Soil Biodiversity 2011

SOIL BIODIVERSITY: THE FACTORY OF LIFE

2010 International Year of Biodiversity

JRC
EUROPEAN COMMISSION

The soil as a Habitat

(K. Ritz)

The scale at which the majority of life exists within soil is unfamiliar to most of us. The first two images show soil as we are used to seeing it, appearing to exist as a two-dimensional planar surface. Increasing the magnification further (third image) allows us to see the fine roots of plants which wind their way through the complicated three-dimensional pore structure, sometimes creating pores of their own in the case of bigger roots. At this scale, mycorrhizal fungi, which form a symbiotic relationship with plant roots, are also visible. The fourth image shows a highly magnified thin section of soil, where the pore spaces between the soil aggregates allow yellow light to pass through. The third and forth images give some impression of just how high a proportion of soil is actually space, containing either air, water or living matter.

SOIL BIODIVERSITY IS ONE OF THE FUNDAMENTAL COMPONENTS FOR SUPPORTING LIFE ON THE PLANET.

Most ecosystem processes and global functions that occur within soil are driven by living organisms that, in turn, sustain life above ground. Despite the fact that soils are home to a quarter of all living species on Earth, life within the soil is often hidden away and suffers by being ‘out of sight and out of mind’.

This calendar and the related **European Atlas of Soil Biodiversity** is an initiative of the European Commission Joint Research Centre to bring the issue of soil biota to the attention of society as a whole.

What kind of life is there in soil? What do we mean by soil biodiversity? What is special about soil biology? How do our activities affect soil ecosystems? What are the links between soil biota and climate change?

The first ever EUROPEAN ATLAS OF SOIL BIODIVERSITY uses informative texts, stunning photographs and maps to answer these questions and other issues. The EUROPEAN ATLAS OF SOIL BIODIVERSITY functions as a comprehensive guide allowing non-specialists to access information about this unseen world.

The initial part of the atlas provides an overview of the below-ground environment, soil biota in general, the ecosystem functions that soil organisms perform, the important value it has for human activities and relevance for global biogeochemical cycles.

The second part is an ‘Encyclopedia of Soil Biodiversity’. Starting with the smallest organisms such as the bacteria, this segment works through a range of taxonomic groups such as fungi, nematodes, insects and macro-fauna to illustrate the astonishing levels of heterogeneity of life in soil.

The EUROPEAN ATLAS OF SOIL BIODIVERSITY is more than just a normal atlas. Produced by leading soil biologists and scientists from Europe and around the world under the auspice of the International Year of Biodiversity 2010, this unique document presents a comprehensive overview of this often overlooked and neglected biome that surrounds and affects us all.

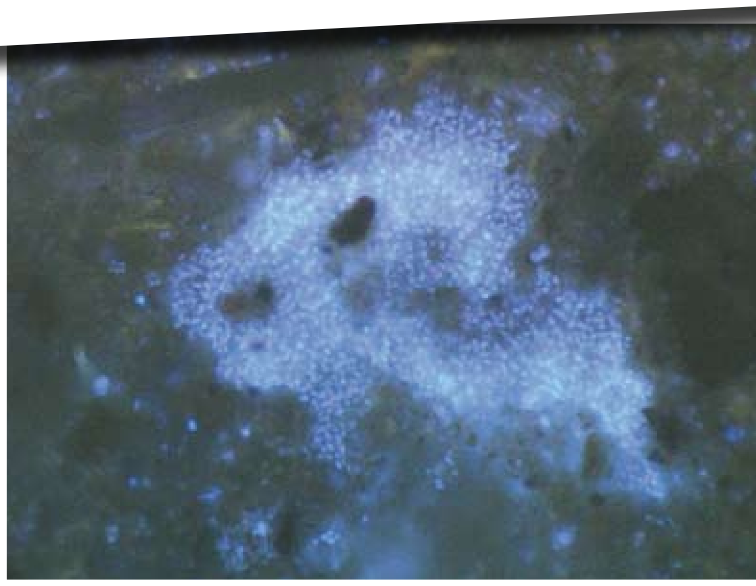
The EUROPEAN ATLAS OF SOIL BIODIVERSITY is an essential reference for the many and varied aspects of soil. The overall goal of this work is to convey the fundamental necessity to safeguard soil biodiversity in order to guarantee life on this planet.

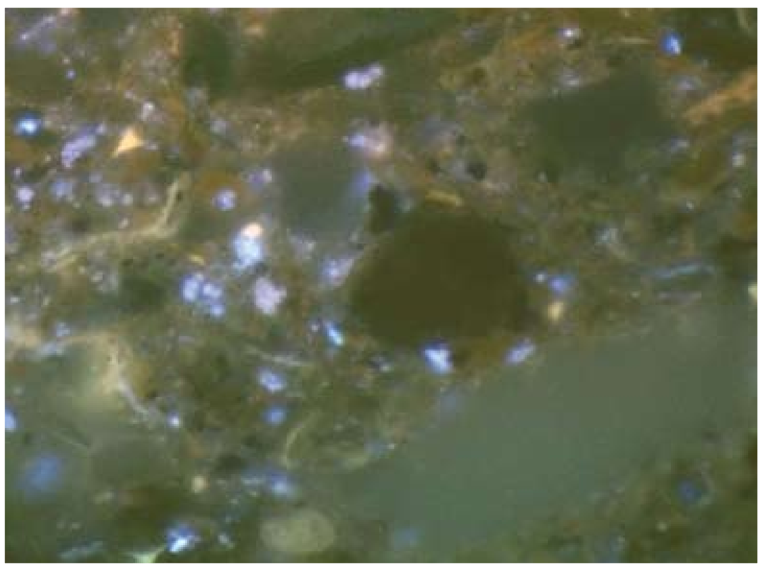
The highly simplified figure below aims to give some idea of the distribution of organisms vertically through the soil profile. It is clearly an oversimplification and in fact microorganisms such as bacteria (c) and protozoa (e) are distributed throughout the soil profile, although with the highest biomass being found near the soil surface which is richer in organic matter. The two collembolans are adapted for living at different soil depths with the species shown in (a) being more adapted for living on or near the soil surface and that shown in (b) being more adapted to living at deeper levels.

