have a bright idea and fish out your cellphone. You explain that you are going to call a modern professor whom Linnaeus would certainly like to talk to. While you hope and pray that the operator has unusually good coverage, Linnaeus looks inquisitively at the phone's many small buttons. You tell him that the professor is Ulfur Arnason and that he is researching evolutionary molecular systems at Lund University, an awkward term, perhaps, but all the more exciting. His research is focused on finding out the relationship between various animal species with the aid of DNA technology.

Finally, Ulf Arnason answers the phone in another time warp. You turn on the loudspeaker, Linnaeus says Hello and Arnason immediately starts to describe the work of his research group. He explains that DNA technology has been of great significance for the modern system, for both animals and plants. "For example, new discoveries show that the whale's nearest relation is the hippopotamus," he says. The technology is the same whether one is investigating animals or plants. You have to pick out and analyse genetic material, DNA, from cells of different species and then examine the difference between the species. Species with the least genetic difference are the most closely related. Detective work at the molecular level.

Linnaeus listens attentively. He himself was the driving force for improving the system for the animal kingdom and not only in botany. For example, he moved whales and bats to the mammals. Previously, 18th-century scientists generally believed that whales belonged to the fish group and bats belonged to the bird group. Linnaeus was also bold enough to place human beings and apes in a common group in the animal kingdom. "I did that already in the first edition of *Systema Naturae* in 1735," he says into the phone.

"Well, the history of human development is still an extremely exciting and sensitive subject, you know," Arnason replies with a smile. According to the present theories, the common line of development for humans and our closest relative, the chimpanzee, divided about five million years ago. But Ulfur Arnason and his research group have calculated that humans and chimpanzees must have separated much earlier, at least eight million years ago.

In many scientific circles, this calculation is considered controversial, but Arnason takes the criticism lightly and finds it natural that old truths are revised. "In our research group we don't actually know if we are right about the actual point in time that we propose with our calculation. The only thing we know is that our results reject the existing truth," he says.

Then he focuses on the very core of scientific method, whatever the subject being researched. A scientist can never claim to have found the final truth but can only repudiate an existing truth by demonstrating analytical faults, or faults in the underlying data, he explains. In other words, research can never show that a theory is the final right one, only that one theory is better than another. "So, as a researcher you must never fall in love with a theory for sentimental reasons," says Arnason.

Then Linnaeus and you round off the conversation with the professor from Lund and thank him for all his information. But when you start to put the cellphone away, Linnaeus grabs your wrist. He looks you intensely in the eye, says that it was fascinating to hear about millions of years being tossed in the air and then wonders if it would be possible to call a geology researcher to discuss the age of the earth. You nod and smile – realising that this is going to be an expensive afternoon.

What the Swedish 100-kronor Note Tells us About Linnaeus

Maybe you have never seen a Swedish 100-kronor note, but you can see one on the opposite page. If you look closely at it, you will certainly recognise the portrait of Carl Linnaeus. The name Carl von Linné and the dates 1707-1778 are in small print in the right-hand corner, but what else can you see?

On the left of the portrait are the drawings of two plants. They are taken from Linnaeus's first essay as a student at Uppsala: *Praeludia Sponsaliorum Plantarum*, "On the Foreplay to the Wedding of Plants", written in 1729. This essay describes the sexual life of plants.

The drawings are of the dog's mercury, *Mercurialis perennis*, which grows wild in fertile and shady places in northern Europe, in Sweden as far north as Stockholm. It is a perennial, grows with a creeping root and has the male and female flowers on separate plants. There are plenty of dog's mercuries in the park at Hammarby, Linnaeus's farm near Uppsala. We might guess that he moved a plant from the University Garden in Uppsala. Perhaps it is the same genetic specimen growing in the park now that Linnaeus drew in his essay. It was well known among botanists in Linnaeus's time that this plant had male and female organs. Linnaeus realised that the plants' stamens and pistils were often uniform in number and appearance and could therefore be used to categorise plants systematically. Dog's mercury is well chosen as the starting point for the presentation of the sexual life of plants since it is dioecious, that is, it has separate sexual organs. A comparison with humans is therefore obvious. Linnaeus expressed the idea by saying that men and women live in separate bridal chambers and dwellings.

