ASK THE PLUM

The foundations of modern plant research

Ecology and the environment

Contents Ecology and the environment

Further information can be found at:

http://www.mpimpgolm.mpg.de/22409/Frag_die_Erbse_Booklet

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What is ecology?

No plant is an island

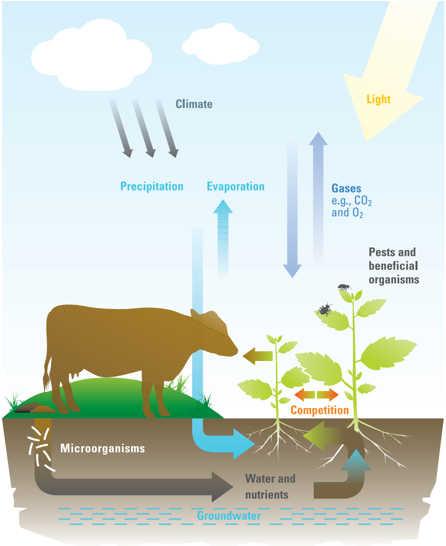
The term ecology comes from the Greek (oikos = household) and originally designated the study of the interactions of organisms with each other and with their living (biotic) and inanimate (abiotic) environments. The term was coined almost 150 years ago by the developmental biologist Ernst Haeckel. Haeckel defined ecology as the extensive descriptive study of the adaptation of an organism to its environment.

Ecology distinguishes between abiotic and biotic factors. All these factors influence whether, when, and where plant and animal communities are found with each other.

What is ecological research concerned with?

Who, what, when, where, and with whom?

The aim of ecological research is to understand the relationships of organisms with each other and with their environment, and to develop models that allow the prediction of changes or the derivation of laws for the system under observation.



Ecological questions are asked on three different levels:

1. Interactions between organisms and environmental factors like, for example, food, light, or temperature

2. Relationships between individuals of one species (e.g., an increase or decrease in the number of organisms within a species depending on local factors) or between different species (e.g., predator-prey relationships)

3. Relationships of entire communities to their environment (e.g., the flow of and cycling of substances) or in other words: the study of ecosystems

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Ecology works interdisciplinarily together with, e.g., climatologists, geologists, and taxonomists. As the chapters about Darwin and Mendel will show, evolutionary biology and genetics are important disciplines of ecology.

In addition to the classical methods, like the determination of local factors and species composition or the description of interactions, methods of genetic engineering have also been incorporated into ecological research. Thus, DNA analysis is used to study the familial relationships of organisms and their evolutionary development, and genetic modifications are made to understand the function of genes.

Resistance gene switched off

Ecological research by means of genetic engineering:

To study, for example, the ability of plants to resist pests in more detail, genetically modified plants are used: plants in which a potential insect resistance gene is switched off may be released under strict regulations for research purposes. If the resistance to enemies is really switched off, then these plants will be more heavily infested with pests. The responsible gene can then be identified and its mode of action studied in more detail.

What is an ecosystem?
Nature's households

An ecosystem is a system that encompasses the entirety of organisms (biocenoses) and their inanimate environment – the habitat (biotope) – in their interactions with each other.

Ecosystems can be very diverse: They span from the deep sea to the highest mountain peaks, from tropical rainforests to land used for agricultural purposes. They can arise naturally or in response to human activity. They differ in their extents, and it is often hard to delimit different ecosystems. As the examples of the deep sea and mountain peaks show, ecosystems can differ markedly from each other, and, in accordance with the local environmental factors, are populated by very different organisms or by different types of the same species. But how do species emerge, and how do new features develop within a single species?

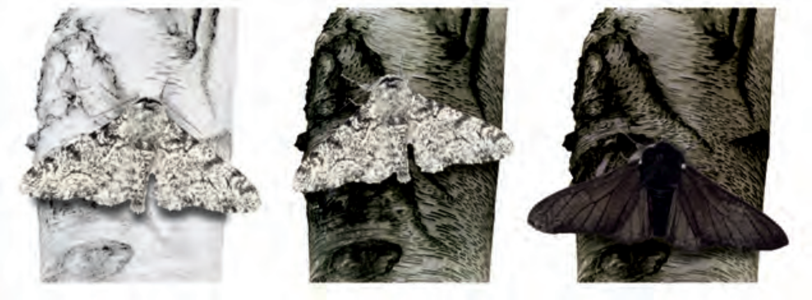
Why are there so many animal and plant species?

The theory of evolution according to Darwin

The term evolution comes from the Latin (evolvere = unroll, unfold) and means development. The question of the descent of species from each other and the development of new species is dealt with in the theory of evolution. This branch of biology, founded in the middle of the 19th century by Charles Darwin is a scientific approach to explaining the emergence and change of organisms in the course of world history.