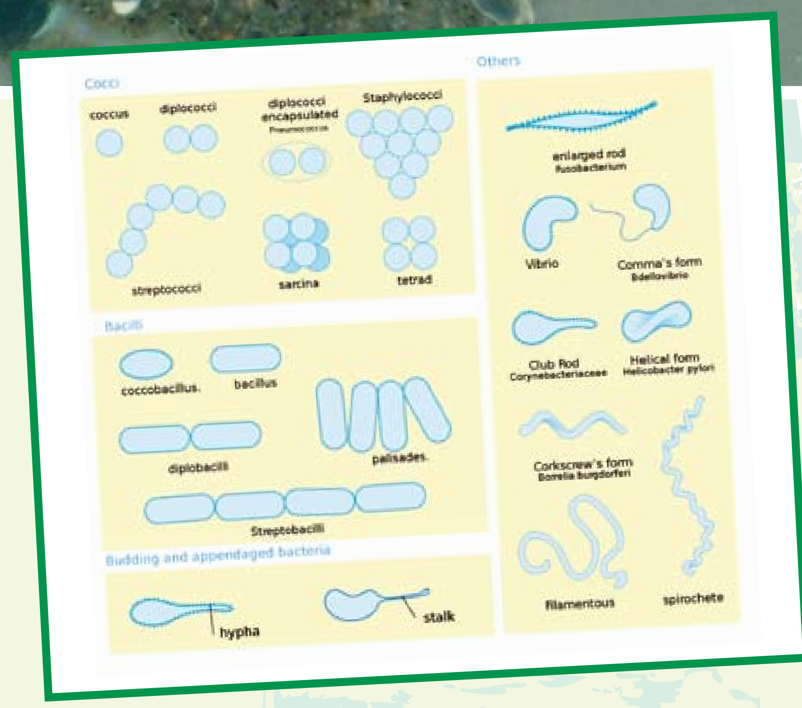
(K. Ritz, Public Domain Images - PDI-)

JANUARY 2011

BACTERIA







Bacteria are a large group of single-celled microorganisms; typically a few micrometres in length but exist in all sort of different shapes. The three images above show bacterial colonies found within the soil, stained blue to highlight them. Bacterial colonies are distributed throughout the soil where they grow in thin films water within the pore spaces between soil aggregates (top left).

Some colonies grow in very restrictive pore spaces (top right). This has advantages and disadvantages in that the colony is unable to grow beyond the size of the pore and is reliant on water and nutrients diffusing through the surrounding soil aggregates from other pore spaces. However, the colony is protected from being grazed upon by bacterial feeders such as protozoa. Furthermore, soil is a highly dynamic system, with ever changing pore spaces. This is because of the effects of wetting and drying cycles and in some instances, by freezing thawing cycles, so it is unlikely that the above colony will be isolated and protected indefinitely.

Nutrients are often limited in the soil system for bacteria, which therefore spend much of their time in an inactive resting state. However, upon increased nutrient availability, most soil bacteria are able to rapidly utilize the available nutrients for increased growth and reproduction before again settling to a more inactive state (bottom left).

Bacteria are incredibly diverse in the functions that they perform as well as their morphologies. These functions range from breaking down of contaminants in the soil, atmospheric gas regulation and nutrient cycling. Furthermore, many different types of soil bacteria, and the compounds that they produce, are used widely for biotechnological applications such as antibiotics.

(Photographs, K. Ritz; Morphological drawing, M. R. Villareal)

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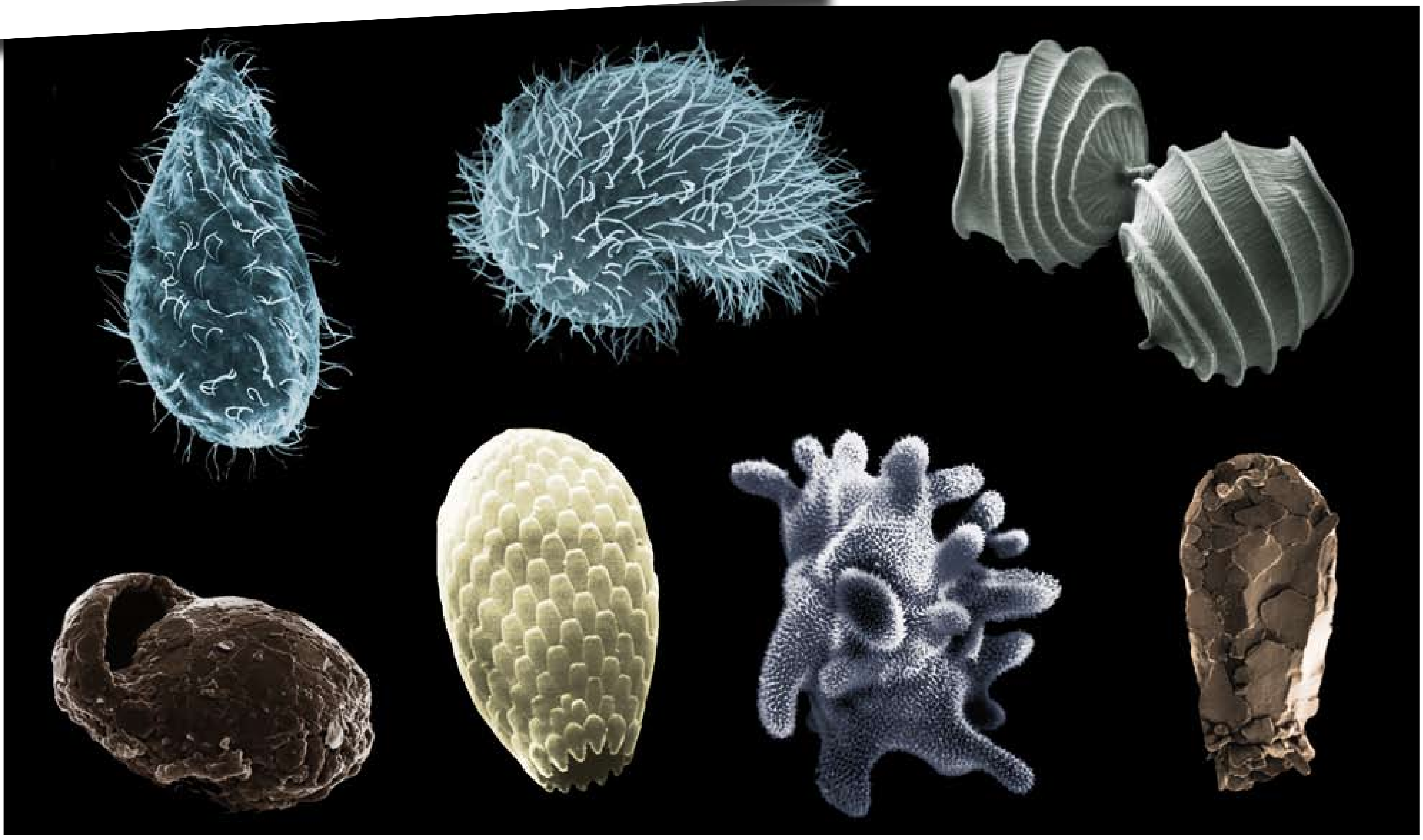
FEBRUARY 2011

PROTOZOA



Protozoa are a group of microorganisms which are classified as “unicellular eukaryotes”. Eukaryote refers to all organisms (including humans) which contain cells with a ‘true nucleus’; a structure that contains the organism’s genetic material (DNA) and can usually be viewed down a light microscope.