There are many details to be discovered on the 100-kronor note, for example, more drawings by Linnaeus and a plan of the University Garden from 1745.

Female dog's mercury plant

Male dog's mercury plant

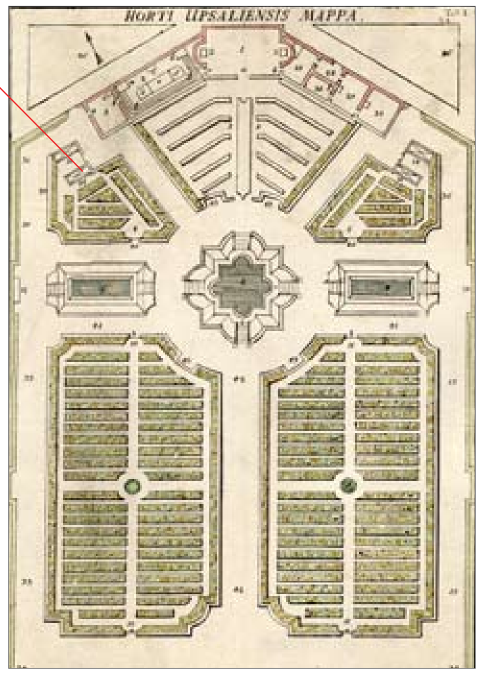
Drawing by Linnaeus on the left of the Swedish 100-kronor note (from Praeludia Sponsaliorum Plantarum, 1729, pages 81 and 87). Top left is a male dog's mercury plant and on the right a female plant. Under the male plant is a flower with its sepals, petals, stamens and pistils. Under the female plant is an egg and below it to the left a seed.

On the 100-kronor note and below to the left is a plan of the University Garden. This garden was used as a teaching garden for students. Apart from many thousands of plants here, Linnaeus had many exotic animals including peacocks, parrots, monkeys and a much loved racoon called Sjupp. Today's Linnaeus Garden is in the same place and the plants are placed according to Linnaeus's sexual system in the same way as in Linnaeus's time.

Linnaeus's motto, "omnia mirari etiamtritissima", (wonder at everything, even the most everyday things)

Portrait of Linnaeus after a painting by the Swedish 18th-century artist Alexander Roslin.

The orangery in Linnaeus's Garden



Plan of the University Garden from 1745

Scientific Thoughts

Knowledge is built up successively – tested and retested – and one piece of the puzzle is added to the next in the building of scientific knowledge. This has been many people's picture of science up to now, but has the public's view of the possibilities for science and research to explain the world changed? Scientific disputes are common and there are not always obvious answers. Yet it is becoming increasingly important to develop the knowledge society and we talk about life-long learning. How shall we orientate ourselves in the boundless mass of information that pours over us?

Think back to Linnaeus's time and try to forget our modern society with electricity, opportunities for communication both physically by car, train or plane and over the Internet. Do not forget, however, to retain respect for the scientists of that time, their ability to think and draw conclusions, their commitment and optimism.

What actually did people know in Linnaeus's time? Before molecular biology's charting of human DNA, before ecology had permeated biological thinking, before classical genetics' understanding of heredity, before Darwin and the theory of evolution…

Linnaeus's ambition was to describe and name all living plants and animals, and he stands out as the father of systematics, but later he realised that there were more living organisms than he would ever be able to study. Even with today's resources we realise that it is impossible to describe all the species on earth.

In physics, Newton's mechanical world ruled, while chemistry did not begin to develop as a separate science until the 18th century. Sweden was prominent in chemistry at an early date, with the apothecary Carl Wilhelm Scheele as the leading light. In the late 18th century Scheele produced and identified oxygen and showed that air is not an element but contains nitrogen and oxygen.