Species diversity (biodiversity) is underpinned by the fact that progeny can possess different features than their parents. The new properties may be advantageous to the organism or might also be disadvantageous – every new character has to prove itself in nature. Environmental influences such as climate, light, and soil conditions, enemies, or population density are (selection) factors, that act on the organisms in a given location and bring about selection pressure. The development of all organisms follows the principle of natural selection: It is unavoidable and has no previously determined aim. It gives rise to individuals that are initially by chance better adapted to their environment. The more adapted an organism is to its environment or the faster that it can adapt to changing conditions, the better are its chances of prevailing over other individuals and of passing on its genetic material to its progeny and in this way of reproducing ("Darwinian Fitness"). In the course of many generations, this process leads to a clear change in the genetic material within the individuals of a species (ecotype; natural variations) culminating in the emergence of a new species.

In turn, species that can quickly adapt to changing environmental conditions hold an advantage over those who cannot. This eventually leads to a species shift in the respective location. In the end, this interplay between different animal and plant species is the basis for the species diversity in a given place.



Peppered moths in England, a classic example of natural selection:
Originally, the moths were well protected from birds on the light-colored trunks of birch trees through their light-speckled wings. Air pollution caused by industrialization led to the tree trunks becoming darker. Moths that were coincidentally darker in color were now better disguised than light-colored ones. They could therefore enhance their reproduction and pass on the dark coloring to their offspring. Natural selection resulted in the adaptation to altered environmental conditions.

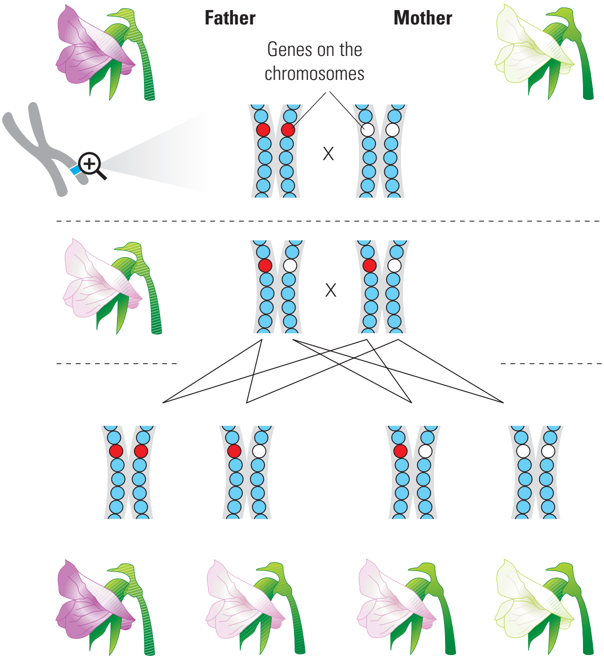
What is the connection between Darwin and Mendel?

Evolution and genetics

Even though Darwin assumed that characteristics were inherited, he did not know what this inheritance was based on. He could explain the extinction of uncompetitive species and the selection of useful adaptations, but not the emergence of new species or the development of new adaptations. One of the missing pieces of the puzzle for understanding the emergence of species and the mechanisms of adaptation was provided by Gregor Mendel in 1866 with his targeted crosses of peas. On the one hand, he could prove with his experiments that the transfer of traits to the next generation was subject to certain rules (Mendel's laws). On the other hand, it was also apparent in his experiments that the progeny of a cross possessed the features of the parents in a mixture with varying strength of expression. Thus, children can possess different features than their parents ➥ **ASK THE GRAPE, PART 1**. This is of great significance for the emergence of new species and for better adaptation to a given location.

The four varieties of pea used by Mendel to study seed shape and color

Mendel's laws



Mendel's 1st law:
The **1st filial generation** is uniform.

Mendel's 2nd law:
The **2nd filial generation** splits up into the genotypes of the parents and the 1st filial generation in a 1:2:1 ratio.

The progeny of a cross can possess the features of the parents in a mixture with varying strength of expression.

Some of the new compositions of features of the children prove themselves to be more advantageous for survival at the location than others, and in this way, increase the Darwinian fitness. Since Mendel, more and more pieces of the puzzle of heredity and the emergence of species have been filled in. Molecular experiments eventually revealed that progeny may not only possess the features of their parents in new combinations but may even exhibit completely new properties. This is based on mechanisms that function on the level of chromosomes and genes. ➥ **ASK THE GRAPE, PART 1**

left: typical tomato leaves,
right: mutant lacking leaf pigment

What does co-evolution mean?
The game doesn’t stop

Co-evolution describes the mutual influence that two species exert on each other’s development. In addition to environmental factors like light, temperature, and nutrients that decide on the preservation or emergence of a species, the relationships and communication between its organisms also plays a decisive role for the diversity of a location.

An example of these adaptations and counteradaptations can be observed in the case of wild tobacco (*Nicotiana attenuata*): Normally, this plant poisons its enemies with nicotine. However, some caterpillars have managed to develop a defense mechanism against the poison. It can be said that they have acquired tolerance to the nicotine. In response, the wild tobacco has generated a new strategy to defend itself also against these caterpillars. Using fragrances that the tobacco produces itself, it summons the natural enemies of these caterpillars, for example, parasitic wasps, and in some leaves even produces additional substances that give the pests an upset stomach by disrupting their digestion.