Protozoa are microscopic and can grow up to approximately 1 mm in size in some rare instances. However, they are more usually between 10 and 50 µm in size. They feed on organic matter, such as small sections of decomposed plant matter or excreted compounds such as sugars, or alternatively can be in the form of bacteria and other small celled organisms such as algae and small fungal cells, upon which the protozoa ‘graze’.

Currently, over 30,000 different species of protozoa are known to exist in aquatic environments and the soil. The numbers of protozoa found in soil is highly variable and depends on many different factors. Soil moisture is a big determinant as to which species of protozoa are likely to be present and active in a soil. A soil many contain ‘just’ a few thousand cells per teaspoon of soil where as a more fertile soil may contain a million or more cells per teaspoon of soil!

(W. Foissner)

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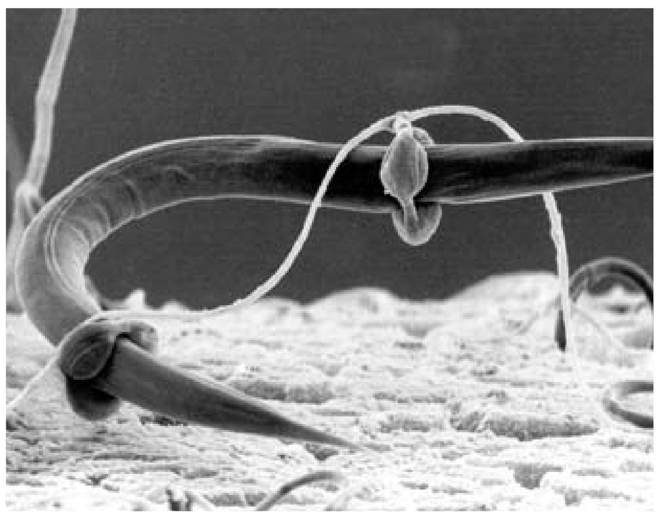
MARCH 2011

FUNGI






A selection of photographs of different fungi showing a range of diverse structures.

- a “thin section of soil” viewed down a microscope with fungal hyphae (stained blue) growing through the soil pore space
- a puff ball, the fruiting body of *Calvatia gigantea*. The puff ball is full of spores which are dispersed over a wide area when the puff ball bursts
- the fruiting bodies of *Pilobilus* sp., which actually produces the fastest acceleration rates in the living world; faster than a missile or a speeding bullet! The black ends are spores which can be shot up to two metres due to the fluid sacks behind each spore filling slowly with fluid until they burst dispersing the spores
- the fruiting body of *Amanita muscari*, the classic ‘toadstool’ seen in fairytale drawings
- the fruiting body of *Lacrymaria* sp.
- the carnivorous fungi *Drechslerella anchonia* which captures nematodes in rings which grow along its hyphae; the rings penetrate the skin and consumes the nematode from the inside out!
- the fruiting body of *Hygrocybe punicea.*

Fungi are familiar to many people in the form of mushrooms, but these structures are just the fruiting bodies of one group of this very diverse range of organisms. Fungi occupy a distinct taxonomic kingdom, separate from prokaryotes, plants and animals. They occur in all soils and can form the largest part of the biomass below-ground, particularly in soils that are high in organic matter. Fungi are hugely important in the functioning of soil systems as they are involved in a wide range of roles (e.g. decomposition). A handful of grassland soil typically contains several kilometres of fugal hyphae.

(K. Ritz, K. Turnau, L. Deacon, G. Barron, N. Allin)

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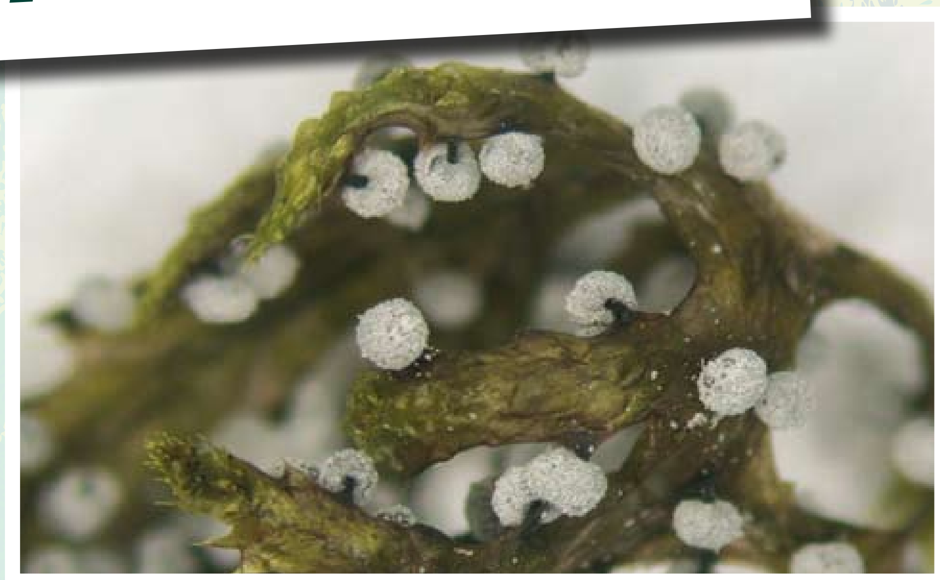
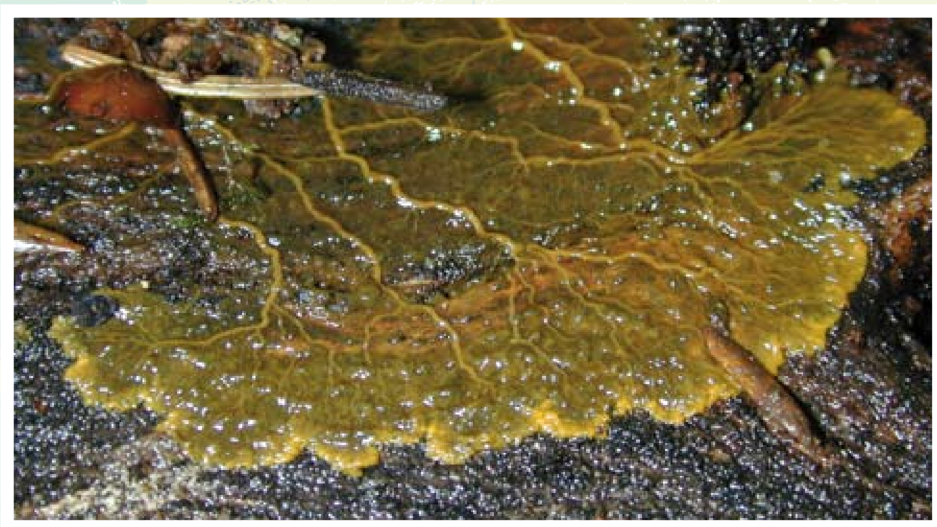
APRIL 2011