In Linnaeus's time, no one knew about the movement of continental plates or that Sweden had been covered with ice. Linneaus and his contemporaries believed that land elevation, which is due to the inland ice, was caused by the level of water in the oceans sinking. The general understanding was that the world was about 6,000 years old, but as fossils and layers of rocks began to be studied, people realised that the earth must be considerably older. Linnaeus, too, wondered about fossils, which seemed to belong to the sea, and the for-

In Linnaeus's treatise of 1759 "Bisexual Reproduction", there are interesting openings for comparison between the knowledge people had in his time and in our own time.

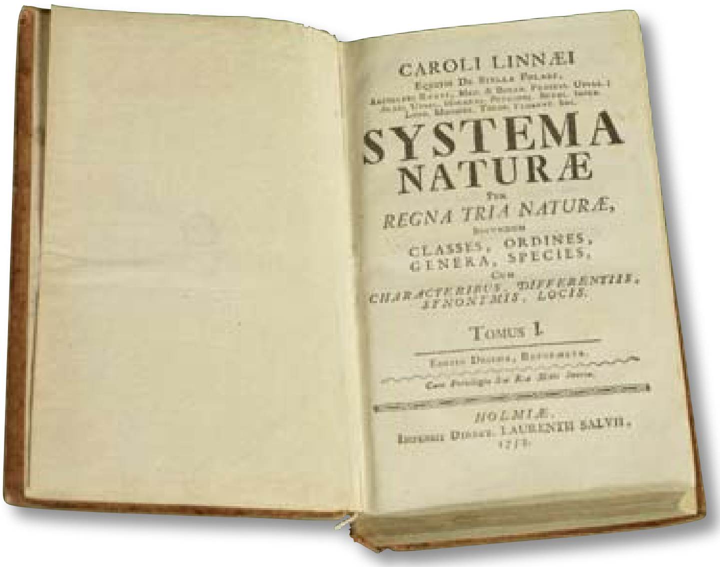
"*The reproduction of animals and plants is Nature's finest and most hidden phenomenon. All researchers of Nature up to now have energetically sought after the origin of life and the source of all life, but no one so far has been able to find it.*"

"*Just as it is indubitably so that without eggs no reproduction can take place, it is certain that no egg can become fertile without male seed. But why this is so indispensable, in what way the two sexes combine and with how much each sex contributes are questions to which no one has yet been able to provide answers, although many have sought eagerly after them*"

In Linnaeus's time people began to understand how reproduction works, but a great deal was still unclear. What would you tell Linnaeus about reproduction and heredity if you had a chance to explain what we know today?

At the end of the 17th century, Antonie van Leeuwenhoek, a skilful Dutch constructor of microscopes, made microscopes with a magnification of up to 500 times. He studied seminal fluid and observed tiny, moving objects that he called "seed worms". He thought that a seed worm could penetrate the egg. Linnaeus studied seminal fluid from dogs in a microscope and saw the "seed worms", but unlike Leeuwenhoek he did not consider that they were alive, with their own ability to move; he thought they were merely floating around in the fluid. But Linnaeus, too, thought that they were "the active substance in male seed."

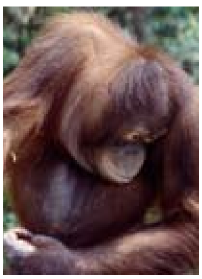
What was it that Leeuwenhoek and Linnaeus saw in the microscope? Who was right, Linnaeus or Leeuwenhoek? Explain how the "seed worms" can move.



mation of layered rocks. Yet he never doubted that God was the Creator of the earth and all its living organisms.

The next chapter about Linnaeus the doctor mentions his doctoral thesis on malaria. He presents many causes of this disease that he has heard from various quarters but rejects them all by logical proof. He himself asserts that malaria must have some connection with wetlands, which he proves by means of his own observations. So far this agrees with our own knowledge today. But it was not until the late 19th century that the malarial parasite was discovered and people understood the significance of the malarial mosquito. Different pieces of the puzzle were put together in this way to provide a valid explanation.