Thus, co-evolution ensures that the balance of power between organisms is constantly changing.

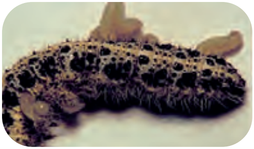
Feeding damage by caterpillars induces the production of plant fragrances that attract beneficial insects

A pest attacks a plant

A parasitic wasp finds the plant under attack

Oviposition of the parasitic wasp inside the caterpillar

Parasitized caterpillar



How do ecosystems behave?

Good times, bad times

Ecosystems appear stable, but viewed in geological time frames they are in fact anything but. As a consequence of the mechanisms of evolution and co-evolution, the species composition changes constantly – from that of microorganisms (fungi, bacteria) in the soil to mammals or trees. All the organisms in a biotope are as dependent on its abiotic factors (light, temperature, minerals) as their "contemporaries" with which they share the location. The so-called ecological balance is a dynamic rather than a static equilibrium. Change of just one factor – be it a biotic or abiotic factor – can lead to changes in the entire ecosystem.

Natural factors can change ecosystems very quickly and abruptly. For example, forest or steppe fires caused by lightning allow the overall development of a location to start over, whereby some organisms have adapted so well to the recurring fires that they use it to their advantage. The immigration of new species can change an ecosystem completely. An extinction of the "historical" species can for example happen if the new species represents an enemy for the already present species or if it is more competitive in evolutionary terms.

Humans are – along with many others – one factor that influence the development of a location.

Ecological = natural = good?
A change in the term ecology

Rapid developments in production and changes in the industrial and agricultural sectors after the Second World War, on the one hand, led to increased prosperity in Germany and in the whole of Europe. On the other hand, these processes also affected the environment. Consequences included air, water, and soil pollution. The aim was to counteract these.

Encouraged by increasing prosperity, adequate food production, and even overproduction and low unemployment rates, an enhanced level of attention could be paid to these negative consequences. First coined by Haeckel, the term ecology underwent a change in meaning: since the 1960s and -70s it has no longer been used to describe interactions between organisms and the environment, but has rather been used to describe the relationship between humans and the environment. The aim was to protect nature and the environment from the negative consequences of human activity. The word ecology was from then on used in connection with environmental protection and conservation, or rather as a synonym for an unspoiled state, naturalness, or completeness; ecological was used in the sense of environmentally friendly, clean, thoughtful or healthy.

With the notable exceptions of natural catastrophes, epidemics or starvation, nature is now positively regarded in its entirety – at least in the Western world.

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Two terms for the same thing?
Ecology and conservation

Along with fundamental ecological research, which is concerned with the relationships between organisms and their environment, **applied ecology** also plays an important role. It attempts to apply the knowledge of the relationships between organisms and the environment to practical questions of the conservation of nature and its species. For example, before a major change in the use of a space can be approved, appraisals must be made. In these, it is described, investigated and evaluated what consequences the project has for humans, animals, plants, soil, water, air, climate, and agriculture, as well as cultural and material assets. The interactions of different factors with each other are just as much the subject of such appraisals as measures to avoid, reduce, or balance the investigated consequences.

Photo: istockphoto, elxeneize

What does concomitant or safety research mean and what findings has it yielded?

25 years of research shows that genetically modified plants pose no specific risk

The aim of concomitant or safety research was to study the relationships between genetically modified plants and their surroundings. These projects tackled the objections and fears that were discussed in the public debate around green gene technology.

Since 1987, the Federal Ministry of Education and Research (BMBF) has financed more than 300 projects on biological safety research with more than €100 million. The resulting scientific studies came to the conclusion that there are no specific risks connected with the genetically modified organisms that have been released so far.

The results of the BMBF-financed studies have been confirmed by research work of the EU and neighboring European countries. For example, the Swiss National Research Programme (NRP 59) "Benefits and risks of the deliberate release of genetically modified plants", which was funded with CHF 12 million over five years, also came to the conclusion in its final report in 2012 that no specific health or environmental risks could be determined for green gene technology. This outcome was also in agreement with over 1,000 studies that were performed throughout the world and which were evaluated within the scope of NRP 59.

In the scope of safety research, it is also investigated whether the cultivation of genetically modified maize that can, with the help of the Bt protein, protect itself against larval damage caused by the European corn borer, has any impact on animals that should not be affected by the plant protection measure, e.g., peacock butterflies or ladybirds.
Photo source: 1st, BBA, Dr. Bernd Hommel; 2nd and 3rd, i-bio

Since 2014, there is also a summary of results from 25 years of EU safety research funded with €300 million, which also comes to the conclusion that genetic engineering does not pose greater risks than conventional methods of plant breeding.

Unfortunately, the results of the safety research are barely reflected in social debate or political decision making processes.

The research on and with genetically modified plants or their usage in agriculture is taking place in an area of conflict between science, society and politics, even though the scientific basis is retreating more and more to the background at the expense of an increasingly political discussion and socio-political consensus-building.

Sources: Brochures on 25 years of BMBF research programs on biological safety research

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