MYCETOZOANS






Mycetozoans (commonly called slime moulds) are eukaryotic, spore producing, fungus-like organisms that feed primarily upon bacteria and other microorganisms in terrestrial habitats throughout the world. Although formerly classified as fungi, mycetozoans are not true fungi as they actually have more in common with protozans such as amoebae than they do with the true fungi.

Slime moulds occur as two types:
- **Plasmodial slime moulds** (commonly referred to as myxomycetes) are the largest group (with approximately 900 species) and best known of the mycetozoans, as well as the only examples that can be observed directly in nature (shown above).
- The **cellular slime moulds** (also known as dictyostelids) are less familiar organisms only rarely observed under field conditions as they are microscopic in size for much of their lifecycles.

The primary habitats for myxomycetes are decaying wood, litter (dead plant matter on the ground), the bark surface of living trees and soil, where they are major predators of other microorganisms such as bacteria, yeasts, cyanobacteria and green algae. They form a significant component of the soil protistan biota and represent a major active part of the soil biomass. This would suggest that these organisms have considerable ecological significance. However, because of their cryptic life cycle and the fact that the number of specialists studying them is relatively small, myxomycetes are among the most understudied groups of soil organisms.

(R. Darrah, K. Flemming, K. Turnau)

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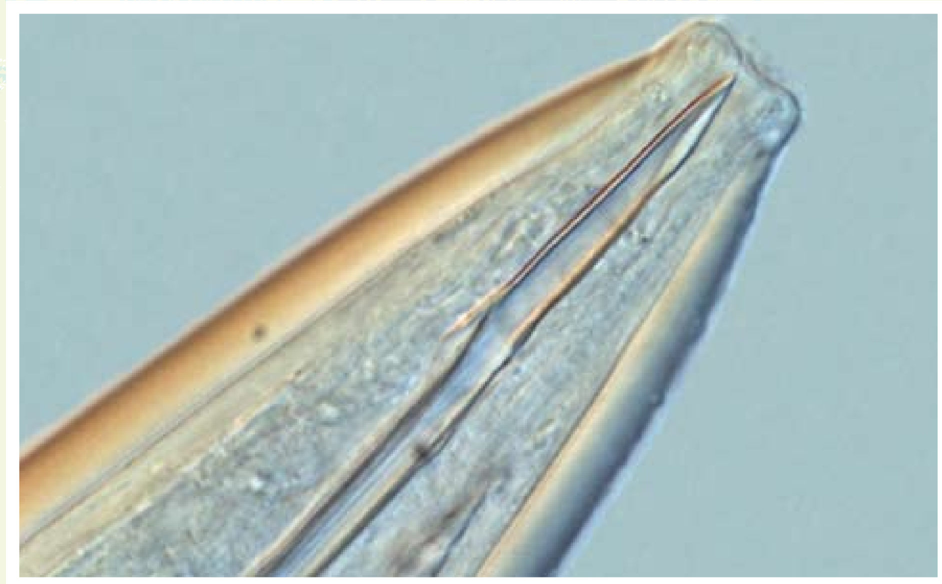
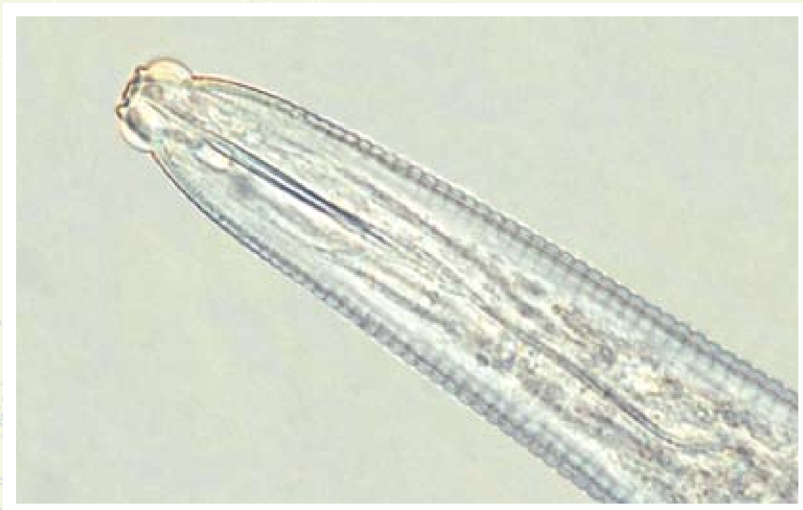
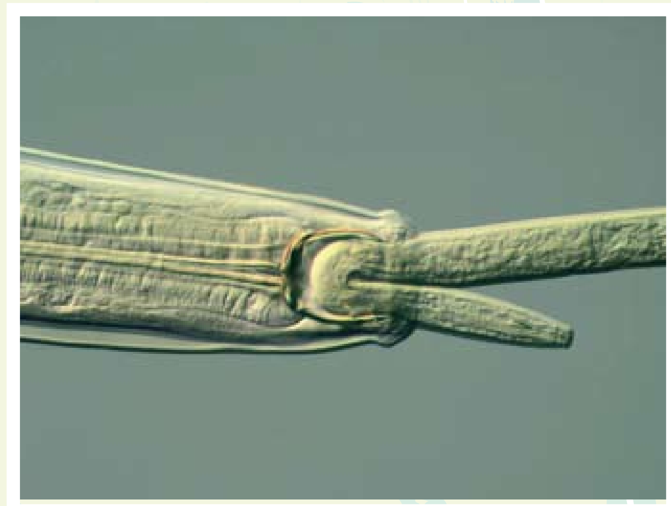
MAY 2011

NEMATODES







The name *Nematode* is derived from ancient Greek and means “thread like”. This is an apt description as nematodes are essentially thin multi-cellular cylindrical tubes encapsulating all the necessary organs required for survival. Nematodes are also sometimes known as roundworms or eelworms.