Linnaeus lived in a period of transition in science. His works (including his travel journals) often present a modern, scientific way of reasoning in which he tests and rejects popular misconceptions and superstitions. In other contexts, however, he presents uncritically cock and bull stories about remarkable human-like beings that he has heard about from travellers from distant lands. He evaluates and re-examines the medicinal properties of various plants but prescribes medicines that are prepared from strange ingredients according to traditions handed down over the centuries.

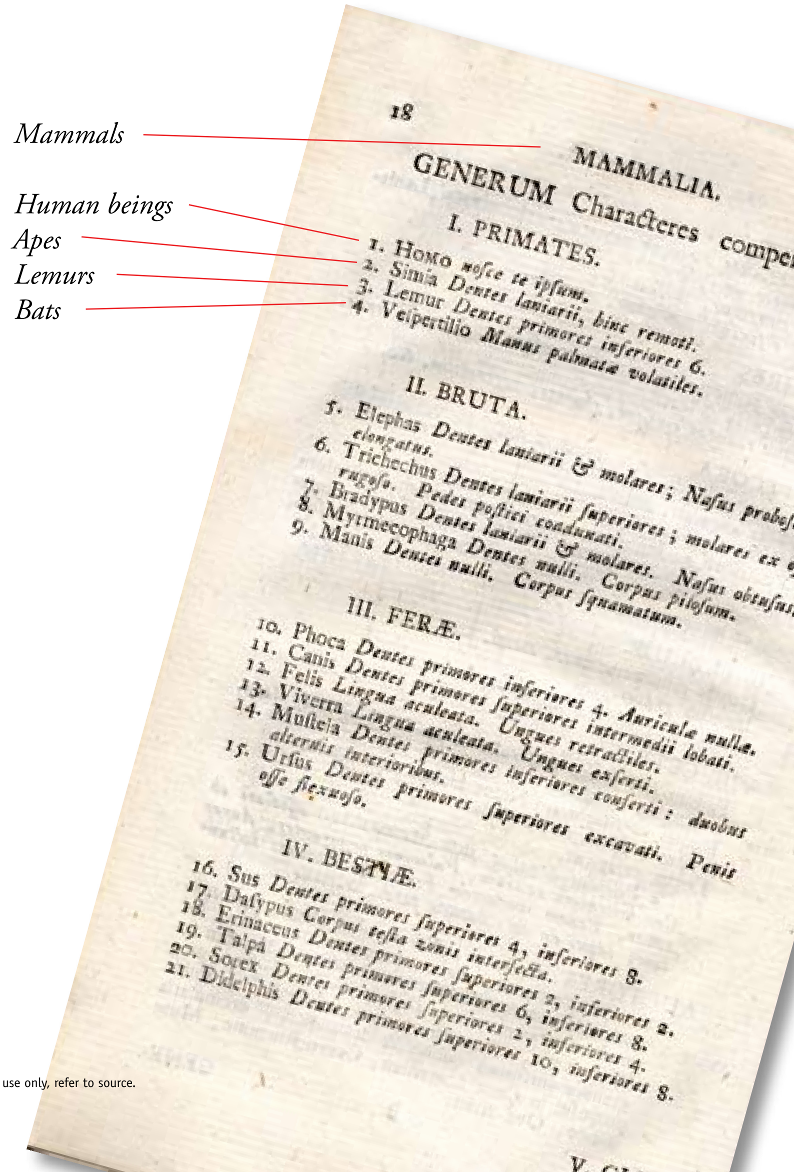


Orang-outang

Today we also meet questions concerning science and non-science. For example, faith in therapies that lack a scientific basis is increasing and information about the results of scientific research sometimes has difficulty in reaching the public and being accepted.

Scientific work begins with observations that lead to thoughts about the conclusions that can be drawn from them. Only then is an idea, a hypothesis, formulated that can be tested. On the basis of the results of these tests, conclusions can then be drawn as to whether the original idea is valid or must be reconsidered. Do what Linnaeus did, train your powers of observation and scientific thinking by studying life in its various forms.