Nematodes are generally considered to be aquatic organisms and, in soil, inhabit the water film around soil particles. They are arguably the most abundant multi-cellular organism phylum on Earth with respect to both species richness (number of species) and abundance (number of individuals). In cultivated land, 1 to 10 million individuals can be found in 1 m^3 of soil. Approximately 30,000 nematode species are known to science, but this is considered to be only about 5% of the estimated total number of nematode species globally.

Free-living nematodes have been classified into eight feeding groups, of which the five main feeding types are bacterivores (bottom left), fungivores (bottom middle), omnivores (top right), plant parasites (top left) and predators (bottom right). These main five are used as indicators of the soil quality. It is difficult to identify nematodes to species level, but it is relatively easy to distinguish the different nematode feeding groups based on the shape and size of their mouthparts.

Nematodes have adapted to survive in the harshest of environments and examples can be found in arctic and desert environments. Depending upon their life cycle, some nematodes can use animals, insects, humans and plants as their host. In the developing world, although not exclusively, some serious human diseases are caused by nematode infections (e.g. Guinea worm, elephantiasis).

(M. Rutgers, H. van Megen)

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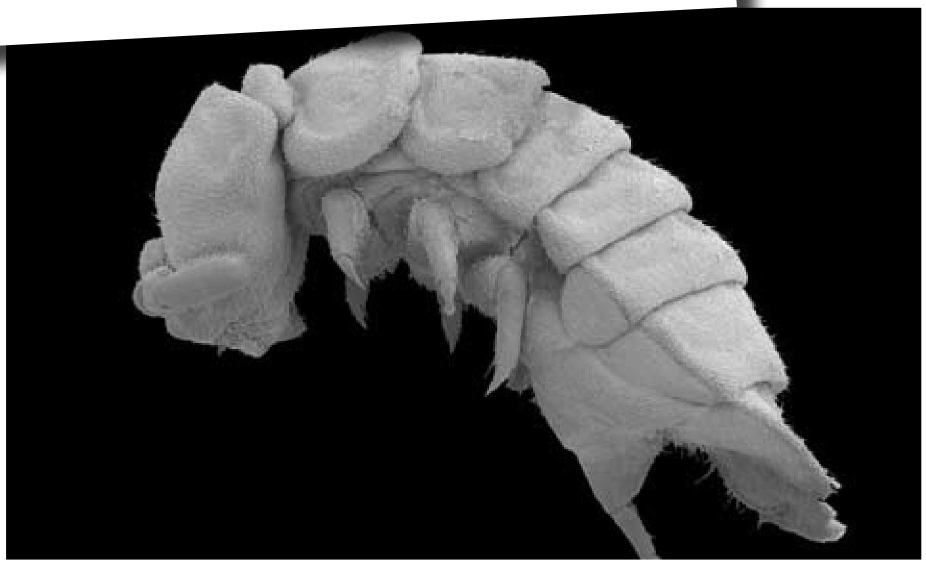
JUNE 2011

COLLEMBOLA



Collembola, also known as springtails, are small arthropods which are found in soils throughout the world, even in Antarctica! They are classified as 'hexapods', the largest group of arthropods, and includes all six legged arthropods such as insects. Although collembola (along with protura and diplura) are no longer considered insects.

Many species of collembola have a tail-like organ called a furcula at the end of their abdominal section (top left). This is usually folded beneath the organisms and held under tension which can be released when the organism is threatened causing the 'tail' to 'spring' and throw the organism into the air.

Collembola are thought to be the most abundant hexapods on Earth and are found in soil, leaf litter, fallen branches and even shorelines. There are over 6,000 known species of collembola, and in just one handful of grassland soil there can be hundreds or thousands of individual collembola, representing hundreds of different species.

Collembola are primarily detritivores and microbivores that feed on fungal hypahe and other organic detritus. Along with nematodes, collembola are one of the main biocontrol agents of microbial populations.

The distribution of collembola in the soil is stratified both vertically and horizontally. Some species are better adapted to living in leaf litter or at the soil surface, and these organisms are usually pigmented with relatively long limbs (top and bottom right) and scales or hairs to help prevent desiccation. Those species which live in deeper soil layers usually have diminished eyes and limbs as well as lacking pigmentation (bottom left). Collembola play an important role in nutrient cycling through their influence on microbial decompositions.

(J. Mourek, P. H. Krog, U. Tartes)

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JULY 2011

ACARI

Soil mites, together with collembolans, are the most numerous arthropods in the soil. Depending on the habitat, numbers can range from thousands or tens of thousands to several hundreds of thousands of individuals per cubic metre. They are present in all types of soils throughout the world, including extremely cold soil habitats.

They inhabit many other habitats where dead organic matter is present such as peat, mosses, lichens, tree bark and rotting wood. Mites are also numerous in above-ground ecosystems, mostly living as parasites on animals (e.g. ticks, gamasid mites, bee-mites) or plants (e.g. spider-mites, gall and rust mites, etc.). Others types feed on different kinds of organic detritus (e.g. feather-mites, dust- and house-mites) or are free living and predatory. A large and diverse group of mites live in water habitats (i.e. water mites, Hydracarina). Soil mites, with the body being generally between 0.2-0.8 mm in size, are considered to be an important group of soil mesofauna.

Mites are evolutionary very old. Contemporary oribatid mites are very similar to fossils of mites from 400 million years ago. The presence of the same forms throughout this time demonstrates the very high relative stability of ecological conditions in soil and the very high value of soil biodiversity at both genetic and species level.

(U. Tartes, D. Walter, E. Halberg, J. Mourek)

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AUGUST 2011

EARTHWORMS





Earthworms are found in soils all over the world, even in Antarctica, and are very important organisms in maintaining soil fertility. They feed on organic matter in the soil but don't have the digestive enzymes to break down the cellular structure of plant material. This means that they must rely on other organisms in the soil biota to start the digestion process. To reach their daily calorific intake, earthworms generally have to eat between 10 and 30 times their own body weight in soil. The soil passes through their body and is deposited on the surface as an earthworm casts by some species such as *Lumbricus terrestris*. Soils that contain lots of earthworms are regularly mixed by this activity and up to 5 mm of fresh soil material can be brought to the surface every year by this action.