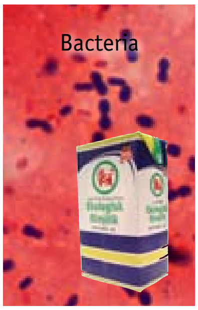
Linnaeus classified humans along with apes, which was a very radical step in his time. In the 1758 edition of Systema Naturae he introduced the term Mammalia. He called the first order primates. He also included among human beings another species, Homo troglodytes, which he never managed to see himself, nor has anyone else after him!



The World of Organisms Then and Now

In Linnaeus's time

Today



Linnaeus classified Nature in three kingdoms: plant, animal and mineral. In his classification of the world of organisms, he used both artificial systems that were simple and practical, and systems that showed the actual relationship between organisms, called natural systems.

As early as the end of the 17th century, microscopes were constructed that were so good that even individual bacterial cells could be observed, but in Linnaeus's time people did not understand what they saw in the microscope. Linnaeus himself did not use a microscope much, but gradually microscope studies gained great significance for our understanding of cells and organisms.

Modern DNA technology has revolutionised research concerning the classification of organisms. Not until now has it been possible to discover the actual relationship between various species by studying similarities and differences in DNA between different organisms. This gives us new possibilities to understand the history of evolution.

The world of organisms is now divided into three main categories: Archaea, Bacteria and Eukarya. Archaea and Bacteria are one-celled organisms, while Eukarya can consist of both one-celled and multi-celled organisms.

Archaea and Bacteria have very many forms, not always in appearance but in the chemical reactions of their metabolism. Genetic investigations show that Archaea differ considerably from both Bacteria and Eukarya. Among Archaea are found the most extreme salt and heat-loving organisms on earth. Both Archaea and Bacteria play an important role in decomposition and the natural cycle, but some bacteria can make us ill. Among the bacteria are Cyanobacteria, which can manage photosynthesis in the same way as green plants.

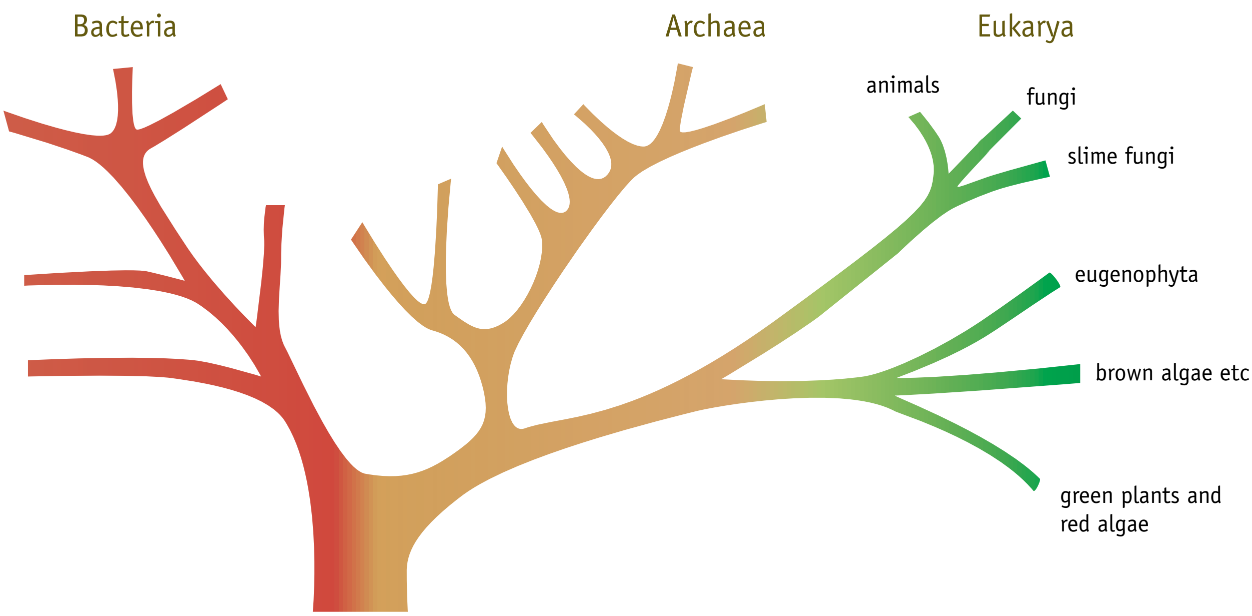
A common feature of the third group, Eukarya, is that all the organisms have a cell nucleus, that is, a clearly-defined part of the cell that contains DNA and is surrounded by a membrane. Eukarya include fungi, plants, animals, various kinds of one-celled and multi-celled algae and other one-celled organisms.