- **Epigeic species** - also called litter species are surface-dwelling species that live at the soil surface, in leaf litter, humus layers, manure, compost and sometimes within the first few centimetres of the soil. They are generally small, being 1—5 cm in length and are a dark red in colour.

- **Anecic species** - also called topsoil species are soil-dwelling species that live in long (5—6 m) permanent, vertical (or close to vertical) burrows which are connected to the soil surface. Anecic species are generally the longest earthworms being 10-110 cm in length. They are variable in colour, being either red, dark grey or brown.

- **Endogeic species** – also subsoil species are soil-dwelling species that live within the soil, almost never going to the surface. These species are generally medium to large, being 1– 20 cm in length. They are usually slightly coloured, being pink to light grey.

(D. Cluzeau, M. Bartlett)

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SEPTEMBER 2011

MYRIAPODS






Myriapods are arthropods which are characterised by an elongated body with many similarly shaped segments bearing one or two pairs of legs. Four classes of Myriapods exist: Symphyla, Pauropoda, (both being small, mostly soil dwelling microarthropods), Diplopoda (millipedes), and Chilopoda (centipedes) (both of which are classified as soil macrofauna).

- **Symphyla** are a small group of soil-dwelling myriapods, also known as garden centipedes or glasshouse symphylans (top left). They resemble centipedes, but are smaller and, unlike centipedes, are translucent. The body size is generally in the range of few millimetres.
- **Pauropoda** are between 0.5 and 2 mm in size. They have a soft, elongated body with nine pairs of legs in adult (top middle). From an evolution ary point of view, they appear to be closely related to millipedes. Like other organisms that are adapted to the life below-ground they are blind but they have a pair of organs which are sensitive to vibrations called *pseudoculi*.
- **Diplopoda** (millipedes) are arthropods which range in size between 2 and 280 mm (bottom middle). They can be easily distinguished from other terrestrial arthropods as for most of their length they have two pairs of uniform legs per segment. The exceptions are the first segment behind the head, which does not have any appendages at all, and the next few segments which only have one pair of legs.
- **Chilopoda** (centipedes) are common predators in soil and litter habitats (top and bottom right). Their size can range from a few millimetres to about 30 cm in length. Centipedes have an ancestry dating back some 430 million years; together with millipedes, they are among the earliest terrestrial animals. The bodies of centipedes are elongated, composed of several segments, each of which has a single pair of legs. The first segment of the body holds a pair of forcipules (modified legs) which are very strong organs that have poison ducts at their tips (bottom left). These are used for catching the prey.

(L. Kováč, D. Maddison, F. Trnka, J. Mourek)

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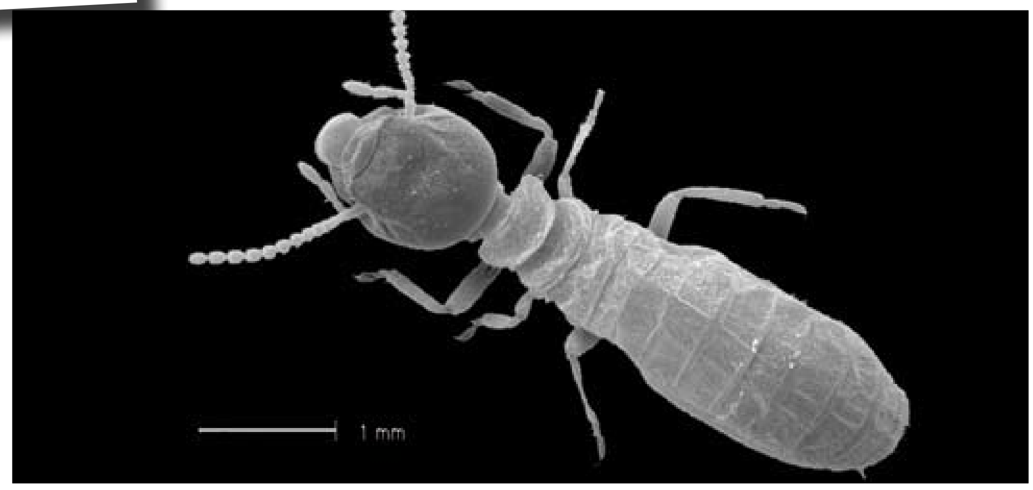
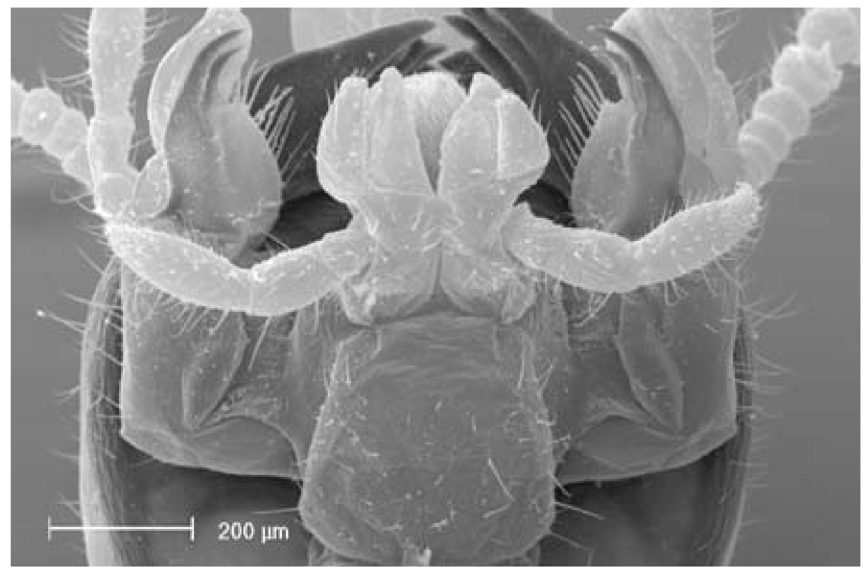
OCTOBER 2011

TERMITES





The name “termite” comes from the Latin and can be translated as “woodworm”. This refers to the diet of many species of the order Isoptera to which termites belong. This word in turn is derived from the Greek *ísos* (same) and *pterón* (wing), which refers to the two pairs of straight and very similar wings that termites have as reproductive adults.

Termites are small insects (5-15 mm on average), white to tan or sometimes black in colour. Although they may sometimes look similar to ants, they are more closely related to cockroaches and have existed on Earth for more than 180 million years. More than 2,600 species of termites have been described worldwide with the greatest diversity being found in Africa, with over 1000 species. North America has 50 species while Europe only has 10. It is estimated that termites represent about 15-33% of the Earth’s terrestrial animal biomass. The two main factors which are thought to be behind the success of termites are their social organisation and their highly efficient digestive system, including very effective mouthparts (top right).

Termites are social insects that live in a caste system based on division of labour, with morphologically and functionally different individuals: nymphs, workers (top left), soldiers (bottom right) and reproductive termites known as reproductives (bottom left). Unlike bees and ants, termite society is unique among social insects as members of all castes can be either males or females.

Termites are among the few animals able to feed on the lignocellulose that is found in plants or indirectly from fungus growing on decaying material. The termite gut is considered nature’s most efficient bioreactor, able to convert up to 95% of the cellulose material into simple sugars within 24 hrs.

Termites play a major role in decomposition processes and nutrient recycling: it is estimated that every year about 1/3 of all plant material is consumed by these insects!

(E. Chiappini, L .Pizzocaro, L .Maistrello)

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NOVEMBER 2011

ANTS





Ants are insects which belong to the order Hymenoptera (the same as bees and wasps) and to the family Formicidae. They should not be confused with Termites which belong to the order Isoptera and are more closely related to cockroaches and mantids.

Ant sizes varies from 0.75 to 53 mm, with the majority of the species being generally red or black in colour (a few species are yellow, green or with a metallic lustre). An ant body is divided into three parts: head, thorax and abdomen. Elbowed antennae on the head, metapleural glands in the thorax and a strong constriction of the second abdominal segment into a node-like structure (petiole) are the three features that discriminate the ants from the other insects.

It has been discovered that a species of Argentinean ant (*Linepithema humile*), introduced into Europe on imported plants about 90 years ago, has developed the largest super-colony ever recorded, stretching approximately 6,000 km from northern Italy, through the south of France to the Atlantic coast of Spain. The colony is made up of billions of related ants occupying millions of nests. While ants from rival nests normally fight each other, ants from the super-colony recognise each other and co-operate.

Ants have two stomachs: one for itself and one for sharing food with other ants. Ants are very diverse as well as numerous; 43 ant species were found on a single tree in Peru while 668 species were found in 4 hectares of forest in Borneo. There is a large morphological diversity in ant forms, particularly the heads, a small sample of which can be seen at the top of this page.

(A. Mori, D. Grasso, J. Bihn)

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DECEMBER 2011

MAMMALS

Mammals are also soil dwellers. The mole (Family: Talpidae) is one of only a very few vertebrates that live permanently in the soil. A mole's diet consists primarily of earthworms and other small invertebrates found in the soil. Because their saliva contains a toxin that can paralyse earthworms, moles are able to store their still living prey for later consumption in special underground store rooms. Moles excavate extensive burrows, with the waste material being ejected as characteristic molehills. Despite their often negative perception amongst gardeners for the damage they cause to lawns, moles are a valuable indicator of a healthy soil. Being a high-order predator, moles require a functioning soil ecosystem and supporting biodiversity in order to survive. Molehills can therefore be regarded as an indicator of healthy soil biomes.

While moles can be found in most parts of North America, Asia and Europe, there are no moles in Ireland.

Other mammals also make their homes in soil although unlike moles they all generally only venture below-ground to sleep and to avoid predators. These mammals include rabbits, foxes and badgers.

(A. Jones, PDI)

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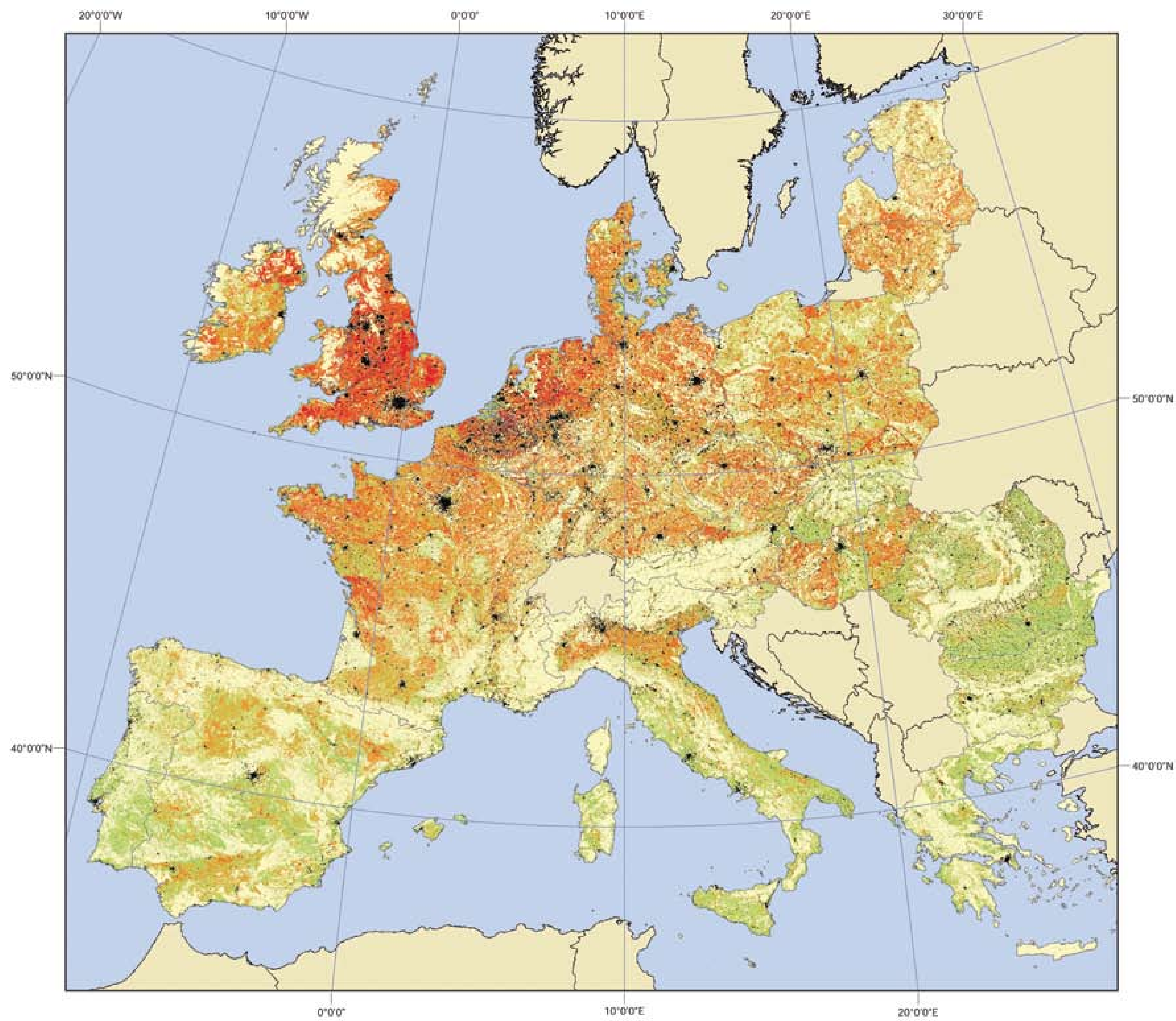
European Atlas of Soil Biodiversity

To raise awareness of the general public, policy makers and other scientists of the global perspective and importance of soil biodiversity particularly, in the context of the UN's International Year for Biodiversity, the European Commission's Joint Research Centre (located in Ispra, Italy) has collaborated with soil scientists from all over Europe to produce the first ever European Atlas of Soil Biodiversity.