Linnaeus described, classified and named an impressive number of organisms: about 7,700 plants and 4,000 animals. Originally, his aim was to classify all organisms, but later he realised that that was impossible. Linnaeus's work is being continued today in "The Swedish taxonomy Initiative", begun in 2005 and continuing for 20 years, whose aim is to investigate and describe all the 50,000 or so multi-celled eukaryotes in Sweden and possibly some of the one-celled organisms as well.

Even though some of Linnaeus's classifications have been reassessed in our time, he was in many respects a pioneer. He was the first to place whales among mammals. In *Systema Naturae*, 1758, he introduced the term *Mammalia* for animals that breast-feed their young, and that led him to reclassify whales, which had previously had been placed among fishes (see the previous Fact text).

Linnaeus also placed humans, apes, lemurs and bats in the same group. It was revolutionary in Linnaeus's time to classify humans with apes. Only now, when the DNA of both humans and chimpanzees has been mapped, do we understand how right he was concerning the relationship between us and our closest relatives. The correspondence between the DNA of chimpanzees and humans is on average about 99 per cent, and in certain respects there is only a difference of degree between the abilities that humans have compared with those of chimpanzees. One interesting field of research is to investigate the differences in DNA that have meant that humans have been able to develop culture and theoretical thinking, and have established themselves in every conceivable environment.

Linnaeus designed his own coat of arms with parts that were essential for his scientific work. In the centre is an egg. Linnaeus considered that the egg was the origin of all life. The three fields symbolise the division that he made: the mineral, plant and animal kingdoms. The coat of arms is surrounded by Linnaeus's own plant, Linnea borealis (twinflower).



Linnaeus the Scientist

Carl Linnaeus is perhaps Sweden's internationally best-known scientist. When he was a professor at Uppsala (1741-1778), systematic botany developed into a science. His ideas spread throughout the world thanks to his travelling students and the very extensive correspondence he had with colleagues in many countries. Many foreign students and scientists also visited Uppsala to share his thoughts and listen to his lectures.

Linnaeus had many talents and was interested in most aspects of Nature. During his first stay in Uppsala he got to know another student, Peter Artedi. They worked closely together but realised after a time the advantages of dividing up the world of organisms between them. Artedi took amphibians, reptiles and fishes while Linnaeus took birds, insects and plants. They both worked on minerals and mammals. Artedi died young, but his work on fish systematics was of lasting value. Linnaeus's discussions with Artedi were probably of great importance for the way in which he developed the principles for classifying organisms.

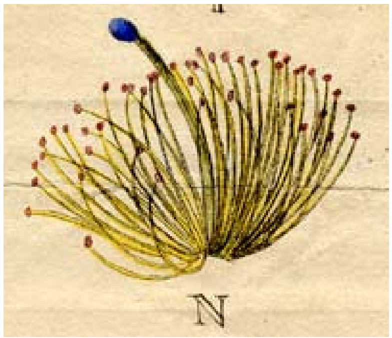
Linnaeus may be said to be a pioneer in ecology, and his thoughts on gradual differences between the smallest organisms in particular lead towards evolutionary theories. He often had a utilitarian approach to Nature and did not neglect, for example, to tell his students about the uses of plants. He was also interested in political economy. His journeys in Sweden were mainly aimed at developing Sweden's economy by utilising regional resources more effectively. Linnaeus's efforts to improve the balance of trade by reducing the amount of imported goods are shown by the briefs he gave his disciples before they left on their travels abroad.

What characterised his scientific work are his attempts to systematise and organise, and in this respect he laid the foundations of modern biology. Linnaeus may be called the father of systematics. The quotation "God created and Linnaeus classified" reveals Linnaeus's view of his work. His lasting scientific achievement is above all the system for naming living organisms that he introduced consistently and which is still used internationally. Organisms are given a Latin name consisting first of a name for a group of organisms (generic name) and then a name that defines a certain species (species epithet). Before Linnaeus, descriptions of plants were generally long and complicated and there was no simple system for organising plants in a systematic way.

Linnaeus chose to base his system on the sexual organs of plants and constructed a system that enabled him to classify an unknown plant in a simple way. Linnaeus's sexual system could be used for plants all over the world. He classified flowering plants in 23 classes according to the number and position of the stamens. After that he worked mainly from the number of pistils to group the plants in orders within the classes. A 24th class comprised plants without flowers like mosses and ferns. Linnaeus himself was aware that this was not a natural system that showed the plants' real relationships, but it made it possible to describe and categorise a large number of unknown plants.

Among Linnaeus's more important works mention should be made of *Species Plantarum* (1753) and *Genera Plantarum* (5th ed. 1754), which are still the starting point for botanic nomenclature. *Systema naturae* (vol 1, 10 ed. 1758) is in the same way the starting point for animal nomenclature. In an earlier edition of *Systema naturae* (1753) a description of the sexual system was published for the first time.

LINNAEUS NAMED ANIMALS AND PLANTS AFTER BOTH FRIENDS AND ENEMIES. For example, he called a dreary weed *Siegesbeckia* after one of his harshest critics, Johann Siegesbeck. The family *Rudbeckia*, a fine plant with beautiful flowers that is still grown in many gardens, was called after Olof Rudbeck the Younger, Professor of Medicine at Uppsala who supported Linnaeus in various ways during his early years in Uppsala.



What characteristics are good for classifying plants?

To the right is a series of pictures of wood anemones in which the number of sepals varies from six to ten. So the number of sepals is not a good characteristic for classifying wood anemones. Linnaeus chose to classify plants on the basis of the number of stamens and their placing – a method that could be used for plants from all over the world. Organisms are affected by both environment and heredity. A plant that grows on poor soil will usually be small and slight, while a plant of the same species that gets plenty of nutrients will be strong, with well-developed leaves. So characteristics affected by the environment cannot be used for classification either.

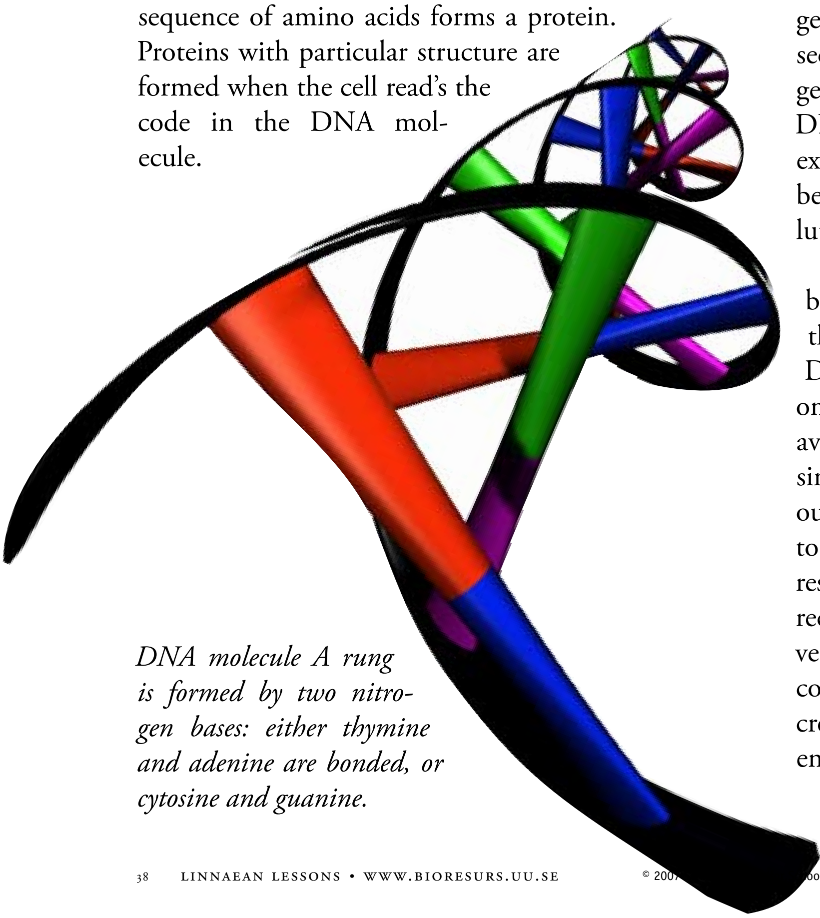
At the top you can see a hepatica that belongs to the same class (No. XIII Polyandria) as the wood anemone. These flowers have many stamens (more than 12), placed closely under the base of the pistil. Below that is a crane's bill with 10 stamens (Class X Decandria) and at the bottom a wild tulip with six stamens (Class VI Hexandria). On the right of each flower is a drawing of stamens and pistils illustrating the class the plant belongs to. The drawings are by Georg Dionys Ehret and were commissioned by Linnaeus in 1736.