Soil organisms represent around a quarter of all biodiversity on Earth, yet are widely neglected in conservation efforts. Worldwide, only eight soil species are protected under CITES, the international rules on trade in endangered species: three scorpions, four tarantulas and one beetle. This is not because soil species are not endangered: it is simply because so little is known about them and because their habitat and functioning are complex. However, taking steps to protect them may be doubly useful as efforts to protect soil communities are very likely to help above ground habitats.

For more details on the atlas, including how to obtain a copy, please see http://eusoils.jrc.ec.europa.eu/library/maps/biodiversity_atlas/



Soil biodiversity potential threats were selected and ranked in significance on the basis of an expert evaluation. The following pressures were used to calculate the indicator, where data existed: land use change/habitat disruption, human intensive exploitation, invasive species, soil compaction, soil erosion, soil organic matter decline and soil pollution

For each of the above parameters, a 1 km grid map was created where the values present in each cell were classified into 5 classes. These values were weighted using the coefficients obtained from the expert evaluation. The final indicator was calculated, with an operation of map algebra, as the sum of the individual raster values. The values displayed on the map are related to the potential threats on soil biodiversity, for twenty three EU countries. The high score (high potential threats) of several parts of the UK and central Europe are determined by the combined effect of a high intensity agriculture, with a high number of invasive species and by the risk of the soil losing organic carbon. Compared to these areas, the intensive agricultural regions of southern Europe are less affected by the risk of losing organic carbon, and by the effect of invasive species.

It should be noted that the map indicates an evaluation of the potential risk of soil biodiversity decline (with respect to the current situation) and is not a representation of the actual level of soil biodiversity.

JRC

EUROPEAN COMMISSION

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies.

As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.
The JRC consists of seven different institutes, each with its own focus of expertise, on five separate sites around Europe. The Institutional and Scientific relations provides coordination and serves as a link between the institutes and the policymakers.

http://www.jrc.ec.europa.eu/

Institute for Environment and Sustainability

Located in Ispra (Italy), the Institute for Environment and Sustainability is one of the seven institutes that constitute the Joint Research Centre of the European Commission.

In line with the JRC mission, the aim of IES is to provide scientific and technical support to European Union strategies for the protection of the environment contributing to a sustainable development. IES works in close collaboration with official laboratories, research centres and industries of the EU's Member States, creating a bridge between the EU's policies and the European citizen.
The combination of complementary expertise in the fields of experimental sciences, modelling and remote sensing puts the IES in a strong position to contribute to the implementation of the European Research Area and to the achievement of a sustainable environment.

Institute for Environment and Sustainability
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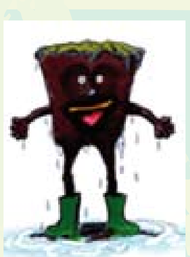
Helping to protect soil biodiversity

Growing pressures from an ever increasing global population, climate change and soil erosion are placing increasing stresses on the ability of soil to sustain its important role in the planet's survival. Evidence suggests that while increased use of mono-cultures and intensive agriculture has led to a decline in soil biodiversity in some areas, the precise consequences of this loss are not always clear.

For this reason, scientists from the Joint Research Centre, together with an international group of experts, have produced the first ever "European Atlas of Soil Biodiversity". This innovative atlas is a step towards raising awareness on the key role of life within the soil in maintaining life on Earth. The atlas represents a major contribution to the new EU target of halting the loss of biodiversity and ecosystem services in the EU by 2020, and insofar as possible, restoring them.

Given that at least a quarter of the Earth's biodiversity can be found in the soil, and in order to achieve our own biodiversity targets, we must protect soil biodiversity. As an integral part of its Soil Thematic Strategy, the European Commission has proposed a Soil Framework Directive in an attempt to prevent further soil degradation across the European Union, and to repair the damage that has already been done. This is a growing problem, and unless we tackle it soon and in a coordinated manner, it will cost a lot more to put it right.

Sandy



Pete

*The authors of this calendar, Arwyn Jones, Simon Jeffry, Ciro Gardi and Luca Montanarella gratefully acknowledge all contributions, in particular all the collaborators who provided texts and images for the **European Atlas of Soil Biodiversity**. Sources of the photographs used in this calendar are indicated next to the images. See link to the atlas on the preceding page for more information.*

Front Cover

A healthy soil depends on a vibrant range of life forms living below the ground, from bacteria and fungi to insects, earthworms and moles. Together, this rich assemblage of life brings immeasurable benefits to the planet we live on. The images on front cover provide a sample of life in the soil. They include from left to right:

1st row – Alga of species Dictyococcus cf. varians (B. P. Skowroňska); Collembola (J. Mourek); Fungus of species Amanita muscari (K. Ritz); Root nodules containing symbiotic bacteria (K. Ritz).

2nd row – Predatory nematode of genus Monochoides (H. van Megen); Earthworms mating (M. Bartlett); Winged queen ants of species Messor structor (A. Mori, D. Grasso); Termite of species Reticulitermes lucifugus (E. Chiappini).

3rd row – Testate amoeba (K. Ritz); Protozoa of species Bresslauides discoldeus (W. Foissner); Surface dwelling soil mite (U. Tartes).

4th row – Fruiting biodies of a myxomycete (slime mould) (KF); Millipede of species Narceus americanus (J. Mourek); Scorpion of species Heterometrus longimanus (PDI).

5th row – Soil mite of species Hypoaspis aculeifer attacking an enchytraeid (T. Moser); Carabid beetle (P. Brandmayr); Isopod of species Porcello dilatatus (R. Innocenti).

(Soil-net.com = Cranfield University; Sandy and Pete – The Macaulay Land Use Research Institute; Naked Mole Rat – PDI)