The Helix of Life

Modern systematics is much influenced by studies of the DNA of organisms. The helical-shaped DNA molecule contains information that makes it possible to show how organisms are related and how the evolution of organisms has taken place.

DNA molecules are built up of smaller molecules called nucleotides. Each nucleotide consists of a carbohydrate-group (deoxyribose), a phosphate-group and one of four possible nitrogen-bases A, T, C and G (adenine, thymine, cytosine and guanine). The DNA molecule is double-stranded, each strand consisting of a chain of nucleotides. The nucleotides in the strands are linked by transverse bonds, thymine being combined with adenine and cytosine with guanine.

A combination of three nucleotides along the DNA strand makes a unit that codes for one of 20 different amino acids. The code in the DNA molecule is translated first into another type of nucleic acid, RNA, which in turn is translated into an amino acid sequence. The sequence of amino acids forms a protein. Proteins with particular structure are formed when the cell read's the code in the DNA molecule.



DNA molecule A rung is formed by two nitrogen bases: either thymine and adenine are bonded, or cytosine and guanine.

A few short amino acid sequences from the protein myoglobin taken from different groups of animals

```
Human      SDGEWQLVLNVWGKVEADIPGHGQEVL
SchimpanzeeSDGEWQLVLNVWGKVEADIPGHGQEVL
Gorilla    SDGEWQLVLNVWGKVEADISGHGQEVL
Pig        SDGEWQLVLNVWGKVEADVAGHGQEVL
Tuna fish  --ADFDAVLKCWGPVEADYTTMGGLVL
              ::. **. ** **** .  *  **
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* the amino acid residues correspond exactly .
Other colours show that the amino acid residues varies among species.

The possible variations in the structure of proteins are almost endless. Proteins have many functions in the body. For example, enzymes control cell reactions while other proteins form the tissues of the body.

The DNA material in an organism or a single cell is called the genome. All cells in an organism except the sex cells (gametes) have the same DNA content. The genomes of more than 350 organisms have already been sequenced. The overall description of the whole human genome was published in 2001. Our knowledge of the DNA sequences of organisms is of great importance, for example for discovering the causes of deseases and for being able to determine the relationships and early evolution of organisms.

The new field of science, bioinformatics, combines biology, computer science and mathematics to manage the enormous amount of information on proteins and DNA that is available. This material is freely accessible on Internet and can be managed with the aid of freely available soft ware. Databases can be used to look for similar amino acid or nucleotide sequences from various organisms. A computer program makes it possible to compare the sequences; they are aligned so that corresponding amino acids or nucleotides are placed directly above each other. In this way organisms that are very distantly related and different in appearance can be compared with each other. This then forms the basis for creating family trees built on the similarities and differences in DNA.